

## ASME BPVC VIII-1 2023

PTB-4-2021 / E4.4.1; E4.4.2; E4.4.3; E4.4.4; E4.4.5

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### Layout

Input values:	1.234	or	1.234
Calculated values:	<b>1.234</b>	or	<b>1.234</b>
Critical values:	<b>1.234</b>	or	<b>1.234</b>
Estimated values:	<b>1.234</b>	or	<b>1.234</b>





# ASME BPVC VIII-1 2023

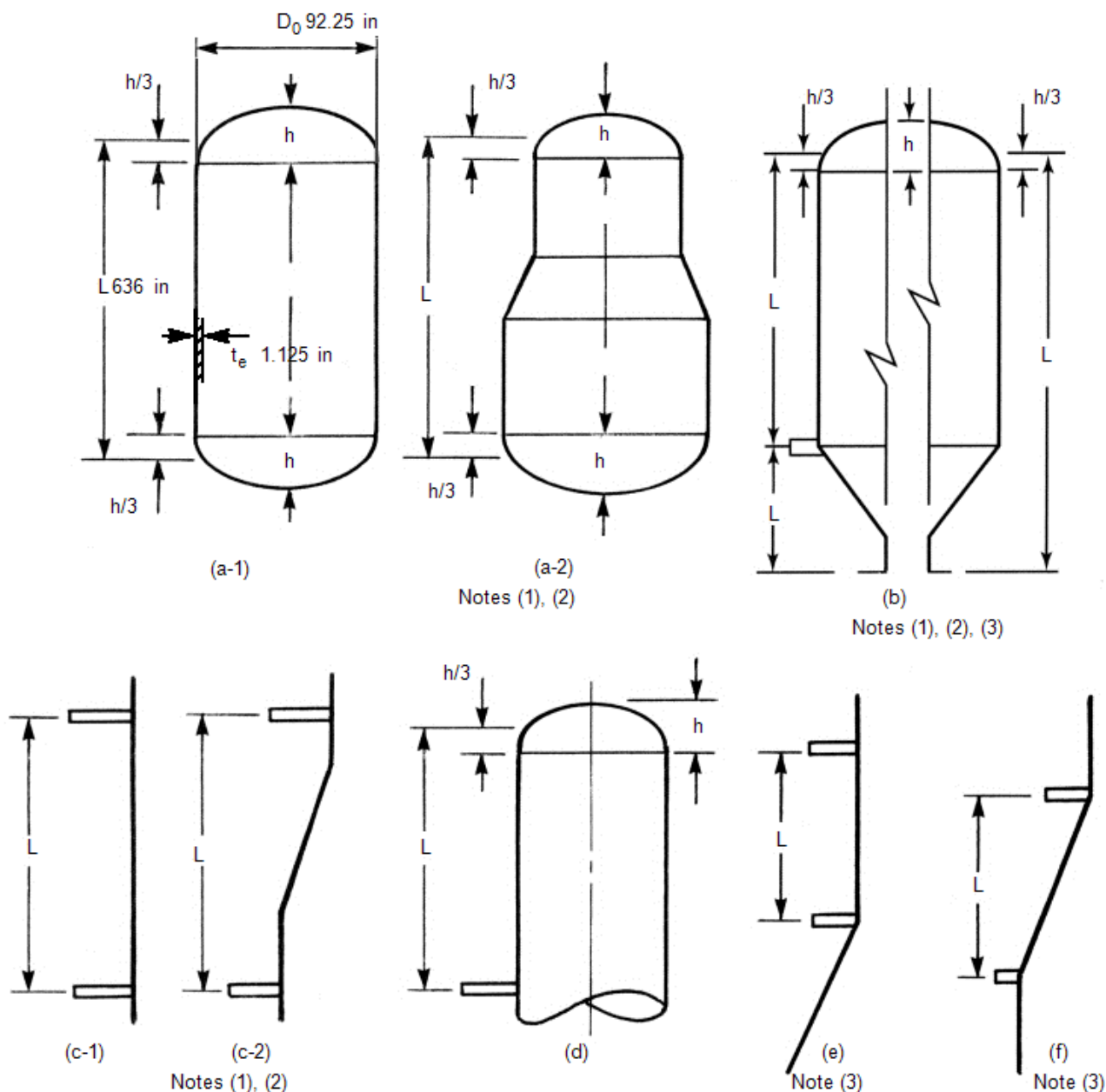
PTB-4-2021 / E4.4.1; E4.4.2; E4.4.3; E4.4.4; E4.4.5

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

### Cylindrical shells under external pressure

External design pressure  
Hydrostatic head  
External calculation pressure  
Calculation temperature

$p_D$  2 psi  
 $D_p$  0 psi  
 $p_0$  2 psi  
 $T_0$  300 °F



Outside diameter  
Design wall thickness  
Wall thickness allowance  
Allowance (corrosion)  
Buckling length

$D_0$  92.25 in  
 $t_e$  1.125 in  
 $c_1$  0 in  
 $c_2$  0.125 in  
 $L$  636 in



## ASME BPVC VIII-1 2023

PTB-4-2021 / E4.4.1; E4.4.2; E4.4.3; E4.4.4; E4.4.5

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-IID\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

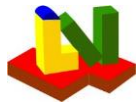
Remark

### Equations

$$\frac{D_0}{t_0} \geq 10 \Leftrightarrow 92.25 \geq 10 \quad \text{UG-28 c) (1)}$$

$$Pa(B) = \frac{4 \cdot B}{3 \cdot \frac{D_0}{t_0}} = \frac{4 \cdot 19.31 \text{ MPa}}{3 \cdot 92.25} = 0.279 \text{ MPa} \quad \text{Step 6}$$

$$Pa(E) = \frac{2 \cdot A \cdot E}{3 \cdot \frac{D_0}{t_0}} = \frac{2 \cdot 1.884e-4 \cdot 195067 \text{ MPa}}{3 \cdot 92.25} = 0.2656 \text{ MPa} \quad \text{Step 7}$$



# ASME BPVC VIII-1 2023

PTB-4-2021 / E4.4.1; E4.4.2; E4.4.3; E4.4.4; E4.4.5

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

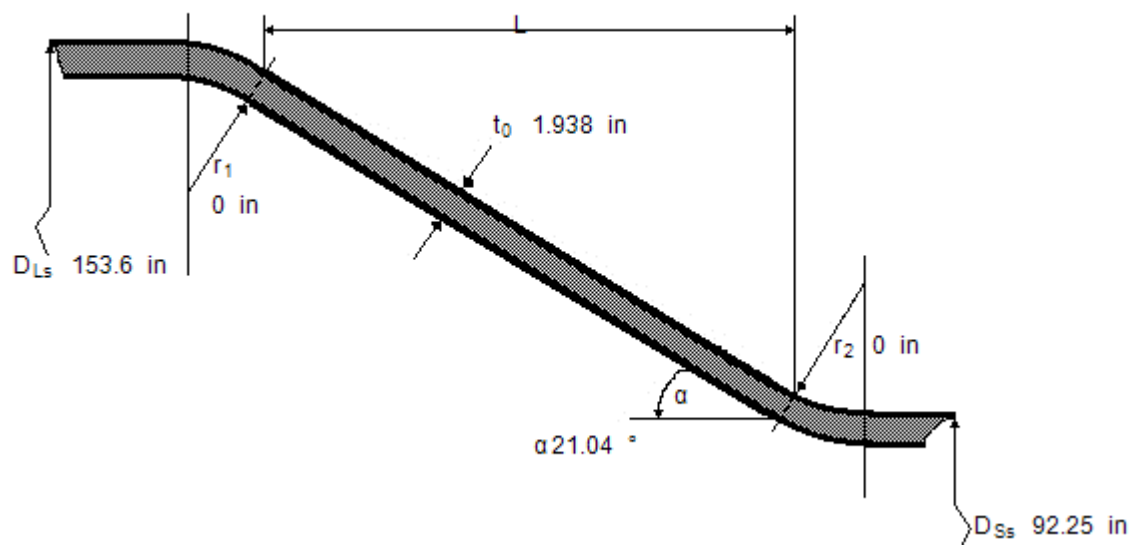
### Conical shells under external pressure acc. UG-33(f)

External design pressure  
Hydrostatic head  
Calculation pressure  
Calculation temperature

$p_D$  2 psi  
 $D_p$  0 psi  
 $p_0$  2 psi  
 $T_0$  300 °F

Material K02700-SA-516-70  
Spec. Min. Yield  
Allowable stress  
Applicable material chart  
Modulus of elasticity

$S_y$  33600 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

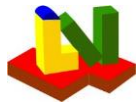
Is a cylinder connected, which does not act as line of support?

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  
 $\alpha$  21.04 °

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



# ASME BPVC VIII-1 2023

PTB-4-2021 / E4.4.1; E4.4.2; E4.4.3; E4.4.4; E4.4.5

## Results

Effective thickness	$t_e = t \cdot \cos(\alpha)$	$t_e$	<b>1.692</b> in
Axial length of the cone		L	<b>79.79</b> in
Design length		$L_e$	<b>63.85</b> in
Ratio		$L_e/D_L$	<b>0.4156</b>
Ratio		$D_L/t_e$	<b>90.81</b>
Factor according to fig. 5-UGO-28.0		A	<b>0.004054</b>
Factor (see material chart)		B	<b>16850</b> psi
Factor	$2 \cdot \text{Min}(S_0; 9 \cdot B)$	S	<b>31589</b> psi
Allowable external pressure (for $t_0$ )		P	<b>247.4</b> psi
Allowable pressure without hydrostatic head		MEP	<b>247.4</b> psi
Required thickness (for $P_0$ )		t	<b>0.1667</b> in
Required thickness incl. allowances		$t+c_1+c_2$	<b>0.2917</b> 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 2023

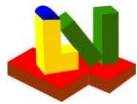
PTB-4-2021 / E4.4.1; E4.4.2; E4.4.3; E4.4.4; E4.4.5

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

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



## ASME BPVC VIII-1 2023

PTB-4-2021 / E4.4.1; E4.4.2; E4.4.3; E4.4.4; E4.4.5

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

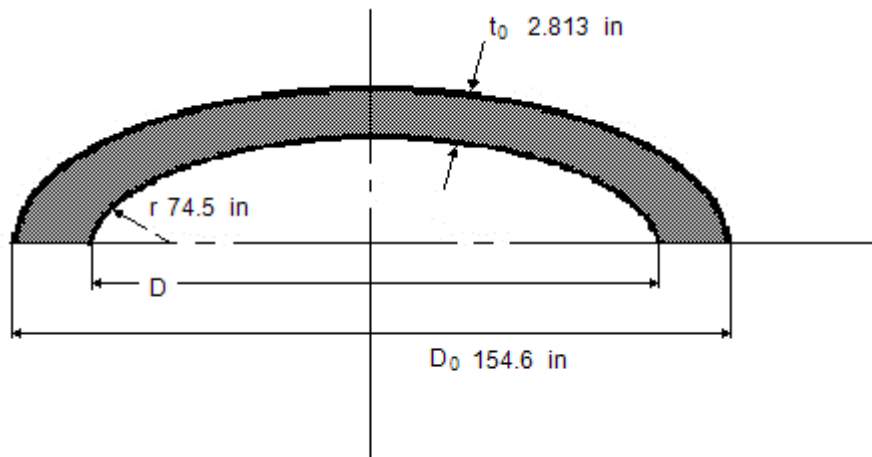
#### Torispherical heads

External design pressure  
Hydrostatic head  
Calculation pressure  
Calculation temperature

$p_D$  615.3 psi  
 $D_p$  0 psi  
 $p_0$  **615.3** psi  
 $T_0$  300 °F

Design wall thickness  
Wall thickness allowance  
Allowance (corrosion)  
Effective thickness

$t_e$  2.813 in  
 $c_1$  0 in  
 $c_2$  0 in  
 $t_0$  **2.813** in



Outside diameter of the head skirt  
Type of head Hemispherical head  
Outside calotte radius  
Knuckle radius

$D_0$  154.6 in  
 $R_0$  **77.31** in  
 $r$  **74.5** in

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

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

$S_y$  60190 psi  
 $S_0$  24366 psi  
Fig CS-2  
 $E$  2.9e+7 psi

#### Results

Ratio

$R_0/t_0$  **27.49**

Factor (see material chart)

$B$  15700 psi

Allowable external pressure  
Allowable pressure without hydrostatic head  
Required thickness  
Required thickness incl. allowances

$P$  **571.1** psi  
MEP **571.1** psi  
 $t$  2.789 in  
 $t+c_1+c_2$  2.789 in

Remark **Pressure not allowable**



**ASME BPVC VIII-1 2023**

PTB-4-2021 / E4.4.1; E4.4.2; E4.4.3; E4.4.4; E4.4.5

**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



## ASME BPVC VIII-1 2023

PTB-4-2021 / E4.4.1; E4.4.2; E4.4.3; E4.4.4; E4.4.5

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

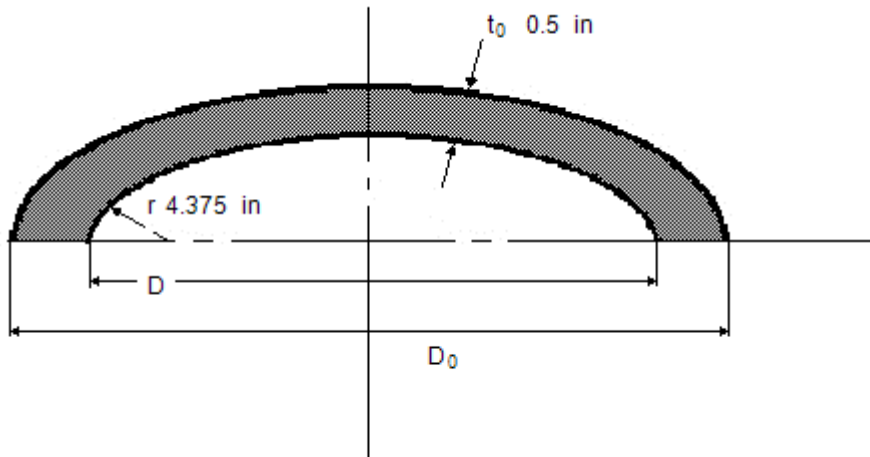
#### Torispherical heads

External design pressure  
Hydrostatic head  
Calculation pressure  
Calculation temperature

$p_D$  762061 psi  
 $D_p$  0 psi  
 $p_0$  **762061** psi  
 $T_0$  650 °F

Design wall thickness  
Wall thickness allowance  
Allowance (corrosion)  
Effective thickness

$t_e$  0.625 in  
 $c_1$  0 in  
 $c_2$  0.125 in  
 $t_0$  **0.5** in



Outside diameter of the head skirt  
Type of head Torispherical head  
Outside calotte radius  
Knuckle radius

$D_0$  in  
 $R_0$  72.63 in  
 $r$  4.375 in

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

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

$S_y$  34809 psi  
 $S_0$  17114 psi  
Fig CS-2  
 $E$  2.512e+7 psi

#### Results

Ratio

$R_0/t_0$  **145.3**

Factor (see material chart)

$B$  8100 psi

Allowable external pressure  
Allowable pressure without hydrostatic head  
Required thickness  
Required thickness incl. allowances

$P$  **55.77** psi  
MEP **55.77** psi  
 $t$  72.62 in  
 $t+c_1+c_2$  72.75 in

Remark **Pressure not allowable**

**ASME BPVC VIII-1 2023**

PTB-4-2021 / E4.4.1; E4.4.2; E4.4.3; E4.4.4; E4.4.5

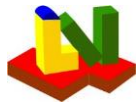
**Equations**

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

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

PTB-4-2021 / E4.4.1; E4.4.2; E4.4.3; E4.4.4; E4.4.5

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

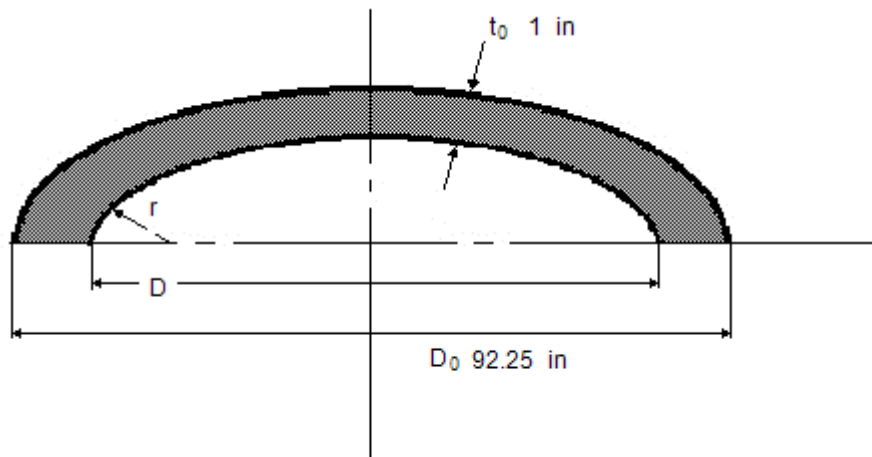
#### Torispherical heads

External design pressure  
Hydrostatic head  
Calculation pressure  
Calculation temperature

$p_D$  1 psi  
 $D_p$  0 psi  
 $p_0$  1 psi  
 $T_0$  300 °F

Design wall thickness  
Wall thickness allowance  
Allowance (corrosion)  
Effective thickness

$t_e$  1.125 in  
 $c_1$  0 in  
 $c_2$  0.125 in  
 $t_0$  1 in



Outside diameter of the head skirt  
Type of head Torispherical head  
Outside calotte radius  
Knuckle radius

$D_0$  92.25 in  
 $R_0$  83.02 in  
 $r$  in

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

#### Results

Ratio

$R_0/t_0$  83.02

Factor (see material chart)

$B$  13795 psi

Allowable external pressure  
Allowable pressure without hydrostatic head  
Required thickness  
Required thickness incl. allowances

$P$  166.2 psi  
MEP 166.2 psi  
 $t$  0.06239 in  
 $t+c_1+c_2$  0.1874 in

Remark

**ASME BPVC VIII-1 2023**

PTB-4-2021 / E4.4.1; E4.4.2; E4.4.3; E4.4.4; E4.4.5

**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