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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

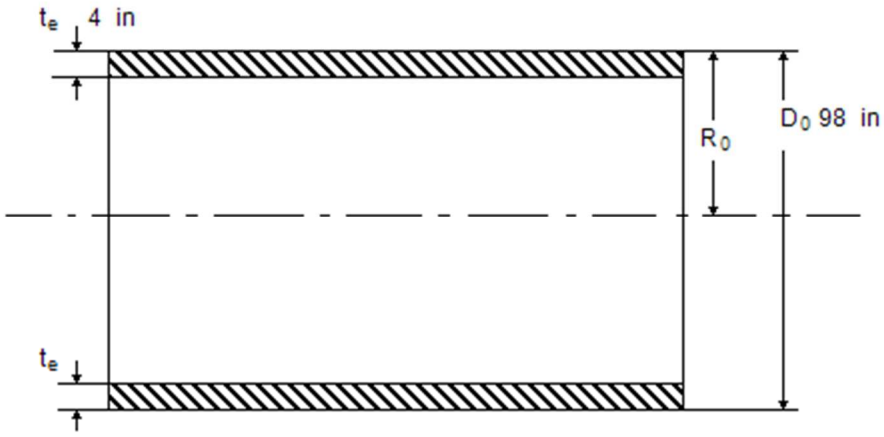
Strength Calculation Software	Program System ATLAS	Version	**8.33.8**
Developed by Lauterbach Verfahrenstechnik GmbH			
	Certificate Number 01 100		
Certified per DIN EN ISO 9001:2015	044763		

	LV Soft		ASME	Diff [%]
Example E4.3.1 - Cylinder Shell				
Required thickness tc [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			in	
Allowable Pressure P [psi]	9.34 bar	135.42 Psi	135.30 in	**0.09%**
Example E4.3.5 - Elliptical Head				
Allowable Pressure P [psi]	30.51 bar	442.57 Psi	442.23 in	**0.08%**

E4.3.1 - Thickness of cylindrical shells under internal pressure - ASME BPVC VIII-1 UG-27 & Appendix-1: 2021

Cylindrical shells

Design pressure	p_D	356	psi
Hydrostatic head	D_p	0	psi
Calculation pressure	P_0	**356**	psi
Calculation 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 (or Cast Quality Factor)	E	1	
Circumferential weld joint efficiency for Eq. 2	E_c	1	

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 without condition acc. UG-16			t_{UG-27} **20.62**	mm
Minimum wall thickness acc. UG-16			t_{UG-16} 0.05906	in
Required wall thickness for circumferential seam			t_{long} **0.4002**	in
$t = Max\{Min[t_R;t_{R0}],t_{UG-16}\}$			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

For calculation of openings according to UG-37

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

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

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

Equations

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

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

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

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

UG-27 (1)

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

UG-27 (1)

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

or with the outside radius R_0

App. 1-1 (1)

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

App. 1-1 (1)

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

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

Longitudinal Stress (Circumferential Joints)

UG-27 (2)

$$t_{long} = \frac{P_0 \cdot R}{2 \cdot S \cdot E_c + 0.4 \cdot P_0} = \frac{24.55\ \text{bar} \cdot 1146\ \text{mm}}{2 \cdot 137.9\ \text{N/mm}^2 \cdot 1 + 0.4 \cdot 24.55\ \text{bar}} = 10.16\ \text{mm}$$

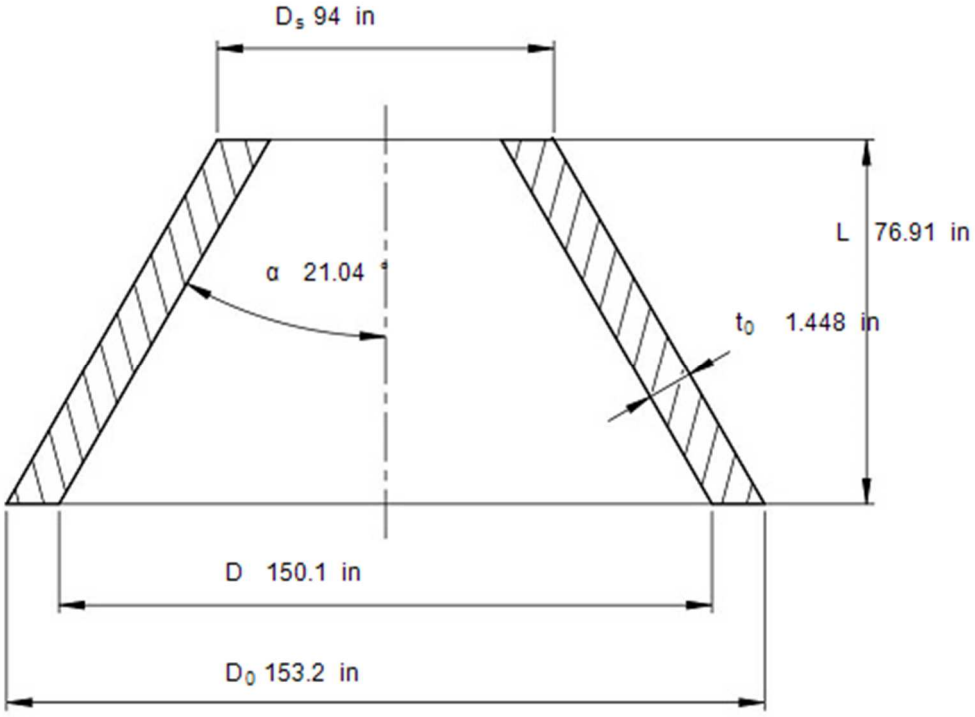
UG-27 (2)

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

E4.3.2 - Cone without knuckle under internal pressure - ASME BPVC VIII-1 UG-32 & Appendix-1: 2021

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 without 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 (or Cast Quality 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)

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

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

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

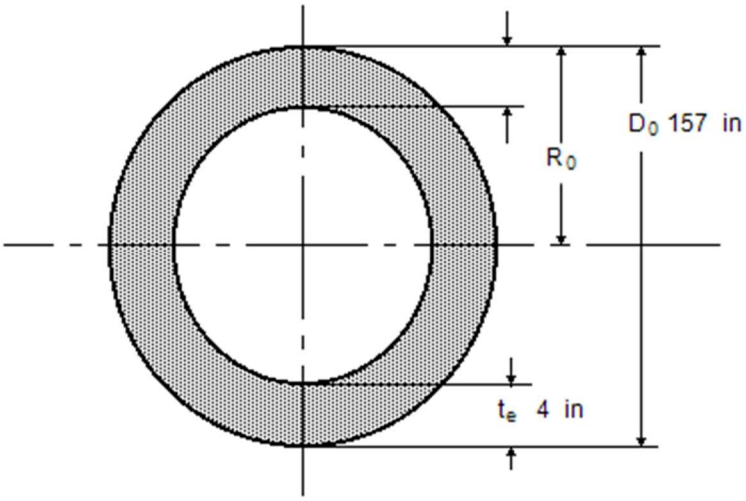
$$P=\frac{2\cdot S\cdot E\cdot t_0\cdot\cos(\alpha)}{D+1.2\cdot t_0\cdot\cos(\alpha)}=\frac{2\cdot 137.9\text{ N/mm}^2\cdot 1\cdot 36.78\text{ mm}\cdot 0.9333}{3812\text{ mm}+1.2\cdot 36.78\text{ mm}\cdot 0.9333}=2.457\text{ MPa}$$

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

E4.3.3 - Thickness of spherical shells under internal pressure - ASME BPVC VIII-1 UG-27 & Appendix-1: 2021

Spherical shells

Design pressure	p_D	2080	psi
Hydrostatic head	D_p	0	psi
Calculation pressure	P_0	**2080**	psi
Calculation 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 (or Cast Quality Factor)	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 without condition acc. UG-16	t_{UG-27}	**94.65**	mm
Minimum wall thickness acc. UG-16	t_{UG-16}	0.05906	in
Minimum $t = Max\{Min[t_R;t_{R0}],t_{UG-16}\}$	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

Remark

For calculation of openings according to UG-37

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

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

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

$P_0 \le 0.665 \cdot S \cdot E \Leftrightarrow 143.4\ \text{bar} \le 97.29\ \text{N/mm}^2$

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

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

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

or with the outside radius R_0

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

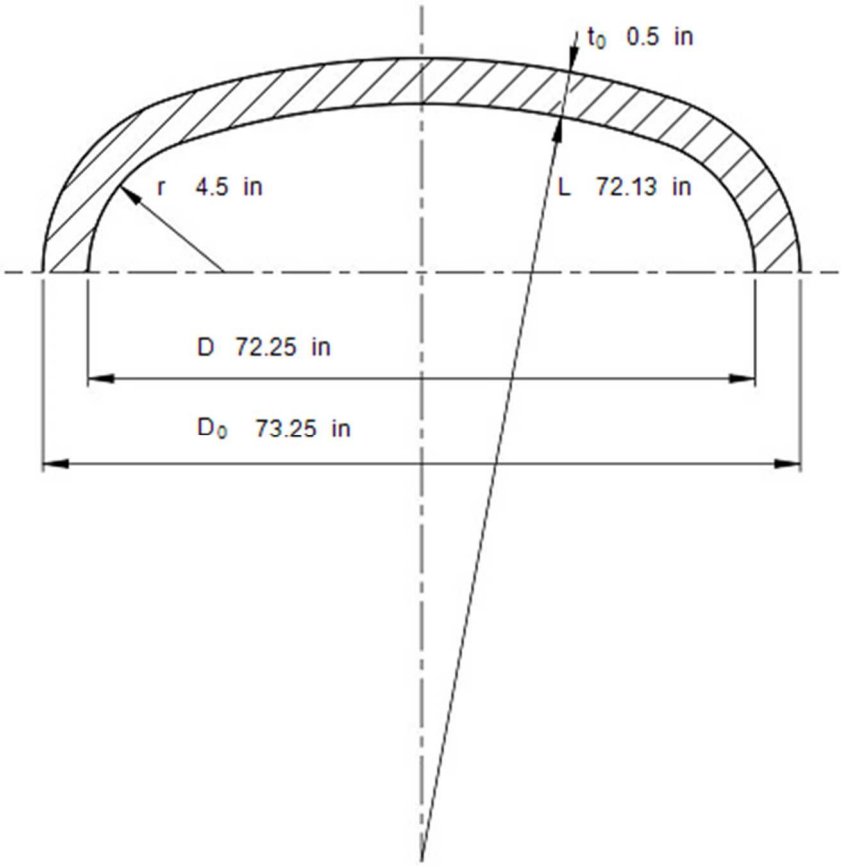
$$P(R_0) = \frac{2 \cdot S \cdot E \cdot t_0}{R_0 - 0.8 \cdot t_0} = \frac{2 \cdot 144.8\ \text{N/mm}^2 \cdot 1 \cdot 101.6\ \text{mm}}{1994\ \text{mm} - 0.8 \cdot 101.6\ \text{mm}} = 15.38\ \text{MPa}$$ App. 1-1 (2)

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

E4.3.4 - Torispherical heads (Kloepper, Korbbogen, Semi-spherical) under internal pressure - ASME BPVC VIII-1 UG-32 & Appendix-1: 2021

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 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	**1848**	mm
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:

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(d) or endnote 90	S	**17114**	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).

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 d for welded, brazed, and flued connections acc. UG 36(c)3

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

Remark

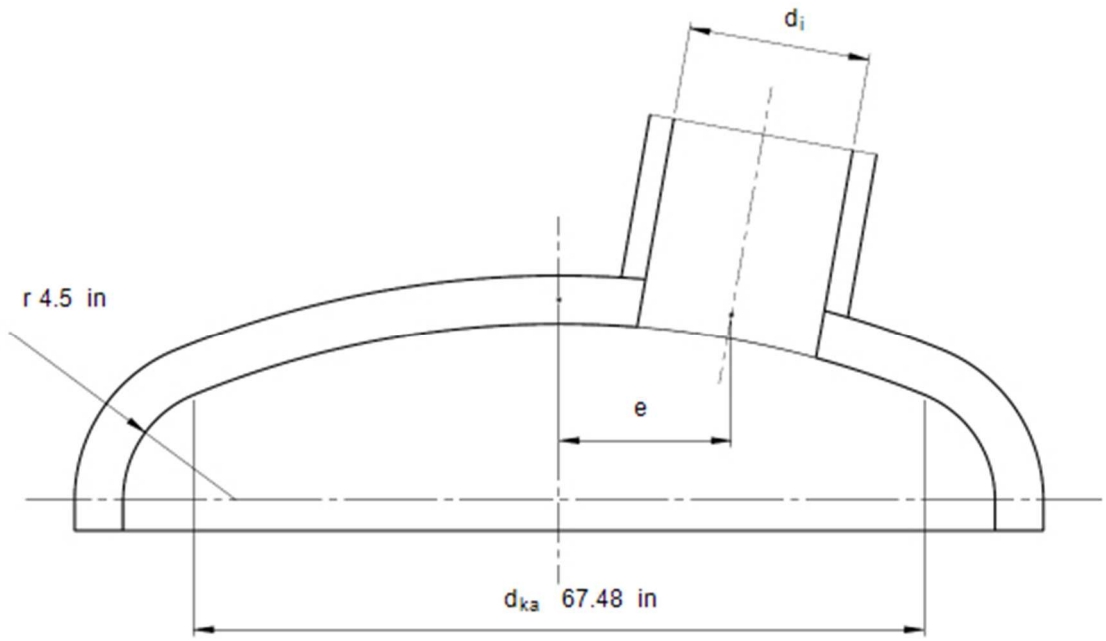
Equations

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

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

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

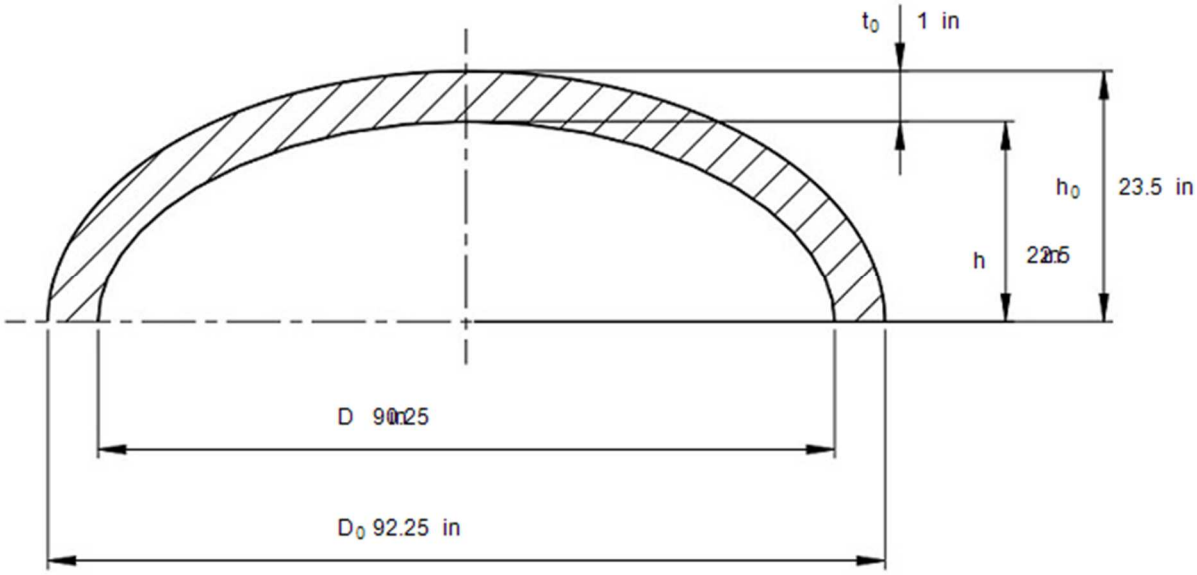
Available reinforcement width of the crown	b'		in
Diameter of the crown region	d_{ka}	**67.48**	in
Angle of the knuckle region		**62.24**	°
Arc length of the knuckle region	b''	**5.567**	in

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

E4.3.5 - Elliptical heads under internal pressure - ASME BPVC VIII-1 UG-32 & Appendix-1: 2021

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 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 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 outside diameter	$2\cdot(K_1\cdot D+t_E)$	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 ≤ 89 mm (3.5 in.) for t ≤10 mm (3/8 in.)
d ≤ 60 mm (2 3/8 in.) for t > 10 mm (3/8 in.)

Remark

Equations according to UG-32

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

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