

ASME BPVC VIII-1 2021

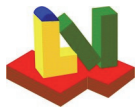
Example E4.4.7 - E4.4.8 PTB-4-2023

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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

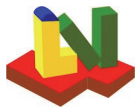


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Example E4.4.7 - E4.4.8 PTB-4-2023

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										
						LV Soft				ASME		Diff [%]	
Example E4.4.7 - Conical transition Without a knuckle (large End)													
			Required area ArL			1008,88 mm ²		1,56 in ²		1,56 in ²		0,10%	
			Required area AeL			13064,03 mm ²		20,25 in ²		20,38 in ²		0,64%	
Large End/Line-of-support			Required moment of inertia Is			33871336,00 mm ⁴		81,38 in ⁴		81,85 in ⁴		0,57%	
			Required moment of inertia I's			43504464,00 mm ⁵		104,52 in ⁵		105,12 in ⁵		0,57%	
Example E4.4.7 - Conical transition Without a knuckle (Small End)													
			Required area ArS			715,96 mm ²		1,11 in ²		1,11 in ²		0,08%	
			Required area AeS			8001,92 mm ²		13,12 in ²		13,12 in ²		0,01%	
Small End/Line-of-support			Required moment of inertia Is			6975754,00 mm ⁴		16,76 in ⁴		16,76 in ⁴		0,02%	
			Required moment of inertia I's			8959684,00 mm ⁴		21,53 in ⁴		21,53 in ⁴		0,02%	
Example E4.4.8 - Conical transition With a knuckle													
Large End/Line-of-support			Required moment of inertia Is			5850143,00 mm ⁴		14,06 in ⁴		13,82 in ⁴		1,70%	
			Required moment of inertia I's			7513945,00 mm ⁴		18,05 in ⁴		17,75 in ⁴		1,70%	



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Example E4.4.7 - E4.4.8 PTB-4-2023

E 4.4.7 Large End - Formed heads pressure under external pressure - ASME BPVC VIII-1 UG-33 & Appendix-1: 2023

Area at the wide end of a cone-cylinder-juncture without knuckle acc. App.1-8

Type of stiffener

No stiffener

External design pressure

p_D 14.7 psi

Hydrostatic head

D_p 0 psi

Calculation pressure

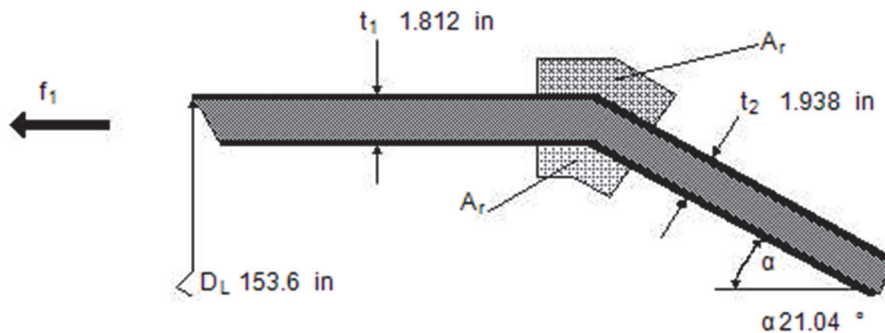
p_0 14.7 psi

Calculation temperature

T_0 300 °F

Axial additional load as line load (positive for tension) e.g. wind load, dead weight, traffic load, etc. but no loads resulting from internal / external pressure

f_1 497.1 lbf/in



Cylinder

Final wall thickness

t_1 1.812 in

Wall thickness allowance

c_1 0 in

Allowance (corrosion)

c_2 0.125 in

Final thickness without allowances

t_s 1.687 in

Outside diameter

D_L 153.6 in

Tip radius ($=D_L/2$)

R_L 76.81 in

Required thickness without allowances (UG-28)

t_{1r} 0.9549 in

Required thickness with allowances (UG-28)

t_{1r+} 1.08 in

Joint efficiency factor

E_1 1

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

Allowable stress

S_s 20015 psi

Modulus of elasticity

E_s 2.9e+7 psi

Cone

Final wall thickness

t_2 1.938 in

Wall thickness allowance

c_1 0 in

Allowance (corrosion)

c_2 0.125 in

Final thickness without allowances

t_c 1.813 in

Half apex angle ($\leq 60^\circ$)

α 21.04 °

Required thickness without allowances (UG-33)

t_{2r} 0.3639 in

Required thickness with allowances (UG-33)

t_{2r+} 0.4889 in

Joint efficiency factor

E_2 1

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

Allowable stress

S_c 20015 psi

Modulus of elasticity

E_c 2.9e+7 psi

Stiffening ring

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

Actual cross section of the stiffener

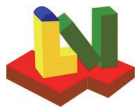
A_r 34 in²

Allowable stress

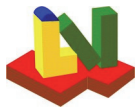
S_r 20015 psi

Modulus of elasticity

E_r 2.9e+7 psi



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Example E4.4.7 - E4.4.8 PTB-4-2023



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Example E4.4.7 - E4.4.8 PTB-4-2023

Results

Factor (≥ 1)	k	1
Ratio	$P_0/S_s E_1$	7.344e-4
Angle	D_{el}	2.818 °
Effective load	Q_L	1062 lbf/in
Cross sectional area	A_{rL}	1.564 in ²
Effective area	A_{eL}	20.25 in ²
Required cross section of reinforcement	A_{req}	0 in ²
Remark	Stiffening required acc. App. 1-8 (b)	

Equations

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

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

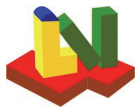
$$Q_L = P_0 \cdot \frac{R_L}{2} + f_1 = 1.014 \text{ bar} \cdot \frac{1951 \text{ mm}}{2} + 87.06 \text{ N/mm} = 185.9 \text{ N/mm}$$

$$A_{rL} = \frac{k \cdot Q_L \cdot R_L \cdot \tan(\alpha)}{S_s \cdot E_1} \cdot \left(1 - \frac{P_0 \cdot R_L - Q_L}{4 \cdot Q_L} \cdot \frac{D_{el}}{\alpha} \right) = \quad (1)$$

$$\frac{1 \cdot 185.9 \text{ N/mm} \cdot 1951 \text{ mm} \cdot 0.3846}{138 \text{ N/mm}^2 \cdot 1} \cdot \left(1 - \frac{1.014 \text{ bar} \cdot 1951 \text{ mm} - 185.9 \text{ N/mm}}{4 \cdot 185.9 \text{ N/mm}} \cdot \frac{2.818^\circ}{21.04^\circ} \right) = 1009 \text{ mm}^2$$

$$A_{eL} = 0.55 \cdot \sqrt{(D_L \cdot t_s)} \cdot \left(\frac{t_s + t_c}{\cos(\alpha)} \right) = \quad (2)$$

$$0.55 \cdot \sqrt{(3902 \text{ mm} \cdot 42.86 \text{ mm})} \cdot \left(\frac{42.86 \text{ mm} + 46.04 \text{ mm}}{0.9333} \right) = 13064 \text{ mm}^2$$



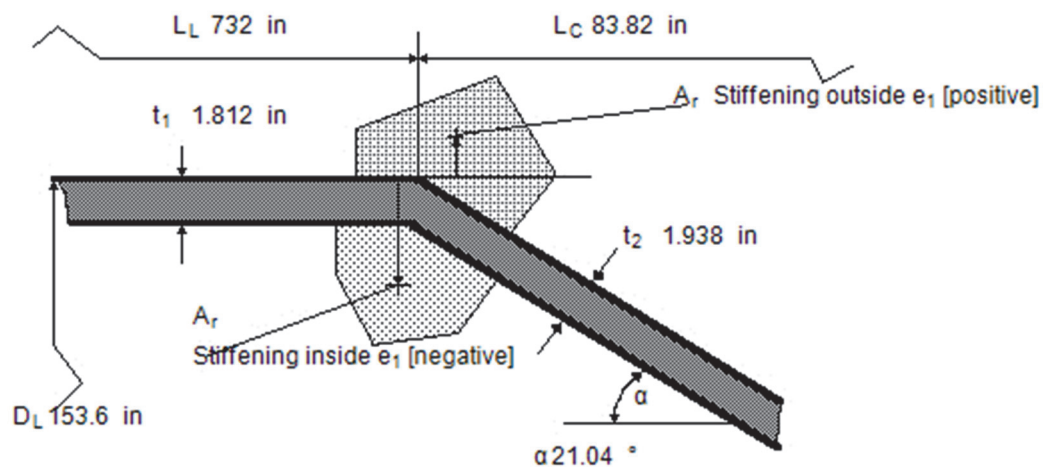
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Example E4.4.7 - E4.4.8 PTB-4-2023

E 4.4.7 Large End/Line-of-support - Formed heads pressure under external pressure - ASME BPVC VIII-1 UG-33 & Appendix-1: 2023

Moment of inertia at the wide end of a cone-cylinder-juncture under external pressure acc. App. 1-8 (Line-of-support)

External design pressure	p_D	14.7 psi
Hydrostatic head	D_p	0 psi
Calculation pressure	p_0	14.7 psi
Calculation temperature	T_0	300 °F
Axial additional load as line load (positive for tension) e.g. wind load, dead weight, traffic load, etc. but no loads resulting from internal / external pressure	f_1	497.1 lbf/in



Cylinder

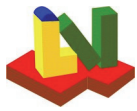
Design wall thickness	t_1	1.812 in
Wall thickness allowance	c_1	0 in
Allowance (corrosion)	c_2	0.125 in
Final thickness without allowances	t_s	1.687 in
Required thickness without allowances (UG-28)	t_{1r}	0.9549 in
Required thickness with allowances (UG-28)	t_{1r+}	1.08 in
Outside diameter	D_L	153.6 in
Tip radius ($=D_L/2$)	R_L	76.81 in
Buckling length	L_L	732 in

Cone

Design wall thickness	t_2	1.938 in
Wall thickness allowance	c_1	0 in
Allowance (corrosion)	c_2	0.125 in
Final thickness without allowances	t_c	1.813 in
Required thickness without allowances (UG-33)	t_{2r}	0.3639 in
Required thickness with allowances (UG-33)	t_{2r+}	0.4889 in
Half apex angle ($\leq 60^\circ$)	α	21.04 °
Buckling length	L_C	83.82 in

Stiffening ring

Material	K02700-SA-516-70-Class:-Size:	
Spec. Min. Yield	S_y	2.9e+7 psi
Applicable material chart	Fig	CS-2
Radial distance between the centroid of the stiffening ring and the outer surface of the cylinder	e_1	in
Cross sectional area	A_r	0 in ²
Moment of inertia	I_r	in ⁴



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Example E4.4.7 - E4.4.8 PTB-4-2023

Results

Equivalent length	M	393.8 in
Effective load	F_L	5980 lbf/in
Reference area	A_{TL}	693.6 in ²
Factor	B	993.4 psi
Factor (see material chart)	A	6.96e-5
Required moment of inertia	I_s	81.38 in ⁴
Required moment of inertia	I'_s	104.5 in ⁴
Length of support	$0.55 \cdot \sqrt{(D \cdot t_s)}$	8.856 in
Available moment of inertia	I'	in ⁴

Remark

Equations

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

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

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

$$R_s = R_L - L_C \cdot \sin(\alpha) = 1951 \text{ mm} - 2129 \text{ mm} \cdot 0.359 = 1172 \text{ mm}$$

$$M = \frac{-R_L \cdot \tan(\alpha)}{2} + \frac{L_L}{2} + \frac{R_L^2 - R_s^2}{3 \cdot R_L \cdot \tan(\alpha)} = \frac{-1951 \text{ mm} \cdot 0.3846}{2} + \frac{18593 \text{ mm}}{2} + \frac{(1951 \text{ mm})^2 - (1172 \text{ mm})^2}{3 \cdot 1951 \text{ mm} \cdot 0.3846} = 10002 \text{ mm}$$

App. 1-8 b-3) Step 1

$$F_L = P_0 \cdot M + f_1 \cdot \tan(\alpha) = 1.014 \text{ bar} \cdot 10002 \text{ mm} + 87.06 \text{ N/mm} \cdot 0.3846 = 1047 \text{ N/mm}$$

App. 1-8 b-3) Step 1

$$A_{TL} = L_L \cdot \frac{t_s}{2} + L_C \cdot \frac{t_c}{2} + A_s = 18593 \text{ mm} \cdot \frac{42.86 \text{ mm}}{2} + 2129 \text{ mm} \cdot \frac{46.04 \text{ mm}}{2} + 0 \text{ mm}^2 = 447474 \text{ mm}^2$$

App. 1-8 a)

$$B = \frac{3}{4} \cdot \frac{F_L \cdot D_L}{A_{TL}} = \frac{3}{4} \cdot \frac{1047 \text{ N/mm} \cdot 3902 \text{ mm}}{447474 \text{ mm}^2} = 6.849 \text{ N/mm}^2$$

App. 1-8 b-3) Step 1

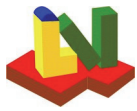
$$I_s = A \cdot D_L^2 \cdot \frac{A_{TL}}{14} = 6.96e-5 \cdot (3902 \text{ mm})^2 \cdot \frac{447474 \text{ mm}^2}{14} = 3.387e+7 \text{ mm}^4$$

App. 1-8 b-3) Step 6

$$I'_s = A \cdot D_L^2 \cdot \frac{A_{TL}}{10.9} = 6.96e-5 \cdot (3902 \text{ mm})^2 \cdot \frac{447474 \text{ mm}^2}{10.9} = 4.35e+7 \text{ mm}^4$$

App. 1-8 b-3) Step 6

$$0.55 \cdot \sqrt{(D \cdot t_s)} = 0.55 \cdot \sqrt{(3902 \text{ mm} \cdot 42.86 \text{ mm})} = 224.9 \text{ mm}$$



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Example E4.4.7 - E4.4.8 PTB-4-2023

E 4.4.7 Small End - Formed heads pressure under external pressure - ASME BPVC VIII-1 UG-33 & Appendix-1: 2023

Area at the small end of a cone-cylinder-juncture without knuckle

Type of stiffener

No stiffener

External design pressure

p_D 14.7 psi

Hydrostatic head

D_p 0 psi

Calculation pressure

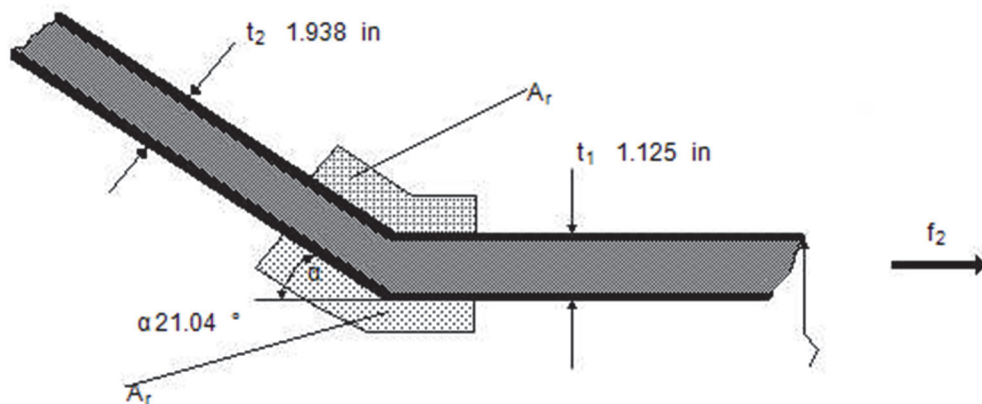
p_0 14.7 psi

Calculation temperature

T_0 300 °F

Axial additional load as line load (positive for tension) e.g. wind load, dead weight, traffic load, etc. but no loads resulting from internal / external pressure

f_2 913 lbf/in



Cylinder

Final wall thickness

t_1 1.125 in

Wall thickness allowance

c_1 0 in

Allowance (corrosion)

c_2 0.125 in

Final thickness without allowances

t_s 1 in

Outside diameter

D_S 92.25 in

Tip radius ($=D_S/2$)

R_S 46.12 in

Required thickness without allowances (UG-28)

t_{1r} 0.6718 in

Required thickness with allowances (UG-28)

t_{1r+} 0.7968 in

Joint efficiency factor

E_1 1

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

Allowable stress

S_s 20015 psi

Modulus of elasticity

E_s 2.9e+7 psi

Cone

Final wall thickness

t_2 1.938 in

Wall thickness allowance

c_1 0 in

Allowance (corrosion)

c_2 0.125 in

Final thickness without allowances

t_c 1.813 in

Semi aperture angle ($\leq 60^\circ$)

α 21.04 °

Required thickness without allowances (UG-33)

t_{2r} 0.3639 in

Required thickness with allowances (UG-33)

t_{2r+} 0.4889 in

Joint efficiency factor

E_2 1

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

Allowable stress

S_c 20015 psi

Modulus of elasticity

E_c 2.9e+7 psi

Stiffening ring

Material

Actual cross section of the stiffener

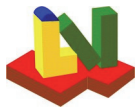
A_r in²

Allowable stress

S_r psi

Modulus of elasticity

E_r psi



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Example E4.4.7 - E4.4.8 PTB-4-2023

Results

Factor	k	1 ≥ 1
Effective load	Q_S	1252 lbf/in
Cross sectional area	A_{rS}	1.11 in ²
Effective area	A_{eS}	12.4 in ²
Required cross section of the stiffener	A_{req}	0 in ²
Remark		

Equations

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

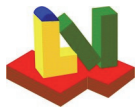
$$\tan(\alpha) = \tan(\alpha) = \tan(21.04^\circ) = 0.3846$$

$$Q_S = P_0 \cdot \frac{R_S}{2} + f_2 = 1.014 \text{ bar} \cdot \frac{1172 \text{ mm}}{2} + 159.9 \text{ N/mm} = 219.3 \text{ N/mm}$$

$$A_{rS} = \frac{k \cdot Q_S \cdot R_S \cdot \tan(\alpha)}{S_s \cdot E_1} = \frac{1 \cdot 219.3 \text{ N/mm} \cdot 1172 \text{ mm} \cdot 0.3846}{138 \text{ N/mm}^2 \cdot 1} = 716 \text{ mm}^2 \quad (3)$$

$$A_{eS} = 0.55 \cdot \sqrt{D_S \cdot t_s} \cdot \left[\frac{t_s - t + (t_c - t_r)}{\cos(\alpha)} \right] = \quad (4)$$

$$0.55 \cdot \sqrt{2343 \text{ mm} \cdot 25.4 \text{ mm}} \cdot \left[\frac{25.4 \text{ mm} - 17.06 \text{ mm} + (46.05 \text{ mm} - 9.242 \text{ mm})}{0.9333} \right] = 8002 \text{ mm}^2$$



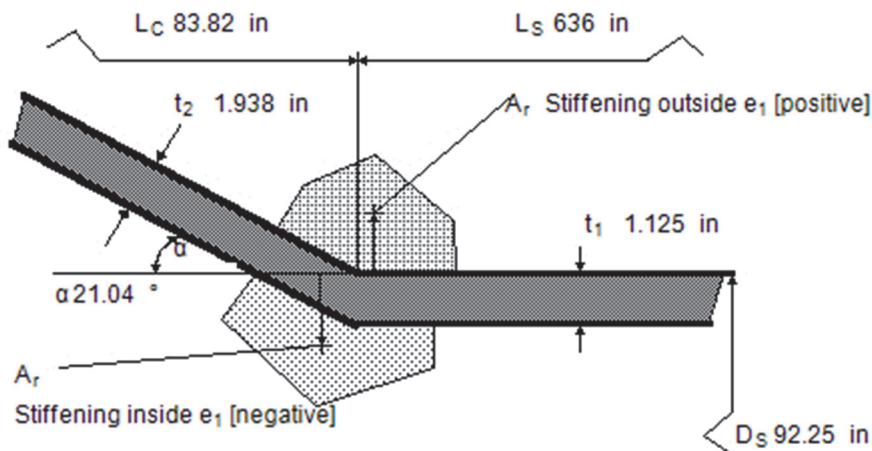
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Example E4.4.7 - E4.4.8 PTB-4-2023

E 4.4.7 Small End/Line-of-support - Formed heads pressure under external pressure - ASME BPVC VIII-1 UG-33 & Appendix-1: 2023

Moment of inertia at the small end of a cone-cylinder-juncture under external pressure acc. App.1-8 (Line-of-support)

External design pressure	p_D	14.7 psi
Hydrostatic head	D_p	0 psi
Calculation pressure	p_0	14.7 psi
Calculation temperature	T_0	300 °F
Axial additional load as line load (positive for tension) e.g. wind load, dead weight, traffic load, etc. but no loads resulting from internal / external pressure	f_2	913 lbf/in



Cylinder

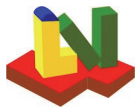
Final wall thickness	t_1	1.125 in
Wall thickness allowance	c_1	0 in
Allowance (corrosion)	c_2	0.125 in
Final thickness without allowances	t_s	1 in
Required thickness without allowances (UG-28)	t_{1r}	0.6718 in
Required thickness with allowances (UG-28)	t_{1r+}	0.7968 in
Outside diameter	D_S	92.25 in
Tip radius ($=D_S/2$)	R_S	46.12 in
Buckling length	L_S	636 in

Cone

Final wall thickness	t_2	1.938 in
Wall thickness allowance	c_1	0 in
Allowance (corrosion)	c_2	0.125 in
Final thickness without allowances	t_c	1.813 in
Required thickness without allowances (UG-33)	t_{2r}	0.3639 in
Required thickness with allowances (UG-33)	t_{2r+}	0.4889 in
Semi-apex angle ($\leq 60^\circ$)	α	21.04 °
Buckling length	L_C	83.82 in

Stiffening ring

Material	K02700-SA-516-70-Class:-Size:	
Spec. Min. Yield	S_y	2.9e+7 psi
Applicable material chart	Fig	CS-2
Radial distance between the centroid of the stiffening ring and the outer surface of the cylinder	e_1	in
Cross sectional area	A_r	0 in ²
Moment of inertia	I_r	in ⁴



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Example E4.4.7 - E4.4.8 PTB-4-2023

Results

Equivalent length	N	362.3 in
Effective load	F _S	5677 lbf/in
Reference area	A _{TS}	394 in ²
Factor	B	997 psi
Factor (see material chart)	A	6.998e-5
Required moment of inertia	I _s	16.76 in ⁴
Required moment of inertia	I' _s	21.53 in ⁴
Length of support	0.55 · √(D · t _s)	5.283 in
Available moment of inertia	I'	in ⁴

Remark

Equations

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

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

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

$$R_s = R_L - L_C \cdot \sin(\alpha) = 1952 \text{ mm} - 2129 \text{ mm} \cdot 0.359 = 1172 \text{ mm}$$

$$N = \frac{R_s \cdot \tan(\alpha)}{2} + \frac{L_s}{2} + \frac{RL^2 - RS^2}{6 \cdot R_s \cdot \tan(\alpha)} =$$

$$\frac{1172 \text{ mm} \cdot 0.3846}{2} + \frac{16154 \text{ mm}}{2} + \frac{(1952 \text{ mm})^2 - (1172 \text{ mm})^2}{6 \cdot 1172 \text{ mm} \cdot 0.3846} = 9203 \text{ mm}$$

$$994.3 \text{ N/mm} = 1.014 \text{ bar} \cdot 9203 \text{ mm} + 159.9 \text{ N/mm} \cdot 0.3846$$

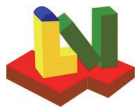
$$A_{TS} = L_s \cdot \frac{t_s}{2} + L_C \cdot \frac{t_c}{2} + A_s = 16154 \text{ mm} \cdot \frac{25.4 \text{ mm}}{2} + 2129 \text{ mm} \cdot \frac{46.05 \text{ mm}}{2} + 0 \text{ mm}^2 = 254182 \text{ mm}^2$$

$$B = \frac{3}{4} \cdot \frac{F_s \cdot D_s}{A_{TS}} = \frac{3}{4} \cdot \frac{994.3 \text{ N/mm} \cdot 2343 \text{ mm}}{254182 \text{ mm}^2} = 6.874 \text{ N/mm}^2$$

$$I_s = \frac{A \cdot DS^2 \cdot A_{TS}}{14} = \frac{6.998e-5 \cdot (2343 \text{ mm})^2 \cdot 254182 \text{ mm}^2}{14} = 6975754 \text{ mm}^4$$

$$I'_s = \frac{A \cdot DS^2 \cdot A_{TS}}{10.9} = \frac{6.998e-5 \cdot (2343 \text{ mm})^2 \cdot 254182 \text{ mm}^2}{10.9} = 8959684 \text{ mm}^4$$

$$0.55 \cdot \sqrt{(D \cdot t_s)} = 0.55 \cdot \sqrt{(D \cdot 25.4 \text{ mm})} = 134.2 \text{ mm}$$



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Example E4.4.7 - E4.4.8 PTB-4-2023

E 4.4.8 Large and Small End - Formed heads pressure under external pressure - ASME BPVC VIII-1 UG-33 & Appendix-1: 2023

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

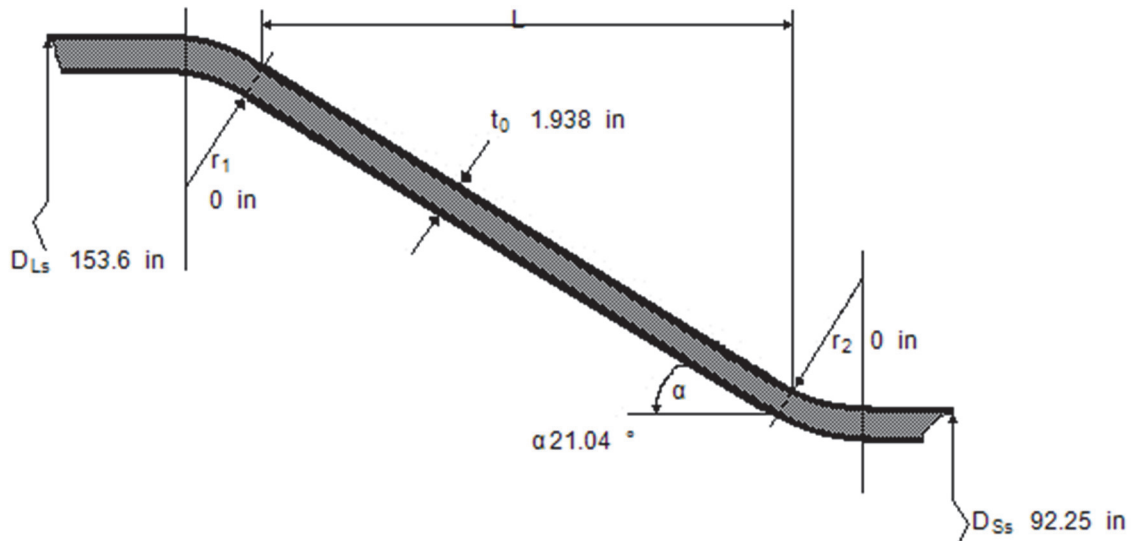
External design pressure
Hydrostatic head
Calculation pressure
Calculation temperature

p_D 14.7 psi
 D_p 0 psi
 p_0 14.7 psi
 T_0 300 °F

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

Spec. Min. Yield
Allowable stress
Applicable material chart
Modulus of elasticity

S_y 37710 psi
 S_0 20015 psi
Fig CS-2
 E 2.9e+7 psi



Cone wall thickness with allowances
Wall thickness allowance
Allowance (corrosion)
Cone wall thickness without allowances

t_0 1.938 in
 c_1 0 in
 c_2 0.125 in
 t 1.813 in

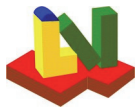
Is a cylinder connected, which does not act as line of support?

N (Y/N)

Outside diameter (wide end)
Knuckle radius (wide end)
Outside diameter (small end)
Knuckle radius (small end)
Half apex angle ($\leq 60^\circ$)

D_{Ls} 153.6 in
 r_1 0 in
 D_{Ss} 92.25 in
 r_2 0 in
 α 21.04 °

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



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Example E4.4.7 - E4.4.8 PTB-4-2023

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	0.3664 in
Required thickness incl. allowances		$t+c_1+c_2$	0.4914 in

Remark

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 $D_L/t_0 \geq 10$

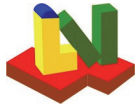
$$Pa(B) = \frac{4 \cdot B}{3 \cdot \left(\frac{D_L}{t_0} \right)} = \frac{4 \cdot 116.2 \text{ N/mm}^2}{3 \cdot 90.81} = 1.706 \text{ N/mm}^2$$

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 $D_L/t_0 < 10$



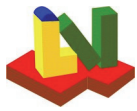
ASME BPVC VIII-1 2021
Example E4.4.7 - E4.4.8 PTB-4-2023

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

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



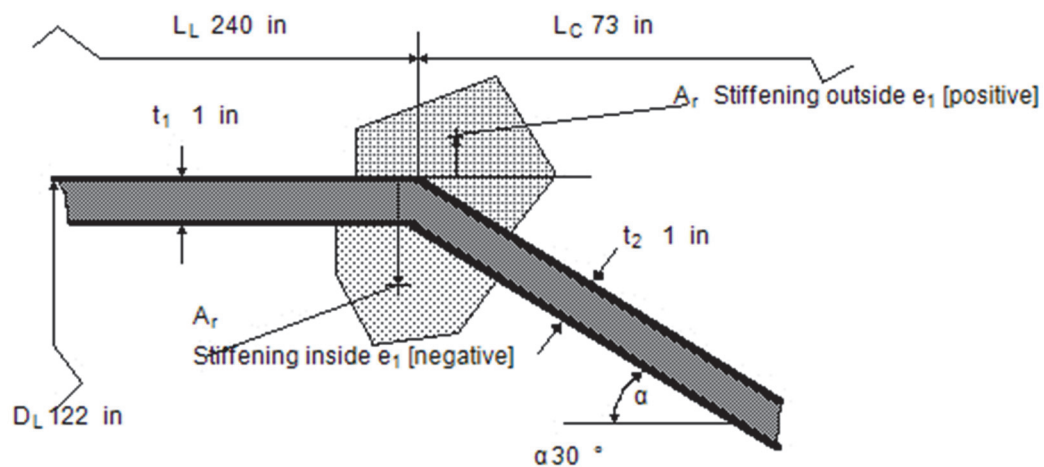
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Example E4.4.7 - E4.4.8 PTB-4-2023

E 4.4.8 Large End/Line-of-support - Formed heads pressure under external pressure - ASME BPVC VIII-1 UG-33 & Appendix-1: 2023

Moment of inertia at the wide end of a cone-cylinder-juncture under external pressure acc. App. 1-8 (Line-of-support)

External design pressure	p_D	14.7 psi
Hydrostatic head	D_p	0 psi
Calculation pressure	p_0	14.7 psi
Calculation temperature	T_0	300 °F
Axial additional load as line load (positive for tension) e.g. wind load, dead weight, traffic load, etc. but no loads resulting from internal / external pressure	f_1	145 lbf/in



Cylinder

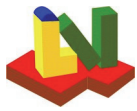
Design wall thickness	t_1	1 in
Wall thickness allowance	c_1	0 in
Allowance (corrosion)	c_2	0 in
Final thickness without allowances	t_s	1 in
Required thickness without allowances (UG-28)	t_{1r}	0.5205 in
Required thickness with allowances (UG-28)	t_{1r+}	0.5205 in
Outside diameter	D_L	122 in
Tip radius ($=D_L/2$)	R_L	61 in
Buckling length	L_L	240 in

Cone

Design wall thickness	t_2	1 in
Wall thickness allowance	c_1	0 in
Allowance (corrosion)	c_2	0 in
Final thickness without allowances	t_c	1 in
Required thickness without allowances (UG-33)	t_{2r}	0.3358 in
Required thickness with allowances (UG-33)	t_{2r+}	0.3358 in
Half apex angle ($\leq 60^\circ$)	α	30 °
Buckling length	L_C	73 in

Stiffening ring

Material	K02700-SA-516-70-Class:-Size:	
Spec. Min. Yield	S_y	2.9e+7 psi
Applicable material chart	Fig	CS-2
Radial distance between the centroid of the stiffening ring and the outer surface of the cylinder	e_1	0 in
Cross sectional area	A_r	0 in ²
Moment of inertia	I_r	0 in ⁴



ASME BPVC VIII-1 2021

Example E4.4.7 - E4.4.8 PTB-4-2023

Results

Equivalent length	M	134.7 in
Effective load	F_L	2064 lbf/in
Reference area	A_{TL}	156.5 in ²
Factor	B	1207 psi
Factor (see material chart)	A	8.447e-5
Required moment of inertia	I_s	14.06 in ⁴
Required moment of inertia	I'_s	18.05 in ⁴
Length of support	$0.55 \cdot \sqrt{(D \cdot t_s)}$	6.075 in
Available moment of inertia	I'	18.15 in ⁴

Remark **Stiffening required**

Equations

$$\cos(\alpha) = \cos(30^\circ) = 0.866$$

$$\sin(\alpha) = \sin(30^\circ) = 0.5$$

$$\tan(\alpha) = \tan(30^\circ) = 0.5774$$

$$R_s = R_L - L_C \cdot \sin(\alpha) = 1549 \text{ mm} - 1854 \text{ mm} \cdot 0.5 = 445 \text{ mm}$$

$$M = \frac{-R_L \cdot \tan(\alpha)}{2} + \frac{L_L}{2} + \frac{R_L^2 - R_s^2}{3 \cdot R_L \cdot \tan(\alpha)} = \frac{-1549 \text{ mm} \cdot 0.5774}{2} + \frac{6096 \text{ mm}}{2} + \frac{(1549 \text{ mm})^2 - (445 \text{ mm})^2}{3 \cdot 1549 \text{ mm} \cdot 0.5774} = 3421 \text{ mm}$$

App. 1-8 b-3) Step 1

$$F_L = P_0 \cdot M + f_1 \cdot \tan(\alpha) = 1.014 \text{ bar} \cdot 3421 \text{ mm} + 25.39 \text{ N/mm} \cdot 0.5774 = 361.4 \text{ N/mm}$$

App. 1-8 b-3) Step 1

$$A_{TL} = L_L \cdot \frac{t_s}{2} + L_C \cdot \frac{t_c}{2} + A_s = 6096 \text{ mm} \cdot \frac{25.4 \text{ mm}}{2} + 1854 \text{ mm} \cdot \frac{25.4 \text{ mm}}{2} + 0 \text{ mm}^2 = 100968 \text{ mm}^2$$

App. 1-8 a)

$$B = \frac{3}{4} \cdot \frac{F_L \cdot D_L}{A_{TL}} = \frac{3}{4} \cdot \frac{361.4 \text{ N/mm} \cdot 3099 \text{ mm}}{100968 \text{ mm}^2} = 8.32 \text{ N/mm}^2$$

App. 1-8 b-3) Step 1

$$I_s = A \cdot D_L^2 \cdot \frac{A_{TL}}{14} = 8.447\text{e-}5 \cdot (3099 \text{ mm})^2 \cdot \frac{100968 \text{ mm}^2}{14} = 5850143 \text{ mm}^4$$

App. 1-8 b-3) Step 6

$$I'_s = A \cdot D_L^2 \cdot \frac{A_{TL}}{10.9} = 8.447\text{e-}5 \cdot (3099 \text{ mm})^2 \cdot \frac{100968 \text{ mm}^2}{10.9} = 7513945 \text{ mm}^4$$

App. 1-8 b-3) Step 6

$$0.55 \cdot \sqrt{(D \cdot t_s)} = 0.55 \cdot \sqrt{(3099 \text{ mm} \cdot 25.4 \text{ mm})} = 154.3 \text{ mm}$$