(l) Heads concave to pressure, intended for attachment by brazing, shall have a skirt length sufficient to meet the requirements for circumferential joints in Part UB.

(m) Any taper at a welded joint within a formed head shall be in accordance with UW-9. The taper at a circumferential welded joint connecting a formed head to a main shell shall meet the requirements of UW-13 for the respective type of joint shown therein.

(n) 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 eq. UG-34(c)(2)(1), using $C = 0.25$.

(o) Openings in formed heads under internal pressure shall comply with the requirements of UG-36 through UG-46.

(p) A stayed jacket that completely covers a formed inner head or any of the types included in this paragraph shall also meet the requirements of UG-47(c).

**UG-33 FORMED HEADS, PRESSURE ON CONVEX SIDE**

(a) General. The required thickness at the thinnest point after forming of ellipsoidal, torispherical, hemispherical, toriconical, and conical heads and conical segments under pressure on the convex side (minus heads) shall be computed by the appropriate formulas given in this paragraph (see UG-16). Heads with bolting flanges shall meet the requirements of UG-35.1. In addition, provisions shall be made for any other loading given in UG-22. The required thickness for heads due to pressure on the convex side shall be determined as follows.

1. For ellipsoidal and torispherical heads, the required thickness shall be the greater of the following:
   - (a) the thickness computed by the procedure given in UG-32 for heads with pressure on the concave side (plus heads) using a design pressure $1.67$ times the design pressure on the convex side, assuming a joint efficiency $E = 1.00$ for all cases; or
   - (b) the thickness as computed by the appropriate procedure given in (d) or (e) below.

   In determining the maximum allowable working pressure on the convex side of ellipsoidal or torispherical heads, reverse the procedures in (a) and (b) above, and use the smaller of the pressures obtained.

2. For hemispherical heads, the required thickness shall be determined by the rules given in (c) below.

3. For conical and toriconical heads and conical sections, the required thickness shall be determined by the rules given in (f) below.

(b) Nomenclature. The nomenclature defined below is used in this paragraph. Figure 1-4 shows principal dimensions of typical heads.
A, B, E, and P are as defined in UG-28(b)

\( D_o = \) outside diameter of the head skirt

\( D_o/2h_o = \) ratio of the major to the minor axis of ellipsoidal heads, which equals the outside diameter of the head skirt divided by twice the outside height of the head (see Table UG-33.1)

\( D_L = \) outside diameter at large end of conical section under consideration

\( D_s = \) outside diameter at small end of conical section under consideration

\( D_{ss} = \) outside diameter at small end of conical section under consideration

\( h_o = \) one-half of the length of the outside minor axis of the ellipsoidal head, or the outside height of the ellipsoidal head measured from the tangent line (head-bend line)

\( K_o = \) factor depending on the ellipsoidal head proportions \( D_o/2h_o \) (see Table UG-33.1)

\( L_c = \) axial length of cone or conical section (see Figure UG-33.1).

\( L_e = \) equivalent length of conical head or Section between lines of support [see (g)]

\( R_o = \) for hemispherical heads, the outside radius

\( = \) for ellipsoidal heads, the equivalent outside spherical radius taken as \( K_o D_o \)

\( = \) for torispherical heads, the outside radius of the crown portion of the head

\( t = \) minimum required thickness of head after forming, in. (mm)

\( t_e = \) effective thickness of conical section

\( = t \cos \alpha \)

\( \alpha = \) one-half the apex angle in conical heads and sections, deg

(c) Hemispherical Heads. The required thickness of a hemispherical head having pressure on the convex side shall be determined in the same manner as outlined in UG-28(d) for determining the thickness for a spherical shell.

(d) Ellipsoidal Heads. The required thickness of an ellipsoidal head having pressure on the convex side, either seamless or of built-up construction with butt joints, shall not be less than that determined by the following procedure.

Step 1. Assume a value for \( t \) and calculate the value of factor \( A \) using the following formula:

\[
A = \frac{0.125}{R_o/t}
\]
### Table UG-33.1

Values of Spherical Radius Factor $K_o$ for Ellipsoidal Head With Pressure on Convex Side

<table>
<thead>
<tr>
<th>$D_o / 2h_o$</th>
<th>3.0</th>
<th>2.8</th>
<th>2.6</th>
<th>2.4</th>
<th>2.2</th>
<th>2.0</th>
<th>1.8</th>
<th>1.6</th>
<th>1.4</th>
<th>1.2</th>
<th>1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K_o$</td>
<td>1.36</td>
<td>1.27</td>
<td>1.18</td>
<td>1.08</td>
<td>0.99</td>
<td>0.90</td>
<td>0.81</td>
<td>0.73</td>
<td>0.65</td>
<td>0.57</td>
<td>0.50</td>
</tr>
</tbody>
</table>

GENERAL NOTE: Interpolation permitted for intermediate values.

### Figure UG-33.1

Length $L_c$ of Some Typical Conical Sections for External Pressure

(a) Length $L_c$ of a typical conical section.

(b) Length $L_c$ of a different conical section.

(c) Length $L_c$ of a third conical section.

(d) Length $L_c$ of a fourth conical section.

(e) Length $L_c$ of a fifth conical section.
Step 2. Using the value of \( A \) calculated in Step 1, follow the same procedure as that given for spherical shells in UG-28(d), Steps 2 through 6.

(e) Torispherical Heads. The required thickness of a torispherical head having pressure on the convex side, either seamless or of built-up construction with butt joints, shall not be less than that determined by the same design procedure as is used for ellipsoidal heads given in (d) above, using the appropriate value for \( R_w \).

(f) Conical Heads and Sections. When the cone-to-cylinder junction is not a line-of-support, the required thickness of a conical head or section under pressure on the convex side, either seamless or of built-up construction with butt joints shall not be less than the required thickness of the adjacent cylindrical shell and, when a knuckle is not provided, the reinforcement requirement of 1-8 shall be satisfied (see Figure UG-28.1). When the cone-to-cylinder junction is a line-of-support, the required thickness shall be determined in accordance with the following subparagraphs.

(1) When \( \alpha \) is equal to or less than 60 deg:

(a) cones having \( D_L/t_e \) values \( \geq 10 \):

Step 1. Assume a value for \( t_e \) and determine the ratios

\[
\frac{L_c}{D_L} \text{ and } \frac{D_L}{D},
\]

Step 2. Enter Section II, Part D, Subpart 3, Figure G at a value of \( L/D_L \) equivalent to the value of \( L_c/D_L \) determined in Step 1. For values of \( L_c/D_L \) greater than 50, enter the chart at a value of \( L_c/D_L = 50 \).

Step 3. Move horizontally to the line for the value of \( D_L/t_e \) equivalent to the value of \( D_L/t_e \) determined in Step 1. Interpolation may be made for intermediate values of \( D_L/t_e \); extrapolation is not permitted. From this point of intersection move vertically downwards to determine the value of factor \( A \).

Step 4. Using the value of \( A \) calculated in Step 3, enter the applicable material chart in Section II, Part D, Subpart 3 for the material under consideration. Move vertically to an intersection with the material/temperature line for the design temperature (see UG-20). Interpolation may be made between lines for intermediate temperatures.

In cases where the value of \( A \) falls to the right of the end of the material/temperature line, assume an intersection with the horizontal projection of the upper end of the material/temperature line. For values of \( A \) falling to the left of the material/temperature line, see Step 7.

Step 5. From the intersection obtained in Step 4, move horizontally to the right and read the value of factor \( B \).

Step 6. Using this value of \( B \), calculate the value of the maximum allowable external working pressure \( P_a \) using the following formula:

\[
P_a = \frac{4B}{3(D_L/t_e)}
\]

Step 7. For values of \( A \) falling to the left of the applicable material/temperature line, the value of \( P_a \) can be calculated using the following formula:

\[
P_a = \frac{2AE}{3(D_L/t_e)}
\]

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Step 8. Compare the calculated value of \( P_a \) obtained in Step 6 or Step 7 with \( P \). If \( P_a \) is smaller than \( P \), select a larger value for \( t \) and repeat the design procedure until a value of \( P_a \) is obtained that is equal to or greater than \( P \).

Step 9. Provide adequate moment of inertia and reinforcement at the cone-to-cylinder junction in accordance with 1-8. For a junction with a knuckle, the reinforcement calculation is not required, and the moment of inertia calculation may be performed either by considering the presence of the knuckle or by assuming the knuckle is not present whereby the cone is assumed to intersect the adjacent cylinder.

(b) cones having \( D_L/t_e \) values <10:

Step 1. Using the same procedure as given in (a) above, obtain the value of \( B \). For values of \( D_L/t_e \) less than 4, the value of \( \alpha \) can be calculated using the following formula:

\[
\alpha = \frac{1.1}{(D_L/t_e)^2}
\]

For values of \( A \) greater than 0.10, use a value of 0.10.

Step 2. Using the value of \( B \) obtained in Step 1, calculate a value \( P_{a1} \) using the following formula:

\[
P_{a1} = \left[ \frac{2.167}{(D_L/t_e)} - 0.0833 \right] B
\]

Step 3. Calculate a value \( P_{a2} \) using the following formula:

\[
P_{a2} = \frac{2S}{D_L/t_e} \left[ 1 - \frac{1}{D_L/t_e} \right]
\]

where

\[
S = \text{the lesser of two times the maximum allowable stress value in tension at design metal temperature, from the applicable table referenced by UG-23, or 0.9 times the yield strength of the material at design temperature}
\]

Values of yield strength are obtained from the applicable external pressure chart as follows.

(a) For a given temperature curve, determine the \( B \) value that corresponds to the right hand side termination point of the curve.

(b) The yield strength is twice the \( B \) value obtained in (a) above.