(a) All formed heads, thicker than the shell and concave to pressure, for butt welded attachment, shall have a skirt length sufficient to meet the requirements of Fig. NC-3358.1(a)-1 when a tapered transition is required.

(b) Any taper at a welded joint within a formed head shall be in accordance with NC-3361. The taper at a circumferential welded joint connecting a formed head to a main shell shall meet the requirements of NC-3358 for the respective type of joint shown therein.

(c) All formed heads concave to pressure and for butt welded attachment need not have an integral skirt when the thickness of the head is equal to or less than the thickness of the shell. When a skirt is provided, its thickness shall be at least that required for a seamless shell of the same diameter.

(d) The inside crown radius to which an unstayed head is dished shall be not greater than the outside diameter of the skirt of the head. The inside knuckle radius of a torispherical head shall be not less than 6% of the outside diameter of the skirt of the head but in no case less than three times the head thickness.

(e) When an ellipsoidal, torispherical, hemispherical, conical, or toriconical head is of a lesser thickness than required by the rules of this paragraph, it shall be stayed as a flat surface according to the rules of NC-3329.

(f) If a torispherical, ellipsoidal, or hemispherical head is formed with a flattened spot or surface, the diameter of the flat spot shall not exceed that permitted for flat heads as given by eqs. [NC-3325.2(b)(5) or NC-3325.2(b)(6)] using C = 0.25.

(g) Openings in formed heads under internal pressure shall comply with the requirements of NC-3330.

NC-3324.6 Ellipsoidal Heads.

(a) Ellipsoidal Heads. The required thickness of a dished head of semiellipsoidal form, in which one-half the minor axis, inside depth of the head minus the skirt, equals one-fourth the inside diameter of the head skirt, shall be determined by:

\[ t = \frac{PD}{2S - 0.2P} \quad \text{or} \quad P = \frac{2St}{D + 0.2t} \]

(b) Ellipsoidal Heads of Other Ratios. The minimum required thickness of an ellipsoidal head of other than a 2:1 ratio shall be determined by:

\[ t = \frac{PDK}{2S - 0.2P} \quad \text{or} \quad P = \frac{2St}{KD + 0.2t} \]

NC-3324.7 Hemispherical Heads.

(a) When the thickness of a hemispherical head does not exceed 0.356L or P does not exceed 0.665S, the following equations shall apply:

\[ t = \frac{PL}{2S - 0.2P} \quad \text{or} \quad P = \frac{2St}{L + 0.2t} \]

(b) When the thickness of the hemispherical head under internal pressure exceeds 0.356L, or when P exceeds 0.665S, the following equations shall apply:

\[ t = L\left(\frac{Y^{1/3}}{3} - 1\right) = L_0\left(\frac{Y^{1/3}}{3} - 1\right) \quad \text{where} \quad \left(Y = \left(\frac{L_0 + t}{L_0 - t}\right)^{\frac{1}{2}}\right) \]

\[ P = 2S\left(\frac{Y - 1}{Y + 2}\right) \]

NC-3324.8 Torispherical Heads.

(a) Torispherical Heads With a 6% Knuckle Radius. The required thickness of a torispherical head in which the knuckle radius is 6% of the inside crown radius shall be determined by:

\[ t = \frac{0.885PL}{S - 0.1P} \quad \text{or} \quad P = \frac{St}{0.885L + 0.1t} \]
\( h_0 \) = gasket moment arm, equal to the radial distance from the centerline of the bolts to the line of the gasket reaction, as shown in Table XI-3221.1-2

\( l \) = length of flange of flanged heads, measured from the tangent line of knuckle, as indicated in Fig. NC-3325-1, sketch (a)

\( m \) = the ratio of \( t_r / t_h \); dimensionless

\( P \) = Design Pressure

\( r \) = inside corner radius on a head formed by flanging or forging

\( S \) = maximum allowable stress value from Tables 1A, 1B, and 3, Section II, Part D, Subpart 1

\( t \) = minimum required thickness of flat head or cover, exclusive of corrosion allowance

\( t_f \) = actual thickness of the flange on a forged head, at the large end, exclusive of corrosion allowance, as indicated in Fig. NC-3325-1, sketches (b-1) and (b-2)

\( t_h \) = actual thickness of flat head or cover, exclusive of corrosion allowance

\( t_s \) = required thickness of shell, for pressure

\( t_{s1} \) = actual thickness of shell, exclusive of corrosion allowance

\( W \) = total bolt load given for circular heads for eqs. (3) and (4), XI-3223

**NC-3325.2 Thickness.** The thickness of flat unstayed heads, covers, and blind flanges shall conform to one of the following two requirements.\(^{18}\)

(a) Circular blind flanges of ferrous materials conforming to ASME B16.5 shall be acceptable for the diameters and pressure-temperature ratings in Tables 2 to 8 of that Standard, when of the types shown in Fig. NC-3325-1, sketches (d) and (e).

(b) The minimum required thickness of flat unstayed circular heads, covers, and blind flanges shall be calculated by the equation

\[
\begin{align*}
    t &= d \sqrt{CP/S} \\
    &\text{except when the head, cover, or blind flange is attached by bolts causing an edge moment [Fig. NC-3325-1, sketches (d) and (e)], in which case the thickness shall be calculated by}
\end{align*}
\]

\[
\begin{align*}
    t &= d \sqrt{CP/S + 1.27W_hh_c/SD^3} \\
\end{align*}
\]

When using eq. (6), the thickness \( t \) shall be recalculated for both service loadings and gasket seating, and the greater of the two values shall be used. For service loadings, the value of \( P \) shall be the Design Pressure, and the values of \( S \) at the Design Temperature and \( W \) from eq. (3) of XI-3223 shall be used. For gasket seating, \( P \) equals zero, and the values of \( S \) at atmospheric temperature and \( W \) from eq. (4) of XI-3223 shall be used.

**NC-3325.3 Values of \( C \).** For the types of construction shown in Figs. NC-3325-1, NC-4243-1, NC-4243-2, and NC-4243.1-1, the minimum values of \( C \) to be used in eqs. NC-3325.2(b)(5) and NC-3325.2(b)(6) shall be as given in (a) through (g) for Fig. NC-3325-1 and in (h) for Figs. NC-4243.1-1 and NC-4243-1, in (i) for Fig. NC-4243-2, and in (j) for Fig. NC-4243.1-1.

(a) In sketch (a), \( C = 0.17 \) for flanged circular heads forged integral with or butt welded to the vessel with an inside corner radius not less than three times the required head thickness, with no special requirement with regard to length of flange.

(1) \( C = 0.10 \) for circular heads, when the flange length for heads of the above design is not less than

\[
\begin{align*}
    l &= \left[ 1.1 - 0.8 \frac{t_s^2}{t_h^2} \right]^{1/3} \\
\end{align*}
\]

(2) \( C = 0.10 \) for circular heads, when the flange length \( l \) is less than the requirement in (1) above but the shell thickness is not less than

\[
\begin{align*}
    t_s &= 1.12t_h\sqrt{1.1 - l/2d_{th}} \\
\end{align*}
\]

for a length of at least \( 2\sqrt{d_{th}} \).

(3) When \( C = 0.10 \) is used, the taper shall be 1:4.

(b) In sketch (b-1), \( C = 0.17 \) for forged circular heads integral with or butt welded to the vessel, where the flange thickness is not less than two times the shell thickness, the corner radius on the inside is not less than three times the flange thickness, and the welding meets all the requirements of NC-4000.

(c) In sketch (b-2), \( C = 0.33m \) but not less than 0.2 for forged circular heads integral with or butt welded to the vessel, where the flange thickness is not less than the shell thickness and the corner radius on the inside is not less than 1.5 times the flange thickness. See Fig. NC-4243.1-1 sketches (a) and (b) for the special cases where \( t_f = t_s \).

(d) In sketch (c), \( C = 0.13 \) for integral flat circular heads when the dimension \( d \) does not exceed 24 in. (600 mm), the ratio of thickness of the head to the dimension \( d \) is not less than 0.05 nor greater than 0.25, the head thickness \( t_h \) is not less than the shell thickness \( t_s \), the inside corner radius is not less than 0.25\( t_s \), and the construction is obtained by special techniques of upsetting and spinning the end of the shell, such as employed in closing header ends.

(e) In sketches (d) and (e), \( C = 0.2 \) for circular heads and covers bolted to the vessel as indicated in the figures. Note that eq. NC-3325.2(b)(6) shall be used because of the extra moment applied to the cover by the bolting. When the cover plate is grooved for a peripheral gasket as shown in sketch (e), the net cover plate thickness under the groove or between the groove and the outer edge of the cover plate shall be not less than \( d \sqrt{1.27W_{h_c}/SD^3} \) for circular heads and covers.

(f) In sketches (f), (g), and (h), \( C = 0.2 \) for a circular plate inserted into the end of a vessel and held in place by a positive mechanical locking arrangement, and when all possible means of failure (by shear, tension, compression,