CONICAL TRANSITIONS (PART 2): Design of Conical Transitions under External Pressure

In ASME Section VIII, Division 1, the design rules for conical transition are provided in the paragraph UG-32 for internal pressure and paragraph UG-33 for external pressure. The design rules for internal pressure were addressed in an earlier article. This article will address the design rules for external pressure.

UG-33(f): CONICAL HEADS AND SECTIONS UNDER EXTERNAL PRESSURE

(We will collectively refer to these as conical transitions)

NOMENCLATURE

A = Factor determined from Section II, Part D, Subpart 3, Figure G

B = Factor determined from applicable material chart in Section II, Part D, Subpart 3

D_L = Outside diameter at large end of conical transition

D_O = Outside diameter of the head skirt

D_S = Outside diameter at small end of conical transition

E = Modulus of elasticity of material at design temperature

L_C = Axial length of conical transition

P = External design pressure

P_a = Calculated value of maximum allowable external working pressure for the assumed value of t

t = Minimum required thickness of conical transition after forming

t_e = Effective thickness of conical transition (t cos α)

α = One-half apex angle in conical transitions

WHEN CONE-TO-CYLINDER JUNCTION IS NOT A LINE OF SUPPORT

- The required thickness of conical transitions with butt joints shall not be less than the required thickness of the adjacent cylindrical shell.
- When knuckle is not provided, the reinforcement requirements of Mandatory Appendix 1, 1-8 shall be satisfied.

WHEN CONE-TO-CYLINDER JUNCTION IS A LINE OF SUPPORT

The required thickness of conical transitions with butt joints shall be determined in accordance with the following:

1) When the half-apex angle, α, is equal to or less than 60°:

   a) Conical transitions having D_L/t_e values ≥ 10:

      Step 1: Assume a value for t_e and determine the ratios L_e/D_L and D_L/t_e.

      Step 2: Enter Section II, Part D, Subpart 3, Figure G at value L/D_o equivalent to the value of L_e/D_L. For values of L_e/D_L greater than 50, enter the chart at a value of L_e/D_L = 50.

      Step 3: Move horizontally to the line for the value of D_o/t equivalent to the value of D_L/t_e. From this point of intersection, move vertically downwards to determine the value of Factor A.

Step 4: Using the value of A, 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.

In case where the applicable 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 the value of A falling to the left of the material/ temperature line, see Step 7.

Figure G
Geometric Chart for Components Under External or Compressive Loadings (for All Materials)

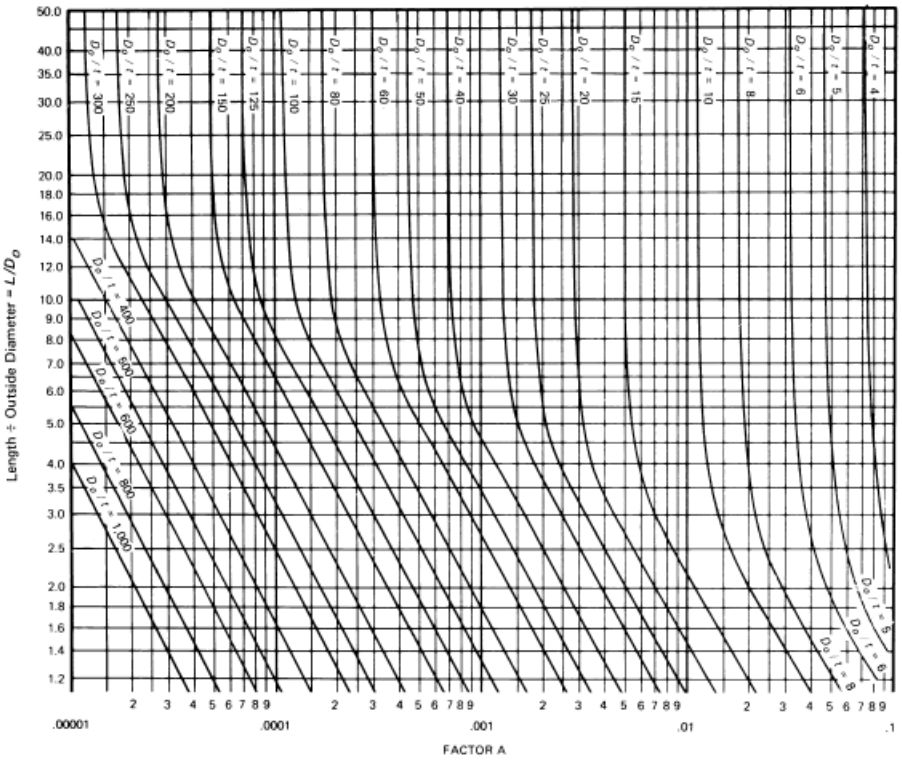
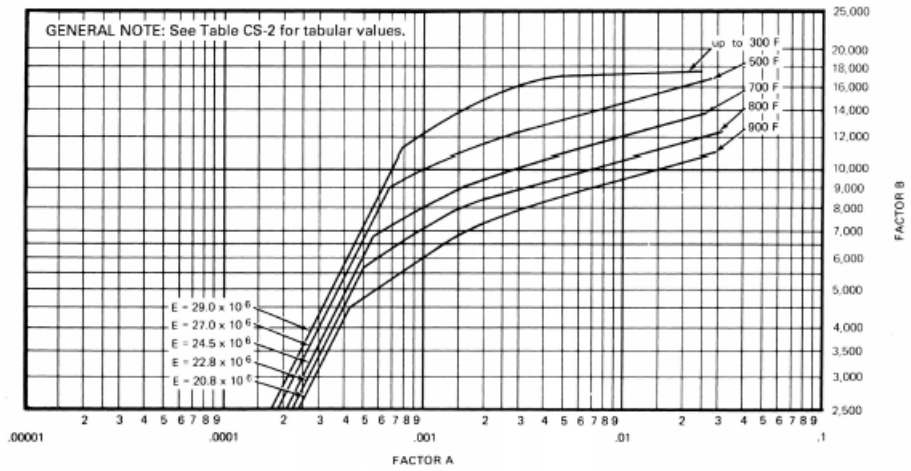


Figure CS-2
Chart for Determining Shell Thickness of Components Under External Pressure Developed for Carbon or Low Alloy Steels With Specified Minimum Yield Strength 30,000 psi and Higher



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:

$$P_a = \frac{4\,B}{3\,(D_L/t_e)}$$

Step 7: For the 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:

$$P_a = \frac{2\,A\,E}{3\,(D_L/t_e)}$$

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

b) Conical transitions 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 Factor A can be calculated using the following formula:

$$A = \frac{1.1}{(D_L/t_e)^2}$$

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

Step 2: Using the value of B, calculate the value of P_{a1} using the following formula:

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

Step 3: Calculate the value P_{a2} using the following formula:

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

Where S = lesser of two times the maximum allowable stress value in tension at the design temperature, 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.

Step 4: The smaller of the values P_{a1} or P_{a2} shall be used for the maximum allowable external working pressure P_a. Compare P_a with P. If P_a is smaller than P, select a larger value for t and repeat the design procedure until a value for P_a is obtained that is equal to or greater than P.

2) When the half-apex angle, α, is greater than 60°, the thickness of the conical transition shall be the same as the required thickness for a flat head, the diameter of which equals the large diameter of the conical transition.

3) The thickness of an eccentric conical transition shall be taken as the greater of the two thicknesses obtained using both the smaller and the larger α in the calculations.

EQUIVALENT LENGTH OF CONICAL TRANSITION

Equivalent length of conical transition, L_e, is determined as follows:

1) For sketches (a) and (b) in Figure UG-33.1,

$$L_e = (L_c/2)(1 + D_S/D_L)$$

2) For sketch (c) in Figure UG-33.1,

$$L_e = r_1 \sin\alpha + \frac{L_c}{2}\left(\frac{D_L+D_S}{D_{LS}}\right)$$

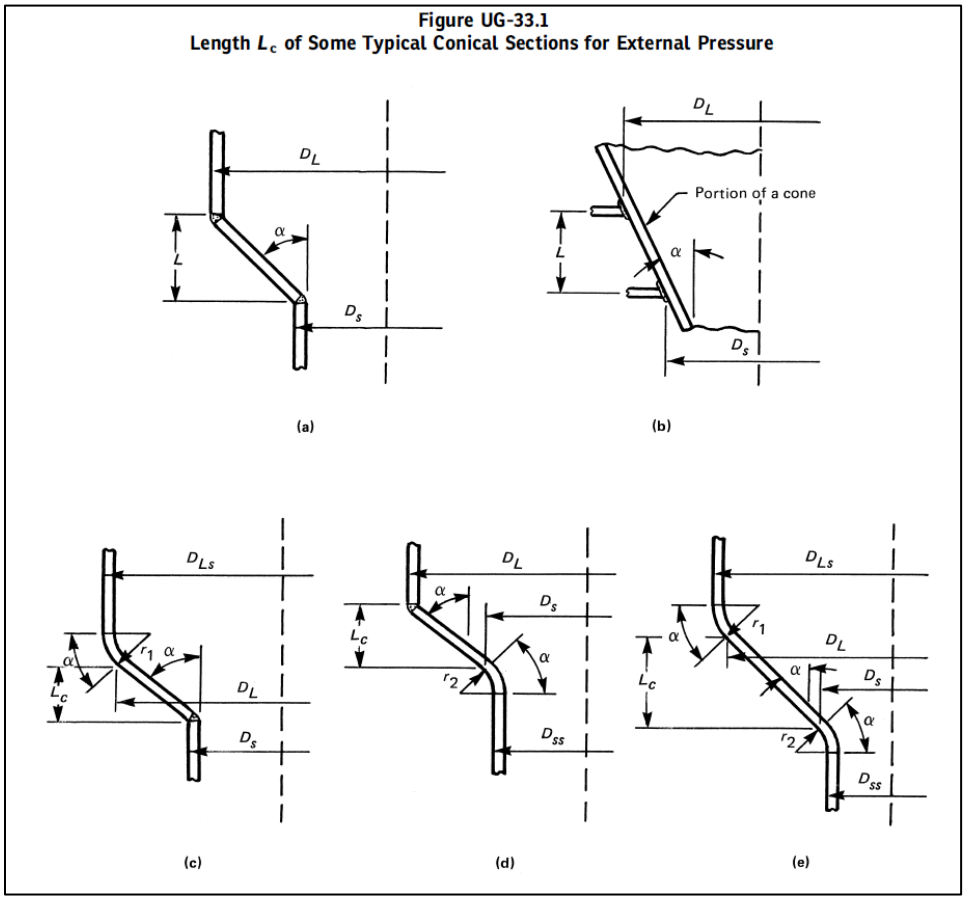
3) For sketch (d) in Figure UG-33.1,

$$L_e = r_2 \frac{D_{SS}}{D_L} \sin\alpha + \frac{L_c}{2}\left(\frac{D_L+D_S}{D_L}\right)$$

4) For sketch (e) in Figure UG-33.1,

$$L_e = \left(r_1 + r_2 \frac{D_{SS}}{D_{LS}}\right) \sin\alpha + \frac{L_c}{2}\left(\frac{D_L+D_S}{D_{LS}}\right)$$

Figure UG-33.1
Length L_c of Some Typical Conical Sections for External Pressure



MANDATORY APPENDIX 1, 1-8

The reinforcement requirements of cone-to-cylinder junction of a conical transition will be discussed in a future article.

Reference:

ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 (Edition 2023).

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