

ASME BPVC VIII-1 2023

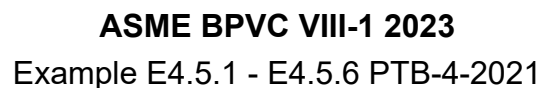
Example E4.5.1 - E4.5.6 PTB-4-2021

Table of contents

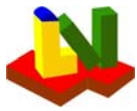
Table of contents	1
Summary.....	2
Thickness of cylindrical shells under internal pressure - ASME BPVC VIII-1 UG-27 & Appendix-1: 2023	3
E 4.5.1 - Protruding nozzles without reinforcement - ASME BPVC VIII-1 UG-37: 2023	5
E 4.5.2 Step5 F=1 - Protruding nozzles without reinforcement - ASME BPVC VIII-1 UG-37: 2023	10
E 4.5.3 - Protruding nozzles without reinforcement - ASME BPVC VIII-1 UG-37: 2023	15
Elliptical heads under internal pressure - ASME BPVC VIII-1 UG-32 & Appendix-1: 2023	20
E4.5.5 - Set-on nozzles with reinforcement - ASME BPVC VIII-1 UG-37: 2023	22
E.4.5.4 - Set-on nozzles with reinforcement - ASME BPVC VIII-1 UG-37: 2023	27
E.4.5.6 - Protruding nozzles without reinforcement - ASME BPVC VIII-1 UG-37: 2023	32

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



Strength Calculation Software		Program System ATLAS			Version	10.0.107
Developed by Lauterbach Verfahrenstechnik GmbH						
Certified per DIN EN ISO 9001:2008		Certificate Number 01100 044763				
		LV Soft			ASME	Diff [%]
Example E4.5.1 - Radial Nozzle in Cylindrical Shell						
	Required area A	14159,79	mm ²	21,95 in ²	21,97 in ²	0,08%
	Available area A1	3531,71	mm ²	5,47 in ²	5,46 in ²	0,32%
	Available area Aavl	28003,63	mm ²	43,41 in ²	43,39 in ²	0,04%
Example E4.5.2 - Hillside Nozzle in Cylindrical Shell						
	Required area A	6863,13	mm ²	10,64 in ²	10,64 in ²	0,00%
	Available area A1	1704,99	mm ²	2,64 in ²	2,64 in ²	0,00%
	Available area Aavl	11453,94	mm ²	17,75 in ²	17,75 in ²	0,00%
Example E4.5.3 - Radial Nozzle in Cylindrical Shell						
	Required area A	5429,32	mm ²	8,42 in ²	8,42 in ²	0,08%
	Available area A1	1135,99	mm ²	1,76 in ²	1,75 in ²	0,40%
	Available area Aavl	7014,28	mm ²	10,87 in ²	10,86 in ²	0,07%
Example E4.5.4 - Radial Nozzle in Cylindrical Shell						
	Required area A	19037,86	mm ²	29,51 in ²	29,55 in ²	0,15%
	Available area A1	1118,35	mm ²	1,73 in ²	1,69 in ²	2,69%
	Available area Aavl	21735,78	mm ²	33,69 in ²	33,65 in ²	0,13%
Example E4.5.5 - Radial Nozzle in Cylindrical Shell						
	Required area A	15075,45	mm ²	23,37 in ²	23,37 in ²	0,00%
	Available area A1	1860,00	mm ²	2,88 in ²	2,88 in ²	0,00%
	Available area Aavl	15080,66	mm ²	23,38 in ²	23,37 in ²	0,00%
Example E4.5.6 - Radial Nozzle in Cylindrical Shell						
	Required area A	487,24	mm ²	0,76 in ²	0,76 in ²	0,01%
	Available area A1	495,11	mm ²	0,77 in ²	0,77 in ²	0,02%
	Available area Aavl	737,66	mm ²	1,14 in ²	1,14 in ²	0,16%

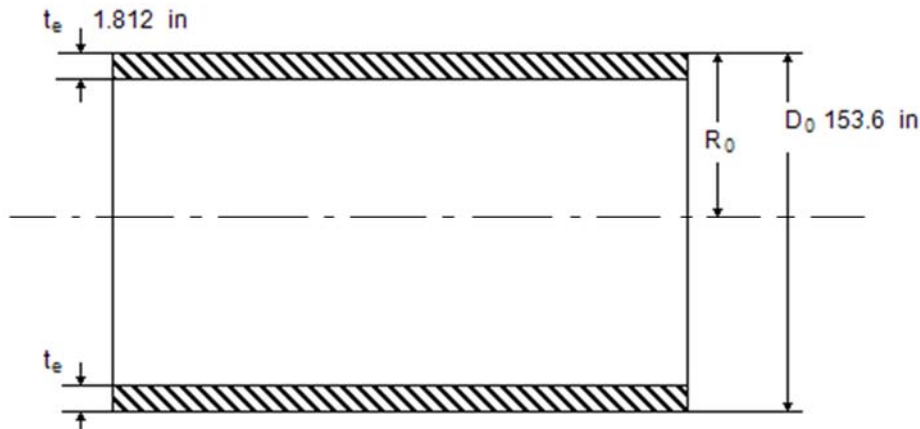


ASME BPVC VIII-1 2023
Example E4.5.1 - E4.5.6 PTB-4-2021

Thickness of cylindrical shells under internal pressure - ASME BPVC VIII-1 UG-27 & Appendix-1: 2023

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

Required thickness	$t(R_0)$	Yes $t(R)$
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
$t = \text{Max}\{\text{Min}[t_R; t_{R0}], t_{UG-16}\}$		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

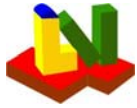
Remark

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

$d \leq 89 \text{ mm}$ for $t \leq 10 \text{ mm}$	or	$d \leq 3 \frac{1}{2} \text{ in}$ for $t \leq \frac{3}{8} \text{ in}$
$d \leq 60 \text{ mm}$ for $t > 10 \text{ mm}$	or	$d \leq 2 \frac{3}{8} \text{ in}$ for $t > \frac{3}{8} \text{ in}$



ASME BPVC VIII-1 2023

Example E4.5.1 - E4.5.6 PTB-4-2021

Equations

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

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

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

1) Thin shell For $P_0 \leq 0.385 \cdot S \cdot E \Leftrightarrow 24.55 \text{ bar} \leq 53.13 \text{ N/mm}^2$

and
with the inside radius R

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

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

UG-27 (1)

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

UG-27 (1)

or with the outside radius R_0

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

App. 1-1 (1)

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

App. 1-1 (1)

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

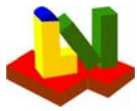
Longitudinal Stress (Circumferential Joints)

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

UG-27 (2)

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

UG-27 (2)



ASME BPVC VIII-1 2023 **Example E4.5.1 - E4.5.6 PTB-4-2021**

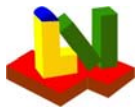
E 4.5.1 - Protruding nozzles without reinforcement - ASME BPVC VIII-1 UG-37: 2023

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 <i>K02700-SA-516-70-Class:-Size:</i>		
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



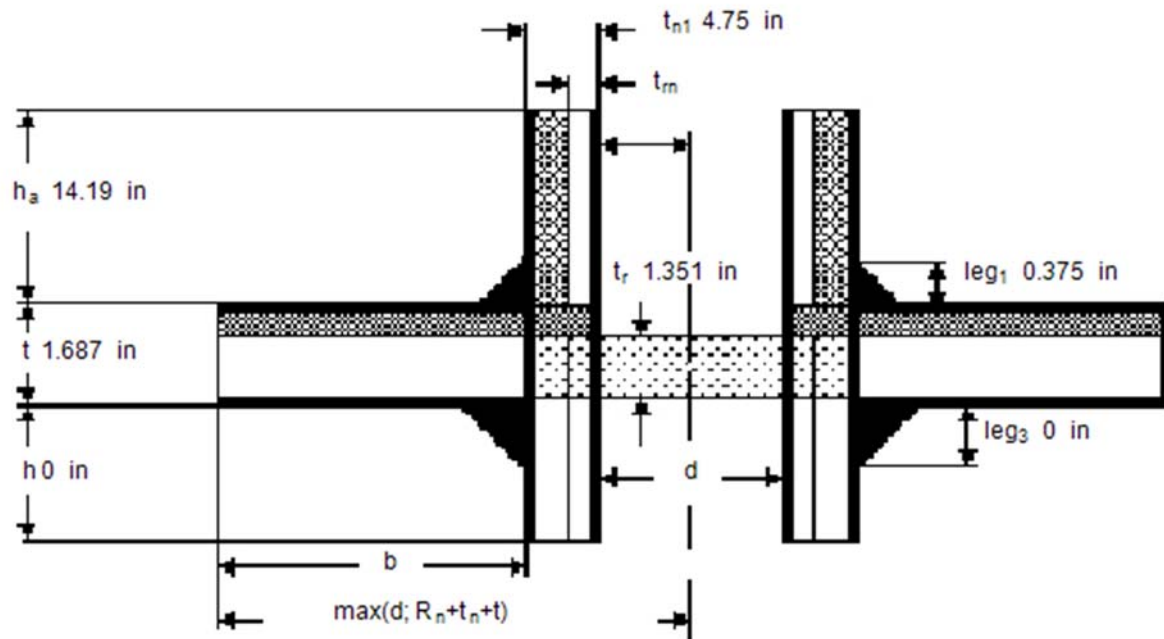
ASME BPVC VIII-1 2023

Example E4.5.1 - E4.5.6 PTB-4-2021

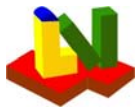
Nozzle

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	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	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	t_{b1}	1.476 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



ASME BPVC VIII-1 2023

Example E4.5.1 - E4.5.6 PTB-4-2021

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 ΣA
 Required area A/Γ
 Utilization
 Allowable pressure (approx.: p_D /utilization)

	UG-40	App.1-7
F	1	
$(E_1 \cdot t - F \cdot t_r)$	0.3369 in	
b	8.125 in	in
h'_a	4.219 in	4.219 in
h'_i	0 mm	0
t_{rn}	0.1461 in	0.1461 in
A	21.95 in ²	in ²
A_1	5.474 in ²	in ²
A_v	37.93 in ²	in ²
A_{avl}	43.41 in ²	in ²
A_{req}	21.95 in ²	in ²
A_{req}/A_{avl}	50.56 %	%
	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}	$= [A_2 + A_3 + A_{41} + A_{43} + 2 \cdot t_n \cdot f_{r1}] \cdot S_v$	$= 1071638$ lbf

Strength of nozzle wall, fillet and groove welds

Fillet shell /nozzle	$\pi/2 \cdot d_a \cdot \text{leg}_1 \cdot 0.49 \cdot \min(S_v; S_n)$	$= 147316$ 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	$\pi/2 \cdot d_m \cdot t_n \cdot 0.70 \cdot S_n$	$= 2124806$ 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

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

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)

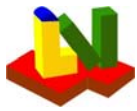
$$A = d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) =$$

Fig. UG-37.1

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

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

$t + C_{1s} + C_{2s}$	t_s	1.812 in
$t_r + C_{1s} + C_{2s}$	t_{sr}	1.476 in
	t_{m+}	0.2711 in



ASME BPVC VIII-1 2023

Example E4.5.1 - E4.5.6 PTB-4-2021

Areas according to UG-40

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

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

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

(internal pressure)

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

$$\text{Max} \left\{ \begin{array}{l} 412.8 \text{ mm} \cdot 8.557 \text{ mm} - 2 \cdot 117.5 \text{ mm} \cdot 8.557 \text{ mm} \cdot (1 - 1) \\ 2 \cdot (42.86 \text{ mm} + 117.5 \text{ mm}) \cdot 8.557 \text{ mm} - 2 \cdot 117.5 \text{ mm} \cdot 8.557 \text{ mm} \cdot (1 - 1) \end{array} \right. = 3532 \text{ mm}^2$$

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

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

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

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

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

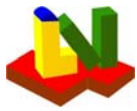
App.1-7 is additionally required acc. to UG-36(b) if

D_a	$3902 \leq 1520 \text{ mm (60in.)}$	d_a	$647.7 > \text{Min [$	$3902/2; 508 \text{ mm (20in.)}]$
D_a	$3902 > 1520 \text{ mm (60in.)}$	d_a	$647.7 > \text{Min [$	$3902/3; 1000 \text{ mm (40in.)}]$

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

not required

Total available area		A_{avl}	in^2
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	in^2
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



ASME BPVC VIII-1 2023

Example E4.5.1 - E4.5.6 PTB-4-2021

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)

$$S_m \leq S$$

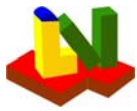
Bending stress S_b acc. to App. 1-7(b)(2)

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

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

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

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



ASME BPVC VIII-1 2023

Example E4.5.1 - E4.5.6 PTB-4-2021

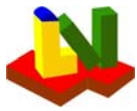
E 4.5.2 Step5 F=1 - Protruding nozzles without reinforcement - ASME BPVC VIII-1 UG-37: 2023

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	<i>K02700-SA-516-70-Class:-Size:</i>	
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



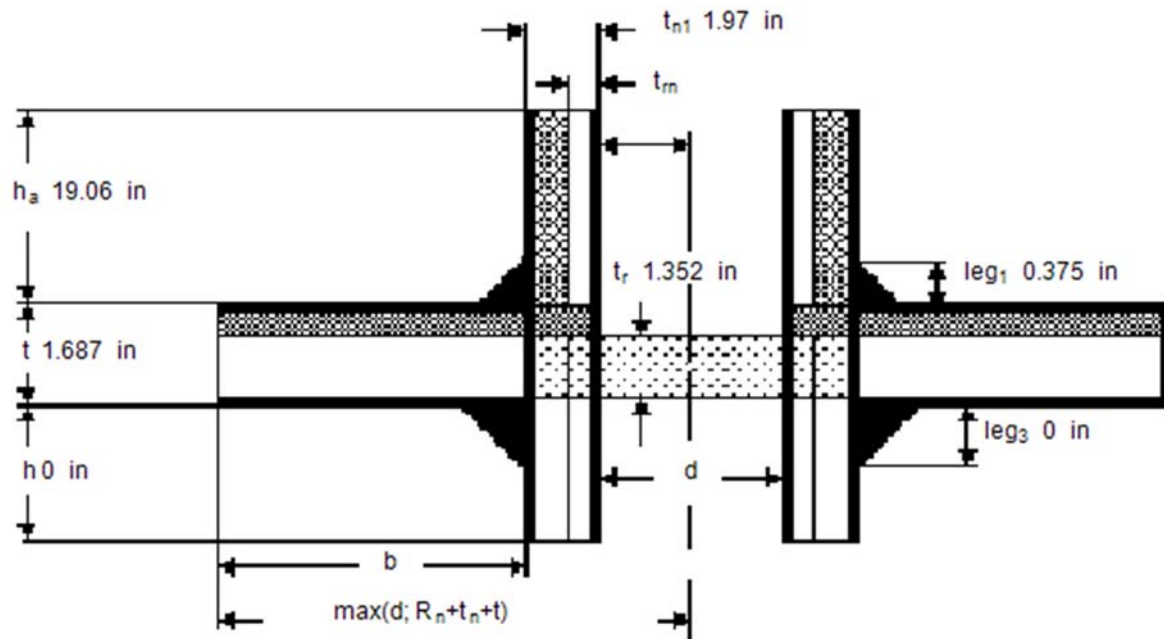
ASME BPVC VIII-1 2023

Example E4.5.1 - E4.5.6 PTB-4-2021

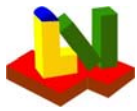
Nozzle

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	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	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	t_{b1}	1.475 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	



ASME BPVC VIII-1 2023

Example E4.5.1 - E4.5.6 PTB-4-2021

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/Γ
 Utilization
 Allowable pressure (approx.: p_D /utilization)

	UG-40	1	App.1-7
F			
$(E_1 \cdot t - F \cdot t_r)$		0.3358 in	
b		3.935 in	
h'_a		4.219 in	4.219 in
h'_i		0 mm	0
t_{rn}		0.07075 in	0.07075 in
A		10.64 in ²	
A_1		2.643 in ²	
A_v		15.11 in ²	
A_{avl}		17.75 in ²	
A_{req}		10.64 in ²	
A_{req}/A_{avl}		59.92 %	%
		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}	$= [A_2 + A_3 + A_{41} + A_{43} + 2 \cdot t_n \cdot f_{r1}] \cdot S_v$	$=$	427082 lbf

Strength of nozzle wall, fillet and groove welds

Fillet shell /nozzle	$\pi/2 \cdot d_a \cdot \text{leg}_1 \cdot 0.49 \cdot \min(S_v, S_n)$	$=$	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
				\geq	184826 lbf
2-2	66783 lbf	+	0 lbf	$=$	66783 lbf
				\geq	184826 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)

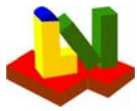
$$A = d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) =$$

Fig. UG-37.1

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

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

$t + C_{1s} + C_{2s}$	t_s	1.812 in
$t_r + C_{1s} + C_{2s}$	t_{sr}	1.477 in
	t_{m+}	0.1957 in



ASME BPVC VIII-1 2023

Example E4.5.1 - E4.5.6 PTB-4-2021

Areas according to UG-40

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

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

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

(internal pressure)

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

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

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

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

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

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

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

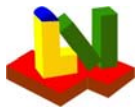
App.1-7 is additionally required acc. to UG-36(b) if

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

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

not required

Total available area		A_{avl}	in^2
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	in^2
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



ASME BPVC VIII-1 2023

Example E4.5.1 - E4.5.6 PTB-4-2021

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)

$$S_m \leq S$$

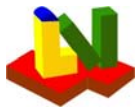
Bending stress S_b acc. to App. 1-7(b)(2)

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

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

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

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



ASME BPVC VIII-1 2023 **Example E4.5.1 - E4.5.6 PTB-4-2021**

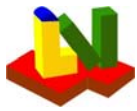
E 4.5.3 - Protruding nozzles without reinforcement - ASME BPVC VIII-1 UG-37: 2023

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	<i>K02700-SA-516-70-Class:-Size:</i>	
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



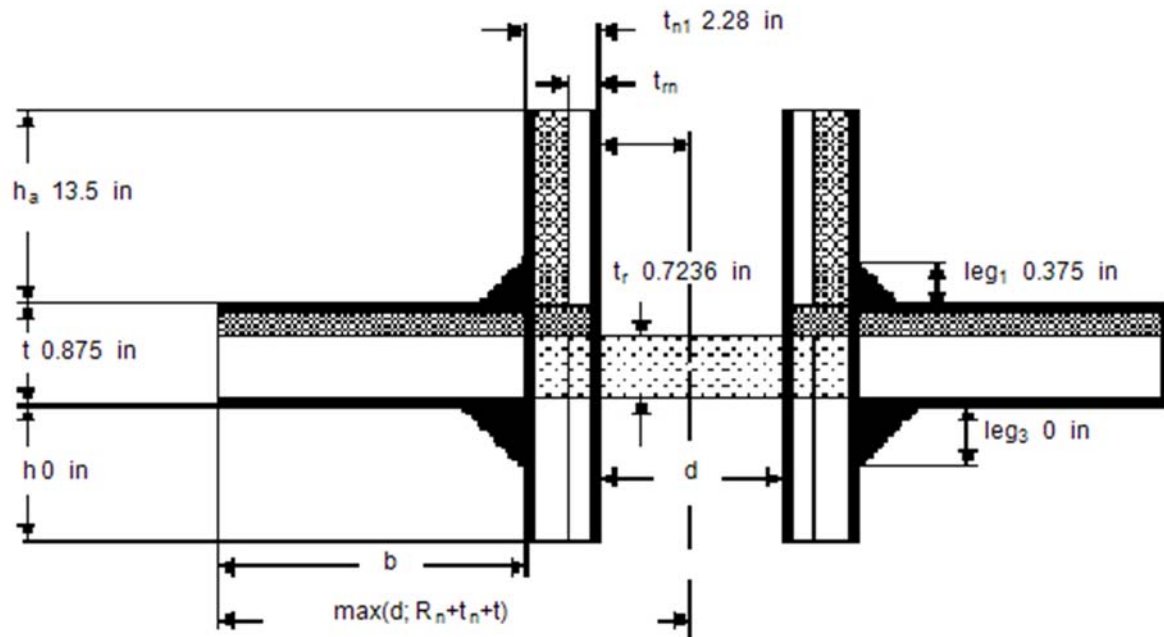
ASME BPVC VIII-1 2023

Example E4.5.1 - E4.5.6 PTB-4-2021

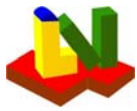
Nozzle

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	20015 psi
Nominal thickness with allowances	t_n	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	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	t_{b1}	0.527 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



ASME BPVC VIII-1 2023

Example E4.5.1 - E4.5.6 PTB-4-2021

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 ΣA
 Required area A/Γ
 Utilization
 Allowable pressure (approx.: p_D /utilization)

	UG-40	App.1-7
F	1	
$(E_1 \cdot t - F \cdot t_r)$	0.1514 in	
b	5.815 in	in
h'_a	2.188 in	2.188 in
h'_i	0 mm	0
t_{rn}	0.1045 in	0.1045 in
A	8.415 in ²	in ²
A_1	1.761 in ²	in ²
A_v	9.111 in ²	in ²
A_{avl}	10.87 in ²	in ²
A_{req}	8.415 in ²	in ²
A_{req}/A_{avl}	77.4 %	%
	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}	$= [A_2 + A_3 + A_{41} + A_{43} + 2 \cdot t_n \cdot f_{r1}] \cdot S_v$	$= 257849$ lbf

Strength of nozzle wall, fillet and groove welds

Fillet shell /nozzle	$\pi/2 \cdot d_a \cdot \text{leg}_1 \cdot 0.49 \cdot \min(S_v; S_n)$	$= 92087$ 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	$\pi/2 \cdot d_m \cdot t_n \cdot 0.70 \cdot S_n$	$= 653785$ 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
					≥ 146256 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)

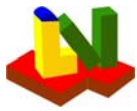
$$A = d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) =$$

Fig. UG-37.1

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

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

$t + C_{1s} + C_{2s}$	t_s	1 in
$t_r + C_{1s} + C_{2s}$	t_{sr}	0.8486 in
	t_{m+}	0.2295 in



ASME BPVC VIII-1 2023

Example E4.5.1 - E4.5.6 PTB-4-2021

Areas according to UG-40

$$h'_a = \text{Min} \left\{ \begin{array}{l} 2.5 \cdot t \\ 2.5 \cdot t_n \\ h_a \end{array} \right\} = \text{Min} \left\{ \begin{array}{l} 2.5 \cdot t \\ 2.5 \cdot t_n \\ h_a \end{array} \right\} = 55.56 \text{ mm}$$

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

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

(internal pressure)

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

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

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

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

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

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

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

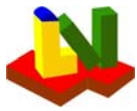
App.1-7 is additionally required acc. to UG-36(b) if

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

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

not required

Total available area		A_{avl}	in^2
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	in^2
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



ASME BPVC VIII-1 2023

Example E4.5.1 - E4.5.6 PTB-4-2021

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)

$$S_m \leq S$$

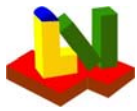
Bending stress S_b acc. to App. 1-7(b)(2)

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

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

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

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



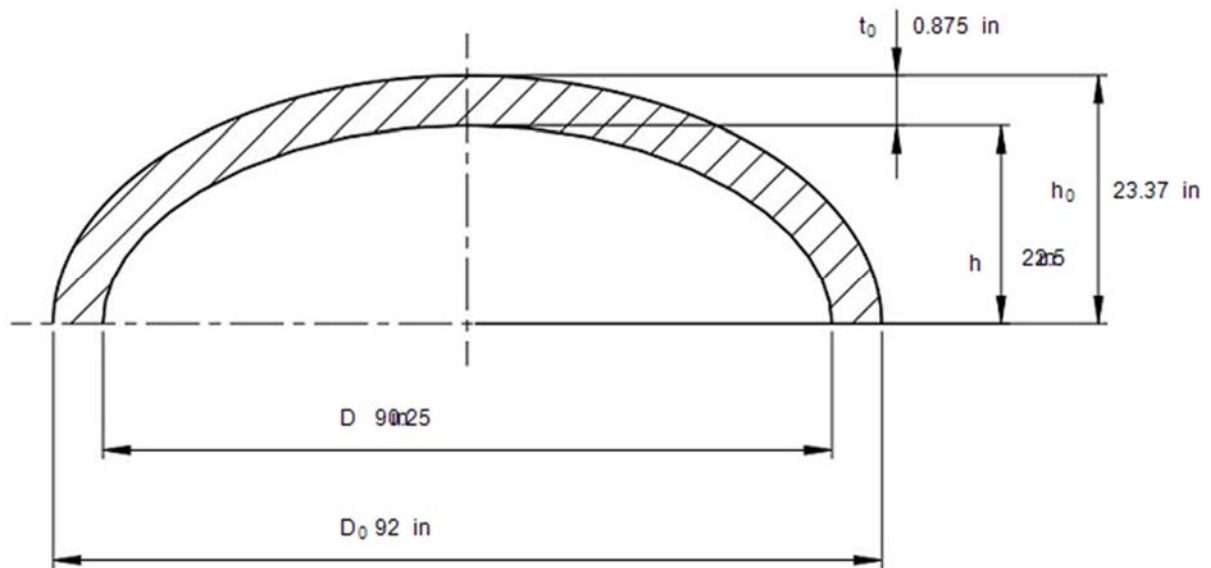
ASME BPVC VIII-1 2023

Example E4.5.1 - E4.5.6 PTB-4-2021

Elliptical heads under internal pressure - ASME BPVC VIII-1 UG-32 & Appendix-1: 2023

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



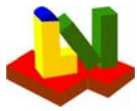
Outside diameter of cylindrical shell	D_0	92 in
Inside diameter of cylindrical shell (= $D_0 - 2t_0$)	D	90.25 in
Outer height of head	h_0	23.37 in
Inside depth of head (minor semi-axis = $h_0 - t_0$)	h	22.5 in
Weld joint efficiency (or Cast Quality Factor)	E	1

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 K_1 acc. Table UG-37	K_1	0.9
Required thickness	t	0.804 in
incl. allowances (t_e 1 in $\geq t$)	t_+	0.929 in
Allowable excess pressure incl. hydrostatic Head	P	387.4 psi
Allowable excess pressure without hydrostatic Head	MAWP	387.4 psi



ASME BPVC VIII-1 2023

Example E4.5.1 - E4.5.6 PTB-4-2021

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

Using UG-32 with $E=1$

Section (c) in the centre circle ($< 0.8 \cdot D$)

Equivalent spherical outside diameter $2 \cdot (K_1 \cdot D + t_E)$

$t(E=1)$ **0.804** in

$t_1(E=1)$ **0.7236** in

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

$d \leq 89$ mm (3.5 in.) for $t \leq 10$ mm (3/8 in.)

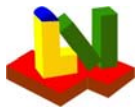
$d \leq 60$ mm (2 3/8 in.) for $t > 10$ mm (3/8 in.)

Remark

Equations according to UG-32

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

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



ASME BPVC VIII-1 2023

Example E4.5.1 - E4.5.6 PTB-4-2021

E4.5.5 - Set-on nozzles with reinforcement - ASME BPVC VIII-1 UG-37: 2023

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

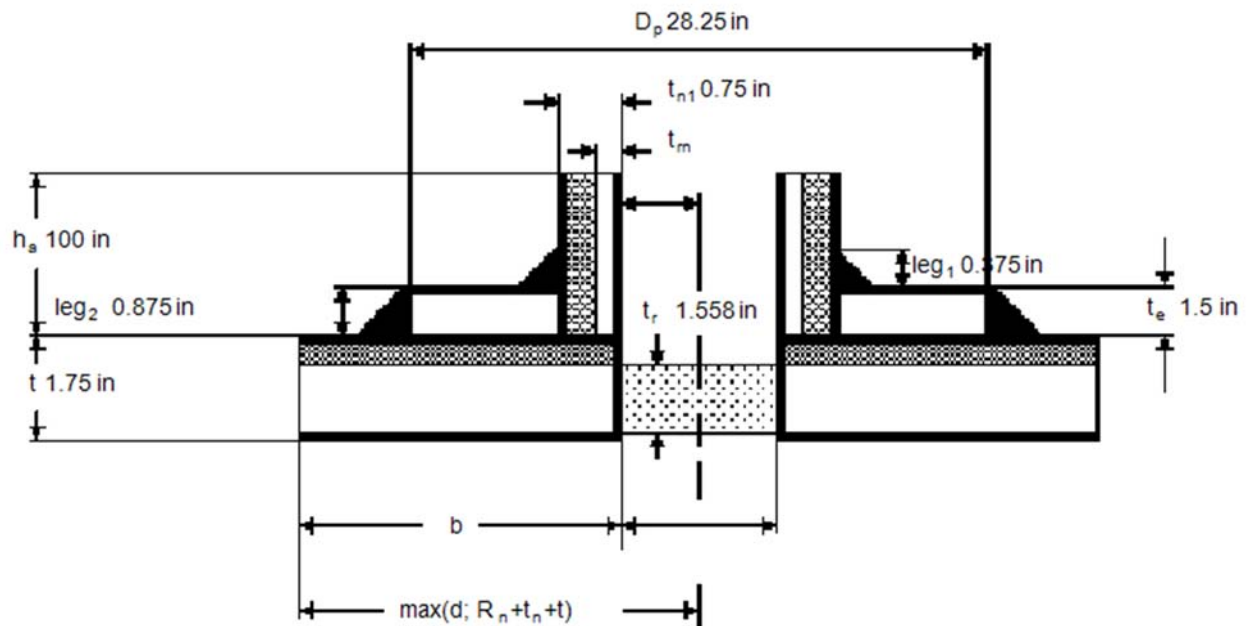
Shape of the shell	cylindrical	
Outside diameter	D_a	87 in
Nominal thickness without allowances	t	1.75 in
Available shell length for reinforcement	b_a	50 in
Joint efficiency factor (or Cast Quality Factor)	E_1	1
Material		
Material strength	K	psi
Safety factor	S	
Allowable stress value	S_v	13700 psi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

ASME BPVC VIII-1 2023
Example E4.5.1 - E4.5.6 PTB-4-2021

Nozzle

Nº

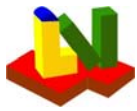
1



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	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	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	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

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 ($\leq t_n$)	leg_4	0.5 in
Groove reinforcement / nozzle ($\leq t_e$)	leg_5	0.5 in



ASME BPVC VIII-1 2023

Example E4.5.1 - E4.5.6 PTB-4-2021

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)

Minimum required thickness of nozzle

Projected Area

Area of shell reserve

Area of reinforcement (A_2 to A_5)

Total available area ΣA

Required area A/Γ

Utilization

Allowable pressure (Approx.: pD/utilization)

UG-40

1

App.1-7

F		
$(E_1 \cdot t - F \cdot t_r)$	0.1922	in
b	7.5	in
h'_a	2.75	in
t_{rn}	0.2799	in
A	23.37	in ²
A_1	2.883	in ²
A_v	20.49	in ²
ΣA	23.38	in ²
A/H	23.37	in ²
A_{req}/A_{avl}	99.97	%
	500.2	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	$\pi/2 \cdot d_a \cdot \text{leg}_1 \cdot 0.49 \cdot \min(S_p; S_n)$	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
							18515	lbf

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

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

$$b = \text{Max} \left\{ \frac{d}{2}, \frac{d}{t_n + t} \right\} = \text{Max} \left\{ \frac{d}{2}, \frac{d}{t_n + t} \right\} = 190.5 \text{ mm}$$

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)

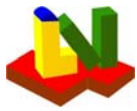
$$A = \frac{2}{3} \cdot d \cdot t_r \cdot F$$

Fig. UG-37.1

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

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

$t + C_{1s} + C_{2s}$	t_s	2	in
$t_r + C_{1s} + C_{2s}$	t_{sr}	1.808	in
	t_{m+}	0.5299	in



ASME BPVC VIII-1 2023

Example E4.5.1 - E4.5.6 PTB-4-2021

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)

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

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

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

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

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

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

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

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

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

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

D_a	$2210 \leq 1520 \text{ mm (60in.)}$	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^2
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	in^2
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



ASME BPVC VIII-1 2023
Example E4.5.1 - E4.5.6 PTB-4-2021

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

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

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

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

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)

$$S_m \leq S$$

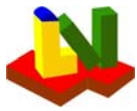
Bending stress S_b acc. to App. 1-7(b)(2)

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

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

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

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



ASME BPVC VIII-1 2023

Example E4.5.1 - E4.5.6 PTB-4-2021

E.4.5.4 - Set-on nozzles with reinforcement - ASME BPVC VIII-1 UG-37: 2023

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

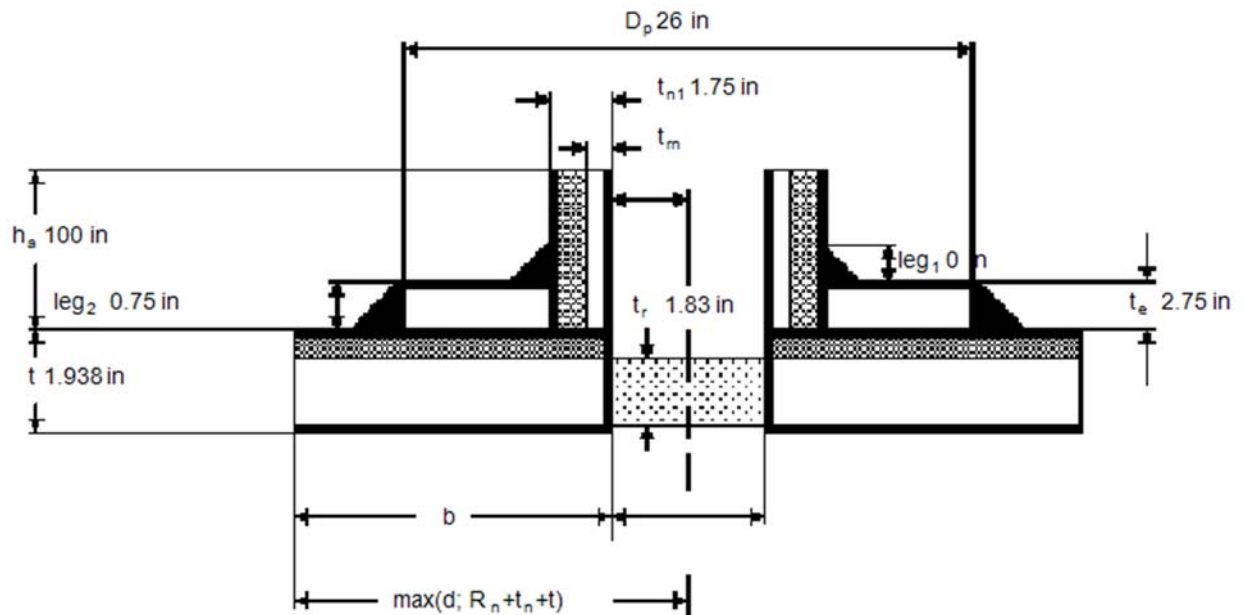
Shape of the shell	cylindrical	
Outside diameter	D_a	100 in
Nominal thickness without allowances	t	1.938 in
Available shell length for reinforcement	b_a	1000 in
Joint efficiency factor (or Cast Quality Factor)	E_1	1
Material	<i>K02700-SA-516-70-Class:-Size:</i>	
Material strength	K	11993 psi
Safety factor	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

ASME BPVC VIII-1 2023
Example E4.5.1 - E4.5.6 PTB-4-2021

Nozzle

Nº

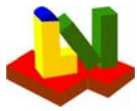
1



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	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	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	t_{b1}	1.803 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



ASME BPVC VIII-1 2023

Example E4.5.1 - E4.5.6 PTB-4-2021

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)
 Minimum required thickness of nozzle
 Projected Area
 Area of shell reserve
 Area of reinforcement (A_2 to A_5)
 Total available area ΣA
 Required area A/Γ
 Utilization
 Allowable pressure (Approx.: pD/utilization)

	UG-40	1	App.1-7
F			
$(E_1 \cdot t - F \cdot t_r)$	0.1075	in	
b	8.062	in	
h'_a	4.844	in	4.844 in
t_{rn}	0.2919	in	0.2919 in
A	29.51	in ²	in ²
A_1	1.733	in ²	in ²
A_v	31.96	in ²	in ²
ΣA	33.69	in ²	in ²
A/H	29.51	in ²	in ²
A_{req}/A_{avl}	87.59	%	%
	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	$\pi/2 \cdot d_a \cdot \text{leg}_1 \cdot 0.49 \cdot \min(S_p; S_n)$	0 lbf
Reinf./shell	$\pi/2 \cdot D_p \cdot \text{leg}_2 \cdot 0.49 \cdot \min(S_p; S_v)$	179999 lbf

Groove weld

Shell /Nozzle	$\pi/2 \cdot d_a \cdot \text{leg}_4 \cdot 0.60 \cdot \min(S_v; S_n)$	163483 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	179999 lbf	+	163483 lbf	=	343482 lbf
				\geq	333102 lbf
2-2	0 lbf	+	0 lbf	+	163483 lbf
				\geq	162137 lbf

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

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

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)

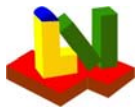
$$A = \frac{2}{3} \cdot d \cdot t_r \cdot F$$

App.1-7(a)(1)

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

Fig. UG-37.1

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



ASME BPVC VIII-1 2023

Example E4.5.1 - E4.5.6 PTB-4-2021

Areas according to UG-40

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

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

(internal pressure)

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

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

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

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

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

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

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

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

D_a	$2540 \leq 1520 \text{ mm (60 in.)}$	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^2
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	in^2
Support length nozzle	$\text{Min}[h_a; t_e + (R_{nm} \cdot t_n)^{0.5}]$	in
Support length shell	$\text{Min}[b_a; (R_m \cdot t_e)^{0.5}]$	in

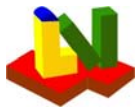
Conditions according to 1-7(b)(1) for radial nozzles

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



ASME BPVC VIII-1 2023
Example E4.5.1 - E4.5.6 PTB-4-2021

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)

$$S_m \leq S$$

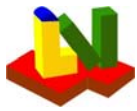
Bending stress S_b acc. to App. 1-7(b)(2)

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

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

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

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



ASME BPVC VIII-1 2023

Example E4.5.1 - E4.5.6 PTB-4-2021

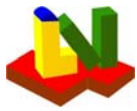
E.4.5.6 - Protruding nozzles without reinforcement - ASME BPVC VIII-1 UG-37: 2023

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



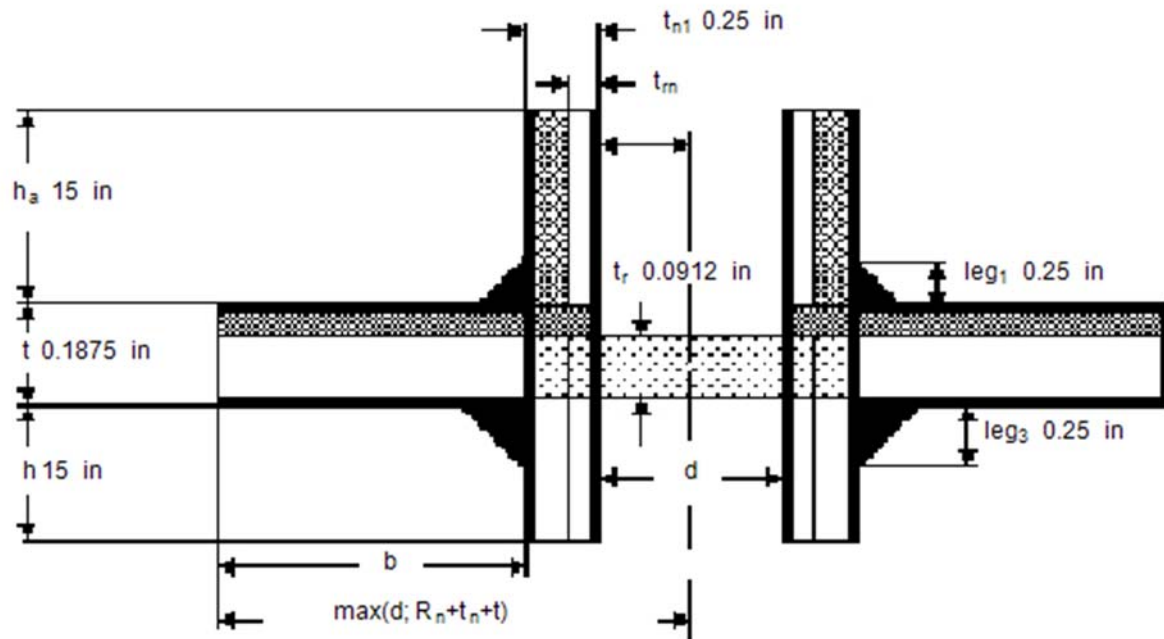
ASME BPVC VIII-1 2023

Example E4.5.1 - E4.5.6 PTB-4-2021

Nozzle

Nº

1



Access opening

Outside diameter

Joint efficiency factor (or Cast Quality Factor)

Material S31600-SA-249-TP316-Class:-Size:

Material strength

Wall thickness allowance

Allowance (corrosion)

Safety factor

Allowable stress K_n/S

Nominal thickness with allowances

Required wall thickness acc. Table UG-45 with corrosion allowance

Nominal inside diameter = $d_a - 2 \cdot t_2$

Inside diameter, corroded = $d_a - 2 \cdot t_n$

External projection

Internal projection

Angle between the shell axis and the sectional plane through the opening center

Nominal thickness without allowances

Required nozzle neck thickness per UG-27

Required shell wall thickness where the nozzle neck attaches to the vessel

with joint efficiency $E=1.0$

Minimum nozzle neck thickness per UG-16

Required nozzle neck thickness per UG-45

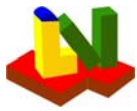
Fillet weld nozzle / shell outside

Fillet weld nozzle / shell inside

Groove weld nozzle / shell ($\leq t$)

No

d_a	8.625 in
E_n	1
K_n	12116 psi
c_1	0 in
c_2	0 in
S	1
S_n	12116 psi
t_{n1}	0.25 in
t_{b3}	0.2819 in
d_{iN}	8.125 in
d	8.125 in
h_a	15 in
h	15 in
Θ	0 °
t_n	0.25 in
t_a	0.05067 in
t_{b1}	0.05906 in
t_{UG-16}	0.05906 in
t_{UG-45}	0.05906 in
leg_1	0.25 in
leg_3	0.25 in
leg_4	0 in



ASME BPVC VIII-1 2023

Example E4.5.1 - E4.5.6 PTB-4-2021

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 ΣA
 Required area A/Γ
 Utilization
 Allowable pressure (approx.: p_D /utilization)

	UG-40	1	App.1-7
F			
$(E_1 \cdot t - F \cdot t_r)$		0.0963 in	
b		4.063 in	in
h'_a		0.4688 in	0.4688 in
h'_i		11.91 mm	0
t_{rn}		0.05067 in	0.05067 in
A		0.7552 in ²	in ²
A_1		0.7674 in ²	in ²
A_v		0.376 in ²	in ²
A_{avl}		1.143 in ²	in ²
A_{req}		0.7552 in ²	in ²
A_{req}/A_{avl}		66.05 %	%
		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}	$= [A_2 + A_3 + A_{41} + A_{43} + 2 \cdot t_n \cdot f_{r1}] \cdot S_v$	$=$	7754 lbf

Strength of nozzle wall, fillet and groove welds

Fillet shell /nozzle	$\pi/2 \cdot d_a \cdot \text{leg}_1 \cdot 0.49 \cdot \min(S_v, S_n)$	$=$	20109 lbf
Fillet shell /nozzle	$\pi/2 \cdot d_a \cdot \text{leg}_3 \cdot 0.49 \cdot \min(S_v, S_n)$	$=$	20109 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	$\pi/2 \cdot d_m \cdot t_n \cdot 0.70 \cdot S_n$	$=$	27894 lbf

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

1-1	20109 lbf	+	27894 lbf	$=$	48003 lbf
				\geq	368.4 lbf
2-2	20109 lbf	+	0 lbf	$=$	40217 lbf
				\geq	368.4 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)

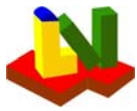
$$A = d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) =$$

Fig. UG-37.1

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

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

$t + C_{1s} + C_{2s}$	t_s	0.1875 in
$t_r + C_{1s} + C_{2s}$	t_{sr}	0.0912 in
	t_{m+}	0.05067 in



ASME BPVC VIII-1 2023

Example E4.5.1 - E4.5.6 PTB-4-2021

Areas according to UG-40

$$h'_a = \text{Min} \left\{ \begin{array}{l} 2.5 \cdot t \\ 2.5 \cdot t_n = 11.91 \text{ mm} \\ h_a \end{array} \right.$$

$$h' = \text{Min} \left\{ \begin{array}{l} 2.5 \cdot t \\ 2.5 \cdot t_n = 11.91 \text{ mm} \\ h \end{array} \right.$$

(internal pressure)

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

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

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

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

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

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

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

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

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

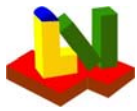
App.1-7 is additionally required acc. to UG-36(b) if

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

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

not required

Total available area	A_{avl}	in^2
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	in^2
Support length nozzle	$\text{Min}[h_a; t_e + (R_{nm} \cdot t_n)^{0.5}]$	in
Support length shell	$\text{Min}[b_a; (R_m \cdot t_e)^{0.5}]$	in



ASME BPVC VIII-1 2023

Example E4.5.1 - E4.5.6 PTB-4-2021

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)

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

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

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

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