(2) the room temperature ratio of the specified minimum yield strength to specified minimum tensile strength for the material does not exceed 0.7;

(3) the value for S_Y at temperature can be obtained from Table Y-1 of Section II, Part D.

UG-24 CASTINGS

(a) Quality Factors. A casting quality factor as specified below shall be applied to the allowable stress values for cast materials given in Subsection C except for castings permitted by Part UCI. At a welded joint in a casting, only the lesser of the casting quality factor or the weld joint efficiency specified in UW-12 applies, but not both. NDE methods and acceptance standards are given in Appendix 7.

(1) A factor not to exceed 80% shall be applied to static castings that are examined in accordance with the minimum requirements of the material specification. In addition to the minimum requirements of the material specification, all surfaces of centrifugal castings shall be machined after heat treatment to a finish not coarser than 250 μin. (6.3 μm) arithmetical average deviation, and a factor not to exceed 85% shall be applied.

(2) For nonferrous and ductile cast iron materials, a factor not to exceed 90% shall be applied if in addition to the minimum requirements of UG-24(a)(1):

(a) each casting is subjected to a thorough examination of all surfaces, particularly such as are exposed by machining or drilling, without revealing any defects;

(b) at least three pilot castings[13] representing the first lot of five castings made from a new or altered design are sectioned or radiographed at all critical sections (see footnote 1, Appendix 7) without revealing any defects;

(c) one additional casting taken at random from every subsequent lot of five is sectioned or radiographed at all critical sections without revealing any defects; and

(d) all castings other than those that have been radiographed are examined at all critical sections by the magnetic particle or liquid penetrant methods in accordance with the requirements of Appendix 7.

(3) For nonferrous and ductile cast iron materials, a factor not to exceed 90% may be used for a single casting that has been radiographed at all critical sections and found free of defects.

(4) For nonferrous and ductile cast iron materials, a factor not to exceed 90% may be used for a casting that has been machined to the extent that all critical sections are exposed for examination for the full wall thickness; as in tubesheets drilled with holes spaced no farther apart than the wall thickness of the casting. The examination afforded may be taken in lieu of destructive or radiographic testing required in (2)(b) above.

(5) For carbon, low alloy, or high alloy steels, higher quality factors may be applied if in addition to the minimum requirements of (a)(1) above, additional examinations are made as follows.

(a) For centrifugal castings, a factor not to exceed 90% may be applied if the castings are examined by the magnetic particle or liquid penetrant methods in accordance with the requirements of Appendix 7.

(b) For static and centrifugal castings a factor not to exceed 100% may be applied if the castings are examined in accordance with all of the requirements of Appendix 7.

(6) The following additional requirements apply when castings (including those permitted in UG-11) are to be used in vessels to contain lethal substances (UW-2).

(a) Castings of cast iron (UCI-2) and cast ductile iron (UCD-2) are prohibited.

(b) Each casting of nonferrous material permitted by this Division shall be radiographed at all critical sections (see footnote 1, Appendix 7) without revealing any defects. The quality factor for nonferrous castings for lethal service shall not exceed 90%.

(c) Each casting of steel material permitted by this Division shall be examined per Appendix 7 for severe service applications [7-3(b)]. The quality factor for lethal service shall not exceed 100%.

(b) Defects. Imperfections defined as unacceptable by either the material specification or by Appendix 7, 7-3, whichever is more restrictive, are considered to be defects and shall be the basis for rejection of the casting. Where defects have been repaired by welding, the completed repair shall be subject to reexamination and, when required by either the rules of this Division or the requirements of the castings specification, the repaired casting shall be postweld heat treated and, to obtain a 90% or 100% quality factor, the repaired casting shall be stress relieved.

(c) Identification and Marking. Each casting to which a quality factor greater than 80% is applied shall be marked with the name, trademark, or other traceable identification of the manufacturer and the casting identification, including the casting quality factor and the material designation.

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. Where corrosion allowances are not provided, this fact shall be indicated on the Data Report.

(b) Vessels or parts of vessels subject to thinning by corrosion, erosion, or mechanical abrasion shall have provision made for the desired life of the vessel by a suitable

[13] *Pilot casting* — Any one casting, usually one of the first from a new pattern, poured of the same material and using the identical foundry procedure (risering, gating, pouring, and melting) as the castings it is intended to represent. Any pilot casting or castings taken to represent a lot and the castings of that lot shall be poured from a heat of metal from which the castings on the current order are poured.

increase in the thickness of the material over that determined by the design formulas, or by using some other suitable method of protection. (See Appendix E.)

NOTE: When using high alloys and nonferrous materials either for solid wall or clad or lined vessels, refer to UHA-6, UCL-3, and UNF-4, as appropriate.

(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. Telltale holes may be used to provide some positive indication when the thickness has been reduced to a dangerous degree. Telltale holes shall not be used in vessels that are to contain lethal substances [see UW-2(a)], except as permitted by ULW-76 for vent holes in layered construction. When telltale holes are provided, they shall have a diameter of $\frac{1}{16}$ in. to $\frac{3}{16}$ in. (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. These holes shall be provided in the opposite surface to that where deterioration is expected. [For telltale holes in clad or lined vessels, see UCL-25(b).]

(f) Openings for Drain. Vessels subject to corrosion shall be supplied with a suitable drain opening at the lowest point practicable in the vessel; or a pipe may be used extending inward from any other location to within $\frac{1}{4}$ in. (6 mm) of the lowest point.

UG-26 LININGS

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 (see Appendix F).

UG-27 THICKNESS OF SHELLS UNDER INTERNAL PRESSURE

(a) The minimum required thickness of shells under internal pressure shall not be less than that computed by the following formulas,[14] except as permitted by Appendix 1 or 32. In addition, provision shall be made for any of the loadings listed in UG-22, when such loadings are expected. The provided thickness of the shells shall also meet the requirements of UG-16, except as permitted in Appendix 32.

(b) The symbols defined below are used in the formulas of this paragraph.

E = joint efficiency for, or the efficiency of, appropriate joint in cylindrical or spherical shells, or the efficiency of ligaments between openings, whichever is less.
For welded vessels, use the efficiency specified in UW-12.
For ligaments between openings, use the efficiency calculated by the rules given in UG-53.

P = internal design pressure (see UG-21)

R = inside radius of the shell course under consideration,[15]

S = maximum allowable stress value (see UG-23 and the stress limitations specified in UG-24)

t = minimum required thickness of shell

(c) Cylindrical Shells. The minimum thickness or maximum allowable working pressure of cylindrical shells shall be the greater thickness or lesser pressure as given by (1) or (2) below.

(1) 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:

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

(2) Longitudinal Stress (Circumferential Joints).[16] When the thickness does not exceed one-half of the inside radius, or P does not exceed $1.25SE$, the following formulas shall apply:

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

(d) 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:

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

(e) When necessary, vessels shall be provided with stiffeners or other additional means of support to prevent overstress or large distortions under the external loadings listed in UG-22 other than pressure and temperature.

[14] Formulas in terms of the outside radius and for thicknesses and pressures beyond the limits fixed in this paragraph are given in 1-1 to 1-3.

[15] For pipe, the inside radius R is determined by the nominal outside radius minus the nominal wall thickness.

[16] These formulas will govern only when the circumferential joint efficiency is less than one-half the longitudinal joint efficiency, or when the effect of supplementary loadings (UG-22) causing longitudinal bending or tension in conjunction with internal pressure is being investigated. An example illustrating this investigation is given in L-2.1 and L-2.2.

Appendices

APPENDIX A

GUIDE TO ASME SECTION VIII, DIVISION 1

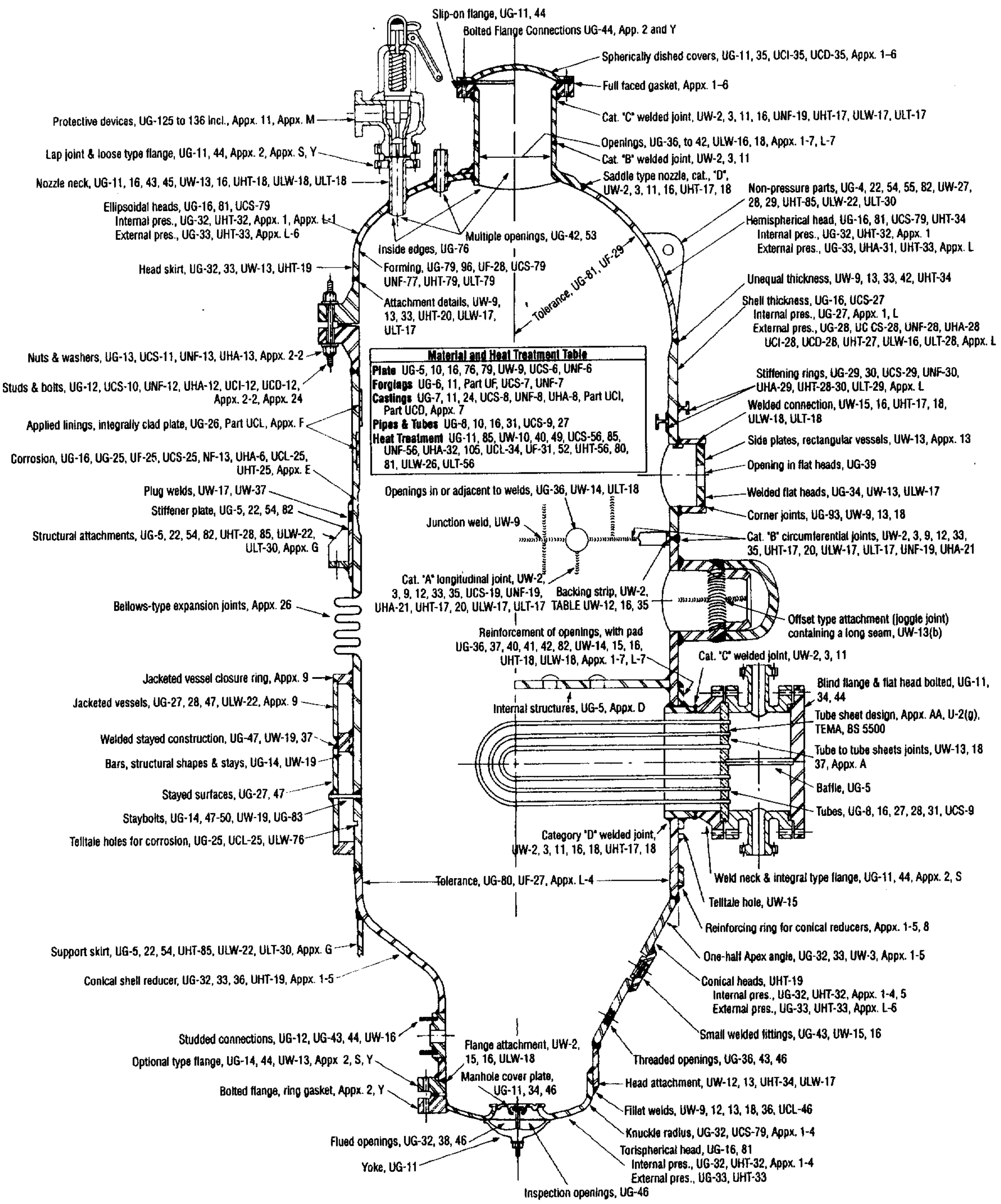


Figure continued on next page

2. Types of service
   a. Manways
   b. Inspection openings
   c. PSV
   e. Instrument connections
   d. Vents
   f. Drains
   g. Process connections

Flanges

1. Types
   a. Slip on
   b. Weld neck, long weld neck
   c. Lap joint
   d. Blind
   e. Screwed
   f. Plate flanges
   g. Studding outlets
   h. Reverse-type flange
   i. Reducing flange
   j. Graylock hub connector
   k. Socket weld
2. Flange Facing
   a. Flat face
   b. Raised face
   c. Finish (smooth, standard, serrated)
   d. Ring joint
   e. Tongue and groove
   f. Male and female

Gaskets

1. Types
   a. Ring, nonasbestos sheet
   b. Flat metal
   c. Spiral wound
   d. Metal jacketed
   e. Corrugated metal
   f. Rings (hexagonal or oval)
   g. Yielding metal gaskets (lens ring, delta ring, rectangular ring)
   h. Elastomeric (rubber, cork, etc.)

Internals

1. Types
   a. Trays, seal pans
   b. Piping distributors
   c. Baffles
   d. Demisters
   e. Packing
   f. Liquid distributors
   g. Vortex breakers
   h. Bed supports
   i. Coils

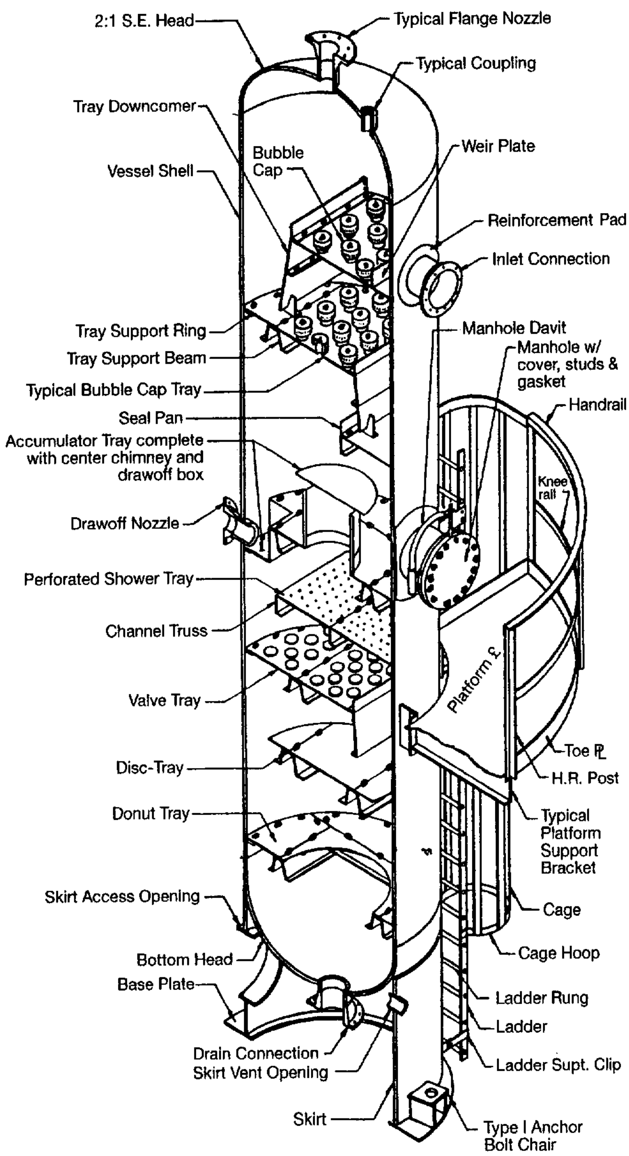
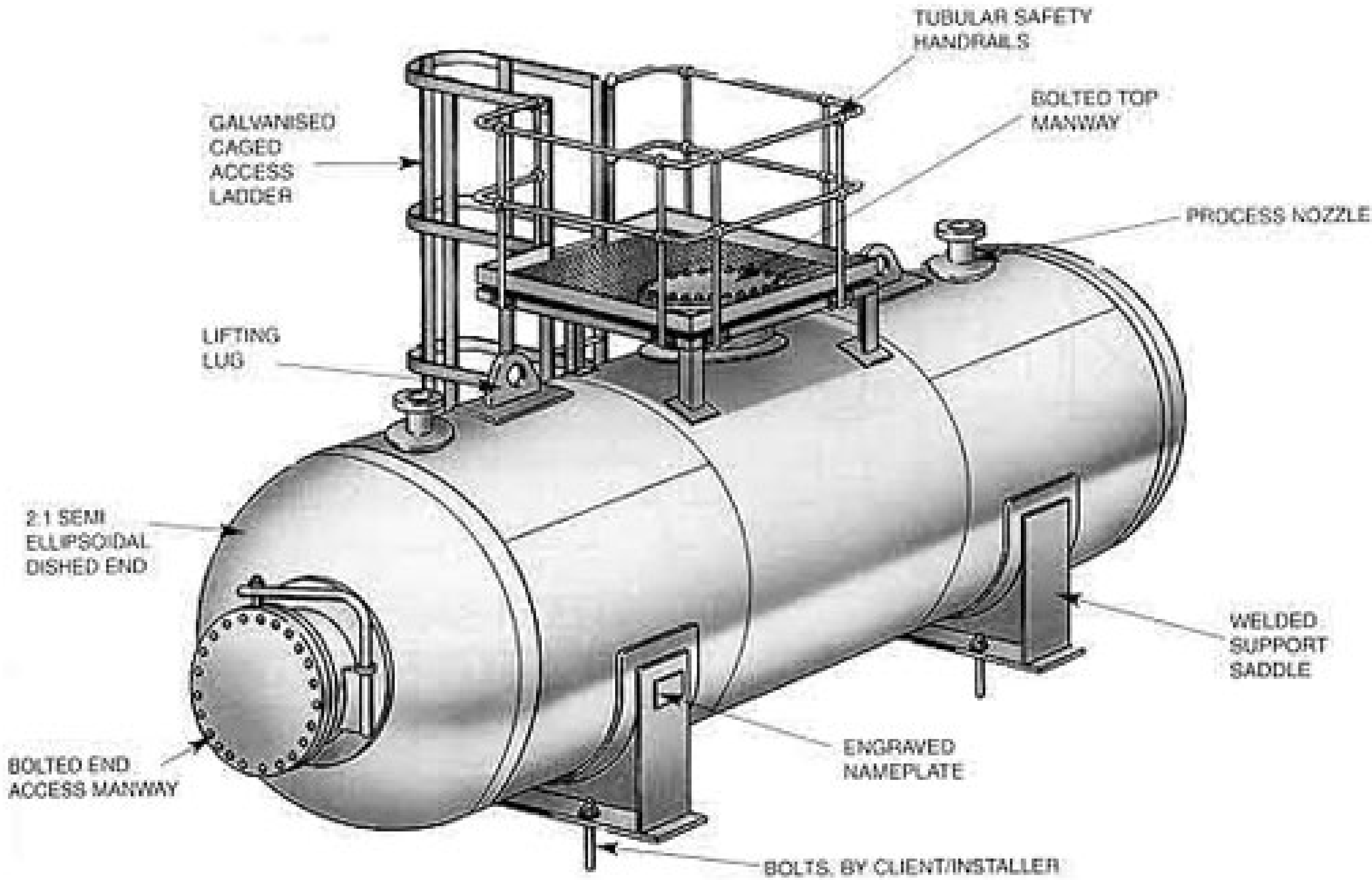


Figure F-1. Typical trayed column.



TUBULAR SAFETY
HANDRAILS
GALVANISED
CAGED
ACCESS
LADDER
BOLTED TOP
MANWAY
PROCESS NOZZLE
LIFTING
LUG
2:1 SEMI
ELLIPSOIDAL
DISHED END
WELDED
SUPPORT
SADDLE
ENGRAVED
NAMEPLATE
BOLTED END
ACCESS MANWAY
BOLTS, BY CLIENT/INSTALLER

APPENDIX H

MATERIAL SELECTION GUIDE

<table>
<tr><th colspan="2">Design Temperature, °F</th><th>Material</th><th>Plate</th><th>Pipe</th><th>Forgings</th><th>Fittings</th><th>Bolting</th></tr>
<tr><td rowspan="2">Cryogenic</td><td>−425 to −321</td><td>Stainless steel</td><td>SA-240-304, 304L, 347, 316, 316L</td><td>SA-312-304, 304L, 347, 316, 316L</td><td>SA-182-304, 304L, 347, 316, 316L</td><td>SA-403-304, 304L, 347, 316, 316L</td><td rowspan="2">SA-320-B8 with SA-194-8</td></tr>
<tr><td>−320 to −151</td><td>9 nickel</td><td>SA-353</td><td>SA-333-8</td><td>SA-522-1</td><td>SA-420-WPL8</td></tr>
<tr><td rowspan="5">Low temperature</td><td>−150 to −76</td><td>3½ nickel</td><td>SA-203-D</td><td rowspan="2">SA-333-3</td><td rowspan="2">SA-350-LF63</td><td rowspan="2">SA-420-WPL3</td><td rowspan="3">SA-320-L7 with SA-194-4</td></tr>
<tr><td>−75 to −51</td><td>2½ nickel</td><td>SA-203-A</td></tr>
<tr><td>−50 to −21</td><td rowspan="4">Carbon steel</td><td>SA-516-55, 60 to SA-20</td><td>SA-333-6</td><td rowspan="2">SA-350-LF2</td><td rowspan="2">SA-420-WPL6</td></tr>
<tr><td>−20 to 4</td><td>SA-516-All</td><td>SA-333-1 or 6</td><td rowspan="6">SA-193-B7 with SA-194-2H</td></tr>
<tr><td>5 to 32</td><td>SA-285-C</td><td rowspan="2">SA-53-B
SA-106-B</td><td rowspan="2">SA-105
SA-181-60,70</td><td rowspan="2">SA-234-WPB</td></tr>
<tr><td>Intermediate</td><td>33 to 60
61 to 775</td><td>SA-516-All
SA-515-All
SA-455-II</td></tr>
<tr><td rowspan="7">Elevated Temperature</td><td>776 to 875</td><td>C-½Mo</td><td>SA-204-B</td><td>SA-335-P1</td><td>SA-182-F1</td><td>SA-234-WP1</td></tr>
<tr><td rowspan="2">876 to 1000</td><td>1Cr-½Mo</td><td>SA-387-12-1</td><td>SA-335-P12</td><td>SA-182-F12</td><td>SA-234-WP12</td></tr>
<tr><td>1Cr-½Mo</td><td>SA-387-11-2</td><td>SA-335-P11</td><td>SA-182-F11</td><td>SA-234-WP11</td></tr>
<tr><td>1001 to 1100</td><td>2¼Cr-1Mo</td><td>SA-387-22-1</td><td>SA-335-P22</td><td>SA-182-F22</td><td>SA-234-WP22</td><td>with SA-193-B5 SA-194-3</td></tr>
<tr><td rowspan="2">1101 to 1500</td><td>Stainless steel</td><td>SA-240-347H</td><td>SA-312-347H</td><td>SA-182-347H</td><td>SA-403-347H</td><td rowspan="3">SA-193-BB with SA-194-B</td></tr>
<tr><td>Incoloy</td><td>SB-424</td><td>SB-423</td><td>SB-425</td><td>SB-366</td></tr>
<tr><td>Above 1500</td><td>Inconel</td><td>SB-443</td><td>SB-444</td><td>SB-446</td><td>SB-366</td></tr>
</table>

From Bednar, H.H., *Pressure Vessel Design Handbook*, Van Nostrand Reinhold Co., 1981.

Table J-2
Values of Yield Strength, ksi

Material	Temp									
	100°	200°	300°	400°	500°	600°	700°	800°	900°	1000°
SA-285c, SA-516-55	30	27.4	26.6	25.7	24.3	22.2	21.6	20.0	19.1	16.7
SA-516-60	32	29.2	28.4	27.5	26	23.7	23.1	21.3	20.3	17.8
SA-516-65	35	31.9	31	30	28.3	25.9	25.2	23.3	22.2	19.5
SA-105	36	32.9	31.9	30.9	29.2	26.6	26	24.0	22.9	20.1
SA-516-70	38	34.7	33.7	32.6	30.8	28.1	27.4	25.3	24.1	21.2
SA-204-B (C – ½Mo)	40	37.6	36.1	34.8	33.8	32.7	31.5	30.0	27.9	25.2
SA-302-B (Mn – Mo)	50	47.2	45.3	44.5	43.2	42.0	40.6	38.8	34.9	28.4
SA-387-2-2 (½Cr – Mo)	–	–	–	–	–	–	–	–	–	–
SA-387-12-2 (1Cr – ½Mo)	40	36.9	35.1	33.7	32.5	31.4	30.2	28.8	27.2	25.0
SA-387-11-2 (1¼Cr – ½Mo)	45	41.5	39.5	37.9	36.5	35.3	34.0	32.4	30.6	28.2
SA-387-22-2 (2¼Cr – 1Mo)	45	41.3	39.2	38.3	37.2	36.5	35.6	34.3	32.5	29.7
T-405 (13Cr)	25	23.0	22.2	21.8	21.5	21.1	20.2	18.9	16.9	14.4
T-410/T-430 (13/17Cr)	30	27.6	26.6	26.1	25.8	25.3	24.2	22.7	20.3	17.2
T-304 SST	30	25.1	22.5	20.8	19.4	18.3	17.7	16.9	16.3	15.6
T-304L SST	25	21.4	19.2	17.5	16.4	15.5	14.9	14.5	14.0	13.3
T-316 SST	30	25.9	23.4	21.4	20.0	18.9	18.1	17.6	17.3	17.0
T-321 SST	30	25.5	22.7	20.7	19.2	18.2	17.6	17.2	17.0	16.8
T-347 SST	30	27.6	25.7	24.0	22.5	21.5	20.7	20.4	20.2	20.1
SA-203-B (2½ Ni)	40	–	–	–	–	–	–	–	–	–
SA-203-D (3½ Ni)	37	–	–	–	–	–	–	–	–	–
Nickel 200	15	15	15	15	15	15	–	–	–	–
Monel 400	28	24.7	22.4	22.2	22.2	22.2	22.2	21.4	–	–
Inconel 600	35	32.7	31.0	29.9	28.8	27.9	27	26.1	–	–
Incoloy 800	30	27.6	26.0	25.0	24.1	23.9	23.5	23.0	–	–

Source: ASME Section VIII, Div. 2.

Table 2-1
General Vessel Formulas

Part	Stress Formula	Thickness, t		Pressure, P		Stress, S	
		I.D.	O.D.	I.D.	O.D.	I.D.	O.D.
Shell							
Longitudinal [1, Section UG-27(c)(2)]	$\sigma_x = \frac{PR_m}{0.2t}$	$\frac{PR_i}{2SE+0.4P}$	$\frac{PR_o}{2SE+1.4P}$	$\frac{2SEt}{R_i-0.4t}$	$\frac{2SEt}{R_o-1.4t}$	$\frac{P(R_i-0.4t)}{2Et}$	$\frac{P(R_o-1.4t)}{2Et}$
Circumferential [1, Section UG-27(c)(1); Section 1-1(a)(1)]	$\sigma_\phi = \frac{PR_m}{t}$	$\frac{PR_i}{SE-0.6P}$	$\frac{PR_o}{SE+0.4P}$	$\frac{SEt}{R_i+0.6t}$	$\frac{SEt}{R_o-0.4t}$	$\frac{P(R_i+0.6t)}{Et}$	$\frac{P(R_o-0.4t)}{Et}$
Heads							
Hemi sphere [1, Section 1-1(a)(2); Section UG-27(d)]	$\sigma_x = \sigma_\phi = \frac{PR_m}{2t}$	$\frac{PR_i}{2SE-0.2P}$	$\frac{PR_o}{2SE+0.8P}$	$\frac{2SEt}{R_i+0.2t}$	$\frac{2SEt}{R_o-0.8t}$	$\frac{P(R_i+0.2t)}{2Et}$	$\frac{P(R_o-0.8t)}{2Et}$
Ellipsoidal [1, Section 1-4(c)]	See Procedure 2-2	$\frac{PD_iK}{2SE-0.2P}$	$\frac{PD_oK}{2SE+2P(K-0.1)}$	$\frac{2SEt}{KD_i+0.2t}$	$\frac{2SEt}{KD_o-2t(K-0.1)}$	See Procedure 2-2	
2:1 S.E. [1, Section UG-32(d)]	"	$\frac{PD_i}{2SE-0.2P}$	$\frac{PD_o}{2SE+1.8P}$	$\frac{2SEt}{D_i+0.2t}$	$\frac{2SEt}{D_o-1.8t}$	"	
100%–6% Torispherical [1, Section UG-32(e)]	"	$\frac{0.885PL_i}{SE-0.1P}$	$\frac{0.885PL_o}{SE+0.8P}$	$\frac{SEt}{0.885L_i+0.1t}$	$\frac{SEt}{0.885L_o-0.8t}$	"	
Torispherical L/r < 16.66 [1, Section 1-4(d)]	"	$\frac{PL_iM}{2SE-0.2P}$	$\frac{PL_oM}{2SE+P(M-0.2)}$	$\frac{2SEt}{L_iM+0.2t}$	$\frac{2SEt}{L_oM-t(M-0.2)}$	"	
Cone							
Longitudinal	$\sigma_x = \frac{PR_m}{2t\cos\alpha}$	$\frac{PD_i}{4\cos\alpha\,(SE+0.4P)}$	$\frac{PD_o}{4\cos\alpha\,(SE+1.4P)}$	$\frac{4SEt\cos\alpha}{D_i-0.8t\cos\alpha}$	$\frac{4SEt\cos\alpha}{D_o-2.8t\cos\alpha}$	$\frac{P(D_i-0.8t\cos\alpha)}{4Et\cos\alpha}$	$\frac{P(D_o-2.8t\cos\alpha)}{4Et\cos\alpha}$
Circumferential [1, Section 1-4(e); Section UG-32(g)]	$\sigma_\phi = \frac{PR_m}{t\cos\alpha}$	$\frac{PD_i}{2\cos\alpha\,(SE-0.6P)}$	$\frac{PD_o}{2\cos\alpha\,(SE+0.4P)}$	$\frac{2SEt\cos\alpha}{D_i+1.2t\cos\alpha}$	$\frac{2SEt\cos\alpha}{D_o-0.8t\cos\alpha}$	$\frac{P(D_i+1.2t\cos\alpha)}{2Et\cos\alpha}$	$\frac{P(D_o-0.8t\cos\alpha)}{2Et\cos\alpha}$

Step 7: The horizontal seismic force, F_h, will then be equal to $V - F_t$. This will be applied to the vessel in accordance with one of the appropriate procedures contained in this chapter.

Step 8: If the procedure is based on a horizontal seismic factor, C_h, this factor shall be as follows:

$$C_h = \frac{V}{W_o}$$

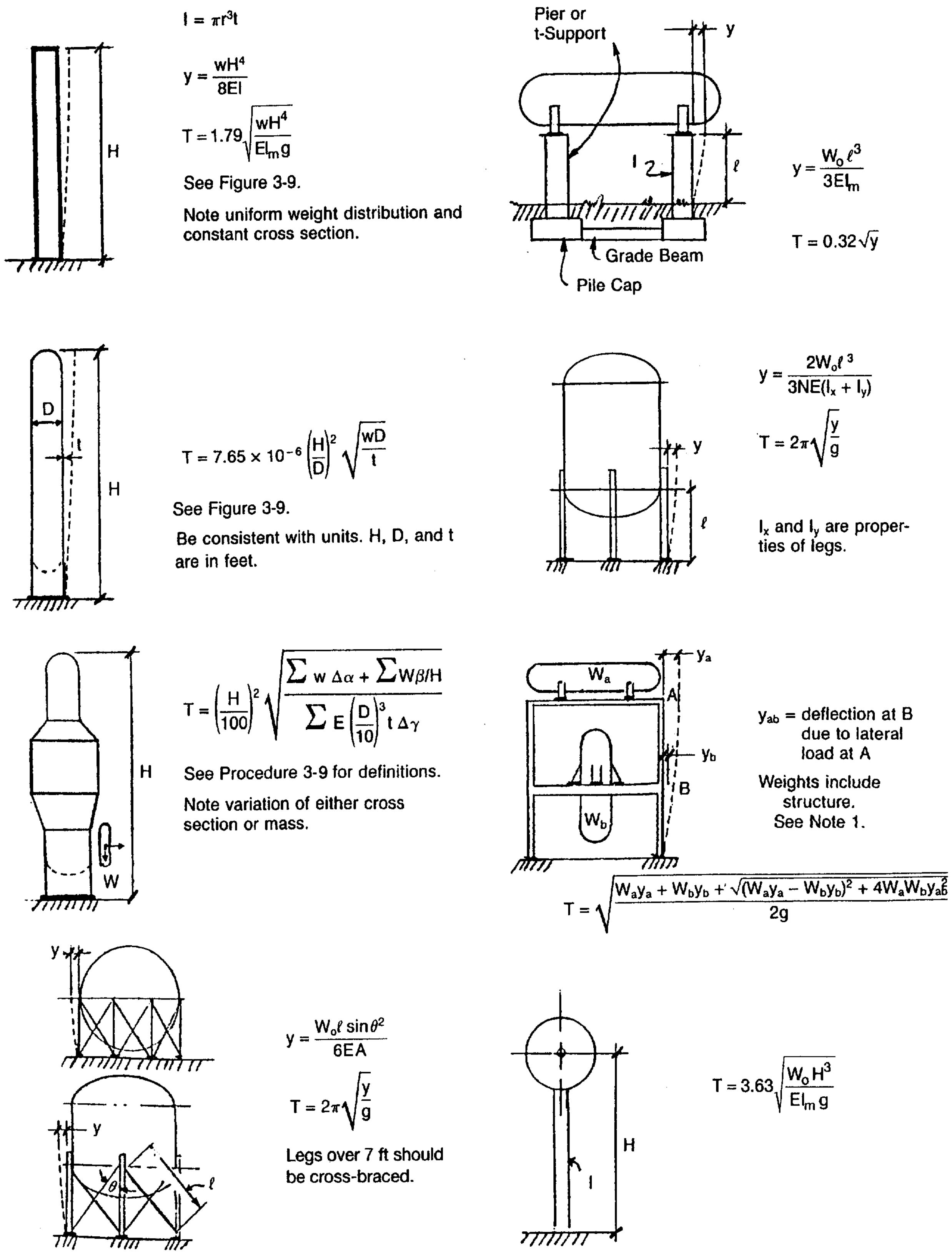


Figure 3-7. Formulas for period of vibration, T, and deflection, y.

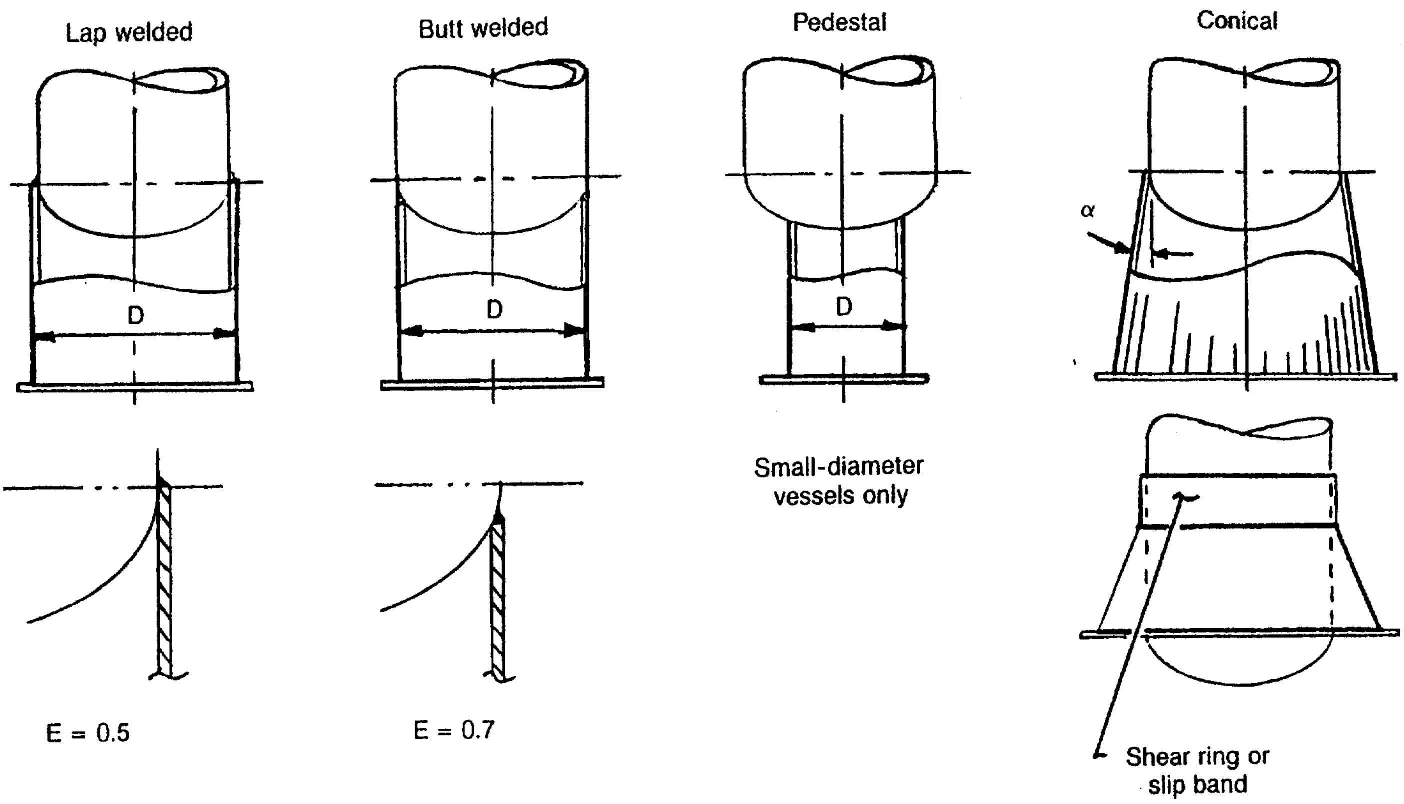


Figure 3-69. Skirt types.

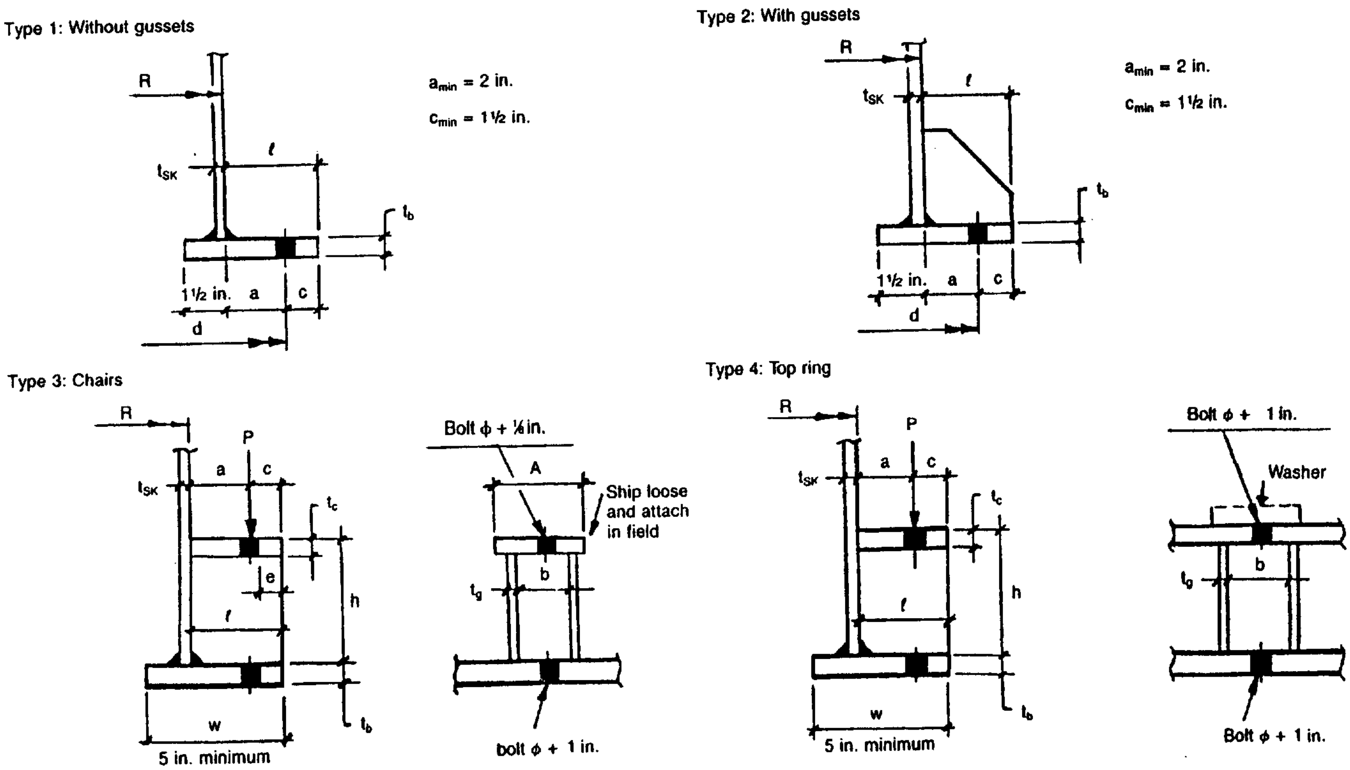
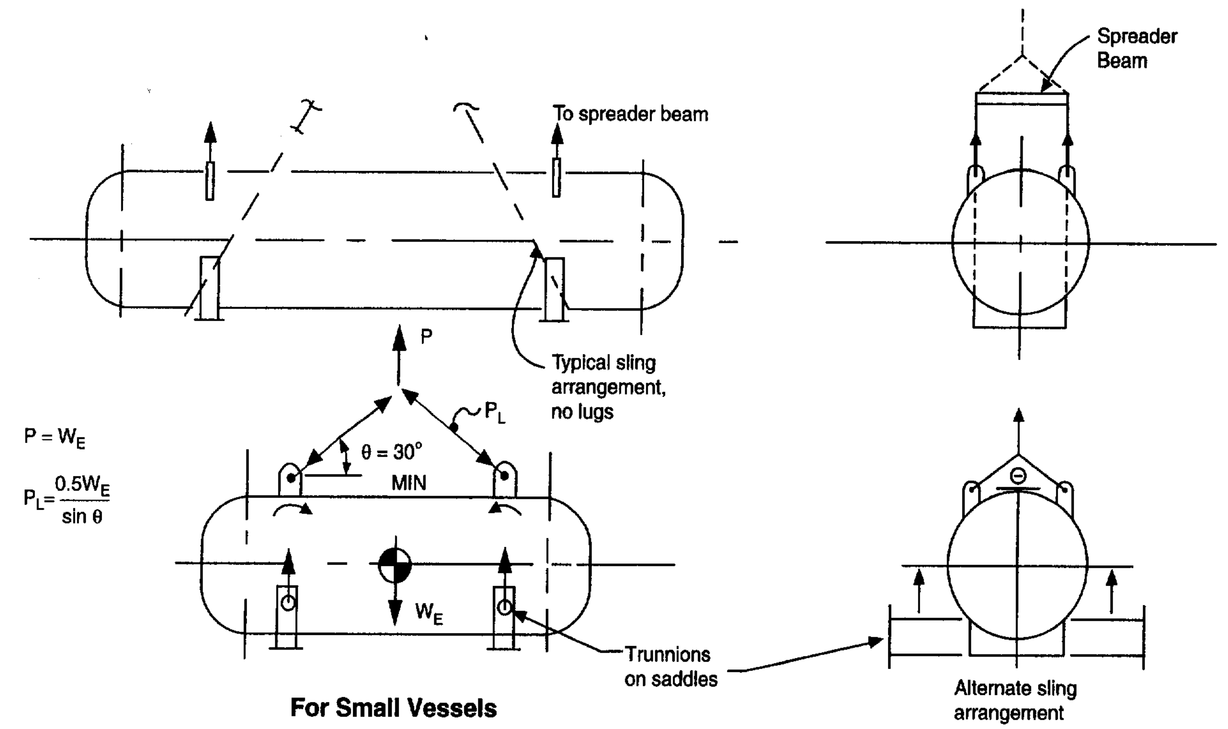
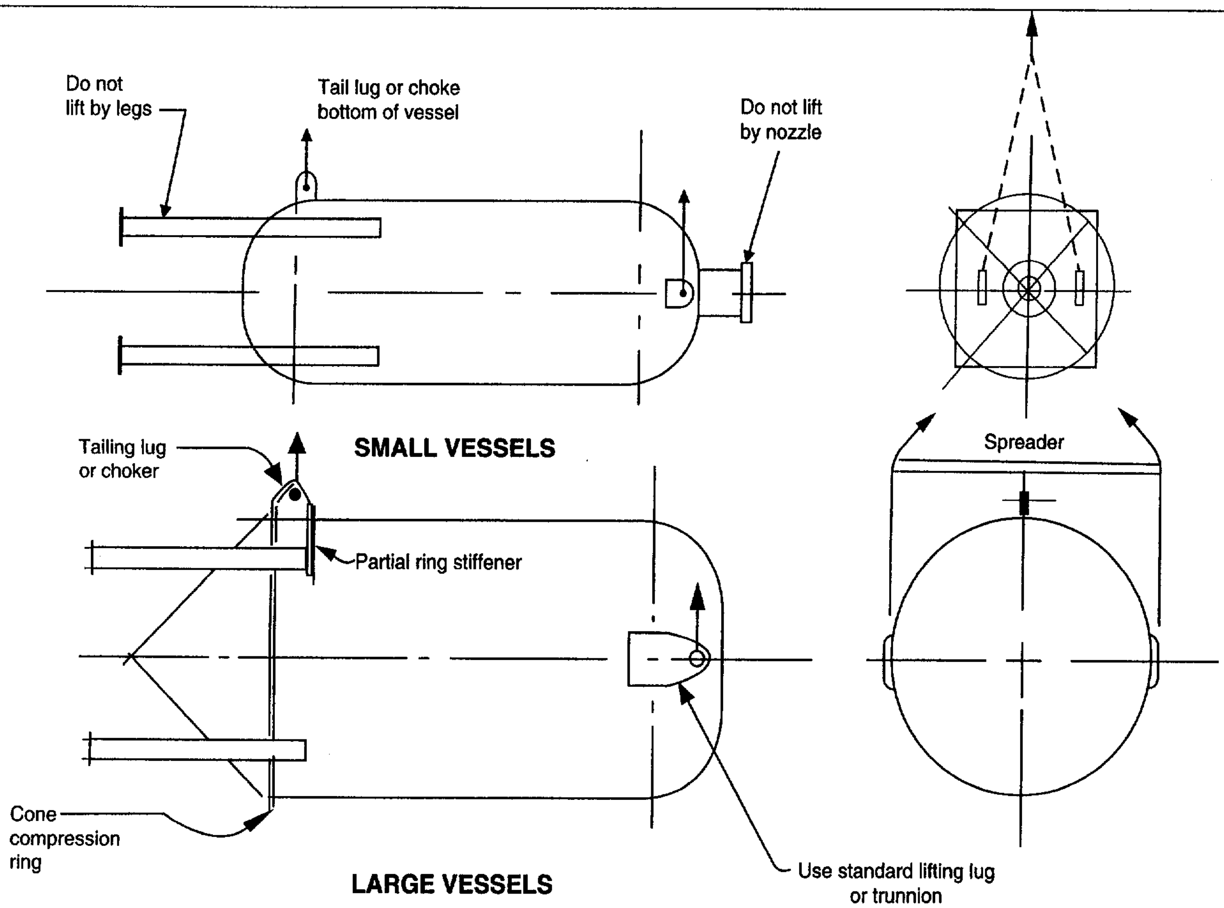


Figure 3-70. Base details of various types of skirt-supported vessels.

HORIZONTAL VESSELS



VESSELS, BINS, AND HOPPERS ON LEGS



Examples of Road Transport

If a vessel is too heavy for one trailer and too short to span two trailers, then a pair of outrigger beams can be used to span the trailers and still distribute the load to the trailers. A wide variety of trailers, self-propelled transporters, and beam configurations have been utilized for these applications. Short, squat, heavy vessels are the most common.