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Thanks for visiting our site,

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MAP/MAV - of a SELF SUPPORTING SHALLOW CONE ROOF

BASIS: This spreadsheet calculates the internal and external pressure capability of a shallow cone roof.

REFERENCES: API-650

NOTE: Always begin a new case by retrieving the original file. Direct entry of data in cells that originally contain table lookups could cause functions to be lost, or incorrect calculations. I format cells requiring entry colored **RED**; calculated values are black.

1.) Enter identification at [C4].
2.) Enter the tank diameter at [C6].
3.) Enter the roof pitch at [F6] (imperial, as inches per foot, e.g.; 3/12 would be input as a 3, if metric the same would be input as as millimeter per meter as 250 [250/1000]). The resulting angle in degrees is calculated and shown at [F7]. If the angle in degrees is known input it at [F7]. One half of the apex of this angle to the vertical plane is calculated and shown at [F8]. The cosine of this angle is calculated and reflected at [F8].
4.) Enter roof plate thickness at [C8].
5.) Enter corrosion allowance at [C9]. The resulting "effective plate thickness" is shown at [H20].
6.) Enter allowable stress at [C10], typical selections are 18,000 PSI (124,106 kPa) for carbon steel and 20,000 PSI (137,895 kPa) for alloy steel.
7.) Enter modulus of elasiticity at [C11], typical selections are 30,000,000 PSI or (2.0684272e+8 kPa).
8.) Enter the weld joint efficiency at [C12].
9.) Enter any additional roof loading, e.g; agitators, railing, etc.. in pounds or kg at [F12].

The MAP is calculated and shown at [F21] and the MAV is calculated and shown at [F30].

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MAP/MAV - of a SELF SUPPORTING CONE ROOF

SERVICE: Boiler Water Storage Tank; 31D-9

Tank Diameter:	288	(D), in.	Roof Pitch:	3	inches/foot
or:	24.00	feet	Roof Angle:	14.04	deg.
Plate Thickness:	0.25	in.	1/2 Apex Angle:	75.96	(α)
Corrosion Allow:	0.0000	in.	Cos(α) =	0.2425	
Allowable Stress:	18000	psi (S)	Roof Area, Ax =	452	sq. ft.
Elastic Modulus:	30.0E+6	psi (ε)	Roof Wt, Wr =	4609	lbs.
Joint Efficiency:	0.85	(E)	Add'l Load, Wd =	0	lbs.

t = 0.2500 in. - shell thickness less corrosion allowance

..... **MAP CALCULATION** .....

$$MAP = \frac{2 \cdot S \cdot E \cdot t \cdot \cos(\alpha)}{D + 1.2 \cdot t \cdot \cos(\alpha)} = 6.441 \text{ psi}$$

..... **MAV CALCULATION** .....

$$MAV = \frac{\sin(\theta)^2 \cdot t^2 \cdot \varepsilon}{5 \cdot D_o^2} \cdot \frac{W_r + W_d}{144 \cdot A_x} = 0.195 \text{ psi}$$

MAP/MAV - of a SELF SUPPORTING CONE ROOF

SERVICE: Boiler Water Storage Tank; 31D-9

Tank Diameter:	7315.2	(D), mm	Roof Pitch:	250	mm/meter
or:	7.32	meter	Roof Angle:	14.04	deg.
Plate Thickness:	6.35	mm	1/2 Apex Angle:	75.96	(α)
Corrosion Allow:	0.0000	mm	Cos(α) =	0.2425	
Allowable Stress:	124105.6	kPa (S)	Roof Area, Ax =	42.0	sq. meter
Elastic Modulus:	206.8E+6	kPa (ε)	Roof Wt, Wr =	2090	kg
Joint Efficiency:	0.85	(E)	Add'l Load, Wd =	0	kg

t = 6.3500 mm - shell thickness less corrosion allowance

..... **MAP CALCULATION** .....

$$MAP = \frac{2 \cdot S \cdot E \cdot t \cdot \cos(\alpha)}{D + 1.2 \cdot t \cdot \cos(\alpha)} = 44.407$$

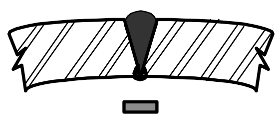
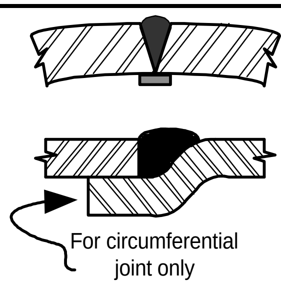
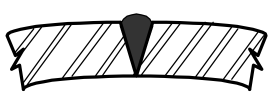
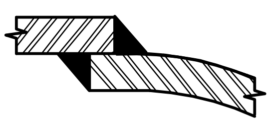
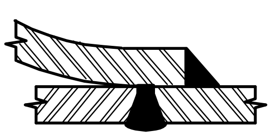
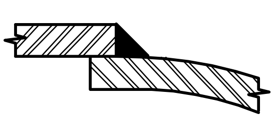
kPa, or 0.44 bar

..... **MAV CALCULATION** .....

$$MAV := \left[\frac{\left(\sin(\theta)^2 \cdot t^2 \cdot \varepsilon\right)}{5 \cdot D_o^{\,2}}\right] - \left[\frac{\left(W_r + W_d\right)}{\left(A_x \cdot 10^6\right) \cdot 9806.65}\right] = 1.346$$

kPa, or 0.01 bar

TYPES OF WELDED JOINTS

TYPES CODE UW-12		JOINT EFFICIENCY, E When the Joint: a. Fully Radio-graphed	b. Spot Examined	c. Not Examined
1. 	Butt joints as attained by double-welding or by other means which will obtain the same quality of deposited weld metal on the inside and outside weld surface. Backing strip if used shall be removed after completion of weld.	1.00	0.85	0.70
2. 	Single-welded butt joint with backing strip which remains in place after welding.	0.90	0.80	0.65
3. 	Single-welded butt joint without use of backing strip.	---	---	0.60
4. 	Double-full fillet lap joint.	---	---	0.55
5. 	Single-full fillet lap joint with plug welds.	---	---	0.50
6. 	Single-full fillet lap joint without plug welds.	---	---	0.45

Carbon Steel Plate			Stainless Steel Plate	
Thickness	Lbs/Ft2	Thickness	Thickness	Lbs/Ft2
0.187	7.66	**3/16**	0.187	8.58
0.250	10.21	**1/4**	0.250	11.16
0.312	12.76	**5/16**	0.312	13.75
0.375	15.32	**3/8**	0.375	16.50
0.500	21.66	**1/2**	0.500	21.66
0.625	26.83	**5/8**	0.625	26.83
0.750	32.12	**3/4**	0.750	32.12
1.000	42.66	**1**	1.000	42.67
1.250	53.22	**1-1/4**	1.250	53.00
1.500	63.87	**1-1/2**	1.500	63.34
2.000	85.16	**2**	2.000	84.01

Steel Sheets		Gauge	Stainless St
Thickness	Lbs/Ft^2		Thickness
-	0.245	**38**	-
0.0064	0.261	**37**	-
0.0067	0.273	**36**	-
0.0075	0.306	**35**	-
0.0082	0.335	**34**	-
0.0090	0.367	**33**	-
0.0097	0.396	**32**	-
0.0105	0.428	**31**	-
0.0120	0.900	**30**	0.0125
0.0135	0.551	**29**	0.0140
0.0149	0.608	**28**	0.0150
0.0164	0.669	**27**	0.0171
0.0179	0.730	**26**	0.0180
0.0209	0.853	**25**	-
0.0239	0.975	**24**	0.0240
0.0269	1.097	**23**	0.0281
0.0299	1.220	**22**	0.0300
0.0329	1.342	**21**	0.0343
0.0359	1.465	**20**	0.0360
0.0418	1.705	**19**	0.0420
0.0478	1.950	**18**	0.0480
0.0538	2.195	**17**	-
0.0598	2.440	**16**	0.0600
0.0673	2.746	**15**	-
0.0747	3.047	**14**	0.0750
0.0897	3.659	**13**	0.0900
0.1046	4.267	**12**	0.1050
0.1196	4.879	**11**	0.1200
0.1345	5.487	**10**	0.1350
0.1495	6.099	**9**	-
0.1644	6.707	**8**	0.1650
0.1793	7.315	**7**	0.1874
0.1943	7.926	**6**	-
0.2092	8.534	**5**	-
0.2242	9.146	**4**	-
0.2391	9.754	**3**	-
-	-	**2**	-
-	-	**1**	-
-	-	**0**	-

MAP/MAV - of a Flat Circular Plate, Full Edge Support

BASIS: This program is for internal and external pressure on a flat circular plate. Options allow calculation for the top, side, or bottom plate of a vessel. The MAV calculation subtracts the dead load of the plate (W/A) from the top segment.

NOTE: Always begin a new case by retrieving the original file. Direct entry of data in cells that originally contain table lookups could cause functions to be lost, or incorrect calculations. I format cells requiring entry colored **RED**; calculated values are black.

1. Enter identification at [C4].
2. Enter diameter at [C7].
3. Enter thickness at [C8].
4. Enter corrosion allowance at [C9].
5. Enter allowable stress at [C10], typical selections are 18,000 PSI (124,106 kPa) for carbon steel and 20,000 PSI (137,895 kPa) for alloy steel.
6. For the MAP without liquid, select NO LIQUID LOAD with the drop-down at [G6] BEFORE inputting data.
7. Enter liquid height at [G8].
8. Enter liquid specific gravity at [G9], if calculating with liquid.

The MAP is calculated and shown at [G18].

MAV Calculation

9. To use for a top plate - or - bottom/side plate, select appropriately with the drop-down at [G26]. The dead load penality is appropriately applied to the calculation.

The MAV is calculated and shown at [G34].

Print out using direct Excel commands. This application is provided by Chemical Engineers Resource Website, vis cheresources.com for additional selections.

Print out using direct EXCEL commands.

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MAP/MAV - of a Flat Circular Plate, Full Edge Support

SERVICE: Decarbonating Tower Flat Top Plate

Plate			**Liquid Loading**		
Diameter:	48.0	in. (d)			
Thickness:	0.2500	in.	Height :	12	in.
Corrosion Allow:	0.0000	in.	Specific Gravity:	1.001	
Allowable Stress:	18000	PSI (S)			
			P(liquid) :	0.433	psi

t = 0.25 in. - shell thickness less corrosion allowance

MAP Calculation

$$MAP = 6.17 \cdot \frac{t^2 \cdot S}{d^2} - P(liquid) = 2.579 \text{ psi}$$

MAV Calculation

Top Plate

Area, A =	1809.6	sq. in.
Weight, W =	128.0	lbs.
W / A =	0.07075	psi

$$MAV = 6.17 \cdot \frac{t^2 \cdot S}{d^2} - \frac{W}{A} = 2.94 \text{ psi}$$

MAP/MAV - of a Flat Circular Plate, Full Edge Support

SERVICE: Decarbonating Tower Flat Top Plate

Plate			Liquid Loading		
Diameter:	1219.2	mm (d)			
Thickness:	6.3500	mm	Height :	304.8	mm
Corrosion Allow:	0.0000	mm	Specific Gravity:	1.001	
Allowable Stress:	124106	kPa (S)			
			P(liquid) :	2.992	kPa

t = 6.35 mm - shell thickness less corrosion allowance

MAP Calculation

$$MAP = 6.17 \cdot \frac{t^2 \cdot S}{d^2} - P(liquid) = 17.779809 \text{ kPa}$$

MAV Calculation — **Top Plate**

Area, A = 1167454.0 sq. mm
Weight, W = 58.068638 kgs
W / A = 0.4877784 kPa

$$MAV = 6.17 \cdot \frac{t^2 \cdot S}{d^2} - \frac{W}{A} = 20.284086 \text{ kPa}$$

MAP/MAV - Reinforced Circular Plate, Evenly Spaced Support

BASIS: This program is for internal and external pressure on a reinforced circular plate with evenly spaced supports.

NOTE: Always begin a new case by retrieving the original file. Direct entry of data in cells that originally contain table lookups could cause functions to be lost, or incorrect calculations. I format cells requiring entry colored **RED**; calculated values are black.

1.) Enter the vessel identification at [C4].
2.) Enter plate diameter at [C7].
3.) Enter plate thickness at [C8].
4.) Enter corrosion allowance at [C9].
5.) Enter allowable stress at [C10], typical selections are 18,000 PSI (124,106 kPa) for carbon steel and 20,000 PSI (137,895 kPa) for alloy steel.
The plate area and weight is determined at C11 & C12.
6.) For the MAP without liquid, select NO LIQUID LOAD with the drop-down at [G6] BEFORE inputting data.
7.) If liquid is used enter the height at [G8].
8.) Enter the specific gravity of the liquid at [G9].
9.) Use the drop-down combo box to select the type of support at [G18].
10.) Enter the number of supports/beams at [H20].
11.) Enter the size of the supports at [H21] Use "=" then scroll down to the desired size in the angle, channel, or I-beam, then [ENTER] eg. [=E72] is a C6 x 8.2 imperial or C150 x 12 metric) channel. If the beam used is NOT in the tables or it is non-standard; select "OTHER" from the drop-down box and then enter the combined beam weight at [H23] and the beam section modulus at [H24].

NOTE: The section modulus (Z) is automatically looked up and appears at [H24] NOTE: The modulus in the tables is only for the strongest direction, ie. angles are mounted with one leg flat, channels are on edge, and I-beams are flat on their flange. If they are used differently, or if a different steel section is used, the correct modulus must be directly entered at [H24]. The MAP for both the plate and beams are calculated and the controlling MAP is shown at [C29].

12.) Select either Top or Bottom/Side plate with the drop-down at [G35]. This applies the dead load penality if the Top is selected (weight of top reduces vacuum capability).

The MAV for both the plate & beams are calculated. The controlling MAV is shown on row 44.

Print out using direct Excel commands. This application is provided by Chemical Engineers Resource Website, vis cheresources.com for additional selections.

Print out using direct EXCEL commands.

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This Spreadsheet Requires MACROS to be ENABLED to ASSURE proper operation.
See the Workbook Help Sheet for Additional Instructions on Use.

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MAP/MAV - Reinforced Circular Plate, Evenly Spaced Support

SERVICE: Alcohol Tank #30; Endplates

Plate

Diameter, d:	76.0	in.
Thickness:	0.2500	in.
Corrosion Allow:	0.0000	in.
Allowable Stress:	18000	psi (S)
Plate Area, A:	4536	sq. in.
Plate Weight, Wp:	321	lb.

Liquid Loading

Height :	12	in.
Specific Gravity:	1.000	
P(liquid) :	0.433	psi

t = 0.25 in. - shell thickness less corrosion allowance

MAP Calculation

Plate

$$P = 41.6 \frac{t^2 * S}{d^2} = 8.102 \text{ psi}$$

Angle

Number Beams:	4	
Size:	4 x 4 x 1/4	
Beam Length, L:	270.53	in.
Beam Weight, Wb:	148.8	lb.
Section Modulus, Z:	1.05	cu. in.

$$P = 40.0 \frac{S * Z}{d^3} = 1.722 \text{ psi}$$

Final

MAP = P(beams) - P(liquid)

MAP = 1.289 psi, limited by beams

MAV Calculation

Plate

$$P = 41.6 \frac{t^2 * S}{d^2} = 8.102 \text{ psi}$$

Bottom / Side

$$P = 40.0 \frac{S * Z}{d^3} = 1.722 \text{ psi}$$

Final

MAV = P(beams)

MAV = 1.722 psi, limited by beams

MAP/MAV - Reinforced Circular Plate, Evenly Spaced Support

SERVICE: Alcohol Tank #30; Endplates

Plate

Diameter, d:	1930.4	mm
Thickness:	6.3500	mm
Corrosion Allow:	0.0000	mm
Allowable Stress:	124106	kPa (S)
Plate Area, A:	2926742	sq. mm
Plate Weight, Wp:	145.6	kgs

Liquid Loading

Height :	304.8	mm
Specific Gravity:	1.000	
P(liquid) :	2.989	kPa

t = 6.35 mm - shell thickness less corrosion allowance

MAP Calculation

Plate

$$P = 9.5 \frac{t^2 * S}{d^2} = 12.758 \text{ kPa}$$

Angle

Number Beams:	1	
Size:	C100 x 8	
Beam Length, L:	1930.4	mm
Beam Weight, Wb:	15.4	kgs
Section Modulus, Z:	31600	cu. mm

$$P = 16.0 \frac{S * Z}{d^3} = 8.723 \text{ kPa}$$

Final

MAP = P(beams) - P(liquid)

MAP = 5.734 kPa, limited by beams

MAV Calculation

Plate

$$P = 9.5 \frac{t^2 * S}{d^2} = 12.758 \text{ kPa}$$

Top Plate

$$P = 16.0 \frac{S * Z}{d^3} = 8.723 \text{ kPa}$$

Final

$$MAV = P(beams) - \frac{Wp + Wb}{A}$$

MAV = 8.183 kPa, limited by beams

MAP/MAV - Reinforced Circular Plate, Unevenly Spaced Support

BASIS: This program is for internal and external pressure on a reinforced circular plate with unevenly spaced supports.

NOTE: Always begin a new case by retrieving the original file. Direct entry of data in cells that originally contain table lookups could cause functions to be lost, or incorrect calculations. I format cells requiring entry colored **RED**; calculated values are black.

1.) Enter the vessel identification at [C4].
2.) Enter plate diameter at [C7].
3.) Enter plate thickness at [C8].
4.) Enter corrosion allowance at [C9].
5.) Enter allowable stress at [C10], typical selections are 18,000 PSI (124,106 kPa) for carbon steel and 20,000 PSI (137,895 kPa) for alloy steel.
The plate area and weight is determined at C11 & C12.
6.) For the MAP without liquid, select NO LIQUID LOAD with the drop-down at [G6] BEFORE inputting data.
7.) If liquid is used enter the height at [G8].
8.) Enter the specific gravity of the liquid at [G9].
9.) Use the drop-down combo box to select the type of support at [G18].
10.) Enter the MAXIMUM spacing between the supports/beams at [H20].
11.) Enter the size of the supports at [H21] Use "=" then scroll down to the desired size in the angle, channel, or I-beam, then [ENTER] eg. [=E72] is a C6 x 8.2 imperial or C150 x 12 metric) channel. If the beam used is NOT in the tables or it is non-standard; select "OTHER" from the drop-down box and then enter the combined beam weight at [H23] and the beam section modulus at [H24].

NOTE: The section modulus (Z) is automatically looked up and appears at [H24] NOTE: The modulus in the tables is only for the strongest direction, ie. angles are mounted with one leg flat, channels are on edge, and I-beams are flat on their flange. If they are used differently, or if a different steel section is used, the correct modulus must be directly entered at [H24]. The MAP for both the plate and beams are calculated and the controlling MAP is shown at [C29].

12.) Select either Top or Bottom/Side plate with the drop-down at [G35]. This applies the dead load penality if the Top is selected (weight of top reduces vacuum capability).

The MAV for both the plate & beams are calculated. The controlling MAV is shown on row 44.

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Print out using direct EXCEL commands.

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04/17/04

MAP/MAV - Reinforced Circular Plate, Unevenly Spaced Support

SERVICE: Alcohol Tank #30; Endplates

Plate

Diameter, d:	76.0	in.
Thickness:	0.7500	in.
Corrosion Allow:	0.0000	in.
Allowable Stress:	18000	psi (S)
Plate Area, A:	4536	sq. in.
Plate Weight, Wp:	963	lb.

Liquid Loading

Height :	12	in.
Specific Gravity:	1.000	
P(liquid) :	0.433	psi

t = 0.75 in. - shell thickness less corrosion allowance

MAP Calculation

Plate

$$P = \frac{S \cdot t^2}{0.6 \cdot X^2} = 3.000 \text{ psi}$$

Angle

MAX Spacing, X:	75	in.
Size:	4 x 4 x 1/4	
Beam Length, L:	270.53	in.
Beam Weight, Wb:	148.8	lb.
Section Modulus, Z:	1.05	cu. in.

$$P = \frac{8 \cdot S \cdot Z}{d^2 \cdot X} = 0.349 \text{ psi}$$

Final

MAP = P(beams) - P(liquid)

MAP = -0.084 psi, limited by beams

MAV Calculation

Plate

$$P = \frac{S \cdot t^2}{0.6 \cdot X^2} = 3.000 \text{ psi}$$

Bottom/Side

$$P = \frac{8 \cdot S \cdot Z}{d^2 \cdot X} = 0.349 \text{ psi}$$

Final

MAV = P(plate) = 0.349 psi, limited by beams

MAP/MAV - Reinforced Circular Plate, Unevenly Spaced Support

SERVICE: Alcohol Tank #30; Endplates

Plate | **Liquid Loading**

Diameter, d:	1930.4	mm			
Thickness:	19.0500	mm	Height :	304.8	mm
Corrosion Allow:	0.0000	mm	Specific Gravity:	1.000	
Allowable Stress:	124106	kPa (S)			
Plate Area, A:	2926742	sq. mm	P(liquid) :	2.989	kPa
Plate Weight, Wp:	436.7	kgs			

t = 19.05 mm - shell thickness less corrosion allowance

MAP Calculation

Plate

$$P = \frac{S * t^2}{0.6 * X^2} = 20.684 \text{ kPa}$$

Angle

MAX Spacing, X: 1905 mm

Size: 100 x 100 x 6

Beam Length, L: 6871.5 mm

Beam Weight, Wb: 62.8 kgs

Section Modulus, Z: 15700.00 cu. mm

$$P = \frac{8 * S * Z}{d^2 * X} = 2.196 \text{ kPa}$$

Final

MAP = P(beams) - P(liquid)

MAP = -0.793 kPa, limited by beams

MAV Calculation

Plate

$$P = \frac{S * t^2}{0.6 * X^2} = 20.684 \text{ kPa}$$

Bottom/Side

$$P = \frac{8 * S * Z}{d^2 * X} = 2.196 \text{ kPa}$$

Final

MAV = P(plate) = 2.196 kPa, limited by plate

Drop-Down Calculation Information

Case	Selection	Test	Calculation Basis
Liquid Loadi	Liquid Loadi	1	··· MAP - Reinforced Circular Plate, Unevenly Spaced Support, Liquid ···
No Liquid Lo			··· MAP - Reinforced Circular Plate, Unevenly Spaced Support ···
Top Plate	Bottom/Side	0	··· MAV - Reinforced Circular Plate, Top, Unevenly Spaced Supports ···
Bottom/Side			··· MAV - Reinforced Circular Plate, Bottom Or Side, Evenly Spaced Supports ···

Angle

size	Z	lb/ft
1 x 1 x 1/8	0.031	0.80
1 x 1 x 3/16	0.044	1.16
1 x 1 x 1/4	0.056	1.49
1 1/4 x 1 1/4 x 1/8	0.049	1.01
1 1/4 x 1 1/4 x 3/16	0.071	1.48
1 1/4 x 1 1/4 x 1/4	0.091	1.92
1 1/2 x 1 1/2 x 1/8	0.072	1.23
1 1/2 x 1 1/2 x 5/32	0.088	1.52
1 1/2 x 1 1/2 x 3/16	0.104	1.80
1 1/2 x 1 1/2 x 1/4	0.134	2.34
1 3/4 x 1 3/4 x 1/8	0.099	1.44
1 3/4 x 1 3/4 x 3/16	0.144	2.12
1 3/4 x 1 3/4 x 1/4	0.186	2.77
2 x 2 x 1/8	0.131	1.65
2 x 2 x 3/16	0.190	2.44
2 x 2 x 1/4	0.247	3.19
2 x 2 x 5/16	0.300	3.92
2 x 2 x 3/8	0.351	4.70
2 1/2 x 2 1/2 x 3/16	0.303	3.07
2 1/2 x 2 1/2 x 1/4	0.394	4.10
2 1/2 x 2 1/2 x 5/16	0.482	5.00
2 1/2 x 2 1/2 x 3/8	0.566	5.90
2 1/2 x 2 1/2 x 1/2	0.724	7.70
3 x 3 x 3/16	0.441	3.71
3 x 3 x 1/4	0.577	4.90
3 x 3 x 5/16	0.707	6.10
3 x 3 x 3/8	0.833	7.20
3 x 3 x 7/16	0.954	8.30
3 x 3 x 1/2	1.070	9.40
3 1/2 x 3 1/2 x 1/4	0.794	5.80
3 1/2 x 3 1/2 x 5/16	0.976	7.20
3 1/2 x 3 1/2 x 3/8	1.150	8.50
3 1/2 x 3 1/2 x 7/16	1.320	9.80
3 1/2 x 3 1/2 x 1/2	1.490	11.10
4 x 4 x 1/4	1.050	6.60
4 x 4 x 5/16	1.290	8.20
4 x 4 x 3/8	1.520	9.80
4 x 4 x 7/16	1.750	11.30
4 x 4 x 1/2	1.970	12.80
4 x 4 x 5/8	2.400	15.70
4 x 4 x 3/4	2.810	18.50
5 x 5 x 5/16	2.040	10.30
5 x 5 x 3/8	2.420	12.30
5 x 5 x 7/16	2.790	14.30
5 x 5 x 1/2	3.160	16.20
5 x 5 x 5/8	3.860	20.00
5 x 5 x 3/4	4.530	23.60
5 x 5 x 7/8	5.170	27.20
6 x 6 x 5/16	2.970	12.40
6 x 6 x 3/8	3.530	14.90
6 x 6 x 7/16	4.080	17.20
6 x 6 x 1/2	4.610	19.60
6 x 6 x 9/16	5.140	21.90
6 x 6 x 5/8	5.660	24.20
6 x 6 x 3/4	6.660	28.70
6 x 6 x 7/8	7.630	33.10
6 x 6 x 1	8.570	37.40
8 x 8 x 1/2	8.360	26.40
8 x 8 x 9/16	9.340	29.60
8 x 8 x 5/8	10.300	32.70
8 x 8 x 3/4	12.200	38.00
8 x 8 x 7/8	14.000	45.00
8 x 8 x 1	15.800	51.00
8 x 8 x 1 1/8	17.500	56.90

Channel

size	Z (x-x)	lb/ft
C 3 x 4.1	1.100	4.10
C 3 x 5	1.240	5.00
C 3 x 6	1.380	6.00
C 4 x 5.4	1.930	5.40
C 4 x 7.25	2.290	7.25
C 5 x 6.7	3.000	6.70
C 5 x 9	3.560	9.00
C 6 x 8.2	4.380	8.20
C 6 x 10.5	5.060	10.50
C 6 x 13	5.800	13.00
C 7 x 9.8	6.080	9.80
C 7 x 12.25	6.930	12.25
C 7 x 14.75	7.780	14.75
C 8 x 11.5	8.140	11.50
C 8 x 13.75	9.030	13.75
C 8 x 18.75	11.000	18.75
C 9 x 13.4	10.600	13.40
C 9 x 15	11.300	15.00
C 9 x 20	13.500	20.00
C 10 x 15.3	13.500	15.30
C 10 x 20	15.800	20.00
C 10 x 25	18.200	25.00
C 10 x 30	20.700	30.00
C 12 x 20.7	21.500	20.70
C 12 x 25	24.100	25.00
C 12 x 30	27.000	30.00
C 15 x 33.9	42.000	33.90
C 15 x 40	46.500	40.00
C 15 x 50	53.800	50.00

I Beam

size	Z (x-x)	lb/ft
S 3 x 5.7	1.680	5.70
S 3 x 7.5	1.950	7.50
S 4 x 7.7	3.040	7.70
S 4 x 9.5	3.390	9.50
S 5 x 10	4.920	10.00
S 5 x 14.75	6.090	14.75
S 6 x 12.5	7.370	12.50
S 6 x 17.25	8.770	17.25
S 7 x 15.3	10.500	15.30
S 7 x 20	12.100	20.00
S 8 x 18.4	14.400	18.40
S 8 x 23	16.200	23.00
S 10 x 25.4	24.700	25.40
S 10 x 35	29.400	35.00
S 12 x 31.8	36.400	31.80
S 12 x 35	38.200	35.00
S 12 x 40.8	45.400	40.80
S 12 x 50	50.800	50.00
S 15 x 42.9	59.600	42.90
S 15 x 50	64.800	50.00
S 18 x 54.7	89.400	54.70
S 18 x 70	103.000	70.00
S 20 x 65.4	118.000	65.40
S 20 x 75	128.000	75.00
S 20 x 85	152.000	85.00
S 20 x 95	161.000	95.00
S 24 x 79.9	175.000	79.90
S 24 x 90	187.000	90.00
S 24 x 100	199.000	100.00
S 24 x 105.9	236.000	105.90
S 24 x 120	252.000	120.00

Beam Drop-Down Information

Case	Selection	Test
Angle	Angle	1
Channel		
I Beam		
Other		

MAP/MAV - CONE NO KNUCKLE RADIUS

BASIS: ASME Sec. VIII, Div. 1, Part UG-33. This program is for internal & external pressure on a cone section.

REFERENCES: ASME Boiler & Pressure Vessel Code, Section VIII - Division 1 - Pressure Vessels; Part UG-28 "Thickness Shells Under External Pressure", & Subpart 3 Figure G (UGO-28.0), Figure CS-1 (UCS-28.1), and Figure CS-2 (UCS 28.2).

LIMITATIONS: The default spreadsheet is limited to a maximum temperature of 700 ºF with carbon or low alloy steel only. For other materials or higher temperatures see information below:

NOTE: Always begin a new case by retrieving the original file. Direct entry of data in cells that originally contain table lookups could cause functions to be lost, or incorrect calculations. I format cells requiring entry colored **RED**; calculated values are black.

1.) Enter identification at [C4].
2.) Enter large diameter at [C7].
3.) Enter the shell thickness at [C8].
4.) Enter axial length at [C9]. One half of the cone apex angle is calculated and shown at [C10]. The cosine of the cone angle is calculated and shown at [C11].
5.) Enter allowable stress at [C12], typical selections are 18,000 PSI (124,106 kPa) for carbon steel and 20,000 PSI (137,895 kPa) for alloy steel.
6.) Enter the weld joint efficiency at [C13].
7.) For the MAP without liquid, select NO LIQUID LOAD with the drop-down at [G6] BEFORE inputting data.
8.) Enter liquid height at [G8], if calculating with liquid head.
9.) Enter liquid specific gravity at [G9], if calculating with a liquid head.
10.) Enter corrosion allowance at [G13].
11.) The effective thickness (nominal thickness - corrosion allowance) is calculated and shown at [D15]. The MAP is calculated and shown at [F20].
12.) Enter small diameter at [C30].
13.) Enter service temperature at [C31].
14.) Two ranges of yield stress are used in the spreadsheet. Select the appropriate value from the drop-down box at [G30
15.) Enter modulus of elasiticity at [G33], typical selections are 30,000,000 PSI or (2.0684272e+8 kPa).
16.) Dl/te & Le/Dl are calculated and shown at [C36] & [C37]. `A' is determined via UGO 28.0 Figure G lookup functions and reflected at [C34]. `B' is then determined from Figure CS-1 (UCS-28.1) or Figure CS-2 (UCS-28.2) according to yield stress and shown at [C35]. Tables 1 & 2 are based on ASME Tables 5, UGO-28.1 & UGO-28.2 If `A' is to left the `B' curve, the program automatically uses 2AE/(3Do/t) for MAV. The MAV is calculated and shown at [F42].

NOTE: For shells with more than one wall thickness, check each thickness at its maximum liquid depth to find lowest MAP. For no liquid, use minimum thickness.

Temperatures > 700 ºF

1.) Enter correct value for `E' at design temperature in [G33]. See the material curves in ASME Appendix 5 for values. Interpolate between temperatures as required.
2.) If A is within the default program limits it will be calculated as above, otherwise enter the `A' value from the ASME curve or table at [C34].
3.) Enter `B' from the material curve or table in ASME Appendix 5 at [C35]. If `A' is to the left of the curve, enter "#N

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04/17/04

MAP/MAV - CONE NO KNUCKLE RADIUS

SERVICE: Venturi Scrubber; Eq.#07-VJ-756100, Segment A

Cone

Large Diameter, Di:	76	inches
Shell Thickness:	0.25	inches
Cone Axial Length, L:	108	inches
1/2 Apex Angle:	18.91	(α)
Cos(α):	0.9460	
Allowable Stress:	18000	psi (S)
Joint Efficiency:	0.85	(E)

Liquid Loading

Height :	12	in.
Specific Gravity:	1.000	
P(liquid) :	0.433	psi
Corrosion Allowance:	0.0000	in.

t = 0.2500 in. - shell thickness less corrosion allowance

MAP Calculation

$$MAP = \frac{2 \cdot S \cdot E \cdot t \cdot \cos(a)}{D + 1.2 \cdot t \cdot \cos(a)} - P(liquid) \qquad 94.44 \text{ psi}$$

MAV Calculation

Small Diameter, Ds:	2	inches
Service Temperature:	500	°F.
Effective Thickness, te:	0.2365057	inches
ASME Factor A:	0.0003287	
ASME Factor B:	5314	
Di/te =	321.34535	
Le/DI =	0.7292244	

Yield Stress

24000 < Sy < 30000

Elastic Modulus: 3.0E+07 psi (E)

$$L_e := \frac{L \cdot \left(1 + \frac{D_s}{D_i}\right)}{2} = 55.421053 \text{ inches}$$

$$MAV = \frac{4 \cdot B}{3 \cdot (DI/te)} \qquad 22.05 \text{ psi}$$

MAV > 14.7, use MAV = Full Vacuum.

MAP/MAV - CONE NO KNUCKLE RADIUS

SERVICE: Venturi Scrubber; Eq.#07-VJ-756100, Segment A

Cone

Large Diameter, Di:	3175	mm
Shell Thickness:	7.9375	mm
Cone Axial Length, L:	2946.4	mm
1/2 Apex Angle:	27.93	(α)
Cos(α):	0.8835	
Allowable Stress:	124106	kPa (S)
Joint Efficiency:	0.85	(E)

Liquid Loading

Height :	304.8	mm
Specific Gravity:	1.000	
P(liquid) :	2.989	kPa
Corrosion Allowance:	0.0000	mm

t = 7.9375 mm - shell thickness less corrosion allowance

MAP Calculation

$$MAP = \frac{2 \cdot S \cdot E \cdot t \cdot \cos(a)}{D + 1.2 \cdot t \cdot \cos(a)} - P(liquid) \quad 461.79 \text{ kPa}$$

MAV Calculation

Small Diameter, Ds:	50.8	mm
Service Temperature:	260	°C.
Effective Thickness, te:	7.0128595	mm
ASME Factor A:	0.0003162	
ASME Factor B:	35747	
Di/te =	452.73971	
Le/DI =	0.471424	

Yield Stress

165475 < Sy < 206840

Elastic Modulus: 206.8E+6 kPa (E)

$$L_e := \frac{L \cdot \left(1 + \frac{D_s}{D_i}\right)}{2} = 1496.7712 \text{ mm}$$

$$MAV = \frac{4 \cdot B}{3 \cdot (DI/te)} \quad 105.28 \text{ kPa}$$

MAV > 101.325, Rated for Full Vacuum.

MAP/MAV - CYLINDRICAL SHELL

BASIS: ASME Sec. VIII, Div. 1, Part UG-33. This program is for internal & external pressure on a cylindrical sl section.

REFERENCES: ASME Boiler & Pressure Vessel Code, Section VIII - Division 1 - Pressure Vessels; Part UG-28 "Thickr Shells Under External Pressure", & Subpart 3 Figure G (UGO-28.0), Figure CS-1 (UCS-28.1), and Figure CS-2 (UCS 28.2).

LIMITATIONS: The default spreadsheet is limited to a maximum temperature of 700 ºF with carbon or low alloy ste only. For other materials or higher temperatures see information below:

NOTE: Always begin a new case by retrieving the original file. Direct entry of data in cells that originally con table lookups could cause functions to be lost, or incorrect calculations. I format cells requiring entr colored **RED**; calculated values are black.

1. Enter identification at [C4].
2. Enter the shell height at [C6].
3. Enter shell inside diameter at [C7].
4. Enter the shell thickness at [C8].
5. Enter allowable stress at [C12], typical selections are 18,000 PSI (124,106 kPa) for carbon steel and 20,000 PSI (137,895 kPa) for alloy steel.
6. Enter corrosion allowance at [C10].
7. Enter the weld joint efficiency at [C11].
8. For the MAP without liquid, select NO LIQUID LOAD with the drop-down at [G5] BEFORE inputting data.
9. Enter liquid height at [G7], if calculating with liquid head.
10. Enter liquid specific gravity at [G8], if calculating with a liquid head.
11. The effective thickness (nominal thickness - corrosion allowance) is calculated and shown at [D13]. The MAP is calculated and shown at [G18].

12. Two ranges of yield stress are used in the spreadsheet. Select the appropriate value from the drop-down box a
13. Enter service temperature at [G30].
14. Enter modulus of elasiticity at [G31], typical selections are 30,000,000 PSI or (2.0684272e+8 kPa).

NOTES: If the shell has reinforcing rings or other stiffening enter the correct length for the calculation directly into [C6] Do/t & L/Do are calculated and show at [C28] & [C29]. \`A' is determined via UGO 28.0 Figure G lookup functio \`B' is then determined from Figure CS-1 (UCS-28.1) or Figure CS-2 (UCS-28.2) according to yield stress. Table 1 & 2 are based on ASME Tables 5, UGO-28.1 & UGO-28.2 If \`A' is to left of the \`B' curve, the program autom uses 2AE/(3Do/t) for MAV.

For shells with more than one wall thickness, check each thickness at its maximum liquid depth to find lowest For no liquid, use minimum thickness.

The MAV is calculated and shown at [E37].

Temperatures > 700 °F

1.) Enter correct value for \`E' at design temperature in [G31]. See the material curves in ASME Appendix 5 for valu Interpolate between temperatures as required.
2.) If A is within the default program limits it will be calculated as above, otherwise enter the \`A' value from the A curve or table at [C30].
3.) Enter \`B' from the material curve or table in ASME Appendix 5 at [C31]. If \`A' is to the left of the curve, ente

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This Spreadsheet Requires MACROS to be ENABLED to ASSURE proper operation.
See the Workbook Help Sheet for Additional Instructions on Use.

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MAP/MAV - CYLINDRICAL SHELL

SERVICE: Flammable Liquid Hold Tanks

Shell

Height:	48	inches or 4.00 feet
Inside Diameter, D:	170	inches or 14.17 feet
Shell Thickness:	0.2500	inches
Allowable Stress:	18000	psi (S)
Corrosion Allow:	0.0000	in.
Joint Eff:	0.85	(E)

Liquid Loading

Height :	12	in.
Specific Gravity:	1.000	
P(liquid) :	0.433	psi

t = 0.2500 in. - shell thickness less corrosion allowance

MAP Calculation

$$MAP = \frac{2 \cdot S \cdot E \cdot t}{D + 1.2 \cdot t} - P(liquid) = 44.49 \text{ psi}$$

MAV Calculation

UGO 28.0

Do/t:	680
L/Do:	0.282
ASME Factor A:	0.000295
ASME Factor B:	4956

Yield Stress

24000 < Sy < 30000

Service Temp:	500	ºF.
Elastic Modulus:	2.9E+07	psi (E)

$$MAV = \frac{4 \cdot B}{3 \cdot (Do/t)} \quad 9.72 \text{ psi}$$

MAP/MAV - CYLINDRICAL SHELL

SERVICE: Flammable Liquid Hold Tanks

Shell

Height:	100	mm
Inside Diameter, D:	345	mm
Shell Thickness:	6.3500	mm
Allowable Stress:	124106	kPa (S)
Corrosion Allow:	0.0000	mm
Joint Eff:	0.85	(E)

Liquid Loading

Height :	304.8	mm
Specific Gravity:	1.000	
P(liquid) :	2.989	kPa

t = 6.3500 mm - shell thickness less corrosion allowance

MAP Calculation

$$MAP = \frac{2 \cdot S \cdot E \cdot t}{D + 1.2 \cdot t} - P(liquid) = 3796.35 \text{ kPa}$$

MAV Calculation

UGO 28.0

Do/t:	54.33071
L/Do:	0.290
ASME Factor A:	0.014684
ASME Factor B:	34168

Yield Stress

165475 < Sy < 206840

Service Temp:	260	ºC.
Elastic Modulus:	206.8E+6	kPa (E)

$$MAV = \frac{4 \cdot B}{3 \cdot (Do/t)} \quad 838.51 \text{ kPa}$$

MAV > 101.325, Rated for Full Vacuum.

MAP/MAV - ELLIPSOIDAL HEADS

BASIS: ASME Sec. VIII, Div. 1, Part UG-33. This program is for internal & external pressure on an ellipsoic

REFERENCES: ASME Boiler & Pressure Vessel Code, Section VIII - Division 1 - Pressure Vessels; Part UG-32 "For Heads, and Sections, Pressure on Concave Side" and Part UG-33 "Formed Heads, Pressure on Co Side".

LIMITATIONS: The default spreadsheet is limited to a maximum temperature of 700 ºF with carbon or low alloy ste only. For other materials or higher temperatures see information below:

NOTE: Always begin a new case by retrieving the original file. Direct entry of data in cells that originally c table lookups could cause functions to be lost, or incorrect calculations. I format cells requiring e colored **RED**; calculated values are black.

1.) Enter identification at [C4].
2.) Enter inside diameter at [C6].
3.) Enter thickness at [C7].
4.) Enter allowable stress at [C8], typical selections are 18,000 PSI (124,106 kPa) for carbon steel and 20,000 PS (137,895 kPa) for alloy steel.
5.) Enter corrosion allowance at [C9].
6.) Enter the weld joint efficiency at [C10].
7.) For the MAP without liquid, select NO LIQUID LOAD with the drop-down at [G5] BEFORE inputting data.
8.) Enter liquid height at [G7], if calculating with liquid.
9.) Enter liquid specific gravity at [G8], if calculating with liquid.
10.) The controlling MAP is shown at [F17].

11.) Two ranges of yield stress are used in the spreadsheet. Select the appropriate value from the drop-down b [G28].
12.) Enter modulus of elasiticity at [G28], typical selections are 30,000,000 PSI or (2.0684272e+8 kPa).
13.) Enter (Ho) the head height, excluding any straight flange length at [G29].
14.) Enter service temperature at [G30].
15.) The controlling MAV is shown at [F46].

NOTE: Do/2Ho, Ro, Ro/t, and A are calculated and show on lines 30 thru 35. Ko is looked up in Table 3, function of Do/2Ho. Table 3 provides a linear interpolation of ASME TABLE UG-33.1 `B' is determi Table 1 or Table 2 according to yield stress. Tables 1 & 2 also interpolate linearly, AND are based c Tables 5, UGO-28.1 & UGO-28.2. If 'A' is to the left of the 'B' curve, the program automatically use: 0.0625 E/(Ro/t)^2 for case #1.

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MAP/MAV - ELLIPSOIDAL HEADS

SERVICE: Vacuum Separators 9C-800 & 9C-801

Shell

Inside Diameter, D:	108	inches or 9.00 feet
Shell Thickness:	0.25	inches
Allowable Stress:	18000	psi (S)
Corrosion Allow:	0.0000	inches
Joint Eff:	0.85	(E)

Liquid Loading

Height :	12	in.
Specific Gravity:	1.000	
P(liquid) :	0.433	psi

t = 0.2500 in. - shell thickness less corrosion allowance

MAP Calculation

$$MAP = \frac{2 \cdot S \cdot E \cdot t}{D + 0.2 \cdot t} - P\,(liquid) = 70.368 \text{ psi}$$

MAV Calculation

UGO 28.0

Ro = KoDo :	146.88
Ro/t :	587.52
Do/2Ho :	3.00
Ko :	1.36
A = 0.125/(Ro/t) :	0.000213
B :	4003

Yield Stress

24000 < Sy < 30000

Elastic Modulus :	2.90E+07	psi (E)
Head Height :	5	in. (Ho)
Service Temp :	300	ºF.

Case 1

$$MAV = \frac{B}{(Ro/t)} = 6.813 \text{ psi}$$

Case 2

$$MAV = \frac{2 \cdot S \cdot E \cdot t}{1.67 \cdot (D + 0.2 \cdot t)} = 42.396 \text{ psi}$$

Final

MAV = 6.813 psi

MAP/MAV - ELLIPSOIDAL HEADS

SERVICE: Vacuum Separators 9C-800 & 9C-801

Shell			**Liquid Loading**		
Inside Diameter, D:	2743.2	mm			
Shell Thickness:	6.35	mm	Height :	304.8	mm
Allowable Stress:	124106	kPa (S)	Specific Gravity:	1.000	
Corrosion Allow:	0.0000	mm			
Joint Eff:	0.85	(E)	P(liquid) :	2.989	kPa

t = 6.3500 mm - shell thickness less corrosion allowance

MAP Calculation

$$MAP = \frac{2 \cdot S \cdot E \cdot t}{D + 0.2 \cdot t} - P\,(liquid) = 485.165 \text{ kPa}$$

MAV Calculation

UGO 28.0

Ro = KoDo :	3730.752
Ro/t :	587.52
Do/2Ho :	3.00
Ko :	1.36
A = 0.125/(Ro/t) :	0.000213
B :	23431

Yield Stress

Sy > 206840

Elastic Modulus :	206.8E+6	kPa (E)
Head Height :	127	mm (Ho)
Service Temp :	148.89	ºC.

Case 1

$$MAV = \frac{B}{(Ro/t)} = 39.881 \text{ kPa}$$

Case 2

$$MAV = \frac{2 \cdot S \cdot E \cdot t}{1.67 \cdot (D + 0.2 \cdot t)} = 292.308 \text{ kPa}$$

Final

MAV = 39.881 kPa

MAP/MAV - TORISPHERICAL (Flanged & Dished) HEADS

BASIS: ASME Sec. VIII, Div. 1, Part UG-33. This program is for internal & external pressure on a torispherical head.

REFERENCES: ASME Boiler & Pressure Vessel Code, Section VIII - Division 1 - Pressure Vessels; Part UG-32 "Formed Heads, and Sections, Pressure on Concave Side" and Part UG-33 "Formed Heads, Pressure on Convex Side".

LIMITATIONS: The default spreadsheet is limited to a maximum temperature of 700 ºF with carbon or low alloy steel only. For other materials or higher temperatures see information below:

NOTE: Always begin a new case by retrieving the original file. Direct entry of data in cells that originally contain table lookups could cause functions to be lost, or incorrect calculations. I format cells requiring entry colored **RED**; calculated values are black.

1.) Enter identification at [C4].
2.) Enter inside diameter at [C6].
3.) Enter inside crown radius at [C7] or accept default of 100% of diameter.
4.) Enter thickness at [C8].
5.) Enter allowable stress at [C9], typical selections are 18,000 PSI (124,106 kPa) for carbon steel and 20,000 PSI (137,895 kPa) for alloy steel.
6.) Enter corrosion allowance at [C10].
7.) Enter the weld joint efficiency at [C11].
8.) For the MAP without liquid, select NO LIQUID LOAD with the drop-down at [G5] BEFORE inputting data.
9.) Enter liquid height at [G7], if calculating with liquid.
10.) Enter liquid specific gravity at [G8], if calculating with liquid.
The controlling MAP is shown at [G18].

11.) Two ranges of yield stress are used in the spreadsheet. Select the appropriate value from the drop-down box at [G27].
12.) Enter modulus of elasiticity at [G29], typical selections are 30,000,000 PSI or (2.0684272e+8 kPa).
13.) Enter service temperature at [G30].
14.) The controlling MAV is shown at [G36].

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MAP/MAV - TORISPHERICAL (Flanged & Dished) HEADS

SERVICE: Vacuum Separators 9C-800 & 9C-801

Shell			**Liquid Loading**		
Inside Diameter, D:	108	inches or 9.00 feet			
nside Crown Radius, L:	108	inches or 9.00 feet	Height :	12	in.
Shell Thickness:	0.25	inches	Specific Gravity:	1.000	
Allowable Stress:	18000	psi (S)			
Corrosion Allow:	0.0000	inches	P(liquid) :	0.433	psi
Joint Eff:	0.85	(E)			

t = 0.2500 in. - shell thickness less corrosion allowance

MAP Calculation

$$MAP = \frac{S \cdot E \cdot t}{0.885 \cdot L + 0.1 \cdot t} - P(liqui \quad 39.575 \text{ psi}$$

MAV Calculation

UGO 28.0

Ro = L :	108
Ro/t :	432
A = 0.125/(Ro/t) :	0.000289
B :	4842

Yield Stress

Sy > 30000

Elastic Modulus :	2.90E+07	psi (E)
Service Temp :	300	ºF.

$$MAV = \frac{B}{(Ro/t)} = 11.209 \text{ psi}$$

MAP/MAV - TORISPHERICAL (Flanged & Dished) HEADS

SERVICE: Vacuum Separators 9C-800 & 9C-801

··············· Shell ···············			········ Liquid Loading ········		
Inside Diameter, D:	2743.2	mm			
nside Crown Radius, L:	2743.2	mm	Height :	304.8	mm
Shell Thickness:	6.35	mm	Specific Gravity:	1.000	
Allowable Stress:	124106	kPa (S)			
Corrosion Allow:	0.0000	mm	P(liquid) :	2.989	kPa
Joint Eff:	0.85	(E)			

t = 6.3500 mm - shell thickness less corrosion allowance

····· MAP Calculation ······

$$MAP = \frac{S \cdot E \cdot t}{0.885 \cdot L + 0.1 \cdot t} - P(liqui \quad 272.860 \text{ kPa}$$

····· MAV Calculation ·····

······ UGO 28.0 ······

Ro = L :	2743.2
Ro/t :	432
A = 0.125/(Ro/t) :	0.000289
B :	33386

·············· Yield Stress ··············

Sy > 206840

Elastic Modulus :	206.8E+6	kPa (E)
Service Temp :	148.89	ºC.

$$MAV = \frac{B}{(Ro/t)} = 77.281 \text{ kPa}$$

MAP/MAV - Square Plates, full edge support

BASIS: This spreadsheet is for internal & external pressure on a square plate. Options allow calculation for the top, side, or bottom plate of a vessel. The MAV calculation subtracts the dead load of the plate (W/A) from the top segment.

NOTE: Always begin a new case by retrieving the original file. Direct entry of data in cells that originally contain table lookups could cause functions to be lost, or incorrect calculations. I format cells requiring entry colored **RED**; calculated values are black.

1.) Enter identification at [C4].
2.) Enter length of a side at [C6].
3.) Enter thickness at [C7].
4.) Enter corrosion allowance at [C8].
5.) Enter allowable stress at [C11], typical selections are 18,000 PSI (124,106 kPa) for carbon steel and 20,000 PSI (137,895 kPa) for alloy steel.
6.) For the MAP without liquid, select NO LIQUID LOAD with the drop-down at [G5] BEFORE inputting data.
7.) Enter liquid height at [G7].
8.) Enter liquid specific gravity at [G8].

The MAP is calculated and shown at [G17].

9.) To use for a top plate - or - bottom/side plate, select appropriately with the drop-down at [G24]. The dead load penality is appropriately applied to the calculation.

The MAV is calculated and shown at [F32].

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04/17/04

MAP / MAV - Square Plates, full edge support

SERVICE: BLEACHED STOCK HEADBOX

Plate			Liquid Loading		
Side Length:	30	in. (a & b)			
Thickness:	0.25	in.	Height :	12	in.
Corrosion Allow:	0	in.	Specific Gravity:	1.000	
Allowable Stress:	18000	psi (S)			
			P(liquid) :	0.433	psi

t = 0.25 in. - shell thickness less corrosion allowance

MAP Calculation

$$MAP = 3.56 \cdot S \cdot t^2 \frac{(a^2 + b^2)}{(a^2 \cdot b^2)} - P(liquid) = 8.4670996 \text{ psi}$$

MAV Calculation Top Plate

Top Area, A :	900	sq in
Weight, W :	63.68	lbs.
Weight / Area :	0.071	psi

$$MAV = 3.56 \cdot S \cdot t^2 \frac{(a^2 + b^2)}{(a^2 \cdot b^2)} - \frac{W}{A} = 8.82925 \text{ psi}$$

MAP / MAV - Square Plates, full edge support

SERVICE: BLEACHED STOCK HEADBOX

Plate			Liquid Loading		
Side Length:	3000	mm (a & b)			
Thickness:	20	mm	Height :	304.8	mm
Corrosion Allow:	0.0000	mm	Specific Gravity:	1.000	
Allowable Stress:	124106	kPa (S)			
			P(liquid) :	2.989	kPa

t = 20 mm - shell thickness less corrosion allowance

MAP Calculation

$$MAP = 3.56 \cdot S \cdot t^2 * \frac{(a^2 + b^2)}{(a^2 \cdot b^2)} - P(liquid) = 36.283587 \text{ kPa}$$

MAV Calculation — **Top Plate**

Top Area, A :	9000000	sq mm
Weight, W :	1409.94	kg
Weight / Area :	1.53631	kPa

$$MAV = 3.56 \cdot S \cdot t^2 * \frac{(a^2 + b^2)}{(a^2 \cdot b^2)} - \frac{W}{A} = 37.736344 \text{ kPa}$$

MAP/MAV - Rectangular Plates, full edge support

BASIS: This program is for internal and external pressure on a retangular plate. Options allow calculation for the top, side, or bottom plate of a vessel. The MAV calculation subtracts the dead load of the plate (W/A) from the top segment.

NOTE: Always begin a new case by retrieving the original file. Direct entry of data in cells that originally contain table lookups could cause functions to be lost, or incorrect calculations. I format cells requiring entry colored **RED**; calculated values are black.

1.) Enter identification at [C4].
2.) Enter length of long side at [C7].
3.) Enter length of short side at [C8].
4.) Enter thickness at [C9].
5.) Enter corrosion allowance at [C10].
6.) Enter allowable stress at [C11], typical selections are 18,000 PSI (124,106 kPa) for carbon steel and 20,000 PSI (137,895 kPa) for alloy steel.
7.) For the MAP without liquid, select NO LIQUID LOAD with the drop-down at [G6] BEFORE inputting data.
8.) Enter liquid height at [G8].
9.) Enter liquid specific gravity at [G9].

The MAP is calculated and shown at [F20].

10.) To use for a top plate - or - bottom/side plate, select appropriately with the drop-down at [G27]. The dead load penality is appropriately applied to the calculation.

The MAV is calculated and shown at [E35].

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This Spreadsheet Requires MACROS to be ENABLED to ASSURE proper operation.
See the Workbook Help Sheet for Additional Instructions on Use.

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MAP/MAV - Rectangular Plate, full edge support

SERVICE: VENTURI SCRUBBER; EQ.#07-VJ-756100, SEGMENT G

Plate — No Liquid Load

Long Side:	48	in. (a)	
Short Side:	33	in. (b)	48
Thickness:	0.25	in.	1.72
Corrosion Allow:	0.0000	in.	
Allowable Stress:	18000	psi (S)	

t = 0.25 in. - shell thickness less corrosion allowance

MAP Calculation

$$MAP = \frac{S * t^2 * (a^2 + b^2)}{(0.281 * a^2 * b^2)} = 5.41401815 \text{ psi}$$

MAV Calculation — Top Plate

Top Area, A =	1584	sq. in.
Weight, W =	112.068	lbs.
W / A =	0.07075	psi

$$MAV = \frac{S * t^2 * (a^2 + b^2)}{(0.281 * a^2 * b^2)} - \frac{W}{A} = 5.34326815 \text{ psi}$$

04/17/04

MAP/MAV - Rectangular Plate, full edge support

SERVICE: VENTURI SCRUBBER; EQ.#07-VJ-756100, SEGMENT G

Plate / **Liquid Loading**

Long Side:	1219.2	mm (a)			
Short Side:	1219.2	mm (b)	Height :	1219.2	mm
Thickness:	6.35	mm	Specific Gravity:	1.72	
Corrosion Allow:	0.0000	mm			
Allowable Stress:	124106	kPa (S)	P(liquid) :	20.565	kPa

t = 6.35 mm - shell thickness less corrosion allowance

MAP Calculation

$$MAP = \frac{S * t^2 * (a^2 + b^2)}{(0.281 * a^2 * b^2)} - P(liquid) = 3.39671932 \text{ kPa, or } 0.03 \text{ bar}$$

MAV Calculation / **Top Plate**

Top Area, A = 1486448.64 sq mm
Weight, W = 73.9352865 kg

Weight / Area = 0.48777836 kPa

$$MAV = \frac{S * t^2 * (a^2 + b^2)}{(0.281 * a^2 * b^2)} - \frac{W}{A} = 23.4737214 \text{ kPa, or } 0.23 \text{ bar}$$

MAP/MAV - Triangular Plates, full edge support

BASIS: Internal & external pressure on a triangular segment. The spreadsheet is set up for MAP determination of top, side, or bottom plates of a vessel with or without liquid loading. The MAV of the same with the top plate less the dead load of the plate (W/A).

NOTE: Always begin a new case by retrieving the original file. Direct entry of data in cells that originally contain table lookups could cause functions to be lost, or incorrect calculations. I format cells requiring entry colored **RED**; calculated values are black.

1.) Enter identification at [C4].
2.) Enter the length of a side at [C7]. Two-thirds of the triangle height will be calculated & shown at C8.
3.) Enter thickness at [C9].
4.) Enter corrosion allowance at [C10].
5.) Enter allowable stress at [C11], typical selections are 18,000 PSI (124,106 kPa) for carbon steel and 20,000 PSI (137,895 kPa) for alloy steel.
7.) For the MAP without liquid, select NO LIQUID LOAD with the drop-down at [G6] BEFORE inputting data.
8.) Enter liquid height at [G8].
9.) Enter liquid specific gravity at [G9].

The MAP is calculated and shown at [E20].

MAV Calculation

To use for a top plate - or - bottom/side plate, select appropriately with the drop-down at [G27]. The dead load penality is appropriately applied to the calculation.

The MAV is calculated and shown at [F35].

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MAP/MAV - Triangular Plates, full edge support

SERVICE: FN-7 DUST COLLECTOR - CONE SIDE PLATE

Plate | **Liquid Loading**

Side Length:	36	in. (b)			
2/3 Height:	20.78	in. (a)	Height :	48	in.
Thickness:	0.25	in.	Specific Gravity:	1.72	
Corrosion Allow:	0.0000	in.			
Allowable Stress:	18000	psi (S)	P(liquid) :	2.978	psi

t = 0.25 in. - shell thickness less corrosion allowance

MAP Calculation

$$MAP = 3.56 \cdot S \cdot t^2 \frac{(a^2 + b^2)}{(a^2 \cdot b^2)} - P(liquid) = 9.3833001 \text{ psi}$$

MAV Calculation | **Top Plate**

Top Area, A =	561.18	sq. in.
Top Weight, W =	39.70	lbs.
Weight / Area =	0.071	psi

$$MAV = 3.56 \cdot S \cdot t^2 \frac{(a^2 + b^2)}{(a^2 \cdot b^2)} - \frac{W}{A} = 12.290905 \text{ psi}$$

MAP/MAV - Triangular Plates, full edge support

SERVICE: FN-7 DUST COLLECTOR - CONE SIDE PLATE

Plate

Side Length:	1500	mm (b)
2/3 Height:	866.00	mm (a)
Thickness:	6.35	mm
Corrosion Allow:	0.0000	mm
Allowable Stress:	124106	kPa (S)

Liquid Loading

Height :	1219.2	mm
Specific Gravity:	1.72	
P(liquid) :	20.565	kPa

t = 6.35 mm - shell thickness less corrosion allowance

MAP Calculation

$$MAP = 3.56 \cdot S \cdot t^2 \frac{(a^2 + b^2)}{(a^2 \cdot b^2)} - P(liquid) = 11.108045 \text{ kPa}$$

MAV Calculation

Top Plate

Top Area, A =	1299000	sq. mm
Top Weight, W =	64.611675	kg
Weight / Area =	4.974E-05	kg/sq mm
=	0.4877784	kPa

$$MAV = 3.56 \cdot S \cdot t^2 \frac{(a^2 + b^2)}{(a^2 \cdot b^2)} - \frac{W}{A} = 31.185047 \text{ kPa}$$

MAP/MAV - self supporting dome roof (spherical section)

BASIS: This spreadsheet is for internal/external pressure on a spherical (dome or umbrella) roof with single fillet lap joint construction.

REFERENCES: ASME Boiler & Pressure Vessel Code, Section VIII - Division 1 - Pressure Vessels; Part UG-32 Forme Heads, and Sections, Pressure on Concave Side" and Part UG-33 "Formed Heads, Pressure on Cor Side".

NOTE: Always begin a new case by retrieving the original file. Direct entry of data in cells that originally co table lookups could cause functions to be lost, or incorrect calculations. I format cells requiring er colored **RED**; calculated values are black.

LIMITS: The variables listed at the right are limit in the calculation as indicated. For oth materials or higher temps see NOTE: (

	min.	max.
Temp.		700
A		0.1
material	*	*
welding	*	*

NOTE: **Ro/t, and A are calculated and show on lines 28 & 29. `B' is determined from ASME Table CS-1 or CS-2 according to yield stress. Factor 'B' is calculated based on an equation fitted to the ASME tabular data for the appropriate temperature as input. If `A' is to the left of the 'B' curve, the program automatically uses the value of 0.0625*E/(Ro/t)^2 for determining 2P.**

1.) Enter identification at [C4].
2.) Enter the vessel diameter at [C6].
3.) Enter spherical radius at [C7].
4.) Enter thickness at [C8].
5.) Enter corrosion allowance at [C9].
6.) Enter allowable stress at [C10], typical selections are 18,000 PSI (124,106 kPa) for carbon steel and 20,000 PS (137,895 kPa) for alloy steel.
7.) Enter the weld joint efficiency at [C11].
8.) Enter modulus of elasiticity at [G6], typical selections are 30,000,000 PSI or (2.0684272e+8 kPa).
9.) Enter service temperature at [G7].
10.) Enter any roof dead load at [G10].
11.) Two ranges of yield stress are used in the spreadsheet. Select the appropriate value from the drop-down box at [G26].

The MAP is calculated and shown at [E19].

The MAV is calculated and shows at [F39].

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MAP/MAV - self supporting dome roof (spherical section)

SERVICE: TURPENTINE STORAGE

Diameter:	125	in. or 10.42 ft.	Elastic Modulus:	30.0E+6	psi (E)
Roof Spherical Radius:	96	in. (R) or 8.00 ft.	Service Temp:	650	ºF.
Thickness:	0.045	in.	Roof Area:	85.28	sq. ft.
Corrosion Allow:	0.0000	in.	Area, Ax:	85	sq. ft.
Allowable Stress:	18000	psi (S)	Roof Wt, Wr:	156	lbs.
Joint Efficiency:	0.8	(E)	Add'l Load, Wd:	0	lbs.

t = 0.045 in. - shell thickness less corrosion allowance

······· MAP Calculation ·······

$$MAP = \frac{2 \cdot S \cdot E \cdot t}{R + 0.2 \cdot t} = 13.509 \text{ psi}$$

······· MAV Calculation ·······

Yield Stress, psi: 24000 < Sy < 30000

Ro/t = 2133

A = 0.125/(Ro/t) = 0.000059

B = #N/A

$$2P = \frac{0.0625 \cdot E}{(Ro/t)^2} = 0.412 \text{ psi}$$

(2P used for lap joint)

$$MAV = P - \frac{Wr + Wd}{144\ Ax} = 0.193 \text{ psi}$$

MAP/MAV - self supporting dome roof (spherical section)

SERVICE: TURPENTINE STORAGE

Diameter:	4876.8	mm	Elastic Modulus:	206.8E+6	kPa (E)
Roof Spherical Radius:	2438.4	mm (R)	Service Temp:	343	ºC.
Thickness:	9.525	mm	Area, Ax:	18.679265	sq. meter
Corrosion Allow:	9.0000	mm	Roof Wt, Wr:	77	kg
Allowable Stress:	124106	kPa (S)	Add'l Load, Wd:	0	kg
Joint Efficiency:	0.8	(E)			

t = 0.525 mm - shell thickness less corrosion allowance

.... MAP Calculation ....

$$MAP = \frac{2 \cdot S \cdot E \cdot t}{R + 0.2 \cdot t} = 42.85805$$ kPa, or 0.43 bar

.... MAV Calculation ....

Yield Stress, kPa: 165475 < Sy < 206840

Ro/t = 4645

A = 0.125/(Ro/t) = 0.000027

(2P used for lap joint)

B = #N/A

$$2P = \frac{0.0625 \cdot E}{(Ro/t)^2} = 0.599$$ kPa, or 0.01 bar

$$MAV := P - \left[\frac{(W_r + W_d)}{(10^6 \cdot A_x) \cdot 9806.65} \right] = 0.259$$ kPa, or 0.00 bar

MAP/MAV - FRP (Fiberglass Reinforced Plastic) ELLIPSOIDAL HEAD

BASIS: This spreadsheet is for internal/external pressure of a **Fiberglass Reinforced Plastic Ellipsoidal Head.**

REFERENCES: Calculation basis ASME SECTION X RD-1173 - 1995

NOTE: Always begin a new case by retrieving the original file. Direct entry of data in cells that originally contain table lookups could cause functions to be lost, or incorrect calculations. I format cells requiring entry colored **RED**; calculated values are black.

1.) Enter identification at [C4].
2.) Enter inside diameter at [C7].
3.) Enter the head thickness at [C8].
4.) Enter the longitudinal tensile modulus at [C9].
5.) Enter the circumferential tensile modulus at [C10].
6.) Enter the service temperature at [C11].
7.) For the MAP without liquid, select NO LIQUID LOAD with the drop-down at [G6] BEFORE inputting data.
8.) Enter liquid height at [G8], if calculating with liquid.
9.) Enter liquid specific gravity at [G9], if calculating with liquid.
The MAP is calculated and shown at [G23].
10.) Enter head major axis at [C34].
11.) Enter head minor axis at [C35].
The head radius factor is calculated and shown at C36.
This value (Ko) is dependant on the ellipsoidal head proportions. The radius of curvature of an ellipsoidal head varies along its meridian, thus permitting an average or equivalent radius to be determined from the from the major-to-minor axis. For unknown head axis dimensions the methodology used for steel ellipsoidal heads may be substituted as follows: Compare the major-to-minor axis ratio = (Do/2ho), which is the oustide diameter of the head divided by twice the outside height of the head (measured from the tangent or head-bend line) to the table values for Ko at A53. DO NOT use values outside the limits of the table. Manually enter this value at [C36].
The Design Factor is given at G34, this cell is unprotected but as defined by ASME it equals 10. It is recommended NOT to change.
11.) Enter material's Poisson's ratio for the major direction at [G35].
12.) Enter material's Poisson's ratio for the minor direction at [G36]. Poisson's ratio is the negative of the ratio of the lateral strain to uniaxial strain, in axial loading. Its value for many solids, is close to 1/3. For elastomers it is just under 1/2.
The strength (MAV) will be calculated as shown at [G41].

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MAP/MAV - FRP (Fiberglass Reinforced Plastic) ELLIPSOIDAL HEAD

SERVICE: DILUTE ACID STORAGE TANK - BOTTOM HEAD

Head

Inside Diameter, D :	96	inches
Head Thickness, t :	0.4375	inches
Tensile Modulus, E1 :	897,776	psi, longitudinal
Tensile Modulus, E2 :	2,228,369	psi, circumferential
Service Temperature :	180	°F.

Liquid Loading

Height :	48	in.
Specific Gravity:	1.001	
P(liquid) :	1.733	psi

calculation basis for MAP is a re-arrangement of:

$$t = \frac{P \cdot D}{2 \cdot (0.001 \cdot E - 0.6 \cdot P)}$$

MAP Calculation

$$P = 0.01 \cdot t \cdot \frac{E}{(6 \cdot t + 5 \cdot D)} - P(liquid) = 6.40501425 \text{ psi}$$

MAV Calculation

Head Major Axis :	48	in.	Design Factor:	10	F
Head Minor Axis :	48	in.	Poisson's Ratio Major :	0.46	v1
Radius Factor:	0.500	Ko	Poisson's Ratio Minor :	0.16	v2

$$P = \frac{0.41 \cdot (E / F) \cdot t^2}{[3 \cdot (1 - v_1 \cdot v_2)]^{0.5} \cdot (K_o \cdot D)^2} = 1.8342798 \text{ psi}$$

MAP/MAV - FRP (Fiberglass Reinforced Plastic) ELLIPSOIDAL HEAD

SERVICE: DILUTE ACID STORAGE TANK - BOTTOM HEAD

Head			**Liquid Loading**		
Inside Diameter, D :	2438.4	mm			
Head Thickness, t :	11.1125	mm	Height :	1219.2	mm
Tensile Modulus, E1 :	6,189,948	kPa, longitudinal	Specific Gravity:	1.001	
Tensile Modulus, E2 :	15,364,063	kPa, circumferential			
Service Temperature :	82.2	°C.	P(liquid) :	11.968	kPa

calculation basis for MAP is a re-arrangement of:

$$t = \frac{P \cdot D}{2 \cdot (0.001 \cdot E - 0.6 \cdot P)}$$

MAP Calculation

$$P = 0.01 \cdot t \cdot \frac{E}{(6 \cdot t + 5 \cdot D)} - P(liquid) = 44.1437072 \text{ kPa}$$

MAV Calculation

Head Major Axis :	1219.2	mm	Design Factor:	10	F
Head Minor Axis :	1219.2	mm	Poisson's Ratio Major :	0.46	v1
Radius Factor:	0.500	Ko	Poisson's Ratio Minor :	0.16	v2

$$P = \frac{0.41 \cdot (E / F) \cdot t^2}{[3 \cdot (1 - v_1 \cdot v_2)]^{0.5} \cdot (K_o \cdot D)^2} = 12.646914 \text{ kPa}$$

MAP/MAV - FRP (Fiberglass Reinforced Plastic) Cylindrical Shell

BASIS: This program is for internal/external pressure on a fiberglass reinforced plastic **(FRP)** cylindrical shell of **FILAMENT WOUND CONSTRUCTION METHODS**.

REFERENCES: Calculation basis ASME SECTION X RD-1173 - 1995

NOTE: Always begin a new case by retrieving the original file. Direct entry of data in cells that originally contain table lookups could cause functions to be lost, or incorrect calculations. I format cells requiring entry colored **RED**; calculated values are black.

1. Enter identification at [C4].
2. Enter the inside diameter at [C6].
3. Enter thickness at [C7].
4. Enter the longitudinal tensile modulus at [C8].
5. Enter the circumferential tensile modulus at [C9].
6. Enter the service temperature at [C10].
7. For the MAP without liquid, select NO LIQUID LOAD with the drop-down at [G5] BEFORE inputting data.
8. Enter liquid height at [G7], if calculating with liquid head.
9. Enter liquid specific gravity at [G8], if calculating with a liquid head.

NOTE: For shells with more than one wall thickness, check each thickness at its maximum liquid depth to find lowest MAP.
For no liquid, use minimum thickness.
The MAP is calculated and shown at [E25].

10. Enter the shell length between stiffeners at [D34].
11. Enter the poisson's ratio major direction (longitudinal) at [D35].
12. Enter the poisson's ratio minor direction (circumferential) at [D36].
13. The Design Factor is given at D37, this cell is unprotected but as defined by ASME it equals 5. It is recommended NOT to change.
14. The strength will be calculated as shown "case 1 & case 2" the actual controlling equation and resulting value is based on the critical length comparison of Lc/Do vs. L/Do. The MAV will be given at [G57].

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MAP/MAV - FRP (Fiberglass Reinforced Plastic) Cylindrical Shell

TANK: PREMIX TANK - FRP MAP RATING

··· Shell ···			··· Liquid Loading ···		
Inside Diameter, D :	12	inches			
Shell Thickness, t :	0.1	inches	Height :	48	in.
Tensile Modulus, E1 :	500000	psi, longitudinal	Specific Gravity:	1.001	
Tensile Modulus, E2 :	500000	psi, circumferential			
Service Temperature :	180	°F.	P(liquid) :	1.733	psi

Case 1, Longitudinal Stress

$$P := 0.01 \cdot t_1 \cdot \left[\frac{E_1}{(6 \cdot t_1 + 5 \cdot R)}\right] - P(\text{liquid}) = 14.606536 \text{ psig}$$

Case 1, Circumferential Stress

$$P := 0.005 \cdot t_2 \cdot \left[\frac{E_2}{(3 \cdot t_2 + 5 \cdot R)}\right] - P(\text{liquid}) = 6.5174917 \text{ psig}$$

Case 2, - Governs **MAP =** 6.5174917 psig

MAV Calculation

Shell Length, L =	24	in. - between supports	Do =	12.20
Poisson's ratio, v1:	0.46	major direction	Do/t =	122.00
Poisson's ratio, v2:	0.16	minor direction	L/Do =	1.967
Design Factor:	5	F	t/Do =	0.0082
Critical Length:	150.71	Lc	Lc/Do =	12.35

Case 1

$$P_a := \left[2 \cdot \frac{\left(\frac{E_2}{F}\right)}{(1 - v_1 \cdot v_2)}\right] \cdot \left(\frac{t}{D_o}\right)^3 = 0.1188918 \text{ psi}$$

Case 2

$$P_a := \frac{2.42 \cdot \left(\frac{E_2}{F}\right) \cdot \left[\left(\frac{t}{D_o}\right)^{2.5}\right]}{(1 - v_1 \cdot v_2)^{0.75} \cdot \left[\left(\frac{L}{D_o}\right) - 0.45 \cdot \left(\frac{t}{D_o}\right)^{0.5}\right]} = 0.8091968 \text{ psi}$$

Case 1, - Governs

MAV = 0.1188918 psi

04/17/04

MAP/MAV - FRP (Fiberglass Reinforced Plastic) Cylindrical Shell

TANK: PREMIX TANK - FRP MAP RATING

.... **Shell** .... **Liquid Loading** ....

Inside Diameter, D :	304.8	mm			
Shell Thickness, t :	2	mm	Height :	1219.2	mm
Tensile Modulus, E1 :	3447378.6	kPa, longitudinal	Specific Gravity:	1.001	
Tensile Modulus, E2 :	3447378.6	kPa, circumferential			
Service Temperature :	82.2	°C.	P(liquid) :	11.968	kPa

.... **Case 1, Longitudinal Stress** ....

$$P := 0.01 \cdot t_1 \cdot \left[\frac{E_1}{(6 \cdot t_1 + 5 \cdot R)} \right] - P(liquid) = 77.111326 \text{ kPa}$$

..... **Case 1, Circumferential Stress** .....

$$P := 0.005 \cdot t_2 \cdot \left[\frac{E_2}{(3 \cdot t_2 + 5 \cdot R)} \right] - P(liquid) = 32.919518 \text{ kPa}$$

.... **Case 2, - Governs** .... **MAP =** 32.919518 kPa

.... **MAV Calculation** ....

Shell Length, L =	609.6	mm - between supports	Do =	308.80
Poisson's ratio, v1:	0.46	major direction	Do/t =	154.40
Poisson's ratio, v2:	0.16	minor direction	L/Do =	1.974
Design Factor:	5	F	t/Do =	0.0065
Critical Length:	4291.46	Lc	Lc/Do =	13.90

.... **Case 1** ....

$$P_a := \left[2 \cdot \frac{\left(\frac{E_2}{F}\right)}{(1 - v_1 \cdot v_2)} \right] \cdot \left(\frac{t}{D_o}\right)^3 = 0.4043976 \text{ kPa}$$

.... **Case 2** ....

$$P_a := \frac{2.42 \cdot \left(\frac{E_2}{F}\right) \cdot \left[\left(\frac{t}{D_o}\right)^{2.5}\right]}{(1 - v_1 \cdot v_2)^{0.75} \cdot \left[\left(\frac{L}{D_o}\right) - 0.45 \cdot \left(\frac{t}{D_o}\right)^{0.5}\right]} = 3.0781566 \text{ kPa}$$

.... **Case 1, - Governs** ....

MAV = 0.4043976 kPa