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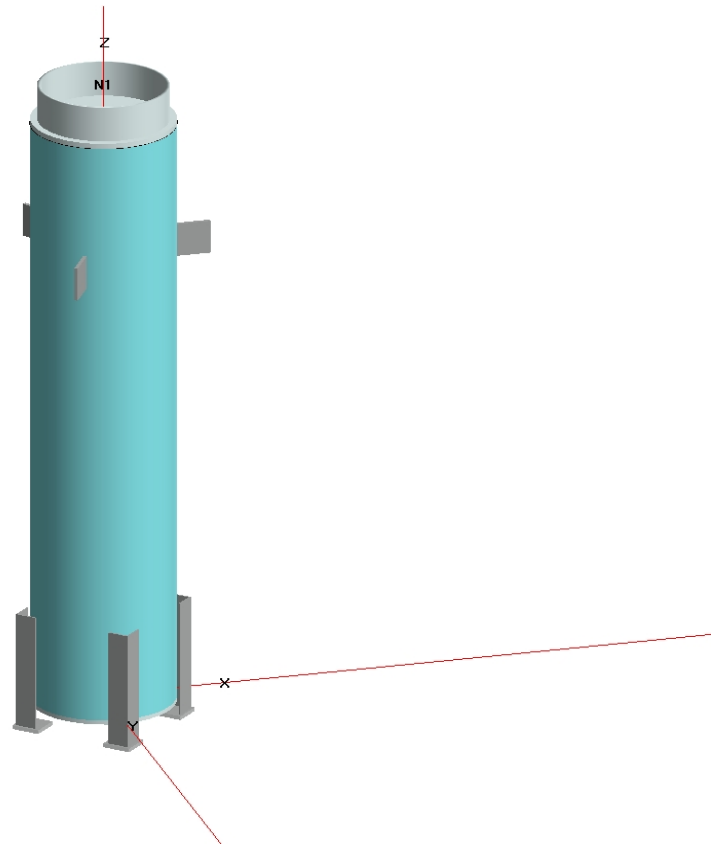

COMPRESS Pressure Vessel Design Calculations

Item:	DES Vessel Vacuum Jacket
Revision	A
Customer:	Fermi National Accelerator Laboratory
Diameter/Thk	20" Std Wt Pipe (.375" Wall)
Design Pressure	Full Vacuum / 3 psig
Revision Date	July 30, 2007

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Engineering Notes

The support legs analyzed in these calculations vary somewhat from the actual design which is shown on drawing 07-1963-0500. This software uses standard pre-designed configurations for vessel legs, skirts, saddles, lugs, etc. that are widely accepted in the pressure vessel industry and the ASME pressure vessel code. When particular support requirements are invoked that vary from these, such as the case in this vessel, the supports are analyzed as close as possible with conservative judgement. In this case the support design is conservative due to the fact that the actual legs do not extend below the bottom of the vessel. In addition, the rectangular tube (fork lift staves) provide increased rigidity due to the integral attachment to the vessel, the legs and the floor (or base). Also, we have incorporated cap plates on the top of the legs which are welded all around. This practice has been proven to enhance the strength of open structures and provides for more uniformly distributed stresses into the vessel wall.

Nozzle Schedule

Nozzle mark	Service	Size	Materials								
			Nozzle	Impact	Norm	Fine Grain	Pad	Impact	Norm	Fine Grain	Flange
N1	Nozzle #1	18" Std Weight	SA-312 TP304 Wld pipe	No	No	No	N/A	N/A	N/A	N/A	N/A

Nozzle Summary

Nozzle mark	OD (in)	t_n (in)	Req t_n (in)	A_1?	A_2?	Shell			Reinforcement Pad		Corr (in)	A_a/A_r (%)
						Nom t (in)	Design t (in)	User t (in)	Width (in)	t_{pad} (in)		
N1	18.00	0.3750	0.3750	Yes	Yes	0.7500*	0.5480		N/A	N/A	0.0000	100.0

t_n: Nozzle thickness

Req t_n: Nozzle thickness required per UG-45/UG-16

Nom t: Vessel wall thickness

Design t: Required vessel wall thickness due to pressure + corrosion allowance per UG-37

User t: Local vessel wall thickness (near opening)

A_a: Area available per UG-37, governing condition

A_r: Area required per UG-37, governing condition

Corr: Corrosion allowance on nozzle wall

* Head minimum thickness after forming

Pressure Summary

Pressure Summary for Chamber bounded by Welded Cover #1 and Welded Cover #2

Identifier	P Design (psi)	T Design (°F)	MAWP (psi)	MAP (psi)	MAEP (psi)	T_e external (°F)	MDMT (°F)	MDMT Exemption	Total Corrosion Allowance (in)	Impact Test
Welded Cover #2	3.0	120.0	92.00	92.00	92.00	120.0	-320.0	Note 1	0.000	No
Cylinder #1	3.0	120.0	485.43	485.43	175.22	120.0	-155.0	Note 2	0.000	No
Welded Cover #1	3.0	120.0	53.03	53.03	53.03	120.0	-155.0	Note 3	0.000	No
Legs #1	3.0	120.0	3.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Clip #1	3.0	120.0	3.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Clip #2	3.0	120.0	3.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Clip #3	3.0	120.0	3.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nozzle #1 (N1)	3.0	120.0	49.60	49.60	49.12	120.0	-320.0	Note 4	0.000	No

Chamber design MDMT is -20.00°F
Chamber rated MDMT is -155.00°F @ 3.00 psi

Chamber MAWP hot & corroded is 3.00 psi @ 120.0°F

Chamber MAP cold & new is 49.60 psi @ 70.0°F

Chamber MAEP is 49.12 psi @ 120.0°F
Vacuum rings did not govern the external pressure rating.

Notes for MDMT Rating:

Note #	Exemption	Details
1.	Impact test exempt per UHA-51(g)(coincident ratio = 0.03261)	
2.	Material is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.00626)	
3.	Head is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.05658).	
4.	Impact test exempt per UHA-51(g)(coincident ratio = 0.00464)	

Design notes are available on the Settings Summary page.

Settings Summary

COMPRESS Build 6252

Units: U.S. Customary

Datum Line Location: 0.00" from bottom seam

Design

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Design or Rating:	Get Thickness from Pressure
Minimum thickness:	1/16" per UG-16(b)
Design for cold shut down only:	No
Design for lethal service (full radiography required):	No
Design nozzles for:	Design P, find nozzle MAWP and MAP
Corrosion weight loss:	100% of theoretical loss
UG-23 Stress Increase:	1.20
Skirt/legs stress increase:	1.0
Minimum nozzle projection:	1.5000"
Juncture calculations for $\alpha > 30$ only:	Yes
Preheat P-No 1 Materials > 1.25" and <= 1.50" thick:	No

Butt welds are tapered per Figure UCS-66.3(a).

Hydro/Pneumatic Test

Shop Hydrotest Pressure:	1.3 times vessel MAWP
Test liquid specific gravity:	1.00
Maximum stress during test:	90% of yield

Required Marking - UG-116

UG-116 (e) Radiography:	None
UG-116 (f) Postweld heat treatment:	None

Code Interpretations

Use Code Case 2547:	No
Apply interpretation VIII-1-83-66:	Yes
Apply interpretation VIII-1-86-175:	Yes
Apply interpretation VIII-1-83-115:	Yes
Apply interpretation VIII-1-01-37:	Yes
Disallow UG-20(f) exemptions:	No

UG-22 Loadings

UG-22 (a) Internal or External Design Pressure :	Yes
UG-22 (b) Weight of the vessel and normal contents under operating or test conditions:	Yes

UG-22 (c) Superimposed static reactions from weight of attached equipment (external loads):	Yes
UG-22 (d)(2) Vessel supports such as lugs, rings, skirts, saddles and legs:	Yes
UG-22 (f) Wind reactions:	Yes
UG-22 (f) Seismic reactions:	Yes

Note: UG-22 (b),(c) and (f) loads only considered when supports are present.

Thickness Summary

Component Identifier	Material	Diameter (in)	Length (in)	Nominal t (in)	Design t (in)	Joint E	Load
Welded Cover #2	SA-240 304	0.00 ID	0.75	0.7500*	0.3028	1.0000	External
Cylinder #1	SA-53 E/B Wld pipe	20.00 OD	90.00	0.3750	0.1200	1.0000	External
Welded Cover #1	SA-36	0.00 ID	0.63	0.6250*	0.3324	1.0000	External

Nominal t: Vessel wall nominal thickness

Design t: Required vessel thickness due to governing loading + corrosion

Joint E: Longitudinal seam joint efficiency

* Head minimum thickness after forming

Load

internal: Circumferential stress due to internal pressure governs

external: External pressure governs

Wind: Combined longitudinal stress of pressure + weight + wind governs

Seismic: Combined longitudinal stress of pressure + weight + seismic governs

Weight Summary

Component	Weight (lb) Contributed by Vessel Elements						
	Metal New*	Metal Corroded*	Insulation & Supports	Lining	Piping + Liquid	Operating Liquid	Test Liquid
Welded Cover #2	7.95	7.95	0.00	0.00	0.00	0.00	44.29
Cylinder #1	588.87	588.87	0.00	0.00	0.00	0.00	945.51
Welded Cover #1	51.48	51.48	0.00	0.00	0.00	0.00	0.00
Legs #1	39.53	39.53	0.00	0.00	0.00	0.00	0.00
TOTAL:	**687.83**	**687.83**	**0.00**	**0.00**	**0.00**	**0.00**	**989.80**

* Shells with attached nozzles have weight reduced by material cut out for opening.

Component	Weight (lb) Contributed by Attachments								
	Body Flanges		Nozzles & Flanges		Packed Beds	Ladders & Platforms	Trays & Supports	Rings & Clips	Vertical Loads
	New	Corroded	New	Corroded					
Welded Cover #2	0.00	0.00	36.13	36.13	0.00	0.00	0.00	0.00	0.00
Cylinder #1	0.00	0.00	18.06	18.06	0.00	0.00	0.00	10.61	1,095.00*
Welded Cover #1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Legs #1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL:	**0.00**	**0.00**	**54.19**	**54.19**	**0.00**	**0.00**	**0.00**	**10.61**	**1,095.00***

* This number includes vertical loads which are not present in all conditions.

Vessel operating weight, Corroded: 1,848 lb
Vessel operating weight, New: 1,848 lb
Vessel empty weight, Corroded: 1,848 lb
Vessel empty weight, New: 1,848 lb
Vessel test weight, New: 1,742 lb

Vessel center of gravity location - from datum - lift condition

Vessel Lift Weight, New: 753 lb
Center of Gravity: 43.96"

Vessel Capacity

Vessel Capacity** (New): 113 US gal
Vessel Capacity** (Corroded): 113 US gal
**The vessel capacity does not include volume of nozzle, piping or other attachments.

Vacuum Summary

Component	Line of Support	Elevation above Datum (in)	Length Le (in)
Welded Cover #2	-	90.75	N/A
-	1/3 depth of Welded Cover #2	90.00	N/A
Cylinder #1 Top	-	90.00	90.00
Cylinder #1 Bottom	-	0.00	90.00
-	1/3 depth of Welded Cover #1	0.00	N/A
Welded Cover #1	-	-0.63	N/A

Note
For main components, the listed value of 'Le' is the largest unsupported length for the component.

Vertical Load #1

Load Orientation:	Vertical Load
Elevation above datum:	45.00"
Direction angle:	0.00 degrees
Distance from center of vessel:	0.00"
Magnitude of force:	1095.00 lb

Present when operating:	Yes
Included in vessel lift weight:	No
Present when vessel is empty:	Yes
Present during hydrotest:	No

Seismic Code

Method of seismic analysis:	**UBC 1997 building mounted**
Seismic Zone:	4
R_p Factor (Table 16-O):	R_p = 3.0000
Soil profile: (Table 16-Q):	SD
Importance Factor:	I_p = 1.0000
Near Source Factor (Table 16-S):	Na = 1.0000
Component Amplification Factor:	a_p = 1.0000
x/h Ratio	1.0000
Vertical Accelerations Considered:	Yes
Force Multiplier:	= 0.3333
Minimum Weight Multiplier:	= 0.6500

Vessel Characteristics

Vessel height: 7.8958 ft
Vessel Weight:

Operating, Corroded: 1,848 lb
Empty, Corroded: 1,848 lb
Vacuum, Corroded: 1,848 lb

Period of Vibration Calculation

Fundamental Period, T:

Operating, Corroded: 0.016 sec (f = 62.6 Hz)
Empty, Corroded: 0.016 sec (f = 62.9 Hz)
Vacuum, Corroded: 0.016 sec (f = 62.6 Hz)

The fundamental period of vibration T (above) is calculated using the Rayleigh method of approximation:

T = 2 * PI * Sqr({Sum(W_i * y_i^2)} / {g * Sum(W_i * y_i)}), where

W_i is the weight of the i^{th} lumped mass, and
y_i is its deflection when the system is treated as a cantilever beam.

Seismic Shear Reports:

Operating, Corroded
Empty, Corroded
Vacuum, Corroded

Base Shear Calculations

Seismic Shear Report: Operating, Corroded

Component	Elevation of bottom above base (in)	Elastic modulus E (10^6 psi)	Inertia I (ft^4)	Seismic shear at Bottom (lbf)	Bending Moment at Bottom (lbf-ft)
Welded Cover #2	94.00	28.0	0.3788	52.06	1.62
Cylinder #1 (top)	4.00	29.2	0.0537	771.05	3,305.57

Legs #1	0.00	29.0	0.0002	774.45	3,563.33
Cylinder #1 (bottom)	4.00	29.2	0.0537	2.70	0.28
Welded Cover #1	4.00	29.2	0.3788	2.43	0.06

Seismic Shear Report: Empty, Corroded

Component	Elevation of bottom above base (in)	Elastic modulus E (10^6 psi)	Inertia I (ft^4)	Seismic shear at Bottom (lbf)	Bending Moment at Bottom (lbf-ft)
Welded Cover #2	94.00	28.3	0.3788	52.06	1.62
Cylinder #1 (top)	4.00	29.4	0.0537	771.05	3,305.57
Legs #1	0.00	29.0	0.0002	774.45	3,563.33
Cylinder #1 (bottom)	4.00	29.4	0.0537	2.70	0.28
Welded Cover #1	4.00	29.4	0.3788	2.43	0.06

Seismic Shear Report: Vacuum, Corroded

Component	Elevation of bottom above base (in)	Elastic modulus E (10^6 psi)	Inertia I (ft^4)	Seismic shear at Bottom (lbf)	Bending Moment at Bottom (lbf-ft)
Welded Cover #2	94.00	28.0	0.3788	52.06	1.62
Cylinder #1 (top)	4.00	29.2	0.0537	771.05	3,305.57
Legs #1	0.00	29.0	0.0002	774.45	3,563.33
Cylinder #1 (bottom)	4.00	29.2	0.0537	2.70	0.28
Welded Cover #1	4.00	29.2	0.3788	2.43	0.06

Vertical Acceleration Term, V_{Accel}

Factor is applied to dead load.
Compressive Side: $= 1.0 + V_{Accel}$

V_{Accel} Term is: greater of (Force Mult * Base Shear / Weight) or (Min. Weight Mult.)				
Force multiplier = 0.3333		Minimum Weight Multiplier = 0.6500		
Condition	**Base Shear (lbf)**	**Weight (lb)**	**Force Mult * Shear / Weight**	**V_{Accel}**
Operating, Corroded	774.25	1,848	0.1397	0.6500
Operating, New	774.25	1,848	0.1397	0.6500
Empty, Corroded	774.25	1,848	0.1397	0.6500
Empty, New	774.25	1,848	0.1397	0.6500
Vacuum, Corroded	774.25	1,848	0.1397	0.6500

Base Shear Calculations

Operating, Corroded
Empty, Corroded

Vacuum, Corroded

Base Shear Calculations: Operating, Corroded

V(32-1) = 4 * C_a * I_p * W_p = 4 * 0.4400 * 1.0000 * 1847.6378 = 3251.8425
V(32-2) = a_p * C_a * I_p * (1 + 3 * (x/h)) * W_p / R_p = 1.0000 * 0.4400 * 1.0000 * (1 + 3 * 1.0000) * 1847.6378 / 3.0000 = 1083.9475
V(32-3) = 0.70 * C_a * I_p * W_p = 0.7 * 0.4400 * 1.0000 * 1847.6378 = 569.0724
To obtain V, take the greater of V(32-2) and V(32-3).
Then take the lesser of this and V(32-1), and divide by 1.4, giving 774.25 lb

Base Shear Calculations: Empty, Corroded

V(32-1) = 4 * C_a * I_p * W_p = 4 * 0.4400 * 1.0000 * 1847.6378 = 3251.8425
V(32-2) = a_p * C_a * I_p * (1 + 3 * (x/h)) * W_p / R_p = 1.0000 * 0.4400 * 1.0000 * (1 + 3 * 1.0000) * 1847.6378 / 3.0000 = 1083.9475
V(32-3) = 0.70 * C_a * I_p * W_p = 0.7 * 0.4400 * 1.0000 * 1847.6378 = 569.0724
To obtain V, take the greater of V(32-2) and V(32-3).
Then take the lesser of this and V(32-1), and divide by 1.4, giving 774.25 lb

Base Shear Calculations: Vacuum, Corroded

V(32-1) = 4 * C_a * I_p * W_p = 4 * 0.4400 * 1.0000 * 1847.6378 = 3251.8425
V(32-2) = a_p * C_a * I_p * (1 + 3 * (x/h)) * W_p / R_p = 1.0000 * 0.4400 * 1.0000 * (1 + 3 * 1.0000) * 1847.6378 / 3.0000 = 1083.9475
V(32-3) = 0.70 * C_a * I_p * W_p = 0.7 * 0.4400 * 1.0000 * 1847.6378 = 569.0724
To obtain V, take the greater of V(32-2) and V(32-3).
Then take the lesser of this and V(32-1), and divide by 1.4, giving 774.25 lb

Wind Code

Building Code:	**UBC 1997**
Elevation of base above grade:	0.0000 ft
Increase effective outer diameter by:	0.0000 ft
Wind Force Coefficient C_q:	0.5600
Basic Wind Speed:, V:	45.0000 mph
Importance Factor:, I_w:	1.0000
Exposure category:	B

Vessel Characteristics	
Vessel height, h:	7.8958 ft
Vessel Minimum Diameter	
Operating, Corroded:	1.6667 ft
Empty, Corroded:	1.6667 ft
Fundamental Frequency	
Operating, Corroded:	62.6354 Hz
Empty, Corroded:	62.8629 Hz
Damping coefficient, β	
Operating, Corroded:	0.0200
Empty, Corroded:	0.0200

Wind Deflection Reports:

Operating, Corroded
Empty, Corroded
Vacuum, Corroded

Wind Pressure Calculations

Wind Deflection Report: Operating, Corroded

Component	Elevation of bottom above base (in)	Effective OD (ft)	Elastic modulus E (10^6 psi)	Inertia I (ft^4)	Platform wind shear at Bottom (lbf)	Total wind shear at Bottom (lbf)	bending moment at Bottom (lbf-ft)	Deflection at top (in)
Welded Cover #2	94.00	1.67	28.0	0.3788	0.00	0.46	0.01	0.0002
Cylinder #1 (top)	4.00	1.67	29.2	0.0537	0.00	54.53	203.93	0.0002
Legs #1	0.00	0.00	29.0	0.0002392	0.00	55.52	222.37	0.0000
Cylinder #1 (bottom)	4.00	1.67	29.2	0.0537	0.00	0.99	0.07	0.0000
Welded Cover #1	4.00	1.67	29.2	0.3788	0.00	0.38	0.01	0.0000

Wind Deflection Report: Empty, Corroded

Component	Elevation of bottom above base (in)	Effective OD (ft)	Elastic modulus E (10^6 psi)	Inertia I (ft^4)	Platform wind shear at Bottom (lbf)	Total wind shear at Bottom (lbf)	bending moment at Bottom (lbf-ft)	Deflection at top (in)
Welded Cover #2	94.00	1.67	28.3	0.3788	0.00	0.46	0.01	0.0002
Cylinder #1 (top)	4.00	1.67	29.4	0.0537	0.00	54.53	203.93	0.0002

Legs #1	0.00	0.00	29.0	0.0002392	0.00	55.52	222.37	0.0000
Cylinder #1 (bottom)	4.00	1.67	29.4	0.0537	0.00	0.99	0.07	0.0000
Welded Cover #1	4.00	1.67	29.4	0.3788	0.00	0.38	0.01	0.0000

Wind Deflection Report: Vacuum, Corroded

Component	Elevation of bottom above base (in)	Effective OD (ft)	Elastic modulus E (10^6 psi)	Inertia I (ft^4)	Platform wind shear at Bottom (lbf)	Total wind shear at Bottom (lbf)	bending moment at Bottom (lbf-ft)	Deflection at top (in)
Welded Cover #2	94.00	1.67	28.0	0.3788	0.00	0.46	0.01	0.0002
Cylinder #1 (top)	4.00	1.67	29.2	0.0537	0.00	54.53	203.93	0.0002
Legs #1	0.00	0.00	29.0	0.0002392	0.00	55.52	222.37	0.0000
Cylinder #1 (bottom)	4.00	1.67	29.2	0.0537	0.00	0.99	0.07	0.0000
Welded Cover #1	4.00	1.67	29.2	0.3788	0.00	0.38	0.01	0.0000

Wind Pressure (WP) Calculations

Wind stagnation pressure q_s = 12.6000 psf
[Table 16-F, page 2-28]

Wind Pressure WP $= C_e * C_q * q_s * I_w$
$= C_e * 0.5600 * 12.6000 * 1.0000$
$= 7.0560 * C_e$
[Equation (20-1), page 2-7]

Design Wind Pressures

Height (')	C_e	WP (psf)
15.0	0.62	4.3747

Welded Cover #2

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Component:	Welded Cover
Material specification:	SA-240 304 (II-D p. 82, ln. 38)

Impact test exempt per UHA-51(g)(coincident ratio = 0.03261)

Internal design pressure: P = 3.0000 psi @ 120.00°F
External design pressure: P_e = 15.0000 psi @ 120.00°F

Static liquid head:

P_{th}=0.3474 psi(SG=1.0000, H_s=9.6250", Horizontal test head)

Corrosion allowance:	Inner C = 0.0000"	Outer C = 0.0000"

Design MDMT = -20.00°F	No impact test performed
Rated MDMT = -320.00°F	Material is not normalized
	Material is not produced to Fine Grain Practice
	PWHT is not performed

Radiography:	Category A joints -	Seamless No RT
Estimated weight:	New = 8.0 lb	corr = 8.0 lb

Head outside diameter = 20.0000"
Cover thickness = 0.7500"

Factor C from Fig. UG-34, sketch (h)

Factor C = 0.33

Design thickness, (at 120.00 °F) UG-34 (c)(2)

t = d*Sqr(C*P/(S*E)) + Corrosion
= 19.25*Sqr(0.33*3/(20,000.00*1)) + 0
= 0.1354 in

Maximum allowable working pressure, (at 120.00 °F)

$P = (S*E/C)*(t/d)^2 - P_s$
$= (20,000.00*1/0.33)*(0.75/19.25)^2 - 0$
= 91.998 psi

Maximum allowable pressure, (At 70.00 °F)

$P = (S*E/C)*(t/d)^2$
$= (20,000.00*1/0.33)*(0.75/19.25)^2$
= 91.998 psi

Design thickness for external pressure, (at 120.00 °F) UG-34(c)(2)

t = d*Sqr(C*P_e/(S*E)) + Corrosion
= 19.25*Sqr(0.33*15/(20,000.00*1)) + 0
= 0.3028 in

Maximum allowable external pressure, (At 120.00 °F)

$P = (S*E/C)*(t/d)^2$
$= (20{,}000.00*1/0.33)*(0.75/19.25)^2$
= 91.998 psi

Nozzle #1 (N1)

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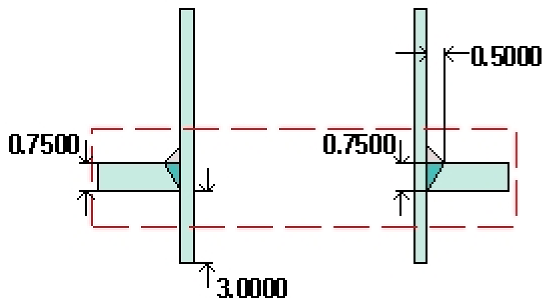

$t_{w(lower)}$ = 0.7500 in
Leg_{41} = 0.5000 in
Leg_{43} = 0.0000 in
h_{new} = 3.0000 in

.

Note: round inside edges per UG-76(c)

Located on:	Welded Cover #2
Liquid static head included:	0 psi
Nozzle material specification:	SA-312 TP304 Wld pipe (II-D p. 86, ln. 11)
Nozzle longitudinal joint efficiency:	1.00
Nozzle description:	18" Std Weight
Nozzle orientation:	0°
Local vessel minimum thickness:	0.75 in
Nozzle inside diameter, new:	17.25 in
Nozzle nominal wall thickness:	0.375 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	5.25 in
Distance to head center, R:	0 in

Reinforcement Calculations for Internal Pressure

Available reinforcement per UG-39 governs the MAWP of this nozzle.

UG-39 Area Calculation Summary (in^2) **For P = 49.6 psi @ 120 °F** **The opening is adequately reinforced**							**UG-45 Nozzle Wall Thickness Summary (in)** **The nozzle passes UG-45**	
A required	**A available**	**A_1**	**A_2**	**A_3**	**A_5**	**A welds**	**t_{req}**	**t_{min}**
4.7809	4.7890	3.4153	0.5635	0.5977	--	0.2125	0.3281	0.3281

Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(1)

UW-16 Weld Sizing Summary			
Weld description	**Required weld throat size (in)**	**Actual weld throat size (in)**	**Status**

Nozzle to shell fillet (Leg_{41})	0.2500	0.3500	weld size is adequate

Reinforcement Calculations for MAP

Available reinforcement per UG-39 governs the MAP of this nozzle.

UG-39 Area Calculation Summary (in^2) For P = 49.6 psi @ 70 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
4.7809	4.7890	3.4153	0.5635	0.5977	--	0.2125	0.3281	0.3281

Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(1)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.3500	weld size is adequate

Reinforcement Calculations for External Pressure

UG-39 Area Calculation Summary (in^2) For Pe = 49.12 psi @ 120 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
4.7573	4.7582	3.4618	0.4862	0.5977	--	0.2125	0.3281	0.3281

Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.3500	weld size is adequate

Cylinder #1

ASME Section VIII Division 1, 2004 Edition, A06 Addenda

Component:	Cylinder
Material specification:	SA-53 E/B Wld pipe (II-D p. 10, ln. 2)
Pipe NPS and Schedule:	20" Sch 20 (Std)

Material is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.00626)

Internal design pressure: P = 3 psi @ 120°F
External design pressure: P_e = 15 psi @ 120°F

Static liquid head:

P_{th}=0.6949 psi(SG=1.0000, H_s=19.2500", Horizontal test head)

Corrosion allowance: Inner C = 0.0000" Outer C = 0.0000"

Design MDMT = -20.00°F	No impact test performed
Rated MDMT = -155.00°F	Material is not normalized
	Material is not produced to Fine Grain Practice
	PWHT is not performed

Radiography:	Longitudinal joint -	Seamless No RT
	Top circumferential joint -	None UW-11(c) Type 2
	Bottom circumferential joint -	None UW-11(c) Type 2

Estimated weight:	New = 588.8704 lb	corr = 588.8704 lb
Capacity:	New = 113.3919 gal	corr = 113.3919 gal

OD = 20.0000"
Length L_c = 90.0000"
t = 0.3750"

Design thickness, (at 120.00°F) Appendix 1-1

t = $P*R_o/(S*E + 0.40*P)$ + Corrosion
= 3.00*10.0000/(14600*1.00 + 0.40*3.00) + 0.0000
= 0.0021"

Maximum allowable working pressure, (at 120.00°F) Appendix 1-1

P = $S*E*t/(R_o - 0.40*t) - P_s$
= 14600*1.00*0.3281 / (10.0000 - 0.40*0.3281) - 0.0000
= 485.4338 psi

Maximum allowable pressure, (at 70.00°F) Appendix 1-1

P = $S*E*t/(R_o - 0.40*t)$
= 14600*1.00*0.3281 / (10.0000 - 0.40*0.3281)
= 485.4338 psi

External Pressure, (Corroded & at 120.00°F) UG-28(c)

L/D_o = 90.0000/20.0000 = 4.5000
D_o/t = 20.0000/0.120035 = 166.6180
From table G: A = 0.000131
From table CS-2: B = 1874.4591 psi

P_a = 4*B/(3*(D_o/t))
= 4*1874.4591/(3*(20.0000/0.120035))
= 15.0001 psi

Design thickness for external pressure P_a = 15.0001 psi

= t + Corrosion = 0.120035 + 0.0000 = 0.1200"

Maximum Allowable External Pressure, (Corroded & at 120.00°F) UG-28(c)

L/D_o = 90.0000/20.0000 = 4.5000
D_o/t = 20.0000/0.3281 = 60.9524
From table G: A = 0.000556
From table CS-2: B = 8010.0127 psi

P_a = 4*B/(3*(D_o/t))
= 4*8010.0127/(3*(20.0000/0.3281))
= 175.2190 psi

External Pressure + Weight + Wind Loading Check (Bergman, ASME paper 54-A-104)

$P_v = W / (2*\pi*R_m) + M / (\pi*R_m^2)$
$= 1805.43 / (2*\pi*9.8125) + 2447.13 / (\pi*9.8125^2)$
= 37.3734 lb/in

$\alpha = P_v / (P_e*D_o)$
= 37.373432 / (15.0000*20.0000)
= 0.1246

n = 2

$m = 1.23 / (L/D_o)^2$
$= 1.23 / (90.000000/20.0000)^2$
= 0.0607

Ratio $P_e = (n^2 - 1 + m + m*\alpha) / (n^2 - 1 + m)$
$= (2^2 - 1 + 0.060741 + 0.060741*0.124578) / (2^2 - 1 + 0.060741)$
= 1.0025

Ratio $P_e * P_e \leq$ MAEP design cylinder thickness is satisfactory.

External Pressure + Weight + Wind Loading Check at Bottom Seam (Bergman, ASME paper 54-A-104)

$P_v = W / (2*\pi*R_m) + M / (\pi*R_m^2)$
$= 1805.43 / (2*\pi*9.8125) + 0.80 / (\pi*9.8125^2)$
= 29.2861 lb/in

$\alpha = P_v / (P_e*D_o)$
$= 29.286104 / (15.0000*20.0000)$
$= 0.0976$

$n = 2$

$m = 1.23 / (L/D_o)^2$
$= 1.23 / (90.000000/20.0000)^2$
$= 0.0607$

Ratio $P_e = (n^2 - 1 + m + m*\alpha) / (n^2 - 1 + m)$
$= (2^2 - 1 + 0.060741 + 0.060741*0.097620) / (2^2 - 1 + 0.060741)$
$= 1.0019$

Ratio P_e * $P_e \leq$ MAEP design cylinder thickness is satisfactory.

External Pressure + Weight + Seismic Loading Check (Bergman, ASME paper 54-A-104)

$P_v = (1 + VAccel)*W / (2*\pi*R_m) + M / (\pi*R_m^2)$
$= 1.6500*1805.43 / (2*\pi*9.8125) + 39666.87 / (\pi*9.8125^2)$
$= 179.4527$ lb/in

$\alpha = P_v / (P_e*D_o)$
$= 179.452713 / (15.0000*20.0000)$
$= 0.5982$

$n = 2$

$m = 1.23 / (L/D_o)^2$
$= 1.23 / (90.000000/20.0000)^2$
$= 0.0607$

Ratio $P_e = (n^2 - 1 + m + m*\alpha) / (n^2 - 1 + m)$
$= (2^2 - 1 + 0.060741 + 0.060741*0.598176) / (2^2 - 1 + 0.060741)$
$= 1.0119$

Ratio P_e * $P_e \leq$ MAEP design cylinder thickness is satisfactory.

External Pressure + Weight + Seismic Loading Check at Bottom Seam(Bergman, ASME paper 54-A-104)

$P_v = (1 + VAccel)*W / (2*\pi*R_m) + M / (\pi*R_m^2)$
$= 1.6500*1805.43 / (2*\pi*9.8125) + 3.34 / (\pi*9.8125^2)$
$= 48.3287$ lb/in

$\alpha = P_v / (P_e*D_o)$
$= 48.328735 / (15.0000*20.0000)$
$= 0.1611$

$n = 2$

$m = 1.23 / (L/D_o)^2$
$= 1.23 / (90.000000/20.0000)^2$
$= 0.0607$

Ratio $P_e = (n^2 - 1 + m + m*\alpha) / (n^2 - 1 + m)$
$= (2^2 - 1 + 0.060741 + 0.060741*0.161096) / (2^2 - 1 + 0.060741)$
$= 1.0032$

Ratio $P_e * P_e \leq$ MAEP design cylinder thickness is satisfactory.

Design thickness = 0.1200"

The governing condition is due to external pressure.

The cylinder thickness of 0.3750" is adequate.

Thickness Required Due to Pressure + External Loads

Condition	Pressure P (psi)	Allowable Stress Before UG-23 Stress Increase (psi)		Temperature (°F)	Corrosion C (in)	Location	Load	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
		S_t	S_c						
Operating, Hot & Corroded	3.00	17176.47	16844.48	120.00	0.0000	Top	Wind	0.0003	0.0011
							Seismic	0.0056	0.0082
						Bottom	Wind	0.0007	0.0007
							Seismic	0.0007	0.0017
Operating, Hot & New	3.00	17176.47	16844.48	120.00	0.0000	Top	Wind	0.0003	0.0011
							Seismic	0.0056	0.0082
						Bottom	Wind	0.0007	0.0007
							Seismic	0.0007	0.0017
Hot Shut Down, Corroded	0.00	17176.47	16844.48	120.00	0.0000	Top	Wind	0.0010	0.0018
							Seismic	0.0049	0.0089
						Bottom	Wind	0.0014	0.0014
							Seismic	0.0014	0.0024
Hot Shut Down, New	0.00	17176.47	16844.48	120.00	0.0000	Top	Wind	0.0010	0.0018
							Seismic	0.0049	0.0089
						Bottom	Wind	0.0014	0.0014
							Seismic	0.0014	0.0024
Empty, Corroded	0.00	17176.47	16844.48	0.00	0.0000	Top	Wind	0.0010	0.0018
							Seismic	0.0049	0.0089
						Bottom	Wind	0.0014	0.0014
							Seismic	0.0014	0.0024
Empty, New	0.00	17176.47	16844.48	0.00	0.0000	Top	Wind	0.0010	0.0018
							Seismic	0.0049	0.0089
						Bottom	Wind	0.0014	0.0014
							Seismic	0.0014	0.0024
Vacuum	-15.00	17176.47	16844.48	120.00	0.0000	Top	Wind	0.0046	0.0054
							Seismic	0.0014	0.0124
						Bottom	Wind	0.0050	0.0050
							Seismic	0.0050	0.0060

Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0.00	17176.47	16844.48	120.00	0.0000	Top	Weight	0.0017	0.0017
						Bottom	Weight	0.0017	0.0017

Legs #1

Leg material:			ASME SA36
Leg description:			3x3x1/4 Equal Angle (Leg in)
Number of legs:	N =	4	
Overall length:		18.0000	in
Base to girth seam length:		4.0000	in
Bolt circle:		17.6875	in
Anchor bolt size:		0.625	inch series 8 threaded
Anchor bolt material:			
Anchor bolts/leg:		1	
Anchor bolt allowable stress:	S_b =	20,000	psi
Anchor bolt corrosion allowance:		0.0000	in
Anchor bolt hole clearance:		0.0620	in
Base plate width:		4.0000	in
Base plate length:		4.0000	in
Base plate thickness:		0.5625	in (0.5316 in required)
Base plate allowable stress:		24,000	psi
Foundation allowable bearing stress:		750	psi
Effective length coefficient:	K =	1.2	
Coefficient:	C_m =	0.85	
Leg yield stress:	F_y =	36,000	psi
Leg elastic modulus:	E =	29,000,000	psi
Leg to shell fillet weld:		0.1880	in (0.0165 in required)
Legs braced:		No	

Note: The support attachment point is assumed to be 1 in up from the cylinder circumferential seam.

Conditions Investigated (Only Governing Condition Reported)

Wind operating corroded
Wind empty corroded
Wind vacuum corroded
Seismic operating corroded
Seismic empty corroded
Seismic vacuum corroded

Loading	Force attack angle °	Leg position °	Axial end load (1) lb_f	Shear resisted lb_f	Axial f_a psi	Bending f_{bx} psi	Bending f_{by} psi	Ratio H_{1-1}	Ratio H_{1-2}
Governing Condition **Seismic operating corroded** **Moment = 3,305.3 lb-ft**	**0**	0	-1,531.0	78.1	-1,063	3,377	0	0.0602	0.0929
		90	746.0	309.1	518	1,292	1,656	0.1349	0.1480
		180	2,729.2	78.1	1,895	5,451	0	0.3032	0.3172
		270	746.0	309.1	518	1,292	1,656	0.1349	0.1480
	45	0	-1,531.0	193.6	-1,063	3,924	733	0.1060	0.1468
		90	-1,531.0	193.6	-1,063	3,924	733	0.1060	0.1468
		180	2,729.2	193.6	1,895	5,998	733	0.3491	0.3711
		270	2,729.2	193.6	1,895	5,998	733	0.3491	0.3711

(1) Axial end load includes consideration of seismic vertical acceleration.

Leg Calculations (AISC manual ninth edition)

Axial end load, P_1 (Based on vessel total bending moment acting at leg attachment elevation)

$P_1 = W_t/N + 48*M_t/(N*D) + V_v/N$
= 1,808.589/ 4 + 48*3,305.294/(4*20) + 1,175.583/ 4
= 2,729.2192 lb

Allowable axial compressive stress, F_a (AISC chapter E)

Local buckling check (AISC 5-99)

b/t = (3/0.25) < (76 / Sqr(36)) so Q_s = 1

Flexural-torsional buckling (AISC 5-317)

Shear center distance w_o = 1.013991
$r_o^2 = w_o^2 + (I_z + I_w)/A$
= 1.013991^2 + (0.5001664 + 1.979786)/1.44
= 2.750366

Torsional constant J = 0.03
Shear modulus G = 11,165.00 kips/in^2

$F_{ej} = G*J / (A*r_o^2)$
= 11,165.00*0.03 / (1.44*2.750366)
= 84.57207

$K*l/r_w$ = 1.2*5/1.172541 = 5.117094

$F_{ew} = \pi^2*E/(Kl/r_w)^2$
= π^2*29,000.00/(5.117094)^2
= 10,930.77

$H = 1 - (w_o^2 / r_o^2)$
= 1 - (1.013991^2 / 2.750366)
= 0.6261672

$F_e = ((F_{ew} + F_{ej})/(2*H))*(1 - Sqr(1 - (4*F_{ew}*F_{ej}*H)/(F_{ew} + F_{ej})^2))$

$= ((10,930.77 + 84.57207)/(2*0.6261672))*(1 - Sqr(1 - (4*10,930.77*84.57207*0.6261672)/(10,930.77 + 84.57207)^2))$
$= 84.32698$

Equivalent slenderness ratio

$Kl/r = \pi*Sqr(E/F_e)$
$= \pi*Sqr(29,000.00/84.32698)$
$= 58.25935$

$C_c = Sqr(2*\pi^2*E/(F_y*Q_s))$
$= Sqr(2*\pi^2*29,000,000/(36,000.00*1))$
$= 126.0993$

$K*l/r= 1.2*5/0.5893537 = 10.18064$

$F_a = 1 * (1 - (Kl/r)^2/(2*C_c^2))*F_y / (5/3 + 3*(Kl/r)/(8*C_c)-(Kl/r)^3/(8*C_c^3))$
$= 1 * (1 - (58.25935)^2/(2*126.0993^2))*36,000.00 / (5/3 + 3*(58.25935)/(8*126.0993)-(58.25935)^3/(8*126.0993^3))$
$= 17,595.71$ psi

Allowable axial compression and bending (AISC chapter H)

Note: r is divided by 1.35 - See AISC 6.1.4, pg. 5-314

$F'_{ex} = 1*12*\pi^2*E/(23*(Kl/r)^2)$
$= 1*12*\pi^2*29,000,000/(23*(13.74387)^2)$
$= 790,556.8$ psi

$F'_{ey} = 1*12*\pi^2*E/(23*(Kl/r)^2)$
$= 1*12*\pi^2*29,000,000/(23*(6.908077)^2)$
$= 3,129,225$ psi

$F_b = 1*0.66*F_y$
$= 23,760.00$ psi

Compressive axial stress

$f_a = P_1/A$
$= 2,729.219/1.44$
$= 1,895.291$ psi

Bending stresses

$f_{bx} = F*Cos(\alpha)*L/(I_x/C_x) + P_1*E_{cc}/(I_x/C_x)$
$= 193.6087*Cos(135)*5/(0.5001664/0.9305325) + 2,729.219*0.9305/(0.5001664/0.9305325)$
$= 5,998.168$ psi

$f_{by}= F*Sin(\alpha)*L/(I_y/C_y)$
$= 193.6087*Sin(135)*5/(1.979786/2.1213)$
$= 733.4388$ psi

AISC equation H_{1-1}

$H_{1-1} = f_a/F_a + C_{mx}*f_{bx}/((1 - f_a/F'_{ex})*F_{bx}) + C_{my}*f_{by}/((1 - f_a/F'_{ey})*F_{by})$
$= 1,895.291/17,595.71 + 0.85*5,998.168/((1 - 1,895.291/790,556.8)*23,760.00) + 0.85*733.4388/((1 - 1,895.291/3,129,225)*23,760.00)$
$= 0.3490641$

AISC equation H_{1-2}

$H_{1-2} = f_a/(0.6*1*F_y) + f_{bx}/F_{bx} + f_{by}/F_{by}$

= 1,895.291/(0.6*1*36,000.00) + 5,998.168/23,760.00 + 733.4388/23,760.00
= 0.3710617

4, 3x3x1/4 Equal Angle legs are adequate.

Anchor bolts - Seismic operating corroded condition governs

Tensile loading per leg (1 bolt per leg)

R = 48*M/(N*BC) - W/N
= 48*3,563.326/(4*17.6875) - 1,848.118/4
= 1,955.492 lb_f

Required area per bolt

A_b = R/(S_b*n)
= 1,955.492/(20,000.00*1)
= 0.0978 in^2

Area of a 0.625 inch series 8 threaded bolt (corroded) = 0.202 in^2

0.625 inch series 8 threaded bolts are satisfactory.

Check the leg to vessel fillet weld, Bednar 10.3, Seismic operating corroded governs

Note: continuous welding is assumed for all support leg fillet welds.

The following leg attachment weld analysis assumes the fillet weld is present on three sides (leg top closure plate is used).

Z_w = (2*b*d + d^2)/3
= (2*4.2426*13 + 13^2)/3
= 93.10253

J_w = (b + 2*d)^3/12 - d^2*(b + d)^2/(b + 2*d)
= (4.2426 + 2*13)^3/12 - 13^2*(4.2426 + 13)^2/(4.2426 + 2*13)
= 643.6319

E = d^2/(b + 2*d)
= 13^2/(4.2426 + 2*13)
= 5.588144

Governing weld load f_x = Cos(45)*193.6087 = 136.902 lb_f
Governing weld load f_y = Sin(45)*193.6087 = 136.902 lb_f

f_1 = P_1/L_{weld}
= 2,729.219/30.2426
= 90.2442 lb_f/in (V_L direct shear)

f_2= f_y*L_{leg}*0.5*b/J_w
= 136.902*5*0.5*4.2426/643.6319
= 2.256027 lb_f/in (V_L torsion shear)

f_3 = f_y/L_{weld}
= 136.902/30.2426
= 4.526794 lb_f/in (V_c direct shear)

f_4 = f_y*L_{leg}*E/J_w
= 136.902*5*5.588144/643.6319
= 5.943057 lb_f/in (V_c torsion shear)

$f_5 = f_x*L_{leg}/Z_w$
= 136.902*5/93.10253
= 7.352217 lb_f/in (M_L bending)

$f_6 = f_x/L_{weld}$
= 136.902/30.2426
= 4.526793 lb_f/in (Direct outward radial shear)

f = Sqr($(f_1 + f_2)^2 + (f_3 + f_4)^2 + (f_5 + f_6)^2$)
= Sqr($(90.2442 + 2.256027)^2 + (4.526794 + 5.943057)^2 + (7.352217 + 4.526793)^2$)
= 93.84573 lb_f/in (Resultant shear load)

Required leg to vessel fillet weld leg size (welded both sides + top)

t_w = f / (0.707*0.55*S_a)
= 93.84573 / (0.707*0.55*14,600.00)
= 0.0165 in

The 0.1880 in leg to vessel attachment fillet weld size is adequate.

Base plate thickness check, AISC 3-106

f_p = P/(B*N)
= 3,179.871/(4*4)
= 198.7419 psi

Required base plate thickness is the largest of the following: (0.5316 in)

t_b = Sqr(0.5*P/S_b)
= Sqr(0.5*3,179.871/24,000.00)
= 0.2574 in

t_b = 0.5*(N - d)*Sqr(3*f_p/S_b)
= 0.5*(4 - 3)*Sqr(3*198.7419/24,000.00)
= 0.0788 in

t_b = Sqr(3*P_t*0.5*Abs(OD - BC)/S_b)
= Sqr(3*1,955.492*0.5*Abs(20 - 17.6875)/24,000.00)
= 0.5316 in

The base plate thickness is adequate.

Check the leg to vessel attachment stresses, WRC-107 (Seismic vacuum corroded governs)

Applied Loads

Radial load:	P_r =	-136.90	lb_f
Circumferential moment:	M_c =	0.00	lb_f-in
Circumferential shear:	V_c =	0.00	lb_f
Longitudinal moment:	M_L =	2,109.13	lb_f-in
Longitudinal shear:	V_L =	-1,531.03	lb_f
Torsion moment:	M_t =	0.00	lb_f-in
Internal pressure:	P =	-15.000	psi
Mean shell radius:	R_m =	9.8125	in
Local shell thickness:	t =	0.3750	in
Shell yield stress:	S_y =	34,160.00	psi

Maximum stresses due to the applied loads at the leg edge (includes pressure)

R_m/t =26.1667

C_1 = 2.1213, C_2 = 8.4852 in

Note: Actual lug C_1/C_2 < 1/4, C_1/C_2 = 1/4 used as this is the minimum ratio covered by WRC 107.

Local circumferential pressure stress = $P*R_i/t$ = -385 psi

Local longitudinal pressure stress = $P*R_i/2t$ = -192 psi

Maximum combined stress (P_L+P_b+Q) = -738.00 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-43,800.00 psi

The maximum combined stress (P_L+P_b+Q) is within allowable limits.

Maximum local primary membrane stress (P_L) = -397.00 psi
Allowable local primary membrane (P_L) = +-1.5*S = +-21,900.00 psi

The maximum local primary membrane stress (P_L) is within allowable limits.

Stresses at the leg edge per WRC Bulletin 107										
Figure	**value**	**β**	**A_u**	**A_l**	**B_u**	**B_l**	**C_u**	**C_l**	**D_u**	**D_l**
3C*	0.9279	0.6399	0	0	0	0	35	35	35	35
4C*	2.0535	0.5188	76	76	76	76	0	0	0	0
1C	0.0610	0.3805	0	0	0	0	356	-356	356	-356
2C-1	0.0156	0.3805	91	-91	91	-91	0	0	0	0
3A*	1.0600	0.3432	0	0	0	0	0	0	0	0
1A	0.0675	0.4419	0	0	0	0	0	0	0	0
3B*	1.2473	0.5448	-88	-88	88	88	0	0	0	0
1B-1	0.0110	0.4833	-209	209	209	-209	0	0	0	0
Pressure stress*			-385	-385	-385	-385	-385	-385	-385	-385
Total circumferential stress			-515	-279	79	-521	6	-706	6	-706
Primary membrane circumferential stress*			-397	-397	-221	-221	-350	-350	-350	-350
3C*	0.9279	0.5188	35	35	35	35	0	0	0	0
4C*	2.0535	0.6399	0	0	0	0	76	76	76	76
1C-1	0.0231	0.5405	135	-135	135	-135	0	0	0	0
2C	0.0300	0.5405	0	0	0	0	175	-175	175	-175
4A*	2.4947	0.3432	0	0	0	0	0	0	0	0
2A	0.0293	0.6074	0	0	0	0	0	0	0	0
4B*	0.6854	0.5448	-87	-87	87	87	0	0	0	0
2B-1	0.0207	0.6668	-285	285	285	-285	0	0	0	0
Pressure stress*			-192	-192	-192	-192	-192	-192	-192	-192
Total longitudinal stress			-394	-94	350	-490	59	-291	59	-291
Primary membrane longitudinal stress*			-244	-244	-70	-70	-116	-116	-116	-116
Shear from M_t			0	0	0	0	0	0	0	0
Circ shear from V_c			0	0	0	0	0	0	0	0
Long shear from V_L			0	0	0	0	120	120	-120	-120
Total Shear stress			0	0	0	0	120	120	-120	-120
Combined stress (P_L+P_b+Q)			-515	-279	350	-521	246	-738	246	-738

Note: * denotes primary stress.

Welded Cover #1

ASME Section VIII Division 1, 2004 Edition, A06 Addenda

Component: Welded Cover
Material specification: SA-36 (II-D p. 6, ln. 18)
Head is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.05658).

Internal design pressure: P = 3.0000 psi @ 120.00°F
External design pressure: P_e = 15.0000 psi @ 120.00°F

Static liquid head:

P_{th}=0.3474 psi(SG=1.0000, H_s=9.6250", Horizontal test head)

Corrosion allowance: Inner C = 0.0000" Outer C = 0.0000"

Design MDMT = -20.00°F
Rated MDMT = -155.00°F

No impact test performed
Material is not normalized
Material is not produced to Fine Grain Practice
PWHT is not performed

Radiography: Category A joints - Seamless No RT

Estimated weight: New = 51.5 lb corr = 51.5 lb

Head outside diameter = 20.0000"
Cover thickness = 0.6250"

Factor C from Fig. UG-34, sketch (h)

Factor C = 0.33

Design thickness, (at 120.00 °F) UG-34 (c)(2)

t = d*Sqr(C*P/(S*E)) + Corrosion
= 19.25*Sqr(0.33*3/(16,600.00*1)) + 0
= 0.1487 in

Maximum allowable working pressure, (at 120.00 °F)

$P = (S*E/C)*(t/d)^2 - P_s$
$= (16,600.00*1/0.33)*(0.625/19.25)^2 - 0$
= 53.026 psi

Maximum allowable pressure, (At 70.00 °F)

$P = (S*E/C)*(t/d)^2$
$= (16,600.00*1/0.33)*(0.625/19.25)^2$
= 53.026 psi

Design thickness for external pressure, (at 120.00 °F) UG-34(c)(2)

t = d*Sqr(C*P_e/(S*E)) + Corrosion
= 19.25*Sqr(0.33*15/(16,600.00*1)) + 0
= 0.3324 in

Maximum allowable external pressure, (At 120.00 °F)

$P = (S*E/C)*(t/d)^2$
$= (16,600.00*1/0.33)*(0.625/19.25)^2$
= 53.026 psi

Clip #1

Geometry

Height(radial):	5.0000"
Width (circumferential):	0.5000"
Length	5.0000"
Fillet Weld Size:	0.2500"
Location Angle:	0.00°

Applied Loads

Radial load:	P_r =	0.00	lb_f
Circumferential moment:	M_c =	0.00	lb_f-in
Circumferential shear:	V_c =	0.00	lb_f
Longitudinal moment:	M_L =	19,452.00	lb_f-in
Longitudinal shear:	V_L =	0.00	lb_f
Torsion moment:	M_t =	0.00	lb_f-in
Internal pressure:	P =	3.000	psi
Mean shell radius:	R_m =	9.8125	in
Shell yield stress:	S_y =	34,160.00	psi

Maximum stresses due to the applied loads at the lug edge (includes pressure)

R_m/t =26.1667

C_1 = 0.5000, C_2 = 2.0000 in

Note: Actual lug C_1/C_2 < 1/4, C_1/C_2 = 1/4 used as this is the minimum ratio covered by WRC 107.

Local circumferential pressure stress = P*R_i/t = 77 psi

Local longitudinal pressure stress = P*R_i/2t = 38 psi

Maximum combined stress (P_L+P_b+Q) = 43,794.00 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-43,800.00 psi

The maximum combined stress (P_L+P_b+Q) is within allowable limits.

Maximum local primary membrane stress (P_L) = 7,563.00 psi
Allowable local primary membrane (P_L) = +-1.5*S = +-21,900.00 psi

The maximum local primary membrane stress (P_L) is within allowable limits.

Stresses at the lug edge per WRC Bulletin 107										
Figure	**value**	**β**	**A_u**	**A_l**	**B_u**	**B_l**	**C_u**	**C_l**	**D_u**	**D_l**
3C*	3.4639	0.1508	0	0	0	0	0	0	0	0
4C*	4.5298	0.1223	0	0	0	0	0	0	0	0
1C	0.1593	0.0897	0	0	0	0	0	0	0	0
2C-1	0.1198	0.0897	0	0	0	0	0	0	0	0
3A*	0.5349	0.0809	0	0	0	0	0	0	0	0
1A	0.0998	0.1042	0	0	0	0	0	0	0	0
3B*	2.7129	0.1284	-7,486	-7,486	7,486	7,486	0	0	0	0
1B-1	0.0488	0.1139	-36,231	36,231	36,231	-36,231	0	0	0	0
Pressure stress*			77	77	77	77	77	77	77	77
Total circumferential stress			-43,640	28,822	43,794	-28,668	77	77	77	77
Primary membrane circumferential stress*			-7,409	-7,409	7,563	7,563	77	77	77	77
3C*	3.9322	0.1223	0	0	0	0	0	0	0	0
4C*	4.2883	0.1508	0	0	0	0	0	0	0	0
1C-1	0.1291	0.1274	0	0	0	0	0	0	0	0
2C	0.0879	0.1274	0	0	0	0	0	0	0	0
4A*	0.6886	0.0809	0	0	0	0	0	0	0	0
2A	0.0523	0.1432	0	0	0	0	0	0	0	0
4B*	0.7914	0.1284	-3,910	-3,910	3,910	3,910	0	0	0	0
2B-1	0.0632	0.1572	-34,011	34,011	34,011	-34,011	0	0	0	0
Pressure stress*			38	38	38	38	38	38	38	38
Total longitudinal stress			-37,883	30,139	37,959	-30,063	38	38	38	38
Primary membrane longitudinal stress*			-3,872	-3,872	3,948	3,948	38	38	38	38
Shear from M_t			0	0	0	0	0	0	0	0
Circ shear from V_c			0	0	0	0	0	0	0	0
Long shear from V_L			0	0	0	0	0	0	0	0
Total Shear stress			0	0	0	0	0	0	0	0
Combined stress (P_L+P_b+Q)			-43,640	30,139	43,794	-30,063	77	77	77	77

Note: * denotes primary stress.

Clip #2

Geometry

Height(radial):	5.0000"
Width (circumferential):	0.5000"
Length	5.0000"
Fillet Weld Size:	0.2500"
Location Angle:	120.00°

Applied Loads

Radial load:	P_r =	0.00	lb_f
Circumferential moment:	M_c =	10,356.00	lb_f-in
Circumferential shear:	V_c =	0.00	lb_f
Longitudinal moment:	M_L =	0.00	lb_f-in
Longitudinal shear:	V_L =	0.00	lb_f
Torsion moment:	M_t =	0.00	lb_f-in
Internal pressure:	P =	3.000	psi
Mean shell radius:	R_m =	9.8125	in
Shell yield stress:	S_y =	34,160.00	psi

Maximum stresses due to the applied loads at the lug edge (includes pressure)

R_m/t =26.1667

C_1 = 0.5000, C_2 = 2.0000 in

Note: Actual lug C_1/C_2 < 1/4, C_1/C_2 = 1/4 used as this is the minimum ratio covered by WRC 107.

Local circumferential pressure stress = $P*R_i/t$ = 77 psi

Local longitudinal pressure stress = $P*R_i/2t$ = 38 psi

Maximum combined stress (P_L+P_b+Q) = 43,750.00 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-43,800.00 psi

The maximum combined stress (P_L+P_b+Q) is within allowable limits.

Maximum local primary membrane stress (P_L) = 1,211.00 psi
Allowable local primary membrane (P_L) = +-1.5*S = +-21,900.00 psi

The maximum local primary membrane stress (P_L) is within allowable limits.

Stresses at the lug edge per WRC Bulletin 107										
Figure	**value**	**β**	**A_u**	**A_l**	**B_u**	**B_l**	**C_u**	**C_l**	**D_u**	**D_l**
3C*	3.4639	0.1508	0	0	0	0	0	0	0	0
4C*	4.5298	0.1223	0	0	0	0	0	0	0	0
1C	0.1593	0.0897	0	0	0	0	0	0	0	0
2C-1	0.1198	0.0897	0	0	0	0	0	0	0	0
3A*	0.5349	0.0809	0	0	0	0	-527	-527	527	527
1A	0.0998	0.1042	0	0	0	0	-43,146	43,146	43,146	-43,146
3B*	2.7129	0.1284	0	0	0	0	0	0	0	0
1B-1	0.0488	0.1139	0	0	0	0	0	0	0	0
Pressure stress*			77	77	77	77	77	77	77	77
Total circumferential stress			77	77	77	77	-43,596	42,696	43,750	-42,542
Primary membrane circumferential stress*			77	77	77	77	-450	-450	604	604
3C*	3.9322	0.1223	0	0	0	0	0	0	0	0
4C*	4.2883	0.1508	0	0	0	0	0	0	0	0
1C-1	0.1291	0.1274	0	0	0	0	0	0	0	0
2C	0.0879	0.1274	0	0	0	0	0	0	0	0
4A*	0.6886	0.0809	0	0	0	0	-1,173	-1,173	1,173	1,173
2A	0.0523	0.1432	0	0	0	0	-16,451	16,451	16,451	-16,451
4B*	0.7914	0.1284	0	0	0	0	0	0	0	0
2B-1	0.0632	0.1572	0	0	0	0	0	0	0	0
Pressure stress*			38	38	38	38	38	38	38	38
Total longitudinal stress			38	38	38	38	-17,586	15,316	17,662	-15,240
Primary membrane longitudinal stress*			38	38	38	38	-1,135	-1,135	1,211	1,211
Shear from M_t			0	0	0	0	0	0	0	0
Circ shear from V_c			0	0	0	0	0	0	0	0
Long shear from V_L			0	0	0	0	0	0	0	0
Total Shear stress			0	0	0	0	0	0	0	0
Combined stress (P_L+P_b+Q)			77	77	77	77	-43,596	42,696	43,750	-42,542

Note: * denotes primary stress.

Clip #3

Geometry

Height(radial):	5.0000"
Width (circumferential):	0.5000"
Length	5.0000"
Fillet Weld Size:	0.2500"
Location Angle:	240.00°

Applied Loads

Radial load:	P_r =	5,670.00	lb_f
Circumferential moment:	M_c =	0.00	lb_f-in
Circumferential shear:	V_c =	0.00	lb_f
Longitudinal moment:	M_L =	0.00	lb_f-in
Longitudinal shear:	V_L =	0.00	lb_f
Torsion moment:	M_t =	0.00	lb_f-in
Internal pressure:	P =	3.000	psi
Mean shell radius:	R_m =	9.8125	in
Shell yield stress:	S_y =	34,160.00	psi

Maximum stresses due to the applied loads at the lug edge (includes pressure)

R_m/t =26.1667

C_1 = 0.5000, C_2 = 2.0000 in

Note: Actual lug C_1/C_2 < 1/4, C_1/C_2 = 1/4 used as this is the minimum ratio covered by WRC 107.

Local circumferential pressure stress = P*R_i/t = 77 psi

Local longitudinal pressure stress = P*R_i/2t = 38 psi

Maximum combined stress (P_L+P_b+Q) = -43,798.00 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-43,800.00 psi

The maximum combined stress (P_L+P_b+Q) is within allowable limits.

Maximum local primary membrane stress (P_L) = -6,903.00 psi
Allowable local primary membrane (P_L) = +-1.5*S = +-21,900.00 psi

The maximum local primary membrane stress (P_L) is within allowable limits.

Stresses at the lug edge per WRC Bulletin 107										
Figure	**value**	**β**	**A_u**	**A_l**	**B_u**	**B_l**	**C_u**	**C_l**	**D_u**	**D_l**
3C*	3.4639	0.1508	0	0	0	0	-5,337	-5,337	-5,337	-5,337
4C*	4.5298	0.1223	-6,980	-6,980	-6,980	-6,980	0	0	0	0
1C	0.1593	0.0897	0	0	0	0	-38,538	38,538	-38,538	38,538
2C-1	0.1198	0.0897	-28,982	28,982	-28,982	28,982	0	0	0	0
3A*	0.5349	0.0809	0	0	0	0	0	0	0	0
1A	0.0998	0.1042	0	0	0	0	0	0	0	0
3B*	2.7129	0.1284	0	0	0	0	0	0	0	0
1B-1	0.0488	0.1139	0	0	0	0	0	0	0	0
Pressure stress*			77	77	77	77	77	77	77	77
Total circumferential stress			-35,885	22,079	-35,885	22,079	-43,798	33,278	-43,798	33,278
Primary membrane circumferential stress*			-6,903	-6,903	-6,903	-6,903	-5,260	-5,260	-5,260	-5,260
3C*	3.9322	0.1223	-6,059	-6,059	-6,059	-6,059	0	0	0	0
4C*	4.2883	0.1508	0	0	0	0	-6,608	-6,608	-6,608	-6,608
1C-1	0.1291	0.1274	-31,232	31,232	-31,232	31,232	0	0	0	0
2C	0.0879	0.1274	0	0	0	0	-21,265	21,265	-21,265	21,265
4A*	0.6886	0.0809	0	0	0	0	0	0	0	0
2A	0.0523	0.1432	0	0	0	0	0	0	0	0
4B*	0.7914	0.1284	0	0	0	0	0	0	0	0
2B-1	0.0632	0.1572	0	0	0	0	0	0	0	0
Pressure stress*			38	38	38	38	38	38	38	38
Total longitudinal stress			-37,253	25,211	-37,253	25,211	-27,835	14,695	-27,835	14,695
Primary membrane longitudinal stress*			-6,021	-6,021	-6,021	-6,021	-6,570	-6,570	-6,570	-6,570
Shear from M_t			0	0	0	0	0	0	0	0
Circ shear from V_c			0	0	0	0	0	0	0	0
Long shear from V_L			0	0	0	0	0	0	0	0
Total Shear stress			0	0	0	0	0	0	0	0
Combined stress (P_L+P_b+Q)			-37,253	25,211	-37,253	25,211	-43,798	33,278	-43,798	33,278

Note: * denotes primary stress.