

# PRESSURE VESSEL DESIGN COURSE BASED ON ASME SEC. VIII DIV. I

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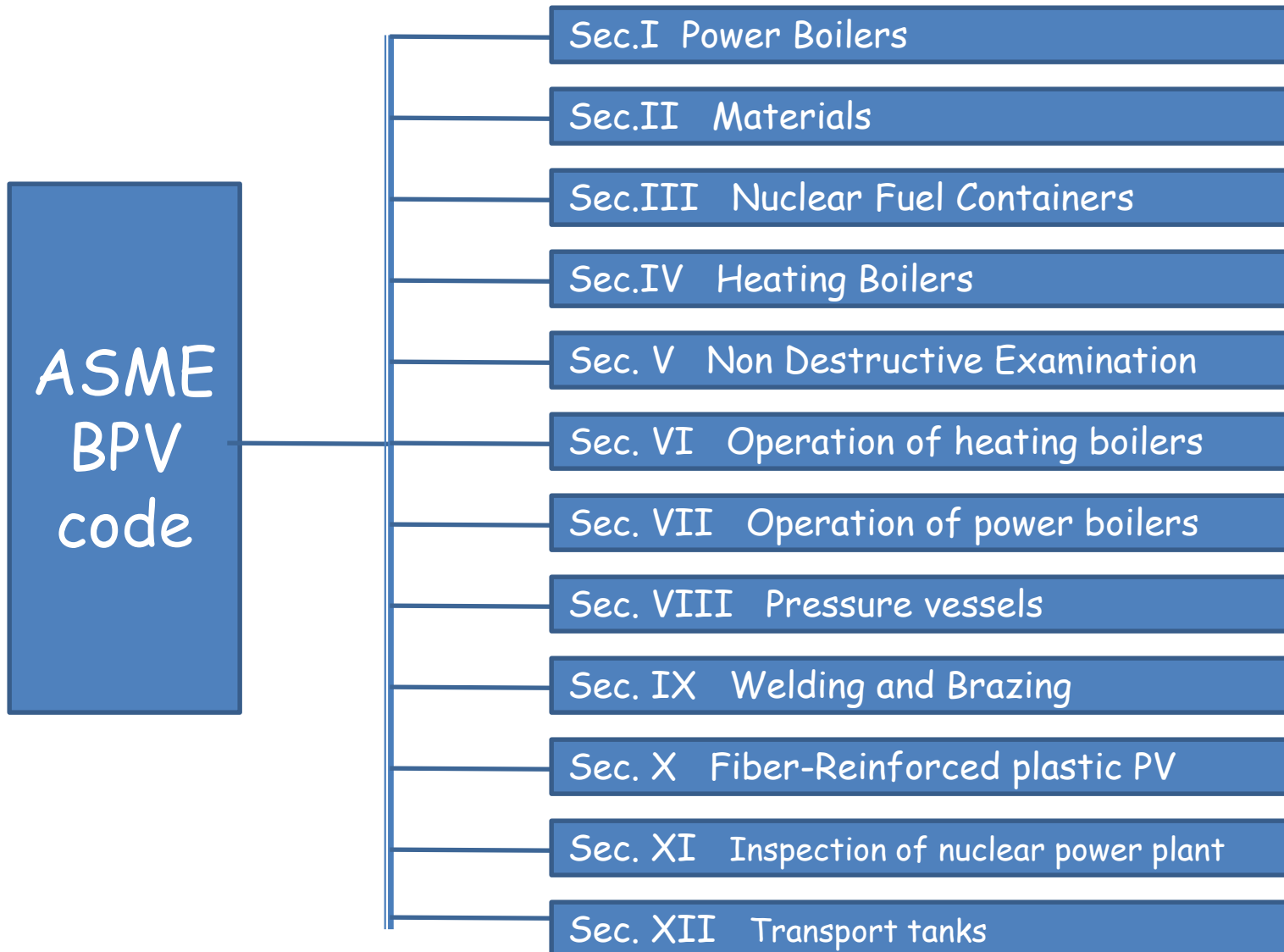
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# Pressure vessel Course

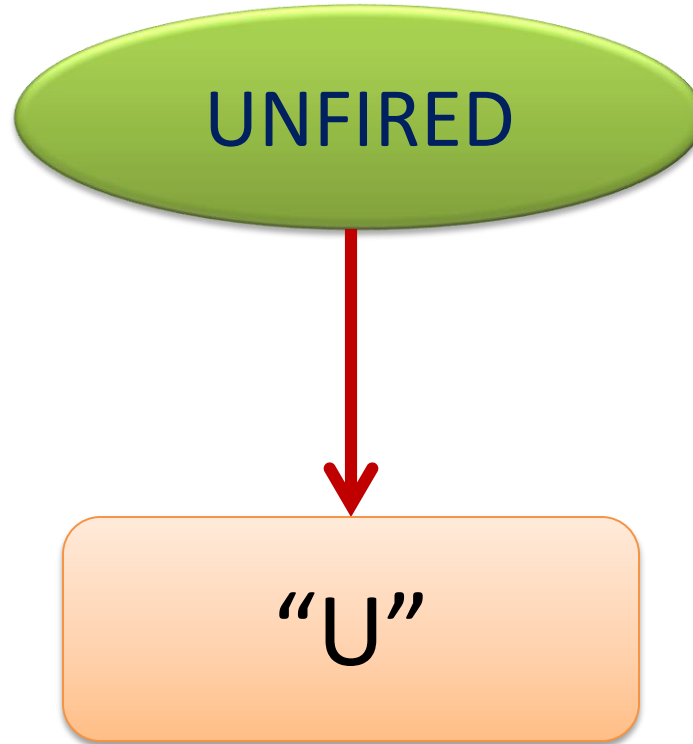
- What will we have during this course?
  1. INTRODUCTION TO ASME CODE
  2. GENERAL REQUIREMENTS
  3. MATERIAL REQUIREMENTS
  4. GENERAL DESIGN REQUIREMENTS
  5. DESIGN FOR INTERNAL PRESSURE
  6. DESIGN FOR BUCKLING
  7. DESIGN OF FLAT HEADS & COVERS
  8. DESIGN OF OPENINGS
  9. REQUIREMENTS FOR VESSELS FABRICATED BY WELDING
  10. REQUIREMENTS FOR CARBON & LOW ALLOY STEELS
  11. REQUIREMENTS FOR HIGH ALLOY STEELS
  12. CODE APPENDICES
  13. EXAMPLE PROBLEMS



# Pressure vessel Course

- **COMPARSION OF PRESSURE VESSEL CODES:**
- Div. I UP TO 3000 PSI : DESIGN BY FORMULA
- Div. II UP TO 10000 PSI: ALTERNATIVE RULES (BASED ON ANALYSIS)
- Div III FOR MORE THAN 10000 PSI: ALTERNATIVE RULES FOR CONSTRUCTION OF HIGH PRESSURE VESSELS (BASED ON ANALYSIS)

# Pressure vessel Course



# Pressure vessel Course

- **IMPORTANT NOTES :**

For the scope of this Division, pressure vessels are containers for the containment of pressure, either internal or external. This pressure may be obtained from an external source, or by the application of heat from a direct or indirect source, or any combination thereof.

# Pressure vessel Course

- **IMPORTANT NOTES :**
- Code rules do not address deterioration due to Service
- Code is not a design handbook. Engineering judgment must be exercised
- Code does not address all aspects
- Code does not prohibit the use of computer programs
- Code does not deal with care and inspection
- Code does not approve or endorse proprietary items
- Revisions become mandatory six months after publication
- Code Cases become effective on approval

# Pressure vessel Course

- **IMPORTANT NOTES :**

The Authorized Inspector (A.I.) has certain duties, including:

- Make a II the inspections specified by the Code
- Monitor the quality control and NDE performed by the Manufacturer
- Verify that calculations have been made
- Witness over-pressure test
- Authorize the application of Code symbol and witness name plate attachment
- Sign the Data report



# Pressure vessel Course

- Contents of ASME Section VIII, Div.1
  - Subsection A : *General Requirements (UG)*
  - Subsection B : *Methods of Fabrication (UW, UF, UB)*
  - Subsection C : *Classes of Materials (UCS, UHA, ...)* and Part UHX
  - *Mandatory Appendices*
  - *Non-mandatory Appendices*

# Pressure vessel Course

- SCOPE OF SECTION ASME Section VIII, Div.1 (U-1)

Following classes of vessels are not included in the scope of this Division:

(-a) those within the scope of other Sections;

(-b) fired process tubular heaters;

(-c) pressure containers which are integral parts

or components of rotating or reciprocating mechanical

devices, such as pumps, compressors

(-d) structures whose primary function is the transport of fluids from one location to another within a system of which it is an integral part, that is, pipng systems;

(-e) piping components

# Pressure vessel Course

- SCOPE OF SECTION ASME Section VIII, Div.1 (U-1)

(-f) a vessel for containing water<sup>1</sup> under pressure, including those containing air the compression of which serves only as a cushion, when none of the following limitations are exceeded:

(-1) a design pressure of 300 psi (2 MPa);

(-2) a design temperature of 210°F (99°C);

(-g) a hot water supply storage tank

(-h) vessels not exceeding the design pressure (see 3-2), at the top of the vessel, limitations below, with no limitation on size [see UG-28(f), 9-1(c)]:

(-1) vessels having an internal or external pressure not exceeding 15 psi (100 kPa);

(-2) combination units having an internal or external pressure in each chamber not exceeding 15 psi (100 kPa) and differential pressure on the common elements not exceeding 15 psi (100 kPa) [see UG-19(a)];

# Pressure vessel Course

- SCOPE OF SECTION ASME Section VIII, Div.1 (U-1)

(-i) vessels having an inside diameter, width,height, or cross section diagonal not exceeding 6 in.(152 mm), with no limitation on length of vessel or pressure;

(-j) pressure vessels for human occupancy

# Pressure vessel Course

- SCOPE OF SECTION ASME Section VIII, Div.1 (U-1)
  - ❖ The rules of this Division have been formulated on the basis of design principles and construction practices applicable to vessels designed for pressures not exceeding 3,000 psi

# INTRODUCTION

## DESIGN REFERENCES:

- **CODE:**

- ✓ ASME BPV-SEC. VIII, DIV. I
- ✓ ASME BPV-SEC. II

- **SPECIFICATIONS:**

- ✓ Contractor or Owner specifications such as Foster wheeler company design manual, IPS std., NIOC std. and...



## SCOPE (U-1)

(e) In relation to the geometry of pressure containing parts, the scope of this Division shall include the following:

(1) where external piping; other pressure vessels including heat exchangers; or mechanical devices, such as pumps, mixers, or compressors, are to be connected to the vessel:

(-a) the welding end connection for the first circumferential joint for welded connections [see UW-13(h)];

(-b) the first threaded joint for screwed connections;

(-c) the face of the first flange for bolted, flanged connections;

(-d) the first sealing surface for proprietary connections or fittings;

(2) Nonpressure parts

(3) pressure retaining covers for vessel openings, such as manhole or handhole covers, and bolted covers with their attaching bolting and nuts;

(4) fittings



## SCOPE (U-1)

- (f) The scope of the Division includes provisions for pressure relief devices
- (g) Vessels That Generate Steam
- (h) Pressure vessels or parts subject to direct firing from the combustion of fuel (solid, liquid, or gaseous), which are not within the scope of Sections I, III, or IV may be constructed in accordance with the rules of this Division
- (i) Gas fired jacketed steam

# GENERAL (U-2)

- Designer shall establish the design requirements for pressure vessels, taking into consideration factors:
  - NORMAL OPERATION
  - CONDITIONS AS STARTUP
  - CONDITIONS AS SHUTDOWN
  - ABNORMAL CONDITIONS WHICH MAY BECOME A GOVERNING DESIGN CONSIDERATION

# RESPONSIBILITIES (U-2)

- **Manufacturer :**
- The preparation and accuracy of design calculations
- Signature on the Manufacturer's Data Report Form
- Shall be available for the Inspector's review
- Ensure that all work so performed complies with all the applicable requirements of this Division



# RESPONSIBILITIES (U-2)

## (e) Inspector:

- ❖ Make all of the inspections specified by the rules of this Division
- ❖ Monitor the quality control and the examinations made by the Manufacturer
- ❖ Other inspections as in his judgment are necessary
- ❖ certification that the vessel has been designed and constructed in accordance with the minimum requirements
- ❖ Verifying that the applicable design calculations have been made

ANY QUESTIONS CONCERNING THE CALCULATIONS RAISED BY THE INSPECTOR MUST BE RESOLVED. SEE UG-90(C)(1).



(g) This Division of Section VIII does **not** contain rules to cover **all details of design and construction**. Where complete details are not given, it is intended that the **Manufacturer**, subject to the acceptance of the Inspector, **shall provide details of design and construction** which will be as **safe** as those provided by the rules of this Division.

# U-3 STANDARDS REFERENCED BY THIS DIVISION

Table U-3.

Year of Acceptable Edition of Referenced Standards in This Division			
Title	Number	Year	Note
Seat Tightness of Pressure Relief Valves	API Std. 527	1991 (R2007)	[Note (1)]
Unified Inch Screw Threads (UN and UNR Thread Form)	ASME B1.1	Latest edition	
Pipe Threads, General Purpose (Inch)	ANSI/ASME B1.20.1	Latest edition	
Cast Iron Pipe Flanges and Flanged Fittings, Classes 25, 125, and 250	ASME B16.1	2010	
Pipe Flanges and Flanged Fittings, NPS ½ Through NPS 24 Metric/Inch Standard Factory-Made Wrought Buttwelding Fittings	ASME B16.5	2013 [Note (2)]	
Forged Fittings, Socket-Welding and Threaded	ASME B16.9	Latest edition	
Cast Copper Alloy Threaded Fittings, Classes 125 and 250	ASME B16.11	Latest edition	
Metallic Gaskets for Pipe Flanges — Ring-Joint, Spiral-Wound, and Jacketed	ASME B16.15	Latest edition	
Cast Copper Alloy Pipe Flanges and Flanged Fittings, Class 150, 300, 600, 900, 1500, and 2500	ASME B16.20	Latest edition	
Ductile Iron Pipe Flanges and Flanged Fittings, Class 150 and 300	ASME B16.24	2011	
Large Diameter Steel Flanges, NPS 26 Through NPS 60 Metric/Inch Standard	ASME B16.42	2011	
Nuts for General Applications Machine Screw Nuts, Hex, Square, Hex Flange, and Coupling Nuts (Inch Series)	ASME B16.47	Latest edition	
Welded and Seamed, Wrought Steel Pipe	ASME B18.2.2	Latest edition	
Guidelines for Pressure Boundary Bolted Flange Joint Assembly	ASME B36.10M	Latest edition	
Repair of Pressure Equipment and Piping	ASME PCC-1	2013	
Pressure Relief Devices	ASME PCC-2	2011	
Qualifications for Authorized Inspection	ASME PTC 25	2014	
ASNT Central Certification Program	ASME QM-1	Latest edition [Note (3)]	
ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel	ASNT CP-189	Rev 7	
Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing	ASNT SNT-TC-1A	2006	
Standard Test Method for Flash Point by Tag Closed Tester	ASTM D56	Latest edition	
Standard Test Methods for Flash Point by Pensky-Martens Closed Cup Tester	ASTM D93	Latest edition	
Standard Guide for Preparation of Metallographic Specimens	ASTM E3	2001 (R2007)	
Pressure Relieving and Depressuring Systems	ANSI/API Std. S21	5th Ed., January 2007	
Standard Reference Photographs for Magnetic Particle Indications on Ferrous Castings	ASTM E125	1993 (R2008) [Note (1)]	
Standard Hardness Conversion Tables for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, and Scleroscope Hardness	ASTM E140	Latest edition	
Standard Reference Radiographs for Heavy-Walled (2 to 4½-in. (51 to 114-mm)) Steel Castings	ASTM E186	2010	
Standard Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels	ASTM E208	2006	
Standard Reference Radiographs for Heavy-Walled (4½ to 12-in. (114 to 305-mm)) Steel Castings	ASTM E280	2010	
Standard Reference Radiographs for Steel Castings up to 2 in. (51 mm) in Thickness	ASTM B46	2010	
Marking and Labeling Systems	ANSI/UL 969	Latest edition	
Metallic Materials — Charpy Pendulum Impact Test Part 1: Test Method	ISO 148-1	2009	
Metallic Materials — Charpy Pendulum Impact Test Part 2: Verification of Testing Machines	ISO 148-2	2008	
Metallic Materials — Charpy Pendulum Impact Test Part 3: Preparation and Characterization of Charpy V-Notch Test Pieces for Indirect Verification of Pendulum Impact Machines	ISO 148-3	2008	
<b>Metric Standards</b>			
Metric Screw Thread — M Profile	ASME B1.13M	Latest edition	
Metric Screw Thread — M Profile	ASME B1.21M	Latest edition	
Metric Heavy Hex Screws	ASME B18.2.3M	Latest edition	
Metric Hex Bolts	ASME B18.2.3.5M	Latest edition	
Metric Heavy Hex Bolts	ASME B18.2.3.6M	Latest edition	
Metric Fasteners for Use in Structural Applications	ASME B18.2.6M	Latest edition	
Standard Test Method for Compressive Strength of Carbon and Graphite	ASTM D695	1991	
Standard Terminology Relating to Manufactured Carbon and Graphite	ASTM C709	2009	

## U-5 TOLERANCES

The Code **does not** fully address **tolerances**. When dimensions, sizes, or other parameters are not specified with tolerances, the values of these parameters are considered NOMINAL, and allowable tolerances or local variances may be considered acceptable when based on **engineering judgment and standard practices** as determined by the DESIGNER.

## UG-4 Materials

(a) Material subject to stress due to pressure shall conform to one of the specifications given in *Section II, Part D*



**SECTION II**  
MATERIALS

**2015**

ASME Boiler and  
Pressure Vessel Code  
An International Code

**Part D**  
Properties (Customary)

<b>Subpart 1</b>	<b>Stress Tables</b> .....	1
	Statement of Policy on Information Provided in the Stress Tables .....	1
	Guideline on Locating Materials in Stress Tables, and in Tables of Mechanical and Physical Properties .....	2
<b>Subpart 2</b>	<b>Physical Properties Tables</b> .....	752
	Introduction .....	752
<b>Subpart 3</b>	<b>Charts and Tables for Determining Shell Thickness of Components Under External Pressure</b> .....	793
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<b>Mandatory Appendix 10</b>	<b>Basis for Establishing Maximum Allowable Stress Values for Tables 5A and 5B</b> .....	945
<b>Nonmandatory Appendix A</b>	<b>Issues Associated With Materials Used in ASME Code Construction</b> ...	947
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<b>Nonmandatory Appendix D</b>	<b>Guidelines for Rounding Minimum Specified Tensile and Yield Strength Values and for Establishing Anchor Points for Tensile and Yield Strength Trend Curves in Tables 1A, 1B, 2A, 2B, 3, 4, 5A, 5B, U, U-2, and Y-1</b> .....	973

## Section II, Part D

Table 1A

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graph TD; A([Table 1A]) --> B([Maximum Allowable Stress Values S for Ferrous Materials]);
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Maximum Allowable Stress  
Values S for Ferrous  
Materials

**Table 1A (Cont'd)**  
**Section I; Section III, Classes 2 and 3;\* Section VIII, Division 1; and Section XII**  
**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		Size/Thickness, in.	P-No.	Group No.
					Desig./UNS No.	Class/Condition/ Temper			
1	Carbon steel	Wld. pipe	SA-134	A283C	K02401 ...	...	...	1	1
2	Carbon steel	Plate	SA-283	C	K02401 ...	...	...	1	1
3	Carbon steel	Plate	SA-285	C	K02801 ...	...	...	1	1
4	Carbon steel	Smls. & wld. pipe	SA-333	1	K03008 ...	...	...	1	1
5	Carbon steel	Smls. & wld. tube	SA-334	1	K03008 ...	...	...	1	1
6	Carbon steel	Wld. tube	SA-334	1	K03008 ...	...	...	1	1
7	Carbon steel	Plate	SA-516	55	K01800 ...	...	...	1	1
8	Carbon steel	Smls. pipe	SA-524	II	K02104 ...	...	...	1	1
9	Carbon steel	Wld. pipe	SA-671	CA55	K02801 ...	...	...	1	1
10	Carbon steel	Wld. pipe	SA-671	CE55	K02202 ...	...	...	1	1
11	Carbon steel	Wld. pipe	SA-672	A55	K02801 ...	...	...	1	1
12	Carbon steel	Wld. pipe	SA-672	B55	K02001 ...	...	...	1	1
13	Carbon steel	Wld. pipe	SA-672	C55	K01800 ...	...	...	1	1
14	Carbon steel	Wld. pipe	SA-672	E55	K02202 ...	...	...	1	1
15	Carbon steel	Sheet	SA-414	C	K02503 ...	...	...	1	1
16	Carbon steel	Plate	SA/EN 10028-3	P275NH	...	...	≤2 <sup>1</sup> / <sub>4</sub>	1	1
17	Carbon steel	Bar	SA-36	...	K02600 ...	...	...	1	1

**Applicability and Max. Temperature Limits**

(NP = Not Permitted)

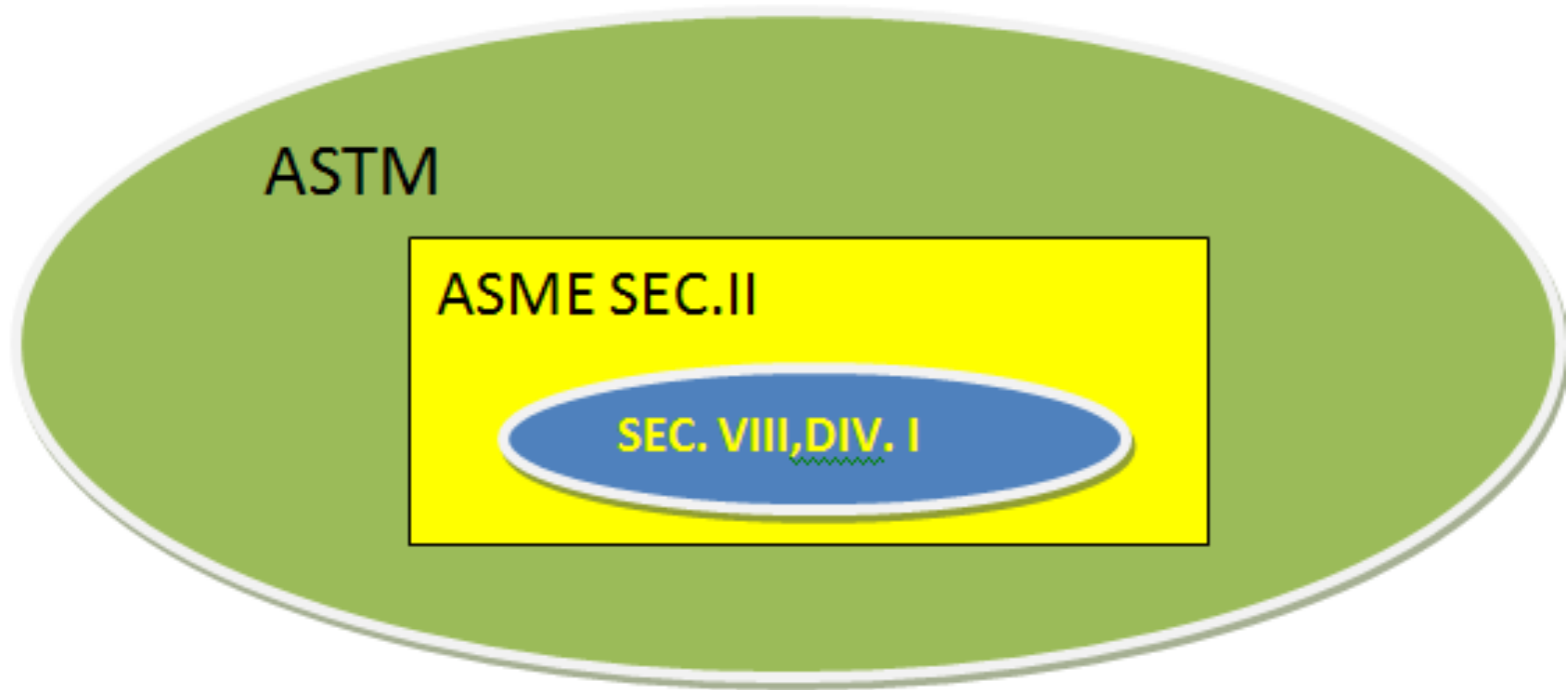
(SPT = Supports Only)

Line No.	Min. Tensile Strength, ksi	Min. Yield Strength, ksi	Applicability and Max. Temperature Limits				External Pressure Chart No.	Notes
			I	III	VIII-1	XII		
1	55	30	NP	300 (Cl. 3 only)	NP	NP	CS-2	W12
2	55	30	NP	300 (Cl. 3 only)	650	650	CS-2	...
3	55	30	900	700	900	650	CS-2	G10, S1, T2
4	55	30	NP	700	650	650	CS-2	W12, W14
5	55	30	NP	700	650	650	CS-2	W12, W14
6	55	30	NP	NP	650	650	CS-2	G24, W6
7	55	30	850	700	1000	650	CS-2	G10, S1, T2
8	55	30	NP	NP	1000	650	CS-2	G10, T2
9	55	30	NP	700	NP	NP	CS-2	S6, W10, W12
10	55	30	NP	700	NP	NP	CS-2	S6, W10, W12
11	55	30	NP	700	NP	NP	CS-2	S6, W10, W12
12	55	30	NP	700	NP	NP	CS-2	S6, W10, W12
13	55	30	NP	700	NP	NP	CS-2	S6, W10, W12
14	55	30	NP	700	NP	NP	CS-2	S6, W10, W12
15	55	33	NP	700	900	650	CS-2	G10, T1
16	56.5	...	NP	NP	400	400	CS-2	G10, G18
17	58	36	650	650 (SPT)	900	650	CS-2	G10, G15, T1
18	58	36	NP	700	650	650	CS-2	G9, G10, T1

**Maximum Allowable Stress, ksi (Multiply by 1000 to Obtain psi), for Metal Temperature, °F, Not Exceeding**

Line No.	-20													
	100	150	200	250	300	400	500	600	650	700	750	800	850	900
1	15.7	...	15.7	...	15.7	...	...	...	...	...	...	...	...	...
2	15.7	15.7	15.7	...	15.7	15.7	15.7	15.3	14.8	...	...	...	...	...
3	15.7	15.7	15.7	...	15.7	15.7	15.7	15.3	14.8	14.3	13.0	10.8	8.7	5.9
4	15.7	...	15.7	...	15.7	15.7	15.7	15.3	14.8	14.3	...	...	...	...
5	15.7	...	15.7	...	15.7	15.7	15.7	15.3	14.8	14.3	...	...	...	...
6	13.4	13.4	13.4	...	13.4	13.4	13.4	13.0	12.6	...	...	...	...	...
7	15.7	15.7	15.7	...	15.7	15.7	15.7	15.3	14.8	14.3	13.0	10.8	8.7	5.9
8	15.7	15.7	15.7	...	15.7	15.7	15.7	15.3	14.8	14.3	13.0	10.8	8.7	5.9
9	15.7	...	15.7	...	15.7	15.7	15.7	15.3	14.8	14.3	...	...	...	...
10	15.7	...	15.7	...	15.7	15.7	15.7	15.3	14.8	14.3	...	...	...	...
11	15.7	...	15.7	...	15.7	15.7	15.7	15.3	14.8	14.3	...	...	...	...
12	15.7	...	15.7	...	15.7	15.7	15.7	15.3	14.8	14.3	...	...	...	...
13	15.7	...	15.7	...	15.7	15.7	15.7	15.3	14.8	14.3	...	...	...	...
14	15.7	...	15.7	...	15.7	15.7	15.7	15.3	14.8	14.3	...	...	...	...
15	15.7	15.7	15.7	...	15.7	15.7	15.7	15.7	15.7	15.6	13.0	10.8	8.7	5.9
16	16.1	16.1	16.1	...	16.1	16.1	...	...	...	...	...	...	...	...
17	16.6	16.6	16.6	...	16.6	16.6	16.6	16.6	16.6	15.6	13.0	10.8	8.7	5.9
18	16.6	...	16.6	...	16.6	16.6	16.6	16.6	16.6	15.6	...	...	...	...
19	16.6	16.6	16.6	...	16.6	16.6	16.6	16.6	16.6	15.6	...	...	...	...
20	17.0	...	17.0	...	17.0	17.0	17.0	17.0	16.5	...	...	...	...	...
21	17.0	...	17.0	...	17.0	17.0	17.0	17.0	16.5	...	...	...	...	...
22	17.0	...	17.0	...	17.0	17.0	17.0	17.0	16.5	...	...	...	...	...

# UG-4 Materials





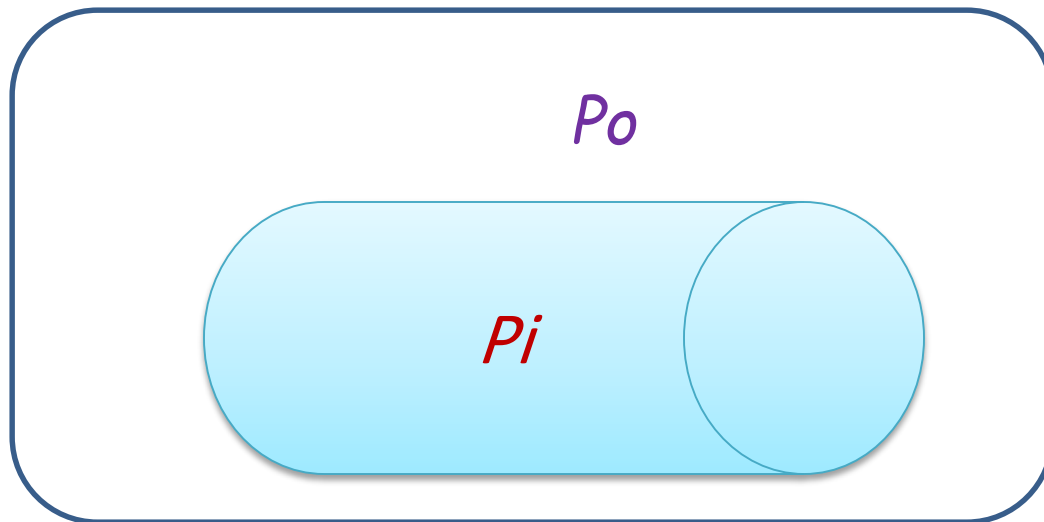
PRESSURE PARTS or NON PRESSURE PARTS



# UG-4 Materials

- Consider a vessel with an internal pressure  $p_i$  and external pressure  $p_o$  and

$P_i \neq P_o$  :



## UG-4 Materials

(b) Material for nonpressure parts, such as skirts, supports, baffles, lugs, clips, and extended heat transfer surfaces, need not conform to the specifications for the material to which they are attached or to a material specification permitted in this Division, but if attached to the vessel by welding shall be of weldable quality

# UG-4 Materials

The allowable stress values for material **not identified** in accordance with

UG-93 shall not exceed **80%** of the maximum allowable stress value

permitted for similar material in Subsection C.

**UG-93 ??**



## UG-93 a)

- Certificates or Material Test Reports
- Material specification
- Traceability to material specification and grade and type and class



KEY

POINTS

## UG-93 b)

- when some requirements of a material specification of Section II have been **completed by other** than the vessel Manufacturer shall obtain supplementary material test reports or certificates than the material manufacturer and the Inspector shall examine these documents



KEY

POINTS

## UG-93 c)

- When requirements or provisions of this Division applicable to materials exceed or supplement the requirements of the material specification of Section II, Manufacturer shall obtain supplementary material test reports or certificates than the material manufacturer and the Inspector shall examine these documents



**KEY**

**POINTS**

## UG-93 d)

- when requirements All materials to be used in constructing a pressure vessel shall be examined before fabrication for the purpose of detecting, as far as possible, imperfections which would affect the safety of the vessel



KEY

POINTS

## UG-93 (Summary)

The All pressure boundary materials have to be traceable to material documentation

- Materials should preferably be laid out so that original identification markings will be visible on vessel
- The Inspector has duty to inspect materials for proper identification
- Manufacturer responsible to maintain traceability and has the following options:
  - Transfer all markings to cut pieces
  - Use a coded system traceable to the original markings
  - Use as-built sketches to assure traceability



## UG-4 Materials

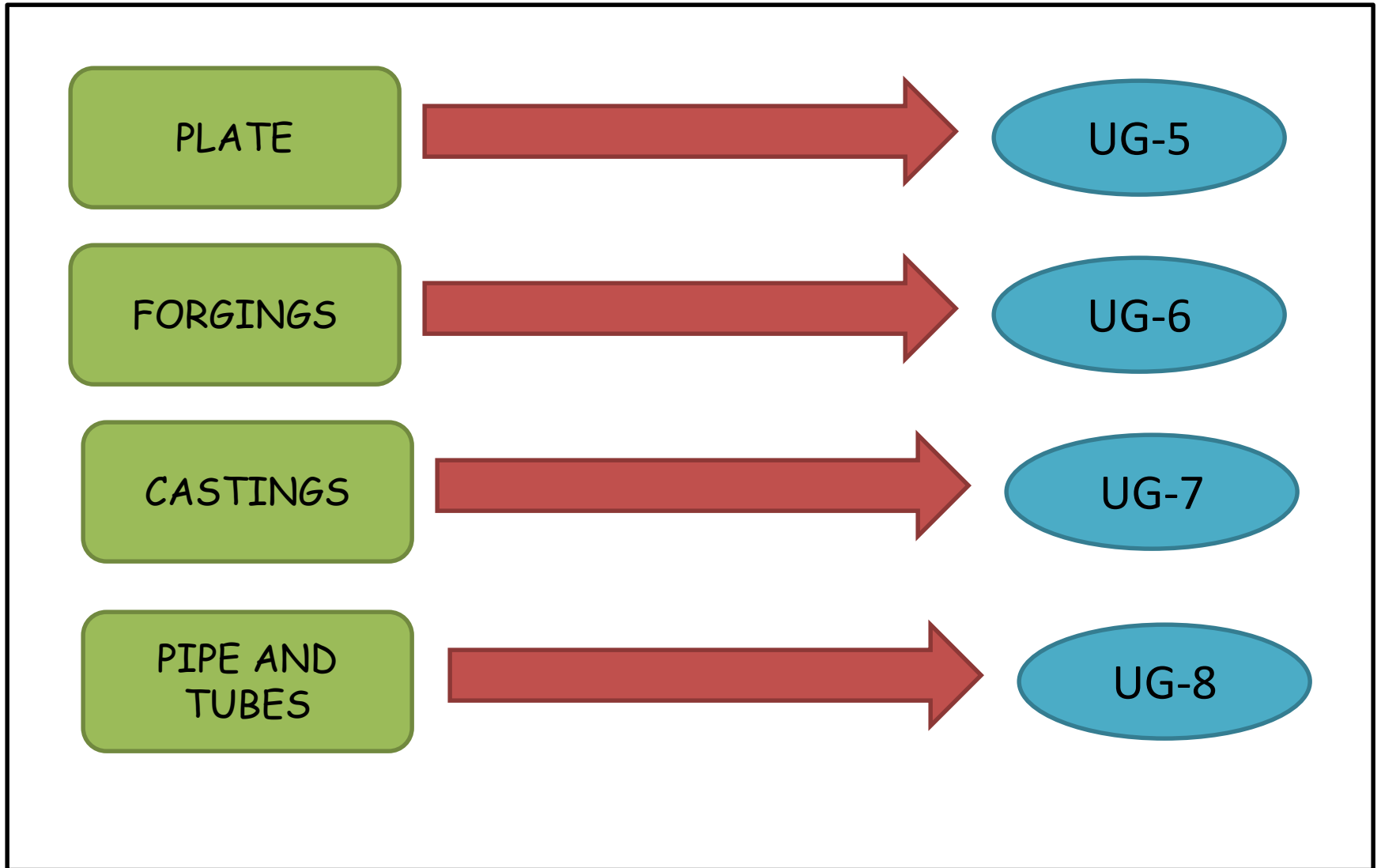
- (d) Materials other than those allowed by the rules of this Division shall not be used.
- (e) Materials outside the limits of size and/or thickness given in the title or scope clause of the specifications given in Section II, and permitted by the applicable part of Subsection C, may be used if the material is in compliance with the other requirements of the specification, and no size or thickness limitation is given in the stress tables. In those specifications in which chemical composition or mechanical properties vary with size or thickness, materials outside the range shall be required to conform to the composition and mechanical properties shown for the nearest specified range.
- (f) Service requirements to be considered by designer (corrosion, erosion, oxidation, and other deterioration during their intended service life)- See Section II, Part D, Non-mandatory Appendix A

## Case to Study!

(d) Respecting to clause UG-4 (f), Please do research about service requirements and following items:

- Sour service
- Lethal service
- H<sub>2</sub>s Service
- Toxic service
- HIC test
- SSC Test

# UG-5,6,7,8



## UG-5~8

- Materials Which are used for construction of pressure parts shall be confirm to one of specified specification in ASME SEC II.
- Allowable stress value are given in UG-23



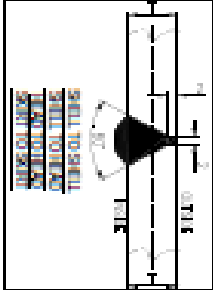
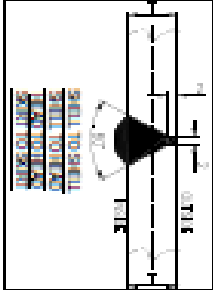
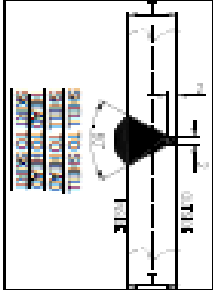
KEY

POINTS

# UG-9 WELDING MATERIALS

- Welding materials used for production shall comply with the requirements of this Division, those of Section IX, and the applicable qualified welding procedure specification.

# WELDING PROCEDURE SPECIFICATION (WPS)

WELDING PROCEDURE SPECIFICATION		PAGE: 1 OF 67	REV: 3
WPS NO.:	PWS-107	SUPPORT P./Q.R. NO.:	PQ-01/120
WELDING PROCESS:	SMAW	WELDING TYPE:	MANUAL
<b>BASE METAL (QW-403)</b>			
P NO.:	1	TO P NO.:	1
Q NO.:	1,2	TO Q NO.:	1,2
THICKNESS RANGE: 1.6-12 mm			
WELD METAL THICKNESS RANGE:			
WARRANTY INFORMATION			
SA-308 (SA-308), SA-316 TO SA-108 & SA-108 SA-324 (WB)			
OTHER: IMPACT TEST IS NOT REQUIRED			
<b>FILLER METAL (QW-404)</b>			
P NO.:	4	OTHERS:	4
Q NO.:	1	OTHERS:	1
SP. NO.:	E T	OTHERS:	E T
ANS. NO.:	E 7018	OTHERS:	E 7018
SIZE (mm):	3.25	OTHERS:	4
MANUFACTURER:	OSAKI	OTHERS:	12345
MANUFACTURER:	AAA	OTHERS:	AAA
SHAWING CONDITION:	300-350°C / 2hr	OTHERS:	300-350°C / 2hr
<b>FLUX (QW-404)</b>			
ELECTRODE-FLUX COMPARISON:			
PARAMETER TYPE AND SIZE CLASS:	NA		
BRAND NAME:			
MANUFACTURER:			
SHAWING CONDITION:			
<b>TECHNIQUE (QW-410)</b>			
STRESS OR HEAT TREATMENT:	NONE		
SPRUE CLEANING:	GRINDING		
INTER-PASS CLEANING:	GRINDING & BRUSHING		
METHOD OF BACK CLEANING:	GRINDING		
ELECTRODE NUMBER:	SINGLE		
WALL THICK. OF SINGLE PASS (PER SIDE):	MAX THICK.		
OTHER:			
<b>ELECTRICAL CHARACTERISTICS (QW-405)</b>			
PHASE:	WELDING	SIZE:	CURRENT
AC/DC:	(INV)	POLARITY:	CURRENT
WIRE FEED RATE:	3.25	AMPERE:	VOLTAGE
WIRE DIAMETER:	4	TYPE OF GAS:	(mm/min)
WIRE SPEED:	3.25	W. COMPOSITION:	(mm/min)
		SHAWING GAS:	(mm/min)
		FLOW RATE:	(mm/min)
		TRAILING SHAWING GAS COMPOSITION:	(mm/min)
		OTHER:	(mm/min)
<b>PREHEAT (QW-406)</b>			
PREHEAT TEMPERATURE:			
MINIMUM TO TEMP. MAXIMUM:			
PREHEAT MAINTENANCE:			
TEMPERATURE METHOD:			
OTHER:			
<b>PREHEAT (QW-407)</b>			
TEMPERATURE:			
TIME:			
OTHER:			
<b>GAS (QW-408)</b>			
TYPE OF GAS:			
W. COMPOSITION:			
SHAWING GAS:			
FLOW RATE:			
TRAILING SHAWING GAS COMPOSITION:			
OTHER:			
<b>JOINT DESIGN (QW-409)</b>			
SINGLE V GROOVE BUTT JOINT			
			
SHAWING: NO ROOT SPACING: max 2mm (ACC. TO DWG.) ROOT FACE: max 2mm POSITION (QW-409): 1 G POSITION OF GROOVE: 1 G WELD PROPOSITION: 1 G OTHER:			
<b>PREHEAT (QW-406)</b>			
PREHEAT TEMPERATURE:			
MINIMUM TO TEMP. MAXIMUM:			
PREHEAT MAINTENANCE:			
TEMPERATURE METHOD:			
OTHER:			
<b>PREHEAT (QW-407)</b>			
TEMPERATURE:			
TIME:			
OTHER:			
<b>GAS (QW-408)</b>			
TYPE OF GAS:			
W. COMPOSITION:			
SHAWING GAS:			
FLOW RATE:			
TRAILING SHAWING GAS COMPOSITION:			
OTHER:			
<b>JOINT DESIGN (QW-409)</b>			
SINGLE V GROOVE BUTT JOINT			
			
SHAWING: NO ROOT SPACING: max 2mm (ACC. TO DWG.) ROOT FACE: max 2mm POSITION (QW-409): 1 G POSITION OF GROOVE: 1 G WELD PROPOSITION: 1 G OTHER:			
<b>PREHEAT (QW-406)</b>			
PREHEAT TEMPERATURE:			
MINIMUM TO TEMP. MAXIMUM:			
PREHEAT MAINTENANCE:			
TEMPERATURE METHOD:			
OTHER:			
<b>PREHEAT (QW-407)</b>			
TEMPERATURE:			
TIME:			
OTHER:			
<b>GAS (QW-408)</b>			
TYPE OF GAS:			
W. COMPOSITION:			
SHAWING GAS:			
FLOW RATE:			
TRAILING SHAWING GAS COMPOSITION:			
OTHER:			
<b>JOINT DESIGN (QW-409)</b>			
SINGLE V GROOVE BUTT JOINT			
			
SHAWING: NO ROOT SPACING: max 2mm (ACC. TO DWG.) ROOT FACE: max 2mm POSITION (QW-409): 1 G POSITION OF GROOVE: 1 G WELD PROPOSITION: 1 G OTHER:			

NOTE: 1- The deposited weld bead width shall not be more than twice of electrode diameter.  
2-Excess speed

WELDING SEQUENCE: 1-Edge preparation, 2-Cleaning, 3-Assembly, 4-Back Chipping, 5-PT, 6-Non-Destructive Testing

- Material identified with or produced to a specification not permitted by this division, and material not fully identified
  - (a) Identified Material With Complete Certification From the Material Manufacturer
  - (b) Material Identified to a Particular Production Lot as Required by a Specification Permitted by This Division but Which Cannot Be Qualified Under (a).
  - (c) Material Not Fully Identified

(a) Identified Material With Complete Certification From the Material Manufacturer :

- Materials identified with a specification not permitted by this division
- Materials procured to chemical composition requirements

Could be recertify as per below conditions:

- 1) Recertification by an Organization Other Than the Vessel or Part Manufacturer
- 2) Recertification by the Vessel or Part Manufacturer



- 1- Recertification by an Organization Other Than the Vessel or Part Manufacturer
  - a) when all requirements such as melting method, melting practice and etc. was done as per the requirements of this code!
  - B) a copy of all documentation of material analysis is required which show the material has been prepared and purchased fully in accordance to requirements of this division.
  - C) certification that the material was manufactured and tested in accordance with the requirements of the specification to which the material is recertified
  - D) recertified and with the notation "Certified per UG-10."

## 2) Recertification by the Vessel or Part Manufacturer

- a) A copy of the certification by the material manufacturer of the chemical analysis required by the permitted specification, with documentation showing the requirements to which the material was produced and purchased, and which demonstrates that there is no conflict with the requirements of the permitted specification, is available to the Inspector.
- b) Mention the cautionary notes such as Maximum allowable stresses
- c) Documentation is available to the Inspector that demonstrates that the metallurgical structure, mechanical property, and hardness requirements of the permitted specification have been met.
- d) Other material structure operations should be available to the inspector
- e) Materials should be marked

(b) Material Identified to a Particular Production Lot as Required by a Specification Permitted by This Division but Which Cannot Be Qualified Under (a).

- (1) Recertification by an Organization Other Than the Vessel or Part Manufacturer.  
**Not permitted.**
- (2) Recertification by the Vessel or Part Manufacturer

(c) Material Not Fully Identified : should have following condition to be acceptable

(1) Qualification by an Organization Other Than the Vessel or Part Manufacturer.

**Not permitted.**

(2) Qualification by the Vessel or Part Manufacturer:

(-a) Each piece is tested to show that it meets the chemical composition for product analysis and the mechanical properties requirements of the permitted specification.

## UG-10 Summary

All materials must have valid certificate

Inspector shall check all documentation

Mechanical and chemical test should be done

Component analysis to be checked

# UG-12,13,14

BOLTS AND  
STUDS



UG-12

NUTS AND  
WASHERS



UG-13

RODS AND  
BARS



UG-14

# UG-16 (Design-General)

(b) Minimum Thickness (After Forming) of Pressure Retaining Components:

General



1.5 mm + C.A.

Unfired  
Steam boilers



6 mm + C.A.

Air, Water &  
Steam  
Service



2.5 mm + C.A.

## UG-16 (Design-General)

### Notes:

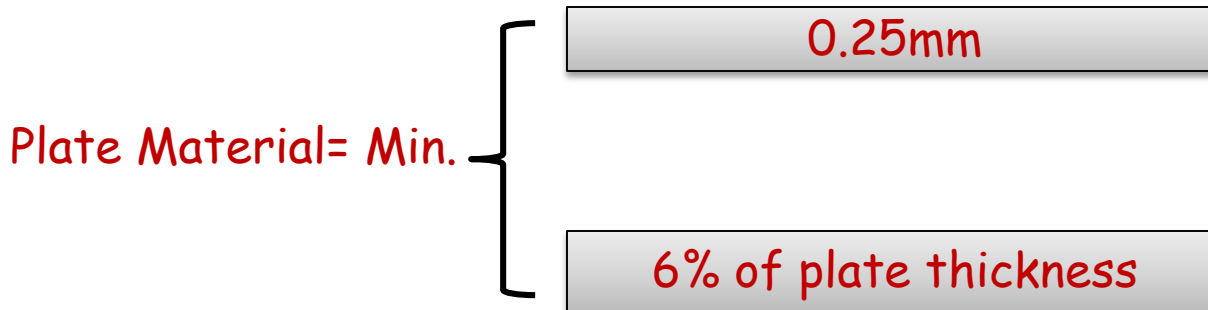
1. The minimum thickness does not apply to heat transfer plates of plate-type heat exchangers
2. this minimum thickness does not apply to the inner pipe of double pipe heat exchangers nor to pipes and tubes that are enclosed and protected from mechanical damage by a shell, casing, or ducting, where such pipes or tubes are NPS 6 (DN 150) and less.
3. This minimum thickness does not apply to the tubes in air cooled and cooling tower heat exchangers if all the following provisions are met:
  - (- a) Tubes shall not be used for lethal service applications
  - (- b) The Tubes shall be protected by fins or other mechanical means
  - (-c) the tube outside diameter shall be a minimum of 3/8 in. (10 mm) and a maximum of 1 1/2 in. (38 mm)
  - (-d) the minimum thickness used shall not be less than that calculated by the formulas given in UG-27 or 1-1 and in no case less than 0.022 in. (0.5 mm).



# UG-16 (Design-General)

(C) Mill Under tolerance:

1- Plate material shall be ordered not thinner than the design thickness



Pipe Material= 12.5 % of Nominal Thickness

(Minimum Thickness = Nominal Pipe thickness  $\times$  0.875)

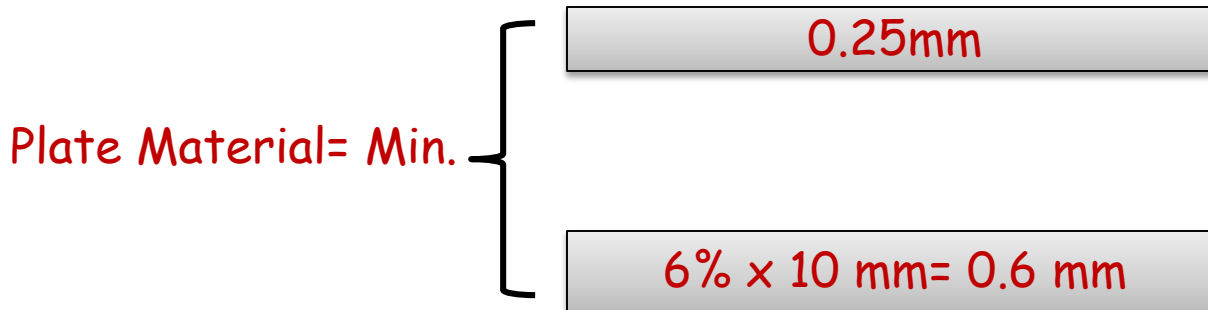
(e) Corrosion Allowance in Design Formulas:

Corrosion allowance to be added to all formulas

# UG-16 (Design-General)

## Example:

1- Plate material with nominal thickness of 10 mm



So, Minimum thickness with above mentioned ordered thickness is:  
 $10 - 0.25 = 9.75$  mm

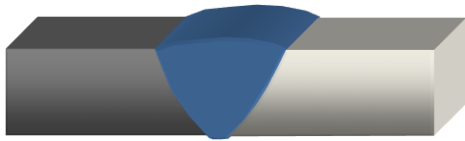
2- Pipe 10" sch. Std (Nominal thickness = 9.27mm) :

Minimum Thickness =  $9.27 \times 0.875 = 8.11$  mm

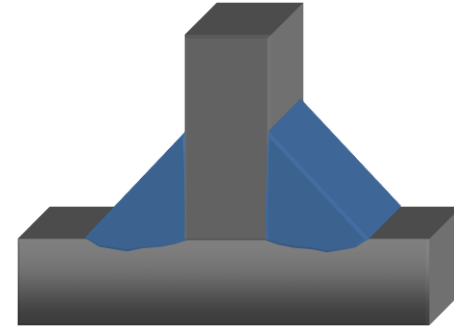
# WELDING

- According to AWS A2.4 we have following type of welds:
  1. GROOVE WELD (جوش شیارى)
  2. Fillet WELD (جوش نبشى)
  3. PLUG OR SLOT WELDS (جوش هاى دكمه اى)
  4. STUD WELDS (جوش هاى زائده اى)
  5. SPOT OR PROJECTION WELDS (جوش هاى نقطه اى)
  6. SEAM WELDS (جوش هاى نوارى)
  7. BACK OR BACKING WELDS (جوش هاى پشت بند)
  8. SURFACING WELDS (جوش هاى سطحى)
  9. EDGE WELDS (جوش هاى لبه اى)

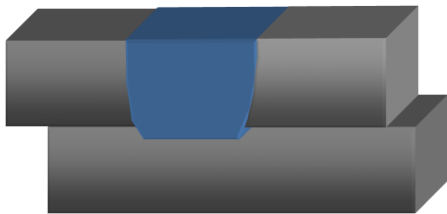
# WELDING



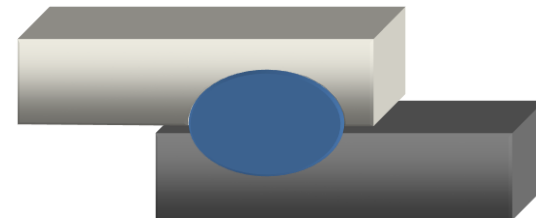
Groove



Fillet



Plug



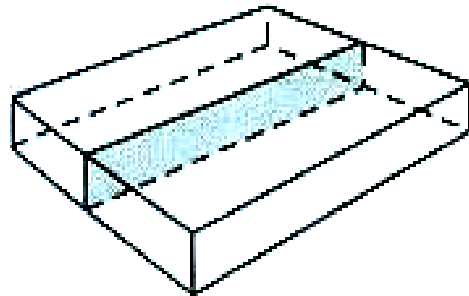
Spot

# WELDING

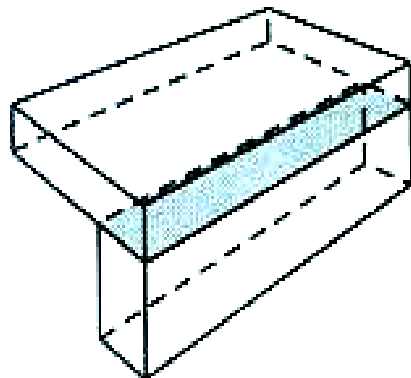
## TYPE OF JOINTS:

1. Butt joint (لب به لب)
2. Corner joint (گوشه ای)
3. T-joint (سپری)
4. Lap joint (لبه روی هم)
5. Edge joint (لبه ای)

# WELDING












(A) BUTT JOINT

















(B) CORNER JOINT

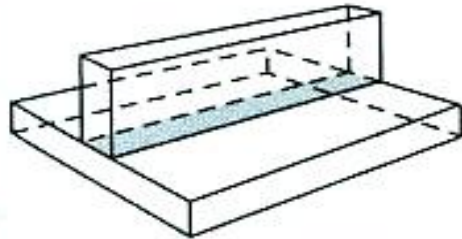
## APPLICABLE WELDS and WELD SYMBOL

	Bevel-Groove		U-Groove
	Flare-Bevel-Groove		V-Groove
	Flare-V-Groove		Edge Weld
	J-Groove		Scarf (for braze joint)
	Square-Groove		

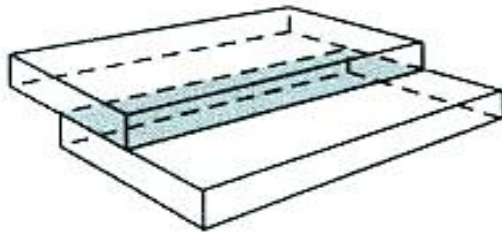
## APPLICABLE WELDS and WELD SYMBOL

	Fillet		Edge Weld
	Bevel-Groove		Plug
	Flare-Bevel-Groove		Slot
	Flare-V-Groove		Spot
	J-Groove		Seam
	Square-Groove		Projection
	U-Groove		V-Groove

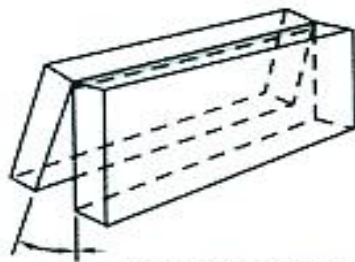
# WELDING



(C) T-JOINT













(D) LAP JOINT



(E) EDGE JOINT

## APPLICABLE WELDS and WELD SYMBOL

	Fillet		Slot
	Bevel-Groove		Spot
	Flare-V-Groove		Seam
	J-Groove		Projection
	Square-Groove		Plug

## APPLICABLE WELDS and WELD SYMBOL

	Fillet		Slot
	Bevel-Groove		Spot
	Flare-V-Groove		Seam
	J-Groove		Projection
	Square-Groove		*Braze
	Plug		

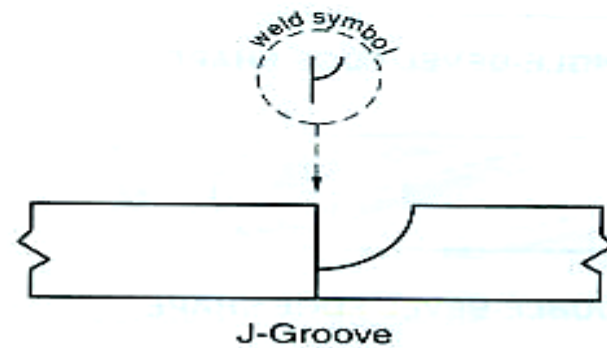
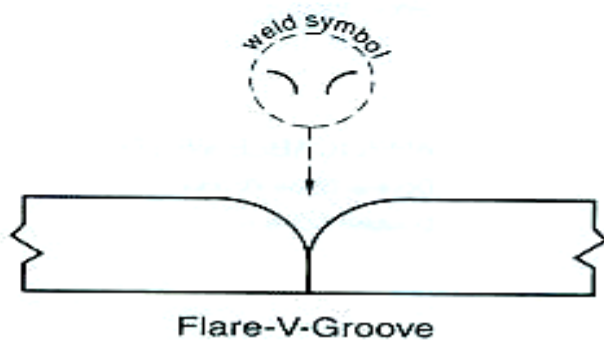
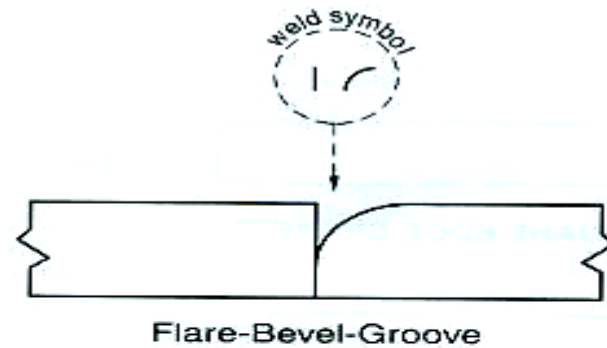
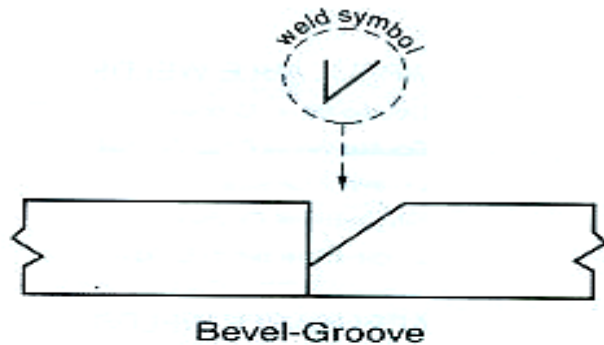
## APPLICABLE WELDS and WELD SYMBOL

	Bevel-Groove		U-Groove
	Flare-Bevel-Groove		V-Groove
	Flare-V-Groove		Edge
	J-Groove		Seam
	Square-Groove		

# WELDING

## TYPE OF GROOVE:

Butt joint

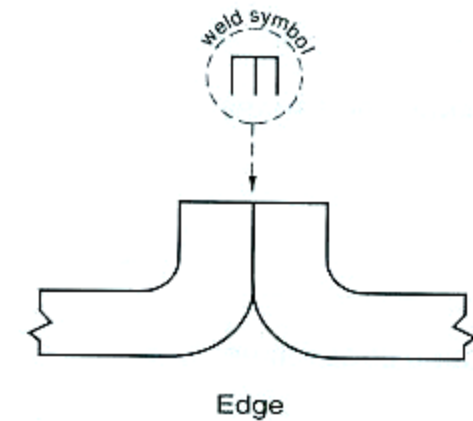
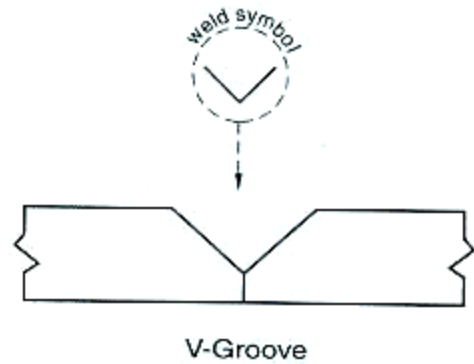
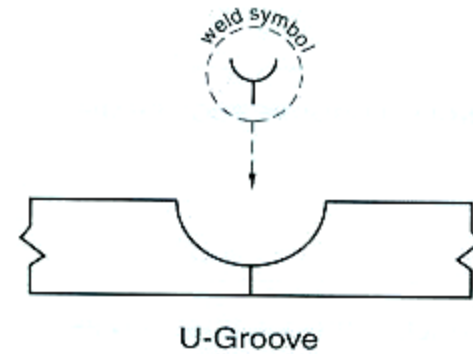
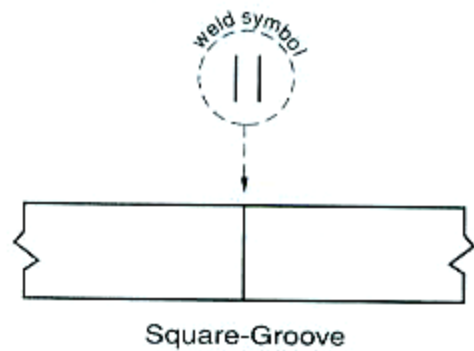




# WELDING

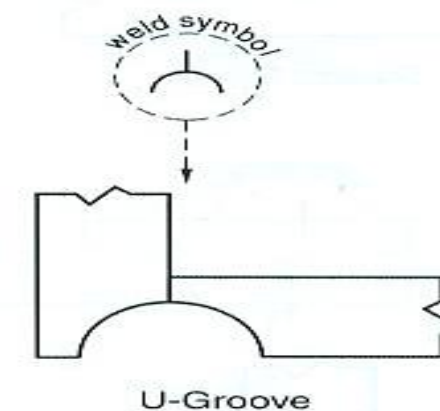
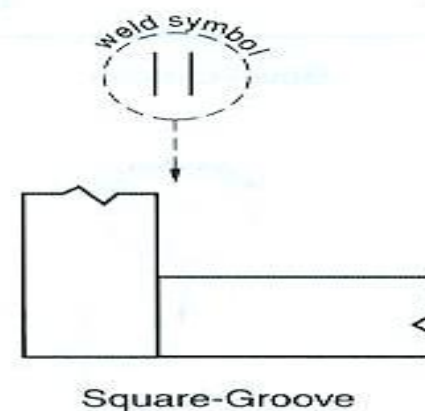
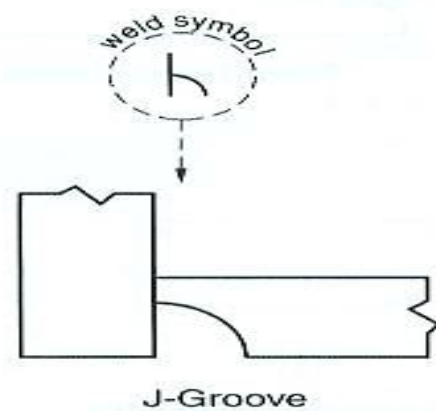
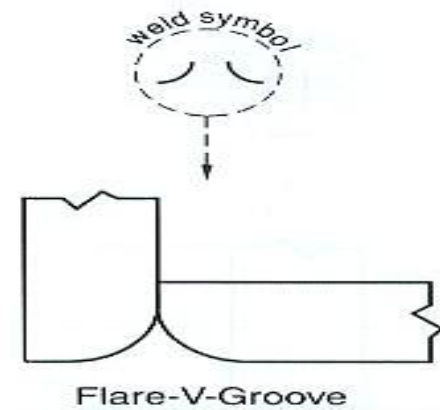
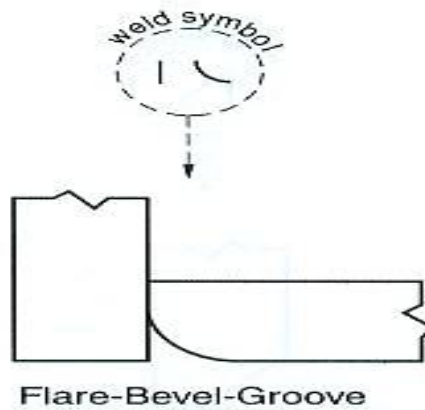
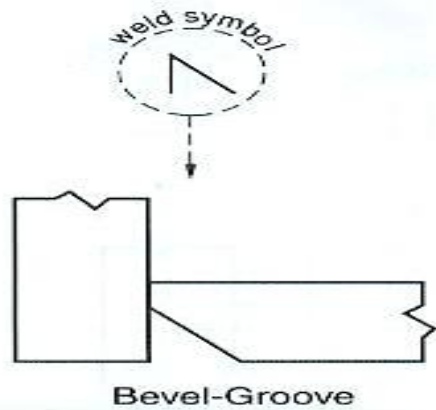
## TYPE OF GROOVE:

### Butt joint

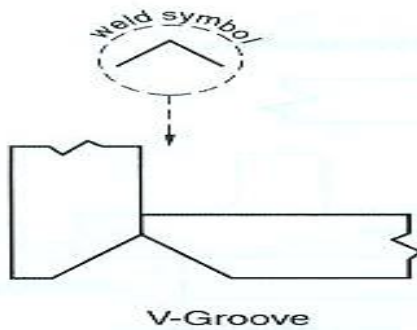


# WELDING

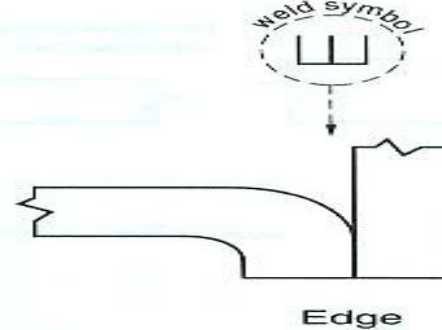
Corner joint (گوشه ای)



# WELDING

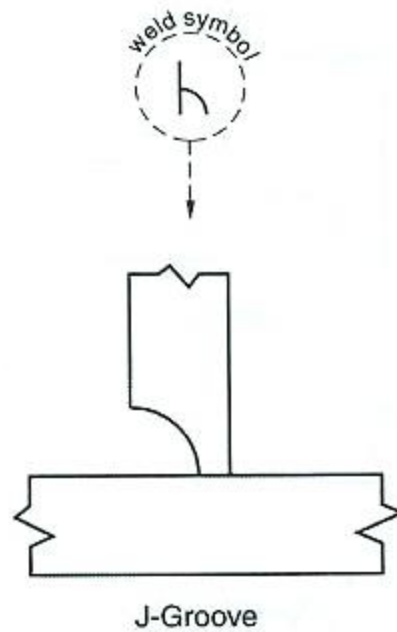


V-Groove

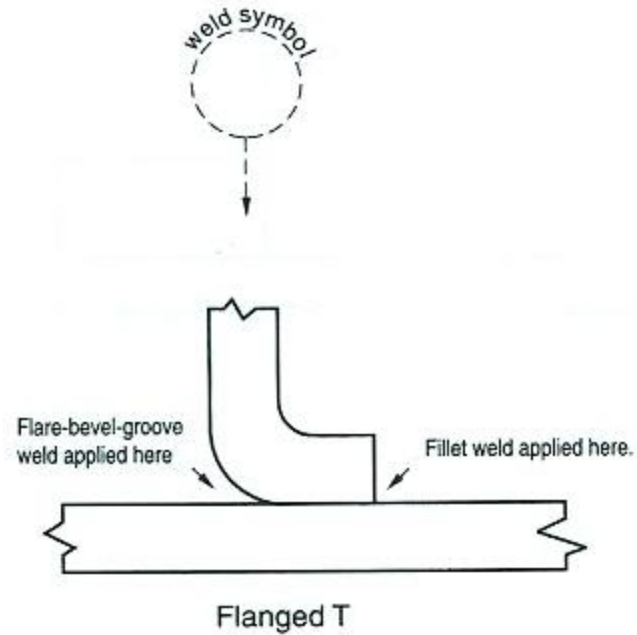


Edge

T-joint (سپری)

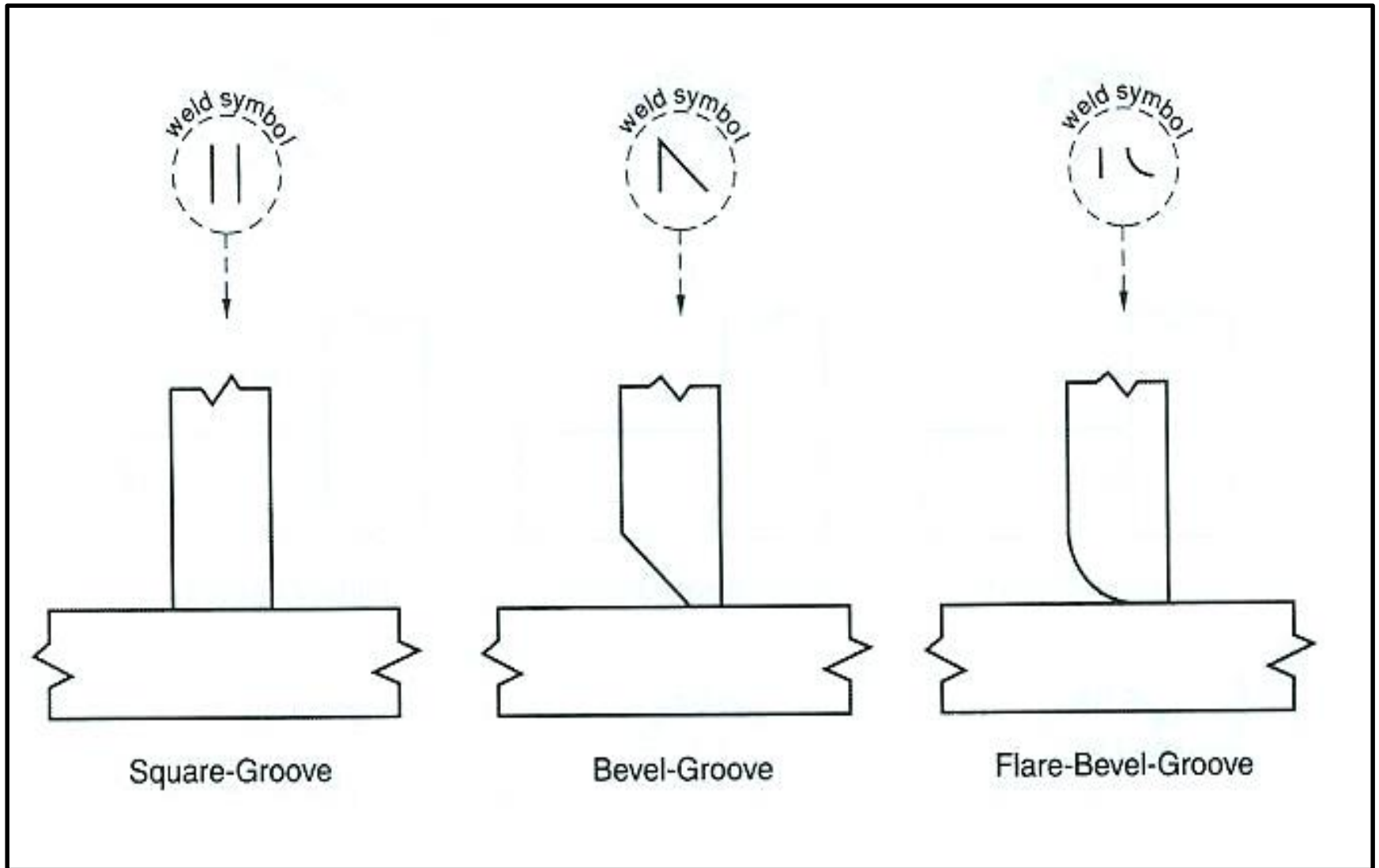


J-Groove



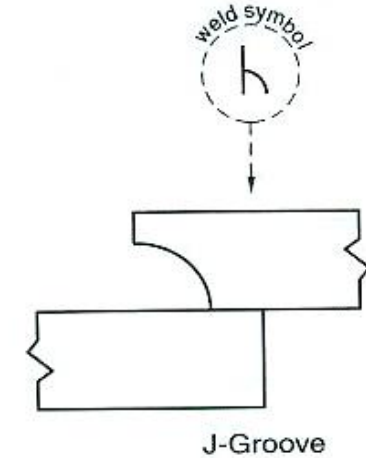
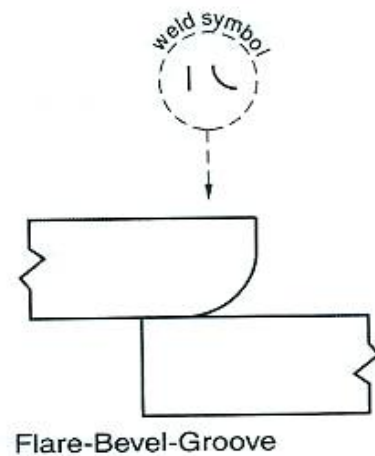
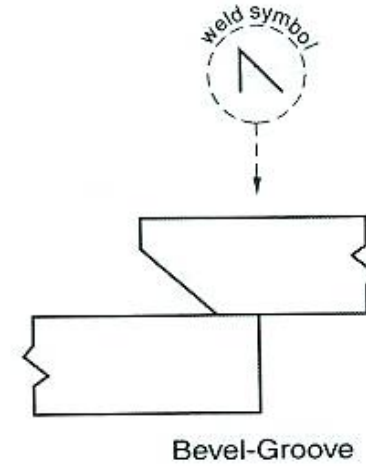
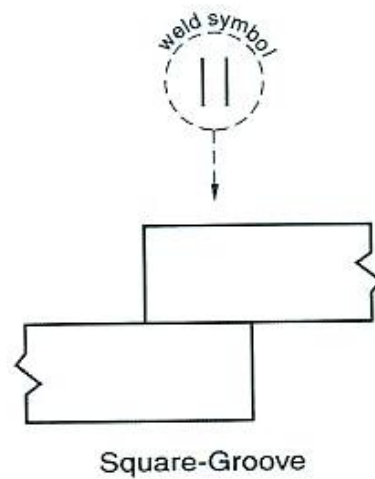
Flanged T

# WELDING



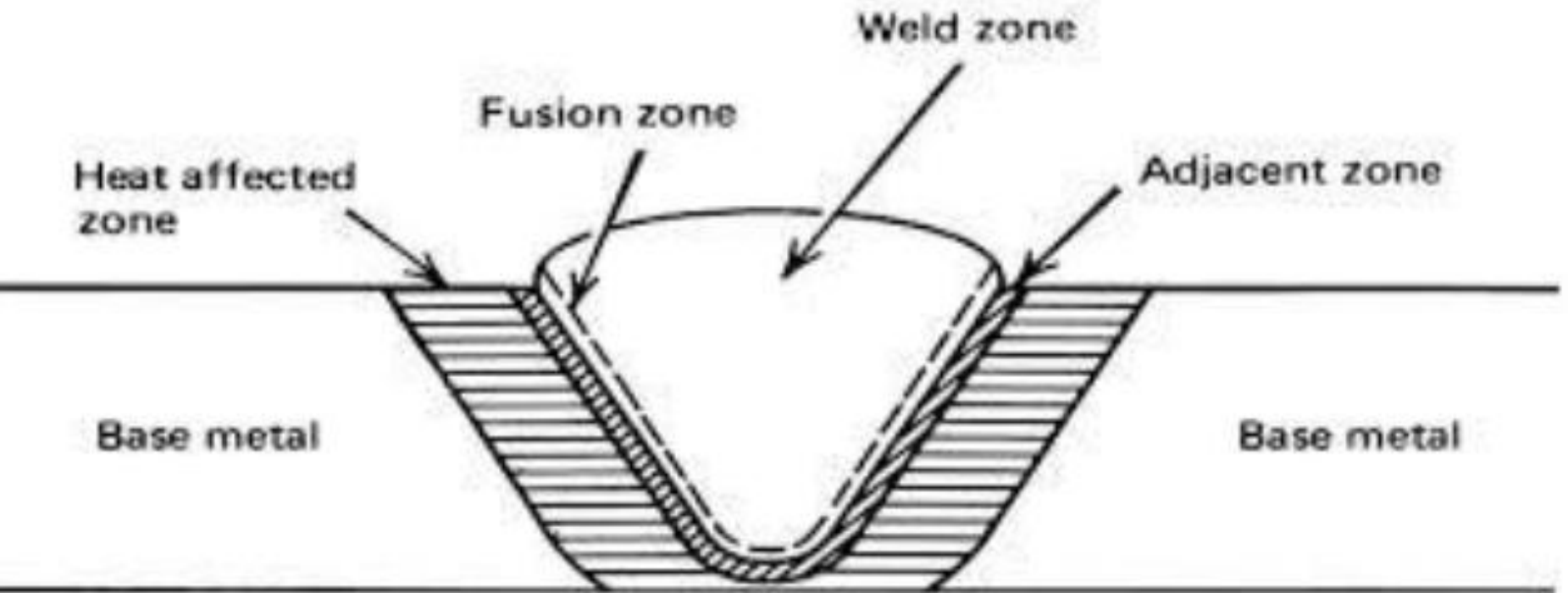
# WELDING

Lap joint (لبه روی هم)



# UG-18 (HAZ)

## HAZ



# UG-19 (SPECIAL CONSTRUCTIONS)

- **(a) Combination unit:** A combination unit is a pressure vessel that consists of more than one independent or dependent pressure chamber, operating at the same or different pressures and temperatures
- **common elements:** The parts separating each pressure chamber are the common elements
- **General Design Condition:** Each element, including the common elements, shall be designed for at least the most severe condition of coincident pressure and temperature expected in normal operation
- **Common Element Design:** It is permitted to design each common element for a differential pressure less than the maximum of the design pressures of its adjacent chambers (differential pressure design) or a mean metal temperature less than the maximum of the design temperatures of its adjacent chambers (mean metal temperature design), or both, **ONLY** when the vessel is to be installed in a system that controls the common element design conditions.

## UG-19 (SPECIAL CONSTRUCTIONS)

- **Differential Pressure Design:** A When differential pressure design is permitted, the common element design pressure shall be the maximum differential design pressure expected between the adjacent chambers.
- **Mean Metal Temperature Design:** the maximum common element design temperature determined in accordance with UG-20(a) may be less than the greater of the maximum design temperatures of its adjacent chambers; however, it shall not be less than the lower of the maximum design temperatures of its adjacent chambers.



# Design Data

Design Code

Size and dimensions

Materials

Service

Design Pressure

Design Temperature

Corrosion Allowance

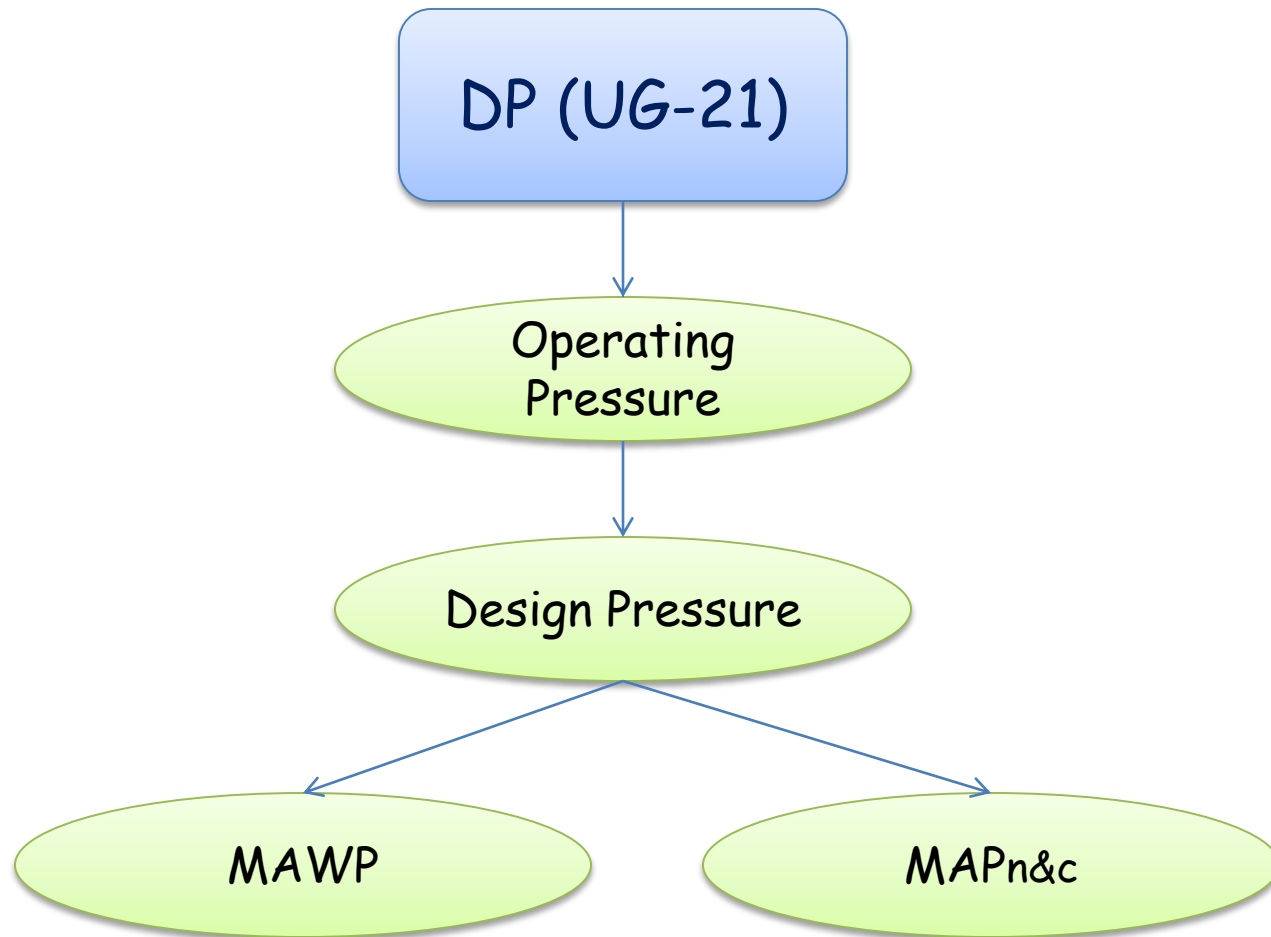
Joint Efficiencies (Radiography)

Wind and Seismic data

# Design Data

DESIGN DATA		
ITEM NO.		30-D-2007
SERVICE		DISULFIDES SEPARATOR
QTY		1
FLUID		CAUSTIC SOLUTION+AIR+DISULFIDES
SERVICE TYPE (SOUR SERVICE/LETHAL)		-/-
INSIDE DIAMETER	mm	3500
LENGTH (TL/TL)	mm	17500
VOLUME	m <sup>3</sup>	200
OPERATING TEMPERATURE	°C	48 (26)
OPERATING PRESSURE	Barg	5.1 (26)
DESIGN TEMPERATURE	°C	82
DESIGN PRESSURE	Barg	6.6
MINIMUM DESIGN METAL TEMP.	°C	-15
EXTERNAL DESIGN PRESSURE	Bara	F.V. @ 150°C
DESIGN CODE		ASME SEC.VIII, DIV.1
VESSEL HEAD TYPE		ELLIPTICAL 2:1
CORROSION ALLOWANCE (SHELL / HEAD / INTERNAL)	mm	3 / 3 / 1.5 (33)
MAXIMUM ALLOWABLE WORKING MPRESSURE	Barg	BY VENDOR
HYDROSTATIC PRESSURE	Barg	ACCORDING TO CODE [UG-99b(34)]
JOINT EFFICIENCY (SHELL / HEAD / SHELL TO HEAD)		1 / 1 / 1
RADIOGRAPHY (SHELL / HEAD / SHELL TO HEAD)		FULL / FULL / FULL
DENSITY OF LIQUID	Kg/m <sup>3</sup>	1200
PWHT		YES (PROCESS REASON)
IMPACT TEST		AS PER CODE
INSULATION		YES
INSULATION (TYPE / THK) (14,17)	mm	HOT / 30
FIRE PROOFING / DENSITY	-/Kg/m <sup>3</sup>	HOLD / 3100
FIRE PROOFING THK.	mm	- (22)
WIND DESIGN CODE		UBC 97
WIND DATA		120 Km/hr, EXPOSURE D, I,F=1,15
SEISMIC DESIGN CODE		UBC 97
SEISMIC DATA		ZONE 4, Cd=0.44, Cv=0.768, I,F=1.25, Nv=1.2
EQUIPMENT INSTALLATION POINT (ON FOUNDATION OR STRUCTURE)		ON STRUCTURE
EQUIPMENT BASE ELEVATION FROM GROUND LEVEL	mm	7112
z / h RATIO / qp		0.65 / 1
LIFTING LUG		REQUIRED
EARTHING LUG		REQUIRED
LAEDER AND PLATFORM		REQUIRED
INSULATION SUPPORTS		REQUIRED
FIRE PROOFING CLIPS (ON SADDLE)		YES (ON SADDLE)

# Design Pressure (UG-21)

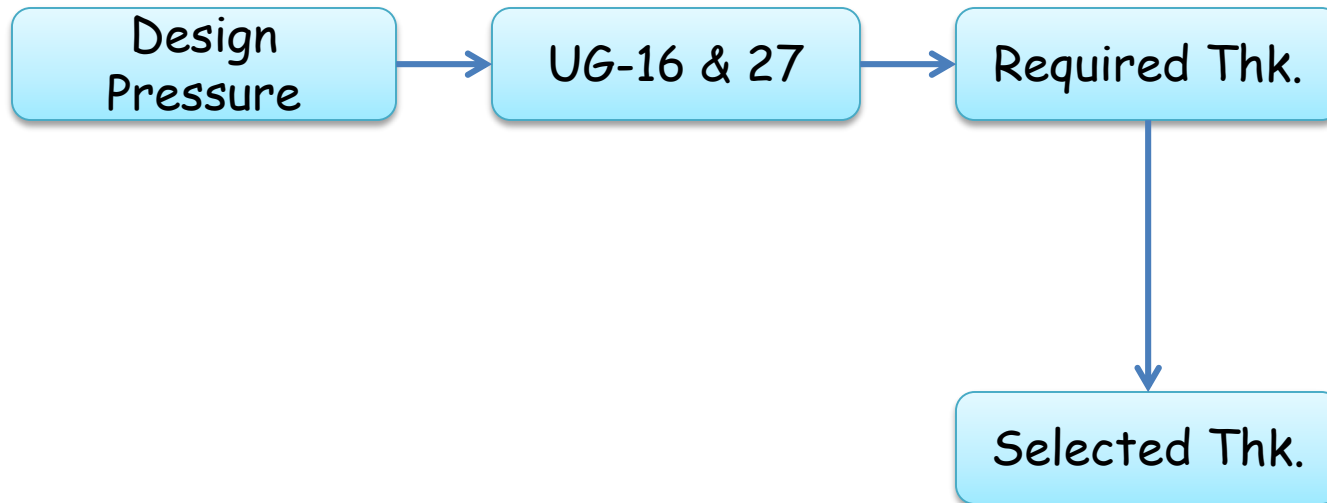


# Design Pressure (UG-21)

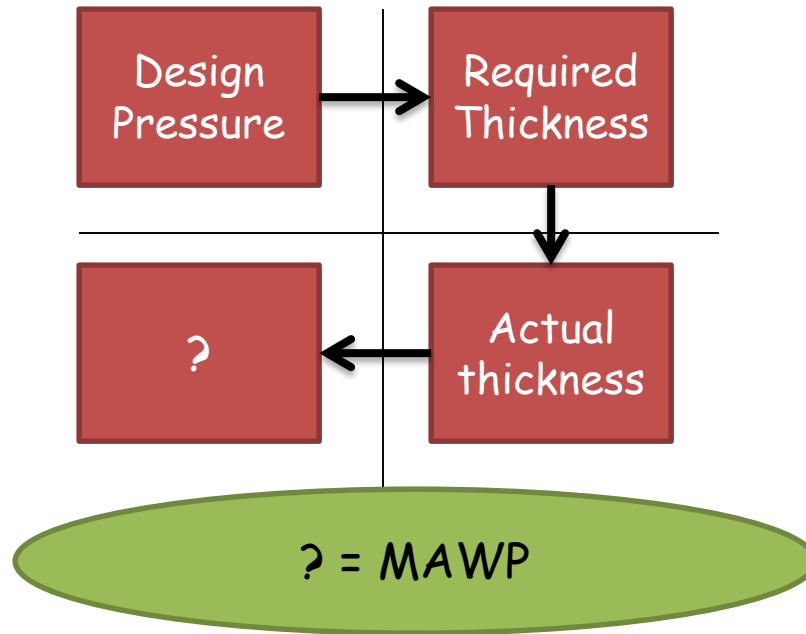
- ❖ Operating Pressure: Operating pressure is a normal pressure which we will expect in normal operation condition.
- ❖ Design Pressure : The most severe condition of coincident pressure (including coincident static head in the operating position) and temperature expected in normal operation.

As per Megysey Handbook: Design Pressure = Max. ( $OP \times 1.1$  or  $OP + 30$  Psi)

- ❖ MAWP :Maximum Allowable Working Pressure (corroded and in service condition)
- ❖ MAWPn&c (MAPn&c): Maximum Allowable Working Pressure New and Cold



# MAWP



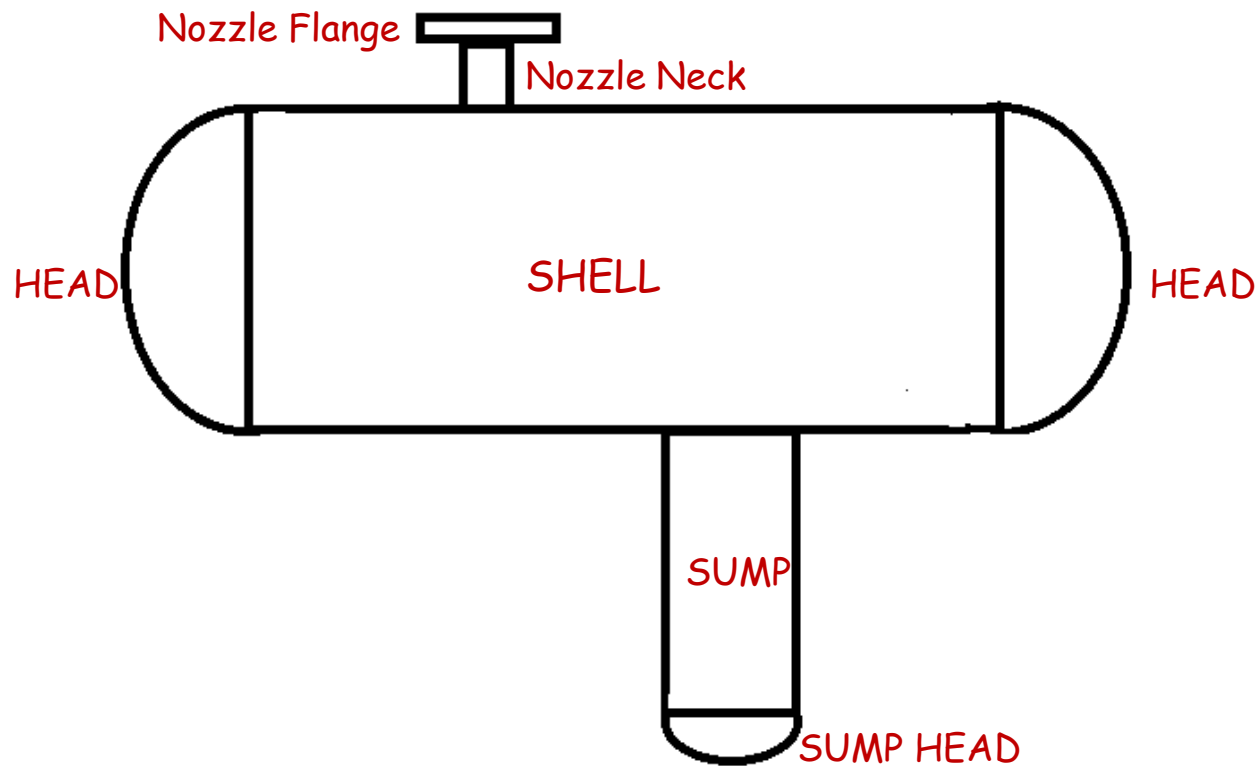
MAWP > Design Pressure

# Design Pressure (UG-21)

- ❖ Minor Parts : Parts such as Nozzle, Flange, Reinforcement pad, etc.
- ❖ Major Parts: Parts such as Shell, head, body flange, etc.
- Note based on Design specifications:

<<MAWP shall not governed by a Minor parts of pressure vessels>>

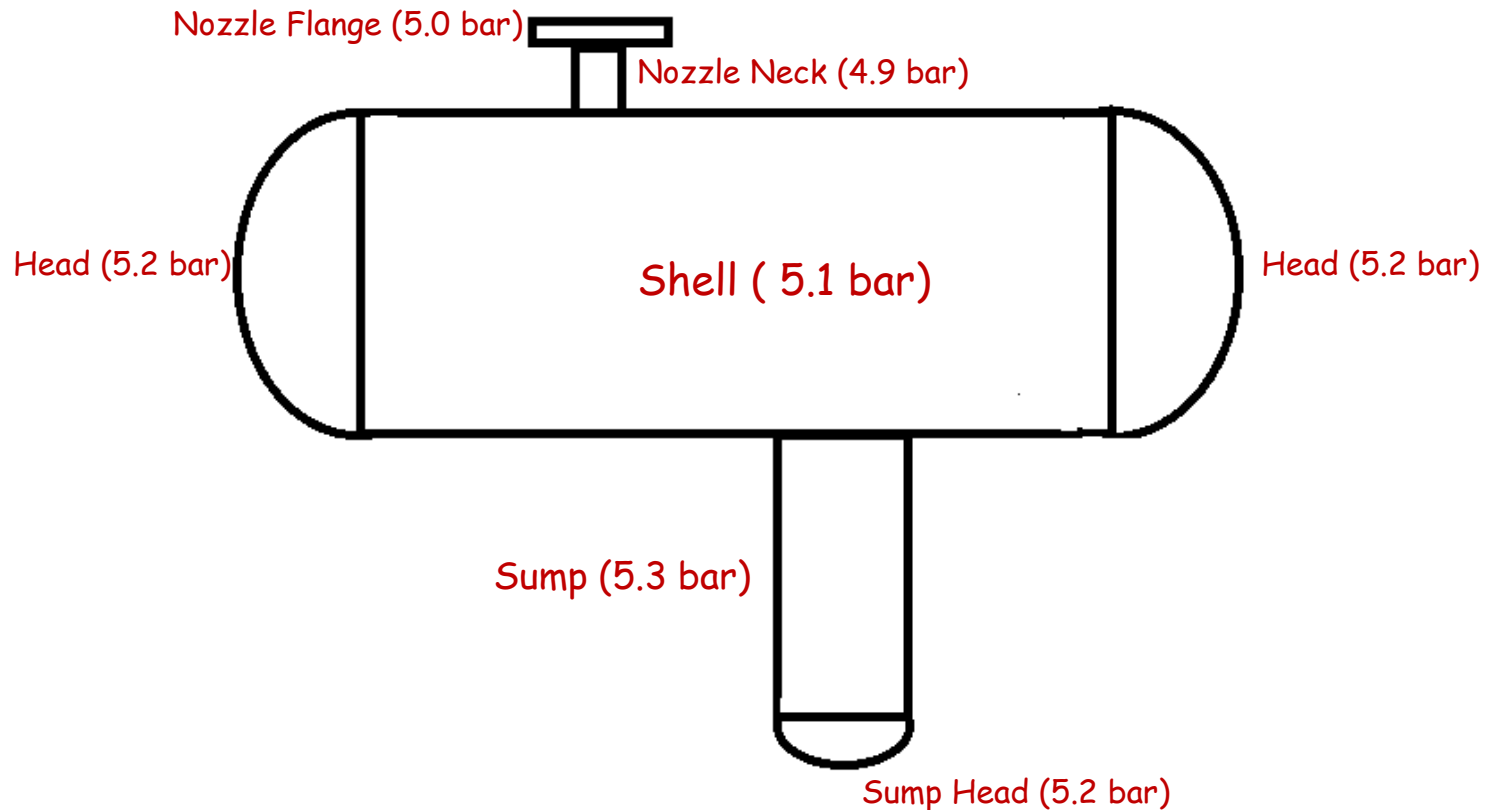
# MAWP



$$\text{MAWP total} = \text{Min.} (\text{MAWP}_{\text{shell}}, \text{MAWP}_{\text{head}}, \text{MAWP}_{\text{sump}}, \text{MAWP}_{\text{nozzle}}, \text{MAWP}_{\text{Flange}})$$



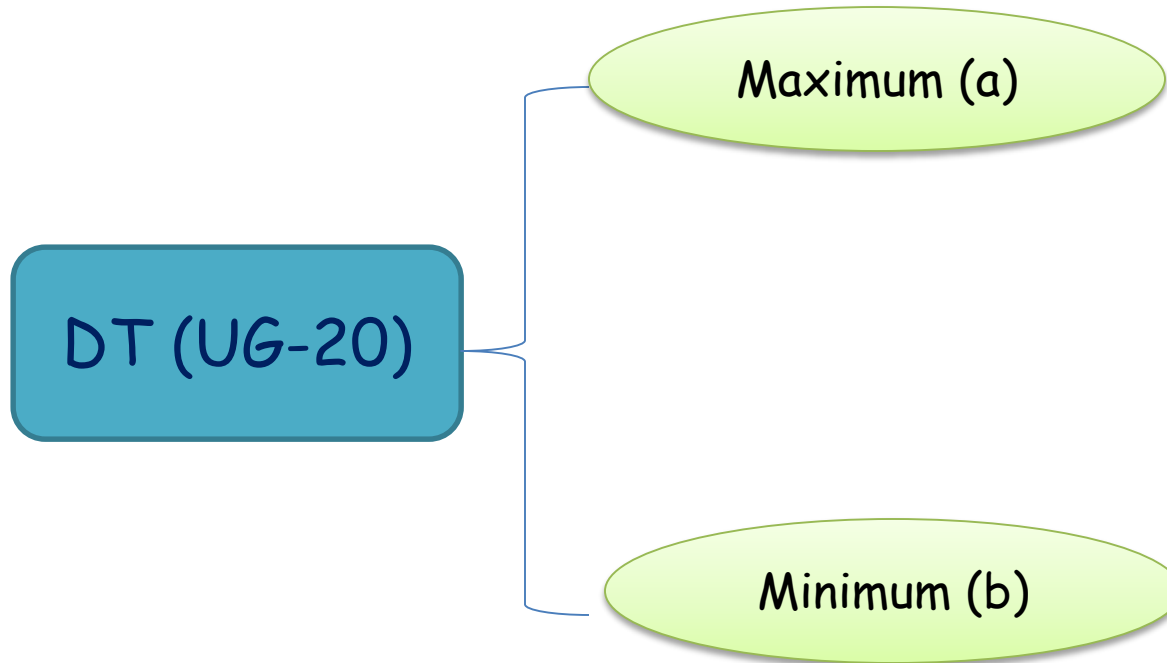
# MAWP (EXAMPLE)



MAWP total = Min. (5.1 bar, 5.2 bar, 5.3 bar, 4.9 bar, 5.0 bar) = 4.9 bar

So, MAWP is Governed by a Nozzle neck (if we increase schedule of nozzle the next part which will governed MAWP is Nozzle Flange!)

# Design Temperature (UG-20)



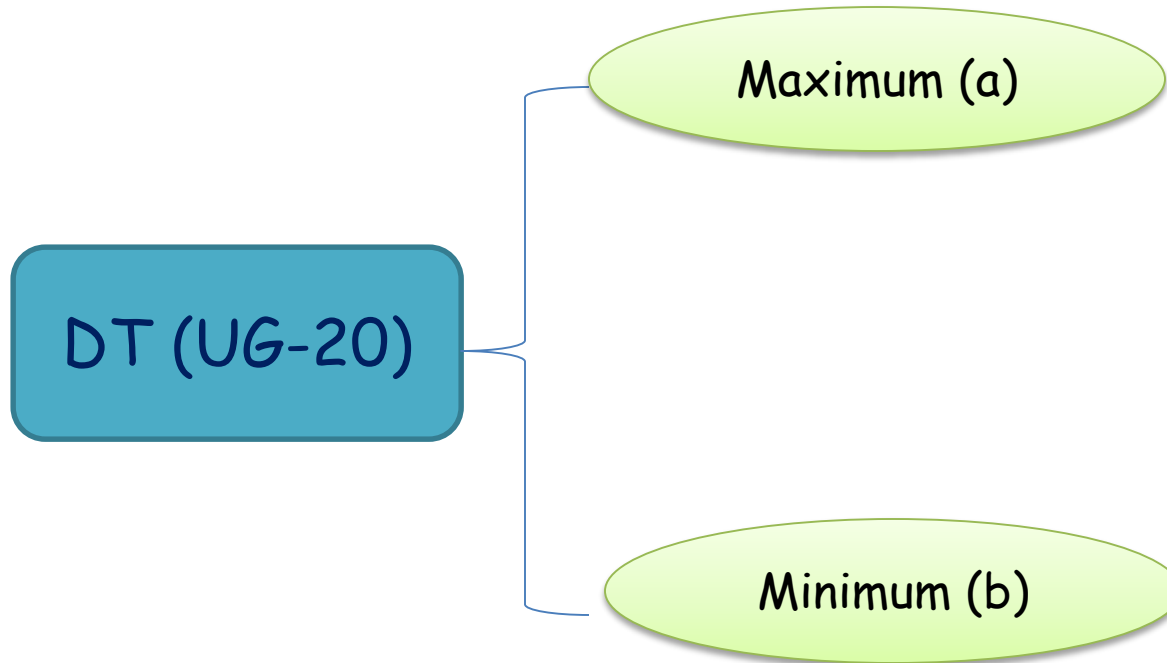
Other Consideration : Impact Test, MDMT

## Answer to Rounding Question

- Whenever it needs to round the parameters according to ASME code, we must round it in a most conservative approach. So, to rounding pressure which vessel could be retain we should round Down and to compute and order thicknesses for pressure retaining parts rounding up must be done.



# Design Temperature (UG-20)



Other Consideration : Impact Test, MDMT

# Design Temperature (UG-20)

- (a) The maximum temperature used in design shall be not less than the mean metal temperature (through the thickness????) expected under operating conditions for the part considered .

## NOTE(WRC Bulletin 470 ):

The user and Manufacturer are cautioned that certain fabrication details allowed by this Division may result in cracking at welds and associated heat affected zones (HAZ) for vessels designed for use at elevated temperature. WRC Bulletin 470, “Recommendations for Design of vessels for Elevated Temperature Service” has information that may prove helpful to the vessel designer. WRC Bulletin 470 contains recommended design details for use at elevated temperature service, which is for the purposes of this Division, when the allowable stresses in Section II, Part D are based on time-dependent properties. The use of these details does not relieve the Manufacturer of design responsibility with regard to consideration of stresses associated with both steady state conditions and transient events, such as startup, shutdown, intermittent operation, thermal cycling, etc., as defined by the user.

# Design Temperature (UG-20)

- (a) The minimum metal temperature(MMT) used in design shall be the lowest expected in service except when lower temperatures are permitted by the rules of this Division.
- Consideration to compute MMT shall includes:
  - ❖ The lowest operating temperature
  - ❖ Operational upsets
  - ❖ Autorefrigeration
  - ❖ Atmospheric temperature
  - ❖ Any other sources of cooling

# Design Temperature (UG-20)

✓ IMPORTANT NOTE:

The MDMT marked on the nameplate shall correspond to a coincident pressure equal to the MAWP.

But, What does it mean??!

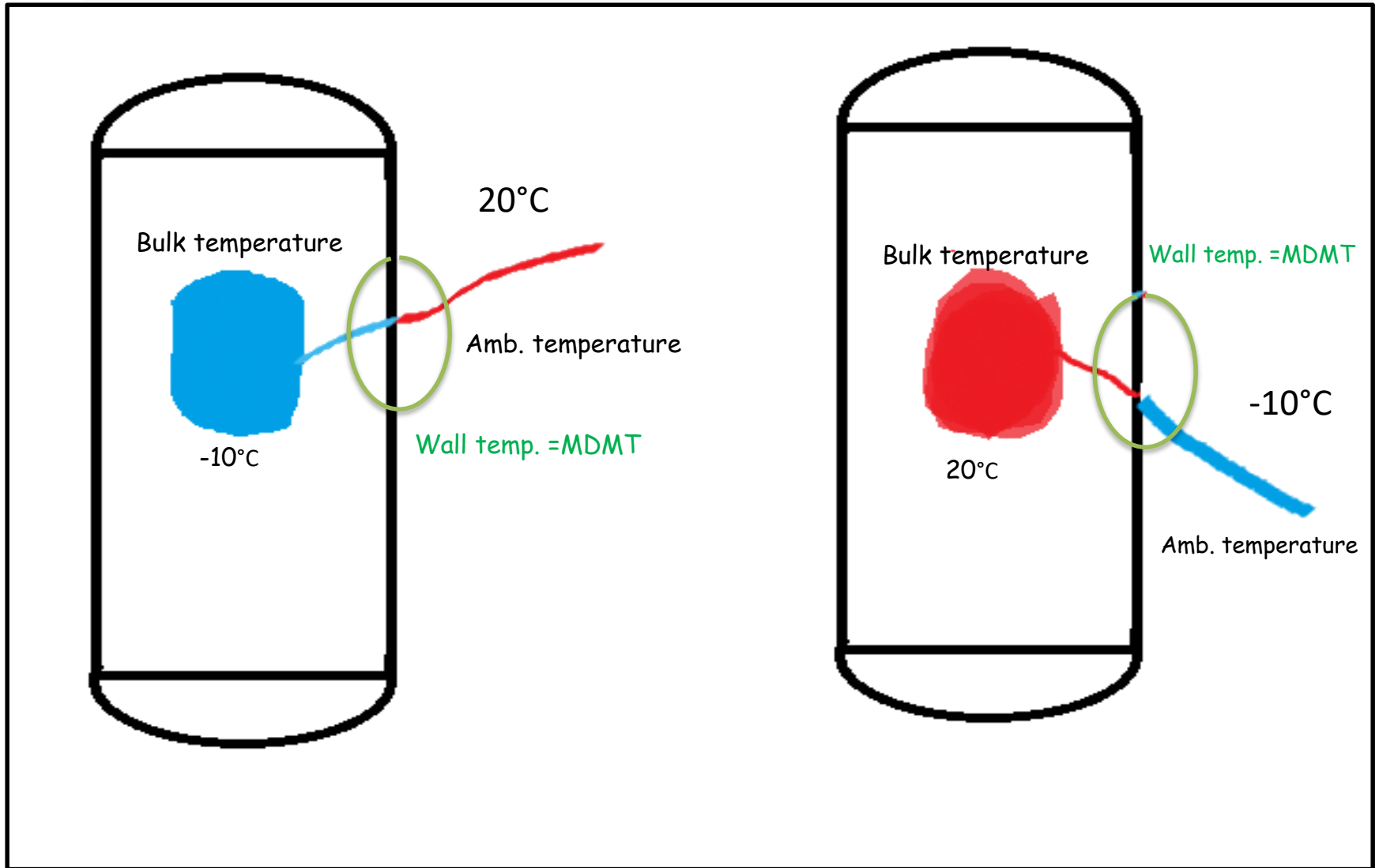


# Design Temperature (UG-20)

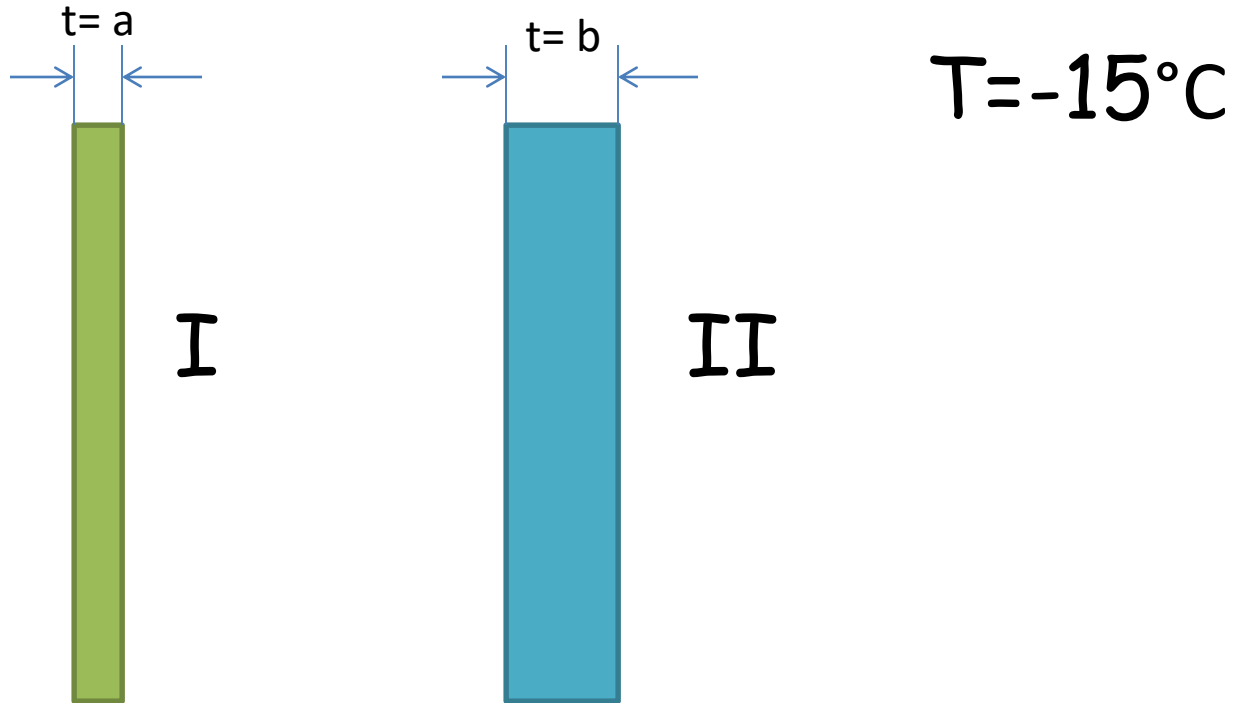
- ✓ What is MDMT?
- ✓ MDMT is minimum design metal temperature.
- ✓ The MDMT which was defined by Process is a minimum design required temperature based on MMT.
- ✓ The MDMT that will be computed by Mechanical is allowed minimum temperature which vessel could be suffer without any fail.



# Design Temperature (UG-20)



# Design Temperature (UG-20)



1. consider  $b > a$ , and MDT (Minimum Design Temperature) in both condition is the **same**.
2. Brittleness in number II is more than I. So, Vessel's MDMT in  $\text{II} < \text{I}$
3. Thickness has direct effect on vessel's MDMT and it should be calculated by Mechanical calculation in accordance to UCS-66

# Design Temperature (UG-20)

- (c) Design temperatures that exceed the temperature limit in the applicability column shown in Section II, Part D, Subpart 1, Tables 1A, 1B, and 3 are not permitted. In addition, design temperatures for vessels under external pressure shall not exceed the maximum temperatures given on the external pressure charts.
- (e) See Nonmandatory Appendix C to see Suggested methods for obtaining the operating temperature of vessel walls in service.
- (f) Impact testing per UG-84 is not mandatory for pressure vessel materials that satisfy all of the following

# Design Temperature (UG-20)

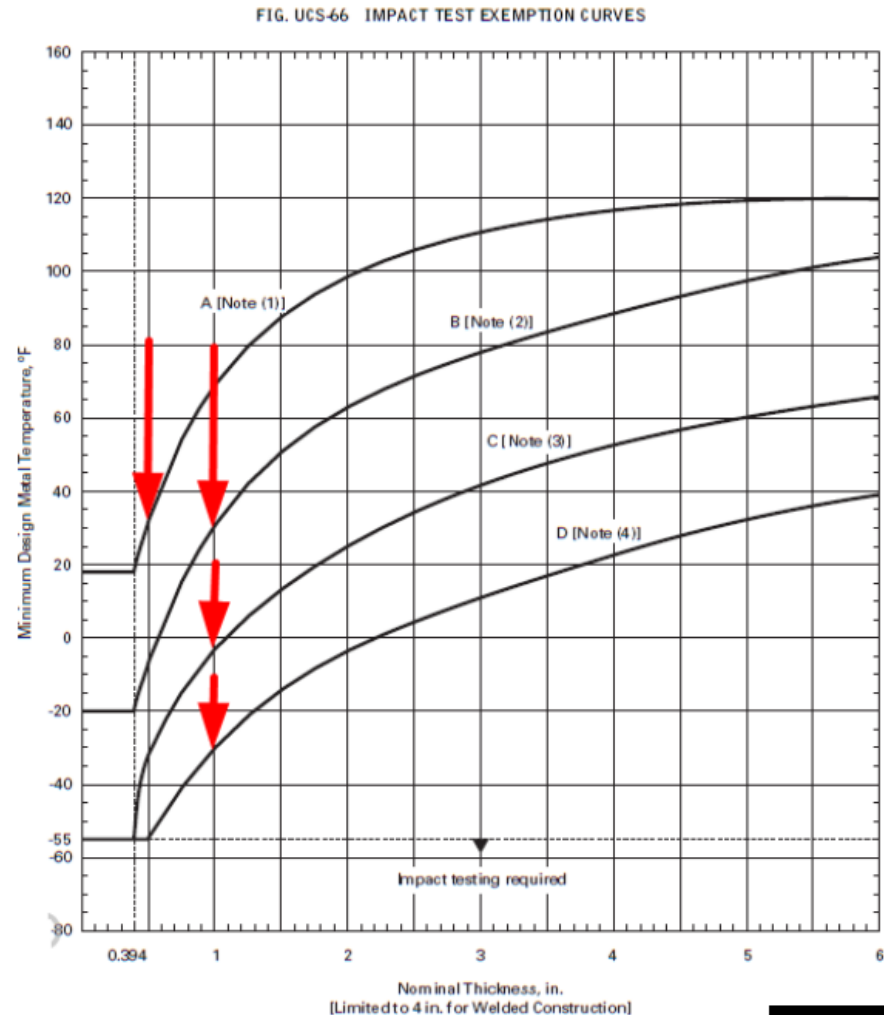
## UG-20 (f)

- (1) Material is limited to P-No.1 Gr. No.1 or 2 and the thicknesses don't exceed the following:
  - (-a) 13 mm for materials listed in Curve A of Figure UCS-66;
  - (-b) 25 mm for materials listed in Curve B, C, or D of Figure UCS-66.
- (2) The completed vessel shall be hydrostatically tested.
- (3) Design temperature is no warmer than 345°C nor colder than -29°C.
- (4) The thermal or mechanical shock loadings are not a controlling design requirement.
- (5) Cyclical loading is not a controlling design requirement.

# Design Temperature (UG-20)

1. Material is limited to P-No.1 Gr. No.1 or 2 and the thicknesses don't exceed the following:
  - (a) 1/2 in. for materials listed in Curve A of Fig. UCS-66;
  - (b) 1 in for materials from Curve B, C or D of Fig. UCS-66;

All of the conditions of UG-20(f) must be met to take this exemption from impact testing.



# Design Temperature (UG-20)

- (c) Design temperatures that exceed the temperature limit in the applicability column shown in Section II, Part D, Subpart 1, Tables 1A, 1B, and 3 are not permitted. In addition, design temperatures for vessels under external pressure shall not exceed the maximum temperatures given on the external pressure charts.
- (e) See Nonmandatory Appendix C to see Suggested methods for obtaining the operating temperature of vessel walls in service.
- (f) Impact testing per UG-84 is not mandatory for pressure vessel materials that satisfy all of the following

# Design Temperature (UG-20)

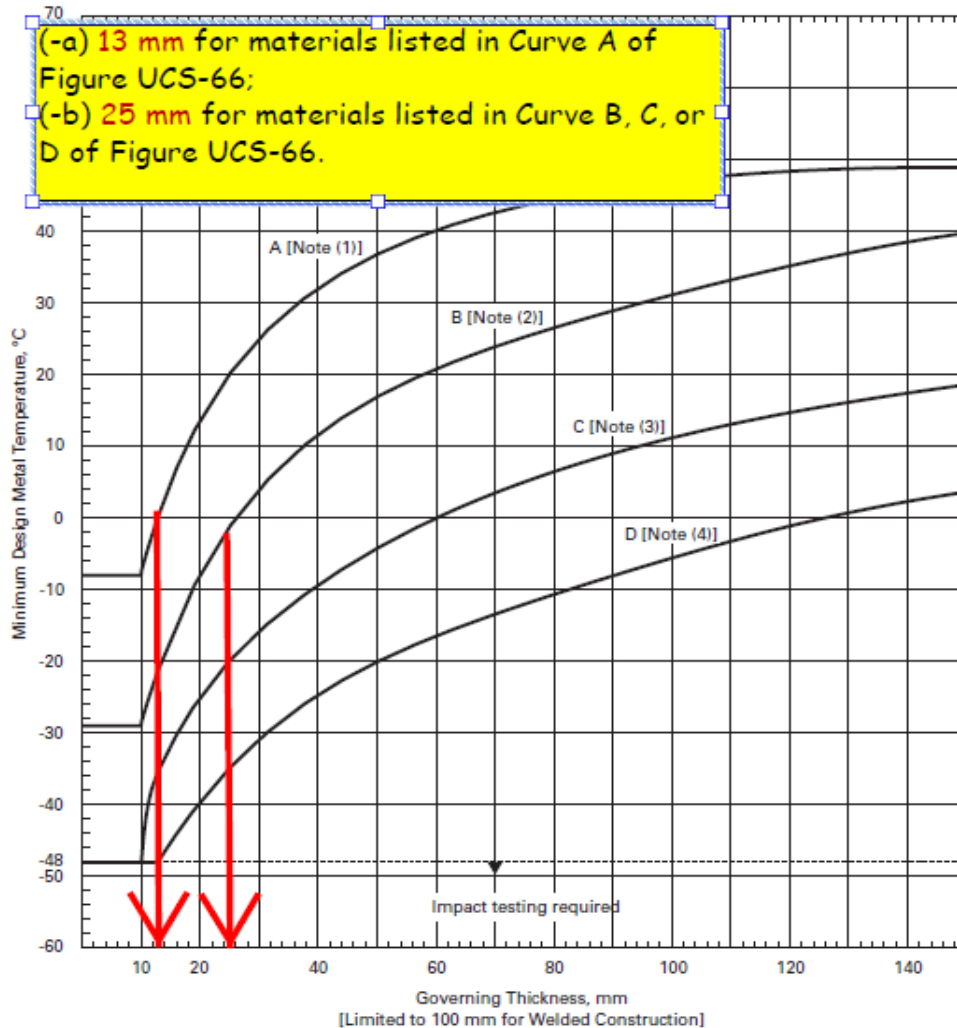
## UG-20 (f)

- (1) Material is limited to P-No.1 Gr. No.1 or 2 and the thicknesses don't exceed the following:
  - (-a) 13 mm for materials listed in Curve A of Figure UCS-66;
  - (-b) 25 mm for materials listed in Curve B, C, or D of Figure UCS-66.
- (2) The completed vessel shall be hydrostatically tested.
- (3) Design temperature is no warmer than 345°C nor colder than -29°C.
- (4) The thermal or mechanical shock loadings are not a controlling design requirement.
- (5) Cyclical loading is not a controlling design requirement.

# Design Temperature (UG-20)

Figure UCS-66M  
Impact Test Exemption Curves

(15)





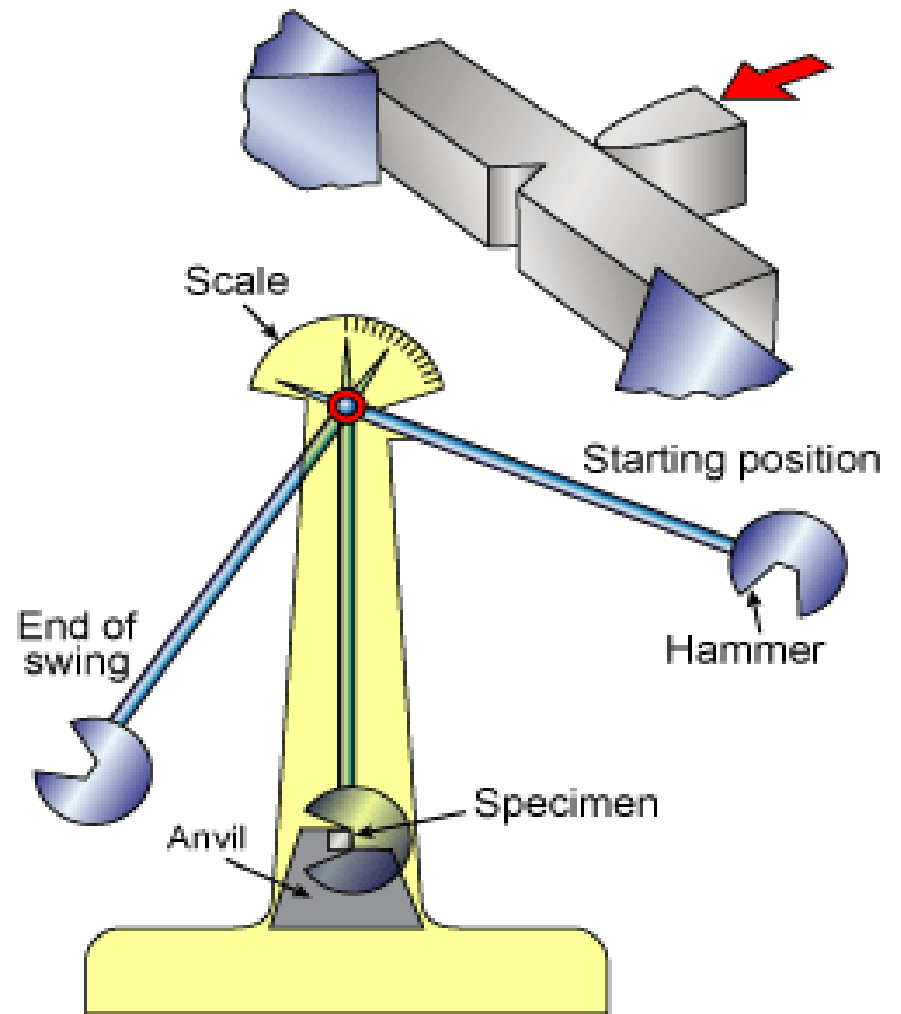
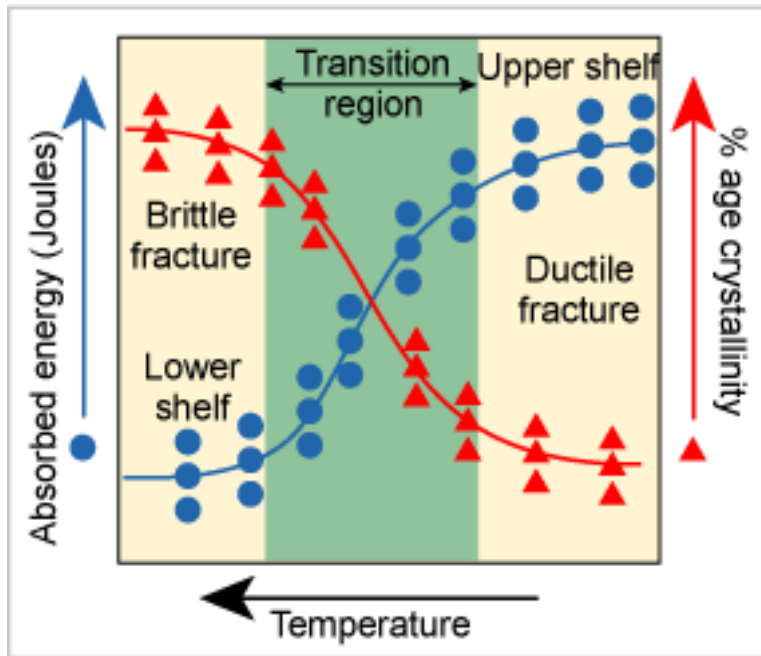
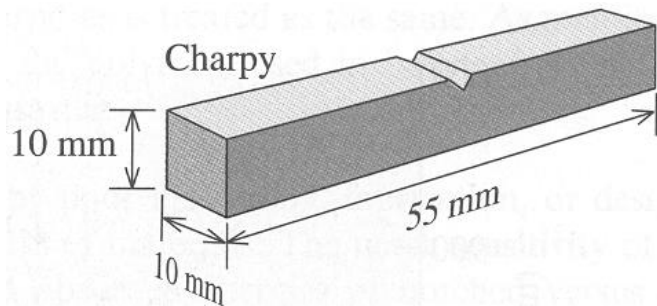
# IMPACT TEST

- ❖ **Toughness:** Toughness is, broadly, a measure of the amount of **energy** required to cause an item - a test piece or a bridge or a pressure vessel - to **fracture and fail**. The **more energy** that is required then the **tougher the material**. So, The ability of a material to withstand an impact blow is referred to as notch toughness.
- ❖ **context of an impact test:** a measure of the metal's resistance to brittle or fast fracture in the presence of a flaw or notch and fast loading conditions
- ❖ **There are two main forms of impact test**, the Izod and the Charpy test. Both involve striking a standard specimen with a controlled weight pendulum travelling at a set speed. The amount of energy absorbed in fracturing the test piece is measured and this gives an indication of the notch toughness of the test material.

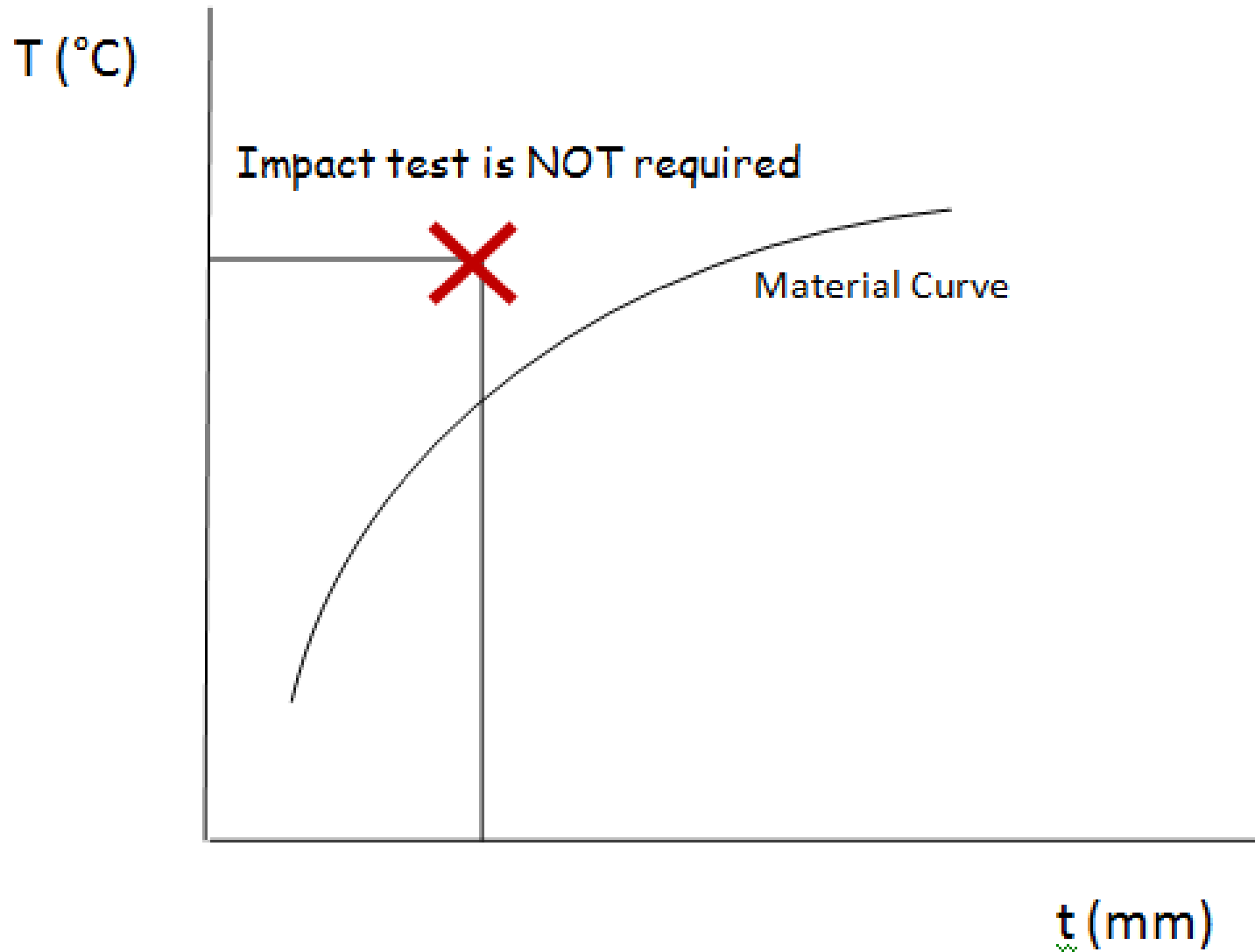
# IMPACT TEST

- ❖ These tests show that metals can be classified as being either 'brittle' or 'ductile'. A brittle metal will absorb a small amount of energy when impact tested, a tough ductile metal a large amount of energy.
- ❖ The energy absorbed is the difference in height between initial and final position of the hammer. The material fractures at the notch and the structure of the cracked surface will help indicate whether it was a brittle or ductile fracture.

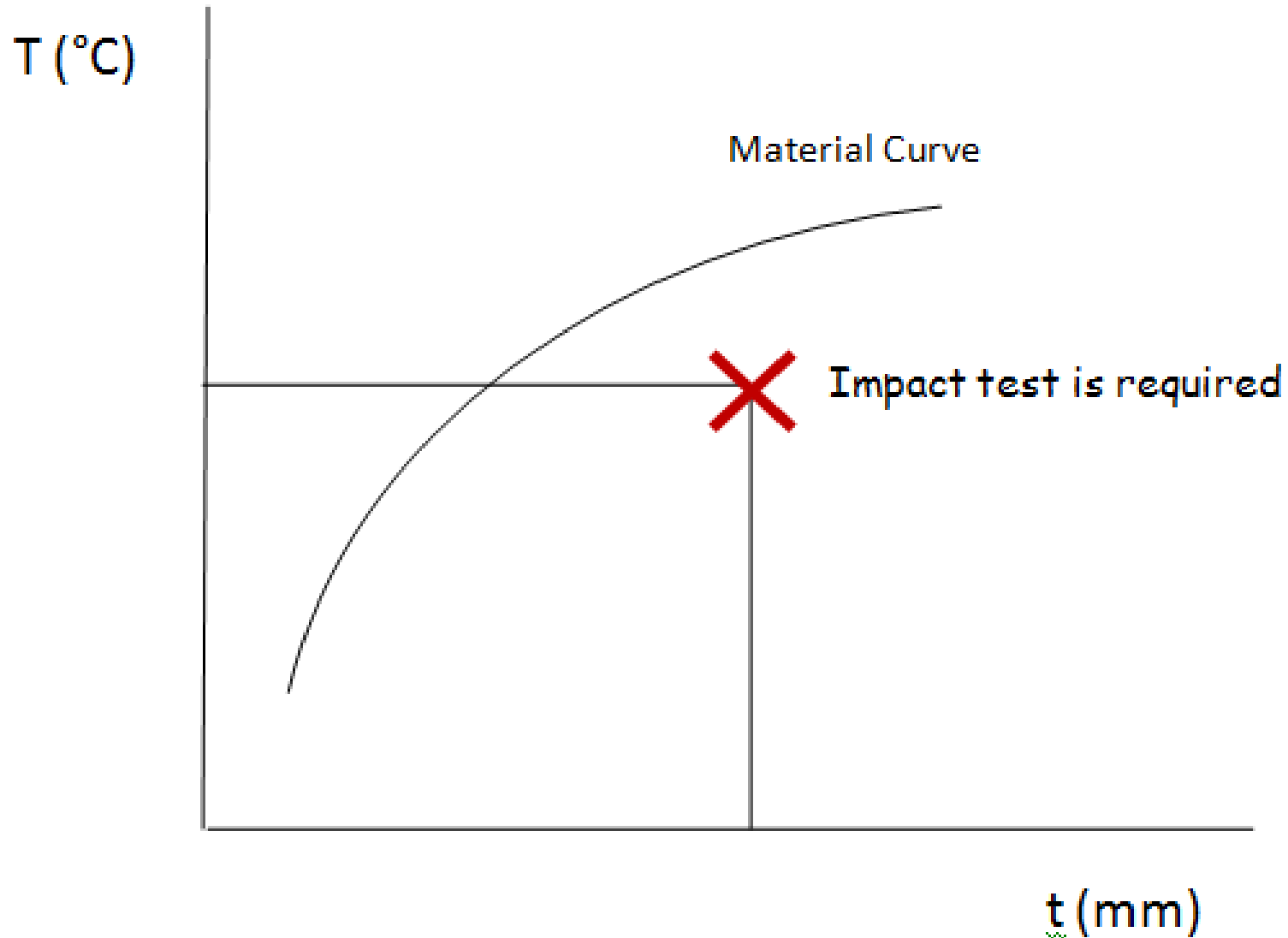
# IMPACT TEST



# IMPACT TEST



# IMPACT TEST



# IMPACT TEST

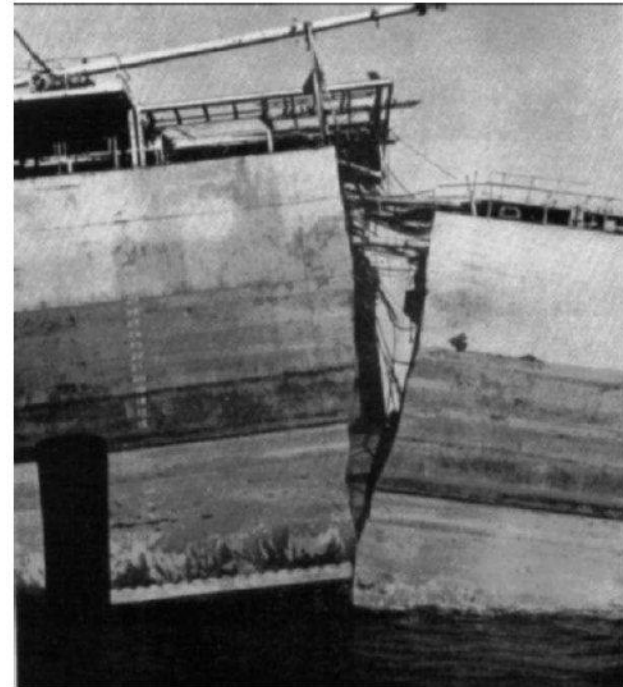
	<b>Alloy</b>	<b>Impact energy [J (ft·lb)]</b>
1.	1040 carbon steel	180 (133)
2.	8630 low-alloy steel	55 (41)
3.	c. 410 stainless steel	34 (25)
4.	L2 tool steel	26 (19)
5.	Ferrous superalloy (410)	34 (25)
6.	a. Ductile iron, quench	9 (7)
7.	b. 2048, plate aluminum	10.3 (7.6)
8.	a. AZ31B magnesium	4.3 (3.2)
	b. AM100A casting magnesium	0.8 (0.6)
9.	a. Ti-5Al-2.5Sn	23 (17)
10.	Aluminum bronze, 9% (copper alloy)	48 (35)
11.	Monel 400 (nickel alloy)	298 (220)
13.	50:50 solder (lead alloy)	21.6 (15.9)
14.	Nb-1 Zr (refractory metal)	174 (128)

Table 8.1

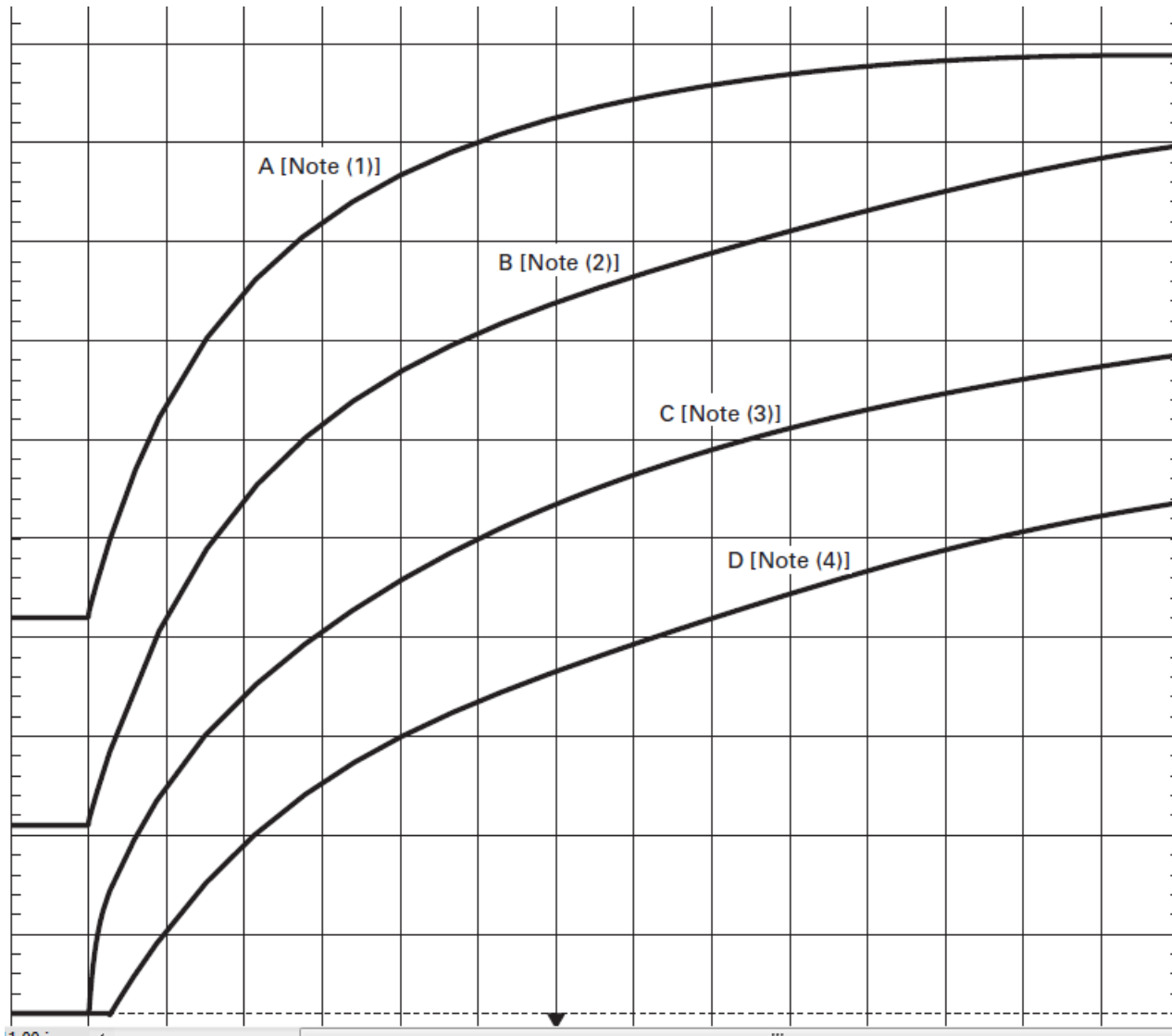
*Impact Test (Charpy) Data for Some of the Alloys of Table 6.1.*

# Brittle Fracture

- Failure of Liberty ships in WW II - Low-carbon steels were ductile at RT tensile tests, they became brittle when exposed to lower-temperature ocean environments. The ships were built and used in the Pacific Ocean but when they were employed in the Atlantic Ocean, which is colder, the ship's material underwent a ductile to brittle transition.



# UCS-66





# UCS-66

## (1) Curve A applies to:

- (a) all carbon and all low alloy steel plates, structural shapes, and bars not listed in Curves B, C, and D below;
- (b) SA-216 Grades WCB and WCC if normalized and tempered or water-quenched and tempered; SA-217 Grade WC6 if normalized and tempered or water-quenched and tempered.

## (2) Curve B applies to:

(a) see below:

- SA-216 Grade WCA if normalized and tempered or water-quenched and tempered
- SA-216 Grades WCB and WCC for thicknesses not exceeding 2 in. (50 mm) , if produced to fine grain practice and water-quenched and tempered
- SA-217 Grade WC9 if normalized and tempered
- SA-285 Grades A and B
- SA-414 Grade A
- SA-515 Grade 60
- SA-516 Grades 65 and 70 if not normalized
- SA-612 if not normalized
- SA-662 Grade B if not normalized

## (2) Curve B applies to:

- SA/EN 10028-2 Grades P235GH, P265GH, P295GH, and P355GH as rolled SA/AS 1548 Grades PT430NR and PT460NR (b) except for cast steels, all materials of Curve A, if produced to fine grain practice and normalized, that are not listed in Curves C and D below;
- (c) all pipe, fittings, forgings and tubing not listed for Curves C and D below;
- (d) parts permitted under UG-11 shall be included in Curve B even when fabricated from plate that otherwise would be assigned to a different curve.

## (3) Curve C applies to:

(a) see below:

- SA-182 Grades F21 and F22 if normalized and tempered SA-302 Grades C and D
- SA-336 F21 and F22 if normalized and tempered, or liquid quenched and tempered
- SA-387 Grades 21 and 22 if normalized and tempered, or liquid quenched and tempered
- SA-516 Grades 55 and 60 if not normalized
- SA-533 Types B and C Class 1
- SA-662 Grade A
- SA/EN 10028-2 Grade 10CrMo 9-10 if normalized and tempered

(b) all materials listed in 2(a) and 2(c) for Curve B if produced to fine grain practice and normalized, normalized and tempered, or liquid quenched and tempered as permitted in the material specification, and not listed for Curve D below.

## (4) Curve D applies to:

- SA-203
- SA-508 Grade 1
- SA-516 if normalized or quenched and tempered
- SA-524 Classes 1 and 2
- SA-537 Classes 1, 2, and 3
- SA-612 if normalized
- SA-662 if normalized
- SA-738 Grade A
- SA-738 Grade A with Cb and V deliberately added in accordance with the provisions of the material specification, not colder than  $-20^{\circ}\text{F}$  ( $-29^{\circ}\text{C}$ )
- SA-738 Grade B not colder than  $-20^{\circ}\text{F}$  ( $-29^{\circ}\text{C}$ )
- SA/AS 1548 Grades PT430N and PT460N
- SA/EN 10028-2 Grades P235GH, P265GH, P295GH, and P355GH if normalized
- SA/EN 10028-3 Grade P275NH

# UG-22 (Loadings)

Loads to be considered for design of PV

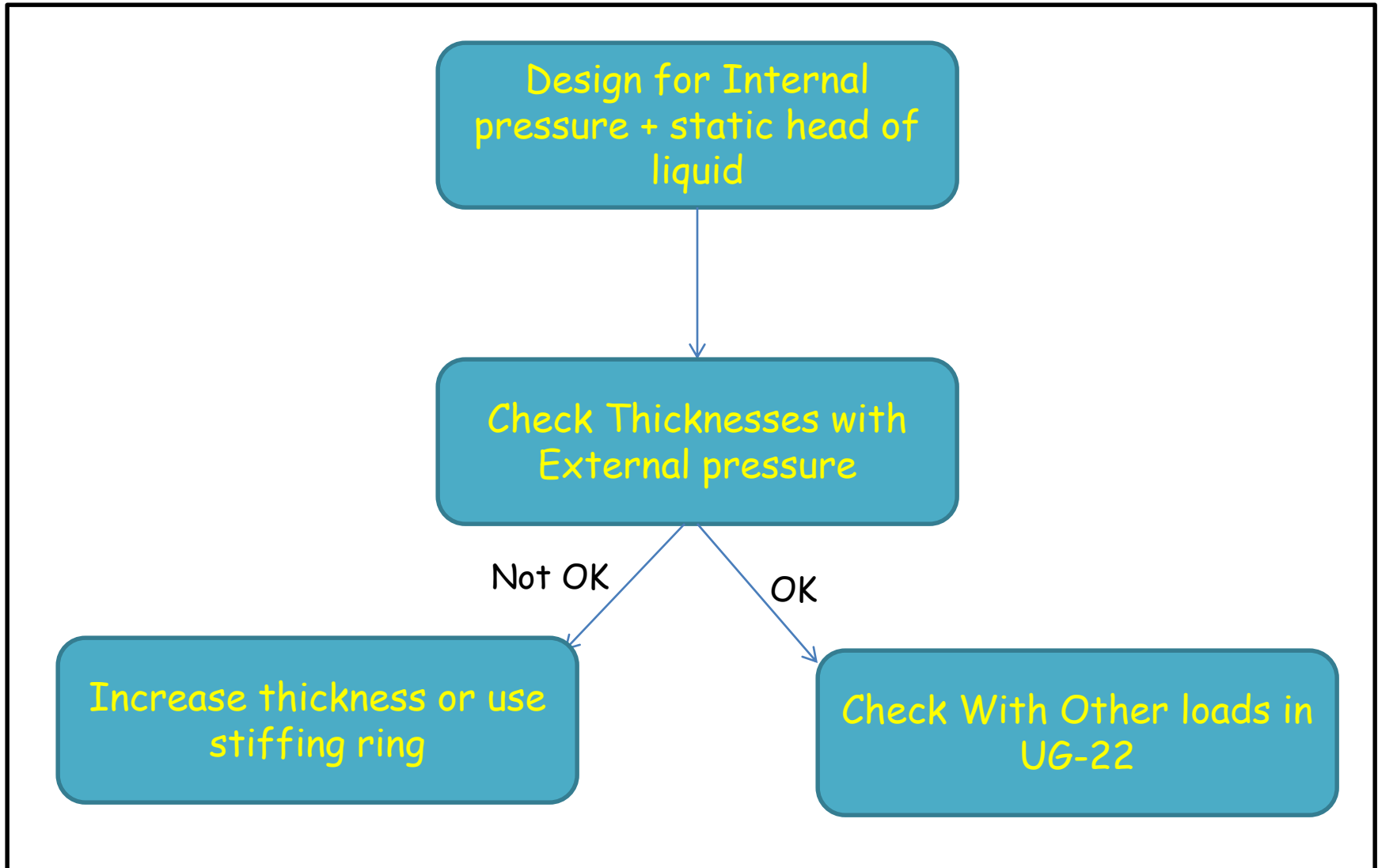
1. Pressure including Internal, External, Static head of liquid, Hydrotest, abnormal pressure
2. Weights including weight of the vessel and normal contents under operating or test conditions, weight of attached equipment, internals, vessel supports
3. temperature gradients and differential thermal expansion;
4. Wind, snow, and seismic reactions
5. Cyclic and dynamic reactions

# UG-22 (Loadings)

Loads to be considered for design of PV

1. Pressure including Internal, External, Static head of liquid, Hydrotest, abnormal pressure
2. Weights including weight of the vessel and normal contents under operating or test conditions, weight of attached equipment, internals, vessel supports
3. temperature gradients and differential thermal expansion;
4. Wind, snow, and seismic reactions
5. Cyclic and dynamic reactions

# Sequence of design



MAXIMUM ALLOWABLE  
STRESS VALUES

```
graph LR; A[\"MAXIMUM ALLOWABLE STRESS VALUES\"] --> B[\"Max. Allowable Tensile stress (Subpart 1 of Section II, Part D. Section II)\"]; A --> C[\"Max. Allowable longitudinal compressive stress\"];
```

Max. Allowable Tensile  
stress (Subpart 1 of Section II,  
Part D. Section II)

Max. Allowable  
longitudinal compressive  
stress



## UG-23

- Max. Allowable longitudinal compressive stress shall be the smaller of the following values:
- (1) the maximum allowable tensile stress value permitted in (a) above;
- (2) the value of the factor B determined by the following procedure where

2-1- calculate the value of factor A using the following equation

$$A = \frac{0.125}{(R_o/t)}$$

2-2- Using the value of A calculated in Step 1, enter the applicable material chart in Section II, Part D, Subpart 3 for the material under consideration

## UG-23

- The wall thickness of a vessel computed by these rules shall be determined such that, for any combination of loadings listed in UG-22 that induce primary stress and are expected to occur simultaneously during normal operation<sup>13</sup> of the vessel, the induced maximum general primary membrane stress does not exceed the maximum allowable stress value in tension.
- The maximum allowable stress values that are to be used in the thickness calculations are to be taken from the tables at the temperature that is expected to be maintained in the metal under the conditions of loading being considered. Maximum stress values may be interpolated for intermediate temperatures.

- Primary membrane stress:

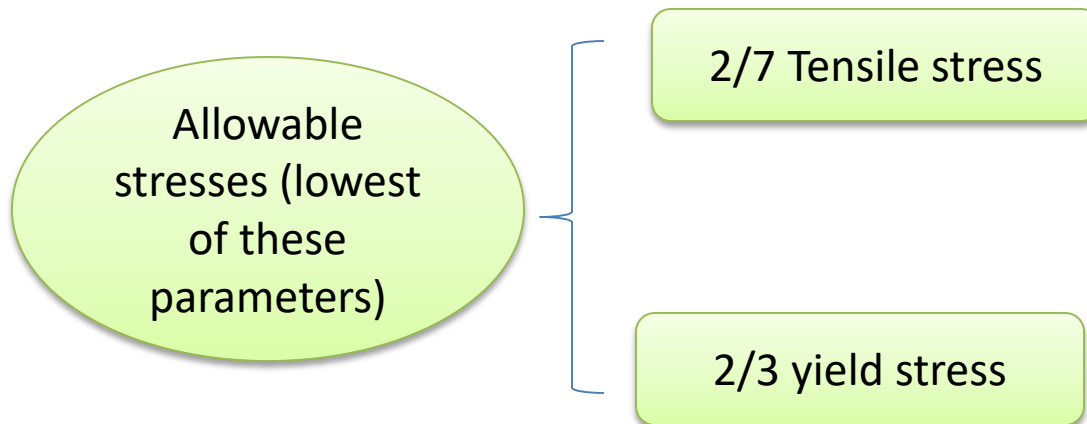
A stress developed by the imposed loading that is necessary to satisfy the simple laws of equilibrium of external and internal forces and moments. Primary stress can be either membrane or bending stress. Primary membrane stress may be of two types: general and local. A general primary membrane stress is one that is so distributed in the structure that no redistribution of load occurs as a result of yielding. A local primary membrane stress is one that is produced by pressure or other mechanical loading and that is associated with a primary and/or discontinuity effect. Examples of primary stress are

(a) general membrane stress in a circular cylinder or a spherical shell due to internal pressure or to distributed loads;

(b) bending stress

## Section II, Part D-MANDATORY APPENDIX 1

- The maximum allowable stress value is the lowest of the following:
- (1) the specified minimum tensile strength at room temperature divided by 3.5
- (2) the tensile strength at temperature divided by 3.5
- (3) two-thirds of the specified minimum yield strength at room temperature
- (4) two-thirds of the yield strength at temperature



## Section II, Part D-MANDATORY APPENDIX 1

**Table 1-100**  
**Criteria for Establishing Allowable Stress Values for Tables 1A and 1B**

Product/Material	Room Temperature and Below		Above Room Temperature						
	Tensile Strength	Yield Strength	Tensile Strength		Yield Strength		Stress Rupture	Creep Rate	
Wrought or cast ferrous and nonferrous	$\frac{S_T}{3.5}$	$\frac{2}{3} S_Y$	$\frac{S_T}{3.5}$	$\frac{1.1}{3.5} S_T R_T$	$\frac{2}{3} S_Y$	$\frac{2}{3} S_Y R_Y$ or $0.9 S_Y R_Y$ [Note (1)]	$F_{avg} S_{R avg}$	$0.8 S_{R min}$	$1.0 S_c$
Welded pipe or tube, ferrous and nonferrous	$\frac{0.85}{3.5} S_T$	$\frac{2}{3} \times 0.85 S_Y$	$\frac{0.85}{3.5} S_T$	$\frac{(1.1 \times 0.85)}{3.5} S_T R_T$	$\frac{2}{3} \times 0.85 S_Y$	$\frac{2}{3} \times 0.85 S_Y R_Y$ or $0.9 \times 0.85 S_Y R_Y$ [Note (1)]	$(F_{avg} \times 0.85) S_{R avg}$	$(0.8 \times 0.85) S_{R min}$	$0.85 S_c$

**NOTE:**

(1) Two sets of allowable stress values may be provided for austenitic stainless steels in Table 1A, and nickel alloys and cobalt alloys in Table 1B, having an  $S_Y/S_T$  ratio less than 0.625. The lower values are not specifically identified by a footnote. These lower values do not exceed two-thirds of the yield strength at temperature. The higher alternative allowable stresses are identified by a footnote. These higher stresses may exceed two-thirds but do not exceed 90% of the yield strength at temperature. The higher values should be used only where slightly higher deformation is not in itself objectionable. These higher stresses are not recommended for the design of flanges or for other strain-sensitive applications.

- The **higher alternative allowable stresses** are identified by a footnote to the tables. These stresses exceed two-thirds but do not exceed **90% of the minimum yield strength** at temperature. The higher stress values should be used only where slightly higher deformation is not in itself objectionable. These higher stresses are **not** recommended for the design of flanges or other strain-sensitive applications.

- UG-23(d) permits an increase in allowable stress when earthquake or wind loading is considered in combination with other loads and pressure defined in UG-22. The 1.2 increase permitted is equivalent to a load reduction factor of 0.833. Some standards which define applicable load combinations do not permit an increase in allowable stress, however a load reduction factor (typically 0.75) is applied to multiple transient loads (e.g., wind plus live load, seismic plus live load, etc.).

- UG-23(d) permits an increase in allowable stress when earthquake or wind loading is considered in combination with other loads and pressure defined in UG-22. The 1.2 increase permitted is equivalent to a load reduction factor of 0.833. Some standards which define applicable load combinations do not permit an increase in allowable stress, however a load reduction factor (typically 0.75) is applied to multiple transient loads (e.g., wind plus live load, seismic plus live load, etc.).



## UG-25 CORROSION

- (a) The user or his designated agent (see U-2) shall specify corrosion allowances other than those required by the rules of this Division.
- (b) corrosion, erosion, or mechanical abrasion
- (c) Material added for these purposes need not be of the same thickness for all parts of the vessel if different rates of attack are expected for the various parts.
- (d) No additional thickness need be provided when previous experience in like service has shown that corrosion does not occur or is of only a superficial nature.
- (e) Telltale Holes : shall have a diameter 1.5 mm to 5 mm and have a depth not less than 80% of the thickness required for a seamless shell of like dimensions.

## UG-26 LININGS

- (a) The user Corrosion resistant or abrasion resistant linings, whether or not attached to the wall of a vessel, shall not be considered as contributing to the strength of the wall except as permitted in Part UCL

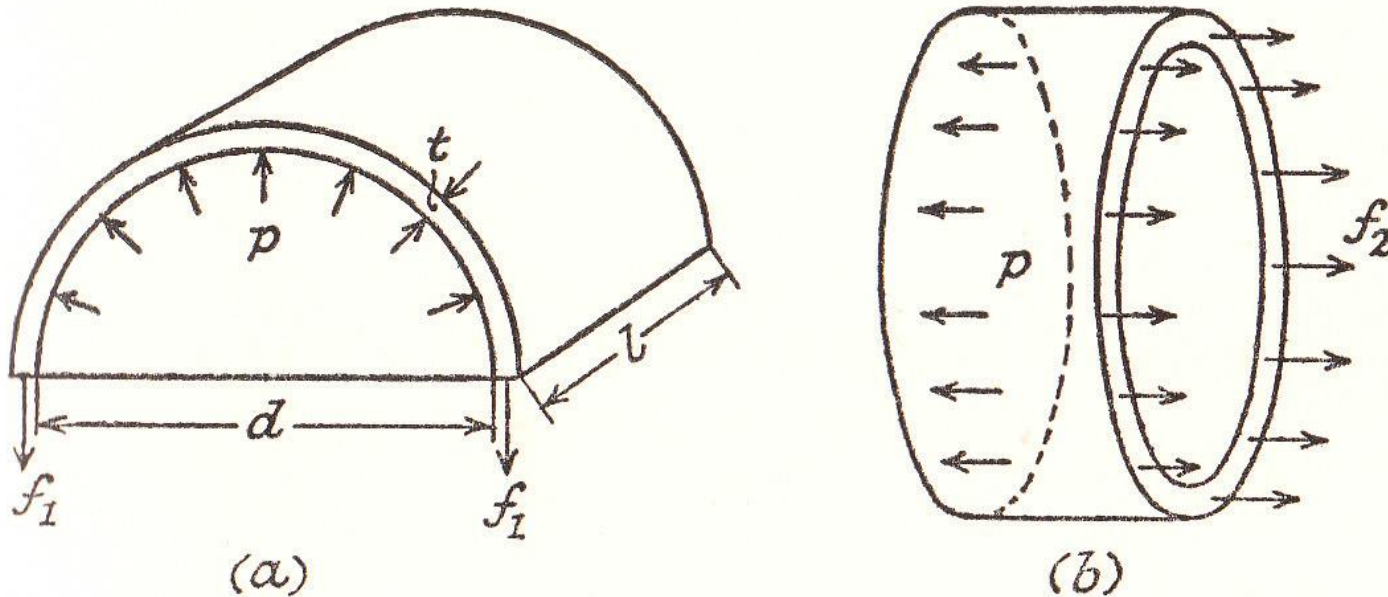
Lining

cladding

Refractory

Coating

- Hoop (circumferential) stress :
- This is the stress trying to split the vessel open along its length. Confusingly, this acts on the longitudinal weld seam (if there is one).



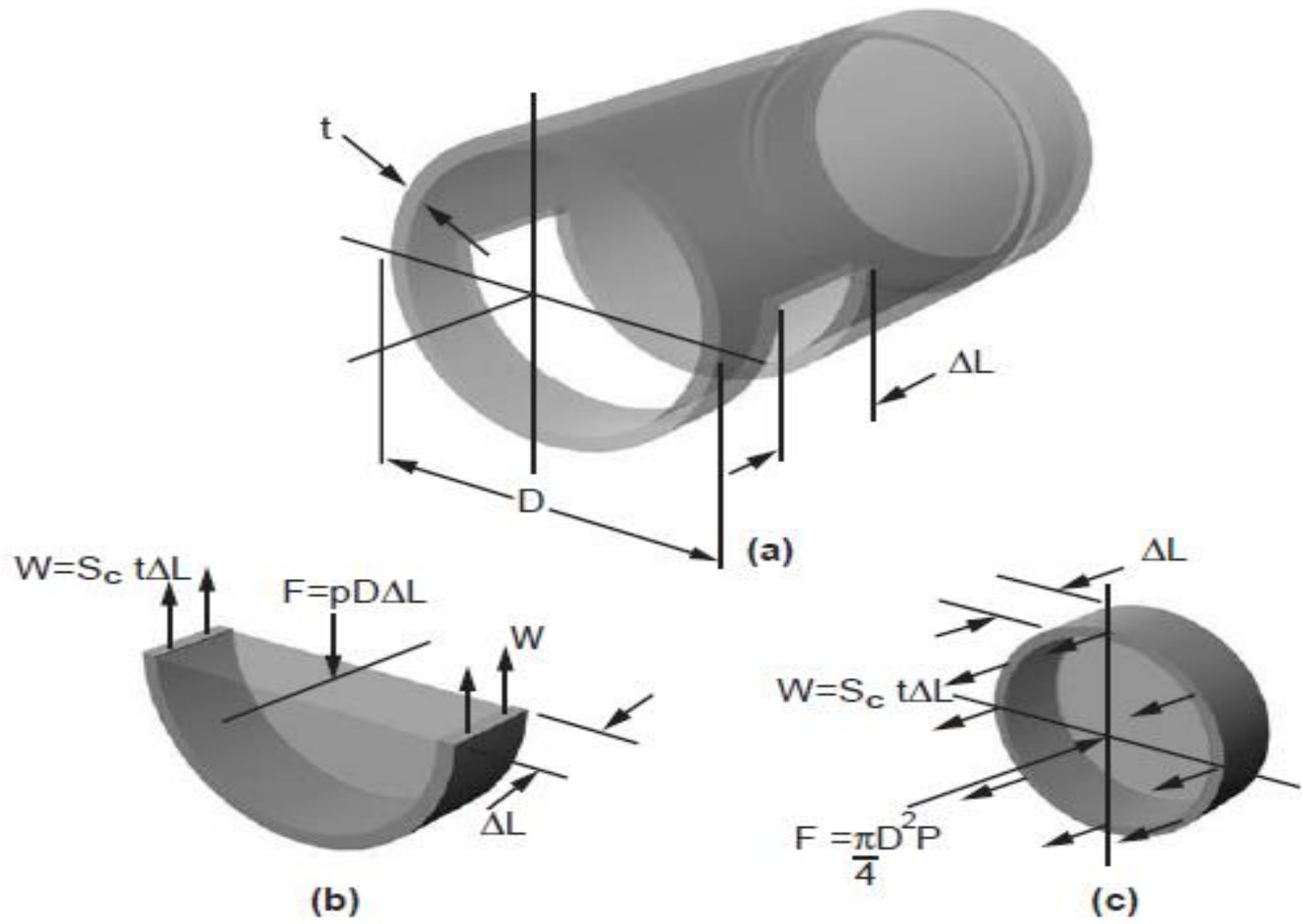


Figure 7.1 Forces and stresses in a pressurized cylinder.

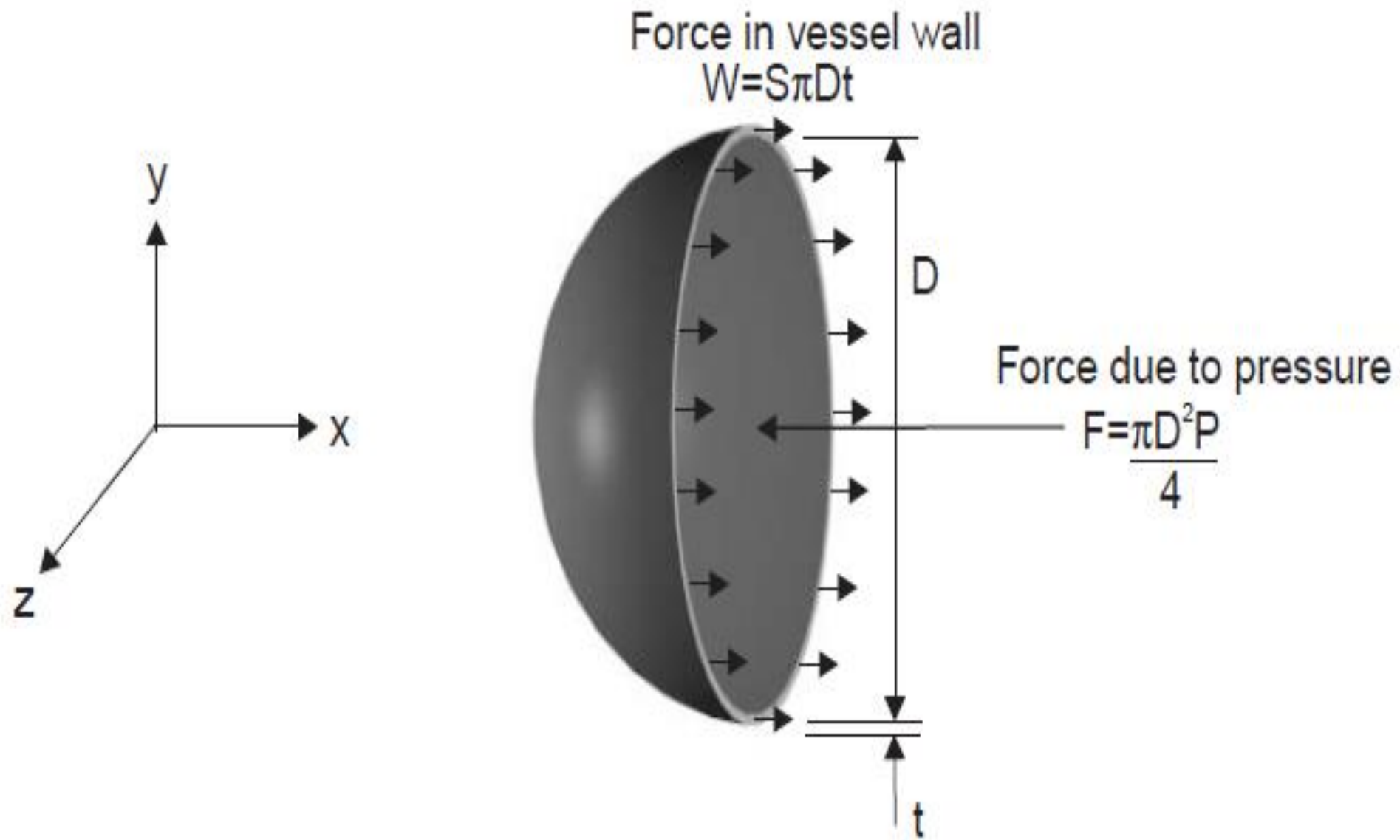


Figure 7.2 Forces and stresses in a sphere under pressure.

- circumferential stress :

$$S_C = \frac{RP}{t}$$

where: R = inside radius of the cylinder

t = thickness of cylinder

P = internal pressure

- Longitudinal stress :

$$S_L = \frac{RP}{2t}$$

where: R = inside radius of the cylinder

t = thickness of cylinder

P = internal pressure

## UG-27 (Question)

- According to our knowledge about circumferential and longitudinal stresses, Failure could be happen in a pressure vessel in which direction?

## UG-27 (Question)

- Circumferential Stress (Longitudinal Joints): When the thickness does not exceed one-half of the inside radius, or  $P$  does not exceed  $0.385SE$ , the following formulas shall apply:

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

- Longitudinal Stress (Circumferential Joints). When the thickness does not exceed one-half of the inside radius, or  $P$  does not exceed  $1.25SE$ , the following formulas shall apply:

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

- Spherical Shells. When the thickness of the shell of a wholly spherical vessel does not exceed  $0.356R$ , or  $P$  does not exceed  $0.665SE$ , the following formulas shall apply:

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

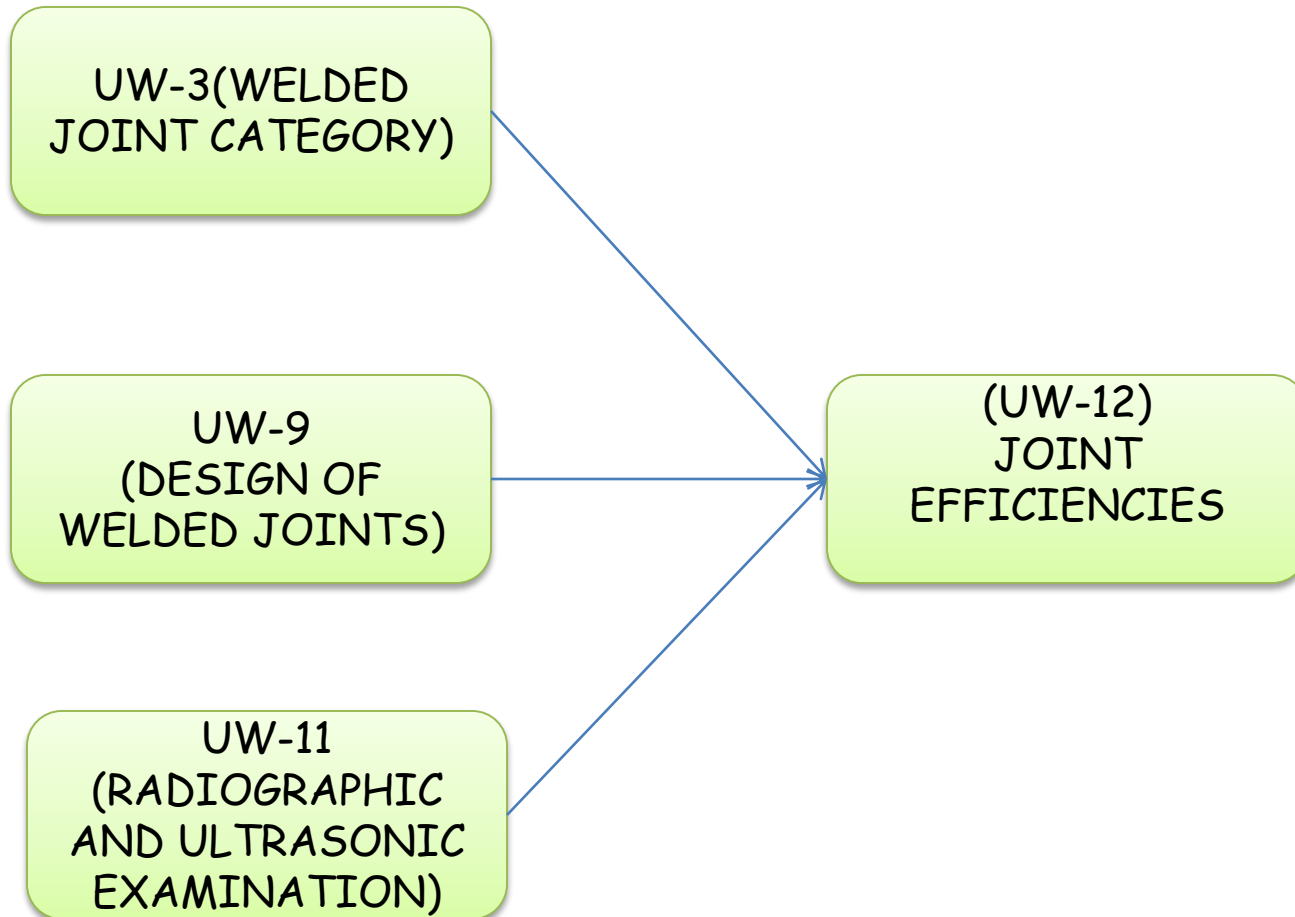


**Table UW-12**  
**Maximum Allowable Joint Efficiencies for Arc and Gas Welded Joints**

Type No.	Joint Description	Limitations	Joint Category	Degree of Radiographic Examination		
				(a) Full [Note (1)]	(b) Spot [Note (2)]	(c) None
(1)	Butt joints as attained by double-welding or by other means that will obtain 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 that remain in place are excluded.	None	A, B, C, and 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, and D	0.90	0.80	0.65
		(b) Circumferential butt joints with one plate offset; see UW-13(b)(4) and Figure UW-13.1, sketch (i)	A, B, and C	0.90	0.80	0.65
(3)	Single-welded butt joint without use of backing strip	Circumferential butt joints only, not over $\frac{5}{8}$ in. (16 mm) thick and not over 24 in. (600 mm) outside diameter	A, B, and C	NA	NA	0.60
(4)	Double full fillet lap joint	(a) Longitudinal joints not over $\frac{3}{8}$ in. (10 mm) thick	A	NA	NA	0.55
		(b) Circumferential joints not over $\frac{5}{8}$ in. (16 mm) thick	B and C [Note (3)]	NA	NA	0.55
(5)	Single full fillet lap joints with plug welds conforming to UW-17	(a) Circumferential joints [Note (4)] for attachment of heads not over 24 in. (600 mm) outside diameter to shells not over $\frac{1}{2}$ in. (13 mm) thick	B	NA	NA	0.50
		(b) Circumferential joints for the attachment to shells of jackets not over $\frac{5}{8}$ 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 $1\frac{1}{2}$ times the diameter of the hole for the plug.	C	NA	NA	0.50
(6)	Single full fillet lap joints without plug welds	(a) For the attachment of heads convex to pressure to shells not over $\frac{5}{8}$ in. (16 mm) required thickness, only with use of fillet weld on inside of shell; or	A and B	NA	NA	0.45
		(b) for attachment of heads having pressure on either side, to shells not over 24 in. (600 mm) inside diameter and not over $\frac{1}{4}$ in. (6 mm) required thickness with fillet weld on outside of head flange only	A and B	NA	NA	0.45
(7)	Corner joints, full penetration, partial penetration, and/or fillet welded	As limited by Figure UW-13.2 and Figure UW-16.1	C and D [Note (5)]	NA	NA	NA

## Joint efficiency issue!

- For joint efficiency issue we must review below clauses:



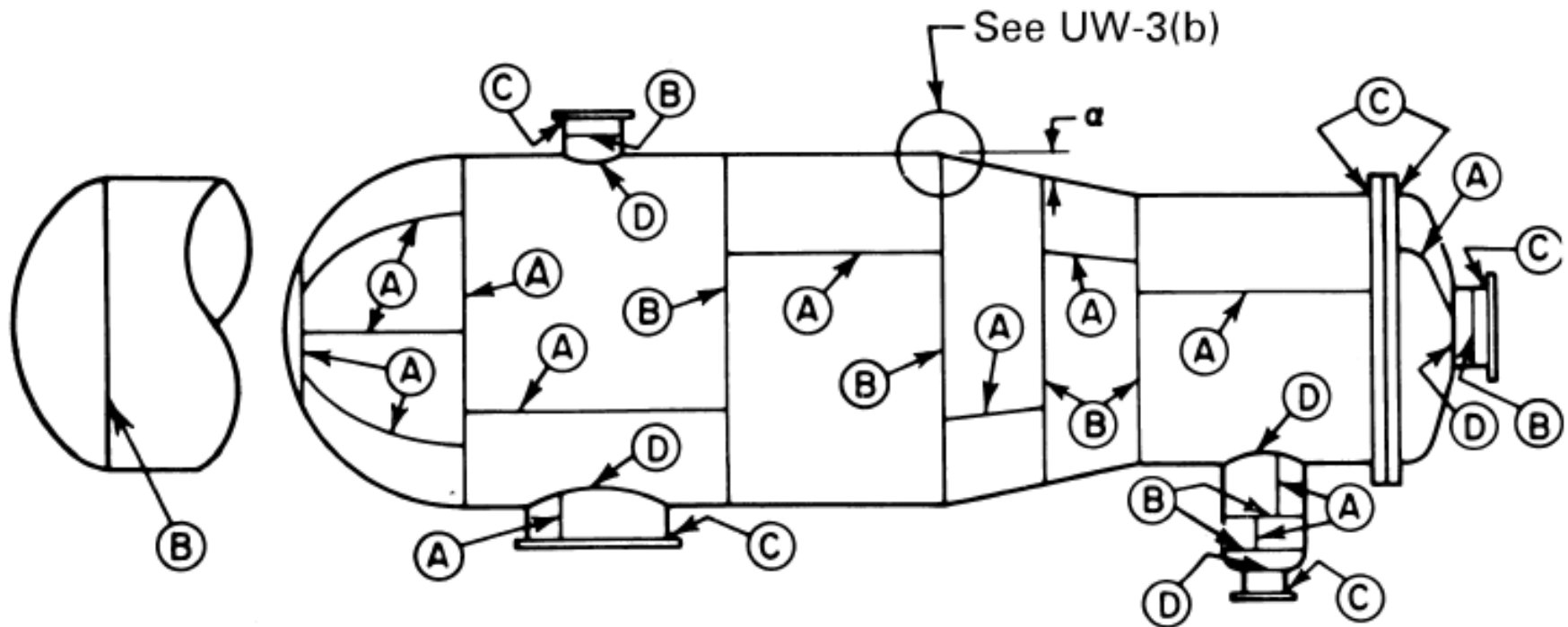
## UW-3 WELDED JOINT CATEGORY

- ❖ The term "Category" as used herein defines the location of a joint in a vessel, but not the type of joint.
- (a) Category A: Longitudinal and spiral welded joints within the main shell, communicating chambers or any other joints.
- (b) Category B: Circumferential welded joints within the main shell, communicating chambers or any other joints.
- (c) Category C. Welded joints connecting flanges and tubesheets, or flat heads to main shell, to formed heads, to transitions in diameter, to nozzles, or to communicating chambers
- (d) Category D. Welded joints connecting communicating chambers<sup>66</sup> or nozzles to main shells, to spheres, to transitions in diameter, to heads, or to flat-sided vessels

# UW-3 WELDED JOINT CATEGORY

## Figure UW-3

### Illustration of Welded Joint Locations Typical of Categories A, B, C, and D



## UW-11 (RADIOGRAPHIC AND ULTRASONIC EXAMINATION)

### ❖ (a) Full Radiography

- (1) all butt welds in the shell and heads of vessels used to contain lethal substances
- (2) all butt welds in the shell and heads of vessels in which the nominal thickness [the definition of nominal thickness at the welded joint under consideration shall be the nominal thickness of the thinner of the two parts joined] at the welded joint exceeds 1 1/2 in. (38 mm).
- (3) all butt welds in the shell and heads of unfired steam boilers having design pressures
  - (-a) exceeding 50 psi (350 kPa) [see UW-2(c)];
  - (-b) not exceeding 50 psi (350 kPa) but with nominal thickness at the welded joint exceeding the thickness specified in (2) above;

## UW-11 (RADIOGRAPHIC AND ULTRASONIC EXAMINATION)

### ❖ (a) Full Radiography

- (4) all butt welds in nozzles, communicating chambers, etc., with the nominal thickness at the welded joint that exceeds the thickness in (2) above or attached to the shell or heads of vessels under (1), (2), or (3) above that are required to be fully radiographed; however, Categories B and C butt welds in nozzles and communicating chambers that neither exceed NPS 10 (DN 250) nor 11/8 in. (29 mm) wall thickness do not require any radiographic examination;
- (5) all Category A and D butt welds in the shell and heads of vessels where the design of the joint or part is based on a joint efficiency permitted by UW-12(a), in which case:
  - (-a) Category A and B welds connecting the shell or heads of vessels shall be of Type No. (1) or Type No. (2) of Table UW-12;

## UW-11 (RADIOGRAPHIC AND ULTRASONIC EXAMINATION)

### ❖ (a) Full Radiography

- (-b) Category B or C butt welds [but not including those in nozzles and communicating chambers except as required in (4) above] which intersect the Category A butt welds in the shell or heads of vessels or connect seamless vessel shell or heads shall, as a minimum, meet the requirements for spot radiography in accordance with UW-52.
- (7) all Category A welds in a tubesheet shall be of Type (1) of Table UW-12;

## UW-11 (RADIOGRAPHIC AND ULTRASONIC EXAMINATION)

### ❖ (b) Spot Radiography

- Except when spot radiography is required for Category B or C butt welds by (a)(5)(-b) above, butt welded joints made in accordance with Type No. (1) or (2) of Table UW-12 which are not required to be fully radiographed by (a) above, may be examined by spot radiography. Spot radiography shall be in accordance with UW-52. If spot radiography is specified for the entire vessel, radiographic examination is not required of Category B and C butt welds in nozzles and communicating chambers that exceed neither NPS 10 (DN 250) nor 11/8 in. (29 mm) wall thickness.
- NOTE: This requirement specifies spot radiography for butt welds of Type No. (1) or No. (2) that are used in a vessel, but does not preclude the use of fillet and/or corner welds permitted by other paragraphs, such as for nozzle and manhole attachments, welded stays, flat heads, etc., which need not be spot radiographed.



## UW-11 (RADIOGRAPHIC AND ULTRASONIC EXAMINATION)

### ❖ (C) No Radiography

- (c) No Radiography. Except as required in (a) above, no radiographic examination of welded joints is required when the vessel or vessel part is designed for **external pressure only!**

**Table UW-12**  
**Maximum Allowable Joint Efficiencies for Arc and Gas Welded Joints**

Type No.	Joint Description	Limitations	Joint Category	Degree of Radiographic Examination		
				(a) Full [Note (1)]	(b) Spot [Note (2)]	(c) None
(1)	Butt joints as attained by double-welding or by other means that will obtain 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 that remain in place are excluded.	None	A, B, C, and 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, and D	0.90	0.80	0.65
		(b) Circumferential butt joints with one plate offset; see UW-13(b)(4) and Figure UW-13.1, sketch (i)	A, B, and C	0.90	0.80	0.65
(3)	Single-welded butt joint without use of backing strip	Circumferential butt joints only, not over $\frac{5}{8}$ in. (16 mm) thick and not over 24 in. (600 mm) outside diameter	A, B, and C	NA	NA	0.60
(4)	Double full fillet lap joint	(a) Longitudinal joints not over $\frac{3}{8}$ in. (10 mm) thick	A	NA	NA	0.55
		(b) Circumferential joints not over $\frac{5}{8}$ in. (16 mm) thick	B and C [Note (3)]	NA	NA	0.55
(5)	Single full fillet lap joints with plug welds conforming to UW-17	(a) Circumferential joints [Note (4)] for attachment of heads not over 24 in. (600 mm) outside diameter to shells not over $\frac{1}{2}$ in. (13 mm) thick	B	NA	NA	0.50
		(b) Circumferential joints for the attachment to shells of jackets not over $\frac{5}{8}$ 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 $1\frac{1}{2}$ times the diameter of the hole for the plug.	C	NA	NA	0.50
(6)	Single full fillet lap joints without plug welds	(a) For the attachment of heads convex to pressure to shells not over $\frac{5}{8}$ in. (16 mm) required thickness, only with use of fillet weld on inside of shell; or	A and B	NA	NA	0.45
		(b) for attachment of heads having pressure on either side, to shells not over 24 in. (600 mm) inside diameter and not over $\frac{1}{4}$ in. (6 mm) required thickness with fillet weld on outside of head flange only	A and B	NA	NA	0.45
(7)	Corner joints, full penetration, partial penetration, and/or fillet welded	As limited by Figure UW-13.2 and Figure UW-16.1	C and D [Note (5)]	NA	NA	NA

## Question!

❖ The following information is given in a data sheet. Please compute required and selected thickness for shell.

- Cylindrical shell:

- Design pressure : 5 barg
- Design Temperature: 150 °C
- Material : SA-516 70
- C.A.: 3 mm
- Vessel I.D : 3000 mm

- Spherical shell:

- Design pressure : 5 barg
- Design Temperature: 150 °C
- Material : SA-516 70
- C.A.: 3 mm
- Vessel I.D : 3000 mm

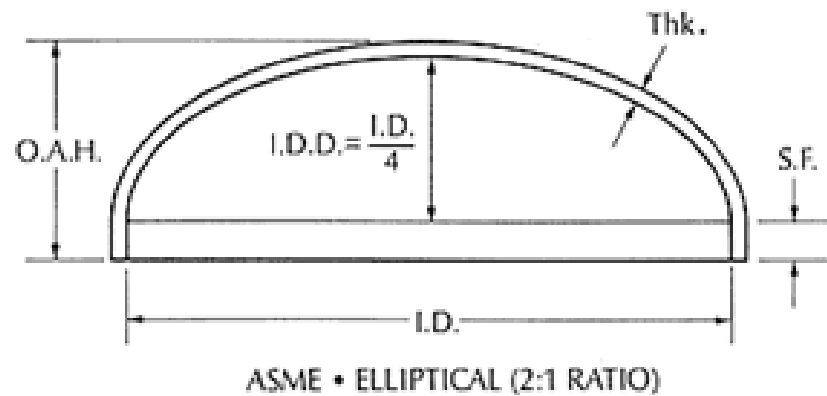


## UG-32 FORMED HEADS, AND SECTIONS, PRESSURE ON CONCAVE SIDE

- (a) The minimum required thickness at the thinnest point after forming of ellipsoidal, torispherical, hemispherical, conical, and toriconical heads under pressure on the concave side (plus heads) shall be computed by the appropriate formulas in this paragraph

# UG-32 FORMED HEADS, AND SECTIONS, PRESSURE ON CONCAVE SIDE

- (c) Ellipsoidal Heads

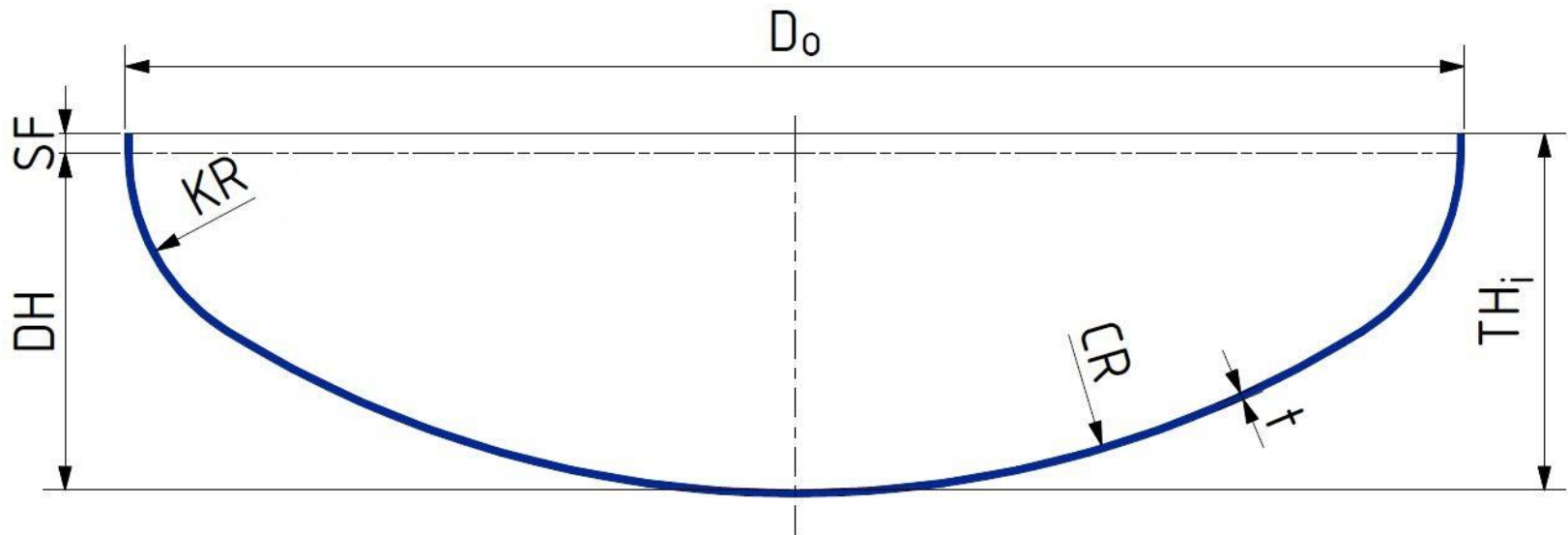


- ❑ Do research about skirt of head (straight Flange)



## UG-32 FORMED HEADS, AND SECTIONS, PRESSURE ON CONCAVE SIDE

- An acceptable approximation of a **2:1 ellipsoidal** head is one with a knuckle radius of **0.17D** and a spherical radius of **0.90D**.



## UG-32 FORMED HEADS, AND SECTIONS, PRESSURE ON CONCAVE SIDE

- (c) Ellipsoidal Heads ( $t \leq s/L \geq 0.002$ ):
- The required thickness of a dished head of semiellipsoidal form, in which half the minor axis (inside depth of the head minus the skirt) equals one-fourth of the inside diameter of the head skirt, shall be determined by

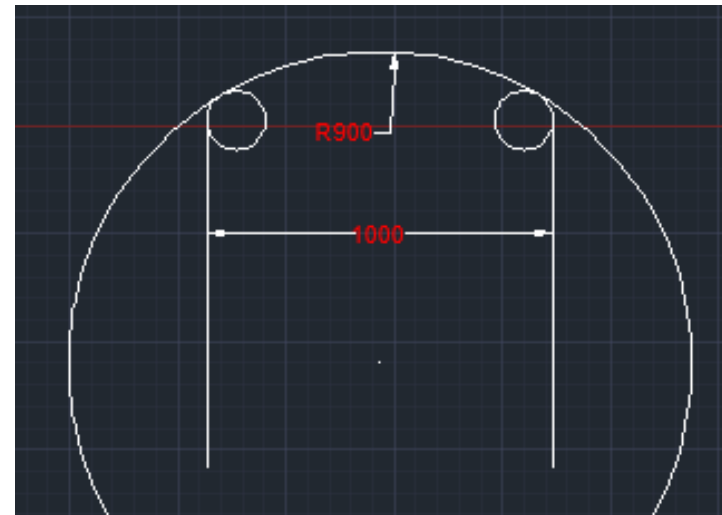
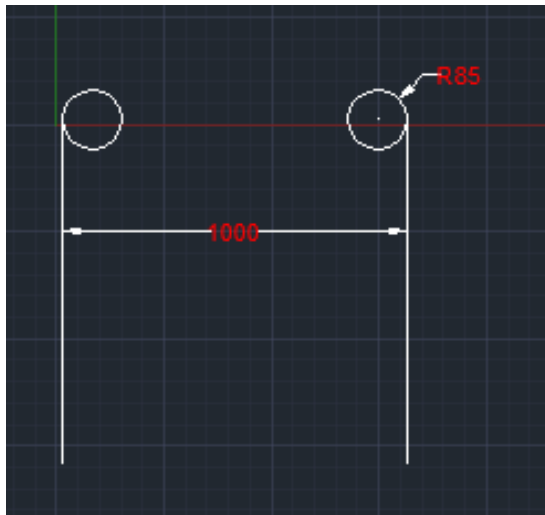
$$t = \frac{PD}{2SE - 0.2P} \quad \text{or} \quad P = \frac{2SEt}{D + 0.2t}$$

- NOTE: For ellipsoidal heads with  $t \leq s/L < 0.002$ , the rules of 1-4(f) shall also be met



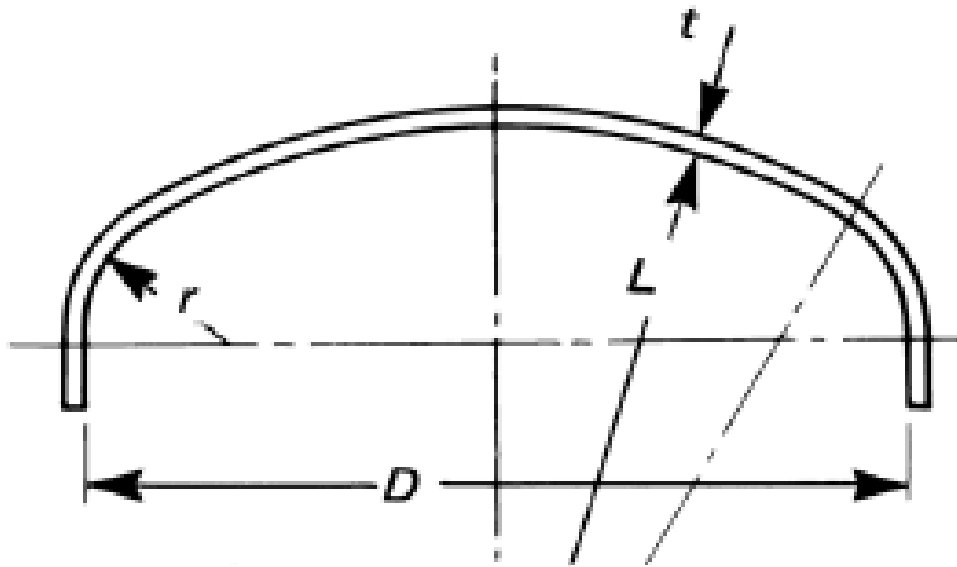
# UG-32 FORMED HEADS, AND SECTIONS, PRESSURE ON CONCAVE SIDE

- (c) Ellipsoidal Heads:



## UG-32 FORMED HEADS, AND SECTIONS, PRESSURE ON CONCAVE SIDE

- (d) Torispherical Heads With  $t \leq s/L \leq 0.002$ :



**(b) Spherically Dished  
(Torispherical)**

## UG-32 FORMED HEADS, AND SECTIONS, PRESSURE ON CONCAVE SIDE

- (d) Torispherical Heads With  $t \leq s/L \geq 0.002$ :
- The required thickness of a torispherical head for the case in which the knuckle radius is 6% of the inside crown radius and the inside crown radius equals the outside diameter of the skirt [see (i)] shall be determined by

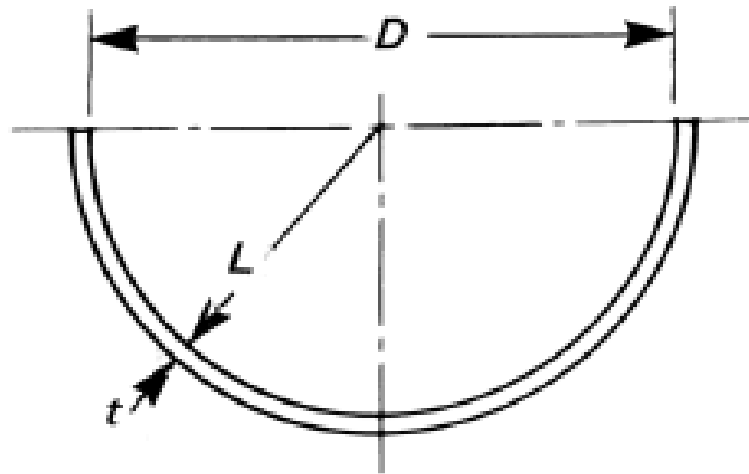
$$t = \frac{0.885PL}{SE - 0.1P} \quad \text{or} \quad P = \frac{SEt}{0.885L + 0.1t}$$

- Torispherical heads made of materials having a specified minimum tensile strength exceeding 70,000 psi (485 MPa) shall be designed using a value of  $S$  equal to 20,000 psi (138 MPa) at room temperature and reduced in proportion to the reduction in maximum allowable stress values at temperature for the material

## UG-32 FORMED HEADS, AND SECTIONS, PRESSURE ON CONCAVE SIDE

- (e) Hemispherical Heads :
- The When the thickness of a hemispherical head does not exceed  $0.356L$ , or  $P$  does not exceed  $0.665SE$ , the following formulas shall apply:

$$t = \frac{PL}{2SE - 0.2P} \quad \text{or} \quad P = \frac{2SEt}{L + 0.2t}$$

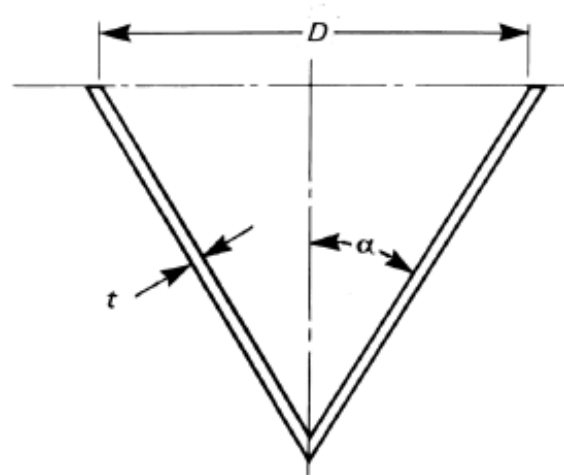


(c) Hemispherical

## UG-32 FORMED HEADS, AND SECTIONS, PRESSURE ON CONCAVE SIDE

- (f) Conical Heads and Sections (Without Transition Knuckle).
- The required thickness of conical heads or conical shell sections that have a half apex-angle  $\alpha$  not greater than 30 deg shall be determined by

$$t = \frac{PD}{2 \cos \alpha (SE - 0.6P)} \quad \text{or} \quad P = \frac{2SEt \cos \alpha}{D + 1.2t \cos \alpha}$$



(d) Conical

## UG-32 FORMED HEADS, AND SECTIONS, PRESSURE ON CONCAVE SIDE

**Note 1:** A reinforcing ring shall be provided when required by the rule in 1-5(d) and 1-5(e).

**Note 2:** Conical heads or sections having a half apex-angle a greater than 30 deg without a transition knuckle shall comply with eq. (4) and 1-5(g).

### (g) Toriconical Heads and Sections.

- The required thickness of the conical portion of a toriconical head or section, in which the knuckle radius is neither less than 6% of the outside diameter of the head skirt nor less than three times the knuckle thickness, shall be determined by eq. (f)(4) in (f) above, using  $D_i$  in place of  $D$ . The required thickness of the knuckle shall be determined by eq. 1-4(d)(3) in which

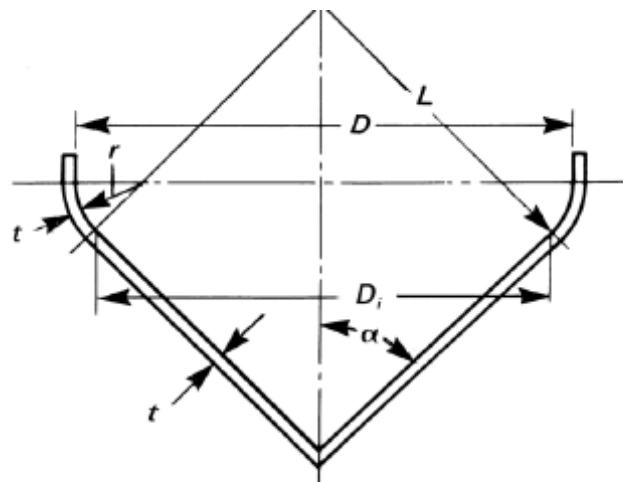
$$L = \frac{D_i}{2 \cos \alpha}$$

- Toriconical heads or sections may be used when the angle  $\alpha \leq 30$  deg and are mandatory for conical head designs when the angle  $\alpha$  exceeds 30 deg, unless the design complies with 1-5(g).

## (g) Toriconical Heads and Sections.

- The required thickness of the conical portion of a toriconical head or section, in which the knuckle radius is neither less than 6% of the outside diameter of the head skirt nor less than three times the knuckle thickness, shall be determined by eq. (f)(4) in (f) above, using  $D_i$  in place of  $D$ . The required thickness of the knuckle shall be determined by eq. 1-4(d)(3) in which

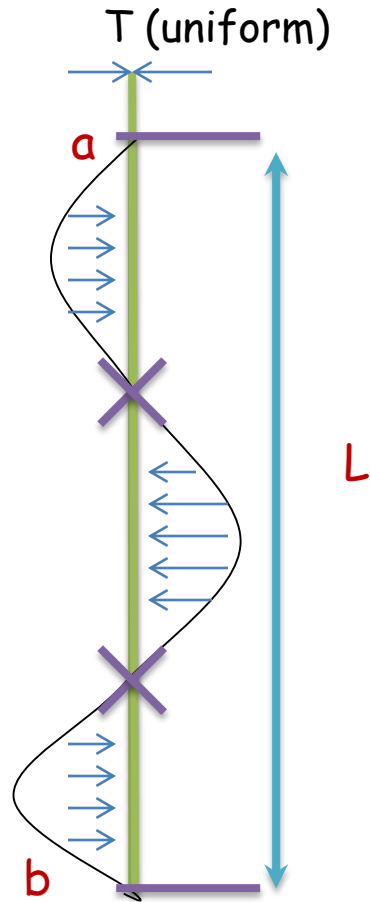
$$L = \frac{D_i}{2 \cos \alpha}$$



(e) Toriconical  
(Cone Head With Knuckle)



## ❖ Sturm-Liouville Equations (Singular Sturm-Liouville problems)

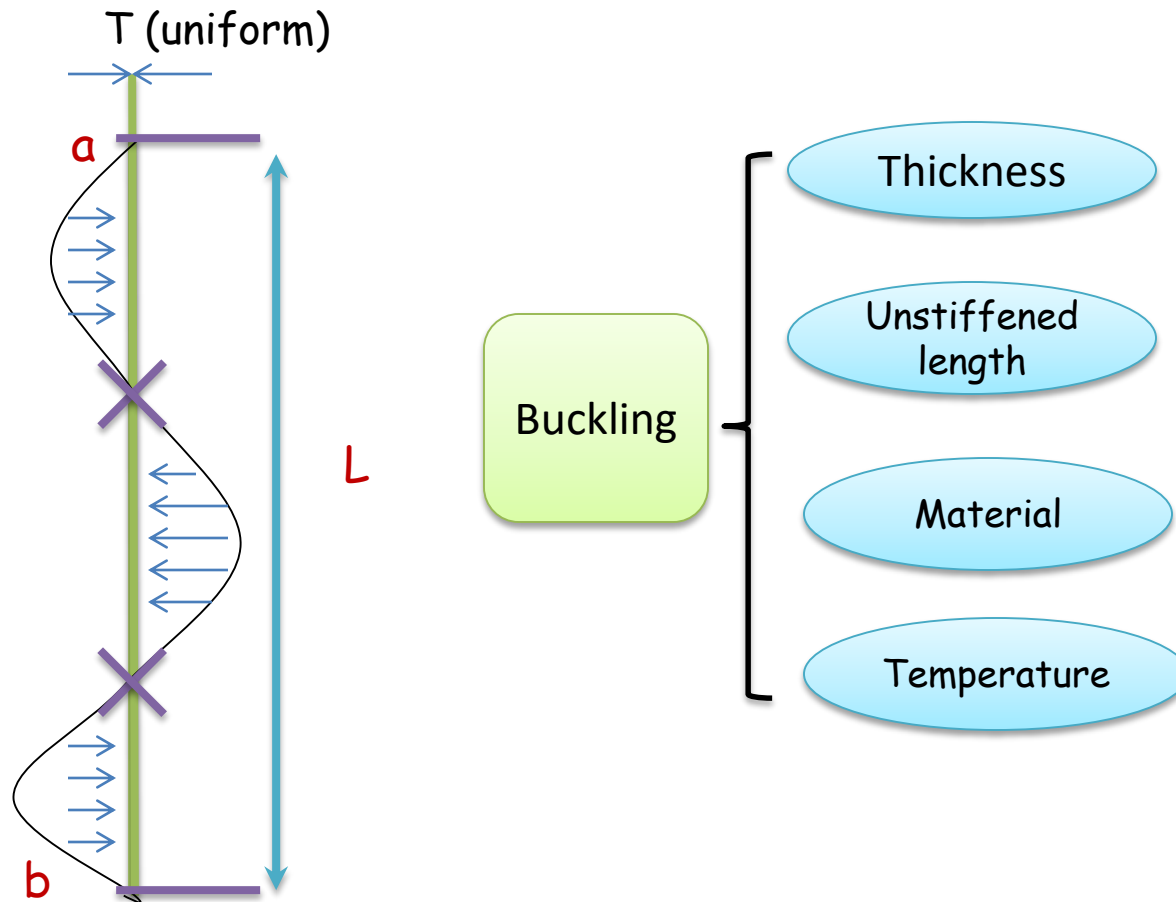


In most practical situations an eigenvalue is associated with an important physical characteristic of the problem, such as the **frequency of vibration of a string or of a metal plate**. In such cases the eigenfunction can be considered to describe a “snapshot” of a particular mode of vibration of the string or plate when it vibrates at the frequency determined by the associated eigenvalue. This application, and others that lead to Sturm–Liouville problems, will be developed in detail when partial differential equations are discussed in the context of *separation of variables*.

Ref. : Advanced engineering mathematics by Alan Jeffrey (University of Newcastle-upon-Tyne)

## UG-28 (External pressure)

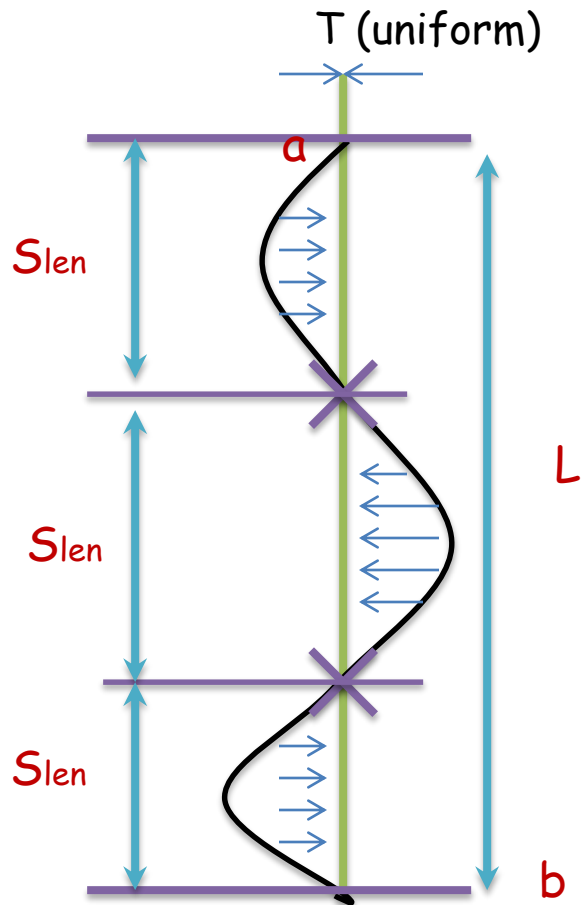
### ❖ Buckling Problem!



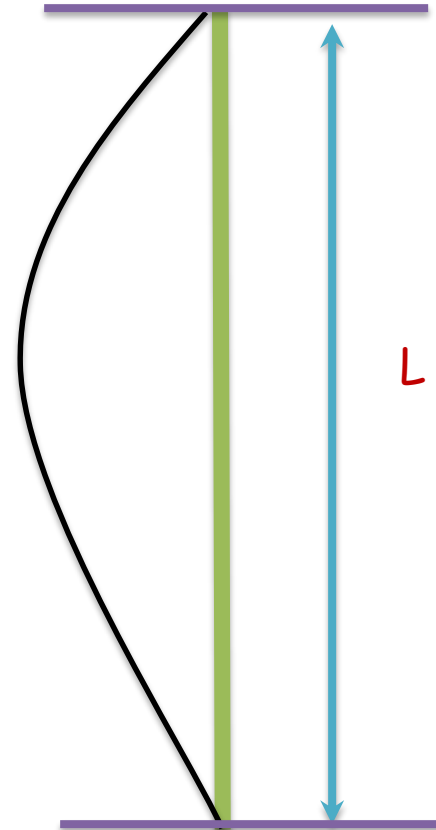
❖ See TABLE 8.1 Shear, moment, slope, and deflection formulas for elastic straight beams

# UG-28 (External pressure)

## ❖ Cylinder of pressure vessel



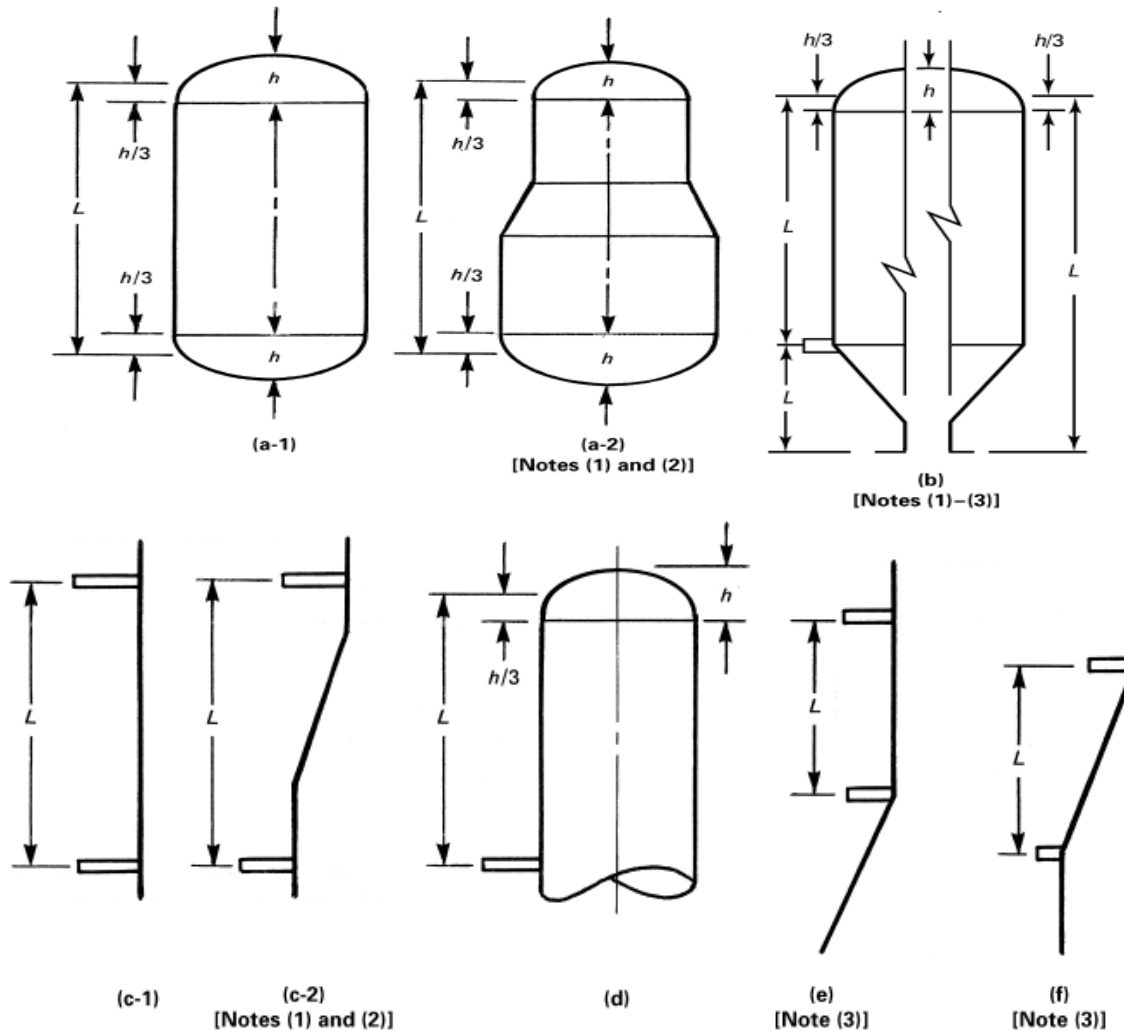
OR



❖ See TABLE 8.1 Shear, moment, slope, and deflection formulas for elastic straight beams

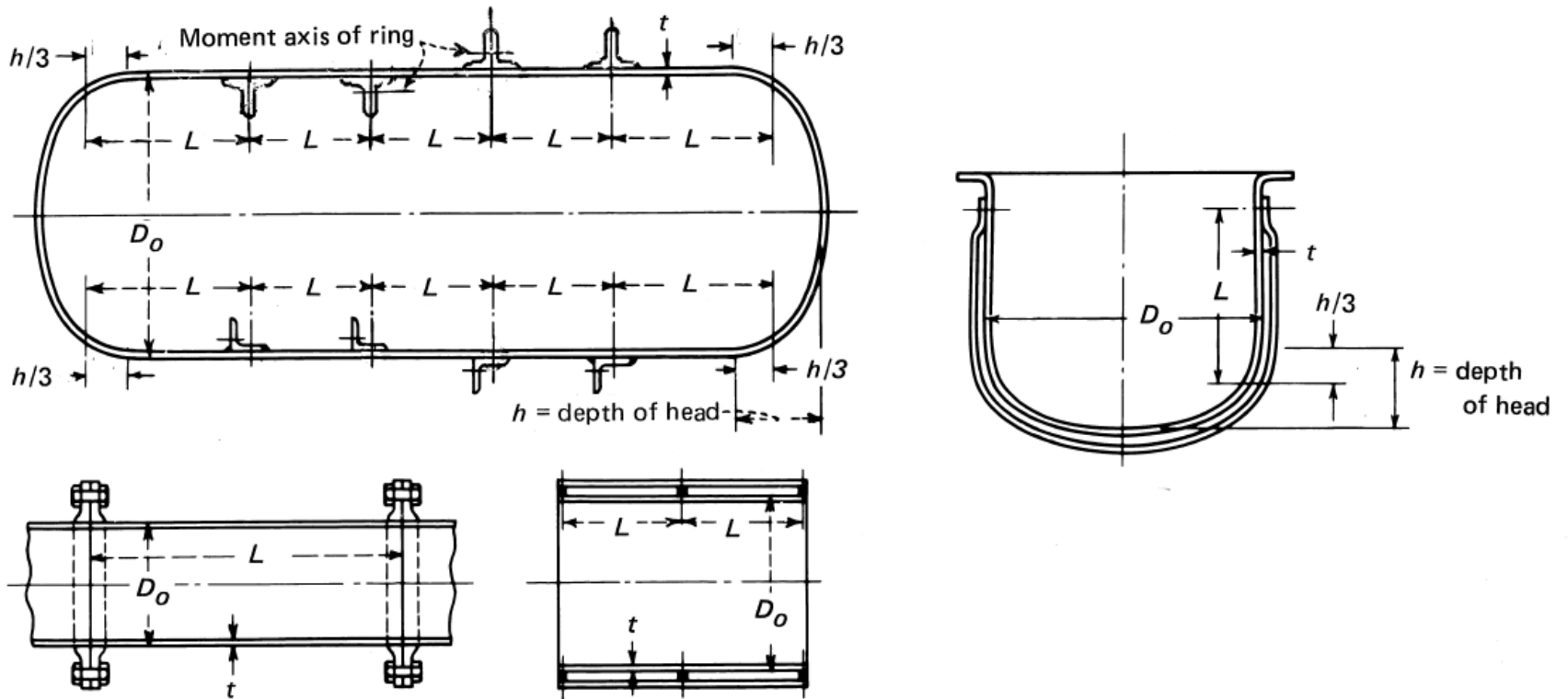
# UG-28 (External pressure)

Figure UG-28.1  
Diagrammatic Representation of Lines of Support for Design of Cylindrical Vessels Subjected to External Pressure



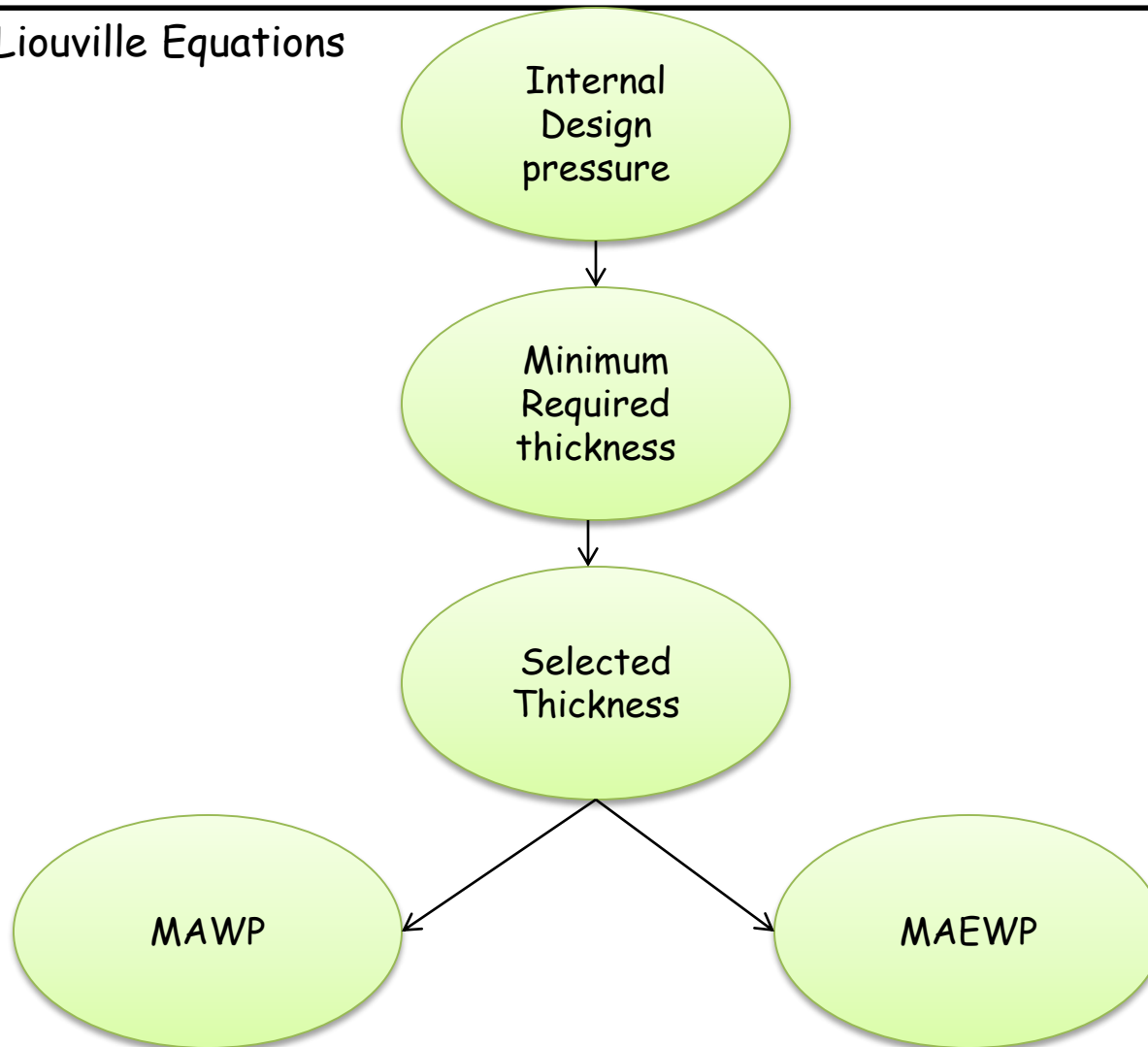
# UG-28 (External pressure)

**Figure UG-28**  
**Diagrammatic Representation of Variables for Design of Cylindrical Vessels Subjected to External Pressure**



## UG-28 (External pressure)

### ❖ Sturm-Liouville Equations



## UG-28 (External pressure)

As a general Low:

❖ MAWP is always more than Design pressure

And

❖ MAEWP is always more than External Design pressure

If External Design pressure be more than MAWEP (Pa) we have to increase thickness of vessel or using stiffing ring or using both of them!

So, Simply we must calculate Pa (MAWEP) and compare it with external design pressure

## UG-28 (External pressure)

As a general Low:

- ❖ (1) Cylinders having  $D_o/t$  values  $\geq 10$ :

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

- ❖ To compute B we have to know parameter "A" which is depend to "L", "t", and "D" and could be gain form Figure G of ASME SEC. II, Part D.

Note:

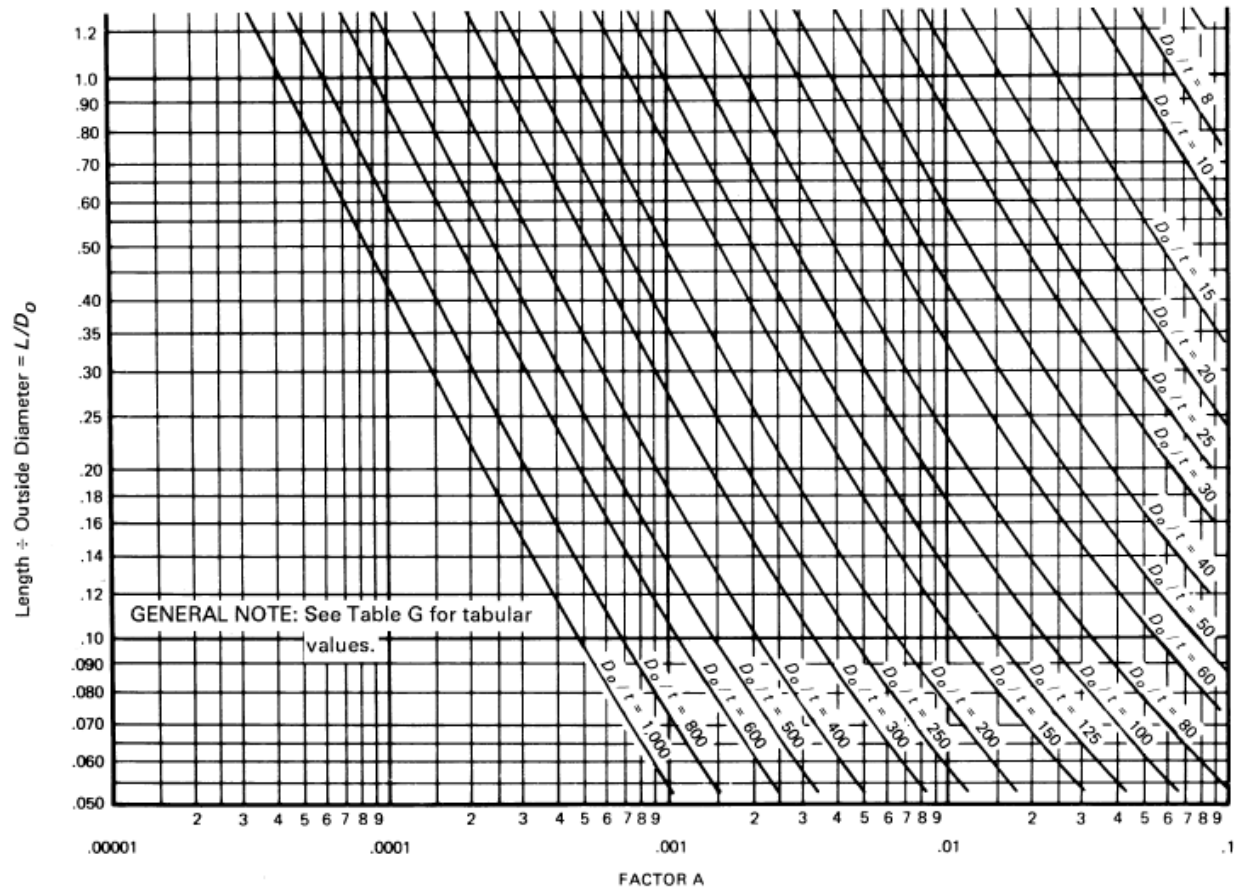
- 1- For values of  $L/D_o$  greater than 50, enter the chart at a value of  $L/D_o = 50$ .
- 2- For values of  $L/D_o$  less than 0.05, enter the chart at a value of  $L/D_o = 0.05$ .
- 3- For values of A falling to the left of the applicable material/temperature line, the value of  $P_a$  can be calculated using the following equation:

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



# UG-28 (External pressure)

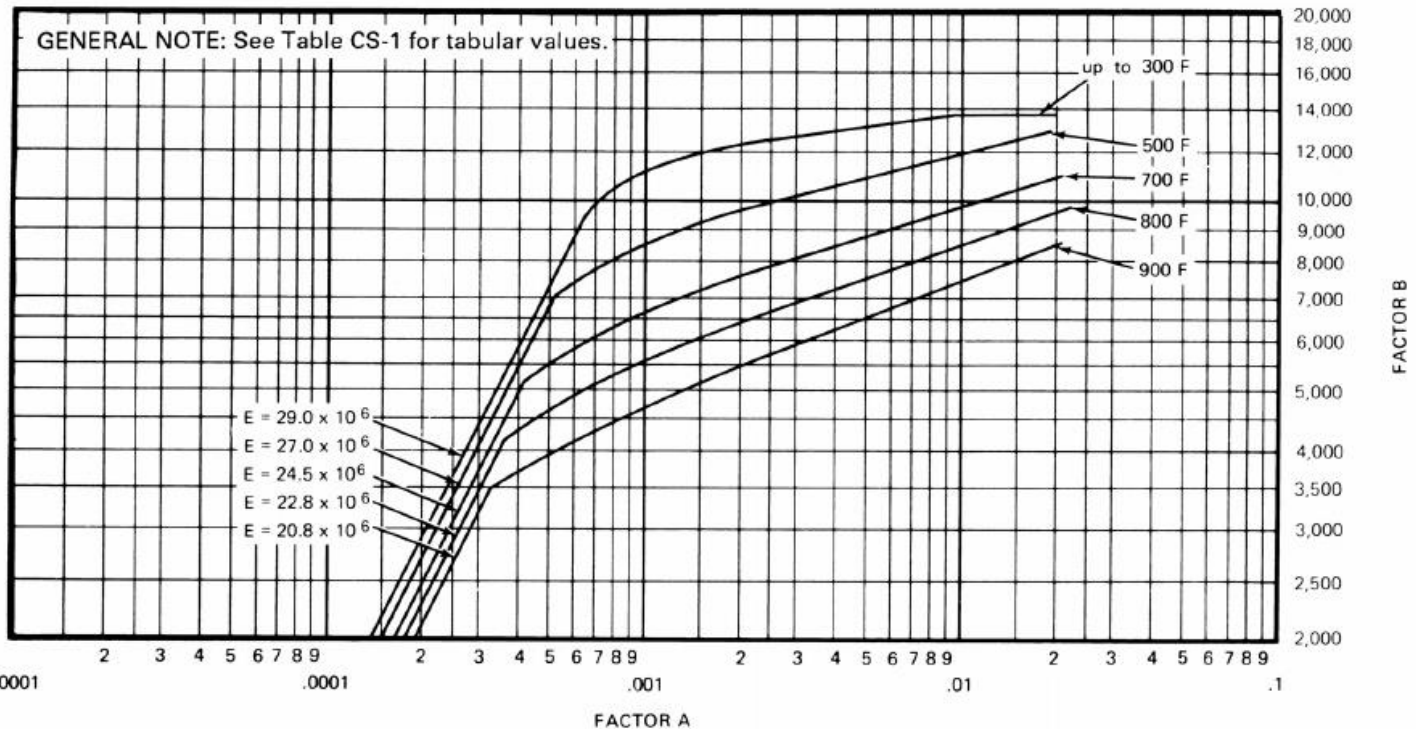
Figure G  
Geometric Chart for Components Under External or Compressive Loadings (for All Materials) (Cont'd)



GENERAL NOTE: Extrapolation is not permitted except as explicitly allowed by the Construction Code.

# UG-28 (External pressure)

**Figure CS-1**  
**Chart for Determining Shell Thickness of Components Under External Pressure Developed for Carbon or Low Alloy Steels With Specified Minimum Yield Strength Less Than 30,000 psi**



**GENERAL NOTES:**

- (a) The external pressure charts do not account for reduction of buckling strength due to creep under long-term loads. The effect of creep on buckling shall be considered at temperatures for which allowable stresses are shown italicized in Tables 1A, 1B, 2A, 2B, 5A, and 5B.
- (b) The external pressure chart assigned for a particular material is obtained from stress tables 1A, 1B, 2A, 2B, 5A, and 5B under the column for External Pressure Chart No. for that material and is mandatory, with the exception of Tables 5A and 5B.

## UG-28 (External pressure)

- ❖ (2) Cylinders having  $D_o/t$  values  $< 10$ :
  - Using the same procedure as given in (1), obtain the value of B. For values of  $D_o/t$  less than 4, the value of factor A can be calculated using the following equation:

$$A = \frac{1.1}{(D_o/t)^2}$$

## Question!

- ❖ The following information is given in a data sheet. Please compute required and selected thickness for shell.
- Cylindrical shell:
  - Design pressure : 5 barg / F.V.
  - Design Temperature: 150 °C
  - Material : SA-516 70
  - C.A.: 3 mm
  - Vessel I.D : 3000 mm
  - Vessel T.L to T.L : 7000 mm

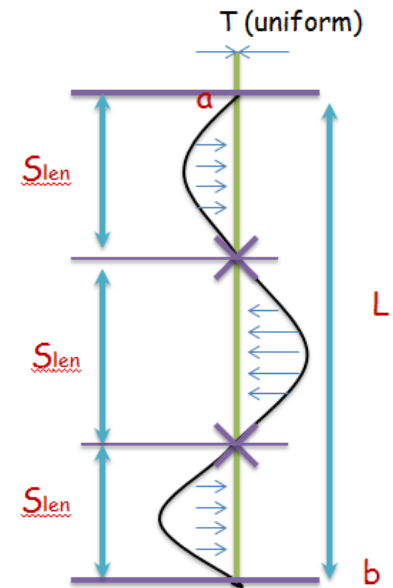


## UG-29 (STIFFENING RINGS)

- (a) External stiffening rings shall be attached to the shell by welding or brazing as per UG-30
- ❖ the available moment of inertia of a circumferential stiffening ring shall be not less than that determined by one of the following two formulas:

$$I_s = \left[ D_o^2 L_s (t + A_s/L_s) A \right] / 14$$

$$I'_s = \left[ D_o^2 L_s (t + A_s/L_s) A \right] / 10.9$$



- ❖ The adequacy of the moment of inertia for a stiffening ring shall be determined in accordance to UG-29 and could be referred to D.R. Moss hand book

## UG-29 (STIFFENING RINGS)

- The Code provides two methods for sizing stiffening rings. Method (a) is based on the stiffening ring providing all additional stiffening, and method (b) is based on a combination of the stiffening ring and a part of the shell providing the additional stiffening. Both methods require that one assume an initial size and shape for the ring.
  - (a) Stiffening ring alone:
  - (b) The stiffening ring/shell combination:

EASY AS

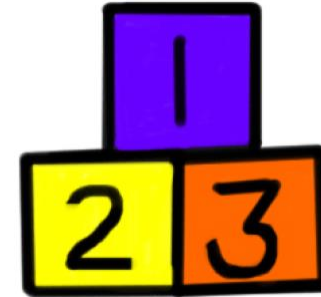
123



## UG-29 (STIFFENING RINGS)

- (a) Stiffening ring alone:
- 1) Determine B, where:

$$B = 0.75 \left( \frac{PD_o}{t + A_S/L_S} \right)$$



$A_S$  = cross-sectional area of stiffening ring, square inches.

$L_S$  = distance between support lines on both sides of the stiffening ring, inches.

$D_o$  = outside diameter of shell, inches.

- 2) Enter appropriate external pressure chart in Section II, Part D and determine Factor A that corresponds to the calculated Factor B.



## UG-29 (STIFFENING RINGS)

- 3) Determine the required moment of inertia of the stiffening ring only,  $I_S$ :

$$I_S = \frac{\left[ D_o^2 L_S \left( t + \frac{A_S}{L_S} \right) A \right]}{14}$$

- 4) Determine actual moment of inertia of ring only,  $I$ , in.4
- 5)  $I$  must be equal to or greater than  $I_S$

## UG-29 (STIFFENING RINGS)

### (b) The stiffening ring/shell combination:

$$B = 0.75 \left( \frac{PD_o}{t + A_S/L_S} \right)$$

1) Determine B, where:

- $A_S$  = cross-sectional area of stiffening ring, square inches.
- $L_S$  = distance between support lines on both sides of the stiffening ring, inches.
- $D_o$  = outside diameter of shell, inches.
- 2) Enter appropriate external pressure chart in Section II, Part D and determine Factor A that corresponds to the calculated Factor B.
- 3) Determine the required moment of inertia of the ring/shell combination,  $I_S'$ , in.4

$$I_S = \frac{\left[ D_o^2 L_S \left( t + \frac{A_S}{L_S} \right) A \right]}{14}$$

$$I_S' = \frac{\left[ D_o^2 L_S \left( t + \frac{A_S}{L_S} \right) A \right]}{10.9}$$

## UG-29 (STIFFENING RINGS)

- 4) Determine the moment of inertia of the combined ring and shell section acting together,  $I'$ ,  $\text{inch}^4$ . The length of shell used in the calculation shall not be greater than  $1.10 (D_0 + t)h$ . No overlap of contribution is allowed.
- 5)  $I'$  shall be equal to or greater than  $I_s'$ .
- Note that the formulas for  $B$  are identical. If the value of  $B$  falls below the left end of the material/temperature curve, then  $A$  is calculated using  $A = 2B/E$  where  $E$  is the modulus of elasticity. If different materials are used for the shell and stiffening ring, then use the external pressure chart that gives the lowest value of  $A$ .

## UG-29 (STIFFENING RINGS)

What is line of support:

- (a) a **stiffening ring** that meets the requirements of this paragraph;
- (b) a circumferential connection to a **jacket for a jacketed section** of a cylindrical shell;
- (c) a circumferential line on a head **at one-third the depth of the head** from the head tangent line as shown on Figure UG-28;
- (d) a **cone-to-cylinder** junction.

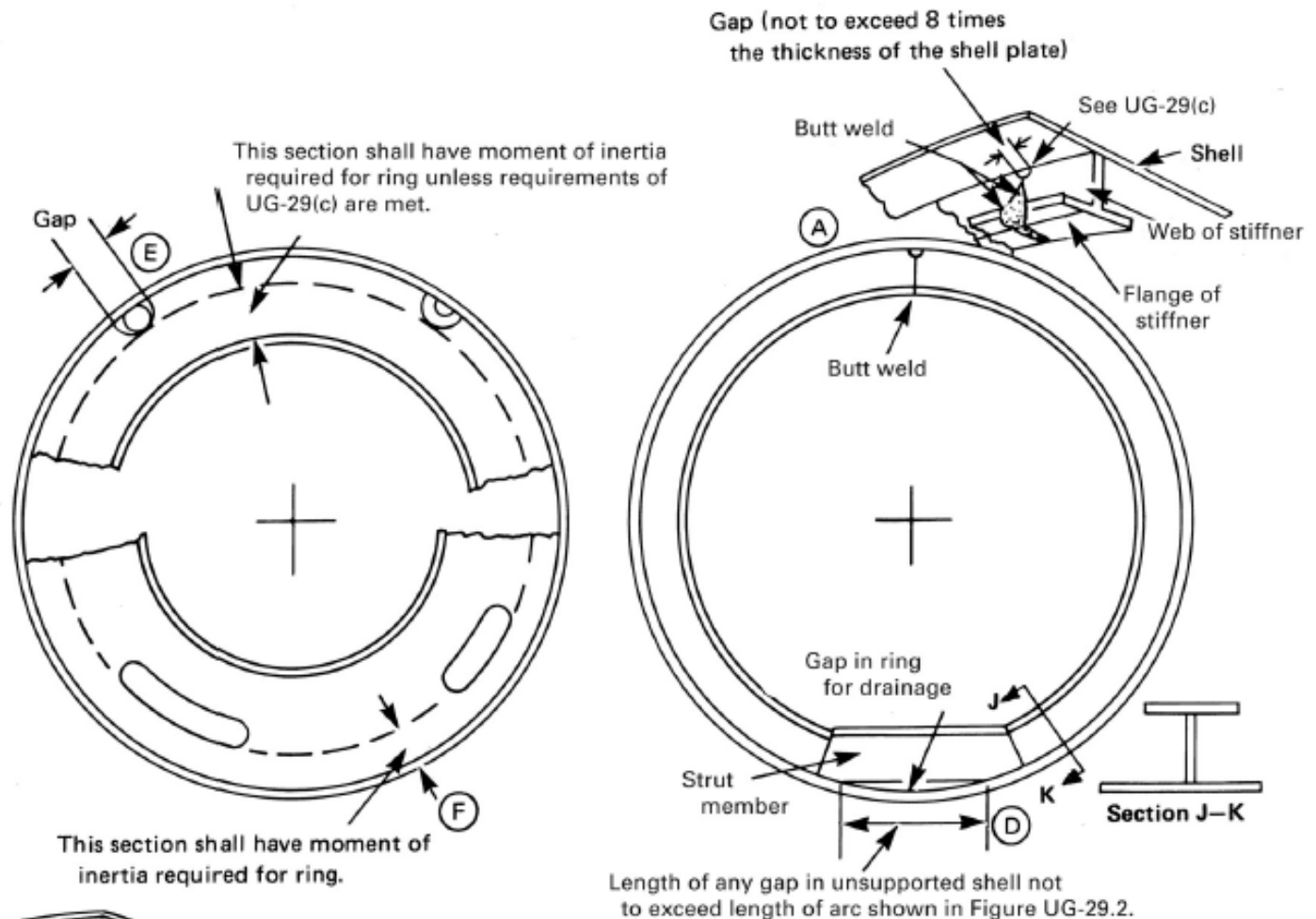


## UG-29 (STIFFENING RINGS)

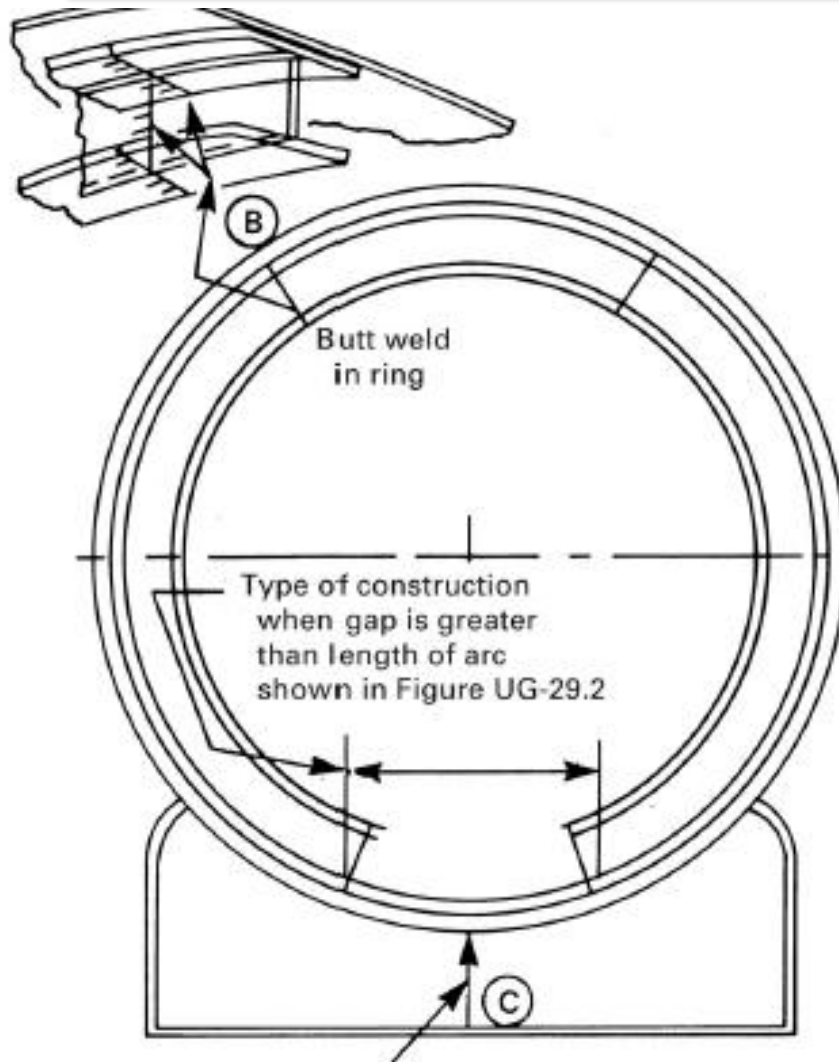
- (b) The adequacy of the moment of inertia for a stiffening ring shall be determined in (b) Stiffening rings shall extend completely around the circumference of the cylinder except as permitted in C below. Any joints between the ends or sections of such rings, such as shown in Figure UG-29.1 (A) and (B), and any connection between adjacent portions of a stiffening ring lying inside or outside the shell as shown in Figure UG-29.1 (C) shall be made so that the required moment of inertia of the combined ring-shell section is maintained.
- (c) Stiffening rings placed on the inside of a vessel may be arranged as shown in Figure UG-29.1 (E) and (F) provided that the required moment of inertia of the ring in (E) or of the combined ring-shell section in (F) is maintained within the sections indicated. Where the gap at (A) or (E) does not exceed eight times the thickness of the shell plate, the combined moment of inertia of the shell and stiffener may be used.

# UG-29 (STIFFENING RINGS)

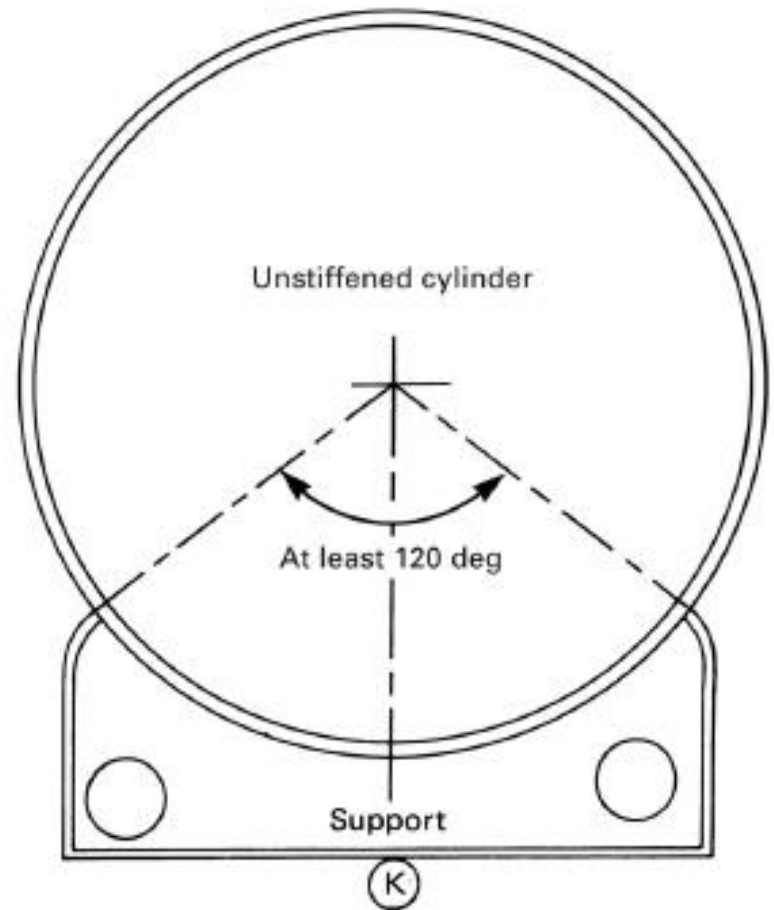
**Figure UG-29.1**  
**Various Arrangements of Stiffening Rings for Cylindrical Vessels Subjected to External Pressure**



# UG-29 (STIFFENING RINGS)



This section shall have moment of inertia required for ring.



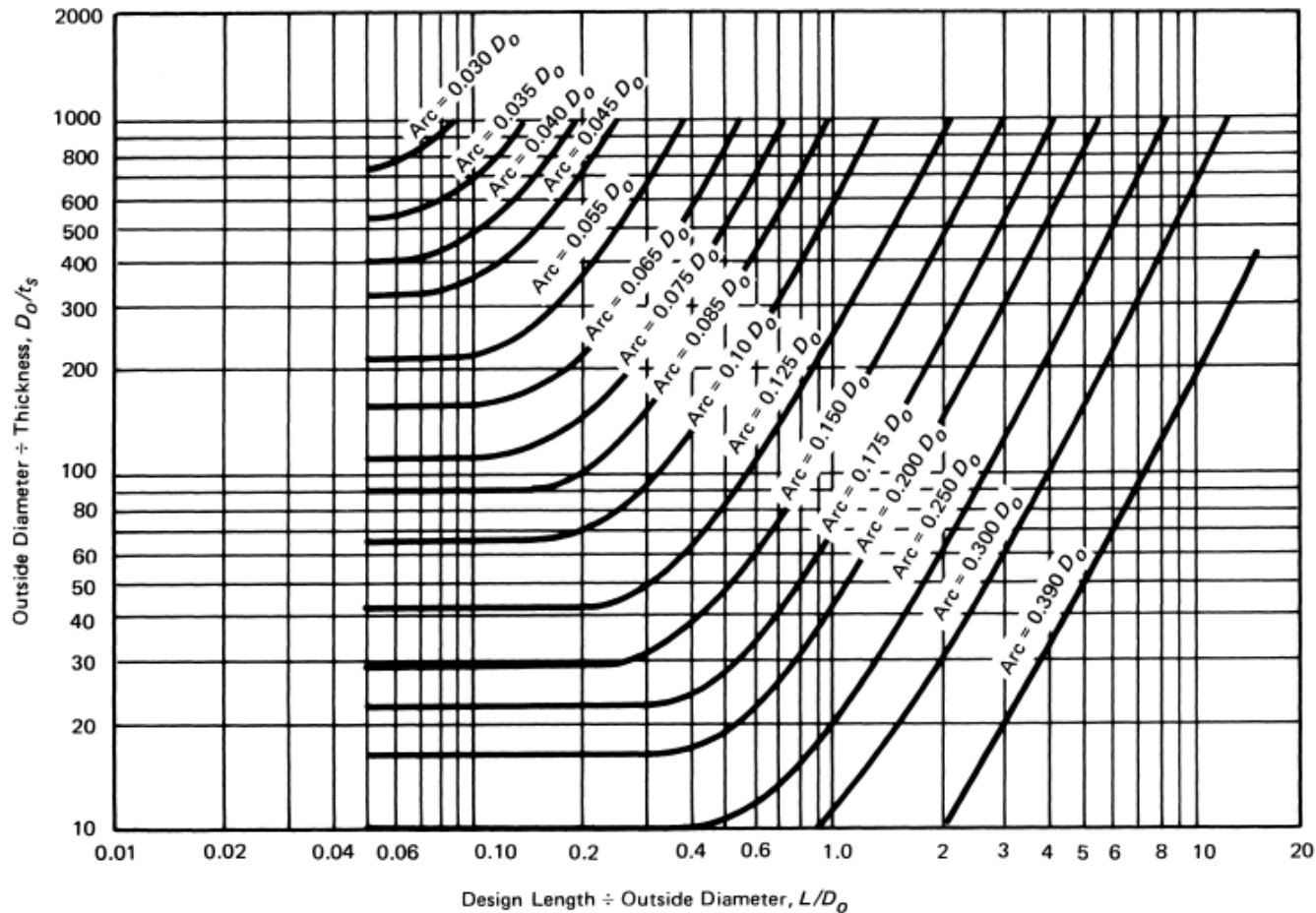
## UG-29 (STIFFENING RINGS)

- (b) Any gap in that portion of a stiffening ring supporting the shell, such as shown in Figure UG-29.1 (D) and (E), shall not exceed the length of arc given in Figure UG-29.2 unless additional reinforcement is provided as shown in Figure UG-29.1 (C) or unless the following conditions are met:
  - (1) only one unsupported shell arc is permitted per ring; and
  - (2) the length of the unsupported shell arc does not exceed 90 deg; and
  - (3) the unsupported arcs in adjacent stiffening rings are staggered 180 deg; and
  - (4) the dimension  $L$  defined in UG-28(b) is taken as the larger of the following: the distance between alternate stiffening rings, or the distance from the head tangent line to the second stiffening ring plus one-third of the head depth.



# UG-29 (STIFFENING RINGS)

Figure UG-29.2  
Maximum Arc of Shell Left Unsupported Because of Gap in Stiffening Ring of Cylindrical Shell Under External Pressure



## UG-29 (STIFFENING RINGS)

- (d) When internal plane structures perpendicular to the longitudinal axis of the cylinder (such as bubble trays or baffle plates) are used in a vessel, they may also be considered to act as stiffening rings provided they are designed to function as such.
- (e) Any internal stays or supports used as stiffeners of the shell shall bear against the shell of the vessel through the medium of a substantially continuous ring.
- (f) When closure bars or other rings are attached to both the inner shell and outer jacket of a vessel, with pressure in the space between the jacket and inner shell, this construction has adequate inherent stiffness, and therefore the rules of this paragraph **do not apply**.

## Question!

❖ The following information is given in a data sheet. Please compute required and selected thickness for shell by using stiffening ring.

- Cylindrical shell:
  - Design pressure : 5 barg / F.V.
  - Design Temperature: 150 °C
  - Material : SA-516 70
  - C.A.: 3 mm
  - Vessel I.D : 3000 mm
  - Vessel T.L to T.L : 7000 mm

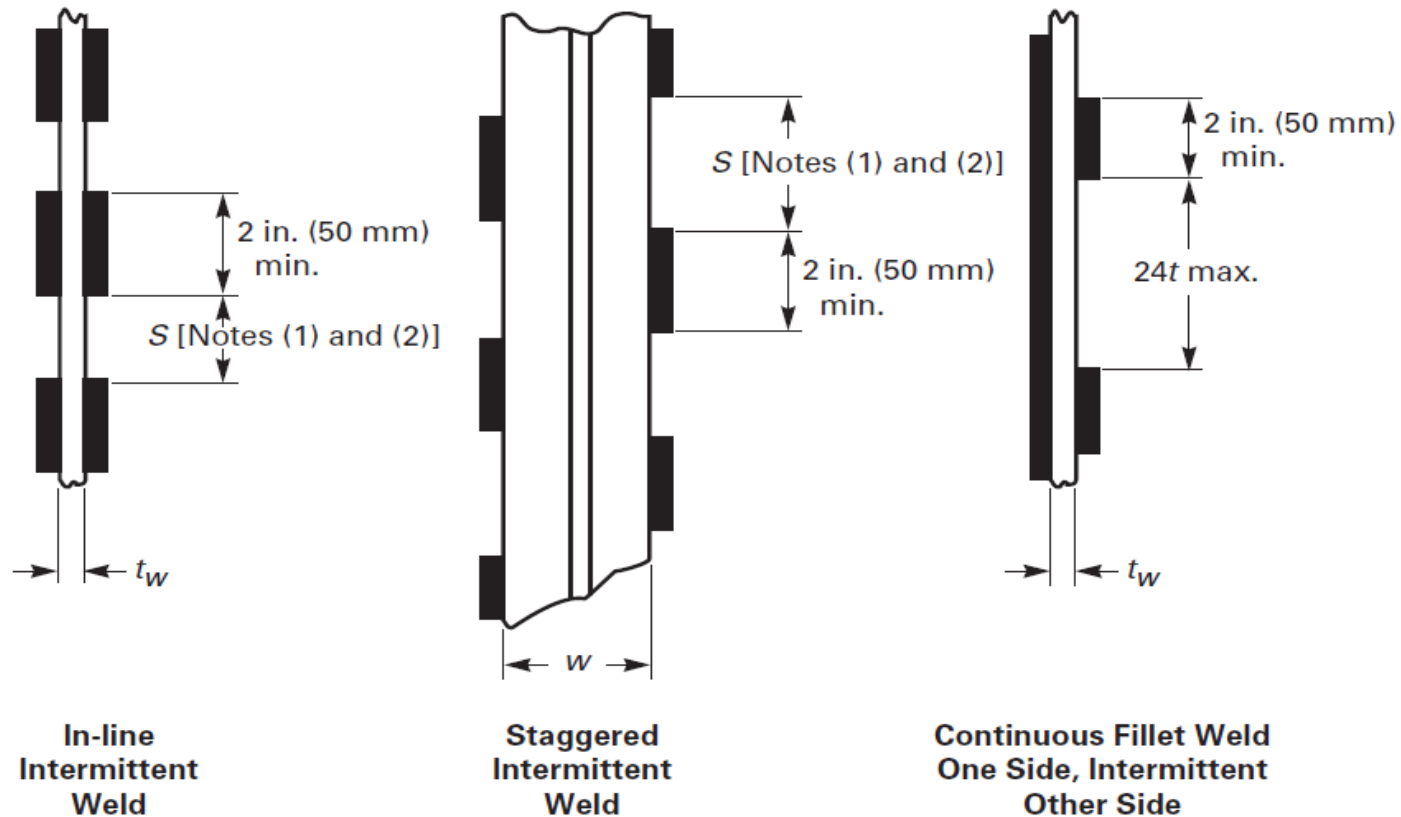


## UG-30 (ATTACHMENT OF STIFFENING RINGS)

- (a) Stiffening rings may be placed on the inside or outside of a vessel, and except for the configurations permitted by UG-29, shall be attached to the shell by welding or brazing
- (b) Stiffening rings may be attached to the shell by continuous, intermittent, or a combination of continuous and intermittent welds or brazes.
- Some acceptable methods of attaching stiffening rings are illustrated in Figure UG-30

# UG-30 (ATTACHMENT OF STIFFENING RINGS)

Figure UG-30  
Some Acceptable Methods of Attaching Stiffening Rings



## NOTES:

- (1) For external stiffeners,  $S \leq 8t$ .
- (2) For internal stiffeners,  $S \leq 12t$ .

## UG-30 (ATTACHMENT OF STIFFENING RINGS)

- (c) Intermittent welding shall be placed **on both sides** of the stiffener and may be either **staggered or in-line**. Length of individual fillet weld segments shall not be less than 2 in. (**50 mm**) and shall have a **maximum clear spacing** between **toes of adjacent weld** segments of 8t for external rings and 12t for internal rings where t is the shell thickness at the attachment.

## UG-30 (ATTACHMENT OF STIFFENING RINGS)

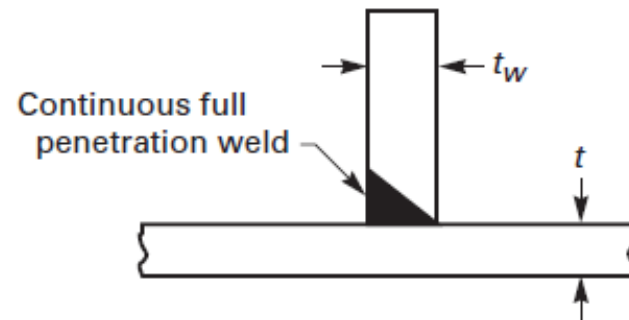
Min. length of Weld on  
each side of stiffening  
ring

Rings on the outside:  
 $0.5 \times \pi \times \text{Vessel OD}$

Rings on the inside:  
 $1/3 \times \pi \times \text{Vessel ID}$

## UG-30 (ATTACHMENT OF STIFFENING RINGS)

- (d) Which type of welds will be acceptable?
- ❖ A continuous full penetration weld is permitted

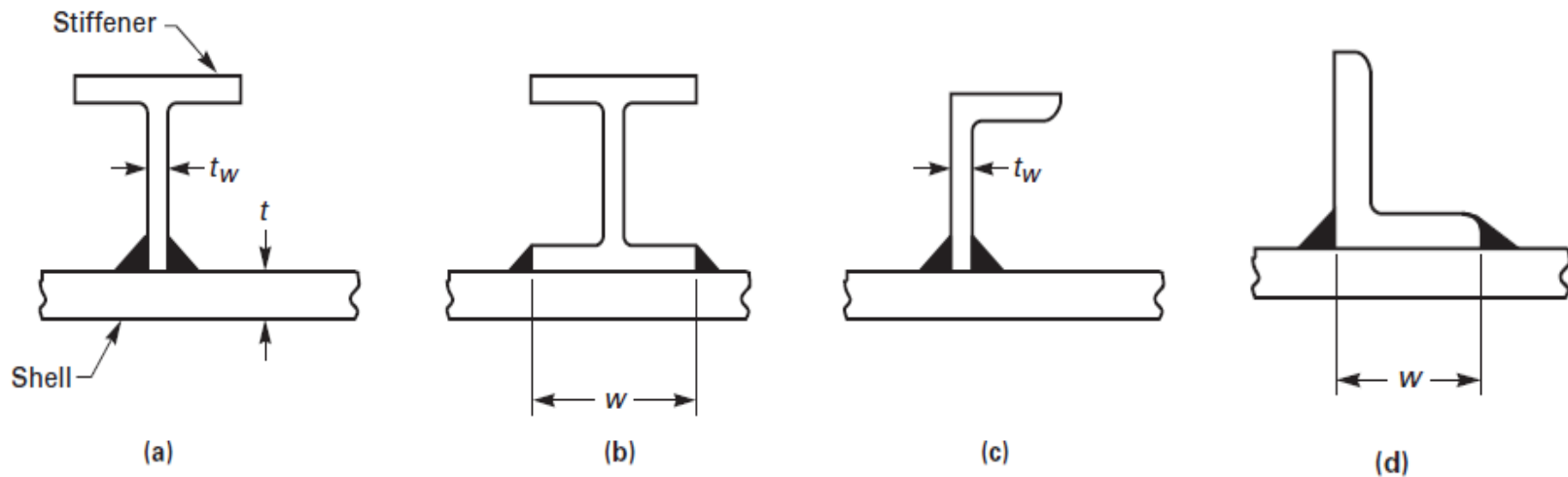


(e)

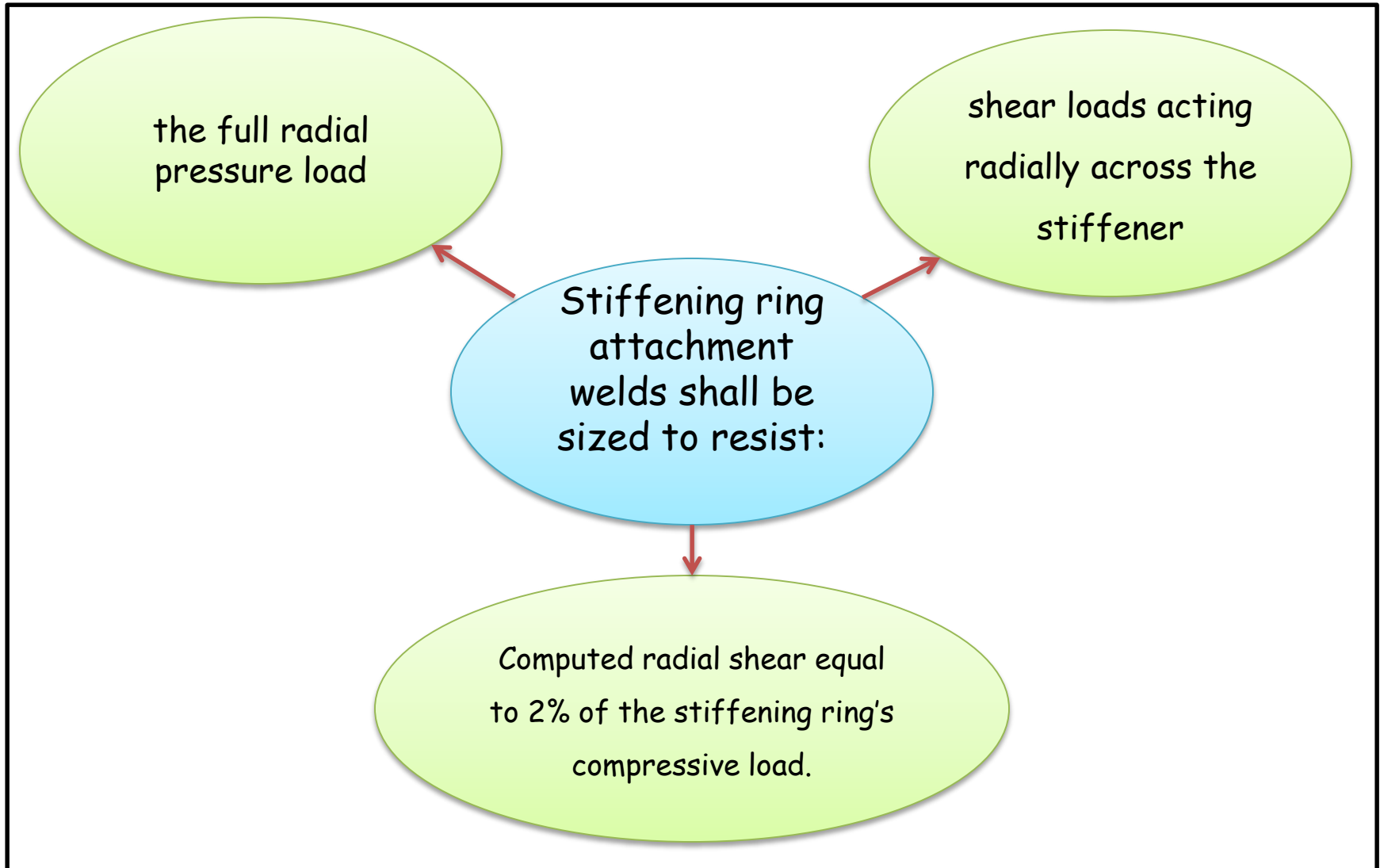


## UG-30 (ATTACHMENT OF STIFFENING RINGS)

- Continuous fillet welding on one side of the stiffener with intermittent Welding on the other side is permitted when the thickness  $t_w$  of the outstanding stiffening element [sketches (a) and (c)] or width  $w$  of the stiffening element mating to the shell [sketches (b) and (d)] is not more than **25 mm**. The weld segments shall be not **less than 50 mm** long and shall have a **maximum** clear spacing between toes of adjacent weld segments of  **$24t$**



## UG-30 (ATTACHMENT OF STIFFENING RINGS)



## UG-30 (ATTACHMENT OF STIFFENING RINGS)

### ❖ (e) Strength of Attachment Welds :

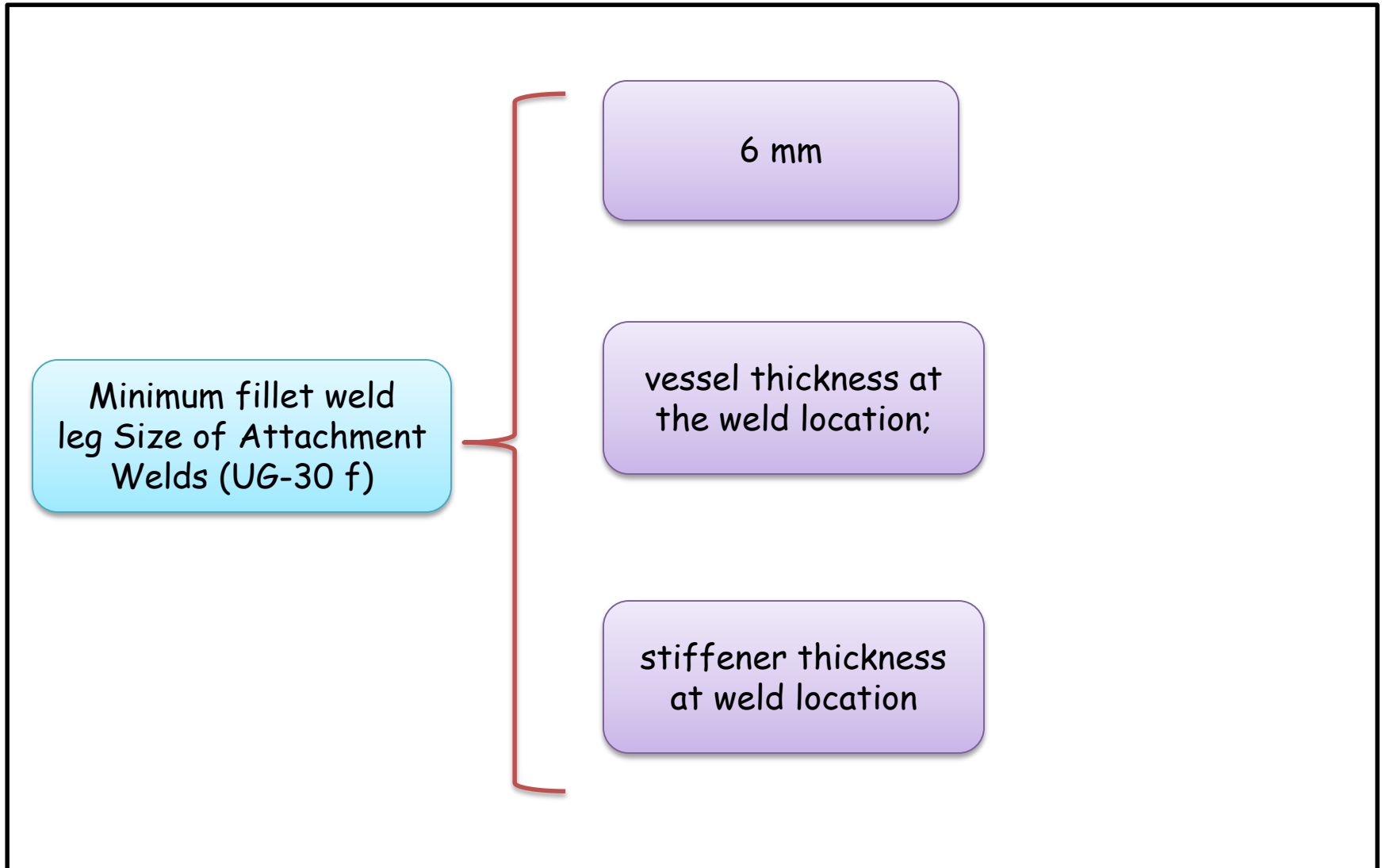
1: The radial pressure load from shell, lb/in., is equal to  $PL_s$ .

2: The radial shear load is equal to  $0.01PL_sD_o$ .

Where,

- $L_s$  = one-half of the distance from the centerline of the stiffening ring to the next line of support on one side, plus one-half of the centerline distance to the next line of support on the other side of the stiffening ring, both measured parallel to the axis of the cylinder.
- $P$  = external design pressure
- $D_o$  = outside diameter of cylindrical shell course

## UG-30 (ATTACHMENT OF STIFFENING RINGS)



## UG-31 (TUBES, AND PIPE WHEN USED AS TUBES OR SHELLS)

- (a) Internal Pressure. For required wall thickness under internal pressure see UG-27
- (b) External Pressure. For required wall thickness under external pressure see UG-28.
- (C) The thickness as determined under (a) or (b) above shall be increased when necessary to meet the following requirements:
  - (1) Additional wall thickness should be provided when corrosion, erosion, or wear due to cleaning operations is expected.
  - (2) Where ends are threaded, additional wall thickness is to be provided in the amount of  $20/n$  mm ( $0.8/n$  in.)

Note : where  $n$  equals the number of threads per inch

## UG-34 (UNSTAYED FLAT HEADS AND COVERS)

- The thickness of flat unstayed heads, covers, and blind flanges shall conform to one of the following three requirements.
- (1) Circular blind flanges conforming to any of the flange standards listed in Table U-3 and further limited in UG-44 shall be acceptable for the diameters and pressure-temperature ratings in the respective standard when the blind flange is of the types shown in Figure UG-34 sketches (j) and (k).
- (2) The minimum required thickness of flat unstayed circular heads, covers and blind flanges shall be calculated by the following formula:

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

## UG-34 (UNSTAYED FLAT HEADS AND COVERS)

- except when the head, cover, or blind flange is attached by bolts causing an edge moment [sketches (j) and (k)] in which case the thickness shall be calculated by

$$t = d\sqrt{CP/SE + 1.9Wh_G/SEd^3}$$

- When using eq. (2), the thickness  $t$  shall be calculated for both operating conditions and gasket seating, and the greater of the two values shall be used. For operating conditions, the value of  $P$  shall be the design pressure, and the values of  $S$  at the design temperature and  $W$  from eq. 2-5(e)(4) shall be used. For gasket seating,  $P$  equals zero, and the values of  $S$  at atmospheric temperature and  $W$  from eq. 2-5(e)(5) shall be used.

## UG-34 (UNSTAYED FLAT HEADS AND COVERS)

- (3) Flat unstayed heads, covers, or blind flanges may be square, rectangular, elliptical, obround, segmental, or otherwise noncircular. Their required thickness shall be calculated by the following formula:

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

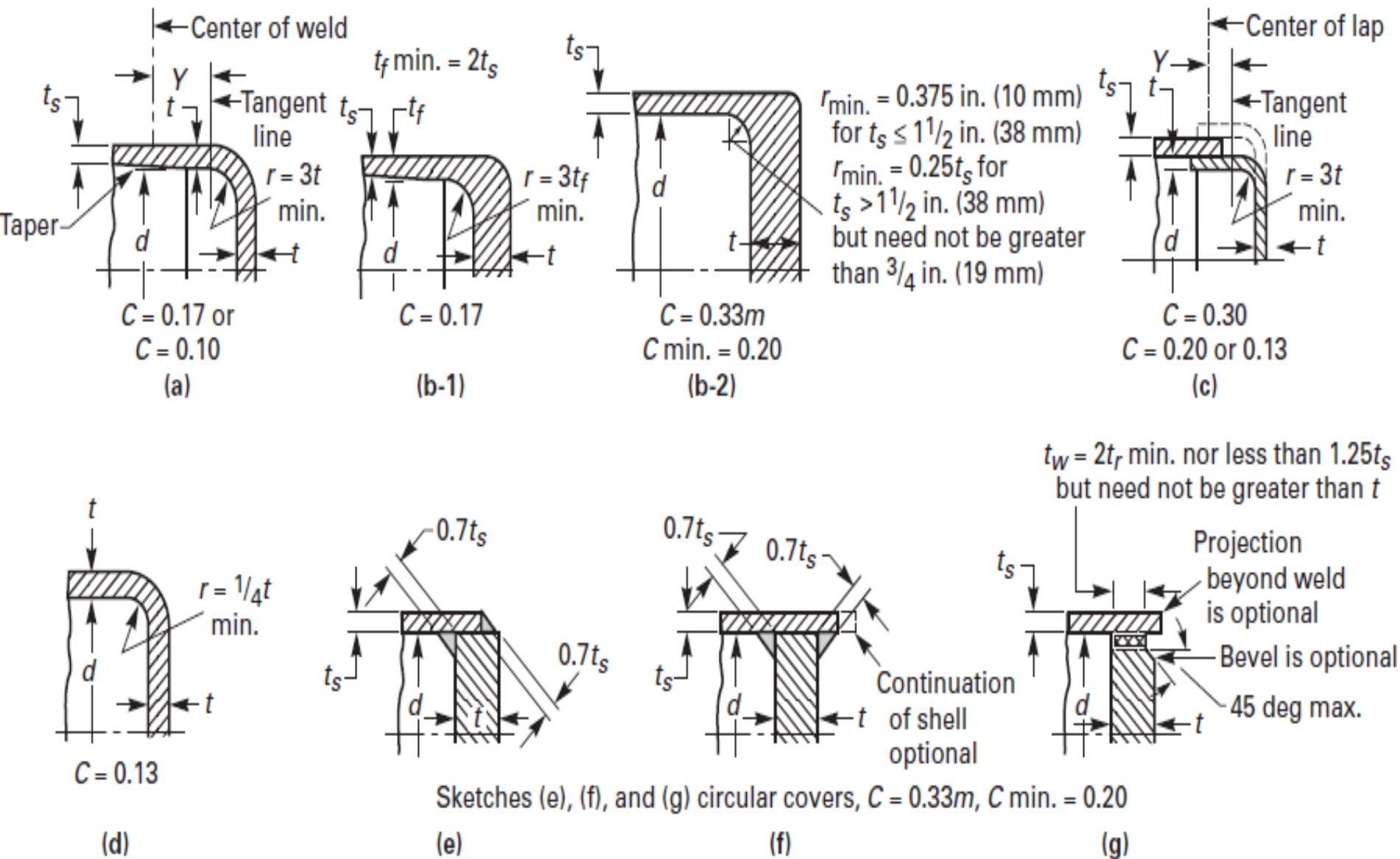
- Where

$$Z = 3.4 - \frac{2.4d}{D}$$

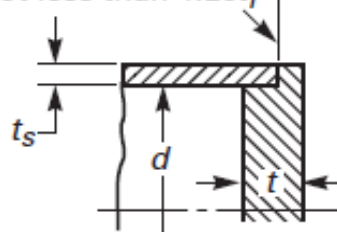
- with the limitation that Z need not be greater than two and one-half (2.5).
- Equation (3) does not apply to noncircular heads, covers, or blind flanges attached by bolts causing a bolt edge moment [Figure UG-34, sketches (j) and (k)].



**Figure UG-34**  
**Some Acceptable Types of Unstayed Flat Heads and Covers**



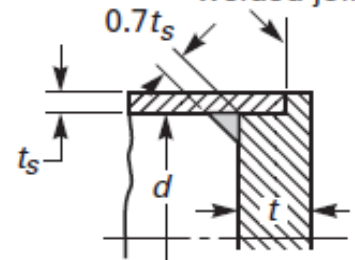
See Fig. UW-13.2 sketches (a) to (g), inclusive, for details of welded joint  
 $t_s$  not less than  $1.25t_r$



$C = 0.33$

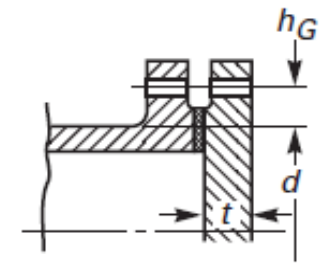
(h)

See Fig. UW-13.2 sketches (a) to (g), inclusive, for details of outside welded joint



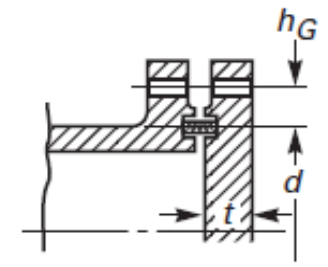
$C = 0.33m$   
 $C \text{ min.} = 0.20$

(i)



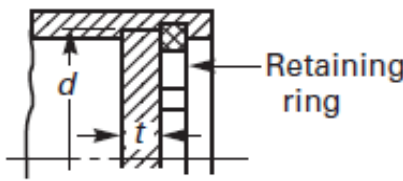
$C = 0.3$

(j) [See Note (1)]



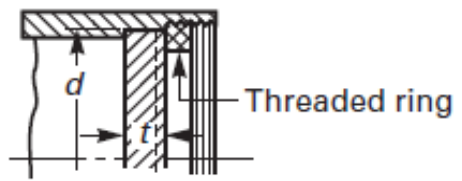
$C = 0.3$

(k) [See Note (1)]



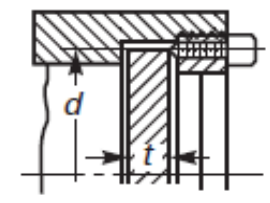
$C = 0.30$

(m)



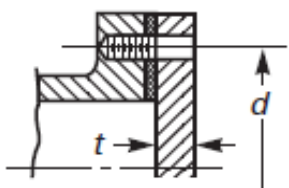
$C = 0.30$

(n)



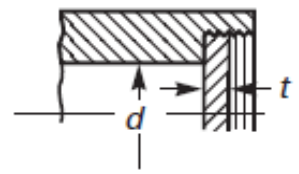
$C = 0.30$

(o)



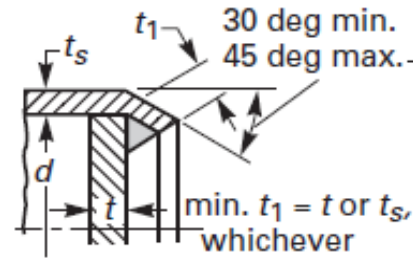
$C = 0.25$

(p)



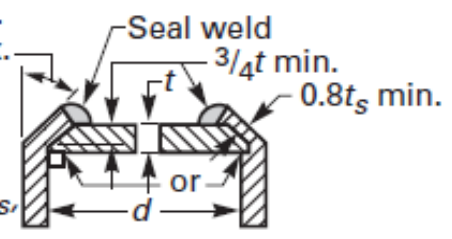
$C = 0.75$

(q) [See Note (2)]



$C = 0.33$

(r)



$C = 0.33$

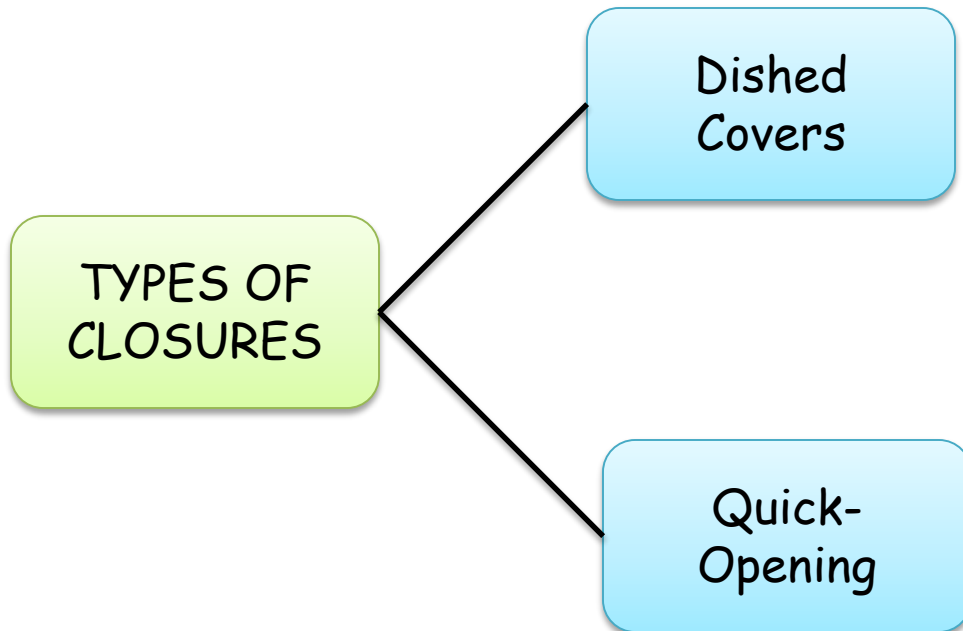
(s)

GENERAL NOTE: The above illustrations are diagrammatic only. Other designs that meet the requirements of UG-34 are acceptable.

NOTES:

(1) Use UG-34(c)(2) eq. (2) or UG-34(c)(3) eq. (5).

(2) When pipe threads are used, see Table UG-43.



## UG-35 CLOSURES

- UG-35.1

Requirements for design of dished heads with bolting flanges are given in 1-6.

- UG-35.2 Quick-Actuating (Quick-Opening) Closures

(a) Definitions

- (1) Quick-actuating or quick-opening closures are those that permit substantially **faster access** to the contents space of a pressure vessel than would be expected with a standard bolted flange connection (bolting through one or both flanges). Closures with swing bolts are not considered quick-actuating (quick-opening).

## UG-35 CLOSURES

- (2) **Holding elements** are parts of the closure used to hold the cover to the vessel, and/or to provide the load required to seal the closure. Hinge pins or bolts can be holding elements.
- (3) **Locking components** are parts of the closure that prevent a reduction in the load on a holding element that provides the force required to seal the closure, or prevent the release of a holding element. Locking components may also be used as holding elements.
- (4) **The locking mechanism or locking device** may consist of a combination of locking components.
- (5) The use of a multi-link component, such as a **chain**, as a **holding element** is **not** permitted.

### (b) General Design Requirements

- (1) Quick-actuating closures shall be designed such that the locking elements will be engaged prior to or upon application of pressure and will not disengage until the pressure is released.
- (2) Quick-actuating closures shall be designed such that the failure of a single locking component while the vessel is pressurized (or contains a static head of liquid acting at the closure) will not:
  - (-a) cause or allow the closure to be opened or leak; or
  - (-b) result in the failure of any other locking component or holding element; or
  - (-c) increase the stress in any other locking component or holding element by more than 50% above the allowable stress of the component.

- (b) *General Design Requirements*
- (3) Quick-actuating closures shall be designed and installed such that it may be determined by visual external observation that the holding elements are in satisfactory condition.
- (4) Quick-actuating closures shall also be designed so that all locking components can be verified to be fully engaged by visual observation or other means prior to the application of pressure to the vessel.
- (5) When installed, all vessels having quick-actuating closures shall be provided with a pressure indicating device visible from the operating area and suitable to detect pressure at the closure.

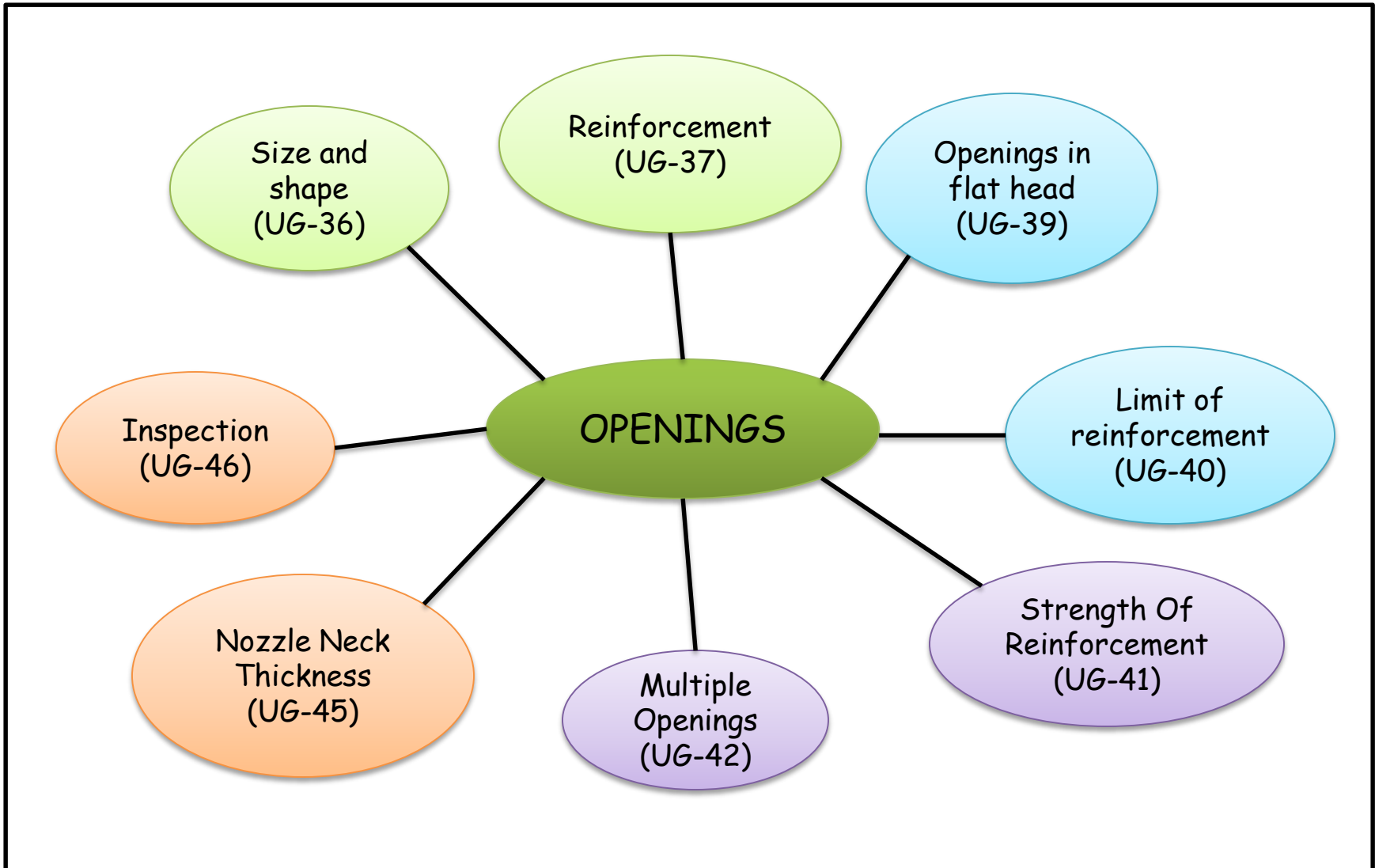
- (c) Specific Design Requirements

- (1) Quick-actuating closures that are held in position by positive locking devices and that are fully released by partial rotation or limited movement of the closure itself or the locking mechanism, and any closure that is other than manually operated, shall be so designed that when the vessel is installed the following conditions are met.
  - (-a) The closure and its holding elements are fully engaged in their intended operating position before pressure can be applied in the vessel.
  - (-b) Pressure tending to force the closure open or discharge the vessel contents clear of the vessel shall be released before the closure can be fully opened for access.
  - (-c) In the event that compliance with (-a) and (-b) above is not inherent in the design of the closure and its holding elements, provisions shall be made so that devices to accomplish this can be added when the vessel is installed.



- (c) **Specific Design Requirements**
- (2) The design rules of Mandatory Appendix 2 of this Division may not be applicable to design quick-actuating or quick-opening closures; see 2-1(e).
- (3) The designer shall consider the effects of cyclic loading, other loadings (see UG-22) and mechanical wear on the holding and locking components.
- (4) It is recognized that it is impractical to write requirements to cover the multiplicity of devices used for quick access, or to prevent negligent operation or the circumventing of safety devices. Any device or devices that will provide the safeguards broadly described in (1)(-a), (1)(-b), and (1)(-c) above will meet the intent of this Division.

# OPENINGS IN PRESSURE VESSELS



## UG-36 (OPENINGS IN PRESSURE VESSELS)

(a) Shape of Opening:

1- Circular



2- Elliptical



3- Obround



- Note: 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.

## UG-36 (OPENINGS IN PRESSURE VESSELS)

- (1) 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.
- (2) Openings may be of other shapes than those given in (1) above, and all corners shall be provided with a suitable radius.

## UG-36 (OPENINGS IN PRESSURE VESSELS)

(b) Size of opening  
(Type of Opening):

1- Small opening

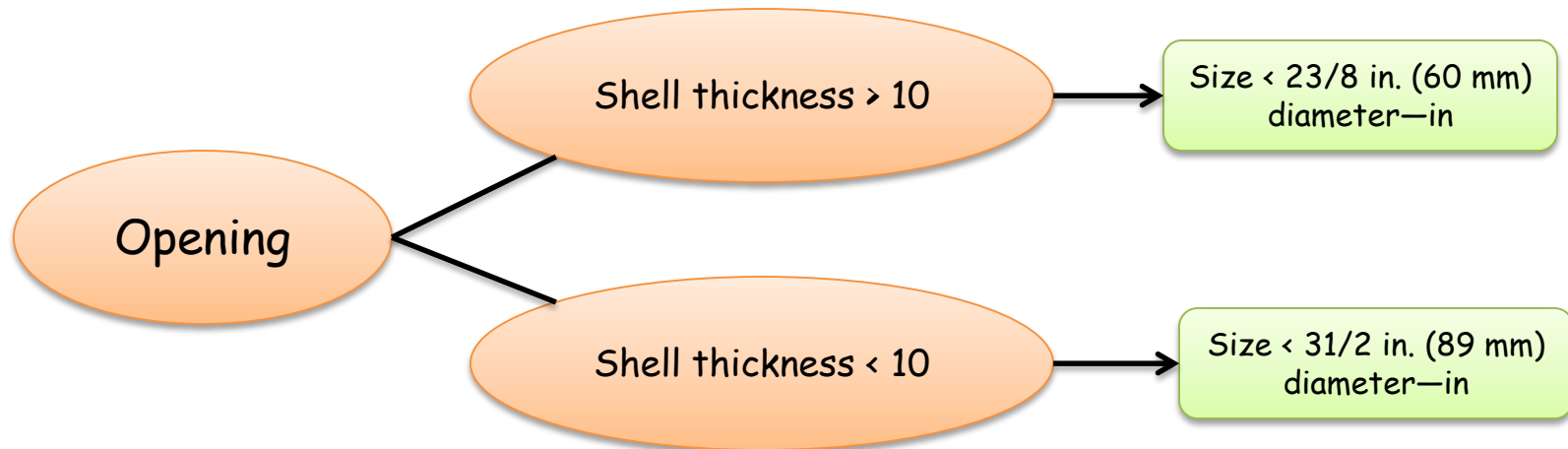
2- Normal size

3- Large opening

## UG-36 (OPENINGS IN PRESSURE VESSELS)

1- Small opening as defined in UG-37 b and UG-36 (c) (3) **Need not be confirmed to calculation of UG-37 :**

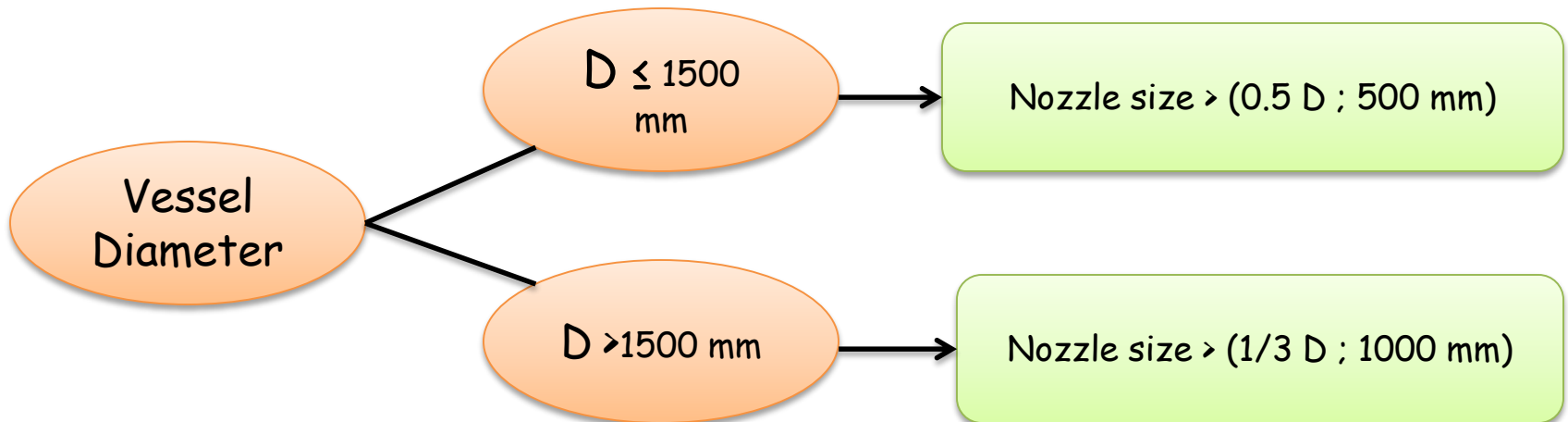
- (-1) **3 1/2 in. (89 mm)** diameter—in vessel shells or heads with a required minimum thickness of **3/8 in.(10 mm)** or **less**;
- (-2) **2 3/8 in. (60 mm)** diameter—in vessel shells or heads over a required minimum thickness of **3/8 in. (10 mm)**;



## UG-36 (OPENINGS IN PRESSURE VESSELS)

2- **Normal size** : Not identified as small opening nor large opening is called Normal size and will be design as per UG-37

3- **Large opening** as defined in UG-36 b :



- For openings exceeding these limits, supplemental rules of 1-7 shall be satisfied in addition to the rules of this paragraph.
- Alternatively, openings in cylindrical or conical shells exceeding these limits may be designed for internal pressure using the rules of 1-10

## UG-36 (OPENINGS IN PRESSURE VESSELS)

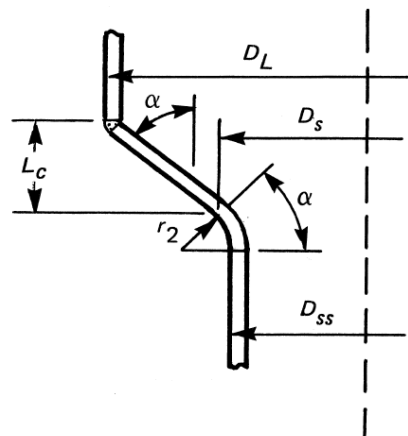
UG-36(b)(2):

- **1-** Reinforced openings in formed heads and spherical shells are not limited in size
- **2-** For an opening in an end closure, which is larger than one-half the inside diameter of the shell, one of the following alternatives to reinforcement may also be used:
  - ✓ **(-a)** a conical section as shown in Figure UG-36 sketch (a);
  - ✓ **(-b)** a cone with a knuckle radius at the large end as shown in Figure UG-36 sketch (b);
  - ✓ **(-c)** a reverse curve section as shown in Figure UG-36 sketches (c) and (d); or
  - ✓ **(-d)** using a flare radius at the small end as shown in Figure UG-33.1 sketch (d).

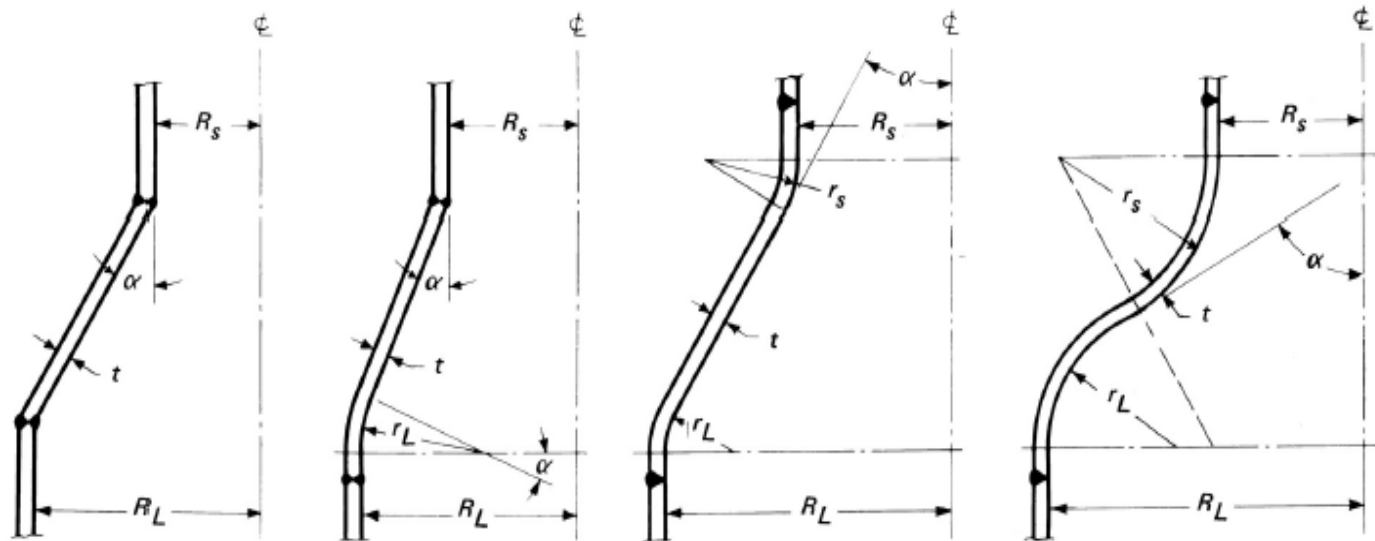


**Figure UG-36**  
**Large Head Openings — Reverse-Curve and Conical Shell-Reducer Sections**

**Figure UG-33.1**



(d)

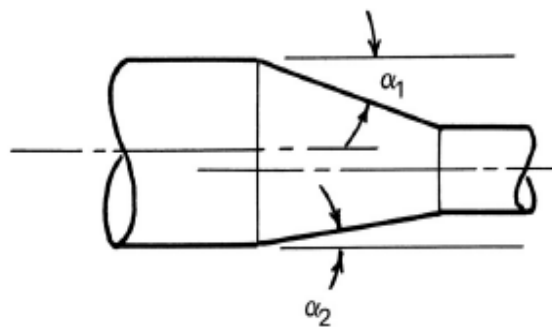


(a) [See Note(1)]

(b) [See Note(1)]

(c) [See Note(1)]

(d) [See Note(1)]



(e) [See Note(2)]

**NOTES:**

- (1)  $r_L$  shall not be less than the greater of  $0.12(R_L + t)$  or  $3t$ ;  $r_s$  has no dimensional requirement.
- (2)  $\alpha_1 > \alpha_2$ ; therefore, use  $\alpha_1$  in design equations.

## UG-36 (OPENINGS IN PRESSURE VESSELS)

### (c) Strength and Design of Finished Openings

- **1-** All references to dimensions apply to the finished construction after deduction for material added as corrosion allowance.
- **2-** Openings in cylindrical or conical shells, or formed heads shall be reinforced to satisfy the requirements in UG-37 except as noted in UG-36 C,d and 3.
- (-b) Openings in flat heads shall be reinforced as required by UG-39.
- (-c) Openings in cylindrical and conical shells subjected to internal pressure may be designed to satisfy the requirements in Mandatory Appendix 1, 1-9 in lieu of the internal pressure requirements in UG-37.

## UG-36 (OPENINGS IN PRESSURE VESSELS)

- 3- Openings in vessels not subject to rapid fluctuations in pressure **do not require reinforcement** other than that inherent in the construction under the following conditions:
  - (a) opening not larger than:
    - (-1) **3 1/2 in. (89 mm)** diameter—in vessel shells or heads with a required minimum thickness of **3/8 in.(10 mm)** or **less**;
    - (-2) **2 3/8 in. (60 mm)** diameter—in vessel shells or heads over a required minimum thickness of **3/8 in. (10 mm)**;

## UG-36 (OPENINGS IN PRESSURE VESSELS)

- (-b) threaded, studded, or expanded connections in which the hole cut in the shell or head is not greater than 23/8 in. (60 mm) diameter;
- Distance between unreinforced opening:
- (-c) No two isolated unreinforced openings (in accordance with (-a) or (-b) above), shall have their centers closer to each other than the **sum of their diameters**;
- (-d) no two unreinforced openings, in a cluster of three or more unreinforced openings in accordance with (-a) or (-b) above, shall have their centers closer to each other than the following:
  - for cylindrical or conical shells,  $(1 + 1.5 \cos \theta)(d_1 + d_2)$ ;
  - for doubly curved shells and formed or flat heads  $2.5(d_1 + d_2)$
- Where,  $d_1, d_2$  = the finished diameter of the two adjacent openings

## UG-36 (OPENINGS IN PRESSURE VESSELS)

The centerline of an unreinforced opening as defined in (-a) and (-b) above shall not be closer than its finished diameter to any material used for reinforcement of an **adjacent reinforced opening**.

- (d) Openings Through Welded Joints. Additional provisions governing openings through welded joints are given in UW-14.

## UG-14 (OPENINGS IN OR ADJACENT TO WELDS)

- UG-36 (c) (3) (d) Openings Through Welded Joints. Additional provisions governing openings through welded joints are given in UW-14.
- (a) Any type of opening that meets the requirements for reinforcement given in UG-37 or UG-39 may be located in a welded joint.
- There is two condition for such welds:
  - 1- There is a single opening and it is in accordance to UG-36 (C) (3)
  - 2- There are multiple opening meeting the requirements given in UG-36 (C) (3)

## UG-14 (OPENINGS IN OR ADJACENT TO WELDS)

- 1- There is a single opening and it is in accordance to UG-36 (C) (3)
- may be located in head-to-shell or Category B or C butt welded joints, provided the weld meets the radiographic requirements in UW-51 for a length equal to three times the diameter of the opening with the center of the hole at midlength.

## UG-14 (OPENINGS IN OR ADJACENT TO WELDS)

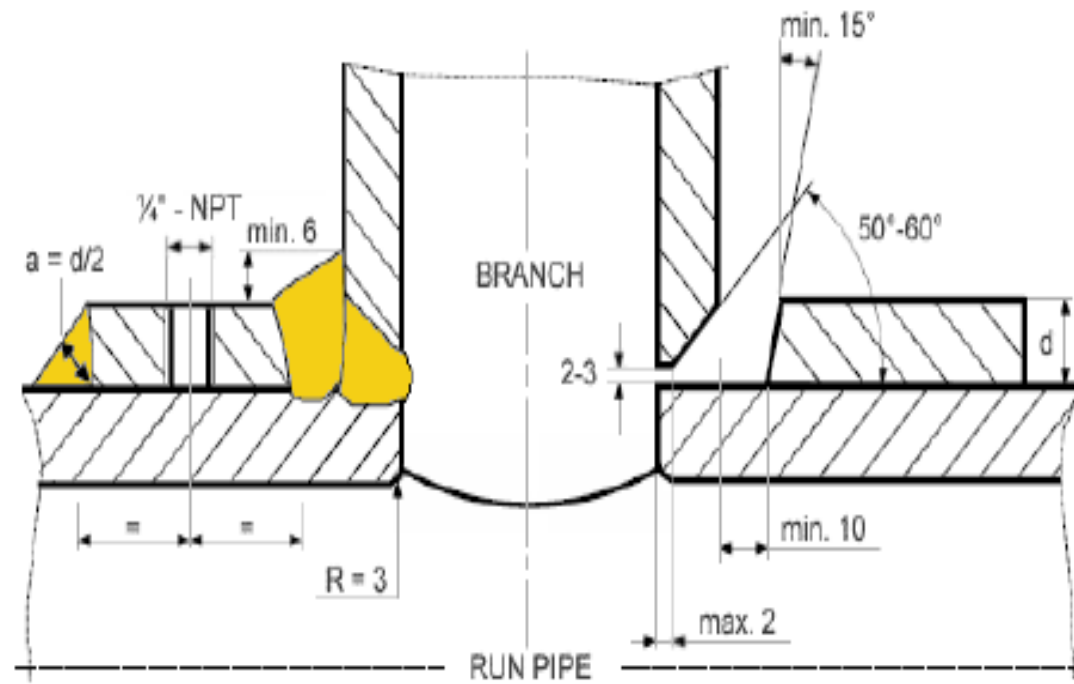
- 2- There are multiple opening meeting the requirements given in UG-36 (C) (3)
- the requirements of UG-53 shall be met or the openings shall be reinforced in accordance with UG-37 through UG-42.



## UG-37 (REINFORCEMENT of OPENINGS)

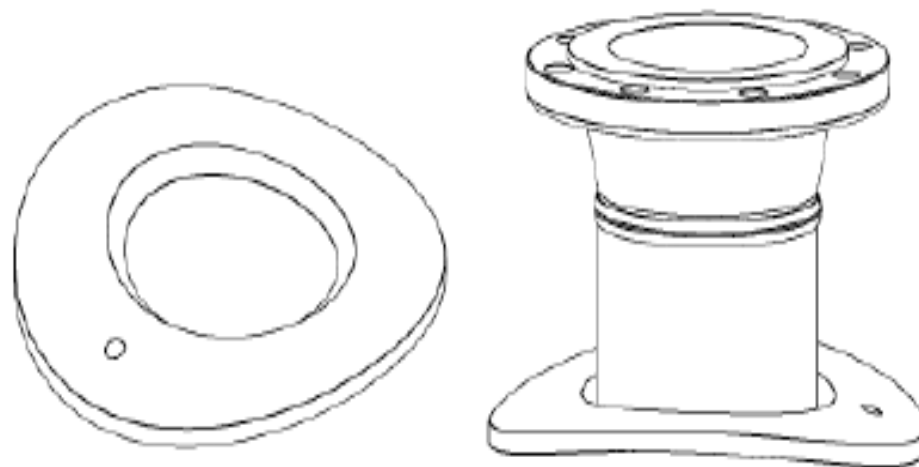
- Rules in this paragraph apply to all openings other than:
  - (1) small openings covered by UG-36(c)(3);
  - (2) openings in flat heads covered by UG-39;
  - (3) openings designed as reducer sections covered by UG-36(e);
  - (4) large head openings covered by UG-36(b)(2);
  - (5) tube holes with ligaments between them conforming to the rules of UG-53.

## Branch Connection with Reinforcing Pad (Set-On type)



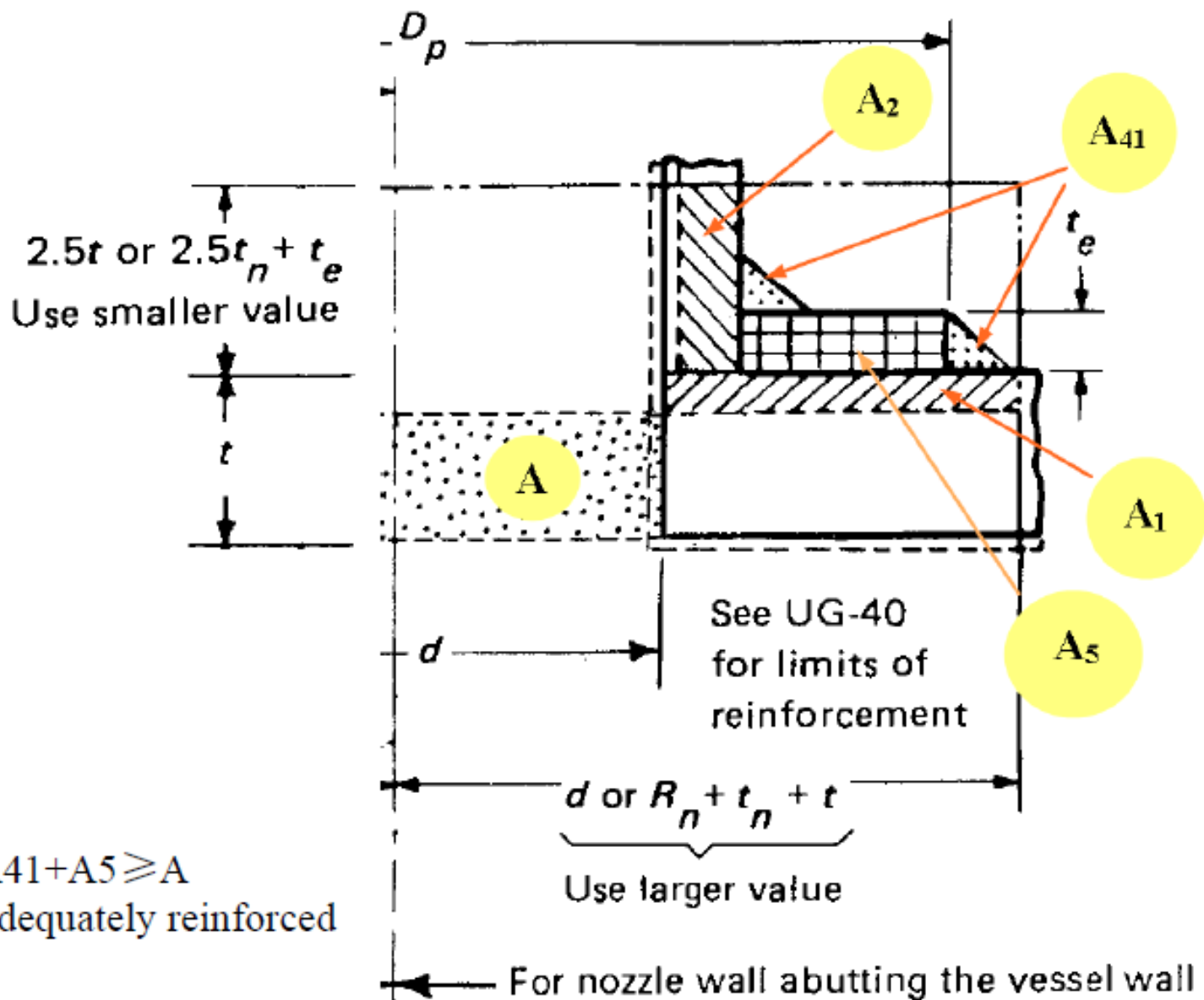
- ASME VIII, UG-37  
Is the nozzle sufficiently reinforced

- ASME VIII, UW-16  
Are the nozzle welds of adequate sizes.



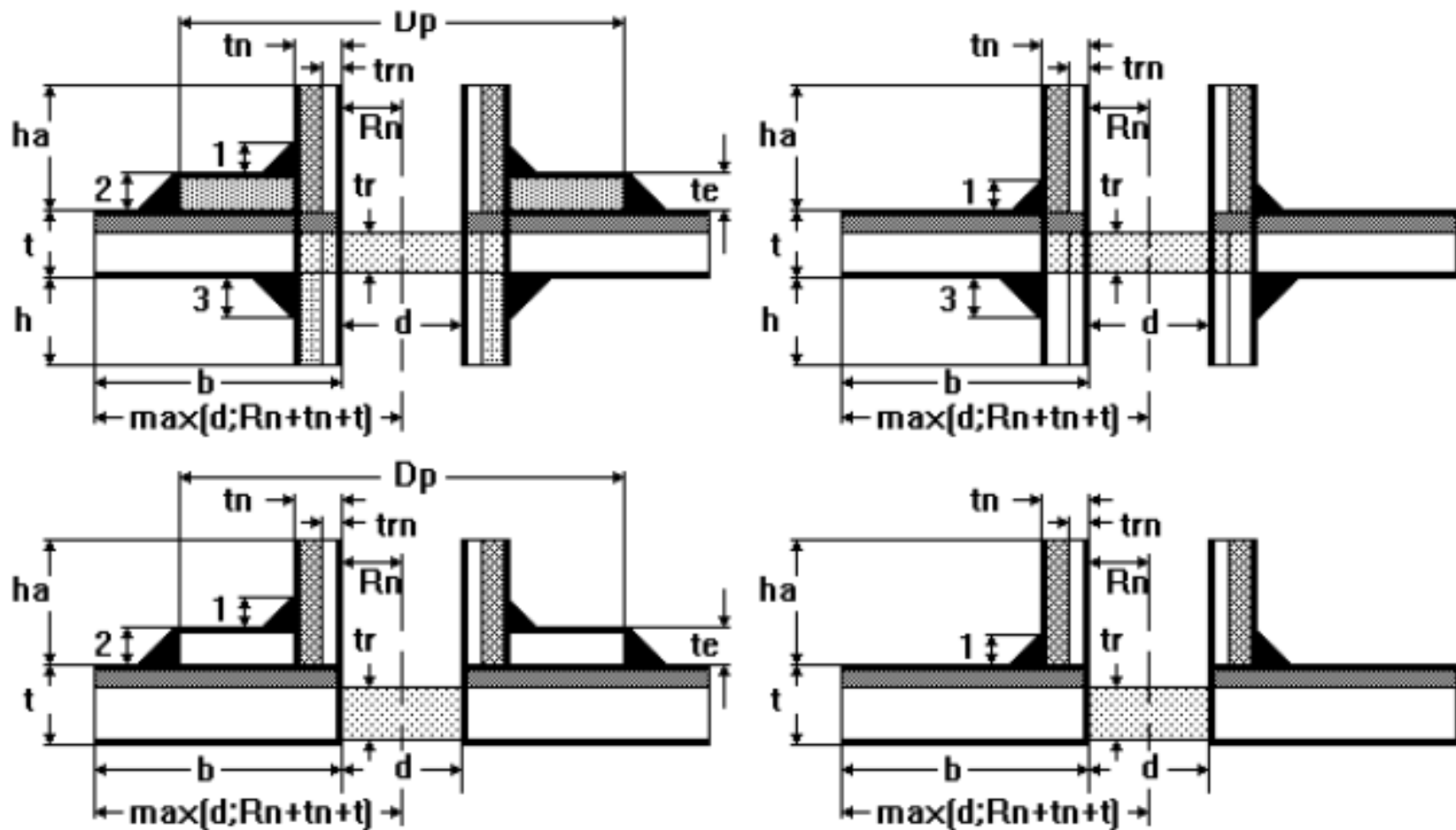
**(a) Nomenclature.** The symbols used in this paragraph are defined as follows:

- $A$  = total cross-sectional area of reinforcement required in the plane under consideration (see Fig. UG-37.1) (includes consideration of nozzle area through shell if  $S_n / S_v < 1.0$ )
- $A_1$  = area in excess thickness in the vessel wall available for reinforcement (see Fig. UG-37.1) (includes consideration of nozzle area through shell if  $S_n / S_v < 1.0$ )
- $A_2$  = area in excess thickness in the nozzle wall available for reinforcement (see Fig. UG-37.1)
- $A_3$  = area available for reinforcement when the nozzle extends inside the vessel wall (see Fig. UG-37.1) (Not in the exam)
- $A_5$  = cross-sectional area of material added as reinforcement (see Fig. UG-37.1)
- $A_{41}, A_{42}, A_{43}$  = cross-sectional area of various welds available for reinforcement (see Fig. UG-37.1)



If  $A_1 + A_2 + A_{41} + A_5 \geq A$   
 Opening is adequately reinforced

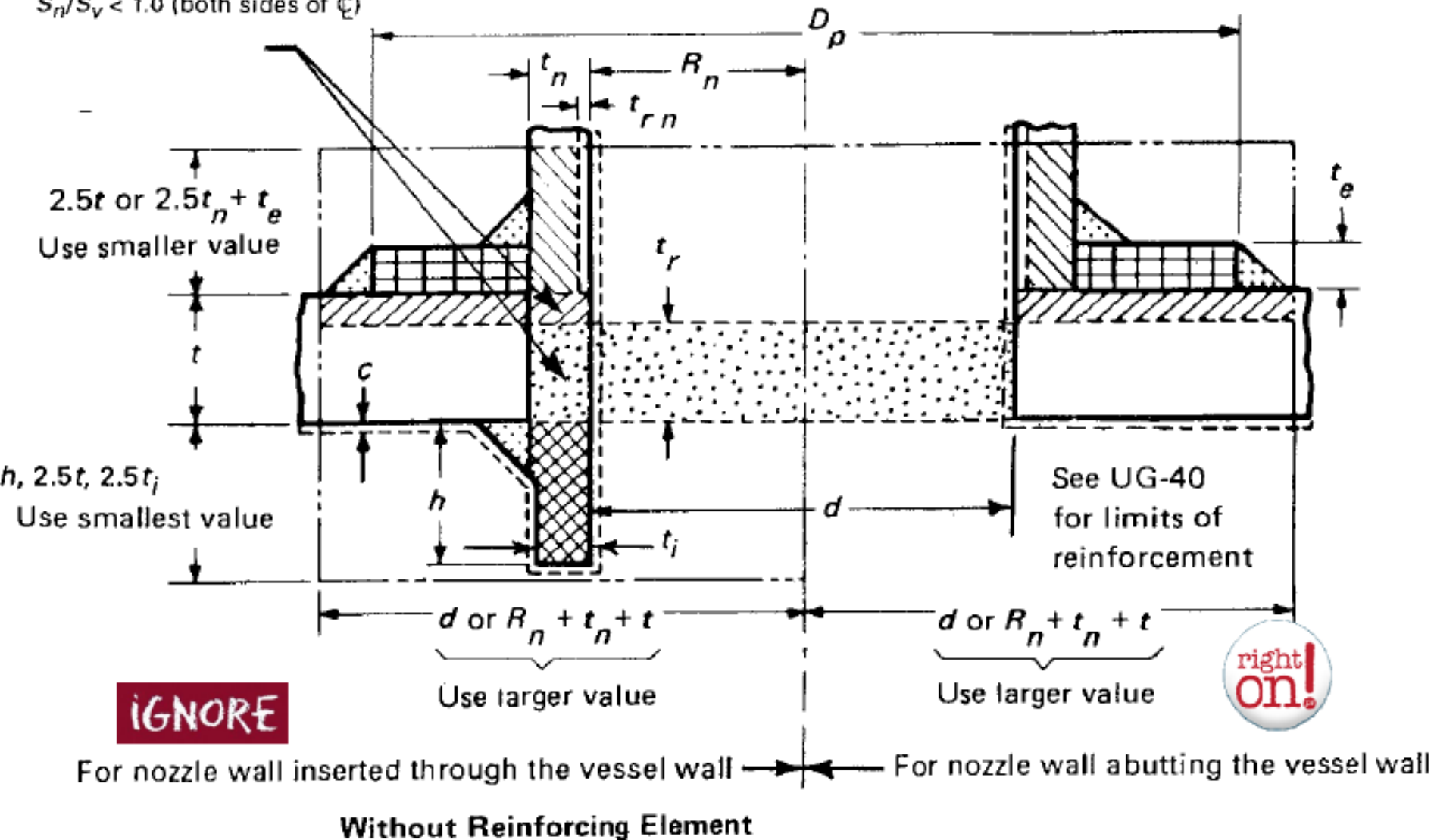
ASME VIII, UG-37 The code uses the principle of the area replacement method



**GENERAL NOTE:**

Includes consideration of these areas if  $S_n/S_v < 1.0$  (both sides of  $\phi$ )

**FIG. UG-37.1 NOMENCLATURE AND FORMULAS FOR REINFORCED OPENINGS**



**IGNORE**

For nozzle wall inserted through the vessel wall  
**Without Reinforcing Element**

### Without Reinforcing Element



$$= A = d t_r F + 2 t_n t_r F (1 - f_{r1})$$

Area required



$$= A_1 \begin{cases} = d(E_1 t - F t_r) - 2 t_n (E_1 t - F t_r) (1 - f_{r1}) \\ = 2(t + t_n)(E_1 t - F t_r) - 2 t_n (E_1 t - F t_r) (1 - f_{r1}) \end{cases}$$

Area available in shell; use larger value



$$= A_2 \begin{cases} = 5(t_n - t_{rn}) f_r 2t \\ = 5(t_n - t_{rn}) f_r 2t_n \end{cases}$$

Area available in nozzle projecting outward; use smaller value



$$= A_3 = \begin{aligned} &= 5 t_i f_{r2} \\ &= 5 t_j f_{r2} \\ &= 2 h t_i f_{r2} \end{aligned}$$

Area available in inward nozzle; use smallest value



$$= A_{41} = \text{outward nozzle weld} = (\text{leg})^2 f_{r2}$$

Area available in outward weld



$$= A_{43} = \text{inward nozzle weld} = (\text{leg})^2 f_{r2}$$

Area available in inward weld

$$\text{If } A_1 + A_2 + A_3 + A_{41} + A_{43} \geq A$$

Opening is adequately reinforced

$$\text{If } A_1 + A_2 + A_3 + A_{41} + A_{43} < A$$

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


$A_1$  = same as  $A_1$ , above


$$A_2 \begin{cases} = 5(t_n - t_{rn}) f_{r2} t \\ = 2(t_n - t_{rn}) (2.5t_n + t_e) f_{r2} \end{cases}$$

$A_3$  = same as  $A_3$ , above

 =  $A_{41}$  = outward nozzle weld =  $(\text{leg})^2 f_{r3}$

 =  $A_{42}$  = outer element weld =  $(\text{leg})^2 f_{r4}$

 =  $A_{43}$  = inward nozzle weld =  $(\text{leg})^2 f_{r2}$

 =  $A_5 = (D_p - d - 2t_n) t_e f_{r4}$  [Note (1)]

If  $A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5 \geq A$

Area required

Area available

Area available in nozzle projecting outward; use smaller area

Area available in inward nozzle

Area available in outward weld

Area available in outer weld

Area available in inward weld

Area available in element

Opening is adequately reinforced



## UG-37 (Required cross sectional area of reinforcement)

- The total cross sectional area of reinforcement  $A$  required in any given plane through the opening for a shell or formed head under internal pressure shall be not less than :

**Required cross sectional  
area of reinforcement**

Internal pressure :

$$A = dt_r F + 2t_n t_r F (1 - f_{r1})$$

External pressure:

50% of required area for  
internal

- Reinforcing plates and saddles of nozzles attached to the outside of a vessel shall be provided with **at least one telltale hole 11 mm** that may be tapped with straight or tapered threads.
- These telltale holes may be left **open** or may be **plugged** when the vessel is in service. If the holes are plugged, the plugging material used shall not be capable of sustaining pressure between the reinforcing plate and the vessel wall.

- Segmental reinforcing elements are allowed provided the individual segments are joined by full penetration butt welds. These butt welds shall comply with all the applicable requirements of Part UW. Each segment of the reinforcing element shall have a telltale hole as required by (g). Unless the provisions given below are satisfied, the **area A5** as defined in Figure UG-37.1 shall be **multiplied by 0.75**.  
The area A5 does not require any reduction if one of the following is satisfied:
  - (1) Each butt weld is radiographed or ultrasonically examined to confirm full penetration, or
  - (2) For openings in cylinders, the weld is oriented at least 45 deg from the longitudinal axis of the cylinder.

**Nozzle Attachment**

FVC Catalogue ...  
Coupling Lookup ...  
Just Like ...

New Nozzle Description : Noz N1 Fr 10

Nozzle Material : SA-106 B

Schedule | Diameter : 40  in.

Dia. Basis | Thickness Basis : ID

Total CA. | Actual Thk. : 3 0 mm.

Is this Nozzle Connected to another Nozzle?

Parent Nozzle :

Distance from 'From' Node|Elev : 0 0 mm.

Layout Angle : 0 deg.

Radial Nozzle :

Angled or Lateral Nozzle :

Centerline Tilt Angle : 0 deg.

Cyl./Cone Offset Dimension L : 0 mm.

Projection Outside | Inside : 150 0 mm.

Limits [ Diameter | Thickness ] : 0 0 mm.

Overriding Weight : 0 kg.

UG-37 (h)



Material : SA-516 70

Pad Diameter / Width : 270 50 mm.

Pad Thickness : 6 mm.

Groove Weld Depth : 6 mm.

Weld Leg at Pad OD : 4 mm.

For VIII-1 split pads, multiply A5 by 0.75 per UG-37(h) :

**Additional Weld Data**

Nozzle to Pad Fillet Weld Leg : 10 mm.

Nozzle to Shell Inside Fillet Weld Leg : 0 mm.

Nozzle to Shell Groove Weld Depth : 5.99999 mm.

ASME Weld Type : None

**Miscellaneous**

Flange Material : SA-105

Flange Class | Grade : 150 GR 1.1

Flange Type : Weld Neck

Neglect Areas : None

Tapped Hole Area Loss : 0 m<sup>2</sup>

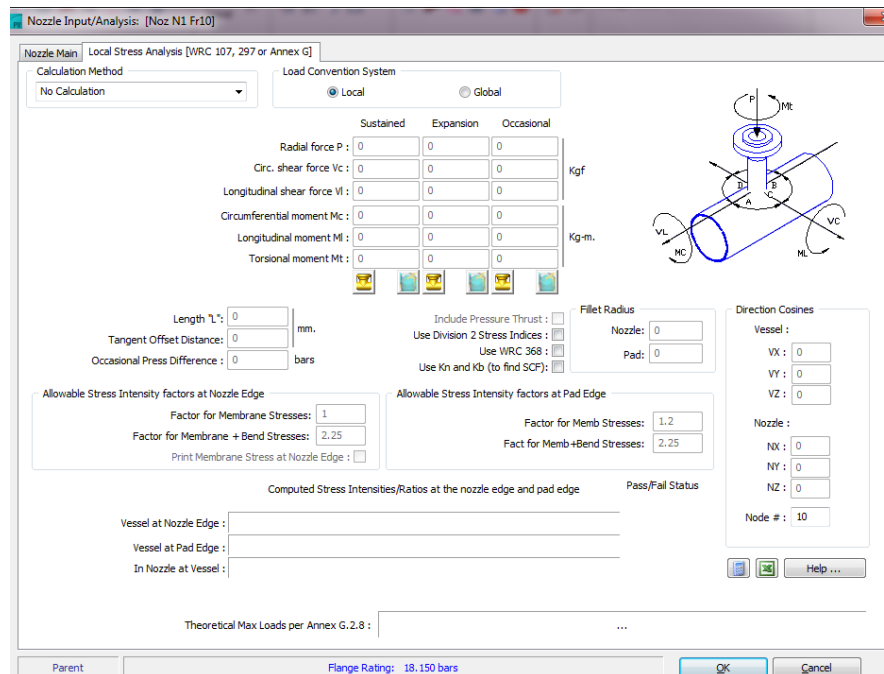
Nozzle Eff. | Shell Eff. : 1 1

Local Shell Thk. | User Tr : 0 0 mm.

Blind Attached? :  Manway/Acs Ope ? :

Fatigue Calc ? :  Shell Fatigue Curve: Table 3.F.1

- The reinforcement rules in this Division are applicable for internal or external pressure and do not address the requirements for openings under the action of externally applied loadings (such as pipe reactions).



## UG-40 (LIMITS OF REINFORCEMENT)

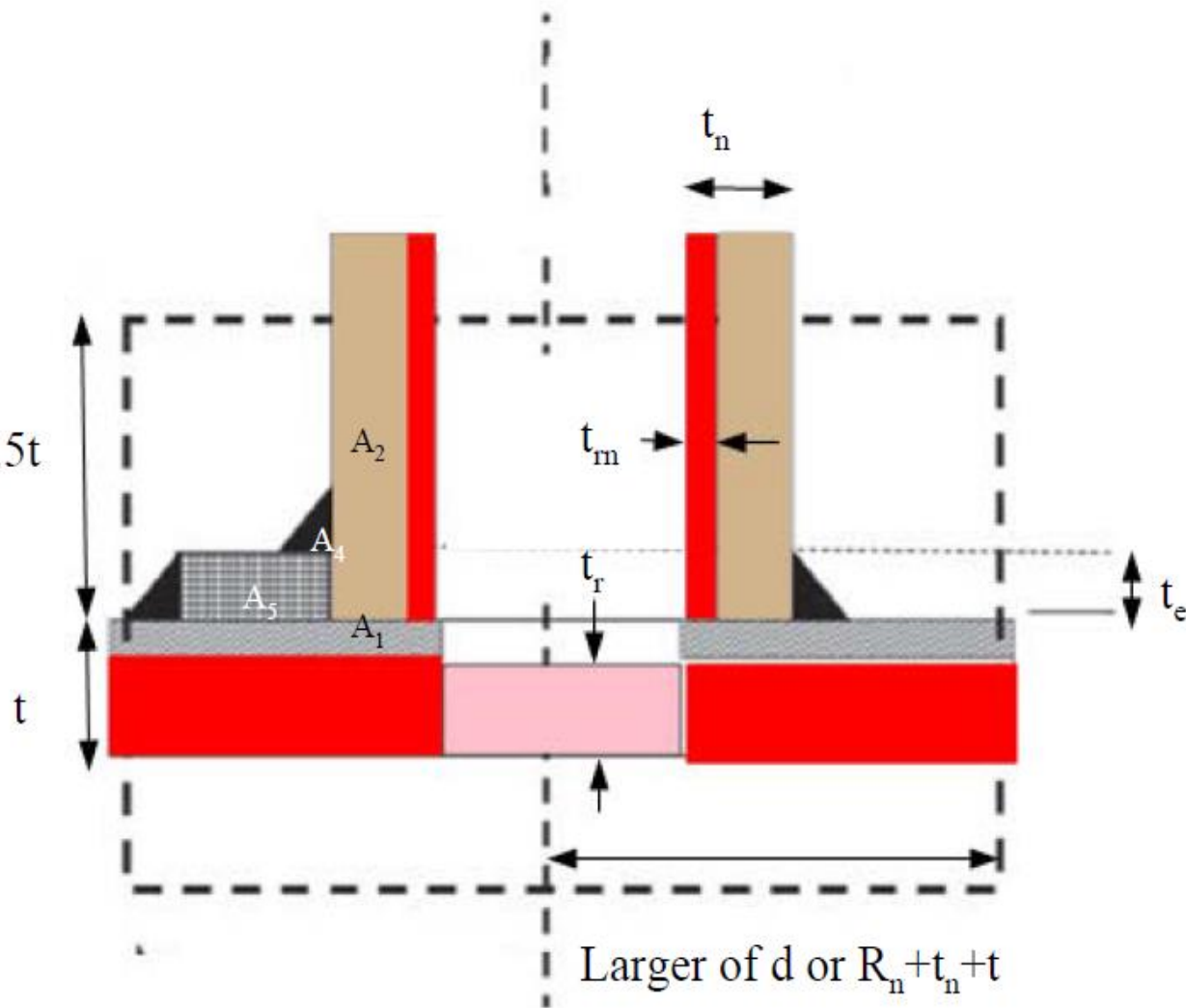
- The boundaries of the cross sectional area in any plane normal to the vessel wall and passing through the center of the opening within which metal must be located in order to have value as reinforcement are designated as the limits of reinforcement for that plane.

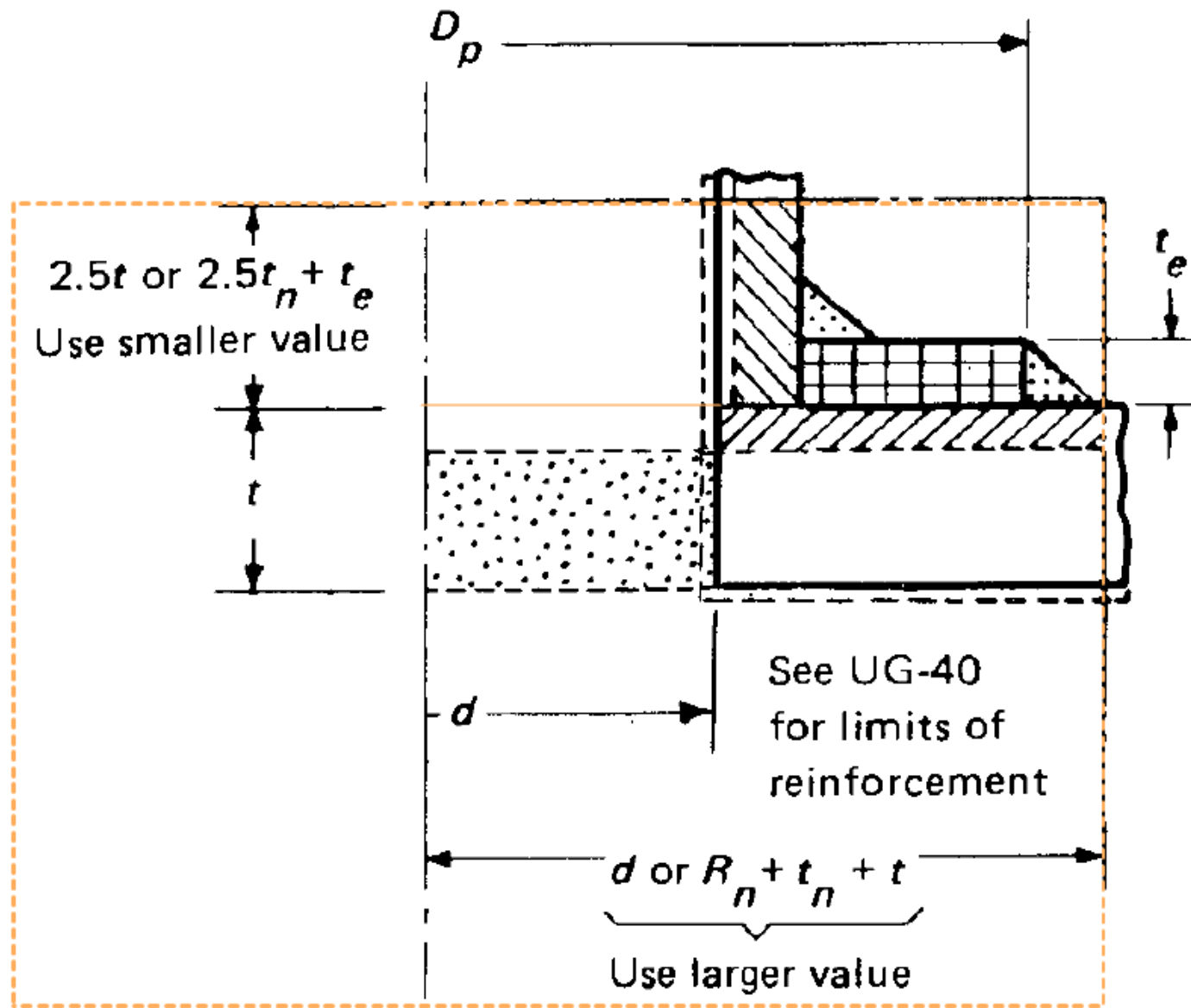
Required cross sectional  
area of reinforcement

Normal to vessel wall

Parallel to vessel wall

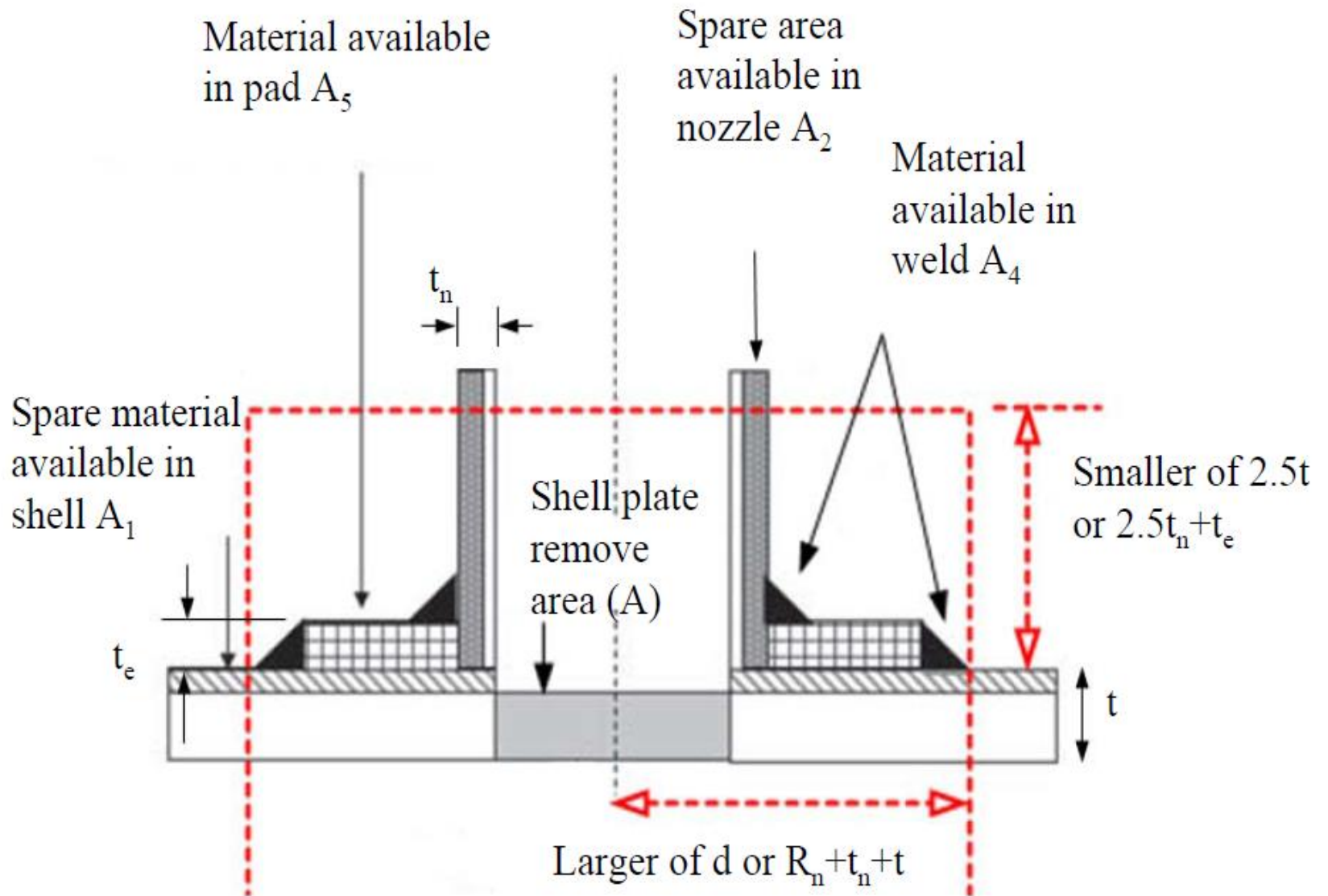
Smaller of  $2.5t$   
or  $2.5t_n+t_e$





← For nozzle wall abutting the vessel wall





## UG-40 (LIMITS OF REINFORCEMENT)

- The limits of reinforcement, measured parallel to the vessel wall is greater of following:
  - ❖ (1) the diameter  $d$  of the finished opening;
  - ❖ (2) the inside radius,  $R_n$ , of the nozzle plus the vessel wall thickness  $t$ , plus the nozzle wall thickness  $t_n$ .

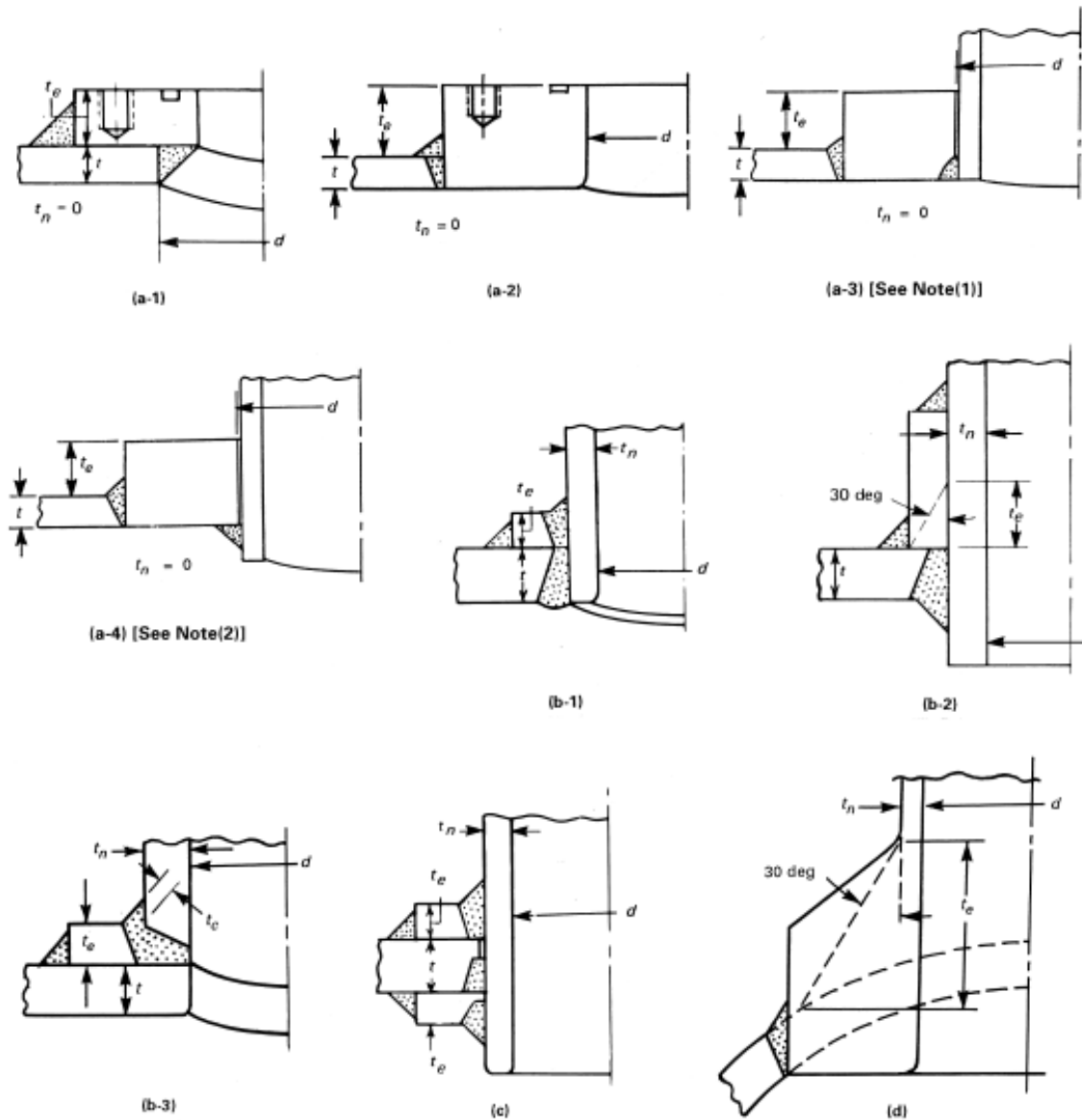
$$\text{Max. } ( d ; (R_n + t + t_n) )$$

## UG-40 (LIMITS OF REINFORCEMENT)

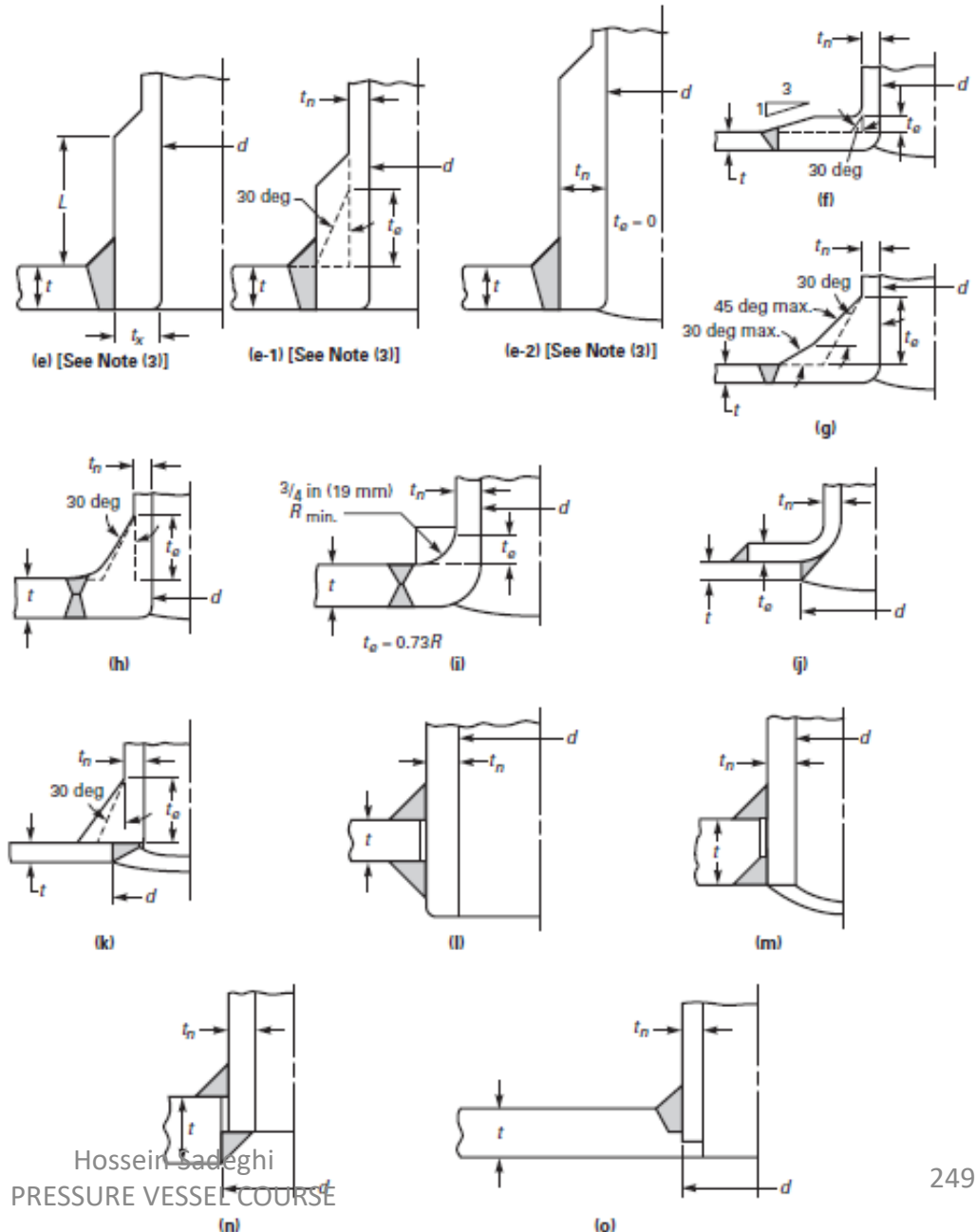
- The limits of reinforcement, measured normal to the vessel wall is Smaller of following: :
  - ❖ (1) 2 1/2 times the vessel wall thickness  $t$  ;
  - ❖ (2) 2 1/2 times the nozzle wall thickness  $t_n$  plus the thickness  $t_e$  as defined in Figure UG-40.

$$\text{Min. ( } 2.5 t ; (2.5 t_n + t_e) \text{ )}$$

**Figure UG-40**  
**Some Representative Configurations Describing the Reinforcement Dimension  $t_e$  and the Opening Dimension  $d$**

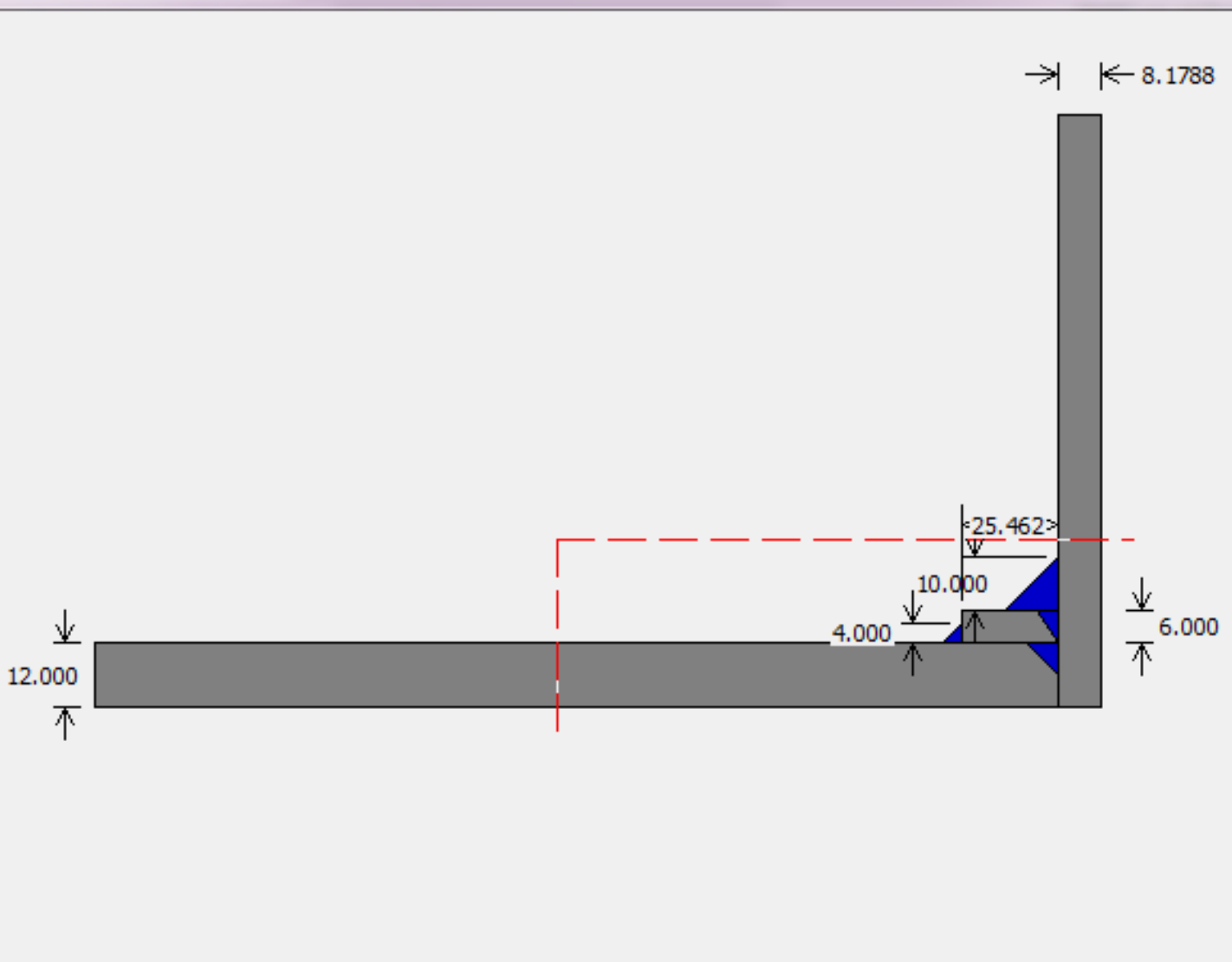


**Figure UG-40**  
**Some Representative Configurations Describing the Reinforcement Dimension  $t_e$  and the Opening Dimension  $d$  (Cont'd)**



**NOTES:**

- 1) See Figure UW-16.1, sketch (v-2) for limitations.
- 2) See Figure UW-16.1, sketch (w-2) for limitations.
- 3) If  $L < 2.5t_x$ , use sketch (e-1); if  $L \geq 2.5t_x$ , use sketch (e-2).



Units : mm.

Print

Close

Width : 6  
OD : 4 4.243  
Welds, multiply A5 by 0.75 per UC

Weld Leg : 10 5.  
Weld Leg : 0  
Weld Depth : 6  
Weld Type : None

Weld Strength OK

Material : SA-105  
Grade : 150 GR 1.1  
Type : Weld Neck  
Stress : None  
Loss : 0  
Eff. : 1 1  
Cor Tr : 0 0  
Manway/Acs  
Stress Curve: Table 3.F.1  
Piping Attache

ailed]

Plot...

## Notes about opening

- ❖ The Vessels 18" to 36" I. D. must have a manhole or at least 2 hand holes or two threaded openings
- ❖ All vessels over 36" I. D. must have a manhole
- ❖ When inspection openings are required, they must meet the following
  - ✓ An elliptical manhole shall not be less than 12" X 16"
  - ✓ A circular manhole shall not be less than 16"
  - ✓ A handhole shall not be less than 2"x 3"
- ❑ Ref. ASME Continuing education institute booklet

## UG-41 (STRENGTH OF REINFORCEMENT)

- (a) Material used for reinforcement **shall** have an allowable stress value **equal** to or **greater** than that of the material in the **vessel wall**.

- IF SUCH MATERIAL IS NOT AVAILABLE ?!



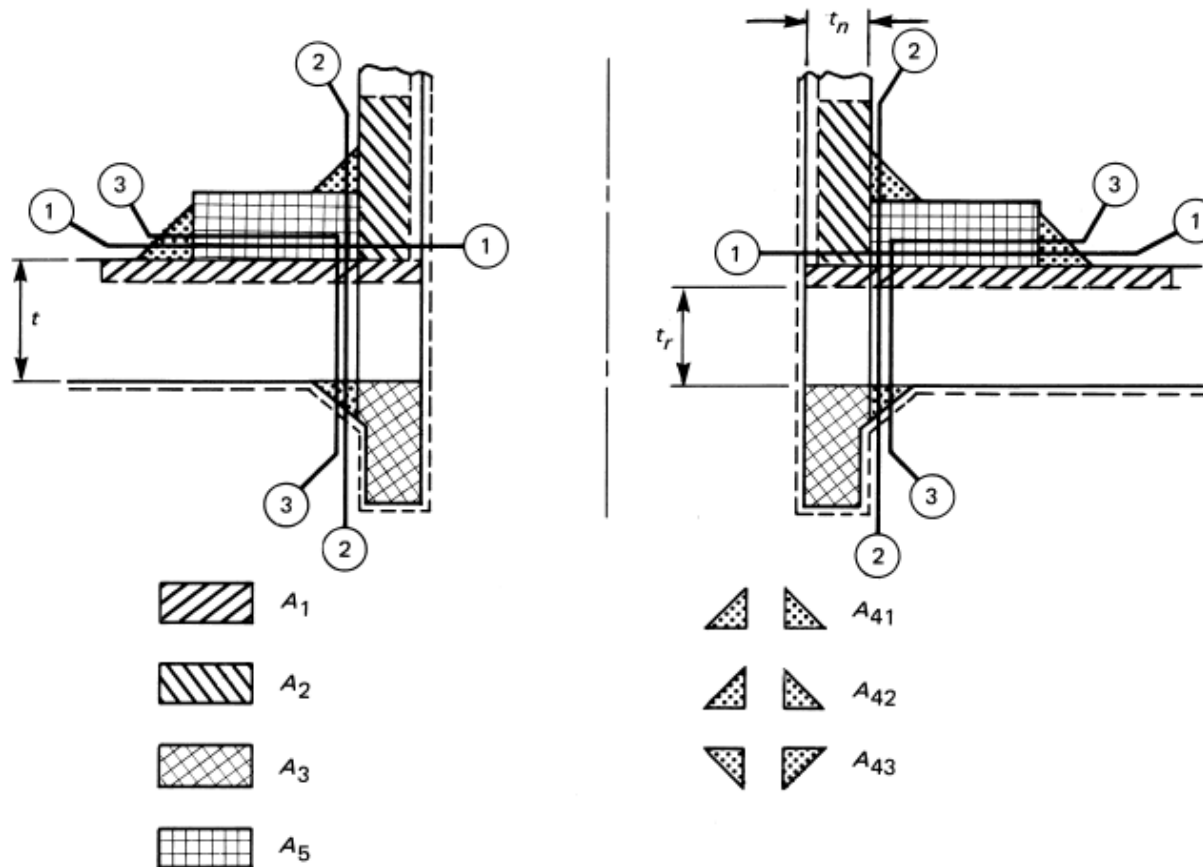
- Lower strength material may be used, provided the area of reinforcement is increased in inverse proportion to the ratio of the allowable stress values of the two materials to compensate for the lower allowable stress value of the reinforcement.



## UG-41 (STRENGTH OF REINFORCEMENT)

- No credit may be taken for the additional strength of any reinforcement having a higher allowable stress value than that of the vessel wall.
- weld metal outside of either the vessel wall or any reinforcing pad used as reinforcement shall be credited with an allowable stress value equivalent to the *weaker of the materials connected by the weld.*

**Figure UG-41.1**  
**Nozzle Attachment Weld Loads and Weld Strength Paths to Be Considered**



$$\begin{aligned}
 W &= \text{total weld load [UG-41(b)(2)]} \\
 &= [A - A_1 + 2t_n f_{r1} (E_1 t - F t_r)] S_V \\
 W_{1-1} &= \text{weld load for strength path 1-1 [UG-41(b)(1)]} \\
 &= (A_2 + A_5 + A_{41} + A_{42}) S_V \\
 W_{2-2} &= \text{weld load for strength path 2-2 [UG-41(b)(1)]} \\
 &= (A_2 + A_3 + A_{41} + A_{43} + 2t_n t_{f1}) S_V \\
 W_{3-3} &= \text{weld load for strength path 3-3 [UG-41(b)(1)]} \\
 &= (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2t_n t_{f1}) S_V
 \end{aligned}$$

Hossein Sadeghi  
 (a) Depicts Typical Nozzle Detail With Neck Inserted Through the Vessel Wall  
 PRESSURE VESSEL COURSE

## UG-42 (Reinforcement of Multiple Openings)

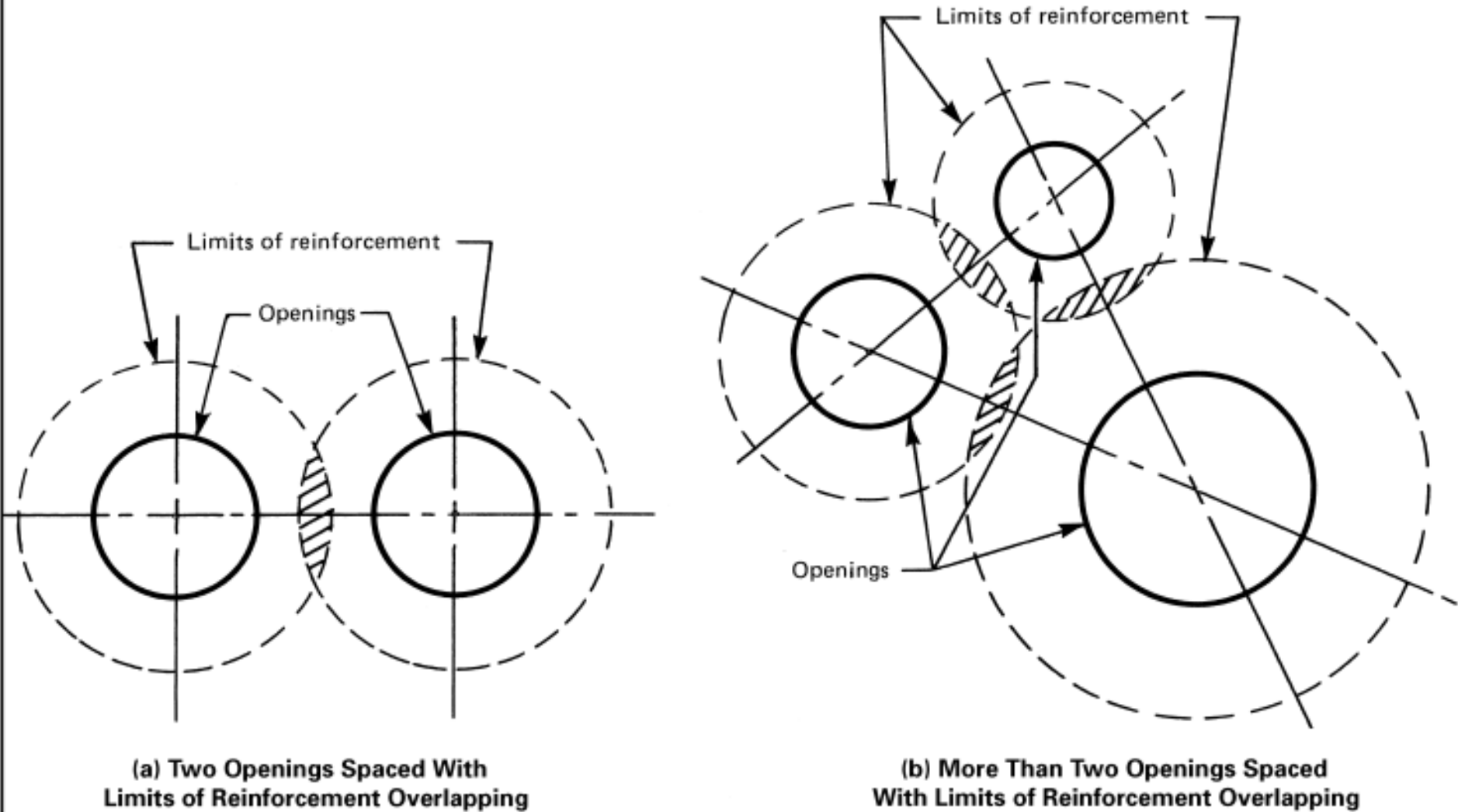
- When the spacing between two openings is less than two times their average diameter, the reinforcement must satisfy the requirements for multiple openings. There are three general procedures for reinforcing multiple openings.

They are:

- ❖ (1) standard reinforcement practice with restrictions on the distribution of the reinforcement,
- ❖ (2) reinforcement based on a large opening that encompasses the multiple openings
- ❖ (3) the ligaments rules of UG-53.

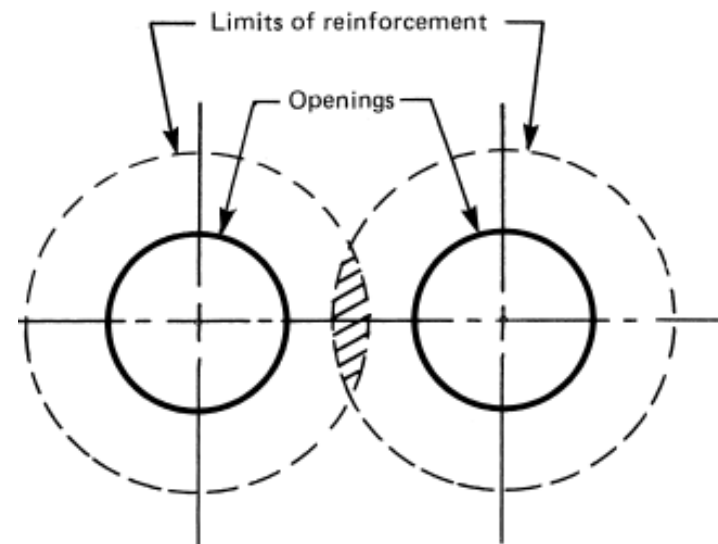
**Ref. : CASTI Guidebook**

**Figure UG-42**  
**Examples of Multiple Openings**



## UG-42 (Reinforcement of Multiple Openings)

- When any two openings are spaced such that their reinforcement overlaps, the reinforcement in the plane connecting the centers of the two openings must be equal to or greater than the sum of the area required for each opening and must satisfy all standard reinforcement requirements (UG-37, 38, 40, and 41).
- (1) The overlap area shall be proportioned between the two openings by the ratio of their diameters.
- (2) For cylinders and cones, if the area of reinforcement between the two openings is less than 50% of the total required for the two openings, the supplemental rules of 1-7(a) and 1-7(c) shall be used.



(a) Two Openings Spaced With Limits of Reinforcement Overlapping

## UG-42 (Reinforcement of Multiple Openings)

- (b) When more than two openings are spaced as in (a) above [see Figure UG-42 sketch (b)], and are to be provided with a combined reinforcement, the minimum distance between centers of any two of these openings shall be **11/3 times their average diameter**, and the area of reinforcement between any two openings shall be at least equal to **50% of the total required for the two openings**. If the distance between centers of two such openings is less than 11/3 times their average diameter, no credit for reinforcement shall be taken for any of the material between these openings. Such openings must be reinforced as described in (c) below.

## UG-42 (Reinforcement of Multiple Openings)

- (C) Alternatively, any number of adjacent openings, in any arrangement, may be reinforced by using an assumed opening enclosing all such openings. The limits for reinforcement of the assumed opening shall be those given in UG-40(b)(1) and UG-40(c)(1). The **nozzle walls** of the actual openings shall not be considered to have reinforcing value. For cylinders and cones, when the diameter of the assumed opening exceeds the limit is in UG-36(b)(1), the supplemental rules of **1-7(a) and 1-7(c)** shall also be used.

## UG-43 (Methods Of Attachment Of Pipe And Nozzle Necks To Vessel Walls)

### (a) General:

- Nozzles may be attached to the shell or head of a vessel by any of the methods of attachment given in this paragraph, except as limited in UG-36.

### (b) Welded Connections :

- Attachment by welding shall be in accordance with the requirements of UW-15 and UW-16.



## UW-16 (Minimum requirements for attachment welds at openings)

- $D_o$  = outside diameter of neck or tube attached by welding on inside of vessel shell only
- $G$  = radial clearance between hole in vessel wall and outside diameter of nozzle neck or tube
- $r_1$  = minimum inside corner radius, the lesser of  $1/4t$  or  $1/8$  in. (3 mm)

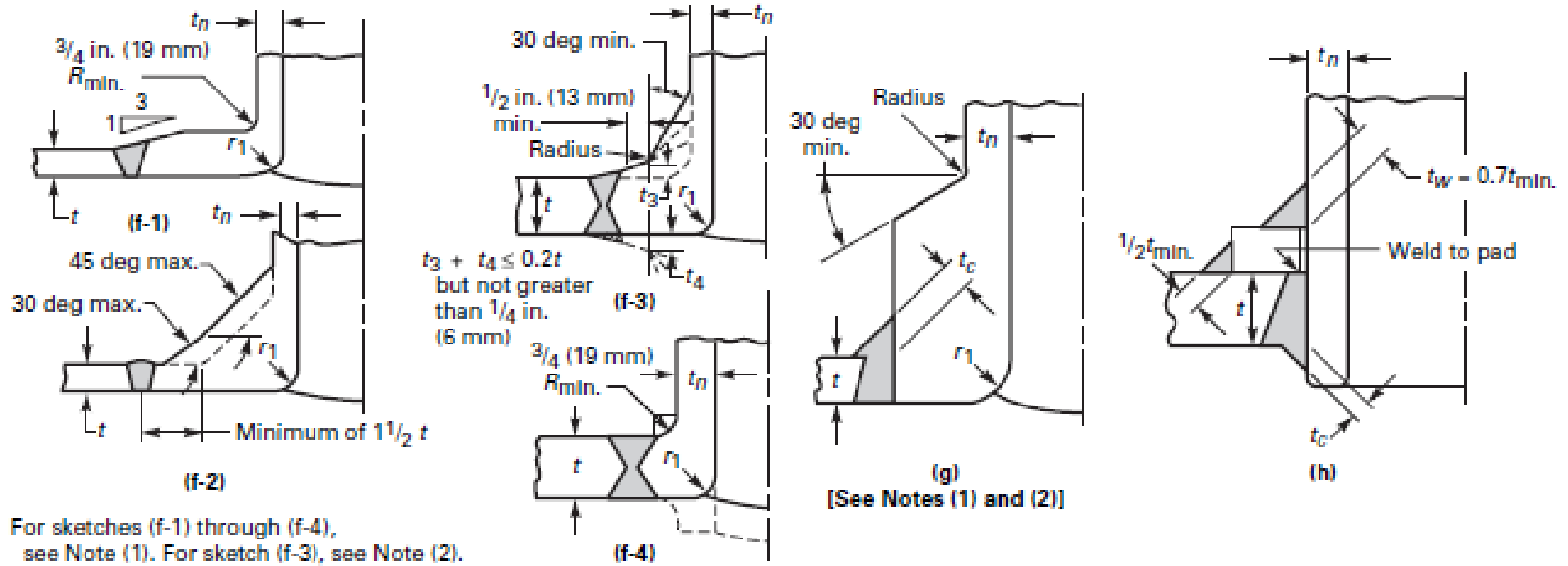
Radius =  $1/8$  in. (3 mm) minimum blend radius

- $t$  = nominal thickness of vessel shell or head,
- $t_1$  or  $t_2$  = not less than the smaller of  $1/4$  in. (6 mm) or  $0.7t_{\min}$
- $t_c$  = not less than the smaller of  $1/4$  in. (6 mm) or  $0.7t$  min (inside corner welds may be further limited by a lesser length of projection of the nozzle wall beyond the inside face of the vessel wall)
- $t_e$  = thickness of reinforcing plate, as defined in G-40



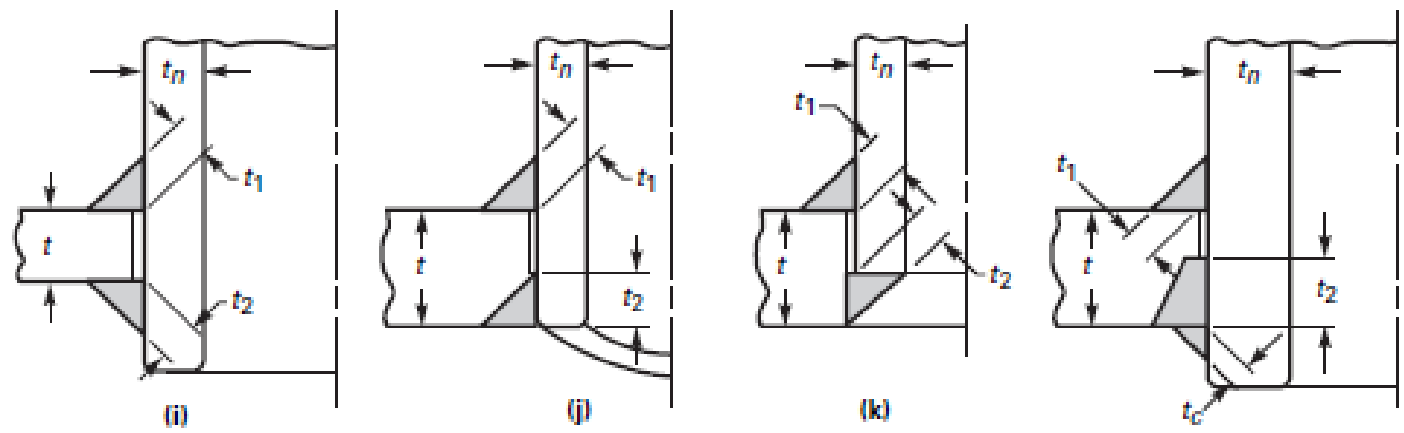
Figure UW-16.1

Some Acceptable Types of Welded Nozzles and Other Connections to Shells, Heads, etc. (Cont'd)



For sketches (f-1) through (f-4), see Note (1). For sketch (f-3), see Note (2).

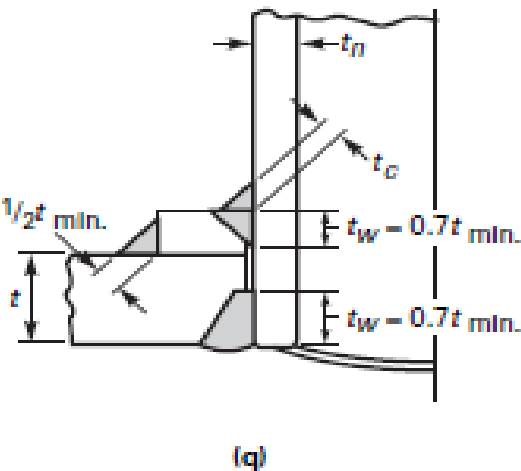
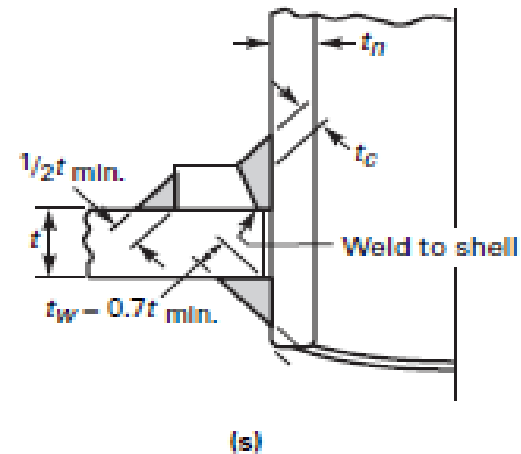
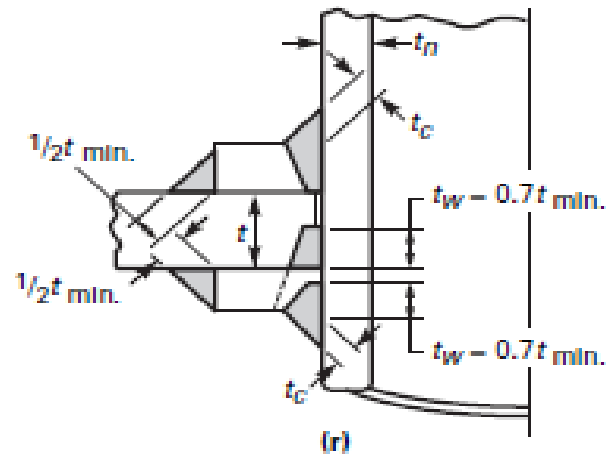
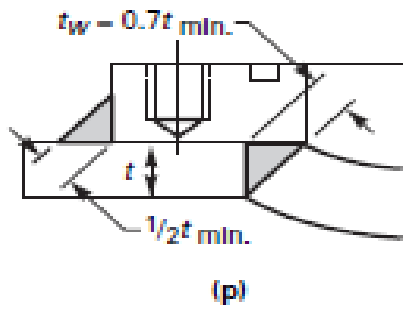
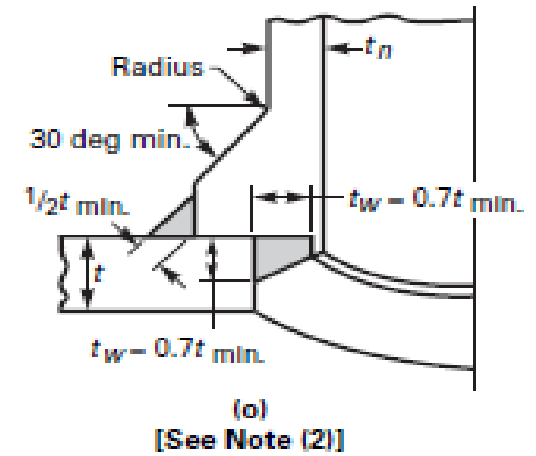
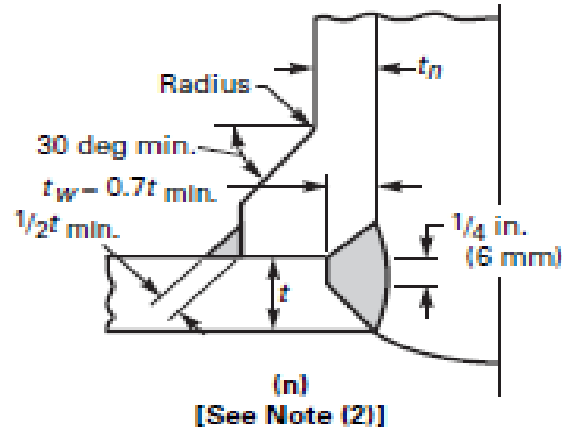
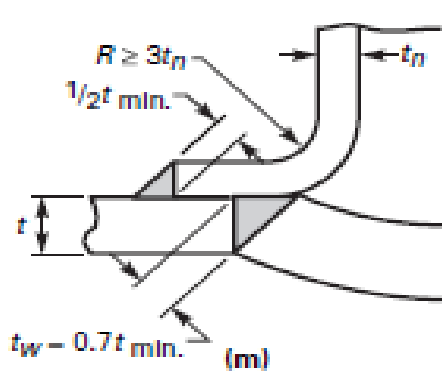
[See Notes (1) and (2)]



$t_1 + t_2 \geq 1\frac{1}{4}t_{min.}$   
 $t_1$  or  $t_2$  not less than the smaller of 1/4 in. (6 mm) or  $0.7t_{min.}$

**Figure UW-16.1**

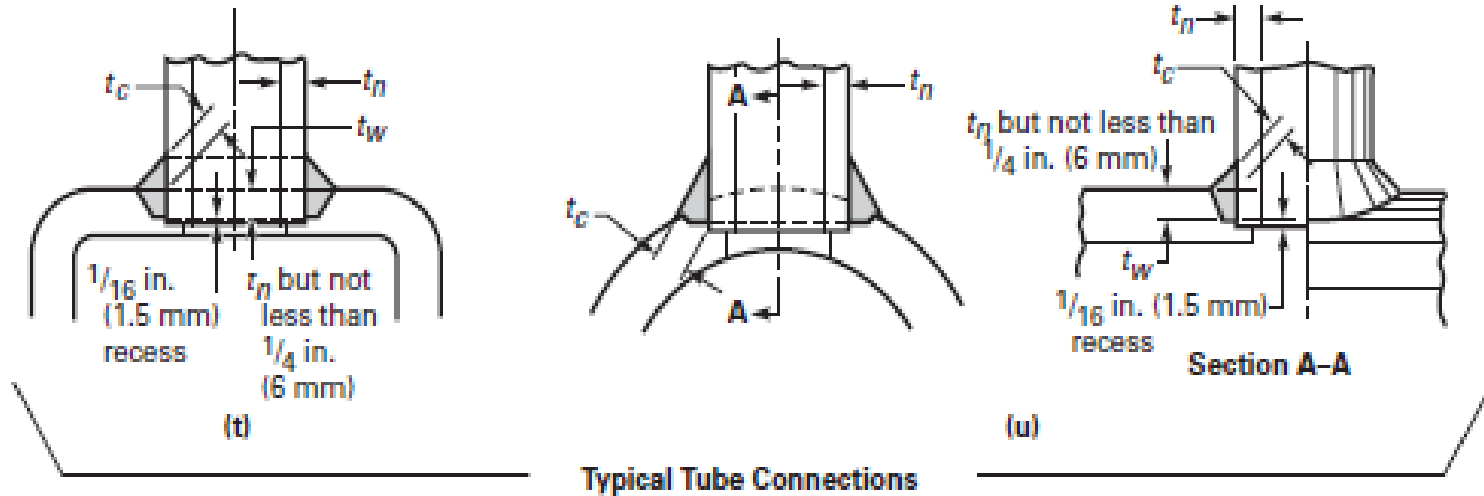
**Some Acceptable Types of Welded Nozzles and Other Connections to Shells, Heads, etc. (Cont'd)**



Notes follow on last page of this figure

**Figure UW-16.1**

**Some Acceptable Types of Welded Nozzles and Other Connections to Shells, Heads, etc. (Cont'd)**



(When used for other than square, round, or oval headers, round off corners)

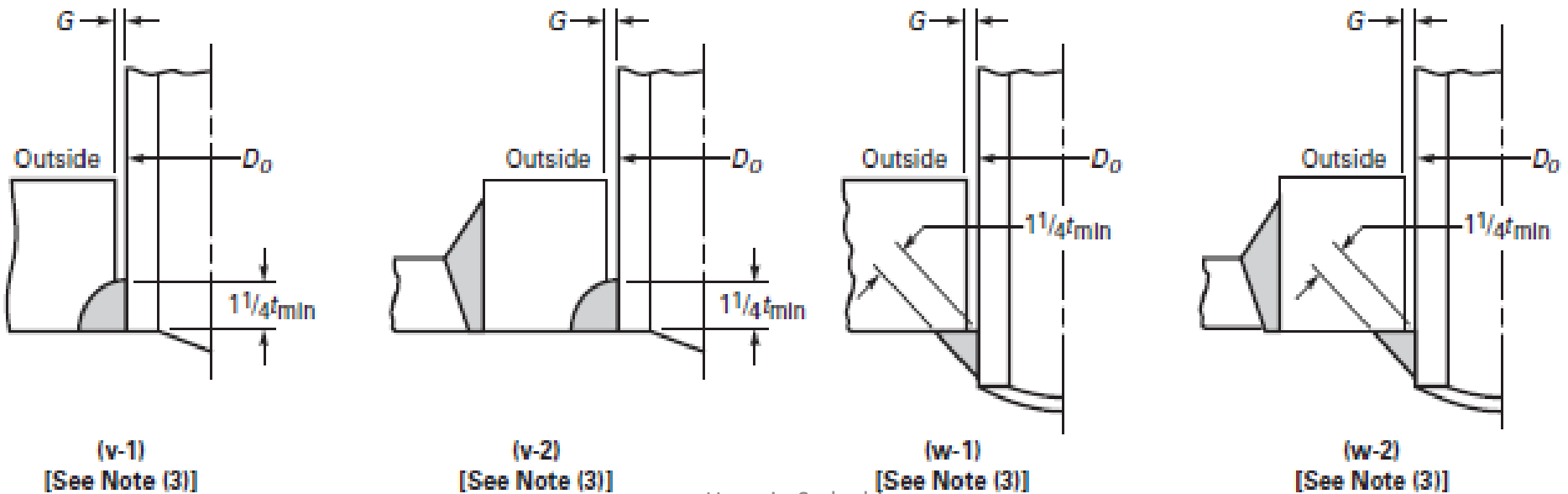
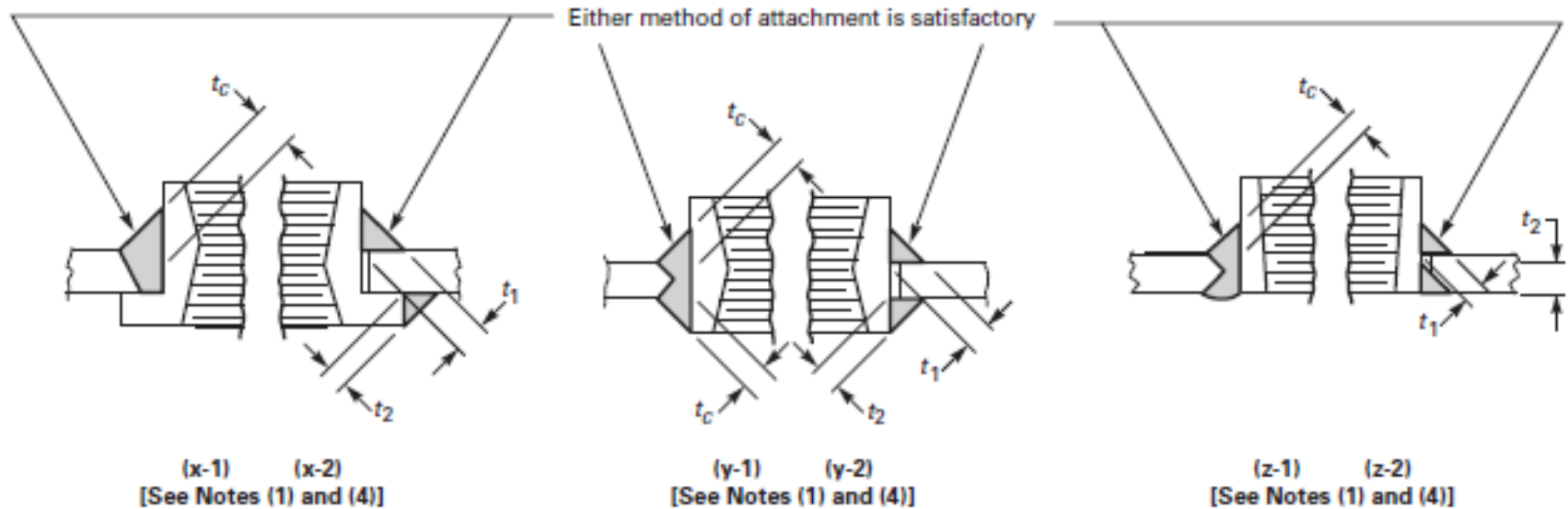


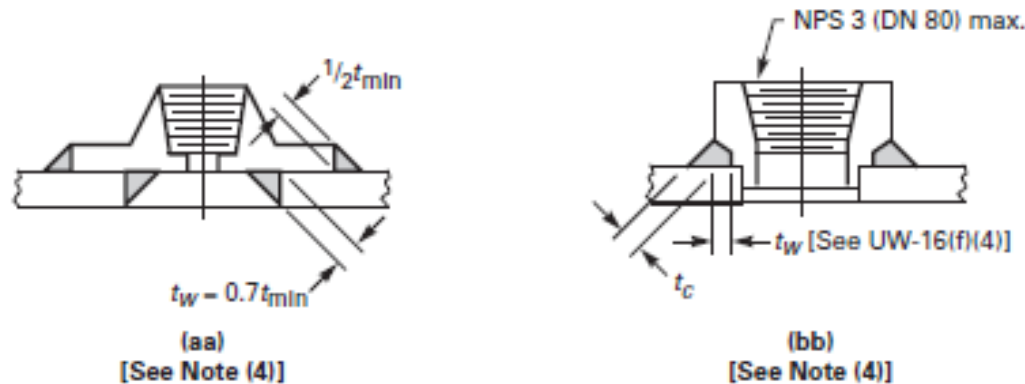
Figure UW-16.1

Some Acceptable Types of Welded Nozzles and Other Connections to Shells, Heads, etc. (Cont'd)



$$t_1 + t_2 \geq 1\frac{1}{4}t_{min}$$

$$t_1 \text{ or } t_2 \text{ not less than the smaller of } \frac{1}{4} \text{ in. (6 mm) or } 0.7t_{min}$$



NOTES:

(1) Sketches (a), (b), (c), (d), (e), (f-1) through (f-4), (g), (x-1), (y-1), and (z-1) are examples of nozzles with integral reinforcement.

(2) Where the term *Radius* appears, provide a  $\frac{3}{16}$  in. (3 mm) minimum blend radius.

(3) For sketches (v-1) through (w-2):

(a) For applications where there are no external loads,  $G = \frac{3}{16}$  in. (3 mm) max.





(b) With external loads

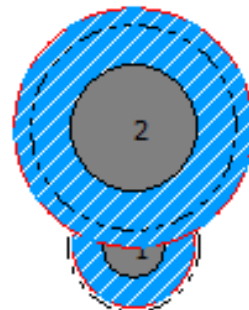
$G = 0.005$  for  $D_o \leq 1$  in. (25 mm);  $G = 0.010$  for  $1$  in. (25 mm)  $< D_o \leq 4$  in. (100 mm);  $G = 0.015$  for  $4$  in. (100 mm)  $< D_o \leq 6\frac{5}{8}$  in. (170 mm)

(4) For NPS 3 (DN 80) and smaller, see exemptions in UW-16(f)(2).

# Element Plan/Layout View

- 1 - Noz N1 Fr10, 152.4 mm., 40
- 2 - Noz N2 Fr10, 304.8 mm., 40

-  : Pad Dia.
-  : Nozzle Dia.
-  : Dia. Limit
-  : ANSI Flange Dia.



270°

0°, 360°

90°

180°

Print

Close

## UW-16 (Minimum Requirements For Attachment Welds At Openings)

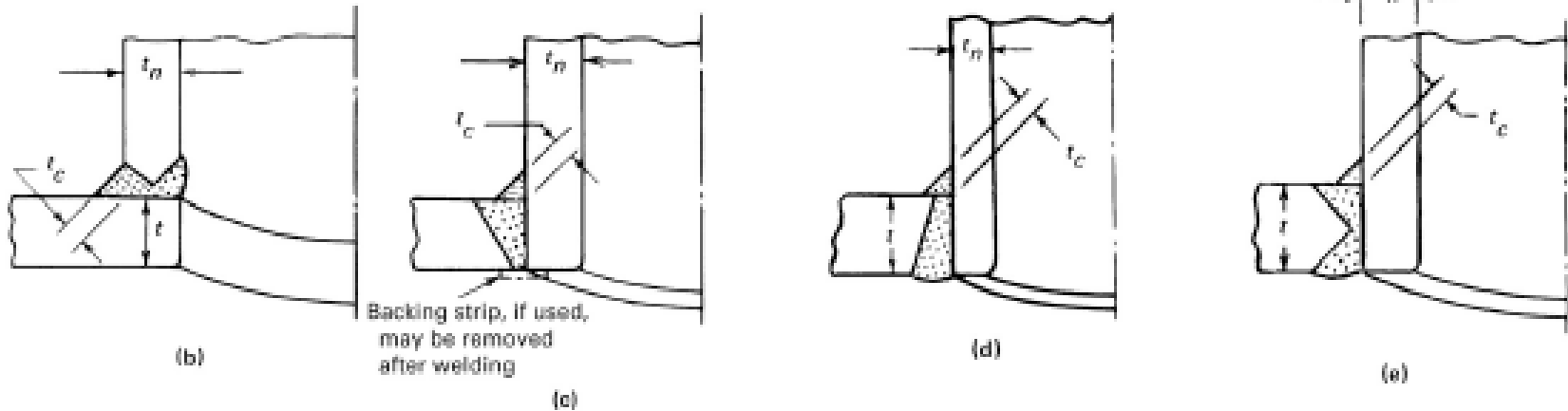
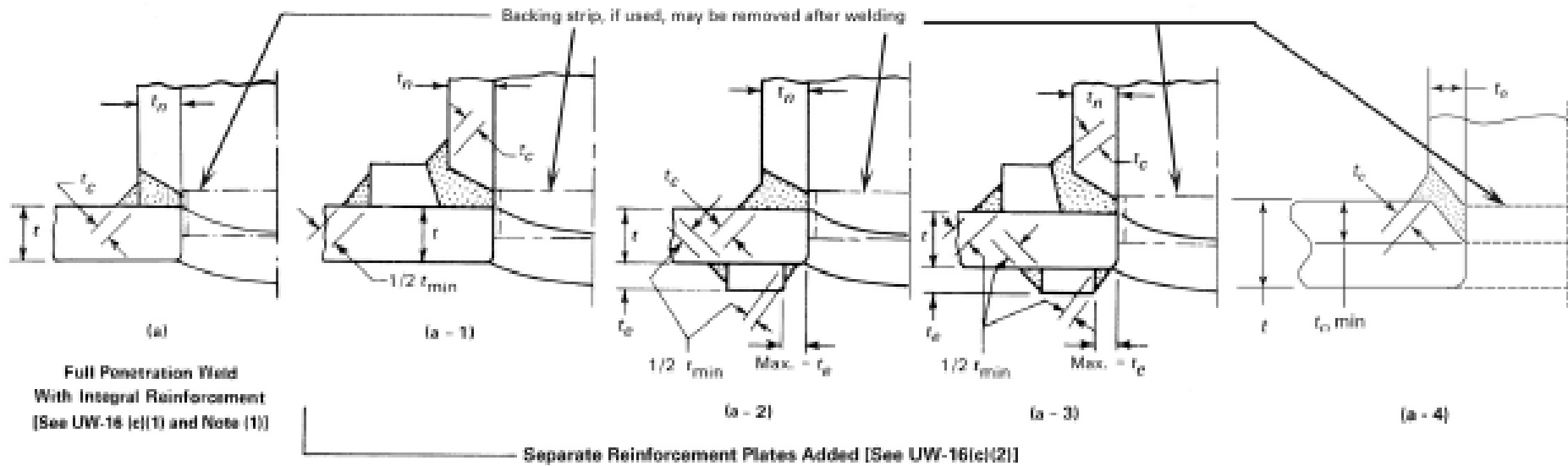
### (c) Necks Attached by a Full Penetration Weld.

- ❖ Necks abutting a vessel wall shall be attached by a full penetration groove weld.(See Figure UW-16.1 sketches (a) and(b) for examples)
- ❖ Necks inserted through the vessel wall may be attached by a full penetration groove weld. See Figure UW-16.1 sketches (c), (d), and (e).
- ❖ When complete joint penetration cannot be verified by visual inspection or other means permitted in this Division, backing strips or equivalent shall be used with full penetration welds deposited from one side.
- ❖ If additional reinforcement is required it shall be provided as integral reinforcement or by the addition of separate reinforcement elements (plates) attached by welding.



**Figure UW-16.1**

**Some Acceptable Types of Welded Nozzles and Other Connections to Shells, Heads, etc.**

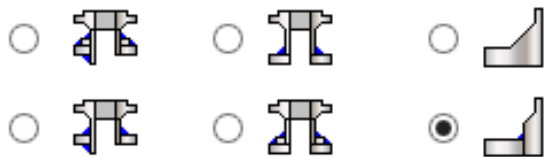


**Full Penetration Welds to Which Separate Reinforcement Plates May Be Added [See UW-16(c)(2) and Note (1)]**

## UW-16 (Integral Reinforcement)

- Integral reinforcement is that reinforcement provided in the form of extended or thickened necks, thickened shell plates, forging type inserts, or weld buildup which is an integral part of the shell or nozzle wall and, where required, is attached by full penetration welds. See Figure UW-16.1 sketches (a), (b), (c), (d), (e), (f-1), (f-2), (f-3), (f-4), (g), (x-1), (y-1), and (z-1) for examples of nozzles with integral reinforcement where the F factor in Figure UG-37 may be used.

Nozzle Attachment



FVC Catalogue ...

Coupling Lookup ...

Just Like ...

Pad or Hub Properties

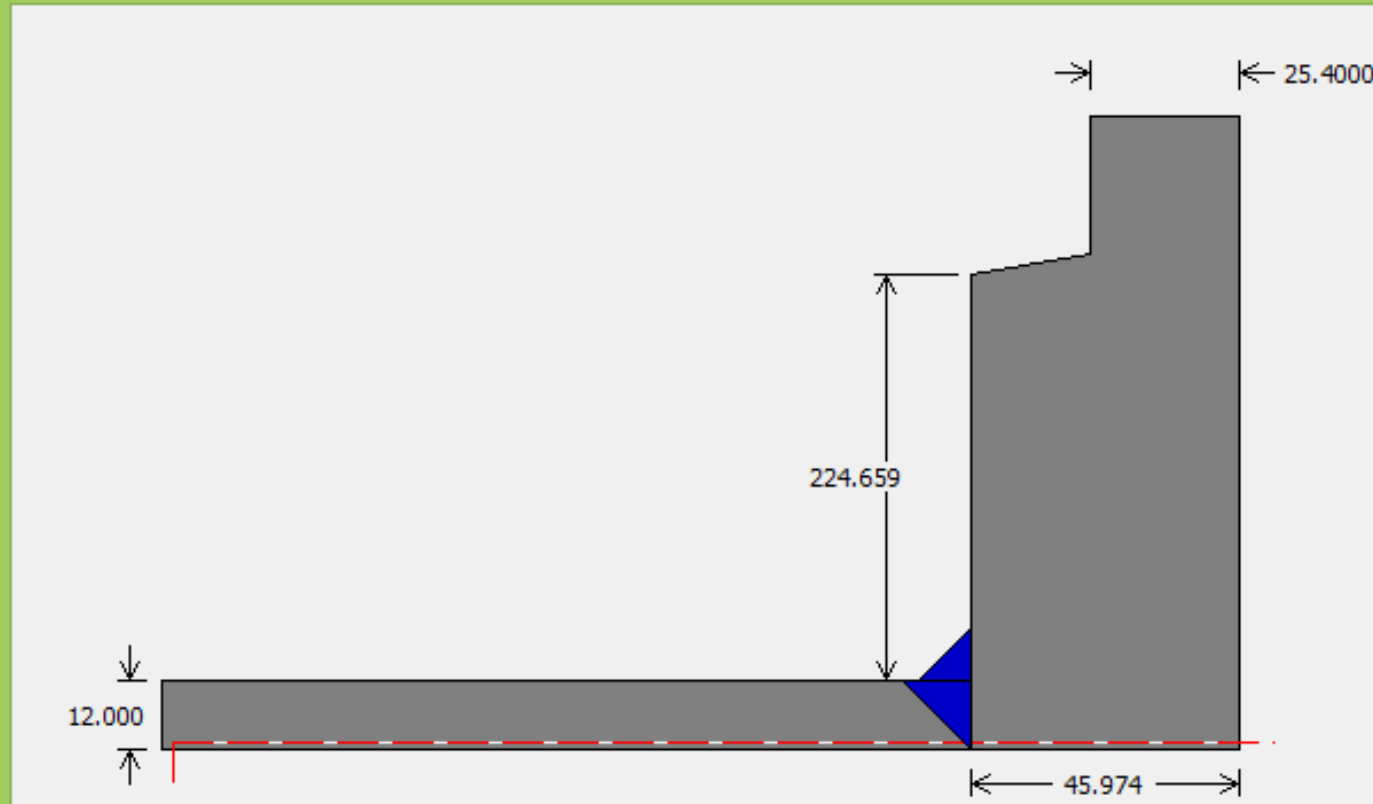
Hub Thickness : 45.974

Hub Height : 224.659

Bevel Height : 11.8784

Obtain ASME Bevel Angle

Nozzle Graphics Noz N1 Fr10



Inside Fillet Weld Leg : 9.525

Outside Fillet Weld Leg : 0

Groove Weld Depth : 12

ASME Weld Type : None

Weld Strength

Flange Material : SA-106 B

Class | Grade : 150 | GR

Flange Type : Weld Neck

Neglect Areas : None

Weld Area Loss : 0

Eff. | Shell Eff. : 1 | 1

Thk. | User Tr : 0 | 0

Attached? :  Manwa

Shell Fatigue Curve: Table 3.F.

Piping

8.351 [Passed]

Units : mm.

Thickness Limit: Fig. UG-40 [e-2]

Bevel Angle: 30.0 Bevel Angle:

Print

Close

Delete

Plot...

## UW-16 (Integral Reinforcement)

### (d) Neck Attached by Fillet or Partial Penetration Welds

- (1) Necks inserted into or through the vessel wall may be attached by fillet or partial penetration welds, one on each face of the vessel wall. The welds may be any desired combination of fillet, single-bevel, and single-J welds. The dimension of  $t_1$  or  $t_2$  for each weld shall be not less than the smaller of  $1/4$  in. (6 mm) or  $0.7t_{\min}$ , and their sum shall be not less than  $1\frac{1}{4}t_{\min}$ . See Figure UW-16.1 sketches (i), (j), (k), and (l).

## UW-16 (Integral Reinforcement)

If additional reinforcement is required, it may be provided in the form of extended or thickened necks, thickened shell plates, forgings, and/or separate reinforcement elements (plates) attached by welding. Weld requirements shall be the same as given in (c)(2) above, except as follows. The welds attaching the neck to the vessel wall or to the reinforcement plate shall consist of one of the following:

- (-a) a single-bevel or single-J weld in the shell plate, and a single-bevel or single-J weld in each reinforcement plate. The dimension  $t_w$  of each weld shall be not less than  $0.7t$  min. See Figure UW-16.1 sketches (q) and (r).
- (-b) a full penetration groove weld in each reinforcement plate, and a fillet, single-bevel, or single-J weld with a weld dimension  $t_w$  not less than  $0.7t_{min}$  in the shell plate. See Figure UW-16.1 sketch (s).

## UW-16 (Integral Reinforcement)

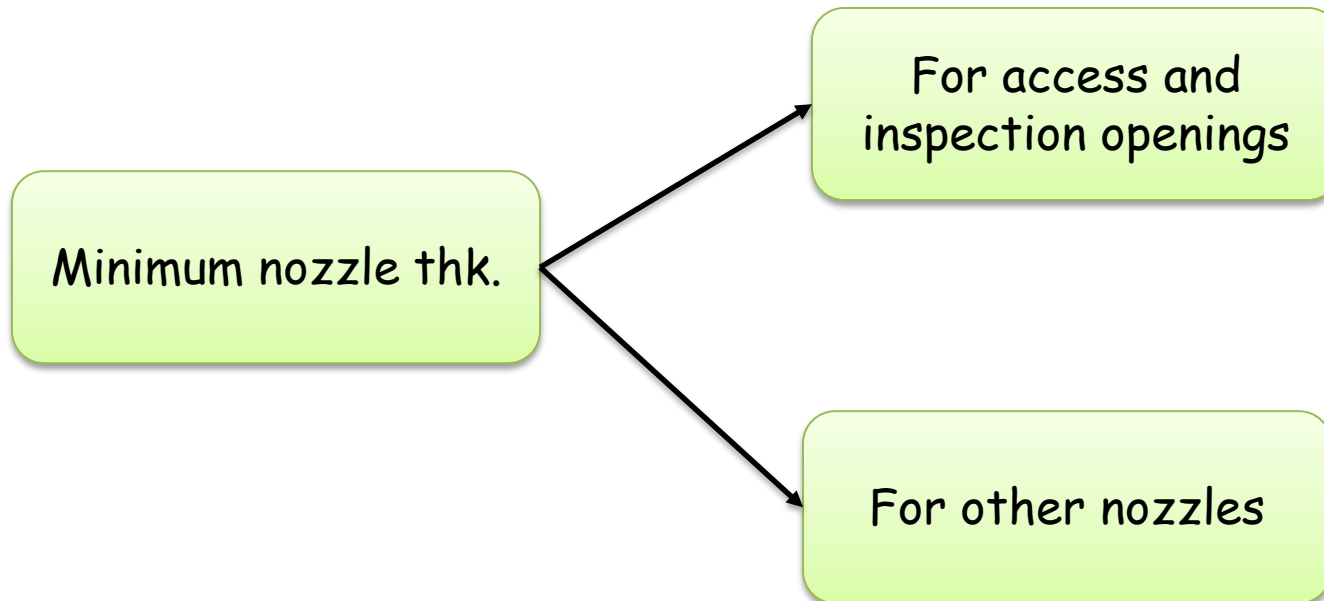
- (2) Nozzle necks, flared necks, and studding outlet type flanges may be attached by fillet welds or partial penetration welds between the outside diameter or the attachment and the outside surface of the shell and at the inside of the opening in the shell. The throat dimension of the outer attachment weld shall not be less than  $1/2t_{min}$ . The dimension  $t_w$  of the weld at the inside of the shell cutout shall not be less than  $0.7t_{min}$ . See Figure UW-16.1 sketches (m), (n), (o), and (p).

## UW-16 (Integral Reinforcement)

- (f) Standard Fittings: ASME/ANSI or Manufacturer's Standard. The attachment of standard fittings shall meet the following requirements; see (g) for the attachment of bolting pads:
- fittings shall be attached by a full penetration groove weld or by two fillet or partial penetration welds, one on each face of the vessel wall. The minimum weld dimensions shall be as shown in Figure UW-16.1 sketches (x), (y), (z), and (aa).
- **Exemptions:**
- Fittings not exceeding NPS 3 (sketches (x), (y), (z), (aa), and (bb)) -see UW-16 (3) and (4)
- Flange-type fittings not exceeding NPS 2

## UG-45 (NOZZLE NECK THICKNESS)

- The minimum wall thickness of nozzle necks shall be determined as given below.





## UG-45 (NOZZLE NECK THICKNESS)

- For access openings and openings used only for inspection:

$$t_{UG-45} = t_a$$

- For other nozzles:

Determine  $t_b$ .

$$t_b = \min [t_{b3}, \max (t_{b1}, t_{b2})]$$

$$t_{UG-45} = \max (t_a, t_b)$$

## UG-45 (NOZZLE NECK THICKNESS)

where

$t_a$  = minimum neck thickness required for internal and external pressure using UG-27 and UG-28 (plus corrosion and threading allowance), as applicable. The effects of external forces and moments from supplemental loads (see UG-22) shall be considered. Shear stresses caused by UG-22 loadings shall not exceed 70% of the allowable tensile stress for the nozzle material.

$t_{b1}$  = for vessels under internal pressure, the thickness (plus corrosion allowance) required for pressure (assuming  $E = 1.0$ ) for the shell or head at the location where the nozzle neck or other connection attaches to the vessel but in no case less than the minimum thickness specified for the material in UG-16(b).

$t_{b2}$  = for vessels under external pressure, the thickness (plus corrosion allowance) obtained by using the external design pressure as an equivalent internal design pressure (assuming  $E = 1.0$ ) in the formula for the shell or head at the location where the nozzle neck or other connection attaches to the vessel but in no case less than the minimum thickness specified for the material in UG-16(b).

$t_{b3}$  = the thickness given in Table UG-45 plus the thickness added for corrosion allowance.

$t_{UG-45}$  = minimum wall thickness of nozzle necks

## UG-45 (NOZZLE NECK THICKNESS)

**Table UG-45  
Nozzle Minimum Thickness Requirements**

Nominal Size	Minimum Wall Thickness [See UG-16(d)]	
	in.	mm
NPS 1/8 (DN 6)	0.060	1.51
NPS 1/4 (DN 8)	0.077	1.96
NPS 3/8 (DN 10)	0.080	2.02
NPS 1/2 (DN 15)	0.095	2.42
NPS 3/4 (DN 20)	0.099	2.51
NPS 1 (DN 25)	0.116	2.96
NPS 1 1/4 (DN 32)	0.123	3.12
NPS 1 1/2 (DN 40)	0.127	3.22
NPS 2 (DN 50)	0.135	3.42
NPS 2 1/2 (DN 65)	0.178	4.52
NPS 3 (DN 80)	0.189	4.80
NPS 3 1/2 (DN 90)	0.198	5.02
NPS 4 (DN 100)	0.207	5.27
NPS 5 (DN 125)	0.226	5.73
NPS 6 (DN 150)	0.245	6.22
NPS 8 (DN 200)	0.282	7.16
NPS 10 (DN 250)	0.319	8.11
≥ NPS 12 (DN 300)	0.328	8.34

GENERAL NOTE: For nozzles having a specified outside diameter not equal to the outside diameter of an equivalent standard NPS (DN) size, the NPS (DN) size chosen from the table shall be one having an equivalent outside diameter larger than the nozzle outside diameter.

Schedule | Diameter : 40 6 ... in.  
Dia. Basis | Thickness Basis : ID Nominal  
Total CA. | Actual Thk. : 3.175 7.112 mm.

Is this Nozzle Connected to another Nozzle?   
Parent Nozzle :  
Distance from 'From' Node|Elev : 0 0 mm.  
Layout ...

Layout Angle : 0 deg.  
Radial Nozzle :   
Angled or Lateral Nozzle :   
Centerline Tilt Angle : 0 deg.  
Cyl./Cone Offset Dimension L : 0 mm.

Projection Outside | Inside : 152.4 0 mm.  
Limits [ Diameter | Thickness ] : 0 0 mm.  
Overriding Weight : 0 kg. Calc

A1: 0.306 A2: 0.947 A3: 0.000 A4: 1.179 A5: 4.839 Aav.: 7.271 Ar: 6.973 [UG-45 Failed]

Noz:[1 of 1] Previous Nozzle Add New Nozzle Delete Plot... Help

Additional Weld Data  
Nozzle to Pad Fillet Weld Leg : 9.525 3.898 mm.  
Nozzle to Shell Inside Fillet Weld Leg : 0 mm.  
Nozzle to Shell Groove Weld Depth : 6.35 mm.  
ASME Weld Type : None

Weld Strength OK

Miscellaneous  
Flange Material : SA-105 Matl...  
Flange Class | Grade : 150 GR 1.1  
Flange Type : Weld Neck  
Neglect Areas : None  
Tapped Hole Area Loss : 0 cm<sup>2</sup>  
Nozzle Eff. | Shell Eff. : 1 1  
Local Shell Thk. | User Tr : 0 0 mm

Blind Attached?:  Manway/Acs Ope ? :

Fatigue Calc ? :  Shell Fatigue Curve: Table 3.F.1  
Piping Attached ...

Parent Flange Rating: 17.900 bars OK Cancel

## UG-46 (INSPECTION OPENINGS)

- (a) All pressure vessels for use with:
  - ❖ compressed air
  - ❖ subject to internal corrosion
  - ❖ having parts subject to erosion or mechanical abrasion

shall be provided with suitable:

- ✓ Manhole
- ✓ Handhole
- ✓ inspection openings for examination and cleaning.

## UG-46 (INSPECTION OPENINGS)

(a) All pressure vessels for use with:

- ❖ compressed air
- ❖ subject to internal corrosion
- ❖ having parts subject to erosion or mechanical abrasion

shall be provided with suitable:

- ✓ Manhole
- ✓ Handhole
- ✓ inspection openings for examination and cleaning.

## UG-46 (INSPECTION OPENINGS)

- (c) Vessels over 12 in. (300 mm) I.D. under air pressure:

that also contain, substances that will prevent corrosion need not have openings for inspection only, provided the vessel contains suitable openings through which inspection can be made conveniently, and provided such openings are equivalent in size and number to the requirements for inspection openings in (f) below.

- (d) For vessels 12 in. (300 mm) or less in inside diameter:

openings for inspection only may be omitted if there are at least two removable pipe connections not less than NPS 3/4 (DN 20).

## UG-46 (INSPECTION OPENINGS)

- (e) Vessels less than 16 in. (400 mm) and over 12 in. (300 mm) I.D. :
  - shall have at least two handholes
  - or two threaded pipe plug inspection openings of not less than NPS 11/2 (DN 40)
  - except as permitted by the following:
- when vessels to be installed so that inspection cannot be made without removing the vessel from the assembly, openings for inspection only may be omitted provided there are at least two removable pipe connections of not less than NPS 11/2 (DN 40).



## UG-46 (INSPECTION OPENINGS)

- (f) Vessels that require access or inspection openings shall be equipped as follows.
- (1) All vessels less than 18 in. (450 mm) and over 12 in. (300 mm) I.D. shall have at least two handholes or two plugged, threaded inspection openings of not less than NPS 1 1/2 (DN 40).
- (2) All vessels 18 in. (450 mm) to 36 in. (900 mm), inclusive, I.D. shall have a manhole or at least two handholes or two plugged, threaded inspection openings of not less than NPS 2 (DN 50).
- (3) All vessels over 36 in. (900 mm) I.D. shall have a manhole, except that those whose shape or use makes one impracticable shall have at least two handholes 4 in. × 6 in. (100 mm × 150 mm) or two equal openings of equivalent area.

## UG-46 (INSPECTION OPENINGS)

- (g) When inspection or access openings are required, they shall comply at least with the following requirements:
  - (1) An elliptical or obround manhole shall be not less than 12 in. × 16 in. (300 mm × 400 mm). A circular manhole shall be not less than 16 in. (400 mm) I.D.
  - (2) A handhole opening shall be not less than 2 in. × 3 in. (50 mm × 75 mm), but should be as large as is consistent with the size of the vessel and the location of the opening.

## Summary of openings Error and warnings

- 1- Rating of flange has been failed
- 2- Nozzles have clash and do not distanced as per limit of reinforcement
- 3- UG-37 failed
- 4- UG-45 Failed
- 5- WRC at nozzle or pad has been failed

## UG-46 (INSPECTION OPENINGS)

(a) All pressure vessels for use with:

- ❖ compressed air
- ❖ subject to internal corrosion
- ❖ having parts subject to erosion or mechanical abrasion

shall be provided with suitable:

- ✓ Manhole
- ✓ Handhole
- ✓ inspection openings for examination and cleaning.

## UG-46 (INSPECTION OPENINGS)

- (c) Vessels over 12 in. (300 mm) I.D. under air pressure:

that also contain, substances that will prevent corrosion need not have openings for inspection only, provided the vessel contains suitable openings through which inspection can be made conveniently, and provided such openings are equivalent in size and number to the requirements for inspection openings in (f) below.

- (d) For vessels 12 in. (300 mm) or less in inside diameter:

openings for inspection only may be omitted if there are at least two removable pipe connections not less than NPS 3/4 (DN 20).

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- (e) Vessels less than 16 in. (400 mm) and over 12 in. (300 mm) I.D. :
  - shall have at least two handholes
  - or two threaded pipe plug inspection openings of not less than NPS 11/2 (DN 40)
  - **except as permitted by the following:**
- when vessels to be installed so that inspection cannot be made without removing the vessel from the assembly, openings for inspection only may be omitted provided there are at least two removable pipe connections of not less than NPS 11/2 (DN 40).

## UG-46 (INSPECTION OPENINGS)

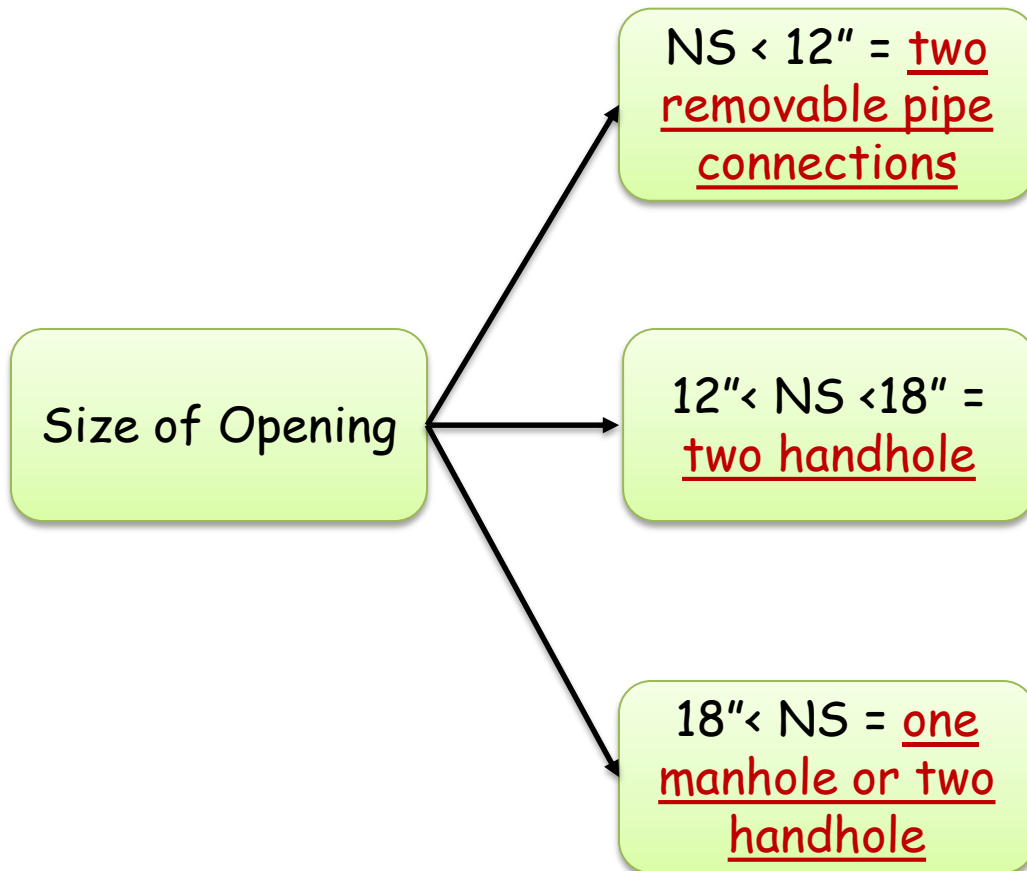
- (f) Vessels that require access or inspection openings shall be equipped as follows.
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- (2) All vessels 18 in. (450 mm) to 36 in. (900 mm), inclusive, I.D. shall have a manhole or at least two handholes or two plugged, threaded inspection openings of not less than NPS 2 (DN 50).
- (3) All vessels over 36 in. (900 mm) I.D. shall have a manhole, except that those whose shape or use makes one impracticable shall have at least two handholes 4 in. × 6 in. (100 mm × 150 mm) or two equal openings of equivalent area.

## UG-46 (INSPECTION OPENINGS)

- (g) When inspection or access openings are required, they shall comply at least with the following requirements:
  - (1) An elliptical or obround manhole shall be not less than 12 in. × 16 in. (300 mm × 400 mm). A circular manhole shall be not less than 16 in. (400 mm) I.D.
  - (2) A handhole opening shall be not less than 2 in. × 3 in. (50 mm × 75 mm), but should be as large as is consistent with the size of the vessel and the location of the opening.



## UG-46 (Summary Size of opening)



## 1-7 Large openings in cylindrical and conical shells

### (a) Reinforcement shall comply with the following rules:

- Two-thirds of the required reinforcement shall be within the following limits:
  - (1) parallel to vessel wall: the larger of three-fourths times the limit in UG-40(b)(1), or equal to the limit in UG-40(b)(2);
  - (2) normal to vessel wall: the smaller of the limit in UG-40(c)(1), or in UG-40(c)(2).

### (b) In addition to above condition :

- openings for radial nozzles and with below condition:
  - (-a) vessel diameters greater than 60 in. (1 520 mm) I.D.;
  - (-b) nozzle diameters that exceed 40 in. (1 020 mm) I.D. and also exceed  $3.4\sqrt{Rt}$
  - (-c) the ratio  $R_n/R$  does not exceed 0.7

## 1-7 Large openings in cylindrical and conical shells

- Membrane stress  $S_m$  shall not exceed  $S$
- The maximum combined membrane stress  $S_m$  and bending stress  $S_b$  shall not exceed  $1.5S$  at design conditions.

Case A (see Figure 1-7-1)

$$S_m = P \left( \frac{R(R_n + t_n + \sqrt{R_m t}) + R_n(t + t_e + \sqrt{R_{nm} t_n})}{A_s} \right) \quad (1)$$

Case B (see Figure 1-7-1)

$$S_m = P \left( \frac{R(R_n + t_n + \sqrt{R_m t}) + R_n(t + \sqrt{R_{nm} t_n})}{A_s} \right) \quad (2)$$

Cases A and B (See Figure 1-7-1 or Figure 1-7-2)

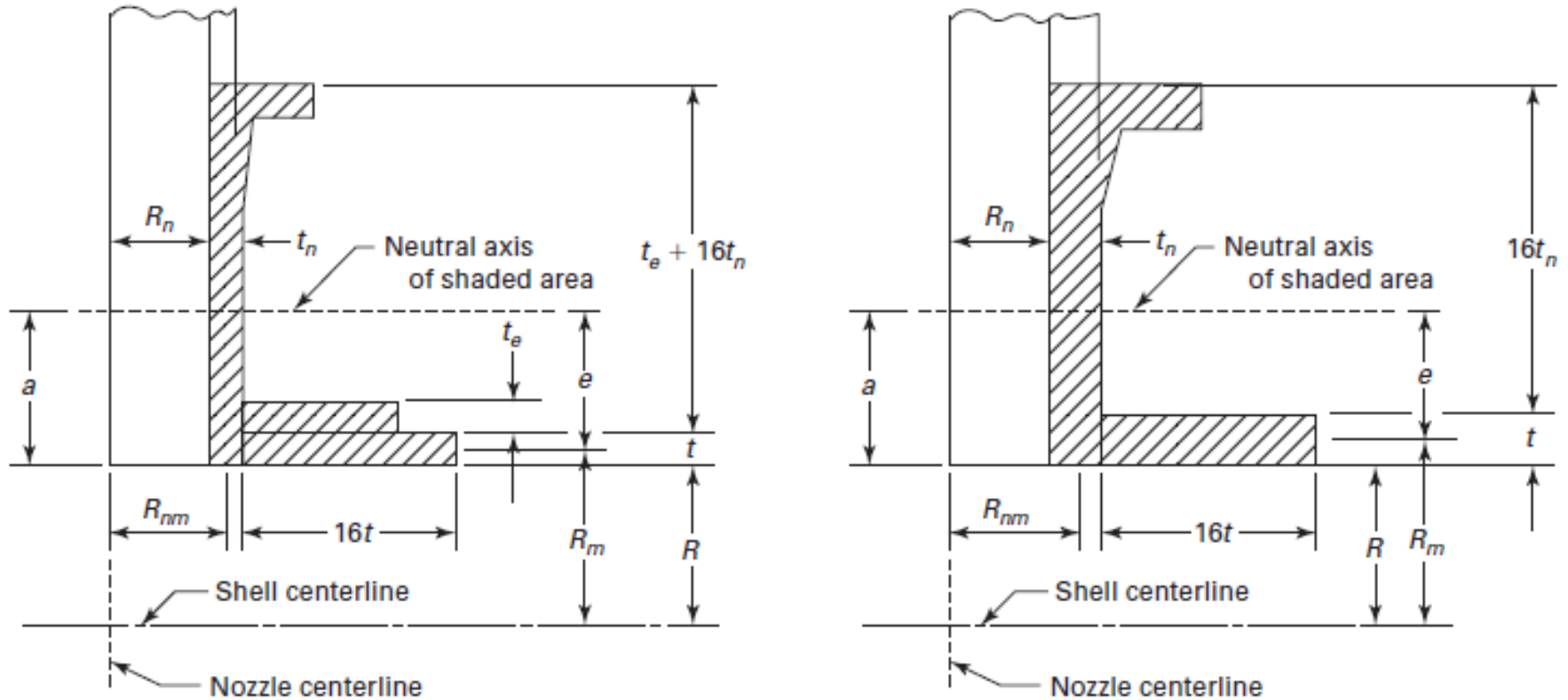
$$M = \left( \frac{R_n^3}{6} + RR_n^e \right) P \quad (3)$$

$$a = e + t/2 \quad (4)$$

$$S_b = \frac{Ma}{I} \quad (5)$$



Figure 1-7-2



Case A: Nozzle With Reinforcing Pad

Case B: Nozzle With Integral-Type Reinforcement

GENERAL NOTE: When any part of a flange is located within the greater of the  $\sqrt{R_{nm}t_n} + t_e$  or  $16t_n + t_e$  limit as indicated in Figure 1-7-1 or Figure 1-7-2 Case A, or the greater of  $\sqrt{R_{nm}t_n}$  or  $16t_n$  for Figure 1-7-1 or Figure 1-7-2 Case B, the flange may be included as part of the section that resists bending moment.

## Summary of openings Error and warnings

- 1- Rating of flange has been failed
- 2- Nozzles have clash and do not distanced as per limit of reinforcement
- 3- UG-37 failed
- 4- UG-45 Failed
- 5- WRC at nozzle or pad has been failed

## UG-54 SUPPORTS

- (a) All vessels shall be so supported and the supporting members shall be arranged and/or attached to the vessel wall in such a way as to provide for the maximum imposed loadings (see UG-22 and UG-82).

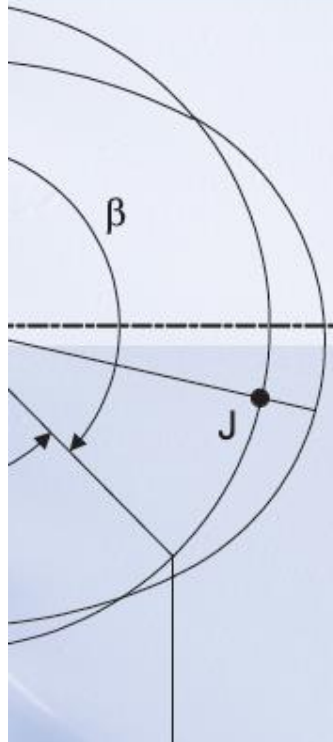
- All Type of Supports:
- 1- Saddle (for a horizontal vessel)
- 2- Skirt (for a vertical vessel)
- 3- Leg (for a vertical vessel)
- 4- Lug (for a vertical vessel)



# VIII

## Rules for Construction of Pressure Vessels

### Division 2 Alternative Rules



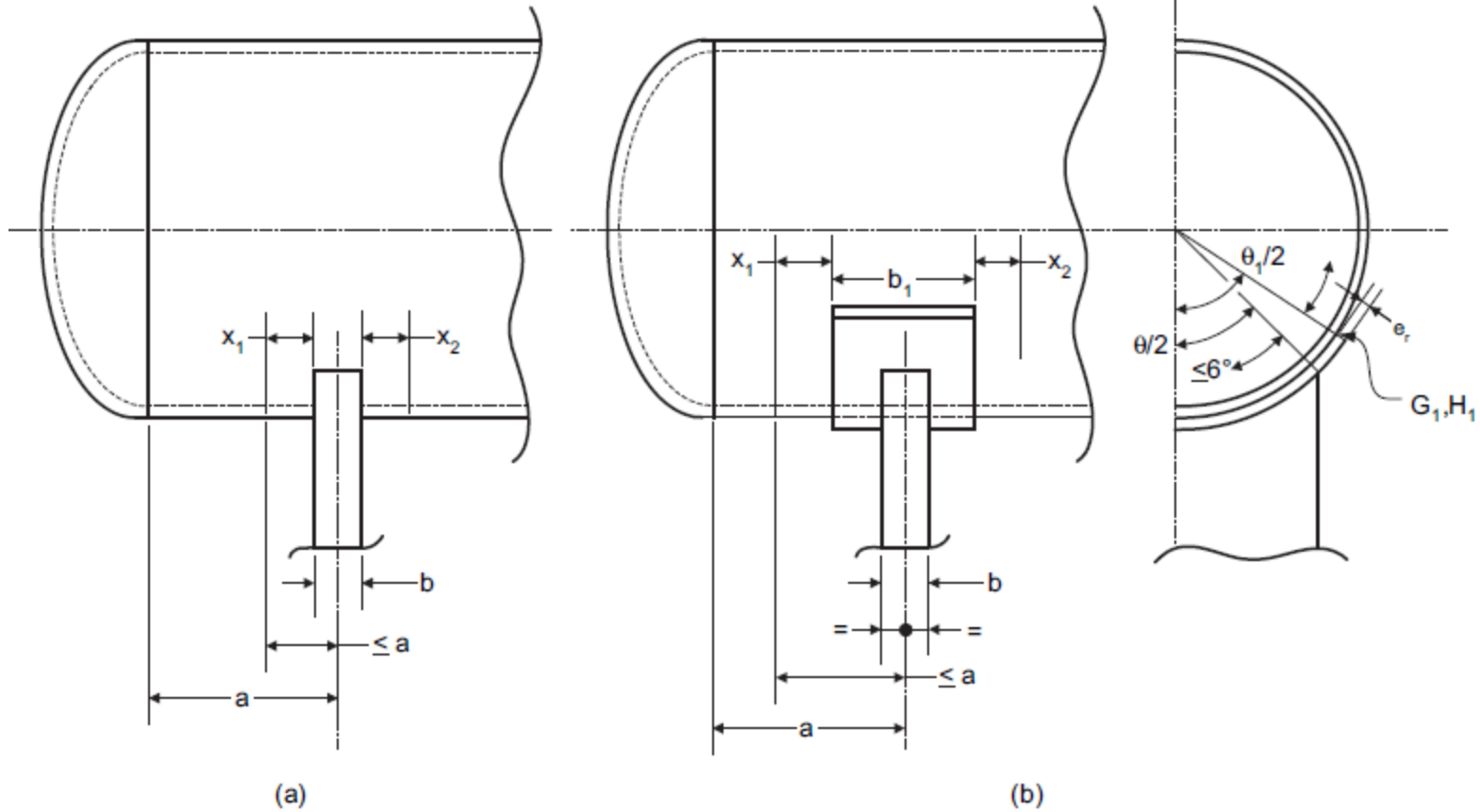
## Section VIII-Div 2 (Saddle)

- The design method in this paragraph is based on an analysis of the longitudinal stresses exerted within the cylindrical shell by the overall bending of the vessel, considered as a beam on two single supports
- Saddle supports for horizontal vessels shall be configured to provide continuous support for at least one-third of the shell circumference or  $\theta \geq 120$  deg.

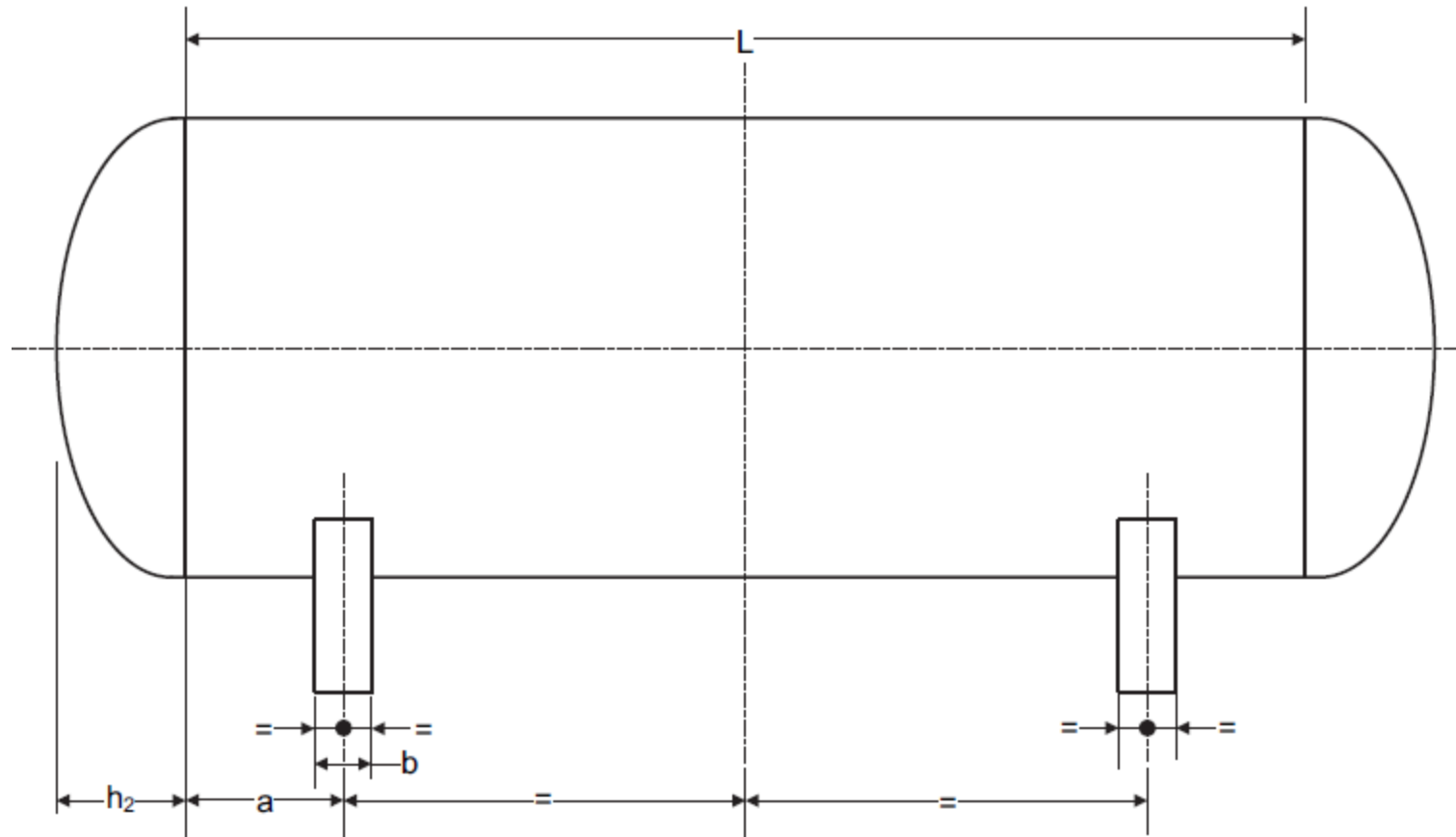
- Wear Plate: 
$$b_1 = \min\left[ \left( b + 1.56\sqrt{R_m t} \right), 2a \right]$$

$$\theta_1 = \theta + \frac{\theta}{12}$$

# Section VIII-Div 2 (Saddle)

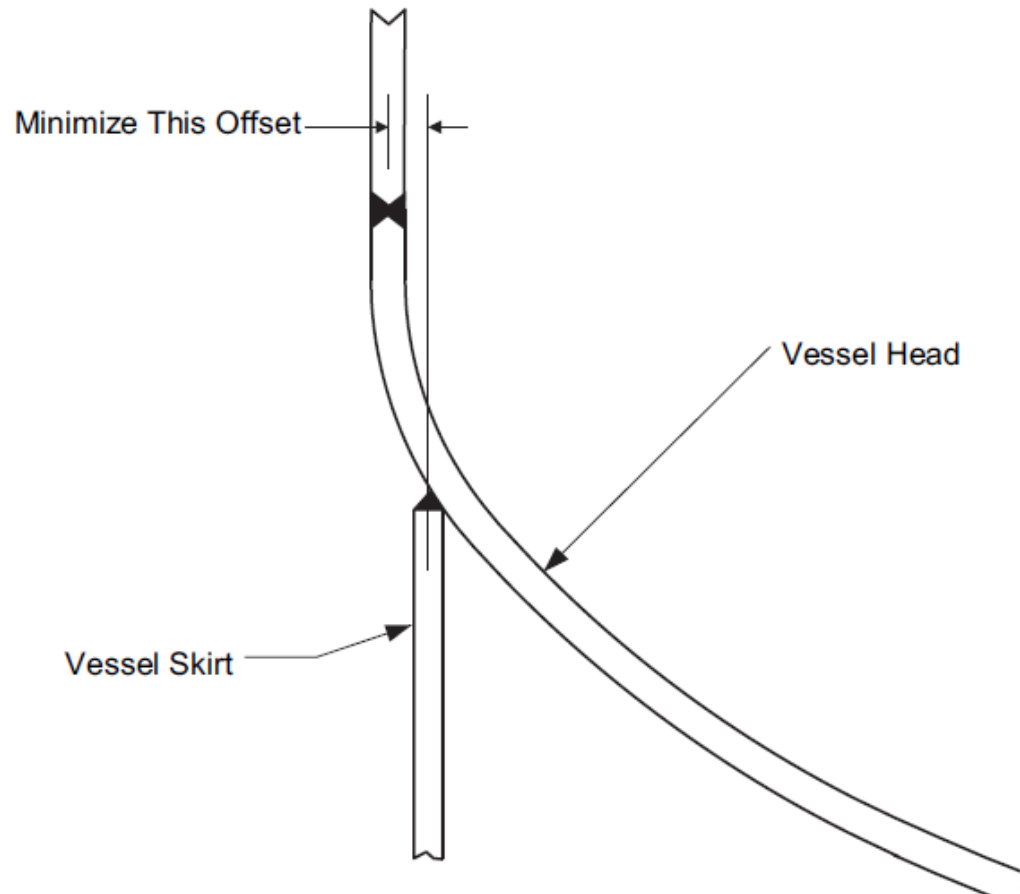


## Section VIII-Div 2 (Saddle)



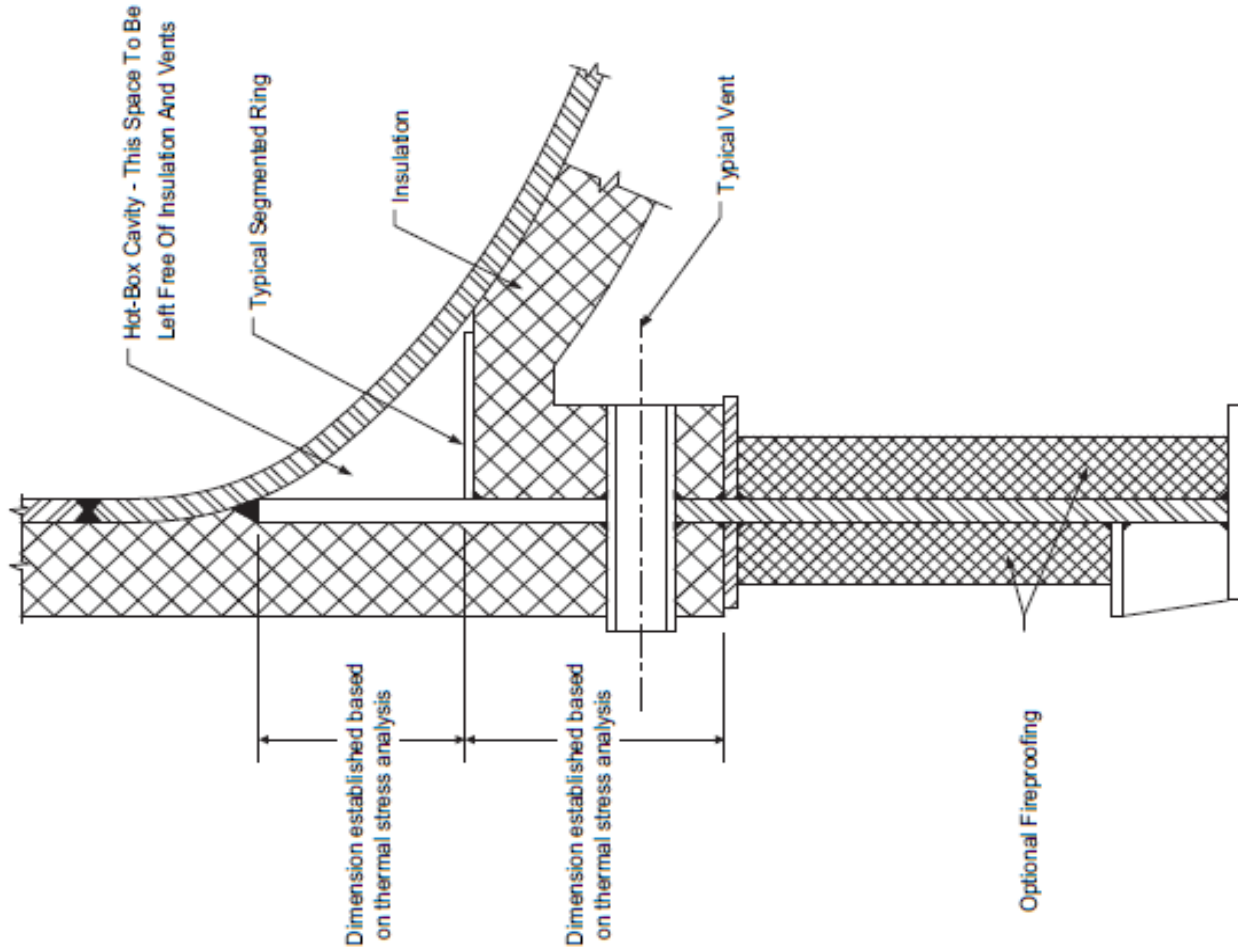
- $a \leq 0.25 L$

Figure 4.15.7  
Skirt Attachment Location on Vertical Vessels



# Section VIII-Div 2 (SKirt) / Research about Hot Box!

Figure 4.15.8  
A Typical Hot-Box Arrangement for Skirt Supported Vertical Vessels



## UG-55 Lugs and Clips

- (a) Lugs or clips may be welded, brazed, or bolted to the outside or inside of the vessel to support ladders, platforms, piping, motor or machinery mounts, and attachment of insulating jackets (see UG-22).
- The material of the lugs or clips shall be in accordance with UG-4.
- (b) External piping connected to a pressure vessel shall be installed **so as not to overstress the vessel wall** (see UG-22 and UG-82).
- (c) Nonmandatory Appendix G provides guidance on the design of attachments.

## Study!

- Study Non-Mandatory Appendix G and summarized its points!



## UG-79 FORMING PRESSURE PARTS

- (a) Limits are provided on cold working of all carbon and low alloy steels high alloy steels, and ferritic steels with tensile properties enhanced by heat treatment.
- Forming strains or extreme fiber elongation shall be determined by the equations in Table UG-79-1.

**Table UG-79-1  
Equations for Calculating Forming Strains**

Type of Part Being Formed	Forming Strain
Cylinders formed from plate	$\epsilon_f = \left( \frac{50t}{R_f} \right) \left( 1 - \frac{R_f}{R_o} \right)$
For double curvature (e.g., heads)	$\epsilon_f = \left( \frac{75t}{R_f} \right) \left( 1 - \frac{R_f}{R_o} \right)$
Tube and pipe bends	$\epsilon_f = \frac{100r}{R}$

**GENERAL NOTE:**

$\epsilon_f$  = calculated forming strain or extreme fiber elongation

$R$  = nominal bending radius to centerline of pipe or tube

$R_f$  = final mean radius

$R_o$  = original mean radius, equal to infinity for a flat plate

$r$  = nominal outside radius of pipe or tube

$t$  = nominal thickness of the plate, pipe, or tube before forming

## UG-79 FORMING PRESSURE PARTS

- (b) If the plates are to be rolled, the adjoining edges of longitudinal joints of cylindrical vessels shall first be shaped to the proper curvature by preliminary rolling or forming in order to avoid having objectionable flat spots along the completed joints.
- (c) When the vessel shell section, heads, or other pressure boundary parts are cold formed by other than the manufacturer of the vessel, the required certification for the part shall indicate whether or not the part has been heat-treated.

(d) A reduction in weld thickness due to a forming operation is acceptable provided all of the following conditions are met:

- ❖ The reduced weld thickness, at any point, shall not be less than the minimum required thickness of the component.
- ❖ The reduction in thickness shall not exceed  $1/32$  in. (1 mm) or 10% of the nominal thickness of the adjoining surface, whichever is less.

## UCS-79 FORMING PRESSURE PARTS

- (a) The following provisions shall apply in addition to the general rules for forming given in UG-79.
  - (b) Carbon and low alloy steel plates shall not be formed cold by blows.
  - (c) Carbon and low alloy steel plates may be formed by blows at a forging temperature provided the blows do not objectionably deform the plate and it is subsequently postweld heat treated.
- ❖ Forging temperature is the temperature at which a metal becomes substantially more soft, but is lower than the melting temperature. Bringing a metal to its forging temperature allows the metal's shape to be changed by applying a relatively small force, without creating cracks.

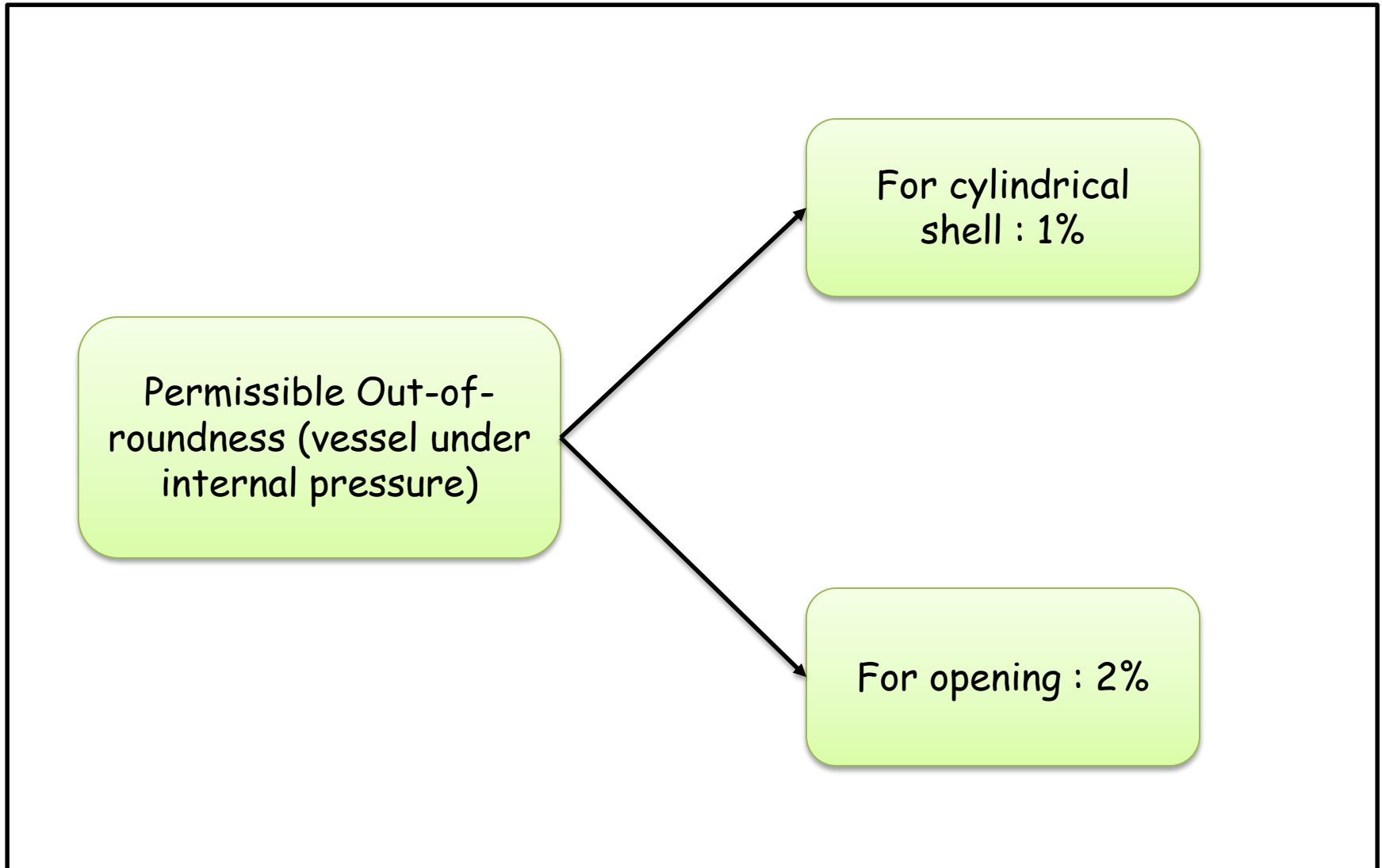
## UCS-79 FORMING PRESSURE PARTS

- (d) Except when made of P-No. 1, Group Nos. 1 and 2; and P-No. 15E materials, all vessel shell sections, heads, and other pressure parts fabricated by cold forming shall be heat treated subsequently (see UCS-56) when the resulting extreme fiber elongation exceeds 5% from the supplied condition.
- For P-No. 1, Group Nos. 1 and 2, this subsequent heat treatment is required when the extreme fiber elongation exceeds 40%, or if the extreme fiber elongation exceeds 5% and any of the following conditions exist:

## UCS-79 FORMING PRESSURE PARTS

- (1) The vessel will contain lethal substances either liquid or gaseous (see UW-2).
- (2) The material is not exempt from impact testing by the rules of this Division or impact testing is required by the material specification.
- (3) The thickness of the part before cold forming exceeds 5/8 in. (16 mm).
- (4) The reduction by cold forming from the as-rolled thickness is more than 10% at any location where the extreme fiber elongation exceeds 5%.
- (5) The temperature of the material during forming is in the range of 250°F to 900°F (120°C to 480°C).

## UG-80 Permissible Out-of-roundness





## UG-80 Permissible Out-of-roundness

- (1) The difference between the maximum and minimum inside diameters at any cross section shall not exceed 1% of the nominal diameter at the cross section under consideration. The diameters may be measured on the inside or outside of the vessel
- (2) When the cross section passes through an opening or within I.D. of the opening measured from the center of the opening, the permissible difference in inside diameters given above may be increased by 2% of the inside diameter of the opening. When the cross section passes through any other location normal to the axis of the vessel, including head-to-shell junctions, the difference in diameters shall not exceed 1%.

## UG-80 Permissible Out-of-roundness

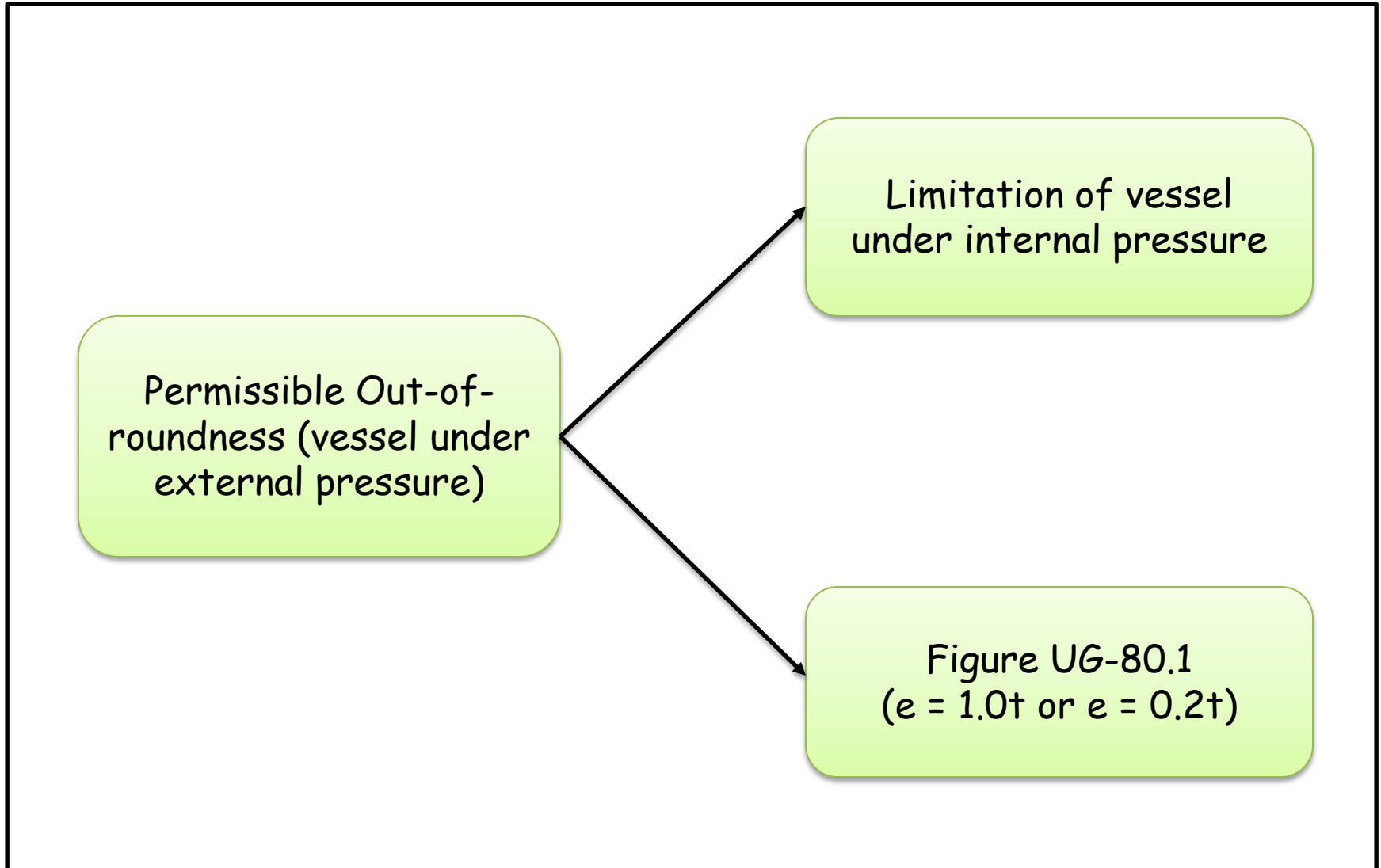
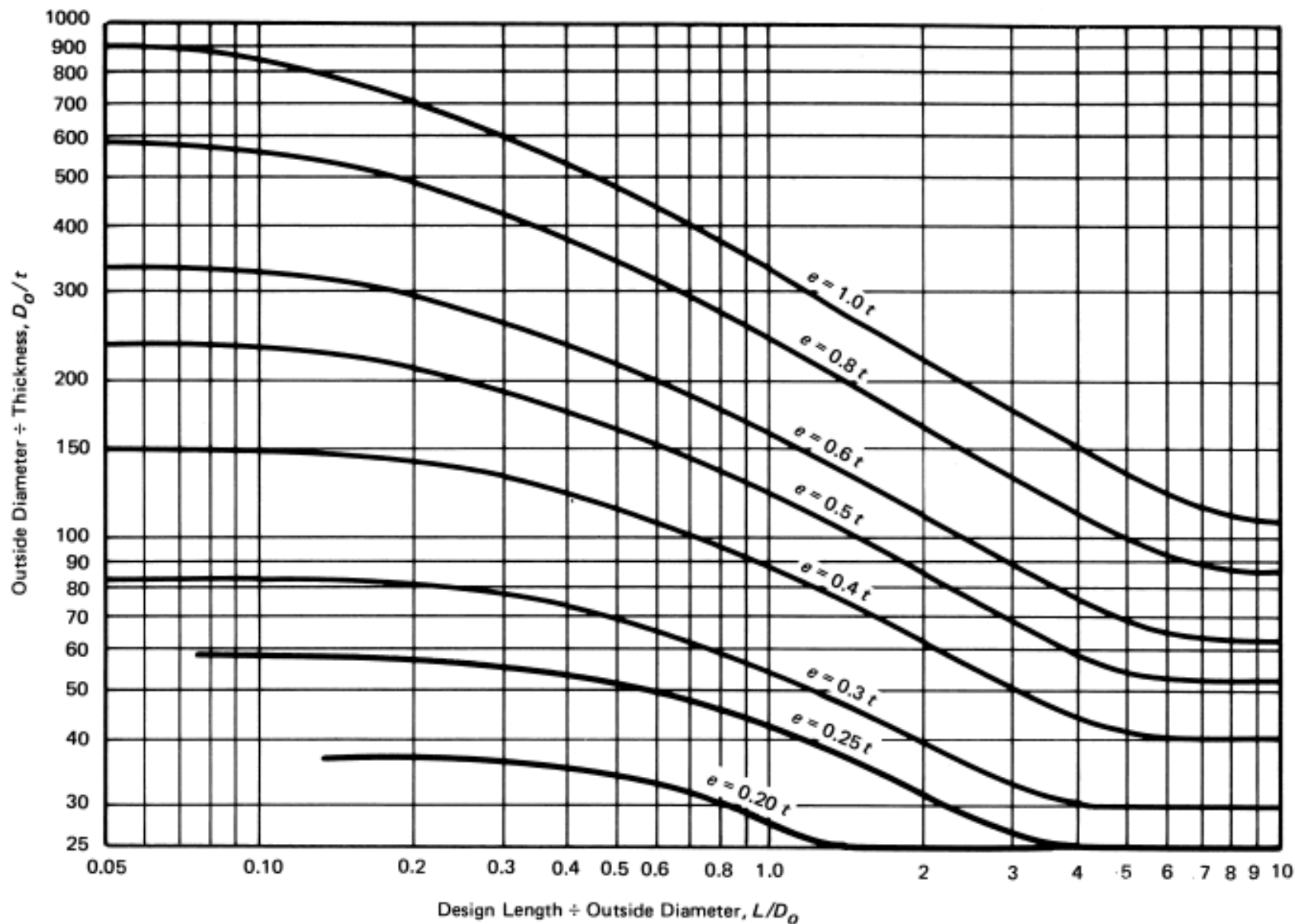
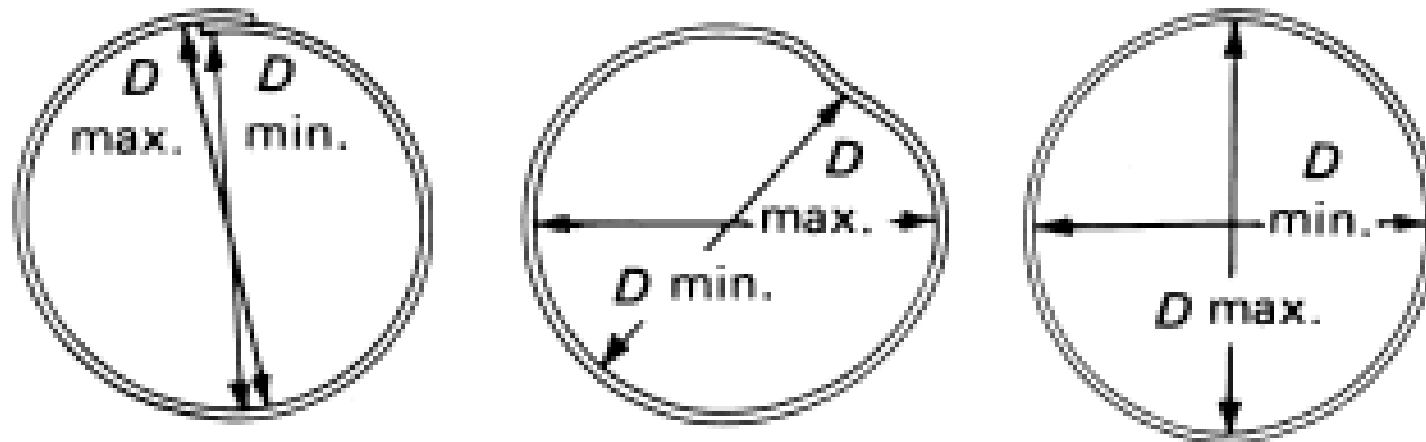


Figure UG-80.1

Maximum Permissible Deviation From a Circular Form  $e$  for Vessels Under External Pressure



**Figure UG-80.2**  
**Example of Differences Between Maximum and Minimum Inside Diameters in Cylindrical, Conical, and Spherical Shells**



## UG-81 TOLERANCE FOR FORMED HEADS

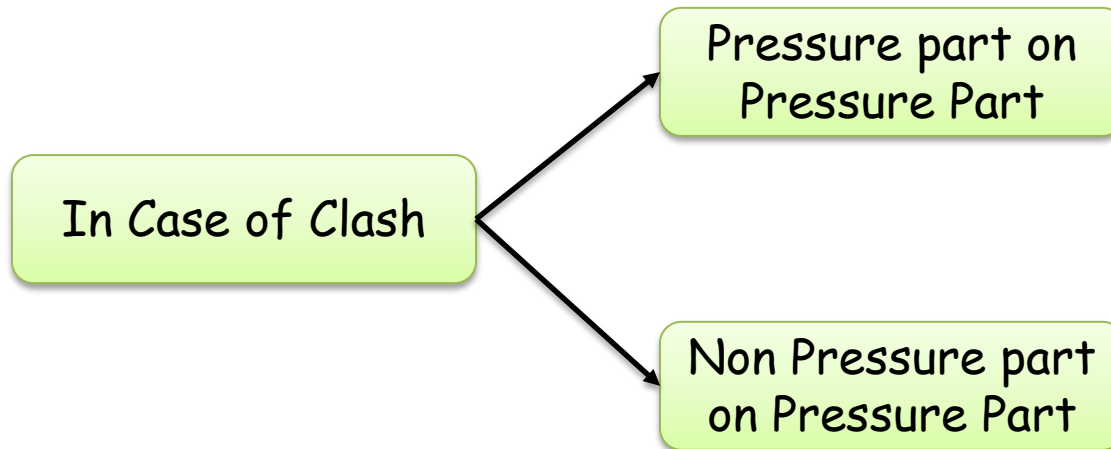
- (a) The inner surface of a torispherical, toriconical, hemispherical, or ellipsoidal head shall not deviate outside of the specified shape by more than  $1\frac{1}{4}\%$  of  $D$  nor inside the specified shape by more than  $\frac{5}{8}\%$  of  $D$ , where  $D$  is the nominal inside diameter of the vessel shell at point of attachment. Such deviations shall be measured perpendicular to the specified shape and shall not be abrupt. The knuckle radius shall not be less than that specified.

## UG-81 TOLERANCE FOR FORMED HEADS

- (b) Hemispherical heads or any spherical portion of a torispherical or ellipsoidal head designed for external pressure shall, in addition to satisfying (a) above, meet the tolerances specified for spheres in UG-80(b) using a value of 0.5 for  $L/D_o$ .
- (d) The skirts of heads shall be sufficiently true to round so that the difference between the maximum and minimum inside diameters shall not exceed 1% of the nominal diameter.

## UG-82 Lugs and fitting attachments

- All lugs, brackets, saddle type nozzles, manhole frames, reinforcement around openings, and other appurtenances shall be formed and fitted to conform reasonably to the curvature of the shell or surface to which they are attached.



## UG-82 Lugs and fitting attachments

- (a) When pressure parts, such as saddle type nozzles, manhole frames, and reinforcement around openings, extend over pressure retaining welds, such welds shall be ground flush for the portion of the weld to be covered.
- (b) When nonpressure parts, such as lugs, brackets, and support legs and saddles, extend over pressure retaining welds, such welds shall be ground flush as described in a) above, or such parts shall be notched or coped to clear those welds.



Except when the longitudinal joints are radiographed 4 in. (100 mm) each side of each circumferential welded intersection, vessels made up of two or more courses shall have the centers of the welded longitudinal joints of adjacent courses staggered or separated by a distance of **at least five times the thickness of the thicker plate.**

- Except when the adjacent butt weld satisfies the requirement for radiography in (b) above, the edge of openings in solid plate meeting the requirements of UG-36(c)(3) shall not be placed closer than 1/2 in. (13 mm) from the edge of a Category A, B, or C weld for material 1 1/2 in. (38 mm) thick or less.

## INSPECTION AND TESTS

- Following paragraph has been explained general inspection and tests requirements:



UG-90 ~ UG-103

## OVERPRESSURE PROTECTION

- UG-125 General
- (a) Other than unfired steam boilers, all pressure vessels within the scope of this Division, irrespective of size or pressure, shall be provided with overpressure protection in accordance with the requirements of UG-125 through UG-138, or with overpressure protection by system design in accordance with the requirements of UG-140, or a combination of the two. Unfired steam boilers shall be provided with overpressure protection in accordance with the requirements of UG-125 through UG-138. In addition, the following shall apply:

## OVERPRESSURE PROTECTION

- (1) It is the user's or his/her designated agent's responsibility to identify all potential overpressure scenarios and the method of overpressure protection used to mitigate each scenario.
- (2) It is the responsibility of the user to ensure that the required overpressure protection system is properly installed prior to initial operation.
- (3) If a pressure relief device(s) is to be installed, it is the responsibility of the user or his/her designated agent to size and select the pressure relief device(s) based on its intended service. Intended service considerations shall include, but not necessarily be limited to, the following:
  - (-a) normal operating and upset conditions
  - (-b) fluids
  - (-c) fluid phases

## OVERPRESSURE PROTECTION

- (4) The overpressure protection system need not be supplied by the vessel Manufacturer.
- (5) Unless otherwise defined in this Division, the definitions relating to pressure relief devices in Section 2 of ASME PTC 25 shall apply.
- (b) An unfired steam boiler shall be equipped with pressure relief devices required by Section I insofar as they are applicable to the service of the particular installation.
- (c) Other than unfired steam boilers, when a pressure relief device is provided, it shall prevent the pressure from rising more than 10% or 3 psi (20 kPa), whichever

## OVERPRESSURE PROTECTION

### UG-125 General

- (a) Other than unfired steam boilers, all pressure vessels within the scope of this Division, **irrespective of size or pressure**, shall be provided with overpressure protection in accordance with the requirements of **UG-125 through UG-138**, or with **overpressure protection** by system design in accordance with the requirements of **UG-140**, or a combination of the two. In addition, the following shall apply:

## OVERPRESSURE PROTECTION

- (1) It is the **user's or his/her designated agent's responsibility** to identify all potential **overpressure scenarios** and the method of overpressure protection used to mitigate each scenario.
- (2) It is the **responsibility of the user** to ensure that the required overpressure protection system is properly installed **prior** to initial operation.
- (3) If a pressure relief device(s) is to be installed, it is the **responsibility of the user or his/her designated agent** to size and select the pressure relief device(s) based on its intended service. Intended service considerations shall include, but not necessarily be limited to, the following:
  - (-a) normal operating and upset conditions
  - (-b) fluids
  - (-c) fluid phases



## OVERPRESSURE PROTECTION

- (4) The overpressure protection system *need not be supplied by the vessel*

*Manufacturer.*

- Note: (c) Other than unfired steam boilers, when a pressure relief device is provided, it shall prevent the pressure from rising more than 10% or 3 psi (20 kPa), whichever is greater above the maximum allowable working pressure.

## OVERPRESSURE PROTECTION

- When a pressure vessel can be exposed to fire or other unexpected sources of external heat, the pressure relief device(s) shall be capable of preventing:
  - pressure from rising more than 21% above the maximum allowable working pressure.
  - Supplemental pressure relief devices shall be installed to protect against this source of excessive pressure

# REQUIREMENTS FOR PRESSURE VESSELS FABRICATED BY WELDING

**Lethal:**

By "lethal substances" are meant poisonous gases or liquids of such a nature that a very small amount of the gas or of the vapor of the liquid mixed or unmixed with air is dangerous to life when inhaled. For purposes of this Division, this class includes substances of this nature which are stored under pressure or may generate a pressure if stored in a closed vessel.

- Vessels in lethal service:

- shall be **fully radiographed**
- When fabricated of carbon or low alloy steel, such vessels shall be **postweld heat treated**

- POST WELD HEAT TREATMENT IS REQUIRED FOR BELOW THREE

CONDITION:

- THICKNESS REQUIREMENT
- SERVICE CONDITION
- MAINTANANCE REQUIREMNTS

**Table UCS-56-1**  
**Postweld Heat Treatment Requirements for Carbon and Low Alloy Steels — P-No. 1**

Material	Normal Holding Temperature, °F (°C), Minimum	Minimum Holding Time at Normal Temperature for Nominal Thickness [See UW-40(f)]		
		Up to 2 in. (50 mm)	Over 2 in. to 5 in. (50 mm to 125 mm)	Over 5 in. (125 mm)
P-No. 1 Gr. Nos. 1, 2, 3	1,100 (595)	1 hr/in. (25 mm), 15 min minimum	2 hr plus 15 min for each additional inch (25 mm) over 2 in. (50 mm)	2 hr plus 15 min for each additional inch (25 mm) over 2 in. (50 mm)
Gr. No. 4	NA	None	None	None

**GENERAL NOTES:**

- (a) When it is impractical to postweld heat treat at the temperature specified in this Table, it is permissible to carry out the postweld heat treatment at lower temperatures for longer periods of time in accordance with Table UCS-56.1.
- (b) Postweld heat treatment is mandatory under the following conditions:
- (1) for welded joints over 1½ in. (38 mm) nominal thickness;
  - (2) for welded joints over 1¼ in. (32 mm) nominal thickness through 1½ in. (38 mm) nominal thickness unless preheat is applied at a minimum temperature of 200°F (95°C) during welding. This preheat need not be applied to SA-841 Grades A and B, provided that the carbon content and carbon equivalent (CE) for the plate material, by heat analysis, do not exceed 0.14% and 0.40%, respectively, where

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

(3) for welded joints of all thicknesses if required by UW-2, except postweld heat treatment is not mandatory under the conditions specified below:

(a) for groove welds not over ½ in. (13 mm) size and fillet welds with a throat not over ½ in. (13 mm) that attach nozzle connections that have a finished inside diameter not greater than 2 in. (50 mm), provided the connections do not form ligaments

**Table UCS-56-2**  
**Postweld Heat Treatment Requirements for Carbon and Low Alloy Steels — P-No. 3**

Material	Normal Holding Temperature, °F (°C), Minimum	Minimum Holding Time at Normal Temperature for Nominal Thickness [See UW-40(f)]		
		Up to 2 in. (50 mm)	Over 2 in. to 5 in. (50 mm to 125 mm)	Over 5 in. (125 mm)
P-No. 3 Gr. Nos. 1, 2, 3	1,100 (595)	1 hr/in. (25 mm), 15 min minimum	2 hr plus 15 min for each additional inch (25 mm) over 2 in. (50 mm)	2 hr plus 15 min for each additional inch (25 mm) over 2 in. (50 mm)

**GENERAL NOTES:**

- (a) When it is impractical to postweld heat treat at the temperatures specified in this Table, it is permissible to carry out the postweld heat treatment at lower temperatures for longer periods of time in accordance with Table UCS-56.1.
- (b) Postweld heat treatment is mandatory on P-No. 3 Gr. No. 3 material in all thicknesses.
- (c) Except for the exemptions in General Note (d), postweld heat treatment is mandatory under the following conditions:
- (1) on P-No. 3 Gr. No. 1 and P-No. 3 Gr. No. 2 over  $\frac{5}{8}$  in. (16 mm) nominal thickness. For these materials, postweld heat treatment is mandatory on material up to and including  $\frac{5}{8}$  in. (16 mm) nominal thickness unless a welding procedure qualification described in UCS-56(a) has been made in equal or greater thickness than the production weld.
  - (2) on material in all thicknesses if required by UW-2.
- (d) For welding connections and attachments to pressure parts, postweld heat treatment is not mandatory under the conditions specified below:
- (1) for attaching to pressure parts that have a specified maximum carbon content of not more than 0.25% (SA material specification carbon content, except when further limited by the purchaser to a value within the specification limits) or nonpressure parts with groove welds not over  $\frac{1}{2}$  in. (13 mm) in size or fillet welds that have a throat thickness of  $\frac{1}{2}$  in. (13 mm) or less, provided preheat to a minimum temperature of 200°F (95°C) is applied;
  - (2) for circumferential butt welds in pipe or tube where the pipe or tube have both a nominal wall thickness of  $\frac{1}{2}$  in. (13 mm) or less and a specified maximum carbon content of not more than 0.25% (SA material specification carbon content, except when further limited by the purchaser to a value within the specification limits);
  - (3) for studs welded to pressure parts that have a specified maximum carbon content of not more than 0.25% (SA material speci-

**Table UCS-56-3  
Postweld Heat Treatment Requirements for Carbon and Low Alloy Steels — P-No. 4**

Material	Normal Holding Temperature, °F (°C), Minimum	Minimum Holding Time at Normal Temperature for Nominal Thickness [See UW-40(f)]		
		Up to 2 in. (50 mm)	Over 2 in. to 5 in. (50 mm to 125 mm)	Over 5 in. (125 mm)
P-No. 4 Gr. Nos. 1, 2	1,200 (650)	1 hr/in. (25 mm), 15 min minimum	1 hr/in. (25 mm)	5 hr plus 15 min for each additional inch (25 mm) over 5 in. (125 mm)

**GENERAL NOTES:**

- (a) Except for exemptions in General Note (b), postweld heat treatment is mandatory under the following conditions:
  - (1) on material of all thicknesses if required by UW-2;
  - (2) on all other P-No. 4 Gr. Nos. 1 and 2 materials.
- (b) Postweld heat treatment is not mandatory under the conditions specified below:
  - (1) for circumferential butt welds in pipe or tube of P-No. 4 materials where the pipe or tubes comply with all of the following conditions:
    - (a) a maximum nominal thickness of  $\frac{5}{8}$  in. (16 mm);
    - (b) a maximum specified carbon content of not more than 0.15% (SA material specification carbon content, except when further limited by the purchaser to a value within the specification limits);
    - (c) a minimum preheat of 250°F (120°C).
  - (2) for P-No. 4 pipe or tube materials meeting the requirements of (1)(a) and (1)(b) above, having nonpressure attachments fillet welded to them provided:
    - (a) the fillet welds have a maximum throat thickness of  $\frac{1}{2}$  in. (13 mm);
    - (b) a minimum preheat temperature of 250°F (120°C) is applied.
  - (3) for P-No. 4 pipe or tube materials meeting the requirements of (1)(a) and (1)(b) above, having studs welded to them, a minimum preheat temperature of 250°F (120°C) is applied.
  - (4) for P-No. 4 pipe or tube materials meeting the requirements of (1)(a) and (1)(b) above, having extended heat absorbing fins electrically resistance-welded to them provided:



**Table UHA-32-1  
Postweld Heat Treatment Requirements for High Alloy Steels — P-No. 6**

Material	Normal Holding Temperature, °F (°C), Minimum	Minimum Holding Time at Normal Temperature for Nominal Thickness [See UHA-32(d)]		
		Up to 2 in. (50 mm)	Over 2 in. to 5 in. (50 mm to 125 mm)	Over 5 in. (125 mm)
P-No. 6 Gr. Nos. 1, 2, 3	1,400 (760)	1 hr/in. (25 mm), 15 min minimum	2 hr plus 15 min for each additional inch (25 mm) over 2 in. (50 mm)	2 hr plus 15 min for each additional inch (25 mm) over 2 in. (50 mm)

**GENERAL NOTES:**

- (a) Postweld heat treatment is not required for vessels constructed of Type 410 material for SA-182 Grade F6a, SA-240, SA-268, and SA-479 with carbon content not to exceed 0.08% and welded with electrodes that produce an austenitic chromium–nickel weld deposit or a non-air-hardening nickel–chromium–iron weld deposit, provided the nominal thickness does not exceed  $\frac{3}{8}$  in. (10 mm), and for nominal thicknesses over  $\frac{3}{8}$  in. (10 mm) to  $1\frac{1}{2}$  in. (38 mm) provided a preheat of 450°F (230°C) is maintained during welding and that the joints are completely radiographed.
- (b) Postweld heat treatment shall be performed as prescribed in UW-40 and UCS-56(e).

**Table UHA-32-2**  
**Postweld Heat Treatment Requirements for High Alloy Steels — P-No. 7**

Material	Normal Holding Temperature, °F (°C), Minimum	Minimum Holding Time at Normal Temperature for Nominal Thickness [See UHA-32(d)]		
		Up to 2 in. (50 mm)	Over 2 in. to 5 in. (50 mm to 125 mm)	Over 5 in. (125 mm)
P-No. 7 Gr. Nos. 1, 2	1,350 (730)	1 hr/in. (25 mm), 15 min minimum	2 hr plus 15 min for each additional inch (25 mm) over 2 in. (50 mm)	2 hr plus 15 min for each additional inch (25 mm) over 2 in. (50 mm)

**GENERAL NOTES:**

- (a) Postweld heat treatment is not required for vessels constructed of SA-1010 UNS S41003 Type 405, Type 410S, or Type 430 Ti materials for SA-240 and SA-268 with carbon content not to exceed 0.08%, welded with electrodes that produce an austenitic-chromium-nickel weld deposit or a non-air-hardening nickel-chromium-iron weld deposit, provided the nominal thickness does not exceed  $\frac{3}{8}$  in. (10 mm) and for thicknesses over  $\frac{3}{8}$  in. (10 mm) to  $1\frac{1}{2}$  in. (38 mm) provided a preheat of 450°F (230°C) is maintained during welding and that the joints are completely radiographed.
- (b) Postweld heat treatment shall be performed as prescribed in UW-40 and UCS-56(e) except that the cooling rate shall be a maximum of 100°F/hr (56°C/h) in the range above 1,200°F (650°C) after which the cooling rate shall be sufficiently rapid to prevent embrittlement.
- (c) Postweld heat treatment is not required for vessels constructed of Grade TP XM-8 material for SA-268 and SA-479 or of Grade TP 18Cr-2Mo for SA-240 and SA-268.

## MANDATORY APPENDIX 1 (Supplementary Design Formulas)

- Thickness Of Different Parts as per Appendix 1:
- Following formulas could be used instead of UG-27 to obtain cylindrical and spherical shells :

For cylindrical shells

$$t = \frac{PR_o}{SE + 0.4P} \quad \text{or} \quad P = \frac{SEt}{R_o - 0.4t}$$

For spherical shells

$$t = \frac{PR_o}{2SE + 0.8P} \quad \text{or} \quad P = \frac{2SEt}{R_o - 0.8t}$$

- Which,  $R_o$  is outside radius of the shell course under consideration

## MANDATORY APPENDIX 1 (Supplementary Design Formulas)

- **Circumferential Stress In Cylindrical Shells :** When the thickness of the cylindrical shell under internal design pressure exceeds one-half of the inside radius, or when  $P$  exceeds  $0.385SE$ , the following equations shall apply. The following equations may be used in lieu of those given in UG-27(c):

$$t = R \left( \exp \left[ \frac{P}{SE} \right] - 1 \right) = R_o \left( 1 - \exp \left[ \frac{-P}{SE} \right] \right)$$

## MANDATORY APPENDIX 1 (Supplementary Design Formulas)

- **Longitudinal Stress In Cylindrical Shells** : When the thickness of the cylindrical shell under internal design pressure exceeds one-half of the inside radius, or when  $P$  exceeds  $1.25SE$ , the following equations shall apply:

$$t = R \left( Z^{1/2} - 1 \right) = R_o \left( \frac{Z^{1/2} - 1}{Z^{1/2}} \right)$$

where

$$Z = \left( \frac{P}{SE} + 1 \right)$$

## MANDATORY APPENDIX 1 (Supplementary Design Formulas)

- **Spherical Shells** : When the thickness of the shell of a wholly spherical vessel or of a hemispherical head under internal design pressure exceeds  $0.356R$ , or when  $P$  exceeds  $0.665SE$ , the following equations shall apply. The following equations may be used in lieu of those given in UG-27(d).

$$t = R \left( \exp \left[ \frac{0.50 \cdot P}{SE} \right] - 1 \right) = R_o \left( 1 - \exp \left[ \frac{-0.50 \cdot P}{SE} \right] \right)$$

## MANDATORY APPENDIX 1 (Supplementary Design Formulas)

- **Formed head:** The equations of this paragraph provide for the design of formed heads of proportions other than those given in UG-32, in terms of inside and outside diameter. The equations in (c) and (d) given below shall be used for  $t/L \geq 0.002$ .

- (c) Ellipsoidal Heads

$$t = \frac{PDK}{2SE - 0.2P} \text{ or } P = \frac{2SEt}{KD + 0.2t} \quad (1)$$

$$t = \frac{PD_oK}{2SE + 2P(K - 0.1)}$$

or

$$P = \frac{2SEt}{KD_o - 2t(K - 0.1)} \quad (2)$$

where

$$K = \frac{1}{6} \left[ 2 + \left( \frac{D}{2h} \right)^2 \right]$$

## MANDATORY APPENDIX 1 (Supplementary Design Formulas)

- Numerical values of the factor  $K$  are given in Table 1-4.1.

**Table 1-4.1**  
**Values of Factor  $K$**

$D/2h$	3.0	2.9	2.8	2.7	2.6	2.5	2.4	2.3	2.2	2.1	2.0
$K$	1.83	1.73	1.64	1.55	1.46	1.37	1.29	1.21	1.14	1.07	1.00
$D/2h$	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1.0	...
$K$	0.93	0.87	0.81	0.76	0.71	0.66	0.61	0.57	0.53	0.50	...

GENERAL NOTE: Use nearest value of  $D/2h$ ; interpolation unnecessary.



## MANDATORY APPENDIX 1 (Supplementary Design Formulas)

- (d) Torispherical Heads

$$t = \frac{PLM}{2SE - 0.2P} \text{ or } P = \frac{2SEt}{LM + 0.2t}$$

$$t = \frac{PL_oM}{2SE + P(M - 0.2)}$$

or

$$P = \frac{2SEt}{ML_o - t(M - 0.2)}$$

where

$$M = \frac{1}{4} \left( 3 + \sqrt{\frac{L}{r}} \right)$$

## MANDATORY APPENDIX 1 (Supplementary Design Formulas)

- Numerical values of the factor  $M$  are given in Table 1-4.2.

**Table 1-4.2**  
**Values of Factor  $M$**

<i>L/r</i>	1.0	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50
<i>M</i>	1.00	1.03	1.06	1.08	1.10	1.13	1.15	1.17	1.18	1.20	1.22
<i>L/r</i>	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0
<i>M</i>	1.25	1.28	1.31	1.34	1.36	1.39	1.41	1.44	1.46	1.48	1.50
<i>L/r</i>	9.5	10.00	10.5	11.0	11.5	12.0	13.0	14.0	15.0	16.0	16 <sup>2/3</sup> [Note (1)]
<i>M</i>	1.52	1.54	1.56	1.58	1.60	1.62	1.65	1.69	1.72	1.75	1.77

GENERAL NOTE: Use nearest value of  $L/r$ ; interpolation unnecessary.

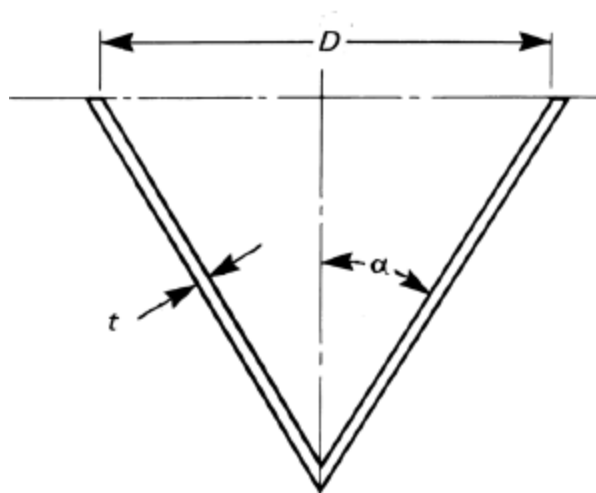
NOTE:

(1) Maximum ratio allowed by UG-32(i) when  $L$  equals the outside diameter of the skirt of the head.

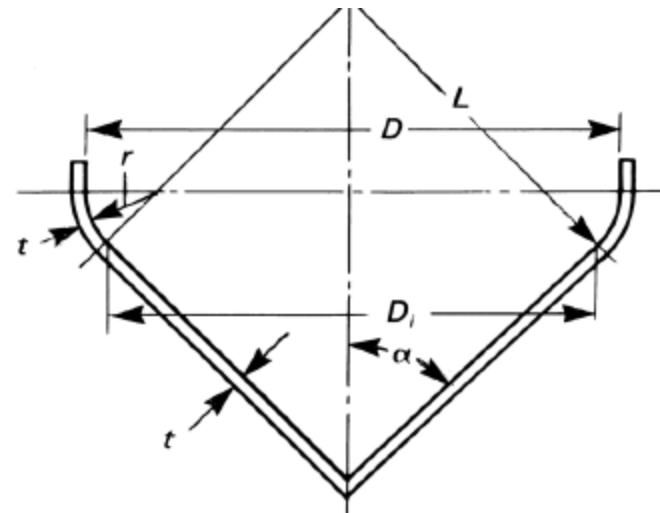
## MANDATORY APPENDIX 1 (Supplementary Design Formulas)

### 1-5 Rules for conical reducer sections and conical heads under internal pressure

(a) The below equations provide for the design of reinforcement, *if needed*, at the large and small ends for conical reducer sections and conical heads where all the elements have a common axis and the half-apex angle  $\alpha \leq 30$  deg.

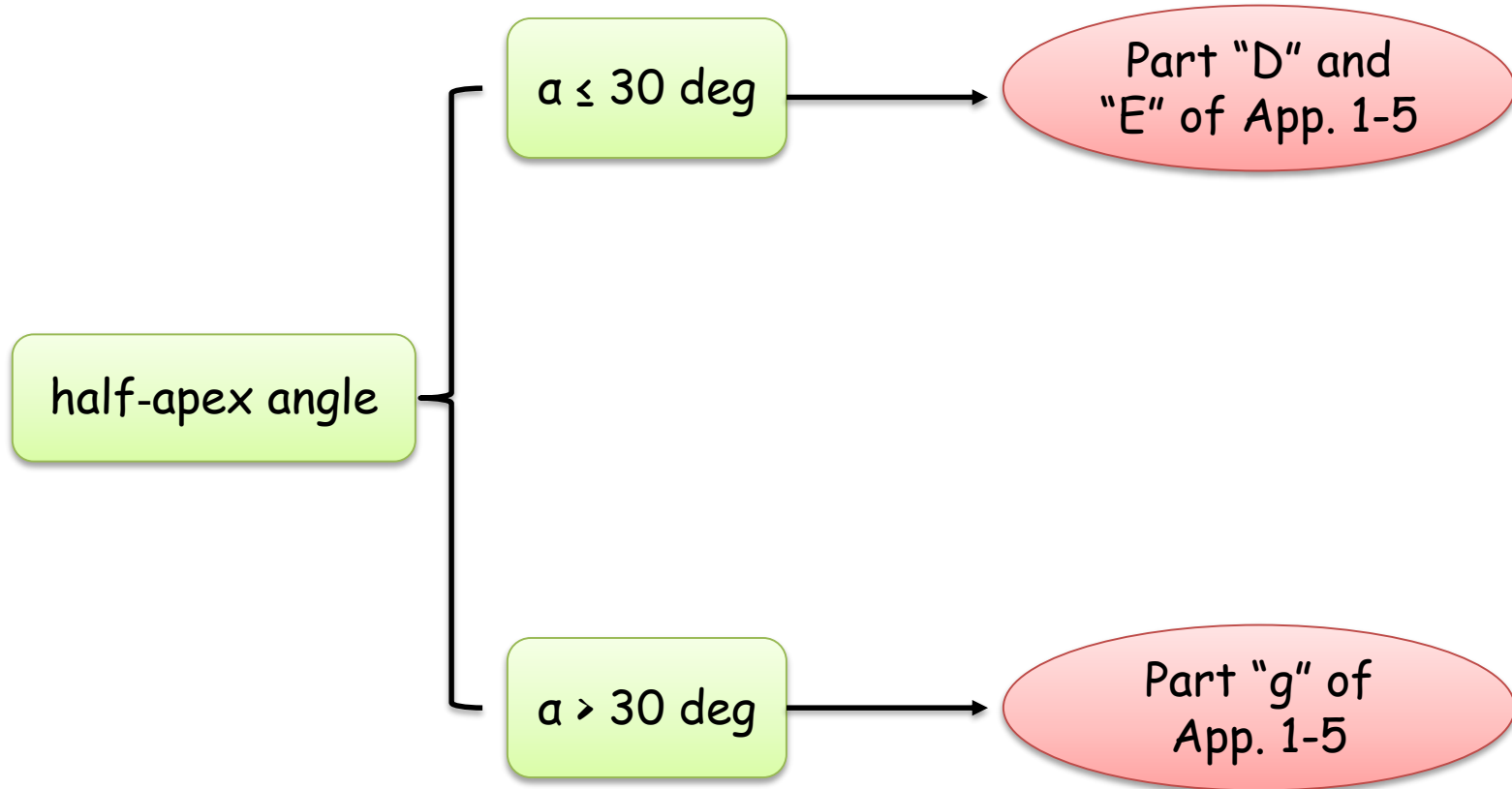


(d) Conical



(e) Toriconical  
(Cone Head With Knuckle)

## MANDATORY APPENDIX 1 (Supplementary Design Formulas)



In the design of reinforcement at the large and small ends of cones and conical reducers, the requirements of UG-41 shall be met.

## UG-41 (STRENGTH OF REINFORCEMENT)

- (a) Material used for reinforcement **shall** have an allowable stress value **equal** to or **greater** than that of the material in the **vessel wall**.

- IF SUCH MATERIAL IS NOT AVAILABLE ?!



- Lower strength material may be used, provided the area of reinforcement is increased in inverse proportion to the ratio of the allowable stress values of the two materials to compensate for the lower allowable stress value of the reinforcement.

## UG-41 (STRENGTH OF REINFORCEMENT)

- No credit may be taken for the additional strength of any reinforcement having a higher allowable stress value than that of the vessel wall.
- weld metal outside of either the vessel wall or any reinforcing pad used as reinforcement shall be credited with an allowable stress value equivalent to the weaker of the materials connected by the weld.

## MANDATORY APPENDIX 1 (Supplementary Design Formulas)

- (c) For reinforcement of conical reducers and conical heads, at both large and small end the following values shall be determined:

(1) When a cylinder having a minimum length of  $2.0\sqrt{R_L t_s}$  is attached to the large end of the cone, determine  $P/S_s E_1$  and then determine  $\Delta$  at the large end from Table 1-5.1.

NOTE: If a cylinder is not present or does not meet the minimum length requirement,  $\Delta$  is not calculated.

(2) When a cylinder having a minimum length of  $1.4\sqrt{R_s t_s}$  is attached to the small end of the cone, determine  $P/S_s E_1$  and then determine  $\Delta$  at the small end from Table 1-5.2.

(3) Determine  $k$ :

**Table 1-5.1**  
**Values of  $\Delta$  for Junctions at the Large**  
**Cylinder for  $\alpha \leq 30$  deg**

$P/S_s E_1$	0.001	0.002	0.003	0.004	0.005
$\Delta$ , deg	11	15	18	21	23
$P/S_s E_1$	0.006	0.007	0.008	0.009 [Note (1)]	...
$\Delta$ , deg	25	27	28.5	30	...

NOTE:

(1)  $\Delta = 30$  deg for greater values of  $P/S_s E_1$ .



**Table 1-5.2**  
**Values of  $\Delta$  for Junctions at the Small**  
**Cylinder for  $\alpha \leq 30$  deg**

$P/S_s E_1$	0.002	0.005	0.010	0.02
$\Delta$ , deg	4	6	9	12.5
$P/S_s E_1$	0.04	0.08	0.10	0.125 [Note (1)]
$\Delta$ , deg	17.5	24	27	30

NOTE:

(1)  $\Delta = 30$  deg for greater values of  $P/S_s E_1$ .

## MANDATORY APPENDIX 1 (Supplementary Design Formulas)

$$k = \begin{cases} 1 & \text{when additional area of reinforcement is not required} \\ y/S_r E_r & \text{when a stiffening ring is required, but } k \text{ is not less than } 1.0 \end{cases}$$

- Reinforcement shall be provided at the large end of the cone when  $Q_L$  is in tension:

$$A_{rL} = \frac{k Q_L R_L}{S_s E_1} \left( 1 - \frac{\Delta}{\alpha} \right) \tan \alpha$$

- Reinforcement shall be provided at the small end of the cone when  $Q_L$  is in tension:

$$A_{rS} = \frac{k Q_S R_S}{S_s E_1} \left( 1 - \frac{\Delta}{\alpha} \right) \tan \alpha$$

- The effective area of reinforcement can be determined in accordance with the following formula:

$$A_{eL} = (t_s - t) \sqrt{R_L t_s} + (t_c - t_r) \sqrt{R_L t_c / \cos \alpha}$$

Any additional area of reinforcement that is required shall be situated within a distance of  $\sqrt{R_L t_s}$  from the junction of the reducer and the cylinder. The centroid of the added area shall be within a distance of  $0.25 \times \sqrt{R_L t_s}$  from the junction.

- The effective area of reinforcement can be determined in accordance with the following formula:

$$A_{es} = 0.78\sqrt{R_s t_s} \left[ (t_s - t) + (t_c - t_r) / \cos \alpha \right]$$

Any additional area of reinforcement which is required shall be situated within a distance of  $\sqrt{R_s t_s}$  from the junction, and the centroid of the added area shall be within a distance of  $0.25\sqrt{R_s t_s}$  from the junction.

## MANDATORY APPENDIX 9 (JACKETED VESSELS)

- The rules in Mandatory Appendix 9 cover minimum requirements for the design, fabrication, and inspection of the jacketed portion of a pressure vessel.
- **What is a jacketed portion in a pressure vessel?**
- The jacketed portion of the vessel is defined as the inner and outer walls, the closure devices, and all other penetrations or parts within the jacket which are subjected to pressure stresses. Parts such as nozzle closure members and stiffening or stay rings are included.

### SCOPE

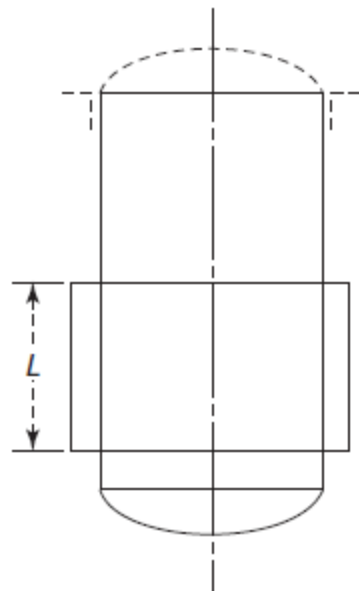
- 1) Where the internal design pressure is 15 psi (100 kPa) or less, and any combination of pressures and vacuum in the vessel and jacket will produce a total external pressure greater than 15 psi (100 kPa) on the inner vessel wall, then the entire jacket shall be interpreted as within the scope of this part.
- 2) Half-pipe jackets are not within the scope of this Appendix.
- 3) As stated in U-2(g), this Division does not contain rules to cover all details of design and construction. These rules are therefore established to cover most common jacket types, but are not intended to limit configurations to those illustrated or otherwise described herein.

### Why we use jackets?!

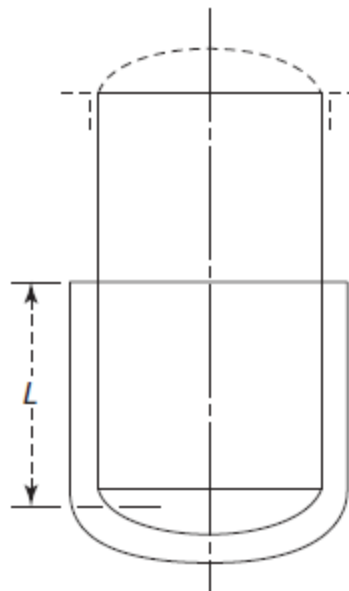
- (1) to heat the vessel and its contents;
- (2) to cool the vessel and its contents;
- (3) to provide a sealed insulation chamber for the vessel.

## TYPES OF JACKETED VESSELS

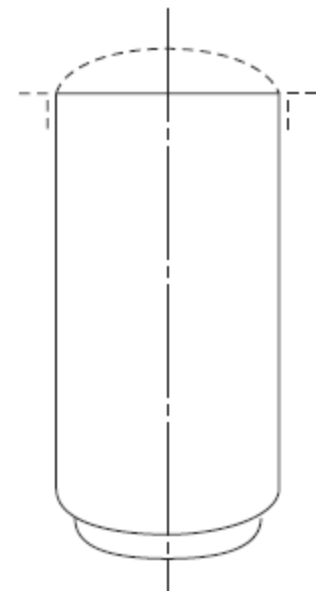
Figure 9-2  
Some Acceptable Types of Jacketed Vessels



Type 1 [Note (1)]



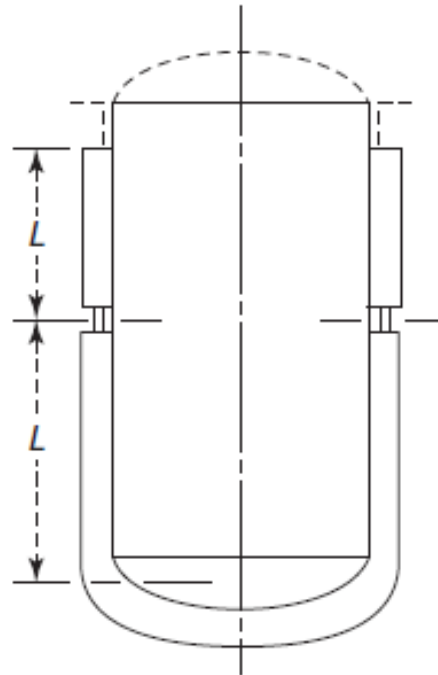
Type 2 [Note (2)]



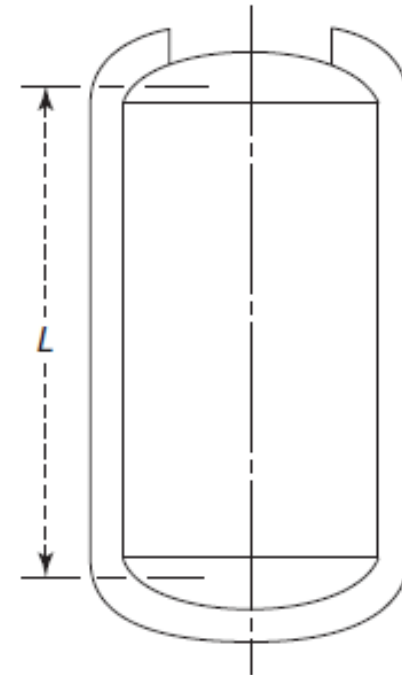
Type 3 [Note (3)]



## MANDATORY APPENDIX 9 (JACKETED VESSELS)



Type 4 [Note (4)]



Type 5 [Note (5)]

### NOTES:

- (1) Jacket of any length confined entirely to cylindrical shell.
- (2) Jacket covering a portion of cylindrical shell and one head.
- (3) Jacket covering a portion of head.
- (4) Jacket with addition of stay or equalizer rings to the cylindrical shell portion to reduce effective length.
- (5) Jacket covering cylindrical shell and any portion of either head.

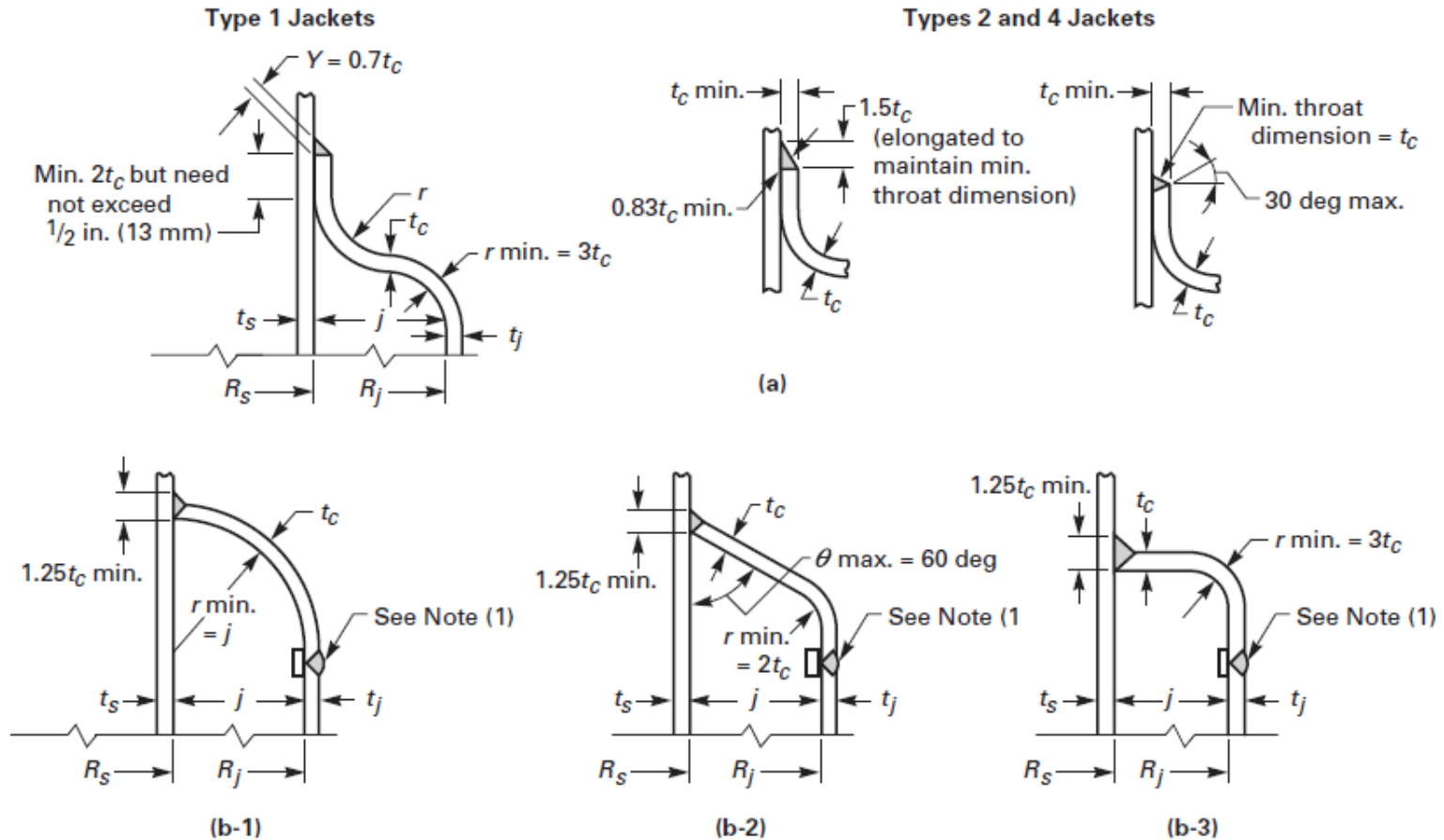
### DESIGN OF JACKET SHELLS AND JACKET HEADS

- Shell and head thickness shall be determined by the appropriate formula given in Subsection A. In consideration of the loadings given in UG-22, particular attention to the effects of local internal and external loads and expansion differentials at design temperatures shall be given.
- Where vessel supports are attached to the jacket, consideration shall be given to the transfer of the supported load of the inner vessel and contents.

# MANDATORY APPENDIX 9 (JACKETED VESSELS)

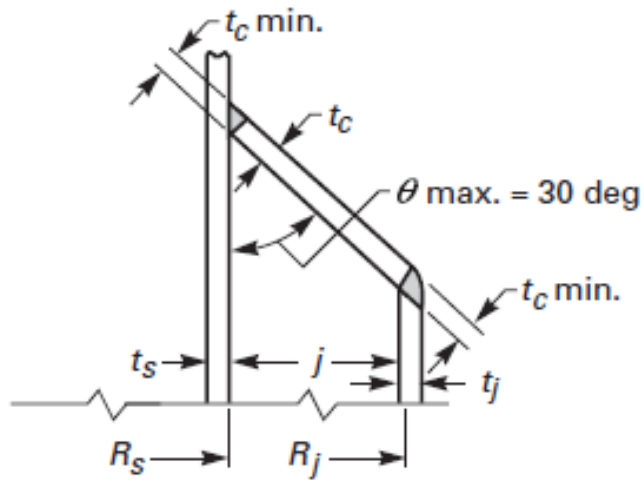
## CLOSURE MEMBER OF JACKET TO VESSEL

Figure 9-5  
Some Acceptable Types of Jacket Closures

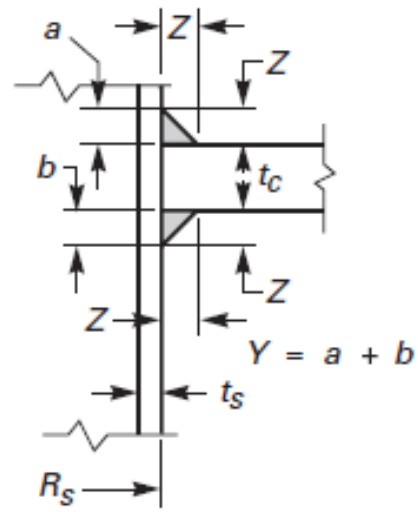


# MANDATORY APPENDIX 9 (JACKETED VESSELS)

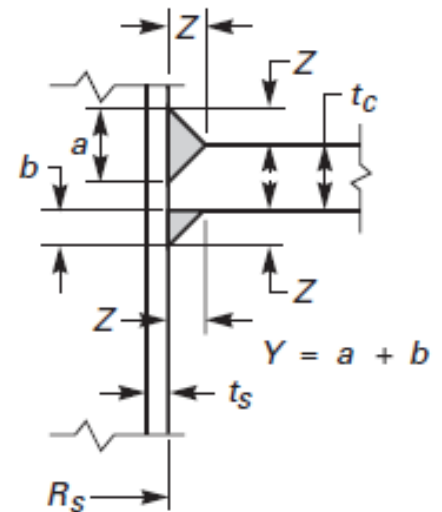
- CLOSURE MEMBER OF JACKET TO VESSEL



(c)



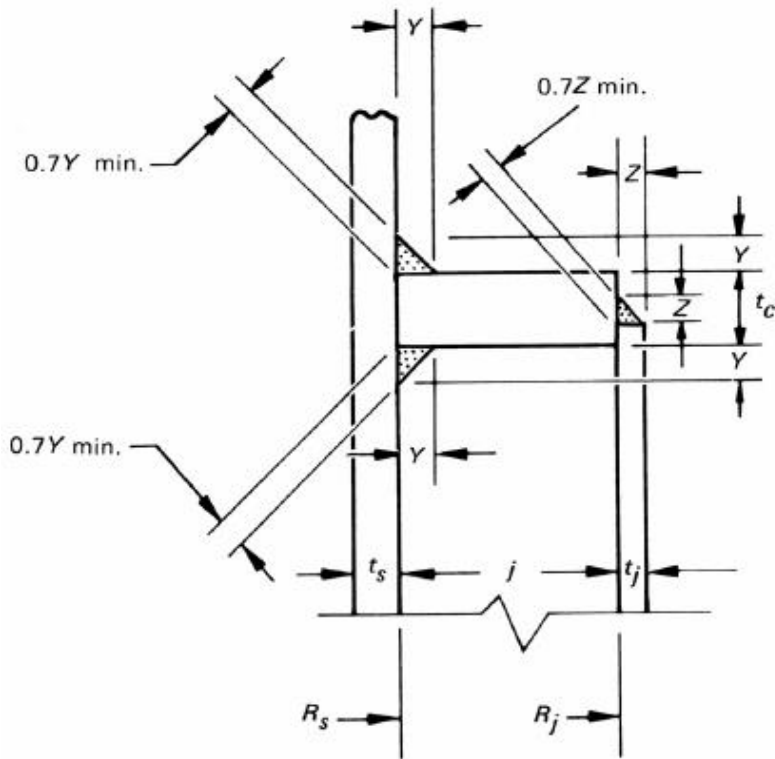
(f-1)



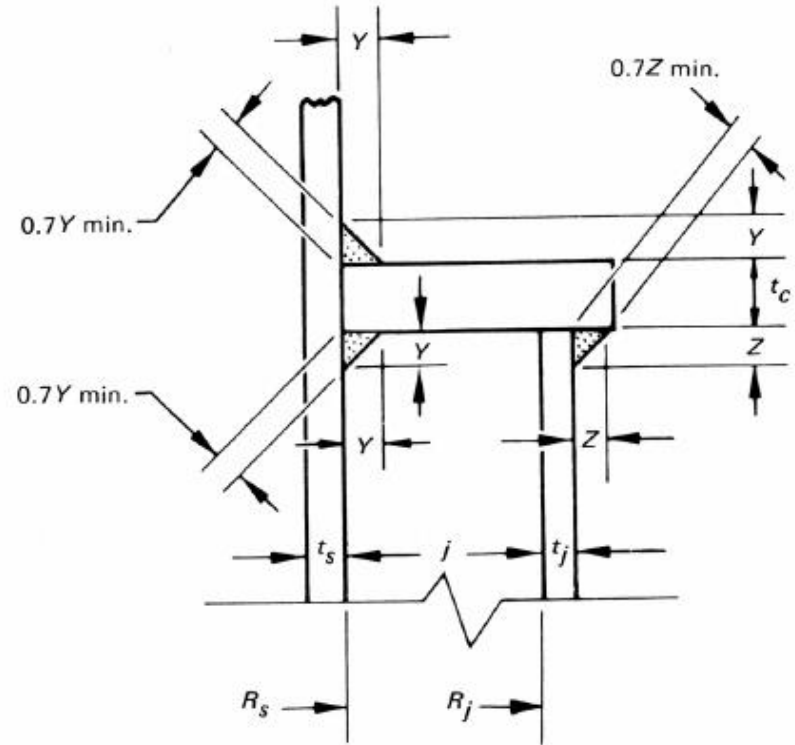
(f-2)

# MANDATORY APPENDIX 9 (JACKETED VESSELS)

## • CLOSURE MEMBER OF JACKET TO VESSEL



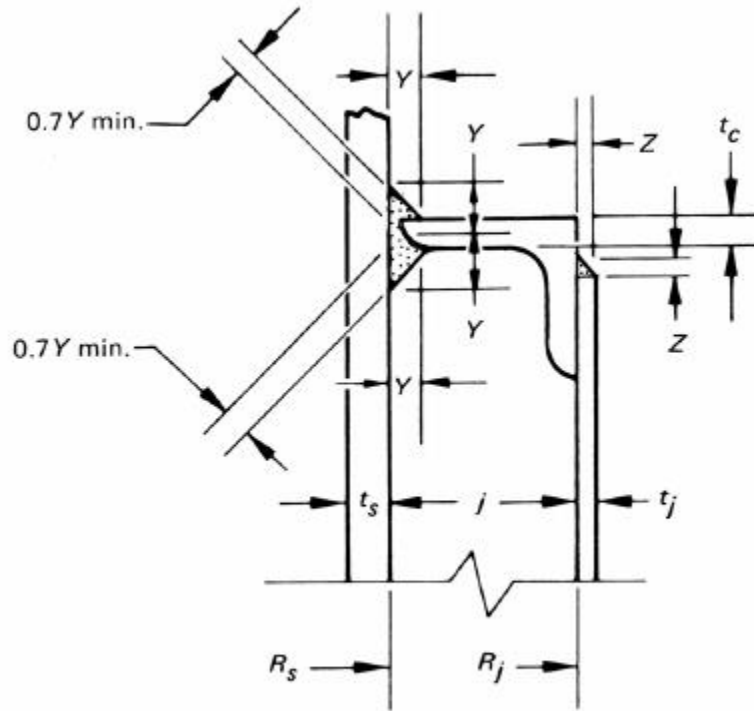
(d-1)



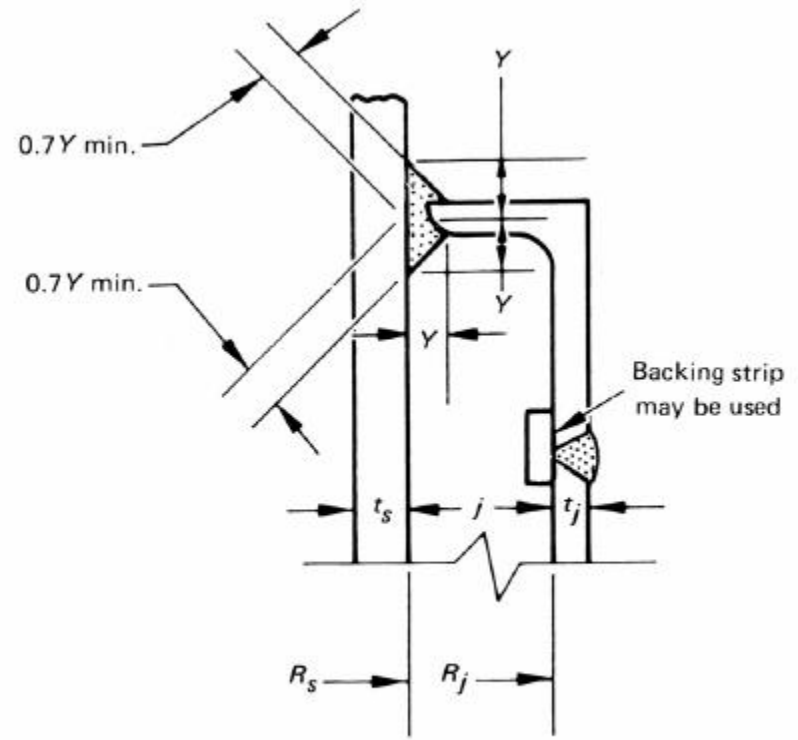
(d-2)

# MANDATORY APPENDIX 9 (JACKETED VESSELS)

- CLOSURE MEMBER OF JACKET TO VESSEL



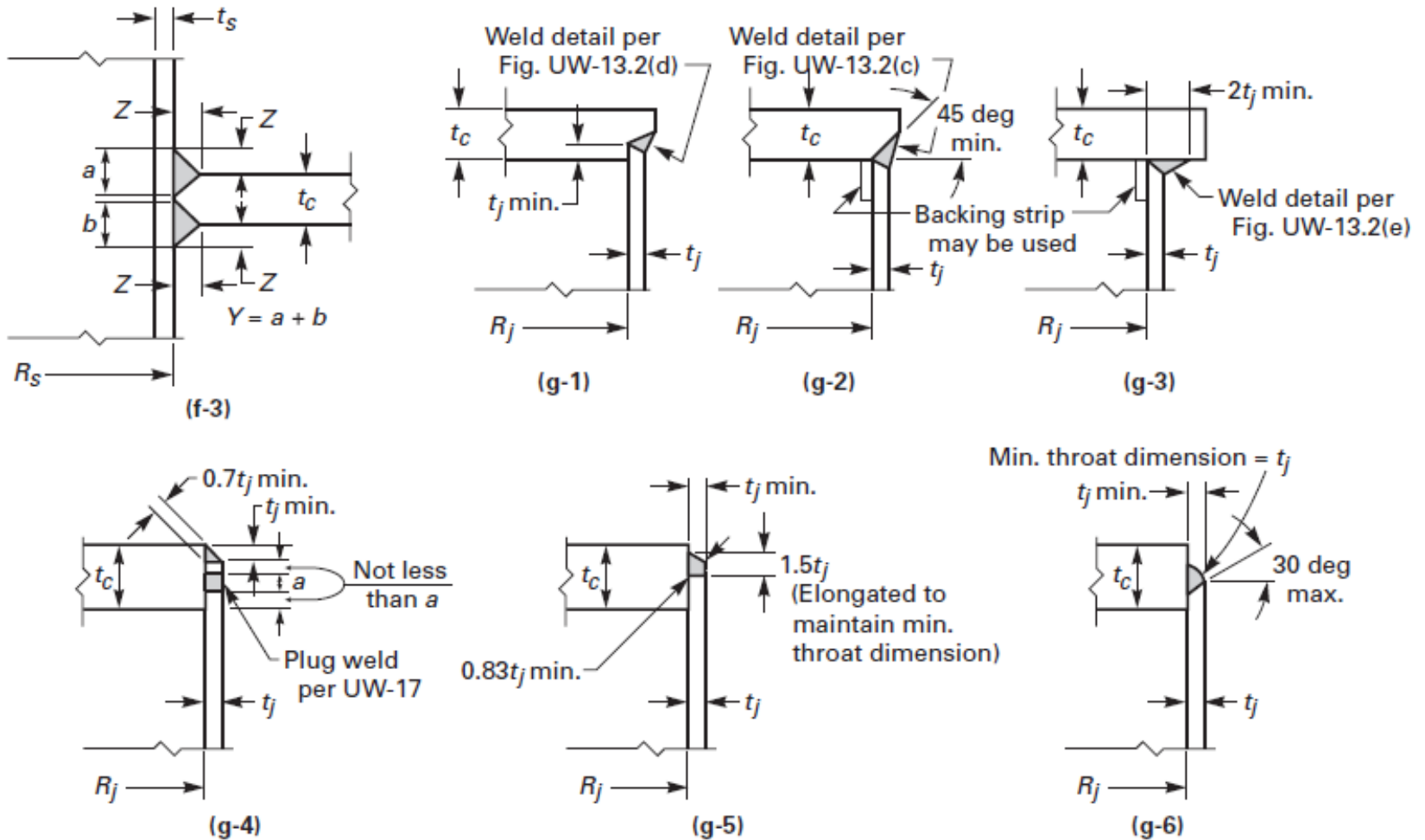
(e-1)



(e-2)

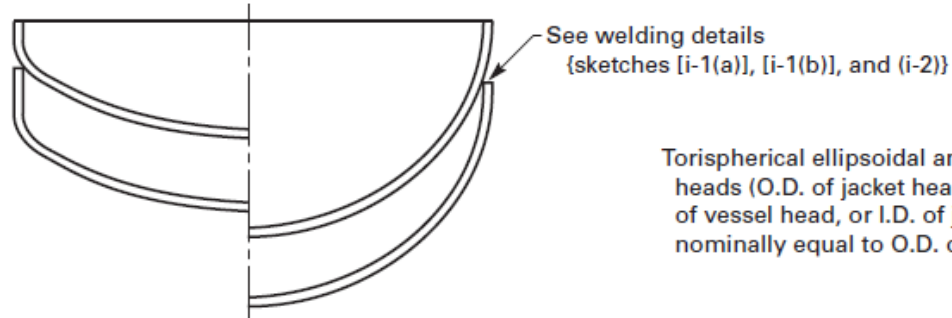
# MANDATORY APPENDIX 9 (JACKETED VESSELS)

## CLOSURE MEMBER OF JACKET TO VESSEL



# MANDATORY APPENDIX 9 (JACKETED VESSELS)

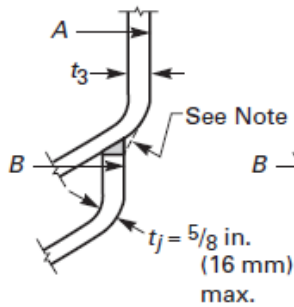
## CLOSURE MEMBER OF JACKET TO VESSEL



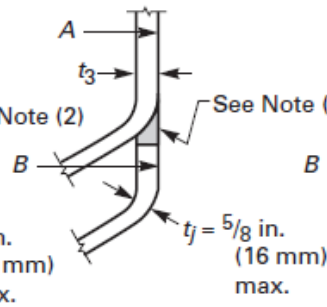
Torispherical ellipsoidal and hemispherical heads (O.D. of jacket head not greater than O.D. of vessel head, or I.D. of jacket head nominally equal to O.D. of vessel head)

(h)

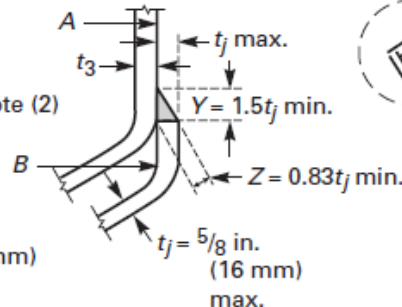
See details [sketches (f-1) to (f-3) and (g-1) to (g-6)]



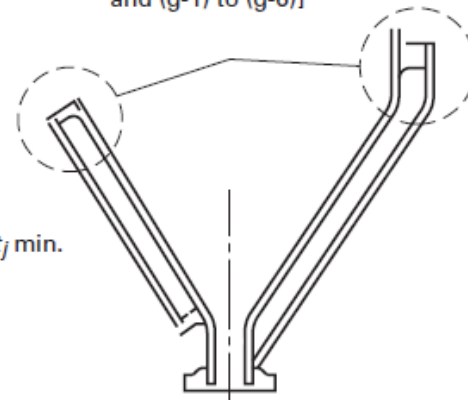
[i-1(a)]  
A > B



[i-1(b)]  
A = B



(i-2)  
A < B



Conical and Toriconical  
(k) (l)

### NOTES:

- (1) Closure and shell one-piece construction or full-penetration butt weld. Backing strip may be used.
- (2) Full-penetration weld.



## MANDATORY APPENDIX 9 (JACKETED VESSELS)

### • DESIGN OF CLOSURE MEMBER OF JACKET TO VESSEL

Sketch ID in Figure 9-5	Description
(b-1) & (b-2)	Minimum thickness is equal to required minimum thickness of outer jacket wall
(b-3)	minimum thickness of outer jacket wall and not be less than $t_{rc} = 0.707j\sqrt{P/S}$
(c)	1)shall be used only on Type 1 jacketed vessels shown in Figure 9-2. 2)The closure thickness $t_{rc}$ shall be determined by eq. UG-32(f)(4), but shall be not less than $t_{rj}$ . D6The angle $\theta$ shall be limited to 30 deg maximum
(d-1), (d-2), (e-1), and (e-2)	1)shall be used only on Type 1 jacketed vessels shown in Figure 9-2. 2)required minimum thickness of outer jacket wall does not exceed 16 mm 3)The required minimum thickness for the closure bar shall be the greater of the following: $t_{rc} = 1.414\sqrt{(PR_s j) / S}$ $j = \frac{2St_s^2}{PR_j} - 0.5(t_s + t_j)$

## MANDATORY APPENDIX 9 (JACKETED VESSELS)

### • DESIGN OF CLOSURE MEMBER OF JACKET TO VESSEL

Sketch ID in Figure 9-5	Description
(f-1), (f-2), and (f-3)	<p>1) may be used on any of the types of jacketed vessels shown in Figure 9-2.                      2) For Type 1 jacketed vessels, the required minimum closure bar thickness shall be determined from the below equations</p> $t_{rc} = 1.414 \sqrt{(PR_s j) / S}$ $j = \frac{2St_s^2}{PR_j} - 0.5(t_s + t_j)$ <p>For all other types of jacketed vessels, the required minimum closure bar thickness and the maximum allowable width of the jacket space shall be determined from the following formulas</p> $t_{rc} = 1.414 \sqrt{(PR_s j) / S}$ $j = \frac{2St_s^2}{PR_j} - 0.5(t_s + t_j)$

## MANDATORY APPENDIX 9 (JACKETED VESSELS)

### • DESIGN OF CLOSURE MEMBER OF JACKET TO VESSEL

Sketch ID in Figure 9-5	Description
(g-1), (g-2), and (g-3)	may be used on any of the types of jacketed vessels shown in Figure 9-2.
(g-4), (g-5), and (g-6)	may be used on any of the types of jacketed vessels shown in Figure 9-2 where $tr_j$ (required minimum thickness of outer jacket wall) does not exceed 16 mm.
(h)	may be used on Type 3 jacketed vessels shown in Figure 9-2 shall have attachment welds in accordance with Figure 9-5 sketch (i-1) or (i-2). This construction is limited to jackets where $tr_j$ (required minimum thickness of outer jacket wall) does not exceed 16 mm.
(k) and (l)	shall comply with the requirements for Type 2 jacketed vessels shown in Figure 9-2.