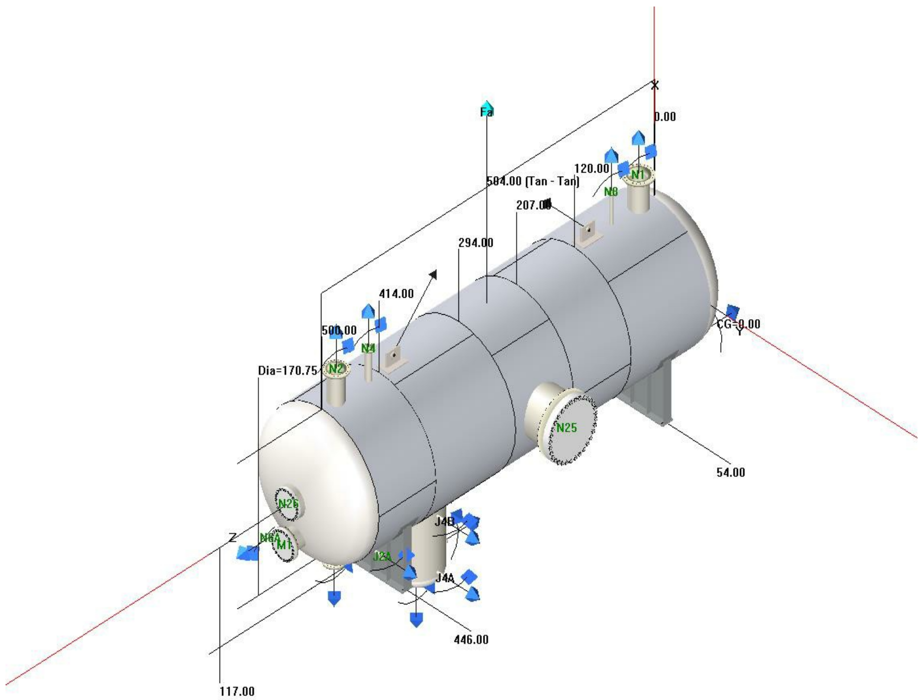
Your Company Name

Your Company Address



COMPRESS Pressure Vessel Design Calculations

Item:

Vessel No:

Customer:

Contract:

Designer:

Date: Tuesday, May 30, 2023

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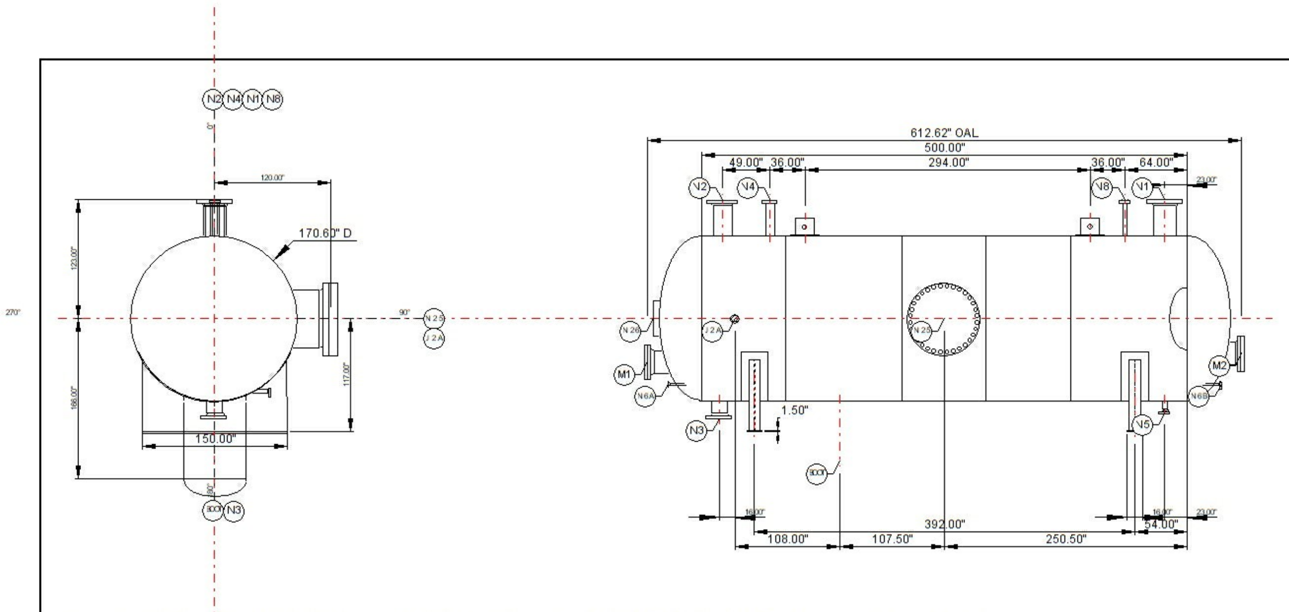


DESIGN DATA

Design Pressure	250 psi
Vacuum Pressure	15 psi
Test Pressure (Shop)	332.46 psi
Design Temperature	600 °F
MDMT	-49 °F
Corrosion Allowance	0.25 "
Radiography	RT4
PWHT	HT

Estimated Weights

Dry: 212,074 lb Wet: 212,074 lb

Weight at left saddle: 107,171 lb (Oper), 340,164 lb (Test)
Weight at right saddle: 104,902 lb (Oper), 332,684 lb (Test)

Materials

Cylinder(s): SA-516 70
Head(s): SA-516 70
Transition(s):
Support: SA516-70N

NOZZLE SCHEDULE

MARK	NOZZLE	SIZE & SCH	FLANGE	MARK	NOZZLE	SIZE & SCH	FLANGE
J3A	2" 300# RFLWN LEVE	3.31 OD x 0.655	NPS 2 LWN Class 300	M2	24" 300# RFWN MAN	24 OD x 1.25	NPS 24 WN Class 300
BOOT	60" BOOT	64 OD x 2		N8	4" 300# RFWN VENT	NPS 4 Sch 160	NPS 4 WN Class 300
J2A	3" 300# RFWN LG/LT (	NPS 3 Sch 160	NPS 3 WN Class 300	N5	4" 300# RFWN DRAIN	NPS 4 Sch 160	NPS 4 WN Class 300
N4	8" 300# RFWN VENT	NPS 8 Sch 120	NPS 8 WN Class 300	N1	24" 300# RFWN FEED	24 OD x 1.25	NPS 24 WN Class 300
N3	16" 300# RFWN HY	NPS 16 Sch 100	NPS 16 WN Class 300	N25	Nozzle #25	NPS 60 (Thk = 1.250")	NPS 60 WN Class 400
N2	20" 300# RFWN VAP	20 OD x 1	NPS 20 WN Class 300	N7	4" 300# RFWN WATE	NPS 4 Sch 160	NPS 4 WN ~~Class 300~~
N26	Nozzle #26	36 OD x 6		J4B	2" 300# RFLWN LEVE	3.31 OD x 0.655	NPS 2 LWN Class 300
N6A	2" 300# RFWN STEAM	NPS 2 XXS	NPS 2 WN Class 300	J4A	2" 300# RFLWN LEVE	3.31 OD x 0.655	NPS 2 LWN Class 300
M1	24" 300# RFWN MAN	24 OD x 1.25	NPS 24 WN Class 300	J3B	2" 300# RFLWN LEVE	3.31 OD x 0.655	NPS 2 LWN Class 300

REVISIONS

REV	DATE	DESCRIPTION
0	03/22/2007	FOR APPROVAL

ABC Fabricators Inc.
2600 Washington Blvd.
Dallas, TX, 75204

DWN BY:
CHK BY:
DATE:

General Arrangement

DWG NO. 145685-1 Rev 0

COMPRESS.CW7

Deficiencies Summary

Deficiencies for 24" 300# RFWN MANWAY (M1)
Overlapping limits of reinforcement between nozzles M1 and N26 detected - user intervention may be required.
Overlapping limits of reinforcement between nozzles M1 and N26 detected - user intervention may be required. (MAP Condition)

Deficiencies for 3" 300# RFWN LG/LT (SIS) BRIDLE (J2A)
UG-36(a)(1): More analysis is required. Additional reinforcement may be necessary as the long opening dimension exceeds twice the short dimension.

Deficiencies for Lifting Lug - 1
The local stresses in the WRC 107 calculation are excessive.

Deficiencies for Lifting Lug - 2
The local stresses in the WRC 107 calculation are excessive.

Deficiencies for Nozzle #25 (N25)
Bolt MDMT is only -40°F: -49°F is required
Large opening is outside of the scope of Appendix 1-7(b) as an internal projection is specified. Either an Appendix 1-10 or separate U-2(g) analysis is required.
Nozzle assembly MDMT is only -4.3°F: -49°F is required

Deficiencies for Nozzle #26 (N26)
Overlapping limits of reinforcement between nozzles N26 and M1 detected - user intervention may be required.
Nozzle assembly MDMT is only 19.1°F: -49°F is required
The inner fillet weld (Leg_{41} = 0.3571 in) is less than the minimum of 0.3571 in.
Overlapping limits of reinforcement between nozzles N26 and M1 detected - user intervention may be required. (MAP Condition)
UG-43(g): Thread engagement (1.63") is insufficient (require 1.6447").

Nozzle Schedule

Specifications									
Nozzle mark	Identifier	Size	Materials		Impact Tested	Normalized	Fine Grain	Flange	Blind
BOOT	60" BOOT	64 OD x 2	Nozzle	SA-516 70	Yes	Yes	Yes	N/A	No
			Pad	SA-516 70	Yes	Yes	Yes		
	Ellipsoidal Head #3	ID = 60" x Thk = 1.5"	Ellipsoidal Head	SA-516 70	Yes	Yes	Yes	N/A	N/A
J2A	3" 300# RFWN LG/LT (SIS) BRIDLE	NPS 3 Sch 160	Nozzle	SA-333 6 Wld & smls pipe	No	No	No	NPS 3 Class 300 WN A350 LF2 Cl.1	No
			Pad	SA-516 70	Yes	Yes	Yes		
J3A	2" 300# RFLWN LEVEL TRANS	3.31 OD x 0.655	Nozzle	SA-350 LF2 Cl 1	No	No	No	NPS 2 Class 300 LWN A350 LF2 Cl.1	No
J3B	2" 300# RFLWN LEVEL TRANS	3.31 OD x 0.655	Nozzle	SA-350 LF2 Cl 1	No	No	No	NPS 2 Class 300 LWN A350 LF2 Cl.1	No
J4A	2" 300# RFLWN LEVEL TRANS	3.31 OD x 0.655	Nozzle	SA-350 LF2 Cl 1	No	No	No	NPS 2 Class 300 LWN A350 LF2 Cl.1	No
J4B	2" 300# RFLWN LEVEL TRANS	3.31 OD x 0.655	Nozzle	SA-350 LF2 Cl 1	No	No	No	NPS 2 Class 300 LWN A350 LF2 Cl.1	No
M1	24" 300# RFWN MANWAY	24 OD x 1.25	Nozzle	SA-516 70	Yes	Yes	Yes	NPS 24 Class 300 WN A350 LF2 Cl.1	NPS 24 Class 300 A350 LF2 Cl.1
			Pad	SA-516 70	Yes	Yes	Yes		
M2	24" 300# RFWN MANWAY	24 OD x 1.25	Nozzle	SA-516 70	Yes	Yes	Yes	NPS 24 Class 300 WN A350 LF2 Cl.1	NPS 24 Class 300 A350 LF2 Cl.1
			Pad	SA-516 70	Yes	Yes	Yes		
N1	24" 300# RFWN FEED INLET	24 OD x 1.25	Nozzle	SA-516 70	Yes	Yes	Yes	NPS 24 Class 300 WN A350 LF2 Cl.1	No
			Pad	SA-516 70	Yes	Yes	Yes		
N2	20" 300# RFWN VAPOUR OUTLET	20 OD x 1	Nozzle	SA-516 70	No	No	No	NPS 20 Class 300 WN A350 LF2 Cl.1	No
			Pad	SA-516 70	Yes	Yes	Yes		
N25	Nozzle #25	NPS 60 (Thk = 1.250")	Nozzle	SA-106 B Smls pipe	No	No	No	NPS 60 Class 400 WN A105 Series A	NPS 60 Class 400 A105 Series A
			Pad	SA-516 70	No	No	No		
N26	Nozzle #26	36 OD x 6	Nozzle	SA-106 B Smls pipe	No	No	No	N/A	NPS 24 Class 300 A105
N3	16" 300# RFWN HYDROCARBON OUTLET	NPS 16 Sch 100	Nozzle	SA-333 6 Wld & smls pipe	No	No	No	NPS 16 Class 300 WN A350 LF2 Cl.1	No
			Pad	SA-516 70	Yes	Yes	Yes		
N4	8" 300# RFWN VENT	NPS 8 Sch 120	Nozzle	SA-333 6 Wld & smls pipe	No	No	No	NPS 8 Class 300 WN A350 LF2 Cl.1	No
			Pad	SA-516 70	Yes	Yes	Yes		
N5	4" 300# RFWN DRAIN	NPS 4 Sch 160	Nozzle	SA-333 6 Wld & smls pipe	No	No	No	NPS 4 Class 300 WN A350 LF2 Cl.1	No
			Pad	SA-516 70	Yes	Yes	Yes		
N6A	2" 300# RFWN STEAM OUT	NPS 2 XXS	Nozzle	SA-333 6 Wld & smls pipe	No	No	No	NPS 2 Class 300 WN A350 LF2 Cl.1	No
			Pad	SA-516 70	Yes	Yes	Yes		

N6B	2" 300# RFWN STEAM OUT	NPS 2 XXS	Nozzle	SA-333 6 Wld & smls pipe	No	No	No	NPS 2 Class 300 WN A350 LF2 Cl.1	No
			Pad	SA-516 70	Yes	Yes	Yes		
N7	4" 300# RFWN WATER OUTLET	NPS 4 Sch 160	Nozzle	SA-333 6 Wld & smls pipe	No	No	No	NPS 4 Class 300 WN A350 LF2 Cl.1	No
N8	4" 300# RFWN VENT	NPS 4 Sch 160	Nozzle	SA-333 6 Wld & smls pipe	No	No	No	NPS 4 Class 300 WN A350 LF2 Cl.1	No
			Pad	SA-516 70	Yes	Yes	Yes		

Nozzle Summary

Dimensions												
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)		
BOOT	64	2	0.3896	Yes	Yes	1.25	1.0909		12	2	0	104.4
J2A	3.5	0.438	0.216	Yes	Yes	1.375	1.0909		3	1	0	127.6
J3A	3.31	0.655	0.3896	Yes	Yes	2	0.3896		N/A	N/A	0.25	864.1
J3B	3.31	0.655	0.3896	Yes	Yes	2	0.3896		N/A	N/A	0.25	864.1
J4A	3.31	0.655	0.3896	Yes	Yes	2	0.3896		N/A	N/A	0.25	864.1
J4B	3.31	0.655	0.3896	Yes	Yes	2	0.3896		N/A	N/A	0.25	864.1
M1	24	1.25	0.3281	Yes	Yes	1.3*	0.9755		6	1	0	122.9
M2	24	1.25	0.3281	Yes	Yes	1.3*	0.9755		6	1	0	124.8
N1	24	1.25	0.3281	Yes	Yes	1.375	1.0909		6	1.5	0	137.6
N2	20	1	0.3281	Yes	Yes	1.375	1.0909		5	1.5	0	136.1
N25	60	1.25	0.4846	Yes	Yes	1.375	1.0909		15	1.375	0	107.0
N26	36	6	0.375	Yes	Yes	1.3*	0.9755		N/A	N/A	0	168.6
N3	16	1.031	0.375	Yes	Yes	1.375	1.0909		4	1.5	0	143.0
N4	8.625	0.719	0.322	Yes	Yes	1.375	1.0909		2.75	1	0	138.1
N5	4.5	0.531	0.237	Yes	Yes	1.375	1.0909		2	1	0	154.6
N6A	2.375	0.436	0.154	Yes	Yes	1.3*	1.0839		2	1	0	158.6
N6B	2.375	0.436	0.154	Yes	Yes	1.3*	1.0839		2	1	0	158.6
N7	4.5	0.531	0.237	Yes	Yes	1.5*	N/A		N/A	N/A	0	Exempt
N8	4.5	0.531	0.237	Yes	Yes	1.375	1.0909		2	1	0	154.6
*Head minimum thickness after forming												

Definitions	
t_n	Nozzle thickness
Req t_n	Nozzle thickness required per UG-45/UG-16 Increased for pipe to account for 12.5% pipe thickness tolerance
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

Pressure Summary

Component Summary									
Identifier	P Design (psi)	T Design (°F)	MAWP (psi)	MAP (psi)	MAEP (psi)	T_e external (°F)	MDMT (°F)	MDMT Exemption	Impact Tested
Ellipsoidal Head #2	250	600	299.77	309.05	97.01	400	-66.3	Note 1	Yes
Straight Flange on Ellipsoidal Head #2	250	600	314.47	324.2	42.99	400	-70.3	Note 2	Yes
Cylinder #1	250	600	314.47	324.2	42.99	400	-70.3	Note 2	Yes
Cylinder #2	250	600	286.14	294.99	34.38	400	-62.4	Note 3	Yes
Cylinder #3	250	600	314.47	324.2	42.99	400	-70.3	Note 2	Yes
Cylinder #4	250	600	314.47	324.2	42.99	400	-70.3	Note 2	Yes
Cylinder #5	250	600	314.47	324.2	42.99	400	-70.3	Note 2	Yes
Straight Flange on Ellipsoidal Head #1	250	600	314.47	324.2	42.99	400	-70.3	Note 2	Yes
Ellipsoidal Head #1	250	600	299.77	309.05	97.01	400	-66.3	Note 1	Yes
Saddle #1	250	600	255.74	N/A	N/A	N/A	N/A	N/A	N/A
60" BOOT (BOOT)	250	600	255.74	263.64	34.38	400	-62.4	Nozzle Note 4	Yes
								Pad Note 5	Yes
Straight Flange on Ellipsoidal Head #3	250	600	1,243.59	1,282.05	634.76	400	-155	Note 7	Yes
Ellipsoidal Head #3	250	600	965.17	995.02	400.36	400	-155	Note 6	Yes
3" 300# RFWN LG/LT (SIS) BRIDLE (J2A)	250	600	284.6	291.29	42.99	400	-55	Nozzle Note 8	No
								Pad Note 9	Yes
2" 300# RFLWN LEVEL TRANS (J3A)	250	600	570	740	34.38	400	-55	Note 10	No
2" 300# RFLWN LEVEL TRANS (J3B)	250	600	570	740	34.38	400	-55	Note 10	No
2" 300# RFLWN LEVEL TRANS (J4A)	250	600	570	740	34.38	400	-55	Note 10	No
2" 300# RFLWN LEVEL TRANS (J4B)	250	600	570	740	34.38	400	-55	Note 10	No
24" 300# RFWN MANWAY (M1)	250	600	278.01	286.61	42.99	400	-55	Nozzle Note 8	Yes
								Pad Note 11	Yes
24" 300# RFWN MANWAY (M2)	250	600	280.35	289.02	42.99	400	-55	Nozzle Note 8	Yes
								Pad Note 11	Yes
24" 300# RFWN FEED INLET (N1)	250	600	295.63	304.78	42.99	400	-55	Nozzle Note 8	Yes
								Pad Note 9	Yes
20" 300# RFWN VAPOUR OUTLET (N2)	250	600	293.76	302.84	42.99	400	-55	Nozzle Note 8	No
								Pad Note 9	Yes
Nozzle #25 (N25)	250	600	258.57	265.65	42.99	400	-4.3	Nozzle Note 12	No
								Pad Note 13	No
Nozzle #26 (N26)	250	600	333.02	343.28	42.99	400	19.1	Note 14	No
16" 300# RFWN HYDROCARBON OUTLET (N3)	250	600	303.24	310.43	42.99	400	-55	Nozzle Note 8	No
								Pad Note 9	Yes
8" 300# RFWN VENT (N4)	250	600	297.58	304.18	42.99	400	-55	Nozzle Note 8	No
								Pad Note 9	Yes
4" 300# RFWN DRAIN (N5)	250	600	314.47	322.06	42.99	400	-55	Nozzle Note 8	No
								Pad Note 9	Yes
2" 300# RFWN STEAM OUT (N6A)	250	600	299.77	309.04	42.99	400	-55	Nozzle Note 8	No
								Pad Note 15	Yes
2" 300# RFWN STEAM OUT (N6B)	250	600	299.77	309.04	42.99	400	-55	Nozzle Note 8	No
								Pad Note 15	Yes
4" 300# RFWN WATER OUTLET (N7)	250	600	570	693.9	318.38	400	-55	Note 8	No
4" 300# RFWN VENT (N8)	250	600	314.47	322.06	42.99	400	-55	Nozzle Note 8	No
								Pad Note 9	Yes

Chamber Summary	
Design MDMT	-49 °F
Rated MDMT	19.1 °F @ 255.74 psi
MAWP hot & corroded	255.74 psi @ 600 °F
MAP cold & new	263.64 psi @ 70 °F
MAEP	34.38 psi @ 400 °F

Notes for MDMT Rating		
Note #	Exemption	Details
1.	Material is impact tested per UG-84 to -49°F.	UCS-66(i) reduction of 17.3°F applied (ratio = 0.8273).
2.	Material is impact tested per UG-84 to -49°F.	UCS-66(i) reduction of 21.3°F applied (ratio = 0.7872).
3.	Material is impact tested per UG-84 to -49°F.	UCS-66(i) reduction of 13.4°F applied (ratio = 0.8659).
4.	Nozzle is impact tested per UG-84 to -49°F.	UCS-66(i) reduction of 13.4°F applied (ratio = 0.8659).
5.	Pad is impact tested per UG-84 to -49°F.	UCS-66(i) reduction of 13.4°F applied (ratio = 0.8659).
6.	Straight Flange governs MDMT	
7.	Material is impact tested per UG-84 to -49°F.	Stress ratio = 0.1933 ≤ 0.35, MDMT per UCS-66(b)(3) = -155°F.
8.	Flange rating governs: Flange rated MDMT = -155°F Bolts rated MDMT per Fig UCS-66 note (e) = -55°F Flange is impact tested per material specification to -50°F.	Stress ratio = 0.3456 ≤ 0.35, MDMT per UCS-66(b)(3) = -155°F.
9.	Pad is impact tested per UG-84 to -49°F.	UCS-66(i) reduction of 21.3°F applied (ratio = 0.7872).
10.	LWN rated MDMT per UCS-66(c)(4) Flange rated MDMT = -155°F Bolts rated MDMT per Fig UCS-66 note (e) = -55°F Flange is impact tested per material specification to -50°F.	Stress ratio = 0.3456 ≤ 0.35, MDMT per UCS-66(b)(3) = -155°F.
11.	Pad is impact tested per UG-84 to -49°F.	UCS-66(i) reduction of 25.5°F applied (ratio = 0.7446).
12.	Nozzle impact test exemption temperature from Fig UCS-66 Curve B = 35.5°F 30°F MDMT reduction per UCS-68(c) applies. Fig UCS-66.1 MDMT reduction = 95.3°F, (coincident ratio = 0.3967) Rated MDMT of -89.8°F is limited to -55°F by UCS-66(b)(2)	UCS-66 governing thickness = 1.0938 in.
13.	Pad impact test exemption temperature from Fig UCS-66 Curve B = 47°F 30°F MDMT reduction per UCS-68(c) applies. Fig UCS-66.1 MDMT reduction = 21.3°F, (coincident ratio = 0.7872)	UCS-66 governing thickness = 1.375 in.
14.	Pad impact test exemption temperature from Fig UCS-66 Curve B = 44.6°F Fig UCS-66.1 MDMT reduction = 25.5°F, (coincident ratio = 0.7446) UCS-66 governing thickness = 1.3 in.	Bolts rated MDMT per Fig UCS-66 note (e) = -55°F
15.	Pad is impact tested per UG-84 to -49°F.	UCS-66(i) reduction of 17.3°F applied (ratio = 0.8273).

Settings Summary

COMPRESS 2023 Build 8300	
ASME Section VIII Division 1, 2004 Edition, A06 Addenda	
Units	U.S. Customary
Datum Line Location	0.00" from right seam
Vessel Design Mode	Rating Mode (Analysis)
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	Design P only
Corrosion weight loss	100% of theoretical loss
UG-23 Stress Increase	1.20
Skirt/legs stress increase	1.0
Minimum nozzle projection	12"
Juncture calculations for α > 30 only	Yes
Preheat P-No 1 Materials > 1.25" and <= 1.50" thick	No
UG-37(a) shell tr calculation considers longitudinal stress	No
Cylindrical shells made from pipe are entered as minimum thickness	No
Nozzles made from pipe are entered as minimum thickness	No
ASME B16.9 fittings are entered as minimum thickness	No
Butt welds	Tapered per Figure UCS-66.3(a)
Disallow Appendix 1-5, 1-8 calculations under 15 psi	No
Hydro/Pneumatic Test	
Shop Hydrotest Pressure	1.3 times vessel MAWP [UG-99(b)]
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	HT
Code Cases\Interpretations	
Use Code Case 2547	No
Use Code Case 2901	No
Use Code Case 3035	No
Apply interpretation VIII-1-83-66	Yes
Apply interpretation VIII-1-86-175	Yes
Apply interpretation VIII-1-83-115	Yes
Apply interpretation VIII-1-01-37	Yes
Apply interpretation VIII-1-01-150	No
Apply interpretation VIII-1-07-50	No
Apply interpretation VIII-1-16-85	No
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
UG-22(c) Superimposed static reactions from weight of attached equipment (external loads)	Yes
UG-22(d)(2) Vessel supports such as lugs, rings, skirts, saddles and legs	Yes
UG-22(f) Wind reactions	Yes
UG-22(f) Seismic reactions	No

Note: UG-22(b),(c) and (f) loads only considered when supports are present.
Note 2: UG-22(d)(1),(e),(f)-snow,(g),(h),(i) are not considered. If these loads are present, additional calculations must be performed.

License Information	
Company Name	Codeware, Inc.
License	Commercial
License Key ID	81004
Support Expires	June 03, 2023

Radiography Summary

UG-116 Radiography							
Component	Longitudinal Seam		Left Circumferential Seam		Right Circumferential Seam		Mark
	Category (Fig UW-3)	Radiography / Joint Type	Category (Fig UW-3)	Radiography / Joint Type	Category (Fig UW-3)	Radiography / Joint Type	
Ellipsoidal Head #2	A	Full UW-11(a) / Type 1	N/A	N/A	B	Full UW-11(a) / Type 1	RT1
Cylinder #1	A	Full UW-11(a) / Type 1	B	Full UW-11(a) / Type 1	B	Full UW-11(a) / Type 1	RT1
Cylinder #2	A	Full UW-11(a) / Type 1	B	Full UW-11(a) / Type 1	B	Full UW-11(a) / Type 1	RT1
Ellipsoidal Head #3	N/A	Seamless No RT	B	Full UW-11(a) / Type 1	N/A	N/A	RT1
Cylinder #3	A	Full UW-11(a) / Type 1	B	Full UW-11(a) / Type 1	B	Full UW-11(a) / Type 1	RT1
Cylinder #4	A	Full UW-11(a) / Type 1	B	Full UW-11(a) / Type 1	B	Full UW-11(a) / Type 1	RT1
Cylinder #5	A	Full UW-11(a) / Type 1	B	Full UW-11(a) / Type 1	B	Full UW-11(a) / Type 1	RT1
Ellipsoidal Head #1	A	Full UW-11(a) / Type 1	B	Full UW-11(a) / Type 1	N/A	N/A	RT1
Nozzle	Longitudinal Seam		Nozzle to Vessel Circumferential Seam		Nozzle free end Circumferential Seam		
24" 300# RFWN MANWAY (M1)	A	Full UW-11(a) / Type 1	D	N/A / Type 7	C	Full UW-11(a) / Type 1	RT1
2" 300# RFWN STEAM OUT (N6A)	A	Welded pipe	D	N/A / Type 7	C	UW-11(a)(4) exempt / Type 1	RT3
Nozzle #26 (N26)	N/A	Seamless No RT	D	N/A / Type 7	N/A	N/A	N/A
20" 300# RFWN VAPOUR OUTLET (N2)	A	Full UW-11(a) / Type 1	D	N/A / Type 7	C	Full UW-11(a) / Type 1	RT1
16" 300# RFWN HYDROCARBON OUTLET (N3)	A	Welded pipe	D	N/A / Type 7	C	Full UW-11(a) / Type 1	RT4
8" 300# RFWN VENT (N4)	A	Welded pipe	D	N/A / Type 7	C	UW-11(a)(4) exempt / Type 1	RT3
3" 300# RFWN LG/LT (SIS) BRIDLE (J2A)	A	Welded pipe	D	N/A / Type 7	C	UW-11(a)(4) exempt / Type 1	RT3
60" BOOT (BOOT)	A	Full UW-11(a) / Type 1	D	N/A / Type 7	B	Full UW-11(a) / Type 1	RT1
4" 300# RFWN WATER OUTLET (N7)	A	Welded pipe	D	N/A / Type 7	C	UW-11(a)(4) exempt / Type 1	RT3
2" 300# RFLWN LEVEL TRANS (J3A)	N/A	Seamless No RT	D	N/A / Type 7	C	N/A	N/A
2" 300# RFLWN LEVEL TRANS (J3B)	N/A	Seamless No RT	D	N/A / Type 7	C	N/A	N/A
2" 300# RFLWN LEVEL TRANS (J4A)	N/A	Seamless No RT	D	N/A / Type 7	C	N/A	N/A
2" 300# RFLWN LEVEL TRANS (J4B)	N/A	Seamless No RT	D	N/A / Type 7	C	N/A	N/A
Nozzle #25 (N25)	N/A	Seamless No RT	D	N/A / Type 7	C	Full UW-11(a) / Type 1	RT1
24" 300# RFWN FEED INLET (N1)	A	Full UW-11(a) / Type 1	D	N/A / Type 7	C	Full UW-11(a) / Type 1	RT1
4" 300# RFWN DRAIN (N5)	A	Welded pipe	D	N/A / Type 7	C	UW-11(a)(4) exempt / Type 1	RT3
4" 300# RFWN VENT (N8)	A	Welded pipe	D	N/A / Type 7	C	UW-11(a)(4) exempt / Type 1	RT3
24" 300# RFWN MANWAY (M2)	A	Full UW-11(a) / Type 1	D	N/A / Type 7	C	Full UW-11(a) / Type 1	RT1
2" 300# RFWN STEAM OUT (N6B)	A	Welded pipe	D	N/A / Type 7	C	UW-11(a)(4) exempt / Type 1	RT3
Nozzle Flange	Longitudinal Seam		Flange Face		Nozzle to Flange Circumferential Seam		

ASME B16.5/16.47 flange attached to 24" 300# RFWN MANWAY (M1)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	Full UW-11(a) / Type 1	RT1
ASME B16.5/16.47 flange attached to 2" 300# RFWN STEAM OUT (N6A)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	UW-11(a)(4) exempt / Type 1	N/A
ASME B16.5/16.47 flange attached to 20" 300# RFWN VAPOUR OUTLET (N2)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	Full UW-11(a) / Type 1	RT1
ASME B16.5/16.47 flange attached to 16" 300# RFWN HYDROCARBON OUTLET (N3)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	Full UW-11(a) / Type 1	RT1
ASME B16.5/16.47 flange attached to 8" 300# RFWN VENT (N4)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	UW-11(a)(4) exempt / Type 1	N/A
ASME B16.5/16.47 flange attached to 3" 300# RFWN LG/LT (SIS) BRIDLE (J2A)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	UW-11(a)(4) exempt / Type 1	N/A
ASME B16.5/16.47 flange attached to 4" 300# RFWN WATER OUTLET (N7)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	UW-11(a)(4) exempt / Type 1	N/A
ASME B16.5/16.47 flange attached to 2" 300# RFLWN LEVEL TRANS (J3A)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	N/A	N/A
ASME B16.5/16.47 flange attached to 2" 300# RFLWN LEVEL TRANS (J3B)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	N/A	N/A
ASME B16.5/16.47 flange attached to 2" 300# RFLWN LEVEL TRANS (J4A)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	N/A	N/A
ASME B16.5/16.47 flange attached to 2" 300# RFLWN LEVEL TRANS (J4B)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	N/A	N/A
ASME B16.5/16.47 flange attached to Nozzle #25 (N25)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	Full UW-11(a) / Type 1	RT1
ASME B16.5/16.47 flange attached to 24" 300# RFWN FEED INLET (N1)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	Full UW-11(a) / Type 1	RT1
ASME B16.5/16.47 flange attached to 4" 300# RFWN DRAIN (N5)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	UW-11(a)(4) exempt / Type 1	N/A
ASME B16.5/16.47 flange attached to 4" 300# RFWN VENT (N8)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	UW-11(a)(4) exempt / Type 1	N/A
ASME B16.5/16.47 flange attached to 24" 300# RFWN MANWAY (M2)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	Full UW-11(a) / Type 1	RT1
ASME B16.5/16.47 flange attached to 2" 300# RFWN STEAM OUT (N6B)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	UW-11(a)(4) exempt / Type 1	N/A
UG-116(e) Required Marking: **RT4**							

Thickness Summary

Component Data								
Component Identifier	**Material**	**Diameter (in)**	**Length (in)**	**Nominal t (in)**	**Design t (in)**	**Total Corrosion (in)**	**Joint E**	**Load**
Ellipsoidal Head #2	SA-516 70	168 ID	43.3	1.3*	1.0839	0	1.00	Internal
Straight Flange on Ellipsoidal Head #2	SA-516 70	168 ID	2	1.375	1.091	0	1.00	Internal
Cylinder #1	SA-516 70	168 ID	86	1.375	1.091	0	1.00	Internal
Cylinder #2	SA-516 70	168 ID	120	1.25	1.091	0	1.00	Internal
Cylinder #3	SA-516 70	168 ID	87	1.375	1.091	0	1.00	Internal
Cylinder #4	SA-516 70	168 ID	87	1.375	1.091	0	1.00	Internal
Cylinder #5	SA-516 70	168 ID	120	1.375	1.091	0	1.00	Internal
Straight Flange on Ellipsoidal Head #1	SA-516 70	168 ID	2	1.375	1.091	0	1.00	Internal
Ellipsoidal Head #1	SA-516 70	168 ID	43.3	1.3*	1.0839	0	1.00	Internal
Straight Flange on Ellipsoidal Head #3	SA-516 70	60 ID	2	2	0.3897	0	1.00	Internal
Ellipsoidal Head #3	SA-516 70	60 ID	16.5	1.5*	0.3871	0	1.00	Internal
*Head minimum thickness after forming								

Definitions	
Nominal t	Vessel wall nominal thickness
Design t	Required vessel thickness due to governing loading + corrosion
Joint E	Longitudinal seam joint efficiency
Load	
Internal	Circumferential stress due to internal pressure governs
External	External pressure governs
Wind	Combined longitudinal stress of pressure + weight + wind governs
Seismic	Combined longitudinal stress of pressure + weight + seismic governs

Weight Summary

Component	Metal New*	Metal Corroded	Insulation	Insulation Supports	Lining	Piping + Liquid	Operating Liquid New	Operating Liquid Corroded	Test Liquid New	Test Liquid Corroded
Ellipsoidal Head #2	12,065.5	12,065.5	1,401.4	50	0	0	0	0	24,231	24,231
Cylinder #1	17,579.9	17,579.9	1,967.2	50	0	0	0	0	69,220.1	69,220.1
Cylinder #2	21,433.3	21,433.3	2,741	50	0	0	0	0	105,492.3	105,495.1
Cylinder #3	16,913.7	16,913.7	1,990.1	50	0	0	0	0	71,659.4	71,659.4
Cylinder #4	18,013.9	18,013.9	1,990.1	50	0	0	0	0	69,614.5	69,614.5
Cylinder #5	24,658.3	24,658.3	2,745	50	0	0	0	0	96,440.8	96,440.8
Ellipsoidal Head #1	12,439.9	12,439.9	1,401.4	50	0	0	0	0	24,116.5	24,116.5
Saddle #1	6,702	6,702	0	0	0	0	0	0	0	0
TOTAL:	**129,806.4**	**129,806.4**	**14,236.2**	**350**	**0**	**0**	**0**	**0**	**460,774.6**	**460,777.4**

Weight (lb) Contributed by Vessel Elements

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

Weight (lb) Contributed by Attachments

Component	Body Flanges New	Body Flanges Corroded	Nozzles & Flanges New	Nozzles & Flanges Corroded	Packed Beds	Trays	Tray Supports	Rings & Clips	Vertical Loads
Ellipsoidal Head #2	0	0	4,162.6	4,162.6	0	0	0	0	0
Cylinder #1	0	0	2,003.3	2,003.3	0	0	0	0	0
Cylinder #2	0	0	13,577.3	13,550.9	0	0	0	578.5	0
Cylinder #3	0	0	17,000.2	17,000.2	0	0	0	0	7,700*
Cylinder #4	0	0	0	0	0	0	0	0	18,243
Cylinder #5	0	0	1,819.2	1,819.2	0	0	0	578.5	0
Ellipsoidal Head #1	0	0	2,018.4	2,018.4	0	0	0	0	0
TOTAL:	**0**	**0**	**40,580.9**	**40,554.6**	**0**	**0**	**0**	**1,157.1**	**25,943***

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

Vessel Totals

	New	Corroded
Operating Weight (lb)	212,074	212,047
Empty Weight (lb)	212,074	212,047
Test Weight (lb)	672,848	672,825
Capacity** (US gal)	53,738	53,738

**The vessel capacity does not include volume of nozzle, piping or other attachments.

Vessel Lift Condition

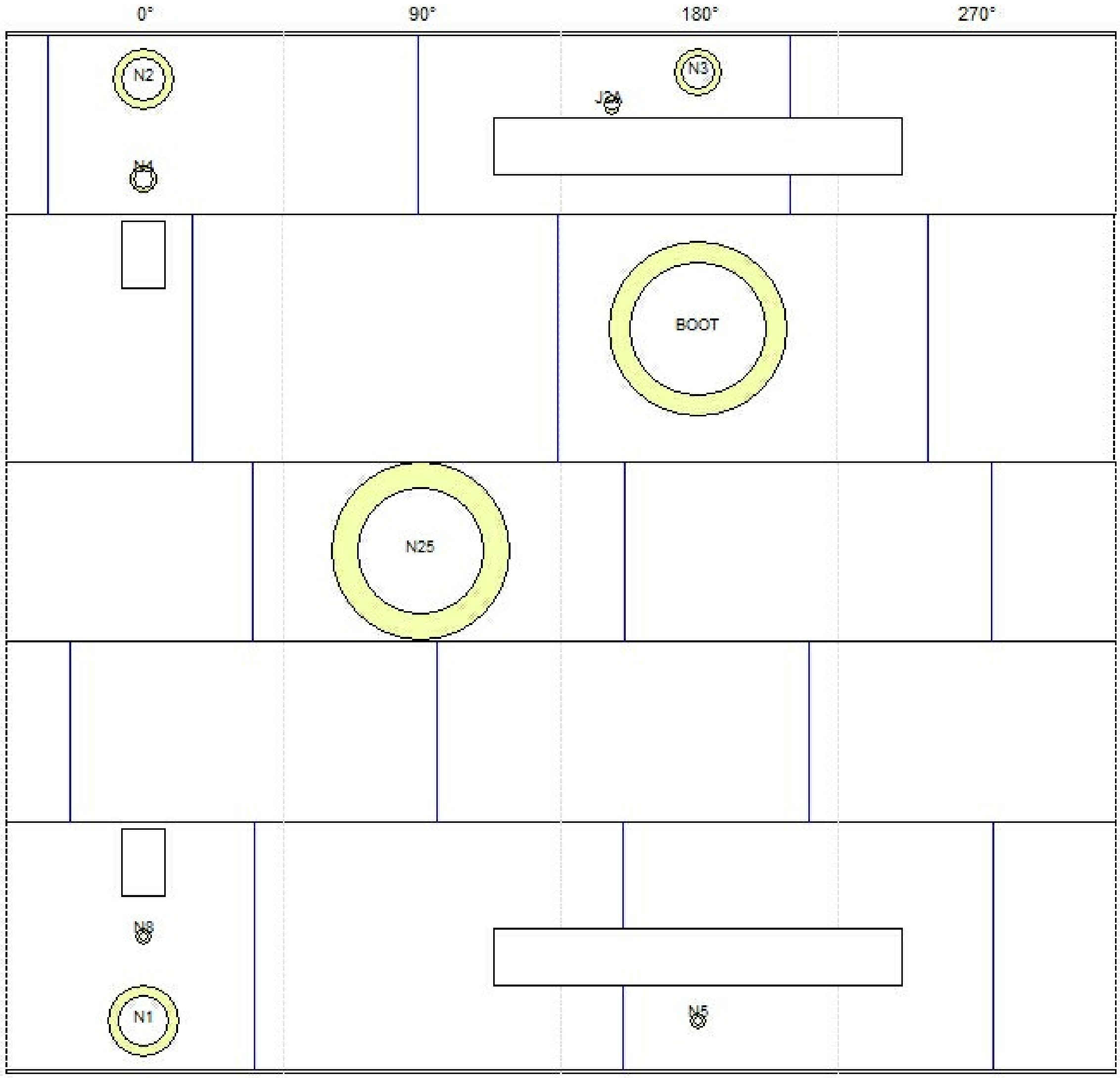
Vessel Lift Weight, New (lb)	204,374
Center of Gravity from Datum (in)	252.3915

Long Seam Summary

Shell Long Seam Angles			
Component	Seam 1	Seam 2	Seam 3
Cylinder #1	89°	209.4268°	328.5732°
Cylinder #2	15.5158°	134.4842°	255°
Cylinder #3	35.4268°	155.8537°	275°
Cylinder #4	95.1463°	215.5731°	336°
Cylinder #5	36°	155.1463°	275.5731°

Shell Plate Lengths				
Component	Starting Angle	Plate 1	Plate 2	Plate 3
Cylinder #1	89°	178"	176.1073"	178"
Cylinder #2	15.5158°	175.7145"	178"	178"
Cylinder #3	35.4268°	178"	176.1073"	178"
Cylinder #4	95.1463°	178"	178"	176.1073"
Cylinder #5	36°	176.1073"	178"	178"

Note
1) Plate Lengths use the circumference of the vessel based on the mid diameter of the components.



Shell Rollout

Hydrostatic Test

Horizontal shop hydrostatic test based on MAWP per UG-99(b)

Gauge pressure at 70°F $= 1.3 \cdot MAWP \cdot LSR$

$= 1.3 \cdot 255.74 \cdot 1$

$= 332.46 \quad \text{psi}$

Horizontal shop hydrostatic test							
Identifier	Local test pressure (psi)	Test liquid static head (psi)	UG-99(b) stress ratio	UG-99(b) pressure factor	Stress during test (psi)	Allowable test stress (psi)	Stress excessive?
Ellipsoidal Head #2	339.93	7.472	1.0309	1.30	19,768	34,200	No
Straight Flange on Ellipsoidal Head #2	339.93	7.472	1.0309	1.30	20,936	34,200	No
Cylinder #1	339.93	7.472	1.0309	1.30	20,936	34,200	No
Cylinder #2	339.93	7.472	1.0309	1.30	23,013	34,200	No
Cylinder #3	339.93	7.472	1.0309	1.30	20,936	34,200	No
Cylinder #4	339.93	7.472	1.0309	1.30	20,936	34,200	No
Cylinder #5	339.93	7.472	1.0309	1.30	20,936	34,200	No
Straight Flange on Ellipsoidal Head #1	339.93	7.472	1.0309	1.30	20,936	34,200	No
Ellipsoidal Head #1	339.93	7.472	1.0309	1.30	19,768	34,200	No
Straight Flange on Ellipsoidal Head #3	342.962	10.504	1.0309	1.30	5,314	34,200	No
Ellipsoidal Head #3	343.504	11.046	1.0309	1.30	6,183	34,200	No
16" 300# RFWN HYDROCARBON OUTLET (N3) (1)	340.63	8.172	1	1.30	20,608	51,300	No
2" 300# RFLWN LEVEL TRANS (J3A)	342.746	10.288	1.087	1.30	5,594	51,300	No
2" 300# RFLWN LEVEL TRANS (J3B)	340.363	7.905	1.087	1.30	5,555	51,300	No
2" 300# RFLWN LEVEL TRANS (J4A)	342.746	10.288	1.087	1.30	5,594	51,300	No
2" 300# RFLWN LEVEL TRANS (J4B)	340.363	7.905	1.087	1.30	5,555	51,300	No
2" 300# RFWN STEAM OUT (N6A)	339.374	6.916	1	1.30	16,225	51,300	No
2" 300# RFWN STEAM OUT (N6B)	339.374	6.916	1	1.30	16,225	51,300	No
20" 300# RFWN VAPOUR OUTLET (N2)	333.816	1.358	1.0309	1.30	21,888	51,300	No
24" 300# RFWN FEED INLET (N1)	333.816	1.358	1.0309	1.30	21,118	51,300	No
24" 300# RFWN MANWAY (M1)	338.911	6.452	1.0309	1.30	23,813	51,300	No
24" 300# RFWN MANWAY (M2)	338.586	6.128	1.0309	1.30	23,507	51,300	No
3" 300# RFWN LG/LT (SIS) BRIDLE (J2A)	339.653	7.195	1	1.30	16,335	51,300	No
4" 300# RFWN DRAIN (N5)	340.413	7.955	1	1.30	18,898	51,300	No
4" 300# RFWN VENT (N8)	333.816	1.358	1	1.30	18,532	51,300	No
4" 300# RFWN WATER OUTLET (N7)	343.778	11.32	1	1.30	8,061	51,300	No
60" BOOT (BOOT)	342.89	10.432	1.0309	1.30	22,453	51,300	No
8" 300# RFWN VENT (N4)	333.816	1.358	1	1.30	20,912	51,300	No
Nozzle #25 (N25)	337.936	5.478	1	1.30	31,488	51,300	No
Nozzle #26 (N26)	337.331	4.873	1	1.30	9,321	51,300	No

(1) 16" 300# RFWN HYDROCARBON OUTLET (N3) limits the UG-99(b) 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.

The test temperature of 70 °F is warmer than the minimum recommended temperature of 49.1 °F so the brittle fracture provision of UG-99(h) has been met.

Vacuum Summary

Largest Unsupported Length Le			
Component	Line of Support	Elevation above Datum (in)	Length Le (in)
Ellipsoidal Head #2	-	545.3	N/A
-	1/3 depth of Ellipsoidal Head #2	516	N/A
Straight Flange on Ellipsoidal Head #2 Left	-	502	532
Straight Flange on Ellipsoidal Head #2 Right	-	500	532
Cylinder #1 Left	-	500	532
Cylinder #1 Right	-	414	532
Cylinder #2 Left	-	414	532
Cylinder #2 Right	-	294	532
Cylinder #3 Left	-	294	532
Cylinder #3 Right	-	207	532
Cylinder #4 Left	-	207	532
Cylinder #4 Right	-	120	532
Cylinder #5 Left	-	120	532
Cylinder #5 Right	-	0	532
Straight Flange on Ellipsoidal Head #1 Left	-	0	532
Straight Flange on Ellipsoidal Head #1 Right	-	-2	532
-	1/3 depth of Ellipsoidal Head #1	-16	N/A
Ellipsoidal Head #1	-	-45.3	N/A

Foundation Load Summary

Saddle #1: Total Loading at Base (Right Sliding Saddle)				
Load	**Vessel Condition**	**Longitudinal Base Shear (lb_f)**	**Transverse Base Shear (lb_f)**	**Vertical Force (lb_f)**
Weight	Operating, New	20,980	0	104,902
Weight	Operating, Corroded	20,979	0	104,895
Wind	Operating, New	21,675	12,140	124,113
Wind	Operating, Corroded	21,674	12,140	124,106
Wind	External Pressure, Corroded	21,674	12,140	124,106

Saddle #1: Total Loading at Base (Left Fixed Saddle)				
Load	**Vessel Condition**	**Longitudinal Base Shear (lb_f)**	**Transverse Base Shear (lb_f)**	**Vertical Force (lb_f)**
Weight	Operating, New	20,980	0	107,171
Weight	Operating, Corroded	20,979	0	107,152
Wind	Operating, New	21,675	12,140	126,382
Wind	Operating, Corroded	21,674	12,140	126,363
Wind	External Pressure, Corroded	21,674	12,140	126,363

Shear and moment values reported above are presented without applicable load combination factors.

Support Information	
Support Type	Saddle
Number of Saddles	2
Base Plate Length	150"
Base Plate Width	16"
Base Plate Thickness	1.5"
Base Plate Separation Distance CL-to-CL	392"
Right Saddle Distance from Datum	54"
Number of Anchor Bolts Per Base Plate	4
Bolt Size and Type	1-1/2" series 8 bolt
Bolt Hole Clearance	0.25"
Slotted Hole Length	3.0749"
Center of Gravity (Distance from Datum)	252.3915"

Bill of Materials

Heads / Covers						
Item #	**Type**	**Material**	**Thk [in]**	**Dia. [in]**	**Wt. [lb] (ea.)**	**Qty**
H1	Ellipsoidal Head	SA-516 70 (N, FGP, Impact (-49 °F))	1.3 (min.)	168 ID	12,608	2
H2	Ellipsoidal Head	SA-516 70 (N, FGP, Impact (-49 °F))	1.5 (min.)	60 ID	2,093.1	1
H3	ASME B16.5/B16.47 Blind NPS 24 Class 300	A350 LF2 Cl.1	2.75	36 OD	914	2
H4	ASME B16.5/B16.47 Blind NPS 24 Class 300	A105	2.75	36 OD	914	1
H5	ASME B16.5/B16.47 Blind NPS 60 Class 400	A105	7.56	74.25 OD	9,735	1

Shells							
Item #	**Type**	**Material**	**Thk [in]**	**Dia. [in]**	**Length [in]**	**Wt. [lb] (ea.)**	**Qty**
S1	Cylinder	SA-516 70 (N, FGP, Impact (-49 °F))	1.375	168 ID	86	17,806.8	1
S2	Cylinder	SA-516 70 (N, FGP, Impact (-49 °F))	1.25	168 ID	120	22,571.3	1
S3	Cylinder	SA-516 70 (N, FGP, Impact (-49 °F))	1.375	168 ID	87	18,013.9	2
S4	Cylinder	SA-516 70 (N, FGP, Impact (-49 °F))	1.375	168 ID	120	24,846.7	1

Nozzles							
Item #	**Type**	**Material**	**NPS**	**Thk [in]**	**Dia. [in]**	**Length [in]**	**Wt. [lb]**
Noz1	Nozzle	SA-516 70 (N, FGP, Impact (-49 °F))	-	1.25	24 OD	63.2	2,364.8
Noz2	Nozzle	SA-333 6 Wld & smls pipe	NPS 2 XXS	0.436	2.375 OD	37.3	43.6
Noz3	Nozzle	SA-516 70	-	1	20 OD	33.2	727.8
Noz4	Nozzle	SA-333 6 Wld & smls pipe	NPS 16 Sch 100	1.031	16 OD	14	298.9
Noz5	Nozzle	SA-333 6 Wld & smls pipe	NPS 8 Sch 120	0.719	8.625 OD	34.7	203.3
Noz6	Nozzle	SA-333 6 Wld & smls pipe	NPS 3 Sch 160	0.438	3.5 OD	20	41.2
Noz7	Nozzle	SA-516 70 (N, FGP, Impact (-49 °F))	-	2	64 OD	88.3	11,360
Noz8	Nozzle	SA-333 6 Wld & smls pipe	NPS 4 Sch 160	0.531	4.5 OD	49.9	109.8
Noz9	Nozzle	SA-106 B Smls pipe	NPS 60 (Thk = 1.250")	1.25	60 OD	31.7	3,445.2

Nozzles - Studding Outlets							
Item #	**Type**	**Material**	**# Bolts**	**Thk [in]**	**Dia. [in]**	**Wt. [lb]**	**Qty**
SP1	Studding Outlet Custom Size - Contoured Base	SA-106 B Smls pipe	24	7.3	36 OD x 24 ID	1,139.7	1

Flanges						
Item #	**Type**	**Material**	**NPS**	**Dia. [in]**	**Wt. [lb] (ea.)**	**Qty**
AF1	ASME B16.5 Welding Neck - Class 300	A350 LF2 Cl.1	24	36 x 21.5	580	3
AF2	ASME B16.5 Welding Neck - Class 300	A350 LF2 Cl.1	2	6.5 x 2.07	9	2
AF3	ASME B16.5 Welding Neck - Class 300	A350 LF2 Cl.1	20	30.5 x 18	400	1
AF4	ASME B16.5 Welding Neck - Class 300	A350 LF2 Cl.1	16	25.5 x 13.938	250	1
AF5	ASME B16.5 Welding Neck - Class 300	A350 LF2 Cl.1	8	15 x 7.98	67	1
AF6	ASME B16.5 Welding Neck - Class 300	A350 LF2 Cl.1	3	8.25 x 3.07	15	1
AF7	ASME B16.5 Long Weld Neck - Class 300 - 14" len.	A350 LF2 Cl.1	2	Flange 6.5 x 2; Nozzle 0.655 thk. x 3.31 OD dia.	29.4	4
AF8	ASME B16.5 Welding Neck - Class 300	A350 LF2 Cl.1	4	10 x 4.03	25	3
AF9	ASME B16.47 Welding Neck - Class 400 - Series A	A105	60	74.25 x 57.5	3,820	1

Gaskets				
Item #	**Type**	**Size [in]**	**Thk [in]**	**Qty**
G1	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel (ASME B16.20 Kammprofile)	NPS 24 - Class 300	0.145	3
G2	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel (ASME B16.20 Kammprofile)	NPS 2 - Class 300	0.145	5
G3	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel (ASME B16.20 Kammprofile)	NPS 20 - Class 300	0.145	1
G4	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel (ASME B16.20 Kammprofile)	NPS 16 - Class 300	0.145	1
G5	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel (ASME B16.20 Kammprofile)	NPS 8 - Class 300	0.145	1
G6	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel (ASME B16.20 Kammprofile)	NPS 3 - Class 300	0.145	1
G7	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel (ASME B16.20 Kammprofile)	NPS 4 - Class 300	0.145	3
There are 2 flanges that do not include gasket information.				

Fasteners				
Item #	**Description**	**Material**	**Length [in]**	**Qty**
FB1	1-1/2" series 8 bolt	SA-193 B7 Bolt <= 2 1/2	-	24
FB2	1-1/2" series 8 bolt	SA-193 B7 Bolt <= 2 1/2	7.8	72
FB3	5/8" coarse bolt	SA-193 B7 Bolt <= 2 1/2	3	48
FB4	1-1/4" series 8 bolt	SA-193 B7 Bolt <= 2 1/2	7	24
FB5	1-1/4" series 8 bolt	SA-193 B7 Bolt <= 2 1/2	6.3	20
FB6	7/8" coarse bolt	SA-193 B7 Bolt <= 2 1/2	4.8	12
FB7	3/4" coarse bolt	SA-193 B7 Bolt <= 2 1/2	3.5	8
FB8	3/4" coarse bolt	SA-193 B7 Bolt <= 2 1/2	3.8	24
FB9	2-3/4" series 8 bolt	SA-193 B7 Bolt (2 1/2 < t <= 4)	21.3	32
SB1	1-1/2" series 8 bolt	ASTM 325	-	8
All listed flange bolts require associated nuts and washers in accordance with Division 1, UCS-11.				

Insulation				
Item #	**Thk [in]**	**Density [lb/cu ft]**	**Wt. [lb]**	**Qty [ft^2]**
IN1	4	18	14,236.2	2,372.69

Plates				
Item #	**Material**	**Thk [in]**	**Wt. [lb]**	**Qty [ft^2]**
Plate1	SA-516 70 (N, FGP, Impact (-49 °F))	1	690.7	16.95
Plate1 - Note: Applies to nozzle pad				
Plate2	SA-516 70 (N, FGP, Impact (-49 °F))	1.5	616.1	15.12
Plate2 - Note: Applies to nozzle pad				
Plate3	SA-516 70 (N, FGP, Impact (-49 °F))	2	1,721.2	42.24
Plate3 - Note: Applies to nozzle pad				
Plate4	SA-516 70	1.375	1,800.4	44.18
Plate4 - Note: Applies to nozzle pad				
Plate5	SA516-70N	0.375	1,168.9	76.66
Plate5 - Note: Applies to saddle wear plate				
Plate6	SA516-70N	1.5	2,037.6	33.33
Plate6 - Note: Applies to saddle base plate				
Plate7	SA516-70N	0.625	2,237.1	87.83
Plate7 - Note: Applies to saddle web plate				
Plate8	SA516-70N	0.5	1,259.3	61.8
Plate8 - Note: Applies to saddle rib plate				
Plate9	SA-516-70N	3	577.3	4.72
Plate9 - Note: Applies to lift lug plates				
Plate10	SA-516-70N	1.5	458.5	7.5
Plate10 - Note: Applies to lift lug pad plates				

Wind Code

Building Code: NBC 1995	
Elevation of base above grade	21.80 ft (6.64 m)
Increase effective outer diameter by	0.33 ft (0.10 m)
Reference Wind Pressure, q	0.0611 psi (0.4213 kPa)
Exposure Category	B
Hazardous, toxic, or explosive contents	No
Location	Fort McMurray, Alberta

Wind Pressure (WP) Calculations

Determine Wind Pressure P_w for saddle wind shear calculations:

Factor C_e = 0.5000 [Commentary, Figure B-1]

$$\begin{aligned} P_w &= q \cdot C_e \\ &= 0.0611 \cdot 0.5000 \\ &= 0.0306 \text{ psi} \\ &= 4.4000 \text{ psf} \end{aligned}$$

Shear calculations are reported in the saddle report.

Data Sheet note 1.6 - piping approx.

ASME Section VIII Division 1, 2004 Edition, A06 Addenda	
Inputs	
Load Orientation	Vertical Load
Position from datum	261.95"
Direction Angle	0.00°
Magnitude of Force	7,700 lb
Loading Conditions	
Present When Operating	Yes
Included in Vessel Lift Weight	No
Present When Vessel is Empty	Yes
Present During Test	Yes

Lateral Force #1

ASME Section VIII Division 1, 2004 Edition, A06 Addenda	
Inputs	
Load Orientation	Lateral Force
Elevation Above Datum	251.5"
Magnitude of Force	7,700 lb_f
Direction Angle	0.00°
Loading Conditions	
Present When Operating	Yes
Present When Vessel is Empty	Yes
Present During Test	Yes

Misc Weight

ASME Section VIII Division 1, 2004 Edition, A06 Addenda	
Inputs	
Load Orientation	Vertical Load
Position from datum	179"
Direction Angle	0.00°
Magnitude of Force	18,243 lb
Loading Conditions	
Present When Operating	Yes
Included in Vessel Lift Weight	Yes
Present When Vessel is Empty	Yes
Present During Test	Yes

Ellipsoidal Head #2

<table>
<tr><th colspan="6">ASME Section VIII Division 1, 2004 Edition, A06 Addenda</th></tr>
<tr><td colspan="2">Component</td><td colspan="4">Ellipsoidal Head</td></tr>
<tr><td colspan="2">Material</td><td colspan="4">SA-516 70 (II-D p. 14, ln. 20)</td></tr>
<tr><td colspan="2">Attached To</td><td colspan="4">Cylinder #1</td></tr>
<tr><td>Impact Tested</td><td>Normalized</td><td>Fine Grain Practice</td><td colspan="2">PWHT</td><td>Maximize MDMT/ No MAWP</td></tr>
<tr><td>Yes (-49°F)</td><td>Yes</td><td>Yes</td><td colspan="2">Yes</td><td>No</td></tr>
<tr><td colspan="2"></td><td>Design Pressure (psi)</td><td colspan="2">Design Temperature (°F)</td><td>Design MDMT (°F)</td></tr>
<tr><td colspan="2">Internal</td><td>250</td><td colspan="2">600</td><td rowspan="2">-49</td></tr>
<tr><td colspan="2">External</td><td>15</td><td colspan="2">400</td></tr>
<tr><th colspan="6">Static Liquid Head</th></tr>
<tr><td colspan="2">Condition</td><td>P_s (psi)</td><td colspan="2">H_s (in)</td><td>SG</td></tr>
<tr><td colspan="2">Test horizontal</td><td>7.47</td><td colspan="2">207</td><td>1</td></tr>
<tr><th colspan="6">Dimensions</th></tr>
<tr><td colspan="2">Inner Diameter</td><td colspan="4">168"</td></tr>
<tr><td colspan="2">Head Ratio</td><td colspan="4">2</td></tr>
<tr><td colspan="2">Minimum Thickness</td><td colspan="4">1.3"</td></tr>
<tr><td rowspan="2">Corrosion</td><td>Inner</td><td colspan="4">0"</td></tr>
<tr><td>Outer</td><td colspan="4">0"</td></tr>
<tr><td colspan="2">Length L_{sf}</td><td colspan="4">2"</td></tr>
<tr><td colspan="2">Nominal Thickness t_{sf}</td><td colspan="4">1.375"</td></tr>
<tr><th colspan="6">Weight and Capacity</th></tr>
<tr><td colspan="2"></td><td colspan="3">Weight (lb)[1]</td><td>Capacity (US gal)[1]</td></tr>
<tr><td colspan="2">New</td><td colspan="3">12,065.45</td><td>2,878.84</td></tr>
<tr><td colspan="2">Corroded</td><td colspan="3">12,065.45</td><td>2,878.84</td></tr>
<tr><th colspan="6">Insulation</th></tr>
<tr><td colspan="2"></td><td>Thickness (in)</td><td colspan="2">Density (lb/ft^3)</td><td>Weight (lb)</td></tr>
<tr><td colspan="2">Insulation</td><td>4</td><td colspan="2">18</td><td>1,401.37</td></tr>
<tr><td colspan="2"></td><td>Spacing(in)</td><td colspan="2">Individual Weight (lb)</td><td>Total Weight (lb)</td></tr>
<tr><td colspan="2">Insulation Supports</td><td>145</td><td colspan="2">50</td><td>50</td></tr>
<tr><th colspan="6">Radiography</th></tr>
<tr><td colspan="2">Category A joints</td><td colspan="4">Full UW-11(a) Type 1</td></tr>
<tr><td colspan="2">Head to shell seam</td><td colspan="4">Full UW-11(a) Type 1</td></tr>
</table>

[1] includes straight flange

Results Summary	
Governing condition	internal pressure
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	1.0839"
Design thickness due to external pressure (t_e)	0.4459"
Maximum allowable working pressure (MAWP)	299.77 psi
Maximum allowable pressure (MAP)	309.05 psi
Maximum allowable external pressure (MAEP)	97.01 psi
Rated MDMT	-66.3°F

UCS-66 Material Toughness Requirements	
Material impact test temperature per UG-84 =	-49°F
$t_r = \frac{255.74 \cdot 168}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 255.74} =$	1.0755"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{1.0755 \cdot 1}{1.3 - 0} =$	0.8273
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	17.3°F
$MDMT = \max\left[T_{impact} - T_R, -155\right] = \max\left[-49 - 17.3, -155\right] =$	-66.3°F
Design MDMT of -49°F is acceptable.	

Design thickness for internal pressure, (Corroded at 600 °F) UG-32(d)(1)

$$t = \frac{P \cdot D}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion} = \frac{250 \cdot 168}{2 \cdot 19{,}400 \cdot 1 - 0.2 \cdot 250} + 0 = 1.0839"$$

Maximum allowable working pressure, (Corroded at 600 °F) UG-32(d)(1)

$$P = \frac{2 \cdot S \cdot E \cdot t}{D + 0.2 \cdot t} - P_s = \frac{2 \cdot 19{,}400 \cdot 1 \cdot 1.3}{168 + 0.2 \cdot 1.3} - 0 = 299.77 \text{ psi}$$

Maximum allowable pressure, (New at 70 °F) UG-32(d)(1)

$$P = \frac{2 \cdot S \cdot E \cdot t}{D + 0.2 \cdot t} - P_s = \frac{2 \cdot 20{,}000 \cdot 1 \cdot 1.3}{168 + 0.2 \cdot 1.3} - 0 = 309.05 \text{ psi}$$

Design thickness for external pressure, (Corroded at 400 °F) UG-33(d)

Equivalent outside spherical radius
$R_o = K_o \cdot D_o = 0.8865 \cdot 170.6 = 151.2351 \text{ in}$

$$A = \frac{0.125}{R_o \;/\; t} = \frac{0.125}{151.2351 \;/\; 0.445813} = 0.000368$$

From Table CS-2: B = 5,088.5176 psi

$$P_a = \frac{B}{R_o \;/\; t} = \frac{5{,}088.5176}{151.2351 \;/\; 0.4458} = 15 \text{ psi}$$

$$t = 0.4458" + \text{Corrosion} = 0.4458" + 0" = 0.4458"$$

Check the external pressure per UG-33(a)(1) UG-32(d)(1)

$$t = \frac{1.67 \cdot P_e \cdot D}{2 \cdot S \cdot E - 0.2 \cdot 1.67 \cdot P_e} + \text{Corrosion} = \frac{1.67 \cdot 15 \cdot 168}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 1.67 \cdot 15} + 0 = 0.1052"$$

The head external pressure design thickness (t_e) is 0.4458".

Maximum Allowable External Pressure, (Corroded at 400 °F) UG-33(d)

Equivalent outside spherical radius
$R_o = K_o \cdot D_o = 0.8865 \cdot 170.6 = 151.2351 \text{ in}$

$$A = \frac{0.125}{R_o \;/\; t} = \frac{0.125}{151.2351 \;/\; 1.3} = 0.001074$$

From Table CS-2: B = 11,285.56 psi

$$P_a = \frac{B}{R_o \;/\; t} = \frac{11{,}285.56}{151.2351 \;/\; 1.3} = 97.0094 \text{ psi}$$

Check the Maximum External Pressure, UG-33(a)(1) UG-32(d)(1)

$$P = \frac{2 \cdot S \cdot E \cdot t}{(D + 0.2 \cdot t) \cdot 1.67} = \frac{2 \cdot 20{,}000 \cdot 1 \cdot 1.3}{(168 + 0.2 \cdot 1.3) \cdot 1.67} = 185.06 \text{ psi}$$

The maximum allowable external pressure (MAEP) is 97.01 psi.

% Extreme fiber elongation - UCS-79(d)

$$EFE = \left(\frac{75 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{75 \cdot 1.375}{29.2475}\right) \cdot \left(1 - \frac{29.2475}{\infty}\right) = 3.5259\,\%$$

The extreme fiber elongation does not exceed 5%.

Straight Flange on Ellipsoidal Head #2

ASME Section VIII Division 1, 2004 Edition, A06 Addenda				
Component		Cylinder		
Material		SA-516 70 (II-D p. 14, ln. 20)		
Impact Tested	**Normalized**	**Fine Grain Practice**	**PWHT**	**Maximize MDMT/ No MAWP**
Yes (-49°F)	Yes	Yes	Yes	No
		Design Pressure (psi)	**Design Temperature (°F)**	**Design MDMT (°F)**
Internal		250	600	-49
External		15	400	
Static Liquid Head				
Condition		**P_s (psi)**	**H_s (in)**	**SG**
Test horizontal		7.47	207	1
Dimensions				
Inner Diameter		168"		
Length		2"		
Nominal Thickness		1.375"		
Corrosion	**Inner**	0"		
	Outer	0"		
Weight and Capacity				
		Weight (lb)		**Capacity (US gal)**
New		414.11		191.92
Corroded		414.11		191.92
Insulation				
		Thickness (in)	**Density (lb/ft^3)**	**Weight (lb)**
Insulation		4	18	0
		Spacing(in)	**Individual Weight (lb)**	**Total Weight (lb)**
Insulation Supports		0	0	0
Radiography				
Longitudinal seam		Full UW-11(a) Type 1		
Right Circumferential seam		Full UW-11(a) Type 1		

Results Summary	
Governing condition	Internal pressure
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	1.091"
Design thickness due to external pressure (t_e)	0.8941"
Maximum allowable working pressure (MAWP)	314.47 psi
Maximum allowable pressure (MAP)	324.2 psi
Maximum allowable external pressure (MAEP)	42.99 psi
Rated MDMT	-70.3 °F

UCS-66 Material Toughness Requirements	
Material impact test temperature per UG-84 =	-49°F
$t_r = \frac{255.74 \cdot 84}{20{,}000 \cdot 1 - 0.6 \cdot 255.74} =$	1.0824"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{1.0824 \cdot 1}{1.375 - 0} =$	0.7872
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	21.3°F
$MDMT = \max\ [T_{impact} - T_R, -155] = \max\ [-49 - 21.3, -155] =$	-70.3°F
Design MDMT of -49°F is acceptable.	

Design thickness, (at 600 °F) UG-27(c)(1)

$$t = \frac{P \cdot R}{S \cdot E - 0.60 \cdot P} + \text{Corrosion} = \frac{250 \cdot 84}{19{,}400 \cdot 1.00 - 0.60 \cdot 250} + 0 = 1.091"$$

Maximum allowable working pressure, (at 600 °F) UG-27(c)(1)

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} - P_s = \frac{19{,}400 \cdot 1.00 \cdot 1.375}{84 + 0.60 \cdot 1.375} - 0 = 314.47 \text{ psi}$$

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

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} = \frac{20{,}000 \cdot 1.00 \cdot 1.375}{84 + 0.60 \cdot 1.375} = 324.2 \text{ psi}$$

External Pressure, (Corroded & at 400 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{532}{170.75} = 3.1157$$

$$\frac{D_o}{t} = \frac{170.75}{0.8941} = 190.9811$$

From table G: $A = 0.000157$

From table CS-2: $B = 2{,}148.5374 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 2{,}148.54}{3 \cdot (170.75/0.8941)} = 15 \text{ psi}$$

Design thickness for external pressure P_a = 15 psi

$$t_a = t + \text{Corrosion} = 0.8941 + 0 = 0.8941"$$

Maximum Allowable External Pressure, (Corroded & at 400 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{532}{170.75} = 3.1157$$

$$\frac{D_o}{t} = \frac{170.75}{1.375} = 124.1818$$

From table G: $A = 0.000290$

From table CS-2: $B = 4{,}004.3077 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 4,004.31}{3 \cdot (170.75/1.375)} = \underline{42.99} \text{ psi}$$

% Extreme fiber elongation - UCS-79(d)

$$EFE = \left(\frac{50 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{50 \cdot 1.375}{84.6875}\right) \cdot \left(1 - \frac{84.6875}{\infty}\right) = 0.8118\,\%$$

The extreme fiber elongation does not exceed 5%.

Allowable Compressive Stress, Hot and Corroded- S_{cHC}, (table CS-2)

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{85.375/1.375} = 0.002013$$

$$B = 10{,}328 \quad \text{psi}$$

$$S = \frac{19{,}400}{1.00} = 19{,}400 \quad \text{psi}$$

$S_{cHC} \;=\; \min\,(B,S) =$ 10,328 psi

Allowable Compressive Stress, Hot and New- S_{cHN}

$$S_cHN = S_cHC = 10{,}328 \quad \text{psi}$$

Allowable Compressive Stress, Cold and New- S_{cCN}, (table CS-2)

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{85.375/1.375} = 0.002013$$

$$B = 15{,}019 \quad \text{psi}$$

$$S = \frac{20{,}000}{1.00} = 20{,}000 \quad \text{psi}$$

$S_{cCN} \;=\; \min\,(B,S) =$ 15,019 psi

Allowable Compressive Stress, Cold and Corroded- S_{cCC}

$$S_{cC} = S_{cCN} = 15{,}019 \quad \text{psi}$$

Allowable Compressive Stress, Vacuum and Corroded- S_{cVC}, (table CS-2)

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{85.375/1.375} = 0.002013$$

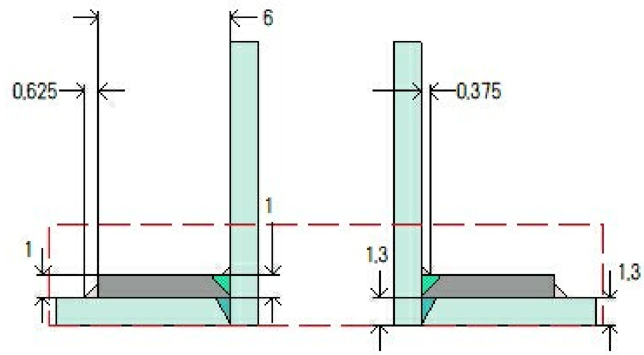
$$B = 13{,}139 \quad \text{psi}$$

$$S = \frac{20{,}000}{1.00} = 20{,}000 \quad \text{psi}$$

$S_{cVC} \;=\; \min\,(B,S) =$ 13,139 psi

24" 300# RFWN MANWAY (M1)

ASME Section VIII Division 1, 2004 Edition, A06 Addenda	



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

Location and Orientation	
Located on	Ellipsoidal Head #2
Orientation	180°
End of nozzle to datum line	556.308"
Calculated as hillside	Yes
Distance to head center, R	45"
Passes through a Category A joint	No
Nozzle	
Access opening	No
Material specification	SA-516 70 (II-D p. 14, ln. 20) (normalized)
Inside diameter, new	21.5"
Nominal wall thickness	1.25"
Corrosion allowance	0"
Opening chord length	22.5847"
Projection available outside vessel, Lpr	7.7596"
Projection available outside vessel to flange face, Lf	14.3796"
Local vessel minimum thickness	1.3"
Liquid static head included	0 psi
Reinforcing Pad	
Material specification	SA-516 70 (II-D p. 14, ln. 20) (normalized)
Diameter, D_p	37.1744"
Thickness, t_e	1"
Is split	No
Welds	
Inner fillet, Leg_{41}	0.375"
Outer fillet, Leg_{42}	0.625"
Nozzle to vessel groove weld	1.3"
Pad groove weld	1"
Radiography	
Longitudinal seam	Full UW-11(a) Type 1
Circumferential seam	Full UW-11(a) Type 1

ASME B16.5-2003 Flange	
Description	NPS 24 Class 300 WN A350 LF2 Cl.1
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, ln. 33)
Blind included	Yes
Rated MDMT	-55°F
Liquid static head	0 psi
MAWP rating	570 psi @ 600°F
MAP rating	740 psi @ 70°F
Hydrotest rating	1,125 psi @ 70°F
PWHT performed	Yes
Impact Tested	No
Circumferential joint radiography	Full UW-11(a) Type 1
Bore diameter, B (specified by purchaser)	21.5"
Gasket	
Type	ASME B16.20 Kammprofile
Description	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel
Factor, m	2
Seating Stress, y	2,500 psi
Thickness, T	0.145"
Inner Diameter	24.87"
Outer Diameter	26.87"
Notes	
Flange is impact tested per material specification to -50°F. Stress ratio = 0.3456 ≤ 0.35, MDMT per UCS-66(b)(3) = -155°F. Bolts rated MDMT per Fig UCS-66 note (e) = -55°F	

UCS-66 Material Toughness Requirements Nozzle	
Material impact test temperature per UG-84 =	-49°F
$t_r = \frac{255.74 \cdot 10.75}{20{,}000 \cdot 1 - 0.6 \cdot 255.74} =$	0.1385"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.1385 \cdot 1}{1.25 - 0} =$	0.1108
Stress ratio ≤ 0.35, MDMT per UCS-66(b)(3) =	-155°F
$MDMT = \min[-49, -155] =$	-155°F
Design MDMT of -49°F is acceptable.	

UCS-66 Material Toughness Requirements Pad	
Material impact test temperature per UG-84 =	-49°F
$t_r = \frac{255.74 \cdot 0.9 \cdot 168}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 255.74} =$	0.9679"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.9679 \cdot 1}{1.3 - 0} =$	0.7446
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	25.5°F
$MDMT = \max[T_{impact} - T_R, -155] = \max[-49 - 25.5, -155] =$	-74.5°F
Design MDMT of -49°F is acceptable.	

Reinforcement Calculations for MAWP

Available reinforcement per UG-37 governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 278.01 psi @ 600 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
24.5026	24.5036	4.8575	7.1149	–	12	0.5312	0.3281	1.25

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
391,546.18	381,134.34	953,541.94	203,806.7	1,379,167.34	444,184.34	1,050,500.83

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})	0.375	0.4375	weld size is adequate

% Extreme fiber elongation - UCS-79(d)

$$EFE = \left(\frac{50 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{50 \cdot 1.25}{11.375}\right) \cdot \left(1 - \frac{11.375}{\infty}\right) = 5.4945\,\%$$

Reinforcement Calculations for MAP

Available reinforcement per UG-37 governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 286.61 psi @ 70 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
24.503	24.5034	4.8573	7.1149	–	12	0.5312	0.3281	1.25

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
403,668.21	392,922	983,032.93	210,110	1,421,822	457,922	1,082,990.55

Reinforcement Calculations for MAEP

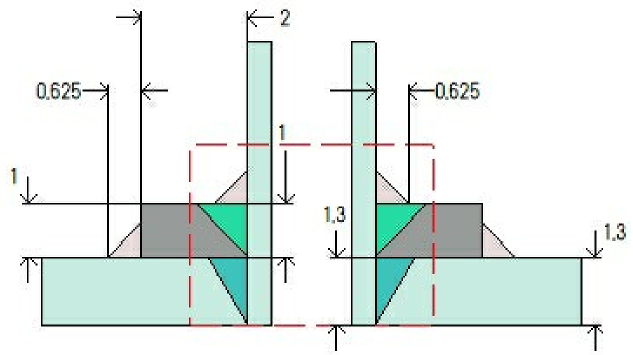
UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 42.99 psi @ 400 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
8.5083	32.2536	12.3453	7.3771	–	12	0.5312	0.1806	1.25

UG-41 Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

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})	0.375	0.4375	weld size is adequate

2" 300# RFWN STEAM OUT (N6A)

ASME Section VIII Division 1, 2004 Edition, A06 Addenda	



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

Location and Orientation	
Located on	Ellipsoidal Head #2
Orientation	212°
End of nozzle to datum line	535.3684"
Calculated as hillside	Yes
Distance to head center, R	80"
Passes through a Category A joint	No
Nozzle	
Description	NPS 2 XXS
Access opening	No
Material specification	SA-333 6 Wld & smls pipe (II-D p. 10, ln. 8)
Inside diameter, new	1.503"
Pipe nominal wall thickness	0.436"
Pipe minimum wall thickness[1]	0.3815"
Corrosion allowance	0"
Opening chord length	2.6821"
Projection available outside vessel, Lpr	14.0551"
Projection available outside vessel to flange face, Lf	16.8051"
Local vessel minimum thickness	1.3"
Liquid static head included	0 psi
Reinforcing Pad	
Material specification	SA-516 70 (II-D p. 14, ln. 20) (normalized)
Diameter, D_p	8.0104"
Thickness, t_e	1"
Is split	No
Welds	
Inner fillet, Leg_{41}	0.625"
Outer fillet, Leg_{42}	0.625"
Nozzle to vessel groove weld	1.3"
Pad groove weld	1"
Radiography	
Longitudinal seam	Welded pipe
Circumferential seam	Full UW-11(a) Type 1

[1]Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

ASME B16.5-2003 Flange	
Description	NPS 2 Class 300 WN A350 LF2 Cl.1
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, ln. 33)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0 psi
Consider External Loads on Flange MAWP Rating	No
MAWP rating	570 psi @ 600°F
MAP rating	740 psi @ 70°F
Hydrotest rating	1,125 psi @ 70°F
PWHT performed	Yes
Impact Tested	No
Circumferential joint radiography	Full UW-11(a) Type 1
Gasket	
Type	ASME B16.20 Kammprofile
Description	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel
Factor, m	2
Seating Stress, y	2,500 psi
Thickness, T	0.145"
Inner Diameter	2.75"
Outer Diameter	3.5"
Notes	
Flange is impact tested per material specification to -50°F. Stress ratio = 0.3456 ≤ 0.35, MDMT per UCS-66(b)(3) = -155°F. Bolts rated MDMT per Fig UCS-66 note (e) = -55°F	

UCS-66 Material Toughness Requirements Nozzle	
Impact test temperature per material specification =	-50°F
External nozzle loadings per UG-22 govern the coincident ratio used.	
$\text{Stress ratio} = \dfrac{t_r \cdot E^*}{t_n - c} = \dfrac{0.0523 \cdot 1}{0.3815 - 0} =$	0.1372
Stress ratio ≤ 0.35, MDMT per UCS-66(b)(3) =	-155°F
$MDMT = \min\left[T_{impact} - T_{UCS-66(g)}, -155\right] = \min\left[-50 - 5, -155\right] =$	-155°F
Material is exempt from impact testing at the Design MDMT of -49°F.	

UCS-66 Material Toughness Requirements Pad	
Material impact test temperature per UG-84 =	-49°F
$t_r = \dfrac{255.74 \cdot 168}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 255.74} =$	1.0755"
$\text{Stress ratio} = \dfrac{t_r \cdot E^*}{t_n - c} = \dfrac{1.0755 \cdot 1}{1.3 - 0} =$	0.8273
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	17.3°F
$MDMT = \max\left[T_{impact} - T_R, -155\right] = \max\left[-49 - 17.3, -155\right] =$	-66.3°F
Design MDMT of -49°F is acceptable.	

Reinforcement Calculations for MAWP

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 299.77 psi @ 600 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
3.6212	4.0527	--	1.5647	--	2.1437	0.3443	0.1348	0.3815

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
70,250.79	78,622.38	90,652.66	56,418.21	142,718.2	98,005.99	144,381.22

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.25	0.4375	weld size is adequate
Pad to shell fillet (Leg_{42})	0.375	0.4375	weld size is adequate

WRC 107												
Load Case	P (psi)	P_r (lb_f)	M_1 (lb_f-in)	V_2 (lb_f)	M_2 (lb_f-in)	V_1 (lb_f)	M_t (lb_f-in)	Max Comb Stress (psi)	Allow Comb Stress (psi)	Max Local Primary Stress (psi)	Allow Local Primary Stress (psi)	Over stressed
Load case 1	299.77	-710	-2,208	0	2,208	0	0	**18,442**	**58,200**	**17,625**	**29,100**	No
Load case 1 (Hot Shut Down)	0	-710	-2,208	0	2,208	0	0	922	58,200	105	29,100	No

Reinforcement Calculations for MAP

The vessel wall thickness governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 309.04 psi @ 70 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
3.6551	3.9972	--	1.5164	--	2.1468	0.334	0.1348	0.3815

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
73,102.64	79,944	92,964.73	56,392.56	146,527.93	99,328.56	148,846.62

Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 42.99 psi @ 400 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
1.0702	5.7936	1.8286	1.455	--	2.176	0.334	0.1348	0.3815

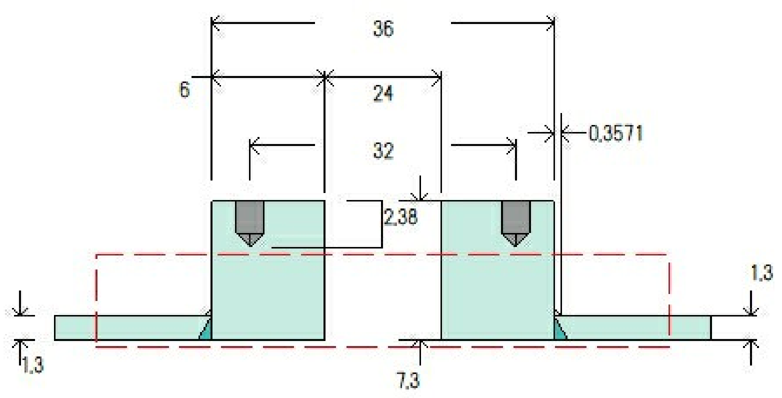
UG-41 Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

UW-16 Weld Sizing Summary

Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.25	0.4375	weld size is adequate
Pad to shell fillet (Leg_{42})	0.375	0.4375	weld size is adequate

Nozzle #26 (N26)

ASME Section VIII Division 1, 2004 Edition, A06 Addenda	



Note: round inside edges per UG-76(c)	
Note: Thread engagement shall comply with the requirements of UG-43(g).	
Location and Orientation	
Located on	Ellipsoidal Head #2
Orientation	0°
End of nozzle to datum line	550.325"
Calculated as hillside	No
Distance to head center, R	0"
Passes through a Category A joint	No
Nozzle	
Description	Studding Outlet Custom Size - Contoured
Access opening	No
Material specification	SA-106 B Smls pipe (II-D p. 10, ln. 5)
Bolt material specification	SA-193 B7 Bolt ≤ 2 1/2 (II-D p. 382, ln. 33)
Bolt rated MDMT	-55°F
Pad inner diameter	24"
Pad outer diameter, D_p	36"
Pad thickness	7.3"
Figure UG-40 thickness, t_e	5.94"
Tapped hole diameter	1.5"
Tapped hole depth	2.38"
Tapped hole bolt circle	32"
Raised face height	0.06"
Raised face outer diameter	27.25"
Corrosion allowance	0"
Projection available outside vessel, Lpr	5.94"
Projection available outside vessel to flange face, Lf	6"
Local vessel minimum thickness	1.3"
Liquid static head included	0 psi
Welds	
Inner fillet, Leg_{41}	0.3571"
Nozzle to vessel groove weld	1.3"
Radiography	
Longitudinal seam	Seamless No RT

ASME B16.5-2003 Blind	
Description	NPS 24 Class 300 Blind A105
Rated MDMT	-55°F
Liquid static head	0 psi
MAWP rating	570 psi @ 600°F
MAP rating	740 psi @ 70°F
Hydrotest rating	1,125 psi @ 70°F
Impact Tested	No
Notes	
Blind rated MDMT per UCS-66(b)(3) = -155°F (Coincident ratio = 0.3456) Bolts rated MDMT per Fig UCS-66 note (e) = -55°F	

UCS-66 Material Toughness Requirements Pad	
Governing thickness, t_g =	1.3"
Exemption temperature from Fig UCS-66 Curve B =	44.6°F
$t_r = \frac{255.74 \cdot 0.9 \cdot 168}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 255.74} =$	0.9679"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.9679 \cdot 1}{1.3 - 0} =$	0.7446
Reduction in MDMT, T_R from Fig UCS-66.1 =	25.5°F
$MDMT = \max\left[MDMT - T_R, -55\right] = \max\left[44.6 - 25.5, -55\right] =$	19.1°F
Bolts rated MDMT per Fig UCS-66 note (e) =	-55°F
Rated MDMT of 19.1°F > Design MDMT of -49°F.	

Reinforcement Calculations for MAWP

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 333.02 psi @ 600 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
33.0502	34.487	–	–	–	34.3746	0.1124	0.3281	5.25

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
Pad to shell fillet (Leg_{41})	0.25	0.25	***weld size is NOT adequate***

Reinforcement Calculations for MAP

Available reinforcement per UG-37 governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 343.28 psi @ 70 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
33.4576	33.4578	0.0038	–	–	33.345	0.109	0.3281	5.25

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(1)

Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 42.99 psi @ 400 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
9.6964	45.6211	12.1671	--	--	33.345	0.109	0.1806	5.25

UG-41 Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Pad to shell fillet (Leg_{41})	0.25	0.25	***weld size is NOT adequate***

Cylinder #1

ASME Section VIII Division 1, 2004 Edition, A06 Addenda					
Component		Cylinder			
Material		SA-516 70 (II-D p. 14, ln. 20)			
Impact Tested	**Normalized**	**Fine Grain Practice**	**PWHT**		**Maximize MDMT/ No MAWP**
Yes (-49°F)	Yes	Yes	Yes		No
		Design Pressure (psi)	**Design Temperature (°F)**		**Design MDMT (°F)**
Internal		250	600		-49
External		15	400		
Static Liquid Head					
Condition		**P_s (psi)**	**H_s (in)**		**SG**
Test horizontal		7.47	207		1
Dimensions					
Inner Diameter		168"			
Length		86"			
Nominal Thickness		1.375"			
Corrosion	**Inner**	0"			
	Outer	0"			
Weight and Capacity					
		Weight (lb)			**Capacity (US gal)**
New		17,579.87			8,252.68
Corroded		17,579.87			8,252.68
Insulation					
		Thickness (in)	**Density (lb/ft^3)**		**Weight (lb)**
Insulation		4	18		1,967.23
		Spacing(in)	**Individual Weight (lb)**		**Total Weight (lb)**
Insulation Supports		145	50		50
Radiography					
Longitudinal seam		Full UW-11(a) Type 1			
Left Circumferential seam		Full UW-11(a) Type 1			
Right Circumferential seam		Full UW-11(a) Type 1			

Results Summary	
Governing condition	Internal pressure
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	1.091"
Design thickness due to external pressure (t_e)	0.8941"
Maximum allowable working pressure (MAWP)	314.47 psi
Maximum allowable pressure (MAP)	324.2 psi
Maximum allowable external pressure (MAEP)	42.99 psi
Rated MDMT	-70.3 °F

UCS-66 Material Toughness Requirements	
Material impact test temperature per UG-84 =	-49°F
$t_r = \frac{255.74 \cdot 84}{20{,}000 \cdot 1 - 0.6 \cdot 255.74} =$	1.0824"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{1.0824 \cdot 1}{1.375 - 0} =$	0.7872
$\text{Stress ratio longitudinal} = \frac{8{,}057 \cdot 1}{20{,}000 \cdot 1} =$	0.4029
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	21.3°F
$MDMT = \max\left[T_{impact} - T_R, -155\right] = \max\left[-49 - 21.3, -155\right] =$	-70.3°F
Design MDMT of -49°F is acceptable.	

Design thickness, (at 600 °F) UG-27(c)(1)

$$t = \frac{P \cdot R}{S \cdot E - 0.60 \cdot P} + \text{Corrosion} = \frac{250 \cdot 84}{19{,}400 \cdot 1.00 - 0.60 \cdot 250} + 0 = \underline{1.091}"$$

Maximum allowable working pressure, (at 600 °F) UG-27(c)(1)

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} - P_s = \frac{19{,}400 \cdot 1.00 \cdot 1.375}{84 + 0.60 \cdot 1.375} - 0 = \underline{314.47}\ \text{psi}$$

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

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} = \frac{20{,}000 \cdot 1.00 \cdot 1.375}{84 + 0.60 \cdot 1.375} = \underline{324.2}\ \text{psi}$$

External Pressure, (Corroded & at 400 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{532}{170.75} = 3.1157$$

$$\frac{D_o}{t} = \frac{170.75}{0.8941} = 190.9811$$

From table G: $A = 0.000157$

From table CS-2: $B = 2{,}148.5374\ \text{psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 2{,}148.54}{3 \cdot (170.75/0.8941)} = 15\ \text{psi}$$

Design thickness for external pressure P_a = 15 psi

$$t_a = t + \text{Corrosion} = 0.8941 + 0 = \underline{0.8941}"$$

Maximum Allowable External Pressure, (Corroded & at 400 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{532}{170.75} = 3.1157$$

$$\frac{D_o}{t} = \frac{170.75}{1.375} = 124.1818$$

From table G: $A = 0.000290$

From table CS-2: $B = 4{,}004.3077$ psi

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 4{,}004.31}{3 \cdot (170.75/1.375)} = \underline{42.99} \text{ psi}$$

% Extreme fiber elongation - UCS-79(d)

$$EFE = \left(\frac{50 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{50 \cdot 1.375}{84.6875}\right) \cdot \left(1 - \frac{84.6875}{\infty}\right) = 0.8118\,\%$$

The extreme fiber elongation does not exceed 5%.

Allowable Compressive Stress, Hot and Corroded- S_{cHC}, (table CS-2)

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{85.375/1.375} = 0.002013$$

$$B = 10{,}328 \ \ \text{psi}$$

$$S = \frac{19{,}400}{1.00} = 19{,}400 \ \ \text{psi}$$

$S_{cHC} \ = \ \min\ (B,S) =$ 10,328 psi

Allowable Compressive Stress, Hot and New- S_{cHN}

$$S_cHN = S_cHC = 10{,}328 \ \ \text{psi}$$

Allowable Compressive Stress, Cold and New- S_{cCN}, (table CS-2)

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{85.375/1.375} = 0.002013$$

$$B = 15{,}019 \ \ \text{psi}$$

$$S = \frac{20{,}000}{1.00} = 20{,}000 \ \ \text{psi}$$

$S_{cCN} \ = \ \min\ (B,S) =$ 15,019 psi

Allowable Compressive Stress, Cold and Corroded- S_{cCC}

$$S_{cC} = S_{cCN} = 15{,}019 \ \ \text{psi}$$

Allowable Compressive Stress, Vacuum and Corroded- S_{cVC}, (table CS-2)

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{85.375/1.375} = 0.002013$$

$$B = 13{,}139 \ \ \text{psi}$$

$$S = \frac{20{,}000}{1.00} = 20{,}000 \ \ \text{psi}$$

$S_{cVC} \ = \ \min\ (B,S) =$ 13,139 psi

20" 300# RFWN VAPOUR OUTLET (N2)

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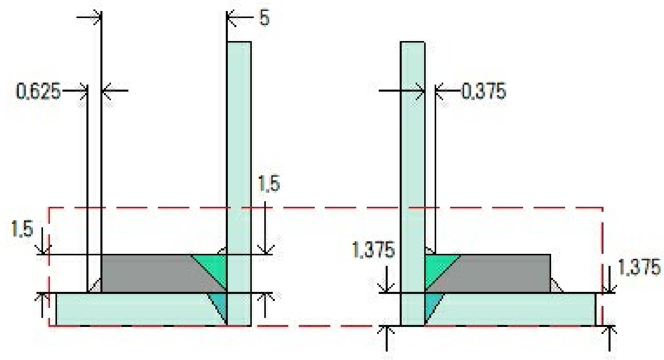


Note: round inside edges per UG-76(c)

Location and Orientation	
Located on	Cylinder #1
Orientation	0°
Nozzle center line offset to datum line	479"
End of nozzle to shell center	123"
Passes through a Category A joint	No
Nozzle	
Access opening	No
Material specification	SA-516 70 (II-D p. 14, ln. 20)
Inside diameter, new	18"
Nominal wall thickness	1"
Corrosion allowance	0"
Projection available outside vessel, Lpr	31.245"
Projection available outside vessel to flange face, Lf	37.625"
Local vessel minimum thickness	1.375"
Liquid static head included	0 psi
Reinforcing Pad	
Material specification	SA-516 70 (II-D p. 14, ln. 20) (normalized)
Diameter, D_p	30"
Thickness, t_e	1.5"
Is split	No
Welds	
Inner fillet, Leg_{41}	0.375"
Outer fillet, Leg_{42}	0.625"
Nozzle to vessel groove weld	1.375"
Pad groove weld	1.5"
Radiography	
Longitudinal seam	Full UW-11(a) Type 1
Circumferential seam	Full UW-11(a) Type 1

ASME B16.5-2003 Flange	
Description	NPS 20 Class 300 WN A350 LF2 Cl.1
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, ln. 33)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0 psi
Consider External Loads on Flange MAWP Rating	No
MAWP rating	570 psi @ 600°F
MAP rating	740 psi @ 70°F
Hydrotest rating	1,125 psi @ 70°F
PWHT performed	Yes
Impact Tested	No
Circumferential joint radiography	Full UW-11(a) Type 1
Bore diameter, B (specified by purchaser)	18"
Gasket	
Type	ASME B16.20 Kammprofile
Description	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel
Factor, m	2
Seating Stress, y	2,500 psi
Thickness, T	0.145"
Inner Diameter	20.87"
Outer Diameter	22.87"
Notes	
Flange is impact tested per material specification to -50°F. Stress ratio = 0.3456 ≤ 0.35, MDMT per UCS-66(b)(3) = -155°F. Bolts rated MDMT per Fig UCS-66 note (e) = -55°F	

UCS-66 Material Toughness Requirements Nozzle	
External nozzle loadings per UG-22 govern the coincident ratio used.	
Stress ratio $= \frac{t_r \cdot E^*}{t_n - c} = \frac{0.14 \cdot 1}{1 - 0} =$	0.14
Stress ratio ≤ 0.35, MDMT per UCS-66(b)(3) =	-155°F
Material is exempt from impact testing at the Design MDMT of -49°F.	

UCS-66 Material Toughness Requirements Pad	
Material impact test temperature per UG-84 =	-49°F
$t_r = \frac{255.74 \cdot 84}{20{,}000 \cdot 1 - 0.6 \cdot 255.74} =$	1.0824"
Stress ratio $= \frac{t_r \cdot E^*}{t_n - c} = \frac{1.0824 \cdot 1}{1.375 - 0} =$	0.7872
Stress ratio longitudinal $= \frac{8{,}057 \cdot 1}{20{,}000 \cdot 1} =$	0.4029
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	21.3°F
$MDMT = \max\left[T_{impact} - T_R, -155\right] = \max\left[-49 - 21.3, -155\right] =$	-70.3°F
Design MDMT of -49°F is acceptable.	

Reinforcement Calculations for MAWP

Available reinforcement per UG-37 governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 293.76 psi @ 600 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
23.1048	23.1061	1.6452	5.9297	–	15	0.5312	0.3281	1

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
419,862.56	416,341.46	685,271.68	171,113.82	1,408,635.16	469,691.46	900,109.49

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})	0.375	0.4375	weld size is adequate

WRC 107												
Load Case	P (psi)	P_r (lb_f)	M_c (lb_f-in)	V_c (lb_f)	M_L (lb_f-in)	V_L (lb_f)	M_t (lb_f-in)	Max Comb Stress (psi)	Allow Comb Stress (psi)	Max Local Primary Stress (psi)	Allow Local Primary Stress (psi)	Over stressed
Load case 1	293.76	-6,295	-313,068	0	313,068	0	0	**26,077**	**58,200**	**20,583**	**29,100**	No
Load case 1 (Hot Shut Down)	0	-6,295	-313,068	0	313,068	0	0	8,131	58,200	1,800	29,100	No

% Extreme fiber elongation - UCS-79(d)

$$EFE = \left(\frac{50 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{50 \cdot 1}{9.5}\right) \cdot \left(1 - \frac{9.5}{\infty}\right) = 5.2632\,\%$$

Reinforcement Calculations for MAP

Available reinforcement per UG-37 governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 302.84 psi @ 70 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
23.1048	23.1061	1.6452	5.9297	–	15	0.5312	0.3281	1

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
432,848	429,218	706,465.64	176,406	1,452,201.2	484,218	927,947.93

Reinforcement Calculations for MAEP

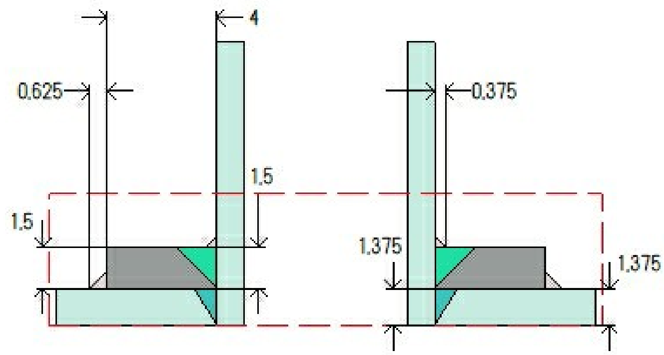
UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 42.99 psi @ 400 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
12.375	21.509	--	5.9778	--	15	0.5312	0.1808	1

UG-41 Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

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})	0.375	0.4375	weld size is adequate

16" 300# RFWN HYDROCARBON OUTLET (N3)

ASME Section VIII Division 1, 2004 Edition, A06 Addenda	



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

Location and Orientation	
Located on	Cylinder #1
Orientation	180°
Nozzle center line offset to datum line	482"
End of nozzle to shell center	103.375"
Passes through a Category A joint	No
Nozzle	
Description	NPS 16 Sch 100
Access opening	No
Material specification	SA-333 6 Wld & smls pipe (II-D p. 10, ln. 8)
Inside diameter, new	13.938"
Pipe nominal wall thickness	1.031"
Pipe minimum wall thickness[1]	0.9021"
Corrosion allowance	0"
Projection available outside vessel, Lpr	12.25"
Projection available outside vessel to flange face, Lf	18"
Local vessel minimum thickness	1.375"
Liquid static head included	0 psi
Reinforcing Pad	
Material specification	SA-516 70 (II-D p. 14, ln. 20) (normalized)
Diameter, D_p	24"
Thickness, t_e	1.5"
Is split	No
Welds	
Inner fillet, Leg_{41}	0.375"
Outer fillet, Leg_{42}	0.625"
Nozzle to vessel groove weld	1.375"
Pad groove weld	1.5"
Radiography	
Longitudinal seam	Welded pipe
Circumferential seam	Full UW-11(a) Type 1

[1]Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

ASME B16.5-2003 Flange	
Description	NPS 16 Class 300 WN A350 LF2 Cl.1
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, ln. 33)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0 psi
Consider External Loads on Flange MAWP Rating	No
MAWP rating	570 psi @ 600°F
MAP rating	740 psi @ 70°F
Hydrotest rating	1,125 psi @ 70°F
PWHT performed	Yes
Impact Tested	No
Circumferential joint radiography	Full UW-11(a) Type 1
Bore diameter, B (specified by purchaser)	13.938"
Gasket	
Type	ASME B16.20 Kammprofile
Description	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel
Factor, m	2
Seating Stress, y	2,500 psi
Thickness, T	0.145"
Inner Diameter	16.63"
Outer Diameter	18.37"
Notes	
Flange is impact tested per material specification to -50°F. Stress ratio = 0.3456 ≤ 0.35, MDMT per UCS-66(b)(3) = -155°F. Bolts rated MDMT per Fig UCS-66 note (e) = -55°F	

UCS-66 Material Toughness Requirements Nozzle	
Impact test temperature per material specification =	-50°F
External nozzle loadings per UG-22 govern the coincident ratio used.	
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.1374 \cdot 1}{0.9021 - 0} =$	0.1523
Stress ratio ≤ 0.35, MDMT per UCS-66(b)(3) =	-155°F
$MDMT = \min\left[T_{impact} - T_{UCS-66(g)}, -155\right] = \min\left[-50 - 5, -155\right] =$	-155°F
Material is exempt from impact testing at the Design MDMT of -49°F.	

UCS-66 Material Toughness Requirements Pad	
Material impact test temperature per UG-84 =	-49°F
$t_r = \frac{255.74 \cdot 84}{20{,}000 \cdot 1 - 0.6 \cdot 255.74} =$	1.0824"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{1.0824 \cdot 1}{1.375 - 0} =$	0.7872
$\text{Stress ratio longitudinal} = \frac{8{,}057 \cdot 1}{20{,}000 \cdot 1} =$	0.4029
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	21.3°F
$MDMT = \max\left[T_{impact} - T_R, -155\right] = \max\left[-49 - 21.3, -155\right] =$	-70.3°F
Design MDMT of -49°F is acceptable.	

Reinforcement Calculations for MAWP

Available reinforcement per UG-37 governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 303.24 psi @ 600 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
18.7981	18.7983	0.6786	5.6052	–	12	0.5145	0.3281	0.9021

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
353,266.16	351,522.18	514,158.51	159,624.93	1,116,286.4	400,002.57	720,087.59

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})	0.375	0.4375	weld size is adequate

WRC 107												
Load Case	P (psi)	P_r (lb_f)	M_c (lb_f-in)	V_c (lb_f)	M_L (lb_f-in)	V_L (lb_f)	M_t (lb_f-in)	Max Comb Stress (psi)	Allow Comb Stress (psi)	Max Local Primary Stress (psi)	Allow Local Primary Stress (psi)	Over stressed
Load case 1	303.24	-5,035	-198,360	0	198,360	0	0	**25,802**	**58,200**	**20,042**	**29,100**	No
Load case 1 (Hot Shut Down)	0	-5,035	-198,360	0	198,360	0	0	7,277	58,200	1,517	29,100	No

Reinforcement Calculations for MAP

Available reinforcement per UG-37 governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 310.43 psi @ 70 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
18.7367	18.7373	0.8039	5.4226	–	12	0.5108	0.3281	0.9021

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
360,734.9	358,668	521,085.72	159,338.78	1,148,368.35	407,150.78	742,358.34

Reinforcement Calculations for MAEP

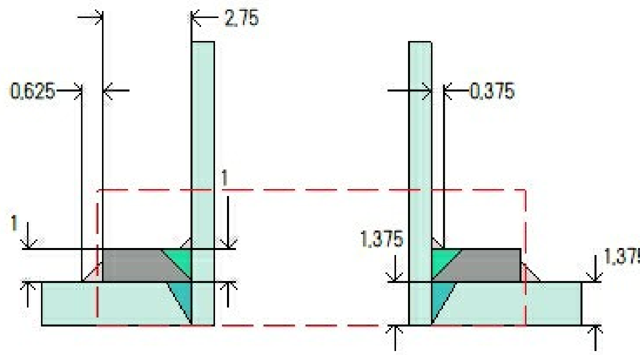
UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 42.99 psi @ 400 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
9.7879	18.0788	–	5.568	–	12	0.5108	0.1808	0.9021

UG-41 Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

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})	0.375	0.4375	weld size is adequate

8" 300# RFWN VENT (N4)

ASME Section VIII Division 1, 2004 Edition, A06 Addenda	



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

Location and Orientation	
Located on	Cylinder #1
Orientation	0°
Nozzle center line offset to datum line	430"
End of nozzle to shell center	123"
Passes through a Category A joint	No
Nozzle	
Description	NPS 8 Sch 120
Access opening	No
Material specification	SA-333 6 Wld & smls pipe (II-D p. 10, ln. 8)
Inside diameter, new	7.187"
Pipe nominal wall thickness	0.719"
Pipe minimum wall thickness[1]	0.6291"
Corrosion allowance	0"
Projection available outside vessel, Lpr	33.245"
Projection available outside vessel to flange face, Lf	37.625"
Local vessel minimum thickness	1.375"
Liquid static head included	0 psi
Reinforcing Pad	
Material specification	SA-516 70 (II-D p. 14, ln. 20) (normalized)
Diameter, D_p	14.125"
Thickness, t_e	1"
Is split	No
Welds	
Inner fillet, Leg_{41}	0.375"
Outer fillet, Leg_{42}	0.625"
Nozzle to vessel groove weld	1.375"
Pad groove weld	1"
Radiography	
Longitudinal seam	Welded pipe
Circumferential seam	Full UW-11(a) Type 1

[1]Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

ASME B16.5-2003 Flange	
Description	NPS 8 Class 300 WN A350 LF2 Cl.1
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, ln. 33)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0 psi
Consider External Loads on Flange MAWP Rating	No
MAWP rating	570 psi @ 600°F
MAP rating	740 psi @ 70°F
Hydrotest rating	1,125 psi @ 70°F
PWHT performed	Yes
Impact Tested	No
Circumferential joint radiography	Full UW-11(a) Type 1
Gasket	
Type	ASME B16.20 Kammprofile
Description	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel
Factor, m	2
Seating Stress, y	2,500 psi
Thickness, T	0.145"
Inner Diameter	9"
Outer Diameter	10.5"
Notes	
Flange is impact tested per material specification to -50°F. Stress ratio = 0.3456 ≤ 0.35, MDMT per UCS-66(b)(3) = -155°F. Bolts rated MDMT per Fig UCS-66 note (e) = -55°F	

UCS-66 Material Toughness Requirements Nozzle	
Impact test temperature per material specification =	-50°F
External nozzle loadings per UG-22 govern the coincident ratio used.	
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.1014 \cdot 1}{0.6291 - 0} =$	0.1611
Stress ratio ≤ 0.35, MDMT per UCS-66(b)(3) =	-155°F
$MDMT = \min\left[T_{impact} - T_{UCS-66(g)}, -155\right] = \min\left[-50 - 5, -155\right] =$	-155°F
Material is exempt from impact testing at the Design MDMT of -49°F.	

UCS-66 Material Toughness Requirements Pad	
Material impact test temperature per UG-84 =	-49°F
$t_r = \frac{255.74 \cdot 84}{20{,}000 \cdot 1 - 0.6 \cdot 255.74} =$	1.0824"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{1.0824 \cdot 1}{1.375 - 0} =$	0.7872
$\text{Stress ratio longitudinal} = \frac{8{,}057 \cdot 1}{20{,}000 \cdot 1} =$	0.4029
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	21.3°F
$MDMT = \max\left[T_{impact} - T_R, -155\right] = \max\left[-49 - 21.3, -155\right] =$	-70.3°F
Design MDMT of -49°F is acceptable.	

Reinforcement Calculations for MAWP

Available reinforcement per UG-37 governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 297.58 psi @ 600 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
9.5682	9.5684	0.523	3.2814	–	5.5	0.264	0.2818	0.6291

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
177,309.62	175,480.76	238,702.28	99,872.13	504,499.75	209,290.07	399,254.55

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})	0.375	0.4375	weld size is adequate

WRC 107												
Load Case	P (psi)	P_r (lb_f)	M_c (lb_f-in)	V_c (lb_f)	M_L (lb_f-in)	V_L (lb_f)	M_t (lb_f-in)	Max Comb Stress (psi)	Allow Comb Stress (psi)	Max Local Primary Stress (psi)	Allow Local Primary Stress (psi)	Over stressed
Load case 1	297.58	-2,520	-50,544	0	50,544	0	0	**22,149**	**58,200**	**19,205**	**29,100**	No
Load case 1 (Hot Shut Down)	0	-2,520	-50,544	0	50,544	0	0	3,970	58,200	656	29,100	No

Reinforcement Calculations for MAP

Available reinforcement per UG-37 governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 304.18 psi @ 70 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
9.5353	9.5355	0.5978	3.1774	–	5.5	0.2603	0.2818	0.6291

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
180,855.67	178,754	242,779.23	99,762.98	518,786.24	212,564.98	411,602.63

Reinforcement Calculations for MAEP

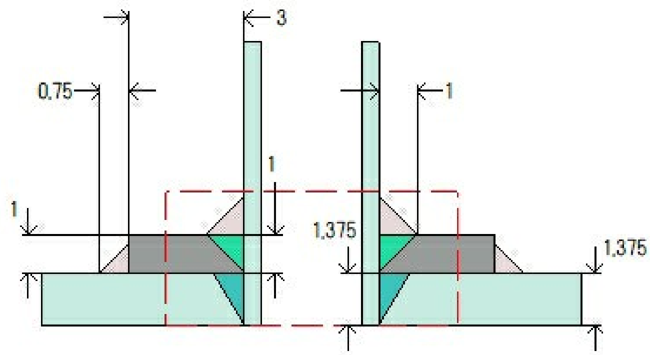
UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 42.99 psi @ 400 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
5.0844	8.817	–	3.0567	–	5.5	0.2603	0.1808	0.6291

UG-41 Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

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})	0.375	0.4375	weld size is adequate

3" 300# RFWN LG/LT (SIS) BRIDLE (J2A)

ASME Section VIII Division 1, 2004 Edition, A06 Addenda	



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

Location and Orientation	
Located on	Cylinder #1
Orientation	90°
Nozzle center line offset to datum line	466"
End of nozzle to shell center	57.2916"
Offset from center, Lo	75"
Passes through a Category A joint	No
Nozzle	
Description	NPS 3 Sch 160
Access opening	No
Material specification	SA-333 6 Wld & smls pipe (II-D p. 10, ln. 8)
Inside diameter, new	2.624"
Pipe nominal wall thickness	0.438"
Pipe minimum wall thickness[1]	0.3833"
Corrosion allowance	0"
Opening chord length	5.6967"
Projection available outside vessel, Lpr	10.3158"
Projection available outside vessel to flange face, Lf	13.4358"
Local vessel minimum thickness	1.375"
Liquid static head included	0 psi
Reinforcing Pad	
Material specification	SA-516 70 (II-D p. 14, ln. 20) (normalized)
Diameter, D_p	13.3486"
Thickness, t_e	1"
Is split	No
Welds	
Inner fillet, Leg_{41}	1"
Outer fillet, Leg_{42}	0.75"
Nozzle to vessel groove weld	1.375"
Pad groove weld	1"
Radiography	
Longitudinal seam	Welded pipe
Circumferential seam	Full UW-11(a) Type 1

[1]Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

ASME B16.5-2003 Flange	
Description	NPS 3 Class 300 WN A350 LF2 Cl.1
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, ln. 33)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0 psi
Consider External Loads on Flange MAWP Rating	No
MAWP rating	570 psi @ 600°F
MAP rating	740 psi @ 70°F
Hydrotest rating	1,125 psi @ 70°F
PWHT performed	Yes
Impact Tested	No
Circumferential joint radiography	Full UW-11(a) Type 1
Gasket	
Type	ASME B16.20 Kammprofile
Description	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel
Factor, m	2
Seating Stress, y	2,500 psi
Thickness, T	0.145"
Inner Diameter	3.87"
Outer Diameter	4.87"
Notes	
Flange is impact tested per material specification to -50°F. Stress ratio = 0.3456 ≤ 0.35, MDMT per UCS-66(b)(3) = -155°F. Bolts rated MDMT per Fig UCS-66 note (e) = -55°F	

UCS-66 Material Toughness Requirements Nozzle	
Impact test temperature per material specification =	-50°F
External nozzle loadings per UG-22 govern the coincident ratio used.	
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.058 \cdot 1}{0.3833 - 0} =$	0.1512
Stress ratio ≤ 0.35, MDMT per UCS-66(b)(3) =	-155°F
$MDMT = \min\left[T_{impact} - T_{UCS-66(g)}, -155\right] = \min\left[-50 - 5, -155\right] =$	-155°F
Material is exempt from impact testing at the Design MDMT of -49°F.	

UCS-66 Material Toughness Requirements Pad	
Material impact test temperature per UG-84 =	-49°F
$t_r = \frac{255.74 \cdot 84}{20{,}000 \cdot 1 - 0.6 \cdot 255.74} =$	1.0824"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{1.0824 \cdot 1}{1.375 - 0} =$	0.7872
$\text{Stress ratio longitudinal} = \frac{8{,}057 \cdot 1}{20{,}000 \cdot 1} =$	0.4029
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	21.3°F
$MDMT = \max\left[T_{impact} - T_R, -155\right] = \max\left[-49 - 21.3, -155\right] =$	-70.3°F
Design MDMT of -49°F is acceptable.	

Reinforcement Calculations for MAWP

Available reinforcement per UG-37 governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 284.6 psi @ 600 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
7.2115	7.2117	0.737	1.5485	–	4.0448	0.8814	0.189	0.3833

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
127,578.52	125,609.18	174,707.86	67,736	233,515.76	146,205.12	258,014.44

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.25	0.7	weld size is adequate
Pad to shell fillet (Leg_{42})	0.375	0.525	weld size is adequate

WRC 107												
Load Case	P (psi)	P_r (lb_f)	M_c (lb_f-in)	V_c (lb_f)	M_L (lb_f-in)	V_L (lb_f)	M_t (lb_f-in)	Max Comb Stress (psi)	Allow Comb Stress (psi)	Max Local Primary Stress (psi)	Allow Local Primary Stress (psi)	Over stressed
Load case 1	284.6	-945	-5,136	0	5,136	0	0	**18,421**	**58,200**	**17,523**	**29,100**	No
Load case 1 (Hot Shut Down)	0	-945	-5,136	0	5,136	0	0	1,035	58,200	137	29,100	No

Reinforcement Calculations for MAP

Available reinforcement per UG-37 governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 291.29 psi @ 70 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
7.1929	7.1932	0.7847	1.5003	–	4.0532	0.855	0.189	0.3833

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
130,273.54	128,170	179,331.29	67,702.95	239,313.18	148,766.95	265,994.27

Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 42.99 psi @ 400 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
3.9795	6.2672	--	1.438	--	3.9742	0.855	0.1808	0.3833

UG-41 Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.25	0.7	weld size is adequate
Pad to shell fillet (Leg_{42})	0.375	0.525	weld size is adequate

Cylinder #2

ASME Section VIII Division 1, 2004 Edition, A06 Addenda					
Component		Cylinder			
Material		SA-516 70 (II-D p. 14, ln. 20)			
Impact Tested	**Normalized**	**Fine Grain Practice**	**PWHT**	**Maximize MDMT/ No MAWP**	
Yes (-49°F)	Yes	Yes	Yes	No	
		Design Pressure (psi)	**Design Temperature (°F)**	**Design MDMT (°F)**	
Internal		250	600	-49	
External		15	400		
Static Liquid Head					
Condition		**P_s (psi)**	**H_s (in)**	**SG**	
Test horizontal		7.47	207	1	
Dimensions					
Inner Diameter		168"			
Length		120"			
Nominal Thickness		1.25"			
Corrosion	**Inner**	0"			
	Outer	0"			
Weight and Capacity					
		Weight (lb)		**Capacity (US gal)**	
New		21,433.27		11,515.37	
Corroded		21,433.27		11,515.37	
Insulation					
		Thickness (in)	**Density (lb/ft^3)**	**Weight (lb)**	
Insulation		4	18	2,741.05	
		Spacing(in)	**Individual Weight (lb)**	**Total Weight (lb)**	
Insulation Supports		145	50	50	
Radiography					
Longitudinal seam		Full UW-11(a) Type 1			
Left Circumferential seam		Full UW-11(a) Type 1			
Right Circumferential seam		Full UW-11(a) Type 1			

Results Summary	
Governing condition	Internal pressure
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	1.091"
Design thickness due to external pressure (t_e)	0.8932"
Maximum allowable working pressure (MAWP)	286.14 psi
Maximum allowable pressure (MAP)	294.99 psi
Maximum allowable external pressure (MAEP)	34.38 psi
Rated MDMT	-62.4 °F

UCS-66 Material Toughness Requirements	
Material impact test temperature per UG-84 =	-49°F
$t_r = \dfrac{255.74 \cdot 84}{20{,}000 \cdot 1 - 0.6 \cdot 255.74} =$	1.0824"
Stress ratio $= \dfrac{t_r \cdot E^*}{t_n - c} = \dfrac{1.0824 \cdot 1}{1.25 - 0} =$	0.8659
Stress ratio longitudinal $= \dfrac{8{,}057 \cdot 1}{20{,}000 \cdot 1} =$	0.4029
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	13.4°F
$MDMT = \max\left[T_{impact} - T_R, -155\right] = \max\left[-49 - 13.4, -155\right] =$	-62.4°F
Design MDMT of -49°F is acceptable.	

Design thickness, (at 600 °F) UG-27(c)(1)

$$t = \frac{P \cdot R}{S \cdot E - 0.60 \cdot P} + \text{Corrosion} = \frac{250 \cdot 84}{19{,}400 \cdot 1.00 - 0.60 \cdot 250} + 0 = 1.091"$$

Maximum allowable working pressure, (at 600 °F) UG-27(c)(1)

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} - P_s = \frac{19{,}400 \cdot 1.00 \cdot 1.25}{84 + 0.60 \cdot 1.25} - 0 = 286.14 \text{ psi}$$

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

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} = \frac{20{,}000 \cdot 1.00 \cdot 1.25}{84 + 0.60 \cdot 1.25} = 294.99 \text{ psi}$$

External Pressure, (Corroded & at 400 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{532}{170.5} = 3.1202$$

$$\frac{D_o}{t} = \frac{170.5}{0.8932} = 190.8780$$

From table G: $A = 0.000156$

From table CS-2: $B = 2{,}147.3783 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 2{,}147.38}{3 \cdot (170.5/0.8932)} = 15 \text{ psi}$$

Design thickness for external pressure P_a = 15 psi

$$t_a = t + \text{Corrosion} = 0.8932 + 0 = 0.8932"$$

Maximum Allowable External Pressure, (Corroded & at 400 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{532}{170.5} = 3.1202$$

$$\frac{D_o}{t} = \frac{170.5}{1.25} = 136.4000$$

From table G: $A = 0.000255$

From table CS-2: $B = 3{,}516.96$ psi

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 3,516.96}{3 \cdot (170.5/1.25)} = \underline{34.38} \text{ psi}$$

% Extreme fiber elongation - UCS-79(d)

$$EFE = \left(\frac{50 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{50 \cdot 1.25}{84.625}\right) \cdot \left(1 - \frac{84.625}{\infty}\right) = 0.7386\,\%$$

The extreme fiber elongation does not exceed 5%.

Allowable Compressive Stress, Hot and Corroded- S_{cHC}, (table CS-2)

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{85.25/1.25} = 0.001833$$

$$B = 10{,}131 \text{ psi}$$

$$S = \frac{19{,}400}{1.00} = 19{,}400 \text{ psi}$$

$S_{cHC} = \min(B, S) =$ 10,131 psi

Allowable Compressive Stress, Hot and New- S_{cHN}

$$S_c HN = S_c HC = 10{,}131 \text{ psi}$$

Allowable Compressive Stress, Cold and New- S_{cCN}, (table CS-2)

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{85.25/1.25} = 0.001833$$

$$B = 14{,}630 \text{ psi}$$

$$S = \frac{20{,}000}{1.00} = 20{,}000 \text{ psi}$$

$S_{cCN} = \min(B, S) =$ 14,630 psi

Allowable Compressive Stress, Cold and Corroded- S_{cCC}

$$S_{cC} = S_{cCN} = 14{,}630 \text{ psi}$$

Allowable Compressive Stress, Vacuum and Corroded- S_{cVC}, (table CS-2)

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{85.25/1.25} = 0.001833$$

$$B = 12{,}847 \text{ psi}$$

$$S = \frac{20{,}000}{1.00} = 20{,}000 \text{ psi}$$

$S_{cVC} = \min(B, S) =$ 12,847 psi

60" BOOT (BOOT)

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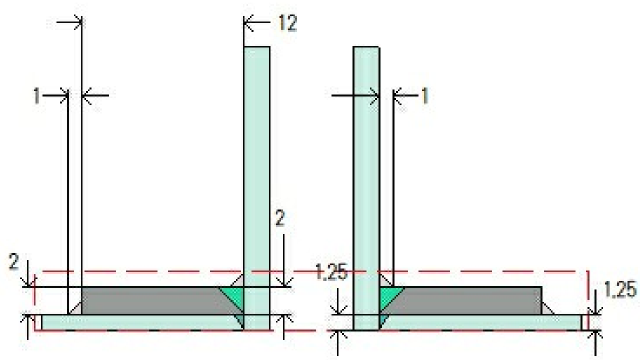

Note: round inside edges per UG-76(c)

Location and Orientation	
Located on	Cylinder #2
Orientation	180°
Nozzle center line offset to datum line	358"
End of nozzle to shell center	166"
Passes through a Category A joint	No
Nozzle	
Access opening	No
Material specification	SA-516 70 (II-D p. 14, ln. 20) (normalized)
Inside diameter, new	60"
Nominal wall thickness	2"
Corrosion allowance	0"
Projection available outside vessel, Lpr	80.75"
Local vessel minimum thickness	1.25"
User input radial limit of reinforcement	56"
Liquid static head included	0 psi
Reinforcing Pad	
Material specification	SA-516 70 (II-D p. 14, ln. 20) (normalized)
Diameter, D_p	88"
Thickness, t_e	2"
Is split	No
Welds	
Inner fillet, Leg_{41}	1"
Outer fillet, Leg_{42}	1"
Nozzle to vessel groove weld	1.25"
Pad groove weld	2"
Radiography	
Longitudinal seam	Full UW-11(a) Type 1
Circumferential seam	Full UW-11(a) Type 1

UCS-66 Material Toughness Requirements Nozzle At Intersection	
Material impact test temperature per UG-84 =	-49°F
$t_r = \frac{255.74 \cdot 84}{20{,}000 \cdot 1 - 0.6 \cdot 255.74} =$	1.0824"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{1.0824 \cdot 1}{1.25 - 0} =$	0.8659
$\text{Stress ratio longitudinal} = \frac{8{,}057 \cdot 1}{20{,}000 \cdot 1} =$	0.4029
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	13.4°F
$MDMT = \max\left[T_{impact} - T_R, -155\right] = \max\left[-49 - 13.4, -155\right] =$	-62.4°F
Design MDMT of -49°F is acceptable.	

UCS-66 Material Toughness Requirements Nozzle	
Material impact test temperature per UG-84 =	-49°F
$t_r = \frac{255.74 \cdot 30}{20{,}000 \cdot 1 - 0.6 \cdot 255.74} =$	0.3866"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.3866 \cdot 1}{2 - 0} =$	0.1933
Stress ratio ≤ 0.35, MDMT per UCS-66(b)(3) =	-155°F
$MDMT = \min\left[-49, -155\right] =$	-155°F
Design MDMT of -49°F is acceptable.	

UCS-66 Material Toughness Requirements Pad	
Material impact test temperature per UG-84 =	-49°F
$t_r = \frac{255.74 \cdot 84}{20{,}000 \cdot 1 - 0.6 \cdot 255.74} =$	1.0824"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{1.0824 \cdot 1}{1.25 - 0} =$	0.8659
$\text{Stress ratio longitudinal} = \frac{8{,}057 \cdot 1}{20{,}000 \cdot 1} =$	0.4029
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	13.4°F
$MDMT = \max\left[T_{impact} - T_R, -155\right] = \max\left[-49 - 13.4, -155\right] =$	-62.4°F
Design MDMT of -49°F is acceptable.	

Reinforcement Calculations for MAWP

Available reinforcement per UG-37 governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 255.74 psi @ 600 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
66.9684	66.9694	6.9607	10.0087	–	48	2	0.3986	2

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
1,174,536.92	1,164,168.78	3,959,110.44	310,568.78	5,646,120.56	1,261,168.78	3,118,043.26

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.25	0.7	weld size is adequate
Pad to shell fillet (Leg_{42})	0.375	0.7	weld size is adequate

Check Large Opening per Appendix 1-7(a)

Area required within 75 percent of the limits of reinforcement
= 2 / 3*A = (2 / 3)*66.9684 = 44.6456 in^2

$$L_R = \max\left[d,\ \ R_n + (t_n - C_n) + (t - C)\right]$$
$$= \max\left[60,\ \ 30 + (2 - 0) + (1.25 - 0)\right]$$
$$= 45 \ \ \text{in}$$

$$A_1 = (2 \cdot L_R - d) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$$
$$= (2 \cdot 45 - 60) \cdot (1 \cdot 1.25 - 1 \cdot 1.1161) - 2 \cdot 2 \cdot (1 \cdot 1.25 - 1 \cdot 1.1161) \cdot (1 - 1)$$
$$= 4.0158 \ \ \text{in}^2$$

$$A_5 = (D_p - d - 2 \cdot t_n) \cdot t_e \cdot f_{r4}$$
$$= (88 - 60 - 2 \cdot 2) \cdot 2 \cdot 1$$
$$= 48 \ \ \text{in}^2$$

$$\text{Area} = A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$$
$$= 4.0158 + 10.0087 + 0 + 1 + 1 + 0 + 48$$
$$= 64.0245 \ \text{in}^2$$

The area replacement requirements of Appendix 1-7(a) are satisfied.

Check Large Opening per Appendix 1-7(b)

1-7(b)(1)(a)	$D_i = 168 \ \ \text{in} > 60 \ \ \text{in}$	True
1-7(b)(1)(b)	$d = 60 \ \ \text{in} > 40 \ \ \text{in}$	True
1-7(b)(1)(b)	$d = 60 \ \ \text{in} > 3.4 \cdot \sqrt{84 \cdot 1.25} = 34.8396 \ \ \text{in}$	True
1-7(b)(1)(c)	$\frac{R_n}{R} = \frac{30}{84} = 0.3571 \le 0.7$	True
1-7(b)(1)	Radial nozzle in cylinder or cone	True
1-7(b)(1)	Internal projection not present	True

$$S_m = P \cdot \left(\frac{R \cdot \left(R_n + t_n + \sqrt{R_m \cdot t}\right) + R_n \cdot \left(t + t_e + \sqrt{R_{nm} \cdot t_n}\right)}{A_s} \right)$$

$$= 255.7371 \cdot \left(\frac{84 \cdot \left(30 + 2 + \sqrt{84.625 \cdot 1.25}\right) + 30 \cdot \left(1.25 + 2 + \sqrt{31 \cdot 2}\right)}{55.67427} \right)$$

$$= 17{,}849 \quad \text{psi}$$

Note that area A_s includes consideration of UG-41.

$$M = \left(\frac{R_n^3}{6} + R \cdot R_n \cdot e \right) \cdot P$$

$$= \left(\frac{30^3}{6} + 84 \cdot 30 \cdot 10.355649 \right) \cdot 255.7371$$

$$= 7{,}824{,}591.2 \quad \text{lb}_f\text{-in}$$

$$S_b = \frac{M \cdot a}{I}$$

$$= \frac{7{,}824{,}591.2 \cdot 10.980649}{14{,}934.06983}$$

$$= 5{,}753 \quad \text{psi}$$

Allowable bending stress need not include a strength reduction factor per UG-41.

$S_m + S_b = 23{,}602 \le 1.5 \cdot 19{,}400 = 29{,}100$; satisfactory.

$S_m = 17{,}849 \le 19{,}400$; satisfactory.

R_n / R = 0.3571 does not exceed 0.7 so a U-2(g) analysis is not required per 1-7(b)(1)(c).

% Extreme fiber elongation - UCS-79(d)

$$EFE = \left(\frac{50 \cdot t}{R_f} \right) \cdot \left(1 - \frac{R_f}{R_o} \right) = \left(\frac{50 \cdot 2}{31} \right) \cdot \left(1 - \frac{31}{\infty} \right) = 3.2258\,\%$$

The extreme fiber elongation does not exceed 5%.

Reinforcement Calculations for MAP

Available reinforcement per UG-37 governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 263.64 psi @ 70 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
66.9672	66.9705	6.9618	10.0087	–	48	2	0.3986	2

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
1,210,818.4	1,200,174	4,081,557.16	320,174	5,820,742.84	1,300,174	3,214,477.59

Check Large Opening per Appendix 1-7(a)

Area required within 75 percent of the limits of reinforcement
= 2 / 3*A = (2 / 3)*66.9672 = 44.6448 in^2

L_R = $\max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$

= $\max\left[60,\ 30 + (2 - 0) + (1.25 - 0)\right]$

= $45\ \text{in}$

A_1 = $(2 \cdot L_R - d) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$

= $(2 \cdot 45 - 60) \cdot (1 \cdot 1.25 - 1 \cdot 1.1161) - 2 \cdot 2 \cdot (1 \cdot 1.25 - 1 \cdot 1.1161) \cdot (1 - 1)$

= $4.0164\ \text{in}^2$

A_5 = $(D_p - d - 2 \cdot t_n) \cdot t_e \cdot f_{r4}$

= $(88 - 60 - 2 \cdot 2) \cdot 2 \cdot 1$

= $48\ \text{in}^2$

Area = $A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$

= $4.0164 + 10.0087 + 0 + 1 + 1 + 0 + 48$

= 64.0251 in^2

The area replacement requirements of Appendix 1-7(a) are satisfied.

Check Large Opening per Appendix 1-7(b)

1-7(b)(1)(a)	$D_i = 168\ \text{in} > 60\ \text{in}$	True
1-7(b)(1)(b)	$d = 60\ \text{in} > 40\ \text{in}$	True
1-7(b)(1)(b)	$d = 60\ \text{in} > 3.4 \cdot \sqrt{84 \cdot 1.25} = 34.8396\ \text{in}$	True
1-7(b)(1)(c)	$\frac{R_n}{R} = \frac{30}{84} = 0.3571 \le 0.7$	True
1-7(b)(1)	Radial nozzle in cylinder or cone	True
1-7(b)(1)	Internal projection not present	True

$$S_m = P \cdot \left(\frac{R \cdot \left(R_n + t_n + \sqrt{R_m \cdot t}\right) + R_n \cdot \left(t + t_e + \sqrt{R_{nm} \cdot t_n}\right)}{A_s}\right)$$

$$= 263.6406 \cdot \left(\frac{84 \cdot \left(30 + 2 + \sqrt{84.625 \cdot 1.25}\right) + 30 \cdot \left(1.25 + 2 + \sqrt{31 \cdot 2}\right)}{55.67427}\right)$$

$$= 18{,}400\ \text{psi}$$

Note that area A_s includes consideration of UG-41.

M = $\left(\frac{R_n^3}{6} + R \cdot R_n \cdot e\right) \cdot P$

= $\left(\frac{30^3}{6} + 84 \cdot 30 \cdot 10.355649\right) \cdot 263.6406$

= $8{,}066{,}410.9\ \text{lb}_f\text{-in}$

$$S_b = \frac{M \cdot a}{I}$$

$$= \frac{8{,}066{,}410.9 \cdot 10.980649}{14{,}934.06983}$$

$$= 5{,}931 \ \ \text{psi}$$

Allowable bending stress need not include a strength reduction factor per UG-41.

$S_m + S_b = 24{,}331 \leq 1.5 \cdot 20{,}000 = 30{,}000$; satisfactory.

$S_m = 18{,}400 \leq 20{,}000$; satisfactory.

R_n / R = 0.3571 does not exceed 0.7 so a U-2(g) analysis is not required per 1-7(b)(1)(c).

Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 34.38 psi @ 400 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
37.5	60.3795	--	10.3795	--	48	2	0.3393	2

UG-41 Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.25	0.7	weld size is adequate
Pad to shell fillet (Leg_{42})	0.375	0.7	weld size is adequate

Check Large Opening per Appendix 1-7(a)

Area required within 75 percent of the limits of reinforcement
= 2 / 3*A = (2 / 3)*37.5 = 25 in^2

$$L_R = \max\left[d,\ \ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[60,\ \ 30 + (2 - 0) + (1.25 - 0)\right]$$

$$= 45 \ \ \text{in}$$

$$A_1 = (2 \cdot L_R - d) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$$

$$= (2 \cdot 45 - 60) \cdot (1 \cdot 1.25 - 1 \cdot 1.25) - 2 \cdot 2 \cdot (1 \cdot 1.25 - 1 \cdot 1.25) \cdot (1 - 1)$$

$$= 0 \ \ \text{in}^2$$

$$A_5 = (D_p - d - 2 \cdot t_n) \cdot t_e \cdot f_{r4}$$

$$= (88 - 60 - 2 \cdot 2) \cdot 2 \cdot 1$$

$$= 48 \ \ \text{in}^2$$

Area	=	$A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$
	=	$0 + 10.3795 + 0 + 1 + 1 + 0 + 48$
	=	60.3795 in^2

The area replacement requirements of Appendix 1-7(a) are satisfied.

2" 300# RFLWN LEVEL TRANS (J3A)

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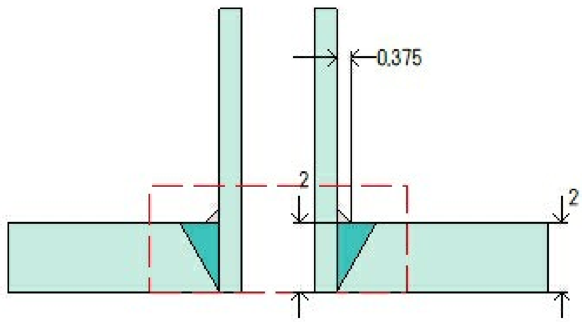


Note: round inside edges per UG-76(c)

Location and Orientation	
Located on	60" BOOT (BOOT)
Orientation	180°
Nozzle center line offset to face of parent nozzle	5"
End of nozzle to shell center	44"
Passes through a Category A joint	No
Nozzle	
Access opening	No
Material specification	SA-350 LF2 Cl 1 (II-D p. 14, ln. 11)
Inside diameter, new	2"
Nominal wall thickness	0.655"
Corrosion allowance	0.25"
Projection available outside vessel, Lpr	11.12"
Projection available outside vessel to flange face, Lf	12"
Local vessel minimum thickness	2"
Liquid static head included	0 psi
Welds	
Inner fillet, Leg_{41}	0.375"
Nozzle to vessel groove weld	2"
Radiography	
Longitudinal seam	Seamless No RT

ASME B16.5-2003 Flange	
Description	NPS 2 Class 300 LWN A350 LF2 Cl.1
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, ln. 33)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0 psi
Consider External Loads on Flange MAWP Rating	No
MAWP rating	570 psi @ 600°F
MAP rating	740 psi @ 70°F
Hydrotest rating	1,125 psi @ 70°F
PWHT performed	Yes
Impact Tested	No
Gasket	
Type	ASME B16.20 Kammprofile
Description	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel
Factor, m	2
Seating Stress, y	2,500 psi
Thickness, T	0.145"
Inner Diameter	2.75"
Outer Diameter	3.5"
Notes	
Flange is impact tested per material specification to -50°F. Stress ratio = 0.3456 ≤ 0.35, MDMT per UCS-66(b)(3) = -155°F. Bolts rated MDMT per Fig UCS-66 note (e) = -55°F	

UCS-66 Material Toughness Requirements	
LWN rated MDMT per UCS-66(c)(4) =	-55°F
Material is exempt from impact testing at the Design MDMT of -49°F.	

Reinforcement Calculations for MAWP

The attached ASME B16.5 flange limits the nozzle MAWP.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 570 psi @ 600 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
2.2806	6.0936	5.2582	0.702	–	–	0.1334	0.439	0.655

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})	0.25	0.2625	weld size is adequate

WRC 107												
Load Case	**P (psi)**	**P_r (lb_f)**	**M_c (lb_f-in)**	**V_c (lb_f)**	**M_L (lb_f-in)**	**V_L (lb_f)**	**M_t (lb_f-in)**	**Max Comb Stress (psi)**	**Allow Comb Stress (psi)**	**Max Local Primary Stress (psi)**	**Allow Local Primary Stress (psi)**	**Over stressed**
Load case 1	569.99	-710	-2,208	0	2,208	0	0	**10,131**	**58,200**	**9,761**	**29,100**	No
Load case 1 (Hot Shut Down)	0	-710	-2,208	0	2,208	0	0	545	58,200	46	29,100	No

Reinforcement Calculations for MAP

The attached ASME B16.5 flange limits the nozzle MAP.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 740 psi @ 70 °F							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	0.655

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

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

Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 34.38 psi @ 400 °F							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)							0.3125	0.655

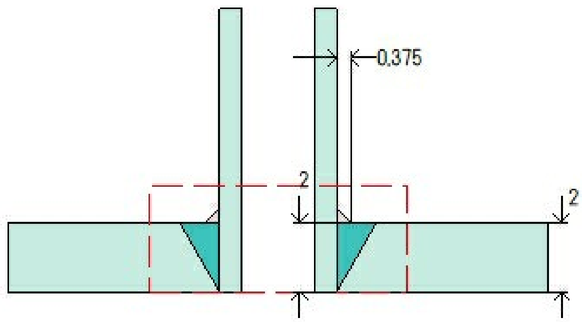
UG-41 Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.25	0.2625	weld size is adequate

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

2" 300# RFLWN LEVEL TRANS (J3B)

ASME Section VIII Division 1, 2004 Edition, A06 Addenda	



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

Location and Orientation	
Located on	60" BOOT (BOOT)
Orientation	180°
Nozzle center line offset to face of parent nozzle	71"
End of nozzle to shell center	44"
Passes through a Category A joint	No
Nozzle	
Access opening	No
Material specification	SA-350 LF2 Cl 1 (II-D p. 14, ln. 11)
Inside diameter, new	2"
Nominal wall thickness	0.655"
Corrosion allowance	0.25"
Projection available outside vessel, Lpr	11.12"
Projection available outside vessel to flange face, Lf	12"
Local vessel minimum thickness	2"
Liquid static head included	0 psi
Welds	
Inner fillet, Leg_{41}	0.375"
Nozzle to vessel groove weld	2"
Radiography	
Longitudinal seam	Seamless No RT

ASME B16.5-2003 Flange	
Description	NPS 2 Class 300 LWN A350 LF2 Cl.1
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, ln. 33)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0 psi
Consider External Loads on Flange MAWP Rating	No
MAWP rating	570 psi @ 600°F
MAP rating	740 psi @ 70°F
Hydrotest rating	1,125 psi @ 70°F
PWHT performed	Yes
Impact Tested	No
Notes	
Flange is impact tested per material specification to -50°F. Stress ratio = 0.3456 ≤ 0.35, MDMT per UCS-66(b)(3) = -155°F. Bolts rated MDMT per Fig UCS-66 note (e) = -55°F	

UCS-66 Material Toughness Requirements	
LWN rated MDMT per UCS-66(c)(4) =	-55°F
Material is exempt from impact testing at the Design MDMT of -49°F.	

Reinforcement Calculations for MAWP

The attached ASME B16.5 flange limits the nozzle MAWP.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 570 psi @ 600 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
2.2806	6.0936	5.2582	0.702	–	–	0.1334	0.439	0.655

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})	0.25	0.2625	weld size is adequate

WRC 107												
Load Case	P (psi)	P_r (lb_f)	M_c (lb_f-in)	V_c (lb_f)	M_L (lb_f-in)	V_L (lb_f)	M_t (lb_f-in)	Max Comb Stress (psi)	Allow Comb Stress (psi)	Max Local Primary Stress (psi)	Allow Local Primary Stress (psi)	Over stressed
Load case 1	569.99	-710	-2,208	0	2,208	0	0	**10,131**	**58,200**	**9,761**	**29,100**	No
Load case 1 (Hot Shut Down)	0	-710	-2,208	0	2,208	0	0	545	58,200	46	29,100	No

Reinforcement Calculations for MAP

The attached ASME B16.5 flange limits the nozzle MAP.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 740 psi @ 70 °F							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	0.655

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

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

Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 34.38 psi @ 400 °F							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)							0.3125	0.655

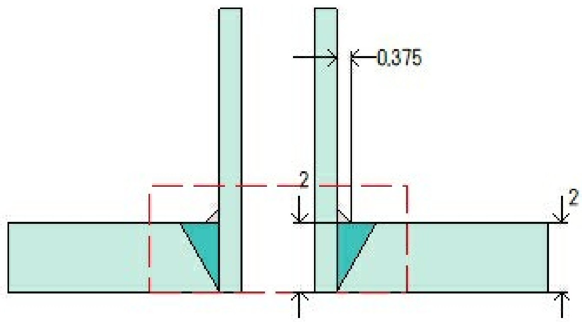
UG-41 Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.25	0.2625	weld size is adequate

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

2" 300# RFLWN LEVEL TRANS (J4A)

ASME Section VIII Division 1, 2004 Edition, A06 Addenda



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

Location and Orientation	
Located on	60" BOOT (BOOT)
Orientation	90°
Nozzle center line offset to face of parent nozzle	5"
End of nozzle to shell center	44"
Passes through a Category A joint	No

Nozzle	
Access opening	No
Material specification	SA-350 LF2 Cl 1 (II-D p. 14, ln. 11)
Inside diameter, new	2"
Nominal wall thickness	0.655"
Corrosion allowance	0.25"
Projection available outside vessel, Lpr	11.12"
Projection available outside vessel to flange face, Lf	12"
Local vessel minimum thickness	2"
Liquid static head included	0 psi

Welds	
Inner fillet, Leg_{41}	0.375"
Nozzle to vessel groove weld	2"

Radiography	
Longitudinal seam	Seamless No RT

ASME B16.5-2003 Flange	
Description	NPS 2 Class 300 LWN A350 LF2 Cl.1
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, ln. 33)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0 psi
Consider External Loads on Flange MAWP Rating	No
MAWP rating	570 psi @ 600°F
MAP rating	740 psi @ 70°F
Hydrotest rating	1,125 psi @ 70°F
PWHT performed	Yes
Impact Tested	No
Gasket	
Type	ASME B16.20 Kammprofile
Description	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel
Factor, m	2
Seating Stress, y	2,500 psi
Thickness, T	0.145"
Inner Diameter	2.75"
Outer Diameter	3.5"
Notes	
Flange is impact tested per material specification to -50°F. Stress ratio = 0.3456 ≤ 0.35, MDMT per UCS-66(b)(3) = -155°F. Bolts rated MDMT per Fig UCS-66 note (e) = -55°F	

UCS-66 Material Toughness Requirements	
LWN rated MDMT per UCS-66(c)(4) =	-55°F
Material is exempt from impact testing at the Design MDMT of -49°F.	

Reinforcement Calculations for MAWP

The attached ASME B16.5 flange limits the nozzle MAWP.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 570 psi @ 600 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
2.2806	6.0936	5.2582	0.702	–	–	0.1334	0.439	0.655

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})	0.25	0.2625	weld size is adequate

WRC 107												
Load Case	**P (psi)**	**P_r (lb_f)**	**M_c (lb_f-in)**	**V_c (lb_f)**	**M_L (lb_f-in)**	**V_L (lb_f)**	**M_t (lb_f-in)**	**Max Comb Stress (psi)**	**Allow Comb Stress (psi)**	**Max Local Primary Stress (psi)**	**Allow Local Primary Stress (psi)**	**Over stressed**
Load case 1	569.99	-710	-2,208	0	2,208	0	0	**10,131**	**58,200**	**9,761**	**29,100**	No
Load case 1 (Hot Shut Down)	0	-710	-2,208	0	2,208	0	0	545	58,200	46	29,100	No

Reinforcement Calculations for MAP

The attached ASME B16.5 flange limits the nozzle MAP.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 740 psi @ 70 °F							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	0.655

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

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

Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 34.38 psi @ 400 °F							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)							0.3125	0.655

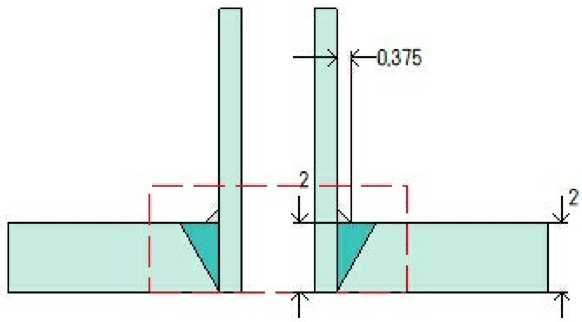
UG-41 Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.25	0.2625	weld size is adequate

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

2" 300# RFLWN LEVEL TRANS (J4B)

ASME Section VIII Division 1, 2004 Edition, A06 Addenda	



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

Location and Orientation	
Located on	60" BOOT (BOOT)
Orientation	90°
Nozzle center line offset to face of parent nozzle	71"
End of nozzle to shell center	44"
Passes through a Category A joint	No
Nozzle	
Access opening	No
Material specification	SA-350 LF2 Cl 1 (II-D p. 14, ln. 11)
Inside diameter, new	2"
Nominal wall thickness	0.655"
Corrosion allowance	0.25"
Projection available outside vessel, Lpr	11.12"
Projection available outside vessel to flange face, Lf	12"
Local vessel minimum thickness	2"
Liquid static head included	0 psi
Welds	
Inner fillet, Leg_{41}	0.375"
Nozzle to vessel groove weld	2"
Radiography	
Longitudinal seam	Seamless No RT

ASME B16.5-2003 Flange	
Description	NPS 2 Class 300 LWN A350 LF2 Cl.1
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, ln. 33)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0 psi
Consider External Loads on Flange MAWP Rating	No
MAWP rating	570 psi @ 600°F
MAP rating	740 psi @ 70°F
Hydrotest rating	1,125 psi @ 70°F
PWHT performed	Yes
Impact Tested	No
Gasket	
Type	ASME B16.20 Kammprofile
Description	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel
Factor, m	2
Seating Stress, y	2,500 psi
Thickness, T	0.145"
Inner Diameter	2.75"
Outer Diameter	3.5"
Notes	
Flange is impact tested per material specification to -50°F. Stress ratio = 0.3456 ≤ 0.35, MDMT per UCS-66(b)(3) = -155°F. Bolts rated MDMT per Fig UCS-66 note (e) = -55°F	

UCS-66 Material Toughness Requirements	
LWN rated MDMT per UCS-66(c)(4) =	-55°F
Material is exempt from impact testing at the Design MDMT of -49°F.	

Reinforcement Calculations for MAWP

The attached ASME B16.5 flange limits the nozzle MAWP.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 570 psi @ 600 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
2.2806	6.0936	5.2582	0.702	–	–	0.1334	0.439	0.655

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})	0.25	0.2625	weld size is adequate

WRC 107												
Load Case	P (psi)	P_r (lb_f)	M_c (lb_f-in)	V_c (lb_f)	M_L (lb_f-in)	V_L (lb_f)	M_t (lb_f-in)	Max Comb Stress (psi)	Allow Comb Stress (psi)	Max Local Primary Stress (psi)	Allow Local Primary Stress (psi)	Over stressed
Load case 1	569.99	-710	-2,208	0	2,208	0	0	**10,131**	**58,200**	**9,761**	**29,100**	No
Load case 1 (Hot Shut Down)	0	-710	-2,208	0	2,208	0	0	545	58,200	46	29,100	No

Reinforcement Calculations for MAP

The attached ASME B16.5 flange limits the nozzle MAP.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 740 psi @ 70 °F							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	0.655

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

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

Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 34.38 psi @ 400 °F							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)							0.3125	0.655

UG-41 Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.25	0.2625	weld size is adequate

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

Straight Flange on Ellipsoidal Head #3

ASME Section VIII Division 1, 2004 Edition, A06 Addenda				
Component		Cylinder		
Material		SA-516 70 (II-D p. 14, ln. 20)		
Attached To		60" BOOT (BOOT)		
Impact Tested	**Normalized**	**Fine Grain Practice**	**PWHT**	**Maximize MDMT/ No MAWP**
Yes (-49°F)	Yes	Yes	Yes	No
		Design Pressure (psi)	**Design Temperature (°F)**	**Design MDMT (°F)**
Internal		250	600	-49
External		15	400	
Static Liquid Head				
Condition		**P_s (psi)**	**H_s (in)**	**SG**
Test horizontal		10.5	291	1
Dimensions				
Inner Diameter		60"		
Length		2"		
Nominal Thickness		2"		
Corrosion	**Inner**	0"		
	Outer	0"		
Weight and Capacity				
		Weight (lb)		**Capacity (US gal)**
New		220.49		24.48
Corroded		220.49		24.48
Radiography				
Longitudinal seam		Seamless No RT		
Left Circumferential seam		Full UW-11(a) Type 1		

Results Summary	
Governing condition	Internal pressure
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	0.3897"
Design thickness due to external pressure (t_e)	0.2382"
Maximum allowable working pressure (MAWP)	1,243.59 psi
Maximum allowable pressure (MAP)	1,282.05 psi
Maximum allowable external pressure (MAEP)	634.76 psi
Rated MDMT	-155 °F

UCS-66 Material Toughness Requirements	
Material impact test temperature per UG-84 =	-49°F
$t_r = \dfrac{255.74 \cdot 30}{20{,}000 \cdot 1 - 0.6 \cdot 255.74} =$	0.3866"
$\text{Stress ratio} = \dfrac{t_r \cdot E^*}{t_n - c} = \dfrac{0.3866 \cdot 1}{2 - 0} =$	0.1933
Stress ratio ≤ 0.35, MDMT per UCS-66(b)(3) =	-155°F
$MDMT = \min\left[-49, -155\right] =$	-155°F
Design MDMT of -49°F is acceptable.	

Design thickness, (at 600 °F) UG-27(c)(1)

$$t = \frac{P \cdot R}{S \cdot E - 0.60 \cdot P} + \text{Corrosion} = \frac{250 \cdot 30}{19{,}400 \cdot 1.00 - 0.60 \cdot 250} + 0 = \underline{0.3897}"$$

Maximum allowable working pressure, (at 600 °F) UG-27(c)(1)

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} - P_s = \frac{19{,}400 \cdot 1.00 \cdot 2}{30 + 0.60 \cdot 2} - 0 = \underline{1{,}243.59} \text{ psi}$$

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

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} = \frac{20{,}000 \cdot 1.00 \cdot 2}{30 + 0.60 \cdot 2} = \underline{1{,}282.05} \text{ psi}$$

External Pressure, (Corroded & at 400 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{87.75}{64} = 1.3711$$

$$\frac{D_o}{t} = \frac{64}{0.2382} = 268.6608$$

From table G: $A = 0.000220$

From table CS-2: $B = 3{,}022.4368 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 3{,}022.44}{3 \cdot (64/0.2382)} = 15 \text{ psi}$$

Design thickness for external pressure P_a = 15 psi

$$t_a = t + \text{Corrosion} = 0.2382 + 0 = \underline{0.2382}"$$

Maximum Allowable External Pressure, (Corroded & at 400 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{87.75}{64} = 1.3711$$

$$\frac{D_o}{t} = \frac{64}{2} = 32.0000$$

From table G: $A = 0.005477$

From table CS-2: $B = 15{,}234.1744 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 15{,}234.17}{3 \cdot (64/2)} = \underline{634.76} \text{ psi}$$

% Extreme fiber elongation - UCS-79(d)

$$EFE = \left(\frac{50 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{50 \cdot 2}{31}\right) \cdot \left(1 - \frac{31}{\infty}\right) = 3.2258\,\%$$

The extreme fiber elongation does not exceed 5%.

Ellipsoidal Head #3

ASME Section VIII Division 1, 2004 Edition, A06 Addenda					
Component		Ellipsoidal Head			
Material		SA-516 70 (II-D p. 14, ln. 20)			
Attached To		60" BOOT (BOOT)			
Impact Tested	**Normalized**	**Fine Grain Practice**	**PWHT**	**Maximize MDMT/ No MAWP**	
Yes (-49°F)	Yes	Yes	Yes	No	
		Design Pressure (psi)	**Design Temperature (°F)**	**Design MDMT (°F)**	
Internal		250	600	-49	
External		15	400		
Static Liquid Head					
Condition		**P_s (psi)**	**H_s (in)**	**SG**	
Test horizontal		11.05	306	1	
Dimensions					
Inner Diameter		60"			
Head Ratio		2			
Minimum Thickness		1.5"			
Corrosion	**Inner**	0"			
	Outer	0"			
Length L_{sf}		2"			
Nominal Thickness t_{sf}		2"			
Weight and Capacity					
		Weight (lb)[1]		**Capacity (US gal)[1]**	
New		2,086.32		146.88	
Corroded		2,086.32		146.88	
Radiography					
Category A joints		Seamless No RT			
Head to shell seam		Full UW-11(a) Type 1			

[1] includes straight flange

Results Summary	
Governing condition	internal pressure
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	0.3871"
Design thickness due to external pressure (t_e)	0.1596"
Maximum allowable working pressure (MAWP)	965.17 psi
Maximum allowable pressure (MAP)	995.02 psi
Maximum allowable external pressure (MAEP)	400.36 psi
Straight Flange governs MDMT	-155°F

Design thickness for internal pressure, (Corroded at 600 °F) UG-32(d)(1)

$$t = \frac{P \cdot D}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion} = \frac{250 \cdot 60}{2 \cdot 19{,}400 \cdot 1 - 0.2 \cdot 250} + 0 = 0.3871"$$

Maximum allowable working pressure, (Corroded at 600 °F) UG-32(d)(1)

$$P = \frac{2 \cdot S \cdot E \cdot t}{D + 0.2 \cdot t} - P_s = \frac{2 \cdot 19{,}400 \cdot 1 \cdot 1.5}{60 + 0.2 \cdot 1.5} - 0 = 965.17 \text{ psi}$$

Maximum allowable pressure, (New at 70 °F) UG-32(d)(1)

$$P = \frac{2 \cdot S \cdot E \cdot t}{D + 0.2 \cdot t} - P_s \; = \frac{2 \cdot 20{,}000 \cdot 1 \cdot 1.5}{60 + 0.2 \cdot 1.5} - 0 \; = \underline{995.02} \text{ psi}$$

Design thickness for external pressure, (Corroded at 400 °F) UG-33(d)

Equivalent outside spherical radius
$R_o = K_o \cdot D_o = 0.8591 \cdot 63 = 54.1227 \text{ in}$

$$A = \frac{0.125}{R_o \; / \; t} = \frac{0.125}{54.1227 \; / \; 0.159544} = 0.000368$$

From Table CS-2: B = 5,088.5205 psi

$$P_a = \frac{B}{R_o \; / \; t} = \frac{5{,}088.5205}{54.1227 \; / \; 0.1595} = 15 \text{ psi}$$

$$t \quad = \quad 0.1595\text{''} + \text{Corrosion} = 0.1595\text{''} + 0\text{''} = 0.1595\text{''}$$

Check the external pressure per UG-33(a)(1) UG-32(d)(1)

$$t = \frac{1.67 \cdot P_e \cdot D}{2 \cdot S \cdot E - 0.2 \cdot 1.67 \cdot P_e} + \text{Corrosion} \; = \frac{1.67 \cdot 15 \cdot 60}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 1.67 \cdot 15} + 0 \; = 0.0376\text{''}$$

The head external pressure design thickness (t_e) is 0.1595".

Maximum Allowable External Pressure, (Corroded at 400 °F) UG-33(d)

Equivalent outside spherical radius
$R_o = K_o \cdot D_o = 0.8591 \cdot 63 = 54.1227 \text{ in}$

$$A = \frac{0.125}{R_o \; / \; t} = \frac{0.125}{54.1227 \; / \; 1.5} = 0.003464$$

From Table CS-2: B = 14,445.66 psi

$$P_a = \frac{B}{R_o \; / \; t} = \frac{14{,}445.66}{54.1227 \; / \; 1.5} = 400.3585 \text{ psi}$$

Check the Maximum External Pressure, UG-33(a)(1) UG-32(d)(1)

$$P = \frac{2 \cdot S \cdot E \cdot t}{(D + 0.2 \cdot t) \cdot 1.67} \; = \frac{2 \cdot 20{,}000 \cdot 1 \cdot 1.5}{(60 + 0.2 \cdot 1.5) \cdot 1.67} = 595.82 \text{ psi}$$

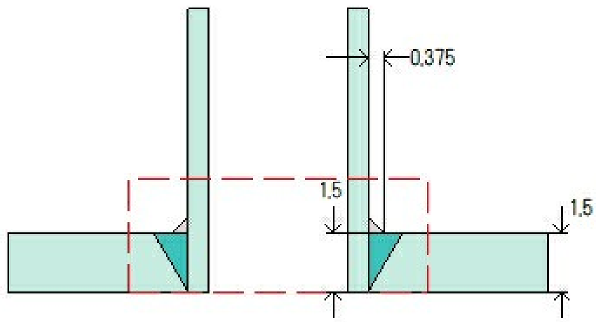
The maximum allowable external pressure (MAEP) is 400.36 psi.

% Extreme fiber elongation - UCS-79(d)

$$EFE = \left(\frac{75 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{75 \cdot 2}{11.2}\right) \cdot \left(1 - \frac{11.2}{\infty}\right) = 13.3929\,\%$$

4" 300# RFWN WATER OUTLET (N7)

ASME Section VIII Division 1, 2004 Edition, A06 Addenda	



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

Location and Orientation	
Located on	Ellipsoidal Head #3
Orientation	0°
End of nozzle to datum line	0"
Calculated as hillside	No
Distance to head center, R	0"
Passes through a Category A joint	No
Nozzle	
Description	NPS 4 Sch 160
Access opening	No
Material specification	SA-333 6 Wld & smls pipe (II-D p. 10, ln. 8)
Inside diameter, new	3.438"
Pipe nominal wall thickness	0.531"
Pipe minimum wall thickness[1]	0.4646"
Corrosion allowance	0"
Projection available outside vessel, Lpr	2.7679"
Projection available outside vessel to flange face, Lf	6.1479"
Local vessel minimum thickness	1.5"
Liquid static head included	0 psi
Welds	
Inner fillet, Leg_{41}	0.375"
Nozzle to vessel groove weld	1.5"
Radiography	
Longitudinal seam	Welded pipe
Circumferential seam	Full UW-11(a) Type 1

[1]Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

ASME B16.5-2003 Flange	
Description	NPS 4 Class 300 WN A350 LF2 Cl.1
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, ln. 33)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0 psi
Consider External Loads on Flange MAWP Rating	No
MAWP rating	570 psi @ 600°F
MAP rating	740 psi @ 70°F
Hydrotest rating	1,125 psi @ 70°F
PWHT performed	Yes
Impact Tested	No
Circumferential joint radiography	Full UW-11(a) Type 1
Gasket	
Type	ASME B16.20 Kammprofile
Description	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel
Factor, m	2
Seating Stress, y	2,500 psi
Thickness, T	0.145"
Inner Diameter	4.87"
Outer Diameter	6.06"
Notes	
Flange is impact tested per material specification to -50°F. Stress ratio = 0.3456 ≤ 0.35, MDMT per UCS-66(b)(3) = -155°F. Bolts rated MDMT per Fig UCS-66 note (e) = -55°F	

UCS-66 Material Toughness Requirements Nozzle	
Impact test temperature per material specification =	-50°F
External nozzle loadings per UG-22 govern the coincident ratio used.	
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0671 \cdot 1}{0.4646 - 0} =$	0.1444
Stress ratio ≤ 0.35, MDMT per UCS-66(b)(3) =	-155°F
$MDMT = \min\left[T_{impact} - T_{UCS-66(g)}, -155\right] = \min\left[-50 - 5, -155\right] =$	-155°F
Material is exempt from impact testing at the Design MDMT of -49°F.	

Reinforcement Calculations for MAWP

The attached ASME B16.5 flange limits the nozzle MAWP.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 570 psi @ 600 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
2.8356	4.0231	2.7724	1.1268	–	–	0.1239	0.2074	0.4646

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})	0.25	0.2625	weld size is adequate

WRC 107												
Load Case	P (psi)	P_r (lb_f)	M_1 (lb_f-in)	V_2 (lb_f)	M_2 (lb_f-in)	V_1 (lb_f)	M_t (lb_f-in)	Max Comb Stress (psi)	Allow Comb Stress (psi)	Max Local Primary Stress (psi)	Allow Local Primary Stress (psi)	Over stressed
Load case 1	569.99	-1,260	-9,648	0	9,648	0	0	**15,828**	**58,200**	**13,623**	**29,100**	No
Load case 1 (Hot Shut Down)	0	-1,260	-9,648	0	9,648	0	0	2,397	58,200	192	29,100	No

Reinforcement Calculations for MAP

Available reinforcement per UG-37 governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 693.9 psi @ 70 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
3.3766	3.3766	2.1884	1.068	–	–	0.1202	0.2074	0.4646

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(1)

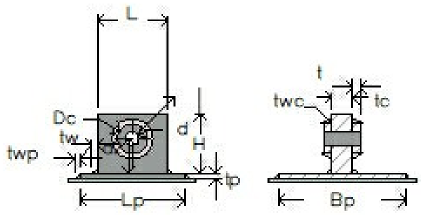
Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 318.38 psi @ 400 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
2.2062	2.2063	1.0615	1.0246	–	–	0.1202	0.2074	0.4646

UG-41 Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.25	0.2625	weld size is adequate

Lifting Lug - 1

Geometry Inputs	
	
Attached To	Cylinder #2
Material	SA-516-70N
Orientation	Longitudinal
Distance of Lift Point From Datum	394"
Angular Position	0°
Length, L	20"
Height, H	17"
Thickness, t	3"
Hole Diameter, d	3.875"
Pin Diameter, Dp	3.75"
Load Eccentricity, a_1	0"
Distance from Load to Shell or Pad, a_2	10"
Load Angle Normal to Vessel, β	-45°
Load Angle from Vertical, ϕ	-45°
Welds	
Size, t_w	1.5"
Collar	
Thickness, t_c	1"
Diameter, D_c	8.5"
Weld Size, t_{wc}	1.5"
Reinforcement Pad	
Width, B_p	18"
Length, L_p	30"
Thickness, t_p	1.5"
Weld Size, t_{wp}	1.5"

Intermediate Values	
Load Factor	1.8000
Vessel Weight (new, incl. Load Factor), W	367,872.5 lb
Lug Weight (new), W_{lug}	578.5 lb
Distance from Center of Gravity to this lug, x_1	141.6085"
Distance from Center of Gravity to second lug, x_2	152.3915"
Allowable Stress, Tensile, σ_t	22,800 psi
Allowable Stress, Shear, σ_s	15,200 psi
Allowable Stress, Bearing, σ_p	34,200 psi
Allowable Stress, Bending, σ_b	25,080 psi
Allowable Stress, Weld Shear, $\tau_{allowable}$	15,200 psi
Allowable Stress set to 1/3 Sy per ASME B30.20	No

Summary Values	
Required Lift Pin Diameter, d_{reqd}	3.3607"
Required Lug Thickness, t_{reqd}	0.5914"
Required Lug Collar Thickness, $t_{c\ reqd}$	0"
Lug Stress Ratio, σ_{ratio}	0.52
Weld Shear Stress Ratio, τ_{ratio}	0.91
Lug Design	Acceptable
Local Stresses WRC 107	**Unacceptable**

Lift Forces

F_r = force on vessel at lug

$$F_r = \left[\frac{W}{\cos(\phi_1)}\right] \cdot \left(1 - \frac{x_1}{x_1 + x_2}\right) = \frac{367{,}872.5}{\cos(-45)} \cdot \left(1 - \frac{141.6085}{141.6085 + 152.3915}\right) = 269{,}666\ lb_f$$

where 'x$_1$' is the distance between this lug and the center of gravity

'x$_2$' is the distance between the second lift lug and the center of gravity

Lug Pin Diameter - Shear stress

$$d_{\text{reqd}} = \sqrt{\frac{2 \cdot F_v}{\pi \cdot \sigma_s}}$$

$$= \sqrt{\frac{2 \cdot 269{,}666}{\pi \cdot 15{,}200}} = 3.3607''$$

$$\frac{d_{reqd}}{D_p} = \frac{3.3607}{3.75} = 0.90$$ Acceptable

$$\sigma = \frac{F_v}{A}$$

$$= \frac{F_v}{2 \cdot \left(0.25 \cdot \pi \cdot D_p^2\right)}$$

$$= \frac{269{,}666}{2 \cdot \left(0.25 \cdot \pi \cdot 3.75^{\,2}\right)} = 12{,}208 \ \text{psi}$$

$$\frac{\sigma}{\sigma_s} = \frac{12{,}208}{15{,}200} = 0.8$$ Acceptable

Lug Thickness - Tensile stress

$$t_{\text{reqd}} = \frac{F_v}{L \cdot \sigma_t}$$

$$= \frac{269{,}666}{20 \cdot 22{,}800} = 0.5914''$$

$$\frac{t_{\text{reqd}}}{t} = \frac{0.5914}{3} = 0.20$$ Acceptable

$$\sigma = \frac{F_v}{A}$$

$$= \frac{F_v}{L \cdot t}$$

$$= \frac{269{,}666}{20 \cdot 3} = 4{,}494 \ \text{psi}$$

$$\frac{\sigma}{\sigma_t} = \frac{4{,}494}{22{,}800} = 0.2$$ Acceptable

Lug Thickness - Bearing stress

$$t_{\text{reqd}} = \frac{F_v}{D_p \cdot \sigma_p}$$

$$= \frac{269{,}666}{3.75 \cdot 34{,}200} = 2.1027"$$

$$T = t + 2 \cdot t_c$$

$$= 3 + 2 \cdot 1 = 5$$

$$\frac{T_{\text{reqd}}}{T} = \frac{2.1027}{5} = 0.42$$ Acceptable

Collar required thickness

$$t_{\text{c reqd}} = \max(0, 0.5 \cdot (T_{\text{reqd}} - t))$$

$$= \max(0, 0.5 \cdot (2.1027 - 3))$$

= 0"

$$\frac{t_{\text{c reqd}}}{t_c} = \frac{0}{1} = 0.00$$ Acceptable

$$\sigma = \frac{F_v}{A_{\text{bearing}}}$$

$$= \frac{F_v}{D_p \cdot (t + 2 \cdot t_c)}$$

$$= \frac{269{,}666}{3.75 \cdot (3 + 2 \cdot 1)} = 14{,}382 \text{ psi}$$

$$\frac{\sigma}{\sigma_p} = \frac{14{,}382}{34{,}200} = 0.42$$ Acceptable

Lug Thickness - Shear stress

$$t_{\text{reqd}} = \frac{\frac{F_v}{\sigma_s} - 4 \cdot t_c \cdot L_c}{2 \cdot L_{\text{shear}}}$$

$$= \frac{\frac{269{,}666}{15{,}200} - 4 \cdot (1 \cdot 3.4901)}{2 \cdot 5.815} = 0.3251"$$

$$\frac{t_{\text{reqd}}}{t} = \frac{0.3251}{3} = 0.11$$ Acceptable

Collar required thickness

$$t_{\text{c reqd}} = \frac{\frac{F_v}{\sigma_s} - 2 \cdot t \cdot L_{\text{shear}}}{4 \cdot L_c}$$

$$= \frac{\frac{269{,}666}{15{,}200} - 2 \cdot (3 \cdot 5.815)}{4 \cdot 3.4901} = 0$$

$$\frac{t_{\text{c reqd}}}{t_c} = \frac{0}{1} = 0.00$$ Acceptable

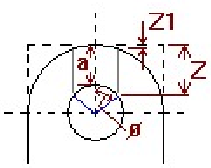
$$\tau = \frac{F_v}{A_{\text{shear}}}$$

$$= \frac{F_v}{2 \cdot t \cdot L_{\text{shear}} + 4 \cdot t_c \cdot L_c}$$

$$= \frac{269{,}666}{2 \cdot 3 \cdot 5.815 + 4 \cdot 1 \cdot 3.4901} = 5{,}520 \text{ psi}$$

$$\frac{\tau}{\sigma_s} = \frac{5{,}520}{15{,}200} = 0.36$$ Acceptable

Shear stress length (per Pressure Vessel and Stacks, A. Keith Escoe)



$$\phi = 55 \cdot \frac{D_p}{d}$$

$$= 55 \cdot \frac{3.75}{3.875}$$

$$= 53.2258^\circ$$

$$L_{\text{shear}} = (H - a2 - 0.5 \cdot d) + 0.5 \cdot D_p \cdot (1 - \cos(\phi))$$

$$= (17 - 10 - 0.5 \cdot 3.875) + 0.5 \cdot 3.75 \cdot (1 - \cos(53.2258))$$

= 5.815"

L_c = Collar shear plane length

= 3.4901"

Lug Plate Stress

Lug stress tensile + bending during lift:

$$\sigma_{\text{ratio}} = \left[\frac{F_{\text{ten}}}{A_{\text{ten}} \cdot \sigma_t}\right] + \left[\frac{M_{\text{bend}}}{Z_{\text{bend}} \cdot \sigma_b}\right] \le 1$$

$$= \left[\frac{F_r \cdot \cos(\beta)}{t \cdot L \cdot \sigma_t}\right] + \left[\frac{6 \cdot |F_r \cdot \sin(\beta) \cdot \text{Hght} - F_r \cdot \cos(\beta) \cdot a_1|}{t \cdot L_2 \cdot \sigma_b}\right] \le 1$$

$$= 269{,}666 \cdot \frac{\cos(-45.0)}{3 \cdot 20 \cdot 22{,}800} + 6 \cdot \frac{|269{,}666 \cdot \sin(-45.0) \cdot 10 - 269{,}666 \cdot \cos(-45.0) \cdot 0|}{3 \cdot 20^2 \cdot 25{,}080}$$

= 0.52 Acceptable

Weld Stress

Weld stress, tensile, bending and shear during lift:

Direct shear:

Shear stress at lift angle -45.00°; lift force = 269,666 lb_f

$$A_{\text{weld}} = 2 \cdot (0.707) \cdot t_w \cdot (L + t)$$

$$= 2 \cdot (0.707) \cdot 1.5 \cdot (20 + 3) = 48.783 \text{ in}^2$$

$$\tau_t = F_{\text{lug}} \cdot \frac{\cos(\beta)}{A_{\text{weld}}}$$

$$= 269{,}666 \cdot \frac{\cos(-45.0)}{48.783} = 3{,}909 \text{ psi}$$

$$\tau_s = F_{\text{lug}} \cdot \frac{\sin(\beta)}{A_{\text{weld}}}$$

$$= 269{,}666 \cdot \frac{\sin(-45.0)}{48.783} = -3{,}909 \text{ psi}$$

$$\tau_b = M \cdot \frac{c}{I}$$

$$= 3 \cdot \frac{F_{\text{lug}} \cdot \sin(\beta) \cdot Hght - F_{\text{lug}} \cdot \cos(\beta) \cdot a_1}{0.707 \cdot h \cdot L \cdot (3 \cdot t + L)}$$

$$= 3 \cdot \frac{|269{,}666 \cdot \sin(-45.0) \cdot 10 - 269{,}666 \cdot \cos(-45.0) \cdot (0)|}{615.0900}$$

$$= 9{,}300 \text{ psi}$$

$$\tau_{\text{ratio}} = \frac{\sqrt{(\tau_t + \tau_b)^2 + \tau_s^2}}{\tau_{\text{allowable}}} \leq 1$$

$$= \frac{\sqrt{(3{,}909 + 9{,}300)^2 + (-3{,}909)^2}}{15{,}200}$$

= 0.91 Acceptable

Collar Weld Stress:

$$\tau_c = \frac{F_r}{A_{weld}}$$

$$= \frac{269{,}666}{2 \cdot 0.707 \cdot 1.5 \cdot \pi \cdot 8.5} = 4{,}761 \text{ psi}$$

$$\tau_{ratio} = \frac{\tau_c}{\tau_{\text{allowable}}} \leq 1$$

$$= \frac{4{,}761}{15{,}200}$$ = 0.31 Acceptable

Pad Weld Stress, tensile, bending and shear during lift:

Direct shear:

Shear stress at lift angle -45.00°; lift force = 269,666 lb_f

$$A_{\text{weld}} = 2 \cdot (0.707) \cdot t_{w\_}p \cdot (L_p + B_p)$$

$$= 2 \cdot (0.707) \cdot 1.5 \cdot (30 + 18) = 101.808 \text{ in}^2$$

$$\tau_t = F_{\text{lug}} \cdot \frac{\cos(\beta)}{A_{\text{weld}}}$$

$$= 269{,}666 \cdot \frac{\cos(-45.0)}{101.808} = 1{,}873 \text{ psi}$$

$$\tau_s = F_{\text{lug}} \cdot \frac{\sin(\beta)}{A_{\text{weld}}}$$

$$= 269{,}666 \cdot \frac{\sin(-45.0)}{101.808} = -1{,}873 \text{ psi}$$

$$\tau_b = M \cdot \frac{c}{I}$$

$$= 3 \cdot \frac{F_{\text{lug}} \cdot \sin(\beta) \cdot Hght - F_{\text{lug}} \cdot \cos(\beta) \cdot a_1}{0.707 \cdot h_p \cdot L_p \cdot (3 \cdot W_p + L_p)}$$

$$= 3 \cdot \frac{|269{,}666 \cdot \sin(-45.0) \cdot 11.5 - 269{,}666 \cdot \cos(-45.0) \cdot (0)|}{2672.4600}$$

$$= 2{,}462 \text{ psi}$$

$$\tau_{\text{ratio}} = \frac{\sqrt{(\tau_t + \tau_b)^2 + \tau_s^2}}{\tau_{\text{allowable}}} \leq 1$$

$$= \frac{\sqrt{(1{,}873 + 2{,}462)^2 + (-1{,}873)^2}}{15{,}200}$$

= 0.31 Acceptable

WRC 107 Analysis

Geometry	
Height (radial)	17"
Width (circumferential)	3"
Length	20"
Fillet Weld Size:	1.5"
Located On	Cylinder #2 (30" from left end)
Location Angle	0.00°
Reinforcement Pad	
Thickness	1.5"
Width	18"
Length	30"
Weld Size	1.5"

Applied Loads	
Radial load, P_r	-190,682.53 lb_f
Circumferential moment, M_c	0 lb_f-in
Circumferential shear, V_c	0 lb_f
Longitudinal moment, M_L	-2,192,849.1 lb_f-in
Longitudinal shear, V_L	-190,682.53 lb_f
Torsion moment, M_t	0 lb_f-in
Internal pressure, P	0 psi
Mean shell radius, R_m	84.625"
Design factor	3

Maximum stresses due to the applied loads at the lug edge

$$\gamma = \frac{R_m}{T} = \frac{84.625}{2.75} = 30.7727$$

$$C_1 = 3, C_2 = 11.5 \text{ in}$$

Local circumferential pressure stress $= \frac{P \cdot R_i}{T} = 0$ psi

Local longitudinal pressure stress $= \frac{P \cdot R_i}{2 \cdot T} = 0$ psi

Maximum combined stress $(P_L + P_b + Q) = 44{,}458$ psi

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 60{,}000$ psi

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

Maximum local primary membrane stress $(P_L) = 6{,}885$ psi

Allowable local primary membrane stress $(P_L) = \pm 1.5 \cdot S = \pm 30{,}000$ psi

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

Stresses at the lug edge per WRC Bulletin 107										
Figure	value	β	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	4.8731	0.1022	0	0	0	0	3,993	3,993	3,993	3,993
4C*	5.6236	0.0831	4,608	4,608	4,608	4,608	0	0	0	0
1C	0.1859	0.0612	0	0	0	0	28,124	-28,124	28,124	-28,124
2C-1	0.1476	0.0612	22,330	-22,330	22,330	-22,330	0	0	0	0
3A*	0.4277	0.0555	0	0	0	0	0	0	0	0
1A	0.1042	0.0705	0	0	0	0	0	0	0	0
3B*	2.6675	0.0868	2,277	2,277	-2,277	-2,277	0	0	0	0
1B-1	0.0539	0.0769	14,403	-14,403	-14,403	14,403	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total circumferential stress			43,618	-29,848	10,258	-5,596	32,117	-24,131	32,117	-24,131
Primary membrane circumferential stress*			6,885	6,885	2,331	2,331	3,993	3,993	3,993	3,993
3C*	5.2058	0.0831	4,265	4,265	4,265	4,265	0	0	0	0
4C*	5.4456	0.1022	0	0	0	0	4,462	4,462	4,462	4,462
1C-1	0.159	0.0865	24,054	-24,054	24,054	-24,054	0	0	0	0
2C	0.1166	0.0865	0	0	0	0	17,640	-17,640	17,640	-17,640
4A*	0.5618	0.0555	0	0	0	0	0	0	0	0
2A	0.0566	0.0956	0	0	0	0	0	0	0	0
4B*	0.7251	0.0868	1,094	1,094	-1,094	-1,094	0	0	0	0
2B-1	0.0768	0.1049	15,045	-15,045	-15,045	15,045	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total longitudinal stress			44,458	-33,740	12,180	-5,838	22,102	-13,178	22,102	-13,178
Primary membrane longitudinal stress*			5,359	5,359	3,171	3,171	4,462	4,462	4,462	4,462
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	1,507	1,507	-1,507	-1,507
Total Shear stress			0	0	0	0	1,507	1,507	-1,507	-1,507
Combined stress (P_L+P_b+Q)			44,458	-33,740	12,180	-5,838	32,339	-24,335	32,339	-24,335
* denotes primary stress.										

Maximum stresses due to the applied loads at the pad edge

$$\gamma = \frac{R_m}{T} = \frac{84.625}{1.25} = 67.7$$

$$C_1 = 10.5, C_2 = 16.5 \ \text{ in}$$

Local circumferential pressure stress $= \dfrac{P \cdot R_i}{T} = 0 \ \text{ psi}$

Local longitudinal pressure stress $= \dfrac{P \cdot R_i}{2 \cdot T} = 0 \ \text{ psi}$

Maximum combined stress $(P_L + P_b + Q) = 77{,}591 \ \text{ psi}$

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 60{,}000 \ \text{ psi}$

WRC 107: The combined stress (P_L+P_b+Q) is excessive (at pad edge)

Maximum local primary membrane stress $(P_L) = 24{,}809 \ \text{ psi}$

Allowable local primary membrane stress $(P_L) = \pm 1.5 \cdot S = \pm 30{,}000 \ \text{ psi}$

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*	4.8657	0.1917	0	0	0	0	8,771	8,771	8,771	8,771
4C*	9.1776	0.1706	16,544	16,544	16,544	16,544	0	0	0	0
1C	0.0738	0.1465	0	0	0	0	54,038	-54,038	54,038	-54,038
2C-1	0.042	0.1465	30,753	-30,753	30,753	-30,753	0	0	0	0
3A*	2.713	0.1443	0	0	0	0	0	0	0	0
1A	0.0754	0.1552	0	0	0	0	0	0	0	0
3B*	6.6154	0.1677	8,265	8,265	-8,265	-8,265	0	0	0	0
1B-1	0.0257	0.1585	16,132	-16,132	-16,132	16,132	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total circumferential stress			71,694	-22,076	22,900	-6,342	62,809	-45,267	62,809	-45,267
Primary membrane circumferential stress*			24,809	24,809	8,279	8,279	8,771	8,771	8,771	8,771
3C*	5.6624	0.1706	10,207	10,207	10,207	10,207	0	0	0	0
4C*	8.5882	0.1917	0	0	0	0	15,481	15,481	15,481	15,481
1C-1	0.0623	0.1744	45,617	-45,617	45,617	-45,617	0	0	0	0
2C	0.0387	0.1744	0	0	0	0	28,337	-28,337	28,337	-28,337
4A*	5.0757	0.1443	0	0	0	0	0	0	0	0
2A	0.0339	0.1799	0	0	0	0	0	0	0	0
4B*	2.6745	0.1677	4,266	4,266	-4,266	-4,266	0	0	0	0
2B-1	0.0318	0.1808	17,501	-17,501	-17,501	17,501	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total longitudinal stress			77,591	-48,645	34,057	-22,175	43,818	-12,856	43,818	-12,856
Primary membrane longitudinal stress*			14,473	14,473	5,941	5,941	15,481	15,481	15,481	15,481
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	2,311	2,311	-2,311	-2,311
Total Shear stress			0	0	0	0	2,311	2,311	-2,311	-2,311
Combined stress (P_L+P_b+Q)			77,591	-48,645	34,057	-22,175	63,086	-45,431	63,086	-45,431

* denotes primary stress.

Cylinder #3

ASME Section VIII Division 1, 2004 Edition, A06 Addenda					
Component		Cylinder			
Material		SA-516 70 (II-D p. 14, ln. 20)			
Impact Tested	**Normalized**	**Fine Grain Practice**	**PWHT**	**Maximize MDMT/ No MAWP**	
Yes (-49°F)	Yes	Yes	Yes	No	
		Design Pressure (psi)	**Design Temperature (°F)**	**Design MDMT (°F)**	
Internal		250	600	-49	
External		15	400		
Static Liquid Head					
Condition		**P_s (psi)**	**H_s (in)**	**SG**	
Test horizontal		7.47	207	1	
Dimensions					
Inner Diameter		168"			
Length		87"			
Nominal Thickness		1.375"			
Corrosion	**Inner**	0"			
	Outer	0"			
Weight and Capacity					
		Weight (lb)		**Capacity (US gal)**	
New		16,913.67		8,348.64	
Corroded		16,913.67		8,348.64	
Insulation					
		Thickness (in)	**Density (lb/ft^3)**	**Weight (lb)**	
Insulation		4	18	1,990.11	
		Spacing(in)	**Individual Weight (lb)**	**Total Weight (lb)**	
Insulation Supports		145	50	50	
Radiography					
Longitudinal seam		Full UW-11(a) Type 1			
Left Circumferential seam		Full UW-11(a) Type 1			
Right Circumferential seam		Full UW-11(a) Type 1			

Results Summary	
Governing condition	Internal pressure
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	1.091"
Design thickness due to external pressure (t_e)	0.8941"
Maximum allowable working pressure (MAWP)	314.47 psi
Maximum allowable pressure (MAP)	324.2 psi
Maximum allowable external pressure (MAEP)	42.99 psi
Rated MDMT	-70.3 °F

UCS-66 Material Toughness Requirements	
Material impact test temperature per UG-84 =	-49°F
$t_r = \frac{255.74 \cdot 84}{20{,}000 \cdot 1 - 0.6 \cdot 255.74} =$	1.0824"
Stress ratio $= \frac{t_r \cdot E^*}{t_n - c} = \frac{1.0824 \cdot 1}{1.375 - 0} =$	0.7872
Stress ratio longitudinal $= \frac{8{,}057 \cdot 1}{20{,}000 \cdot 1} =$	0.4029
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	21.3°F
$MDMT = \max\left[T_{impact} - T_R, -155\right] = \max\left[-49 - 21.3, -155\right] =$	-70.3°F
Design MDMT of -49°F is acceptable.	

Design thickness, (at 600 °F) UG-27(c)(1)

$$t = \frac{P \cdot R}{S \cdot E - 0.60 \cdot P} + \text{Corrosion} = \frac{250 \cdot 84}{19{,}400 \cdot 1.00 - 0.60 \cdot 250} + 0 = 1.091"$$

Maximum allowable working pressure, (at 600 °F) UG-27(c)(1)

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} - P_s = \frac{19{,}400 \cdot 1.00 \cdot 1.375}{84 + 0.60 \cdot 1.375} - 0 = 314.47 \text{ psi}$$

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

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} = \frac{20{,}000 \cdot 1.00 \cdot 1.375}{84 + 0.60 \cdot 1.375} = 324.2 \text{ psi}$$

External Pressure, (Corroded & at 400 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{532}{170.75} = 3.1157$$

$$\frac{D_o}{t} = \frac{170.75}{0.8941} = 190.9811$$

From table G: $A = 0.000157$

From table CS-2: $B = 2{,}148.5374 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 2{,}148.54}{3 \cdot (170.75/0.8941)} = 15 \text{ psi}$$

Design thickness for external pressure P_a = 15 psi

$$t_a = t + \text{Corrosion} = 0.8941 + 0 = 0.8941"$$

Maximum Allowable External Pressure, (Corroded & at 400 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{532}{170.75} = 3.1157$$

$$\frac{D_o}{t} = \frac{170.75}{1.375} = 124.1818$$

From table G: $A = 0.000290$

From table CS-2: $B = 4{,}004.3077$ psi

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 4,004.31}{3 \cdot (170.75/1.375)} = \underline{42.99} \text{ psi}$$

% Extreme fiber elongation - UCS-79(d)

$$EFE = \left(\frac{50 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{50 \cdot 1.375}{84.6875}\right) \cdot \left(1 - \frac{84.6875}{\infty}\right) = 0.8118\,\%$$

The extreme fiber elongation does not exceed 5%.

Allowable Compressive Stress, Hot and Corroded- S_{cHC}, (table CS-2)

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{85.375/1.375} = 0.002013$$

$$B = 10{,}328 \text{ psi}$$

$$S = \frac{19{,}400}{1.00} = 19{,}400 \text{ psi}$$

$S_{cHC} = \min(B, S) =$ 10,328 psi

Allowable Compressive Stress, Hot and New- S_{cHN}

$$S_c HN = S_c HC = 10{,}328 \text{ psi}$$

Allowable Compressive Stress, Cold and New- S_{cCN}, (table CS-2)

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{85.375/1.375} = 0.002013$$

$$B = 15{,}019 \text{ psi}$$

$$S = \frac{20{,}000}{1.00} = 20{,}000 \text{ psi}$$

$S_{cCN} = \min(B, S) =$ 15,019 psi

Allowable Compressive Stress, Cold and Corroded- S_{cCC}

$$S_{cC} = S_{cCN} = 15{,}019 \text{ psi}$$

Allowable Compressive Stress, Vacuum and Corroded- S_{cVC}, (table CS-2)

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{85.375/1.375} = 0.002013$$

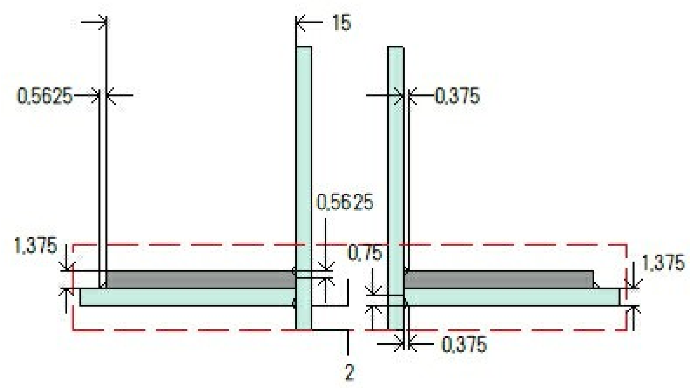
$$B = 13{,}139 \text{ psi}$$

$$S = \frac{20{,}000}{1.00} = 20{,}000 \text{ psi}$$

$S_{cVC} = \min(B, S) =$ 13,139 psi

Nozzle #25 (N25)

ASME Section VIII Division 1, 2004 Edition, A06 Addenda	



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

Location and Orientation	
Located on	Cylinder #3
Orientation	90°
Nozzle center line offset to datum line	250.5"
End of nozzle to shell center	120"
Passes through a Category A joint	No
Nozzle	
Description	NPS 60 (Thk = 1.250")
Access opening	No
Material specification	SA-106 B Smls pipe (II-D p. 10, ln. 5)
Inside diameter, new	57.5"
Pipe nominal wall thickness	1.25"
Pipe minimum wall thickness[1]	1.0938"
Corrosion allowance	0"
Projection available outside vessel, Lpr	21.815"
Internal projection, h_{new}	2"
Projection available outside vessel to flange face, Lf	34.625"
Local vessel minimum thickness	1.375"
Liquid static head included	0 psi
Reinforcing Pad	
Material specification	SA-516 70 (II-D p. 14, ln. 20)
Diameter, D_p	90"
Thickness, t_e	1.375"
Is split	No
Welds	
Inner fillet, Leg_{41}	0.375"
Outer fillet, Leg_{42}	0.5625"
Lower fillet, Leg_{43}	0.375"
Nozzle to vessel groove weld	0.75"
Pad groove weld	0.5625"
Radiography	
Longitudinal seam	Seamless No RT
Circumferential seam	Full UW-11(a) Type 1

[1]Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

ASME B16.47-1996 Flange	
Description	NPS 60 Class 400 WN A105 Series A
Bolt Material	SA-193 B7 Bolt (2 1/2 < t <= 4) (II-D p. 382, ln. 32)
Blind included	Yes
Rated MDMT	-40°F
Liquid static head	0 psi
MAWP rating	730 psi @ 600°F
MAP rating	990 psi @ 70°F
Hydrotest rating	1,500 psi @ 70°F
PWHT performed	Yes
Impact Tested	No
Circumferential joint radiography	Full UW-11(a) Type 1
Bore diameter, B (specified by purchaser)	57.5"
Bolt MDMT is only -40°F: -49°F is required	
Notes	
Flange and blind rated MDMT per UCS-66(b)(3) = -155°F (Coincident ratio = 0.2583) Bolts rated MDMT per Fig UCS-66 note (e) = -40°F	

UCS-66 Material Toughness Requirements Nozzle	
Governing thickness, t_g =	1.0938"
Exemption temperature from Fig UCS-66 Curve B =	35.5°F
$t_r = \frac{255.74 \cdot 28.75}{17{,}100 \cdot 1 - 0.6 \cdot 255.74} =$	0.4339"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.4339 \cdot 1}{1.0938 - 0} =$	0.3967
Reduction in MDMT, T_R from Fig UCS-66.1 =	95.3°F
Reduction in MDMT, T_{PWHT} from UCS-68(c) =	30°F
$MDMT = \max\left[MDMT - T_R - T_{PWHT}, -55\right] = \max\left[35.5 - 95.3 - 30, -55\right] =$	-55°F
Material is exempt from impact testing at the Design MDMT of -49°F.	

UCS-66 Material Toughness Requirements Pad	
Governing thickness, t_g =	1.375"
Exemption temperature from Fig UCS-66 Curve B =	47°F
$t_r = \frac{255.74 \cdot 84}{20{,}000 \cdot 1 - 0.6 \cdot 255.74} =$	1.0824"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{1.0824 \cdot 1}{1.375 - 0} =$	0.7872
$\text{Stress ratio longitudinal} = \frac{8{,}057 \cdot 1}{20{,}000 \cdot 1} =$	0.4029
Reduction in MDMT, T_R from Fig UCS-66.1 =	21.3°F
Reduction in MDMT, T_{PWHT} from UCS-68(c) =	30°F
$MDMT = \max\left[MDMT - T_R - T_{PWHT}, -55\right] = \max\left[47 - 21.3 - 30, -55\right] =$	-4.3°F
Rated MDMT of -4.3°F > Design MDMT of -49°F.	

Reinforcement Calculations for MAWP

Available reinforcement per UG-37 governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 258.57 psi @ 600 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
65.2303	65.2312	14.0938	4.9162	4.407	41.25	0.5642	0.4387	1.0938

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
1,002,580.05	904,166.1	2,136,735.58	244,455.76	2,368,116.82	1,050,843.92	2,066,836.13

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})	0.375	0.3938	weld size is adequate
Nozzle to inside shell fillet (Leg_{43})	0.25	0.2625	weld size is adequate
Nozzle to pad groove (Upper)	0.525	0.5625	weld size is adequate
Nozzle to shell groove (Lower)	0.525	0.75	weld size is adequate

Check Large Opening per Appendix 1-7(a)

Area required within 75 percent of the limits of reinforcement
= 2 / 3*A = (2 / 3)*65.2303 = 43.4869 in^2

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$
$$= \max\left[57.5,\ 28.75 + (1.25 - 0) + (1.375 - 0)\right]$$
$$= 43.125 \text{ in}$$

$$A_1 = (2 \cdot L_R - d) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$$
$$= (2 \cdot 43.125 - 57.5) \cdot (1 \cdot 1.375 - 1 \cdot 1.1286) - 2 \cdot 1.25 \cdot (1 \cdot 1.375 - 1 \cdot 1.1286) \cdot (1 - 0.8814)$$
$$= 7.0104 \text{ in}^2$$

$$A_{42} = Leg^2 \cdot f_{r4}$$
$$= 0^2 \cdot 1$$
$$= 0 \text{ in}^2$$

(Part of the weld is outside of the limits)

$$A_5 = (D_p - d - 2 \cdot t_n) \cdot t_e \cdot f_{r4}$$
$$= (86.25 - 57.5 - 2 \cdot 1.25) \cdot 1.375 \cdot 1$$
$$= 36.0938 \text{ in}^2$$

Area	=	$A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$
	=	$7.0104 + 4.9162 + 4.407 + 0.1239 + 0 + 0.1239 + 36.0938$
	=	52.6752 in^2

The area replacement requirements of Appendix 1-7(a) are satisfied.

Check Large Opening per Appendix 1-7(b)

1-7(b)(1)(a)	$D_i = 168 \text{ in} > 60 \text{ in}$	True
1-7(b)(1)(b)	$d = 57.5 \text{ in} > 40 \text{ in}$	True
1-7(b)(1)(b)	$d = 57.5 \text{ in} > 3.4 \cdot \sqrt{84 \cdot 1.375} = 36.5401 \text{ in}$	True
1-7(b)(1)(c)	$\frac{R_n}{R} = \frac{28.75}{84} = 0.3423 \leq 0.7$	True
1-7(b)(1)	Radial nozzle in cylinder or cone	True
1-7(b)(1)	Internal projection not present	False

The opening is within the size range defined by 1-7(b)(1)(a) and (b) so the requirements of 1-7(b)(2),(3) and (4) apply.

R_n / R = 0.3423 does not exceed 0.7 so a U-2(g) analysis is not required per 1-7(b)(1)(c).

***** WARNING! The opening is outside the scope of Appendix 1-7(b) as an internal projection is specified. A U-2(g) analysis is required.***

Reinforcement Calculations for MAP

Available reinforcement per UG-37 governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 265.65 psi @ 70 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
65.0774	65.0817	14.3021	4.6978	4.275	41.25	0.5568	0.4508	1.0938

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
1,026,206.26	927,688	2,160,114.92	243,045.25	2,423,039.72	1,074,373.25	2,121,599.98

Check Large Opening per Appendix 1-7(a)

Area required within 75 percent of the limits of reinforcement
= 2 / 3*A = (2 / 3)*65.0774 = 43.3849 in^2

L_R	=	$\max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$
	=	$\max\left[57.5,\ 28.75 + (1.25 - 0) + (1.375 - 0)\right]$
	=	43.125 in

A_1	=	$(2 \cdot L_R - d) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$
	=	$(2 \cdot 43.125 - 57.5) \cdot (1 \cdot 1.375 - 1 \cdot 1.1247) - 2 \cdot 1.25 \cdot (1 \cdot 1.375 - 1 \cdot 1.1247) \cdot (1 - 0.855)$
	=	7.1057 in^2

A_{42}	=	$Leg^2 \cdot f_{r4}$
	=	$0^2 \cdot 1$
	=	0 in^2

(Part of the weld is outside of the limits)

A_5	=	$(D_p - d - 2 \cdot t_n) \cdot t_e \cdot f_{r4}$
	=	$(86.25 - 57.5 - 2 \cdot 1.25) \cdot 1.375 \cdot 1$
	=	$36.0938 \ \text{in}^2$

Area	=	$A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$
	=	$7.1057 + 4.6978 + 4.275 + 0.1202 + 0 + 0.1202 + 36.0938$
	=	52.4127 in^2

The area replacement requirements of Appendix 1-7(a) are satisfied.

Check Large Opening per Appendix 1-7(b)

1-7(b)(1)(a)	$D_i = 168 \ \text{in} > 60 \ \text{in}$	True
1-7(b)(1)(b)	$d = 57.5 \ \text{in} > 40 \ \text{in}$	True
1-7(b)(1)(b)	$d = 57.5 \ \text{in} > 3.4 \cdot \sqrt{84 \cdot 1.375} = 36.5401 \ \text{in}$	True
1-7(b)(1)(c)	$\frac{R_n}{R} = \frac{28.75}{84} = 0.3423 \leq 0.7$	True
1-7(b)(1)	Radial nozzle in cylinder or cone	True
1-7(b)(1)	Internal projection not present	False

The opening is within the size range defined by 1-7(b)(1)(a) and (b) so the requirements of 1-7(b)(2),(3) and (4) apply.

R_n / R = 0.3423 does not exceed 0.7 so a U-2(g) analysis is not required per 1-7(b)(1)(c).

***** WARNING! The opening is outside the scope of Appendix 1-7(b) as an internal projection is specified. A U-2(g) analysis is required.***

Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 42.99 psi @ 400 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
39.7805	51.9535	–	5.8717	4.275	41.25	0.5568	0.2511	1.0938

UG-41 Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

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})	0.375	0.3938	weld size is adequate
Nozzle to inside shell fillet (Leg_{43})	0.25	0.2625	weld size is adequate
Nozzle to pad groove (Upper)	0.525	0.5625	weld size is adequate
Nozzle to shell groove (Lower)	0.525	0.75	weld size is adequate

Check Large Opening per Appendix 1-7(a)

Area required within 75 percent of the limits of reinforcement
= 2 / 3*A = (2 / 3)*39.7805 = 26.5203 in^2

L_R = $\max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$

= $\max\left[57.5,\ 28.75 + (1.25 - 0) + (1.375 - 0)\right]$

= 43.125 in

A_1 = $(2 \cdot L_R - d) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$

= $(2 \cdot 43.125 - 57.5) \cdot (1 \cdot 1.375 - 1 \cdot 1.375) - 2 \cdot 1.25 \cdot (1 \cdot 1.375 - 1 \cdot 1.375) \cdot (1 - 0.855)$

= 0 in^2

A_{42} = $Leg^2 \cdot f_{r4}$

= $0^2 \cdot 1$

= 0 in^2

(Part of the weld is outside of the limits)

A_5 = $(D_p - d - 2 \cdot t_n) \cdot t_e \cdot f_{r4}$

= $(86.25 - 57.5 - 2 \cdot 1.25) \cdot 1.375 \cdot 1$

= 36.0938 in^2

Area = $A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$

= $0 + 5.8717 + 4.275 + 0.1202 + 0 + 0.1202 + 36.0938$

= 46.4809 in^2

The area replacement requirements of Appendix 1-7(a) are satisfied.

Cylinder #4

<table>
<tr><th colspan="5">ASME Section VIII Division 1, 2004 Edition, A06 Addenda</th></tr>
<tr><td colspan="2">Component</td><td colspan="3">Cylinder</td></tr>
<tr><td colspan="2">Material</td><td colspan="3">SA-516 70 (II-D p. 14, ln. 20)</td></tr>
<tr><td>Impact Tested</td><td>Normalized</td><td>Fine Grain Practice</td><td>PWHT</td><td>Maximize MDMT/ No MAWP</td></tr>
<tr><td>Yes (-49°F)</td><td>Yes</td><td>Yes</td><td>Yes</td><td>No</td></tr>
<tr><td colspan="2"></td><td>Design Pressure (psi)</td><td>Design Temperature (°F)</td><td>Design MDMT (°F)</td></tr>
<tr><td colspan="2">Internal</td><td>250</td><td>600</td><td rowspan="2">-49</td></tr>
<tr><td colspan="2">External</td><td>15</td><td>400</td></tr>
<tr><th colspan="5">Static Liquid Head</th></tr>
<tr><td colspan="2">Condition</td><td>P_s (psi)</td><td>H_s (in)</td><td>SG</td></tr>
<tr><td colspan="2">Test horizontal</td><td>7.47</td><td>207</td><td>1</td></tr>
<tr><th colspan="5">Dimensions</th></tr>
<tr><td colspan="2">Inner Diameter</td><td colspan="3">168"</td></tr>
<tr><td colspan="2">Length</td><td colspan="3">87"</td></tr>
<tr><td colspan="2">Nominal Thickness</td><td colspan="3">1.375"</td></tr>
<tr><td rowspan="2">Corrosion</td><td>Inner</td><td colspan="3">0"</td></tr>
<tr><td>Outer</td><td colspan="3">0"</td></tr>
<tr><th colspan="5">Weight and Capacity</th></tr>
<tr><td colspan="2"></td><td colspan="2">Weight (lb)</td><td>Capacity (US gal)</td></tr>
<tr><td colspan="2">New</td><td colspan="2">18,013.89</td><td>8,348.64</td></tr>
<tr><td colspan="2">Corroded</td><td colspan="2">18,013.89</td><td>8,348.64</td></tr>
<tr><th colspan="5">Insulation</th></tr>
<tr><td colspan="2"></td><td>Thickness (in)</td><td>Density (lb/ft^3)</td><td>Weight (lb)</td></tr>
<tr><td colspan="2">Insulation</td><td>4</td><td>18</td><td>1,990.11</td></tr>
<tr><td colspan="2"></td><td>Spacing(in)</td><td>Individual Weight (lb)</td><td>Total Weight (lb)</td></tr>
<tr><td colspan="2">Insulation Supports</td><td>145</td><td>50</td><td>50</td></tr>
<tr><th colspan="5">Radiography</th></tr>
<tr><td colspan="2">Longitudinal seam</td><td colspan="3">Full UW-11(a) Type 1</td></tr>
<tr><td colspan="2">Left Circumferential seam</td><td colspan="3">Full UW-11(a) Type 1</td></tr>
<tr><td colspan="2">Right Circumferential seam</td><td colspan="3">Full UW-11(a) Type 1</td></tr>
</table>

Results Summary	
Governing condition	Internal pressure
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	1.091"
Design thickness due to external pressure (t_e)	0.8941"
Maximum allowable working pressure (MAWP)	314.47 psi
Maximum allowable pressure (MAP)	324.2 psi
Maximum allowable external pressure (MAEP)	42.99 psi
Rated MDMT	-70.3 °F

UCS-66 Material Toughness Requirements	
Material impact test temperature per UG-84 =	-49°F
$t_r = \frac{255.74 \cdot 84}{20{,}000 \cdot 1 - 0.6 \cdot 255.74} =$	1.0824"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{1.0824 \cdot 1}{1.375 - 0} =$	0.7872
$\text{Stress ratio longitudinal} = \frac{8{,}057 \cdot 1}{20{,}000 \cdot 1} =$	0.4029
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	21.3°F
$MDMT = \max\left[T_{impact} - T_R, -155\right] = \max\left[-49 - 21.3, -155\right] =$	-70.3°F
Design MDMT of -49°F is acceptable.	

Design thickness, (at 600 °F) UG-27(c)(1)

$$t = \frac{P \cdot R}{S \cdot E - 0.60 \cdot P} + \text{Corrosion} = \frac{250 \cdot 84}{19{,}400 \cdot 1.00 - 0.60 \cdot 250} + 0 = 1.091"$$

Maximum allowable working pressure, (at 600 °F) UG-27(c)(1)

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} - P_s = \frac{19{,}400 \cdot 1.00 \cdot 1.375}{84 + 0.60 \cdot 1.375} - 0 = 314.47 \text{ psi}$$

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

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} = \frac{20{,}000 \cdot 1.00 \cdot 1.375}{84 + 0.60 \cdot 1.375} = 324.2 \text{ psi}$$

External Pressure, (Corroded & at 400 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{532}{170.75} = 3.1157$$

$$\frac{D_o}{t} = \frac{170.75}{0.8941} = 190.9811$$

From table G: $A = 0.000157$

From table CS-2: $B = 2{,}148.5374 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 2{,}148.54}{3 \cdot (170.75/0.8941)} = 15 \text{ psi}$$

Design thickness for external pressure P_a = 15 psi

$$t_a = t + \text{Corrosion} = 0.8941 + 0 = 0.8941"$$

Maximum Allowable External Pressure, (Corroded & at 400 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{532}{170.75} = 3.1157$$

$$\frac{D_o}{t} = \frac{170.75}{1.375} = 124.1818$$

From table G: $A = 0.000290$

From table CS-2: $B = 4{,}004.3077$ psi

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 4,004.31}{3 \cdot (170.75/1.375)} = 42.99 \text{ psi}$$

% Extreme fiber elongation - UCS-79(d)

$$EFE = \left(\frac{50 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{50 \cdot 1.375}{84.6875}\right) \cdot \left(1 - \frac{84.6875}{\infty}\right) = 0.8118\,\%$$

The extreme fiber elongation does not exceed 5%.

Allowable Compressive Stress, Hot and Corroded- S_{cHC}, (table CS-2)

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{85.375/1.375} = 0.002013$$

$$B = 10{,}328 \ \text{ psi}$$

$$S = \frac{19{,}400}{1.00} = 19{,}400 \ \text{ psi}$$

S_{cHC} = min (B, S) = 10,328 psi

Allowable Compressive Stress, Hot and New- S_{cHN}

$$S_cHN = S_cHC = 10{,}328 \ \text{ psi}$$

Allowable Compressive Stress, Cold and New- S_{cCN}, (table CS-2)

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{85.375/1.375} = 0.002013$$

$$B = 15{,}019 \ \text{ psi}$$

$$S = \frac{20{,}000}{1.00} = 20{,}000 \ \text{ psi}$$

S_{cCN} = min (B, S) = 15,019 psi

Allowable Compressive Stress, Cold and Corroded- S_{cCC}

$$S_{cC} = S_{cCN} = 15{,}019 \ \text{ psi}$$

Allowable Compressive Stress, Vacuum and Corroded- S_{cVC}, (table CS-2)

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{85.375/1.375} = 0.002013$$

$$B = 13{,}139 \ \text{ psi}$$

$$S = \frac{20{,}000}{1.00} = 20{,}000 \ \text{ psi}$$

S_{cVC} = min (B, S) = 13,139 psi

Cylinder #5

ASME Section VIII Division 1, 2004 Edition, A06 Addenda					
Component		Cylinder			
Material		SA-516 70 (II-D p. 14, ln. 20)			
Impact Tested	Normalized	Fine Grain Practice	PWHT	Maximize MDMT/ No MAWP	
Yes (-49°F)	Yes	Yes	Yes	No	
		Design Pressure (psi)	Design Temperature (°F)	Design MDMT (°F)	
Internal		250	600	-49	
External		15	400		
Static Liquid Head					
Condition		P_s (psi)	H_s (in)	SG	
Test horizontal		7.47	207	1	
Dimensions					
Inner Diameter		168"			
Length		120"			
Nominal Thickness		1.375"			
Corrosion	Inner	0"			
	Outer	0"			
Weight and Capacity					
		Weight (lb)		Capacity (US gal)	
New		24,658.33		11,515.37	
Corroded		24,658.33		11,515.37	
Insulation					
		Thickness (in)	Density (lb/ft^3)	Weight (lb)	
Insulation		4	18	2,744.98	
		Spacing(in)	Individual Weight (lb)	Total Weight (lb)	
Insulation Supports		145	50	50	
Radiography					
Longitudinal seam		Full UW-11(a) Type 1			
Left Circumferential seam		Full UW-11(a) Type 1			
Right Circumferential seam		Full UW-11(a) Type 1			

Results Summary	
Governing condition	Internal pressure
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	1.091"
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Maximum allowable external pressure (MAEP)	42.99 psi
Rated MDMT	-70.3 °F

UCS-66 Material Toughness Requirements	
Material impact test temperature per UG-84 =	-49°F
$t_r = \frac{255.74 \cdot 84}{20{,}000 \cdot 1 - 0.6 \cdot 255.74} =$	1.0824"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{1.0824 \cdot 1}{1.375 - 0} =$	0.7872
$\text{Stress ratio longitudinal} = \frac{8{,}057 \cdot 1}{20{,}000 \cdot 1} =$	0.4029
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	21.3°F
$MDMT = \max\left[T_{impact} - T_R, -155\right] = \max\left[-49 - 21.3, -155\right] =$	-70.3°F
Design MDMT of -49°F is acceptable.	

Design thickness, (at 600 °F) UG-27(c)(1)

$$t = \frac{P \cdot R}{S \cdot E - 0.60 \cdot P} + \text{Corrosion} = \frac{250 \cdot 84}{19{,}400 \cdot 1.00 - 0.60 \cdot 250} + 0 = \underline{1.091}"$$

Maximum allowable working pressure, (at 600 °F) UG-27(c)(1)

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} - P_s = \frac{19{,}400 \cdot 1.00 \cdot 1.375}{84 + 0.60 \cdot 1.375} - 0 = \underline{314.47} \text{ psi}$$

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

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} = \frac{20{,}000 \cdot 1.00 \cdot 1.375}{84 + 0.60 \cdot 1.375} = \underline{324.2} \text{ psi}$$

External Pressure, (Corroded & at 400 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{532}{170.75} = 3.1157$$

$$\frac{D_o}{t} = \frac{170.75}{0.8941} = 190.9811$$

From table G: $A = 0.000157$

From table CS-2: $B = 2{,}148.5374 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 2{,}148.54}{3 \cdot (170.75/0.8941)} = 15 \text{ psi}$$

Design thickness for external pressure P_a = 15 psi

$$t_a = t + \text{Corrosion} = 0.8941 + 0 = \underline{0.8941}"$$

Maximum Allowable External Pressure, (Corroded & at 400 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{532}{170.75} = 3.1157$$

$$\frac{D_o}{t} = \frac{170.75}{1.375} = 124.1818$$

From table G: $A = 0.000290$

From table CS-2: $B = 4{,}004.3077$ psi

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o / t)} = \frac{4 \cdot 4,004.31}{3 \cdot (170.75/1.375)}$$ = 42.99 psi

% Extreme fiber elongation - UCS-79(d)

$$EFE = \left(\frac{50 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{50 \cdot 1.375}{84.6875}\right) \cdot \left(1 - \frac{84.6875}{\infty}\right) = 0.8118\,\%$$

The extreme fiber elongation does not exceed 5%.

Allowable Compressive Stress, Hot and Corroded- S_{cHC}, (table CS-2)

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{85.375/1.375} = 0.002013$$

$$B = 10{,}328 \text{ psi}$$

$$S = \frac{19{,}400}{1.00} = 19{,}400 \text{ psi}$$

$S_{cHC} = \min(B, S) =$ 10,328 psi

Allowable Compressive Stress, Hot and New- S_{cHN}

$$S_c HN = S_c HC = 10{,}328 \text{ psi}$$

Allowable Compressive Stress, Cold and New- S_{cCN}, (table CS-2)

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{85.375/1.375} = 0.002013$$

$$B = 15{,}019 \text{ psi}$$

$$S = \frac{20{,}000}{1.00} = 20{,}000 \text{ psi}$$

$S_{cCN} = \min(B, S) =$ 15,019 psi

Allowable Compressive Stress, Cold and Corroded- S_{cCC}

$$S_{cC} = S_{cCN} = 15{,}019 \text{ psi}$$

Allowable Compressive Stress, Vacuum and Corroded- S_{cVC}, (table CS-2)

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{85.375/1.375} = 0.002013$$

$$B = 13{,}139 \text{ psi}$$

$$S = \frac{20{,}000}{1.00} = 20{,}000 \text{ psi}$$

$S_{cVC} = \min(B, S) =$ 13,139 psi

Saddle #1

ASME Section VIII Division 1, 2004 Edition, A06 Addenda		
Saddle Material	SA516-70N	
Saddle Construction	Centered web	
Welded to Vessel	Yes	
Saddle Allowable Stress, S_s	20,000 psi	
Saddle Yield Stress, S_y	38,000 psi	
Foundation Allowable Stress	750 psi	
Design Pressure	**Left Saddle**	**Right Saddle**
Operating & New	255.74 psi	
Operating & Corr	255.74 psi	
Test	339.93 psi	
Vacuum	15 psi	
Dimensions		
Right saddle distance to datum	54"	
Tangent To Tangent Length, L	504"	
Saddle separation, L_s	392"	
Vessel Radius, R	85.375"	
Tangent Distance Left, A_l	56"	
Tangent Distance Right, A_r	56"	
Saddle Height, H_s	117"	
Saddle Contact Angle, θ	120°	
Web Plate Thickness, t_s	0.625"	
Base Plate Length, E	150"	
Base Plate Width, F	16"	
Base Plate Thickness, t_b	1.5"	
Number of Stiffening Ribs, n	7	
Largest Stiffening Rib Spacing, d_i	24.75"	
Stiffening Rib Thickness, t_w	0.5"	
Saddle Width, b	12"	
Reinforcing Plate		
Thickness, t_p	0.375"	
Width, W_p	28"	
Contact Angle, θ_w	132°	
Bolting		
Material	ASTM 325	
Bolt Allowable Shear	20,000 psi	
Description	1.5" series 8 threaded	
Corrosion on root	0.125"	
Anchor Bolts per Saddle	4	
Base coefficient of friction, μ	0.2	
Hole Diameter	1.75"	
Slotted Hole in Which Saddle	Right Saddle	
Slotted Hole Length	3.0749"	
Weight		
	Left Saddle	**Right Saddle**
Operating, Corroded	103,801 lb	101,544 lb

Operating, New	103,820 lb	101,551 lb
Hydrotest	336,813 lb	329,333 lb
Weight of Saddle Pair	6,702 lb	

Notes
(1) Saddle calculations are based on the method presented in "Stresses in Large Cylindrical Pressure Vessels on Two Saddle Supports" by L.P. Zick.

Stress Summary

Load	Condition	Saddle	Bending + pressure between saddles (psi)				Bending + pressure at the saddle (psi)			
			S_1 (+)	allow (+)	S_1 (-)	allow (-)	S_2 (+)	allow (+)	S_2 (-)	allow (-)
Wind	Operating & New	Right Saddle	8,057	23,280	246	12,394	8,014	23,280	203	12,394
		Left Saddle					8,014	23,280	203	12,394
	Operating & Corr	Right Saddle	8,057	23,280	246	12,394	8,014	23,280	203	12,394
		Left Saddle					8,014	23,280	203	12,394
	Test	Right Saddle	11,069	34,200	685	18,022	11,041	34,200	657	18,022
		Left Saddle					11,041	34,200	657	18,022
	Vacuum	Right Saddle	246	24,000	704	15,766	203	24,000	661	15,766
		Left Saddle					203	24,000	661	15,766
Weight	Operating & New	Right Saddle	8,019	19,400	207	10,328	8,014	19,400	203	10,328
		Left Saddle					8,014	19,400	203	10,328
	Operating & Corr	Right Saddle	8,019	19,400	207	10,328	8,014	19,400	203	10,328
		Left Saddle					8,014	19,400	203	10,328
	Vacuum	Right Saddle	207	20,000	665	13,139	203	20,000	661	13,139
		Left Saddle					203	20,000	661	13,139

Stress Summary

Load	Condition	Saddle	Tangential shear (psi)		Circumferential stress (psi)		Stress over saddle (psi)		Splitting (psi)	
			S_3	allow	S_4 (horns)	allow (+/-)	S_5	allow	S_6	allow
Wind	Operating & New	Right Saddle	902	15,520	-4,057	29,100	2,664	14,550	869	13,333
		Left Saddle	925	15,520	-4,133	29,100	2,714	14,550	885	13,333
	Operating & Corr	Right Saddle	902	15,520	-4,057	29,100	2,664	14,550	869	13,333
		Left Saddle	925	15,520	-4,132	29,100	2,714	14,550	885	13,333
	Test	Right Saddle	2,363	27,360	-11,276	34,200	7,405	34,200	2,415	34,200
		Left Saddle	2,438	27,360	-11,528	34,200	7,570	34,200	2,469	34,200
	Vacuum	Right Saddle	902	16,000	-4,057	30,000	2,664	16,250	869	13,333
		Left Saddle	925	16,000	-4,132	30,000	2,714	16,250	885	13,333
Weight	Operating & New	Right Saddle	709	15,520	-3,411	29,100	2,240	14,550	731	13,333
		Left Saddle	732	15,520	-3,488	29,100	2,290	14,550	747	13,333
	Operating & Corr	Right Saddle	709	15,520	-3,411	29,100	2,240	14,550	731	13,333
		Left Saddle	732	15,520	-3,487	29,100	2,290	14,550	747	13,333
	Vacuum	Right Saddle	709	16,000	-3,411	30,000	2,240	16,250	731	13,333
		Left Saddle	732	16,000	-3,487	30,000	2,290	16,250	747	13,333

Saddle reactions due to weight + wind

Wind longitudinal reaction, Q_l	
Wind transverse reaction, Q_t	
Wind pressure, P_w	4.4 psf
Equations	

$V_{wt} = P_w \cdot G \cdot \left(C_{f(\text{shell})} \cdot (\text{Projected shell area}) + C_{f(\text{saddle})} \cdot (\text{Projected saddle area})\right)$
$V_{we} = P_w \cdot G \cdot \left(\dfrac{C_{f(\text{shell})} \cdot \pi \cdot R_o^2}{144} + C_{f(\text{saddle})} \cdot (\text{Projected saddle area})\right)$
$Q_t = \dfrac{V_{wt} \cdot H_s}{R_o \cdot \text{Sin}(\theta \ / \ 2)}$
$Q_l = \dfrac{V_{we} \cdot H_s}{L_s}$
$Q = W + \max\left[Q_t, Q_l\right]$

Results

Operating & New	Right Saddle	$V_{wt} = 4.4 \cdot 0.85 \cdot (8.8 \cdot 368.2644 + 2 \cdot 2.6354)$	12,140.03 lb_f
		$V_{we} = 4.4 \cdot 0.85 \cdot \left(\dfrac{0.5 \cdot \pi \cdot 91.375^{\ 2}}{144} + 2 \cdot 47.3344\right)$	694.69 lb_f
		$Q_t = \dfrac{12{,}140.03 \cdot 117}{85.375 \cdot \text{Sin}(120 \ / \ 2)}$	19,210.75 lb_f
		$Q_l = \dfrac{694.69 \cdot 117}{392}$	207.34 lb_f
		$Q = 101{,}551 + \max\left[19{,}210.75, 207.34\right]$	120,761.75 lb_f
	Left Saddle	$V_{wt} = 4.4 \cdot 0.85 \cdot (8.8 \cdot 368.2644 + 2 \cdot 2.6354)$	12,140.03 lb_f
		$V_{we} = 4.4 \cdot 0.85 \cdot \left(\dfrac{0.5 \cdot \pi \cdot 91.375^{\ 2}}{144} + 2 \cdot 47.3344\right)$	694.69 lb_f
		$Q_t = \dfrac{12{,}140.03 \cdot 117}{85.375 \cdot \text{Sin}(120 \ / \ 2)}$	19,210.75 lb_f
		$Q_l = \dfrac{694.69 \cdot 117}{392}$	207.34 lb_f
		$Q = 103{,}820 + \max\left[19{,}210.75, 207.34\right]$	123,030.75 lb_f
Operating & Corr	Right Saddle	$V_{wt} = 4.4 \cdot 0.85 \cdot (8.8 \cdot 368.2644 + 2 \cdot 2.6354)$	12,140.03 lb_f
		$V_{we} = 4.4 \cdot 0.85 \cdot \left(\dfrac{0.5 \cdot \pi \cdot 91.375^{\ 2}}{144} + 2 \cdot 47.3344\right)$	694.69 lb_f
		$Q_t = \dfrac{12{,}140.03 \cdot 117}{85.375 \cdot \text{Sin}(120 \ / \ 2)}$	19,210.75 lb_f
		$Q_l = \dfrac{694.69 \cdot 117}{392}$	207.34 lb_f
		$Q = 101{,}544 + \max\left[19{,}210.75, 207.34\right]$	120,754.75 lb_f
	Left Saddle	$V_{wt} = 4.4 \cdot 0.85 \cdot (8.8 \cdot 368.2644 + 2 \cdot 2.6354)$	12,140.03 lb_f
		$V_{we} = 4.4 \cdot 0.85 \cdot \left(\dfrac{0.5 \cdot \pi \cdot 91.375^{\ 2}}{144} + 2 \cdot 47.3344\right)$	694.69 lb_f
		$Q_t = \dfrac{12{,}140.03 \cdot 117}{85.375 \cdot \text{Sin}(120 \ / \ 2)}$	19,210.75 lb_f
		$Q_l = \dfrac{694.69 \cdot 117}{392}$	207.34 lb_f

		$Q = 103{,}801 + \max\left[19{,}210.75, 207.34\right]$	123,011.75 lb_f
Test	Right Saddle	$V_{wt} = 1.45 \cdot 0.85 \cdot (8.8 \cdot 368.2644 + 2 \cdot 2.6354)$	4,006.21 lb_f
		$V_{we} = 1.45 \cdot 0.85 \cdot \left(\frac{0.5 \cdot \pi \cdot 91.375^{\ 2}}{144} + 2 \cdot 47.3344\right)$	229.25 lb_f
		$Q_t = \frac{4{,}006.21 \cdot 117}{85.375 \cdot \mathrm{Sin}(120 \ / \ 2)}$	6,339.55 lb_f
		$Q_l = \frac{229.25 \cdot 117}{392}$	68.42 lb_f
		$Q = 329{,}333 + \max\left[6{,}339.55, 68.42\right]$	335,672.55 lb_f
	Left Saddle	$V_{wt} = 1.45 \cdot 0.85 \cdot (8.8 \cdot 368.2644 + 2 \cdot 2.6354)$	4,006.21 lb_f
		$V_{we} = 1.45 \cdot 0.85 \cdot \left(\frac{0.5 \cdot \pi \cdot 91.375^{\ 2}}{144} + 2 \cdot 47.3344\right)$	229.25 lb_f
		$Q_t = \frac{4{,}006.21 \cdot 117}{85.375 \cdot \mathrm{Sin}(120 \ / \ 2)}$	6,339.55 lb_f
		$Q_l = \frac{229.25 \cdot 117}{392}$	68.42 lb_f
		$Q = 336{,}813 + \max\left[6{,}339.55, 68.42\right]$	343,152.55 lb_f

Load Case 1: Wind, Operating & New

Longitudinal stress between saddles (Wind, Operating & New, left saddle loading and geometry govern)

$$S_1 = \pm \frac{3 \cdot K_1 \cdot Q \cdot (L \ / \ 12)}{\pi \cdot R^2 \cdot t} = \frac{3 \cdot 0.491 \cdot 123{,}030.75 \cdot (504 \ / \ 12)}{\pi \cdot 84.6875^{\ 2} \cdot 1.375} = 246 \ \ \mathrm{psi}$$

$$S_p = \frac{P \cdot R}{2 \cdot t} = \frac{255.74 \cdot 84}{2 \cdot 1.375} = 7{,}812 \ \ \mathrm{psi}$$

Maximum tensile stress S_{1t} = S_1 + S_p = 8,057 psi
Maximum compressive stress (shut down) S_{1c} = S_1 = 246 psi

Tensile stress is acceptable ($\leq 1.2 \cdot S \cdot E = 23{,}280 \ \ \mathrm{psi}$)

Compressive stress is acceptable ($\leq 1.2 \cdot S_c = 12{,}394 \ \ \mathrm{psi}$)

Longitudinal stress at the right saddle (Wind, Operating & New)

$$L_e = \frac{2 \cdot H_l}{3} + L + \frac{2 \cdot H_r}{3} = \frac{2 \cdot 43.3}{3} + 504 + \frac{2 \cdot 43.3}{3} = 561.7333 \ \ \mathrm{in}$$

$$w = \frac{W_t}{L_e} = \frac{205{,}371}{561.7333} = 365.6 \ \ \mathrm{lb}_f/\mathrm{in}$$

Bending moment at the right saddle:

$$M_q = w \cdot \left(\frac{2 \cdot H_r \cdot A_r}{3} + \frac{A_r^2}{2} - \frac{R^2 - H_r^2}{4}\right)$$

$$= 365.6 \cdot \left(\frac{2 \cdot 43.3 \cdot 56}{3} + \frac{56^2}{2} - \frac{85.375^{\ 2} - 43.3^{\ 2}}{4}\right)$$

$$= 669{,}429.9 \ \ \mathrm{lb}_f\text{-in}$$

$$S_2 = \pm\frac{M_q \cdot K_1'}{\pi \cdot R^2 \cdot t} = \frac{669{,}429.9 \cdot 9.3799}{\pi \cdot 84.6875^{\ 2} \cdot 1.375} = 203 \ \text{psi}$$

$$S_p = \frac{P \cdot R}{2 \cdot t} = \frac{255.74 \cdot 84}{2 \cdot 1.375} = 7{,}812 \ \text{psi}$$

Maximum tensile stress S_{2t} = S_2 + S_p = 8,014 psi
Maximum compressive stress (shut down) S_{2c} = S_2 = 203 psi

Tensile stress is acceptable ($\leq 1.2 \cdot S = 23{,}280 \ \text{psi}$)

Compressive stress is acceptable ($\leq 1.2 \cdot S_c = 12{,}394 \ \text{psi}$)

Tangential shear stress in the shell (right saddle, Wind, Operating & New)

$$Q_{shear} = Q - w \cdot \left(A_r + \frac{2 \cdot H_r}{3}\right) = 120{,}761.75 - 365.6 \cdot \left(56 + \frac{2 \cdot 43.3}{3}\right) = 89{,}734.3 \ \text{lb}_f$$

$$S_3 = \frac{K_{2.2} \cdot Q_{shear}}{R \cdot t} = \frac{1.1707 \cdot 89{,}734.3}{84.6875 \cdot 1.375} = 902 \ \text{psi}$$

Tangential shear stress is acceptable ($\leq 0.8 \cdot S = 15{,}520 \ \text{psi}$)

Circumferential stress at the right saddle horns (Wind, Operating & New)

$$S_4 = \frac{-Q}{4 \cdot t \cdot \left(b + 1.56 \cdot \sqrt{R_o \cdot t}\right)} - \frac{12 \cdot K_3 \cdot Q \cdot R}{L \cdot t^2}$$
$$= \frac{-120{,}761.75}{4 \cdot 1.375 \cdot \left(12 + 1.56 \cdot \sqrt{85.375 \cdot 1.375}\right)} - \frac{12 \cdot 0.0256 \cdot 120{,}761.75 \cdot 84.6875}{504 \cdot 1.375^{\ 2}}$$
$$= -4{,}057 \ \text{psi}$$

Circumferential stress at saddle horns is acceptable ($\leq 1.5 \cdot S_a = 29{,}100 \ \text{psi}$)

The wear plate was not considered in the calculation of S_4 because the wear plate width is not at least $\left\{b + 1.56 \cdot \sqrt{R_o \cdot t}\right\} = 28.9021 \ \text{in}$

Ring compression in shell over right saddle (Wind, Operating & New)

$$S_5 = \frac{K_5 \cdot Q}{\left(t + t_p\right) \cdot \left(t_s + 1.56 \cdot \sqrt{R_o \cdot t_c}\right)}$$
$$= \frac{0.7603 \cdot 120{,}761.75}{\left(1.375 + 0.375\right) \cdot \left(0.625 + 1.56 \cdot \sqrt{85.375 \cdot 1.75}\right)}$$
$$= 2{,}664 \ \text{psi}$$

Ring compression in shell is acceptable ($\leq 0.5 \cdot S_y = 14{,}550 \ \text{psi}$)

Saddle splitting load (right, Wind, Operating & New)

Area resisting splitting force = Web area + wear plate area

$A_e = H_{eff} \cdot t_s + t_p \cdot W_p = 28.4583 \cdot 0.625 + 0.375 \cdot 28$ = 28.2865 in^2

$$S_6 = \frac{K_8 \cdot Q}{A_e} = \frac{0.2035 \cdot 120{,}761.75}{28.2865} = 869 \ \text{psi}$$

Stress in saddle is acceptable $\left(\leq \frac{2}{3} \cdot S_s = 13{,}333 \ \text{psi}\right)$

Longitudinal stress at the left saddle (Wind, Operating & New)

$$L_e = \frac{2 \cdot H_l}{3} + L + \frac{2 \cdot H_r}{3} = \frac{2 \cdot 43.3}{3} + 504 + \frac{2 \cdot 43.3}{3} = 561.7333 \ \text{in}$$

$$w = \frac{W_t}{L_e} = \frac{205{,}371}{561.7333} = 365.6 \quad \text{lb}_f/\text{in}$$

Bending moment at the left saddle:

$$M_q = w \cdot \left(\frac{2 \cdot H_l \cdot A_l}{3} + \frac{A_l^2}{2} - \frac{R^2 - H_l^2}{4} \right)$$

$$= 365.6 \cdot \left(\frac{2 \cdot 43.3 \cdot 56}{3} + \frac{56^{\,2}}{2} - \frac{85.375^{\,2} - 43.3^{\,2}}{4} \right)$$

$$= 669{,}429.9 \quad \text{lb}_f\text{-in}$$

$$S_2 = \pm \frac{M_q \cdot K_1{}'}{\pi \cdot R^2 \cdot t} = \frac{669{,}429.9 \cdot 9.3799}{\pi \cdot 84.6875^{\,2} \cdot 1.375} = 203 \quad \text{psi}$$

$$S_p = \frac{P \cdot R}{2 \cdot t} = \frac{255.74 \cdot 84}{2 \cdot 1.375} = 7{,}812 \quad \text{psi}$$

Maximum tensile stress $S_{2t} = S_2 + S_p$ = 8,014 psi
Maximum compressive stress (shut down) $S_{2c} = S_2$ = 203 psi

Tensile stress is acceptable ($\leq 1.2 \cdot S = 23{,}280$ psi)

Compressive stress is acceptable ($\leq 1.2 \cdot S_c = 12{,}394$ psi)

Tangential shear stress in the shell (left saddle, Wind, Operating & New)

$$Q_{shear} = Q - w \cdot \left(A_l + \frac{2 \cdot H_l}{3} \right) = 123{,}030.75 - 365.6 \cdot \left(56 + \frac{2 \cdot 43.3}{3} \right) = 92{,}003.3 \quad \text{lb}_f$$

$$S_3 = \frac{K_{2.2} \cdot Q_{shear}}{R \cdot t} = \frac{1.1707 \cdot 92{,}003.3}{84.6875 \cdot 1.375} = 925 \quad \text{psi}$$

Tangential shear stress is acceptable ($\leq 0.8 \cdot S = 15{,}520$ psi)

Circumferential stress at the left saddle horns (Wind, Operating & New)

$$S_4 = \frac{-Q}{4 \cdot t \cdot \left(b + 1.56 \cdot \sqrt{R_o \cdot t}\right)} - \frac{12 \cdot K_3 \cdot Q \cdot R}{L \cdot t^2}$$

$$= \frac{-123{,}030.75}{4 \cdot 1.375 \cdot \left(12 + 1.56 \cdot \sqrt{85.375 \cdot 1.375}\right)} - \frac{12 \cdot 0.0256 \cdot 123{,}030.75 \cdot 84.6875}{504 \cdot 1.375^{\,2}}$$

$$= -4{,}133 \quad \text{psi}$$

Circumferential stress at saddle horns is acceptable ($\leq 1.5 \cdot S_a = 29{,}100$ psi)

The wear plate was not considered in the calculation of S_4 because the wear plate width is not at least $\left\{b + 1.56 \cdot \sqrt{R_o \cdot t}\right\} = 28.9021$ in

Ring compression in shell over left saddle (Wind, Operating & New)

$$S_5 = \frac{K_5 \cdot Q}{(t + t_p) \cdot \left(t_s + 1.56 \cdot \sqrt{R_o \cdot t_c}\right)}$$

$$= \frac{0.7603 \cdot 123{,}030.75}{(1.375 + 0.375) \cdot \left(0.625 + 1.56 \cdot \sqrt{85.375 \cdot 1.75}\right)}$$

$$= 2{,}714 \quad \text{psi}$$

Ring compression in shell is acceptable ($\leq 0.5 \cdot S_y = 14{,}550$ psi)

Saddle splitting load (left, Wind, Operating & New)

Area resisting splitting force = Web area + wear plate area

$A_e = H_{eff} \cdot t_s + t_p \cdot W_p = 28.4583 \cdot 0.625 + 0.375 \cdot 28$ = 28.2865 in^2

$$S_6 = \frac{K_8 \cdot Q}{A_e} = \frac{0.2035 \cdot 123{,}030.75}{28.2865} = 885 \text{ psi}$$

Stress in saddle is acceptable $\left(\leq \frac{2}{3} \cdot S_s = 13{,}333 \text{ psi}\right)$

Load Case 2: Wind, Operating & Corr

Longitudinal stress between saddles (Wind, Operating & Corr, left saddle loading and geometry govern)

$$S_1 = \pm \frac{3 \cdot K_1 \cdot Q \cdot (L \ / \ 12)}{\pi \cdot R^2 \cdot t} = \frac{3 \cdot 0.491 \cdot 123{,}011.75 \cdot (504 \ / \ 12)}{\pi \cdot 84.6875^{\ 2} \cdot 1.375} = 246 \text{ psi}$$

$$S_p = \frac{P \cdot R}{2 \cdot t} = \frac{255.74 \cdot 84}{2 \cdot 1.375} = 7{,}812 \text{ psi}$$

Maximum tensile stress $S_{1t} = S_1 + S_p$ = 8,057 psi
Maximum compressive stress (shut down) $S_{1c} = S_1$ = 246 psi

Tensile stress is acceptable ($\leq 1.2 \cdot S \cdot E = 23{,}280 \text{ psi}$)

Compressive stress is acceptable ($\leq 1.2 \cdot S_c = 12{,}394 \text{ psi}$)

Longitudinal stress at the right saddle (Wind, Operating & Corr)

$$L_e = \frac{2 \cdot H_l}{3} + L + \frac{2 \cdot H_r}{3} = \frac{2 \cdot 43.3}{3} + 504 + \frac{2 \cdot 43.3}{3} = 561.7333 \text{ in}$$

$$w = \frac{W_t}{L_e} = \frac{205{,}345}{561.7333} = 365.56 \text{ lb}_f\text{/in}$$

Bending moment at the right saddle:

$$M_q = w \cdot \left(\frac{2 \cdot H_r \cdot A_r}{3} + \frac{A_r^2}{2} - \frac{R^2 - H_r^2}{4} \right)$$
$$= 365.56 \cdot \left(\frac{2 \cdot 43.3 \cdot 56}{3} + \frac{56^2}{2} - \frac{85.375^{\ 2} - 43.3^{\ 2}}{4} \right)$$
$$= 669{,}345.2 \text{ lb}_f\text{-in}$$

$$S_2 = \pm \frac{M_q \cdot K_1'}{\pi \cdot R^2 \cdot t} = \frac{669{,}345.2 \cdot 9.3799}{\pi \cdot 84.6875^{\ 2} \cdot 1.375} = 203 \text{ psi}$$

$$S_p = \frac{P \cdot R}{2 \cdot t} = \frac{255.74 \cdot 84}{2 \cdot 1.375} = 7{,}812 \text{ psi}$$

Maximum tensile stress $S_{2t} = S_2 + S_p$ = 8,014 psi
Maximum compressive stress (shut down) $S_{2c} = S_2$ = 203 psi

Tensile stress is acceptable ($\leq 1.2 \cdot S = 23{,}280 \text{ psi}$)

Compressive stress is acceptable ($\leq 1.2 \cdot S_c = 12{,}394 \text{ psi}$)

Tangential shear stress in the shell (right saddle, Wind, Operating & Corr)

$$Q_{shear} = Q - w \cdot \left(A_r + \frac{2 \cdot H_r}{3} \right) = 120{,}754.75 - 365.56 \cdot \left(56 + \frac{2 \cdot 43.3}{3} \right) = 89{,}731.23 \text{ lb}_f$$

$$S_3 = \frac{K_{2.2} \cdot Q_{shear}}{R \cdot t} = \frac{1.1707 \cdot 89{,}731.23}{84.6875 \cdot 1.375} = 902 \text{ psi}$$

Tangential shear stress is acceptable ($\leq 0.8 \cdot S = 15{,}520 \text{ psi}$)

Circumferential stress at the right saddle horns (Wind, Operating & Corr)

$$S_4 = \frac{-Q}{4 \cdot t \cdot \left(b + 1.56 \cdot \sqrt{R_o \cdot t}\right)} - \frac{12 \cdot K_3 \cdot Q \cdot R}{L \cdot t^2}$$

$$= \frac{-120{,}754.75}{4 \cdot 1.375 \cdot \left(12 + 1.56 \cdot \sqrt{85.375 \cdot 1.375}\right)} - \frac{12 \cdot 0.0256 \cdot 120{,}754.75 \cdot 84.6875}{504 \cdot 1.375^2}$$

$$= \underline{-4{,}057} \text{ psi}$$

Circumferential stress at saddle horns is acceptable ($\leq 1.5 \cdot S_a = 29{,}100 \text{ psi}$)

The wear plate was not considered in the calculation of S_4 because the wear plate width is not at least $\left\{b + 1.56 \cdot \sqrt{R_o \cdot t}\right\} = 28.9021 \text{ in}$

Ring compression in shell over right saddle (Wind, Operating & Corr)

$$S_5 = \frac{K_5 \cdot Q}{(t + t_p) \cdot \left(t_s + 1.56 \cdot \sqrt{R_o \cdot t_c}\right)}$$

$$= \frac{0.7603 \cdot 120{,}754.75}{(1.375 + 0.375) \cdot \left(0.625 + 1.56 \cdot \sqrt{85.375 \cdot 1.75}\right)}$$

$$= \underline{2{,}664} \text{ psi}$$

Ring compression in shell is acceptable ($\leq 0.5 \cdot S_y = 14{,}550 \text{ psi}$)

Saddle splitting load (right, Wind, Operating & Corr)

Area resisting splitting force = Web area + wear plate area

$$A_e = H_{eff} \cdot t_s + t_p \cdot W_p = 28.4583 \cdot 0.625 + 0.375 \cdot 28 = 28.2865 \text{ in}^2$$

$$S_6 = \frac{K_8 \cdot Q}{A_e} = \frac{0.2035 \cdot 120{,}754.75}{28.2865} = \underline{869} \text{ psi}$$

Stress in saddle is acceptable $\left(\leq \frac{2}{3} \cdot S_s = 13{,}333 \text{ psi}\right)$

Longitudinal stress at the left saddle (Wind, Operating & Corr)

$$L_e = \frac{2 \cdot H_l}{3} + L + \frac{2 \cdot H_r}{3} = \frac{2 \cdot 43.3}{3} + 504 + \frac{2 \cdot 43.3}{3} = 561.7333 \text{ in}$$

$$w = \frac{W_t}{L_e} = \frac{205{,}345}{561.7333} = 365.56 \text{ lb}_f/\text{in}$$

Bending moment at the left saddle:

$$M_q = w \cdot \left(\frac{2 \cdot H_l \cdot A_l}{3} + \frac{A_l^2}{2} - \frac{R^2 - H_l^2}{4}\right)$$

$$= 365.56 \cdot \left(\frac{2 \cdot 43.3 \cdot 56}{3} + \frac{56^2}{2} - \frac{85.375^2 - 43.3^2}{4}\right)$$

$$= 669{,}345.2 \text{ lb}_f\text{-in}$$

$$S_2 = \pm \frac{M_q \cdot K_1{}'}{\pi \cdot R^2 \cdot t} = \frac{669{,}345.2 \cdot 9.3799}{\pi \cdot 84.6875^2 \cdot 1.375} = 203 \text{ psi}$$

$$S_p = \frac{P \cdot R}{2 \cdot t} = \frac{255.74 \cdot 84}{2 \cdot 1.375} = 7{,}812 \text{ psi}$$

Maximum tensile stress S_{2t} = S_2 + S_p = 8,014 psi
Maximum compressive stress (shut down) S_{2c} = S_2 = 203 psi

Tensile stress is acceptable ($\leq 1.2 \cdot S = 23{,}280$ psi)

Compressive stress is acceptable ($\leq 1.2 \cdot S_c = 12{,}394$ psi)

Tangential shear stress in the shell (left saddle, Wind, Operating & Corr)

$$Q_{shear} = Q - w \cdot \left(A_l + \frac{2 \cdot H_l}{3}\right) = 123{,}011.75 - 365.56 \cdot \left(56 + \frac{2 \cdot 43.3}{3}\right) = 91{,}988.23 \ \text{lb}_f$$

$$S_3 = \frac{K_{2.2} \cdot Q_{shear}}{R \cdot t} = \frac{1.1707 \cdot 91{,}988.23}{84.6875 \cdot 1.375} = 925 \ \text{psi}$$

Tangential shear stress is acceptable ($\leq 0.8 \cdot S = 15{,}520$ psi)

Circumferential stress at the left saddle horns (Wind, Operating & Corr)

$$S_4 = \frac{-Q}{4 \cdot t \cdot \left(b + 1.56 \cdot \sqrt{R_o \cdot t}\right)} - \frac{12 \cdot K_3 \cdot Q \cdot R}{L \cdot t^2}$$

$$= \frac{-123{,}011.75}{4 \cdot 1.375 \cdot \left(12 + 1.56 \cdot \sqrt{85.375 \cdot 1.375}\right)} - \frac{12 \cdot 0.0256 \cdot 123{,}011.75 \cdot 84.6875}{504 \cdot 1.375^2}$$

$$= -4{,}132 \ \text{psi}$$

Circumferential stress at saddle horns is acceptable ($\leq 1.5 \cdot S_a = 29{,}100$ psi)

The wear plate was not considered in the calculation of S_4 because the wear plate width is not at least $\left\{b + 1.56 \cdot \sqrt{R_o \cdot t}\right\} = 28.9021$ in

Ring compression in shell over left saddle (Wind, Operating & Corr)

$$S_5 = \frac{K_5 \cdot Q}{(t + t_p) \cdot \left(t_s + 1.56 \cdot \sqrt{R_o \cdot t_c}\right)}$$

$$= \frac{0.7603 \cdot 123{,}011.75}{(1.375 + 0.375) \cdot \left(0.625 + 1.56 \cdot \sqrt{85.375 \cdot 1.75}\right)}$$

$$= 2{,}714 \ \text{psi}$$

Ring compression in shell is acceptable ($\leq 0.5 \cdot S_y = 14{,}550$ psi)

Saddle splitting load (left, Wind, Operating & Corr)

Area resisting splitting force = Web area + wear plate area

$A_e = H_{eff} \cdot t_s + t_p \cdot W_p = 28.4583 \cdot 0.625 + 0.375 \cdot 28$ = 28.2865 in^2

$$S_6 = \frac{K_8 \cdot Q}{A_e} = \frac{0.2035 \cdot 123{,}011.75}{28.2865} = 885 \ \text{psi}$$

Stress in saddle is acceptable $\left(\leq \frac{2}{3} \cdot S_s = 13{,}333 \ \text{psi}\right)$

Load Case 3: Wind, Test

Longitudinal stress between saddles (Wind, Test, left saddle loading and geometry govern)

$$S_1 = \pm \frac{3 \cdot K_1 \cdot Q \cdot (L \ / \ 12)}{\pi \cdot R^2 \cdot t} = \frac{3 \cdot 0.491 \cdot 343{,}152.55 \cdot (504 \ / \ 12)}{\pi \cdot 84.6875^2 \cdot 1.375} = 685 \ \text{psi}$$

$$S_p = \frac{P \cdot R}{2 \cdot t} = \frac{339.93 \cdot 84}{2 \cdot 1.375} = 10{,}383 \ \text{psi}$$

Maximum tensile stress $S_{1t} = S_1 + S_p$ = 11,069 psi
Maximum compressive stress (shut down) $S_{1c} = S_1$ = 685 psi

Tensile stress is acceptable ($\leq 0.9 \cdot S_y \cdot E = 34{,}200 \;\; \text{psi}$)

Compressive stress is acceptable ($\leq 1.2 \cdot S_c = 18{,}022 \;\; \text{psi}$)

Longitudinal stress at the right saddle (Wind, Test)

$$L_e = \frac{2 \cdot H_l}{3} + L + \frac{2 \cdot H_r}{3} = \frac{2 \cdot 43.3}{3} + 504 + \frac{2 \cdot 43.3}{3} = 561.7333 \;\; \text{in}$$

$$w = \frac{W_t}{L_e} = \frac{666{,}146}{561.7333} = 1{,}185.88 \;\; \text{lb}_f/\text{in}$$

Bending moment at the right saddle:

$$M_q = w \cdot \left(\frac{2 \cdot H_r \cdot A_r}{3} + \frac{A_r^2}{2} - \frac{R^2 - H_r^2}{4} \right)$$
$$= 1{,}185.88 \cdot \left(\frac{2 \cdot 43.3 \cdot 56}{3} + \frac{56^2}{2} - \frac{85.375^{\;2} - 43.3^{\;2}}{4} \right)$$
$$= 2{,}171{,}378 \;\; \text{lb}_f\text{-in}$$

$$S_2 = \pm \frac{M_q \cdot K_1{}'}{\pi \cdot R^2 \cdot t} = \frac{2{,}171{,}378 \cdot 9.3799}{\pi \cdot 84.6875^{\;2} \cdot 1.375} = 657 \;\; \text{psi}$$

$$S_p = \frac{P \cdot R}{2 \cdot t} = \frac{339.93 \cdot 84}{2 \cdot 1.375} = 10{,}383 \;\; \text{psi}$$

Maximum tensile stress $S_{2t} = S_2 + S_p$ = 11,041 psi
Maximum compressive stress (shut down) $S_{2c} = S_2$ = 657 psi

Tensile stress is acceptable ($\leq 0.9 \cdot S_y = 34{,}200 \;\; \text{psi}$)

Compressive stress is acceptable ($\leq 1.2 \cdot S_c = 18{,}022 \;\; \text{psi}$)

Tangential shear stress in the shell (right saddle, Wind, Test)

$$Q_{shear} = Q - w \cdot \left(A_r + \frac{2 \cdot H_r}{3} \right) = 335{,}672.55 - 1{,}185.88 \cdot \left(56 + \frac{2 \cdot 43.3}{3} \right) = 235{,}031.22 \;\; \text{lb}_f$$

$$S_3 = \frac{K_{2.2} \cdot Q_{shear}}{R \cdot t} = \frac{1.1707 \cdot 235{,}031.22}{84.6875 \cdot 1.375} = 2{,}363 \;\; \text{psi}$$

Tangential shear stress is acceptable ($\leq 0.8 \cdot (0.9 \cdot S_y) = 27{,}360 \;\; \text{psi}$)

Circumferential stress at the right saddle horns (Wind, Test)

$$S_4 = \frac{-Q}{4 \cdot t \cdot \left(b + 1.56 \cdot \sqrt{R_o \cdot t}\right)} - \frac{12 \cdot K_3 \cdot Q \cdot R}{L \cdot t^2}$$
$$= \frac{-335{,}672.55}{4 \cdot 1.375 \cdot \left(12 + 1.56 \cdot \sqrt{85.375 \cdot 1.375}\right)} - \frac{12 \cdot 0.0256 \cdot 335{,}672.55 \cdot 84.6875}{504 \cdot 1.375^{\;2}}$$
$$= -11{,}276 \;\; \text{psi}$$

Circumferential stress at saddle horns is acceptable ($\leq 0.9 \cdot S_y = 34{,}200 \;\; \text{psi}$)

The wear plate was not considered in the calculation of S_4 because the wear plate width is not at least $\left\{b + 1.56 \cdot \sqrt{R_o \cdot t}\right\} = 28.9021 \;\; \text{in}$

Ring compression in shell over right saddle (Wind, Test)

$$S_5 = \frac{K_5 \cdot Q}{(t + t_p) \cdot (t_s + 1.56 \cdot \sqrt{R_o \cdot t_c})}$$

$$= \frac{0.7603 \cdot 335{,}672.55}{(1.375 + 0.375) \cdot (0.625 + 1.56 \cdot \sqrt{85.375 \cdot 1.75})}$$

$= 7{,}405$ psi

Ring compression in shell is acceptable ($\leq 0.9 \cdot S_y = 34{,}200$ psi)

Saddle splitting load (right, Wind, Test)

Area resisting splitting force = Web area + wear plate area

$A_e = H_{eff} \cdot t_s + t_p \cdot W_p = 28.4583 \cdot 0.625 + 0.375 \cdot 28$ = 28.2865 in^2

$$S_6 = \frac{K_8 \cdot Q}{A_e} = \frac{0.2035 \cdot 335{,}672.55}{28.2865} = 2{,}415 \text{ psi}$$

Stress in saddle is acceptable ($\leq 0.9 \cdot S_y = 34{,}200$ psi)

Longitudinal stress at the left saddle (Wind, Test)

$$L_e = \frac{2 \cdot H_l}{3} + L + \frac{2 \cdot H_r}{3} = \frac{2 \cdot 43.3}{3} + 504 + \frac{2 \cdot 43.3}{3} = 561.7333 \text{ in}$$

$$w = \frac{W_t}{L_e} = \frac{666{,}146}{561.7333} = 1{,}185.88 \text{ lb}_f\text{/in}$$

Bending moment at the left saddle:

$$M_q = w \cdot \left(\frac{2 \cdot H_l \cdot A_l}{3} + \frac{A_l^2}{2} - \frac{R^2 - H_l^2}{4} \right)$$

$$= 1{,}185.88 \cdot \left(\frac{2 \cdot 43.3 \cdot 56}{3} + \frac{56^2}{2} - \frac{85.375^2 - 43.3^2}{4} \right)$$

$= 2{,}171{,}378$ lb$_f$-in

$$S_2 = \pm \frac{M_q \cdot K_1{}'}{\pi \cdot R^2 \cdot t} = \frac{2{,}171{,}378 \cdot 9.3799}{\pi \cdot 84.6875^2 \cdot 1.375} = 657 \text{ psi}$$

$$S_p = \frac{P \cdot R}{2 \cdot t} = \frac{339.93 \cdot 84}{2 \cdot 1.375} = 10{,}383 \text{ psi}$$

Maximum tensile stress $S_{2t} = S_2 + S_p$ = 11,041 psi
Maximum compressive stress (shut down) $S_{2c} = S_2$ = 657 psi

Tensile stress is acceptable ($\leq 0.9 \cdot S_y = 34{,}200$ psi)

Compressive stress is acceptable ($\leq 1.2 \cdot S_c = 18{,}022$ psi)

Tangential shear stress in the shell (left saddle, Wind, Test)

$$Q_{shear} = Q - w \cdot \left(A_l + \frac{2 \cdot H_l}{3} \right) = 343{,}152.55 - 1{,}185.88 \cdot \left(56 + \frac{2 \cdot 43.3}{3} \right) = 242{,}511.22 \text{ lb}_f$$

$$S_3 = \frac{K_{2.2} \cdot Q_{shear}}{R \cdot t} = \frac{1.1707 \cdot 242{,}511.22}{84.6875 \cdot 1.375} = 2{,}438 \text{ psi}$$

Tangential shear stress is acceptable ($\leq 0.8 \cdot (0.9 \cdot S_y) = 27{,}360$ psi)

Circumferential stress at the left saddle horns (Wind, Test)

$$S_4 = \frac{-Q}{4 \cdot t \cdot \left(b + 1.56 \cdot \sqrt{R_o \cdot t}\right)} - \frac{12 \cdot K_3 \cdot Q \cdot R}{L \cdot t^2}$$

$$= \frac{-343{,}152.55}{4 \cdot 1.375 \cdot \left(12 + 1.56 \cdot \sqrt{85.375 \cdot 1.375}\right)} - \frac{12 \cdot 0.0256 \cdot 343{,}152.55 \cdot 84.6875}{504 \cdot 1.375^{2}}$$

$= \underline{-11{,}528}$ psi

Circumferential stress at saddle horns is acceptable ($\leq 0.9 \cdot S_y = 34{,}200$ psi)

The wear plate was not considered in the calculation of S_4 because the wear plate width is not at least $\left\{b + 1.56 \cdot \sqrt{R_o \cdot t}\right\} = 28.9021$ in

Ring compression in shell over left saddle (Wind, Test)

$$S_5 = \frac{K_5 \cdot Q}{(t + t_p) \cdot \left(t_s + 1.56 \cdot \sqrt{R_o \cdot t_c}\right)}$$

$$= \frac{0.7603 \cdot 343{,}152.55}{(1.375 + 0.375) \cdot \left(0.625 + 1.56 \cdot \sqrt{85.375 \cdot 1.75}\right)}$$

$= \underline{7{,}570}$ psi

Ring compression in shell is acceptable ($\leq 0.9 \cdot S_y = 34{,}200$ psi)

Saddle splitting load (left, Wind, Test)

Area resisting splitting force = Web area + wear plate area

$A_e = H_{eff} \cdot t_s + t_p \cdot W_p = 28.4583 \cdot 0.625 + 0.375 \cdot 28$ = 28.2865 in^2

$$S_6 = \frac{K_8 \cdot Q}{A_e} = \frac{0.2035 \cdot 343{,}152.55}{28.2865} = \underline{2{,}469} \text{ psi}$$

Stress in saddle is acceptable ($\leq 0.9 \cdot S_y = 34{,}200$ psi)

Load Case 4: Wind, Vacuum

Longitudinal stress between saddles (Wind, Vacuum, left saddle loading and geometry govern)

$$S_1 = \pm \frac{3 \cdot K_1 \cdot Q \cdot (L \;/\; 12)}{\pi \cdot R^2 \cdot t} = \frac{3 \cdot 0.491 \cdot 123{,}011.75 \cdot (504 \;/\; 12)}{\pi \cdot 84.6875^{2} \cdot 1.375} = 246 \text{ psi}$$

$$S_p = \frac{P \cdot R}{2 \cdot t} = \frac{15 \cdot 84}{2 \cdot 1.375} = 458 \text{ psi}$$

Maximum tensile stress (shut down) S_{1t} = S_1 = 246 psi
Maximum compressive stress S_{1c} = S_1 + S_p = 704 psi

Tensile stress is acceptable ($\leq 1.2 \cdot S \cdot E = 24{,}000$ psi)

Compressive stress is acceptable ($\leq 1.2 \cdot S_c = 15{,}766$ psi)

Longitudinal stress at the right saddle (Wind, Vacuum)

$$L_e = \frac{2 \cdot H_l}{3} + L + \frac{2 \cdot H_r}{3} = \frac{2 \cdot 43.3}{3} + 504 + \frac{2 \cdot 43.3}{3} = 561.7333 \text{ in}$$

$$w = \frac{W_t}{L_e} = \frac{205{,}345}{561.7333} = 365.56 \text{ lb}_f/\text{in}$$

Bending moment at the right saddle:

$$M_q = w \cdot \left(\frac{2 \cdot H_r \cdot A_r}{3} + \frac{A_r^2}{2} - \frac{R^2 - H_r^2}{4}\right)$$

$$= 365.56 \cdot \left(\frac{2 \cdot 43.3 \cdot 56}{3} + \frac{56^2}{2} - \frac{85.375^{2} - 43.3^{2}}{4}\right)$$

$= 669{,}345.2 \;\; lb_f\text{-in}$

$$S_2 = \pm\frac{M_q \cdot K_1{}'}{\pi \cdot R^2 \cdot t} = \frac{669{,}345.2 \cdot 9.3799}{\pi \cdot 84.6875^{\,2} \cdot 1.375} = 203 \;\; \text{psi}$$

$$S_p = \frac{P \cdot R}{2 \cdot t} = \frac{15 \cdot 84}{2 \cdot 1.375} = 458 \;\; \text{psi}$$

Maximum tensile stress (shut down) S_{2t} = S_2 = 203 psi
Maximum compressive stress S_{2c} = S_2 + S_p = 661 psi

Tensile stress is acceptable ($\leq 1.2 \cdot S = 24{,}000$ psi)

Compressive stress is acceptable ($\leq 1.2 \cdot S_c = 15{,}766$ psi)

Tangential shear stress in the shell (right saddle, Wind, Vacuum)

$$Q_{shear} = Q - w \cdot \left(A_r + \frac{2 \cdot H_r}{3}\right) = 120{,}754.75 - 365.56 \cdot \left(56 + \frac{2 \cdot 43.3}{3}\right) = 89{,}731.23 \;\; lb_f$$

$$S_3 = \frac{K_{2.2} \cdot Q_{shear}}{R \cdot t} = \frac{1.1707 \cdot 89{,}731.23}{84.6875 \cdot 1.375} = 902 \;\; \text{psi}$$

Tangential shear stress is acceptable ($\leq 0.8 \cdot S = 16{,}000$ psi)

Circumferential stress at the right saddle horns (Wind, Vacuum)

$$S_4 = \frac{-Q}{4 \cdot t \cdot \left(b + 1.56 \cdot \sqrt{R_o \cdot t}\right)} - \frac{12 \cdot K_3 \cdot Q \cdot R}{L \cdot t^2}$$

$$= \frac{-120{,}754.75}{4 \cdot 1.375 \cdot \left(12 + 1.56 \cdot \sqrt{85.375 \cdot 1.375}\right)} - \frac{12 \cdot 0.0256 \cdot 120{,}754.75 \cdot 84.6875}{504 \cdot 1.375^{\,2}}$$

$= -4{,}057$ psi

Circumferential stress at saddle horns is acceptable ($\leq 1.5 \cdot S_a = 30{,}000$ psi)

The wear plate was not considered in the calculation of S_4 because the wear plate width is not at least $\left\{b + 1.56 \cdot \sqrt{R_o \cdot t}\right\} = 28.9021$ in

Ring compression in shell over right saddle (Wind, Vacuum)

$$S_5 = \frac{K_5 \cdot Q}{(t + t_p) \cdot \left(t_s + 1.56 \cdot \sqrt{R_o \cdot t_c}\right)}$$

$$= \frac{0.7603 \cdot 120{,}754.75}{(1.375 + 0.375) \cdot \left(0.625 + 1.56 \cdot \sqrt{85.375 \cdot 1.75}\right)}$$

$= 2{,}664$ psi

Ring compression in shell is acceptable ($\leq 0.5 \cdot S_y = 16{,}250$ psi)

Saddle splitting load (right, Wind, Vacuum)

Area resisting splitting force = Web area + wear plate area

$A_e = H_{eff} \cdot t_s + t_p \cdot W_p = 28.4583 \cdot 0.625 + 0.375 \cdot 28$ = 28.2865 in^2

$$S_6 = \frac{K_8 \cdot Q}{A_e} = \frac{0.2035 \cdot 120{,}754.75}{28.2865} = 869 \;\; \text{psi}$$

Stress in saddle is acceptable $\left(\leq \frac{2}{3} \cdot S_s = 13{,}333 \;\; \text{psi}\right)$

Longitudinal stress at the left saddle (Wind, Vacuum)

$$L_e = \frac{2 \cdot H_l}{3} + L + \frac{2 \cdot H_r}{3} = \frac{2 \cdot 43.3}{3} + 504 + \frac{2 \cdot 43.3}{3} = 561.7333 \text{ in}$$

$$w = \frac{W_t}{L_e} = \frac{205{,}345}{561.7333} = 365.56 \text{ lb}_f/\text{in}$$

Bending moment at the left saddle:

$$M_q = w \cdot \left(\frac{2 \cdot H_l \cdot A_l}{3} + \frac{A_l^2}{2} - \frac{R^2 - H_l^2}{4} \right)$$

$$= 365.56 \cdot \left(\frac{2 \cdot 43.3 \cdot 56}{3} + \frac{56^2}{2} - \frac{85.375^{\ 2} - 43.3^{\ 2}}{4} \right)$$

$$= 669{,}345.2 \text{ lb}_f\text{-in}$$

$$S_2 = \pm \frac{M_q \cdot K_1{}'}{\pi \cdot R^2 \cdot t} = \frac{669{,}345.2 \cdot 9.3799}{\pi \cdot 84.6875^{\ 2} \cdot 1.375} = 203 \text{ psi}$$

$$S_p = \frac{P \cdot R}{2 \cdot t} = \frac{15 \cdot 84}{2 \cdot 1.375} = 458 \text{ psi}$$

Maximum tensile stress (shut down) S_{2t} = S_2 = 203 psi
Maximum compressive stress S_{2c} = S_2 + S_p = 661 psi

Tensile stress is acceptable ($\le 1.2 \cdot S = 24{,}000$ psi)

Compressive stress is acceptable ($\le 1.2 \cdot S_c = 15{,}766$ psi)

Tangential shear stress in the shell (left saddle, Wind, Vacuum)

$$Q_{shear} = Q - w \cdot \left(A_l + \frac{2 \cdot H_l}{3} \right) = 123{,}011.75 - 365.56 \cdot \left(56 + \frac{2 \cdot 43.3}{3} \right) = 91{,}988.23 \text{ lb}_f$$

$$S_3 = \frac{K_{2.2} \cdot Q_{shear}}{R \cdot t} = \frac{1.1707 \cdot 91{,}988.23}{84.6875 \cdot 1.375} = 925 \text{ psi}$$

Tangential shear stress is acceptable ($\le 0.8 \cdot S = 16{,}000$ psi)

Circumferential stress at the left saddle horns (Wind, Vacuum)

$$S_4 = \frac{-Q}{4 \cdot t \cdot \left(b + 1.56 \cdot \sqrt{R_o \cdot t}\right)} - \frac{12 \cdot K_3 \cdot Q \cdot R}{L \cdot t^2}$$

$$= \frac{-123{,}011.75}{4 \cdot 1.375 \cdot \left(12 + 1.56 \cdot \sqrt{85.375 \cdot 1.375}\right)} - \frac{12 \cdot 0.0256 \cdot 123{,}011.75 \cdot 84.6875}{504 \cdot 1.375^{\ 2}}$$

$$= -4{,}132 \text{ psi}$$

Circumferential stress at saddle horns is acceptable ($\le 1.5 \cdot S_a = 30{,}000$ psi)

The wear plate was not considered in the calculation of S_4 because the wear plate width is not at least $\left\{b + 1.56 \cdot \sqrt{R_o \cdot t}\right\} = 28.9021$ in

Ring compression in shell over left saddle (Wind, Vacuum)

$$S_5 = \frac{K_5 \cdot Q}{(t + t_p) \cdot \left(t_s + 1.56 \cdot \sqrt{R_o \cdot t_c}\right)}$$

$$= \frac{0.7603 \cdot 123{,}011.75}{(1.375 + 0.375) \cdot \left(0.625 + 1.56 \cdot \sqrt{85.375 \cdot 1.75}\right)}$$

$$= 2{,}714 \text{ psi}$$

Ring compression in shell is acceptable ($\le 0.5 \cdot S_y = 16{,}250$ psi)

Saddle splitting load (left, Wind, Vacuum)

Area resisting splitting force = Web area + wear plate area

$A_e = H_{eff} \cdot t_s + t_p \cdot W_p = 28.4583 \cdot 0.625 + 0.375 \cdot 28$ = 28.2865 in^2

$$S_6 = \frac{K_8 \cdot Q}{A_e} = \frac{0.2035 \cdot 123{,}011.75}{28.2865} = 885 \text{ psi}$$

Stress in saddle is acceptable $\left(\leq \frac{2}{3} \cdot S_s = 13{,}333 \text{ psi} \right)$

Load Case 5: Weight, Operating & New

Longitudinal stress between saddles (Weight, Operating & New, left saddle loading and geometry govern)

$$S_1 = \pm \frac{3 \cdot K_1 \cdot Q \cdot (L \;/\; 12)}{\pi \cdot R^2 \cdot t} = \frac{3 \cdot 0.491 \cdot 103{,}820 \cdot (504 \;/\; 12)}{\pi \cdot 84.6875^{\,2} \cdot 1.375} = 207 \text{ psi}$$

$$S_p = \frac{P \cdot R}{2 \cdot t} = \frac{255.74 \cdot 84}{2 \cdot 1.375} = 7{,}812 \text{ psi}$$

Maximum tensile stress $S_{1t} = S_1 + S_p$ = 8,019 psi
Maximum compressive stress (shut down) $S_{1c} = S_1$ = 207 psi

Tensile stress is acceptable $(\leq S \cdot E = 19{,}400 \text{ psi})$

Compressive stress is acceptable $(\leq S_c = 10{,}328 \text{ psi})$

Longitudinal stress at the right saddle (Weight, Operating & New)

$$L_e = \frac{2 \cdot H_l}{3} + L + \frac{2 \cdot H_r}{3} = \frac{2 \cdot 43.3}{3} + 504 + \frac{2 \cdot 43.3}{3} = 561.7333 \text{ in}$$

$$w = \frac{W_t}{L_e} = \frac{205{,}371}{561.7333} = 365.6 \text{ lb}_f/\text{in}$$

Bending moment at the right saddle:

$$M_q = w \cdot \left(\frac{2 \cdot H_r \cdot A_r}{3} + \frac{A_r^2}{2} - \frac{R^2 - H_r^2}{4} \right)$$

$$= 365.6 \cdot \left(\frac{2 \cdot 43.3 \cdot 56}{3} + \frac{56^{\,2}}{2} - \frac{85.375^{\,2} - 43.3^{\,2}}{4} \right)$$

$$= 669{,}429.9 \text{ lb}_f\text{-in}$$

$$S_2 = \pm \frac{M_q \cdot K_1{}'}{\pi \cdot R^2 \cdot t} = \frac{669{,}429.9 \cdot 9.3799}{\pi \cdot 84.6875^{\,2} \cdot 1.375} = 203 \text{ psi}$$

$$S_p = \frac{P \cdot R}{2 \cdot t} = \frac{255.74 \cdot 84}{2 \cdot 1.375} = 7{,}812 \text{ psi}$$

Maximum tensile stress $S_{2t} = S_2 + S_p$ = 8,014 psi
Maximum compressive stress (shut down) $S_{2c} = S_2$ = 203 psi

Tensile stress is acceptable $(\leq S = 19{,}400 \text{ psi})$

Compressive stress is acceptable $(\leq S_c = 10{,}328 \text{ psi})$

Tangential shear stress in the shell (right saddle, Weight, Operating & New)

$$Q_{shear} = Q - w \cdot \left(A_r + \frac{2 \cdot H_r}{3} \right) = 101{,}551 - 365.6 \cdot \left(56 + \frac{2 \cdot 43.3}{3} \right) = 70{,}523.55 \text{ lb}_f$$

$$S_3 = \frac{K_{2.2} \cdot Q_{shear}}{R \cdot t} = \frac{1.1707 \cdot 70{,}523.55}{84.6875 \cdot 1.375} = 709 \text{ psi}$$

Tangential shear stress is acceptable ($\leq 0.8 \cdot S = 15{,}520$ psi)

Circumferential stress at the right saddle horns (Weight, Operating & New)

$$S_4 = \frac{-Q}{4 \cdot t \cdot \left(b + 1.56 \cdot \sqrt{R_o \cdot t}\right)} - \frac{12 \cdot K_3 \cdot Q \cdot R}{L \cdot t^2}$$
$$= \frac{-101{,}551}{4 \cdot 1.375 \cdot \left(12 + 1.56 \cdot \sqrt{85.375 \cdot 1.375}\right)} - \frac{12 \cdot 0.0256 \cdot 101{,}551 \cdot 84.6875}{504 \cdot 1.375^{2}}$$
$$= -3{,}411 \text{ psi}$$

Circumferential stress at saddle horns is acceptable ($\leq 1.5 \cdot S_a = 29{,}100$ psi)

The wear plate was not considered in the calculation of S_4 because the wear plate width is not at least $\left\{b + 1.56 \cdot \sqrt{R_o \cdot t}\right\} = 28.9021$ in

Ring compression in shell over right saddle (Weight, Operating & New)

$$S_5 = \frac{K_5 \cdot Q}{(t + t_p) \cdot \left(t_s + 1.56 \cdot \sqrt{R_o \cdot t_c}\right)}$$
$$= \frac{0.7603 \cdot 101{,}551}{(1.375 + 0.375) \cdot \left(0.625 + 1.56 \cdot \sqrt{85.375 \cdot 1.75}\right)}$$
$$= 2{,}240 \text{ psi}$$

Ring compression in shell is acceptable ($\leq 0.5 \cdot S_y = 14{,}550$ psi)

Saddle splitting load (right, Weight, Operating & New)

Area resisting splitting force = Web area + wear plate area

$A_e = H_{eff} \cdot t_s + t_p \cdot W_p = 28.4583 \cdot 0.625 + 0.375 \cdot 28 = 28.2865$ in^2

$$S_6 = \frac{K_8 \cdot Q}{A_e} = \frac{0.2035 \cdot 101{,}551}{28.2865} = 731 \text{ psi}$$

Stress in saddle is acceptable $\left(\leq \frac{2}{3} \cdot S_s = 13{,}333 \text{ psi}\right)$

Longitudinal stress at the left saddle (Weight, Operating & New)

$$L_e = \frac{2 \cdot H_l}{3} + L + \frac{2 \cdot H_r}{3} = \frac{2 \cdot 43.3}{3} + 504 + \frac{2 \cdot 43.3}{3} = 561.7333 \text{ in}$$

$$w = \frac{W_t}{L_e} = \frac{205{,}371}{561.7333} = 365.6 \text{ lb}_f/\text{in}$$

Bending moment at the left saddle:

$$M_q = w \cdot \left(\frac{2 \cdot H_l \cdot A_l}{3} + \frac{A_l^2}{2} - \frac{R^2 - H_l^2}{4}\right)$$
$$= 365.6 \cdot \left(\frac{2 \cdot 43.3 \cdot 56}{3} + \frac{56^2}{2} - \frac{85.375^{2} - 43.3^{2}}{4}\right)$$
$$= 669{,}429.9 \text{ lb}_f\text{-in}$$

$$S_2 = \pm \frac{M_q \cdot K_1'}{\pi \cdot R^2 \cdot t} = \frac{669{,}429.9 \cdot 9.3799}{\pi \cdot 84.6875^{2} \cdot 1.375} = 203 \text{ psi}$$

$$S_p = \frac{P \cdot R}{2 \cdot t} = \frac{255.74 \cdot 84}{2 \cdot 1.375} = 7{,}812 \ \text{psi}$$

Maximum tensile stress S_{2t} = S_2 + S_p = 8,014 psi
Maximum compressive stress (shut down) S_{2c} = S_2 = 203 psi

Tensile stress is acceptable ($\leq S = 19{,}400 \ \text{psi}$)

Compressive stress is acceptable ($\leq S_c = 10{,}328 \ \text{psi}$)

Tangential shear stress in the shell (left saddle, Weight, Operating & New)

$$Q_{shear} = Q - w \cdot \left(A_l + \frac{2 \cdot H_l}{3}\right) = 103{,}820 - 365.6 \cdot \left(56 + \frac{2 \cdot 43.3}{3}\right) = 72{,}792.55 \ \text{lb}_f$$

$$S_3 = \frac{K_{2.2} \cdot Q_{shear}}{R \cdot t} = \frac{1.1707 \cdot 72{,}792.55}{84.6875 \cdot 1.375} = 732 \ \text{psi}$$

Tangential shear stress is acceptable ($\leq 0.8 \cdot S = 15{,}520 \ \text{psi}$)

Circumferential stress at the left saddle horns (Weight, Operating & New)

$$S_4 = \frac{-Q}{4 \cdot t \cdot \left(b + 1.56 \cdot \sqrt{R_o \cdot t}\right)} - \frac{12 \cdot K_3 \cdot Q \cdot R}{L \cdot t^2}$$
$$= \frac{-103{,}820}{4 \cdot 1.375 \cdot \left(12 + 1.56 \cdot \sqrt{85.375 \cdot 1.375}\right)} - \frac{12 \cdot 0.0256 \cdot 103{,}820 \cdot 84.6875}{504 \cdot 1.375^2}$$
$$= -3{,}488 \ \text{psi}$$

Circumferential stress at saddle horns is acceptable ($\leq 1.5 \cdot S_a = 29{,}100 \ \text{psi}$)

The wear plate was not considered in the calculation of S_4 because the wear plate width is not at least $\left\{b + 1.56 \cdot \sqrt{R_o \cdot t}\right\} = 28.9021 \ \text{in}$

Ring compression in shell over left saddle (Weight, Operating & New)

$$S_5 = \frac{K_5 \cdot Q}{(t + t_p) \cdot \left(t_s + 1.56 \cdot \sqrt{R_o \cdot t_c}\right)}$$
$$= \frac{0.7603 \cdot 103{,}820}{(1.375 + 0.375) \cdot \left(0.625 + 1.56 \cdot \sqrt{85.375 \cdot 1.75}\right)}$$
$$= 2{,}290 \ \text{psi}$$

Ring compression in shell is acceptable ($\leq 0.5 \cdot S_y = 14{,}550 \ \text{psi}$)

Saddle splitting load (left, Weight, Operating & New)

Area resisting splitting force = Web area + wear plate area

$A_e = H_{eff} \cdot t_s + t_p \cdot W_p = 28.4583 \cdot 0.625 + 0.375 \cdot 28$ = 28.2865 in^2

$$S_6 = \frac{K_8 \cdot Q}{A_e} = \frac{0.2035 \cdot 103{,}820}{28.2865} = 747 \ \text{psi}$$

Stress in saddle is acceptable $\left(\leq \frac{2}{3} \cdot S_s = 13{,}333 \ \text{psi}\right)$

Load Case 6: Weight, Operating & Corr

Longitudinal stress between saddles (Weight, Operating & Corr, left saddle loading and geometry govern)

$$S_1 = \pm \frac{3 \cdot K_1 \cdot Q \cdot (L \ / \ 12)}{\pi \cdot R^2 \cdot t} = \frac{3 \cdot 0.491 \cdot 103{,}801 \cdot (504 \ / \ 12)}{\pi \cdot 84.6875^2 \cdot 1.375} = 207 \ \text{psi}$$

$$S_p = \frac{P \cdot R}{2 \cdot t} = \frac{255.74 \cdot 84}{2 \cdot 1.375} = 7{,}812 \text{ psi}$$

Maximum tensile stress $S_{1t} = S_1 + S_p$ = 8,019 psi
Maximum compressive stress (shut down) $S_{1c} = S_1$ = 207 psi

Tensile stress is acceptable ($\leq S \cdot E = 19{,}400$ psi)

Compressive stress is acceptable ($\leq S_c = 10{,}328$ psi)

Longitudinal stress at the right saddle (Weight, Operating & Corr)

$$L_e = \frac{2 \cdot H_l}{3} + L + \frac{2 \cdot H_r}{3} = \frac{2 \cdot 43.3}{3} + 504 + \frac{2 \cdot 43.3}{3} = 561.7333 \text{ in}$$

$$w = \frac{W_t}{L_e} = \frac{205{,}345}{561.7333} = 365.56 \text{ lb}_f/\text{in}$$

Bending moment at the right saddle:

$$M_q = w \cdot \left(\frac{2 \cdot H_r \cdot A_r}{3} + \frac{A_r^2}{2} - \frac{R^2 - H_r^2}{4} \right)$$
$$= 365.56 \cdot \left(\frac{2 \cdot 43.3 \cdot 56}{3} + \frac{56^2}{2} - \frac{85.375^2 - 43.3^2}{4} \right)$$
$$= 669{,}345.2 \text{ lb}_f\text{-in}$$

$$S_2 = \pm \frac{M_q \cdot K_1'}{\pi \cdot R^2 \cdot t} = \frac{669{,}345.2 \cdot 9.3799}{\pi \cdot 84.6875^2 \cdot 1.375} = 203 \text{ psi}$$

$$S_p = \frac{P \cdot R}{2 \cdot t} = \frac{255.74 \cdot 84}{2 \cdot 1.375} = 7{,}812 \text{ psi}$$

Maximum tensile stress $S_{2t} = S_2 + S_p$ = 8,014 psi
Maximum compressive stress (shut down) $S_{2c} = S_2$ = 203 psi

Tensile stress is acceptable ($\leq S = 19{,}400$ psi)

Compressive stress is acceptable ($\leq S_c = 10{,}328$ psi)

Tangential shear stress in the shell (right saddle, Weight, Operating & Corr)

$$Q_{shear} = Q - w \cdot \left(A_r + \frac{2 \cdot H_r}{3} \right) = 101{,}544 - 365.56 \cdot \left(56 + \frac{2 \cdot 43.3}{3} \right) = 70{,}520.48 \text{ lb}_f$$

$$S_3 = \frac{K_{2.2} \cdot Q_{shear}}{R \cdot t} = \frac{1.1707 \cdot 70{,}520.48}{84.6875 \cdot 1.375} = 709 \text{ psi}$$

Tangential shear stress is acceptable ($\leq 0.8 \cdot S = 15{,}520$ psi)

Circumferential stress at the right saddle horns (Weight, Operating & Corr)

$$S_4 = \frac{-Q}{4 \cdot t \cdot \left(b + 1.56 \cdot \sqrt{R_o \cdot t}\right)} - \frac{12 \cdot K_3 \cdot Q \cdot R}{L \cdot t^2}$$
$$= \frac{-101{,}544}{4 \cdot 1.375 \cdot \left(12 + 1.56 \cdot \sqrt{85.375 \cdot 1.375}\right)} - \frac{12 \cdot 0.0256 \cdot 101{,}544 \cdot 84.6875}{504 \cdot 1.375^2}$$
$$= -3{,}411 \text{ psi}$$

Circumferential stress at saddle horns is acceptable ($\leq 1.5 \cdot S_a = 29{,}100$ psi)

The wear plate was not considered in the calculation of S_4 because the wear plate width is not at least $\left\{b + 1.56 \cdot \sqrt{R_o \cdot t}\right\} = 28.9021$ in

Ring compression in shell over right saddle (Weight, Operating & Corr)

$$S_5 = \frac{K_5 \cdot Q}{(t + t_p) \cdot \left(t_s + 1.56 \cdot \sqrt{R_o \cdot t_c}\right)}$$

$$= \frac{0.7603 \cdot 101{,}544}{(1.375 + 0.375) \cdot \left(0.625 + 1.56 \cdot \sqrt{85.375 \cdot 1.75}\right)}$$

$$= \underline{2{,}240} \quad \text{psi}$$

Ring compression in shell is acceptable ($\le 0.5 \cdot S_y = 14{,}550 \quad \text{psi}$)

Saddle splitting load (right, Weight, Operating & Corr)

Area resisting splitting force = Web area + wear plate area

$A_e = H_{eff} \cdot t_s + t_p \cdot W_p = 28.4583 \cdot 0.625 + 0.375 \cdot 28$ = 28.2865 in^2

$$S_6 = \frac{K_8 \cdot Q}{A_e} = \frac{0.2035 \cdot 101{,}544}{28.2865} = \underline{731} \quad \text{psi}$$

Stress in saddle is acceptable $\left(\le \frac{2}{3} \cdot S_s = 13{,}333 \quad \text{psi} \right)$

Longitudinal stress at the left saddle (Weight, Operating & Corr)

$$L_e = \frac{2 \cdot H_l}{3} + L + \frac{2 \cdot H_r}{3} = \frac{2 \cdot 43.3}{3} + 504 + \frac{2 \cdot 43.3}{3} = 561.7333 \quad \text{in}$$

$$w = \frac{W_t}{L_e} = \frac{205{,}345}{561.7333} = 365.56 \quad \text{lb}_f/\text{in}$$

Bending moment at the left saddle:

$$M_q = w \cdot \left(\frac{2 \cdot H_l \cdot A_l}{3} + \frac{A_l^2}{2} - \frac{R^2 - H_l^2}{4} \right)$$

$$= 365.56 \cdot \left(\frac{2 \cdot 43.3 \cdot 56}{3} + \frac{56^{\ 2}}{2} - \frac{85.375^{\ 2} - 43.3^{\ 2}}{4} \right)$$

$$= 669{,}345.2 \quad \text{lb}_f\text{-in}$$

$$S_2 = \pm \frac{M_q \cdot K_1{}'}{\pi \cdot R^2 \cdot t} = \frac{669{,}345.2 \cdot 9.3799}{\pi \cdot 84.6875^{\ 2} \cdot 1.375} = 203 \quad \text{psi}$$

$$S_p = \frac{P \cdot R}{2 \cdot t} = \frac{255.74 \cdot 84}{2 \cdot 1.375} = 7{,}812 \quad \text{psi}$$

Maximum tensile stress $S_{2t} = S_2 + S_p$ = 8,014 psi
Maximum compressive stress (shut down) $S_{2c} = S_2$ = 203 psi

Tensile stress is acceptable ($\le S = 19{,}400 \quad \text{psi}$)

Compressive stress is acceptable ($\le S_c = 10{,}328 \quad \text{psi}$)

Tangential shear stress in the shell (left saddle, Weight, Operating & Corr)

$$Q_{shear} = Q - w \cdot \left(A_l + \frac{2 \cdot H_l}{3} \right) = 103{,}801 - 365.56 \cdot \left(56 + \frac{2 \cdot 43.3}{3} \right) = 72{,}777.48 \quad \text{lb}_f$$

$$S_3 = \frac{K_{2.2} \cdot Q_{shear}}{R \cdot t} = \frac{1.1707 \cdot 72{,}777.48}{84.6875 \cdot 1.375} = \underline{732} \quad \text{psi}$$

Tangential shear stress is acceptable ($\le 0.8 \cdot S = 15{,}520 \quad \text{psi}$)

Circumferential stress at the left saddle horns (Weight, Operating & Corr)

$$S_4 = \frac{-Q}{4 \cdot t \cdot \left(b + 1.56 \cdot \sqrt{R_o \cdot t}\right)} - \frac{12 \cdot K_3 \cdot Q \cdot R}{L \cdot t^2}$$

$$= \frac{-103{,}801}{4 \cdot 1.375 \cdot \left(12 + 1.56 \cdot \sqrt{85.375 \cdot 1.375}\right)} - \frac{12 \cdot 0.0256 \cdot 103{,}801 \cdot 84.6875}{504 \cdot 1.375^{2}}$$

$= \underline{-3{,}487}$ psi

Circumferential stress at saddle horns is acceptable ($\leq 1.5 \cdot S_a = 29{,}100$ psi)

The wear plate was not considered in the calculation of S_4 because the wear plate width is not at least $\left\{b + 1.56 \cdot \sqrt{R_o \cdot t}\right\} = 28.9021$ in

Ring compression in shell over left saddle (Weight, Operating & Corr)

$$S_5 = \frac{K_5 \cdot Q}{(t + t_p) \cdot \left(t_s + 1.56 \cdot \sqrt{R_o \cdot t_c}\right)}$$

$$= \frac{0.7603 \cdot 103{,}801}{(1.375 + 0.375) \cdot \left(0.625 + 1.56 \cdot \sqrt{85.375 \cdot 1.75}\right)}$$

$= \underline{2{,}290}$ psi

Ring compression in shell is acceptable ($\leq 0.5 \cdot S_y = 14{,}550$ psi)

Saddle splitting load (left, Weight, Operating & Corr)

Area resisting splitting force = Web area + wear plate area

$A_e = H_{eff} \cdot t_s + t_p \cdot W_p = 28.4583 \cdot 0.625 + 0.375 \cdot 28$ = 28.2865 in^2

$$S_6 = \frac{K_8 \cdot Q}{A_e} = \frac{0.2035 \cdot 103{,}801}{28.2865} = \underline{747} \text{ psi}$$

Stress in saddle is acceptable $\left(\leq \frac{2}{3} \cdot S_s = 13{,}333 \text{ psi}\right)$

Load Case 7: Weight, Vacuum

Longitudinal stress between saddles (Weight, Vacuum, left saddle loading and geometry govern)

$$S_1 = \pm \frac{3 \cdot K_1 \cdot Q \cdot (L \ / \ 12)}{\pi \cdot R^2 \cdot t} = \frac{3 \cdot 0.491 \cdot 103{,}801 \cdot (504 \ / \ 12)}{\pi \cdot 84.6875^{2} \cdot 1.375} = 207 \text{ psi}$$

$$S_p = \frac{P \cdot R}{2 \cdot t} = \frac{15 \cdot 84}{2 \cdot 1.375} = 458 \text{ psi}$$

Maximum tensile stress (shut down) S_{1t} = S_1 = 207 psi
Maximum compressive stress S_{1c} = S_1 + S_p = 665 psi

Tensile stress is acceptable ($\leq S \cdot E = 20{,}000$ psi)

Compressive stress is acceptable ($\leq S_c = 13{,}139$ psi)

Longitudinal stress at the right saddle (Weight, Vacuum)

$$L_e = \frac{2 \cdot H_l}{3} + L + \frac{2 \cdot H_r}{3} = \frac{2 \cdot 43.3}{3} + 504 + \frac{2 \cdot 43.3}{3} = 561.7333 \text{ in}$$

$$w = \frac{W_t}{L_e} = \frac{205{,}345}{561.7333} = 365.56 \text{ lb}_f/\text{in}$$

Bending moment at the right saddle:

$$M_q = w \cdot \left(\frac{2 \cdot H_r \cdot A_r}{3} + \frac{A_r^2}{2} - \frac{R^2 - H_r^2}{4} \right)$$
$$= 365.56 \cdot \left(\frac{2 \cdot 43.3 \cdot 56}{3} + \frac{56^2}{2} - \frac{85.375^2 - 43.3^2}{4} \right)$$
$$= 669{,}345.2 \ \text{lb}_f\text{-in}$$

$$S_2 = \pm \frac{M_q \cdot K_1'}{\pi \cdot R^2 \cdot t} = \frac{669{,}345.2 \cdot 9.3799}{\pi \cdot 84.6875^2 \cdot 1.375} = 203 \ \text{psi}$$

$$S_p = \frac{P \cdot R}{2 \cdot t} = \frac{15 \cdot 84}{2 \cdot 1.375} = 458 \ \text{psi}$$

Maximum tensile stress (shut down) S_{2t} = S_2 = 203 psi
Maximum compressive stress S_{2c} = S_2 + S_p = 661 psi

Tensile stress is acceptable ($\leq S = 20{,}000 \ \text{psi}$)

Compressive stress is acceptable ($\leq S_c = 13{,}139 \ \text{psi}$)

Tangential shear stress in the shell (right saddle, Weight, Vacuum)

$$Q_{shear} = Q - w \cdot \left(A_r + \frac{2 \cdot H_r}{3} \right) = 101{,}544 - 365.56 \cdot \left(56 + \frac{2 \cdot 43.3}{3} \right) = 70{,}520.48 \ \text{lb}_f$$

$$S_3 = \frac{K_{2.2} \cdot Q_{shear}}{R \cdot t} = \frac{1.1707 \cdot 70{,}520.48}{84.6875 \cdot 1.375} = 709 \ \text{psi}$$

Tangential shear stress is acceptable ($\leq 0.8 \cdot S = 16{,}000 \ \text{psi}$)

Circumferential stress at the right saddle horns (Weight, Vacuum)

$$S_4 = \frac{-Q}{4 \cdot t \cdot \left(b + 1.56 \cdot \sqrt{R_o \cdot t}\right)} - \frac{12 \cdot K_3 \cdot Q \cdot R}{L \cdot t^2}$$
$$= \frac{-101{,}544}{4 \cdot 1.375 \cdot \left(12 + 1.56 \cdot \sqrt{85.375 \cdot 1.375}\right)} - \frac{12 \cdot 0.0256 \cdot 101{,}544 \cdot 84.6875}{504 \cdot 1.375^2}$$
$$= -3{,}411 \ \text{psi}$$

Circumferential stress at saddle horns is acceptable ($\leq 1.5 \cdot S_a = 30{,}000 \ \text{psi}$)

The wear plate was not considered in the calculation of S_4 because the wear plate width is not at least $\left\{b + 1.56 \cdot \sqrt{R_o \cdot t}\right\} = 28.9021 \ \text{in}$

Ring compression in shell over right saddle (Weight, Vacuum)

$$S_5 = \frac{K_5 \cdot Q}{(t + t_p) \cdot \left(t_s + 1.56 \cdot \sqrt{R_o \cdot t_c}\right)}$$
$$= \frac{0.7603 \cdot 101{,}544}{(1.375 + 0.375) \cdot \left(0.625 + 1.56 \cdot \sqrt{85.375 \cdot 1.75}\right)}$$
$$= 2{,}240 \ \text{psi}$$

Ring compression in shell is acceptable ($\leq 0.5 \cdot S_y = 16{,}250 \ \text{psi}$)

Saddle splitting load (right, Weight, Vacuum)

Area resisting splitting force = Web area + wear plate area

$$A_e = H_{eff} \cdot t_s + t_p \cdot W_p = 28.4583 \cdot 0.625 + 0.375 \cdot 28 = 28.2865 \ \text{in}^2$$

$$S_6 = \frac{K_8 \cdot Q}{A_e} = \frac{0.2035 \cdot 101{,}544}{28.2865} = 731 \ \text{psi}$$

Stress in saddle is acceptable $\left(\leq \frac{2}{3} \cdot S_s = 13{,}333 \text{ psi} \right)$

Longitudinal stress at the left saddle (Weight, Vacuum)

$$L_e = \frac{2 \cdot H_l}{3} + L + \frac{2 \cdot H_r}{3} = \frac{2 \cdot 43.3}{3} + 504 + \frac{2 \cdot 43.3}{3} = 561.7333 \text{ in}$$

$$w = \frac{W_t}{L_e} = \frac{205{,}345}{561.7333} = 365.56 \text{ lb}_f/\text{in}$$

Bending moment at the left saddle:

$$M_q = w \cdot \left(\frac{2 \cdot H_l \cdot A_l}{3} + \frac{A_l^2}{2} - \frac{R^2 - H_l^2}{4} \right)$$

$$= 365.56 \cdot \left(\frac{2 \cdot 43.3 \cdot 56}{3} + \frac{56^2}{2} - \frac{85.375^2 - 43.3^2}{4} \right)$$

$$= 669{,}345.2 \text{ lb}_f\text{-in}$$

$$S_2 = \pm \frac{M_q \cdot K_1{}'}{\pi \cdot R^2 \cdot t} = \frac{669{,}345.2 \cdot 9.3799}{\pi \cdot 84.6875^2 \cdot 1.375} = 203 \text{ psi}$$

$$S_p = \frac{P \cdot R}{2 \cdot t} = \frac{15 \cdot 84}{2 \cdot 1.375} = 458 \text{ psi}$$

Maximum tensile stress (shut down) S_{2t} = S_2 = 203 psi
Maximum compressive stress S_{2c} = S_2 + S_p = 661 psi

Tensile stress is acceptable $(\leq S = 20{,}000 \text{ psi})$

Compressive stress is acceptable $(\leq S_c = 13{,}139 \text{ psi})$

Tangential shear stress in the shell (left saddle, Weight, Vacuum)

$$Q_{shear} = Q - w \cdot \left(A_l + \frac{2 \cdot H_l}{3} \right) = 103{,}801 - 365.56 \cdot \left(56 + \frac{2 \cdot 43.3}{3} \right) = 72{,}777.48 \text{ lb}_f$$

$$S_3 = \frac{K_{2.2} \cdot Q_{shear}}{R \cdot t} = \frac{1.1707 \cdot 72{,}777.48}{84.6875 \cdot 1.375} = 732 \text{ psi}$$

Tangential shear stress is acceptable $(\leq 0.8 \cdot S = 16{,}000 \text{ psi})$

Circumferential stress at the left saddle horns (Weight, Vacuum)

$$S_4 = \frac{-Q}{4 \cdot t \cdot \left(b + 1.56 \cdot \sqrt{R_o \cdot t}\right)} - \frac{12 \cdot K_3 \cdot Q \cdot R}{L \cdot t^2}$$

$$= \frac{-103{,}801}{4 \cdot 1.375 \cdot \left(12 + 1.56 \cdot \sqrt{85.375 \cdot 1.375}\right)} - \frac{12 \cdot 0.0256 \cdot 103{,}801 \cdot 84.6875}{504 \cdot 1.375^2}$$

$$= -3{,}487 \text{ psi}$$

Circumferential stress at saddle horns is acceptable $(\leq 1.5 \cdot S_a = 30{,}000 \text{ psi})$

The wear plate was not considered in the calculation of S_4 because the wear plate width is not at least $\left\{ b + 1.56 \cdot \sqrt{R_o \cdot t} \right\} = 28.9021 \text{ in}$

Ring compression in shell over left saddle (Weight, Vacuum)

$$S_5 = \frac{K_5 \cdot Q}{(t + t_p) \cdot \left(t_s + 1.56 \cdot \sqrt{R_o \cdot t_c}\right)}$$

$$= \frac{0.7603 \cdot 103{,}801}{(1.375 + 0.375) \cdot \left(0.625 + 1.56 \cdot \sqrt{85.375 \cdot 1.75}\right)}$$

$= 2{,}290$ psi

Ring compression in shell is acceptable ($\leq 0.5 \cdot S_y = 16{,}250$ psi)

Saddle splitting load (left, Weight, Vacuum)

Area resisting splitting force = Web area + wear plate area

$A_e = H_{eff} \cdot t_s + t_p \cdot W_p = 28.4583 \cdot 0.625 + 0.375 \cdot 28$ = 28.2865 in^2

$$S_6 = \frac{K_8 \cdot Q}{A_e} = \frac{0.2035 \cdot 103{,}801}{28.2865} = 747 \text{ psi}$$

Stress in saddle is acceptable $\left(\leq \frac{2}{3} \cdot S_s = 13{,}333 \text{ psi}\right)$

Shear stress in anchor bolting, one end slotted

Maximum seismic or wind base shear $= 694.69$ lb$_f$

Thermal expansion base shear $= W \cdot \mu$ = 104,902*0.2 $= 20{,}980.4$ lb$_f$

Corroded root area for a 1.5" series 8 threaded bolt $= 0.9289$ in^2 (4 per saddle)

Bolt shear stress = $\frac{20{,}980.4}{0.9289 \cdot 1 \cdot 4} = 5{,}647$ psi

Anchor bolt stress is acceptable (≤ 20,000 psi)

Shear stress in anchor bolting, transverse

Maximum seismic or wind base shear $= 24{,}280.06$ lb$_f$

Corroded root area for a 1.5" series 8 threaded bolt $= 0.9289$ in^2 (4 per saddle)

Bolt shear stress = $\frac{24{,}280.06}{0.9289 \cdot 2 \cdot 4} = 3{,}267$ psi

Anchor bolt stress is acceptable (≤ 20,000 psi)

Web plate buckling check (Escoe pg 251)

Allowable compressive stress S_c = min(20,000 , 21,394) = 20,000 psi

$$S_c = \frac{K_i \cdot \pi^2 \cdot E}{12 \cdot \left(1 - 0.3^2\right) \cdot \left(\frac{d_i}{t_s}\right)^2} = \frac{1.28 \cdot \pi^2 \cdot 29\text{E+06}}{12 \cdot \left(1 - 0.3^2\right) \cdot \left(\frac{24.75}{0.625}\right)^2} = 21{,}394 \text{ psi}$$

Allowable compressive load on the saddle

$$b_e = \frac{d_i \cdot t_s}{(d_i \cdot t_s) + 2 \cdot t_w \cdot (b - 1)} = \frac{24.75 \cdot 0.625}{(24.75 \cdot 0.625) + 2 \cdot 0.5 \cdot (12 - 1)} = 0.5844$$

$$F_b = n \cdot (A_s + 2 \cdot b_e \cdot t_s) \cdot S_c = 7 \cdot (5.6875 + 2 \cdot 0.5844 \cdot 0.625) \cdot 20{,}000 = 898{,}522.73 \text{ lb}_f$$

Saddle loading of 346,503.55 lb$_f$ is ≤ F_b; satisfactory.

Primary bending + axial stress in the saddle due to end loads (assumes one saddle slotted)

$$\sigma_b = \frac{V \cdot (H_s - x_o) \cdot y}{I} + \frac{Q}{A} = \frac{694.69 \cdot (117 - 70.6046) \cdot 6}{504.89} + \frac{123{,}030.75}{132.2336} = 1{,}313 \text{ psi}$$

The primary bending + axial stress in the saddle ≤ S_s = 20,000 psi; satisfactory.

Secondary bending + axial stress in the saddle due to end loads (includes thermal expansion, assumes one saddle slotted)

$$\sigma_b = \frac{V \cdot (H_s - x_o) \cdot y}{I} + \frac{Q}{A} = \frac{21{,}675.09 \cdot (117 - 70.6046) \cdot 6}{504.89} + \frac{120{,}761.75}{132.2336} = 12{,}864 \ \text{ psi}$$

The secondary bending + axial stress in the saddle ≤ 2*S_y = 76,000 psi; satisfactory.

Saddle base plate thickness check (Roark sixth edition, Table 26, case 7a)

where $a = 24.75, b = 7.6875 \ \text{ in}$

$$t_b = \sqrt{\frac{\beta_1 \cdot q \cdot b^2}{1.5 \cdot S_a}} = \sqrt{\frac{3 \cdot 144 \cdot 7.6875 \ ^2}{1.5 \cdot 20{,}000}} = 0.9237 \ \text{ in}$$

The base plate thickness of 1.5 in is adequate.

Foundation bearing check

$$S_f = \frac{Q_{\max}}{F \cdot E} = \frac{346{,}503.55}{16 \cdot 150} = 144 \ \text{ psi}$$

Concrete bearing stress ≤ 750 psi ; satisfactory.

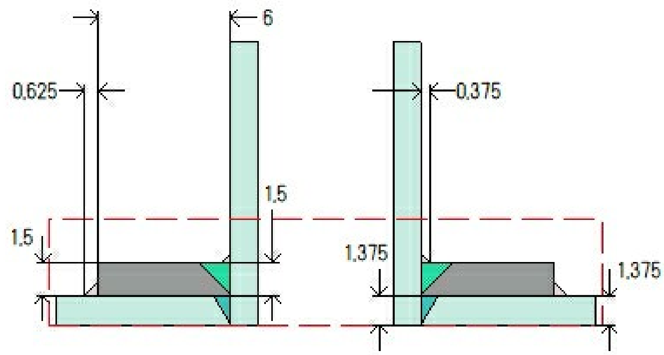
Slotted hole length (Process Industry Practices VEFV1100)

$$\Delta_t = \max\left[|T_{amb} - T_s|, |T_{amb} - MDMT|\right] = \max\left[|70 - 600|, |70 - -49|\right] = 530^\circ F$$

$$S_L = 2 \cdot L_s \cdot \alpha \cdot \Delta_t = 2 \cdot 392 \cdot 7.4\text{E-}06 \cdot 530 = 3.0748''$$

Actual slot length is greater than or equal to the minimum (3.0749" ≥ 3.0748"); satisfactory.

24" 300# RFWN FEED INLET (N1)



ASME Section VIII Division 1, 2004 Edition, A06 Addenda	
Note: round inside edges per UG-76(c)	
Location and Orientation	
Located on	Cylinder #5
Orientation	0°
Nozzle center line offset to datum line	23"
End of nozzle to shell center	123"
Passes through a Category A joint	No
Nozzle	
Access opening	No
Material specification	SA-516 70 (II-D p. 14, ln. 20) (normalized)
Inside diameter, new	21.5"
Nominal wall thickness	1.25"
Corrosion allowance	0"
Projection available outside vessel, Lpr	31.005"
Projection available outside vessel to flange face, Lf	37.625"
Local vessel minimum thickness	1.375"
Liquid static head included	0 psi
Reinforcing Pad	
Material specification	SA-516 70 (II-D p. 14, ln. 20) (normalized)
Diameter, D_p	36"
Thickness, t_e	1.5"
Is split	No
Welds	
Inner fillet, Leg_{41}	0.375"
Outer fillet, Leg_{42}	0.625"
Nozzle to vessel groove weld	1.375"
Pad groove weld	1.5"
Radiography	
Longitudinal seam	Full UW-11(a) Type 1
Circumferential seam	Full UW-11(a) Type 1

ASME B16.5-2003 Flange	
Description	NPS 24 Class 300 WN A350 LF2 Cl.1
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, ln. 33)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0 psi
Consider External Loads on Flange MAWP Rating	No
MAWP rating	570 psi @ 600°F
MAP rating	740 psi @ 70°F
Hydrotest rating	1,125 psi @ 70°F
PWHT performed	Yes
Impact Tested	No
Circumferential joint radiography	Full UW-11(a) Type 1
Bore diameter, B (specified by purchaser)	21.5"
Gasket	
Type	ASME B16.20 Kammprofile
Description	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel
Factor, m	2
Seating Stress, y	2,500 psi
Thickness, T	0.145"
Inner Diameter	24.87"
Outer Diameter	26.87"
Notes	
Flange is impact tested per material specification to -50°F. Stress ratio = 0.3456 ≤ 0.35, MDMT per UCS-66(b)(3) = -155°F. Bolts rated MDMT per Fig UCS-66 note (e) = -55°F	

UCS-66 Material Toughness Requirements Nozzle	
Material impact test temperature per UG-84 =	-49°F
External nozzle loadings per UG-22 govern the coincident ratio used.	
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.1491 \cdot 1}{1.25 - 0} =$	0.1192
Stress ratio ≤ 0.35, MDMT per UCS-66(b)(3) =	-155°F
$MDMT = \min\left[-49, -155\right] =$	-155°F
Design MDMT of -49°F is acceptable.	

UCS-66 Material Toughness Requirements Pad	
Material impact test temperature per UG-84 =	-49°F
$t_r = \frac{255.74 \cdot 84}{20{,}000 \cdot 1 - 0.6 \cdot 255.74} =$	1.0824"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{1.0824 \cdot 1}{1.375 - 0} =$	0.7872
$\text{Stress ratio longitudinal} = \frac{8{,}057 \cdot 1}{20{,}000 \cdot 1} =$	0.4029
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	21.3°F
$MDMT = \max\left[T_{impact} - T_R, -155\right] = \max\left[-49 - 21.3, -155\right] =$	-70.3°F
Design MDMT of -49°F is acceptable.	

Reinforcement Calculations for MAWP

Available reinforcement per UG-37 governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 295.63 psi @ 600 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
27.7748	27.7762	1.7877	7.4573	–	18	0.5312	0.3281	1.25

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
508,182.03	504,176.9	942,581.86	214,086.76	1,690,362.19	570,864.4	1,080,131.39

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})	0.375	0.4375	weld size is adequate

WRC 107												
Load Case	P (psi)	P_r (lb_f)	M_c (lb_f-in)	V_c (lb_f)	M_L (lb_f-in)	V_L (lb_f)	M_t (lb_f-in)	Max Comb Stress (psi)	Allow Comb Stress (psi)	Max Local Primary Stress (psi)	Allow Local Primary Stress (psi)	Over stressed
Load case 1	295.63	-7,555	-428,580	0	428,580	0	0	**26,679**	**58,200**	**20,318**	**29,100**	No
Load case 1 (Hot Shut Down)	0	-7,555	-428,580	0	428,580	0	0	8,619	58,200	1,896	29,100	No

% Extreme fiber elongation - UCS-79(d)

$$EFE = \left(\frac{50 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{50 \cdot 1.25}{11.375}\right) \cdot \left(1 - \frac{11.375}{\infty}\right) = 5.4945\,\%$$

Reinforcement Calculations for MAP

Available reinforcement per UG-37 governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 304.78 psi @ 70 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
27.7752	27.7758	1.7873	7.4573	–	18	0.5312	0.3281	1.25

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
523,914.6	519,770	971,733.87	220,708	1,742,641.44	588,520	1,113,537.51

Reinforcement Calculations for MAEP

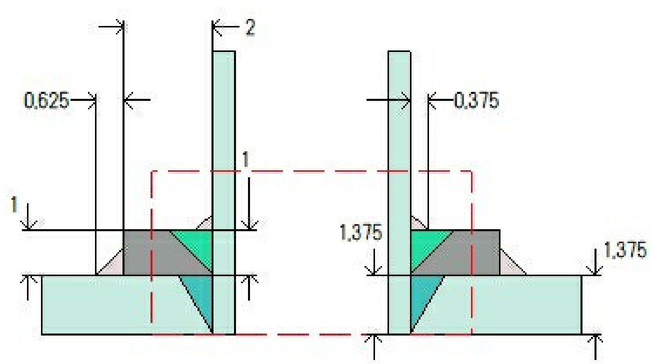
UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 42.99 psi @ 400 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
14.7813	26.1353	–	7.6041	–	18	0.5312	0.1808	1.25

UG-41 Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

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})	0.375	0.4375	weld size is adequate

4" 300# RFWN DRAIN (N5)

ASME Section VIII Division 1, 2004 Edition, A06 Addenda	



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

Location and Orientation	
Located on	Cylinder #5
Orientation	180°
Nozzle center line offset to datum line	23"
End of nozzle to shell center	97.375"
Passes through a Category A joint	No
Nozzle	
Description	NPS 4 Sch 160
Access opening	No
Material specification	SA-333 6 Wld & smls pipe (II-D p. 10, ln. 8)
Inside diameter, new	3.438"
Pipe nominal wall thickness	0.531"
Pipe minimum wall thickness[1]	0.4646"
Corrosion allowance	0"
Projection available outside vessel, Lpr	8.62"
Projection available outside vessel to flange face, Lf	12"
Local vessel minimum thickness	1.375"
Liquid static head included	0 psi
Reinforcing Pad	
Material specification	SA-516 70 (II-D p. 14, ln. 20) (normalized)
Diameter, D_p	8.5"
Thickness, t_e	1"
Is split	No
Welds	
Inner fillet, Leg_{41}	0.375"
Outer fillet, Leg_{42}	0.625"
Nozzle to vessel groove weld	1.375"
Pad groove weld	1"
Radiography	
Longitudinal seam	Welded pipe
Circumferential seam	Full UW-11(a) Type 1

[1]Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

ASME B16.5-2003 Flange	
Description	NPS 4 Class 300 WN A350 LF2 Cl.1
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, ln. 33)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0 psi
Consider External Loads on Flange MAWP Rating	No
MAWP rating	570 psi @ 600°F
MAP rating	740 psi @ 70°F
Hydrotest rating	1,125 psi @ 70°F
PWHT performed	Yes
Impact Tested	No
Circumferential joint radiography	Full UW-11(a) Type 1
Gasket	
Type	ASME B16.20 Kammprofile
Description	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel
Factor, m	2
Seating Stress, y	2,500 psi
Thickness, T	0.145"
Inner Diameter	4.87"
Outer Diameter	6.06"
Notes	
Flange is impact tested per material specification to -50°F. Stress ratio = 0.3456 ≤ 0.35, MDMT per UCS-66(b)(3) = -155°F. Bolts rated MDMT per Fig UCS-66 note (e) = -55°F	

UCS-66 Material Toughness Requirements Nozzle	
Impact test temperature per material specification =	-50°F
External nozzle loadings per UG-22 govern the coincident ratio used.	
Stress ratio $= \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0671 \cdot 1}{0.4646 - 0} =$	0.1444
Stress ratio ≤ 0.35, MDMT per UCS-66(b)(3) =	-155°F
$MDMT = \min\left[T_{impact} - T_{UCS-66(g)}, -155\right] = \min\left[-50 - 5, -155\right] =$	-155°F
Material is exempt from impact testing at the Design MDMT of -49°F.	

UCS-66 Material Toughness Requirements Pad	
Material impact test temperature per UG-84 =	-49°F
$t_r = \frac{255.74 \cdot 84}{20{,}000 \cdot 1 - 0.6 \cdot 255.74} =$	1.0824"
Stress ratio $= \frac{t_r \cdot E^*}{t_n - c} = \frac{1.0824 \cdot 1}{1.375 - 0} =$	0.7872
Stress ratio longitudinal $= \frac{8{,}057 \cdot 1}{20{,}000 \cdot 1} =$	0.4029
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	21.3°F
$MDMT = \max\left[T_{impact} - T_R, -155\right] = \max\left[-49 - 21.3, -155\right] =$	-70.3°F
Design MDMT of -49°F is acceptable.	

Reinforcement Calculations for MAWP

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 314.47 psi @ 600 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
4.9003	4.9415	0.0001	2.0675	–	2.75	0.1239	0.2074	0.4646

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
95,064.98	95,863.16	118,953.05	67,482.21	263,217.26	120,832.21	218,856.5

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})	0.375	0.4375	weld size is adequate

WRC 107												
Load Case	P (psi)	P_r (lb_f)	M_c (lb_f-in)	V_c (lb_f)	M_L (lb_f-in)	V_L (lb_f)	M_t (lb_f-in)	Max Comb Stress (psi)	Allow Comb Stress (psi)	Max Local Primary Stress (psi)	Allow Local Primary Stress (psi)	Over stressed
Load case 1	314.47	-1,260	-9,648	0	9,648	0	0	**20,969**	**58,200**	**19,417**	**29,100**	No
Load case 1 (Hot Shut Down)	0	-1,260	-9,648	0	9,648	0	0	1,758	58,200	206	29,100	No

Reinforcement Calculations for MAP

Available reinforcement per UG-37 governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 322.06 psi @ 70 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
4.9062	4.9063	0.0334	2.0027	–	2.75	0.1202	0.2074	0.4646

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
97,621.09	97,458	121,406.44	67,428.28	270,671.08	122,428.28	225,625.26

Reinforcement Calculations for MAEP

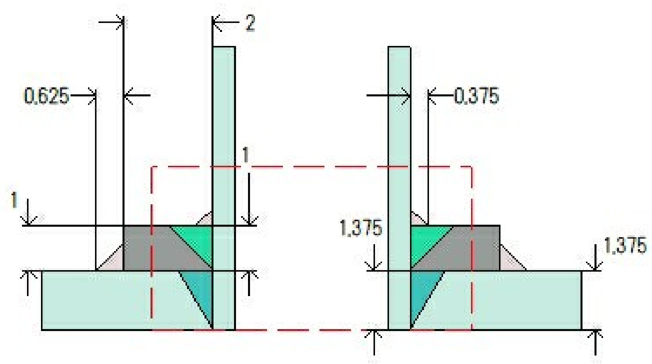
UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 42.99 psi @ 400 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
2.4695	4.8491	–	1.9789	–	2.75	0.1202	0.1808	0.4646

UG-41 Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

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})	0.375	0.4375	weld size is adequate

4" 300# RFWN VENT (N8)

ASME Section VIII Division 1, 2004 Edition, A06 Addenda	



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

Location and Orientation	
Located on	Cylinder #5
Orientation	0°
Nozzle center line offset to datum line	64"
End of nozzle to shell center	123"
Passes through a Category A joint	No
Nozzle	
Description	NPS 4 Sch 160
Access opening	No
Material specification	SA-333 6 Wld & smls pipe (II-D p. 10, ln. 8)
Inside diameter, new	3.438"
Pipe nominal wall thickness	0.531"
Pipe minimum wall thickness[1]	0.4646"
Corrosion allowance	0"
Projection available outside vessel, Lpr	34.245"
Projection available outside vessel to flange face, Lf	37.625"
Local vessel minimum thickness	1.375"
Liquid static head included	0 psi
Reinforcing Pad	
Material specification	SA-516 70 (II-D p. 14, ln. 20) (normalized)
Diameter, D_p	8.5"
Thickness, t_e	1"
Is split	No
Welds	
Inner fillet, Leg_{41}	0.375"
Outer fillet, Leg_{42}	0.625"
Nozzle to vessel groove weld	1.375"
Pad groove weld	1"
Radiography	
Longitudinal seam	Welded pipe
Circumferential seam	Full UW-11(a) Type 1

[1]Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

ASME B16.5-2003 Flange	
Description	NPS 4 Class 300 WN A350 LF2 Cl.1
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, ln. 33)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0 psi
Consider External Loads on Flange MAWP Rating	No
MAWP rating	570 psi @ 600°F
MAP rating	740 psi @ 70°F
Hydrotest rating	1,125 psi @ 70°F
PWHT performed	Yes
Impact Tested	No
Circumferential joint radiography	Full UW-11(a) Type 1
Gasket	
Type	ASME B16.20 Kammprofile
Description	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel
Factor, m	2
Seating Stress, y	2,500 psi
Thickness, T	0.145"
Inner Diameter	4.87"
Outer Diameter	6.06"
Notes	
Flange is impact tested per material specification to -50°F. Stress ratio = 0.3456 ≤ 0.35, MDMT per UCS-66(b)(3) = -155°F. Bolts rated MDMT per Fig UCS-66 note (e) = -55°F	

UCS-66 Material Toughness Requirements Nozzle	
Impact test temperature per material specification =	-50°F
External nozzle loadings per UG-22 govern the coincident ratio used.	
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0671 \cdot 1}{0.4646 - 0} =$	0.1444
Stress ratio ≤ 0.35, MDMT per UCS-66(b)(3) =	-155°F
$MDMT = \min\left[T_{impact} - T_{UCS-66(g)}, -155\right] = \min\left[-50 - 5, -155\right] =$	-155°F
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Material impact test temperature per UG-84 =	-49°F
$t_r = \frac{255.74 \cdot 84}{20{,}000 \cdot 1 - 0.6 \cdot 255.74} =$	1.0824"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{1.0824 \cdot 1}{1.375 - 0} =$	0.7872
$\text{Stress ratio longitudinal} = \frac{8{,}057 \cdot 1}{20{,}000 \cdot 1} =$	0.4029
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	21.3°F
$MDMT = \max\left[T_{impact} - T_R, -155\right] = \max\left[-49 - 21.3, -155\right] =$	-70.3°F
Design MDMT of -49°F is acceptable.	

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The vessel wall thickness governs the MAWP of this nozzle.

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WRC 107												
Load Case	P (psi)	P_r (lb_f)	M_c (lb_f-in)	V_c (lb_f)	M_L (lb_f-in)	V_L (lb_f)	M_t (lb_f-in)	Max Comb Stress (psi)	Allow Comb Stress (psi)	Max Local Primary Stress (psi)	Allow Local Primary Stress (psi)	Over stressed
Load case 1	314.47	-1,260	-9,648	0	9,648	0	0	**20,969**	**58,200**	**19,417**	**29,100**	No
Load case 1 (Hot Shut Down)	0	-1,260	-9,648	0	9,648	0	0	1,758	58,200	206	29,100	No

Reinforcement Calculations for MAP

Available reinforcement per UG-37 governs the MAP of this nozzle.

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4.9062	4.9063	0.0334	2.0027	–	2.75	0.1202	0.2074	0.4646

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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
97,621.09	97,458	121,406.44	67,428.28	270,671.08	122,428.28	225,625.26

Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 42.99 psi @ 400 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
2.4695	4.7663	–	1.8961	–	2.75	0.1202	0.1808	0.4646

UG-41 Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
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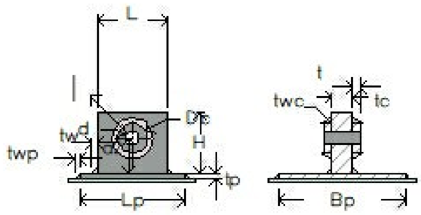
Lifting Lug - 2

Geometry Inputs



Attached To	Cylinder #5
Material	SA-516-70N
Orientation	Longitudinal
Distance of Lift Point From Datum	100"
Angular Position	0°
Length, L	20"
Height, H	17"
Thickness, t	3"
Hole Diameter, d	3.875"
Pin Diameter, Dp	3.75"
Load Eccentricity, a_1	0"
Distance from Load to Shell or Pad, a_2	10"
Load Angle Normal to Vessel, β	45°
Load Angle from Vertical, ϕ	45°
Welds	
Size, t_w	1.5"
Collar	
Thickness, t_c	1"
Diameter, D_c	8.5"
Weld Size, t_{wc}	1.5"
Reinforcement Pad	
Width, B_p	18"
Length, L_p	30"
Thickness, t_p	1.5"
Weld Size, t_{wp}	1.5"

Intermediate Values	
Load Factor	1.8000
Vessel Weight (new, incl. Load Factor), W	367,872.5 lb
Lug Weight (new), W_{lug}	578.5 lb
Distance from Center of Gravity to this lug, x_1	152.3915"
Distance from Center of Gravity to second lug, x_2	141.6085"
Allowable Stress, Tensile, σ_t	22,800 psi
Allowable Stress, Shear, σ_s	13,500 psi
Allowable Stress, Bearing, σ_p	30,000 psi
Allowable Stress, Bending, σ_b	22,000 psi
Allowable Stress, Weld Shear, $\tau_{allowable}$	13,500 psi
Allowable Stress set to 1/3 Sy per ASME B30.20	No

Summary Values	
Required Lift Pin Diameter, d_{reqd}	3.4376"
Required Lug Thickness, t_{reqd}	0.5495"
Required Lug Collar Thickness, $t_{c\ reqd}$	0"
Lug Stress Ratio, σ_{ratio}	0.53
Weld Shear Stress Ratio, τ_{ratio}	0.95
Lug Design	Acceptable
Local Stresses WRC 107	**Unacceptable**

Lift Forces

F_r = force on vessel at lug

$$F_r = \left[\frac{W}{\cos(\phi_1)}\right] \cdot \left(1 - \frac{x_1}{x_1 + x_2}\right) = \frac{367{,}872.5}{\cos(45)} \cdot \left(1 - \frac{152.3915}{152.3915 + 141.6085}\right) = 250{,}585\ lb_f$$

where 'x$_1$' is the distance between this lug and the center of gravity

'x$_2$' is the distance between the second lift lug and the center of gravity

Lug Pin Diameter - Shear stress

$$d_{\text{reqd}} = \sqrt{\frac{2 \cdot F_v}{\pi \cdot \sigma_s}}$$

$$= \sqrt{\frac{2 \cdot 250{,}585}{\pi \cdot 13{,}500}} = \text{3.4376"}$$

$$\frac{d_{reqd}}{D_p} = \frac{3.4376}{3.75} = 0.92$$ Acceptable

$$\sigma = \frac{F_v}{A}$$

$$= \frac{F_v}{2 \cdot \left(0.25 \cdot \pi \cdot D_p^2\right)}$$

$$= \frac{250{,}585}{2 \cdot \left(0.25 \cdot \pi \cdot 3.75^{\ 2}\right)} = 11{,}344 \ \text{psi}$$

$$\frac{\sigma}{\sigma_s} = \frac{11{,}344}{13{,}500} = 0.84$$ Acceptable

Lug Thickness - Tensile stress

$$t_{\text{reqd}} = \frac{F_v}{L \cdot \sigma_t}$$

$$= \frac{250{,}585}{20 \cdot 22{,}800} = \text{0.5495"}$$

$$\frac{t_{\text{reqd}}}{t} = \frac{0.5495}{3} = 0.18$$ Acceptable

$$\sigma = \frac{F_v}{A}$$

$$= \frac{F_v}{L \cdot t}$$

$$= \frac{250{,}585}{20 \cdot 3} = 4{,}176 \ \text{psi}$$

$$\frac{\sigma}{\sigma_t} = \frac{4{,}176}{22{,}800} = 0.18$$ Acceptable

Lug Thickness - Bearing stress

$t_{\text{reqd}} = \dfrac{F_v}{D_p \cdot \sigma_p}$

$= \dfrac{250{,}585}{3.75 \cdot 30{,}000} = 2.2274"$

$T = t + 2 \cdot t_c$

$= 3 + 2 \cdot 1 = 5$

$\dfrac{T_{\text{reqd}}}{T} = \dfrac{2.2274}{5} = 0.45$ Acceptable

Collar required thickness

$t_{\text{c reqd}} = \max(0, 0.5 \cdot (T_{\text{reqd}} - t))$

$= \max(0, 0.5 \cdot (2.2274 - 3))$

= 0"

$\dfrac{t_{\text{c reqd}}}{t_c} = \dfrac{0}{1} = 0.00$ Acceptable

$\sigma = \dfrac{F_v}{A_{\text{bearing}}}$

$= \dfrac{F_v}{D_p \cdot (t + 2 \cdot t_c)}$

$= \dfrac{250{,}585}{3.75 \cdot (3 + 2 \cdot 1)} = 13{,}365 \text{ psi}$

$\dfrac{\sigma}{\sigma_p} = \dfrac{13{,}365}{30{,}000} = 0.45$ Acceptable

Lug Thickness - Shear stress

$t_{\text{reqd}} = \dfrac{\frac{F_v}{\sigma_s} - 4 \cdot t_c \cdot L_c}{2 \cdot L_{\text{shear}}}$

$= \dfrac{\frac{250{,}585}{13{,}500} - 4 \cdot (1 \cdot 3.4901)}{2 \cdot 5.815} = 0.3956"$

$\dfrac{t_{\text{reqd}}}{t} = \dfrac{0.3956}{3} = 0.13$ Acceptable

Collar required thickness

$t_{\text{c reqd}} = \dfrac{\frac{F_v}{\sigma_s} - 2 \cdot t \cdot L_{\text{shear}}}{4 \cdot L_c}$

$= \dfrac{\frac{250{,}585}{13{,}500} - 2 \cdot (3 \cdot 5.815)}{4 \cdot 3.4901} = 0$

$\dfrac{t_{\text{c reqd}}}{t_c} = \dfrac{0}{1} = 0.00$ Acceptable

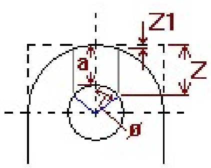
$$\tau = \frac{F_v}{A_{\text{shear}}}$$

$$= \frac{F_v}{2 \cdot t \cdot L_{\text{shear}} + 4 \cdot t_c \cdot L_c}$$

$$= \frac{250{,}585}{2 \cdot 3 \cdot 5.815 + 4 \cdot 1 \cdot 3.4901} = 5{,}130 \text{ psi}$$

$$\frac{\tau}{\sigma_s} = \frac{5{,}130}{13{,}500} = 0.38$$ Acceptable

Shear stress length (per Pressure Vessel and Stacks, A. Keith Escoe)



$$\phi = 55 \cdot \frac{D_p}{d}$$

$$= 55 \cdot \frac{3.75}{3.875}$$

$$= 53.2258^\circ$$

$$L_{\text{shear}} = (H - a2 - 0.5 \cdot d) + 0.5 \cdot D_p \cdot (1 - \cos(\phi))$$

$$= (17 - 10 - 0.5 \cdot 3.875) + 0.5 \cdot 3.75 \cdot (1 - \cos(53.2258))$$

= 5.815"

L_c = Collar shear plane length

= 3.4901"

Lug Plate Stress

Lug stress tensile + bending during lift:

$$\sigma_{\text{ratio}} = \left[\frac{F_{\text{ten}}}{A_{\text{ten}} \cdot \sigma_t}\right] + \left[\frac{M_{\text{bend}}}{Z_{\text{bend}} \cdot \sigma_b}\right] \leq 1$$

$$= \left[\frac{F_r \cdot \cos(\beta)}{t \cdot L \cdot \sigma_t}\right] + \left[\frac{6 \cdot |F_r \cdot \sin(\beta) \cdot \text{Hght} - F_r \cdot \cos(\beta) \cdot a_1|}{t \cdot L_2 \cdot \sigma_b}\right] \leq 1$$

$$= 250{,}585 \cdot \frac{\cos(45.0)}{3 \cdot 20 \cdot 22{,}800} + 6 \cdot \frac{|250{,}585 \cdot \sin(45.0) \cdot 10 - 250{,}585 \cdot \cos(45.0) \cdot 0|}{3 \cdot 20^2 \cdot 22{,}000}$$

= 0.53 Acceptable

Weld Stress

Weld stress, tensile, bending and shear during lift:

Direct shear:

Shear stress at lift angle 45.00°; lift force = 250,585 lb_f

$$A_{\text{weld}} = 2 \cdot (0.707) \cdot t_w \cdot (L + t)$$

$$= 2 \cdot (0.707) \cdot 1.5 \cdot (20 + 3) = 48.783 \text{ in}^2$$

τ_t = $F_{\text{lug}} \cdot \dfrac{\cos(\beta)}{A_{\text{weld}}}$

= $250{,}585 \cdot \dfrac{\cos(45.0)}{48.783}$ $= 3{,}632$ psi

τ_s = $F_{\text{lug}} \cdot \dfrac{\sin(\beta)}{A_{\text{weld}}}$

= $250{,}585 \cdot \dfrac{\sin(45.0)}{48.783}$ $= 3{,}632$ psi

τ_b = $M \cdot \dfrac{c}{I}$

= $3 \cdot \dfrac{F_{\text{lug}} \cdot \sin(\beta) \cdot Hght - F_{\text{lug}} \cdot \cos(\beta) \cdot a_1}{0.707 \cdot h \cdot L \cdot (3 \cdot t + L)}$

= $3 \cdot \dfrac{|250{,}585 \cdot \sin(45.0) \cdot 10 - 250{,}585 \cdot \cos(45.0) \cdot (0)|}{615.0900}$

= 8,642 psi

τ_{ratio} = $\dfrac{\sqrt{(\tau_t + \tau_b)^2 + \tau_s^2}}{\tau_{\text{allowable}}} \leq 1$

= $\dfrac{\sqrt{(3{,}632 + 8{,}642)^2 + (3{,}632)^2}}{13{,}500}$

= 0.95 Acceptable

Collar Weld Stress:

τ_c = $\dfrac{F_r}{A_{weld}}$

= $\dfrac{250{,}585}{2 \cdot 0.707 \cdot 1.5 \cdot \pi \cdot 8.5}$ $= 4{,}424$ psi

τ_{ratio} = $\dfrac{\tau_c}{\tau_{\text{allowable}}} \leq 1$

= $\dfrac{4{,}424}{13{,}500}$ = 0.33 Acceptable

Pad Weld Stress, tensile, bending and shear during lift:

Direct shear:

Shear stress at lift angle 45.00°; lift force = 250,585 lb_f

A_{weld} = $2 \cdot (0.707) \cdot t_{w\_p} \cdot (L_p + B_p)$

= $2 \cdot (0.707) \cdot 1.5 \cdot (30 + 18)$ $= 101.808$ in^2

$$\tau_t = F_{\text{lug}} \cdot \frac{\cos(\beta)}{A_{\text{weld}}}$$

$$= 250{,}585 \cdot \frac{\cos(45.0)}{101.808} = 1{,}740 \quad \text{psi}$$

$$\tau_s = F_{\text{lug}} \cdot \frac{\sin(\beta)}{A_{\text{weld}}}$$

$$= 250{,}585 \cdot \frac{\sin(45.0)}{101.808} = 1{,}740 \quad \text{psi}$$

$$\tau_b = M \cdot \frac{c}{I}$$

$$= 3 \cdot \frac{F_{\text{lug}} \cdot \sin(\beta) \cdot Hght - F_{\text{lug}} \cdot \cos(\beta) \cdot a_1}{0.707 \cdot h_p \cdot L_p \cdot (3 \cdot W_p + L_p)}$$

$$= 3 \cdot \frac{|250{,}585 \cdot \sin(45.0) \cdot 11.5 - 250{,}585 \cdot \cos(45.0) \cdot (0)|}{2672.4600}$$

$$= 2{,}287 \quad \text{psi}$$

$$\tau_{\text{ratio}} = \frac{\sqrt{(\tau_t + \tau_b)^2 + \tau_s^2}}{\tau_{\text{allowable}}} \leq 1$$

$$= \frac{\sqrt{(1{,}740 + 2{,}287)^2 + (1{,}740)^2}}{13{,}500}$$

= 0.33 Acceptable

WRC 107 Analysis

Geometry	
Height (radial)	17"
Width (circumferential)	3"
Length	20"
Fillet Weld Size:	1.5"
Located On	Cylinder #5 (30" from left end)
Location Angle	0.00°
Reinforcement Pad	
Thickness	1.5"
Width	18"
Length	30"
Weld Size	1.5"

Applied Loads	
Radial load, P_r	-177,190.01 lb_f
Circumferential moment, M_c	0 lb_f-in
Circumferential shear, V_c	0 lb_f
Longitudinal moment, M_L	2,037,685.1 lb_f-in
Longitudinal shear, V_L	177,190.01 lb_f
Torsion moment, M_t	0 lb_f-in
Internal pressure, P	0 psi
Mean shell radius, R_m	84.6875"
Design factor	3

Maximum stresses due to the applied loads at the lug edge

$$\gamma = \frac{R_m}{T} = \frac{84.6875}{2.875} = 29.4565$$

$$C_1 = 3, C_2 = 11.5 \text{ in}$$

Local circumferential pressure stress $= \dfrac{P \cdot R_i}{T} = 0 \text{ psi}$

Local longitudinal pressure stress $= \dfrac{P \cdot R_i}{2 \cdot T} = 0 \text{ psi}$

Maximum combined stress $(P_L + P_b + Q) = 38{,}184 \text{ psi}$

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 60{,}000 \text{ psi}$

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

Maximum local primary membrane stress $(P_L) = 5{,}829 \text{ psi}$

Allowable local primary membrane stress $(P_L) = \pm 1.5 \cdot S = \pm 30{,}000 \text{ psi}$

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

Stresses at the lug edge per WRC Bulletin 107										
Figure	value	β	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	4.7001	0.1022	0	0	0	0	3,420	3,420	3,420	3,420
4C*	5.4011	0.083	3,931	3,931	3,931	3,931	0	0	0	0
1C	0.1877	0.0612	0	0	0	0	24,142	-24,142	24,142	-24,142
2C-1	0.1493	0.0612	19,203	-19,203	19,203	-19,203	0	0	0	0
3A*	0.3967	0.0554	0	0	0	0	0	0	0	0
1A	0.1044	0.0706	0	0	0	0	0	0	0	0
3B*	2.4942	0.0868	-1,898	-1,898	1,898	1,898	0	0	0	0
1B-1	0.0541	0.077	-12,270	12,270	12,270	-12,270	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total circumferential stress			8,966	-4,900	37,302	-25,644	27,562	-20,722	27,562	-20,722
Primary membrane circumferential stress*			2,033	2,033	5,829	5,829	3,420	3,420	3,420	3,420
3C*	5.0131	0.083	3,648	3,648	3,648	3,648	0	0	0	0
4C*	5.2332	0.1022	0	0	0	0	3,808	3,808	3,808	3,808
1C-1	0.1611	0.0864	20,721	-20,721	20,721	-20,721	0	0	0	0
2C	0.1184	0.0864	0	0	0	0	15,229	-15,229	15,229	-15,229
4A*	0.518	0.0554	0	0	0	0	0	0	0	0
2A	0.0569	0.096	0	0	0	0	0	0	0	0
4B*	0.6773	0.0868	-910	-910	910	910	0	0	0	0
2B-1	0.0776	0.105	-12,905	12,905	12,905	-12,905	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total longitudinal stress			10,554	-5,078	38,184	-29,068	19,037	-11,421	19,037	-11,421
Primary membrane longitudinal stress*			2,738	2,738	4,558	4,558	3,808	3,808	3,808	3,808
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	-1,340	-1,340	1,340	1,340
Total Shear stress			0	0	0	0	-1,340	-1,340	1,340	1,340
Combined stress (P_L+P_b+Q)			10,554	-5,078	38,184	-29,068	27,768	-20,911	27,768	-20,911
* denotes primary stress.										

Maximum stresses due to the applied loads at the pad edge

$$\gamma = \frac{R_m}{T} = \frac{84.6875}{1.375} = 61.5909$$

$C_1 = 10.5, C_2 = 16.5 \text{ in}$

Local circumferential pressure stress $= \frac{P \cdot R_i}{T} = 0 \text{ psi}$

Local longitudinal pressure stress $= \frac{P \cdot R_i}{2 \cdot T} = 0 \text{ psi}$

Maximum combined stress $(P_L + P_b + Q) = 62{,}525 \text{ psi}$

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 60{,}000 \text{ psi}$

WRC 107: The combined stress (P_L+P_b+Q) is excessive (at pad edge)

Maximum local primary membrane stress $(P_L) = 19{,}547 \text{ psi}$

Allowable local primary membrane stress $(P_L) = \pm 1.5 \cdot S = \pm 30{,}000 \text{ psi}$

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*	4.7294	0.1916	0	0	0	0	7,197	7,197	7,197	7,197
4C*	8.5426	0.1705	12,999	12,999	12,999	12,999	0	0	0	0
1C	0.0768	0.1464	0	0	0	0	43,186	-43,186	43,186	-43,186
2C-1	0.0442	0.1464	24,855	-24,855	24,855	-24,855	0	0	0	0
3A*	2.4544	0.1441	0	0	0	0	0	0	0	0
1A	0.0768	0.1558	0	0	0	0	0	0	0	0
3B*	6.1939	0.1676	-6,548	-6,548	6,548	6,548	0	0	0	0
1B-1	0.0269	0.1589	-12,925	12,925	12,925	-12,925	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total circumferential stress			18,381	-5,479	57,327	-18,233	50,383	-35,989	50,383	-35,989
Primary membrane circumferential stress*			6,451	6,451	19,547	19,547	7,197	7,197	7,197	7,197
3C*	5.4764	0.1705	8,333	8,333	8,333	8,333	0	0	0	0
4C*	8.0258	0.1916	0	0	0	0	12,213	12,213	12,213	12,213
1C-1	0.0652	0.1743	36,663	-36,663	36,663	-36,663	0	0	0	0
2C	0.0394	0.1743	0	0	0	0	22,155	-22,155	22,155	-22,155
4A*	4.4855	0.1441	0	0	0	0	0	0	0	0
2A	0.0349	0.1806	0	0	0	0	0	0	0	0
4B*	2.454	0.1676	-3,327	-3,327	3,327	3,327	0	0	0	0
2B-1	0.0337	0.1812	-14,202	14,202	14,202	-14,202	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total longitudinal stress			27,467	-17,455	62,525	-39,205	34,368	-9,942	34,368	-9,942
Primary membrane longitudinal stress*			5,006	5,006	11,660	11,660	12,213	12,213	12,213	12,213
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	-1,953	-1,953	1,953	1,953
Total Shear stress			0	0	0	0	-1,953	-1,953	1,953	1,953
Combined stress (P_L+P_b+Q)			27,467	-17,455	62,525	-39,205	50,618	-36,135	50,618	-36,135

* denotes primary stress.

Straight Flange on Ellipsoidal Head #1

ASME Section VIII Division 1, 2004 Edition, A06 Addenda				
Component		Cylinder		
Material		SA-516 70 (II-D p. 14, ln. 20)		
Impact Tested	**Normalized**	**Fine Grain Practice**	**PWHT**	**Maximize MDMT/ No MAWP**
Yes (-49°F)	Yes	Yes	Yes	No
		Design Pressure (psi)	**Design Temperature (°F)**	**Design MDMT (°F)**
Internal		250	600	-49
External		15	400	
Static Liquid Head				
Condition		**P_s (psi)**	**H_s (in)**	**SG**
Test horizontal		7.47	207	1
Dimensions				
Inner Diameter		168"		
Length		2"		
Nominal Thickness		1.375"		
Corrosion	**Inner**	0"		
	Outer	0"		
Weight and Capacity				
		Weight (lb)		**Capacity (US gal)**
New		414.11		191.92
Corroded		414.11		191.92
Insulation				
		Thickness (in)	**Density (lb/ft^3)**	**Weight (lb)**
Insulation		4	18	0
		Spacing(in)	**Individual Weight (lb)**	**Total Weight (lb)**
Insulation Supports		0	0	0
Radiography				
Longitudinal seam		Full UW-11(a) Type 1		
Left Circumferential seam		Full UW-11(a) Type 1		

Results Summary	
Governing condition	Internal pressure
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	1.091"
Design thickness due to external pressure (t_e)	0.8941"
Maximum allowable working pressure (MAWP)	314.47 psi
Maximum allowable pressure (MAP)	324.2 psi
Maximum allowable external pressure (MAEP)	42.99 psi
Rated MDMT	-70.3 °F

UCS-66 Material Toughness Requirements	
Material impact test temperature per UG-84 =	-49°F
$t_r = \frac{255.74 \cdot 84}{20{,}000 \cdot 1 - 0.6 \cdot 255.74} =$	1.0824"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{1.0824 \cdot 1}{1.375 - 0} =$	0.7872
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	21.3°F
$MDMT = \max\left[T_{impact} - T_R, -155\right] = \max\left[-49 - 21.3, -155\right] =$	-70.3°F
Design MDMT of -49°F is acceptable.	

Design thickness, (at 600 °F) UG-27(c)(1)

$$t = \frac{P \cdot R}{S \cdot E - 0.60 \cdot P} + \text{Corrosion} = \frac{250 \cdot 84}{19{,}400 \cdot 1.00 - 0.60 \cdot 250} + 0 = 1.091"$$

Maximum allowable working pressure, (at 600 °F) UG-27(c)(1)

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} - P_s = \frac{19{,}400 \cdot 1.00 \cdot 1.375}{84 + 0.60 \cdot 1.375} - 0 = 314.47 \text{ psi}$$

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

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} = \frac{20{,}000 \cdot 1.00 \cdot 1.375}{84 + 0.60 \cdot 1.375} = 324.2 \text{ psi}$$

External Pressure, (Corroded & at 400 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{532}{170.75} = 3.1157$$

$$\frac{D_o}{t} = \frac{170.75}{0.8941} = 190.9811$$

From table G: $A = 0.000157$

From table CS-2: $B = 2{,}148.5374 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 2{,}148.54}{3 \cdot (170.75/0.8941)} = 15 \text{ psi}$$

Design thickness for external pressure P_a = 15 psi

$$t_a = t + \text{Corrosion} = 0.8941 + 0 = 0.8941"$$

Maximum Allowable External Pressure, (Corroded & at 400 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{532}{170.75} = 3.1157$$

$$\frac{D_o}{t} = \frac{170.75}{1.375} = 124.1818$$

From table G: $A = 0.000290$

From table CS-2: $B = 4{,}004.3077 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 4,004.31}{3 \cdot (170.75/1.375)} = \underline{42.99} \text{ psi}$$

% Extreme fiber elongation - UCS-79(d)

$$EFE = \left(\frac{50 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{50 \cdot 1.375}{84.6875}\right) \cdot \left(1 - \frac{84.6875}{\infty}\right) = 0.8118\,\%$$

The extreme fiber elongation does not exceed 5%.

Allowable Compressive Stress, Hot and Corroded- S_{cHC}, (table CS-2)

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{85.375/1.375} = 0.002013$$

$$B = 10{,}328 \quad \text{psi}$$

$$S = \frac{19{,}400}{1.00} = 19{,}400 \quad \text{psi}$$

$S_{cHC} = \min(B, S) =$ 10,328 psi

Allowable Compressive Stress, Hot and New- S_{cHN}

$$S_c HN = S_c HC = 10{,}328 \quad \text{psi}$$

Allowable Compressive Stress, Cold and New- S_{cCN}, (table CS-2)

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{85.375/1.375} = 0.002013$$

$$B = 15{,}019 \quad \text{psi}$$

$$S = \frac{20{,}000}{1.00} = 20{,}000 \quad \text{psi}$$

$S_{cCN} = \min(B, S) =$ 15,019 psi

Allowable Compressive Stress, Cold and Corroded- S_{cCC}

$$S_{cC} = S_{cCN} = 15{,}019 \quad \text{psi}$$

Allowable Compressive Stress, Vacuum and Corroded- S_{cVC}, (table CS-2)

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{85.375/1.375} = 0.002013$$

$$B = 13{,}139 \quad \text{psi}$$

$$S = \frac{20{,}000}{1.00} = 20{,}000 \quad \text{psi}$$

$S_{cVC} = \min(B, S) =$ 13,139 psi

Ellipsoidal Head #1

ASME Section VIII Division 1, 2004 Edition, A06 Addenda					
Component		Ellipsoidal Head			
Material		SA-516 70 (II-D p. 14, ln. 20)			
Attached To		Cylinder #5			
Impact Tested	**Normalized**	**Fine Grain Practice**	**PWHT**		**Maximize MDMT/ No MAWP**
Yes (-49°F)	Yes	Yes	Yes		No
		Design Pressure (psi)	**Design Temperature (°F)**		**Design MDMT (°F)**
Internal		250	600		-49
External		15	400		
Static Liquid Head					
Condition		**P_s (psi)**	**H_s (in)**		**SG**
Test horizontal		7.47	207		1
Dimensions					
Inner Diameter		168"			
Head Ratio		2			
Minimum Thickness		1.3"			
Corrosion	**Inner**	0"			
	Outer	0"			
Length L_{sf}		2"			
Nominal Thickness t_{sf}		1.375"			
Weight and Capacity					
		Weight (lb)[1]			**Capacity (US gal)**[1]
New		12,439.93			2,878.84
Corroded		12,439.93			2,878.84
Insulation					
		Thickness (in)	**Density (lb/ft^3)**		**Weight (lb)**
Insulation		4	18		1,401.37
		Spacing(in)	**Individual Weight (lb)**		**Total Weight (lb)**
Insulation Supports		145	50		50
Radiography					
Category A joints		Full UW-11(a) Type 1			
Head to shell seam		Full UW-11(a) Type 1			

[1] includes straight flange

Results Summary	
Governing condition	internal pressure
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	1.0839"
Design thickness due to external pressure (t_e)	0.4459"
Maximum allowable working pressure (MAWP)	299.77 psi
Maximum allowable pressure (MAP)	309.05 psi
Maximum allowable external pressure (MAEP)	97.01 psi
Rated MDMT	-66.3°F

UCS-66 Material Toughness Requirements	
Material impact test temperature per UG-84 =	-49°F
$t_r = \frac{255.74 \cdot 168}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 255.74} =$	1.0755"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{1.0755 \cdot 1}{1.3 - 0} =$	0.8273
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	17.3°F
$MDMT = \max\left[T_{impact} - T_R, -155\right] = \max\left[-49 - 17.3, -155\right] =$	-66.3°F
Design MDMT of -49°F is acceptable.	

Design thickness for internal pressure, (Corroded at 600 °F) UG-32(d)(1)

$$t = \frac{P \cdot D}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion} = \frac{250 \cdot 168}{2 \cdot 19{,}400 \cdot 1 - 0.2 \cdot 250} + 0 = 1.0839"$$

Maximum allowable working pressure, (Corroded at 600 °F) UG-32(d)(1)

$$P = \frac{2 \cdot S \cdot E \cdot t}{D + 0.2 \cdot t} - P_s = \frac{2 \cdot 19{,}400 \cdot 1 \cdot 1.3}{168 + 0.2 \cdot 1.3} - 0 = 299.77 \text{ psi}$$

Maximum allowable pressure, (New at 70 °F) UG-32(d)(1)

$$P = \frac{2 \cdot S \cdot E \cdot t}{D + 0.2 \cdot t} - P_s = \frac{2 \cdot 20{,}000 \cdot 1 \cdot 1.3}{168 + 0.2 \cdot 1.3} - 0 = 309.05 \text{ psi}$$

Design thickness for external pressure, (Corroded at 400 °F) UG-33(d)

Equivalent outside spherical radius

$R_o = K_o \cdot D_o = 0.8865 \cdot 170.6 = 151.2351 \text{ in}$

$$A = \frac{0.125}{R_o \ / \ t} = \frac{0.125}{151.2351 \ / \ 0.445813} = 0.000368$$

From Table CS-2: B = 5,088.5176 psi

$$P_a = \frac{B}{R_o \ / \ t} = \frac{5{,}088.5176}{151.2351 \ / \ 0.4458} = 15 \text{ psi}$$

$$t = 0.4458" + \text{Corrosion} = 0.4458" + 0" = 0.4458"$$

Check the external pressure per UG-33(a)(1) UG-32(d)(1)

$$t = \frac{1.67 \cdot P_e \cdot D}{2 \cdot S \cdot E - 0.2 \cdot 1.67 \cdot P_e} + \text{Corrosion} = \frac{1.67 \cdot 15 \cdot 168}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 1.67 \cdot 15} + 0 = 0.1052"$$

The head external pressure design thickness (t_e) is 0.4458".

Maximum Allowable External Pressure, (Corroded at 400 °F) UG-33(d)

Equivalent outside spherical radius

$R_o = K_o \cdot D_o = 0.8865 \cdot 170.6 = 151.2351 \text{ in}$

$$A = \frac{0.125}{R_o \ / \ t} = \frac{0.125}{151.2351 \ / \ 1.3} = 0.001074$$

From Table CS-2: B = 11,285.56 psi

$$P_a = \frac{B}{R_o \ / \ t} = \frac{11{,}285.56}{151.2351 \ / \ 1.3} = 97.0094 \ \text{psi}$$

Check the Maximum External Pressure, UG-33(a)(1) UG-32(d)(1)

$$P = \frac{2 \cdot S \cdot E \cdot t}{(D + 0.2 \cdot t) \cdot 1.67} = \frac{2 \cdot 20{,}000 \cdot 1 \cdot 1.3}{(168 + 0.2 \cdot 1.3) \cdot 1.67} = 185.06 \ \text{psi}$$

The maximum allowable external pressure (MAEP) is 97.01 psi.

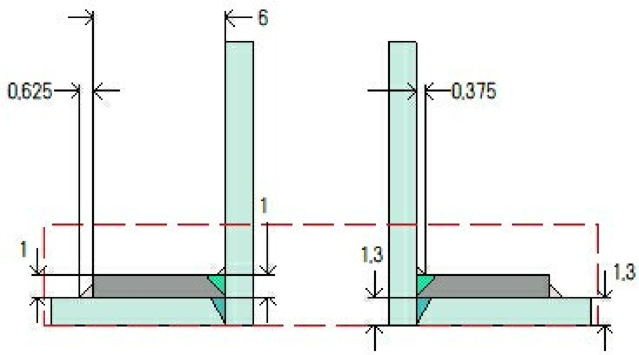
% Extreme fiber elongation - UCS-79(d)

$$EFE = \left(\frac{75 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{75 \cdot 1.375}{29.2475}\right) \cdot \left(1 - \frac{29.2475}{\infty}\right) = 3.5259\,\%$$

The extreme fiber elongation does not exceed 5%.

24" 300# RFWN MANWAY (M2)

ASME Section VIII Division 1, 2004 Edition, A06 Addenda



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

Location and Orientation	
Located on	Ellipsoidal Head #1
Orientation	180°
End of nozzle to datum line	-56.308"
Calculated as hillside	Yes
Distance to head center, R	36"
Passes through a Category A joint	No
Nozzle	
Access opening	No
Material specification	SA-516 70 (II-D p. 14, ln. 20) (normalized)
Inside diameter, new	21.5"
Nominal wall thickness	1.25"
Corrosion allowance	0"
Opening chord length	22.1095"
Projection available outside vessel, Lpr	6.1372"
Projection available outside vessel to flange face, Lf	12.7572"
Local vessel minimum thickness	1.3"
Liquid static head included	0 psi
Reinforcing Pad	
Material specification	SA-516 70 (II-D p. 14, ln. 20) (normalized)
Diameter, D_p	36.6608"
Thickness, t_e	1"
Is split	No
Welds	
Inner fillet, Leg_{41}	0.375"
Outer fillet, Leg_{42}	0.625"
Nozzle to vessel groove weld	1.3"
Pad groove weld	1"
Radiography	
Longitudinal seam	Full UW-11(a) Type 1
Circumferential seam	Full UW-11(a) Type 1

ASME B16.5-2003 Flange	
Description	NPS 24 Class 300 WN A350 LF2 Cl.1
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, ln. 33)
Blind included	Yes
Rated MDMT	-55°F
Liquid static head	0 psi
MAWP rating	570 psi @ 600°F
MAP rating	740 psi @ 70°F
Hydrotest rating	1,125 psi @ 70°F
PWHT performed	Yes
Impact Tested	No
Circumferential joint radiography	Full UW-11(a) Type 1
Bore diameter, B (specified by purchaser)	21.5"
Gasket	
Type	ASME B16.20 Kammprofile
Description	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel
Factor, m	2
Seating Stress, y	2,500 psi
Thickness, T	0.145"
Inner Diameter	24.87"
Outer Diameter	26.87"
Notes	
Flange is impact tested per material specification to -50°F. Stress ratio = 0.3456 ≤ 0.35, MDMT per UCS-66(b)(3) = -155°F. Bolts rated MDMT per Fig UCS-66 note (e) = -55°F	

UCS-66 Material Toughness Requirements Nozzle	
Material impact test temperature per UG-84 =	-49°F
$t_r = \frac{255.74 \cdot 10.75}{20{,}000 \cdot 1 - 0.6 \cdot 255.74} =$	0.1385"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.1385 \cdot 1}{1.25 - 0} =$	0.1108
Stress ratio ≤ 0.35, MDMT per UCS-66(b)(3) =	-155°F
$MDMT = \min\left[-49, -155\right] =$	-155°F
Design MDMT of -49°F is acceptable.	

UCS-66 Material Toughness Requirements Pad	
Material impact test temperature per UG-84 =	-49°F
$t_r = \frac{255.74 \cdot 0.9 \cdot 168}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 255.74} =$	0.9679"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.9679 \cdot 1}{1.3 - 0} =$	0.7446
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	25.5°F
$MDMT = \max\left[T_{impact} - T_R, -155\right] = \max\left[-49 - 25.5, -155\right] =$	-74.5°F
Design MDMT of -49°F is acceptable.	

Reinforcement Calculations for MAWP

Available reinforcement per UG-37 governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 280.35 psi @ 600 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
24.1896	24.1904	4.5528	7.1064	–	12	0.5312	0.3281	1.25

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
390,940.3	380,969.44	948,748.77	203,641.8	1,379,167.34	444,019.44	1,045,707.66

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})	0.375	0.4375	weld size is adequate

% Extreme fiber elongation - UCS-79(d)

$$EFE = \left(\frac{50 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{50 \cdot 1.25}{11.375}\right) \cdot \left(1 - \frac{11.375}{\infty}\right) = 5.4945\,\%$$

Reinforcement Calculations for MAP

Available reinforcement per UG-37 governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 289.02 psi @ 70 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
24.1891	24.1908	4.5532	7.1064	–	12	0.5312	0.3281	1.25

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
403,015.39	392,752	978,091.51	209,940	1,421,822	457,752	1,078,049.14

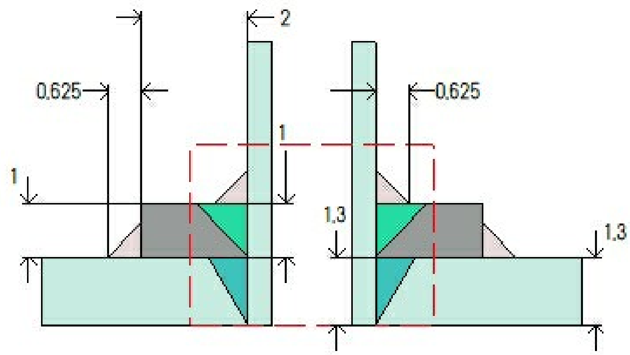
Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 42.99 psi @ 400 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
8.3289	32.0495	12.0851	7.4332	–	12	0.5312	0.1806	1.25

UG-41 Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

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})	0.375	0.4375	weld size is adequate

2" 300# RFWN STEAM OUT (N6B)

ASME Section VIII Division 1, 2004 Edition, A06 Addenda	
	
Note: round inside edges per UG-76(c)	
Location and Orientation	
Located on	Ellipsoidal Head #1
Orientation	148°
End of nozzle to datum line	-35.3684"
Calculated as hillside	Yes
Distance to head center, R	80"
Passes through a Category A joint	No
Nozzle	
Description	NPS 2 XXS
Access opening	No
Material specification	SA-333 6 Wld & smls pipe (II-D p. 10, ln. 8)
Inside diameter, new	1.503"
Pipe nominal wall thickness	0.436"
Pipe minimum wall thickness[1]	0.3815"
Corrosion allowance	0"
Opening chord length	2.6821"
Projection available outside vessel, Lpr	14.0551"
Projection available outside vessel to flange face, Lf	16.8051"
Local vessel minimum thickness	1.3"
Liquid static head included	0 psi
Reinforcing Pad	
Material specification	SA-516 70 (II-D p. 14, ln. 20) (normalized)
Diameter, D_p	8.0104"
Thickness, t_e	1"
Is split	No
Welds	
Inner fillet, Leg_{41}	0.625"
Outer fillet, Leg_{42}	0.625"
Nozzle to vessel groove weld	1.3"
Pad groove weld	1"
Radiography	
Longitudinal seam	Welded pipe
Circumferential seam	Full UW-11(a) Type 1

[1]Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

ASME B16.5-2003 Flange	
Description	NPS 2 Class 300 WN A350 LF2 Cl.1
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, ln. 33)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0 psi
Consider External Loads on Flange MAWP Rating	No
MAWP rating	570 psi @ 600°F
MAP rating	740 psi @ 70°F
Hydrotest rating	1,125 psi @ 70°F
PWHT performed	Yes
Impact Tested	No
Circumferential joint radiography	Full UW-11(a) Type 1
Gasket	
Type	ASME B16.20 Kammprofile
Description	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel
Factor, m	2
Seating Stress, y	2,500 psi
Thickness, T	0.145"
Inner Diameter	2.75"
Outer Diameter	3.5"
Notes	
Flange is impact tested per material specification to -50°F. Stress ratio = 0.3456 ≤ 0.35, MDMT per UCS-66(b)(3) = -155°F. Bolts rated MDMT per Fig UCS-66 note (e) = -55°F	

UCS-66 Material Toughness Requirements Nozzle	
Impact test temperature per material specification =	-50°F
External nozzle loadings per UG-22 govern the coincident ratio used.	
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0523 \cdot 1}{0.3815 - 0} =$	0.1372
Stress ratio ≤ 0.35, MDMT per UCS-66(b)(3) =	-155°F
$MDMT = \min\left[T_{impact} - T_{UCS-66(g)}, -155\right] = \min\left[-50 - 5, -155\right] =$	-155°F
Material is exempt from impact testing at the Design MDMT of -49°F.	

UCS-66 Material Toughness Requirements Pad	
Material impact test temperature per UG-84 =	-49°F
$t_r = \frac{255.74 \cdot 168}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 255.74} =$	1.0755"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{1.0755 \cdot 1}{1.3 - 0} =$	0.8273
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	17.3°F
$MDMT = \max\left[T_{impact} - T_R, -155\right] = \max\left[-49 - 17.3, -155\right] =$	-66.3°F
Design MDMT of -49°F is acceptable.	

Reinforcement Calculations for MAWP

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 299.77 psi @ 600 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
3.6212	4.0527	--	1.5647	--	2.1437	0.3443	0.1348	0.3815

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
70,250.79	78,622.38	90,652.66	56,418.21	142,718.2	98,005.99	144,381.22

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.25	0.4375	weld size is adequate
Pad to shell fillet (Leg_{42})	0.375	0.4375	weld size is adequate

WRC 107												
Load Case	P (psi)	P_r (lb_f)	M_1 (lb_f-in)	V_2 (lb_f)	M_2 (lb_f-in)	V_1 (lb_f)	M_t (lb_f-in)	Max Comb Stress (psi)	Allow Comb Stress (psi)	Max Local Primary Stress (psi)	Allow Local Primary Stress (psi)	Over stressed
Load case 1	299.77	-710	-2,208	0	2,208	0	0	**18,442**	**58,200**	**17,625**	**29,100**	No
Load case 1 (Hot Shut Down)	0	-710	-2,208	0	2,208	0	0	922	58,200	105	29,100	No

Reinforcement Calculations for MAP

The vessel wall thickness governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 309.04 psi @ 70 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
3.6551	3.9972	--	1.5164	--	2.1468	0.334	0.1348	0.3815

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
73,102.64	79,944	92,964.73	56,392.56	146,527.93	99,328.56	148,846.62

Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 42.99 psi @ 400 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
1.0702	5.7936	1.8286	1.455	--	2.176	0.334	0.1348	0.3815

UG-41 Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

UW-16 Weld Sizing Summary			
Weld description	**Required weld size (in)**	**Actual weld size (in)**	**Status**
Nozzle to pad fillet (Leg_{41})	0.25	0.4375	weld size is adequate
Pad to shell fillet (Leg_{42})	0.375	0.4375	weld size is adequate