## Table of contents



## Layout

| | | | |
|---|---|---|---|
| Input values: | *1.234* | or | 1.234 |
| Calculated values: | ***1.234*** | or | **1.234** |
| Critical values: | *1.234* | or | 1.234 |
| Estimated values: | *1.234* | or | 1.234 |

## Summary

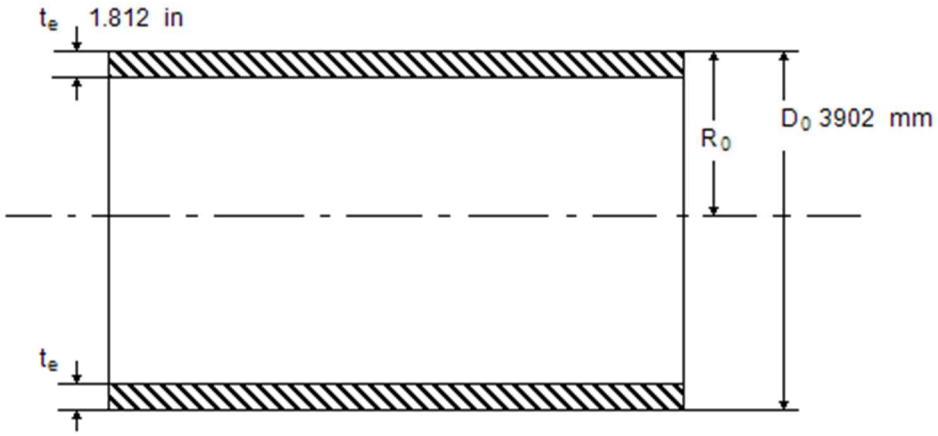
| | | |
|---|---|---|
| Strength Calculation Software<br>Developed by Lauterbach Verfahrenstechnik GmbH | Program System ATLAS | Version **8.29.1** |
| Certified per DIN EN ISO 9001:2015 | Certificate Number 01 100 044763 | |

| | LV Soft | | ASME | Diff [%] |
|---|---|---|---|---|
| Example E4.5.1 - Radial Nozzle in Cylindrical Shell | | | | |
| Required area A | 14159,79 mm² | 21,95 in² | 21,97 in² | **0,08%** |
| Available area A1 | 3531,71 mm² | 5,47 in² | 5,46 in² | **0,32%** |
| Available area Aavl | 28003,63 mm² | 43,41 in² | 43,39 in² | **0,04%** |
| | | | | |
| Example E4.5.2 - Hillside Nozzle in Cylindrical Shell | | | | |
| Required area A | 6863,13 mm² | 10,64 in² | 10,64 in² | **0,00%** |
| Available area A1 | 1704,99 mm² | 2,64 in² | 2,64 in² | **0,00%** |
| Available area Aavl | 11453,94 mm² | 17,75 in² | 17,75 in² | **0,00%** |
| | | | | |
| Example E4.5.3 - Radial Nozzle in Cylindrical Shell | | | | |
| Required area A | 5429,32 mm² | 8,42 in² | 8,42 in² | **0,08%** |
| Available area A1 | 1135,99 mm² | 1,76 in² | 1,75 in² | **0,40%** |
| Available area Aavl | 7014,28 mm² | 10,87 in² | 10,86 in² | **0,07%** |
| | | | | |
| Example E4.5.4 - Radial Nozzle in Cylindrical Shell | | | | |
| Required area A | 19037,86 mm² | 29,51 in² | 29,55 in² | **0,15%** |
| Available area A1 | 1118,35 mm² | 1,73 in² | 1,75 in² | **1,16%** |
| Available area Aavl | 21735,78 mm² | 33,69 in² | 33,65 in² | **0,13%** |
| | | | | |
| Example E4.5.5 - Radial Nozzle in Cylindrical Shell | | | | |
| Required area A | 15075,45 mm² | 23,37 in² | 23,37 in² | **0,00%** |
| Available area A1 | 1860,00 mm² | 2,88 in² | 2,88 in² | **0,00%** |
| Available area Aavl | 15080,66 mm² | 23,38 in² | 23,37 in² | **0,00%** |
| | | | | |
| Example E4.5.5 - Radial Nozzle in Cylindrical Shell | | | | |
| Required area A | 487,24 mm² | 0,76 in² | 0,76 in² | **0,01%** |
| Available area A1 | 495,11 mm² | 0,77 in² | 0,77 in² | **0,02%** |
| Available area Aavl | 737,66 mm² | 1,14 in² | 1,14 in² | **0,16%** |

## Thickness of cylindrical shells under internal pressure - ASME BPVC VIII-1 UG-27 & Appendix-1: 2017

**Cylindrical shells**

| | | | |
|---|---|---|---|
| Design pressure | $p_D$ | 24.55 | bar |
| Hydrostatic head | $D_p$ | 0 | bar |
| Calculation pressure | $P_0$ | **24.55** | bar |
| Calculation temperature | $T_0$ | 148.9 | °C |




| | | | |
|---|---|---|---|
| Outside diameter | $D_0$ | 3902 | mm |
| Design wall thickness | $t_e$ | 1.812 | in |
| Wall thickness allowance | $c_1$ | 0 | in |
| Allowance (corrosion) | $c_2$ | 0.125 | in |
| Weld joint efficiency | E | 1 | |
| Circumferential weld joint efficiency for Eq. 2 | $E_c$ | | |

Material K02700-SA-516-70-Class:-Size:

| | | | |
|---|---|---|---|
| Allowable stress | S | 138 | N/mm² |

**Results**

| | | | |
|---|---|---|---|
| Outside radius | $R_0$ | **1951** | mm |
| Effective thickness | $t_0$ | **1.687** | in |
| Calculation as thin shell is applicable | | **Yes** | |
| Required thickness $t(R_0)$ | t(R) | | |
| Minimum wall thickness without condition acc. UG-16 | $t_{UG-27}$ | **34.31** | mm |
| Minimum wall thickness acc. UG-16 | $t_{UG-16}$ | 0.05906 | in |
| Required wall thickness for circumferential seam | $t_{long}$ | | in |
| $t = Max\{Min[t_R;t_{R0}],t_{UG-16}\}$ | t | ***1.351*** | in |
| with allowances | $t+c_1+c_2$ | **1.476** | in |
| Allowable excess pressure | P | **30.59** | bar |
| Allowable excess pressure for longitudinal stress for Eq. (2) | $P_{long}$ | | bar |
| Allowable excess pressure without hydrostatic head | MAWP | **443.6** | psi |

Remark

**For calculation of openings according to UG-37**

| | | | |
|---|---|---|---|
| Required thickness | t(E=1) | **1.351** | in |

Allowable unreinforced opening diameter d for welded, brazed, and flued connections acc. UG 36(c)3

| | | |
|---|---|---|
| d ≤ 89 mm for t ≤10 mm | or | d ≤ 3 1/2 in for t ≤3/8 in |
| d ≤ 60 mm for t > 10 mm | or | d ≤ 2 3/8 in for t > 3/8 in |

**Equations**

$$R_0 = \frac{D_0}{2} = \frac{3902\ \text{mm}}{2} = 1951\ \text{mm}$$

$$t+c1+c2 = t + c_1 + c_2 = 34.31\ \text{mm} + 0\ \text{mm} + 3.175\ \text{mm} = 37.48\ \text{mm}$$

corroded inside radius

$$R = R_0 - t_0 = 1951\ \text{mm} - 42.86\ \text{mm} = 1908\ \text{mm}$$

$$\text{Log}(x) = \text{Ln}(x)$$

Longitudinal Stress (Circumferential Joints)

UG-27 (2)

$$t_{long} = \frac{P_0 \cdot R}{2 \cdot S \cdot E_c + 0.4 \cdot P_0} = \frac{24.55\ \text{bar} \cdot 1908\ \text{mm}}{2 \cdot 138\ \text{N/mm}^2 \cdot E_c + 0.4 \cdot 24.55\ \text{bar}} = t_{long}$$

UG-27 (2)

$$P_{long} = \frac{2 \cdot S \cdot E_c \cdot t_0}{R - 0.4 \cdot t_0} = \frac{2 \cdot 138\ \text{N/mm}^2 \cdot E_c \cdot 42.86\ \text{mm}}{1908\ \text{mm} - 0.4 \cdot 42.86\ \text{mm}} = P_{long}$$

## E 4.5.1 - Protruding nozzles without reinforcement - ASME BPVC VIII-1 UG-37: 2017

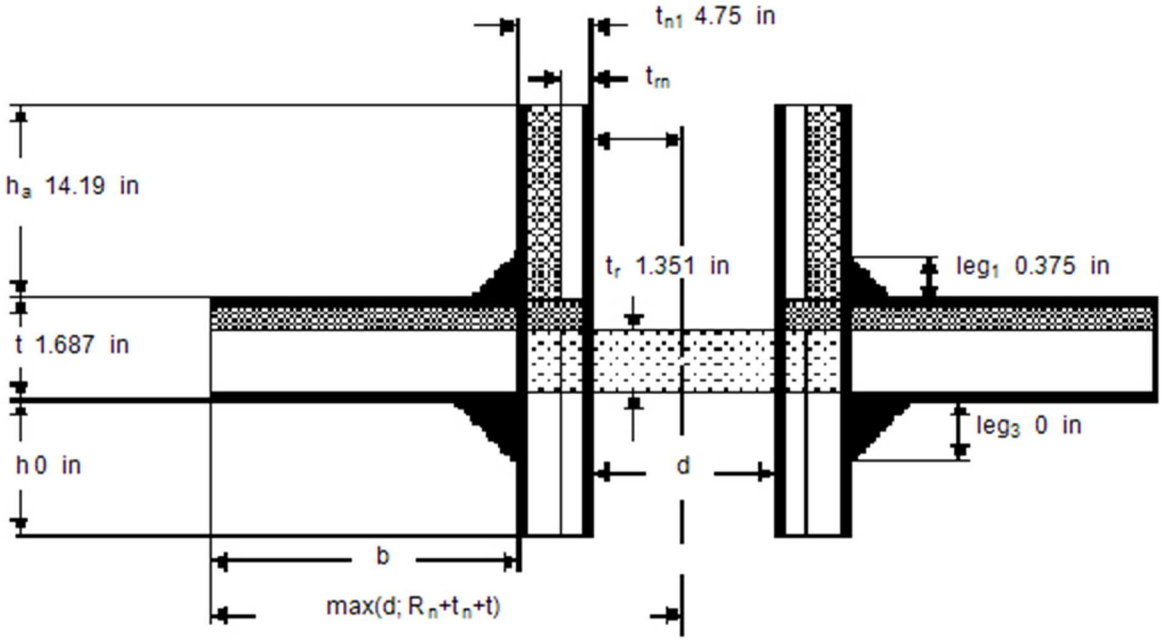
**Protruding nozzle without reinforcement**

| | | | |
|---|---|---|---|
| Design pressure | $p_D$ | 356 | psi |
| Hydrostatic head | $D_p$ | 0 | psi |
| Calculation pressure | $p_0$ | ***356*** | psi |
| Calculation temperature | $T_0$ | *300* | °F |
| Factor (1=internal pressure; 2=external pressure) | $\Gamma$ | 1 | |

**Shell**

| | | | |
|---|---|---|---|
| Straight cross section (=Y), as cylinders acc. UG-36(b)(1) and flat heads acc. UG-39(b)(1) or circular cross section (=N) as spheres | Cyl | Y | (N=No) |
| Outside diameter | $D_a$ | *153.6* | in |
| Nominal thickness without allowances | t | 1.687 | in |
| Available shell length for reinforcement | $b_a$ | 50 | in |
| Joint efficiency factor | $E_1$ | 1 | |
| Material *K02700-SA-516-70-Class:-Size:* | | | |
| Material strength | K | 20015 | psi |
| Safety factor | S | 1 | |
| Allowable stress value | $S_v$ | ***20015*** | psi |
| Wall thickness allowance | $c_{1s}$ | *0* | in |
| Corrosion allowance | $c_{2s}$ | *0.125* | in |

**Nozzle** Nº 1




| | | | |
|---|---|---|---|
| Access opening | | No | |
| Outside diameter | $d_a$ | 25.5 | in |
| Joint efficiency factor | $E_n$ | 1 | |
| Material K02700-SA-516-70-Class:-Size: | | | |
| Material strength | $K_n$ | 20015 | psi |
| Wall thickness allowance | $c_1$ | 0 | in |
| Allowance (corrosion) | $c_2$ | 0.125 | in |
| Safety factor | S | 1 | |
| Allowable stress $K_n$/S | $S_n$ | **20015** | psi |
| Nominal thickness with allowances | $t_{n1}$ | 4.75 | in |
| Required wall thickness acc. Table UG-45 with corrosion allowance | $t_{b3}$ | **0.4533** | in |
| Nominal inside diameter = da-2*t2 | $d_{iN}$ | **16** | in |
| Inside diameter, corroded = $d_a$-2·$t_n$ | d | **16.25** | in |
| External projection | $h_a$ | 14.19 | in |
| Internal projection | h | 0 | in |
| Angle between the shell axis and the sectional plane through the opening center | Θ | 0 | ° |
| Nominal thickness without allowances | $t_n$ | **4.625** | in |
| Required nozzle neck thickness per UG-16 | $t_{UG-16}$ | 1.5 | mm |
| Required nozzle neck thickness per UG-45 | $t_{UG-45}$ | **0.4533** | in |
| Fillet weld nozzle / shell outside | $leg_1$ | 0.375 | in |
| Fillet weld nozzle / shell inside | $leg_3$ | 0 | in |
| Groove weld nozzle / shell (≤t) | $leg_4$ | 0 | in |

| **Calculation according to** | | **UG-40** | | **App.1-7** | |
|---|---|---|---|---|---|
| Correction factor (Fig.UG-37, int. pres.) | F | **1** | | | |
| Reserve of shell | $(E_1 \cdot t - F \cdot t_r)$ | **0.3369** | in | | |
| Limit length of vessel acc. to UG-40(b) | b | **8.125** | in | | in |
| Limit length of nozzle outside, UG40(c) | $h'_a$ | **4.219** | in | **4.219** | in |
| Limit length of nozzle inside,Fig.UG37 | h' | **0** | in | 0 | |
| Minimum required thickness of nozzle | $t_{rn}$ | **0.1461** | in | **0.1461** | in |
| Required area for internal pressure | A | **21.95** | in² | | in² |
| Area of shell reserve | $A_1$ | **5.474** | in² | | in² |
| Area of reinforcement ($A_2$ to $A_5$) | $A_V$ | **37.93** | in² | | in² |
| Total available area ∑A | $A_{avl}$ | **43.41** | in² | | in² |
| Required area A/Γ | $A_{req}$ | **21.95** | in² | | in² |
| Utilization | $A_{req}/A_{avl}$ | **50.56** | % | | % |
| Allowable pressure (approx.: $p_D$/utilization) | | **704.1** | psi | | psi |

**Weld loads according to UG-41**

| | | | | |
|---|---|---|---|---|
| W | = $[A-A_1+2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t-F \cdot t_r)] \cdot S_V$ | = | **1744104** | N |
| $W_1$-1 | = $[A_2+A_{41}] \cdot S_V$ | = | **3377125** | N |
| $W_2$-2 | = $[A_2+A_3+A_41+A_{43}+2 \cdot t \cdot t_n \cdot f_{r1}] \cdot S_V$ | = | **4766860** | N |

**Strength of nozzle wall, fillet and groove welds**

| | | | | |
|---|---|---|---|---|
| Fillet shell /nozzle | $\pi/2 \cdot d_a \cdot leg_1 \cdot 0.49 \cdot \min(S_V;S_n)$ | = | **655292** | N |
| Fillet shell /nozzle | $\pi/2 \cdot d_a \cdot leg_3 \cdot 0.49 \cdot \min(S_V;S_n)$ | = | **0** | N |
| Groove shell /nozzle | $\pi/2 \cdot d_a \cdot leg_4 \cdot 0.74 \cdot \min(S_V;S_n)$ | = | **0** | N |
| Nozzle wall | $\pi/2 \cdot d_m \cdot t_n \cdot 0.70 \cdot S_n$ | = | **9451564** | N |

**Comparison of weld loads on path 1-1 and 2-2**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1-1 | **655292** | N | + | **9451564** | N | = | **1.011e+7** | N |
| | | | | | | ≥ | **1744104** | N |
| 2-2 | **655292** | N | + | **0** | N | + | **0** | N | = | **8520546** | N |
| | | | | | | ≥ | **1744104** | N |

**Equations according to UG-40 and App.1-7**

Fig. UG-37.1, UG-40(b)

$$b = Max\left\{\begin{matrix}\frac{d}{2} \\ t_n + t\end{matrix}\right. = Max\left\{\begin{matrix}\frac{d}{2} \\ t_n + t\end{matrix}\right. = 206.4 \text{ mm}$$

App.1-7(a)(1)

$$b = Max\left\{\begin{matrix}\frac{3 \cdot d/2}{4} \\ t_n + t\end{matrix}\right.$$

App.1-7(a)(1)

$$A = \frac{2}{3} \cdot (d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}))$$

Fig. UG-37.1

$$A = d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) =$$

$$412.8 \text{ mm} \cdot 34.31 \text{ mm} \cdot 1 + 2 \cdot 117.5 \text{ mm} \cdot 34.31 \text{ mm} \cdot 1 \cdot (1 - 1) = 14160 \text{ mm}^2$$

| | | | | |
|---|---|---|---|---|
| Available shell thickness with allowances | $t+c_{1s}+c_{2s}$ | $t_s$ | ***1.812*** | in |
| Required shell thickness with allowances | $t_r+c_{1s}+c_{2s}$ | $t_{sr}$ | **1.476** | in |
| Required nozzle thickness with allowances | | $t_{rn+}$ | **0.2711** | in |

**Areas according to UG-40**

$$h'_a = Min\begin{Bmatrix} 2.5\cdot t \\ 2.5\cdot t_n \\ h_a \end{Bmatrix} = Min\begin{Bmatrix} 2.5\cdot t \\ 2.5\cdot t_n \\ h_a \end{Bmatrix} = 107.2\ \text{mm}$$

$$h' = Min\begin{Bmatrix} 2.5\cdot t \\ 2.5\cdot t_n \\ h \end{Bmatrix} = Min\begin{Bmatrix} 2.5\cdot t \\ 2.5\cdot t_n \\ h \end{Bmatrix} = 0\ \text{mm}$$

$$A_1 = Max\begin{Bmatrix} d\cdot(E_1\cdot t - F\cdot t_r) - 2\cdot t_n\cdot(E_1\cdot t - F\cdot t_r)\cdot(1-f_{r1}) \\ 2\cdot(t+t_n)\cdot(E_1\cdot t - F\cdot t_r) - 2\cdot t_n\cdot(E_1\cdot t - F\cdot t_r)\cdot(1-f_{r1}) \end{Bmatrix} =$$

$$Max\begin{Bmatrix} 412.8\ \text{mm}\cdot 8.557\ \text{mm} - 2\cdot 117.5\ \text{mm}\cdot 8.557\ \text{mm}\cdot(1-1) \\ 2\cdot(42.86\ \text{mm}+117.5\ \text{mm})\cdot 8.557\ \text{mm} - 2\cdot 117.5\ \text{mm}\cdot 8.557\ \text{mm}\cdot(1-1) \end{Bmatrix} = 3532\ \text{mm}^2$$

$$A_2 = 2\cdot(t_n - t_{rn})\cdot f_{r2}\cdot h'_a = 2\cdot(117.5\ \text{mm} - 3.71\ \text{mm})\cdot 1\cdot 107.2\ \text{mm} = 24381\ \text{mm}^2$$

$$A_3 = 2\cdot(t_n - c_2)\cdot f_{r2}\cdot h' = 2\cdot(117.5\ \text{mm} - 3.175\ \text{mm})\cdot 1\cdot 0\ \text{mm} = 0\ \text{mm}^2$$

$$A_{41} = (leg_1)^2\cdot f_{r2} = (9.525\ \text{mm})^2\cdot 1 = 90.73\ \text{mm}^2$$

$$A_{43} = (leg_3)^2\cdot f_{r2} = (0\ \text{mm})^2\cdot 1 = 0\ \text{mm}^2$$

$$A_V = A_2 + A_3 + A_{41} + A_{43} = A_2 + A_3 + A_{41} + A_{43} = 24472\ \text{mm}^2$$

**App.1-7** is additionally required acc. to UG-36(b) if

| | | | | | |
|---|---|---|---|---|---|
| $D_a$ | *3902* ≤ 1520mm (60in.): | $d_a$ | 647.7 > Min [ | *3902*/2; 508mm (20in.)] |
| $D_a$ | *3902* > 1520mm (60in.): | $d_a$ | 647.7 > Min [ | *3902*/3; 1000mm (40in.)] |

**Additional rules for cylindr. shells, App.1-7(b)** not required

| | | | |
|---|---|---|---|
| Total available area | | $A_{avl}$ | in² |
| Inside radius of shell | | R | in |
| Inside radius of nozzle | | $R_n$ | in |
| Mean radius of shell | | $R_m$ | in |
| Mean radius of nozzle | | $R_{nm}$ | in |
| Allowable stress value | | S | psi |
| Distance e | | e | in |
| Moment of inertia | | I | mm^4 |
| Material area acc. to Fig.1-7-1 | | $A_s$ | in² |
| Support length nozzle | Min[$h_a$; $t_e$ +($R_{nm}$·$t_n$)$^{0.5}$] | $l_{nm}$ | in |
| Support length shell | Min[$b_a$; ($R_m$·$t_e$)$^{0.5}$] | $l_m$ | in |

**Conditions according to 1-7(b)(1) for radial nozzles**

(a) $2\cdot R = $ [redacted] > 1524 *mm* (60 *in.*)

(b) $2\cdot R_n = $ [redacted] > 1016 mm (40 in.) and $2\cdot R_n > 3.4\cdot\sqrt{R\cdot t} = $ [redacted]

(c) $\frac{R_n}{R} = \frac{\text{[redacted]}}{\text{[redacted]}} = $ [redacted] ≤ 0.7

**Membrane stress Sm acc. App. 1-7(b)(2)**

$$S_m = P \cdot \frac{[R \cdot (R_n + t_n + l_m) + R_n \cdot (t + l_{nm})]}{A_s}$$

$$A_s = l_m \cdot t + (t_n + l_{nm}) \cdot t_n \cdot f_{r2}$$

$$l_m = Min\left\{ \frac{b_a}{\sqrt{R_m \cdot t}} \right.$$

$$l_{nm} = Min\left\{ \begin{matrix} h_a \\ t_e + \sqrt{R_{nm} \cdot t_n} \end{matrix} \right.$$

Reduction factors, only for $f_{r2}$ or $f_{r4}$ < 0.8 acc. to App.1-7(b)(4)

$$S_m = \leq S$$

**Bending stress Sb acc. to App. 1-7(b)(2)**

$$M = \left( \frac{R_n^3}{6} + R \cdot R_n \cdot e \right) \cdot P$$

$$a = e + \frac{t}{2} = e + \frac{42.86\ \text{mm}}{2} = a$$

$$S_b = M \cdot \frac{a}{I}$$

$$(S_m + S_b) \leq 1.5 \cdot S$$

## E 4.5.2 Step5 F=1 - Protruding nozzles without reinforcement - ASME BPVC VIII-1 UG-37: 2017

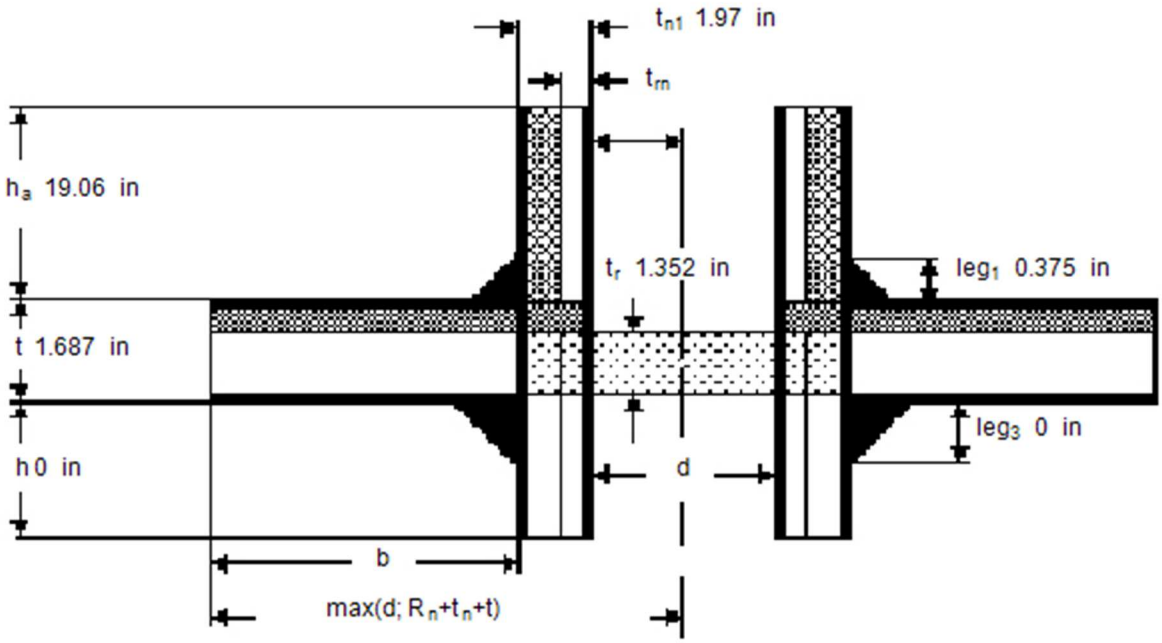
**Protruding nozzle without reinforcement**

| | | | |
|---|---|---|---|
| Design pressure | $p_D$ | 356 | psi |
| Hydrostatic head | $D_p$ | 0 | psi |
| Calculation pressure | $p_0$ | ***356*** | psi |
| Calculation temperature | $T_0$ | *300* | °F |
| Factor (1=internal pressure; 2=external pressure) | $\Gamma$ | 1 | |

**Shell**

| | | | |
|---|---|---|---|
| Straight cross section (=Y), as cylinders acc. UG-36(b)(1) and flat heads acc. UG-39(b)(1) or circular cross section (=N) as spheres | Cyl | Y | (N=No) |
| Outside diameter | $D_a$ | *153.6* | in |
| Nominal thickness without allowances | t | 1.687 | in |
| Available shell length for reinforcement | $b_a$ | 60 | in |
| Joint efficiency factor | $E_1$ | 1 | |
| Material *K02700-SA-516-70-Class:-Size:* | | | |
| Material strength | K | 20015 | psi |
| Safety factor | S | 1 | |
| Allowable stress value | $S_v$ | ***20015*** | psi |
| Wall thickness allowance | $c_{1s}$ | *0* | in |
| Corrosion allowance | $c_{2s}$ | *0.125* | in |

**Nozzle** Nº 1




| | | | |
|---|---|---|---|
| Access opening | | No | |
| Outside diameter | $d_a$ | 11.56 | in |
| Joint efficiency factor | $E_n$ | 1 | |
| Material K02700-SA-516-70-Class:-Size: | | | |
| Material strength | $K_n$ | 20015 | psi |
| Wall thickness allowance | $c_1$ | 0 | in |
| Allowance (corrosion) | $c_2$ | 0.125 | in |
| Safety factor | S | 1 | |
| Allowable stress $K_n$/S | $S_n$ | **20015** | psi |
| Nominal thickness with allowances | $t_{n1}$ | 1.97 | in |
| Required wall thickness acc. Table UG-45 with corrosion allowance | $t_{b3}$ | **0.4533** | in |
| Nominal inside diameter = da-2*t2 | $d_{iN}$ | **7.62** | in |
| Inside diameter, corroded = $d_a$-2·$t_n$ | d | **7.87** | in |
| External projection | $h_a$ | 19.06 | in |
| Internal projection | h | 0 | in |
| Angle between the shell axis and the sectional plane through the opening center | Θ | 0 | ° |
| Nominal thickness without allowances | $t_n$ | **1.845** | in |
| Required nozzle neck thickness per UG-16 | $t_{UG-16}$ | 1.5 | mm |
| Required nozzle neck thickness per UG-45 | $t_{UG-45}$ | **0.4533** | in |
| Fillet weld nozzle / shell outside | $leg_1$ | 0.375 | in |
| Fillet weld nozzle / shell inside | $leg_3$ | 0 | in |
| Groove weld nozzle / shell (≤t) | $leg_4$ | 0 | in |

| **Calculation according to** | | **UG-40** | | **App.1-7** | |
|---|---|---|---|---|---|
| Correction factor (Fig.UG-37, int. pres.) | F | **1** | | | |
| Reserve of shell | $(E_1 \cdot t - F \cdot t_r)$ | **0.3358** | in | | |
| Limit length of vessel acc. to UG-40(b) | b | **3.935** | in | | in |
| Limit length of nozzle outside, UG40(c) | $h'_a$ | **4.219** | in | **4.219** | in |
| Limit length of nozzle inside,Fig.UG37 | h' | **0** | in | 0 | |
| Minimum required thickness of nozzle | $t_{rn}$ | **0.07075** | in | **0.07075** | in |
| Required area for internal pressure | A | **10.64** | in² | | in² |
| Area of shell reserve | $A_1$ | **2.643** | in² | | in² |
| Area of reinforcement ($A_2$ to $A_5$) | $A_V$ | **15.11** | in² | | in² |
| Total available area ∑A | $A_{avl}$ | **17.75** | in² | | in² |
| Required area A/Γ | $A_{req}$ | **10.64** | in² | | in² |
| Utilization | $A_{req}/A_{avl}$ | **59.92** | % | | % |
| Allowable pressure (approx.: $p_D$/utilization) | | **594.1** | psi | | psi |

**Weld loads according to UG-41**

| | | | | |
|---|---|---|---|---|
| W | = $[A-A_1+2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)] \cdot S_V$ | = | **822143** | N |
| $W_1$-1 | = $[A_2+A_{41}] \cdot S_V$ | = | **1345355** | N |
| $W_2$-2 | = $[A_2+A_3+A_41+A_{43}+2 \cdot t \cdot t_n \cdot f_{r1}] \cdot S_V$ | = | **1899746** | N |

**Strength of nozzle wall, fillet and groove welds**

| | | | | |
|---|---|---|---|---|
| Fillet shell /nozzle | $\pi/2 \cdot d_a \cdot leg_1 \cdot 0.49 \cdot \min(S_V;S_n)$ | = | **297066** | N |
| Fillet shell /nozzle | $\pi/2 \cdot d_a \cdot leg_3 \cdot 0.49 \cdot \min(S_V;S_n)$ | = | **0** | N |
| Groove shell /nozzle | $\pi/2 \cdot d_a \cdot leg_4 \cdot 0.74 \cdot \min(S_V;S_n)$ | = | **0** | N |
| Nozzle wall | $\pi/2 \cdot d_m \cdot t_n \cdot 0.70 \cdot S_n$ | = | **1754707** | N |

**Comparison of weld loads on path 1-1 and 2-2**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1-1 | | **297066** N | + | **1754707** N | = | **2051773** N | | |
| | | | | | ≥ | **822143** N | | |
| 2-2 | **297066** N | + | **0** N | + | **0** N | = | **297066** N | |
| | | | | | ≥ | **822143** N | | |

**Equations according to UG-40 and App.1-7**

Fig. UG-37.1, UG-40(b)

$$b = Max\left\{\begin{matrix}\frac{d}{2} \\ t_n + t\end{matrix}\right. = Max\left\{\begin{matrix}\frac{d}{2} \\ t_n + t\end{matrix}\right. = 99.95 \text{ mm}$$

App.1-7(a)(1)

$$b = Max\left\{\begin{matrix}\frac{3 \cdot d/2}{4} \\ t_n + t\end{matrix}\right.$$

App.1-7(a)(1)

$$A = \frac{2}{3} \cdot (d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}))$$

Fig. UG-37.1

$$A = d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) =$$

$$199.9 \text{ mm} \cdot 34.33 \text{ mm} \cdot 1 + 2 \cdot 46.86 \text{ mm} \cdot 34.33 \text{ mm} \cdot 1 \cdot (1 - 1) = 6863 \text{ mm}^2$$

| | | | | |
|---|---|---|---|---|
| Available shell thickness with allowances | $t+c_{1s}+c_{2s}$ | $t_s$ | ***1.812*** | in |
| Required shell thickness with allowances | $t_r+c_{1s}+c_{2s}$ | $t_{sr}$ | **1.477** | in |
| Required nozzle thickness with allowances | | $t_{rn+}$ | **0.1957** | in |

**Areas according to UG-40**

$$h'_a = Min\begin{Bmatrix} 2.5\cdot t \\ 2.5\cdot t_n \\ h_a \end{Bmatrix} = Min\begin{Bmatrix} 2.5\cdot t \\ 2.5\cdot t_n \\ h_a \end{Bmatrix} = 107.2\ \text{mm}$$

$$h' = Min\begin{Bmatrix} 2.5\cdot t \\ 2.5\cdot t_n \\ h \end{Bmatrix} = Min\begin{Bmatrix} 2.5\cdot t \\ 2.5\cdot t_n \\ h \end{Bmatrix} = 0\ \text{mm}$$

$$A_1 = Max\begin{Bmatrix} d\cdot(E_1\cdot t - F\cdot t_r) - 2\cdot t_n\cdot(E_1\cdot t - F\cdot t_r)\cdot(1-f_{r1}) \\ 2\cdot(t+t_n)\cdot(E_1\cdot t - F\cdot t_r) - 2\cdot t_n\cdot(E_1\cdot t - F\cdot t_r)\cdot(1-f_{r1}) \end{Bmatrix} =$$

$$Max\begin{Bmatrix} 199.9\ \text{mm}\cdot 8.529\ \text{mm} - 2\cdot 46.86\ \text{mm}\cdot 8.529\ \text{mm}\cdot(1-1) \\ 2\cdot(42.86\ \text{mm}+46.86\ \text{mm})\cdot 8.529\ \text{mm} - 2\cdot 46.86\ \text{mm}\cdot 8.529\ \text{mm}\cdot(1-1) \end{Bmatrix} = 1705\ \text{mm}^2$$

$$A_2 = 2\cdot(t_n - t_{rn})\cdot f_{r2}\cdot h'_a = 2\cdot(46.86\ \text{mm} - 1.797\ \text{mm})\cdot 1\cdot 107.2\ \text{mm} = 9658\ \text{mm}^2$$

$$A_3 = 2\cdot(t_n - c_2)\cdot f_{r2}\cdot h' = 2\cdot(46.86\ \text{mm} - 3.175\ \text{mm})\cdot 1\cdot 0\ \text{mm} = 0\ \text{mm}^2$$

$$A_{41} = (leg_1)^2\cdot f_{r2} = (9.525\ \text{mm})^2\cdot 1 = 90.73\ \text{mm}^2$$

$$A_{43} = (leg_3)^2\cdot f_{r2} = (0\ \text{mm})^2\cdot 1 = 0\ \text{mm}^2$$

$$A_V = A_2 + A_3 + A_{41} + A_{43} = A_2 + A_3 + A_{41} + A_{43} = 9749\ \text{mm}^2$$

**App.1-7** is additionally required acc. to UG-36(b) if

| | | | | | |
|---|---|---|---|---|---|
| $D_a$ | *3901* ≤ 1520mm (60in.): | $d_a$ | 293.6 > Min [ | *3901*/2; 508mm (20in.)] | |
| $D_a$ | *3901* > 1520mm (60in.): | $d_a$ | 293.6 > Min [ | *3901*/3; 1000mm (40in.)] | |

**Additional rules for cylindr. shells, App.1-7(b)** not required

| | | | |
|---|---|---|---|
| Total available area | | $A_{avl}$ | in² |
| Inside radius of shell | | R | in |
| Inside radius of nozzle | | $R_n$ | in |
| Mean radius of shell | | $R_m$ | in |
| Mean radius of nozzle | | $R_{nm}$ | in |
| Allowable stress value | | S | psi |
| Distance e | | e | in |
| Moment of inertia | | I | mm^4 |
| Material area acc. to Fig.1-7-1 | | $A_s$ | in² |
| Support length nozzle | Min[$h_a$; $t_e$ +($R_{nm}$·$t_n$)$^{0.5}$] | $l_{nm}$ | in |
| Support length shell | Min[$b_a$; ($R_m$·$t_e$)$^{0.5}$] | $l_m$ | in |

**Conditions according to 1-7(b)(1) for radial nozzles**

(a) $2\cdot R =$ [redacted] > 1524 *mm* (60 *in.*)

(b) $2\cdot R_n =$ [redacted] > 1016 mm (40 in.) and $2\cdot R_n > 3.4\cdot\sqrt{R\cdot t} =$ [redacted]

(c) $\frac{R_n}{R} =$ [redacted] = [redacted] ≤ 0.7

**Membrane stress Sm acc. App. 1-7(b)(2)**

$$S_m = P \cdot \frac{[R \cdot (R_n + t_n + l_m) + R_n \cdot (t + l_{nm})]}{A_s}$$

$$A_s = l_m \cdot t + (t_n + l_{nm}) \cdot t_n \cdot f_{r2}$$

$$l_m = Min\left\{ \frac{b_a}{\sqrt{R_m \cdot t}} \right.$$

$$l_{nm} = Min\left\{ \begin{matrix} h_a \\ t_e + \sqrt{R_{nm} \cdot t_n} \end{matrix} \right.$$

Reduction factors, only for $f_{r2}$ or $f_{r4}$ < 0.8 acc. to App.1-7(b)(4)

$$S_m = \leq S$$

**Bending stress Sb acc. to App. 1-7(b)(2)**

$$M = \left( \frac{R_n^3}{6} + R \cdot R_n \cdot e \right) \cdot P$$

$$a = e + \frac{t}{2} = e + \frac{42.86\ \text{mm}}{2} = a$$

$$S_b = M \cdot \frac{a}{I}$$

$$(S_m + S_b) \leq 1.5 \cdot S$$

## E 4.5.3 - Protruding nozzles without reinforcement - ASME BPVC VIII-1 UG-37: 2017

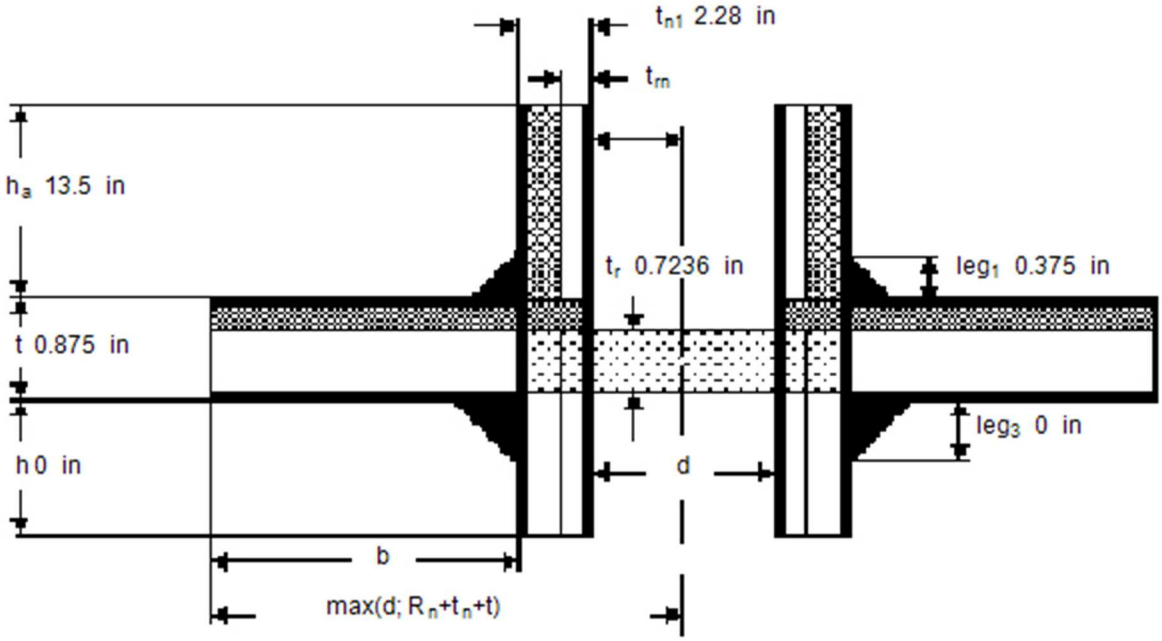
**Protruding nozzle without reinforcement**

| | | | | |
|---|---|---|---|---|
| Design pressure | $p_D$ | | 356 | psi |
| Hydrostatic head | $D_p$ | | 0 | psi |
| Calculation pressure | $p_0$ | | ***356*** | psi |
| Calculation temperature | $T_0$ | | *300* | °F |
| Factor (1=internal pressure; 2=external pressure) | $\Gamma$ | | 1 | |

**Shell**

| | | | | |
|---|---|---|---|---|
| Straight cross section (=Y), as cylinders acc. UG-36(b)(1) and flat heads acc. UG-39(b)(1) or circular cross section (=N) as spheres | Cyl | N | | (N=No) |
| Outside diameter | $D_a$ | | *92* | in |
| Nominal thickness without allowances | t | | 0.875 | in |
| Available shell length for reinforcement | $b_a$ | | 40 | in |
| Joint efficiency factor | $E_1$ | | 1 | |
| Material *K02700-SA-516-70-Class:-Size:* | | | | |
| Material strength | K | | 20015 | psi |
| Safety factor | S | | 1 | |
| Allowable stress value | $S_v$ | | ***20015*** | psi |
| Wall thickness allowance | $c_{1s}$ | | *0* | in |
| Corrosion allowance | $c_{2s}$ | | *0.125* | in |

**Nozzle** Nº 1




| | | | |
|---|---|---|---|
| Access opening | | No | |
| Outside diameter | $d_a$ | 15.94 | in |
| Joint efficiency factor | $E_n$ | 1 | |
| Material K02700-SA-516-70-Class:-Size: | | | |
| Material strength | $K_n$ | 20015 | psi |
| Wall thickness allowance | $c_1$ | 0 | in |
| Allowance (corrosion) | $c_2$ | 0.125 | in |
| Safety factor | S | 1 | |
| Allowable stress $K_n$/S | $S_n$ | **20015** | psi |
| Nominal thickness with allowances | $t_{n1}$ | 2.28 | in |
| Required wall thickness acc. Table UG-45 with corrosion allowance | $t_{b3}$ | **0.4533** | in |
| Nominal inside diameter = da-2*t2 | $d_{iN}$ | **11.38** | in |
| Inside diameter, corroded = $d_a$-2·$t_n$ | d | **11.63** | in |
| External projection | $h_a$ | 13.5 | in |
| Internal projection | h | 0 | in |
| Angle between the shell axis and the sectional plane through the opening center | Θ | 0 | ° |
| Nominal thickness without allowances | $t_n$ | **2.155** | in |
| Required nozzle neck thickness per UG-16 | $t_{UG-16}$ | 1.5 | mm |
| Required nozzle neck thickness per UG-45 | $t_{UG-45}$ | **0.4533** | in |
| Fillet weld nozzle / shell outside | $leg_1$ | 0.375 | in |
| Fillet weld nozzle / shell inside | $leg_3$ | 0 | in |
| Groove weld nozzle / shell (≤t) | $leg_4$ | 0 | in |

| **Calculation according to** | | **UG-40** | | **App.1-7** | |
|---|---|---|---|---|---|
| Correction factor (Fig.UG-37, int. pres.) | F | **1** | | | |
| Reserve of shell | $(E_1 \cdot t - F \cdot t_r)$ | **0.1514** | in | | |
| Limit length of vessel acc. to UG-40(b) | b | **5.815** | in | | in |
| Limit length of nozzle outside, UG40(c) | $h'_a$ | **2.188** | in | **2.188** | in |
| Limit length of nozzle inside,Fig.UG37 | h' | **0** | in | 0 | |
| Minimum required thickness of nozzle | $t_{rn}$ | **0.1045** | in | **0.1045** | in |
| Required area for internal pressure | A | **8.415** | in² | | in² |
| Area of shell reserve | $A_1$ | **1.761** | in² | | in² |
| Area of reinforcement ($A_2$ to $A_5$) | $A_V$ | **9.111** | in² | | in² |
| Total available area ∑A | $A_{avl}$ | **10.87** | in² | | in² |
| Required area A/Γ | $A_{req}$ | **8.415** | in² | | in² |
| Utilization | $A_{req}/A_{avl}$ | **77.4** | % | | % |
| Allowable pressure (approx.: $p_D$/utilization) | | **459.9** | psi | | psi |

**Weld loads according to UG-41**

| | | | | |
|---|---|---|---|---|
| W | = $[A-A_1+2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)] \cdot S_V$ | = | **650577** | N |
| $W_1$-1 | = $[A_2+A_{41}] \cdot S_V$ | = | **811204** | N |
| $W_2$-2 | = $[A_2+A_3+A_41+A_{43}+2 \cdot t \cdot t_n \cdot f_{r1}] \cdot S_V$ | = | **1146966** | N |

**Strength of nozzle wall, fillet and groove welds**

| | | | | |
|---|---|---|---|---|
| Fillet shell /nozzle | $\pi/2 \cdot d_a \cdot leg_1 \cdot 0.49 \cdot \min(S_V;S_n)$ | = | **409622** | N |
| Fillet shell /nozzle | $\pi/2 \cdot d_a \cdot leg_3 \cdot 0.49 \cdot \min(S_V;S_n)$ | = | **0** | N |
| Groove shell /nozzle | $\pi/2 \cdot d_a \cdot leg_4 \cdot 0.74 \cdot \min(S_V;S_n)$ | = | **0** | N |
| Nozzle wall | $\pi/2 \cdot d_m \cdot t_n \cdot 0.70 \cdot S_n$ | = | **2908168** | N |

**Comparison of weld loads on path 1-1 and 2-2**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1-1 | | | **409622** | N | + | **2908168** | N | = | **3317790** | N |
| | | | | | | | | ≥ | **650577** | N |
| 2-2 | **409622** | N | + | **0** | N | + | **0** | N | = | **409622** | N |
| | | | | | | | | ≥ | **650577** | N |

**Equations according to UG-40 and App.1-7**

Fig. UG-37.1, UG-40(b)

$$b = Max\left\{\begin{matrix}\frac{d}{2} \\ t_n + t\end{matrix}\right. = Max\left\{\begin{matrix}\frac{d}{2} \\ t_n + t\end{matrix}\right. = 147.7 \text{ mm}$$

App.1-7(a)(1)

$$b = Max\left\{\begin{matrix}\frac{3 \cdot d/2}{4} \\ t_n + t\end{matrix}\right.$$

App.1-7(a)(1)

$$A = \frac{2}{3} \cdot (d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}))$$

Fig. UG-37.1

$$A = d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) =$$

$$295.4 \text{ mm} \cdot 18.38 \text{ mm} \cdot 1 + 2 \cdot 54.74 \text{ mm} \cdot 18.38 \text{ mm} \cdot 1 \cdot (1 - 1) = 5429 \text{ mm}^2$$

| | | | | |
|---|---|---|---|---|
| Available shell thickness with allowances | $t+c_{1s}+c_{2s}$ | $t_s$ | ***1*** | in |
| Required shell thickness with allowances | $t_r+c_{1s}+c_{2s}$ | $t_{sr}$ | **0.8486** | in |
| Required nozzle thickness with allowances | | $t_{rn+}$ | **0.2295** | in |

**Areas according to UG-40**

$$h'_a = Min\begin{Bmatrix} 2.5\cdot t \\ 2.5\cdot t_n \\ h_a \end{Bmatrix} = Min\begin{Bmatrix} 2.5\cdot t \\ 2.5\cdot t_n \\ h_a \end{Bmatrix} = 55.56\ \text{mm}$$

$$h' = Min\begin{Bmatrix} 2.5\cdot t \\ 2.5\cdot t_n \\ h \end{Bmatrix} = Min\begin{Bmatrix} 2.5\cdot t \\ 2.5\cdot t_n \\ h \end{Bmatrix} = 0\ \text{mm}$$

$$A_1 = Max\begin{Bmatrix} d\cdot(E_1\cdot t - F\cdot t_r) - 2\cdot t_n\cdot(E_1\cdot t - F\cdot t_r)\cdot(1-f_{r1}) \\ 2\cdot(t+t_n)\cdot(E_1\cdot t - F\cdot t_r) - 2\cdot t_n\cdot(E_1\cdot t - F\cdot t_r)\cdot(1-f_{r1}) \end{Bmatrix} =$$

$$Max\begin{Bmatrix} 295.4\ \text{mm}\cdot 3.846\ \text{mm} - 2\cdot 54.74\ \text{mm}\cdot 3.846\ \text{mm}\cdot(1-1) \\ 2\cdot(22.23\ \text{mm}+54.74\ \text{mm})\cdot 3.846\ \text{mm} - 2\cdot 54.74\ \text{mm}\cdot 3.846\ \text{mm}\cdot(1-1) \end{Bmatrix} = 1136\ \text{mm}^2$$

$$A_2 = 2\cdot(t_n - t_{rn})\cdot f_{r2}\cdot h'_a = 2\cdot(54.74\ \text{mm} - 2.655\ \text{mm})\cdot 1\cdot 55.56\ \text{mm} = 5788\ \text{mm}^2$$

$$A_3 = 2\cdot(t_n - c_2)\cdot f_{r2}\cdot h' = 2\cdot(54.74\ \text{mm} - 3.175\ \text{mm})\cdot 1\cdot 0\ \text{mm} = 0\ \text{mm}^2$$

$$A_{41} = (leg_1)^2\cdot f_{r2} = (9.525\ \text{mm})^2\cdot 1 = 90.73\ \text{mm}^2$$

$$A_{43} = (leg_3)^2\cdot f_{r2} = (0\ \text{mm})^2\cdot 1 = 0\ \text{mm}^2$$

$$A_V = A_2 + A_3 + A_{41} + A_{43} = A_2 + A_3 + A_{41} + A_{43} = 5878\ \text{mm}^2$$

**App.1-7** is additionally required acc. to UG-36(b) if

| | | | | | |
|---|---|---|---|---|---|
| $D_a$ | *2337* ≤ 1520mm (60in.): | $d_a$ | 404.9 > Min [ | *2337*/2; 508mm (20in.)] | |
| $D_a$ | *2337* > 1520mm (60in.): | $d_a$ | 404.9 > Min [ | *2337*/3; 1000mm (40in.)] | |

**Additional rules for cylindr. shells, App.1-7(b)** not required

| | | | |
|---|---|---|---|
| Total available area | | $A_{avl}$ | in² |
| Inside radius of shell | | R | in |
| Inside radius of nozzle | | $R_n$ | in |
| Mean radius of shell | | $R_m$ | in |
| Mean radius of nozzle | | $R_{nm}$ | in |
| Allowable stress value | | S | psi |
| Distance e | | e | in |
| Moment of inertia | | I | mm^4 |
| Material area acc. to Fig.1-7-1 | | $A_s$ | in² |
| Support length nozzle | Min[$h_a$; $t_e$ +($R_{nm}$·$t_n$)$^{0.5}$] | $l_{nm}$ | in |
| Support length shell | Min[$b_a$; ($R_m$·$t_e$)$^{0.5}$] | $l_m$ | in |

**Conditions according to 1-7(b)(1) for radial nozzles**

(a) $2\cdot R =$ [redacted] > 1524 *mm* (60 *in.*)

(b) $2\cdot R_n =$ [redacted] > 1016 mm (40 in.) and $2\cdot R_n > 3.4\cdot\sqrt{R\cdot t} =$ [redacted]

(c) $\frac{R_n}{R} =$ [redacted] = [redacted] ≤ 0.7

**Membrane stress Sm acc. App. 1-7(b)(2)**

$$S_m = P \cdot \frac{[R \cdot (R_n + t_n + l_m) + R_n \cdot (t + l_{nm})]}{A_s}$$

$$A_s = l_m \cdot t + (t_n + l_{nm}) \cdot t_n \cdot f_{r2}$$

$$l_m = Min\left\{ \frac{b_a}{\sqrt{R_m \cdot t}} \right.$$

$$l_{nm} = Min\left\{ t_e + \frac{h_a}{\sqrt{R_{nm} \cdot t_n}} \right.$$

Reduction factors, only for $f_{r2}$ or $f_{r4}$ < 0.8 acc. to App.1-7(b)(4)

$$S_m = \leq S$$

**Bending stress Sb acc. to App. 1-7(b)(2)**

$$M = \left( \frac{R_n^3}{6} + R \cdot R_n \cdot e \right) \cdot P$$

$$a = e + \frac{t}{2} = e + \frac{22.23\ \text{mm}}{2} = a$$

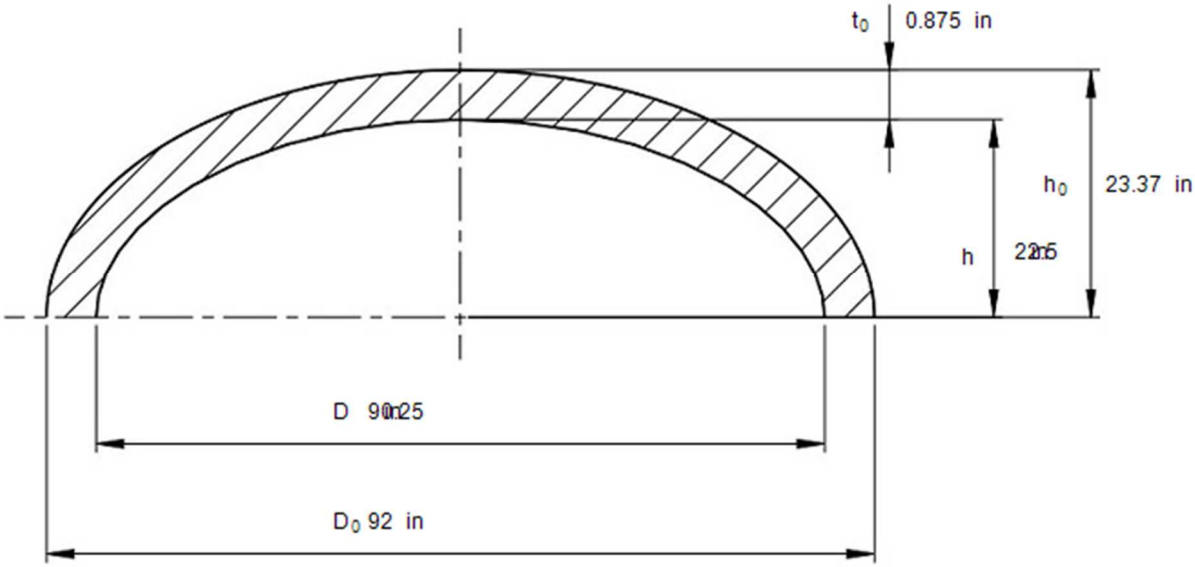
$$S_b = M \cdot \frac{a}{I}$$

$$(S_m + S_b) \leq 1.5 \cdot S$$

## Elliptical heads under internal pressure - ASME BPVC VIII-1 UG-32 & Appendix-1: 2017

**Ellipsoidal heads acc. UG-32(c) and Appendix 1-4(f)**

| | | | |
|---|---|---|---|
| Design pressure | $p_D$ | 24.55 | bar |
| Hydrostatic head | $D_p$ | 0 | bar |
| Calculation pressure | $p_0$ | **356** | psi |
| Calculation temperature | $T_0$ | 148.9 | °C |
| Final wall thickness | $t_e$ | 1 | in |
| Wall thickness allowance | $c_1$ | 0 | in |
| Allowance (corrosion) | $c_2$ | 0.125 | in |
| Effective thickness without allowances | $t_0$ | **0.875** | in |




| | | | | |
|---|---|---|---|---|
| Outside diameter of cylindrical shell | | $D_0$ | **92** | in |
| Inside diameter of cylindrical shell | (= $D_0$-2$t_0$) | D | 90.25 | in |
| Outer height of head | | $h_0$ | **23.37** | in |
| Inside depth of head | (minor semi-axis= $h_0$-$t_0$) | h | 22.5 | in |
| Weld joint efficiency | | E | 1 | |

**Material data**

| | | | |
|---|---|---|---|
| Material | K02700-SA-516-70-Class:-Size: | | |
| Elasticity modulus | | $E_T$ | 195067 MPa |
| Elastic limit | | $S_y$ | 33668 psi |
| Reduce allowable*) stress for $R_{m20}$ > 485 MPa? | | | Yes (Yes/No) |
| Tensile strength at 20°C | | $R_{m20}$ | 70343 psi |
| Allowable stress | | | |
| at working temperature acc. ASME-table | | $S_T$ | 20015 psi |
| at 20°C | | $S_{20}$ | 20015 psi |
| acc. UG-32(c) or App. 1-4(c) | | S | **20015** psi |

*) According to App. 1-4(c,d), the allowable stress must be reduced to 138 * $S_T$ /$S_{20}$ (=20 ksi*...) for $R_{m20}$ > 485 MPa (70 ksi).

**Results**

| | | | |
|---|---|---|---|
| Ratio | | D/2h | **2** |
| Factor | | K | **1** |
| Factor K1 acc. Table UG-37 | | $K_1$ | **0.9** |
| Required thickness | | t | **0.804** in |
| incl. allowances | ($t_e$ 1 in ≥t+) | t+ | **0.929** in |
| Allowable excess pressure incl. hydrostatic Head | | P | **387.4** psi |
| Allowable excess pressure without hydrostatic Head | | MAWP | **387.4** psi |

**Required thickness for openings acc. to UG-37(a) in nomenclature for $t_r$**

| | | | | |
|---|---|---|---|---|
| Using UG-32 with E=1 | | t(E=1) | **0.804** | in |
| Section (c) in the centre circle (< 0.8·D) | | $t_1$(E=1) | ***0.7236*** | in |
| Equivalent spherical outside diameter | $2\cdot(K_1\cdot D+t_E)$ | $D_s$ | **164.5** | in |

Geometrical conditions

**valid**

Strength

**Wall thickness acceptable**

Allowable unreinforced opening diameter d for welded, brazed, and flued connections acc. UG 36(c)3

d ≤ 89 mm (3.5 in.) for t ≤10 mm (3/8 in.)
d ≤ 60 mm (2 3/8 in.) for t > 10 mm (3/8 in.)

Remark

**Equations according to UG-32**

$$t=\frac{P_0\cdot D\cdot K}{2\cdot S\cdot E-0.2\cdot P_0}=\frac{24.55\text{ bar}\cdot 2292\text{ mm}\cdot 1}{2\cdot 138\text{ N/mm}^2\cdot 1-0.2\cdot 24.55\text{ bar}}=20.42\text{ mm}$$

$$P=\frac{2\cdot S\cdot E\cdot t_0}{K\cdot D+0.2\cdot t_0}=\frac{2\cdot 138\text{ N/mm}^2\cdot 1\cdot 22.23\text{ mm}}{1\cdot 2292\text{ mm}+0.2\cdot 22.23\text{ mm}}=2.671\text{ MPa}$$

## E4.5.5 - Set-on nozzles with reinforcement - ASME BPVC VIII-1 UG-37: 2017

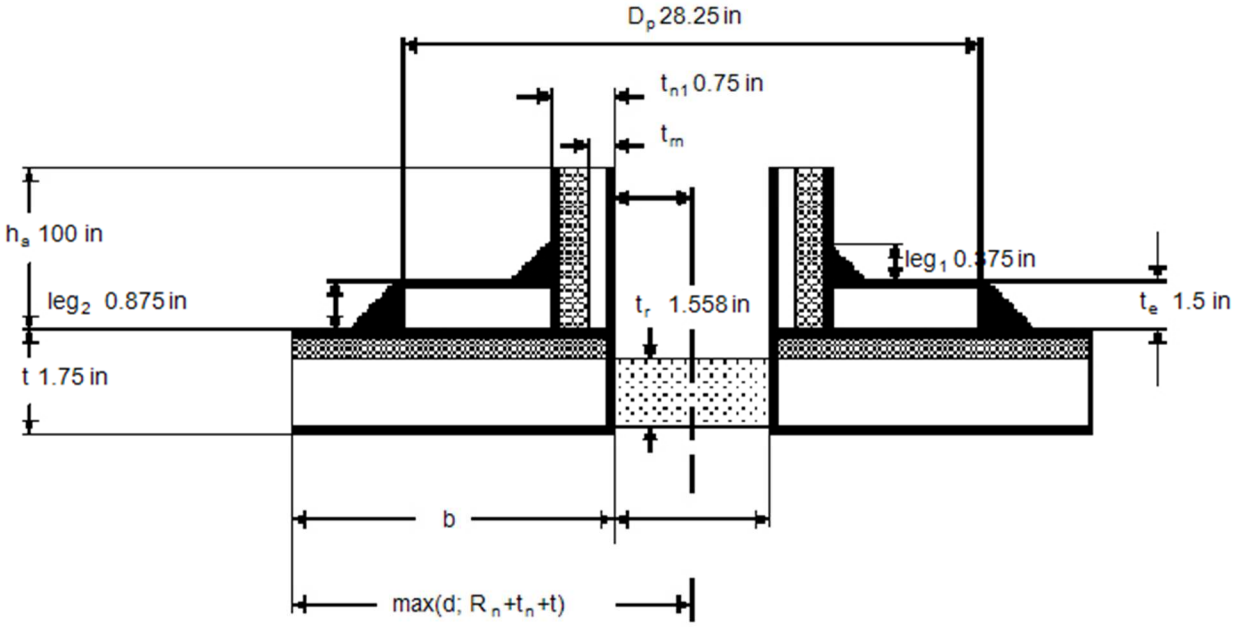
**Set-on nozzle with reinforcement**

| | | | | |
|---|---|---|---|---|
| Design pressure | $p_D$ | | 500 | psi |
| Hydrostatic head | $D_p$ | | 0 | psi |
| Calculation pressure | $p_0$ | | ***500*** | psi |
| Calculation temperature | $T_0$ | | *400* | °F |
| Factor (1=internal pressure; 2=external pressure) | $\Gamma$ | | 1 | |

**Shell**

| | | | | |
|---|---|---|---|---|
| Straight cross section (=Y), as cylinders acc. UG-36(b)(1) and flat heads acc. UG-39(b)(1) or circular cross section (=N) as spheres | Cyl | Y | | (N=No) |
| Outside diameter | $D_a$ | | *87* | in |
| Nominal thickness without allowances | t | | 1.75 | in |
| Available shell length for reinforcment | $b_a$ | | 50 | in |
| Joint efficiency factor | $E_1$ | | 1 | |
| Material | | | | |
| Material strength | K | | | psi |
| Safety factor | S | | | |
| Allowable stress value K/S | $S_v$ | | *13700* | psi |
| Wall thickness allowance | $c_{1s}$ | | *0* | in |
| Corrosion allowance | $c_{2s}$ | | *0.25* | in |

**Nozzle** Nº 1




| | | | |
|---|---|---|---|
| Access opening | | No | |
| Outside diameter | $d_a$ | 16 | in |
| Joint efficiency factor | $E_n$ | 1 | |
| Material | | | |
| Material strength | $K_n$ | **13700** | psi |
| Wall thickness allowance | $c_1$ | 0 | in |
| Allowance (corrosion) | $c_2$ | 0.25 | in |
| Safety factor | $S$ | 1 | |
| Allowable stress value $K_n/S$ | $S_n$ | 13700 | psi |
| Nominal thickness with allowances | $t_{n1}$ | 0.75 | in |
| Required wall thickness acc. Table UG-45 with corrosion allowance | $t_{b3}$ | **0.5783** | in |
| Nominal inside diameter = da-2*t2 | $d_{iN}$ | **14.5** | in |
| Inside diameter, corroded = $d_a$-2·$t_n$ | $d$ | **15** | in |
| External projection | $h_a$ | 100 | in |
| Angle between the shell axis and the sectional plane through the opening center | $\Theta$ | 0 | ° |
| Nominal thickness without allowances | $t_n$ | **0.5** | in |
| Required nozzle neck thickness per UG-16 | $t_{UG-16}$ | 1.5 | mm |
| Required nozzle neck thickness per UG-45 | $t_{UG-45}$ | | in |

**Reinforcing element**

| | | | |
|---|---|---|---|
| Thickness | $t_e$ | 1.5 | in |
| Outside diameter | $D_p$ | 28.25 | in |
| Material | | | |
| Material strength | $K_p$ | | psi |
| Safety factor | $S$ | | |
| Allowable stress | $S_p$ | 1987007 | psi |
| Fillet nozzle/ reinforcement outside | $leg_1$ | 0.375 | in |
| Fillet of reinforcement / shell outside | $leg_2$ | 0.875 | in |
| Groove nozzle / shell (≤tn) | $leg_4$ | 0.5 | in |
| Groove reinforcement / nozzle(≤te) | $leg_5$ | 0.5 | in |

| Calculation according to | | UG-40 | | App.1-7 | |
|---|---|---|---|---|---|
| Correction factor (Fig.UG-37, int. pres.) | F | 1 | | | |
| Reserve of shell | $(E_1 \cdot t - F \cdot t_r)$ | 0.1922 | in | | |
| Limit length of vessel acc. to UG-40(b) | b | 7.5 | in | | in |
| Limit length of nozzle outside, UG40(c) | $h'_a$ | 2.75 | in | 2.75 | in |
| Minimum required thickness of nozzle | $t_{rn}$ | 0.2799 | in | 0.2799 | in |
| Projected Area | A | 23.37 | in² | | in² |
| Area of shell reserve | $A_1$ | 2.883 | in² | | in² |
| Area of reinforcement ($A_2$ to $A_5$) | $A_V$ | 20.49 | in² | | in² |
| Total available area ∑A | ∑A | 23.38 | in² | | in² |
| Required area A/Γ | A/H | 23.37 | in² | | in² |
| Utilization | $A_{req}/A_{avl}$ | 99.97 | % | | % |
| Allowable pressure (Approx.: pD/utilization) | | 500.2 | psi | | psi |

**Weld loads according to UG-41**

| | | | | |
|---|---|---|---|---|
| W | = $[A-A_1+2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t-F \cdot t_r)] \cdot S_v$ | = | 1248316 | N |
| $W_1$-1 | = $[A_2+A_5+A_{41}+A_{42}] \cdot S_v$ | = | 1248808 | N |
| $W_2$-2 | = $[A_2+A_{41}] \cdot S_v$ | = | 82358 | N |

**Strength of fillet welds**

| | | | |
|---|---|---|---|
| Reinf./nozzle | $\pi/2 \cdot d_a \cdot leg_1 \cdot 0.49 \cdot \min(S_p;S_n)$ | 281435 | N |
| Reinf./shell | $\pi/2 \cdot D_p \cdot leg_2 \cdot 0.49 \cdot \min(S_p;S_v)$ | 1159453 | N |

**Groove weld**

| | | | |
|---|---|---|---|
| Shell /Nozzle | $\pi/2 \cdot d_a \cdot leg_4 \cdot 0.60 \cdot \min(S_v;S_n)$ | 445127 | N |
| Reinf./nozzle | $\pi/2 \cdot d_a \cdot leg_5 \cdot 0.74 \cdot \min(S_p;S_n)$ | 566699 | N |

**Comparison of loads on path 1-1 and 2-2**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1-1 | | | 1159453 | N | + | 445127 | N | = | 1604580 | N |
| | | | | | | | | ≥ | 1248316 | N |
| 2-2 | 566699 | N | + | 281435 | N | + | 445127 | N | = | 1293260 | N |
| | | | | | | | | ≥ | 82358 | N |

**Equations according to UG-40 and App.1-7**

Fig. UG-37.1, UG-40(b)

$$b = Max\left\{\begin{matrix}\frac{d}{2} \\ t_n + t\end{matrix}\right. = Max\left\{\begin{matrix}\frac{d}{2} \\ t_n + t\end{matrix}\right. = 190.5 \text{ mm}$$

App.1-7(a)(1)

$$b = Max\left\{\begin{matrix}\frac{3 \cdot d/2}{4} \\ t_n + t\end{matrix}\right.$$

App.1-7(a)(1)

$$A = \frac{2}{3} \cdot d \cdot t_r \cdot F$$

Fig. UG-37.1

$$A = d \cdot t_r \cdot F = 381 \text{ mm} \cdot 39.57 \text{ mm} \cdot 1 = 15075 \text{ mm}^2$$

| | | | | |
|---|---|---|---|---|
| Available shell thickness with allowances | $t+c_{1s}+c_{2s}$ | $t_s$ | 2 | in |
| Required shell thickness with allowances | $t_r+c_{1s}+c_{2s}$ | $t_{sr}$ | 1.808 | in |
| Required nozzle thickness with allowances | | $t_{rn+}$ | 0.5299 | in |

**Areas according to UG-40**

$$h'_a = Min\begin{cases} 2.5 \cdot t \\ 2.5 \cdot t_n + t_e = 69.85\ \text{mm} \\ h_a \end{cases}$$

$$A_1 = Max\begin{cases} d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \end{cases} =$$

$$Max\begin{cases} 381\ \text{mm} \cdot 4.882\ \text{mm} - 2 \cdot 12.7\ \text{mm} \cdot 4.882\ \text{mm} \cdot (1 - f_{r1}) \\ 2 \cdot (44.45\ \text{mm} + 12.7\ \text{mm}) \cdot 4.882\ \text{mm} - 2 \cdot 12.7\ \text{mm} \cdot 4.882\ \text{mm} \cdot (1 - f_{r1}) \end{cases} = 1860\ \text{mm}^2$$

$$A_2 = 2 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot h'_a = 2 \cdot (12.7\ \text{mm} - 7.108\ \text{mm}) \cdot 1 \cdot 69.85\ \text{mm} = 781.2\ \text{mm}^2$$

$$A_{41} = (leg_1)^2 \cdot f_{r3} = (9.525\ \text{mm})^2 \cdot 1 = 90.73\ \text{mm}^2$$

$$A_{42} = (leg_2)^2 \cdot f_{r4} = (22.23\ \text{mm})^2 \cdot 1 = 494\ \text{mm}^2$$

$$A_5 = (D_p - d - 2 \cdot t_n) \cdot t_e \cdot f_{r4} = (717.5\ \text{mm} - 381\ \text{mm} - 2 \cdot 12.7\ \text{mm}) \cdot 38.1\ \text{mm} \cdot 1 = 11855\ \text{mm}^2$$

$$A_V = A_2 + A_{41} + A_{42} + A_5 = A_2 + A_{41} + A_{42} + A_5 = 13221\ \text{mm}^2$$

**App.1-7** is additionally required according to UG-36(b), if

| | | | | | |
|---|---|---|---|---|---|
| $D_a$ | *2210* ≤ 1520mm (60in.): | $d_a$ | 406.4 | > Min [ | *2210*/2; 508mm (20in.)] |
| $D_a$ | *2210* > 1520mm (60in.): | $d_a$ | 406.4 | > Min [ | *2210*/3; 1000mm (40in.)] |

**Large cylinder opening acc. Appendix 1-7(b)** not required

| | | | |
|---|---|---|---|
| Total available area | | $A_{avl}$ | in² |
| Inside radius of shell | | R | in |
| Inside radius of nozzle | | $R_n$ | in |
| Mean radius of shell | | $R_m$ | in |
| Mean radius of nozzle | | $R_{nm}$ | in |
| Allowable stress value | | S | psi |
| Distance e | | e | in |
| Moment of inertia | | I | mm^4 |
| Material area acc. to Fig.1-7-1 | | $A_s$ | in² |
| Support length nozzle | $Min[h_a; t_e + (R_{nm} \cdot t_n)^{0.5}]$ | $l_{nm}$ | in |
| Support length shell | $Min[b_a; (R_m \cdot t_e)^{0.5}]$ | $l_m$ | in |

**Conditions according to 1-7(b)(1) for radial nozzles**

(a) $2 \cdot R = > 1524 mm (60 in.)$

(b) $2 \cdot R_n =$ > 1016 mm (40 in.) and $2 \cdot R_n > 3.4 \cdot \sqrt{R \cdot t}$

(c) $\frac{R_n}{R} = \frac{\text{[redacted]}}{\text{[redacted]}} = \text{[redacted]} \le 0.7$

**Membrane stress Sm acc. App. 1-7(b)(2)**

$$S_m = P \cdot \frac{R \cdot (R_n + t_n + l_m) + R_n \cdot (t + l_{nm})}{As}$$

$$A_s = l_m \cdot t + (t_n + l_{nm}) \cdot t_n \cdot f_{r2} + \frac{(D_p - d_a)}{2} \cdot t_e \cdot f_{r4}$$

$$l_m = Min\left\{ \frac{b_a}{\sqrt{R_m \cdot t}} \right.$$

$$l_{nm} = Min\left\{ \frac{h_a}{\sqrt{R_{nm} \cdot t_n}} \right.$$

Reduction factors, only for $f_{r2}$ or $f_{r4} < 0.8$ acc. App.1-7(b)(4)

$$S_m \le S$$

**Bending stress Sb acc. to App. 1-7(b)(2)**

$$M = \left( \frac{R_n^3}{6} + R \cdot R_n \cdot e \right) \cdot P$$

$$a = e + \frac{t}{2} = e + \frac{44.45\ \text{mm}}{2} = a$$

$$S_b = M \cdot \frac{a}{I}$$

$$(S_m + S_b) \le 1.5 \cdot S$$

## E.4.5.4 - Set-on nozzles with reinforcement - ASME BPVC VIII-1 UG-37: 2017

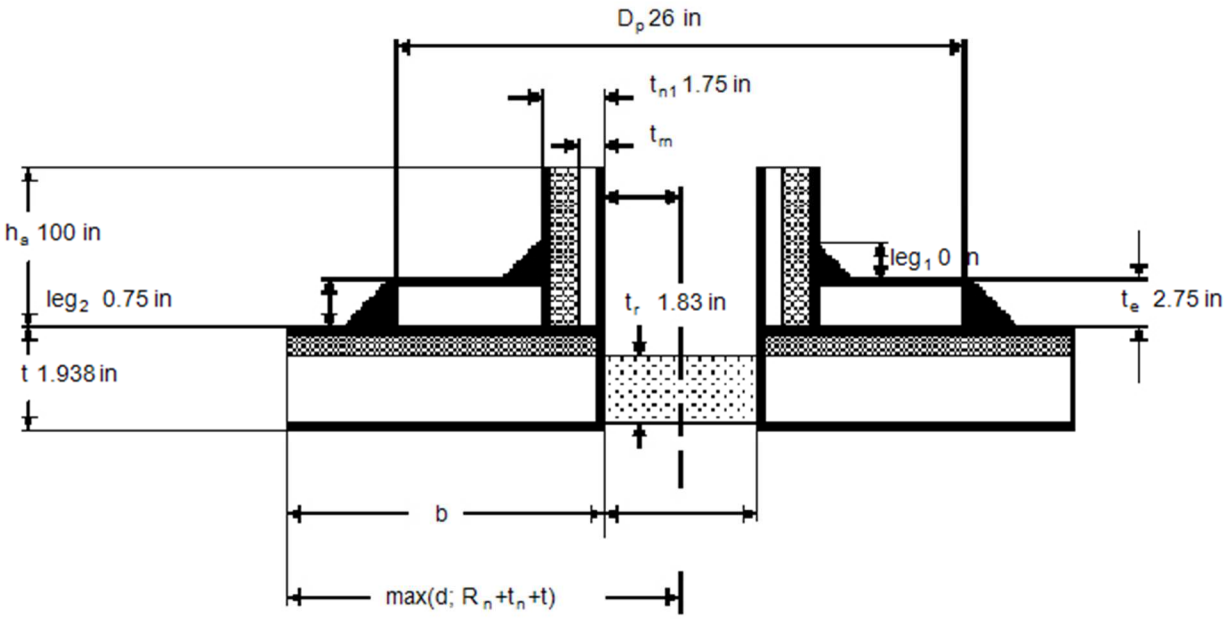
**Set-on nozzle with reinforcement**

| | | | |
|---|---|---|---|
| Design pressure | $p_D$ | 425 | psi |
| Hydrostatic head | $D_p$ | 0 | psi |
| Calculation pressure | $p_0$ | ***425*** | psi |
| Calculation temperature | $T_0$ | *800* | °F |
| Factor (1=internal pressure; 2=external pressure) | $\Gamma$ | 1 | |

**Shell**

| | | | |
|---|---|---|---|
| Straight cross section (=Y), as cylinders acc. UG-36(b)(1) and flat heads acc. UG-39(b)(1) or circular cross section (=N) as spheres | Cyl | Y | (N=No) |
| Outside diameter | $D_a$ | *100* | in |
| Nominal thickness without allowances | t | 1.938 | in |
| Available shell length for reinforcment | $b_a$ | 1000 | in |
| Joint efficiency factor | $E_1$ | 1 | |
| Material *K02700-SA-516-70-Class:-Size:* | | | |
| Material strength | K | 11993 | psi |
| Safety factor | S | 1 | |
| Allowable stress value K/S | $S_v$ | ***11993*** | psi |
| Wall thickness allowance | $c_{1s}$ | *0* | in |
| Corrosion allowance | $c_{2s}$ | *0.0625* | in |

**Nozzle** Nº 1




| | | | |
|---|---|---|---|
| Access opening | | No | |
| Outside diameter | $d_a$ | 19.5 | in |
| Joint efficiency factor | $E_n$ | 1 | |
| Material K02700-SA-516-70-Class:-Size: | | | |
| Material strength | $K_n$ | 11993 | psi |
| Wall thickness allowance | $c_1$ | 0 | in |
| Allowance (corrosion) | $c_2$ | 0.0625 | in |
| Safety factor | S | 1 | |
| Allowable stress value $K_n$/S | $S_n$ | **11993** | psi |
| Nominal thickness with allowances | $t_{n1}$ | 1.75 | in |
| Required wall thickness acc. Table UG-45 with corrosion allowance | $t_{b3}$ | **0.3908** | in |
| Nominal inside diameter = da-2*t2 | $d_{iN}$ | **16** | in |
| Inside diameter, corroded = $d_a$-2·$t_n$ | d | **16.12** | in |
| External projection | $h_a$ | 100 | in |
| Angle between the shell axis and the sectional plane through the opening center | Θ | 0 | ° |
| Nominal thickness without allowances | $t_n$ | **1.687** | in |
| Required nozzle neck thickness per UG-16 | $t_{UG-16}$ | 1.5 | mm |
| Required nozzle neck thickness per UG-45 | $t_{UG-45}$ | **0.3908** | in |

**Reinforcing element**

| | | | |
|---|---|---|---|
| Thickness | $t_e$ | 2.75 | in |
| Outside diameter | $D_p$ | 26 | in |
| Material K02700-SA-516-70-Class:-Size: | | | |
| Material strength | $K_p$ | 11993 | psi |
| Safety factor | S | 1 | |
| Allowable stress | $S_p$ | **11993** | psi |
| Fillet nozzle/ reinforcement outside | $leg_1$ | 0 | in |
| Fillet of reinforcement / shell outside | $leg_2$ | 0.75 | in |
| Groove nozzle / shell (≤tn) | $leg_4$ | 0.812 | in |
| Groove reinforcement / nozzle(≤te) | $leg_5$ | 0 | in |

| Calculation according to | | | UG-40 | | App.1-7 | |
|---|---|---|---|---|---|---|
| Correction factor (Fig.UG-37, int. pres.) | | F | 1 | | | |
| Reserve of shell | | $(E_1 \cdot t - F \cdot t_r)$ | 0.1075 | in | | |
| Limit length of vessel acc. to UG-40(b) | | b | 8.062 | in | | in |
| Limit length of nozzle outside, UG40(c) | | $h'_a$ | 4.844 | in | 4.844 | in |
| Minimum required thickness of nozzle | | $t_{rn}$ | 0.2919 | in | 0.2919 | in |
| Projected Area | | A | 29.51 | in² | | in² |
| Area of shell reserve | | $A_1$ | 1.733 | in² | | in² |
| Area of reinforcement ($A_2$ to $A_5$) | | $A_V$ | 31.96 | in² | | in² |
| Total available area ∑A | | ∑A | 33.69 | in² | | in² |
| Required area A/Γ | | A/H | 29.51 | in² | | in² |
| Utilization | | $A_{req}/A_{avl}$ | 87.59 | % | | % |
| Allowable pressure | (Approx.: pD/utilization) | | 485.2 | psi | | psi |

**Weld loads according to UG-41**

| | | | | |
|---|---|---|---|---|
| W | = $[A-A_1+2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t-F \cdot t_r)] \cdot S_V$ | = | 1481705 | N |
| $W_1$-1 | = $[A_2+A_5+A_{41}+A_{42}] \cdot S_V$ | = | 1704787 | N |
| $W_2$-2 | = $[A_2+A_{41}] \cdot S_V$ | = | 721217 | N |

**Strength of fillet welds**

| | | | |
|---|---|---|---|
| Reinf./nozzle | $\pi/2 \cdot d_a \cdot leg_1 \cdot 0.49 \cdot \min(S_p;S_n)$ | 0 | N |
| Reinf./shell | $\pi/2 \cdot D_p \cdot leg_2 \cdot 0.49 \cdot \min(S_p;S_V)$ | 800672 | N |

**Groove weld**

| | | | |
|---|---|---|---|
| Shell /Nozzle | $\pi/2 \cdot d_a \cdot leg_4 \cdot 0.60 \cdot \min(S_V;S_n)$ | 727203 | N |
| Reinf./nozzle | $\pi/2 \cdot d_a \cdot leg_5 \cdot 0.74 \cdot \min(S_p;S_n)$ | 0 | N |

**Comparison of loads on path 1-1 and 2-2**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1-1 | | | 800672 | N | + | 727203 | N | = | 1527875 | N |
| | | | | | | | | ≥ | 1481705 | N |
| 2-2 | 0 | N | + | 0 | N | + | 727203 | N | = | 727203 | N |
| | | | | | | | | ≥ | 721217 | N |

**Equations according to UG-40 and App.1-7**

Fig. UG-37.1, UG-40(b)

$$b = Max\left\{\begin{matrix}\frac{d}{2} \\ t_n + t\end{matrix}\right. = Max\left\{\begin{matrix}\frac{d}{2} \\ t_n + t\end{matrix}\right. = 204.8 \text{ mm}$$

App.1-7(a)(1)

$$b = Max\left\{\begin{matrix}\frac{3 \cdot d/2}{4} \\ t_n + t\end{matrix}\right.$$

App.1-7(a)(1)

$$A = \frac{2}{3} \cdot d \cdot t_r \cdot F$$

Fig. UG-37.1

$$A = d \cdot t_r \cdot F = 409.6 \text{ mm} \cdot 46.48 \text{ mm} \cdot 1 = 19038 \text{ mm}^2$$

| | | | | |
|---|---|---|---|---|
| Available shell thickness with allowances | $t+c_{1s}+c_{2s}$ | $t_s$ | 2 | in |
| Required shell thickness with allowances | $t_r+c_{1s}+c_{2s}$ | $t_{sr}$ | 1.893 | in |
| Required nozzle thickness with allowances | | $t_{rn+}$ | 0.3544 | in |

**Areas according to UG-40**

$$h'_a = Min\begin{cases} 2.5 \cdot t \\ 2.5 \cdot t_n + t_e = 123\ \text{mm} \\ h_a \end{cases}$$

$$A_1 = Max\begin{cases} d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \end{cases} =$$

$$Max\begin{cases} 409.6\ \text{mm} \cdot 2.731\ \text{mm} - 2 \cdot 42.86\ \text{mm} \cdot 2.731\ \text{mm} \cdot (1 - f_{r1}) \\ 2 \cdot (49.21\ \text{mm} + 42.86\ \text{mm}) \cdot 2.731\ \text{mm} - 2 \cdot 42.86\ \text{mm} \cdot 2.731\ \text{mm} \cdot (1 - f_{r1}) \end{cases} = 1118\ \text{mm}^2$$

$$A_2 = 2 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot h'_a = 2 \cdot (42.86\ \text{mm} - 7.415\ \text{mm}) \cdot 1 \cdot 123\ \text{mm} = 8722\ \text{mm}^2$$

$$A_{41} = (leg_1)^2 \cdot f_{r3} = (0\ \text{mm})^2 \cdot 1 = 0\ \text{mm}^2$$

$$A_{42} = (leg_2)^2 \cdot f_{r4} = (19.05\ \text{mm})^2 \cdot 1 = 362.9\ \text{mm}^2$$

$$A_5 = (D_p - d - 2 \cdot t_n) \cdot t_e \cdot f_{r4} = (660.4\ \text{mm} - 409.6\ \text{mm} - 2 \cdot 42.86\ \text{mm}) \cdot 69.85\ \text{mm} \cdot 1 = 11532\ \text{mm}^2$$

$$A_V = A_2 + A_{41} + A_{42} + A_5 = A_2 + A_{41} + A_{42} + A_5 = 20617\ \text{mm}^2$$

**App.1-7** is additionally required according to UG-36(b), if

| | | | | | |
|---|---|---|---|---|---|
| $D_a$ | *2540* ≤ 1520mm (60in.): | $d_a$ | 495.3 | > Min [ | *2540*/2; 508mm (20in.)] |
| $D_a$ | *2540* > 1520mm (60in.): | $d_a$ | 495.3 | > Min [ | *2540*/3; 1000mm (40in.)] |

**Large cylinder opening acc. Appendix 1-7(b)** not required

| | | | |
|---|---|---|---|
| Total available area | | $A_{avl}$ | in² |
| Inside radius of shell | | R | in |
| Inside radius of nozzle | | $R_n$ | in |
| Mean radius of shell | | $R_m$ | in |
| Mean radius of nozzle | | $R_{nm}$ | in |
| Allowable stress value | | S | psi |
| Distance e | | e | in |
| Moment of inertia | | I | mm^4 |
| Material area acc. to Fig.1-7-1 | | $A_s$ | in² |
| Support length nozzle | Min[$h_a$; $t_e$ +($R_{nm} \cdot t_n$)$^{0.5}$] | $l_{nm}$ | in |
| Support length shell | Min[$b_a$; ($R_m \cdot t_e$)$^{0.5}$] | $l_m$ | in |

**Conditions according to 1-7(b)(1) for radial nozzles**

(a) $2 \cdot R = > 1524 mm (60 in.)$

(b) $2 \cdot R_n =$ > 1016 mm (40 in.) and $2 \cdot R_n > 3.4 \cdot \sqrt{R \cdot t}$

(c) $\frac{R_n}{R} =$ ▒▒▒▒▒▒▒▒ = ▒▒▒▒▒▒▒▒ ≤ 0.7

**Membrane stress Sm acc. App. 1-7(b)(2)**

$$S_m = P \cdot \frac{R \cdot (R_n + t_n + l_m) + R_n \cdot (t + l_{nm})}{As}$$

$$A_s = l_m \cdot t + (t_n + l_{nm}) \cdot t_n \cdot f_{r2} + \frac{(D_p - d_a)}{2} \cdot t_e \cdot f_{r4}$$

$$l_m = Min\left\{ \frac{b_a}{\sqrt{R_m \cdot t}} \right.$$

$$l_{nm} = Min\left\{ \frac{h_a}{\sqrt{R_{nm} \cdot t_n}} \right.$$

Reduction factors, only for $f_{r2}$ or $f_{r4} < 0.8$ acc. App.1-7(b)(4)

$$S_m \le S$$

**Bending stress Sb acc. to App. 1-7(b)(2)**

$$M = \left( \frac{R_n^3}{6} + R \cdot R_n \cdot e \right) \cdot P$$

$$a = e + \frac{t}{2} = e + \frac{49.21\ \text{mm}}{2} = a$$

$$S_b = M \cdot \frac{a}{I}$$

$$(S_m + S_b) \le 1.5 \cdot S$$

## E.4.5.6 - Protruding nozzles without reinforcement - ASME BPVC VIII-1 UG-37: 2017

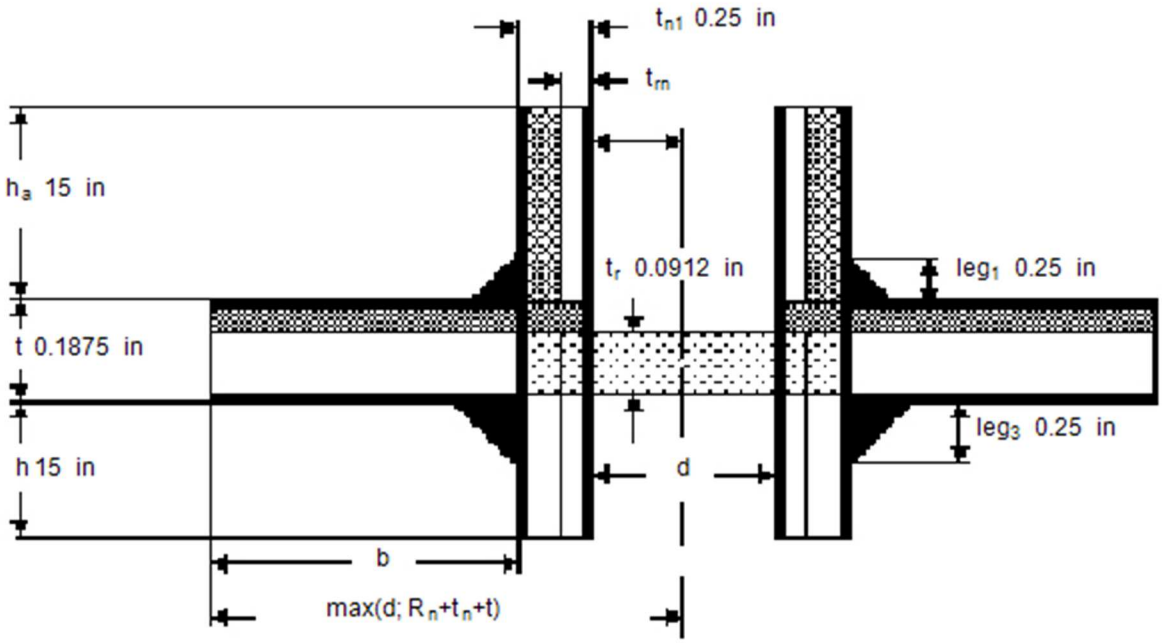
**Protruding nozzle without reinforcement**

| | | | |
|---|---|---|---|
| Design pressure | $p_D$ | 150 | psi |
| Hydrostatic head | $D_p$ | 0 | psi |
| Calculation pressure | $p_0$ | ***150*** | psi |
| Calculation temperature | $T_0$ | *400* | °F |
| Factor (1=internal pressure; 2=external pressure) | $\Gamma$ | 1 | |

**Shell**

| | | | |
|---|---|---|---|
| Straight cross section (=Y), as cylinders acc. UG-36(b)(1) and flat heads acc. UG-39(b)(1) or circular cross section (=N) as spheres | Cyl | N | (N=No) |
| Outside diameter | $D_a$ | *24* | in |
| Nominal thickness without allowances | t | 0.1875 | in |
| Available shell length for reinforcement | $b_a$ | 1000 | in |
| Joint efficiency factor | $E_1$ | 1 | |
| Material *S31651-SA-376-TP316N-Class:-Size:* | | | |
| Material strength | K | 17604 | psi |
| Safety factor | S | 1 | |
| Allowable stress value | $S_v$ | ***17604*** | psi |
| Wall thickness allowance | $c_{1s}$ | *0* | in |
| Corrosion allowance | $c_{2s}$ | *0* | in |

**Nozzle** Nº 1




| | | | |
|---|---|---|---|
| Access opening | | No | |
| Outside diameter | $d_a$ | 8.625 | in |
| Joint efficiency factor | $E_n$ | 1 | |
| Material S31600-SA-249-TP316-Class:-Size: | | | |
| Material strength | $K_n$ | 12116 | psi |
| Wall thickness allowance | $c_1$ | 0 | in |
| Allowance (corrosion) | $c_2$ | 0 | in |
| Safety factor | S | 1 | |
| Allowable stress $K_n$/S | $S_n$ | **12116** | psi |
| Nominal thickness with allowances | $t_{n1}$ | 0.25 | in |
| Required wall thickness acc. Table UG-45 with corrosion allowance | $t_{b3}$ | **0.2819** | in |
| Nominal inside diameter = da-2*t2 | $d_{iN}$ | **8.125** | in |
| Inside diameter, corroded = $d_a$-2·$t_n$ | d | **8.125** | in |
| External projection | $h_a$ | 15 | in |
| Internal projection | h | 15 | in |
| Angle between the shell axis and the sectional plane through the opening center | Θ | 0 | ° |
| Nominal thickness without allowances | $t_n$ | **0.25** | in |
| Required nozzle neck thickness per UG-16 | $t_{UG-16}$ | 1.5 | mm |
| Required nozzle neck thickness per UG-45 | $t_{UG-45}$ | **0.05906** | in |
| Fillet weld nozzle / shell outside | $leg_1$ | 0.25 | in |
| Fillet weld nozzle / shell inside | $leg_3$ | 0.25 | in |
| Groove weld nozzle / shell (≤t) | $leg_4$ | 0 | in |

| **Calculation according to** | | **UG-40** | | **App.1-7** | |
|---|---|---|---|---|---|
| Correction factor (Fig.UG-37, int. pres.) | F | **1** | | | |
| Reserve of shell | $(E_1 \cdot t - F \cdot t_r)$ | **0.0963** | in | | |
| Limit length of vessel acc. to UG-40(b) | b | **4.063** | in | | in |
| Limit length of nozzle outside, UG40(c) | $h'_a$ | **0.4688** | in | **0.4688** | in |
| Limit length of nozzle inside,Fig.UG37 | h' | **0.4688** | in | 0 | |
| Minimum required thickness of nozzle | $t_{rn}$ | **0.05067** | in | **0.05067** | in |
| Required area for internal pressure | A | **0.7552** | in² | | in² |
| Area of shell reserve | $A_1$ | **0.7674** | in² | | in² |
| Area of reinforcement ($A_2$ to $A_5$) | $A_V$ | **0.376** | in² | | in² |
| Total available area ∑A | $A_{avl}$ | **1.143** | in² | | in² |
| Required area A/Γ | $A_{req}$ | **0.7552** | in² | | in² |
| Utilization | $A_{req}/A_{avl}$ | **66.05** | % | | % |
| Allowable pressure (approx.: $p_D$/utilization) | | **227.1** | psi | | psi |

**Weld loads according to UG-41**

| | | | | |
|---|---|---|---|---|
| W | = $[A-A_1+2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)] \cdot S_V$ | = | **1639** | N |
| $W_1$-1 | = $[A_2+A_{41}] \cdot S_V$ | = | **13440** | N |
| $W_2$-2 | = $[A_2+A_3+A_41+A_{43}+2 \cdot t \cdot t_n \cdot f_{r1}] \cdot S_V$ | = | **34493** | N |

**Strength of nozzle wall, fillet and groove welds**

| | | | | |
|---|---|---|---|---|
| Fillet shell /nozzle | $\pi/2 \cdot d_a \cdot leg_1 \cdot 0.49 \cdot \min(S_V;S_n)$ | = | **89447** | N |
| Fillet shell /nozzle | $\pi/2 \cdot d_a \cdot leg_3 \cdot 0.49 \cdot \min(S_V;S_n)$ | = | **89447** | N |
| Groove shell /nozzle | $\pi/2 \cdot d_a \cdot leg_4 \cdot 0.74 \cdot \min(S_V;S_n)$ | = | **0** | N |
| Nozzle wall | $\pi/2 \cdot d_m \cdot t_n \cdot 0.70 \cdot S_n$ | = | **124078** | N |

**Comparison of weld loads on path 1-1 and 2-2**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1-1 | **89447** N | + | **124078** N | = | **213525** N |
| | | | | ≥ | **1639** N |
| 2-2 | **89447** N | + | **0** N | + | **89447** N | = | **178894** N |
| | | | | ≥ | **1639** N |

**Equations according to UG-40 and App.1-7**

Fig. UG-37.1, UG-40(b)

$$b = Max\left\{\begin{matrix}\frac{d}{2} \\ t_n + t\end{matrix}\right. = Max\left\{\begin{matrix}\frac{d}{2} \\ t_n + t\end{matrix}\right. = 103.2 \text{ mm}$$

App.1-7(a)(1)

$$b = Max\left\{\begin{matrix}\frac{3 \cdot d/2}{4} \\ t_n + t\end{matrix}\right.$$

App.1-7(a)(1)

$$A = \frac{2}{3} \cdot (d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}))$$

Fig. UG-37.1

$$A = d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) =$$

$$206.4 \text{ mm} \cdot 2.316 \text{ mm} \cdot 1 + 2 \cdot 6.35 \text{ mm} \cdot 2.316 \text{ mm} \cdot 1 \cdot (1 - 0.6882) = 487.2 \text{ mm}^2$$

| | | | | |
|---|---|---|---|---|
| Available shell thickness with allowances | $t+c_{1s}+c_{2s}$ | $t_s$ | ***0.1875*** | in |
| Required shell thickness with allowances | $t_r+c_{1s}+c_{2s}$ | $t_{sr}$ | **0.0912** | in |
| Required nozzle thickness with allowances | | $t_{rn+}$ | **0.05067** | in |

**Areas according to UG-40**

$$h'_a = Min\begin{Bmatrix} 2.5\cdot t \\ 2.5\cdot t_n \\ h_a \end{Bmatrix} = Min\begin{Bmatrix} 2.5\cdot t \\ 2.5\cdot t_n \\ h_a \end{Bmatrix} = 11.91\ \text{mm}$$

$$h' = Min\begin{Bmatrix} 2.5\cdot t \\ 2.5\cdot t_n \\ h \end{Bmatrix} = Min\begin{Bmatrix} 2.5\cdot t \\ 2.5\cdot t_n \\ h \end{Bmatrix} = 11.91\ \text{mm}$$

$$A_1 = Max\begin{Bmatrix} d\cdot(E_1\cdot t - F\cdot t_r) - 2\cdot t_n\cdot(E_1\cdot t - F\cdot t_r)\cdot(1-f_{r1}) \\ 2\cdot(t+t_n)\cdot(E_1\cdot t - F\cdot t_r) - 2\cdot t_n\cdot(E_1\cdot t - F\cdot t_r)\cdot(1-f_{r1}) \end{Bmatrix} =$$

$$Max\begin{Bmatrix} 206.4\ \text{mm}\cdot 2.446\ \text{mm} - 2\cdot 6.35\ \text{mm}\cdot 2.446\ \text{mm}\cdot(1-0.6882) \\ 2\cdot(4.762\ \text{mm}+6.35\ \text{mm})\cdot 2.446\ \text{mm} - 2\cdot 6.35\ \text{mm}\cdot 2.446\ \text{mm}\cdot(1-0.6882) \end{Bmatrix} = 495.1\ \text{mm}^2$$

$$A_2 = 2\cdot(t_n - t_{rn})\cdot f_{r2}\cdot h'_a = 2\cdot(6.35\ \text{mm} - 1.287\ \text{mm})\cdot 0.6882\cdot 11.91\ \text{mm} = 82.98\ \text{mm}^2$$

$$A_3 = 2\cdot(t_n - c_2)\cdot f_{r2}\cdot h' = 2\cdot(6.35\ \text{mm} - 0\ \text{mm})\cdot 0.6882\cdot 11.91\ \text{mm} = 104.1\ \text{mm}^2$$

$$A_{41} = (leg_1)^2\cdot f_{r2} = (6.35\ \text{mm})^2\cdot 0.6882 = 27.75\ \text{mm}^2$$

$$A_{43} = (leg_3)^2\cdot f_{r2} = (6.35\ \text{mm})^2\cdot 0.6882 = 27.75\ \text{mm}^2$$

$$A_V = A_2 + A_3 + A_{41} + A_{43} = A_2 + A_3 + A_{41} + A_{43} = 242.5\ \text{mm}^2$$

**App.1-7** is additionally required acc. to UG-36(b) if

| | | | | | |
|---|---|---|---|---|---|
| $D_a$ | *609.6* ≤ 1520mm (60in.): | $d_a$ | 219.1 > Min [ | *609.6*/2; 508mm (20in.)] |
| $D_a$ | *609.6* > 1520mm (60in.): | $d_a$ | 219.1 > Min [ | *609.6*/3; 1000mm (40in.)] |

**Additional rules for cylindr. shells, App.1-7(b)** not required

| | | | |
|---|---|---|---|
| Total available area | | $A_{avl}$ | in² |
| Inside radius of shell | | R | in |
| Inside radius of nozzle | | $R_n$ | in |
| Mean radius of shell | | $R_m$ | in |
| Mean radius of nozzle | | $R_{nm}$ | in |
| Allowable stress value | | S | psi |
| Distance e | | e | in |
| Moment of inertia | | I | mm^4 |
| Material area acc. to Fig.1-7-1 | | $A_s$ | in² |
| Support length nozzle | Min[$h_a$; $t_e$ +($R_{nm}$·$t_n$)$^{0.5}$] | $l_{nm}$ | in |
| Support length shell | Min[$b_a$; ($R_m$·$t_e$)$^{0.5}$] | $l_m$ | in |

**Conditions according to 1-7(b)(1) for radial nozzles**

(a) $2\cdot R =$ [redacted] > 1524 *mm* (60 *in.*)

(b) $2\cdot R_n =$ [redacted] > 1016 mm (40 in.) and $2\cdot R_n > 3.4\cdot\sqrt{R\cdot t} =$ [redacted]

(c) $\frac{R_n}{R} =$ [redacted] = [redacted] ≤ 0.7

**Membrane stress Sm acc. App. 1-7(b)(2)**

$$S_m = P \cdot \frac{[R \cdot (R_n + t_n + l_m) + R_n \cdot (t + l_{nm})]}{A_s}$$

$$A_s = l_m \cdot t + (t_n + l_{nm}) \cdot t_n \cdot f_{r2}$$

$$l_m = Min\left\{ \frac{b_a}{\sqrt{R_m \cdot t}} \right.$$

$$l_{nm} = Min\left\{ \begin{matrix} h_a \\ t_e + \sqrt{R_{nm} \cdot t_n} \end{matrix} \right.$$

Reduction factors, only for $f_{r2}$ or $f_{r4}$ < 0.8 acc. to App.1-7(b)(4)

$$S_m = \leq S$$

**Bending stress Sb acc. to App. 1-7(b)(2)**

$$M = \left( \frac{R_n^3}{6} + R \cdot R_n \cdot e \right) \cdot P$$

$$a = e + \frac{t}{2} = e + \frac{4.762\ \text{mm}}{2} = a$$

$$S_b = M \cdot \frac{a}{I}$$

$$(S_m + S_b) \leq 1.5 \cdot S$$