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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

Summary

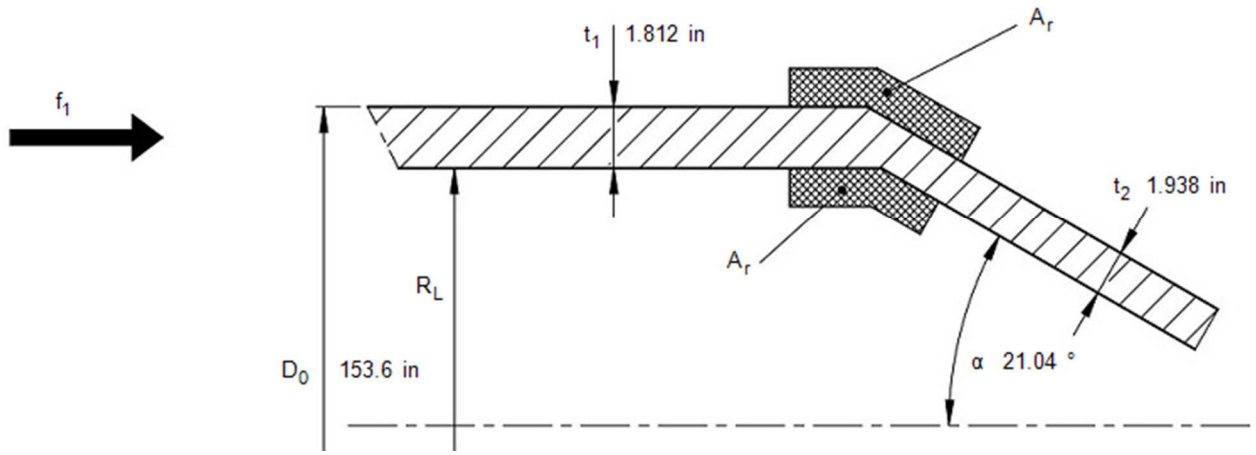
Strength Calculation Software	Program System ATLAS	Version	**8.29.1**
Developed by Lauterbach Verfahrenstechnik GmbH			
Certified per DIN EN ISO 9001:2015	Certificate Number 01 100 044763		

		LV Soft				ASME		Diff [%]
Example E4.3.7 - Conical transition Without a knuckle (large End)								
	Req. cylinder thickness t	37,48	mm	1,48	in	1,48	in	**0,08%**
	Req. cone thickness tr	39,93	mm	1,57	in	1,57	in	**0,08%**
Example E4.3.7 - Conical transition Without a knuckle (Smal End)					in			
	Req. cylinder thickness t	23,78	mm	0,94	in	0,94	in	**0,07%**
	Req. cone thickness tr	25,25	mm	0,99	in	0,99	in	**0,07%**
	Required area Ars	2.087,34	mm^2	3,24	in^2	3,24	in^2	**0,03%**
	Required area Aes	4.054,38	mm^2	6,28	in^2	6,28	in^2	**0,11%**
Example E4.3.8 - Conical transition With a knuckle								
	Req. knuckle thickness t	17,20	mm	0,68	in	0,68	in	**0,07%**
	Req. cone thickness tr	24,74	mm	0,97	in	0,97	in	**0,08%**

E4.3.7 Large End - Cone-to-cylinder junction at large end under internal pressure - ASME BPVC VIII-1 UG-32 & Appendix-1: 2017

Cone-to-cylinder junction (wide end)

Type of reinforcing ring			
(0 = no, 1 = at the cylinder, 2 = at the cone)		0	
Without stiffener			
Design pressure	p_D	24.55	bar
Hydrostatic head	D_p	0	bar
Calculation pressure	p_0	**356**	psi
Calculation temperature	T_0	148.9	°C
Axial load based on circumference (for compression negative)	f_1	0	lbf/in



Cylinder

Outside diameter		D_0	153.6	in
Final wall thickness		t_1	1.812	in
Material	K02700-SA-516-70-Class:-Size:			
Wall thickness allowance		c_1	0	in
Allowance (corrosion)		c_2	0.125	in
Thickness without allowances		t_s	**1.687**	in
Inside radius	(= $D_0/2-t_s$)	R_L	**75.12**	in
Allowable stress		S_s	20015	psi
Modulus of elasticity		E_s	2.829e+7	psi
Joint efficiency factor		E_1	1	

Cone

Half-apex angle (≤30°)		α	21.04	°
Final wall thickness		t_2	1.938	in
Material	K02700-SA-516-70-Class:-Size:			
Wall thickness allowance		c_1	0	in
Allowance (corrosion)		c_2	0.125	in
Effective thickness		t_c	**1.813**	in
Allowable stress		S_c	20015	psi
Modulus of elasticity		E_c	2.829e+7	psi
Joint efficiency factor		E_2	1	

Results

Geometrical conditions
valid

Strength condition
Wall thickness acceptable

Factor				k	**1**	
Ratio			P_0/S_sE_1		**0.01779**	
Angle	(Reinforcement required if Δ < α	21.04 °	)	Δ	**30**	°
Effective load				Q_L	**13371**	lbf/in
Required thickness cylinder (UG-27)				t	**1.351**	in
with allowances	(t_1	1.812 in	≥t+)	t+	**1.476**	in
Required thickness cone (UG-32)				t_r	**1.447**	in
with allowances	(t_2	1.938 in	≥t_r+)	t_r+	**1.572**	in
Required cross sectional area				A_{rL}	**0**	in²
Available cross section				A_{eL}	**8.209**	in²
Required area of reinforcement				A_r	**0**	in²
Available area of reinforcement			$b_v \cdot t_v$	A_v	**0**	in²
Maximum distance from the connection point of the						
complete reinforcing area			$\sqrt{[R_L \cdot t_s]}$		**11.26**	in
centroid of reinforcing area			$0.25 \cdot \sqrt{[R_L \cdot t_s]}$		**2.815**	in

Equations

$cos(\alpha) = cos(\alpha) \Leftrightarrow cos(21.04°) = 0.9333$

$tan(\alpha) = tan(\alpha) \Leftrightarrow tan(21.04°) = 0.3846$

$$Q_L = P_0 \cdot \frac{R_L}{2} + f_1 = 24.55\ \text{bar} \cdot \frac{1908\ \text{mm}}{2} + 0\ \text{N/mm} = 2342\ \text{N/mm}$$

$$A_{rL} = \frac{k \cdot Q_L \cdot R_L}{S_s \cdot E_1} \cdot \left[1 - \frac{D_{el}}{\alpha}\right] \cdot \tan(\alpha) = \frac{1 \cdot 2342\ \text{N/mm} \cdot 1908\ \text{mm}}{138\ \text{N/mm}^2 \cdot 1} \cdot \left[1 - \frac{30°}{21.04°}\right] \cdot 0.3846 = 0\ \text{mm}^2$$

$$t = \frac{P_0 \cdot R_L}{S_s \cdot E_1 - 0.6 \cdot P_0} = \frac{24.55\ \text{bar} \cdot 1908\ \text{mm}}{138\ \text{N/mm}^2 \cdot 1 - 0.6 \cdot 24.55\ \text{bar}} = 34.3\ \text{mm}$$

$$t_r = \frac{P_0 \cdot \frac{R_L}{\cos(\alpha)}}{S_c \cdot E_2 - 0.6 \cdot P_0} = \frac{24.55\ \text{bar} \cdot \frac{1908\ \text{mm}}{0.9333}}{138\ \text{N/mm}^2 \cdot 1 - 0.6 \cdot 24.55\ \text{bar}} = 36.75\ \text{mm}$$

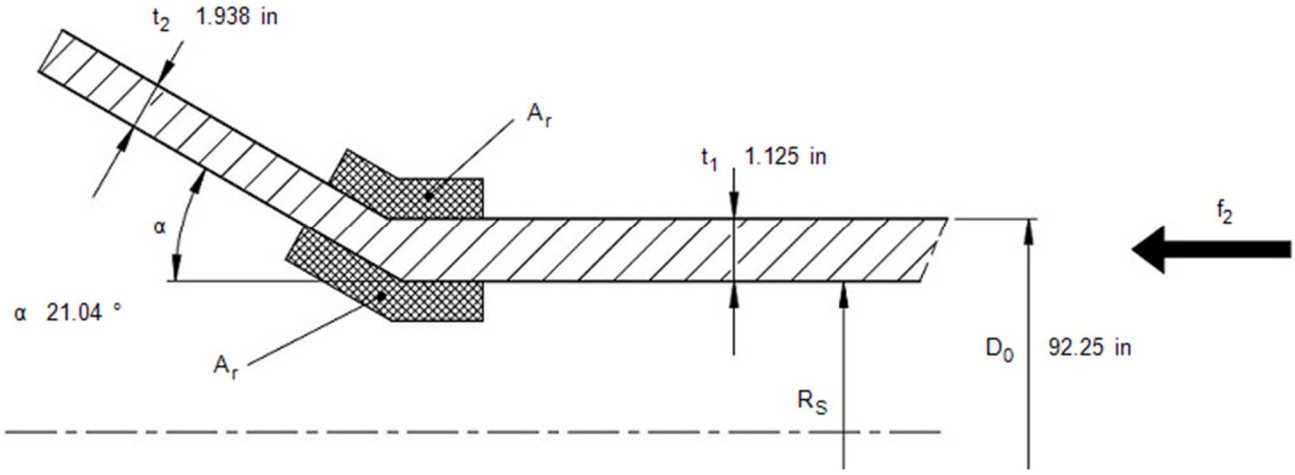
$$A_{eL} = (t_s - t) \cdot \sqrt{R_L \cdot t_s} + (t_c - t_r) \cdot \sqrt{R_L \cdot \frac{t_c}{\cos(\alpha)}} =$$

$$(42.86\ \text{mm} - 34.3\ \text{mm}) \cdot \sqrt{1908\ \text{mm} \cdot 42.86\ \text{mm}} + (46.04\ \text{mm} - 36.75\ \text{mm}) \cdot \sqrt{1908\ \text{mm} \cdot \frac{46.04\ \text{mm}}{0.9333}} = 5296\ \text{mm}^2$$

E4.3.7 Small End - Cone-to-cylinder junction at small end under internal pressure - ASME BPVC VIII-1 UG-32 & Appendix-1: 2017

Cone-to-cylinder junction (small end)

Type of reinforcing ring			
(0 = no, 1 = at the cylinder, 2 = at the cone)		0	
Without stiffener			
Design pressure	p_D	24.55	bar
Hydrostatic head	D_p	0	bar
Calculation pressure	p_0	**356**	psi
Calculation temperature	T_0	148.9	°C
Axial load based on circumference (for compression negative)	f_2	396.9	lbf/in



Cylinder

Outside diameter		D_0	92.25	in
Final wall thickness		t_1	1.125	in
Material	K02700-SA-516-70-Class:-Size:			
Wall thickness allowance		c_1	0	in
Allowance (corrosion)		c_2	0.125	in
Effective thickness		t_s	**1**	in
Inside radius	(= $D_0/2-t_s$)	R_S	**45.12**	in
Allowable stress		S_s	20015	psi
Modulus of elasticity		E_s	2.829e+7	psi
Joint efficiency factor		E_1	1	

Cone

Half-apex angle (≤30°)		α	21.04	°
Final wall thickness		t_2	1.938	in
Material	K02700-SA-516-70-Class:-Size:			
Wall thickness allowance		c_1	0	in
Allowance (corrosion)		c_2	0.125	in
Thickness without allowances		t_c	**1.813**	in
Allowable stress		S_c	20015	psi
Modulus of elasticity		E_c	2.829e+7	psi
Joint efficiency factor		E_2	1	

Results

Geometrical conditions
valid

Strength condition
Wall thickness acceptable

Factor				k	**1**	
Ratio			P_0/S_sE_1		**0.01779**	
Angle				Δ	**11.73**	°
Effective load				Q_S	**1476**	N/mm
Required thickness cylinder (UG-27)				t	**0.8113**	in
with allowances	(t_1	1.125 in	≥t+)	t+	**0.9363**	in
Required thickness cone (UG-32)				t_r	**0.8692**	in
with allowances	(t_2	1.938 in	≥t_r+)	t_r+	**0.9942**	in
Required cross sectional area				A_{rS}	**3.235**	in²
Available cross section				A_{eS}	**6.284**	in²
Required area of reinforcement				A_r	**0**	in²
Available area of reinforcement			$b_v \cdot t_v$	A_v	**0**	in²
Maximum distance from the connection point of the						
complete reinforcing area			$\sqrt{[R_L \cdot t_s]}$		**9.044**	in
centroid of reinforcing area			$0.25 \cdot \sqrt{[R_L \cdot t_s]}$		**2.261**	in

Equations

$$cos(\alpha) = cos(\alpha) \Leftrightarrow cos(21.04°) = 0.9333$$

$$tan(\alpha) = tan(\alpha) \Leftrightarrow tan(21.04°) = 0.3846$$

$$QS = P0 \cdot \frac{RS}{2} + f2 = 24.55\ \text{bar} \cdot \frac{1146\ \text{mm}}{2} + 69.5\ \text{N/mm} = 1476\ \text{N/mm}$$

$$ArS = \frac{k \cdot QS \cdot RS}{SS \cdot E1} \cdot \left[1 - \frac{Del}{\alpha}\right] \cdot tan(\alpha) = \frac{1 \cdot 1476\ \text{N/mm} \cdot 1146\ \text{mm}}{138\ \text{N/mm}^2 \cdot 1} \cdot \left[1 - \frac{11.73°}{21.04°}\right] \cdot 0.3846 = 2087\ \text{mm}^2$$

$$t = \frac{P0 \cdot RS}{Ss \cdot E1 - 0.6 \cdot P0} = \frac{24.55\ \text{bar} \cdot 1146\ \text{mm}}{138\ \text{N/mm}^2 \cdot 1 - 0.6 \cdot 24.55\ \text{bar}} = 20.61\ \text{mm}$$

$$tr = \frac{P0 \cdot \frac{RS}{(cos(\alpha))}}{Sc \cdot E2 - 0.6 \cdot P0} = \frac{24.55\ \text{bar} \cdot \frac{1146\ \text{mm}}{0.9333}}{138\ \text{N/mm}^2 \cdot 1 - 0.6 \cdot 24.55\ \text{bar}} = 22.08\ \text{mm}$$

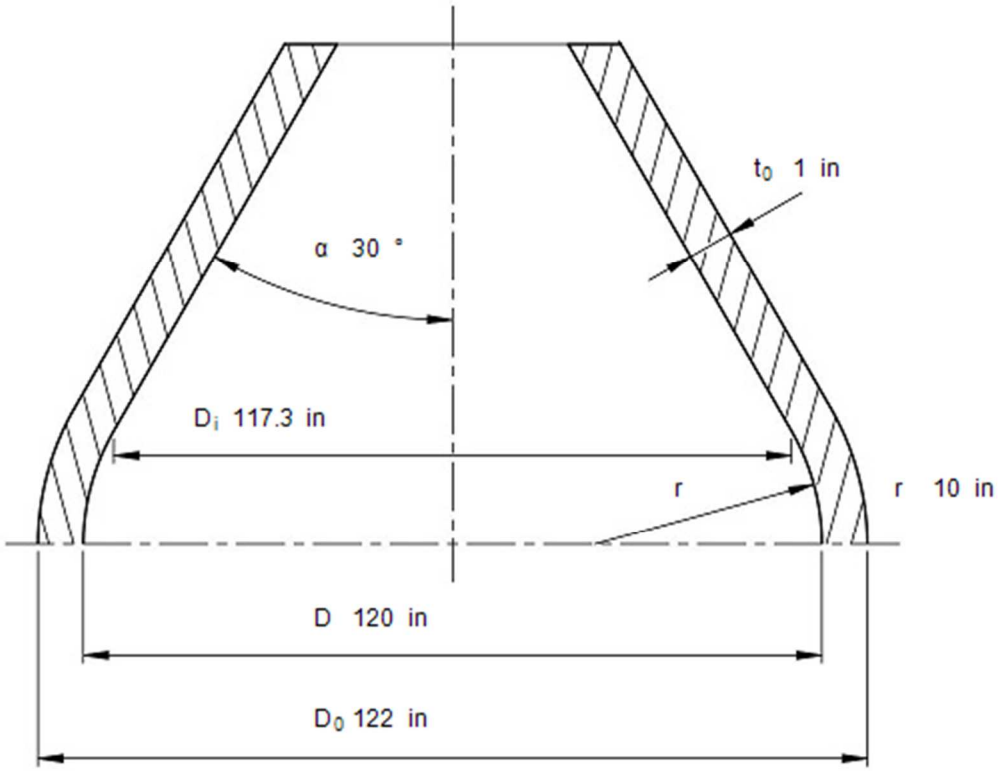
$$AeS = 0.78 \cdot \sqrt{RS \cdot ts} \cdot \left[(ts - t) + \frac{(tc - tr)}{cos(\alpha)}\right] =$$

$$0.78 \cdot \sqrt{1146\ \text{mm} \cdot 25.4\ \text{mm}} \cdot \left[(25.4\ \text{mm} - 20.61\ \text{mm}) + \frac{(46.04\ \text{mm} - 22.08\ \text{mm})}{0.9333}\right] = 4054\ \text{mm}^2$$

E4.3.8 - Cone with knuckle under internal pressure - ASME BPVC VIII-1 UG-32 & Appendix-1: 2017

Toriconical sections

Design pressure	p_D	19.68	bar
Hydrostatic head	D_p	0	bar
Calculation pressure	p_0	**285.4**	psi
Calculation temperature	T_0	148.9	°C
Final wall thickness	t_e	1	in
Wall thickness allowance	c_1	0	in
Allowance (corrosion)	c_2	0	in
Effective thickness without allowances	t_0	**1**	in



Outside diameter of cylindrical shell		D_0	122	in
Inside diameter of cylindrical shell	(= D_0-2t_0)	D	**120**	in
Semi-apex angle		α	30	°
Knuckle radius (≥0.06·D_0, ≥3·t_e)		r	10	in
Weld joint efficiency factor		E	1	
Material	K02700-SA-516-70-Class:-Size:			
Allowable stress		S	**20015**	psi

Calculation

Largest inside diameter of cone		D_i	**117.3**	in
Equivalent radius		L	**67.74**	in
Ratio		L/r	**6.774**	
Factor		M	**1.401**	
Required knuckle thickness		t	**0.6773**	in
Allowable inside pressure of knuckle		P	**421**	psi
Calculation diameter of cone		D_1	**117.3**	in
Required cone thickness at D_1		t_1	**0.9741**	in
Allowable inside pressure of cone		P_1	**292.9**	psi
Remark				
Required thickness incl. allowances	$t+c_1+c_2$	t+	**0.9741**	in
Allowable excess pressure	Min(P, P_1)	P_m	**292.9**	psi
Allowable excess pressure without hydr. Head		MAWP	**292.9**	psi

Geometrical conditions

valid

Strength condition

Wall thickness acceptable

Equations knuckle

$cos(\alpha)=cos(\alpha) \Leftrightarrow cos(30°)=0.866$

$$D_i = D - 2 \cdot r \cdot (1-\cos(\alpha)) = 3048\ \text{mm} - 2 \cdot 254\ \text{mm} \cdot (1-0.866) = 2980\ \text{mm}$$

$$L = \frac{D_i}{2 \cdot \cos(\alpha)} = \frac{2980\ \text{mm}}{2 \cdot 0.866} = 1720\ \text{mm}$$

$$t = \frac{P_0 \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P_0} = \frac{19.68\ \text{bar} \cdot 1720\ \text{mm} \cdot 1.401}{2 \cdot 138\ \text{N/mm}^2 \cdot 1 - 0.2 \cdot 19.68\ \text{bar}} = 17.2\ \text{mm}$$

$$P = \frac{2 \cdot S \cdot E \cdot t_0}{L \cdot M + 0.2 \cdot t_0} = \frac{2 \cdot 138\ \text{N/mm}^2 \cdot 1 \cdot 25.4\ \text{mm}}{1720\ \text{mm} \cdot 1.401 + 0.2 \cdot 25.4\ \text{mm}} = 2.903\ \text{MPa}$$

Equations cone

$$t_1 = \frac{P_0 \cdot D_1}{2 \cdot \cos(\alpha) \cdot (S \cdot E - 0.6 \cdot P_0)} = \frac{19.68\ \text{bar} \cdot 2980\ \text{mm}}{2 \cdot 0.866 \cdot (138\ \text{N/mm}^2 \cdot 1 - 0.6 \cdot 19.68\ \text{bar})} = 24.74\ \text{mm}$$

$$P = \frac{2 \cdot S \cdot E \cdot t_0 \cdot \cos(\alpha)}{D_1 + 1.2 \cdot t_0 \cdot \cos(\alpha)} = \frac{2 \cdot 138\ \text{N/mm}^2 \cdot 1 \cdot 25.4\ \text{mm} \cdot 0.866}{2980\ \text{mm} + 1.2 \cdot 25.4\ \text{mm} \cdot 0.866} = 2.019\ \text{MPa}$$

Appendix: Material documentation

Section 1: Zylinder/E4.3.7 Large End
Section 1: Kegel/E4.3.7 Large End
Section 2: Zylinder/E4.3.7 Small End
Section 2: Kegel/E4.3.7 Small End
Section 3: Boden/E4.3.8

Material specification:

Regulation: ASMET1A:2017Spec. No.: SA-516 Product: Plate
Material code: K02700-SA-516-70-Class:-Size: Short name: Carbon steel

Design conditions and dimensions:

Temperature [°C]: 148,8889 Pressure [bar]: 0
Thickness [mm]: 46,0375 Outside diameter [mm]: 3901,757

Material values for test and design conditions:

	Test condition	Operating condition
Nominal design strength [N/mm²]:	138.00	138.00
Safety factor:		
Allowable stress [N/mm²]:	138.00	138.00
Modulus of elasticity [kN/mm²]:	202,35	195,0667

Wall thickness tolerance [mm]: 0.00 acc. to SA-516
Notes:
G10 General Requirements
Upon prolonged exposure to temperatures above 425°C, the carbide phase of carbon steel may be converted to graphite. See Nonmandatory Appendix A, A–201 and A–202.

S1 Size Requirements
For Section I applications, stress values at temperatures of 450°C and above are permissible but, except for tubular products 75 mm O.D. or less enclosed within the boiler setting, use of these materials at these temperatures is not current practice.

T2 Time-Dependent Properties
Allowable stresses for temperatures of 400°C and above are values obtained from time–dependent properties.

--
Creep rupture strength for 100000 h [MPa]:

Tensile strength and yield stress at ambient temperature:

Diam./ Thick. <= mm	Tensile str. Rm min MPa	Rm max MPa	ReH MPa	Rupture elong. lngt. %	Rupture elong. lat. %

K-values as function of the temperature

Diam./ Thickn. <= mm	50°C MPa	100°C MPa	150°C MPa	200°C MPa	250°C MPa	300°C MPa	350°C MPa	400°C MPa
		138	138	138	138	136	128	101

K-values as function of the temperature

Diam./ Thickn. <= mm	450°C MPa	500°C MPa	550°C MPa	600°C MPa	650°C MPa	700°C MPa	800°C MPa
	67.1	33.6	12.9				

Modulus of elasticity in dependence of the temperature:

Static modulus of elasticity in [kN/mm²] at the temperature of

-75	-200	-125	25	100	150	200	250	300	350	400	450	500	550
209	216	212	202	198	195	192	189	185	179	171	162	151	137

Coefficient of linear expansion:

Thermal coefficient of expansion between 20°C and

Density (20 °C) kg/dm³	100°C 10E-6/K	200°C 10E-6/K	300°C 10E-6/K	400°C 10E-6/K	500°C 10E-6/K	600°C 10E-6/K	700°C 10E-6/K	800°C 10E-6/K	Heat cond. W/Km	Heat capac. J/kgK
7.85	12,1	12,7	13,3	13,8	14,4	14.8	15.1	15.4		