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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

Comparison - Form for equations

Equation form

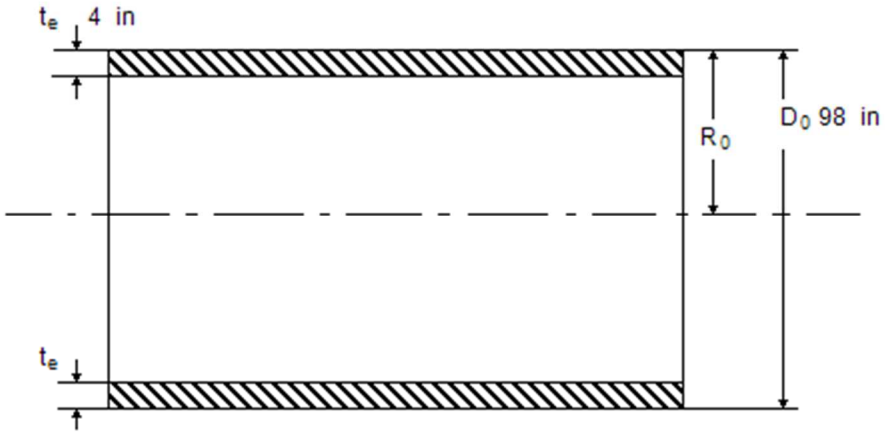
Comment
Results for example E4.3 acc. ASME and Lauterbach Verfahrenstechnik GmbH (LV)
The LV-program uses formulas for thick Shells acc.ASME VIII Div.1 UG27/32 and App.1.

Equations		Value
Conversion factor	mm2in = 0.03937	**0.03937**
.	MPa2psi = 145.037	**145**
'Results Ex. E4.3.1 LV and ASME		**0**
Required thickness t acc. LV	t1 = mm2in*#6(1)	**0.8119**
Required thickness tc ASME	tc1Asme = 0.8119	**0.8119**
Difference in %	Diff1 = (t1-tc1Asme)/tc1Asme*100	**-6.9e-4**
'Results Ex. E4.3.2 LV and ASME		**0**
Required thickness acc. LV	t2 = mm2in*#15(7)	**1.446**
Required thickness ASME	tc2Asme = 1.448	**1.448**
Difference in %	Diff2 = (t2-tc2Asme)/tc2Asme*100	**-0.1055**
'Results Ex. E4.3.3 LV and ASME		**0**
Required thickness t acc. LV	t3 = mm2in*#25(8)	**3.726**
Required thickness tc ASME	tc3Asme = 3.726	**3.726**
Difference in %	Diff3 = (t3-tc3Asme)/tc3Asme*100	**0.01141**
'Results Ex. E4.3.4 LV and ASME		**0**
Allowable Pressure P acc. LV	P4 = MPa2psi*#16(5)	**135.4**
Allowable Pressure P ASME	P4Asme = 135.302	**135.3**
Difference in %	Diff4 = (P4-P4Asme)/P4Asme*100	**0.0861**
'Results Ex. E4.3.5 LV and ASME		**0**
Allowable Pressure P acc. LV	P5 = MPa2psi*#16(9)	**442.6**
Allowable Pressure P ASME	P5Asme = 442.233	**442.2**
Difference in %	Diff5 = (P5-P5Asme)/P5Asme*100	**0.07557**
'Maximum difference between LV and ASME		**0**
Dmax = Max(|Diff1|;|Diff2|;|Diff3|;|Diff4|;|Diff5|)		**0.1055**

E4.3.1 - Thickness of shells under internal pressure ASME BPVC VIII UG-27 & APPENDIX-1, 2017 Edition

Cylindrical shells

Design pressure	p_D	356	psi
Hydrostatic head	D_p	0	psi
Calculation pressure	p_0	**356**	psi
Calulation temperature	T_0	300	°F



Outside diameter	D_0	98	in
Design wall thickness	t_e	4	in
Wall thickness allowance	c_1	0.125	in
Allowance (corrosion)	c_2	0	in
Weld joint efficiency	E	1	
Circumferential weld joint efficiency for Eq. 2	E_c		

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

Allowable stress	S	20000	psi

Results

Outside radius	R_0	**49**	in
Effective thickness	t_0	**3.875**	in

Calculation as thin shell is applicable				**Yes**	
Required thickness	$t(R_0)$			t(R)	
thin shell acc. UG-27		**0.866**	in	**0.8119**	in
thick shell (not applicable)		**0.8645**	in	**0.8104**	in
Minimum wall thickness acc. UG-16				t_{UG-16} 0.05906	in
Required wall thickness for circumferential seam				t_{long}	in
$t = Max\{Min[t(R);t(R_0)],t_{UG-16}\}$				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}		psi
Allowable excess pressure without hydrostatic head	MAWP	**1633**	psi

For calculation of openings according to UG-37

Required thickness t(E=1) **0.8119** in

Allowable unreinforced opening diameter dA for welded, brazed, and flued connections acc. UG 36(c)3

dA ≤ 89 mm for t ≤10 mm	or	dA ≤ 3 1/2 in for t ≤3/8 in
dA ≤ 60 mm for t > 10 mm	or	dA ≤ 2 3/8 in for t > 3/8 in

For a vessel thickness > 2*t(E=1)+c_1+c_2 , the reinforcement of the vessel alone is sufficient for unreinforced openings, unless additional conditions acc. to UG-37 apply.

Equations

$$P_0 = 0.1 \cdot p_0 = 0.1 \cdot 24.55\ \text{bar} = 24.55\ \text{bar}$$

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

$$t+c1+c2 = t + c_1 + c_2 = 20.62\ \text{mm} + 3.175\ \text{mm} + 0\ \text{mm} = 23.8\ \text{mm}$$

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

1) Thin shell For

$$P_0 \le 0.385 \cdot S \cdot E \Leftrightarrow 24.55\ \text{bar} \le 53.09\ \text{N/mm}^2$$

and

with the inside radius R

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

$$t(R) = \frac{P_0 \cdot R}{S \cdot E - 0.6 \cdot P_0} = \frac{24.55\ \text{bar} \cdot 1146\ \text{mm}}{137.9\ \text{N/mm}^2 \cdot 1 - 0.6 \cdot 24.55\ \text{bar}} = 20.62\ \text{mm} \qquad \text{UG-27 (1)}$$

$$P(R) = \frac{S \cdot E \cdot t_0}{R + 0.6 \cdot t_0} = \frac{137.9\ \text{N/mm}^2 \cdot 1 \cdot 98.42\ \text{mm}}{1146\ \text{mm} + 0.6 \cdot 98.42\ \text{mm}} = 11.26\ \text{MPa} \qquad \text{UG-27 (1)}$$

or with the outside radius R_0

$$t(R_0) = \frac{P_0 \cdot R_0}{S \cdot E + 0.4 \cdot P_0} = \frac{24.55\ \text{bar} \cdot 1245\ \text{mm}}{137.9\ \text{N/mm}^2 \cdot 1 + 0.4 \cdot 24.55\ \text{bar}} = 22\ \text{mm} \qquad \text{App. 1-1 (1)}$$

$$P(R_0) = \frac{S \cdot E \cdot t_0}{R_0 - 0.4 \cdot t_0} = \frac{137.9\ \text{N/mm}^2 \cdot 1 \cdot 98.42\ \text{mm}}{1245\ \text{mm} - 0.4 \cdot 98.42\ \text{mm}} = 11.26\ \text{MPa} \qquad \text{App. 1-1 (1)}$$

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

Longitudinal Stress (Circumferential Joints)

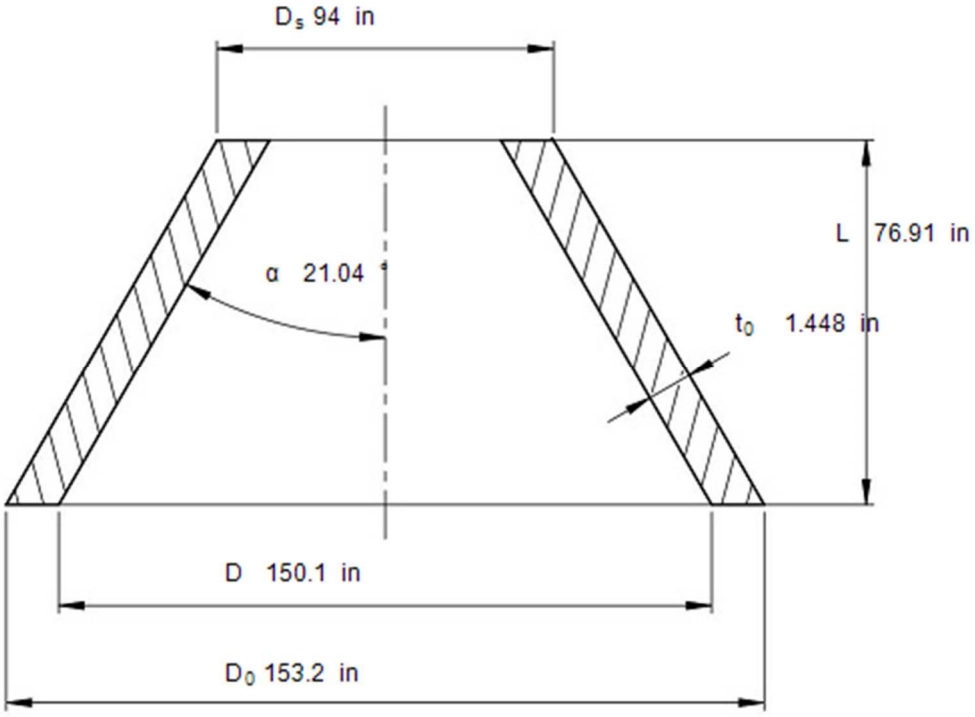
$$t_{long} = \frac{P_0 \cdot R}{2 \cdot S \cdot E_c + 0.4 \cdot P_0} = \frac{24.55\ \text{bar} \cdot 1146\ \text{mm}}{2 \cdot 137.9\ \text{N/mm}^2 \cdot E_c + 0.4 \cdot 24.55\ \text{bar}} = t_{long} \qquad \text{UG-27 (2)}$$

$$P_{long} = \frac{2 \cdot S \cdot E_c \cdot t_0}{R - 0.4 \cdot t_0} = \frac{2 \cdot 137.9\ \text{N/mm}^2 \cdot E_c \cdot 98.42\ \text{mm}}{1146\ \text{mm} - 0.4 \cdot 98.42\ \text{mm}} = P_{long} \qquad \text{UG-27 (2)}$$

E4.3.2 - Dished heads and cones under internal pressure ASME VIII UG-32 and APPENDIX-1 BPVC 2017 Edition

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	**356** psi
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 witout allowances	t_0	**1.448** in



Half-apex angle (≤ 30° 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 factor	E	1
Material		
Allowable stress	S	20000 psi

Calculation

Required thickness			t	**1.446**	in
incl. allowances	(t_e 1.573 in	≥t+)	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)

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

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

$$t=\frac{P_0\cdot D}{2\cdot\cos(\alpha)\cdot(S\cdot E-0.6\cdot P_0)}=\frac{24.55\text{ bar}\cdot 3812\text{ mm}}{2\cdot 0.9333\cdot(137.9\text{ N/mm}^2\cdot 1-0.6\cdot 24.55\text{ bar})}=36.74\text{ mm}$$

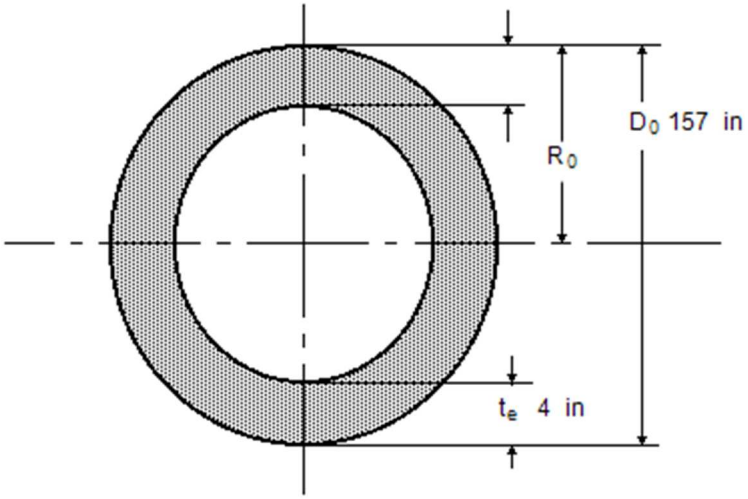
$$P=\frac{2\cdot S\cdot E\cdot t_0\cdot\cos(\alpha)}{D+1.2\cdot t_0\cdot\cos(\alpha)}=\frac{2\cdot 137.9\text{ N/mm}^2\cdot 1\cdot 36.78\text{ mm}\cdot 0.9333}{3812\text{ mm}+1.2\cdot 36.78\text{ mm}\cdot 0.9333}=2.457\text{ MPa}$$

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

E4.3.3 - Thickness of shells under internal pressure ASME BPVC VIII UG-27 & APPENDIX-1, 2017 Edition

Spherical shells

Design pressure	p_D	2080	psi
Hydrostatic head	D_p	0	psi
Calculation pressure	p_0	**2080**	psi
Calulation temperature	T_0	850	°F



Outside diameter	D_0	157	in
Design wall thickness	t_e	4	in
Wall thickness allowance	c_1	0	in
Allowance (corrosion)	c_2	0	in
Weld joint efficiency	E	1	-

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

Allowable stress	S	21000	psi

Results

Outside radius			R_0	**78.5**	in
Effective thickness			t_0	**4**	in
Calculation as thin shell is applicable				**Yes**	
Required thickness	$t(R_0)$		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 acc. UG-16			t_{UG-16}	0.05906	in
Minimum t = Max{Min[t(R);t(R_0)],t_{UG-16}}			t	**3.726**	in
with allowances			$t+c_1+c_2$	**3.726**	in
Allowable excess pressure			P	**2231**	psi
Allowable excess pressure without hydrostatic head			MAWP	**2231**	psi

For calculation of openings according to UG-37

Minimum required thickness for openings t(E=1) **3.726** in

Allowable unreinforced opening diameter dA for welded, brazed, and flued connections acc. UG 36(c)3

dA ≤ 89 mm for t ≤10 mm	or	dA ≤ 3 1/2 in for t ≤3/8 in
dA ≤ 60 mm for t > 10 mm	or	dA ≤ 2 3/8 in for t > 3/8 in

For a vessel thickness > 2*t(E=1)+c_1+c_2 , the reinforcement of the vessel alone is sufficient for unreinforced openings, unless additional conditions acc. to UG-37 apply.

Equations

$$P_0 = 0.1 \cdot p_0 = 0.1 \cdot 143.4\ \text{bar} = 143.4\ \text{bar}$$

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

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

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

1) Thin shell For

$$P_0 \le 0.665 \cdot S \cdot E \Leftrightarrow 143.4\ \text{bar} \le 97.29\ \text{N/mm²}$$

and

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

with the inside radius R

$$t(R) = \frac{P_0 \cdot R}{2 \cdot S \cdot E - 0.2 \cdot P_0} = \frac{143.4\ \text{bar} \cdot 1892\ \text{mm}}{2 \cdot 144.8\ \text{N/mm²} \cdot 1 - 0.2 \cdot 143.4\ \text{bar}} = 94.65\ \text{mm}$$ UG-27 (3)

$$P(R) = \frac{2 \cdot S \cdot E \cdot t_0}{R + 0.2 \cdot t_0} = \frac{2 \cdot 144.8\ \text{N/mm²} \cdot 1 \cdot 101.6\ \text{mm}}{1892\ \text{mm} + 0.2 \cdot 101.6\ \text{mm}} = 15.38\ \text{MPa}$$ UG-27 (3)

or with the outside radius R_0

$$t(R_0) = \frac{P_0 \cdot R_0}{2 \cdot S \cdot E + 0.8 \cdot t_0} = \frac{143.4\ \text{bar} \cdot 1994\ \text{mm}}{2 \cdot 144.8\ \text{N/mm²} \cdot 1 + 0.8 \cdot 143.4\ \text{bar}} = 94.98\ \text{mm}$$ App. 1-1 (2)

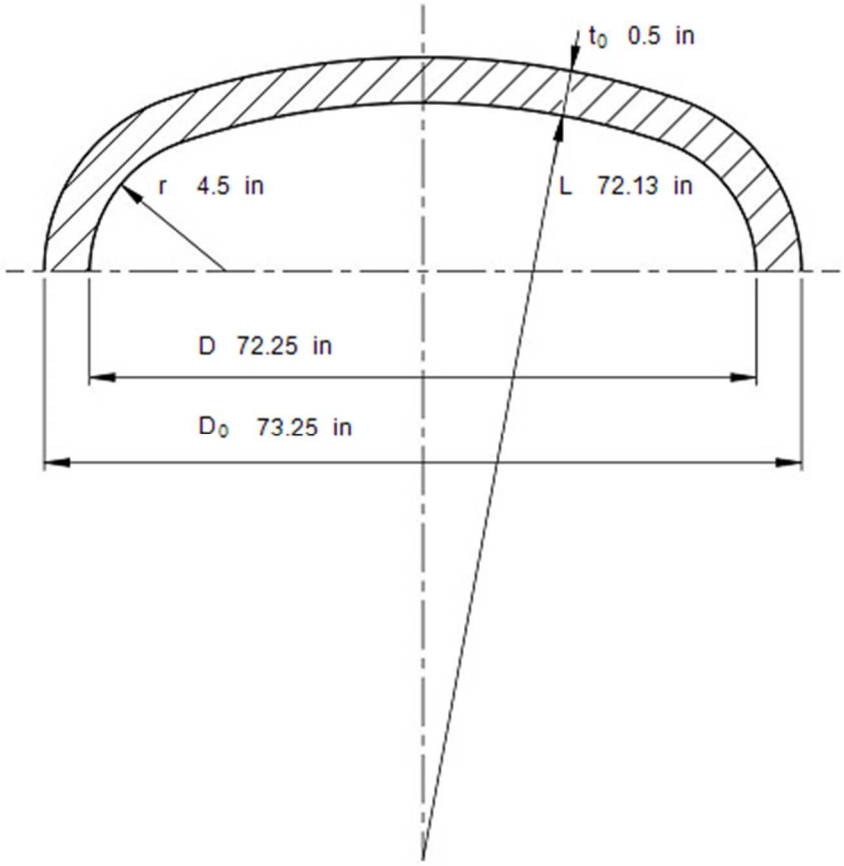
$$P(R_0) = \frac{2 \cdot S \cdot E \cdot t_0}{R_0 - 0.8 \cdot t_0} = \frac{2 \cdot 144.8\ \text{N/mm²} \cdot 1 \cdot 101.6\ \text{mm}}{1994\ \text{mm} - 0.8 \cdot 101.6\ \text{mm}} = 15.38\ \text{MPa}$$ App. 1-1 (2)

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

E4.3.4 - Dished heads and cones under internal pressure ASME VIII UG-32 and APPENDIX-1 BPVC 2017 Edition

Type of head

(1=Kloepper-, 2=Korbbogen-, 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	**136** psi
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 witout 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	**1848** mm
Inside crown radius	(= L_0-t_0)	L	**72.13** in
Knuckle radius		r	4.5 in
Weld joint efficiency		E	1

Material data

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

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	17114	psi	
at 20°C	S_{20}	17100	psi	
acc. UG-32(e) or App. 1-4(c)	S	**17114**	psi	

*) According to App. 1-4(c), the allowable stress must be reduced to 138 * 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	**0.5021**	in
incl. allowances (t_e 0.625 in ≥t+)	t+	**0.6271**	in
Allowable excess pressure incl. hydrost. head	P	**135.4**	psi
Allowable excess pressure without hydrostatic Head	MAWP	**135.4**	psi

Geometrical conditions

valid

Strength condition

Final wall thickness 15,875 < 15,9296 = 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)	**0.5021**	in
acc. section (a) in the crown region	t_1(E=1)	**0.2868**	in

Allowable unreinforced opening diameter dA for welded, brazed, and flued connections acc. UG 36(c)3

d_A ≤ 89 mm (3.5 in.) for t ≤10 mm (3/8 in.)
d_A ≤ 60 mm (2 3/8 in.) for t > 10 mm (3/8 in.)

Remark

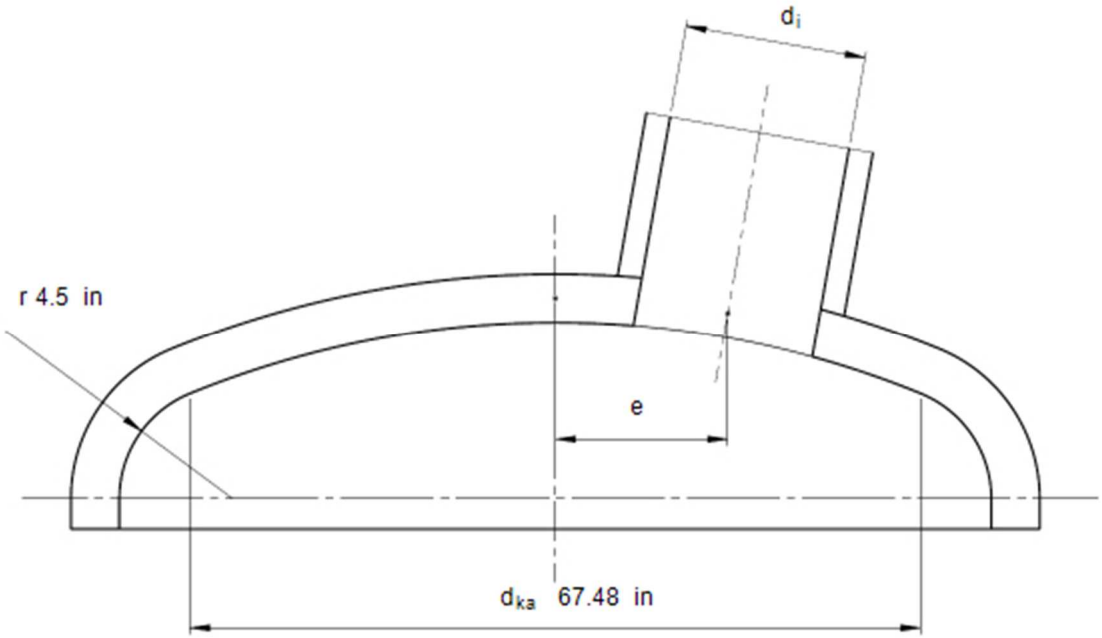
Equations

$$t = \frac{P_0 \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P_0} = \frac{9.377\ \text{bar} \cdot 1832\ \text{mm} \cdot 1.751}{2 \cdot 118\ \text{N/mm}^2 \cdot 1 - 0.2 \cdot 9.377\ \text{bar}} = 12.75\ \text{mm}$$

$$P = \frac{2 \cdot S \cdot E \cdot t_0}{L \cdot M + 0.2 \cdot t_0} = \frac{2 \cdot 118\ \text{N/mm}^2 \cdot 1 \cdot 12.7\ \text{mm}}{1832\ \text{mm} \cdot 1.751 + 0.2 \cdot 12.7\ \text{mm}} = 0.9337\ \text{MPa}$$

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

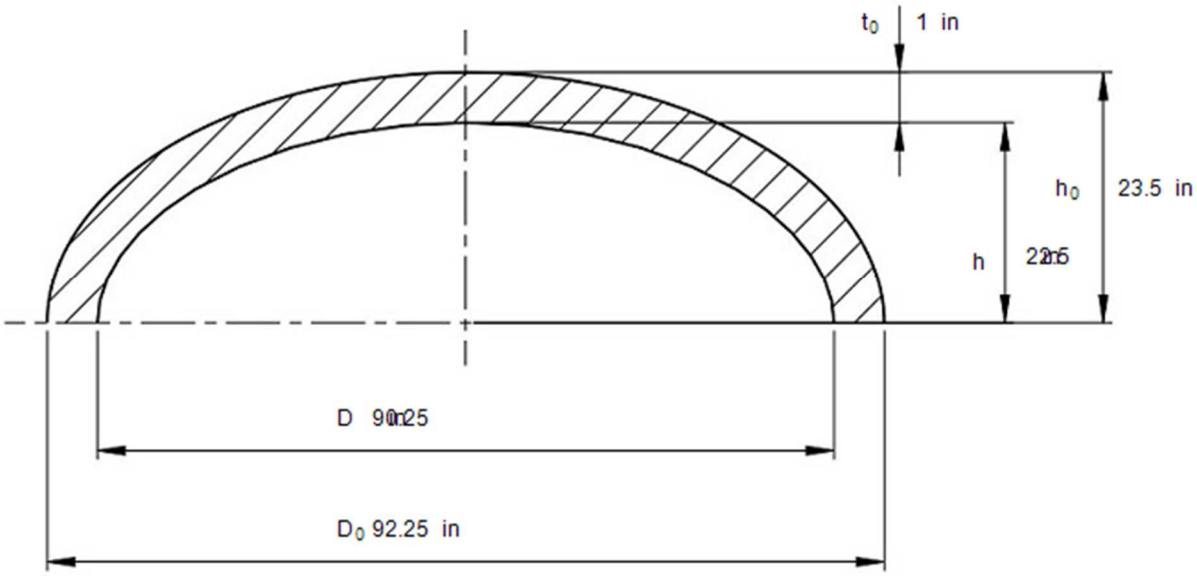
Available reinforcement width of the crown	b'		in
Diameter of the crown region	d_{ka}	**67.48**	in
Angle of the knuckle region		**62.24**	°
Arc length of the knuckle region	b''	**5.567**	in

$d_{ka} = (2 \cdot L + t_e) \cdot (D/2 - r)/(L - r)$
$\varphi = \arccos((D/2 - r)/(L - r))$
$b' = (d_{ka} - d_i)/2 - e$
$b'' = (r + t_e) \cdot \varphi$

E4.3.5 - Dished heads and cones under internal pressure ASME VIII UG-32 and APPENDIX-1 BPVC 2017 Edition

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	**442.2**	psi
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 witout 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		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(e) or App. 1-4(c)	S	**20015**	psi

*) According to App. 1-4(c), 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 K1 acc. Table UG-37	K_1	**0.9**	
Required thickness	t	**0.9992**	in
incl. allowances (t_e 1.125 in ≥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

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

Using UG-32 with E=1	t(E=1)	**0.9992**	in
Section (c) in the centre circle (< 0.8·D)	t_1(E=1)	**0.8993**	in
Equivalent spherical diameter $2 \cdot K_1 \cdot D_0$	D_s	**168.3**	in

Geometrical conditions

valid

Strength

Wall thickness acceptable

Allowable unreinforced opening diameter dA for welded, brazed, and flued connections acc. UG 36(c)3

$d_A \leq 89$ mm (3.5 in.) for t ≤10 mm (3/8 in.)
$d_A \leq 60$ mm (2 3/8 in.) for t > 10 mm (3/8 in.)

Remark

Equations according to UG-32

$$t = \frac{P_0 \cdot D \cdot K}{2 \cdot S \cdot E - 0.2 \cdot P_0} = \frac{30.49 \text{ bar} \cdot 2292 \text{ mm} \cdot 1}{2 \cdot 138 \text{ N/mm}^2 \cdot 1 - 0.2 \cdot 30.49 \text{ bar}} = 25.38 \text{ mm}$$

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

Appendix: Material documentation

Section 2: Schale/UG27

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]: 24,55
Thickness [mm]: 101,6 Outside diameter [mm]: 2489,2

Material values for test and design conditions:

	Test condition	Operating condition
Nominal design strength [N/mm²]:	138,00	138,00
Safety factor:	1,00	1,00
Allowable stress [N/mm²]:	138,00	138,00
Modulus of elasticity [kN/mm²]:	202	195,0667

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. längs %	Rupture elong quer %

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					

Section 4: Schale/UG27

Material specification:

Regulation:	ASMET1A:2017	Spec. No.:	SA-542	Product:	Plate
Material code:	K31835-SA-542-D-Class:4a-Size:			Short name:	2.25Cr-1Mo-V

Design conditions and dimensions:

Temperature [°C]:	454,44	Pressure [bar]:	143,41
Thickness [mm]:	101,6	Outside diameter [mm]:	3987,8

Material values for test and design conditions:

	Test condition	Operating condition
Nominal design strength [N/mm²]:	168,00	144,29
Safety factor:	1,00	1,00
Allowable stress [N/mm²]:	168,00	144,29
Modulus of elasticity [kN/mm²]:	200	149,5062

Notes:

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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. längs %	Rupture elong quer %

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
		168	168	168	168	165	159	153

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
	145	137					

Modulus of elasticity in dependence of the temperature:

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

260	370	480	425	20	150
186	169	143	157	200	200

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
...	12,1	12,7	13,3	13,8	14,4	...	...	...	...	...

Section 5: Boden/UG32

Material specification:

Regulation: ASMET1A:2017Spec. No.: SA-387 Product: Plate
Material code: K11789-SA-387-11-Class:1-Size: Short name: 1.25Cr-0.5Mo-Si

Design conditions and dimensions:

Temperature [°C]: 343,33 Pressure [bar]: 0
Thickness [mm]: 15,88 Outside diameter [mm]: 1860,55

Material values for test and design conditions:

	Test condition	Operating condition
Nominal design strength [N/mm²]:	118,00	118,00
Safety factor:	1,00	1,00
Allowable stress [N/mm²]:	118,00	118,00
Modulus of elasticity [kN/mm²]:	204	183,4002

Notes:
S4 Size Requirements
For Section I applications, stress values at temperatures of 625°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.

T4 Time-Dependent Properties
Allowable stresses for temperatures of 480°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. längs %	Rupture elong quer %
...	...	...	...	...	...

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
...	...	118	118	118	118	118	118	118

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
...	114	74.7	36.5	17.6	8.08	...	...

Modulus of elasticity in dependence of the temperature:

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

650	-75	-200	-125	25	100	150	200	250	300	350	400	450	500	550
150	210	218	213	204	200	197	193	190	186	183	179	174	169	164

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

600	700			
157	142			

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					

Section 6: Boden/UG32

Material specification:

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

Design conditions and dimensions:

Temperature [°C]:	148,89	Pressure [bar]:	0
Thickness [mm]:	28,58	Outside diameter [mm]:	2343,15

Material values for test and design conditions:

	Test condition	Operating condition
Nominal design strength [N/mm²]:	138,00	138,00
Safety factor:	1,00	1,00
Allowable stress [N/mm²]:	138,00	138,00
Modulus of elasticity [kN/mm²]:	202	195,0666

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.

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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. längs %	Rupture elong quer %

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					