

ASME BPVC VIII-1 2025

PTB-4-2021 / E4.3.1; E4.3.2; E4.3.3; E4.3.4; E4.3.5

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Layout

Input values:	1.234	or	1.234
Calculated values:	1.234	or	1.234
Critical values:	1.234	or	1.234
Estimated values:	1.234	or	1.234



ASME BPVC VIII-1 2025

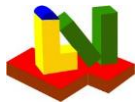
PTB-4-2021 / E4.3.1; E4.3.2; E4.3.3; E4.3.4; E4.3.5

Summary

Strength Calculation Software	Program System ATLAS --- version : 11.0.8.24
Developed by Lauterbach Verfahrenstechnik GmbH	
Certified per DIN EN ISO 9001:2008	Certificate Number 01 100 044763

		LV Soft			ASME		Diff [%]
Example E4.3.1 - Cylinder Shell							
	Required thickness t_c [in]	20,62 mm	0,81 in		0,81 in		0,00%
	Required thickness t_{long} [in]	10,16 mm	0,40 in		0,40 in		0,00%
Example E4.3.2 - Conical Shell							
	Required thickness t [in]	39,92 mm	1,57 in		1,57 in		0,11%
Example E4.3.3 - spherical Shell							
	Required thickness t [in]	94,65 mm	3,73 in		3,73 in		0,00%
Example E4.3.4 - Torispherical Head							
	Allowable Pressure P [psi]	0,93 Mpa	135,29 Psi		135,30 Psi		0,01%
Example E4.3.5 - Elliptical Head							
	Allowable Pressure P [psi]	3,05 Mpa	442,57 Psi		442,23 Psi		0,08%

*)	Anmerkung zum Berechnungswert gemäß ASME.
	Dieser Wert wurde durch Handrechnung ermittelt gemäß den Gleichungen im PTB-4 2021 Example E4.3.4 - Abschnitt b,c
	Handrechnung wurde angewendet da kein expliziter Berechnungswert angegeben wurde.
	Die Abweichung zwischen der Handrechnung und der Berechnungssoftware (LV Soft) beträgt 0,01%
	Die Validierung der Berechnungsformel in der Berechnungssoftware (LV Soft) konnte somit durchgeführt werden.
	Note on the calculation value according to ASME.
	This value was determined by hand calculation according to the equations in PTB-4 2021 Example E4.3.4 - Section b,c.
	Manual calculation was used as no explicit calculation value was given.
	The validation of the calculation formula in the calculation software (LV Soft) could therefore be carried out.



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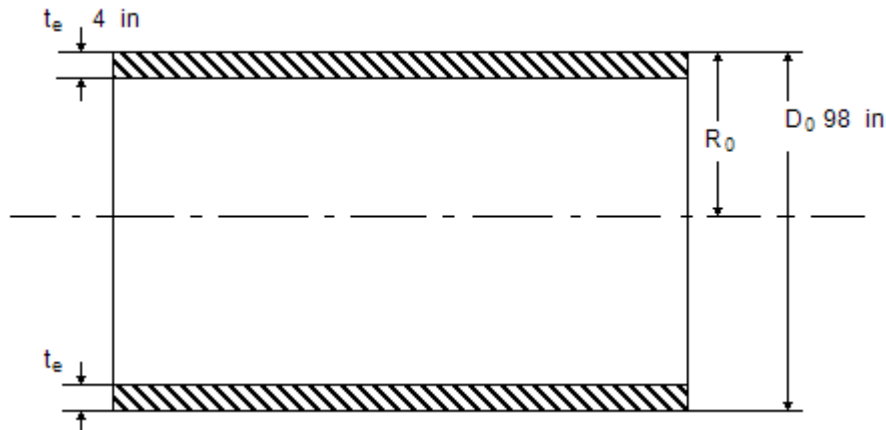
PTB-4-2021 / E4.3.1; E4.3.2; E4.3.3; E4.3.4; E4.3.5

E4.3.1 - Thickness of cylindrical shells under internal pressure - ASME BPVC VIII-1 UG-27 & Appendix-1: 2025

Cylindrical shells

Design pressure	p_D	356 psi
Hydrostatic head	D_p	0 psi
Calculation pressure	P_0	356 psi
Calculation temperature	T_0	148.9 °C

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



Design wall thickness	t_e	4 in
Wall thickness allowance	c_1	0.125 in
Allowance (corrosion)	c_2	0 in
Weld joint efficiency (or Cast Quality Factor)	E	1
Circumferential weld joint efficiency for Eq. 2	E_c	1

Outside diameter	D_o	98 in
corroded inside radius	R	45.12 in

Results

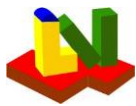
Allowable stress	S	20000 psi
Outside radius	R_o	49 in
Effective thickness	t_0	3.875 in

Calculation as thin shell is applicable

Required thickness	$t(R_o)$	0.866 in
thin shell acc. UG-27	JA	0.8119 in
Minimum wall thickness without condition acc. UG-16	t_{UG-27}	0.8119 in
Minimum wall thickness acc. UG-16	t_{UG-16}	0.05906 in
Required wall thickness for circumferential seam	t_{long}	0.4002 in
$t = \text{Max}\{\text{Min}[t_R; t_{R0}], t_{UG-16}\}$	t	0.8119 in
with allowances	$t+c_1+c_2$	0.9369 in

Allowable excess pressure	P	1633 psi
Allowable excess pressure for longitudinal stress for Eq. (2)	P_{long}	3557 psi
Allowable excess pressure without hydrostatic head	MAWP	1633 psi

Remark



ASME BPVC VIII-1 2025

PTB-4-2021 / E4.3.1; E4.3.2; E4.3.3; E4.3.4; E4.3.5

For calculation of openings according to UG-37

Required thickness

$t(E=1)$ **0.866** in

Calculated with outside diameter

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 $t \leq 3/8 \text{ in}$

$d \leq 60 \text{ mm}$ for $t > 10 \text{ mm}$

or

$d \leq 2 \frac{3}{8} \text{ in}$ for $t > 3/8 \text{ in}$

Equations

$$R_0 = \frac{D_0}{2} = \frac{2489 \text{ mm}}{2} = 1245 \text{ mm}$$

$$t+c_1+c_2=t+c_1+c_2=20.62 \text{ mm}+3.175 \text{ mm}+0 \text{ mm}=23.8 \text{ mm}$$

corroded inside
radius

$$R=R_0-t_0=1245 \text{ mm}-98.42 \text{ mm}=1146 \text{ mm}$$

1) Thin shell For

$$P_0 \leq 0.385 \cdot S \cdot E \Leftrightarrow 2.455 \text{ MPa} \leq 53.09 \text{ MPa}$$

and

with the inside radius R

$$t_e \leq \frac{(R_0 - t_e)}{2} \Leftrightarrow 101.6 \text{ mm} \leq 571.5 \text{ mm}$$

$$t(R) = \frac{P_0 \cdot R}{S \cdot E - 0.6 \cdot P_0} = \frac{2.455 \text{ MPa} \cdot 1146 \text{ mm}}{137.9 \text{ MPa} \cdot 1 - 0.6 \cdot 2.455 \text{ MPa}} = 20.62 \text{ mm}$$

UG-27 (1)

$$P(R) = \frac{S \cdot E \cdot t_0}{R + 0.6 \cdot t_0} = \frac{137.9 \text{ MPa} \cdot 1 \cdot 98.42 \text{ mm}}{1146 \text{ mm} + 0.6 \cdot 98.42 \text{ mm}} = 11.26 \text{ MPa}$$

UG-27 (1)

or with the outside radius R_0

$$t(R_0) = \frac{P_0 \cdot R_0}{S \cdot E + 0.4 \cdot P_0} = \frac{2.455 \text{ MPa} \cdot 1245 \text{ mm}}{137.9 \text{ MPa} \cdot 1 + 0.4 \cdot 2.455 \text{ MPa}} = 22 \text{ mm}$$

App. 1-1 (1)

$$P(R_0) = \frac{S \cdot E \cdot t_0}{R_0 - 0.4 \cdot t_0} = \frac{137.9 \text{ MPa} \cdot 1 \cdot 98.42 \text{ mm}}{1245 \text{ mm} - 0.4 \cdot 98.42 \text{ mm}} = 11.26 \text{ MPa}$$

App. 1-1 (1)

$\log(x) = \ln(x)$

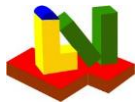
Longitudinal Stress (Circumferential Joints)

$$t_{long} = \frac{P_0 \cdot R}{2 \cdot S \cdot E_c + 0.4 \cdot P_0} = \frac{2.455 \text{ MPa} \cdot 1146 \text{ mm}}{2 \cdot 137.9 \text{ MPa} \cdot 1 + 0.4 \cdot 2.455 \text{ MPa}} = 10.16 \text{ mm}$$

UG-27 (2)

$$P_{long} = \frac{2 \cdot S \cdot E_c \cdot t_0}{R - 0.4 \cdot t_0} = \frac{2 \cdot 137.9 \text{ MPa} \cdot 1 \cdot 98.42 \text{ mm}}{1146 \text{ mm} - 0.4 \cdot 98.42 \text{ mm}} = 24.53 \text{ MPa}$$

UG-27 (2)



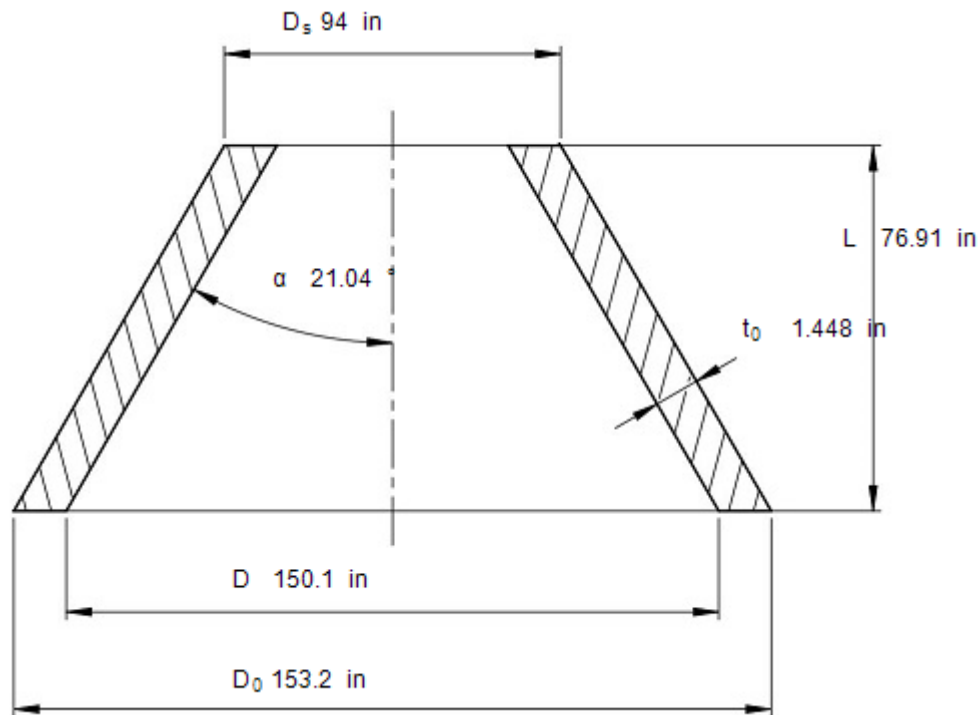
ASME BPVC VIII-1 2025

PTB-4-2021 / E4.3.1; E4.3.2; E4.3.3; E4.3.4; E4.3.5

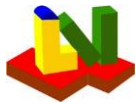
E4.3.2 - Cone without knuckle under internal pressure - ASME BPVC VIII-1 UG-32 & Appendix-1: 2025

Conical sections without knuckle acc. to UG-32(f)

Design pressure	p_D	356 psi
Hydrostatic head	D_p	0 psi
Calculation pressure	p_0	2.455 MPa
Calculation temperature	T_0	300 °F
Final wall thickness	t_e	1.573 in
Wall thickness allowance	c_1	0 in
Allowance (corrosion)	c_2	0.125 in
Effective thickness without allowances	t_0	1.448 in



Half-apex angle ($\leq 30^\circ$ without knuckle)	α	21.04 °
Outside diameter at the large end	D_0	153.2 in
Inside diameter at the large end	D	150.1 in
Outside diameter at the small end	D_s	94 in
Cone length	L	76.91 in
Weld joint efficiency (or Cast Quality Factor)	E	1
Material		
Allowable stress	S	20000 psi



ASME BPVC VIII-1 2025

PTB-4-2021 / E4.3.1; E4.3.2; E4.3.3; E4.3.4; E4.3.5

Calculation

Required thickness		t	1.446	in
incl. allowances (t _e)	1.573 in	t+	1.571	in
Allowable excess pressure incl. hydrost. head		P	356.4	psi
Allowable excess pressure without hydrostatic Head		MAWP	356.4	psi

Remark

Geometrical conditions

valid

Strength condition

Wall thickness acceptable

For calculation of openings according to UG-37(a) in nomenclature for t_r

Design diameter according to UG-37(a):tr(b)	D ₁	in
Required thickness	t(E=1)	in

Equations according to UG-32(g)

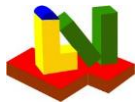
$$\cos(\alpha) = \cos(\alpha) \Leftrightarrow \cos(21.04^\circ) = 0.9333$$

$$D = D_0 - 2 \cdot \frac{t_0}{\cos(\alpha)} = 3891 \text{ mm} - 2 \cdot \frac{36.78 \text{ mm}}{0.9333} = 3812 \text{ mm}$$

$$t = \frac{P_0 \cdot D}{2 \cdot \cos(\alpha) \cdot (S \cdot E - 0.6 \cdot P_0)} = \frac{2.455 \text{ MPa} \cdot 3812 \text{ mm}}{2 \cdot 0.9333 \cdot (137.9 \text{ MPa} \cdot 1 - 0.6 \cdot 2.455 \text{ MPa})} = 36.74 \text{ mm}$$

$$P = \frac{2 \cdot S \cdot E \cdot t_0 \cdot \cos(\alpha)}{D + 1.2 \cdot t_0 \cdot \cos(\alpha)} = \frac{2 \cdot 137.9 \text{ MPa} \cdot 1 \cdot 36.78 \text{ mm} \cdot 0.9333}{3812 \text{ mm} + 1.2 \cdot 36.78 \text{ mm} \cdot 0.9333} = 2.457 \text{ MPa}$$

Rem.: App.1-5(d) or (e) indicates if a reinforcement ring is required.



ASME BPVC VIII-1 2025

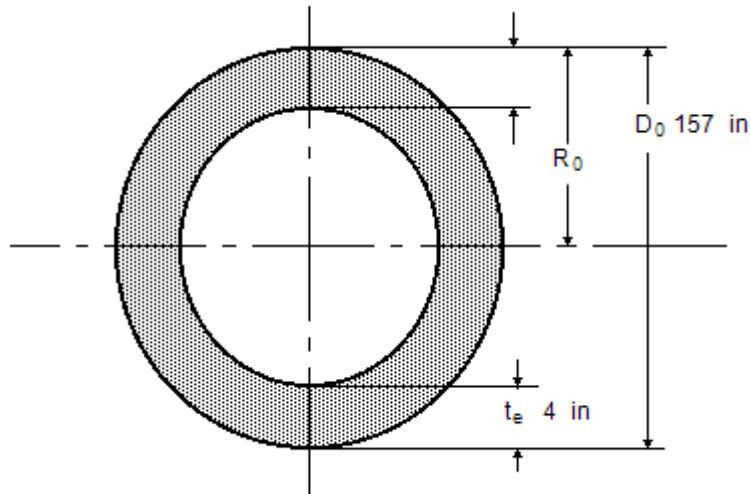
PTB-4-2021 / E4.3.1; E4.3.2; E4.3.3; E4.3.4; E4.3.5

E4.3.3 - Thickness of spherical shells under internal pressure - ASME BPVC VIII-1 UG-27 & Appendix-1: 2025

Spherical shells

Design pressure
Hydrostatic head
Calculation pressure
Calculation temperature

p_D 2080 psi
 D_p 0 psi
 P_0 **2080** psi
 T_0 454.4 °C



Outside diameter
Design wall thickness
Wall thickness allowance
Allowance (corrosion)
Weld joint efficiency (or Cast Quality Factor)

D_0 157 in
 t_e 4 in
 c_1 0 in
 c_2 0 in
 E 1 -

Material K31835-SA-542-D-Class:4a-Size:

Allowable stress

S **21000** psi

Results

Outside radius
Effective thickness

R_0 **78.5** in
 t_0 **4** in

Calculation as thin shell is applicable

Required thickness

$t(R_0)$

JA
 $t(R)$

thin shell acc. UG-27

3.739 in

3.726 in

thick shell (not applicable)

3.793 in

3.782 in

Minimum wall thickness without condition acc. UG-16

Minimum wall thickness acc. UG-16

t_{UG-27} **3.726** in

t_{UG-16} 0.05906 in

Minimum $t = \text{Max}\{\text{Min}[t_R; t_{R0}], t_{UG-16}\}$
with allowances

t **3.726** in

$t+c_1+c_2$ **3.726** in

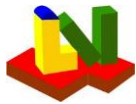
Allowable excess pressure

P **2231** psi

Allowable excess pressure without hydrostatic head

MAWP **2231** psi

Remark



ASME BPVC VIII-1 2025

PTB-4-2021 / E4.3.1; E4.3.2; E4.3.3; E4.3.4; E4.3.5

For calculation of openings according to UG-37

Minimum required thickness for openings

$$t(E=1) \quad \mathbf{3.726} \text{ in}$$

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

$$d \leq 2 \frac{3}{8} \text{ in for } t > \frac{3}{8} \text{ in}$$

Equations

$$R_0 = \frac{D_0}{2} = \frac{3988 \text{ mm}}{2} = 1994 \text{ mm}$$

$$94.65 \text{ mm} = 94.65 \text{ mm} + 0 \text{ mm} + 0 \text{ mm}$$

corroded inside
radius

$$R = R_0 - t_0 = 1994 \text{ mm} - 101.6 \text{ mm} = 1892 \text{ mm}$$

1) Thin shell For

$$P_0 \leq 0.665 \cdot S \cdot E \Leftrightarrow 14.34 \text{ MPa} \leq 97.29 \text{ MPa}$$

and

$$t_e \leq 0.356 \cdot (R_0 - t_e) \Leftrightarrow 101.6 \text{ mm} \leq 673.7 \text{ mm}$$

with the inside radius R

$$t(R) = \frac{P_0 \cdot R}{2 \cdot S \cdot E - 0.2 \cdot P_0} = \frac{14.34 \text{ MPa} \cdot 1892 \text{ mm}}{2 \cdot 144.8 \text{ MPa} \cdot 1 - 0.2 \cdot 14.34 \text{ MPa}} = 94.65 \text{ mm}$$

UG-27 (3)

$$P(R) = \frac{2 \cdot S \cdot E \cdot t_0}{R + 0.2 \cdot t_0} = \frac{2 \cdot 144.8 \text{ MPa} \cdot 1 \cdot 101.6 \text{ mm}}{1892 \text{ mm} + 0.2 \cdot 101.6 \text{ mm}} = 15.38 \text{ MPa}$$

UG-27 (3)

or with the outside radius R_0

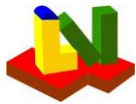
$$t(R_0) = \frac{P_0 \cdot R_0}{2 \cdot S \cdot E + 0.8 \cdot t_0} = \frac{14.34 \text{ MPa} \cdot 1994 \text{ mm}}{2 \cdot 144.8 \text{ MPa} \cdot 1 + 0.8 \cdot 14.34 \text{ MPa}} = 94.98 \text{ mm}$$

App. 1-1 (2)

$$P(R_0) = \frac{2 \cdot S \cdot E \cdot t_0}{R_0 - 0.8 \cdot t_0} = \frac{2 \cdot 144.8 \text{ MPa} \cdot 1 \cdot 101.6 \text{ mm}}{1994 \text{ mm} - 0.8 \cdot 101.6 \text{ mm}} = 15.38 \text{ MPa}$$

App. 1-1 (2)

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



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PTB-4-2021 / E4.3.1; E4.3.2; E4.3.3; E4.3.4; E4.3.5

E4.3.4 - Torispherical heads (Kloepper, Korbogen, Semi-spherical) under internal pressure - ASME BPVC VIII-1 UG-32 & Appendix-1: 2025

Type of head

(1=Kloepper-, 2=Korbogen-, 3=Torispherical, 4=Hemispherical,
5=Elliptical 2:1)

3

Torispherical

Design pressure

p_D 136 psi

Hydrostatic head

D_p 0 psi

Calculation pressure

p_0 **0.9377** MPa

Calculation temperature

T_0 650 °F

Final wall thickness

t_e 0.625 in

Wall thickness allowance

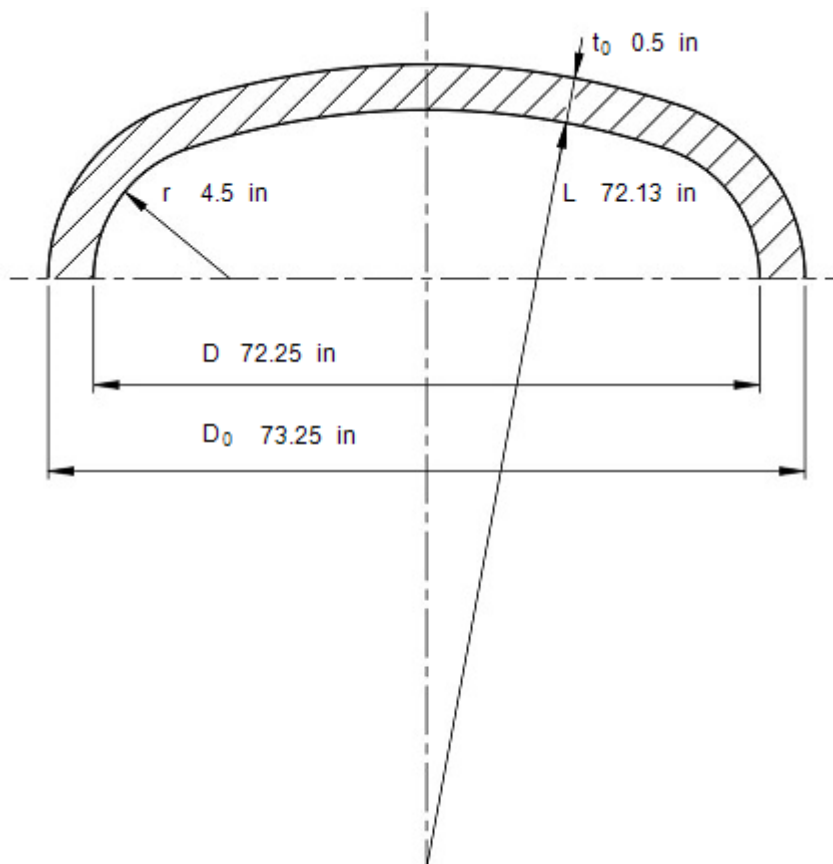
c_1 0 in

Allowance (corrosion)

c_2 0.125 in

Effective thickness without allowances

t_0 **0.5** in



Outside diameter of cylindrical shell

D_0 73.25 in

Inside diameter of cylindrical shell

(= $D_0 - 2t_0$) D **72.25** in

Outside crown radius

L_0 72.63 in

Outside crown radius with allowances

L_1 **72.75** in

Inside crown radius

(= $L_0 - t_0$) L **72.13** in

Knuckle radius

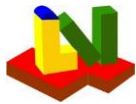
r 4.5 in

Weld joint efficiency (or Cast Quality Factor)

E 1

Material data

Material K11789-SA-387-11-Class:1-Size:



ASME BPVC VIII-1 2025

PTB-4-2021 / E4.3.1; E4.3.2; E4.3.3; E4.3.4; E4.3.5

Elasticity modulus	E_T	2.66e+7	psi
Elastic limit	S_y	26948	psi
Reduce allowable*) stress for $R_{m20} > 485$ MPa?	Yes		(Yes/No)
Tensile strength at 20°C	R_{m20}	60190	psi
Allowable stress			
at working temperature acc. ASME-table	S_T	17100	psi
at 20°C	S_{20}	17114	psi
acc. UG-32(d) or endnote 90	S	17100	psi

) According to App. 1-4(c,d), the allowable stress must be reduced to $138 \cdot S_T / S_{20}$ (=20 ksi...) for $R_{m20} > 485$ MPa (70 ksi).

Calculation

Ratio	L/r	16.03
Factor	M	1.751
Required thickness without allowance	t	0.5026 in
incl. allowances (t_e 0.625 in $\geq t$)	t_+	0.6276 in
Allowable excess pressure incl. hydrost. head	P	135.3 psi
Allowable excess pressure without hydrostatic Head	MAWP	135.3 psi

Geometrical conditions
valid

Strength condition
Final wall thickness 15,875 < 15,940328 = required thickness

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

Using UG-32 with $E=1$	$t(E=1)$	0.5026 in
acc. section (a) in the crown region	$t_1(E=1)$	0.287 in

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

$$t = \frac{P_0 \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P_0} = \frac{0.9377 \text{ MPa} \cdot 1832 \text{ mm} \cdot 1.751}{2 \cdot 117.9 \text{ MPa} \cdot 1 - 0.2 \cdot 0.9377 \text{ MPa}} = 12.77 \text{ mm}$$

$$P = \frac{2 \cdot S \cdot E \cdot t_0}{L \cdot M + 0.2 \cdot t_0} = \frac{2 \cdot 117.9 \text{ MPa} \cdot 1 \cdot 12.7 \text{ mm}}{1832 \text{ mm} \cdot 1.751 + 0.2 \cdot 12.7 \text{ mm}} = 0.9329 \text{ MPa}$$



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PTB-4-2021 / E4.3.1; E4.3.2; E4.3.3; E4.3.4; E4.3.5

For openings in the crown region with

Opening diameter

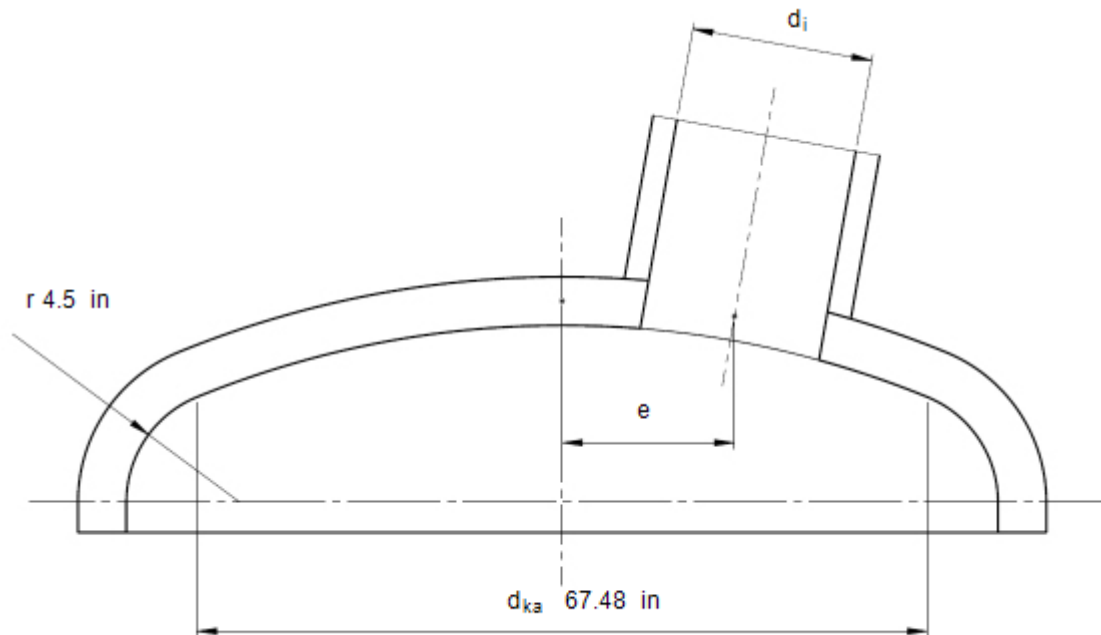
d_i

in

Distance between opening center and head center

e

in



Available reinforcement width acc. UG37

Available reinforcement width of the crown

b'

in

Diameter of the crown region

d_{ka}

67.48 in

Angle of the knuckle region

ϕ

62.24 °

Arc length of the knuckle region

b''

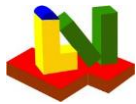
5.567 in

$$d_{ka} = (2 \cdot L + t_e) \cdot (D/2 - r) / (L - r)$$

$$\phi = \arccos((D/2 - r) / (L - r))$$

$$b' = (d_{ka} - d_i) / 2 - e$$

$$b'' = (r + t_e) \cdot \phi$$



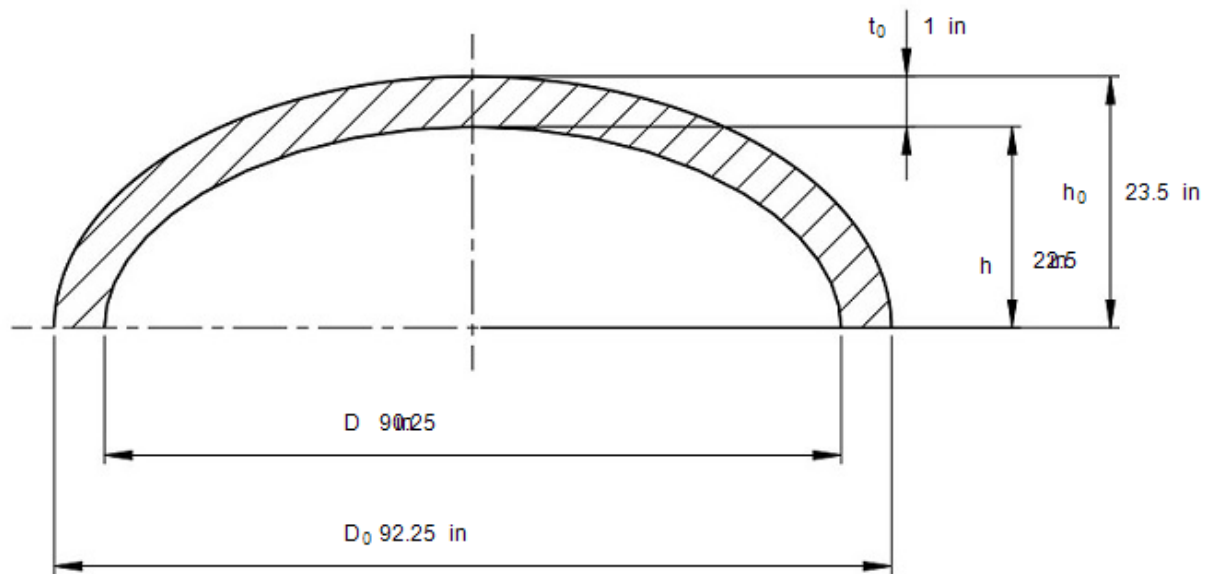
ASME BPVC VIII-1 2025

PTB-4-2021 / E4.3.1; E4.3.2; E4.3.3; E4.3.4; E4.3.5

E4.3.5 - Elliptical heads under internal pressure - ASME BPVC VIII-1 UG-32 & Appendix-1: 2025

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

Design pressure	p_D	442.2 psi
Hydrostatic head	D_p	0 psi
Calculation pressure	p_0	3.049 MPa
Calculation temperature	T_0	300 °F
Final wall thickness	t_e	1.125 in
Wall thickness allowance	c_1	0 in
Allowance (corrosion)	c_2	0.125 in
Effective thickness without allowances	t_0	1 in



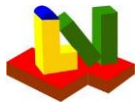
Outside diameter of cylindrical shell	D_0	92.25 in
Inside diameter of cylindrical shell (= $D_0 - 2t_0$)	D	90.25 in
Outer height of head	h_0	23.5 in
Inside depth of head (minor semi-axis = $h_0 - t_0$)	h	22.5 in
Weld joint efficiency (or Cast Quality Factor)	E	1

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}	20000 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	0.9992 in
incl. allowances (t_e 1.125 in $\geq t$)	t_+	1.124 in
Allowable excess pressure incl. hydrostatic Head	P	442.6 psi
Allowable excess pressure without hydrostatic Head	MAWP	442.6 psi



ASME BPVC VIII-1 2025

PTB-4-2021 / E4.3.1; E4.3.2; E4.3.3; E4.3.4; E4.3.5

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 $2 \cdot (K_1 \cdot D + t_E)$

$t(E=1)$ **0.9992** in

$t_1(E=1)$ **0.8993** in

D_s **164.7** 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

$$t = \frac{P_0 \cdot D \cdot K}{2 \cdot S \cdot E - 0.2 \cdot P_0} = \frac{3.049 \text{ MPa} \cdot 2292 \text{ mm} \cdot 1}{2 \cdot 138 \text{ MPa} \cdot 1 - 0.2 \cdot 3.049 \text{ MPa}} = 25.38 \text{ mm}$$

$$P = \frac{2 \cdot S \cdot E \cdot t_0}{K \cdot D + 0.2 \cdot t_0} = \frac{2 \cdot 138 \text{ MPa} \cdot 1 \cdot 25.4 \text{ mm}}{1 \cdot 2292 \text{ mm} + 0.2 \cdot 25.4 \text{ mm}} = 3.051 \text{ MPa}$$