طراحي مخازن تحت فشار بر اساس:

ASME Sec.VIII Division1

سيروس يحيي پور:

ASNT Level III

ASME Authorized Inspector

International Welding Engineer (IWE)

Countries accepting ASME Code

Countries accepting ASME Code Construction and Requirement Boilers and Pressure Vessels

113 Countries

Albania *
Algeria
Argentina
Australia
Austria *
Bahamas
Bahrain
Bangladesh
Barbados
Belarus *
Belgium *
Bermuda
Bolivia
Bosnia and Herzegovina *
Brazil
Burma (Myanmar) *
Canada
Chile
China *
Colombia
Costa Rica
Croatia *
Cuba
Cyprus
Denmark *
Djibouti
Dominican Republic
Ecuador

* Egypt
* Estonia
Ethiopia
* Finland
Fiji
* France
Gambia
* Georgia
* Germany
Ghana
* Greece
* Hong Kong
* Hungary
* Iceland
* India
Indonesia
* Iraq
* Ireland
Israel
* Italy
Ivory Coast
Jamaica
* Japan
Jordan
Kazakhstan
* Kenya
Korea
Kuwait
Latvia

Lebanon
Libya
Lithuania *
Luxembourg *
Malawi
Malaysia
Malta *
Mauritius *
Mexico
Moldowa *
Morocco
Mozambique
Netherlands *
New Zealand
Nicaragua *
Nigeria *
Norway
Oman *
Pakistan
Paraguay *
Peru
Philippines
Poland *
Portugal
Puerto Rico *
Quatar *
Romania
Saint Lucia *
Saudi Arabia *

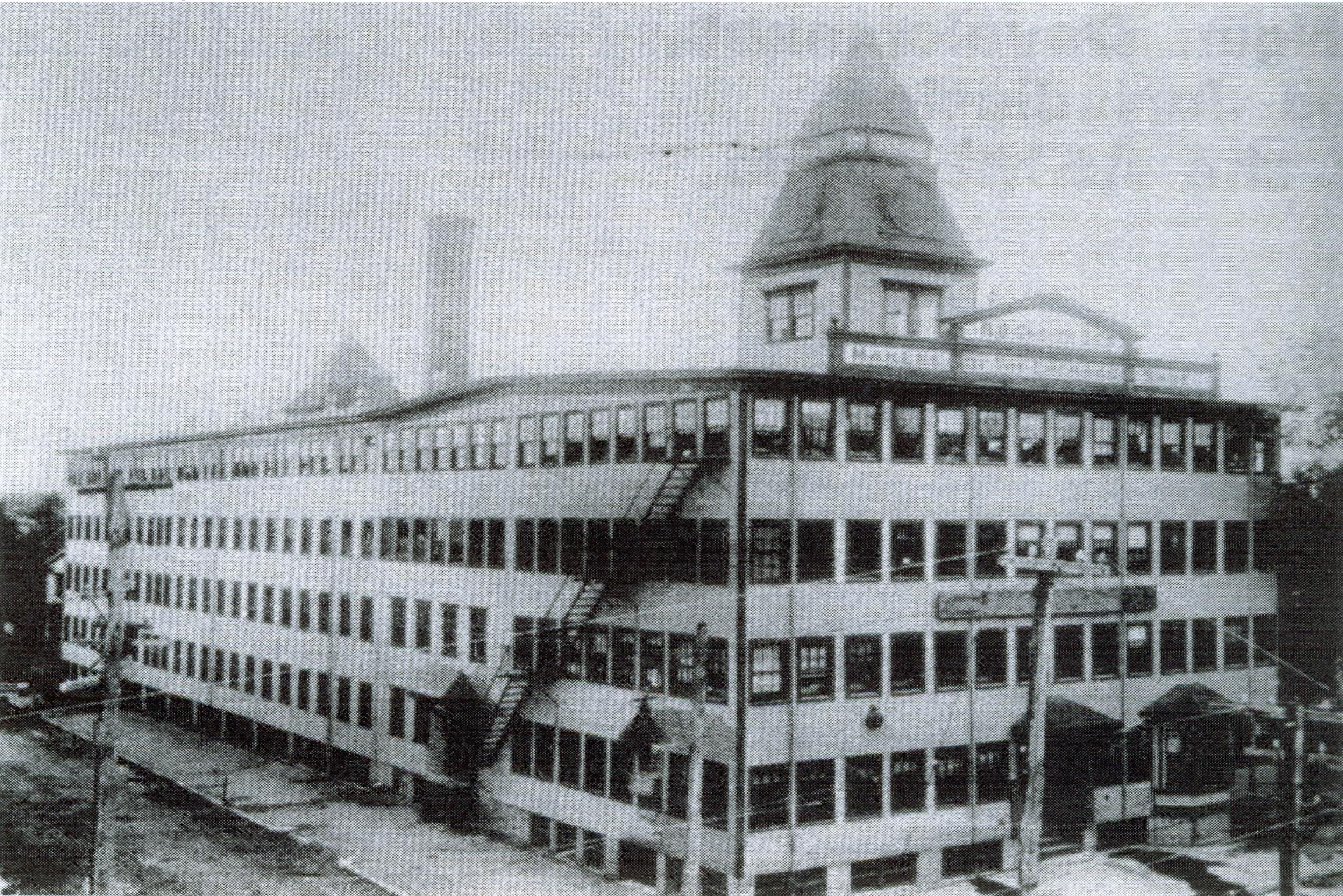
* Serbia
Singapore
South Africa
* Spain
Sri Lanka
Sudan
Swaziland
* Sweden
* Switzerland
Syria
Taiwan
Tanzania
Thailand
The Russian Federation
Trinidad and Tobago
* Tunisia
* Turkey
* United Arab Emirates
United Kingdom
* Uganda
Uruguay
USA
Venezuela
Yemen
Yugoslavia
Zambia
Zimbabwe

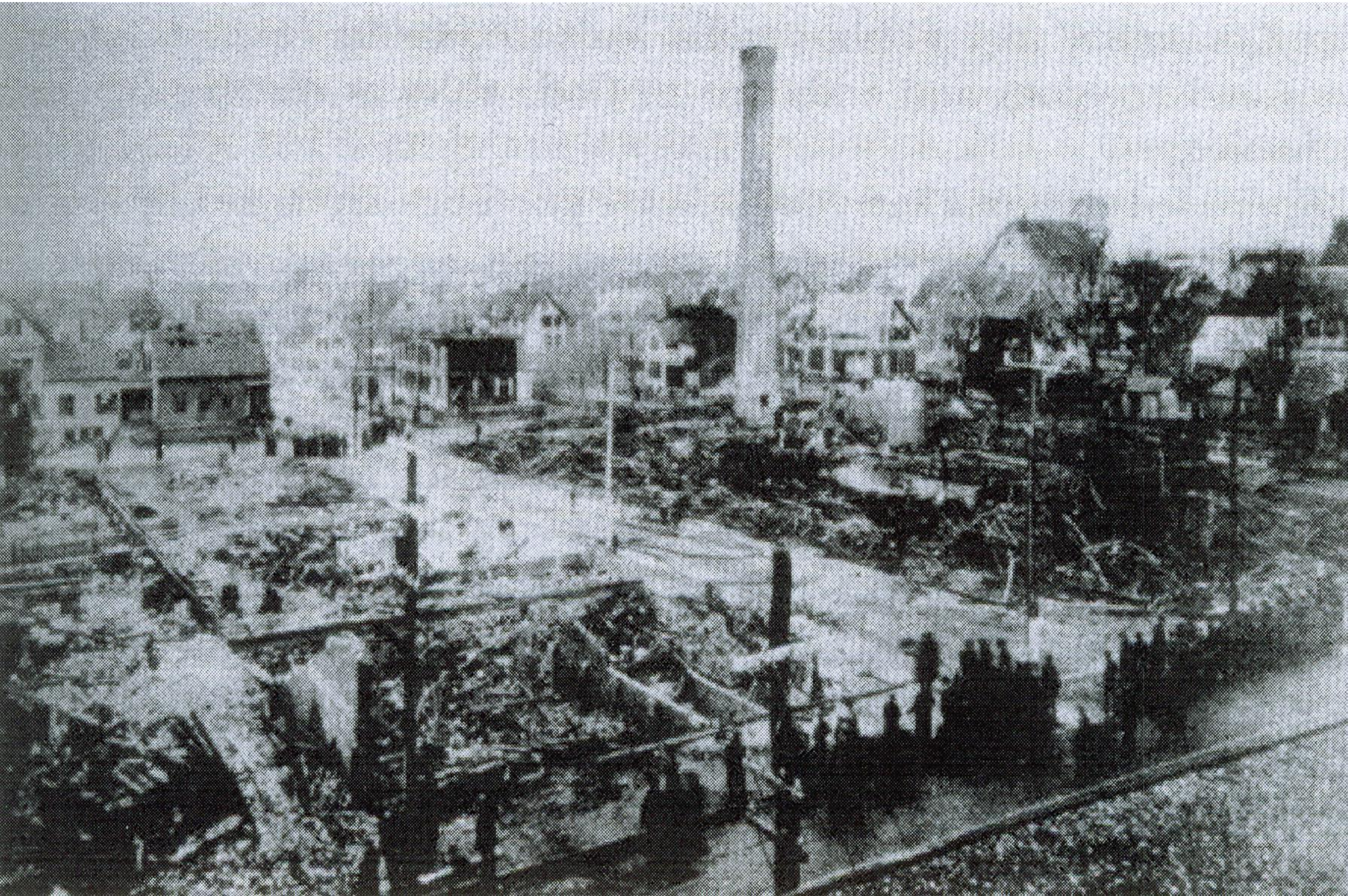
* Subject to approval of local authority

Source: Technical help to Exporters, British Standard Inst. (June 2004)

Section VIII Division 1

- مقدمه
- معرفی Sec. VIII Div.1
  - مسئولیت سازندگان
  - محدوده تحت پوشش Sec. VIII Div.1
- مواد
- طراحی
  - حداکثر فشارکاری مجاز(MAWP)و حداقل دمای طراحی فلز(MDMT)
  - درزهای اتصال،انواع جوش و طبقه بندی آن
  - شرایط خاص سیال
  - Openings





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FORE WORD

(پیش گفتار)

- انجمن مهندسین مکانیک آمریکا در سال **1911** کمیته‌ای را پایه‌گذاری کرد که مقررات استانداردی را برای ساخت[1] دیگ‌های بخار و دیگر مخازن تحت فشار ایجاد کند. این کمیته در حال حاضر **"Boiler and Pressure Vessel Committee"** نامیده می‌شود
- **ASME B&P** شامل الزامات اجباری ممنوعیت‌های مشخص شده و راهنمایی‌های غیر اجباری جهت عملیات ساخت است. کد شامل تمامی اطلاعاتی که در حین ساخت لازم است نمی‌شود و هر آنچه که در کد مشخصاً بیان نشده ممنوع نیست.
- کد **Hand book** نیست و نمی‌تواند جایگزین تحصیلات، دانش و تجربه شود و نباید بنحوی مورد قضاوت مهندسی **Engineering Judgment** قرار گیرد که الزامات اجباری یا ممنوعیت‌های مشخص آن نادیده گرفته شود.

[1] واژه ساخت در این پیش گفتار شامل تمامی موارد نظیر مواد ساخت آزمایش بازرسی**Examination**، **Test**، صدور گواهینامه و **Pressure Relief** است.

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SECTIONS

I Rules for Construction of Power Boilers
II Materials
- Part A — Ferrous Material Specifications
- Part B — Nonferrous Material Specifications
- Part C — Specifications for Welding Rods, Electrodes, and Filler Metals
- Part D — Properties

III Subsection NCA — General Requirements for Division 1 and Division 2
III Division 1
- Subsection NB — Class 1 Components
- Subsection NC — Class 2 Components
- Subsection ND — Class 3 Components
- Subsection NE — Class MC Components
- Subsection NF — Supports
- Subsection NG — Core Support Structures
- Subsection NH — Class 1 Components in Elevated Temperature Service
- Appendices

III Division 2 — Code for Concrete Reactor Vessels and Containments
III Division 3 — Containment Systems for Storage and Transport Packagings of Spent Nuclear Fuel and High Level Radioactive Material and Waste
IV Rules for Construction of Heating Boilers
V Nondestructive Examination
VI Recommended Rules for the Care and Operation of Heating Boilers
VII Recommended Guidelines for the Care of Power Boilers
VIII Rules for Construction of Pressure Vessels
- Division 1
- Division 2 — Alternative Rules
- Division 3 — Alternative Rules for Construction of High Pressure Vessels

IX Welding and Brazing Qualifications
X Fiber-Reinforced Plastic Pressure Vessels
XI Rules for Inservice Inspection of Nuclear Power Plant Components

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ارتباط بخش‌هاي مختلف كد ASME با يكدي□ر و ب ا كدهاي دي□ر

▪ASME – Boiler & Pressure Vessel Code

Construction- Code

Section 1 Power Boilers	Section III 1.2.3 Nuclear Power	Section IV Heating Boilers	Section VIII 1.2.3 Pressure Vessels	Section X Fiber Plastics	ASME B31.1 Power Piping	ASME B31.3 Process Piping

Referenced Code

ASME B31.1 Power Piping	Section II Materials	Section V NDE	Section IX Welding

“Inservice”- Code

Section VI Heating Boilers	Section VII Power Boilers	Section XI Nuclear Power

Standards, Recommendations

ANSI	ASTM	AWS	ASNT

▪National Board Inspection Code NBIC

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انتشارات کد ASME B & P

Editions — هر سه سال یک بار در ۱ July (۹۵،۹۸،۲۰۰۱،۲۰۰۴....) انتشارمی‌یابد.

Addenda — هر سال به صورت رنگی در ۱ July انتشار می‌یابدو شامل تغییرات، حذف‌ها و جابجایی‌هاست. ۶ ماه بعد از انتشار اجباری خواهد شد.

Interpretoutations — تفسیرهای سئوالات رسیده توسط کمیته‌های ASME منتشر می‌شوند امّا جزو کد نیستند (Non mandatory)

Code cases — بوسیله کمیته ASME جهت توضیح و روشن شدن الزامات موجود در کد یا تهیه مقررات جدیدی که الزم آن در کد حس می‌شود انتشار می‌یابند.

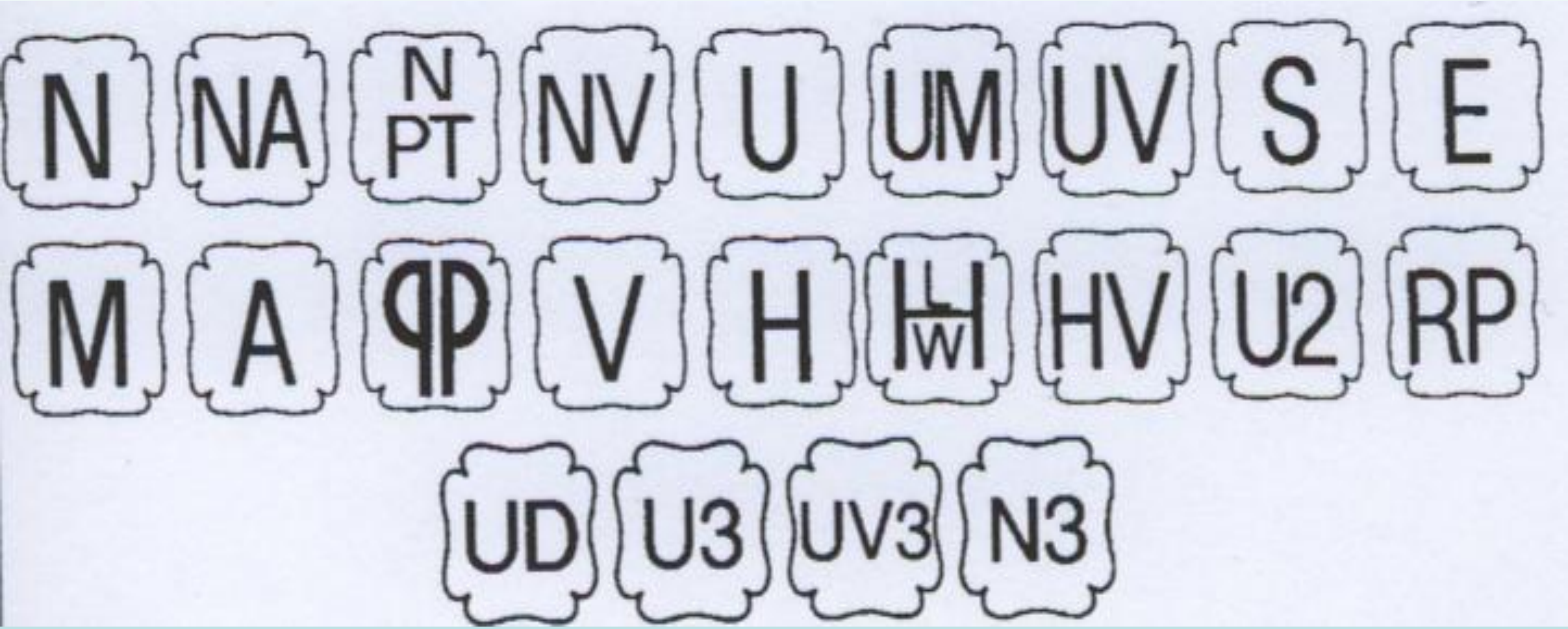
Errata — به محض انتشار اجباري هستند.

Re-affirmed — عبارتند از کدها و استانداردهای مرجع.

برخي از عبارت‌هاي كليدي كد

Shall	الزامات اجباري
May not	ممنوعيت
May **Can**	توصيه‌ها يا معافيت‌ها از ممنوعيت
Should	توصيه‌ها

ASME Code Symbol Stamps



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ASME Code Symbol Stamps

ASME Boiler & Pressure Vessel Code

Section I - Steam Boilers

S	steam boilers (master)
A	assembly only
E	electric boilers
M	miniature boilers
PP	power piping (B31.1)
V *	safety valves

Section IV - Heating Boilers

H *	cast iron heating boilers
H	wrought steel heatig boilers
HLW	potable water heaters
HV *	safety valves

Section VIII Div. 1 - Pressure Vessels

U	pressure vessels
UM *	miniature vessels
UV *	safety valves
UD *	rupture disk devices

Section VIII Div. 2 - Alternative Rules

U2	pressure vessels

Section VIII Div. 3 - Druckbehälter

U3	High Pressure Vessels
UV3*	safety valves

Section X - Fibre reinforced Plastic Pressure Vessels

RP	pressure vessels

National Board Inspection Code

R	repair and alteration
VR*	repair of safety valves

* Components not subject to Authorized Inspection, ASME Audit of the Manufacturer

SECO.PPT 11/98

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ASME Code Symbol Stamps

ASME Code Section III (Nuclear Components)

N	**Nuclear Components** Vessels, Piping Systems, Valves, Pumps, etc.
NA	**Nuclear Installer** Assembly of Components
NPT	**Nuclear Parts** Welded Parts of Nuclear Components
NV	**Nuclear Safety Valves**
NS	**Nuclear Supports** Certificate of Accreditation
QSC	**Quality System Certificate** Material Manufacturers

نهان کاوش
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آدرس‌هاي مفيد

ASME Boiler and Pressure Vessel Code — **ASME Order Department, WWW.asme.org**

Rao. K.R. (Editor) — **ASME Press, NY 2002 ($160)**

Companion Guide to the ASME Boiler & Pressure Vessel Code (Vol.1&2)

Carroll, D.E & Carroll D.E. Jr.:
The ASME Code Simplified – Power Boiler, — **McGraw-Hill, New York, 1997 ($60)**

Chuse, R. & Carson, Bryce Sr.:
The ASME Code Simplified – Pressure Vessels, — **McGraw-Hill, New York, 1997 ($60)**

Jawad, M.H. & Farr, J.R.:
Structural Analysis and Design of Process Equipment, Wiley- Interscience Publication, 1984

Jawad, M.H. & Farr, J.R.:
Guidebook for the desing of ASME Section VIII pressure vessels
ASME PRESS NY 1998 (65$)

Brownell, L.E & Young, E.H.
Process Equipment Design — **John Wiley & Sons, New York 1959**

Steingress, F.M. & Frost, H.J.
High Pressure Boiler — **American Technical Publishers, Homewood IL, 1994 ($35)**

Houle, Michael J.
Practical Giude to ASME Section IX — **CASTI Publishing Inc. Edmonton, Alberta Canada ($90)**

Ernst, Richard:
Wörterbuch der industriellen Technik, — **Oskar Brandstetter Verlag**

VDEh (hrsg):
Stahleisen- Wörterbuch, — **Verlag Stahleisen mbh, 6 Auflage, 1994**

واحدها

Length:	in	=	25,4 mm
	ft	=	304,8 mm
	Yd	=	914,4 mm
Area:	sq in	=	6,4516 cm^2
	sq ft	=	0,0929…m^2
Volume:	cu in	=	16,387 cm
	cu ft	=	28,317 l
Force:	lb f	=	4,448 N
Energy:	ft lb	=	1,355818 Nm (=J)
Pressure	psi	=	0,06894757 bar
Temperature	□F	=	32+1,8*T_c

Section VIII Division 1

- مقدمه
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- طراحی
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  - درزهای اتصال،انواع جوش و طبقه بندی آن
  - شرایط خاص سیال
  - Openings

ASME BOILER AND PRESSURE VESSEL CODE
AN INTERNATIONAL CODE

RULES FOR CONSTRUCTION OF PRESSURE VESSELS

VIII

Division 1

2002 Addenda
July 1, 2002

ASME BOILER AND PRESSURE VESSEL COMMITTEE
SUBCOMMITTEE ON PRESSURE VESSELS

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
NEW YORK, NEW YORK

CONTENTS

A Detailed Contents Precedes Each Part and the Appendices

ASME Section VIII Div.1 مندرجات

Foreword		
Introduction:	U-1, U-2, U-3	
Subsection A:	UG **- General Requirements**	
Subsection B:	**Methods of Fabrication**	
	UW - Welding	
	UF - Forging	
	UB – Brazing	
Subsection C:	**Classes of Material - Special Constructions**	
	UCS -	Carbon and Low Alloy Steel
	UNF -	Non ferrous Materials
	UHA -	High Alloy Steel
	UCI -	Cast Iron
	UCL -	Cladding and Lining
	UCD -	Cast Ductile Iron
	UHT -	Ferritic Steels with Heat Treatment
	ULW -	Layered Constructions
	ULT -	Low Temperature Service
Add. 2003:	UHX -	Rules for Shell and Tube Heat Exchangers
Mandatory and Nonmandatory Appendices		
Index		

Section VIII Division 1 محدوده تحت پوشش

- MAWP بالا تر از ۱۵psi(۱/۰۳bar)
- تحت فشار داخلی یا خارجی
- تا فشار طراحی ۳۰۰۰psi
- قطرداخلی بالا تر از ۱۵۲ mm

مواردی که تحت پوشش Div.1 قرار ندارند:

- ماشین آلات دورانی یا رفت و برگشتی
- لوله ها و اجزاء آن
- مخازنی که درمحدوده استاندارد های دیگر قرار دارند
- دیگهای بخار و مخازن آتش خوار
- مخازن آب با فشار تا ۳۰۰psi یا 210ºF

Section VIII Division 1 محدود است به:

- اولین درز جوش لوله ها یا نازلها
- اولین رزوه در اتصالات
- اولین سطح فلنجها
- اولین واشر آب بندی
- جوشکاری اجزاء non press. Part به press. part
- Pressure retaining covers
- اولین شیر اطمینان

Section VIII Division 1

- فشار کاری تا ۳۰۰۰ psi
- محاسبه تنش بر اساس فرمولهای ساده
- عدم نیاز به انالیز تنش
- استفاده رایج در ساخت مخازن تحت فشار

Section VIII Division 2

- فشار کاری تا ۱۰۰۰۰ psi
- نیاز به ارائه شرایط بهره برداری و طراحی توسط کار فرما
- نیاز به انالیز تنش های خستگی،خزش و...
- کاهش ضخامت بدنه و صرفه جویی در هزینه ها
- آزمایشات غیر مخرب کامل تر
- بکار گیری تنش های مجاز بالا تر
- استفاده از مهندسین ماهر

Section VIII Division3

- فشار کاری از ۱۰۰۰۰ psi به بالا
- انالیز تنش اجباری است
- توجه ویژه به prestressed components
- هزینه زیاد آزمایشات غیر مخرب
- بکارگیری محدود مواد

علائم ASME در Sec.VIII

- طراحی علامتی ندارد
- ساخت مخازن تحت فشار با Div.1 (U)
  - ساخت مخازن تحت فشار با Div.2 (U2)
  - ساخت مخازن تحت فشار با Div.3 (U3)
  - جوشکاری بخش هایی از مخازن تحت فشار (U,U2,U3)
  - مونتاژ مخازن تحت فشار در سایت (U,U2,U3)
  - ساخت مخازن تحت فشار کوچک (UM)
  - شیرهای اطمینان مخازن تحت فشار (UV)
  - شیرهای اطمینان مخازن با فشارهای بالا (UV3)
  - Rupture Discs,Div.1 (UD)

Section VIII Division 1 U-2

مسئولیت های استفاده کننده یا کار فرما:

- مشخص کردن نیاز های طراحی
- مشخص کردن شرایط محیطی شامل:
  - شرایط بهره برداری
  - شرایط خارج کردن از سرویس
  - ضخامت مجاز خردگی
  - سمی بودن سیال
  - شرایط خاص PWHT

مسئولیت های سازنده

- رعایت تمام ملاحظات کد
- اطمینان از رعایت ملاحظات کد توسط سازندگان جزء یا فروشندگان
  - در دسترس بودن مدارک طراحی
  - اطمینان از جاری بودن الزامات کنترل کیفیت
  - اطمینان از انجام یافتن آزمایشات غیر مخرب بر اساس ملاحظات کد
  - تنظیم مراحل کاری به گونه ای که بازرسی به راحتی صورت گیرد

Section VIII Division 1

- مقدمه
- معرفی Sec. VIII Div.1
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  - شرایط خاص سیال
  - Openings

Section VIII Div.1 Materials

- ورق UG-5
- Forgings UG-6
- ریخته گری UG-7
- لوله UG-8
- مواد جوشکاری UG-9
- پذیرفتن موادی که در کد لیست نشده اند UG-10
- قسمت های نیمه آماده مخازن تحت فشار UG-11

TABLE 1A
SECTION I; SECTION III, CLASS 2 AND 3;* AND SECTION VIII, DIVISION 1
MAXIMUM ALLOWABLE STRESS VALUES *S* FOR FERROUS MATERIALS
(*See Maximum Temperature Limits for Restrictions on Class)

Line No.	Nominal Composition	Product Form	Spec No.	Type/Grade	Alloy Desig./ UNS No.	Class/ Cond./ Temper	Size/ Thickness, in.	P-No.	Group No.
1	Carbon steel	Sheet	SA-620	...	K00040	...	...	1	1
2	Carbon steel	Bar	SA-675	45	...	...	...	1	1
3	Carbon steel	Wld. pipe	SA-134	A283A	...	...	...	1	1
4	Carbon steel	Plate	SA-283	A	...	...	...	1	1
5	Carbon steel	Plate	SA-285	A	K01700	...	...	1	1
6	Carbon steel	Plate	SA-285	A	K01700	...	...	1	1
7	Carbon steel	Wld. pipe	SA-672	A45	K01700	...	...	1	1
8	Carbon steel	Sheet	SA-414	A	K01501	...	...	1	1
9	Carbon steel	Wld. tube	SA-178	A	K01200	...	...	1	1
10	Carbon steel	Wld. tube	SA-178	A	K01200	...	...	1	1
11	Carbon steel	Wld. tube	SA-178	A	K01200	...	...	1	1
12	Carbon steel	Wld. tube	SA-178	A	K01200	...	...	1	1

TABLE 1A
SECTION I; SECTION III, CLASS 2 AND 3;* AND SECTION VIII, DIVISION 1 MAXIMUM ALLOWABLE STRESS VALUES *S* FOR FERROUS MATERIALS
(*See Maximum Temperature Limits for Restrictions on Class)

Line No.	Min. Tensile Strength, ksi	Min. Yield Strength, ksi	Applic. and Max. Temp. Limits (NP = Not Permitted) (SPT = Supports Only)			External Pressure Chart No.	Notes
			I	III	VIII-1		
1	40	20	NP	NP	650	CS-6	...
2	45	22.5	NP	650 (Cl. 3 only)	900	CS-6	G10, G22, G35, T2
3	45	24	NP	300 (Cl. 3 only)	NP	CS-1	G37, W12
4	45	24	NP	300 (Cl. 3 only)	650	CS-1	G34, G37
5	45	24	900	NP	NP	CS-1	G10, T2
6	45	24	NP	700	900	CS-1	G10, G35, T2
7	45	24	NP	700	NP	CS-1	S6, W10, W12
8	45	25	NP	NP	900	CS-1	G10, G35, T2
9	47	26	1000	NP	NP	CS-1	G10, S1, T2, W13
10	47	26	1000	NP	NP	CS-1	G4, G10, S1, T2

TABLE 1A
SECTION I; SECTION III, CLASS 2 AND 3;* AND SECTION VIII, DIVISION 1
MAXIMUM ALLOWABLE STRESS VALUES *S* FOR FERROUS MATERIALS
(*See Maximum Temperature Limits for Restrictions on Class)

Line	Maximum Allowable Stress, ksi (Multiply by 1000 to Obtain psi), for Metal Temperature, °F, Not Exceeding													
No.	–20 to 100	150	200	250	300	400	500	600	650	700	750	800	850	900
1	11.4	11.4	11.4	...	11.4	11.4	10.9	10.2	9.9	...	...	...	...	...
2	12.9	12.9	12.9	...	12.9	12.8	12.2	11.5	11.1	10.7	*10.4*	*9.0*	*7.8*	*5.0*
3	12.9	...	12.9	...	12.9	...	...	...	...	...	...	...	...	...
4	12.9	12.9	12.9	...	12.9	12.9	12.9	12.3	11.9	...	...	...	...	...
5	12.9	...	12.9	...	12.9	12.9	12.9	12.3	11.9	11.5	*10.7*	*8.3*	*6.6*	*5.0*
6	12.9	12.9	12.9	...	12.9	12.9	12.9	12.3	11.9	11.5	*10.7*	*9.0*	*7.8*	*6.5*
7	12.9	...	12.9	...	12.9	12.9	12.9	12.3	11.9	11.5	...	...	...	...
8	12.9	12.9	12.9	...	12.9	12.9	12.9	12.8	12.4	11.9	*10.7*	*9.0*	*7.8*	*6.5*
9	13.4	...	13.4	...	13.4	13.4	13.4	13.3	12.8	12.4	*10.7*	*9.0*	*7.1*	*5.0*
10	13.4	...	13.4	...	13.4	13.4	13.4	13.3	12.8	12.4	*10.7*	*9.0*	*7.1*	*4.3*
11	11.4	...	11.4	...	11.4	11.4	11.4	11.3	10.9	10.5	*9.1*	*7.7*	*6.1*	*4.3*
12	11.4	11.4	11.4	...	11.4	11.4	11.4	11.3	10.9	10.5	*9.1*	*7.8*	*6.7*	*5.5*

ASME Material Specification

A – 516 (90) Gr 60

ASTM Material

Acceptance for use in Code Constructions

ASME Code Committee on Materials

SA – 516 Gr 60 (Type, Class)

ASME Material

Published in Section II Part A/B

no year

Society for ASME

نهان کاوش
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Section II Part C SFA-Numbers

SFA-5.1	Carbon Steel Electrodes for Shielded Metal Arc welding
SFA-5.2	Carbon and Low Steel Rods for Oxyfuel Gas Welding
SFA-5.3	Aluminum and Aluminum Alloy Electrodes for Shielded Metal Arc Welding
SFA-5.4	Stainless Steel Electrodes for. Shielded Metal Arc Welding
SFA-5.5	Low – Alloy Steel Electrodes for Shielded Metal Arc Welding
SFA-5.6	Covered Copper and Copper Alloy Arc Welding Electrodes
SFA-5.7	Copper and Copper Alloy Bare Welding Rods and electroes
SFA-5.8	Filler metal for Brazing and Braze Welding
SFA-5.9	Bare Stainless Steel Welding Electrodes and Rods
SFA-5.10	Bare Aluminum and Aluminum Alloy Welding Electrodes and Rods
SFA-5.11	Nickel and Nickel Alloy Welding Electrodes for Shielded Metal Arc Welding
SFA-5.12	Tungsten and Tungsten Alloy Electrodes. For Arc Welding and Cutting
SFA-5.13	Solid Surfacing Welding Rods and Electrodes
SFA-5.14	Nickel and Nickel Alloy Bare Welding Electrodes and Rods
SFA-5.15	Welding Electrodes and Rods for Case Iron
SFA-5.16	Titanium and Titanium Alloy Welding Rods and Electrodes
SFA-5.17	Carbon Steel Electrodes and Fluxes for Submerged Arc Welding
SFA-5.18	Carbon Steel Filler metals for Gas Shielded Arc Welding
SFA-5.20	Carbon Steel Electrodes for Flux Cored Arc Welding
SFA-5.21	Composite Surfacing Welding Rods and Electrodes
SFA-5.22	Stainless Steel Electrodes for Flux Cored Arc Welding and Stainless Steel Flux Cored Rods for Gas Tungsten Arc Weling
SFA-5.23	Low Alloy Steel Electrodes and Fluxes for Submerged Arc Weldi

Section II- C Filler Metals شناسایی فلزات پرکننده در AWS

SFA-5.1, 5.4: SMAW Electrode Classification

E7018, E7018M, E7016-1HzR

E XXX X X XX

Electrode

Strength in KSI

Position
- 1= All Position
- 2= Flat and horizontal fillets
- 4= Vertical down

- 0= DCEP d
- 1= AC or DCEP d
- 2= AC or DCEN m
- 3= AC or DC i
- 4= AC or DC i
- 5= DCEP m
- 6= AC or DCEP m
- 7= AC or DCEP m

“penetration”

Chemical Composition of weld Deposit

Section VIII Division 1

- مقدمه
- معرفی Sec. VIII Div.1
  - مسئولیت سازندگان
  - محدوده تحت پوشش Sec. VIII Div.1
- مواد
- طراحی
  - حداکثر فشارکاری مجاز(MAWP)و حداقل دمای طراحی فلز(MDMT)
  - درزهای اتصال،انواع جوش و طبقه بندی آن
  - شرایط خاص سیال
  - Openings

Design

Section VIII Div.1 Design

- ملاحظات کلی UG-16
- روشهای ویژه در ساخت UG-19
- دمای طراحی UG-20
- فشار طراحی UG-21
- بارهای وارده UG-22
- تنش مجاز مواد UG-23
- ریخته گری (ضریب کیفیت) UG-24

Section VIII Div.1 Design

- ضخامت بدنه (تحت فشار داخلی) UG-27
- ضخامت بدنه(تحت فشار خارجی) UG-28
- Formed heads UG-32
- Flat heads UG-34
- Quick actuating closures UG-36
- فلنچ و اتصالات لوله UG- 44
- Braced& stayed surfaces UG-47
- Ligaments UG-53
- پایه ها ug-54

Section VIII Div.1 Design

Design Loads

- بارهای وارده
  - ✓ فشار طراحی(داخلی یا خارجی)
  - ✓ بار مرده
  - ✓ نیروی باد
  - ✓ نیروی زلزله
  - ✓ نیروهای ناشی از تغییرات دما
  - ✓ نیروی piping
  - ✓ Impact or cyclic loads

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Section VIII Div.1 Addenda 2003

▪ تغییرات اساسی در ساخت مبدل های حرارتی

– بخش **UHX** که الزامات آن اجباری است جهت ساخت مبدل هایی از نوع لوله و بدنه به کد اضافه شد

– **Appendix Aa** حذف شد و به بخش **UHX** انتقال یافت

– بند **UW-20** که در مورد درز اتصال **Tube to Tube Sheet** بود حذف و به بخش **UHX** انتقال یافت

– استفاده از **TEMA** یا **AD-Merkblatter** برای طراحی **Tube Sheet** ممنوع شد

Section VIII Div.1 UG-98

حداکثر فشار کاری(MAWP)

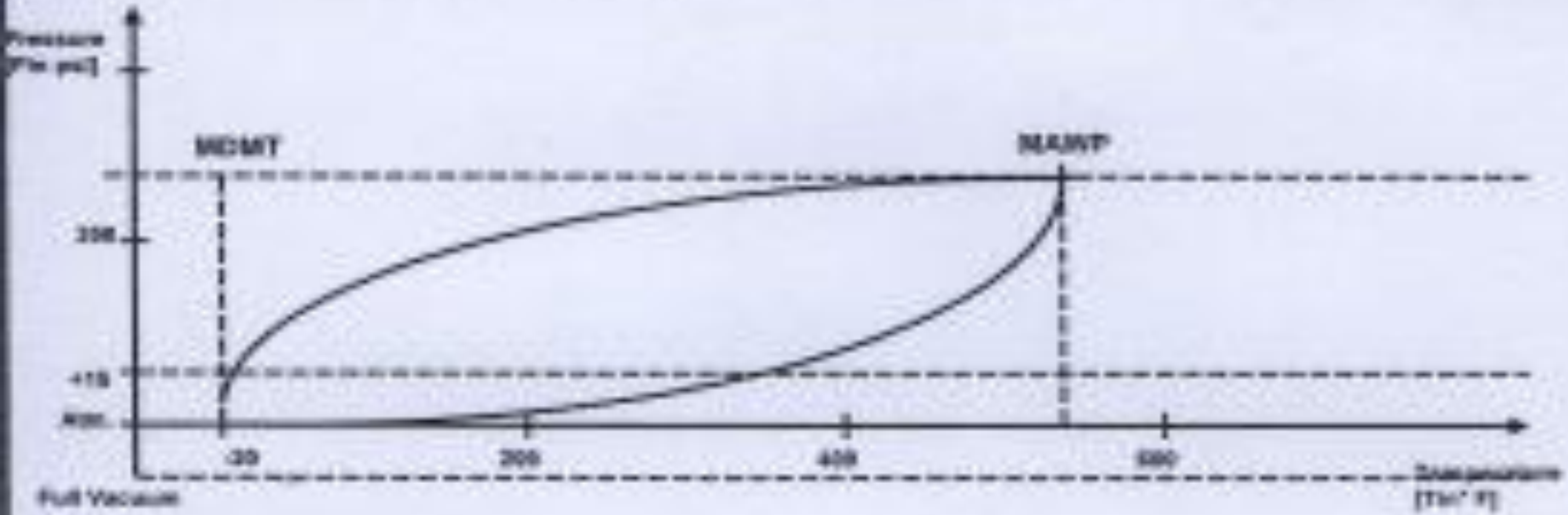
– **UG-98(a)** حداکثر فشار کاری مجاز در یک مخزن عبارت است از حداکثر فشار مجاز در بالاترین قسمت مخزن در شرایط عادی بهره برداری تحت دمای مشخص طراحی

- **UG-98(b)** حداکثر فشار کاری مجاز برای بخشی از مخزن عبارت است از حداکثر فشار داخلی یا خارجی که شامل فشار ستون مایع و دیگر نیروهای وارده به مخزن که در **UG-22** لیست شده اند و ضخامت خوردگی مجاز می شود(**UG-25**).

- **UG-98(c)** حداکثر فشار کاری مجاز ممکن است به وسیله چند دمای طراحی که در بخشهای مختلف مخزن کاربرد دارند و بر اساس تنش مجاز هر یک از دماها مشخص گردد.

Section VIII Div.1 UG-98

UG-20 & 21 Operating Conditions



NAMEPLATE

Certified by Rusty Tank Corp.

→ MAWP 290 psi at 572° F

→ MDMT -20° F at 290 psi

Section VIII Div.1 UG-20

▪دمای طراحی

– بجز مواردی که در UW-2(d)(3) آمده است حداکثر دمای طراحی نباید کمتر از دمای فلز باشد مگر آنکه بنا به شرایط بهره برداری ممکن نباشد(رجوع کنید به 2-3). در صورت لزوم دمای طراحی را باید بر اساس دمای جداره دستگاهایی که در شرایط مشابه کار می کنند مشخص نمود.

– حداقل دمای فلز باید کمتر از دمای بهره برداری باشد مگر آنکه بر اساس UCS-66 و UCS- 160 دمای بالاتر مجاز شود. هر گاه چند MAWP داشته باشیم حداقل دمای طراحی باید با توجه به بالاترین MAWP انتخاب شود.

– دمای طراحی بالاتر از آنچه که در جدول UG-23 آمده است مجاز نیست.

– در Appendix C روشی مناسب برای بدست آوردن دمای جداره مخازن حین بهره برداری معرفی شده است.

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ASME Sec.VIII Div.1

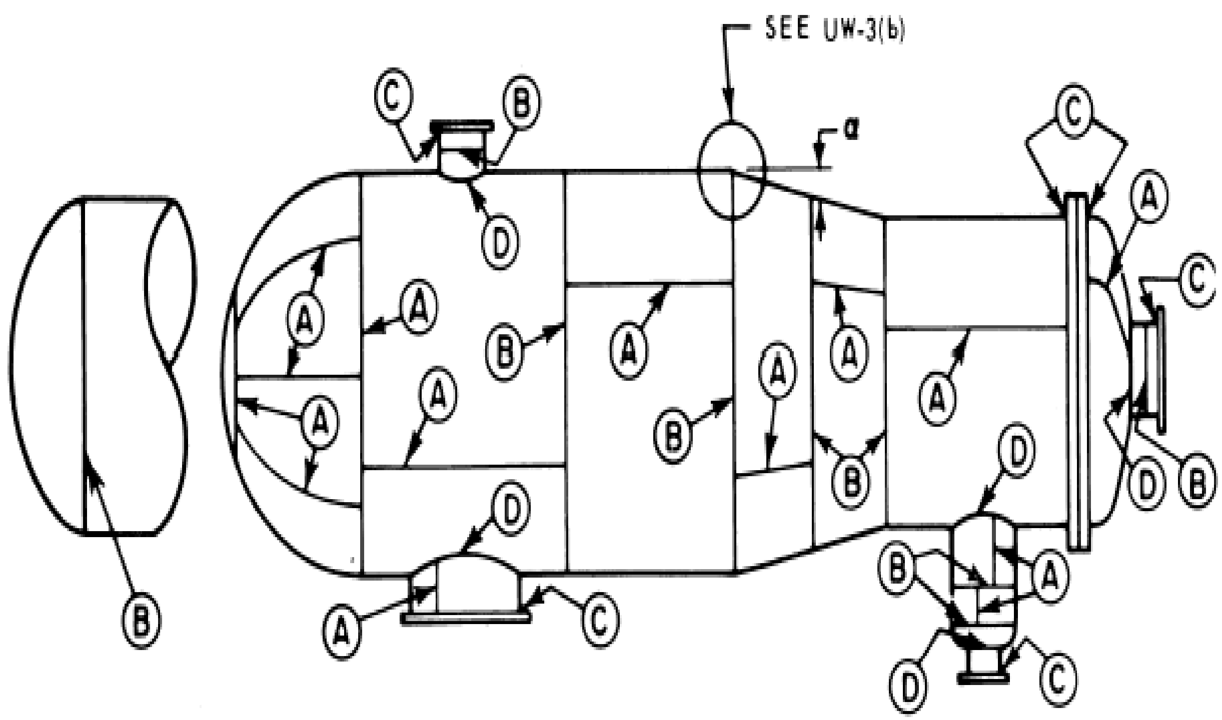

FIG. UW-3 ILLUSTRATION OF WELDED JOINT LOCATIONS TYPICAL OF CATEGORIES A, B, C, AND D

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Section VIII Div.1 UW-12

- انواع درزهای اتصال

TYPES OF WELDED JOINTS

LIMITATIONS IN APPLYING VARIOUS WELD TYPES	NOTES
FOR TYPE 1: NONE Joint Category: A, B, C, D **FOR TYPE 2: NONE** Joint Category: A, B, C, D Except butt weld with one plate off-set — for circumferential joints only. **FOR TYPE 3:** Joint Category: A, B, C Circumferential joints only, not over 5/8 in. thick and not over 24 in. outside diameter. **FOR TYPE 4:** (a) Longitudinal joints not over 3/8 in. thick. Joint Category: A (b) Circumferential joints not over 5/8 in. thick. Joint Category B,C For C joints these limitations not applicable for bolted flange connections. **FOR TYPE 5:** (a) Circumferential joints for attachment of heads not over 24 in. outside diameter to shells not over ½ in. thick. Joints attaching hemispherical heads to shells are excluded. Joint Category B: (b) Circumferential joints for the attachment to shells of jackets not over 5/8 in. in nominal thickness where the distance from the center of the plug weld to the edge of the plate is not less than 1½ times the diameter of the hole for the plug. Joint Category: C **FOR TYPE 6:** (a) For the attachment of heads convex to pressure to shells not over 5/8 in. required thickness, only with use of fillet weld on inside of shell: Joint Category: A, B (b) For attachment of heads having pressure on either side, to shells not over 24 in. inside diameter and not over ¼ required thickness with fillet weld on outside of flange only. Joint Category: A, B	1. In this table are shown the types of welded joints which are permitted by the Code in arc and gas welding processes. 2. The shape of the edges to be joined by butt-weld shall be such as to permit complete fusion and penetration. 3. Butt joints shall be free from undercuts, overlaps and abrupt ridges and valleys. To assure that the weld-grooves are completely filled, weld metal may be built up as reinforcement. The thickness of the reinforcement shall not exceed the following thicknesses. Plate thickness in. / Maximum reinf. in. up to ½ incl. — 3/32 over ½ to 1 incl. — 1/8 over 1 — 3/16 4. Before welding the second side of a double welded butt joint, the impurities of the first side welding shall be removed by chipping, grinding or melting out to secure sound metal for complete penetration and fusion. For submerged arc welding, chipping out a groove in the crater is recommended. 5. The maximum allowable joint efficiencies given in this table are to be used in formulas, when the joints made by arc or gas welding processes. 6. Joint efficiency, E = 1 for butt joints in compression.

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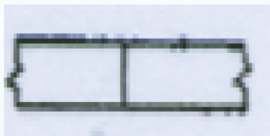
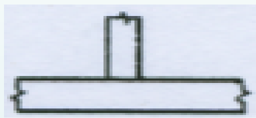
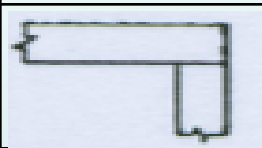
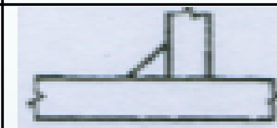
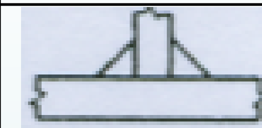
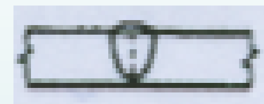
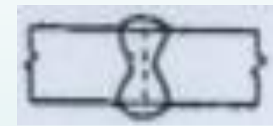
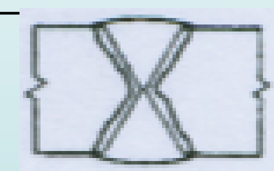
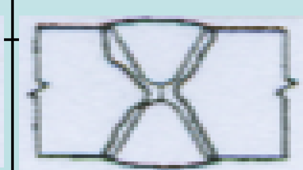
نوع اتصال

Butt	
Tee	
Corner	
Angle	
Lap	
Edge	

نوع جوش

	Single	**Double**
Fillet		
Square		
Bevel Groove		
Vee Groove		
J Groove		
U Groove		

Section VIII Div.1 UW-12

■ انواع درزهای اتصال

–اتصال سر به سر با نفوذ کامل

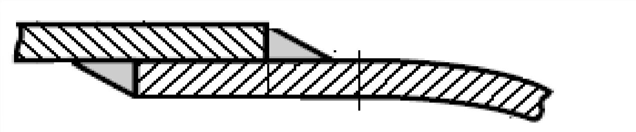
(جوش دو طرفه ،یا تسمه پشتبند جدا شونده یا روشهای دیگر)

–اتصال سر به سر یک طرفه با پشتبند دائمی

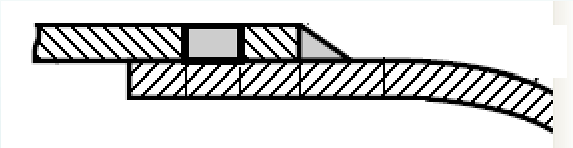
–اتصال سر به سر یک طرفه بدون پشتبند

Section VIII Div.1 UW-12

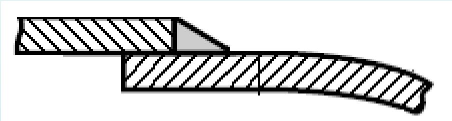
▪انواع درزهای اتصال(ادامه)



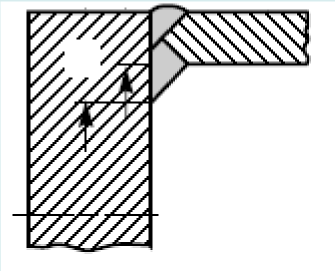
–اتصال دو طرفه **Lap joint**



–اتصال یک طرفه **Lap** با **Plug weld**

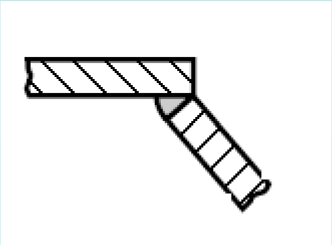


–اتصال یک طرفه **Lap**



–اتصال گوشه با نفوذ کامل یا ناقص

(به **UW-13.2** و **UW-16.1** رجوع شود)



–اتصال زاویه ای بر اساس **U-2(g)** برای **Category B&C** بکار میرود.

Section VIII Div.1 UG-27

- محاسبه ضخامت جداره مخازن استوانه ای تحت فشار داخلی

– تنش محیطی

$$t = \frac{PR}{SE - 0.6P} \quad \text{or} \quad P = \frac{SEt}{R + 0.6t} \qquad (1)$$

– تنش طولی

$$t = \frac{PR}{2SE + 0.4P} \quad \text{or} \quad P = \frac{2SEt}{R - 0.4t} \qquad (2)$$

– بدنه کروی

$$t = \frac{PR}{2SE - 0.2P} \quad \text{or} \quad P = \frac{2SEt}{R + 0.2t} \qquad (3)$$

t = ضخامت بر اساس فشار داخلی (in.)

P= فشار طراحی (psi)

R= قطر داخلی(in.)

S= تنش مجاز(psi)

E= کمترین مقدارضریب اتصال (به**UW-12**یا **UG-53** رجوع شود)

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Section VIII Div.1 Design

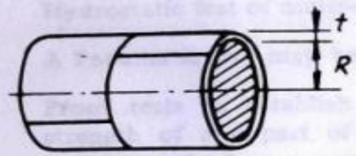
INTERNAL PRESSURE

FORMULAS IN TERMS OF INSIDE DIMENSIONS

NOTATION

P = Design pressure or max. allowable working pressure psi
S = Stress value of material psi. page 189
E = Joint efficiency, page 172
R = Inside radius, inches
D = Inside diameter, inches
t = Wall thickness, inches
$C.A.$ = Corrosion allowance, inches

A — CYLINDRICAL SHELL (LONG SEAM)[1]

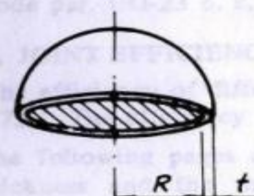


$$t=\frac{PR}{SE-0.6P}$$

$$P=\frac{SE\,t}{R+0.6t}$$

1. Usually the stress in the long seam is governing. See preceding page.
2. When the wall thickness exceeds one half of the inside radius or P exceeds 0.385 SE, the formulas given in the Code Appendix 1-2 shall be applied.

B — SPHERE and HEMISPHERICAL HEAD

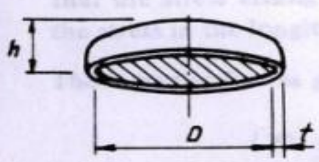


$$t=\frac{PR}{2SE-0.2P}$$

$$P=\frac{2SE\,t}{R+0.2t}$$

1. For heads without a straight flange, use the efficiency of the head to shell joint if it less than the efficiency of the seams in the head.
2. When the wall thickness exceeds 0.356 R or P exceeds 0.665 SE, the formulas given in the Code Appendix 1-3, shall be applied.

C — 2:1 ELLIPSOIDAL HEAD



h = D/4

$$t=\frac{PD}{2SE-0.2P}$$

$$P=\frac{2SEt}{D+0.2t}$$

1. For ellipsoidal heads, where the ratio of the major and minor axis is other than 2:1, see Code Appendix 1-4(c).

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INTERNAL PRESSURE

FORMULAS IN TERMS OF INSIDE DIMENSIONS

NOTATION

P = Design pressure or max. allowable working pressure psi
S = Stress value of material psi, page 189
E = Joint efficiency, page 172
R = Inside radius, inches
D = Inside diameter, inches
α = One half of the included (apex) angle, degrees
L = Inside radius of dish, inches
r = Inside knuckle radius, inches
t = Wall thickness, inches
$C.A.$ = Corrosion allowance, inches

D

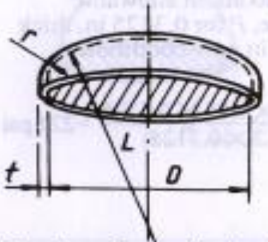
CONE AND CONICAL SECTION

$$t=\frac{PD}{2\cos\alpha\,(SE-0.6P)}$$

$$P=\frac{2SEt\cos\alpha}{D+1.2t\cos\alpha}$$

1. The half apex angle, α not greater than 30°
2. When α is greater than 30°, special analysis is required. (Code Appendix 1-5(g))

E



When the min. tensile strength of material exceeds 70,000 psi. see Code UG-32(e)

ASME FLANGED AND DISHED HEAD (TORISPHERICAL HEAD)

When $L/r = 16\frac{2}{3}$

$$t=\frac{0.885PL}{SE-0.1P}$$

$$P=\frac{SEt}{0.885L+0.1t}$$

When L/r less than $16\frac{2}{3}$

$$t=\frac{PLM}{2SE-0.2P}$$

$$P=\frac{2SEt}{LM+0.2t}$$

VALUES OF FACTOR "M"

L/r	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50	4.00	4.50	5.00	5.50	6.00	6.50
M	1.00	1.03	1.06	1.08	1.10	1.13	1.15	1.17	1.18	1.20	1.22	1.25	1.28	1.31	1.34	1.36	1.39
L/r	7.00	7.50	8.00	8.50	9.00	9.50	10.0	10.5	11.0	11.5	12.0	13.0	14.0	15.0	16.0	$16\frac{2}{3}$	*
M	1.41	1.44	1.46	1.48	1.50	1.52	1.54	1.56	1.58	1.60	1.62	1.65	1.69	1.72	1.75	1.77	

* THE MAXIMUM ALLOWED RATIO : L = D + 2t (see note 2 on facing page)

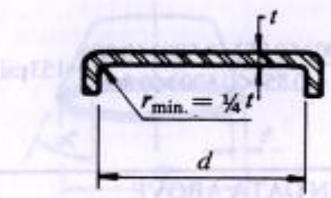
Section VIII Div.1 Design

INTERNAL OR EXTERNAL PRESSURE FORMULAS

NOTATION

P = Internal or external design pressure psi E = joint efficiency
d = Inside diameter of shell, in.
S = Maximum allowable stress value of material, psi
t = Minimum required thickness of head, exclusive of corrosion allowance, in.
t_h = Actual thickness of head exclusive of corrosion allowance, in.
t_r = Minimum required thickness of seamless shell for pressure, in.
t_s = Actual thickness of shell, exclusive of corrosion allowance, in.

A



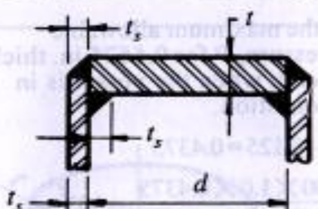
CIRCULAR FLAT HEADS

$$t = d\sqrt{0.13\,P/SE}$$

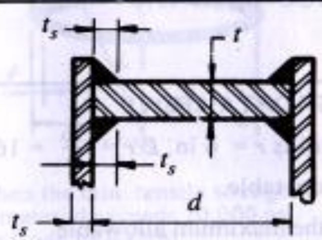
This formula shall be applied:

1. When d does not exceed 24 in.
2. t_h/d is not less than 0.05 nor greater than 0.25
3. The head thickness, t_h is not less than the shell thickness, t_s

B



C



$$t = d\sqrt{CP/SE}$$

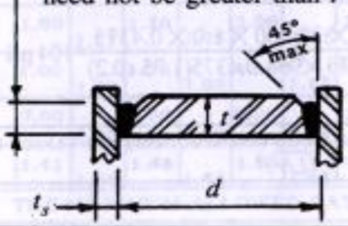
$$C = 0.33\,t_r/t_s$$

$$C\ \text{min.} = 0.20$$

If a value of t_r/t_s less than 1 is used in calculating t, the shell thickness t_s shall be maintained along a distance inwardly from the inside face of the head equal to at least $2\sqrt{dt_s}$

D

2 $t_r$min. nor less than 1.25t_s need not be greater than t



Non-circular, bolted flat heads, covers, blind flanges Code UG-34; other types of closures Code UG-35

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EXTERNAL PRESSURE

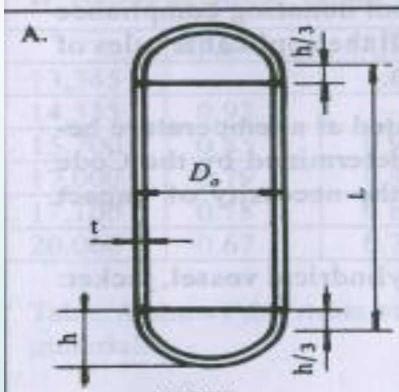
FORMULAS

NOTATION

P = External design pressure, psig.
P_a = Maximum allowable working pressure, psig.
D_o = Outside diameter, in.
L = the length, in. of vessel section between:
1. circumferential line on a head at one-third the depth of the head-tangent line,
2. stiffening rings
3. jacket closure
4. cone-to-cylinder junction or knuckle-to-cylinder junction of a toriconical head or section,
5. tube sheets (see page 39)

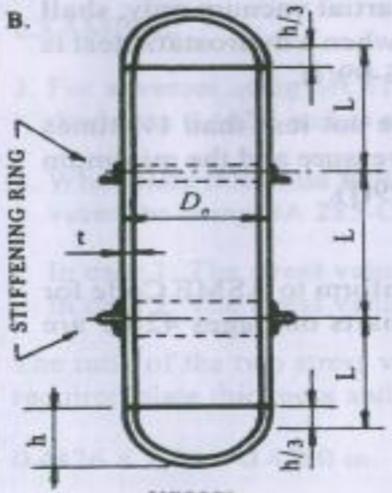
t = Minimum required wall thickness, in.

A.



VESSEL
WITHOUT STIFFENING RING

B.



VESSEL
WITH STIFFENING RING

CYLINDRICAL SHELL
Seamless or with Longitudinal Butt Joints

When D_o/t equal to or greater than 10 the maximum allowable pressure:

$$P_a = \frac{4B}{3(D_o/t)}$$

The value of B shall be determined by the following procedure:

1. Assume a value for t; (See pages 49-51) Determine L/D_o and D_o/t
2. Enter Fig. G (Page 42) at the value of L/D_o. Enter at 50 when L/D_o is greater than 50, and at 0.05 when L/D_o is less than 0.05.
3. Move horizontally to the line representing D_o/t. From the point of intersection move vertically to determine the value of factor A.
4. Enter the applicable material chart (pages 43-47) at the value of A. Move vertically to the applicable temperature line*.
5. From the intersection move horizontally and read the value of B.

Compute the maximum allowable working pressure, P_a.

If the maximum allowable working pressure is smaller than the design pressure, the design procedure must be repeated increasing the vessel thickness or decreasing L by stiffening ring.

*For values of A falling to the left of the applicable temperature line, the value of P_a can be calculated by the formula:

$$P_a = \frac{2AE}{3(D_o/t)}$$

When the value of D_o/t is less than 10, the formulas given in the Code UG-28(c)(2) shall be applied.

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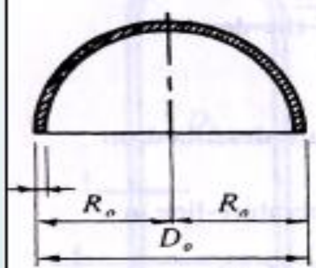
EXTERNAL PRESSURE

FORMULAS

NOTATION

- P = External design pressure psig.
- P_a = Maximum allowable working pressure psig.
- D_o = Outside diameter of the head, in.
- R_o = Outside radius of sphere or hemisphereical head, $0.9D_o$ for ellipsoidal heads, inside crown radius of flanged and dished heads, in.
- t = Minimum required wall thickness, inches.
- E = Modulus of elasticity of material, psi. (page 43)



SPHERE and HEMISPHERICAL HEAD

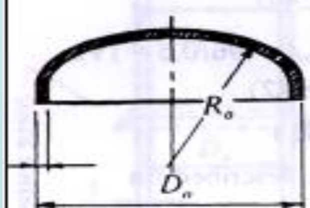
The maximum allowable pressure: $P_a = \dfrac{B}{(R_o/t)}$

The value of B shall be determined by the following procedure:

1. Assume the value for t and calculate the value of A using the formula: $A = 0.125/(R_o/t)$ (see page 49)
2. Enter the applicable material chart (pages 43-47) at the value of A. Move vertically to the applicable temperature line.*
3. From the intersection move horizontally and read the value of B.

*For values of A falling to the left of the applicable temperature line, the value of P_a can be calculated by the formula: $P_a = 0.0625E/(R_o/t)^2$

If the maximum allowable working pressure P_a computed by the formula above, is smaller than the design pressure, a greater value for t must be selected and the design procedure repeated.

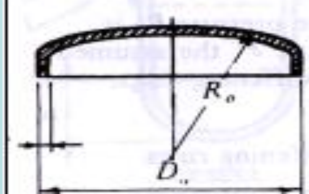


2:1 ELLIPSOIDAL HEAD

The required thickness shall be the greater of the following thicknesses.

(1) The thickness as computed by the formulas given for internal pressure using a design pressure 1.67 times the external pressure and joint efficiency $E = 1.00$.

(2) The thickness proofed by formula $P_a = B/R_o/t$ where $R_o = 0.9\ D_o$, and B to be determined as for sphere.



ASME FLANGED AND DISHED HEAD (TORISPHERICAL HEAD)

The required thickness and maximum allowable pressure shall be computed by the procedures given for ellipsoidal heads. (See above) R_o maximum $= D_o$

Section VIII Div.1 Design

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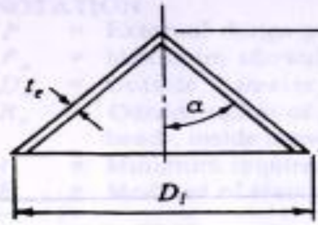
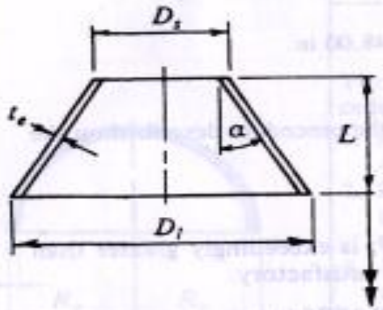
EXTERNAL PRESSURE

FORMULAS





NOTATION

- A = factor determined from fig.UGO-28.0 (page 42
- B = factor determined from charts (pages 43–47)
- α = one half of the included (apex) angle, degrees
- D_l = outside diameter at the large end, in.
- D_s = outside diameter at the small end, in.
- E = modulus of elasticity of material (page 43)
- L = length of cone, in. (see page 39)
- L_e = equivalent length of conical section, in.$(L/2)(1+D_s/D_l)$
- P = external design pressure, psi.
- P_a = Maximum allowable working pressure, psi
- t = minimum required thickness, in.
- t_e = effective thickness, in. $= t \cos \alpha$

CONE AND CONICAL SECTION

Seamless or with Butt Joints

WHEN α IS EQUAL TO OR LESS THAN 60° and $D_l/t_e \geq 10$

The maximum allowable pressure:

$$P_a = \frac{4B}{3(D_l/t_e)}$$

1. Assume a value for thickness, t_e. The values of B shall be determined by the following procedure:
2. Determine t_e, L_e, and the ratios L_e/D_l and D_l/t_e
3. Enter chart G (page 42) at the value of L_e/D_l (L/D_o) (Enter at 50 when L_e/D_l is greater than 50) Move horizontally to the line representing D_o/t. From the point of intersection move vertically and read the value of A.
4. Enter the applicable material chart at the value of A* and move vertically to the line of applicable temperature. From the intersection move horizontally and read the value of B.
5. Compute the maximum allowable working pressure, P_a.

If P_a is smaller than the design pressure, the design, the design procedure must be repeated increasing the thickness or decreasing L by using of stiffening rings.

*For values of A falling to the left of the applicable line, the value of P can be calculated by the formula:

$$P_a = 2AE/3(D_l/t_e)$$

For cones having D /t ratio smaller than 10, see Code UG-33 (f)(b)

WHEN α IS GREATER THAN 60°

The thickness of the cones shall be the same as the required thickness for a flat head, the diameter of which equals the largest outside diameter of the cone.

Provide adequate reinforcing of the cone-to-cylinder juncture. See page 159

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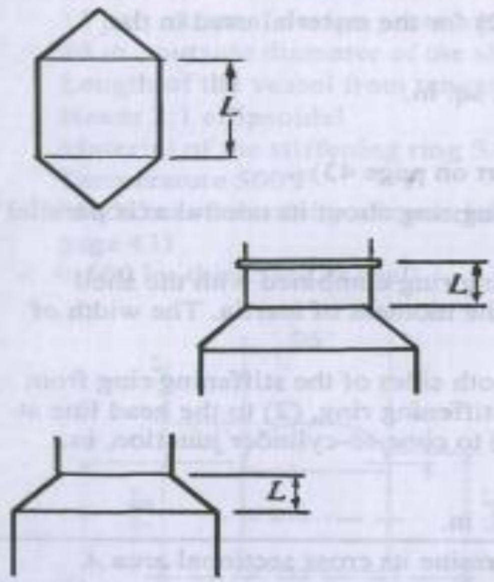
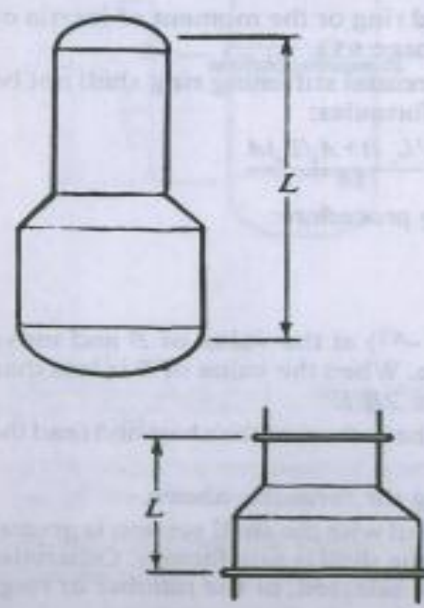
EXTERNAL PRESSURE

FORMULAS



Use *L* in calculation as shown when the strength of joints of cone to cylinder does not meet the requirements described on pages 163 - 169. It will result the thickness for the cone not less than the minimum required thickness for the joining cylindrical shell.



Use *L* in calculation as shown when the strength of joints of cone to cylinder meets the requirements described on pages 163 - 169

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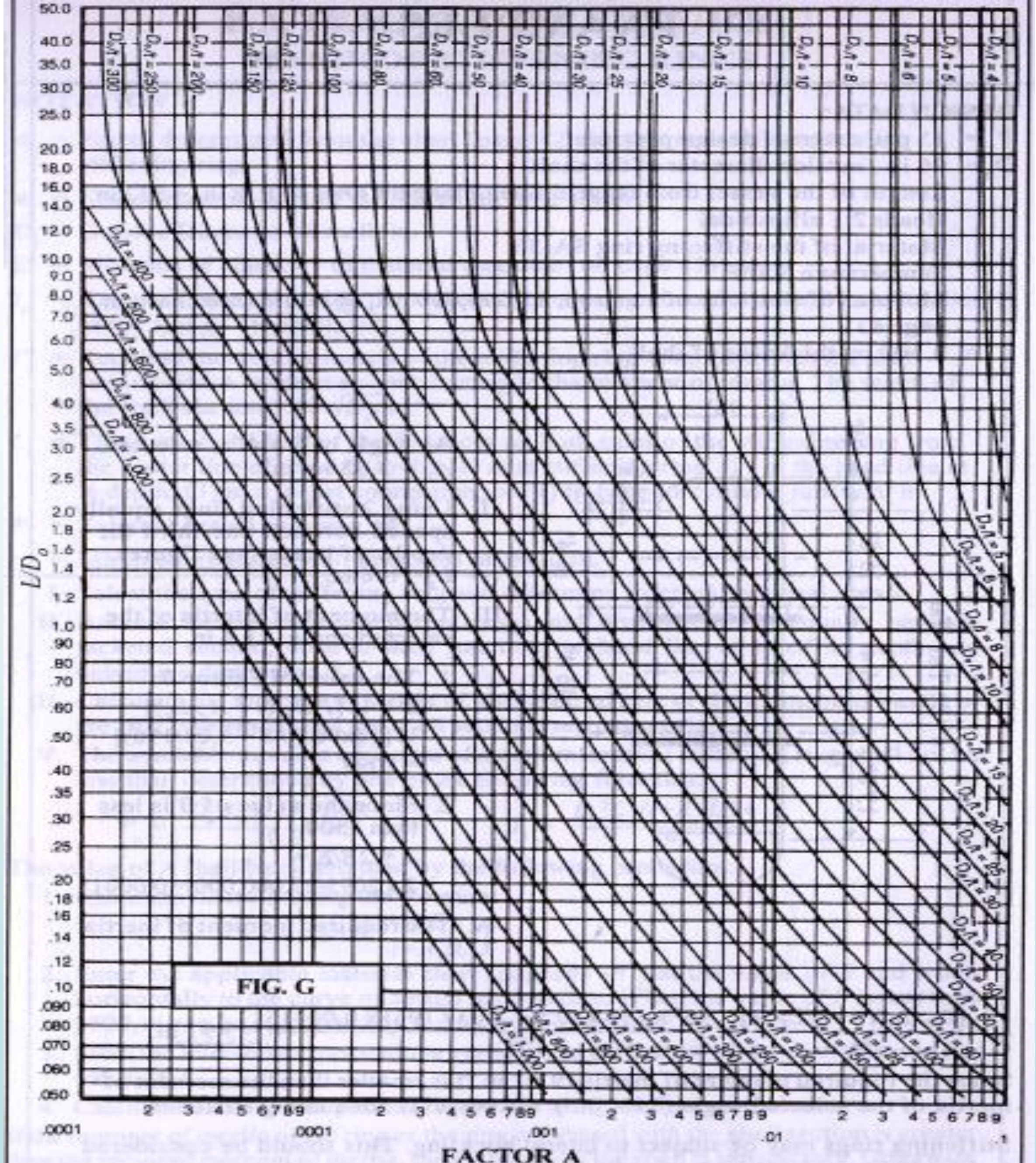
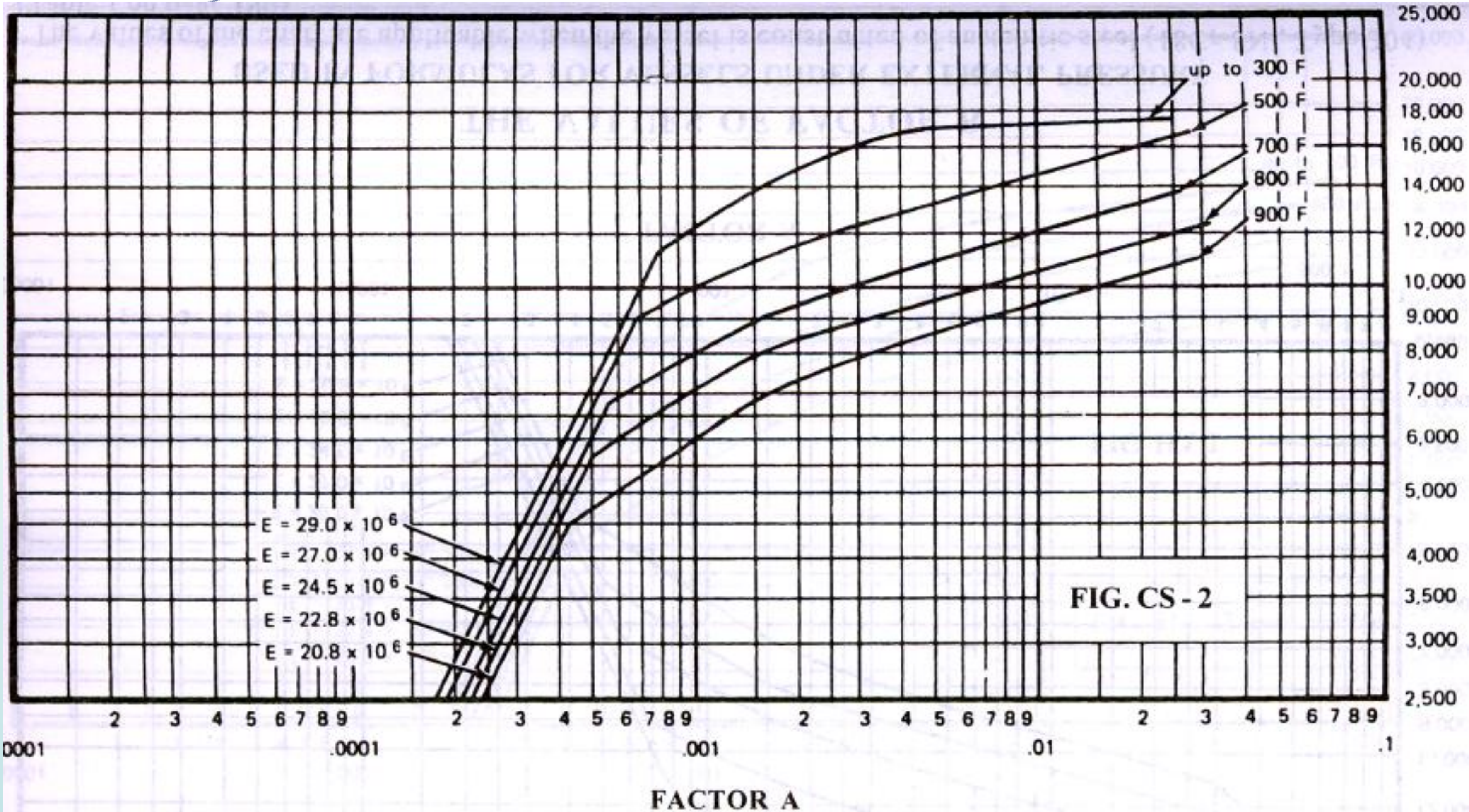


THE VALUES OF FACTOR A
USED IN FORMULAS FOR VESSELS UNDER EXTERNAL PRESSURE



THE VALUES OF FACTOR B

USED IN FORMULAS FOR VESSELS UNDER EXTERNAL PRESSURE

The values of the chart are applicable when the vessel is constructed of carbon steel and the specified yield strenth 30,000 psi. and over. To this category belong the following most frequently used materials:

SA - 283 C	SA - 515 } All Grades	SA - 53 - B	Type 405 } Stainless Steel
SA - 285 C	SA - 516 }	SA - 106 - B	Type 410 }

DESIGN OF TALL TOWERS
WIND LOAD

The computation of wind load is based on Standard ANSI/ASCE 7-95, approved 1996.

The basic wind speed shall be taken from the map on the following pages.

The basic wind speed is 105 mph. in Hawaii and 125 mph. in Puerto Rico.

The minimum design wind pressure shall not be less than 10 lb./sq. ft.

When records and experience indicates that the wind speeds are higher than those reflected in the map, the higher values of wind speed shall be applied.

The wind pressure on the projected area of a cylindrical tower shall be calculated by the following formula.

$F = q_z \, G \, C_f \, A_f$

Table 6-1 ANSI/ASCE 7-95 STANDARD
(Numbers of tables and paragraphs are references to this Standard.)

- A_f = $(D \times H)$ Projected area of tower, sq. ft.
  - H = height of tower considered, ft.
  - D = outside diameter of tower, ft.
- C_f = Shape factor = 0.8 for cylindrical tower (Table 6-7)
- G = Gust response factor = $(G_h \,\&\, G_z)$* (Para. 6.6)
  When the tower is located:
  in urban, suburban areas, Exposure *B* 0.8;
  in open terrain with scattered obstruction, Exposure *C* 0.85;
  in flat, unobstructed areas, Exposure *D* 0.85.
- q_z = Velocity pressure at height *z* above ground, lb./sq. in.
  $0.00256 \, K_z K_{zt} V^2 I$ lb./sq. ft. (Table 6-1)
  - I = Importance factor = 1.0 for structures that present low hazard to human life in event of failure (Para. 6.2).
  - V = Wind speed, mph. (Map 6-1)
  - K_{zt} = Topographic factor = 1.0 when wind speed-up over hills and escarpment is not present. (Para. 6.5.5)
  - K_z = Velocity Pressure Exposure Coefficient* Exposures *B*, *C* & *D* (Table 6-3)
- F = Design Wind Force, lb. on projected area of tower. (Para. 6.2)

* See tables below for values of *q* and for combined values of G_h, G_z, and K_z in Exposures *B*, *C*, and *D*.

VELOCITY PRESSURE, *q*

Basic wind speed, mph, V	70	80	90	100	110	120	130
Velocity Pressure psf $0.00256\,V^2$, q	13	17	21	26	31	37	44

DESIGN OF TALL TOWERS

WIND LOAD
(Continued)

COEFFICIENT *G* (Gust response factor combined with Exposure Coefficient)

HEIGHT Above Ground, ft.	EXPOSURE B	EXPOSURE C	EXPOSURE D
0-15	0.6	1.1	1.4
20	0.7	1.2	1.5
40	0.8	1.3	1.6
60	0.9	1.4	1.7
80	1.0	1.5	1.8
100	1.1	1.6	1.9
140	1.2	1.7	2.0
200	1.4	1.9	2.1
300	1.6	2.0	2.2
500	1.9	2.3	2.4

The area of caged ladder may be approximated as 1 sq. ft. per lineal ft. Projected are of platform 8 sq. ft.

Users of vessels usually specify wind pressure for manufacturers without referenc to the height zones or map areas. For example: 30 lb. per sq. ft. This specified pres sure shall be considered to be uniform on the whole vessel.

The total pressure on a tower is the product of the unit pressure and the projecte area of the tower. With good arrangement of the equipment, the exposed area of th wind can be reduced considerably. For example, by locating the ladder 90 degree from the vapor line.

EXAMPLE:

Determine the wind load, *F*
DESIGN DATA:

the wind speed, *V*	=	100 m.p.h
diameter of tower, *D*	=	6 ft.
height of tower, *H*	=	80 ft.
the tower located in flat, unobstructed area, exposure:		*D*

The wind load, $F = q_z \times G \times C_f\ A_f$

q from table	=	26 psf
G from table	=	1.8
Shape factor	=	0.8

Area, $A_f = DH = 6 \times 80 = 480$ sq. ft.
$F = 26 \times 1.8 \times 0.8 \times 480 = 17{,}971$ lbs.

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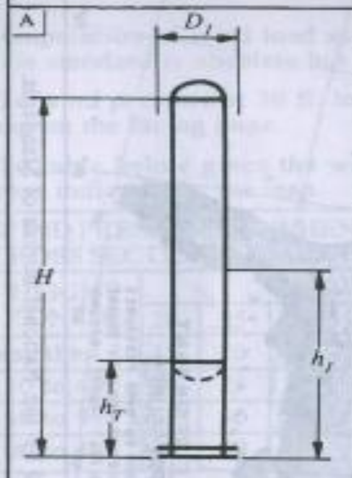
DESIGN OF TALL TOWERS

WIND LOAD

(Continuation)

A



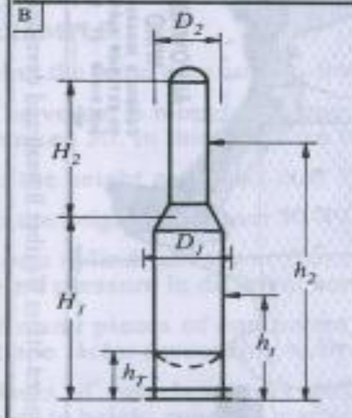
FORMULAS

SHEAR	MOMENT	STRESS	REQUIRED THICKNESS
$V = P_w D_{1,2} H_{1,2}$	$M = P_w D_{1,2} H_{1,2} h_{1,2}$ $M_T = M - h_T(V - 0.5\,P_w D_1 h_T)$	$S = \dfrac{12M}{R^2 \pi t}$	$t = \dfrac{12M}{R^2 \pi S E}$

NOTATION

$D_1 D_2$ = Width of the vessel with insulation etc., ft.
E = Efficiency of the welded joints.
$h_1 h_2$ = Lever arm, ft.
h_T = Distance from base to section under consideration, ft.
$H, H_1 H_2$ = Length of vessel or vessel section, ft.
M = Maximum moment (at the base) ft. lb.
M_T = Moment at height h_T, ft. lb.
P_w = Wind pressure, lb. per sq. ft.
R = Mean radius of vessel, in.
S = Stress value of material or actual stress psi.
V = Total shear, lb.
t = Required thickness, corrosion excluded, in.

B



EXAMPLE:

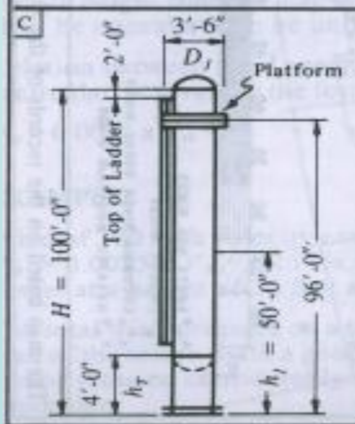
Given: D_1 = 4'-0" D_2 = 3'-0" H_1 = 56'-0" H_2 = 44'-0"
h_T = 4'-0" P_w = 30 psf

Determine the wind moment
$h_1 = H_1/2$ = 28'-0" $h_2 = H_1 + (H_2/2)$ = 78'-0"
$P_w \times D \times H = V \times h = M$

Lower Section 30 × 4 × 56 = 6720 × 28 = 188,160
Upper Section 30 × 3 × 44 = 3,960 × 78 = 308,880
Total V = 10,680 M 497,040 ft. lb.

Moment at the bottom tangent line
$M_T = M - h_T\,(V - 0.5\,P_w D_1 h_T) =$
497,040 − 4 (10,680 − 0.5 × 30 × 4 × 4) = 455,280 ft. lb.

C



EXAMPLE:

Given: D_1 = 3 ft. 6 in. H = 100 ft. 0 in. h_T = 4 ft. 0 in.
P_w = 30 psf

Determine the wind moment
$h_1 = H/2$ = 50 ft. 0 in.

	$P_w \times D_1 \times H =$	$V \times h_1 =$	M
Vessel	30 × 3.5 × 100	= 10,500 × 50	= 525,000
Ladder	30 × 98 lin. ft.	= 2,940 = 49	= 144,060
Platform	30 × 8 lin. ft.	= 240 × 96	= 23,040
Total		V = 13,680	M = 692,100 ft. lb

Moment at the bottom tangent line
$M_T = M - h_T\,(V - 0.5\,P_w D_1 h_T) =$
692,100 − 4 (13,680 − 0.5 × 30 × 3.5 × 4) = 638,220 ft. lb

SEE EXAMPLES FOR COMBINED LOADS ON PAGE: 69

WEIGHT OF THE VESSEL

The weight of the vessel results compressive stress only when eccentricity does not exist and the resultant force coincides with the axis of the vessel. Usually the compression due to the weight is insignificant and is not controlling.

The weight shall be calculated for the various conditions of the tower as follows:

A. **Erection weight**, which includes the weight of the:

1. shell
2. heads
3. internal plate work
4. tray supports
5. insulation rings
6. openings
7. skirt
8. base ring
9. anchor ring
10. anchor lugs
11. miscellaneous
12. + 6% of the weight of items 1 through 11 for overweight of the plates and weight added by the weldings

Equipments:

13. insulation
14. fireproofing
15. platform
16. ladder
17. piping
18. miscellaneous

Erection weight: the sum of items 1 through 18.

B. **Operating weight**, which includes the weight of the:

1. vessel in erection condition
2. trays
3. operating liquid

C. **Test weight**, which includes the weight of the:

1. vessel in erection condition
2. test water

The compressive stress due to the weight given by:

$$S = \frac{W}{ct}$$ where

S = unit stress, psi
W = weight of vessel above the section under consideration, lb.
c = circumference of shell or skirt on the mean diameter, in.
t = thickness of the shell or skirt, in.

The weight of different vessel elements are given in tables beginning on page 374

Section VIII Div.1 Design

DESIGN OF TALL TOWERS
VIBRATION

As a result of wind, tall towers develop vibration. The period of the vibration should be limited, since large natural periods of vibration can lead to fatigue failure. The allowable period has been computed from the maximum permissible deflection.

The so called harmonic vibration is not discussed in this Handbook since the trays as usually applied and their supports prevent the arising of this problem.

FORMULAS

Period of Vibration:	T sec.	$T = 0.0000265 \left(\frac{H}{D}\right)^2 \sqrt{\frac{wD}{t}}$
Maximum Allowable Period of Vibration, T_a sec.		$T_a = 0.80 \sqrt{\frac{WH}{Vg}}$

NOTATION

D = Outside diameter of vessel, ft.
H = Length of vessel including skirt, ft.
g = 32.2 ft. per sec. squared, acceleration
t = Thickness of skirt at the base, in.
V = Total shear, lb. CW, see page 61
W = Weight of tower, lb.
w = Weight of tower per foot of height, lb.

EXAMPLE

Given:

Determine the actual and maximum allowable period of vibration

D = 3.125 ft. 0 in.
H = 100 ft. 0 in.
g = 32.2 ft/sec^2
t = 0.75 in.
V = 1440 lb.
W = 36,000 lb. in operating condition
w = 360

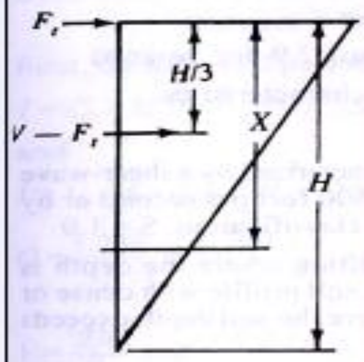
$$T = 0.0000265 \left(\frac{100}{3.125}\right)^2 \sqrt{\frac{360 \times 3.125}{0.75}} = 1.05 \text{ sec.}$$

$$T_a = 0.80 \sqrt{\frac{36000 \times 100}{1440 \times 32.2}} = 7.05 \text{ sec.}$$

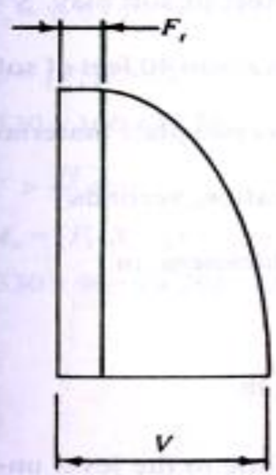
The actual vibration does not exceed the allowable vibration.

DESIGN OF TALL TOWERS
SEISMIC LOAD (EARTHQUAKE)

The loading condition of a tower under seismic forces is similar to that of a cantilever beam when the load increases uniformly toward the free end. The design method below is based on Uniform Building Code, 1997 (UBC).



(a) Seismic Loading Diagram



(b) Seismic Shear Diagram

Base Shear

FORMULAS

SHEAR	MOMENT
$V=\frac{ZIC}{R_w}W$	$M=[F_t \times H+(V-F_t)\times(2H/3)]$ $M_x=[F_t \times X]$ for $X \le H/3$ $M_x=[F_t \times H+(V-F_t)\times(X-H/3)]$ for $X > H/3$

Base Shear

The base shear is the total horizontal seismic shear at the base of a tower. The triangular loading pattern and the shape of the tower shear diagram due to that loading are shown in Fig. (a) and (b). A portion of F_t of total horizontal seismic force V is assumed to be applied at the top of the tower. The remainder of the base shear is distributed throughout the length of the tower, including the top.

Overturning Moment

The overturning moment at any level is the algebraic sum of the moments of all the forces above that level.

NOTATION

C = Numerical coefficient $= \frac{2.35S}{T^{2/3}}$ (need not exceed 2.75)

C = Numerical coefficient = 0.035

D = Outside diameter of vessel, ft.

E = Efficiency of welded joints

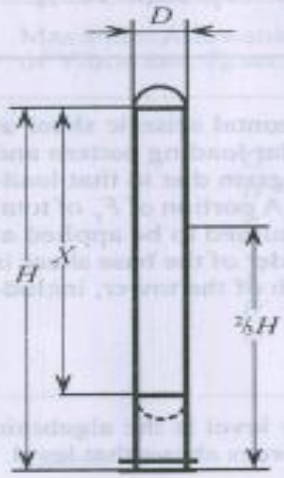
F_t = Total horizontal seismic force at top of the vessel, lb. determined from the following formula:

$F_t = 0.07\,TV$ (F_t need not exceed $0.25V$)

$= 0$, for $T \le 0.7$

H = Length of vessel including skirt, ft.

SEISMIC LOAD (EARTHQUAKE)
(Continuation)



NOTATION

I = Occupancy importance coefficient (use 1.0 for vessels)

M = Maximum moment (at the base), ft-lb.

M_x = Moment at distance X, ft-lb.

R = Mean radius of vessel, in.

R_w = Numerical coefficient (use 2.9 for vessels)

S = Site coefficient for soil characteristics

A soil profile with either:

a) A rock-like material characterized by a shear-wave velocity greater than 2,500 feet per second or by other suitable means of classification. S = 1.0

b) Stiff or dense soil condition where the depth is less than 200 ft. S = 1. A soil profile with dense or stiff soil conditions, where the soil depth exceeds 200 feet. $S = 1.2$.

A soil profile of 40 feet or more in depth and containing more than 20 feet of soft to medium stiff clay, but not more than 40 feet of soft clay. S = 1.5.

A soil profile containing more than 40 feet of soft clay. S = 2.0.

S_t = Allowable tensile stress of vessel plate material, psi.

T = Fundamental period of vibration, seconds $= C_t \times H^{3/4}$

t = Required corroded vessel thickness, in.

$$\frac{12\,M}{\pi R^2 S_t E} \quad \text{or} \quad \frac{12 M_x}{\pi R^2 S_t E}$$

V = Total seismic shear at base, lb.

W = Total weight of tower, lb.

X = Distance from top tangent line to the level under consideration, ft.

Z = Seismic zone factor,
0.075 for zone 1
0.15 for zone 2A
0.2 for zone 2B
0.3 for zone 3
0.4 for zone 4

(see map on the following pages for zoning).

Section VIII Div.1 Design

DESIGN OF TALL TOWERS

SEISMIC LOAD (EARTHQUAKE)

EXAMPLE

Given:

Seismic zone: 2B — $Z = 0.2$

$D = 37.5$ in. $= 3.125$ ft. — $X = 96$ ft,. 0 in.

$H = 100$ ft., 0 in. — $W = 35{,}400$ lb.

Determine: The overturning moment due to earthquake at the base and at a distance X from top tangent line.

First, fundamental period of vibration shall be calculated.

$$T = C_t \times H^{3/4} = 0.035 \times 100^{3/4} = 1.1 \text{ sec.}$$

and

$$I = 1, \quad S = 1.5, \quad R_w = 2.9,$$

$$C = \frac{1.25S}{T^{2/3}} = \frac{1.25 \times 1.5}{1.1^{2/3}} = 1.76 < 2.75$$

$$V = \frac{ZIC}{R_w} \times W = \frac{0.2 \times 1 \times 1.76}{2.9} \times 35{,}400 = 4{,}296 \text{ lb.}$$

$$F_t = 0.07\,TV = 0.07 \times 1.1 \times 4{,}296 = 330 \text{ lb.}$$

$$M = [F_t H + (V - F_t)(2H/3)] =$$

$$[330 \times 100 + (4{,}296 - 330)(2 \times 100/3)] = 294{,}756 \text{ ft. - lb.}$$

$$X > \frac{H}{3} \text{ thus}$$

$$M_x = [F_t X + (V - F_t)(X - H/3)] =$$

$$[330 \times 96 + (4{,}296 - 330)(100 - 33)] = 281{,}138 \text{ ft. - lb.}$$

ECCENTRIC LOAD

Towers and their internal equipment are usually symmetrical around the vertical axis and thus the weight of the vessel sets up compressive stress only. Equipment attached to the vessel on the outside can cause unsymmetrical distribution of the loading due to the weight and result in bending stress. This unsymmetrical arrangement of small equipment, pipes and openings may be neglected, but the bending stresses exerted by heavy equipment are additional to the bending stresses resulting from wind or seismic load.

FORMULAS		
MOMENT	STRESS	REQUIRED THICKNESS
$M = We$	$S = \dfrac{12We}{\pi R^2 t}$	$t = \dfrac{12We}{R^2 \pi SE}$

NOTATION

e = Eccentricity, the distance from the tower axis to center of eccentric load, ft.
E = Efficiency of welded joints.
M = Moment of eccentric load, ft. lb.
R = Mean radius of vessel, in.
S = Stress value of material, or actual bending stress, psi
t = Thickness of vessel, excluding corrosion allowance, in.
W = Eccentric load, lb.

EXAMPLE

Given:
e = 4 ft. 0 in.
R = 15 in.
t = 0.25 in.
W = 1000 lb.

Determine moment, M, and stress, S.

Moment, $M = We = 1000 \times 4 = 4000$ ft. lb.

$$S = \frac{12\ We}{\pi\ R^2 t} = \frac{12 \times 1000 \times 4}{3.14 \times 15^2 \times 0.25} = 272 \text{ psi}$$

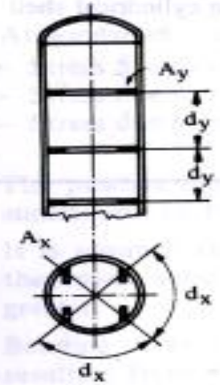
When there is more than one eccentric load, the moments shall be summarized, taking the resultant of all eccentric loads.

Design of Tall Towers

ELASTIC STABILITY

A tower under axial compression may fail in two ways because of instability:
1. By buckling of the whole vessel (Euler buckling)
2. By local buckling

In thin-walled vessels (when the thickness of the shell is less than one-tenth of the inside radius) local buckling may occur at a unit load less than that required to cause failure of the whole vessel. The out of roundness of the shell is a very significant factor in the resulting instability. The formulas for investigation of elastic stability are given in this Handbook, developed by Wilson and Newmark. Elements of the vessel which are primarily used for other purposes (tray supports, downcomer bars) may be considered also as stiffeners against buckling if closely spaced. Longitudinal stiffeners increase the rigidity of the tower more effectively than circumferential stiffeners. If the rings are not continuous around the shell, its stiffening effect shall be calculated with the restrictions outlined in the Code UG-29 (c).



FORMULAS

ALLOWABLE STRESS (S)

Without Stiffener	With Stiffener
$S = 1{,}500{,}000 \frac{t}{R} (\leq \frac{1}{3}$ yield point)	$S = \frac{1{,}500{,}000}{R}\sqrt{t_y t_x}$ ($\leq \frac{1}{3}$ yield p.)

NOTATIONS:

A_x = Cross sectional area of one logitudinal stiffener, sq. in.
A_y = Cross sectional area of one circumferential stiffener, sq. in.
d_x = Distance between logitudinal stiffeners, in.
d_y = Distance between circumferential stiffeners, in.
R = Mean radius of the vessel, in.
S = Allowable compressive stress, psi
t = Thickness of shell, in.
$t_x = t + \frac{A_x}{d_x}$ The equivalent thickness of the shell when longitudinally stiffened, in.
$t_y = t + \frac{A_y}{d_y}$ The equivalent thickness of the shell when circumferentially stiffened, in.

EXAMPLE

Given: R = 18 in.
t = 0.25 in.

Determine the allowable compressive stress (S)

$$S = \frac{1{,}500{,}000 \times t}{R} = \frac{1{,}500{,}000 \times 0.25}{18} = 20{,}833 \text{ psi}$$

Given: A_y = 1 sq. in.
d_y = 24 in.

Determine the allowable compressive stress (S) using stiffener rings

Longitudinal stiffener is not used, then:
$t_x = t = 0.25$ in.
$t_y = t + \frac{1}{24} =$
$= 0.25 + 0.04 = 0.29$

$$S = \frac{1{,}500{,}000}{R}\sqrt{t_y t_x} =$$

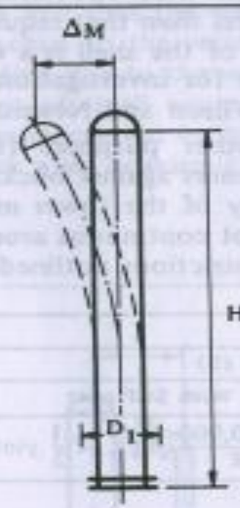
$$\frac{1{,}500{,}000}{18}\sqrt{0.25 \times 0.29} = 22{,}438 \text{ PSI}$$

Reference: Wilson, W. M., and Newmark N. M.: The Strength of Thin Cylindrical Shells as Columns, Eng. Exp. Sta. Univ. Ill. bull. 255, 1933.

Section VIII Div.1 Design

DEFLECTION

Towers should be designed to deflect no more than 6 inches per 100 feet of height. The deflection due to the wind load may be calculated by using the formula for uniformly loaded cantilever beam.



FORMULA

$$\Delta_M = \frac{P_w D_1 H (12H)^3}{8EI}$$

NOTATIONS

Δ_M = Maximum deflection (at the top), in.
D_1 = Width of the tower with insulation, etc. ft.
E = Modulus of elasticity, psi
H = Length of vessel, included skirt, ft.
I = $R^3\pi t$, moment of inertia for thin cylindrical shell (when $R > 10t$)
R = Mean radius of the tower, in.
t = Thickness of skirt, in.
P_w = Wind pressure, psf

EXAMPLE

Given:

D_1 = 2 ft., 6 in.
E = 30,000,000
H = 48 ft., 0 in.
I = $R^3 \pi$ 0.3125
P_w = 30 psf
R = 12 in.
t = 0.3125 in.

Determine the maximum deflection: Δ_M

$$\Delta_M = \frac{P_w D_1 H\,(12H)^3}{8EI}$$

$$\Delta_M = \frac{30 \times 2.5 \times 48\,(12 \times 48)^3}{8 \times 30{,}000{,}000 \times 12^3 \times 3.14 \times 0.3125} = 1.69 \text{ in.}$$

The maximum allowable deflection 6 inches per 100 ft. of height:

$$\text{for } 48'\text{-}0'' = \frac{48 \times 6}{100} = 2.88 \text{ in.}$$

Since the actual deflection does not exceed this limit, the designed thickness of the skirt is satisfactory.

COMBINATION OF STRESSES

The stresses induced by the previously described loadings shall be investigated in combination to establish the governing stresses.

Combination of wind load (or earthquake load), internal pressure and weight of the vessel:

Stress Condition	
At windward side	At leeward side
+ Stress due to wind	– Stress due to wind
+ Stress due to int. press.	+ Stress due to int. press.
– Stress due to weight	– Stress due to weight

Combination of wind load (or earthquake load), external pressure and weight of the vessel:

Stress Condition	
At windward side	At leeward side
+ Stress due to wind	– Stress due to wind
– Stress due to ext. press.	– Stress due to ext. press.
– Stress due to weight	– Stress due to weight

The positive signs denote tension and the negative signs denote compression. The summation of the stresses indicate whether tension or compression is governing.

It is assumed that wind and earthquake loads do not occur simultaneously, thus the tower should be designed for either wind or earthquake load whichever is greater.

Bending stress caused by excentricity shall be summarized with the stresses resulting from wind or earthquake load.

The stresses shall be calculated at the following locations:

1. At the bottom of the tower
2. At the joint of the skirt to the head
3. At the bottom head to the shell joint
4. At changes of diameter or thickness of the vessel

The stresses furthermore shall be examined in the following conditions:

1. During erection or dismantling
2. During test
3. During operation

Under these different conditions, the weight of the vessel and consequently, the stress conditions are also different. Besides, during erection or dismantling the vessel is not under internal or external pressure.

For analyzing the strength of tall towers under various loadings by this Handbook, the maximum stress theory has been applied.

COMBINATION OF STRESSES (cont.)

The bending moment due to wind is decreasing from the bottom to the top of the tower, thus the plate thickness can also be decreased accordingly.
Table A and Figure B are convenient aids to find the distance down from the top of the tower for which a certain thickness is adequate.

t_w/t_p	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7
m	1.0	0.91	0.84	0.79	0.74	0.71	0.67	0.64	0.62	0.60	0.58	0.56	0.54
t_w/t_p	1.8	1.9	2.0	2.2	2.4	2.6	2.8	3.0	3.3	3.6	4.0	4.5	5.0
m	0.53	0.51	0.50	0.48	0.46	0.44	0.42	0.41	0.39	0.37	0.35	0.33	0.32

TABLE A, VALUES OF FACTOR m

Since the longitudinal stress due to internal pressure is one half of the circumferential stress, one half of the required wall thickness for internal pressure is available to resist the bending force of the wind. From Table A, using factor m can be found the distance X down from the top tangent line within which the thickness calculated for internal pressure satisfactory also to resist the wind pressure.

$X = H \times m$

t_p = The required thickness for internal pressure (Hoop Tension) in.

t_w = The required thickness for wind pressure at the bottom head joint to shell, in.

EXAMPLE: t_p = 0.233 in., t_w = 0.644 in. t_w/t_p = 0.644/0.233 = 2.7

H = 100 ft.

From Table m = 0.43 and $X = mH = 0.43 \times 100$ = 43 ft.

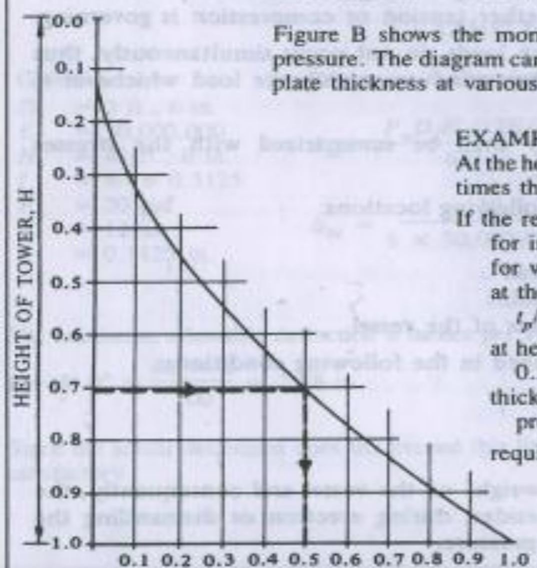


Fig. B

Ratio of plate thickness required at the bottom ($t_p/2 + t_w$) to thickness required at the considered height.

Figure B shows the moment diagram of a tower under wind pressure. The diagram can also be used to select the appropriate plate thickness at various heights.

EXAMPLE:
At the height of 0.71 H the required thickness is 0.5 times the thickness required at the bottom.

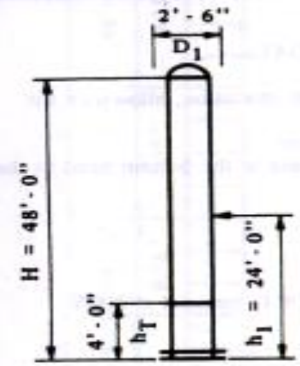
If the required thickness is:

for internal pressure, t_p = 0.250 in.
for wind load, t_w = 0.625 in.
at the bottom required
$t_p/2 + t_w$ = 0.750 in.
at height 0.71 H:
0.5 × 0.750 = 0.375 in.
thickness for internal pressure $t_p/2$ = 0.125 in.
required thickness at 0.71 H = 0.500 in.

DESIGN OF TALL TOWERS

EXAMPLE - A

Required thickness of cylindrical shell under internal pressure and wind load.



DESIGN CONDITIONS

D = 2 ft. 0 in. inside diameter of vessel
D_1 = 2 ft. 6 in. width of tower with insulation, etc.
E = 0.85 efficiency of welded joints
H = 48 ft. 0 in. length of tower
h_T = 4 ft. 0 in. distance from the base to the bottom head to shell joint
P = 250 psi internal pressure
P_w = 30 psf wind pressure
R = 12 in. inside radius of vessel
S = 15700 psi stress value of SA 285 C material at 200°F temperature
V = Total shear lb.

No allowance for corrosion.

Minimum required thickness for internal pressure considering the strength of the long seams:

$$t = \frac{PR}{SE - 0.6P} = \frac{250 \times 12}{15700 \times 0.85 - 0.6 \times 250} = \frac{3{,}000}{13{,}195} = 0.228 \text{ in.}$$

Minimum required thickness for internal pressure considering the strength of the girth seams:

$$t = \frac{PR}{2SE + 0.4P} = \frac{250 \times 12}{2 \times 15{,}700 \times 0.85 + 0.4 \times 250} = \frac{3{,}000}{26{,}790} = 0.112 \text{ in.}$$

Required thickness for longitudinal bending due to wind pressure. Moment at the base (M):

$$P_w \times D_1 \times H = V \times h_1 = M$$
$$30 \times 2.5 \times 48 = 3{,}600 \times 24 = 86{,}400 \text{ ft. lb.}$$

Moment at the bottom seam (M_T)

$$M_T = M - h_T (V - 0.5 P_w D_1 h_T) = 86{,}400 - 4 (3{,}600 - 0.5 \times 30 \times 2.5 \times 4)$$
$$= 86{,}400 - 13{,}800 = 72{,}600 \text{ ft. lb.} = 72{,}600 \times 12 = 871{,}200 \text{ in. lb.}$$

Required thickness:

$$t = \frac{M_T}{R^2 \pi SE} = \frac{871{,}200}{12^2 \times 3.14 \times 15{,}700 \times 0.85} = \frac{871{,}200}{6{,}037{,}135} = 0.145 \text{ in.}$$

The required thickness calculated with the strength of the bottom girth seam:

For wind pressure	0.145 in
For int. pressure	0.112 in.
TOTAL	0.254

This is greater than the thickness calculated with the strength of the longitudinal seam therefore, this minimum thickness 0.257 in. shall be used.

For simple vessels where the moment due to wind is small, the above calculation is satisfactory. Vessels which are subject to larger loadings may need closer investigation with respect also to economical viewpoints. See pages 76-84 for skirt, base and anchor bolt design.

Section VIII Div.1 Design

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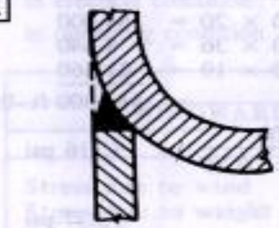
DESIGN OF SKIRT SUPPORT

A skirt is the most frequently used and the most satisfactory support for vertical vessels. It is attached by continuous welding to the head and usually the required size of this welding determines the thickness of the skirt.

Figures A and B show the most common type of skirt to head attachment. In the calculation of the required weld size, the values of joint efficiency given by the Code (UW12) may be used.

A



B

FORMULA

$$t = \frac{12\,M_T}{R^2\,\pi SE} + \frac{W}{D\,\pi SE}$$

NOTATIONS

D = Outside diameter of skirt, in.
E = Efficiency of skirt to head joint. (0.6 for butt weld, Fig. A, 0.45 for lap weld, Fig. B)
M_T = Moment at the skirt to head joint, ft. lb.
R = Outside radius of skirt, in.
S = Stress value of the head or skirt material whichever is smaller, psi.
t = Required thickness of skirt, in.
W = Weight of the tower above the skirt to the head joint, in operating condition.

NOTE: Using extremely high skirt, the stresses at the base may govern. To calculate the required thickness of the skirt, in this case the above formula can be used, considering the moment and weight at the base; $E = 1$.

EXAMPLE

Given the same vessel considered in Example B.

D = 37.5 in.
E = 0.60 for butt joint
M_T = 638,220 ft. lb.
R = 18.75 in.
S = 15,700 stress value of $SA-285-C$ plate
W = 31,000 lb.

Determine the required skirt thickness.

For wind: $t = \frac{12\,M_T}{R^2\,\pi SE} + \frac{12 \times 638{,}220}{18.75^2 \times 3.14 \times 15{,}700 \times 0.6} = 0.736$ in.

For weight: $t = \frac{W}{D \times 3.14 \times SE} = \frac{31{,}000}{3.75 \times 3.14 \times 15700 \times 0.6} = 0.028$ in.

TOTAL = 0.764 in.

Use 13/16" thick plate for skirt.

REFERENCES: Thermal stresses are discussed in these works:
Brownell, Lloyd E., and Young, Edwin H., "Process Equipment Design," John Wiley and Sons, Inc., 1959. Weil, N.A., and J. J. Murphy Design and Analysis of Welded Pressure Vessel Skirt Supports. Asme. Trans. Industrial Engineering for Industry, Vol. 82, Ser. B., Feb., 1960.

DESIGN OF ANCHOR BOLT

Vertical vessels, stacks and towers must be fastened to the concrete foundation, skid or other structural frame by means of anchor bolts and the base (bearing) ring.

The number of anchor bolts. The anchor bolts must be in multiple of four and for tall towers it is preferred to use minimum eight bolts.

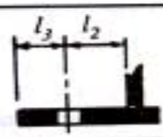
Spacing of anchor bolts. The strength of too closely spaced anchor bolts is not fully developed in concrete foundation. It is advisable to set the anchor bolts not closer than about 10 inches. To hold this minimum spacing, in the case of small diameter vessel the enlarging of the bolt circle may be necessary by using conical skirt or wider base ring with gussets.

Diameter of anchor bolts. Computing the required size of bolts the area within the root of the threads only can be taken into consideration. The root areas of bolts are shown below in Table A. For corrosion allowance one eighth of an inch should be added to the calculated diameter of anchor bolts.

For anchor bolts and base design on the following pages are described:

1. An approximate method which may be satisfactory in a number of cases.
2. A method which offers closer investigation when the loading conditions and other circumstances make it necessary.

TABLE A



Bolt Size	Bolt * Root Area sq. in.	Dimension in. l_2	Dimension in. l_3
1/2	0.126	7/8	5/8
5/8	0.202	1	3/4
3/4	0.302	1-1/8	13/16
7/8	0.419	1-1/4	15/16
1	0.551	1-3/8	1-1/16
1 1/8	0.693	1-1/2	1-1/8
1 1/4	0.890	1-3/4	1-1/4
1 3/8	1.054	1-7/8	1-3/8
1 1/2	1.294	2	1-1/2
1 5/8	1.515	2-1/8	1-5/8
1 3/4	1.744	2-1/4	1-3/4
1 7/8	2.049	2-3/8	1-7/8
2	2.300	2-1/2	2
2 1/4	3.020	2-3/4	2-1/4
2 1/2	3.715	3-1/16	2-3/8
2 3/4	4.618	3-3/8	2-5/8
3	5.621	3-5/8	2-7/8

* For bolts with standard threads.

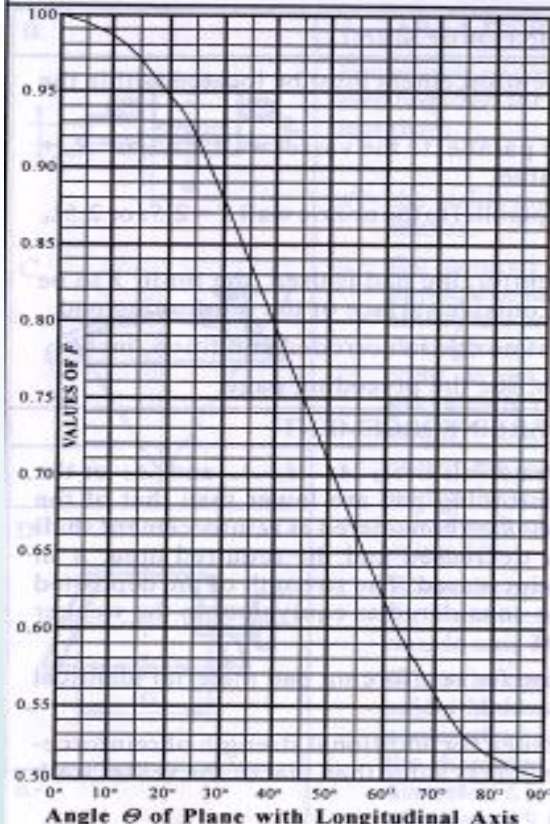
TABLE B
NUMBER OF ANCHOR BOLTS

Diameter of Bolt circle in.	Minimum	Maximum
24 to 36	4	4
42 to 54	8	8
60 to 78	12	12
84 to 102	12	16
108 to 126	16	20
132 to 144	20	24

TABLE C
MAXIMUM ALLOWABLE STRESSES FOR BOLTS USED AS ANCHOR BOLT

Specification Number	Diameter in.	Max. allow. Stress psi.
SA 307	All diameters	15,000
SA 193 B 7	2½ and under	19,000
SA 193 B16	2½ and under	17,000
SA 193 B 7	Over 2½ to 4 incl.	18,000
SA 193 B16	Over 2½ to 4 incl.	15,000

REINFORCEMENT FOR OPENINGS
DESIGN FOR INTERNAL PRESSURE
(continued)



Factor F - Fig. UG-37

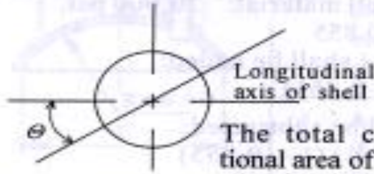
5. REINFORCEMENT IN DIFFERENT PLANES FOR INTERNAL PRESSURE

Since the circumferential stress in cylindrical shells and cones is two times greater than the longitudinal stress, at the opening the plane containing the axis of the shell is the plane of the greatest unit loading due to pressure. On the plane perpendicular to the vessel axis the unit loading is one half of this.

Chart shows the variation of the stresses on different planes. (Factor F)

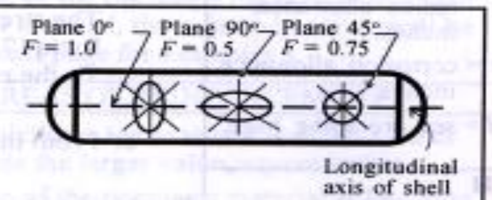
When the long dimension of an elliptical or obround opening exceeds twice the short dimensions, the reinforcement across the short dimensions shall be increased as necessary to provide against excessive distortion due to twisting moment. Code UG-36(a)(1).

Factor F shall not be less than 1.0, except for integrally reinforced openings in cylindrical shells and cones it may be less.



The total cross-sectional area of reinforcement in any planes shall be:

$$A = d \times t_r \times F$$



(Notations on preceeding pages.)

DESIGN FOR EXTERNAL PRESSURE

The reinforcement required for openings in a single-walled vessel subject to external pressure need be only 50 percent of that required for internal pressure where t_r is the wall thickness required by the rules for vessels under external pressure. Code UG-37(d)(1).

$$A = \frac{d \times t_r \times F}{2}$$

(See Notations on preceeding pages.)

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Section VIII Div.1 Table UW-12

- حداکثر ضریب اتصال برای جوشکاری قوسی وگاز

TABLE UW-12
MAXIMUM ALLOWABLE JOINT EFFICIENCIES[1,5] FOR ARC AND GAS WELDED JOINTS

Type No.	Joint Description	Limitations	Joint Category	Degree of Radiographic Examination (a) Full[2]	(b) Spot[3]	(c) None
(1)	Butt joints as attained by double-welding or by other means which will obain the same quality of deposited weld metal on the inside and outside weld surfaces to agree with the requirements of UW-35. Welds using metal backing strips which remain in place are excluded.	None	A, B, C, & D	1.00	0.85	0.70
(2)	Single-welded butt joint with backing strip other than those included under (1)	*(a)* None except as in (b) below	A, B, C, & D	0.90	0.80	0.65
		(b) Circumferential butt joints with one plate offset; see UW-13(b)(4) and Fig. UW-13.1, sketch (k)	A, B, & C	0.90	0.80	0.65
(3)	Single-welded butt joint without use of backing strip	Circumferential butt joints only, not over 5/8 in. (16 mm) thick and not over 24 in. (610 mm) outside diameter	A, B, & C	NA	NA	0.60
(4)	Double full fillet lap joint	*(a)* Longitudinal joints not over 3/8 in. (10 mm) thick	A	NA	NA	0.55
		(b) Circumferential joints not over 5/8 in. (16 mm) thick	B & C[4]	NA	NA	0.55
(5)	Single full fillet lap joints with plug welds conforming to UW-17	*(a)* Circumferential joints[4] for attachment of heads not over 24 in. (610 mm) outside diameter to shells not over 1/2 in. (13 mm) thick	B	NA	NA	0.50
		(b) Circumferential joints for the attachment to shells of jackets not over 5/8 in. (16 mm) in nominal thickness where the distance from the center of the plug weld to the edge of the plate is not less than 1 1/2 times the diameter of the hole for the plug.	C	NA	NA	0.50

Section VIII Div.1 Table UW-12

- حداکثر ضریب اتصال برای جوشکاری قوسی وگاز(ادامه)

A02

TABLE UW-12
MAXIMUM ALLOWABLE JOINT EFFICIENCIES[1,5] FOR ARC AND GAS WELDED JOINTS (CONT'D)

				Degree of Radiographic Examination		
Type No.	Joint Description	Limitations	Joint Category	(a) Full[2]	(b) Spot[3]	(c) None
(6)	Single full fillet lap joints without plug welds	*(a)* For the attachment of heads convex to pressure to shells not over 5/8 in. (16 mm) required thickness, only with use of fillet weld on inside of shell; or	A & B	NA	NA	0.45
		(b) for attachment of heads having pressure on either side, to shells not over 24 in. (610 mm) inside diameter and not over 1/4 in. (6 mm) required thickness with fillet weld on outside of head flange only	A & B	NA	NA	0.45
(7)	Corner joints, full penetration, partial penetration, and/or fillet welded	As limited by Fig. UW-13.2 and Fig UW-16.1	C[7] & D[7]	NA	NA	NA
(8)	Angle joints	Design per U-2(g) for Category B and C joints	B, C, & D	NA	NA	NA

NOTES:
(1) The single factor shown for each combination of joint category and degree of radiographic examination replaces both the stress reduction factor and the joint efficiency factor considerations previously used in this Division.
(2) See UW-12(a) and UW-51.
(3) See UW-12(b) and UW-52.
(4) Joints attaching hemispherical heads to shells are excluded.
(5) E = 1.0 for butt joints in compression.
(6) For Type No. 4 Category C joint, limitation not applicable for bolted flange connections.
(7) There is no joint efficiency E in the design formulas of this Division for Category C and D corner joints. When needed, a value of E not greater than 1.00 may be used.

Section VIII Div.1 Table UW-12

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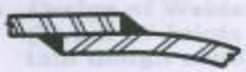
TYPES OF WELDED JOINTS

TYPES CODE UW-12		JOINT EFFICIENCY, E When the Joint:		
		a. Fully Radio-graphed	b. Spot Examined	c. Not Examined
1 	Butt joints as attained by double-welding or by other means which will obtain the same quality of deposited weld metal on the inside and outside weld surface. Backing strip if used shall be removed after completion of weld.	1.00	0.85	0.70
2  For circumferential joint only	Single-welded butt joint with backing strip which remains in place after welding	0.90	0.80	0.65
3 	Single-welded butt joint without use of backing strip	–	–	0.60
4 	Double-full fillet lap joint	–	–	0.55
5 	Single-full fillet lap joint with plug welds	–	–	0.50
6 	Single full fillet lap joint without plug welds	–	–	0.45

- حداکثر ضریب اتصال در جوشکاری قوسی وگاز

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Special Service Requirements

- **سیال سمی UW-2(a)**
  - اتصال سر به سر با نفوذ کامل
  - تنش زدایی برای فولادهای کربنی و کم آلیاژی
  - پرتو نگاری ۱۰۰٪ از جوشهای سر به سر
- **بهره برداری با دماهای پایین UW-2(b)**
  - درزهای اتصال مخصوص
  - برای محدودیت دما به UCS رجوع شود.
- **دیگهای بخار غیر آتش خوار UW-2(c)**
  - درزهای اتصال مخصوص
  - تنش برای فولادهای کربنی و کم آلیاژی
  - پرتو نگاری ۱۰۰٪ از جوشهای سر به سر
- **مخازنی که مستقیماً در معرض شعله قرار دارند UW-2(d)**
  - درزهای اتصال مخصوص
  - تنش زدایی برای فولادهای کربنی وکم آلیاژی
  - دمای طراحی حداقل باید معادل دمای سطح فلز بدنه باشد

Section VIII Div.1 Design

UW-2 Service Restriction

▪سیال سمی(ادامه)

–(a)اگر مخازن محتوی سیال سمی باشند...درزهای اتصالbutt باید۱۰۰٪ پرتونگاری شوند،مگر آنکه از بند های UW-2(a)(2) و UW-2(a)(3)و UW-11(a)(4) پیروی شود.

–مخازنی که با فولادهای کربنی یا کم آلیاژی ساخته شوند باید تنش زدایی گردند.

–طبق UCI-2وUCD-2در مخازن محتوی سیال سمی نمی توان از چدن خاکستری یا چدن ضربه خور استفاده کرد.

۱) از انواع درزهای اتصال (UW-3)به این شرح باید استفاده کرد:

- درزهای اتصال Category Aباید از نوع شماره(۱) جدول UW-12 باشند.
- درزهای اتصال Categories B&Cباید از نوع شماره (۱)یا(۲) باشند.
- تمام درزهای اتصال Category C در موارد fabricated lap joint stub ends باید طبق شکل UW-13.5 باشند.
- تمام درزهای اتصال Category Dباید نفوذ کامل داشته باشند.

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UW-2 Service Restriction

- سیال سمی(ادامه)

2) آزمایش پرتو نگاری درز جوش لوله و تیوپ ها در مبدل های حرارتی لازم است.

3) اگر فقط یک طرف مبدل حاوی سیال سمی باشد،در ساخت سمت دیگر آن نیازی نیست که از ملاحظات سیال سمی پیروی شود.

❖ منظور از سیال سمی هر نوع گاز یا مایعی است که مقدار کمی از آن برای انسان خطرناک باشد.

Section VIII Division 1

- مقدمه
- معرفی Sec. VIII Div.1
  - مسئولیت سازندگان
  - محدوده تحت پوشش Sec. VIII Div.1
- مواد
- طراحی
  - حداکثر فشارکاری مجاز(MAWP)و حداقل دمای طراحی فلز(MDMT)
  - درزهای اتصال،انواع جوش و طبقه بندی آن
  - شرایط خاص سیال
  - Openings

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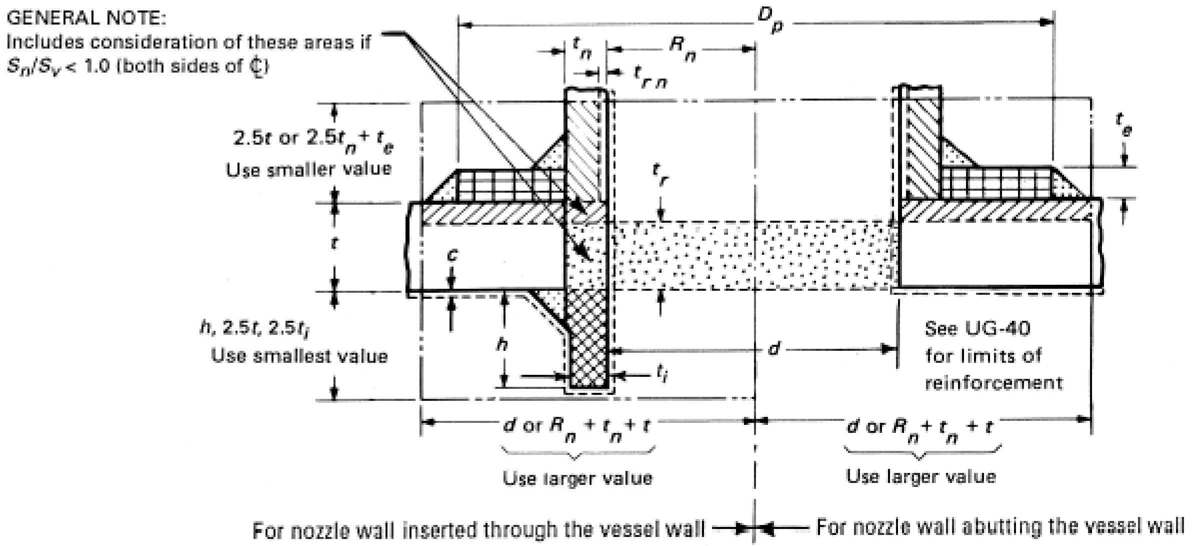
Section VIII Div.1 Design

UG-36 Opening & Reinforcments



Without Reinforcing Element

(dotted) = A	$= d\,t_r\,F + 2t_n\,t_r\,F(1 - f_{r1})$	Area required
(hatched) = A_1	$= d(E_1\,t - Ft_r) - 2t_n\,(E_1 t - Ft_r)\,(1 - f_{r1})$ $= 2(t + t_n)(E_1 t - Ft_r) - 2t_n(E_1 t - Ft_r)(1 - f_{r1})$	Area available in shell; use larger value
(reverse hatched) = A_2	$= 5(t_n - t_{rn})\,f_{r2}t$ $= 5(t_n - t_{rn})\,f_{r2}t_n$	Area available in nozzle projecting outward; use smaller value
(cross-hatched) = A_3	$= 5t\,t_i\,f_{r2}$ $= 5t_i\,t_i\,f_{r2}$ $= 2h\,t_i\,f_{r2}$	Area available in inward nozzle; use smallest value

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$= A_{41}$ = outward nozzle weld $= (\text{leg})^2 f_{r2}$	Area available in outward weld
$= A_{43}$ = inward nozzle weld $= (\text{leg})^2 f_{r2}$	Area available in inward weld
If $A_1 + A_2 + A_3 + A_{41} + A_{43} \geq A$	Opening is adequately reinforced
If $A_1 + A_2 + A_3 + A_{41} + A_{43} < A$	Opening is not adequately reinforced so reinforcing elements must be added and/or thicknesses must be increased

With Reinforcing Element Added

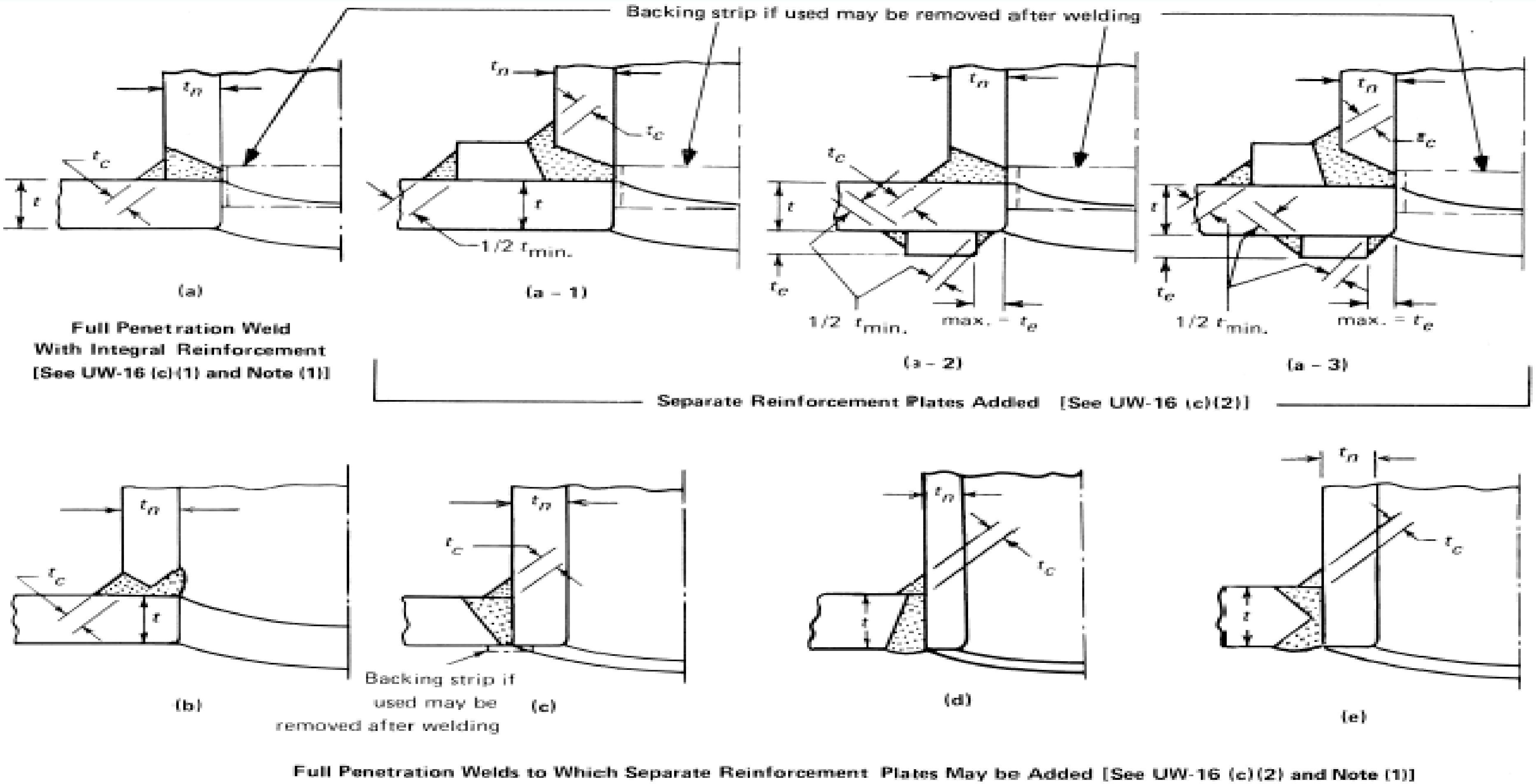
A = same as A, above	Area required
A_1 = same as A_1, above	Area available
$A_2 \begin{cases} = 5(t_n - t_{rn}) f_{r2} t \\ = 2(t_n - t_{rn})(2.5t_n + t_e) f_{r2} \end{cases}$	Area available in nozzle projecting outward: use smaller area
A_3 = same as A_3, above	Area available in inward nozzle
$= A_{41}$ = outward nozzle weld $= (\text{leg})^2 f_{r3}$	Area available in outward weld
$= A_{42}$ = outer element weld $= (\text{leg})^2 f_{r4}$	Area available in outer weld
$= A_{43}$ = inward nozzle weld $= (\text{leg})^2 f_{r2}$	Area available in inward weld
$= A_5 = (D_p - d - 2t_n) t_e \; f_{r4}$ [Note (1)]	Area available in element
If $A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5 \geq A$	Opening is adequately reinforced

NOTE:
(1) This formula is applicable for a rectangular cross-sectional element that falls within the limits of reinforcement.

FIG. UG-37.1 NOMENCLATURE AND FORMULAS FOR REINFORCED OPENINGS
(This Figure Illustrates a Common Nozzle Configuration and Is Not Intended to Prohibit Other Configurations Permitted by the Code.)

Section VIII Div.1 Design

UG-36 Opening & Reinforcments



Notes follow on last page of this Figure

FIG. UW-16.1 SOME ACCEPTABLE TYPES OF WELDED NOZZLES AND OTHER CONNECTIONS TO SHELLS, HEADS, ETC.