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## Layout

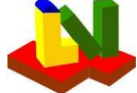
Input values:	1.234	or	1.234
Calculated values:	<b>1.234</b>	or	<b>1.234</b>
Critical values:	<b>1.234</b>	or	<b>1.234</b>
Estimated values:	<b>1.234</b>	or	<b>1.234</b>



## ASME BPVC VIII-1 2023 / PTB-4-2021

E4.5.1; E4.5.2; E4.5.6; E4.5.3; E4.5.4; E4.5.5; E4.5.6

Strength Calculation Software			Program System ATLAS --- Version : 11.0.7.161					
Developed by Lauterbach Verfahrenstechnik GmbH								
Certified per DIN EN ISO 9001:2008			Certificate Number 01 100 044763					



**ASME BPVC VIII-1 2023 / PTB-4-2021**  
E4.5.1; E4.5.2; E4.5.6; E4.5.3; E4.5.4; E4.5.5; E4.5.6

**E 4.5.1 - Protruding nozzles without reinforcement - ASME BPVC VIII-1 UG-37: 2023**

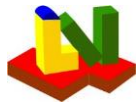
Protruding nozzle without reinforcement

**Protruding nozzle without reinforcement**

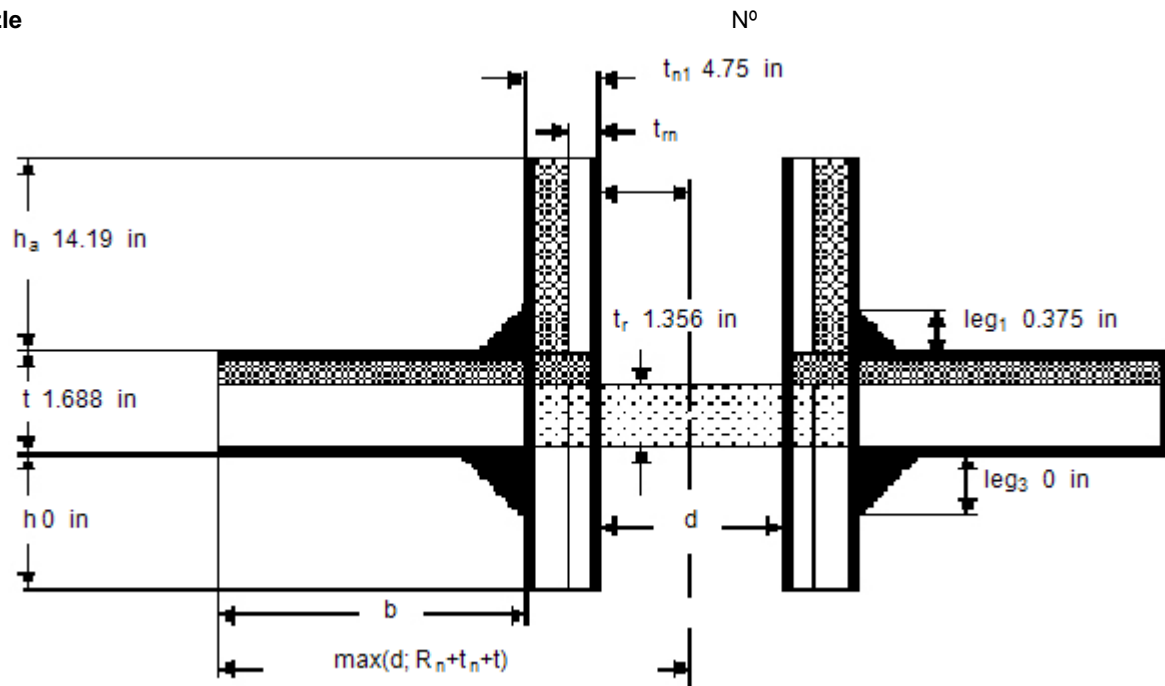
Design pressure	$p_D$	356 psi
Hydrostatic head	$D_p$	0 psi
Calculation pressure	$p_0$	<b>356</b> psi
Calculation temperature	$T_0$	300 °F
Factor (1=internal pressure; 2=external pressure)	$\Gamma$	Internal pressure

**Shell**

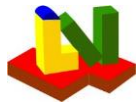
Shape of the shell	cylindrical	
Outside diameter	$D_a$	153.6 in
Nominal thickness without allowances	$t$	1.688 in
Available shell length for reinforcement	$b_a$	50 in
Joint efficiency factor (or Cast Quality Factor)	$E_1$	1
Material K02700-SA-516-70-Class:-Size:		
Material strength	$K$	20015 psi
Safety factor	$S$	1
Allowable stress value	$S_v$	<b>20015</b> psi
Wall thickness allowance	$c_{1s}$	0 in
Corrosion allowance	$c_{2s}$	<b>0.125</b> in
Required thickness without allowances	$t_r$	1.356 in



**Nozzle**



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	$K_n/S$		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 = $d_a - 2 \cdot t_2$	$d_{iN}$		16 in
Inside diameter, corroded = $d_a - 2 \cdot t_n$	$d$		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	$\Theta$		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	$t_{b1}$		1.481 in
with joint efficiency $E=1.0$			
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 ( $\leq t$ )	$leg_4$		0 in



**Calculation according to**

Correction factor (Fig.UG-37, int. pres.)  
Reserve of shell  
Limit length of vessel acc. to UG-40(b)  
Limit length of nozzle outside, UG40(c)  
Limit length of nozzle inside, Fig.UG37  
Minimum required thickness of nozzle  
Required area for internal pressure  
Area of shell reserve  
Area of reinforcement ( $A_2$  to  $A_5$ )  
Total available area  $\sum A$   
Required area  $A/\Gamma$   
Utilization  
Allowable pressure

	UG-40	App.1-7
$F$	<b>1</b>	
$(E_1 \cdot t - F \cdot t_r)$	<b>0.332</b> in	
$b$	<b>8.125</b> in	
$h'_a$	<b>4.22</b> in	<b>4.22</b> in
$h'$	<b>0</b> in	0
$t_m$	<b>0.1447</b> in	<b>0.1447</b> in
$A$	<b>22.04</b> in <sup>2</sup>	
$A_1$	<b>5.395</b> in <sup>2</sup>	
$A_v$	<b>37.95</b> in <sup>2</sup>	
$A_{avl}$	<b>43.35</b> in <sup>2</sup>	
$A_{req}$	<b>22.04</b> in <sup>2</sup>	
$(A_{req}/A_{avl})$	<b>50.83</b> %	%
	<b>499.3</b> psi	psi

**Weld loads according to UG-41**

$W$	$= [A - A_1 + 2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)] \cdot S_v$	$=$	<b>394522</b> lbf
$W_{1-1}$	$= [A_2 + A_{41}] \cdot S_v$	$=$	<b>759673</b> lbf
$W_{2-2}$	$= [A_2 + A_3 + A_{41} + A_{43} + 2 \cdot t_n \cdot f_{r1}] \cdot S_v$	$=$	<b>1072192</b> lbf

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

Fillet shell /nozzle	$\pi/2 \cdot d_a \cdot \text{leg}_1 \cdot 0.49 \cdot \min(S_v; S_n)$	$=$	<b>147316</b> lbf
Fillet shell /nozzle	$\pi/2 \cdot d_a \cdot \text{leg}_3 \cdot 0.49 \cdot \min(S_v; S_n)$	$=$	<b>0</b> lbf
Groove shell /nozzle	$\pi/2 \cdot d_a \cdot \text{leg}_4 \cdot 0.74 \cdot \min(S_v; S_n)$	$=$	<b>0</b> lbf
Nozzle wall	$\pi/2 \cdot d_m \cdot t_n \cdot 0.70 \cdot S_n$	$=$	<b>2124806</b> lbf

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

1-1	<b>147316</b> lbf	+	<b>2124806</b> lbf	$=$	<b>2272122</b> lbf
				$\geq$	<b>394522</b> lbf
2-2	<b>147316</b> lbf	+	<b>0</b> lbf	$=$	<b>147316</b> lbf
				$\geq$	<b>394522</b> lbf

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

$$b = \text{Max} \left\{ \frac{d}{2}, \frac{d}{t_n + t} \right\} = \text{Max} \left\{ \frac{d}{2}, \frac{d}{t_n + t} \right\} = 206.4 \text{ mm}$$

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

$$b = \text{Max} \left\{ \frac{3 \cdot d/2}{4}, \frac{d}{t_n + t} \right\}$$

App.1-7(a)(1)

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

App.1-7(a)(1)

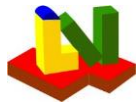
$$A = d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) =$$

Fig. UG-37.1

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

Available shell thickness with allowances  
Required shell thickness with allowances  
Required nozzle thickness with allowances

$t + C_{1s} + C_{2s}$	$t_s$	<b>1.813</b> in
$t_r + C_{1s} + C_{2s}$	$t_{sr}$	<b>1.481</b> in
	$t_{m+}$	<b>0.2711</b> in



**Areas according to UG-40**

$$h'_a = \min \left\{ \begin{array}{l} 2.5 \cdot t \\ 2.5 \cdot t_n = \min \left\{ \begin{array}{l} 2.5 \cdot t \\ 2.5 \cdot t_n = 107.2 \text{ mm} \end{array} \right. \\ h_a \end{array} \right.$$

$$h' = \min \left\{ \begin{array}{l} 2.5 \cdot t \\ 2.5 \cdot t_n = \min \left\{ \begin{array}{l} 2.5 \cdot t \\ 2.5 \cdot t_n = 0 \text{ mm} \end{array} \right. \\ h \end{array} \right.$$

$$t_m = p_0 \cdot \frac{\frac{d}{20}}{(S_n - 0.06 \cdot p_0)} = 2.455 \text{ MPa} \cdot \frac{\frac{412.8 \text{ mm}}{20}}{(138 \text{ MPa} - 0.06 \cdot 2.455 \text{ MPa})} = 3.675 \text{ mm} \quad (\text{internal pressure})$$

$$A_1 = \max \left\{ \begin{array}{l} d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \end{array} \right. =$$

$$\max \left\{ \begin{array}{l} 412.8 \text{ mm} \cdot 8.433 \text{ mm} - 2 \cdot 117.5 \text{ mm} \cdot 8.433 \text{ mm} \cdot (1 - 1) \\ 2 \cdot (42.88 \text{ mm} + 117.5 \text{ mm}) \cdot 8.433 \text{ mm} - 2 \cdot 117.5 \text{ mm} \cdot 8.433 \text{ mm} \cdot (1 - 1) \end{array} \right. = 3481 \text{ mm}^2$$

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

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

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

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

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

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

$D_a$	$3901 \leq 1520 \text{ mm (60 in.)}$	$d_a$	$647.7 > \min [$	$3901/2; 508 \text{ mm (20 in.)}]$
$D_a$	$3901 > 1520 \text{ mm (60 in.)}$	$d_a$	$647.7 > \min [$	$3901/3; 1000 \text{ mm (40 in.)}]$

**Additional rules for cylindr. shells, App.1-7(b)**

not required

Total available area		$A_{avl}$	$\text{in}^2$
Inside radius of shell		$R$	$\text{in}$
Inside radius of nozzle		$R_n$	$\text{in}$
Mean radius of shell		$R_m$	$\text{in}$
Mean radius of nozzle		$R_{nm}$	$\text{in}$
Allowable stress value		$S$	$\text{psi}$
Distance e		$e$	$\text{in}$
Moment of inertia		$I$	$\text{in}^4$
Material area acc. to Fig.1-7-1		$A_s$	$\text{in}^2$
Support length nozzle	$\min[h_a; t_e + (R_{nm} \cdot t_n)^{0.5}]$	$l_{nm}$	$\text{in}$
Support length shell	$\min[b_a; (R_m \cdot t_e)^{0.5}]$	$l_m$	$\text{in}$



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

- (a)  $2 \cdot R = \text{[redacted]} > 1524 \text{ mm (60 in.)}$
- (b)  $2 \cdot R_n = \text{[redacted]} > 1016 \text{ mm (40 in.)}$  and  $2 \cdot R_n > 3.4 \cdot \sqrt{R \cdot t} = \text{[redacted]}$
- (c)  $\frac{R_n}{R} = \frac{\text{[redacted]}}{\text{[redacted]}} = \text{[redacted]} \leq 0.7$

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

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

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

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

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

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

$$S_m \leq S$$

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

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

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

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

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



## ASME BPVC VIII-1 2023 / PTB-4-2021

E4.5.1; E4.5.2; E4.5.6; E4.5.3; E4.5.4; E4.5.5; E4.5.6

### E 4.5.2 Step5 F=1 - Protruding nozzles without reinforcement - ASME BPVC VIII-1 UG-37: 2023

Protruding nozzle without reinforcement

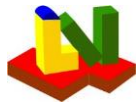
#### Protruding nozzle without reinforcement

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)	$\Gamma$	Internal pressure

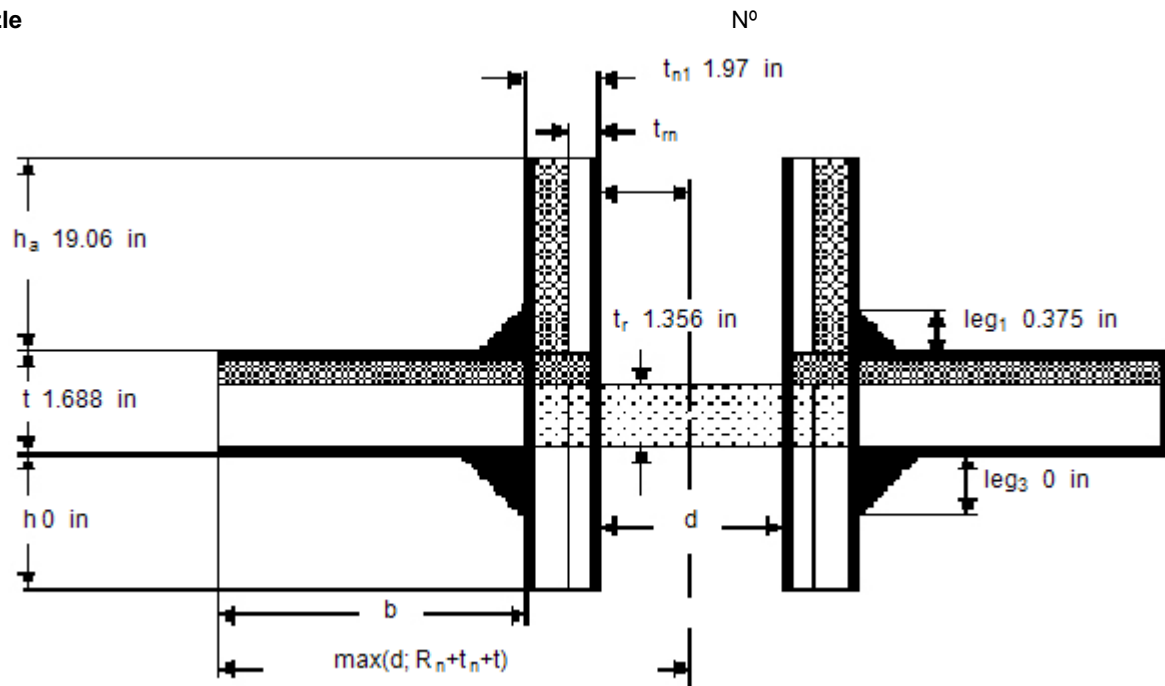
#### Shell

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

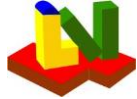




**Nozzle**



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	$K_n/S$	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 = $d_a - 2 \cdot t_2$	$d_{iN}$	7.62 in
Inside diameter, corroded = $d_a - 2 \cdot t_n$	$d$	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	$\Theta$	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	$t_{b1}$	1.481 in
with joint efficiency $E=1.0$		
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 ( $\leq t$ )	$leg_4$	0 in



**Calculation according to**

Correction factor (Fig.UG-37, int. pres.)  
Reserve of shell  
Limit length of vessel acc. to UG-40(b)  
Limit length of nozzle outside, UG40(c)  
Limit length of nozzle inside, Fig.UG37  
Minimum required thickness of nozzle  
Required area for internal pressure  
Area of shell reserve  
Area of reinforcement ( $A_2$  to  $A_5$ )  
Total available area  $\Sigma A$   
Required area  $A/\Gamma$   
Utilization  
Allowable pressure

	UG-40	App.1-7
F	1	
$(E_1 \cdot t - F \cdot t_r)$	0.332 in	
b	3.935 in	in
$h'_a$	4.22 in	4.22 in
$h'$	0 in	0
$t_m$	0.07006 in	0.07006 in
A	10.67 in <sup>2</sup>	in <sup>2</sup>
$A_1$	2.613 in <sup>2</sup>	in <sup>2</sup>
$A_v$	15.12 in <sup>2</sup>	in <sup>2</sup>
$A_{avl}$	17.73 in <sup>2</sup>	in <sup>2</sup>
$A_{req}$	10.67 in <sup>2</sup>	in <sup>2</sup>
$(A_{req}/A_{avl})$	60.18 %	%
	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
$W_{2-2}$	=	$[A_2 + A_3 + A_{41} + A_{43} + 2 \cdot t_n \cdot f_{r1}] \cdot S_v$	=	427323 lbf

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

Fillet shell /nozzle	$\pi/2 \cdot d_a \cdot \text{leg}_1 \cdot 0.49 \cdot \min(S_v; S_n)$	=	66783 lbf
Fillet shell /nozzle	$\pi/2 \cdot d_a \cdot \text{leg}_3 \cdot 0.49 \cdot \min(S_v; S_n)$	=	0 lbf
Groove shell /nozzle	$\pi/2 \cdot d_a \cdot \text{leg}_4 \cdot 0.74 \cdot \min(S_v; S_n)$	=	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	=	66783 lbf
				≥	185821 lbf

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

$$b = \text{Max} \left\{ \frac{d}{2}, \frac{d}{t_n + t} \right\} = \text{Max} \left\{ \frac{d}{2}, \frac{d}{t_n + t} \right\} = 99.95 \text{ mm}$$

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

$$b = \text{Max} \left\{ \frac{3 \cdot d/2}{4}, \frac{d}{t_n + t} \right\}$$

App.1-7(a)(1)

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

App.1-7(a)(1)

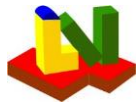
$$A = d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) =$$

Fig. UG-37.1

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

Available shell thickness with allowances  
Required shell thickness with allowances  
Required nozzle thickness with allowances

$t + C_{1s} + C_{2s}$	$t_s$	1.813 in
$t_r + C_{1s} + C_{2s}$	$t_{sr}$	1.481 in
	$t_{m+}$	0.1957 in



**Areas according to UG-40**

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

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

$$t_m = p_0 \cdot \frac{\frac{d}{20}}{(S_n - 0.06 \cdot p_0)} = 2.455 \text{ MPa} \cdot \frac{\frac{199.9 \text{ mm}}{20}}{(138 \text{ MPa} - 0.06 \cdot 2.455 \text{ MPa})} = 1.78 \text{ mm} \quad (\text{internal pressure})$$

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

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

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

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

$$A_{41} = (\text{leg}_1)^2 \cdot f_{r2} = (9.525 \text{ mm})^2 \cdot 1 = 90.73 \text{ mm}^2$$

$$A_{43} = (\text{leg}_3)^2 \cdot f_{r2} = (0 \text{ mm})^2 \cdot 1 = 0 \text{ mm}^2$$

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

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

$D_a$	$3901 \leq 1520 \text{ mm (60 in.)}$	$d_a$	$293.6 > \text{Min [$	$3901/2; 508 \text{ mm (20 in.)}]$
$D_a$	$3901 > 1520 \text{ mm (60 in.)}$	$d_a$	$293.6 > \text{Min [$	$3901/3; 1000 \text{ mm (40 in.)}]$

**Additional rules for cylindr. shells, App.1-7(b)**

not required

Total available area		$A_{avl}$	$\text{in}^2$
Inside radius of shell		$R$	$\text{in}$
Inside radius of nozzle		$R_n$	$\text{in}$
Mean radius of shell		$R_m$	$\text{in}$
Mean radius of nozzle		$R_{nm}$	$\text{in}$
Allowable stress value		$S$	$\text{psi}$
Distance e		$e$	$\text{in}$
Moment of inertia		$I$	$\text{in}^4$
Material area acc. to Fig.1-7-1		$A_s$	$\text{in}^2$
Support length nozzle	$\text{Min}[h_a; t_e + (R_{nm} \cdot t_n)^{0.5}]$	$l_{nm}$	$\text{in}$
Support length shell	$\text{Min}[b_a; (R_m \cdot t_e)^{0.5}]$	$l_m$	$\text{in}$



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

- (a)  $2 \cdot R = \text{[redacted]} > 1524 \text{ mm (60 in.)}$
- (b)  $2 \cdot R_n = \text{[redacted]} > 1016 \text{ mm (40 in.)}$  and  $2 \cdot R_n > 3.4 \cdot \sqrt{R \cdot t} = \text{[redacted]}$
- (c)  $\frac{R_n}{R} = \frac{\text{[redacted]}}{\text{[redacted]}} = \text{[redacted]} \leq 0.7$

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

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

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

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

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

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

$$S_m \leq S$$

**Bending stress  $S_b$  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: 2023

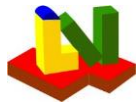
Protruding nozzle without reinforcement

#### 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)	$\Gamma$	Internal pressure

#### Shell

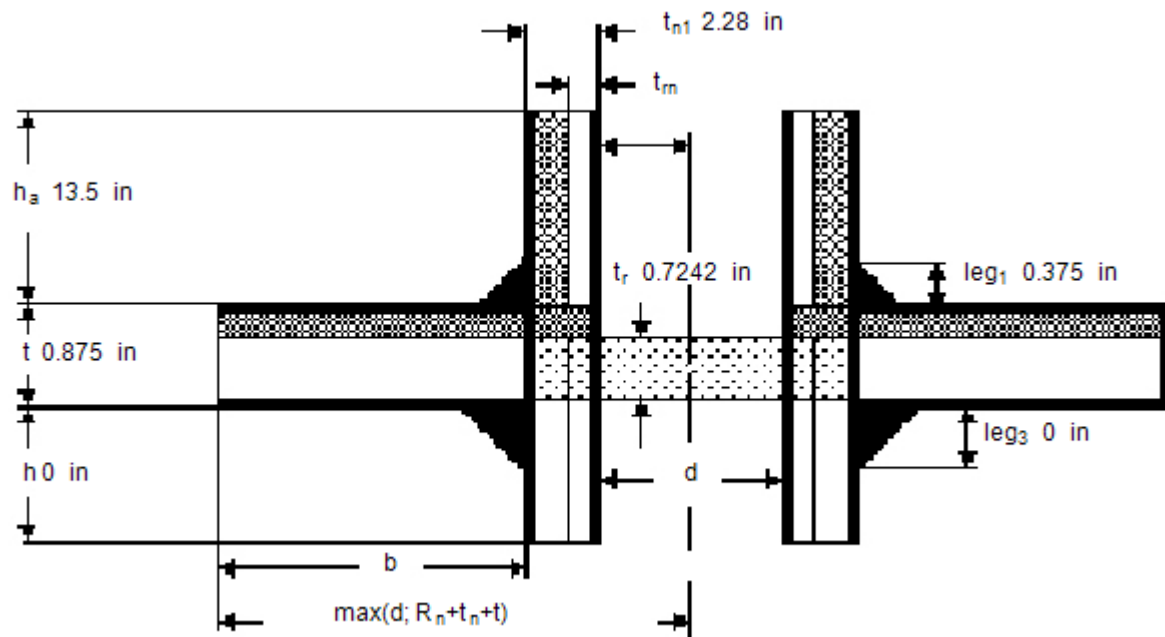
Shape of the shell	cylindrical	
Outside diameter	$D_a$	92 in
Nominal thickness without allowances	$t$	0.875 in
Available shell length for reinforcement	$b_a$	40 in
Joint efficiency factor (or Cast Quality Factor)	$E_1$	1
Material K02700-SA-516-70-Class:-Size:		
Material strength	$K$	20015 psi
Safety 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



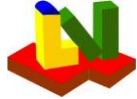
**Nozzle**

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	$K_n/S$		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 = $d_a - 2 \cdot t_2$	$d_{iN}$		11.38 in
Inside diameter, corroded = $d_a - 2 \cdot t_n$	$d$		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	$\Theta$		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	$t_{b1}$		0.9374 in
with joint efficiency $E=1.0$			
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 ( $\leq t$ )	$leg_4$		0 in



**Calculation according to**

Correction factor (Fig.UG-37, int. pres.)  
Reserve of shell  
Limit length of vessel acc. to UG-40(b)  
Limit length of nozzle outside, UG40(c)  
Limit length of nozzle inside, Fig.UG37  
Minimum required thickness of nozzle  
Required area for internal pressure  
Area of shell reserve  
Area of reinforcement ( $A_2$  to  $A_5$ )  
Total available area  $\sum A$   
Required area  $A/\Gamma$   
Utilization  
Allowable pressure

	UG-40	App.1-7
$F$	<b>1</b>	
$(E_1 \cdot t - F \cdot t_r)$	<b>0.1508</b> in	
$b$	<b>5.815</b> in	
$h'_a$	<b>2.188</b> in	<b>2.188</b> in
$h'$	<b>0</b> in	<b>0</b>
$t_m$	<b>0.1035</b> in	<b>0.1035</b> in
$A$	<b>8.422</b> in <sup>2</sup>	
$A_1$	<b>1.754</b> in <sup>2</sup>	
$A_v$	<b>9.116</b> in <sup>2</sup>	
$A_{avl}$	<b>10.87</b> in <sup>2</sup>	
$A_{req}$	<b>8.422</b> in <sup>2</sup>	
$(A_{req}/A_{avl})$	<b>77.49</b> %	
	<b>404.4</b> psi	<b>psi</b>

**Weld loads according to UG-41**

$W$	$= [A - A_1 + 2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)] \cdot S_v$	<b>= 146484</b> lbf
$W_{1-1}$	$= [A_2 + A_{41}] \cdot S_v$	<b>= 182455</b> lbf
$W_{2-2}$	$= [A_2 + A_3 + A_{41} + A_{43} + 2 \cdot t_n \cdot f_{r1}] \cdot S_v$	<b>= 257937</b> lbf

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

Fillet shell /nozzle	$\pi/2 \cdot d_a \cdot \text{leg}_1 \cdot 0.49 \cdot \min(S_v; S_n)$	<b>= 92087</b> lbf
Fillet shell /nozzle	$\pi/2 \cdot d_a \cdot \text{leg}_3 \cdot 0.49 \cdot \min(S_v; S_n)$	<b>= 0</b> lbf
Groove shell /nozzle	$\pi/2 \cdot d_a \cdot \text{leg}_4 \cdot 0.74 \cdot \min(S_v; S_n)$	<b>= 0</b> lbf
Nozzle wall	$\pi/2 \cdot d_m \cdot t_n \cdot 0.70 \cdot S_n$	<b>= 653785</b> lbf

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

1-1	<b>92087</b> lbf	+	<b>653785</b> lbf	<b>= 745872</b> lbf
				<b>≥ 146484</b> lbf
2-2	<b>92087</b> lbf	+	<b>0</b> lbf	<b>= 92087</b> lbf
				<b>≥ 146484</b> lbf

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

$$b = \text{Max} \left\{ \frac{d}{2}, \frac{d}{t_n + t} \right\} = \text{Max} \left\{ \frac{d}{2}, \frac{d}{t_n + t} \right\} = 147.7 \text{ mm}$$

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

$$b = \text{Max} \left\{ \frac{3 \cdot d/2}{4}, \frac{d}{t_n + t} \right\}$$

App.1-7(a)(1)

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

App.1-7(a)(1)

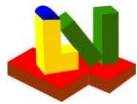
$$A = d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) =$$

Fig. UG-37.1

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

Available shell thickness with allowances  
Required shell thickness with allowances  
Required nozzle thickness with allowances

$t + C_{1s} + C_{2s}$	$t_s$	<b>1</b> in
$t_r + C_{1s} + C_{2s}$	$t_{sr}$	<b>0.8492</b> in
	$t_{m+}$	<b>0.2295</b> in



**Areas according to UG-40**

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

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

$$t_m = p_0 \cdot \frac{\frac{d}{20}}{(S_n - 0.06 \cdot p_0)} = 2.455 \text{ MPa} \cdot \frac{\frac{295.4 \text{ mm}}{20}}{(138 \text{ MPa} - 0.06 \cdot 2.455 \text{ MPa})} = 2.63 \text{ mm} \quad (\text{internal pressure})$$

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

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

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

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

$$A_{41} = (\text{leg}_1)^2 \cdot f_{r2} = (9.525 \text{ mm})^2 \cdot 1 = 90.73 \text{ mm}^2$$

$$A_{43} = (\text{leg}_3)^2 \cdot f_{r2} = (0 \text{ mm})^2 \cdot 1 = 0 \text{ mm}^2$$

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

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

$D_a$	$2337 \leq 1520 \text{ mm (60 in.)}$	$d_a$	$404.9 > \text{Min [$	$2337/2; 508 \text{ mm (20 in.)}]$
$D_a$	$2337 > 1520 \text{ mm (60 in.)}$	$d_a$	$404.9 > \text{Min [$	$2337/3; 1000 \text{ mm (40 in.)}]$

**Additional rules for cylindr. shells, App.1-7(b)**

not required

Total available area		$A_{avl}$	$\text{in}^2$
Inside radius of shell		$R$	$\text{in}$
Inside radius of nozzle		$R_n$	$\text{in}$
Mean radius of shell		$R_m$	$\text{in}$
Mean radius of nozzle		$R_{nm}$	$\text{in}$
Allowable stress value		$S$	$\text{psi}$
Distance e		$e$	$\text{in}$
Moment of inertia		$I$	$\text{in}^4$
Material area acc. to Fig.1-7-1		$A_s$	$\text{in}^2$
Support length nozzle	$\text{Min}[h_a; t_e + (R_{nm} \cdot t_n)^{0.5}]$	$l_{nm}$	$\text{in}$
Support length shell	$\text{Min}[b_a; (R_m \cdot t_e)^{0.5}]$	$l_m$	$\text{in}$





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

- (a)  $2 \cdot R = \text{ } > 1524 \text{ mm (60 in.)}$
- (b)  $2 \cdot R_n = \text{ } > 1016 \text{ mm (40 in.)}$  and  $2 \cdot R_n > 3.4 \cdot \sqrt{R \cdot t} = \text{ }$
- (c)  $\frac{R_n}{R} = \frac{\text{ }}{\text{ }} = \text{ } \leq 0.7$

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

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

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

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

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

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

$$S_m \leq S$$

**Bending stress  $S_b$  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: 2023

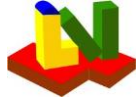
Set-on nozzle with reinforcement

##### 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)	$\Gamma$	Internal pressure

##### Shell

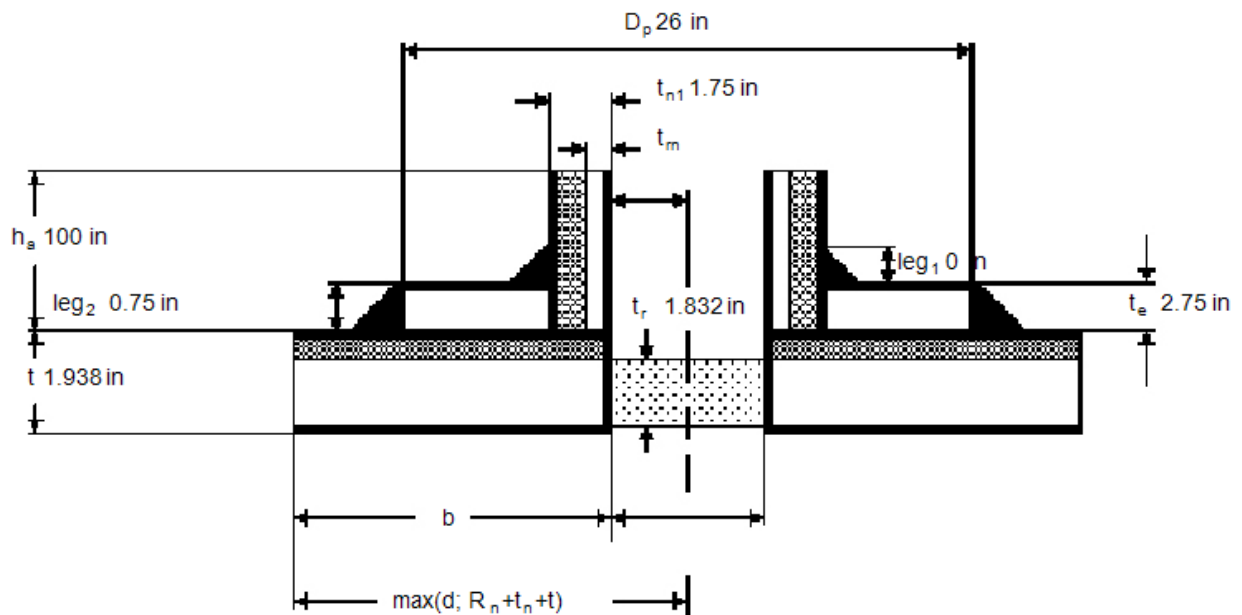
Shape of the shell	cylindrical	
Outside diameter	$D_a$	100 in
Nominal thickness without allowances	$t$	1.938 in
Available shell length for reinforcement	$b_a$	1000 in
Joint efficiency factor (or Cast Quality Factor)	$E_1$	1
Material K02700-SA-516-70-Class:-Size:		
Material strength	$K$	11400 psi
Safety 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



**ASME BPVC VIII-1 2023 / PTB-4-2021**  
E4.5.1; E4.5.2; E4.5.6; E4.5.3; E4.5.4; E4.5.5; E4.5.6

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	$K_n/S$	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 = $d_a - 2 \cdot t_2$	$d_{iN}$	16 in	
Inside diameter, corroded = $d_a - 2 \cdot t_n$	$d$	16.12 in	
External projection	$h_a$	100 in	
Angle between the shell axis and the sectional plane through the opening center	$\Theta$	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	$t_{b1}$	1.899 in	
with joint efficiency $E=1.0$			
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 ( $\leq t_n$ )	$leg_4$	0.812 in	
Groove reinforcement / nozzle ( $\leq t_e$ )	$leg_5$	0 in	

Calculation according to

UG-40

App.1-7



**ASME BPVC VIII-1 2023 / PTB-4-2021**  
E4.5.1; E4.5.2; E4.5.6; E4.5.3; E4.5.4; E4.5.5; E4.5.6

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	$t_m$	0.2863 in	0.2863 in
Projected Area	A	29.55 in <sup>2</sup>	in <sup>2</sup>
Area of shell reserve	$A_1$	1.695 in <sup>2</sup>	in <sup>2</sup>
Area of reinforcement ( $A_2$ to $A_5$ )	$A_v$	32.01 in <sup>2</sup>	in <sup>2</sup>
Total available area $\Sigma A$	$\Sigma A$	33.71 in <sup>2</sup>	in <sup>2</sup>
Required area $A/\Gamma$	A/H	29.55 in <sup>2</sup>	in <sup>2</sup>
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	$\pi/2 \cdot d_a \cdot \text{leg}_1 \cdot 0.49 \cdot \min(S_p; S_n)$	0 lbf
Reinf./shell	$\pi/2 \cdot D_p \cdot \text{leg}_2 \cdot 0.49 \cdot \min(S_p; S_v)$	171104 lbf

**Groove weld**

Shell /Nozzle	$\pi/2 \cdot d_a \cdot \text{leg}_4 \cdot 0.60 \cdot \min(S_v; S_n)$	155404 lbf
Reinf./nozzle	$\pi/2 \cdot d_a \cdot \text{leg}_5 \cdot 0.74 \cdot \min(S_p; S_n)$	0 lbf

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

1-1	171104 lbf	+	155404 lbf	=	326509 lbf
				$\geq$	317524 lbf
2-2	0 lbf	+	0 lbf	+	155404 lbf
				$\geq$	154743 lbf

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

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

$$b = \text{Max} \left\{ \frac{d}{2}, \frac{d}{t_n + t} \right\} = \text{Max} \left\{ \frac{d}{2}, \frac{d}{t_n + t} \right\} = 204.8 \text{ mm}$$

App.1-7(a)(1)

$$b = \text{Max} \left\{ \frac{3 \cdot d/2}{4}, \frac{d}{t_n + t} \right\}$$

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		$t_{m+}$	0.3544 in



**Areas according to UG-40**

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

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

(internal pressure)

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

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

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

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

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

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

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

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

$D_a$	$2540 \leq 1520 \text{ mm (60 in.)}$	$d_a$	$495.3 > \text{Min [$	$2540/2; 508 \text{ mm (20 in.)}]$
$D_a$	$2540 > 1520 \text{ mm (60 in.)}$	$d_a$	$495.3 > \text{Min [$	$2540/3; 1000 \text{ mm (40 in.)}]$

**Large cylinder opening acc. Appendix 1-7(b)**

not required

Total available area		$A_{avl}$	in <sup>2</sup>
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 <sup>4</sup>
Material area acc. to Fig.1-7-1		$A_s$	in <sup>2</sup>
Support length nozzle	$\text{Min}[h_a; t_e + (R_{nm} \cdot t_n)^{0.5}]$	$l_{nm}$	in
Support length shell	$\text{Min}[b_a; (R_m \cdot t_e)^{0.5}]$	$l_m$	in

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

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

(b)  $2 \cdot R_n = > 1016 \text{ mm (40 in.) and}$

$$2 \cdot R_n > 3.4 \cdot \sqrt{R \cdot t}$$

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



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

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

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

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

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

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

$$S_m \leq S$$

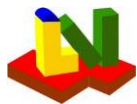
**Bending stress  $S_b$  acc. to App. 1-7(b)(2)**

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

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

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

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



### E.4.5.5 - Set-on nozzles with reinforcement - ASME BPVC VIII-1 UG-37: 2023

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)	$\Gamma$	Internal pressure

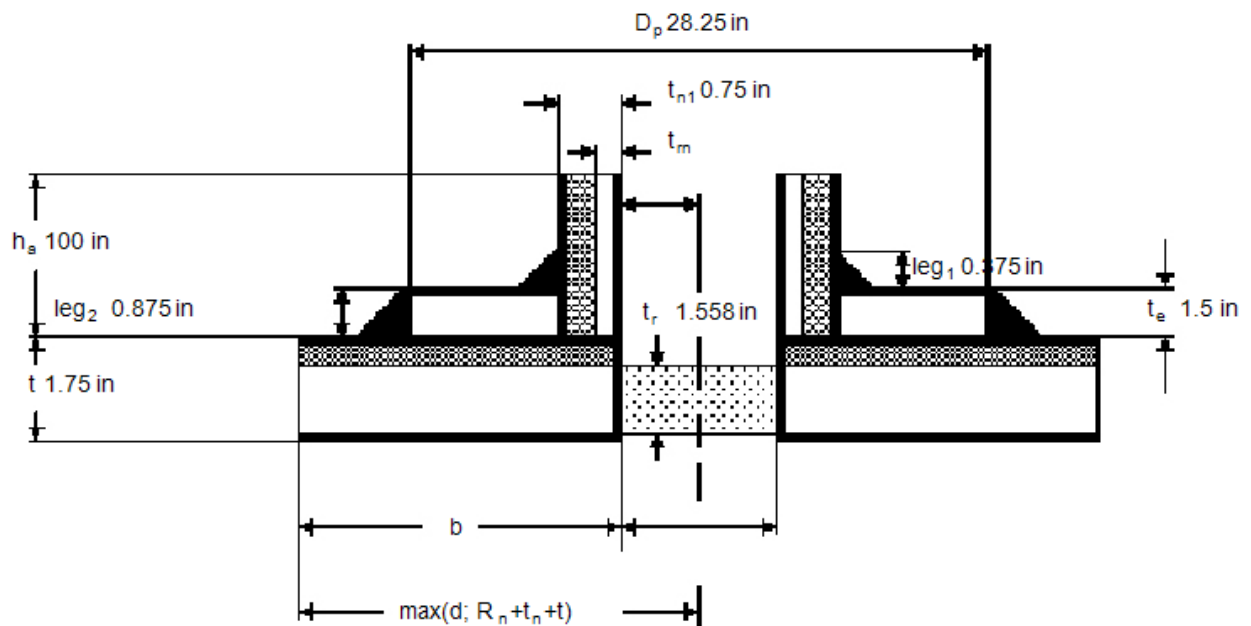
#### Shell

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



		NEIN	
Access opening			
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	$K_n/S$		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 = $d_a - 2 \cdot t_2$	$d_{iN}$		14.5 in
Inside diameter, corroded = $d_a - 2 \cdot t_n$	$d$		15 in
External projection	$h_a$		100 in
Angle between the shell axis and the sectional plane through the opening center	$\Theta$		0 °
Nominal thickness without allowances	$t_n$		0.5 in
Required nozzle neck thickness per UG-27	$t_a$		0.5299 in
Required shell wall thickness where the nozzle neck attaches to the vessel	$t_{b1}$		in
with joint efficiency $E=1.0$			
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

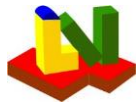
Reinforcing element		
Thickness	$t_e$	1.5 in
Outside diameter	$D_p$	28.25 in
Material		
Material strength	$K_p$	psi
Safety factor	$S$	
Allowable stress	$S_p$	1987009 psi
Fillet nozzle/ reinforcement outside	$leg_1$	0.375 in
Fillet of reinforcement / shell outside	$leg_2$	0.875 in
Groove nozzle / shell ( $\leq t_n$ )	$leg_4$	0.5 in
Groove reinforcement / nozzle ( $\leq t_e$ )	$leg_5$	0.5 in

### Calculation according to

## UG-40

**App.1-7**





# ASME BPVC VIII-1 2023 / PTB-4-2021

## E4.5.1; E4.5.2; E4.5.6; E4.5.3; E4.5.4; E4.5.5; E4.5.6

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
Limit length of nozzle outside, UG40(c)	$h'_a$	2.75	in
Minimum required thickness of nozzle	$t_m$	0.2743	in
Projected Area	A	23.37	in <sup>2</sup>
Area of shell reserve	$A_1$	2.883	in <sup>2</sup>
Area of reinforcement ( $A_2$ to $A_5$ )	$A_v$	20.52	in <sup>2</sup>
Total available area $\Sigma A$	$\Sigma A$	23.41	in <sup>2</sup>
Required area $A/\Gamma$	A/H	23.37	in <sup>2</sup>
Utilization	$(A_{req}/A_{avl})$	99.84	%
Allowable pressure			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	$\pi/2 \cdot d_a \cdot \text{leg}_1 \cdot 0.49 \cdot \min(S_p; S_n)$	63269	lbf
Reinf./shell	$\pi/2 \cdot D_p \cdot \text{leg}_2 \cdot 0.49 \cdot \min(S_p; S_v)$	260657	lbf

### Groove weld

Shell /Nozzle	$\pi/2 \cdot d_a \cdot \text{leg}_4 \cdot 0.60 \cdot \min(S_v; S_n)$	100069	lbf
Reinf./nozzle	$\pi/2 \cdot d_a \cdot \text{leg}_5 \cdot 0.74 \cdot \min(S_p; S_n)$	127400	lbf

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

1-1	260657	lbf	+	100069	lbf	=	360726	lbf
						$\geq$	280634	lbf
2-2	127400	lbf	+	63269	lbf	+	100069	lbf
						$\geq$	290738	lbf
							18932	lbf

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

$$b = \text{Max} \left\{ \frac{d}{2} = \text{Max} \left\{ \frac{d}{2} = 190.5 \text{ mm} \right. \right.$$

$$\left. \frac{t_n + t}{t_n + t} \right\}$$

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

$$b = \text{Max} \left\{ \frac{3 \cdot d/2}{4} \right.$$

$$\left. \frac{t_n + t}{t_n + t} \right\}$$

App.1-7(a)(1)

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

App.1-7(a)(1)

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

Fig. UG-37.1

Available shell thickness with allowances	$t + C_{1s} + C_{2s}$	$t_s$	2	in
Required shell thickness with allowances	$t_r + C_{1s} + C_{2s}$	$t_{sr}$	1.808	in
Required nozzle thickness with allowances		$t_{m+}$	0.5299	in



**Areas according to UG-40**

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

(internal pressure)

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

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

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

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

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

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

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

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

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

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

$D_a$	$2210 \leq 1520 \text{ mm (60in.)}$	$d_a$	$406.4 > \text{Min [$	$2210/2; 508 \text{ mm (20in.)}]$
$D_a$	$2210 > 1520 \text{ mm (60in.)}$	$d_a$	$406.4 > \text{Min [$	$2210/3; 1000 \text{ mm (40in.)}]$

**Large cylinder opening acc. Appendix 1-7(b)**

not required

Total available area		$A_{avl}$	in <sup>2</sup>
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 <sup>4</sup>
Material area acc. to Fig.1-7-1		$A_s$	in <sup>2</sup>
Support length nozzle	$\text{Min}[h_a; t_e + (R_{nm} \cdot t_n)^{0.5}]$	$l_{nm}$	in
Support length shell	$\text{Min}[b_a; (R_m \cdot t_e)^{0.5}]$	$l_m$	in



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

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

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

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

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

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

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

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

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

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

$$S_m \leq S$$

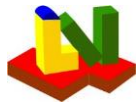
**Bending stress  $S_b$  acc. to App. 1-7(b)(2)**

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

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

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

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



### E 4.5.6 - Protruding nozzles without reinforcement - ASME BPVC VIII-1 UG-37: 2023

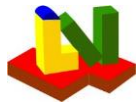
Protruding nozzle without reinforcement

**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)	$\Gamma$	Internal pressure

**Shell**

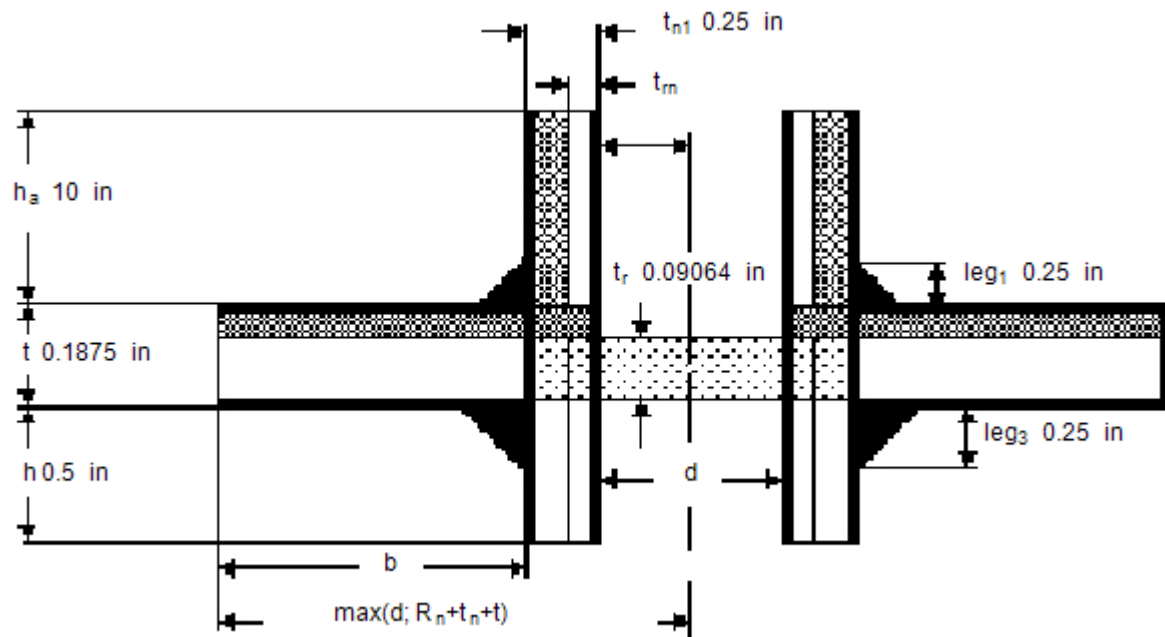
Shape of the shell	spherical	
Outside diameter	D <sub>a</sub>	24 in
Nominal thickness without allowances	t	0.1875 in
Available shell length for reinforcement	b <sub>a</sub>	200 in
Joint efficiency factor (or Cast Quality Factor)	E <sub>1</sub>	1
Material	S31651-SA-376-TP316N-Class:-Size:	
Material strength	K	17604 psi
Safety factor	S	1
Allowable stress value	S <sub>v</sub>	17604 psi
Wall thickness allowance	c <sub>1s</sub>	0 in
Corrosion allowance	c <sub>2s</sub>	0 in
Required thickness without allowances	t <sub>r</sub>	0.09064 in



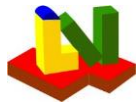
**Nozzle**

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	$K_n/S$	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 = $d_a - 2 \cdot t_2$	$d_{iN}$	8.125 in
Inside diameter, corroded = $d_a - 2 \cdot t_n$	$d$	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	$\Theta$	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	$t_{b1}$	0.1019 in
with joint efficiency $E=1.0$		
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 ( $\leq t$ )	$leg_4$	0 in



**Calculation according to**

Correction factor (Fig.UG-37, int. pres.)  
Reserve of shell  
Limit length of vessel acc. to UG-40(b)  
Limit length of nozzle outside, UG40(c)  
Limit length of nozzle inside, Fig.UG37  
Minimum required thickness of nozzle  
Required area for internal pressure  
Area of shell reserve  
Area of reinforcement ( $A_2$  to  $A_5$ )  
Total available area  $\Sigma A$   
Required area  $A/\Gamma$   
Utilization  
Allowable pressure

	UG-40	App.1-7
$F$	<b>1</b>	
$(E_1 \cdot t - F \cdot t_r)$	<b>0.09686</b> in	
$b$	<b>4.063</b> in	in
$h'_a$	<b>0.4688</b> in	<b>0.4688</b> in
$h'$	<b>0.4688</b> in	0
$t_m$	<b>0.05033</b> in	<b>0.05033</b> in
$A$	<b>0.7506</b> in <sup>2</sup>	in <sup>2</sup>
$A_1$	<b>0.7719</b> in <sup>2</sup>	in <sup>2</sup>
$A_v$	<b>0.3762</b> in <sup>2</sup>	in <sup>2</sup>
$A_{avl}$	<b>1.148</b> in <sup>2</sup>	in <sup>2</sup>
$A_{req}$	<b>0.7506</b> in <sup>2</sup>	in <sup>2</sup>
$(A_{req}/A_{avl})$	<b>65.38</b> %	%
	<b>185.5</b> psi	psi

**Weld loads according to UG-41**

$W$	$= [A - A_1 + 2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)] \cdot S_v$	$=$	<b>211.6</b> lbf
$W_{1-1}$	$= [A_2 + A_{41}] \cdot S_v$	$=$	<b>3025</b> lbf
$W_{2-2}$	$= [A_2 + A_3 + A_{41} + A_{43} + 2 \cdot t_n \cdot f_{r1}] \cdot S_v$	$=$	<b>7758</b> lbf

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

Fillet shell /nozzle	$\pi/2 \cdot d_a \cdot \text{leg}_1 \cdot 0.49 \cdot \min(S_v; S_n)$	$=$	<b>20109</b> lbf
Fillet shell /nozzle	$\pi/2 \cdot d_a \cdot \text{leg}_3 \cdot 0.49 \cdot \min(S_v; S_n)$	$=$	<b>20109</b> lbf
Groove shell /nozzle	$\pi/2 \cdot d_a \cdot \text{leg}_4 \cdot 0.74 \cdot \min(S_v; S_n)$	$=$	<b>0</b> lbf
Nozzle wall	$\pi/2 \cdot d_m \cdot t_n \cdot 0.70 \cdot S_n$	$=$	<b>27894</b> lbf

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

1-1	<b>20109</b> lbf	+	<b>27894</b> lbf	$=$	<b>48003</b> lbf
				$\geq$	<b>211.6</b> lbf
2-2	<b>20109</b> lbf	+	<b>0</b> lbf	$=$	<b>40217</b> lbf
				$\geq$	<b>211.6</b> lbf

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

$$b = \text{Max} \left\{ \frac{d}{2}, \frac{d}{t_n + t} \right\} = \text{Max} \left\{ \frac{d}{2}, \frac{d}{t_n + t} \right\} = 103.2 \text{ mm}$$

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

$$b = \text{Max} \left\{ \frac{3 \cdot d/2}{4}, \frac{d}{t_n + t} \right\}$$

App.1-7(a)(1)

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

App.1-7(a)(1)

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

Fig. UG-37.1

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

Available shell thickness with allowances  
Required shell thickness with allowances  
Required nozzle thickness with allowances

$t_{s+C1s+C2s}$	$t_s$	<b>0.1875</b> in
$t_{r+C1s+C2s}$	$t_{sr}$	<b>0.09064</b> in
	$t_{m+}$	<b>0.05067</b> in



**Areas according to UG-40**

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

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

(internal pressure)

$$t_m = p_0 \cdot \frac{\frac{d}{20}}{(S_n - 0.06 \cdot p_0)} = \frac{1.034 \text{ MPa} \cdot \frac{206.4 \text{ mm}}{20}}{(83.54 \text{ MPa} - 0.06 \cdot 1.034 \text{ MPa})} = 1.278 \text{ mm}$$

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

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

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

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

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

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

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

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

$D_a$	$609.6 \leq 1520 \text{ mm (60 in.)}$	$d_a$	$219.1 > \text{Min [$	$609.6/2; 508 \text{ mm (20 in.)}]$
$D_a$	$609.6 > 1520 \text{ mm (60 in.)}$	$d_a$	$219.1 > \text{Min [$	$609.6/3; 1000 \text{ mm (40 in.)}]$

**Additional rules for cylindr. shells, App.1-7(b)**

not required

Total available area		$A_{avl}$	$\text{in}^2$
Inside radius of shell		$R$	$\text{in}$
Inside radius of nozzle		$R_n$	$\text{in}$
Mean radius of shell		$R_m$	$\text{in}$
Mean radius of nozzle		$R_{nm}$	$\text{in}$
Allowable stress value		$S$	$\text{psi}$
Distance e		$e$	$\text{in}$
Moment of inertia		$I$	$\text{in}^4$
Material area acc. to Fig.1-7-1		$A_s$	$\text{in}^2$
Support length nozzle	$\text{Min}[h_a; t_e + (R_{nm} \cdot t_n)^{0.5}]$	$l_{nm}$	$\text{in}$
Support length shell	$\text{Min}[b_a; (R_m \cdot t_e)^{0.5}]$	$l_m$	$\text{in}$



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

- (a)  $2 \cdot R = \text{[redacted]} > 1524 \text{ mm (60 in.)}$
- (b)  $2 \cdot R_n = \text{[redacted]} > 1016 \text{ mm (40 in.)}$  and  $2 \cdot R_n > 3.4 \cdot \sqrt{R \cdot t} = \text{[redacted]}$
- (c)  $\frac{R_n}{R} = \frac{\text{[redacted]}}{\text{[redacted]}} = \text{[redacted]} \leq 0.7$

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

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

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

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

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

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

$$S_m \leq S$$

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

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

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

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

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