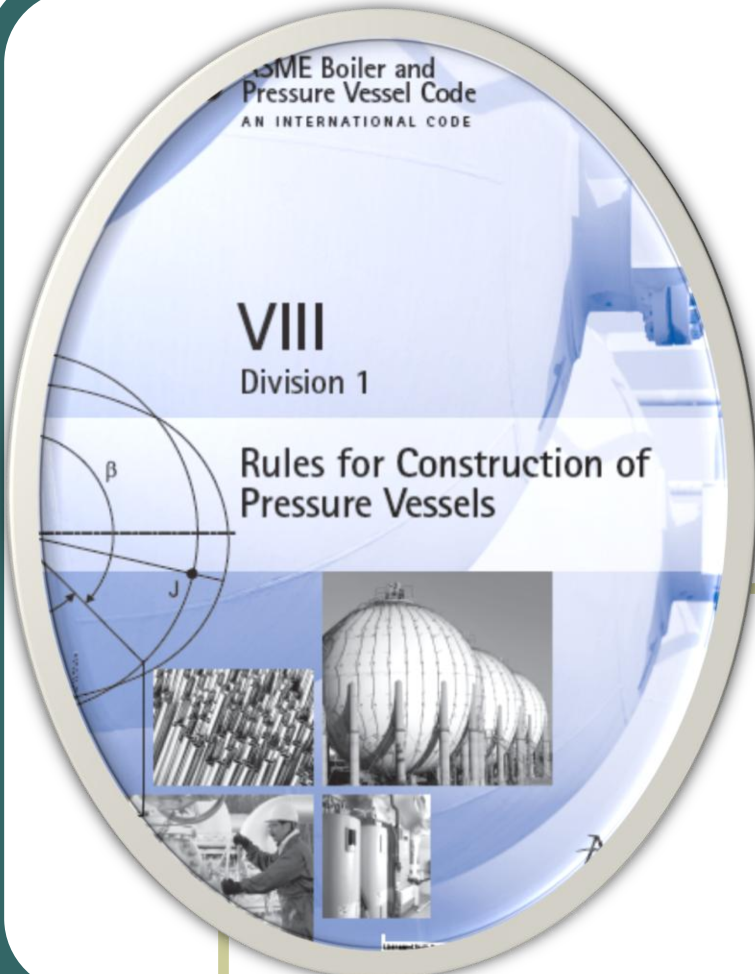
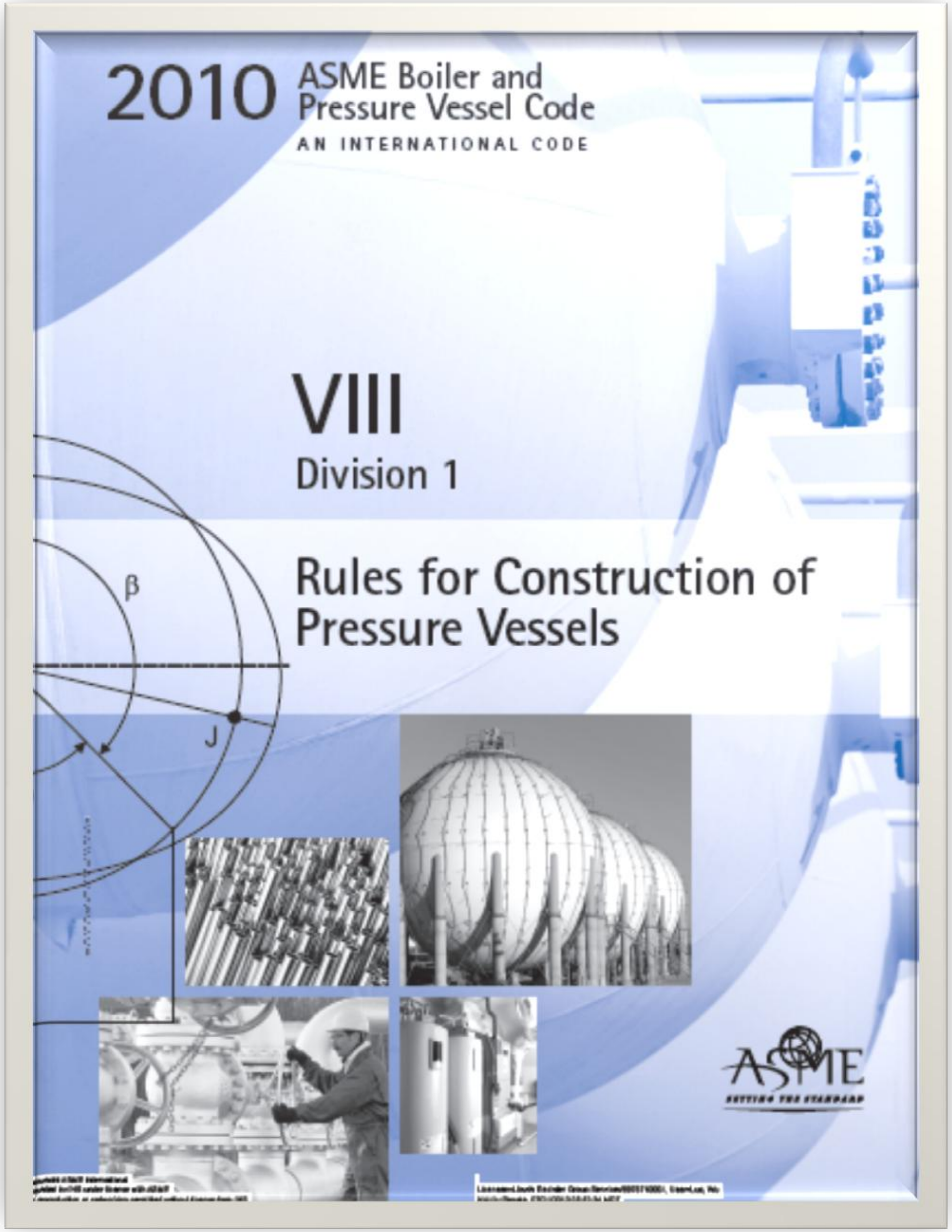


Pressure Vessel Design, fabrication and test

ASME section VIII, div. 1

Esmael Kaynejad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AN INTERNATIONAL CODE
VIII
Division 1
Rules for Construction of Pressure Vessels
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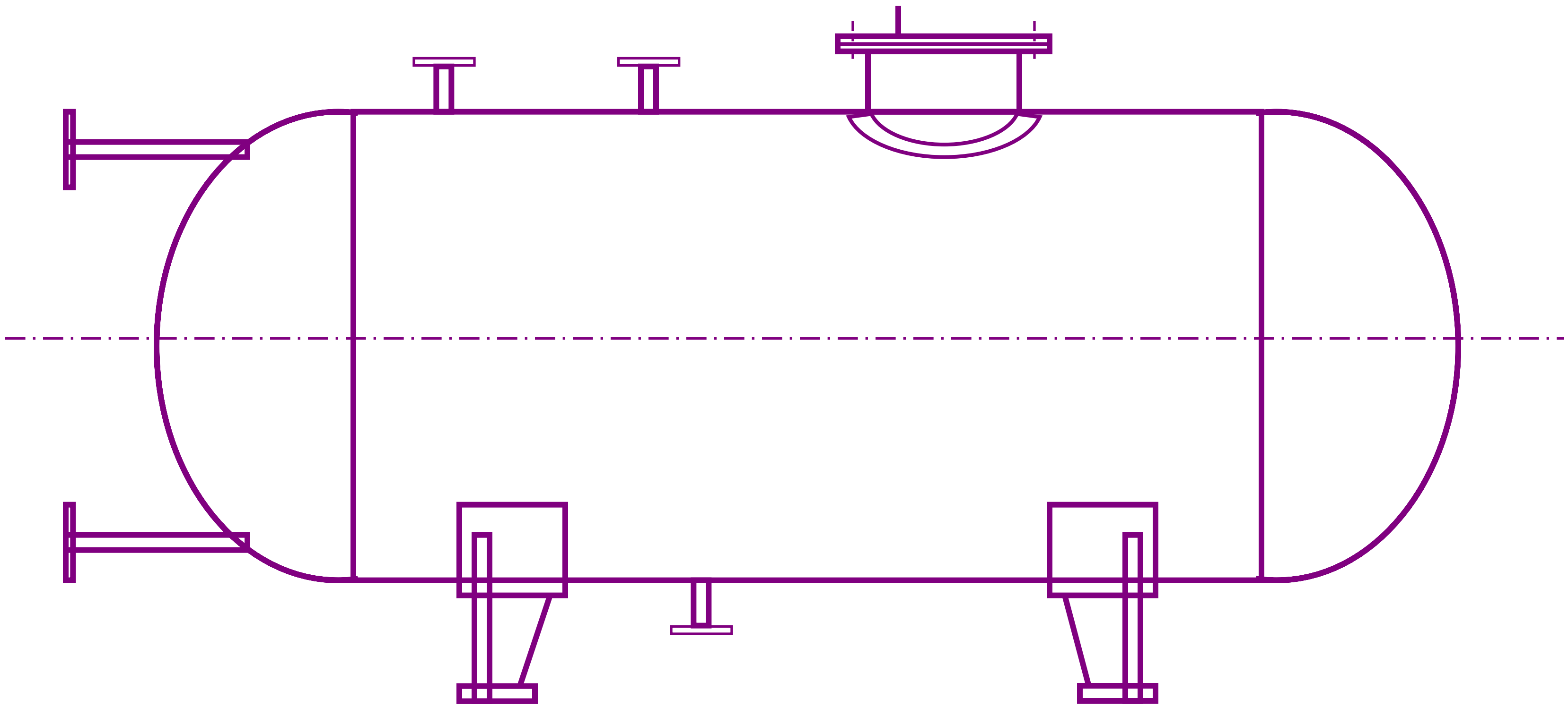
Structure of vessels:



ASME Section VIII Division 1
Content

- **Subsection A**

  General Requirements

- **Subsection B**

  Requirements Pertaining to Methods of Fabrication of Pressure Vessels

- **Subsection C**

  Requirements Pertaining to Classes of Materials

Subsection A
ASME VIII Div.1

General Requirements for All Methods of Construction and All Materials

Part UG

Scope
Materials
Design
Openings and Reinforcements
Braced and Stayed Surfaces
Ligaments
Fabrication
Inspection and Tests
Marking and Reports
Pressure Relief Devices

ASME Section VIII Div. 1 Part UG Materials

- **UG-1 scope**
- **UG-4 general**
- **UG-5 Plate**
- **UG-6 Forgings**
- **UG-7 Castings**
- **UG-8 Pipe and Tubes**
- **UG-9 Welding Materials**
- **UG-10 Material Identified With or Produced to a Specification Not Permitted by This Division, and Material Not Fully Identified**
- **UG-11 Prefabricated or Preformed Pressure Parts**
- **UG-12 Bolts and Studs**
- **UG-13 Nuts and Washers**
- **UG-14 Rods and Bars**
- **UG-15 Product Specification**

ASME Section VIII Div. 1 Part UG

Design

- UG-16 General
- UG- 17 Methods of Fabrication in Combination
- UG-18 Materials in Combination
- UG-19 Special Constructions
- UG-20 Design Temperature
- UG-21 Design Pressure
- UG-22 Loadings
- UG-23 Maximum Allowable Stress Values
- UG-24 Castings
- UG-25 Corrosion
- UG-26 Linings

ASME Section VIII Div. 1 Part UG Design(cont.)

- UG-27 Thickness of Shells Under Internal Pressure
- UG-28 Thickness of Shells and Tubes Under External Pressure
- UG-29 Stiffening Rings for Cylindrical Shells Under External Pressure
- UG-30 Attachment of Stiffening Rings
- UG-31 Tubes, and Pipe When Used as Tubes or Shells
- UG-32 Formed Heads, and Sections, Pressure on Concave Side
- UG-33 Formed Heads, Pressure on Convex Side
- UG-34 Unstayed Flat Heads and Covers
- UG-35 Other Types of Closures

UG-23 MAXIMUM ALLOWABLE STRESS VALUES

The maximum allowable stress value is the maximum unit stress permitted in a given material used in a vessel constructed under these rules. The maximum allowable tensile stress values permitted for different materials are given in Subpart 1 of Section II, Part D.

TABLE 1A
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 Designation/ UNS No.	Class/ Condition/ Temper	Size/Thickness, mm	P-No.	Group No.
1	Carbon steel	Sheet	SA-1008	CS-A	...	...	...	1	1
2	Carbon steel	Sheet	SA-1008	CS-B	...	...	...	1	1
3	Carbon steel	Bar	SA-675	45	...	...	...	1	1
4	Carbon steel	Wld. pipe	SA-134	A283A	...	...	...	1	1
5	Carbon steel	Plate	SA-283	A	...	...	...	1	1
6	Carbon steel	Plate	SA-285	A	K01700	...	...	1	1
7	Carbon steel	Wld. pipe	SA-672	A45	K01700	...	...	1	1
8	Carbon steel	Sheet	SA-414	A	K01501	...	...	1	1
9	Carbon steel	Wld. tube	SA-178	A	K01200	...	...	1	1
10	Carbon steel	Wld. tube	SA-178	A	K01200	...	...	1	1
11	Carbon steel	Smls. tube	SA-179	...	K01200	...	...	1	1
12	Carbon steel	Smls. tube	SA-192	...	K01201	...	...	1	1
13	Carbon steel	Wld. tube	SA-214	...	K01807	...	...	1	1
14	Carbon steel	Smls. tube	SA-556	A2	K01807	...	...	1	1
15	Carbon steel	Wld. tube	SA-557	A2	K01807	...	...	1	1
16	Carbon steel	Wld. pipe	SA-53	E/A	K02504	...	...	1	1

TABLE 1A
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.	Min. Tensile Strength, MPa	Min. Yield Strength, MPa	Applicability and Max. Temperature Limits (NP = Not Permitted) (SPT = Supports Only) I	III	VIII-1	XII	External Pressure Chart No.	Notes
1	275	140	NP	NP	343	NP	CS-6	...
2	275	140	NP	NP	343	NP	CS-6	...
3	310	155	NP	343 (Cl. 3 only)	482	343	CS-6	G10, G22, T10
4	310	165	NP	149 (Cl. 3 only)	NP	NP	CS-1	W12
5	310	165	NP	149 (Cl. 3 only)	343	343	CS-1	...
6	310	165	482	371	482	343	CS-1	G10, T2
7	310	165	NP	371	NP	NP	CS-1	S6, W10, W12
8	310	170	NP	NP	482	343	CS-1	G10, T2
9	325	180	538	NP	NP	NP	CS-1	G4, G10, S1, T2, W13
10	325	180	538	NP	538	343	CS-1	G3, G10, G24, S1, T2, W6
11	325	180	NP	NP	482	343	CS-1	G10, T2
12	325	180	538	NP	538	343	CS-1	G10, S1, T2
13	325	180	NP	NP	538	343	CS-1	G24, T2, W6
14	325	180	NP	NP	538	343	CS-1	G10, T2
15	325	180	NP	NP	538	343	CS-1	G24, T2, W6

TABLE 1A
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.	Maximum Allowable Stress, MPa (Multiply by 1000 to Obtain kPa), for Metal Temperature, °C, Not Exceeding														
	–30 to 40	65	100	125	150	200	250	300	325	350	375	400	425	450	475
1	78.6	78.6	78.6	78.6	78.6	78.6	76.0	71.6	69.6	67.8	...	...	...	...	...
2	78.6	78.6	78.6	78.6	78.6	78.6	76.0	71.6	69.6	67.8	...	...	...	...	...
3	88.9	88.9	88.9	88.9	88.9	88.4	85.0	80.7	78.4	75.8	73.5	71.5	*64.0*	*56.1*	*44.5*
4	88.9	88.9	88.9	88.9	88.9	...	...	...	...	...	...	...	...	...	...
5	88.9	88.9	88.9	88.9	88.9	88.9	88.9	86.3	83.8	81.4	...	...	...	...	...
6	88.9	88.9	88.9	88.9	88.9	88.9	88.9	86.3	83.8	81.4	78.8	*73.4*	*64.0*	*56.1*	*44.5*
7	88.9	88.9	88.9	88.9	88.9	88.9	88.9	86.3	83.8	81.4	78.8	...	...	...	...
8	88.9	88.9	88.9	88.9	88.9	88.9	88.9	88.5	87.5	84.8	81.2	*73.4*	*64.0*	*56.1*	*44.5*
9	92.4	92.4	92.4	92.4	92.4	92.4	92.4	91.9	90.7	87.8	84.3	*73.3*	*63.9*	*56.2*	*44.5*
10	78.6	78.6	78.6	78.6	78.6	78.6	78.6	78.1	77.1	74.7	71.4	*62.3*	*54.2*	*47.6*	*37.7*
11	92.4	92.4	92.4	92.4	92.4	92.4	92.4	91.9	90.7	87.8	84.3	*73.3*	*63.9*	*56.2*	*44.5*
12	92.4	92.4	92.4	92.4	92.4	92.4	92.4	91.9	90.7	87.8	84.3	*73.3*	*63.9*	*56.2*	*44.5*
13	78.6	78.6	78.6	78.6	78.6	78.6	78.6	78.1	77.1	74.7	71.4	*62.3*	*54.2*	*47.6*	*37.7*
14	92.4	92.4	92.4	92.4	92.4	92.4	92.4	91.9	90.7	87.8	84.3	*73.3*	*63.9*	*56.2*	*44.5*
15	78.6	78.6	78.6	78.6	78.6	78.6	78.6	78.1	77.1	74.7	71.4	*62.3*	*54.2*	*47.6*	*37.7*
16	80.7	80.7	80.7	80.7	80.7	80.7	80.7	80.7	80.7	79.8	71.6	*62.3*	*53.7*	*43.9*	*32.9*

Openings and Reinforcements

- UG-36 Openings in Pressure Vessels
- UG-37 Reinforcement Required for Openings in Shells and Formed Heads
- UG-38 Flued Openings in Shells and Formed Heads
- UG-39 Reinforcement Required for Openings in Flat Heads
- UG-40 Limits of Reinforcement
- UG-41 Strength of Reinforcement
- UG-42 Reinforcement of Multiple Openings
- UG-43 Methods of Attachment of Pipe and Nozzle Necks to Vessel Walls
- UG-44 Flanges and Pipe Fittings
- UG-45 Nozzle Neck Thickness
- UG-46 Inspection Openings

Braced and Stayed Surfaces

- UG-47 Braced and Stayed Surfaces
- UG-48 Staybolts
- UG-49 Location of Staybolts
- UG-50 Dimensions of Staybolts
- **Ligaments**
- UG-53 Ligaments
- UG-54 Supports
- UG-55 Lugs for Platforms, Ladders, and Other Attachments to Vessel Walls

ASME Section VIII Div. 1 Part UG

Fabrication

- **UG-75 General**
- **UG-76 Cutting Plates and Other Stock**
- **UG-77 Material Identification (See UG-85)**
- **UG-78 Repair of Defects in Materials**
- **UG-79 Forming Shell Sections and Heads**
- **UG-80 Permissible Out-of-Roundness of Cylindrical, Conical, and Spherical Shells**
- **UG-81 Tolerance for Formed Heads**
- **UG-82 Lugs and Fitting Attachments**
- **UG-83 Holes for Screw Stays**
- **UG-84 Charpy Impact Tests**
- **UG-85 Heat Treatment**

ASME Section VIII Div. 1 Part UG Inspection and Tests

- UG-90 General
- UG-91 The Inspector
- UG-92 Access for Inspector
- UG-93 Inspection of Materials
- UG-94 Marking on Materials
- UG-95 Examination of Surfaces During Fabrication
- UG-96 Dimensional Check of Component Parts
- UG-97 Inspection During Fabrication
- UG-98 Maximum Allowable Working Pressure
- UG-99 Standard Hydrostatic Test
- UG-100 Pneumatic Test (See UW-50)
- UG-101 Proof Tests to Establish Maximum Allowable Working Pressure
- UG-102 Test Gages
- UG-103 Nondestructive Testing

Standard's terminology

- Inspection, examination, and testing are activities carried out to ensure that system meet the minimum requirements of the standard or code and the engineering design.

- inspection and examination do not mean the same thing.

ASME B31.3 Code

	Inspection [¶340.1, ¶340.2]	Examination [¶341.1, ¶341.2]
Corporate Responsibility:	Owner.	Manufacturer, Fabricator, or Erector.
Individual Responsibility:	Owner's inspector or delegates of the owner's inspector.	Examination (QC) personnel.
Work Description:	Verify that all required examinations and tests have been completed. Inspect piping to the extent necessary to be satisfied that it conforms to all applicable examination requirements of the Code and the engineering design.	Perform examinations required by B31.3. (Note that most QC manuals have sections devoted specifically to completion of examinations, such as material control, welding control, NDE control, pressure testing, and record keeping.)
Primary Quality Management Function:	Quality assurance, including quality audit.	Quality control.

	Owner's Inspectors [¶340.4]	Examination Personnel [¶342.1, ¶342.2]
Appointment	Inspectors shall be designated by the owner, and shall be the owner, an employee of the owner, an employee of an engineering or scientific organization, or of a recognized insurance or inspection company acting as the owner's agent.	B31.3 does not list any specific requirements. Examiners are usually employees of the manufacturer, fabricator, or erector, or employees of a service agency subcontracted by the manufacturer, fabricator, or erector.
Restrictions	Inspectors shall not represent or be an employee of the piping manufacturer, fabricator, or erector, unless the owner is also the manufacturer, fabricator, or erector.	In-process examinations must be performed by personnel other than those performing the production work [¶342.2].
Education and Experience	B31.3 requires that inspectors have 10 or more years experience in the design, fabrication, or inspection of industrial piping (3). However, each 20% of satisfactorily completed work toward an engineering degree recognized by the Accreditation Board for Engineering and Technology can be considered equivalent to 1 year of experience, up to 5 years total [¶340.4(b)].	B31.3 is very loose regarding personnel qualification and certification. It simply states that "examiners shall have training and experience commensurate with the needs of the specified examinations." By a reference note to [¶342.1], for evaluation of personnel, B31.3 indicates that SNT-TC-1A may be used as a guide. (2)
Certification	No requirements stated.	B31.3 requires that the employer certify records of examiners employed, showing dates and results of personnel qualifications, and maintain the records and make them available to the inspector.

UG-91 THE INSPECTOR

(a) All references to *Inspectors* throughout this Division mean the Authorized Inspector as defined in this paragraph. All inspections required by this Division of Section VIII shall be:

(1) by an Inspector regularly employed by an ASME accredited Authorized Inspection Agency,[33] i.e., the

---

[32] See UG-90(b) and UG-90(c)(1) for summaries of the responsibilities of the Manufacturer and the duties of the Inspector.

[33] Whenever *Authorized Inspection Agency* or *AIA* is used in this Code, it shall mean an Authorized Inspection Agency accredited by ASME in accordance with the requirements in the latest edition of ASME QAI-1.

inspection organization of a state or municipality of the United States, a Canadian province, or an insurance company authorized to write boiler and pressure vessel insurance, except that

(2) inspections may be by the regularly employed user's Inspector in the case of a User-Manufacturer which manufactures pressure vessels exclusively for its own use and not for resale [see UG-116(a)(1)].

Except as permitted in (2) above, the Inspector shall not be in the employ of the Manufacturer. All Inspectors shall have been qualified by a written examination under the rules of any state of the United States or province of Canada which has adopted the Code.

(b) In addition to the duties specified, the Inspector has the duty to monitor the Manufacturer's Quality Control System as required in Appendix 10.

APPENDIX 10 of Section VIII
QUALITY CONTROL SYSTEM

- 10-1 GENERAL
- 10-2 OUTLINE OF FEATURES TO BE INCLUDED IN THE WRITTEN DESCRIPTION OF THE QUALITY CONTROL SYSTEM
- 10-3 AUTHORITY AND RESPONSIBILITY
- 10-4 ORGANIZATION
- 10-5 DRAWINGS, DESIGN CALCULATIONS, AND SPECIFICATION CONTROL
- 10-6 MATERIAL CONTROL
- 10-7EXAMINATION AND INSPECTION
- PROGRAM
- 10-8CORRECTION OF
- NONCONFORMITIES
- 10-9 WELDING
- 10-10 NONDESTRUCTIVE EXAMINATION
- 10-11 HEAT TREATMENT
- 10-12 CALIBRATION OF MEASUREMENT AND TEST EQUIPMENT
- 10-13 RECORDS RETENTION
- 10-14 SAMPLE FORMS
- 10-15 INSPECTION OF VESSELS AND
- VESSEL PARTS
- 10-16 INSPECTION OF PRESSURE
- RELIEF VALVES

Note: These are like ISO9001 requirements in nature

Subsection B
ASME VIII Div.1

Requirements Pertaining to Methods of Fabrication of Pressure Vessels

- **Part UW**

  Requirements for Pressure Vessels Fabricated by Welding

- **Part UF**

  Requirements for Pressure Vessels Fabricated by Forging

- **Part UB**

  Requirements for Pressure Vessels Fabricated by Brazing

Part UW

Requirements for Pressure Vessels Fabricated by Welding

- General
- Materials
- Design
- Fabrication
- Inspection and Tests
- Marking and Reports
- Pressure Relief Devices

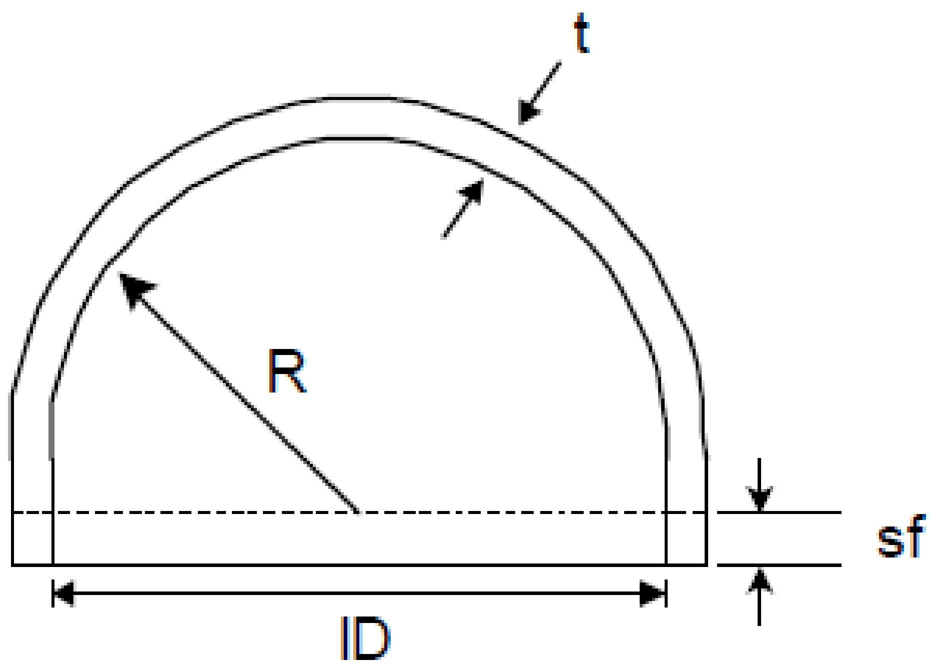
Part UW

General

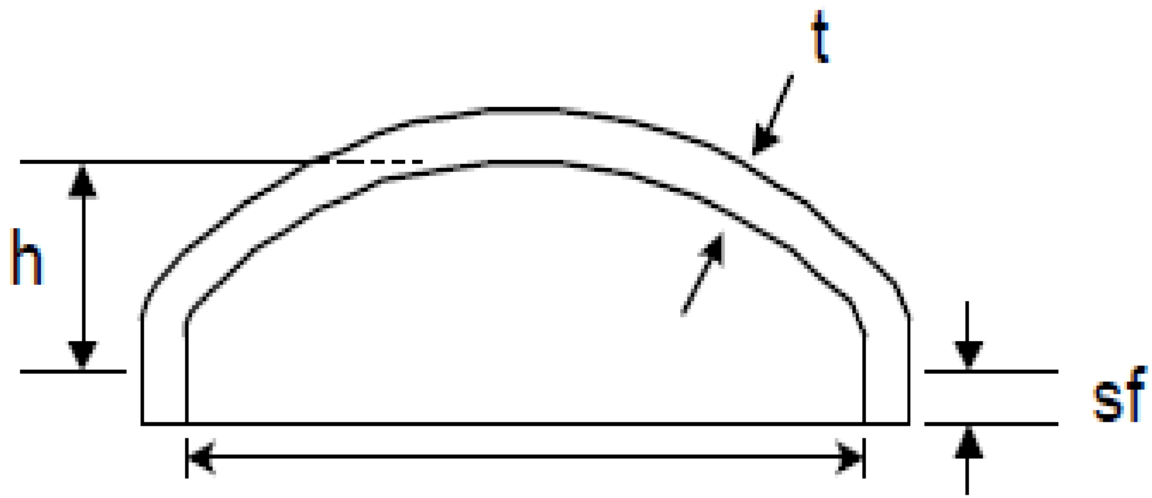
- **UW-1 Scope**
- **UW-2 Service Restrictions**
- **UW-3 Welded Joint Category**

Heads

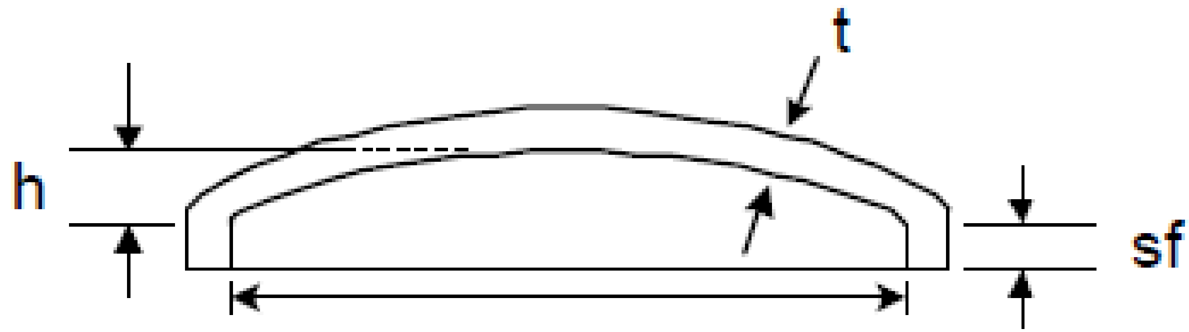
- Figurs show typical types of closure heads. Elliptical, hemispherical, and torispherical are the most commonly used head types. Note that all head types have a straight flange (sf) section, which simplifies welding the head to the adjacent cylindrical shell section. The elliptical and torispherical heads have an indicated head depth (h), which is measured from the straight flange to the maximum point of curvature on the inside surface.



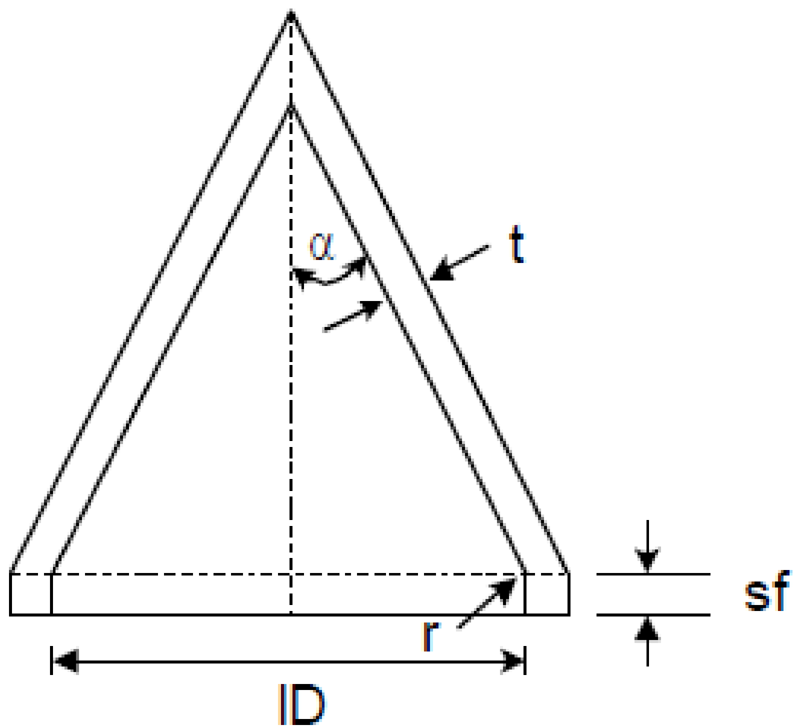
Hemispherical



Elliptical



Flanged and Dished (torispherical)

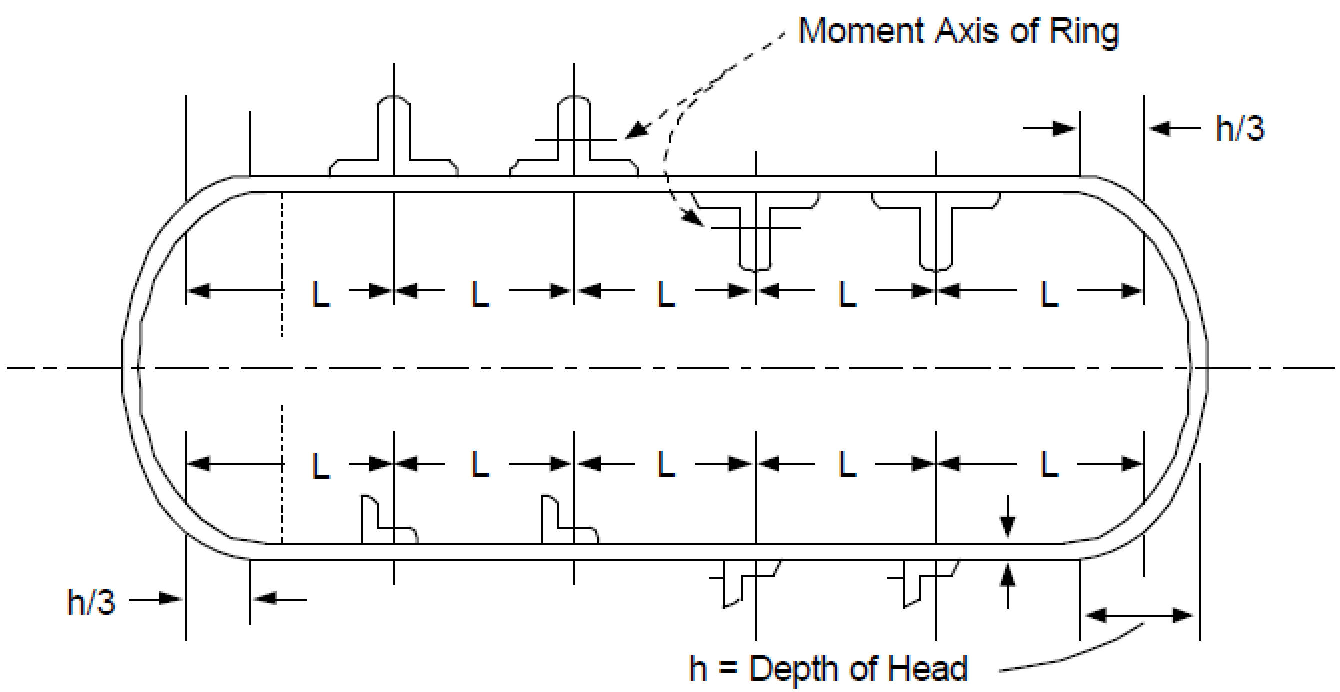


Toriconical

Part	Thickness, t, in.	Pressure, P, psi	Stress, S, psi
Cylindrical shell	$\frac{Pr}{SE_1 - 0.6P}$	$\frac{SE_1 t}{r + 0.6t}$	$\frac{P(r + 0.6t)}{tE_1}$
Spherical shell	$\frac{Pr}{2SE_1 - 0.2P}$	$\frac{2SEt}{r + 0.2t}$	$\frac{P(r + 0.2t)}{2tE}$
2:1 Semi -Elliptical head	$\frac{PD}{2SE - 0.2P}$	$\frac{2SEt}{D + 0.2t}$	$\frac{P(D + 0.2t)}{2tE}$
Torispherical head with 6% knuckle	$\frac{0.885PL}{SE - 0.1P}$	$\frac{SEt}{0.885L + 0.1t}$	$\frac{P(0.885L + 0.1t)}{tE}$
Conical Section (α = 30°)	$\frac{PD}{2\cos\alpha(SE - 0.6P)}$	$\frac{2SEt\cos\alpha}{D + 1.2t\cos\alpha}$	$\frac{P(D + 1.2t\cos\alpha)}{2tE\cos\alpha}$

Summary of ASME Code Equations

Stiffener ring



Stiffener Rings on Pressure Vessel Cylinders

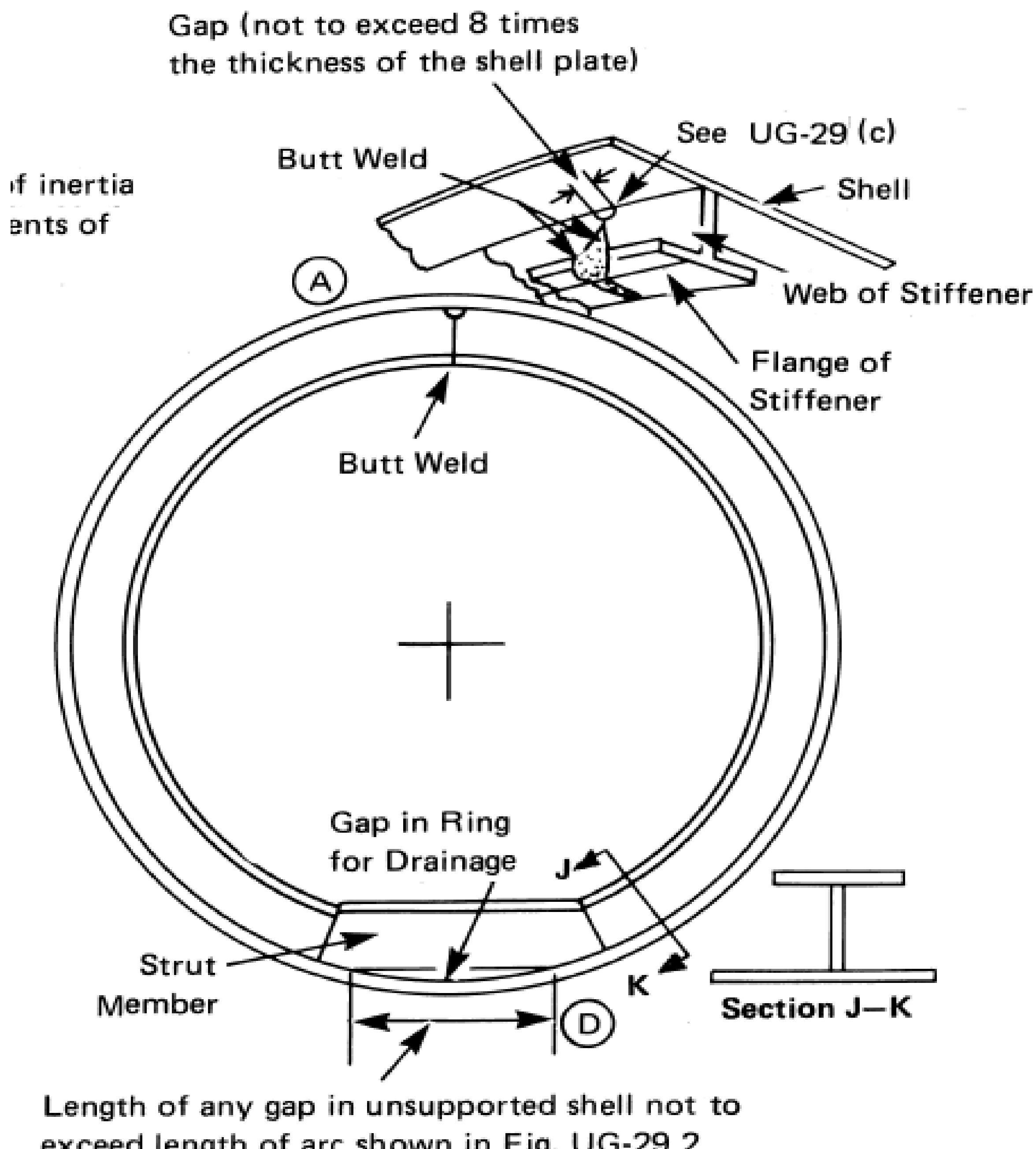

Gap (not to exceed 8 times
the thickness of the shell plate)
See UG-29 (c)
Butt Weld
Shell
if inertia
ents of
Web of Stiffener
A
Flange of
Stiffener
Butt Weld
Gap in Ring
for Drainage
J
Strut
Member
K
Section J—K
D
Length of any gap in unsupported shell not to
exceed length of arc shown in Fig. UG-29.2

FIG. UG-29.2 MAXIMUM ARC OF SHELL LEFT UNSUPPORTED BECAUSE OF GAP IN STIFFENING RING OF CYLINDRICAL SHELL UNDER EXTERNAL PRESSURE

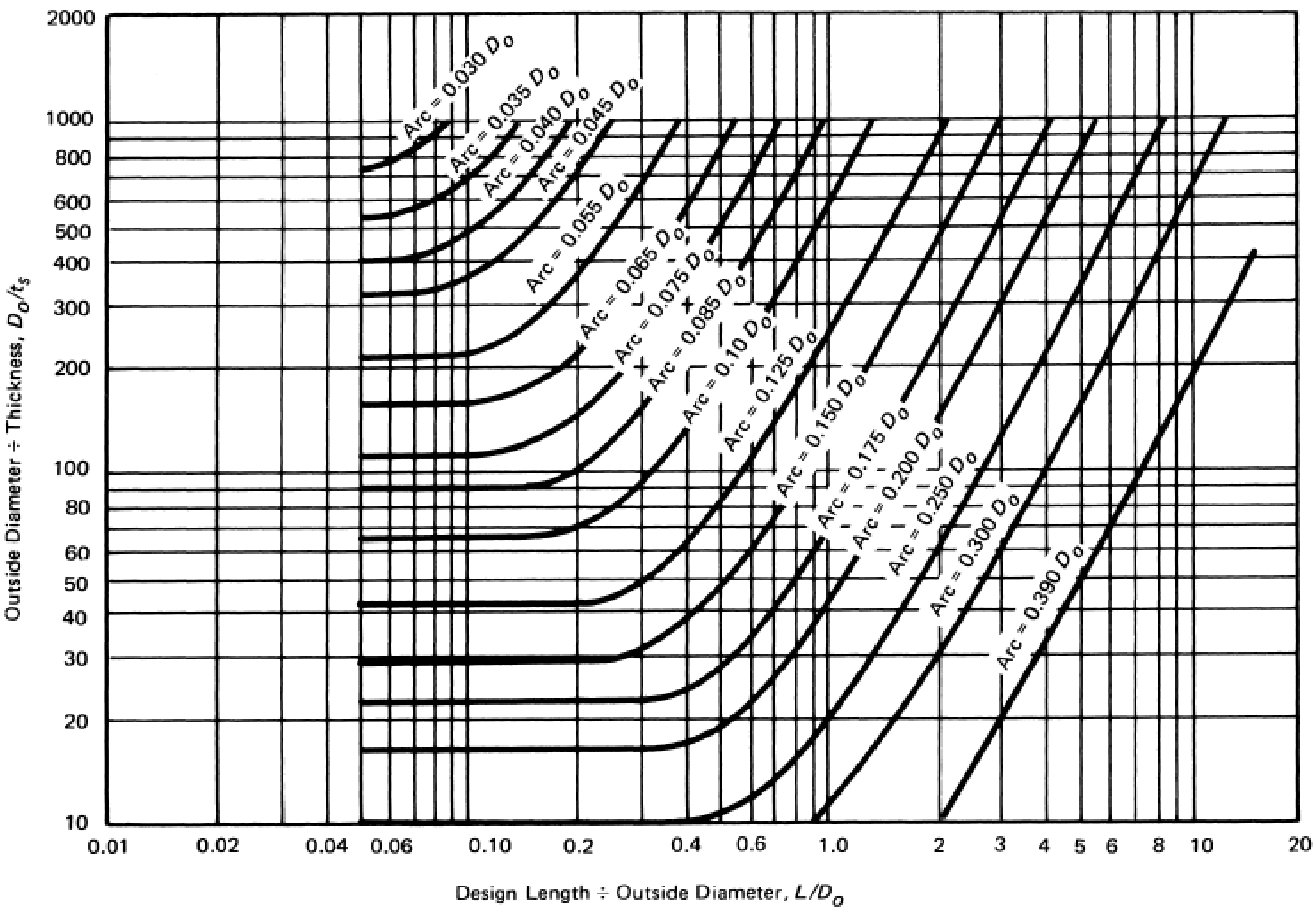
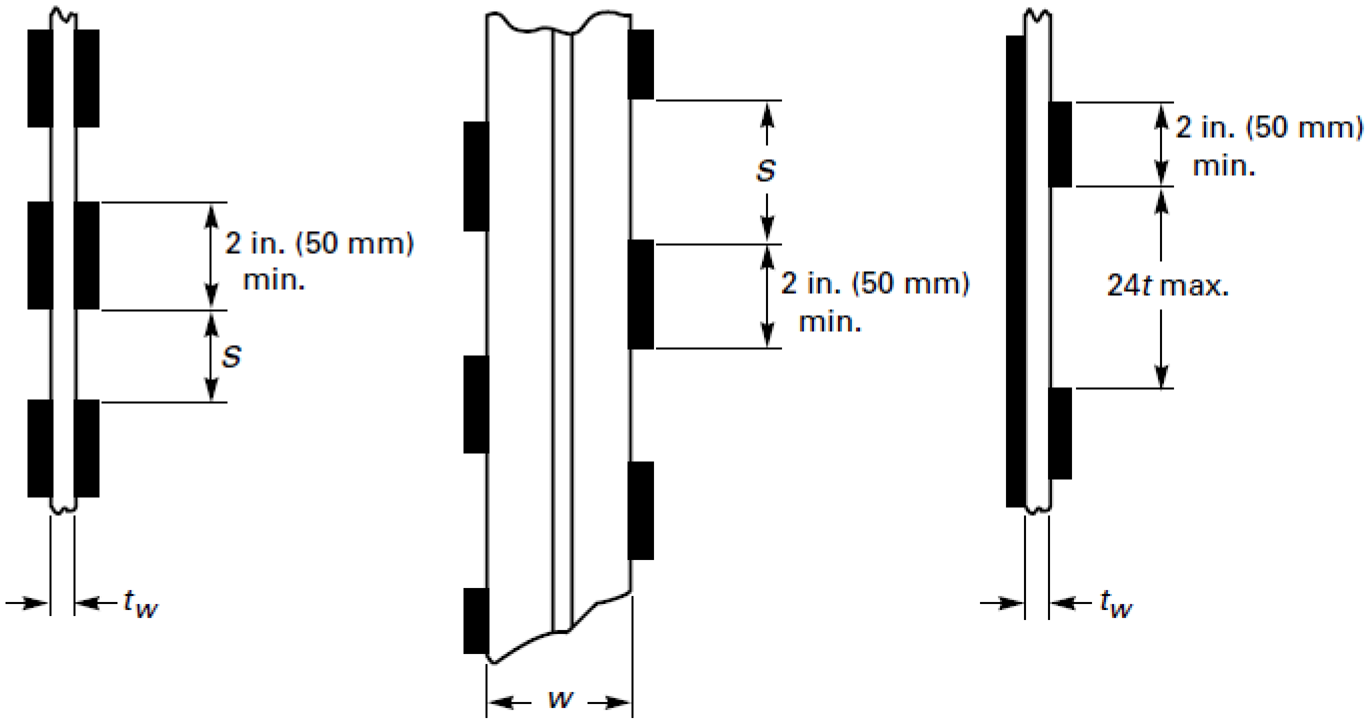


FIG. UG-30 SOME ACCEPTABLE METHODS OF ATTACHING STIFFENING RINGS

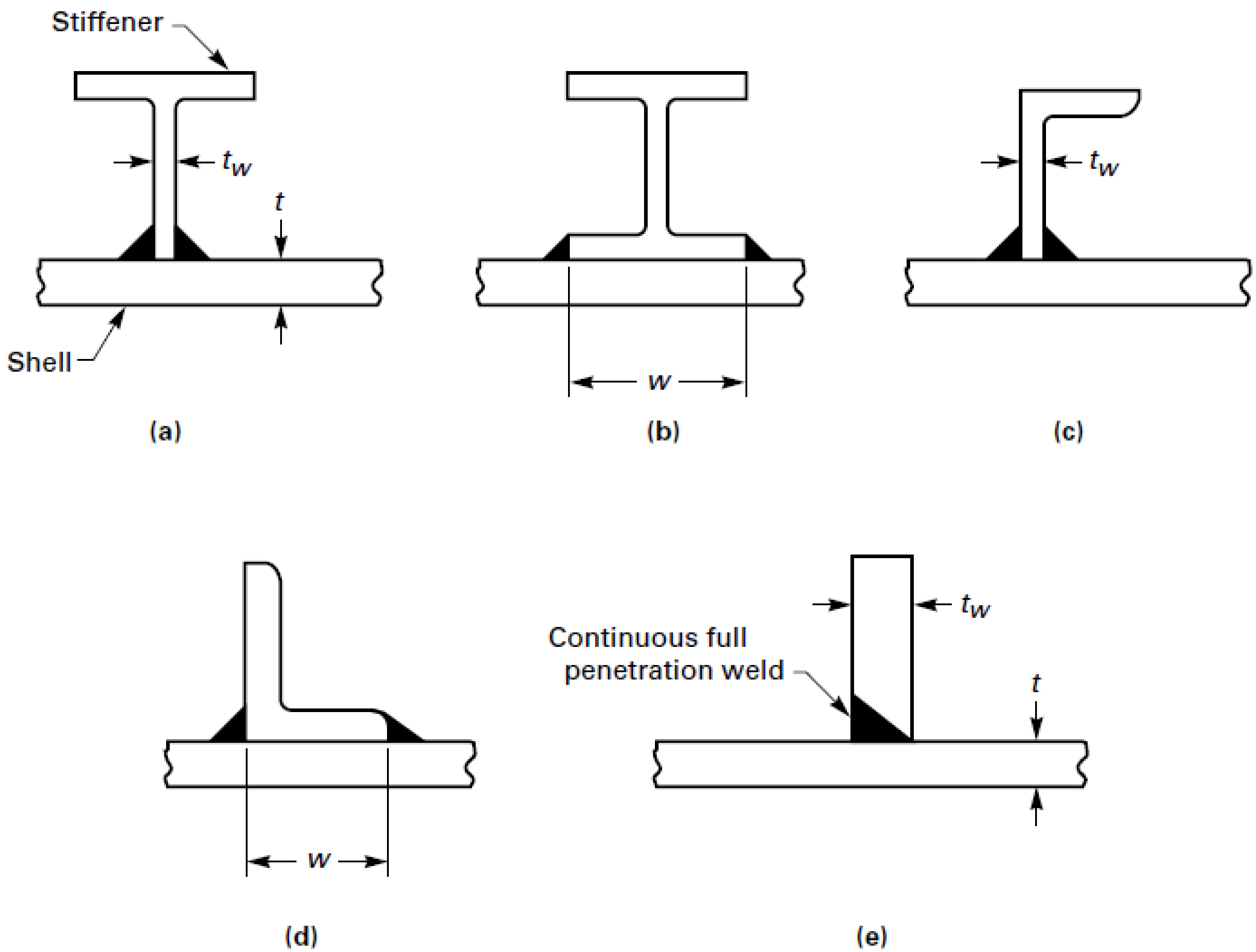


In-line Intermittent Weld

Staggered Intermittent Weld

Continuous Fillet Weld One Side, Intermittent Other Side

$S \leq 8t$ external stiffeners
$S \leq 12t$ internal stiffeners



Stiffener
t_w
t
Shell
w
(a)
(b)
(c)
t_w
w
Continuous full penetration weld
t_w
t
(d)
(e)

Part UW-Design

- UW-8 General
- UW-9 Design of Welded Joints
- UW-10 Postweld Heat Treatment
- UW-11 Radiographic and Ultrasonic Examination
- UW-12 Joint Efficiencies
- UW-13 Attachment Details
- UW-14 Openings in or Adjacent to Welds
- UW-15 Welded Connections
- UW-16 Minimum Requirements for Attachment Welds at Openings UW-17 Plug Welds
- UW-18 Fillet Welds
- UW-19 Welded Stayed Construction
- UW-20 Tube-to-Tubesheet Welds
- UW-21 Flange to Nozzle Neck Welds

UW-9 DESIGN OF WELDED JOINTS

(a)Permissible Types.
(b)Welding Grooves.
(c) Tapered Transitions.
(d)Vessels made up of two or more courses- Staggering of longitudinal joints
(e) Lap Joints.
(f) Welded Joints Subject to Bending Stresses
(g) Minimum Weld Sizes.

Fabrication

- UW-26 General
- UW-27 Welding Processes
- UW-28 Qualification of Welding Procedure
- UW-29 Tests of Welders and Welding Operators
- UW-30 Lowest Permissible Temperatures for Welding
- UW-31 Cutting, Fitting, and Alignment
- UW-32 Cleaning of Surfaces to Be Welded
- UW-33 Alignment Tolerance
- UW-34 Spin-Holes
- UW-35 Finished Longitudinal and Circumferential Joints
- UW-36 Fillet Welds
- UW-37 Miscellaneous Welding Requirements
- UW-38 Repair of Weld Defects
- UW-39 Peening
- UW-40 Procedures for Postweld Heat Treatment
- UW-41 Sectioning of Welded Joints
- UW-42 Surface Weld Metal Buildup .

Subsection C
ASME VIII Div.1

Requirements Pertaining to Classes of Materials

Subsection C of ASME VIII Div.1

- **Part UCS**

  Requirements for Pressure Vessels Constructed of Carbon and Low Alloy Steels

- **Part UNF**

  Requirements for Pressure Vessels Constructed of Nonferrous Materials

- **Part UHA**

  Requirements for Pressure Vessels Constructed of High Alloy Steel

Subsection C of ASME VIII Div.1

Requirements Pertaining to Classes of Materials.

- **Part UCI**

  Requirements for Pressure Vessels Constructed of Cast Iron

- **Part UCL**

  Requirements for Welded Pressure Vessels Constructed of Material With Corrosion Resistant Integral Cladding, Weld Metal Overlay Cladding, or With Applied Linings

- **Part UCD**

  Requirements for Pressure Vessels Constructed of Cast Ductile Iron

Subsection C
Cont.

- **Part UHT**

  Requirements for Pressure Vessels Constructed of Ferritic Steels With Tensile Properties Enhanced by Heat Treatment

- **Part ULW**

  Requirements for Pressure Vessels Fabricated by Layered Construction

- **Part ULT**

  Alternative Rules for Pressure Vessels Constructed of Materials Having Higher Allowable Stresses at Low Temperature

Part UCS

Requirements for Pressure Vessels Constructed of Carbon and Low Alloy Steels

Two important issues for carbon and low alloy steels:

- **Post weld heat treatment**

- **Impact test**

- ***Temperatures to Consider***
- Minimum Design Metal Temperature (MDMT)
- Lowest temperature at which component has adequate fracture toughness

PWHT

(stress relieving at around 600 centigrade)

- Postweld heat treatment is mandatory under the following conditions:
- (a) for welded joints over 11⁄2 in. (38 mm) nominal thickness;
- b) for welded joints over 11⁄4 in. (32 mm) nominal thickness through 11⁄2 in. (38 mm) nominal thickness unless preheat is applied at a minimum temperature of 200°F (95°C) during welding;

TABLE UCS-56
POSTWELD HEAT TREATMENT IS REQUIRED AS THE THICKNESS OR ALLOYING ELEMNTS INCREASE

TABLE UCS-56
POSTWELD HEAT TREATMENT REQUIREMENTS FOR CARBON AND LOW ALLOY STEELS

Material	Normal Holding Temperature, °F (°C), Minimum	Minimum Holding Time at Normal Temperature for Nominal Thickness [See UW-40(f)]		
		Up to 2 in. (51 mm)	Over 2 in. to 5 in. (51 mm to 127 mm)	Over 5 in. (127 mm)
P-No. 1 Gr. Nos. 1, 2, 3	1100 (593)	1 hr/in. (25 mm), 15 min minimum	2 hr plus 15 min for each additional inch (25 mm) over 2 in. (51 mm)	2 hr plus 15 min for each additional inch (25 mm) over 2 in. (51 mm)
Gr. No. 4	NA	None	None	None

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
A 514	E	K21604	110 (760)	11B	2	102	3.1	1.75Cr–0.5Mo–Cu	Plate, 2½ in. (64 mm) max.
A 514	P	K21650	100 (690)	11B	8	102	3.1	1.25Ni–1Cr–0.5Mo	Plate > 2½ in.–6 in. (64 mm–152 mm), incl.
A 514	P	K21650	110 (760)	11B	8	102	3.1	1.25Ni–1Cr–0.5Mo	Plate, 2½ in. (64 mm) max.
A 514	Q	. . .	100 (690)	11B	9	102	3.1	1.3Ni–1.3Cr–0.5Mo–V	Plate > 2½ in.–6 in. (64 mm–152 mm), incl.
A 514	Q	. . .	110 (760)	11B	9	102	3.1	1.3Ni–1.3Cr–0.5Mo–V	Plate, 2½ in. (64 mm) max.
SA-515	60	K02401	60 (415)	1	1	101	1.1	C	Plate
SA-515	65	K02800	65 (450)	1	1	101	11.1	C–Si	Plate
SA-515	70	K03101	70 (485)	1	2	101	11.1	C–Si	Plate
SA-516	55	K01800	55 (380)	1	1	101	1.1	C–Si	Plate
SA-516	60	K02100	60 (415)	1	1	101	1.1	C–Mn–Si	Plate
SA-516	65	K02403	65 (450)	1	1	101	1.1	C–Mn–Si	Plate
SA-516	70	K02700	70 (485)	1	2	101	11.1	C–Mn–Si	Plate
SA-517	F	K11576	115 (795)	11B	3	101	3.1	0.75Ni–0.5Cr–0.5Mo–V	Plate ≤ 2½ in. (64 mm)
SA-517	B	K11630	115 (795)	11B	4	101	3.1	0.5Cr–0.2Mo–V	Plate ≤ 1¼ in. (32 mm)
SA-517	A	K11856	115 (795)	11B	1	101	3.1	0.5Cr–0.25Mo–Si	Plate ≤ 1¼ in. (32 mm)
SA-517	E	K21604	105 (725)	11B	2	102	3.1	1.75Cr–0.5Mo–Cu	Plate > 2½ in.–6 in. (64 mm–152 mm), incl.
SA-517	E	K21604	115 (795)	11B	2	102	3.1	1.75Cr–0.5Mo–Cu	Plate ≤ 2½ in. (64 mm)
SA-517	P	K21650	105 (725)	11B	8	102	3.1	1.25Ni–1Cr–0.5Mo	Plate > 2½ in.–4 in. (64 mm–102 mm), incl.
SA-517	P	K21650	115 (795)	11B	8	102	3.1	1.25Ni–1Cr–0.5Mo	Plate ≤ 2½ in. (64 mm)
A 519	1018 HR	G10180	. . .	1	1	101	1.1	C	Tube
A 519	1018 CW	G10180	. . .	1	2	101	1.1	C	Tube
A 519	1020 HR	G10200	. . .	1	1	101	1.1	C	Tube
A 519	1020 CW	G10200	. . .	1	2	101	1.1	C	Tube
A 519	1022 HR	G10220	. . .	1	1	101	1.1	C	Tube

Impact Testing

at minimum design temperature

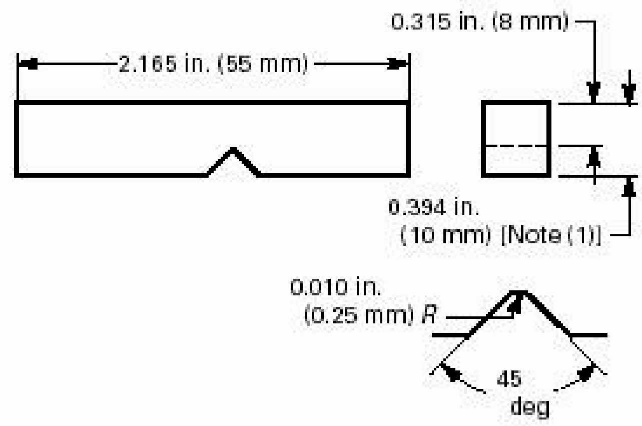


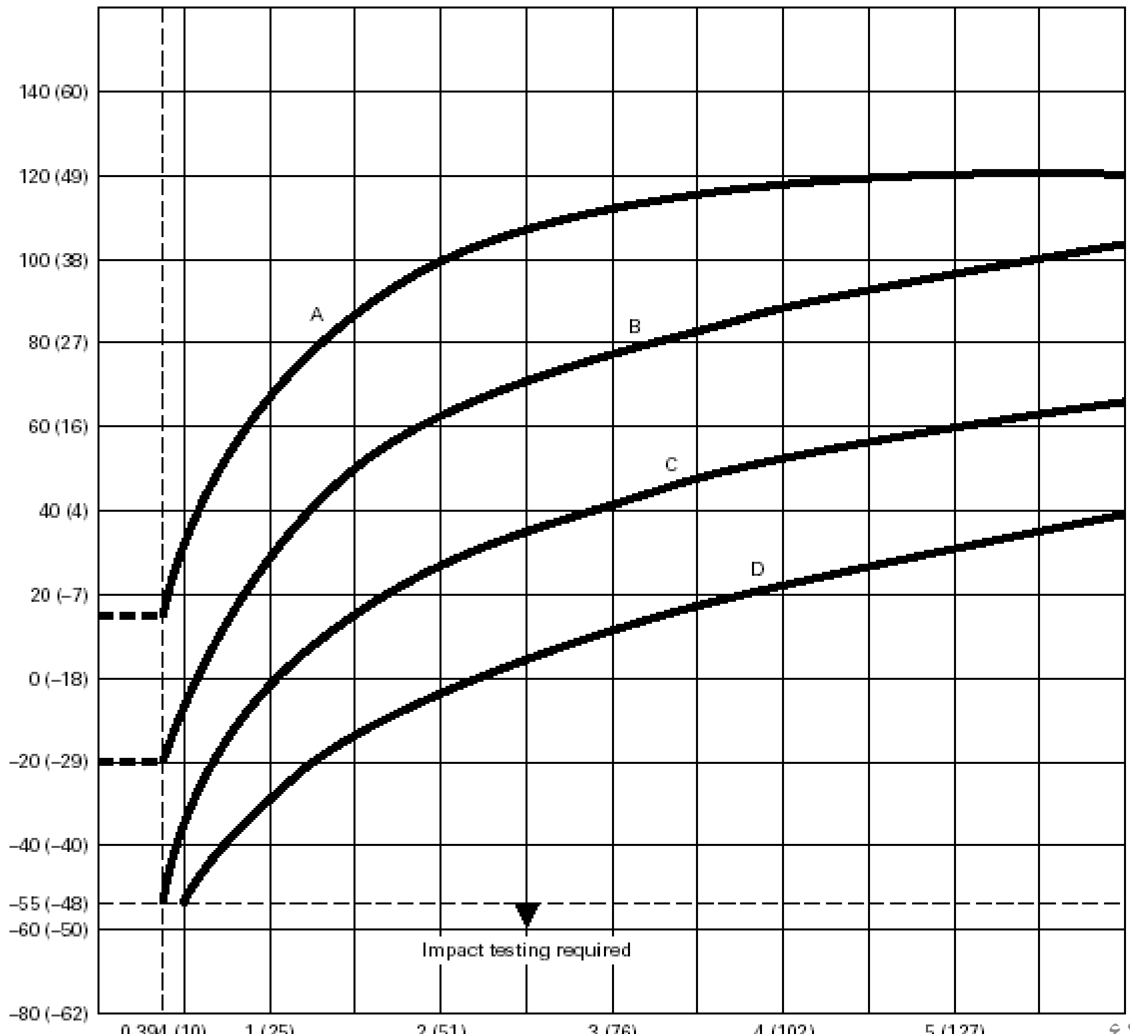
FIG. UG-84 SIMPLE BEAM IMPACT TEST SPECIMENS (CHARPY TYPE TEST)

GRAPH UCS-66:

IMPACT TEST IS REQUIRED BELOW THE CURVE .

AS THE SERVICE TEMPERATURE DECREASE OR THICKNESS INCREASE

Minimum Design Metal Temperature



Thickness

Material Groups

MATERIAL GROUP	APPLICABLE MATERIALS
Curve A	• All carbon and low alloy steel plates, structural shapes, and bars not listed in Curves B, C & D • SA-216 Gr. WCB & WCC, SA-217 Gr. WC6, if normalized and tempered or water-quenched and tempered
Curve B	• SA-216 Gr. WCA, if normalized and tempered or water-quenched and tempered • SA-216 Gr. WCB & WCC for maximum thickness of 2 in., if produced to fine grain practice and water-quenched and tempered • SA-285 Gr. A & B • SA-414 Gr. A • SA-515 Gr. 60 • SA-516 Gr. 65 & 70, if not normalized • Except for cast steels, all materials of Curve A if produced to fine grain practice and normalized which are not included in Curves C & D • All pipe, fittings, forging, and tubing which are not included in Curves C & D

Material Groups, cont'd

MATERIAL GROUP	APPLICABLE MATERIALS
Curve C	• SA-182 Gr. 21 & 22, if normalized and tempered • SA-302 Gr. C & D • SA-336 Gr. F21 & F22, if normalized and tempered • SA-387 Gr. 21 & 22, if normalized and tempered • SA-516 Gr. 55 & 60, if not normalized • SA-533 Gr. B & C • SA-662 Gr. A • All material of Curve B if produced to fine grain practice and normalized which are not included in Curve D
Curve D	• SA-203 • SA-508 Cl. 1 • SA-516, if normalized • SA-524 Cl. 1 & 2 • SA-537 Cl. 1, 2 & 3 • SA-612, if normalized • SA-662, if normalized • SA-738 Gr. A

UG 84.1

Energy Requirement in Impact Testing

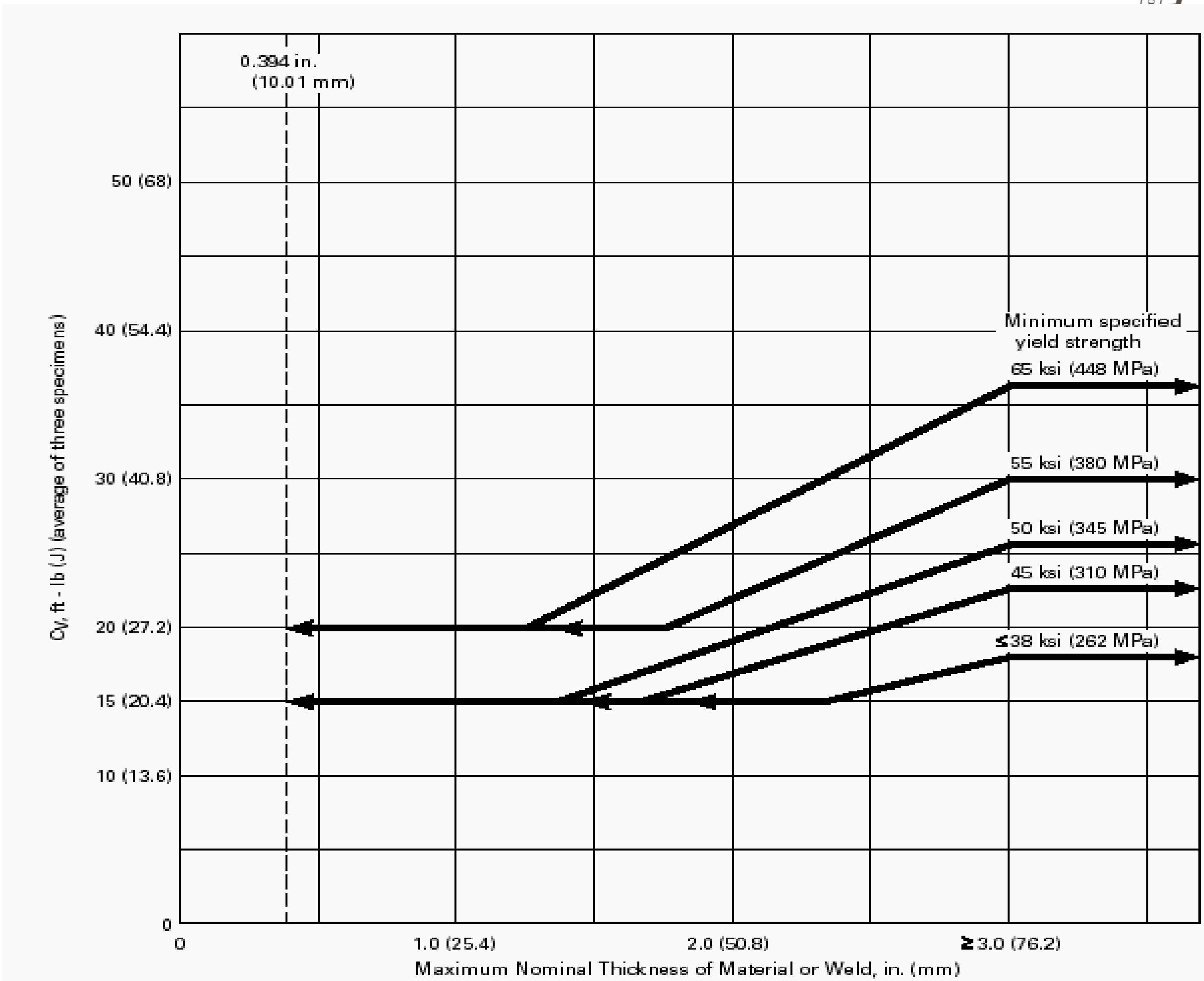


TABLE A2.15
GENERALLY AVAILABLE GRADE-THICKNESS-MINIMUM TEST TEMPERATURE COMBINATIONS MEETING CHARPY V-NOTCH REQUIREMENTS INDICATED (NORMALIZED OR QUENCHED AND TEMPERED CONDITION) (CONT'D)

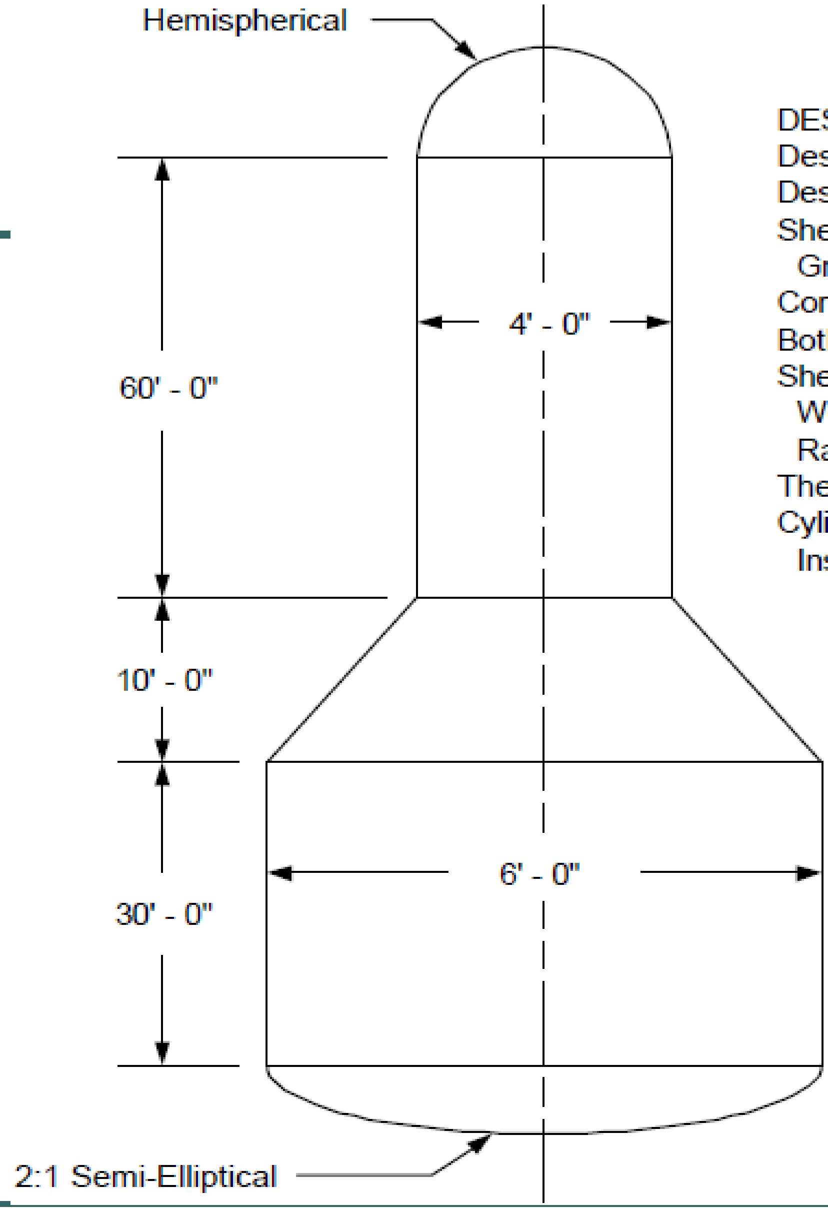
Acceptance Criteria Charpy V-Notch — Energy Absorption				Test Temperature, °C, for Plate Thicknesses (Unless Otherwise Agreed Upon)			
Class[A]	Minimum Average For 3 Specimens[B], J	Minimum for 1 Specimen[B], J	Specification and Grade	25 mm and Under	Over 25 mm to 50 mm, Incl.	Over 50 mm to 75 mm, Incl.	Over 75 mm to 125 mm, Incl.
V	27	20	A 203 Grade F	−107	−107	. . .	. . .
			A 537 Class 2 (64 mm max.)	−68	−68	−68	. . .
			A 612	−46	. . .	. . .	. . .
			A 724 Grade A	−46	. . .	. . .	. . .
	Lateral Expansion mm, Minimum Each Specimen Transverse Test						
VI	0.38	. . .	A 353	−196	−196	. . .	. . .
			A 553 Type I	−196	−196	. . .	. . .
			A 553 Type II	−170	−170	. . .	. . .
			A 645	−170	−170	. . .	. . .
			A 517 all (64 mm max. thickness)	C	C	. . .	. . .
			A 724 Grade B	−46	. . .	. . .	. . .

TABLE UCS-57 THICKNESS ABOVE WHICH FULL RADIOGRAPHIC EXAMINATION OF BUTT WELDED JOINTS IS MANDATORY

P-No. & Gr. No. Classification of Material	Nominal Thickness Above Which Butt Welded Joints Shall Be Fully Radiographed, in. (mm)
1 Gr. 1, 2, 3	$1\frac{1}{4}$ (32)
3 Gr. 1, 2, 3	$\frac{3}{4}$ (19)
4 Gr. 1, 2	$\frac{5}{8}$ (16)
5A, 5B Gr. 1	0 (0)
9A Gr. 1	$\frac{5}{8}$ (16)
9B Gr. 1	$\frac{5}{8}$ (16)
10A Gr. 1	$\frac{3}{4}$ (19)
10B Gr. 2	$\frac{5}{8}$ (16)
10C Gr. 1	$\frac{5}{8}$ (16)
10F Gr. 6	$\frac{3}{4}$ (19)

Sample Problem 1 – Design for Internal Pressure

- The geometry and design data of a vertical ylindrical pressure vessel are specified in next Figure Cost estimates are being prepared for this vessel. It is your job to estimate the required component hicknesses.
- **A. What are the minimum required thicknesses for the two cylindrical sections?**



DESIGN INFORMATION

Design Pressure = 250 psig

Design Temperature = 700° F

Shell and Head Material is SA-515 Gr. 60

Corrosion Allowance = 0.125"

Both Heads are Seamless

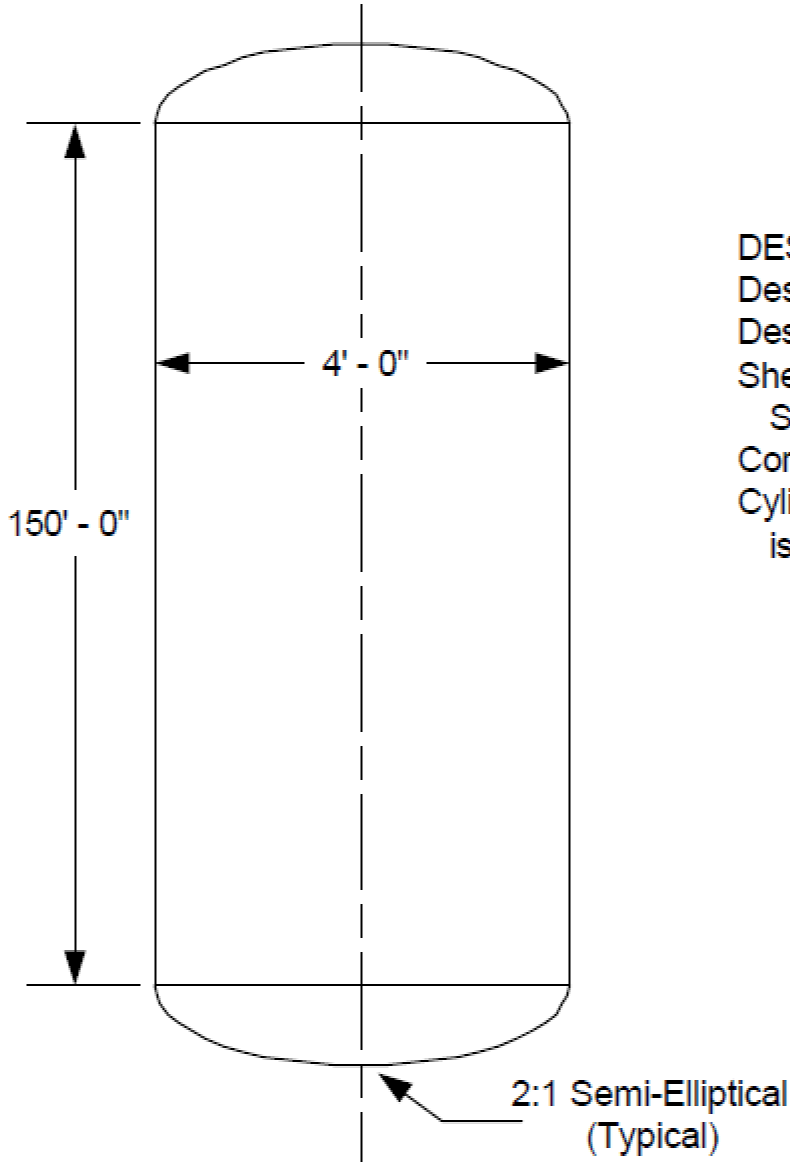
Shell and Cone Welds are Double Welded and will be Spot Radiographed

The Vessel is in All Vapor Service

Cylinder Dimensions Shown are Inside Diameters

Sample Problem 2 - External Pressure Calculation

- The vendor has proposed that the wall thickness of the tower shown in next slide be 7/16 in., and no stiffener rings have been specified. Is the 7/16 in. thickness acceptable for external pressure? If it is not acceptable, what minimum thickness is required? Round your answer upward to the nearest 1/16 in.



DESIGN INFORMATION
Design Pressure = Full Vacuum
Design Temperature = 500° F
Shell and Head Material is
SA-285 Gr. B, Yield Stress = 27 ksi
Corrosion Allowance = 0.0625"
Cylinder Dimension Shown
is Inside Diameter

Sample peoblem 3

- **Required Thickness for Internal Pressure**
- Determine the minimum required thickness for the cylindrical shell and heads of the following pressure vessel:
- · Inside Diameter - 10' - 6"
- · Design Pressure - 650 psig
- · Design Temperature - 700°F
- · Shell & Head Material - SA-516 Grade 70
- · Corrosion Allowance - 0.125"
- · 2:1 Semi-Elliptical heads, seamless
- · 100% radiography of cylindrical shell welds
- · The vessel is in an all vapor service (i.e., no liquid loading)

Reinforcement of opening

To determine whether an opening is adequately reinforced, it is first necessary to determine whether the areas of reinforcement available will be sufficient without the use of a pad.

- the total cross-sectional area of reinforcement required(in square inches) is indicated by the letter A,which is equal to the diameter(plus C.A.)times the required thickness.the area of reinforcement available without a pad includes:

1. The area of excess thickness in the shell or head, A_1
2. The area of excess thickness in the nozzle wall, A_2
3. The cross-sectional area of welds, A_3.

If $A_1 + A_2 + A_3 = A$, the opening is adequately reinforced.
If $A_1 + A_2 + A_3 < A$, a pad is needed.

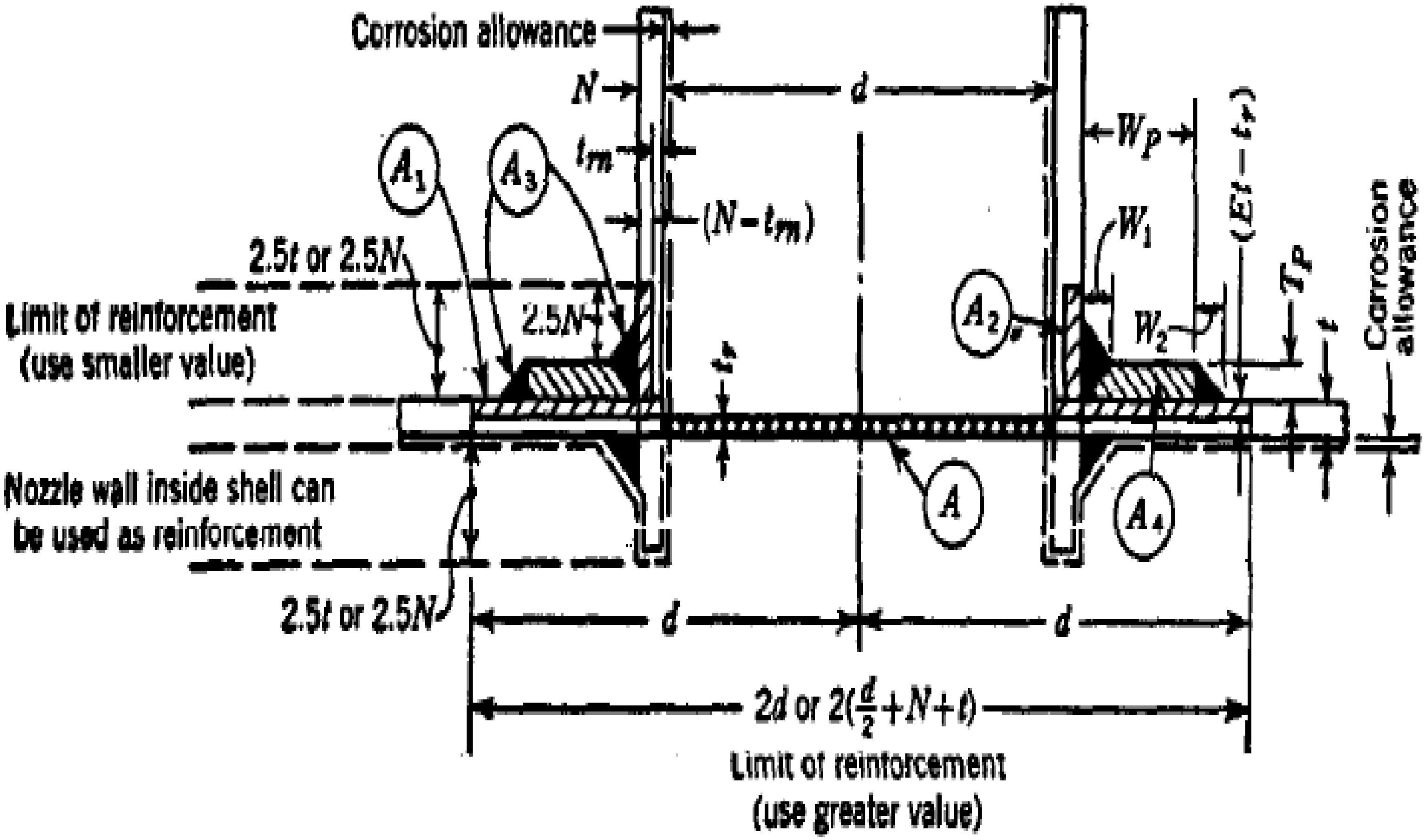
If the reinforcement is found to be inadequate, then the area of pad needed (A_4) may be calculated as follows:

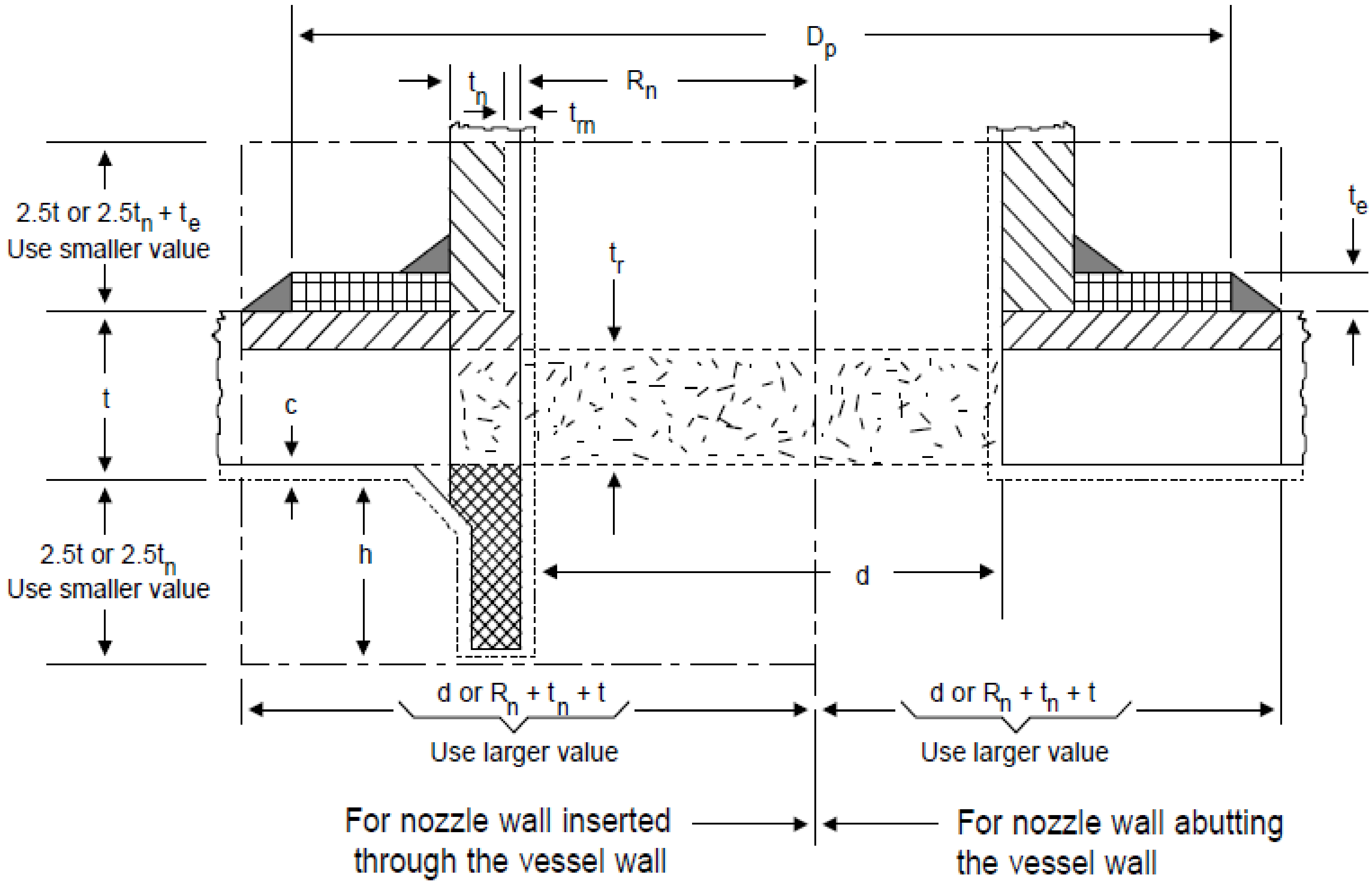
$$A_4 = A - (A_1 + A_2 + A_3)$$

- If a pad is used,the factor(2.5N) in the equation for A2(see slide 253)is measured from the top surface of the pad and therefore becomes: 2.5N+Tp.the area A2 must berecalculated on this basis and the smaller value again used.then:

If $A_1 + A_2 + A_3 + A_4 = A$, the opening is adequately reinforced.

- All values except E are in inches


Corrosion allowance
N
d
t_{rn}
$(N-t_{rn})$
A_1
A_3
2.5t or 2.5N
Limit of reinforcement
(use smaller value)
2.5N
t_r
W_p
W_1
W_2
A_2
$(Et-t_r)$
T_P
t
Corrosion allowance
Nozzle wall inside shell can be used as reinforcement
A
A_4
2.5t or 2.5N
d
d
$2d$ or $2(\frac{d}{2}+N+t)$
Limit of reinforcement
(use greater value)



Cross-Sectional View of Nozzle Opening

d = diameter in the plane under consideration of the finished opening in its corroded condition

t = nominal thickness of shell or head, less corrosion allowance

t_r = required thickness of shell or head as defined in Code Par. UG–37

t_{rn} = required thickness of a seamless nozzle wall

T_p = thickness of reinforcement pad

W_p = width of reinforcement pad

N = nominal thickness of nozzle wall, less corrosion allowance

W_1 = cross-sectional area of weld

W_2 = cross-sectional area of weld

E = 1 when an opening is in the solid plate or passes through a circumferential joint in a shell or cone

= the longitudinal joint efficiency when any part of the opening passes through any other joint

SHELL OR HEAD DATA		NOZZLE DATA	
		$P =$ pressure, psi	
		$S =$ allowable stress, psi	
		$r =$ inside radius of nozzle, in.	
		$E =$ joint efficiency, per cent	
		$t_{rn} = \dfrac{Pr}{SE - 0.6P} =$	
$t =$ actual thickness of shell or head (minus corrosion)		$N =$ actual thickness of nozzle (minus corrosion)	
$t_r =$ calculated thickness of shell or head		$t_{rn} =$ calculated thickness of nozzle	
$Et - t_r =$ excess thickness in shell or head		$N - t_{rn} =$ excess thickness in nozzle	

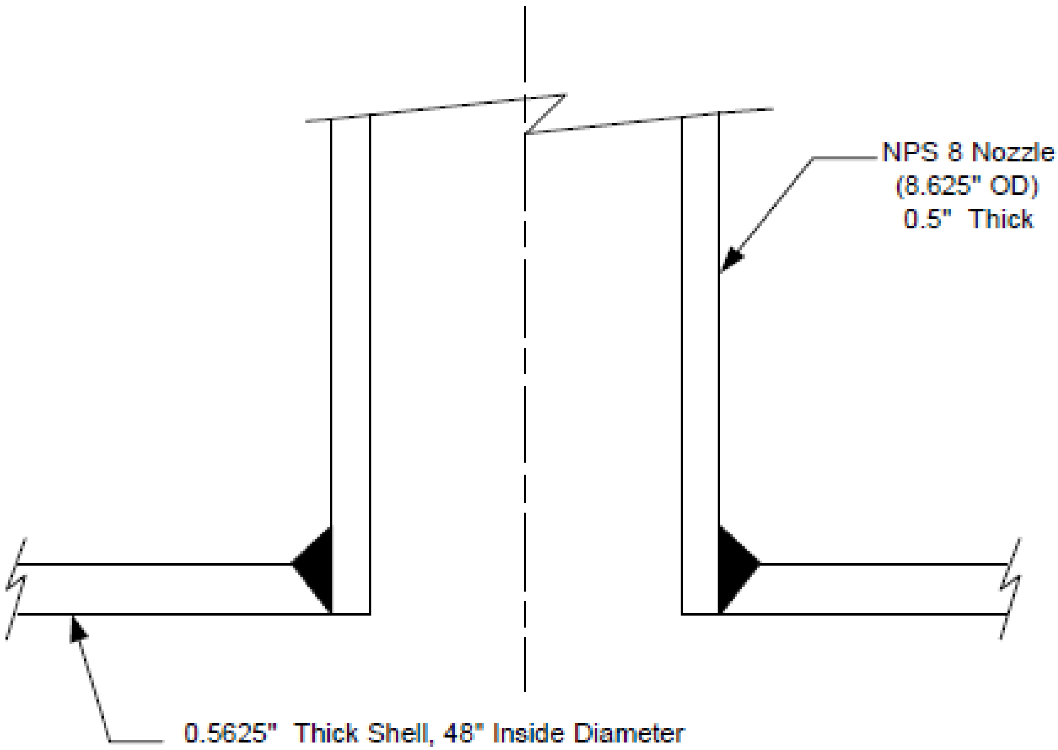
Area of reinforcement required	$A = dt_r$	= ______
Area of reinforcement available without pad	$(A_1 + A_2 + A_3)$	
Area of excess thickness in shell or head (use greater value)	$A_1 = (Et - t_r)d$ or $A_1 = 2(Et - t_r)(t + N)$	= ______
Area of excess thickness in nozzle wall (use smaller value)	$A_2 = 2(2.5N)^*(N - t_{rn})$ or $A_2 = 2(2.5t)(N - t_{rn})$	= ______
Cross-sectional area of welds	$A_3 = 2\left(\frac{(W_1)^2 + (W_2)^2}{2}\right)$	= ______
Area in pad	$A_4 = 2W_pT_p$	= ______
	Total area available	______

* If reinforcing pad is used, the factor $(2.5N)$ becomes $(2.5N + T_p)$

Sample problem 4

- You are reviewing the nozzle design details that are proposed by a vendor for a new drum and have selected an NPS 8 nozzle into the shell for detailed evaluation. The vendor has not provided any reinforcement for this nozzle, and he has not provided any calculations to verify that use of the nozzle without reinforcement is acceptable. Determine if this nozzle requires additional reinforcement. If it does, assume that a 0.5 in. thick reinforcement pad of SA-516, Gr. 60 material is used. What must the minimum pad diameter be? Neglect any contribution of weld areas in these calculations since they are insignificant. The information that is needed to perform your evaluation is next slide.

DESIGN INFORMATION
Design Pressure = 300 psig
Design Temperature = 200°F
Shell Material is SA-516 Gr. 60
Nozzle Material is SA-53 Gr. B, Seamless
Corrosion Allowance = 0.0625"
Vessel is 100% Radiographed
Nozzle does not pass through Vessel Weld Seam



فلنج ها flanges

- امکان جدا کردن قطعات از یکدیگر به منظور تعمیر ، تعویض و تغییرات در سیستم را می دهند . همچنین باعث تسهیل در مونتاژ مجموعه می شوند .

مهمترین انواع فلنج :

- Welding neck
- Slip – on/lap joint
- Blind
- Socket weld
- threded

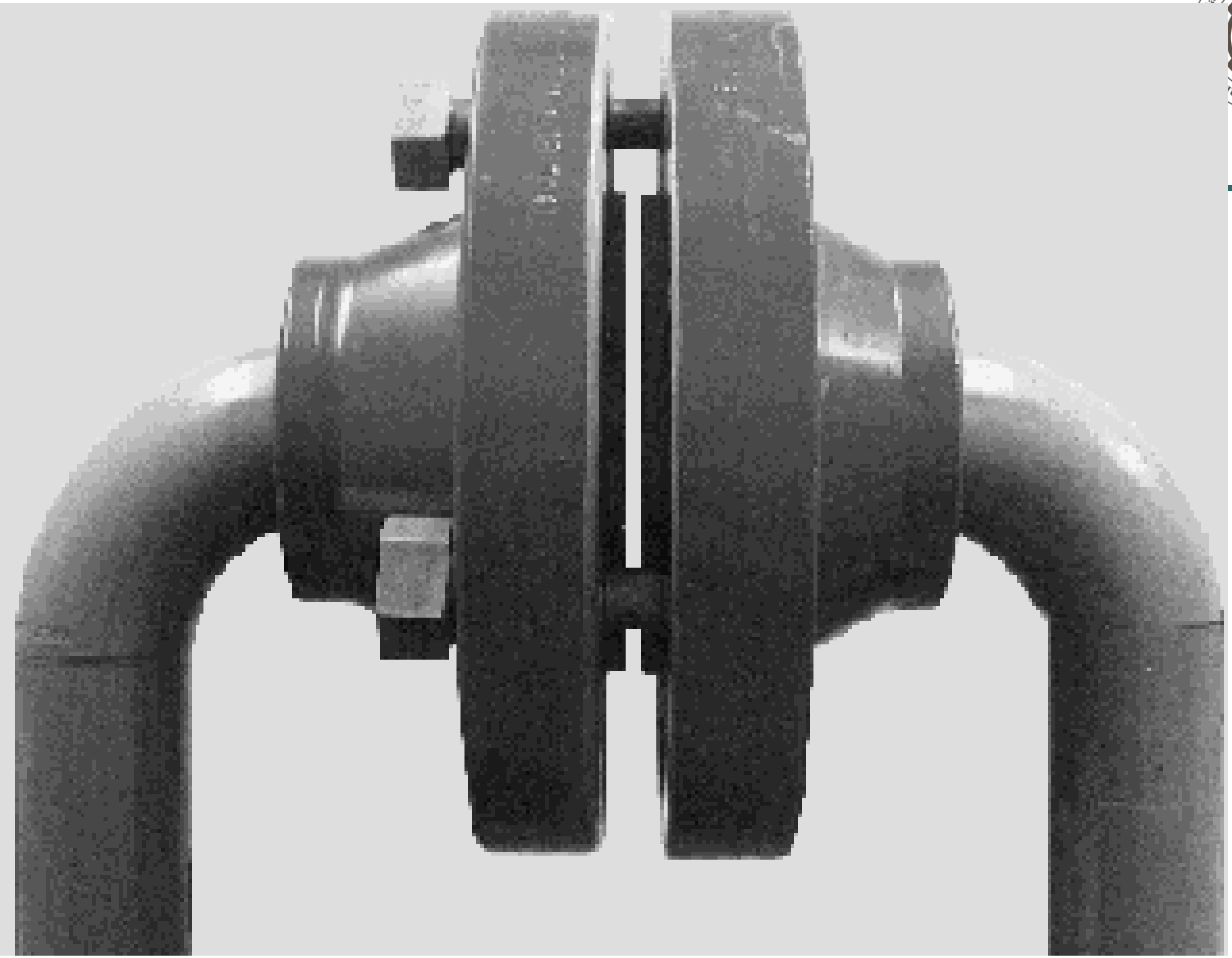
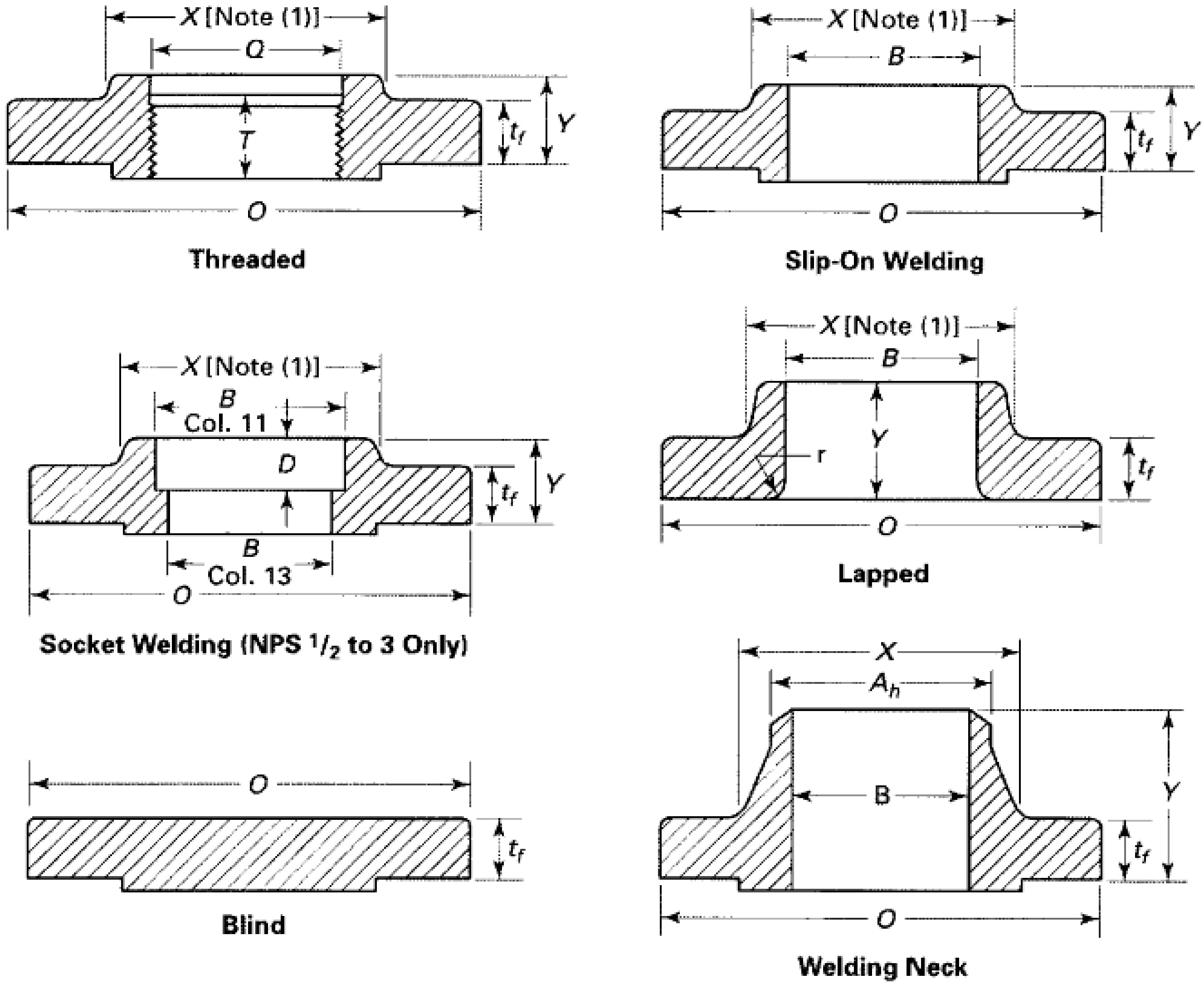
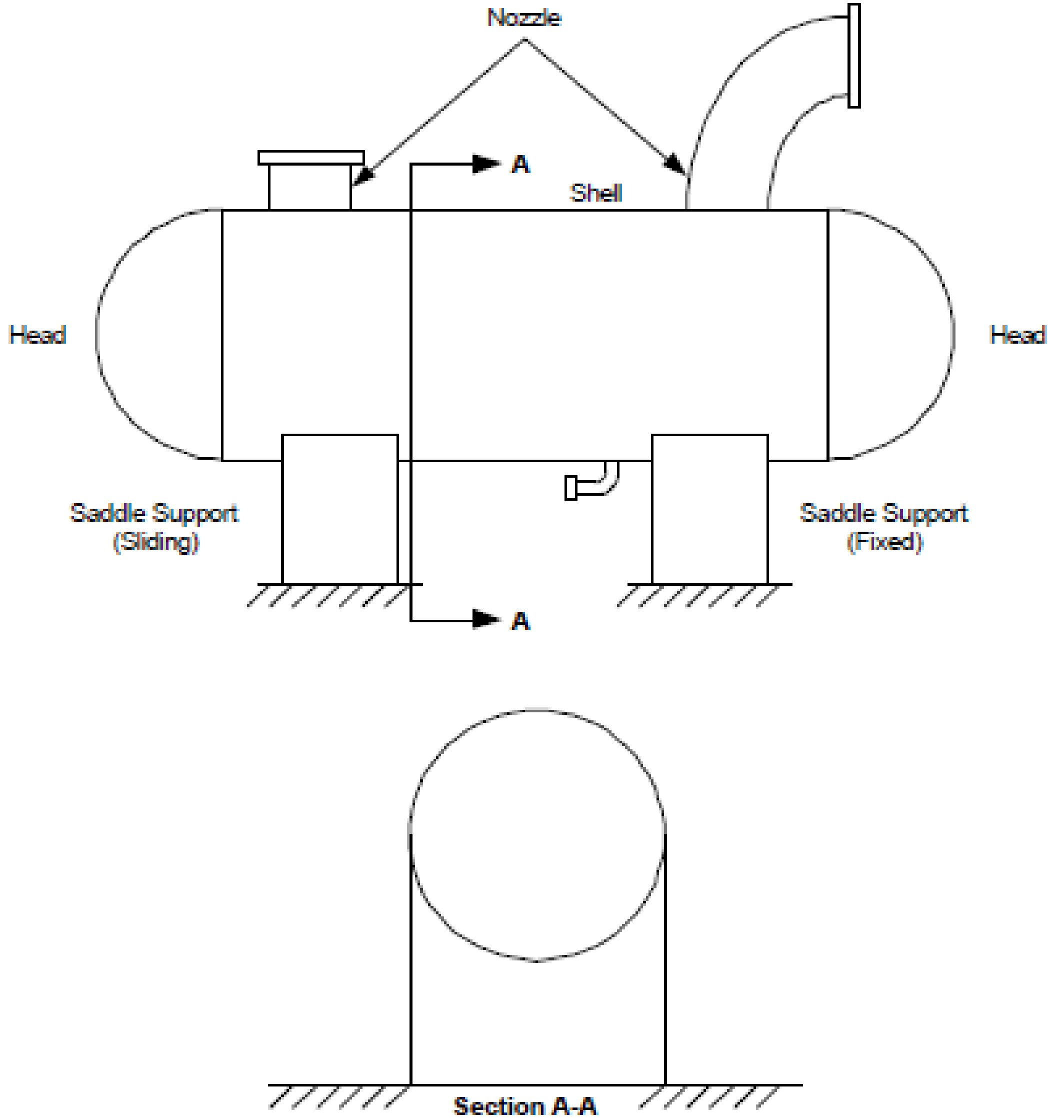


Table 8 Dimensions of Class 150 Flanges

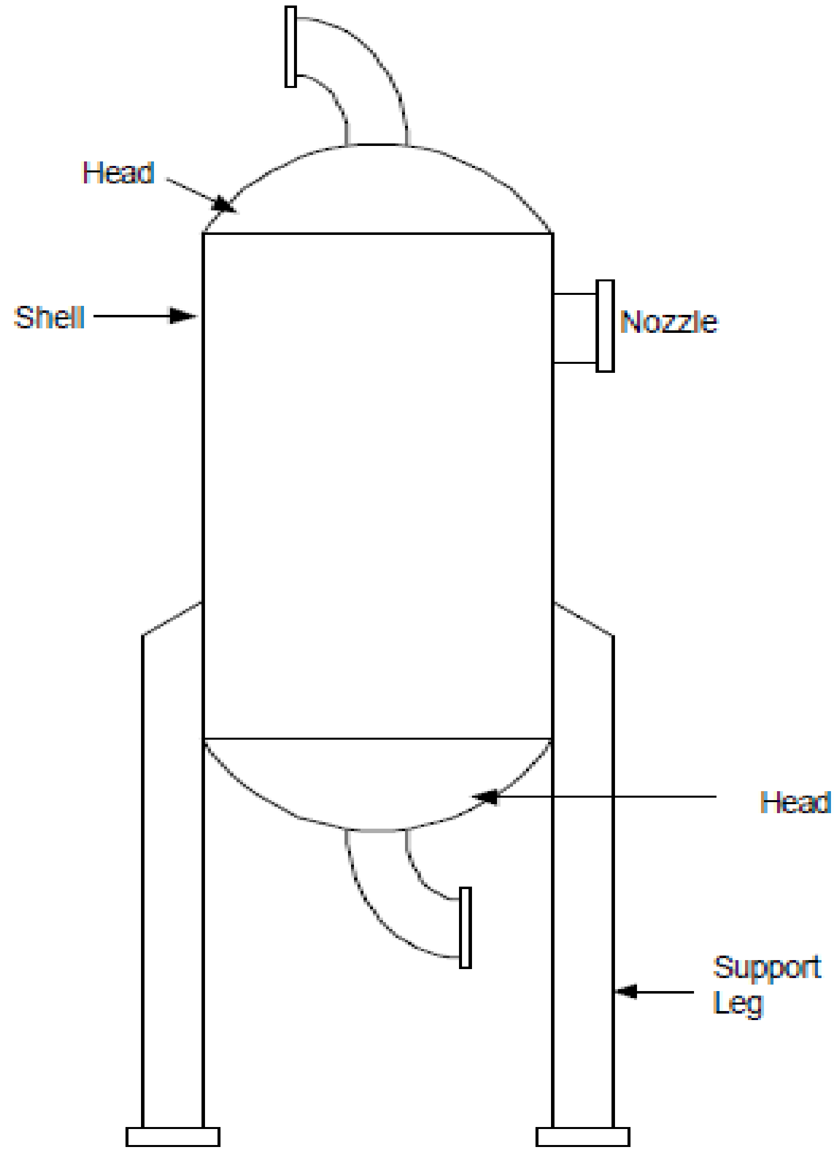


Sample Problem 4

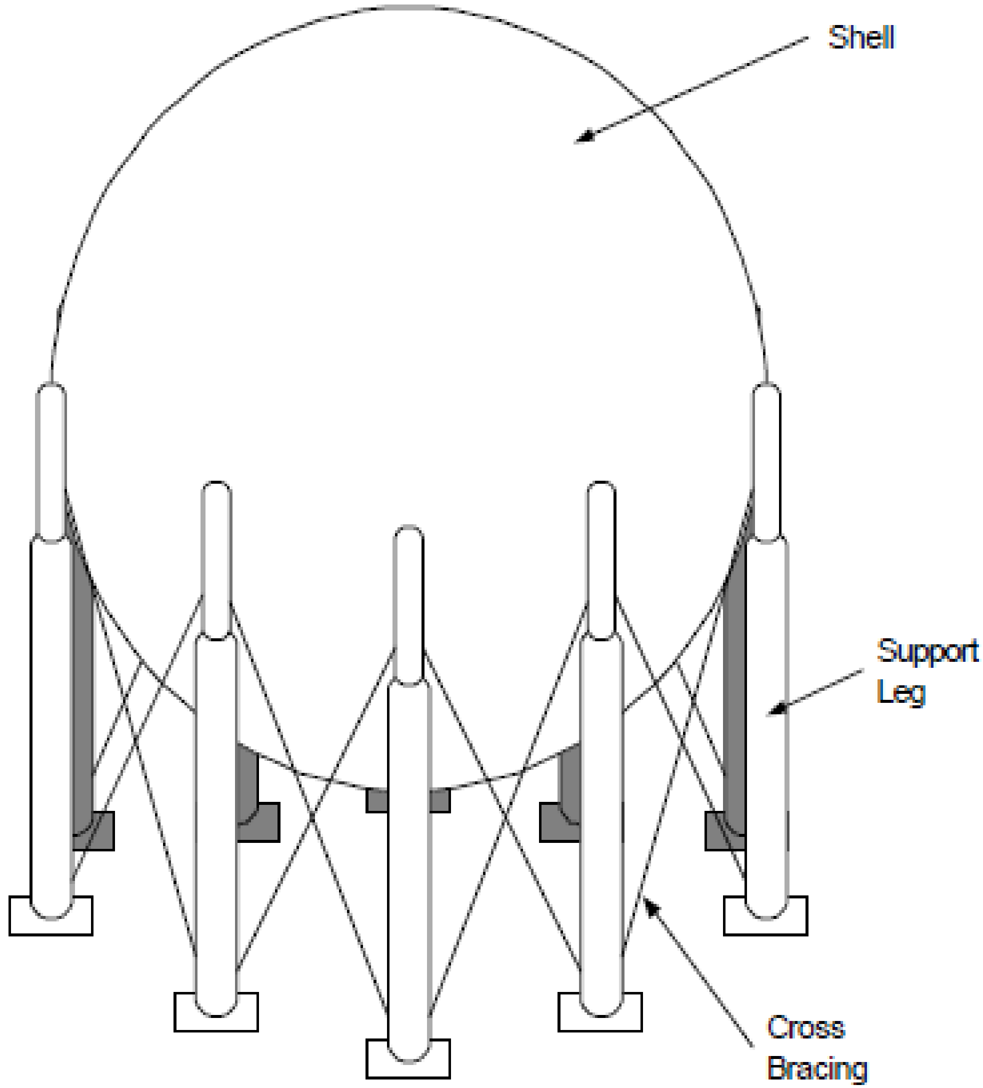
- Determine Required Flange Rating
- Pressure Vessel Data:
- Shell and Heads: SA-516 Gr.70
- Flanges: SA-105
- Design Temperature: 375°C
- Design Pressure: 19 bar



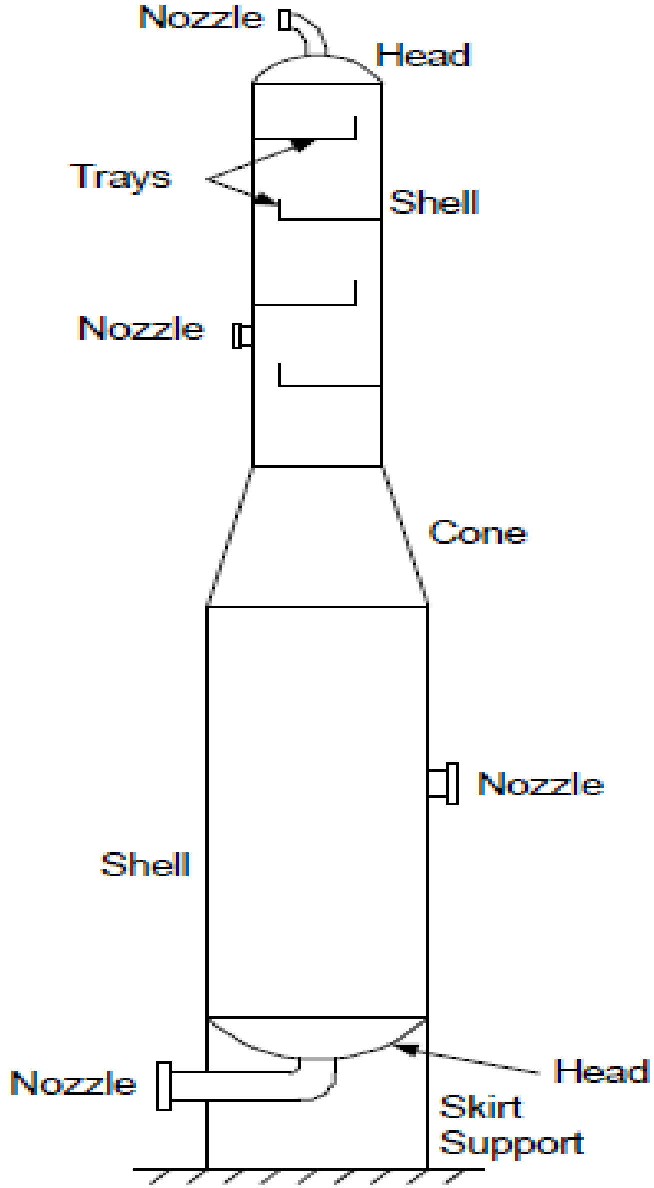
Horizontal Drum on Saddle Supports



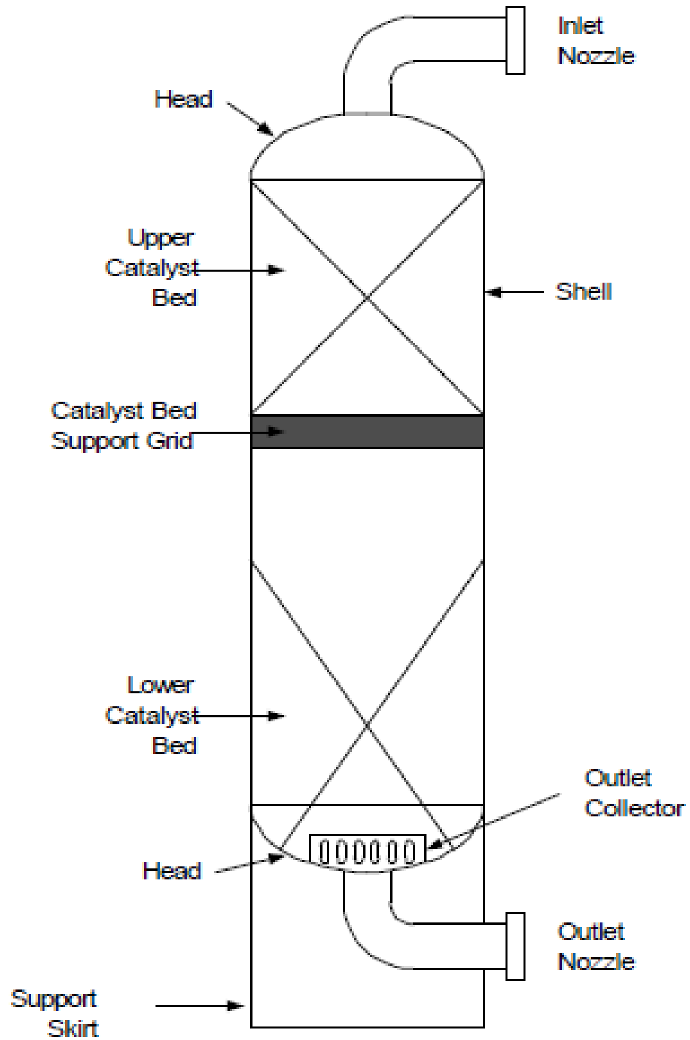
Vertical Drum on Leg Supports



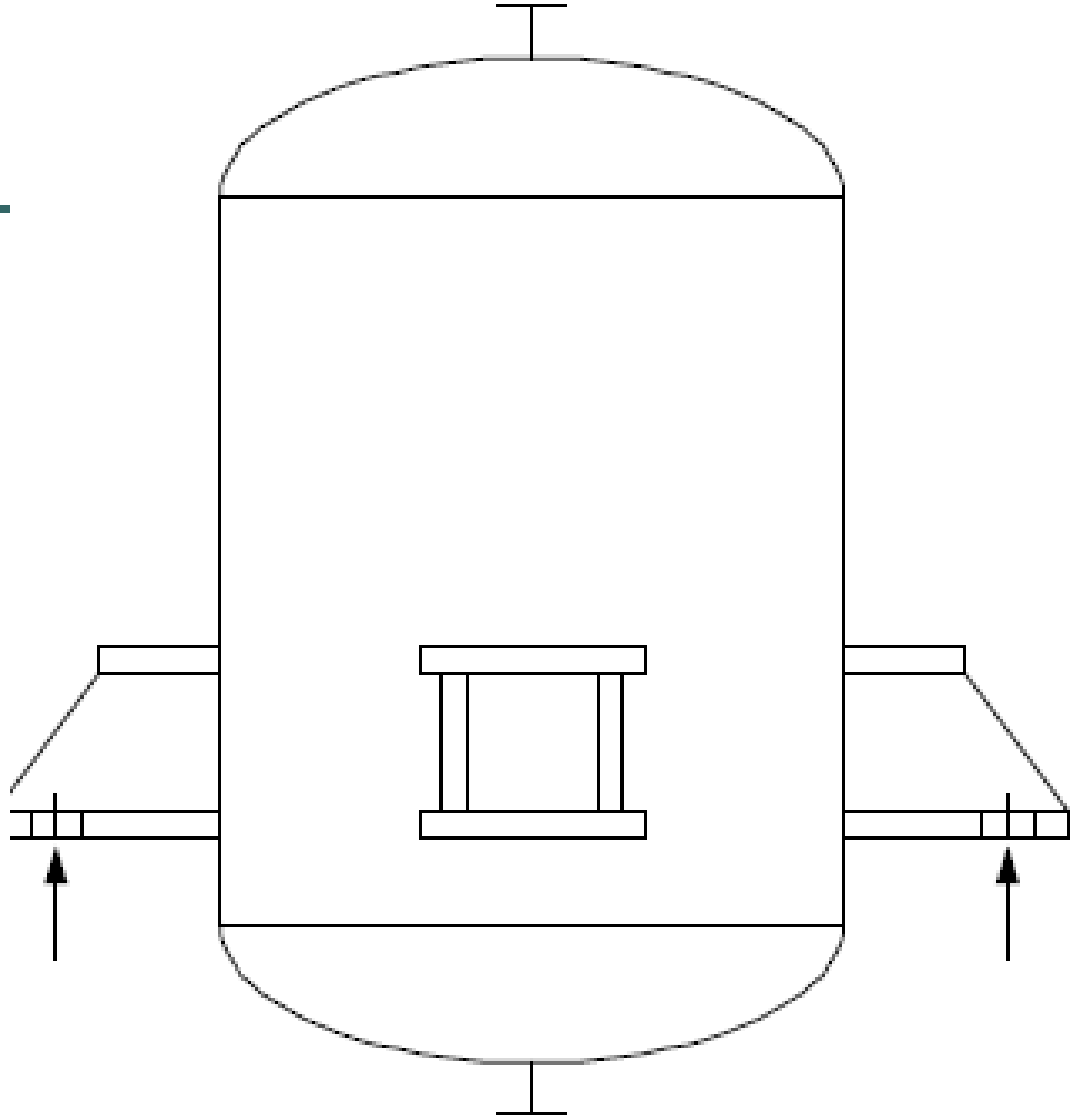
Spherical Pressurized Storage Vessel



Tall Vertical Tower



Vertical Reactor



Vertical Vessel on Lug Supports

Fabrication

- Head Forming

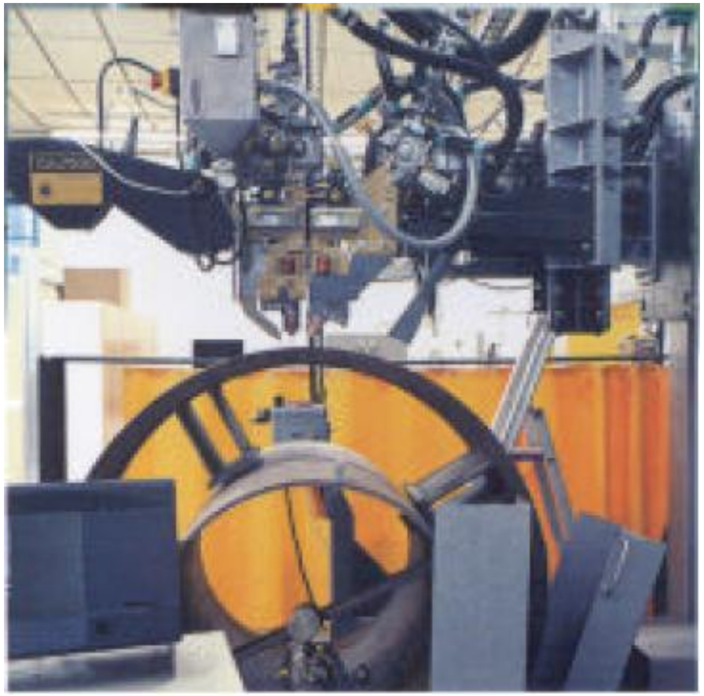
Fabrication

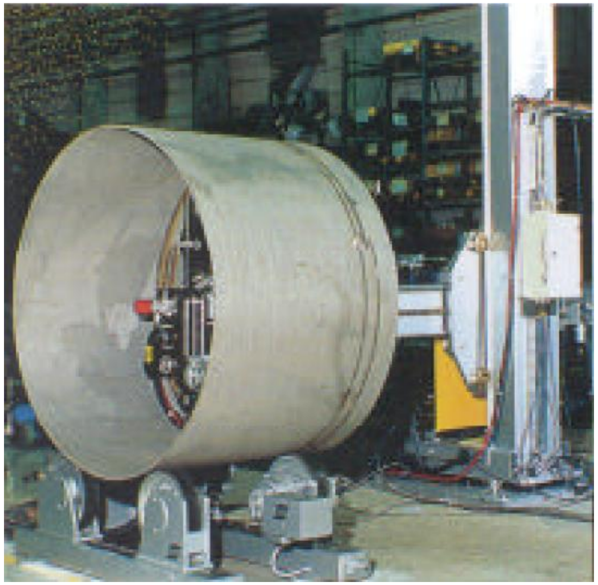
- Shell Forming

- Dimension control with meter

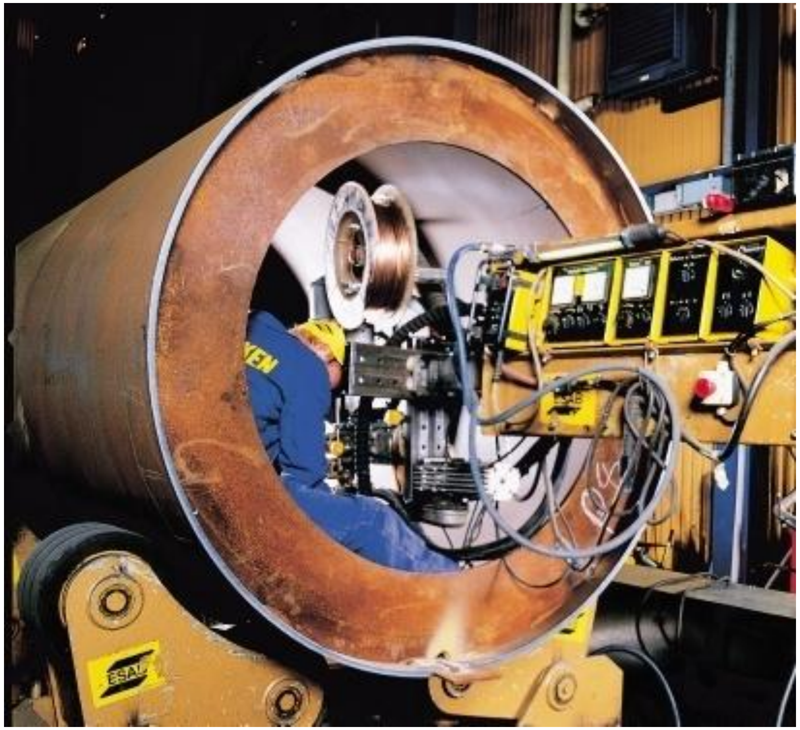
Fabrication

- Welding of shell sections
- Fixing with fixture



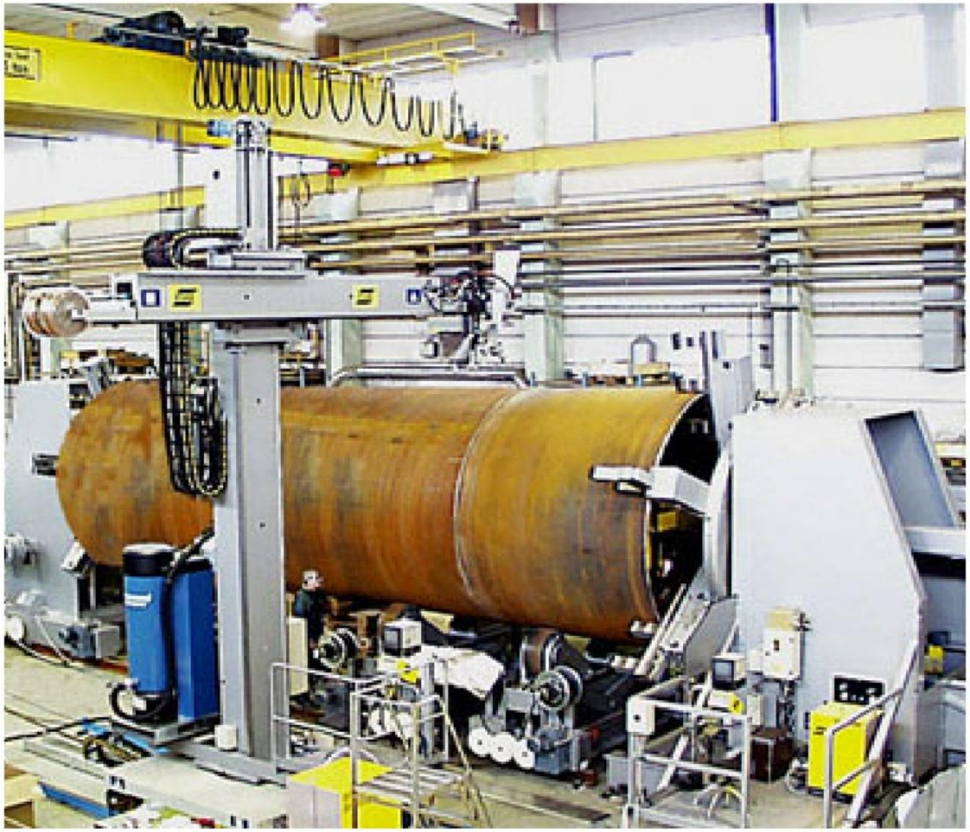


Fabrication



Fabrication

- Shell sections assembling
- Welding
- Back gouging
- Back weld
- PT



Fabrication

- Head to shell attachment
- Welding
- Back gouging
- Back weld
- PT

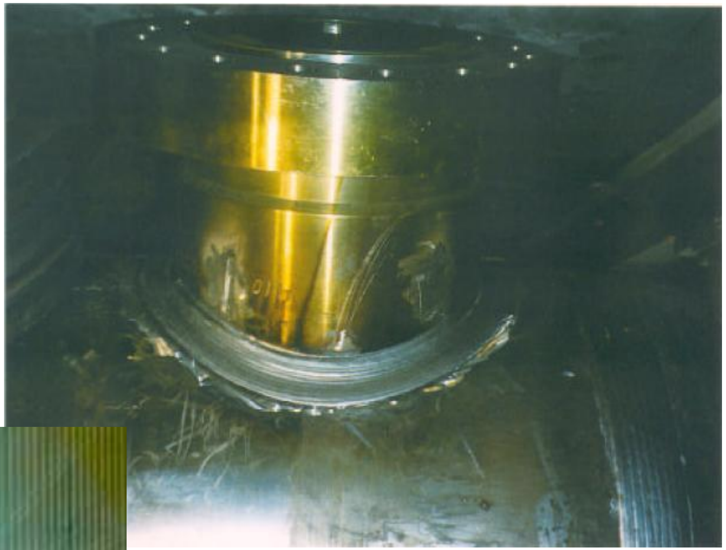
Fabrication

- Head to shell attachment
- Welding
- Back gouging
- Back weld
- PT

Fabrication

- Welding of nozzles sections
- 9) Flange to nozzle welding
- 10) Nozzle place cutting in shell
- Oxygen cutting
- Grinding

Fabrication



- Nozzle to shell assembling
- 12) Nozzle to shell welding
- Welding
- Back gouging
- Back weld
- PT

Fabrication

Fabrication

- Transferring the vessel to the site