ASME UG 37 Nozzles

$d := 1066$ Hole Diameter

$t := 25$ Actual Shell Thickness, Corroded

$t_r := 7.117$ Required Shell Thickness From Calculations

$t_n := 25$ Nozzle Wall Thickness, Corroded

$t_{rn} := 4.477$ Required Nozzle Thickness From Calculations

$f_{r1} := 1$ Sn/Sv For Set In Nozzle Only, Maximum =1

$f_{r2} := 1$ Sn/Sv Maximum =1

$f_{r3} := 1$ The Lesser Of Sn or Sp /Sv Maximum =1

$f_{r4} := 1$ Sp/Sv

$E_1 := 1$ 1 if in solid plate or cat B Joint

Note:- Design Stress Notation
Sv = Vessel Shell
Sn = Nozzle Design Stress
Sp = Pad design stress

Limits Nozzles less than 1/2 D AND 508mm, in cylindrical shells < = 1520mm Dia
Nozzles less than 1/3 D AND 1000mm, in cylindrical shells > 1524mm Dia
No restriction on Formed Heads (UG 36)

Set Through Nozzles

$h := 0$ Distance nozzle extends below shell; must not exceed the smaller of 2.5 x t or 2.5 x tj

$t_j := t_n$ Wall thickness of nozzle below shell

Reinforcing Elements (Pads)

$D_p := 0$ Diameter Of Reinforcing Pad, must not extend beyond reinforcement limit

$t_e := 0$ Thickness of Reinforcing Pad

Correction Factor F Fig UG37

$\theta := 0°$ Plane of Interest Relative to Longitudinal axis, Always = 0 except when considering Ligaments between adjacent openings.

$$F := \frac{1 + \cos(\theta)^2}{2} \qquad F = 1$$

Required Area A

$$A := d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot \left(1 - f_{r1}\right) \qquad A = 7.587 \times 10^3$$

The second term of the above equation is to compensate for the portion of a set in nozzle adjacent to tr that has a lower allowable design stress than the shell. If the nozzle is set on, or if set in has the same design stress as the shell, and F = 1: this equation reduces to A = d x tr.

Area Available In Shell, Larger Of

$A_{11} := d\cdot(E_1\cdot t - F\cdot t_r) - 2\cdot t_n\cdot(E_1\cdot t - F\cdot t_r)\cdot(1 - f_{r1})$ $\quad A_{11} = 1.906\times 10^4$

$A_{12} := 2\cdot(t + t_n)\cdot(E_1\cdot t - F\cdot t_r) - 2\cdot t_n\cdot(E_1\cdot t - F\cdot t_r)\cdot(1 - f_{r1})$ $\quad A_{12} = 1.788\times 10^3$

The compensation area extends the larger of d or Rn+t+tn. A11 calculates the compensation area based on it extending d, A12 calculates it based on it extending Rn+t+tn. The second term of the above equations is discussed in the note above concerning A.

$A_1 := \max(A_{11}, A_{12})$ $\quad A_1 = 1.906\times 10^4$

Area Available In Nozzle, Smaller Value

$A_{21} := 5\cdot(t_n - t_{rn})\cdot f_{r2}\cdot t$ $\quad A_{21} = 2.565\times 10^3$

$A_{22} := 2\cdot(t_n - t_{rn})\cdot(2.5\cdot t_n + t_e)\cdot f_{r2}$ $\quad A_{22} = 2.565\times 10^3$

Nozzle compensation extends a distance from the surface of the shell to the smaller of :-
2.5 x t (Considered in equation A21) or 2.5 x tn + te (Considered in equation A22).

$A_2 := \min(A_{21}, A_{22})$ $\quad A_2 = 2.565\times 10^3$

Reinforcement Area Below Shell (Set Through)

$A_3 := 5\cdot h\cdot t_j$ $\quad A_3 = 0$

Fillet Welds $\quad leg := 9$

$A_4 := leg^2$

All fillet welds within the reinforcement limit can be considered as contributing to compensation, and as there is a fillet weld on either side of the joint, the area for each joint is equal to the leg length of the weld squared. This area may have to be factored by fr2, fr3, or fr4 depending on weld location and design stresses.

Reinforcing Pads

$A_5 := (D_p - d - 2\cdot t_n)\cdot t_e\cdot f_{r4}$ $\quad A_5 = 0$

Reinforcement Limit For Shell, Measured from Bore of Nozzle

$$\text{Limit\_shell} := \max\left(\frac{d}{2}, t_n + t\right) \qquad \text{Limit\_shell} = 533$$

Reinforcement Limit For Nozzle, Measured from Shell Surface below any Reinforcing Pad

$$\text{Limit\_Nozzle} := \min\left(2.5 \cdot t, 2.5 \cdot t_n + t_e\right) \qquad \text{Limit\_Nozzle} = 62.5$$

Therefore Area Required A < = A1 + A2 + A3 + A4 + A5

$$A = 7.587 \times 10^3 \;<=\; A_1 + A_2 + A_3 + A_4 + A_5 = 2.171 \times 10^4$$

External Pressure Compensation, UG37 d) 1.

$$A = 7.587 \times 10^3 \;<=\; 2 \cdot \left(A_1 + A_2 + A_3 + A_4 + A_5\right) = 4.342 \times 10^4$$

Note:- F is always equal to 1 and tr and tn are calculated using external pressure rules

Large Opening Check

1-7a) For al nozzles outside the limits in UG36 (See Above) two thirds of the required reinforcement must fit in :- half the limit along the shell measured from the nozzle bore or 3/4 d measured from the centre (assuming limit is based on d) plus the full limit along the branch.

$$A_{13} := \frac{1}{2} d \cdot \left(E_1 \cdot t - F \cdot t_r\right) - 2 \cdot t_n \cdot \left(E_1 \cdot t - F \cdot t_r\right) \cdot \left(1 - f_{r1}\right)$$

$$A_1 := \max\left(A_{13}, A_{12}\right)$$

$$\frac{2}{3} \cdot A = 5.058 \times 10^3 \;<=\; A_1 + A_2 + A_3 + A_4 = 1.218 \times 10^4$$

1-7b) For Radial Nozzles with no internal projection, In Cylinders.
Nozzles greater than :- 1016mm ID AND 3.4 Sqr(Ri t) Diameter, in cylindrical shells > 1524mm ID

Rn / R < 0.7 (Inside Nozzle Radius / Inside Shell Radius)

$P := 1.233$ Design Pressure

$R := \left(\frac{1620}{2}\right)$ Inside Radius Of Shell

$R_m := R + \frac{t}{2}$ Mean Radius Of Shell

$R_n := \frac{d}{2}$ Inside Radius Of Nozzle

$R_{nm} := R_n + \frac{t_n}{2}$ Mean Radius Of Nozzle

Shaded Area As, Fig 1-7-1

$l_s := \sqrt{R_m \cdot t}$ $l_s = 143.396$ Length Of Shell Considered

$l_n := t_e + t + \sqrt{R_{nm} \cdot t_n}$ $l_n = 141.78$ Length Of Nozzle Considered

$l_p := \max\left[\left(D_p - d - 2 \cdot t_n\right), l_s\right]$ $l_p = 143.396$ Length Of Pad Considered

$A_s := \left(t \cdot l_s\right) + l_p \cdot t_e + \left(t_n \cdot l_n\right) + 40$ $A_s = 7.169 \times 10^3$

Membrane Stress, must not exceed S

$$S_m := P \cdot \left[\frac{R \cdot \left(R_n + t_n + \sqrt{R_m \cdot t}\right) + R_n \cdot \left(t + t_e + \sqrt{R_{nm} \cdot t_n}\right)}{A_s}\right]$$ $S_m = 110.704$

Bending Stress

$l_s := \max\left(\sqrt{R_m \cdot t}, 16 \cdot t\right)$ $l_s = 400$

$l_n := \max\left[\left(t_e + t + \sqrt{R_{nm} \cdot t_n}\right), t_e + t + 16 \cdot t_n\right]$ $l_n = 425$

$l_p := \mathrm{if}\left[\left(D_p - d - 2 \cdot t_n\right) > l_s, \left(D_p - d - 2 \cdot t_n\right), l_s\right]$ $l_p = 400$ Length Of Pad Considered

Note: The value for ls and ln is the greatest value from Fig 1-7-1 and 1-7-2

Calculate neutral axis and second moment of inertia of nozzle and shell

$$\text{Width} := \begin{pmatrix} t_n \\ l_s \\ l_p \end{pmatrix} \qquad \text{Depth} := \begin{pmatrix} l_n \\ t \\ t_e \end{pmatrix} \qquad Y := \begin{pmatrix} \frac{l_n}{2} \\ \frac{t}{2} \\ t + \frac{t_e}{2} \end{pmatrix}$$

$$\text{Ybar} := \frac{\sum_{j=0}^{2} \left(\text{Width}_j \cdot \text{Depth}_j \cdot Y_j\right)}{\sum_{i=0}^{2} \left(\text{Width}_i \cdot \text{Depth}_i\right)}$$

$\text{Ybar} = 115.53$ $\qquad a := \text{Ybar}$

$$I := \sum_{j=0}^{2} \left[\left[\frac{\text{Width}_j \cdot \left(\text{Depth}_j\right)^3}{12} \right] + \left[\text{Width}_j \cdot \text{Depth}_j \cdot \left(Y_j - \text{Ybar}\right)^2 \right] \right]$$

$a = 115.53$ Distance To Neutral Axis

$I = 3.665 \times 10^8$ Second Moment Of Area I, for greatest shaded area in Fig 1-7-1 and 1-7-2

$$e := a - \frac{t}{2}$$

$M := \left(\frac{{R_n}^3}{6} + R \cdot R_n \cdot e \right) \cdot P$ $\qquad M = 8.596 \times 10^7$ Section Bending Moment

$S_b := \frac{M \cdot a}{I}$ $\qquad S_b = 27.0968$ Bending Stress

$S_c := S_m + S_b$ $S_c = 137.801$ Combined Bending and Membrane Stress. Must Not Exceed Sv x 1.5

Note: Nozzle design stress divided by shell design stress, Sn / Sv < 0.8 For above large opening analysis. If necessary reduce Sv to maintain ratio.

UG45 Minimum Nozzle Thickness

UG45a Max(Nozzle Thickness required for pressure, Nozzle thickness to withstand any nozzle loads according to UG22) + Corrosion Allowance

UG45b Min(b1, b2, b3, b4)
b1 For P > 0 The minimum shell thickness assumong E=1 + Corrosion allowance (must be greater than the code min thickness defined in UG16b plus corrosion allowance)
b2 For P < 0 (The shell thickness assuming that the External Pressure is acting internally plus corrosion allowance)
b3 When P can be both > 0 And < 0, The greater of b1 or b2 above.
b4 The Nominal bore pipe size for a pipe of standard thickness minus under-tolerance, typically 12.5% plus corrosion allowance.

Minimum Nozzle thickness = Max(UG45a, UG45b)