Key Design Engineering

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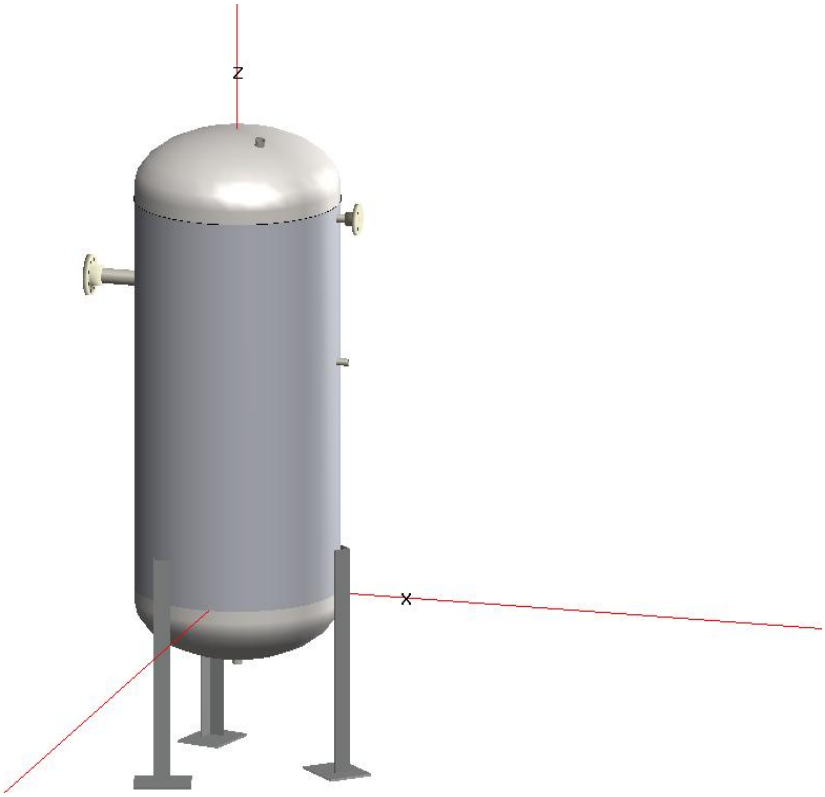

COMPRESS Pressure Vessel Design Calculations

Item: Sample Calculation: 36" Air Receiver
Customer: ABC Industries
Job: KEY-Design-Air Receiver Sample
Designer: Michael Rodgers
Date: Monday, September 15, 2008

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Deficiencies Summary

No deficiencies found.

Nozzle Schedule

Nozzle mark	Service	Size	Materials								
			Nozzle	Impact	Norm	Fine Grain	Pad	Impact	Norm	Fine Grain	Flange
N1	3000# 1/2" HC	0.500" Class 3000 - threaded	SA-234 WPB	No	No	No	N/A	N/A	N/A	N/A	N/A
N3	2" w/ 2" 300# RFWN	2" Sch 80 (XS)	SA-106 B Smls pipe	No	No	No	N/A	N/A	N/A	N/A	WN A105 Class 300
N4	N4 3000# 1" HC	1" Class 3000 - threaded	SA-234 WPB	No	No	No	N/A	N/A	N/A	N/A	N/A
N5	1 " with 1 " RFWN	1" Sch 80 (XS)	SA-106 B Smls pipe	No	No	No	N/A	N/A	N/A	N/A	WN A105 Class 300
N6	3000# 1" HC	1" Class 3000 - threaded	SA-234 WPB	No	No	No	N/A	N/A	N/A	N/A	N/A

Nozzle Summary

Nozzle mark	OD (in)	t_n (in)	Req t_n (in)	A_1?	A_2?	Shell			Reinforcement Pad		Corr (in)	A_a/A_r (%)
						Nom t (in)	Design t (in)	User t (in)	Width (in)	t_{pad} (in)		
N1	1.125	0.1425	0.1164	Yes	Yes	0.5	N/A		N/A	N/A	0	Exempt
N3	2.375	0.218	0.154	Yes	Yes	0.5	N/A		N/A	N/A	0	Exempt
N4	1.75	0.2175	0.1269	Yes	Yes	0.5*	N/A		N/A	N/A	0	Exempt
N5	1.315	0.179	0.133	Yes	Yes	0.5	N/A		N/A	N/A	0	Exempt
N6	1.75	0.2175	0.1269	Yes	Yes	0.5*	N/A		N/A	N/A	0	Exempt

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

Pressure Summary for Chamber bounded by 36" Lower 2:1 Semi-Elliptical head and 36" Upper 2:1 Semi Elliptical head

Identifier	P Design (psi)	T Design (°F)	MAWP (psi)	MAP (psi)	MAEP (psi)	T_e external (°F)	MDMT (°F)	MDMT Exemption	Impact Tested
36" Upper 2:1 Semi Elliptical head	375	200	484.33	484.33	237.32	200	-55	Note 1	No
Straight Flange on 36" Upper 2:1 Semi Elliptical head	375	200	477.53	477.53	233.57	200	-55	Note 2	No
36" OD 5/8" Shell	375	200	477.53	477.53	233.57	212	-40.1	Note 3	No
Straight Flange on 36" Lower 2:1 Semi-Elliptical head	375	200	477.53	477.53	233.57	200	-55	Note 2	No
36" Lower 2:1 Semi-Elliptical head	375	200	484.33	484.33	237.32	200	-55	Note 1	No
Legs 3 X 3 X 3/8	375	200	375	N/A	N/A	N/A	N/A	N/A	N/A
3000# 1/2" HC (N1)	375	200	561.74	561.74	233.57	212	-155	Note 4	No
2" w/ 2" 300# RFWN (N3)	375	200	561.74	561.74	233.57	212	-55	Note 5	No
N4 3000# 1" HC (N4)	375	200	624.97	624.97	233.57	200	-155	Note 6	No
1 " with 1 " RFWN (N5)	375	200	561.74	561.74	233.57	212	-55	Note 5	No
3000# 1" HC (N6)	375	200	624.97	624.97	233.57	200	-155	Note 6	No

Chamber design MDMT is -20 °F
Chamber rated MDMT is -40.1 °F @ 375 psi

Chamber MAWP hot & corroded is 375 psi @ 200 °F

Chamber MAP cold & new is 477.53 psi @ 70 °F

Chamber MAEP is 233.57 psi @ 200 °F
Vacuum rings did not govern the external pressure rating.

Notes for MDMT Rating:

Note #	Exemption	Details
1.	Material impact test exemption temperature from Fig UCS-66 Curve D = -55 °F Fig UCS-66.1 MDMT reduction = 33.8 °F, (coincident ratio = 0.6618601) Rated MDMT is governed by UCS-66(b)(2)	UCS-66 governing thickness = 0.5 in
2.	Material impact test exemption temperature from Fig UCS-66 Curve D = -55 °F Fig UCS-66.1 MDMT reduction = 33.1 °F, (coincident ratio = 0.6690962) Rated MDMT is governed by UCS-66(b)(2)	UCS-66 governing thickness = 0.5 in
3.	Material impact test exemption temperature from Fig UCS-66 Curve B = -7 °F Fig UCS-66.1 MDMT reduction = 33.1 °F, (coincident ratio = 0.6690962)	UCS-66 governing thickness = 0.5 in
4.	Nozzle is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.0655).	
5.	Flange rating governs:	UCS-66(b)(1)(b)
6.	Nozzle is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.06718).	

Design notes are available on the Settings Summary page.

Revision History

No.	Date	Operator	Notes
0	9/ 3/2008	Administrator	New vessel created ASME Section VIII Division 1 [Build 6259]

Settings Summary

COMPRESS Build 6259

Units: U.S. Customary

Datum Line Location: 0.00" from bottom seam

Design

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

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

Hydro/Pneumatic Test

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

Required Marking - UG-116

UG-116 (e) Radiography:	RT3
UG-116 (f) Postweld heat treatment:	None

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
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):	No
UG-22 (d)(2) Vessel supports such as lugs, rings, skirts, saddles and legs:	Yes
UG-22 (f) Wind reactions:	No
UG-22 (f) Seismic reactions:	No

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

Thickness Summary

Component Identifier	Material	Diameter (in)	Length (in)	Nominal t (in)	Design t (in)	Total Corrosion (in)	Joint E	Load
36" Upper 2:1 Semi Elliptical head	SA-516 70	36 OD	9.25	0.5*	0.3894	0	0.85	Internal
Straight Flange on 36" Upper 2:1 Semi Elliptical head	SA-516 70	36 OD	2	0.5	0.3936	0	0.85	Internal
36" OD 5/8" Shell	SA-516 70	36 OD	62	0.5	0.3936	0	0.85	Internal
Straight Flange on 36" Lower 2:1 Semi-Elliptical head	SA-516 70	36 OD	2	0.5	0.3936	0	0.85	Internal
36" Lower 2:1 Semi-Elliptical head	SA-516 70	36 OD	9.25	0.5*	0.3894	0	0.85	Internal

Nominal t: Vessel wall nominal thickness

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

Joint E: Longitudinal seam joint efficiency

* Head minimum thickness after forming

Load

internal: Circumferential stress due to internal pressure governs

external: External pressure governs

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

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

Weight Summary

Component	Weight (lb) Contributed by Vessel Elements						
	Metal New*	Metal Corroded*	Insulation & Supports	Lining	Piping + Liquid	Operating Liquid	Test Liquid
36" Upper 2:1 Semi Elliptical head	238.1	238.1	0	0	0	0	272.1
36" OD 5/8" Shell	977.5	977.5	0	0	0	0	2,154
36" Lower 2:1 Semi-Elliptical head	238.1	238.1	0	0	0	0	272.1
Legs 3 X 3 X 3/8	69.5	69.5	0	0	0	0	0
TOTAL:	**1,523.2**	**1,523.2**	**0**	**0**	**0**	**0**	**2,698.2**

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

Component	Weight (lb) Contributed by Attachments								
	Body Flanges		Nozzles & Flanges		Packed Beds	Ladders & Platforms	Trays & Supports	Rings & Clips	Vertical Loads
	New	Corroded	New	Corroded					
36" Upper 2:1 Semi Elliptical head	0	0	0.3	0.3	0	0	0	0	0
36" OD 5/8" Shell	0	0	16.4	16.4	0	0	0	0	0
36" Lower 2:1 Semi-Elliptical head	0	0	0.4	0.4	0	0	0	0	0
Legs 3 X 3 X 3/8	0	0	0	0	0	0	0	0	0
TOTAL:	**0**	**0**	**17**	**17**	**0**	**0**	**0**	**0**	**0**

Vessel operating weight, Corroded: 1,540 lb
Vessel operating weight, New: 1,540 lb
Vessel empty weight, Corroded: 1,540 lb
Vessel empty weight, New: 1,540 lb
Vessel test weight, New: 4,238 lb

Vessel center of gravity location - from datum - lift condition

Vessel Lift Weight, New: 1,540 lb
Center of Gravity: 29.3161"

Vessel Capacity

Vessel Capacity** (New): 323 US gal
Vessel Capacity** (Corroded): 323 US gal
**The vessel capacity does not include volume of nozzle, piping or other attachments.

Shop test pressure determination for Chamber bounded by 36" Lower 2:1 Semi-Elliptical head and 36" Upper 2:1 Semi Elliptical head based on MAWP per UG-99(b)

Shop hydrostatic test gauge pressure is 487.5 psi at 70 °F (the chamber MAWP = 375 psi)

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

Identifier	Local test pressure psi	Test liquid static head psi	UG-99 stress ratio	UG-99 pressure factor	Stress during test psi	Allowable test stress psi	Stress excessive?
36" Upper 2:1 Semi Elliptical head (1)	488.926	1.426	1	1.30	15,401	34,200	No
Straight Flange on 36" Upper 2:1 Semi Elliptical head	488.926	1.426	1	1.30	17,356	34,200	No
36" OD 5/8" Shell	488.926	1.426	1	1.30	17,356	34,200	No
Straight Flange on 36" Lower 2:1 Semi-Elliptical head	488.926	1.426	1	1.30	17,356	34,200	No
36" Lower 2:1 Semi-Elliptical head	488.926	1.426	1	1.30	15,401	34,200	No
1 " with 1 " RFWN (N5)	487.644	0.144	1	1.30	19,707	47,250	No
2" w/ 2" 300# RFWN (N3)	489.269	1.769	1	1.30	22,826	47,250	No
3000# 1" HC (N6)	488.318	0.818	1	1.30	18,452	47,250	No
3000# 1/2" HC (N1)	487.644	0.144	1	1.30	19,557	47,250	No
N4 3000# 1" HC (N4)	488.107	0.607	1	1.30	18,444	47,250	No

Notes:
(1) 36" Upper 2:1 Semi Elliptical head limits the UG-99 stress ratio.
(2) P_L stresses at nozzle openings have been estimated using the method described in PVP-Vol. 399, pages 77-82.
(3) VIII-2, AD-151.1(b) used as the basis for nozzle allowable test stress.
(4) The zero degree angular position is assumed to be up, and the test liquid height is assumed to the top-most flange.

The field test condition has not been investigated for the Chamber bounded by 36" Lower 2:1 Semi-Elliptical head and 36" Upper 2:1 Semi Elliptical head.

The test temperature of 70 °F is warmer than the minimum recommended temperature of -10.1 °F so the brittle fracture provision of UG-99(h) has been met.

Vacuum Summary

Component	Line of Support	Elevation above Datum (in)	Length Le (in)
36" Upper 2:1 Semi Elliptical head	-	73.25	N/A
-	1/3 depth of 36" Upper 2:1 Semi Elliptical head	66.9167	N/A
Straight Flange on 36" Upper 2:1 Semi Elliptical head Top	-	64	71.8333
Straight Flange on 36" Upper 2:1 Semi Elliptical head Bottom	-	62	71.8333
36" OD 5/8" Shell Top	-	62	71.8333
36" OD 5/8" Shell Bottom	-	0	71.8333
Straight Flange on 36" Lower 2:1 Semi-Elliptical head Top	-	0	71.8333
Straight Flange on 36" Lower 2:1 Semi-Elliptical head Bottom	-	-2	71.8333
-	1/3 depth of 36" Lower 2:1 Semi-Elliptical head	-4.9167	N/A
36" Lower 2:1 Semi-Elliptical head	-	-11.25	N/A

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

36" Upper 2:1 Semi Elliptical head

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Component: Ellipsoidal Head
Material Specification: SA-516 70 (II-D p.18, ln. 22)
Material impact test exemption temperature from Fig UCS-66 Curve D = -55 °F
Fig UCS-66.1 MDMT reduction = 33.8 °F, (coincident ratio = 0.6618601)
Rated MDMT is governed by UCS-66(b)(2)
UCS-66 governing thickness = 0.5 in

Internal design pressure: P = 375 psi @ 200 °F
External design pressure: P_e = 15 psi @ 200 °F

Static liquid head:

P_s= 0 psi (SG=1, H_s=0" Operating head)
P_{th}= 1.4258 psi (SG=1, H_s=39.5" Horizontal test head)

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

Design MDMT = -20°F
Rated MDMT = -55°F

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

Radiography:	Category A joints -	Spot UW-11(b) Type 1
	Head to shell seam -	Spot UW-11(b) Type 1

Estimated weight*:	new = 238.1 lb	corr = 238.1 lb
Capacity*:	new = 32.6 US gal	corr = 32.6 US gal

* includes straight flange

Outer diameter	=	36"
Minimum head thickness	=	0.5"
Head ratio D/2h	=	2 (new)
Head ratio D/2h	=	2 (corroded)
Straight flange length L_{sf}	=	2"
Nominal straight flange thickness t_{sf}	=	0.5"

Results Summary

The governing condition is internal pressure.

Minimum thickness per UG-16	=	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	=	0.3894"
Design thickness due to external pressure (t_e)	=	0.0911"
Maximum allowable working pressure (MAWP)	=	484.33 psi
Maximum allowable pressure (MAP)	=	484.33 psi
Maximum allowable external pressure (MAEP)	=	237.32 psi

K (Corroded)

$K=(1/6)*[2 + (D / (2*h))^2]=(1/6)*[2 + (35 / (2*8.75))^2]=1$

K (New)

$K=(1/6)*[2 + (D / (2*h))^2]=(1/6)*[2 + (35 / (2*8.75))^2]=1$

Design thickness for internal pressure, (Corroded at 200 °F) Appendix 1-4(c)

t = $P*D_o*K / (2*S*E + 2*P*(K - 0.1)) + Corrosion$
= 375*36*1 / (2*20,000*0.85 + 2*375*(1 - 0.1)) + 0
= 0.3893"

The head internal pressure design thickness is 0.3894".

Maximum allowable working pressure, (Corroded at 200 °F) Appendix 1-4(c)

P = $2*S*E*t / (K*D_o - 2*t*(K - 0.1)) - P_s$
= 2*20,000*0.85*0.5 / (1*36 - 2*0.5*(1 - 0.1)) - 0
= 484.33 psi

The maximum allowable working pressure (MAWP) is 484.33 psi.

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

P = $2*S*E*t / (K*D_o - 2*t*(K - 0.1)) - P_s$
= 2*20,000*0.85*0.5 / (1*36 - 2*0.5*(1 - 0.1)) - 0
= 484.33 psi

The maximum allowable pressure (MAP) is 484.33 psi.

Design thickness for external pressure, (Corroded at 200 °F) UG-33(d)

Equivalent outside spherical radius (R_o)
R_o = K_o*D_o
= 0.8757 * 36
= 31.5243 in

A = $0.125 / (R_o/t)$
= 0.125 / (31.5243/0.09105)
= 0.000361

From Table CS-2: B=5,193.4541 psi

P_a = $B/(R_o/t)$
= 5,193.454/(31.5243/0.09105)
= 15 psi

t = 0.0911" + Corrosion = 0.0911" + 0" = 0.0911"
Check the external pressure per UG-33(a)(1) Appendix 1-4(c)

t = $1.67*P_e*D_o*K / (2*S*E + 2*1.67*P_e*(K - 0.1)) + Corrosion$
= 1.67*15*36*1 / (2*20,000*1 + 2*1.67*15*(1 - 0.1)) + 0
= 0.0225"

The head external pressure design thickness (t_e) is 0.0911".

Maximum Allowable External Pressure, (Corroded at 200 °F) UG-33(d)

Equivalent outside spherical radius (R_o)

R_o = $K_o * D_o$
= 0.8757 * 36
= 31.5243 in

A = 0.125 / (R_o/t)
= 0.125 / (31.5243/0.5)
= 0.001983

From Table CS-2: B=14,962.51 psi

P_a = B/(R_o/t)
= 14,962.51/(31.5243/0.5)
= 237.3169 psi

Check the Maximum External Pressure, UG-33(a)(1) Appendix 1-4(c)

P = 2*S*E*t / ((K*D_o - 2*t*(K - 0.1))*1.67) - P_{s2}
= 2*20,000*1*0.5 / ((1*36 - 2*0.5*(1 - 0.1))*1.67) - 0
= 341.2 psi

The maximum allowable external pressure (MAEP) is 237.32 psi.

% Extreme fiber elongation - UCS-79(d)

= (75*t / R_f)*(1 - R_f / R_o)
= (75*0.5 / 6.2)*(1 - 6.2 / ∞)
= 6.0484%

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

Straight Flange on 36" Upper 2:1 Semi Elliptical head

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Component: Straight Flange
Material specification: SA-516 70 (II-D p. 18, ln. 22)
Material impact test exemption temperature from Fig UCS-66 Curve D = -55 °F
Fig UCS-66.1 MDMT reduction = 33.1 °F, (coincident ratio = 0.6690962)
Rated MDMT is governed by UCS-66(b)(2)
UCS-66 governing thickness = 0.5 in

Internal design pressure: P = 375 psi @ 200 °F
External design pressure: P_e = 15 psi @ 200 °F

Static liquid head:

P_{th} = 1.43 psi (SG = 1, H_s = 39.5", Horizontal test head)

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

Design MDMT = -20 °F
Rated MDMT = -55 °F

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

Radiography: Longitudinal joint - Spot UW-11(b) Type 1
Circumferential joint - Spot UW-11(b) Type 1

Estimated weight	New = 31.6 lb	corr = 31.6 lb
Capacity	New = 8.33 US gal	corr = 8.33 US gal

OD = 36"
Length L_c = 2"
t = 0.5"

Design thickness, (at 200 °F) Appendix 1-1

$t = P*R_o / (S*E + 0.40*P) + Corrosion$
$= 375*18 / (20{,}000*0.85 + 0.40*375) + 0$
$= 0.3936"$

Maximum allowable working pressure, (at 200 °F) Appendix 1-1

$P = S*E*t / (R_o - 0.40*t) - P_s$
$= 20{,}000*0.85*0.5 / (18 - 0.40*0.5) - 0$
$= 477.53$ psi

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

$P = S*E*t / (R_o - 0.40*t)$
$= 20{,}000*0.85*0.5 / (18 - 0.40*0.5)$
$= 477.53$ psi

External Pressure, (Corroded & at 200 °F) UG-28(c)

$L / D_o = 71.8333 / 36 = 1.9954$
$D_o / t = 36 / 0.1537 = 234.1948$

From table G: A = 0.000184
From table CS-2: B = 2,635 psi

P_a = 4*B / (3*(D_o / t))
= 4*2634.7036 / (3*(36 / 0.1537))
= 15 psi

Design thickness for external pressure P_a = 15 psi

t_a = t + Corrosion = 0.1537 + 0 = 0.1537"

Maximum Allowable External Pressure, (Corroded & at 200 °F) UG-28(c)

L / D_o = 71.8333 / 36 = 1.9954

D_o / t = 36 / 0.5 = 72.0000

From table G: A = 0.001092
From table CS-2: B = 12,613 psi

P_a = 4*B / (3*(D_o / t))
= 4*12612.9219 / (3*(36 / 0.5))
= 233.57 psi

% Extreme fiber elongation - UCS-79(d)

EFE = (50 * t / R_f) * (1 - R_f / R_o)
= (50 * 0.5 / 17.75) * (1 - 17.75 / ∞)
= 1.4085 %

Design thickness = 0.3936"

The governing condition is due to internal pressure.

The cylinder thickness of 0.5" is adequate.

Thickness Required Due to Pressure + External Loads

Condition	Pressure P (psi)	Allowable Stress Before UG-23 Stress Increase (psi)		Temperature (°F)	Corrosion C (in)	Load	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
		S_t	S_c					
Operating, Hot & Corroded	375	20,000	16,502	200	0	Weight	0.192	0.192
Operating, Hot & New	375	20,000	16,502	200	0	Weight	0.192	0.192
Hot Shut Down, Corroded	0	20,000	16,502	200	0	Weight	0.0001	0.0001
Hot Shut Down, New	0	20,000	16,502	200	0	Weight	0.0001	0.0001
Empty, Corroded	0	20,000	16,502	0	0	Weight	0.0001	0.0001
Empty, New	0	20,000	16,502	0	0	Weight	0.0001	0.0001
Vacuum	-15	20,000	16,502	200	0	Weight	0.0081	0.0081
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0	20,000	16,502	200	0	Weight	0.0001	0.0001

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

A = 0.125 / (R_o / t)
= 0.125 / (18 / 0.5)
= 0.003472

B = 16,502 psi

S = 20,000 / 1.00 = 20,000 psi

S_{cHC} = min(B, S) = 16,502 psi

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

S_{cHN} = S_{cHC}
= 16502.1563 psi

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

A = 0.125 / (R_o / t)
= 0.125 / (18 / 0.5)
= 0.003472

B = 16,502 psi

S = 20,000 / 1.00 = 20,000 psi

S_{cCN} = min(B, S) = 16,502 psi

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

S_{cCC} = S_{cCN}
= 16502.1563 psi

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

A = 0.125 / (R_o / t)
= 0.125 / (18 / 0.5)
= 0.003472

B = 16,502 psi

S = 20,000 / 1.00 = 20,000 psi

S_{cVC} = min(B, S) = 16,502 psi

Operating, Hot & Corroded, Bottom Seam

t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|) (Pressure)
= 375*17.5 / (2*20,000*1.00*0.85 + 0.40*|375|)
= 0.1922"

t_m = M / (π*R_m^2*S_t*K_s*E_c) (bending)
= 2 / (π*17.75^2*20,000*1.00*0.85)
= 0"

t_w = W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 238.7 / (2*π*17.75*20,000*1.00*0.85)
= 0.0001"

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0.1922 + 0 - (0.0001)$
$= 0.192"$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0 + (0.0001) - (0.1922)|$
$= 0.192"$

Maximum allowable working pressure, Longitudinal Stress

$P = 2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w))$
$= 2*20,000*1.00*0.85*(0.5 - 0 + (0.0001)) / (17.5 - 0.40*(0.5 - 0 + (0.0001))$
$= 982.91$ psi

Operating, Hot & New, Bottom Seam

$t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
$= 375*17.5 / (2*20,000*1.00*0.85 + 0.40*|375|)$
$= 0.1922"$

$t_m = M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
$= 2 / (\pi*17.75^2*20,000*1.00*0.85)$
$= 0"$

$t_w = W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 238.7 / (2*\pi*17.75*20,000*1.00*0.85)$
$= 0.0001"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0.1922 + 0 - (0.0001)$
$= 0.192"$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0 + (0.0001) - (0.1922)|$
$= 0.192"$

Maximum allowable working pressure, Longitudinal Stress

$P = 2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w))$
$= 2*20,000*1.00*0.85*(0.5 - 0 + (0.0001)) / (17.5 - 0.40*(0.5 - 0 + (0.0001))$
$= 982.91$ psi

Hot Shut Down, Corroded, Bottom Seam

$t_p = 0"$ (Pressure)
$t_m = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 2 / (\pi*17.75^2*16,502.16*1.00)$
$= 0"$

$t_w = W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 238.7 / (2*\pi*17.75*16,502.16*1.00)$
$= 0.0001"$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)

= |0 + 0 - (0.0001)|
= 0.0001"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0 + (0.0001) - (0)
= 0.0001"

Hot Shut Down, New, Bottom Seam

t_p = 0" (Pressure)
t_m = $M / (\pi * R_m^2 * S_c * K_s)$ (bending)
= $2 / (\pi * 17.75^2 * 16{,}502.16 * 1.00)$
= 0"

t_w = $W / (2 * \pi * R_m * S_c * K_s)$ (Weight)
= $238.7 / (2 * \pi * 17.75 * 16{,}502.16 * 1.00)$
= 0.0001"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= |0 + 0 - (0.0001)|
= 0.0001"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0 + (0.0001) - (0)
= 0.0001"

Empty, Corroded, Bottom Seam

t_p = 0" (Pressure)
t_m = $M / (\pi * R_m^2 * S_c * K_s)$ (bending)
= $2 / (\pi * 17.75^2 * 16{,}502.16 * 1.00)$
= 0"

t_w = $W / (2 * \pi * R_m * S_c * K_s)$ (Weight)
= $238.7 / (2 * \pi * 17.75 * 16{,}502.16 * 1.00)$
= 0.0001"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= |0 + 0 - (0.0001)|
= 0.0001"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0 + (0.0001) - (0)
= 0.0001"

Empty, New, Bottom Seam

t_p = 0" (Pressure)
t_m = $M / (\pi * R_m^2 * S_c * K_s)$ (bending)
= $2 / (\pi * 17.75^2 * 16{,}502.16 * 1.00)$
= 0"

t_w = $W / (2 * \pi * R_m * S_c * K_s)$ (Weight)
= $238.7 / (2 * \pi * 17.75 * 16{,}502.16 * 1.00)$

= 0.0001"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= $|0 + 0 - (0.0001)|$
= 0.0001"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= $0 + (0.0001) - (0)$
= 0.0001"

Vacuum, Bottom Seam

t_p = $P*R / (2*S_c*K_s + 0.40*|P|)$ (Pressure)
= $-15*17.5 / (2*16{,}502.16*1.00 + 0.40*|15|)$
= -0.008"

t_m = $M / (\pi*R_m^2*S_c*K_s)$ (bending)
= $2 / (\pi*17.75^2*16{,}502.16*1.00)$
= 0"

t_w = $W / (2*\pi*R_m*S_c*K_s)$ (Weight)
= $238.7 / (2*\pi*17.75*16{,}502.16*1.00)$
= 0.0001"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= $|-0.008 + 0 - (0.0001)|$
= 0.0081"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= $0 + (0.0001) - (-0.008)$
= 0.0081"

Hot Shut Down, Corroded, Weight & Eccentric Moments Only, Bottom Seam

t_p = 0" (Pressure)
t_m = $M / (\pi*R_m^2*S_c*K_s)$ (bending)
= $2 / (\pi*17.75^2*16{,}502.16*1.00)$
= 0"

t_w = $W / (2*\pi*R_m*S_c*K_s)$ (Weight)
= $238.7 / (2*\pi*17.75*16{,}502.16*1.00)$
= 0.0001"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= $|0 + 0 - (0.0001)|$
= 0.0001"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= $0 + (0.0001) - (0)$
= 0.0001"

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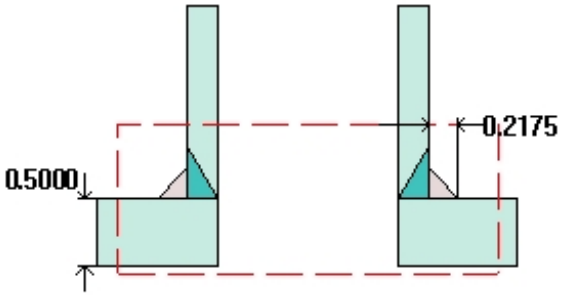
$t_{w(lower)}$ = 0 in
Leg_{41} = 0.2175 in



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

Located on:	36" Upper 2:1 Semi Elliptical head
Liquid static head included:	0 psi
Nozzle material specification:	SA-234 WPB (II-D p. 14, ln. 7)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	1" Class 3000 - threaded
Nozzle orientation:	45°
Calculated as hillside:	no
Local vessel minimum thickness:	0.5 in
End of nozzle to datum line:	73.02 in
Nozzle inside diameter, new:	1.315 in
Nozzle nominal wall thickness:	0.2175 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	1 in
Distance to head center, R:	8 in

Reinforcement Calculations for Internal Pressure

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 624.97 psi @ 200 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.0625	0.2175

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1523	0.1523	weld size is adequate

Calculations for internal pressure 624.97 psi @ 200 °F

Nozzle is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.06718).

Nozzle UCS-66 governing thk: 0.2175 in
Nozzle rated MDMT: -155 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall: $(R_n + t_n + t) = 1.375$ in
Normal to the vessel wall outside: $2.5*(t_n - C_n) + t_e = 0.5438$ in

Nozzle required thickness per UG-27(c)(1)

$t_{rn} = P*R_n/(S_n*E - 0.6*P)$
$= 624.9657*0.6575/(17,100*1 - 0.6*624.9657)$
$= 0.0246$ in

Required thickness t_r from UG-37(a)(c)

$t_r = P*K_1*D_o/(2*S*E + 0.8*P)$
$= 624.9657*0.9*36/(2*20,000*1 + 0.8*624.9657)$
$= 0.5$ in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.2175 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.1523 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.2175 = 0.1523 in

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (a).

ASME B16.11 Coupling Wall Thickness Check

Interpretation VIII-1-83-66 has been applied.

Wall thickness req'd per ASME B16.11 2.1.1:	t_{r1} = 0.0315 in (E =1)
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in

Available nozzle wall thickness new, t_n = 0.2175 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

The vessel wall thickness governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 624.97 psi @ 70 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.0625	0.2175

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1523	0.1523	weld size is adequate

Calculations for internal pressure 624.97 psi @ 70 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall:	$(R_n + t_n + t) = 1.375$ in
Normal to the vessel wall outside:	$2.5*(t_n - C_n) + t_e = 0.5438$ in

Nozzle required thickness per UG-27(c)(1)

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 624.9657*0.6575/(17,100*1 - 0.6*624.9657)
= 0.0246 in

Required thickness t_r from UG-37(a)(c)

t_r = $P*K_1*D_o/(2*S*E + 0.8*P)$
= 624.9657*0.9*36/(2*20,000*1 + 0.8*624.9657)
= 0.5 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.2175 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.1523 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.2175 = 0.1523 in

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (a).

ASME B16.11 Coupling Wall Thickness Check

Interpretation VIII-1-83-66 has been applied.

Wall thickness req'd per ASME B16.11 2.1.1:	t_{r1} = 0.0315 in (E =1)
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in

Available nozzle wall thickness new, t_n = 0.2175 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (in^2) For Pe = 233.57 psi @ 200 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1269	0.2175

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})	0.1523	0.1523	weld size is adequate

Calculations for external pressure 233.57 psi @ 200 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall: $(R_n + t_n + t)$ = 1.375 in
Normal to the vessel wall outside: $2.5*(t_n - C_n) + t_e$ = 0.5438 in

Nozzle required thickness per UG-28 t_{rn} = 0.0191 in

From UG-37(d)(1) required thickness t_r = 0.4939 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.2175 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.1523 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.2175 = 0.1523 in

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (a).

UG-45 Nozzle Neck Thickness Check

Interpretation VIII-1-83-66 has been applied.

Wall thickness per UG-45(a):	t_{r1} = 0.0191 in
Wall thickness per UG-45(b)(2):	t_{r2} = 0.208 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.1269 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 0.208 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.1269 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.1269 in

Available nozzle wall thickness new, t_n = 0.2175 in

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 200 °F) UG-28(c)

L / D_o = 1.0005 / 1.75 = 0.5717

D_o / t = 1.75 / 0.0191 = 91.6922

From table G: A = 0.002869

From table CS-2: B = 16,063 psi

P_a = 4*B / (3*(D_o / t))
= 4*16062.8770 / (3*(1.75 / 0.0191))
= 233.58 psi

Design thickness for external pressure P_a = 233.58 psi

t_a = t + Corrosion = 0.0191 + 0 = 0.0191"

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Component: Cylinder
Material specification: SA-516 70 (II-D p. 18, ln. 22)
Material impact test exemption temperature from Fig UCS-66 Curve B = -7 °F
Fig UCS-66.1 MDMT reduction = 33.1 °F, (coincident ratio = 0.6690962)
UCS-66 governing thickness = 0.5 in

Internal design pressure: P = 375 psi @ 200 °F
External design pressure: P_e = 15 psi @ 212 °F

Static liquid head:

P_{th} = 1.43 psi (SG = 1, H_s = 39.5", Horizontal test head)

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

Design MDMT = -20 °F
Rated MDMT = -40.1 °F

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

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

Estimated weight	New = 978.4 lb	corr = 978.4 lb
Capacity	New = 258.23 US gal	corr = 258.23 US gal

OD = 36"
Length L_c = 62"
t = 0.5"

Design thickness, (at 200 °F) Appendix 1-1

t = $P*R_o$ / (S*E + 0.40*P) + Corrosion
= 375*18 / (20,000*0.85 + 0.40*375) + 0
= 0.3936"

Maximum allowable working pressure, (at 200 °F) Appendix 1-1

P = $S*E*t / (R_o - 0.40*t) - P_s$
= 20,000*0.85*0.5 / (18 - 0.40*0.5) - 0
= 477.53 psi

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

P = $S*E*t / (R_o - 0.40*t)$
= 20,000*0.85*0.5 / (18 - 0.40*0.5)
= 477.53 psi

External Pressure, (Corroded & at 212 °F) UG-28(c)

L / D_o = 71.8333 / 36 = 1.9954
D_o / t = 36 / 0.1537 = 234.1948

From table G: A = 0.000184
From table CS-2: B = 2,635 psi

P_a = 4*B / (3*(D_o / t))
= 4*2634.7036 / (3*(36 / 0.1537))
= 15 psi

Design thickness for external pressure P_a = 15 psi

t_a = t + Corrosion = 0.1537 + 0 = 0.1537"

Maximum Allowable External Pressure, (Corroded & at 212 °F) UG-28(c)

L / D_o = 71.8333 / 36 = 1.9954

D_o / t = 36 / 0.5 = 72.0000

From table G: A = 0.001092
From table CS-2: B = 12,613 psi

P_a = 4*B / (3*(D_o / t))
= 4*12612.9219 / (3*(36 / 0.5))
= 233.57 psi

% Extreme fiber elongation - UCS-79(d)

EFE = (50 * t / R_f) * (1 - R_f / R_o)
= (50 * 0.5 / 17.75) * (1 - 17.75 / ∞)
= 1.4085 %

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

P_v = W / (2*π*R_m) + M / (π*R_m^2)
= 1,217.8 / (2*π*17.75) + 219 / (π*17.75^2)
= 11.1399 lb/in

α = P_v / (P_e*D_o)
= 11.1399 / (15*36)
= 0.0206

n = 3

m = 1.23 / (L / D_o)^2
= 1.23 / (71.8333 / 36)^2
= 0.3089

Ratio P_e = (n^2 - 1 + m + m*α) / (n^2 - 1 + m)
= (3^2 - 1 + 0.3089 + 0.3089*0.0206) / (3^2 - 1 + 0.3089)
= 1.0008

Ratio P_e * P_e ≤ MAEP design cylinder thickness is satisfactory.

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

P_v = $W / (2*\pi*R_m) + M / (\pi*R_m^2)$
= $1{,}217.8 / (2*\pi*17.75) + 0 / (\pi*17.75^2)$
= 10.9190 lb/in

α = $P_v / (P_e*D_o)$
= $10.9190 / (15*36)$
= 0.0202

n = 3

m = $1.23 / (L / D_o)^2$
= $1.23 / (71.8333 / 36)^2$
= 0.3089

Ratio P_e = $(n^2 - 1 + m + m*\alpha) / (n^2 - 1 + m)$
= $(3^2 - 1 + 0.3089 + 0.3089*0.0202) / (3^2 - 1 + 0.3089)$
= 1.0008

Ratio P_e * P_e ≤ MAEP design cylinder thickness is satisfactory.

Design thickness = 0.3936"

The governing condition is due to internal pressure.

The cylinder thickness of 0.5" is adequate.

Thickness Required Due to Pressure + External Loads

Condition	Pressure P (psi)	Allowable Stress Before UG-23 Stress Increase (psi)		Temperature (°F)	Corrosion C (in)	Location	Load	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
		S_t	S_c						
Operating, Hot & Corroded	375	20,000	16,502	200	0	Top	Weight	0.1629	0.1629
						Bottom	Weight	0.1629	0.1629
Operating, Hot & New	375	20,000	16,502	200	0	Top	Weight	0.1629	0.1629
						Bottom	Weight	0.1629	0.1629
Hot Shut Down, Corroded	0	20,000	16,502	200	0	Top	Weight	0.0006	0.0007
						Bottom	Weight	0.0007	0.0007
Hot Shut Down, New	0	20,000	16,502	200	0	Top	Weight	0.0006	0.0007
						Bottom	Weight	0.0007	0.0007
Empty, Corroded	0	20,000	16,502	0	0	Top	Weight	0.0006	0.0007
						Bottom	Weight	0.0007	0.0007
Empty, New	0	20,000	16,502	0	0	Top	Weight	0.0006	0.0007
						Bottom	Weight	0.0007	0.0007
Vacuum	-15	20,000	16,502	212	0	Top	Weight	0.0086	0.0086
						Bottom	Weight	0.0086	0.0086
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0	20,000	16,502	200	0	Top	Weight	0.0006	0.0007
						Bottom	Weight	0.0007	0.0007

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

A = 0.125 / (R_o / t)
= 0.125 / (18 / 0.5)
= 0.003472

B = 16,502 psi

S = 20,000 / 1.00 = 20,000 psi

S_{cHC} = min(B, S) = 16,502 psi

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

S_{cHN} = S_{cHC}
= 16502.1563 psi

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

A = 0.125 / (R_o / t)
= 0.125 / (18 / 0.5)
= 0.003472

B = 16,502 psi

S = 20,000 / 1.00 = 20,000 psi

S_{cCN} = min(B, S) = 16,502 psi

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

S_{cCC} = S_{cCN}
= 16502.1563 psi

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

A = 0.125 / (R_o / t)
= 0.125 / (18 / 0.5)
= 0.003472

B = 16,502 psi

S = 20,000 / 1.00 = 20,000 psi

S_{cVC} = min(B, S) = 16,502 psi

Operating, Hot & Corroded, Above Support Point

t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|) (Pressure)
= 375*17.5 / (2*20,000*1.00*1.00 + 0.40*|375|)
= 0.1634"

t_m = M / (π*R_m^2*S_t*K_s*E_c) (bending)
= 219 / (π*17.75²*20,000*1.00*1.00)
= 0"

t_w = W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 1,217.8 / (2*π*17.75*20,000*1.00*1.00)
= 0.0005"

t_t = t_p + t_m - t_w (total required, tensile)

$= 0.1634 + 0 - (0.0005)$

$= 0.1629"$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)

$= |0 + (0.0005) - (0.1634)|$

$= 0.1629"$

Maximum allowable working pressure, Longitudinal Stress

$P = 2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w))$

$= 2*20,000*1.00*1.00*(0.5 - 0 + (0.0005)) / (17.5 - 0.40*(0.5 - 0 + (0.0005))$

$= 1,157.32$ psi

Operating, Hot & New, Above Support Point

$t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)

$= 375*17.5 / (2*20,000*1.00*1.00 + 0.40*|375|)$

$= 0.1634"$

$t_m = M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)

$= 219 / (\pi*17.75^2*20,000*1.00*1.00)$

$= 0"$

$t_w = W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)

$= 1,217.8 / (2*\pi*17.75*20,000*1.00*1.00)$

$= 0.0005"$

$t_t = t_p + t_m - t_w$ (total required, tensile)

$= 0.1634 + 0 - (0.0005)$

$= 0.1629"$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)

$= |0 + (0.0005) - (0.1634)|$

$= 0.1629"$

Maximum allowable working pressure, Longitudinal Stress

$P = 2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w))$

$= 2*20,000*1.00*1.00*(0.5 - 0 + (0.0005)) / (17.5 - 0.40*(0.5 - 0 + (0.0005))$

$= 1,157.32$ psi

Hot Shut Down, Corroded, Above Support Point

$t_p = 0"$ (Pressure)

$t_m = M / (\pi*R_m^2*S_c*K_s)$ (bending)

$= 219 / (\pi*17.75^2*16,502.16*1.00)$

$= 0"$

$t_w = W / (2*\pi*R_m*S_c*K_s)$ (Weight)

$= 1,217.8 / (2*\pi*17.75*16,502.16*1.00)$

$= 0.0007"$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)

$= |0 + 0 - (0.0007)|$

= 0.0006"

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0 + (0.0007) - (0)
= 0.0007"

Hot Shut Down, New, Above Support Point

t_p = 0" (Pressure)
$t_m = M / (\pi * R_m^2 * S_c * K_s)$ (bending)
= 219 / (π*17.75²*16,502.16*1.00)
= 0"

$t_w = W / (2 * \pi * R_m * S_c * K_s)$ (Weight)
= 1,217.8 / (2*π*17.75*16,502.16*1.00)
= 0.0007"

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
= |0 + 0 - (0.0007)|
= 0.0006"

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0 + (0.0007) - (0)
= 0.0007"

Empty, Corroded, Above Support Point

t_p = 0" (Pressure)
$t_m = M / (\pi * R_m^2 * S_c * K_s)$ (bending)
= 219 / (π*17.75²*16,502.16*1.00)
= 0"

$t_w = W / (2 * \pi * R_m * S_c * K_s)$ (Weight)
= 1,217.8 / (2*π*17.75*16,502.16*1.00)
= 0.0007"

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
= |0 + 0 - (0.0007)|
= 0.0006"

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0 + (0.0007) - (0)
= 0.0007"

Empty, New, Above Support Point

t_p = 0" (Pressure)
$t_m = M / (\pi * R_m^2 * S_c * K_s)$ (bending)
= 219 / (π*17.75²*16,502.16*1.00)
= 0"

$t_w = W / (2 * \pi * R_m * S_c * K_s)$ (Weight)
= 1,217.8 / (2*π*17.75*16,502.16*1.00)
= 0.0007"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= $|0 + 0 - (0.0007)|$
= 0.0006"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= $0 + (0.0007) - (0)$
= 0.0007"

Vacuum, Above Support Point

t_p = $P*R / (2*S_c*K_s + 0.40*|P|)$ (Pressure)
= $-15*17.5 / (2*16,502.16*1.00 + 0.40*|15|)$
= -0.008"

t_m = $M / (\pi*R_m^2*S_c*K_s)$ (bending)
= $219 / (\pi*17.75^2*16,502.16*1.00)$
= 0"

t_w = $W / (2*\pi*R_m*S_c*K_s)$ (Weight)
= $1,217.8 / (2*\pi*17.75*16,502.16*1.00)$
= 0.0007"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= $|-0.008 + 0 - (0.0007)|$
= 0.0086"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= $0 + (0.0007) - (-0.008)$
= 0.0086"

Hot Shut Down, Corroded, Weight & Eccentric Moments Only, Above Support Point

t_p = 0" (Pressure)
t_m = $M / (\pi*R_m^2*S_c*K_s)$ (bending)
= $219 / (\pi*17.75^2*16,502.16*1.00)$
= 0"

t_w = $W / (2*\pi*R_m*S_c*K_s)$ (Weight)
= $1,217.8 / (2*\pi*17.75*16,502.16*1.00)$
= 0.0007"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= $|0 + 0 - (0.0007)|$
= 0.0006"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= $0 + (0.0007) - (0)$
= 0.0007"

Operating, Hot & Corroded, Below Support Point

t_p = $P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
= $375*17.5 / (2*20,000*1.00*1.00 + 0.40*|375|)$
= 0.1634"

t_m = M / (π*R_m^2*S_t*K_s*E_c) (bending)
= 0 / (π*17.75^2*20,000*1.00*1.00)
= 0"

t_w = W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 1,217.8 / (2*π*17.75*20,000*1.00*1.00)
= 0.0005"

t_t = t_p + t_m - t_w (total required, tensile)
= 0.1634 + 0 - (0.0005)
= 0.1629"

t_c = |t_{mc} + t_{wc} - t_{pc}| (total, net tensile)
= |0 + (0.0005) - (0.1634)|
= 0.1629"

Maximum allowable working pressure, Longitudinal Stress

P = 2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w))
= 2*20,000*1.00*1.00*(0.5 - 0 + (0.0005)) / (17.5 - 0.40*(0.5 - 0 + (0.0005))
= 1,157.35 psi

Operating, Hot & New, Below Support Point

t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|) (Pressure)
= 375*17.5 / (2*20,000*1.00*1.00 + 0.40*|375|)
= 0.1634"

t_m = M / (π*R_m^2*S_t*K_s*E_c) (bending)
= 0 / (π*17.75^2*20,000*1.00*1.00)
= 0"

t_w = W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 1,217.8 / (2*π*17.75*20,000*1.00*1.00)
= 0.0005"

t_t = t_p + t_m - t_w (total required, tensile)
= 0.1634 + 0 - (0.0005)
= 0.1629"

t_c = |t_{mc} + t_{wc} - t_{pc}| (total, net tensile)
= |0 + (0.0005) - (0.1634)|
= 0.1629"

Maximum allowable working pressure, Longitudinal Stress

P = 2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w))
= 2*20,000*1.00*1.00*(0.5 - 0 + (0.0005)) / (17.5 - 0.40*(0.5 - 0 + (0.0005))
= 1,157.35 psi

Hot Shut Down, Corroded, Below Support Point

t_p = 0" (Pressure)

t_m = M / (π*R_m^2*S_c*K_s) (bending)
= 0 / (π*17.75^2*16,502.16*1.00)
= 0"

t_w = W / (2*π*R_m*S_c*K_s) (Weight)
= 1,217.8 / (2*π*17.75*16,502.16*1.00)
= 0.0007"

t_t = |t_p + t_m - t_w| (total, net compressive)
= |0 + 0 - (0.0007)|
= 0.0007"

t_c = t_{mc} + t_{wc} - t_{pc} (total required, compressive)
= 0 + (0.0007) - (0)
= 0.0007"

Hot Shut Down, New, Below Support Point

t_p = 0" (Pressure)

t_m = M / (π*R_m^2*S_c*K_s) (bending)
= 0 / (π*17.75^2*16,502.16*1.00)
= 0"

t_w = W / (2*π*R_m*S_c*K_s) (Weight)
= 1,217.8 / (2*π*17.75*16,502.16*1.00)
= 0.0007"

t_t = |t_p + t_m - t_w| (total, net compressive)
= |0 + 0 - (0.0007)|
= 0.0007"

t_c = t_{mc} + t_{wc} - t_{pc} (total required, compressive)
= 0 + (0.0007) - (0)
= 0.0007"

Empty, Corroded, Below Support Point

t_p = 0" (Pressure)

t_m = M / (π*R_m^2*S_c*K_s) (bending)
= 0 / (π*17.75^2*16,502.16*1.00)
= 0"

t_w = W / (2*π*R_m*S_c*K_s) (Weight)
= 1,217.8 / (2*π*17.75*16,502.16*1.00)
= 0.0007"

t_t = |t_p + t_m - t_w| (total, net compressive)
= |0 + 0 - (0.0007)|
= 0.0007"

t_c = t_{mc} + t_{wc} - t_{pc} (total required, compressive)
= 0 + (0.0007) - (0)
= 0.0007"

Empty, New, Below Support Point

t_p = 0" (Pressure)

t_m = $M / (\pi * R_m^2 * S_c * K_s)$ (bending)
= $0 / (\pi * 17.75^2 * 16{,}502.16 * 1.00)$
= 0"

t_w = $W / (2 * \pi * R_m * S_c * K_s)$ (Weight)
= $1{,}217.8 / (2 * \pi * 17.75 * 16{,}502.16 * 1.00)$
= 0.0007"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= $|0 + 0 - (0.0007)|$
= 0.0007"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= $0 + (0.0007) - (0)$
= 0.0007"

Vacuum, Below Support Point

t_p = $P * R / (2 * S_c * K_s + 0.40 * |P|)$ (Pressure)
= $-15 * 17.5 / (2 * 16{,}502.16 * 1.00 + 0.40 * |15|)$
= -0.008"

t_m = $M / (\pi * R_m^2 * S_c * K_s)$ (bending)
= $0 / (\pi * 17.75^2 * 16{,}502.16 * 1.00)$
= 0"

t_w = $W / (2 * \pi * R_m * S_c * K_s)$ (Weight)
= $1{,}217.8 / (2 * \pi * 17.75 * 16{,}502.16 * 1.00)$
= 0.0007"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= $|-0.008 + 0 - (0.0007)|$
= 0.0086"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= $0 + (0.0007) - (-0.008)$
= 0.0086"

Hot Shut Down, Corroded, Weight & Eccentric Moments Only, Below Support Point

t_p = 0" (Pressure)

t_m = $M / (\pi * R_m^2 * S_c * K_s)$ (bending)
= $0 / (\pi * 17.75^2 * 16{,}502.16 * 1.00)$
= 0"

t_w = $W / (2 * \pi * R_m * S_c * K_s)$ (Weight)
= $1{,}217.8 / (2 * \pi * 17.75 * 16{,}502.16 * 1.00)$
= 0.0007"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= $|0 + 0 - (0.0007)|$

$= 0.0007"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)

$= 0 + (0.0007) - (0)$

$= 0.0007"$

Legs 3 X 3 X 3/8

Leg material:			38W
Leg description:			3x3x1/4 Equal Angle (Leg in)
Number of legs:	N =	3	
Overall length:		36	in
Base to girth seam length:		28.8	in
Bolt circle:		44	in
Anchor bolt size:		0.375	inch coarse threaded
Anchor bolt material:			SA-193-B7
Anchor bolts/leg:		2	
Anchor bolt allowable stress:	S_b =	20,000	psi
Anchor bolt corrosion allowance:		0	in
Anchor bolt hole clearance:		0.375	in
Base plate width:		8	in
Base plate length:		10	in
Base plate thickness:		0.375	in (0.1041 in required)
Base plate allowable stress:		24,000	psi
Foundation allowable bearing stress:		1,658	psi
Effective length coefficient:	K =	1.2	
Coefficient:	C_m =	0.85	
Leg yield stress:	F_y =	38,000	psi
Leg elastic modulus:	E =	29,000,000	psi
Leg to shell fillet weld:		0.25	in (0.003 in required)
Legs braced:		No	

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

Loading	Force attack angle °	Leg position °	Axial end load lb_f	Shear resisted lb_f	Axial f_a psi	Bending f_{bx} psi	Bending f_{by} psi	Ratio H_{1-1}	Ratio H_{1-2}
Governing Condition		0	505.3	0.0	351	875	0	0.0494	0.0503
		120	521.5	0.0	362	903	0	0.0510	0.0519
Weight operating corroded **Moment = 18.2 lb-ft**	**0**	240	521.5	0.0	362	903	0	0.0510	0.0519

Loading	Force attack angle °	Leg position °	Axial end load lb_f	Shear resisted lb_f	Axial f_a psi	Bending f_{bx} psi	Bending f_{by} psi	Ratio H_{1-1}	Ratio H_{1-2}
Weight empty corroded		0	505.3	0.0	351	875	0	0.0494	0.0503
		120	521.5	0.0	362	903	0	0.0510	0.0519
Moment = 18.2 lb-ft	**0**	240	521.5	0.0	362	903	0	0.0510	0.0519

Loading	Force attack angle °	Leg position °	Axial end load lb_f	Shear resisted lb_f	Axial f_a psi	Bending f_{bx} psi	Bending f_{by} psi	Ratio H_{1-1}	Ratio H_{1-2}
Weight vacuum corroded		0	505.3	0.0	351	875	0	0.0494	0.0503
		120	521.5	0.0	362	903	0	0.0510	0.0519
Moment = 18.2 lb-ft	**0**	240	521.5	0.0	362	903	0	0.0510	0.0519

Leg Calculations (AISC manual ninth edition)

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

$P_1 = W/N + 48*M_t/(N*D)$
$= 1{,}540.24/ 3 + 48*18.2/(3*36)$
$= 521.51\ lb_f$

Allowable axial compressive stress, F_a (AISC chapter E)

Local buckling check (AISC 5-99)

$b/t = (3/0.25) < (76 / Sqr(38))$ so $Q_s = 1$

Flexural-torsional buckling (AISC 5-317)

Shear center distance $w_o = 1.014$
$r_o^2 = w_o^2 + (I_z + I_w)/A$
$= 1.014^2 + (0.5 + 1.98)/1.44$
$= 2.75\ in^2$

Torsional constant $J = 0.03\ in^4$
Shear modulus $G = 11{,}165$ ksi

$F_{ej} = G*J / (A*r_o^2)$
$= 11{,}165{,}000*0.03 / (1.44*2.7504)$
$= 85$ ksi

$K*l/r_w = 1.2*26.8/1.1725 = 27.4276$

$F_{ew} = \pi^2*E/(Kl/r_w)^2$
$= \pi^2*29{,}000/(27.4276)^2$
$= 380$ ksi

$H = 1 - (w_o^2 / r_o^2)$
$= 1 - (1.014^2 / 2.7504)$
$= 0.6261672$

$F_e = ((F_{ew} + F_{ej})/(2*H))*(1 - Sqr(1 - (4*F_{ew}*F_{ej}*H)/(F_{ew} + F_{ej})^2))$
$= ((380 + 85)/(2*0.6262))*(1 - Sqr(1 - (4*380*85*0.6262)/(380 + 85)^2))$
$= 77$ ksi

Equivalent slenderness ratio

$Kl/r = \pi*Sqr(E/F_e)$
$= \pi*Sqr(29{,}000/77)$
$= 60.8809$

$C_c = Sqr(2*\pi^2*E/(F_y*Q_s))$
$= Sqr(2*\pi^2*29{,}000{,}000/(38{,}000*1))$
$= 122.736$

$K*l/r = 1.2*26.8/0.5894 = 54.5683$

$F_a = 1 * (1 - (Kl/r)^2/(2*C_c^2))*F_y / (5/3 + 3*(Kl/r)/(8*C_c)-(Kl/r)^3/(8*C_c^3))$
$= 1 * (1 - (60.8809)^2/(2*122.736^2))*38{,}000 / (5/3 + 3*(60.8809)/(8*122.736)-(60.8809)^3/(8*122.736^3))$
$= 18{,}137$ psi

Allowable axial compression and bending (AISC chapter H)

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

$F'_{ex} = 1*12*\pi^2*E/(23*(Kl/r)^2)$
$= 1*12*\pi^2*29{,}000{,}000/(23*(73.6671)^2)$
= 27,517 psi

$F'_{ey} = 1*12*\pi^2*E/(23*(Kl/r)^2)$
$= 1*12*\pi^2*29{,}000{,}000/(23*(37.0273)^2)$
= 108,920 psi

$F_b = 1*0.66*F_y$
$= 1*0.66*38{,}000$
= 25,080 psi

Compressive axial stress

$f_a = P_1/A$
$= 521.51/1.44$
= 362 psi

Bending stresses

$f_{bx} = F*\cos(\alpha)*L/(I_x/C_x) + P_1*E_{cc}/(I_x/C_x)$
$= 0*\text{abs}(\cos(120))*26.8/(0.5002/0.9305) + 521.51*0.9305/(0.5002/0.9305)$
= 903 psi

$f_{by} = F*\sin(\alpha)*L/(I_y/C_y)$
$= 0*\sin(120)*26.8/(1.98/2.12)$
= 0 psi

AISC equation $H_{1\text{-}1}$

$H_{1\text{-}1} = f_a/F_a + C_{mx}*f_{bx}/((1 - f_a/F'_{ex})*F_{bx}) + C_{my}*f_{by}/((1 - f_a/F'_{ey})*F_{by})$
$= 362/18{,}137 + 0.85*903/((1 - 362/27{,}517)*25{,}080) + 0.85*0/((1 - 362/108{,}920)*25{,}080)$
= 0.051

AISC equation $H_{1\text{-}2}$

$H_{1\text{-}2} = f_a/(0.6*1*F_y) + f_{bx}/F_{bx} + f_{by}/F_{by}$
$= 362/(0.6*1*38{,}000) + 903/25{,}080 + 0/25{,}080$
= 0.0519

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

Anchor bolts - Weight operating corroded condition governs

Tensile loading per leg (2 bolts per leg)

$R = 48*M/(N*BC) - W/N$
$= 48*18.2/(3*44) - 1{,}540.24/3$
$= -506.78\ lb_f$
There is no net uplift (R is negative).

0.375 inch coarse threaded bolts are satisfactory.

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

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

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

$Z_w = (2*b*d + d^2)/3$
$= (2*4.2426*9.2 + 9.2^2)/3$
$= 54.2346\ in^2$

$J_w = (b + 2*d)^3/12 - d^2*(b + d)^2/(b + 2*d)$
$= (4.2426 + 2*9.2)^3/12 - 9.2^2*(4.2426 + 9.2)^2/(4.2426 + 2*9.2)$
$= 291.8959\ in^3$

$E = d^2/(b + 2*d)$
$= 9.2^2/(4.2426 + 2*9.2)$
$= 3.738087\ in$

Governing weld load $f_x = Cos(120)*0 = 0\ lb_f$
Governing weld load $f_y = Sin(120)*0 = 0\ lb_f$

$f_1 = P_1/L_{weld}$
$= 521.51/22.6426$
$= 23.03\ lb_f/in$ (V_L direct shear)

$f_2 = f_y*L_{leg}*0.5*b/J_w$
$= 0*26.8*0.5*4.2426/291.8959$
$= 0\ lb_f/in$ (V_L torsion shear)

$f_3 = f_y/L_{weld}$
$= 0/22.6426$
$= 0\ lb_f/in$ (V_c direct shear)

$f_4 = f_y*L_{leg}*E/J_w$
$= 0*26.8*3.7381/291.8959$
$= 0\ lb_f/in$ (V_c torsion shear)

$f_5 = f_x*L_{leg}/Z_w$
$= 0*26.8/54.2346$
$= 0\ lb_f/in$ (M_L bending)

$f_6 = f_x/L_{weld}$
$= 0/22.6426$
$= 0\ lb_f/in$ (Direct outward radial shear)

$f = Sqr((f_1 + f_2)^2 + (f_3 + f_4)^2 + (f_5 + f_6)^2)$
$= Sqr((23.03 + 0)^2 + (0 + 0)^2 + (0 + 0)^2)$
$= 23.03\ lb_f/in$ (Resultant shear load)

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

$t_w = f / (0.707*0.55*S_a)$
$= 23.03 / (0.707*0.55*20{,}000)$
$= 0.003$ in

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

Base plate thickness check, AISC 3-106

$f_p = P/(B*N)$
$= 520.04/(8*10)$
$= 7$ psi

Required base plate thickness is the largest of the following: (0.1041 in)

$t_b = Sqr(0.5*P/S_b)$
$= Sqr(0.5*520.04/24,000)$
$= 0.1041$ in

$t_b = 0.5*(N - d)*Sqr(3*f_p/S_b)$
$= 0.5*(10 - 3)*Sqr(3*7/24,000)$
$= 0.0998$ in

The base plate thickness is adequate.

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

Applied Loads

Radial load:	$P_r =$	0	lb_f
Circumferential moment:	$M_c =$	0	lb_f-in
Circumferential shear:	$V_c =$	0	lb_f
Longitudinal moment:	$M_L =$	485.27	lb_f-in
Longitudinal shear:	$V_L =$	521.51	lb_f
Torsion moment:	$M_t =$	0	lb_f-in
Internal pressure:	$P =$	375	psi
Mean shell radius:	$R_m =$	17.75	in
Local shell thickness:	$t =$	0.5	in
Shell yield stress:	$S_y =$	34,800	psi

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

R_m/t =35.5

C_1 = 2.1213, C_2 = 7.302 in

Local circumferential pressure stress = $P*R_i/t$ =13,125 psi

Local longitudinal pressure stress = $P*R_i/2t$ =6,562 psi

Maximum combined stress (P_L+P_b+Q) = 13,209 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) = 13,149 psi
Allowable local primary membrane (P_L) = +-1.5*S = +-30,000 psi

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

Stresses at the leg edge per WRC Bulletin 107										
Figure	**value**	β	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	1.8964	0.3224	0	0	0	0	0	0	0	0
4C*	4.3707	0.2637	0	0	0	0	0	0	0	0
1C	0.0741	0.1966	0	0	0	0	0	0	0	0
2C-1	0.0415	0.1966	0	0	0	0	0	0	0	0
3A*	1.4209	0.1805	0	0	0	0	0	0	0	0
1A	0.0768	0.2236	0	0	0	0	0	0	0	0
3B*	3.0429	0.2725	-24	-24	24	24	0	0	0	0
1B-1	0.0223	0.2428	-60	60	60	-60	0	0	0	0
Pressure stress*			13,125	13,125	13,125	13,125	13,125	13,125	13,125	13,125
Total circumferential stress			13,041	13,161	13,209	13,089	13,125	13,125	13,125	13,125
Primary membrane circumferential stress*			13,101	13,101	13,149	13,149	13,125	13,125	13,125	13,125
3C*	2.4326	0.2637	0	0	0	0	0	0	0	0
4C*	3.7984	0.3224	0	0	0	0	0	0	0	0
1C-1	0.0512	0.2742	0	0	0	0	0	0	0	0
2C	0.031	0.2742	0	0	0	0	0	0	0	0
4A*	2.5231	0.1805	0	0	0	0	0	0	0	0
2A	0.0317	0.2977	0	0	0	0	0	0	0	0
4B*	1.4139	0.2725	-19	-19	19	19	0	0	0	0
2B-1	0.0295	0.3221	-60	60	60	-60	0	0	0	0
Pressure stress*			6,562	6,562	6,562	6,562	6,562	6,562	6,562	6,562
Total longitudinal stress			6,483	6,603	6,641	6,521	6,562	6,562	6,562	6,562
Primary membrane longitudinal stress*			6,543	6,543	6,581	6,581	6,562	6,562	6,562	6,562
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	-36	-36	36	36
Total Shear stress	0	0	0	0	-36	-36	36	36
Combined stress (P_L+P_b+Q)	13,041	13,161	13,209	13,089	13,125	13,125	13,125	13,125

Note: * denotes primary stress.

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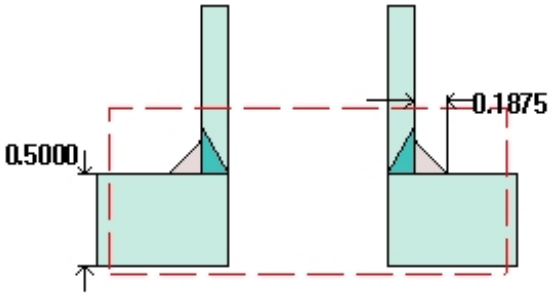
$t_{w(lower)}$ = 0 in
Leg_{41} = 0.1875 in



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

Located on:	36" OD 5/8" Shell
Liquid static head included:	0 psi
Nozzle material specification:	SA-234 WPB (II-D p. 14, ln. 7)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	0.500" Class 3000 - threaded
Nozzle orientation:	0°
Local vessel minimum thickness:	0.5 in
Nozzle center line offset to datum line:	37 in
End of nozzle to shell center:	20 in
Nozzle inside diameter, new:	0.84 in
Nozzle nominal wall thickness:	0.1425 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	2 in

Reinforcement Calculations for Internal Pressure

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 561.74 psi @ 200 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.0625	0.1425

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.0997	0.1312	weld size is adequate

Calculations for internal pressure 561.74 psi @ 200 °F

Nozzle is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.0655).

Nozzle UCS-66 governing thk: 0.1425 in
Nozzle rated MDMT: -155 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall: $(R_n + t_n + t) = 1.0625$ in
Normal to the vessel wall outside: $2.5*(t_n - C_n) + t_e = 0.3563$ in

Nozzle required thickness per UG-27(c)(1)

$t_{rn} = P*R_n/(S_n*E - 0.6*P)$
$= 561.7399*0.42/(17,100*1 - 0.6*561.7399)$
$= 0.0141$ in

Required thickness t_r from UG-37(a)

$t_r = P*R_o/(S*E + 0.4*P)$
$= 561.7399*18/(20,000*1 + 0.4*561.7399)$
$= 0.4999$ in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.1425 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.0997 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.1875 = 0.1313 in

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (a).

ASME B16.11 Coupling Wall Thickness Check

Wall thickness req'd per ASME B16.11 2.1.1:	t_{r1} = 0.0182 in (E =1)
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in

Available nozzle wall thickness new, t_n = 0.1425 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

The vessel wall thickness governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 561.74 psi @ 70 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.0625	0.1425

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.0997	0.1312	weld size is adequate

Calculations for internal pressure 561.74 psi @ 70 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall:	$(R_n + t_n + t)$ = 1.0625 in
Normal to the vessel wall outside:	$2.5*(t_n - C_n) + t_e$ = 0.3563 in

Nozzle required thickness per UG-27(c)(1)

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 561.7399*0.42/(17,100*1 - 0.6*561.7399)
= 0.0141 in

Required thickness t_r from UG-37(a)

t_r = $P*R_o/(S*E + 0.4*P)$
= 561.7399*18/(20,000*1 + 0.4*561.7399)
= 0.4999 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.1425 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.0997 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.1875 = 0.1313 in

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (a).

ASME B16.11 Coupling Wall Thickness Check

Wall thickness req'd per ASME B16.11 2.1.1:	t_{r1} = 0.0182 in (E =1)
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in

Available nozzle wall thickness new, t_n = 0.1425 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (in^2) For Pe = 233.57 psi @ 212 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1164	0.1425

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})	0.0997	0.1312	weld size is adequate

Calculations for external pressure 233.57 psi @ 212 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall: $(R_n + t_n + t)$ = 1.0625 in
Normal to the vessel wall outside: $2.5*(t_n - C_n) + t_e$ = 0.3563 in

Nozzle required thickness per UG-28 t_{rn} = 0.0153 in

From UG-37(d)(1) required thickness t_r = 0.5 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.1425 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.0997 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.1875 = 0.1313 in

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (a).

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	t_{r1} = 0.0153 in
Wall thickness per UG-45(b)(2):	t_{r2} = 0.2092 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.1164 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 0.2092 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.1164 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.1164 in

Available nozzle wall thickness new, t_n = 0.1425 in

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 212 °F) UG-28(c)

L / D_o = 2.0088 / 1.125 = 1.7856

D_o / t = 1.125 / 0.0153 = 73.6862

From table G: A = 0.001184

From table CS-2: B = 12,909 psi

P_a = 4*B / (3*(D_o / t))
= 4*12908.5664 / (3*(1.125 / 0.0153))
= 233.58 psi

Design thickness for external pressure P_a = 233.58 psi

t_a = t + Corrosion = 0.0153 + 0 = 0.0153"

2" w/ 2" 300# RFWN (N3)

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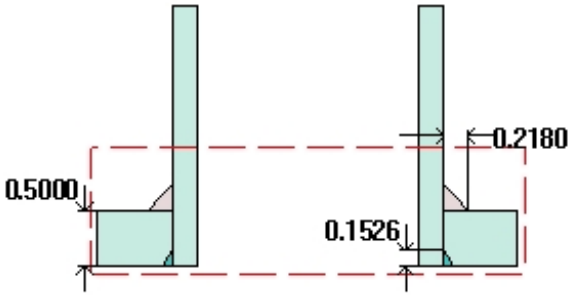

$t_{w(lower)}$ = 0.1526 in
Leg_{41} = 0.218 in

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

Located on:	36" OD 5/8" Shell
Liquid static head included:	0 psi
Nozzle material specification:	SA-106 B Smls pipe (II-D p. 14, ln. 5)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	2" Sch 80 (XS)
Flange description:	2 inch Class 300 WN A105
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 348, ln. 33)
Flange rated MDMT: (UCS-66(b)(1)(b))	-55°F
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	680 psi @ 200°F
ASME B16.5 flange rating MAP:	740 psi @ 70°F
ASME B16.5 flange hydro test:	1125 psi @ 70°F
Nozzle orientation:	180°
Local vessel minimum thickness:	0.5 in
Nozzle center line offset to datum line:	48 in
End of nozzle to shell center:	27 in
Nozzle inside diameter, new:	1.939 in
Nozzle nominal wall thickness:	0.218 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	8.12 in
Projection available outside vessel to flange face, Lf:	9 in

Reinforcement Calculations for Internal Pressure

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 561.74 psi @ 200 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1348	0.1908

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

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

Calculations for internal pressure 561.74 psi @ 200 °F

Fig UCS-66.2 general note (1) applies.

Nozzle is impact test exempt per UCS-66(d) (NPS 4 or smaller pipe).

Nozzle UCS-66 governing thk: 0.1908 in
Nozzle rated MDMT: -155 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall: d = 1.939 in
Normal to the vessel wall outside: $2.5*(t_n - C_n) + t_e$ = 0.545 in

Nozzle required thickness per UG-27(c)(1)

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 561.7399*0.9695/(17,100*1 - 0.6*561.7399)
= 0.0325 in

Required thickness t_r from UG-37(a)

t_r = $P*R_o/(S*E + 0.4*P)$

= 561.7399*18/(20,000*1 + 0.4*561.7399)
= 0.4999 in

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

UW-16(d) Weld Check

t_{min} = lesser of 0.75 or t_n or t = 0.218 in
$t_{1(min)}$ or $t_{2(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.1526 in
$t_{1(actual)}$ = 0.7*Leg = 0.7*0.218 = 0.1526 in
The weld size t_1 is satisfactory.
$t_{2(actual)}$ = 0.1526 in
The weld size t_2 is satisfactory.

$t_1 + t_2 = 0.3052 >= 1.25*t_{min}$

The combined weld sizes for t_1 and t_2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	t_{r1} = 0.0325 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 0.4999 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.1348 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 0.4999 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.1348 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.1348 in

Available nozzle wall thickness new, t_n = 0.875*0.218 = 0.1908 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

The vessel wall thickness governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 561.74 psi @ 70 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1348	0.1908

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

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

Calculations for internal pressure 561.74 psi @ 70 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall: d = 1.939 in

Normal to the vessel wall outside: $2.5*(t_n - C_n) + t_e$ = 0.545 in

Nozzle required thickness per UG-27(c)(1)

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$

= 561.7399*0.9695/(17,100*1 - 0.6*561.7399)

= 0.0325 in

Required thickness t_r from UG-37(a)

t_r = $P*R_o/(S*E + 0.4*P)$

= 561.7399*18/(20,000*1 + 0.4*561.7399)

= 0.4999 in

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

UW-16(d) Weld Check

t_{min} = lesser of 0.75 or t_n or t = 0.218 in
$t_{1(min)}$ or $t_{2(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.1526 in
$t_{1(actual)}$ = 0.7*Leg = 0.7*0.218 = 0.1526 in
The weld size t_1 is satisfactory.
$t_{2(actual)}$ = 0.1526 in
The weld size t_2 is satisfactory.

$t_1 + t_2$ = 0.3052 >= 1.25*t_{min}

The combined weld sizes for t_1 and t_2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	t_{r1} = 0.0325 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 0.4999 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.1348 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 0.4999 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.1348 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.1348 in

Available nozzle wall thickness new, t_n = 0.875*0.218 = 0.1908 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (in^2) For Pe = 233.57 psi @ 212 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1348	0.1908

UG-41 Weld Failure Path Analysis Summary
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 shell fillet (Leg_{41})	0.1526	0.1526	weld size is adequate
Nozzle to shell groove (Lower)	0.1526	0.1526	weld size is adequate

Calculations for external pressure 233.57 psi @ 212 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall: d = 1.939 in
Normal to the vessel wall outside: 2.5*(t_n - C_n) + t_e = 0.545 in

Nozzle required thickness per UG-28 t_{rn} = 0.0406 in

From UG-37(d)(1) required thickness t_r = 0.5 in

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

UW-16(d) Weld Check

t_{min} = lesser of 0.75 or t_n or t = 0.218 in
$t_{1(min)}$ or $t_{2(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.1526 in

$t_{1(actual)}$ = 0.7*Leg = 0.7*0.218 = 0.1526 in
The weld size t_1 is satisfactory.
$t_{2(actual)}$ = 0.1526 in
The weld size t_2 is satisfactory.

$t_1 + t_2$ = 0.3052 >= 1.25*t_{min}

The combined weld sizes for t_1 and t_2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	t_{r1} = 0.0406 in
Wall thickness per UG-45(b)(2):	t_{r2} = 0.2092 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.1348 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 0.2092 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.1348 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.1348 in

Available nozzle wall thickness new, t_n = 0.875*0.218 = 0.1908 in

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 212 °F) UG-28(c)

L / D_o = 9.0392 / 2.375 = 3.8060

D_o / t = 2.375 / 0.0406 = 58.5674

From table G: A = 0.000711
From table CS-2: B = 10,260 psi

P_a = 4*B / (3*(D_o / t))
= 4*10259.6055 / (3*(2.375 / 0.0406))
= 233.57 psi

Design thickness for external pressure P_a = 233.57 psi

t_a = t + Corrosion = 0.0406 + 0 = 0.0406"

1 " with 1 " RFWN (N5)

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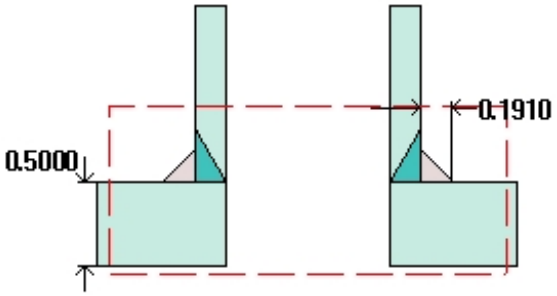

$t_{w(lower)}$ = 0 in
Leg_{41} = 0.191 in

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

Located on:	36" OD 5/8" Shell
Liquid static head included:	0 psi
Nozzle material specification:	SA-106 B Smls pipe (II-D p. 14, ln. 5)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	1" Sch 80 (XS)
Flange description:	1 inch Class 300 WN A105
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 348, ln. 33)
Flange rated MDMT: (UCS-66(b)(1)(b))	-55°F
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	680 psi @ 200°F
ASME B16.5 flange rating MAP:	740 psi @ 70°F
ASME B16.5 flange hydro test:	1125 psi @ 70°F
Nozzle orientation:	0°
Local vessel minimum thickness:	0.5 in
Nozzle center line offset to datum line:	60 in
End of nozzle to shell center:	22 in
Nozzle inside diameter, new:	0.957 in
Nozzle nominal wall thickness:	0.179 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	3.31 in
Projection available outside vessel to flange face, Lf:	4 in

Reinforcement Calculations for Internal Pressure

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 561.74 psi @ 200 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1164	0.1566

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1253	0.1337	weld size is adequate

Calculations for internal pressure 561.74 psi @ 200 °F

Fig UCS-66.2 general note (1) applies.

Nozzle is impact test exempt per UCS-66(d) (NPS 4 or smaller pipe).

Nozzle UCS-66 governing thk: 0.1566 in
Nozzle rated MDMT: -155 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall: $(R_n + t_n + t) = 1.1575$ in
Normal to the vessel wall outside: $2.5*(t_n - C_n) + t_e = 0.4475$ in

Nozzle required thickness per UG-27(c)(1)

$t_{rn} = P*R_n/(S_n*E - 0.6*P)$
$= 561.7399*0.4785/(17,100*1 - 0.6*561.7399)$
$= 0.016$ in

Required thickness t_r from UG-37(a)

$t_r = P*R_o/(S*E + 0.4*P)$
$= 561.7399*18/(20,000*1 + 0.4*561.7399)$

= 0.4999 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.179 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.1253 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.191 = 0.1337 in

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (a).

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	t_{r1} = 0.016 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 0.4999 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.1164 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 0.4999 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.1164 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.1164 in

Available nozzle wall thickness new, t_n = 0.875*0.179 = 0.1566 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

The vessel wall thickness governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 561.74 psi @ 70 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1164	0.1566

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1253	0.1337	weld size is adequate

Calculations for internal pressure 561.74 psi @ 70 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall: $(R_n + t_n + t)$ = 1.1575 in

Normal to the vessel wall outside: $2.5*(t_n - C_n) + t_e$ = 0.4475 in

Nozzle required thickness per UG-27(c)(1)

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$

= 561.7399*0.4785/(17,100*1 - 0.6*561.7399)

= 0.016 in

Required thickness t_r from UG-37(a)

t_r = $P*R_o/(S*E + 0.4*P)$

= 561.7399*18/(20,000*1 + 0.4*561.7399)

= 0.4999 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.179 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.1253 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.191 = 0.1337 in

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (a).

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	t_{r1} = 0.016 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 0.4999 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.1164 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 0.4999 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.1164 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.1164 in

Available nozzle wall thickness new, t_n = 0.875*0.179 = 0.1566 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (in^2) For Pe = 233.57 psi @ 212 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1164	0.1566

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})	0.1253	0.1337	weld size is adequate

Calculations for external pressure 233.57 psi @ 212 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall: $(R_n + t_n + t)$ = 1.1575 in
Normal to the vessel wall outside: $2.5*(t_n - C_n) + t_e$ = 0.4475 in

Nozzle required thickness per UG-28 t_{rn} = 0.0203 in

From UG-37(d)(1) required thickness t_r = 0.5 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.179 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.1253 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.191 = 0.1337 in

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (a).

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	t_{r1} = 0.0203 in
Wall thickness per UG-45(b)(2):	t_{r2} = 0.2092 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.1164 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 0.2092 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.1164 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.1164 in

Available nozzle wall thickness new, t_n = 0.875*0.179 = 0.1566 in

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 212 °F) UG-28(c)

L / D_o = 4.012 / 1.315 = 3.0510

D_o / t = 1.315 / 0.0203 = 64.9204

From table G: A = 0.000795

From table CS-2: B = 11,373 psi

P_a = 4*B / (3*(D_o / t))
= 4*11373.0518 / (3*(1.315 / 0.0203))
= 233.58 psi

Design thickness for external pressure P_a = 233.58 psi

t_a = t + Corrosion = 0.0203 + 0 = 0.0203"

Straight Flange on 36" Lower 2:1 Semi-Elliptical head

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Component: Straight Flange
Material specification: SA-516 70 (II-D p. 18, ln. 22)
Material impact test exemption temperature from Fig UCS-66 Curve D = -55 °F
Fig UCS-66.1 MDMT reduction = 33.1 °F, (coincident ratio = 0.6690962)
Rated MDMT is governed by UCS-66(b)(2)
UCS-66 governing thickness = 0.5 in

Internal design pressure: P = 375 psi @ 200 °F
External design pressure: P_e = 15 psi @ 200 °F

Static liquid head:

P_{th} = 1.43 psi (SG = 1, H_s = 39.5", Horizontal test head)

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

Design MDMT = -20 °F
Rated MDMT = -55 °F

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

Radiography: Longitudinal joint - Spot UW-11(b) Type 1
Circumferential joint - Spot UW-11(b) Type 1

Estimated weight	New = 31.6 lb	corr = 31.6 lb
Capacity	New = 8.33 US gal	corr = 8.33 US gal

OD = 36"
Length L_c = 2"
t = 0.5"

Design thickness, (at 200 °F) Appendix 1-1

$t = P*R_o / (S*E + 0.40*P) + Corrosion$
$= 375*18 / (20{,}000*0.85 + 0.40*375) + 0$
$= 0.3936"$

Maximum allowable working pressure, (at 200 °F) Appendix 1-1

$P = S*E*t / (R_o - 0.40*t) - P_s$
$= 20{,}000*0.85*0.5 / (18 - 0.40*0.5) - 0$
$= 477.53$ psi

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

$P = S*E*t / (R_o - 0.40*t)$
$= 20{,}000*0.85*0.5 / (18 - 0.40*0.5)$
$= 477.53$ psi

External Pressure, (Corroded & at 200 °F) UG-28(c)

$L / D_o = 71.8333 / 36 = 1.9954$
$D_o / t = 36 / 0.1537 = 234.1948$

From table G: A = 0.000184
From table CS-2: B = 2,635 psi

P_a = 4*B / (3*(D_o / t))
= 4*2634.7036 / (3*(36 / 0.1537))
= 15 psi

Design thickness for external pressure P_a = 15 psi

t_a = t + Corrosion = 0.1537 + 0 = 0.1537"

Maximum Allowable External Pressure, (Corroded & at 200 °F) UG-28(c)

L / D_o = 71.8333 / 36 = 1.9954

D_o / t = 36 / 0.5 = 72.0000

From table G: A = 0.001092
From table CS-2: B = 12,613 psi

P_a = 4*B / (3*(D_o / t))
= 4*12612.9219 / (3*(36 / 0.5))
= 233.57 psi

% Extreme fiber elongation - UCS-79(d)

EFE = (50 * t / R_f) * (1 - R_f / R_o)
= (50 * 0.5 / 17.75) * (1 - 17.75 / ∞)
= 1.4085 %

Design thickness = 0.3936"

The governing condition is due to internal pressure.

The cylinder thickness of 0.5" is adequate.

Thickness Required Due to Pressure + External Loads

Condition	Pressure P (psi)	Allowable Stress Before UG-23 Stress Increase (psi)		Temperature (°F)	Corrosion C (in)	Load	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
		S_t	S_c					
Operating, Hot & Corroded	375	20,000	16,502	200	0	Weight	0.1923	0.1923
Operating, Hot & New	375	20,000	16,502	200	0	Weight	0.1923	0.1923
Hot Shut Down, Corroded	0	20,000	16,502	200	0	Weight	0.0001	0.0001
Hot Shut Down, New	0	20,000	16,502	200	0	Weight	0.0001	0.0001
Empty, Corroded	0	20,000	16,502	0	0	Weight	0.0001	0.0001
Empty, New	0	20,000	16,502	0	0	Weight	0.0001	0.0001
Vacuum	-15	20,000	16,502	200	0	Weight	0.0078	0.0078
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0	20,000	16,502	200	0	Weight	0.0001	0.0001

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

A = 0.125 / (R_o / t)
= 0.125 / (18 / 0.5)
= 0.003472

B = 16,502 psi

S = 20,000 / 1.00 = 20,000 psi

S_{cHC} = min(B, S) = 16,502 psi

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

S_{cHN} = S_{cHC}
= 16502.1563 psi

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

A = 0.125 / (R_o / t)
= 0.125 / (18 / 0.5)
= 0.003472

B = 16,502 psi

S = 20,000 / 1.00 = 20,000 psi

S_{cCN} = min(B, S) = 16,502 psi

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

S_{cCC} = S_{cCN}
= 16502.1563 psi

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

A = 0.125 / (R_o / t)
= 0.125 / (18 / 0.5)
= 0.003472

B = 16,502 psi

S = 20,000 / 1.00 = 20,000 psi

S_{cVC} = min(B, S) = 16,502 psi

Operating, Hot & Corroded, Top Seam

t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|) (Pressure)
= 375*17.5 / (2*20,000*1.00*0.85 + 0.40*|375|)
= 0.1922"

t_m = M / (π*R_m^2*S_t*K_s*E_c) (bending)
= 0 / (π*17.75^2*20,000*1.00*0.85)
= 0"

t_w = W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= -238.8 / (2*π*17.75*20,000*1.00*0.85)
= -0.0001"

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0.1922 + 0 - (-0.0001)$
$= 0.1923"$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0 + (-0.0001) - (0.1922)|$
$= 0.1923"$

Maximum allowable working pressure, Longitudinal Stress

$P = 2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w))$
$= 2*20,000*1.00*0.85*(0.5 - 0 + (-0.0001)) / (17.5 - 0.40*(0.5 - 0 + (-0.0001))$
$= 982.41$ psi

Operating, Hot & New, Top Seam

$t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
$= 375*17.5 / (2*20,000*1.00*0.85 + 0.40*|375|)$
$= 0.1922"$

$t_m = M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
$= 0 / (\pi*17.75^2*20,000*1.00*0.85)$
$= 0"$

$t_w = W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= -238.8 / (2*\pi*17.75*20,000*1.00*0.85)$
$= -0.0001"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0.1922 + 0 - (-0.0001)$
$= 0.1923"$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0 + (-0.0001) - (0.1922)|$
$= 0.1923"$

Maximum allowable working pressure, Longitudinal Stress

$P = 2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w))$
$= 2*20,000*1.00*0.85*(0.5 - 0 + (-0.0001)) / (17.5 - 0.40*(0.5 - 0 + (-0.0001))$
$= 982.41$ psi

Hot Shut Down, Corroded, Top Seam

$t_p = 0"$ (Pressure)

$t_m = M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
$= 0 / (\pi*17.75^2*20,000*1.00*0.85)$
$= 0"$

$t_w = W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= -238.8 / (2*\pi*17.75*20,000*1.00*0.85)$
$= -0.0001"$

$t_t = t_p + t_m - t_w$

(total required, tensile)

= 0 + 0 - (-0.0001)

= 0.0001"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)

= |0 + (-0.0001) - (0)|

= 0.0001"

Hot Shut Down, New, Top Seam

t_p = 0" (Pressure)

t_m = $M / (\pi * R_m^2 * S_t * K_s * E_c)$ (bending)

= $0 / (\pi * 17.75^2 * 20{,}000 * 1.00 * 0.85)$

= 0"

t_w = $W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)

= -238.8 / (2*π*17.75*20,000*1.00*0.85)

= -0.0001"

t_t = $t_p + t_m - t_w$ (total required, tensile)

= 0 + 0 - (-0.0001)

= 0.0001"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)

= |0 + (-0.0001) - (0)|

= 0.0001"

Empty, Corroded, Top Seam

t_p = 0" (Pressure)

t_m = $M / (\pi * R_m^2 * S_t * K_s * E_c)$ (bending)

= $0 / (\pi * 17.75^2 * 20{,}000 * 1.00 * 0.85)$

= 0"

t_w = $W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)

= -238.8 / (2*π*17.75*20,000*1.00*0.85)

= -0.0001"

t_t = $t_p + t_m - t_w$ (total required, tensile)

= 0 + 0 - (-0.0001)

= 0.0001"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)

= |0 + (-0.0001) - (0)|

= 0.0001"

Empty, New, Top Seam

t_p = 0" (Pressure)

t_m = $M / (\pi * R_m^2 * S_t * K_s * E_c)$ (bending)
= $0 / (\pi * 17.75^2 * 20{,}000 * 1.00 * 0.85)$
= 0"

t_w = $W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)
= $-238.8 / (2 * \pi * 17.75 * 20{,}000 * 1.00 * 0.85)$
= -0.0001"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0 + 0 - (-0.0001)
= 0.0001"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0 + (-0.0001) - (0)|
= 0.0001"

Vacuum, Top Seam

t_p = $P * R / (2 * S_c * K_s + 0.40 * |P|)$ (Pressure)
= $-15 * 17.5 / (2 * 16{,}502.16 * 1.00 + 0.40 * |15|)$
= -0.008"

t_m = $M / (\pi * R_m^2 * S_c * K_s)$ (bending)
= $0 / (\pi * 17.75^2 * 16{,}502.16 * 1.00)$
= 0"

t_w = $W / (2 * \pi * R_m * S_c * K_s)$ (Weight)
= $-238.8 / (2 * \pi * 17.75 * 16{,}502.16 * 1.00)$
= -0.0001"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= |-0.008 + 0 - (-0.0001)|
= 0.0078"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0 + (-0.0001) - (-0.008)
= 0.0078"

Hot Shut Down, Corroded, Weight & Eccentric Moments Only, Top Seam

t_p = 0" (Pressure)

t_m = $M / (\pi * R_m^2 * S_t * K_s * E_c)$ (bending)
= $0 / (\pi * 17.75^2 * 20{,}000 * 1.00 * 0.85)$
= 0"

t_w = $W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)
= $-238.8 / (2 * \pi * 17.75 * 20{,}000 * 1.00 * 0.85)$
= -0.0001"

t_t = $t_p + t_m - t_w$

(total required, tensile)

= 0 + 0 - (-0.0001)

= 0.0001"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)

= |0 + (-0.0001) - (0)|

= 0.0001"

36" Lower 2:1 Semi-Elliptical head

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Component: Ellipsoidal Head
Material Specification: SA-516 70 (II-D p.18, ln. 22)
Material impact test exemption temperature from Fig UCS-66 Curve D = -55 °F
Fig UCS-66.1 MDMT reduction = 33.8 °F, (coincident ratio = 0.6618601)
Rated MDMT is governed by UCS-66(b)(2)
UCS-66 governing thickness = 0.5 in

Internal design pressure: P = 375 psi @ 200 °F
External design pressure: P_e = 15 psi @ 200 °F

Static liquid head:

P_s= 0 psi (SG=1, H_s=0" Operating head)
P_{th}= 1.4258 psi (SG=1, H_s=39.5" Horizontal test head)

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

Design MDMT = -20°F
Rated MDMT = -55°F

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

Radiography:	Category A joints -	Spot UW-11(b) Type 1
	Head to shell seam -	Spot UW-11(b) Type 1

Estimated weight*:	new = 238.1 lb	corr = 238.1 lb
Capacity*:	new = 32.6 US gal	corr = 32.6 US gal

* includes straight flange

Outer diameter	=	36"
Minimum head thickness	=	0.5"
Head ratio D/2h	=	2 (new)
Head ratio D/2h	=	2 (corroded)
Straight flange length L_{sf}	=	2"
Nominal straight flange thickness t_{sf}	=	0.5"

Results Summary

The governing condition is internal pressure.

Minimum thickness per UG-16	=	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	=	0.3894"
Design thickness due to external pressure (t_e)	=	0.0911"
Maximum allowable working pressure (MAWP)	=	484.33 psi
Maximum allowable pressure (MAP)	=	484.33 psi
Maximum allowable external pressure (MAEP)	=	237.32 psi

K (Corroded)

$K=(1/6)*[2 + (D / (2*h))^2]=(1/6)*[2 + (35 / (2*8.75))^2]=1$

K (New)

$K=(1/6)*[2 + (D / (2*h))^2]=(1/6)*[2 + (35 / (2*8.75))^2]=1$

Design thickness for internal pressure, (Corroded at 200 °F) Appendix 1-4(c)

t = $P*D_o*K / (2*S*E + 2*P*(K - 0.1)) + Corrosion$
= 375*36*1 / (2*20,000*0.85 + 2*375*(1 - 0.1)) + 0
= 0.3893"

The head internal pressure design thickness is 0.3894".

Maximum allowable working pressure, (Corroded at 200 °F) Appendix 1-4(c)

P = $2*S*E*t / (K*D_o - 2*t*(K - 0.1)) - P_s$
= 2*20,000*0.85*0.5 / (1*36 - 2*0.5*(1 - 0.1)) - 0
= 484.33 psi

The maximum allowable working pressure (MAWP) is 484.33 psi.

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

P = $2*S*E*t / (K*D_o - 2*t*(K - 0.1)) - P_s$
= 2*20,000*0.85*0.5 / (1*36 - 2*0.5*(1 - 0.1)) - 0
= 484.33 psi

The maximum allowable pressure (MAP) is 484.33 psi.

Design thickness for external pressure, (Corroded at 200 °F) UG-33(d)

Equivalent outside spherical radius (R_o)
R_o = K_o*D_o
= 0.8757 * 36
= 31.5243 in

A = $0.125 / (R_o/t)$
= 0.125 / (31.5243/0.09105)
= 0.000361

From Table CS-2: B=5,193.4541 psi

P_a = $B/(R_o/t)$
= 5,193.454/(31.5243/0.09105)
= 15 psi

t = 0.0911" + Corrosion = 0.0911" + 0" = 0.0911"
Check the external pressure per UG-33(a)(1) Appendix 1-4(c)

t = $1.67*P_e*D_o*K / (2*S*E + 2*1.67*P_e*(K - 0.1)) + Corrosion$
= 1.67*15*36*1 / (2*20,000*1 + 2*1.67*15*(1 - 0.1)) + 0
= 0.0225"

The head external pressure design thickness (t_e) is 0.0911".

Maximum Allowable External Pressure, (Corroded at 200 °F) UG-33(d)

Equivalent outside spherical radius (R_o)

R_o = $K_o * D_o$
= 0.8757 * 36
= 31.5243 in

A = 0.125 / (R_o/t)
= 0.125 / (31.5243/0.5)
= 0.001983

From Table CS-2: B=14,962.51 psi

P_a = B/(R_o/t)
= 14,962.51/(31.5243/0.5)
= 237.3169 psi

Check the Maximum External Pressure, UG-33(a)(1) Appendix 1-4(c)

P = 2*S*E*t / ((K*D_o - 2*t*(K - 0.1))*1.67) - P_{s2}
= 2*20,000*1*0.5 / ((1*36 - 2*0.5*(1 - 0.1))*1.67) - 0
= 341.2 psi

The maximum allowable external pressure (MAEP) is 237.32 psi.

% Extreme fiber elongation - UCS-79(d)

= (75*t / R_f)*(1 - R_f / R_o)
= (75*0.5 / 6.2)*(1 - 6.2 / ∞)
= 6.0484%

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

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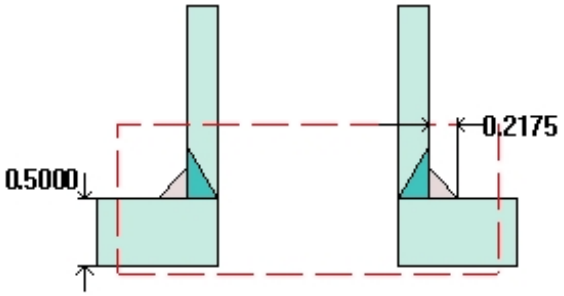
$t_{w(lower)}$ = 0 in
Leg_{41} = 0.2175 in



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

Located on:	36" Lower 2:1 Semi-Elliptical head
Liquid static head included:	0 psi
Nozzle material specification:	SA-234 WPB (II-D p. 14, ln. 7)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	1" Class 3000 - threaded
Nozzle orientation:	0°
Calculated as hillside:	no
Local vessel minimum thickness:	0.5 in
End of nozzle to datum line:	-12.4816 in
Nozzle inside diameter, new:	1.315 in
Nozzle nominal wall thickness:	0.2175 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	1.2426 in
Distance to head center, R:	0 in

Reinforcement Calculations for Internal Pressure

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 624.97 psi @ 200 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.0625	0.2175

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1523	0.1523	weld size is adequate

Calculations for internal pressure 624.97 psi @ 200 °F

Nozzle is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.06718).

Nozzle UCS-66 governing thk: 0.2175 in
Nozzle rated MDMT: -155 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall: $(R_n + t_n + t) = 1.375$ in
Normal to the vessel wall outside: $2.5*(t_n - C_n) + t_e = 0.5438$ in

Nozzle required thickness per UG-27(c)(1)

$t_{rn} = P*R_n/(S_n*E - 0.6*P)$
$= 624.9657*0.6575/(17,100*1 - 0.6*624.9657)$
$= 0.0246$ in

Required thickness t_r from UG-37(a)(c)

$t_r = P*K_1*D_o/(2*S*E + 0.8*P)$
$= 624.9657*0.9*36/(2*20,000*1 + 0.8*624.9657)$
$= 0.5$ in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.2175 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.1523 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.2175 = 0.1523 in

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (a).

ASME B16.11 Coupling Wall Thickness Check

Interpretation VIII-1-83-66 has been applied.

Wall thickness req'd per ASME B16.11 2.1.1:	t_{r1} = 0.0315 in (E =1)
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in

Available nozzle wall thickness new, t_n = 0.2175 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

The vessel wall thickness governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 624.97 psi @ 70 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.0625	0.2175

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1523	0.1523	weld size is adequate

Calculations for internal pressure 624.97 psi @ 70 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall: $(R_n + t_n + t) = 1.375$ in

Normal to the vessel wall outside: $2.5*(t_n - C_n) + t_e = 0.5438$ in

Nozzle required thickness per UG-27(c)(1)

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$

= 624.9657*0.6575/(17,100*1 - 0.6*624.9657)

= 0.0246 in

Required thickness t_r from UG-37(a)(c)

t_r = $P*K_1*D_o/(2*S*E + 0.8*P)$

= 624.9657*0.9*36/(2*20,000*1 + 0.8*624.9657)

= 0.5 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.2175 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.1523 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.2175 = 0.1523 in

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (a).

ASME B16.11 Coupling Wall Thickness Check

Interpretation VIII-1-83-66 has been applied.

Wall thickness req'd per ASME B16.11 2.1.1:	t_{r1} = 0.0315 in (E =1)
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in

Available nozzle wall thickness new, t_n = 0.2175 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (in^2) For Pe = 233.57 psi @ 200 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1269	0.2175

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})	0.1523	0.1523	weld size is adequate

Calculations for external pressure 233.57 psi @ 200 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall: $(R_n + t_n + t)$ = 1.375 in
Normal to the vessel wall outside: $2.5*(t_n - C_n) + t_e$ = 0.5438 in

Nozzle required thickness per UG-28 t_{rn} = 0.0198 in

From UG-37(d)(1) required thickness t_r = 0.4939 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.2175 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.1523 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.2175 = 0.1523 in

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (a).

UG-45 Nozzle Neck Thickness Check

Interpretation VIII-1-83-66 has been applied.

Wall thickness per UG-45(a):	t_{r1} = 0.0198 in
Wall thickness per UG-45(b)(2):	t_{r2} = 0.208 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.1269 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 0.208 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.1269 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.1269 in

Available nozzle wall thickness new, t_n = 0.2175 in

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 200 °F) UG-28(c)

L / D_o = 1.2426 / 1.75 = 0.7100

D_o / t = 1.75 / 0.0198 = 88.5515

From table G: A = 0.002387

From table CS-2: B = 15,513 psi

P_a = 4*B / (3*(D_o / t))
= 4*15512.5361 / (3*(1.75 / 0.0198))
= 233.57 psi

Design thickness for external pressure P_a = 233.57 psi

t_a = t + Corrosion = 0.0198 + 0 = 0.0198"