PV Newsletter

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Pressure Vessel Support - Skirt

A skirt support consists of a cylindrical or conical shell welded to the bottom head of the vessel. A base ring at the bottom of the skirt transmits the load to the foundations through the anchor bolts.

The skirt is generally welded to the bottom head using any of the three arrangements shown in Figure 1 - the second arrangement is usually the most preferred one.

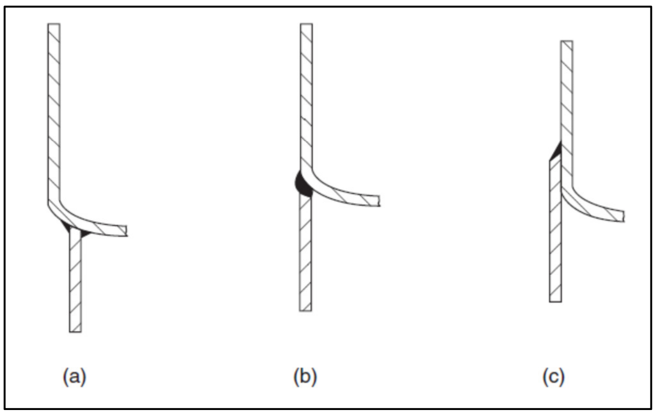

Figure 1: Skirt Supports

Skirt supports do not impose concentrated loads on the vertical shell. They are particularly suitable for use with tall columns subject to wind loading. Openings must be provided in the skirt for access and any connecting pipes.

Support Skirt Design

The skirt thickness must be sufficient to withstand the dead weight loads and bending moments imposed on it by the vessel; it will not be under vessel pressure.

The resultant stresses in the skirt will be:

σ_s (tensile) = $\sigma_{bs} - \sigma_{ws}$

σ_s (compressive) = $\sigma_{bs} + \sigma_{ws}$

σ_{bs} = Bending stress in skirt

= $\frac{4M_s}{\pi(D_s+t_s)t_sD_s}$ where M_s = Maximum bending moment, evaluated at the base of the skirt

t_s = Skirt thickness

D_s = Inside diameter of skirt, at the base

σ_{ws} = Dead weight in skirt

= $\frac{W}{\pi(D_s+t_s)t_s}$ where W = Total weight of vessel and contents

The skirt thickness should be such that under the worst combination of wind and dead weight loading, the following design criteria are not exceeded:

σ_s (tensile) $\leq$ f_s (Maximum allowable design stress for the skirt material at ambient temperature)

σ_s (compressive) $\leq$ $0.125E\left(\frac{t_s}{D_s}\right)$

A large factor of safety is used in the expression for allowable compressive stress because a slight out-of-roundness can have significant consequences. ASME uses an approximate factor of safety of 10.0.

The minimum thickness of the skirt should not be less than 1/4" (6 mm). Where the vessel wall will be at a significantly higher temperature than the skirt, discontinuity stresses will be set up due to the differences in thermal expansion. Methods for calculating the thermal stresses in support skirts are given by Weil and Murphy (1960) and Bergman (1963).

Anchor Bolt Design

The loads carried by the skirt are transmitted to the foundation by the skirt base ring (bearing plates). The moment produce by wind and earthquake forces will tend to overturn the vessel; this will be opposed by the couple set up by the weight of the vessel and the tensile load in the anchor bolts. For large columns, a base ring design using double ring stiffened by gussets is often employed as shown in Figure 2.

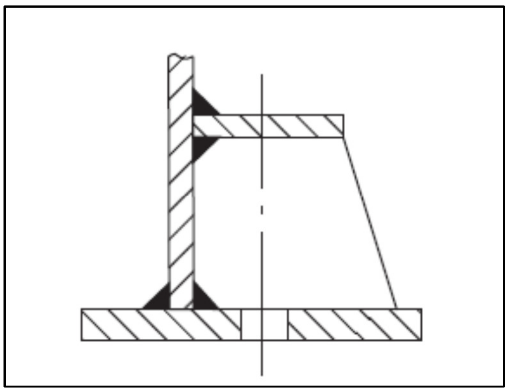

Figure 2: Base Ring Design Using Double Rings

The anchor bolts are assumed to share the overturning load equally, and the bolt area required is given by:

$$A_b = \frac{1}{N_b f_b}\left[\frac{4M_s}{D_b} - W\right]$$

where

A_b = Root area of one bolt, mm^2

N_b = Number of bolts

f_b = Maximum allowable bolt stress, N/mm^2 (typical design value: 125 N/mm^2 or 18,000 psi)

M_s = Bending moment at base, Nm

W = Weight of vessel, N

D_b = Bolt circle diameter, m

Following guide rules are generally used while selecting the anchor bolts:

1) Bolts smaller than 1 in (25 mm) diameter should not be used.
2) Minimum number of bolts is eight.
3) Use number of bolts in multiples of four.
4) Bolt pitch should not be less than 2 ft (600 mm). If this minimum bolt pitch cannot be accommodated with a cylindrical skirt, a conical skirt should be used.

Base Ring Design

The base ring must be sufficiently wide to distribute the load to the foundation. The total compressive load on the base ring is given by:

$$F_b = \left[\frac{4M_s}{\pi {D_s}^2} + \frac{W}{\pi D_s}\right]$$

where F_b = Compressive load on the base ring, N/m

D_s = Skirt diameter, m

The minimum width of the base ring is given by:

$$L_b = \frac{F_b}{f_c} x \frac{1}{10^3}$$

where L_b = Base ring width, mm (see Figure 3)

f_c = Maximum allowable bearing pressure on the concrete foundation pad, which will depend on the mix used; and will typically range from 3.5 to 7 N/mm^2 (500 - 1000 psi)

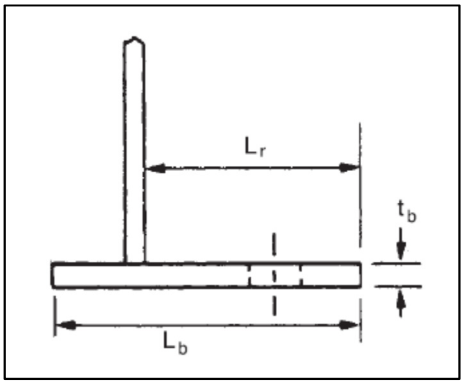

Figure 3: Base Ring Dimensions

The required thickness of the base ring is found by treating the ring as a cantilever beam. The minimum thickness is given by:

$$t_b = L_r\sqrt{\frac{3f_c}{f_r}}$$

where L_r = Distance from the edge of the skirt to the outer edge of the ring

f'_c = Actual bearing pressure on base, N/mm^2

f_r = Allowable design stress in the ring material, typically 140 N/mm^2

Sources:

1. Coulson and Richardson's Chemical Engineering, 3rd Edition *by* R. K. Sinnott

***** E N D O F T H E A R T I C L E *****

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CoDESIGN Engineering

CoDesign Engineering is involved in providing training and consultancy services as described below:

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- Pressure vessel & heat exchanger design (ASME Section VIII, Div. 1 and Div. 2, TEMA)
- Power and process piping and piping system design (ASME B31.1, B31.3, and Valves)
- Solar PV power plant design

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Ramesh Tiwari holds a Master's degree in Mechanical Engineering from Clemson University in South Carolina, and is a registered Professional Engineer from the state of Maryland in the United States. He has over 22 years of experience designing pressure vessels, heat exchangers and tanks. Ramesh is a member of ASME Section VIII Subgroup on Heat Transfer Equipment. He is also an approved pressure vessel instructor at National Thermal Power Corporation (NTPC), a premier thermal power generating company in India.