Training Course & Workshop
in

Process Piping in Accordance with ASME B31.3

Design, Construction, and Mechanical Integrity

May 25 -26, 2006
Singapore

Don Frikken

Becht Engineering Company

5515 HWY 50
Gerald, MO 63037
573-764-6744

(dfrikken@becht.com)

Introduction to
Process Piping in Accordance with
ASME B31.3
Design, Construction, and Mechanical Integrity

May 25 -26, 2006
Singapore

Don Frikken
Becht Engineering Company
5515 HWY 50
Gerald, MO 63037
573-764-6744
(dfrikken@becht.com)

Workshop Objectives

The aim of this workshop is to provide the participants with an overview of the area of Piping Technology with an emphasis on process piping. The workshop covers design, fabrication, examination and testing requirements of ASME B31.3. It covers Code requirements from design through start-up of new piping systems, as well as standards for inspection and repair of piping systems that have been in service, as provided in API 570, Piping Inspection Code.

This workshop provides a foundation of knowledge necessary for those responsible for assuring the mechanical integrity of existing piping systems, as well as those responsible for designing and constructing new piping systems.

Who Should Attend

Engineers, senior designers, maintenance, quality assurance, inspection and manufacturing personnel who work with process piping (e.g., in the chemical, petroleum, plastic processing, pulp and paper fields) will find it a time-saving means to broaden and update their knowledge of piping.

Workshop Contents

The workshop will review the basic requirements of the ASME B31 Code for Pressure Piping with emphasis on B31.3, Process Piping. General topics in the workshop include Code organization and intent, pressure design, design for sustained loads including support design, flexibility analysis, equipment loads, flanges, expansion joints, supports and restraints, materials, fabrication, examination, testing, and, for existing piping systems, mechanical integrity. Applications of these concepts, including simple hand analysis methods and computer-based analysis methods, will be demonstrated. Included will be comparisons between ASME B31.3 and ASME B31.1, Power Piping. Inspection and maintenance (mechanical integrity) of existing piping systems will be covered, as provided in API 570, Piping Inspection Code.

Each session will be conducted in a lecture/discussion/problem solving format designed to provide intensive instruction and guidance on understanding Code requirements. The instructors will be available following each day’s session to provide participants with further opportunity for discussion and consideration of specific problems.

ABOUT THE INSTRUCTOR

Don Frikken is an internationally recognized authority in piping design. Now employed by Becht Engineering, Don had been with Solutia, Inc. and Monsanto Company for 34 years; working on a wide range of activities including piping and mechanical design, project engineering, and engineering standards. However, Don’s principal specialty is piping design, including design of complex piping systems, piping flexibility analysis, selection of piping components including valves, development of piping standards and specifications, and developing and teaching numerous piping seminars and workshops.

He is an ASME Fellow and has been active on various ASME standards committees. He is past Chair of the ASME B31.3 Process Piping Code committee, Chair of the B31 Standards Committee, which oversees all B31 Piping Code committees, member of the B16 Standards Committee, member of the Board on Pressure Technology Codes and Standards, member of the Codes and Standards Board of Directors, which oversees the development and maintenance of six hundred ASME codes and standards, and recently completed a three year term as an ASME Senior Vice President.

Don has received a number of awards, and recently was awarded the ASME Melvin R. Green Codes and Standards Medal, which recognizes outstanding contributions to the development of documents used in ASME programs of technical codification, standardization and certification. Don graduated with a B.S.M.E. from Kansas State University and has a master's degree in civil engineering from the University of Missouri-Rolla.

B31.3 Workshop Outline

Section	Title	Topics Covered
1	Introduction	➢ General Definitions ➢ Piping Development Process ➢ Piping System Standards ➢ B31.3 Scope ➢ Organization of the Code ➢ Fluid Service Definitions
2	Metallic Pipe & Fitting Selection	➢ Piping System Failure ➢ Bases for Selection ➢ Listed versus Unlisted Piping Components ➢ Fluid Service Requirements ➢ Pipe ➢ Fittings ➢ Branch Connections ➢ Flanges ➢ Gaskets ➢ Bolting ➢ Flanged Joints
3	Materials	➢ Strength of Materials ➢ Bases for Design Stresses ➢ B31.3 Material Requirements ▪ Listed and Unlisted Materials ▪ Temperature Limits ▪ Toughness Requirements ▪ Deterioration in Service
4	Pressure Design (metallic)	➢ Design Pressure & Temperature ➢ Quality Factors ➢ Weld Joint Strength Factor ➢ Pressure Design of Components ▪ Four Methods ▪ Straight Pipe ▪ Fittings ▪ Fabricated Branch Connections ▪ Flanges and Blanks ▪ Other Components ➢ Piping Material Specifications

Section	Title	Topics Covered
5	Valve Selection	➢ Code Requirements ➢ Selection by Valve Type ▪ Gate ▪ Globe ▪ Check ▪ Butterfly ▪ Ball ▪ Plug
6	Introduction to Flexibility Analysis	➢ What are we trying to achieve? ➢ Flexibility Analysis Example
7	Layout and Support	➢ General Considerations ➢ Support Spacing ➢ Support Locations ➢ Support Elements
8	Flexibility	➢ General Considerations ➢ Friction ➢ Stress Intensification ➢ Thermal Expansion ➢ Spring Hangers ➢ The Displacement Load Analysis
9	Reactions	➢ General Considerations ➢ Fabricated Equipment ➢ Rotating Equipment ➢ Supports ➢ Cold Spring
10	Flexibility Analysis	➢ When to Perform a Detailed Analysis ➢ Considerations
11	Designing with Expansion Joints	➢ Types of Expansion Joints ➢ Pressure Thrust ➢ Installation of Expansion Joints ➢ Metal Bellows Expansion Joints
12	Fabrication and Installation	➢ Welder/Brazer Qualification ➢ Welding Processes ➢ Weld Preparation ➢ Typical Welds ➢ Preheating & Heat Treatment ➢ Typical Owner Added Requirements ➢ Installation ➢ Flange Joints
13	Inspection, Examination and Testing	➢ Inspection ➢ Examination ▪ Methods ▪ Requirements ▪ Acceptance Criteria ➢ Leak Testing ▪ Methods ▪ Requirements

Section	Title	Topics Covered
15	Nonmetallic Piping Systems	➢ General ➢ Design, Fabrication and Installation for o Thermoplastics o Reinforced thermosetting resins o Reinforced concrete o Vitrified clay o Borosilicate glass o Piping lined with nonmetals ➢ Limitations
16	Category M Fluid Service	➢ General ➢ B31.3 Requirements o Design o Fabrication o Examination o Testing ➢ Typical Owner Added Requirements
17	High Pressure Piping	➢ General ➢ Materials ➢ Pressure Design ➢ Limitations ➢ Fabrication ➢ Examination ➢ Testing
18	In-service Piping - Inspection, Repair, Alteration and Rerating	➢ API 570 Piping Inspection Code ➢ Responsibilities ➢ What to Inspect ➢ Types of Inspection ➢ Inspection Practices ➢ Frequency and Extent of Inspection ➢ Remaining Life Calculation ➢ Repairs and Alterations ➢ Rerating
19	What's Different in B31.1	➢ Scope ➢ Organization of the Code ➢ Fluid Service Requirements ➢ Bases for Allowable Stresses ➢ Material Requirements ➢ Pressure Design Requirements ➢ Valve Requirements ➢ Fabrication and Installation ➢ Inspection, Examination and Testing

ASME B31.3 Process Piping

Charles Becht IV, PhD, PE

Don Frikken, PE

Instructors

Scope of B31.3 Course

This course covers piping as typically used in process plants.

Not covered:

- Pipelines
- Plumbing
- Nuclear plant piping

Topics Covered

1. Introduction
2. Metallic Pipe & Fitting Selection
3. Materials
4. Pressure Design
5. Valve Selection
6. Flexibility Analysis
7. Layout and Support
8. Flexibility
9. Support and Equipment Load Limits
10. Flexibility Analysis Methods

More Topics Covered

11. Designing with Expansion Joints
12. Fabrication and Installation
13. Inspection, Examination and Testing
14. Category M Fluid Service
15. Nonmetallic Piping Systems
16. High Pressure Piping
17. Inspection, Repair, Alteration and Rerating
18. What's Different in B31.1

1. Introduction

- General Definitions
- Piping Development Process
- Piping System Standards
- B31.3 Scope
- Organization of the Code
- Fluid Service Definitions

Definitions: (300.2)

piping: assemblies of piping components used…[for] fluid flows. Piping also includes pipe supporting elements, but does not include support structures…or equipment…

piping system: interconnected piping subject to the same design conditions

More Definitions:

piping components: mechanical elements suitable for joining or assembly into pressure-tight fluid-containing piping systems…pipe, tubing, fittings, flanges, gaskets, bolting, valves and devices such as expansion joints, flexible joints, pressure hoses, traps, strainers, inline portions of instruments and separators.

& More Definitions:

design pressure: the pressure at the most severe condition of internal or external pressure and temperature expected during service

design temperature: the temperature at which, under the coincident pressure, the greatest thickness or highest component rating is required

Piping Development Process

1. Establish applicable system standard(s)
2. Establish design conditions
3. Make overall piping material decisions
   - Pressure Class
   - Reliability
   - Materials of construction
4. Fine tune piping material decisions
   - Materials
   - Determine wall thicknesses
   - Valves
5. Establish preliminary piping system layout & support configuration
6. Perform flexibility analysis
7. Finalize layout and bill of materials
8. Fabricate and install
9. Examine and test

Piping System Standards

Provide a set of requirements for obtaining a safe, reliable and economical installation.

Are frequently called Codes; for example, B31 piping system standards are called Codes.

ASME Piping System Standards

B31.1	Power Piping
B31.3	Process Piping
B31.4	Liquid Transportation Pipelines
B31.5	Refrigeration Piping
B31.8	Gas Transportation Pipelines
B31.9	Building Services Piping
B31.11	Slurry Transportation Pipelines

More ASME Piping System Standards

BPE-1	Bioprocessing Equipment
PVHO-1	Pressure Vessels for Human Occupancy
HPS	High Pressure Systems

B&PV Code, Section III for Nuclear Power Plants

Other Piping System Standards

NFPA 13 – Installation of Sprinkler Systems

NFPA 24 – Installation of Private Mains

NFPA 50 – Bulk Oxygen Systems

NFPA 54 – National Fuel Gas Code

CGA – Handling of Anhydrous Ammonia (K61.1)

Chlorine Institute #6 – Piping Systems for Chlorine

See the longer list, pages 2-3 in the supplement.

BECHT ENGINEERING COMPANY, INC. Introduction - 13

B31.3 Scope

Rules for the Process Piping Code Section B31.3 have been developed considering piping typically found in petroleum refineries; chemical, pharmaceutical, textile, paper semiconductor, and cryogenic plants; and related processing plants and terminals. (300.1)

BECHT ENGINEERING COMPANY, INC. Introduction - 14

B31.3 Scope

This Code prescribes requirements for

- materials and components
- design
- fabrication
- assembly
- erection
- examination
- inspection
- testing

of piping [300.1.1(a)]

B31.3 Scope

This Code applies for <u>all fluids</u>, including:

(1) raw, intermediate, and finished chemicals;
(2) petroleum products;
(3) gas, steam, air, and water;
(4) fluidized solids;
(5) refrigerants; and
(6) cryogenic fluids.

[300.1.1(b)]

B31.3 Scope

Exclusions: (300.1.3)

- Piping systems designed for
  - pressure >0 and <15 psig (105 kPa)
  - nonflammable
  - nontoxic
  - not damaging to human tissue, and
  - temperature -20 to 366ºF (-29 to 186ºC)

BECHT *ENGINEERING COMPANY, INC.* Introduction - 17

B31.3 Scope

More Exclusions: (300.1.3)

- boilers and piping required to conform to B31.1
- tubes and manifolds of fired heaters
- pressure equipment such as pressure vessels and pumps, including internal piping

BECHT *ENGINEERING COMPANY, INC.* Introduction - 18

B31.3 Scope

Intent of the Code [300(c)]

1) …set forth engineering requirements deemed necessary for safe design and construction…
2) …not intended to apply to…piping that has been placed in service.

B31.3 Scope

More Intent of the Code [300(c)]

3) …requirements…, while considered necessary and adequate for safe design, generally employ a simplified approach… A designer capable of applying a more rigorous analysis shall have the latitude to do so…the approach must be…accepted by the owner…

B31.3 Scope

More Intent of the Code [300(c)]

4) …Piping elements neither specifically approved nor specifically prohibited…may be used provided they are qualified…
5) The engineering design shall specify any unusual requirements…

B31.3 Scope

More Intent of the Code [300(c)]

6) Compatibility of materials with the service and hazards from instability of contained fluids are not within the scope of this Code.

B31.3 Scope

Responsibilities [300(b)]

(1) *Owner.* …for compliance with this Code, and for establishing the requirements for design, construction, examination, inspection, and testing which will govern the entire fluid handling or process installation of which the piping is a part. The owner is also responsible for designating piping in certain fluid services and for determining if a specific Quality System is to be employed…

B31.3 Scope

Responsibilities [300(b)]

(2) *Designer.* The designer is responsible to the owner for assurance that the engineering design of piping complies with the requirements of this Code and with any additional requirements established by the owner.

B31.3 Scope

Responsibilities [300(b)]

(3) *Manufacturer, Fabricator, and Erector.* The manufacturer, fabricator, and erector of piping are responsible for providing materials, components, and workmanship in compliance with the requirements of this Code and of the engineering design.

BECHT *ENGINEERING COMPANY, INC.* Introduction - 25

B31.3 Scope

Responsibilities [300(b)]

(4) *Owner's Inspector.* The owner's Inspector (see para. 340) is responsible to the owner for ensuring that the requirements of this Code for inspection, examination, and testing are met. If a Quality System is specified by the owner to be employed, the owner's inspector is responsible for verifying that it is implemented.

BECHT *ENGINEERING COMPANY, INC.* Introduction - 26

Organization of the Code

"Base Code" Chapters:

- I Scope and Definitions
- II Design
- III Materials
- IV Standards for Piping Components
- V Fabrication, Assembly, and Erection
- VI Inspection, Examination and Testing

Organization of the Code

- VII Nonmetallic Piping and Piping Lined with Nonmetals (A)
- VIII Piping for Category M Fluid Service (M) & (MA)
- IX High Pressure Piping (K)

These chapters follow the same format as the "base Code", and refer to the base Code requirements whenever applicable.

Organization of the Code

Appendices

- A – Allowable Stresses & Quality Factors – Metals
- B – Stresses and Allowable Pressures – Nonmetals
- C – Physical Properties of Piping Materials
- D – Flexibility & Stress Intensification Factors
- E – Reference Standards
- F – Precautionary Considerations
- G – Safeguarding
- H – Sample Calculations
- J – Nomenclatures

Organization of the Code

More Appendices

- K – Allowable Stresses for High Pressure Piping
- L – Aluminum Alloy Pipe Flanges
- M – Guide to Classifying Fluid Services
- Q – Quality System Program
- V – Allowable Variations in Elevated Temperature Service
- X – Metallic Bellows Expansion Joints
- Z – Preparation of Technical Inquiries

B31.3 Fluid Service Definitions

- Fluid Service
- Category D
- Category M
- High Pressure
- Normal

B31.3 Fluid Service Definitions

Fluid Service: a general term concerning the application of a piping system, considering the combination of fluid properties, operating conditions and other factors which establish the basis for design…

- What fluid properties are important?
- What operating conditions are important?
- What other factors are important?

B31.3 Fluid Service Definitions

Category D: The fluid handled is nonflammable, nontoxic and not damaging to human tissue. The design pressure does not exceed 150 psig (1035 kPa). The design temperature is greater than -20°F (-29°C) and does not exceed 366 °F (186°C).

Often characterized as "utility"

B31.3 Fluid Service Definitions

Category M: A fluid service in which the potential for personnel exposure is judged to be significant and in which a single exposure to a very small quantity of a toxic fluid, caused by leakage, can produce serious irreversible harm to persons upon breathing or on bodily contact, even when prompt restorative measures are taken.

Often characterized as "lethal"

B31.3 Fluid Service Definitions

High Pressure: A service for which the owner specifies the use of Chapter IX [of B31.3] for piping design and construction… considered to be in excess of Class 2500 (PN 420).

Characterized as "high pressure"

Normal: Everything else.

Often characterized as "process"

B31.3 Definitions

Severe Cyclic Conditions: Conditions applying to specific piping components or joints in which S_E … exceeds 0.8 S_A, and the equivalent number of cycles exceeds 7000; or conditions which the designer determines will produce and equivalent effect.

Flammable: A fluid which under ambient or expected operating conditions is a vapor or produces a vapor that can be ignited and continue to burn in air.

Fluid Service Selection

Workshop: What B31.3 fluid service definition is most nearly applicable for the following services:

Steam condensate	650 psig (45 bar) Steam
Chlorine	Heat transfer oil
Sulfuric acid	Styrene monomer
Gasoline	Lime-water slurry

See Supplement page 7 for details

ASME B31.3 Process Piping

Charles Becht IV, PhD, PE
Don Frikken, PE
Instructors

Piping Development Process

1. Establish applicable system standard(s)
2. Establish design conditions
3. Make overall piping material decisions
   - Pressure Class
   - Reliability
   - Materials of construction
4. Fine tune piping material decisions
   - Materials
   - Determine wall thicknesses
   - Valves
5. Establish preliminary piping system layout & support configuration
6. Perform flexibility analysis
7. Finalize layout and bill of materials
8. Fabricate and install
9. Examine and test

2. Metallic Pipe & Fitting Selection

- Piping System Failure
- Bases for Selection
- Listed versus Unlisted Piping Components
- Fluid Service Requirements
- Pipe
- Fittings
- Branch Connections
- Flanges
- Gaskets
- Bolting
- Flanged Joints

The Material in This Section is Addressed by B31.3 in:

Chapter II - Design

Chapter IV - Standards for Piping Components

Appendix G - Safeguarding

Piping System Failure

How can you recognize a failure in a piping system?

Bases for Selection

- Pressure Class
- Reliability
  - Robustness
  - Fire Resistance
  - Blow-out Resistance
  - Tendencies to leak
- Material of Construction
  - Corrosion Resistance
  - Material Toughness
- Cost

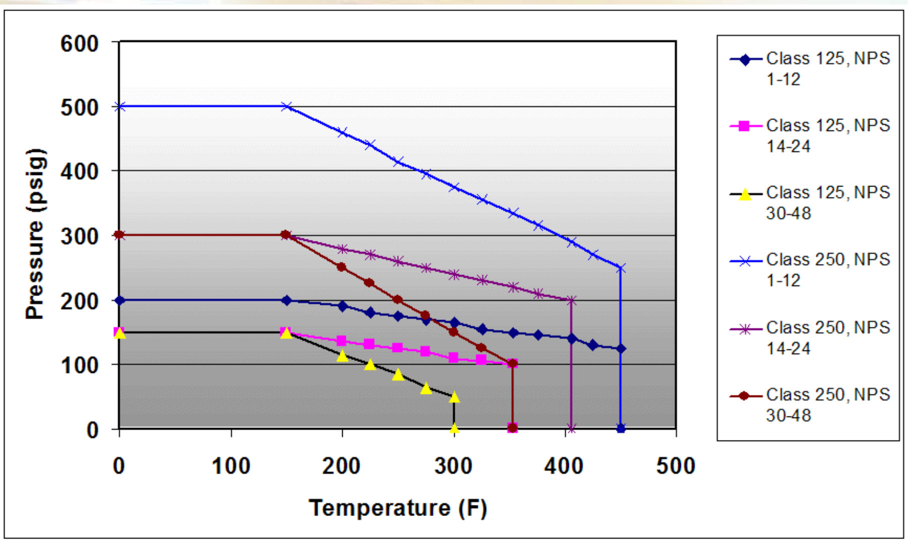
Pressure Class

Ratings for above ground metallic systems are generally governed by their joints. Frequently these are flanged joints manufactured in accordance with ASME B16.1 (iron flanges) and ASME B16.5 (other metallic flanges).

Ratings for flanges (and some other piping components) are designated by pressure class.

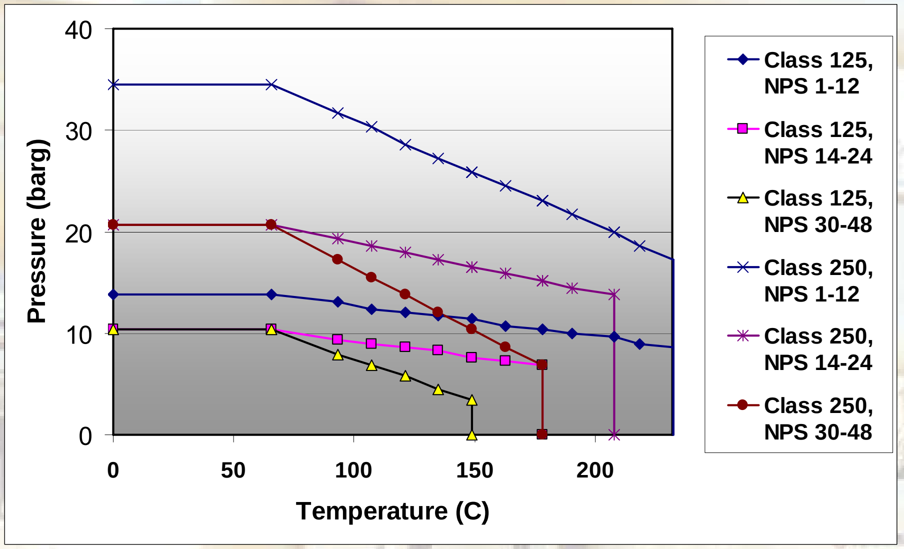
Flange P-T Ratings– Gray Iron (psi)

(Class Rated in accordance with ASME B16.1)



Flange P-T Ratings– Gray Iron (bar)

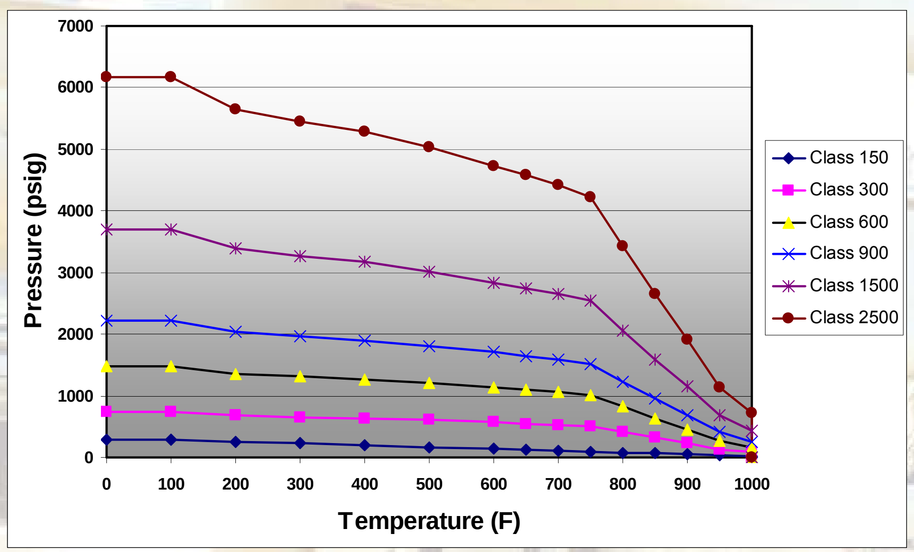
(Class Rated in accordance with ASME B16.1)



BECHT ENGINEERING COMPANY, INC. Metallic Pipe & Fitting Selection - 9

Flange P-T Ratings – Carbon Steel (psi)

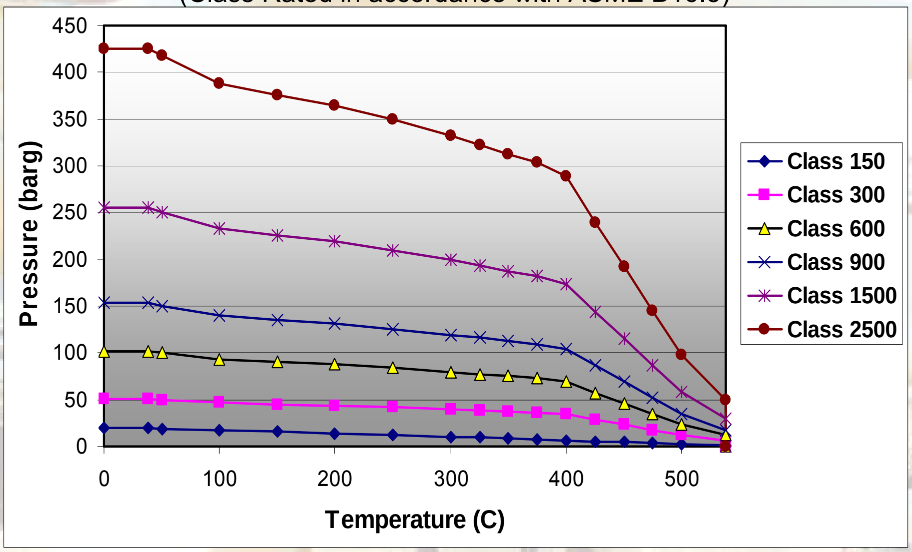
(Class Rated in accordance with ASME B16.5)



BECHT ENGINEERING COMPANY, INC. Metallic Pipe & Fitting Selection - 10

Flange P-T Ratings – Carbon Steel (bar)

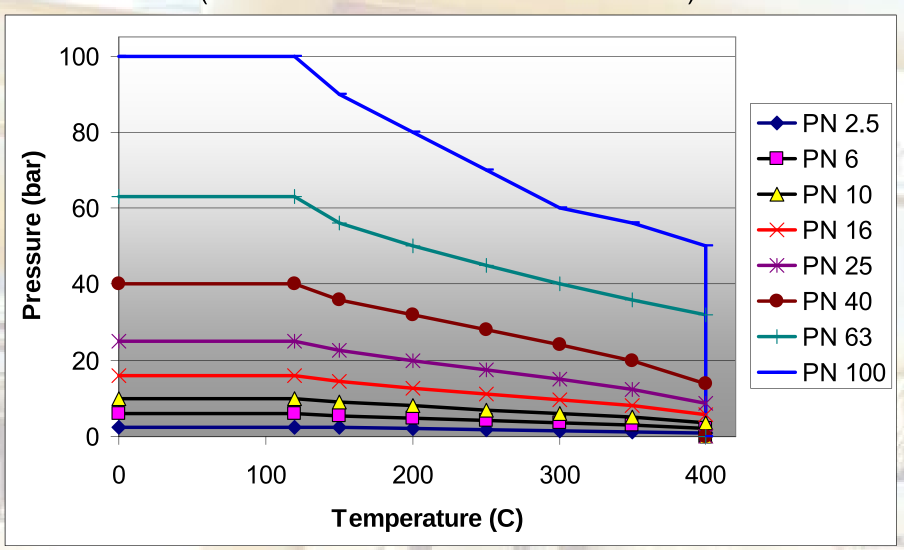
(Class Rated in accordance with ASME B16.5)



BECHT ENGINEERING COMPANY, INC. Metallic Pipe & Fitting Selection - 11

Flange P-T Ratings – Carbon Steel (bar)

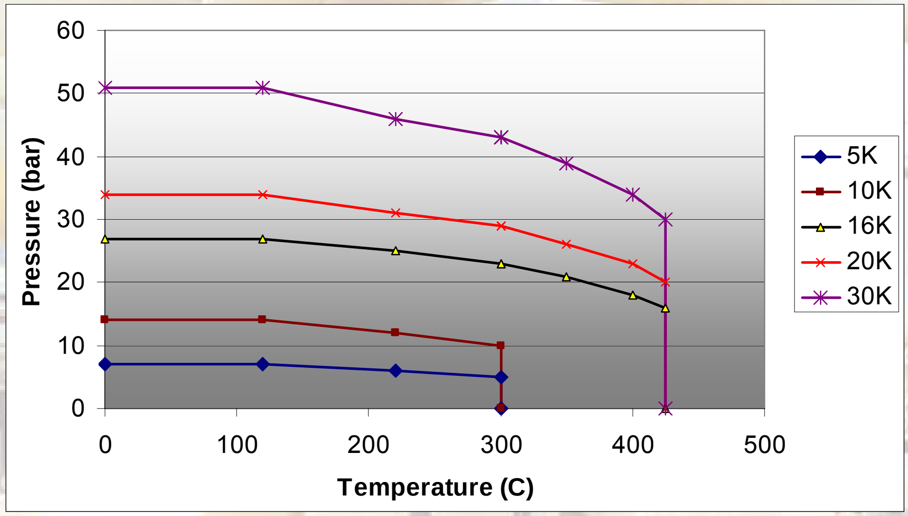
(PN Rated in accordance with EN 1092-1)



BECHT ENGINEERING COMPANY, INC. Metallic Pipe & Fitting Selection - 12

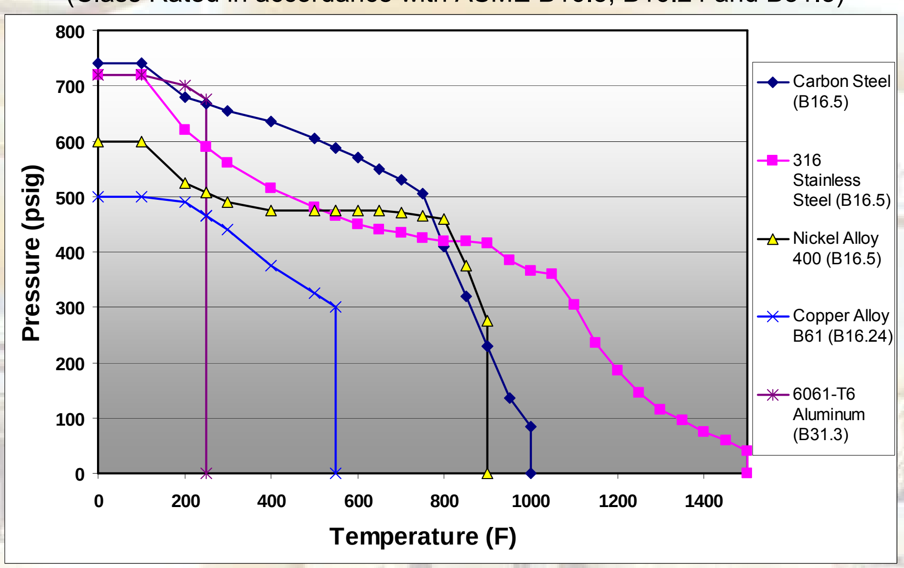
Flange P-T Ratings – Carbon Steel (bar)

(K Rated in accordance with JIS B2220)



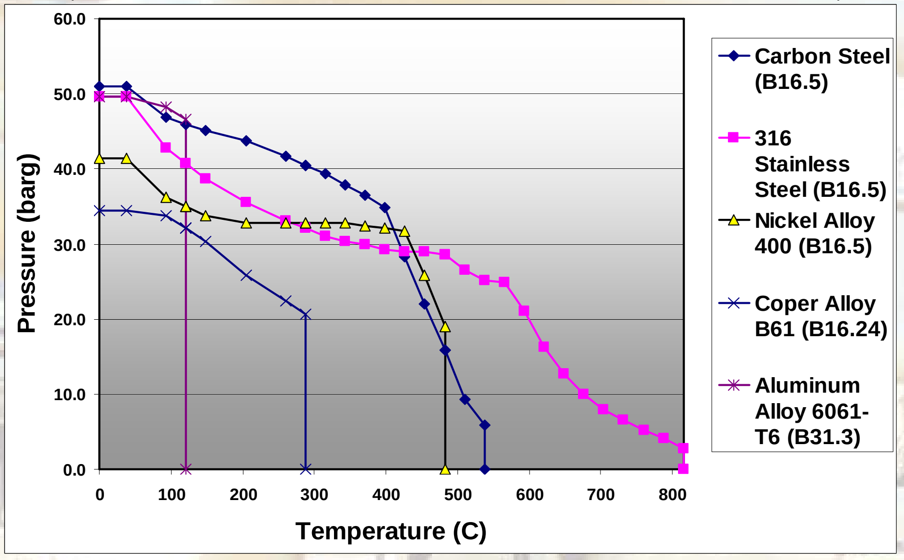
Cl 300 Flange Ratings – Several Materials (psi)

(Class Rated in accordance with ASME B16.5, B16.24 and B31.3)



Cl 300 Flange Ratings – Several Materials (bar)

(Class Rated in accordance with ASME B16.5, B16.24 and B31.3)



Reliability

- Robustness
- Fire Resistance
- Blow-out Resistance
- Tendencies to Leak

Robustness

Able to withstand exposure to loads such as:

- Being stepped on
- Dropped tool
- Dropped tool box
- Forklift traffic
- Truck traffic
- Crane booms

Fire Resistance

Usual Definition: Components able to maintain piping system integrity if subjected to approximately 1200ºF (650ºC) for 30 minutes.

Fire Resistance

Fire resistant components are used

- where there is a sufficient probability of a fire, and
- where there is a significant consequence as a result of piping system failure such as
  - adding fuel to the fire
  - exposure of fire fighters to danger due to leaking fluids

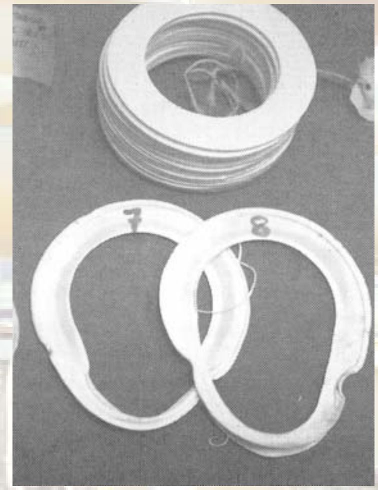
Being able to continue operation after a fire is usually not a consideration.

Blow-out Resistance

Gaskets and seals able to withstand high pressure without failing by extrusion or fracture. A short-term leak could be resealed by tightening the bolting. The intent is to avoid large leaks

- when a flanged joint is not tightened properly
- when the piping system is subjected to pressures much higher than design
- when large bending moments are applied to the flanged joint

Blow-out Resistance



Failure by Extrusion

Failure by Fracture

Tendencies to Leak

Some joints are more leak prone than others. These are usually a strong function of the construction and maintenance practices at a particular site. Examples:

- Threaded joints
- Unions
- Elastomeric seals such as o-rings

Corrosion Resistance

- Where corrosion is more or less uniform, extra pipe wall material can be provided in the form of a "corrosion allowance".
- Where material degradation is localized, either preventive measures must be used or a more resistant material must be provided. Examples of localized material problems:
  - Erosion
  - Stress-Corrosion Cracking
  - Hydrogen Embrittlement
  - Intergranular
  - Microbiological

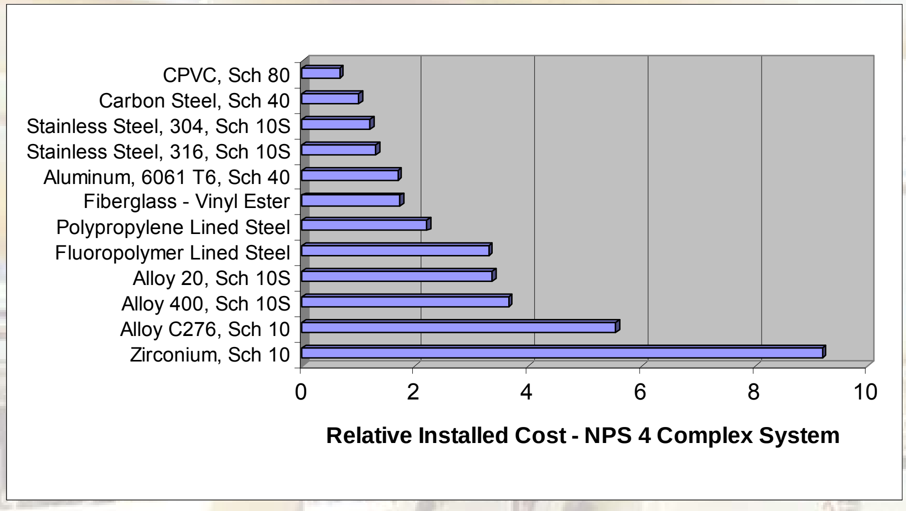
Material Toughness

- Measured by energy necessary to suddenly propagate a crack to failure
- Mostly of concern for carbon steels
- Generally decreases as temperature decreases
- Factors affecting fracture toughness include:
  - Chemical composition or alloying elements
  - Heat treatment
  - Grain size

Example of Brittle Fracture

Example of Ductile Deformation

Cost



Piping Component Standards

Provide consistent dimensions and ratings so that components will fit together and can be used interchangeably

- *Listed Components:* Those listed by standard number in Table 326.1 and Appendix A
- *Unlisted Components:* Those not so listed.

Some Listed Components - ASME

B16.1 – Cast Iron Pipe Flanges
B16.3 – Malleable Iron Threaded Fittings
B16.5 – Pipe Flanges and Flanged Fittings
B16.9 – Wrought Steel Buttweld Fittings
B16.11 – Forged Fittings, Socket Welding & Threaded
B16.20 – Metallic Gaskets
B16.22 – Wrought Copper Solder Joint Fittings
B16.34 – Valves Flanged, Threaded and Welded

See page 8 of the supplement.

Some Listed Components - Other

MSS	SP-80	Bronze Valves
MSS	SP-97	Branch Outlet Fittings
API	602	Compact Steel Gate Valves
API	608	Metal Ball Valves
ASTM	A53	Steel Pipe
ASTM	A312	Stainless Steel Pipe
AWWA	C110	Ductile & Gray Iron Fittings
AWWA	C151	Ductile Iron Pipe

See the pages 9 - 11 in the supplement.

Listed Components

Can be used within their pressure-temperature ratings and any additional limitations described in the Code.

Some Unlisted Components

- ASME B16.33 – Manually Operated Metallic Gas Valves or Use in Gas Piping Systems
- ASME B16.50 – Wrought Copper and Copper Alloy Braze-Joint Pressure Fittings
- MSS SP-68 – High Pressure-Offset Seat Butterfly Valves
- MSS SP-108 – Resilient-Seated Cast Iron-Eccentric Plug Valves
- API 6D – Pipeline Valves (Gate, Plug, Ball, and Check)
- AWWA C153 – Ductile-Iron Compact Fittings for Water Service

Unlisted Components [302.2.3, 326.2.1]

Can be used within Code limitations if they:

- have dimensions that "conform to those of comparable listed components insofar as practicable"
- "provide strength and performance equivalent to standard components", and
- satisfy one of the following:
  - "composition, mechanical properties, method of manufacture, and quality control are comparable to listed components"; and have pressure-temperature ratings that conform with para. 304, or
  - are "qualified for pressure design as required by para. 304.7.2."

Fluid Service Requirements

- Specific requirements for components and joints are described in paras. 305-318.
- Some components are permitted for certain fluid services only when safeguarded.
- "Safeguarding is the provision of protective measures to minimize the risk of accidental damage to the piping or to minimize the harmful consequences of possible piping failure." Para. G300

Fluid Service Requirements

Safeguarding examples:

- Brazed or soldered copper water tube is not inherently fire resistant, but may be protected against fire exposure by insulation or by water sprays.
- Thermoplastic piping is not inherently blow-out resistant and is sensitive to abuse, but may be protected from both hazards by routing the piping in a secondary containment.

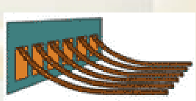
Piping Components

- Pipe
- Fittings
- Branch Connections
- Flanges
- Gaskets
- Bolting
- Flanged Joints

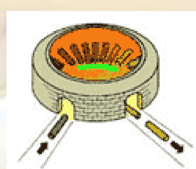
Pipe

"Pipe includes components designated as 'tube' or 'tubing' in the material specification, when intended for pressure service." *Para. 305*

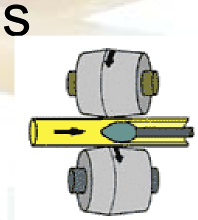
Pipe - seamless



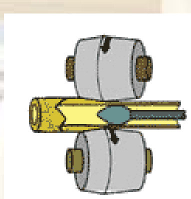
Strand Caster



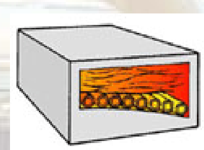
Billet Heating



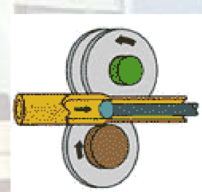
Rotary Piercing Mill



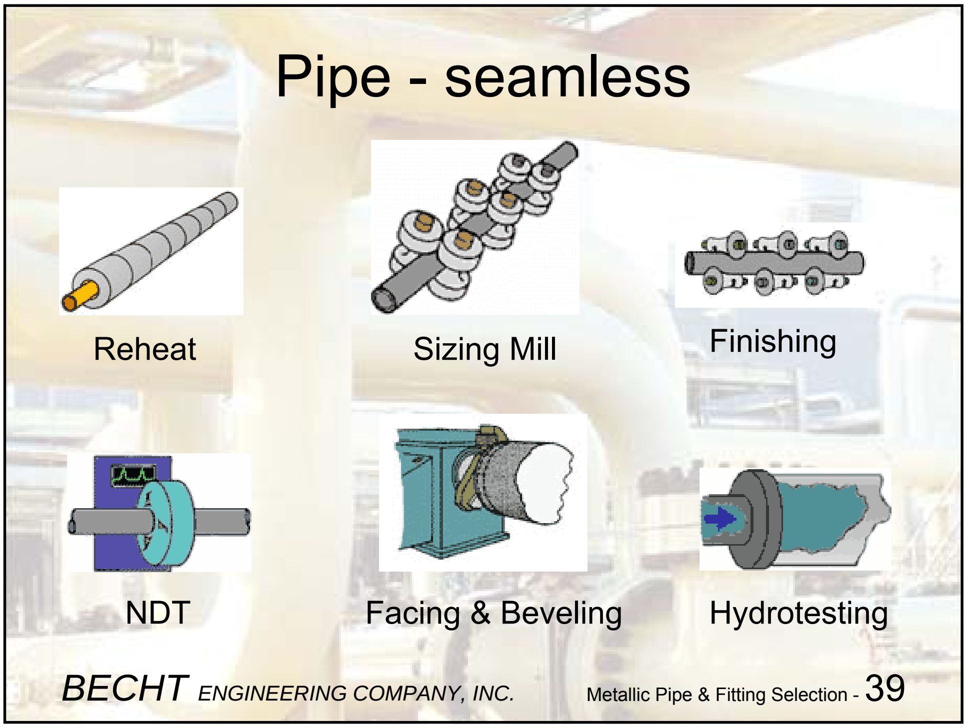
Elongator

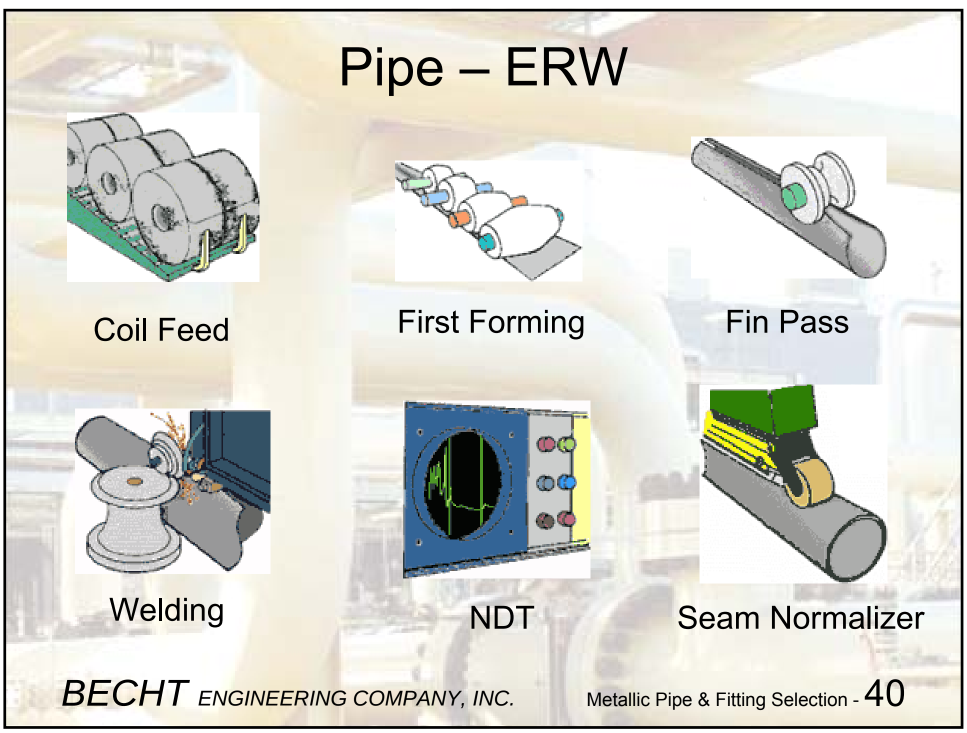


Reheat

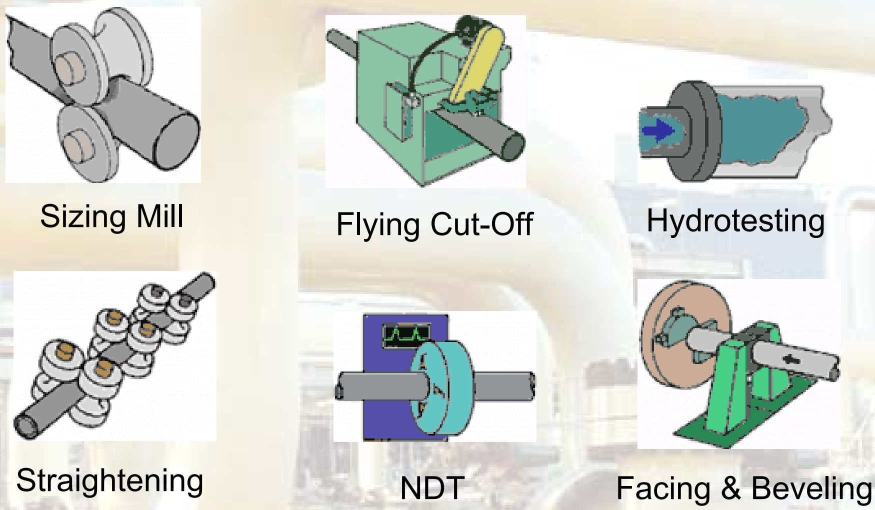


Pug Rolling Mill


Pipe - seamless
Reheat
Sizing Mill
Finishing
NDT
Facing & Beveling
Hydrotesting
BECHT ENGINEERING COMPANY, INC.
Metallic Pipe & Fitting Selection - 39


Pipe – ERW
Coil Feed
First Forming
Fin Pass
Welding
NDT
Seam Normalizer
BECHT ENGINEERING COMPANY, INC.
Metallic Pipe & Fitting Selection - 40

Pipe - ERW



Weld Joint Quality Factor E_j

Type of Weld	Factor (Table 302.2.4)
None (seamless)	1.00
Electric Resistance Weld	0.85
Furnace Butt Weld	0.60
Single Fusion Weld	0.80 to 1.00*
Double Fusion Weld	0.85 to 1.00*
API 5L SAW, GMAW	0.95

*Depending on level of examination

Pipe Fluid Service Requirements

- Some specifications, including all furnace butt welded, are limited to Category D Fluid Service
- Some specifications may be used only in Category D Fluid Service unless safeguarded
- Only pipe listed in para. 305.2.3 may be used for Severe Cyclic Conditions

Fittings

Fittings are selected primarily by the way they are joined to the pipe.

- Threading
- Socket Welding
- Buttwelding
- OD Tubing (Compression fitting, Flare)
- Water Tubing (Solder, Braze)
- Others

Fittings: Threaded

- **Common materials**
  - Gray iron (ASME B16.4)
  - Malleable iron (ASME B16.3)
  - Steel (ASME B16.11)

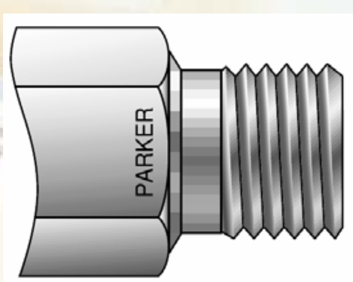
- **Size usually limited to ~NPS 2**
  - Potential injury for installers
  - Ability to get a good seal

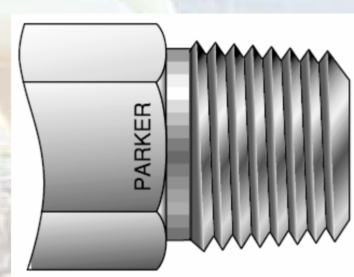
- **Generally not used where leaks cannot be tolerated**

BECHT *ENGINEERING COMPANY, INC.* Metallic Pipe & Fitting Selection - 45

Threaded Joint Fluid Service Requirements

- Straight threaded coupling mating to taper thread permitted only for Category D



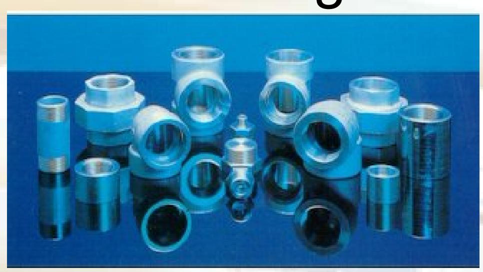


BECHT *ENGINEERING COMPANY, INC.* Metallic Pipe & Fitting Selection - 46

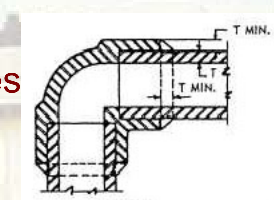
Threaded Joint Fluid Service Requirements

- NPS 1-1/2 and smaller tapered joints must be Sch 80 for notch sensitive material in Normal Service
- May be used for Severe Cyclic Conditions only if:
  - For taper threads must be, non-moment bearing such as for a thermowell
  - For straight threads with seating surface, must be safeguarded

Fittings: Socket Welding

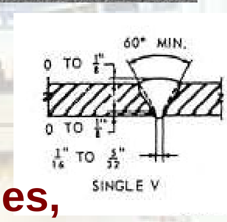


- **Common materials (ASME B16.11)**
  - Carbon Steel
  - Stainless Steel
- **Size usually limited to ~NPS 1-1/2**
- **Not used in services where**
  - Corrosion is accelerated in crevices
  - Severe erosion may occur

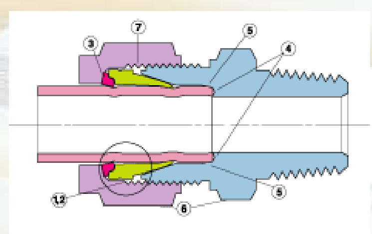


Fittings: Buttwelding

- **Common materials (ASME B16.9)**
  - Carbon Steel
  - Stainless Steel
  - Nickel alloys
- **Used in most piping systems ~NPS 2 and larger**
- **Use generally not restricted**
- **Welding is difficult in small sizes, especially for thin wall**



Fittings: OD Tubing



- **Common materials**
  - Copper
  - Steel
  - Nickel alloys
- **Compression Fittings**
- **Flared Fittings (ASME B16.26)**
- **Generally not used in most severe services because of leak potential**
  - Must be safeguarded for Severe Cyclic Service

Fittings: Water Tube

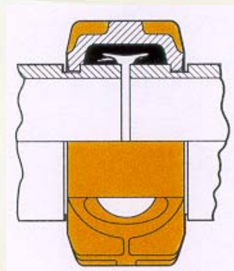
- **Common material: copper**
- **Solder joint (ASME B16.18 & B16.22)**
- **Braze joint (ASME B16.50)**
- **Not fire resistant**

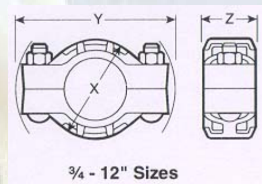
Solder & Brazed Joint Fluid Service Requirements

- Solder joints are permitted only for Category D Fluid Service
- Brazed joints are :
  - permitted for Normal Fluid Service
  - permitted for fluids that are flammable, toxic or damaging to human tissue if safeguarded
  - prohibited for Severe Cyclic Conditions

Fittings: Grooved

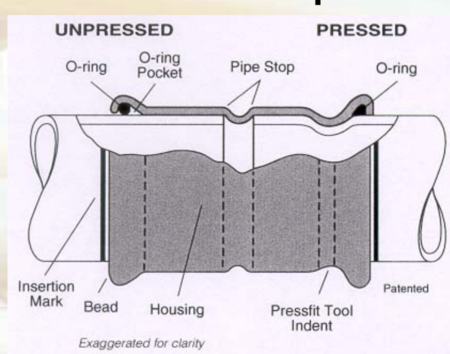
Fittings that use grooves in pipe – elastomeric seal required

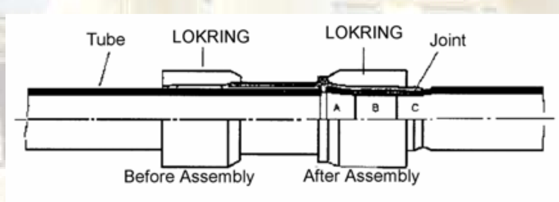




Fittings: Compression for Pipe

Pressfit by Victaullic (B16.51 draft for copper)





Lokring (metal-to-metal seal)

Miter Bend Fluid Service Requirements

- A bend with α greater than 45º may be used only in Category D Fluid Service
- For Severe Cyclic Conditions, α must be less than or equal to 22.5º.

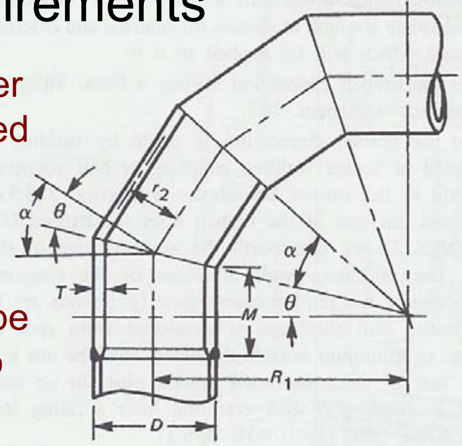


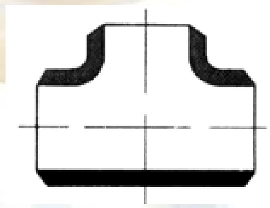
FIG. 304.2.3 NOMENCLATURE FOR MITER BENDS

Branches

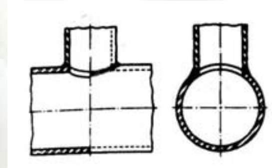
- **Generally many choices NPS 3 and larger**
- **Choices include:**
  - Tee
  - Unreinforced Fabricated Tee
  - Reinforced Fabricated Tee
  - Branch Connection Fitting

Branches

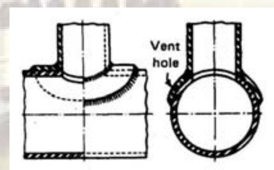
Tee



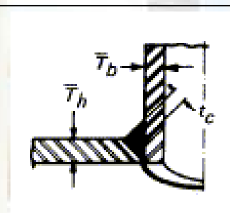
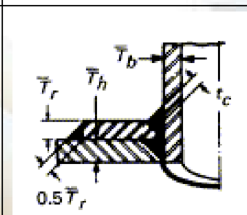
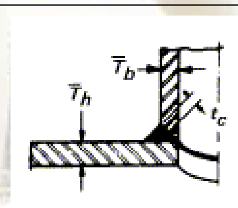
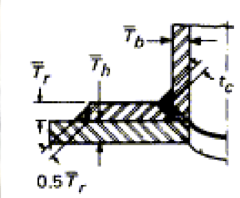
Unreinforced Fabricated Tee
(Capable of less than full pressure)



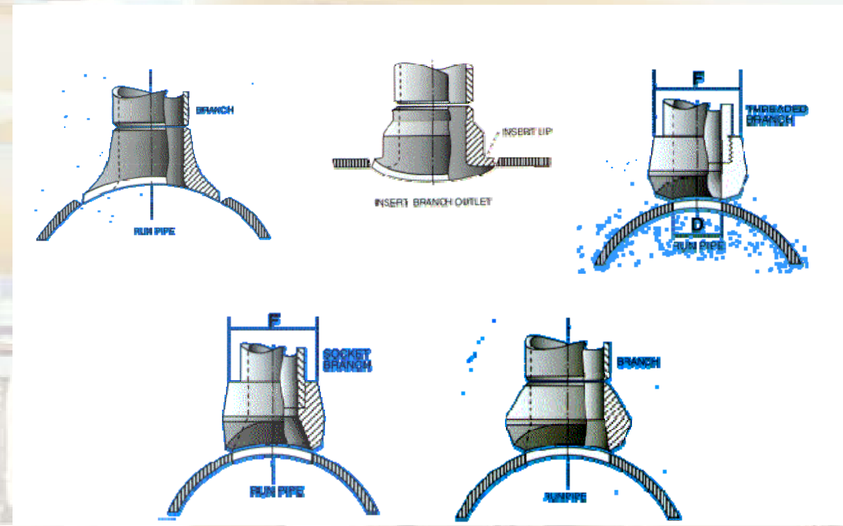
Reinforced Fabricated Tee



Fabricated Branches

	Unreinforced	Reinforced
Stub in		
Stub on		

Branches - Branch Connection Fittings



Branches

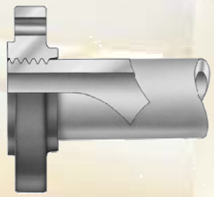
Basis for selection:

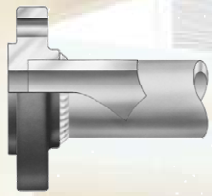
- **Cost: depends on material, sizes & fabricator**
- **Resistance to external moment**
- **Ability to examine fabrication**

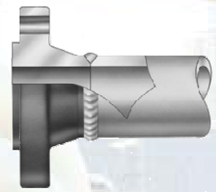
See table on page 19 in the supplement.

Flanges (ASME B16.5)

Flange types designated by joining method


Threaded


Socket welding

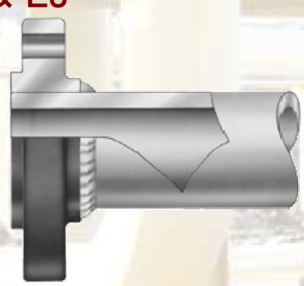

Welding Neck (buttweld)

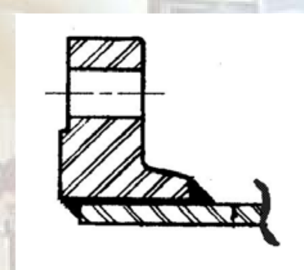
These flanges have the same advantages and restrictions as fittings with the same joining method. (Note that welding neck flanges are required for Severe Cyclic Conditions.)

Flanges (ASME B16.5)

Other types of flanges - Slip-on

- Has no crevice if installed with two welds
- Easier to get good alignment
- Unable to seat metal gaskets as well as WN & LJ





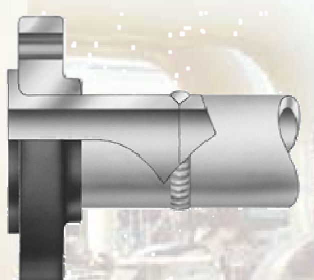
Slip-on Flange Fluid Service Requirements

- Required to be double welded for:
  - Severe erosion, crevice corrosion or cyclic loading
  - Flammable, toxic, or damaging to human tissue
  - Under Severe Cyclic Conditions
  - At temperatures below -101ºC (-150ºF)
- Should be avoided where many large temperature cycles are expected

Flanges (ASME B16.5)

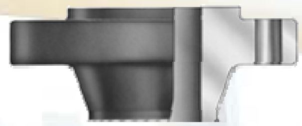
Other types of flanges - Lapped joint

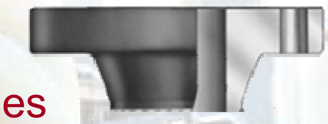
- Flange can be made from cheaper material
- Easier to fabricate and install than WN



Flanges Facings (ASME B16.5)

Raised – normal choice





Flat

- Standard for gray iron flanges
- More gasket has to be compressed, so only "softer" gaskets can be used
- Less likely to break flange when bolting (applicable to brittle materials like gray iron)

Gaskets

Important Gasket Characteristics

- Resists deterioration in normal service
  - Chemical resistance
  - Temperature resistance
- Low enough leak rate
- Blowout resistance
- Fire resistance

Gaskets – Rubber

Chemical Resistant	OK for most
Approximate Max. Temp.	200°F (95°C)
Leak Performance	Best
Blowout Resistant	No
Fire Resistant	No
Bolt Strength Needed	Low

(Thermoseal)

Gaskets – Reinforced Rubber

Chemical Resistant	OK for most
Approximate Max. Temp.	325°F (160°C)
Leak Performance	Fair
Blowout Resistant	No
Fire Resistant	No
Bolt Strength Needed	Low

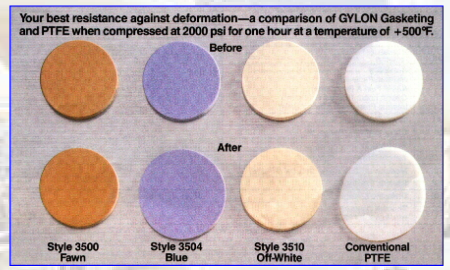
(Garlock)

Gaskets – Fluoropolymer

Chemical Resistant	OK for almost all
Approximate Max. Temp.	350°F (180°C)
Leak Performance	Good
Blowout Resistant	No
Fire Resistant	No
Bolt Strength Needed	Low


(Gore)


(Teadit)



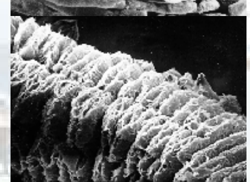
(Garlock)

Gaskets – Flexible Graphite

Chemical Resistant	OK for almost all
Approximate Max. Temp.	900 or 625°F (480 or 330°C)
Leak Performance	Good
Blowout Resistant	Not without heavier insert
Fire Resistant	Yes
Bolt Strength Needed	Medium

Natural Graphite Flake

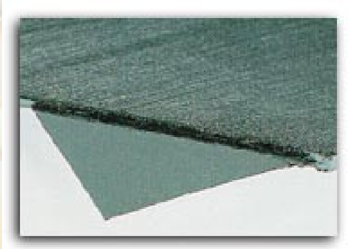
Thermally Decomposed (Worms)



Worms Compressed Into Foils

(SGL Carbon Group)

Gaskets – Flexible Graphite



(Teadit)

Foil Inserted

- Insert is usually 0.002” (0.05 mm) type 316 stainless steel
- Adhesive bonded

(Teadit)

Tang Inserted

- Insert is usually 0.004” (0.10 mm) type 316 stainless steel
- Mechanically bonded

Gaskets – Flexible Graphite

(Garlock)

Corrugated Insert

- Insert is usually 0.018” (0.46 mm) type 316 stainless steel
- Adhesive bonded
- Blowout resistant
- Lower hand cutting potential
- Lower sealing stress
- Cannot be cut from sheet

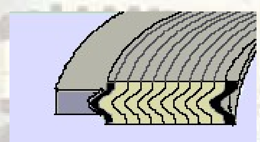
Gaskets – Flexible Graphite

Flexible graphite tends to stick to flanges, but special coatings can help.

Gaskets – Spiral Wound

Chemical Resistant	Both metal winding & filler must be OK
Approximate Max. Temp.	1500°F (820°C)
Leak Performance	Good
Blowout Resistant	Yes
Fire Resistant	Depends on Filler
Bolt Strength Needed	High

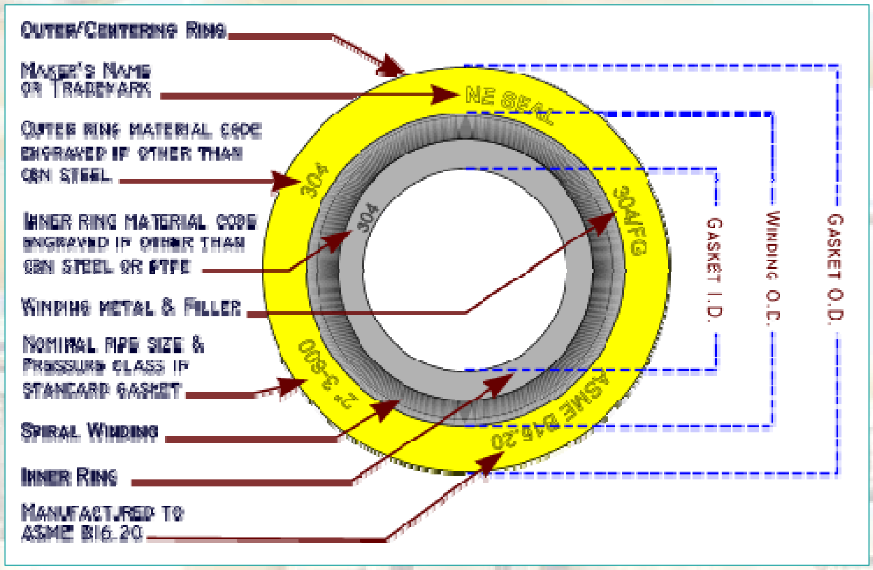
(Garlock)



(Flexitallic)

Gaskets – Spiral Wound

(NE Seal)



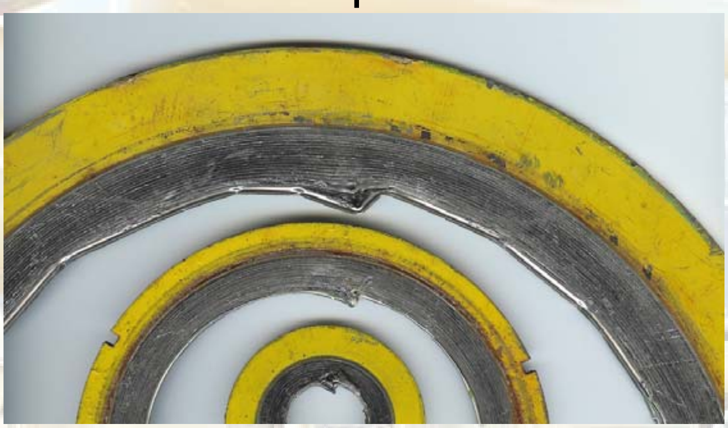
Gaskets – Spiral Wound

Winding Material	Ring Edge Color Code
304 SS	Yellow
316L SS	Green
Nickel 200	Red
Alloy C276	Beige
Alloy 400	Orange

Gaskets – Spiral Wound

Filler Material	Ring Stripe Color Code	Fire Resistant	Maximum Temp ^{0}F/ ^{0}C
Asbestos	None	Yes	1500 / 820
Flexible Graphite	Gray	Yes	900 / 480
Mica Graphite	Pink	No	325 / 160
PTFE	White	No	350 / 180
Vermiculite	No standard	Yes	1500 / 820

Gaskets – Spiral Wound



Internal buckling is a concern to some, especially in higher pressure classes and larger sizes.

Gaskets - Kammprofile

Chemical Resistant	Both metal & sealing material must be OK
Approximate Max. Temp.	1500°F (820°C)
Leak Performance	Good
Blowout Resistant	Yes
Fire Resistant	Depends on sealing material
Bolt Strength Needed	Medium

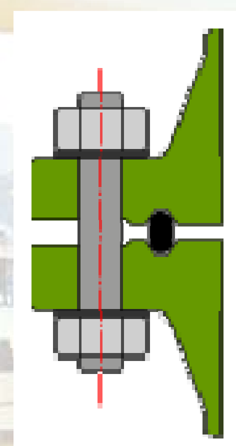
(Garlock)

Gaskets – Ring Joint

Chemical Resistant	Metal must be OK
Approximate Max. Temp.	1500°F (820°C)
Leak Performance	Very Good
Blowout Resistant	Yes
Fire Resistant	Yes
Bolt Strength Needed	High

Oval

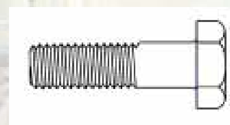
Octagonal



(NE Seal)

Bolting

- Has to be strong enough to seat the gasket
- Consider need to be corrosion resistant to process fluid
- Studs versus bolts



1st and 2nd degree burns…

after being sprayed with hot water. The bonnet of the valve had separated from the valve body due to corroded bonnet bolts.

Bolting Fluid Service Requirements

- Low strength bolting [SMYS not greater than 207 MPa (30 ksi)] may not be used with
  - Pressure classes higher than 300
  - Metal gaskets
- Carbon steel bolting may not be used with
  - Pressure classes higher than 300
  - Temperatures outside -29ºC to 204ºC (-20ºF to 400ºF) range
- Galvanized carbon steel bolting must be to heavy hex dimensions

More Bolting Fluid Service Requirements

- Low strength bolting shall be used for weaker and more brittle flanged joints unless
  - Both flanges are flat faced and a full face gasket is used, or
  - A careful bolt-up procedure is used
- Low strength bolting may not be used for Severe Cyclic Conditions

Flanged Joints

"A flanged joint is composed of three separate and independent, although interrelated components: the flanges, the gasket, and the bolting, which are assembled by yet another influence, the assembler. Proper controls must be exercised in the selection and application for all these elements to attain a joint which has acceptable leak tightness." [B16.5]

Flanged Joints

Flange A	Flange B	Fire Resist?	Blow-out Resist?	Facing	Gaskets	Bolting Strength
Class 125 gray iron	Class 125 gray iron	No	No			
Class 125 gray iron	Class 150 carbon stl	No	No			
Class 150 carbon stl	Class 150 carbon stl	Yes	Yes			
Class 150 stainless	Class 150 stainless	No	Yes			
Class 150 carbon stl	Class 125 gray iron	Yes	No			

Pipe & Fitting Selection

Workshop: What basic piping system characteristics would you provide for the following services:

Steam condensate	650 psig (45 bar) Steam
Chlorine	Heat transfer oil
Sulfuric acid	Styrene monomer
Gasoline	Lime-water slurry

See Supplement page 7 for details.

ASME B31.3 Process Piping

Charles Becht IV, PhD, PE
Don Frikken, PE
Instructors

Piping Development Process

1. Establish applicable system standard(s)
2. Establish design conditions
3. Make overall piping material decisions
   - Pressure Class
   - Reliability
   - Materials of construction
4. Fine tune piping material decisions
   - Materials
   - Determine wall thicknesses
   - Valves
5. Establish preliminary piping system layout & support configuration
6. Perform flexibility analysis
7. Finalize layout and bill of materials
8. Fabricate and install
9. Examine and test

3. Materials

- Strength of Materials
- Bases for Design Stresses
- B31.3 Material Requirements
  - Listed and Unlisted Materials
  - Temperature Limits
  - Toughness Requirements
  - Deterioration in Service

BECHT *ENGINEERING COMPANY, INC.* Materials - 3

The Material in This Section is Addressed by B31.3 in:

Chapter II - Design

Chapter III - Materials

Appendix A - Allowable Stresses & Quality Factors – Metals

Appendix F - Precautionary Considerations

BECHT *ENGINEERING COMPANY, INC.* Materials - 4

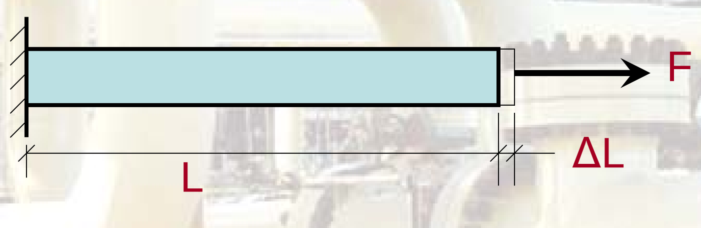
Strength of Materials

- Stress
- Strain
- Stress-Strain Diagram
  - Elastic Modulus
  - Yield Strength
  - Ultimate Strength
- Creep
- Fatigue
- Brittle versus Ductile Behavior

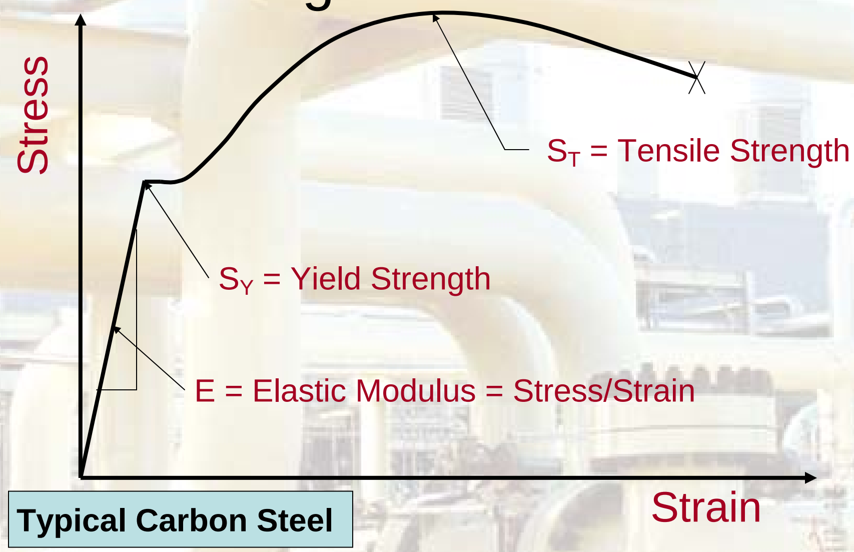
Strength of Materials

Stress (S): force (F) divided by area (A) over which force acts, pounds force/inch^2 (psi), Pascals (Newtons/meter^2)

Strain (ε): change in length (ΔL) divided by the original length (L)

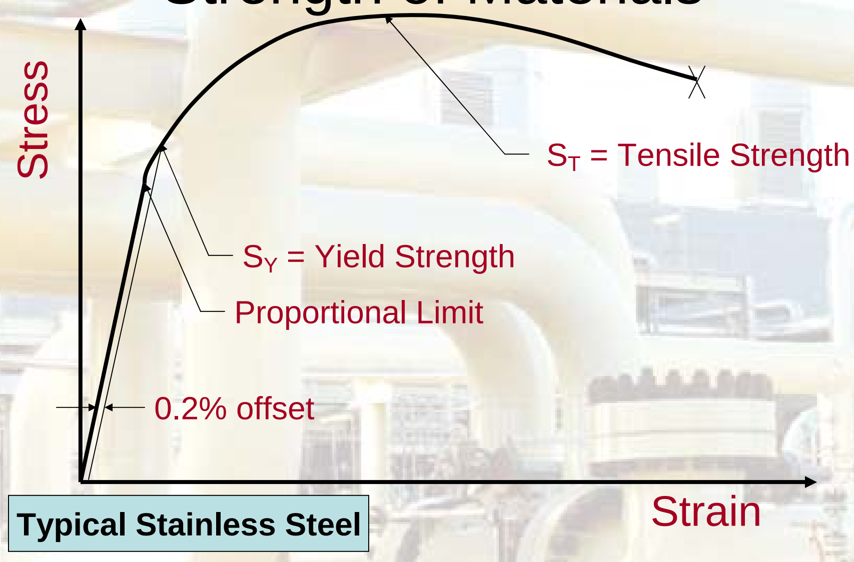


Strength of Materials



BECHT ENGINEERING COMPANY, INC. Materials - 7

Strength of Materials



BECHT ENGINEERING COMPANY, INC. Materials - 8

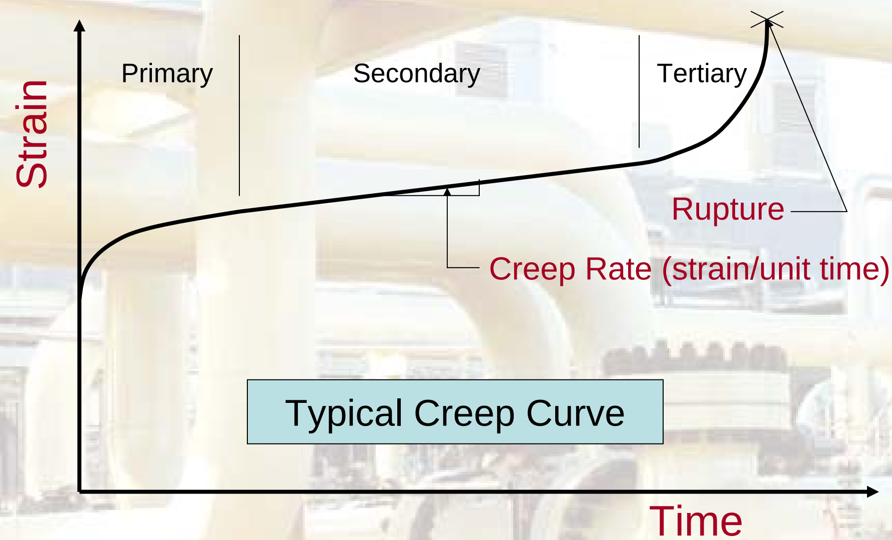
Strength of Materials

Creep: progressive permanent deformation of material subjected to constant stress, AKA time dependent behavior. Creep is of concern for

- Carbon steels above ~700ºF (~370ºC)
- Stainless steels above ~950ºF (~510ºC)
- Aluminum alloys above ~300ºF (~150ºC)

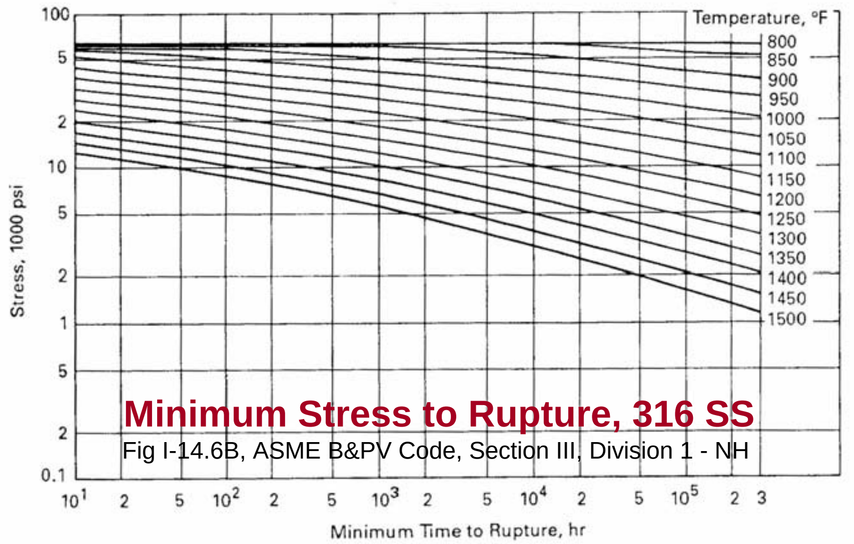
BECHT *ENGINEERING COMPANY, INC.* Materials - 9

Strength of Materials



BECHT *ENGINEERING COMPANY, INC.* Materials - 10

Strength of Materials

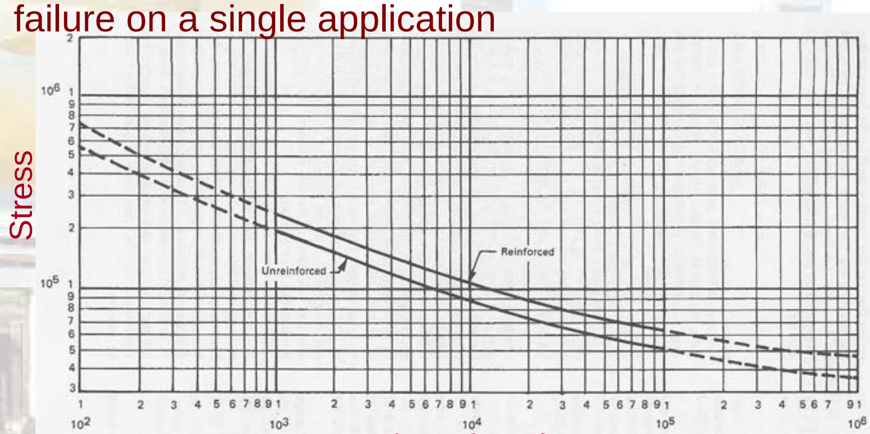


Minimum Stress to Rupture, 316 SS

Fig I-14.6B, ASME B&PV Code, Section III, Division 1 - NH

Strength of Materials

Fatigue failure: a failure which results from a repetitive load lower than that required to cause failure on a single application



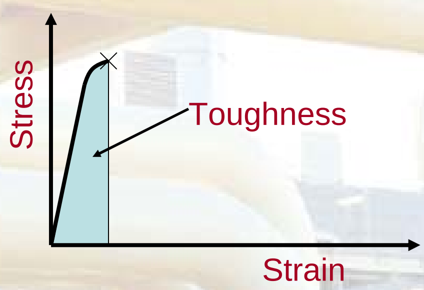
Strength of Materials

Brittle failure:

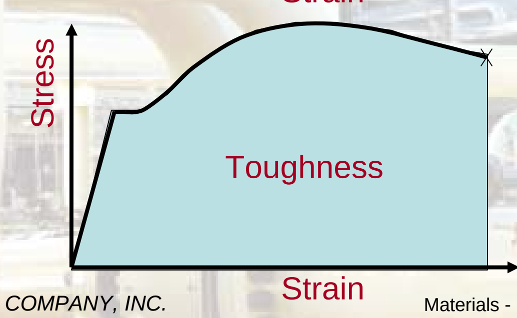
Ductile deformation:

Strength of Materials

Brittle failure:

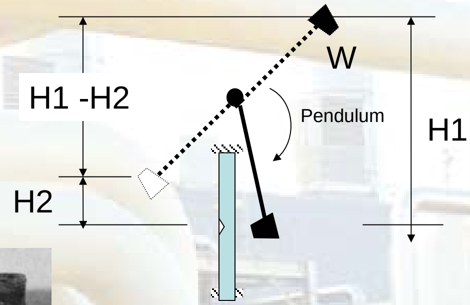


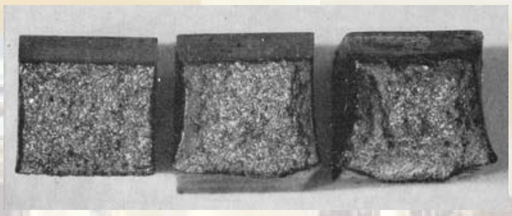
Ductile failure:



Strength of Materials

Measuring Toughness using a Charpy impact test





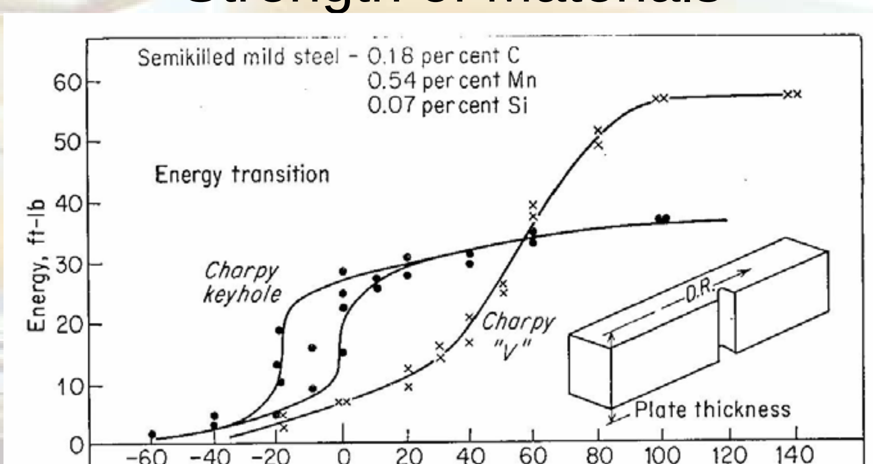
Specimens tested at 40, 100 and 212ºF (4, 38 and 100ºC)

Charpy Impact Test

C_v = W(H1 - H2)

= Energy Absorbed

Strength of Materials



Ductile to Brittle Transition for a Carbon Steel

Bases for Design Stresses

Most Materials – (materials other than gray iron, malleable iron and bolting) below the creep range, the lowest of (302.3.2)

- 1/3 of specified minimum tensile strength (S_T)
- 1/3 of tensile strength at temperature
- 2/3 of specified minimum yield strength (S_Y)
- 2/3 of yield strength at temperature; except for austenitic stainless steels and nickel alloys with similar behavior, 90% of yield strength at temperature

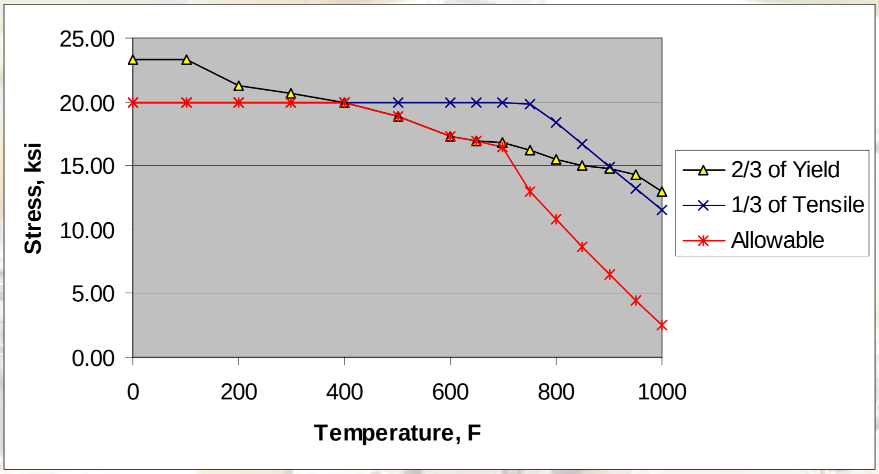
Bases for Design Stresses

Most Materials – additional bases in the creep range, the lowest of (302.3.2)

- 100% of the average stress for a creep rate of 0.01% per 1000 hours
- 67% of the average stress for rupture at the end of 100,000 hours
- 80% of the minimum stress for rupture at the end of 100,000 hours

Bases for Design Stresses

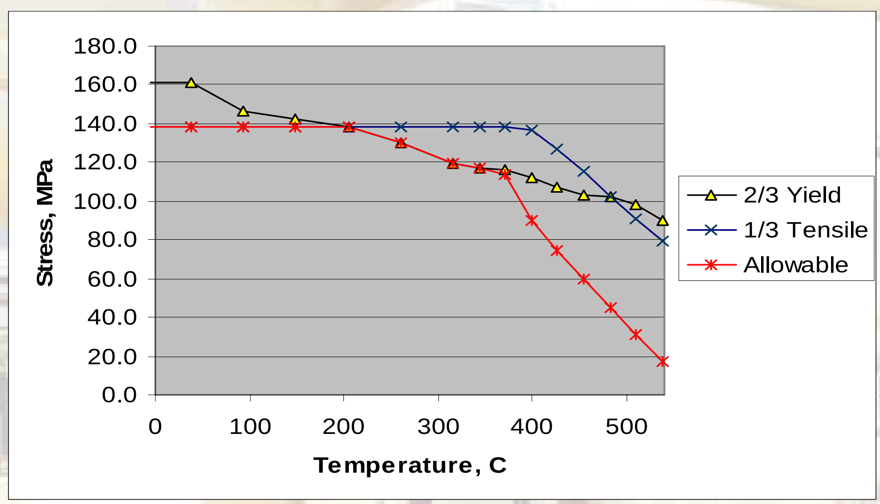
ASTM A106 Grade B Carbon Steel (US Customary Units)



BECHT ENGINEERING COMPANY, INC.

Bases for Design Stresses

ASTM A106 Grade B Carbon Steel (Metric Units)



BECHT ENGINEERING COMPANY, INC.

Bases for Design Stresses

Additional Notes

- For structural grade materials, design stresses are 0.92 times the value determined for most materials (302.3.2)
- Stress values above 2/3 S_Y are not recommended for flanged joints and other components in which slight deformation can cause leakage or malfunction (302.3.2)
- Design stresses for temperatures below the minimum are the same as at the minimum

B31.3 Material Requirements

- Listed and Unlisted Materials
- Temperature Limits
- Impact Test Methods & Acceptance
- Toughness Requirements
- Deterioration in Service

Listed and Unlisted Materials

- ***Listed Material:*** a material that conforms to a specification in Appendix A or to a standard in Table 326.1 – may be used (323.1.1)
- ***Unlisted Material:*** a material that is not so listed – may be used under certain conditions (323.1.2)
- ***Unknown Material:*** may not be used (323.1.3)

Listed and Unlisted Materials

An unlisted material may be used if (323.1.2)

- It conforms to a published specification covering chemistry, mechanical properties, method of manufacture, heat treatment, and quality control
- Otherwise meets the requirements of the Code
- Allowable stresses are determined in accordance with Code bases, and
- Qualified for service…all temperatures (323.2.3)

Temperature Limits

Listed materials may be used above the maximum described in the Code if (323.2.1)

- There is no prohibition in the Code
- The designer verifies serviceability of the material, considering the quality of mechanical property data used to determine allowable stresses and resistance of the material to deleterious effects in the planned fluid service (323.2.4)

Temperature Limits

Listed materials may be used within the temperature range described in the Code if (323.2.2)

- The base metal, weld deposits and heat affected zone (HAZ) are qualified in accordance with Column A of Table 323.2.2.

Table 323.2.2

Requirements for Low Temperature Toughness Tests

TABLE 323.2.2
REQUIREMENTS FOR LOW TEMPERATURE TOUGHNESS TESTS FOR METALS
These Toughness Test Requirements Are in Addition to Tests Required by the Material Specification

Type of Material	Column A Design Minimum Temperature at or Above Min. Temp. in Table A-1 or Fig. 323.2.2A		Column B Design Minimum Temperature Below Min. Temp. in Table A-1 or Fig. 323.2.2A
1 Gray cast iron	A-1 No additional requirements		B-1 No additional requirements
2 Malleable and ductile cast iron; carbon steel per Note (1)	A-2 No additional requirements		B-2 Materials designated in Box 2 shall not be used.
	(a) Base Metal	(b) Weld Metal and Heat Affected Zone (HAZ) [Note (2)]	
3 Other carbon steels; low and intermediate alloy steels; high alloy ferritic steels; duplex stainless steels	A-3 (a) No additional requirements	A-3 (b) Weld metal deposits shall be impact tested per para. 323.3 if design min. temp. <−29°C (−20°F), except as provided in Notes (3) and (5), and except as follows: for materials listed for Curves C and D of Fig. 323.2.2A, where corresponding welding consumables are qualified by impact testing at the design minimum temperature or lower in accordance with the applicable AWS specification, additional testing is not required.	B-3 Except as provided in Notes (3) and (5), heat treat base metal per applicable ASTM specification listed in para. 323.3.2; then impact test base metal, weld deposits, and HAZ per para. 323.3 [see Note (2)]. When materials are used at design min. temp. below the assigned curve as permitted by Notes (2) and (3) of Fig. 323.2.2A, weld deposits and HAZ shall be impact tested [see Note (2)].

See page 20 of the supplement.

Temperature Limits

Listed materials may be used <u>below</u> the minimum described in the Code if (323.2.2)

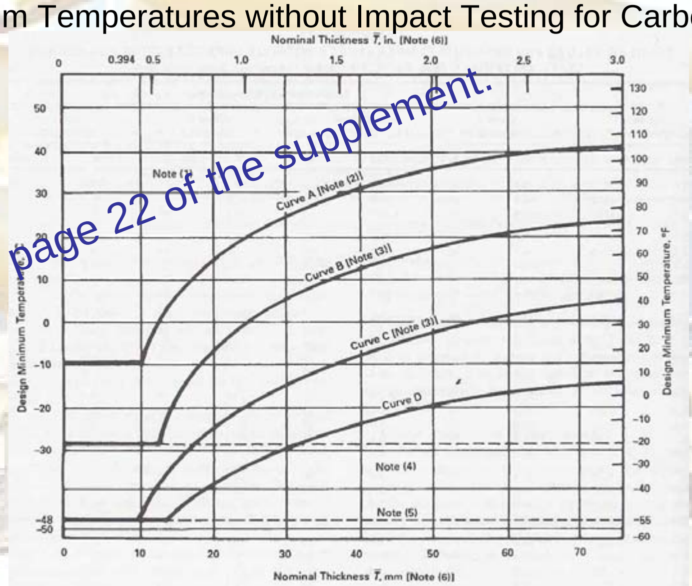
- There is no prohibition in the Code
- The base metal, weld deposits and heat affected zone (HAZ) are qualified in accordance with Column B of Table 323.2.2.

Carbon Steel Lower Temperature Limits

- Most carbon steels have a letter designation in the column for minimum temperature in Appendix A
- See page 25 of the supplement
- For those that do, the minimum temperature is defined by Figure 323.2.2A

Figure 323.2.2A

Minimum Temperatures without Impact Testing for Carbon Steel



See page 22 of the supplement.

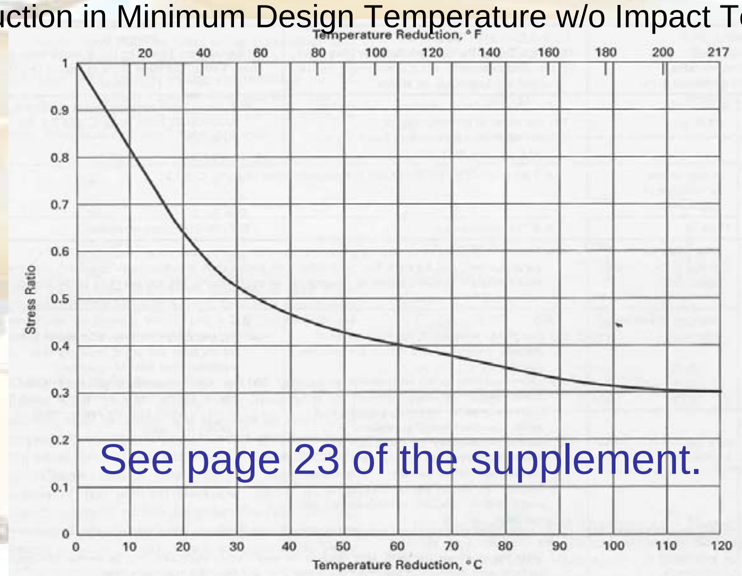
Carbon Steel Lower Temperature Limits

- Impact testing is not required down to -55ºF (-48ºC) if stress ratio does not exceed the value defined by Figure 323.2.2B
- Impact testing is not required down to -155ºF (-104ºC) if stress ratio does not exceed 0.3

BECHT *ENGINEERING COMPANY, INC.*

Fig.323.2.2B

Reduction in Minimum Design Temperature w/o Impact Testing



See page 23 of the supplement.

BECHT *ENGINEERING COMPANY, INC.*

Carbon Steel Lower Temperature Limits

Fig.323.2.2B provides a further basis for use of carbon steel without impact testing. If used:

- Hydrotesting is required
- Safeguarding is required for components with wall thicknesses greater than ½ in. (13 mm)

Stress Ratio is the largest of

- Nominal pressure stress / S
- Pressure / pressure rating
- Combined longitudinal stress / S

Carbon Steel Lower Temperature Limits

650 psig (45 bar) steam superheated to 735°F (390°C). Relief pressure is 725 psig (50 bar). Pipe material is ASTM A53 Gr B seamless.

What options are available to deal with expected ambient temperatures down to -30°F (-34°C)?

NPS	Nominal WT in (mm)	Stress Ratio
1	0.178 (4.52)	0.71
4	0.237 (6.02)	0.74
12	0.500 (12.70)	0.86
30	1.000 (25.40)	0.97

Deterioration in Service

- Selection of material to resist deterioration in service is not within the scope of the Code. (323.5)
- Recommendations for material selection are presented in Appendix F.
  - General considerations
  - Specific material considerations

Deterioration in Service

- General considerations
  - Fire resistance
  - Possibility of brittle fracture
  - Susceptibility to crevice corrosion
  - Possibility of galvanic corrosion
  - Chilling effect of the loss of pressure
  - Compatibility of materials such as
    - Packing
    - Gaskets
    - Thread sealants

Deterioration in Service

- Specific material considerations
  - Carbon and low alloy steel
  - High alloy steel
  - Nickel and nickel alloys
  - Aluminum and aluminum alloys
  - Copper and copper alloys
  - And more…

ASME B31.3 Process Piping

Charles Becht IV, PhD, PE
Don Frikken, PE
Instructors

Piping Development Process

1. Establish applicable system standard(s)
2. Establish design conditions
3. Make overall piping material decisions
   - Pressure Class
   - Reliability
   - Materials of construction
4. Fine tune piping material decisions
   - Materials
   - Determine wall thicknesses
   - Valves
5. Establish preliminary piping system layout & support configuration
6. Perform flexibility analysis
7. Finalize layout and bill of materials
8. Fabricate and install
9. Examine and test

4. Pressure Design of Metals

- Design Pressure & Temperature
- Quality Factors
- Weld Joint Strength Factor
- Pressure Design of Components
  - Four Methods
  - Straight Pipe
  - Fittings
  - Fabricated Branch Connections
  - Flanges and Blanks
  - Other Components
- Piping Material Specifications

The Material in This Section is Addressed by B31.3 in:

Chapter II - Design

Appendix V - Allowable Variations in Elevated Temperature Service

Design Pressure & Temperature

design pressure: the pressure at the most severe condition of internal or external pressure and temperature expected during service (301.2)

- The most severe condition is that which results in the greatest required component thickness and the highest component rating.
- The inside pipe in jacketed piping shall be designed for the most severe combination of conditions expected during service.
- Short-term variations may be considered separately. (302.2.4)

Design Pressure & Temperature

design pressure:

- Provisions shall be made to safely contain or relieve any pressure to which the piping may be subjected.
- Sources of pressure to be considered include
  - Ambient influences
  - Pressure oscillations
  - Improper operation
  - Decomposition of fluids
  - Static head
  - Failure of control devices

Design Pressure & Temperature

design temperature: the temperature at which, under the coincident pressure, the greatest thickness or highest component rating is required (301.3). For insulated piping:

- May be taken as fluid temperature
- May be based on calculated average wall temperature, or
- May be based on measurements or tests
- Consider heat tracing and other sources of heat

Design Pressure & Temperature

design temperature: Uninsulated piping

- <u>fluid temperatures below 150ºF (65ºC):</u> Shall be taken as fluid temperature, unless solar radiation or other effects make the temperature higher
- <u>fluid temperatures 150ºF (65ºC) and above:</u>
  - May be taken as fluid temperature
  - May be based on calculated average wall temperature, or
  - Presumptive reductions described in para. 301.3.3 may be used

Design Pressure & Temperature

design minimum temperature: the lowest component temperature expected in service

- May be taken as fluid temperature
- May be based on calculated average wall temperature, or
- May be based on measurements or tests

Design Pressure & Temperature

allowance for pressure and temperature variation: The Code allows the design pressure to be set below the most severe coincident pressure and temperature under certain conditions:

- No cast iron or other non-ductile components
- Nominal pressure stresses don't exceed yield strength at temperature
- Longitudinal stresses are within the allowable

Design Pressure & Temperature

allowance for pressure and temperature variation: more conditions:

- The number of excursions beyond design does not exceed 1000
- The increased pressure does not exceed the test pressure
- With the owners permission can exceed allowable by 33% for no more than 10 hr/event and no more than 100 hr/year
- With the owners permission can exceed allowable by 20% for no more than 50 hr/event and nor more than 500 hr/year

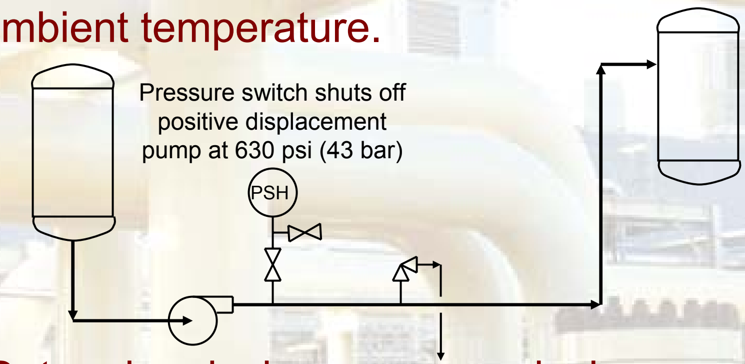
Design Pressure & Temperature

allowance for pressure and temperature variation: more conditions:

- Without the owners permission, can exceed allowable by 20% for no more than 50 hr/event and nor more than 500 hr/year for self-limiting events such as pressure relieving
- Effects of the variations must be evaluated, e.g. by rules described in Appendix V
- Differential pressure on valve closures should not exceed maximum established by valve manufacturer

Design Pressure & Temperature

Workshop Problem 1: Styrene monomer at ambient temperature.



Determine design pressure, design temperature and relief valve set pressure.

See Page 24 of the supplement.

Design Pressure & Temperature

Workshop Problem 2: If the line in problem 1 is steam cleaned with 50 psi (3.5 bar) steam superheated to 735°F (390°C)

- What should the design pressure be?
- What should the design temperature be?
- What should the relief valve setting be?

Quality Factors

Casting quality factor E_c (302.3.3)

- Used for cast components not having ratings
- E_c = 1.00 for gray and malleable iron
- E_c = varies from 0.80 to 1.00 depending on the level of examination
- Table A-1A lists E_c for specific products

Weld joint quality factor E_j (302.3.4)

- Table 322.3.4 lists factors used for pipe
- Some factors may be increased when additional examination is performed
- Table A-1B lists E_j for specific products

Weld Joint Quality Factor E_j

Type of Weld	Factor (Table 302.2.4)
None (seamless)	1.00
Electric Resistance Weld	0.85
Furnace Butt Weld	0.60
Single Fusion Weld	0.80 to 1.00*
Double Fusion Weld	0.85 to 1.00*
API 5L SAW, GMAW	0.95

*Depending on level of examination

Weld Joint Strength Factor

Weld joint strength reduction factor W (302.3.5)

- Used to account for the long-term (creep) strength of welds that may be lower than the base material
- In the absence of more applicable data, W shall be
  - 1.00 for all materials 950ºF (510ºC) and below
  - 0.50 for all materials at 1500ºF (815ºC)
  - Linearly interpolated for intermediate temperatures
- W values are based on testing of selected low alloys, stainless steels, and nickel alloys

Pressure Design of Components

- Four Methods for Pressure Design
- Straight Pipe
- Fittings
  - Pipe Bends
  - Miter Bends
  - Reducers
- Fabricated Branch Connections
- Flanges and Blanks
- Other Components

Four Methods for Pressure Design

- Calculations in accordance with Code formula
- Ratings given in a component standard
- Ratings same as straight seamless pipe
- Qualification by calculation plus experience, analysis or test

Straight Pipe

Total thickness required is the sum of

1. Pressure design thickness
2. Manufacturing tolerance (usually 12.5% of the nominal wall thickness)
3. Corrosion (or erosion) allowance
4. Mechanical allowances, e.g. threading

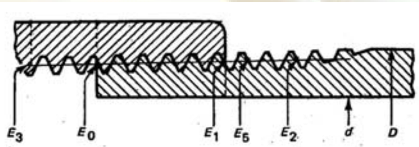


FIG. 3 AMERICAN NATIONAL STANDARD TAPER PIPE THREAD NOTATION

Straight Pipe

Threading allowance – nominal thread depth described in ASME B1.20.1

NPS	Depth (in.)	Depth (mm)
½ & ¾	0.057	1.45
1 thru 2	0.069	1.77

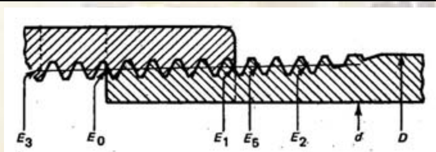


FIG. 3 AMERICAN NATIONAL STANDARD TAPER PIPE THREAD NOTATION

Straight Pipe

$$t = PD / [2 (SEW + PY)]$$

Where:

- t = pressure design thickness
- P = design pressure
- D = outside diameter of pipe
- S = stress value for material from Appendix A
- E = quality factor
- W = weld joint strength reduction factor
- Y = coefficient (function of material and temperature), usually 0.4

Coefficient Y

	≤900ºF ≤482ºC	950ºF 510ºC	1000ºF 538ºC	1050ºF 566ºC	1100ºF 593ºC	≥1150ºF ≥ 621ºC
Ferritic Steels	0.4	0.5	0.7	0.7	0.7	0.7
Austenitic Steels	0.4	0.4	0.4	0.4	0.5	0.7
Other Ductile Metals	0.4	0.4	0.4	0.4	0.4	0.4
Cast Iron	0.0	---	---	---	---	---

Straight Pipe Wall Thickness

Workshop: What is the required nominal pipe wall thickness for the following case:

- Styrene monomer service
- ASTM A53 Gr B ERW carbon steel pipe
- Design pressure and temperature from Problems 1 and 2, page 24 of the supplement.
- S = 20,000 psi (138 MPa) - verify
- Corrosion allowance = 1/8" (3.2 mm)
- Socket welding thru NPS 1½
- Buttwelding NPS 2 and larger

See Supplement starting on page 31.

Pipe Wall Thicknesses

Carbon Steel	Also for Carbon Steel	Stainless Steel
STD WT	Sch 10	Sch 5S
XS WT	Sch 20	**Sch 10S**
XXS WT	Sch 30	**Sch 40S**
	Sch 40	Sch 80S
	Sch 60	
	Sch 80	
	Sch 160	

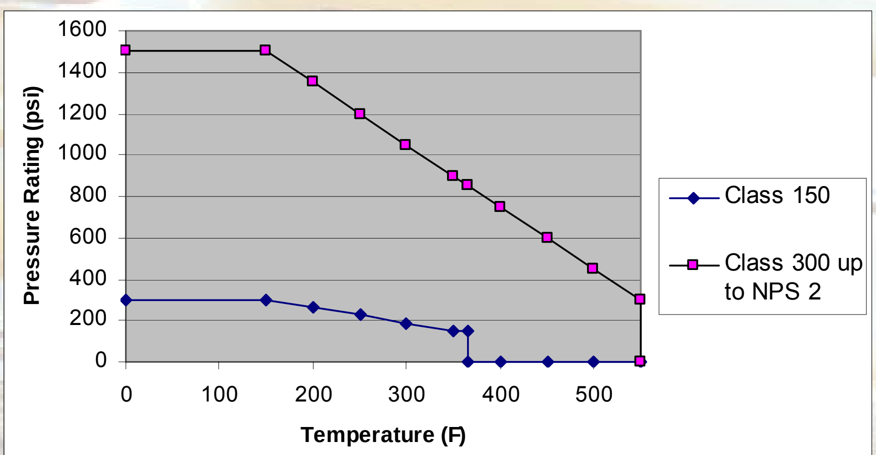
Pipe Wall Thickness

- STD WT and Sch 40 are the same NPS 1/8 through 10
- STD WT is 3/8" (9.52 mm) NPS 12 and larger
- XS WT and Sch 80 are the same NPS 1/8 through 8
- XS WT is 1/2" (12.70 mm) NPS 8 and larger
- Sch 40S is the same as STD WT
- Sch 80S is the same as XS WT

Fittings

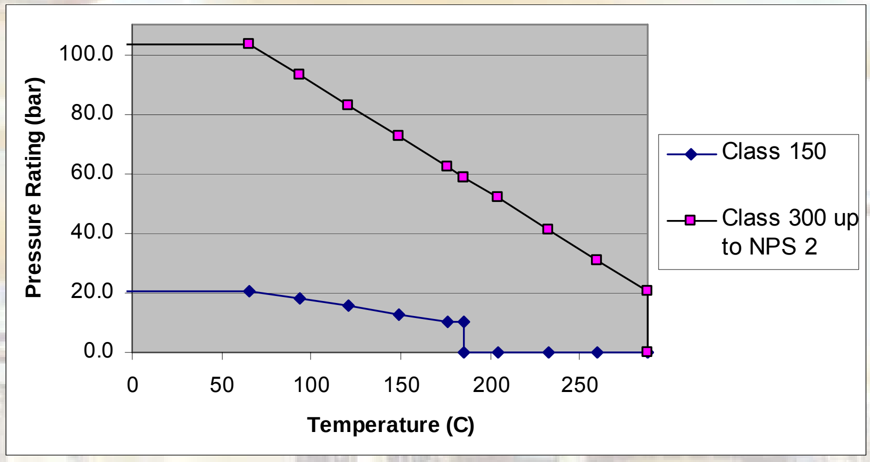
- *Listed Fittings* – Can be used within their pressure-temperature ratings
- *Unlisted Fittings* – Must have pressure-temperature ratings that conform with para. 304
  - Rules for specific geometries in paras. 304.2 through 304.6
  - Rules for other geometries in para. 304.7

Fittings - Listed Fitting Example



B16.3 – Malleable Iron Threaded Fittings
(US Customary Units)

Fittings - Listed Fitting Example



B16.3 – Malleable Iron Threaded Fittings
(Metric Units)

Fittings - Listed Fitting Example

B16.9 – Wrought Steel Buttweld Fittings

The allowable pressure ratings for fittings designed in accordance with this standard may be calculated as for straight seamless pipe of equivalent material…in accordance with the rules established in the applicable sections of ASME B31…Pipe size, wall thickness…and material identity on the fittings are in lieu of pressure rating markings.

Fittings - Listed Fitting Example

B16.11 – Forged Fittings, Socket Welding & Threaded

Design temperature and other service conditions shall be limited as provided by the applicable piping code or regulation for the material of construction of the fittings. Within these limits the maximum allowable pressure of a fitting shall be that computed for straight seamless pipe of equivalent material…

Fittings - Listed Fitting Example

B16.11 – Forged Fittings, Socket Welding & Threaded The schedule of pipe corresponding to each Class of fitting for rating purposes is shown…

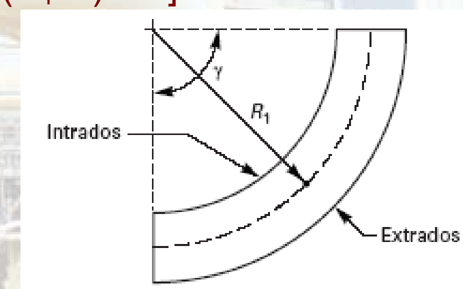
Class	Thd/SW	Sch No.	Wall
2000	Thd	80	XS
3000	Thd	160	---
6000	Thd	---	XXS
3000	SW	80	XS
6000	SW	160	---
9000	SW	---	XXS

Pipe Bends

$$t = PD / [2 (SEW/I + PY)]$$

Where:

- $I = [4(R_1/D) – 1] / [4(R_1/D) – 2]$ at the intrados
- $I = [4(R_1/D) + 1] / [4(R_1/D) + 2]$ at the extrados
- $I =$ 1.0 at the side centerline
- $R_1 =$ Bend radius

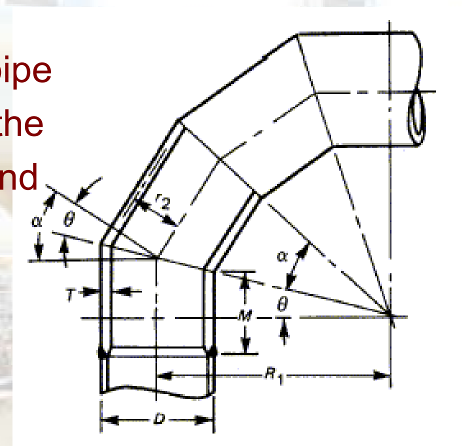


Miter Bends

$$P_m = [SEW(T-c)/r_2] * GF$$

Where:

- $r_2 =$ mean radius of pipe
- GF = factor based on the miter angle (α) and bend radius



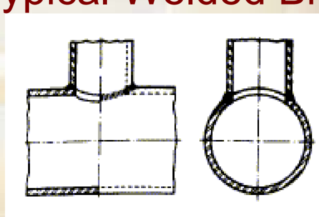
Reducers

May be designed in accordance with rules in ASME B&PV Code, Section VIII, Division 1 for conical or toriconical sections.

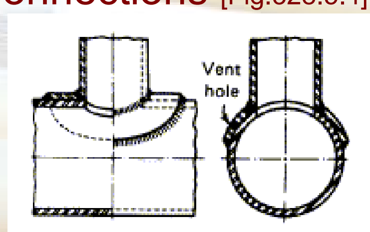
BECHT *ENGINEERING COMPANY, INC.* Pressure Design of Metals - 35

Fabricated Branch Connections

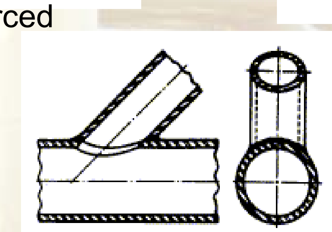
Typical Welded Branch Connections [Fig.328.5.4]



Unreinforced



Reinforced



Lateral (angular branch)

BECHT *ENGINEERING COMPANY, INC.* Pressure Design of Metals - 36

Fabricated Branch Connections

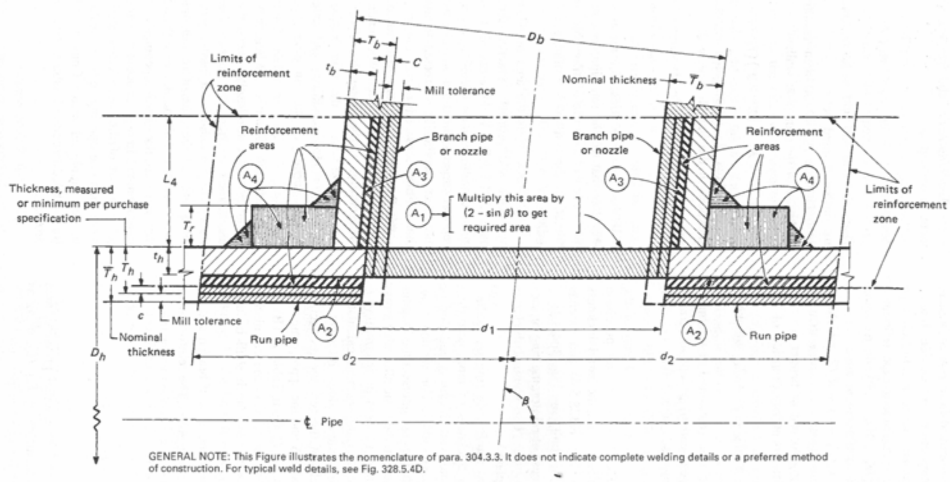


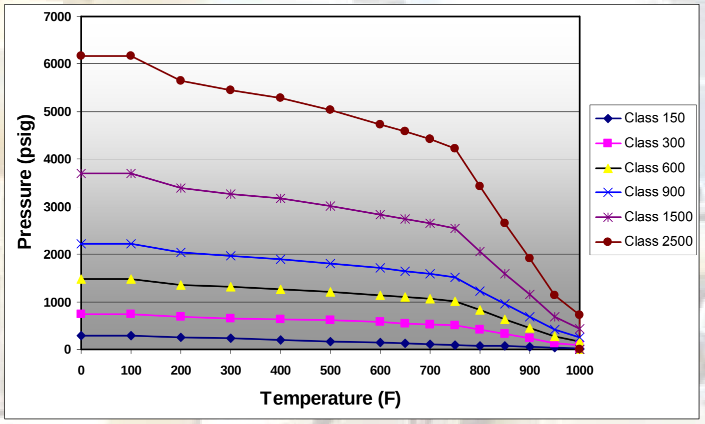
FIG. 304.3.3 BRANCH CONNECTION NOMENCLATURE

Flanges and Blanks

- *Listed Flanges & Blanks* – Can be used within their pressure-temperature ratings
- *Unlisted Flanges & Blanks* – Must have pressure-temperature ratings that conform with
  - Rules for specific geometries in paras. 304.5
  - Rules for other geometries in para. 304.7

Flanges and Blanks

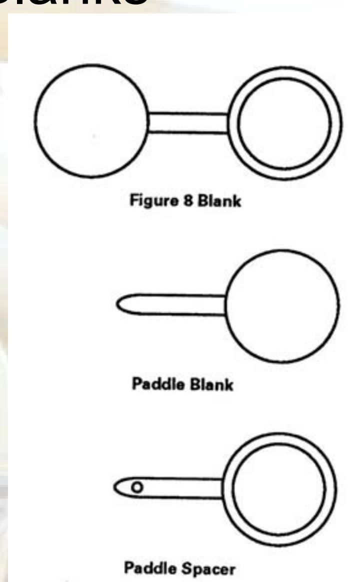
Listed Flange Example: B16.5 – Pipe Flanges and Flanged Fittings



Flanges and Blanks

Listed Blank Example:
B16.48 – Steel Line Blanks

- Ratings the same as for flanges of corresponding material
- Blank thicknesses were determined in accordance with B31.3 rules



Flanges and Blanks

Unlisted Flanges & Banks:

- Flanges may be designed in accordance with ASME B&PV Code, Section VIII, Division 1, Appendix 2 with B31.3 allowable stresses
- Blanks may be designed in accordance with para. 304.5.3

Other Components [304.7.2]

Components for which there are no specific rules require:

- Calculations consistent with the design criteria of B31.3, and
- Substantiation of the calculations by
  - Extensive successful experience
  - Experimental stress analysis
  - Proof test, or
  - Finite element stress analysis
- Documentation available for owner's approval
- Interpolation between sizes & thicknesses allowed

Piping Material Specifications

Descriptions of components in a piping material specification should include as applicable:

- Generic description of the component
- Material specification, usually ASTM (include material grade)
- Rating or wall thickness
- Product specification, usually B16 or MSS
- Ends (buttweld, socket weld, threaded)
- Type and facing for flanges

ASME B31.3 Process Piping

Charles Becht IV, PhD, PE
Don Frikken, PE
Instructors

Piping Development Process

1. Establish applicable system standard(s)
2. Establish design conditions
3. Make overall piping material decisions
   - Pressure Class
   - Reliability
   - Materials of construction
4. Fine tune piping material decisions
   - Materials
   - Determine wall thicknesses
   - Valves
5. Establish preliminary piping system layout & support configuration
6. Perform flexibility analysis
7. Finalize layout and bill of materials
8. Fabricate and install
9. Examine and test

5. Valve Selection

- Code Requirements
- Selection by Valve Type
  - Gate
  - Globe
  - Check
  - Butterfly
  - Ball
  - Plug

The Material in This Section is Addressed by B31.3 in:

Chapter IV - Standards for Piping Components

Code Requirements

Listed Valves

- Can be used within their pressure-temperature ratings and any additional limitations described in the Code
- Except that bolted bonnets secured by fewer than 4 bolts or a U-bolt may only be used in Category D Fluid Service.

[307]

Code Requirements

Unlisted Valves can be used within Code limitations if they:

- have dimensions that “conform to those of comparable listed components insofar as practicable”
- “provide strength and performance equivalent to standard components”, and
- satisfy one of the following:
  - pressure-temperature ratings established by the method described in Annex F of ASME B16.34, or
  - are qualified for pressure design as required by para. 304.7.2.

Selection by Valve Type

- Gate
- Globe
- Check
- Butterfly
- Ball
- Plug

BECHT *ENGINEERING COMPANY, INC.* Valve Selection - 7

Gate Valve

From

API 603

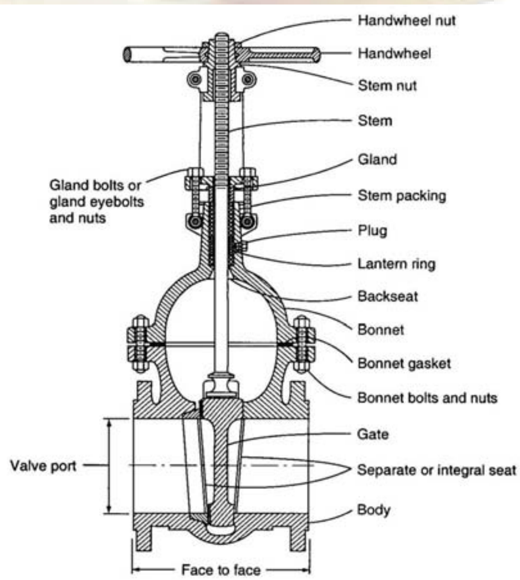
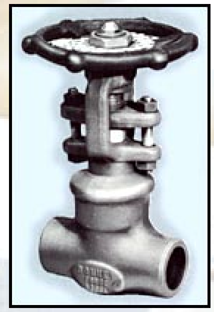


Figure 1—Typical Bolted Bonnet Gate Valve Nomenclature

BECHT *ENGINEERING COMPANY, INC.* Valve Selection - 8

Gate Valve Bonnets


Bolted

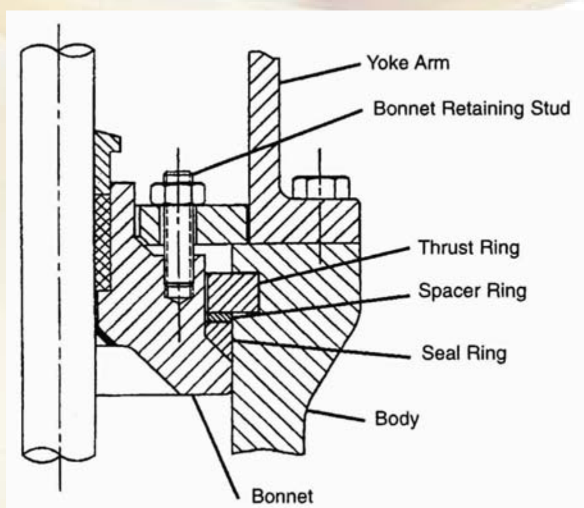

Welded


Screwed


Union

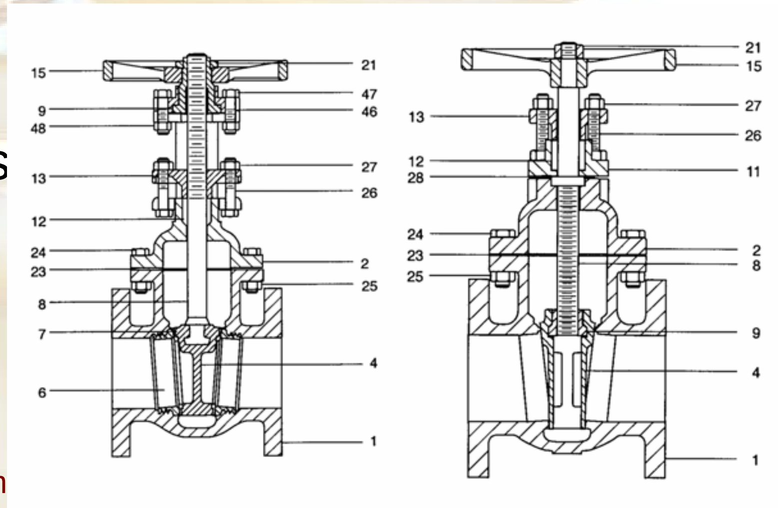
From
Bonney
Stockham
Milwaukee

Gate Valve Bonnets



Pressure Seal Body to Bonnet Joint

Gate Valve Stems



From Stockham

Outside Screw and Yoke (OS&Y)

Inside Screw Non-rising Stem

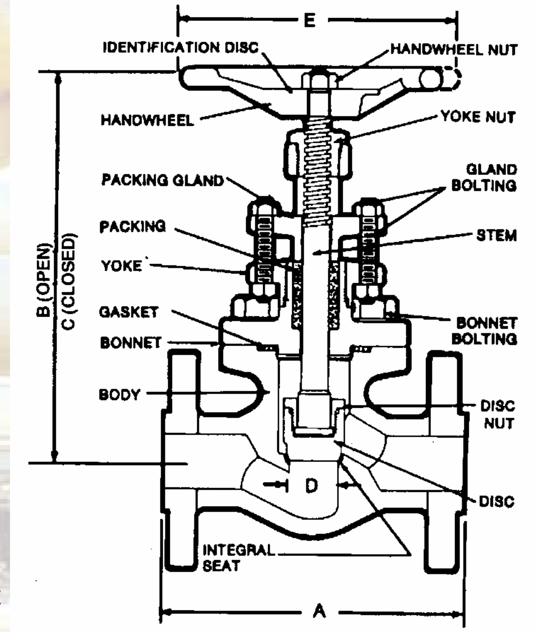
BECHT *ENGINEERING COMPANY, INC.* Valve Selection - 11

Gate Valve Attributes

- On-off applications (Not considered suitable for throttling)
- Works as well with flow from either direction
- Suitable for use in wide range of conditions
- Can be made fire resistant and blow-out resistant
- Available in any size
- Blocked-in volume when the valve is closed
- Almost always leaks through the seat

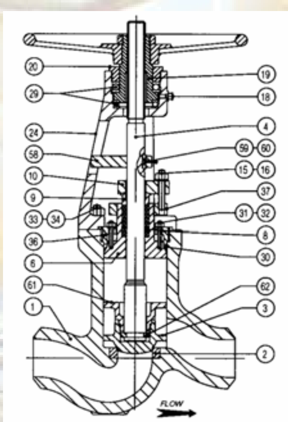
BECHT *ENGINEERING COMPANY, INC.* Valve Selection - 12

Globe Valve

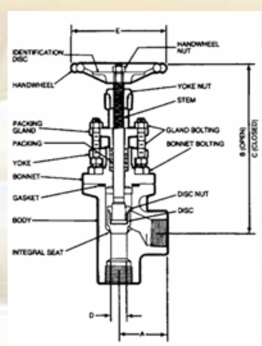


From Vogt

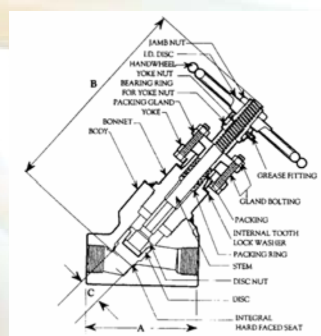
Globe Valve



Straight-pattern Globe with Pressure-seal Bonnet (Ramondi)



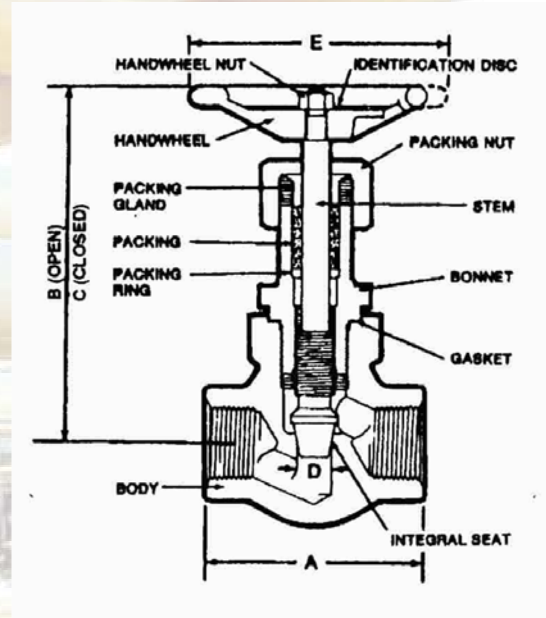
Angle Globe (Vogt)



Y-Pattern Globe (Vogt)

Needle Instrument Valve

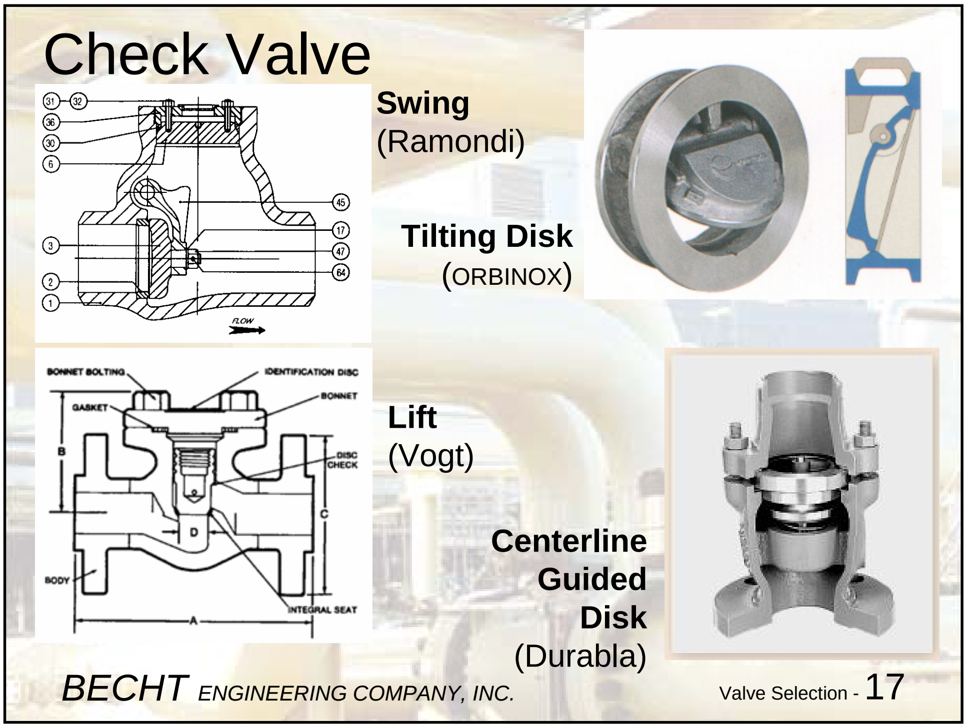
MSS-SP-105

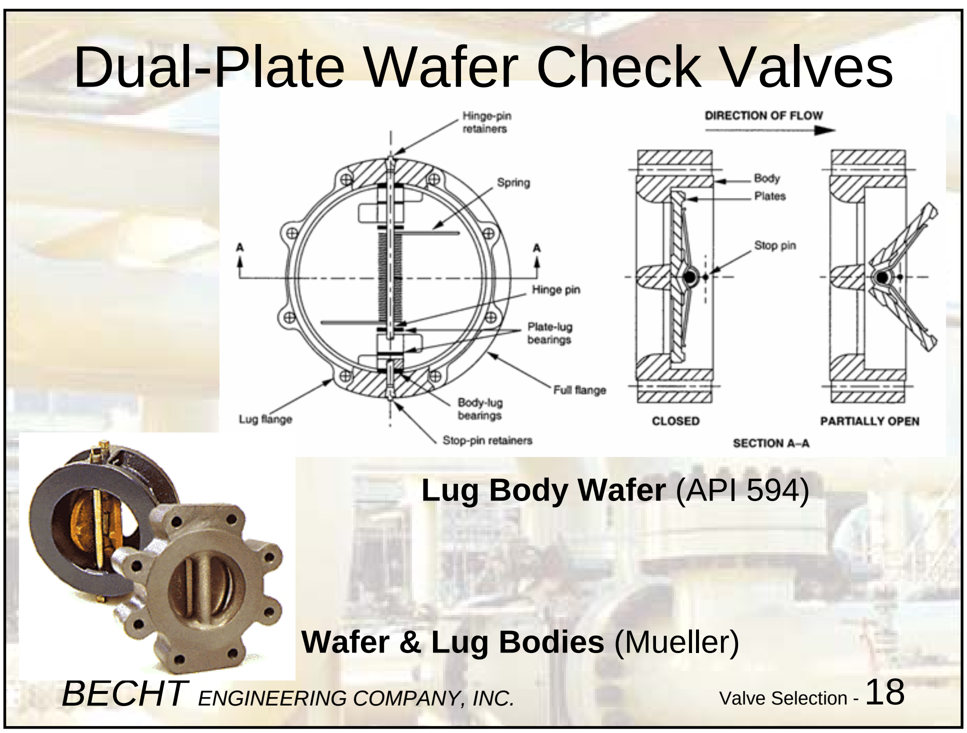


From Vogt

Globe Valve Attributes

- Suitable for on-off applications and throttling
- Works best with flow from one direction
- Suitable for use in wide range of conditions
- Can be made fire resistant and blow-out resistant
- Available in sizes up to about NPS 14
- No blocked-in volume when the valve is closed
- Almost always leaks through the seat, but less than a gate valve


Check Valve
Swing
(Ramondi)
Tilting Disk
(ORBINOX)
Lift
(Vogt)
Centerline
Guided
Disk
(Durabla)
FLOW
BONNET BOLTING
IDENTIFICATION DISC
BONNET
GASKET
DISC CHECK
BODY
INTEGRAL SEAT
BECHT ENGINEERING COMPANY, INC.
Valve Selection - 17


Dual-Plate Wafer Check Valves
Hinge-pin retainers
DIRECTION OF FLOW
Spring
Body
Plates
Stop pin
Hinge pin
Plate-lug bearings
Full flange
Body-lug bearings
Lug flange
Stop-pin retainers
CLOSED
PARTIALLY OPEN
SECTION A–A
Lug Body Wafer (API 594)
Wafer & Lug Bodies (Mueller)
BECHT ENGINEERING COMPANY, INC.
Valve Selection - 18

Check Valve Attributes

- Works only with flow from one direction
- Suitable for use in wide range of conditions
- Can be made fire resistant and blow-out resistant
- Available in any size
- No blocked-in volume when the valve is closed
- Almost always leaks through the seat, but much more than a gate valve

Check Valve Attributes

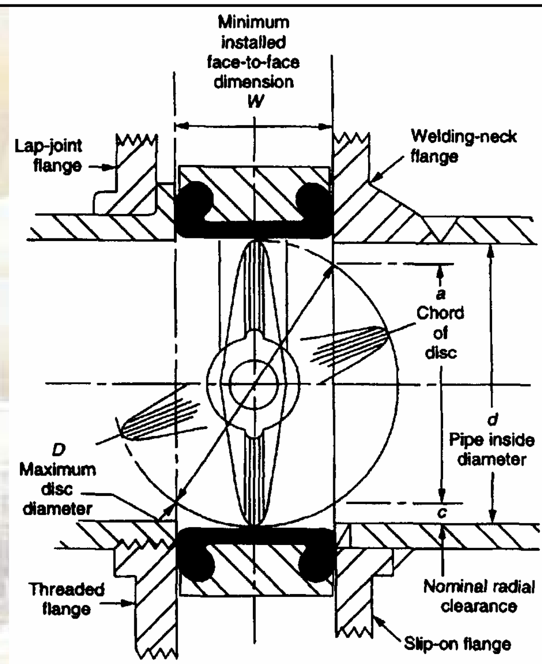
- Check valves check about 95% of the time
- Check valves can close suddenly when the flow is reversed, causing severe water hammer

Valve Type	Slam Characteristics
Swing	Severe (improved with weight or spring)
Lift	Severe (improved with spring return)
Wafer	Good
Tilting Disk	Excellent
C/L Disk	Excellent

Butterfly Valve – Low Pressure

From API 609

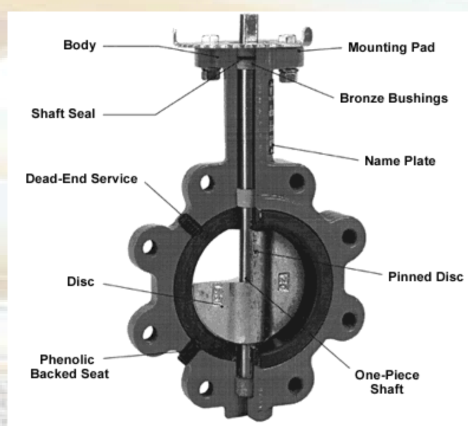
Category A



BECHT *ENGINEERING COMPANY, INC.* Valve Selection - 21

Butterfly Valve – Low Pressure

Wafer Body, PTFE Lined (Durco)



Lug Body (Contromatics)

BECHT *ENGINEERING COMPANY, INC.* Valve Selection - 22

Butterfly Valve – Low Pressure

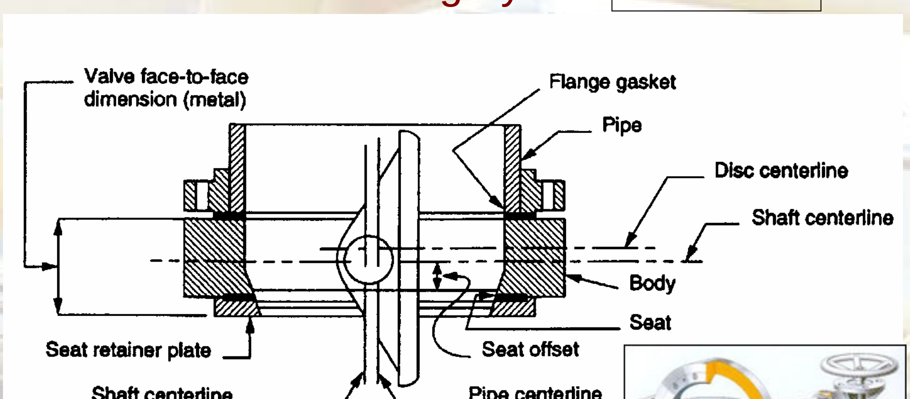
- Suitable for on-off applications and throttling
- Works as well with flow from either direction
- Suitable for use up to ~200°F (95°C), 150 psig (10 bar)
- Cannot be made fire resistant or blow-out resistant
- Generally available NPS 3 and larger
- No blocked-in volume when the valve is closed
- Usually does not leak through the seat
- Can be PTFE Lined

BECHT *ENGINEERING COMPANY, INC.* Valve Selection - 23

Butterfly Valve – High Pressure

From API 609 - Category B

Double offset

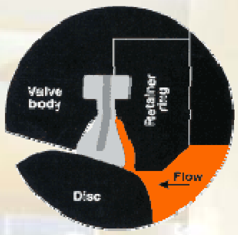


BECHT *ENGINEERING COMPANY, INC.* Valve Selection - 24

Butterfly Valve – High Pressure

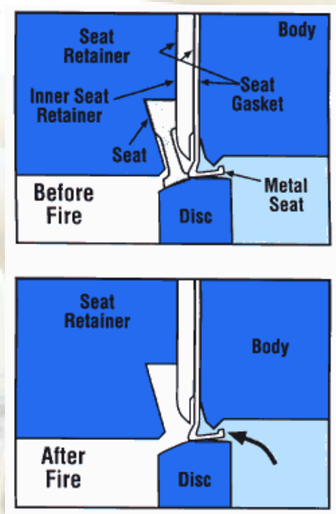
Valve Seats

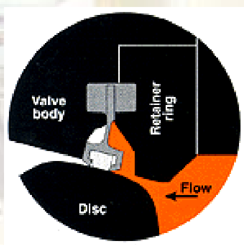
Double offset



PTFE Seat
(Xomox)

Fire Resistant Seat
(Contromatics)





Fire Resistant Seat
(Xomox)

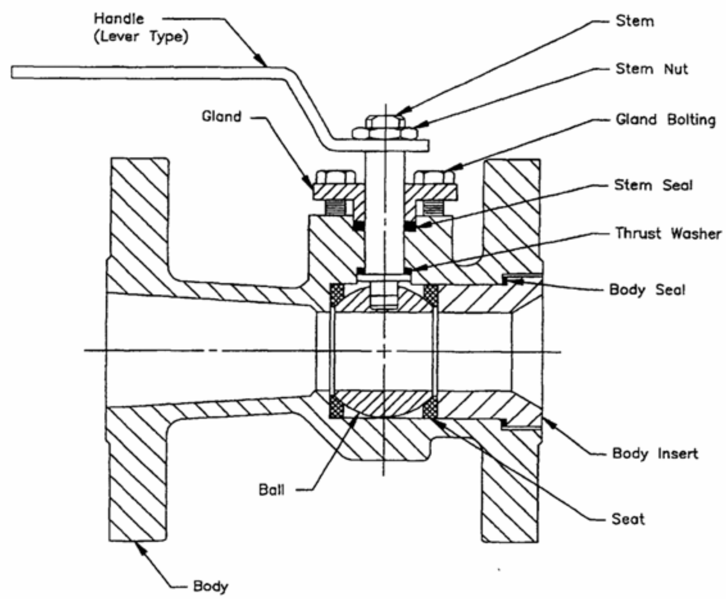
Butterfly Valve – High Pressure

- Suitable for on-off applications and throttling
- Generally works as well with flow from either direction
- Suitable for use in wide range of conditions, but PTFE seats limited to ~400°F (200°C)
- Can be made fire resistant and blow-out resistant
- Generally available NPS 3 and larger
- No blocked-in volume when the valve is closed
- Usually does not leak through the seat

Ball Valve

From API 608

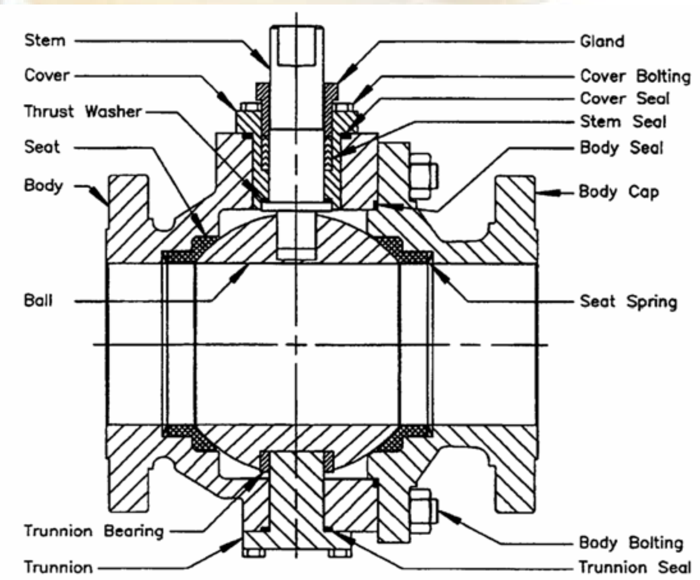
Floating Ball, End Entry



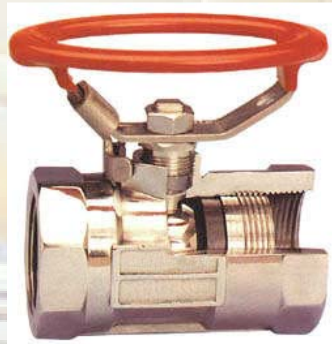
Ball Valve

From API 608

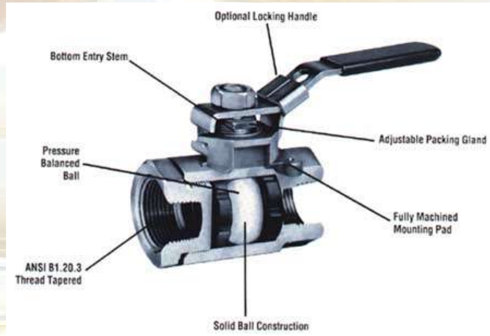
Trunnion Mounted, Two Piece



Ball Valve

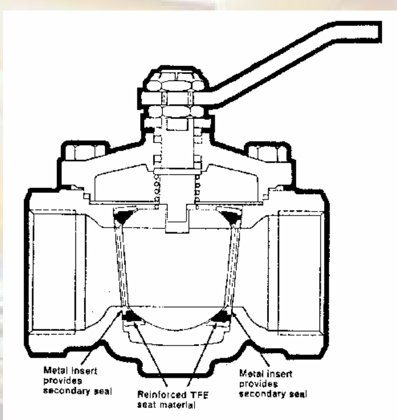


End Entry
Oval Handle
(Contromatics)

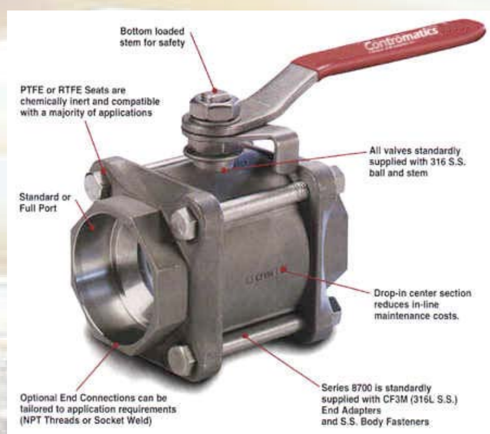


Two Piece
Lever Handle
(Contromatics)

Ball Valve

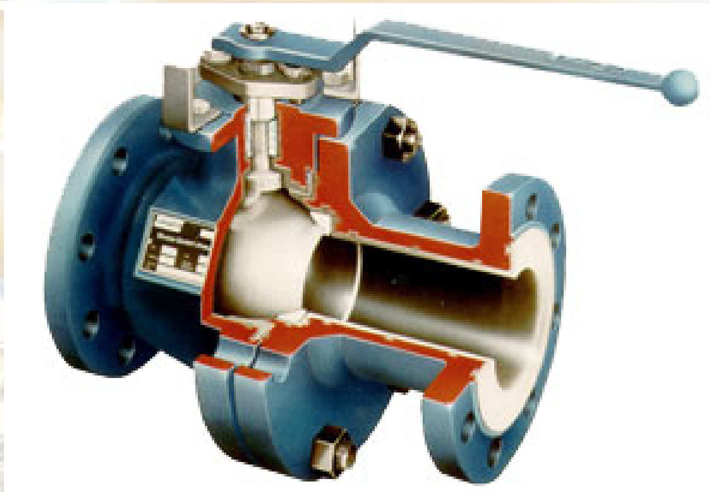


Top Entry



Three Piece (Swing-out)
(Contromatics)

Ball Valve



Two Piece, Fully Lined (Xomox)

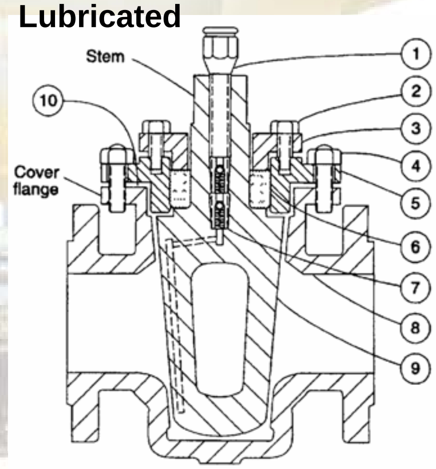
Ball Valve Attributes

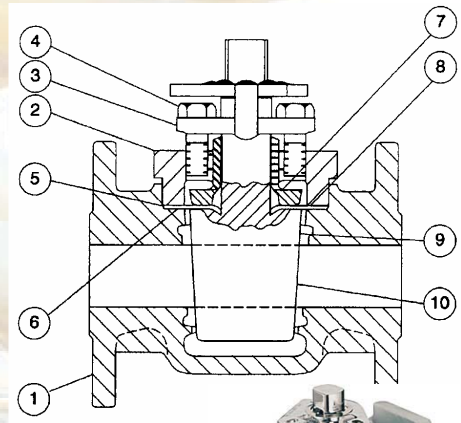
- On-off applications (not considered suitable for throttling)
- Works as well with flow from either direction
- Suitable for use in wide range of conditions, but PTFE seats limited to ~400 °F (200°C)
- Can be made fire resistant and blow-out resistant
- Available in any size
- Blocked-in volume when the valve is closed
- Usually does not leak through the seat

Plug Valve

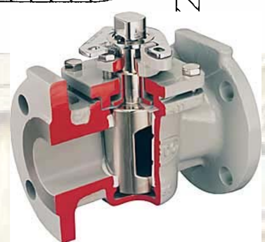
From API 599

Lubricated



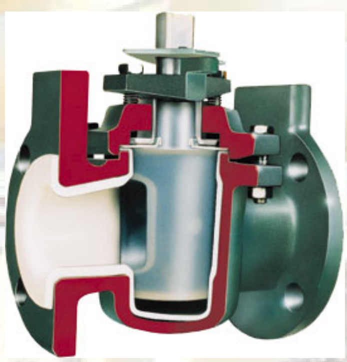


Sleeve Lined

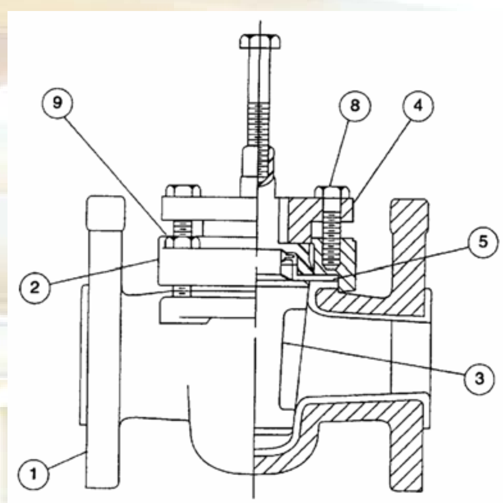


Plug Valve

Fully Lined



(Durco)



API 599

Plug Valve Attributes

- On-off applications and non-severe throttling
- Works as well with flow from either direction
- Suitable for use in wide range of conditions, but PTFE seats limited to ~400 °F (200°C)
- Can be made fire resistant (only lubricated type) and blow-out resistant
- Generally available up to ~NPS 12
- Blocked-in volume when the valve is closed
- Usually does not leak through the seat

Valve Selection Workshop

What valve attributes and block, throttle and check valve types would you select for the following services:

- Steam condensate
- Dry chlorine liquid
- Sulfuric acid
- Gasoline
- 650 psig (45 bar) Steam
- Heat transfer oil
- Styrene monomer
- Lime/water slurry

ASME B31.3 Process Piping

Charles Becht IV, PhD, PE
Don Frikken, PE
Instructors

Piping Development Process

1. Establish applicable system standard(s)
2. Establish design conditions
3. Make overall piping material decisions
   - Pressure Class
   - Reliability
   - Materials of construction
4. Fine tune piping material decisions
   - Materials
   - Determine wall thicknesses
   - Valves
5. Establish preliminary piping system layout & support configuration
6. Perform flexibility analysis
7. Finalize layout and bill of materials
8. Fabricate and install
9. Examine and test

6. Flexibility Analysis

- What are we trying to achieve?
- Flexibility Analysis Example

The Material in This Section is Addressed by B31.3 in:

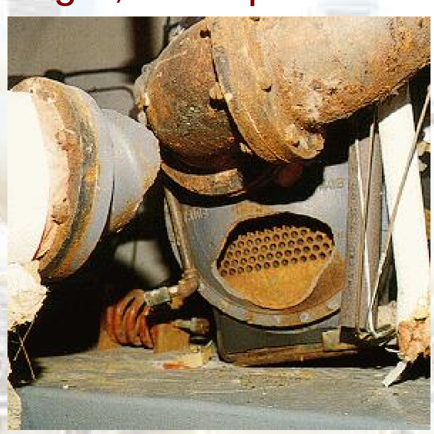
Chapter II - Design

What are we trying to achieve?

1. Provide adequate <u>support</u>;
2. Provide sufficient <u>flexibility</u>; and
3. Prevent the piping from exerting excessive <u>reactions</u>

What are we trying to achieve?

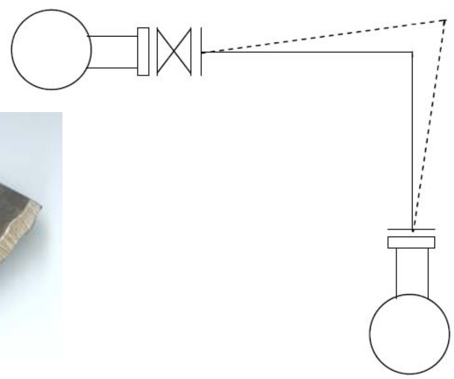
1. Provide adequate <u>support</u> to resist loads such as pressure, weight, earthquake and wind



January 17 1994 Northridge Earthquake

What are we trying to achieve?

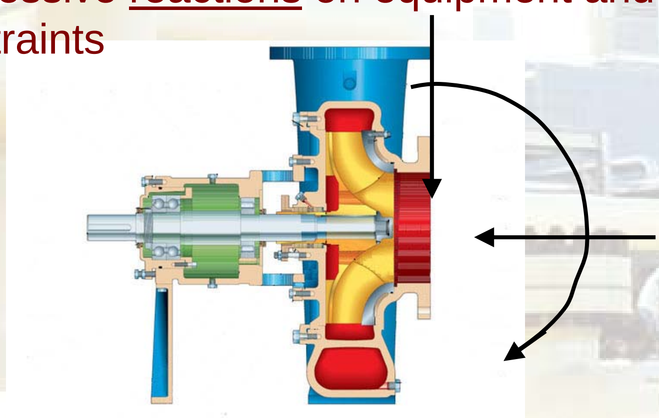
2. Provide sufficient flexibility to safely accommodate changes in length resulting from temperature variations



BECHT ENGINEERING COMPANY, INC. Flexibility Analysis - 7

What are we trying to achieve?

3. Provide sufficient support and flexibility to prevent the piping from exerting excessive reactions on equipment and restraints



BECHT ENGINEERING COMPANY, INC. Flexibility Analysis - 8

What are we trying to achieve?

And we do that in order to

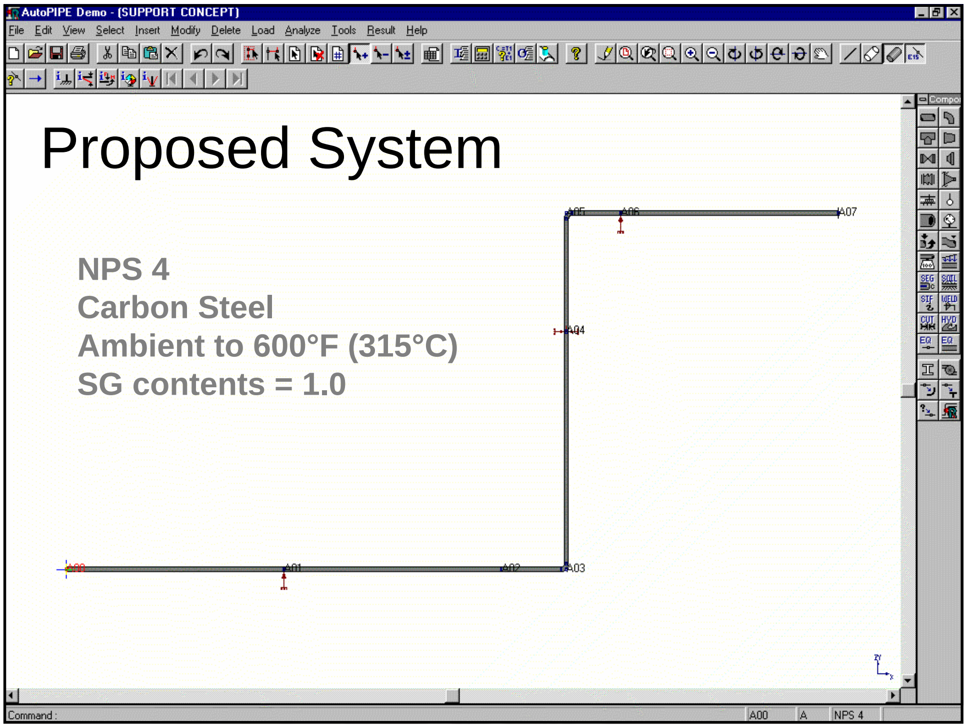
- make the piping look well supported to the facility engineers and operators
- prevent collapse of the piping
- prevent leaks due to fatigue cracks
- prevent joint leakage caused by excessive forces , and
- prevent failure or malfunction of attached equipment caused by excessive reactions

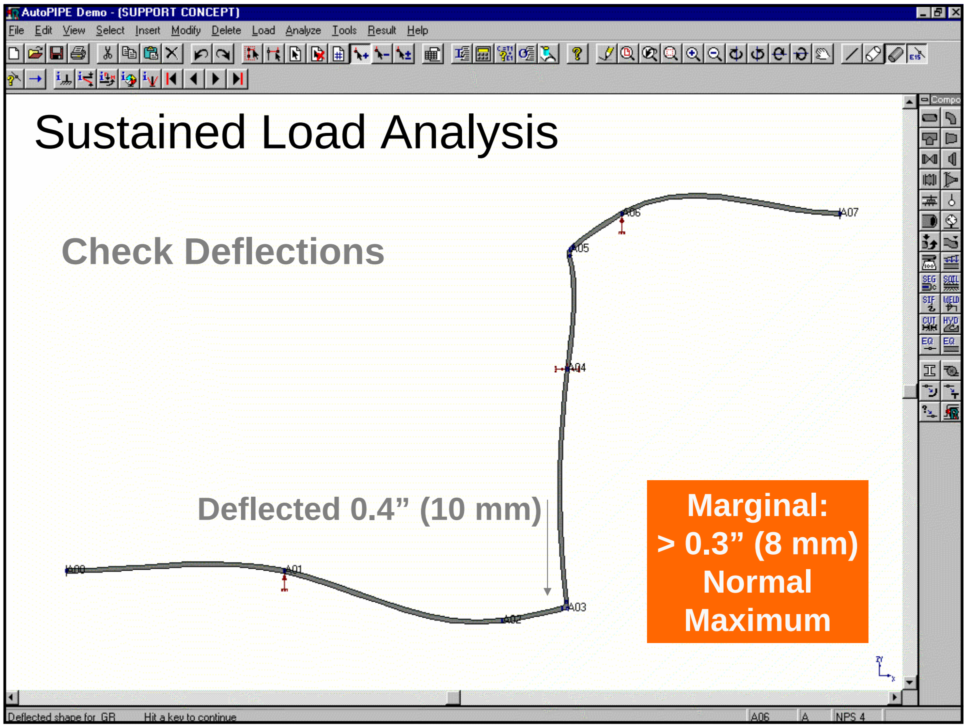
Flexibility Analysis Example

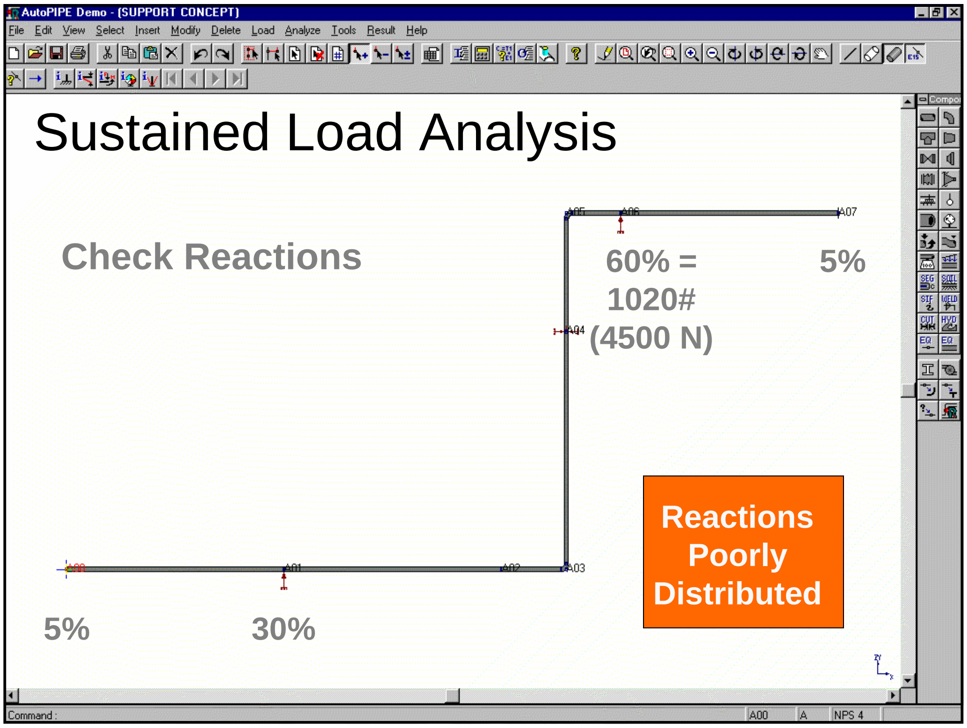
A two step analysis is shown.

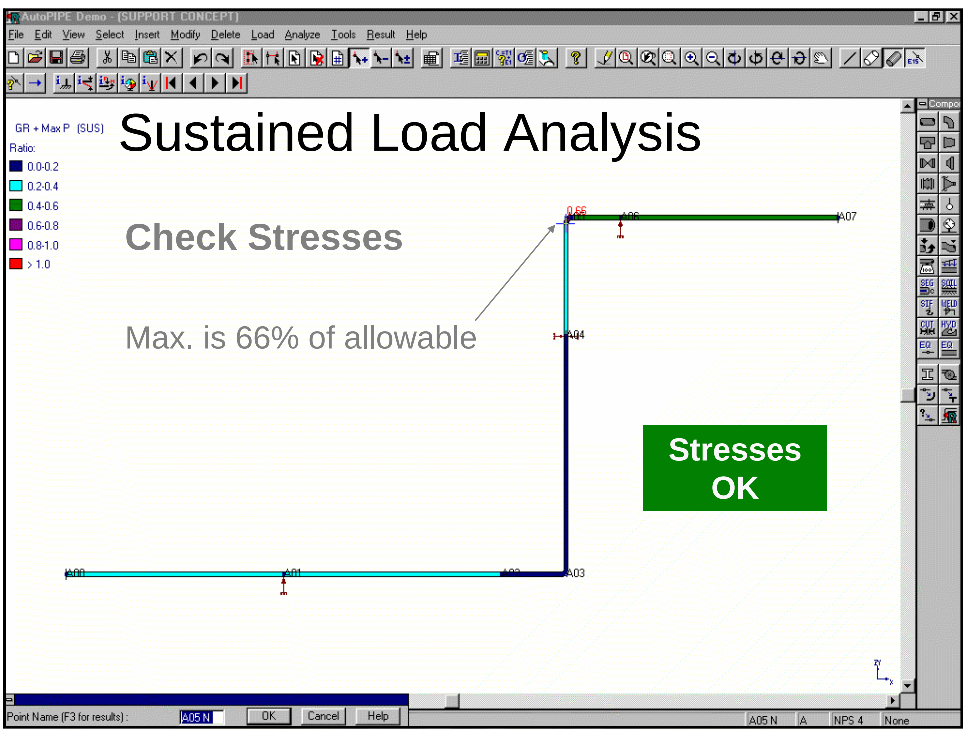
1. Weight and Pressure Loads – verify proper support and check reactions

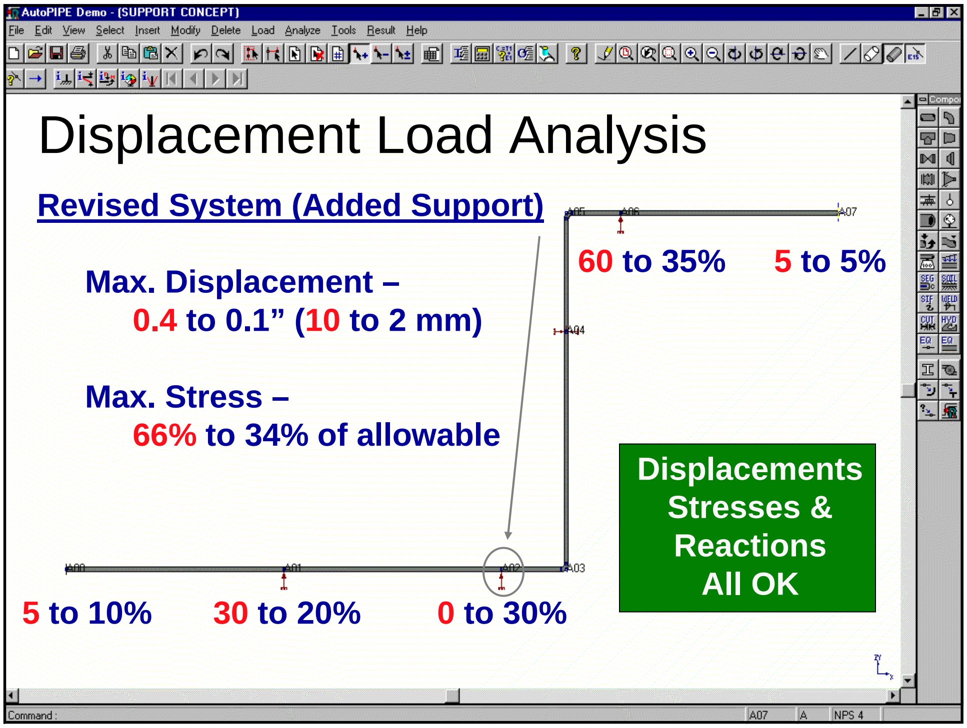
2. Thermal Expansion Load – verify adequate flexibility and check reactions

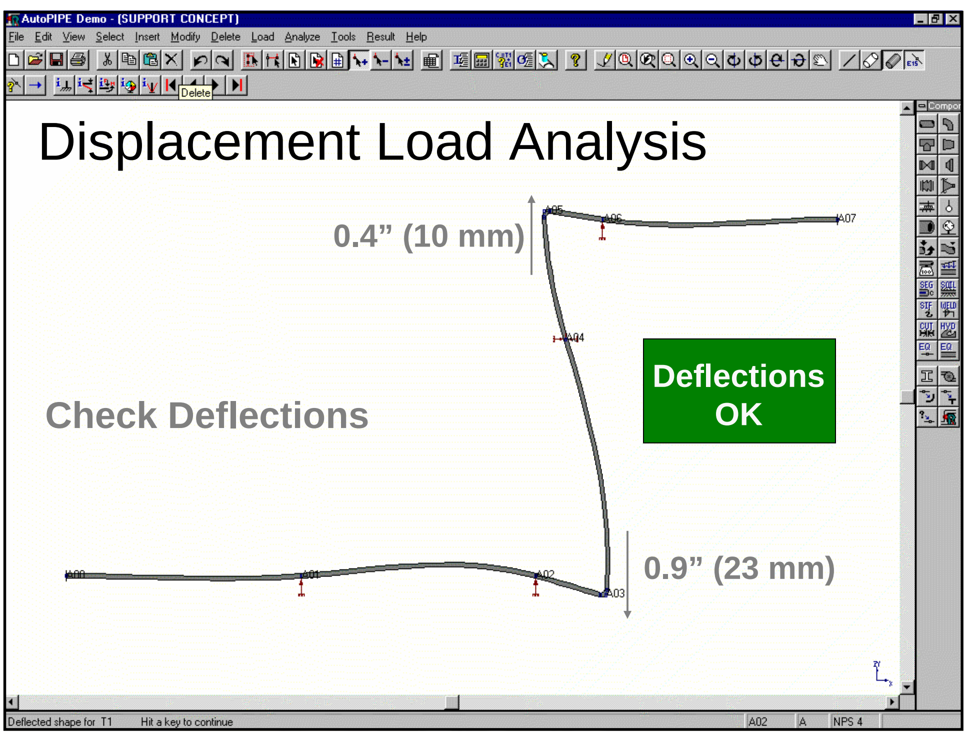

AutoPIPE Demo - [SUPPORT CONCEPT]
Proposed System
NPS 4
Carbon Steel
Ambient to 600°F (315°C)
SG contents = 1.0

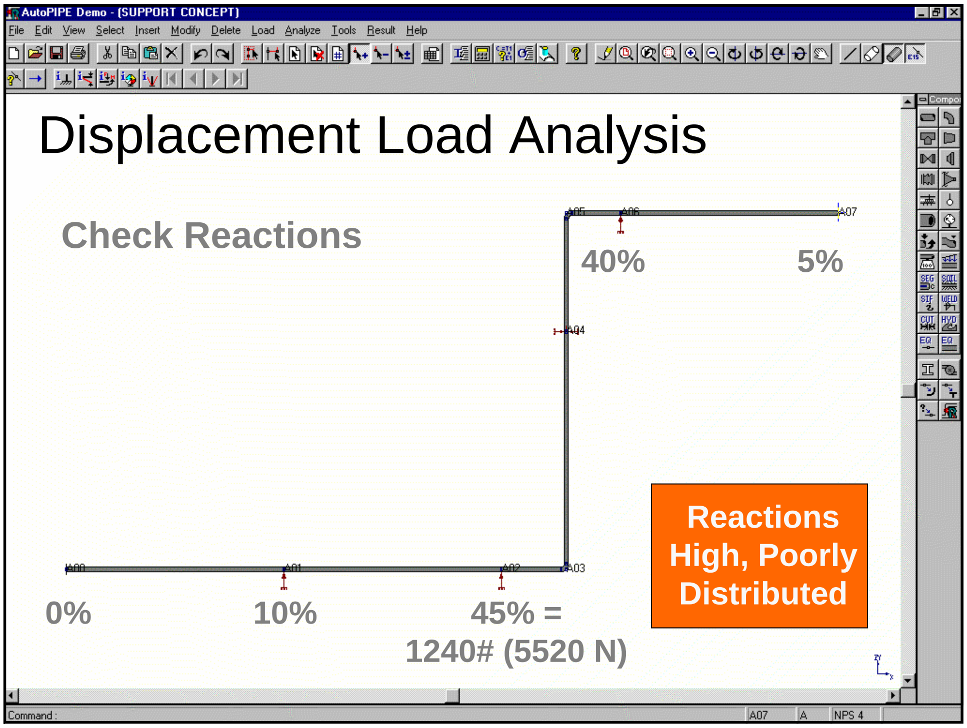

AutoPIPE Demo - [SUPPORT CONCEPT]
Sustained Load Analysis
Check Deflections
Deflected 0.4” (10 mm)
Marginal:
> 0.3” (8 mm)
Normal
Maximum

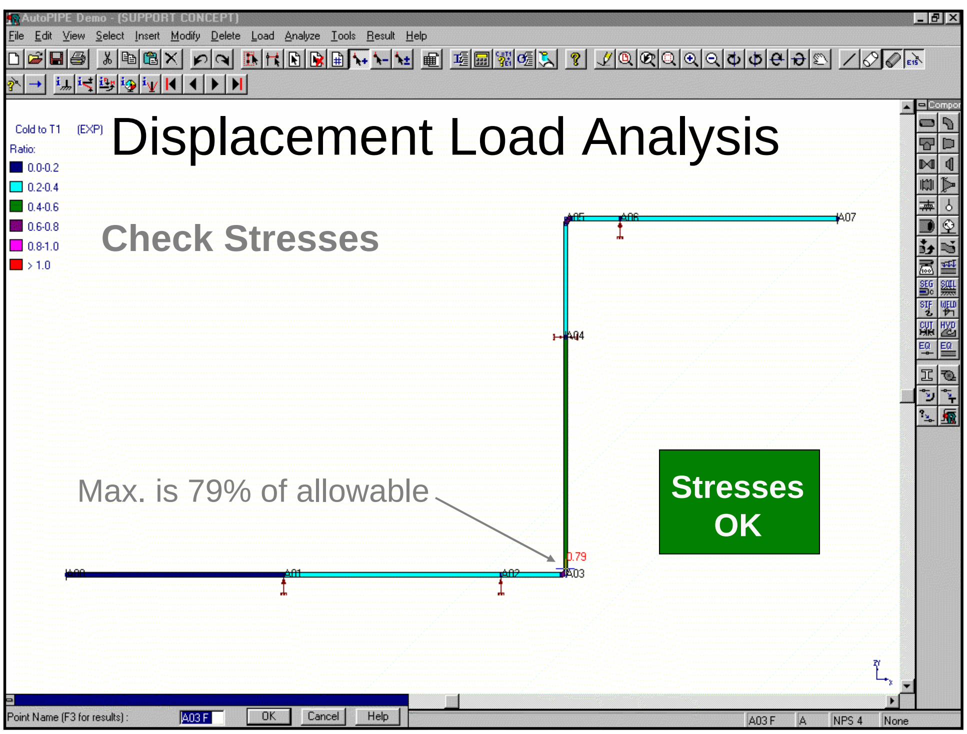

Sustained Load Analysis
Check Reactions
60% =
1020#
(4500 N)
5%
5%
30%
Reactions Poorly Distributed

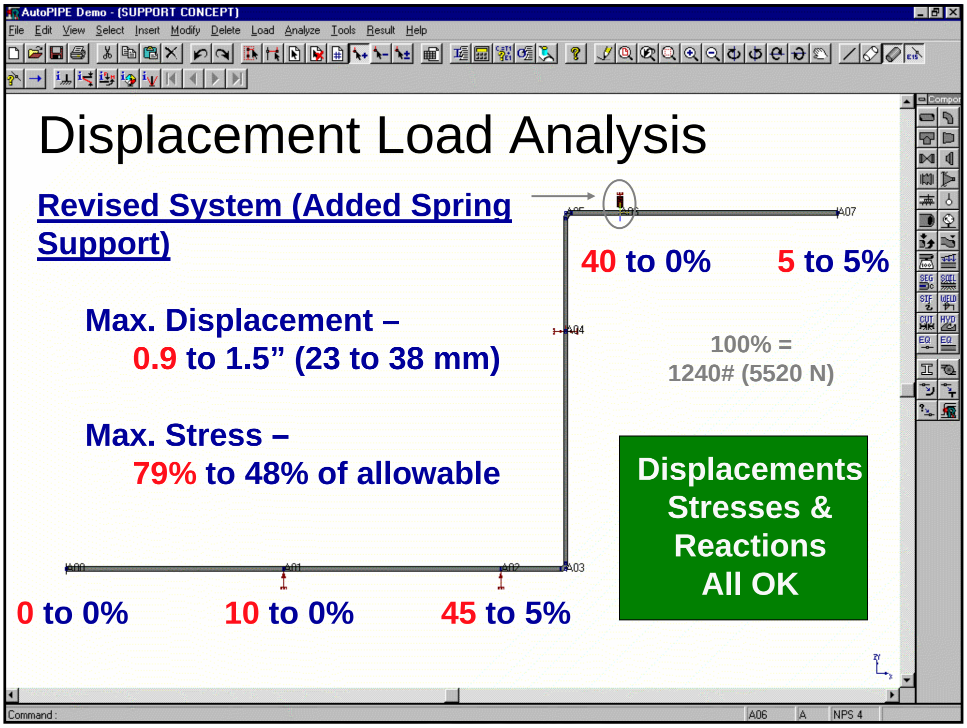

Sustained Load Analysis
GR + Max P (SUS)
Ratio:
0.0-0.2
0.2-0.4
0.4-0.6
0.6-0.8
0.8-1.0
> 1.0
Check Stresses
Max. is 66% of allowable
Stresses OK


AutoPIPE Demo - [SUPPORT CONCEPT]
Displacement Load Analysis
Revised System (Added Support)
Max. Displacement –
0.4 to 0.1” (10 to 2 mm)
Max. Stress –
66% to 34% of allowable
60 to 35%
5 to 5%
Displacements Stresses & Reactions All OK
5 to 10%
30 to 20%
0 to 30%


AutoPIPE Demo - [SUPPORT CONCEPT]
Displacement Load Analysis
0.4” (10 mm)
Check Deflections
Deflections OK
0.9” (23 mm)


AutoPIPE Demo - [SUPPORT CONCEPT]
Displacement Load Analysis
Check Reactions
40%
5%
Reactions High, Poorly Distributed
0%
10%
45% = 1240# (5520 N)


AutoPIPE Demo - [SUPPORT CONCEPT]
Displacement Load Analysis
Cold to T1 (EXP)
Ratio:
0.0-0.2
0.2-0.4
0.4-0.6
0.6-0.8
0.8-1.0
> 1.0
Check Stresses
Max. is 79% of allowable
0.79
Stresses OK



Flexibility Analysis

Is the process of calculating the strains, and resultant stresses and forces in a piping system to determine if the system

- has adequate support
- has sufficient flexibility to safely accommodate changes in length resulting from temperature variations
- exerts sufficiently low reaction forces at restraints and equipment

ASME B31.3 Process Piping

Charles Becht IV, PhD, PE
Don Frikken, PE
Instructors

Piping Development Process

1. Establish applicable system standard(s)
2. Establish design conditions
3. Make overall piping material decisions
   - Pressure Class
   - Reliability
   - Materials of construction
4. Fine tune piping material decisions
   - Materials
   - Determine wall thicknesses
   - Valves
5. Establish preliminary piping system layout & support configuration
6. Perform flexibility analysis
7. Finalize layout and bill of materials
8. Fabricate and install
9. Examine and test

7. Layout and Support

- General Considerations
- Support Spacing
- Support Locations
- Support Elements

BECHT ENGINEERING COMPANY, INC. Layout and Support - 3

The Material in This Section is Addressed by B31.3 in:

Chapter II - Design

BECHT ENGINEERING COMPANY, INC. Layout and Support - 4

General Considerations

- Access for operation (valves)
- Access for maintenance of in-line devices
  - instrumentation
  - Traps
  - strainers, etc.
- Avoiding interference with other activities
  - Removing heat exchanger bundles
  - Clearance for pump maintenance, etc.
- Appearance

General Considerations

- Drainage (slope) requirements
- Pressure drop
- Cost of piping, including maximizing use of existing supports
- Avoiding interference with other piping
  - Clearance for application of insulation
  - Clearance for piping displacement, etc.
- Provisions for future additions

Support Spacing

Loads to consider

- Dead Weight
  - Pipe
  - Insulation
  - Valves, specialty items and instruments
- Live loads
  - Pipe contents
  - Ice, snow
  - People

Support Spacing

Two principal sources:

1. Recognized codes & standards
   - ASME B31.1
   - MSS SP-69: Pipe Hangers and Supports – Selection and Application
2. Owner or designer calculated values

Support Spacing

NPS	MSS SP-69		Typical Calculated	
	ft	m	ft	m
1	7	2.1	14	4.3
2	10	3.0	20	6.1
4	14	4.3	26	7.9
6	17	5.2	30	9.1
8	19	5.8	32	9.8
10	22	6.1	34	10.4
12	23	7.0	36	11.0

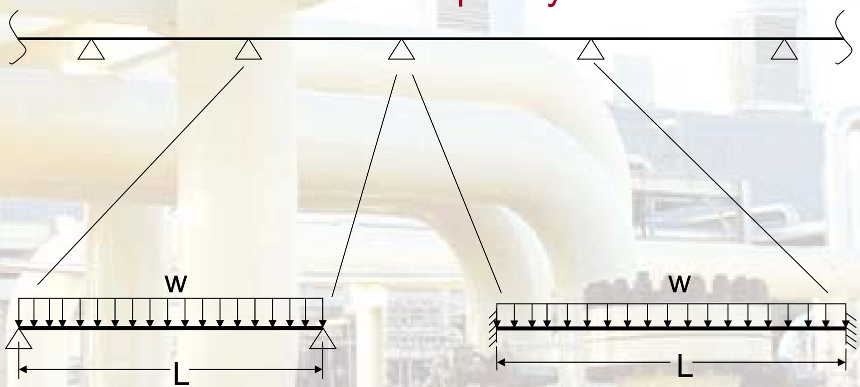
Support Spacing

Usually based on simplifying assumptions

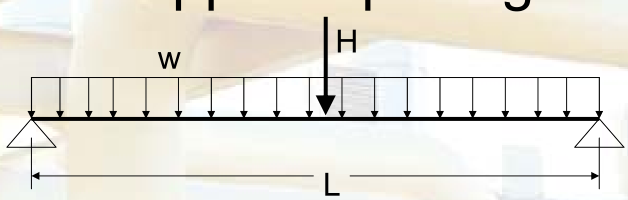
- Combination of pipe material and wall thickness used in the facility that gives the shortest spans
- Contents specific gravity, usually 1.0
- Typical insulation thickness and density
- Person walking on pipe for larger sizes

Support Spacing

Two Models Frequently Used



Support Spacing



S_L = stresses caused by bending moment and pressure

= M/Z + PD/4t

= $(wL^2 + 2HL) / (8Z) + PD/4t$

Support Spacing

$$S_L = (wL^2 + 2HL) / (8Z) + PD/4t$$

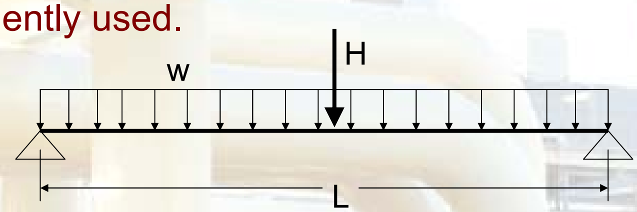
Where

- D = pipe outside diameter
- H = concentrated load (people)
- L = trial length for support spacing
- M = bending moment
- P = design pressure
- t = pipe wall thickness nominal wall thickness less mechanical, corrosion and erosion allowances
- w = uniform load due to pipe, contents & insulation
- Z = pipe section modulus

BECHT *ENGINEERING COMPANY, INC.* Layout and Support - 13

Support Spacing

Some designers limit support spacing using an arbitrary deflection criterion. 0.5 in. (12 mm) is frequently used.



$$\Delta_{max} = (5wL^4 / 384EI) + (HL^3 / 48EI)$$

Where

- **E = pipe material elastic modulus**
- **I = pipe moment of inertia**

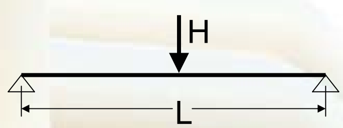
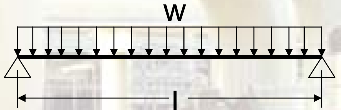
BECHT *ENGINEERING COMPANY, INC.* Layout and Support - 14

Support Spacing

- This calculation method is only applicable to straight pipe with more-or-less uniformly spaced supports.
- Using the simply supported beam model versus the fixed beam supported model adds some conservatism to the calculation.
- Other models that can be used are shown on succeeding slides.

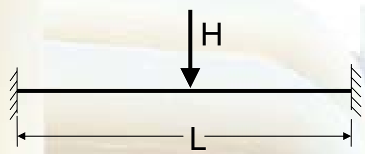
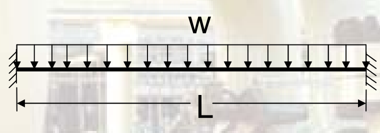
Support Spacing

Assuming simply supported ends

Concentrated load		$M = HL/4$ $\Delta_{max} = HL^3/48EI$
Uniform load		$M = wL^2/8$ $\Delta_{max} = 5wL^4/384EI$

Support Spacing

Assuming Fixed ends

Concentrated load		$M = HL/8$ $\Delta_{max} =$ $HL^3/192EI$
Uniform load		$M = wL^2/12$ $\Delta_{max} =$ $wL^4/384EI$

Support Locations

Supports must be located such that $S_L \leq S_h$. Following these rules of thumb will help:

- Piping running up the side of vessels should be supported from the vessel, generally near the top of the run.
- Locate concentrated loads (e.g. valves) near supports.
- Use rigid supports (i.e. not spring supports) at safety valves.

Support Locations

Following these rules of thumb will help when doing the flexibility analysis:

- As much as possible, attach supports to straight pipe rather than elbows or other fittings.
- Provide space for adding loops to piping near load sensitive equipment, e.g. in pump suction lines.
- Consider the need to add friction reducing slides between the piping and support steel.

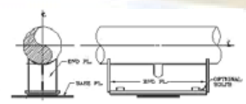
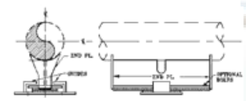
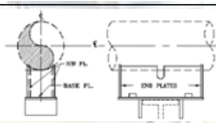
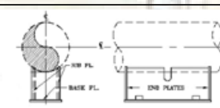
Support Locations

Following these rules of thumb will help operation and maintenance:

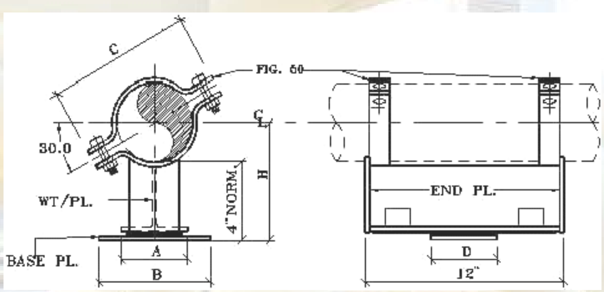
- Attach supports to pipe, not valves, flanges or instruments.
- Provide supports near instruments, and other devices that are likely to be removed for maintenance.
- Support piping such that spools to be removed for equipment maintenance can be removed without adding temporary supports.
- Minimize the use of spring hangers.

Support Elements

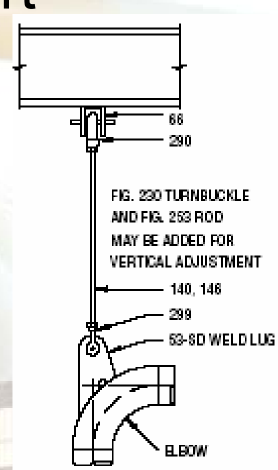
Support elements are classified by the degree of restraint provided to the piping

Simple Support	Only provides vertical restraint	
Guide	Restrains lateral movement (and sometimes vertical movement as well)	
Longitudinal Pipe Restraint	Restrains axial movement (and sometimes vertical movement as well)	
Anchor	Restrains movement in all directions (welded to support steel)	

Simple Support

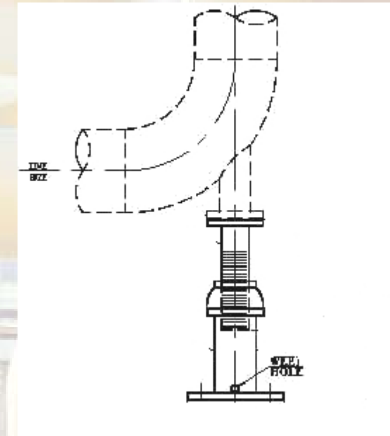


(from Piping Technology & Products)

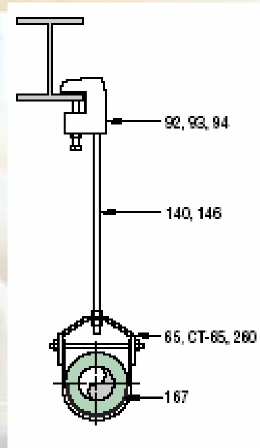


(from Anvil International)

Simple Support

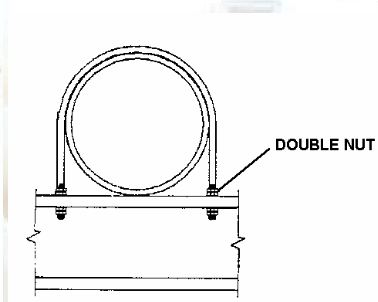


(from Piping Technology & Products)



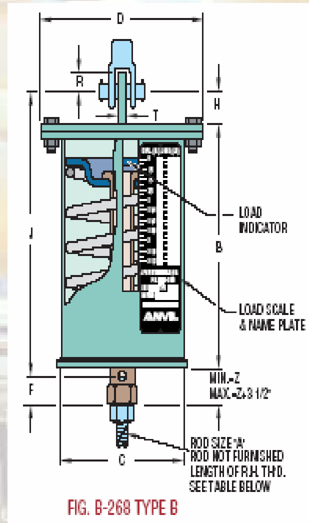
(from Anvil International)

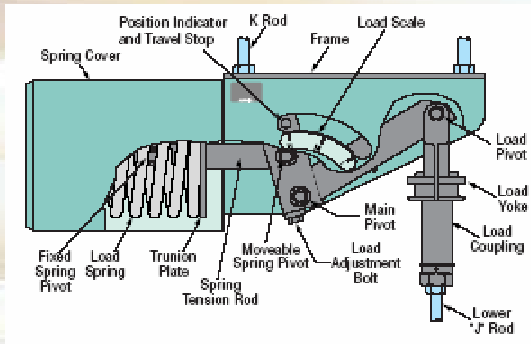
Guide



(from Anvil International)

Spring Hangers





(from Anvil International)

Constant Type

Variable Type

Special Purpose Supports

(from Anvil International)

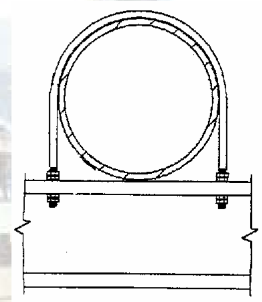
Sway strut – used to prevent horizontal movement.

Hydraulic snubber – used to prevent sudden horizontal movement but allow slowly applied displacement.

Support Element Selection

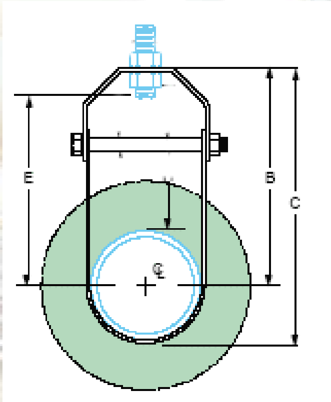
Resting pipe directly on structural steel should be avoided when:

- Carbon steel pipe is in a wet environment and failure by corrosion is not tolerable
- Stainless steel pipe would be in contact with galvanized steel and failure by liquid metal embrittlement during a fire is not tolerable



Support Element Selection

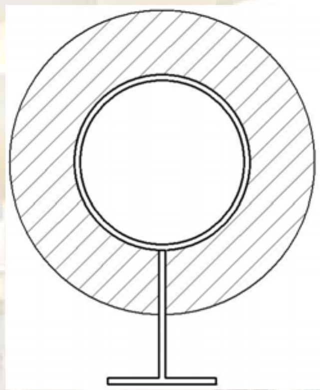
Support elements on outdoor insulated piping should penetrate the insulation on the bottom of the pipe.



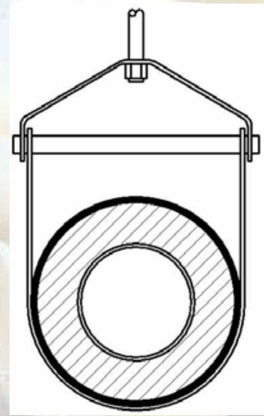
(from Anvil International)

Support Element Selection

Some solutions:



Use pipe shoes

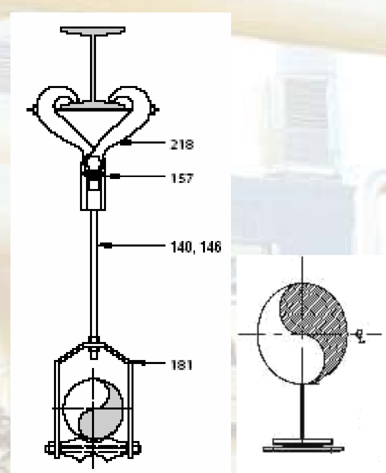


Support outside the insulation

BECHT ENGINEERING COMPANY, INC. Layout and Support - 29

Support Element Selection

In aggressive external corrosion environments, support should be via structural steel under the pipe rather than hanger rods with multiple threaded connections that may fail in a few years.



(from Anvil International)

BECHT ENGINEERING COMPANY, INC. Layout and Support - 30

ASME B31.3 Process Piping

Charles Becht IV, PhD, PE
Don Frikken, PE
Instructors

Piping Development Process

1. Establish applicable system standard(s)
2. Establish design conditions
3. Make overall piping material decisions
   - Pressure Class
   - Reliability
   - Materials of construction
4. Fine tune piping material decisions
   - Materials
   - Determine wall thicknesses
   - Valves
5. Establish preliminary piping system layout & support configuration
6. Perform flexibility analysis
7. Finalize layout and bill of materials
8. Fabricate and install
9. Examine and test

8. Flexibility

- General Considerations
- Friction
- Stress Intensification
- Thermal Expansion
- Spring Hangers
- The Displacement Load Analysis

The Material in This Section is Addressed by B31.3 in:

Chapter II - Design

Appendix D - Flexibility & Stress Intensification Factors

General Considerations

- Main purpose is to provide sufficient flexibility to safely accommodate changes in length resulting from temperature variations, avoiding failure caused by
  - Fatigue
  - Creep-fatigue
  - Ratchet
- Another purpose is to keep movement of piping within a manageable range
  - Avoiding interference with other stuff
  - Supports designed to handle displacements

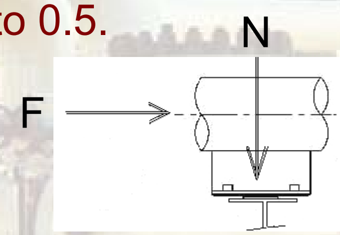
General Considerations

- Loads are actions that cause one end of a pipe segment to move relative to the other end and actions that have an equivalent effect
  - Thermal expansion of attached equipment
  - Temperature changes in the piping
- Peak stresses are accounted for using stress intensification factors
- Acceptance criterion is based on the stress range

Friction

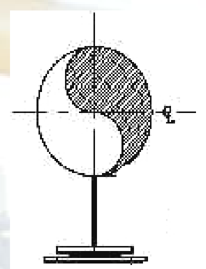
- Displacement causes piping to move over sliding supports
- Friction forces are in one direction when the pipe is heating and in the opposite direction when cooling
- The coefficient of friction used for steel on steel ranges from 0.3 to 0.5.

$$F = \mu N$$

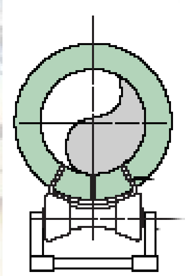


Friction

- The coefficient of friction can be reduced to 0.1 by using PTFE or graphite impregnated plates



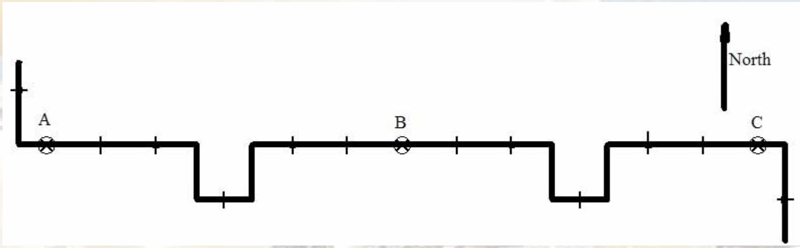
- Using roller supports can further reduce the coefficient of friction to 0.02



Friction Workshop

Calculate the east-west reactions at the anchors caused by friction.

- Assume steel on steel
- Line is NPS 6, std WT steel, uninsulated and full of water



BECHT *ENGINEERING COMPANY, INC.* Flexibility - 9

Stress Intensification

- Stress intensification factors (SIF's) are used to account for higher stresses that may exist at discontinuities in the piping at fittings and joints
- The calculated stresses at a fitting or joint are taken as the stress calculated for a perfect circular cylinder times the SIF
- SIF's are given in Appendix D of B31.3

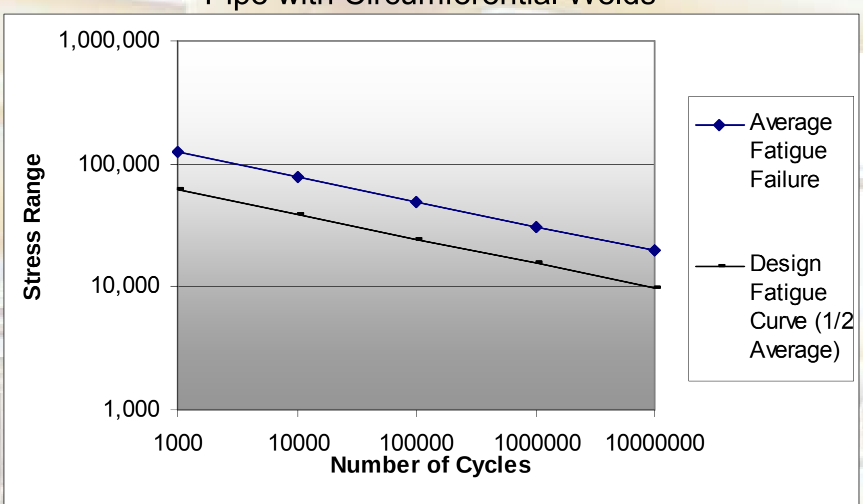
BECHT *ENGINEERING COMPANY, INC.* Flexibility - 10

Stress Intensification

- SIF's are based on Markl testing of piping components
  - Primarily A106 Gr B pipe, with some types 316 and 347 stainless steel
  - NPS 4 Sch 40
  - Fully reversed bending
  - Displacement controlled tests
- Markl started with a fatigue curve generated by fatigue tests on pipe with circumferential welds

Stress Intensification

Pipe with Circumferential Welds

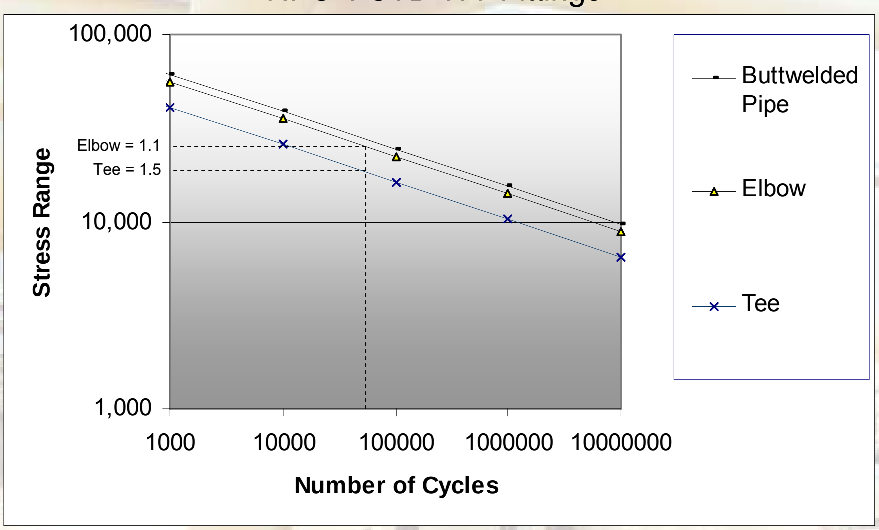


Stress Intensification

- Components such as tees and elbows were similarly fatigue tested
- The SIF for a component is the ratio of the nominal stress in the circumferentially welded pipe divided by the nominal stress in the component at failure for the same number of cycles
- Even though the component may have thicker walls, the evaluation is based on the dimensions of the pipe

Stress Intensification

NPS 4 STD WT Fittings



Thermal Expansion

Thermal Expansion of metals can be calculated by

$$\Delta L = \alpha \, \Delta T \, L$$

Where:

- α = Coefficient of thermal expansion
- L = Length of piping
- ΔL = Change in length of piping
- ΔT = Change in temperature, usually temperature range

BECHT ENGINEERING COMPANY, INC. Flexibility - 15

Thermal Expansion

Thermal Expansion of metals can also be calculated by

$$\Delta L = Exp \, L$$

Where:

- Exp = Total thermal expansion, in/100 ft (mm/m)
- L = Length of piping, 100 ft (m)
- ΔL = Change in length of piping, in (mm)

BECHT ENGINEERING COMPANY, INC. Flexibility - 16

Thermal Expansion

What is the change in length of a carbon steel line that has

- An original length of 60 ft (18.3 m)
- Has a minimum expected temperature of -29ºF (-34ºC), and
- Has a maximum expected temperature of 300ºF (150ºC)

See pages 41-44 of the supplement.

Spring Hangers

Spring hangers are used to provide support for piping while allowing vertical movement of the piping caused by displacement loads.

Variable Type

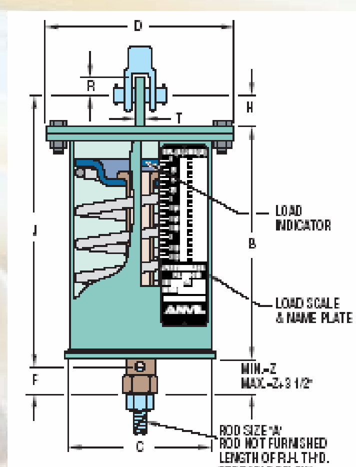


FIG. B-268 TYPE B

Spring Hangers

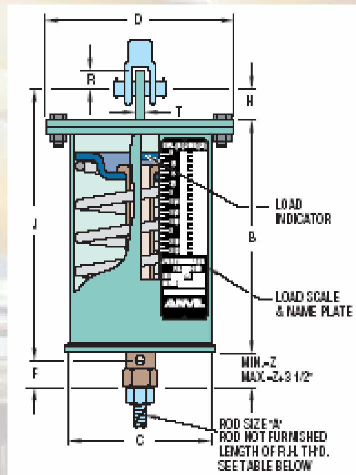
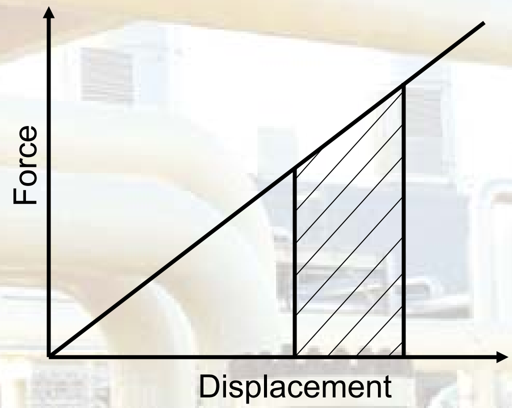


FIG. B-268 TYPE B



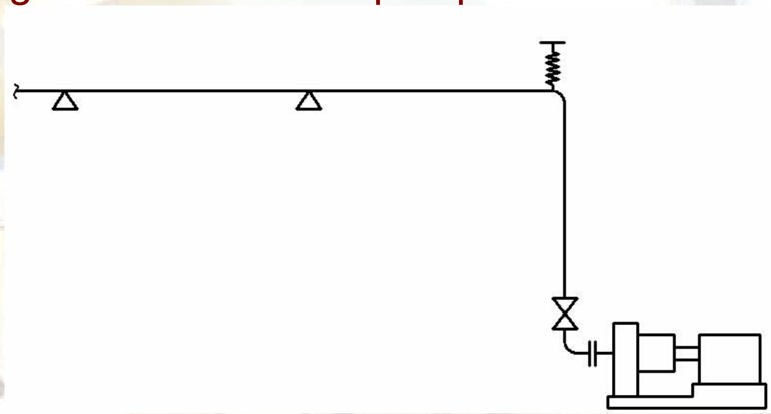
Spring Hangers

Selection Process

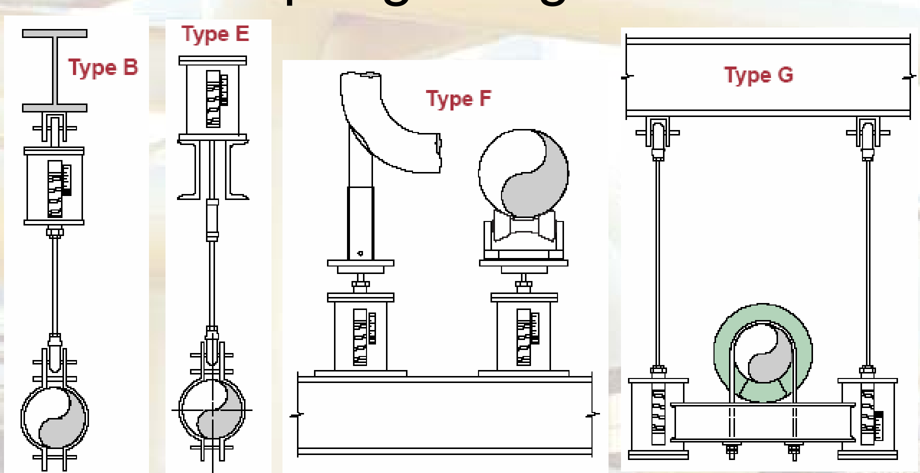
- Calculate weight to be supported
- Calculate movement of the line at the support location
- Select hanger size based on the load
- Decide allowable load variation
  - Usually less than 25%
  - Less if needed to meet stress or reaction requirements
- Select hanger from manufacturer's table

Spring Hanger Workshop

Select a spring hanger that will minimize the weight reaction on the pump.



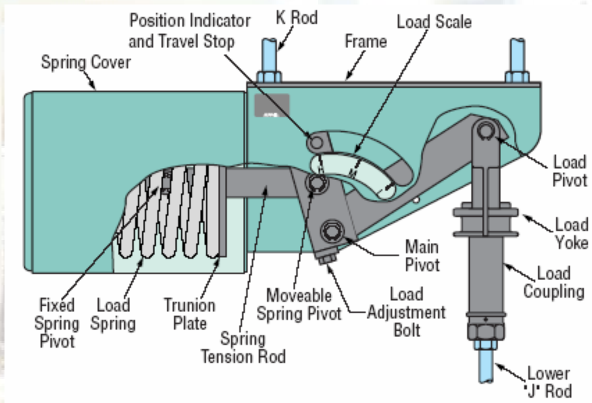
Spring Hangers



Variable Spring Hanger Installation (Anvil International)
[Note that springs are always in compression.]

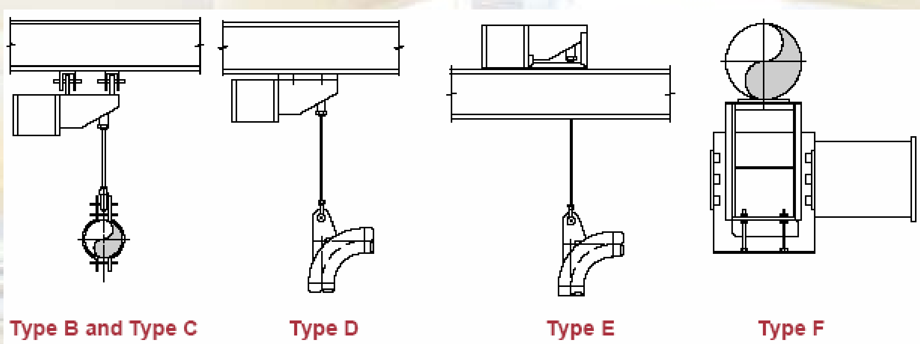
Spring Hangers

Constant type spring hangers are used when the load variation on a variable type spring hanger would be too high.



Constant Type

Spring Hangers



Constant Support Hanger Installation (Anvil International)

The Displacement Load Analysis

- Temperature Range
- Displacement Stress Calculation
- Calculation Methods

BECHT *ENGINEERING COMPANY, INC.* Flexibility - 25

Temperature Range

- B31.3 requires that we consider "…the algebraic difference between strains in the extreme displacement condition and the original (as-installed) condition (or any anticipated condition with a greater differential effect)…"(319.2.3(b))
- The minimum and maximum temperatures used don't necessarily correspond to the design temperature and the design minimum temperature

BECHT *ENGINEERING COMPANY, INC.* Flexibility - 26

Temperature Range

design temperature: the temperature at which, under the coincident pressure, the greatest thickness or highest component rating is required (301.3).

design minimum temperature: the lowest component temperature expected in service (301.3.1)

Temperature Range

- Minimum temperature may be due to
  - Normal operation
  - Excursion operation
  - Expected winter temperature
- Maximum temperature may be due to
  - Normal operation
  - Excursion operation
  - Piping exposed to hot summer sun [120ºF, 50ºC]
  - Empty piping exposed to heat tracing
  - Steam cleaning

Temperature Range Examples

- Outdoor cooling tower water line:
  - Minimum water temperature is 45ºF (7ºC)
  - Maximum water temperature is 90ºF (32ºC)
  - The piping is installed during February, which has an average daily temperature of 53ºF (12ºC)
  - Minimum average daily temperature is 30ºF (-1ºC)
  - Temperature range is _______ to ________

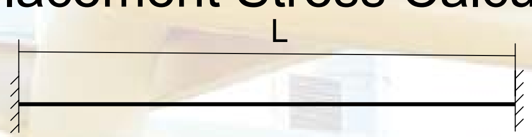
Temperature Range Examples

- Outdoor compressed air piping
  - Minimum compressed air temperature is ambient
  - Maximum compressed air temperature is 150ºF (65ºC)
  - The piping is installed during July, which has an average daily temperature of 64ºF (18ºC)
  - Minimum average daily temperature is -30ºF (-35ºC)
  - Temperature range is _______ to ________

Temperature Range Examples

- Outdoor steam traced water line:
  - Minimum water temperature is 40ºF (4ºC)
  - Maximum water temperature is 60ºF (16ºC)
  - The piping is installed during September, which has an average daily temperature of 76ºF (24ºC)
  - Minimum average daily temperature is 30ºF (-1ºC)
  - Calculated maximum temperature for no flow condition with steam tracing on is 280ºF (140ºC)
  - Temperature range is ________ to ________

Displacement Stress Calculation



$$\sigma = E \cdot \Delta L / L$$

$$\Delta L = \alpha \cdot \Delta T \cdot L$$

$$\sigma = E \cdot \alpha \cdot \Delta T$$

1. What is σ for carbon steel and ΔT = 330ºF (185ºC)?
   E for carbon steel = 29E6 psi (200 GPa)
2. What is σ for stainless steel under the same condition?
   E for stainless steel = 28.3E6 psi (195 GPa)

Calculation Methods

The Code describes four acceptable methods to demonstrate adequate flexibility

1. Formal analysis
2. Duplicate of a successful system
3. System that can be judged adequate by comparison
4. Empirical equation for piping that meets certain requirements

Calculation Methods

The empirical equation is:

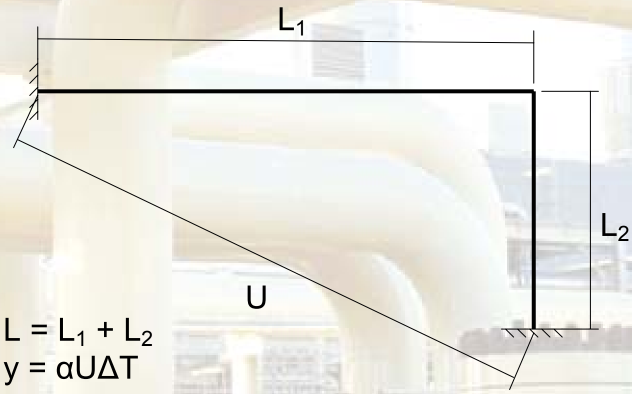
$$Dy/(L - U)^2 \leq 30S_A/E_a \text{ (in/ft)}^2$$

$$Dy/(L - U)^2 \leq 208{,}000S_A/E_a \text{ (mm/m)}^2$$

Where:

- D = Pipe outside diameter (in) (mm)
- L = Developed length of piping between anchors (ft) (m)
- U = Distance between anchors (ft) (m)
- Y = Total displacement strain to be absorbed by the piping (in) (mm)
- S_A = Allowable stress range
- E_a = Elastic modulus at room temperature

Calculation Methods



$L = L_1 + L_2$
$y = \alpha U \Delta T$

Calculation Methods

- The empirical equation can be used if the piping system:
  - Is of uniform size
  - Has no more than two points of fixation
  - Has no intermediate restraints
- The equation is not applicable to systems subject to severe cyclic conditions.
- The equation may not be accurate for certain geometries.

Calculation Methods

The Code describes four acceptable methods to demonstrate adequate flexibility

1. Formal analysis
2. Duplicate of a successful system
3. System that can be judged adequate by comparison
4. Empirical equation for piping that meets certain requirements

Calculation Methods

Formal analyses can be simple or complex. The complex analyses are done using computer programs such as

- Autopipe, Siber Technology, http://www.siber.co.uk/rebis/autopipe.shtml
- CAEPIPE, SST Systems, Inc., http://www.sstusa.com/
- Caesar, Coade, Inc., http://www.caesarii.com/
- PipePak, Algor, http://www.pipepak.com/products/Profes1504/default.asp
- SIMFLEX, Peng Engineering, http://www.pipestress.com/
- TRIFLEX, Nor-Par a.s, http://www.norpar.com/triflex.htm

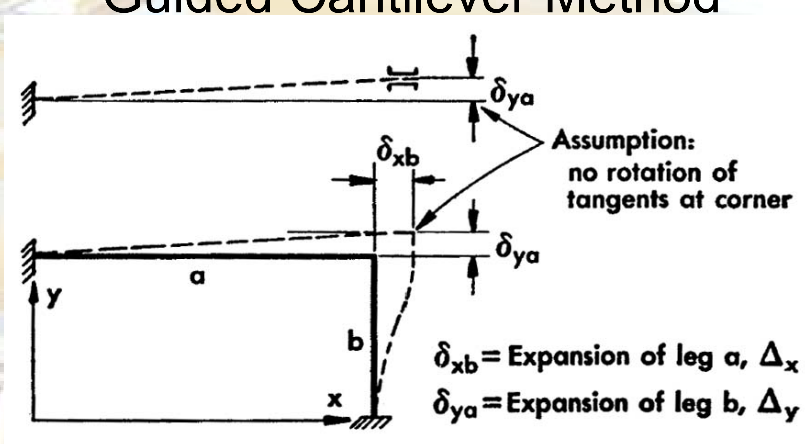
Calculation Methods

The simple analyses are done using equations, charts and graphs such as described in

- Design of Piping Systems, The M.W. Kellogg Company, John Wiley & Sons, Inc., First Edition 1941
- Piping Design and Engineering, Grinnell Corporation, First Edition 1963

One of the simplest methods is the guided cantilever method described in the Kellogg book.

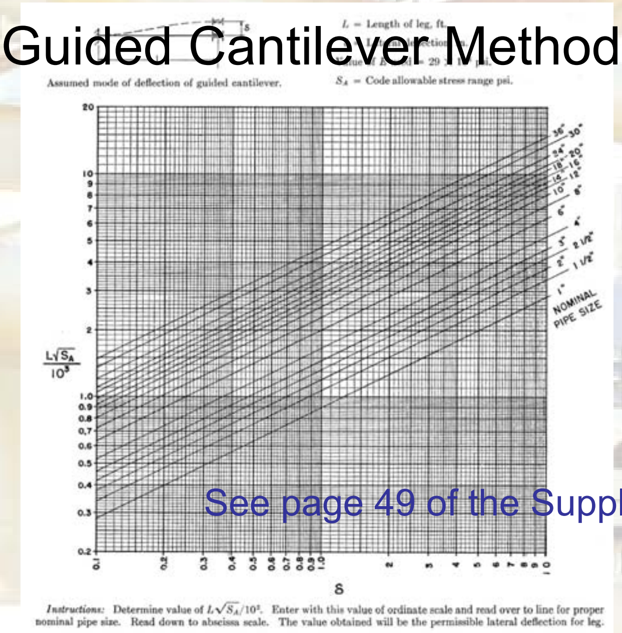
Guided Cantilever Method



$$\delta = 48L^2S_A/E_aD$$

Where δ = maximum permissible displacement

Guided Cantilever Method

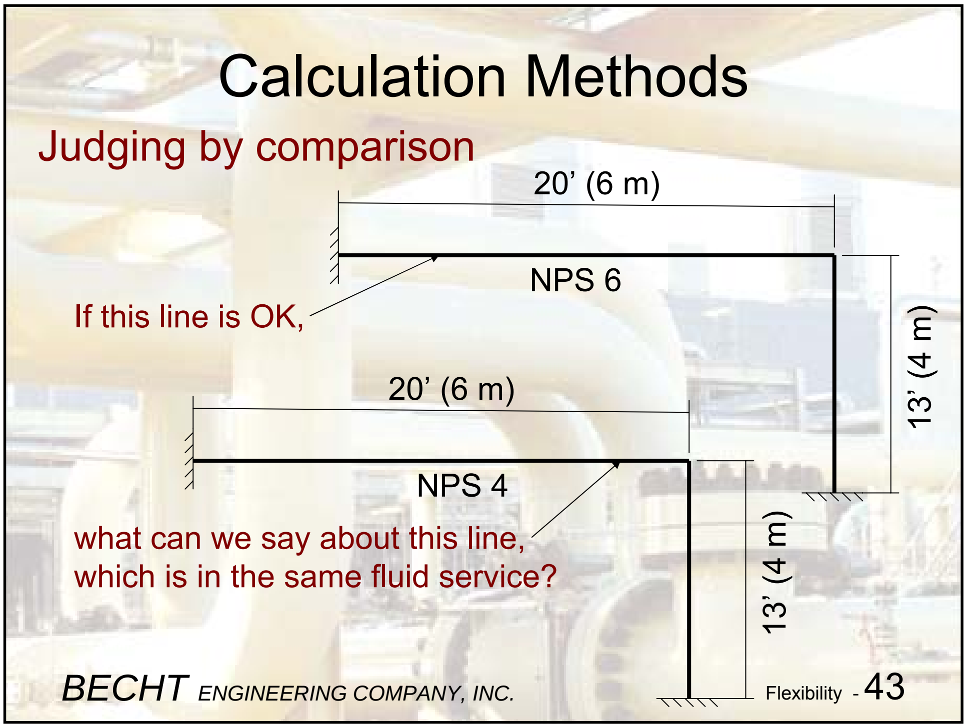


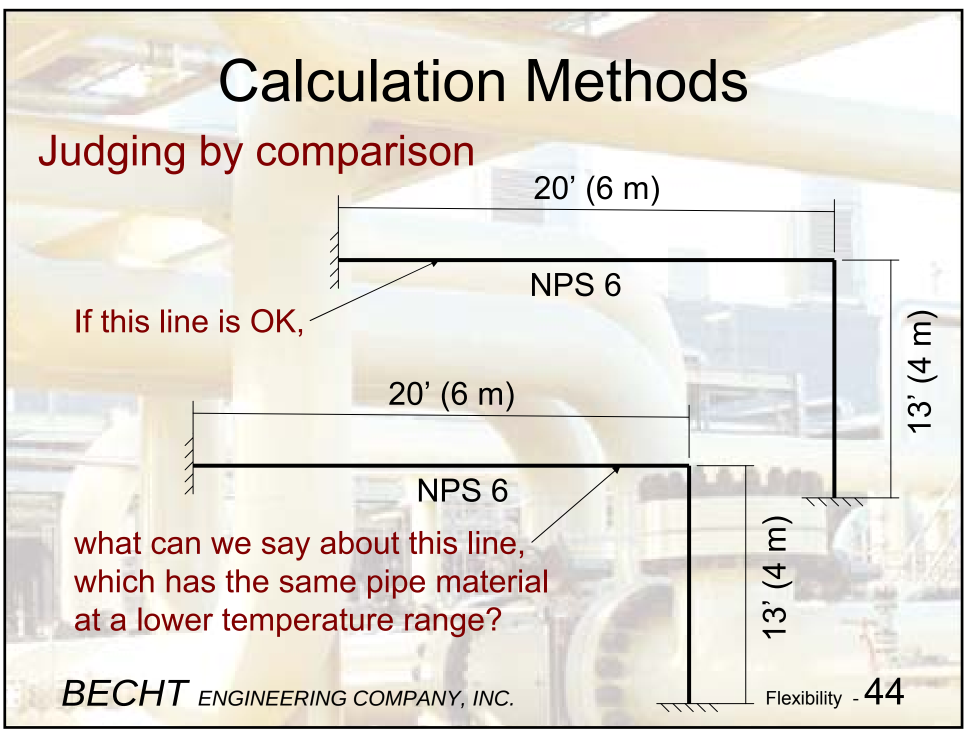
See page 49 of the Supplement.

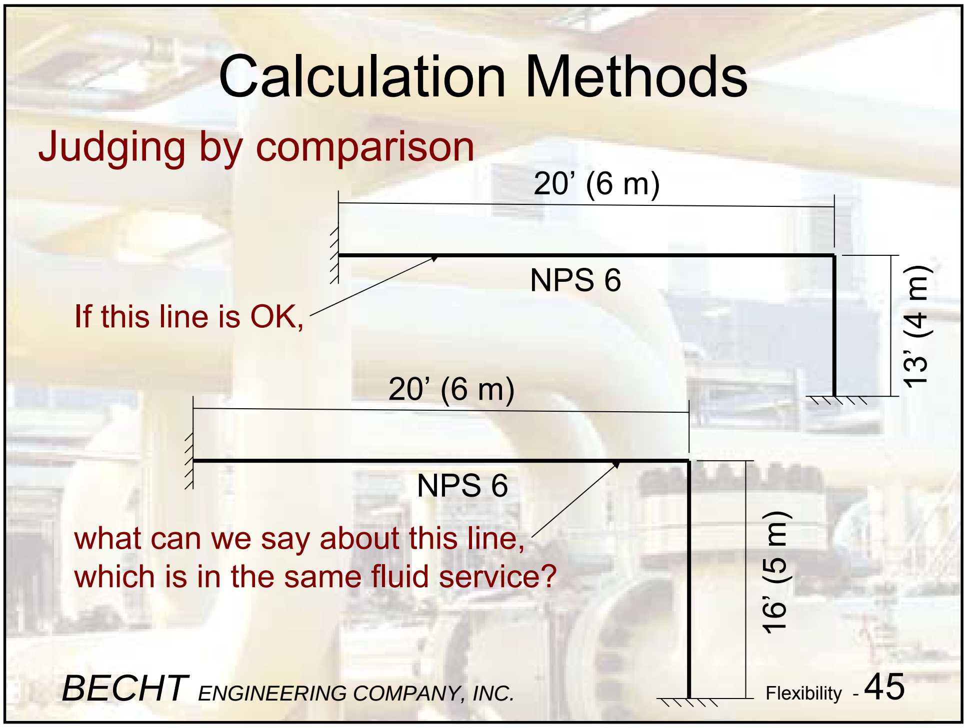
Calculation Methods

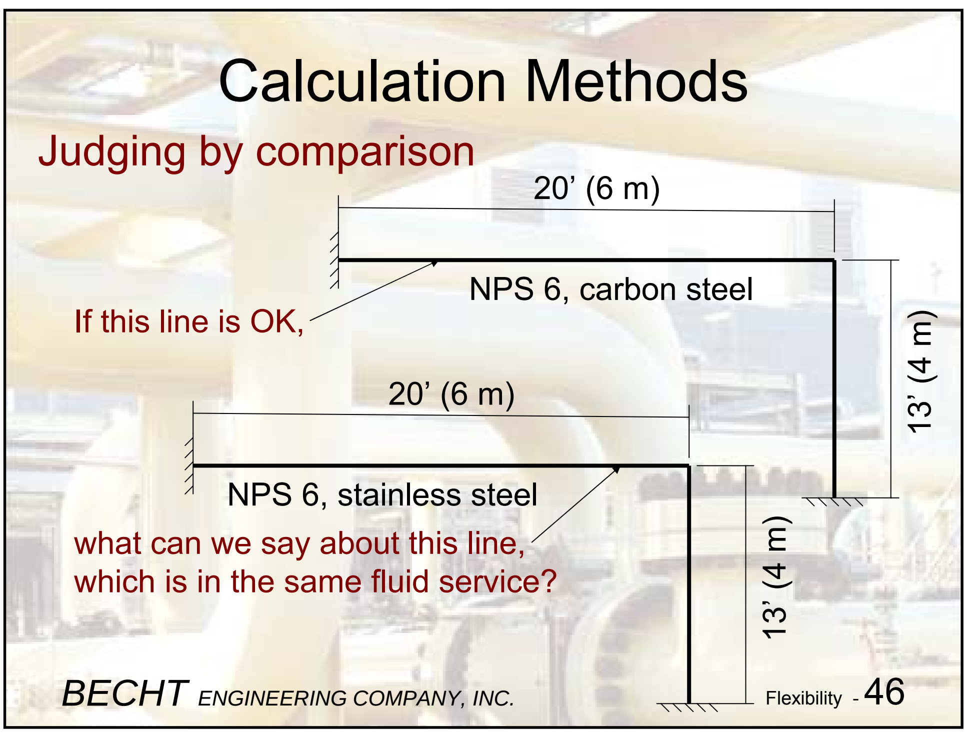
The Code describes four acceptable methods to demonstrate adequate flexibility

1. Formal analysis
2. Duplicate of a successful system
3. System that can be judged adequate by comparison
4. Empirical equation for piping that meets certain requirements


Calculation Methods
Judging by comparison
20' (6 m)
NPS 6
If this line is OK,
13' (4 m)
20' (6 m)
NPS 4
what can we say about this line,
which is in the same fluid service?
13' (4 m)
BECHT ENGINEERING COMPANY, INC.
Flexibility - 43


Calculation Methods
Judging by comparison
20' (6 m)
NPS 6
If this line is OK,
13' (4 m)
20' (6 m)
NPS 6
what can we say about this line,
which has the same pipe material
at a lower temperature range?
13' (4 m)
BECHT ENGINEERING COMPANY, INC.
Flexibility - 44


Calculation Methods
Judging by comparison
20' (6 m)
NPS 6
13' (4 m)
If this line is OK,
20' (6 m)
NPS 6
what can we say about this line,
which is in the same fluid service?
16' (5 m)
BECHT ENGINEERING COMPANY, INC.
Flexibility - 45


Calculation Methods
Judging by comparison
20' (6 m)
NPS 6, carbon steel
13' (4 m)
If this line is OK,
20' (6 m)
NPS 6, stainless steel
what can we say about this line,
which is in the same fluid service?
13' (4 m)
BECHT ENGINEERING COMPANY, INC.
Flexibility - 46

ASME B31.3 Process Piping

Charles Becht IV, PhD, PE
Don Frikken, PE
Instructors

Piping Development Process

1. Establish applicable system standard(s)
2. Establish design conditions
3. Make overall piping material decisions
   - Pressure Class
   - Reliability
   - Materials of construction
4. Fine tune piping material decisions
   - Materials
   - Determine wall thicknesses
   - Valves
5. Establish preliminary piping system layout & support configuration
6. Perform flexibility analysis
7. Finalize layout and bill of materials
8. Fabricate and install
9. Examine and test

9. Reactions

- General Considerations
- Fabricated Equipment
- Rotating Equipment
- Supports
- Cold Spring

BECHT *ENGINEERING COMPANY, INC.* Reactions - 3

The Material in This Section is Addressed by B31.3 in:

Chapter II - Design

BECHT *ENGINEERING COMPANY, INC.* Reactions - 4

General Considerations

- Main purpose is to provide sufficient support and flexibility to prevent the piping from exerting excessive reactions on equipment and restraints
- The calculation methods are different for fabricated equipment than for rotating equipment or supports
- Reaction limits are determined differently for fabricated equipment than for rotating equipment or supports

Fabricated Equipment

- Calculation Methods
- Reaction Limits
- Nozzle Flexibility

Calculation Methods

- Usually the accuracy of a formal analysis using a computer stress analysis program is required
- Both sustained loads and displacement loads are considered
- Failure modes for fabricated equipment include:
  - Gross deformation or collapse
  - Fatigue

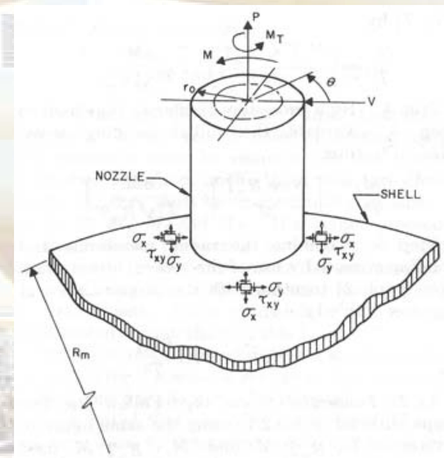
Calculation Methods

- In order to evaluate fatigue, the entire range of loads must be considered, so the temperature range for this calculation is the same as for calculating the displacement stress range

Reaction Limits

Reaction limits for nozzles are calculated using

- Welding Research Council Bulletin 107 "Local Stresses in …Shells due to External Loadings"
- Finite element analysis



Reaction Limits

- Allowable stresses values used in the calculation are taken from the applicable Code, and stress evaluation is usually done using the stress evaluation criteria described in ASME B&PV Code Section VIII, Division 2, Alternate Rules for Pressure Vessels
- Advantages to doing these calculations yourself
  - Cycle time is reduced considerably
  - Easier to decide between reinforcing the nozzle and lowering the reactions

Rotating Equipment

- Calculation Methods
- Reaction Limits

Calculation Methods

- Usually the accuracy of a formal analysis using a computer stress analysis program is required
- Failure modes for rotating equipment include:
  - Detrimental misalignment
  - Rubbing interference
- In order to evaluate failure modes, only the magnitude of the loads during operation needs to be considered, so the temperature range from the installed condition to the operating condition is used

Temperature Range Examples

- Outdoor cooling tower water line:
  - Minimum water temperature is 45ºF (7ºC)
  - Maximum water temperature is 90ºF (32ºC)
  - The piping is installed during February, which has an average daily temperature of 53ºF (12ºC)
  - Minimum average daily temperature is 30ºF (-1ºC)
  - Temperature range is _______ to ________

BECHT ENGINEERING COMPANY, INC. Reactions - 13

Temperature Range Examples

- Outdoor compressed air piping
  - Minimum compressed air temperature is ambient
  - Maximum compressed air temperature is 150ºF (65ºC)
  - The piping is installed during July, which has an average daily temperature of 64ºF (18ºC)
  - Minimum average daily temperature is -30ºF (-35ºC)
  - Temperature range is _______ to ________

BECHT ENGINEERING COMPANY, INC. Reactions - 14

Temperature Range Examples

- Outdoor steam traced water line:
  - Minimum water temperature is 40ºF (4ºC)
  - Maximum water temperature is 60ºF (16ºC)
  - The piping is installed during September, which has an average daily temperature of 76ºF (24ºC)
  - Minimum average daily temperature is 30ºF (-1ºC)
  - Calculated maximum temperature for no flow condition with steam tracing on is 280ºF (140ºC)
  - Temperature range is _______ to ________

Reaction Limits

- Limits are specified by the equipment manufacturers
- Manufacturers of certain types of equipment are required to at least meet the allowable reaction requirements in applicable industry standards, so
- Many manufacturers refer the users to these standards

Reaction Limits

Equipment	Industry Standard
Centrifugal Pumps	ASME B73.1 API 610
Steam Turbines	NEMA SM-23 API 611 API 612
Centrifugal Compressors	API 617
Positive Displacement Compressors	API 619

Supports

- Calculation Methods
- Reaction limits

Calculation Methods

- Usually the accuracy of a formal analysis using a computer stress analysis program is required
- The failure modes of concern for supports is collapse and excessive deformation
- The structural codes don't recognize the distinction between displacement and sustained loads, so only the magnitude of the loading extremes needs to be considered, so
- The temperature range from the installed condition to the operating condition is used
- Some codes differentiate between "normal" loads and "occasional" loads

Reaction Limits

Reaction limits are determined by either the maximum stress or the stability limit of the structure.

Cold Spring

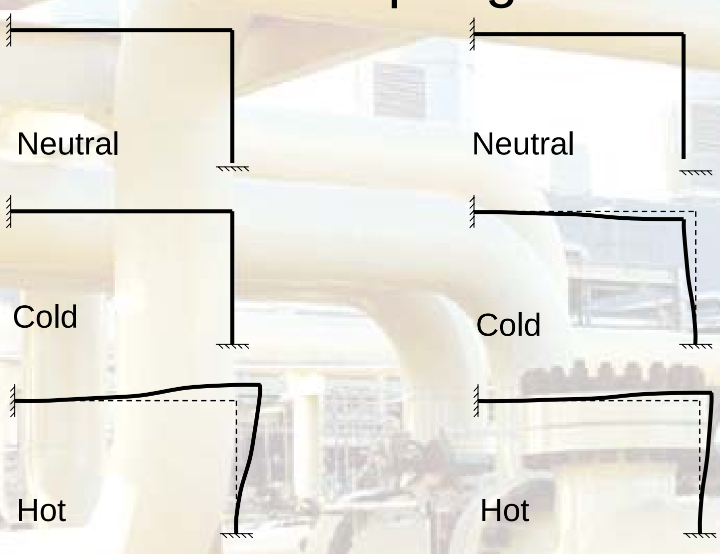
Cold spring is the intentional deformation of piping during assembly to produce a desired initial displacement and stress. (319.2.4)

Cold springing:

- Does not change the stress range
- Does not change the reaction range
- Is not helpful for reducing reaction ranges at fabricated equipment
- Can be helpful for reducing reactions rotating equipment and supports
- Can be used to control displacements

BECHT *ENGINEERING COMPANY, INC.* Reactions - 21

Cold Spring



BECHT *ENGINEERING COMPANY, INC.* Reactions - 22

Cold Spring

Because cold spring is difficult to achieve accurately in practice, B31.3 permits only partial credit in calculating reaction forces

- For two anchor systems with no intermediate restraints, B31.3 gives equations for estimating reactions giving 2/3 credit for cold spring (319.5.1)
- For other systems, B31.3 requires that each case be studied to estimate reactions (319.5.2)

BECHT *ENGINEERING COMPANY, INC.*

Cold Spring

Note that unintentional cold spring (misalignment) has the same effect as intentional cold spring.

- The Code says "Any distortion of piping to bring it into alignment for joint assembly which introduces a detrimental strain in equipment or piping components is prohibited." (335.1.1)
- Some owners are more restrictive than the Code on misalignment.

BECHT *ENGINEERING COMPANY, INC.*

ASME B31.3 Process Piping

Charles Becht IV, PhD, PE
Don Frikken, PE
Instructors

Piping Development Process

1. Establish applicable system standard(s)
2. Establish design conditions
3. Make overall piping material decisions
   - Pressure Class
   - Reliability
   - Materials of construction
4. Fine tune piping material decisions
   - Materials
   - Determine wall thicknesses
   - Valves
5. Establish preliminary piping system layout & support configuration
6. Perform flexibility analysis
7. Finalize layout and bill of materials
8. Fabricate and install
9. Examine and test

10. Detailed Flexibility Analysis

- When to Perform a Detailed Analysis
- Considerations

The Material in This Section is Addressed by B31.3 in:

Chapter II - Design

When to Perform a Detailed Analysis

When the other methods the Code describes don't give satisfactory results.

1. Formal analysis
   - Simple
   - **Detailed**
2. Duplicate of a successful system
3. System that can be judged adequate by comparison
4. Empirical equation for piping that meets certain requirements

Considerations

- Temperatures and pressures during
  - start-up
  - normal operation
  - steam out/decoking
  - depressuring (autorefrigeration)
  - shutdown (ambient effects)
  - excursion operation
  - no-flow branch
  - regeneration
  - heat tracing

Note that frequently only the most severe condition is documented at this stage of design.

Considerations

- Effects due to
  - expansion and contraction
  - differential settlement
  - relief valve reactions
  - weight
  - wind
  - seismic, and
  - other mechanical loadings
- The effect of frictional resistance to thermal movement

Considerations

- External bending moments on flanges
- Forces due to unsteady operation, such as
  - two phase flow
  - pulsating flow
  - water hammer
- Maximum sag deflections of, for example, 1/2 inch (13 mm)
- Thermal movement of equipment to which the piping is attached

Considerations

- Differential movement of support structures during an earthquake
- Tank settlement
- Need for control in construction and maintenance when gaps or other “unusual” tactics are used
- Supports from which the pipe lifts off when hot
- Records that need to be kept

ASME B31.3 Process Piping

Charles Becht IV, PhD, PE
Don Frikken, PE
Instructors

Piping Development Process

1. Establish applicable system standard(s)
2. Establish design conditions
3. Make overall piping material decisions
   - Pressure Class
   - Reliability
   - Materials of construction
4. Fine tune piping material decisions
   - Materials
   - Determine wall thicknesses
   - Valves
5. Establish preliminary piping system layout & support configuration
6. Perform flexibility analysis
7. Finalize layout and bill of materials
8. Fabricate and install
9. Examine and test

11. Designing with Expansion Joints

- Types of Expansion Joints
- Pressure Thrust
- Installation of Expansion Joints
- Metal Bellows Expansion Joints

(Hanjo)

(General Rubber)

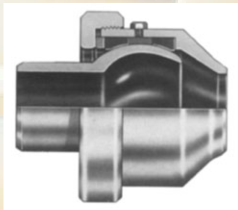
(Hyspan)

The Material in This Section is Addressed by B31.3 in:

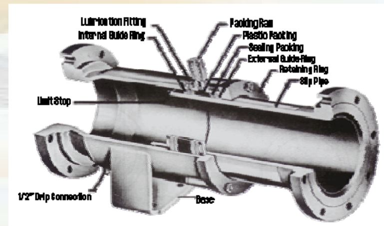
Chapter II - Design

Appendix X - Metallic Bellows Expansion Joints

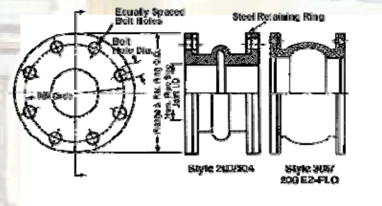
Types of Expansion Joints



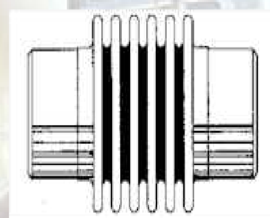
Ball



Slip



Rubber Bellows



Metal Bellows

Pressure Thrust

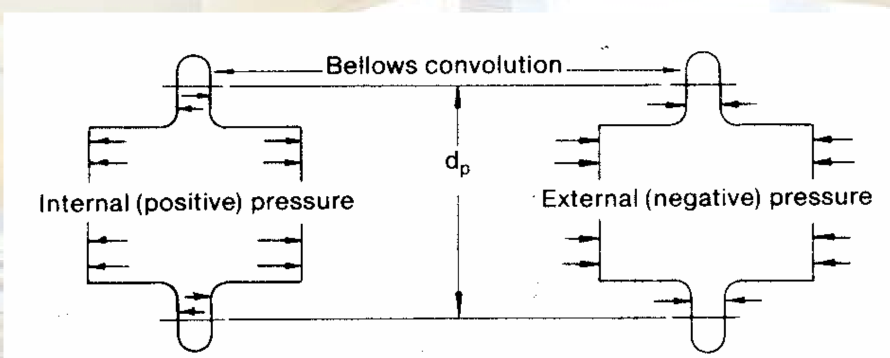
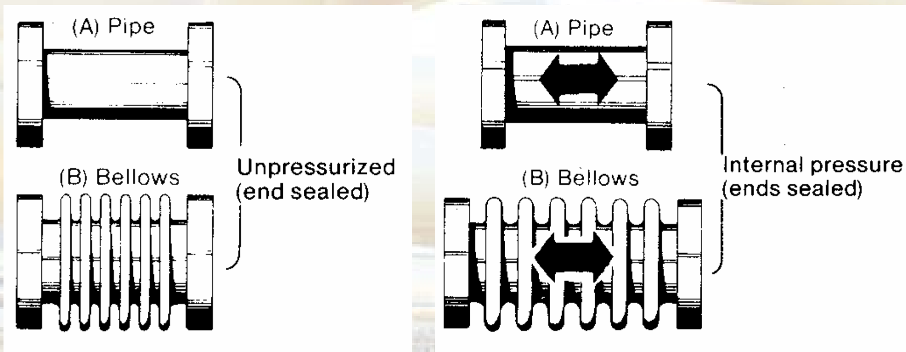


Fig. B-5 Pressure Thrust

Expansion Joint Manufacturer's Association (EJMA)

Pressure Thrust



(EJMA)

Which types of expansion joints have this problem?

Pressure Thrust

For a bellows type expansion joint, the pressure thrust force is the effective thrust area recommended by the manufacturer times the pressure. In the absence of this information:

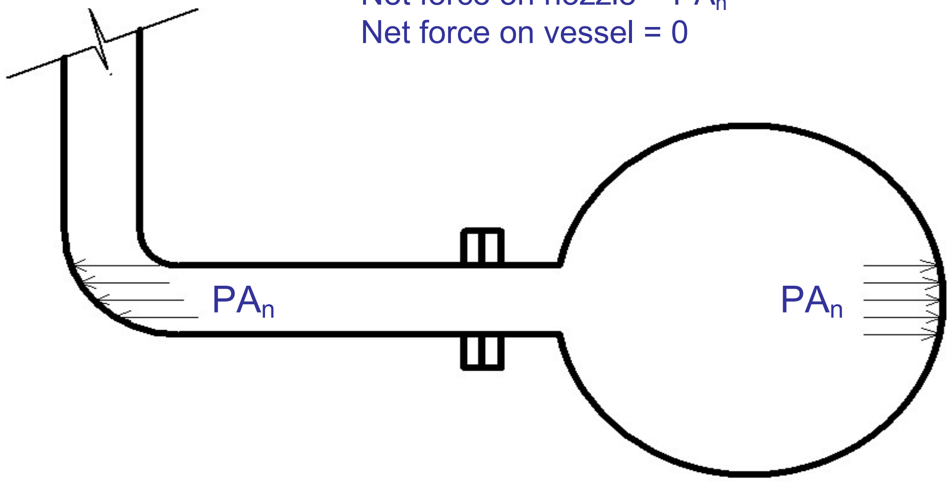
$$F = P * \frac{\pi * d_p^2}{4}$$

Where

- F = pressure thrust force
- P = pressure
- d_p = mean diameter of bellows

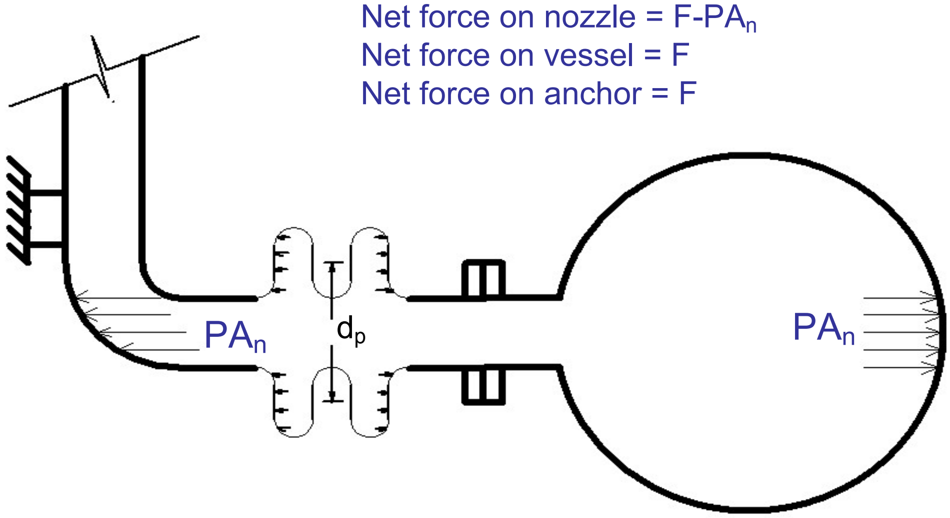
Pressure Thrust

Net force on nozzle = PA_n
Net force on vessel = 0



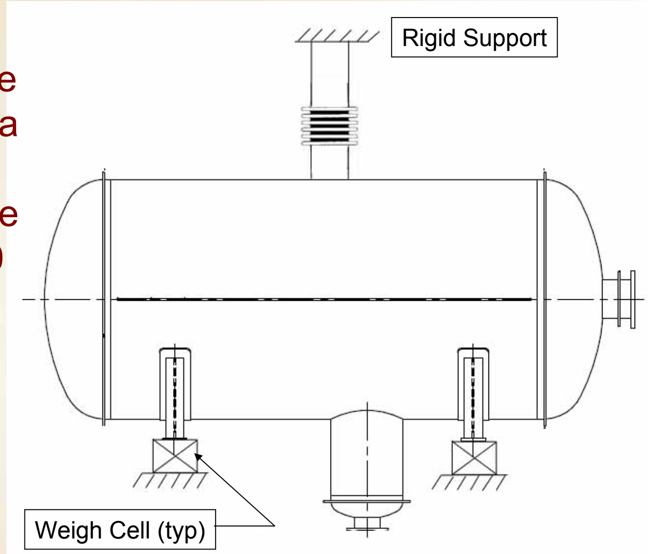
Pressure Thrust

Net force on nozzle = $F-PA_n$
Net force on vessel = F
Net force on anchor = F



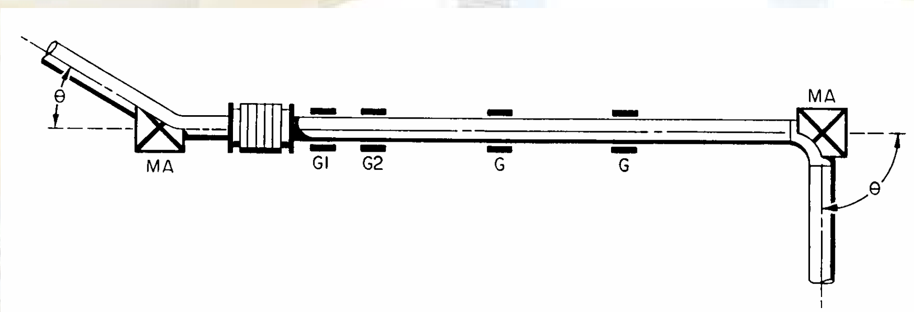
Pressure Thrust Workshop

What is the apparent change in the weight of a vessel caused by increasing the pressure by 100 psi (700 kPa)?



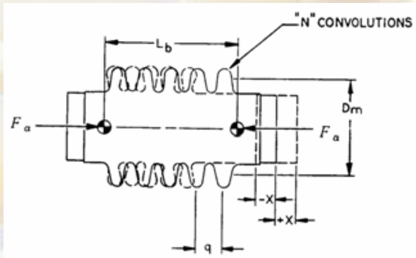
See the supplement, page 52.

Installation of Expansion Joints

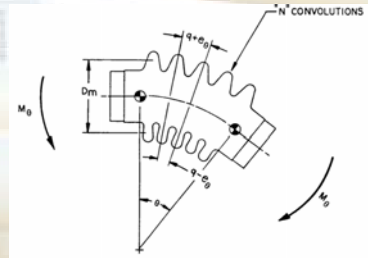


Anchors must be designed for full pressure thrust based on maximum operating pressure. (EJMA)

Bellows Movement

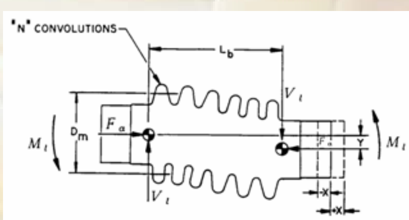


Axial (EJMA)



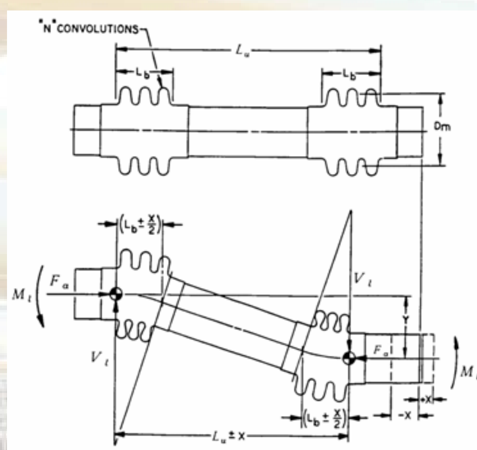
Rotation (EJMA)

Bellows Movement



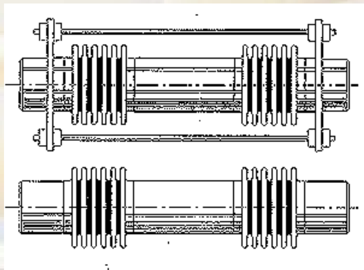
Lateral (EJMA)
Inefficient for bellows

Bellows are not intended to take torsional displacement.



Efficient use of bellows for Lateral movement (EJMA)

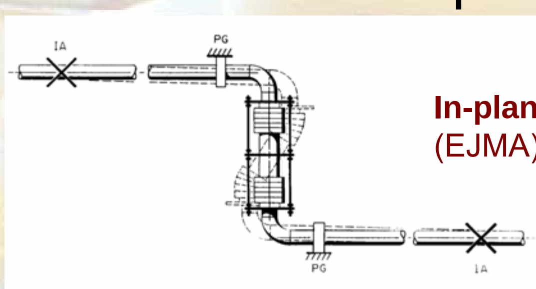
Universal Expansion Joint



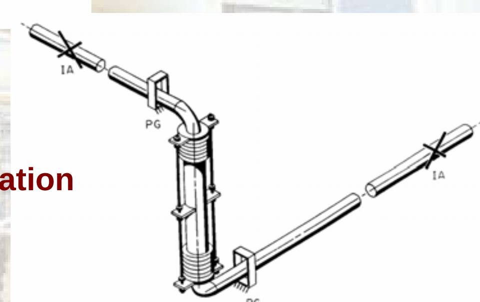
Piping Technology & Products (PTP)

(PTP)

Universal Expansion Joint

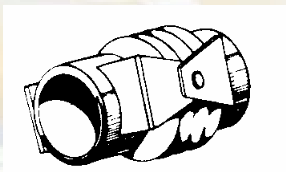


In-plane application
(EJMA)



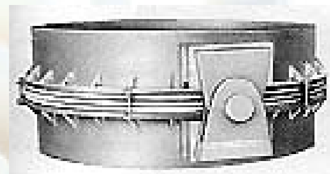
3-dimensional application
(EJMA)

Hinged Expansion Joint



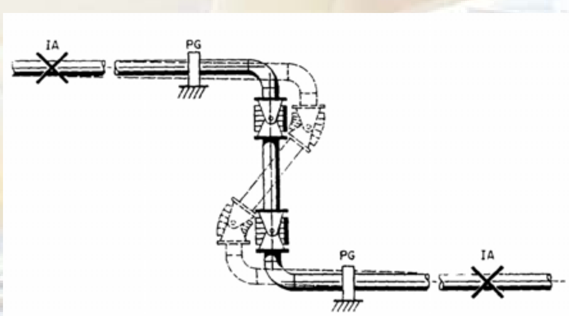
(EJMA)

(Adsco)

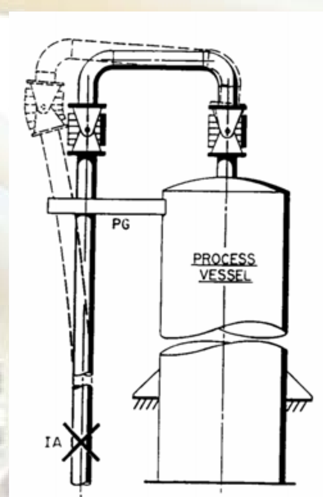


(Hae Jo Industrial)

Hinged Expansion Joint

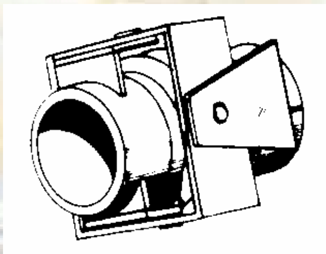


(EJMA)



(EJMA)

Gimbal Expansion Joint

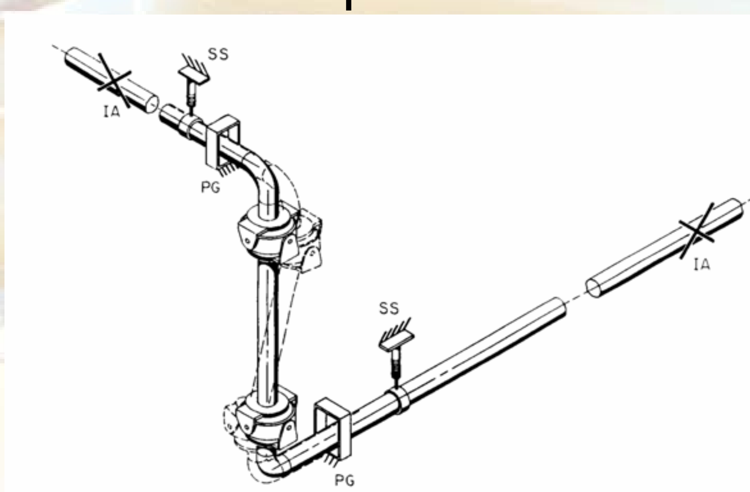


(EJMA)

(Adsco)

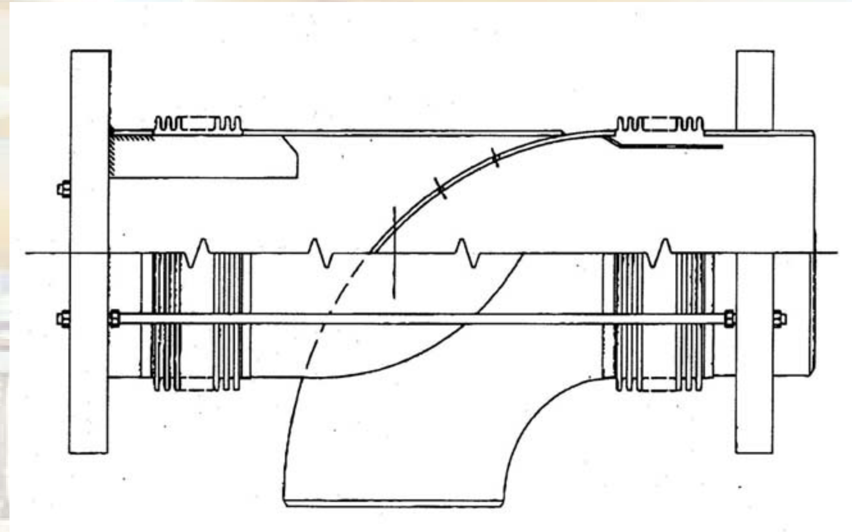
(Hae Jo Industrial)

Gimbal Expansion Joint

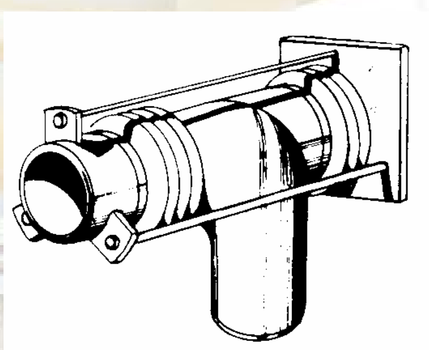


(EJMA)

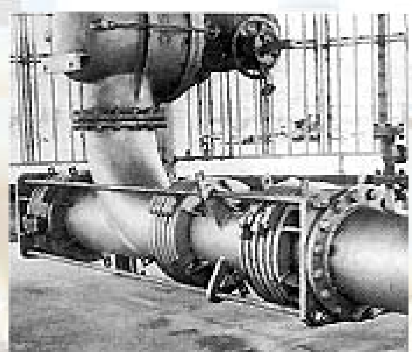
Pressure Balanced Expansion Joint



Pressure Balanced Expansion Joint

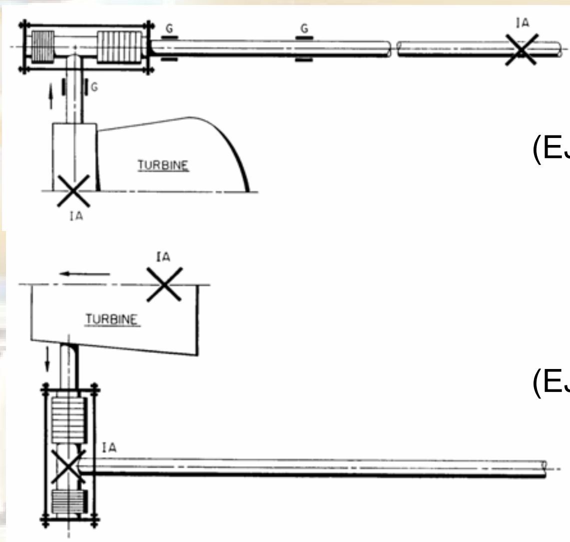


(EJMA)



(Hae Jo Industrial)

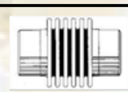
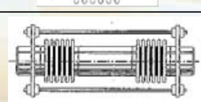
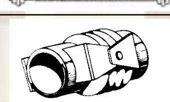
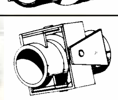
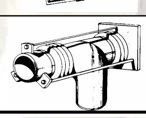
Pressure Balanced Expansion Joint



(EJMA)

(EJMA)

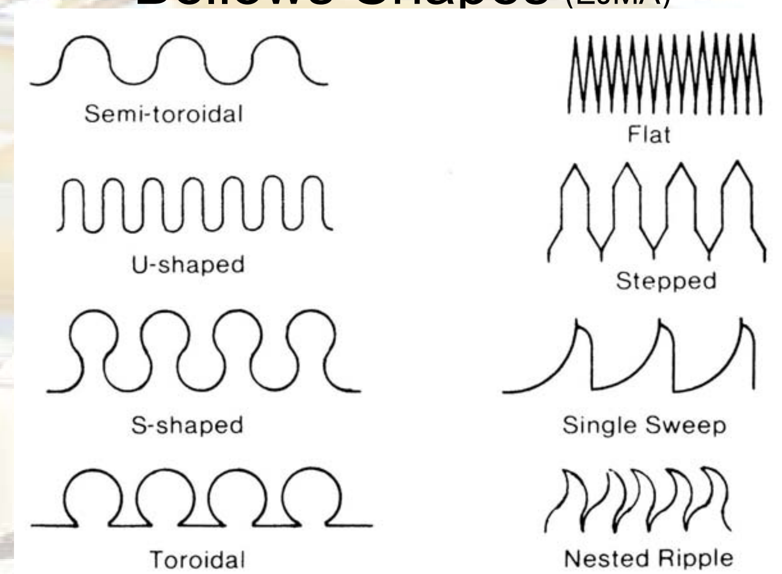
Bellows Expansion Joint Types

Type	Type	Axial	Lateral	Rotation	Pressure Thrust
Single		Yes	Small	Yes	Yes
Universal (tied)			Yes	Yes	
Hinged				Yes	
Gimbal				Yes	
Pressure Balanced		Yes	Small	Yes	

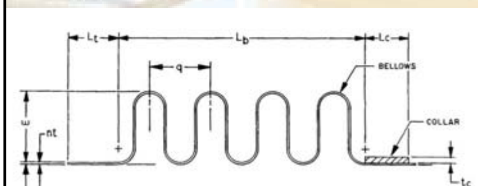
Metal Bellows Expansion Joints

- Bellows Shapes
- Failure Modes

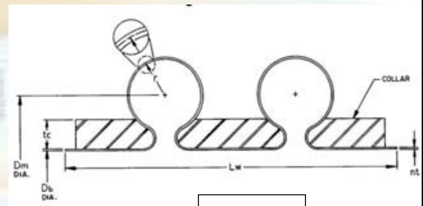
Bellows Shapes (EJMA)



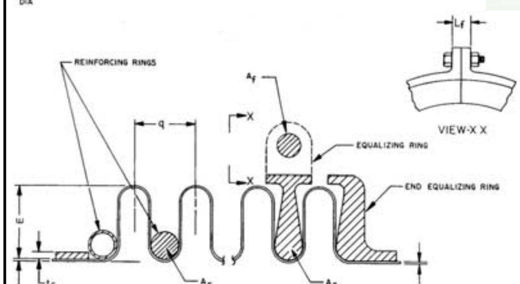
Bellows Shapes (EJMA)



Unreinforced U



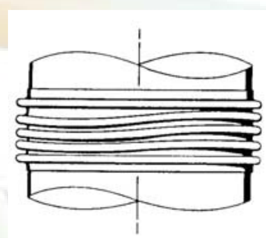
Toroidal

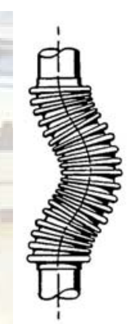


Reinforced U

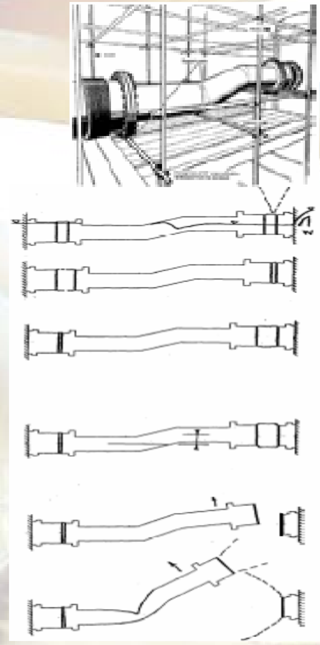
Metal Bellows Failure Modes

- In-plane squirm
- Column squirm
- Fatigue
  (Design Factor = 2.6 on cycles)
- Creep-fatigue
- Burst, collapse, over stretching
  (Design Factor = 3.0 on burst)
- Corrosion


In-plane squirm


Column squirm

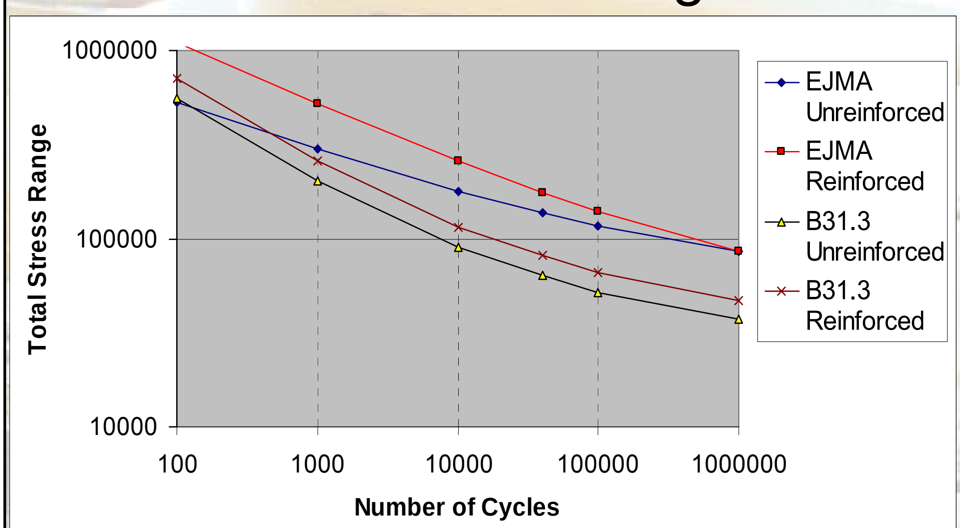
Flixborough Disaster



- 1974 cyclohexane vapor cloud explosion (UK)
- Killed 28, injured 89, damaged 1821 homes
- Caused by plant personnel's failure to recognize expansion joint pressure thrust problem

BECHT *ENGINEERING COMPANY, INC.* Designing with Expansion Joints - 29

Metal Bellows Fatigue



BECHT *ENGINEERING COMPANY, INC.* Designing with Expansion Joints - 30

ASME B31.3 Process Piping

Charles Becht IV, PhD, PE
Don Frikken, PE
Instructors

Piping Development Process

1. Establish applicable system standard(s)
2. Establish design conditions
3. Make overall piping material decisions
   - Pressure Class
   - Reliability
   - Materials of construction
4. Fine tune piping material decisions
   - Materials
   - Determine wall thicknesses
   - Valves
5. Establish preliminary piping system layout & support configuration
6. Perform flexibility analysis
7. Finalize layout and bill of materials
8. Fabricate and install
9. Examine and test

12. Fabrication and Installation

- Welder/Brazer Qualification
- Welding Processes
- Weld Preparation
- Typical Welds
- Preheating & Heat Treatment
- Typical Owner Added Requirements
- Installation
- Flange Joints

The Material in This Section is Addressed by B31.3 in:

Chapter V - Fabrication, Assembly, and Erection

Welder Qualification

Welders are required to use an approved procedure in accordance with B&PV Code Section IX

- Prepare the welding procedure specification (WPS)
  - Essential variables (P-no., thickness, PWHT, etc.)
  - Nonessential variables (Groove design, position, technique, etc)
- Procedure Qualification Test – to determine that weldment is capable of having required properties
- Test of procedure, not welder (normally done by good welders)
- Must pass tensile test and bend test
- May be required to pass supplemental tests (e.g. impact)
- The test record is documented as Procedure Qualification Record (PQR), which is retained by the employer

Welder Qualification

Welders are required to be qualified by test in accordance with B&PV Code Section IX

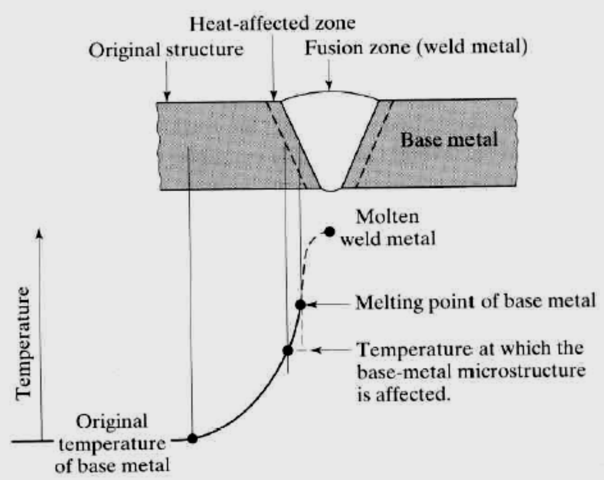
- Performance Qualifications Test – to determine that the welder is capable of depositing sound weld metal
- Additional essential variables, e.g. position, pipe diameter
- The test record is documented as Welder Performance Qualification (WPQ), which is retained by the employer
- Need to weld with manual (or automatic) process periodically, if not for 6 months, re-qualification required (could be on production weld that is X Rayed)
- Procedure and performance qualifications may be by other than the employer under certain conditions if the Inspector approves.

Brazer Qualification

Brazers are required to used an approved procedure and be qualified by test, also in accordance with B&PV Code Section IX

- Prepare the brazing procedure specification (BPS)
- The procedure test record is documented as Procedure Qualification Record (PQR), which is retained by the employer
- The performance test record is documented as Brazer Performance Qualification (BPQ), which is retained by the employer
- The owner may waive these qualifications for Category D Fluid Service.

Welding Processes – Fusion Weld



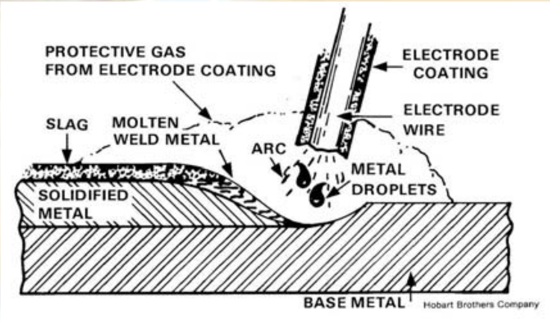
Characteristics of the fusion weld joint

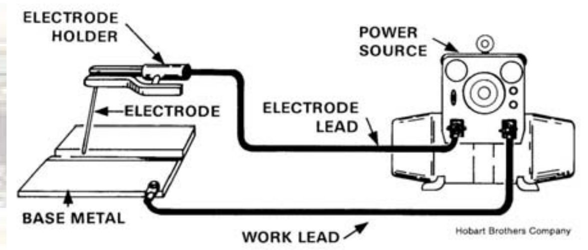
(Manufacturing Engineering and Technology: p820)

Welding Processes – Electric Arc

- Shielded Metal Arc Welding (SMAW), a.k.a. stick welding
- Gas Metal Arc Welding (GMAW), a.k.a. MIG
- Flux Cored Arc Welding (FCAW)
- Gas Tungsten Arc Welding (GTAW), a.k.a. TIG

Shielded Metal Arc Welding

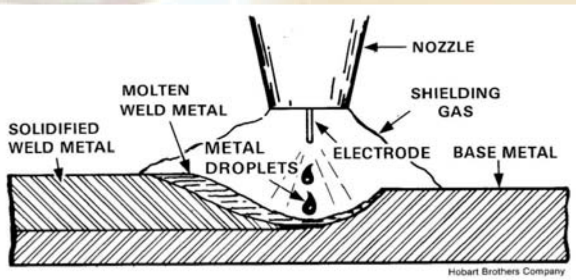


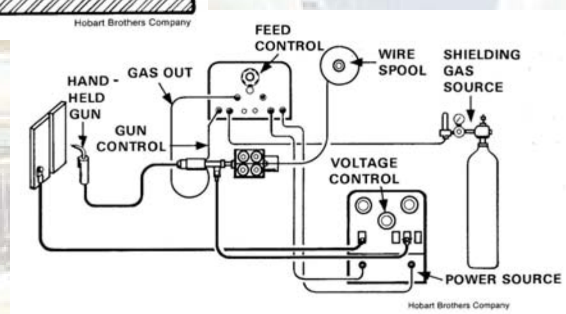


Shielded Metal Arc Welding

- Suitable for windy, outdoor conditions
- Low cost equipment
- All position capabilities
- Good choice for on-site welding

Gas Metal Arc Welding

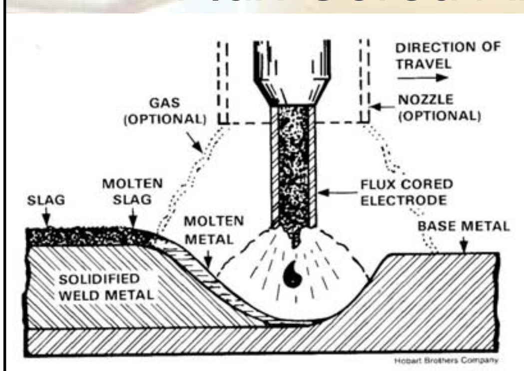


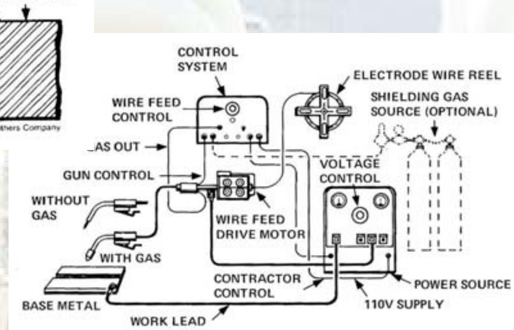


Gas Metal Arc Welding

- Not suitable for windy, outdoor conditions
- Moderate cost equipment
- All position capabilities
- Fast welding speeds possible
- No slag to clean

Flux Cored Arc Welding

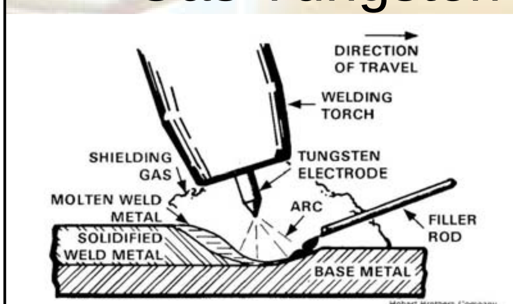


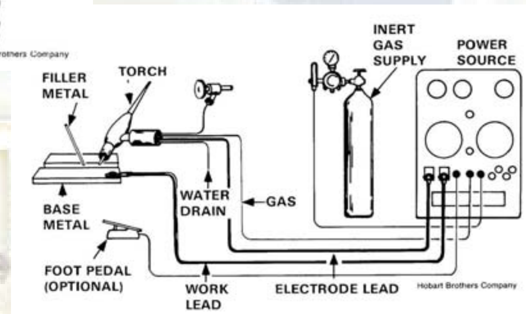


Flux Cored Arc Welding

- Suitable for windy, outdoor conditions
- Same equipment as for GMAW
- Out of position capabilities
- High metal deposition rate

Gas Tungsten Arc Welding





Gas Tungsten Arc Welding

- Not suitable for windy, outdoor conditions
- Moderate cost equipment
- All position capabilities
- Low metal deposition rate
- No slag to clean
- Highest quality, most precise welds

Welding Processes

Process	Materials	Skill Level Required
SMAW	Steel, Stainless Steel	Moderate
GMAW	Steel, Stainless Steel, Aluminum	Low
FCAW	Steel, Stainless Steel	Moderate
GTAW	Steel, Stainless Steel, Aluminum, Titanium, Nickel Alloys	High

Welding Processes Accepted

Process	Generally Accepted for
SMAW	Most fluid services with GTAW root. Sometimes restricted to larger sizes.
GMAW	Like SMAW, but approval of specific process may be required.
FCAW	Like SMAW, but approval of specific process may be required.
GTAW	Everything

Weld Preparation

- Surfaces to be welded are required to be clean
- End preparation required to meet WPS, ASME B16.25 is accepted practice

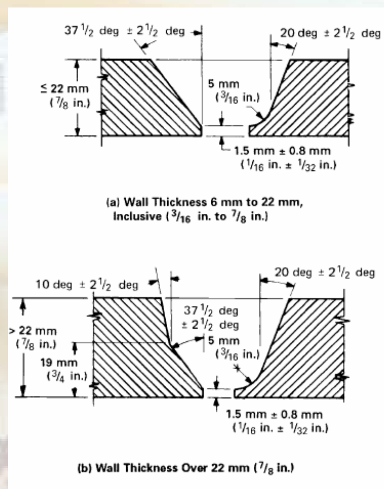
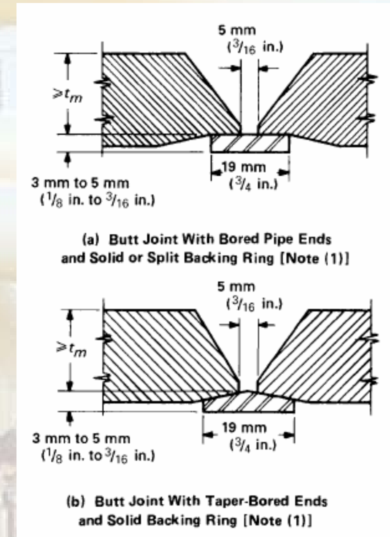


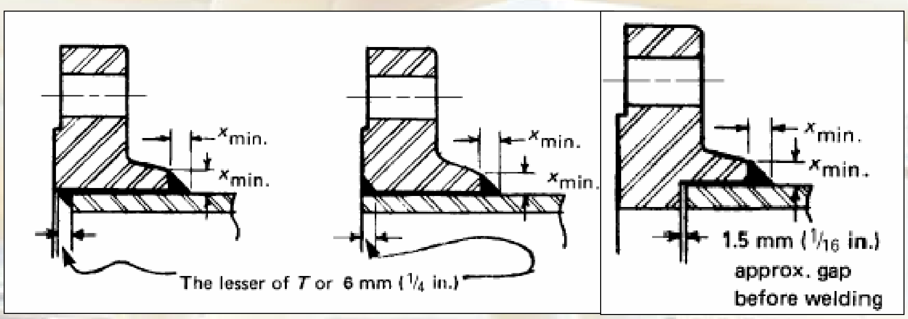
FIG. 328.4.2 TYPICAL BUTT WELD END PREPARATION

Weld Preparation

- Use of backing rings is permitted
- Alignment is required to be in accordance with the WPS



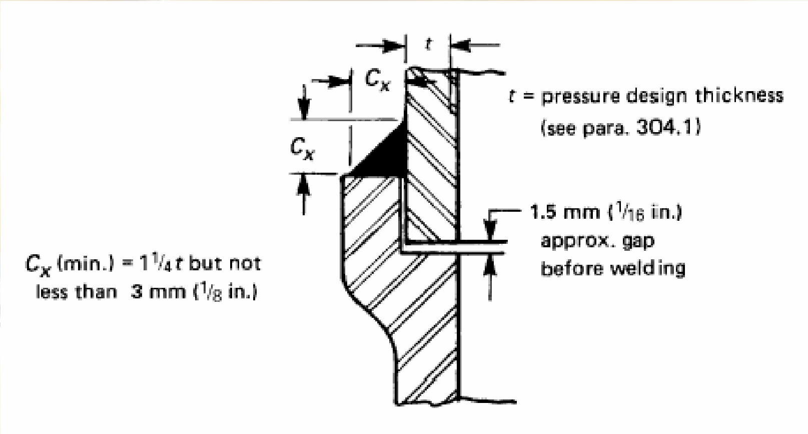
Typical Welds



Slip-on Flange

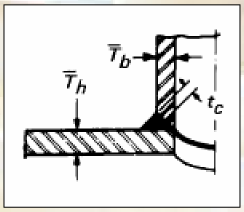
Socket Welding Flange

Typical Welds

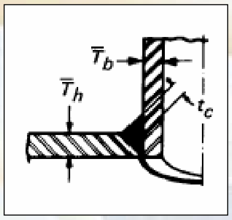


Socket Weld

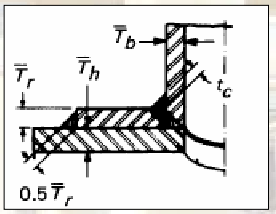
Typical Welds



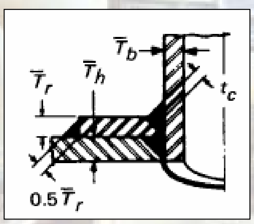
Unreinforced Stubon



Unreinforced Stubin



Reinforced Stubon



Reinforced Stubin

Preheating

Preheating:

- Prevents cracking caused by differential thermal expansion in the area of the weld
- Drives off moisture that could contribute to hydrogen in the welds
- Slows the cooling rate for the deposited weld metal

The Code:

- Recommends preheat to 50ºF (10ºC) for most carbon steels and stainless steels
- Requires preheat to 300ºF (150ºC) or more for low alloy steels

No welding is permitted if water is present in the weld area or if there is excessive wind. See Table 330.1.1.

Heat Treatment

Heat treatment

- Relieves residual stresses caused by welding, bending and forming
- Facilitates diffusion of hydrogen out of the weld

The Code requires heat treatment for:

- Carbon steels thicker than ¾ in. (19 mm)
- Most low alloy steels thicker than ½ in. (13 mm)

See Table 331.1.1.

Typical Owner Added Requirements

- Requirements on use of particular welding processes
- Restrictions on the use of repairs
- Requirements for traceability
- Requirements for marking of piping
  - Stamping not permitted on certain materials
  - Inks containing low melting point metals not permitted on certain materials
- Specific end preparation and alignment requirements

Typical Owner Added Requirements (Continued)

- Requirements for socket welds
- Prohibition of the use of single welded slip-on flanges
- Prohibition on the use of backing rings
- Requirements for fabricated branches
- Bolt hole orientation for flanges
- Dimensional tolerances
- Additional heat treatment requirements

Typical Owner Added Requirements
(Continued)

- Requirements for flow meter runs
- Cleaning requirements
- Shipping and storage requirements
- Requirements for records

Installation

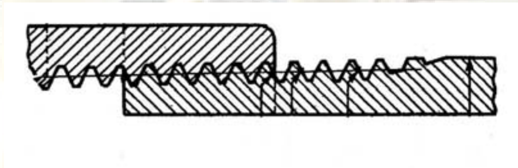
Code Requirements

- Detrimental distortion of piping to bring it into alignment is prohibited
- Examination of installation for errors prior to cold spring is required.
- Flange faces are required to be parallel to design plane within ½% prior to bolt up.
- Flanges are required to be properly tightened
- No more than one gasket can be used
- Bolts can be one thread short of a full nut
- Thread sealant shall be suitable for the service

Installation

Code Requirements

- Threaded joints to be seal welded shall be made up without thread compound
- Threaded joints that leak during testing may be seal welded provided compound is removed from exposed threads
- Seal welds shall cover all exposed threads



Installation

Typical Owner Added Requirements

- Maximum distance a bolt can extend through a nut
- Requirements for connecting to in-service piping
- Cleanliness requirements
- Requirements for installation of isolation kits
- Require threads to conform to ASME B1.20.1
- Requirements for thread sealant(s)
- Prohibition of the use of seal welds
- Prohibit use of gasket compounds

Installation

Typical Owner Added Requirements (cont.)

- Requirements for use of bolt lubricants
- Requirements for use (or not) of washers
- Requirements for flanged joint tightening
- Requirements for valve orientations
- Requirements for alignment by heating (rose budding)
- Requirements for bolting to rotating equipment; e.g., in accordance with API 686

BECHT *ENGINEERING COMPANY, INC.* Fabrication and Installation - 33

Typical Owner Added Requirements (cont.)

- Clearance from obstructions such as support steel

Flange Joints

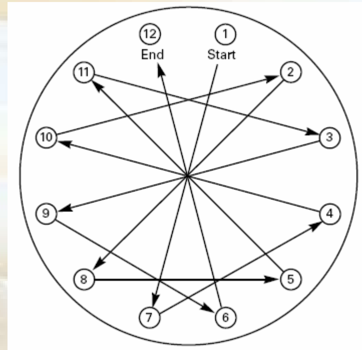
Guidelines for installation are provided in ASME PCC-1 – *Guidelines for Pressure Boundary Bolted Flange Joint Assembly.* Topics addressed include:

- Qualification of assemblers
- Gasket contact surfaces
  - Correct facing finish
  - Good condition
- Flange alignment
- Correct gasket type, size & placement

Flange Joints

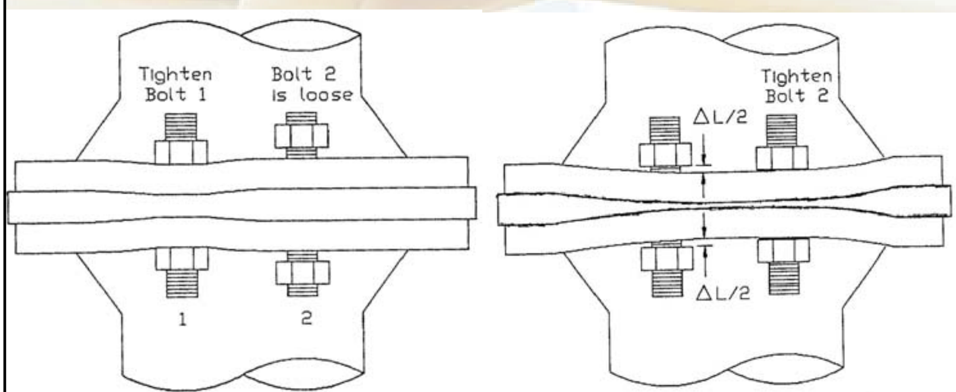
More topics addressed:

- Lubrication of bolting, back facing
- Numbering of bolts
- Tighten bolting uniformly in criss-cross pattern is small steps
- Target bolt stress is typically 50 ksi (340 MPa)



BECHT *ENGINEERING COMPANY, INC.* Fabrication and Installation - 37

Flange Joints

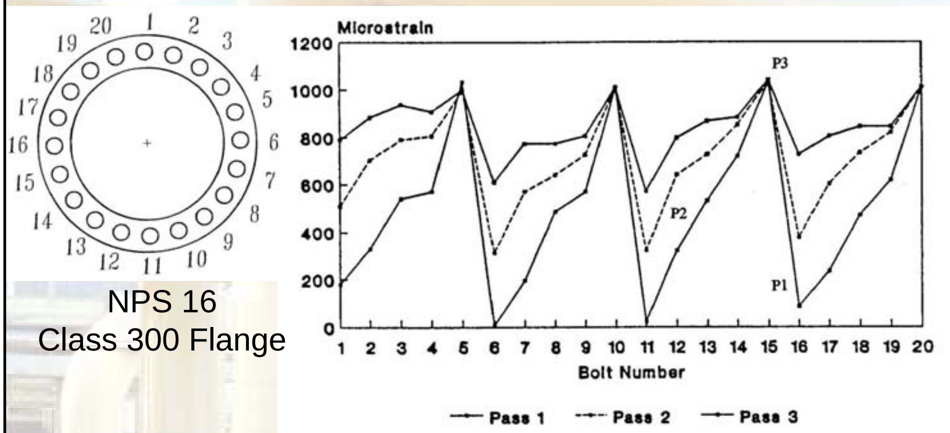


Elastic Interaction

(WRC Bulletin 408)

BECHT *ENGINEERING COMPANY, INC.* Fabrication and Installation - 38

Flange Joints



Bolt Tension after 1, 2 and 3 Passes

(WRC Bulletin 408)

Flange Joints

ASME PCC-1 describes bolt-up procedure using torque to gage bolt tension

- Snug up bolting
- Tighten to 20% of target torque using cross pattern
- Tighten to 50 to 70% of target torque using cross pattern
- Tighten to 100% of target torque using cross pattern
- Continue tightening to 100% target torque using rotational pattern until no movement
- Wait 4 hours or longer and repeat rotational pattern to 100% target torque until no movement

Flange Joint

Target torque for 50 ksi (345 MPa) bolt stress:

Bolt Size	Non-Coated Bolts in-lb – N-m		Coated Bolts in-lb – N-m	
1/2	60	80	45	60
5/8	120	160	90	120
3/4	210	280	160	220
7/8	350	470	250	340
1	500	680	400	540
1-1/8	750	1000	550	750
1-1/4	1050	1400	800	1100
1-3/8	1400	1900	1050	1400
1-1/2	1800	2450	1400	1900

ASME B31.3 Process Piping

Charles Becht IV, PhD, PE
Don Frikken, PE
Instructors

Piping Development Process

1. Establish applicable system standard(s)
2. Establish design conditions
3. Make overall piping material decisions
   - Pressure Class
   - Reliability
   - Materials of construction
4. Fine tune piping material decisions
   - Materials
   - Determine wall thicknesses
   - Valves
5. Establish preliminary piping system layout & support configuration
6. Perform flexibility analysis
7. Finalize layout and bill of materials
8. Fabricate and install
9. Examine and test

13. Inspection, Examination & Testing

- Inspection
- Examination
  - Methods
  - Requirements
  - Acceptance Criteria
- Leak Testing
  - Methods
  - Requirements

The Material in This Section is Addressed by B31.3 in:

Chapter VI - Inspection, Examination and Testing

Inspection

"(4) *Owner's Inspector.* The owner's Inspector (see para. 340) is responsible to the owner for ensuring that the requirements of this Code for inspection, examination, and testing are met..." [300(b)]

"This Code distinguishes between examination (see para. 341) and inspection. Inspection applies to functions performed for the owner by the owner's Inspector or the Inspector's delegates." [340.1]

BECHT ENGINEERING COMPANY, INC. Inspection, Examination and Testing - 5

Inspection

The owner's inspector:

- Verifies that all required examinations and testing have been completed
- Has access to any place where work is being performed
- Must be independent of organizations performing fabrication, examination, installation or testing
- Must have 10 years experience or 5 years experience plus an engineering degree

BECHT ENGINEERING COMPANY, INC. Inspection, Examination and Testing - 6

Examination

"Examination applies to quality control functions performed by the manufacturer (for components only), fabricator, or erector. Reference in this Code to an examiner is to a person who performs quality control examinations." [341.1]

Examination

The examiner:

- Examines piping in accordance with Code requirements
- Examines piping is accordance with additional requirements described in the engineering design
- Prepares suitable examination records for use by the inspector
- Shall have training and experience commensurate with the needs of the specified examinations

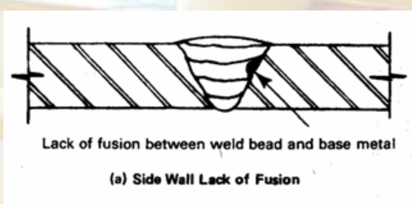
Examination

Examination is performed in order to assure that:

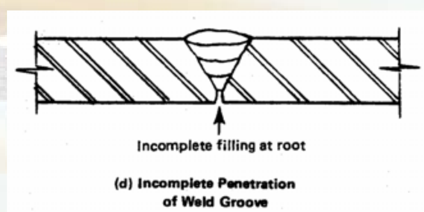
- Components conform to the specifications for
  - Material of construction
  - Design
  - Freedom from defects
- Piping is installed with the proper
  - Support
  - Alignment
  - Joint assembly
- Discontinuities are sufficiently small that they don't grow into leaks during operation

BECHT *ENGINEERING COMPANY, INC.* Inspection, Examination and Testing - 9

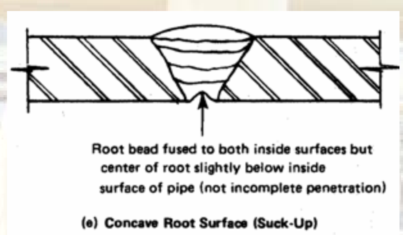
Typical Weld Imperfections



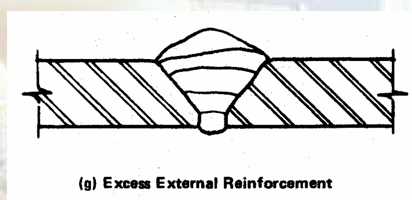
Lack of Fusion



Incomplete Penetration



Suck Up



Excess Reinforcement

BECHT *ENGINEERING COMPANY, INC.* Inspection, Examination and Testing - 10

Examination Methods

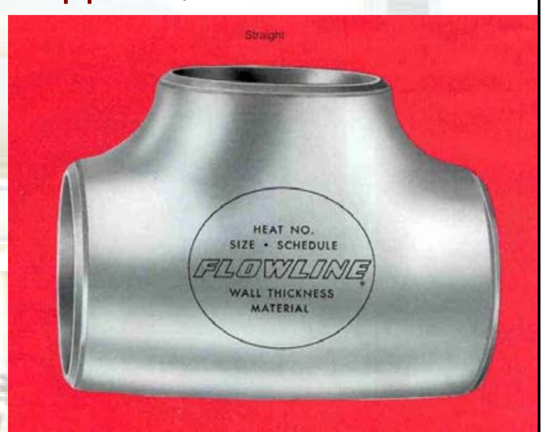
Examination methods include

- Visual (VT)
- Positive Material Identification (PMI)
- Liquid Dye Penetrant (PT)
- Magnetic Particle (MT)
- Radiography (RT)
- Ultrasonic (UT)
- In-Process

Examination Methods

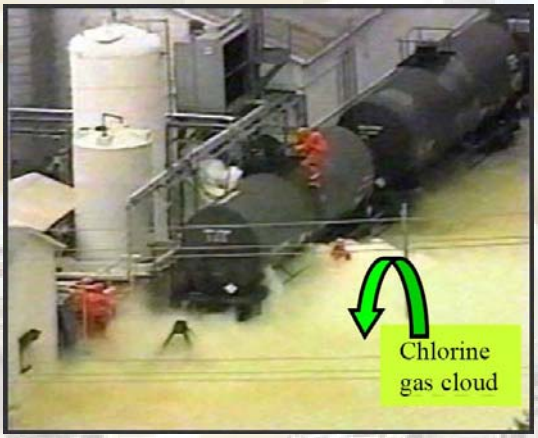
Visual – Includes examination of materials, fabrication (welds), supports, and installation.

- Least expensive
- Most effective



Examination Methods

Positive Material Identification – Verifies material of construction is as specified.



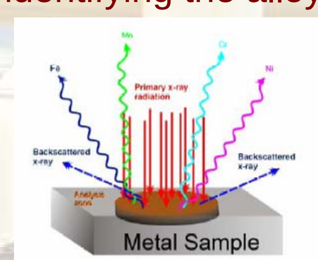
The ruptured hose should have had an Alloy C-276 exterior metal braiding. Instead, the braiding was stainless steel and was easily corroded by chlorine permeation through the Teflon liner. The hose failed after less than 2 months of service. Both the purchase and shipping papers indicated that the hose was constructed of the proper materials, but it was not. (CCPS Beacon, Aug '04)

BECHT ENGINEERING COMPANY, INC. Inspection, Examination and Testing - 13

Examination Methods

Positive Material Identification – Verifies material of construction is as specified.

- X-ray fluorescence – Sample is exposed to low radioactive or x-rays. Reflected energy is different for every element. This energy is measured, thus identifying the alloy elements.



DCI, Inc.

BECHT ENGINEERING COMPANY, INC. Inspection, Examination and Testing - 14

Examination Methods

Positive Material Identification – Verifies material of construction is as specified.

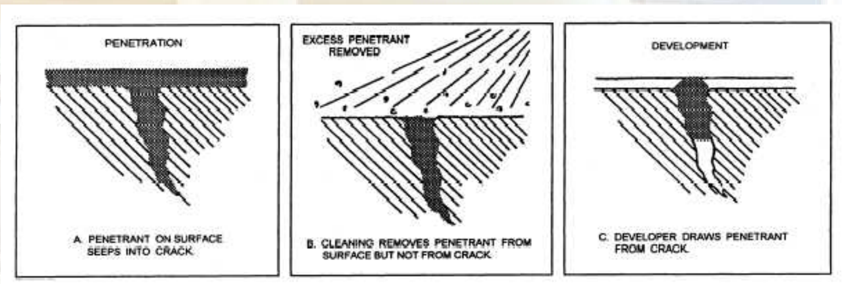
- Spark emission spectrography - A spark is released that vaporizes a small portion of the sample. The instrument optically measures the atoms in the vapor to determine the components of the material.

Spectro

BECHT *ENGINEERING COMPANY, INC.* Inspection, Examination and Testing - 15

Examination Methods

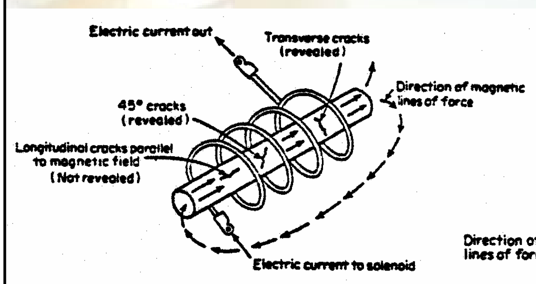
Liquid Dye Penetrant – Employs a dye penetrant applied to the surface and a developer. This method is used to detect fine cracks.

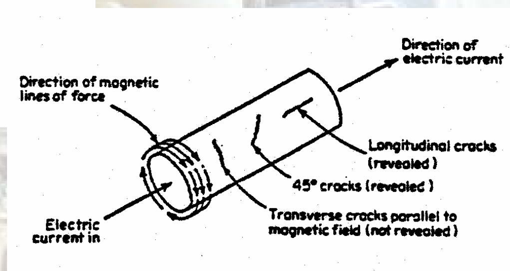


BECHT *ENGINEERING COMPANY, INC.* Inspection, Examination and Testing - 16

Examination Methods

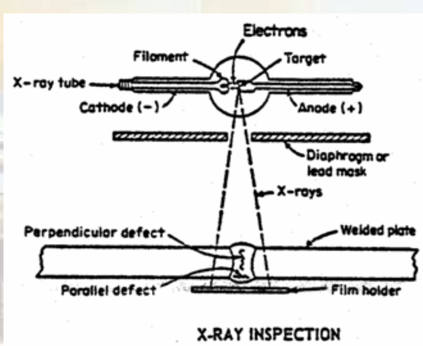
Magnetic Particle – This method is also used to detect fine cracks.

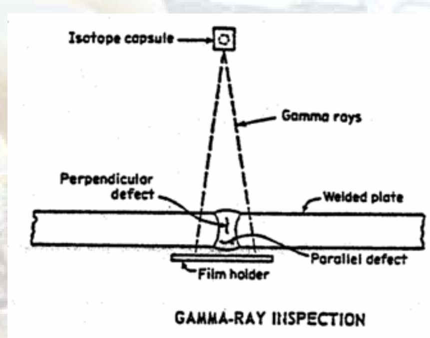




Examination Methods

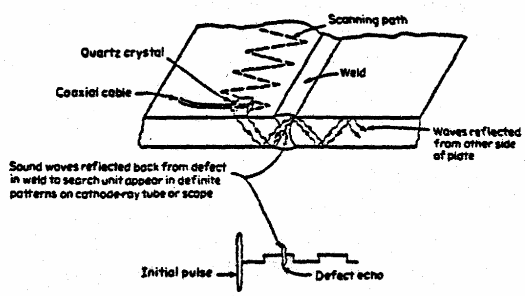
Radiography – Used to detect internal defects and defects on the inside of of the weld for welds which cannot be visually examined on the inside. Will detect some surface defects.





Examination Methods

Ultrasonic – Used to detect internal defects and defects on the inside of of the weld for welds which cannot be visually examined on the inside. Can be used to characterize surface defects.



ULTRASONIC WELD INSPECTION

Examination Methods

In-Process – Used to verify work is performed in such a way that it is likely to produce an acceptable joint. Visual observation of the following is required

- Joint preparation and cleanliness
- Preheating
- Fit-up, clearance and alignment
- For welding
  - Filler material, position and electrode
  - Condition of root pass after cleaning
  - Weld condition between passes
  - Appearance of finished weld

Examination Requirements

Progressive Sampling for Examination [341.3.4]

- For examinations that are not 100%
- When spot or random exam reveals a defect
  - Two additional samples of the same kind are examined the same way
  - If the two samples are acceptable, then lot is acceptable
  - If not, then two further samples of the same kind are examined for each defective sample the same way
  - If all the further samples examined are acceptable, then lot is acceptable
  - If not, then all items in the lot must be examined

Examination Requirements

Progressive Sampling for Examination

- For welds, the work product of each welder or welding operator must be included in the samples being examined
- Defective items must be repaired or replaced and reexamined
- “Same kind” for welds means joints made by the same welder or welding operator

Examination Requirements - VT

	Normal	Severe Cyclic	Category D
Materials & components	Random to extent needed to satisfy the examiner		Random to extent needed to satisfy the examiner
Fabrication, including welds	5% Random	100%	
Longitudinal welds	100%	100%	
Bolted, threaded & other joints	Random to extent needed…, except 100% for pneumatic test	100%	
Supports, alignment, erected piping	Random	100%	

Examination Requirements - Other

	Normal	Severe Cyclic	Category D
Circumferential groove welds	5% Random RT or UT	100% RT	No additional examination required
Socket welds and branch connection welds not radiographed	No additional examination required	100% MT or PT	
Brazed joints	5% in-process examination	(brazed joints not permitted)	
Solder joints	(solder joints not permitted)	(solder joints not permitted)	

Examination Requirements

- In-process examination can be substituted for RT or UT in normal service if specified in the engineering design
- UT can be substituted for RT under severe cyclic conditions if specified in the engineering design

Acceptance Criteria for Welds

Described in Table 341.3.2

TABLE 341.3.2
ACCEPTANCE CRITERIA FOR WELDS AND EXAMINATION METHODS FOR EVALUATING WELD IMPERFECTIONS

Criteria [illegible] [Note (1)]																	Examination Methods				
Normal and Category [illegible] Service				Severe Cyclic Conditions				Category D Fluid Service													
Type of Weld				Type of Weld				Type of Weld													
Girth, Miter Groove & Branch Connection [Note (4)]	Longitudinal Groove [Note (2)]	Fillet [Note (3)]		Girth, Miter Groove & Branch Connection [Note (4)]	Longitudinal Groove [Note (2)]	Fillet [Note (3)]		Girth and Miter Groove	Longitudinal Groove [Note (2)]	Fillet [Note (3)]	Branch Connection [Note (4)]		Weld Imperfection	Visual	Radiography		Magnetic Particle	Liquid Penetrant
A	A	A	. . .	A	A	A	. . .	A	A	A	A		Crack	✓	✓	. . .	✓	✓
A	A	A	. . .	A	A	A	. . .	C	A	N/A	A	. . .	Lack of fusion	✓	✓	. . .	. . .	. . .
B	A	N/A	. . .	A	A	N/A	. . .	C	A	N/A	B	. . .	Incomplete penetration	✓	✓	. . .	. . .	. . .
E	E	N/A	. . .	D	D	N/A	. . .	N/A	N/A	N/A	N/A	. . .	Internal porosity	. . .	✓	. . .	. . .	. . .
G	G	N/A	. . .	F	F	N/A	. . .	N/A	N/A	N/A	N/A	. . .	Internal slag inlcusion, tungsten inclusion, or elongated indication	. . .	✓	. . .	. . .	. . .
H	A	H	. . .	A	A	A	. . .	I	A	H	H	. . .	Undercutting	. . .	✓	. . .	. . .	. . .
A	A	A	. . .	A	A	A	. . .	A	A	A	A	. . .	Surface porosity or exposed slug inclusion [Note (6)]	✓	. . .	. . .	. . .	. . .
N/A	N/A	N/A	. . .	J	J	J	. . .	N/A	N/A	N/A	N/A	. . .	Surface finish	✓	. . .	. . .	. . .	. . .
K	K	N/A	. . .	K	K	N/A	. . .	K	K	N/A	K	. . .	Concave root surface (suck up)	✓	✓	. . .	. . .	. . .
L	L	L	. . .	L	L	L	. . .	M	M	M	M	. . .	Weld reinforcement or internal protrusion	✓	. . .	. . .	. . .	. . .

GENERAL NOTES:
(a) Weld imperfections are evaluated by one [illegible] types of examination methods given, as specified in para[illegible] or by the engineering design.
(b) N/A the Code does not establish acceptance criteria or does not require evaluation of this kind of imperfection for this type of yield.
(c) * Alternative Leak Test requires examination of these welds, see para. 345.9
(d) ✓ examination method generally used for evaluating this kind of weld imperfection
(e) . . . examination method not generally used for evaluating this kind and weld imperfection.

See page 83 of the supplement.

Testing

Testing is performed to assure that there are no unacceptable leaks in the system prior to operation. Leak test methods include

- Hydrostatic
- Pneumatic
- Initial service
- Sensitive
- Alternate

Leak Test Methods

Hydrostatic – Filling the piping system with liquid, pressurizing and checking for leaks. Test liquid:

- Shall be water unless there are adverse effects
- Other liquid shall be non-toxic with a flash point at least 120ºF (49ºC)
- Chlorides in test water < 50 ppm
- Only dead bugs in water (residual chlorine)

Leak Test Methods

Hydrostatic – Test pressure:

$$P_T = 1.5\ P\ (S_T / S)$$

Where:

- P_T= Minimum test pressure
- P= Design pressure
- S_T= Stress value at test temperature
- S= Stress value at design temperature

- (S_T / S) not to exceed 6.5
- If P_T would produce a nominal stress above S_Y, P_T may be reduced

Leak Test Methods

Pneumatic – Pressurizing the piping system with gas and checking for leaks.

- Care must be taken to minimize the chance of brittle failure
- A pressure relief device is required
- Gas shall be nonflammable and nontoxic
- Test pressure shall be 110% of design pressure
- Preliminary leak check is required
- Leak check is made after pressure is lowed to design pressure

Leak Test Methods

Initial Service – Pressurizing the piping with the service fluid and checking for leaks.

- Pressure increased in steps to operating pressure
- Preliminary leak check is required if test fluid is a gas
- Leak check is made at operating pressure

Leak Test Methods

Sensitive – Pressurizing the piping with a gas and checking for leaks using a method that can detect leaks as small as 10^{-3} atm-ml/sec.

- Test pressure is at least the lesser of 15 psi (105 kPa) and 25% of the design pressure
- Preliminary leak check is required
- Leak check is made at test pressure

Leak Test Methods

Alternative – Verifying weld integrity in lieu of pressurizing above design pressure and checking for leaks.

- Groove welds shall be 100% RT or UT
- All other welds shall be MT or PT
- A formal flexibility analysis is required
- A sensitive leak test is required

Leak Tests Required

A hydrostatic test is required except:

- The owner may choose to use the initial service leak test for Category D fluid service
- The owner may choose a pneumatic leak test if s/he considers the hydrostatic test impractical
- The owner may use the alternative leak test if s/he considers both the hydrostatic and pneumatic tests impractical, and if
  - Hydrostatic test would cause damage or residual liquid would be hazardous, or there is danger of brittle fracture; and
  - Pneumatic test would present an undue hazard, or there is danger of brittle fracture

Other Leak Test Provisions

- Leak tests shall be maintained for at least 10 minutes
- All joints and connections shall be checked for leaks
- Leak tests shall be conducted after heat treatment
- Piping may be tested as subassemblies
- Flanged joints with blanks need not be tested
- Closure welds need not be tested if subjected to
  - In-process examination, and
  - 100% RT or UT examination

Other Leak Test Provisions

- Externally pressurized piping shall be tested at the higher of 1.5 times the design pressure or 15 psi (105 kPa)
- The internal pipe in jacketed piping shall leak tested before the jacket is completed
- For minor repairs and additions following testing, the owner may waive retesting when measures are taken to assure sound construction
- All joints, including structural attachments, must be left exposed for examination during the leak test
- Joints may be painted prior to hydrostatic or pneumatic leak test

Other Leak Test Provisions

- Temporary supports may be needed to support piping during a hydrotest
- Piping with expansion joints
  - Joints that depend on external main anchors to restrain pressure shall be tested in place
  - Such joints shall be tested at the lesser of 1.5 times the design pressure and the test pressure
  - When the test pressure is higher than 1.5 times the design pressure, temporary restraints may be added to limit main anchor loads

Exam & Test Workshop

What examination and leak test requirements would you specify for the following services:

Steam condensate	650 psig (45 bar) Steam
Chlorine	Heat transfer oil
Sulfuric acid	Styrene monomer
Gasoline	Lime-water slurry

ASME B31.3 Process Piping

Charles Becht IV, PhD, PE
Don Frikken, PE
Instructors

Piping Development Process

1. Establish applicable system standard(s)
2. Establish design conditions
3. Make overall piping material decisions
   - Pressure Class
   - Reliability
   - Materials of construction
4. Fine tune piping material decisions
   - Materials
   - Determine wall thicknesses
   - Valves
5. Establish preliminary piping system layout & support configuration
6. Perform flexibility analysis
7. Finalize layout and bill of materials
8. Fabricate and install
9. Examine and test

15. Nonmetallic Piping

- General
- Design, Fabrication, and Installation for
  - Thermoplastics
  - Reinforced thermosetting resins
  - Reinforced concrete
  - Vitrified clay
  - Borosilicate glass
  - Piping lined with nonmetals
- Limitations

The Material in This Section is Addressed by B31.3 in:

Chapter VII - Nonmetallic Piping and Piping Lined with Nonmetals

Appendix B - Stress Tables and Allowable Pressure Tables for Nonmetals

General

- Chapter VII has requirements for
  - Thermoplastics
  - Reinforced thermosetting resins
  - Reinforced concrete
  - Vitrified clay
  - Borosilicate glass
  - Piping lined with nonmetals

General

- Trend toward the use of nonmetals is increasing
- Nonmetals are used when the metallic alternative is judged to be too expensive
- Allowances for variations of pressure and temperature described in Chapter II are not permitted for nonmetallic piping
- Increased allowable stresses for occasional loads described in Chapter II are not permitted

Thermoplastics

- Materials that can be repeatedly softened by heating and hardened by cooling
- Pipe is extruded
- Fittings are usually injection molded, but sometimes fabricated
- Valve parts are usually injection molded

(Durapipe)

(Charlotte Pipe)

(Durapipe)

Thermoplastics

Commonly used thermoplastics

- ABS Acrylonitrile-butadiene-styrene
- CPVC Chlorinated polyvinyl chloride
- FEP Perfluoro ethylene propylene
- (HD)PE (High density) polyethylene
- PFA Polyperfluoroalkoxy Alkane
- PP Polypropylene
- PVC Polyvinyl chloride
- PVDF Polyvinylidene fluoride

Thermoplastics

B31.3 recommended temperature limits:

Material	Min (F)	Max (F)	Min (C)	Max (C)
ABS	-40	176	-40	80
CPVC	0	210	-18	99
FEP	-325	400	-198	204
PE	-30	180	-34	82
PFA	-40	450	-40	250
PP	30	210	-1	99
PVC	0	150	-18	66
PVDF	0	275	-18	135

Thermoplastics

Characteristics

- High coefficient of thermal expansion
  - 4” in 100’ (3 mm/m) of expansion for 50ºF (25ºC) temperature change [HDPE]
  - More in some thermoplastics, less in others
- Creep at room temperature
- Low elastic modulus
- Longitudinal strain due to internal pressure can be significant

Thermoplastics

Allowable Stress

Hydrostatic design stress (HDS) is the hoop stress that when applied continuously, will cause failure of the pipe at 100,000 hours multiplied by a suitable design factor (usually 0.5)

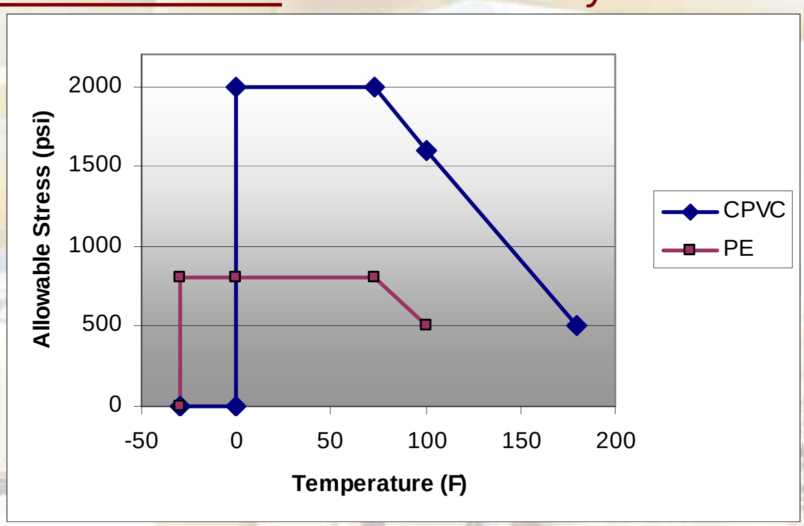
Material	Short-term (ksi)	HDS* (ksi)	Short-term (MPa)	HDS* (MPa)
CPVC	7.53	2.00	51.9	13.8
PE	2.96	0.80	20.4	5.5
PVC	7.53	2.00	51.9	13.8

* HDS at 23ºC (73ºF)

BECHT *ENGINEERING COMPANY, INC.* Nonmetallic Piping - 11

Thermoplastics

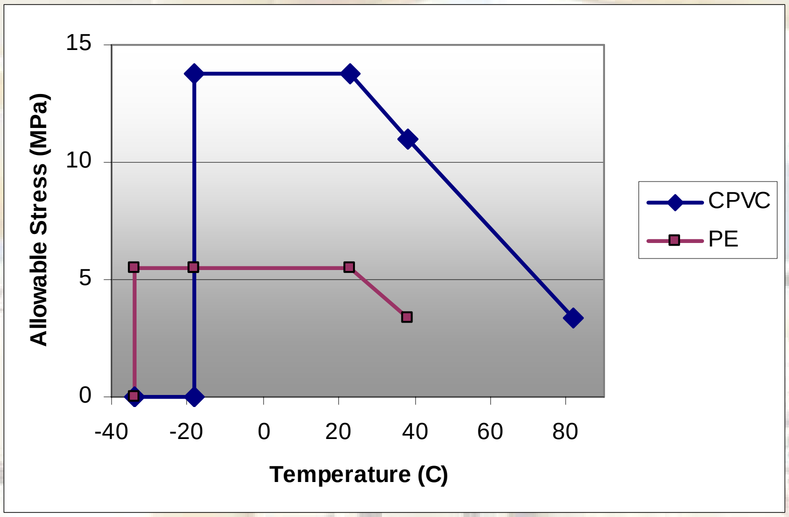
Allowable Stress – US Customary Units



BECHT *ENGINEERING COMPANY, INC.* Nonmetallic Piping - 12

Thermoplastics

Allowable Stress – Metric Units



BECHT *ENGINEERING COMPANY, INC.* Nonmetallic Piping - 13

Thermoplastics

Pressure Design – Straight Pipe

$$t = PD / [2 (S + P)]$$

Where:

- t = pressure design thickness
- P = design pressure
- D = outside diameter of pipe
- S = HDS value for material from Appendix B

No specific rules for external pressure design

BECHT *ENGINEERING COMPANY, INC.* Nonmetallic Piping - 14

Thermoplastics

Support

Because of the low modulus and low allowable stress, thermoplastics require more support than similar sized metallic pipe. For 68ºF (20ºC):

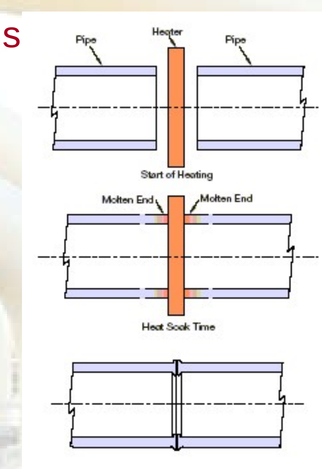
NPS	PP (Asahi)		Typical Metallic	
	ft	m	ft	m
1	3.5	1.1	14	4.3
2	4.5	1.4	20	6.1
4	6.0	1.8	26	7.9
6	7.0	2.1	30	9.1

BECHT ENGINEERING COMPANY, INC. Nonmetallic Piping - 15

Thermoplastics

Fabrication – Butt fusion fittings are joined to the pipe using a butt fusion welding process. (PE, PP, PVDF, others)

(Asahi)



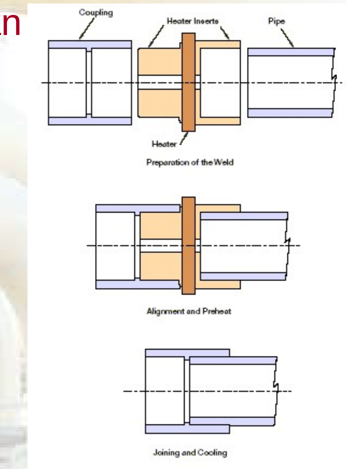
(Asahi)

BECHT ENGINEERING COMPANY, INC. Nonmetallic Piping - 16

Thermoplastics

Fabrication – Socket fittings can be joined to the pipe using a socket fusion welding process. (PE, PP, PVDF, others)

(Spears)



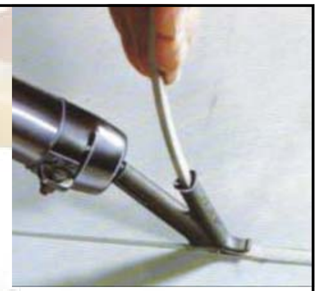
(Asahi)

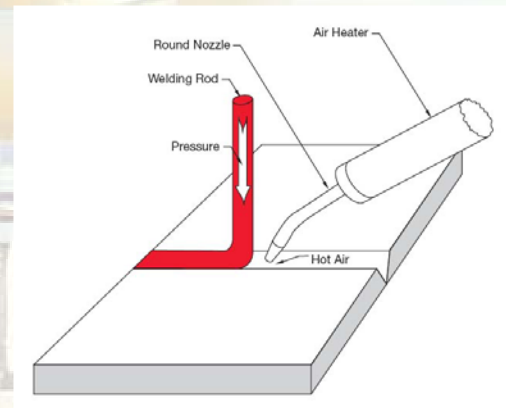
Thermoplastics

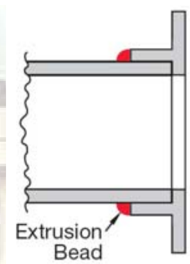
Fabrication – Socket fittings can be joined to the pipe using a solvent cementing process. (ABS, PVC, CPVC)

Thermoplastics

Fabrication – Piping can also be joined using a hot gas welding process. (PE, PP, PVDF, others)







Thermoplastics

Bonders are required to use a qualified bonding procedure specification. The BPS shall specify

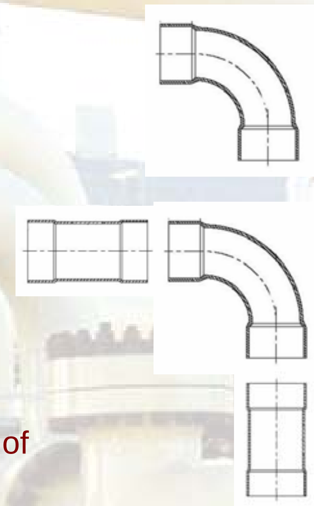
- Procedure for making the bonds
- Materials, including storage requirements
- Tools, including proper care and handling
- Environmental requirements (clean, dry, warm)
- Joint preparation
- Dimensional requirements, including tolerances
- Cure time
- Protection of work
- Acceptance criteria

[A328.2].

Thermoplastics

Fabrication

- A warm, dry and clean environment is required for fabrication
- A leak at an elbow requires
  1. Cutting out the elbow and adjacent pipe
  2. Fabricating a piece with an elbow and two couplings
  3. And installing it, hoping none of the six new joints leak



Reinforced Thermosetting Resins

- Materials that harden when heated and cannot be re-melted
- Pipe is filament wound, contact molded, or centrifugally cast
- Fittings are molded, filament wound or fabricated
- Few RTR valves are available

(Smith Fibercast)

Reinforced Thermosetting Resins

Commonly used resins

- Polyester
- Vinylester
- Epoxy
- Furan

Commonly used reinforcements

- Glass fiber
- Carbon fiber

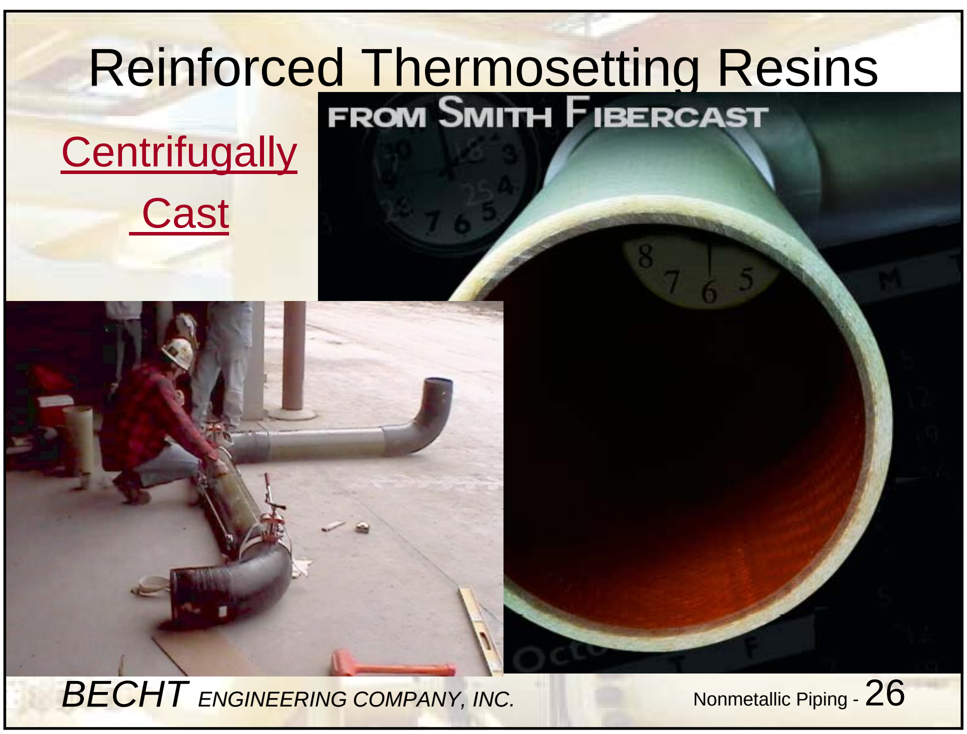
BECHT *ENGINEERING COMPANY, INC.* Nonmetallic Piping - 23

Reinforced Thermosetting Resins

Filament wound

(Smith Fibercast)


Reinforced Thermosetting Resins
Contact Molded


Reinforced Thermosetting Resins
Centrifugally Cast
FROM SMITH FIBERCAST
BECHT ENGINEERING COMPANY, INC.
Nonmetallic Piping - 26

Reinforced Thermosetting Resins

Reinforced plastic mortar pipe

- Has aggregate (usually sand) in addition to fiber reinforcement to stiffen the wall of the pipe
- Is used mostly underground
- Usually has bell and spigot joints, but may have socket joints like other RTR piping

BECHT *ENGINEERING COMPANY, INC.* Nonmetallic Piping - 27

Reinforced Thermosetting Resins

Vendor recommended temperature limits

- Range from 180 to 275ºF (82 to 135ºC)
- Are somewhat dependent on the resin
- But are more dependent on the construction of the pipe and fittings…amount of reinforcement in the liner and structural layers
- Can be significantly lowered depending on the chemical being handled

BECHT *ENGINEERING COMPANY, INC.* Nonmetallic Piping - 28

Reinforced Thermosetting Resins

Characteristics

- Higher coefficient of thermal expansion…about twice that of steel, but 1/5 of thermoplastics
- Creep at room temperature
- Low elastic modulus (3 to 10% of steel), but 3 to 10 times thermoplastics

Reinforced Thermosetting Resins

Allowable Stress – Filament Wound and Centrifugally Cast

Hydrostatic design stress (HDS) is the hoop stress that when applied continuously, will cause failure of the pipe at 100,000 hours multiplied by a design factor. The design factor is:

- Not more than 1.0 if stress is determined using the pressure cycling method
- Not more than 0.5 if stress is determined using the static pressure method

Typical HDS values are 8,000 to 13,000 psi (55 to 90 MPa)

Reinforced Thermosetting Resins

Allowable Stress – Contact Molded

Design stress (DS) is 1/10 of the minimum tensile strength

Pressure Design – Same as for thermoplastic pipe

Reinforced Thermosetting Resins

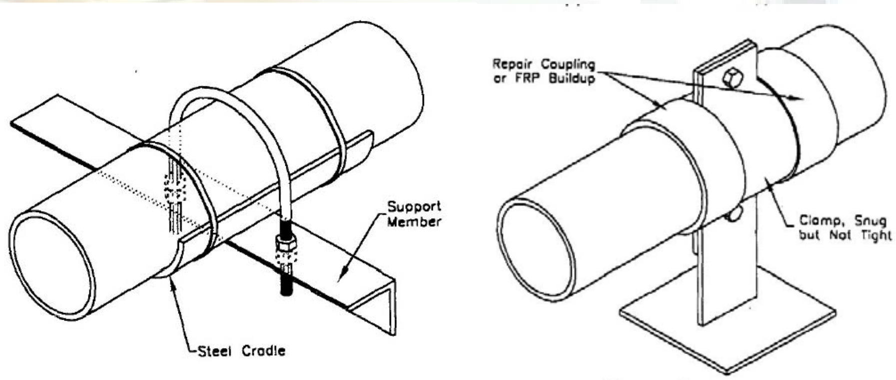
Support

Because of the lower modulus and lower allowable stress, RTR pipe requires more support than similar sized metallic pipe. For 75ºF (24ºC):

	Green Thread (Smith Fibercast)		Typical Metallic	
NPS	**ft**	**m**	**ft**	**m**
1	10.9	3.3	14	4.3
2	14.1	4.3	20	6.1
4	17	5.2	26	7.9
6	20.5	6.2	30	9.1

Reinforced Thermosetting Resins

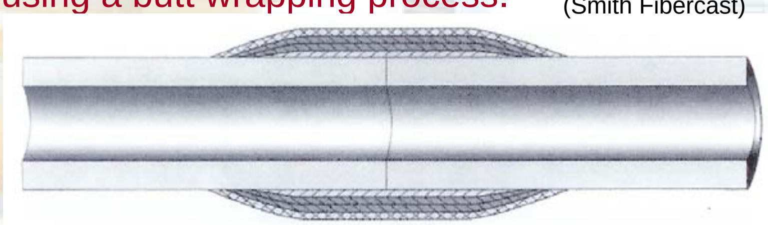
Support – Support elements must be designed to provide low concentrated stresses and protect the piping from abrasion.



(Typical guide and anchor – Conley)

Reinforced Thermosetting Resins

Fabrication - Butt fittings are joined to the pipe using a butt wrapping process. (Smith Fibercast)



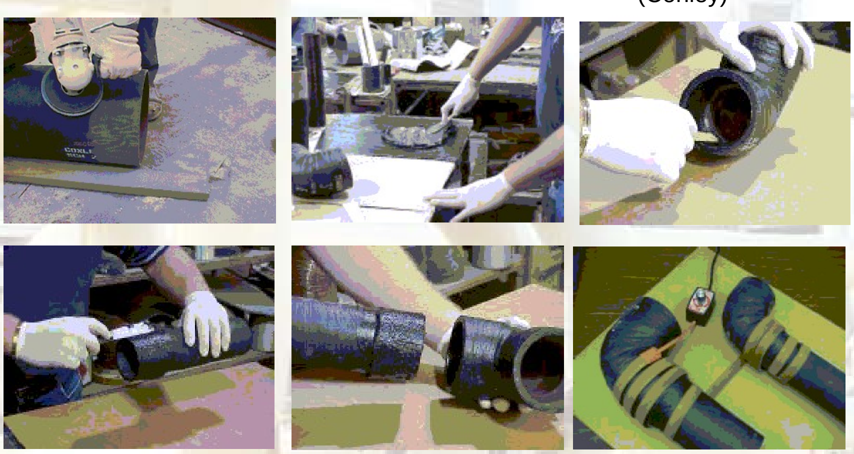
Reinforced Thermosetting Resins

Fabrication – Doing it in a warm, clean, dry environment is sometimes a challenge.

Reinforced Thermosetting Resins

Socket fittings are joined to the pipe using an adhesive.

(Conley)

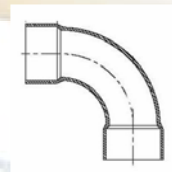


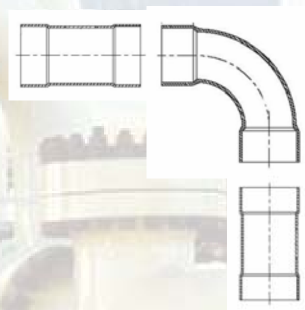
Reinforced Thermosetting Resins

<u>Fabrication</u>

A leak at an elbow requires

1. Cutting out the elbow and adjacent pipe
2. Fabricating a piece with an elbow and two couplings
3. And installing it, hoping none of the six new joints leak



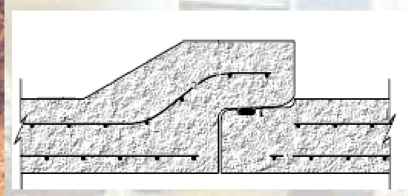


Reinforced Thermosetting Resins

<u>BPS and Bonder Qualification Tests</u> are required as for thermoplastic piping, except test pressure is 3 times manufacturer's rating

Reinforced Concrete

- Typically 15 to 250 psi (1 to 17 bar) ambient temperature water service
- Made to ASTM and AWWA standards with specific B31.3 pressure ratings

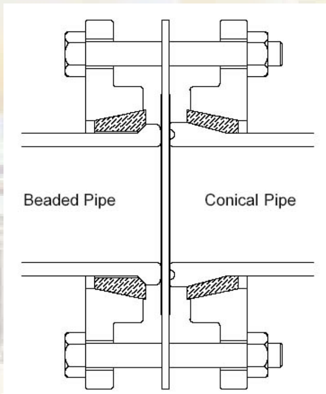


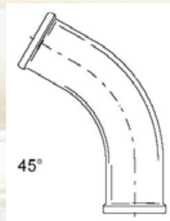
Vitrified clay

- Manufactured from clay fired in furnaces
- Joined with
  - Rubber seals
  - Caulking
  - Mortar
- B31.3 mentions, but has no specific requirements

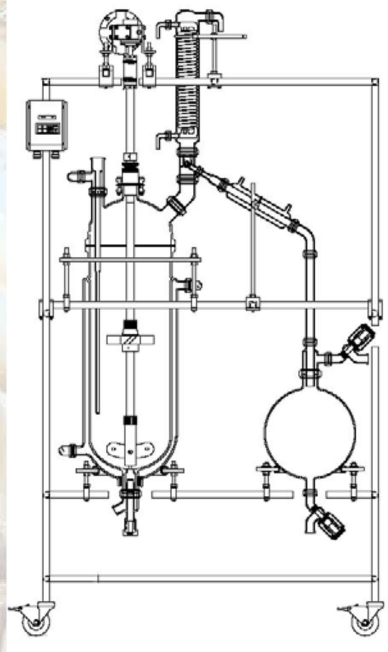
Borosilicate Glass

- Manufactured from molten glass
- Joined with clamps, rubber seals





(H.S. Martin)

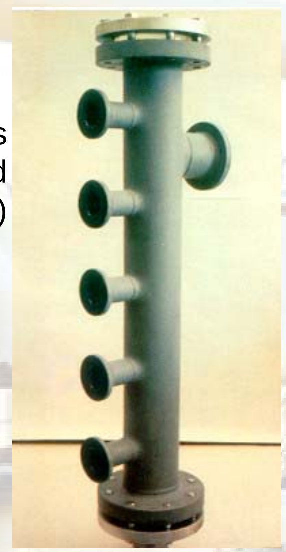


Piping Lined with Nonmetals

Common liners include

- Fluoropolymer
- Polypropylene
- PVDF
- Glass

Glass Lined (Estrella)



Polypropylene Lined (Resistoflex)

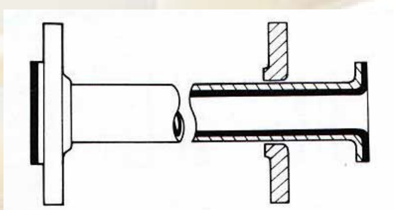
Piping Lined with Nonmetals

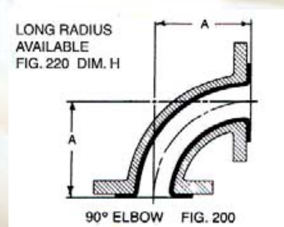
- Thermoplastic liners can be “locked-in” or loose
- PTFE and FEP lined systems require vent holes
- Thermoplastic lined pipe and fittings are usually ductile iron and steel
- Glass lined pipe and fittings are steel
- Systems usually have many flanged joints

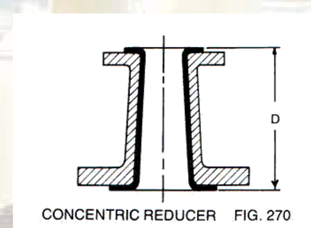
BECHT *ENGINEERING COMPANY, INC.* Nonmetallic Piping - 43

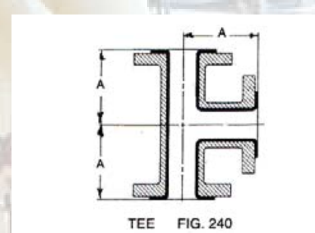
Piping Lined with Nonmetals

Typical Fittings





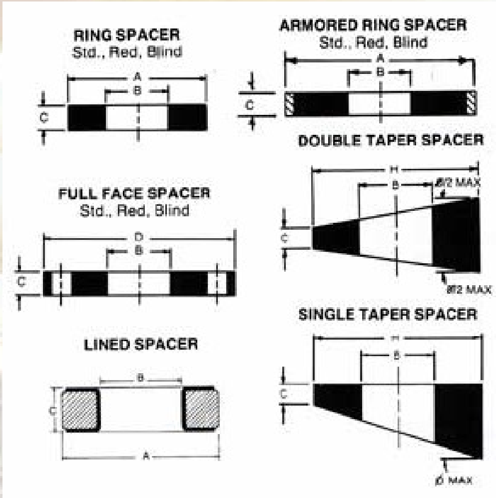




BECHT *ENGINEERING COMPANY, INC.* Nonmetallic Piping - 44

Piping Lined with Nonmetals

Untypical Fittings



Piping Lined with Nonmetals

Common Thermoplastic Liners

- Fluoropolymer
  - FEP Perfluoro ethylene propylene
  - PTFE Polytetrafluorethylene
  - PFA Polyperfluoroalkoxy Alkane
- Polypropylene
- PVDF

Piping Lined with Nonmetals

B31.3 recommended temperature limits for liners:

Material	Min (F)	Max (F)	Min (C)	Max (C)
FEP	-325	400	-198	204
PTFE	-325	500	-198	260
PFA	-325	500	-198	260
PP	0	225	-18	107
PVDF	0	275	-18	135
Glass	Limited by the metal.			

Piping Lined with Nonmetals

- The metallic portions of piping lined with nonmetals for
  - Design
  - Fabrication
  - Examination, and
  - Testing

  shall conform to the rules of Chapters I through VI
- Liners must be qualified for external pressure in order to prevent liner collapse

Piping Lined with Nonmetals

Failures frequently occur at the flange joints. Following the ASME PCC-1 bolt-up procedure greatly improves the chances of success

- Snug up bolting
- Tighten to 20% of target torque using cross pattern
- Tighten to 50 to 70% of target torque using cross pattern
- Tighten to 100% of target torque using cross pattern
- Continue tightening to 100% target torque using rotational pattern until no movement
- Wait 4 hours or longer and repeat rotational pattern to 100% target torque until no movement

BECHT *ENGINEERING COMPANY, INC.* Nonmetallic Piping - 49

Limitations

Thermoplastic Piping

- may not be used in above ground flammable fluid service unless
  - NPS 1 and smaller
  - Owner approves
  - The piping is safeguarded, and
  - The following are considered
    - The possibility of exposure of piping to fire
    - The susceptibility to brittle failure or failure due to thermal shock when exposed to fire
    - The ability of thermal insulation to protect the piping when exposed to fire
- shall be safeguarded when used in other than Category D fluid service

BECHT *ENGINEERING COMPANY, INC.* Nonmetallic Piping - 50

Limitations

- PVC and CPVC may not be used in compressed gas service
- RPM Piping shall be safeguarded when used in other than Category D fluid service
- RTR Piping shall be safeguarded when used in toxic or flammable fluid services
- Borosilicate Glass Piping
  - Shall be safeguarded when used in toxic or flammable fluid services
  - Shall be safeguarded against large, rapid temperature changes

ASME B31.3 Process Piping

Charles Becht IV, PhD, PE
Don Frikken, PE
Instructors

Piping Development Process

1. Establish applicable system standard(s)
2. Establish design conditions
3. Make overall piping material decisions
   - Pressure Class
   - Reliability
   - Materials of construction
4. Fine tune piping material decisions
   - Materials
   - Determine wall thicknesses
   - Valves
5. Establish preliminary piping system layout & support configuration
6. Perform flexibility analysis
7. Finalize layout and bill of materials
8. Fabricate and install
9. Examine and test

16. Category M Fluid Service

- General
- B31.3 Requirements
  - Design
  - Fabrication
  - Examination
  - Testing
- Typical Owner Added Requirements

The Material in This Section is Addressed by B31.3 in:

Chapter VIII - Piping for Category M Fluid Service

General

Category M: A fluid service in which the potential for personnel exposure is judged to be significant and in which a single exposure to a very small quantity of a toxic fluid, caused by leakage, can produce serious irreversible harm to persons upon breathing or on bodily contact, even when prompt restorative measures are taken.

Often characterized as "lethal"

Design Requirements

- Consideration of need for safeguarding is required
- There are no provisions for piping under severe cyclic conditions
- Impact, shock and vibration loads must be considered
- Allowances for variations in pressure and temperature are not permitted
- Maximum relief pressure limited to 110% of design pressure

Design Requirements

- Consideration of valve design features that prevent stem leakage is required
- Valve body joints to be
  - Flanged and secured by 4 or more bolts
  - Pressure seal design
  - Welded , or
  - Union with a seal weld
- Instrument tubing to be 5/8" (16 mm) OD or less and have an accessible block valve to isolate tubing from piping
- The use of flared laps is restricted

BECHT *ENGINEERING COMPANY, INC.* Category M Fluid Service - 7

Design Requirements

- Metallic piping, B31.3 prohibits the use of
  - MSS SP-43 "CR" fittings
  - Type C stubends
  - Taper threaded flanges
  - Taper threaded joints > NPS 1
  - Socket welding joints > NPS 2
  - Caulked joints
  - Solder and brazed joints
  - Adhesive joints
  - Cast irons except ductile
  - Single joint miters >22.5º
  - Corrugated bends

BECHT *ENGINEERING COMPANY, INC.* Category M Fluid Service - 8

Design Requirements

- Nonmetallic piping, B31.3 prohibits the use of
  - Thermoplastic piping
  - Nonmetallic valves
  - Nonmetallic specialty components
  - Threaded flanges
  - Threaded joints
  - Adhesive bonded joints
  - Caulked joints

Fabrication Requirements

- Metallic
  - Fabricated branch construction is permitted only if suitable fittings are not available
  - Heat treatment in accordance with base code requirements is required following any “rose budding”
  - Slip-on flanges must be double welded
- Nonmetallic
  - Fabricated branch construction is prohibited
  - Fabricated miter bends are prohibited
  - Fabricated laps are prohibited

Examination Requirements - VT

Metallic Piping	Normal	Category M
Materials & components	Random to extent needed to satisfy the examiner	Random to extent needed to satisfy the examiner
Fabrication, including welds	5% Random	100%
Longitudinal welds	100%	100%
Bolted, threaded & other joints	Random to extent needed…, except 100% for pneumatic test	100%, threads to be examined for cleanliness and compliance with ASME B1.20.1 prior to assembly
Supports, alignment, erected piping	Random	Random

Examination Requirements - Other

Metallic Piping	Normal	Category M
Circumferential groove welds	5% Random RT or UT	20% Random RT or UT
Brazed joints	5% in-process examination	(brazed joints not permitted)
Solder joints	(solder joints not permitted)	(solder joints not permitted)

Metallic Leak Test Requirements

- A hydrostatic test is required except:
  - The owner may choose a pneumatic leak test if s/he considers the hydrostatic test impractical
  - The owner may use the alternative leak test if s/he considers both the hydrostatic and pneumatic tests impractical, and if
    - Hydrostatic test would cause damage or residual liquid would be hazardous, or there is danger of brittle fracture; and
    - Pneumatic test would present an undue hazard, or there is danger of brittle fracture
- A Sensitive leak test is also required

Nonmetallic Examination and Testing Requirements

Examination and testing requirements are the same as that for nonmetallic piping in normal service, except

- All fabrication shall be visually examined
- All mechanical joints shall be visually examined
- A sensitive leak test is required

Typical Owner Added Requirements

- Fire resistance
- Blow-out resistance
- No nonmetallic components
- All welds to be suitable for radiography
- 100% radiographic examination of welds
- Special examination procedures for valves

ASME B31.3 Process Piping

Charles Becht IV, PhD, PE
Don Frikken, PE
Instructors

Piping Development Process

1. Establish applicable system standard(s)
2. Establish design conditions
3. Make overall piping material decisions
   - Pressure Class
   - Reliability
   - Materials of construction
4. Fine tune piping material decisions
   - Materials
   - Determine wall thicknesses
   - Valves
5. Establish preliminary piping system layout & support configuration
6. Perform flexibility analysis
7. Finalize layout and bill of materials
8. Fabricate and install
9. Examine and test

17. High Pressure Piping

- General
- Materials
- Pressure Design
- Limitations
- Fabrication
- Examination
- Testing

(Autoclave Engineers)

The Material in This Section is Addressed by B31.3 in:

Chapter IX - High Pressure Piping

Appendix K - Allowable Stresses for High Pressure Piping

General

High Pressure: A service for which the owner specifies the use of Chapter IX [of B31.3] for piping design and construction… considered to be in excess of Class 2500 (6000 psi, 42 MPa).

There are no specified pressure limitations for application of these rules. [K300(a)]

General

- Most applications are in the range of 20,000 psi (150 MPa) and higher
- Nonmetallic piping is excluded
- No provisions are made for Category M fluid service
- The temperature is required to be below the creep range
- Allowances for variations in pressure and temperature are not permitted

Materials

- Allowable stress for materials other than bolting
  - 2/3 of specified minimum yield strength (S_Y)
  - 2/3 of yield strength at temperature; except for austenitic stainless steels and nickel alloys with similar behavior, 90% of yield strength at temperature

Material	Base Code (ksi)	High Pressure (ksi)	Base Code (MPa)	High Pressure (MPa)
A106 Gr B	20.0	23.3	138	161
API 5L X80	30.0	53.3	207	368

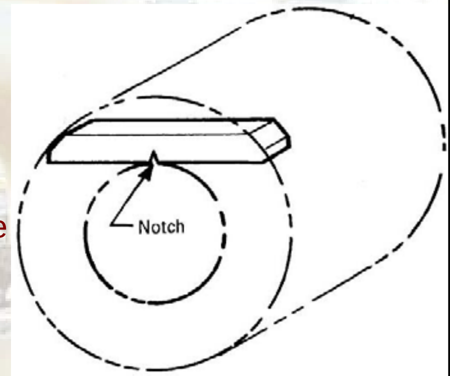
Materials

- Castings and welded components are required to be such that the quality factors are equal to 1.0
- Conformance of materials to the product analysis chemical requirements of the applicable specification shall be verified.
- Cast irons are not permitted
- Zinc coated materials are not permitted, nor are zinc coated materials permitted to be welded to pressure containing components

Materials

Impact Test Requirements

- Impact testing is required for all materials from which a suitable test specimen can be machined
- The impact test temperature shall be no higher than the lowest temperature at which the piping is subjected to a stress greater than 6 ksi (41 MPa)…lower if subsize specimens are required
- Minimum acceptable impact values are higher than for the base code



BECHT *ENGINEERING COMPANY, INC.* High Pressure Piping - 9

Pressure Design – Straight Pipe

$$t = (D/2)\,[1 - \exp(-1.155P/S)]$$

Where:

t = pressure design thickness

D = outside diameter of pipe

P = design pressure

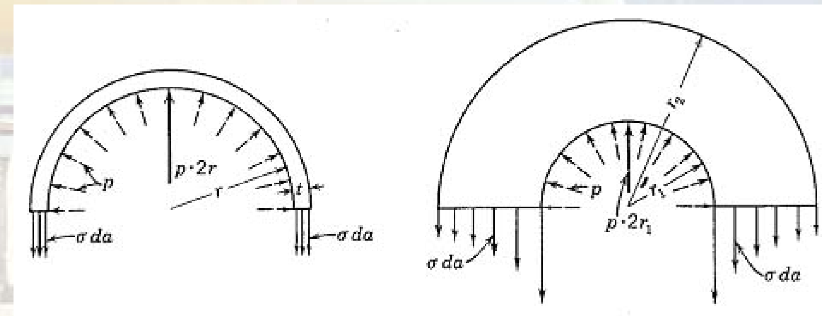
S = stress value for material from Appendix K

(Autoclave Engineers)

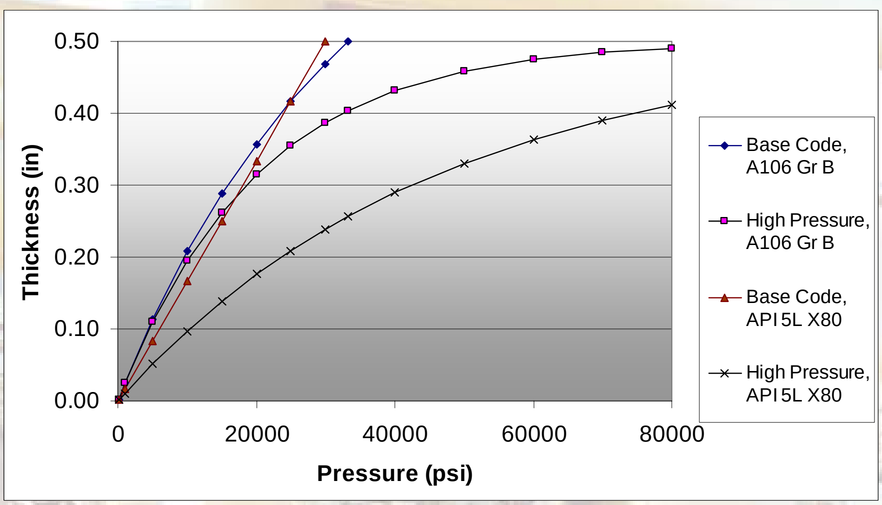
BECHT *ENGINEERING COMPANY, INC.* High Pressure Piping - 10

Pressure Design – Straight Pipe

- The equation is based on through thickness yielding pressure as a basis for design
- The equation provides a factor of two on through thickness yielding

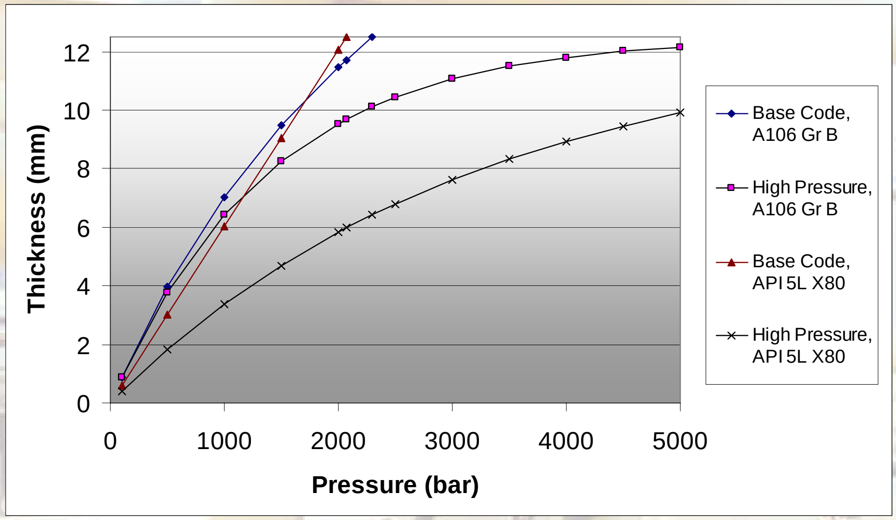


Pressure Design – Straight Pipe



(1 in. OD tubing)

Pressure Design – Straight Pipe

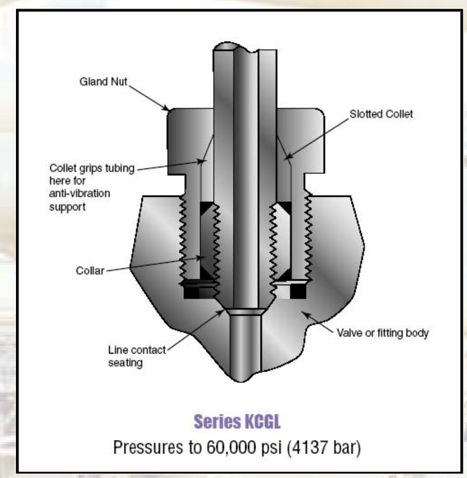


(25 mm OD tubing)

Pressure Design

Thread depth need not be subtracted from the pipe wall thickness when

- Thread depth does not exceed 20% of the wall thickness
- D/d is greater than 1.1
- The internally threaded attachment provides adequate reinforcement
- The thread undercut area does not extend beyond the reinforcement by a distance greater than the pipe wall thickness



(Autoclave Engineers)

Pressure Design [K304.7.2]

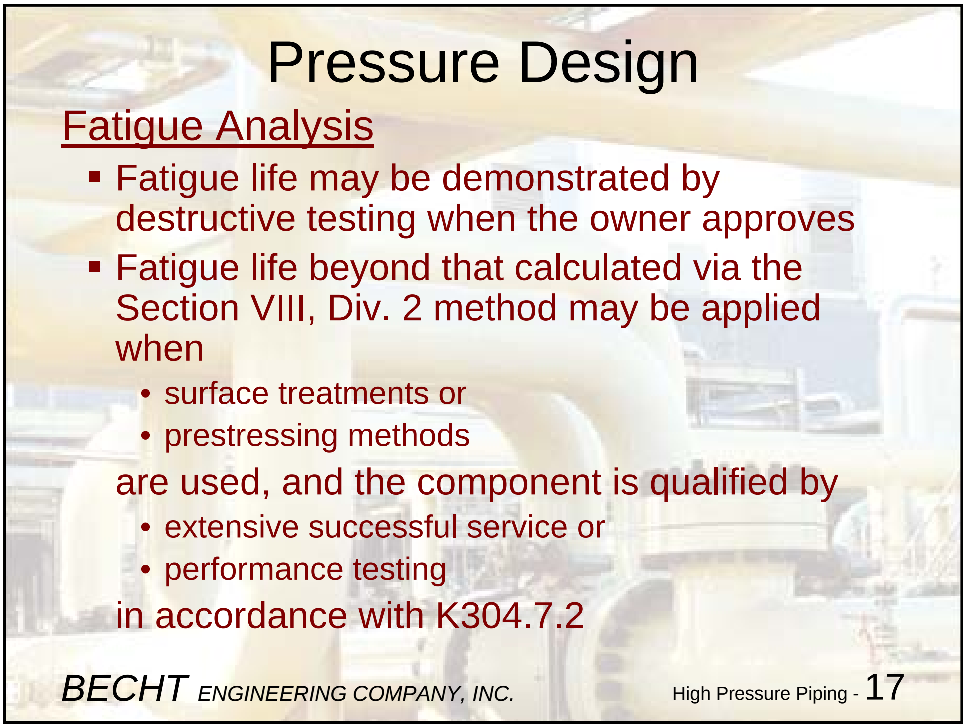
Components for which there are no specific rules require:

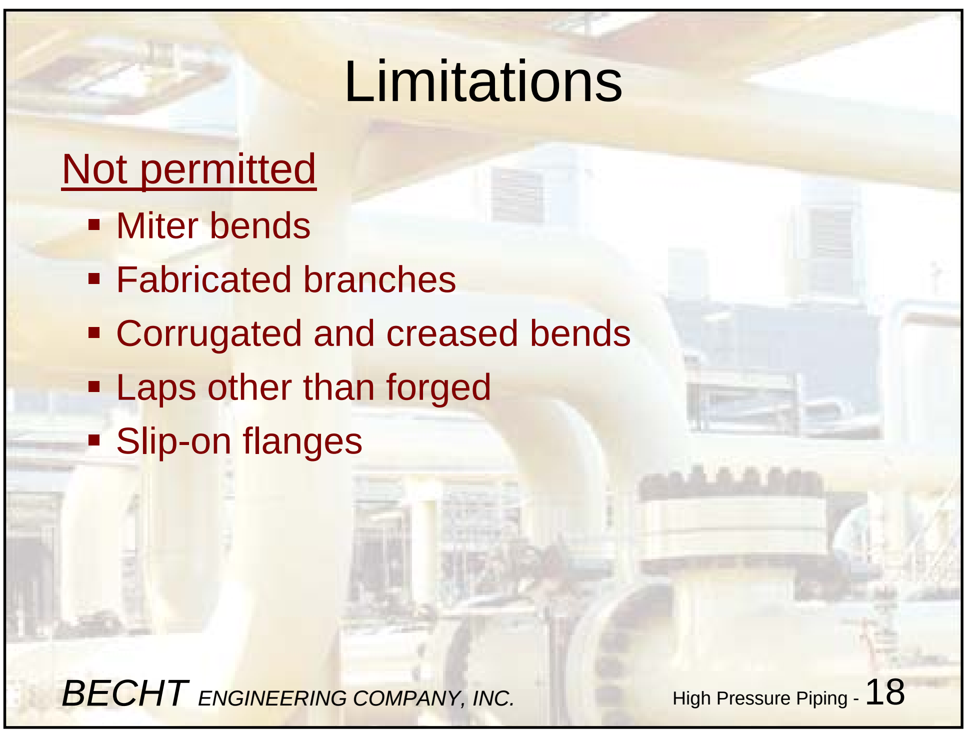
- Calculations consistent with the design philosophy of Chapter IX, and
- Substantiation of the calculations by
  - Extensive successful experience
  - Performance testing, or
  - Finite element stress analysis
- Interpolation between sizes & thicknesses allowed

Pressure Design

Fatigue Analysis

- Fatigue analysis in accordance with ASME B&PV Code, Section VIII, Div. 2 is required
- Pressure is the primary load, but alternating sustained loads and displacement loads must also be included
- High stresses at the inner surface of the pipe wall and stress concentrations must be considered
- An inelastic analysis is required if the stress on the inside surface of the pipe exceeds three times the allowable stress (twice yield)


Pressure Design
Fatigue Analysis
Fatigue life may be demonstrated by destructive testing when the owner approves
Fatigue life beyond that calculated via the Section VIII, Div. 2 method may be applied when
surface treatments or
prestressing methods
are used, and the component is qualified by
extensive successful service or
performance testing
in accordance with K304.7.2
BECHT ENGINEERING COMPANY, INC.
High Pressure Piping - 17


Limitations
Not permitted
Miter bends
Fabricated branches
Corrugated and creased bends
Laps other than forged
Slip-on flanges
BECHT ENGINEERING COMPANY, INC.
High Pressure Piping - 18

Limitations

Joints Not permitted

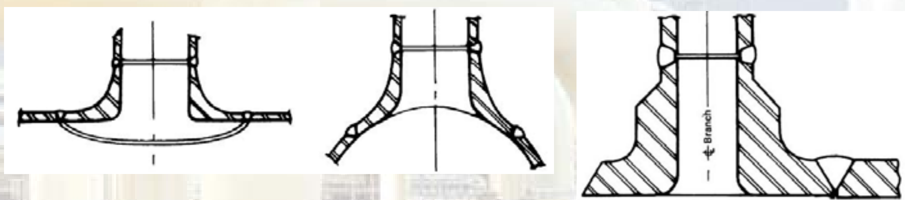
- Ordinary threaded, except for instrumentation up to NPS ½
- Socket welding
- Expanded
- Solder
- Compression and flared tubing
- Caulked
- Bell type
- Adhesive

Fabrication

- Welder qualification is like for the base Code, except
  - Impact tests are required for all procedure and performance qualifications
  - More testing is required for weld procedure and performance qualifications
  - Performance and procedure qualification by others is not permitted

Fabrication

- Seal welds are not permitted
- Welded branch construction must provide for 100% interpretable radiographic examination



Examination Requirements - VT

Metallic Piping	Normal	High Pressure
Materials & components	Random to extent needed to satisfy the examiner	100%
Fabrication, including welds	5% Random	100%
Longitudinal welds	100%	100%
Bolted, threaded & other joints	Random to extent needed…, except 100% for pneumatic test	100%, threads to be examined for finish and fit, and compliance with applicable standard
Supports, alignment, erected piping	Random	100%

Examination Requirements - Other

Metallic Piping	Normal	High Pressure
Circumferential groove welds	5% Random RT or UT	100% RT
Longitudinal welds		100% RT
Branch connection welds		100% RT

- Neither ultrasonic examination nor in-process examination may be substituted for radiographic examination.
- Acceptance criteria are more stringent than the base Code

Testing

- A hydrostatic or a pneumatic test at 1.5 times the design pressure corrected for temperature is required
- Protection of people and property from missile fragments, shock waves and other consequences of failure must be provided
- A leak test of the installed piping at 1.1 times the design pressure is required unless the main leak test was done on the installed piping
- For all welded systems, the closing weld may be tested at 1.1 times the design pressure

ASME B31.3 Process Piping

Charles Becht IV, PhD, PE
Don Frikken, PE
Instructors

18. In-Service Piping

- API 570 Piping Inspection Code
- Responsibilities
- What to Inspect
- Types of Inspection
- Inspection Practices
- Frequency and Extent of Inspection
- Remaining Life Calculation
- Repairs and Alterations
- Rerating

API 570 Piping Inspection Code

- For inspection, repair, alteration, and rerating of in-service metallic piping systems
- Applicable to piping systems constructed in accordance with ASME B31.3
- First Edition, June 1993
- Second Edition, October 1998
  - Addendum 1, February 2000
  - Addendum 2, December 2001

API 570 Piping Inspection Code

API 570 includes flammable and toxic services. It excludes specific requirements for:

- Water, steam, steam-condensate, boiler feed water and Category D fluid service
- Piping systems that are an integral part or component of rotating or reciprocating mechanical devices
- Piping or tubing with an OD ≤ NPS 1/2
- Nonmetallic piping and polymeric or glass-lined piping
- Plumbing
- fired heater and boiler internals are also excluded

The excluded piping can be included at the owner-user's option.

Responsibilities

Owner-user:

Has overall responsibility for compliance with API 570 and developing, documenting, implementing, and executing the inspection, repair, alteration, and rerating

Piping Engineer:

Responsible to the owner-user for design, engineering review, analysis, and evaluation of piping systems

Repair Organization:

Responsible to owner-user for providing materials, equipment, quality control, and workmanship to maintain and repair the piping system in accordance with API 570

Inspector:

Responsible to owner-user for determining that the inspection, examination and testing requirements of API 570 are met. Qualifications in terms of experience and education are specified in Appendix A of API 570

What to Inspect

API 570 directs attention to the following types and areas of deterioration

- Injection points
- Dead legs
- Corrosion under insulation (CUI)
- Soil-to-air interfaces
- Service specific and local corrosion
- Erosion and corrosion/erosion
- Environmental cracking
- Corrosion beneath linings and deposits
- Fatigue cracking
- Creep cracking
- Brittle fracture
- Freeze damage

What to Inspect

API 570 doesn't cover everything.

External Inspection Checklist

(API 570 Appendix D)

- Leaks
  - Process
  - Steam Tracing
  - Existing Clamps (temporary repairs)
- Misalignment
  - Piping misalignment/restricted movement
  - Expansion joint misalignment
- Vibration
  - Excessive overhung weight
  - Inadequate support
  - Thin, small-bore, or alloy piping
  - Threaded connections
  - Loose supports causing metal wear

External Inspection Checklist

- Supports
  - Shoes off support
  - Hanger distortion or breakage
  - Bottomed-out springs
  - Brace distortion/breakage
  - Loose brackets
  - Slide plates/rollers
  - Counter balance condition
  - Support corrosion
- Corrosion
  - Bolting support points under clamps
  - Coating/painting deterioration
  - Soil-to-air interface
  - Insulation interfaces
  - Biological growth

External Inspection Checklist

- Insulation
  - Damage/penetrations
  - Missing jacketing/insulation
  - Sealing deterioration
  - Bulging
  - Banding (broken/missing)

Types of Inspection

- Internal visual
- Thickness measurement
- External visual
- Vibrating piping
- Supplemental

Types of Inspection

- Internal visual inspection is not normally used for most piping systems
- But may be scheduled for very large diameter piping
- Or may be performed using remote viewing technique
- Should be performed when given the opportunity like at disconnected flange joints

Types of Inspection

- Thickness is measured via UT or radiography
- At least the minimum thickness should be determined and recorded
- The locations of TMLs should be recorded on a drawing and marked on the pipe to permit repetitive measurements at the same TMLs
- Generally should include measurements in each of the four quadrants of pipe and fittings
- Generally should include inside and outside radius of elbows and tees where corrosion/erosion could increase rate of metal loss
- Also required in areas of continuing corrosion under insulation, soil/air interfaces, and other areas of localized or general corrosion

Types of Inspection

- No specific numeric guidelines for number of thickness measurement locations (TMLs) provided in API 570
- More TMLs should be provided when there is
  - Higher potential for creating a safety or environmental emergency in the event of a leak
  - Higher expected or experienced corrosion rates
  - Higher potential for localized corrosion
  - More complexity in terms of fittings, branches, dead legs, injection points, and other similar items
  - Higher potential for CUI
- Ultrasonic thickness measurement preferred for pipe larger than NPS 1
- Radiography preferred for pipes NPS 1 and smaller

Types of Inspection

External visual inspection is performed to determine the condition of the outside of the piping, insulation system, painting and coating systems, and associated hardware; and to check for signs of misalignment, vibration, and leakage. Some specific things to check:

- Cracked or broken hangers, "bottoming out" of spring supports, support shoes displaced from support members
- Bellows expansion for unusual deformations, misalignment, or displacements that may exceed design
- Any components in the service that may be unsuitable for long-term operation

Types of Inspection

- Vibrating or swaying piping should be reported to the inspector or piping engineer for assessment.
- Supplementary inspection should be specified when needed to assess the condition of piping. Examples are
  - Thermography to check for hot spots in refractory lined systems
  - Acoustic emission testing
  - Acoustic leak detection
  - Ultrasonic or radiographic examination for detecting localized corrosion.

Inspection Practices

- Pressure testing not normally conducted except for alterations, major repairs, and sometimes with rerating.
- TMLs are not normally required on valves, due to their greater wall thickness, but valve thicknesses should generally be checked when removed for service

Inspection Practices

- Welds are not required to meet the radiographic acceptance criteria for new construction random radiography
- Defects resulting from environmental cracking shall be assessed by the piping engineer
- Defects resulting from original weld fabrication should be investigated using one or more of the following
  - Inspector judgment
  - Certified welding inspector judgment
  - Piping engineer judgment
  - Engineering fitness-for-service analysis

Inspection Practices

Potential causes of leaks in a flange joint include:

- Uneven bolt tightening
- Improper flange alignment
- Excessive external moments from piping
- Improper gasket placement
- Improper, dirty or damaged flange facing finish
- Improper gasket type or size
- Using a gasket that has already been compressed
- Thermal shock
- Bolt relaxation
- Differential expansion between bolts and flange

Frequency and Extent of Inspection

- An inspection strategy based on
  - likelihood and
  - consequence of failure

  is referred to as risk-based inspection.
- For the purposes of defining consequence of failure, API 570 defines 3 service classes.
- The owner/user may devise a more extensive classification scheme that more accurately assesses consequence

Frequency and Extent of Inspection

Class 1 - greatest hazard (safety or environmental) should a leak occur

Hydrofluoric acid, anhydrous hydrogen sulfide, piping over or adjacent to water and piping over public throughways, pressurized services that rapidly vaporize during release, that could result in vapor cloud explosions, etc.

Class 2 - includes services that are not Class 1 or Class 3

Hydrogen, fuel gas, natural gas, hydrocarbons that slowly vaporize during release, on-site strong acids and caustics

Class 3 - flammable services that do not significantly vaporize when they leak and are not located in high-activity areas. Also, services potentially harmful to human tissue that are located in remote areas

Off-site acids and caustics, on-site hydrocarbons that will not significantly vaporize during release

BECHT *ENGINEERING COMPANY, INC.* In-Service Piping - 21

Inspection Intervals

- Considerations in setting inspection intervals
  - Corrosion rate and remaining life calculations (Interval can affect MAWP)
  - Piping service classification
  - Applicable jurisdictional requirements
  - Judgment based on operating conditions, previous inspection history, current inspection results, and conditions that may warrant supplemental inspections
- Inspection intervals should not exceed 1/2 the calculated remaining life or that shown in the following table

BECHT *ENGINEERING COMPANY, INC.* In-Service Piping - 22

Inspection Intervals

Recommended Maximum Inspection Intervals (Years)

Type of Circuit	Thickness Measured	External Visual
Class 1	5	5
Class 2	10	5
Class 3	10	10
Injection Points	3	By Class
Soil-to-air interfaces		By Class

(Table 6-1 from API 570)

Extent of CUI Inspections

API 570 recommends that a percentage of the areas with potential for corrosion under insulation be inspected

	Areas with Damaged Insulation	Suspect Areas with Susceptible Temperature Ranges
Class 1	75%	50%
Class 2	50%	33%
Class 3	25%	10%

(Table 6-2 from API 570)

Remaining Life Calculation

Remaining Life = (t_{actual} – t_{reqd}) / Corrosion Rate

Where:

t_{actual} = The actual minimum thickness determined at the time of inspection

t_{reqd} = The required minimum thickness

Corrosion rate is determined based on thickness measurements.

Remaining Life Calculation

Corrosion Rate = (t_{init} – t_{actual}) / Time

Where:

t_{init} = Initial thickness (long-term corrosion rate) or thickness measured in a previous inspection (short-term corrosion rate)

t_{actual} = The actual minimum thickness determined at the time of inspection

Time is between thickness measurements.

Maximum Allowable Working Pressure

- Calculated in accordance with applicable code
- If the material is unknown, use the lowest grade of material and joint efficiency in the applicable code
- To calculate the MAWP, use the current thickness minus two times the anticipated corrosion that will occur between the current time and the next inspection time

Required Minimum Thickness

- The required minimum thickness shall be based on
  - Pressure
  - Mechanical, and
  - Structural considerations

  using the appropriate design formulae and code allowable stress
- For services with high potential consequences, the piping engineer should consider increasing the required minimum thickness above the calculated minimum thickness to provide for
  - Unanticipated or unknown loadings
  - Undiscovered metal loss, or
  - Resistance to abuse

Assessment of Inspection Findings

- Pressure containing components found to have degradation that could affect their load carrying capability (pressure loads and other applicable loads including weight, wind and thermal expansion) shall be evaluated for continued service.
- Fitness-for-service techniques, such as those documented in API RP 579 and ASME B31G, may be used for this evaluation.
- Local wall thinning below the required minimum thickness might be found to be acceptable using this approach.

BECHT ENGINEERING COMPANY, INC. In-Service Piping - 29

Repairs and Alterations

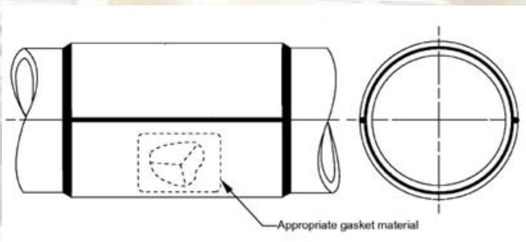
- Can be made by the owner or user, or by contractors acceptable to them
- Must be authorized by the inspector
- Alterations must also have approval of the piping engineer
- Repairs of cracks that occurred in-service should not be made without prior consultation with the piping engineer in order to identify and correct the cause of the cracking

BECHT ENGINEERING COMPANY, INC. In-Service Piping - 30

Temporary Repairs

Temporary repairs, including on-stream repairs are permitted. These include

- Full encirclement welded split sleeve
- Box-type enclosures designed by the piping engineer
- Fillet welding a split coupling or plate patch over an area of local corrosion
- Bolted leak clamps (design must consider pressure thrust)



Temporary Repairs

- Repair of piping with longitudinal cracks should not be commenced unless the piping engineer determines that the crack will not propagate from under the sleeve or enclosure.
- Temporary repairs shall be replaced with permanent repairs at the next available maintenance opportunity

Fabrication and Examination

- The inspector shall verify that the materials are consistent with the selected or specified construction materials
- Qualifications and procedures are generally required to be in accordance with ASME B31.3, or the code to which the piping was originally constructed
- Some exceptions are provided for weld preheat and PWHT
- Examinations are required to be in accordance with ASME B31.3, or the code to which the piping was originally constructed

Leak Testing

- Normally required after alterations or major repairs
- The decision as to whether or not to pressure test is by the inspector, considering practicality and necessity
- Final closure joints may be exempted from pressure testing, conditional on design, radiographic or ultrasonic examination, and additional requirements

Rerating

Piping may be rerated. Requirements include:

- Calculations must be performed by the piping engineer that demonstrate that the pipe is acceptable for the new conditions
- If the prior leak test was not sufficient for the new conditions, a new leak test is required
- Current inspection records must verify that it is acceptable for the new service
- Piping flexibility must be adequate for the new conditions

ASME B31.3 Process Piping

Charles Becht IV, PhD, PE
Don Frikken, PE
Instructors

19. What's Different in B31.1

- Scope
- Organization of the Code
- Fluid Service Requirements
- Bases for Allowable Stresses
- Material Requirements
- Pressure Design Requirements
- Valve Requirements
- Fabrication and Installation
- Inspection, Examination and Testing

B31.1 Scope

Rules for this Code Section have been developed considering the needs for applications which include piping typically found in electric power generating stations, industrial and institutional plants, geothermal heating systems and central and district heating and cooling systems. (100.1)

B31.1 Scope

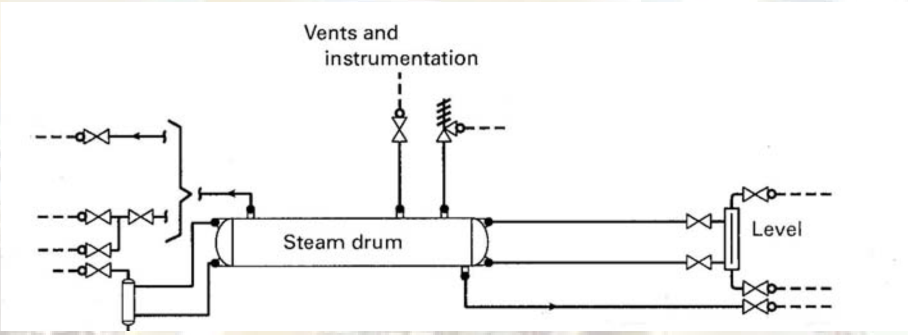
Power piping systems as covered by this Code apply to all piping and their component parts…They include but are not limited to

- steam
- water
- oil
- gas
- air

[100.1.2]

Boiler External Piping (BEP)

Generally defined as piping between the boiler and the first block valve.



Boiler External Piping

- Technical requirements are in accordance with B31.1
- Administrative requirements are defined in ASME B&PV Code Section I and include requirements for
  - B&PV Code stamp
  - Data reports
  - Quality control
  - Inspection

Organization of the Code

- I Scope and Definitions
- II Design
- III Materials
- IV Dimensional Requirements
- V Fabrication, Assembly, and Erection
- VI Inspection, Examination and Testing

Organization of the Code

Appendices similar to B31.3 except

- II Rules for Design of Safety Valve Installations
- IV Corrosion Control
- V Recommended Practice for Operation, Maintenance and Modification
- VII Design of Restrained Underground Piping

Organization of the Code

B31.1 provides specific requirements for

- Boiler External Piping (Steam, Feedwater, Blowoff, Blowdown and Drains)
- Blowoff and Blowdown Piping (Non-BEP)
- Instrument, Control and Sample Piping
- Spray Type Desuperheater Piping
- Pressure Reducing Valves
- Pressure Relief Piping

BECHT *ENGINEERING COMPANY, INC.* What's Different in B31.1 - 9

Organization of the Code

B31.1 provides specific requirements for

- Piping for Flammable or Combustible Liquids
- Piping for Flammable Gases and Toxic Fluids
- Piping for Corrosive Fluids
- Temporary Piping
- Steam Trap Piping
- Pump Suction and Discharge Piping
- District Heating and Steam Distribution Systems

BECHT *ENGINEERING COMPANY, INC.* What's Different in B31.1 - 10

Fluid Service Requirements

- B31.1 does not define specific fluid services, but does have limitations for piping systems handling certain fluids
- Specific requirements for components and joints are described in paras. 105-118.

Pipe Fluid Service Requirements

- Furnace butt welded pipe is not permitted for flammable, combustible or toxic fluids

Joint Fluid Service Requirements

- Socket welding size limited for BEP and toxic fluids
- Threaded joints size limited by temperature and pressure; example maximum pressure for NPS 3 joint is 400 psi (2750 kPa)
- Pipe thinner than STD WT may not be threaded
- Pipe shall be Sch 80 seamless for
  - Steam over 250 psi (1750 kPa)
  - Water over 100 psi (700 kPa) and 220ºF (105ºC)

More Joint Fluid Service Requirements

- OD tubing compression and flared tubing limited to 2 in. (50 mm)
- Brazed joint may not be used for flammable or toxic fluids in fire hazard areas
- Soldered joints may not be used for flammable or toxic fluids
- Soldered joints may not be used in piping subject to vibration

Flanged Joint Requirements

B31.1 has detailed requirements for flanged joints. Requirements include:

- Class 150 steel flanges bolted to Class 125 cast iron flanges are required to be flat faced…gasket required to be full face
- Bolting dimensions for both US customary and metric bolting
- Bolt material requirements as a function of flanges and gaskets

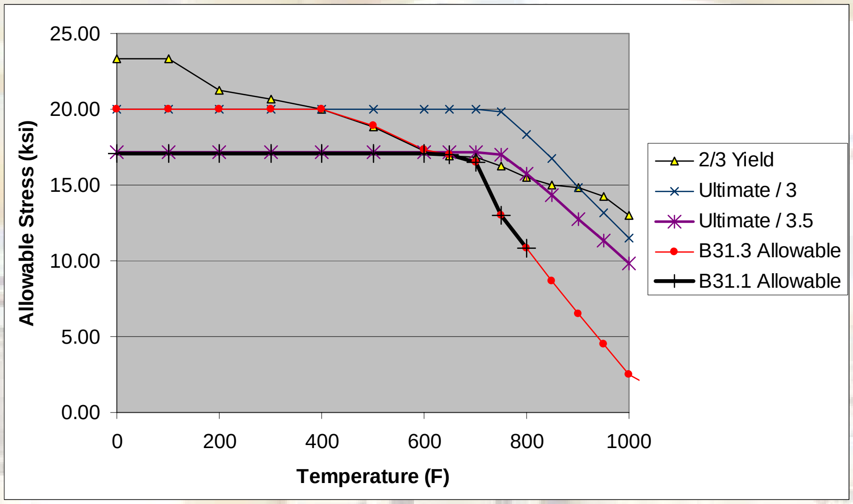
Bases for Design Stresses

Most Materials – (materials other than gray iron, malleable iron and bolting) below the creep range, the lowest of

- the specified minimum tensile strength divided by 3.5
- 1/3 of tensile strength at temperature
- 2/3 of specified minimum yield strength
- 2/3 of yield strength at temperature; except for austenitic stainless steels and nickel alloys with similar behavior, 90% of yield strength at temperature

Bases for Design Stresses

ASTM A106 Grade B Carbon Steel (US Customary Units)



B31.1 Material Requirements

- Materials for BEP must meet ASME B&PV Code requirements; unlisted materials may not be used
- Unlisted materials may be used for OD tubing compression and flared tube fittings
- Use at temperatures above maximum in stress tables generally not permitted
- No rules for use at temperatures below -20ºF (-29ºC)

Pressure Design

The rules for pressure design are essentially the same as for B31.3, but they are not identical.

The two Section Committees are working to make the requirements the same.

Design Pressure & Temperature

allowance for pressure and temperature variation: The Code allows the design pressure to be set below the most severe coincident pressure and temperature for the following variations:

- Can exceed allowable by 20% for no more than 1 hr/event and no more than 80 hr/year
- Can exceed allowable by 15% for no more than 8 hr/event and nor more than 800 hr/year

Design Pressure & Temperature

allowance for pressure and temperature variation - conditions:

- Except as limited by component standards
- Except as limited by manufacturers
- No limitations on cast iron or other non-ductile components
- No limitations on yield strength
- No limitations on longitudinal
- No limitations with respect to test pressure
- No permission from the owner required

BECHT ENGINEERING COMPANY, INC. What's Different in B31.1 - 21

Valve Requirements

Standard Valves Can be used within their pressure-temperature ratings and any additional limitations described in the Code

Nonstandard Valves Shall be of a design… which the manufacturer recommends for the service

BECHT ENGINEERING COMPANY, INC. What's Different in B31.1 - 22

Valve Requirements

All Valves

- must have "blow-out proof" stems
- OS&Y required for NPS 3 and larger above 600 psi (4150 kPa)
- screwed bonnets not permitted for steam above 250 psi (1750 kPa)

Fabrication and Installation

- Welder & brazer qualification and bending & forming requirements are very similar but not identical
- Preheating and heat treatment requirements are different
  - B31.3 requires neither preheating or heat treatment for carbon steel with thickness less than or equal to 3/4 in. (19.0 mm)
  - B31.1 requires preheating to 200ºF (95ºC) <u>or</u> heat treatment for the same thickness range

Fabrication and Installation

- Minimum socket weld size is 1.09 times nominal wall thickness versus B31.3 requirement for 1.25 time pressure design thickness
- Flange faces are required to be fitted so that gasket contact surfaces bear uniformly on the gasket
- Bolts must be threaded trough the nut

BECHT *ENGINEERING COMPANY, INC.* What's Different in B31.1 - 25

Inspection, Examination and Testing

- Similar distinction between inspection and examination, but no specific "owner's inspector"
- Authorized inspector required for boiler external piping, ASME B&PV Code, Section I
- B31.1 does not include the concept of random with progressive examination… either 100% or none

BECHT *ENGINEERING COMPANY, INC.* What's Different in B31.1 - 26

Inspection, Examination and Testing

Examination is as required by Table 136.4:

Over 750°F (400°C)	Over 1025 psig (70 bar) and 350 to 750°F (175 to 400°C)	All Others
Visual plus For NPS ≤ 2, MP or LP For NPS > 2, 100% radiography	Visual plus For wall thickness ≥ ¾" (19 mm), 100% radiography	Visual only

Inspection, Examination and Testing

- Visual examination is required for all welds with para. 136.4.2 acceptance criteria
  - No surface cracks
  - No surface undercut <1/32 in. (1.0 mm)
  - Limits on weld reinforcement
  - No surface lack of fusion
  - No incomplete penetration…applies when inside surface is readily accessible

Inspection, Examination and Testing

- BEP requires hydrotest in accordance with ASME B&PV Code, Section I
- Non BEP requires hydrotest or, at the owner's option, pneumatic, sensitive leak or initial service leak testing
- Lines open to the atmosphere do not require testing
- Joints must be exposed for examination during leak testing, except that insulated systems may be tested by fluid loss over time method

Inspection, Examination and Testing

- Pressure must be held a minimum of 10 minutes, and then may be reduced to design pressure for leak examination period
- Stress during hydrotest is limited to 90% S_Y, rather than 100% S_Y
- Hydrotest pressure is 1.5 times the design pressure…no temperature correction
- Pneumatic testing requires owner's approval
- Pneumatic test pressure is 1.2 to 1.5 times the design pressure

CONTENTS

ASME B31 Piping System Standards

No.	Title	Typical Coverage
B31.1	Power Piping	piping typically found in electric power generating stations, in industrial and institutional plants, geothermal heating systems, and central and district heating and cooling systems
B31.3	Process Piping	piping typically found in petroleum refineries, chemical, textile, paper, semiconductor and cryogenic plants, and related processing plants and terminals
B31.4	Liquid transportation Piping	piping transporting products which are predominately liquid between plants and terminals and within terminals, pumping, regulating and metering stations
B31.5	Refrigeration Piping	piping for refrigerants and secondary coolants
B31.8	Gas Transportation and Distribution Piping	piping transporting products which are predominately gas between sources and terminals, including compressor, regulating, and metering stations; gas gathering pipelines
B31. 9	Building Services Piping	piping typically found in industrial, institutional, commercial, and public buildings, and in multi-unit residences which does not require the range of sizes, pressures, and temperatures covered in B31.1
B31.11	Slurry Transportation Piping	piping transporting aqueous slurries between plants and terminals and within terminals, pumping and regulating stations
BPE-1	Bioprocessing Equipment	piping and equipment for bioprocess applications, including requirements for sterility and cleanability, surface finish, material joining and seals
PVHO-1	Pressure Vessels for Human Occupancy	piping in pressure vessels occupied by humans such as submersibles, diving bells, decompression chambers, and hyperbaric chambers, in addition to the requirements for the PVHO
HPS	High Pressure Systems	piping system requirements for high pressure systems not covered in B31.3 and equipment requirements not covered the ASME B&PV Code
B&PV Code Section III	Nuclear Power Plants	NB-3600 – Class 1 Piping NC/ND-3600 – Class 2/3 Piping (similar to B31.1) Code Case N47 – Class 1 components in elevated temperature service

National Fire Protection Association (NFPA) Piping System Standards (selected)

No.	Title
13	Installation of Sprinkler Systems
14	Installation of Standpipe, Private Hydrant, and Hose Systems
15	Water Spray Fixed Systems for Fire Protection
16	Installation of Foam-Water Sprinkler and Foam-Water Spray Systems
24	Installation of Private Fire Service Mains and Their Appurtenances
54	National Fuel Gas Code
58	Liquefied Petroleum Gas Code
59A	Production, Storage, and Handling of Liquefied Natural Gas (LNG)

Canadian Standards Association

No.	Title
Z662	Oil and Gas Pipeline Systems

Compressed Gas Association (CGA) Piping System Standards (selected)

No.	Title
G2.1	Requirements for the Storage and Handling of Anhydrous Ammonia (ANSI K61.1)
G4.4	Industrial Practices for Gaseous Oxygen Transmission and Distribution Piping Systems
G5.4	Standard for Hydrogen Piping Systems at Consumer Locations

Chlorine Institute Piping System Standards (selected)

No.	Title
006	Piping Systems for Dry Chlorine
060	Chlorine Pipelines
094	Sodium Hydroxide Solution and Potassium Hydroxide Solution (Caustic): Storage Equipment and Piping Systems
163	Hydrochloric Acid Storage and Piping Systems

HISTORY OF B31.3

In 1926 the American Standards Institute initiated Project B31 to develop a piping code. ASME was the sole administrative sponsor. The fIrst publication of this document, American Tentative Standard code for Pressure Piping, occurred in 1935. From 1942 through 1955, the code was published as the American Standard Code for Pressure Piping, ASA B31.1. It was composed of separate sections for different industries.

These sections were split off, starting in 1955 with the Gas Transmission and Distribution Piping Systems, ASA B31.8. ASA B31.3, Petroleum Refinery Piping Code Section was first published in 1959. A number of separate sections have been prepared, most of which have been published. The various section designations follow.

B31.1 Power Piping
B31.2 Fuel Gas Piping (withdrawn in 1988)
B31.3 Process Piping
B31.4 Liquid Transportation Systems for Hydrocarbons, Liquid Petroleum Gas, Anhydrous Ammonia, and Alcohols
B31.5 Refrigeration Piping
B31.6 Chemical Plant Piping (never published)
B31.7 Nuclear Piping (moved to B&PV Code Section III)
B31.8 Gas Transmission and Distribution Piping Systems
B31.9 Building Services Piping
B31.10 Cryogenic Piping (never published)
B31.11 Slurry Piping
B31.12 Hydrogen Piping (project started in 2004)

A draft of the section for Chemical Plant Piping, B31.6, was completed in 1974. However, it was decided to merge this section into B31.3 because the two code sections were closely related. A joint code section, Chemical Plant and Petroleum Refinery Piping, was published in 1976. It was at this time that items such as fluid service categories such as Category M, nonmetallic piping, and safeguarding were introduced into B31.3.

In 1980 the nonmetals portions of the B31.3 Code were gathered and combined into one chapter, Chapter VII.

A draft code for Cryogenic Piping had been prepared by Section Committee B31.10 and was ready for approval in 1981. Again, since the coverage overlapped with B31.3, it was decided to merge the Section Committees and develop a single inclusive Code. This Code was issued in 1984.

In addition, in 1984 another potentially separate code was added as new chapter to B31.3, High Pressure Piping, Chapter IX.

The resulting document is a Code that is very broad in scope. It covers fluids as benign as water and as hazardous as mustard gas. It covers temperatures from cryogenic conditions to I500°F and beyond. It covers pressures from vacuum and atmospheric to 50,000 psi and higher. Part of the philosophy of the Code stems from this broad coverage. There is a great deal of responsibility placed with the Owner and latitude to use good engineering.

With respect to the initials that appear in front of B31.3, these have been ASA, ANSI and ASME. It is currently correct to refer to the Code as ASME B31.3. The initial designation ASA referred to the American Standards Association. This became the United States of America Standards Institute and then the American National Standards Institute between 1967 and 1969. Thus, ASA was changed to ANSI. In 1978, the Standards Committee was reorganized as a committee operating under ASME procedures with ANSI accreditation. Therefore, the initials ASME now appear in front of B31.3. These changes in acronyms have not changed the B31.3 committee structure or the Code.

CODE ORGANIZATION

Chapter I	Scope and Definitions
Chapter II	Design
Part 1	Conditions and Criteria
Part 2	Pressure Design of Piping Components
Part 3	Fluid Service Requirements for Piping Components
Part 4	Fluid Service Requirements for Piping Joints
Part 5	Flexibility and Support
Part 6	Systems
Chapter III	Materials
Chapter IV	Standards and Piping Components
Chapter V	Fabrication, Assembly, and Erection
Chapter VI	Inspection, Examination and Testing
Chapter VII	Nonmetallic Piping and Piping Lined with Nonmetals
Chapter VIII	Piping for Category M Fluid Service
Chapter IX	High Pressure Piping
Appendices	
A	Allowable Stresses and Quality Factors for Metallic Piping and Bolting Materials
B	Stress Tables and Allowable Pressure Tables for Nonmetals
C	Physical Properties of Piping Materials
D	Flexibility and Stress Intensification Factors
E	Reference Standards
F	Precautionary Considerations
G	Safeguarding
H	Sample Calculations for Branch Reinforcement
J	Nomenclature
K	Allowable Stress for High Pressure Piping
L	Aluminum Alloy Pipe Flanges
M	Guide to Classifying Fluid Services
Q	Quality System Program
V	Allowable Variations in Elevated Temperature Service
X	Metallic Bellows Expansion Joints
Z	Preparation of Technical Inquiries

ASME B31.3 FLUID SERVICE CONTAINMENT SYSTEM CHARACTERISTICS

B31.3 Fluid Service	B31.3 Definition	Containment System Characteristics
Category D [Utility]	*Category D fluid Service:* a fluid service in which all of the following apply: 1) the fluid handled is nonflammable, nontoxic, and not damaging to human tissues… 2) the design gage pressure does not exceed 1035 kPa (150 psi), and 3) the design temperature is from -29ºC (-20ºF) to 186ºC (366ºF).	Lowest cost Usually not fire resistant Usually not blow-out resistant
Normal [Process]	*Normal Fluid Service:* a fluid service pertaining to most piping covered by this Code, i.e., not subject to the rules of Category D, Category M or High Pressure Fluid Service.	Moderate cost May be fire resistant or not May be blow-out resistant or not
High Pressure	*High Pressure Fluid Service:* a fluid service for which the owner specifies the use of Chapter IX for piping design and construction.	High cost Usually fire resistant Usually blow-out resistant
Category M [Lethal]	*Category M Fluid Service:* a fluid service in which the potential for personnel exposure is judged to be significant and in which a single exposure to a very small quantity of a toxic fluid, caused by leakage, can produce serious irreversible harm to persons on breathing or bodily contact, even when prompt restorative measures are taken.	High cost Usually fire resistant Usually blow-out resistant

ASME B31.3 FLUID SERVICE WORKSHOP For the fluid services described, what B31.3 fluid service definition is most nearly applicable?		**PIPE AND FITTING SELECTION WORKSHOP** For the fluid services described, what piping system attributes and components would you select?				
Fluid Service	**B31.3 Fluid Service**	**Fire Resistant?**	**Blow-out Resistant?**	**Material of Construction**	**Pressure Class**	**Thd, SW or BW NPS < 2?**
Steam condensate piping NPS ½ - 8. Downstream of an atmospheric flash tank, so maximum temperature is 212°F (100°C). Maximum pressure is 90 psig (6 bar).						
Dry chlorine liquid, NPS ¾ - 4. Chlorine rail car to vaporizer. Relief pressure is 710 psig (49 bar) and temperatures range from -29°F to 140°F (-34°C to 60°C). Some studies indicate that there may be some human fatalities resulting from a 30-min exposure to 50 ppm and higher concentrations.						
96% sulfuric acid, NPS ¾ - 4. Type 316 stainless steel is required for line velocities greater than 3 ft/sec (1 m/sec), otherwise carbon steel is acceptable. Fluoropolymer lined steel is acceptable. Temperature is ambient, maximum pressure is 120 psig (8 bar).						
Gasoline, NPS ½ - 8. Temperature is ambient, max. pressure is 60 psig (4 bar).						
650 psig (45 bar) steam superheated to 735°F (390°C), NPS ¾ - 16. Relief pressure is 725 psig (50 bar).						
Therminol 66 heat transfer oil, NPS ¾ - 6. Max. temperature is 560°F (295°C), max. pressure is 120 psig (8 bar).						
Styrene monomer, NPS ¾ - 12. Ambient temperature, max. pressure is 105 psig (7 bar). Flammable. Polymerizes when left stagnant at ambient temperature for long periods of time.						
Lime/water slurry, NPS ¾ to 4. Ambient temperature, maximum pressure is 140 psig (9.5 bar).						

ASME B16 Piping Component Standards

No.	Title
B16.1	Cast Iron Pipe Flanges and Flanged Fittings
B16.3	Malleable Iron Threaded Fittings
B16.4	Gray Iron Threaded Fittings
B16.5	Pipe Flanges and Flanged Fittings
B16.9	Factory-Made Wrought Steel Buttwelding Fittings
B16.10	Face-to-Face and End-to-End Dimensions of Valves
B16.11	Forged Fittings, Socket Welding and Threaded
B16.12	Cast Iron Threaded Drainage Fittings
B16.14	Ferrous Pipe Plugs, Bushings and Locknuts with Pipe Threads
B16.15	Cast Bronze Threaded Fittings
B16.18	Cast Copper Alloy Solder Joint Pressure Fittings
B16.20	Metallic Gaskets for Pipe Flanges – Ring Joint, Spiral Wound and Jacketed
B16.21	Nonmetallic Flat Gaskets for Pipe Flanges
B16.22	Wrought Copper and Copper Alloy Solder Joint Pressure Fittings
*B16.23	Cast Copper Alloy Solder Joint Drainage Fittings – DWV
B16.24	Cast Copper Alloy Pipe Flanges and Flanged Fittings
B16.25	Buttwelding Ends
B16.26	Cast Copper Alloy fittings for Flared Copper Tube
*B16.29	Wrought Copper and Wrought Copper Alloy Solder Joint Drainage Fittings – DWV
*B16.32	Cast Copper Alloy Solder Joint Fittings for Sovent Drainage Systems
*B16.33	Manually Operated Metallic Gas Valves or Use in Gas Piping Systems up to 125 psig
B16.34	Valves – Flanged, Threaded and Welding End
B16.36	Orifice Flanges
*B16.38	Large Metallic Valves for Gas Distribution
B16.39	Malleable Iron Threaded Pipe Unions
*B16.40	Manually Operated Thermoplastic Gas Shutoffs and Valves in Gas Distribution
*B16.41	Functional Qualification Requirement for Power Operated Active Valve Assemblies for Nuclear Power Plants
B16.42	Ductile Iron Pipe Flanges and Flanged Fittings
*B16.44	Manually Operated Metallic Gas Valves for Use in House Piping Systems
*B16.45	Cast Iron Fittings for Sovent Drainage Systems
B16.47	Large Diameter Steel Flanges
B16.48	Steel Line Blanks
*B16.49	Factory-Made Wrought Steel Buttwelding Induction Bends for Transportation and Distribution Systems
*B16.50	Wrought Copper and Copper Alloy Braze-Joint Pressure Fittings
*B16.51	Cast and Wrought Copper and Copper Alloy Press-Connect Pressure Fittings (draft)

* Not listed in ASME B31.3

MSS (Manufacturers Standardization Society of the Valve and Fittings Industry) Piping Component Standards

No.	Title
SP-42	Class 150 Corrosion Resistant Gate, Globe, Angle, Check Valves with Flanged, Butt Weld Ends
SP-43	Wrought Stainless Steel Butt-Welding Fittings
SP-44	Steel Pipeline Flanges
SP-51	Class 150LW Corrosion Resistant Cast Flanged Fittings
SP-58	Pipe Hangers and Supports -- Materials, Design and Manufacture
*SP-60	Connecting Flange Joint Between Tapping Sleeves and Tapping Valves
SP-65	High Pressure Chemical Industry Flanges and Threaded Stubs for Use with Lens Gaskets
*SP-67	Butterfly Valves
*SP-68	High Pressure-Offset Seat Butterfly Valves
*SP-69	Pipe Hangers and Supports -- Selection and Application
SP-70	Cast Iron Gate Valves, Flanged and Threaded Ends
SP-71	Cast Iron Swing Check valves, Flanged and Threaded Ends
SP-72	Ball Valves with Flanged or Butt-Welding Ends for General Service
SP-75	Specification for High Test Wrought Butt Welding Fittings
*SP-78	Cast Iron Plug Valves, Flanged and Threaded Ends
SP-79	Socket-Welding Reducer Inserts
SP-80	Bronze Gate, Globe, Angle and Check Valves
SP-81	Stainless Steel, Bonnetless, Flanged, Knife Gate Valves
SP-83	Class 3000 Steel Pipe Unions, Socket-Welding and Threaded
SP-85	Cast Iron Globe & Angle Valves, Flanged and Threaded Ends
*SP-87	Factory-Made Butt-Welding Fittings for Call 1 Nuclear Piping Applications
SP-88	Diaphragm Type Valves
SP-95	Swage(d) Nipples and Bull Plugs
SP-97	Integrally Reinforced Forged Branch Outley Fittings
*SP-99	Instrument Valves
*SP-103	Wrought Copper and Copper Alloy Insert Fittings for Polybutylene Systems
*SP-104	Wrought Copper Solder Joint Pressure Fittings
SP-105	Instrument Valves for Code Applications
*SP-106	Cast Copper Alloy Flanges and Flanged Fittings, Class 125, 150 and 300
*SP-107	Transition Union Fittings for Joining Metal and Plastic Products
*SP-108	Resilient-Seated Cast Iron-Eccentric Plug Valves
*SP-109	Welded Fabricated Copper Solder Joint Pressure Fittings
*SP-110	Ball Valves Threaded, Socket-Welding, Solder Joint, Grooved and Flared Ends
*SP-111	Gray-Iron and Ductile-Iron Tapping Sleeves
*SP-114	Corrosion Resistant Pipe Fittings Threaded and Socket Welding, Class 150 and 1000
*SP-115	Excess Flow Valves for Natural Gas Service
*SP-116	Service Line Valves and Fittings for Drinking Water Systems
*SP-118	Compact Steel Globe & Check Valves -- Flanged, Flangeless, Threaded and Welding Ends

No.	Title
SP-119	Belled End Socket Welding Fittings, Stainless Steel and Copper Nickel
*SP-122	Plastic Industrial Ball Valves
*SP-123	Non-Ferrous Threaded and Solder-Joint Unions for Use With Copper Water Tube
*SP-124	Fabricated Tapping Sleeves
*SP-125	Gray Iron and Ductile Iron In-Line, Spring-Loaded, Center-Guided Check Valves
*SP-127	Bracing for Piping Systems Seismic-Wind-Dynamic Design, Selection, Application

* Not listed in ASME B31.3

API Piping Component Standards (selected)

No.	Title
5L	Line Pipe
*6D	Pipeline Valves (Gate, Plug, Ball, and Check Valves)
594	Check Valves: Wafer, Wafer-lug and Double Flanged Type
599	Metal Plug Valves – Flanged and Welding Ends
600	Bolted Bonnet Steel Gate Valves for Petroleum and Natural Gas Industries – Modified National Adoption of ISO 10434
602	Compact Steel Gate Valves – Flanged, Threaded, Welding, and Extended Body Ends
603	Corrosion-Resistant, Bolted Bonnet Gate Valves--Flanged and Butt-Welding Ends
608	Metal Ball Valves – Flanged, Threaded and Butt-Welding Ends
609	Butterfly Valves: Double Flanged, Lug- and Wafer-Type

* Not listed in ASME B31.3

ASTM Piping Component Standards (selected)

No.	Title
A53	Pipe, Steel, Black and Hot-Dipped, Zinc Coated, Welded and Seamless
A106	Seamless Carbon Steel Pipe for High-Temperature Service
A234	Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperature
A312	Seamless and Welded Austenitic Stainless Steel Pipe
A333	Seamless and Welded Steel Pipe for Low-Temperature Service
A403	Wrought Austenitic Stainless Steel Piping Fittings
B75	Seamless Copper Tube
B88	Seamless Copper Water Tube
B165	Nickel-Copper Alloy (UNS N04400) Seamless Pipe and Tube
B167	Nickel-Chromium-Iron Alloy (UNS N06600-N06690) Seamless Pipe and Tube
B241	Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube
B280	Seamless Copper Tube for Air Conditioning and Refrigeration Fluid Service
B337	Seamless and Welded Titanium and Titanium Alloy Pipe
B361	Factory-Made Wrought Aluminum and Aluminum-Alloy Welding Fittings
B366	Factory-Made Wrought Nickel and Nickel-Alloy Welding Fittings
B658	Zirconium and Zirconium Alloy Seamless and Welded Pipe
C599	Process Glass Pipe and Fittings
D1785	PVC Plastic Pipe

No.	Title
D2282	ABS Plastic Pipe (SDR-PR)
D2464	Threaded PVC Plastic Pipe Fittings, Sch 80
D2468	Socket-Type ABS Plastic Pipe Fittings, Sch 40
D2517	Reinforced Epoxy Resin Gas Pressure Pipe and Fittings
D2846	CPVC Plastic Hot and Cold Water Distribution Systems
D3261	Butt Heat Fusion PE Plastic Fittings for PE Plastic Pipe and Tubing
D5421	Contact Molded Fiberglass RTR Flanges
F423	PTFE Plastic-Lined Ferrous Metal Pipe and Fittings
F492	Polypropylene and PP Plastic-Lined Ferrous Metal Pipe and Fittings

AWWA Piping Component Standards (selected)

No.	Title
*C104	Cement-Mortar Lining for Ductile-Iron Pipe and Fittings for Water
C110	Ductile-Iron and Gray-Iron Fittings, 3 In.-48 In. (76 mm-1,219 mm), for Water
C115	Flanged Ductile-Iron Pipe with Ductile-Iron or Gray-Iron Threaded Flanges
C151	Ductile-Iron Pipe, Centrifugally Cast, for Water
*C153	Ductile-Iron Compact Fittings for Water Service
C300	Reinforced Concrete Pressure Pipe, Steel Cylinder Type, for Water and Other Liquids
C302	Reinforced Concrete Pressure Pipe, Noncylinder Type, for Water and Other Liquids
*C501	Cast-Iron Sluice Gates
*C502	Dry-Barrel Fire Hydrants
*C503	Wet-Barrel Fire Hydrants
C504	Rubber-Seated Butterfly Valves
*C507	Ball Valves, 6 In. Through 48 In. (150 mm Through 1,200 mm)
*C508	Swing-Check Valves for Waterworks Service, 2 In. (50 mm) Through 24 In.(600 mm) NPS
*C509	Resilient-Seated Gate Valves for Water Supply Service
*C510	Double Check Valve Backflow Prevention Assembly
*C511	Reduced-Pressure Principle Backflow Prevention Assembly
C900	PVC Pressure Pipe, 4-inch through 12-inch, for Water
C950	Glass-Fiber-Reinforced Thermosetting Resin Pressure Pipe

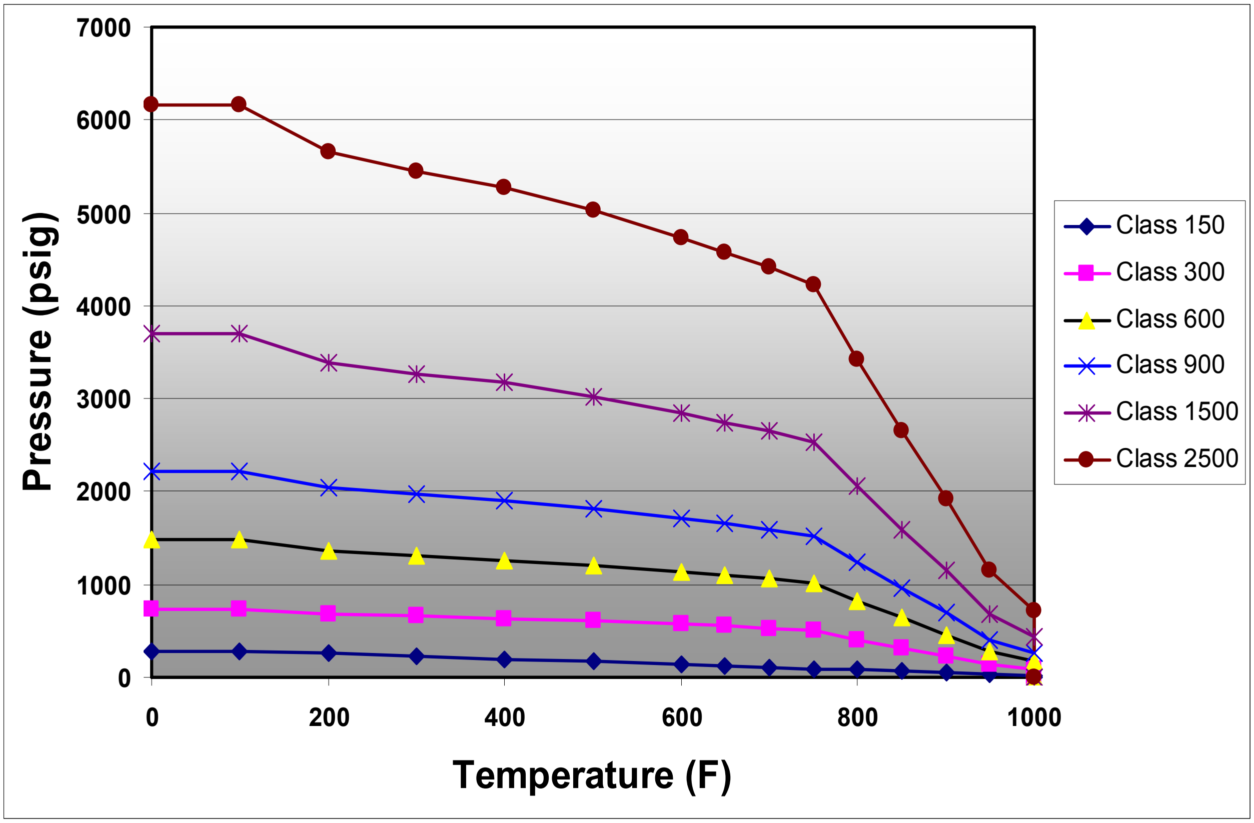
* Not listed in ASME B31.3

Canadian Standards Association

No.	Title
*Z245.1	Steel Pipe
*Z245.6	Coiled Aluminum Line Pipe and Accessories
*Z245.11	Steel Fittings
*Z245.12	Steel Flanges
*Z245.15	Steel Valves

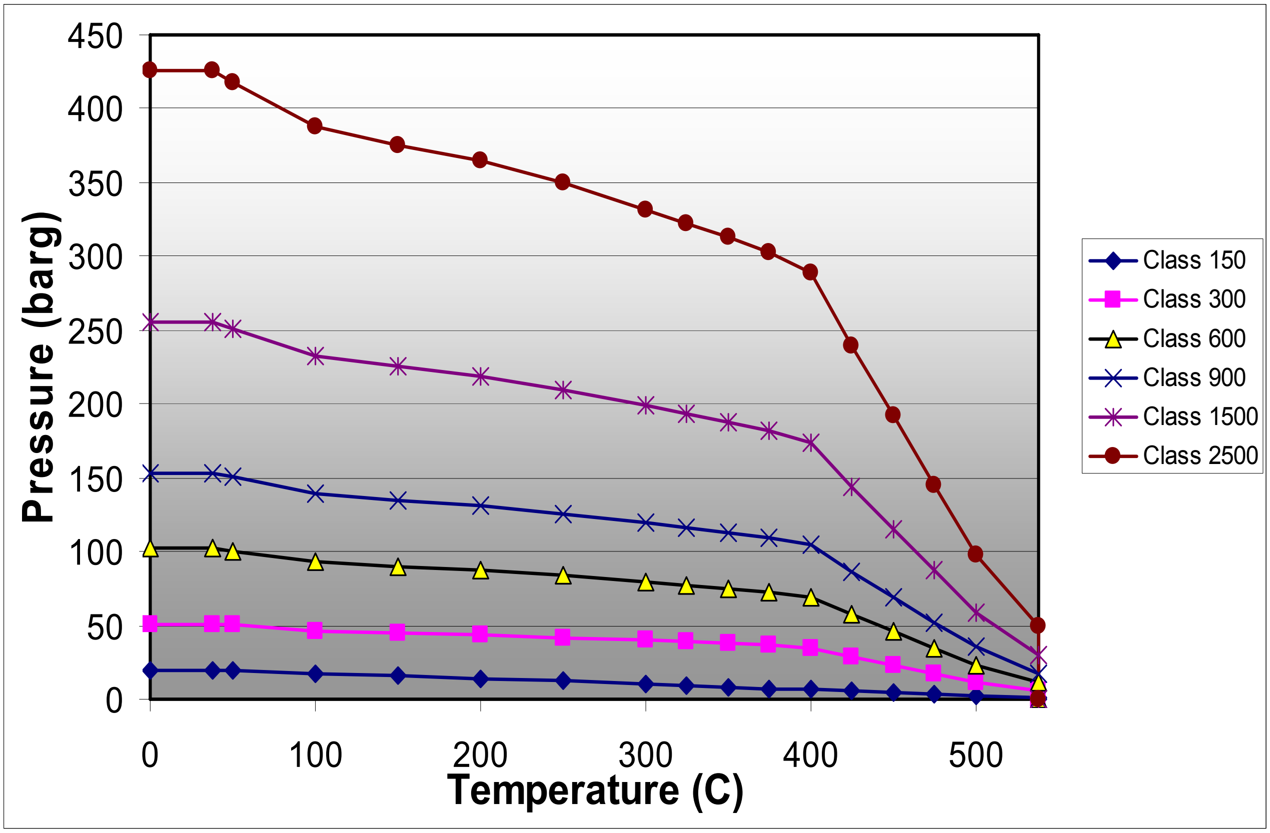
* Not listed in ASME B31.3

ASME B16.5 Flange Ratings - Carbon Steel (US Customary Units - psi)



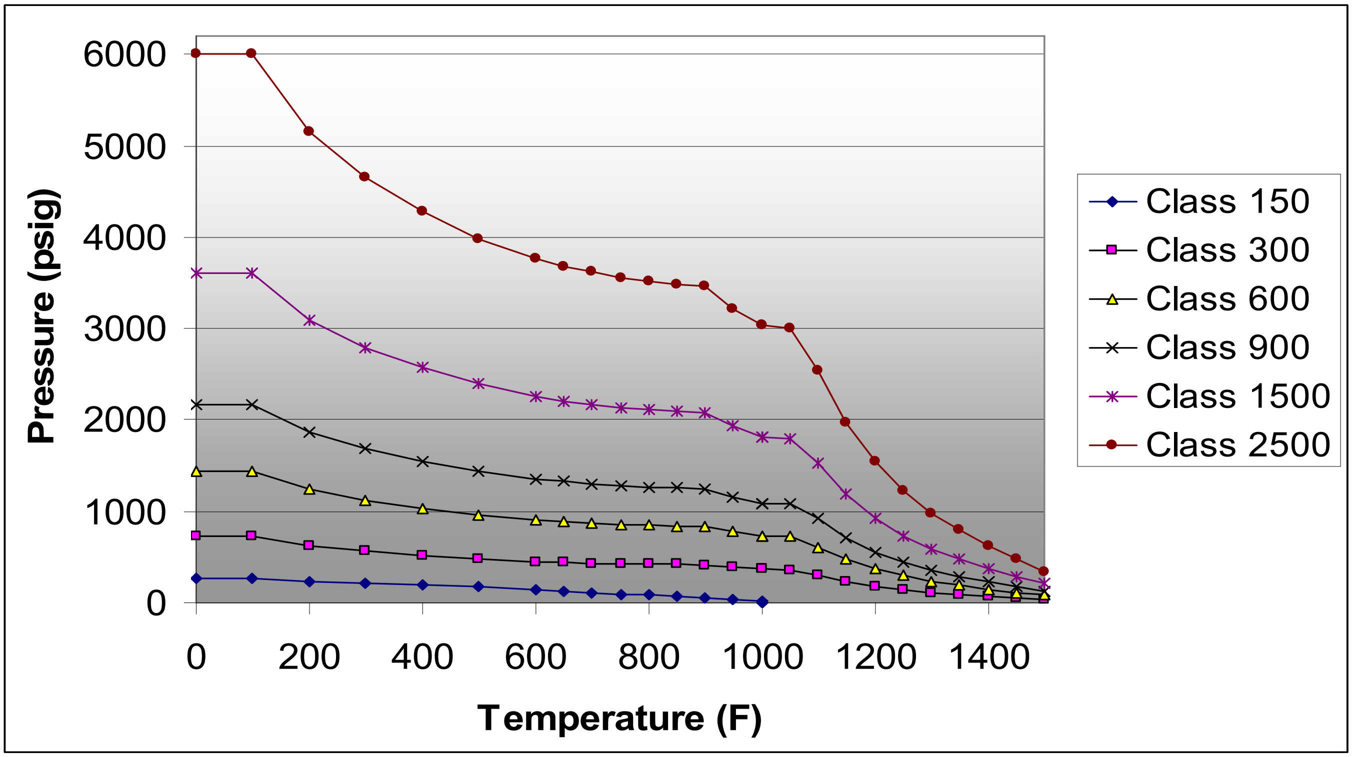
Temp (F)	Class 150	Class 300	Class 600	Class 900	Class 1500	Class 2500
min to 100	285	740	1480	2220	3705	6170
200	260	680	1360	2035	3395	5655
300	230	655	1310	1965	3270	5450
400	200	635	1265	1900	3170	5280
500	170	605	1205	1810	3015	5025
600	140	570	1135	1705	2840	4730
650	125	550	1100	1650	2745	4575
700	110	530	1060	1590	2655	4425
750	95	505	1015	1520	2535	4230
800	80	410	825	1235	2055	3430
850	65	320	640	955	1595	2655
900	50	230	460	690	1150	1915
950	35	135	275	410	685	1145
1000	20	85	170	255	430	715

ASME B16.5 Flange Ratings - Carbon Steel (Metric Units - bar)



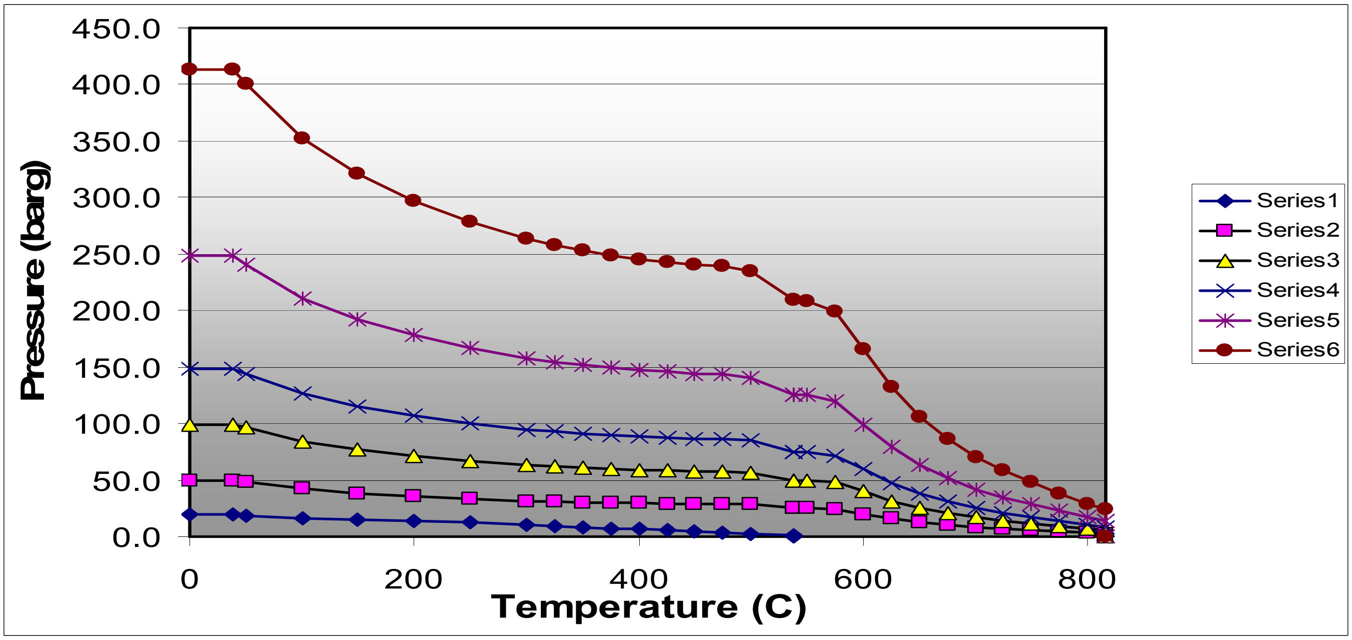
Temp (C)	Class 150	Class 300	Class 600	Class 900	Class 1500	Class 2500
min to 38	19.6	51.1	102.1	153.2	255.3	425.5
50	19.2	50.1	100.2	150.4	250.6	417.7
100	17.7	46.6	93.2	139.8	233.0	388.3
150	15.8	45.1	90.2	135.2	225.4	375.6
200	13.8	43.8	87.6	131.4	219.0	365.0
250	12.1	41.9	83.9	125.8	209.7	349.5
300	10.2	39.8	79.6	119.5	199.1	331.8
325	9.3	38.7	77.4	116.1	193.6	322.6
350	8.4	37.6	75.1	112.7	187.8	313.0
375	7.4	36.4	72.7	109.1	181.8	303.1
400	6.5	34.7	69.4	104.2	173.6	289.3
425	5.5	28.8	57.5	86.3	143.8	239.7
450	4.6	23.0	46.0	69.0	115.0	191.7
475	3.7	17.4	34.9	52.3	87.2	145.3
500	2.8	11.8	23.5	35.3	58.8	97.9
538	1.4	5.9	11.8	17.7	29.5	49.2

ASME B16.5 Flange Ratings – Type 316 Stainless Steel (US Customary Units - psi)



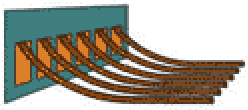
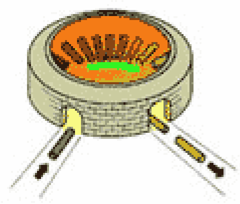
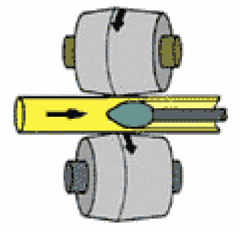
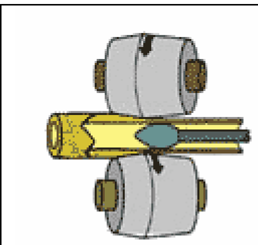
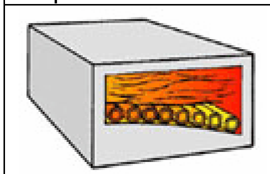
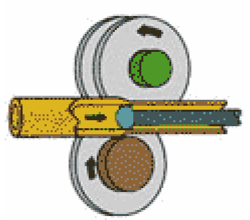
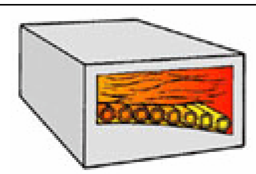
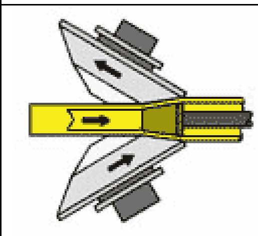
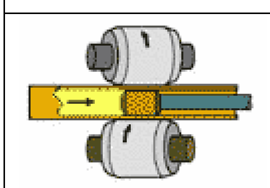
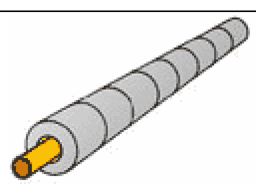
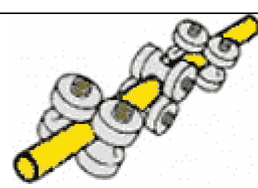
Temp (F)	Class 150	Class 300	Class 600	Class 900	Class 1500	Class 2500
min to 100	275	720	1440	2160	3600	6000
200	235	620	1240	1860	3095	5160
300	215	560	1120	1680	2795	4660
400	195	515	1025	1540	2570	4280
500	170	480	955	1435	2390	3980
600	140	450	900	1355	2255	3760
650	125	440	885	1325	2210	3680
700	110	435	870	1305	2170	3620
750	95	425	855	1280	2135	3560
800	80	420	845	1265	2110	3520
850	65	420	835	1255	2090	3480
900	50	415	830	1245	2075	3460
950	35	385	775	1160	1930	3220
1000	20	365	725	1090	1820	3030
1050		360	720	1080	1800	3000
1100		305	610	915	1525	2545
1150		235	475	710	1185	1970
1200		185	370	555	925	1545
1250		145	295	440	735	1230
1300		115	235	350	585	970
1350		95	190	290	480	800
1400		75	150	225	380	630
1450		60	115	175	290	485
1500		40	85	125	205	345

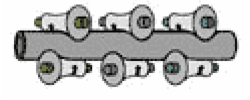
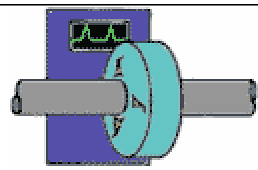
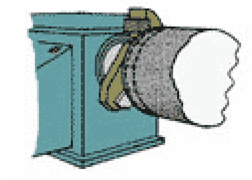
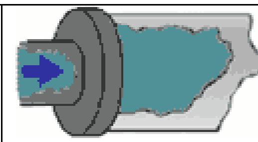
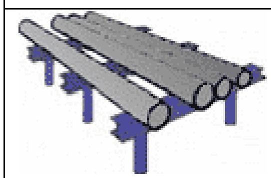
ASME B16.5 Flange Ratings – Type 316 Stainless Steel (Metric Units - bar)



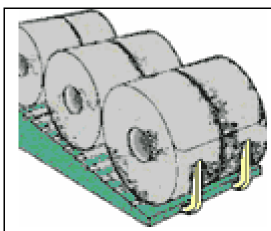
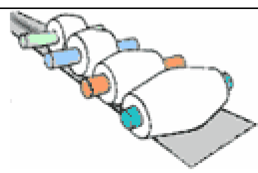
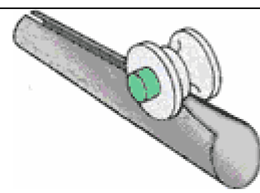
Temp (C)	Class 150	Class 300	Class 600	Class 900	Class 1500	Class 2500
38	19.0	49.6	99.3	148.9	248.2	413.7
50	18.4	48.1	96.2	144.3	240.6	400.9
100	16.2	42.2	84.4	126.6	211.0	351.6
150	14.8	38.5	77.0	115.5	192.5	320.8
200	13.7	35.7	71.3	107.0	178.3	297.2
250	12.1	33.4	66.8	100.1	166.9	278.1
300	10.2	31.6	63.2	94.9	158.1	263.5
325	9.3	30.9	61.8	92.7	154.4	257.4
350	8.4	30.3	60.7	91.0	151.6	252.7
375	7.4	29.9	59.8	89.6	149.4	249.0
400	6.5	29.4	58.9	88.3	147.2	245.3
425	5.5	29.1	58.3	87.4	145.7	242.9
450	4.6	28.8	57.7	86.5	144.2	240.4
475	3.7	28.7	57.3	86.0	143.4	238.9
500	2.8	28.2	56.5	84.7	140.9	235.0
538	1.4	25.2	50.0	75.2	125.5	208.9
550		25.0	49.8	74.8	124.9	208.0
575		24.0	47.9	71.8	119.7	199.5
600		19.9	39.8	59.7	99.5	165.9
625		15.8	31.6	47.4	79.1	131.8
650		12.7	25.3	38.0	63.3	105.5
675		10.3	20.6	31.0	51.6	86.0
700		8.4	16.8	25.1	41.9	69.8
725		7.0	14.0	21.0	34.9	58.2
750		5.9	11.7	17.6	29.3	48.9
775		4.6	9.0	13.7	22.8	38.0
800		3.5	7.0	10.5	17.4	29.2
816		2.8	5.9	8.6	14.1	23.8

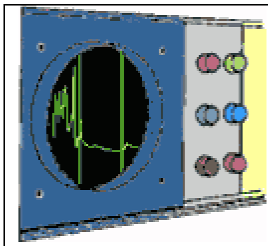
SEAMLESS MANUFACTURING PROCESS AT USS TUBULAR #3 MILL - 10.75" TO 26" O.D.
(http://www.usstubular.com/facilities/splplo.htm)

 **Modern 6-Strand Caster** Lorain's 6-strand continuous caster incorporates the latest steel processing technology. This unit is capable of producing more than 600.000 annual tons [550,000 metric tons] of high quality rounds for superior seamless tubular products. These rounds are conditioned, as required, after visual inspection.	 **Rotary Billet Heating** The billets are now brought to the proper temperature for piercing by heating them in a rotary hearth furnace.	 **Rotary Piercing Mill (RPM)** The billet is gripped by the rolls, which rotate and advance it over the piercer point, forming a hole through its length. Large sizes go through a second piercing mill.	 **Second Piercer (Elongator)** This piercing operation further increases the diameter and length and decreases the wall thickness.
 **Reheating Furnace** Before further working, the pierced billets are again brought to forging temperature in the reheat furnace.	 **Plug Rolling Mill** In this operation the pierced billet is rolled over a plug to reduce the diameter and wall thickness and to increase the length.	 **Reheating Furnace** Shells must again be heated to forging temperatures for further working.	 **Rotary Expanding Mill** For pipe NPS 16 and over, the diameter is enlarged and the wall thickness reduced to approximate finished dimensions in the rotary mill.
 **Reeling Mill** The rolls of the reeling mill grip the pipe and advance it over a mandrel, burnishing both the inside and outside surfaces of the pipe.	 **Reheating Furnace** The purpose of reheating at this stage is to obtain uniformity of temperature for sizing.	 **Sizing Mill** The pipe, reheated if necessary, passes through a series of rolls where it is formed into a true round, and sized to the exact required diameter.	 **Cooling Table** After sizing, the pipe is allowed to cool on a slowly moving conveyer table.

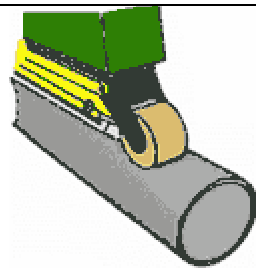
 **Rotary Straightener** Here the pipe is brought to the required straightness. The "crop ends" of standard seamless are then cut off before end beveling.	 **NDT Inspection** At this station pipe is electromagnetically inspected to detect body wall imperfections.	 **Facing and Beveling** An expanding arbor holds the pipe in line while a revolving head faces and bevels the end of the pipe.	 **Hydrostatic Testing** The finished pipe is visually inspected and is subjected to a hydrostatic test as a strength and leak check before shipping.
 **Final Inspection** A final visual inspection is given the pipe prior to stenciling, loading and shipping.			

ELECTRIC RESISTANCE WELD (ERW) MANUFACTURING PROCESS AT USS TUBULAR- 8.625" TO 20" O.D. (http://www.usstubular.com/facilities/erw.htm)

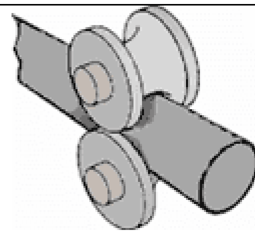
 **Coil Feed Ramp** Coils are removed from storage and placed on a feed ramp. Here each coil is positioned on the center line of the mill and fed into the uncoiling unit. The leading edge feeds into the pinch rolls preceding the flattener. An electrically operated shear cuts off the end of each coil so that the coils can be welded together to form a continuous strip.	 **First Forming Section** The first forming section, composed of breakdown strands, begins the transformation of the strip from flat steel to a round pipe section. The roll transition section receives the product from the first forming section and continues the "rounding-up" process.	 **Fin Pass Section** The section of the forming rolls finishes the rounding process and contours the edges of the strip for welding.	 **High Frequency Welder** The High Frequency Welder heats the edges of the strip to approximately 2600ºF [1400ºC] at the fusion point location. Pressure rolls then squeeze the heated edges together to form a fusion weld.



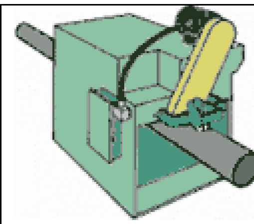
In-Process Weld Non-Destructive Inspection After welding, the weld is inspected by independent non-destructive inspection units.



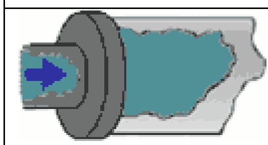
Seam Normalizer Here the weld area is subjected to the proper post-weld treatment as metallurgically required to remove welding stresses and produce a uniform normalized grain structure.



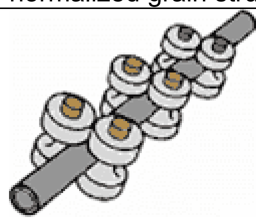
Sizing Mill Here the pipe passes through the sizing mill with idler side-closing rolls between the strands. This process sizes the pipe to proper outside diameter and straightens the pipe at the same time.



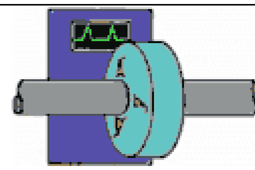
Flying Cut-Off As the continuous length moves down the mill, the flying cut-off cuts a designated length of pipe without interrupting continuous product flow of the mill.



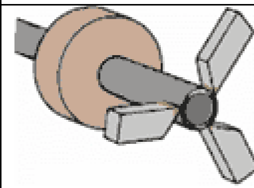
Hydrostatic Testing Each length of pipe is subjected to a hydrostatic test as a strength and leak check.



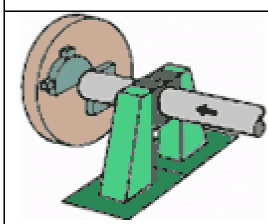
Straightening Any bow in the pipe is now removed by a series of horizontal deflection rolls.



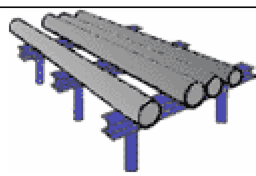
Non-Destructive Inspection The pipe now enters the finishing floor where the weld is ultrasonically inspected and the pipe body is examined by electromagnetic means.



Cut-Off Facilities This facility provides test barrels as required and cuts out defects detected by nondestructive inspection.

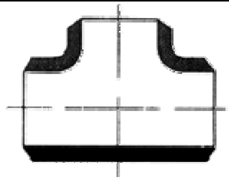
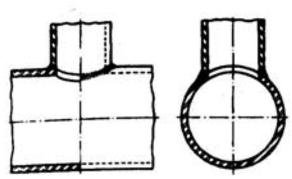
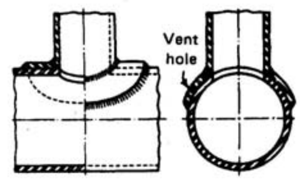


Facing and Beveling Carbide tools cut the desired end finish on the pipe.



Final Inspection A final visual inspection is given the pipe prior to computerized weighing and measuring in preparation for stenciling, loading and shipping.

BRANCH CONNECTIONS

	Tee	Unreinforced Fabricated Tee	Reinforced Fabricated Tee	Branch Connection Fitting
				
Stress Intensification Factor (NPS 8 STD WT header)	2.3	4.9	2.5	2.2
Effective examination methods	Radiographic Visual	Visual	Visual	Visual

CHARACTERISTICS OF SELECTED GASKET TYPES

Gasket Type	Chemical Resistance	Approximate Max Temp		Fire Resistance	Blow-out Resistance	Leak Performance	Strength of Bolting Required
		°F	°C				
Rubber	OK for most	200	95	No	No	Best	Low
Reinforced Rubber	OK for most	325	160	No	No	Fair	Low
PTFE	OK for almost all	350	180	No	No	Good	Low
Flexible Graphite	OK for almost all	900 (625)	480 (330)	Yes	No, unless thicker metal insert	Good	Medium
Kammprofile	Both metal & sealing material have to be OK	1500	820	Depends on sealing material	Yes	Good	Medium
Spiral Wound	Both metal winding & filler have to be OK	1500	820	Depends on filler	Yes	Good	Medium to High
Ring Joint	Metal has to be OK	1500	820	Yes	Yes	Good	High

CHARACTERISTICS OF SELECTED BOLTING

Material	Low Strength	Medium Strength	High Strength
Carbon Steel	A307 SAE Gr 1 SAE Gr 5		
Low Alloy Steel	SAE Gr 5	A193 Gr B7M, hardness controlled	A193 Gr B7 A193 Gr B16, high temperature A320 Gr L7, low temperature
Stainless Steel	A193 Gr B8 – 304 SS A193 Gr B8M – 316 SS	A193 Gr B8 Cl 2– 304 SS A193 Gr B8M Cl2 – 316 SS	

TABLE 323.2.2
REQUIREMENTS FOR LOW TEMPERATURE TOUGHNESS TESTS FOR METALS
These Toughness Test Requirements Are in Addition to Tests Required by the Material Specification

	Type of Material	Column A Design Minimum Temperature at or Above Min. Temp. in Table A-1 or Fig. 323.2.2A		Column B Design Minimum Temperature Below Min. Temp. in Table A-1 or Fig. 323.2.2A
Listed materials	1 Gray cast iron	A-1 No additional requirements		B-1 No additional requirements
Listed materials	2 Malleable and ductile cast iron; carbon steel per Note (1)	A-2 No additional requirements		B-2 Materials designated in Box 2 shall not be used.
Listed materials		(a) Base Metal	(b) Weld Metal and Heat Affected Zone (HAZ) [Note (2)]	
Listed materials	3 Other carbon steels; low and intermediate alloy steels; high alloy ferritic steels; duplex stainless steels	A-3 (a) No additional requirements	A-3 (b) Weld metal deposits shall be impact tested per para. 323.3 if design min. temp. < −29°C (−20°F), except as provided in Notes (3) and (5), and except as follows: for materials listed for Curves C and D of Fig. 323.2.2A, where corresponding welding consumables are qualified by impact testing at the design minimum temperature or lower in accordance with the applicable AWS specification, additional testing is not required.	B-3 Except as provided in Notes (3) and (5), heat treat base metal per applicable ASTM specification listed in para. 323.3.2; then impact test base metal, weld deposits, and HAZ per para. 323.3 [see Note (2)]. When materials are used at design min. temp. below the assigned curve as permitted by Notes (2) and (3) of Fig. 323.2.2A, weld deposits and HAZ shall be impact tested [see Note (2)].
Listed materials	4 Austenitic stainless steels	A-4 (a) If: (1) carbon content by analysis > 0.1%; or (2) material is not in solution heat treated condition; then, impact test per para. 323.3 for design min. temp. < −29°C (−20°F) except as provided in Notes (3) and (6)	A-4 (b) Weld metal deposits shall be impact tested per para. 323.3 if design min. temp. < −29°C (−20°F) except as provided in para. 323.2.2 and in Notes (3) and (6)	B-4 Base metal and weld metal deposits shall be impact tested per para. 323.3. See Notes (2), (3), and (6).
Listed materials	5 Austenitic ductile iron, ASTM A 571	A-5 (a) No additional requirements	A-5 (b) Welding is not permitted	B-5 Base metal shall be impact tested per para. 323.3. Do not use < −196°C (−320°F). Welding is not permitted.
Materials	6 Aluminum, copper, nickel, and their alloys; unalloyed titanium	A-6 (a) No additional requirements	A-6 (b) No additional requirements unless filler metal composition is outside the range for base metal composition; then test per column B-6	B-6 Designer shall be assured by suitable tests [see Note (4)] that base metal, weld deposits, and HAZ are suitable at the design min. temp.
Unlisted	7 An unlisted material shall conform to a published specification. Where composition, heat treatment, and product form are comparable to those of a listed material, requirements for the corresponding listed material shall be met. Other unlisted materials shall be qualified as required in the applicable section of column B.			

See notes on the next page.

NOTES:

(1) Carbon steels conforming to the following are subject to the limitations in Box B-2; plates per ASTM A 36, A 283, and A 570; pipe per ASTM A 134 when made from these plates; and pipe per ASTM A 53 Type F and API 5L Gr. A25 buttweld.

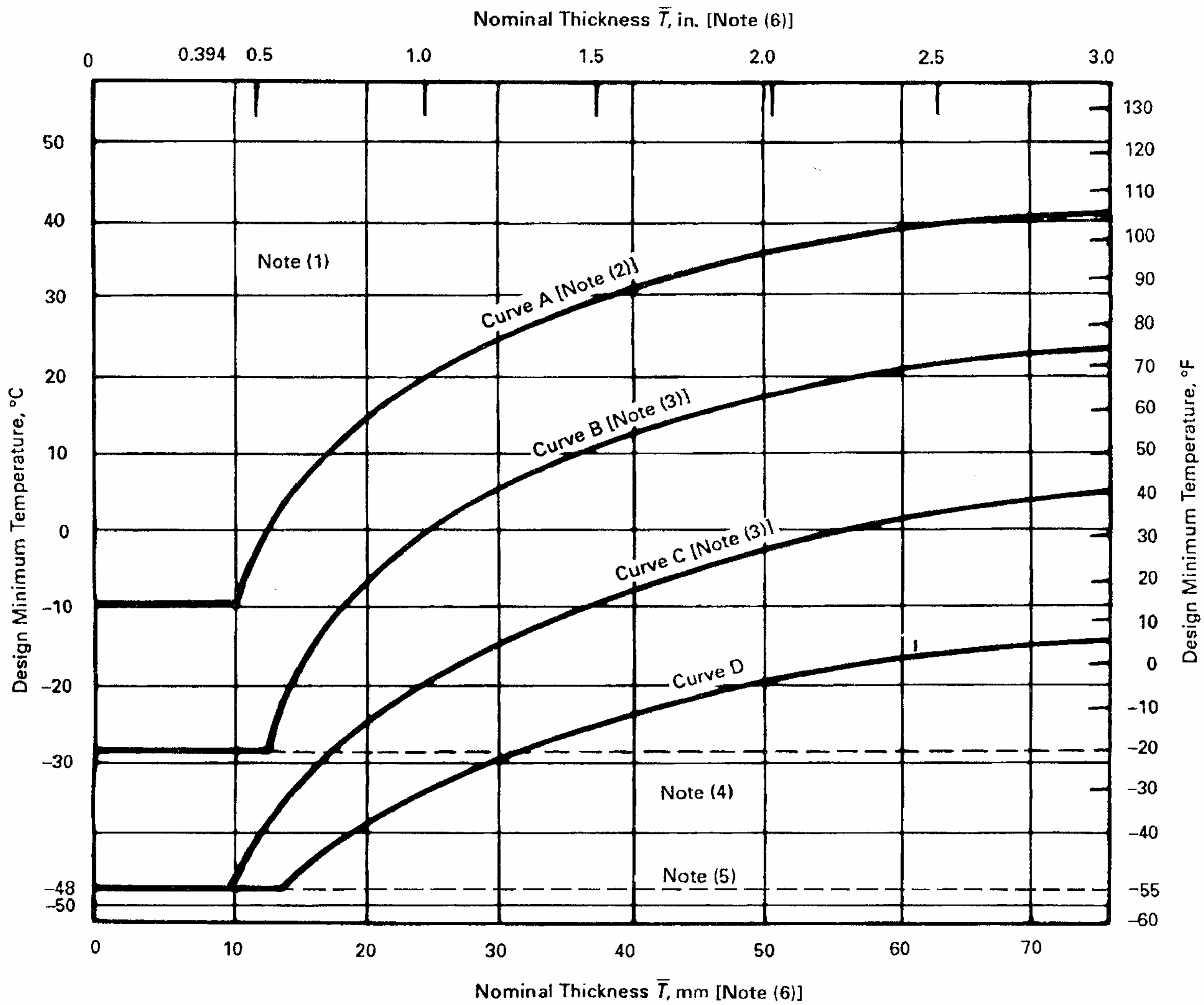
(2) Impact tests that meet the requirements of Table 323.3.1, which are performed as part of the weld procedure qualification, will satisfy all requirements of para. 323.2.2, and need not be repeated for production welds.

(3) Impact testing is not required if the design minimum temperature is below −29°C (−20°F) but at or above −104°C (−155°F) and the Stress Ratio defined in Fig. 323.2.2B does not exceed 0.3 times *S*.

(4) Tests may include tensile elongation, sharp-notch tensile strength (to be compared with unnotched tensile strength), and/or other tests, conducted at or below design minimum temperature. See also para. 323.3.4.

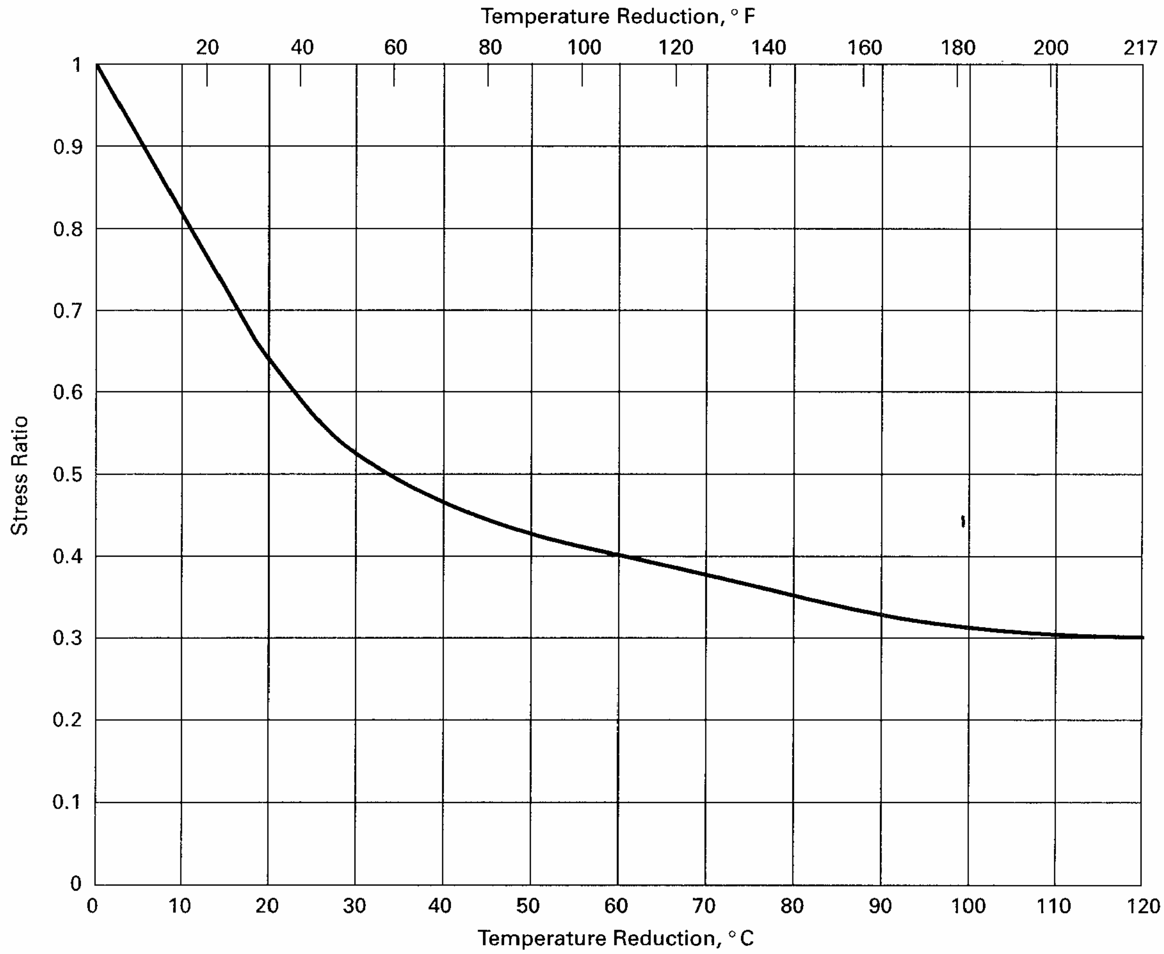
(5) Impact tests are not required when the maximum obtainable Charpy specimen has a width along the notch of less than 2.5 mm (0.098 in.). Under these conditions, the design minimum temperature shall not be less than the lower of −48°C (−55°F) or the minimum temperature for the material in Table A-1.

(6) Impact tests are not required when the maximum obtainable Charpy specimen has a width along the notch of less than 2.5 mm (0.098 in.).



NOTES:
(1) Any carbon steel material may be used to a minimum temperature of −29°C (−20°F) for Category D Fluid Service.
(2) X Grades of API 5L, and ASTM A 381 materials, may be used in accordance with Curve B if normalized or quenched and tempered
(3) The following materials may be used in accordance with Curve D if normalized:
(a) ASTM A 516 Plate, all grades:
(b) ASTM A 671 Pipe, Grades CE55, CE60, and all grades made with A 516 plate;
(c) ASTM A 672 Pipe, Grades E55, E60, and all grades made with A 516 plate.
(4) A welding procedure for the manufacture of pipe or components shall include impact testing of welds and HAZ for any design minimun temperature below −29°C (−20°F), except as provided in Table 323.2.2, A-3(b).
(5) Impact testing in accordance with para. 323.3 is required for any design minimum temperature below −48°C (−55°F), except a: permitted by Note (3) in Table 323.2.2.
(6) For blind flanges and blanks, $\overline{T}$ shall be 1/4 of the flange thickness.

FIG. 323.2.2A MINIMUM TEMPERATURES WITHOUT IMPACT TESTING FOR CARBON STEEL MATERIALS
(See Table A-1 for Designated Curve for a Listed Material)
(See Table 323.2.2A for tabular values)



GENERAL NOTES:

(a) The Stress Ratio is defined as the maximum of the following:

   (1) nominal pressure stress (based on minimum pipe wall thickness less allowances) divided by *S* at the design minimum temperature;

   (2) for piping components with pressure ratings, the pressure for the condition under consideration divided by the pressure rating at the design minimum termperature;

   (3) combined longitudinal stess due to pressure, dead weight, and displacement strain (stress intensification factors are not included in this calulation) divided by *S* at the design minimum temperature. In calculating longitudinal stress, the forces and moments in the piping system shall be calculated using nominal dimensions and the stresses shall be calculated using section properties based on the nominal dimensions less corrosion, erosion, and mechanical allowances.

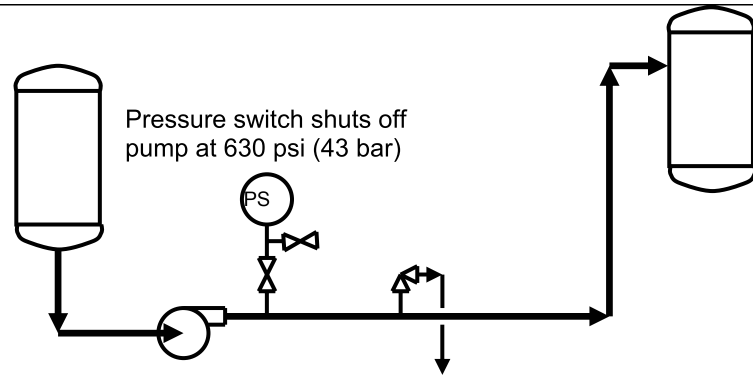
(b) Loadings coincident with the metal temperature under consideration shall be used in determining the Stress Ratio as defined above.

FIG. 323.2.2B REDUCTION IN MINIMUM DESIGN METAL TEMPERATURE WITHOUT IMPACT TESTING

DESIGN PRESSURE AND TEMPERATURE WORKSHOP

Problem 1: Ambient temperature styrene monomer is pumped from a holding tank to a reactor. The normal discharge pressure is 390 psi (27 bar), and the pressure switch shuts off the positive displacement pump when the pressure reaches 630 psi (43 bar). The material of construction for the line is carbon steel. The piping is capable of 740 psi (51.1 bar).

- o What should the design pressure be?
- o What should the design temperature be?
- o What should the relief valve setting be?



Problem 2: If the line in problem 1 is steam cleaned with 50 psi (3.5 bar) steam superheated to 735°F (390°C)

- o What should the design pressure be?
- o What should the design temperature be?
- o What should the relief valve setting be?

Problem 3: Styrene monomer at ambient temperature on outdoor pipe rack. The maximum operating pressure is 95 psig. The piping is capable of 275 psi (19.6 bar).

- o What should the design pressure be?
- o What should the design temperature be?
- o What should the relief valve setting be?

B31.3 Appendix A – Allowable Stresses: Carbon Steel Example (1 of 2)

TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	Grade	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi Tensile	Specified Min. Strength, ksi Yield	Min. Temp. to 100	200	300
Carbon Steel										
Pipes and Tubes (2)										
A 285 Gr. A	A 134	1	...	(8b)(57)	B	45	24	15.0	14.6	14.2
A 285 Gr. A	A 672	1	A45	(57)(59)(67)	B	45	24	15.0	14.6	14.2
Butt weld	API 5L	S-1	A25	(8a)	−20	45	25	15.0	15.0	14.5
Smls & ERW	API 5L	S-1	A25	(57)(59)	B	45	25	15.0	15.0	14.5
...	A 179	1	...	(57)(59)	−20	47	26	15.7	15.0	14.2
Type F	A 53	1	Gr. A	(8a)(77)	20	48	30	16.0	16.0	16.0
...	A 139	S-1	A	(8b)(77)	A	48	30	16.0	16.0	16.0
...	A 587	1	...	(57)(59)	−20	48	30	16.0	16.0	16.0
...	A 53	1	A	(57)(59)						
...	A 106	1	A	(57)						
...	A 135	1	A	(57)(59)	B	48	30	16.0	16.0	16.0
...	A 369	1	FPA	(57)						
...	API 5L	S-1	A	(57)(59)(77)						
A 285 Gr. B	A 134	1	...	(8b)(57)	B	50	27	16.7	16.4	16.0
A 285 Gr. B	A 672	1	A50	(57)(59)(67)	B	50	27	16.7	16.4	16.0
A 285 Gr. C	A 134	1	...	(8b)(57)	A	55	30	18.3	18.3	17.7
...	A 524	1	Gr. II	(57)	−20	55	30	18.3	18.3	17.7
...	A 333	1	1							
...	A 334	1	1	(57)(59)	−50	55	30	18.3	18.3	17.7
A 285 Gr. C	A 671	1	CA55	(59)(67)	A					
A 285 Gr. C	A 672	1	A55	(57)(59)(67)	A					
A 516 Gr. 55	A 672	1	C55	(57)(67)	C	55	30	18.3	18.3	17.7
A 516 Gr. 60	A 671	1	CC60	(57)(67)	C	60	32	20.0	19.5	18.9
A 515 Gr. 60	A 671	1	CB60							
A 515 Gr. 60	A 672	1	B60	(57)(67)	B	60	32	20.0	19.5	18.9
A 516 Gr. 60	A 672	1	C60	(57)(67)	C					
...	A 139	S-1	B	(8b)	A	60	35	20.0	20.0	20.0
...	A 135	1	B	(57)(59)	B					
...	A 524	1	Gr. 1	(57)	−20	60	35	20.0	20.0	20.0
...	A 53	1	B	(57)(59)						
...	A 106	1	B	(57)	B					
...	A 333									
...	A 334	1	6	(57)	−50	60	35	20.0	20.0	20.0
...	A 369	1	FPB	(57)	−20					
...	A 381	S-1	Y35	...	A					
...	API 5L	S-1	B	(57)(59)(77)	B					

(continued)

B31.3 Appendix A – Allowable Stresses: Carbon Steel Example (2 of 2)

TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)														
400	500	600	650	700	750	800	850	900	950	1000	1050	1100	Grade	Spec. No.
														Carbon Steel Pipe and Tubes (2)
13.7	13.0	11.8	11.6	11.5	10.3	9.0	7.8	6.5	...	...	...	...	...	A 134
13.7	13.0	11.8	11.6	11.5	10.3	9.0	7.8	6.5	4.5	2.5	1.6	1.0	A45	A 672
13.8	...	...	...	...	...	...	...	...	...	...	...	...	A25	API 5L
13.8	...	...	...	...	...	...	...	...	...	...	...	...	A25	API 5L
13.5	12.8	12.1	11.8	11.5	10.6	9.2	7.9	6.5	4.5	2.5	1.6	1.0	...	A 179
16.0	...	...	...	...	...	...	...	...	...	...	...	...	Gr. A	A 53
...	...	...	...	...	...	...	...	...	...	...	...	...	A	A 139
16.0	16.0	14.8	14.5	14.4	10.7	9.3	7.9	...	...	...	...	...	...	A 587
													A	A 53
													A	A 106
16.0	16.0	14.8	14.5	14.4	10.7	9.3	7.9	6.5	4.5	2.5	1.6	1.0	A	A 135
													FPA	A 369
													A	API 5L
15.4	14.6	13.3	13.1	13.0	11.2	9.6	8.1	6.5	...	...	...	...	...	A 134
15.4	14.6	13.3	13.1	13.0	11.2	9.6	8.1	6.5	4.5	2.5	1.6	1.0	A 50	A 672
17.2	16.2	14.8	14.5	14.4	12.0	10.2	8.3	6.5	...	...	...	...	...	A 134
17.2	16.2	14.8	14.5	14.4	12.0	10.2	8.3	6.5	4.5	2.5	...	...	Gr. II	A 524
													1	A 333
17.2	16.2	14.8	14.5	14.4	12.0	10.2	8.3	6.5	4.5	2.5	1.6	1.0	1	A 334
													CA55	A 671
													A55	A 672
17.2	16.2	14.8	14.5	14.4	12.1	10.2	8.4	6.5	4.5	2.5	1.6	1.0	C55	A 672
18.3	17.3	15.8	15.5	15.4	13.0	10.8	8.7	6.5	4.5	2.5	...	...	CC60	A 671
													CB60	A 671
18.3	17.3	15.8	15.5	15.4	13.0	10.8	8.7	6.5	4.5	2.5	1.6	1.0	B60	A 672
													C60	A 672
...	...	...	...	...	...	...	...	...	...	...	...	...	B	A 139
													B	A 135
20.0	18.9	17.3	17.0	16.5	13.0	10.8	8.7	6.5	4.5	2.5	...	...	Gr. 1	A 524
													B	A 53
													B	A 106
													6	A 333
20.0	18.9	17.3	17.0	16.5	13.0	10.8	8.7	6.5	4.5	2.5	1.6	1.0	6	A 334
													FPB	A 369
													Y35	A 381
													B	API 5L

(continued)

B31.3 Appendix A – Allowable Stresses: Stainless Steel Example (1 of 2)

Table A-1 ASME B31.3-2002

TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	Grade	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi Tensile	Specified Min. Strength, ksi Yield	Min. Temp. to 100	200	300	400	500	600
Stainless Steel (3) (4) (Cont'd)													
Pipes and Tubes (2) (Cont'd)													
18Cr-10Ni-Cb pipe	A 312	8	TP347	...	–425								
Type 347 A 240	A 358	8	347	(30)(36)	–425								
18Cr-10Ni-Cb pipe	A 376	8	TP347	(30)(36)	–425								
18Cr-10Ni-Cb pipe	A 409	8	TP347	(30)(36)	–425	75	30	20.0	*20.0*	*20.0*	*20.0*	*19.9*	19.3
18Cr-10Ni-Cb pipe	A 312	8	TP348	...	–325								
Type 348 A 240	A 358	8	348	(30)(36)	–325								
18Cr-10Ni-b pipe	A 376	8	TP348	(30)(36)	–325								
18Cr-10Ni-Cb pipe	A 409	8	TP348	(30)(36)	–325								
23Cr-13Ni	A 451	8	CPH10 or CPH20	(12)(14)(28)(35)(39)	–325	70	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	19.2
25Cr-20Ni pipe	A 312	8	TP310	(28)(29)(35)(39)	–325	75	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	19.2
Type 310S A 240	A 358	8	310S	(28)(29)(31)(35)(36)									
18Cr-10Ni-Cb	A 451	8	CPF8C	(28)	–325	70	30	20.0	*20.0*	*20.0*	*20.0*	19.3	18.3
18Cr-10Ni-Ti pipe	A 312	8	TP321	(28)(30)									
smls ≤ 3/8 in. thk; wld													
Type 321 A 240	A 358	8	321										
18Cr-10Ni-Ti pipe	A 376				–425	75	30	20.0	*20.0*	*20.0*	*20.0*	19.3	18.3
≤ 3/8 in. thick		8	TP321	(28)(30)(36)									
18Cr-10Ni-Ti pipe	A 409												
18Cr-10Ni-Ti pipe	A 376	8	TP321H	(30)(36)	–325								
≤ 3/8 in. thick													
18Cr-10Ni-Ti pipe	A 312	8	TP321H	...	–325								
smls ≤ 3/8 in. thk; wld													
16Cr-12Ni-Mo tube	A 269	8	TP316	(14)(26)(28)(31)(36)	–425								
16Cr-12Ni-2Mo pipe	A 312	8	TP316	(26)(28)	–425								
Type 316 A 240	A 358	8	316	(26)(28)(31)(36)	–425								
16Cr-12Ni-2Mo pipe	A 376	8	TP316	(26)(28)(31)(36)	–425	75	30	20.0	*20.0*	*20.0*	19.3	17.9	17.0
16Cr-12Ni-2Mo pipe	A 409	8	TP316	(26)(28)(31)(36)	–425								
18Cr-3Ni-3Mo pipe	A 312	8	TP317	(26)(28)	–325								
18Cr-3Ni-3Mo pipe	A 409	8	TP317	(26)(28)(31)(36)	–325								
16Cr-12Ni-2Mo pipe	A 376	8	TP316H	(26)(31)(36)	–325								
16Cr-12Ni-2Mo pipe	A 312	8	TP316H	(26)	–325	75	30	20.0	*20.0*	*20.0*	19.3	17.9	17.0
18Cr-10Ni-Cb pipe	A 376	8	TP347H	(30)(36)	–325								
18Cr-0Ni-Cb pipe	A 312	8	TP347	(28)	–425								
Type 347 A 240	A 358	8	347	(28)(30)(36)	–425								
18Cr-10Ni-Cb pipe	A 376	8	TP347	(28)(30)(36)	–425								
18Cr-10Nib pipe	A 409	8	TP347	(28)(30)(36)	–425	75	30	20.0	*20.0*	*20.0*	*20.0*	*19.9*	19.3
18Cr-10Ni-b pipe	A 312	8	TP348	(28)	–325								
Type 348 A 240	A 358	8	348	(28)(30)(36)	–325								
18Cr-10Ni-Cb pipe	A 376	8	TP348	(28)(30)(36)	–325								
18Cr-10Ni-Cb pipe	A 409	8	TP348	(28)(30)(36)	–325								
18Cr-10Ni-Cb pipe	A 312	8	TP347H										
18Cr-10Ni-Cb pipe	A 312	8	TP348H	...	–325	75	30	20.0	*20.0*	*20.0*	*20.0*	*19.9*	19.3

(continued)

B31.3 Appendix A – Allowable Stresses: Stainless Steel Example (2 of 2)

TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)																			
650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	Grade	Spec. No.
																		Stainless Steel (3) (4) (Cont'd) Pipes and Tubes (2) (Cont'd)	
19.0	18.6	18.5	18.4	*18.2*	*18.1*	*18.1*	*18.0*	*12.1*	9.1	6.1	4.4	3.3	2.2	1.5	1.2	0.9	0.8	TP347	A 312
																		347	A 358
																		TP347	A 376
																		TP347	A 409
																		TP348	A 312
																		348	A 358
																		TP348	A 376
																		TP348	A 409
18.8	18.3	18.0	17.4	*13.5*	*13.3*	*12.4*	10.5	8.4	6.4	5.0	3.7	2.9	2.3	1.7	1.3	0.9	0.8	CPH10 or CPH20	A 451
18.8	18.3	18.0	17.5	*14.6*	*13.9*	*12.5*	11.0	9.8	8.5	7.3	6.0	4.8	3.5	2.3	1.6	1.1	0.8	TP310	A 312
																		310S	A 358
18.0	17.5	17.2	17.1	*14.0*	*13.9*	*13.7*	*13.4*	*13.0*	*10.8*	8.0	5.0	3.5	2.7	2.0	1.4	1.1	1.0	CPF8C	A 451
17.9	17.5	17.2	16.9	*16.7*	*16.6*	*16.4*	*16.2*	*11.7*	9.1	6.9	5.4	4.1	3.2	2.5	1.9	1.5	1.1	TP321	A 312
																		321	A 358
																		TP321	A 376
																		TP321	A 409
																		TP321H	A 376
																		TP321H	A 312
16.7	16.3	16.1	15.9	15.7	15.5	15.4	15.3	*14.5*	*12.4*	9.8	7.4	5.5	4.1	3.1	2.3	1.7	1.3	TP316	A 269
																		TP316	A 312
																		316	A 358
																		TP316	A 376
																		TP316	A 409
																		TP317	A 312
																		TP317	A 409
																		TP316H	A 376
16.7	16.3	16.1	15.9	15.7	15.5	15.4	15.3	*14.5*	*12.4*	9.8	7.4	5.5	4.1	3.1	2.3	1.7	1.3	TP316H	A 312
19.0	18.6	18.5	18.4	18.2	18.1	18.1	18.0	*17.1*	*14.2*	10.5	7.9	5.9	4.4	3.2	2.5	1.8	1.3	TP347H	A 376
																		TP347	A 312
																		347	A 358
																		TP347	A 376
																		TP347	A 409
																		TP348	A 312
																		348	A 358
																		TP348	A 376
																		TP348	A 409
19.0	18.6	18.5	18.4	18.2	18.1	18.1	18.0	*17.1*	*14.2*	10.5	7.9	5.9	4.4	3.2	2.5	1.8	1.3	TP347H	A 312
																		TP348H	A 312

(continued)

B31.3 Appendix A – Quality Factors Example (1 of 2)

TABLE A-1B
BASIC QUALITY FACTORS FOR LONGITUDINAL WELD JOINTS IN PIPES, TUBES, AND FITTINGS E_j

These quality factors are determined in accordance with para. 302.3.4(a). See also para. 302.3.4(b) and Table 302.3.4 for increased quality factors applicable in special cases. Specifications, except API, are ASTM.

Spec. No.	Class (or Type)	Description	E_j (2)	Appendix A Notes
Carbon Steel				
API 5L	...	Seamless pipe	1.00	...
	...	Electric resistance welded pipe	0.85	...
	...	Electric fusion welded pipe, double butt, straight or spiral seam	0.95	...
	...	Furnace butt welded	0.60	...
A 53	Type S	Seamless pipe	1.00	...
	Type E	Electric resistance welded pipe	0.85	...
	Type F	Furnace butt welded pipe	0.60	...
A 105	...	Forgings and fittings	1.00	(9)
A 106	...	Seamless pipe	1.00	...
A 134	...	Electric fusion welded pipe, single butt, straight or spiral seam	0.80	...
A 135	...	Electric resistance welded pipe	0.85	...
A 139	...	Electric fusion welded pipe, straight or spiral seam	0.80	...
A 179	...	Seamless tube	1.00	...
A 181	...	Forgings and fittings	1.00	(9)
A 234	...	Seamless and welded fittings	1.00	(16)
A 333	...	Seamless pipe	1.00	...
	...	Electric resistance welded pipe	0.85	...
A 334	...	Seamless tube	1.00	...
A 350	...	Forgings and fittings	1.00	(9)
A 369	...	Seamless pipe	1.00	...
A 381	...	Electric fusion welded pipe, 100% radiographed	1.00	(18)
	...	Electric fusion welded pipe, spot radiographed	0.90	(19)
	...	Electric fusion welded pipe, as manufactured	0.85	...
A 420	...	Welded fittings, 100% radiographed	1.00	(16)
A 524	...	Seamless pipe	1.00	...
A 587	...	Electric resistance welded pipe	0.85	...
A 671	12, 22, 32, 42, 52	Electric fusion welded pipe, 100% radiographed	1.00	...
	13, 23, 33, 43, 53	Electric fusion welded pipe, double butt seam	0.85	...
A 672	12, 22, 32, 42, 52	Electric fusion welded pipe, 100% radiographed	1.00	...
	13, 23, 33, 43, 53	Electric fusion welded pipe, double butt seam	0.85	...
A 691	12, 22, 32, 42, 52	Electric fusion welded pipe, 100% radiographed	1.00	...
	13, 23, 33, 43, 53	Electric fusion welded pipe, double butt seam	0.85	...
Low and Intermediate Alloy Steel				
A 182	...	Forgings and fittings	1.00	(9)
A 234	...	Seamless and welded fittings	1.00	(16)
A 333	...	Seamless pipe	1.00	...
	...	Electric resistance welded pipe	0.85	...

(continued)

B31.3 Appendix A – Quality Factors Example (2 of 2)

Table A-1B

ASME B31.3-2002

TABLE A-1B (CONT'D)
BASIC QUALITY FACTORS FOR LONGITUDINAL WELD JOINTS IN PIPES, TUBES, AND FITTINGS E_j

These quality factors are determined in accordance with para. 302.3.4(a). See also para. 302.3.4(b) and Table 302.3.4 for increased quality factors applicable in special cases. Specifications, except API, are ASTM.

Spec. No.	Class (or Type)	Description	E_j (2)	Appendix A Notes
Low and Intermediate Alloy Steel (Cont'd)				
A 334	...	Seamless tube	1.00	...
A 335	...	Seamless pipe	1.00	...
A 350	...	Forgings and fittings	1.00	...
A 369	...	Seamless pipe	1.00	...
A 420	...	Welded fittings, 100% radiographed	1.00	(16)
A 671	12, 22, 32, 42, 52	Electric fusion welded pipe, 100% radiographed	1.00	...
	13, 23, 33, 43, 53	Electric fusion welded pipe, double butt seam	0.85	...
A 672	12, 22, 32, 42, 52	Electric fusion welded pipe, 100% radiographed	1.00	...
	13, 23, 33, 43, 53	Electric fusion welded pipe, double butt seam	0.85	...
A 691	12, 22, 32, 42, 52	Electric fusion welded pipe, 100% radiographed	1.00	...
	13, 23, 33, 43, 53	Electric fusion welded pipe, double butt seam	0.85	...
Stainless Steel				
A 182	...	Forgings and fittings	1.00	...
A 268	...	Seamless tube	1.00	...
	...	Electric fusion welded tube, double butt seam	0.85	...
	...	Electric fusion welded tube, single butt seam	0.80	...
A 269	...	Seamless tube	1.00	...
	...	Electric fusion welded tube, double butt seam	0.85	...
	...	Electric fusion welded tube, single butt seam	0.80	...
A 312	...	Seamless tube	1.00	...
	...	Electric fusion welded tube, double butt seam	0.85	...
	...	Electric fusion welded tube, single butt seam	0.80	...
A 358	1, 3, 4	Electric fusion welded pipe, 100% radiographed	1.00	...
	5	Electric fusion welded pipe, spot radiographed	0.90	...
	2	Electric fusion welded pipe, double butt seam	0.85	...
A 376	...	Seamless pipe	1.00	...
A 403	...	Seamless fittings	1.00	...
	...	Welded fitting, 100% radiographed	1.00	(16)
	...	Welded fitting, double butt seam	0.85	...
	...	Welded fitting, single butt seam	0.80	...
A 409	...	Electric fusion welded pipe, double butt seam	0.85	...
	...	Electric fusion welded pipe, single butt seam	0.80	...
A 487	...	Steel castings	0.80	(9)(40)
A 789	...	Seamless tube	1.00	...
	...	Electric fusion welded, 100% radiographed	1.00	...
	...	Electric fusion welded, double butt	0.85	...
	...	Electric fusion welded, single butt	0.80	...
A 790	...	Seamless pipe	1.00	...
	...	Electric fusion welded, 100% radiographed	1.00	...
	...	Electric fusion welded, double butt	0.85	...
	...	Electric fusion welded, single butt	0.80	...

(continued)

CALCULATING REQUIRED WALL THICKNESS FOR STRAIGHT PIPE

$$t = \frac{PD}{2\,(SEW + PY)}$$

Where:

t = **pressure design thickness**
P = internal design gauge pressure
D = outside diameter of pipe
S = allowable stress value for material from piping code at the design temperature
E = longitudinal weld joint quality factor from piping code (next page)
W = weld joint strength reduction factor
 = 1.0 for all materials 950ºF (510ºC) and cooler
Y = coefficient. See the next page. The following values generally apply:
 = 0.4 for ductile metals 900ºF (482ºC) and cooler
 = 0.0 for cast iron

The minimum nominal new thickness required is the sum of:

pressure design thickness (t)
\+ manufacturing tolerance (ASTM A53 allows plus or minus 12.5%)
\+ corrosion (or erosion) allowance
\+ threading allowance

STRAIGHT PIPE WALL THICKNESS WORKSHOP

1. What is the required nominal pipe wall thickness for NPS 1 and NPS 8 for the following case?
   Styrene monomer service
   ASTM A53 Gr B ERW carbon steel pipe
   Design pressure and temperature from Problems 1 and 2, page 25
   S = 20,000 psi (138 MPa) - verify
   Corrosion allowance = 1/8” (3.2 mm)
   Socket welding thru NPS 1½
   Buttwelding NPS 2 and larger

2. If the construction was threading instead of socket welding NPS ¾ through 1½, what would the wall thickness have to be for NPS 1? [See discussion on Threaded Joint Fluid Service Requirements in Section 2 and para. 314.]

VALUES OF COEFFICIENT Y

When the pressure design thickness is less than 1/6 of the pipe outside diameter, the following values apply:

	≤900ºF ≤482ºC	950ºF 510ºC	1000ºF 538ºC	1050ºF 566ºC	1100ºF 593ºC	≥1150ºF ≥ 621ºC
Ferritic Steels	0.4	0.5	0.7	0.7	0.7	0.7
Austenitic Steels	0.4	0.4	0.4	0.4	0.5	0.7
Other Ductile Metals	0.4	0.4	0.4	0.4	0.4	0.4
Cast Iron	0.0	---	---	---	---	---

The factor Y increases with increasing temperature. At elevated temperatures, when creep effects become significant, creep leads to a more even distribution of stress across the pipe wall thickness. The larger factor Y leads to a decrease in the calculated wall thickness for the same allowable stress.

When the pressure design thickness is greater than or equal to 1/6 of the pipe outside diameter, the following equation applies:

$$Y = \frac{d + 2c}{D + d + 2c}$$

Where:

d = inside diameter of the pipe
D = outside diameter of the pipe
c = corrosion (or erosion) allowance plus threading allowance

TABLE 302.3.4
LONGITUDINAL WELD JOINT QUALITY FACTOR, E_j

No.	Type of Joint		Type of Seam	Examination	Factor, E_j
1	Furnace butt weld, continuous weld		Straight	As required by listed specification	0.60 [Note (1)]
2	Electric resistance weld		Straight or spiral	As required by listed specification	0.85 [Note (1)]
3	Electric fusion weld				
	(a) Single butt weld		Straight or spiral	As required by listed specification or this Code	0.80
	(with or without filler metal)			Additionally spot radiographed per para. 341.5.1	0.90
				Additionally 100% radiographed per para. 344.5.1 and Table 341.3.2	1.00
	(b) Double butt weld		Straight or spiral [except as provided in 4(a) below]	As required by listed specification or this Code	0.85
	(with or without filler metal)			Additionally spot radiographed per para. 341.5.1	0.90
				Additionally 100% radiographed per para. 344.5.1 and Table 341.3.2	1.00
4	Per specific specification				
	(a) API 5L	Submerged arc weld (SAW) Gas metal arc weld (GMAW) Combined GMAW, SAW 	Straight with one or two seams Spiral	As required by specification	0.95

NOTE:
(1) It is not permitted to increase the joint quality factor by additional examination for joint 1 or 2.

PIPE DIMENSIONS AND PROPERTIES IN US CUSTOMARY UNITS

NPS	OD, in.	ID	Schedule	Wall Thickness, in.	Inside Diameter, in.	Weight of Steel Pipe, lbm/ft	Weight of Water, lbm/ft	Moment of Inertia, in4	Section Modulus, in3
1/8	0.405	STD	40	0.068	0.269	0.244	0.025	0.0011	0.0053
		XS	80	0.095	0.215	0.314	0.016	0.0012	0.0060
1/4	0.540	STD	40	0.088	0.364	0.424	0.045	0.0033	0.0123
		XS	80	0.119	0.302	0.534	0.031	0.0038	0.0139
3/8	0.675	STD	40	0.091	0.493	0.567	0.083	0.0073	0.0216
		XS	80	0.126	0.423	0.738	0.061	0.0086	0.0255
1/2	0.840	-	10S	0.083	0.674	0.670	0.155	0.0143	0.0341
		STD	40	0.109	0.622	0.850	0.132	0.0171	0.0407
		XS	80	0.147	0.546	1.09	0.101	0.0201	0.0478
		-	160	0.188	0.464	1.31	0.073	0.0222	0.0528
		XXS	-	0.294	0.252	1.71	0.022	0.0242	0.0577
3/4	1.050	-	10S	0.083	0.884	0.856	0.266	0.0297	0.0566
		STD	40	0.113	0.824	1.13	0.231	0.0370	0.0705
		XS	80	0.154	0.742	1.47	0.187	0.0448	0.0853
		-	160	0.219	0.612	1.94	0.127	0.0528	0.101
		XXS	-	0.308	0.434	2.44	0.064	0.0579	0.110
1	1.315	-	10S	0.109	1.097	1.40	0.410	0.0757	0.115
		STD	40	0.133	1.049	1.68	0.375	0.0873	0.133
		XS	80	0.178	0.959	2.16	0.313	0.105	0.160
		-	160	0.250	0.815	2.84	0.226	0.125	0.190
		XXS	-	0.358	0.599	3.66	0.122	0.140	0.214
1-1/4	1.660	-	10S	0.109	1.442	1.80	0.708	0.160	0.193
		STD	40	0.140	1.380	2.27	0.648	0.195	0.235
		XS	80	0.191	1.278	2.99	0.556	0.242	0.291
		-	160	0.250	1.160	3.76	0.458	0.284	0.342
		XXS	-	0.382	0.896	5.21	0.273	0.341	0.411
1-1/2	1.900	-	10S	0.109	1.682	2.08	0.963	0.247	0.260
		STD	40	0.145	1.610	2.71	0.882	0.310	0.326
		XS	80	0.200	1.500	3.63	0.766	0.391	0.412
		-	160	0.281	1.338	4.85	0.609	0.482	0.508
		XXS	-	0.400	1.100	6.40	0.412	0.568	0.598
2	2.375	-	10S	0.109	2.157	2.64	1.58	0.499	0.420
		STD	40	0.154	2.067	3.65	1.45	0.666	0.561
		XS	80	0.218	1.939	5.02	1.28	0.868	0.731
		-	160	0.344	1.687	7.45	0.969	1.16	0.980
		XXS	-	0.436	1.503	9.02	0.769	1.31	1.10
2-1/2	2.875	-	10S	0.120	2.635	3.53	2.36	0.987	0.687
		STD	40	0.203	2.469	5.79	2.07	1.53	1.06
		XS	80	0.276	2.323	7.65	1.84	1.92	1.34
		-	160	0.375	2.125	10.0	1.54	2.35	1.64
		XXS	-	0.552	1.771	13.7	1.07	2.87	2.00
3	3.500	-	5S	0.083	3.334	3.03	3.78	1.30	0.744
		-	10S	0.120	3.260	4.33	3.62	1.82	1.04
		STD	40	0.216	3.068	7.57	3.20	3.02	1.72
		XS	80	0.300	2.900	10.2	2.86	3.89	2.23
		-	160	0.438	2.624	14.3	2.34	5.04	2.88

NPS	OD, in.	ID	Schedule	Wall Thickness, in.	Inside Diameter, in.	Weight of Steel Pipe, lbm/ft	Weight of Water, lbm/ft	Moment of Inertia, in4	Section Modulus, in3
		XXS	-	0.600	2.300	18.6	1.80	5.99	3.42
4	4.500	-	5S	0.083	4.334	3.91	6.39	2.81	1.25
		-	10S	0.120	4.260	5.61	6.18	3.96	1.76
		STD	40	0.237	4.026	10.8	5.52	7.23	3.21
		XS	80	0.337	3.826	15.0	4.98	9.61	4.27
6	6.625	-	5S	0.109	6.407	7.58	14.0	11.8	3.58
		-	10S	0.134	6.357	9.28	13.8	14.4	4.35
		STD	40	0.280	6.065	19.0	12.5	28.1	8.50
		XS	80	0.432	5.761	28.5	11.3	40.5	12.2
8	8.625	-	5S	0.109	8.407	9.90	24.1	26.4	6.13
		-	10S	0.148	8.329	13.4	23.6	35.4	8.21
		STD	40	0.322	7.981	28.5	21.7	72.5	16.8
		XS	80	0.500	7.625	43.3	19.8	105.7	24.5
10	10.750	-	5S	0.134	10.482	15.2	37.4	63.0	11.7
		-	10S	0.165	10.420	18.6	37.0	76.9	14.3
		STD	40	0.365	10.020	40.4	34.2	161	29.9
		XS	-	0.500	9.750	54.7	32.4	212	39.4
		-	80	0.594	9.562	64.4	31.1	245	45.6
12	12.750	-	5S	0.156	12.438	21.0	52.7	122	19.2
		-	10S	0.180	12.390	24.1	52.2	140	22.0
		STD	-	0.375	12.000	49.5	49.0	279	43.8
		-	40	0.406	11.938	53.5	48.5	300	47.1
		XS	-	0.500	11.750	65.3	47.0	362	56.7
		-	80	0.688	11.374	88.5	44.0	476	74.6
14	14.000	-	5S	0.156	13.688	23.0	63.8	163	23.2
		-	10S	0.188	13.624	27.7	63.2	195	27.8
		STD	-	0.375	13.250	54.5	59.8	373	53.3
		-	40	0.438	13.124	63.4	58.6	429	61.4
		XS	-	0.500	13.000	72.0	57.5	484	69.1
		-	80	0.750	12.500	106	53.2	687	98.2
16	16.000	-	5S	0.165	15.670	27.9	83.6	257	32.2
		-	10S	0.188	15.624	31.7	83.1	292	36.5
		STD	-	0.375	15.250	62.5	79.2	562	70.3
		XS	40	0.500	15.000	82.7	76.6	732	91.5
		-	80	0.844	14.312	136	69.7	1157	145
18	18.000	-	5S	0.165	17.670	31.4	106	368	40.8
		-	10S	0.188	17.624	35.7	106	417	46.4
		STD	-	0.375	17.250	70.5	101	807	89.6
		XS	-	0.500	17.000	93.4	98.4	1053	117
		-	40	0.562	16.876	105	96.9	1171	130
		-	80	0.938	16.124	171	88.5	1835	204
20	20.000	-	5S	0.188	19.624	39.7	131	574	57.4
		-	10S	0.218	19.564	46.0	130	663	66.3
		STD	-	0.375	19.250	78.5	126	1113	111
		XS	-	0.500	19.000	104	123	1457	146
		-	40	0.594	18.812	123	120	1706	171
22	22.000	-	5S	0.188	21.624	43.7	159	766	69.7

NPS	OD, in.	ID	Schedule	Wall Thickness, in.	Inside Diameter, in.	Weight of Steel Pipe, lbm/ft	Weight of Water, lbm/ft	Moment of Inertia, in4	Section Modulus, in3
		-	10S	0.218	21.564	50.7	158	885	80.4
		STD	-	0.375	21.250	86.5	154	1490	135
		XS	-	0.500	21.000	115	150	1952	177
24	24.000	-	5S	0.218	23.564	55.3	189	1152	96.0
		-	10S	0.250	23.500	63.3	188	1315	110
		STD	-	0.375	23.250	94.5	184	1942	162
		XS	-	0.500	23.000	125	180	2549	212
		-	40	0.688	22.624	171	174	3426	285
26	26.000	STD	-	0.375	25.250	103	217	2478	191
		XS	-	0.500	25.000	136	213	3257	251
28	28.000	STD	-	0.375	27.250	111	253	3105	222
		XS	-	0.500	27.000	147	248	4085	292
30	30.000	-	5S	0.250	29.500	79.3	296	2585	172
		-	10S	0.312	29.376	98.8	294	3206	214
		STD	-	0.375	29.250	119	291	3829	255
		XS	-	0.500	29.000	157	286	5042	336

PIPE DIMENSIONS AND PROPERTIES IN SI METRIC UNITS

NPS	DN	OD, mm	ID	Schedule	Wall Thickness, mm	Inside Diameter, mm	Weight of Steel Pipe, Kg/m	Weight of Water, Kg/m	Moment of Inertia, mm4	Section Modulus, mm3
1/8	-	10.3	STD	40	1.73	6.83	0.365	0.037	443	86.1
		10.3	XS	80	2.41	5.46	0.469	0.023	506	98.4
1/4	-	13.7	STD	40	2.24	9.25	0.633	0.067	1379	201
		13.7	XS	80	3.02	7.67	0.797	0.046	1567	229
3/8	10	17.1	STD	40	2.31	12.52	0.846	0.123	3035	354
		17.1	XS	80	3.20	10.74	1.10	0.091	3587	418
1/2	15	21.3	-	10S	2.11	17.12	1.00	0.230	5956	558
		21.3	STD	40	2.77	15.80	1.27	0.196	7114	667
		21.3	XS	80	3.73	13.87	1.62	0.151	8357	783
		21.3	-	160	4.78	11.79	1.95	0.109	9225	865
		21.3	XXS	-	7.47	6.40	2.55	0.032	1.009E+04	946
3/4	20	26.7	-	10S	2.11	22.45	1.28	0.396	1.236E+04	927
		26.7	STD	40	2.87	20.93	1.68	0.344	1.542E+04	1156
		26.7	XS	80	3.91	18.85	2.20	0.279	1.864E+04	1398
		26.7	-	160	5.56	15.54	2.90	0.190	2.197E+04	1647
		26.7	XXS	-	7.82	11.02	3.64	0.095	2.411E+04	1808
1	25	33.4	-	10S	2.77	27.86	2.09	0.610	3.151E+04	1887
		33.4	STD	40	3.38	26.64	2.50	0.558	3.635E+04	2177
		33.4	XS	80	4.52	24.36	3.22	0.466	4.381E+04	2624
		33.4	-	160	6.35	20.70	4.24	0.337	5.208E+04	3119
		33.4	XXS	-	9.09	15.21	5.45	0.182	5.846E+04	3501
1-1/4	32	42.2	-	10S	2.77	36.63	2.69	1.05	6.680E+04	3169
		42.2	STD	40	3.56	35.05	3.39	0.965	8.104E+04	3844

NPS	DN	OD, mm	ID	Schedule	Wall Thickness, mm	Inside Diameter, mm	Weight of Steel Pipe, Kg/m	Weight of Water, Kg/m	Moment of Inertia, mm4	Section Modulus, mm3
		42.2	XS	80	4.85	32.46	4.46	0.828	1.006E+05	4774
		42.2	-	160	6.35	29.46	5.61	0.682	1.182E+05	5604
		42.2	XXS	-	9.70	22.76	7.77	0.407	1.420E+05	6734
1-1/2	40	48.3	-	10S	2.77	42.72	3.11	1.43	1.027E+05	4258
		48.3	STD	40	3.68	40.89	4.05	1.31	1.290E+05	5346
		48.3	XS	80	5.08	38.10	5.41	1.14	1.628E+05	6748
		48.3	-	160	7.14	33.99	7.24	0.907	2.008E+05	8321
		48.3	XXS	-	10.16	27.94	9.55	0.613	2.364E+05	9795
2	50	60.3	-	10S	2.77	54.79	3.93	2.36	2.078E+05	6889
		60.3	STD	40	3.91	52.50	5.44	2.16	2.771E+05	9187
		60.3	XS	80	5.54	49.25	7.48	1.91	3.613E+05	1.198E+04
		60.3	-	160	8.74	42.85	11.1	1.44	4.846E+05	1.607E+04
		60.3	XXS	-	11.07	38.18	13.5	1.14	5.458E+05	1.810E+04
2-1/2	65	73.0	-	10S	3.05	66.93	5.26	3.52	4.109E+05	1.125E+04
		73.0	STD	40	5.16	62.71	8.63	3.09	6.366E+05	1.744E+04
		73.0	XS	80	7.01	59.00	11.4	2.73	8.009E+05	2.194E+04
		73.0	-	160	9.53	53.98	14.9	2.29	9.793E+05	2.682E+04
		73.0	XXS	-	14.02	44.98	20.4	1.59	1.195E+06	3.273E+04
3	80	88.9	-	5S	2.11	84.68	4.51	5.63	5.416E+05	1.218E+04
		88.9	-	10S	3.05	82.80	6.45	5.39	7.584E+05	1.706E+04
		88.9	STD	40	5.49	77.93	11.3	4.77	1.256E+06	2.825E+04
		88.9	XS	80	7.62	73.66	15.3	4.26	1.621E+06	3.647E+04
		88.9	-	160	11.13	66.65	21.3	3.49	2.097E+06	4.719E+04
		88.9	XXS	-	15.24	58.42	27.7	2.68	2.494E+06	5.611E+04
4	100	114.3	-	5S	2.11	110.08	5.83	9.52	1.170E+06	2.046E+04
		114.3	-	10S	3.05	108.20	8.36	9.20	1.649E+06	2.886E+04
		114.3	STD	40	6.02	102.26	16.1	8.21	3.010E+06	5.268E+04
		114.3	XS	80	8.56	97.18	22.3	7.42	4.000E+06	6.999E+04
6	150	168.3	-	5S	2.77	162.74	11.3	20.8	4.930E+06	5.860E+04
		168.3	-	10S	3.40	161.47	13.8	20.5	5.993E+06	7.122E+04
		168.3	STD	40	7.11	154.05	28.3	18.6	1.171E+07	1.392E+05
		168.3	XS	80	10.97	146.33	42.6	16.8	1.685E+07	2.003E+05
8	200	219.1	-	5S	2.77	213.54	14.8	35.8	1.101E+07	1.005E+05
		219.1	-	10S	3.76	211.56	20.0	35.2	1.474E+07	1.346E+05
		219.1	STD	40	8.18	202.72	42.5	32.3	3.017E+07	2.755E+05
		219.1	XS	80	12.70	193.68	64.6	29.5	4.400E+07	4.017E+05
10	250	273.1	-	5S	3.40	266.24	22.6	55.7	2.621E+07	1.920E+05
		273.1	-	10S	4.19	264.67	27.8	55.0	3.199E+07	2.343E+05
		273.1	STD	40	9.27	254.51	60.3	50.9	6.690E+07	4.900E+05
		273.1	XS	-	12.70	247.65	81.5	48.2	8.822E+07	6.462E+05
		273.1	-	80	15.09	242.87	96.0	46.3	1.021E+08	7.475E+05
12	300	323.9	-	5S	3.96	315.93	31.3	78.4	5.094E+07	3.146E+05
		323.9	-	10S	4.57	314.71	36.0	77.8	5.845E+07	3.610E+05
		323.9	STD	-	9.53	304.80	73.8	73.0	1.163E+08	7.180E+05
		323.9	-	40	10.31	303.23	79.7	72.2	1.250E+08	7.717E+05
		323.9	XS	-	12.70	298.45	97.5	70.0	1.505E+08	9.294E+05
		323.9	-	80	17.48	288.90	132	65.6	1.980E+08	1.223E+06

NPS	DN	OD, mm	ID	Schedule	Wall Thickness, mm	Inside Diameter, mm	Weight of Steel Pipe, Kg/m	Weight of Water, Kg/m	Moment of Inertia, mm4	Section Modulus, mm3
14	350	355.6	-	5S	3.96	347.68	34.4	94.9	6.766E+07	3.806E+05
		355.6	-	10S	4.78	346.05	41.3	94.1	8.098E+07	4.555E+05
		355.6	STD	-	9.53	336.55	81.3	89.0	1.552E+08	8.726E+05
		355.6	-	40	11.13	333.35	94.5	87.3	1.788E+08	1.005E+06
		355.6	XS	-	12.70	330.20	107	85.6	2.014E+08	1.132E+06
		355.6	-	80	19.05	317.50	158	79.2	2.861E+08	1.609E+06
16	400	406.4	-	5S	4.19	398.02	41.6	124	1.071E+08	5.271E+05
		406.4	-	10S	4.78	396.85	47.3	124	1.215E+08	5.979E+05
		406.4	STD	-	9.53	387.35	93.2	118	2.340E+08	1.151E+06
		406.4	XS	40	12.70	381.00	123	114	3.047E+08	1.499E+06
		406.4	-	80	21.44	363.52	204	104	4.818E+08	2.371E+06
18	450	457	-	5S	4.19	448.82	46.8	158	1.530E+08	6.694E+05
		457	-	10S	4.78	447.65	53.3	157	1.737E+08	7.597E+05
		457	STD	-	9.53	438.15	105	151	3.357E+08	1.469E+06
		457	XS	-	12.70	431.80	139	146	4.384E+08	1.918E+06
		457	-	40	14.27	428.65	156	144	4.876E+08	2.133E+06
		457	-	80	23.83	409.55	255	132	7.638E+08	3.341E+06
20	500	508	-	5S	4.78	498.45	59.3	195	2.390E+08	9.409E+05
		508	-	10S	5.54	496.93	68.6	194	2.759E+08	1.086E+06
		508	STD	-	9.53	488.95	117	188	4.635E+08	1.825E+06
		508	XS	-	12.70	482.60	155	183	6.064E+08	2.387E+06
		508	-	40	15.09	477.82	183	179	7.102E+08	2.796E+06
22	550	559	-	5S	4.78	549.25	65.2	237	3.189E+08	1.141E+06
		559	-	10S	5.54	547.73	75.6	236	3.683E+08	1.318E+06
		559	STD	-	9.53	539.75	129	229	6.200E+08	2.219E+06
		559	XS	-	12.70	533.40	171	223	8.127E+08	2.909E+06
24	600	610	-	5S	5.54	598.53	82.5	281	4.793E+08	1.573E+06
		610	-	10S	6.35	596.90	94.5	280	5.475E+08	1.796E+06
		610	STD	-	9.53	590.55	141	274	8.084E+08	2.652E+06
		610	XS	-	12.70	584.20	187	268	1.061E+09	3.481E+06
		610	-	40	17.48	574.65	255	259	1.426E+09	4.678E+06
26	650	660	STD	-	9.53	641.35	153	323	1.032E+09	3.124E+06
		660	XS	-	12.70	635.00	203	317	1.356E+09	4.106E+06
28	700	711	STD	-	9.53	692.15	165	376	1.292E+09	3.635E+06
		711	XS	-	12.70	685.80	219	369	1.700E+09	4.781E+06
30	750	762	-	5S	6.35	749.30	118	441	1.076E+09	2.824E+06
		762	-	10S	7.92	746.15	147	437	1.335E+09	3.503E+06
		762	STD	-	9.53	742.95	177	434	1.594E+09	4.184E+06
		762	XS	-	12.70	736.60	235	426	2.099E+09	5.508E+06

PIPING MATERIAL SPECIFICATION WORKSHOP

Develop a piping material specification for styrene monomer.
Design conditions are from Problems 1 and 2 on page 25.

- Condition 1: _____________ psi (bar) at _____________ ºF (ºC)
- Condition 2: 50 psi (3.5 bar) at 735ºF (390ºC)
- Pipe wall thicknesses are as determined from calculations on page 32.

Pressure Class ____**300**________

Item	NPS Range	Sch/Rating	Description
Pipe	**¾**	**160**	**Seamless carbon steel pipe, ASTM A106 Gr B, ASTM A53 Type S Gr B, or API 5L Gr B**
	1 – 2	**XS**	**Seamless carbon steel pipe, ASTM A106 Gr B, ASTM A53 Type S Gr B, or API 5L Gr B**
	3 - 12	**STD**	**Seamless carbon steel pipe, ASTM A106 Gr B, ASTM A53 Type S Gr B, or API 5L Gr B**
Nipples	**¾ - 1½**	**160**	**Seamless carbon steel pipe, ASTM A106 Gr B, ASTM A53 Type S Gr B, or API 5L Gr B**
Fittings			
	¾	**6000**	**Forged carbon steel, ASTM A105, ASME B16.11, socket weld 90 EL, 45 EL, TEE, PLUG, COUPLING, CAP, AND REDUCER. UNIONS are prohibited.**
	1 - 1 ½	**3000**	**Forged carbon steel, ASTM A105, ASME B16.11, socket weld 90 EL, 45 EL, TEE, PLUG, COUPLING, CAP, AND REDUCER. UNIONS are prohibited.**
	2 – 12	**Match pipe**	**Wrought carbon steel, ASTM A234, ASME B16.9, buttweld 90 LR EL, 45 LR EL, TEE, CAP AND REDUCER**
Flanges	**¾ - 1 ½**	**300**	**Forged carbon steel, ASTM A105, ASME B16.5 socket welding raised face**
	2 - 12	**300**	**Forged carbon steel, ASTM A105, ASME B16.5 welding neck raised face, bore to match pipe**
Gaskets	**¾ - 12**	**300**	**Spiral wound ASME B16.20 with 304 SS windings (yellow centering ring), flexible graphite filler (gray stripe) and standard inner ring NPS 10 and larger**
Bolting	**¾ - 12**	**-**	**Low alloy steel bolting, ASTM A193 Gr B7 stud with 2 ASTM A194 Gr 2H nuts**

What should be used for branch construction? [Note that the answer will different for different size combinations.]

Sample from Process Industry Practices (PIP) PN03CS1S01

90° BRANCH CONNECTION
Legend and Chart

BRANCH SIZE																				
48	T																			
42	P	T																		
36	P	P	T																	
30	P	P	P	T																
24	P	P	P	P	T															
20	P	P	P	P	P	T														
18	P	P	P	P	P	P	T													
16	P	P	P	P	P	P	P	T												
14	P	P	P	P	P	P	P	P	T											
12	P	P	P	P	P	P	P	P	P	T										
10	W	W	W	W	W	W	W	W	W	W	T									
8	W	W	W	W	W	W	W	W	W	W	W	T								
6	W	W	W	W	W	W	W	W	W	W	W	W	T							
4	W	W	W	W	W	W	W	W	W	W	W	W	W	T						
3	W	W	W	W	W	W	W	W	W	W	W	W	W	W	T					
2	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	T				
1-1/2	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	E	T			
1	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	E	E	T		
3/4	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	E	E	E	T	
1/2	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	E	E	E	E	T
	48	**42**	**36**	**30**	**24**	**20**	**18**	**16**	**14**	**12**	**10**	**8**	**6**	**4**	**3**	**2**	**1-1/2**	**1**	**3/4**	**1/2**

HEADER SIZE

E Reducing Tee
P Branch Weld w/ Reinforcing Pad (Pad thickness equals run pipe thickness. Pad width equals 1/2 branch OD.)
S Sockolet
T Tee
W Weldolet (Note 05)

Note that when branch connection fittings (Weldolet) are specified, the requirements for these components should be described as well, e.g., "Forged carbon steel ASTM A105, MSS SP-97". When ordering buttweld branch connection fittings, both the header and branch wall thicknesses should be specified.

Sample Notes:

NOTES:
01 The pipe and fittings are adequate for the full flange rating.
02 All buttwelding component thicknesses shall match pipe thicknesses.
03 Threaded joints are permitted only at outlet of vent and drain valves, at hydrostatic connections, at outlet of instrument take-off valves, and to match equipment.
05 Integrally reinforced branch connections are permitted outside the sizes shown in the branch connection table.
13 Welding neck flanges shall be used against buttweld fittings.
19 Sch 160 pipe and pipe nipples shall be used for threaded connections for sizes NPS 1/2 – 1-1/2.
26 To be used only when indicated on the P&ID.
27 Pipe and pipe components thicker than 1/2-inch may require impact tested materials when the minimum design metal temperature is below 100F (38C) (See ASME B31.3, paragraph 323.2.2).
136 Sch XS pipe shall be used for threaded connections for NPS 2.

MEAN THERMAL EXPANSION COEFFICIENT BETWEEN 70ºF AND THE INDICATED TEMPERATURE (1×10^{-6}/ºF)

Temp, ºF	Carbon Steels	Stainless Steels	Copper & its Alloys	Aluminum	Ni-Fe-Cr	Ni-Cr-Fe
-300	5.07	8.21	7.94	10.04		
-250	5.21	8.34	8.26	10.33		
-200	5.35	8.47	8.51	10.61		
-150	5.50	8.54	8.72	10.90		
-100	5.65	8.66	8.89	11.25		
-50	5.80	8.90	9.04	11.60		
0	5.90	8.98	9.17	11.86		
50	6.01	9.07	9.28	12.12		
100	6.13	9.16	9.39	12.39		7.20
150	6.25	9.25	9.48	12.67		7.30
200	6.38	9.34	9.56	12.95	7.90	7.40
250	6.49	9.41	9.64	13.12	8.01	7.48
300	6.60	9.47	9.71	13.28	8.35	7.56
350	6.71	9.53	9.78	13.44	8.57	7.63
400	6.82	9.59	9.84	13.60	8.80	7.70
450	6.92	9.65	9.89	13.75	8.85	7.75
500	7.02	9.70	9.94	13.90	8.90	7.80
550	7.12	9.76	9.99	14.05	8.95	7.85
600	7.23	9.82	10.04	14.02	9.00	7.90
650	7.33	9.87			9.05	7.95
700	7.44	9.92			9.10	8.00
750	7.54	9.99			9.15	8.05
800	7.65	10.05			9.20	8.10
850	7.75	10.11			9.25	
900	7.84	10.16			9.30	
950	7.91	10.23			9.35	
1000	7.97	10.29			9.40	
1050	8.05	10.34			9.45	
1100	8.12	10.39			9.50	
1150	8.16	10.44			9.55	
1200	8.19	10.48			9.60	
1250	8.24	10.51			9.68	
1300	8.28	10.54			9.75	
1350	8.32	10.57			9.83	
1400	8.36	10.60			9.90	
1450		10.68			9.98	
1500		10.77			10.05	

TOTAL THERMAL EXPANSION BETWEEN 70ºF AND THE INDICATED TEMPERATURE (IN/100 FT)

Temp, ºF	Carbon Steels	Stainless Steels	Copper & its Alloys	Aluminum	Ni-Fe-Cr	Ni-Cr-Fe
-300	-2.25	-3.65	-3.53	-4.46		
-250	-2.00	-3.20	-3.17	-3.97		
-200	-1.73	-2.74	-2.76	-3.44		
-150	-1.45	-2.25	-2.30	-2.88		
-100	-1.15	-1.77	-1.81	-2.30		
-50	-0.84	-1.28	-1.30	-1.67		
0	-0.50	-0.75	-0.77	-1.00		
50	-0.14	-0.22	-0.22	-0.29		
100	0.22	0.33	0.34	0.45		0.26
150	0.60	0.89	0.91	1.22		0.70
200	1.00	1.46	1.49	2.02	1.23	1.15
250	1.40	2.03	2.08	2.83	1.73	1.62
300	1.82	2.61	2.68	3.67	2.30	2.09
350	2.25	3.20	3.29	4.52	2.88	2.56
400	2.70	3.80	3.90	5.39	3.48	3.05
450	3.16	4.40	4.51	6.27	4.04	3.53
500	3.62	5.01	5.13	7.17	4.59	4.02
550	4.10	5.62	5.75	8.09	5.16	4.52
600	4.60	6.25	6.39	8.92	5.72	5.02
650	5.10	6.87			6.30	5.53
700	5.62	7.50			6.88	6.05
750	6.15	8.15			7.47	6.57
800	6.70	8.80			8.06	7.10
850	7.25	9.46			8.66	
900	7.81	10.12			9.26	
950	8.35	10.80			9.87	
1000	8.89	11.48			10.49	
1050	9.47	12.16			11.11	
1100	10.04	12.84			11.74	
1150	10.58	13.53			12.38	
1200	11.11	14.21			13.02	
1250	11.67	14.88			13.71	
1300	12.22	15.56			14.39	
1350	12.78	16.24			15.10	
1400	13.34	16.92			15.80	
1450		17.69			16.53	
1500		18.48			17.25	

MEAN THERMAL EXPANSION COEFFICIENT BETWEEN 20ºC AND THE INDICATED TEMPERATURE (1×10^{-6}/ºC)

Temp, ºC	Carbon Steels	Stainless Steels	Copper & its Alloys	Aluminum	Ni-Fe-Cr	Ni-Cr-Fe
-175	2.86	4.58	4.36	5.62		
-150	2.89	4.66	4.63	5.78		
-125	2.97	4.71	4.74	5.89		
-100	3.06	4.78	4.84	6.06		
-75	3.14	4.86	4.94	6.25		
-50	3.22	4.94	5.02	6.44		
-25	3.25	4.98	5.08	6.56		
0	3.31	5.02	5.14	6.67		
25	3.37	5.06	5.18	6.80		3.96
50	3.77	5.11	5.24	6.96		4.03
75	3.51	5.15	5.28	7.06		4.07
100	3.56	5.19	5.32	7.22	4.42	4.12
125	3.61	5.23	5.36	7.29	4.51	4.16
150	3.67	5.26	5.39	7.38	4.64	4.20
175	3.73	5.29	5.44	7.47	4.76	4.24
200	3.79	5.32	5.46	7.54	4.88	4.28
225	3.83	5.35	5.48	7.62	4.91	4.29
250	3.88	5.38	5.51	7.69	4.93	4.32
275	3.93	5.41	5.54	7.77	4.96	4.34
300	3.98	5.44	5.61	7.85	4.98	4.38
325	4.03	5.46			5.01	4.39
350	4.09	5.49			5.03	4.42
375	4.14	5.51			5.06	4.44
400	4.19	5.55			5.08	4.47
425	4.25	5.58			5.11	4.50
450	4.3	5.61			5.13	
475	4.34	5.63			5.16	
500	4.38	5.67			5.18	
525	4.41	5.70			5.21	
550	4.45	5.73			5.23	
575	4.48	5.75			5.26	
600	4.52	5.78			5.28	
625	4.53	5.80			5.31	
650	4.55	5.82			5.33	
675	4.58	5.84			5.38	
700	4.60	5.86			5.41	
725	4.62	5.87			5.45	
750	4.63	5.88			5.48	
775		5.91			5.52	
800		5.96			5.56	

TOTAL THERMAL EXPANSION BETWEEN 20ºC AND THE INDICATED TEMPERATURE (mm/m)

Temp, ºC	Carbon Steels	Stainless Steels	Copper & its Alloys	Aluminum	Ni-Fe-Cr	Ni-Cr-Fe
-175	-0.56	-0.89	-0.85	-1.10		
-150	-0.49	-0.79	-0.79	-0.98		
-125	-0.43	-0.68	-0.69	-0.85		
-100	-0.37	-0.57	-0.58	-0.73		
-75	-0.30	-0.46	-0.47	-0.59		
-50	-0.23	-0.35	-0.35	-0.45		
-25	-0.15	-0.22	-0.23	-0.30		
0	-0.07	-0.10	-0.10	-0.13		
25	0.02	0.03	0.03	0.03		
50	0.10	0.15	0.16	0.21		
75	0.19	0.28	0.29	0.39		
100	0.28	0.42	0.43	0.58	0.35	0.33
125	0.38	0.55	0.56	0.77	0.47	0.44
150	0.48	0.68	0.70	0.96	0.60	0.55
175	0.58	0.82	0.84	1.16	0.74	0.66
200	0.68	0.96	0.98	1.36	0.88	0.77
225	0.79	1.10	1.12	1.56	1.01	0.88
250	0.89	1.24	1.27	1.77	1.13	0.99
275	1.00	1.38	1.41	1.98	1.26	1.11
300	1.11	1.52	1.57	2.20	1.39	1.23
325	1.23	1.67			1.53	1.34
350	1.35	1.81			1.66	1.46
375	1.47	1.96			1.80	1.58
400	1.59	2.11			1.93	1.70
425	1.72	2.26			2.07	1.82
450	1.85	2.41			2.21	
475	1.97	2.56			2.35	
500	2.10	2.72			2.49	
525	2.23	2.88			2.63	
550	2.36	3.04			2.77	
575	2.49	3.19			2.92	
600	2.62	3.35			3.06	
625	2.74	3.51			3.21	
650	2.87	3.67			3.36	
675	3.00	3.83			3.52	
700	3.13	3.98			3.68	
725	3.26	4.14			3.84	
750	3.38	4.29			4.00	
775		4.46			4.17	
800		4.65			4.34	

SPRING HANGAR LOAD TABLE FROM ANVIL INTERNATIONAL, INC. (Part 1)

Spring Hanger Size and Series Selection

How to use hanger selection table:

In order to choose a proper size hanger, it is necessary to know the actual load which the spring is to support and the amount and direction of the pipe line movement from the cold to the hot position.

Find the actual load of the pipe in the load table. As it is desirable to support the actual weight of the pipe when the line is hot, the actual load is the hot load. To determine the cold load, read the spring scale, up or down, for the amount of expected movement.

The chart must be read opposite from the direction of the pipe's movement. The load arrived at is the cold load.

If the cold load falls outside of the working load range of the hanger selected, relocate the actual or hot load in the adjacent column and find the cold load. When the hot and cold loads are both within the working range of a hanger, the size number of that hanger will be found at the top of the column.

Load Table (lbs) for Selection of Hanger Size (sizes 10 through 22 on next page)

Working Range (in) Shaded Rows Show Overtravel					Hanger size											
Figure No.					B-268 Only		Fig. 82, Fig. B-268, Fig. 98, Triple & Quadruple Spring									
Quad.	Triple	98	B-268	82	000	00	0	1	2	3	4	5	6	7	8	9
2	1½	1	½	¼	7	19	43	63	81	105	141	189	252	336	450	600
					7	20	44	66	84	109	147	197	263	350	469	625
					8	22	46	68	88	114	153	206	273	364	488	650
					9	24	48	71	91	118	159	213	284	378	506	675
0	0	0	0	0	10	26	50	74	95	123	165	221	294	392	525	700
					11	28	52	76	98	127	170	228	305	406	544	725
					12	30	54	79	101	131	176	236	315	420	563	750
					12	31	56	81	105	136	182	244	326	434	581	775
2	1½	1	½	¼	14	34	58	84	108	140	188	252	336	448	600	800
					14	35	59	87	111	144	194	260	347	462	619	825
					15	38	61	89	115	149	200	268	357	476	638	850
					16	40	63	92	118	153	206	276	368	490	656	875
4	3	2	1	½	17	41	65	95	122	158	212	284	378	504	675	900
					18	43	67	97	125	162	217	291	389	518	694	925
					19	45	69	100	128	166	223	299	399	532	713	950
					20	47	71	102	132	171	229	307	410	546	731	975
6	4½	3	1½	¾	21	49	73	105	135	175	235	315	420	560	750	1,000
					21	50	74	108	138	179	241	323	431	574	769	1,025
					22	53	76	110	142	184	247	331	441	588	788	1,050
					23	55	78	113	145	188	253	339	452	602	806	1,075
8	6	4	2	1	24	56	80	116	149	193	258	347	462	616	825	1,100
					25	58	82	118	152	197	264	354	473	630	844	1,125
					26	60	84	121	155	201	270	362	483	644	863	1,150
					27	62	86	123	159	206	276	370	494	658	881	1,175
10	7½	5	2½	1¼	28	64	88	126	162	210	282	378	504	672	900	1,200
2	1½	1	½	¼	28	66	89	129	165	214	288	386	515	686	919	1,225
					29	68	91	131	169	219	294	394	525	700	938	1,250
					30	70	93	134	172	223	300	402	536	714	956	1,275
					31	72	95	137	176	228	306	410	546	728	975	1,300

Spring Rate (lbs/In)

Figure No.	000	00	0	1	2	3	4	5	6	7	8	9
82	–	–	30	42	54	70	94	126	168	224	300	400
B-268	7	15	15	21	27	35	47	63	84	112	150	200
98	–	–	7	10	13	17	23	31	42	56	75	100
Triple	–	–	5	7	9	12	16	21	28	37	50	67
Quadruple	–	–	4	5	7	9	12	16	21	28	38	50

Note: General rule for series selection use Fig. 82 for up to ½" of movement up to 1" use Fig. B-268, up to 2" use Fig. 98, up to 3" use a Triple, up to 4" use a Quadruple. Double check to assure desired variability is achieved.

SPRING HANGAR LOAD TABLE FROM ANVIL INTERNATIONAL, INC. (Part 2)

Spring Hanger Size and Series Selection

How to use hanger selection table (cont.):

Should it be impossible to select a hanger in a particular series such that both loads occur within the working range, consideration should be given to a variable spring hanger with a wider working range or a constant support hanger.

The cold load is calculated by adding (for up movement) or subtracting (for down movement) the product of spring rate times movement to or from the hot load.

Cold load = (hot load) ± (movement) x (spring rate)

A key criteria in selecting the size and series of a variable spring is a factor known as variability. This is a measurement of the percentage change in supporting force between the hot and cold positions of a spring and is calculated from the formula:

Variability = (Movement) x (Spring Rate) / (Hot Load)

If an allowable variability is not specified, good practice would be to use 25% as recommended by MSS-SP-58.

Load Table (lbs) for Selection of Hanger Size (Cont. from previous page)

Hanger size – Fig. 82, Fig. B-268, Fig. 98, Triple & Quadruple Spring													Working Range (in) Shaded Rows Show Overtravel – Figure No.				
10	11	12	13	14	15	16	17	18	19	20	21	22	82	B-268	98	Triple	Quad
780	1,020	1,350	1,800	2,400	3,240	4,500	6,000	7,990	10,610	14,100	18,750	25,005					
813	1,063	1,406	1,875	2,500	3,375	4,688	6,250	8,322	11,053	14,588	19,531	26,047	¼	½	1	1½	2
845	1,105	1,463	1,950	2,600	3,510	4,875	6,500	8,655	11,495	15,275	20,313	27,089					
878	1,148	1,519	2,025	2,700	3,645	5,063	6,750	8,987	11,938	15,863	21,094	28,131					
910	1,190	1,575	2,100	2,800	3,780	5,250	7,000	9,320	12,380	16,450	21,875	29,173	0	0	0	0	0
943	1,233	1,631	2,175	2,900	3,915	5,438	7,250	9,652	12,823	17,038	22,656	30,215					
975	1,275	1,688	2,250	3,000	4,050	5,625	7,500	9,985	13,265	17,625	23,438	31,256					
1,008	1,318	1,744	2,325	3,100	4,185	5,813	7,750	10,317	13,708	18,213	24,219	32,298					
1,040	1,360	1,800	2,400	3,200	4,320	6,000	8,000	10,650	14,150	18,800	25,000	33,340	¼	½	1	1½	2
1,073	1,403	1,856	2,475	3,300	4,455	6,188	8,250	10,982	14,592	19,388	25,781	34,382					
1,105	1,445	1,913	2,550	3,400	4,590	6,375	8,500	11,315	15,035	19,975	26,563	35,424					
1,138	1,488	1,969	2,625	3,500	4,725	6,563	8,750	11,647	15,477	20,563	27,344	36,466					
1,170	1,530	2,025	2,700	3,600	4,860	6,750	9,000	11,980	15,920	21,150	28,125	37,508	½	1	2	3	4
1,203	1,573	2,081	2,775	3,700	4,995	6,938	9,250	12,312	16,362	21,738	28,906	38,549					
1,235	1,615	2,138	2,850	3,800	5,130	7,125	9,500	12,645	16,805	22,325	29,688	39,591					
1,268	1,658	2,194	2,925	3,900	5,265	7,313	9,750	12,977	17,247	22,913	30,469	40,633					
1,300	1,700	2,250	3,000	4,000	5,400	7,500	10,000	13,310	17,690	23,500	31,250	41,675	¾	1½	3	4½	6
1,333	1,743	2,306	3,075	4,100	5,535	7,688	10,250	13,642	18,132	24,088	32,031	42,717					
1,365	1,785	2,363	3,150	4,200	5,670	7,875	10,500	13,975	18,575	24,675	32,813	43,759					
1,398	1,828	2,419	3,225	4,300	5,805	8,063	10,750	14,307	19,017	25,263	33,594	44,801					
1,430	1,870	2,475	3,300	4,400	5,940	8,250	11,000	14,640	19,460	25,850	34,375	45,843	1	2	4	6	8
1,463	1,913	2,531	3,375	4,500	6,075	8,438	11,250	14,972	19,902	26,438	35,156	46,885					
1,495	1,955	2,588	3,450	4,600	6,210	8,625	11,500	15,305	20,345	27,025	35,938	47,926					
1,528	1,998	2,644	3,525	4,700	6,345	8,813	11,750	15,637	20,787	27,613	36,719	48,968					
1,560	2,040	2,700	3,600	4,800	6,480	9,000	12,000	15,970	21,230	28,200	37,500	50,010	1¼	2½	5	7½	10
1,593	2,083	2,756	3,675	4,900	6,615	9,188	12,250	16,302	21,672	28,788	38,281	51,052					
1,625	2,125	2,813	3,750	5,000	6,750	9,375	12,500	16,635	22,115	29,375	39,063	52,094	¼	½	1	1½	2
1,658	2,168	2,869	3,825	5,100	6,885	9,563	12,750	16,967	22,557	29,963	39,844	53,136					
1,690	2,210	2,925	3,900	5,200	7,020	9,750	13,000	17,300	23,000	30,550	40,625	54,178					
Spring Rate (lbs/In)																	
520	680	900	1,200	1,600	2,160	3,000	4,000	5,320	7,080	9,400	12,500	16,670	82				
260	340	450	600	800	1,080	1,500	2,000	2,660	3,540	4,700	6,250	8,335	B-268				
130	170	225	300	400	540	750	1,000	1,330	1,770	2,350	3,125	4,167	98				
87	113	150	200	267	360	500	667	887	1,180	1,567	2,083	2,778	Triple				
65	85	113	150	200	270	375	500	665	885	1,175	1,563	2,084	Quadruple				

Note: General rule for series selection use Fig. 82 for up to ½" of movement up to 1" use Fig. B-268, up to 2" use Fig. 98, up to 3" use a Triple-, up to 4" use a Quadruple. Double check to assure desired variability is achieved.

Fig. 82, Fig. B-268, Fig. 98, Triple Spring, and Quadruple Spring
Fig. C-82, Fig. C-268, Fig. C-98, Triple-CR, and Quadruple-CR Spring (Corrosion Resistant)

Design features:

- Precompression.
  Precompressing the spring into the hanger casing provides the following advantages:
  (1) Saves up to 50% in headroom by reducing the length of the hanger.
  (2) Reduces the installed height of the overall hanger assembly.
  (3) Prevents the spring supporting force from exceeding the normal safe limits of variations.
  (4) Saves valuable erection time because spring is precompressed close to ½" of the working range.
- Calibration: all Anvil Variable Spring Hangers and supports are calibrated for accurate loading conditions.
- Load indicator is clearly seen in the slot, simplifying reading of the scale plate. Load is read from bottom of indicator.
- Cold set at the factory upon request.
- Spring and casing are fabricated of steel and are rugged and compact.
- Piston cap serves as a centering device or guide maintaining spring alignment.
- Casing protects the spring from damage and weather conditions.

Standard Finish: Painted with semi-gloss primer.

Corrosion Resistant:

Anvil offers corrosion-resistant and weather-resistant Variable Spring Hangers to fill vital needs in the chemical and refinery industries as well as in modern outdoor power plant construction.

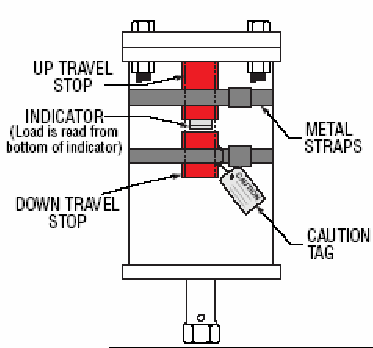
For protection against severe weather conditions or moderate corrosive conditions, the parts of the hanger are galvanized per ASTM A-153, except the spring which has a protective coating and the load column for Type F which is electro-galvanized.

Advantages of a Protective Coating:

- Protects from a wide range of corrosives.
- Does not affect the flex life of the spring.
- Recommended for ambient temperatures up to 200° F

Travel stop:

The functional design of the pre-compressed variable spring hanger permits the incorporation of a two-piece travel stop that locks the hanger spring against upward or downward movement for temporary conditions of underload or overload. The complete travel stop, the up travel stop only for cold set purposes or the down travel stop only which may be employed during erection, hydrostatic test (Anvil permits a hydrostatic test load of 2 times the normal operating load for the spring hanger) or chemical cleanout will be furnished only when specified. The travel stop is painted red and is installed at the factory with a caution tag attached calling attention that the device must be removed before the pipe line is put in service. Permanently attached travel stops available upon request.



Approvals: WW-H-171E (Types 51, 56 and 57) and MSS-SP-69 (Types 51, 52 and 53).

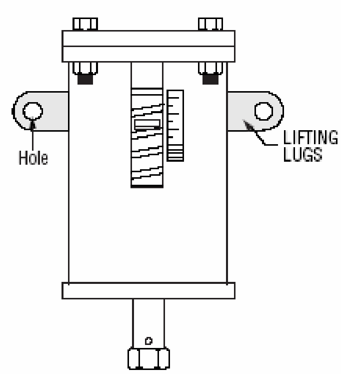
Specifications: Anvil Variable Spring Hangers are welded in strict accordance with ASME Section IX.

Size Range: The Anvil Variable Spring Hanger in five series and seven types is offered in twenty-three sizes (Fig. B-268 only is offered in twenty-five sizes). The hanger can be furnished to take loads 10 lbs. to 50,000 lbs.

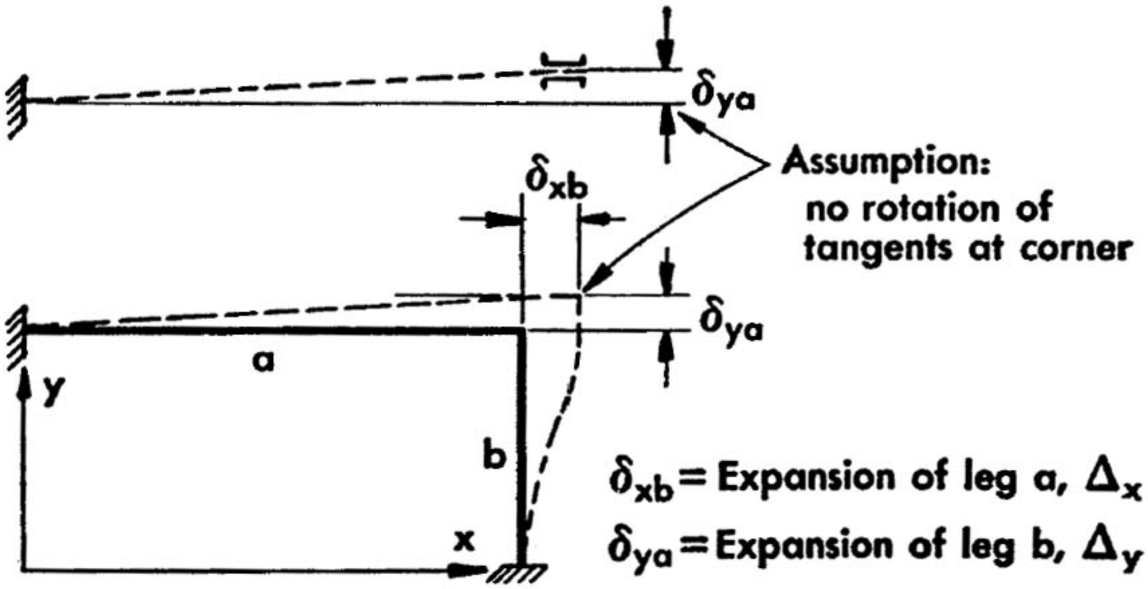
Ordering:

(1) Size
(2) Type
(3) Figure number
(4) Product name
(5) Desired supporting force in operating position
(6) Calculated amount and direction of pipe movement from installed to operating position.
(7) Customer's identification number (if any)
(8) When ordering Type F spring specify if roller or guided, load column is to be furnished.
(9) When ordering Type G, specify total load and load per spring plus center to center rod dimensions.
(10) If required, specify with travel stop
(11) When ordering corrosion resistant, specify C-268, C-82, C-98, Triple-CR, or Quadruple-CR " completely galvanized except coated spring coil".

Note: To help alleviate the problem of lifting large size spring hangers into position for installation, this product is available with lifting lugs (if required) on sizes weighing one hundred pounds or more.



GUIDED CANTILEVER METHOD – KELLOGG

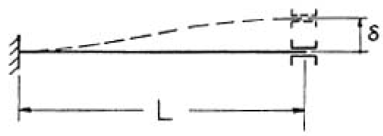


$\delta = 48L^2S_A/E_aD$

Where:

δ	=	maximum permissible displacement
D	=	pipe outside diameter
E_a	=	elastic modulus of pipe material
L	=	length of leg under consideration
S_A	=	allowable stress range

GUIDED CANTILEVER CHART – KELLOGG



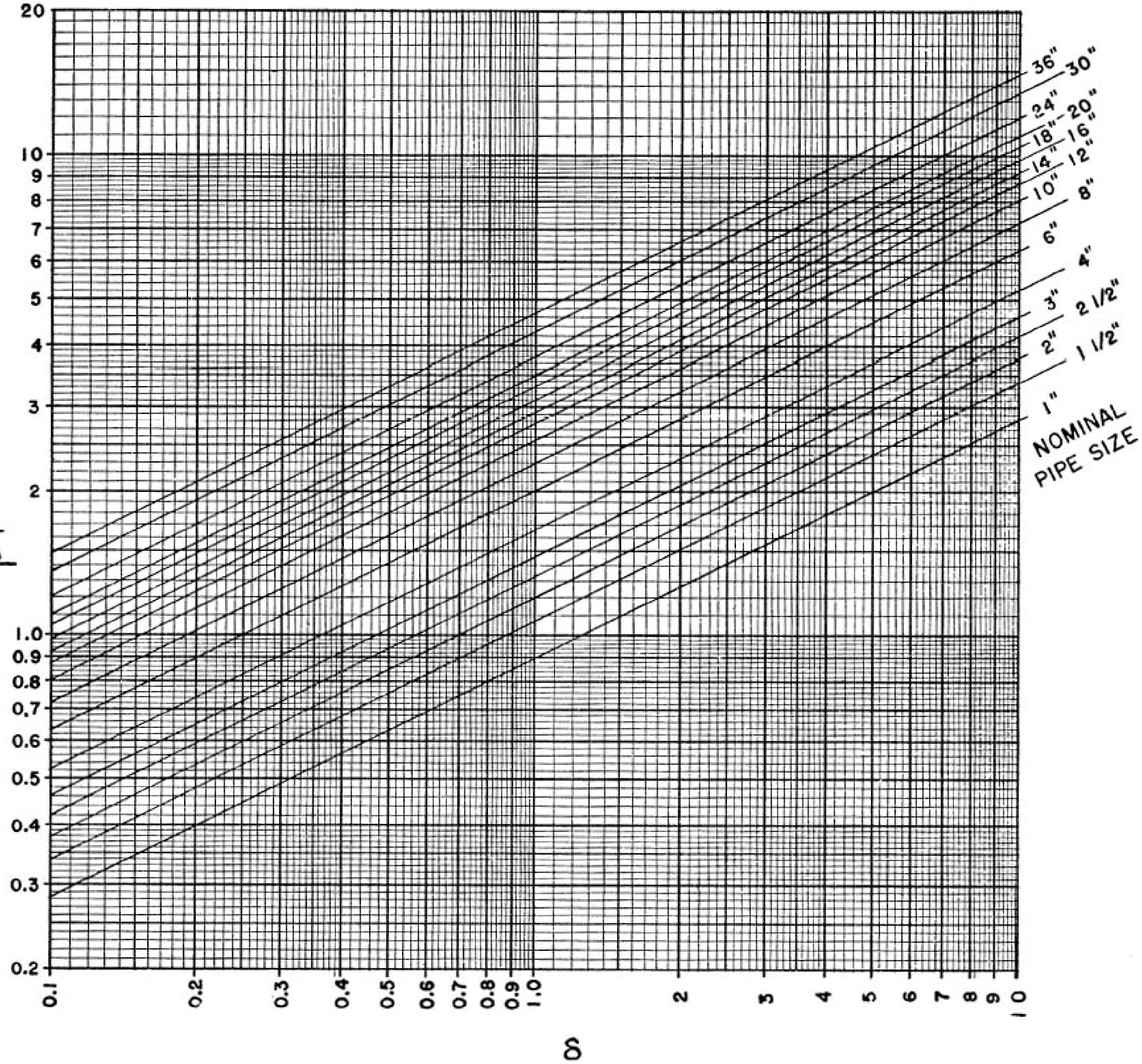
Assumed mode of deflection of guided cantilever.

L = Length of leg, ft.

δ = Lateral deflection, in.

Value of E used = 29×10^6 psi.

S_A = Code allowable stress range psi.

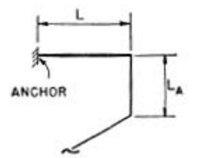


Instructions: Determine value of $L\sqrt{S_A}/10^3$. Enter with this value of ordinate scale and read over to line for proper nominal pipe size. Read down to abscissa scale. The value obtained will be the permissible lateral deflection for leg.

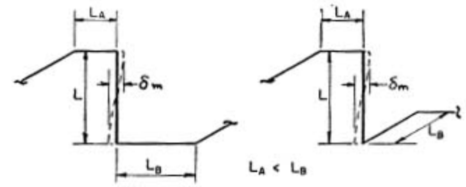
GUIDED CANTILEVER CORRECTION FACTORS – KELLOGG

Multiply f times δ to get the maximum permissible displacement for the geometry under consideration.

Correction Factor *f*, Guided Cantilever Method

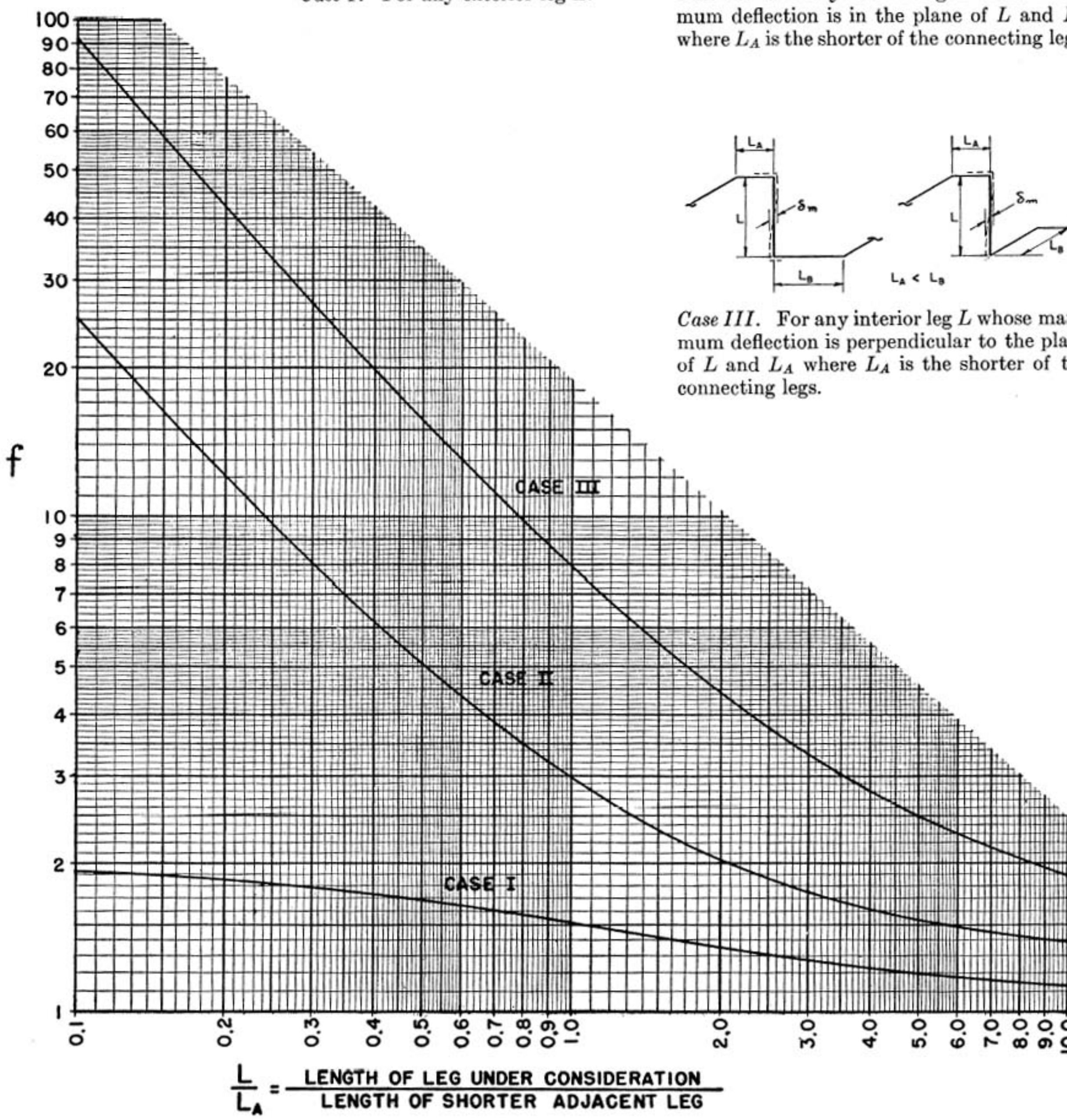


Case I. For any exterior leg *L*.

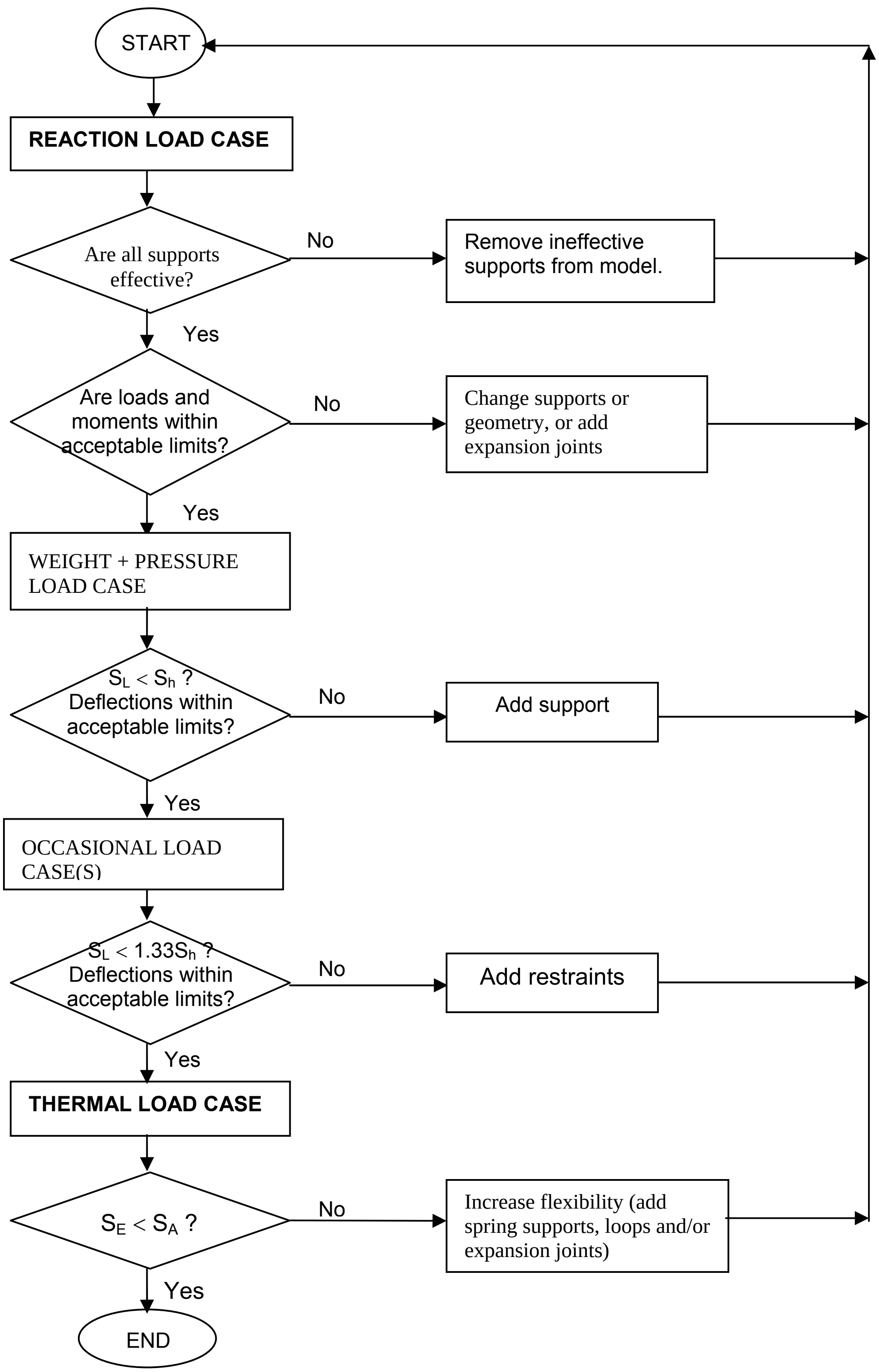


Case II. For any interior leg *L* whose maximum deflection is in the plane of *L* and L_A where L_A is the shorter of the connecting legs.

Case III. For any interior leg *L* whose maximum deflection is perpendicular to the plane of *L* and L_A where L_A is the shorter of the connecting legs.

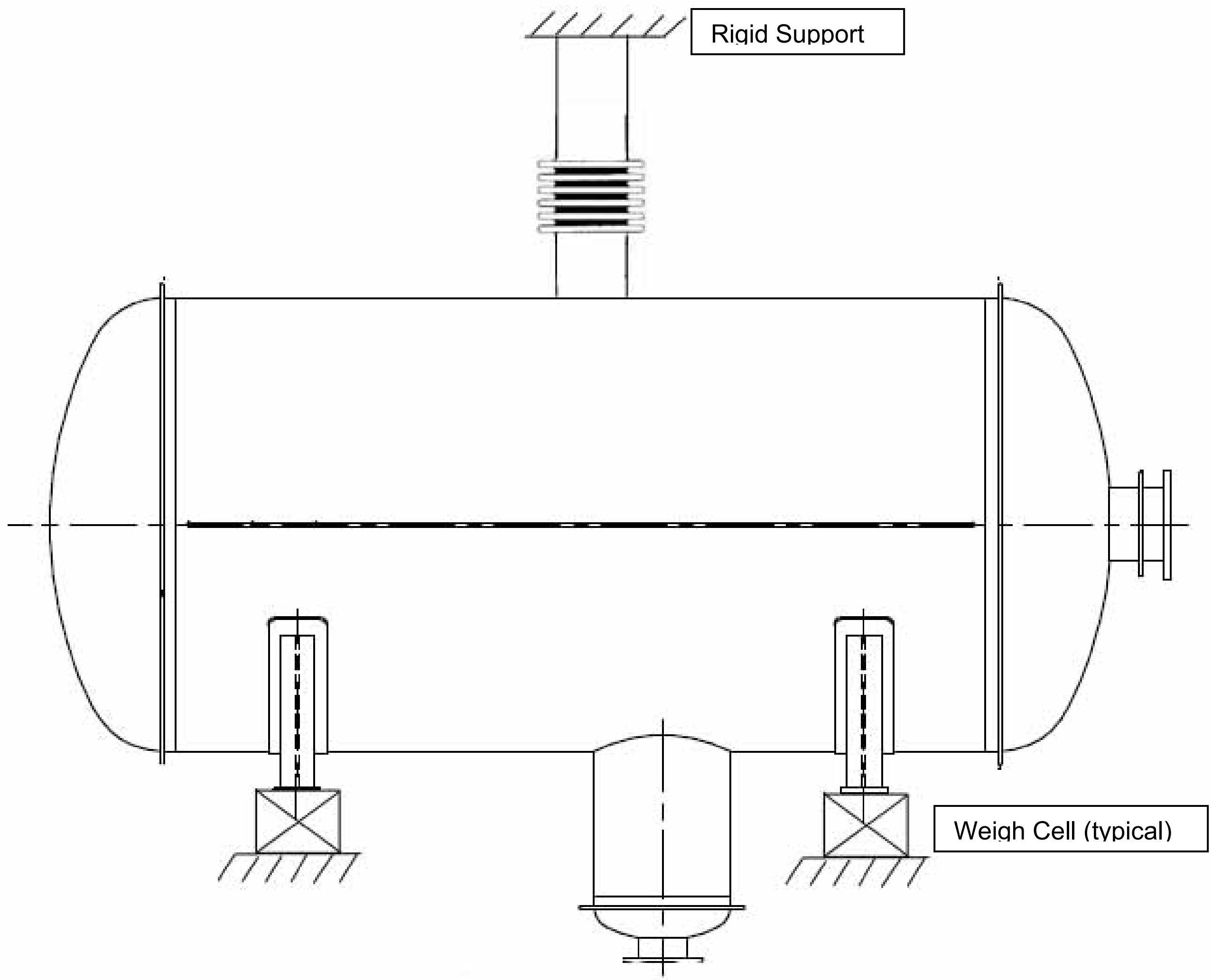


THE PIPING FLEXIBILITY ANALYSIS PROCESS



EXPANSION JOINT PRESSURE THRUST WORKSHOP

What is the apparent change in the weight of the vessel caused by increasing the pressure by 100 psig (700 kPa)?



The pitch diameter of the bellows is 6.87 in. (175 mm).

TYPES OF EXAMINATION

Visual examination means using the unaided eye (except for corrective lenses) to inspect the exterior and readily accessible internal surface areas of piping assemblies or components. It does not include nor require remote examination such as by use of boroscopes. Visual examination is used to check materials and components for conformance to specifications and freedom from defects; fabrication including welds, assembly of threaded bolted and other joints; piping during erection; and piping after erection. Further, visual examination can be substituted for radiography, as described later, which is called in-process examination. Requirements for visual examination are provided in the ASME B&PV Code, Section V, Article 9. Records of visual examinations are not required other than those of in-process examination.

Radiographic Examination means using X ray or gamma ray radiation to produce a picture of the subject part, including subsurface features, on radiographic film for subsequent interpretation. It is a volumetric examination procedure that provides a means of detecting defects that are not observable on the surface of the material. Radiographic examination is used to inspect welds and, in some circumstances, castings. Requirements for radiographic examination of welds are provided in the ASME B&PV Code, Section V, Article 2.

Ultrasonic Examination means detecting subsurface defects using high-frequency sound impulses. The defects are detected by the reflection of sound waves from them. It is also a volumetric examination method that can be used to detect subsurface defects. It can be used as an alternative to radiography for weld examination. The requirements for ultrasonic examination of welds are provide in the ASME B&PV Code, Section V, Article 5, with an alternative for basic calibration blocks provided in para. 344.6.

In-Process Examination is a visual examination of the entire joining process, as described in para. 344.7. It is applicable to welding and brazing for metals, and bonding for non-metals. Since radiographic examination is not considered to provide useful results in brazing and bonding, in-process examination is used for these instead of radiography. For welding, it is permitted as a substitute for radiographic examination if specified in the engineering design or specifically authorized by the Inspector. This is not as effective a quality control procedure as random radiography and should only be considered for welds when special circumstances warrant.

Liquid Penetrant Examination means detecting surface defects by spreading a liquid dye penetrant on the surface, removing the dye after sufficient time has passed for the dye to penetrate into any surface discontinuity, and applying a thin coat of developer to the surface which draws the dye from defects. The defects are observable by the contrast between the color of the dye penetrant and the color of the developer. It is used to detect surface defects, and is used for examination of socket welds and branch connections in severe cyclic service than cannot be radiographed, and for all welds including structural attachment welds that are not radiographed when the alternative leak test (para. 345.9) is used. Further, liquid penetrant examination of metallic bellows is required by Appendix X, para. X302.2.2. The requirements for liquid penetrant examination of welds and components other than castings are provided in the ASME B&PV Code, Section V, Article 6.

Magnetic Particle Examination employs either electric coils wound around the part or prods to create a magnetic field. A magnetic powder is applied to the surface and defects are revealed by patterns the powder forms in response to the magnetic field disturbances caused by defects. This technique reveals surface and shallow subsurface defects. As such, it can provide more information than liquid penetrant examination. However, its use is limited to magnetic materials. It is an alternative to liquid penetrant examination wherever such an examination is required in ASME B31.3 (except in the case of metallic bellows). The requirements for magnetic particle examination of welds and components other than castings are provided in the ASME B&PV Code, Section V, Article 7.

Hardness Testing is required after heat treatment under some circumstances, as specified in Table 331.1.1. Hardness testing is not required for carbon steel (P-1), ferritic and austenitic stainless steel (P-7 & P-8), high nickel alloys (P-9A & P-9B), as well as some less commonly used alloys. For welds, the hardness check includes both the weld and the heat affected zone.

WELD ACCEPTANCE CRITERIA

TABLE 341.3.2
ACCEPTANCE CRITERIA FOR WELDS AND EXAMINATION METHODS FOR EVALUATING WELD IMPERFECTIONS

Criteria (A to M) for Types of Welds and for Service Conditions [Note (1)]														Examination Methods				
Normal and Category M Fluid Service				Severe Cyclic Conditions				Category D Fluid Service										
Type of Weld				Type of Weld				Type of Weld										
Girth, Miter Groove & Branch Connection [Note (4)]	Longitudinal Groove [Note (2)]	Fillet [Note (3)]		Girth, Miter Groove & Branch Connection [Note (4)]	Longitudinal Groove [Note (2)]	Fillet [Note (3)]		Girth and Miter Groove	Longitudinal Groove [Note (2)]	Fillet [Note (3)]	Branch Connection [Note (4)]		Weld Imperfection	Visual	Radiography		Magnetic Particle	Liquid Penetrant
A	A	A	. . .	A	A	A	. . .	A	A	A	A		Crack	✓	✓	. . .	✓	✓
A	A	A	. . .	A	A	A	. . .	C	A	N/A	A	. . .	Lack of fusion	✓	✓	. . .	. . .	. . .
B	A	N/A	. . .	A	A	N/A	. . .	C	A	N/A	B	. . .	Incomplete penetration	✓	✓	. . .	. . .	. . .
E	E	N/A	. . .	D	D	N/A	. . .	N/A	N/A	N/A	N/A	. . .	Internal porosity	. . .	✓	. . .	. . .	. . .
G	G	N/A	. . .	F	F	N/A	. . .	N/A	N/A	N/A	N/A	. . .	Internal slag inlcusion, tungsten inclusion, or elongated indication	. . .	✓	. . .	. . .	. . .
H	A	H	. . .	A	A	A	. . .	I	A	H	H	. . .	Undercutting	. . .	✓	. . .	. . .	. . .
A	A	A	. . .	A	A	A	. . .	A	A	A	A	. . .	Surface porosity or exposed slug inclusion [Note (6)]	✓	. . .	. . .	. . .	. . .
N/A	N/A	N/A	. . .	J	J	J	. . .	N/A	N/A	N/A	N/A	. . .	Surface finish	✓	. . .	. . .	. . .	. . .
K	K	N/A	. . .	K	K	N/A	. . .	K	K	N/A	K	. . .	Concave root surface (suck up)	✓	✓	. . .	. . .	. . .
L	L	L	. . .	L	L	L	. . .	M	M	M	M	. . .	Weld reinforcement or internal protrusion	✓	. . .	. . .	. . .	. . .

GENERAL NOTES:
(a) Weld imperfections are evaluated by one or more of the types of examination methods given, as specified in paras. 341.4.1, 341.4.2, 341.4.3 and M341.4, or by the engineering design.
(b) N/A the Code does not establish acceptance criteria or does not require evaluation of this kind of imperfection for this type of yield.
(c) * Alternative Leak Test requires examination of these welds, see para. 345.9
(d) ✓ examination method generally used for evaluating this kind of weld imperfection
(e) . . . examination method not generally used for evaluating this kind and weld imperfection.

Criterion Value Notes for Table 341.3.2

Symbol	Criterion: Measure	Acceptable Value Limits [Note (6)]	
A	Extent of imperfection	Zero (no evident imperfection)	
B	Depth of incomplete penetration Cumulative length of incomplete penetration	≤ 1 mm ($^1/_{32}$ in.) and ≤ $0.2\overline{T}_w$ ≤ 38 mm (1.5 in.) in any 150 mm (6 in.) weld length	
C	Depth of lack of fusion and incomplete penetration Cumulative length of lack of fusion and incomplete penetration [Note (7)]	≤ $0.2\overline{T}_w$ ≤ 38 mm (1.5 in.) in any 150 mm (6 in.) weld length	
D	Size and distribution of internal porosity	See BPV Code, Section VIII, Division 1, Appendix 4	
E	Size and distribution of internal porosity	For $\overline{T}_w$ ≤ 6 mm ($^1/_4$ in.), limit is same as D For $\overline{T}_w$ > 6 mm ($^1/_4$ in.), limit is 1.5 × D	
F	Slag inclusion, tungsten inclusion, or elongated indication Individual length Individual width Cumulative length	 ≤ $\overline{T}_w/3$ ≤ 2.5 mm ($^3/_{32}$ in.) and ≤ $\overline{T}_w/3$ ≤ $\overline{T}_w$ in any $12\overline{T}_w$ weld length	
G	Slag inclusion, tungsten inclusion, or elongated indication Individual length Individual width Cumulative length	 ≤ $2\overline{T}_w$ ≤ 3 mm ($^1/_8$ in.) and ≤ $\overline{T}_w/2$ ≤ $4\overline{T}_w$ in any 150 mm (6 in.) weld length	
H	Depth of undercut	≤ 1 mm ($^1/_{32}$ in.) and ≤ $\overline{T}_w/4$	
I	Depth of undercut	≤ 1.5 mm ($^1/_{16}$ in.) and ≤ [$\overline{T}_w/4$ or 1 mm ($^1/_{32}$ in.)]	
J	Surface roughness	≤ 500 min. Ra per ASME B46.1	
K	Depth of root surface concavity	Total joint thickness, incl. weld reinf., ≥ $\overline{T}_w$	
L	Height of reinforcement or internal protrusion [Note (8)] in any plane through the weld shall be within limits of the applicable height value in the tabulation at right, except as provided in Note (9). Weld metal shall merge smoothly into the component surfaces.	For $\overline{T}_w$, mm (in.) ≤ 6 ($^1/_4$) > 6 ($^1/_4$), ≤ 13 ($^1/_2$) > 13 ($^1/_2$), ≤ 25 (1) > 25 (1)	Height, mm (in.) ≤ 1.5 ($^1/_{16}$) ≤ 3 ($^1/_8$) ≤ 4 ($^5/_{32}$) ≤ 5 ($^3/_{16}$)
M	Height of reinforcement or internal protrusion [Note (8)] as described in L. Note (9) does not apply.	Limit is twice the value applicable for L above	

X = required examination NA = not applicable . . . = not required

Notes follow on next page

Second B31.3 Piping Engineering Workshop and Seminar

The Second Workshop and Seminar was held in 24 to 26 May 2006 at New Park Hotel, Singapore. The two events were each attended by about 60 delegates.

The events were very successful in view of the good participation and interest shown by the delegates during the presentation sessions as well as the Q&A session.

With the kind permission from the tutor and speakers, the presentation materials are available from the links provided at the frame on the left.

http://www.psig.sg/Workshop2006%20Frame.html

Below are some photos which shown the highlight of the two events.

Workshop by Mr Don Frikken

Group Photograph of delegates of the Workshop

PSIG Committee and organisation committee members

Q and A session

PSIG Chair Mr Leong Yee Hong present memento to Mr Tan Geok Leng,

speaker from MOM

Note. The workshop and training course material was collected by Eng. Abdel Halim Galala, Chairman Assistant for Engineering, Cairo Oil Refining Co. (CORC).