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

Date Printed: 10/27/2008

VESSEL DESCRIPTION

Horizontal Retention Tank

Vessel designed per the ASME Boiler & Pressure Vessel Code,
Section VIII, Division 1,2007 Edition
with Advanced Pressure Vessel, Version: 10.0.2
Vessel is ASME Code Stamped

Job No: Sample Vessel 3
Vessel Number: Horizontal Vessel

NAMEPLATE INFORMATION

Vessel MAWP: 75.00 PSI at 150 °F
MDMT: -20 °F at 75.00 PSI

Serial Number(s): _____

National Board Number(s): _____
Year Built: 2008
Radiography: NONE
Postweld Heat Treated: NONE

Signatures

Mechanical Technologist:_____ Date: ____/____/____
Alex Turvey

P.Eng:_____ Date: ____/____/____
Laurence Brundrett

1	REVISED	10/22/2008	ART
0	RELEASE	5/23/2002	LB
REV	DESCRIPTION	DATE	INITIALS

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Shell 1

Job No: Sample Vessel 3 — Vessel Number: Horizontal Vessel

Number: 1 — Mark Number: S1

Date Printed: 10/27/2008

Cylindrical Shell Design Information

Design Pressure:	75.00	PSI	Design Temperature:	150	°F
Static Head:	3.50	PSI	Long. Joint Efficiency:	70	%
Shell Material:	SA-516 Gr 70		Factor B Chart:	CS-2	
			Material Stress (hot):	20000	PSI
Shell Length:	120.0000	in.	Material Stress (cold):	20000	PSI
			Compressive Stress:	11484	PSI
Corrosion Allowance:	0.0000	in.	Actual Circumferential Stress:	17180	PSI
External Corrosion Allowance:	0.0000	in.	Actual Longitudinal Stress:	8534	PSI
Outside Diameter (new):	96.0000	in.			
Outside Diameter (corroded):	96.0000	in.	Specific Gravity:	1.00	
Shell Surface Area:	251.33	Sq. Ft.	Weight of Fluid:	31008.13	lb.
Shell Estimated Volume:	3711.74	Gal.	Total Flooded Shell Weight:	34198.36	lb.
Circ. Joint Efficiency:	70	%	Shell Weight:	3190.24	lb.

Minimum Design Metal Temperature Data

Min. Temperature Curve:	B		Pressure at MDMT:	75.00	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)

$$\mathbf{t} = \frac{PR}{2SE + 0.4P} = \frac{78.50 * 47.6875}{2 * 20000 * 0.70 + 0.4 * 78.50} = 0.1335 + 0.0000_{\text{(corrosion)}} + 0.0000_{\text{(ext. corrosion)}}$$ = minimum of **0.1335** in.

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

$$\mathbf{t} = \frac{PR_O}{SE + 0.4P} = \frac{78.50 * 48.0000}{20000 * 0.70 + 0.4 * 78.50} = 0.2686 + 0.0000_{\text{(corrosion)}} + 0.0000_{\text{(ext. corrosion)}}$$ = minimum of **0.2686** in.

Extreme Fiber Elongation Calculation per Paragraph UCS-79

$$\textbf{Elongation} = \frac{50t}{Rf} = \frac{50 * 0.3125}{47.8438}$$ = elongation of **0.33** %

Nominal Shell Thickness Selected = **0.3125** in.

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Right Side Head

Job No: Sample Vessel 3 — Vessel Number: Horizontal Vessel

Number: 1 — Mark Number: H2

Date Printed: 10/27/2008

Ellipsoidal Head Design Information

Design Pressure:	75.00	PSI	Design Temperature:	150	°F
Static Head:	3.50	PSI	Joint Efficiency:	85	%
Head Material:	SA-516 Gr 70		Factor B Chart:	CS-2	
			Material Stress (hot):	20000	PSI
Corrosion Allowance:	0.0000	in.	Material Stress (cold):	20000	PSI
External Corrosion Allowance:	0.0000	in.	Actual Head Stress:	15637	PSI
Head Location:	Right		Straight Flange :	1.5000	in.
Outside Diameter :	96.0000	in.	Head Depth (ho) :	24.1563	in.
Thin Out :	0.0305	in.			
K = ⅙[2 + (D/2h)²] :	1.00				
Head Surface Area:	72.44	Sq. Ft.	Specific Gravity:	1.00	
Head Estimated Volume:	538.07	Gal.	Weight of Fluid:	4487.55	lb.
Head Weight:	922.50	lb.	Total Flooded Head Weight:	5410.04	lb.

Minimum Design Metal Temperature Data

Min. Temperature Curve:	B	Pressure at MDMT:	75.00 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)

$$\mathbf{t} = \frac{PD_oK}{2SE + 2P(K - 0.1)} = \frac{78.50 * 96.0000 * 1.00}{2 * 20000 * 0.85 + 2 * 78.50 * (1.00 - 0.1)}$$

$= 0.2208 + 0.0000_{\text{(corrosion)}} + 0.0000_{\text{(ext. corrosion)}} + 0.0305_{\text{(thin out)}}$ = minimum of **0.2513** in.

Extreme Fiber Elongation Calculation per Paragraph UCS-79

$$\textbf{elongation} = \frac{75t}{R_f} = \frac{75 * 0.3125}{16.2669}$$

= elongation of **1.44** %

Nominal Head Thickness Selected = **0.3125** in.

Minimum Thickness after forming, t_S (uncorroded) = **0.2820** in.

Pressure Vessel Engineering, Ltd.

Left Side Head

Job No: Sample Vessel 3 Vessel Number: Horizontal Vessel

Number: 2 Mark Number: H1

Date Printed: 10/27/2008

Ellipsoidal Head Design Information

Design Pressure:	75.00	PSI	Design Temperature:	150	°F
Static Head:	3.50	PSI	Joint Efficiency:	85	%
Head Material:	SA-516 Gr 70		Factor B Chart:	CS-2	
			Material Stress (hot):	20000	PSI
Corrosion Allowance:	0.0000	in.	Material Stress (cold):	20000	PSI
External Corrosion Allowance:	0.0000	in.	Actual Head Stress:	15637	PSI
Head Location:	Left		Straight Flange :	1.5000	in.
Outside Diameter :	96.0000	in.	Head Depth (ho) :	24.1563	in.
Thin Out :	0.0305	in.			
K = ⅙[2 + (D/2h)²] :	1.00				
Head Surface Area:	72.44	Sq. Ft.	Specific Gravity:	1.00	
Head Estimated Volume:	538.07	Gal.	Weight of Fluid:	4487.55	lb.
Head Weight:	922.50	lb.	Total Flooded Head Weight:	5410.04	lb.

Minimum Design Metal Temperature Data

Min. Temperature Curve:	B		Pressure at MDMT:	75.00	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)

$$\mathbf{t} = \frac{PD_oK}{2SE + 2P(K - 0.1)} = \frac{78.50 * 96.0000 * 1.00}{2 * 20000 * 0.85 + 2 * 78.50 * (1.00 - 0.1)}$$

$= 0.2208 + 0.0000_{\text{(corrosion)}} + 0.0000_{\text{(ext. corrosion)}} + 0.0305_{\text{(thin out)}}$ = minimum of **0.2513** in.

Extreme Fiber Elongation Calculation per Paragraph UCS-79

$$\textbf{elongation} = \frac{75t}{R_f} = \frac{75 * 0.3125}{16.2669}$$

= elongation of **1.44** %

Nominal Head Thickness Selected = **0.3125** in.

Minimum Thickness after forming, t_S (uncorroded) = **0.2820** in.

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A - 3/4" 3000# Cplg

Job No: Sample Vessel 3 Vessel Number: Horizontal Vessel
Number: 9 Mark Number: A
ID Number: A

Date Printed: 10/27/2008

Nozzle Design Information

Design Pressure:	75.00	PSI	Design Temperature:	150	°F
Static Head:	3.50	PSI	Nozzle Efficiency (E):	100	%
Nozzle Material:	SA-105		Joint Efficiency (E_1):	1.00	
			Factor B Chart:	CS-6	
External Projection:	0.6270	in.	Allowable Stress at Design Temperature (S_n):	20000	PSI
Internal Projection:	0.0000	in.	Allowable Stress at Ambient Temperature:	20000	PSI
Inside Corrosion Allowance:	0.0000	in.	Correction Factor (F):	1.00	
External Corrosion Allowance:	0.0000	in.	Nozzle Path:	None	
Nozzle ID (new):	1.0650	in.	Nozzle Wall Thickness(new):	0.1625	in.
Nozzle ID (corroded):	1.0650	in.	Nozzle Wall Thickness(corroded):	0.1625	in.
Outer "h" Limit:	0.4063	in.	Upper Weld Leg Size(Weld 41):	0.2500	in.
Internal "h" Limit:	0.4063	in.	Internal Weld Leg Size(Weld 43):	0.0000	in.
OD, Limit of Reinforcement:	2.1300	in.	Outside Groove Weld Depth:	0.3125	in.

Minimum Design Metal Temperature

Min. Temp. Curve:	A	Pressure at MDMT:	75.00 PSI
UCS-66(b) reduction:	Yes	Minimum Design Metal Temperature:	-20 °F
UCS-68(c) reduction:	No	Computed Minimum Temperature:	-122 °F

Host Component: Shell 1 - Shell 1

Material:	SA-516 Gr 70	Shell wall thickness(new):	0.3125 in.
Material Stress(S_v):	20000 PSI	Shell wall thickness(corroded):	0.3125 in.

Nozzle Detail Information

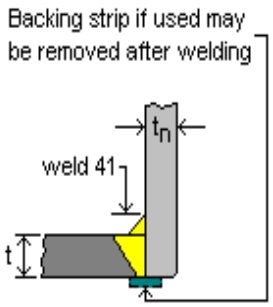

Fig. UW-16.1 (c)

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

Nozzle Wall Thickness(t_n): 0.1625 in.

Outside Groove Weld Depth: 0.3125 in.

Nozzle passes through the vessel, attached by a groove 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 Shell Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{PRo}{SE + 0.4P} = \frac{78.50 * 48.0000}{20000 * 1 + 0.4 * 78.50}$$ = **0.1881** in.

Nozzle Required Thickness Calculations

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

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{78.50 * 0.5325}{20000 * 1 - 0.6 * 78.50}$$ = **0.0021** in.

Strength Reduction Factors

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

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

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

UG-45 Thickness Calculations

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

$$\mathbf{t} = \frac{PRn}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{78.50 * 0.5325}{20000 * 1.00 - 0.6 * 78.50} + 0.0000 + 0.0000$$ = **0.0021** in.

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

$$\mathbf{t} = \frac{PRo}{SE + 0.4P} + Ca + \text{ext. } Ca = \frac{78.50 * 48.0000}{20000 * 1 + 0.4 * 78.50} + 0.0000 + 0.0000$$ = **0.1881** 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 = **0.1225** in.

Nozzle Minimum Thickness per Paragraph UG-45(b)

t = Smallest of UG-45(b)(1) or UG-45(b)(4) = **0.1225** in.

Wall thickness = tn = **0.1625** is greater than or equal to UG-45 value of **0.1225**

Nozzle Weld Strength Calculations

Attachment Weld Strength per Paragraph UW-16

Weld 41 tmin = smaller of 0.75, t, or tn = smaller of 0.75, 0.3125, or 0.1625 = **0.1625** in.

Weld 41 Leg min. = $\frac{\text{(smaller of 0.25 or (tmin * 0.7)) + ext. CA}}{0.7} = \frac{0.1138}{0.7}$ = **0.1625** in.

Weld 41, 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 * 20000 = **14000** PSI
Upper fillet, Weld 41, in shear = 0.49 * Material Stress = 0.49 * 20000 = **9800** PSI
Vessel groove weld, in tension = 0.74 * Material Stress = 0.74 * 20000 = **14800** PSI

Strength of Connection Elements

Nozzle wall in shear = ½ * π * mean nozzle diameter * tn * Nozzle wall in shear unit stress =
½ * π * 1.2275 * 0.1625 * 14000 = **4380** lb.
Upper fillet in shear = ½ * π * Nozzle OD * weld leg * upper fillet in shear unit stress = ½ * π * 1.3900 * 0.2500 * 9800 = **5350** lb.
Groove Weld in Tension = ½ * π * Nozzle OD * groove depth * groove weld tension unit stress =
½ * π * 1.3900 * 0.3125 * 14800 = **10100** 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 = [0.2003 - 0.1325 + 2 * 0.1625 * 1.0000 * (1.00 * 0.3125 - 1.0000 * 0.1881)] * 20000 = **2160** lb.
W1-1 = (A2 + A5 + A41 + A42) * Sv = (0.1303 + 0.0000 + 0.0625 + 0.0000) * 20000 = **3860** lb.
W2-2 = (A2 + A3 + A41 + A43 + 2 tn t fr1) Sv = (0.1303 + 0.0000 + 0.0625 + 0.0000 + 2 * 0.1625 * 0.3125 * 1.0000) * 20000 = **5890** lb.
W3-3 = (A2 + A3 + A5 + A41 + A42 + A43 + 2 tn t fr1) * Sv =
(0.1303 + 0.0000 + 0.0000 + 0.0625 + 0.0000 + 0.0000 + 2 * 0.1625 * 0.3125 * 1.0000) * 20000 = **5890** lb.

Check Strength Paths

Path 1-1 = Upper fillet in shear + Nozzle wall in shear = 5350 + 4380 = **9730** lb.
Path 2-2 = Upper fillet in shear + Groove weld in tension + Inner fillet in shear =
5350 + 10100 + 0 = **15450** lb.
Path 3-3 = Upper fillet in shear + Inner fillet in shear + Groove weld in tension = 5350 + 0 + 10100 = **15450** lb.

Pressure Vessel Engineering, Ltd.

B - 6" Pipe

Job No: Sample Vessel 3 — Vessel Number: Horizontal Vessel
Number: 1 — Mark Number: B
ID Number: 1

Date Printed: 10/27/2008

Nozzle Design Information

Design Pressure:	75.00	PSI	Design Temperature:	150	°F
Static Head:	3.50	PSI	Nozzle Efficiency (E):	100	%
Nozzle Material:	SA-106 Gr B		Joint Efficiency (E_1):	1.00	
			Factor B Chart:	CS-2	
External Projection:	4.0000	in.	Allowable Stress at Design Temperature (S_n):	17100	PSI
Internal Projection:	1.0000	in.	Allowable Stress at Ambient Temperature:	17100	PSI
Inside Corrosion Allowance:	0.0000	in.	Correction Factor (F):	1.00	
External Corrosion Allowance:	0.0000	in.	Nozzle Path:	None	
Nozzle Pipe Size:	6		Nozzle Pipe Schedule:	80	
Nozzle ID (new):	5.7610	in.	Nozzle Wall Thickness(new):	0.4320	in.
Nozzle ID (corroded):	5.7610	in.	Nozzle Wall Thickness(corroded):	0.4320	in.
Developed Opening:	7.4700	in.	Tangential Dimension L:	34.5000	in.
Outer "h" Limit:	0.7050	in.	Upper Weld Leg Size(Weld 41):	0.3125	in.
Internal "h" Limit:	0.7050	in.	Internal Weld Leg Size(Weld 43):	0.3125	in.
OD, Limit of Reinforcement:	14.9400	in.	Outside Groove Weld Depth:	0.2820	in.

Minimum Design Metal Temperature

Min. Temp. Curve:	B	Pressure at MDMT:	3.50	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 2 - Left Side Head

Material:	SA-516 Gr 70		Head wall thickness(new):	0.3125	in.
Material Stress(S_v):	20000	PSI	Head wall thickness - thin out (corroded):	0.2820	in.

Nozzle Detail Information

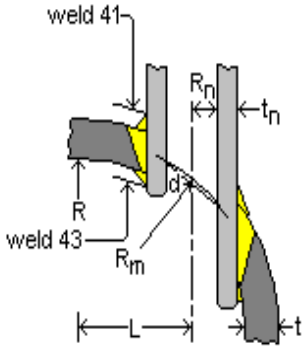

Fig. UW-16.1 (c)

Upper Weld Leg Size(Weld 41): 0.3125 in.

Internal Weld Leg Size(Weld 43): 0.3125 in.

Nozzle Wall Thickness(t_n): 0.4320 in.

Outside Groove Weld Depth: 0.2820 in.

tangential to the vessel wall, attached by a groove weld.
Pipe Size: 6 Schedule: 80
Nozzle is adequate for UG-45 requirements.
Opening is adequately reinforced for Internal Pressure.
Weld Strength Paths are adequate.

Required Head Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{P\ K1\ Do}{(2SE + 0.8P)} = \frac{78.50 * 0.9000 * 96.0000}{(2 * 20000 * 1 + 0.8 * 78.50)}$$ = **0.1693** in.

Nozzle Required Thickness Calculations

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

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{78.50 * 2.8805}{17100 * 1 - 0.6 * 78.50}$$ = **0.0133** in.

Strength Reduction Factors

fr1 = $\min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{17100}{20000}, 1.0000\right) = 0.8550$ **fr2** = $\min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{17100}{20000}, 1.0000\right) = 0.8550$

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)

$$\mathbf{t} = \frac{PRn}{SE - 0.6P} + Ca + ext.\ Ca = \frac{78.50 * 2.8805}{17100 * 1.00 - 0.6 * 78.50} + 0.0000 + 0.0000$$ = **0.0133** in.

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

$$\mathbf{t} = \frac{P\ K\ Do}{(2SE + 2P(K - 0.1))} + Ca + ext.\ Ca = \frac{78.50 * 1.0000 * 96.0000}{(2 * 20000 * 1 + 2 * 78.50 * (1.0000 - 0.1))} + 0.0000 + 0.0000$$ = **0.1877** 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 = **0.2450** in.

Nozzle Minimum Thickness per Paragraph UG-45(b)

t = Smallest of UG-45(b)(1) or UG-45(b)(4) = **0.1877** in.

Wall thickness = tn * 0.875(pipe) = **0.3780** is greater than or equal to UG-45 value of **0.1877**

Nozzle Reinforcement Calculations

Area Required for Internal Pressure

A = d tr F + 2 tn tr F (1 - fr1) = (7.4700 * 0.1693 * 1.00) + (2 * 0.4320 * 0.1693 * 1.00 * (1 - 0.8550)) = **1.2859** sq. in.

Area Available - Internal Pressure

A1 Formula 1 = d(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
7.4700 * (1.00 * 0.2820 - 1.00 * 0.1693) - 2 * 0.4320 * (1.00 * 0.2820 - 1.00 * 0.1693) * (1 - 0.8550) = *0.8277* sq. in.

A1 Formula 2 = 2(t + tn)(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
2 * (0.2820 + 0.4320)(1.00 * 0.2820 - 1.00 * 0.1693) - 2 * 0.4320 * (1.00 * 0.2820 - 1.00 * 0.1693) * (1 - 0.8550)

= *0.1468* sq. in.

A1 = Larger value of *A1 Formula 1* and *A1 Formula 2* = **0.8277** sq. in.

A2 Formula 1 = 5(tn - trn) fr2 t = 5(0.4320 - 0.0133) * 0.8550 * 0.2820 = *0.5048* sq. in.
A2 Formula 2 = 5(tn - trn) fr2 tn = 5(0.4320 - 0.0133) * 0.8550 * 0.4320 = *0.7733* sq. in.
A2 = Smaller value of *A2 Formula 1* and *A2 Formula 2* = **0.5048** sq. in.

A3 = Smaller value of the following :
$5 * t * t_i * f_{r2}$ = 5 * 0.2820 * 0.4320 * 0.8550 = 0.5208 sq. in.
$5 * t_i * t_i * f_{r2}$ = 5 * 0.4320 * 0.4320 * 0.8550 = 0.7978 sq. in.
$2 * h * t_i * f_{r2}$ = 2 * 1.0000 * 0.4320 * 0.8550= 0.7387 sq. in.
= **0.5208** sq. in.

A41 = $(leg)^2 * fr2 = (0.3125)^2 * 0.8550$ = **0.0835** sq. in.

A43 = $(leg)^2 * fr2 = (0.3125)^2 * 0.8550$ = **0.0835** sq. in.

Area Available (Internal Pressure) = A1 + A2 + A3 + A41 + A43 = 2.0203 sq. in., which is **greater** than A (1.2859)

Nozzle Weld Strength Calculations

Attachment Weld Strength per Paragraph UW-16

Weld 41 tmin = smaller of 0.75, t, or tn = smaller of 0.75, 0.2820, or 0.4320 = **0.2820** in.

$$\text{Weld 41 Leg min.} = \frac{\text{(smaller of 0.25 or (tmin * 0.7)) + ext. CA}}{0.7} = \frac{0.1974}{0.7}$$ = **0.2820** in.

Weld 41, actual weld leg = **0.3125** in.

Weld 43 tmin = smaller of 0.75, t, or tn = smaller of 0.75, 0.2820, or 0.4320 = **0.2820** in.

$$\text{Weld 43 Leg min.} = \frac{\text{(smaller of 0.25 or (tmin * 0.7)) + ca}}{0.7} = \frac{\text{(smaller of 0.25 or (0.2820 * 0.7)) + 0.0000}}{0.7} = \frac{0.1974}{0.7}$$ = **0.2820** in.

Weld 43, actual weld leg = **0.3125** 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
Inner fillet, Weld 43, in shear = 0.49 * Material Stress = 0.49 * 17100 = **8379** PSI

Strength of Connection Elements

Nozzle wall in shear = ½ * π * mean nozzle diameter * tn * Nozzle wall in shear unit stress =
½ * π * 6.1930 * 0.4320 * 11970 = **50300** lb.
Upper fillet in shear = ½ * π * Nozzle OD * weld leg * upper fillet in shear unit stress = ½ * π * 6.6250 * 0.3125 * 8379 = **27200** lb.
Groove Weld in Tension = ½ * π * Nozzle OD * groove depth * groove weld tension unit stress =
½ * π * 6.6250 * 0.2820 * 12654 = **37100** lb.
Inner fillet in shear = ½ * π * Nozzle OD * weld leg * inner fillet in shear unit stress = ½ * π * 6.6250 * 0.3125 * 8379 = **27200** 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 = [1.2859 - 0.8277 + 2 * 0.4320 * 0.8550 * (1.00 * 0.2820 - 1.0000 * 0.1693)] * 20000 = **10800** lb.
W1-1 = (A2 + A5 + A41 + A42) * Sv = (0.5048 + 0.0000 + 0.0835 + 0.0000) * 20000 = **11800** lb.
W2-2 = (A2 + A3 + A41 + A43 + 2 tn t fr1) Sv = (0.5048 + 0.5208 + 0.0835 + 0.0835 + 2 * 0.4320 * 0.2820 * 0.8550) * 20000 = **28000** lb.
W3-3 = (A2 + A3 + A5 + A41 + A42 + A43 + 2 tn t fr1) * Sv =
(0.5048 + 0.5208 + 0.0000 + 0.0835 + 0.0000 + 0.0835 + 2 * 0.4320 * 0.2820 * 0.8550) * 20000 = **28000** lb.

Check Strength Paths

Path 1-1 = Upper fillet in shear + Nozzle wall in shear = 27200 + 50300 = **77500** lb.
Path 2-2 = Upper fillet in shear + Groove weld in tension + Inner fillet in shear =
27200 + 37100 + 27200 = **91500** lb.
Path 3-3 = Upper fillet in shear + Inner fillet in shear + Groove weld in tension = 27200 + 27200 + 37100 = **91500** lb.

Pressure Vessel Engineering, Ltd.

C - 6" Pipe

Job No: Sample Vessel 3 — Vessel Number: Horizontal Vessel
Number: 7 — Mark Number: C
ID Number: C

Date Printed: 10/27/2008

Nozzle Design Information

Design Pressure:	75.00	PSI	Design Temperature:	150	°F
Static Head:	3.50	PSI	Nozzle Efficiency (E):	100	%
Nozzle Material:	SA-106 Gr B		Joint Efficiency (E_1):	1.00	
			Factor B Chart:	CS-2	
External Projection:	4.0000	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:	0.0000	in.	Correction Factor (F):	1.00	
External Corrosion Allowance:	0.0000	in.	Nozzle Path:	None	
Nozzle Pipe Size:	6		Nozzle Pipe Schedule:	80	
Nozzle ID (new):	5.7610	in.	Nozzle Wall Thickness(new):	0.4320	in.
Nozzle ID (corroded):	5.7610	in.	Nozzle Wall Thickness(corroded):	0.4320	in.
Developed Opening:	6.8000	in.	Tangential Dimension L:	5.2500	in.
Outer "h" Limit:	0.7050	in.	Upper Weld Leg Size(Weld 41):	0.3125	in.
Internal "h" Limit:	0.7050	in.	Internal Weld Leg Size(Weld 43):	0.0000	in.
OD, Limit of Reinforcement:	10.0000	in.	Outside Groove Weld Depth:	0.2820	in.

Minimum Design Metal Temperature

Min. Temp. Curve:	B	Pressure at MDMT:	3.50 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):	0.3125	in.	Repad to Vessel Weld Leg Size(Weld 42):	0.2500	in.
OD, Reinforcing Plate(D_p):	12.0000	in.	Repad to Nozzle Groove Weld Depth:	0.0000	in.

Host Component: Head 1 - Right Side Head

Material:	SA-516 Gr 70		Head wall thickness(new):	0.3125	in.
Material Stress(S_v):	20000	PSI	Head wall thickness - thin out (corroded):	0.2820	in.

Nozzle Detail Information

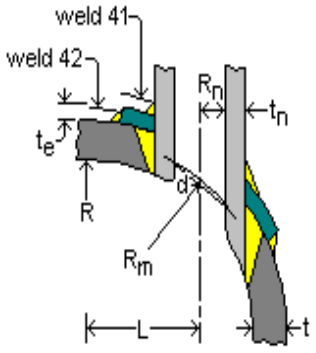

Fig. UW-16.1 (c)

Upper Weld Leg Size(Weld 41): 0.3125 in.

Nozzle Wall Thickness(t_n): 0.4320 in.

Outside Groove Weld Depth: 0.2820 in.

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

Repad Thickness(t_e): 0.3125 in.

tangential to the vessel wall, attached by a groove weld.
Pipe Size: 6 Schedule: 80
Nozzle is adequate for UG-45 requirements.
Opening is adequately reinforced for Internal Pressure.
Weld Strength Paths are adequate.

Pressure Vessel Engineering, Ltd.

C - 6" Pipe

Job No: Sample Vessel 3 — Vessel Number: Horizontal Vessel

Number: 7 — Mark Number: C

ID Number: C

Date Printed: 10/27/2008

Required Head Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{P\ K\ Do}{(2SE + 2P(K - 0.1))} = \frac{78.50 * 1.0000 * 96.0000}{(2 * 20000 * 1 + 2 * 78.50 * (1.0000 - 0.1))}$$ = **0.1877** in.

Nozzle Required Thickness Calculations

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

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{78.50 * 2.8805}{17100 * 1 - 0.6 * 78.50}$$ = **0.0133** in.

Strength Reduction Factors

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

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

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

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)

$$\mathbf{t} = \frac{PRn}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{78.50 * 2.8805}{17100 * 1.00 - 0.6 * 78.50} + 0.0000 + 0.0000$$ = **0.0133** in.

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

$$\mathbf{t} = \frac{P\ K\ Do}{(2SE + 2P(K - 0.1))} + Ca + \text{ext. } Ca = \frac{78.50 * 1.0000 * 96.0000}{(2 * 20000 * 1 + 2 * 78.50 * (1.0000 - 0.1))} + 0.0000 + 0.0000$$ = **0.1877** 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 = **0.2450** in.

Nozzle Minimum Thickness per Paragraph UG-45(b)

t = Smallest of UG-45(b)(1) or UG-45(b)(4) = **0.1877** in.

Wall thickness = tn * 0.875(pipe) = **0.3780** is greater than or equal to UG-45 value of **0.1877**

Nozzle Reinforcement Calculations

Area Required for Internal Pressure

A = d tr F + 2 tn tr F (1 - fr1) = (6.8000 * 0.1877 * 1.00) + (2 * 0.4320 * 0.1877 * 1.00 * (1 - 0.8550)) = **1.2999** sq. in.

Area Available - Internal Pressure

A1 = $(d_{LR}$ - d)(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
(10.0000 - 6.8000) * * (1.00 * 0.2820 - 1.00 * 0.1877) - 2 * 0.4320 * (1.00 * 0.2820 - 1.00 * 0.1877) * (1 - 0.8550) = **0.2899** sq. in.

A2 Formula 1 = 5(tn - trn) fr2 t = 5(0.4320 - 0.0133) * 0.8550 * 0.2820 = *0.5048* sq. in.
A2 Formula 2 = 2(tn - trn) fr2 (2.5 tn + te) = 2(0.4320 - 0.0133) * 0.8550 * (2.5 * 0.4320 + 0.3125) = *0.9970* sq. in.
A2 = Smaller value of *A2 Formula 1* and *A2 Formula 2* = **0.5048** sq. in.

A3 = Smaller value of the following :
5 * t * t_i * f_{r2} = 5 * 0.2820 * 0.4320 * 0.8550 = 0.5208 sq. in.
5 * t_i * t_i * f_{r2} = 5 * 0.4320 * 0.4320 * 0.8550 = 0.7978 sq. in.
2 * h * t_i * f_{r2} = 2 * 0.0000 * 0.4320 * 0.8550= 0.0000 sq. in.
= **0.0000** sq. in.

A41 = (leg)² * fr3 = (0.3125)² * 0.8550 = **0.0835** sq. in.

A42 = Allowable Weld 42 area * fr4 = 0.0000 * 1.0000 = **0.0000** sq. in.

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

A5 = (Dp - d - 2tn) te fr4 = (10.0000 - 6.8000 - 2 * 0.4320) * 0.3125 * 1.0000 = **0.7300** sq. in.

Area Available (Internal Pressure) = A1 + A2 + A3 + A41 + A42 + A43 + A5 = 1.6082 sq. in., which is **greater** than A (1.2999)

Nozzle Weld Strength Calculations

Attachment Weld Strength per Paragraph UW-16

Weld 41 tmin = smaller of 0.75, te, or tn = smaller of 0.75, 0.3125, or 0.4320 = **0.3125** in.

Weld 41 Leg min. = $\frac{\text{(smaller of 0.25 or (tmin * 0.7)) + ext. CA}}{0.7} = \frac{0.2188}{0.7}$ = **0.3125** in.

Weld 41, actual weld leg = **0.3125** in.

Weld 42 tmin = smaller of 0.75, t, or te = smaller of 0.75, 0.2820, or 0.3125 = **0.2820** in.

Weld 42 Leg min. = $\frac{0.5 * \text{tmin + ext. CA}}{0.7} = \frac{0.5 * 0.2820 + 0.0000}{0.7}$ = **0.2014** 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

Strength of Connection Elements

Nozzle wall in shear = ½* π * mean nozzle diameter * tn * Nozzle wall in shear unit stress =
½* π * 6.1930 * 0.4320 * 11970 = **50300** lb.
Upper fillet in shear = ½* π * Nozzle OD * weld leg * upper fillet in shear unit stress = ½* π * 6.6250 * 0.3125 * 8379 = **27200** lb.
Groove Weld in Tension = ½* π * Nozzle OD * groove depth * groove weld tension unit stress =
½* π * 6.6250 * 0.2820 * 12654 = **37100** lb.
Outer fillet in shear = ½* π * Plate OD * weld leg * outer fillet in shear unit stress = ½* π * 12.0000 * 0.2500 * 9800 = **46200** 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 = [1.2999 - 0.2899 + 2 * 0.4320 * 0.8550 * (1.00 * 0.2820 - 1.0000 * 0.1877)] * 20000 = **21600** lb.
W1-1 = (A2 + A5 + A41 + A42) * Sv = (0.5048 + 0.7300 + 0.0835 + 0.0000) * 20000 = **26400** lb.
W2-2 = (A2 + A3 + A41 + A43 + 2 tn t fr1) Sv = (0.5048 + 0.0000 + 0.0835 + 0.0000 + 2 * 0.4320 * 0.2820 * 0.8550) * 20000 = **15900** lb.
W3-3 = (A2 + A3 + A5 + A41 + A42 + A43 + 2 tn t fr1) * Sv =
(0.5048 + 0.0000 + 0.7300 + 0.0835 + 0.0000 + 0.0000 + 2 * 0.4320 * 0.2820 * 0.8550) * 20000 = **30500** lb.

Check Strength Paths

Path 1-1 = Outer fillet in shear + Nozzle wall in shear = 46200 + 50300 = **96500** lb.
Path 2-2 = Upper fillet in shear + Groove weld in tension + Inner fillet in shear =
27200 + 37100 + 0 = **64300** lb.
Path 3-3 = Outer fillet in shear + Inner fillet in shear + Groove weld in tension = 46200 + 0 + 37100 = **83300** lb.

Plate Strength = A5 * Sp = 0.7300 * 20000 = **14600** lb.

Outer fillet weld strength(46200) is greater than plate strength(14600).

Pressure Vessel Engineering, Ltd.

D - 12x16" MWY

Job No: Sample Vessel 3 Vessel Number: Horizontal Vessel
Number: 6 Mark Number: D
ID Number: D

Date Printed: 10/27/2008

Nozzle Design Information

Design Pressure:	75.00 PSI		Design Temperature:	150	°F
Static Head:	3.50 PSI		Nozzle Efficiency (E):	100	%
Nozzle Material:	SA-106 Gr B		Joint Efficiency (E_1):	1.00	
			Factor B Chart:	CS-2	
External Projection:	2.0000 in.		Allowable Stress at Design Temperature (S_n):	17100	PSI
Internal Projection:	1.0000 in.		Allowable Stress at Ambient Temperature:	17100	PSI
Inside Corrosion Allowance:	0.0000 in.		Correction Factor (F):	1.00	
External Corrosion Allowance:	0.0000 in.		Nozzle Path:	None	
Nozzle ID (new):	16.0000 in.		Nozzle Wall Thickness(new):	0.7500	in.
Nozzle ID (corroded):	16.0000 in.		Nozzle Wall Thickness(corroded):	0.7500	in.
Outer "h" Limit:	0.7050 in.		Upper Weld Leg Size(Weld 41):	0.3125	in.
Internal "h" Limit:	0.7050 in.		Internal Weld Leg Size(Weld 43):	0.3125	in.
OD, Limit of Reinforcement:	32.0000 in.		Outside Groove Weld Depth:	0.2820	in.

Minimum Design Metal Temperature

Min. Temp. Curve:	B	Pressure at MDMT:	75.00 PSI
UCS-66(b) reduction:	Yes	Minimum Design Metal Temperature:	-20 °F
UCS-68(c) reduction:	No	Computed Minimum Temperature:	-125 °F

Host Component: Head 2 - Left Side Head

Material:	SA-516 Gr 70	Head wall thickness(new):	0.3125 in.
Material Stress(S_v):	20000 PSI	Head wall thickness - thin out (corroded):	0.2820 in.

Nozzle Detail Information

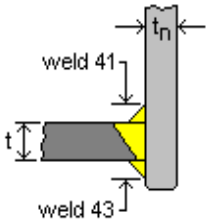

Fig. UW-16.1 (c)

Upper Weld Leg Size(Weld 41): 0.3125 in.

Internal Weld Leg Size(Weld 43): 0.3125 in.

Nozzle Wall Thickness(t_n): 0.7500 in.

Outside Groove Weld Depth: 0.2820 in.

Nozzle passes through 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 Head Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{P\ K1\ Do}{(2SE + 0.8P)} = \frac{78.50 * 0.9000 * 96.0000}{(2 * 20000 * 1 + 0.8 * 78.50)}$$ = **0.1693** in.

Nozzle Required Thickness Calculations

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

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{78.50 * 8.0000}{17100 * 1 - 0.6 * 78.50}$$ = **0.0368** in.

Strength Reduction Factors

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

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

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

UG-45 Thickness Calculations

This calculation is for an access or inspection opening.

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

$$\mathbf{t} = \frac{PRn}{SE - 0.6P} + Ca + ext.\ Ca = \frac{78.50 * 8.0000}{17100 * 1.00 - 0.6 * 78.50} + 0.0000 + 0.0000$$ = **0.0368** in.

Nozzle Reinforcement Calculations

Area Required for Internal Pressure

A = d tr F + 2 tn tr F (1 - fr1) = (16.0000 * 0.1693 * 1.00) + (2 * 0.7500 * 0.1693 * 1.00 * (1 - 0.8550)) = **2.7456** sq. in.

Area Available - Internal Pressure

A1 Formula 1 = d(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
16.0000 * (1.00 * 0.2820 - 1.00 * 0.1693) - 2 * 0.7500 * (1.00 * 0.2820 - 1.00 * 0.1693) * (1 - 0.8550) = *1.7787* sq. in.

A1 Formula 2 = 2(t + tn)(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
2 * (0.2820 + 0.7500)(1.00 * 0.2820 - 1.00 * 0.1693) - 2 * 0.7500 * (1.00 * 0.2820 - 1.00 * 0.1693) * (1 - 0.8550)

= *0.2081* sq. in.

A1 = Larger value of *A1 Formula 1* and *A1 Formula 2* = **1.7787** sq. in.

A2 Formula 1 = 5(tn - trn) fr2 t = 5(0.7500 - 0.0368) * 0.8550 * 0.2820 = *0.8598* sq. in.
A2 Formula 2 = 5(tn - trn) fr2 tn = 5(0.7500 - 0.0368) * 0.8550 * 0.7500 = *2.2867* sq. in.
A2 = Smaller value of *A2 Formula 1* and *A2 Formula 2* = **0.8598** sq. in.

A3 = Smaller value of the following :
$5 * t * t_i * f_{r2}$ = 5 * 0.2820 * 0.7500 * 0.8550 = 0.9042 sq. in.
$5 * t_i * t_i * f_{r2}$ = 5 * 0.7500 * 0.7500 * 0.8550 = 2.4047 sq. in.
$2 * h * t_i * f_{r2}$ = 2 * 1.0000 * 0.7500 * 0.8550= 1.2825 sq. in.
= **0.9042** sq. in.

A41 = $(leg)^2$ * fr2 = $(0.3125)^2$ * 0.8550 = **0.0835** sq. in.

A43 = $(leg)^2$ * fr2 = $(0.3125)^2$ * 0.8550 = **0.0835** sq. in.

Area Available (Internal Pressure) = A1 + A2 + A3 + A41 + A43 = 3.7097 sq. in., which is **greater** than A (2.7456)

Nozzle Weld Strength Calculations

Attachment Weld Strength per Paragraph UW-16

Weld 41 tmin = smaller of 0.75, t, or tn = smaller of 0.75, 0.2820, or 0.7500 = **0.2820** in.

Weld 41 Leg min. = $\frac{\text{(smaller of 0.25 or (tmin * 0.7)) + ext. CA}}{0.7} = \frac{0.1974}{0.7}$ = **0.2820** in.

Weld 41, actual weld leg = **0.3125** in.

Weld 43 tmin = smaller of 0.75, t, or tn = smaller of 0.75, 0.2820, or 0.7500 = **0.2820** in.

Weld 43 Leg min. = $\frac{\text{(smaller of 0.25 or (tmin * 0.7)) + ca}}{0.7} = \frac{\text{(smaller of 0.25 or (0.2820 * 0.7)) + 0.0000}}{0.7} = \frac{0.1974}{0.7}$ = **0.2820** in.

Weld 43, actual weld leg = **0.3125** 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
Inner fillet, Weld 43, in shear = 0.49 * Material Stress = 0.49 * 17100 = **8379** PSI

Strength of Connection Elements

Nozzle wall in shear = ½* π * mean nozzle diameter * tn * Nozzle wall in shear unit stress =
½* π * 16.7500 * 0.7500 * 11970 = **236100** lb.
Upper fillet in shear = ½* π * Nozzle OD * weld leg * upper fillet in shear unit stress = ½* π * 17.5000 * 0.3125 * 8379 = **71900** lb.
Groove Weld in Tension = ½* π * Nozzle OD * groove depth * groove weld tension unit stress =
½* π * 17.5000 * 0.2820 * 12654 = **98000** lb.
Inner fillet in shear = ½* π * Nozzle OD * weld leg * inner fillet in shear unit stress = ½* π * 17.5000 * 0.3125 * 8379 = **71900** 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 = [2.7456 - 1.7787 + 2 * 0.7500 * 0.8550 * (1.00 * 0.2820 - 1.0000 * 0.1693)] * 20000 = **22200** lb.
W1-1 = (A2 + A5 + A41 + A42) * Sv = (0.8598 + 0.0000 + 0.0835 + 0.0000) * 20000 = **18900** lb.
W2-2 = (A2 + A3 + A41 + A43 + 2 tn t fr1) Sv = (0.8598 + 0.9042 + 0.0835 + 0.0835 + 2 * 0.7500 * 0.2820 * 0.8550) * 20000 = **45900** lb.
W3-3 = (A2 + A3 + A5 + A41 + A42 + A43 + 2 tn t fr1) * Sv =
(0.8598 + 0.9042 + 0.0000 + 0.0835 + 0.0000 + 0.0835 + 2 * 0.7500 * 0.2820 * 0.8550) * 20000 = **45900** lb.

Check Strength Paths

Path 1-1 = Upper fillet in shear + Nozzle wall in shear = 71900 + 236100 = **308000** lb.
Path 2-2 = Upper fillet in shear + Groove weld in tension + Inner fillet in shear =
71900 + 98000 + 71900 = **241800** lb.
Path 3-3 = Upper fillet in shear + Inner fillet in shear + Groove weld in tension = 71900 + 71900 + 98000 = **241800** lb.

Pressure Vessel Engineering, Ltd.

E - 12x16" MWY

Job No: Sample Vessel 3 Vessel Number: Horizontal Vessel
Number: 2 Mark Number: E
ID Number: E

Date Printed: 10/27/2008

Nozzle Design Information

Design Pressure:	75.00 PSI		Design Temperature:	150	°F
Static Head:	3.50 PSI		Nozzle Efficiency (E):	100	%
Nozzle Material:	SA-106 Gr B		Joint Efficiency (E_1):	1.00	
			Factor B Chart:	CS-2	
External Projection:	2.0000 in.		Allowable Stress at Design Temperature (S_n):	17100	PSI
Internal Projection:	1.0000 in.		Allowable Stress at Ambient Temperature:	17100	PSI
Inside Corrosion Allowance:	0.0000 in.		Correction Factor (F):	1.00	
External Corrosion Allowance:	0.0000 in.		Nozzle Path:	None	
Nozzle ID (new):	16.0000 in.		Nozzle Wall Thickness(new):	0.7500	in.
Nozzle ID (corroded):	16.0000 in.		Nozzle Wall Thickness(corroded):	0.7500	in.
Outer "h" Limit:	0.7050 in.		Upper Weld Leg Size(Weld 41):	0.3125	in.
Internal "h" Limit:	0.7050 in.		Internal Weld Leg Size(Weld 43):	0.3125	in.
OD, Limit of Reinforcement:	32.0000 in.		Outside Groove Weld Depth:	0.2820	in.

Minimum Design Metal Temperature

Min. Temp. Curve:	B	Pressure at MDMT:	75.00 PSI
UCS-66(b) reduction:	Yes	Minimum Design Metal Temperature:	-20 °F
UCS-68(c) reduction:	No	Computed Minimum Temperature:	-125 °F

Host Component: Head 1 - Right Side Head

Material:	SA-516 Gr 70	Head wall thickness(new):	0.3125 in.
Material Stress(S_v):	20000 PSI	Head wall thickness - thin out (corroded):	0.2820 in.

Nozzle Detail Information

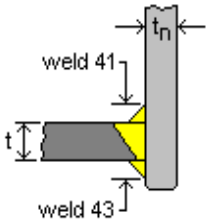

Fig. UW-16.1 (c)

Upper Weld Leg Size(Weld 41): 0.3125 in.

Internal Weld Leg Size(Weld 43): 0.3125 in.

Nozzle Wall Thickness(t_n): 0.7500 in.

Outside Groove Weld Depth: 0.2820 in.

Nozzle passes through 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 Head Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{P\ K1\ Do}{(2SE + 0.8P)} = \frac{78.50 * 0.9000 * 96.0000}{(2 * 20000 * 1 + 0.8 * 78.50)}$$ = **0.1693** in.

Nozzle Required Thickness Calculations

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

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{78.50 * 8.0000}{17100 * 1 - 0.6 * 78.50}$$ = **0.0368** in.

Strength Reduction Factors

fr1 $= \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{17100}{20000}, 1.0000\right) = 0.8550$ **fr2** $= \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{17100}{20000}, 1.0000\right) = 0.8550$

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

UG-45 Thickness Calculations

This calculation is for an access or inspection opening.

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

$$\mathbf{t} = \frac{PRn}{SE - 0.6P} + Ca + ext.\ Ca = \frac{78.50 * 8.0000}{17100 * 1.00 - 0.6 * 78.50} + 0.0000 + 0.0000$$ = **0.0368** in.

Nozzle Reinforcement Calculations

Area Required for Internal Pressure

A = d tr F + 2 tn tr F (1 - fr1) = (16.0000 * 0.1693 * 1.00) + (2 * 0.7500 * 0.1693 * 1.00 * (1 - 0.8550)) = **2.7456** sq. in.

Area Available - Internal Pressure

A1 Formula 1 = d(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
16.0000 * (1.00 * 0.2820 - 1.00 * 0.1693) - 2 * 0.7500 * (1.00 * 0.2820 - 1.00 * 0.1693) * (1 - 0.8550) = *1.7787* sq. in.

A1 Formula 2 = 2(t + tn)(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
2 * (0.2820 + 0.7500)(1.00 * 0.2820 - 1.00 * 0.1693) - 2 * 0.7500 * (1.00 * 0.2820 - 1.00 * 0.1693) * (1 - 0.8550)

= *0.2081* sq. in.

A1 = Larger value of *A1 Formula 1* and *A1 Formula 2* = **1.7787** sq. in.

A2 Formula 1 = 5(tn - trn) fr2 t = 5(0.7500 - 0.0368) * 0.8550 * 0.2820 = *0.8598* sq. in.
A2 Formula 2 = 5(tn - trn) fr2 tn = 5(0.7500 - 0.0368) * 0.8550 * 0.7500 = *2.2867* sq. in.
A2 = Smaller value of *A2 Formula 1* and *A2 Formula 2* = **0.8598** sq. in.

A3 = Smaller value of the following :
$5 * t * t_i * f_{r2}$ = 5 * 0.2820 * 0.7500 * 0.8550 = 0.9042 sq. in.
$5 * t_i * t_i * f_{r2}$ = 5 * 0.7500 * 0.7500 * 0.8550 = 2.4047 sq. in.
$2 * h * t_i * f_{r2}$ = 2 * 1.0000 * 0.7500 * 0.8550= 1.2825 sq. in.
= **0.9042** sq. in.

A41 = $(leg)^2 * fr2 = (0.3125)^2 * 0.8550$ = **0.0835** sq. in.

A43 = $(leg)^2 * fr2 = (0.3125)^2 * 0.8550$ = **0.0835** sq. in.

Area Available (Internal Pressure) = A1 + A2 + A3 + A41 + A43 = 3.7097 sq. in., which is **greater** than A (2.7456)

Nozzle Weld Strength Calculations

Attachment Weld Strength per Paragraph UW-16

Weld 41 tmin = smaller of 0.75, t, or tn = smaller of 0.75, 0.2820, or 0.7500 = **0.2820** in.

Weld 41 Leg min. = $\frac{\text{(smaller of 0.25 or (tmin * 0.7)) + ext. CA}}{0.7} = \frac{0.1974}{0.7}$ = **0.2820** in.

Weld 41, actual weld leg = **0.3125** in.

Weld 43 tmin = smaller of 0.75, t, or tn = smaller of 0.75, 0.2820, or 0.7500 = **0.2820** in.

Weld 43 Leg min. = $\frac{\text{(smaller of 0.25 or (tmin * 0.7)) + ca}}{0.7} = \frac{\text{(smaller of 0.25 or (0.2820 * 0.7)) + 0.0000}}{0.7} = \frac{0.1974}{0.7}$ = **0.2820** in.

Weld 43, actual weld leg = **0.3125** 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
Inner fillet, Weld 43, in shear = 0.49 * Material Stress = 0.49 * 17100 = **8379** PSI

Strength of Connection Elements

Nozzle wall in shear = ½* π * mean nozzle diameter * tn * Nozzle wall in shear unit stress =
½* π * 16.7500 * 0.7500 * 11970 = **236100** lb.
Upper fillet in shear = ½* π * Nozzle OD * weld leg * upper fillet in shear unit stress = ½* π * 17.5000 * 0.3125 * 8379 = **71900** lb.
Groove Weld in Tension = ½* π * Nozzle OD * groove depth * groove weld tension unit stress =
½* π * 17.5000 * 0.2820 * 12654 = **98000** lb.
Inner fillet in shear = ½* π * Nozzle OD * weld leg * inner fillet in shear unit stress = ½* π * 17.5000 * 0.3125 * 8379 = **71900** 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 = [2.7456 - 1.7787 + 2 * 0.7500 * 0.8550 * (1.00 * 0.2820 - 1.0000 * 0.1693)] * 20000 = **22200** lb.
W1-1 = (A2 + A5 + A41 + A42) * Sv = (0.8598 + 0.0000 + 0.0835 + 0.0000) * 20000 = **18900** lb.
W2-2 = (A2 + A3 + A41 + A43 + 2 tn t fr1) Sv = (0.8598 + 0.9042 + 0.0835 + 0.0835 + 2 * 0.7500 * 0.2820 * 0.8550) * 20000 = **45900** lb.
W3-3 = (A2 + A3 + A5 + A41 + A42 + A43 + 2 tn t fr1) * Sv =
(0.8598 + 0.9042 + 0.0000 + 0.0835 + 0.0000 + 0.0835 + 2 * 0.7500 * 0.2820 * 0.8550) * 20000 = **45900** lb.

Check Strength Paths

Path 1-1 = Upper fillet in shear + Nozzle wall in shear = 71900 + 236100 = **308000** lb.
Path 2-2 = Upper fillet in shear + Groove weld in tension + Inner fillet in shear =
71900 + 98000 + 71900 = **241800** lb.
Path 3-3 = Upper fillet in shear + Inner fillet in shear + Groove weld in tension = 71900 + 71900 + 98000 = **241800** lb.

Pressure Vessel Engineering, Ltd.

F - 12x16" MWY

Job No: Sample Vessel 3 Vessel Number: Horizontal Vessel
Number: 4 Mark Number: F
ID Number: F

Date Printed: 10/27/2008

Nozzle Design Information

Design Pressure:	75.00 PSI		Design Temperature:	150	°F
Static Head:	3.50 PSI		Nozzle Efficiency (E):	100	%
Nozzle Material:	SA-106 Gr B		Joint Efficiency (E_1):	1.00	
			Factor B Chart:	CS-2	
External Projection:	2.0000 in.		Allowable Stress at Design Temperature (S_n):	17100	PSI
Internal Projection:	1.0000 in.		Allowable Stress at Ambient Temperature:	17100	PSI
Inside Corrosion Allowance:	0.0000 in.		Correction Factor (F):	1.00	
External Corrosion Allowance:	0.0000 in.		Nozzle Path:	None	
Nozzle ID (new):	16.0000 in.		Nozzle Wall Thickness(new):	0.7500	in.
Nozzle ID (corroded):	16.0000 in.		Nozzle Wall Thickness(corroded):	0.7500	in.
Outer "h" Limit:	0.7813 in.		Upper Weld Leg Size(Weld 41):	0.3125	in.
Internal "h" Limit:	0.7813 in.		Internal Weld Leg Size(Weld 43):	0.3125	in.
OD, Limit of Reinforcement:	32.0000 in.		Outside Groove Weld Depth:	0.3125	in.

Minimum Design Metal Temperature

Min. Temp. Curve:	B	Pressure at MDMT:	75.00 PSI
UCS-66(b) reduction:	Yes	Minimum Design Metal Temperature:	-20 °F
UCS-68(c) reduction:	No	Computed Minimum Temperature:	-125 °F

Host Component: Shell 1 - Shell 1

Material:	SA-516 Gr 70	Shell wall thickness(new):	0.3125 in.
Material Stress(S_v):	20000 PSI	Shell wall thickness(corroded):	0.3125 in.

Nozzle Detail Information

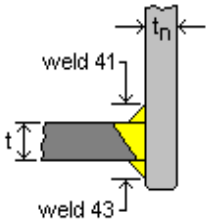

Fig. UW-16.1 (c)

Upper Weld Leg Size(Weld 41): 0.3125 in.

Internal Weld Leg Size(Weld 43): 0.3125 in.

Nozzle Wall Thickness(t_n): 0.7500 in.

Outside Groove Weld Depth: 0.3125 in.

Nozzle passes through 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 Shell Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{PRo}{SE + 0.4P} = \frac{78.50 * 48.0000}{20000 * 1 + 0.4 * 78.50}$$ = **0.1881** in.

Nozzle Required Thickness Calculations

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

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{78.50 * 8.0000}{17100 * 1 - 0.6 * 78.50}$$ = **0.0368** in.

Strength Reduction Factors

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

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

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

UG-45 Thickness Calculations

This calculation is for an access or inspection opening.

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

$$\mathbf{t} = \frac{PRn}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{78.50 * 8.0000}{17100 * 1.00 - 0.6 * 78.50} + 0.0000 + 0.0000$$ = **0.0368** in.

Nozzle Reinforcement Calculations

Area Required for Internal Pressure

A = d tr F + 2 tn tr F (1 - fr1) = (16.0000 * 0.1881 * 1.00) + (2 * 0.7500 * 0.1881 * 1.00 * (1 - 0.8550)) = **3.0505** sq. in.

Area Available - Internal Pressure

A1 Formula 1 = d(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
16.0000 * (1.00 * 0.3125 - 1.00 * 0.1881) - 2 * 0.7500 * (1.00 * 0.3125 - 1.00 * 0.1881) * (1 - 0.8550) = *1.9633* sq. in.

A1 Formula 2 = 2(t + tn)(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
2 * (0.3125 + 0.7500)(1.00 * 0.3125 - 1.00 * 0.1881) - 2 * 0.7500 * (1.00 * 0.3125 - 1.00 * 0.1881) * (1 - 0.8550)

= *0.2373* sq. in.

A1 = Larger value of *A1 Formula 1* and *A1 Formula 2* = **1.9633** sq. in.

A2 Formula 1 = 5(tn - trn) fr2 t = 5(0.7500 - 0.0368) * 0.8550 * 0.3125 = *0.9528* sq. in.
A2 Formula 2 = 5(tn - trn) fr2 tn = 5(0.7500 - 0.0368) * 0.8550 * 0.7500 = *2.2867* sq. in.
A2 = Smaller value of *A2 Formula 1* and *A2 Formula 2* = **0.9528** sq. in.

A3 = Smaller value of the following :
$5 * t * t_i * f_{r2}$ = 5 * 0.3125 * 0.7500 * 0.8550 = 1.0020 sq. in.
$5 * t_i * t_i * f_{r2}$ = 5 * 0.7500 * 0.7500 * 0.8550 = 2.4047 sq. in.
$2 * h * t_i * f_{r2}$ = 2 * 1.0000 * 0.7500 * 0.8550= 1.2825 sq. in.
= **1.0020** sq. in.

A41 = $(leg)^2 * fr2 = (0.3125)^2 * 0.8550$ = **0.0835** sq. in.

A43 = $(leg)^2 * fr2 = (0.3125)^2 * 0.8550$ = **0.0835** sq. in.

Area Available (Internal Pressure) = A1 + A2 + A3 + A41 + A43 = 4.0851 sq. in., which is **greater** than A (3.0505)

Nozzle Weld Strength Calculations

Attachment Weld Strength per Paragraph UW-16

Weld 41 tmin = smaller of 0.75, t, or tn = smaller of 0.75, 0.3125, or 0.7500 = **0.3125** in.

Weld 41 Leg min. = $\frac{\text{(smaller of 0.25 or (tmin * 0.7)) + ext. CA}}{0.7} = \frac{0.2188}{0.7}$ = **0.3125** in.

Weld 41, actual weld leg = **0.3125** in.

Weld 43 tmin = smaller of 0.75, t, or tn = smaller of 0.75, 0.3125, or 0.7500 = **0.3125** in.

Weld 43 Leg min. = $\frac{\text{(smaller of 0.25 or (tmin * 0.7)) + ca}}{0.7} = \frac{\text{(smaller of 0.25 or (0.3125 * 0.7)) + 0.0000}}{0.7} = \frac{0.2188}{0.7}$ = **0.3125** in.

Weld 43, actual weld leg = **0.3125** 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
Inner fillet, Weld 43, in shear = 0.49 * Material Stress = 0.49 * 17100 = **8379** PSI

Strength of Connection Elements

Nozzle wall in shear = ½* π * mean nozzle diameter * tn * Nozzle wall in shear unit stress =
½* π * 16.7500 * 0.7500 * 11970 = **236100** lb.
Upper fillet in shear = ½* π * Nozzle OD * weld leg * upper fillet in shear unit stress = ½* π * 17.5000 * 0.3125 * 8379 = **71900** lb.
Groove Weld in Tension = ½* π * Nozzle OD * groove depth * groove weld tension unit stress =
½* π * 17.5000 * 0.3125 * 12654 = **108600** lb.
Inner fillet in shear = ½* π * Nozzle OD * weld leg * inner fillet in shear unit stress = ½* π * 17.5000 * 0.3125 * 8379 = **71900** 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 = [3.0505 - 1.9633 + 2 * 0.7500 * 0.8550 * (1.00 * 0.3125 - 1.0000 * 0.1881)] * 20000 = **24900** lb.
W1-1 = (A2 + A5 + A41 + A42) * Sv = (0.9528 + 0.0000 + 0.0835 + 0.0000) * 20000 = **20700** lb.
W2-2 = (A2 + A3 + A41 + A43 + 2 tn t fr1) Sv = (0.9528 + 1.0020 + 0.0835 + 0.0835 + 2 * 0.7500 * 0.3125 * 0.8550) * 20000 = **50500** lb.
W3-3 = (A2 + A3 + A5 + A41 + A42 + A43 + 2 tn t fr1) * Sv =
(0.9528 + 1.0020 + 0.0000 + 0.0835 + 0.0000 + 0.0835 + 2 * 0.7500 * 0.3125 * 0.8550) * 20000 = **50500** lb.

Check Strength Paths

Path 1-1 = Upper fillet in shear + Nozzle wall in shear = 71900 + 236100 = **308000** lb.
Path 2-2 = Upper fillet in shear + Groove weld in tension + Inner fillet in shear =
71900 + 108600 + 71900 = **252400** lb.
Path 3-3 = Upper fillet in shear + Inner fillet in shear + Groove weld in tension = 71900 + 71900 + 108600 = **252400** lb.

Pressure Vessel Engineering, Ltd.

G - 1-1/2" 3000# Cplg

Job No: Sample Vessel 3
Number: 5
ID Number: G

Vessel Number: Horizontal Vessel
Mark Number: G

Date Printed: 10/27/2008

Nozzle Design Information

Design Pressure:	75.00	PSI	Design Temperature:	150	°F
Static Head:	3.50	PSI	Nozzle Efficiency (E):	100	%
Nozzle Material:	SA-105		Joint Efficiency (E_1):	1.00	
			Factor B Chart:	CS-6	
External Projection:	1.1875	in.	Allowable Stress at Design Temperature (S_n):	20000	PSI
Internal Projection:	0.0000	in.	Allowable Stress at Ambient Temperature:	20000	PSI
Inside Corrosion Allowance:	0.0000	in.	Correction Factor (F):	1.00	
External Corrosion Allowance:	0.0000	in.	Nozzle Path:	None	
Nozzle ID (new):	1.6750	in.	Nozzle Wall Thickness(new):	0.2955	in.
Nozzle ID (corroded):	1.6750	in.	Nozzle Wall Thickness(corroded):	0.2955	in.
Outer "h" Limit:	0.7388	in.	Upper Weld Leg Size(Weld 41):	0.3125	in.
Internal "h" Limit:	0.7388	in.	Internal Weld Leg Size(Weld 43):	0.0000	in.
OD, Limit of Reinforcement:	3.3500	in.	Outside Groove Weld Depth:	0.3125	in.

Minimum Design Metal Temperature

Min. Temp. Curve:	A	Pressure at MDMT:	75.00 PSI
UCS-66(b) reduction:	Yes	Minimum Design Metal Temperature:	-20 °F
UCS-68(c) reduction:	No	Computed Minimum Temperature:	-122 °F

Host Component: Shell 1 - Shell 1

Material:	SA-516 Gr 70	Shell wall thickness(new):	0.3125 in.
Material Stress(S_v):	20000 PSI	Shell wall thickness(corroded):	0.3125 in.

Nozzle Detail Information

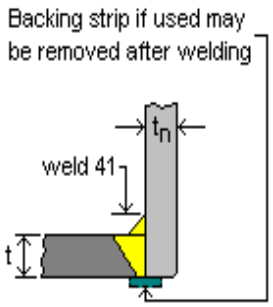

Fig. UW-16.1 (c)

Upper Weld Leg Size(Weld 41): 0.3125 in.

Nozzle Wall Thickness(t_n): 0.2955 in.

Outside Groove Weld Depth: 0.3125 in.

Nozzle passes through the vessel, attached by a groove 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.

Pressure Vessel Engineering, Ltd.

G - 1-1/2" 3000# Cplg

Job No: Sample Vessel 3 | Vessel Number: Horizontal Vessel

Number: 5 | Mark Number: G

ID Number: G

Date Printed: 10/27/2008

Required Shell Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{PRo}{SE + 0.4P} = \frac{78.50 * 48.0000}{20000 * 1 + 0.4 * 78.50}$$ = **0.1881** in.

Nozzle Required Thickness Calculations

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

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{78.50 * 0.8375}{20000 * 1 - 0.6 * 78.50}$$ = **0.0033** in.

Strength Reduction Factors

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

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

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

UG-45 Thickness Calculations

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

$$\mathbf{t} = \frac{PRn}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{78.50 * 0.8375}{20000 * 1.00 - 0.6 * 78.50} + 0.0000 + 0.0000$$ = **0.0033** in.

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

$$\mathbf{t} = \frac{PRo}{SE + 0.4P} + Ca + \text{ext. } Ca = \frac{78.50 * 48.0000}{20000 * 1 + 0.4 * 78.50} + 0.0000 + 0.0000$$ = **0.1881** 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 = **0.1347** in.

Nozzle Minimum Thickness per Paragraph UG-45(b)

t = Smallest of UG-45(b)(1) or UG-45(b)(4) = **0.1347** in.

Wall thickness = tn = **0.2955** is greater than or equal to UG-45 value of **0.1347**

Nozzle Weld Strength Calculations

Attachment Weld Strength per Paragraph UW-16

Weld 41 tmin = smaller of 0.75, t, or tn = smaller of 0.75, 0.3125, or 0.2955 = **0.2955** in.

Weld 41 Leg min. = $\frac{\text{(smaller of 0.25 or (tmin * 0.7)) + ext. CA}}{0.7} = \frac{0.2068}{0.7}$ = **0.2955** in.

Weld 41, actual weld leg = **0.3125** in.

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

Nozzle wall in shear = 0.70 * Sn = 0.70 * 20000 = **14000** PSI
Upper fillet, Weld 41, in shear = 0.49 * Material Stress = 0.49 * 20000 = **9800** PSI
Vessel groove weld, in tension = 0.74 * Material Stress = 0.74 * 20000 = **14800** PSI

Strength of Connection Elements

Nozzle wall in shear = ½ * π * mean nozzle diameter * tn * Nozzle wall in shear unit stress =
½ * π * 1.9705 * 0.2955 * 14000 = **12800** lb.
Upper fillet in shear = ½ * π * Nozzle OD * weld leg * upper fillet in shear unit stress = ½ * π * 2.2660 * 0.3125 * 9800 = **10900** lb.
Groove Weld in Tension = ½ * π * Nozzle OD * groove depth * groove weld tension unit stress =
½ * π * 2.2660 * 0.3125 * 14800 = **16500** 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 = [0.3151 - 0.2084 + 2 * 0.2955 * 1.0000 * (1.00 * 0.3125 - 1.0000 * 0.1881)] * 20000 = **3600** lb.
W1-1 = (A2 + A5 + A41 + A42) * Sv = (0.4317 + 0.0000 + 0.0977 + 0.0000) * 20000 = **10600** lb.
W2-2 = (A2 + A3 + A41 + A43 + 2 tn t fr1) Sv = (0.4317 + 0.0000 + 0.0977 + 0.0000 + 2 * 0.2955 * 0.3125 * 1.0000) * 20000 = **14300** lb.
W3-3 = (A2 + A3 + A5 + A41 + A42 + A43 + 2 tn t fr1) * Sv =
(0.4317 + 0.0000 + 0.0000 + 0.0977 + 0.0000 + 0.0000 + 2 * 0.2955 * 0.3125 * 1.0000) * 20000 = **14300** lb.

Check Strength Paths

Path 1-1 = Upper fillet in shear + Nozzle wall in shear = 10900 + 12800 = **23700** lb.
Path 2-2 = Upper fillet in shear + Groove weld in tension + Inner fillet in shear =
10900 + 16500 + 0 = **27400** lb.
Path 3-3 = Upper fillet in shear + Inner fillet in shear + Groove weld in tension = 10900 + 0 + 16500 = **27400** lb.

Saddle Design Information

Design Temperature:	150 °F		Support Type:	Type I	
Material:	SA-36 Plate		Stiffener Quantity:	5	
Condition:			Material Stress (hot):	16600	PSI
Length (d):	68.2500 in.		Material Stress (cold):	16600	PSI
Top Width (b'):	10.0000 in.		Yield Strength:	33800	PSI
Bottom Width ($b_{b'}$):	10.0000 in.		Density:	0.2830	lb/in.^3
Outside Stiffener Thickness (t_{so}):	0.5000 in.		Web Plate Thickness (t_w):	0.5000	in.
Inside Stiffener Thickness (t_{si}):	0.5000 in.		Vessel Centerline Height (h):	66.0000	in.
Saddle Angle of contact (θ):	150.0 °		Elevation above grade (g):	0.0000	in.
Dist. from saddle centerline to tang. line (A):	13.5000 in.				
Support Design Condition:	Shell stiffened by heads (A/R <= 1/2)				

Wear Plate Information

Design Temperature:	150 °F				
Material:	SA-36 Plate		Material Stress (hot):	16600	PSI
Condition:			Material Stress (cold):	16600	PSI
Extension (j_w):	10.2500 in.		Use for S2:	Yes	
Width (b_w):	12.0000 in.		Use for S3:	Yes	
Thickness (t_{wp}):	0.3750 in.		Use for S5:	Yes	

Base Plate Information

Design Temperature:	150 °F		Ultimate 28 Day Concrete Strength:	3000.00	PSI
Material:	SA-36 Plate		Yield Strength:	33800	PSI
Condition:			Length (m):	70.0000	in.
Width (b_b):	12.0000 in.		Thickness (t_b):	0.7500	in.

Anchor Bolt Information

Material:	SA-193 Gr B7 <=2.5"		Material Stress (hot):	25000	PSI
Condition:			Material Stress (cold):	25000	PSI
Size:	1"		Number of Threads per in. :	8.0000	
Quantity:	2		Root Area:	0.5510	sq. in.

ASME Flange Design Information

Host	Description	Type	Size (in.)	Material	ASME Class	Material Group	MAP (PSI)
B - 6" Pipe	ASME Flange 1	Slip-On	6	SA-105	150	1.1	272.50
C - 6" Pipe	ASME Flange 2	Slip-On	6	SA-105	150	1.1	272.50

Zick Analysis

Test Condition

Saddle Support Loads

$$Q_L = \frac{F_L h}{L - 2A} = \frac{0 * 66.0000}{123.0000 - 2 * 13.5000}$$ = **0** lb.

$$Q_T = \frac{1.5\ F_T\ h}{d} = \frac{1.5\ * 0 * 66.0000}{68.2500}$$ = **0** lb.

$$Q_W = \frac{W}{2} = \frac{45063}{2}$$ = **22532** lb.

$Q_N = Q_W = 22532$ = **22532** lb.

Saddle Load for Vessel Stress Analysis

$Q = Q_N = 22532$ = **22532** lb.

Saddle Load for Support Stress Analysis

$Q_S = Q_N = 22532$ = **22532** lb.

Zick Calculations

Longitudinal Stress Due to Internal Pressure

$$S_p = \frac{P\ R}{2\ t} = \frac{75.00\ *\ 47.8438}{2\ *\ 0.3125}$$ = **5741** PSI

Longitudinal Compressive Stress Due to External Pressure

S_{pe} = = **0** PSI

Longitudinal Bending Stress in the Shell at the Midpoint

$Z_1 = \pi\ R^2\ t = 3.1416\ *\ 47.8438^2\ *\ 0.3125$ = **2247** in.³

$$S_1 = \frac{K_1\ Q\ L}{4\ Z_1} = \frac{0.53213\ *\ 22532\ *\ 123.0000}{4\ *\ 2247}$$ = **164** PSI

Longitudinal Bending Stress in the Shell in the Plane of the Saddle

$$S_1' = \frac{K_1'\ Q\ L}{4\ Z_1} = \frac{0.04938\ *\ 22532\ *\ 123.0000}{4\ *\ 2247}$$ = **15** PSI

Saddle Plane Tangential Shear Stress

$t_e = t + t_{wp} = 0.3125 + 0.3750$ = **0.6875** in.

$$S_2 = \frac{K_2\ Q}{R\ t_e} = \frac{0.48517\ *\ 22532}{47.8438\ *\ 0.6875}$$ = **332** PSI

$$S_{2w} = \frac{K_{2w}\ Q}{R\ t} = \frac{0.38022\ *\ 22532}{47.8438\ *\ 0.3125}$$ = **573** PSI

$$S_{2H} = \frac{K_2\ Q}{R\ t_H} = \frac{0.48517\ *\ 22532}{47.8438\ *\ 0.2820}$$ = **810** PSI

Circumferential Stress at the Horn of the Saddle

$t_e^2 = t^2 + t_{wp}^2 = 0.3125^2 + 0.3750^2$ = **0.2383** sq. in.

$$S_3 = -\left[\frac{Q}{4\ t_e\ (b + 1.56\sqrt{R\ t})}\right] - \left[\frac{12\ K_3\ Q\ R}{L\ t_e^2}\right]$$

$$= -\left[\frac{22532}{4\ *\ 0.6875\ *\ (10.0000 + 1.56\ *\ \sqrt{47.8438\ *\ 0.3125})}\right] - \left[\frac{12\ *\ 0.00792\ *\ 22532\ *\ 47.8438}{123.0000\ *\ 0.2383}\right]$$

= **-4007** PSI

Circumferential Stress at End of the Wear Plate

$$S_{3w} = -\left[\frac{Q}{4\ t\ (b_w + 1.56\sqrt{R\ t})}\right] - \left[\frac{12\ K_{3w}\ Q\ R}{L\ t^2}\right]$$

$$= -\left[\frac{22532}{4\ *\ 0.3125\ *\ (12.0000 + 1.56\ *\ \sqrt{47.8438\ *\ 0.3125})}\right] - \left[\frac{12\ *\ 0.00631\ *\ 22532\ *\ 47.8438}{123.0000\ *\ 0.3125^2}\right]$$

= **-7795** PSI

Additional Stresses in Head Used as a Stiffener

$$S_4 = \frac{K_4\ Q}{R\ t_H} = \frac{0.29525\ *\ 22532}{47.8438\ *\ 0.2820}$$ = **493** PSI

Ring Compression in the Shell Over the Saddle

$\mathbf{t_e} = t + t_{wp} = 0.3125 + 0.3750$ = **0.6875** in.

$$\mathbf{S_5} = \frac{K_5\, Q}{t_e\,(b + 1.56\sqrt{R\,t})} = \frac{0.67330 * 22532}{0.6875 * (0.5000 + 1.56 * \sqrt{47.8438 * 0.3125})}$$ = **3378** PSI

Maximum Splitting Force

$\mathbf{F_S} = K_8 Q_S = 0.25937 * 22532$ = **5844** lb.

Vessel Stress Ratio Calculations

Any ratio greater than 1 represents an overstressed condition

$$\mathbf{R}_{1t} = \frac{S_1 + S_p}{S_{Shell}\, E} = \frac{164 + 5741}{20000 * 0.70} = \mathbf{0.4218}$$

$$\mathbf{R}_{1C} = \frac{-S_1}{-\,\mathrm{Min}(S_{Shell}, B_{Shell})} = \frac{-164}{-\mathrm{Min}(20000,11484)} = \mathbf{0.0143}$$

$$\mathbf{R}_{1t}' = \frac{S_1' + S_p}{S_{Shell}\, E} = \frac{15 + 5741}{20000 * 0.70} = \mathbf{0.4112}$$

$$\mathbf{R}_{1C}' = \frac{-S_1'}{-\,\mathrm{Min}(S_{Shell}, B_{Shell})} = \frac{-15}{-\mathrm{Min}(20000,11484)} = \mathbf{0.0013}$$

$$\mathbf{R}_{2} = \frac{S_2}{0.8\, S_{Shell}} = \frac{332}{0.8 * 20000} = \mathbf{0.0208}$$

$$\mathbf{R}_{2W} = \frac{S_{2W}}{0.8\, S_{Shell}} = \frac{573}{0.8 * 20000} = \mathbf{0.0358}$$

$$\mathbf{R}_{2H} = \frac{S_{2H}}{0.8\, S_{Head}} = \frac{810}{0.8 * 20000} = \mathbf{0.0506}$$

$$\mathbf{R}_{3} = \frac{S_3}{-\,(1.25\, S_{Shell})} = \frac{-4007}{-\,(1.25 * 20000)} = \mathbf{0.1603}$$

$$\mathbf{R}_{3w} = \frac{S_{3W}}{-\,(1.25\, S_{Shell})} = \frac{-7795}{-\,(1.25 * 20000)} = \mathbf{0.3118}$$

$$\mathbf{R}_{4} = \frac{S_4 + S_{pH}}{1.25\, S_{Head}} = \frac{493 + 15637}{1.25 * 20000} = \mathbf{0.6452}$$

$$\mathbf{R}_{5} = \frac{S_5}{0.5\, Y_{Shell}} = \frac{3378}{0.5 * 35700} = \mathbf{0.1892}$$

MDMT Report by Components

Design MDMT is -20 °F

Component	Material	Curve	Pressure	MDMT
Shell 1	SA-516 Gr 70	B	75.00 PSI	-20 °F
F - 12x16" MWY	SA-106 Gr B	B	75.00 PSI	-125 °F
G - 1-1/2" 3000# Cplg	SA-105	A	75.00 PSI	-122 °F
A - 3/4" 3000# Cplg	SA-105	A	75.00 PSI	-122 °F
Right Side Head	SA-516 Gr 70	B	75.00 PSI	-20 °F
E - 12x16" MWY	SA-106 Gr B	B	75.00 PSI	-125 °F
C - 6" Pipe	SA-106 Gr B	B	3.50 PSI	-155 °F
Left Side Head	SA-516 Gr 70	B	75.00 PSI	-20 °F
B - 6" Pipe	SA-106 Gr B	B	3.50 PSI	-155 °F
D - 12x16" MWY	SA-106 Gr B	B	75.00 PSI	-125 °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.

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	75.00 PSI	3.50 PSI	87.88 PSI	91.38 PSI	87.88 PSI
F - 12x16" MWY	75.00 PSI	3.50 PSI	88.39 PSI	91.89 PSI	88.39 PSI
G - 1-1/2" 3000# Cplg	75.00 PSI	3.50 PSI	127.06 PSI	130.56 PSI	127.06 PSI
A - 3/4" 3000# Cplg	75.00 PSI	3.50 PSI	127.06 PSI	130.56 PSI	127.06 PSI
Right Side Head	75.00 PSI	3.50 PSI	87.81 PSI	91.31 PSI	87.81 PSI
E - 12x16" MWY	75.00 PSI	3.50 PSI	88.86 PSI	92.36 PSI	88.86 PSI
C - 6" Pipe	75.00 PSI	3.50 PSI	87.81 PSI	91.31 PSI	87.81 PSI
ASME Flange Class: 150 Gr:1.1		3.50 PSI	281.50 PSI	272.50 PSI	269.00 PSI
Left Side Head	75.00 PSI	3.50 PSI	88.86 PSI	92.36 PSI	88.86 PSI
B - 6" Pipe	75.00 PSI	3.50 PSI	97.69 PSI	101.19 PSI	97.69 PSI
ASME Flange Class: 150 Gr:1.1		3.50 PSI	281.50 PSI	272.50 PSI	269.00 PSI
D - 12x16" MWY	75.00 PSI	3.50 PSI	88.86 PSI	92.36 PSI	88.86 PSI

NC = Not Calculated Inc = Incomplete

Summary

Component with the lowest vessel MAWP(New & Cold) : **Right Side Head**
The lowest vessel MAWP(New & Cold) : **87.81** PSI

Component with the lowest vessel MAWP(Hot & Corroded) : **Right Side Head**
The lowest vessel MAWP(Hot & Corroded) : **87.81** PSI

Pressures are exclusive of any external loads.

Flange pressures listed here do not consider external loadings

Summary Information

	Dry Weight	Flooded Weight
Shell	3190.24 lb.	34198.36 lb.
Head	1844.99 lb.	10820.08 lb.
Nozzle	141.78 lb.	141.78 lb.
ASME Flange	38.00 lb.	38.00 lb.
Totals	5215.01 lb.	45198.23 lb.

	Volume
Shell	3711.74 Gal.
Head	1076.15 Gal.
Nozzle	7.47 Gal.
Totals	4795.36 Gal.

	Area
Shell	251.33 Sq. Ft.
Head	144.88 Sq. Ft.
Nozzle	14.58 Sq. Ft.
Totals	410.78 Sq. Ft.

Hydrostatic Test Information Par. UG-99(b)

Gauge at Top

Calculated Test Pressure: **97.50 PSI**

This calculation assumes one chamber.

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

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