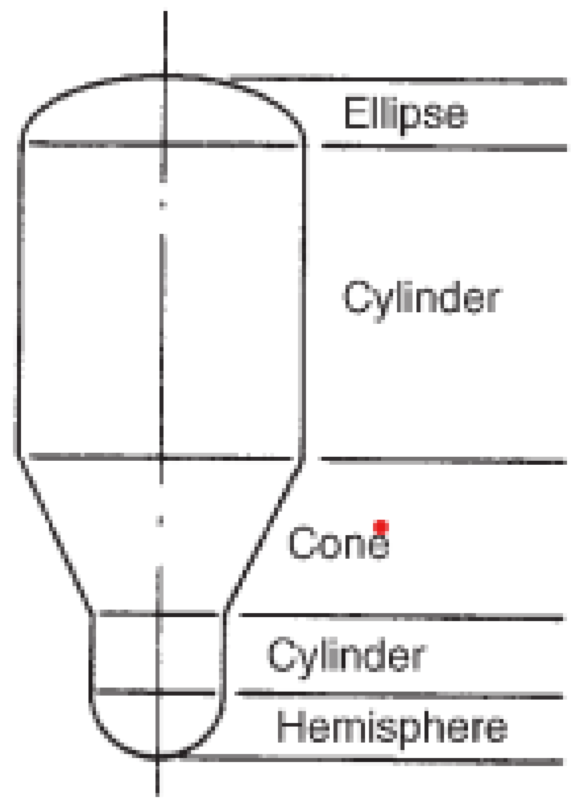
GENERAL DESIGN CONSIDERATIONS: PRESSURE VESSELS

Typical vessel shapes



1. Design pressure

- For vessels under internal pressure, the design pressure is normally taken as the pressure at which the relief device is set.
- This will normally be 5 to 10 per cent above the normal working pressure, to avoid spurious operation during minor process upsets.
- When deciding the design pressure, the hydrostatic pressure in the base of the column should be added to the operating pressure, if significant.

2. Design temperature

- The strength of metals decreases with increasing temperature .
- maximum allowable design stress will depend on the material temperature.
- The design temperature at which the design stress is evaluated should be taken as the maximum working temperature of the material, with due allowance for any uncertainty involved in predicting vessel wall temperatures

3. Materials

- Pressure vessels are constructed from plain carbon steels, low and high alloy steels, other
- alloys, clad plate, and reinforced plastics.
- Selection of a suitable material must take into account the suitability of the material
- for fabrication (particularly welding) as well as the compatibility of the material with the
- process environment.
- The pressure vessel design codes and standards include lists of acceptable materials;
- in accordance with the appropriate material standards.

4. Design stress

Table 13.2. Typical design stresses for plate
(The appropriate material standards should be consulted for particular grades and plate thicknesses)

Material	Tensile strength (N/mm^2)	Design stress at temperature °C (N/mm^2)									
		0 to 50	100	150	200	250	300	350	400	450	500
Carbon steel (semi-killed or silicon killed)	360	135	125	115	105	95	85	80	70		
Carbon-manganese steel (semi-killed or silicon killed)	460	180	170	150	140	130	115	105	100		
Carbon-molybdenum steel, 0.5 per cent Mo	450	180	170	145	140	130	120	110	110		
Low alloy steel (Ni, Cr, Mo, V)	550	240	240	240	240	240	235	230	220	190	170
Stainless steel 18Cr/8Ni unstabilised (304)	510	165	145	130	115	110	105	100	100	95	90
Stainless steel 18Cr/8Ni Ti stabilised (321)	540	165	150	140	135	130	130	125	120	120	115
Stainless steel 18Cr/8Ni Mo $2\frac{1}{2}$ per cent (316)	520	175	150	135	120	115	110	105	105	100	95

5. Welded joint efficiency,

- The strength of a welded joint will depend on the type of joint and the quality of the welding.
- The soundness of welds is checked by visual inspection and by non-destructive testing
- (radiography).
- The possible lower strength of a welded joint compared with the virgin plate is usually
- allowed for in design by multiplying the allowable design stress for the material by a "welded joint factor" J.

5. Welded joint efficiency,

Table 13.3. Maximum allowable joint efficiency

Type of joint	Degree of radiography		
	100 per cent	spot	none
Double-welded butt or equivalent	1.0	0.85	0.7
Single-weld butt joint with bonding strips	0.9	0.80	0.65

5. Welded joint efficiency,

- Category 1: the highest class, requires 100 per cent non-destructive testing (NDT) of the welds; and allows the use of all materials covered by the standard, with no restriction on the plate thickness.
- Category 2: requires less non-destructive testing but places some limitations on the materials which can be used and the maximum plate thickness.
- Category 3: the lowest class, requires only visual inspection of the welds, but is restricted to carbon and carbon-manganese steels, and austenitic stainless steel; and limits are placed on the plate thickness and the nominal design stress. For carbon and carbon manganese steels the plate thickness is restricted to less than 13 mm and the design stress is about half that allowed for categories 1 and 2.

.6. Corrosion allowance

- The “corrosion allowance” is the additional thickness of metal added to allow for material lost by corrosion and erosion, or scaling.
- The allowance to be used should be agreed between the customer and manufacturer. Corrosion is a complex phenomenon, and it is not possible to give specific rules for the estimation of the corrosion allowance required for all circumstances.
- The allowance should be based on experience with the material of construction under similar service conditions to those for the proposed design.
- For carbon and low-alloy steels, where severe corrosion is not expected, a minimum allowance of 2.0 mm should be used;
- where more severe conditions are anticipated this should be increased to 4.0 mm.
- Most design codes and standards specify a minimum allowance of 1.0 mm

THE DESIGN OF THIN-WALLED VESSELS UNDER INTERNAL PRESSURE

1. Cylinders and spherical shells

- For a cylindrical shell the minimum thickness required to resist internal pressure can be determined from equation (1)

$$e = \frac{P_i D_i}{2f - P_i} \qquad ....1$$

If *Di* is internal diameter and e the minimum thickness required, where *f* is the design stress and *Pi* the internal pressure.

- If a welded joint factor is used equation (1a)

$$e = \frac{P_i D_i}{2Jf - P_i} \qquad ....1\ a$$

1. Cylinders and spherical shells

- An equation for the minimum thickness of a sphere can be obtained from equation

$$e = \frac{P_i D_i}{4f - 1.2P_i} \quad \text{.................2}$$

- If a welded joint factor is used equation (2a)

$$e = \frac{P_i D_i}{4Jf - 1.2P_i} \quad \text{..........2 a}$$

- Volume of vessel= 30-40 m3

- 10 kmole ethane, T=55 C, 30 m3
- P= nRT/V= 10000 m(8.314 pa, m3/mole.k)(328)/30= 9 bar
- Pc=48.72 bar,   Tc= 305.33 k.
- Tr= (55+273)/305.33= 1.07, Pr= 8.73/48.72=0.184
- Z= .96,
- P=8.73+ (0.1* 8.73)= 9.6
- Di= 4 m , , h=2.4 m, d/h = 0.5-1, f= 135