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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 : 11.0.8.24
Developed by Lauterbach Verfahrenstechnik GmbH	
Certified per DIn EN ISO 9001:2008	Certificate Number 01 100 044763

	LV Soft		ASME		Diff [%]
Example E4.5.1 - Radial Nozzle in Cylindrical Shell					
Required area A	14216,10 mm^2	22,04 in^2	21,97 in^2		**0,32%**
Available area A1	3480,64 mm^2	5,39 in^2	5,46 in^2		**1,13%**
Available area Aavl	27967,43 mm^2	43,35 in^2	43,39 in^2		**0,09%**
Example E4.5.2 - Hillside Nozzle in Cylindrical Shell					
Required area A	6884,97 mm^2	10,67 in^2	10,64 in^2		**0,32%**
Available area A1	1685,70 mm^2	2,61 in^2	2,64 in^2		**1,13%**
Available area Aavl	11441,21 mm^2	17,73 in^2	17,75 in^2		**0,11%**
Example E4.5.3 - Radial Nozzle in Cylindrical Shell					
Required area A	5433,83 mm^2	8,42 in^2	8,42 in^2		**0,00%**
Available area A1	1131,48 mm^2	1,75 in^2	1,75 in^2		**0,00%**
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	19110,69 mm^2	29,62 in^2	29,55 in^2		**0,23%**
Available area A1	1093,38 mm^2	1,69 in^2	1,69 in^2		**0,40%**
Available area Aavl	21745,80 mm^2	33,71 in^2	33,65 in^2		**0,17%**
Example E4.5.5 - Radial Nozzle in Cylindrical Shell					
Required area A	15145,13 mm^2	23,48 in^2	23,37 in^2		**0,46%**
Available area A1	1859,97 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	484,24 mm^2	0,75 in^2	0,76 in^2		**0,63%**
Available area A1	497,99 mm^2	0,77 in^2	0,77 in^2		**0,60%**
Available area Aavl	740,60 mm^2	1,15 in^2	1,14 in^2		**0,55%**

E 4.5.1 - Protruding nozzles without reinforcement - ASME BPVC VIII-1 UG-37: 2025

Protruding nozzle without reinforcement

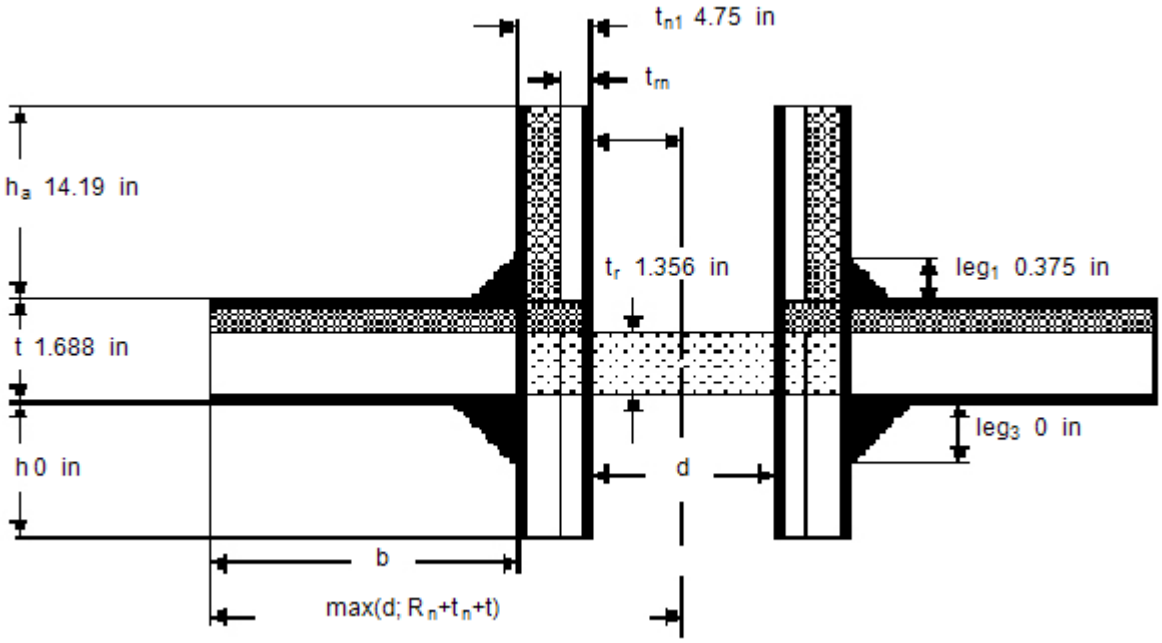
Protruding nozzle without reinforcement

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	1.688	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	1.356	in

Nozzle Nº



Access opening		NEIN	
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}	**1.481**	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	$(E_1 \cdot t - F \cdot t_r)$	**0.332**	in		
Limit length of vessel acc. to UG-40(b)	b	**8.125**	in		in
Limit length of nozzle outside, UG40(c)	h'_a	**4.22**	in	**4.22**	in
Limit length of nozzle inside,Fig.UG37	h'	**0**	in	0	
Minimum required thickness of nozzle	t_{rn}	**0.1447**	in	**0.1447**	in
Required area for internal pressure	A	**22.04**	in²		in²
Area of shell reserve	A_1	**5.395**	in²		in²
Area of reinforcement (A_2 to A_5)	A_V	**37.95**	in²		in²
Total available area ∑A	A_{avl}	**43.35**	in²		in²
Required area A/Γ	A_{req}	**22.04**	in²		in²
Utilization	(A_{req}/A_{avl})	**50.83**	%		%
Allowable pressure		**499.3**	psi		psi

Weld loads according to UG-41

W	= $[A-A_1+2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)] \cdot S_v$	=	**394522**	lbf
W_1-1	= $[A_2+A_{41}] \cdot S_v$	=	**759673**	lbf
W_2-2	= $[A_2+A_3+A_41+A_{43}+2 \cdot t \cdot t_n \cdot f_{r1}] \cdot S_v$	=	**1072192**	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		
				≥	**394522**	lbf		
2-2	**147316** lbf	+	**0** lbf	+	**0** lbf	=	**147316**	lbf
				≥	**394522**	lbf		

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

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

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

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

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

$$412.8 \text{ mm} \cdot 34.44 \text{ mm} \cdot 1 + 2 \cdot 117.5 \text{ mm} \cdot 34.44 \text{ mm} \cdot 1 \cdot (1 - 1) = 14216 \text{ mm}^2$$

Available shell thickness with allowances	$t+c_{1s}+c_{2s}$	t_s	**1.813**	in
Required shell thickness with allowances	$t_r+c_{1s}+c_{2s}$	t_{sr}	**1.481**	in
Required nozzle thickness with allowances		t_{rn+}	**0.2711**	in

Areas according to UG-40

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

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

(internal pressure)

$$t_{rn} = p_0 \cdot \frac{\frac{d}{20}}{(S_n - 0.06 \cdot p_0)} = 2.455\ \text{MPa} \cdot \frac{\frac{412.8\ \text{mm}}{20}}{(138\ \text{MPa} - 0.06 \cdot 2.455\ \text{MPa})} = 3.675\ \text{mm}$$

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

$$Max\begin{Bmatrix} 412.8\ \text{mm} \cdot 8.433\ \text{mm} - 2 \cdot 117.5\ \text{mm} \cdot 8.433\ \text{mm} \cdot (1 - 1) \\ 2 \cdot (42.88\ \text{mm} + 117.5\ \text{mm}) \cdot 8.433\ \text{mm} - 2 \cdot 117.5\ \text{mm} \cdot 8.433\ \text{mm} \cdot (1 - 1) \end{Bmatrix} = 3481\ \text{mm}^2$$

$$A_2 = 2 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot h'_a = 2 \cdot (117.5\ \text{mm} - 3.675\ \text{mm}) \cdot 1 \cdot 107.2\ \text{mm} = 24396\ \text{mm}^2$$

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

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

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

$$A_V = A_2 + A_3 + A_{41} + A_{43} = A_2 + A_3 + A_{41} + A_{43} = 24487\ \text{mm}^2$$

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

D_a	3901 ≤ 1520mm (60in.):	d_a	647.7 > Min [	3901/2; 508mm (20in.)]
D_a	3901 > 1520mm (60in.):	d_a	647.7 > 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) $2 \cdot R = \square > 1524 mm (60 in.)$

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

(c) $\frac{R_n}{R} = \frac{\square}{\square} = \square \leq 0.7$

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)

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

$$a = e + \frac{t}{2} = e + \frac{42.88 \text{ mm}}{2} = a$$

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

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

E 4.5.2 Step5 F=1 - Protruding nozzles without reinforcement - ASME BPVC VIII-1 UG-37: 2025

Protruding nozzle without reinforcement

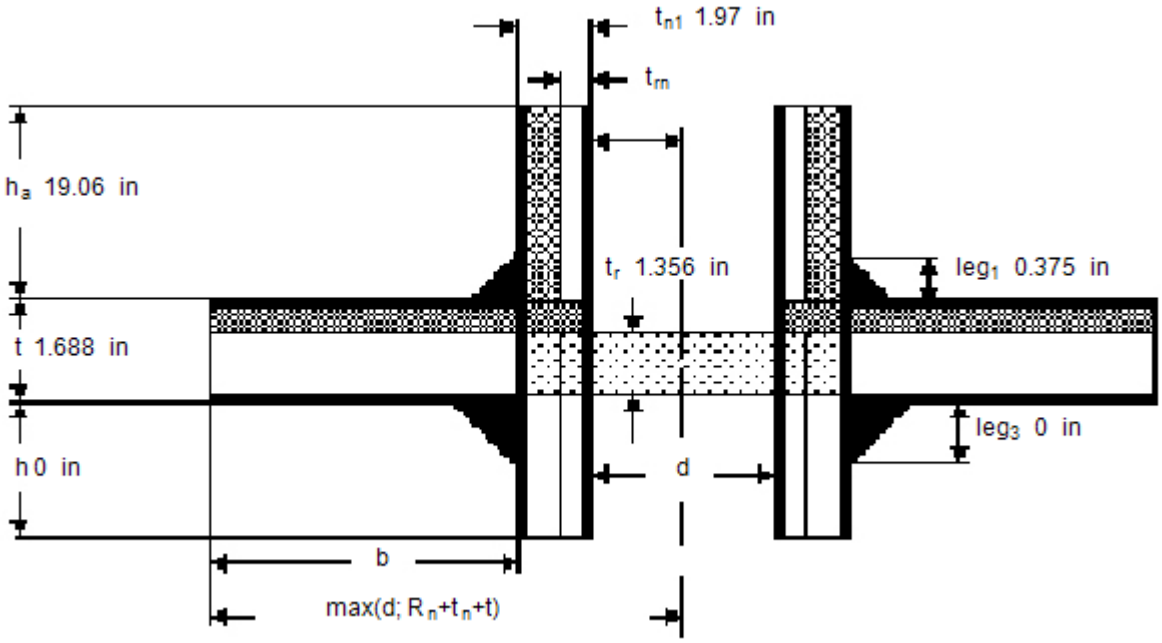
Protruding nozzle without reinforcement

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	1.688	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	1.356	in

Nozzle Nº



Access opening		NEIN	
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}	**1.481**	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	$(E_1 \cdot t - F \cdot t_r)$	**0.332**	in		
Limit length of vessel acc. to UG-40(b)	b	**3.935**	in		in
Limit length of nozzle outside, UG40(c)	h'_a	**4.22**	in	**4.22**	in
Limit length of nozzle inside,Fig.UG37	h'	**0**	in	0	
Minimum required thickness of nozzle	t_{rn}	**0.07006**	in	**0.07006**	in
Required area for internal pressure	A	**10.67**	in²		in²
Area of shell reserve	A_1	**2.613**	in²		in²
Area of reinforcement (A_2 to A_5)	A_V	**15.12**	in²		in²
Total available area ∑A	A_{avl}	**17.73**	in²		in²
Required area A/Γ	A_{req}	**10.67**	in²		in²
Utilization	(A_{req}/A_{avl})	**60.18**	%		%
Allowable pressure		**458.9**	psi		psi

Weld loads according to UG-41

W	= $[A-A_1+2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)] \cdot S_v$	=	**185821**	lbf
W_1-1	= $[A_2+A_{41}] \cdot S_v$	=	**302653**	lbf
W_2-2	= $[A_2+A_3+A_41+A_{43}+2 \cdot t \cdot t_n \cdot f_{r1}] \cdot S_v$	=	**427323**	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
						≥	**185821**	lbf
2-2	**66783**	lbf	+	**0**	lbf	+	**0**	lbf	=	**66783**	lbf
							≥	**185821**	lbf

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

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

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

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

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

$$199.9\ \text{mm} \cdot 34.44\ \text{mm} \cdot 1 + 2 \cdot 46.86\ \text{mm} \cdot 34.44\ \text{mm} \cdot 1 \cdot (1 - 1) = 6885\ \text{mm}^2$$

Available shell thickness with allowances	$t+c_{1s}+c_{2s}$	t_s	**1.813**	in
Required shell thickness with allowances	$t_r+c_{1s}+c_{2s}$	t_{sr}	**1.481**	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)

$$t_{rn} = p_0 \cdot \frac{\frac{d}{20}}{(S_n - 0.06 \cdot p_0)} = 2.455 \text{ MPa} \cdot \frac{\frac{199.9 \text{ mm}}{20}}{(138 \text{ MPa} - 0.06 \cdot 2.455 \text{ MPa})} = 1.78 \text{ mm}$$

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

$$Max\begin{Bmatrix} 199.9 \text{ mm} \cdot 8.433 \text{ mm} - 2 \cdot 46.86 \text{ mm} \cdot 8.433 \text{ mm} \cdot (1 - 1) \\ 2 \cdot (42.88 \text{ mm} + 46.86 \text{ mm}) \cdot 8.433 \text{ mm} - 2 \cdot 46.86 \text{ mm} \cdot 8.433 \text{ mm} \cdot (1 - 1) \end{Bmatrix} = 1686 \text{ mm}^2$$

$$A_2 = 2 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot h'_a = 2 \cdot (46.86 \text{ mm} - 1.78 \text{ mm}) \cdot 1 \cdot 107.2 \text{ mm} = 9665 \text{ mm}^2$$

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

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

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

$$A_V = A_2 + A_3 + A_{41} + A_{43} = A_2 + A_3 + A_{41} + A_{43} = 9756 \text{ mm}^2$$

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)

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

$$a = e + \frac{t}{2} = e + \frac{42.88 \text{ mm}}{2} = a$$

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

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

E 4.5.3 - Protruding nozzles without reinforcement - ASME BPVC VIII-1 UG-37: 2025

Protruding nozzle without reinforcement

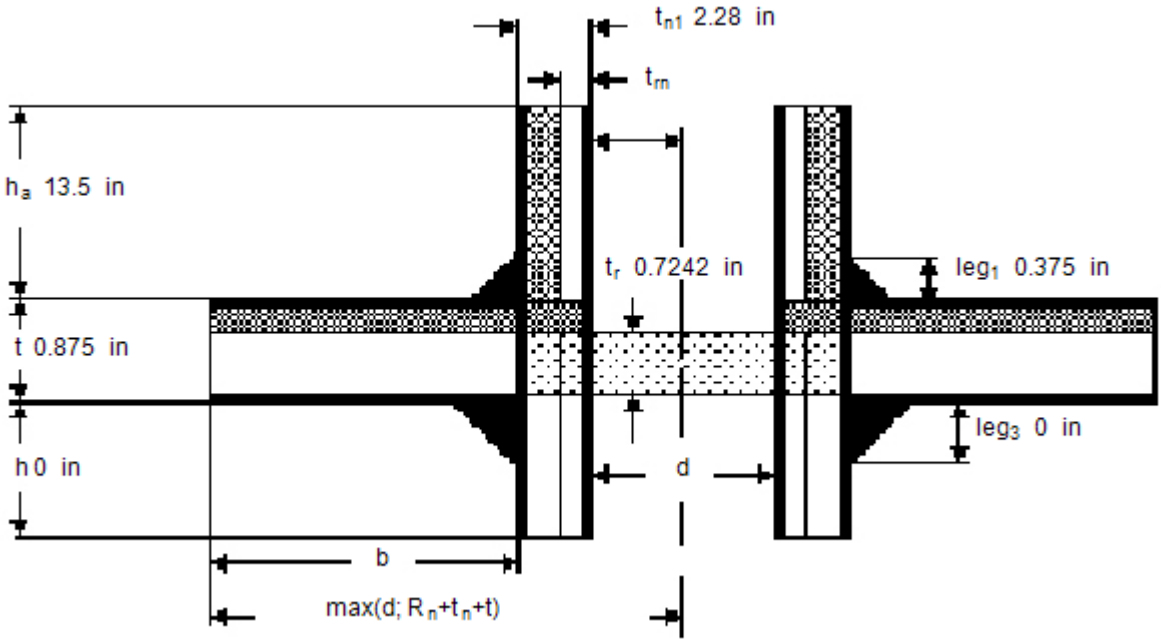
Protruding nozzle without reinforcement

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	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	0.7242	in

Nozzle Nº 1



Access opening		NEIN	
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}	**0.9374**	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	$(E_1 \cdot t - F \cdot t_r)$	**0.1508**	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}	**0.1035**	in	**0.1035**	in
Required area for internal pressure	A	**8.422**	in²		in²
Area of shell reserve	A_1	**1.754**	in²		in²
Area of reinforcement (A_2 to A_5)	A_V	**9.116**	in²		in²
Total available area ∑A	A_{avl}	**10.87**	in²		in²
Required area A/Γ	A_{req}	**8.422**	in²		in²
Utilization	(A_{req}/A_{avl})	**77.49**	%		%
Allowable pressure		**404.4**	psi		psi

Weld loads according to UG-41

W	= $[A-A_1+2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)] \cdot S_v$	=	**146484**	lbf
W_1-1	= $[A_2+A_{41}] \cdot S_v$	=	**182455**	lbf
W_2-2	= $[A_2+A_3+A_41+A_{43}+2 \cdot t \cdot t_n \cdot f_{r1}] \cdot S_v$	=	**257937**	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		
				≥	**146484**	lbf		
2-2	**92087** lbf	+	**0** lbf	+	**0** lbf	=	**92087**	lbf
				≥	**146484**	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

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

$$295.4 \text{ mm} \cdot 18.39 \text{ mm} \cdot 1 + 2 \cdot 54.74 \text{ mm} \cdot 18.39 \text{ mm} \cdot 1 \cdot (1 - 1) = 5434 \text{ mm}^2$$

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}	**0.8492**	in
Required nozzle thickness with allowances		t_{rn+}	**0.2295**	in

Areas according to UG-40

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

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

(internal pressure)

$$t_{rn} = p_0 \cdot \frac{\frac{d}{20}}{(S_n - 0.06 \cdot p_0)} = 2.455 \text{ MPa} \cdot \frac{\frac{295.4 \text{ mm}}{20}}{(138 \text{ MPa} - 0.06 \cdot 2.455 \text{ MPa})} = 2.63 \text{ mm}$$

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

$$Max\begin{Bmatrix} 295.4 \text{ mm} \cdot 3.83 \text{ mm} - 2 \cdot 54.74 \text{ mm} \cdot 3.83 \text{ mm} \cdot (1 - 1) \\ 2 \cdot (22.23 \text{ mm} + 54.74 \text{ mm}) \cdot 3.83 \text{ mm} - 2 \cdot 54.74 \text{ mm} \cdot 3.83 \text{ mm} \cdot (1 - 1) \end{Bmatrix} = 1131 \text{ mm}^2$$

$$A_2 = 2 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot h'_a = 2 \cdot (54.74 \text{ mm} - 2.63 \text{ mm}) \cdot 1 \cdot 55.56 \text{ mm} = 5790 \text{ mm}^2$$

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

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

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

$$A_V = A_2 + A_3 + A_{41} + A_{43} = A_2 + A_3 + A_{41} + A_{43} = 5881 \text{ mm}^2$$

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)

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

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

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

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

E.4.5.4 - Set-on nozzles with reinforcement - ASME BPVC VIII-1 UG-37: 2025

Set-on nozzle with reinforcement

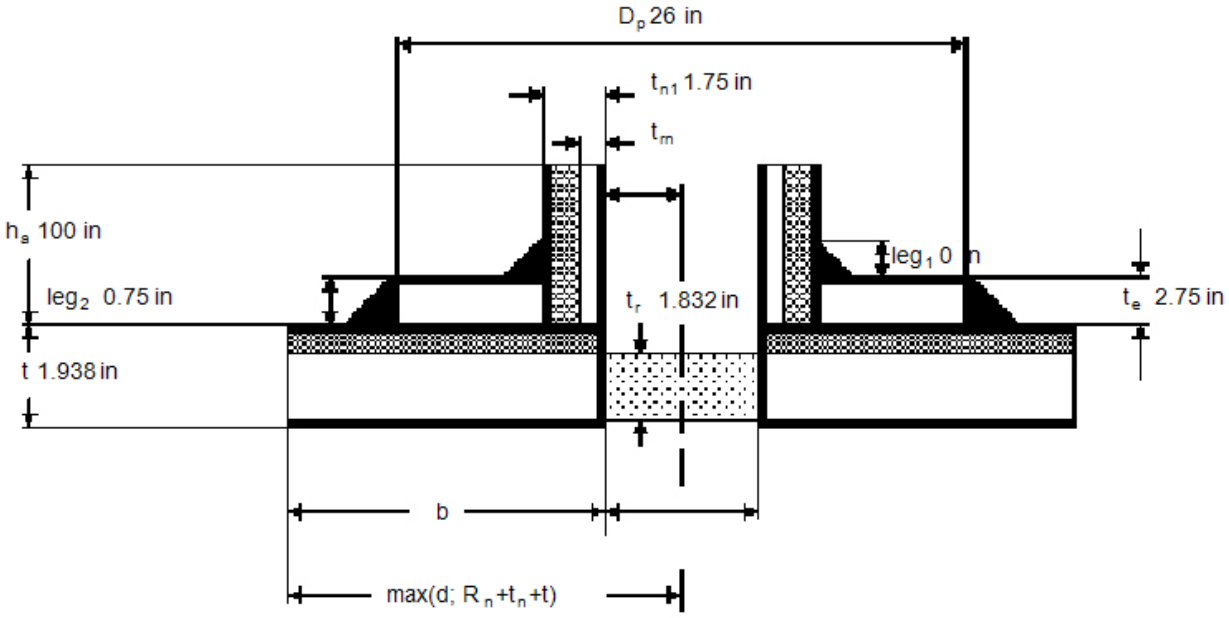
Set-on nozzle with reinforcement

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	11400	psi
Safety factor	S	1	
Allowable stress value	S_v	**11400**	psi
Wall thickness allowance	c_{1s}	0	in
Corrosion allowance	c_{2s}	0.0625	in
Required thickness without allowances	t_r	1.832	in

Nozzle Nº 1



Access opening		NEIN	
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}	**1.899**	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	$(E_1 \cdot t - F \cdot t_r)$	**0.1051**	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}	**0.2863**	in	**0.2863**	in
Projected Area	A	**29.55**	in²		in²
Area of shell reserve	A_1	**1.695**	in²		in²
Area of reinforcement (A_2 to A_5)	A_V	**32.01**	in²		in²
Total available area ∑A	∑A	**33.71**	in²		in²
Required area A/Γ	A/H	**29.55**	in²		in²
Utilization	(A_{req}/A_{avl})	**87.66**	%		%
Allowable pressure		**453.9**	psi		psi

Weld loads according to UG-41

W	= $[A-A_1+2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)] \cdot S_v$	=	**317524** lbf
W_1-1	= $[A_2+A_5+A_{41}+A_{42}] \cdot S_v$	=	**364933** lbf
W_2-2	= $[A_2+A_{41}] \cdot S_v$	=	**154743** 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	$\pi/2 \cdot D_p \cdot leg_2 \cdot 0.49 \cdot \min(S_p;S_v)$	**171104** lbf

Groove weld

Shell /Nozzle	$\pi/2 \cdot d_a \cdot leg_4 \cdot 0.60 \cdot \min(S_v;S_n)$	**155404** 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			**171104** lbf	+	**155404** lbf	=	**326509** lbf	
						≥	**317524** lbf	
2-2	**0** lbf	+	**0** lbf	+	**155404** lbf	=	**155404** lbf	
						≥	**154743** 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)

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

Fig. UG-37.1

$$A = d \cdot t_r \cdot F = 409.6 \text{ mm} \cdot 46.54 \text{ mm} \cdot 1 = 19063 \text{ mm}^2$$

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}	**1.895**	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)

$$t_{rm} = p_0 \cdot \frac{\frac{d}{20}}{(S_n - 0.06 \cdot p_0)} = 2.93 \text{ MPa} \cdot \frac{\frac{409.6 \text{ mm}}{20}}{(82.69 \text{ MPa} - 0.06 \cdot 2.93 \text{ MPa})} = 7.273 \text{ mm}$$

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

$$Max\begin{cases} 409.6 \text{ mm} \cdot 2.67 \text{ mm} - 2 \cdot 42.86 \text{ mm} \cdot 2.67 \text{ mm} \cdot (1 - f_{r1}) \\ 2 \cdot (49.21 \text{ mm} + 42.86 \text{ mm}) \cdot 2.67 \text{ mm} - 2 \cdot 42.86 \text{ mm} \cdot 2.67 \text{ mm} \cdot (1 - f_{r1}) \end{cases} = 1093 \text{ mm}^2$$

$$A_2 = 2 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot h'_a = 2 \cdot (42.86 \text{ mm} - 7.273 \text{ mm}) \cdot 1 \cdot 123 \text{ mm} = 8757 \text{ mm}^2$$

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

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

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

$$A_V = A_2 + A_{41} + A_{42} + A_5 = A_2 + A_{41} + A_{42} + A_5 = 20652 \text{ mm}^2$$

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	$Min[h_a; t_e + (R_{nm} \cdot t_n)^{0.5}]$	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) $\frac{R_n}{R} =$ [redacted] = [redacted] ≤ 0.7

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

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

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

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

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

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.4.5.5 - Set-on nozzles with reinforcement - ASME BPVC VIII-1 UG-37: 2025

Set-on nozzle with reinforcement

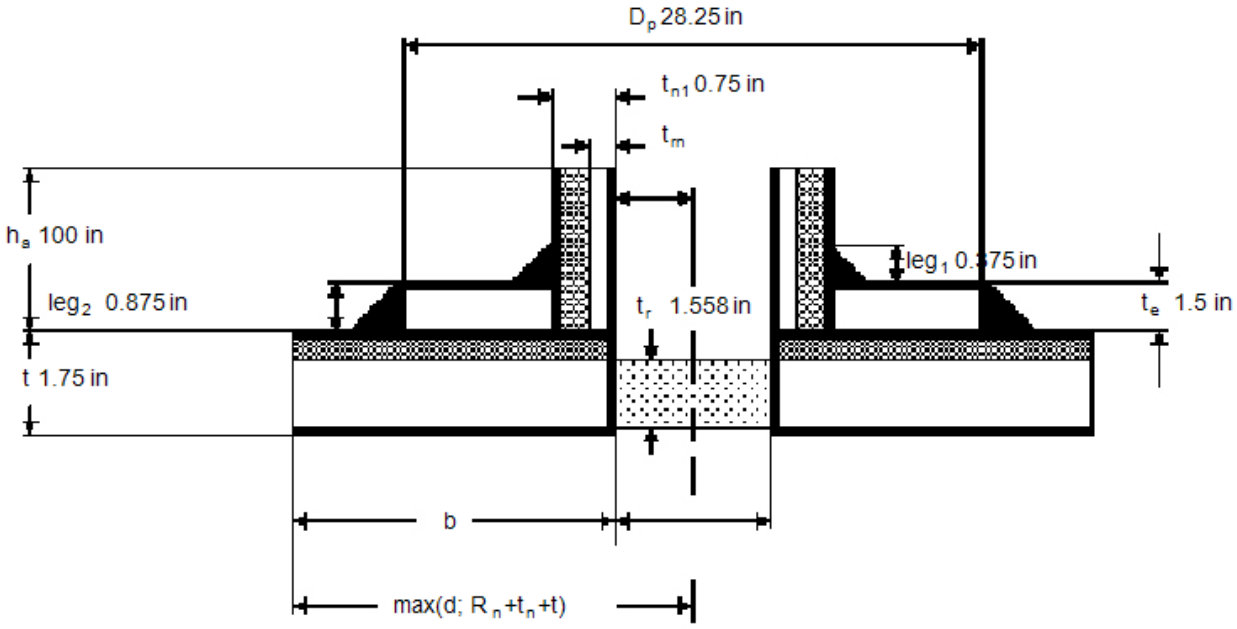
Set-on nozzle with reinforcement

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	60	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		NEIN	
Outside diameter	d_a	16	in
Joint efficiency factor (or Cast Quality Factor)	E_n	1	
Material			
Material strength	K_n		psi
Wall thickness allowance	c_1	0	in
Allowance (corrosion)	c_2	0.25	in
Safety factor	S		
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	1987009	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}	**0.2743**	in	**0.2743**	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	**20.52**	in²		in²
Total available area ∑A	∑A	**23.41**	in²		in²
Required area A/Γ	A/H	**23.37**	in²		in²
Utilization	(A_{req}/A_{avl})	**99.84**	%		%
Allowable pressure			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	= $[A_2+A_5+A_{41}+A_{42}] \cdot S_v$	=	**281161**	lbf
W_2-2	= $[A_2+A_{41}] \cdot S_v$	=	**18932**	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
								≥	**18932** 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)

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

$$3.447 \text{ MPa} \cdot \frac{\frac{381 \text{ mm}}{20}}{(94.46 \text{ MPa} - 0.06 \cdot 3.447 \text{ MPa})} = 6.968 \text{ mm}$$

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

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

$$A_2 = 2 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot h'_a = 2 \cdot (12.7 \text{ mm} - 6.968 \text{ mm}) \cdot 1 \cdot 69.85 \text{ mm} = 800.8 \text{ mm}^2$$

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

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

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

$$A_V = A_2 + A_{41} + A_{42} + A_5 = A_2 + A_{41} + A_{42} + A_5 = 13240 \text{ mm}^2$$

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 4.5.6 - Protruding nozzles without reinforcement - ASME BPVC VIII-1 UG-37: 2025

Protruding nozzle without reinforcement

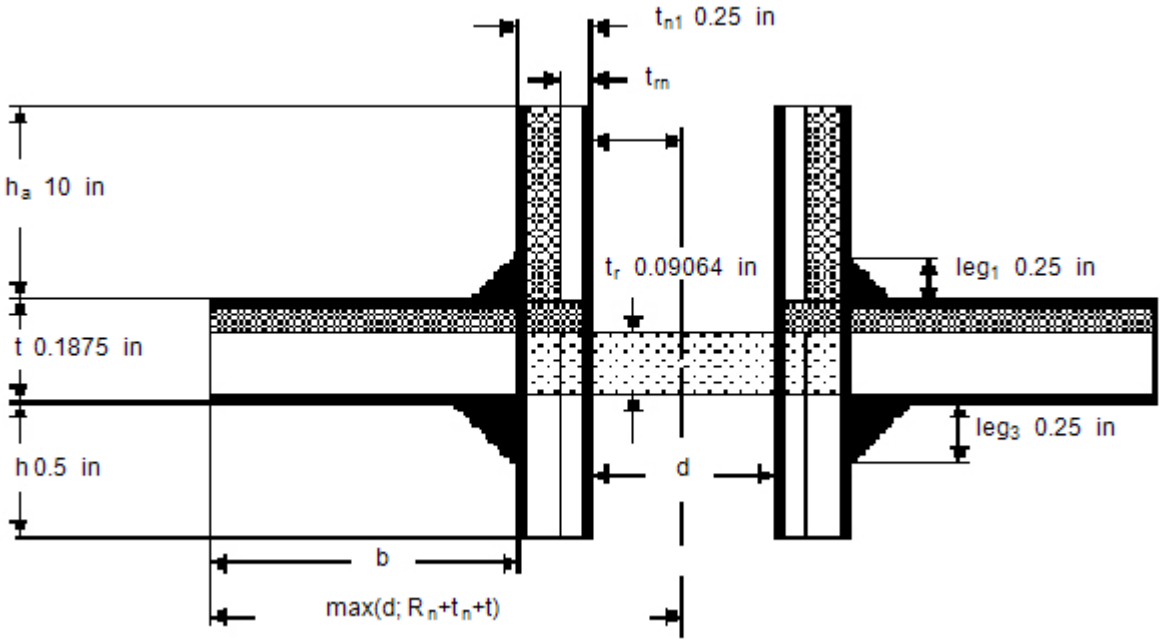
Protruding nozzle without reinforcement

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	200	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	0.09064	in

Nozzle Nº 1



Access opening		NEIN	
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	10	in
Internal projection	h	0.5	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}	**0.1019**	in
Minimum nozzle neck thickness per UG-16	t_{UG-16}	0.05906	in
Required nozzle neck thickness per UG-45	t_{UG-45}	**0.1019**	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	$(E_1 \cdot t - F \cdot t_r)$	**0.09686**	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}	**0.05033**	in	**0.05033**	in
Required area for internal pressure	A	**0.7506**	in²		in²
Area of shell reserve	A_1	**0.7719**	in²		in²
Area of reinforcement (A_2 to A_5)	A_V	**0.3762**	in²		in²
Total available area ∑A	A_{avl}	**1.148**	in²		in²
Required area A/Γ	A_{req}	**0.7506**	in²		in²
Utilization	(A_{req}/A_{avl})	**65.38**	%		%
Allowable pressure		**185.5**	psi		psi

Weld loads according to UG-41

W	= $[A-A_1+2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)] \cdot S_v$	=	**211.6**	lbf
W_1-1	= $[A_2+A_{41}] \cdot S_v$	=	**3025**	lbf
W_2-2	= $[A_2+A_3+A_41+A_{43}+2 \cdot t \cdot t_n \cdot f_{r1}] \cdot S_v$	=	**7758**	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		
				≥	**211.6**	lbf		
2-2	**20109** lbf	+	**0** lbf	+	**20109** lbf	=	**40217**	lbf
				≥	**211.6**	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

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

$$206.4 \text{ mm} \cdot 2.302 \text{ mm} \cdot 1 + 2 \cdot 6.35 \text{ mm} \cdot 2.302 \text{ mm} \cdot 1 \cdot (1 - 0.6882) = 484.2 \text{ mm}^2$$

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}	**0.09064**	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)

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

$$1.034 \text{ MPa} \cdot \frac{\frac{206.4 \text{ mm}}{20}}{(83.54 \text{ MPa} - 0.06 \cdot 1.034 \text{ MPa})} = 1.278 \text{ mm}$$

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

$$Max\begin{Bmatrix} 206.4 \text{ mm} \cdot 2.46 \text{ mm} - 2 \cdot 6.35 \text{ mm} \cdot 2.46 \text{ mm} \cdot (1 - 0.6882) \\ 2 \cdot (4.762 \text{ mm} + 6.35 \text{ mm}) \cdot 2.46 \text{ mm} - 2 \cdot 6.35 \text{ mm} \cdot 2.46 \text{ mm} \cdot (1 - 0.6882) \end{Bmatrix} = 498 \text{ mm}^2$$

$$A_2 = 2 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot h'_a = 2 \cdot (6.35 \text{ mm} - 1.278 \text{ mm}) \cdot 0.6882 \cdot 11.91 \text{ mm} = 83.12 \text{ mm}^2$$

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

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

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

$$A_V = A_2 + A_3 + A_{41} + A_{43} = A_2 + A_3 + A_{41} + A_{43} = 242.7 \text{ mm}^2$$

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

(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)

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

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

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

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