(a) Internal pressure (pressure on the concave side) - the head thickness shall be determined using eq. (4.7.2).

(b) External pressure (pressure on the convex side) - the head thickness shall be determined in accordance with the rules in 4.4.

4.7.5.2 The flange thickness of the head for a Type D Head Configuration shall be determined by the following equations.

\[ T = \max\left[ T_g, T_o \right] \] (4.7.17)

\[ T_g = \frac{M_g}{S_{gb}B + \left( \frac{A + B}{A - B} \right)} \] (4.7.18)

\[ T_o = Q + \sqrt{Q^2 + \frac{M_o}{S_{bo}B} + \left( \frac{A + B}{A - B} \right)} \] (4.7.19)

\[ Q = \frac{P|B\sqrt{4L^2 - B^2}}{8S_{bo}(A - B)} \] (4.7.20)

When determining the flange design moment for the design condition, \( M_o \), using 4.16, the following modifications shall be made. The moment arm, \( h_D \), shall be computed using eq. (4.7.21). An additional moment term, \( M_r \), computed using eq. (4.7.22) shall be added to \( M_o \) as defined 4.16. The term \( M_{oe} \) in the equation for \( M_o \) as defined 4.16 shall be set to zero in this calculation. Note that this term may be positive or negative depending on the orientation of \( t_v, R, A_R \).

\[ h_D = 0.5\left(C - B\right) \] (4.7.21)

\[ M_r = \left[0.785B^2P\cot[\beta]\right]h_r \] (4.7.22)

where

\[ \beta = \arcsin\left[ \frac{B}{2L + t_v} \right] \] (4.7.23)

4.7.5.3 As an alternative to the rules in 4.7.5.1 and 4.7.5.2, the following procedure can be used to determine the required head and flange thickness of a Type D head. This procedure accounts for the continuity between the flange ring and the head, and represents a more accurate method of analysis.

Step 1. Determine the design pressure and temperature of the flange joint. If the pressure is negative, a negative value must be used for \( P \) in all of the equations of this procedure, and

\[ P_e = 0.0 \quad \text{for internal pressure} \] (4.7.24)

\[ P_e = P \quad \text{for external pressure} \] (4.7.25)

Step 2. Determine an initial Type D head configuration geometry (see Figure 4.7.5). The following geometry parameters are required:

(a) The flange bore, \( B \)

(b) The bolt circle diameter, \( C \)
(c) The outside diameter of the flange, $A$
(d) Flange thickness, $T$
(e) Mean head radius, $R$
(f) Head thickness, $t$
(g) Inside depth of flange to the base of the head, $q$

Step 3. Select a gasket configuration and determine the location of the gasket reaction, $G$, and the design bolt loads for the gasket seating, $W_g$, and operating conditions, $W_o$, using the rules of 4.16.

Step 4. Determine the geometry parameters.

$$h_1 = \frac{C - G}{2}$$

$$h_2 = \frac{G - B}{2}$$

$$d = \frac{A - B}{2}$$

$$n = \frac{T}{t}$$

$$K = \frac{A}{B}$$

$$\phi = \arcsin \left( \frac{B}{2R} \right)$$

$$e = q - \frac{1}{2} \left( R + \frac{t}{\cot(\phi)} \right)$$

$$k_1 = 1 - \frac{1 - 2\nu}{2\lambda} \cot(\phi)$$

$$k_2 = 1 - \frac{1 + 2\nu}{2\lambda} \cot(\phi)$$

$$\lambda = \left[ 3(1 - \nu^2) \left( \frac{R}{t} \right)^2 \right]^{0.25}$$

Step 5. Determine the shell discontinuity geometry factors.

$$C_1 = \frac{0.275\pi^3 \cdot \ln(K)}{K_1} - e$$

$$C_2 = \frac{1.1\pi^3 \cdot \ln(K)}{Bk_1} + 1$$

$$C_4 = \frac{\lambda \sin(\phi)}{2} \left( k_2 + \frac{1}{k_1} \right) + \frac{B}{4nd} + \frac{1.65e}{tk_1}$$

$$C_5 = \frac{1.65}{tk_1} \left( 1 + \frac{4\lambda e}{B} \right)$$
**Step 6.** Determine the shell discontinuity load factors for the operating and gasket conditions.

\[
C_{30} = \frac{\pi B^2 P}{4} \left( e \cdot \cot \phi + \frac{2q(T-q)}{B} - h_2 \right) - W_0 h_1
\]  
(4.7.40)

\[
C_{60} = \frac{\pi B^2 P}{4} \left( 4q - B \cdot \cot \phi \frac{4\pi}{4nd} \frac{0.35}{\sin \phi} \right) 
\]  
(4.7.41)

\[
C_{3g} = -W_g h_1
\]  
(4.7.42)

\[
C_{6g} = 0.0
\]  
(4.7.43)

**Step 7.** Determine the shell discontinuity force and moment for the operating and gasket conditions.

\[
V_{do} = \frac{C_6 C_{60} - C_{30} C_5}{C_2 C_4 - C_1 C_5}
\]  
(4.7.44)

\[
M_{do} = \frac{C_1 C_{60} - C_{30} C_4}{C_2 C_4 - C_1 C_5}
\]  
(4.7.45)

\[
V_{dg} = \frac{C_6 C_{6g} - C_{3g} C_5}{C_2 C_4 - C_1 C_5}
\]  
(4.7.46)

\[
M_{dg} = \frac{C_1 C_{6g} - C_{3g} C_4}{C_2 C_4 - C_1 C_5}
\]  
(4.7.47)

**Step 8.** Calculate the stresses in the head and at the head-to-flange junction using Table 4.7.1 and check the stress acceptance criteria. If the stress criteria are satisfied, then the design is complete. If the stress criteria are not satisfied, then re-proportion the bolted head dimensions and go to **Step 3.**

### 4.7.6 NOMENCLATURE

- **A** = flange outside diameter.
- **B** = flange inside diameter.
- **β** = angle formed by the tangent to the center line of the dished cover thickness at its point of intersection with the flange ring, and a line perpendicular to the axis of the dished cover.
- **C** = bolt circle diameter.
- **C_1** = shell discontinuity geometry parameter for the Type D head alternative design procedure.
- **C_2** = shell discontinuity geometry parameter for the Type D head alternative design procedure.
- **C_{3g}** = shell discontinuity load factor for the gasket seating condition for the Type D head alternative design procedure.
- **C_{3o}** = shell discontinuity load factor for the design operating condition for the Type D head alternative design procedure.
- **C_4** = shell discontinuity geometry parameter for the Type D head alternative design procedure.
- **C_5** = shell discontinuity geometry parameter for the Type D head alternative design procedure.
- **C_{6g}** = shell discontinuity load factor for the gasket seating condition for the Type D head alternative design procedure.
- **C_{6o}** = shell discontinuity load factor for the design operating condition for the Type D head alternative design procedure.
- **e** = geometry parameter for the Type D head alternative design procedure.
- **h_r** = moment arm of the head reaction force.
- **h_1** = geometry parameter for the Type D head alternative design procedure.
- **h_2** = geometry parameter for the Type D head alternative design procedure.
- **k_1** = geometry parameter for the Type D head alternative design procedure.
- **k_2** = geometry parameter for the Type D head alternative design procedure.
- **K** = geometry parameter for the Type D head alternative design procedure.
\( L \) = inside crown radius.
\( \lambda \) = geometry parameter for the Type D head alternative design procedure.
\( M_{dg} \) = shell discontinuity moment for the gasket seating condition.
\( M_{do} \) = shell discontinuity moment for design operating condition.
\( M_n \) = flange design moment for the gasket seating condition determined using 4.16.
\( M_i \) = flange design moment for the design condition determined using 4.16 (see 4.7.5.2 for exception)
\( n \) = geometry parameter for the Type D head alternative design procedure.
\( \nu \) = Poisson’s ratio.
\( P \) = design pressure.
\( P_x \) = pressure factor to adjust the design rules for external pressure.
\( \phi \) = one-half central angle of the head for the Type D head alternative design procedure.
\( q \) = inside depth of the flange to the base of the head.
\( R \) = mean radius of a Type D head.
\( r \) = inside knuckle radius. \( S_{fg} \) allowable stress from Annex 3-A for the flange evaluated at the gasket seating condition.
\( S_{fm} \) = membrane stress in the flange.
\( S_{fmbi} \) = membrane plus bending stress on the inside surface of the flange.
\( S_{fmbo} \) = membrane plus bending stress on the outside surface of the flange.
\( S_{fo} \) = allowable stress from Annex 3-A for the flange evaluated at the design temperature.
\( S_{hb} \) = bending stress at the head-to-flange junction.
\( S_{ho} \) = allowable stress from Annex 3-A for the head evaluated at the gasket seating condition.
\( S_{hm} \) = head membrane stress.
\( S_{h} \) = local membrane stress at the head-to-flange junction.
\( S_{hibi} \) = local membrane plus bending stress at the head-to-flange junction on the inside surface of the head.
\( S_{hibo} \) = local membrane plus bending stress at the head-to-flange junction on the outside surface of the head.
\( S_{ho} \) = allowable stress from Annex 3-A for the head evaluated at the design temperature.
\( S_{yT} \) = yield strength from Annex 3-D evaluated at the design temperature.
\( S_u \) = minimum specified ultimate tensile strength from Annex 3-D.
\( T \) = flange thickness.
\( T^* \) = flange thickness for a Type C Head.
\( T_g \) = required flange thickness for the gasket seating condition.
\( T_o \) = required flange thickness for design operating condition.
\( t \) = required head thickness.
\( V_{dg} \) = shell discontinuity shearing force for the gasket seating condition.
\( V_{do} \) = shell discontinuity shearing force for design operating condition.
\( W_g \) = bolt load for the gasket seating condition.
\( W_o \) = bolt load for design operating condition.
4.7.7 TABLES

<table>
<thead>
<tr>
<th>Junction Stress Equations and Acceptance Criteria for a Type D Head</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Operating Conditions</strong></td>
</tr>
<tr>
<td>$S_{hm} = \frac{PR}{2t} + P_e$</td>
</tr>
<tr>
<td>$S_{hl} = \frac{PR}{2t} + \frac{V_d g \cos(\phi)}{\pi B_t} + P_e$</td>
</tr>
<tr>
<td>$S_{hb} = \frac{6M_d B}{\pi B_t^2}$</td>
</tr>
<tr>
<td>$S_{h(b)} = S_{h1} + S_{h2}$</td>
</tr>
<tr>
<td>$S_{h(b)} = S_{h1} - S_{h2}$</td>
</tr>
<tr>
<td>$S_{fm} = \frac{1}{\pi B_t} \left( 4d_p \frac{4d_p}{B} - \cot(\phi) \right) - V_d g \left( \frac{k^2 + 1}{k^2 - 1} \right) + P_e$</td>
</tr>
<tr>
<td>$S_{fb} = \frac{0.525m}{B_t k} \left( V_d g - \frac{4M_d g}{B} \right)$</td>
</tr>
<tr>
<td>$S_{f(mb)} = S_{fm} - S_{fb}$</td>
</tr>
<tr>
<td>$S_{f(mb)} = S_{fm} + S_{fb}$</td>
</tr>
</tbody>
</table>

**Acceptance Criteria**

- $S_{hm} \leq S_{hb}$
- $S_{hl} \leq 1.5S_{hb}$
- $S_{h(b)} \leq 1.5S_{hb}$
- $S_{f(m)} \leq S_{fa}$
- $S_{f(m)} \leq 1.5S_{fa}$
- $S_{f(mb)} \leq 1.5S_{fa}$
- $S_{f(mb)} \leq 1.5S_{fa}$

4.7.8 FIGURES

**Figure 4.7.1**  
Type A Dished Cover With a Bolting Flange

(a) Loose Flange Type  
(b) Integral Flange Type

GENERAL NOTE: See Table 4.2.5, Details 2 and 3 for transition requirements for a head and skirt with different thicknesses.