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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

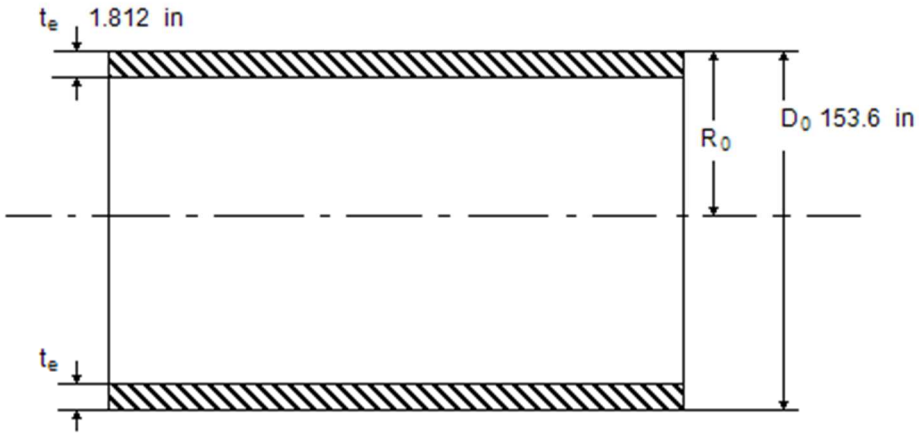
Summary

Strength Calculation Software	Program System ATLAS				Version	8.31.2	
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	1,75	in^2	**1,16%**
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: 2019

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: 2019

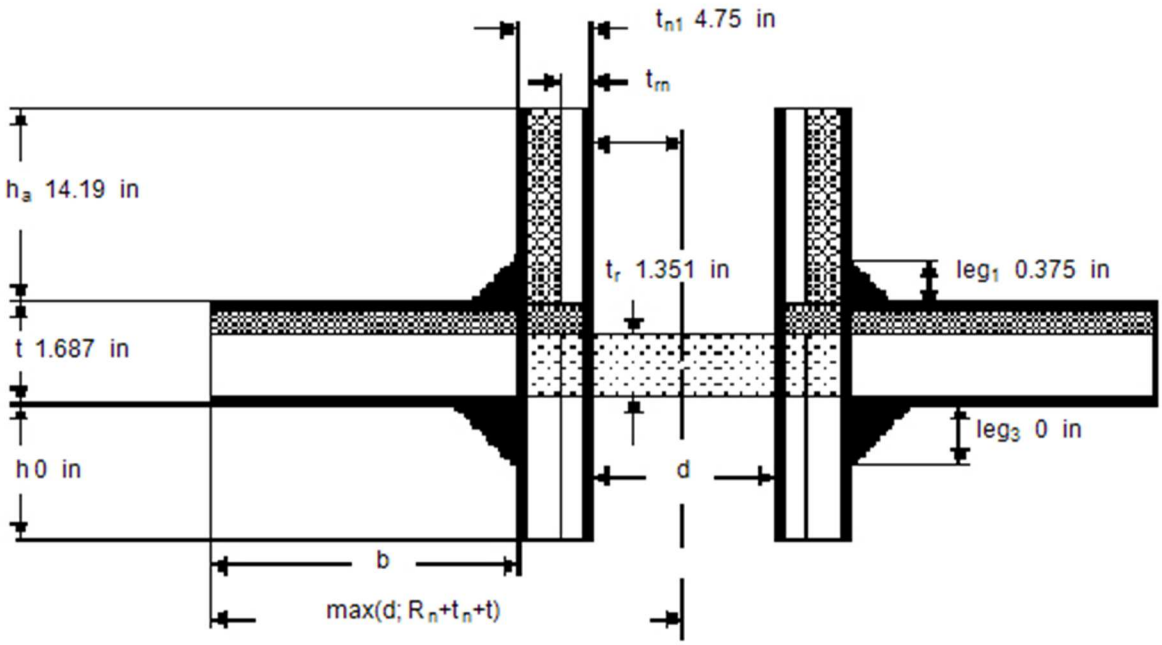
Protruding nozzle without reinforcement

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)

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

App.1-7(a)(1)

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

App.1-7(a)(1)

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

Fig. UG-37.1

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

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

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

Areas according to UG-40

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

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

(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}·t_n)$^{0.5}$]	l_{nm}	in
Support length shell	Min[b_a; (R_m·t_e)$^{0.5}$]	l_m	in

E 4.5.2 Step5 F=1 - Protruding nozzles without reinforcement - ASME BPVC VIII-1 UG-37: 2019

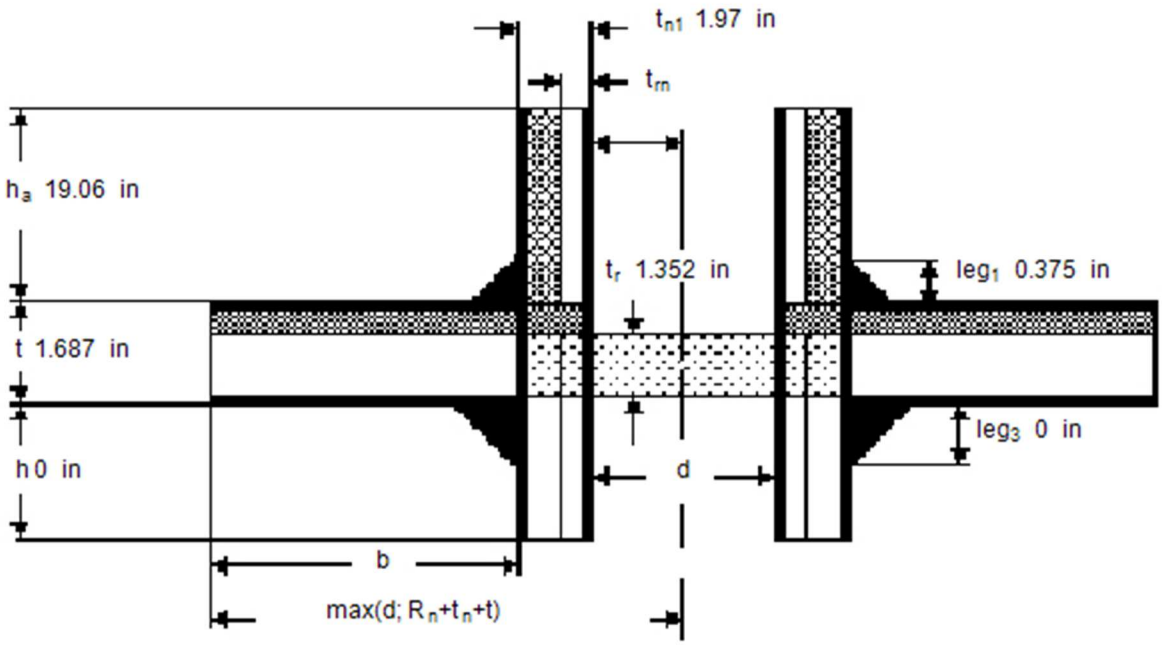
Protruding nozzle without reinforcement

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)

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

App.1-7(a)(1)

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

App.1-7(a)(1)

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

Fig. UG-37.1

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

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

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

Areas according to UG-40

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

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

(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

E 4.5.3 - Protruding nozzles without reinforcement - ASME BPVC VIII-1 UG-37: 2019

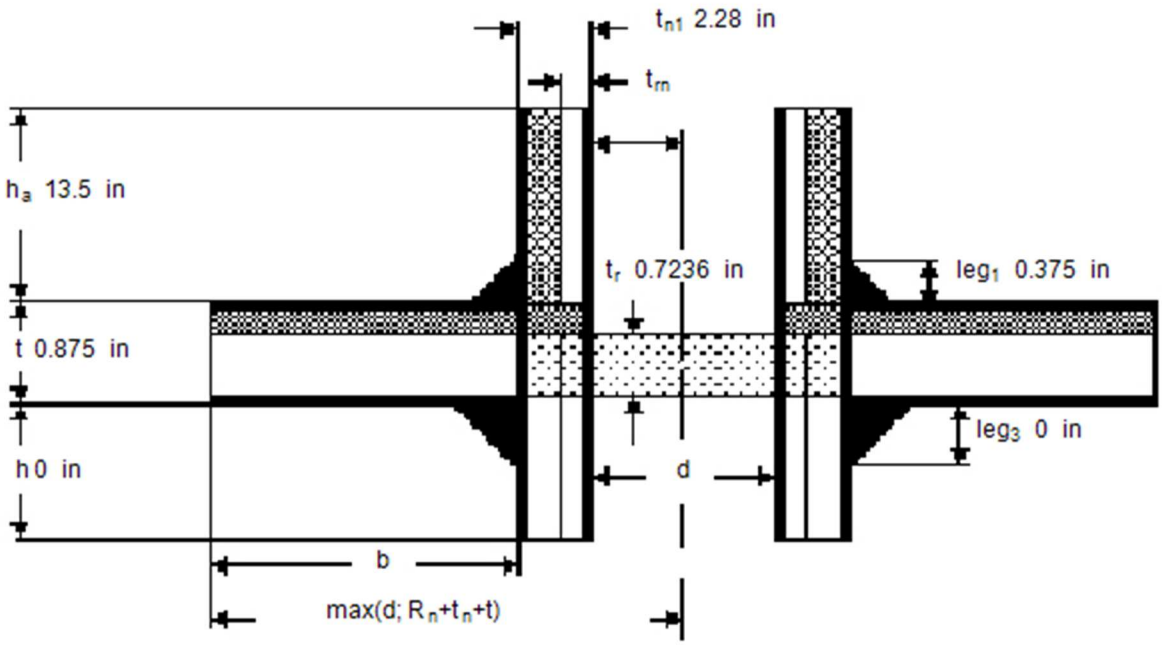
Protruding nozzle without reinforcement

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 Nº 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

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

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

(internal pressure)

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

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

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

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

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

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

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

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

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.)]

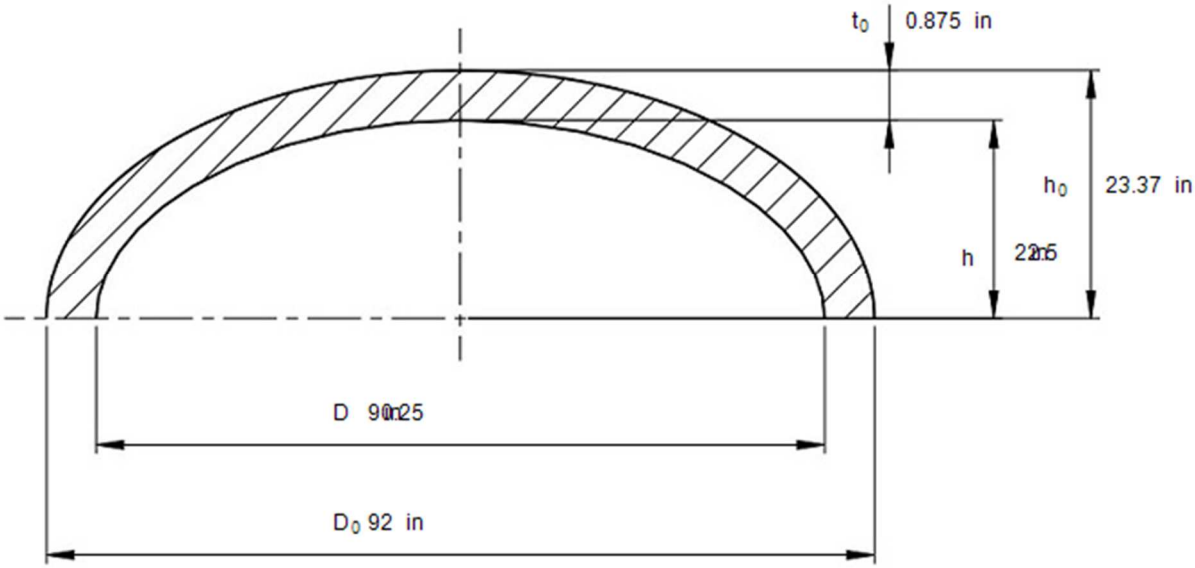
Additional rules for cylindr. shells, App.1-7(b) not required

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}·t_n)$^{0.5}$]	l_{nm}	in
Support length shell	Min[b_a; (R_m·t_e)$^{0.5}$]	l_m	in

Elliptical heads under internal pressure - ASME BPVC VIII-1 UG-32 & Appendix-1: 2019

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: 2019

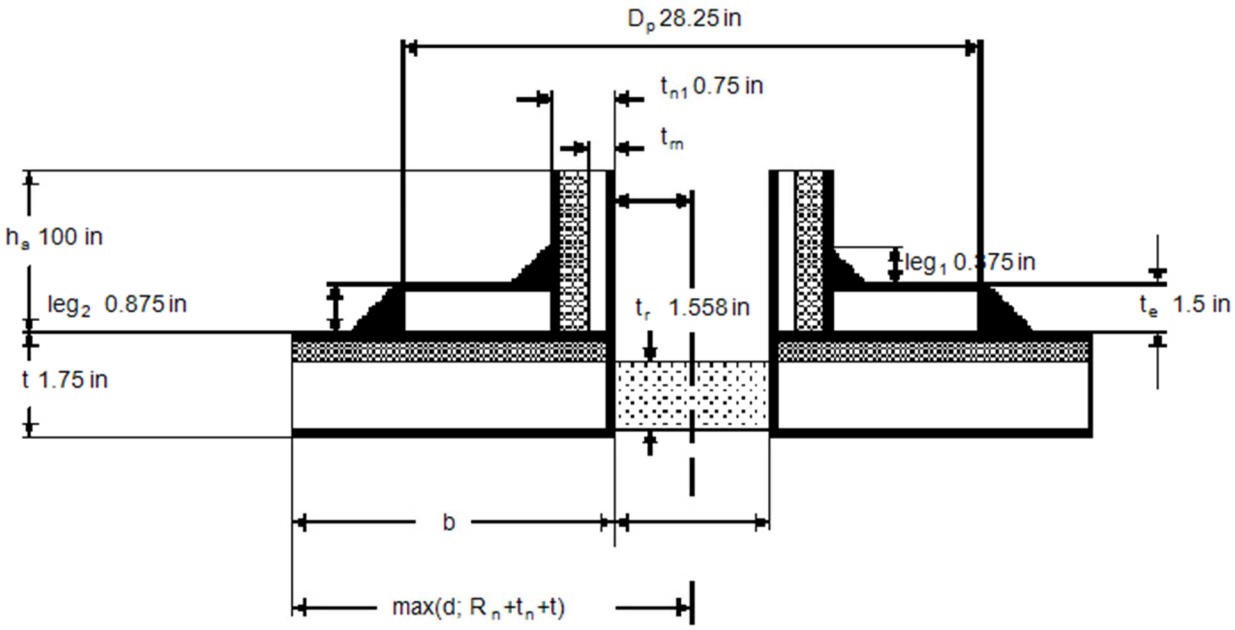
Set-on nozzle with reinforcement

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

E.4.5.4 - Set-on nozzles with reinforcement - ASME BPVC VIII-1 UG-37: 2019

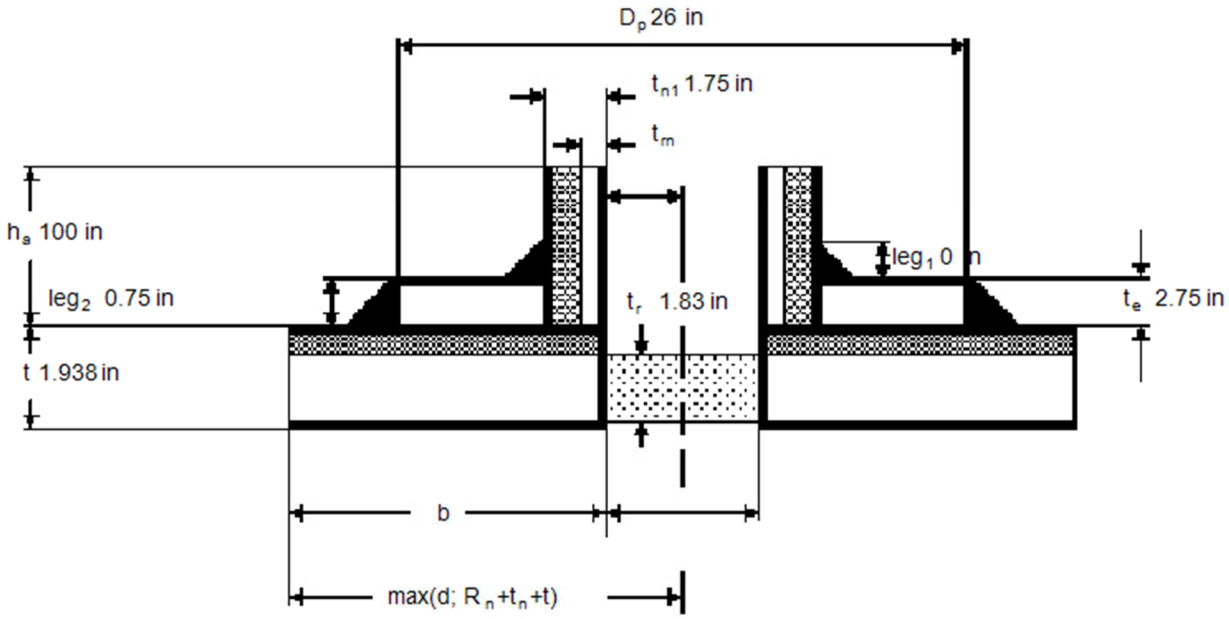
Set-on nozzle with reinforcement

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)

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

Fig. UG-37.1

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

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

Areas according to UG-40

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

(internal pressure)

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

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

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

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

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

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

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

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

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	$Min[h_a; t_e + (R_{nm} \cdot t_n)^{0.5}]$	l_{nm}	in
Support length shell	$Min[b_a; (R_m \cdot t_e)^{0.5}]$	l_m	in

E.4.5.6 - Protruding nozzles without reinforcement - ASME BPVC VIII-1 UG-37: 2019

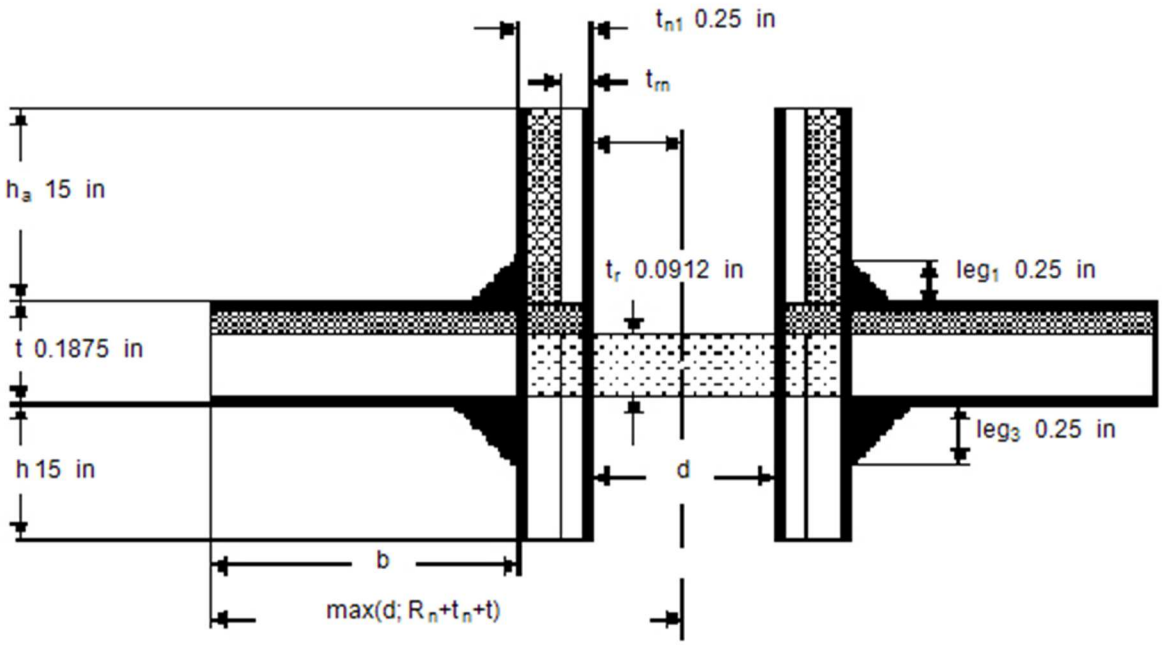
Protruding nozzle without reinforcement

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

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

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

(internal pressure)

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

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

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

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

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

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

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

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

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

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

Appendix: Material documentation

Section 2: Schale/2 UG27
Section 3: Mantel/E 4.5.1
Section 3: Stutzen/E 4.5.1
Section 3: Verstaerkung/E 4.5.1
Section 1: Mantel/E 4.5.2 Step5 F=1
Section 1: Stutzen/E 4.5.2 Step5 F=1
Section 7: Mantel/E 4.5.3
Section 7: Stutzen/E 4.5.3
Section 8: Boden/8 UG32
Section 12: Mantel/E.4.5.4
Section 12: Stutzen/E.4.5.4
Section 12: Verstaerkung/E.4.5.4

Material specification:		
Material code: K02700-SA-516-70-Class:-Size:	Regulation: ASME II.D Table 1A:2017	Spec. No.: SA-516
Short name: Carbon steel	Product: Plate	
Delivery condition:		

Design conditions and dimensions:	
Temperature [°C]: 148.89	Thickness [mm]: 46.04
Pressure [bar]: 24.55	Outside diameter [mm]: 3902.08

Material values for test and design conditions:		
	Test condition	Operating condition
Nominal design strength [N/mm²]:	138	138
Safety factor:	1	1
Allowable stress [N/mm²]:	138	138
Modulus of elasticity [kN/mm²]:	202.4	195.1

Notes:
G10: General Requirements
Upon prolonged exposure to temperatures above 425°C, the carbide phase of carbon steel may be converted to graphite. See Nonmandatory Appendix A, A–201 and A–202.
S1: Size Requirements
For Section I applications, stress values at temperatures of 450°C and above are permissible but, except for tubular products 75 mm O.D. or less enclosed within the boiler setting, use of these materials at these temperatures is not current practice.
T2: Time-Dependent Properties
Allowable stresses for temperatures of 400°C and above are values obtained from time–dependent properties.

Strength values at 20°C		
R_{eH}	density	Tensile strength
.	.	$R_{m,\ min}$
N/mm²	kg/dm³	N/mm²
260	7.85	485

Strength values as a function of temperature										
T	°C	40	100	150	250	325	375	425	475	525
K	N/mm²	138	138	138	138	132	123	83.8	51	21.3

Young's modulus-values in dependence of the temperature															
T	°C	-200	-125	-75	25	100	150	200	250	300	350	400	450	500	550
E	kN/mm²	216	212	209	202	198	195	192	189	185	179	171	162	151	137

Mean coefficient of thermal expansion-values in dependence of the temperature										
T	°C	20	100	200	300	400	500	600	700	800
α_m	1e-6/K	11.5	12.1	12.7	13.3	13.8	14.4	14.8	15.1	15.4

Differential coefficient of thermal expansion-values in dependence of the temperature										
T	°C	20	100	200	300	400	500	600	700	800
α_{diff}	1e-6/K	11.5	12.7	13.8	14.9	15.9	16.7	17.0	17.1	17.7

Design conditions and dimensions:	
Temperature [°C]: 148.89	Thickness [mm]: 42.86
Pressure [bar]: 24.55	Outside diameter [mm]: 3902.08

Design conditions and dimensions:	
Temperature [°C]: 426.67	Thickness [mm]: 49.21
Pressure [bar]: 29.3	Outside diameter [mm]: 2540

Material values for test and design conditions:		
	Test condition	Operating condition
Nominal design strength [N/mm²]:	138	82.69
Safety factor:	1	1
Allowable stress [N/mm²]:	138	82.7
Modulus of elasticity [kN/mm²]:	202.4	166.2

Section 14: Mantel/E.4.5.6

Material specification:		
Material code: S31651-SA-376-TP316N-Class:-Size:	Regulation: ASME II.D Table 1A:2017	Spec. No.: SA-376
Short name: 16Cr-12Ni-2Mo-N	Product: Smls. pipe	
Delivery condition:		

Design conditions and dimensions:	
Temperature [°C]: 204.44	Thickness [mm]: 4.76
Pressure [bar]: 10.34	Outside diameter [mm]: 609.6

Material values for test and design conditions:		
	Test condition	Operating condition
Nominal design strength [N/mm²]:	158	121.38
Safety factor:	1	1
Allowable stress [N/mm²]:	158	121.4
Modulus of elasticity [kN/mm²]:	195.3	182.6

Notes:
G12: General Requirements
At temperatures above 550°C, these stress values apply only when the carbon is 0.04% or higher on heat analysis.
H1: Heat Treatment Requirements
For temperatures above 550°C, these stress values may be used only if the material is heat treated by heating to the minimum temperature specified in the material specification, but not lower than 1040°C, and quenching in water or rapidly cooling by other means.
T8: Time-Dependent Properties
Allowable stresses for temperatures of 595°C and above are values obtained from time–dependent properties.

Strength values at 20°C		
R_{eH}	density	Tensile strength
.	.	$R_{m,\ min}$
N/mm²	kg/dm³	N/mm²
240	7.85	550

Strength values as a function of temperature												
T	°C	40	100	150	250	325	375	425	475	525	575	625
K	N/mm²	158	141	131	115	107	102	98	94.9	91.7	88.5	65.3

Young's modulus-values in dependence of the temperature															
T	°C	25	100	150	200	250	300	350	400	450	500	550	600	650	700
E	kN/mm²	195	189	186	183	179	176	172	169	165	160	156	151	146	140

Mean coefficient of thermal expansion-values in dependence of the temperature										
T	°C	20	100	200	300	400	500	600	700	800
α_m	1e-6/K	15.3	16.2	17.0	17.7	18.1	18.6	18.8	19.2	19.4

Differential coefficient of thermal expansion-values in dependence of the temperature										
T	°C	20	100	200	300	400	500	600	700	800
α_{diff}	1e-6/K	15.3	17.0	18.4	19.1	19.5	20.2	21.1	21.7	19.7

Section 14: Stutzen/E.4.5.6

Material specification:		
Material code: S31600-SA-249-TP316-Class:-Size:	Regulation: ASME II.D Table 1A:2017	Spec. No.: SA-249
Short name: 16Cr-12Ni-2Mo	Product: Wld. tube	
Delivery condition:		

Design conditions and dimensions:	
Temperature [°C]: 204.44	Thickness [mm]:
Pressure [bar]: 10.34	Outside diameter [mm]:

Material values for test and design conditions:		
	Test condition	Operating condition
Nominal design strength [N/mm²]:	117	83.54
Safety factor:	1	1
Allowable stress [N/mm²]:	117	83.5
Modulus of elasticity [kN/mm²]:	195.3	182.6

Notes:
G3: General Requirements
These stress values include a joint efficiency factor of 0.85.
G12: General Requirements
At temperatures above 550°C, these stress values apply only when the carbon is 0.04% or higher on heat analysis.
G24: General Requirements
A factor of 0.85 has been applied in arriving at the maximum allowable stress values in tension for this material. Divide tabulated values by 0.85 for maximum allowable longitudinal tensile stress.
T9: Time-Dependent Properties
Allowable stresses for temperatures of 620°C and above are values obtained from time–dependent properties.

Strength values at 20°C		
R_{eH}	density	Tensile strength
.	.	$R_{m,\ min}$
N/mm²	kg/dm³	N/mm²
205	7.85	515

Strength values as a function of temperature															
T	°C	40	100	150	250	325	375	425	475	525	575	625	675	725	775
K	N/mm²	117	99.8	90.8	78.8	73.3	70.8	69	67.7	66.5	65.3	55.6	33	19.4	11.3

Young's modulus-values in dependence of the temperature															
T	°C	25	100	150	200	250	300	350	400	450	500	550	600	650	700
E	kN/mm²	195	189	186	183	179	176	172	169	165	160	156	151	146	140

Mean coefficient of thermal expansion-values in dependence of the temperature										
T	°C	20	100	200	300	400	500	600	700	800
α_m	1e-6/K	15.3	16.2	17.0	17.7	18.1	18.6	18.8	19.2	19.4

Differential coefficient of thermal expansion-values in dependence of the temperature										
T	°C	20	100	200	300	400	500	600	700	800
α_{diff}	1e-6/K	15.3	17.0	18.4	19.1	19.5	20.2	21.1	21.7	19.7