Pressure Vessel Engineering, Ltd.
120 Randall Dr.   Waterloo, Ontario N2V 1C6

Date Printed: 6/19/2009

CUSTOMER

Pressure Vessel Engineering
120-Randall Drive, Suite B
Waterloo, ON N2V 1C6

VESSEL LOCATION

Pressure Vessel Engineering
120-Randall Drive, Suite B
Waterloo, ON N2V 1C6

VESSEL DESCRIPTION

Vertical Vessel with Bolted Cover

Vessel designed per the ASME Boiler & Pressure Vessel Code,
Section VIII, Division 1,2007 Edition, 2008 Addenda
with Advanced Pressure Vessel, Version: 10.1.5
Vessel is ASME Code Stamped

Job No: PVE Sample 14
Vessel Number: 2

NAMEPLATE INFORMATION

Vessel MAWP:	125.00 PSI at 200 °F
MDMT:	-20 °F at 125.00 PSI
Serial Number(s):	____________________________
National Board Number(s):	____________________________
Year Built:	2009
Radiography:	NONE
Postweld Heat Treated:	NONE
Construction Type:	W

Signatures

Mechanical Technologist:____ Date: ____/____/____
Cameron Moore

P.Eng:____ Date: ____/____/____
Laurence Brundret

Table of Contents

Pressure Vessel Engineering, Ltd.

Shell 1

Customer: **Pressure Vessel Engineering**
Job No: PVE Sample 14 — Vessel Number: 2
Number: 1 — Mark Number: S1

Date Printed: 6/19/2009

Cylindrical Shell Design Information

Design Pressure:	125.00 PSI		Design Temperature:	200	°F
Static Head:	1.95 PSI		Long. Joint Efficiency:	70	%
Shell Material:	SA-516 Gr. 70		Factor B Chart:	CS-2	
			Material Stress (hot):	20000	PSI
Shell Length:	41.8100 in.		Material Stress (cold):	20000	PSI
			Compressive Stress:	13116	PSI
Corrosion Allowance:	0.0625 in.		Actual Circumferential Stress:	17338	PSI
External Corrosion Allowance:	0.0000 in.		Actual Longitudinal Stress:	8578	PSI
Outside Diameter (new):	36.0000 in.				
Outside Diameter (corroded):	36.0000 in.		Specific Gravity:	1.00	
Shell Surface Area:	32.84 Sq. Ft.		Weight of Fluid:	1496.79	lb.
Shell Estimated Volume:	179.17 Gal.		Total Flooded Shell Weight:	1825.50	lb.
Circ. Joint Efficiency:	70 %		Shell Weight:	328.70	lb.

Minimum Design Metal Temperature Data

Min. Temperature Curve:	B	Pressure at MDMT:	125.00	PSI
UCS-66(b) reduction:	No	Minimum Design Metal Temperature:	-20	°F
UCS-68(c) reduction:	No	Computed Minimum Temperature:	-20	°F

Design Thickness Calculations

Longitudinal Stress Calculations per Paragraph UG-27(c)(2)

$$\mathbf{t} = \frac{PR}{2SE + 0.4P} = \frac{126.95 * 17.8125}{2 * 20000 * 0.70 + 0.4 * 126.95}$$

$= \text{Greater Of } (0.0806_{(\text{Calculated})}, 0.0938_{(\text{Minimum Allowed})}) + 0.0625_{\ (\text{corrosion})} + 0.0000_{\ (\text{ext. corrosion})}$ = minimum of **0.1563** in.

Circumferential Stress Calculations per Appendix 1-1(a)(1)

$$\mathbf{t} = \frac{PR_o}{SE + 0.4P} = \frac{126.95 * 18.0000}{20000 * 0.70 + 0.4 * 126.95} = 0.1627 + 0.0625_{\ (\text{corrosion})} + 0.0000_{\ (\text{ext. corrosion})}$$

= minimum of **0.2252** in.

Extreme Fiber Elongation Calculation per Paragraph UCS-79

$$\textbf{Elongation} = \frac{50t}{Rf} = \frac{50 * 0.2500}{17.8750}$$

= elongation of **0.70** %

External loads do not control design.

Nominal Shell Thickness Selected = **0.2500** in.

Customer: **Pressure Vessel Engineering**
Job No: PVE Sample 14
Number: 1
Vessel Number: 2
Mark Number: H1

Date Printed: 6/19/2009

Ellipsoidal Head Design Information

Design Pressure:	125.00	PSI	Design Temperature:	200	°F
Static Head:	1.95	PSI	Joint Efficiency:	85	%
Head Material:	SA-516 Gr. 70		Factor B Chart:	CS-2	
			Material Stress (hot):	20000	PSI
Corrosion Allowance:	0.0625	in.	Material Stress (cold):	20000	PSI
External Corrosion Allowance:	0.0000	in.	Actual Head Stress:	16308	PSI
Head Location:	Bottom		Straight Flange :	2.0000	in.
Outside Diameter :	36.0000	in.	Head Depth (ho) :	9.1250	in.
Thin Out :	0.0240	in.			

$$K = \frac{1}{6}\left[2 + (D/2h)^2\right] : \quad 1.00$$

Head Surface Area:	11.23	Sq. Ft.	Specific Gravity:	1.00	
Head Estimated Volume:	33.93	Gal.	Weight of Fluid:	282.94	lb.
Head Weight:	113.24	lb.	Total Flooded Head Weight:	396.18	lb.

Minimum Design Metal Temperature Data

Min. Temperature Curve:	B	Pressure at MDMT:	125.00	PSI
UCS-66(b) reduction:	No	Minimum Design Metal Temperature:	-20	°F
UCS-68(c) reduction:	No	Computed Minimum Temperature:	-20	°F

Design Thickness Calculations

Design Thickness Calculations per Appendix 1-4(c)

$$\mathbf{t} = \frac{PD_oK}{2SE + 2P(K - 0.1)} = \frac{126.95 * 36.0000 * 1.00}{2 * 20000 * 0.85 + 2 * 126.95 * (1.00 - 0.1)}$$

$= 0.1336 + 0.0625_{\text{(corrosion)}} + 0.0000_{\text{(ext. corrosion)}} + 0.0240_{\text{(thin out)}}$ = minimum of **0.2201** in.

Extreme Fiber Elongation Calculation per Paragraph UCS-79

$$\mathbf{elongation} = \frac{75t}{R_f} = \frac{75 * 0.2500}{6.0775}$$

= elongation of **3.09** %

Nominal Head Thickness Selected = **0.2500** in.
Minimum Thickness after forming, t_s (uncorroded) = **0.2260** in.

Customer: **Pressure Vessel Engineering**
Job No: PVE Sample 14
Number: 1
ID Number: 1

Vessel Number: 2
Mark Number: N1

Date Printed: 6/19/2009

Nozzle Design Information

Design Pressure:	125.00 PSI	Design Temperature:	200	°F
Static Head:	1.95 PSI	Nozzle Efficiency (E):	100	%
Nozzle Material:	SA-106 Gr. B	Joint Efficiency (E_1):	1.00	
		Factor B Chart:	CS-2	
External Projection:	14.5000 in.	Allowable Stress at Design Temperature (S_n):	17100	PSI
Internal Projection:	0.0000 in.	Allowable Stress at Ambient Temperature:	17100	PSI
Inside Corrosion Allowance:	0.0625 in.	Correction Factor (F):	1.00	
External Corrosion Allowance:	0.0000 in.	Nozzle Path:	None	
Nozzle Pipe Size:	18	Nozzle Pipe Schedule:	40	
Nozzle ID (new):	16.8760 in.	Nozzle Wall Thickness(new):	0.5620	in.
Nozzle ID (corroded):	17.0010 in.	Nozzle Wall Thickness(corroded):	0.4995	in.
Outer "h" Limit:	0.4688 in.	Upper Weld Leg Size(Weld 41):	0.2500	in.
Internal "h" Limit:	0.0000 in.	Internal Weld Leg Size(Weld 43):	0.0000	in.
OD, Limit of Reinforcement:	34.0020 in.	Outside Groove Weld Depth:	0.2227	in.

Minimum Design Metal Temperature

Min. Temp. Curve:	B	Pressure at MDMT:	125.00	PSI
UCS-66(b) reduction:	Yes	Minimum Design Metal Temperature:	-20	°F
UCS-68(c) reduction:	No	Computed Minimum Temperature:	-155	°F

Reinforcing Pad Information

Reinforcing Material:	SA-516 Gr. 70	Allowable Stress at Design Temperature(S_p):	20000	PSI
		Allowable Stress at Ambient Temperature:	20000	PSI
Reinforcing Plate Thickness(t_e):	0.2500 in.	Repad to Vessel Weld Leg Size(Weld 42):	0.2500	in.
OD, Reinforcing Plate(D_p):	23.0000 in.	Repad to Nozzle Groove Weld Depth:	0.2500	in.

Host Component: Shell 1 - Shell 1

Material:	SA-516 Gr. 70	Shell wall thickness(new):	0.2500	in.
Material Stress(S_v):	20000 PSI	Shell wall thickness(corroded):	0.1875	in.

Nozzle Detail Information

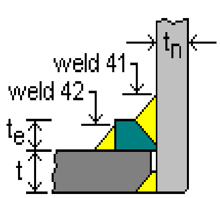


Fig. UW-16.1 (j)

Upper Weld Leg Size(Weld 41): 0.2500 in.

Nozzle Wall Thickness(t_n): 0.5620 in.

Outside Groove Weld Depth: 0.2227 in.

Repad to Vessel Weld Leg Size(Weld 42): 0.2500 in.

Repad Thickness(t_e): 0.2500 in.

Nozzle passes through the vessel, attached by a groove weld.
Pipe Size: 18 Schedule: 40
Nozzle is adequate for UG-45 requirements.
Opening is adequately reinforced for Internal Pressure.
Weld Strength Paths are adequate.

Required Shell Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{PRo}{SE + 0.4P} = \frac{126.95 * 18.0000}{20000 * 1 + 0.4 * 126.95} = \mathbf{0.1140} \text{ in.}$$

Nozzle Required Thickness Calculations

Required Nozzle Thickness for Internal Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{126.95 * 8.5005}{17100 * 1 - 0.6 * 126.95} = \mathbf{0.0634} \text{ in.}$$

Strength Reduction Factors

$$\mathbf{fr1} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{17100}{20000}, 1.0000\right) = 0.8550$$

$$\mathbf{fr2} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{17100}{20000}, 1.0000\right) = 0.8550$$

$$\mathbf{fr3} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{17100}{20000}, 1.0000\right) = 0.8550$$

$$\mathbf{fr4} = \min\left(\frac{Sp}{Sv}, 1.0000\right) = \min\left(\frac{20000}{20000}, 1.0000\right) = 1.0000$$

UG-45 Thickness Calculations

Nozzle Thickness for Pressure Loading (plus corrosion) per Paragraph UG-45(a)

$$\mathbf{t} = \frac{PRn}{SE - 0.6P} + Ca + ext.\ Ca = \frac{126.95 * 8.5005}{17100 * 1.00 - 0.6 * 126.95} + 0.0625 + 0.0000 = \mathbf{0.1259} \text{ in.}$$

Nozzle Thickness for Internal Pressure (plus corrosion) per Paragraph UG-45(b)(1)

$$\mathbf{t} = \frac{PRo}{SE + 0.4P} + Ca + ext.\ Ca = \frac{126.95 * 18.0000}{20000 * 1 + 0.4 * 126.95} + 0.0625 + 0.0000 = \mathbf{0.1765} \text{ in.}$$

Minimum Thickness of Standard Wall Pipe (plus corrosion) per Paragraph UG-45(b)(4)

t = minimum thickness of standard wall pipe + Ca + ext. Ca = **0.3906** in.

Nozzle Minimum Thickness per Paragraph UG-45(b)

t = Smallest of UG-45(b)(1) or UG-45(b)(4) = **0.1765** in.

Wall thickness = tn * 0.875(pipe) = **0.4917** is greater than or equal to UG-45 value of **0.1765**

Nozzle Reinforcement Calculations

Area Required for Internal Pressure

A = d tr F + 2 tn tr F (1 - fr1) = (17.0010 * 0.1140 * 1.00) + (2 * 0.4995 * 0.1140 * 1.00 * (1 - 0.8550)) = **1.9546** sq. in.

Area Available - Internal Pressure

A1 Formula 1 = d(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
17.0010 * (1.00 * 0.1875 - 1.00 * 0.1140) - 2 * 0.4995 * (1.00 * 0.1875 - 1.00 * 0.1140) * (1 - 0.8550) = *1.2389* sq. in.

A1 Formula 2 = 2(t + tn)(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
2 * (0.1875 + 0.4995)(1.00 * 0.1875 - 1.00 * 0.1140) - 2 * 0.4995 * (1.00 * 0.1875 - 1.00 * 0.1140) * (1 - 0.8550)
= *0.0903* sq. in.

A1 = Larger value of *A1 Formula 1* and *A1 Formula 2* = **1.2389** sq. in.

A2 Formula 1 = 5(tn - trn) fr2 t = 5(0.4995 - 0.0634) * 0.8550 * 0.1875 = *0.3496* sq. in.
A2 Formula 2 = 2(tn - trn) fr2 (2.5 tn + te) = 2(0.4995 - 0.0634) * 0.8550 * (2.5 * 0.4995 + 0.2500) = *1.1177* sq. in.
A2 = Smaller value of *A2 Formula 1* and *A2 Formula 2* = **0.3496** sq. in.

A3 = Smaller value of the following :
$5 * t * t_i * f_{r2}$ = 5 * 0.1875 * 0.0000 * 0.8550 = 0.0000 sq. in.
$5 * t_i * t_i * f_{r2}$ = 5 * 0.0000 * 0.0000 * 0.8550 = 0.0000 sq. in.
$2 * h * t_i * f_{r2}$ = 2 * 0.0000 * 0.0000 * 0.8550= 0.0000 sq. in.
= **0.0000** sq. in.

A41 = Allowable Weld 41 area * fr3 = 0.0615 * 0.8550 = **0.0526** sq. in.

A42 = $(leg)^2$ * fr4 = $(0.2500)^2$ * 1.0000 = **0.0625** sq. in.

A43 = $(leg)^2$ * fr2 = 0 * 0.8550 = **0.0000** sq. in.

A5 = (Dp - d - 2tn) te fr4 = (23.0000 - 17.0010 - 2 * 0.4995) * 0.2500 * 1.0000 = **1.2500** sq. in.

Area Available (Internal Pressure) = A1 + A2 + A3 + A41 + A42 + A43 + A5 = 2.9536 sq. in., which is **greater** than A (1.9546)

Nozzle Weld Strength Calculations

Attachment Weld Strength per Paragraph UW-16 (Corroded Condition)

Weld 41 tmin = smaller of 0.75, te, or tn = smaller of 0.75, 0.2500, or 0.4995 = **0.2500** in.

Weld 41 Leg min. = $\frac{\text{(smaller of 0.25 or (tmin * 0.7)) + ext. CA}}{0.7} = \frac{0.1750}{0.7}$ = **0.2500** in.

Weld 41, actual weld leg = **0.2500** in.

Weld 42 tmin = smaller of 0.75, t, or te = smaller of 0.75, 0.1875, or 0.2500 = **0.1875** in.

Weld 42 Leg min. = $\frac{\text{0.5 * tmin + ext. CA}}{0.7} = \frac{0.5 * 0.1875 + 0.0000}{0.7}$ = **0.1339** in.

Weld 42, actual weld leg = **0.2500** in.

Unit Stresses per Paragraphs UG-45(c) and UW-15

Nozzle wall in shear = 0.70 * Sn = 0.70 * 17100 = **11970** PSI
Upper fillet, Weld 41, in shear = 0.49 * Material Stress = 0.49 * 17100 = **8379** PSI
Vessel groove weld, in tension = 0.74 * Material Stress = 0.74 * 17100 = **12654** PSI
Outer fillet, Weld 42, in shear = 0.49 * Material Stress = 0.49 * 20000 = **9800** PSI
Repad groove weld, in tension = 0.74 * Material Stress = 0.74 * 17100 = **12654** PSI

Strength of Connection Elements

Nozzle wall in shear = ½ * π * mean nozzle diameter * tn * Nozzle wall in shear unit stress =
½ * π * 17.5005 * 0.4995 * 11970 = **164300** lb.
Upper fillet in shear = ½ * π * Nozzle OD * weld leg * upper fillet in shear unit stress = ½ * π * 18.0000 * 0.2500 * 8379 = **59200** lb.
Groove Weld in Tension = ½ * π * Nozzle OD * groove depth * groove weld tension unit stress =
½ * π * 18.0000 * 0.1875 * 12654 = **67100** lb.
Outer fillet in shear = ½ * π * Plate OD * weld leg * outer fillet in shear unit stress = ½ * π * 23.0000 * 0.2500 * 9800 = **88500** lb.
Repad groove weld = ½ * π * Nozzle OD * Groove Depth * repad groove weld in tension unit stress =
½ * π * 18.0000 * 0.2500 * 12654 = **89400** lb.

Load to be carried by welds, per UG-41(b)(1) and Fig. UG-41.1 sketch (a)

W = [A - A1 + 2 tn fr1(E1t - Ftr)] Sv = [1.9546 - 1.2389 + 2 * 0.4995 * 0.8550 * (1.00 * 0.1875 - 1.0000 * 0.1140)] * 20000 = **15600** lb.
W1-1 = (A2 + A5 + A41 + A42) * Sv = (0.3496 + 1.2500 + 0.0526 + 0.0625) * 20000 = **34300** lb.
W2-2 = (A2 + A3 + A41 + A43 + 2 tn t fr1) Sv = (0.3496 + 0.0000 + 0.0526 + 0.0000 + 2 * 0.4995 * 0.1875 * 0.8550) * 20000 = **11200** lb.
W3-3 = (A2 + A3 + A5 + A41 + A42 + A43 + 2 tn t fr1) * Sv =
(0.3496 + 0.0000 + 1.2500 + 0.0526 + 0.0625 + 0.0000 + 2 * 0.4995 * 0.1875 * 0.8550) * 20000 = **37500** lb.

Check Strength Paths

Path 1-1 = Outer fillet in shear + Nozzle wall in shear = 88500 + 164300 = **252800** lb.
Path 2-2 = Upper fillet in shear + Repad groove weld + Groove weld in tension + Inner fillet in shear =
59200 + 89400 + 67100 + 0 = **215700** lb.
Path 3-3 = Outer fillet in shear + Inner fillet in shear + Groove weld in tension = 88500 + 0 + 67100 = **155600** lb.

Plate Strength = A5 * Sp = 1.2500 * 20000 = **25000** lb.

Outer fillet weld strength(88500) is greater than plate strength(25000).

Pressure Vessel Engineering, Ltd.

Nozzle 2

Customer: **Pressure Vessel Engineering**
Job No: PVE Sample 14
Number: 2
ID Number: 2

Vessel Number: 2
Mark Number: N2

Date Printed: 6/19/2009

Nozzle Design Information

Design Pressure:	125.00	PSI	Design Temperature:	200	°F
Static Head:	1.95	PSI	Nozzle Efficiency (E):	100	%
Nozzle Material:	SA-106 Gr. B		Joint Efficiency (E_1):	1.00	
			Factor B Chart:	CS-2	
External Projection:	11.0000	in.	Allowable Stress at Design Temperature (S_n):	17100	PSI
Internal Projection:	0.0000	in.	Allowable Stress at Ambient Temperature:	17100	PSI
Inside Corrosion Allowance:	0.0625	in.	Correction Factor (F):	1.00	
External Corrosion Allowance:	0.0000	in.	Nozzle Path:	None	
Nozzle Pipe Size:	4		Nozzle Pipe Schedule:	40	
Nozzle ID (new):	4.0260	in.	Nozzle Wall Thickness(new):	0.2370	in.
Nozzle ID (corroded):	4.1510	in.	Nozzle Wall Thickness(corroded):	0.1745	in.
Outer "h" Limit:	0.4363	in.	Upper Weld Leg Size(Weld 41):	0.3750	in.
Internal "h" Limit:	0.2800	in.	Internal Weld Leg Size(Weld 43):	0.0000	in.
OD, Limit of Reinforcement:	9.5863	in.	Outside Groove Weld Depth:	0.2500	in.

Minimum Design Metal Temperature

Min. Temp. Curve:	B	Pressure at MDMT:	125.00	PSI
UCS-66(b) reduction:	Yes	Minimum Design Metal Temperature:	-20	°F
UCS-68(c) reduction:	No	Computed Minimum Temperature:	-155	°F

Host Component: Shell 1 - Shell 1

Material:	SA-516 Gr. 70		Shell wall thickness(new):	0.2500	in.
Material Stress(S_v):	20000	PSI	Shell wall thickness(corroded):	0.1875	in.

Nozzle Detail Information

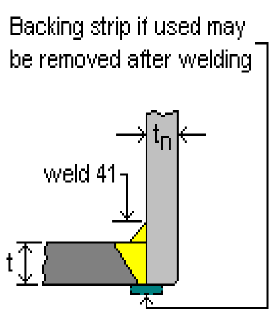


Fig. UW-16.1 (c)

Upper Weld Leg Size(Weld 41): 0.3750 in.

Nozzle Wall Thickness(t_n): 0.2370 in.

Outside Groove Weld Depth: 0.2500 in.

Nozzle passes through the vessel, attached by a groove weld.
Pipe Size: 4 Schedule: 40
Nozzle is adequate for UG-45 requirements.
Opening is adequately reinforced for Internal Pressure.
Weld Strength Paths are adequate.

Required Shell Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{PRo}{SE + 0.4P} = \frac{126.95 * 18.0000}{20000 * 1 + 0.4 * 126.95} = \mathbf{0.1140}\text{ in.}$$

Nozzle Required Thickness Calculations

Required Nozzle Thickness for Internal Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{126.95 * 2.0755}{17100 * 1 - 0.6 * 126.95} = \mathbf{0.0155}\text{ in.}$$

Strength Reduction Factors

$$\mathbf{fr1} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{17100}{20000}, 1.0000\right) = 0.8550$$

$$\mathbf{fr2} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{17100}{20000}, 1.0000\right) = 0.8550$$

$$\mathbf{fr3} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{17100}{20000}, 1.0000\right) = 0.8550$$

UG-45 Thickness Calculations

Nozzle Thickness for Pressure Loading (plus corrosion) per Paragraph UG-45(a)

$$\mathbf{t} = \frac{PRn}{SE - 0.6P} + Ca + ext.\ Ca = \frac{126.95 * 2.0755}{17100 * 1.00 - 0.6 * 126.95} + 0.0625 + 0.0000 = \mathbf{0.0780}\text{ in.}$$

Nozzle Thickness for Internal Pressure (plus corrosion) per Paragraph UG-45(b)(1)

$$\mathbf{t} = \frac{PRo}{SE + 0.4P} + Ca + ext.\ Ca = \frac{126.95 * 18.0000}{20000 * 1 + 0.4 * 126.95} + 0.0625 + 0.0000 = \mathbf{0.1765}\text{ in.}$$

Minimum Thickness of Standard Wall Pipe (plus corrosion) per Paragraph UG-45(b)(4)

t = minimum thickness of standard wall pipe + Ca + ext. Ca = **0.2699** in.

Nozzle Minimum Thickness per Paragraph UG-45(b)

t = Smallest of UG-45(b)(1) or UG-45(b)(4) = **0.1765** in.

Wall thickness = tn * 0.875(pipe) = **0.2074** is greater than or equal to UG-45 value of **0.1765**

Nozzle Reinforcement Calculations

Area Required for Internal Pressure

A = d tr F + 2 tn tr F (1 - fr1) = (4.7932 * 0.1140 * 1.00) + (2 * 0.1745 * 0.1140 * 1.00 * (1 - 0.8550)) = **0.5522** sq. in.

Area Available - Internal Pressure

A1 Formula 1 = d(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
4.7932 * (1.00 * 0.1875 - 1.00 * 0.1140) - 2 * 0.1745 * (1.00 * 0.1875 - 1.00 * 0.1140) * (1 - 0.8550) = *0.3486* sq. in.

A1 Formula 2 = 2(t + tn)(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
2 * (0.1875 + 0.1745)(1.00 * 0.1875 - 1.00 * 0.1140) - 2 * 0.1745 * (1.00 * 0.1875 - 1.00 * 0.1140) * (1 - 0.8550)
= *0.0495* sq. in.

A1 = Larger value of *A1 Formula 1* and *A1 Formula 2* = **0.3486** sq. in.

A2 Formula 1 = 5(tn - trn) fr2 t = 5(0.1745 - 0.0155) * 0.8550 * 0.1875 = *0.1274* sq. in.
A2 Formula 2 = 5(tn - trn) fr2 tn = 5(0.1745 - 0.0155) * 0.8550 * 0.1745 = *0.1186* sq. in.
A2 = Smaller value of *A2 Formula 1* and *A2 Formula 2* = **0.1186** sq. in.

A3 = Smaller value of the following :
$5 * t * t_i * f_{r2}$ = 5 * 0.1875 * 0.1120 * 0.8550 = 0.0898 sq. in.
$5 * t_i * t_i * f_{r2}$ = 5 * 0.1120 * 0.1120 * 0.8550 = 0.0536 sq. in.
$2 * h * t_i * f_{r2}$ = 2 * 0.0000 * 0.1120 * 0.8550= 0.0000 sq. in.
= **0.0000** sq. in.

A41 = (leg)² * fr2 = (0.3750)² * 0.8550 = **0.1202** sq. in.

A43 = (leg)² * fr2 = 0 * 0.8550 = **0.0000** sq. in.

Area Available (Internal Pressure) = A1 + A2 + A3 + A41 + A43 = 0.5874 sq. in., which is **greater** than A (0.5522)

Nozzle Design Information

Design Pressure:	125.00	PSI	Design Temperature:	200	°F
Static Head:	1.95	PSI	Nozzle Efficiency (E):	100	%
Nozzle Material:	SA-105		Joint Efficiency (E_1):	1.00	
			Factor B Chart:	CS-2	
External Projection:	1.1900	in.	Allowable Stress at Design Temperature (S_n):	20000	PSI
			Allowable Stress at Ambient Temperature:	20000	PSI
Inside Corrosion Allowance:	0.0625	in.	Correction Factor (F):	1.00	
External Corrosion Allowance:	0.0000	in.	Nozzle Path:	None	
Nozzle ID (new):	1.3300	in.	Nozzle Wall Thickness(new):	0.2175	in.
Nozzle ID (corroded):	1.4550	in.	Nozzle Wall Thickness(corroded):	0.1550	in.
Outer "h" Limit:	0.3875	in.	Upper Weld Leg Size(Weld 41):	0.3750	in.
OD, Limit of Reinforcement:	2.9100	in.			

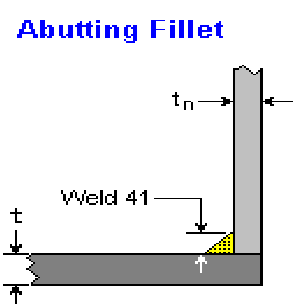
Minimum Design Metal Temperature

Min. Temp. Curve:	B	Pressure at MDMT:	125.00	PSI
UCS-66(b) reduction:	Yes	Minimum Design Metal Temperature:	-20	°F
UCS-68(c) reduction:	No	Computed Minimum Temperature:	-155	°F

Host Component: Head 1 - Head 1

Material:	SA-516 Gr. 70		Head wall thickness(new):	0.2500	in.
Material Stress(S_v):	20000	PSI	Head wall thickness - thin out (corroded):	0.1635	in.

Nozzle Detail Information



Upper Weld Leg Size(Weld 41): 0.3750 in.

Nozzle Wall Thickness(t_n): 0.2175 in.

Nozzle abuts the vessel, attached by a fillet weld.
Nozzle is adequate for UG-45 requirements.
Opening is adequately reinforced for Internal Pressure.
Reinforcement calculations are not required per UG-36(c)(3)(a)See Uw-14 for exceptions.
Weld Strength Paths are adequate.

Required Head Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{P\ K1\ Do}{(2SE + 0.8P)} = \frac{126.95 * 0.9000 * 36.0000}{(2 * 20000 * 1 + 0.8 * 126.95)} = \mathbf{0.1026}\ \text{in.}$$

Nozzle Required Thickness Calculations

Required Nozzle Thickness for Internal Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{126.95 * 0.7275}{20000 * 1 - 0.6 * 126.95} = \mathbf{0.0046}\ \text{in.}$$

Strength Reduction Factors

$$\mathbf{fr2} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{20000}{20000}, 1.0000\right) = 1.0000$$

$$\mathbf{fr3} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{20000}{20000}, 1.0000\right) = 1.0000$$

UG-45 Thickness Calculations

Nozzle Thickness for Pressure Loading (plus corrosion) per Paragraph UG-45(a)

$$\mathbf{t} = \frac{PRn}{SE - 0.6P} + Ca + ext.\ Ca = \frac{126.95 * 0.7275}{20000 * 1.00 - 0.6 * 126.95} + 0.0625 + 0.0000 = \mathbf{0.0671}\ \text{in.}$$

Nozzle Thickness for Internal Pressure (plus corrosion) per Paragraph UG-45(b)(1)

$$\mathbf{t} = \frac{P\ K\ Do}{(2SE + 2P(K - 0.1))} + Ca + ext.\ Ca = \frac{126.95 * 1.0000 * 36.0000}{(2 * 20000 * 1 + 2 * 126.95 * (1.0000 - 0.1))} + 0.0625 + 0.0000 = \mathbf{0.1761}\ \text{in.}$$

Minimum Thickness of Standard Wall Pipe (plus corrosion) per Paragraph UG-45(b)(4)

t = minimum thickness of standard wall pipe + Ca + ext. Ca = **0.1894** in.

Nozzle Minimum Thickness per Paragraph UG-45(b)

t = Smallest of UG-45(b)(1) or UG-45(b)(4) = **0.1761** in.

Wall thickness = tn = **0.2175** is greater than or equal to UG-45 value of **0.1761**

Pressure Vessel Engineering, Ltd.
Threaded Coupling - 2"

Customer: **Pressure Vessel Engineering**
Job No: PVE Sample 14
Number: 4
ID Number: 4

Vessel Number: 2
Mark Number: N4

Date Printed: 6/19/2009

Nozzle Design Information

Design Pressure:	125.00	PSI	Design Temperature:	200	°F
Static Head:	0.00	PSI	Nozzle Efficiency (E):	100	%
Nozzle Material:	SA-105		Joint Efficiency (E_1):	1.00	
			Factor B Chart:	CS-2	
External Projection:	1.6900	in.	Allowable Stress at Design Temperature (S_n):	20000	PSI
			Allowable Stress at Ambient Temperature:	20000	PSI
Inside Corrosion Allowance:	0.0625	in.	Correction Factor (F):	1.00	
External Corrosion Allowance:	0.0000	in.	Nozzle Path:	None	
Nozzle ID (new):	2.3750	in.	Nozzle Wall Thickness(new):	0.3125	in.
Nozzle ID (corroded):	2.5000	in.	Nozzle Wall Thickness(corroded):	0.2500	in.
Outer "h" Limit:	0.6250	in.	Upper Weld Leg Size(Weld 41):	0.3750	in.
OD, Limit of Reinforcement:	11.0000	in.	Outside Groove Weld Depth:	0.3125	in.

Minimum Design Metal Temperature

Min. Temp. Curve:	B	Pressure at MDMT:	125.00	PSI
UCS-66(b) reduction:	Yes	Minimum Design Metal Temperature:	-20	°F
UCS-68(c) reduction:	No	Computed Minimum Temperature:	-155	°F

Host Component: Flange 1 - 36" Blind Flnage

Material:	SA-105		Host Flange wall thickness(new):	4.0000	in.
Material Stress(S_v):	20000	PSI	Host Flange wall thickness(corroded):	4.0000	in.

Nozzle Detail Information

Upper Weld Leg Size(Weld 41): 0.3750 in.

Nozzle Wall Thickness(t_n): 0.3125 in.

Outside Groove Weld Depth: 0.3125 in.

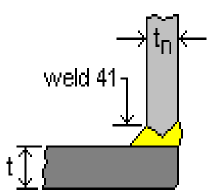


Fig. UW-16.1 (b)

Nozzle abuts the vessel, attached by a groove weld.
Nozzle is adequate for UG-45 requirements.
Opening is adequately reinforced for Internal Pressure.
Weld Strength Paths are adequate.

Required Host Flange Thickness per Paragraph UG-39(b)(1)

$$\mathbf{tr} = G * \sqrt{\frac{CP}{SE} + \frac{1.9\, W_{m1}\, h_G}{SE\, G^3}} = 38.0000 * \sqrt{\frac{0.3000 * 125.00}{20000 * 1} + \frac{1.9 * 141764 * 0.5000}{20000 * 1 * 38.0000^3}} = \mathbf{1.6984} \text{ in.}$$

Nozzle Required Thickness Calculations

Required Nozzle Thickness for Internal Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{125.00 * 1.2500}{20000 * 1 - 0.6 * 125.00} = \mathbf{0.0078} \text{ in.}$$

Strength Reduction Factors

$$\mathbf{fr2} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{20000}{20000}, 1.0000\right) = 1.0000$$

$$\mathbf{fr3} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{20000}{20000}, 1.0000\right) = 1.0000$$

UG-45 Thickness Calculations

Nozzle Thickness for Pressure Loading (plus corrosion) per Paragraph UG-45(a)

$$\mathbf{t} = \frac{PRn}{SE - 0.6P} + Ca + ext.\ Ca = \frac{125.00 * 1.2500}{20000 * 1.00 - 0.6 * 125.00} + 0.0625 + 0.0000 = \mathbf{0.0703} \text{ in.}$$

Nozzle Thickness for Internal Pressure (plus corrosion) per Paragraph UG-45(b)(1)

$$\mathbf{t} = G * \sqrt{\frac{CP}{SE} + \frac{1.9\, W_{m1}\, h_G}{SE\, G^3}} + Ca + ext.\ Ca = 38.0000 * \sqrt{\frac{0.3000 * 125.00}{20000 * 1} + \frac{1.9 * 141764 * 0.5000}{20000 * 1 * 38.0000^3}} + 0.0625 + 0.0000$$

= = **1.7609** in.

Minimum Thickness of Standard Wall Pipe (plus corrosion) per Paragraph UG-45(b)(4)
t = minimum thickness of standard wall pipe + Ca + ext. Ca = **0.2515** in.

Nozzle Minimum Thickness per Paragraph UG-45(b)
t = Smallest of UG-45(b)(1) or UG-45(b)(4) = **0.2515** in.

Wall thickness = tn = **0.3125** is greater than or equal to UG-45 value of **0.2515**

Nozzle Reinforcement Calculations

Area Required for Internal Pressure

A = 0.5 d tr = (0.5 * 2.5000 * 1.6984) = **2.1230** sq. in.

Area Available - Internal Pressure

A1 Formula 1 = d(E1 t - F tr) =
2.5000 * (1.00 * 4.0000 - 1.00 * 1.6984) = *5.7540* sq. in.
A1 Formula 2 = 2(t + tn)(E1 t - F tr) =
2 * (4.0000 + 0.2500)(1.00 * 4.0000 - 1.00 * 1.6984) = *19.5636* sq. in.
A1 = Larger value of *A1 Formula 1* and *A1 Formula 2* = **19.5636** sq. in.

A2 Formula 1 = 5(tn - trn) fr2 t = 5(0.2500 - 0.0078) * 1.0000 * 4.0000 = *4.8440* sq. in.
A2 Formula 2 = 5(tn - trn) fr2 tn = 5(0.2500 - 0.0078) * 1.0000 * 0.2500 = *0.3028* sq. in.
A2 = Smaller value of *A2 Formula 1* and *A2 Formula 2* = **0.3028** sq. in.

A41 = $(leg)^2$ * fr2 = $(0.3750)^2$ * 1.0000 = **0.1406** sq. in.

Area Available (Internal Pressure) = A1 + A2 + A41 = 20.0070 sq. in., which is **greater** than A (2.1230)

Customer: **Pressure Vessel Engineering**
Job No: PVE Sample 14
Mark Number: LEG1
Vessel Number: 2

Date Printed: 6/19/2009

Leg Information

Design Temperature:	200	°F	Factor B Chart:	CS-2	
Material:	SA-36		Material Stress (Hot):	16600	PSI
Condition:			Material Stress (Cold):	16600	PSI
B.P. to Vessel Attachment Length (L):	6.0000	in.	Modulus of Elasticity:	28.6	10^6 PSI
Direction of Applied Force:	0	°	Yield Strength:	33000	PSI
Length of Supports:	31.0000	in.	Dist. From Reference Line:	6.0000	in.
Quantity:	4		Method of Attachment:	Leg In	
Type:	Angle		Molded to Head Curvature:	No	
Description:	3 x 3 x 1/4				
d_1:	3.0000	in.	t_1:	0.2500	in.
d_2:	3.0000	in.	t_2:	0.2500	in.
Weld Attachment Length Top (W_t):	3.0000	in.	Side (W_s):	6.0000	in.
Weld Leg Dimension (W_l):	0.2500	in.			

Base Plate Information

Design Temperature:	200	°F			
Material:	SA-36		Material Stress (Hot):	16600	PSI
Condition:			Material Stress (Cold):	16600	PSI
Length:	6.0000	in.	Yield Strength:	33000	PSI
Width:	6.0000	in.	Thickness:	0.2500	in.
Leg to B.P. Attachment Factor:	0.7500		Bending Coefficient (C_m):	1.0000	
Effective Length Factor (K):	1.5000				

Anchor Bolt Information

Material:	SA-193 Gr. B7		Material Stress (Hot):	25000	PSI
Condition:			Material Stress (Cold):	25000	PSI
Diameter:	0.7500	in.	Root Area:	0.3020	sq. in.
Quantity:	4		Bolt Circle Diameter:	36.0000	in.
Ultimate 28 Day Concrete Strength:	3000	PSI			

Operating Pressurized Condition - Sustained Loads

Support Leg Properties

Section Modulus, S_x $= \frac{I_x}{C_x} = \frac{1.9840}{2.1213}$ **= 0.9353** in.³

Section Modulus, S_y $= \frac{I_y}{C_y} = \frac{0.5044}{1.1913}$ **= 0.4234** in.³

Radius of gyration, r_x $= \sqrt{\frac{I_x}{A}} = \sqrt{\frac{1.9840}{1.4375}}$ **= 1.1748** in.

Radius of gyration, r_y $= \sqrt{\frac{I_y}{A}} = \sqrt{\frac{0.5044}{1.4375}}$ **= 0.5924** in.

Least radius of gyration, r_{min} $= \sqrt{\frac{I_{min}}{A}} = \sqrt{\frac{0.5044}{1.4375}}$ **= 0.5924** in.

Slenderness ratio, SR_x $= \frac{K\,L}{r_x} = \frac{1.5000 * 6.0000}{1.1748}$ **= 7.6609**

Slenderness ratio, SR_y $= \frac{K\,L}{r_y} = \frac{1.5000 * 6.0000}{0.5924}$ **= 15.1924**

SR_{max} $= \frac{K\,L}{r_{min}} = \frac{1.5000 * 6.0000}{0.5924}$ **= 15.1924**

Critical slenderness ratio, C_c $= \sqrt{\frac{2\pi^2 E}{F_y}} = \sqrt{\frac{2 * \pi^2 * (28.6 * 10^6)}{33000}}$ **= 130.79**

F'_{ex} $= \frac{12\pi^2 E}{23\,SR_x^2} = \frac{12 * \pi^2 * (28.6 * 10^6)}{23 * 7.6609^2}$ **= 2509341** PSI

F'_{ey} $= \frac{12\pi^2 E}{23\,SR_y^2} = \frac{12 * \pi^2 * (28.6 * 10^6)}{23 * 15.1924^2}$ **= 638067** PSI

For SR_{max} <= C_c, Allowable compressive stress:

$$F_a = \frac{\left(1 - \frac{SR_{max}^2}{2\,C_c^2}\right) F_y}{\frac{5}{3} + \frac{3\,SR_{max}}{8\,C_c} - \frac{SR_{max}^3}{8\,C_c^3}} = \frac{\left(1 - \frac{15.1924^2}{2 * 130.79^2}\right) * 33000}{\frac{5}{3} + \frac{3 * 15.1924}{8 * 130.79} - \frac{15.1924^3}{8 * 130.79^3}}$$ **= 19168** PSI

Allowable bending stress: S_b $= 0.6\,F_y = 0.6 * 33000$ **= 19800** PSI
Allowable tension stress: S_t $= 0.6\,F_y = 0.6 * 33000$ **= 19800** PSI

Leg to Vessel Weld Properties

Distance between welds along side of legs (b) = **= 3.8891** in.

$L_w = (2 W_s) + W_t = (2 * 6.0000) + 3.0000$ **= 15.0000** in.

$$I_{wy} = \frac{W_s^3 (2 W_t + W_s)}{3 L_w} = \frac{6.0000^3 * (2 * 3.0000 + 6.0000)}{3 * 15.0000}$$ **= 57.6000** in.³

$$I_{wz} = \frac{6 W_s b^2 + W_t^3}{12} = \frac{6 * 6.0000 * 3.8891^2 + 3.0000^3}{12}$$ **= 47.6250** in.³

$J_{wx} = I_{wy} + I_{wz} = 57.6000 + 47.6250$ **= 105.2250** in.³

Distance from weld neutral axis to top of welds:

$$EF_{yt} = \frac{W_s^2}{L_w} = \frac{6.0000^2}{15.0000}$$ **= 2.4000** in.

Distance from weld neutral axis to bottom of welds:

$EF_{yb} = W_s - EF_{yt} = 6.0000 - 2.4000$ **= 3.6000** in.

Distance from weld neutral axis to side of welds:

$$EF_z = MAX\left(\frac{b}{2}, \frac{W_t}{2} \right) = MAX\left(\frac{3.8891}{2}, \frac{3.0000}{2} \right)$$ **= 1.9445** in.

NO Wind Analysis Information

Wind Analysis Calculations

No Wind Load Calculations were performed

NO Seismic Design Information

Seismic Analysis Calculations

No Seismic Analysis Calculations were performed.

Loadings and Stresses on Support Legs

Direction of Applied Force = **0 °**

Leg Orientation °	Moment of Inertia in.^4	Lateral Force lb.	Axial Stress PSI	Bending Stresses (f_{bx}) PSI	Bending Stresses (f_{by}) PSI	Acceptance Ratio (Eqn_1)	Acceptance Ratio (Eqn_2)
0	0.5044	0	-77	0	260	0.0171	
90	1.9840	0	-77	0	260	0.0171	
180	0.5044	0	-77	0	260	0.0171	
270	1.9840	0	-77	0	260	0.0171	

Direction of Worst case Force = **0 °**
Highest Stress Ratio = **0.0171**

Loadings and Stresses on Leg to Vessel attachment welds

Leg Orientation °	Load F_x lb.	Load F_y lb.	Load F_z lb.	Moment M_x in.-lb.	Moment M_y in.-lb.	Moment M_z in.-lb.	Total Stress PSI	Stress Ratio
0	0	0	-110	0	-110	0	40	0.0049
90	0	0	-110	0	-110	0	40	0.0049
180	0	0	-110	0	-110	0	40	0.0049
270	0	0	-110	0	-110	0	40	0.0049

Direction of Worst case Force = **0 °**
Highest Stress Ratio: **0.0049**

Loadings and Pressure on Concrete Foundation

Direction of applied force: = **0 °**

Leg Orientation °	Bearing Pressure PSI	Moment M_x in.-lb.	Moment M_y in.-lb.	Maximum Pressure P_x PSI	Maximum Pressure P_y PSI	Max. Concrete Pressure PSI	Concrete Pressure Ratio
0	3	78	78	2.17	2.17	7.39	0.0082
90	3	78	78	2.17	2.17	7.39	0.0082
180	3	78	78	2.17	2.17	7.39	0.0082
270	3	78	78	2.17	2.17	7.39	0.0082

Direction of Worst case Force: = **0 °**
Highest Stress Ratio = **0.0082**

Loadings and Stresses on BasePlate and Anchor bolts

Leg Orientation °	Moment M_x in.-lb.	Moment M_y in.-lb.	Maximum Pressure P_x PSI	Maximum Pressure P_y PSI	Maximum B.P. Stress PSI	BasePlate Stress Ratio	Anchor Bolt Stress PSI	Anchor Bolt Stress Ratio
0	10	10	966	919	1333	0.0673	3	0.0001
90	10	10	966	919	1333	0.0673	3	0.0001
180	10	10	966	919	1333	0.0673	3	0.0001
270	10	10	966	919	1333	0.0673	3	0.0001

Direction of Worst case Force: = **0 °**
Highest Stress Ratio = **0.0673**

Maximum General Longitudinal Stresses

VE = 1.00 **1.00**

$$S_{L1} = \frac{M_a}{Z} - \frac{W\ VE}{A} + \left(\frac{P * D}{4 * t}\right) = \frac{0}{187.8903} - \frac{441.94 * 1.00}{21.10} + \left(\frac{126.95 * 36.0000}{4 * 0.1875}\right)$$ **= 6073** PSI

$$S_{L2} = -\frac{M_a}{Z} - \frac{W\ VE}{A} = -\frac{0}{187.8903} - \frac{441.94 * 1.00}{21.10}$$ **= -21** PSI

Allowable Tension Stress, S_{ta} = S E = 20000 * 0.70 **= 14000** PSI

Allowable Compressive Stress, S_{ca} = -B = -13116 **= -13116** PSI

$$R_{SL1} = \frac{S_{L1}}{S_{ta}} = \frac{6073}{14000}$$ **= 0.4338**

$$R_{SL2} = \frac{S_{L2}}{S_{ca}} = \frac{-21}{-13116}$$ **= 0.0016**

Summary

Governing external force = **None**

Total Force = **0** lb.

Weight = **441.94** lb.

Base Moment = **0** in.-lb.

Tangent Moment = **0** in.-lb.

Leg Stresses

Maximum combined compressive and bending stress ratio = **0.0171**

Leg BasePlate

Concrete Stress Ratio = **0.0082**

Base Plate Stress Ratio = **0.0673**

Host Stresses

Sl1 ratio = **0.4338**

Sl2 ratio = **0.0016**

Weld Stresses

Leg to vessel weld stress ratio = **0.0049**

Test Conditions

Support Leg Properties

Section Modulus, S_x $= \dfrac{I_x}{C_x} = \dfrac{1.9840}{2.1213}$ **= 0.9353** in.³

Section Modulus, S_y $= \dfrac{I_y}{C_y} = \dfrac{0.5044}{1.1913}$ **= 0.4234** in.³

Radius of gyration, r_x $= \sqrt{\dfrac{I_x}{A}} = \sqrt{\dfrac{1.9840}{1.4375}}$ **= 1.1748** in.

Radius of gyration, r_y $= \sqrt{\dfrac{I_y}{A}} = \sqrt{\dfrac{0.5044}{1.4375}}$ **= 0.5924** in.

Least radius of gyration, r_{min} $= \sqrt{\dfrac{I_{min}}{A}} = \sqrt{\dfrac{0.5044}{1.4375}}$ **= 0.5924** in.

Slenderness ratio, SR_x $= \dfrac{K\ L}{r_x} = \dfrac{1.5000 * 6.0000}{1.1748}$ **= 7.6609**

Slenderness ratio, SR_y $= \dfrac{K\ L}{r_y} = \dfrac{1.5000 * 6.0000}{0.5924}$ **= 15.1924**

SR_{max} $= \dfrac{K\ L}{r_{min}} = \dfrac{1.5000 * 6.0000}{0.5924}$ **= 15.1924**

Critical slenderness ratio, C_c $= \sqrt{\dfrac{2 \pi^2 E}{F_y}} = \sqrt{\dfrac{2 * \pi^2 * (28.6 * 10^6)}{33000}}$ **= 130.79**

F'_{ex} $= \dfrac{12 \pi^2 E}{23\ SR_x^2} = \dfrac{12 * \pi^2 * (28.6 * 10^6)}{23 * 7.6609^2}$ **= 2509341** PSI

F'_{ey} $= \dfrac{12 \pi^2 E}{23\ SR_y^2} = \dfrac{12 * \pi^2 * (28.6 * 10^6)}{23 * 15.1924^2}$ **= 638067** PSI

For SR_{max} $<= C_c$, Allowable compressive stress:

$$F_a = \frac{\left(1 - \dfrac{SR_{max}^2}{2\ C_c^2}\right) F_y}{\dfrac{5}{3} + \dfrac{3\ SR_{max}}{8\ C_c} - \dfrac{SR_{max}^3}{8\ C_c^3}} = \frac{\left(1 - \dfrac{15.1924^2}{2 * 130.79^2}\right) * 33000}{\dfrac{5}{3} + \dfrac{3 * 15.1924}{8 * 130.79} - \dfrac{15.1924^3}{8 * 130.79^3}}$$ **= 19168** PSI

Allowable bending stress: S_b $= 0.6\ F_y = 0.6 * 33000$ **= 19800** PSI
Allowable tension stress: S_t $= 0.6\ F_y = 0.6 * 33000$ **= 19800** PSI

Leg to Vessel Weld Properties

Distance between welds along side of legs (b) = **= 3.8891** in.

$L_w = (2 W_s) + W_t = (2 * 6.0000) + 3.0000$ **= 15.0000** in.

$$I_{wy} = \frac{W_s^3 (2 W_t + W_s)}{3 L_w} = \frac{6.0000^3 * (2 * 3.0000 + 6.0000)}{3 * 15.0000}$$ **= 57.6000** in.³

$$I_{wz} = \frac{6 W_s b^2 + W_t^3}{12} = \frac{6 * 6.0000 * 3.8891^2 + 3.0000^3}{12}$$ **= 47.6250** in.³

$J_{wx} = I_{wy} + I_{wz} = 57.6000 + 47.6250$ **= 105.2250** in.³

Distance from weld neutral axis to top of welds:

$$EF_{yt} = \frac{W_s^2}{L_w} = \frac{6.0000^2}{15.0000}$$ **= 2.4000** in.

Distance from weld neutral axis to bottom of welds:

$EF_{yb} = W_s - EF_{yt} = 6.0000 - 2.4000$ **= 3.6000** in.

Distance from weld neutral axis to side of welds:

$$EF_z = MAX\left(\frac{b}{2}, \frac{W_t}{2}\right) = MAX\left(\frac{3.8891}{2}, \frac{3.0000}{2}\right)$$ **= 1.9445** in.

Wind load calculations are not required for the test condition.

Seismic load calculations are not required for the test condition.

Loadings and Stresses on Support Legs

Direction of Applied Force = **0** °

Leg Orientation °	**Moment of Inertia in.^4**	**Lateral Force lb.**	**Axial Stress PSI**	**Bending Stresses (f_{bx}) PSI**	**Bending Stresses (f_{by}) PSI**	**Acceptance Ratio (Eqn_1)**	**Acceptance Ratio (Eqn_2)**
0	0.5044	0	-386	0	1313	0.0865	
90	1.9840	0	-386	0	1313	0.0865	
180	0.5044	0	-386	0	1313	0.0865	
270	1.9840	0	-386	0	1313	0.0865	

Direction of Worst case Force = **0** °
Highest Stress Ratio = **0.0865**

Loadings and Stresses on Leg to Vessel attachment welds

Leg Orientation °	Load F_x lb.	Load F_y lb.	Load F_z lb.	Moment M_x in.-lb.	Moment M_y in.-lb.	Moment M_z in.-lb.	Total Stress PSI	Stress Ratio
0	0	0	-555	0	-556	0	203	0.0250
90	0	0	-555	0	-556	0	203	0.0250
180	0	0	-555	0	-556	0	203	0.0250
270	0	0	-555	0	-556	0	203	0.0250

Direction of Worst case Force = **0** °
Highest Stress Ratio: **0.0250**

Loadings and Pressure on Concrete Foundation

Direction of applied force: = **0** °

Leg Orientation °	Bearing Pressure PSI	Moment M_x in.-lb.	Moment M_y in.-lb.	Maximum Pressure P_x PSI	Maximum Pressure P_y PSI	Max. Concrete Pressure PSI	Concrete Pressure Ratio
0	15	393	393	10.92	10.92	37.25	0.0414
90	15	393	393	10.92	10.92	37.25	0.0414
180	15	393	393	10.92	10.92	37.25	0.0414
270	15	393	393	10.92	10.92	37.25	0.0414

Direction of Worst case Force: = **0** °
Highest Stress Ratio = **0.0414**

Loadings and Stresses on BasePlate and Anchor bolts

Leg Orientation °	Moment M_x in.-lb.	Moment M_y in.-lb.	Maximum Pressure P_x PSI	Maximum Pressure P_y PSI	Maximum B.P. Stress PSI	BasePlate Stress Ratio	Anchor Bolt Stress PSI	Anchor Bolt Stress Ratio
0	51	48	4870	4634	6723	0.3395	14	0.0006
90	51	48	4870	4634	6723	0.3395	14	0.0006
180	51	48	4870	4634	6723	0.3395	14	0.0006
270	51	48	4870	4634	6723	0.3395	14	0.0006

Direction of Worst case Force: = **0** °
Highest Stress Ratio = **0.3395**

Maximum General Longitudinal Stresses

VE = 1.00 **1.00**

$$\mathbf{S}_{L1} = \frac{M_a}{Z} - \frac{W\,VE}{A} + \left(\frac{P * D}{4 * t}\right) = \frac{0}{249.2165} - \frac{2220.09 * 1.00}{28.08} + \left(\frac{125.00 * 36.0000}{4 * 0.2500}\right)$$ **= 4421** PSI

$$\mathbf{S}_{L2} = -\frac{M_a}{Z} - \frac{W\,VE}{A} = -\frac{0}{249.2165} - \frac{2220.09 * 1.00}{28.08}$$ **= -79** PSI

Allowable Tension Stress, S_{ta} = S E = 20000 * 0.70 **= 14000** PSI
Allowable Compressive Stress, S_{ca} = -B = -13116 **= -13116** PSI

$$\mathbf{R}_{SL1} = \frac{S_{L1}}{S_{ta}} = \frac{4421}{14000}$$ **= 0.3158**

$$\mathbf{R}_{SL2} = \frac{S_{L2}}{S_{ca}} = \frac{-79}{-13116}$$ **= 0.0060**

Summary

Governing external force = **None**

Total Force = **0** lb.

Weight = **2220.09** lb.

Base Moment = **0** in.-lb.

Tangent Moment = **0** in.-lb.

Leg Stresses

Maximum combined compressive and bending stress ratio = **0.0865**

Leg BasePlate

Concrete Stress Ratio = **0.0414**

Base Plate Stress Ratio = **0.3395**

Host Stresses

Sl1 ratio = **0.3158**

Sl2 ratio = **0.0060**

Weld Stresses

Leg to vessel weld stress ratio = **0.0250**

ASME Flange Design Information

Host	Description	Type	Size (in.)	Material	ASME Class	Material Group	MAP (PSI)
Nozzle 1	ASME Flange 1	Weld Neck	18	SA-105	150	1.1	260.00
Nozzle 2	4" Weld Neck Flange	Weld Neck	4	SA-105	150	1.1	260.00
Shell 1	36" Weld Neck Flange		36	SA-105	150	1.1	260.00
	36" Blind Flange		36	SA-105	150	1.1	260.00

MDMT Report by Components

Design MDMT is -20 °F

Component	Material	Curve	Pressure	MDMT
Shell 1	SA-516 Gr. 70	B	125.00 PSI	-20 °F
Nozzle 1	SA-106 Gr. B	B	125.00 PSI	-155 °F
Nozzle 2	SA-106 Gr. B	B	125.00 PSI	-155 °F
Head 1	SA-516 Gr. 70	B	125.00 PSI	-20 °F
Threaded Coupling - 1"	SA-105	B	125.00 PSI	-155 °F
36" Blind Flnage	SA-105	B	125.00 PSI	-51 °F
Threaded Coupling - 2"	SA-105	B	125.00 PSI	-155 °F

Component with highest MDMT: Shell 1.

Computed MDMT = -20 °F

The required design MDMT of -20 °F has been met or exceeded for the calculated MDMT values.

ASME Flanges Are Not Included in MDMT Calculations.

Pressure Vessel Engineering, Ltd.

Vertical Vessel with Bolted Cover

Customer: **Pressure Vessel Engineering**

Job No: PVE Sample 14

Vessel Number: 2

Date Printed: 6/19/2009

MAWP Report by Components

Component	Design Pressure	Static Head	Vessel MAWP New & Cold UG-98(a)	Component MAWP Hot & Corroded UG-98(b)	Vessel MAWP Hot & Corroded UG-98(a)
Shell 1	125.00 PSI	1.95 PSI	193.58 PSI	146.44 PSI	144.49 PSI
ASME Flange Class: 150 Gr:1.1		0.00 PSI	285.00 PSI	260.00 PSI	260.00 PSI
Nozzle 1	125.00 PSI	1.95 PSI	197.67 PSI	159.33 PSI	157.38 PSI
ASME Flange Class: 150 Gr:1.1		1.95 PSI	283.05 PSI	260.00 PSI	258.05 PSI
Nozzle 2	125.00 PSI	1.95 PSI	277.43 PSI	161.57 PSI	159.62 PSI
ASME Flange Class: 150 Gr:1.1		1.95 PSI	283.05 PSI	260.00 PSI	258.05 PSI
Head 1	125.00 PSI	1.95 PSI	213.93 PSI	155.69 PSI	153.74 PSI
Threaded Coupling - 1"	125.00 PSI	1.95 PSI	278.69 PSI	202.73 PSI	200.78 PSI
36" Blind Flnage	125.00 PSI	0.00 PSI	387.92 PSI	387.92 PSI	387.92 PSI
Threaded Coupling - 2"	125.00 PSI	0.00 PSI	693.32 PSI	579.55 PSI	579.55 PSI

NC = Not Calculated   Inc = Incomplete

Summary

Component with the lowest vessel MAWP(New & Cold) : **Shell 1**

The lowest vessel MAWP(New & Cold) : **193.58** PSI

Component with the lowest vessel MAWP(Hot & Corroded) : **Shell 1**

The lowest vessel MAWP(Hot & Corroded) : **144.49** PSI

Pressures are exclusive of any external loads.

Flange pressures listed here do not consider external loadings

Summary Information

	Dry Weight	Flooded Weight
Shell	328.70 lb.	1825.50 lb.
Head	113.24 lb.	396.18 lb.
Nozzle	153.47 lb.	153.47 lb.
Flange	1469.68 lb.	1469.68 lb.
ASME Flange	165.00 lb.	165.00 lb.
Totals	2230.09 lb.	4009.82 lb.

	Volume
Shell	179.17 Gal.
Head	33.93 Gal.
Nozzle	16.53 Gal.
Totals	229.62 Gal.

	Area
Shell	32.84 Sq. Ft.
Head	11.23 Sq. Ft.
Nozzle	10.67 Sq. Ft.
Totals	54.74 Sq. Ft.

Hydrostatic Test Information Par. UG-99(b)
Gauge at Top

Component	Const.	x	STest	/	SDesign	x	Pressure	=	Component Hydro Test Pressure
Head 1	1.3	x	20000	/	20000	x	125.00	=	**162.50**
Nozzle 1	1.3	x	17100	/	17100	x	125.00	=	162.50
Nozzle 2	1.3	x	17100	/	17100	x	125.00	=	162.50
Shell 1	1.3	x	20000	/	20000	x	125.00	=	162.50
Threaded Coupling - 1"	1.3	x	20000	/	20000	x	125.00	=	162.50

Calculated Test Pressure: 162.50 PSI

Special Notes:

This calculation assumes one chamber.

This calculation is limited by the lowest component pressure per chamber.