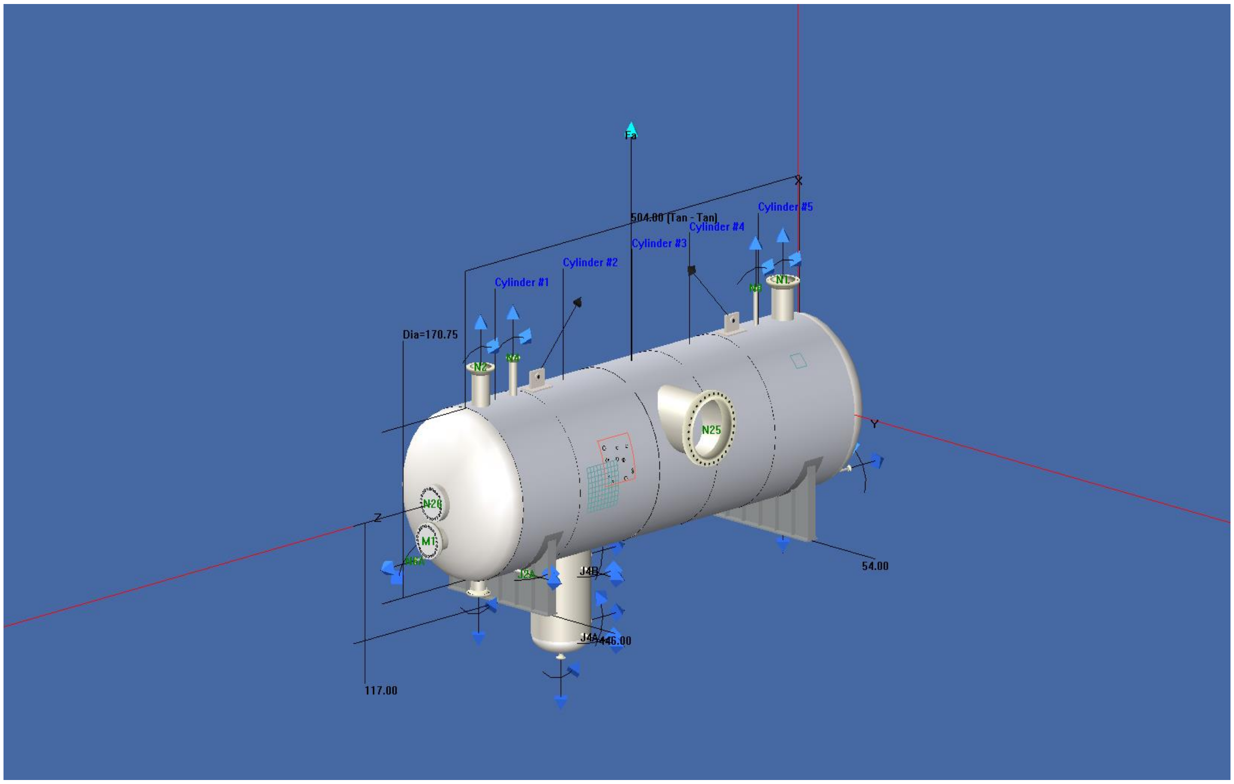
Codeware

5224 Station Way

Sarasota, FL 34233



COMPRESS Pressure Vessel Design Calculations

Item: INSPECT File

Vessel No: 123456

Designer: MH

Date: AUGUST 9, 2007

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Deficiencies Summary

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

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 Metal Loss #1
Geometry restrictions defined in API 579 A.4.1(b) were not met, MAEP calculations are outside the range of applicability. (t = 0.15 ") < 0.1875 "

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 orientation is non-radial. Either an Appendix 1-10 or separate U-2(g) analysis is required.
Nozzle assembly MDMT is only -6.1°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 17.4°F: -49°F is required
Physical interference between nozzles N26 (pad) and M1 (pad) detected.
UG-43(g): Thread engagement (1.63") is insufficient (require 1.6447").

Warnings Summary

Warnings for 16" 300# RFWN HYDROCARBON OUTLET (N3)
ASME B16.5: External loads have not been considered in the flange pressure rating. (warning)
NOTE: Suitable low temperature bolting material is required. (warning)
Table 1A, note W14: These S values do not include a weld factor. For Section VIII, Division 1 applications using welds made without filler metal, the tabulated tensile stress values shall be multiplied by 0.85. For welds made with filler metal, consult UW-12 of Section VIII, Division 1. (warning)

Warnings for 2" 300# RFLWN LEVEL TRANS (J3A)
ASME B16.5: External loads have not been considered in the flange pressure rating. (warning)
NOTE: Suitable low temperature bolting material is required. (warning)
The attached ASME B16.5 flange limits the nozzle MAWP. (warning)

Warnings for 2" 300# RFLWN LEVEL TRANS (J3B)
ASME B16.5: External loads have not been considered in the flange pressure rating. (warning)
NOTE: Suitable low temperature bolting material is required. (warning)
The attached ASME B16.5 flange limits the nozzle MAWP. (warning)

Warnings for 2" 300# RFLWN LEVEL TRANS (J4A)
ASME B16.5: External loads have not been considered in the flange pressure rating. (warning)
NOTE: Suitable low temperature bolting material is required. (warning)
The attached ASME B16.5 flange limits the nozzle MAWP. (warning)

Warnings for 2" 300# RFLWN LEVEL TRANS (J4B)

ASME B16.5: External loads have not been considered in the flange pressure rating. (warning)
NOTE: Suitable low temperature bolting material is required. (warning)
The attached ASME B16.5 flange limits the nozzle MAWP. (warning)

Warnings for 2" 300# RFWN STEAM OUT (N6A)
ASME B16.5: External loads have not been considered in the flange pressure rating. (warning)
NOTE: Suitable low temperature bolting material is required. (warning)
Pad impact test has been performed but was not required. (warning)
Load case 1: WRC 107: Rigid insert assumption questionable (tn < 1.15 in) (warning)
Table 1A, note W14: These S values do not include a weld factor. For Section VIII, Division 1 applications using welds made without filler metal, the tabulated tensile stress values shall be multiplied by 0.85. For welds made with filler metal, consult UW-12 of Section VIII, Division 1. (warning)

Warnings for 2" 300# RFWN STEAM OUT (N6B)
ASME B16.5: External loads have not been considered in the flange pressure rating. (warning)
NOTE: Suitable low temperature bolting material is required. (warning)
Pad impact test has been performed but was not required. (warning)
Load case 1: WRC 107: Rigid insert assumption questionable (tn < 1.15 in) (warning)
Table 1A, note W14: These S values do not include a weld factor. For Section VIII, Division 1 applications using welds made without filler metal, the tabulated tensile stress values shall be multiplied by 0.85. For welds made with filler metal, consult UW-12 of Section VIII, Division 1. (warning)

Warnings for 20" 300# RFWN VAPOUR OUTLET (N2)
ASME B16.5: External loads have not been considered in the flange pressure rating. (warning)
NOTE: Suitable low temperature bolting material is required. (warning)

Warnings for 24" 300# RFWN FEED INLET (N1)
ASME B16.5: External loads have not been considered in the flange pressure rating. (warning)
NOTE: Suitable low temperature bolting material is required. (warning)
Nozzle impact test has been performed but was not required. (warning)

Warnings for 24" 300# RFWN MANWAY (M1)
NOTE: Suitable low temperature bolting material is required. (warning)
Nozzle impact test has been performed but was not required. (warning)
Pad impact test has been performed but was not required. (warning)

Warnings for 24" 300# RFWN MANWAY (M2)
NOTE: Suitable low temperature bolting material is required. (warning)
Nozzle impact test has been performed but was not required. (warning)
Pad impact test has been performed but was not required. (warning)

Warnings for 3" 300# RFWN LG/LT (SIS) BRIDLE (J2A)
ASME B16.5: External loads have not been considered in the flange pressure rating. (warning)
NOTE: Suitable low temperature bolting material is required. (warning)
Part of the pad width is beyond the limits of reinforcement. (warning)
Pad impact test has been performed but was not required. (warning)
Table 1A, note W14: These S values do not include a weld factor. For Section VIII, Division 1 applications using welds made without filler metal, the tabulated tensile stress values shall be multiplied by 0.85. For welds made with filler metal, consult UW-12 of Section VIII, Division 1. (warning)

Warnings for 4" 300# RFWN DRAIN (N5)
ASME B16.5: External loads have not been considered in the flange pressure rating. (warning)
NOTE: Suitable low temperature bolting material is required. (warning)
Pad impact test has been performed but was not required. (warning)
Table 1A, note W14: These S values do not include a weld factor. For Section VIII, Division 1 applications using welds made without filler metal, the tabulated tensile stress values shall be multiplied by 0.85. For welds made with filler metal, consult UW-12 of Section VIII, Division 1. (warning)

Warnings for [4" 300# RFWN VENT (N8)]
ASME B16.5: External loads have not been considered in the flange pressure rating. (warning)
NOTE: Suitable low temperature bolting material is required. (warning)
Pad impact test has been performed but was not required. (warning)
Table 1A, note W14: These S values do not include a weld factor. For Section VIII, Division 1 applications using welds made without filler metal, the tabulated tensile stress values shall be multiplied by 0.85. For welds made with filler metal, consult UW-12 of Section VIII, Division 1. (warning)

Warnings for [4" 300# RFWN WATER OUTLET (N7)]
ASME B16.5: External loads have not been considered in the flange pressure rating. (warning)
NOTE: Suitable low temperature bolting material is required. (warning)
Load case 1: WRC 107: Rigid insert assumption questionable (tn < 0.625 in) (warning)
Nozzle does not satisfy the specified minimum projection length of 12" (warning)
Table 1A, note W14: These S values do not include a weld factor. For Section VIII, Division 1 applications using welds made without filler metal, the tabulated tensile stress values shall be multiplied by 0.85. For welds made with filler metal, consult UW-12 of Section VIII, Division 1. (warning)

Warnings for [8" 300# RFWN VENT (N4)]
ASME B16.5: External loads have not been considered in the flange pressure rating. (warning)
NOTE: Suitable low temperature bolting material is required. (warning)
Pad impact test has been performed but was not required. (warning)
Table 1A, note W14: These S values do not include a weld factor. For Section VIII, Division 1 applications using welds made without filler metal, the tabulated tensile stress values shall be multiplied by 0.85. For welds made with filler metal, consult UW-12 of Section VIII, Division 1. (warning)

Warnings for [Lifting Lug - 1]
Collar weld size should not be greater than collar thickness. (warning)

Warnings for [Lifting Lug - 2]
Collar weld size should not be greater than collar thickness. (warning)

Warnings for [Metal Loss #1]
If the flaw is in the zone for thickness averaging of any nearby nozzles, additional reinforcement calculations will be required. (warning)
Supplemental loads due to saddle supports are not considered in this assessment. (warning)

Warnings for [Metal Loss #2]
Metal Loss #2 and Pitting #1 are overlapping, but have differing values for FCA. The larger of the two values will be used. (warning)
Metal Loss #2 and Pitting #1 are overlapping, but have differing values for LOSS. The larger of the two values will be used. (warning)
If the flaw is in the zone for thickness averaging of any nearby nozzles, additional reinforcement calculations will be required. (warning)
Local metal loss within an area of widespread pitting calculations are performed as per API 579 6.4.3.2(i), but Metal Loss #2 is not completely confined within the damaged region of Pitting #1. (warning)
The measurement intervals are greater than the recommended spacing in API 579 4.3.3.3(e)(1).
L_s = min[0.36*(D*t_{min})^0.5, 2*t_{rd})] = min[0.36*(168*1.091)^0.5, 2*1.1875] = 2.375" (warning)
Supplemental loads due to saddle supports are not considered in this assessment. (warning)

Warnings for [Nozzle #25 (N25)]
NOTE: Suitable low temperature bolting material is required. (warning)
The limits of reinforcement of Nozzle #25 (N25) fall off of Cylinder #3 and on to Cylinder #2, which has a smaller nominal thickness. You may address this issue by relocating the nozzle or specifying a user defined radial limit of reinforcement by clicking on the Calculation Options button in the Detailed Nozzle Design dialog. (warning)

Warnings for [Nozzle #26 (N26)]
NOTE: Suitable low temperature bolting material is required. (warning)

Warnings for Pitting #1

Pitting #1 and Metal Loss #2 are overlapping, but have differing values for FCA. The larger of the two values will be used. (warning)
Pitting #1 and Metal Loss #2 are overlapping, but have differing values for LOSS. The larger of the two values will be used. (warning)
Supplemental loads due to saddle supports are not considered in this assessment. (warning)
If the flaw is in the zone for thickness averaging of any nearby nozzles, additional reinforcement calculations will be required. (warning)

Warnings for Wind Code

NBC Wind Pressure does not match the value from NBC Appendix C. (warning)

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		
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	No
			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	No

			Pad	SA-516 70	Yes	Yes	Yes	Cl.1	
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	0.3986	Yes	Yes	1.25	1.1161		12	2	0	100.0
J2A	3.5	0.438	0.216	Yes	Yes	1.375	1.2422		3	1	0	100.0
J3A	3.31	0.655	0.439	Yes	Yes	2	0.8973		N/A	N/A	0.25	267.2
J3B	3.31	0.655	0.439	Yes	Yes	2	0.8973		N/A	N/A	0.25	267.2
J4A	3.31	0.655	0.439	Yes	Yes	2	0.8973		N/A	N/A	0.25	267.2
J4B	3.31	0.655	0.439	Yes	Yes	2	0.8973		N/A	N/A	0.25	267.2
M1	24	1.25	0.3281	Yes	Yes	1.3*	1.0941		6	1	0	100.0
M2	24	1.25	0.3281	Yes	Yes	1.3*	1.0941		6	1	0	100.0
N1	24	1.25	0.3281	Yes	Yes	1.375	1.2919		6	1.5	0	100.0
N2	20	1	0.3281	Yes	Yes	1.375	1.2836		5	1.5	0	100.0
N25	60	1.25	0.4846	Yes	Yes	1.375	1.0909		14	2	0	109.4
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	1.3214		4	1.5	0	100.0
N4	8.625	0.719	0.322	Yes	Yes	1.375	1.2972		2.75	1	0	100.0
N5	4.5	0.531	0.237	Yes	Yes	1.375	1.375		2	1	0	100.4
N6A	2.375	0.436	0.154	Yes	Yes	1.3*	1.3		2	1	0	111.7
N6B	2.375	0.436	0.154	Yes	Yes	1.3*	1.3		2	1	0	111.7
N7	4.5	0.531	0.237	Yes	Yes	1.25*	0.7894		N/A	N/A	0	100.0
N8	4.5	0.531	0.237	Yes	Yes	1.375	1.375		2	1	0	100.4

*Head minimum thickness after forming

Definitions	
tn	Nozzle thickness
Req tn	Nozzle thickness required per UG-45/UG-16
Nom t	Vessel wall thickness
Design t	Required vessel wall thickness due to pressure + corrosion allowance per UG-37
User t	Local vessel wall thickness (near opening)
A_a	Area available per UG-37, governing condition
A_r	Area required per UG-37, governing condition
Corr	Corrosion allowance on nozzle wall

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	-68.1	Note 1		Yes
Straight Flange on Ellipsoidal Head #2	250	600	314.47	324.2	42.99	400	-72.1	Note 2		Yes
Cylinder #1	250	600	314.47	324.2	42.99	400	-72.1	Note 2		Yes
Cylinder #2	250	600	286.14	294.99	34.38	400	-64.4	Note 3		Yes
Cylinder #3	250	600	314.47	324.2	42.99	400	-72.1	Note 2		Yes
Cylinder #4	250	600	314.47	324.2	42.99	400	-72.1	Note 2		Yes
Cylinder #5	250	600	314.47	324.2	42.99	400	-72.1	Note 2		Yes
Straight Flange on Ellipsoidal Head #1	250	600	314.47	324.2	42.99	400	-72.1	Note 2		Yes
Ellipsoidal Head #1	250	600	299.77	309.05	97.01	400	-68.1	Note 1		Yes
Saddle #1	250	600	250	N/A	N/A	N/A	N/A	N/A		N/A
60" BOOT (BOOT)	250	600	255.74	N/I	34.38	400	-64.4	Nozzle	Note 4	Yes
								Pad	Note 5	Yes
Straight Flange on Ellipsoidal Head #3	250	600	865.37	892.13	416.45	400	-155	Note 7		Yes
Ellipsoidal Head #3	250	600	804.98	829.88	325.28	400	-155	Note 6		Yes
3" 300# RFWN LG/LT (SIS) BRIDLE (J2A)	250	600	284.36	N/I	42.99	400	-55	Nozzle	Note 8	No
								Pad	Note 9	Yes
2" 300# RFLWN LEVEL TRANS (J3A)	250	600	570	N/I	34.38	400	-55	Note 10		No
2" 300# RFLWN LEVEL TRANS (J3B)	250	600	570	N/I	34.38	400	-55	Note 10		No
2" 300# RFLWN LEVEL TRANS (J4A)	250	600	570	N/I	34.38	400	-55	Note 10		No
2" 300# RFLWN LEVEL TRANS (J4B)	250	600	570	N/I	34.38	400	-55	Note 10		No
24" 300# RFWN MANWAY (M1)	250	600	280.35	N/I	42.99	400	-55	Nozzle	Note 8	Yes
								Pad	Note 11	Yes
24" 300# RFWN MANWAY (M2)	250	600	280.35	N/I	42.99	400	-55	Nozzle	Note 8	Yes
								Pad	Note 11	Yes
24" 300# RFWN FEED INLET (N1)	250	600	295.63	N/I	42.99	400	-55	Nozzle	Note 8	Yes
								Pad	Note 9	Yes
20" 300# RFWN VAPOUR OUTLET (N2)	250	600	293.76	N/I	42.99	400	-55	Nozzle	Note 8	No
								Pad	Note 9	Yes
Nozzle #25 (N25)	250	600	250	N/I	42.99	400	-6.1	Nozzle	Note 12	No
								Pad	Note 13	No
Nozzle #26 (N26)	250	600	250	N/I	42.99	400	17.4	Note 14		No
16" 300# RFWN HYDROCARBON OUTLET (N3)	250	600	302.33	N/I	42.99	400	-55	Nozzle	Note 8	No
								Pad	Note 9	Yes
8" 300# RFWN VENT (N4)	250	600	296.84	N/I	42.99	400	-55	Nozzle	Note 8	No
								Pad	Note 9	Yes
4" 300# RFWN DRAIN (N5)	250	600	314.47	N/I	42.99	400	-55	Nozzle	Note 8	No
								Pad	Note 9	Yes
2" 300# RFWN STEAM OUT (N6A)	250	600	299.77	N/I	42.99	400	-55	Nozzle	Note 8	No
								Pad	Note 15	Yes
2" 300# RFWN STEAM OUT (N6B)	250	600	299.77	N/I	42.99	400	-55	Nozzle	Note 8	No
								Pad	Note 15	Yes

4" 300# RFWN WATER OUTLET (N7)	250	600	565.55	N/I	262.44	400	-55	Note 8		No
4" 300# RFWN VENT (N8)	250	600	314.47	N/I	42.99	400	-55	Nozzle	Note 8	No
								Pad	Note 9	Yes

Chamber Summary	
Design MDMT	-49 °F
Rated MDMT	17.4 °F @ 250 psi
MAWP hot & corroded	250 psi @ 600 °F
MAP cold & new	250 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 19.1°F applied (ratio = 0.8087).
2.	Material is impact tested per UG-84 to -49°F.	UCS-66(i) reduction of 23.1°F applied (ratio = 0.7694).
3.	Material is impact tested per UG-84 to -49°F.	UCS-66(i) reduction of 15.4°F applied (ratio = 0.8463).
4.	Nozzle is impact tested per UG-84 to -49°F.	UCS-66(i) reduction of 15.4°F applied (ratio = 0.8463).
5.	Pad is impact tested per UG-84 to -49°F.	UCS-66(i) reduction of 15.4°F applied (ratio = 0.8463).
6.	Straight Flange governs MDMT	
7.	Material is impact tested per UG-84 to -49°F.	Stress ratio = 0.2748 ≤ 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 = 0.3378 ≤ 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 23.1°F applied (ratio = 0.7694).
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 = 0.3378 ≤ 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 27.2°F applied (ratio = 0.7278).
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 = 102.1°F, (coincident ratio = 0.3877) Rated MDMT of -96.6°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 = 23.1°F, (coincident ratio = 0.7694)	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 = 27.2°F, (coincident ratio = 0.7278) 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 19.1°F applied (ratio = 0.8087).

Revision History

Revisions			
No.	Date	Operator	Notes
0	10/19/2007	vbarut	New vessel created ASME Division 1 [Build 6254]

Settings Summary

INSPECT 2015 Build 7500	
ASME Section VIII Division 1, 2004 Edition, A06 Addenda	
Units	U.S. Customary
Datum Line Location	0.00" from right seam
Vessel Design Mode	Get Pressure Rating and Calculate Required Thickness
Minimum thickness	0.0625" per UG-16(b)
Design for cold shut down only	No
Design for lethal service (full radiography required)	No
Rate nozzles for	Find nozzle MAWP
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 $\alpha > 30$ 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
Pipe caps 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
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
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
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.	

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	User Defined (E = 1.00)	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	User Defined (E = 1.00)	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	User Defined (E = 1.00)	D	N/A / Type 7	B	Full UW-11(a) / Type 1	RT1
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	User Defined (E = 1.00)	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	User Defined (E = 1.00)	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 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	1.375	0.3897	0	1.00	Internal
Ellipsoidal Head #3	SA-516 70	60 ID	16.25	1.25*	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

Weight (lb) Contributed by Vessel Elements										
Component	Metal New*	Metal Corroded	Insulation	Insulation Supports	Lining	Piping + Liquid	Operating Liquid		Test Liquid	
							New	Corroded	New	Corroded
Ellipsoidal Head #2	12,065.5	12,065.5	1,401.4	50	0	0	0	0	24,198.6	24,198.6
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	105,492.4	105,495.2
Cylinder #3	16,913.7	16,913.7	1,990.1	50	0	0	0	0	72,592	72,592
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**	**461,675**	**461,677.8**

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

Weight (lb) Contributed by Attachments									
Component	Body Flanges		Nozzles & Flanges		Packed Beds	Trays	Tray Supports	Rings & Clips	Vertical Loads
	New	Corroded	New	Corroded					
Ellipsoidal Head #2	0	0	4,072.1	4,072.1	0	0	0	0	0
Cylinder #1	0	0	2,000.8	2,000.8	0	0	0	0	0
Cylinder #2	0	0	13,169	13,142.6	0	0	0	578.5	0
Cylinder #3	0	0	9,559.3	9,559.3	0	0	0	0	7,700*
Cylinder #4	0	0	0	0	0	0	0	0	18,243
Cylinder #5	0	0	1,818.8	1,818.8	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**	**32,638.4**	**32,612**	**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)	204,131	204,105
Empty Weight (lb)	204,131	204,105
Test Weight (lb)	665,806	665,783
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)	196,431
Center of Gravity from Datum (in)	251.1606

Hydrostatic Test

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

Gauge pressure at 70°F = 1.3*MAWP*LSR
= 1.3*250*1
= 325 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	332.472	7.472	1.0309	1.30	19,335	34,200	No
Straight Flange on Ellipsoidal Head #2	332.472	7.472	1.0309	1.30	20,477	34,200	No
Cylinder #1	332.472	7.472	1.0309	1.30	20,477	34,200	No
Cylinder #2	332.472	7.472	1.0309	1.30	22,508	34,200	No
Cylinder #3	332.472	7.472	1.0309	1.30	20,477	34,200	No
Cylinder #4	332.472	7.472	1.0309	1.30	20,477	34,200	No
Cylinder #5	332.472	7.472	1.0309	1.30	20,477	34,200	No
Straight Flange on Ellipsoidal Head #1	332.472	7.472	1.0309	1.30	20,477	34,200	No
Ellipsoidal Head #1	332.472	7.472	1.0309	1.30	19,335	34,200	No
Straight Flange on Ellipsoidal Head #3	335.504	10.504	1.0309	1.30	7,487	34,200	No
Ellipsoidal Head #3	336.046	11.046	1.0309	1.30	7,259	34,200	No
16" 300# RFWN HYDROCARBON OUTLET (N3) (1)	333.172	8.172	1	1.30	20,157	51,300	No
2" 300# RFLWN LEVEL TRANS (J3A)	335.288	10.288	1.087	1.30	5,625	51,300	No
2" 300# RFLWN LEVEL TRANS (J3B)	332.905	7.905	1.087	1.30	5,585	51,300	No
2" 300# RFLWN LEVEL TRANS (J4A)	335.288	10.288	1.087	1.30	5,625	51,300	No
2" 300# RFLWN LEVEL TRANS (J4B)	332.905	7.905	1.087	1.30	5,585	51,300	No
2" 300# RFWN STEAM OUT (N6A)	331.916	6.916	1	1.30	15,868	51,300	No
2" 300# RFWN STEAM OUT (N6B)	331.916	6.916	1	1.30	15,868	51,300	No
20" 300# RFWN VAPOUR OUTLET (N2)	326.358	1.358	1.0309	1.30	21,399	51,300	No
24" 300# RFWN FEED INLET (N1)	326.358	1.358	1.0309	1.30	20,646	51,300	No
24" 300# RFWN MANWAY (M1)	331.128	6.128	1.0309	1.30	22,989	51,300	No
24" 300# RFWN MANWAY (M2)	331.128	6.128	1.0309	1.30	22,989	51,300	No
3" 300# RFWN LG/LT (SIS) BRIDLE (J2A)	332.195	7.195	1	1.30	15,977	51,300	No
4" 300# RFWN DRAIN (N5)	332.955	7.955	1	1.30	18,484	51,300	No
4" 300# RFWN VENT (N8)	326.358	1.358	1	1.30	18,118	51,300	No
	336.32	11.32	1	1.30	9,328	51,300	No

4" 300# RFWN WATER OUTLET (N7)							
60" BOOT (BOOT)	335.432	10.432	1.0309	1.30	21,964	51,300	No
8" 300# RFWN VENT (N4)	326.358	1.358	1	1.30	20,445	51,300	No
Nozzle #25 (N25)	329.034	4.034	1	1.30	24,783	51,300	No
Nozzle #26 (N26)	329.873	4.873	1	1.30	9,115	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 47.4 °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

Ellipsoidal Head #2

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 #1			
Impact Tested	**Normalized**	**Fine Grain Practice**	**PWHT**		**Optimize MDMT/ Find 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		12,065.45			2,878.84
Corroded		12,065.45			2,878.84
Insulation					
		Thickness (in)	**Density (lb/ft³)**		**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	-68.1°F

UCS-66 Material Toughness Requirements	
Material impact test temperature per UG-84 =	-49°F
t_r = 250*168 / (2*20,000*1 - 0.2*250) =	1.0513"
Stress ratio = t_r*E^* / (t_n - c) = 1.0513*1 / (1.3 - 0) =	0.8087
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	19.1°F
MDMT = max[T_{impact} - T_R, -155] = max[-49 - 19.1 , -155] =	-68.1°F
Design MDMT of -49°F is acceptable.	

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

t = P*D / (2*S*E - 0.2*P) + Corrosion
= 250*168 / (2*19,400*1 - 0.2*250) + 0
= 1.0839"

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

P = 2*S*E*t / (D + 0.2*t) - P_s
= 2*19,400*1*1.3 / (168 +0.2*1.3) - 0
= 299.77 psi

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

P = 2*S*E*t / (D + 0.2*t) - P_s
= 2*20,000*1*1.3 / (168 +0.2*1.3) - 0
= 309.05 psi

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

Equivalent outside spherical radius (R_o)
R_o = K_o*D_o
= 0.8865*170.6
= 151.2351 in

A = 0.125 / (R_o / t)
= 0.125 / (151.2351 / 0.445813)

= 0.000368

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

P_a = B / (R_o / t)
= 5,088.5176 / (151.2351 / 0.4458)
= 15 psi

t = 0.4458" + Corrosion = 0.4458" + 0" = 0.4458"
Check the external pressure per UG-33(a)(1) UG-32(d)(1)

t = 1.67*P_e*D / (2*S*E - 0.2*1.67*P_e) + Corrosion
= 1.67*15*168 / (2*20,000*1 - 0.2*1.67*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)
R_o = K_o*D_o
= 0.8865*170.6
= 151.2351 in

A = 0.125 / (R_o / t)
= 0.125 / (151.2351 / 1.3)
= 0.001074

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

P_a = B / (R_o / t)
= 11,285.56 / (151.2351 / 1.3)
= 97.0094 psi

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

P = 2*S*E*t / ((D + 0.2*t)*1.67)
= 2*20,000*1*1.3 / ((168 +0.2*1.3)*1.67)
= 185.06 psi

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

% Extreme fiber elongation - UCS-79(d)

EFE = (75*t / R_f)*(1 - R_f / R_o)
= (75*1.375 / 29.2475)*(1 - 29.2475 / ∞)
= 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	Optimize MDMT/ Find 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/ft³)	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	-72.1 °F

UCS-66 Material Toughness Requirements	
Material impact test temperature per UG-84 =	-49°F
t_r = 250*84 / (20,000*1 - 0.6*250) =	1.0579"
Stress ratio = t_r*E^* / (t_n - c) = 1.0579*1 / (1.375 - 0) =	0.7694
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	23.1°F
MDMT = max[T_{impact} - T_R, -155] = max[-49 - 23.1 , -155] =	-72.1°F
Design MDMT of -49°F is acceptable.	

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

t = P*R / (S*E - 0.60*P) + Corrosion
= 250*84 / (19,400*1.00 - 0.60*250) + 0
= 1.091"

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

P = S*E*t / (R + 0.60*t) - P_s
= 19,400*1.00*1.375 / (84 + 0.60*1.375) - 0
= 314.47 psi

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

P = S*E*t / (R + 0.60*t)
= 20,000*1.00*1.375 / (84 + 0.60*1.375)
= 324.2 psi

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

L / D_o = 532 / 170.75 = 3.1157
D_o / t = 170.75 / 0.8941 = 190.9811
From table G: A = 0.000157
From table CS-2: B = 2,148.5374 psi

P_a = 4*B / (3*(D_o / t))
= 4*2,148.54 / (3*(170.75 / 0.8941))
= 15 psi

Design thickness for external pressure P_a = 15 psi

t_a = t + Corrosion = 0.8941 + 0 = 0.8941"

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

L / D_o = 532 / 170.75 = 3.1157
D_o / t = 170.75 / 1.375 = 124.1818
From table G: A = 0.000290
From table CS-2: B = 4,004.3077 psi

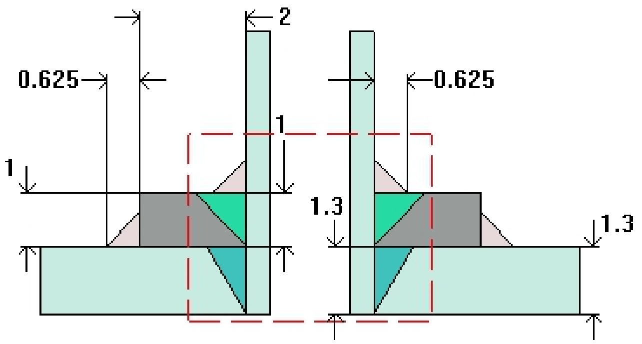
P_a = 4*B / (3*(D_o / t))
= 4*4,004.31 / (3*(170.75 / 1.375))
= 42.99 psi

% Extreme fiber elongation - UCS-79(d)

EFE = (50*t / R_f)*(1 - R_f / R_o)
= (50*1.375 / 84.6875)*(1 - 84.6875 / ∞)
= 0.8118%

The extreme fiber elongation does not exceed 5%.

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"
Nominal wall thickness	0.436"
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
Longitudinal joint efficiency	1
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"

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	
Description	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel
Notes	
Flange is impact tested per material specification to -50°F. Stress ratio = 0.3378 ≤ 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 = t_r*E* / (t_n - c) = 0.0521*1 / (0.3815 - 0) =	0.1366
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 = 250*168 / (2*20,000*1 - 0.2*250) =	1.0513"
Stress ratio = t_r*E* / (t_n - c) = 1.0513*1 / (1.3 - 0) =	0.8087
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	19.1°F
MDMT = max[T_{impact} - T_R, -155] = max[-49 - 19.1 , -155] =	-68.1°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	4.0453	--	1.5573	--	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	78,478.82	90,652.66	56,274.65	142,718.2	97,862.43	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 MAEP

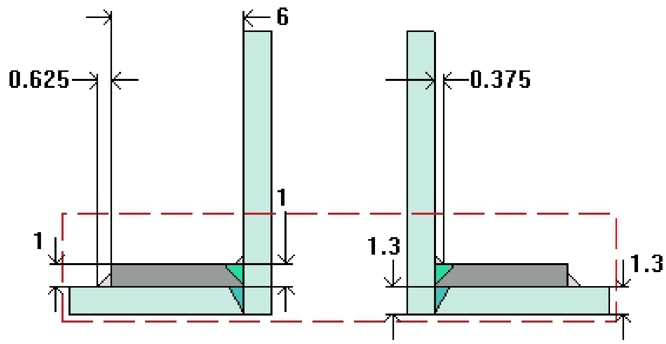
UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 42.99 psi @ 400 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
1.0702	5.7936	1.8286	1.455	--	2.176	0.334	0.1348	0.3815

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

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	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
Longitudinal joint efficiency	1
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"

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
Gasket	
Description	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel
Notes	
Flange is impact tested per material specification to -50°F. Stress ratio = 0.3378 ≤ 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 = 250*10.75 / (20,000*1 - 0.6*250) =	0.1354"
Stress ratio = t_r*E^* / (t_n - c) = 0.1354*1 / (1.25 - 0) =	0.1083
Stress ratio ≤ 0.35, MDMT per UCS-66(b)(3) =	-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 = 250*0.9*168 / (2*20,000*1 - 0.2*250) =	0.9462"
Stress ratio = t_r*E^* / (t_n - c) = 0.9462*1 / (1.3 - 0) =	0.7278
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	27.2°F
MDMT = max[T_{impact} - T_R, -155] = max[-49 - 27.2 , -155] =	-76.2°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 = $(50*t / R_f)*(1 - R_f / R_o)$

= $(50*1.25 / 11.375)*(1 - 11.375 / \infty)$

= 5.4945%

Reinforcement Calculations for MAEP

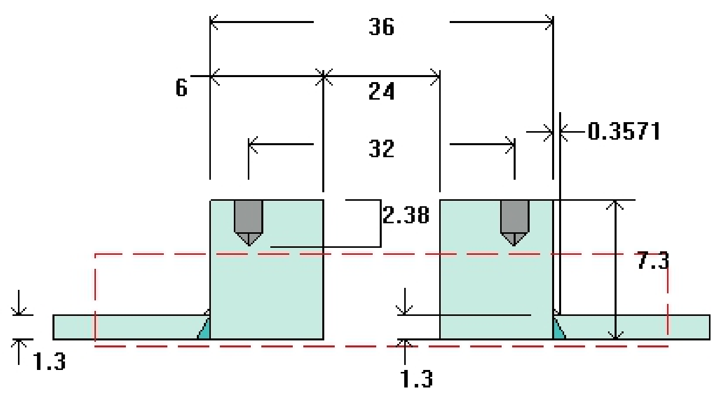
UG-37 Area Calculation Summary (in²)							UG-45 Summary (in)	
For Pe = 42.99 psi @ 400 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
8.3289	32.0495	12.0851	7.4332	--	12	0.5312	0.1806	1.25

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

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	
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
Longitudinal joint efficiency	1
Welds	
Inner Fillet, Leg_{42}	0.3571"
Nozzle to vessel groove weld	1.3"

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 = 0.3378) 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 = 250*0.9*168 / (2*20,000*1 - 0.2*250) =	0.9462"
Stress ratio = t_r*E^* / (t_n - c) = 0.9462*1 / (1.3 - 0) =	0.7278
Reduction in MDMT, T_R from Fig UCS-66.1 =	27.2°F
MDMT = max[MDMT - T_R, -55] = max[44.6 - 27.2 , -55] =	17.4°F
Rated MDMT of 17.4°F > Design MDMT of -49°F.	

Reinforcement Calculations for MAWP

UG-37 Area Calculation Summary (in^2)	

							UG-45 Summary (in)	
For P = 250 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}
24.7998	41.8136	7.3266	--	--	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_{42})	0.25	0.25	weld size is adequate

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_{42})	0.25	0.25	weld size is 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**	**Optimize MDMT/ Find 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/ft³)**	**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	-72.1 °F

UCS-66 Material Toughness Requirements	
Material impact test temperature per UG-84 =	-49°F
t_r = 250*84 / (20,000*1 - 0.6*250) =	1.0579"
Stress ratio = t_r*E^* / (t_n - c) = 1.0579*1 / (1.375 - 0) =	0.7694
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	23.1°F
MDMT = max[T_{impact} - T_R, -155] = max[-49 - 23.1 , -155] =	-72.1°F
Design MDMT of -49°F is acceptable.	

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

t = P*R / (S*E - 0.60*P) + Corrosion
= 250*84 / (19,400*1.00 - 0.60*250) + 0
= 1.091"

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

P = S*E*t / (R + 0.60*t) - P_s
= 19,400*1.00*1.375 / (84 + 0.60*1.375) - 0
= 314.47 psi

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

P = S*E*t / (R + 0.60*t)
= 20,000*1.00*1.375 / (84 + 0.60*1.375)
= 324.2 psi

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

L / D_o = 532 / 170.75 = 3.1157
D_o / t = 170.75 / 0.8941 = 190.9811
From table G: A = 0.000157
From table CS-2: B = 2,148.5374 psi

P_a = 4*B / (3*(D_o / t))
= 4*2,148.54 / (3*(170.75 / 0.8941))
= 15 psi

Design thickness for external pressure P_a = 15 psi

t_a = t + Corrosion = 0.8941 + 0 = 0.8941"

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

L / D_o = 532 / 170.75 = 3.1157
D_o / t = 170.75 / 1.375 = 124.1818
From table G: A = 0.000290
From table CS-2: B = 4,004.3077 psi

P_a = 4*B / (3*(D_o / t))
= 4*4,004.31 / (3*(170.75 / 1.375))
= 42.99 psi

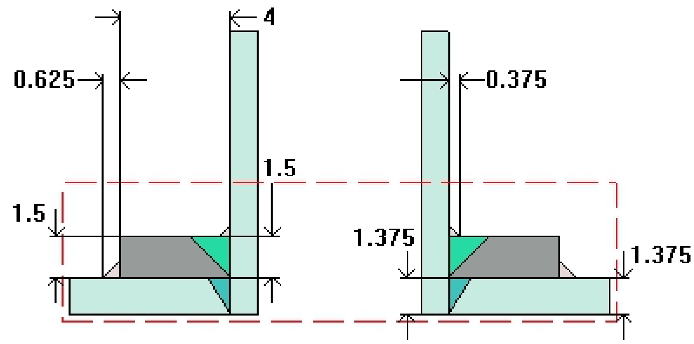
% Extreme fiber elongation - UCS-79(d)

EFE = (50*t / R_f)*(1 - R_f / R_o)
= (50*1.375 / 84.6875)*(1 - 84.6875 / ∞)
= 0.8118%

The extreme fiber elongation does not exceed 5%.

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"
Nominal wall thickness	1.031"
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
Longitudinal joint efficiency	1
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"

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
Gasket	
Description	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel
Notes	
Flange is impact tested per material specification to -50°F. Stress ratio = 0.3378 ≤ 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 = t_r*E^* / (t_n - c) = 0.136*1 / (0.9021 - 0) =	0.1508
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 = 250*84 / (20,000*1 - 0.6*250) =	1.0579"
Stress ratio = t_r*E* / (t_n - c) = 1.0579*1 / (1.375 - 0) =	0.7694
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	23.1°F
MDMT = max[T_{impact} - T_R, -155] = max[-49 - 23.1 , -155] =	-72.1°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 = 302.33 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}
18.7411	18.7413	0.7337	5.4931	--	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
351,232.89	349,347.44	514,158.51	157,450.19	1,116,286.4	397,827.83	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	302.33	-5,035	-198,360	0	198,360	0	0	**25,747**	**58,200**	**19,987**	**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 MAEP

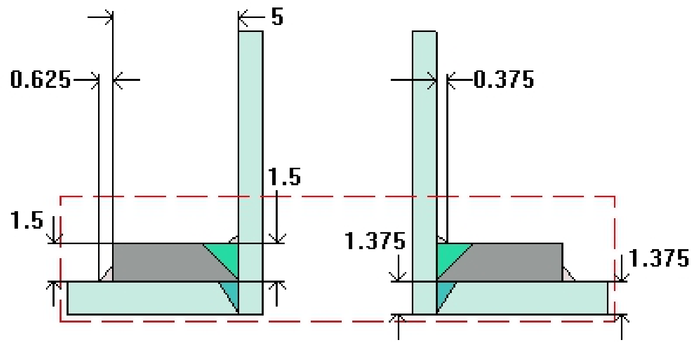
UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 42.99 psi @ 400 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
9.7879	18.0788	--	5.568	--	12	0.5108	0.1808	0.9021

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

20" 300# RFWN VAPOUR OUTLET (N2)

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	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
Longitudinal joint efficiency	1
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"

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
Gasket	
Description	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel
Notes	
Flange is impact tested per material specification to -50°F. Stress ratio = 0.3378 ≤ 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 = t_r*E^* / (t_n - c) = 0.1386*1 / (1 - 0) =	0.1386
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 = 250*84 / (20,000*1 - 0.6*250) =	1.0579"
Stress ratio = t_r*E* / (t_n - c) = 1.0579*1 / (1.375 - 0) =	0.7694
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	23.1°F
MDMT = max[T_{impact} - T_R, -155] = max[-49 - 23.1 , -155] =	-72.1°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)

$$EFE = (50*t / R_f)*(1 - R_f / R_o)$$
$$= (50*1 / 9.5)*(1 - 9.5 / \infty)$$
$$= 5.2632\%$$

Reinforcement Calculations for MAEP

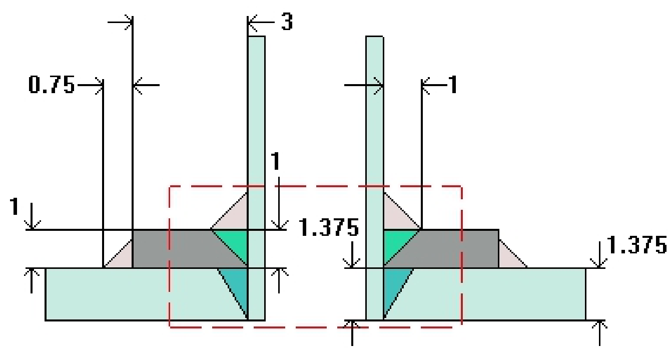
UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 42.99 psi @ 400 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	**A available**	**A_1**	**A_2**	**A_3**	**A_5**	**A welds**	**t_{req}**	**t_{min}**
12.375	21.509	--	5.9778	--	15	0.5312	0.1808	1

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

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"
Nominal wall thickness	0.438"
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
Longitudinal joint efficiency	1
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"

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	
Description	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel
Notes	
Flange is impact tested per material specification to -50°F. Stress ratio = 0.3378 ≤ 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 = t_r*E^* / (t_n - c) = 0.0577*1 / (0.3833 - 0) =	0.1505
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 = 250*84 / (20,000*1 - 0.6*250) =	1.0579"
Stress ratio = t_r*E^* / (t_n - c) = 1.0579*1 / (1.375 - 0) =	0.7694
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	23.1°F
MDMT = max[T_{impact} - T_R, -155] = max[-49 - 23.1 , -155] =	-72.1°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 = 284.36 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}
7.2053	7.2054	0.7429	1.5363	--	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
127,359.68	125,372.5	174,707.86	67,499.32	233,515.76	145,968.44	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	284.36	-945	-5,136	0	5,136	0	0	**18,407**	**58,200**	**17,509**	**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 MAEP

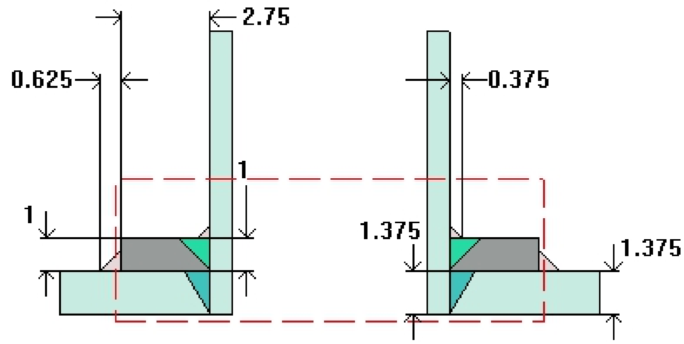
UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 42.99 psi @ 400 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
3.9795	6.2672	--	1.438	--	3.9742	0.855	0.1808	0.3833

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

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"
Nominal wall thickness	0.719"
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
Longitudinal joint efficiency	1
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"

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	
Description	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel
Notes	
Flange is impact tested per material specification to -50°F. Stress ratio = 0.3378 ≤ 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 = t_r*E^* / (t_n - c) = 0.1007*1 / (0.6291 - 0) =	0.16
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 = 250*84 / (20,000*1 - 0.6*250) =	1.0579"
Stress ratio = t_r*E* / (t_n - c) = 1.0579*1 / (1.375 - 0) =	0.7694
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	23.1°F
MDMT = max[T_{impact} - T_R, -155] = max[-49 - 23.1 , -155] =	-72.1°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 = 296.85 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}
9.5444	9.5447	0.5457	3.235	--	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
176,486.44	174,580.6	238,702.28	98,971.97	504,499.75	208,389.91	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	296.85	-2,520	-50,544	0	50,544	0	0	**22,105**	**58,200**	**19,160**	**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 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

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**		**Optimize MDMT/ Find 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/ft³)**		**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	-64.4 °F

UCS-66 Material Toughness Requirements	
Material impact test temperature per UG-84 =	-49°F
t_r = 250*84 / (20,000*1 - 0.6*250) =	1.0579"
Stress ratio = t_r*E^* / (t_n - c) = 1.0579*1 / (1.25 - 0) =	0.8463
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	15.4°F
MDMT = max[T_{impact} - T_R, -155] = max[-49 - 15.4 , -155] =	-64.4°F
Design MDMT of -49°F is acceptable.	

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

t = P*R / (S*E - 0.60*P) + Corrosion
= 250*84 / (19,400*1.00 - 0.60*250) + 0
= 1.091"

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

P = S*E*t / (R + 0.60*t) - P_s
= 19,400*1.00*1.25 / (84 + 0.60*1.25) - 0
= 286.14 psi

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

P = S*E*t / (R + 0.60*t)
= 20,000*1.00*1.25 / (84 + 0.60*1.25)
= 294.99 psi

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

L / D_o = 532 / 170.5 = 3.1202
D_o / t = 170.5 / 0.8932 = 190.8780
From table G: A = 0.000156
From table CS-2: B = 2,147.3783 psi

P_a = 4*B / (3*(D_o / t))
= 4*2,147.38 / (3*(170.5 / 0.8932))
= 15 psi

Design thickness for external pressure P_a = 15 psi

t_a = t + Corrosion = 0.8932 + 0 = 0.8932"

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

L / D_o = 532 / 170.5 = 3.1202
D_o / t = 170.5 / 1.25 = 136.4000
From table G: A = 0.000255
From table CS-2: B = 3,516.96 psi

P_a = 4*B / (3*(D_o / t))
= 4*3,516.96 / (3*(170.5 / 1.25))
= 34.38 psi

% Extreme fiber elongation - UCS-79(d)

EFE = (50*t / R_f)*(1 - R_f / R_o)
= (50*1.25 / 84.625)*(1 - 84.625 / ∞)
= 0.7386%

The extreme fiber elongation does not exceed 5%.

60" BOOT (BOOT)

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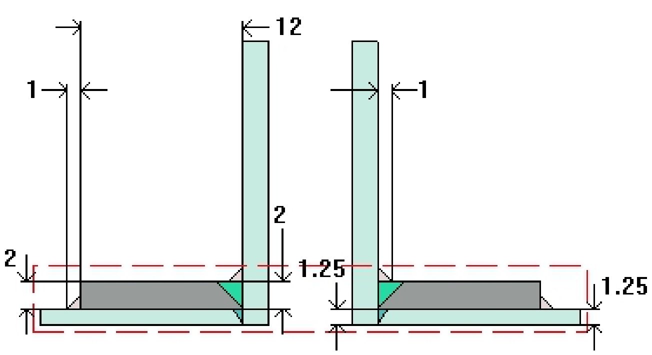


Note: round inside edges per UG-76(c)

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
Longitudinal joint efficiency	1

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"

UCS-66 Material Toughness Requirements Nozzle	
Material impact test temperature per UG-84 =	-49°F
t_r = 250*84 / (20,000*1 - 0.6*250) =	1.0579"
Stress ratio = t_r*E^* / (t_n - c) = 1.0579*1 / (1.25 - 0) =	0.8463
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	15.4°F
MDMT = max[T_{impact} - T_R, -155] = max[-49 - 15.4 , -155] =	-64.4°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 = 250*84 / (20,000*1 - 0.6*250) =	1.0579"
Stress ratio = t_r*E^* / (t_n - c) = 1.0579*1 / (1.25 - 0) =	0.8463
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	15.4°F
MDMT = max[T_{impact} - T_R, -155] = max[-49 - 15.4 , -155] =	-64.4°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(0.75*d, R_n + (t_n - C_n) + (t - C))
= MAX(0.75*60, 30 + (2 - 0) + (1.25 - 0))
= 45 in

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

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

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 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 in > 60 in	True
1-7(b)(1)(b)	d = 60 in > 40 in	True
1-7(b)(1)(b)	d = 60 in > 3.4*(84*1.25)$^{0.5}$ = 34.8396 in	True
1-7(b)(1)(c)	R_n / R = 30 / 84 = 0.3571 ≤ 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 = $P*(R*(R_n + t_n + Sqr(R_m*t)) + R_n*(t + t_e + Sqr(R_{nm}*t_n))) / A_s$
= 255.7371*(84*(30 + 2 + Sqr(84.625*1.25)) + 30*(1.25 + 2 + Sqr(31*2))) / 55.67427
= 17,849 psi

Note that area A_s includes consideration of UG-41.

M = $(R_n^3 / 6 + R*R_n*e)*P$
= $(30^3 / 6 + 84*30*10.355649)*255.7371$
= 7,824,591.2 lb_f-in

S_b = M*a / I
= 7,824,591.2*10.980649 / 14,934.06983
= 5,753 psi

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

$S_m + S_b$ = 23,602 <= 1.5*19,400 = 29,100; satisfactory.

S_m = 17,849 <= 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 = $(50*t / R_f)*(1 - R_f / R_o)$
= $(50*2 / 31)*(1 - 31 / \infty)$
= 3.2258%

The extreme fiber elongation does not exceed 5%.

Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (in²)							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	60.4383	--	10.4383	--	48	2	0.3299	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 = $MAX(0.75*d, R_n + (t_n - C_n) + (t - C))$
= $MAX(0.75*60, 30 + (2 - 0) + (1.25 - 0))$
= 45 in

A_1 = $(2*L_R - d)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= $(2*45 - 60)*(1*1.25 - 1*1.25) - 2*2*(1*1.25 - 1*1.25)*(1 - 1)$
= $0\ in^2$

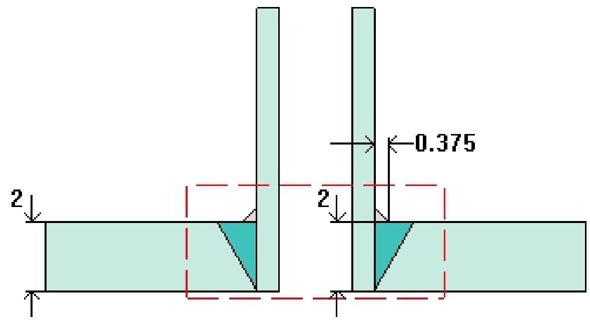
A_5 = $(D_p - d - 2*t_n)*t_e*f_{r4}$
= $(88 - 60 - 2*2)*2*1$
= $48\ in^2$

Area = $A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$
= $0 + 10.4383 + 0 + 1 + 1 + 0 + 48$
= $60.4383\ in^2$

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

2" 300# RFLWN LEVEL TRANS (J3A)

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	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
Longitudinal joint efficiency	1

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

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	
Description	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel
Notes	
Flange is impact tested per material specification to -50°F. Stress ratio = 0.3378 ≤ 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 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)

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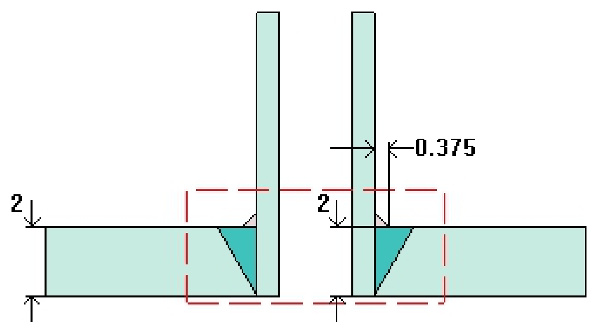


Note: round inside edges per UG-76(c)

Location and Orientation	
Located on	60" BOOT (BOOT)
Orientation	180°
Nozzle center line offset to face of parent nozzle	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
Longitudinal joint efficiency	1
Welds	
Inner Fillet, Leg_{41}	0.375"
Nozzle to vessel groove weld	2"

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 = 0.3378 ≤ 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 (in²)							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 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

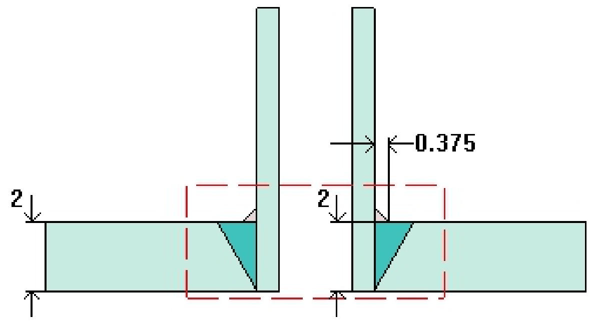
UG-41 Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

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
Longitudinal joint efficiency	1
Welds	
Inner Fillet, Leg_{41}	0.375"
Nozzle to vessel groove weld	2"

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	
Description	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel
Notes	
Flange is impact tested per material specification to -50°F. Stress ratio = 0.3378 ≤ 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 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

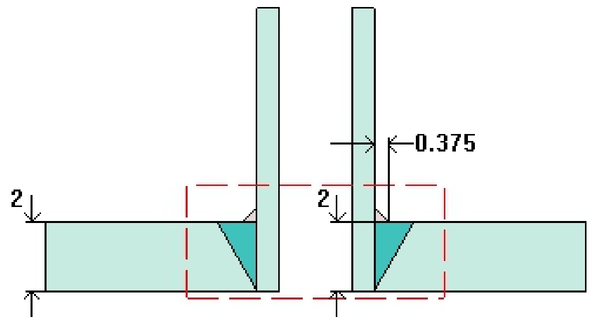
UG-41 Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

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
Longitudinal joint efficiency	1
Welds	
Inner Fillet, Leg_{41}	0.375"
Nozzle to vessel groove weld	2"

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	
Description	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel
Notes	
Flange is impact tested per material specification to -50°F. Stress ratio = 0.3378 ≤ 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 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**	**Optimize MDMT/ Find 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		1.375"		
Corrosion	**Inner**	0"		
	Outer	0"		
Weight and Capacity				
		Weight (lb)		**Capacity (US gal)**
New		150.06		24.48
Corroded		150.06		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)	0.2356"
Maximum allowable working pressure (MAWP)	865.37 psi
Maximum allowable pressure (MAP)	892.13 psi
Maximum allowable external pressure (MAEP)	416.45 psi
Rated MDMT	-155 °F

UCS-66 Material Toughness Requirements	
Material impact test temperature per UG-84 =	-49°F
t_r = 250*30 / (20,000*1 - 0.6*250) =	0.3778"
Stress ratio = t_r*E^* / (t_n - c) = 0.3778*1 / (1.375 - 0) =	0.2748
Stress ratio ≤ 0.35, MDMT per UCS-66(b)(3) =	-155°F
Design MDMT of -49°F is acceptable.	

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

t = P*R / (S*E - 0.60*P) + Corrosion
= 250*30 / (19,400*1.00 - 0.60*250) + 0
= 0.3897"

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

P = S*E*t / (R + 0.60*t) - P_s
= 19,400*1.00*1.375 / (30 + 0.60*1.375) - 0
= 865.37 psi

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

P = S*E*t / (R + 0.60*t)
= 20,000*1.00*1.375 / (30 + 0.60*1.375)
= 892.13 psi

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

L / D_o = 87.75 / 62.75 = 1.3984
D_o / t = 62.75 / 0.2356 = 266.3784
From table G: A = 0.000218
From table CS-2: B = 2,996.7475 psi

P_a = 4*B / (3*(D_o / t))
= 4*2,996.75 / (3*(62.75 / 0.2356))
= 15 psi

Design thickness for external pressure P_a = 15 psi

t_a = t + Corrosion = 0.2356 + 0 = 0.2356"

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

L / D_o = 87.75 / 62.75 = 1.3984
D_o / t = 62.75 / 1.375 = 45.6364

From table G:	A	=	0.003132
From table CS-2:	B	=	14,253.9249 psi

P_a = 4*B / (3*(D_o / t))
= 4*14,253.92 / (3*(62.75 / 1.375))
= 416.45 psi

% Extreme fiber elongation - UCS-79(d)

EFE = (50*t / R_f)*(1 - R_f / R_o)
= (50*1.375 / 30.6875)*(1 - 30.6875 / ∞)
= 2.2403%

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**	**Optimize MDMT/ Find 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		1.25"		
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		1,689.08		146.88
Corroded		1,689.08		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)	0.1595"
Maximum allowable working pressure (MAWP)	804.98 psi
Maximum allowable pressure (MAP)	829.88 psi
Maximum allowable external pressure (MAEP)	325.28 psi
Straight Flange governs MDMT	-155°F

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

t = P*D / (2*S*E - 0.2*P) + Corrosion
= 250*60 / (2*19,400*1 - 0.2*250) + 0
= 0.3871"

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

P = 2*S*E*t / (D + 0.2*t) - P_s
= 2*19,400*1*1.25 / (60 +0.2*1.25) - 0
= 804.98 psi

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

P = 2*S*E*t / (D + 0.2*t) - P_s
= 2*20,000*1*1.25 / (60 +0.2*1.25) - 0
= 829.88 psi

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

Equivalent outside spherical radius (R_o)

R_o = K_o*D_o
= 0.8654*62.5
= 54.0865 in

A = 0.125 / (R_o / t)
= 0.125 / (54.0865 / 0.159437)
= 0.000368

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

P_a = B / (R_o / t)
= 5,088.5176 / (54.0865 / 0.1594)
= 15 psi

t = 0.1594" + Corrosion = 0.1594" + 0" = 0.1594"

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

t	=	$1.67 * P_e * D / (2*S*E - 0.2*1.67*P_e)$ + Corrosion
	=	1.67*15*60 / (2*20,000*1 - 0.2*1.67*15) + 0
	=	0.0376"

The head external pressure design thickness (t_e) is 0.1594".

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

Equivalent outside spherical radius (R_o)

R_o	=	$K_o * D_o$
	=	0.8654*62.5
	=	54.0865 in

A	=	$0.125 / (R_o / t)$
	=	0.125 / (54.0865 / 1.25)
	=	0.002889

From Table CS-2: B = 14,074.69 psi

P_a	=	$B / (R_o / t)$
	=	14,074.69 / (54.0865 / 1.25)
	=	325.2818 psi

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

P	=	2*S*E*t / ((D + 0.2*t)*1.67)
	=	2*20,000*1*1.25 / ((60 +0.2*1.25)*1.67)
	=	496.93 psi

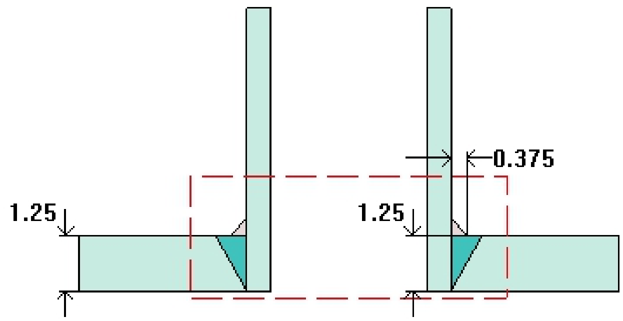
The maximum allowable external pressure (MAEP) is 325.28 psi.

% Extreme fiber elongation - UCS-79(d)

EFE	=	$(75*t / R_f)*(1 - R_f / R_o)$
	=	(75*1.375 / 10.8875)*(1 - 10.8875 / ∞)
	=	9.4719%

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"
Nominal wall thickness	0.531"
Corrosion allowance	0"
Projection available outside vessel, Lpr	3.0179"
Projection available outside vessel to flange face, Lf	6.3979"
Local vessel minimum thickness	1.25"
Liquid static head included	0 psi
Longitudinal joint efficiency	1

Welds	
Inner Fillet, Leg_{41}	0.375"
Nozzle to vessel groove weld	1.25"

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	
Description	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel
Notes	
Flange is impact tested per material specification to -50°F. Stress ratio = 0.3378 ≤ 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 = t_r*E* / (t_n - c) = 0.0667*1 / (0.4646 - 0) =	0.1436
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.	

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)
	The nozzle passes UG-45

For P = 565.55 psi @ 600 °F The opening is adequately reinforced								
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
2.8134	2.8134	1.5826	1.1069	--	--	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	565.55	-1,260	-9,648	0	9,648	0	0	**15,689**	**58,200**	**12,560**	**29,100**	No
Load case 1 (Hot Shut Down)	0	-1,260	-9,648	0	9,648	0	0	3,412	58,200	283	29,100	No

Reinforcement Calculations for MAEP

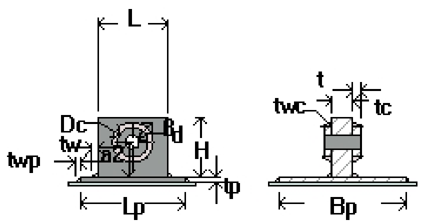
UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 262.44 psi @ 400 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
1.8735	1.8736	0.7049	1.0485	--	--	0.1202	0.2074	0.4646

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	353,575.9 lb
Lug Weight (new), W_{lug}	578.5 lb
Distance from Center of Gravity to this lug, x_1	142.8394"
Distance from Center of Gravity to second lug, x_2	151.1606"
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}	3.2814"
Required Lug Thickness, t_{reqd}	0.5638"
Required Lug Collar Thickness, $t_{c\ reqd}$	0"
Lug Stress Ratio, σ_{ratio}	0.5
Weld Shear Stress Ratio, τ_{ratio}	0.86
Lug Design	Acceptable
Local Stresses WRC 107	**Unacceptable**

Lift Forces

F_r = force on vessel at lug

F_r = $[W / \cos(\phi_1)]*(1 - x_1 / (x_1 + x_2))$

= (353,575.9) / cos(-45°)*(1 - 142.8394/ (142.8394 + 151.1606))

= 257,092 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_{reqd} = $(2*F_r / (\pi*\sigma_s))^{0.5}$

= $(2*257,092 / (\pi*15,200))^{0.5}$ = 3.2814"

d_{reqd} / D_p = 3.2814 / 3.75 = 0.88 Acceptable

σ = F_r / A

= $F_r / (2*(0.25*\pi*D_p^2))$

= $257,092 / (2*(0.25*\pi*3.75^2))$ = 11,639 psi

σ / σ_s = 11,639 / 15,200 = 0.77 Acceptable

Lug Thickness - Tensile stress

t_{reqd} = $F_r / (L*\sigma_t)$
= 257,092 / (20*22,800) = 0.5638"

t_{reqd} / t = 0.5638 / 3 = 0.19 Acceptable

σ = F_r / A
= $F_r / (L*t)$
= 257,092 / (20*3) = 4,285 psi

σ / σ_t = 4,285 / 22,800 = 0.19 Acceptable

Lug Thickness - Bearing stress

T_{reqd} = $F_v / (D_p*\sigma_p)$
= 257,092 / (3.75*34,200) = 2.0046"

T = $t + 2*t_c$
= 3 + 2*1 = 5"

T_{reqd} / T = 2.0046 / 5 = 0.40 Acceptable

Collar required thickness

$t_{c\ reqd}$ = $\max(0, 0.5*(T_{reqd} - t))$
= max(0, 0.5*(2.0046 - 3))
= 0"

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

σ = $F_v / A_{bearing}$
= $F_v / (D_p*(t + 2*t_c))$
= 257,092 / (3.75*(3 + 2*1)) = 13,712 psi

σ / σ_p = 13,712 / 34,200 = 0.4 Acceptable

Lug Thickness - Shear stress

t_{reqd} = $[F_v / \sigma_s - 4*t_c*L_c] / (2*L_{shear})$
= (257,092 / 15,200 - 4*(1*3.4901)) / (2*5.815) = 0.254"

t_{reqd} / t = 0.254 / 3 = 0.08 Acceptable

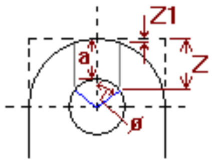
Collar required thickness

$t_{c\ reqd}$ = $[F_v / \sigma_s - 2*t*L_{shear}] / (4*L_c)$
= (257,092 / 15,200 - 2*(3*5.815)) / (4*3.4901) = 0"
$t_{c\ reqd} / t_c$ = 0 / 1 = 0.00 Acceptable

τ = F_v / A_{shear}
= $F_v / (2*t*L_{shear} + 4*t_c*L_c)$
= 257,092 / (2*3*5.815 + 4*1*3.4901) = 5,263 psi

τ / σ_s = 5,263 / 15,200 = 0.35 Acceptable

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



ϕ = $55*D_p / d$
= 55*3.75 / 3.875
= 53.2258°
L_{shear} = $(H - a2 - 0.5*d) + 0.5*D_p*(1 - \cos(\phi))$
= (17 - 10 - 0.5*3.875) + 0.5*3.75*(1 - cos(53.2258))
= 5.815"
L_c = Collar shear plane length
= 3.4901"

Lug Plate Stress

Lug stress tensile + bending during lift:
σ_{ratio} = $[F_{ten} / (A_{ten}*\sigma_t)] + [M_{bend} / (Z_{bend}*\sigma_b)] \leq 1$
= $[(F_r*\cos(\beta)) / (t*L*\sigma_t)] + [(6*abs(F_r*\sin(\beta)*Hght - F_r*\cos(\beta)*a_1)) / (t*L^2*\sigma_b)] \leq 1$
= 257,092*cos(-45.0) / (3*20*22,800) + 6*abs(257,092*sin(-45.0)*10 - 257,092*cos(-45.0)*0) / (3*20²*25,080)
= 0.50 Acceptable

Weld Stress

Weld stress, tensile, bending and shear during lift:

Direct shear:

Shear stress at lift angle -45.00°; lift force = 257,092 lb_f

A_{weld} = $2*(0.707)*t_w*(L + t)$

= 2*(0.707)*1.5*(20 + 3) = 48.783 in^2

= $F_{lug}*\cos(\alpha) / A_{weld}$

τ_t

= 257,092*cos(-45.0) / 48.783 = 3,727 psi

τ_s = F_{lug}*sin(α) / A_{weld}

= 257,092*sin(-45.0) / 48.783 = -3,727 psi

τ_b = M * c / I

= 3*(F_{lug}*sin(β)*Hght - F_{lug}*cos(β)*a_1) / (0.707*h*L*(3*t + L))

= 3*abs(257,092*sin(-45.0)*10 - 257,092*cos(-45.0)*(0)) / (615.0900)

= 8,867 psi

τ_{ratio} = sqr($(\tau_t + \tau_b)^2 + \tau_s^2$) / $\tau_{allowable}$ ≤ 1

= sqr ($(3{,}727 + 8{,}867)^2 + (-3{,}727)^2$) / 15,200

= 0.86 Acceptable

Collar Weld Stress:

τ_c = F_r / A_{weld}

= 257,092 / (2*0.707*1.5*π*8.5) = 4,539 psi

τ_{ratio} = τ_c / $\tau_{allowable}$ ≤ 1

= 4,539 / 15,200 = 0.30 Acceptable

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

Direct shear:

Shear stress at lift angle -45.00°; lift force = 257,092 lb_f

A_{weld} = 2*(0.707)*t_{wp}*(L_p + B_p)

= 2*(0.707)*1.5*(30 + 18) = 101.808 in^2

τ_t = F_{lug}*cos(α) / A_{weld}

= 257,092*cos(-45.0) / 101.808 = 1,786 psi

τ_s = F_{lug}*sin(α) / A_{weld}

= 257,092*sin(-45.0) / 101.808 = -1,786 psi

τ_b = M * c / I

= 3*(F_{lug}*sin(β)*Hght - F_{lug}*cos(β)*a_1) / (0.707*h_p*L_p*(3*W_p + L_p))

= 3*abs(257,092*sin(-45.0)*11.5 - 257,092*cos(-45.0)*(0)) / (2672.4600)

= 2,347 psi

τ_{ratio} = sqr($(\tau_t + \tau_b)^2 + \tau_s^2$) / $\tau_{allowable}$ ≤ 1

= sqr ((1,786 + 2,347)^2 + (-1,786)^2) / 15,200
= 0.30 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	-181,791.67 lb_f
Circumferential moment, M_c	0 lb_f-in
Circumferential shear, V_c	0 lb_f
Longitudinal moment, M_L	-2,090,604.2 lb_f-in
Longitudinal shear, V_L	-181,791.67 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 (includes pressure)

$\gamma = R_m / T$ = 84.625 / 2.75 = 30.7727

C_1 = 3, C_2 = 11.5 in

Local circumferential pressure stress = $P*R_i / T$ =0 psi

Local longitudinal pressure stress = $P*R_i / (2*T)$ =0 psi

Maximum combined stress (P_L+P_b+Q) = 42,387 psi
Allowable combined stress (P_L+P_b+Q) = ±3*S = ±60,000 psi

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

Maximum local primary membrane stress (P_L) = 6,564 psi
Allowable local primary membrane stress (P_L) = ±1.5*S = ±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	3,807	3,807	3,807	3,807
4C*	5.6236	0.0831	4,393	4,393	4,393	4,393	0	0	0	0
1C	0.1859	0.0612	0	0	0	0	26,813	-26,813	26,813	-26,813
2C-1	0.1476	0.0612	21,289	-21,289	21,289	-21,289	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	2,171	2,171	-2,171	-2,171	0	0	0	0
1B-1	0.0539	0.0769	13,731	-13,731	-13,731	13,731	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total circumferential stress			41,584	-28,456	9,780	-5,336	30,620	-23,006	30,620	-23,006
Primary membrane circumferential stress*			6,564	6,564	2,222	2,222	3,807	3,807	3,807	3,807
3C*	5.2058	0.0831	4,067	4,067	4,067	4,067	0	0	0	0
4C*	5.4456	0.1022	0	0	0	0	4,254	4,254	4,254	4,254
1C-1	0.159	0.0865	22,933	-22,933	22,933	-22,933	0	0	0	0
2C	0.1166	0.0865	0	0	0	0	16,817	-16,817	16,817	-16,817
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	1,043	1,043	-1,043	-1,043	0	0	0	0
2B-1	0.0768	0.1049	14,344	-14,344	-14,344	14,344	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total longitudinal stress			42,387	-32,167	11,613	-5,565	21,071	-12,563	21,071	-12,563
Primary membrane longitudinal stress*			5,110	5,110	3,024	3,024	4,254	4,254	4,254	4,254
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	1,437	1,437	-1,437	-1,437
Total Shear stress			0	0	0	0	1,437	1,437	-1,437	-1,437
Combined stress (P_L+P_b+Q)			42,387	-32,167	11,613	-5,565	30,832	-23,200	30,832	-23,200
* denotes primary stress.										

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

$\gamma = R_m / T = 84.625 / 1.25 = 67.7$

$C_1 = 10.5$, $C_2 = 16.5$ in

Local circumferential pressure stress = $P*R_i / T$ =0 psi

Local longitudinal pressure stress = $P*R_i / (2*T)$ =0 psi

Maximum combined stress (P_L+P_b+Q) = 73,973 psi
Allowable combined stress (P_L+P_b+Q) = ±3*S = ±60,000 psi

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

Maximum local primary membrane stress (P_L) = 23,652 psi
Allowable local primary membrane stress (P_L) = ±1.5*S = ±30,000 psi

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

Stresses at the pad edge per WRC Bulletin 107										
Figure	value	β	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	4.8657	0.1917	0	0	0	0	8,362	8,362	8,362	8,362
4C*	9.1776	0.1706	15,772	15,772	15,772	15,772	0	0	0	0
1C	0.0738	0.1465	0	0	0	0	51,518	-51,518	51,518	-51,518
2C-1	0.042	0.1465	29,319	-29,319	29,319	-29,319	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	7,880	7,880	-7,880	-7,880	0	0	0	0
1B-1	0.0257	0.1585	15,380	-15,380	-15,380	15,380	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total circumferential stress			68,351	-21,047	21,831	-6,047	59,880	-43,156	59,880	-43,156
Primary membrane circumferential stress*			23,652	23,652	7,892	7,892	8,362	8,362	8,362	8,362
3C*	5.6624	0.1706	9,731	9,731	9,731	9,731	0	0	0	0
4C*	8.5882	0.1917	0	0	0	0	14,759	14,759	14,759	14,759
1C-1	0.0623	0.1744	43,490	-43,490	43,490	-43,490	0	0	0	0
2C	0.0387	0.1744	0	0	0	0	27,016	-27,016	27,016	-27,016
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	4,067	4,067	-4,067	-4,067	0	0	0	0
2B-1	0.0318	0.1808	16,685	-16,685	-16,685	16,685	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total longitudinal stress			73,973	-46,377	32,469	-21,141	41,775	-12,257	41,775	-12,257
Primary membrane longitudinal stress*			13,798	13,798	5,664	5,664	14,759	14,759	14,759	14,759
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	2,204	2,204	-2,204	-2,204
Total Shear stress			0	0	0	0	2,204	2,204	-2,204	-2,204
Combined stress (P_L+P_b+Q)			73,973	-46,377	32,469	-21,141	60,144	-43,312	60,144	-43,312

* denotes primary stress.

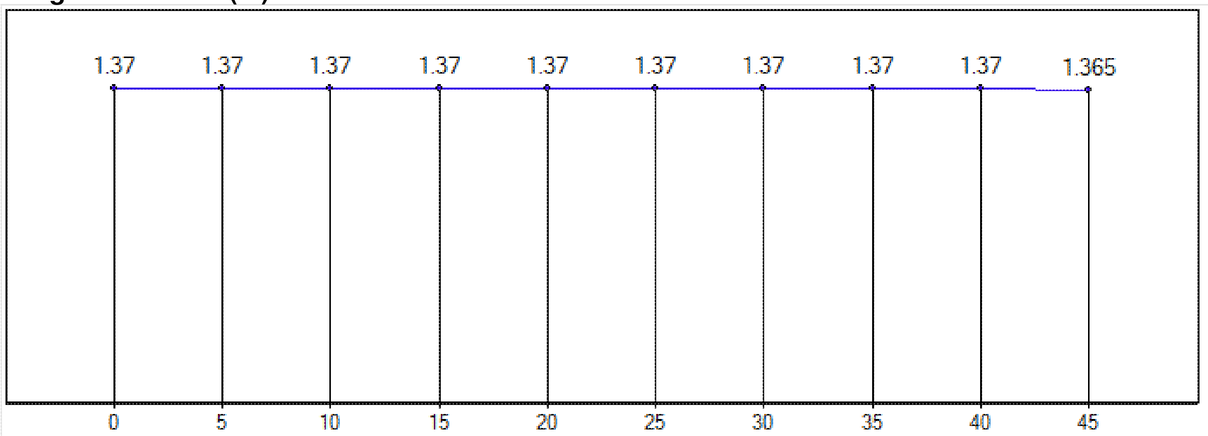
Metal Loss #2

API 579-1, 2007 Edition Part 5, Local Metal Loss Assessment		
Flaw Type		Local Metal Loss within a Region of Widespread Pitting
Widespread Pitting Region		Pitting #1
Flaw Surface		Outside
Uniform Metal Loss, LOSS		0.0625 "
Future Corrosion Allowance, FCA		0.1 "
Allowable Remaining Strength Factor, RSF_a		0.9
Longitudinal Joint Efficiency, E_L		1
Circumferential Joint Efficiency, E_C		1
Measurements		
Minimum Measured Thickness, t_{mm}		1.365 "
Spacing in Longitudinal Direction		5 "
Spacing in Circumferential Direction		5 "
Longitudinal Extent of Flaw, s		45 "
Circumferential Extent of Flaw, c		45 "
Location and Orientation		
Located On		Cylinder #2
Orientation		90.00°
Distance to Major Structural Discontinuity, L_{msd}		25 "
Flaw Center Offset to Parent Left Seam		35 "
Parent Component		
Material	**Spec No.**	SA-516 70
	Code Edition	2004 A06 Addenda
Nominal Thickness, t_{nom}		1.25 "
Inner Diameter		168 "
Internal Design Pressure		250 psi @ 600 °F
External Design Pressure		15 psi @ 400 °F
Operating Static Liquid Head		0 psi
Note that this assessment does not apply to vessels in cyclic service as per API 579 6.2.5.1(c).		

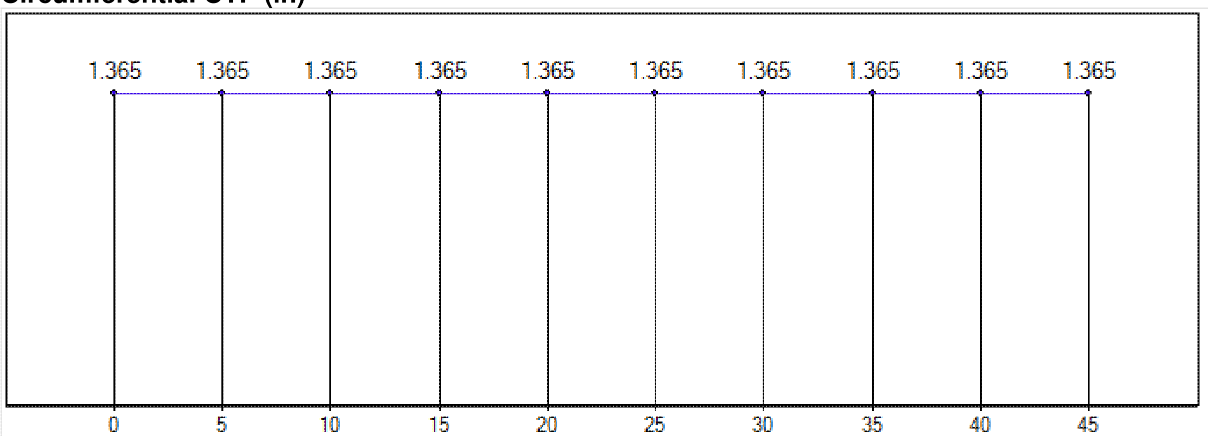
Results Summary	
Maximum Allowable Working Pressure of the Undamaged Component (MAWP) =	249.22 psi
Limiting Flaw Size Criteria Check	Acceptable
Remaining Strength Factor for Widespread Pitting Region (RSF_{pit}) =	0.9903
Level 1 Results	
Remaining Strength Factor for the LTA (RSF_{LTA}) =	1.0978
Combined Remaining Strength Factor for Pitting & LTA (RSF_{comb}) =	1.0871
Reduced Maximum Allowable External Pressure ($MAEP_r$) =	29.42 psi
Longitudinal Extent of the Flaw at Design P	**Unacceptable**
Circumferential Extent of the Flaw Conditions Check	**Unacceptable**
External Pressure Assessment	Acceptable
Level 2 Results	
Remaining Strength Factor for the LTA (RSF_{LTA}) =	1
Combined Remaining Strength Factor for Pitting & LTA (RSF_{comb}) =	0.9903
Reduced Maximum Allowable External Pressure ($MAEP_r$) =	42.07 psi
Longitudinal Extent of the Flaw at Design P	**Unacceptable**
Circumferential Extent of the Flaw Conditions Check	Acceptable
Tensile Stress Factor (TSF) Check	Acceptable
External Pressure Assessment	Acceptable

Thickness Profile (in)											
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**Circumferential CTP**
M1	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.365	1.365
M2	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.365	1.365
M3	1.37	1.37	1.37	1.37	1.38	1.37	1.37	1.37	1.37	1.365	1.365
M4	1.37	1.38	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.365	1.365
M5	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.365	1.365
M6	1.37	1.37	1.37	1.4	1.37	1.37	1.37	1.37	1.37	1.365	1.365
M7	1.37	1.37	1.37	1.37	1.37	1.39	1.37	1.37	1.37	1.365	1.365
M8	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.365	1.365
M9	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.365	1.365
M10	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.365	1.365
Longitudinal CTP	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.365	

Longitudinal CTP (in)



Circumferential CTP (in)



***Supplemental loads due to saddle supports are not considered in this assessment.**

Corroded Wall Thickness	
$t_{rd} = t_{nom}$ - LOSS	
t_{rd} = 1.25 - 0.0625 =	1.1875 "
$t_c = t_{nom}$ - LOSS - FCA	Eqn 5.3
t_c = 1.25 - 0.0625 - 0.1 =	1.0875 "

Longitudinal Flaw Parameter, λ	
t_{mm} =	1.365 "
$R_t = (t_{mm} - FCA) / t_c$	Eqn 5.5
R_t = (1.365 - 0.1) / 1.0875 =	1.1632
$\lambda = 1.285 * s / (D * t_c)^{0.5}$	Eqn 5.6
$\lambda = 1.285 * 45 / (168 * 1.0875)^{0.5}$ =	4.2781

Limiting Flaw Size Criteria Check, 5.4.2.2.e	
R_t >= 0.20	Eqn 5.7
1.1632 >= 0.20	**Acceptable**
t_{mm} - FCA >= 0.1	Eqn 5.8
1.365 - 0.1 >= 0.1	**Acceptable**
$L_{msd} >= 1.8*(D*t_c)^{0.5}$	Eqn 5.9
$25 >= (1.8*(168*1.0875)^{0.5} = 24.33)$	**Acceptable**
The limiting flaw size criteria are acceptable .	

MAWP	
$MAWP^C = S*E*t_c / (R + 0.6*t_c)$	Eqn A.10
$MAWP^C$ = 19,400*1*1.0875 / (84 + 0.6*1.0875) =	249.22 psi
$MAWP^L = 2*S*E*(t_c - t_{sl}) / (R - 0.4*(t_c - t_{sl}))$	Eqn A.16
$MAWP^L$ = 2*19,400*1*(1.0875 - 0) / (84 - 0.4*(1.0875 - 0)) =	504.94 psi
MAWP = min[249.22, 504.94] =	249.22 psi

Part 5, Level 1 Longitudinal Extent of the Flaw Evaluation	
M_t (from Table 5.2) =	2.7375
$RSF_{lta} = R_t / (1 - (1 / M_t) * (1 - R_t))$	Eqn 5.11
RSF_{lta} = 1.1632 / (1 - (1 / 2.7375) * (1 - 1.1632)) =	1.0978
$RSF = RSF_{Comb} = RSF_{pit}*RSF_{lta}$	Eqn 6.17
$RSF = RSF_{Comb}$ = 0.9903*1.0978 =	1.0871
*Due to LTA being inside a region of widespread pitting	
$RSF >= RSF_a$	2.4.2.2
1.0871 >= 0.9	**True**
MAWP >= P	
249.22 >= 250	**False**
The longitudinal extent of the flaw is unacceptable for the current design conditions.	

Part 5, Level 1 Circumferential Extent of the Flaw Evaluation	
Circumferential Flaw Parameter, λ_c	
c =	45 "
λ_c = 1.285 * c / (D * t_c)$^{0.5}$	Eqn 5.13
λ_c = 1.285 * 45 / (168 * 1.0875)$^{0.5}$ =	4.2781
Conditions for Acceptability Check	
λ_c <= 9	Eqn 5.13
4.2781 <= 9	**Acceptable**
D/t_c >= 20	Eqn 5.14
(168/1.0875 = 154.4828) >= 20	**Acceptable**
0.7 <= RSF <= 1.0	Eqn 5.15
0.7 <= 1.0871 <= 1.0	**Unacceptable**
0.7 <= E_L <= 1.0	Eqn 5.16
0.7 <= 1 <= 1.0	**Acceptable**
0.7 <= E_C <= 1.0	Eqn 5.17
0.7 <= 1 <= 1.0	**Acceptable**
The circumferential extent of the flaw conditions are **unacceptable** .	

API 579 Part 5 level 1 analysis does not apply to external pressure. A Part 4 external pressure assessment will be performed instead.

Length for Thickness Averaging, L	
R_t = (t_{mm} - FCA) / t_c	Eqn 4.4
R_t = (1.365 - 0.1) / 1.0875 =	1.1632
Q = 1.123 * [((1 - R_t) / (1 - (R_t / RSF_a)))^2 - 1]$^{0.5}$	Table 4.5
Q = 1.123 * [((1 - 1.1632) / (1 - (1.1632 / 0.9)))^2 - 1]$^{0.5}$ =	50
LOSS =	0.0625 "
L = Q * (D * t_c)$^{0.5}$	Eqn 4.5
L = 50 * (168 * 1.0875)$^{0.5}$ =	675.8328 "

Thickness for MAEP Evaluation	
t^s_{am} =	1.201 "
t^c_{am} =	1.2006 "
t_{eq} = RSF_{pit}*(min[t^s_{am}, t^c_{am}] - FCA)	
t_{eq} = 0.9903*(1.2006 - 0.1) =	1.0899 "

Division 2 4.4.5.1 Equations		
$M_x = L / (R_o*t)^{0.5}$		(4.4.20)
$C_h = 0.55*t / D_o$	for $M_x \geq 2*(D_o / t)^{0.94}$	(4.4.21)
$C_h = 1.12*M_x^{-1.058}$	for $13 < M_x < 2*(D_o / t)^{0.94}$	(4.4.22)
$C_h = 0.92/(M_x-0.579)$	for $1.5 < M_x \leq 13$	(4.4.23)
$C_h = 1$	for $M_x \leq 1.5$	(4.4.24)
$F_{he} = 1.6*C_h*E_y*t / D_o$		(4.4.19)
$F_{ic} = S_y$	for $F_{he} / S_y \geq 2.439$	(4.4.25)
$F_{ic} = 0.7*S_y*(F_{he} / S_y)^{0.4}$	for $0.552 < F_{he} / S_y < 2.439$	(4.4.26)
$F_{ic} = F_{he}$	for $F_{he} / S_y \leq 0.552$	(4.4.27)
$F_{ha} = F_{ic} / FS$		(4.4.29)
$P_a = 2*F_{ha}*t / D_o$		(4.4.28)

Division 2 4.4.5.1 $MAEP_r$	
$M_x = 532 / (85.0899*1.0899)^{0.5} =$	55.2431
$13 < M_x = 55.2431 < 2*(D_o / t)^{0.94} = 230.6413$	
$C_h = 1.12*55.2431^{-1.058} =$	0.0161
$F_{he} = 1.6*0.0161*27.9E+06*1.0899 / 170.1798 =$	4,593 psi
$F_{he} / S_y = 4,593 / 32,500 = 0.1413 \leq 0.552$	
$F_{ic} = F_{he} =$	4,593 psi
FS =	2
$F_{ha} = 4,593 / 2 =$	2,296 psi
$P_a = 2*2,296.49*1.0899 / 170.1798 =$	29.42 psi

4.4.2.2, Level 1 Critical Thickness Profile Assessment	
$MAEP_r >= P_e$	Table 4.4
29.42 >= 15 =	**Acceptable**

The level 1 assessment is complete, beginning the level 2 assessment.

Part 5, Level 2 RSF Calculation								
RSF for the longitudinal CTP, 5.4.3.2(h) Minimum RSF found at each Starting Point								
Starting Point	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Minimum RSF[i]	1	1	1	1	1	1	1	1
The minimum RSF was found at location 2								

Data for Starting Point at Location 2 of the longitudinal CTP								
i Subsection	s^i_s (1) (in)	s^i_e (2) (in)	s^i (3) (in)	λ^i (4)	A^i (5) (in^2)	A^i_o (6) (in^2)	M^i_t (7)	RSF^i (8)
1	2.5	7.5	5	0.4753	0	5.4375	1.0506	1
2	0	10	10	0.9507	0	10.875	1.1825	1

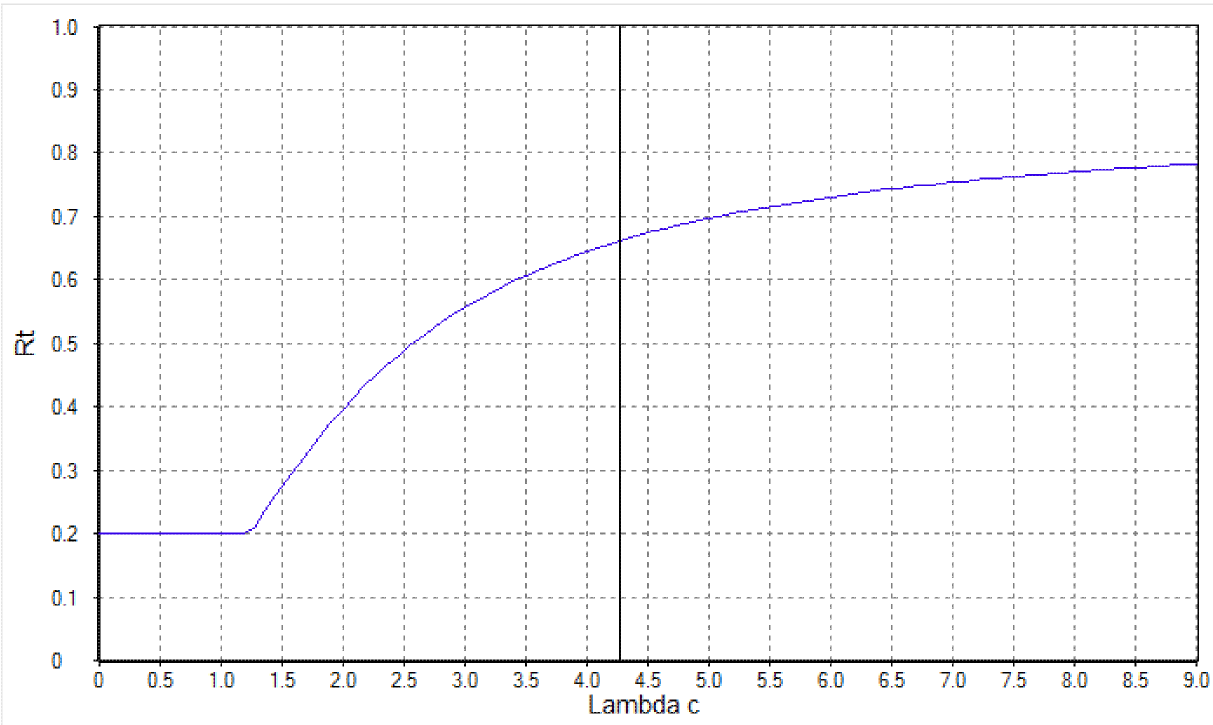
1. Starting location of metal loss region under consideration.
2. Ending location of metal loss region under consideration.
3. Length of metal loss region under consideration.
4. Shell parameter evaluated using Equation 5.6 integration with $s = s^i$.
5. Area of metal loss evauated using trapezoidal rule.
6. Original metal area evaluated using Equation 5.20.
7. Folias factor evaluated using Table 5.2 with $\lambda = \lambda^i$.
8. Remaining Strength Factor, evaluated using Equation 5.19.

RSF_{lta} = Minimum RSF = 1 .
$RSF = RSF_{Comb} = RSF_{pit}*RSF_{lta}$ = 0.9903*1 = 0.9903
*Due to LTA being inside a region of widespread pitting

Part 5, Level 2 Longitudinal Extent of the Flaw Evaluation	
RSF >= RSF_a	2.4.2.2
0.9903 >= 0.9	**True**
MAWP >= P	
249.22 >= 250	**False**
The longitudinal extent of the flaw is unacceptable for the current design conditions.	

Part 5, Level 2 Circumferential Extent of the Flaw Evaluation	
Conditions for Acceptability Check	
λ_c <= 9	Eqn 5.13
4.2781 <= 9	**Acceptable**
D/t_c >= 20	Eqn 5.14
(168/1.0875 = 154.4828) >= 20	**Acceptable**
0.7 <= RSF <= 1.0	Eqn 5.15
0.7 <= 0.9903 <= 1.0	**Acceptable**
0.7 <= E_L <= 1.0	Eqn 5.16
0.7 <= 1 <= 1.0	**Acceptable**
0.7 <= E_C <= 1.0	Eqn 5.17
0.7 <= 1 <= 1.0	**Acceptable**
The circumferential extent of the flaw conditions are acceptable .	

Tensile Stress Factor, TSF	
$TSF = (E_C / (2 * RSF)) * (1 + (4 - 3 * E_L^2)^{0.5} / E_L)$	Eqn 5.18
$TSF = (1 / (2 * 0.9903)) * (1 + (4 - 3 * 1^2)^{0.5} / 1) =$	1.0098
Fig 5.8 Curve Interpolated, TSF = 1.0098, R_t = 1.1632, and λ_c = 4.2781	



$R_t >= R_t$ from Fig 5.8 curve	Fig 5.8
1.1632 >= 0.6623	**Acceptable**
The circumferential extent of the flaw is acceptable.	

Level 2 Cylinder External Pressure Evaluation				
API 5.4.3.3				
Subdivision, i	t_i (in)	$t_{c,i}$*RSF_{pit} (in)	L_i (in)	P^e_i (psi)
1	1.37	1.2576	65	42.12
2	1.37	1.2576	5	42.12
3	1.37	1.2576	5	42.12
4	1.37	1.2576	5	42.12
5	1.37	1.2576	5	42.12
6	1.37	1.2576	5	42.12
7	1.37	1.2576	5	42.12
8	1.37	1.2576	5	42.12
9	1.37	1.2576	5	42.12
10	1.365	1.2527	15	41.71

*$t_{c,i}$ is multiplied by RSF_{pit} to account for pitting damage inside the metal loss area.

$MAEP_r$ = 120 / (65/42.12 + 5/42.12 + 5/42.12 + 5/42.12 + 5/42.12 + 5/42.12 + 5/42.12 + 5/42.12 + 5/42.12 + 15/41.71) = 42.07 psi

($MAEP_r$ = 42.07 psi) >= (P_e = 15 psi)

The flaw is acceptable for operation at the current external pressure of 15 psi.

Metal Loss #2 Subdivision MAEP

Shell Subdivision MAEP Calculations

Division 2 4.4.5.1 Equations		
$M_x = L / (R_o*t)^{0.5}$		(4.4.20)
$C_h = 0.55*t / D_o$	for $M_x \geq 2*(D_o / t)^{0.94}$	(4.4.21)
$C_h = 1.12*M_x^{-1.058}$	for $13 < M_x < 2*(D_o / t)^{0.94}$	(4.4.22)
$C_h = 0.92/(M_x-0.579)$	for $1.5 < M_x \leq 13$	(4.4.23)
$C_h = 1$	for $M_x \leq 1.5$	(4.4.24)
$F_{he} = 1.6*C_h*E_y*t / D_o$		(4.4.19)
$F_{ic} = S_y$	for $F_{he} / S_y \geq 2.439$	(4.4.25)
$F_{ic} = 0.7*S_y*(F_{he} / S_y)^{0.4}$	for $0.552 < F_{he} / S_y < 2.439$	(4.4.26)
$F_{ic} = F_{he}$	for $F_{he} / S_y \leq 0.552$	(4.4.27)
$F_{ha} = F_{ic} / FS$		(4.4.29)
$P_a = 2*F_{ha}*t / D_o$		(4.4.28)

Shell Subdivision #1 MAEP	
$M_x = 532 / (85.2576*1.2576)^{0.5} =$	51.3771
$13 < M_x = 51.3771 < 2*(D_o / t)^{0.94} = 201.9803$	
$C_h = 1.12*51.3771^{-1.058} =$	0.0173
$F_{he} = 1.6*0.0173*27.9E+06*1.2576 / 170.5153 =$	5,711 psi
$F_{he} / S_y = 5,711 / 32,500 = 0.1757 \leq 0.552$	
$F_{ic} = F_{he} =$	5,711 psi
FS =	2
$F_{ha} = 5,711 / 2 =$	2,856 psi
$P_a = 2*2,855.66*1.2576 / 170.5153 =$	42.12 psi

Shell Subdivision #2 MAEP	
M_x = 532 / (85.2576*1.2576)$^{0.5}$ =	51.3771
13 < M_x = 51.3771 < 2*(D_o / t)$^{0.94}$ = 201.9803	
C_h = 1.12*51.3771$^{-1.058}$ =	0.0173
F_{he} = 1.6*0.0173*27.9E+06*1.2576 / 170.5153 =	5,711 psi
F_{he} / S_y = 5,711 / 32,500 = 0.1757 ≤ 0.552	
F_{ic} = F_{he} =	5,711 psi
FS =	2
F_{ha} = 5,711 / 2 =	2,856 psi
P_a = 2*2,855.66*1.2576 / 170.5153 =	42.12 psi

Shell Subdivision #3 MAEP	
M_x = 532 / (85.2576*1.2576)$^{0.5}$ =	51.3771
13 < M_x = 51.3771 < 2*(D_o / t)$^{0.94}$ = 201.9803	
C_h = 1.12*51.3771$^{-1.058}$ =	0.0173
F_{he} = 1.6*0.0173*27.9E+06*1.2576 / 170.5153 =	5,711 psi
F_{he} / S_y = 5,711 / 32,500 = 0.1757 ≤ 0.552	
F_{ic} = F_{he} =	5,711 psi
FS =	2
F_{ha} = 5,711 / 2 =	2,856 psi
P_a = 2*2,855.66*1.2576 / 170.5153 =	42.12 psi

Shell Subdivision #4 MAEP	
M_x = 532 / (85.2576*1.2576)$^{0.5}$ =	51.3771
13 < M_x = 51.3771 < 2*(D_o / t)$^{0.94}$ = 201.9803	
C_h = 1.12*51.3771$^{-1.058}$ =	0.0173
F_{he} = 1.6*0.0173*27.9E+06*1.2576 / 170.5153 =	5,711 psi
F_{he} / S_y = 5,711 / 32,500 = 0.1757 ≤ 0.552	
F_{ic} = F_{he} =	5,711 psi
FS =	2
F_{ha} = 5,711 / 2 =	2,856 psi
P_a = 2*2,855.66*1.2576 / 170.5153 =	42.12 psi

Shell Subdivision #5 MAEP	
$M_x = 532 / (85.2576*1.2576)^{0.5}$ =	51.3771
$13 < M_x = 51.3771 < 2*(D_o / t)^{0.94} = 201.9803$	
$C_h = 1.12*51.3771^{-1.058}$ =	0.0173
F_{he} = 1.6*0.0173*27.9E+06*1.2576 / 170.5153 =	5,711 psi
$F_{he} / S_y = 5{,}711 / 32{,}500 = 0.1757 \leq 0.552$	
$F_{ic} = F_{he}$ =	5,711 psi
FS =	2
F_{ha} = 5,711 / 2 =	2,856 psi
P_a = 2*2,855.66*1.2576 / 170.5153 =	42.12 psi

Shell Subdivision #6 MAEP	
$M_x = 532 / (85.2576*1.2576)^{0.5}$ =	51.3771
$13 < M_x = 51.3771 < 2*(D_o / t)^{0.94} = 201.9803$	
$C_h = 1.12*51.3771^{-1.058}$ =	0.0173
F_{he} = 1.6*0.0173*27.9E+06*1.2576 / 170.5153 =	5,711 psi
$F_{he} / S_y = 5{,}711 / 32{,}500 = 0.1757 \leq 0.552$	
$F_{ic} = F_{he}$ =	5,711 psi
FS =	2
F_{ha} = 5,711 / 2 =	2,856 psi
P_a = 2*2,855.66*1.2576 / 170.5153 =	42.12 psi

Shell Subdivision #7 MAEP	
$M_x = 532 / (85.2576*1.2576)^{0.5}$ =	51.3771
$13 < M_x = 51.3771 < 2*(D_o / t)^{0.94} = 201.9803$	
$C_h = 1.12*51.3771^{-1.058}$ =	0.0173
F_{he} = 1.6*0.0173*27.9E+06*1.2576 / 170.5153 =	5,711 psi
$F_{he} / S_y = 5{,}711 / 32{,}500 = 0.1757 \leq 0.552$	
$F_{ic} = F_{he}$ =	5,711 psi
FS =	2
F_{ha} = 5,711 / 2 =	2,856 psi
P_a = 2*2,855.66*1.2576 / 170.5153 =	42.12 psi

Shell Subdivision #8 MAEP	
$M_x = 532 / (85.2576*1.2576)^{0.5} =$	51.3771
$13 < M_x = 51.3771 < 2*(D_o / t)^{0.94} = 201.9803$	
$C_h = 1.12*51.3771^{-1.058} =$	0.0173
$F_{he} = 1.6*0.0173*27.9E+06*1.2576 / 170.5153 =$	5,711 psi
$F_{he} / S_y = 5{,}711 / 32{,}500 = 0.1757 \leq 0.552$	
$F_{ic} = F_{he} =$	5,711 psi
FS =	2
$F_{ha} = 5{,}711 / 2 =$	2,856 psi
$P_a = 2*2{,}855.66*1.2576 / 170.5153 =$	42.12 psi

Shell Subdivision #9 MAEP	
$M_x = 532 / (85.2576*1.2576)^{0.5} =$	51.3771
$13 < M_x = 51.3771 < 2*(D_o / t)^{0.94} = 201.9803$	
$C_h = 1.12*51.3771^{-1.058} =$	0.0173
$F_{he} = 1.6*0.0173*27.9E+06*1.2576 / 170.5153 =$	5,711 psi
$F_{he} / S_y = 5{,}711 / 32{,}500 = 0.1757 \leq 0.552$	
$F_{ic} = F_{he} =$	5,711 psi
FS =	2
$F_{ha} = 5{,}711 / 2 =$	2,856 psi
$P_a = 2*2{,}855.66*1.2576 / 170.5153 =$	42.12 psi

Shell Subdivision #10 MAEP	
$M_x = 532 / (85.2527*1.2527)^{0.5} =$	51.48
$13 < M_x = 51.48 < 2*(D_o / t)^{0.94} = 202.7196$	
$C_h = 1.12*51.48^{-1.058} =$	0.0173
$F_{he} = 1.6*0.0173*27.9E+06*1.2527 / 170.5053 =$	5,677 psi
$F_{he} / S_y = 5{,}677 / 32{,}500 = 0.1747 \leq 0.552$	
$F_{ic} = F_{he} =$	5,677 psi
FS =	2
$F_{ha} = 5{,}677 / 2 =$	2,839 psi
$P_a = 2*2{,}838.57*1.2527 / 170.5053 =$	41.71 psi

Pitting #1

API 579-1, 2007 Edition Part 6, Pitting Assessment		
Flaw Type		Widespread Pitting
Analysis Type		Level 2
Flaw Surface		Outside
Uniform Metal Loss, LOSS		0.0625 "
Future Corrosion Allowance, FCA		0.1 "
Allowable Remaining Strength Factor, RSF_a		0.9
Longitudinal Joint Efficiency, E_L		1
Circumferential Joint Efficiency, E_C		1
Longitudinal Extent of Flaw, s		45 "
Circumferential Extent of Flaw, c		45 "
Location and Orientation		
Located On		Cylinder #2
Orientation		75.00°
Flaw Center Offset to Parent Right Seam		60 "
Parent Component		
Material	**Spec No.**	SA-516 70
	Code Edition	2004 A06 Addenda
Nominal Thickness, t_{nom}		1.25 "
Inner Diameter		168 "
Internal Design Pressure		250 psi @ 600 °F
External Design Pressure		15 psi @ 400 °F
Operating Static Liquid Head		0 psi
Note that this assessment does not apply to vessels in cyclic service as per API 579 6.2.5.1(c).		

Results Summary	
Maximum Allowable Working Pressure of the Undamaged Component (MAWP) =	249.22 psi
Remaining Strength Factor for the Pitting Damage (RSF_{pit}) =	0.9903
Reduced Maximum Allowable Working Pressure ($MAWP_r$) =	249.22 psi
Internal Pressure Assessment	**Unacceptable**
Reduced Maximum Allowable External Pressure ($MAEP_r$) =	29.25 psi
External Pressure Assessment	Acceptable
Pit Dimensions Check	Acceptable
Metal Loss #2 is within the pitting region. See the local metal loss report for the combined calculations.	

Pit-Couple Measurements						
Pit-Couple,$_k$	***P_k (in)***	***θ_k (Degrees)***	***$d_{i,k}$ (in)***	***$w_{i,k}$ (in)***	***$d_{j,k}$ (in)***	***$w_{j,k}$ (in)***
1	1.3	45	0.1	0.23	0.24	0.1
2	1.29	60	0.2	0.2	0.19	0.2
3	1.3	55	0.15	0.25	0.18	0.15
4	1.2	54	0.36	0.15	0.21	0.36
5	1.1	90	0.1	0.23	0.18	0.1
6	1.27	87	0.15	0.2	0.17	0.15
7	1.3	37	0.3	0.25	0.23	0.3
8	1.05	62	0.32	0.23	0.22	0.32
9	1.12	45	0.26	0.27	0.19	0.26
10	1.22	44	0.1	0.23	0.2	0.1

Corroded Wall Thickness, t_c	
$t_c = t_{nom}$ - LOSS - FCA	Eqn 6.1
t_c = 1.25 - 0.0625 - 0.1 =	1.0875 "

Principal Membrane Stresses	
$\sigma_1 = (P / E_L)*((R / t_c) + 0.6)$	Eqn A.11
$\sigma_1 = (250 / 1)*((84 / 1.0875) + 0.6) =$	19,460.34 psi
$\sigma_2 = (P / (2*E_C))*((R / (t_c - t_{sl})) - 0.4)$	Eqn A.17
$\sigma_2 = (250 / (2*1))*((84 / (1.0875 - 0)) - 0.4) =$	9,605.17 psi

MAWP	
$MAWP^C = S*E*t_c / (R + 0.6*t_c)$	Eqn A.10
$MAWP^C$ = 19,400*1*1.0875 / (84 + 0.6*1.0875) =	249.22 psi
$MAWP^L = 2*S*E*(t_c - t_{sl}) / (R - 0.4*(t_c - t_{sl}))$	Eqn A.16
$MAWP^L$ = 2*19,400*1*(1.0875 - 0) / (84 - 0.4*(1.0875 - 0)) =	504.94 psi
MAWP = min[249.22, 504.94] =	249.22 psi

Pit-Couple Equations	
$w^{avg}_k = (w_{i,k} + w_{j,k}) / 2$	Eqn 6.5
$d^{avg}_k = (d_{i,k} + d_{j,k}) / 2$	Eqn 6.13
$\mu^{avg}_k = (P_k - d^{avg}_k) / P_k$	Eqn 6.12
$\rho_{1,k} = (\sigma_1 / \mu^{avg}_k)$	Eqn 6.10
$\rho_{2,k} = (\sigma_2 / \mu^{avg}_k)$	Eqn 6.11
$\psi_k = [(\cos^4(\theta_k) + \sin^2(2*\theta_k))*\rho_{1,k}^2 - 3*\sin^2(2*\theta_k)*\rho_{1,k}*\rho_{2,k}/2 + (\sin^4(\theta_k) + \sin^2(2*\theta_k))*\rho_{2,k}^2]$	Eqn 6.9
$\phi_k = \mu^{avg}_k*\max(\lvert\rho_{1,k}\rvert, \lvert\rho_{2,k}\rvert, \lvert\rho_{1,k} - \rho_{2,k}\rvert)$	Eqn 6.8
$E^{avg}_k = \min(\phi_k / (\psi_k)^{1/2}, 1)$	Eqn 6.7
$RSF_k = 1 - (w^{avg}_k / t_c)*(1 - E^{avg}_k)$	Eqn 6.6

Pit-Couple Results									
Pit-Couple,$_k$	***$w_{avg,k}$ (in)***	***$d_{avg,k}$ (in)***	$\mu_{avg,k}$	***$\rho_{1,k}$ (psi)***	***$\rho_{2,k}$ (psi)***	***ψ_k (psi)^2***	***ϕ_k (psi)***	***$E_{avg,k}$***	***RSF_k***
1	0.165	0.17	0.8692	22,388.01	11,050.2	408,074,311.98	19,460.34	0.9633	0.9944
2	0.2	0.195	0.8488	22,925.89	11,315.68	303,255,771.89	19,460.34	1	1
3	0.2	0.165	0.8731	22,289.38	11,001.52	329,045,548.44	19,460.34	1	1
4	0.255	0.285	0.7625	25,521.76	12,596.95	442,223,121.03	19,460.34	0.9254	0.9825
5	0.165	0.14	0.8727	22,298.31	11,005.93	121,130,423.06	19,460.34	1	1
6	0.175	0.16	0.874	22,265.44	10,989.7	122,842,510.9	19,460.34	1	1
7	0.275	0.265	0.7962	24,442.95	12,064.47	539,974,458.48	19,460.34	0.8375	0.9589
8	0.275	0.27	0.7429	26,196.62	12,930.04	372,317,429.24	19,460.34	1	1
9	0.265	0.225	0.7991	24,352.61	12,019.88	482,835,745.11	19,460.34	0.8856	0.9721
10	0.165	0.15	0.877	22,188.43	10,951.69	407,213,942.01	19,460.34	0.9644	0.9946
$RSF = RSF_{pit} = SUM(RSF_k) / 10 =$ 0.9903									

Reduced MAWP	
$RSF >= RSF_a$	
0.9903 >= 0.9	**True**
$MAWP_r = MAWP =$	249.22
$MAWP_r >= P$	
249.22 >= 250	**False**
The internal pressure assessment of the pitting damage is **unacceptable** for the current design conditions.	

Pit Dimension Limitation Check Equations	
$R_t = (t_c + FCA - w_{i,k}) / t_c$	Eqn 6.19
$Q = 1.123*[((1 - R_t) / (1 - R_t / RSF_a))^2 - 1]^{1/2}$	Table 4.5
$d <= Q*(D*t_c)^{1/2}$	Eqn 6.18

Individual Pit Dimension Limitation Check										
Pit-Couple,$_k$	***$R_{t\,i,\,k}$***	***$Q_{i,\,k}$***	***$Q_{i,\,k}(D*t_c)^{1/2}$ (in)***	***Diameter Passes? (6.18)***	***R_t >= 0.2 (6.20)***	***$R_{t\,j,\,k}$***	***$Q_{j,\,k}$***	***$Q_{j,\,k}(D*t_c)^{1/2}$ (in)***	***Diameter Passes? (6.18)***	***R_t >= 0.2 (6.20)***
1	0.8805	6.0803	82.1849	Yes	Yes	1	50	675.8328	Yes	Yes
2	0.908	50	675.8328	Yes	Yes	0.908	50	675.8328	Yes	Yes
3	0.8621	3.4995	47.3015	Yes	Yes	0.954	50	675.8328	Yes	Yes
4	0.954	50	675.8328	Yes	Yes	0.7609	1.3257	17.9188	Yes	Yes
5	0.8805	6.0803	82.1849	Yes	Yes	1	50	675.8328	Yes	Yes
6	0.908	50	675.8328	Yes	Yes	0.954	50	675.8328	Yes	Yes
7	0.8621	3.4995	47.3015	Yes	Yes	0.8161	1.9095	25.8098	Yes	Yes
8	0.8805	6.0803	82.1849	Yes	Yes	0.7977	1.6534	22.348	Yes	Yes
9	0.8437	2.5706	34.7461	Yes	Yes	0.8529	2.9488	39.8573	Yes	Yes
10	0.8805	6.0803	82.1849	Yes	Yes	1	50	675.8328	Yes	Yes
Pit dimensions are acceptable as per API 579 6.4.3.2(j).										

***Supplemental loads due to saddle supports are not considered in this assessment.**

Equivalent Thickness	
B = min[RSF / RSF_a, 1.0]	Eqn 6.22
B = min[0.9903 / 0.9, 1.0] =	1
$t_{eq} = B*t_c$	Eqn 6.21
t_{eq} = 1*1.0875 =	1.0875 "

Division 2 4.4.5.1 Equations		
$M_x = L / (R_o*t)^{0.5}$		(4.4.20)
$C_h = 0.55*t / D_o$	for $M_x \geq 2*(D_o / t)^{0.94}$	(4.4.21)
$C_h = 1.12*M_x^{-1.058}$	for $13 < M_x < 2*(D_o / t)^{0.94}$	(4.4.22)
$C_h = 0.92/(M_x-0.579)$	for $1.5 < M_x \leq 13$	(4.4.23)
$C_h = 1$	for $M_x \leq 1.5$	(4.4.24)
$F_{he} = 1.6*C_h*E_y*t / D_o$		(4.4.19)
$F_{ic} = S_y$	for $F_{he} / S_y \geq 2.439$	(4.4.25)
$F_{ic} = 0.7*S_y*(F_{he} / S_y)^{0.4}$	for $0.552 < F_{he} / S_y < 2.439$	(4.4.26)
$F_{ic} = F_{he}$	for $F_{he} / S_y \leq 0.552$	(4.4.27)
$F_{ha} = F_{ic} / FS$		(4.4.29)
$P_a = 2*F_{ha}*t / D_o$		(4.4.28)

Division 2 4.4.5.1 $MAEP_r$	
$M_x = 532 / (85.0875*1.0875)^{0.5}$ =	55.305
$13 < M_x = 55.305 < 2*(D_o / t)^{0.94} = 231.1152$	
$C_h = 1.12*55.305^{-1.058}$ =	0.016
F_{he} = 1.6*0.016*27.9E+06*1.0875 / 170.175 =	4,578 psi
$F_{he} / S_y = 4,578 / 32,500 = 0.1408 \le 0.552$	
$F_{ic} = F_{he}$ =	4,578 psi
FS =	2
F_{ha} = 4,578 / 2 =	2,289 psi
P_a = 2*2,288.77*1.0875 / 170.175 =	29.25 psi

Results, MAEP Assessment	
$MAEP_r >= P_e$	
29.25 >= 15 =	**Acceptable**

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**		**Optimize MDMT/ Find 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/ft³)**		**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	-72.1 °F

UCS-66 Material Toughness Requirements	
Material impact test temperature per UG-84 =	-49°F
t_r = 250*84 / (20,000*1 - 0.6*250) =	1.0579"
Stress ratio = t_r*E* / (t_n - c) = 1.0579*1 / (1.375 - 0) =	0.7694
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	23.1°F
MDMT = max[T_{impact} - T_R, -155] = max[-49 - 23.1 , -155] =	-72.1°F
Design MDMT of -49°F is acceptable.	

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

t = P*R / (S*E - 0.60*P) + Corrosion
= 250*84 / (19,400*1.00 - 0.60*250) + 0
= 1.091"

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

P = S*E*t / (R + 0.60*t) - P_s
= 19,400*1.00*1.375 / (84 + 0.60*1.375) - 0
= 314.47 psi

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

P = S*E*t / (R + 0.60*t)
= 20,000*1.00*1.375 / (84 + 0.60*1.375)
= 324.2 psi

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

L / D_o = 532 / 170.75 = 3.1157
D_o / t = 170.75 / 0.8941 = 190.9811
From table G: A = 0.000157
From table CS-2: B = 2,148.5374 psi

P_a = 4*B / (3*(D_o / t))
= 4*2,148.54 / (3*(170.75 / 0.8941))
= 15 psi

Design thickness for external pressure P_a = 15 psi

t_a = t + Corrosion = 0.8941 + 0 = 0.8941"

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

L / D_o = 532 / 170.75 = 3.1157
D_o / t = 170.75 / 1.375 = 124.1818
From table G: A = 0.000290
From table CS-2: B = 4,004.3077 psi

P_a = 4*B / (3*(D_o / t))
= 4*4,004.31 / (3*(170.75 / 1.375))
= 42.99 psi

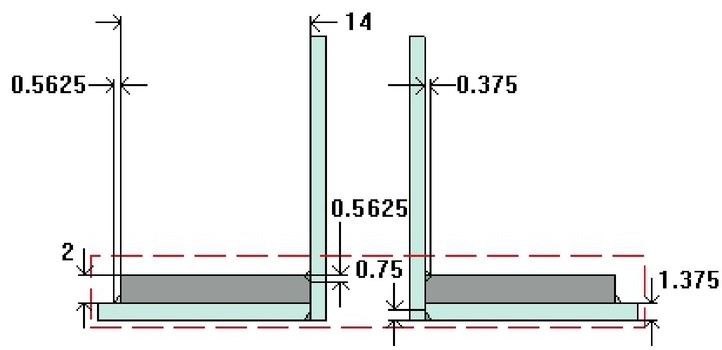
% Extreme fiber elongation - UCS-79(d)

EFE = (50*t / R_f)*(1 - R_f / R_o)
= (50*1.375 / 84.6875)*(1 - 84.6875 / ∞)
= 0.8118%

The extreme fiber elongation does not exceed 5%.

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"
Offset from center, Lo	-40"
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"
Nominal wall thickness	1.25"
Corrosion allowance	0"
Opening chord length	67.1003"
Projection available outside vessel, Lpr	22.4027"
Projection available outside vessel to flange face, Lf	35.2127"
Local vessel minimum thickness	1.375"
Liquid static head included	0 psi
Longitudinal joint efficiency	1

Reinforcing Pad	
Material specification	SA-516 70 (II-D p. 14, ln. 20)

Diameter, D_p	97.9257"
Thickness, t_e	2"
Is split	No
Welds	
Inner Fillet, Leg_{41}	0.375"
Outer Fillet, Leg_{42}	0.5625"
Nozzle to vessel groove weld	0.75"
Pad groove weld	0.5625"

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	No
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
Bolt MDMT is only -40°F: -49°F is required	
Notes	
Flange rated MDMT per UCS-66(b)(3) = -155°F (Coincident ratio = 0.2525) 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 = 250*28.75 / (17,100*1 - 0.6*250) =	0.424"
Stress ratio = t_r*E^* / (t_n - c) = 0.424*1 / (1.0938 - 0) =	0.3877
Reduction in MDMT, T_R from Fig UCS-66.1 =	102.1°F
Reduction in MDMT, T_{PWHT} from UCS-68(c) =	30°F
MDMT = max[MDMT - T_R - T_{PWHT}, -55] = max[35.5 - 102.1 - 30 , -55] =	-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 = 250*84 / (20,000*1 - 0.6*250) =	1.0579"
Stress ratio = t_r*E^* / (t_n - c) = 1.0579*1 / (1.375 - 0) =	0.7694
Reduction in MDMT, T_R from Fig UCS-66.1 =	23.1°F
Reduction in MDMT, T_{PWHT} from UCS-68(c) =	30°F
MDMT = max[MDMT - T_R - T_{PWHT}, -55] = max[47 - 23.1 - 30 , -55] =	-6.1°F
Rated MDMT of -6.1°F > Design MDMT of -49°F.	

Reinforcement Calculations for MAWP

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 250 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}
73.5238	80.4239	18.9783	5.0053	--	56	0.4403	0.424	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
1,070,327.79	1,192,044.64	2,203,305.47	158,284.84	2,071,978.52	1,250,823	1,837,267.71

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 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)*73.5238 = 49.0159 in^2

L_R = MAX(0.75*d, R_n + (t_n - C_n) + (t - C))
= MAX(0.75*67.1003, 33.5502 + (1.25 - 0) + (1.375 - 0))
= 50.3252 in

A_1 = (2*L_R - d)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})
= (2*50.3252 - 67.1003)*(1*1.375 - 1*1.0909) - 2*1.25*(1*1.375 - 1*1.0909)*(1 - 0.8814)
= 9.447 in^2

A_5 = (D_p - d - 2*t_n)*t_e*f_{r4}
= (97.9257 - 69.9257)*2*1
= 56 in^2

Area = A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5
= 9.447 + 5.0053 + 0 + 0.1239 + 0.3164 + 0 + 56
= 70.8926 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 in > 60 in	True
1-7(b)(1)(b)	d = 67.1003 in > 40 in	True
1-7(b)(1)(b)	d = 67.1003 in > 3.4*(84*1.375)$^{0.5}$ = 36.5401 in	True
1-7(b)(1)(c)	R_n / R = 28.75 / 84 = 0.3423 ≤ 0.7	True
1-7(b)(1)	Radial nozzle in cylinder or cone	False

1-7(b)(1)	Internal projection not present	True

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 orientation is non-radial. 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}
46.3452	61.9164	--	5.4798	--	56	0.4366	0.3178	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 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)*46.3452 = 30.8968 in^2

L_R = MAX(0.75*d, R_n + (t_n - C_n) + (t - C))
= MAX(0.75*67.0487, 33.5244 + (1.25 - 0) + (1.375 - 0))
= 50.2865 in

A_1 = (2*L_R - d)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})
= (2*50.2865 - 67.0487)*(1*1.375 - 1*1.375) - 2*1.25*(1*1.375 - 1*1.375)*(1 - 0.855)
= 0 in^2

A_5 = (D_p - d - 2*t_n)*t_e*f_{r4}

$= (97.9257 - 69.9257)*2*1$

$= 56\ in^2$

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

$= 0 + 5.4798 + 0 + 0.1202 + 0.3164 + 0 + 56$

$= 61.9164\ in^2$

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>Optimize MDMT/ Find 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	-72.1 °F

UCS-66 Material Toughness Requirements	
Material impact test temperature per UG-84 =	-49°F
t_r = 250*84 / (20,000*1 - 0.6*250) =	1.0579"
Stress ratio = t_r*E^* / (t_n - c) = 1.0579*1 / (1.375 - 0) =	0.7694
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	23.1°F
MDMT = max[T_{impact} - T_R, -155] = max[-49 - 23.1 , -155] =	-72.1°F
Design MDMT of -49°F is acceptable.	

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

t = P*R / (S*E - 0.60*P) + Corrosion
= 250*84 / (19,400*1.00 - 0.60*250) + 0
= 1.091"

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

P = S*E*t / (R + 0.60*t) - P_s
= 19,400*1.00*1.375 / (84 + 0.60*1.375) - 0
= 314.47 psi

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

P = S*E*t / (R + 0.60*t)
= 20,000*1.00*1.375 / (84 + 0.60*1.375)
= 324.2 psi

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

L / D_o = 532 / 170.75 = 3.1157
D_o / t = 170.75 / 0.8941 = 190.9811
From table G: A = 0.000157
From table CS-2: B = 2,148.5374 psi

P_a = 4*B / (3*(D_o / t))
= 4*2,148.54 / (3*(170.75 / 0.8941))
= 15 psi

Design thickness for external pressure P_a = 15 psi

t_a = t + Corrosion = 0.8941 + 0 = 0.8941"

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

L / D_o = 532 / 170.75 = 3.1157
D_o / t = 170.75 / 1.375 = 124.1818
From table G: A = 0.000290
From table CS-2: B = 4,004.3077 psi

P_a = 4*B / (3*(D_o / t))
= 4*4,004.31 / (3*(170.75 / 1.375))
= 42.99 psi

% Extreme fiber elongation - UCS-79(d)

EFE = (50*t / R_f)*(1 - R_f / R_o)
= (50*1.375 / 84.6875)*(1 - 84.6875 / ∞)
= 0.8118%

The extreme fiber elongation does not exceed 5%.

Cylinder #5

<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">Cylinder</td></tr>
<tr><td colspan="2">**Material**</td><td colspan="4">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 colspan="2">**Optimize MDMT/ Find MAWP**</td></tr>
<tr><td>Yes (-49°F)</td><td>Yes</td><td>Yes</td><td>Yes</td><td colspan="2">No</td></tr>
<tr><td colspan="2"></td><td>**Design Pressure (psi)**</td><td>**Design Temperature (°F)**</td><td colspan="2">**Design MDMT (°F)**</td></tr>
<tr><td colspan="2">**Internal**</td><td>250</td><td>600</td><td colspan="2" rowspan="2">-49</td></tr>
<tr><td colspan="2">**External**</td><td>15</td><td>400</td></tr>
<tr><th colspan="6">Static Liquid Head</th></tr>
<tr><td colspan="2">**Condition**</td><td>**P_s (psi)**</td><td>**H_s (in)**</td><td colspan="2">**SG**</td></tr>
<tr><td colspan="2">**Test horizontal**</td><td>7.47</td><td>207</td><td colspan="2">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">**Length**</td><td colspan="4">120"</td></tr>
<tr><td colspan="2">**Nominal Thickness**</td><td colspan="4">1.375"</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><th colspan="6">Weight and Capacity</th></tr>
<tr><td colspan="2"></td><td colspan="2">**Weight (lb)**</td><td colspan="2">**Capacity (US gal)**</td></tr>
<tr><td colspan="2">**New**</td><td colspan="2">24,658.33</td><td colspan="2">11,515.37</td></tr>
<tr><td colspan="2">**Corroded**</td><td colspan="2">24,658.33</td><td colspan="2">11,515.37</td></tr>
<tr><th colspan="6">Insulation</th></tr>
<tr><td colspan="2"></td><td>**Thickness (in)**</td><td>**Density (lb/ft^3)**</td><td colspan="2">**Weight (lb)**</td></tr>
<tr><td colspan="2">**Insulation**</td><td>4</td><td>18</td><td colspan="2">2,744.98</td></tr>
<tr><td colspan="2"></td><td>**Spacing(in)**</td><td>**Individual Weight (lb)**</td><td colspan="2">**Total Weight (lb)**</td></tr>
<tr><td colspan="2">**Insulation Supports**</td><td>145</td><td>50</td><td colspan="2">50</td></tr>
<tr><th colspan="6">Radiography</th></tr>
<tr><td colspan="2">**Longitudinal seam**</td><td colspan="4">Full UW-11(a) Type 1</td></tr>
<tr><td colspan="2">**Left Circumferential seam**</td><td colspan="4">Full UW-11(a) Type 1</td></tr>
<tr><td colspan="2">**Right Circumferential seam**</td><td colspan="4">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	-72.1 °F

UCS-66 Material Toughness Requirements	
Material impact test temperature per UG-84 =	-49°F
t_r = 250*84 / (20,000*1 - 0.6*250) =	1.0579"
Stress ratio = t_r*E^* / (t_n - c) = 1.0579*1 / (1.375 - 0) =	0.7694
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	23.1°F
MDMT = max[T_{impact} - T_R, -155] = max[-49 - 23.1 , -155] =	-72.1°F
Design MDMT of -49°F is acceptable.	

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

t = P*R / (S*E - 0.60*P) + Corrosion
= 250*84 / (19,400*1.00 - 0.60*250) + 0
= 1.091"

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

P = S*E*t / (R + 0.60*t) - P_s
= 19,400*1.00*1.375 / (84 + 0.60*1.375) - 0
= 314.47 psi

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

P = S*E*t / (R + 0.60*t)
= 20,000*1.00*1.375 / (84 + 0.60*1.375)
= 324.2 psi

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

L / D_o = 532 / 170.75 = 3.1157
D_o / t = 170.75 / 0.8941 = 190.9811
From table G: A = 0.000157
From table CS-2: B = 2,148.5374 psi

P_a = 4*B / (3*(D_o / t))
= 4*2,148.54 / (3*(170.75 / 0.8941))
= 15 psi

Design thickness for external pressure P_a = 15 psi

t_a = t + Corrosion = 0.8941 + 0 = 0.8941"

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

L / D_o = 532 / 170.75 = 3.1157
D_o / t = 170.75 / 1.375 = 124.1818
From table G: A = 0.000290
From table CS-2: B = 4,004.3077 psi

P_a = 4*B / (3*(D_o / t))
= 4*4,004.31 / (3*(170.75 / 1.375))
= 42.99 psi

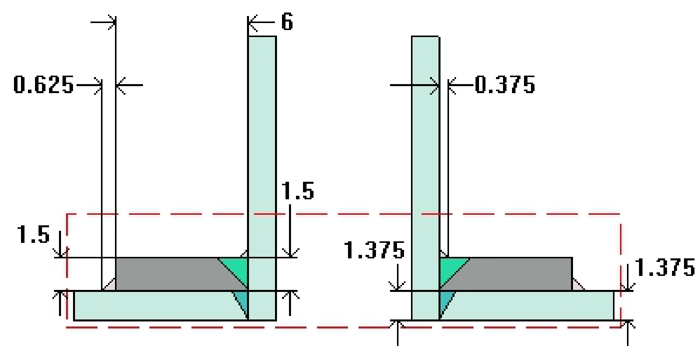
% Extreme fiber elongation - UCS-79(d)

EFE = (50*t / R_f)*(1 - R_f / R_o)
= (50*1.375 / 84.6875)*(1 - 84.6875 / ∞)
= 0.8118%

The extreme fiber elongation does not exceed 5%.

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
Longitudinal joint efficiency	1
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"

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
Gasket	
Description	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel
Notes	
Flange is impact tested per material specification to -50°F. Stress ratio = 0.3378 ≤ 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.	
Stress ratio = t_r*E^* / (t_n - c) = 0.1474*1 / (1.25 - 0) =	0.1179
Stress ratio ≤ 0.35, MDMT per UCS-66(b)(3) =	-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 = 250*84 / (20,000*1 - 0.6*250) =	1.0579"
Stress ratio = t_r*E^* / (t_n - c) = 1.0579*1 / (1.375 - 0) =	0.7694
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	23.1°F
MDMT = max[T_{impact} - T_R, -155] = max[-49 - 23.1 , -155] =	-72.1°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 = $(50*t / R_f)*(1 - R_f / R_o)$

= $(50*1.25 / 11.375)*(1 - 11.375 / \infty)$

= 5.4945%

Reinforcement Calculations for MAEP

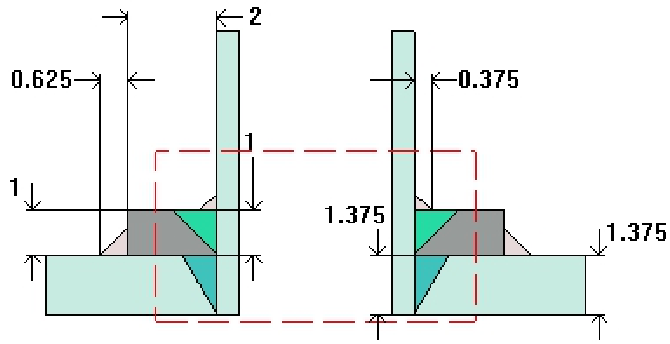
UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 42.99 psi @ 400 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	**A available**	**A_1**	**A_2**	**A_3**	**A_5**	**A welds**	**t_{req}**	**t_{min}**
14.7813	26.1353	--	7.6041	--	18	0.5312	0.1808	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"
Nominal wall thickness	0.531"
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
Longitudinal joint efficiency	1
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"

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	
Description	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel
Notes	
Flange is impact tested per material specification to -50°F. Stress ratio = 0.3378 ≤ 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 = t_r*E^* / (t_n - c) = 0.0667*1 / (0.4646 - 0) =	0.1436
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 = 250*84 / (20,000*1 - 0.6*250) =	1.0579"
Stress ratio = t_r*E^* / (t_n - c) = 1.0579*1 / (1.375 - 0) =	0.7694
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	23.1°F
MDMT = max[T_{impact} - T_R, -155] = max[-49 - 23.1 , -155] =	-72.1°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	4.9214	0.0001	2.0474	--	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	95,473.22	118,953.05	67,092.27	263,217.26	120,442.27	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

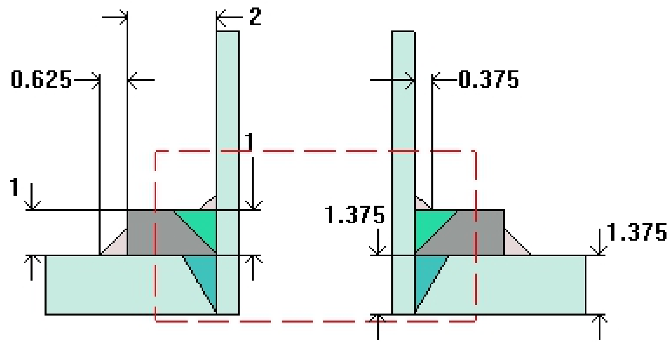
Reinforcement Calculations for MAEP

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"
Nominal wall thickness	0.531"
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
Longitudinal joint efficiency	1
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"

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	
Description	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel
Notes	
Flange is impact tested per material specification to -50°F. Stress ratio = 0.3378 ≤ 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 = t_r*E* / (t_n - c) = 0.0667*1 / (0.4646 - 0) =	0.1436
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 = 250*84 / (20,000*1 - 0.6*250) =	1.0579"
Stress ratio = t_r*E* / (t_n - c) = 1.0579*1 / (1.375 - 0) =	0.7694
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	23.1°F
MDMT = max[T_{impact} - T_R, -155] = max[-49 - 23.1 , -155] =	-72.1°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	4.9214	0.0001	2.0474	--	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	95,473.22	118,953.05	67,092.27	263,217.26	120,442.27	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

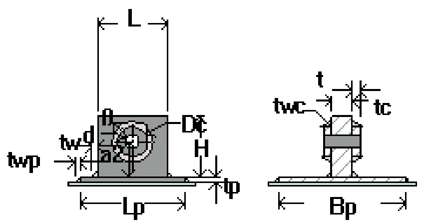
Reinforcement Calculations for MAEP

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
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

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	353,575.9 lb
Lug Weight (new), W_{lug}	578.5 lb
Distance from Center of Gravity to this lug, x_1	151.1606"
Distance from Center of Gravity to second lug, x_2	142.8394"
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}	3.3847"
Required Lug Thickness, t_{reqd}	0.5328"
Required Lug Collar Thickness, $t_{c\ reqd}$	0"
Lug Stress Ratio, σ_{ratio}	0.52
Weld Shear Stress Ratio, τ_{ratio}	0.92
Lug Design	Acceptable
Local Stresses WRC 107	**Unacceptable**

Lift Forces

F_r = force on vessel at lug

F_r = $[W / \cos(\phi_1)]*(1 - x_1 / (x_1 + x_2))$

= (353,575.9) / cos(45°)*(1 - 151.1606/ (151.1606 + 142.8394))

= 242,940 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_{reqd} = $(2*F_r / (\pi*\sigma_s))^{0.5}$

= $(2*242{,}940 / (\pi*13{,}500))^{0.5}$ = 3.3847"

d_{reqd} / D_p = 3.3847 / 3.75 = 0.90 Acceptable

σ = F_r / A

= $F_r / (2*(0.25*\pi*D_p^2))$

= $242{,}940 / (2*(0.25*\pi*3.75^2))$ = 10,998 psi

σ / σ_s = 10,998 / 13,500 = 0.81 Acceptable

Lug Thickness - Tensile stress

t_{reqd} = $F_r / (L*\sigma_t)$
= 242,940 / (20*22,800) = 0.5328"

t_{reqd} / t = 0.5328 / 3 = 0.18 Acceptable

σ = F_r / A
= $F_r / (L*t)$
= 242,940 / (20*3) = 4,049 psi

σ / σ_t = 4,049 / 22,800 = 0.18 Acceptable

Lug Thickness - Bearing stress

T_{reqd} = $F_v / (D_p*\sigma_p)$
= 242,940 / (3.75*30,000) = 2.1595"

T = $t + 2*t_c$
= 3 + 2*1 = 5"

T_{reqd} / T = 2.1595 / 5 = 0.43 Acceptable

Collar required thickness

$t_{c\ reqd}$ = $\max(0, 0.5*(T_{reqd} - t))$
= max(0, 0.5*(2.1595 - 3))
= 0"

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

σ = $F_v / A_{bearing}$
= $F_v / (D_p*(t + 2*t_c))$
= 242,940 / (3.75*(3 + 2*1)) = 12,957 psi

σ / σ_p = 12,957 / 30,000 = 0.43 Acceptable

Lug Thickness - Shear stress

t_{reqd} = $[F_v / \sigma_s - 4*t_c*L_c] / (2*L_{shear})$
= (242,940 / 13,500 - 4*(1*3.4901)) / (2*5.815) = 0.347"

t_{reqd} / t = 0.347 / 3 = 0.12 Acceptable

Collar required thickness

$t_{c\ reqd}$ = $[F_v / \sigma_s - 2*t*L_{shear}] / (4*L_c)$

= (242,940 / 13,500 - 2*(3*5.815)) / (4*3.4901) = 0"

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

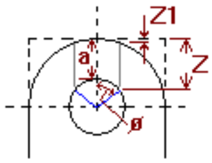
τ = F_v / A_{shear}

= $F_v / (2*t*L_{shear} + 4*t_c*L_c)$

= 242,940 / (2*3*5.815 + 4*1*3.4901) = 4,973 psi

τ / σ_s = 4,973 / 13,500 = 0.37 Acceptable

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



ϕ = $55*D_p / d$

= 55*3.75 / 3.875

= 53.2258°

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

= (17 - 10 - 0.5*3.875) + 0.5*3.75*(1 - cos(53.2258))

= 5.815"

L_c = Collar shear plane length

= 3.4901"

Lug Plate Stress

Lug stress tensile + bending during lift:

σ_{ratio} = $[F_{ten} / (A_{ten}*\sigma_t)] + [M_{bend} / (Z_{bend}*\sigma_b)] \le 1$

= $[(F_r*\cos(\beta)) / (t*L*\sigma_t)] + [(6*abs(F_r*\sin(\beta)*Hght - F_r*\cos(\beta)*a_1)) / (t*L^2*\sigma_b)] \le 1$

= 242,940*cos(45.0) / (3*20*22,800) + 6*abs(242,940*sin(45.0)*10 - 242,940*cos(45.0)*0) / ($3*20^2*22,000$)

= 0.52 Acceptable

Weld Stress

Weld stress, tensile, bending and shear during lift:

Direct shear:

Shear stress at lift angle 45.00°; lift force = 242,940 lb_f

A_{weld} = $2*(0.707)*t_w*(L + t)$

= 2*(0.707)*1.5*(20 + 3) = 48.783 in^2

= $F_{lug}*\cos(\alpha) / A_{weld}$

τ_t

= 242,940*cos(45.0) / 48.783 = 3,521 psi

τ_s = F_{lug}*sin(α) / A_{weld}

= 242,940*sin(45.0) / 48.783 = 3,521 psi

τ_b = M * c / I

= 3*(F_{lug}*sin(β)*Hght - F_{lug}*cos(β)*a_1) / (0.707*h*L*(3*t + L))

= 3*abs(242,940*sin(45.0)*10 - 242,940*cos(45.0)*(0)) / (615.0900)

= 8,378 psi

τ_{ratio} = sqr($(\tau_t + \tau_b)^2 + \tau_s^2$) / $\tau_{allowable} \leq 1$

= sqr ($(3{,}521 + 8{,}378)^2 + (3{,}521)^2$) / 13,500

= 0.92 Acceptable

Collar Weld Stress:

τ_c = F_r / A_{weld}

= 242,940 / (2*0.707*1.5*π*8.5) = 4,289 psi

τ_{ratio} = τ_c / $\tau_{allowable}$ ≤ 1

= 4,289 / 13,500 = 0.32 Acceptable

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

Direct shear:

Shear stress at lift angle 45.00°; lift force = 242,940 lb_f

A_{weld} = 2*(0.707)*t_{wp}*(L_p + B_p)

= 2*(0.707)*1.5*(30 + 18) = 101.808 in^2

τ_t = F_{lug}*cos(α) / A_{weld}

= 242,940*cos(45.0) / 101.808 = 1,687 psi

τ_s = F_{lug}*sin(α) / A_{weld}

= 242,940*sin(45.0) / 101.808 = 1,687 psi

τ_b = M * c / I

= 3*(F_{lug}*sin(β)*Hght - F_{lug}*cos(β)*a_1) / (0.707*h_p*L_p*(3*W_p + L_p))

= 3*abs(242,940*sin(45.0)*11.5 - 242,940*cos(45.0)*(0)) / (2672.4600)

= 2,218 psi

τ_{ratio} = sqr($(\tau_t + \tau_b)^2 + \tau_s^2$) / $\tau_{allowable} \leq 1$

= sqr ((1,687 + 2,218)^2 + (1,687)^2) / 13,500
= 0.32 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	-171,784.21 lb_f
Circumferential moment, M_c	0 lb_f-in
Circumferential shear, V_c	0 lb_f
Longitudinal moment, M_L	1,975,518.4 lb_f-in
Longitudinal shear, V_L	171,784.21 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 (includes pressure)

$\gamma = R_m / T$ = 84.6875 / 2.875 = 29.4565

$C_1 = 3$, $C_2 = 11.5$ in

Local circumferential pressure stress = $P*R_i / T$ =0 psi

Local longitudinal pressure stress = $P*R_i / (2*T)$ =0 psi

Maximum combined stress (P_L+P_b+Q) = 37,020 psi
Allowable combined stress (P_L+P_b+Q) = ±3*S = ±60,000 psi

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

Maximum local primary membrane stress (P_L) = 5,652 psi
Allowable local primary membrane stress (P_L) = ±1.5*S = ±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*	4.7001	0.1022	0	0	0	0	3,316	3,316	3,316	3,316
4C*	5.4011	0.083	3,811	3,811	3,811	3,811	0	0	0	0
1C	0.1877	0.0612	0	0	0	0	23,406	-23,406	23,406	-23,406
2C-1	0.1493	0.0612	18,617	-18,617	18,617	-18,617	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	-1,841	-1,841	1,841	1,841	0	0	0	0
1B-1	0.0541	0.077	-11,896	11,896	11,896	-11,896	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total circumferential stress			8,691	-4,751	36,165	-24,861	26,722	-20,090	26,722	-20,090
Primary membrane circumferential stress*			1,970	1,970	5,652	5,652	3,316	3,316	3,316	3,316
3C*	5.0131	0.083	3,537	3,537	3,537	3,537	0	0	0	0
4C*	5.2332	0.1022	0	0	0	0	3,692	3,692	3,692	3,692
1C-1	0.1611	0.0864	20,089	-20,089	20,089	-20,089	0	0	0	0
2C	0.1184	0.0864	0	0	0	0	14,764	-14,764	14,764	-14,764
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	-882	-882	882	882	0	0	0	0
2B-1	0.0776	0.105	-12,512	12,512	12,512	-12,512	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total longitudinal stress			10,232	-4,922	37,020	-28,182	18,456	-11,072	18,456	-11,072
Primary membrane longitudinal stress*			2,655	2,655	4,419	4,419	3,692	3,692	3,692	3,692
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	-1,299	-1,299	1,299	1,299
Total Shear stress			0	0	0	0	-1,299	-1,299	1,299	1,299
Combined stress (P_L+P_b+Q)			10,232	-4,922	37,020	-28,182	26,921	-20,273	26,921	-20,273
* denotes primary stress.										

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

$\gamma = R_m / T = 84.6875 / 1.375 = 61.5909$

$C_1 = 10.5$, $C_2 = 16.5$ in

Local circumferential pressure stress = $P*R_i / T$ =0 psi

Local longitudinal pressure stress = $P*R_i / (2*T)$ =0 psi

Maximum combined stress (P_L+P_b+Q) = 60,619 psi
Allowable combined stress (P_L+P_b+Q) = ±3*S = ±60,000 psi

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

Maximum local primary membrane stress (P_L) = 18,951 psi
Allowable local primary membrane stress (P_L) = ±1.5*S = ±30,000 psi

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

Stresses at the pad edge per WRC Bulletin 107										
Figure	value	β	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	4.7294	0.1916	0	0	0	0	6,977	6,977	6,977	6,977
4C*	8.5426	0.1705	12,602	12,602	12,602	12,602	0	0	0	0
1C	0.0768	0.1464	0	0	0	0	41,869	-41,869	41,869	-41,869
2C-1	0.0442	0.1464	24,096	-24,096	24,096	-24,096	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	-6,349	-6,349	6,349	6,349	0	0	0	0
1B-1	0.0269	0.1589	-12,530	12,530	12,530	-12,530	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total circumferential stress			17,819	-5,313	55,577	-17,675	48,846	-34,892	48,846	-34,892
Primary membrane circumferential stress*			6,253	6,253	18,951	18,951	6,977	6,977	6,977	6,977
3C*	5.4764	0.1705	8,079	8,079	8,079	8,079	0	0	0	0
4C*	8.0258	0.1916	0	0	0	0	11,840	11,840	11,840	11,840
1C-1	0.0652	0.1743	35,545	-35,545	35,545	-35,545	0	0	0	0
2C	0.0394	0.1743	0	0	0	0	21,480	-21,480	21,480	-21,480
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	-3,226	-3,226	3,226	3,226	0	0	0	0
2B-1	0.0337	0.1812	-13,769	13,769	13,769	-13,769	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total longitudinal stress			26,629	-16,923	60,619	-38,009	33,320	-9,640	33,320	-9,640
Primary membrane longitudinal stress*			4,853	4,853	11,305	11,305	11,840	11,840	11,840	11,840
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	-1,893	-1,893	1,893	1,893
Total Shear stress			0	0	0	0	-1,893	-1,893	1,893	1,893
Combined stress (P_L+P_b+Q)			26,629	-16,923	60,619	-38,009	49,073	-35,033	49,073	-35,033

* denotes primary stress.

Metal Loss #1

API 579-1, 2007 Edition Part 5, Local Metal Loss Assessment		
Flaw Type		Local Metal Loss, Groove-Like Flaw
Flaw Surface		Outside
Uniform Metal Loss, LOSS		0.0625 "
Future Corrosion Allowance, FCA		0.1 "
Allowable Remaining Strength Factor, RSF_a		0.9
Longitudinal Joint Efficiency, E_L		1
Circumferential Joint Efficiency, E_C		1
Groove-Like Flaw Dimensions		
Length, g_l		20 "
Width, g_w		1 "
Radius, g_r		2 "
Orientation to the Longitudinal Axis, β		45°
Longitudinal Extent of Flaw, s		14.8492 "
Circumferential Extent of Flaw, c		14.8492 "
Location and Orientation		
Located On		Cylinder #5
Orientation		45.00°
Distance to Major Structural Discontinuity, L_{msd}		25 "
Flaw Center Offset to Parent Left Seam		60 "
Parent Component		
Material	**Spec No.**	SA-516 70
	Code Edition	2004 A06 Addenda
Nominal Thickness, t_{nom}		1.375 "
Inner Diameter		168 "
Internal Design Pressure		250 psi @ 600 °F
External Design Pressure		15 psi @ 400 °F
Operating Static Liquid Head		0 psi
Note that this assessment does not apply to vessels in cyclic service as per API 579 6.2.5.1(c).		

Results Summary	
Limiting Flaw Size Criteria Check	**Unacceptable**
The flaw did not pass the limiting flaw size criteria check. It is not acceptable for a level 1 or level 2 assessment.	

Groove-Like Flaw Extents	
$s = g_l*\cos(\beta) + g_w*\sin(\beta)$	Eqn 5.1
s = 20*cos(45) + 1*sin(45) =	14.8492 "
$c = g_l*\sin(\beta) + g_w*\cos(\beta)$	Eqn 5.2
c = 20*sin(45) + 1*cos(45) =	14.8492 "

***Supplemental loads due to saddle supports are not considered in this assessment.**

Corroded Wall Thickness	
$t_{rd} = t_{nom}$ - LOSS	
t_{rd} = 1.375 - 0.0625 =	1.3125 "
$t_c = t_{nom}$ - LOSS - FCA	Eqn 5.3
t_c = 1.375 - 0.0625 - 0.1 =	1.2125 "

Longitudinal Flaw Parameter, λ	
t_{mm} =	0.25 "
$R_t = (t_{mm}$ - FCA) / t_c	Eqn 5.5
R_t = (0.25 - 0.1) / 1.2125 =	0.1237
$\lambda = 1.285 * s / (D * t_c)^{0.5}$	Eqn 5.6
$\lambda = 1.285 * 14.8492 / (168 * 1.2125)^{0.5}$ =	1.3369

Limiting Flaw Size Criteria Check, 5.4.2.2.e	
R_t >= 0.20	Eqn 5.7
0.1237 >= 0.20	**Unacceptable**
t_{mm} - FCA >= 0.1	Eqn 5.8
0.25 - 0.1 >= 0.1	**Acceptable**
$L_{msd} >= 1.8*(D*t_c)^{0.5}$	Eqn 5.9
$25 >= (1.8*(168*1.2125)^{0.5} = 25.6902)$	**Unacceptable**
$g_r >= (1 - R_t)*t_c$	Eqn 5.10
2 >= (1 - 0.1237)*1.2125	**Acceptable**
The limiting flaw size criteria are **unacceptable** .	

The flaw did not pass the limiting flaw size criteria check. It is not acceptable for a level 1 or level 2 assessment.

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**		**Optimize MDMT/ Find 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/ft³)**		**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	-72.1 °F

UCS-66 Material Toughness Requirements	
Material impact test temperature per UG-84 =	-49°F
t_r = 250*84 / (20,000*1 - 0.6*250) =	1.0579"
Stress ratio = t_r*E^* / (t_n - c) = 1.0579*1 / (1.375 - 0) =	0.7694
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	23.1°F
MDMT = max[T_{impact} - T_R, -155] = max[-49 - 23.1 , -155] =	-72.1°F
Design MDMT of -49°F is acceptable.	

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

t = P*R / (S*E - 0.60*P) + Corrosion
= 250*84 / (19,400*1.00 - 0.60*250) + 0
= 1.091"

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

P = S*E*t / (R + 0.60*t) - P_s
= 19,400*1.00*1.375 / (84 + 0.60*1.375) - 0
= 314.47 psi

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

P = S*E*t / (R + 0.60*t)
= 20,000*1.00*1.375 / (84 + 0.60*1.375)
= 324.2 psi

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

L / D_o = 532 / 170.75 = 3.1157
D_o / t = 170.75 / 0.8941 = 190.9811
From table G: A = 0.000157
From table CS-2: B = 2,148.5374 psi

P_a = 4*B / (3*(D_o / t))
= 4*2,148.54 / (3*(170.75 / 0.8941))
= 15 psi

Design thickness for external pressure P_a = 15 psi

t_a = t + Corrosion = 0.8941 + 0 = 0.8941"

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

L / D_o = 532 / 170.75 = 3.1157
D_o / t = 170.75 / 1.375 = 124.1818
From table G: A = 0.000290
From table CS-2: B = 4,004.3077 psi

P_a = 4*B / (3*(D_o / t))
= 4*4,004.31 / (3*(170.75 / 1.375))
= 42.99 psi

% Extreme fiber elongation - UCS-79(d)

EFE = (50*t / R_f)*(1 - R_f / R_o)
= (50*1.375 / 84.6875)*(1 - 84.6875 / ∞)
= 0.8118%

The extreme fiber elongation does not exceed 5%.

Ellipsoidal Head #1

<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 #5</td></tr>
<tr><td>Impact Tested</td><td>Normalized</td><td>Fine Grain Practice</td><td>PWHT</td><td colspan="2">Optimize MDMT/ Find MAWP</td></tr>
<tr><td>Yes (-49°F)</td><td>Yes</td><td>Yes</td><td>Yes</td><td colspan="2">No</td></tr>
<tr><td colspan="2"></td><td>Design Pressure (psi)</td><td>Design Temperature (°F)</td><td colspan="2">Design MDMT (°F)</td></tr>
<tr><td colspan="2">Internal</td><td>250</td><td>600</td><td colspan="2" rowspan="2">-49</td></tr>
<tr><td colspan="2">External</td><td>15</td><td>400</td></tr>
<tr><th colspan="6">Static Liquid Head</th></tr>
<tr><td colspan="2">Condition</td><td>P_s (psi)</td><td>H_s (in)</td><td colspan="2">SG</td></tr>
<tr><td colspan="2">Test horizontal</td><td>7.47</td><td>207</td><td colspan="2">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="2">Weight (lb)[1]</td><td colspan="2">Capacity (US gal)[1]</td></tr>
<tr><td colspan="2">New</td><td colspan="2">12,439.93</td><td colspan="2">2,878.84</td></tr>
<tr><td colspan="2">Corroded</td><td colspan="2">12,439.93</td><td colspan="2">2,878.84</td></tr>
<tr><th colspan="6">Insulation</th></tr>
<tr><td colspan="2"></td><td>Thickness (in)</td><td>Density (lb/ft³)</td><td colspan="2">Weight (lb)</td></tr>
<tr><td colspan="2">Insulation</td><td>4</td><td>18</td><td colspan="2">1,401.37</td></tr>
<tr><td colspan="2"></td><td>Spacing(in)</td><td>Individual Weight (lb)</td><td colspan="2">Total Weight (lb)</td></tr>
<tr><td colspan="2">Insulation Supports</td><td>145</td><td>50</td><td colspan="2">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	-68.1°F

UCS-66 Material Toughness Requirements	
Material impact test temperature per UG-84 =	-49°F
t_r = 250*168 / (2*20,000*1 - 0.2*250) =	1.0513"
Stress ratio = t_r*E^* / (t_n - c) = 1.0513*1 / (1.3 - 0) =	0.8087
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	19.1°F
MDMT = max[T_{impact} - T_R, -155] = max[-49 - 19.1 , -155] =	-68.1°F
Design MDMT of -49°F is acceptable.	

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

t = P*D / (2*S*E - 0.2*P) + Corrosion
= 250*168 / (2*19,400*1 - 0.2*250) + 0
= 1.0839"

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

P = 2*S*E*t / (D + 0.2*t) - P_s
= 2*19,400*1*1.3 / (168 +0.2*1.3) - 0
= 299.77 psi

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

P = 2*S*E*t / (D + 0.2*t) - P_s
= 2*20,000*1*1.3 / (168 +0.2*1.3) - 0
= 309.05 psi

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

Equivalent outside spherical radius (R_o)
R_o = K_o*D_o
= 0.8865*170.6
= 151.2351 in

A = 0.125 / (R_o / t)
= 0.125 / (151.2351 / 0.445813)

$= 0.000368$

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

$P_a = B / (R_o / t)$
$= 5{,}088.5176 / (151.2351 / 0.4458)$
$= 15$ psi

$t = 0.4458" + \text{Corrosion} = 0.4458" + 0" = 0.4458"$
Check the external pressure per UG-33(a)(1) UG-32(d)(1)

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

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)
$R_o = K_o*D_o$
$= 0.8865*170.6$
$= 151.2351$ in

$A = 0.125 / (R_o / t)$
$= 0.125 / (151.2351 / 1.3)$
$= 0.001074$

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

$P_a = B / (R_o / t)$
$= 11{,}285.56 / (151.2351 / 1.3)$
$= 97.0094$ psi

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

$P = 2*S*E*t / ((D + 0.2*t)*1.67)$
$= 2*20{,}000*1*1.3 / ((168 + 0.2*1.3)*1.67)$
$= 185.06$ psi

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

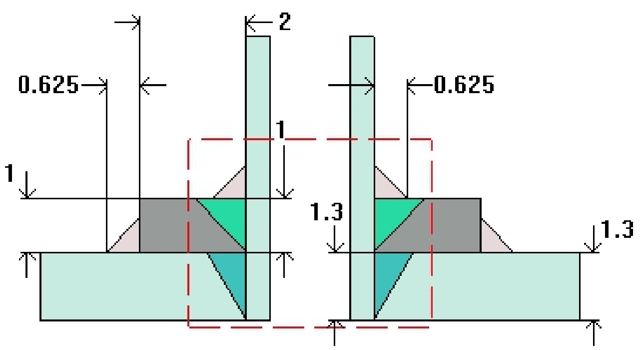
% Extreme fiber elongation - UCS-79(d)

$EFE = (75*t / R_f)*(1 - R_f / R_o)$
$= (75*1.375 / 29.2475)*(1 - 29.2475 / \infty)$
$= 3.5259\%$

The extreme fiber elongation does not exceed 5%.

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"
Nominal wall thickness	0.436"
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
Longitudinal joint efficiency	1
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"

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	
Description	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel
Notes	
Flange is impact tested per material specification to -50°F. Stress ratio = 0.3378 ≤ 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 = t_r*E^* / (t_n - c) = 0.0521*1 / (0.3815 - 0) =	0.1366
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 = 250*168 / (2*20,000*1 - 0.2*250) =	1.0513"
Stress ratio = t_r*E^* / (t_n - c) = 1.0513*1 / (1.3 - 0) =	0.8087
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	19.1°F
MDMT = max[T_{impact} - T_R, -155] = max[-49 - 19.1 , -155] =	-68.1°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	4.0453	--	1.5573	--	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	78,478.82	90,652.66	56,274.65	142,718.2	97,862.43	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

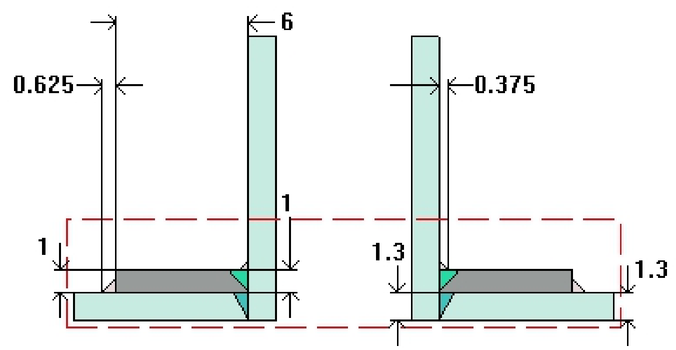
Reinforcement Calculations for MAEP

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

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
Longitudinal joint efficiency	1
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"

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
Gasket	
Description	Flexitallic Solid Metal Core Flexpro Facing; 304 S.S. : Metal; Monel
Notes	
Flange is impact tested per material specification to -50°F. Stress ratio = 0.3378 ≤ 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 = 250*10.75 / (20,000*1 - 0.6*250) =	0.1354"
Stress ratio = t_r*E^* / (t_n - c) = 0.1354*1 / (1.25 - 0) =	0.1083
Stress ratio ≤ 0.35, MDMT per UCS-66(b)(3) =	-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 = 250*0.9*168 / (2*20,000*1 - 0.2*250) =	0.9462"
Stress ratio = t_r*E^* / (t_n - c) = 0.9462*1 / (1.3 - 0) =	0.7278
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1 =	27.2°F
MDMT = max[T_{impact} - T_R, -155] = max[-49 - 27.2 , -155] =	-76.2°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 = $(50*t / R_f)*(1 - R_f / R_o)$
= $(50*1.25 / 11.375)*(1 - 11.375 / \infty)$
= 5.4945%

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

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	250 psi	
Test	332.47 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	
Weight		
	Operating, Corroded	**Hydrotest**
Weight on Left Saddle	99,658 lb	333,015 lb
Weight on Right Saddle	97,745 lb	326,089 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	Right Saddle	7,873	23,280	237	12,394	7,831	23,280	195	12,394
		Left Saddle					7,831	23,280	195	12,394
Wind	Test	Right Saddle	10,833	34,200	678	18,022	10,806	34,200	650	18,022
		Left Saddle					10,806	34,200	650	18,022
Wind	Vacuum	Right Saddle	237	24,000	695	15,766	195	24,000	653	15,766
		Left Saddle					195	24,000	653	15,766

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	Right Saddle	874	15,520	-3,924	29,100	2,577	14,550	840	13,333
		Left Saddle	894	15,520	-3,988	29,100	2,619	14,550	854	13,333
Wind	Test	Right Saddle	2,340	27,360	-11,166	34,200	7,333	34,200	2,391	34,200
		Left Saddle	2,410	27,360	-11,398	34,200	7,485	34,200	2,441	34,200
Wind	Vacuum	Right Saddle	874	16,000	-3,924	30,000	2,577	16,250	840	13,333
		Left Saddle	894	16,000	-3,988	30,000	2,619	16,250	854	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			
$V_{wt} = P_w*G*(C_{f(shell)}*(\text{Projected shell area}) + C_{f(saddle)}*(\text{Projected saddle area}))$			
$V_{we} = P_w*G*(C_{f(shell)}*\pi*R_o^2 / 144 + C_{f(saddle)}*(\text{Projected saddle area}))$			
$Q_t = V_{wt}*H_s / (R_o*Sin(\theta / 2))$			
$Q_l = V_{we}*H_s / L_s$			
$Q = W + max[Q_t , Q_l]$			
Results			
Operating	Right Saddle	V_{wt} = 4.4*0.85*(8.8*365.2766 + 2*2.6354)	12,041.7 lb_f
		V_{we} = 4.4*0.85*(0.5*π*91.375² / 144 + 2*47.3344)	694.69 lb_f
		Q_t = 12,041.7*117 / (85.375*Sin(120 / 2))	19,055.14 lb_f
		Q_l = 694.69*117 / 392	207.34 lb_f
		Q = 97,745 + max[19,055.14 , 207.34]	116,800.14 lb_f
	Left Saddle	V_{wt} = 4.4*0.85*(8.8*365.2766 + 2*2.6354)	12,041.7 lb_f
		V_{we} = 4.4*0.85*(0.5*π*91.375² / 144 + 2*47.3344)	694.69 lb_f
		Q_t = 12,041.7*117 / (85.375*Sin(120 / 2))	19,055.14 lb_f
		Q_l = 694.69*117 / 392	207.34 lb_f
		Q = 99,658 + max[19,055.14 , 207.34]	118,713.14 lb_f
Test	Right Saddle	V_{wt} = 1.45*0.85*(8.8*365.2766 + 2*2.6354)	3,973.76 lb_f
		V_{we} = 1.45*0.85*(0.5*π*91.375² / 144 + 2*47.3344)	229.25 lb_f
		Q_t = 3,973.76*117 / (85.375*Sin(120 / 2))	6,288.2 lb_f
		Q_l = 229.25*117 / 392	68.42 lb_f
		Q = 326,089 + max[6,288.2 , 68.42]	332,377.2 lb_f
	Left Saddle	V_{wt} = 1.45*0.85*(8.8*365.2766 + 2*2.6354)	3,973.76 lb_f
		V_{we} = 1.45*0.85*(0.5*π*91.375² / 144 + 2*47.3344)	229.25 lb_f
		Q_t = 3,973.76*117 / (85.375*Sin(120 / 2))	6,288.2 lb_f
		Q_l = 229.25*117 / 392	68.42 lb_f
		Q = 333,015 + max[6,288.2 , 68.42]	339,303.2 lb_f

Load Case 1: Wind, Operating

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

$S_1 = \pm\ 3*K_1*Q*(L / 12) / (\pi*R^2*t)$
$= 3*0.491*118{,}713.14*(504 / 12) / (\pi*84.6875^2*1.375)$
= 237 psi

$S_p = P*R / (2*t)$
= 250*84 / (2*1.375)
= 7,636 psi

Maximum tensile stress $S_{1t} = S_1 + S_p$ = 7,873 psi
Maximum compressive stress (shut down) $S_{1c} = S_1$ = 237 psi

Tensile stress is acceptable (<=1.2*S*E = 23,280 psi)
Compressive stress is acceptable (<=1.2*S_c = 12,394 psi)

Longitudinal stress at the right saddle (Wind, Operating)

L_e = 2*(Left head depth) / 3 + L + 2*(Right head depth) / 3
= 2*43.3 / 3 + 504 + 2*43.3 / 3
= 561.7333 in

$w = W_t / L_e$ = 197,403 / 561.7333 = 351.42 lb_f/in

Bending moment at the right saddle:

$M_q = w*(2*H*A_r / 3 + A_r^2 / 2 - (R^2 - H^2) / 4)$
$= 351.42*(2*43.3*56 / 3 + 56^2 / 2 - (85.375^2 - 43.3^2) / 4)$
= 643,457.4 lb_f-in

$S_2 = \pm\ M_q*K_1' / (\pi*R^2*t)$
$= 643{,}457.4*9.3799 / (\pi*84.6875^2*1.375)$
= 195 psi

$S_p = P*R / (2*t)$
= 250*84 / (2*1.375)
= 7,636 psi

Maximum tensile stress $S_{2t} = S_2 + S_p$ = 7,831 psi
Maximum compressive stress (shut down) $S_{2c} = S_2$ = 195 psi

Tensile stress is acceptable (<=1.2*S = 23,280 psi)
Compressive stress is acceptable (<=1.2*S_c = 12,394 psi)

Tangential shear stress in the shell (right saddle, Wind, Operating)

$Q_{shear} = Q - w*(a + 2*H / 3)$
= 116,800.14 - 351.42*(56 + 2*43.3 / 3)
= 86,976.5 lb_f

$S_3 = K_{2.2}*Q_{shear} / (R*t)$
= 1.1707*86,976.5 / (84.6875*1.375)
= 874 psi

Tangential shear stress is acceptable (<= 0.8*S = 15,520 psi)

Circumferential stress at the right saddle horns (Wind, Operating)

$S_4 = -Q / (4*t*(b+1.56*Sqr(R_o*t))) - 12*K_3*Q*R / (L*t^2)$

$= -116{,}800.14 / (4*1.375*(12+1.56*Sqr(85.375*1.375))) - 12*0.0256*116{,}800.14*84.6875 / (504*1.375^2)$
= -3,924 psi

Circumferential stress at saddle horns is acceptable ($<=1.5*S_a$ = 29,100 psi)
The wear plate was not considered in the calculation of S_4 because the wear plate width is not at least $\{B + 1.56*(R_o t_c)^{0.5}\}$ =28.9021 in

Ring compression in shell over right saddle (Wind, Operating)

$S_5 = K_5*Q / ((t + t_p)*(t_s + 1.56*Sqr(R_o*t_c)))$
$= 0.7603*116{,}800.14 / ((1.375 + 0.375)*(0.625 + 1.56*Sqr(85.375*1.75)))$
= 2,577 psi

Ring compression in shell is acceptable ($<= 0.5*S_y$ = 14,550 psi)

Saddle splitting load (right, Wind, Operating)

Area resisting splitting force = Web area + wear plate area

$A_e = H_{eff}*t_s + t_p*W_p$
= 28.4583*0.625 + 0.375*28
= 28.2865 in^2

$S_6 = K_8*Q / A_e$
= 0.2035*116,800.14 / 28.2865
= 840 psi

Stress in saddle is acceptable ($<= (2 / 3)*S_s$ = 13,333 psi)

Longitudinal stress at the left saddle (Wind, Operating)

L_e = 2*(Left head depth) / 3 + L + 2*(Right head depth) / 3
= 2*43.3 / 3 + 504 + 2*43.3 / 3
= 561.7333 in

$w = W_t / L_e$ = 197,403 / 561.7333 = 351.42 lb_f/in

Bending moment at the left saddle:

$M_q = w*(2*H*A_l / 3 + A_l^2 / 2 - (R^2 - H^2) / 4)$
$= 351.42*(2*43.3*56 / 3 + 56^2 / 2 - (85.375^2 - 43.3^2) / 4)$
= 643,457.4 lb_f-in

$S_2 = \pm M_q*K_1' / (\pi*R^2*t)$
$= 643{,}457.4*9.3799 / (\pi*84.6875^2*1.375)$
= 195 psi

$S_p = P*R / (2*t)$
= 250*84 / (2*1.375)
= 7,636 psi

Maximum tensile stress $S_{2t} = S_2 + S_p$ = 7,831 psi
Maximum compressive stress (shut down) $S_{2c} = S_2$ = 195 psi

Tensile stress is acceptable ($<=1.2*S$ = 23,280 psi)
Compressive stress is acceptable ($<=1.2*S_c$ = 12,394 psi)

Tangential shear stress in the shell (left saddle, Wind, Operating)

Q_{shear} = Q - w*(a + 2*H / 3)
= 118,713.14 - 351.42*(56 + 2*43.3 / 3)
= 88,889.5 lb_f

$S_3 = K_{2.2}$*Q_{shear} / (R*t)
= 1.1707*88,889.5 / (84.6875*1.375)
= 894 psi

Tangential shear stress is acceptable (<= 0.8*S = 15,520 psi)

Circumferential stress at the left saddle horns (Wind, Operating)

S_4 = -Q / (4*t*(b+1.56*Sqr(R_o*t))) - 12*K_3*Q*R / (L*t^2)
= -118,713.14 / (4*1.375*(12+1.56*Sqr(85.375*1.375))) - 12*0.0256*118,713.14*84.6875 / (504*1.375^2)
= -3,988 psi

Circumferential stress at saddle horns is acceptable (<=1.5*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 {B + 1.56*$(R_o t_c)^{0.5}$} =28.9021 in

Ring compression in shell over left saddle (Wind, Operating)

S_5 = K_5*Q / ((t + t_p)*(t_s + 1.56*Sqr(R_o*t_c)))
= 0.7603*118,713.14 / ((1.375 + 0.375)*(0.625 + 1.56*Sqr(85.375*1.75)))
= 2,619 psi

Ring compression in shell is acceptable (<= 0.5*S_y = 14,550 psi)

Saddle splitting load (left, Wind, Operating)

Area resisting splitting force = Web area + wear plate area

A_e = H_{eff}*t_s + t_p*W_p
= 28.4583*0.625 + 0.375*28
= 28.2865 in^2

S_6 = K_8*Q / A_e
= 0.2035*118,713.14 / 28.2865
= 854 psi

Stress in saddle is acceptable (<= (2 / 3)*S_s = 13,333 psi)

Load Case 2: Wind, Test

Longitudinal stress between saddles (Wind, Test, left saddle loading and geometry govern)

S_1 = ± 3*K_1*Q*(L / 12) / (π*R^2*t)
= 3*0.491*339,303.2*(504 / 12) / (π*84.6875^2*1.375)
= 678 psi

S_p = P*R / (2*t)
= 332.47*84 / (2*1.375)
= 10,156 psi

Maximum tensile stress S_{1t} = S_1 + S_p = 10,833 psi

Maximum compressive stress (shut down) $S_{1c} = S_1 = $ 678 psi

Tensile stress is acceptable (<= $0.9*S_y$ = 34,200 psi)
Compressive stress is acceptable (<=$1.2*S_c$ = 18,022 psi)

Longitudinal stress at the right saddle (Wind, Test)

L_e = 2*(Left head depth) / 3 + L + 2*(Right head depth) / 3
= 2*43.3 / 3 + 504 + 2*43.3 / 3
= 561.7333 in

$w = W_t / L_e$ = 659,104 / 561.7333 = 1,173.34 lb_f/in

Bending moment at the right saddle:

$M_q = w*(2*H*A_r / 3 + A_r^2 / 2 - (R^2 - H^2) / 4)$
= $1,173.34*(2*43.3*56 / 3 + 56^2 / 2 - (85.375^2 - 43.3^2) / 4)$
= 2,148,423.9 lb_f-in

$S_2 = \pm M_q*K_1' / (\pi*R^2*t)$
= $2,148,423.9*9.3799 / (\pi*84.6875^2*1.375)$
= 650 psi

$S_p = P*R / (2*t)$
= 332.47*84 / (2*1.375)
= 10,156 psi

Maximum tensile stress $S_{2t} = S_2 + S_p$ = 10,806 psi
Maximum compressive stress (shut down) $S_{2c} = S_2$ = 650 psi

Tensile stress is acceptable (<= $0.9*S_y$ = 34,200 psi)
Compressive stress is acceptable (<=$1.2*S_c$ = 18,022 psi)

Tangential shear stress in the shell (right saddle, Wind, Test)

$Q_{shear} = Q - w*(a + 2*H / 3)$
= 332,377.2 - 1,173.34*(56 + 2*43.3 / 3)
= 232,799.77 lb_f

$S_3 = K_{2.2}*Q_{shear} / (R*t)$
= 1.1707*232,799.77 / (84.6875*1.375)
= 2,340 psi

Tangential shear stress is acceptable (<= $0.8*(0.9*S_y)$ = 27,360 psi)

Circumferential stress at the right saddle horns (Wind, Test)

$S_4 = -Q / (4*t*(b+1.56*Sqr(R_o*t))) - 12*K_3*Q*R / (L*t^2)$
= $-332,377.2 / (4*1.375*(12+1.56*Sqr(85.375*1.375))) - 12*0.0256*332,377.2*84.6875 / (504*1.375^2)$
= -11,166 psi

Circumferential stress at saddle horns is acceptable (<= $0.9*S_y$ = 34,200 psi)
The wear plate was not considered in the calculation of S_4 because the wear plate width is not at least {B + $1.56*(R_o t_c)^{0.5}$} =28.9021 in

Ring compression in shell over right saddle (Wind, Test)

$S_5 = K_5*Q / ((t + t_p)*(t_s + 1.56*Sqr(R_o*t_c)))$
= 0.7603*332,377.2 / ((1.375 + 0.375)*(0.625 + 1.56*Sqr(85.375*1.75)))
= 7,333 psi

Ring compression in shell is acceptable (<= 0.9*S_y = 34,200 psi)

Saddle splitting load (right, Wind, Test)

Area resisting splitting force = Web area + wear plate area

$A_e = H_{eff}*t_s + t_p*W_p$
= 28.4583*0.625 + 0.375*28
= 28.2865 in^2

$S_6 = K_8*Q / A_e$
= 0.2035*332,377.2 / 28.2865
= 2,391 psi

Stress in saddle is acceptable (<= 0.9*S_y = 34,200 psi)

Longitudinal stress at the left saddle (Wind, Test)

L_e = 2*(Left head depth) / 3 + L + 2*(Right head depth) / 3
= 2*43.3 / 3 + 504 + 2*43.3 / 3
= 561.7333 in

$w = W_t / L_e$ = 659,104 / 561.7333 = 1,173.34 lb_f/in

Bending moment at the left saddle:

$M_q = w*(2*H*A_l / 3 + A_l^2 / 2 - (R^2 - H^2) / 4)$
= 1,173.34*(2*43.3*56 / 3 + 56^2 / 2 - (85.375^2 - 43.3^2) / 4)
= 2,148,423.9 lb_f-in

$S_2 = \pm M_q*K_1' / (\pi*R^2*t)$
= 2,148,423.9*9.3799 / (π*84.6875^2*1.375)
= 650 psi

$S_p = P*R / (2*t)$
= 332.47*84 / (2*1.375)
= 10,156 psi

Maximum tensile stress $S_{2t} = S_2 + S_p$ = 10,806 psi
Maximum compressive stress (shut down) $S_{2c} = S_2$ = 650 psi

Tensile stress is acceptable (<= 0.9*S_y = 34,200 psi)
Compressive stress is acceptable (<=1.2*S_c = 18,022 psi)

Tangential shear stress in the shell (left saddle, Wind, Test)

$Q_{shear} = Q - w*(a + 2*H / 3)$
= 339,303.2 - 1,173.34*(56 + 2*43.3 / 3)
= 239,725.77 lb_f

$S_3 = K_{2.2}*Q_{shear} / (R*t)$
= 1.1707*239,725.77 / (84.6875*1.375)
= 2,410 psi

Tangential shear stress is acceptable (<= $0.8*(0.9*S_y)$ = 27,360 psi)

Circumferential stress at the left saddle horns (Wind, Test)

S_4 = -Q / (4*t*(b+1.56*Sqr(R_o*t))) - 12*K_3*Q*R / (L*t^2)
= -339,303.2 / (4*1.375*(12+1.56*Sqr(85.375*1.375))) - 12*0.0256*339,303.2*84.6875 / (504*1.375^2)
= -11,398 psi

Circumferential stress at saddle horns is acceptable (<= 0.9*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 {B + 1.56*$(R_o t_c)^{0.5}$} =28.9021 in

Ring compression in shell over left saddle (Wind, Test)

S_5 = K_5*Q / ((t + t_p)*(t_s + 1.56*Sqr(R_o*t_c)))
= 0.7603*339,303.2 / ((1.375 + 0.375)*(0.625 + 1.56*Sqr(85.375*1.75)))
= 7,485 psi

Ring compression in shell is acceptable (<= 0.9*S_y = 34,200 psi)

Saddle splitting load (left, Wind, Test)

Area resisting splitting force = Web area + wear plate area

A_e = H_{eff}*t_s + t_p*W_p
= 28.4583*0.625 + 0.375*28
= 28.2865 in^2

S_6 = K_8*Q / A_e
= 0.2035*339,303.2 / 28.2865
= 2,441 psi

Stress in saddle is acceptable (<= 0.9*S_y = 34,200 psi)

Load Case 3: Wind, Vacuum

Longitudinal stress between saddles (Wind, Vacuum, left saddle loading and geometry govern)

S_1 = ± 3*K_1*Q*(L / 12) / (π*R^2*t)
= 3*0.491*118,713.14*(504 / 12) / (π*84.6875^2*1.375)
= 237 psi

S_p = P*R / (2*t)
= 15*84 / (2*1.375)
= 458 psi

Maximum tensile stress (shut down) S_{1t} = S_1 = 237 psi
Maximum compressive stress S_{1c} = S_1 + S_p = 695 psi

Tensile stress is acceptable (<=1.2*S*E = 24,000 psi)
Compressive stress is acceptable (<=1.2*S_c = 15,766 psi)

Longitudinal stress at the right saddle (Wind, Vacuum)

L_e = 2*(Left head depth) / 3 + L + 2*(Right head depth) / 3
= 2*43.3 / 3 + 504 + 2*43.3 / 3

= 561.7333 in

$w = W_t / L_e$ = 197,403 / 561.7333 = 351.42 lb_f/in

Bending moment at the right saddle:

$M_q = w*(2*H*A_r / 3 + A_r^2 / 2 - (R^2 - H^2) / 4)$
$= 351.42*(2*43.3*56 / 3 + 56^2 / 2 - (85.375^2 - 43.3^2) / 4)$
= 643,457.4 lb_f-in

$S_2 = \pm M_q*K_1' / (\pi*R^2*t)$
$= 643,457.4*9.3799 / (\pi*84.6875^2*1.375)$
= 195 psi

$S_p = P*R / (2*t)$
= 15*84 / (2*1.375)
= 458 psi

Maximum tensile stress (shut down) $S_{2t} = S_2$ = 195 psi
Maximum compressive stress $S_{2c} = S_2 + S_p$ = 653 psi

Tensile stress is acceptable (<=1.2*S = 24,000 psi)
Compressive stress is acceptable (<=1.2*S_c = 15,766 psi)

Tangential shear stress in the shell (right saddle, Wind, Vacuum)

$Q_{shear} = Q - w*(a + 2*H / 3)$
= 116,800.14 - 351.42*(56 + 2*43.3 / 3)
= 86,976.5 lb_f

$S_3 = K_{2.2}*Q_{shear} / (R*t)$
= 1.1707*86,976.5 / (84.6875*1.375)
= 874 psi

Tangential shear stress is acceptable (<= 0.8*S = 16,000 psi)

Circumferential stress at the right saddle horns (Wind, Vacuum)

$S_4 = -Q / (4*t*(b+1.56*Sqr(R_o*t))) - 12*K_3*Q*R / (L*t^2)$
$= -116,800.14 / (4*1.375*(12+1.56*Sqr(85.375*1.375))) - 12*0.0256*116,800.14*84.6875 / (504*1.375^2)$
= -3,924 psi

Circumferential stress at saddle horns is acceptable (<=1.5*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 {B + 1.56*$(R_o t_c)^{0.5}$} =28.9021 in

Ring compression in shell over right saddle (Wind, Vacuum)

$S_5 = K_5*Q / ((t + t_p)*(t_s + 1.56*Sqr(R_o*t_c)))$
= 0.7603*116,800.14 / ((1.375 + 0.375)*(0.625 + 1.56*Sqr(85.375*1.75)))
= 2,577 psi

Ring compression in shell is acceptable (<= 0.5*S_y = 16,250 psi)

Saddle splitting load (right, Wind, Vacuum)

Area resisting splitting force = Web area + wear plate area

$A_e = H_{eff}*t_s + t_p*W_p$
= 28.4583*0.625 + 0.375*28
= 28.2865 in^2

$S_6 = K_8*Q / A_e$
= 0.2035*116,800.14 / 28.2865
= 840 psi

Stress in saddle is acceptable (<= (2 / 3)*S_s = 13,333 psi)

Longitudinal stress at the left saddle (Wind, Vacuum)

L_e = 2*(Left head depth) / 3 + L + 2*(Right head depth) / 3
= 2*43.3 / 3 + 504 + 2*43.3 / 3
= 561.7333 in

w = W_t / L_e = 197,403 / 561.7333 = 351.42 lb_f/in

Bending moment at the left saddle:

$M_q = w*(2*H*A_l / 3 + A_l^2 / 2 - (R^2 - H^2) / 4)$
= $351.42*(2*43.3*56 / 3 + 56^2 / 2 - (85.375^2 - 43.3^2) / 4)$
= 643,457.4 lb_f-in

$S_2 = \pm M_q*K_1' / (\pi*R^2*t)$
= $643,457.4*9.3799 / (\pi*84.6875^2*1.375)$
= 195 psi

$S_p = P*R / (2*t)$
= 15*84 / (2*1.375)
= 458 psi

Maximum tensile stress (shut down) $S_{2t} = S_2$ = 195 psi
Maximum compressive stress $S_{2c} = S_2 + S_p$ = 653 psi

Tensile stress is acceptable (<=1.2*S = 24,000 psi)
Compressive stress is acceptable (<=1.2*S_c = 15,766 psi)

Tangential shear stress in the shell (left saddle, Wind, Vacuum)

Q_{shear} = Q - w*(a + 2*H / 3)
= 118,713.14 - 351.42*(56 + 2*43.3 / 3)
= 88,889.5 lb_f

$S_3 = K_{2.2}*Q_{shear} / (R*t)$
= 1.1707*88,889.5 / (84.6875*1.375)
= 894 psi

Tangential shear stress is acceptable (<= 0.8*S = 16,000 psi)

Circumferential stress at the left saddle horns (Wind, Vacuum)

$S_4 = -Q / (4*t*(b+1.56*Sqr(R_o*t))) - 12*K_3*Q*R / (L*t^2)$
= $-118,713.14 / (4*1.375*(12+1.56*Sqr(85.375*1.375))) - 12*0.0256*118,713.14*84.6875 / (504*1.375^2)$
= -3,988 psi

Circumferential stress at saddle horns is acceptable (<=1.5*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 {B + 1.56*$(R_o t_c)^{0.5}$} =28.9021 in

Ring compression in shell over left saddle (Wind, Vacuum)

S_5 = K_5*Q / ((t + t_p)*(t_s + 1.56*Sqr(R_o*t_c)))
= 0.7603*118,713.14 / ((1.375 + 0.375)*(0.625 + 1.56*Sqr(85.375*1.75)))
= 2,619 psi

Ring compression in shell is acceptable (<= 0.5*S_y = 16,250 psi)

Saddle splitting load (left, Wind, Vacuum)

Area resisting splitting force = Web area + wear plate area

A_e = H_{eff}*t_s + t_p*W_p
= 28.4583*0.625 + 0.375*28
= 28.2865 in^2

S_6 = K_8*Q / A_e
= 0.2035*118,713.14 / 28.2865
= 854 psi

Stress in saddle is acceptable (<= (2 / 3)*S_s = 13,333 psi)

Shear stress in anchor bolting, one end slotted

Maximum seismic or wind base shear = 694.69 lb_f

Thermal expansion base shear = W*μ = 103,009*0.2 = 20,601.8 lb_f
Corroded root area for a 1.5" series 8 threaded bolt = 0.9289 in^2 (4 per saddle)

Bolt shear stress = 20,601.8 / (0.9289*1*4) = 5,545 psi

Anchor bolt stress is acceptable (<= 20,000 psi)

Shear stress in anchor bolting, transverse

Maximum seismic or wind base shear = 24,083.39 lb_f
Corroded root area for a 1.5" series 8 threaded bolt = 0.9289 in^2 (4 per saddle)

Bolt shear stress = 24,083.39 / (0.9289*2*4) = 3,241 psi

Anchor bolt stress is acceptable (<= 20,000 psi)

Web plate buckling check (Escoe pg 251)

Allowable compressive stress S_c is the lesser of 20,000 or 21,394 psi: (20,000)

S_c = K_i*π^2*E / (12*(1 - 0.3^2)*(d_i / t_s)^2)
= 1.28*π^2*29E+06 / (12*(1 - 0.3^2)*(24.75 / 0.625)^2)
= 21,394 psi

Allowable compressive load on the saddle

b_e = d_i*t_s / (d_i*t_s + 2*t_w*(b - 1))

= 24.75*0.625 / (24.75*0.625 + 2*0.5*(12 - 1))
= 0.5844

$F_b = n*(A_s + 2*b_e*t_s)*S_c$
= 7*(5.6875 + 2*0.5844*0.625)*20,000
= 898,522.73 lb_f

Saddle loading of 342,654.2 lb_f is <= F_b; satisfactory.

Primary bending + axial stress in the saddle due to end loads (assumes one saddle slotted)
$\sigma_b = V*(H_s - x_o)*y / I + Q / A$
= 694.69*(117 - 70.6046)*6 / 504.89 + 118,713.14 / 132.2336
= 1,281 psi

The primary bending + axial stress in the saddle <= 20,000 psi; satisfactory.

Secondary bending + axial stress in the saddle due to end loads (includes thermal expansion, assumes one saddle slotted)
$\sigma_b = V*(H_s - x_o)*y / I + Q / A$
= 21,296.49*(117 - 70.6046)*6 / 504.89 + 118,713.14 / 132.2336
= 12,640 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 in

$t_b = (\beta_1*q*b^2 / (1.5*S_a))^{0.5}$
= $(3*143*7.6875^2 / (1.5*20,000))^{0.5}$
= 0.9186 in

The base plate thickness of 1.5 in is adequate.

Foundation bearing check

$S_f = Q_{max} / (F*E)$
= 342,654.2 / (16*150)
= 143 psi

Concrete bearing stress ≤ 750 psi ; satisfactory.

Wind Code

Building Code: NBC 1995	
Elevation of base above grade	21.8000 ft (6.6447 m)
Increase effective outer diameter by	0.3333 ft (0.1016 m)
Reference Wind Pressure, q	0.0611 psi (0.4213 kPa)
Exposure category	B
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]

P_w = I_W * q * C_e
= %IW% * 0.0611 * 0.5000
= 0.0306 psi
= 4.4000 psf

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 Hydrotest	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 Hydrotest	Yes

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 Hydrotest	Yes