Chattanooga Boiler and Tank Company

1011 E. Main St.

Chattanooga, TN 37408

COMPRESS Pressure Vessel Design Calculations

Item: Recovered Water Drum
Vessel No: DR0004
Customer: Southern Company, Inc.
Designer: Naveen K Madasetty
Rev-Date: 1 - 5/16/2011
Vessel Name: 2084-02.CW7

Quality Record

MM76380 A

Plant: Kemper County CHATTANOOGA BOILER & TANK CO.
Southern Company Generation
DR0004 2084-02-CALC Rev: 1
PO: MPC10014852

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Revision History

No.	Date	Operator	Notes
0	2/28/2011	bturner	Customer Approval
1	5/16/2011	Naveen K Madasetty	1. All Nozzle's Calcs added 2. Nozzle "C" Size Change, 3. Lifting & Tailing Lug Calcs Added

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Table Of Contents

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Settings Summary

COMPRESS Build 7110

Units: U.S. Customary

Datum Line Location: -2.00" from bottom seam

Design

ASME Section VIII Division 1, 2010 Edition

Design or Rating:	Get Thickness from Pressure
Minimum thickness:	0.0625" per UG-16(b)
Design for cold shut down only:	No
Design for lethal service (full radiography required):	No
Design nozzles for:	Larger of MAWP or MAP
Corrosion weight loss:	100% of theoretical loss
UG-23 Stress Increase:	1.20
Skirt/legs stress increase:	1.0
Minimum nozzle projection:	8"
Juncture calculations for $\alpha > 30$ only:	Yes
Preheat P-No 1 Materials > 1.25&#34 and <= 1.50" thick:	No
UG-37(a) shell tr calculation considers longitudinal stress:	No

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

Hydro/Pneumatic Test

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

Required Marking - UG-116

UG-116(e) Radiography:	RT4
UG-116(f) Postweld heat treatment:	None

Code Cases\Interpretations

Use Code Case 2547:	No
Apply interpretation VIII-1-83-66:	No
Apply interpretation VIII-1-86-175:	Yes
Apply interpretation VIII-1-83-115:	No
Apply interpretation VIII-1-01-37:	Yes
No UCS-66.1 MDMT reduction:	No
No UCS-68(c) MDMT reduction:	No
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

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UG-22(c) Superimposed static reactions from weight of attached equipment (external loads):	No
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
UG-22(j) Test pressure and coincident static head acting during the test:	Yes

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

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Pressure Summary for Chamber bounded by Bottom Head and Top Head

Identifier	P Design (psi)	T Design (°F)	MAWP (psi)	MAP (psi)	MDMT (°F)	MDMT Exemption		Impact Tested
Top Head	55	160	64.36	107.7	-55	Note 1		No
Straight Flange on Top Head	55	160	149.52	225.73	-55	Note 2		No
Shell-02	55	160	92.44	160.08	-55	Note 3		No
Shell-01	55	160	88.22	160.08	-55	Note 4		No
Straight Flange on Bottom Head	55	160	142.52	225.73	-55	Note 6		No
Bottom Head	55	160	56.88	107.7	-55	Note 5		No
Support Legs	55	160	56.88	N/A	N/A	N/A		N/A
Pump Suction (A)	55	160	56.88	107.7	-55	Note 7		No
Inlet (B)	55	160	56.88	107.7	-55	Nozzle	Note 8	No
						Pad	Note 9	No
Vapor Outlet (C)	55	160	56.88	107.7	-55	Note 10		No
Makeup Inlet (D)	55	160	56.88	107.7	-55	Nozzle	Note 11	No
						Pad	Note 12	No
Level Glass (K1)	55	160	56.88	107.7	-55	Note 13		No
Level Glass (K2)	55	160	56.88	107.7	-55	Note 14		No
Level (L1)	55	160	56.88	107.7	-55	Note 13		No
Level (L2)	55	160	56.88	107.7	-55	Note 14		No
Manway (M)	55	160	56.88	107.7	-55	Nozzle	Note 15	No
						Pad	Note 16	No
Nitrogen Inlet (N)	55	160	56.88	107.7	-55	Note 17		No
Recirc Inlet (R)	55	160	56.88	107.7	-55	Note 18		No

Chamber design MDMT is 10 °F
Chamber rated MDMT is -55 °F @ 56.88 psi

Chamber MAWP hot & corroded is 56.88 psi @ 160 °F

Chamber MAP cold & new is 107.7 psi @ 70 °F

This pressure chamber is not designed for external pressure.

Design notes are available on the Settings Summary page.

Thickness Summary

Component Identifier	Material	Diameter (in)	Length (in)	Nominal t (in)	Design t (in)	Total Corrosion (in)	Joint E	Load
Top Head	SA-516 70	66 ID	11.5505	0.3125*	0.2855	0.125	1.00	Internal
Straight Flange on Top Head	SA-516 70	66 ID	2	0.375	0.2175	0.125	1.00	Internal
Shell-02	SA-516 70	66 ID	76	0.3125	0.2392	0.125	0.85	Internal
Shell-01	SA-516 70	66 ID	118	0.3125	0.2474	0.125	0.85	Internal
Straight Flange on Bottom Head	SA-516 70	66 ID	2	0.375	0.2292	0.125	1.00	Internal
Bottom Head	SA-516 70	66 ID	11.5505	0.3125*	0.3071	0.125	1.00	Internal

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

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Weight Summary

Component	Weight (lb) Contributed by Vessel Elements							Surface Area ft²
	Metal New*	Metal Corroded*	Insulation & Supports	Lining	Piping + Liquid	Operating Liquid	Test Liquid	
Top Head	402.8	245.8	45.9	0	0	1,111.8	1,102.7	32
Shell-02	1,395.7	839	151.7	0	0	9,369.3	9,392.7	110
Shell-01	2,128.2	1,279.4	235.6	0	0	14,660	14,697.5	168
Bottom Head	403.2	246	45.9	0	0	1,113.5	1,104.4	32
Support Legs	650.2	650.2	0	0	0	0	0	53
TOTAL:	**4,980**	**3,260.4**	**479**	**0**	**0**	**26,254.5**	**26,297.3**	**395**

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

Component	Weight (lb) Contributed by Attachments									Surface Area ft²
	Body Flanges		Nozzles & Flanges		Packed Beds	Ladders & Platforms	Trays & Supports	Rings & Clips	Vertical Loads	
	New	Corroded	New	Corroded						
Top Head	0	0	58.5	58.1	0	0	0	0	0	3
Shell-02	0	0	70.8	68.3	0	0	0	23.5	0	6
Shell-01	0	0	889.4	888	0	0	0	10	0	18
Bottom Head	0	0	52.7	52.4	0	0	0	0	0	3
Support Legs	0	0	0	0	0	0	0	0	0	0
TOTAL:	**0**	**0**	**1,071.3**	**1,066.8**	**0**	**0**	**0**	**33.5**	**0**	**30**

Vessel operating weight, Corroded: 31,094 lb
Vessel operating weight, New: 32,598 lb
Vessel empty weight, Corroded: 4,840 lb
Vessel empty weight, New: 6,564 lb
Vessel test weight, New: 32,382 lb
Vessel surface area: 425 ft²

Vessel center of gravity location - from datum - lift condition

Vessel Lift Weight, New: 6,085 lb
Center of Gravity: 77.3689"
Note: Vessel lift weight includes weight of insulation supports as they are assumed to be shop installed.

Vessel Capacity

Vessel Capacity** (New): 3,136 US gal
Vessel Capacity** (Corroded): 3,162 US gal
**The vessel capacity does not include volume of nozzle, piping or other attachments.

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Nozzle Schedule

Nozzle mark	Service	Size	Materials								
			Nozzle	Impact	Norm	Fine Grain	Pad	Impact	Norm	Fine Grain	Flange
A	Pump Suction	NPS 8 Sch 40 (Std)	SA-106 B Smls pipe	No	No	No	N/A	N/A	N/A	N/A	WN A105 Class 150
B	Inlet	NPS 8 Sch 40 (Std)	SA-106 B Smls pipe	No	No	No	SA-516 70	No	No	No	WN A105 Class 150
C	Vapor Outlet	NPS 8 Sch 40 (Std)	SA-106 B Smls pipe	No	No	No	N/A	N/A	N/A	N/A	WN A105 Class 150
D	Makeup Inlet	NPS 6 Sch 40 (Std)	SA-106 B Smls pipe	No	No	No	SA-516 70	No	No	No	WN A105 Class 150
K1	Level Glass	NPS 2 Sch 80 (XS)	SA-106 B Smls pipe	No	No	No	N/A	N/A	N/A	N/A	WN A105 Class 150
K2	Level Glass	NPS 2 Sch 80 (XS)	SA-106 B Smls pipe	No	No	No	N/A	N/A	N/A	N/A	WN A105 Class 150
L1	Level	NPS 1.5 Sch 80 (XS)	SA-106 B Smls pipe	No	No	No	N/A	N/A	N/A	N/A	WN A105 Class 150
L2	Level	NPS 1.5 Sch 80 (XS)	SA-106 B Smls pipe	No	No	No	N/A	N/A	N/A	N/A	WN A105 Class 150
M	Manway	23.25 IDx0.38	SA-516 70	No	No	No	SA-516 70	No	No	No	SO A105 Class 150
N	Nitrogen Inlet	NPS 2 Sch 80 (XS)	SA-106 B Smls pipe	No	No	No	N/A	N/A	N/A	N/A	WN A105 Class 150
R	Recirc Inlet	NPS 3 Sch 40 (Std)	SA-106 B Smls pipe	No	No	No	N/A	N/A	N/A	N/A	WN A105 Class 150

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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)		
A	8.625	0.322	0.2664	Yes	Yes	0.3125*	0.1778		N/A	N/A	0	107.5
B	8.625	0.322	0.2637	Yes	Yes	0.3125	0.1783		3	0.25	0	211.5
C	8.625	0.322	0.2509	Yes	Yes	0.3125*	0.1778		N/A	N/A	0	107.5
D	6.625	0.28	0.2529	Yes	Yes	0.3125	0.1783		3	0.25	0	271.0
K1	2.375	0.218	0.154	Yes	Yes	0.3125	N/A		N/A	N/A	0	Exempt
K2	2.375	0.218	0.154	Yes	Yes	0.3125	N/A		N/A	N/A	0	Exempt
L1	1.9	0.2	0.145	Yes	Yes	0.3125	N/A		N/A	N/A	0	Exempt
L2	1.9	0.2	0.145	Yes	Yes	0.3125	N/A		N/A	N/A	0	Exempt
M	24	0.375	0.2312	Yes	Yes	0.3125	0.1783		4	0.375	0	129.9
N	2.375	0.218	0.154	Yes	Yes	0.3125*	N/A		N/A	N/A	0	Exempt
R	3.5	0.216	0.216	Yes	Yes	0.3125	N/A		N/A	N/A	0	Exempt

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

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Hydrostatic Test

Shop test pressure determination for Chamber bounded by Bottom Head and Top Head based on design P per UG-99(b)

Shop hydrostatic test gauge pressure is 71.5 psi at 70 °F (the chamber design P = 55 psi)

The shop test is performed with the vessel in the horizontal position.

Identifier	Local test pressure psi	Test liquid static head psi	UG-99 stress ratio	UG-99 pressure factor	Stress during test psi	Allowable test stress psi	Stress excessive?
Top Head (1)	74.183	2.683	1	1.30	7,834	34,200	No
Straight Flange on Top Head	74.183	2.683	1	1.30	6,565	34,200	No
Shell-02	74.183	2.683	1	1.30	7,871	34,200	No
Shell-01	74.183	2.683	1	1.30	7,871	34,200	No
Straight Flange on Bottom Head	74.183	2.683	1	1.30	6,565	34,200	No
Bottom Head	74.183	2.683	1	1.30	7,834	34,200	No
Inlet (B)	74.483	2.983	1	1.30	8,488	51,300	No
Level (L1)	73.018	1.518	1	1.30	9,649	51,300	No
Level (L2)	73.018	1.518	1	1.30	9,649	51,300	No
Level Glass (K1)	73.026	1.526	1	1.30	10,382	51,300	No
Level Glass (K2)	73.026	1.526	1	1.30	10,382	51,300	No
Makeup Inlet (D)	74.123	2.623	1	1.30	5,299	51,300	No
Manway (M)	71.789	0.289	1	1.30	16,273	51,300	No
Nitrogen Inlet (N)	73.715	2.215	1	1.30	10,565	51,300	No
Pump Suction (A)	73.135	1.635	1	1.30	12,924	51,300	No
Recirc Inlet (R)	74.483	2.983	1	1.30	13,075	51,300	No
Vapor Outlet (C)	73.135	1.635	1	1.30	12,924	51,300	No

Notes:
(1) Top Head limits the UG-99 stress ratio.
(2) P_L stresses at nozzle openings have been estimated using the method described in PVP-Vol. 399, pages 77-82.
(3) $1.5*0.9*S_y$ used as the basis for the maximum local primary membrane stress at the nozzle intersection P_L.
(4) The zero degree angular position is assumed to be up, and the test liquid height is assumed to the top-most flange.

The field test condition has not been investigated for the Chamber bounded by Bottom Head and Top Head.

The test temperature of 70 °F is warmer than the minimum recommended temperature of -25 °F so the brittle fracture provision of UG-99(h) has been met.

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Wind Code

Building Code:	**ASCE 7-05**
Elevation of base above grade:	0.0000 ft
Increase effective outer diameter by:	2.0000 ft
Wind Force Coefficient Cf:	0.8000
Basic Wind Speed:, V:	100.0000 mph
Importance Factor:, I:	1.1500
Exposure category:	C
Wind Directionality Factor, Kd:	0.9500
Top Deflection Limit:	6 in. per 100 ft.
Topographic Factor, Kzt:	1.0000
Enforce min. loading of 10 psf:	No

Vessel Characteristics

Vessel height, h:	22.4625 ft
Vessel Minimum Diameter, b	
Operating, Corroded:	5.8854 ft
Empty, Corroded:	5.8854 ft
Fundamental Frequency, n_1	
Operating, Corroded:	3.0287 Hz
Empty, Corroded:	8.1494 Hz
Damping coefficient, β	
Operating, Corroded:	0.0260
Empty, Corroded:	0.0210

Vortex Shedding Calculations
Table Lookup Values

2.4.1 Basic Load Combinations for Allowable Stress Design
The following load combinations are considered in accordance with ASCE section 2.4.1:

5. $D + P + P_s + W$
7. $0.6D + P + P_s + W$

Where

D = Dead load
P = Internal or external pressure load
P_s = Static head load
W = Wind load

Wind Deflection Reports:

Operating, Corroded
Empty, Corroded
Operating, Corroded,Vortex Shedding
Vacuum, Corroded, Vortex Shedding
Wind Pressure Calculations
Wind Pressures at Critical Speed: Operating, Corroded
Wind Pressures at Critical Speed: Vacuum, Corroded

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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)
Top Head	256	7.89	29.0	*	0	143	92	0.0908
Shell-02	180	7.89	29.0	1.041	0	1,056	4,093	0.0904
Shell-01 (top)	62	7.89	29.0	1.041	0	2,367	23,035	0.0882
Support Legs	0	0	29.0	0.003839	0	2,506	35,908	0.0863
Shell-01 (bottom)	62	7.89	29.0	1.041	0	140	76	0.0863
Bottom Head	62	7.89	29.0	*	0	129	65	0.0863
*Moment of Inertia I varies over the length of the component								

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)
Top Head	256	7.89	29.4	*	0	143	92	0.0907
Shell-02	180	7.89	29.4	1.041	0	1,056	4,093	0.0903
Shell-01 (top)	62	7.89	29.4	1.041	0	2,367	23,035	0.0882
Support Legs	0	0	29.0	0.003839	0	2,506	35,908	0.0863
Shell-01 (bottom)	62	7.89	29.4	1.041	0	140	76	0.0863
Bottom Head	62	7.89	29.4	*	0	129	65	0.0863
*Moment of Inertia I varies over the length of the component								

Wind Deflection Report: Operating, Corroded, Vortex Shedding

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)
Top Head	256	7.89	29.0	*	0	227	148	0.0739
Shell-02	180	7.89	29.0	1.041	0	1,510	5,832	0.0734
Shell-01 (top)	62	7.89	29.0	1.041	0	1,942	24,919	0.0707
Support Legs	0	0	29.0	0.003839	0	1,989	35,168	0.0684
Shell-01 (bottom)	62	7.89	29.0	1.041	0	46	25	0.0684
Bottom Head	62	7.89	29.0	*	0	42	21	0.0684
*Moment of Inertia I varies over the length of the component								

Wind Deflection Report: Vacuum, Corroded, Vortex Shedding

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)
Top Head	256	7.89	29.0	*	0	227	148	0.0739
Shell-02	180	7.89	29.0	1.041	0	1,510	5,832	0.0734
Shell-01 (top)	62	7.89	29.0	1.041	0	1,942	24,919	0.0707
Support Legs	0	0	29.0	0.003839	0	1,989	35,168	0.0684
Shell-01 (bottom)	62	7.89	29.0	1.041	0	46	25	0.0684
Bottom Head	62	7.89	29.0	*	0	42	21	0.0684

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*Moment of Inertia I varies over the length of the component

Wind Pressure (WP) Calculations

Gust Factor (G^-) Calculations

Kz = 2.01 * $(Z/Zg)^{2/\alpha}$
= 2.01 * $(Z/900.0000)^{0.2105}$
qz = 0.00256 * Kz * Kzt * Kd * V^2 * I psf
= 0.00256 * Kz * 1.0000 * 0.9500 * 100.0000^2 * 1.1500
= 27.9680 * Kz
WP = qz * G * Cf
= qz * G * 0.8000

Design Wind Pressures

Height Z (')	Kz	qz (psf)	WP: Operating (psf)	WP: Empty (psf)	WP: hydrotest (psf)	WP: Vacuum (psf)
15.0	0.8489	23.74	17.04	17.04	N.A.	N.A.
20.0	0.9019	25.22	18.11	18.11	N.A.	N.A.
25.0	0.9453	26.44	18.98	18.98	N.A.	N.A.

Design Wind Force determined from: F = Pressure * Af , where Af is the projected area.

Vortex Shedding Calculations

Vortex shedding calculations are based on NBC 1995 building code, Structural Commentaries (Part 4).

Average diameter of vessel (upper third):	D = 5.3434 ft
Aspect ratio:	Ar = 4.2038
Vortex shedding factor, Operating, Corroded:	C_1 = 1.5377
Vortex shedding factor, Operating, Corroded:	C_2 = 0.6000
Vortex shedding factor, Vacuum, Corroded:	C_1 = 1.5377
Vortex shedding factor, Vacuum, Corroded:	C_2 = 0.6000
Weight per foot of vessel, Operating, Corroded, (upper third):	M = 1595.4277 lb/ft
Strouhal number, Operating, Corroded:	S = 0.2000
Weight per foot of vessel, Empty, Corroded, (upper third):	M = 191.9325 lb/ft
Strouhal number, Empty, Corroded:	S = 0.2000
Weight per foot of vessel, Vacuum, Corroded, (upper third):	M = 1595.4277 lb/ft
Strouhal number, Vacuum, Corroded:	S = 0.2000

Critical wind speed at top of vessel, V_h = (n*D/S)*(3600/5280) mph

Operating, Corroded: V_h = (3.0287*5.3434/0.2000)*(3600/5280) = 55.1717 mph (88.7902 km/h)
Empty, Corroded: V_h = (8.1494*5.3434/0.2000)*(3600/5280) = 148.4500 mph (238.9071 km/h)
Vacuum, Corroded: V_h = (3.0287*5.3434/0.2000)*(3600/5280) = 55.1717 mph (88.7902 km/h)

Reference wind speed corresponding to critical wind speed, V_{Ref}

Operating, Corroded: V_{Ref} = 57.4515 mph (92.4591 km/h)
Empty, Corroded: V_{Ref} = 154.5841 mph (248.7790 km/h)

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Vacuum, Corroded: V_{Ref} = 57.4515 mph (92.4591 km/h)

Corresponding reference wind speed, V_{Ref}

Operating, Corroded: V_{Ref} = 100.0000 mph (160.9344 km/h)
Empty, Corroded: V_{Ref} = 100.0000 mph (160.9344 km/h)
Vacuum, Corroded: V_{Ref} = 100.0000 mph (160.9344 km/h)

Speed for empty, corroded condition which produces vortex shedding is greater than reference speed. No further vortex shedding computations were done for this condition.

Corresponding pressure at top of vessel, $q_h = 0.00256 * V_h^2$

Operating, Corroded: $q_h = 0.00256 * (55.1717)^2 = 7.7924$ psf
Vacuum, Corroded: $q_h = 0.00256 * (55.1717)^2 = 7.7924$ psf

Equivalent static loading, FL = q_h*C_1*D / (SQR(Ar)*SQR(β - (C_2*R0*D^2/M)))

Operating, Corroded: FL = 7.7924*1.5377*5.3434 / (SQR(4.2038)*SQR(0.0260 - (0.6000*0.0765*$(5.3434)^2$/1595.4277)))
= 196.8259 lb/ft

Vacuum, Corroded: FL = 7.7924*1.5377*5.3434 / (SQR(4.2038)*SQR(0.0260 - (0.6000*0.0765*$(5.3434)^2$/1595.4277)))
= 196.8259 lb/ft

Static loading FL is applied throughout the top third of the vessel

Wind Pressures at Critical Wind Speed: Operating, Corroded (V_h = 55.1717 mph)

Kz = 2.01 * $(Z/Zg)^{2/\alpha}$
= 2.01 * $(Z/900.0000)^{0.2105}$
qz = 0.00256 * Kz * Kd * Kzt * Vh^2 * I psf
= 0.00256 * Kz * 0.9500 * 1.0000 * $(55.1717)^2$ * 1.1500
= 8.5132 * Kz
WP = qz * G^- * Cf
= qz * 0.8973 * 0.8000

Height Z(')	Kz	qz(psf)	WP(psf)
15.0	0.8489	7.2267	5.1879
20.0	0.9019	7.6779	5.5118
25.0	0.9453	8.0472	5.7769

Wind Pressures at Critical Wind Speed: Vacuum, Corroded (V_h = 55.1717 mph)

Kz = 2.01 * $(Z/Zg)^{2/\alpha}$
= 2.01 * $(Z/900.0000)^{0.2105}$
qz = 0.00256 * Kz * Kd * Kzt * Vh^2* I psf
= 0.00256 * Kz * 0.9500 * 1.0000 * $(55.1717)^2$ * 1.1500
= 8.5132 * Kz
WP = qz * G^- * Cf
= qz * 0.8973 * 0.8000

Height Z(')	Kz	qz(psf)	WP(psf)

Approved

15.0	0.8489	7.2267	5.1879
20.0	0.9019	7.6779	5.5118
25.0	0.9453	8.0472	5.7769

Gust Factor Calculations

Operating, Corroded
Empty, Corroded
Operating, Corroded, Vortex Shedding
Vacuum, Corroded, Vortex Shedding

Gust Factor Calculations: Operating, Corroded

Vessel is considered a rigid structure as n_1 = 3.0287 Hz ≥ 1 Hz.

z^- = 0.60 * h
= 0.60 * 22.4625
= 15.0000

I_{z^-} = c * $(33 / z^-)^{1/6}$
= 0.2000 * $(33 / 15.0000)^{1/6}$
= 0.2281

L_{z^-} = l * $(z^- / 33)^{ep}$
= 500.0000 * $(15.0000 / 33)^{0.2000}$
= 427.0566

Q = Sqr(1 / (1 + 0.63 * ((b + h) / L_{z^-})$^{0.63}$))
= Sqr(1 / (1 + 0.63 * ((5.8854 + 22.4625) / 427.0566)$^{0.63}$))
= 0.9474

G = 0.925 * (1 + 1.7 * g_Q * I_{z^-} * Q) / (1 + 1.7 * g_v * I_{z^-})
= 0.925 * (1 + 1.7 * 3.40* 0.2281 * 0.9474) / (1 + 1.7 * 3.40 * 0.2281)
= 0.8973

Gust Factor Calculations: Empty, Corroded

Vessel is considered a rigid structure as n_1 = 8.1494 Hz ≥ 1 Hz.

z^- = 0.60 * h
= 0.60 * 22.4625
= 15.0000

I_{z^-} = c * $(33 / z^-)^{1/6}$
= 0.2000 * $(33 / 15.0000)^{1/6}$
= 0.2281

L_{z^-} = l * $(z^- / 33)^{ep}$
= 500.0000 * $(15.0000 / 33)^{0.2000}$
= 427.0566

Q = Sqr(1 / (1 + 0.63 * ((b + h) / L_{z^-})$^{0.63}$))
= Sqr(1 / (1 + 0.63 * ((5.8854 + 22.4625) / 427.0566)$^{0.63}$))
= 0.9474

Approved

G = 0.925 * (1 + 1.7 * g_Q * I_{z^-} * Q) / (1 + 1.7 * g_v * I_{z^-})
= 0.925 * (1 + 1.7 * 3.40* 0.2281 * 0.9474) / (1 + 1.7 * 3.40 * 0.2281)
= 0.8973

Gust Factor Calculations: Operating, Corroded, Vortex Shedding

Vessel is considered a rigid structure as n_1 = 3.0287 Hz ≥ 1 Hz.

z^- = 0.60 * h
= 0.60 * 22.4625
= 15.0000

I_{z^-} = c * $(33 / z^-)^{1/6}$
= 0.2000 * $(33 / 15.0000)^{1/6}$
= 0.2281

L_{z^-} = l * $(z^- / 33)^{ep}$
= 500.0000 * $(15.0000 / 33)^{0.2000}$
= 427.0566

Q = Sqr(1 / (1 + 0.63 * ((b + h) / L_{z^-})$^{0.63}$))
= Sqr(1 / (1 + 0.63 * ((5.8854 + 22.4625) / 427.0566)$^{0.63}$))
= 0.9474

G = 0.925 * (1 + 1.7 * g_Q * I_{z^-} * Q) / (1 + 1.7 * g_v * I_{z^-})
= 0.925 * (1 + 1.7 * 3.40* 0.2281 * 0.9474) / (1 + 1.7 * 3.40 * 0.2281)
= 0.8973

Gust Factor Calculations: Vacuum, Corroded, Vortex Shedding

Vessel is considered a rigid structure as n_1 = 3.0287 Hz ≥ 1 Hz.

z^- = 0.60 * h
= 0.60 * 22.4625
= 15.0000

I_{z^-} = c * $(33 / z^-)^{1/6}$
= 0.2000 * $(33 / 15.0000)^{1/6}$
= 0.2281

L_{z^-} = l * $(z^- / 33)^{ep}$
= 500.0000 * $(15.0000 / 33)^{0.2000}$
= 427.0566

Q = Sqr(1 / (1 + 0.63 * ((b + h) / L_{z^-})$^{0.63}$))
= Sqr(1 / (1 + 0.63 * ((5.8854 + 22.4625) / 427.0566)$^{0.63}$))
= 0.9474

G = 0.925 * (1 + 1.7 * g_Q * I_{z^-} * Q) / (1 + 1.7 * g_v * I_{z^-})
= 0.925 * (1 + 1.7 * 3.40* 0.2281 * 0.9474) / (1 + 1.7 * 3.40 * 0.2281)
= 0.8973

Table Lookup Values

α = 9.5000, Zg = 900.0000 '	[Table 6-2, page 78]
c = 0.2000, l = 500.0000, ep = 0.2000	[Table 6-2, page 78]
a^- = 0.1538, b^- = 0.6500	[Table 6-2, page 78]
g_Q = 3.40	[6.5.8.1 page 26]
g_v = 3.40	[6.5.8.1 page 26]

Method of seismic analysis:	**ASCE 7-05 ground supported**
Site Class	C
Importance Factor:	I = 1.2500
Spectral Response Acceleration at short period (% g)	S_s = 20.38%
Spectral Response Acceleration at period of 1 sec (% g)	S_1 = 8.74%
Response Modification Coeficient from Table 15.4-2	R = 2.0000
Acceleration based site co-efficient:	F_a = 1.2000
Velocity based site co-efficient:	F_v = 1.7000
Long-period transition period:	T_L = 8.0000
Redundancy factor:	ρ = 1.0000
User Defined Vertical Accelerations Considered:	No

12.4.2.3 Basic Load Combinations for Allowable Stress Design
The following load combinations are considered in accordance with ASCE section 2.4.1:

5. $D + P + P_s + 0.7E = (1.0 + 0.14S_{DS})D + P + P_s + 0.7\rho Q_E$
8. $0.6D + P + P_s + 0.7E = (0.6 - 0.14S_{DS})D + P + P_s + 0.7\rho Q_E$

Where

D = Dead load
P = Internal or external pressure load
P_s = Static head load
E = Seismic load $= E_h +/- E_v = \rho Q_E +/- 0.2S_{DS}D$

Vessel Characteristics

Vessel height: 22.4625 ft
Vessel Weight:
Operating, Corroded: 31,094 lb
Empty, Corroded: 4,840 lb

Period of Vibration Calculation

Fundamental Period, T:
Operating, Corroded: 0.330 sec (f = 3.0 Hz)
Empty, Corroded: 0.123 sec (f = 8.1 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
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)
Top Head	256	29.0	*	177	103
Shell-02	180	29.0	1.0413	1,228	4,947
Shell-01 (top)	62	29.0	1.0413	2,158	24,299
Support Legs	0	29.0	0.0038	2,217	35,705
Shell-01 (bottom)	62	29.0	1.0413	50	26
Bottom Head	62	29.0	*	46	22
*Moment of Inertia I varies over the length of the component					

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)
Top Head	256	29.4	*	52	54
Shell-02	180	29.4	1.0413	179	1,012
Shell-01 (top)	62	29.4	1.0413	321	5,669
Support Legs	0	29.0	0.0038	345	7,415
Shell-01 (bottom)	62	29.4	1.0413	14	10
Bottom Head	62	29.4	*	13	9
*Moment of Inertia I varies over the length of the component					

11.4.3: Maximum considered earthquake spectral response acceleration

The maximum considered earthquake spectral response acceleration at short period, S_{MS}
$S_{MS} = F_a * S_s = 1.2000 * 20.38 / 100 = 0.2446$
The maximum considered earthquake spectral response acceleration at 1 s period, S_{M1}
$S_{M1} = F_v * S_1 = 1.7000 * 8.74 / 100 = 0.1486$

11.4.4: Design spectral response acceleration parameters

Design earthquake spectral response acceleration at short period, S_{DS}
$S_{DS} = 2 / 3 * S_{MS} = 2 / 3 * 0.2446 = 0.1630$
Design earthquake spectral response acceleration at 1 s period, S_{D1}
$S_{D1} = 2 / 3 * S_{M1} = 2 / 3 * 0.1486 = 0.0991$

12.4.2.3: Seismic Load Combinations: Vertical Term

Factor is applied to dead load.

Compressive Side: $= 1.0 + 0.14 * S_{DS}$
$= 1.0 + 0.14 * 0.1630$
$= 1.0228$

Tensile Side: $= 0.6 - 0.14 * S_{DS}$
$= 0.6 - 0.14 * 0.1630$
$= 0.5772$

Base Shear Calculations

Operating, Corroded
Empty, Corroded

Base Shear Calculations: Operating, Corroded

Paragraph 15.4.4: Period Determination

Fundamental Period is taken from the Rayleigh method listed previously in this report.

T = 0.3302 sec.

12.8.1: Calculation of Seismic Response Coefficient

C_s is the value computed below, bounded by C_sMin and C_sMax:
C_sMin is 0.03; in addition, if S_1 >= 0.6g, C_sMin shall not be less than eqn 15.4-2.
C_sMax calculated with 12.8-3 because (T = 0.3302) <= (T_L = 8.0000)

C_s = S_{DS} / (R / I) = 0.1630 / (2.0000 / 1.2500) = 0.1019
C_sMin = 0.03
C_sMax = S_{D1} / (T * (R / I)) = 0.0991 / (0.3302 * (2.0000 / 1.2500)) = 0.1875
C_s = 0.1019

12.8.1: Calculation of Base Shear

V = C_s * W
= 0.1019 * 31094.2305
= 3,168.50 lb

12.4.2.1 Seismic Load Combinations: Horizontal Seismic Load Effect, E_h
Q_E = V
E_h = 0.7 * ρ * Q_E (Only 70% of seismic load considered as per Section 2.4.1)
= 0.70 * 1.0000 * 3,168.50
= 2,217.95 lb

Base Shear Calculations: Empty, Corroded

Paragraph 15.4.4: Period Determination

Fundamental Period is taken from the Rayleigh method listed previously in this report.

T = 0.1227 sec.

12.8.1: Calculation of Seismic Response Coefficient

C_s is the value computed below, bounded by C_sMin and C_sMax:
C_sMin is 0.03; in addition, if S_1 >= 0.6g, C_sMin shall not be less than eqn 15.4-2.
C_sMax calculated with 12.8-3 because (T = 0.1227) <= (T_L = 8.0000)

C_s = S_{DS} / (R / I) = 0.1630 / (2.0000 / 1.2500) = 0.1019
C_sMin = 0.03
C_sMax = S_{D1} / (T * (R / I)) = 0.0991 / (0.1227 * (2.0000 / 1.2500)) = 0.5045
C_s = 0.1019

12.8.1: Calculation of Base Shear

V = C_s * W
= 0.1019 * 4839.7158
= 493.17 lb

12.4.2.1 Seismic Load Combinations: Horizontal Seismic Load Effect, E_h
Q_E = V
E_h = 0.7 * ρ * Q_E (Only 70% of seismic load considered as per Section 2.4.1)
= 0.70 * 1.0000 * 493.17
= 345.22 lb

Top Head

ASME Section VIII, Division 1, 2010 Edition

Component:	F&D Head
Material Specification:	SA-516 70 (II-D p.18, ln. 19)
Straight Flange governs MDMT	

Internal design pressure: P = 55 psi @ 160 °F

Static liquid head:

P_s= 0.6715 psi (SG=0.99, H_s=18.7892" Operating head)
P_{th}= 2.6825 psi (SG=1, H_s=74.3125" Horizontal test head)

Corrosion allowance: Inner C = 0.125" Outer C = 0"

Design MDMT = 10°F
Rated MDMT = -55°F

No impact test performed
Material is not normalized
Material is not produced to fine grain practice
PWHT is not performed
Do not Optimize MDMT / Find MAWP

Radiography:	Category A joints -	Seamless No RT
	Head to shell seam -	Spot UW-11(a)(5)(b) Type 1

Estimated weight*:	new = 402.8 lb	corr = 245.8 lb
Capacity*:	new = 131.3 US gal	corr = 133.7 US gal

* includes straight flange

Inner diameter	=	66"
Crown radius L	=	66"
Knuckle radius r	=	4.0625"
Minimum head thickness	=	0.3125"
Straight flange length L_{sf}	=	2"
Nominal straight flange thickness t_{sf}	=	0.375"

Insulation thk*:	2"	density: 8 lb/ft^3	weight: 45.8513 lb
Insulation support ring spacing:	0"	individual weight: 0 lb	total weight: 0 lb

* includes straight flange if applicable

Results Summary

The governing condition is internal pressure.

Minimum thickness per UG-16	=	0.0625" + 0.125" = 0.1875"
Design thickness due to internal pressure (t)	=	0.2855"
Maximum allowable working pressure (MAWP)	=	64.36 psi
Maximum allowable pressure (MAP)	=	107.7 psi

M (Corroded)

$M=1/4*[3 + (L / r)^{1/2}]=1/4*[3 + (66.125 / 4.1875)^{1/2}]=1.743449$

M (New)

$M=1/4*[3 + (L / r)^{1/2}]=1/4*[3 + (66 / 4.0625)^{1/2}]=1.757663$

Approved

Design thickness for internal pressure, (Corroded at 160 °F) Appendix 1-4(d)

t = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 55.67*66.125*1.7434 / (2*20,000*1 - 0.2*55.67) + 0.125
= 0.2855"

The head internal pressure design thickness is 0.2855".

Maximum allowable working pressure, (Corroded at 160 °F) Appendix 1-4(d)

P = $2*S*E*t / (L*M + 0.2*t) - P_s$
= 2*20,000*1*0.1875 / (66.125*1.7434 + 0.2*0.1875) - 0.67
= 64.36 psi

The maximum allowable working pressure (MAWP) is 64.36 psi.

Maximum allowable pressure, (New at 70 °F) Appendix 1-4(d)

P = $2*S*E*t / (L*M + 0.2*t) - P_s$
= 2*20,000*1*0.3125 / (66*1.7577 + 0.2*0.3125) - 0
= 107.7 psi

The maximum allowable pressure (MAP) is 107.7 psi.

% Extreme fiber elongation - UCS-79(d)

EFE = $(75*t / R_f)*(1 - R_f / R_o)$
= $(75*0.375 / 4.25)*(1 - 4.25 / \infty)$
= 6.6176%

The extreme fiber elongation exceeds 5 percent. Heat treatment per UCS-56 may be required. See UCS-79(d)(4) or (5).

Approved

Straight Flange on Top Head

ASME Section VIII Division 1, 2010 Edition

Component: Straight Flange
Material specification: SA-516 70 (II-D p. 18, ln. 19)
Material impact test exemption temperature from Fig UCS-66 Curve B = -20 °F
Fig UCS-66.1 MDMT reduction = 115.1 °F, (coincident ratio = 0.3824224)
Rated MDMT is governed by UCS-66(b)(2)
UCS-66 governing thickness = 0.3125 in

Internal design pressure: P = 55 psi @ 160 °F

Static liquid head:

P_s = 0.74 psi (SG = 0.99, H_s = 20.7892",Operating head)
P_{th} = 2.68 psi (SG = 1, H_s = 74.3125", Horizontal test head)

Corrosion allowance Inner C = 0.125" Outer C = 0"

Design MDMT = 10 °F
Rated MDMT = -55 °F

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

Radiography: Longitudinal joint - Seamless No RT
Circumferential joint - Spot UW-11(a)(5)b Type 1

Estimated weight	New = 44.3 lb	corr = 29.6 lb
Capacity	New = 29.62 US gal	corr = 29.85 US gal

ID = 66"
Length L_c = 2"
t = 0.375"
Insulation thk: 2" density: 8 lb/ft^3 Weight: 0 lb

Design thickness, (at 160 °F) UG-27(c)(1)

t = P*R / (S*E - 0.60*P) + Corrosion
= 55.74*33.125 / (20,000*1.00 - 0.60*55.74) + 0.125
= 0.2175"

Maximum allowable working pressure, (at 160 °F) UG-27(c)(1)

P = S*E*t / (R + 0.60*t) - P_s
= 20,000*1.00*0.25 / (33.125 + 0.60*0.25) - 0.74
= 149.52 psi

Maximum allowable pressure, (at 70 °F) UG-27(c)(1)

P = S*E*t / (R + 0.60*t)
= 20,000*1.00*0.375 / (33 + 0.60*0.375)
= 225.73 psi

Approved

% Extreme fiber elongation - UCS-79(d)

EFE = $(50*t / R_f)*(1 - R_f / R_o)$
= $(50*0.375 / 33.1875)*(1 - 33.1875 / \infty)$
= 0.565%

The extreme fiber elongation does not exceed 5%.

Design thickness = 0.2175"

The governing condition is due to internal pressure.

The cylinder thickness of 0.375" 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)	Load	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
		S_t	S_c					
Operating, Hot & Corroded	55	20,000	11,985	160	0.125	Wind	0.0446	0.0445
						Seismic	0.0446	0.0445
Operating, Hot & New	55	20,000	13,556	160	0	Wind	0.0444	0.0443
						Seismic	0.0444	0.0443
Hot Shut Down, Corroded	0	20,000	11,985	160	0.125	Wind	0	0.0001
						Seismic	0	0.0001
Hot Shut Down, New	0	20,000	13,556	160	0	Wind	0.0001	0.0002
						Seismic	0.0001	0.0002
Empty, Corroded	0	20,000	11,985	70	0.125	Wind	0	0.0001
						Seismic	0.0001	0.0001
Empty, New	0	20,000	13,556	70	0	Wind	0.0001	0.0002
						Seismic	0.0001	0.0002
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0	20,000	11,985	160	0.125	Weight	0.0001	0.0001
Operating, Hot & Corroded, Vortex Shedding	55	20,000	11,985	160	0.125	Wind	0.0446	0.0445
Vacuum, Vortex Shedding	0	20,000	11,985	160	0.125	Wind	0	0.0002

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ASME Section VIII Division 1, 2010 Edition

Component: Cylinder
Material specification: SA-516 70 (II-D p. 18, ln. 19)
Material impact test exemption temperature from Fig UCS-66 Curve B = -20 °F
Fig UCS-66.1 MDMT reduction = 51.4 °F, (coincident ratio = 0.5341435)
Rated MDMT is governed by UCS-66(b)(2)
UCS-66 governing thickness = 0.3125 in

Internal design pressure: P = 55 psi @ 160 °F

Static liquid head:

P_s = 3.46 psi (SG = 0.99, H_s = 96.7892",Operating head)
P_{th} = 2.68 psi (SG = 1, H_s = 74.3125", Horizontal test head)

Corrosion allowance Inner C = 0.125" Outer C = 0"

Design MDMT = 10 °F
Rated MDMT = -55 °F

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

Radiography: Longitudinal joint - Spot UW-11(b) Type 1
Top circumferential joint - Spot UW-11(a)(5)b Type 1
Bottom circumferential joint - Spot UW-11(b) Type 1

Estimated weight	New = 1,395.7 lb	corr = 839 lb
Capacity	New = 1,125.59 US gal	corr = 1,134.13 US gal

ID = 66"
Length L_c = 76"
t = 0.3125"
Insulation thk: 2" density: 8 lb/ft^3 Weight: 151.7 lb

Design thickness, (at 160 °F) UG-27(c)(1)

t = P*R / (S*E - 0.60*P) + Corrosion
= 58.46*33.125 / (20,000*0.85 - 0.60*58.46) + 0.125
= 0.2392"

Maximum allowable working pressure, (at 160 °F) UG-27(c)(1)

P = S*E*t / (R + 0.60*t) - P_s
= 20,000*0.85*0.1875 / (33.125 + 0.60*0.1875) - 3.46
= 92.44 psi

Maximum allowable pressure, (at 70 °F) UG-27(c)(1)

P = S*E*t / (R + 0.60*t)
= 20,000*0.85*0.3125 / (33 + 0.60*0.3125)
= 160.08 psi

Approved

% Extreme fiber elongation - UCS-79(d)

EFE = $(50*t / R_f)*(1 - R_f / R_o)$
= $(50*0.3125 / 33.1563)*(1 - 33.1563 / \infty)$
= 0.4713%

The extreme fiber elongation does not exceed 5%.

Design thickness = 0.2392"

The governing condition is due to internal pressure.

The cylinder thickness of 0.3125" 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)	Load	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
		S_t	S_c					
Operating, Hot & Corroded	55	20,000	10,149	160	0.125	Wind	0.0451	0.0436
						Seismic	0.0453	0.0434
Operating, Hot & New	55	20,000	12,874	160	0	Wind	0.0449	0.0433
						Seismic	0.0451	0.0431
Hot Shut Down, Corroded	0	20,000	10,149	160	0.125	Wind	0.0005	0.0017
						Seismic	0.0006	0.002
Hot Shut Down, New	0	20,000	12,874	160	0	Wind	0.0004	0.0016
						Seismic	0.0006	0.0019
Empty, Corroded	0	20,000	10,149	70	0.125	Wind	0.0005	0.0017
						Seismic	0	0.0009
Empty, New	0	20,000	12,874	70	0	Wind	0.0004	0.0016
						Seismic	0.0001	0.001
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0	20,000	10,149	160	0.125	Weight	0.0006	0.0007
Operating, Hot & Corroded, Vortex Shedding	55	20,000	10,149	160	0.125	Wind	0.0454	0.0433
Vacuum, Vortex Shedding	0	20,000	10,149	160	0.125	Wind	0.0008	0.0022

Approved

ASME Section VIII Division 1, 2010 Edition

Component: Cylinder
Material specification: SA-516 70 (II-D p. 18, ln. 19)
Material impact test exemption temperature from Fig UCS-66 Curve B = -20 °F
Fig UCS-66.1 MDMT reduction = 44.2 °F, (coincident ratio = 0.5715572)
Rated MDMT is governed by UCS-66(b)(2)
UCS-66 governing thickness = 0.3125 in

Internal design pressure: P = 55 psi @ 160 °F

Static liquid head:

P_s = 7.68 psi (SG = 0.99, H_s = 214.7892",Operating head)
P_{th} = 2.68 psi (SG = 1, H_s = 74.3125", Horizontal test head)

Corrosion allowance Inner C = 0.125" Outer C = 0"

Design MDMT = 10 °F
Rated MDMT = -55 °F

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

Radiography: Longitudinal joint - Spot UW-11(b) Type 1
Top circumferential joint - Spot UW-11(b) Type 1
Bottom circumferential joint - Spot UW-11(a)(5)b Type 1

Estimated weight	New = 2,128.2 lb	corr = 1,279.4 lb
Capacity	New = 1,747.62 US gal	corr = 1,760.89 US gal

ID = 66"
Length L_c = 118"
t = 0.3125"
Insulation thk: 2" density: 8 lb/ft^3 Weight: 235.6 lb

Design thickness, (at 160 °F) UG-27(c)(1)

t = P*R / (S*E - 0.60*P) + Corrosion
= 62.68*33.125 / (20,000*0.85 - 0.60*62.68) + 0.125
= 0.2474"

Maximum allowable working pressure, (at 160 °F) UG-27(c)(1)

P = S*E*t / (R + 0.60*t) - P_s
= 20,000*0.85*0.1875 / (33.125 + 0.60*0.1875) - 7.68
= 88.22 psi

Maximum allowable pressure, (at 70 °F) UG-27(c)(1)

P = S*E*t / (R + 0.60*t)
= 20,000*0.85*0.3125 / (33 + 0.60*0.3125)
= 160.08 psi

Approved

% Extreme fiber elongation - UCS-79(d)

$$EFE = (50*t / R_f)*(1 - R_f / R_o)$$
$$= (50*0.3125 / 33.1563)*(1 - 33.1563 / \infty)$$
$$= 0.4713\%$$

The extreme fiber elongation does not exceed 5%.

Design thickness = 0.2474"

The governing condition is due to internal pressure.

The cylinder thickness of 0.3125" 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	55	20,000	10,149	160	0.125	Top	Wind	0.0408	0.0339
							Seismic	0.041	0.0337
						Bottom	Wind	0.0433	0.0411
							Seismic	0.0434	0.041
Operating, Hot & New	55	20,000	12,874	160	0	Top	Wind	0.0405	0.0334
							Seismic	0.0409	0.0331
						Bottom	Wind	0.0431	0.041
							Seismic	0.0432	0.0409
Hot Shut Down, Corroded	0	20,000	10,149	160	0.125	Top	Wind	0.0029	0.008
							Seismic	0.0031	0.0084
						Bottom	Wind	0.0053	0.0032
							Seismic	0.0054	0.0031
Hot Shut Down, New	0	20,000	12,874	160	0	Top	Wind	0.0027	0.0068
							Seismic	0.0031	0.0074
						Bottom	Wind	0.0053	0.0032
							Seismic	0.0054	0.0031
Empty, Corroded	0	20,000	10,149	70	0.125	Top	Wind	0.0029	0.008
							Seismic	0.0004	0.0031
						Bottom	Wind	0.0001	0
							Seismic	0.0001	0
Empty, New	0	20,000	12,874	70	0	Top	Wind	0.0027	0.0068
							Seismic	0.0004	0.0032
						Bottom	Wind	0.0001	0.0001
							Seismic	0.0001	0.0001
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0	20,000	10,149	160	0.125	Top	Weight	0.0009	0.0025
						Bottom	Weight	0.0064	0.0064
Operating, Hot & Corroded, Vortex Shedding	55	20,000	10,149	160	0.125	Top	Wind	0.0411	0.0336
						Bottom	Wind	0.0433	0.0411

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Vacuum, Vortex Shedding	0	20,000	10,149	160	0.125	Top	Wind	0.0032	0.0085
						Bottom	Wind	0.0053	0.0032

Approved

Straight Flange on Bottom Head

ASME Section VIII Division 1, 2010 Edition

Component: Straight Flange
Material specification: SA-516 70 (II-D p. 18, ln. 19)
Material impact test exemption temperature from Fig UCS-66 Curve B = -20 °F
Fig UCS-66.1 MDMT reduction = 88 °F, (coincident ratio = 0.4289964)
Rated MDMT is governed by UCS-66(b)(2)
UCS-66 governing thickness = 0.3125 in

Internal design pressure: P = 55 psi @ 160 °F

Static liquid head:

P_s = 7.75 psi (SG = 0.99, H_s = 216.7892",Operating head)
P_{th} = 2.68 psi (SG = 1, H_s = 74.3125", Horizontal test head)

Corrosion allowance Inner C = 0.125" Outer C = 0"

Design MDMT = 10 °F
Rated MDMT = -55 °F

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

Radiography: Longitudinal joint - Seamless No RT
Circumferential joint - Spot UW-11(a)(5)b Type 1

Estimated weight	New = 44.3 lb	corr = 29.6 lb
Capacity	New = 29.62 US gal	corr = 29.85 US gal

ID = 66"
Length L_c = 2"
t = 0.375"
Insulation thk: 2" density: 8 lb/ft^3 Weight: 0 lb

Design thickness, (at 160 °F) UG-27(c)(1)

t = P*R / (S*E - 0.60*P) + Corrosion
= 62.75*33.125 / (20,000*1.00 - 0.60*62.75) + 0.125
= 0.2292"

Maximum allowable working pressure, (at 160 °F) UG-27(c)(1)

P = S*E*t / (R + 0.60*t) - P_s
= 20,000*1.00*0.25 / (33.125 + 0.60*0.25) - 7.75
= 142.52 psi

Maximum allowable pressure, (at 70 °F) UG-27(c)(1)

P = S*E*t / (R + 0.60*t)
= 20,000*1.00*0.375 / (33 + 0.60*0.375)
= 225.73 psi

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% Extreme fiber elongation - UCS-79(d)

EFE = $(50*t / R_f)*(1 - R_f / R_o)$
= $(50*0.375 / 33.1875)*(1 - 33.1875 / \infty)$
= 0.565%

The extreme fiber elongation does not exceed 5%.

Design thickness = 0.2292"

The governing condition is due to internal pressure.

The cylinder thickness of 0.375" 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)	Load	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
		S_t	S_c					
Operating, Hot & Corroded	55	20,000	11,985	160	0.125	Wind	0.0508	0.0483
						Seismic	0.051	0.0482
Operating, Hot & New	55	20,000	13,556	160	0	Wind	0.0507	0.0482
						Seismic	0.0508	0.048
Hot Shut Down, Corroded	0	20,000	11,985	160	0.125	Wind	0.0062	0.0037
						Seismic	0.0064	0.0036
Hot Shut Down, New	0	20,000	13,556	160	0	Wind	0.0062	0.0037
						Seismic	0.0063	0.0036
Empty, Corroded	0	20,000	11,985	70	0.125	Wind	0.0001	0
						Seismic	0.0001	0
Empty, New	0	20,000	13,556	70	0	Wind	0.0001	0.0001
						Seismic	0.0001	0.0001
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0	20,000	11,985	160	0.125	Weight	0.0074	0.0074
Operating, Hot & Corroded, Vortex Shedding	55	20,000	11,985	160	0.125	Wind	0.0508	0.0483
Vacuum, Vortex Shedding	0	20,000	11,985	160	0.125	Wind	0.0062	0.0037

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Bottom Head

ASME Section VIII, Division 1, 2010 Edition

Component:	F&D Head
Material Specification:	SA-516 70 (II-D p.18, ln. 19)
Straight Flange governs MDMT	

Internal design pressure: P = 55 psi @ 160 °F

Static liquid head:

P_s= 8.1533 psi (SG=0.99, H_s=228.1523" Operating head)
P_{th}= 2.6825 psi (SG=1, H_s=74.3125" Horizontal test head)

Corrosion allowance: Inner C = 0.125" Outer C = 0"

Design MDMT = 10°F
Rated MDMT = -55°F

No impact test performed
Material is not normalized
Material is not produced to fine grain practice
PWHT is not performed
Do not Optimize MDMT / Find MAWP

Radiography:	Category A joints -	Seamless No RT
	Head to shell seam -	Spot UW-11(a)(5)(b) Type 1

Estimated weight*:	new = 403.2 lb	corr = 246 lb
Capacity*:	new = 131.3 US gal	corr = 133.7 US gal

* includes straight flange

Inner diameter	=	66"
Crown radius L	=	66"
Knuckle radius r	=	4.0625"
Minimum head thickness	=	0.3125"
Straight flange length L_{sf}	=	2"
Nominal straight flange thickness t_{sf}	=	0.375"

Insulation thk*:	2"	density: 8 lb/ft^3	weight: 45.8513 lb
Insulation support ring spacing:	0"	individual weight: 0 lb	total weight: 0 lb

* includes straight flange if applicable

Results Summary

The governing condition is internal pressure.

Minimum thickness per UG-16	=	0.0625" + 0.125" = 0.1875"
Design thickness due to internal pressure (t)	=	0.3071"
Maximum allowable working pressure (MAWP)	=	56.88 psi
Maximum allowable pressure (MAP)	=	107.7 psi

M (Corroded)

$M=1/4*[3 + (L / r)^{1/2}]=1/4*[3 + (66.125 / 4.1875)^{1/2}]=1.743449$

M (New)

$M=1/4*[3 + (L / r)^{1/2}]=1/4*[3 + (66 / 4.0625)^{1/2}]=1.757663$

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Design thickness for internal pressure, (Corroded at 160 °F) Appendix 1-4(d)

t = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 63.15*66.125*1.7434 / (2*20,000*1 - 0.2*63.15) + 0.125
= 0.3071"

The head internal pressure design thickness is 0.3071".

Maximum allowable working pressure, (Corroded at 160 °F) Appendix 1-4(d)

P = $2*S*E*t / (L*M + 0.2*t) - P_s$
= 2*20,000*1*0.1875 / (66.125*1.7434 + 0.2*0.1875) - 8.15
= 56.88 psi

The maximum allowable working pressure (MAWP) is 56.88 psi.

Maximum allowable pressure, (New at 70 °F) Appendix 1-4(d)

P = $2*S*E*t / (L*M + 0.2*t) - P_s$
= 2*20,000*1*0.3125 / (66*1.7577 + 0.2*0.3125) - 0
= 107.7 psi

The maximum allowable pressure (MAP) is 107.7 psi.

% Extreme fiber elongation - UCS-79(d)

EFE = $(75*t / R_f)*(1 - R_f / R_o)$
= $(75*0.375 / 4.25)*(1 - 4.25 / \infty)$
= 6.6176%

The extreme fiber elongation exceeds 5 percent. Heat treatment per UCS-56 may be required. See UCS-79(d)(4) or (5).

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Support Legs

Leg material:			A36
Leg description:			6x6x1/2 Equal Angle (Leg in)
Number of legs:	N =	4	
Overall length:		78	in
Base to girth seam length:		62	in
Pad length:		18	in
Pad width:		11	in
Pad thickness:		0.3125	in
Bolt circle:		64.625	in
Anchor bolt size:		1	inch -8 UNC 2A bolt
Anchor bolt material:			A325
Anchor bolts/leg:		1	
Anchor bolt allowable stress:	S_b =	20,000	psi
Anchor bolt corrosion allowance:		0.125	in
Anchor bolt hole clearance:		0.25	in
Base plate width:		8	in
Base plate length:		8	in
Base plate thickness:		1	in (0.8618 in required)
Base plate allowable stress:		24,000	psi
Foundation allowable bearing stress:		1,658	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 pad fillet weld:		0.25	in (0.069 in required)
Pad to shell fillet weld:		0.25	in (0.0401 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)

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Wind operating corroded
Wind operating new
Wind empty corroded
Wind empty new
Seismic operating corroded
Seismic operating new
Seismic empty corroded
Seismic empty new
Vortex shedding operating corroded

Loading	Force attack angle °	Leg position °	Axial end load 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 **Wind operating new** **Moment = 22,956.0 lb_f-ft**	**0**	0	694.8	253.9	121	4,018	0	0.1517	0.1747
		90	7,985.1	999.3	1,389	3,451	8,449	0.5220	0.5651
		180	12,081.3	253.9	2,101	8,939	0	0.4808	0.4735
		270	7,985.1	999.3	1,389	3,451	8,449	0.5220	0.5651
	45	0	694.8	626.6	121	6,788	3,746	0.3856	0.4490
		90	694.8	626.6	121	6,788	3,746	0.3856	0.4490
		180	12,081.3	626.6	2,101	11,709	3,746	0.7293	0.7478
		270	12,081.3	626.6	2,101	11,709	3,746	0.7293	0.7478

Leg Calculations (AISC manual ninth edition)

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

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$P_1 = W_t / N + 48*M_t / (N*D)$
$= 31,940.46 / 4 + 48*22,956 / (4*67.25)$
$= 12,081.35$ lb_f

Allowable axial compressive stress, F_a (AISC chapter E)

Local buckling check (AISC 5-99)

$b / t = (6 / 0.5) < (76 / Sqr(36))$ so $Q_s = 1$

Flexural-torsional buckling (AISC 5-317)

Shear center distance $w_o = 2.0223$
$r_o^2 = w_o^2 + (I_z + I_w) / A$
$= 2.0223^2 + (8.06 + 31.74) / 5.75$
$= 11.01$ in^2

Torsional constant $J = 0.48$ in^4
Shear modulus $G = 11,165$ ksi

$F_{ej} = G*J / (A*r_o^2)$
$= 11,165,000*0.48 / (5.75*11.0114)$
$= 85$ ksi

$K*l / r_w = 1.2*63.25 / 2.3493 = 32.3069$

$F_{ew} = \pi^2*E / (K*l / r_w)^2$
$= \pi^2*29,000 / (32.3069)^2$
$= 274$ ksi

$H = 1 - (w_o^2 / r_o^2)$
$= 1 - (2.0223^2 / 11.0114)$
$= 0.6285853$

$F_e = ((F_{ew} + F_{ej}) / (2*H))*(1 - Sqr(1 - (4*F_{ew}*F_{ej}*H) / (F_{ew} + F_{ej})^2))$
$= ((274 + 85) / (2*0.6286))*(1 - Sqr(1 - (4*274*85*0.6286) / (274 + 85)^2))$
$= 74$ ksi

Equivalent slenderness ratio

$K*l / r = \pi*Sqr(E / F_e)$
$= \pi*Sqr(29,000 / 74)$
$= 62.08502$

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

$K*l / r = 1.2*63.25 / 1.1841 = 64.0968$

$F_a = 1 * (1 - (K*l / r)^2 / (2*C_c^2))*F_y / (5 / 3 + 3*(K*l / r) / (8*C_c) - (K*l / r)^3 / (8*C_c^3))$
$= 1 * (1 - (64.0968)^2 / (2*126.0993^2))*36,000 / (5 / 3 + 3*(64.0968) / (8*126.0993) - (64.0968)^3 / (8*126.0993^3))$
$= 17,030$ psi

Allowable axial compression and bending (AISC chapter H)

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

$F'_{ex} = 1*12*\pi^2*E / (23*(K*l / r)^2)$

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$= 1*12*\pi^2*29{,}000{,}000 / (23*(86.5307)^2)$
$= 19{,}944$ psi

$F'_{ey} = 1*12*\pi^2*E / (23*(K*l / r)^2)$
$= 1*12*\pi^2*29{,}000{,}000 / (23*(43.6144)^2)$
$= 78{,}504$ psi

$F_b = 1*0.66*F_y$
$= 1*0.66*36{,}000$
$= 23{,}760$ psi

Compressive axial stress

$f_a = P_1 / A$
$= 12{,}081.35 / 5.75$
$= 2{,}101$ psi

Bending stresses

$f_{bx} = F*\cos(\alpha)*L / (I_x / C_x) + P_1*E_{cc} / (I_x / C_x)$
$= 626.56*\text{abs}(\cos(135))*63.25 / (8.0627 / 1.8667) + 12{,}081.35*1.8667 / (8.0627 / 1.8667)$
$= 11{,}709$ psi

$f_{by} = F*\sin(\alpha)*L / (I_y / C_y)$
$= 626.56*\sin(135)*63.25 / (31.74 / 4.24)$
$= 3{,}746$ psi

AISC equation H_{1-1}

$H_{1-1} = f_a / F_a + C_{mx}*f_{bx} / ((1 - f_a / F'_{ex})*F_{bx}) + C_{my}*f_{by} / ((1 - f_a / F'_{ey})*F_{by})$
$= 2{,}101 / 17{,}030 + 0.85*11{,}709 / ((1 - 2{,}101 / 19{,}944)*23{,}760) + 0.85*3{,}746 / ((1 - 2{,}101 / 78{,}504)*23{,}760)$
$= 0.7293$

AISC equation H_{1-2}

$H_{1-2} = f_a / (0.6*1*F_y) + f_{bx} / F_{bx} + f_{by} / F_{by}$
$= 2{,}101 / (0.6*1*36{,}000) + 11{,}709 / 23{,}760 + 3{,}746 / 23{,}760$
$= 0.7478$

4, 6x6x1/2 Equal Angle legs are adequate.

Anchor bolts - Wind empty corroded condition governs

Tensile loading per leg (1 bolt per leg)

$R = 48*M / (N*BC) - 0.6*W / N$
$= 48*35{,}908.3 / (4*64.625) - 0.6*4{,}839.72 / 4$
$= 5{,}941.74$ lb$_f$

Required area per bolt

$A_b = R / (S_b*n)$
$= 5{,}941.74 / (20{,}000*1)$
$= 0.2971$ in^2

Area of a 1 inch -8 UNC 2A bolt bolt (corroded) = 0.3101 in^2

1 inch -8 UNC 2A bolt bolts are satisfactory.

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Check the leg to pad fillet weld, Bednar 10.3, Seismic operating new 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).

$Z_w = (2*b*d + d^2) / 3$
$= (2*8.4853*14.75 + 14.75^2) / 3$
$= 155.9596 \text{ in}^2$

$J_w = (b + 2*d)^3 / 12 - d^2*(b + d)^2 / (b + 2*d)$
$= (8.4853 + 2*14.75)^3 / 12 - 14.75^2*(8.4853 + 14.75)^2 / (8.4853 + 2*14.75)$
$= 1{,}475.1801 \text{ in}^3$

$E = d^2 / (b + 2*d)$
$= 14.75^2 / (8.4853 + 2*14.75)$
$= 5.727545 \text{ in}$

Governing weld load $f_x = \text{Cos}(45)*581.16 = 410.94 \text{ lb}_f$
Governing weld load $f_y = \text{Sin}(45)*581.16 = 410.94 \text{ lb}_f$

$f_1 = P_1 / L_{weld}$
$= 12{,}696.17 / 37.9853$
$= 334.24 \text{ lb}_f/\text{in}$ (V_L direct shear)

$f_2 = f_y*L_{leg}*0.5*b / J_w$
$= 410.94*63.25*0.5*8.4853 / 1{,}475.1801$
$= 74.75 \text{ lb}_f/\text{in}$ (V_L torsion shear)

$f_3 = f_y / L_{weld}$
$= 410.94 / 37.9853$
$= 10.82 \text{ lb}_f/\text{in}$ (V_c direct shear)

$f_4 = f_y*L_{leg}*E / J_w$
$= 410.94*63.25*5.7275 / 1{,}475.1801$
$= 100.92 \text{ lb}_f/\text{in}$ (V_c torsion shear)

$f_5 = (f_x*L_{leg} + P_1*E_{cc}) / Z_w$
$= (410.94*63.25 + 12{,}696.17*1.8667) / 155.9596$
$= 318.62 \text{ lb}_f/\text{in}$ (M_L bending)

$f_6 = f_x / L_{weld}$
$= 410.94 / 37.9853$
$= 10.82 \text{ lb}_f/\text{in}$ (Direct outward radial shear)

$f = \text{Sqr}((f_1 + f_2)^2 + (f_3 + f_4)^2 + (f_5 + f_6)^2)$
$= \text{Sqr}((334.24 + 74.75)^2 + (10.82 + 100.92)^2 + (318.62 + 10.82)^2)$
$= 536.93 \text{ lb}_f/\text{in}$ (Resultant shear load)

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

$t_w = f / (0.707*0.55*S_a)$
$= 536.93 / (0.707*0.55*20{,}000)$
$= 0.069$ in

The 0.25 in leg to pad attachment fillet weld size is adequate.

Check the pad to vessel fillet weld, Bednar 10.3, Seismic operating new governs

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$Z_w = b*d + d^2 / 3$
$= 11*18 + 18^2 / 3$
$= 306\ in^2$

$J_w = (b + d)^3 / 6$
$= (11 + 18)^3 / 6$
$= 4{,}064.8333\ in^3$

$f_1 = P_1 / L_{weld}$
$= 12{,}696.17 / 58$
$= 218.9\ lb_f/in$ (V_L direct shear)

$f_2 = f_y*L_{leg}*0.5*b / J_w$
$= 410.94*63.25*0.5*11 / 4{,}064.8333$
$= 35.17\ lb_f/in$ (V_L torsion shear)

$f_3 = f_y / L_{weld}$
$= 410.94 / 58$
$= 7.09\ lb_f/in$ (V_c direct shear)

$f_4 = f_y*L_{leg}*0.5*d / J_w$
$= 410.94*63.25*0.5*18 / 4{,}064.8333$
$= 57.55\ lb_f/in$ (V_c torsion shear)

$f_5 = (f_x*L_{leg} + P_1*E_{cc}) / Z_w$
$= (410.94*63.25 + 12{,}696.17*1.8667) / 306$
$= 162.39\ lb_f/in$ (M_L bending)

$f_6 = f_x / L_{weld}$
$= 410.94 / 58$
$= 7.09\ lb_f/in$ (Direct outward radial shear)

$f = Sqr((f_1 + f_2)^2 + (f_3 + f_4)^2 + (f_5 + f_6)^2)$
$= Sqr((218.9 + 35.17)^2 + (7.09 + 57.55)^2 + (162.39 + 7.09)^2)$
$= 312.17\ lb_f/in$ (Resultant shear load)

Required pad to vessel fillet weld leg size (welded all around the pad edge)

$t_w = f / (0.707*0.55*S_a)$
$= 312.17 / (0.707*0.55*20{,}000)$
$= 0.0401$ in

0.25 in pad to vessel attachment fillet weld size is adequate.

Base plate thickness check, AISC 3-106

$f_p = P / (B*N)$
$= 15{,}272.17 / (8*8)$
$= 239\ psi$

Required base plate thickness is the largest of the following: (0.8618 in)

$t_b = Sqr(0.5*P / S_b)$
$= Sqr(0.5*15{,}272.17 / 24{,}000)$
$= 0.5641$ in

$t_b = 0.5*(N - d)*Sqr(3*f_p / S_b)$
$= 0.5*(8 - 6)*Sqr(3*239 / 24{,}000)$

Approved

= 0.1727 in

t_b = Sqr(3*P_t*0.5*Abs(OD - BC) / S_b)
= Sqr(3*5,941.74*0.5*Abs(66.625 - 64.625) / 24,000)
= 0.8618 in

The base plate thickness is adequate.

Check the leg to vessel attachment stresses, WRC-107 (Wind operating corroded governs)

Applied Loads

Radial load:	P_r =	-443.04	lb_f
Circumferential moment:	M_c =	0	lb_f-in
Circumferential shear:	V_c =	0	lb_f
Longitudinal moment:	M_L =	49,874.09	lb_f-in
Longitudinal shear:	V_L =	11,705.96	lb_f
Torsion moment:	M_t =	0	lb_f-in
Internal pressure:	P =	64.557	psi
Mean shell radius:	R_m =	33.2813	in
Local shell thickness:	t =	0.1875	in
Shell yield stress:	S_y =	35,500	psi

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

R_m / t = 33.2813 / 0.1875 = 177.5

C_1 = 5.5, C_2 = 14.2866 in

Local circumferential pressure stress = $P*R_i$ / t =11,427 psi

Local longitudinal pressure stress = $P*R_i$ / (2*t) =5,714 psi

Maximum combined stress (P_L+P_b+Q) = 22,459 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-60,000 psi

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

Maximum local primary membrane stress (P_L) = 15,143 psi
Allowable local primary membrane (P_L) = +-1.5*S = +-30,000 psi

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

Stresses at the pad 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*	1.9355	0.3712	0	0	0	0	137	137	137	137
4C*	10.2157	0.31	725	725	725	725	0	0	0	0
1C	0.06	0.2401	0	0	0	0	4,537	-4,537	4,537	-4,537
2C-1	0.0083	0.2401	628	-628	628	-628	0	0	0	0
3A*	4.2162	0.2272	0	0	0	0	0	0	0	0
1A	0.0495	0.2412	0	0	0	0	0	0	0	0
3B*	5.4586	0.3123	-2,991	-2,991	2,991	2,991	0	0	0	0
1B-1	0.0067	0.2562	-6,688	6,688	6,688	-6,688	0	0	0	0
Pressure stress*			11,427	11,427	11,427	11,427	11,427	11,427	11,427	11,427
Total circumferential stress			3,101	15,221	22,459	7,827	16,101	7,027	16,101	7,027
Primary membrane circumferential stress*			9,161	9,161	15,143	15,143	11,564	11,564	11,564	11,564
3C*	2.6781	0.31	190	190	190	190	0	0	0	0
4C*	7.7866	0.3712	0	0	0	0	553	553	553	553
1C-1	0.014	0.3209	1,059	-1,059	1,059	-1,059	0	0	0	0
2C	0.03	0.3209	0	0	0	0	2,268	-2,268	2,268	-2,268
4A*	14.8033	0.2272	0	0	0	0	0	0	0	0
2A	0.0188	0.2891	0	0	0	0	0	0	0	0
4B*	2.658	0.3123	-2,548	-2,548	2,548	2,548	0	0	0	0
2B-1	0.0098	0.3151	-7,954	7,954	7,954	-7,954	0	0	0	0
Pressure stress*			5,714	5,714	5,714	5,714	5,714	5,714	5,714	5,714
Total longitudinal stress			-3,539	10,251	17,465	-561	8,535	3,999	8,535	3,999
Primary membrane longitudinal stress*			3,356	3,356	8,452	8,452	6,267	6,267	6,267	6,267
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	-1,092	-1,092	1,092	1,092
Total Shear stress			0	0	0	0	-1,092	-1,092	1,092	1,092

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Combined stress (P_L+P_b+Q)	-6,640	15,221	22,459	-8,388	16,255	7,380	16,255	7,380

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Note: * denotes primary stress.

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

$R_m / t = 33.2813 / 0.5 = 66.5625$

$C_1 = 4.2427$, $C_2 = 11.7071$ in

Local circumferential pressure stress = $P*R_i / t$ =11,427 psi

Local longitudinal pressure stress = $P*R_i / (2*t)$ =5,714 psi

Maximum combined stress (P_L+P_b+Q) = 15,886 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-60,000 psi

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

Maximum local primary membrane stress (P_L) = 12,880 psi
Allowable local primary membrane (P_L) = +-1.5*S = +-30,000 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*	2.528	0.2982	0	0	0	0	67	67	67	67
4C*	7.2401	0.2478	193	193	193	193	0	0	0	0
1C	0.0672	0.1902	0	0	0	0	715	-715	715	-715
2C-1	0.0281	0.1902	299	-299	299	-299	0	0	0	0
3A*	2.6006	0.1788	0	0	0	0	0	0	0	0
1A	0.066	0.2052	0	0	0	0	0	0	0	0
3B*	4.7809	0.2508	-1,260	-1,260	1,260	1,260	0	0	0	0
1B-1	0.0167	0.2219	-2,707	2,707	2,707	-2,707	0	0	0	0
Pressure stress*			11,427	11,427	11,427	11,427	11,427	11,427	11,427	11,427
Total circumferential stress			7,952	12,768	15,886	9,874	12,209	10,779	12,209	10,779
Primary membrane circumferential stress*			10,360	10,360	12,880	12,880	11,494	11,494	11,494	11,494
3C*	3.338	0.2478	89	89	89	89	0	0	0	0
4C*	6.199	0.2982	0	0	0	0	165	165	165	165
1C-1	0.0363	0.2568	386	-386	386	-386	0	0	0	0
2C	0.0317	0.2568	0	0	0	0	337	-337	337	-337
4A*	5.5073	0.1788	0	0	0	0	0	0	0	0
2A	0.0251	0.2579	0	0	0	0	0	0	0	0
4B*	2.3594	0.2508	-985	-985	985	985	0	0	0	0
2B-1	0.021	0.2807	-2,691	2,691	2,691	-2,691	0	0	0	0
Pressure stress*			5,714	5,714	5,714	5,714	5,714	5,714	5,714	5,714
Total longitudinal stress			2,513	7,123	9,865	3,711	6,216	5,542	6,216	5,542
Primary membrane longitudinal stress*			4,818	4,818	6,788	6,788	5,879	5,879	5,879	5,879
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

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Long shear from V_L	0	0	0	0	-500	-500	500	500
Total Shear stress	0	0	0	0	-500	-500	500	500
Combined stress (P_L+P_b+Q)	7,952	12,768	15,886	9,874	12,250	10,826	12,250	10,826

Note: * denotes primary stress.

Liquid Level

Location from datum	216.7892"
Operating Liquid Specific Gravity	0.99
Test liquid specific gravity	1

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Pump Suction (A)

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$t_{w(lower)}$ = 0.3125 in
Leg_{41} = 0.3125 in

.

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

Located on:	Bottom Head
Liquid static head included:	8.4811 psi
Nozzle material specification:	SA-106 B Smls pipe (II-D p. 10, ln. 40)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	NPS 8 Sch 40 (Std)
Flange description:	8 inch Class 150 WN A105
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 334, ln. 32)
Flange rated MDMT:	-55°F
(UCS-66(b)(3): Coincident ratio = 0.2293811)	
(Flange rated MDMT = -155 °F Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F)	
Liquid static head on flange:	8.4922 psi
ASME B16.5 flange rating MAWP:	270 psi @ 160°F
ASME B16.5 flange rating MAP:	285 psi @ 70°F
ASME B16.5 flange hydro test:	450 psi @ 70°F
Gasket Description:	Flexitallic Spiral Wound CG 304 S.S.
PWHT performed:	No
Circumferential joint radiography:	None UW-11(c) Type 1
Nozzle orientation:	0°
Calculated as hillside:	No
Local vessel minimum thickness:	0.3125 in
End of nozzle to datum line:	-20.8476 in
Nozzle inside diameter, new:	7.981 in
Nozzle nominal wall thickness:	0.322 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	5.4375 in
Projection available outside vessel to flange face, Lf:	9.4375 in
Distance to head center, R:	0 in

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Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 65.36 psi @ 160 °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}
0.8728	0.9557	0.6264	0.2458	--	--	0.0835	0.2331	0.2818

UG-41 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})	0.1312	0.2188	weld size is adequate

Reinforcement Calculations for MAP

UG-37 Area Calculation Summary (in^2) For P = 107.7 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}
1.4355	1.5425	1.0625	0.3965	--	--	0.0835	0.1778	0.2818

UG-41 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})	0.2188	0.2188	weld size is adequate

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Inlet (B)

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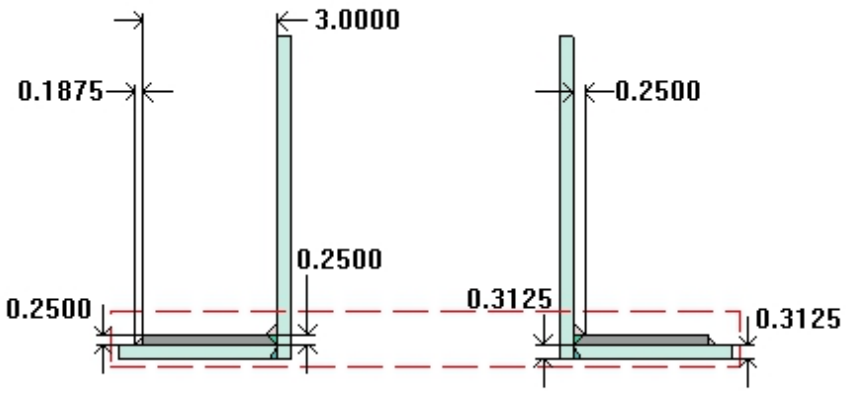

$t_{w(lower)}$ = 0.3125 in
Leg_{41} = 0.25 in
$t_{w(upper)}$ = 0.25 in
Leg_{42} = 0.1875 in
D_p = 14.625 in
t_e = 0.25 in

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

Located on:	Shell-01
Liquid static head included:	6.8177 psi
Nozzle material specification:	SA-106 B Smls pipe (II-D p. 10, ln. 40)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	NPS 8 Sch 40 (Std)
Pad material specification:	SA-516 70 (II-D p. 18, ln. 19)
Pad diameter:	14.625 in
Flange description:	8 inch Class 150 WN A105
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 334, ln. 32)
Flange rated MDMT:	-55°F
(UCS-66(b)(3): Coincident ratio = 0.2230053)	
(Flange rated MDMT = -155 °F Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F)	
Liquid static head on flange:	6.6751 psi
ASME B16.5 flange rating MAWP:	270 psi @ 160°F
ASME B16.5 flange rating MAP:	285 psi @ 70°F
ASME B16.5 flange hydro test:	450 psi @ 70°F
Gasket Description:	Flexitallic Spiral Wound CG 304 S.S.
PWHT performed:	No
Circumferential joint radiography:	None UW-11(c) Type 1
Nozzle orientation:	180°
Local vessel minimum thickness:	0.3125 in
Nozzle center line offset to datum line:	30 in
End of nozzle to shell center:	41.3125 in
Nozzle inside diameter, new:	7.981 in
Nozzle nominal wall thickness:	0.322 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	4 in

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Projection available outside vessel to flange face, Lf: 8 in

Pad is split: No

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 63.7 psi @ 160 °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}
0.8535	2.4792	0.6452	0.2462	--	1.5	0.0878	0.2307	0.2818

UG-41 Weld Failure Path Analysis Summary (lb_f) All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength	Weld load W_{3-3}	Path 3-3 strength
5,066.05	36,680	92,482.24	8,040.82	116,103.98	38,744.82	79,808.73

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.175	0.175	weld size is adequate
Pad to shell fillet (Leg_{42})	0.0937	0.1312	weld size is adequate
Nozzle to pad groove (Upper)	0.175	0.25	weld size is adequate

Reinforcement Calculations for MAP

UG-37 Area Calculation Summary (in^2) For P = 107.7 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}
1.4394	3.0439	1.0588	0.3965	--	1.5	0.0886	0.1783	0.2818

UG-41 Weld Failure Path Analysis Summary (lb_f) All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength	Weld load W_{3-3}	Path 3-3 strength
9,090.59	39,702	92,482.24	12,439.38	141,168	43,143.38	104,872.75

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.175	0.175	weld size is adequate
Pad to shell fillet (Leg_{42})	0.125	0.1312	weld size is adequate

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Nozzle to pad groove (Upper)	0.175	0.25	weld size is adequate

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Vapor Outlet (C)

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$t_{w(lower)}$ = 0.3125 in
Leg_{41} = 0.3125 in

.

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

Located on:	Top Head
Liquid static head included:	0.2699 psi
Nozzle material specification:	SA-106 B Smls pipe (II-D p. 10, ln. 40)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	NPS 8 Sch 40 (Std)
Flange description:	8 inch Class 150 WN A105
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 334, ln. 32)
Flange rated MDMT:	-55°F
(UCS-66(b)(3): Coincident ratio = 0.1995839)	
(Flange rated MDMT = -155 °F Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F)	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	270 psi @ 160°F
ASME B16.5 flange rating MAP:	285 psi @ 70°F
ASME B16.5 flange hydro test:	450 psi @ 70°F
Gasket Description:	Flexitallic Spiral Wound CG 304 S.S.
PWHT performed:	No
Circumferential joint radiography:	None UW-11(c) Type 1
Nozzle orientation:	0°
Calculated as hillside:	No
Local vessel minimum thickness:	0.3125 in
End of nozzle to datum line:	217.562 in
Nozzle inside diameter, new:	7.981 in
Nozzle nominal wall thickness:	0.322 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	4.1519 in
Projection available outside vessel to flange face, Lf:	8.1519 in
Distance to head center, R:	0 in

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Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 57.15 psi @ 160 °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}
0.7631	1.0644	0.7335	0.2474	--	--	0.0835	0.2195	0.2818

UG-41 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})	0.1312	0.2188	weld size is adequate

Reinforcement Calculations for MAP

UG-37 Area Calculation Summary (in^2) For P = 107.7 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}
1.4355	1.5425	1.0625	0.3965	--	--	0.0835	0.1778	0.2818

UG-41 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})	0.2188	0.2188	weld size is adequate

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Makeup Inlet (D)

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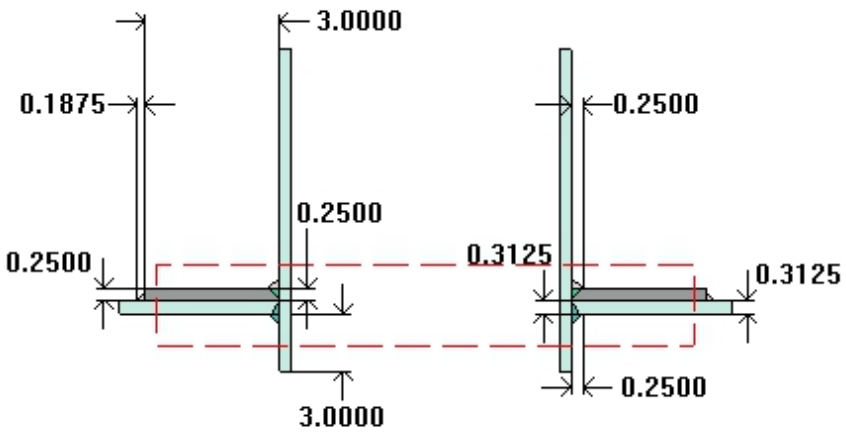

$t_{w(lower)}$ =	0.3125 in
Leg_{41} =	0.25 in
$t_{w(upper)}$ =	0.25 in
Leg_{42} =	0.1875 in
Leg_{43} =	0.25 in
h_{new} =	3 in
D_p =	12.625 in
t_e =	0.25 in

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

Located on:	Shell-02
Liquid static head included:	1.1729 psi
Nozzle material specification:	SA-106 B Smls pipe (II-D p. 10, ln. 40)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	NPS 6 Sch 40 (Std)
Pad material specification:	SA-516 70 (II-D p. 18, ln. 19)
Pad diameter:	12.625 in
Flange description:	6 inch Class 150 WN A105
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 334, ln. 32)
Flange rated MDMT:	-55°F
(UCS-66(b)(3): Coincident ratio = 0.2033194)	
(Flange rated MDMT = -155 °F Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F)	
Liquid static head on flange:	1.0646 psi
ASME B16.5 flange rating MAWP:	270 psi @ 160°F
ASME B16.5 flange rating MAP:	285 psi @ 70°F
ASME B16.5 flange hydro test:	450 psi @ 70°F
Gasket Description:	Flexitallic Spiral Wound CG 304 S.S.
PWHT performed:	No
Circumferential joint radiography:	None UW-11(c) Type 1
Nozzle orientation:	135°
Local vessel minimum thickness:	0.3125 in
Nozzle center line offset to datum line:	187 in
End of nozzle to shell center:	41.3125 in
Nozzle inside diameter, new:	6.065 in
Nozzle nominal wall thickness:	0.28 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	4.5 in

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Internal projection, h_{new}:	3 in
Projection available outside vessel to flange face, Lf:	8 in
Pad is split:	No

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 58.05 psi @ 160 °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}
0.592	2.2978	0.5456	0.2162	0.1027	1.3763	0.057	0.2213	0.245

UG-41 Weld Failure Path Analysis Summary (lb_f) All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength	Weld load W_{3-3}	Path 3-3 strength
1,801.18	32,901	69,844.42	9,313.64	95,409.63	36,838.64	71,546.44

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.175	0.175	weld size is adequate
Pad to shell fillet (Leg_{42})	0.0937	0.1312	weld size is adequate
Nozzle to pad groove (Upper)	0.175	0.25	weld size is adequate

Reinforcement Calculations for MAP

UG-37 Area Calculation Summary (in^2) For P = 107.7 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}
1.0957	2.9698	0.8032	0.3484	0.3352	1.3763	0.1068	0.1783	0.245

UG-41 Weld Failure Path Analysis Summary (lb_f) All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength	Weld load W_{3-3}	Path 3-3 strength
7,135.05	35,561	69,844.42	18,799.7	130,232.47	46,324.7	106,369.27

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.175	0.175	weld size is adequate

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Pad to shell fillet (Leg_{42})	0.125	0.1312	weld size is adequate
Nozzle to pad groove (Upper)	0.175	0.25	weld size is adequate

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Level Glass (K1)

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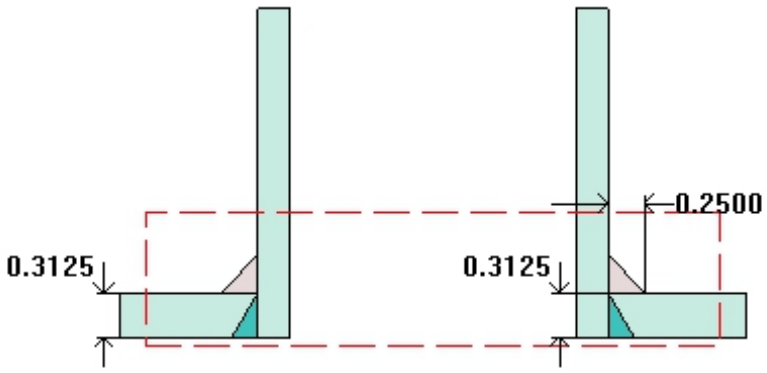
$t_{w(lower)}$ = 0.3125 in
Leg_{41} = 0.25 in



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

Located on:	Shell-01
Liquid static head included:	7.4602 psi
Nozzle material specification:	SA-106 B Smls pipe (II-D p. 10, ln. 40)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	NPS 2 Sch 80 (XS)
Flange description:	2 inch Class 150 WN A105
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 334, ln. 32)
Flange rated MDMT:	-55°F
(UCS-66(b)(3): Coincident ratio = 0.2256387)	
(Flange rated MDMT = -155 °F Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F)	
Liquid static head on flange:	7.4256 psi
ASME B16.5 flange rating MAWP:	270 psi @ 160°F
ASME B16.5 flange rating MAP:	285 psi @ 70°F
ASME B16.5 flange hydro test:	450 psi @ 70°F
Gasket Description:	Flexitallic Spiral Wound CG 304 S.S.
PWHT performed:	No
Circumferential joint radiography:	None UW-11(c) Type 1
Nozzle orientation:	90°
Local vessel minimum thickness:	0.3125 in
Nozzle center line offset to datum line:	9 in
End of nozzle to shell center:	41.3125 in
Nozzle inside diameter, new:	1.939 in
Nozzle nominal wall thickness:	0.218 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	5.5 in
Projection available outside vessel to flange face, Lf:	8 in

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Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 64.34 psi @ 160 °F							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}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1348	0.1908

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(2)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1312	0.175	weld size is adequate

This opening does not require reinforcement per UG-36(c)(3)(a)

Reinforcement Calculations for MAP

UG-37 Area Calculation Summary (in^2) For P = 107.7 psi @ 70 °F							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}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1348	0.1908

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(2)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1526	0.175	weld size is adequate

This opening does not require reinforcement per UG-36(c)(3)(a)

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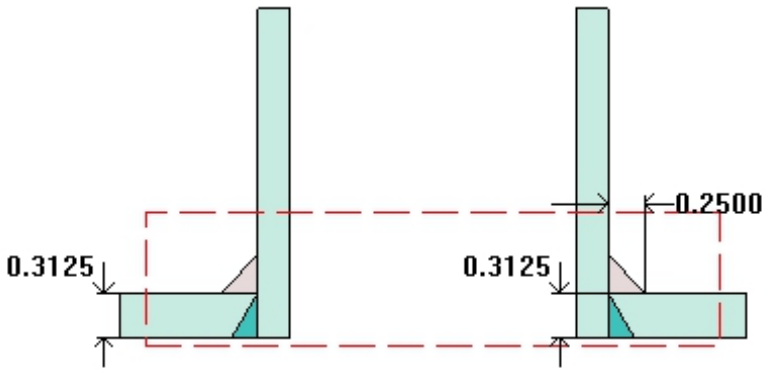
$t_{w(lower)}$ = 0.3125 in
Leg_{41} = 0.25 in



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

Located on:	Shell-02
Liquid static head included:	1.0992 psi
Nozzle material specification:	SA-106 B Smls pipe (II-D p. 10, ln. 40)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	NPS 2 Sch 80 (XS)
Flange description:	2 inch Class 150 WN A105
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 334, ln. 32)
Flange rated MDMT:	-55°F
(UCS-66(b)(3): Coincident ratio = 0.2033194)	
(Flange rated MDMT = -155 °F Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F)	
Liquid static head on flange:	1.0646 psi
ASME B16.5 flange rating MAWP:	270 psi @ 160°F
ASME B16.5 flange rating MAP:	285 psi @ 70°F
ASME B16.5 flange hydro test:	450 psi @ 70°F
Gasket Description:	Flexitallic Spiral Wound CG 304 S.S.
PWHT performed:	No
Circumferential joint radiography:	None UW-11(c) Type 1
Nozzle orientation:	90°
Local vessel minimum thickness:	0.3125 in
Nozzle center line offset to datum line:	187 in
End of nozzle to shell center:	41.3125 in
Nozzle inside diameter, new:	1.939 in
Nozzle nominal wall thickness:	0.218 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	5.5 in
Projection available outside vessel to flange face, Lf:	8 in

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Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 57.98 psi @ 160 °F							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}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1348	0.1908

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(2)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1312	0.175	weld size is adequate

This opening does not require reinforcement per UG-36(c)(3)(a)

Reinforcement Calculations for MAP

UG-37 Area Calculation Summary (in^2) For P = 107.7 psi @ 70 °F							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}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1348	0.1908

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(2)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1526	0.175	weld size is adequate

This opening does not require reinforcement per UG-36(c)(3)(a)

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Level (L2)

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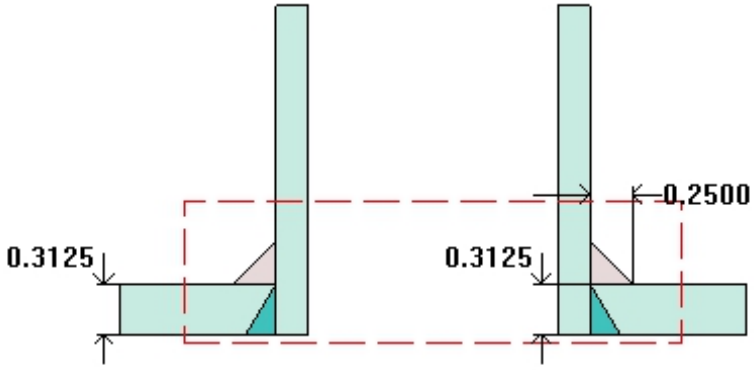
$t_{w(lower)}$ = 0.3125 in
Leg_{41} = 0.25 in



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

Located on:	Shell-02
Liquid static head included:	1.0914 psi
Nozzle material specification:	SA-106 B Smls pipe (II-D p. 10, ln. 40)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	NPS 1.5 Sch 80 (XS)
Flange description:	1.5 inch Class 150 WN A105
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 334, ln. 32)
Flange rated MDMT:	-55°F
(UCS-66(b)(3): Coincident ratio = 0.2033194)	
(Flange rated MDMT = -155 °F Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F)	
Liquid static head on flange:	1.0646 psi
ASME B16.5 flange rating MAWP:	270 psi @ 160°F
ASME B16.5 flange rating MAP:	285 psi @ 70°F
ASME B16.5 flange hydro test:	450 psi @ 70°F
Gasket Description:	Flexitallic Spiral Wound CG 304 S.S.
PWHT performed:	No
Circumferential joint radiography:	None UW-11(c) Type 1
Nozzle orientation:	270°
Local vessel minimum thickness:	0.3125 in
Nozzle center line offset to datum line:	187 in
End of nozzle to shell center:	41.3125 in
Nozzle inside diameter, new:	1.5 in
Nozzle nominal wall thickness:	0.2 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	5.56 in
Projection available outside vessel to flange face, Lf:	8 in

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Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 57.97 psi @ 160 °F							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}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1269	0.175

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(2)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1312	0.175	weld size is adequate

This opening does not require reinforcement per UG-36(c)(3)(a)

Reinforcement Calculations for MAP

UG-37 Area Calculation Summary (in^2) For P = 107.7 psi @ 70 °F							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}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1269	0.175

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(2)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.14	0.175	weld size is adequate

This opening does not require reinforcement per UG-36(c)(3)(a)

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Level (L1)

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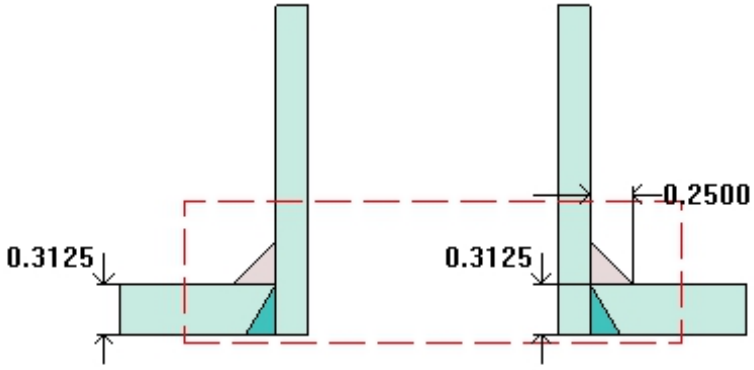
$t_{w(lower)}$ = 0.3125 in
Leg_{41} = 0.25 in



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

Located on:	Shell-01
Liquid static head included:	7.4524 psi
Nozzle material specification:	SA-106 B Smls pipe (II-D p. 10, ln. 40)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	NPS 1.5 Sch 80 (XS)
Flange description:	1.5 inch Class 150 WN A105
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 334, ln. 32)
Flange rated MDMT:	-55°F
(UCS-66(b)(3): Coincident ratio = 0.2256387)	
(Flange rated MDMT = -155 °F Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F)	
Liquid static head on flange:	7.4256 psi
ASME B16.5 flange rating MAWP:	270 psi @ 160°F
ASME B16.5 flange rating MAP:	285 psi @ 70°F
ASME B16.5 flange hydro test:	450 psi @ 70°F
Gasket Description:	Flexitallic Spiral Wound CG 304 S.S.
PWHT performed:	No
Circumferential joint radiography:	None UW-11(c) Type 1
Nozzle orientation:	270°
Local vessel minimum thickness:	0.3125 in
Nozzle center line offset to datum line:	9 in
End of nozzle to shell center:	41.3125 in
Nozzle inside diameter, new:	1.5 in
Nozzle nominal wall thickness:	0.2 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	5.56 in
Projection available outside vessel to flange face, Lf:	8 in

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Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 64.33 psi @ 160 °F							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}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1269	0.175

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(2)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1312	0.175	weld size is adequate

This opening does not require reinforcement per UG-36(c)(3)(a)

Reinforcement Calculations for MAP

UG-37 Area Calculation Summary (in^2) For P = 107.7 psi @ 70 °F							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}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1269	0.175

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(2)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.14	0.175	weld size is adequate

This opening does not require reinforcement per UG-36(c)(3)(a)

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Manway (M)

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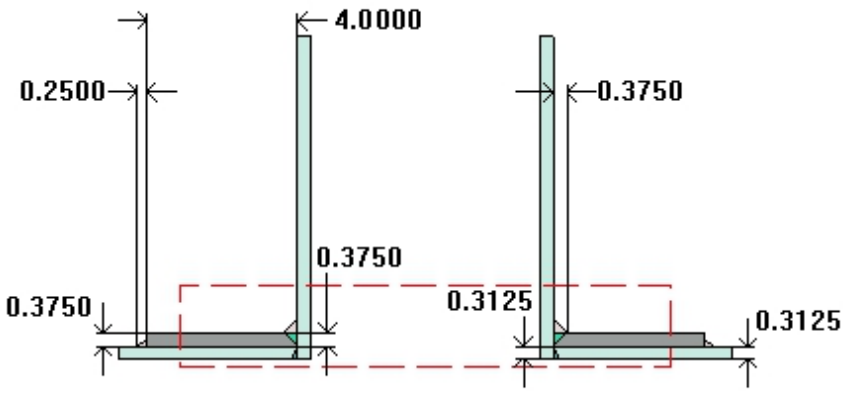

$t_{w(lower)}$ =	0.3125 in
Leg_{41} =	0.375 in
$t_{w(upper)}$ =	0.375 in
Leg_{42} =	0.25 in
D_p =	32 in
t_e =	0.375 in

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

Located on:	Shell-01
Liquid static head included:	7.1263 psi
Nozzle material specification:	SA-516 70 (II-D p. 18, ln. 19)
Nozzle longitudinal joint efficiency:	1
Pad material specification:	SA-516 70 (II-D p. 18, ln. 19)
Pad diameter:	32 in
Flange description:	24 inch Class 150 SO A105
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 334, ln. 32)
Flange rated MDMT:	-55 °F
(UCS-66(b)(3): Coincident ratio = 0.2231309)	
(Flange rated MDMT = -155 °F Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F)	
Liquid static head on flange:	6.7109 psi
ASME B16.5 flange rating MAWP:	270 psi @ 160 °F
ASME B16.5 flange rating MAP:	285 psi @ 70 °F
ASME B16.5 flange hydro test:	450 psi @ 70 °F
Gasket Description:	Flexitallic Spiral Wound CG 304 S.S.
Flange external fillet weld leg (UW-21):	0.5625 in (0.525 in min)
Flange internal fillet weld leg (UW-21):	0.375 in (0.25 in min)
PWHT performed:	No
Nozzle orientation:	0 °
Local vessel minimum thickness:	0.3125 in
Nozzle center line offset to datum line:	29 in
End of nozzle to shell center:	41.3125 in
Nozzle inside diameter, new:	23.25 in
Nozzle nominal wall thickness:	0.375 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	7.625 in

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Projection available outside vessel to flange face, Lf: 8 in

Pad is split: No

Reinforcement Calculations for Internal Pressure

Appendix 1-10 Maximum Local Primary Membrane Stress For P = 64.01 psi @ 160 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
P_L (psi)	S_{allow} (psi)	A_1 (in^2)	A_2 (in^2)	A_3 (in^2)	A_5 (in^2)	A welds (in^2)	t_{req} (in)	t_{min} (in)
18,681	30,000	0.5883	0.681	--	0.7031	0.0703	0.2312	0.375

Division 2 Part 4.5 Strength of Nozzle Attachment Welds Summary Average Shear Stress in Weld												
k_y	L_τ (in)	$L_{\tau p}$ (in)	L_{41T} (in)	L_{42T} (in)	L_{43T} (in)	f_{welds} (lb_f)	τ_1 (psi)	τ_2 (psi)	τ_3 (psi)	τ (psi)	S (psi)	Over stressed
1.0323	18.8496	25.1327	0.2652	0.1768	0	20,430.8	3,315	2,102	6,458	6,458	20,000	No

Division 2 Part 4.5 Strength of Nozzle Attachment Welds Summary Average Shear Stress in Nozzle Wall		
τ_n (psi)	$1.5*S_n$ (psi)	Over stressed
11,926	30,000	No

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.25	0.2625	weld size is adequate
Pad to shell fillet (Leg_{42})	0.0937	0.175	weld size is adequate
Nozzle to pad groove (Upper)	0.2625	0.375	weld size is adequate

% Extreme fiber elongation - UCS-79(d)

$$EFE = (50*t / R_f)*(1 - R_f / R_o)$$
$$= (50*0.375 / 11.8125)*(1 - 11.8125 / \infty)$$
$$= 1.5873\%$$

The extreme fiber elongation does not exceed 5%.

Reinforcement Calculations for MAP

Appendix 1-10 Maximum Local Primary Membrane Stress For P = 107.7 psi @ 70 °F The opening is adequately reinforced	UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45

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P_L (psi)	S_{allow} (psi)	A_1 (in^2)	A_2 (in^2)	A_3 (in^2)	A_5 (in^2)	A welds (in^2)	t_{req} (in)	t_{min} (in)
23,098	30,000	1.267	0.7279	--	1.1719	0.0703	0.1783	0.375

Division 2 Part 4.5 Strength of Nozzle Attachment Welds Summary Average Shear Stress in Weld												
k_y	L_τ (in)	$L_{\tau p}$ (in)	L_{41T} (in)	L_{42T} (in)	L_{43T} (in)	f_{welds} (lb_f)	τ_1 (psi)	τ_2 (psi)	τ_3 (psi)	τ (psi)	S (psi)	Over stressed
1.0323	18.8496	25.1327	0.2652	0.1768	0	21,837.05	2,899	1,838	5,648	5,648	20,000	No

Division 2 Part 4.5 Strength of Nozzle Attachment Welds Summary Average Shear Stress in Nozzle Wall		
τ_n (psi)	$1.5*S_n$ (psi)	Over stressed
14,114	30,000	No

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.25	0.2625	weld size is adequate
Pad to shell fillet (Leg_{42})	0.1562	0.175	weld size is adequate
Nozzle to pad groove (Upper)	0.2625	0.375	weld size is adequate

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Nitrogen Inlet (N)

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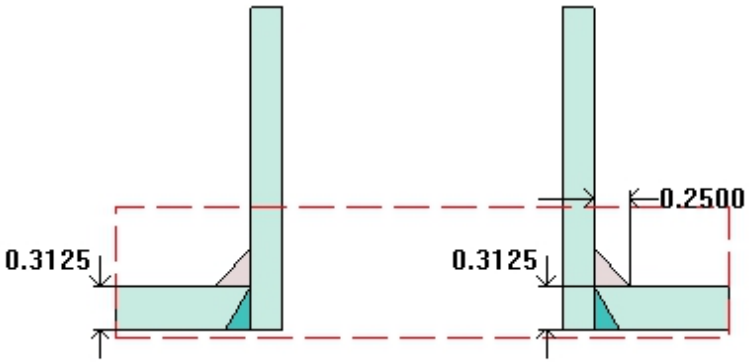
$t_{w(lower)}$ = 0.3125 in
Leg_{41} = 0.25 in



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

Located on:	Top Head
Liquid static head included:	0.4752 psi
Nozzle material specification:	SA-106 B Smls pipe (II-D p. 10, ln. 40)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	NPS 2 Sch 80 (XS)
Flange description:	2 inch Class 150 WN A105
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 334, ln. 32)
Flange rated MDMT:	-55°F
(UCS-66(b)(3): Coincident ratio = 0.2001443)	
(Flange rated MDMT = -155 °F Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F)	
Liquid static head on flange:	0.1597 psi
ASME B16.5 flange rating MAWP:	270 psi @ 160°F
ASME B16.5 flange rating MAP:	285 psi @ 70°F
ASME B16.5 flange hydro test:	450 psi @ 70°F
Gasket Description:	Flexitallic Spiral Wound CG 304 S.S.
PWHT performed:	No
Circumferential joint radiography:	None UW-11(c) Type 1
Nozzle orientation:	135°
Calculated as hillside:	Yes
Local vessel minimum thickness:	0.3125 in
End of nozzle to datum line:	212.3204 in
Nozzle inside diameter, new:	1.939 in
Nozzle nominal wall thickness:	0.218 in
Nozzle corrosion allowance:	0 in
Opening chord length:	2.1239 in
Projection available outside vessel, Lpr:	5.5 in
Projection available outside vessel to flange face, Lf:	8 in

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Distance to head center, R: 27 in

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 57.36 psi @ 160 °F							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}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1348	0.1908

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(2)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1312	0.175	weld size is adequate

This opening does not require reinforcement per UG-36(c)(3)(a)

Reinforcement Calculations for MAP

UG-37 Area Calculation Summary (in^2) For P = 107.7 psi @ 70 °F							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}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1348	0.1908

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(2)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1526	0.175	weld size is adequate

This opening does not require reinforcement per UG-36(c)(3)(a)

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Recirc Inlet (R)

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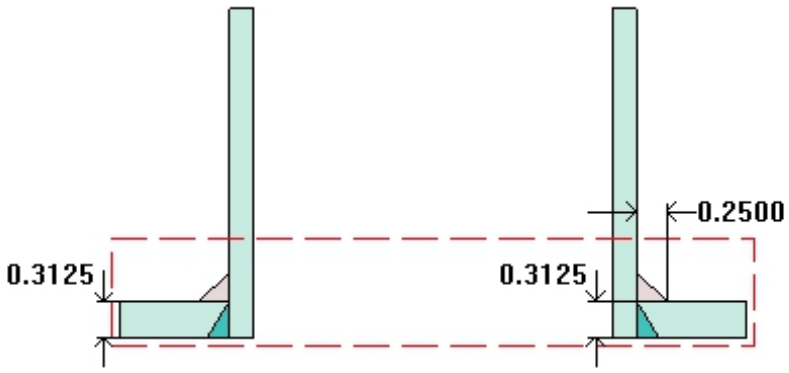
$t_{w(lower)}$ = 0.3125 in
Leg_{41} = 0.25 in



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

Located on:	Shell-02
Liquid static head included:	1.441 psi
Nozzle material specification:	SA-106 B Smls pipe (II-D p. 10, ln. 40)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	NPS 3 Sch 40 (Std)
Flange description:	3 inch Class 150 WN A105
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 334, ln. 32)
Flange rated MDMT:	-55°F
(UCS-66(b)(3): Coincident ratio = 0.2044478)	
(Flange rated MDMT = -155 °F Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F)	
Liquid static head on flange:	1.3862 psi
ASME B16.5 flange rating MAWP:	270 psi @ 160°F
ASME B16.5 flange rating MAP:	285 psi @ 70°F
ASME B16.5 flange hydro test:	450 psi @ 70°F
Gasket Description:	Flexitallic Spiral Wound CG 304 S.S.
PWHT performed:	No
Circumferential joint radiography:	None UW-11(c) Type 1
Nozzle orientation:	180°
Local vessel minimum thickness:	0.3125 in
Nozzle center line offset to datum line:	178 in
End of nozzle to shell center:	41.3125 in
Nozzle inside diameter, new:	3.068 in
Nozzle nominal wall thickness:	0.216 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	5.25 in
Projection available outside vessel to flange face, Lf:	8 in

Approved

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 58.32 psi @ 160 °F							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}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.189	0.189

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(2)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1312	0.175	weld size is adequate

This opening does not require reinforcement per UG-36(c)(3)(a)

Reinforcement Calculations for MAP

UG-37 Area Calculation Summary (in^2) For P = 107.7 psi @ 70 °F							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}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1783	0.189

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(2)

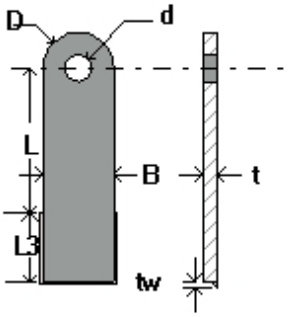
UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1512	0.175	weld size is adequate

This opening does not require reinforcement per UG-36(c)(3)(a)

Approved

Lifting Lug

Minimum report



Geometry Inputs

Attached To	Shell-02
Material	A36
Distance of Lift Point From Datum	206"
Angular Position	90.00° and 270.00°
Length of Lug, L	10"
Width of Lug, B	5"
Thickness of Lug, t	0.5"
Hole Diameter, d	1.875"
Pin Diameter, Dp	1"
Lug Diameter at Pin, D	5"
Weld Size, t_w	0.25"
Weld Length, L_3	5"
Load Angle from Vertical, ϕ	0.0000 °
Has Brace Plate	No

Intermediate Values

Load Factor	1.5000
Vessel Weight (new, incl. Load Factor), W	9127 lb
Lug Weight (new), W_{lug}	23 lb (Qty=2)
Distance from Center of Gravity to Top Lug, l_1	128.6311"
Distance from Center of Gravity to Tail Lug, l_2	69.1189"
Distance from Vessel Center Line to Tail Lug, l_3	36.125"
Allowable Stress, Tensile, σ_t	19980 psi
Allowable Stress, Shear, σ_s	13320 psi

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Allowable Stress, Bearing, σ_p	29970 psi
Allowable Stress, Bending, σ_b	22201 psi
Allowable Stress, Weld Shear, $\tau_{allowable}$	13320 psi
Allowable Stress set to 1/3 Sy per ASME B30.20	No

Summary Values

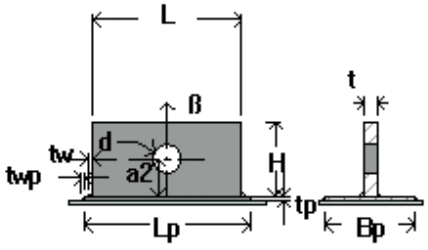
Required Lift Pin Diameter, d_{reqd}	0.467"
Required Lug Thickness, t_{reqd}	0.1523"
Lug Stress Ratio, σ_{ratio}	0.37
Weld Shear Stress Ratio, τ_{ratio}	0.39
Lug Design	Acceptable
Local Stresses	Acceptable
Maximum Out of Plane Lift Angle - Weak Axis Bending	5.79°

COMPRESS recommends a spreader beam be used to prevent weak axis bending of the top lugs.
No consideration is given for any bracing plate from the lug to the vessel.

Approved

Tailing Lug

Minimum report



Geometry Inputs

Attached To	Shell-01
Material	A36
Orientation	Longitudinal
Distance of Lift Point From Datum	8.25"
Angular Position	180.00°
Length of Lug, L	10"
Height of Lug, H	5"
Thickness of Lug, t	0.5"
Hole Diameter, d	1.875"
Pin Diameter, Dp	1"
Load Eccentricity, a_1	0"
Distance from Load to Shell or Pad, a_2	2.5"
Weld Size, t_w	0.25"
Width of Pad, B_p	3"
Length of Pad, L_p	11"
Pad Thickness, t_p	0.3125"
Pad Weld Size, t_{wp}	0.25"
Load Angle Normal to Vessel, β	0.0000 °
Load Angle from Vertical, ϕ	-90.0000 °

Intermediate Values

Load Factor	1.5000
Vessel Weight (new, incl. Load Factor), W	9127 lb
Lug Weight (new), W_{lug}	10 lb
Distance from Center of Gravity to Top Lug, l_1	128.6311"

Approved

Distance from Center of Gravity to Tail Lug, l_2	69.1189"
Distance from Vessel Center Line to Tail Lug, l_3	36.125"
Allowable Stress, Tensile, σ_t	19980 psi
Allowable Stress, Shear, σ_s	13320 psi
Allowable Stress, Bearing, σ_p	29970 psi
Allowable Stress, Bending, σ_b	22201 psi
Allowable Stress, Weld Shear, $\tau_{allowable}$	13320 psi
Allowable Stress set to 1/3 Sy per ASME B30.20	No

Summary Values

Required Lift Pin Diameter, d_{reqd}	0.5327"
Required Lug Thickness, t_{reqd}	0.1981"
Lug Stress Ratio, σ_{ratio}	0.08
Weld Shear Stress Ratio, τ_{ratio}	0.18
Lug Design	Acceptable
Local Stresses	Acceptable

Approved