PAGET EQUIPMENT CO.

417 EAST 29TH STREET   MARSHFIELD, WI 54449

Date Printed: 2/27/2006

Vessel designed per the ASME Boiler & Pressure Vessel Code,
Section VIII, Division 1,2004 Edition, 2005 Addenda
with Advanced Pressure Vessel, Version: 9.1.1
Vessel is ASME Code Stamped

Job No: Example Vessels
Vessel Number: Fixed Tube

NAMEPLATE INFORMATION

Shell MAWP:	200.00 PSI and Full Vacuum at 650 °F
Channel MAWP:	150.00 PSI at 350 °F
MDMT:	-20 °F at 200.00 PSI
Serial Number(s):	____________________________________
National Board Number(s):	____________________________________
Year Built:	2004
Radiography:	RT 1-S, RT 1-T
Postweld Heat Treated:	NONE-S, NONE-T

Signatures

Designed by:____ Date: ____/____/____

Jason Diercks

Cylindrical Shell Design Information

Design Pressure:	200.00	PSI	Design Temperature:	650	°F
Static Head:	0.00	PSI	Joint Efficiency:	100	%
Shell Material:	SA-516 Gr 70		Factor B Chart:	CS-2	
			Material Stress (hot):	18800	PSI
Shell Length:	250.0000	in.	Material Stress (cold):	20000	PSI
Corrosion Allowance:	0.0625	in.	Actual Circumferential Stress:	16970	PSI
External Corrosion Allowance:	0.0000	in.	Actual Longitudinal Stress:	8385	PSI
Inside Diameter (new):	42.0000	in.			
Inside Diameter (corroded):	42.1250	in.	Specific Gravity:	1.00	
Shell Surface Area:	232.48	Sq. Ft.	Weight of Fluid:	12527.48	lb.
Shell Estimated Volume:	1499.57	Gal.	Total Flooded Shell Weight:	15466.45	lb.
			Shell Weight:	2938.97	lb.

Minimum Design Metal Temperature Data

Min. Temperature Curve:	B	Pressure at MDMT:	200.00	PSI
UCS-66(b) reduction:	Yes	Minimum Design Metal Temperature:	-20	°F
UCS-68(c) reduction:	No	Computed Minimum Temperature:	-35	°F

External Pressure Data

Design Pressure (Pa):	15.00	PSI	Design Temperature:	650	°F
Dimension L:	125.0000	in.			
Ext. Minimum t:	0.2783	in.	Ext. Nominal t:	0.3125	in.
Minimum L/Do:	2.9326		Nominal L/Do:	2.9326	
Minimum Do/t:	197.5210		Nominal Do/t:	170.5000	
Minimum Factor A:	0.0001770		Nominal Factor A:	0.0002268	
Minimum Factor B:	2224	PSI	Nominal Factor B:	2849	PSI

Design Thickness Calculations

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

$$\mathbf{t} = \frac{PR}{2SE + 0.4P} = \frac{200.00 * 21.0625}{2 * 18800 * 1.00 + 0.4 * 200.00} = 0.1118 + 0.0625 \text{ (corrosion)} + 0.0000 \text{ (ext. corrosion)}$$

= minimum of **0.1743** in.

Circumferential Stress Calculations per UG-27(c)(1)

$$\mathbf{t} = \frac{PR}{SE - 0.6P} = \frac{200.00 * 21.0625}{18800 * 1.00 - 0.6 * 200.00} = 0.2255 + 0.0625 \text{ (corrosion)} + 0.0000 \text{ (ext. corrosion)}$$

= minimum of **0.2880** in.

Maximum External Pressure Calculation per Paragraph UG-28

$$\mathbf{Pa} \text{ (using } nominal\ t) = \frac{4B}{3(D_o / t)} = \frac{4 * 2849}{3 * (42.6250 / 0.2500)}$$

= maximum external pressure of **22.28** PSI

Extreme Fiber Elongation Calculation per Paragraph UCS-79

$$\mathbf{Elongation} = \frac{50t}{Rf} = \frac{50 * 0.3125}{21.1563}$$

= elongation of **0.74** %

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

Nozzle Design Information

Design Pressure:	200.00 PSI		Design Temperature:	650	°F
Static Head:	0.00 PSI		Nozzle Efficiency (E):	100	%
Nozzle Material:	SA-106 Gr B		Joint Efficiency (E_1):	1.00	
			Factor B Chart:	CS-2	
External Projection:	6.0000	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.	Passes through a Category A Joint:	No	
Nozzle Pipe Size:	5		Nozzle Pipe Schedule:	80	
Nozzle ID (new):	4.8130	in.	Nozzle Wall Thickness(new):	0.3750	in.
Nozzle ID (corroded):	4.9380	in.	Nozzle Wall Thickness(corroded):	0.3125	in.
Outer "h" Limit:	0.6250	in.	Upper Weld Leg Size(Weld 41):	0.2500	in.
Internal "h" Limit:	0.6250	in.	Internal Weld Leg Size(Weld 43):	0.0000	in.
OD, Limit of Reinforcement:	9.8760	in.	Outside Groove Weld Depth:	0.3125	in.

Minimum Design Metal Temperature

Min. Temp. Curve:	B	Pressure at MDMT:	0.00	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):	18800	PSI
			Allowable Stress at Ambient Temperature:	20000	PSI
Reinforcing Plate Thickness(t_e):	0.2500	in.	Repad to Vessel Weld Leg Size(Weld 42):	0.1786	in.
OD, Reinforcing Plate(D_p):	8.0000	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):	0.3125	in.
Material Stress(S_v):	18800 PSI	Shell wall thickness(corroded):	0.2500	in.

Nozzle Detail Information

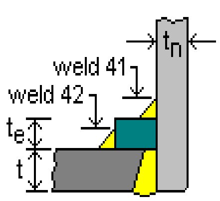


Fig. UW-16.1 (d)

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

Nozzle Wall Thickness(t_n): 0.3750 in.

Outside Groove Weld Depth: 0.3125 in.

Repad to Vessel Weld Leg Size(Weld 42): 0.1786 in.

Repad Thickness(t_e): 0.2500 in.

Nozzle passes through the vessel, attached by a groove weld.
Pipe Size: 5 Schedule: 80
Nozzle is adequate for UG-45 requirements.
Opening is adequately reinforced for Internal Pressure.
Opening is adequately reinforced for External Pressure.
Weld Strength Paths are adequate.

Required Shell Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{PR}{SE - 0.6P} = \frac{200.00 * 21.0625}{18800 * 1 - 0.6 * 200.00} = \mathbf{0.2255} \text{ in.}$$

Nozzle Required Thickness Calculations

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

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{200.00 * 2.4690}{17100 * 1 - 0.6 * 200.00} = \mathbf{0.0291} \text{ in.}$$

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

$$\mathbf{trn} = \frac{3 * Do * Pa}{4B} = \frac{3 * 5.5630 * 15.00}{4 * 3283} = \mathbf{0.0193} \text{ in.}$$

Strength Reduction Factors

$$\mathbf{fr1} = \frac{Sn}{Sv} = \frac{17100}{18800} = 0.9096 \qquad \mathbf{fr2} = \frac{Sn}{Sv} = \frac{17100}{18800} = 0.9096$$

$$\mathbf{fr3} = \frac{Sn}{Sv} = \frac{17100}{18800} = 0.9096 \qquad \mathbf{fr4} = \frac{Sp}{Sv} = \frac{18800}{18800} = 1.0000$$

UG-45 Thickness Calculations

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

$$\mathbf{t} = \frac{PRn}{SE - 0.6P} + Ca + ext.\ Ca = \frac{200.00 * 2.4690}{17100 * 1.00 - 0.6 * 200.00} + 0.0625 + 0.0000 = \mathbf{0.0916} \text{ in.}$$

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

$$\mathbf{t} = \frac{PR}{SE - 0.6P} + Ca + ext.\ Ca = \frac{200.00 * 21.0625}{18800 * 1 - 0.6 * 200.00} + 0.0625 + 0.0000 = \mathbf{0.2880} \text{ in.}$$

Nozzle Thickness for External Pressure (plus corrosion) per Paragraph UG-45(b)(2)

$$\mathbf{t} = \frac{PR}{SE - 0.6P} + Ca + ext.\ Ca = \frac{15.00 * 21.0625}{18800 * 1 - 0.6 * 15.00} + 0.0625 + 0.0000 = \mathbf{0.1250} \text{ in.}$$

Minimum Thickness for Internal and External Pressure per Paragraph UG-45(b)(3)

t = Greater of the thicknesses determined by UG-45(b)(1) or UG-45(b)(2) = **0.2880** 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 = **0.2882** in.

Nozzle Minimum Thickness per Paragraph UG-45(b)

t = Smallest of UG-45(b)(3) or UG-45(b)(4) = **0.2880** in.

Wall thickness = tn * 0.875(pipe) = **0.3281** is greater than or equal to UG-45 value of **0.2880**

Nozzle Reinforcement Calculations

Area Required for Internal Pressure

A = d tr F + 2 tn tr F (1 - fr1) = (4.9380 * 0.2255 * 1.00) + (2 * 0.3125 * 0.2255 * 1.00 * (1 - 0.9096)) = **1.1263** sq. in.

Area Available - Internal Pressure

A1 Formula 1 = d(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
4.9380 * (1.00 * 0.2500 - 1.00 * 0.2255) - 2 * 0.3125 * (1.00 * 0.2500 - 1.00 * 0.2255) * (1 - 0.9096) = *0.1196* sq. in.

A1 Formula 2 = 2(t + tn)(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
2 * (0.2500 + 0.3125)(1.00 * 0.2500 - 1.00 * 0.2255) - 2 * 0.3125 * (1.00 * 0.2500 - 1.00 * 0.2255) * (1 - 0.9096)
= *0.0262* sq. in.

A1 = Larger value of *A1 Formula 1* and *A1 Formula 2* = **0.1196** sq. in.

A2 Formula 1 = 5(tn - trn) fr2 t = 5(0.3125 - 0.0291) * 0.9096 * 0.2500 = *0.3222* sq. in.
A2 Formula 2 = 2(tn - trn) fr2 (2.5 tn + te) = 2(0.3125 - 0.0291) * 0.9096 * (2.5 * 0.3125 + 0.2500) = *0.5317* sq. in.
A2 = Smaller value of *A2 Formula 1* and *A2 Formula 2* = **0.3222** sq. in.

A3 = Smaller value of the following :
$5 * t * t_i * f_{r2}$ = 5 * 0.2500 * 0.2500 * 0.9096 = 0.2842 sq. in.
$5 * t_i * t_i * f_{r2}$ = 5 * 0.2500 * 0.2500 * 0.9096 = 0.2842 sq. in.
$2 * h * t_i * f_{r2}$ = 2 * 0.0000 * 0.2500 * 0.9096= 0.0000 sq. in.
= **0.0000** sq. in.

A41 = (leg)Š * fr3 = (0.2500)Š * 0.9096 = **0.0568** sq. in.

A42 = (leg)Š * fr4 = (0.1786)Š * 1.0000 = **0.0319** sq. in.

A43 = (leg)Š * fr2 = 0 * 0.9096 = **0.0000** sq. in.

A5 = (Dp - d - 2tn) te fr4 = (8.0000 - 4.9380 - 2 * 0.3125) * 0.2500 * 1.0000 = **0.6093** sq. in.

Area Available (Internal Pressure) = A1 + A2 + A3 + A41 + A42 + A43 + A5 = 1.1398 sq. in., which is **greater** than A (1.1263)

Nozzle Reinforcement Calculations

Area Required for External Pressure

A = • * (d tr F + 2 tn tr F (1 - fr1)) = • * ((4.9380 * 0.2158 * 1.0) + (2 * 0.3125 * 0.2158 * 1.0 * (1 - 0.9096))) = **0.5389** sq. in.

Area Available - External Pressure

A1 Formula 1 = d(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
4.9380 * (1.00 * 0.2500 - 1.00 * 0.2158) - 2 * 0.3125 * (1.00 * 0.2500 - 1.00 * 0.2158) * (1 - 0.9096) = *0.1669* sq. in.
A1 Formula 2 = 2(t + tn)(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
2 * (0.2500 + 0.3125)(1.00 * 0.2500 - 1.00 * 0.2158) - 2 * 0.3125 * (1.00 * 0.2500 - 1.00 * 0.2158) * (1 - 0.9096)
= *0.0365* sq. in.
A1 = Larger value of *A1 Formula 1* and *A1 Formula 2* = **0.1669** sq. in.

A2 Formula 1 = 5(tn - trn) fr2 t = 5(0.3125 - 0.0193) * 0.9096 * 0.2500 = *0.3334* sq. in.
A2 Formula 2 = 2(tn - trn) fr2 (2.5 tn + te) = 2(0.3125 - 0.0193) * 0.9096 * (2.5 * 0.3125 + 0.2500) = *0.5500* sq. in.
A2 = Smaller value of *A2 Formula 1* and *A2 Formula 2* = **0.3334** sq. in.

A3 = Smaller value of the following :
$5 * t * t_i * f_{r2}$ = 5 * 0.2500 * 0.2500 * 0.9096 = 0.2842 sq. in.
$5 * t_i * t_i * f_{r2}$ = 5 * 0.2500 * 0.2500 * 0.9096 = 0.2842 sq. in.
$2 * h * t_i * f_{r2}$ = 2 * 0.0000 * 0.2500 * 0.9096= 0.0000 sq. in.
= **0.0000** sq. in.

A41 = (leg)Š * fr3 = (0.2500)Š * 0.9096 = **0.0568** sq. in.

A42 = (leg)Š * fr4 = (0.1786)Š * 1.0000 = **0.0319** sq. in.

A43 = (leg)Š * fr2 = 0 * 0.9096 = **0.0000** sq. in.

A5 = (Dp - d - 2tn) te fr4 = (8.0000 - 4.9380 - 2 * 0.3125) * 0.2500 * 1.0000 = **0.6093** sq. in.

Area Available (External Pressure) = A1 + A2 + A3 + A41 + A42 + A43 + A5 = 1.1983 sq. in., which is **greater** than A (0.5389)

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, 0.2500, or 0.3125 = **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, 0.2500, or 0.2500 = **0.2500** in.

Weld 42 Leg min. = $\frac{\text{0.5 * tmin + ext. CA}}{0.7} = \frac{0.5 * 0.2500 + 0.0000}{0.7}$ = **0.1786** in.

Weld 42, actual weld leg = **0.1786** 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 * 18800 = **9212** PSI
Repad groove weld, in tension = 0.74 * Material Stress = 0.74 * 17100 = **12654** PSI

Strength of Connection Elements

Nozzle wall in shear = • * m * mean nozzle diameter * tn * Nozzle wall in shear unit stress =
• * m * 5.2505 * 0.3125 * 11970 = **30800** lb.
Upper fillet in shear = • * m * Nozzle OD * weld leg * upper fillet in shear unit stress= • * m * 5.5630 * 0.2500 * 8379 = **18300** lb.
Groove Weld in Tension = • * m * Nozzle OD * groove depth * groove weld tension unit stress =
• * m * 5.5630 * 0.2500 * 12654 = **27600** lb.
Outer fillet in shear = • * m * Plate OD * weld leg * outer fillet in shear unit stress= • * m * 8.0000 * 0.1786 * 9212 = **20700** lb.
Repad groove weld = • * m * Nozzle OD * Groove Depth * repad groove weld in tension unit stress =
• * m * 5.5630 * 0.2500 * 12654 = **27600** 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 = [1.1263 - 0.1196 + 2 * 0.3125 * 0.9096 * (1.00 * 0.2500 - 1.0000 * 0.2255)] * 18800 = **19200** lb.
W1-1 = (A2 + A5 + A41 + A42) * Sv = (0.3222 + 0.6093 + 0.0568 + 0.0319) * 18800 = **19200** lb.
W2-2 = (A2 + A3 + A41 + A43 + 2 tn t fr1) Sv = (0.3222 + 0.0000 + 0.0568 + 0.0000 + 2 * 0.3125 * 0.2500 * 0.9096) * 18800 = **9800** lb.
W3-3 = (A2 + A3 + A5 + A41 + A42 + A43 + 2 tn t fr1) * Sv =
(0.3222 + 0.0000 + 0.6093 + 0.0568 + 0.0319 + 0.0000 + 2 * 0.3125 * 0.2500 * 0.9096) * 18800 = **21900** lb.

Check Strength Paths

Path 1-1 = Outer fillet in shear + Nozzle wall in shear = 20700 + 30800 = **51500** lb.
Path 2-2 = Upper fillet in shear + Repad groove weld + Groove weld in tension + Inner fillet in shear =
18300 + 27600 + 27600 + 0 = **73500** lb.
Path 3-3 = Outer fillet in shear + Inner fillet in shear + Groove weld in tension = 20700 + 0 + 27600 = **48300** lb.

Plate Strength = A5 * Sp = 0.6093 * 18800 = **11455** lb.

Outer fillet weld strength(20700) is greater than plate strength(11455).

Nozzle Design Information

Design Pressure:	200.00 PSI		Design Temperature:	650	°F
Static Head:	0.00 PSI		Nozzle Efficiency (E):	100	%
Nozzle Material:	SA-106 Gr B		Joint Efficiency (E_1):	1.00	
			Factor B Chart:	CS-2	
External Projection:	6.0000	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.	Passes through a Category A Joint:	No	
Nozzle Pipe Size:	5		Nozzle Pipe Schedule:	80	
Nozzle ID (new):	4.8130	in.	Nozzle Wall Thickness(new):	0.3750	in.
Nozzle ID (corroded):	4.9380	in.	Nozzle Wall Thickness(corroded):	0.3125	in.
Outer "h" Limit:	0.6250	in.	Upper Weld Leg Size(Weld 41):	0.2500	in.
Internal "h" Limit:	0.6250	in.	Internal Weld Leg Size(Weld 43):	0.0000	in.
OD, Limit of Reinforcement:	9.8760	in.	Outside Groove Weld Depth:	0.3125	in.

Minimum Design Metal Temperature

Min. Temp. Curve:	B	Pressure at MDMT:	0.00	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):	18800	PSI
			Allowable Stress at Ambient Temperature:	20000	PSI
Reinforcing Plate Thickness(t_e):	0.2500	in.	Repad to Vessel Weld Leg Size(Weld 42):	0.1786	in.
OD, Reinforcing Plate(D_p):	8.0000	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):	0.3125	in.
Material Stress(S_v):	18800	PSI	Shell wall thickness(corroded):	0.2500	in.

Nozzle Detail Information

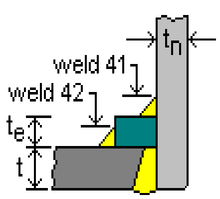


Fig. UW-16.1 (d)

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

Nozzle Wall Thickness(t_n): 0.3750 in.

Outside Groove Weld Depth: 0.3125 in.

Repad to Vessel Weld Leg Size(Weld 42): 0.1786 in.

Repad Thickness(t_e): 0.2500 in.

Nozzle passes through the vessel, attached by a groove weld.
Pipe Size: 5 Schedule: 80
Nozzle is adequate for UG-45 requirements.
Opening is adequately reinforced for Internal Pressure.
Opening is adequately reinforced for External Pressure.
Weld Strength Paths are adequate.

Required Shell Thickness per Paragraph UG-37(a)

$$\textbf{tr} = \frac{PR}{SE - 0.6P} = \frac{200.00 * 21.0625}{18800 * 1 - 0.6 * 200.00} = \textbf{0.2255} \text{ in.}$$

Nozzle Required Thickness Calculations

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

$$\textbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{200.00 * 2.4690}{17100 * 1 - 0.6 * 200.00} = \textbf{0.0291} \text{ in.}$$

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

$$\textbf{trn} = \frac{3 * Do * Pa}{4B} = \frac{3 * 5.5630 * 15.00}{4 * 3283} = \textbf{0.0193} \text{ in.}$$

Strength Reduction Factors

$$\textbf{fr1} = \frac{Sn}{Sv} = \frac{17100}{18800} = 0.9096 \qquad \textbf{fr2} = \frac{Sn}{Sv} = \frac{17100}{18800} = 0.9096$$

$$\textbf{fr3} = \frac{Sn}{Sv} = \frac{17100}{18800} = 0.9096 \qquad \textbf{fr4} = \frac{Sp}{Sv} = \frac{18800}{18800} = 1.0000$$

UG-45 Thickness Calculations

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

$$\textbf{t} = \frac{PRn}{SE - 0.6P} + Ca + ext.\ Ca = \frac{200.00 * 2.4690}{17100 * 1.00 - 0.6 * 200.00} + 0.0625 + 0.0000 = \textbf{0.0916} \text{ in.}$$

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

$$\textbf{t} = \frac{PR}{SE - 0.6P} + Ca + ext.\ Ca = \frac{200.00 * 21.0625}{18800 * 1 - 0.6 * 200.00} + 0.0625 + 0.0000 = \textbf{0.2880} \text{ in.}$$

Nozzle Thickness for External Pressure (plus corrosion) per Paragraph UG-45(b)(2)

$$\textbf{t} = \frac{PR}{SE - 0.6P} + Ca + ext.\ Ca = \frac{15.00 * 21.0625}{18800 * 1 - 0.6 * 15.00} + 0.0625 + 0.0000 = \textbf{0.1250} \text{ in.}$$

Minimum Thickness for Internal and External Pressure per Paragraph UG-45(b)(3)

t = Greater of the thicknesses determined by UG-45(b)(1) or UG-45(b)(2) = **0.2880** 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 = **0.2882** in.

Nozzle Minimum Thickness per Paragraph UG-45(b)

t = Smallest of UG-45(b)(3) or UG-45(b)(4) = **0.2880** in.

Wall thickness = tn * 0.875(pipe) = **0.3281** is greater than or equal to UG-45 value of **0.2880**

Nozzle Reinforcement Calculations

Area Required for Internal Pressure

A = d tr F + 2 tn tr F (1 - fr1) = (4.9380 * 0.2255 * 1.00) + (2 * 0.3125 * 0.2255 * 1.00 * (1 - 0.9096)) = **1.1263** sq. in.

Area Available - Internal Pressure

A1 Formula 1 = d(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
4.9380 * (1.00 * 0.2500 - 1.00 * 0.2255) - 2 * 0.3125 * (1.00 * 0.2500 - 1.00 * 0.2255) * (1 - 0.9096) = *0.1196* sq. in.

A1 Formula 2 = 2(t + tn)(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
2 * (0.2500 + 0.3125)(1.00 * 0.2500 - 1.00 * 0.2255) - 2 * 0.3125 * (1.00 * 0.2500 - 1.00 * 0.2255) * (1 - 0.9096)
= *0.0262* sq. in.

A1 = Larger value of *A1 Formula 1* and *A1 Formula 2* = **0.1196** sq. in.

A2 Formula 1 = 5(tn - trn) fr2 t = 5(0.3125 - 0.0291) * 0.9096 * 0.2500 = *0.3222* sq. in.
A2 Formula 2 = 2(tn - trn) fr2 (2.5 tn + te) = 2(0.3125 - 0.0291) * 0.9096 * (2.5 * 0.3125 + 0.2500) = *0.5317* sq. in.
A2 = Smaller value of *A2 Formula 1* and *A2 Formula 2* = **0.3222** sq. in.

A3 = Smaller value of the following :
$5 * t * t_i * f_{r2}$ = 5 * 0.2500 * 0.2500 * 0.9096 = 0.2842 sq. in.
$5 * t_i * t_i * f_{r2}$ = 5 * 0.2500 * 0.2500 * 0.9096 = 0.2842 sq. in.
$2 * h * t_i * f_{r2}$ = 2 * 0.0000 * 0.2500 * 0.9096= 0.0000 sq. in.
= **0.0000** sq. in.

A41 = (leg)Š * fr3 = (0.2500)Š * 0.9096 = **0.0568** sq. in.

A42 = (leg)Š * fr4 = (0.1786)Š * 1.0000 = **0.0319** sq. in.

A43 = (leg)Š * fr2 = 0 * 0.9096 = **0.0000** sq. in.

A5 = (Dp - d - 2tn) te fr4 = (8.0000 - 4.9380 - 2 * 0.3125) * 0.2500 * 1.0000 = **0.6093** sq. in.

Area Available (Internal Pressure) = A1 + A2 + A3 + A41 + A42 + A43 + A5 = 1.1398 sq. in., which is **greater** than A (1.1263)

Nozzle Reinforcement Calculations

Area Required for External Pressure

A = • * (d tr F + 2 tn tr F (1 - fr1)) = • * ((4.9380 * 0.2158 * 1.0) + (2 * 0.3125 * 0.2158 * 1.0 * (1 - 0.9096))) = **0.5389** sq. in.

Area Available - External Pressure

A1 Formula 1 = d(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
4.9380 * (1.00 * 0.2500 - 1.00 * 0.2158) - 2 * 0.3125 * (1.00 * 0.2500 - 1.00 * 0.2158) * (1 - 0.9096) = *0.1669* sq. in.

A1 Formula 2 = 2(t + tn)(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
2 * (0.2500 + 0.3125)(1.00 * 0.2500 - 1.00 * 0.2158) - 2 * 0.3125 * (1.00 * 0.2500 - 1.00 * 0.2158) * (1 - 0.9096)
= *0.0365* sq. in.

A1 = Larger value of *A1 Formula 1* and *A1 Formula 2* = **0.1669** sq. in.

A2 Formula 1 = 5(tn - trn) fr2 t = 5(0.3125 - 0.0193) * 0.9096 * 0.2500 = *0.3334* sq. in.
A2 Formula 2 = 2(tn - trn) fr2 (2.5 tn + te) = 2(0.3125 - 0.0193) * 0.9096 * (2.5 * 0.3125 + 0.2500) = *0.5500* sq. in.
A2 = Smaller value of *A2 Formula 1* and *A2 Formula 2* = **0.3334** sq. in.

A3 = Smaller value of the following :
$5 * t * t_i * f_{r2}$ = 5 * 0.2500 * 0.2500 * 0.9096 = 0.2842 sq. in.
$5 * t_i * t_i * f_{r2}$ = 5 * 0.2500 * 0.2500 * 0.9096 = 0.2842 sq. in.
$2 * h * t_i * f_{r2}$ = 2 * 0.0000 * 0.2500 * 0.9096= 0.0000 sq. in.
= **0.0000** sq. in.

A41 = (leg)Š * fr3 = (0.2500)Š * 0.9096 = **0.0568** sq. in.

A42 = (leg)Š * fr4 = (0.1786)Š * 1.0000 = **0.0319** sq. in.

A43 = (leg)Š * fr2 = 0 * 0.9096 = **0.0000** sq. in.

A5 = (Dp - d - 2tn) te fr4 = (8.0000 - 4.9380 - 2 * 0.3125) * 0.2500 * 1.0000 = **0.6093** sq. in.

Area Available (External Pressure) = A1 + A2 + A3 + A41 + A42 + A43 + A5 = 1.1983 sq. in., which is **greater** than A (0.5389)

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, 0.2500, or 0.3125 = **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, 0.2500, or 0.2500 = **0.2500** in.

Weld 42 Leg min. = $\frac{\text{0.5 * tmin + ext. CA}}{0.7} = \frac{0.5 * 0.2500 + 0.0000}{0.7}$ = **0.1786** in.

Weld 42, actual weld leg = **0.1786** 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 * 18800 = **9212** PSI

Repad groove weld, in tension = 0.74 * Material Stress = 0.74 * 17100 = **12654** PSI

Strength of Connection Elements

Nozzle wall in shear = • * m * mean nozzle diameter * tn * Nozzle wall in shear unit stress =
• * m * 5.2505 * 0.3125 * 11970 = **30800** lb.

Upper fillet in shear = • * m * Nozzle OD * weld leg * upper fillet in shear unit stress= • * m * 5.5630 * 0.2500 * 8379 = **18300** lb.

Groove Weld in Tension = • * m * Nozzle OD * groove depth * groove weld tension unit stress =
• * m * 5.5630 * 0.2500 * 12654 = **27600** lb.

Outer fillet in shear = • * m * Plate OD * weld leg * outer fillet in shear unit stress= • * m * 8.0000 * 0.1786 * 9212 = **20700** lb.

Repad groove weld = • * m * Nozzle OD * Groove Depth * repad groove weld in tension unit stress =
• * m * 5.5630 * 0.2500 * 12654 = **27600** 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 = [1.1263 - 0.1196 + 2 * 0.3125 * 0.9096 * (1.00 * 0.2500 - 1.0000 * 0.2255)] * 18800 = **19200** lb.

W1-1 = (A2 + A5 + A41 + A42) * Sv = (0.3222 + 0.6093 + 0.0568 + 0.0319) * 18800 = **19200** lb.

W2-2 = (A2 + A3 + A41 + A43 + 2 tn t fr1) Sv = (0.3222 + 0.0000 + 0.0568 + 0.0000 + 2 * 0.3125 * 0.2500 * 0.9096) * 18800 = **9800** lb.

W3-3 = (A2 + A3 + A5 + A41 + A42 + A43 + 2 tn t fr1) * Sv =
(0.3222 + 0.0000 + 0.6093 + 0.0568 + 0.0319 + 0.0000 + 2 * 0.3125 * 0.2500 * 0.9096) * 18800 = **21900** lb.

Check Strength Paths

Path 1-1 = Outer fillet in shear + Nozzle wall in shear = 20700 + 30800 = **51500** lb.

Path 2-2 = Upper fillet in shear + Repad groove weld + Groove weld in tension + Inner fillet in shear =
18300 + 27600 + 27600 + 0 = **73500** lb.

Path 3-3 = Outer fillet in shear + Inner fillet in shear + Groove weld in tension = 20700 + 0 + 27600 = **48300** lb.

Plate Strength = A5 * Sp = 0.6093 * 18800 = **11455** lb.

Outer fillet weld strength(20700) is greater than plate strength(11455).

Nozzle Design Information

Design Pressure:	150.00	PSI	Design Temperature:	350	°F
Static Head:	0.00	PSI	Nozzle Efficiency (E):	100	%
Nozzle Material:	SA-106 Gr B		Joint Efficiency (E_1):	1.00	
			Factor B Chart:	CS-2	
External Projection:	6.0000	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.	Passes through a Category A Joint:	No	
Nozzle Pipe Size:	3.5		Nozzle Pipe Schedule:	80	
Nozzle ID (new):	3.3640	in.	Nozzle Wall Thickness(new):	0.3180	in.
Nozzle ID (corroded):	3.4890	in.	Nozzle Wall Thickness(corroded):	0.2555	in.
Outer "h" Limit:	0.4688	in.	Upper Weld Leg Size(Weld 41):	0.1875	in.
Internal "h" Limit:	0.4688	in.	Internal Weld Leg Size(Weld 43):	0.0000	in.
OD, Limit of Reinforcement:	6.9780	in.	Outside Groove Weld Depth:	0.2500	in.

Minimum Design Metal Temperature

Min. Temp. Curve:	B	Pressure at MDMT:	0.00	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):	0.1875	in.	Repad to Vessel Weld Leg Size(Weld 42):	0.1339	in.
OD, Reinforcing Plate(D_p):	6.0000	in.	Repad to Nozzle Groove Weld Depth:	0.1875	in.

Host Component: 2 - Left Channel Shell

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

Nozzle Detail Information

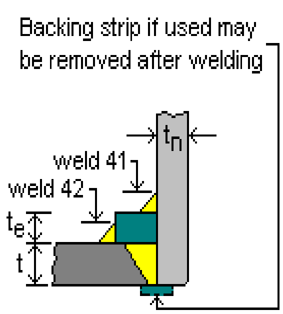


Fig. UW-16.1 (c)

Upper Weld Leg Size(Weld 41): 0.1875 in.

Nozzle Wall Thickness(t_n): 0.3180 in.

Outside Groove Weld Depth: 0.2500 in.

Repad to Vessel Weld Leg Size(Weld 42): 0.1339 in.

Repad Thickness(t_e): 0.1875 in.

Nozzle passes through the vessel, attached by a groove weld.
Pipe Size: 3.5 Schedule: 80
Nozzle is adequate for UG-45 requirements.
Opening is adequately reinforced for Internal Pressure.
Opening is adequately reinforced for External Pressure.
Reinforcement calculations are not required per UG-36(c)(3)(a)See Uw-14 for exceptions.
Weld Strength Paths are adequate.

Required Channel Thickness per Paragraph UG-37(a)

$$\textbf{tr} = \frac{PR}{SE - 0.6P} = \frac{150.00 * 21.0625}{20000 * 1 - 0.6 * 150.00}$$ = **0.1587** in.

Nozzle Required Thickness Calculations

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

$$\textbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{150.00 * 1.7445}{17100 * 1 - 0.6 * 150.00}$$ = **0.0154** in.

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

$$\textbf{trn} = \frac{3 * Do * Pa}{4B} = \frac{3 * 4.0000 * 15.00}{4 * 2931}$$ = **0.0154** in.

Strength Reduction Factors

$$\textbf{fr1} = \frac{Sn}{Sv} = \frac{17100}{20000} = 0.8550$$

$$\textbf{fr2} = \frac{Sn}{Sv} = \frac{17100}{20000} = 0.8550$$

$$\textbf{fr3} = \frac{Sn}{Sv} = \frac{17100}{20000} = 0.8550$$

$$\textbf{fr4} = \frac{Sp}{Sv} = \frac{20000}{20000} = 1.0000$$

UG-45 Thickness Calculations

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

$$\textbf{t} = \frac{PRn}{SE - 0.6P} + Ca + ext.\ Ca = \frac{150.00 * 1.7445}{17100 * 1.00 - 0.6 * 150.00} + 0.0625 + 0.0000$$ = **0.0779** in.

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

$$\textbf{t} = \frac{PR}{SE - 0.6P} + Ca + ext.\ Ca = \frac{150.00 * 21.0625}{20000 * 1 - 0.6 * 150.00} + 0.0625 + 0.0000$$ = **0.2212** in.

Nozzle Thickness for External Pressure (plus corrosion) per Paragraph UG-45(b)(2)

$$\textbf{t} = \frac{PR}{SE - 0.6P} + Ca + ext.\ Ca = \frac{15.00 * 21.0625}{20000 * 1 - 0.6 * 15.00} + 0.0625 + 0.0000$$ = **0.1250** in.

Minimum Thickness for Internal and External Pressure per Paragraph UG-45(b)(3)

t = Greater of the thicknesses determined by UG-45(b)(1) or UG-45(b)(2) = **0.2212** 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 = **0.2602** in.

Nozzle Minimum Thickness per Paragraph UG-45(b)

t = Smallest of UG-45(b)(3) or UG-45(b)(4) = **0.2212** in.

Wall thickness = tn * 0.875(pipe) = **0.2782** is greater than or equal to UG-45 value of **0.2212**

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, 0.1875, or 0.2555 = **0.1875** in.

Weld 41 Leg min. = $\dfrac{\text{(smaller of 0.25 or (tmin * 0.7)) + ext. CA}}{0.7} = \dfrac{0.1313}{0.7}$ = **0.1875** in.

Weld 41, actual weld leg = **0.1875** in.

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

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

Weld 42, actual weld leg = **0.1339** 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 = • * m * mean nozzle diameter * tn * Nozzle wall in shear unit stress =
• * m * 3.7445 * 0.2555 * 11970 = **18000** lb.
Upper fillet in shear = • * m * Nozzle OD * weld leg * upper fillet in shear unit stress= • * m * 4.0000 * 0.1875 * 8379 = **9870** lb.
Groove Weld in Tension = • * m * Nozzle OD * groove depth * groove weld tension unit stress =
• * m * 4.0000 * 0.1875 * 12654 = **14900** lb.
Outer fillet in shear = • * m * Plate OD * weld leg * outer fillet in shear unit stress= • * m * 6.0000 * 0.1339 * 9800 = **12400** lb.
Repad groove weld = • * m * Nozzle OD * Groove Depth * repad groove weld in tension unit stress =
• * m * 4.0000 * 0.1875 * 12654 = **14900** 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 = [0.5655 - 0.0983 + 2 * 0.2555 * 0.8550 * (1.00 * 0.1875 - 1.0000 * 0.1587)] * 20000 = **9600** lb.
W1-1 = (A2 + A5 + A41 + A42) * Sv = (0.1925 + 0.3750 + 0.0301 + 0.0179) * 20000 = **12300** lb.
W2-2 = (A2 + A3 + A41 + A43 + 2 tn t fr1) Sv = (0.1925 + 0.0000 + 0.0301 + 0.0000 + 2 * 0.2555 * 0.1875 * 0.8550) * 20000 = **6090** lb.
W3-3 = (A2 + A3 + A5 + A41 + A42 + A43 + 2 tn t fr1) * Sv =
(0.1925 + 0.0000 + 0.3750 + 0.0301 + 0.0179 + 0.0000 + 2 * 0.2555 * 0.1875 * 0.8550) * 20000 = **13900** lb.

Check Strength Paths

Path 1-1 = Outer fillet in shear + Nozzle wall in shear = 12400 + 18000 = **30400** lb.
Path 2-2 = Upper fillet in shear + Repad groove weld + Groove weld in tension + Inner fillet in shear =
9870 + 14900 + 14900 + 0 = **39670** lb.
Path 3-3 = Outer fillet in shear + Inner fillet in shear + Groove weld in tension = 12400 + 0 + 14900 = **27300** lb.

Plate Strength = A5 * Sp = 0.3750 * 20000 = **7500** lb.

Outer fillet weld strength(12400) is greater than plate strength(7500).

PAGET EQUIPMENT CO.

3.5" Outlet

Job No:	Example Vessels	Vessel Number:	Fixed Tube
Number:	6	Mark Number:	N3
ID Number:	6		

Date Printed: 2/27/2006

Nozzle Design Information

Design Pressure:	150.00	PSI	Design Temperature:	350	°F
Static Head:	0.00	PSI	Nozzle Efficiency (E):	100	%
Nozzle Material:	SA-106 Gr B		Joint Efficiency (E_1):	1.00	
			Factor B Chart:	CS-2	
External Projection:	6.0000	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.	Passes through a Category A Joint:	No	
Nozzle Pipe Size:	3.5		Nozzle Pipe Schedule:	80	
Nozzle ID (new):	3.3640	in.	Nozzle Wall Thickness(new):	0.3180	in.
Nozzle ID (corroded):	3.4890	in.	Nozzle Wall Thickness(corroded):	0.2555	in.
Outer "h" Limit:	0.4688	in.	Upper Weld Leg Size(Weld 41):	0.1875	in.
Internal "h" Limit:	0.4688	in.	Internal Weld Leg Size(Weld 43):	0.0000	in.
OD, Limit of Reinforcement:	6.9780	in.	Outside Groove Weld Depth:	0.2500	in.

Minimum Design Metal Temperature

Min. Temp. Curve:	B	Pressure at MDMT:	200.00	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):	0.1875	in.	Repad to Vessel Weld Leg Size(Weld 42):	0.1339	in.
OD, Reinforcing Plate(D_p):	6.0000	in.	Repad to Nozzle Groove Weld Depth:	0.1875	in.

Host Component: 1 - Right Channel Shell

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

Nozzle Detail Information

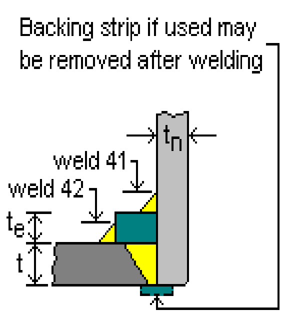


Fig. UW-16.1 (c)

Upper Weld Leg Size(Weld 41): 0.1875 in.

Nozzle Wall Thickness(t_n): 0.3180 in.

Outside Groove Weld Depth: 0.2500 in.

Repad to Vessel Weld Leg Size(Weld 42): 0.1339 in.

Repad Thickness(t_e): 0.1875 in.

Nozzle passes through the vessel, attached by a groove weld.
Pipe Size: 3.5 Schedule: 80
Nozzle is adequate for UG-45 requirements.
Opening is adequately reinforced for Internal Pressure.
Opening is adequately reinforced for External Pressure.
Reinforcement calculations are not required per UG-36(c)(3)(a)See Uw-14 for exceptions.
Weld Strength Paths are adequate.

Required Channel Thickness per Paragraph UG-37(a)

$$\textbf{tr} = \frac{PR}{SE - 0.6P} = \frac{150.00 * 21.0625}{20000 * 1 - 0.6 * 150.00} = \textbf{0.1587} \text{ in.}$$

Nozzle Required Thickness Calculations

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

$$\textbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{150.00 * 1.7445}{17100 * 1 - 0.6 * 150.00} = \textbf{0.0154} \text{ in.}$$

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

$$\textbf{trn} = \frac{3 * Do * Pa}{4B} = \frac{3 * 4.0000 * 15.00}{4 * 2931} = \textbf{0.0154} \text{ in.}$$

Strength Reduction Factors

$$\textbf{fr1} = \frac{Sn}{Sv} = \frac{17100}{20000} = 0.8550 \qquad \textbf{fr2} = \frac{Sn}{Sv} = \frac{17100}{20000} = 0.8550$$

$$\textbf{fr3} = \frac{Sn}{Sv} = \frac{17100}{20000} = 0.8550 \qquad \textbf{fr4} = \frac{Sp}{Sv} = \frac{20000}{20000} = 1.0000$$

UG-45 Thickness Calculations

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

$$\textbf{t} = \frac{PRn}{SE - 0.6P} + Ca + ext.\ Ca = \frac{150.00 * 1.7445}{17100 * 1.00 - 0.6 * 150.00} + 0.0625 + 0.0000 = \textbf{0.0779} \text{ in.}$$

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

$$\textbf{t} = \frac{PR}{SE - 0.6P} + Ca + ext.\ Ca = \frac{150.00 * 21.0625}{20000 * 1 - 0.6 * 150.00} + 0.0625 + 0.0000 = \textbf{0.2212} \text{ in.}$$

Nozzle Thickness for External Pressure (plus corrosion) per Paragraph UG-45(b)(2)

$$\textbf{t} = \frac{PR}{SE - 0.6P} + Ca + ext.\ Ca = \frac{15.00 * 21.0625}{20000 * 1 - 0.6 * 15.00} + 0.0625 + 0.0000 = \textbf{0.1250} \text{ in.}$$

Minimum Thickness for Internal and External Pressure per Paragraph UG-45(b)(3)

t = Greater of the thicknesses determined by UG-45(b)(1) or UG-45(b)(2) = **0.2212** 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 = **0.2602** in.

Nozzle Minimum Thickness per Paragraph UG-45(b)

t = Smallest of UG-45(b)(3) or UG-45(b)(4) = **0.2212** in.

Wall thickness = tn * 0.875(pipe) = **0.2782** is greater than or equal to UG-45 value of **0.2212**

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, 0.1875, or 0.2555 = **0.1875** in.

Weld 41 Leg min. = $\frac{\text{(smaller of 0.25 or (tmin * 0.7)) + ext. CA}}{0.7} = \frac{0.1313}{0.7}$ = **0.1875** in.

Weld 41, actual weld leg = **0.1875** in.

Weld 42 tmin = smaller of 0.75, t, or te = smaller of 0.75, 0.1875, or 0.1875 = **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 = **0.1339** 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 = • * m * mean nozzle diameter * tn * Nozzle wall in shear unit stress =
• * m * 3.7445 * 0.2555 * 11970 = **18000** lb.
Upper fillet in shear = • * m * Nozzle OD * weld leg * upper fillet in shear unit stress= • * m * 4.0000 * 0.1875 * 8379 = **9870** lb.
Groove Weld in Tension = • * m * Nozzle OD * groove depth * groove weld tension unit stress =
• * m * 4.0000 * 0.1875 * 12654 = **14900** lb.
Outer fillet in shear = • * m * Plate OD * weld leg * outer fillet in shear unit stress= • * m * 6.0000 * 0.1339 * 9800 = **12400** lb.
Repad groove weld = • * m * Nozzle OD * Groove Depth * repad groove weld in tension unit stress =
• * m * 4.0000 * 0.1875 * 12654 = **14900** 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 = [0.5655 - 0.0983 + 2 * 0.2555 * 0.8550 * (1.00 * 0.1875 - 1.0000 * 0.1587)] * 20000 = **9600** lb.
W1-1 = (A2 + A5 + A41 + A42) * Sv = (0.1925 + 0.3750 + 0.0301 + 0.0179) * 20000 = **12300** lb.
W2-2 = (A2 + A3 + A41 + A43 + 2 tn t fr1) Sv = (0.1925 + 0.0000 + 0.0301 + 0.0000 + 2 * 0.2555 * 0.1875 * 0.8550) * 20000 = **6090** lb.
W3-3 = (A2 + A3 + A5 + A41 + A42 + A43 + 2 tn t fr1) * Sv =
(0.1925 + 0.0000 + 0.3750 + 0.0301 + 0.0179 + 0.0000 + 2 * 0.2555 * 0.1875 * 0.8550) * 20000 = **13900** lb.

Check Strength Paths

Path 1-1 = Outer fillet in shear + Nozzle wall in shear = 12400 + 18000 = **30400** lb.
Path 2-2 = Upper fillet in shear + Repad groove weld + Groove weld in tension + Inner fillet in shear =
9870 + 14900 + 14900 + 0 = **39670** lb.
Path 3-3 = Outer fillet in shear + Inner fillet in shear + Groove weld in tension = 12400 + 0 + 14900 = **27300** lb.

Plate Strength = A5 * Sp = 0.3750 * 20000 = **7500** lb.

Outer fillet weld strength(12400) is greater than plate strength(7500).

Integral (Fig. 2-4(5)) Flange Design Information

Design Pressure:	200.00 PSI	Design Temperature:	650 °F
Static Head:	0.00 PSI	Corrosion Allowance:	0.0625 in.
Material:	SA-516 Gr 70	Factor B Chart:	CS-2
		Material Stress Hot(S_{fo}):	18800 PSI
Outside Diameter (A):	50.2500 in.	Material Stress Cold(S_{fa}):	20000 PSI
Bolt Circle (C):	47.0000 in.	Inside Diameter (B):	42.0000 in.
Flange Weight:	718.93 lb.	Flange MAWP (at design):	294.89 PSI
Corroded Inside Diameter:	42.1250 in.		
Hub Thickness at Large End(g_1):	0.2500 in.		
Hub Thickness at Small End(g_0):	0.2500 in.		

Minimum Design Metal Temperature

Impacts Required

Bolting Information

Material:	SA-193 Gr B7 <=2.5"	Material Stress Hot (S_b):	25000 PSI
		Material Stress Cold (S_a):	25000 PSI
Bolt Size:	1 5/8	Threads Per Inch:	6
Nominal Bolt Diameter (a):	1.6250 in.	Number of Bolts:	24
Bolt Hole Diameter:	1.7500 in.	Bolt Root Area:	1.5150 sq. in.

Gasket & Facing Information

Material:	Asbestos with suitable binder	Configuration:	Ring
Type:	1/16 in. thick	Seating Stress (y):	3700 PSI
O.D. Contact Face:	45.0000 in.	Gasket Width (N):	1.0000 in.
Factor m:	2.75		
Facing Sketch:	1a(1)	Seating Column:	Column II

Host Component: 2 - Left Channel Shell

Material:	SA-516 Gr 70	Material Stress Hot (S_{no}):	20000 PSI
		Material Stress Cold (S_{na}):	20000 PSI
Inside Diameter:	42.0000 in.	Wall Thickness (t_n):	0.2500 in.

ASME Flange Calculations per Appendix 2

Gasket Seating Calculations(Table 2-5.2)

$\mathbf{b_0} = \frac{N}{2} = \frac{1.0000}{2}$ = **0.5000** in.

Since b_0 > 1/4 in., b = 0.5 $\sqrt{b_0}$ = 0.5 * $\sqrt{0.5000}$ = **0.3536** in.

G = O.D. contact face - 2b = 45.0000 - (2 * 0.3536) = **44.2928** in.

Bolting is Adequate for Flange Design

Nominal Thickness is Adequate for Seating Conditions

Nominal Thickness is Adequate for Operating Conditions

Flange Thickness is Adequate for Flange Design

Load and Bolting Calculations

Minimum $\mathbf{W}_{m2}$ = mbGy = 3.14159 * 0.3536 * 44.2928 * 3700 = **182053** lb.

$\mathbf{H} = \frac{m}{4}$ GŠP = $\frac{3.14159}{4}$ * 44.2928Š * 200.00 = **308167** lb.

$\mathbf{H}_p$ = 2bmGmP = 2 * 0.3536 * 3.14159 * 44.2928 * 2.75 * 200.00 = **54124** lb.

Minimum $\mathbf{W}_{m1}$ = $H + H_p$ = 308167 + 54124 = **362291** lb.

$\mathbf{A}_{m1} = \frac{W_{m1}}{S_b} = \frac{362291}{25000}$ = **14.4916** sq. in.

$\mathbf{A}_{m2} = \frac{W_{m2}}{S_a} = \frac{182053}{25000}$ = **7.2821** sq. in.

$\mathbf{A}_m$ = Greater of A_{m1} or A_{m2} = greater of 14.4916 or 7.2821 = **14.4916** sq. in.

$\mathbf{A}_b$ = Number of Bolts * Bolt Root Area = 24 * 1.5150 = **36.3600** sq. in.

$\mathbf{W} = \frac{(A_m + A_b)S_a}{2} = \frac{(14.4916 + 36.3600) * 25000}{2}$ = **635645** lb.

Ab >= Am, Bolting is Adequate for Flange Design

Moment Calculations - Operating Conditions

$\mathbf{H}_D = \frac{m}{4}$ BŠP = $\frac{3.1416}{4}$ * 42.1250Š * 200.00 = **278740** lb.

$\mathbf{H}_G = W_{m1} - H$ = 362291 - 308167 = **54124** lb.

$\mathbf{H}_T = H - H_D$ = 308167 - 278740 = **29427** lb.

$\mathbf{R} = \frac{C - B}{2} - g_1 = \frac{47.0000 - 42.1250}{2} - 0.1875$ = **2.2500** in.

$\mathbf{h}_D = R + \frac{g_1}{2} = 2.2500 + \frac{0.1875}{2}$ = **2.3438** in.

$\mathbf{h}_G = \frac{C - G}{2} = \frac{47.0000 - 44.2928}{2}$ = **1.3536** in.

$\mathbf{h}_T = \frac{R + g_1 + h_G}{2} = \frac{2.2500 + 0.1875 + 1.3536}{2}$ = **1.8956** in.

$\mathbf{M}_D = H_D h_D$ = 278740 * 2.3438 = **653311** in.-lb.

$\mathbf{M}_G = H_G h_G$ = 54124 * 1.3536 = **73262** in.-lb.

$\mathbf{M}_T = H_T h_T$ = 29427 * 1.8956 = **55782** in.-lb.

$\mathbf{M}_o = M_D + M_G + M_T$ = 653311 + 73262 + 55782 = **782355** in.-lb.

Moment Calculations - Gasket Seating

$\mathbf{M_S} = Wh_G = 635645 * 1.3536$ = **860409** in.-lb.

Shape Constants
Calculated from Figure 2-7.1

$\mathbf{K} = \frac{A}{B} = \frac{50.2500}{42.1250}$ = **1.1929**

$\mathbf{Y} = \frac{1}{K-1}\left[0.66845 + 5.71690\frac{K^2\log_{10}K}{K^2-1}\right] = \frac{1}{1.1929-1}\left[0.66845 + \left(5.7169 * \frac{1.1929^2 * \log_{10}1.1929}{1.1929^2-1}\right)\right]$ = **11.1025**

$\mathbf{T} = \frac{K^2(1 + 8.55246\log_{10}K) - 1}{(1.04720 + 1.9448K^2)(K-1)} = \frac{1.1929^2(1 + 8.55246\log_{10}1.1929) - 1}{[1.04720 + (1.9448 * 1.1929^2)]\,(1.1929 - 1)}$ = **1.8418**

$\mathbf{U} = \frac{K^2(1 + 8.55246\log_{10}K) - 1}{1.36136(K^2-1)(K-1)} = \frac{1.1929^2[1 + (8.55246 * \log_{10}1.1929)] - 1}{1.36136(1.1929^2 - 1)(1.1929 - 1)}$ = **12.2005**

$\mathbf{Z} = \frac{K^2+1}{K^2-1} = \frac{1.1929^2+1}{1.1929^2-1}$ = **5.7280**

$\mathbf{h_0} = \sqrt{Bg_0} = \sqrt{42.1250 * 0.1875}$ = **2.8104** in.

$\frac{\mathbf{h}}{\mathbf{h_0}} = \frac{0.0000}{2.8104}$ = **0.0000**

$\frac{\mathbf{g_1}}{\mathbf{g_0}} = \frac{0.1875}{0.1875}$ = **1.0000**

Calculated from equations from TABLE 2-7.1

F = 0.9089 **V** = 0.5501 **f** = 1.0000

$\mathbf{d} = \left(\frac{U}{V}\right)h_0g_0^2 = \frac{12.2005}{0.5501} * 2.8104 * 0.1875^2$ = **2.1913** in.^{3}

$\mathbf{e} = \frac{F}{h_0} = \frac{0.9089}{2.8104}$ = **0.3234** in.$^{-1}$

$\mathbf{L} = \frac{te+1}{T} + \frac{t^3}{d} = \frac{(4.2500 * 0.3234) + 1}{1.8418} + \frac{4.2500^3}{2.1913}$ = **36.3212**

Bolt Spacing Calculations

$\mathbf{C_f}$ = 1, Correction factor not applied.

Stress Calculations - Operating Conditions

$$\mathbf{S}_H = \frac{fC_fM_o}{Lg_1\text{Š}B} = \frac{1.0000 * 1.0000 * 782355}{36.3212 * 0.1875\text{Š} * 42.1250} = \mathbf{14545}\ \text{PSI}$$

$$\mathbf{S}_R = \frac{(\text{˜ } te + 1)\, C_fM_o}{Lt\text{Š}B} = \frac{(\text{˜ } * 4.2500 * 0.3234 + 1) * 1.0000 * 782355}{36.3212 * 4.2500\text{Š} * 42.1250} = \mathbf{80}\ \text{PSI}$$

$$\mathbf{S}_T = \frac{Y\, C_f\, M_o}{t\text{Š}B} - (Z\, S_R) = \frac{11.1025 * 1.0000 * 782355}{4.2500\text{Š} * 42.1250} - (5.7280 * 80) = \mathbf{10958}\ \text{PSI}$$

$$\frac{S_H + S_R}{2} = \frac{(14545 + 80)}{2} = \mathbf{7313}\ \text{PSI}$$

$$\frac{S_H + S_T}{2} = \frac{(14545 + 10958)}{2} = \mathbf{12752}\ \text{PSI}$$

$$\mathbf{S}_c = \text{Max} \left\{ \frac{S_H + S_R}{2}, \frac{S_H + S_T}{2} \right\} = \mathbf{12752}\ \text{PSI}$$

$$\mathbf{S}_{Hmax} = 1.5\, S_{fo} = 1.5 * 18800 = \mathbf{28200}\ \text{PSI}$$

Since (S_H <= S_{Hmax}), (S_T <= S_{fo}), (S_R <= S_{fo}), (S_c <= S_{fo}), nominal thickness is **ADEQUATE** for operating conditions

Stress Calculations - Gasket Seating

$$\mathbf{S}_H = \frac{fC_fM_s}{Lg_1\text{Š}B} = \frac{1.0000 * 1.0000 * 860409}{36.3212 * 0.1875\text{Š} * 42.1250} = \mathbf{15996}\ \text{PSI}$$

$$\mathbf{S}_R = \frac{(\text{˜ } te + 1)\, C_fM_s}{L\, t\text{Š}\, B} = \frac{[(\text{˜ } * 4.2500 * 0.3234) + 1] * 1.0000 * 860409}{36.3212 * 4.2500\text{Š} * 42.1250} = \mathbf{88}\ \text{PSI}$$

$$\mathbf{S}_T = \frac{Y\, C_f\, M_s}{t\text{Š}\, B} - (Z\, S_R) = \frac{11.1025 * 1.0000 * 860409}{4.2500\text{Š} * 42.1250} - (5.7280 * 88) = \mathbf{12051}\ \text{PSI}$$

$$\frac{S_H + S_R}{2} = \frac{15996 + 88}{2} = \mathbf{8042}\ \text{PSI}$$

$$\frac{S_H + S_T}{2} = \frac{15996 + 12051}{2} = \mathbf{14024}\ \text{PSI}$$

$$\mathbf{S}_c = \text{Max} \left\{ \frac{S_H + S_R}{2}, \frac{S_H + S_T}{2} \right\} = \mathbf{14024}\ \text{PSI}$$

$$\mathbf{S}_{Hmax} = 1.5 * S_{fa} = 1.5 * 20000 = \mathbf{30000}\ \text{PSI}$$

Since (S_H <= S_{Hmax}), (S_R <= S_{fa}), (S_T <= S_{fa}), (S_c <= S_{fa}), nominal thickness is **ADEQUATE** for seating conditions

Rigidity Index per Appendix 2-14 - Operating Conditions

$$J = \frac{52.14\ M_o V}{L E g_0 \text{Š} h_0 K_I} = \frac{52.14 * 782355 * 0.5501}{36.3212 * 26.0\text{x}10\text{Ž} * 0.1875\text{Š} * 2.8104 * 0.3} = \mathbf{0.80}$$

J <= 1, design meets Flange Rigidity requirements for Operating Conditions

Rigidity Index per Appendix 2-14 - Seating Conditions

$$J = \frac{52.14\ M_s V}{L E g_0 \text{Š} h_0 K_I} = \frac{52.14 * 860409 * 0.5501}{36.3212 * 26.0\text{x}10\text{Ž} * 0.1875\text{Š} * 2.8104 * 0.3} = \mathbf{0.88}$$

J <= 1, design meets Flange Rigidity requirements for Seating Conditions

Minimum Thickness = **3.6834** in.

Nominal Thickness Selected = **4.2500** in.

Integral (Fig. 2-4(5)) Flange Design Information

Design Pressure:	150.00 PSI		Design Temperature:	350	°F
Static Head:	0.00 PSI		Corrosion Allowance:	0.0625	in.
Material:	SA-516 Gr 70		Factor B Chart:	CS-2	
			Material Stress Hot(S_{fo}):	20000	PSI
Outside Diameter (A):	50.0000	in.	Material Stress Cold(S_{fa}):	20000	PSI
Bolt Circle (C):	46.7500	in.	Inside Diameter (B):	42.0000	in.
Flange Weight:	654.36	lb.	Flange MAWP (at design):	278.82	PSI
Corroded Inside Diameter:	42.1250	in.			
Hub Thickness at Large End(g_1):	0.2500	in.			
Hub Thickness at Small End(g_0):	0.2500	in.			

Minimum Design Metal Temperature

Impacts Required

Bolting Information

Material:	SA-193 Gr B7 <=2.5"		Material Stress Hot (S_b):	25000	PSI
			Material Stress Cold (S_a):	25000	PSI
Bolt Size:	1 5/8		Threads Per Inch:	6	
Nominal Bolt Diameter (a):	1.6250	in.	Number of Bolts:	24	
Bolt Hole Diameter:	1.7500	in.	Bolt Root Area:	1.5150	sq. in.

Gasket & Facing Information

Material:	Asbestos with suitable binder		Configuration:	Ring	
Type:	1/16 in. thick		Seating Stress (y):	3700	PSI
O.D. Contact Face:	45.0000	in.	Gasket Width (N):	1.0000	in.
Factor m:	2.75				
Facing Sketch:	1a(1)		Seating Column:	Column II	

Host Component: 2 - Left Channel Shell

Material:	SA-516 Gr 70		Material Stress Hot (S_{no}):	20000	PSI
			Material Stress Cold (S_{na}):	20000	PSI
Inside Diameter:	42.0000	in.	Wall Thickness (t_n):	0.2500	in.

ASME Flange Calculations per Appendix 2

Gasket Seating Calculations(Table 2-5.2)

$\mathbf{b_0} = \frac{N}{2} = \frac{1.0000}{2}$ = **0.5000** in.

Since b_0 > 1/4 in., b = 0.5 $\sqrt{b_0}$ = 0.5 * $\sqrt{0.5000}$ = **0.3536** in.

G = O.D. contact face - 2b = 45.0000 - (2 * 0.3536) = **44.2928** in.

Bolting is Adequate for Flange Design

Nominal Thickness is Adequate for Seating Conditions

Nominal Thickness is Adequate for Operating Conditions

Flange Thickness is Adequate for Flange Design

Load and Bolting Calculations

Minimum $\mathbf{W}_{m2}$ = mbGy = 3.14159 * 0.3536 * 44.2928 * 3700 = **182053** lb.

$\mathbf{H} = \frac{m}{4}$ GŠP = $\frac{3.14159}{4}$ * 44.2928Š * 150.00 = **231125** lb.

$\mathbf{H}_p$ = 2bmGmP = 2 * 0.3536 * 3.14159 * 44.2928 * 2.75 * 150.00 = **40593** lb.

Minimum $\mathbf{W}_{m1}$ = $H + H_p$ = 231125 + 40593 = **271718** lb.

$\mathbf{A}_{m1} = \frac{W_{m1}}{S_b} = \frac{271718}{25000}$ = **10.8687** sq. in.

$\mathbf{A}_{m2} = \frac{W_{m2}}{S_a} = \frac{182053}{25000}$ = **7.2821** sq. in.

$\mathbf{A}_m$ = Greater of A_{m1} or A_{m2} = greater of 10.8687 or 7.2821 = **10.8687** sq. in.

$\mathbf{A}_b$ = Number of Bolts * Bolt Root Area = 24 * 1.5150 = **36.3600** sq. in.

$\mathbf{W} = \frac{(A_m + A_b)S_a}{2} = \frac{(10.8687 + 36.3600) * 25000}{2}$ = **590359** lb.

Ab >= Am, Bolting is Adequate for Flange Design

Moment Calculations - Operating Conditions

$\mathbf{H}_D = \frac{m}{4}$ BŠP = $\frac{3.1416}{4}$ * 42.1250Š * 150.00 = **209055** lb.

$\mathbf{H}_G = W_{m1} - H$ = 271718 - 231125 = **40593** lb.

$\mathbf{H}_T = H - H_D$ = 231125 - 209055 = **22070** lb.

$\mathbf{R} = \frac{C - B}{2} - g_1 = \frac{46.7500 - 42.1250}{2} - 0.1875$ = **2.1250** in.

$\mathbf{h}_D = R + \frac{g_1}{2} = 2.1250 + \frac{0.1875}{2}$ = **2.2188** in.

$\mathbf{h}_G = \frac{C - G}{2} = \frac{46.7500 - 44.2928}{2}$ = **1.2286** in.

$\mathbf{h}_T = \frac{R + g_1 + h_G}{2} = \frac{2.1250 + 0.1875 + 1.2286}{2}$ = **1.7706** in.

$\mathbf{M}_D = H_D h_D$ = 209055 * 2.2188 = **463851** in.-lb.

$\mathbf{M}_G = H_G h_G$ = 40593 * 1.2286 = **49873** in.-lb.

$\mathbf{M}_T = H_T h_T$ = 22070 * 1.7706 = **39077** in.-lb.

$\mathbf{M}_o = M_D + M_G + M_T$ = 463851 + 49873 + 39077 = **552801** in.-lb.

Moment Calculations - Gasket Seating

$\mathbf{M_S} = Wh_G = 590359 * 1.2286$ = **725315** in.-lb.

Shape Constants
Calculated from Figure 2-7.1

$\mathbf{K} = \frac{A}{B} = \frac{50.0000}{42.1250}$ = **1.1869**

$\mathbf{Y} = \frac{1}{K - 1}\left(0.66845 + 5.71690\frac{K^2\log_{10}K}{K^2 - 1}\right) = \frac{1}{1.1869 - 1}\left(0.66845 + \left(5.7169 * \frac{1.1869^2 * \log_{10}1.1869}{1.1869^2 - 1}\right)\right)$ = **11.4216**

$\mathbf{T} = \frac{K^2(1 + 8.55246 \log_{10}K) - 1}{(1.04720 + 1.9448K^2)(K - 1)} = \frac{1.1869^2(1 + 8.55246 \log_{10}1.1869) - 1}{[1.04720 + (1.9448 * 1.1869^2)]\,(1.1869 - 1)}$ = **1.8442**

$\mathbf{U} = \frac{K^2(1 + 8.55246 \log_{10}K) - 1}{1.36136(K^2 - 1)(K - 1)} = \frac{1.1869^2[1 + (8.55246 * \log_{10}1.1869)] - 1}{1.36136(1.1869^2 - 1)(1.1869 - 1)}$ = **12.5512**

$\mathbf{Z} = \frac{K^2 + 1}{K^2 - 1} = \frac{1.1869^2 + 1}{1.1869^2 - 1}$ = **5.8932**

$\mathbf{h_0} = \sqrt{Bg_0} = \sqrt{42.1250 * 0.1875}$ = **2.8104** in.

$\frac{\mathbf{h}}{\mathbf{h_0}} = \frac{0.0000}{2.8104}$ = **0.0000**

$\frac{\mathbf{g_1}}{\mathbf{g_0}} = \frac{0.1875}{0.1875}$ = **1.0000**

Calculated from equations from TABLE 2-7.1

F = 0.9089 **V** = 0.5501 **f** = 1.0000

$\mathbf{d} = \left(\frac{U}{V}\right)h_0g_0^2 = \frac{12.5512}{0.5501} * 2.8104 * 0.1875^2$ = **2.2543** in.^{3}

$\mathbf{e} = \frac{F}{h_0} = \frac{0.9089}{2.8104}$ = **0.3234** in.$^{-1}$

$\mathbf{L} = \frac{te + 1}{T} + \frac{t^3}{d} = \frac{(4.0000 * 0.3234) + 1}{1.8442} + \frac{4.0000^3}{2.2543}$ = **29.6339**

Bolt Spacing Calculations

$\mathbf{C_f}$ = 1, Correction factor not applied.

Stress Calculations - Operating Conditions

$$\mathbf{S}_H = \frac{fC_fM_o}{Lg_1\text{Š}B} = \frac{1.0000 * 1.0000 * 552801}{29.6339 * 0.1875\text{Š} * 42.1250} = \mathbf{12596}\ \text{PSI}$$

$$\mathbf{S}_R = \frac{(\text{˜ } te + 1)\, C_fM_o}{Lt\text{Š}B} = \frac{(\text{ ˜ } * 4.0000 * 0.3234 + 1) * 1.0000 * 552801}{29.6339 * 4.0000\text{Š} * 42.1250} = \mathbf{75}\ \text{PSI}$$

$$\mathbf{S}_T = \frac{Y\, C_f\, M_o}{t\text{Š}B} - (Z\, S_R) = \frac{11.4216 * 1.0000 * 552801}{4.0000\text{Š} * 42.1250} - (5.8932 * 75) = \mathbf{8926}\ \text{PSI}$$

$$\frac{S_H + S_R}{2} = \frac{(12596 + 75)}{2} = \mathbf{6336}\ \text{PSI}$$

$$\frac{S_H + S_T}{2} = \frac{(12596 + 8926)}{2} = \mathbf{10761}\ \text{PSI}$$

$$\mathbf{S}_c = \text{Max}\ ¥\ \frac{S_H + S_R}{2},\ \frac{S_H + S_T}{2}\ § = \mathbf{10761}\ \text{PSI}$$

$$\mathbf{S}_{Hmax} = 1.5\, S_{fo} = 1.5 * 20000 = \mathbf{30000}\ \text{PSI}$$

Since (S_H <= S_{Hmax}), (S_T <= S_{fo}), (S_R <= S_{fo}), (S_c <= S_{fo}), nominal thickness is **ADEQUATE** for operating conditions

Stress Calculations - Gasket Seating

$$\mathbf{S}_H = \frac{fC_fM_s}{Lg_1\text{Š}B} = \frac{1.0000 * 1.0000 * 725315}{29.6339 * 0.1875\text{Š} * 42.1250} = \mathbf{16527}\ \text{PSI}$$

$$\mathbf{S}_R = \frac{(\text{˜ } te + 1)\, C_fM_s}{L\, t\text{Š}\, B} = \frac{[(\text{˜ } * 4.0000 * 0.3234) + 1] * 1.0000 * 725315}{29.6339 * 4.0000\text{Š} * 42.1250} = \mathbf{99}\ \text{PSI}$$

$$\mathbf{S}_T = \frac{Y\, C_f\, M_s}{t\text{Š}\, B} - (Z\, S_R) = \frac{11.4216 * 1.0000 * 725315}{4.0000\text{Š} * 42.1250} - (5.8932 * 99) = \mathbf{11708}\ \text{PSI}$$

$$\frac{S_H + S_R}{2} = \frac{16527 + 99}{2} = \mathbf{8313}\ \text{PSI}$$

$$\frac{S_H + S_T}{2} = \frac{16527 + 11708}{2} = \mathbf{14118}\ \text{PSI}$$

$$\mathbf{S}_c = \text{Max}\ ¥\ \frac{S_H + S_R}{2},\ \frac{S_H + S_T}{2}\ § = \mathbf{14118}\ \text{PSI}$$

$$\mathbf{S}_{Hmax} = 1.5 * S_{fa} = 1.5 * 20000 = \mathbf{30000}\ \text{PSI}$$

Since (S_H <= S_{Hmax}), (S_R <= S_{fa}), (S_T <= S_{fa}), (S_c <= S_{fa}), nominal thickness is **ADEQUATE** for seating conditions

Rigidity Index per Appendix 2-14 - Operating Conditions

$$J = \frac{52.14\ M_oV}{LEg_0\text{Š}h_0K_I} = \frac{52.14 * 552801 * 0.5501}{29.6339 * 28.1\text{x}10\text{Ž} * 0.1875\text{Š} * 2.8104 * 0.3} = \mathbf{0.64}$$

J <= 1, design meets Flange Rigidity requirements for Operating Conditions

Rigidity Index per Appendix 2-14 - Seating Conditions

$$J = \frac{52.14\ M_sV}{LEg_0\text{Š}h_0K_I} = \frac{52.14 * 725315 * 0.5501}{29.6339 * 28.1\text{x}10\text{Ž} * 0.1875\text{Š} * 2.8104 * 0.3} = \mathbf{0.84}$$

J <= 1, design meets Flange Rigidity requirements for Seating Conditions

Minimum Thickness = **3.4751** in.

Nominal Thickness Selected = **4.0000** in.

Blind Flange Design Information

Design Pressure:	150.00	PSI	Design Temperature:	350	°F
Static Head:	0.00	PSI	Corrosion Allowance:	0.0625	in.
Material:	SA-516 Gr 70		Factor B Chart:	CS-2	
			Material Stress Hot(S_{fo}):	20000	PSI
Outside Diameter (A):	50.0000	in.	Material Stress Cold(S_{fa}):	20000	PSI
Bolt Circle (C):	46.7500	in.	End Diameter (ID):	42.0000	in.
Flange Weight:	1389.17	lb.	Flange MAWP (at design):	173.71	PSI
Head Factor C:	0.3000				
Weld Efficiency:	100	%			

Minimum Design Metal Temperature

Min. Temperature Curve:	B	Pressure at MDMT:	150.00	PSI
UCS-66(b) Reduction:	Yes	Minimum Design Metal Temperature:	-20	°F
UCS-68(c) Reduction:	Yes	Computed Minimum Design Temperature:	-32	°F

Bolting Information

Material:	SA-193 Gr B7 <=2.5"		Material Stress Hot (S_b):	25000	PSI
			Material Stress Cold (S_a):	25000	PSI
Bolt Size:	1 5/8		Threads Per Inch:	6	
Nominal Bolt Diameter (a):	1.6250	in.	Number of Bolts:	24	
Bolt Hole Diameter:	1.7500	in.	Bolt Root Area:	1.5150	sq. in.

Gasket & Facing Information

Material:	Asbestos with suitable binder		Configuration:	Ring	
Type:	1/16 in. thick		Seating Stress (y):	3700	PSI
O.D. Contact Face:	45.0000	in.	Gasket Width (N):	1.0000	in.
Factor m:	2.75				
Facing Sketch:	1a(1)		Seating Column:	Column II	

ASME Flange Calculations per Appendix 2

Gasket Seating Calculations(Table 2-5.2)

$\mathbf{b_0} = \frac{N}{2} = \frac{1.0000}{2}$ = **0.5000** in.

Since b_0 > 1/4 in., $b = 0.5\sqrt{b_0} = 0.5 * \sqrt{0.5000}$ = **0.3536** in.

G = O.D. contact face - 2b = 45.0000 - (2 * 0.3536) = **44.2928** in.

Bolting is Adequate for Flange Design

Nominal Thickness is Adequate for Seating Conditions

Nominal Thickness is Adequate for Operating Conditions

Flange Thickness is Adequate for Flange Design

Nominal Thickness Selected = **2.5000** in.

Load and Bolting Calculations

Minimum W_{m2} = πbGy = 3.14159 * 0.3536 * 44.2928 * 3700 = **182053** lb.

H = $\frac{\pi}{4} G^2 P = \frac{3.14159}{4} * 44.2928^2 * 150.00$ = **231125** lb.

H_p = $2b\pi GmP$ = 2 * 0.3536 * 3.14159 * 44.2928 * 2.75 * 150.00 = **40593** lb.

Minimum W_{m1} = $H + H_p$ = 231125 + 40593 = **271718** lb.

A_{m1} = $\frac{W_{m1}}{S_b} = \frac{271718}{25000}$ = **10.8687** sq. in.

A_{m2} = $\frac{W_{m2}}{S_a} = \frac{182053}{25000}$ = **7.2821** sq. in.

A_m = Greater of A_{m1} or A_{m2} = greater of 10.8687 or 7.2821 = **10.8687** sq. in.

A_b = Number of Bolts * Bolt Root Area = 24 * 1.5150 = **36.3600** sq. in.

W = $\frac{(A_m + A_b)S_a}{2} = \frac{(10.8687 + 36.3600) * 25000}{2}$ = **590359** lb.

h_G = $\frac{(C - G)}{2} = \frac{(46.7500 - 44.2928)}{2}$ = **1.2286** in.

Ab >= Am, Bolting is Adequate for Flange Design

Thickness Calculations

Operating Minimum t = $G\sqrt{\frac{CP}{SE} + \frac{1.9W_{m1}h_G}{SEG^3}} = 44.2928 * \sqrt{\frac{0.3000 * 150.00}{20000 * 1.00} + \frac{1.9 * 271718 * 1.2286}{20000 * 1.00 * 44.2928^3}}$ = **2.2650** in.

Seating Minimum t = $G\sqrt{\frac{1.9Wh_G}{SEG^3}} = 44.2928 * \sqrt{\frac{1.9 * 590359 * 1.2286}{20000 * 1.00 * 44.2928^3}}$ = **1.2473** in.

Mininum t = maximum(2.2650, 1.2473) + CA = 2.2650 + 0.0625 = **2.3275** in.

Integral (Fig. 2-4(5)) Flange Design Information

Design Pressure:	200.00	PSI	Design Temperature:	650	°F
Static Head:	0.00	PSI	Corrosion Allowance:	0.0625	in.
Material:	SA-516 Gr 70		Factor B Chart:	CS-2	
			Material Stress Hot(S_{fo}):	18800	PSI
Outside Diameter (A):	50.2500	in.	Material Stress Cold(S_{fa}):	20000	PSI
Bolt Circle (C):	47.0000	in.	Inside Diameter (B):	42.0000	in.
Flange Weight:	761.22	lb.	Flange MAWP (at design):	325.57	PSI
Corroded Inside Diameter:	42.1250	in.			
Hub Thickness at Large End(g_1):	0.3125	in.			
Hub Thickness at Small End(g_0):	0.3125	in.			

Minimum Design Metal Temperature

Impacts Required

Bolting Information

Material:	SA-193 Gr B7 <=2.5"		Material Stress Hot (S_b):	25000	PSI
			Material Stress Cold (S_a):	25000	PSI
Bolt Size:	1 5/8		Threads Per Inch:	6	
Nominal Bolt Diameter (a):	1.6250	in.	Number of Bolts:	24	
Bolt Hole Diameter:	1.7500	in.	Bolt Root Area:	1.5150	sq. in.

Gasket & Facing Information

Material:	Asbestos with suitable binder		Configuration:	Ring	
Type:	1/16 in. thick		Seating Stress (y):	3700	PSI
O.D. Contact Face:	45.0000	in.	Gasket Width (N):	1.0000	in.
Factor m:	2.75				
Facing Sketch:	1a(1)		Seating Column:	Column II	

Host Component: Shell 1 - Shell 1

Material:	SA-516 Gr 70		Material Stress Hot (S_{no}):	18800	PSI
			Material Stress Cold (S_{na}):	20000	PSI
Inside Diameter:	42.0000	in.	Wall Thickness (t_n):	0.3125	in.

ASME Flange Calculations per Appendix 2

Gasket Seating Calculations(Table 2-5.2)

$\mathbf{b_0} = \frac{N}{2} = \frac{1.0000}{2}$ = **0.5000** in.

Since b_0 > 1/4 in., $b = 0.5\sqrt{b_0} = 0.5 * \sqrt{0.5000}$ = **0.3536** in.

G = O.D. contact face - 2b = 45.0000 - (2 * 0.3536) = **44.2928** in.

Bolting is Adequate for Flange Design

Nominal Thickness is Adequate for Seating Conditions

Nominal Thickness is Adequate for Operating Conditions

Flange Thickness is Adequate for Flange Design

Load and Bolting Calculations

Minimum $\mathbf{W}_{m2}$ = mbGy = 3.14159 * 0.3536 * 44.2928 * 3700 = **182053** lb.

$\mathbf{H} = \frac{m}{4}\, G\text{Š}P = \frac{3.14159}{4} * 44.2928\text{Š} * 200.00$ = **308167** lb.

$\mathbf{H}_p$ = 2bmGmP = 2 * 0.3536 * 3.14159 * 44.2928 * 2.75 * 200.00 = **54124** lb.

Minimum $\mathbf{W}_{m1}$ = $H + H_p$ = 308167 + 54124 = **362291** lb.

$\mathbf{A}_{m1} = \frac{W_{m1}}{S_b} = \frac{362291}{25000}$ = **14.4916** sq. in.

$\mathbf{A}_{m2} = \frac{W_{m2}}{S_a} = \frac{182053}{25000}$ = **7.2821** sq. in.

$\mathbf{A}_m$ = Greater of A_{m1} or A_{m2} = greater of 14.4916 or 7.2821 = **14.4916** sq. in.

$\mathbf{A}_b$ = Number of Bolts * Bolt Root Area = 24 * 1.5150 = **36.3600** sq. in.

$\mathbf{W} = \frac{(A_m + A_b)S_a}{2} = \frac{(14.4916 + 36.3600) * 25000}{2}$ = **635645** lb.

Ab >= Am, Bolting is Adequate for Flange Design

Moment Calculations - Operating Conditions

$\mathbf{H}_D = \frac{m}{4}\, B\text{Š}P = \frac{3.1416}{4} * 42.1250\text{Š} * 200.00$ = **278740** lb.

$\mathbf{H}_G = W_{m1} - H$ = 362291 - 308167 = **54124** lb.

$\mathbf{H}_T = H - H_D$ = 308167 - 278740 = **29427** lb.

$\mathbf{R} = \frac{C - B}{2} - g_1 = \frac{47.0000 - 42.1250}{2} - 0.2500$ = **2.1875** in.

$\mathbf{h}_D = R + \frac{g_1}{2} = 2.1875 + \frac{0.2500}{2}$ = **2.3125** in.

$\mathbf{h}_G = \frac{C - G}{2} = \frac{47.0000 - 44.2928}{2}$ = **1.3536** in.

$\mathbf{h}_T = \frac{R + g_1 + h_G}{2} = \frac{2.1875 + 0.2500 + 1.3536}{2}$ = **1.8956** in.

$\mathbf{M}_D = H_D h_D$ = 278740 * 2.3125 = **644586** in.-lb.

$\mathbf{M}_G = H_G h_G$ = 54124 * 1.3536 = **73262** in.-lb.

$\mathbf{M}_T = H_T h_T$ = 29427 * 1.8956 = **55782** in.-lb.

$\mathbf{M}_o = M_D + M_G + M_T$ = 644586 + 73262 + 55782 = **773630** in.-lb.

Moment Calculations - Gasket Seating

$\mathbf{M_S} = Wh_G = 635645 * 1.3536$ = **860409** in.-lb.

Shape Constants
Calculated from Figure 2-7.1

$\mathbf{K} = \frac{A}{B} = \frac{50.2500}{42.1250}$ = **1.1929**

$\mathbf{Y} = \frac{1}{K-1}\left[0.66845 + 5.71690\frac{K^2\log_{10}K}{K^2-1}\right] = \frac{1}{1.1929-1}\left[0.66845 + \left(5.7169 * \frac{1.1929^2 * \log_{10}1.1929}{1.1929^2-1}\right)\right]$ = **11.1025**

$\mathbf{T} = \frac{K^2(1 + 8.55246\log_{10}K) - 1}{(1.04720 + 1.9448K^2)(K-1)} = \frac{1.1929^2(1 + 8.55246\log_{10}1.1929) - 1}{[1.04720 + (1.9448 * 1.1929^2)]\,(1.1929 - 1)}$ = **1.8418**

$\mathbf{U} = \frac{K^2(1 + 8.55246\log_{10}K) - 1}{1.36136(K^2-1)(K-1)} = \frac{1.1929^2[1 + (8.55246 * \log_{10}1.1929)] - 1}{1.36136(1.1929^2-1)(1.1929-1)}$ = **12.2005**

$\mathbf{Z} = \frac{K^2+1}{K^2-1} = \frac{1.1929^2+1}{1.1929^2-1}$ = **5.7280**

$\mathbf{h_0} = \sqrt{Bg_0} = \sqrt{42.1250 * 0.2500}$ = **3.2452** in.

$\frac{\mathbf{h}}{\mathbf{h_0}} = \frac{0.0000}{3.2452}$ = **0.0000**

$\frac{\mathbf{g_1}}{\mathbf{g_0}} = \frac{0.2500}{0.2500}$ = **1.0000**

Calculated from equations from TABLE 2-7.1

F = 0.9089 **V** = 0.5501 **f** = 1.0000

$\mathbf{d} = \left(\frac{U}{V}\right)h_0g_0^2 = \frac{12.2005}{0.5501} * 3.2452 * 0.2500^2$ = **4.4984** in.³

$\mathbf{e} = \frac{F}{h_0} = \frac{0.9089}{3.2452}$ = **0.2801** in.$^{-1}$

$\mathbf{L} = \frac{te+1}{T} + \frac{t^3}{d} = \frac{(4.5000 * 0.2801) + 1}{1.8418} + \frac{4.5000^3}{4.4984}$ = **21.4845**

Bolt Spacing Calculations

$\mathbf{C_f}$ = 1, Correction factor not applied.

Stress Calculations - Operating Conditions

$$\mathbf{S}_H = \frac{fC_fM_o}{Lg_1^2B} = \frac{1.0000 * 1.0000 * 773630}{21.4845 * 0.2500^2 * 42.1250} = \mathbf{13677}\ \text{PSI}$$

$$\mathbf{S}_R = \frac{(\beta\ te + 1)\ C_fM_o}{Lt^2B} = \frac{(\beta * 4.5000 * 0.2801 + 1) * 1.0000 * 773630}{21.4845 * 4.5000^2 * 42.1250} = \mathbf{113}\ \text{PSI}$$

$$\mathbf{S}_T = \frac{Y\ C_f\ M_o}{t^2B} - (Z\ S_R) = \frac{11.1025 * 1.0000 * 773630}{4.5000^2 * 42.1250} - (5.7280 * 113) = \mathbf{9422}\ \text{PSI}$$

$$\frac{S_H + S_R}{2} = \frac{(13677 + 113)}{2} = \mathbf{6895}\ \text{PSI}$$

$$\frac{S_H + S_T}{2} = \frac{(13677 + 9422)}{2} = \mathbf{11550}\ \text{PSI}$$

$$\mathbf{S}_c = \text{Max}\left[\frac{S_H + S_R}{2}, \frac{S_H + S_T}{2}\right] = \mathbf{11550}\ \text{PSI}$$

$$\mathbf{S}_{Hmax} = 1.5\ S_{fo} = 1.5 * 18800 = \mathbf{28200}\ \text{PSI}$$

Since ($S_H <= S_{Hmax}$), ($S_T <= S_{fo}$), ($S_R <= S_{fo}$), ($S_c <= S_{fo}$), nominal thickness is **ADEQUATE** for operating conditions

Stress Calculations - Gasket Seating

$$\mathbf{S}_H = \frac{fC_fM_s}{Lg_1^2B} = \frac{1.0000 * 1.0000 * 860409}{21.4845 * 0.2500^2 * 42.1250} = \mathbf{15211}\ \text{PSI}$$

$$\mathbf{S}_R = \frac{(\beta\ te + 1)\ C_fM_s}{L\ t^2\ B} = \frac{[(\beta * 4.5000 * 0.2801) + 1] * 1.0000 * 860409}{21.4845 * 4.5000^2 * 42.1250} = \mathbf{126}\ \text{PSI}$$

$$\mathbf{S}_T = \frac{Y\ C_f\ M_s}{t^2\ B} - (Z\ S_R) = \frac{11.1025 * 1.0000 * 860409}{4.5000^2 * 42.1250} - (5.7280 * 126) = \mathbf{10477}\ \text{PSI}$$

$$\frac{S_H + S_R}{2} = \frac{15211 + 126}{2} = \mathbf{7669}\ \text{PSI}$$

$$\frac{S_H + S_T}{2} = \frac{15211 + 10477}{2} = \mathbf{12844}\ \text{PSI}$$

$$\mathbf{S}_c = \text{Max}\left[\frac{S_H + S_R}{2}, \frac{S_H + S_T}{2}\right] = \mathbf{12844}\ \text{PSI}$$

$$\mathbf{S}_{Hmax} = 1.5 * S_{fa} = 1.5 * 20000 = \mathbf{30000}\ \text{PSI}$$

Since ($S_H <= S_{Hmax}$), ($S_R <= S_{fa}$), ($S_T <= S_{fa}$), ($S_c <= S_{fa}$), nominal thickness is **ADEQUATE** for seating conditions

Rigidity Index per Appendix 2-14 - Operating Conditions

$$J = \frac{52.14\ M_oV}{LEg_0\text{Š}h_0K_I} = \frac{52.14 * 773630 * 0.5501}{21.4845 * 26.0x10\text{Ž} * 0.2500\text{Š} * 3.2452 * 0.3} = \mathbf{0.65}$$

J <= 1, design meets Flange Rigidity requirements for Operating Conditions

Rigidity Index per Appendix 2-14 - Seating Conditions

$$J = \frac{52.14\ M_sV}{LEg_0\text{Š}h_0K_I} = \frac{52.14 * 860409 * 0.5501}{21.4845 * 26.0x10\text{Ž} * 0.2500\text{Š} * 3.2452 * 0.3} = \mathbf{0.73}$$

J <= 1, design meets Flange Rigidity requirements for Seating Conditions

Minimum Thickness = **3.7512** in.

Nominal Thickness Selected = **4.5000** in.

Integral (Fig. 2-4(5)) Flange Design Information

Design Pressure:	200.00 PSI	Design Temperature:	650 °F
Static Head:	0.00 PSI	Corrosion Allowance:	0.0625 in.
Material:	SA-516 Gr 70	Factor B Chart:	CS-2
		Material Stress Hot(S_{fo}):	18800 PSI
Outside Diameter (A):	50.2500 in.	Material Stress Cold(S_{fa}):	20000 PSI
Bolt Circle (C):	47.0000 in.	Inside Diameter (B):	42.0000 in.
Flange Weight:	761.22 lb.	Flange MAWP (at design):	339.78 PSI
Corroded Inside Diameter:	42.1250 in.		
Hub Thickness at Large End(g_1):	0.2500 in.		
Hub Thickness at Small End(g_0):	0.2500 in.		

Minimum Design Metal Temperature

Impacts Required

Bolting Information

Material:	SA-193 Gr B7 <=2.5"	Material Stress Hot (S_b):	25000 PSI
		Material Stress Cold (S_a):	25000 PSI
Bolt Size:	1 5/8	Threads Per Inch:	6
Nominal Bolt Diameter (a):	1.6250 in.	Number of Bolts:	24
Bolt Hole Diameter:	1.7500 in.	Bolt Root Area:	1.5150 sq. in.

Gasket & Facing Information

Material:	Asbestos with suitable binder	Configuration:	Ring
Type:	1/16 in. thick	Seating Stress (y):	3700 PSI
O.D. Contact Face:	45.0000 in.	Gasket Width (N):	1.0000 in.
Factor m:	2.75		
Facing Sketch:	1a(1)	Seating Column:	Column II

Host Component: 1 - Right Channel Shell

Material:	SA-516 Gr 70	Material Stress Hot (S_{no}):	20000 PSI
		Material Stress Cold (S_{na}):	20000 PSI
Inside Diameter:	42.0000 in.	Wall Thickness (t_n):	0.2500 in.

ASME Flange Calculations per Appendix 2

Gasket Seating Calculations(Table 2-5.2)

$\mathbf{b_0} = \frac{N}{2} = \frac{1.0000}{2}$ = **0.5000** in.

Since b_0 > 1/4 in., b = 0.5 $\sqrt{b_0}$ = 0.5 * $\sqrt{0.5000}$ = **0.3536** in.

G = O.D. contact face - 2b = 45.0000 - (2 * 0.3536) = **44.2928** in.

Bolting is Adequate for Flange Design

Nominal Thickness is Adequate for Seating Conditions

Nominal Thickness is Adequate for Operating Conditions

Flange Thickness is Adequate for Flange Design

Load and Bolting Calculations

Minimum W $_{m2}$ = mbGy = 3.14159 * 0.3536 * 44.2928 * 3700 = **182053** lb.

H = $\frac{m}{4}$ GŠP = $\frac{3.14159}{4}$ * 44.2928Š * 200.00 = **308167** lb.

H$_p$ = 2bmGmP = 2 * 0.3536 * 3.14159 * 44.2928 * 2.75 * 200.00 = **54124** lb.

Minimum W $_{m1}$ = H + H $_p$ = 308167 + 54124 = **362291** lb.

A$_{m1}$ = $\frac{W_{m1}}{S_b}$ = $\frac{362291}{25000}$ = **14.4916** sq. in.

A$_{m2}$ = $\frac{W_{m2}}{S_a}$ = $\frac{182053}{25000}$ = **7.2821** sq. in.

A$_m$ = Greater of A $_{m1}$ or A $_{m2}$ = greater of 14.4916 or 7.2821 = **14.4916** sq. in.

A$_b$ = Number of Bolts * Bolt Root Area = 24 * 1.5150 = **36.3600** sq. in.

W = $\frac{(A_m + A_b)S_a}{2}$ = $\frac{(14.4916 + 36.3600) * 25000}{2}$ = **635645** lb.

Ab >= Am, Bolting is Adequate for Flange Design

Moment Calculations - Operating Conditions

H$_D$ = $\frac{m}{4}$ BŠP = $\frac{3.1416}{4}$ * 42.1250Š * 200.00 = **278740** lb.

H$_G$ = W $_{m1}$ - H = 362291 - 308167 = **54124** lb.

H$_T$ = H - H$_D$ = 308167 - 278740 = **29427** lb.

R = $\frac{C - B}{2}$ - g_1 = $\frac{47.0000 - 42.1250}{2}$ - 0.1875 = **2.2500** in.

h$_D$ = R + $\frac{g_1}{2}$ = 2.2500 + $\frac{0.1875}{2}$ = **2.3438** in.

h$_G$ = $\frac{C - G}{2}$ = $\frac{47.0000 - 44.2928}{2}$ = **1.3536** in.

h$_T$ = $\frac{R + g_1 + h_G}{2}$ = $\frac{2.2500 + 0.1875 + 1.3536}{2}$ = **1.8956** in.

M$_D$ = $H_D h_D$ = 278740 * 2.3438 = **653311** in.-lb.

M$_G$ = $H_G \cdot h_G$ = 54124 * 1.3536 = **73262** in.-lb.

M$_T$ = $H_T h_T$ = 29427 * 1.8956 = **55782** in.-lb.

M$_o$ = M $_D$ + M $_G$ + M $_T$ = 653311 + 73262 + 55782 = **782355** in.-lb.

Moment Calculations - Gasket Seating

$\mathbf{M_S} = Wh_G = 635645 * 1.3536$ = **860409** in.-lb.

Shape Constants
Calculated from Figure 2-7.1

$\mathbf{K} = \frac{A}{B} = \frac{50.2500}{42.1250}$ = **1.1929**

$\mathbf{Y} = \frac{1}{K - 1}\left(0.66845 + 5.71690\frac{K^2\log_{10}K}{K^2 - 1}\right) = \frac{1}{1.1929 - 1}\left(0.66845 + \left(5.7169 * \frac{1.1929^2 * \log_{10}1.1929}{1.1929^2 - 1}\right)\right)$ = **11.1025**

$\mathbf{T} = \frac{K^2(1 + 8.55246\log_{10}K) - 1}{(1.04720 + 1.9448K^2)(K - 1)} = \frac{1.1929^2(1 + 8.55246\log_{10}1.1929) - 1}{[1.04720 + (1.9448 * 1.1929^2)](1.1929 - 1)}$ = **1.8418**

$\mathbf{U} = \frac{K^2(1 + 8.55246\log_{10}K) - 1}{1.36136(K^2 - 1)(K - 1)} = \frac{1.1929^2[1 + (8.55246 * \log_{10}1.1929)] - 1}{1.36136(1.1929^2 - 1)(1.1929 - 1)}$ = **12.2005**

$\mathbf{Z} = \frac{K^2 + 1}{K^2 - 1} = \frac{1.1929^2 + 1}{1.1929^2 - 1}$ = **5.7280**

$\mathbf{h_0} = \sqrt{Bg_0} = \sqrt{42.1250 * 0.1875}$ = **2.8104** in.

$\frac{\mathbf{h}}{\mathbf{h_0}} = \frac{0.0000}{2.8104}$ = **0.0000**

$\frac{\mathbf{g_1}}{\mathbf{g_0}} = \frac{0.1875}{0.1875}$ = **1.0000**

Calculated from equations from TABLE 2-7.1

F = 0.9089 **V** = 0.5501 **f** = 1.0000

$\mathbf{d} = \left(\frac{U}{V}\right)h_0g_0^2 = \frac{12.2005}{0.5501} * 2.8104 * 0.1875^2$ = **2.1913** in.^{3}

$\mathbf{e} = \frac{F}{h_0} = \frac{0.9089}{2.8104}$ = **0.3234** in.$^{-1}$

$\mathbf{L} = \frac{te + 1}{T} + \frac{t^3}{d} = \frac{(4.5000 * 0.3234) + 1}{1.8418} + \frac{4.5000^3}{2.1913}$ = **42.9180**

Bolt Spacing Calculations

$\mathbf{C_f}$ = 1, Correction factor not applied.

Stress Calculations - Operating Conditions

S_H = fC_fM_o / Lg_1ŠB = 1.0000 * 1.0000 * 782355 / 42.9180 * 0.1875Š * 42.1250 = **12309** PSI

S_R = (˜ te + 1) C_fM_o / LtŠB = (˜ * 4.5000 * 0.3234 + 1) * 1.0000 * 782355 / 42.9180 * 4.5000Š * 42.1250 = **63** PSI

S_T = $Y C_f M_o$ / tŠB - (Z S_R) = 11.1025 * 1.0000 * 782355 / 4.5000Š * 42.1250 - (5.7280 * 63) = **9822** PSI

$\frac{S_H + S_R}{2} = \frac{(12309 + 63)}{2}$ = **6186** PSI

$\frac{S_H + S_T}{2} = \frac{(12309 + 9822)}{2}$ = **11066** PSI

S_c = Max ¥ $\frac{S_H + S_R}{2}$, $\frac{S_H + S_T}{2}$ § = **11066** PSI

S_{Hmax} = 1.5 S_{fo} = 1.5 * 18800 = **28200** PSI

Since (S_H <= S_{Hmax}), (S_T <= S_{fo}), (S_R <= S_{fo}), (S_c <= S_{fo}), nominal thickness is **ADEQUATE** for operating conditions

Stress Calculations - Gasket Seating

S_H = fC_fM_s / Lg_1ŠB = 1.0000 * 1.0000 * 860409 / 42.9180 * 0.1875Š * 42.1250 = **13537** PSI

S_R = (˜ te + 1) C_fM_s / L tŠ B = [(˜ * 4.5000 * 0.3234) + 1] * 1.0000 * 860409 / 42.9180 * 4.5000Š * 42.1250 = **69** PSI

S_T = $Y C_f M_s$ / tŠ B - (Z S_R) = 11.1025 * 1.0000 * 860409 / 4.5000Š * 42.1250 - (5.7280 * 69) = **10803** PSI

$\frac{S_H + S_R}{2} = \frac{13537 + 69}{2}$ = **6803** PSI

$\frac{S_H + S_T}{2} = \frac{13537 + 10803}{2}$ = **12170** PSI

S_c = Max ¥ $\frac{S_H + S_R}{2}$, $\frac{S_H + S_T}{2}$ § = **12170** PSI

S_{Hmax} = 1.5 * S_{fa} = 1.5 * 20000 = **30000** PSI

Since (S_H <= S_{Hmax}), (S_R <= S_{fa}), (S_T <= S_{fa}), (S_c <= S_{fa}), nominal thickness is **ADEQUATE** for seating conditions

Rigidity Index per Appendix 2-14 - Operating Conditions

$$J = \frac{52.14\ M_oV}{LEg_0\text{Š}h_0K_I} = \frac{52.14 * 782355 * 0.5501}{42.9180 * 26.0\text{x}10\text{Ž} * 0.1875\text{Š} * 2.8104 * 0.3} = \mathbf{0.68}$$

J <= 1, design meets Flange Rigidity requirements for Operating Conditions

Rigidity Index per Appendix 2-14 - Seating Conditions

$$J = \frac{52.14\ M_sV}{LEg_0\text{Š}h_0K_I} = \frac{52.14 * 860409 * 0.5501}{42.9180 * 26.0\text{x}10\text{Ž} * 0.1875\text{Š} * 2.8104 * 0.3} = \mathbf{0.75}$$

J <= 1, design meets Flange Rigidity requirements for Seating Conditions

Minimum Thickness = **3.6834** in.

Nominal Thickness Selected = **4.5000** in.

Integral (Fig. 2-4(5)) Flange Design Information

Design Pressure:	150.00 PSI		Design Temperature:	350	°F
Static Head:	0.00 PSI		Corrosion Allowance:	0.0625	in.
Material:	SA-516 Gr 70		Factor B Chart:	CS-2	
			Material Stress Hot(S_{fo}):	20000	PSI
Outside Diameter (A):	50.0000	in.	Material Stress Cold(S_{fa}):	20000	PSI
Bolt Circle (C):	46.7500	in.	Inside Diameter (B):	42.0000	in.
Flange Weight:	654.36	lb.	Flange MAWP (at design):	278.82	PSI
Corroded Inside Diameter:	42.1250	in.			
Hub Thickness at Large End(g_1):	0.2500	in.			
Hub Thickness at Small End(g_0):	0.2500	in.			

Minimum Design Metal Temperature

Impacts Required

Bolting Information

Material:	SA-193 Gr B7 <=2.5"		Material Stress Hot (S_b):	25000	PSI
			Material Stress Cold (S_a):	25000	PSI
Bolt Size:	1 5/8		Threads Per Inch:	6	
Nominal Bolt Diameter (a):	1.6250	in.	Number of Bolts:	24	
Bolt Hole Diameter:	1.7500	in.	Bolt Root Area:	1.5150	sq. in.

Gasket & Facing Information

Material:	Asbestos with suitable binder		Configuration:	Ring	
Type:	1/16 in. thick		Seating Stress (y):	3700	PSI
O.D. Contact Face:	45.0000	in.	Gasket Width (N):	1.0000	in.
Factor m:	2.75				
Facing Sketch:	1a(1)		Seating Column:	Column II	

Host Component: 1 - Right Channel Shell

Material:	SA-516 Gr 70		Material Stress Hot (S_{no}):	20000	PSI
			Material Stress Cold (S_{na}):	20000	PSI
Inside Diameter:	42.0000	in.	Wall Thickness (t_n):	0.2500	in.

ASME Flange Calculations per Appendix 2

Gasket Seating Calculations(Table 2-5.2)

$\mathbf{b_0} = \frac{N}{2} = \frac{1.0000}{2}$ = **0.5000** in.

Since b_0 > 1/4 in., b = 0.5 $\sqrt{b_0}$ = 0.5 * $\sqrt{0.5000}$ = **0.3536** in.

G = O.D. contact face - 2b = 45.0000 - (2 * 0.3536) = **44.2928** in.

Bolting is Adequate for Flange Design

Nominal Thickness is Adequate for Seating Conditions

Nominal Thickness is Adequate for Operating Conditions

Flange Thickness is Adequate for Flange Design

Load and Bolting Calculations

Minimum W $_{m2}$ = mbGy = 3.14159 * 0.3536 * 44.2928 * 3700 = **182053** lb.

H = $\frac{m}{4}$ GŠP = $\frac{3.14159}{4}$ * 44.2928Š * 150.00 = **231125** lb.

H$_p$ = 2bmGmP = 2 * 0.3536 * 3.14159 * 44.2928 * 2.75 * 150.00 = **40593** lb.

Minimum W $_{m1}$ = H + H $_p$ = 231125 + 40593 = **271718** lb.

A$_{m1}$ = $\frac{W_{m1}}{S_b}$ = $\frac{271718}{25000}$ = **10.8687** sq. in.

A$_{m2}$ = $\frac{W_{m2}}{S_a}$ = $\frac{182053}{25000}$ = **7.2821** sq. in.

A$_m$ = Greater of A $_{m1}$ or A $_{m2}$ = greater of 10.8687 or 7.2821 = **10.8687** sq. in.

A$_b$ = Number of Bolts * Bolt Root Area = 24 * 1.5150 = **36.3600** sq. in.

W = $\frac{(A_m + A_b)S_a}{2}$ = $\frac{(10.8687 + 36.3600) * 25000}{2}$ = **590359** lb.

Ab >= Am, Bolting is Adequate for Flange Design

Moment Calculations - Operating Conditions

H$_D$ = $\frac{m}{4}$ BŠP = $\frac{3.1416}{4}$ * 42.1250Š * 150.00 = **209055** lb.

H$_G$ = W $_{m1}$ - H = 271718 - 231125 = **40593** lb.

H$_T$ = H - H $_D$ = 231125 - 209055 = **22070** lb.

R = $\frac{C - B}{2}$ - g_1 = $\frac{46.7500 - 42.1250}{2}$ - 0.1875 = **2.1250** in.

h$_D$ = R + $\frac{g_1}{2}$ = 2.1250 + $\frac{0.1875}{2}$ = **2.2188** in.

h$_G$ = $\frac{C - G}{2}$ = $\frac{46.7500 - 44.2928}{2}$ = **1.2286** in.

h$_T$ = $\frac{R + g_1 + h_G}{2}$ = $\frac{2.1250 + 0.1875 + 1.2286}{2}$ = **1.7706** in.

M$_D$ = $H_D h_D$ = 209055 * 2.2188 = **463851** in.-lb.

M$_G$ = $H_G h_G$ = 40593 * 1.2286 = **49873** in.-lb.

M$_T$ = $H_T h_T$ = 22070 * 1.7706 = **39077** in.-lb.

M$_o$ = M $_D$ + M $_G$ + M $_T$ = 463851 + 49873 + 39077 = **552801** in.-lb.

Moment Calculations - Gasket Seating

$\mathbf{M_S} = Wh_G = 590359 * 1.2286$ = **725315** in.-lb.

Shape Constants
Calculated from Figure 2-7.1

$\mathbf{K} = \frac{A}{B} = \frac{50.0000}{42.1250}$ = **1.1869**

$\mathbf{Y} = \frac{1}{K-1}\left[0.66845 + 5.71690\frac{K^2\log_{10}K}{K^2-1}\right] = \frac{1}{1.1869-1}\left[0.66845 + \left(5.7169 * \frac{1.1869^2 * \log_{10}1.1869}{1.1869^2-1}\right)\right]$ = **11.4216**

$\mathbf{T} = \frac{K^2(1 + 8.55246\log_{10}K) - 1}{(1.04720 + 1.9448K^2)(K-1)} = \frac{1.1869^2(1 + 8.55246\log_{10}1.1869) - 1}{[1.04720 + (1.9448 * 1.1869^2)](1.1869-1)}$ = **1.8442**

$\mathbf{U} = \frac{K^2(1 + 8.55246\log_{10}K) - 1}{1.36136(K^2-1)(K-1)} = \frac{1.1869^2[1 + (8.55246 * \log_{10}1.1869)] - 1}{1.36136(1.1869^2-1)(1.1869-1)}$ = **12.5512**

$\mathbf{Z} = \frac{K^2+1}{K^2-1} = \frac{1.1869^2+1}{1.1869^2-1}$ = **5.8932**

$\mathbf{h_0} = \sqrt{Bg_0} = \sqrt{42.1250 * 0.1875}$ = **2.8104** in.

$\frac{\mathbf{h}}{\mathbf{h_0}} = \frac{0.0000}{2.8104}$ = **0.0000**

$\frac{\mathbf{g_1}}{\mathbf{g_0}} = \frac{0.1875}{0.1875}$ = **1.0000**

Calculated from equations from TABLE 2-7.1

F = 0.9089 **V** = 0.5501 **f** = 1.0000

$\mathbf{d} = \left(\frac{U}{V}\right)h_0g_0^2 = \frac{12.5512}{0.5501} * 2.8104 * 0.1875^2$ = **2.2543** in.³

$\mathbf{e} = \frac{F}{h_0} = \frac{0.9089}{2.8104}$ = **0.3234** in.$^{-1}$

$\mathbf{L} = \frac{te+1}{T} + \frac{t^3}{d} = \frac{(4.0000 * 0.3234) + 1}{1.8442} + \frac{4.0000^3}{2.2543}$ = **29.6339**

Bolt Spacing Calculations

$\mathbf{C_f}$ = 1, Correction factor not applied.

Stress Calculations - Operating Conditions

$$S_H = \frac{fC_fM_o}{Lg_1\text{Š}B} = \frac{1.0000 * 1.0000 * 552801}{29.6339 * 0.1875\text{Š} * 42.1250} = \mathbf{12596}\ \text{PSI}$$

$$S_R = \frac{(\text{˜ } te + 1)\ C_fM_o}{Lt\text{Š}B} = \frac{(\text{ ˜ } * 4.0000 * 0.3234 + 1) * 1.0000 * 552801}{29.6339 * 4.0000\text{Š} * 42.1250} = \mathbf{75}\ \text{PSI}$$

$$S_T = \frac{Y\ C_f\ M_o}{t\text{Š}B} - (Z\ S_R) = \frac{11.4216 * 1.0000 * 552801}{4.0000\text{Š} * 42.1250} - (5.8932 * 75) = \mathbf{8926}\ \text{PSI}$$

$$\frac{S_H + S_R}{2} = \frac{(12596 + 75)}{2} = \mathbf{6336}\ \text{PSI}$$

$$\frac{S_H + S_T}{2} = \frac{(12596 + 8926)}{2} = \mathbf{10761}\ \text{PSI}$$

$$S_c = \text{Max} \text{ ¥¦} \frac{S_H + S_R}{2}, \frac{S_H + S_T}{2} \text{ §} = \mathbf{10761}\ \text{PSI}$$

$$S_{Hmax} = 1.5\ S_{fo} = 1.5 * 20000 = \mathbf{30000}\ \text{PSI}$$

Since (S_H <= S_{Hmax}), (S_T <= S_{fo}), (S_R <= S_{fo}), (S_c <= S_{fo}), nominal thickness is **ADEQUATE** for operating conditions

Stress Calculations - Gasket Seating

$$S_H = \frac{fC_fM_s}{Lg_1\text{Š}B} = \frac{1.0000 * 1.0000 * 725315}{29.6339 * 0.1875\text{Š} * 42.1250} = \mathbf{16527}\ \text{PSI}$$

$$S_R = \frac{(\text{˜ } te + 1)\ C_fM_s}{L\ t\text{Š}\ B} = \frac{[(\text{˜ } * 4.0000 * 0.3234) + 1] * 1.0000 * 725315}{29.6339 * 4.0000\text{Š} * 42.1250} = \mathbf{99}\ \text{PSI}$$

$$S_T = \frac{Y\ C_f\ M_s}{t\text{Š}\ B} - (Z\ S_R) = \frac{11.4216 * 1.0000 * 725315}{4.0000\text{Š} * 42.1250} - (5.8932 * 99) = \mathbf{11708}\ \text{PSI}$$

$$\frac{S_H + S_R}{2} = \frac{16527 + 99}{2} = \mathbf{8313}\ \text{PSI}$$

$$\frac{S_H + S_T}{2} = \frac{16527 + 11708}{2} = \mathbf{14118}\ \text{PSI}$$

$$S_c = \text{Max} \text{ ¥¦} \frac{S_H + S_R}{2}, \frac{S_H + S_T}{2} \text{ §} = \mathbf{14118}\ \text{PSI}$$

$$S_{Hmax} = 1.5 * S_{fa} = 1.5 * 20000 = \mathbf{30000}\ \text{PSI}$$

Since (S_H <= S_{Hmax}), (S_R <= S_{fa}), (S_T <= S_{fa}), (S_c <= S_{fa}), nominal thickness is **ADEQUATE** for seating conditions

Rigidity Index per Appendix 2-14 - Operating Conditions

$$J = \frac{52.14\ M_o V}{L E g_0 \text{Š} h_0 K_I} = \frac{52.14 * 552801 * 0.5501}{29.6339 * 28.1\text{x}10\text{Ž} * 0.1875\text{Š} * 2.8104 * 0.3} = \mathbf{0.64}$$

J <= 1, design meets Flange Rigidity requirements for Operating Conditions

Rigidity Index per Appendix 2-14 - Seating Conditions

$$J = \frac{52.14\ M_s V}{L E g_0 \text{Š} h_0 K_I} = \frac{52.14 * 725315 * 0.5501}{29.6339 * 28.1\text{x}10\text{Ž} * 0.1875\text{Š} * 2.8104 * 0.3} = \mathbf{0.84}$$

J <= 1, design meets Flange Rigidity requirements for Seating Conditions

Minimum Thickness = **3.4751** in.

Nominal Thickness Selected = **4.0000** in.

Blind Flange Design Information

Design Pressure:	150.00 PSI	Design Temperature:	350 °F
Static Head:	0.00 PSI	Corrosion Allowance:	0.0625 in.
Material:	SA-516 Gr 70	Factor B Chart:	CS-2
		Material Stress Hot(S_{fo}):	18800 PSI
Outside Diameter (A):	50.0000 in.	Material Stress Cold(S_{fa}):	20000 PSI
Bolt Circle (C):	46.7500 in.	End Diameter (ID):	42.0000 in.
Flange Weight:	1389.17 lb.	Flange MAWP (at design):	163.29 PSI
Head Factor C:	0.3000		
Weld Efficiency:	100 %		

Minimum Design Metal Temperature

Min. Temperature Curve:	B	Pressure at MDMT:	150.00 PSI
UCS-66(b) Reduction:	Yes	Minimum Design Metal Temperature:	-20 °F
UCS-68(c) Reduction:	Yes	Computed Minimum Design Temperature:	-29 °F

Bolting Information

Material:	SA-193 Gr B7 <=2.5"	Material Stress Hot (S_b):	25000 PSI
		Material Stress Cold (S_a):	25000 PSI
Bolt Size:		Threads Per Inch:	0
Nominal Bolt Diameter (a):	1.6250 in.	Number of Bolts:	24
Bolt Hole Diameter:	1.7500 in.	Bolt Root Area:	1.5150 sq. in.

Gasket & Facing Information

Material:	Asbestos with suitable binder	Configuration:	Ring
Type:	1/16 in. thick	Seating Stress (y):	3700 PSI
O.D. Contact Face:	45.0000 in.	Gasket Width (N):	1.0000 in.
Factor m:	2.75		
Facing Sketch:	1a(1)	Seating Column:	Column II

ASME Flange Calculations per Appendix 2

Gasket Seating Calculations(Table 2-5.2)

$$\mathbf{b_0} = \frac{N}{2} = \frac{1.0000}{2}$$ = **0.5000** in.

Since b_0 > 1/4 in., b = 0.5 $\sqrt{b_0}$ = 0.5 * $\sqrt{0.5000}$ = **0.3536** in.

G = O.D. contact face - 2b = 45.0000 - (2 * 0.3536) = **44.2928** in.

Bolting is Adequate for Flange Design

Nominal Thickness is Adequate for Seating Conditions

Nominal Thickness is Adequate for Operating Conditions

Flange Thickness is Adequate for Flange Design

Nominal Thickness Selected = **2.5000** in.

Load and Bolting Calculations

Minimum W_{m2} = πbGy = 3.14159 * 0.3536 * 44.2928 * 3700 = **182053** lb.

H = $\frac{\pi}{4} G^2 P = \frac{3.14159}{4} * 44.2928^2 * 150.00$ = **231125** lb.

$\mathbf{H_p}$ = $2b\pi GmP$ = 2 * 0.3536 * 3.14159 * 44.2928 * 2.75 * 150.00 = **40593** lb.

Minimum W_{m1} = $H + H_p$ = 231125 + 40593 = **271718** lb.

$\mathbf{A_{m1}} = \frac{W_{m1}}{S_b} = \frac{271718}{25000}$ = **10.8687** sq. in.

$\mathbf{A_{m2}} = \frac{W_{m2}}{S_a} = \frac{182053}{25000}$ = **7.2821** sq. in.

$\mathbf{A_m}$ = Greater of A_{m1} or A_{m2} = greater of 10.8687 or 7.2821 = **10.8687** sq. in.

$\mathbf{A_b}$ = Number of Bolts * Bolt Root Area = 24 * 1.5150 = **36.3600** sq. in.

$\mathbf{W} = \frac{(A_m + A_b)S_a}{2} = \frac{(10.8687 + 36.3600) * 25000}{2}$ = **590359** lb.

$\mathbf{h_G} = \frac{(C - G)}{2} = \frac{(46.7500 - 44.2928)}{2}$ = **1.2286** in.

Ab >= Am, Bolting is Adequate for Flange Design

Thickness Calculations

Operating Minimum t $= G\sqrt{\frac{CP}{SE} + \frac{1.9W_{m1}h_G}{SEG}} = 44.2928 * \sqrt{\frac{0.3000 * 150.00}{18800 * 1.00} + \frac{1.9 * 271718 * 1.2286}{18800 * 1.00 * 44.2928}}$ = **2.3362** in.

Seating Minimum t $= G\sqrt{\frac{1.9Wh_G}{SEG}} = 44.2928 * \sqrt{\frac{1.9 * 590359 * 1.2286}{20000 * 1.00 * 44.2928}}$ = **1.2473** in.

Mininum t = maximum(2.3362, 1.2473) + CA = 2.3362 + 0.0625 = **2.3987** in.

Integral (Fig. 2-4(5)) Flange Design Information

Design Pressure:	200.00 PSI		Design Temperature:	650	°F
Static Head:	0.00 PSI		Corrosion Allowance:	0.0625	in.
Material:	SA-516 Gr 70		Factor B Chart:	CS-2	
			Material Stress Hot(S_{fo}):	18800	PSI
Outside Diameter (A):	50.2500	in.	Material Stress Cold(S_{fa}):	20000	PSI
Bolt Circle (C):	47.0000	in.	Inside Diameter (B):	42.0000	in.
Flange Weight:	767.98	lb.	Flange MAWP (at design):	332.69	PSI
Corroded Inside Diameter:	42.1250	in.			
Hub Thickness at Large End(g_1):	0.3125	in.			
Hub Thickness at Small End(g_0):	0.3125	in.			

Minimum Design Metal Temperature

Impacts Required

Bolting Information

Material:	SA-193 Gr B7 <=2.5"		Material Stress Hot (S_b):	25000	PSI
			Material Stress Cold (S_a):	25000	PSI
Bolt Size:	1 5/8		Threads Per Inch:	6	
Nominal Bolt Diameter (a):	1.6250	in.	Number of Bolts:	24	
Bolt Hole Diameter:	1.7500	in.	Bolt Root Area:	1.5150	sq. in.

Gasket & Facing Information

Material:	Asbestos with suitable binder		Configuration:	Ring	
Type:	1/16 in. thick		Seating Stress (y):	3700	PSI
O.D. Contact Face:	45.0000	in.	Gasket Width (N):	1.0000	in.
Factor m:	2.75				
Facing Sketch:	1a(1)		Seating Column:	Column II	

Host Component: Shell 1 - Shell 1

Material:	SA-516 Gr 70		Material Stress Hot (S_{no}):	18800	PSI
			Material Stress Cold (S_{na}):	20000	PSI
Inside Diameter:	42.0000	in.	Wall Thickness (t_n):	0.3125	in.

ASME Flange Calculations per Appendix 2

Gasket Seating Calculations(Table 2-5.2)

$\mathbf{b_0} = \frac{N}{2} = \frac{1.0000}{2}$ = **0.5000** in.

Since b_0 > 1/4 in., $b = 0.5\sqrt{b_0} = 0.5 * \sqrt{0.5000}$ = **0.3536** in.

G = O.D. contact face - 2b = 45.0000 - (2 * 0.3536) = **44.2928** in.

Bolting is Adequate for Flange Design

Nominal Thickness is Adequate for Seating Conditions

Nominal Thickness is Adequate for Operating Conditions

Flange Thickness is Adequate for Flange Design

Load and Bolting Calculations

Minimum $W_{m2} = \pi bGy$ = 3.14159 * 0.3536 * 44.2928 * 3700 = **182053** lb.

$H = \frac{\pi}{4} G^2 P = \frac{3.14159}{4}$ * 44.2928² * 200.00 = **308167** lb.

$H_p = 2b\pi GmP$ = 2 * 0.3536 * 3.14159 * 44.2928 * 2.75 * 200.00 = **54124** lb.

Minimum $W_{m1} = H + H_p$ = 308167 + 54124 = **362291** lb.

$A_{m1} = \frac{W_{m1}}{S_b} = \frac{362291}{25000}$ = **14.4916** sq. in.

$A_{m2} = \frac{W_{m2}}{S_a} = \frac{182053}{25000}$ = **7.2821** sq. in.

A_m = Greater of A_{m1} or A_{m2} = greater of 14.4916 or 7.2821 = **14.4916** sq. in.

A_b = Number of Bolts * Bolt Root Area = 24 * 1.5150 = **36.3600** sq. in.

$W = \frac{(A_m + A_b)S_a}{2} = \frac{(14.4916 + 36.3600) * 25000}{2}$ = **635645** lb.

Ab >= Am, Bolting is Adequate for Flange Design

Moment Calculations - Operating Conditions

$H_D = \frac{\pi}{4} B^2 P = \frac{3.1416}{4}$ * 42.1250² * 200.00 = **278740** lb.

$H_G = W_{m1} - H$ = 362291 - 308167 = **54124** lb.

$H_T = H - H_D$ = 308167 - 278740 = **29427** lb.

$R = \frac{C - B}{2} - g_1 = \frac{47.0000 - 42.1250}{2} - 0.2500$ = **2.1875** in.

$h_D = R + \frac{g_1}{2} = 2.1875 + \frac{0.2500}{2}$ = **2.3125** in.

$h_G = \frac{C - G}{2} = \frac{47.0000 - 44.2928}{2}$ = **1.3536** in.

$h_T = \frac{R + g_1 + h_G}{2} = \frac{2.1875 + 0.2500 + 1.3536}{2}$ = **1.8956** in.

$M_D = H_D h_D$ = 278740 * 2.3125 = **644586** in.-lb.

$M_G = H_G h_G$ = 54124 * 1.3536 = **73262** in.-lb.

$M_T = H_T h_T$ = 29427 * 1.8956 = **55782** in.-lb.

$M_o = M_D + M_G + M_T$ = 644586 + 73262 + 55782 = **773630** in.-lb.

Moment Calculations - Gasket Seating

$\mathbf{M_S} = Wh_G = 635645 * 1.3536$ = **860409** in.-lb.

Shape Constants
Calculated from Figure 2-7.1

$\mathbf{K} = \frac{A}{B} = \frac{50.2500}{42.1250}$ = **1.1929**

$\mathbf{Y} = \frac{1}{K - 1}\left(0.66845 + 5.71690\frac{K^2\log_{10}K}{K^2 - 1}\right) = \frac{1}{1.1929 - 1}\left(0.66845 + \left(5.7169 * \frac{1.1929^2 * \log_{10}1.1929}{1.1929^2 - 1}\right)\right)$ = **11.1025**

$\mathbf{T} = \frac{K^2(1 + 8.55246\log_{10}K) - 1}{(1.04720 + 1.9448K^2)(K - 1)} = \frac{1.1929^2(1 + 8.55246\log_{10}1.1929) - 1}{[1.04720 + (1.9448 * 1.1929^2)](1.1929 - 1)}$ = **1.8418**

$\mathbf{U} = \frac{K^2(1 + 8.55246\log_{10}K) - 1}{1.36136(K^2 - 1)(K - 1)} = \frac{1.1929^2[1 + (8.55246 * \log_{10}1.1929)] - 1}{1.36136(1.1929^2 - 1)(1.1929 - 1)}$ = **12.2005**

$\mathbf{Z} = \frac{K^2 + 1}{K^2 - 1} = \frac{1.1929^2 + 1}{1.1929^2 - 1}$ = **5.7280**

$\mathbf{h_0} = \sqrt{Bg_0} = \sqrt{42.1250 * 0.2500}$ = **3.2452** in.

$\frac{\mathbf{h}}{\mathbf{h_0}} = \frac{0.0000}{3.2452}$ = **0.0000**

$\frac{\mathbf{g_1}}{\mathbf{g_0}} = \frac{0.2500}{0.2500}$ = **1.0000**

Calculated from equations from TABLE 2-7.1

F = 0.9089 **V** = 0.5501 **f** = 1.0000

$\mathbf{d} = \left(\frac{U}{V}\right)h_0g_0^2 = \frac{12.2005}{0.5501} * 3.2452 * 0.2500^2$ = **4.4984** in.^{3}

$\mathbf{e} = \frac{F}{h_0} = \frac{0.9089}{3.2452}$ = **0.2801** in.$^{-1}$

$\mathbf{L} = \frac{te + 1}{T} + \frac{t^3}{d} = \frac{(4.5400 * 0.2801) + 1}{1.8418} + \frac{4.5400^3}{4.4984}$ = **22.0356**

Bolt Spacing Calculations

$\mathbf{C_f}$ = 1, Correction factor not applied.

Stress Calculations - Operating Conditions

$$\mathbf{S}_H = \frac{fC_f M_o}{Lg_1\text{Š}B} = \frac{1.0000 * 1.0000 * 773630}{22.0356 * 0.2500\text{Š} * 42.1250} = \mathbf{13335}\ \text{PSI}$$

$$\mathbf{S}_R = \frac{(\text{˜ } te + 1)\ C_f M_o}{Lt\text{Š}B} = \frac{(\text{ ˜ } * 4.5400 * 0.2801 + 1\ ) * 1.0000 * 773630}{22.0356 * 4.5400\text{Š} * 42.1250} = \mathbf{109}\ \text{PSI}$$

$$\mathbf{S}_T = \frac{Y\ C_f\ M_o}{t\text{Š}B} - (Z\ S_R) = \frac{11.1025 * 1.0000 * 773630}{4.5400\text{Š} * 42.1250} - (\ 5.7280 * 109\ ) = \mathbf{9268}\ \text{PSI}$$

$$\frac{S_H + S_R}{2} = \frac{(\ 13335 + 109)}{2} = \mathbf{6722}\ \text{PSI} \qquad \frac{S_H + S_T}{2} = \frac{(\ 13335 + 9268)}{2} = \mathbf{11302}\ \text{PSI}$$

$$\mathbf{S}_c = \text{Max}\ \text{¥¦}\ \frac{S_H + S_R}{2}\ ,\ \frac{S_H + S_T}{2}\ \text{§..} = \mathbf{11302}\ \text{PSI} \qquad \mathbf{S}_{Hmax} = 1.5\ S_{fo} = 1.5 * 18800 = \mathbf{28200}\ \text{PSI}$$

Since (S_H <= S_{Hmax}), (S_T <= S_{fo}), (S_R <= S_{fo}), (S_c <= S_{fo}), nominal thickness is **ADEQUATE** for operating conditions

Stress Calculations - Gasket Seating

$$\mathbf{S}_H = \frac{fC_f M_s}{Lg_1\text{Š}B} = \frac{1.0000 * 1.0000 * 860409}{22.0356 * 0.2500\text{Š} * 42.1250} = \mathbf{14831}\ \text{PSI}$$

$$\mathbf{S}_R = \frac{(\text{˜ } te + 1)\ C_f M_s}{L\ t\text{Š}\ B} = \frac{[(\text{˜ } * 4.5400 * 0.2801) + 1] * 1.0000 * 860409}{22.0356 * 4.5400\text{Š} * 42.1250} = \mathbf{121}\ \text{PSI}$$

$$\mathbf{S}_T = \frac{Y\ C_f\ M_s}{t\text{Š}\ B} - (Z\ S_R) = \frac{11.1025 * 1.0000 * 860409}{4.5400\text{Š} * 42.1250} - (\ 5.7280 * 121) = \mathbf{10309}\ \text{PSI}$$

$$\frac{S_H + S_R}{2} = \frac{14831 + 121}{2} = \mathbf{7476}\ \text{PSI} \qquad \frac{S_H + S_T}{2} = \frac{14831 + 10309}{2} = \mathbf{12570}\ \text{PSI}$$

$$\mathbf{S}_c = \text{Max}\ \text{¥¦}\ \frac{S_H + S_R}{2}\ ,\ \frac{S_H + S_T}{2}\ \text{§..} = \mathbf{12570}\ \text{PSI} \qquad \mathbf{S}_{Hmax} = 1.5 * S_{fa} = 1.5 * 20000 = \mathbf{30000}\ \text{PSI}$$

Since (S_H <= S_{Hmax}), (S_R <= S_{fa}), (S_T <= S_{fa}), (S_c <= S_{fa}), nominal thickness is **ADEQUATE** for seating conditions

Rigidity Index per Appendix 2-14 - Operating Conditions

$$J = \frac{52.14\ M_oV}{LEg_0\text{Š}h_0K_I} = \frac{52.14 * 773630 * 0.5501}{22.0356 * 26.0\text{x}10\text{Ž} * 0.2500\text{Š} * 3.2452 * 0.3} = \mathbf{0.64}$$

J <= 1, design meets Flange Rigidity requirements for Operating Conditions

Rigidity Index per Appendix 2-14 - Seating Conditions

$$J = \frac{52.14\ M_sV}{LEg_0\text{Š}h_0K_I} = \frac{52.14 * 860409 * 0.5501}{22.0356 * 26.0\text{x}10\text{Ž} * 0.2500\text{Š} * 3.2452 * 0.3} = \mathbf{0.71}$$

J <= 1, design meets Flange Rigidity requirements for Seating Conditions

Minimum Thickness = **3.7512** in.

Nominal Thickness Selected = **4.5400** in.

Cylindrical Channel Shell Design Information

Design Pressure:	150.00 PSI		Design Temperature:	350	°F
Static Head:	0.00 PSI		Joint Efficiency:	100	%
Channel Shell Material:	SA-516 Gr 70		Factor B Chart:	CS-2	
			Material Stress (hot):	20000	PSI
Channel Shell Length:	30.0000 in.		Material Stress (cold):	20000	PSI
Corrosion Allowance:	0.0625 in.		Actual Circumferential Stress:	16940	PSI
External Corrosion Allowance:	0.0000 in.		Actual Longitudinal Stress:	8395	PSI
Inside Diameter (new):	42.0000 in.				
Inside Diameter (corroded):	42.1250 in.		Specific Gravity:	1.00	
Channel Shell Surface Area:	27.82 Sq. Ft.		Weight of Fluid:	1503.30	lb.
Channel Shell Estimated Volume:	179.95 Gal.		Total Flooded Channel Shell Weight:	1785.02	lb.
			Channel Shell Weight:	281.72	lb.

Minimum Design Metal Temperature Data

Min. Temperature Curve:	B	Pressure at MDMT:	200.00	PSI
UCS-66(b) reduction:	Yes	Minimum Design Metal Temperature:	-20	°F
UCS-68(c) reduction:	No	Computed Minimum Temperature:	-20	°F

External Pressure Data

Design Pressure (Pa):	15.00 PSI	Design Temperature:	650	°F
Dimension L:	30.0000 in.			
Ext. Minimum t:	0.1849 in.	Ext. Nominal t:	0.2500	in.
Minimum L/Do:	0.7059	Nominal L/Do:	0.7059	
Minimum Do/t:	347.2220	Nominal Do/t:	226.6670	
Minimum Factor A:	0.0003112	Nominal Factor A:	0.0005952	
Minimum Factor B:	3910 PSI	Nominal Factor B:	7268	PSI

Design Thickness Calculations

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

$$t = \frac{PR}{2SE + 0.4P} = \frac{150.00 * 21.0625}{2 * 20000 * 1.00 + 0.4 * 150.00} = 0.0789 + 0.0625 \text{ (corrosion)} + 0.0000 \text{ (ext. corrosion)}$$

= minimum of **0.1414** in.

Circumferential Stress Calculations per UG-27(c)(1)

$$t = \frac{PR}{SE - 0.6P} = \frac{150.00 * 21.0625}{20000 * 1.00 - 0.6 * 150.00} = 0.1587 + 0.0625 \text{ (corrosion)} + 0.0000 \text{ (ext. corrosion)}$$

= minimum of **0.2212** in.

Maximum External Pressure Calculation per Paragraph UG-28

Pa (using *nominal* t) $= \frac{4B}{3(D_o / t)} = \frac{4 * 7268}{3 * (42.5000 / 0.1875)}$

= maximum external pressure of **42.75** PSI

Extreme Fiber Elongation Calculation per Paragraph UCS-79

Elongation $= \frac{50t}{Rf} = \frac{50 * 0.2500}{21.1250}$

= elongation of **0.59** %

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

Cylindrical Channel Shell Design Information

Design Pressure:	150.00 PSI		Design Temperature:	350	°F
Static Head:	0.00 PSI		Joint Efficiency:	100	%
Channel Shell Material:	SA-516 Gr 70		Factor B Chart:	CS-2	
			Material Stress (hot):	20000	PSI
Channel Shell Length:	30.0000 in.		Material Stress (cold):	20000	PSI
Corrosion Allowance:	0.0625 in.		Actual Circumferential Stress:	16940	PSI
External Corrosion Allowance:	0.0000 in.		Actual Longitudinal Stress:	8395	PSI
Inside Diameter (new):	42.0000 in.				
Inside Diameter (corroded):	42.1250 in.		Specific Gravity:	1.00	
Channel Shell Surface Area:	27.82 Sq. Ft.		Weight of Fluid:	1503.30	lb.
Channel Shell Estimated Volume:	179.95 Gal.		Total Flooded Channel Shell Weight:	1785.02	lb.
			Channel Shell Weight:	281.72	lb.

Minimum Design Metal Temperature Data

Min. Temperature Curve:	B	Pressure at MDMT:	200.00	PSI
UCS-66(b) reduction:	Yes	Minimum Design Metal Temperature:	-20	°F
UCS-68(c) reduction:	No	Computed Minimum Temperature:	-20	°F

External Pressure Data

Design Pressure (Pa):	15.00 PSI	Design Temperature:	650	°F
Dimension L:	30.0000 in.			
Ext. Minimum t:	0.1849 in.	Ext. Nominal t:	0.2500	in.
Minimum L/Do:	0.7059	Nominal L/Do:	0.7059	
Minimum Do/t:	347.2220	Nominal Do/t:	226.6670	
Minimum Factor A:	0.0003112	Nominal Factor A:	0.0005952	
Minimum Factor B:	3910 PSI	Nominal Factor B:	7268	PSI

Design Thickness Calculations

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

$$t = \frac{PR}{2SE + 0.4P} = \frac{150.00 * 21.0625}{2 * 20000 * 1.00 + 0.4 * 150.00} = 0.0789 + 0.0625\ _{(corrosion)} + 0.0000\ _{(ext.\ corrosion)}$$ = minimum of **0.1414** in.

Circumferential Stress Calculations per UG-27(c)(1)

$$t = \frac{PR}{SE - 0.6P} = \frac{150.00 * 21.0625}{20000 * 1.00 - 0.6 * 150.00} = 0.1587 + 0.0625\ _{(corrosion)} + 0.0000\ _{(ext.\ corrosion)}$$ = minimum of **0.2212** in.

Maximum External Pressure Calculation per Paragraph UG-28

Pa (using *nominal* t) $= \frac{4B}{3(D_o / t)} = \frac{4 * 7268}{3 * (42.5000 / 0.1875)}$ = maximum external pressure of **42.75** PSI

Extreme Fiber Elongation Calculation per Paragraph UCS-79

Elongation $= \frac{50t}{Rf} = \frac{50 * 0.2500}{21.1250}$ = elongation of **0.59** %

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

TubeSheet Information

Tubesheet Qty:	2		
Material:	SA-516 Gr 70	Design Temperature(T_{ts}):	550 °F
		Configuration:	Type d
Corrosion Allowance Shell Side (ca_{tss}):	0.0625 in.	Material Stress Cold ($S_{a,ts}$):	20000 PSI
Corrosion Allowance Channel Side (ca_{tsc}):	0.0625 in.	Material Stress Hot($S_{o,ts}$):	19700 PSI
Outside Diameter (A):	45.0000 in.	Yield ($S_{y,ts}$):	30050 PSI
		Pass Partition Groove Depth (h_g):	0.0000 in.
Radius to Outermost Hole Center (r_o):	18.6000 in.	Modulus of Elasticity (E_{ts}):	26.9 10Ž PSI
Expanded Length of Tube (ltx):	3.3750 in.	Poisson (r_{ts}):	0.310
Bolt Load (W):	182053 lb.		
Gasket Load Diameter (G_c):	44.2928 in.	Gasket Load Diameter (G_s):	44.2928 in.
Bolt Circle (C):	47.0000 in.		
Nominal Thickness (h):	3.3750 in.	Perform Elastic Plastic calculations:	False
Axial Rigidity of Expansion Joint (K_j):	300000.00 lb./in.	Expansion Joint Convolution ID (D_j):	48.0750 in.
Per UG-23(e), calculate $S_{ps,ts}$ using:	2 x Yield	Calculate using Differential Pressure:	Yes

Minimum Design Metal Temperature per UCS-66

Min. Temperature Curve:	B	Computed MDMT:	-119 °F
UCS-66(b) reduction:	Yes	UCS-68(c) reduction:	No

Shell Information

Description:	Shell 1		
Design Internal Pressure (P_s):	200.00 PSI	Design Temperature (T_s):	650 °F
Static Head :	0.00 PSI	Design Vacuum Pressure ($P_{s,vac}$):	15.00 PSI
Material:	SA-516 Gr 70	Factor B Chart:	CS-2
		Material Stress Cold ($S_{a,s}$):	20000 PSI
Inside Diameter (D_s):	42.0000 in.	Material Stress Hot ($S_{o,s}$):	18800 PSI
Thickness (t_s):	0.3125 in.	Yield ($S_{y,s}$):	28200 PSI
Corrosion Allowance (ca_s):	0.0625 in.	Modulus of Elasticity (E_s):	26.0 10Ž PSI
Poisson (r_s):	0.310		
Per UG-23(e), calculate $S_{ps,s}$ using:	3 x Stress		

Channel Information

Description:	Left Channel Shell		
Design Temperature (Tc):	350 °F		
Material:	SA-516 Gr 70	Factor B Chart:	CS-2
		Material Stress Cold ($S_{a,c}$):	20000 PSI
Inside Diameter (D_c):	42.0000 in.	Material Stress Hot ($S_{o,c}$):	20000 PSI
Thickness (t_c):	0.2500 in.	Yield ($S_{y,c}$):	33050 PSI
Corrosion Allowance (ca_c):	0.0625 in.	Modulus of Elasticity (E_c):	28.1 10Ž PSI
Poisson (r_c):	0.310	Per UG-23(e), calculate $S_{ps,c}$ using:	2 x Yield

Tube Information

Design Internal Pressure (P_t):	150.00 PSI	Design Temperature (T_t):	350 °F
Design Vacuum Pressure ($P_{t,vac}$):	15.00 PSI		
Material:	SA-179	Factor B Chart:	CS-1
		Material Stress Cold ($S_{a,t}$):	13400 PSI
Outside Diameter (d_t):	1.5000 in.	Material Stress Hot ($S_{o,t}$):	13400 PSI
Tube-Tubesheet intersection:	Through Tubesheet		
Inside Corrosion Allowance (ca_t):	0.0050 in.	Outside Corrosion Allowance (ca_{ot}):	0.0050 in.
Thickness (t_t):	0.0650 in.	Yield ($S_{y,t}$):	22600 PSI
Length (L_t):	250.0000 in.	Modulus of Elasticity (E_t):	28.1 10Ž PSI
Poisson (r_t):	0.310	Largest Unsupported Span (l):	10.0000 in.
Number of Tubes (N_t):	400	Pattern:	Square
Expansion Depth Ratio (ρ):	1.0000	Pitch (p):	2.5000 in.
Unsupported Span is Between:	A tubesheet and a tube support		

Design Information (Continued)

Lane Information

Untubed Lane Configurations: No Lanes

Tube-to-Tubesheet Weld Information

Calculate Welds Using: UW 20

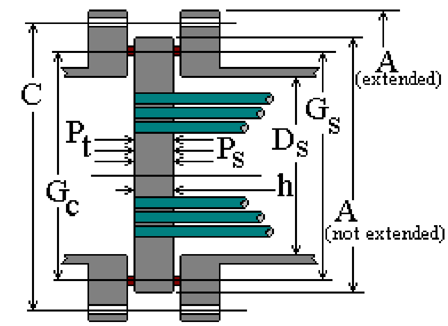
Weld Type: Full Strength

Joint Type: C

Fillet Leg (a_f): 0.0625 in.

Groove Leg (a_g): 0.0625 in.

Fixed Tubesheet



Fixed Tubesheet Calculations per UHX 13.5

Loading Condition	Loading Case	Corroded	P_s (PSI)	S_s (PSI)	$S_{y,s}$ (PSI)	E_s (10Ž PSI)	P_t (PSI)	S_T (PSI)	$S_{y,t}$ (PSI)	E_t (10Ž PSI)
Design	Case 3	Yes	200.00	18800	28200	26.0	150.00	13400	22600	28.1
		No	200.00	18800	28200	26.0	150.00	13400	22600	28.1
	Case 4	Yes	0.00	18800	28200	26.0	0.00	13400	22600	28.1
		No	0.00	18800	28200	26.0	0.00	13400	22600	28.1
	Case 7	Yes	200.00	18800	28200	26.0	150.00	13400	22600	28.1
		No	200.00	18800	28200	26.0	150.00	13400	22600	28.1

Loading Condition	Loading Case	Corroded	S_c (PSI)	$S_{y,c}$ (PSI)	E_c (10Ž PSI)	S_{ts} (PSI)	$S_{y,ts}$ (PSI)	E_{ts} (10Ž PSI)
Design	Case 3	Yes	20000	33050	28.1	19700	30050	26.9
		No	20000	33050	28.1	19700	30050	26.9
	Case 4	Yes	20000	33050	28.1	19700	30050	26.9
		No	20000	33050	28.1	19700	30050	26.9
	Case 7	Yes	20000	33050	28.1	19700	30050	26.9

UHX 13.5 (Continued)

Loading Condition	Loading Case	Corroded	S_c (PSI)	$S_{y,c}$ (PSI)	E_c (10Ž PSI)	S_{ts} (PSI)	$S_{y,ts}$ (PSI)	E_{ts} (10Ž PSI)
Design	Case 7	No	20000	33050	28.1	19700	30050	26.9

$\mathbf{S_{PS,s}} = 3\ S_s = 3 * 18800 =$ 56400 PSI

$\mathbf{S_{PS,c}} = 2\ S_{y,c} = 2 * 33050 =$ 66100 PSI

$\mathbf{S_{PS,ts}} = 2\ S_{y,ts} = 2 * 30050 =$ 60100 PSI

UHX 13.5.1 Step 1

Determination of Effective Dimensions and Ligament Efficiencies per UHX 11.5.1

$\mathbf{D_o} = 2\ r_o + d_t = 2 * 18.6000 + 1.5000 =$ 38.7000 in.

$j = \frac{p - d_t}{p} = \frac{2.5000 - 1.5000}{2.5000} =$ 0.400

$\mathbf{h_g'} = MAX[\ h_g - ca_{tsc}, 0\ ] = MAX[\ 0.0000 - 0.0625\ , 0\ ] =$ 0.0000 in.

$o = \frac{\{_{tx}}{h} = \frac{3.2500}{3.3750} =$ 1.0000

$\mathbf{d^*} = MAX \left\{ \left[d_t - 2\ t_t \left(\frac{E_{t,ts}}{E_{ts}} \right) \left(\frac{S_{t,ts}}{S_{ts}} \right) o \right], (d_t - 2\ t_t) \right\}$

$MAX \left\{ \left[1.5000 - 2 * 0.0600 \left(\frac{26.9 * 10Ž}{26.9 * 10Ž} \right) \left(\frac{13350}{19700} \right) 1.0000 \right], (1.5000 - 2 * 0.0600) \right\} =$ 1.4187 in.

$\mathbf{p^*} = \frac{p}{\sqrt{\left(1 - \frac{4\ MIN(\ A_L, 4D_o p\ )}{mD_oŠ} \right)}} = \frac{2.5000}{\sqrt{\left(1 - \frac{4 * Min(0.0000,\ 4 * 38.7000 * 2.5000\ ),}{m * 38.7000Š} \right)}} =$ 2.5000 in.

$\mathbf{a_o} = \frac{D_o}{2} = \frac{38.7000}{2} =$ 19.3500 in.

$\mathbf{a_s} = \frac{G_s}{2} = \frac{44.2928}{2} =$ 22.1464 in.

$o_s = \frac{a_s}{a_o} = \frac{22.1464}{19.3500} =$ 1.1445

$\mathbf{a_c} = \frac{G_c}{2} = \frac{44.2928}{2} =$ 22.1464 in.

UHX 13.5.1 (Continued)

$$\rho_c = \frac{a_c}{a_o} = \frac{22.1464}{19.3500} =$$ 1.1445

$$\mathbf{x_s} = 1 - N_t \left(\frac{d_t}{2\,a_o} \right)^2 = 1 - 400 \left(\frac{1.4900}{2 * 19.3500} \right)^2 =$$ 0.4071

$$\mathbf{x_t} = 1 - N_t \left(\frac{d_t - 2\,t_t}{2\,a_o} \right)^2 = 1 - 400 \left(\frac{1.4900 - 2 * 0.0550}{2 * 19.3500} \right)^2 =$$ 0.4914

UHX 13.5.2 Step 2

$\mathbf{L}_{t\ (corroded)} = L_{t\ (new)} - (2 * Cats,c) = 250.0000 - (2 * 0.0625) =$ 249.8750 in.

$\mathbf{L} = L_t - 2\,h = 249.8750 - 2 * 3.3750 =$ 243.3750 in.

$$\mathbf{K_s} = \frac{\pi\, t_s\,(D_s + t_s)\,E_s}{L} = \frac{\pi * 0.2500\,(42.1250 + 0.2500)\,26.0 * 10^6}{243.3750} =$$ 3555470 lb./in.

$$\mathbf{K_t} = \frac{\pi\, t_t\,(d_t - t_t)\,E_t}{L} = \frac{\pi * 0.0550\,(1.4900 - 0.0550)\,28.1 * 10^6}{243.3750} =$$ 28628 lb./in.

$$\mathbf{K_{s,t}} = \frac{K_s}{N_t\,K_t} = \frac{3555470}{400 * 28628} =$$ 0.3105

$$\mathbf{J} = \frac{1}{1 + \frac{K_s}{K_j}} = \frac{1}{1 + \frac{3555470}{300000.00}} =$$ 0.077812

$\beta_s =$ 0.0000 $in.^{-1}$

$\mathbf{k_s} =$ 0 lb.

$\lambda_s =$ 0 PSI

$\delta_s =$ 0.000000000000 $in.^3/lb.$

$\beta_c =$ 0.0000 $in.^{-1}$

$\mathbf{k_c} =$ 0 lb.

$\lambda_c =$ 0 PSI

UHX 13.5.2 (Continued)

a_c = 0.000000000000 in.‹/lb.

UHX 13.5.3 Step 3

$j^* = \frac{p^* - d^*}{p^*} = \frac{2.5000 - 1.4187}{2.5000} =$ 0.4325

Determination of Effective Elastic properites per UHX 11.5.2

$\frac{h}{p} = \frac{3.3750}{2.5000} =$ 1.3000

$\frac{E^*}{E_{ts}}$ = $^_0$ + $^_1$ j * + $^_2$ j *Š + $^_3$ j *‹ + $^_4$ j *Œ

$\frac{14.0 * 10Ž}{26.9 * 10Ž}$ = 0.0382 + 1.1579 * 0.4325 + -0.8567 * 0.4325Š + 2.7374 * 0.4325‹ + -2.2893 * 0.4325Œ = 0.5201

r* = $\_{0}$ + $\_{1}$ j * + $\_{2}$ j *Š + $\_{3}$ j *‹ + $\_{4}$ j *Œ

0.3471 + -0.1611 * 0.4325 + 0.0972 * 0.4325 Š + 0.1432 * 0.4325‹ + -0.1293 * 0.4325Œ = 0.303

X_a = i¢ 24 (1 - r*Š) N_t $\frac{E_t t_t (d_t - t_t) a_o Š}{E^* L h‹}$ £¤ •

i¢ 24 (1 - 0.303Š) 400 $\frac{28.1 * 10Ž * 0.0550 (1.4900 - 0.0550) 19.3500Š}{14.0 * 10Ž * 243.3750 * 3.3750‹}$ £¤ • = 2.8049

Loading Condition	Loading Case	CA	Vac.	ber	bei	ber'	bei'	v_1	v_2
Design	Case 3	Yes	No	0.058730	1.757546	-1.305587	0.957593	1.433116	-0.179226
		No	No	0.007637	1.794099	-1.355689	0.945930	1.461769	-0.224246
	Case 4	Yes	No	0.058730	1.757546	-1.305587	0.957593	1.433116	-0.179226
		No	No	0.007637	1.794099	-1.355689	0.945930	1.461769	-0.224246
	Case 7	Yes	No	0.058730	1.757546	-1.305587	0.957593	1.433116	-0.179226
		No	No	0.007637	1.794099	-1.355689	0.945930	1.461769	-0.224246

Z_a = bei' [X_a] v_2 [X_a] - ber' [X_a] v_1 [X_a]

0.957593 * (-0.179226) - (-1.305587) * 1.433116 = 1.699433

$Z_d = \frac{ber [X_a] v_2 [X_a] + bei [X_a] v_1 [X_a]}{X_a‹ Z_a}$

$\frac{0.058730 * (-0.179226) + 1.757546 * 1.433116}{2.8049‹ * 1.699433} =$ 0.066883

UHX 13.5.3 (Continued)

$$\mathbf{Z_v} = \frac{ber'[X_a]\ v_2[X_a] + bei'[X_a]\ v_1[X_a]}{X_a\text{Š}Z_a} =$$

$$\frac{(-1.305587) * (-0.179226) + 0.957593 * 1.433116}{2.8049\text{Š} * 1.699433} = \quad 0.120143$$

$$\mathbf{Z_m} = \frac{ber'[X_a]\text{Š} + bei'[x_a]\text{Š}}{X_a Z_a} = \frac{(-1.305587)\text{Š} + 0.957593\text{Š}}{2.8049 * 1.699433} = \quad 0.549966$$

UHX 13.5.4 Step 4

$$\mathbf{K} = \frac{A}{D_o} = \frac{45.0000}{38.7000} = \quad 1.1628$$

$$\mathbf{F} = \frac{1 - r^*}{E^*}\ (i_s + i_c + E_{ts} \ln K) =$$

$$\frac{1 - 0.303}{14.0 * 10\text{Ž}}\ (0 + 0 + 26.9 * 10\ \text{Ž} * \ln 1.1628) = \quad 0.2020$$

$$c = (1 + r^*)\ F = (1 + 0.303)\ 0.2020 = \quad 0.2632$$

$$\mathbf{Q_1} = \frac{o_s - 1 - c\ Z_v}{1 + c\ Z_m} = \frac{1.1445 - 1 - 0.2632 * 0.120143}{1 + 0.2632 * 0.549966} = \quad 0.098605$$

$$\mathbf{Q_{Z1}} = \frac{(Z_d + Q_1 Z_v)\ X_a\text{Œ}}{2} = \frac{(0.066883 + 0.098605 * 0.120143)\ 2.8049\text{Œ}}{2} = \quad 2.436566$$

$$\mathbf{Q_{Z2}} = \frac{(Z_v + Q_1 Z_m)\ X_a\text{Œ}}{2} = \frac{(0.120143 + 0.098605 * 0.549966)\ 2.8049\text{Œ}}{2} = \quad 5.396563$$

$$\mathbf{U} = \frac{[Z_v + (o_s - 1)\ Z_m]\ X_a\text{Œ}}{1 + c\ Z_m} = \frac{[0.120143 + (1.1445 - 1)\ 0.549966]\ 2.8049\text{Œ}}{1 + 0.2632 * 0.549966} = \quad 10.793132$$

UHX 13.5.5 Step 5

$$t_{\mathbf{s}} = o_s k_s \__s a_s (1 + h\ \__s) = 1.1445 * 0 * 0.0000 * 0.000000000000 * (1 + 3.3750 * 0.0000) = \quad 0.0000 \text{ sq. in.}$$

$$t_{\mathbf{s}}^* = a_o\text{Š}\frac{(o_s\text{Š} - 1)(o_s - 1)}{4} - t_s = 19.3500\text{Š}\frac{(1.1445\text{Š} - 1) * (1.1445 - 1)}{4} - 0.0000 = \quad 4.1914 \text{ sq. in.}$$

$$t_{\mathbf{c}} = o_c k_c \__c a_c (1 + h\ \__c) = 1.1445 * 0 * 0.0000 * 0.000000000000 * (1 + 3.3750 * 0.0000) = \quad 0.0000 \text{ sq. in.}$$

$$t_{\mathbf{c}}^* = a_o\text{Š}\ \text{¥¦}\ \frac{(o_c\text{Š} + 1)(o_c - 1)}{4} - \frac{(o_s - 1)}{2}\ \text{§¨} - t_c =$$

$$19.3500\text{Š}\ \text{¥¦}\ \frac{(1.1445\text{Š} + 1) * (1.1445 - 1)}{4} - \frac{(1.1445 - 1)}{2}\ \text{§¨} - 0.0000 = \quad 4.1914 \text{ sq. in.}$$

UHX 13.5.5 (Continued)

Loading Condition	Loading Case	CA	Vac.	e (in.)
Design	Case 3	Yes	No	0.0000
		No	No	0.0000
	Case 4	Yes	No	-0.4053
		No	No	-0.4051
	Case 7	Yes	No	-0.4053
		No	No	-0.4051

$$e_b = \frac{G_c - G_s}{D_o} = \frac{44.2928 - 44.2928}{38.7000} = \quad 0.0000$$

Loading Condition	Loading Case	CA.	Vac.	T_r (°F)	T_s* (°F)	T_c* (°F)	P_s* (PSI)	P_c* (PSI)
Design	Case 3	Yes	No	NC	NC	NC	NC	NC
		No	No	NC	NC	NC	NC	NC
	Case 4	Yes	No	NC	NC	NC	NC	NC
		No	No	NC	NC	NC	NC	NC
	Case 7	Yes	No	NC	NC	NC	NC	NC
		No	No	NC	NC	NC	NC	NC

UHX 13.5.6 Step 6

$$\mathbf{P'_s} = \left\{x_s + 2(1 - x_s)\,\nu_t + \frac{2}{K_{s,t}}\left(\frac{D_s}{D_o}\right)^2 \rho_s - \frac{\rho_s^2 - 1}{JK_{s,t}} - \frac{(1-J)}{2\,JK_{s,t}}\,\frac{[D_J^2 - (2a_s)^2]}{D_o^2}\right\} P_s =$$

$$\left\{0.4071 + 2(1 - 0.4071)\,0.310 + \frac{2}{0.3105}\left(\frac{42.1250}{38.7000}\right)^2 0.310 - \frac{1.1445^2 - 1}{0.077812 * 0.3105} - \frac{(1 - 0.077812)}{2 * 0.077812 * 0.3105}\,\frac{[48.0750^2 - (2 * 22.1464)^2]}{38.7000^2}\right\} 200.00 = \quad -2827.39 \text{ PSI}$$

$$\mathbf{P'_t} = \left(x_t + 2(1 - x_t)\,\nu_t + \frac{1}{JK_{s,t}}\right) P_t =$$

$$\left(0.4914 + 2(1 - 0.4914)\,0.310 + \frac{1}{0.077812 * 0.3105}\right) 150.00 = \quad 6329.46 \text{ PSI}$$

UHX 13.5.6 (Continued)

$P_e = \frac{N_t K_t}{m a_o Š} e = \frac{400 * 28628}{m * 19.3500Š} 0.0000 =$ 0.00 PSI

$P_W = - \frac{U}{a_o Š} \frac{e_b}{2\,m} W = - \frac{10.793132}{19.3500Š} * \frac{0.0000}{2\,m} * 182053 =$ 0.00 PSI

$P_{rim} = - \frac{U}{a_o Š} (t_s * P_s - t_c * P_t) = - \frac{10.793132}{19.3500Š} * (4.1914 * 200.00 - 4.1914 * 150.00) =$ -6.04 PSI

$P_e = \frac{JK_{s,t}}{1 + JK_{s,t} [Q_{Z1} + (o_s - 1) Q_{Z2}]} (P'_s - P'_t + P_e + P_W + P_{rim}) =$

$\frac{0.077812 * 0.3105}{1 + 0.077812 * 0.3105 [2.436566 + (1.1445 - 1) 5.396563]} * (-2827.39 - 6329.46 + 0.00 + 0.00 + -6.04) =$

-205.42 PSI

Loading Condition	Loading Case	CA	Vac.	P'_s (PSI)	P'_t (PSI)	P_e (PSI)	P_t (PSI)	P_W (PSI)	P_{rim} (PSI)	P_e (PSI)
Design	Case 3	Yes	No	-2827.39	6329.46	0.00	NC	0.00	-6.04	-205.42
		No	No	-3439.52	7349.37	0.00	NC	0.00	-6.29	-209.67
	Case 4	Yes	No	0.00	0.00	-3945.62	NC	0.00	0.00	-88.45
		No	No	0.00	0.00	-4663.18	NC	0.00	0.00	-90.57
	Case 7	Yes	No	-2827.39	6329.46	-3945.62	NC	0.00	-6.04	-293.87
		No	No	-3439.52	7349.37	-4663.18	NC	0.00	-6.29	-300.25

UHX 13.5.7 Step 7

$Q_2 = \frac{(t_s * P_s - t_c * P_t) + \frac{e_b}{2\,m} W}{1 + C Z_m} =$

$\frac{(4.1914 * 200.00 - 4.1914 * 150.00) + \frac{0.0000}{2 * m} * 182053}{1 + 0.2632 * 0.549966} =$

183.072303 lb.

$Q_3 = Q_1 + \frac{2Q_2}{P_e a_o Š} = 0.098605 + \frac{2 * 183.072303}{-205.42 * 19.3500Š} =$ 0.093845

UHX 13.5.7 (Continued)

$$p = \left(\frac{1.5\, F_m}{j^*} \right) \left(\frac{2\, a_o}{h - h'_g} \right) P_e = \left(\frac{1.5 * 0.128058}{0.4325} \right) * \left(\frac{2 * 19.3500}{3.3750 - 0.0000} \right) * -205.42$$

-12936 PSI

Tubesheet bending ratio $= \left| \frac{p}{1.5 * S} \right| = \left| \frac{-12936}{1.5 * 19700} \right| =$ 0.44

Loading Condition	Loading Case	CA	Vac.	Q_2 (lb.)	Q_3	Q_m	Q_v	F_m	p (PSI)	Maximum Allowed Bending Stress (PSI)
Design	Case 3	Yes	No	183.072303	0.093845	0.686419	0.191700	0.128058	-12936	29550
		No	No	183.360960	0.094605	0.686562	0.187591	0.126272	-12073	29550
	Case 4	Yes	No	0.000000	0.098605	0.686419	0.191700	0.129692	-5641	60100
		No	No	0.000000	0.099276	0.696967	0.186604	0.127898	-5282	60100
	Case 7	Yes	No	183.072303	0.095277	0.686419	0.191700	0.128550	-18577	60100
		No	No	183.360960	0.096014	0.696967	0.186604	0.126761	-17355	60100

UHX 13.5.8 Step 8

$$q = \left(\frac{1}{2\, j} \right) \left(\frac{a_o}{h} \right) P_e = \left(\frac{1}{2 * 0.400} \right) \left(\frac{19.3500}{3.3750} \right) -205.42 =$$

-1529 PSI

Tubesheet Shear ratio $= \left| \frac{q}{0.8 * S} \right| = \left| \frac{-1529}{0.8 * 19700} \right| =$ 0.10

Loading Condition	Loading Case	CA	Vac.	q (PSI)	Maximum Allowed Shear Stress (PSI)
Design	Case 3	Yes	No	-1529	15760
		No	No	-1503	15760
	Case 4	Yes	No	-658	15760
		No	No	-649	15760
	Case 7	Yes	No	-2187	15760
		No	No	-2152	15760

UHX 13.5.9 Step 9

$\mathbf{F_q} = \dfrac{(Z_d + Q_3 Z_v) X_a Œ}{2} = \dfrac{(0.066883 + 0.093845 * 0.120143) * 2.8049Œ}{2} =$ 2.418867

$p_{to} = \dfrac{(P_s x_s - P_t x_t) - P_e F_q}{x_t - x_s} = \dfrac{(200.00 * 0.4071 - 150.00 * 0.4914) - -205.42 * 2.418867}{0.4914 - 0.4071} =$ 5986 PSI

Tube stress ratio $= \left|\dfrac{p_{to}}{S_t}\right| = \left|\dfrac{5986}{13400}\right| =$ 0.45

Loading Condition	Loading Case	CA	Vac.	F_q	p_{to} (PSI)	Maximum Allowable Axial Tube Stress (PSI)	Maximum Allowable Buckling Stress (PSI)
Design	Case 3	Yes	No	2.418867	5986	13400	NC
		No	No	2.470042	5250	13400	NC
	Case 4	Yes	No	2.436566	2557	26800	NC
		No	No	2.488040	2262	26800	NC
	Case 7	Yes	No	2.424191	8542	26800	NC
		No	No	2.475471	7513	26800	NC

Tube-To-Tubesheet Welds per UW 20

Weld strength per UW 20.3

$\mathbf{S_w}$ = MIN [$S_{t,ts}$, S_{ts}] = MIN [13350 , 19700] = 13350 PSI

Weld strength factor per UW 20.3

$\mathbf{f_w} = \dfrac{S_{t,ts}}{S_w} = \dfrac{13350}{13350} =$ 1.00

Tube strength factor per UW 20.3

$\mathbf{F_t}$ = t_t m (d_o - t_t) $S_{t,ts}$ = 0.0550 * m (1.4900 - 0.0550) 13350 = 3310 lb.

Ratio of design strength to tube strength per UW 20.3

$\mathbf{f_d}$ = 1.00

Groove Weld strength per UW 20.3

$\mathbf{F_g}$ = MIN [(0.85 m a_g (d_o + 0.67 a_g) S_w) , F_t] =

MIN [(0.85 * m * 0.0625 (1.4900 + 0.67 * 0.0625) 13350) , 3310] = 3310 lb.

Tube-To-Tubesheet Welds (Continued)

Size of Tube-to-Tubesheet strength welds per UW 20.6(c)

$a_r = 2 [\sqrt{(0.75\ d_o)^2 + 1.07\ t_t\ (d_o - t_t)\ f_w\ f_d} - 0.75\ d_o]$

$2 [\sqrt{(0.75 * 1.4900)^2 + 1.07 * 0.0550\ (1.4900 - 0.0550)\ 1.00 * 1.00} - 0.75 * 1.4900] =$ 0.0743 in.

Per UW 20.6(c) $a_f = a_g$

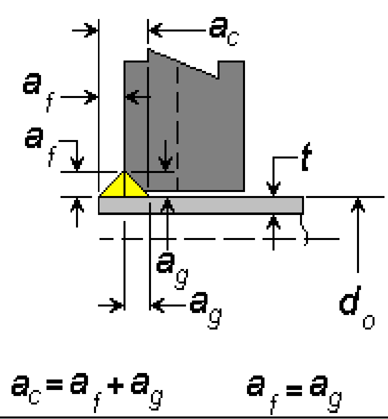
$a_c = Max(a_r, t_t) = Max(0.0743, 0.0550) =$ 0.0743 in.

$a_{fr} = \frac{a_c}{2} = \frac{0.0743}{2} =$ 0.0372 in.

$a_{gr} = \frac{a_c}{2} = \frac{0.0743}{2} =$ 0.0372 in.

$a_f\ ;\ a_{fr} = 0.0625\ ;\ 0.0372$ TRUE
$a_g\ ;\ a_{gr} = 0.0625\ ;\ 0.0372$ TRUE

Weld Image



Tube-To-Tubesheet Welds Summary

Tube Load $= t_t\ \pi\ (d_o - t_t)\ |p_{t,o}| = 0.0550 * \pi * (1.4900 - 0.0550) * |5986| =$ 1484 lb.

$L_{max} = F_t =$ 3310 lb.

Load Ratio = Tube Load / L_{max} = 1484 / 3310 = 0.45

Loading Condition	Loading Case	CA	Vac.	Tube Load (lb.)	L_{max} (lb.)	Load Ratio
Design	Case 3	Yes	No	1484	3310	0.45
		No	No	1538	3912	0.39
	Case 4	Yes	No	634	6620	0.10
		No	No	663	7824	0.08

Tube-To-Tubesheet Welds (Continued)

Loading Condition	Loading Case	CA	Vac.	Tube Load (lb.)	L_{max} (lb.)	Load Ratio
Design	Case 7	Yes	No	2118	6620	0.32
		No	No	2202	7824	0.28

Minimum Design Metal Temperature per UCS-66

$$t_{gh} = \frac{h}{4} = \frac{3.3750}{4} = \quad 0.8438 \text{ in.}$$

$$t_g = t_{gh} = \quad 0.8438 \text{ in.}$$

Loading Condition	Loading Case	Corroded	P_s (PSI)	S_s (PSI)	$S_{y,s}$ (PSI)	E_s (10Ž PSI)	P_t (PSI)	S_T (PSI)	$S_{y,t}$ (PSI)	E_t (10Ž PSI)
MDMT	Case 7	Yes	200.00	20000	38000	29.9	150.00	13400	26000	29.9
		No	200.00	20000	38000	29.9	150.00	13400	26000	29.9

MDMT = -119 °F

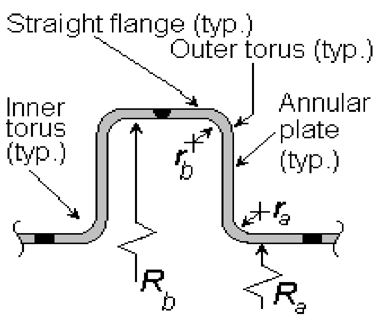
Flexible Element Information

Description:	Thick Wall Expansion Joint 1		
Design Pressure (P):	200.00 PSI	Nominal (t):	0.5625 in.
Temperature:	650 °F	Configuration:	Flanged and Flued
Material:	SA-516 Gr 70	Hot Stress (So):	18800 PSI
		Cold Stress (Sa):	20000 PSI
Axial Rigidity:	300000 lb./in.	Number of Joints:	1
Joint Efficiency (Circ.):	100 %	Joint Efficiency (Long.):	100 %
Corrosion Allowance:	0.0375 in.	Thin Out:	0.0375 in.
Outer Torus (R_b):	24.0000 in.	Outer Torus knuckle radius (r_b):	1.0000 in.
Inner Torus (R_a):	21.0000 in.	Inner Torus knuckle radius (r_a):	1.0000 in.
Outer Straight Flange Length:	1.0000 in.	Inner Straight Flange Length:	3.0000 in.
Calculate Sps by using:	3x Stress	Use High Alloy Min. thickness requirements:	No

Minimum Design Metal Temperature Data

Min. Temperature Curve:	B	Pressure at MDMT:	200.00 PSI
UCS-68(c) reduction:	No	Minimum Design Metal Temperature:	-20 °F
Computed Min. Temperature:	-1 °F		

Thick Wall Expansion Joint



Maximum Allowable Stresses per ASME Appendix 5-3

Maximum Allowable Stress for Pressure Loadings only per ASME Appendix 5-3(a)(1) **= 28200 PSI**

Maximum stress for Pressure plus Axial Deflection loadings per ASME Appendix 5-3(a)(2) **= 56400 PSI**

Outer Flange and Torus Calculations per ASME Appendix 5-3(c) and 5-3(f)

Minimum r_b = 3 * t = 3 * 0.5625 **= 1.6875 in.**

Inner Flange and Torus Calculations per ASME Appendix 5-3(c) and 5-3(f)

Minimum r_a = 3 * t = 3 * 0.5625 **= 1.6875 in.**

Per ASME Appendix 5-3(f) Inner Flange required thickness using UG-27(c)(1)

$$t = \frac{PR}{SE - 0.6P} + Ca + ThinOut = \frac{200.00 * 21.0375}{18800 * 1.00 - 0.6 * 200.00} + 0.0375 + 0.0375 = 0.2998 \text{ in.}$$

Per ASME Appendix 5-3(f) Inner Flange required thickness using UG-27(c)(2)

$$t = \frac{PR}{2SE + 0.4P} + Ca + ThinOut = \frac{200.00 * 21.0375}{2 * 18800 * 1.00 + 0.4 * 200.00} + 0.0375 + 0.0375 = 0.1865 \text{ in.}$$

Minimum thickness requirements

Minimum required thickness per Appendix 5-2 = = 0.1250 in.

Minimum required flange thickness per Appendix 5-3(f) = = 0.3002 in.

Minimum required thickness is the greater 5-2 and 5-3(f) = = 0.3002 in.

Nominal Thickness = = 0.5625 in.

The expansion joint thickness meets or exceeds the required minimum thickness

Cylindrical Tube Design Information

Tube Quantity:	400				
Design Pressure:	150.00	PSI	Design Temperature:	350	°F
Static Head:	0.00	PSI	Joint Efficiency:	100	%
Tube Material:	SA-179		Factor B Chart:	CS-1	
			Material Stress (hot):	13400	PSI
Tube Length:	250.0000	in.	Material Stress (cold):	13400	PSI
Corrosion Allowance:	0.0050	in.	Actual Circumferential Stress:	1972	PSI
External Corrosion Allowance:	0.0050	in.	Actual Longitudinal Stress:	911	PSI
Outside Diameter (new):	1.5000	in.			
Outside Diameter (corroded):	1.4900	in.	Specific Gravity:	1.00	
Tube Surface Area:	3272.49	Sq. Ft.	Weight of Fluid:	5331.71	lb.
Tube Estimated Volume:	638.22	Gal.	Total Flooded Tube Weight:	13624.51	lb.
			Tube Weight:	8292.81	lb.

Minimum Design Metal Temperature Data

Min. Temperature Curve:	B	Pressure at MDMT:	200.00	PSI
UCS-66(b) reduction:	Yes	Minimum Design Metal Temperature:	-20	°F
UCS-68(c) reduction:	No	Computed Minimum Temperature:	-155	°F

External Pressure Data

Design Pressure (Pa):	200.00	PSI	Design Temperature:	650	°F
Dimension L:	15.0000	in.			
Ext. Minimum t:	0.0451	in.	Ext. Nominal t:	0.0650	in.
Minimum L/Do:	10.0671		Nominal L/Do:	10.0671	
Minimum Do/t:	42.4501		Nominal Do/t:	27.0909	
Minimum Factor A:	0.0006465		Nominal Factor A:	0.0015699	
Minimum Factor B:	6383	PSI	Nominal Factor B:	7820	PSI

Design Thickness Calculations

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

$$\mathbf{t} = \frac{PR}{2SE + 0.4P} = \frac{150.00 * 0.6900}{2 * 13400 * 1.00 + 0.4 * 150.00}$$

= Greater Of (0.0039 (Calculated), 0.0625(Minimum Allowed)) + 0.0050 (corrosion) + 0.0050 (ext. corrosion) = minimum of **0.0139** in.

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

$$\mathbf{t} = \frac{PR_o}{SE + 0.4P} = \frac{150.00 * 0.7450}{13400 * 1.00 + 0.4 * 150.00}$$

= Greater of (0.0083 (Calculated), 0.0625(Minimum Allowed)) + 0.0050 (corrosion) + 0.0050 (ext. corrosion) = minimum of **0.0183** in.

Maximum External Pressure Calculation per Paragraph UG-28

Pa (using *nominal* t) $= \frac{4B}{3(D_o / t)} = \frac{4 * 7820}{3 * (1.4900 / 0.0550)}$ = maximum external pressure of **384.88** PSI

Extreme Fiber Elongation Calculation per Paragraph UCS-79

Elongation $= \frac{50t}{Rf} = \frac{50 * 0.0650}{0.0000}$ = elongation of **0.00** %

Tube Selected: Size = **1.5 in.**, Gage = **16**, Diameter = **1.5000** in., Wall = **0.0650** in.

MDMT Report by Components

Design MDMT is -20 °F

Component	Material	Curve	Pressure	MDMT
Shell 1	SA-516 Gr 70	B	200.00 PSI	-35 °F
Flange Pair, Mates to Flange on Left Chann	SA-516 Gr 70			Impacts Required
Flange Pair, Mates to Flange on Right Chan	SA-516 Gr 70			Impacts Required
5" Inlet	SA-106 Gr B	B	0.00 PSI	-155 °F
5" Outlet	SA-106 Gr B	B	0.00 PSI	-155 °F
Fixed-Tube Bundle	SA-179	B	200.00 PSI	-155 °F
Right Channel Shell	SA-516 Gr 70	B	200.00 PSI	-20 °F
Flange Pair, Mates with Flange on Shell	SA-516 Gr 70			Impacts Required
Mates to Blind Cover on Right End	SA-516 Gr 70			Impacts Required
Blind Cover on Right End	SA-516 Gr 70	B	150.00 PSI	-29 °F
3.5" Outlet	SA-106 Gr B	B	200.00 PSI	-155 °F
Left Channel Shell	SA-516 Gr 70	B	200.00 PSI	-20 °F
Flange Pair, Mating to Shell Flange	SA-516 Gr 70			Impacts Required
Mating Flange to Blind Cover on Left End	SA-516 Gr 70			Impacts Required
Blind Cover for Left End	SA-516 Gr 70	B	150.00 PSI	-32 °F
3.5" Inlet	SA-106 Gr B	B	0.00 PSI	-155 °F
Thick Wall Expansion Joint 1	**SA-516 Gr 70**	**B**	**200.00 PSI**	**-1 °F**
Fixed Tubesheet Gasketed to Shell and Channe	SA-516 Gr 70	B	multiple	-119 °F

Component with highest MDMT: Thick Wall Expansion Joint 1.

Computed MDMT = -1 °F

1 component with a caclulated MDMT DOES NOT meet the design MDMT of -20 °F.

ANSI 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	200.00 PSI	0.00 PSI	256.90 PSI	201.18 PSI	201.18 PSI
Flange Pair, Mates to Flange on L	200.00 PSI	0.00 PSI	NC	325.57 PSI	325.57 PSI
Flange Pair, Mates to Flange on R	200.00 PSI	0.00 PSI	NC	332.69 PSI	332.69 PSI
5" Inlet	200.00 PSI	0.00 PSI	256.90 PSI	201.18 PSI	201.18 PSI
5" Outlet	200.00 PSI	0.00 PSI	256.90 PSI	201.18 PSI	201.18 PSI
Right Channel Shell	150.00 PSI	0.00 PSI	236.41 PSI	177.10 PSI	177.10 PSI
Flange Pair, Mates with Flange on	200.00 PSI	0.00 PSI	NC	339.78 PSI	339.78 PSI
Mates to Blind Cover on Right End	150.00 PSI	0.00 PSI	NC	278.82 PSI	278.82 PSI
Blind Cover on Right End	150.00 PSI	0.00 PSI	182.74 PSI	163.29 PSI	163.29 PSI
3.5" Outlet	150.00 PSI	0.00 PSI	236.45 PSI	177.14 PSI	177.14 PSI
Left Channel Shell	150.00 PSI	0.00 PSI	236.41 PSI	177.10 PSI	177.10 PSI
Flange Pair, Mating to Shell Flan	200.00 PSI	0.00 PSI	NC	294.89 PSI	294.89 PSI
Mating Flange to Blind Cover on L	150.00 PSI	0.00 PSI	NC	278.82 PSI	278.82 PSI
Blind Cover for Left End	150.00 PSI	0.00 PSI	182.74 PSI	173.71 PSI	173.71 PSI
3.5" Inlet	150.00 PSI	0.00 PSI	236.45 PSI	177.14 PSI	177.14 PSI

NC = Not Calculated Inc = Incomplete

Summary

Shell Component with the lowest vessel MAWP(New & Cold) : **Shell 1**
Shell The lowest vessel MAWP(New & Cold) : **256.90** PSI

Shell Component with the lowest vessel MAWP(Hot & Corroded) : **Shell 1**
Shell The lowest vessel MAWP(Hot & Corroded) : **201.18** PSI

Channel Component with the lowest vessel MAWP(New & Cold) : **Blind Cover on Right End**
Channel The lowest vessel MAWP(New & Cold) : **182.74** PSI

Channel Component with the lowest vessel MAWP(Hot & Corroded) : **Blind Cover on Right End**
Channel The lowest vessel MAWP(Hot & Corroded) : **163.29** PSI

Pressures are exclusive of any external loads.

Summary Information

	Dry Weight	Flooded Weight
Shell	2938.97 lb.	15466.45 lb.
Channel Shell	563.45 lb.	3570.04 lb.
Tubesheet	1687.85 lb.	1687.85 lb.
Tube	8235.02 lb.	13483.01 lb.
Nozzle	40.19 lb.	40.19 lb.
Flange	7096.41 lb.	7096.41 lb.
Totals	20561.88 lb.	41343.95 lb.

	Volume
Shell	1499.57 Gal.
Channel Shell	359.90 Gal.
Tube	638.22 Gal.
Nozzle	1.82 Gal.
Totals	2499.50 Gal.

	Area
Shell	232.48 Sq. Ft.
Channel Shell	55.63 Sq. Ft.
Tube	3272.49 Sq. Ft.
Nozzle	3.41 Sq. Ft.
Totals	3564.02 Sq. Ft.

Hydrostatic Test Information (UG-99)

Gauge at Top

Component with controlling ratio is : Right Channel Shell
* Component with controlling pressure is : Right Channel Shell

$$\text{Calculated Test Pressure} = P * 1.3 * \frac{\text{Cold Stress}}{\text{Hot Stress}} = 150.00 * 1.3 * \frac{20000}{20000} =$$ **195.00 PSI**

* The controlling component design pressure is less than vessel design pressure and has limited the UG-99 / UG-100 calculated test pressure.

Table of Contents