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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

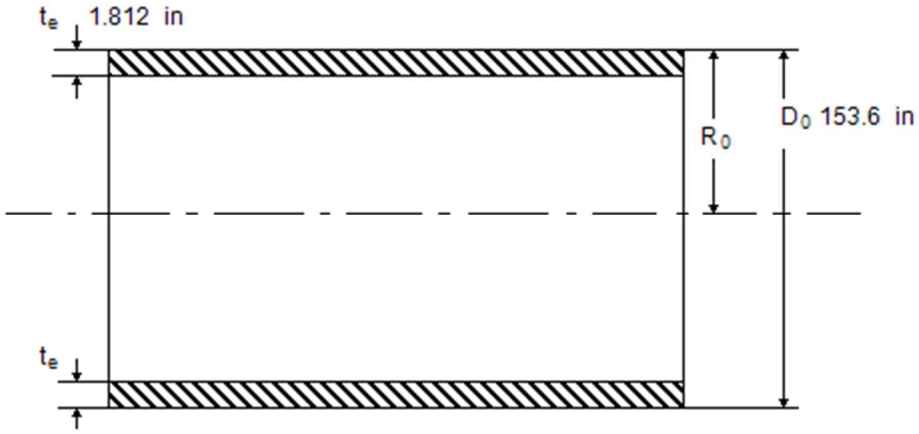
Strength Calculation Software	Program System ATLAS	Version	10.0.98
Developed by Lauterbach Verfahrenstechnik GmbH			
Certified per DIn EN ISO 9001:2015	Certificate Number 01 100 044763		

	LV Soft	ASME	Diff [%]
Example E4.5.1 - Radial Nozzle in Cylindrical Shell			
Required area A	14159.79 mm^2 21.95 in^2	21.97 in^2	**0.08%**
Available area A1	3531.71 mm^2 5.47 in^2	5.46 in^2	**0.32%**
Available area Aavl	28003.63 mm^2 43.41 in^2	43.39 in^2	**0.04%**
Example E4.5.2 - Hillside Nozzle in Cylindrical Shell			
Required area A	6863.13 mm^2 10.64 in^2	10.64 in^2	**0.00%**
Available area A1	1704.99 mm^2 2.64 in^2	2.64 in^2	**0.00%**
Available area Aavl	11453.94 mm^2 17.75 in^2	17.75 in^2	**0.00%**
Example E4.5.3 - Radial Nozzle in Cylindrical Shell			
Required area A	5429.32 mm^2 8.42 in^2	8.42 in^2	**0.08%**
Available area A1	1135.99 mm^2 1.76 in^2	1.75 in^2	**0.40%**
Available area Aavl	7014.28 mm^2 10.87 in^2	10.86 in^2	**0.07%**
Example E4.5.4 - Radial Nozzle in Cylindrical Shell			
Required area A	19037.86 mm^2 29.51 in^2	29.55 in^2	**0.15%**
Available area A1	1118.35 mm^2 1.73 in^2	1.69 in^2	**2.69%**
Available area Aavl	21735.78 mm^2 33.69 in^2	33.65 in^2	**0.13%**
Example E4.5.5 - Radial Nozzle in Cylindrical Shell			
Required area A	15075.45 mm^2 23.37 in^2	23.37 in^2	**0.00%**
Available area A1	1860.00 mm^2 2.88 in^2	2.88 in^2	**0.00%**
Available area Aavl	15080.66 mm^2 23.38 in^2	23.37 in^2	**0.00%**
Example E4.5.6 - Radial Nozzle in Cylindrical Shell			
Required area A	487.24 mm^2 0.76 in^2	0.76 in^2	**0.01%**
Available area A1	495.11 mm^2 0.77 in^2	0.77 in^2	**0.02%**
Available area Aavl	737.66 mm^2 1.14 in^2	1.14 in^2	**0.16%**

Thickness of cylindrical shells under internal pressure - ASME BPVC VIII-1 UG-27 & Appendix-1: 2021

Cylindrical shells

Design pressure	p_D	356	psi
Hydrostatic head	D_p	0	psi
Calculation pressure	P_0	**356**	psi
Calculation temperature	T_0	300	°F



Outside diameter	D_0	153.6	in
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 (or Cast Quality Factor)	E	1	
Circumferential weld joint efficiency for Eq. 2	E_c		

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

Allowable stress	S	20015	psi

Results

Outside radius	R_0	**76.81**	in
Effective thickness	t_0	**1.687**	in

Calculation as thin shell is applicable				**Yes**	
Required thickness	$t(R_0)$			t(R)	
thin shell acc. UG-27		**1.357**	in	**1.351**	in
thick shell (not applicable)		**1.354**	in	**1.348**	in
Minimum wall thickness without condition acc. UG-16				t_{UG-27} **1.351**	in
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	**443.6**	psi
Allowable excess pressure for longitudinal stress for Eq. (2)	P_{long}		psi
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 $R = R_0 - t_0 = 1951\ \text{mm} - 42.86\ \text{mm} = 1908\ \text{mm}$

1) Thin shell For

$$P_0 \le 0.385 \cdot S \cdot E \Leftrightarrow 24.55\ \text{bar} \le 53.13\ \text{N/mm}^2$$

and

with the inside radius R

$$t_e \le \frac{(R_0 - t_e)}{2} \Leftrightarrow 46.04\ \text{mm} \le 952.5\ \text{mm}$$

UG-27 (1)

$$t(R) = \frac{P_0 \cdot R}{S \cdot E - 0.6 \cdot P_0} = \frac{24.55\ \text{bar} \cdot 1908\ \text{mm}}{138\ \text{N/mm}^2 \cdot 1 - 0.6 \cdot 24.55\ \text{bar}} = 34.31\ \text{mm}$$

UG-27 (1)

$$P(R) = \frac{S \cdot E \cdot t_0}{R + 0.6 \cdot t_0} = \frac{138\ \text{N/mm}^2 \cdot 1 \cdot 42.86\ \text{mm}}{1908\ \text{mm} + 0.6 \cdot 42.86\ \text{mm}} = 3.059\ \text{MPa}$$

or with the outside radius R_0

App. 1-1 (1)

$$t(R_0) = \frac{P_0 \cdot R_0}{S \cdot E + 0.4 \cdot P_0} = \frac{24.55\ \text{bar} \cdot 1951\ \text{mm}}{138\ \text{N/mm}^2 \cdot 1 + 0.4 \cdot 24.55\ \text{bar}} = 34.46\ \text{mm}$$

App. 1-1 (1)

$$P(R_0) = \frac{S \cdot E \cdot t_0}{R_0 - 0.4 \cdot t_0} = \frac{138\ \text{N/mm}^2 \cdot 1 \cdot 42.86\ \text{mm}}{1951\ \text{mm} - 0.4 \cdot 42.86\ \text{mm}} = 3.059\ \text{MPa}$$

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

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: 2021

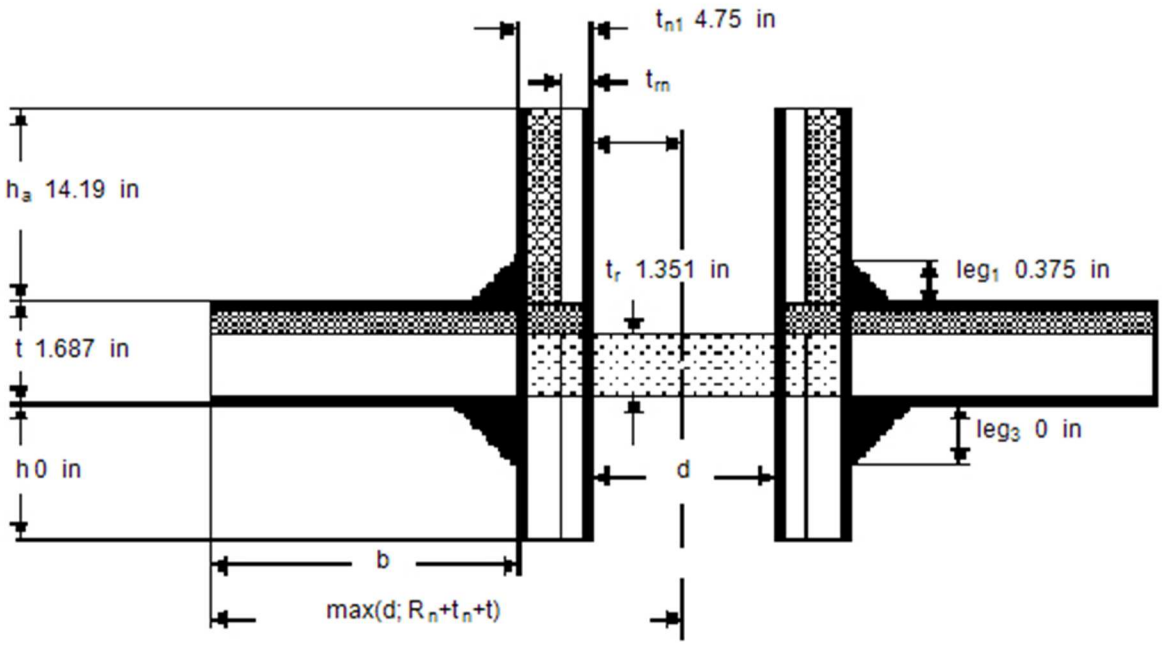
Protruding nozzle without reinforcement

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)	Γ	Internal pressure	

Shell

Shape of the shell	cylindrical		
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 (or Cast Quality 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
Required thickness without allowances	t_r	***1.351***	in

Nozzle Nº 1



Access opening		No	
Outside diameter	d_a	25.5	in
Joint efficiency factor (or Cast Quality 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 = d_a-2·t_2	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-27	t_a	**0.2711**	in
Required shell wall thickness where the nozzle neck attaches to the vessel with joint efficiency E=1.0	t_{b1}	**1.476**	in
Minimum nozzle neck thickness per UG-16	t_{UG-16}	0.05906	in
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**	mm	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	$= [A-A_1+2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)] \cdot S_v$	=	**392092**	lbf
W_1-1	$= [A_2+A_{41}] \cdot S_v$	=	**759212**	lbf
W_2-2	$= [A_2+A_3+A_41+A_{43}+2 \cdot t \cdot t_n \cdot f_{r1}] \cdot S_v$	=	**1071638**	lbf

Strength of nozzle wall, fillet and groove welds

Fillet shell /nozzle	$\pi/2 \cdot d_a \cdot leg_1 \cdot 0.49 \cdot \min(S_v;S_n)$	=	**147316**	lbf
Fillet shell /nozzle	$\pi/2 \cdot d_a \cdot leg_3 \cdot 0.49 \cdot \min(S_v;S_n)$	=	**0**	lbf
Groove shell /nozzle	$\pi/2 \cdot d_a \cdot leg_4 \cdot 0.74 \cdot \min(S_v;S_n)$	=	**0**	lbf
Nozzle wall	$\pi/2 \cdot d_m \cdot t_n \cdot 0.70 \cdot S_n$	=	**2124806**	lbf

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

1-1			**147316** lbf	+	**2124806** lbf	=	**2272122**	lbf
						≥	**392092**	lbf
2-2	**147316** lbf	+	**0** lbf	+	**0** lbf	=	**1915504**	lbf
						≥	**392092**	lbf

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

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

$$b = Max\begin{Bmatrix} \frac{d}{2} \\ t_n + t \end{Bmatrix} = Max\begin{Bmatrix} \frac{d}{2} \\ t_n + t \end{Bmatrix} = 206.4 \text{ mm}$$

App.1-7(a)(1)

$$b = Max\begin{Bmatrix} \frac{3 \cdot d/2}{4} \\ t_n + t \end{Bmatrix}$$

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

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

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

(internal pressure)

$$t_{rn} = p_0 \cdot \frac{\frac{d}{20}}{(S_n - 0.06\cdot p_0)} = 24.55\ \text{bar} \cdot \frac{\frac{412.8\ \text{mm}}{20}}{(138\ \text{N/mm}^2 - 0.06\cdot 24.55\ \text{bar})} = 3.71\ \text{mm}$$

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

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

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

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

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

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

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

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	in^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) $2 \cdot R = \text{[redacted]} > 1524 mm (60 in.)$

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

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

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

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

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

$$l_m = Min \left\{ \begin{array}{l} b_a \\ \sqrt{R_m \cdot t} \end{array} \right.$$

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

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: 2021

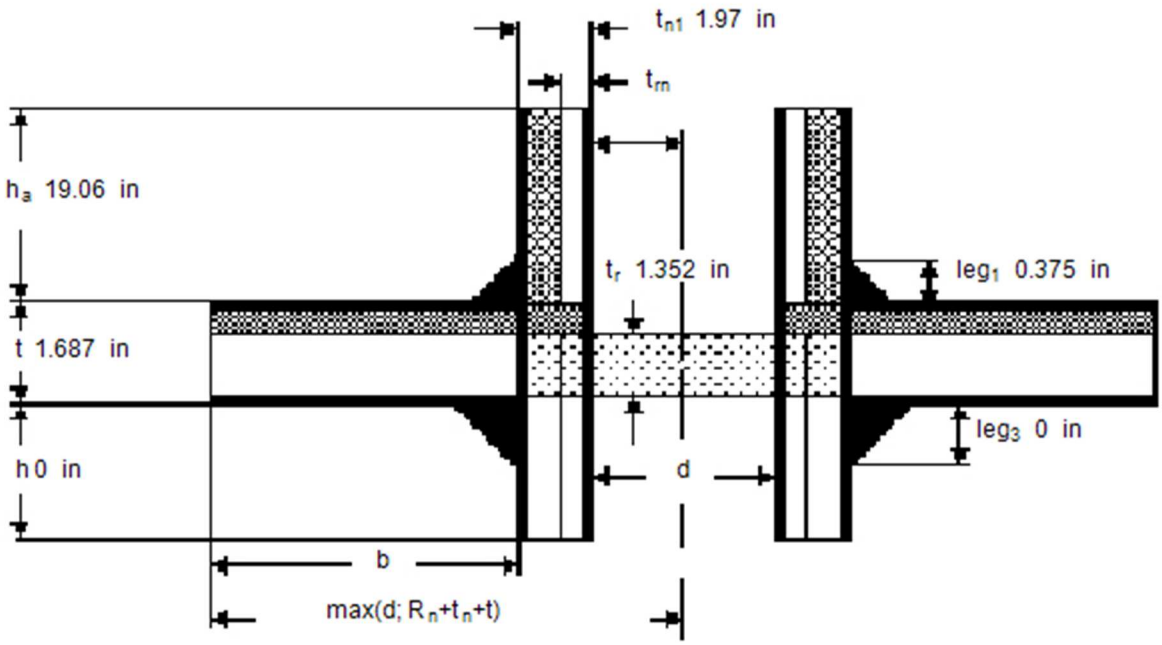
Protruding nozzle without reinforcement

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)	Γ	Internal pressure	

Shell

Shape of the shell		cylindrical	
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 (or Cast Quality 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
Required thickness without allowances	t_r	1.352	in

Nozzle Nº 1



Access opening		No	
Outside diameter	d_a	11.56	in
Joint efficiency factor (or Cast Quality 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 = d_a-2·t_2	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-27	t_a	**0.1957**	in
Required shell wall thickness where the nozzle neck attaches to the vessel with joint efficiency E=1.0	t_{b1}	**1.475**	in
Minimum nozzle neck thickness per UG-16	t_{UG-16}	0.05906	in
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**	mm	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	$= [A-A_1+2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t-F \cdot t_r)] \cdot S_v$	=	**184826**	lbf
W_1-1	$= [A_2+A_{41}] \cdot S_v$	=	**302449**	lbf
W_2-2	$= [A_2+A_3+A_41+A_{43}+2 \cdot t \cdot t_n \cdot f_{r1}] \cdot S_v$	=	**427082**	lbf

Strength of nozzle wall, fillet and groove welds

Fillet shell /nozzle	$\pi/2 \cdot d_a \cdot leg_1 \cdot 0.49 \cdot \min(S_v;S_n)$	=	**66783**	lbf
Fillet shell /nozzle	$\pi/2 \cdot d_a \cdot leg_3 \cdot 0.49 \cdot \min(S_v;S_n)$	=	**0**	lbf
Groove shell /nozzle	$\pi/2 \cdot d_a \cdot leg_4 \cdot 0.74 \cdot \min(S_v;S_n)$	=	**0**	lbf
Nozzle wall	$\pi/2 \cdot d_m \cdot t_n \cdot 0.70 \cdot S_n$	=	**394476**	lbf

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

1-1		**66783** lbf	+	**394476** lbf	=	**461259**	lbf
					≥	**184826**	lbf
2-2	**66783** lbf	+	**0** lbf	+	**0** lbf	=	**66783**	lbf
					≥	**184826**	lbf

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

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

$$b = Max\begin{Bmatrix} \frac{d}{2} \\ t_n + t \end{Bmatrix} = Max\begin{Bmatrix} \frac{d}{2} \\ t_n + t \end{Bmatrix} = 99.95 \text{ mm}$$

App.1-7(a)(1)

$$b = Max\begin{Bmatrix} \frac{3 \cdot d/2}{4} \\ t_n + t \end{Bmatrix}$$

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

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

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

(internal pressure)

$$t_{rn} = p_0 \cdot \frac{\frac{d}{20}}{(S_n - 0.06 \cdot p_0)} = 24.55 \text{ bar} \cdot \frac{\frac{199.9 \text{ mm}}{20}}{(138 \text{ N/mm}^2 - 0.06 \cdot 24.55 \text{ bar})} = 1.797 \text{ mm}$$

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

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

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

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

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

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

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

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	in^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) $2 \cdot R = \text{[redacted]} > 1524 mm (60 in.)$

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

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

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

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

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

$$l_m = Min \left\{ \begin{array}{l} b_a \\ \sqrt{R_m \cdot t} \end{array} \right.$$

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

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: 2021

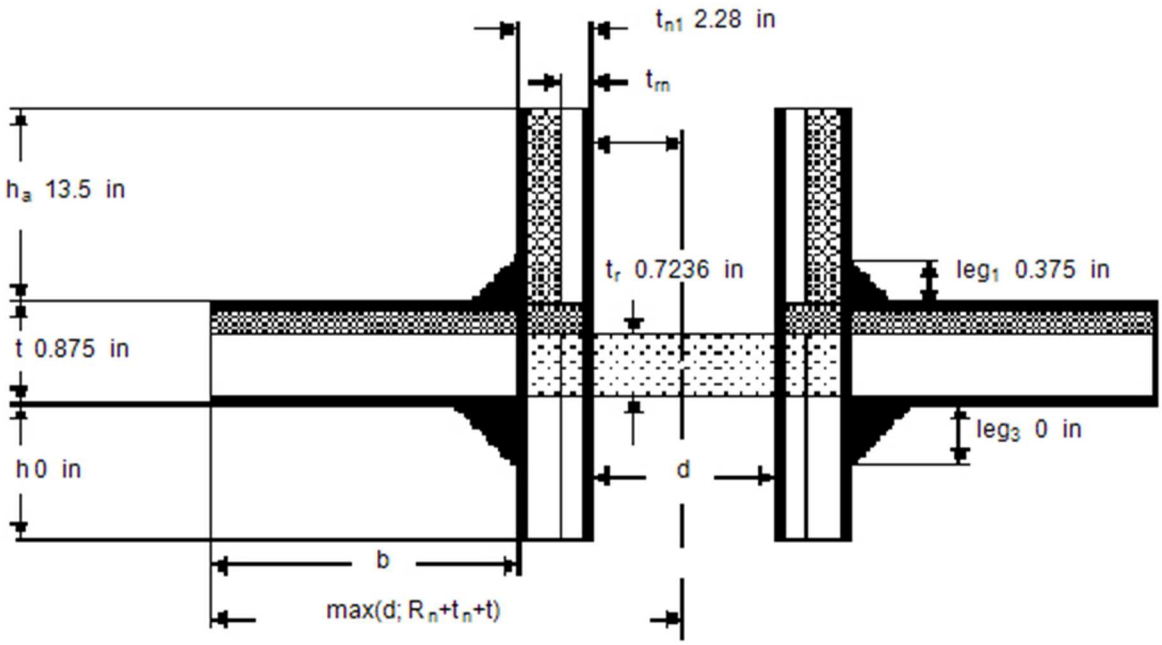
Protruding nozzle without reinforcement

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)	Γ	Internal pressure	

Shell

Shape of the shell	spherical		
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 (or Cast Quality 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
Required thickness without allowances	t_r	0.7236	in

Nozzle N° 1



Access opening		No	
Outside diameter	d_a	15.94	in
Joint efficiency factor (or Cast Quality 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 = d_a-2·t_2	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-27	t_a	**0.2295**	in
Required shell wall thickness where the nozzle neck attaches to the vessel with joint efficiency E=1.0	t_{b1}	**0.527**	in
Minimum nozzle neck thickness per UG-16	t_{UG-16}	0.05906	in
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**	mm	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	$= [A-A_1+2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)] \cdot S_v$	=	**146256**	lbf
W_1-1	$= [A_2+A_{41}] \cdot S_v$	=	**182367**	lbf
W_2-2	$= [A_2+A_3+A_41+A_{43}+2 \cdot t \cdot t_n \cdot f_{r1}] \cdot S_v$	=	**257849**	lbf

Strength of nozzle wall, fillet and groove welds

Fillet shell /nozzle	$\pi/2 \cdot d_a \cdot leg_1 \cdot 0.49 \cdot \min(S_v;S_n)$	=	**92087**	lbf
Fillet shell /nozzle	$\pi/2 \cdot d_a \cdot leg_3 \cdot 0.49 \cdot \min(S_v;S_n)$	=	**0**	lbf
Groove shell /nozzle	$\pi/2 \cdot d_a \cdot leg_4 \cdot 0.74 \cdot \min(S_v;S_n)$	=	**0**	lbf
Nozzle wall	$\pi/2 \cdot d_m \cdot t_n \cdot 0.70 \cdot S_n$	=	**653785**	lbf

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

1-1			**92087** lbf	+	**653785** lbf	=	**745872**	lbf
						≥	**146256**	lbf
2-2	**92087** lbf	+	**0** lbf	+	**0** lbf	=	**92087**	lbf
						≥	**146256**	lbf

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

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

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

(internal pressure)

$$t_{rn} = p_0 \cdot \frac{\frac{d}{20}}{(S_n - 0.06 \cdot p_0)} = 24.55\ \text{bar} \cdot \frac{\frac{295.4\ \text{mm}}{20}}{(138\ \text{N/mm}^2 - 0.06 \cdot 24.55\ \text{bar})} = 2.655\ \text{mm}$$

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

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

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

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

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

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

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

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	in^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) $2 \cdot R = \text{[redacted]} > 1524 mm (60 in.)$

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

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

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

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

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

$$l_m = Min \left\{ \begin{array}{l} b_a \\ \sqrt{R_m \cdot t} \end{array} \right.$$

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

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)

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

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

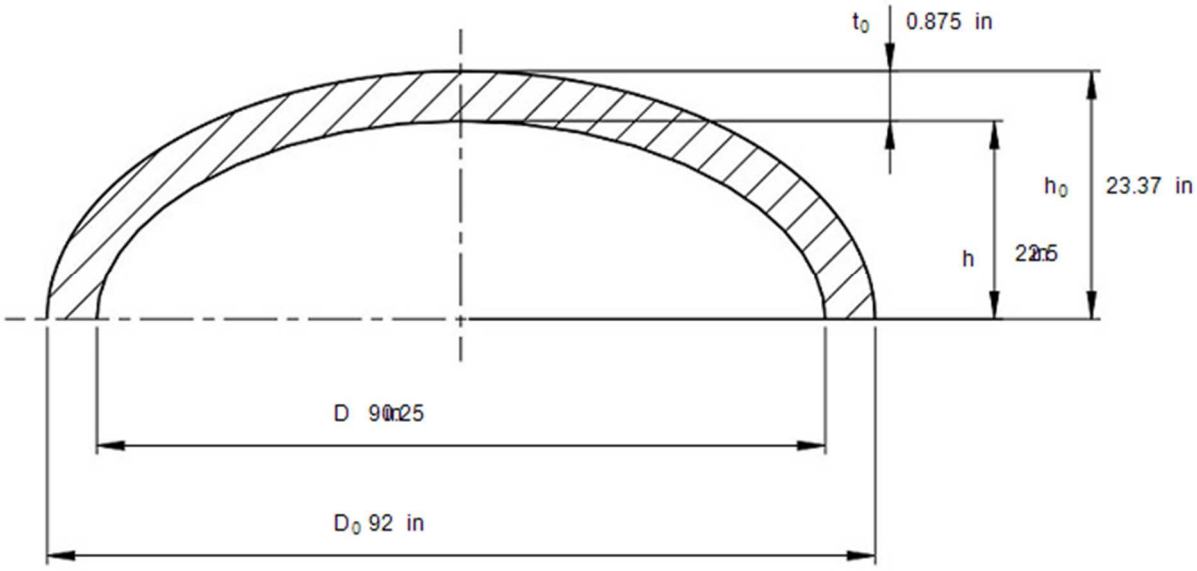
$$S_b = M \cdot \frac{a}{I}$$

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

Elliptical heads under internal pressure - ASME BPVC VIII-1 UG-32 & Appendix-1: 2021

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

Design pressure	p_D	356	psi
Hydrostatic head	D_p	0	psi
Calculation pressure	p_0	**356**	psi
Calculation temperature	T_0	300	°F
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_0-2t_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 (or Cast Quality Factor)		E	1	

Material data

Material	K02700-SA-516-70-Class:-Size:		
Elasticity modulus	E_T	2.829e+7	psi
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: 2021

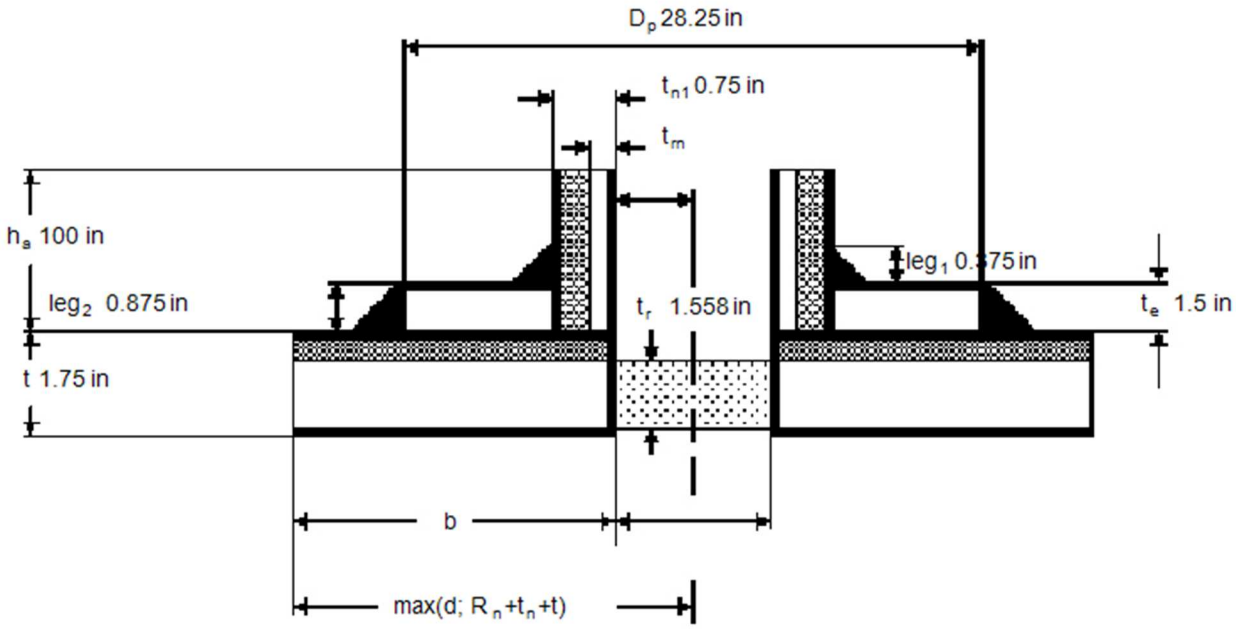
Set-on nozzle with reinforcement

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)	Γ	Internal pressure	

Shell

Shape of the shell	cylindrical		
Outside diameter	D_a	*87*	in
Nominal thickness without allowances	t	1.75	in
Available shell length for reinforcement	b_a	50	in
Joint efficiency factor (or Cast Quality Factor)	E_1	1	
Material			
Material strength	K		psi
Safety factor	S		
Allowable stress value	S_v	*13700*	psi
Wall thickness allowance	c_{1s}	*0*	in
Corrosion allowance	c_{2s}	*0.25*	in
Required thickness without allowances	t_r	1.558	in

Nozzle Nº 1



Access opening		No	
Outside diameter	d_a	16	in
Joint efficiency factor (or Cast Quality 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 = d_a-2·t_2	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	Θ	0	°
Nominal thickness without allowances	t_n	**0.5**	in
Required nozzle neck thickness per UG-27	t_a	**0.5299**	in
Required shell wall thickness where the nozzle neck attaches to the vessel with joint efficiency E=1.0	t_{b1}		in
Minimum nozzle neck thickness per UG-16	t_{UG-16}	0.05906	in
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	= $[A-A_1+2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)] \cdot S_v$	=	**280634**	lbf	
W_1-1	= $[A_2+A_5+A_{41}+A_{42}] \cdot S_v$	=	**280744**	lbf	
W_2-2	= $[A_2+A_{41}] \cdot S_v$	=	**18515**	lbf	

Strength of fillet welds

Reinf./nozzle	$\pi/2 \cdot d_a \cdot leg_1 \cdot 0.49 \cdot \min(S_p;S_n)$	**63269**	lbf
Reinf./shell	$\pi/2 \cdot D_p \cdot leg_2 \cdot 0.49 \cdot \min(S_p;S_v)$	**260657**	lbf

Groove weld

Shell /Nozzle	$\pi/2 \cdot d_a \cdot leg_4 \cdot 0.60 \cdot \min(S_v;S_n)$	**100069**	lbf
Reinf./nozzle	$\pi/2 \cdot d_a \cdot leg_5 \cdot 0.74 \cdot \min(S_p;S_n)$	**127400**	lbf

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

1-1			**260657**	lbf	+	**100069**	lbf	=	**360726** lbf
								≥	**280634** lbf
2-2	**127400**	lbf	+	**63269**	lbf	+	**100069**	lbf	=	**290738** lbf
								≥	**18515** lbf

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

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

(internal pressure)

$$t_{rn} = p_0 \cdot \frac{\frac{d}{20}}{(S_n - 0.06 \cdot p_0)} =$$

$$34.47 \text{ bar} \cdot \frac{\frac{381 \text{ mm}}{20}}{(94.46 \text{ N/mm}^2 - 0.06 \cdot 34.47 \text{ bar})} = 7.108 \text{ mm}$$

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

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

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

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

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

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

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

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	in^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) $\frac{R_n}{R} = \frac{\text{[redacted]}}{\text{[redacted]}} = \text{[redacted]} \leq 0.7$

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

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

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

$$l_m = Min \left\{ \begin{array}{l} b_a \\ \sqrt{R_m \cdot t} \end{array} \right.$$

$$l_{nm} = Min \left\{ \begin{array}{l} h_a \\ \sqrt{R_{nm} \cdot t_n} \end{array} \right.$$

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

$S_m \leq S$

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

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

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

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

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

E.4.5.4 - Set-on nozzles with reinforcement - ASME BPVC VIII-1 UG-37: 2021

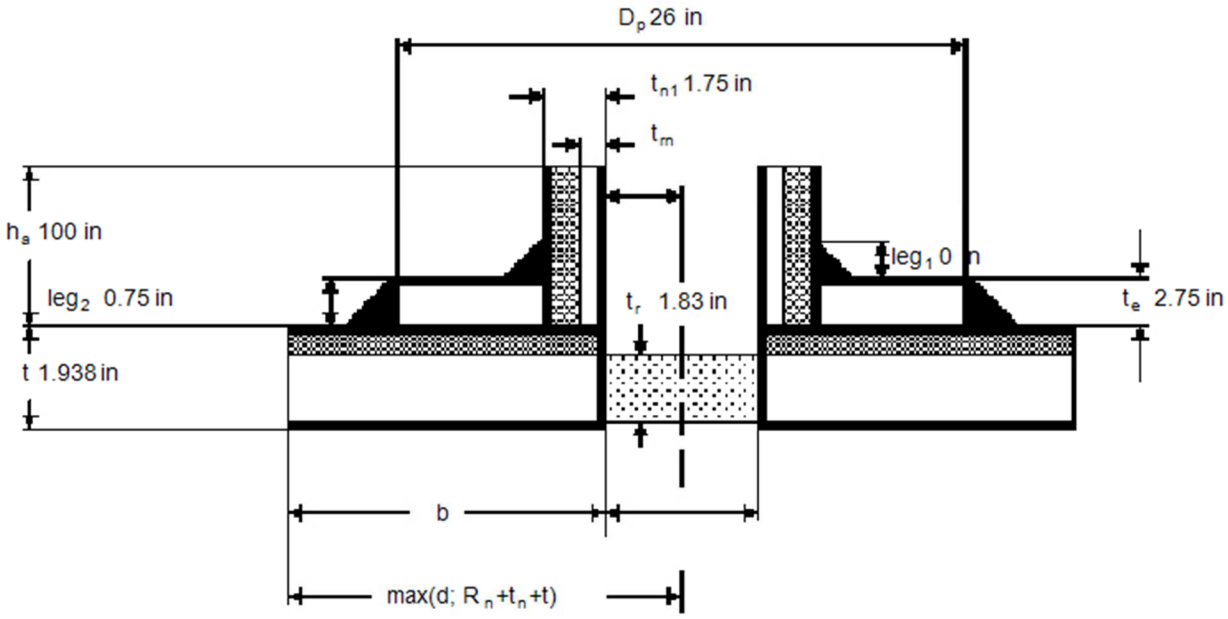
Set-on nozzle with reinforcement

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)	Γ	Internal pressure	

Shell

Shape of the shell	cylindrical		
Outside diameter	D_a	*100*	in
Nominal thickness without allowances	t	1.938	in
Available shell length for reinforcement	b_a	1000	in
Joint efficiency factor (or Cast Quality Factor)	E_1	1	
Material *K02700-SA-516-70-Class:-Size:*			
Material strength	K	11993	psi
Safety factor	S	1	
Allowable stress value	S_v	***11993***	psi
Wall thickness allowance	c_{1s}	*0*	in
Corrosion allowance	c_{2s}	*0.0625*	in
Required thickness without allowances	t_r	1.83	in

Nozzle Nº 1



Access opening		No	
Outside diameter	d_a	19.5	in
Joint efficiency factor (or Cast Quality 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 = d_a-2·t_2	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-27	t_a	**0.3544**	in
Required shell wall thickness where the nozzle neck attaches to the vessel with joint efficiency E=1.0	t_{b1}	**1.803**	in
Minimum nozzle neck thickness per UG-16	t_{UG-16}	0.05906	in
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	= $[A-A_1+2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)] \cdot S_v$	=	**333102**	lbf
W_1-1	= $[A_2+A_5+A_{41}+A_{42}] \cdot S_v$	=	**383253**	lbf
W_2-2	= $[A_2+A_{41}] \cdot S_v$	=	**162137**	lbf

Strength of fillet welds

Reinf./nozzle	$\pi/2 \cdot d_a \cdot leg_1 \cdot 0.49 \cdot \min(S_p;S_n)$	**0**	lbf
Reinf./shell	$\pi/2 \cdot D_p \cdot leg_2 \cdot 0.49 \cdot \min(S_p;S_v)$	**179999**	lbf

Groove weld

Shell /Nozzle	$\pi/2 \cdot d_a \cdot leg_4 \cdot 0.60 \cdot \min(S_v;S_n)$	**163483**	lbf
Reinf./nozzle	$\pi/2 \cdot d_a \cdot leg_5 \cdot 0.74 \cdot \min(S_p;S_n)$	**0**	lbf

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

1-1			**179999**	lbf	+	**163483**	lbf	=	**343482** lbf
								≥	**333102** lbf
2-2	**0**	lbf	+	**0**	lbf	+	**163483**	lbf	=	**163483** lbf
								≥	**162137** lbf

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)

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

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

Fig. UG-37.1

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

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

(internal pressure)

$$t_{rm} = p_0 \cdot \frac{\frac{d}{20}}{(S_n - 0.06 \cdot p_0)} = 29.3 \text{ bar} \cdot \frac{\frac{409.6 \text{ mm}}{20}}{(82.69 \text{ N/mm}^2 - 0.06 \cdot 29.3 \text{ bar})} = 7.415 \text{ mm}$$

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

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

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

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

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

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

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

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

(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: 2021

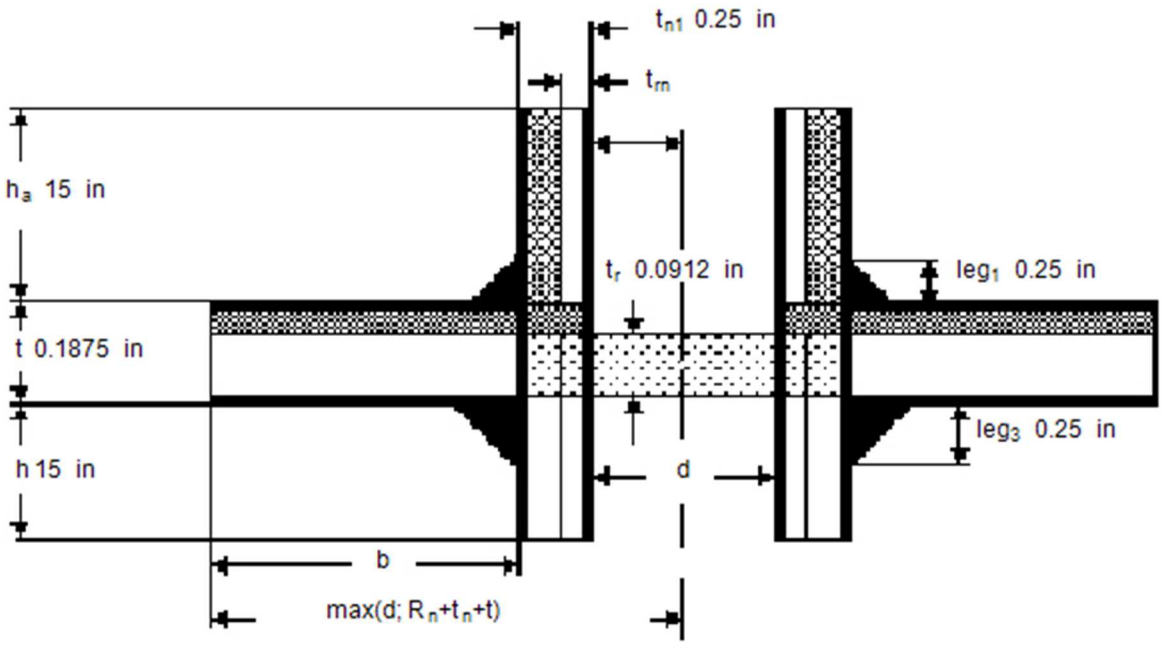
Protruding nozzle without reinforcement

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)	Γ	Internal pressure	

Shell

Shape of the shell	spherical		
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 (or Cast Quality 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
Required thickness without allowances	t_r	0.0912	in

Nozzle Nº 1



Access opening		No	
Outside diameter	d_a	8.625	in
Joint efficiency factor (or Cast Quality 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 = d_a-2·t_2	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-27	t_a	**0.05067**	in
Required shell wall thickness where the nozzle neck attaches to the vessel with joint efficiency E=1.0	t_{b1}	**0.05906**	in
Minimum nozzle neck thickness per UG-16	t_{UG-16}	0.05906	in
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'	**11.91**	mm	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	$= [A-A_1+2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)] \cdot S_v$	=	**368.4**	lbf
W_1-1	$= [A_2+A_{41}] \cdot S_v$	=	**3021**	lbf
W_2-2	$= [A_2+A_3+A_41+A_{43}+2 \cdot t \cdot t_n \cdot f_{r1}] \cdot S_v$	=	**7754**	lbf

Strength of nozzle wall, fillet and groove welds

Fillet shell /nozzle	$\pi/2 \cdot d_a \cdot leg_1 \cdot 0.49 \cdot \min(S_v;S_n)$	=	**20109**	lbf
Fillet shell /nozzle	$\pi/2 \cdot d_a \cdot leg_3 \cdot 0.49 \cdot \min(S_v;S_n)$	=	**20109**	lbf
Groove shell /nozzle	$\pi/2 \cdot d_a \cdot leg_4 \cdot 0.74 \cdot \min(S_v;S_n)$	=	**0**	lbf
Nozzle wall	$\pi/2 \cdot d_m \cdot t_n \cdot 0.70 \cdot S_n$	=	**27894**	lbf

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

1-1			**20109** lbf	+	**27894** lbf	=	**48003**	lbf
						≥	**368.4**	lbf
2-2	**20109** lbf	+	**0** lbf	+	**20109** lbf	=	**40217**	lbf
						≥	**368.4**	lbf

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

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

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

(internal pressure)

$$t_{rn} = p_0 \cdot \frac{\frac{d}{20}}{(S_n - 0.06\cdot p_0)} =$$

$$10.34\ \text{bar} \cdot \frac{\frac{206.4\ \text{mm}}{20}}{(83.54\ \text{N/mm}^2 - 0.06\cdot 10.34\ \text{bar})} = 1.287\ \text{mm}$$

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

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

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

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

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

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

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

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	in^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) $2 \cdot R = \text{[redacted]} > 1524 mm (60 in.)$

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

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

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

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

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

$$l_m = Min \left\{ \begin{array}{l} b_a \\ \sqrt{R_m \cdot t} \end{array} \right.$$

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

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)

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

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

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

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