Part VII
Anchor Bolt Chairs

When anchor bolts are required at supports for a shell, chairs are necessary to distribute the load to the shell. Small tubular columns (less than 4 ft in diameter) may be an exception if the base plate is adequate to resist bending. Otherwise, chairs are always needed to minimize secondary bending in the shell.

For flat-bottom tanks, choose a bolt circle to just barely clear the bottom without notching it. For other structures, follow the minimum clearances shown in Fig. 7-1*a*. The designer must evaluate anchor bolt location for interference with base or bottom plate.

Notation

a = top-plate width, in., along shell

b = top-plate length, in., in radial direction

c = top-plate thickness, in.

d = anchor-bolt diameter, in.

e = anchor-bolt eccentricity, in.

e_{min} = $0.886d + 0.572$, based on a heavy hex nut clearing shell by 1/2 in. See Table 7-1

f = distance, in., from outside of top plate to edge of hole

f_{min} = $d/2 + 1/8$

g = distance, in., between vertical plates (preferred $g = d + 1$) [Additional distance may be required for maintenance.]

h = chair height, in.

j = vertical-plate thickness, in.

k = vertical-plate width, in. (average width for tapered plates)

L = column length, in.

m = bottom or base plate thickness, in.

P = design load, kips; or maximum allowable anchor-bolt load or 1.5 times actual bolt load, whichever is less

r = least radius of gyration, in.

R = nominal shell radius, in., either to inside or centerline of plate (radius normal to cone at bottom end for conical shells)

S = stress at point, ksi

t = shell or column thickness, in.

w = weld size (leg dimension), in.

W = total load on weld, kips per lin. in. of weld

W_H = horizontal load, kips per lin. in. of weld

W_V = vertical load, kips per lin. in. of weld

θ = cone angle, degrees, measured from axis of cone

Z = reduction factor

Top Plate

Critical stress in the top plate occurs between the hole and the free edge of the plate. For convenience we can consider this portion of the top plate as a beam with partially fixed ends, with a portion of the total anchor bolt load distributed along part of the span. See Fig. 7-2.

$$S = \frac{P}{fc^2}(0.375g - 0.22d) \qquad (7\text{-}1)$$

or

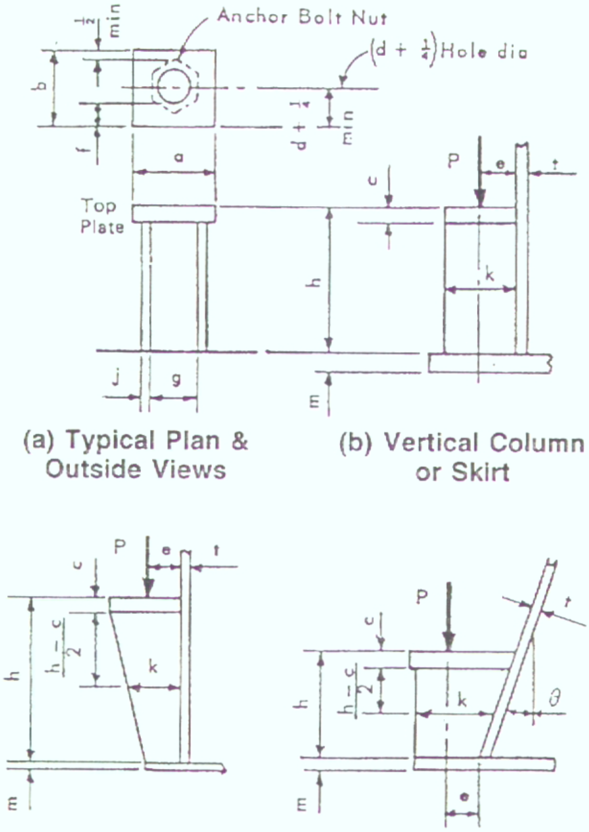
$$c = \left[\frac{P}{Sf}(0.375g - 0.22d)\right]^{1/2} \qquad (7\text{-}2)$$

Top plate may project radially beyond vertical plates as in Fig. 7-1*d*, but no more than 1/2″.

Chair Height

Chair must be high enough to distribute anchor bolt load to shell or column without overstressing it. If the anchor bolt were in line with the shell the problem would be simple — the difficulty lies in the bending caused by eccentricity of the anchor bolt with respect to the shell. Except for the case where a continuous ring is used at the top of chairs, maximum stress occurs in the vertical direction and is a combination of bending plus direct stress. Formulas which follow are approximations, based on the work of Bjilaard.

$$S = \frac{Pe}{t^2}\left[\frac{1.32\,Z}{\frac{1.43\,ah^2}{Rt} + (4ah^2)^{.333}} + \frac{.031}{\sqrt{Rt}}\right] \qquad (7\text{-}3)$$



(a) Typical Plan & Outside Views

(b) Vertical Column or Skirt

(c) Flat Bottom Tank

(d) Conical Skirt

Figure 7-1. Anchor-Bolt Chairs.

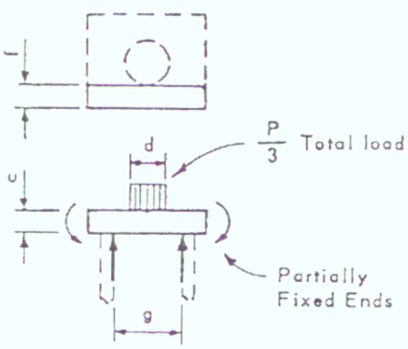


Figure 7-2. Assumed Top-Plate Beam.

Where:
$$Z = \frac{1.0}{\frac{.177\,am}{\sqrt{Rt}}\left(\frac{m}{t}\right)^2 + 1.0} \qquad (7\text{-}4)$$

Maximum recommended stress is 25 ksi. This is a local stress occurring just above the top of the chair. Since it diminishes rapidly away from the chair, a higher than normal stress is justified but an increase for temporary loads, such as earthquake or wind is not recommended. The following general guidelines are recommended.

Minimum chair height $h = 6''$, except use $h = 12''$ when base plate or bottom plate is 3/8″ or thinner and where earthquake or winds over 100 mph must be considered.

Maximum recommended chair height $h = 3a$.

Table 7-1. Top-Plate Dimensions

Based on anchor-bolt stresses up to 12 ksi for 1½-in.-dia. bolts and 15 ksi for bolts 1¾ in. in diameter or larger; higher anchor bolt stresses may be used subject to designer's decision.

Top Plate Dimensions, in.						Bolt Load, kips
d	f	$g = d + 1$	a	e_{min}	c_{min}	P
1½	⅞	2½	4½	1.87	0.734	19.4
1¾	1	2¾	4¾	2.09	0.919	32.7
2	1⅛	3	5	2.30	1.025	43.1
2¼	1¼	3¼	5¼	2.52	1.145	56.6

If chair height calculated is excessive, reduce eccentricity e, if possible, or use more anchor bolts of a smaller diameter. Another solution is to use a continuous ring at top of chairs.

If continuous ring is used, check for maximum stress in circumferential direction, considering the ring as though it were loaded with equally spaced concentrated loads equal to Pe/h. Portion of shell within $16t$ either side of the attachment may be counted as part of the ring. (Refer to Fig. 7-3)

Note that the base plate or bottom is also subjected to this same horizontal force, except inward instead of outward. This is true even if a continuous ring is not used around the top of the chairs — but it should never cause any very high stresses in the base, so we do not normally check it. However, it is a good thing to keep in mind in case you have a very light base ring.

Vertical Side Plates

Be sure top plate does not overhang side plate (as in Fig. 7-1d) by more than 1/2″ radially.

Vertical-plate thickness should be at least j_{min} = 1/2″ or 0.04 $(h - c)$, whichever is greater.

Another requirement is $jk \geq P/25$, where k is the average width if plate is tapered.

These limits assure a maximum L/r of 86.6 and a maximum average stress in the side plates of 12.5

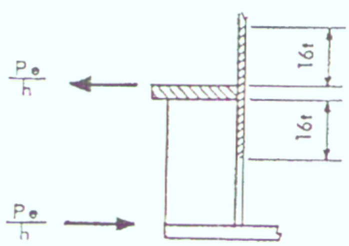


Figure 7-3. Chair with Continuous Ring at Top.

ksi, even assuming no load was transmitted into the shell through the welds.

Assembly of Chair

For field erected structures, ship either the top plate or the entire chair loose for installation after the structure is sitting over the anchor bolts.

Where base plate is welded to skirt or column in shop, attach side plates in the shop and ship top plate loose for field assembly. See Fig. 7-4.

Where base or bottom plate is not welded to shell in the shop, as for flat-bottom tanks and single pedestal tanks, shop attach side plates to top plates and then ship the assembly for field installation. When you do this, weld both sides at top of side plates so shrinkage will not pull side plate out of square. See Fig. 7-5.

Welds between chair and shell must be strong enough to transmit load to shell. ¼″ minimum fillet welds as shown in Figs. 7-4 and 7-5 are nearly always adequate, but you should check them if you have a large anchor bolt with a low chair height. Seal welding may be desired for application in corrosive environments.

Assume a stress distribution as shown in Fig. 7-6 as though there were a hinge at bottom of chair. For the purpose of figuring weld size, the base or bottom plate is assumed to take horizontal thrust only, not moment.

Note that loads are in terms of kips per inch of weld length, not in terms of kips per square inch stress. Critical stress occurs across the top of the chair. The total load per inch on the weld is the resultant of the vertical and horizontal loads.

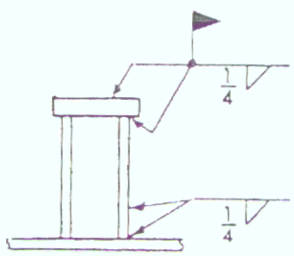


Figure 7-4. Typical Welding, Base Plate Shop Attached.

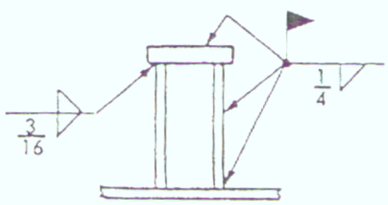


Figure 7-5. Typical Welding, Base or Bottom Field Attached.

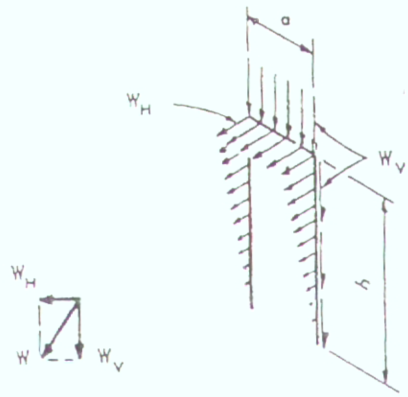


Figure 7-6. Loads on Welds.

Formulas may also be used for cones, although this underrates the vertical welds some.

$$W_v = \frac{P}{a + 2h} \quad (7\text{-}5)$$

$$W_H = \frac{Pe}{ah + 0.667h^2} \quad (7\text{-}6)$$

$$W = \sqrt{W_V^2 + W_H^2} \quad (7\text{-}7)$$

For an allowable stress of 13.6 ksi on a fillet weld, the allowable load per lin. in. is 13.6 × 0.707 = 9.6 kips per in. of weld size. For weld size w, in., the allowable load therefore is

$$9.6w \geq W \quad (7\text{-}8)$$

Design References

H. Bednar, "Pressure Vessel Design Handbook", 1981, pp. 72-93.

M.S. Troitsky, "Tubular Steel Structures", 1982, pp. 5-10 — 5-16.

P.P. Bjilaard, "Stresses From Local Loadings In Cylindrical Pressure Vessels," ASME Transactions, Vol. 77, No. 6, 1955.

P. Buthod, "Pressure Vessel Handbook," 7th Edition, pp. 75-82.