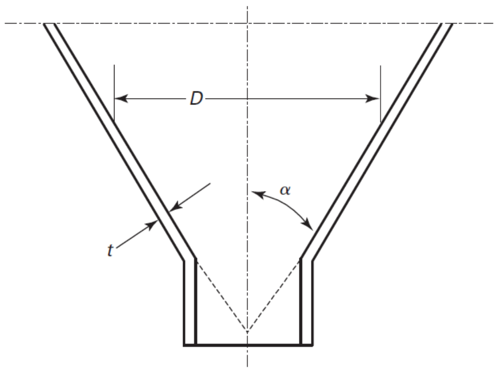
CONICAL TRANSITIONS (PART 1)

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. This article will address the design rules for internal pressure only.

UG-32(f): Required thickness of conical heads without transition knuckle



When half apex angle, α, is not greater than 30°,

$$t = \frac{P\,D}{2\cos\alpha\,(SE-0.6P)} \qquad \text{OR} \qquad P = \frac{2\,S\,E\,t\cos\alpha}{D+1.2\,t\cos\alpha}$$

where, P = Internal design pressure

D = Inside diameter of conical head at the point under consideration

S = Maximum allowable stress at design temperature

E = Joint efficiency

α = Half apex angle of the cone

When half apex angle, α, is greater than 30°, Appendix 46 may be used which provides for the use of alternate rules of ASME Section VIII, Division 2 with some restrictions. Paragraph 4.3.4 and 4.3.10 provide design rules for conical shells when $\alpha \leq 60°$. Paragraph 4.3.11 provides design rules for cylindrical-to-conical shell transition junction without a knuckle. When half apex angle, α, is greater than 60°, the design shall be in accordance with paragraph U-2(g).

The design rules for conical heads with transition knuckles are provided in paragraph UG-32(g) and 4.3.12 (ASME Section VIII, Division 2) and are not addressed in this article.

The large and small ends of the conical transition ned to be evaluated for adequate reinforcement.

Large End of the Conical Transition

a) When a cylinder having a minimum length of $2.0\sqrt{R_L t_S}$ is attached to the large end of the cone, determine the following:

$$\Delta = 326.6\sqrt{\frac{P}{S_S E_1}}$$

where, R_L = Inside radius of large cylinder at large end of cone

t_S = Nominal thickness of cylinder at cone-to-cylinder junction

S_S = Allowable stress of cylinder material at design temperature

E_1 = Efficiency of longitudinal joint of cylinder. For compression (such as large end of the cone), E_1 = 1.0 for butt welds

If $\Delta < \alpha$, reinforcement shall be provided.

The required area of reinforcement shall be at least equal to that indicated by the following formula when Q_L is in tension:

$$A_{rL} = \frac{k\,Q_L\,R_L}{S_S\,E_1}\left(1-\frac{\Delta}{\alpha}\right)\tan\alpha$$

where, $k = \dfrac{y}{S_r\,E_r}$, but k is not less than 1.0

y = Cone-to-cylinder factor

= $S_S\,E_S$ for reinforcing ring on shell

= $S_C\,E_C$ for reinforcing ring on cone

S_C = Allowable stress of cone material at design temperature

S_r = Allowable stress of reinforcing ring at design temperature

E_S = Modulus of elasticity of cylinder material

E_C = Modulus of elasticity of cone material

E_r = Modulus of elasticity of reinforcing ring material

Q_L = Algebraic sum of $\dfrac{P\,R_L}{2}$ and f_1

f_1 = Axial load per unit circumference at large end due to wind, dead load etc., excluding pressure

At the large end of the cone-to-cylinder juncture, the $\dfrac{P\,R_L}{2}$ term is in tension. When f_1 is in compression and the quantity is larger than $\dfrac{P\,R_L}{2}$ term, the design shall be in accordance with paragraph U-2(g).

The effective area of reinforcement can be determined as follows:

$$A_{eL} = (t_S - t)\sqrt{R_L\,t_S} + (t_C - t_r)\sqrt{(R_L\,t_C)/\cos\alpha}$$

where, t = Minimum required thickness of cylinder at cone-to-cylinder junction

t_C = Nominal thickness of cone at cone-to-cylinder junction

t_r = Minimum required thickness of cone at cone-to-cylinder junction

Any additional area of reinforcement that is required shall be situated within a distance of $\sqrt{R_L\,t_S}$ from the junction of the reducer and the cylinder. The centroid of the added area shall be within a distance of 0.25 x $\sqrt{R_L\,t_S}$ from the junction.

b) For cones attached to flat covers, flanges or other components where the length of cylinder, if present, is less than $2.0\sqrt{R_L t_S}$, the required reinforcement shall be at least equal to the following:

$$A_{rL} = \frac{k\,Q_L\,R_L}{S_S\,E_2}\tan\alpha$$

where, E_2 = Efficiency of longitudinal joint in cone. For compression, E_2 = 1.0 for butt weld

The effective area of reinforcement can be determined as follows:

$$A_{eL} = (t_C - t_r)\sqrt{(R_L\, t_C)/\cos\alpha}$$

Any additional area of reinforcement that is required shall be added to the cone.

Small End of the Conical Transition

a) When a cylinder having a minimum length of $1.4\sqrt{R_S t_S}$ is attached to the small end of the cone, determine the following:

$$\Delta = 89\sqrt{\frac{P}{S_S E_1}}$$

where, R_L = Inside radius of small cylinder at small end of cone

t_S = Nominal thickness of cylinder at cone-to-cylinder junction

S_S = Allowable stress of cylinder material at design temperature

E_1 = Efficiency of longitudinal joint of cylinder. For compression, E_1 = 1.0 for butt welds

If $\Delta < \alpha$, reinforcement shall be provided.

The required area of reinforcement shall be at least equal to that indicated by the following formula when Q_S is in tension:

$$A_{rS} = \frac{k\, Q_S\, R_S}{S_S\, E_1}\left(1 - \frac{\Delta}{\alpha}\right)\tan\alpha$$

where, $k = \dfrac{y}{S_r\, E_r}$, but k is not less than 1.0

y = Cone-to-cylinder factor

= $S_S\, E_S$ for reinforcing ring on shell

= $S_C\, E_C$ for reinforcing ring on cone

S_C = Allowable stress of cone material at design temperature

S_r = Allowable stress of reinforcing ring at design temperature

E_S = Modulus of elasticity of cylinder material

E_C = Modulus of elasticity of cone material

E_r = Modulus of elasticity of reinforcing ring material

Q_S = Algebraic sum of $\frac{P\, R_S}{2}$ and f_2

f_2 = Axial load per unit circumference at small end due to wind, dead load etc., excluding pressure

At the small end of the cone-to-cylinder juncture, the $\frac{P\, R_S}{2}$ term is in tension. When f_2 is in compression and the quantity is larger than $\frac{P\, R_S}{2}$ term, the design shall be in accordance with paragraph U-2(g).

The effective area of reinforcement can be determined as follows:

$$A_{eS} = 0.78\left[(t_S - t)\sqrt{R_S\, t_S} + (t_C - t_r)\sqrt{(R_S\, t_C)/\cos\alpha}\right]$$

where, t = Minimum required thickness of cylinder at cone-to-cylinder junction

t_C = Nominal thickness of cone at cone-to-cylinder junction

t_r = Minimum required thickness of cone at cone-to-cylinder junction

Any additional area of reinforcement that is required shall be situated within a distance of $\sqrt{R_S\, t_S}$ from the junction, and the centroid of the added area shall be within a distance of 0.25 x $\sqrt{R_S\, t_S}$ from the junction.

b) For cones attached to flat covers, flanges or other components where the length of cylinder, if present, is less than $1.4\sqrt{R_S t_S}$, the required reinforcement shall be at least equal to the following:

$$A_{rS} = \frac{k\, Q_S\, S}{S_S\, E_2} \tan\alpha$$

where, E_2 = Efficiency of longitudinal joint in cone. For compression, E_2 = 1.0 for butt weld

The effective area of reinforcement can be determined as follows:

$$A_{eS} = 0.78\,(t_C - t_r)\sqrt{(R_S\, t_C)/\cos\alpha}$$

Any additional area of reinforcement that is required shall be added to the cone.

Reference:

ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 and Division 2 (Edition 2023).

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