

ASME BPVC VIII-1 2023

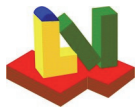
Example E4.4.1 - E4.4.5 PTB-4-2021

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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

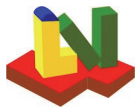


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Example E4.4.1 - E4.4.5 PTB-4-2021

Summary

Strength Calculation Software		Program System ATLAS		Version	10.0.106
Developed by Lauterbach Verfahrenstechnik GmbH					
Certified per DIN EN ISO 9001:2008		Certificate Number 01 100 044763			



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Example E4.4.1 - E4.4.5 PTB-4-2021

E 4.4.1 - Thickness of cylindrical shells and tubes under external pressure - ASME BPVC VIII-1 UG-28 & Appendix 1: 2023

Select Shell Configuration:

1

Cylindrical shells under external pressure

External design pressure	p_D	2 psi
Hydrostatic head	D_p	0 psi
External calculation pressure	p_0	2 psi
Calculation temperature	T_0	300 °F

Outside diameter	D_0	92.25 in
Design wall thickness	t_e	1.125 in
Wall thickness allowance	c_1	0 in
Allowance (corrosion)	c_2	0.125 in
Buckling length	L	636 in

Material K02700-SA-516-70

Spec. Min. Yield	S_y	33600 psi
Allowable stress	S_0	20015 psi
Applicable material chart	Fig	CS-2
Modulus of elasticity	E	2.829e+7 psi

Results

Effective thickness	t_0	1 in
Ratio	L/D_0	6.894
Ratio	D_0/t_0	92.25

Factor according to ASME-IIID\Table G	A	1.884e-4
Factor (see material chart)	B	2800 psi
Factor $2 \cdot \min(S_0, 9 \cdot B)$	S	4860 psi

Required thickness acc. UG-28	t_{UG-28}	0.3002 in
Required thickness acc. UG-16	t_{UG-16}	0.05906 in
Required thickness	t	0.3002 in
Required thickness incl. allowances	$t+c_1+c_2$	0.4252 in
Allowable excess pressure	P	38.52 psi
Allowable pressure without hydrostatic head	MAWP	38.52 psi

Remark

Equations

$$\frac{D_0}{t_0} \geq 10 \Leftrightarrow 92.25 \geq 10$$

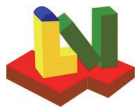
UG-28 c) (1)

$$Pa(B) = \frac{4 \cdot B}{3 \cdot \frac{D_0}{t_0}} = \frac{4 \cdot 19.31 \text{ N/mm}^2}{3 \cdot 92.25} = 0.279 \text{ MPa}$$

Step 6

$$Pa(E) = \frac{2 \cdot A \cdot E}{3 \cdot \frac{D_0}{t_0}} = \frac{2 \cdot 1.884e-4 \cdot 195067 \text{ N/mm}^2}{3 \cdot 92.25} = 0.2656 \text{ MPa}$$

Step 7



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Example E4.4.1 - E4.4.5 PTB-4-2021

E 4.4.2 - Formed heads pressure under external pressure - ASME BPVC VIII-1 UG-33 & Appendix-1: 2023

Conical shells under external pressure acc. UG-33(f)

External design pressure	P_D	2	psi
Hydrostatic head	D_p	0	psi
Calculation pressure	P_0	2	psi
Calculation temperature	T_0	300	°F
Material	K02700-SA-516-70		
Spec. Min. Yield	S_y	33600	psi
Allowable stress	S_0	20015	psi
Applicable material chart	Fig	CS-2	
Modulus of elasticity	E	2.9e+7	psi

Cone wall thickness with allowances	t_0	1.938	in
Wall thickness allowance	c_1	0	in
Allowance (corrosion)	c_2	0.125	in
Cone wall thickness without allowances	t	1.813	in

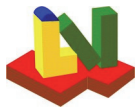
Is a cylinder connected, which does not act as line of support?			N	(Y/N)
Outside diameter	(wide end)	D_{Ls}	153.6	in
Knuckle radius	(wide end)	r_1	0	in
Outside diameter	(small end)	D_{Ss}	92.25	in
Knuckle radius	(small end)	r_2	0	in
Half apex angle ($\leq 60^\circ$)		α	21.04	°

Proof for cross-section area according to App. 1-8 required for cone-connection without knuckle

Results

Effective thickness	$t_e = t \cdot \cos(\alpha)$	t_e	1.692	in
Axial length of the cone		L	79.79	in
Design length		L_e	63.85	in
Ratio		L_e/D_L	0.4156	
Ratio		D_L/t_e	90.81	
Factor according to fig. 5-UGO-28.0		A	0.004054	
Factor (see material chart)		B	16850	psi
Factor	$2 \cdot \min(S_0; 9 \cdot B)$	S	31589	psi
Allowable external pressure (for t_0)		P	247.4	psi
Allowable pressure without hydrostatic head		MEP	247.4	psi
Required thickness (for P_0)		t	0.1667	in
Required thickness incl. allowances		$t+c_1+c_2$	0.2917	in

Remark



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Example E4.4.1 - E4.4.5 PTB-4-2021

Equations

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

$$\sin(\alpha) = \sin(\alpha) = \sin(21.04^\circ) = 0.359$$

$$\tan(\alpha) = \tan(\alpha) = \tan(21.04^\circ) = 0.3846$$

$$D_L = D_{Ls} - r_1 \cdot (1 - \cos(\alpha)) = 3902 \text{ mm} - 0 \text{ mm} \cdot (1 - 0.9333) = 3902 \text{ mm}$$

$$D_S = D_{Ss} + r_2 \cdot (1 - \cos(\alpha)) = 2343 \text{ mm} + 0 \text{ mm} \cdot (1 - 0.9333) = 2343 \text{ mm}$$

$$L = \frac{(D_L - D_S)}{2} \cdot \tan(\alpha) = \frac{(3902 \text{ mm} - 2343 \text{ mm})}{2} \cdot 0.3846 = 2027 \text{ mm}$$

$$L_1 = r_1 \cdot \sin(\alpha) = 0 \text{ mm} \cdot 0.359 = 0 \text{ mm}$$

$$L_2 = r_2 \cdot \left(\frac{D_{Ss}}{D_{Ls}} \right) \cdot \sin(\alpha) = 0 \text{ mm} \cdot 0.6005 \cdot 0.359 = 0 \text{ mm}$$

$$L_3 = \frac{L}{2} \cdot \frac{(D_L + D_S)}{D_{Ls}} = \frac{2027 \text{ mm}}{2} \cdot \frac{(3902 \text{ mm} + 2343 \text{ mm})}{3902 \text{ mm}} = 1622 \text{ mm}$$

$$L_e = L_1 + L_2 + L_3 = 0 \text{ mm} + 0 \text{ mm} + 1622 \text{ mm} = 1622 \text{ mm}$$

1) for $D_L/t_0 \geq 10$

$$Pa(B) = \frac{4 \cdot B}{3 \cdot \left(\frac{D_L}{t_0} \right)} = \frac{4 \cdot 116.2 \text{ N/mm}^2}{3 \cdot 90.81} = 1.706 \text{ N/mm}^2$$

UG-33 f-a) Step 6

$$Pa(E) = \frac{2 \cdot A \cdot E}{3 \cdot \left(\frac{D_L}{t_0} \right)} = \frac{2 \cdot 0.004054 \cdot 199948 \text{ N/mm}^2}{3 \cdot 90.81} = 5.951 \text{ N/mm}^2$$

UG-33 f-a) Step 7

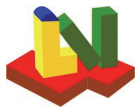
2) for $D_L/t_0 < 10$

$$P_{a1} = \left[\frac{2.167}{\frac{D_L}{t_0}} - 0.0833 \right] \cdot B = \left[\frac{2.167}{90.81} - 0.0833 \right] \cdot 116.2 \text{ N/mm}^2 = -6.905 \text{ N/mm}^2$$

UG-33 f-b) Step 2

$$P_{a2} = \frac{2 \cdot S}{\frac{D_L}{t_0}} \cdot \left[1 - \frac{2 \cdot S}{\frac{D_L}{t_0}} \right] = \frac{2 \cdot 217.8 \text{ N/mm}^2}{90.81} \cdot \left[1 - \frac{2 \cdot 217.8 \text{ N/mm}^2}{90.81} \right] = 4.744 \text{ N/mm}^2$$

UG-33 f-b) Step 3



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Example E4.4.1 - E4.4.5 PTB-4-2021

E 4.4.3 - Formed heads pressure under external pressure - ASME BPVC VIII-1 UG-33 & Appendix-1: 2023

Torispherical heads

External design pressure	p_D	615.3 psi
Hydrostatic head	D_p	0 psi
Calculation pressure	p_0	615.3 psi
Calculation temperature	T_0	300 °F

Design wall thickness	t_e	2.813 in
Wall thickness allowance	c_1	0 in
Allowance (corrosion)	c_2	0 in
Effective thickness	t_0	2.813 in

Outside diameter of the head skirt	D_0	154.6 in
Type of head	Hemispherical head	
Outside calotte radius	R_0	77.31 in
Knuckle radius	r	74.5 in

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

Spec. Min. Yield	S_y	60190 psi
Allowable stress	S_0	24366 psi
Applicable material chart	Fig	CS-2
Modulus of elasticity	E	2.9e+7 psi

Results

Ratio	R_0/t_0	27.49
Factor (see material chart)	B	15700 psi
Allowable external pressure	P	571.1 psi
Allowable pressure without hydrostatic head	MEP	571.1 psi
Required thickness	t	2.789 in
Required thickness incl. allowances	$t+c_1+c_2$	2.789 in

Remark **Betriebsdruck zu hoch**

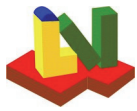
Equations

$$Pa(B) = \frac{B}{\left(R_0/t_0\right)} = \frac{108.2 \text{ N/mm}^2}{27.49} = 3.938 \text{ N/mm}^2$$

UG-28 d) Step 4

$$Pa(E) = 0.0625 \cdot \frac{E}{\left(R_0/t_0\right)^2} = 0.0625 \cdot \frac{199948 \text{ N/mm}^2}{(27.49)^2} = 16.54 \text{ N/mm}^2$$

UG-28 d) Step 5



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Example E4.4.1 - E4.4.5 PTB-4-2021

E 4.4.4 - Formed heads pressure under external pressure - ASME BPVC VIII-1 UG-33 & Appendix-1: 2023

Torispherical heads

External design pressure	p_D	762061 psi
Hydrostatic head	D_p	0 psi
Calculation pressure	p_0	762061 psi
Calculation temperature	T_0	650 °F

Design wall thickness	t_e	0.625 in
Wall thickness allowance	c_1	0 in
Allowance (corrosion)	c_2	0.125 in
Effective thickness	t_0	0.5 in

Outside diameter of the head skirt	D_0	in
Type of head	Torispherical head	
Outside calotte radius	R_0	72.63 in
Knuckle radius	r	4.375 in

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

Spec. Min. Yield	S_y	34809 psi
Allowable stress	S_0	17114 psi
Applicable material chart	Fig	CS-2
Modulus of elasticity	E	2.512e+7 psi

Results

Ratio	R_0/t_0	145.3
Factor (see material chart)	B	8100 psi
Allowable external pressure	P	55.77 psi
Allowable pressure without hydrostatic head	MEP	55.77 psi
Required thickness	t	72.62 in
Required thickness incl. allowances	$t+c_1+c_2$	72.75 in

Remark Betriebsdruck zu hoch

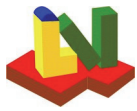
Equations

$$Pa(B) = \frac{B}{\left(R_0/t_0\right)} = \frac{55.85 \text{ N/mm}^2}{145.3} = 0.3845 \text{ N/mm}^2$$

UG-28 d) Step 4

$$Pa(E) = 0.0625 \cdot \frac{E}{\left(R_0/t_0\right)^2} = 0.0625 \cdot \frac{173231 \text{ N/mm}^2}{(145.3)^2} = 0.5132 \text{ N/mm}^2$$

UG-28 d) Step 5



ASME BPVC VIII-1 2023

Example E4.4.1 - E4.4.5 PTB-4-2021

E 4.4.5 - Formed heads pressure under external pressure - ASME BPVC VIII-1 UG-33 & Appendix-1: 2023

Torispherical heads

External design pressure	p_D	1 psi
Hydrostatic head	D_p	0 psi
Calculation pressure	p_0	1 psi
Calculation temperature	T_0	300 °F

Design wall thickness	t_e	1.125 in
Wall thickness allowance	c_1	0 in
Allowance (corrosion)	c_2	0.125 in
Effective thickness	t_0	1 in

Outside diameter of the head skirt	D_0	92.25 in
Type of head	Torispherical head	
Outside calotte radius	R_0	83.03 in
Knuckle radius	r	in

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

Spec. Min. Yield	S_y	37710 psi
Allowable stress	S_0	20015 psi
Applicable material chart	Fig	CS-2
Modulus of elasticity	E	2.9e+7 psi

Results

Ratio	R_0/t_0	83.02
Factor (see material chart)	B	13795 psi
Allowable external pressure	P	166.2 psi
Allowable pressure without hydrostatic head	MEP	166.2 psi
Required thickness	t	0.06239 in
Required thickness incl. allowances	$t+c_1+c_2$	0.1874 in

Remark

Equations

$$Pa(B) = \frac{B}{\left(R_0/t_0\right)} = \frac{95.11 \text{ N/mm}^2}{83.02} = 1.146 \text{ N/mm}^2$$

UG-28 d) Step 4

$$Pa(E) = 0.0625 \cdot \frac{E}{\left(R_0/t_0\right)^2} = 0.0625 \cdot \frac{199948 \text{ N/mm}^2}{(83.02)^2} = 1.813 \text{ N/mm}^2$$

UG-28 d) Step 5