Pressure Vessel Engineering

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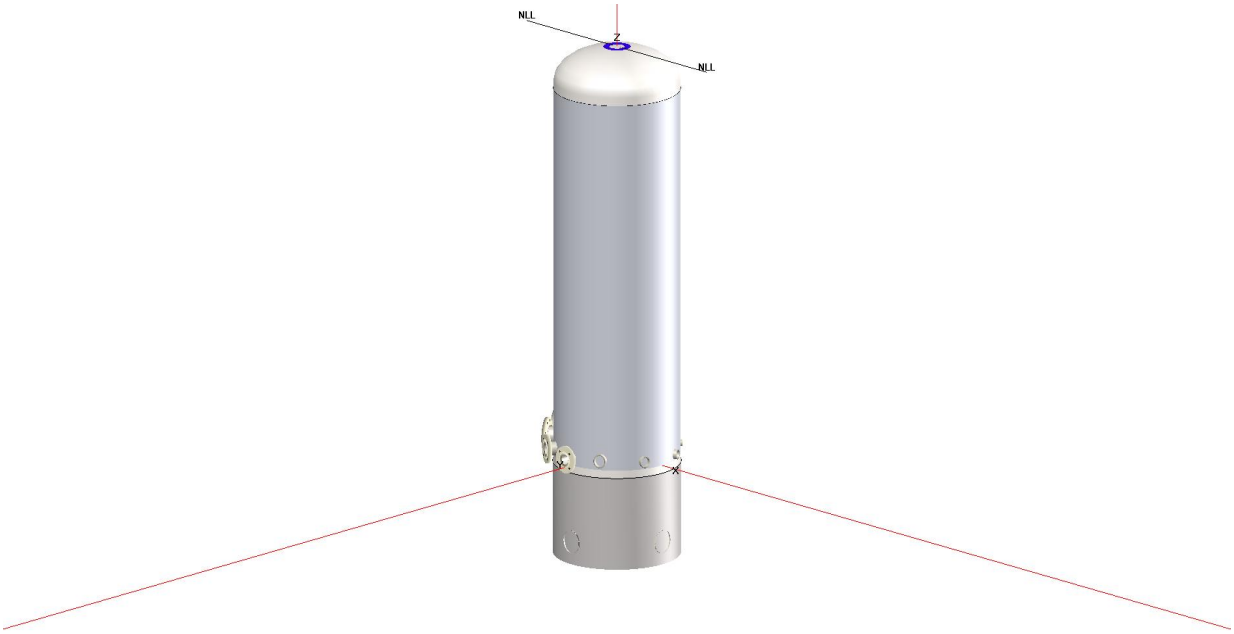

COMPRESS Pressure Vessel Design Calculations

Item: Generic Vessel
Vessel No: PVE-6847
Customer: Pressure Vessel Engineering
Designer: T. Briant, Brandon Twolan, Brian Munn
Date: Tuesday, June 18, 2013

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Settings Summary

COMPRESS 2013 Build 7320

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:	0.0938" per UG-16(b)
Design for cold shut down only:	No
Design for lethal service (full radiography required):	No
Design nozzles for:	Design P only
Corrosion weight loss:	100% of theoretical loss
UG-23 Stress Increase:	1.20
Skirt/legs stress increase:	1.0
Minimum nozzle projection:	1"
Juncture calculations for $\alpha > 30$ only:	No
Preheat P-No 1 Materials > 1.25" 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:	None
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-1-01-37:	Yes
No UCS-66.1 MDMT reduction:	Yes
No UCS-68(c) MDMT reduction:	Yes
Disallow UG-20(f) exemptions:	No

UG-22 Loadings

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

UG-22(c) Superimposed static reactions from weight of attached equipment (external loads):	No
UG-22(d)(2) Vessel supports such as lugs, rings, skirts, saddles and legs:	Yes
UG-22(f) Wind reactions:	Yes
UG-22(f) Seismic reactions:	Yes
UG-22(j) Test pressure and coincident static head acting during the test:	Yes

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

Nozzle Schedule

Nozzle mark	Service	Size	Materials		Impact Tested	Normalized	Fine Grain	Flange	Blind
N1	NPS 4"	NPS 4 Sch 40 (Std)	Nozzle	SA-106 B Smls pipe	No	No	No	NPS 4 Class 150 SO A105	No
N1	NPS 3"	NPS 3 Sch 40 (Std)	Nozzle	SA-106 B Smls pipe	No	No	No	NPS 3 Class 150 SO A105	No
N1	NPS 2.5	NPS 2.5 Sch 40 (Std)	Nozzle	SA-106 B Smls pipe	No	No	No	NPS 2 1/2 Class 150 SO A105	No
N1	NPS 6"	NPS 6 Sch 40 (Std)	Nozzle	SA-106 B Smls pipe	No	No	No	NPS 6 Class 150 SO A105	No
N2	1" CL 3000	NPS 1 Class 3000 - threaded	Nozzle	SA-105	No	No	No	N/A	No
N2	2.5" CL 3000	NPS 2.5 Class 3000 - threaded	Nozzle	SA-105	No	No	No	N/A	No
N2	2" CL 3000	NPS 2 Class 3000 - threaded	Nozzle	SA-105	No	No	No	N/A	No
N2	1.5" CL 3000	NPS 1.5 Class 3000 - threaded	Nozzle	SA-105	No	No	No	N/A	No
N3	1.5" CL 3000	NPS 1.5 Class 3000 - threaded	Nozzle	SA-105	No	No	No	N/A	No
N3	2" CL 3000	NPS 2 Class 3000 - threaded	Nozzle	SA-105	No	No	No	N/A	No
N3	1" CL 3000	NPS 1 Class 3000 - threaded	Nozzle	SA-105	No	No	No	N/A	No

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	4.5	0.237	0.1952	Yes	Yes	0.375	0.1708		N/A	N/A	0	104.7
N1	3.5	0.216	0.1952	Yes	Yes	0.375	0.1708		N/A	N/A	0	101.4
N1	2.875	0.203	0.1952	Yes	Yes	0.375	0.1708		N/A	N/A	0	114.4
N1	6.625	0.28	0.1952	Yes	Yes	0.375	0.1708		N/A	N/A	0	102.4
N2	1.75	0.2175	0.0938	Yes	Yes	0.375	0.1708		N/A	N/A	0	122.4
N2	3.625	0.375	0.0938	Yes	Yes	0.375	0.1708		N/A	N/A	0	100.3
N2	3	0.3125	0.0938	Yes	Yes	0.375	0.1708		N/A	N/A	0	104.3
N2	2.5	0.3	0.0938	Yes	Yes	0.375	0.1708		N/A	N/A	0	113.1
N3	2.5	0.3	0.0938	Yes	Yes	0.2813*	N/A		N/A	N/A	0	Exempt
N3	3	0.3125	0.0938	Yes	Yes	0.2813*	N/A		N/A	N/A	0	Exempt
N3	1.75	0.2175	0.0938	Yes	Yes	0.2813*	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

Pressure Summary for Chamber bounded by Ellipsoidal Head, Bottom and Ellipsoidal Head, Top

Identifier	P Design (psi)	T Design (°F)	MAWP (psi)	MDMT (°F)	MDMT Exemption	Impact Tested
Ellipsoidal Head, Top	200	250	288	-20	Note 1	No
Straight Flange on Ellipsoidal Head, Top	200	250	317.62	-20	Note 2	No
Shell	200	250	310.85	-20	Note 3	No
Straight Flange on Ellipsoidal Head, Bottom	200	250	314.08	-20	Note 2	No
Ellipsoidal Head, Bottom	200	250	284.02	-20	Note 4	No
NPS 6" (N1)	200	250	200	-20	Note 5	No
NPS 4" (N1)	200	250	200	-20	Note 6	No
NPS 3" (N1)	200	250	200	-20	Note 6	No
NPS 2.5 (N1)	200	250	200	-20	Note 6	No
2" CL 3000 (N2)	200	250	200	-20	Note 7	No
1.5" CL 3000 (N2)	200	250	200	-20	Note 8	No
1" CL 3000 (N2)	200	250	200	-20	Note 9	No
2.5" CL 3000 (N2)	200	250	200	-20	Note 10	No
1" CL 3000 (N3)	200	250	200	-20	Note 9	No
1.5" CL 3000 (N3)	200	250	200	-20	Note 11	No
2" CL 3000 (N3)	200	250	200	-20	Note 11	No

Chamber design MDMT is -20 °F
Chamber rated MDMT is -20 °F @ 200 psi

Chamber MAWP hot & corroded is 200 psi @ 250 °F

This pressure chamber is not designed for external pressure.

Notes for Maximum Pressure Rating:

Note #	Details
1.	Option to calculate MAP was not selected. See the Calculation->General tab of the Set Mode dialog.

Notes for MDMT Rating:

Note #	Exemption	Details
1.	Straight Flange governs MDMT	
2.	Material is impact test exempt per UG-20(f)	UCS-66 governing thickness = 0.3125 in
3.	Material is impact test exempt per UG-20(f)	UCS-66 governing thickness = 0.375 in
4.	Straight Flange governs MDMT	
5.	Nozzle is impact test exempt per UG-20(f)	UCS-66 governing thickness = 0.245 in.
6.	Flange rating governs:	UCS-66(b)(1)(b)
7.	Nozzle is impact test exempt per UG-20(f)	UCS-66 governing thickness = 0.3125 in.
8.	Nozzle is impact test exempt per UG-20(f)	UCS-66 governing thickness = 0.3 in.
9.	Nozzle is impact test exempt per UG-20(f)	UCS-66 governing thickness = 0.2175 in.
10.	Nozzle is impact test exempt per UG-20(f)	UCS-66 governing thickness = 0.375 in.
11.	Nozzle is impact test exempt per UG-20(f)	UCS-66 governing thickness = 0.2813 in.

Design notes are available on the Settings Summary page.

Thickness Summary

Component Identifier	Material	Diameter (in)	Length (in)	Nominal t (in)	Design t (in)	Total Corrosion (in)	Joint E	Load
Ellipsoidal Head, Top	SA-414 G	36 OD	9.1406	0.2813*	0.1963	0	0.85	Internal
Straight Flange on Ellipsoidal Head, Top	SA-414 G	36 OD	2	0.3125	0.1975	0	0.85	Internal
Shell	SA-414 G	36 OD	96	0.375	0.2437	0	0.70	Internal
Straight Flange on Ellipsoidal Head, Bottom	SA-414 G	36 OD	2	0.3125	0.2009	0	0.85	Internal
Ellipsoidal Head, Bottom	SA-414 G	36 OD	9.1406	0.2813*	0.2001	0	0.85	Internal
Support Skirt	SA-36	36 ID	24	0.1875	0.0588	0	0.55	Seismic

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										Surface Area ft²
	Metal New*	Metal Corroded*	Insulation	Insulation Supports	Lining	Piping + Liquid	Operating Liquid		Test Liquid		
							New	Corroded	New	Corroded	
Ellipsoidal Head, Top	137.3	137.3	0	0	0	0	281.2	281.2	281.2	281.2	12
Shell	1,130.6	1,130.6	0	0	0	0	3,387.7	3,387.7	3,387.7	3,387.7	75
Ellipsoidal Head, Bottom	136.1	136.1	0	0	0	0	282.2	282.2	281.9	281.9	12
Support Skirt	144.8	144.8	0	0	0	0	0	0	0	0	38
TOTAL:	**1,548.8**	**1,548.8**	**0**	**0**	**0**	**0**	**3,951.2**	**3,951.2**	**3,950.8**	**3,950.8**	**138**

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

Component	Weight (lb) Contributed by Attachments										Surface Area ft²
	Body Flanges		Nozzles & Flanges		Packed Beds	Ladders & Platforms	Trays	Tray Supports	Rings & Clips	Vertical Loads	
	New	Corroded	New	Corroded							
Ellipsoidal Head, Top	0	0	0	0	0	0	0	0	0	0	0
Shell	0	0	61.8	61.8	0	0	0	0	0	0	2
Ellipsoidal Head, Bottom	0	0	6.7	6.7	0	0	0	0	0	0	0
Support Skirt	0	0	0	0	0	0	0	0	0	0	0
TOTAL:	**0**	**0**	**68.5**	**68.5**	**0**	**0**	**0**	**0**	**0**	**0**	**3**

Vessel operating weight, Corroded: 5,568 lb
Vessel operating weight, New: 5,568 lb
Vessel empty weight, Corroded: 1,617 lb
Vessel empty weight, New: 1,617 lb
Vessel test weight, New: 5,568 lb
Vessel test weight, Corroded: 5,568 lb
Vessel surface area: 140 ft²

Vessel center of gravity location - from datum - lift condition

Vessel Lift Weight, New: 1,617 lb
Center of Gravity: 40.7766"

Vessel Capacity

Vessel Capacity** (New): 473 US gal
Vessel Capacity** (Corroded): 473 US gal
**The vessel capacity does not include volume of nozzle, piping or other attachments.

Hydrostatic Test

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

Shop hydrostatic test gauge pressure is 260 psi at 70 °F (the chamber MAWP = 200 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(b) stress ratio	UG-99(b) pressure factor	Stress during test psi	Allowable test stress psi	Stress excessive?
Ellipsoidal Head, Top (1)	261.299	1.299	1	1.30	14,813	40,500	No
Straight Flange on Ellipsoidal Head, Top	261.298	1.298	1	1.30	14,920	40,500	No
Shell	261.295	1.295	1	1.30	12,411	40,500	No
Straight Flange on Ellipsoidal Head, Bottom	261.298	1.298	1	1.30	14,920	40,500	No
Ellipsoidal Head, Bottom	261.299	1.299	1	1.30	14,816	40,500	No
1" CL 3000 (N2)	260.355	0.355	1	1.30	15,039	60,750	No
1" CL 3000 (N3)	261.242	1.242	1	1.30	17,491	60,750	No
1.5" CL 3000 (N2)	260.06	0.06	1	1.30	14,691	60,750	No
1.5" CL 3000 (N3)	260.134	0.134	1	1.30	17,655	60,750	No
2" CL 3000 (N2)	260.063	0.063	1	1.30	15,756	60,750	No
2" CL 3000 (N3)	260.702	0.702	1	1.30	18,889	60,750	No
2.5" CL 3000 (N2)	260.379	0.379	1	1.30	16,439	60,750	No
NPS 2.5 (N1)	260.704	0.704	1	1.30	18,496	60,750	No
NPS 3" (N1)	261.086	1.086	1	1.30	20,181	60,750	No
NPS 4" (N1)	261.352	1.352	1	1.30	22,702	60,750	No
NPS 6" (N1)	261.417	1.417	1	1.30	26,797	60,750	No

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

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

The test temperature of 70 °F is warmer than the minimum recommended temperature of 10 °F so the brittle fracture provision of UG-99(h) has been met.

Ellipsoidal Head, Top

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Component:	Ellipsoidal Head
Material Specification:	SA-414 G (II-D p.22, ln. 21)

Straight Flange governs MDMT

Internal design pressure: P = 200 psi @ 250 °F

Static liquid head:

P_s= 0.32 psi (SG=1, H_s=8.8594" Operating head)
P_{th}= 1.3 psi (SG=1, H_s=35.979" Horizontal test head)

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

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

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

Radiography:	Category A joints -	Seamless No RT
	Head to shell seam -	None UW-11(c) Type 1

Estimated weight*:	new = 137.3 lb	corr = 137.3 lb
Capacity*:	new = 33.7 US gal	corr = 33.7 US gal

* includes straight flange

Outer diameter	=	36"
Minimum head thickness	=	0.2813"
Head ratio D/2h	=	2 (new)
Head ratio D/2h	=	2 (corroded)
Straight flange length L_{sf}	=	2"
Nominal straight flange thickness t_{sf}	=	0.3125"

Results Summary

The governing condition is internal pressure.

Minimum thickness per UG-16	=	0.0938" + 0" = 0.0938"
Design thickness due to internal pressure (t)	=	0.1963"
Maximum allowable working pressure (MAWP)	=	288 psi

K (Corroded)

$K=(1/6)*[2 + (D / (2*h))^2]=(1/6)*[2 + (35.4374 / (2*8.8594))^2]=1$

K (New)

$K=(1/6)*[2 + (D / (2*h))^2]=(1/6)*[2 + (35.4374 / (2*8.8594))^2]=1$

Design thickness for internal pressure, (Corroded at 250 °F) Appendix 1-4(c)

$t = P*D_o*K / (2*S*E + 2*P*(K - 0.1)) + Corrosion$

= 200.32*36*1 / (2*21,400*0.85 + 2*200.32*(1 - 0.1)) + 0
= 0.1963"

The head internal pressure design thickness is 0.1963".

Maximum allowable working pressure, (Corroded at 250 °F) Appendix 1-4(c)

P = $2*S*E*t / (K*D_o - 2*t*(K - 0.1)) - P_s$
= 2*21,400*0.85*0.2813 / (1*36 - 2*0.2813*(1 - 0.1)) - 0.32
= 288 psi

The maximum allowable working pressure (MAWP) is 288 psi.

% Extreme fiber elongation - UCS-79(d)

EFE = $(75*t / R_f)*(1 - R_f / R_o)$
= (75*0.3125 / 6.1806)*(1 - 6.1806 / ∞)
= 3.7921%

The extreme fiber elongation does not exceed 5%.

Straight Flange on Ellipsoidal Head, Top

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Component: Straight Flange
Material specification: SA-414 G (II-D p. 22, ln. 21)
Material is impact test exempt per UG-20(f)
UCS-66 governing thickness = 0.3125 in

Internal design pressure: P = 200 psi @ 250 °F

Static liquid head:

P_s = 0.39 psi (SG = 1, H_s = 10.8594",Operating head)
P_{th} = 1.3 psi (SG = 1, H_s = 35.9478", Horizontal test head)

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

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

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

Radiography: Longitudinal joint - Seamless No RT
Circumferential joint - None UW-11(c) Type 1

Estimated weight	New = 19.8 lb	corr = 19.8 lb
Capacity	New = 8.51 US gal	corr = 8.51 US gal

OD = 36"
Length L_c = 2"
t = 0.3125"

Design thickness, (at 250 °F) Appendix 1-1

$t = P*R_o / (S*E + 0.40*P) + Corrosion$
$= 200.39*18 / (21,400*0.85 + 0.40*200.39) + 0$
$= 0.1975"$

Maximum allowable working pressure, (at 250 °F) Appendix 1-1

$P = S*E*t / (R_o - 0.40*t) - P_s$
$= 21,400*0.85*0.3125 / (18 - 0.40*0.3125) - 0.39$
$= 317.62$ psi

% Extreme fiber elongation - UCS-79(d)

$EFE = (50*t / R_f)*(1 - R_f / R_o)$
$= (50*0.3125 / 17.8438)*(1 - 17.8438 / \infty)$
$= 0.8757\%$

The extreme fiber elongation does not exceed 5%.

Design thickness = 0.1975"

The governing condition is due to internal pressure.

The cylinder thickness of 0.3125" is adequate.

Thickness Required Due to Pressure + External Loads

Condition	Pressure P (psi)	Allowable Stress Before UG-23 Stress Increase (psi)		Temperature (°F)	Corrosion C (in)	Load	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
		S_t	S_c					
Operating, Hot & Corroded	200	21,400	18,519	250	0	Wind	0.0981	0.0981
						Seismic	0.0984	0.0978
Operating, Hot & New	200	21,400	18,519	250	0	Wind	0.0981	0.0981
						Seismic	0.0984	0.0978
Hot Shut Down, Corroded	0	21,400	18,519	250	0	Wind	0	0.0001
						Seismic	0.0002	0.0003
Hot Shut Down, New	0	21,400	18,519	250	0	Wind	0	0.0001
						Seismic	0.0002	0.0003
Empty, Corroded	0	21,400	18,519	70	0	Wind	0	0.0001
						Seismic	0.0001	0.0002
Empty, New	0	21,400	18,519	70	0	Wind	0	0.0001
						Seismic	0.0001	0.0002
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0	21,400	18,519	250	0	Weight	0.0001	0.0001

Shell

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Component: Cylinder
Material specification: SA-414 G (II-D p. 22, ln. 21)
Material is impact test exempt per UG-20(f)
UCS-66 governing thickness = 0.375 in

Internal design pressure: P = 200 psi @ 250 °F

Static liquid head:

P_s = 3.86 psi (SG = 1, H_s = 106.8594",Operating head)
P_{th} = 1.3 psi (SG = 1, H_s = 35.8853", Horizontal test head)

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

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

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

Radiography: Longitudinal joint - None UW-11(c) Type 1
Top circumferential joint - None UW-11(c) Type 1
Bottom circumferential joint - None UW-11(c) Type 1

Estimated weight	New = 1,130.6 lb	corr = 1,130.6 lb
Capacity	New = 405.57 US gal	corr = 405.57 US gal

OD = 36"
Length L_c = 96"
t = 0.375"

Design thickness, (at 250 °F) Appendix 1-1

$t = P*R_o / (S*E + 0.40*P) + Corrosion$
$= 203.86*18 / (21,400*0.70 + 0.40*203.86) + 0$
$= 0.2437"$

Maximum allowable working pressure, (at 250 °F) Appendix 1-1

$P = S*E*t / (R_o - 0.40*t) - P_s$
$= 21,400*0.70*0.375 / (18 - 0.40*0.375) - 3.86$
$= 310.85 \text{ psi}$

% Extreme fiber elongation - UCS-79(d)

$EFE = (50*t / R_f)*(1 - R_f / R_o)$
$= (50*0.375 / 17.8125)*(1 - 17.8125 / \infty)$
$= 1.0526\%$

The extreme fiber elongation does not exceed 5%.

Design thickness = 0.2437"

The governing condition is due to internal pressure.

The cylinder thickness of 0.375" is adequate.

Thickness Required Due to Pressure + External Loads

Condition	Pressure P (psi)	Allowable Stress Before UG-23 Stress Increase (psi)		Temperature (°F)	Corrosion C (in)	Load	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
		S_t	S_c					
Operating, Hot & Corroded	200	21,400	18,692	250	0	Wind	0.0988	0.0955
						Seismic	0.1267	0.0677
Operating, Hot & New	200	21,400	18,692	250	0	Wind	0.0988	0.0955
						Seismic	0.1267	0.0677
Hot Shut Down, Corroded	0	21,400	18,692	250	0	Wind	0.001	0.0019
						Seismic	0.0288	0.0242
Hot Shut Down, New	0	21,400	18,692	250	0	Wind	0.001	0.0019
						Seismic	0.0288	0.0242
Empty, Corroded	0	21,400	18,692	70	0	Wind	0.001	0.0019
						Seismic	0.0079	0.0074
Empty, New	0	21,400	18,692	70	0	Wind	0.001	0.0019
						Seismic	0.0079	0.0074
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0	21,400	18,692	250	0	Weight	0.0006	0.0007

Straight Flange on Ellipsoidal Head, Bottom

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Component: Straight Flange
Material specification: SA-414 G (II-D p. 22, ln. 21)
Material is impact test exempt per UG-20(f)
UCS-66 governing thickness = 0.3125 in

Internal design pressure: P = 200 psi @ 250 °F

Static liquid head:

P_s = 3.93 psi (SG = 1, H_s = 108.8594",Operating head)
P_{th} = 1.3 psi (SG = 1, H_s = 35.9478", Horizontal test head)

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

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

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

Radiography: Longitudinal joint - Seamless No RT
Circumferential joint - None UW-11(c) Type 1

Estimated weight	New = 19.8 lb	corr = 19.8 lb
Capacity	New = 8.51 US gal	corr = 8.51 US gal

OD = 36"
Length L_c = 2"
t = 0.3125"

Design thickness, (at 250 °F) Appendix 1-1

$t = P*R_o / (S*E + 0.40*P) + Corrosion$
$= 203.93*18 / (21,400*0.85 + 0.40*203.93) + 0$
$= 0.2009"$

Maximum allowable working pressure, (at 250 °F) Appendix 1-1

$P = S*E*t / (R_o - 0.40*t) - P_s$
$= 21,400*0.85*0.3125 / (18 - 0.40*0.3125) - 3.93$
$= 314.08 \text{ psi}$

% Extreme fiber elongation - UCS-79(d)

$EFE = (50*t / R_f)*(1 - R_f / R_o)$
$= (50*0.3125 / 17.8438)*(1 - 17.8438 / \infty)$
$= 0.8757\%$

The extreme fiber elongation does not exceed 5%.

Design thickness = 0.2009"

The governing condition is due to internal pressure.

The cylinder thickness of 0.3125" is adequate.

Thickness Required Due to Pressure + External Loads

Condition	Pressure P (psi)	Allowable Stress Before UG-23 Stress Increase (psi)		Temperature (°F)	Corrosion C (in)	Load	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
		S_t	S_c					
Operating, Hot & Corroded	200	21,400	18,519	250	0	Wind	0.0992	0.0958
						Seismic	0.1269	0.0681
Operating, Hot & New	200	21,400	18,519	250	0	Wind	0.0992	0.0958
						Seismic	0.1269	0.0681
Hot Shut Down, Corroded	0	21,400	18,519	250	0	Wind	0.001	0.0019
						Seismic	0.0287	0.0243
Hot Shut Down, New	0	21,400	18,519	250	0	Wind	0.001	0.0019
						Seismic	0.0287	0.0243
Empty, Corroded	0	21,400	18,519	70	0	Wind	0.001	0.0019
						Seismic	0.0079	0.0074
Empty, New	0	21,400	18,519	70	0	Wind	0.001	0.0019
						Seismic	0.0079	0.0074
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0	21,400	18,519	250	0	Weight	0.0006	0.0007

Ellipsoidal Head, Bottom

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Component:	Ellipsoidal Head
Material Specification:	SA-414 G (II-D p.22, ln. 21)

Straight Flange governs MDMT

Internal design pressure: P = 200 psi @ 250 °F

Static liquid head:

P_s= 4.25 psi (SG=1, H_s=117.7187" Operating head)
P_{th}= 1.3 psi (SG=1, H_s=35.9791" Horizontal test head)

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

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

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

Radiography:	Category A joints -	Seamless No RT
	Head to shell seam -	None UW-11(c) Type 1

Estimated weight*:	new = 136.1 lb	corr = 136.1 lb
Capacity*:	new = 33.7 US gal	corr = 33.7 US gal

* includes straight flange

Outer diameter	=	36"
Minimum head thickness	=	0.2813"
Head ratio D/2h	=	2 (new)
Head ratio D/2h	=	2 (corroded)
Straight flange length L_{sf}	=	2"
Nominal straight flange thickness t_{sf}	=	0.3125"

Results Summary

The governing condition is internal pressure.

Minimum thickness per UG-16	=	0.0938" + 0" = 0.0938"
Design thickness due to internal pressure (t)	=	0.2001"
Maximum allowable working pressure (MAWP)	=	284.02 psi

K (Corroded)

$K=(1/6)*[2 + (D / (2*h))^2]=(1/6)*[2 + (35.4375 / (2*8.8594))^2]=1$

K (New)

$K=(1/6)*[2 + (D / (2*h))^2]=(1/6)*[2 + (35.4375 / (2*8.8594))^2]=1$

Design thickness for internal pressure, (Corroded at 250 °F) Appendix 1-4(c)

$t = P*D_o*K / (2*S*E + 2*P*(K - 0.1)) + Corrosion$

= 204.25*36*1 / (2*21,400*0.85 + 2*204.25*(1 - 0.1)) + 0
= 0.2001"

The head internal pressure design thickness is 0.2001".

Maximum allowable working pressure, (Corroded at 250 °F) Appendix 1-4(c)

P = $2*S*E*t / (K*D_o - 2*t*(K - 0.1)) - P_s$
= 2*21,400*0.85*0.2813 / (1*36 - 2*0.2813*(1 - 0.1)) - 4.25
= 284.02 psi

The maximum allowable working pressure (MAWP) is 284.02 psi.

% Extreme fiber elongation - UCS-79(d)

EFE = $(75*t / R_f)*(1 - R_f / R_o)$
= (75*0.3125 / 6.1806)*(1 - 6.1806 / ∞)
= 3.7921%

The extreme fiber elongation does not exceed 5%.

NPS 6" (N1)

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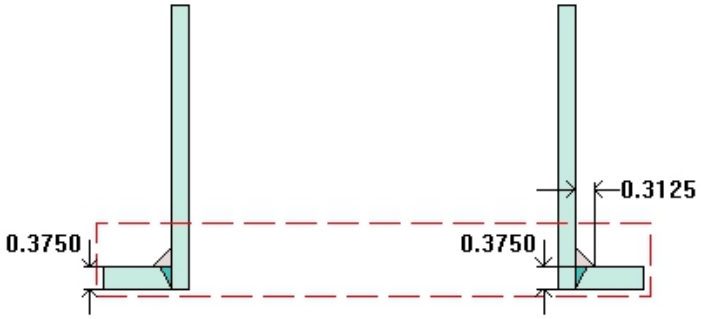
$t_{w(lower)}$ = 0.375 in
Leg_{41} = 0.3125 in



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

Location and Orientation

Located on:	Shell
Orientation:	180°
Nozzle center line offset to datum line:	4.875 in
End of nozzle to shell center:	21 in
Passes through a Category A joint:	No

Nozzle

Access opening:	No
Material specification:	SA-106 B Smls pipe (II-D p. 10, ln. 40)
Description:	NPS 6 Sch 40 (Std)
Inside diameter, new:	6.065 in
Nominal wall thickness:	0.28 in
Corrosion allowance:	0 in
Projection available outside vessel, Lpr:	2.72 in
Projection available outside vessel to flange face, Lf:	3 in
Local vessel minimum thickness:	0.375 in
User input radial limit of reinforcement:	4.875 in
Liquid static head included:	3.7908 psi
Longitudinal joint efficiency:	1

ASME B16.5-2009 Flange

Description:	NPS 6 Class 150 SO A105
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 334, ln. 32)
Blind included:	No
Rated MDMT:	-20°F per UCS-66(b)(1)(b)
Liquid static head:	3.6813 psi
MAWP rating:	245 psi @ 250°F
MAP rating:	285 psi @ 70°F
Hydrotest rating:	450 psi @ 70°F

External fillet weld leg (UW-21):	0.392 in (0.392 in min)
Internal fillet weld leg (UW-21):	0.25 in (0.25 in min)
PWHT performed:	No

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 203.79 psi @ 250 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
1.0549	1.0801	0.7296	0.2725	--	--	0.078	0.1708	0.245

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.196	0.2188	weld size is adequate

NPS 4" (N1)

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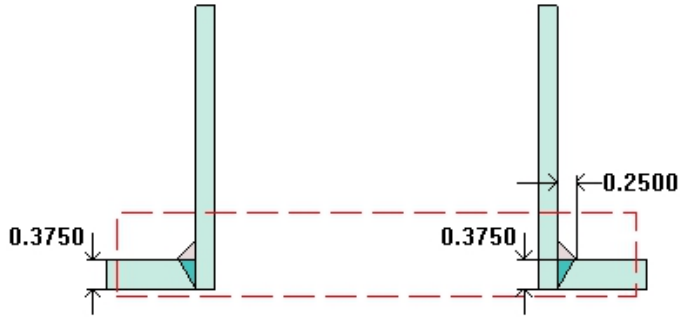
$t_{w(lower)}$ = 0.375 in
Leg_{41} = 0.25 in



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

Location and Orientation

Located on:	Shell
Orientation:	150°
Nozzle center line offset to datum line:	3.25 in
End of nozzle to shell center:	21 in
Passes through a Category A joint:	No

Nozzle

Access opening:	No
Material specification:	SA-106 B Smls pipe (II-D p. 10, ln. 40)
Description:	NPS 4 Sch 40 (Std)
Inside diameter, new:	4.026 in
Nominal wall thickness:	0.237 in
Corrosion allowance:	0 in
Projection available outside vessel, Lpr:	2.763 in
Projection available outside vessel to flange face, Lf:	3 in
Local vessel minimum thickness:	0.375 in
User input radial limit of reinforcement:	3.25 in
Liquid static head included:	3.8127 psi
Longitudinal joint efficiency:	1

ASME B16.5-2009 Flange

Description:	NPS 4 Class 150 SO A105
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 334, ln. 32)
Blind included:	No
Rated MDMT:	-20°F per UCS-66(b)(1)(b)
Liquid static head:	3.74 psi
MAWP rating:	245 psi @ 250°F
MAP rating:	285 psi @ 70°F
Hydrotest rating:	450 psi @ 70°F

External fillet weld leg (UW-21):	0.3318 in (0.3318 in min)
Internal fillet weld leg (UW-21):	0.237 in (0.237 in min)
PWHT performed:	No

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 203.81 psi @ 250 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
0.7038	0.7372	0.4858	0.2015	--	--	0.0499	0.1708	0.2074

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1659	0.175	weld size is adequate

NPS 3" (N1)

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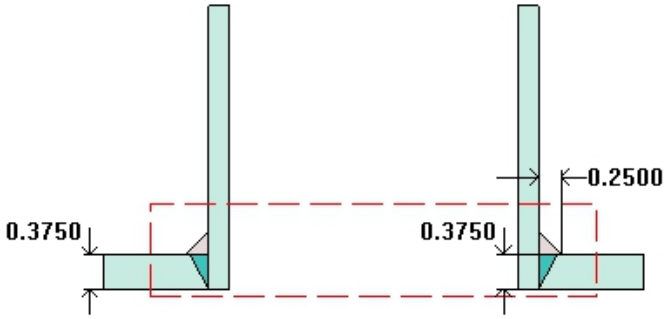
$t_{w(lower)}$ = 0.375 in
Leg_{41} = 0.25 in



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

Location and Orientation

Located on:	Shell
Orientation:	120°
Nozzle center line offset to datum line:	2.375 in
End of nozzle to shell center:	21 in
Passes through a Category A joint:	No

Nozzle

Access opening:	No
Material specification:	SA-106 B Smls pipe (II-D p. 10, ln. 40)
Description:	NPS 3 Sch 40 (Std)
Inside diameter, new:	3.068 in
Nominal wall thickness:	0.216 in
Corrosion allowance:	0 in
Projection available outside vessel, Lpr:	2.784 in
Projection available outside vessel to flange face, Lf:	3 in
Local vessel minimum thickness:	0.375 in
User input radial limit of reinforcement:	2.375 in
Liquid static head included:	3.827 psi
Longitudinal joint efficiency:	1

ASME B16.5-2009 Flange

Description:	NPS 3 Class 150 SO A105
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 334, ln. 32)
Blind included:	No
Rated MDMT:	-20°F per UCS-66(b)(1)(b)
Liquid static head:	3.7716 psi
MAWP rating:	245 psi @ 250°F
MAP rating:	285 psi @ 70°F
Hydrotest rating:	450 psi @ 70°F

External fillet weld leg (UW-21):	0.3024 in (0.3024 in min)
Internal fillet weld leg (UW-21):	0.216 in (0.216 in min)
PWHT performed:	No

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 203.83 psi @ 250 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
0.5388	0.5462	0.3258	0.1705	--	--	0.0499	0.1708	0.189

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

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

NPS 2.5 (N1)

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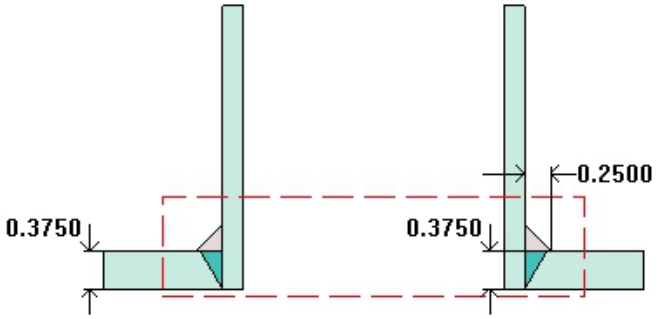
$t_{w(lower)}$ = 0.375 in
Leg_{41} = 0.25 in



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

Location and Orientation

Located on:	Shell
Orientation:	90°
Nozzle center line offset to datum line:	2 in
End of nozzle to shell center:	21 in
Passes through a Category A joint:	No

Nozzle

Access opening:	No
Material specification:	SA-106 B Smls pipe (II-D p. 10, ln. 40)
Description:	NPS 2.5 Sch 40 (Std)
Inside diameter, new:	2.469 in
Nominal wall thickness:	0.203 in
Corrosion allowance:	0 in
Projection available outside vessel, Lpr:	2.797 in
Projection available outside vessel to flange face, Lf:	3 in
Local vessel minimum thickness:	0.375 in
User input radial limit of reinforcement:	2 in
Liquid static head included:	3.8297 psi
Longitudinal joint efficiency:	1

ASME B16.5-2009 Flange

Description:	NPS 2.5 Class 150 SO A105
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 334, ln. 32)
Blind included:	No
Rated MDMT:	-20°F per UCS-66(b)(1)(b)
Liquid static head:	3.7851 psi
MAWP rating:	245 psi @ 250°F
MAP rating:	285 psi @ 70°F
Hydrotest rating:	450 psi @ 70°F

External fillet weld leg (UW-21):	0.2842 in (0.2842 in min)
Internal fillet weld leg (UW-21):	0.203 in (0.203 in min)
PWHT performed:	No

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 203.83 psi @ 250 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
0.4356	0.4985	0.296	0.1526	--	--	0.0499	0.1708	0.1776

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1421	0.175	weld size is adequate

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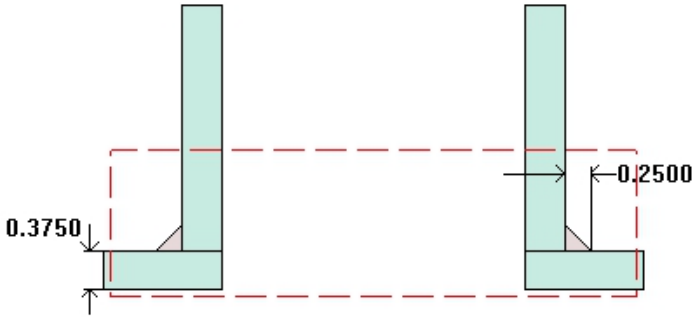
$t_{w(lower)}$ = 0 in
Leg_{41} = 0.25 in



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

Location and Orientation

Located on:	Shell
Orientation:	60°
Nozzle center line offset to datum line:	2.5 in
End of nozzle to shell center:	19 in
Passes through a Category A joint:	No

Nozzle

Access opening:	No
Material specification:	SA-105 (II-D p. 18, ln. 5)
Description:	NPS 2.5 Class 3000 - threaded
Inside diameter, new:	2.875 in
Nominal wall thickness:	0.375 in
Corrosion allowance:	0 in
Projection available outside vessel, Lpr:	1 in
Local vessel minimum thickness:	0.375 in
User input radial limit of reinforcement:	2.5 in
Liquid static head included:	3.819 psi
Longitudinal joint efficiency:	1

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 203.82 psi @ 250 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
0.491	0.4923	0.4339	--	--	--	0.0584	0.0938	0.375

UG-41 Weld Failure Path Analysis Summary (lb_f) All failure paths are stronger than the applicable weld loads				
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength
4,499.97	1,249.76	40,752.35	7,268.51	13,950.63

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1708	0.175	weld size is adequate

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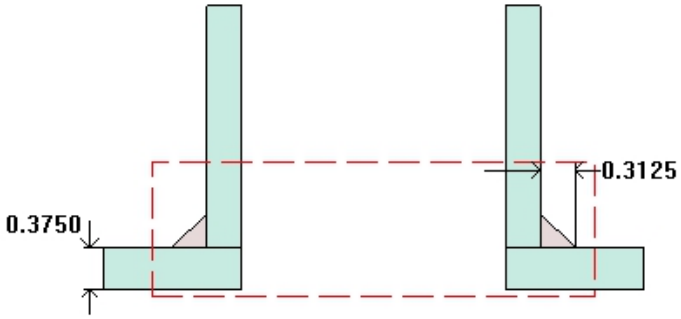
$t_{w(lower)}$ = 0 in
Leg_{41} = 0.3125 in



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

Location and Orientation

Located on:	Shell
Orientation:	20°
Nozzle center line offset to datum line:	2 in
End of nozzle to shell center:	19 in
Passes through a Category A joint:	No

Nozzle

Access opening:	No
Material specification:	SA-105 (II-D p. 18, ln. 5)
Description:	NPS 2 Class 3000 - threaded
Inside diameter, new:	2.375 in
Nominal wall thickness:	0.3125 in
Corrosion allowance:	0 in
Projection available outside vessel, Lpr:	1 in
Local vessel minimum thickness:	0.375 in
User input radial limit of reinforcement:	2 in
Liquid static head included:	3.828 psi
Longitudinal joint efficiency:	1

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 203.83 psi @ 250 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
0.4056	0.4231	0.3318	--	--	--	0.0913	0.0938	0.3125

UG-41 Weld Failure Path Analysis Summary (lb_f) All failure paths are stronger than the applicable weld loads				
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength
4,311.19	1,953.82	32,900.82	6,969.45	14,431.69

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1708	0.2188	weld size is adequate

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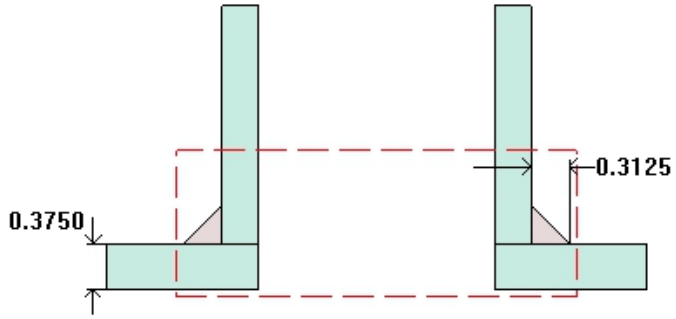
$t_{w(lower)}$ = 0 in
Leg_{41} = 0.3125 in



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

Location and Orientation

Located on:	Shell
Orientation:	340°
Nozzle center line offset to datum line:	1.625 in
End of nozzle to shell center:	19 in
Passes through a Category A joint:	No

Nozzle

Access opening:	No
Material specification:	SA-105 (II-D p. 18, ln. 5)
Description:	NPS 1.5 Class 3000 - threaded
Inside diameter, new:	1.9 in
Nominal wall thickness:	0.3 in
Corrosion allowance:	0 in
Projection available outside vessel, Lpr:	1 in
Local vessel minimum thickness:	0.375 in
User input radial limit of reinforcement:	1.625 in
Liquid static head included:	3.8329 psi
Longitudinal joint efficiency:	1

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 203.83 psi @ 250 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
0.3245	0.367	0.2757	--	--	--	0.0913	0.0938	0.3

UG-41 Weld Failure Path Analysis Summary (lb_f) All failure paths are stronger than the applicable weld loads				
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength
3,666.68	1,953.82	26,540.57	6,768.82	12,026.41

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1708	0.2188	weld size is adequate

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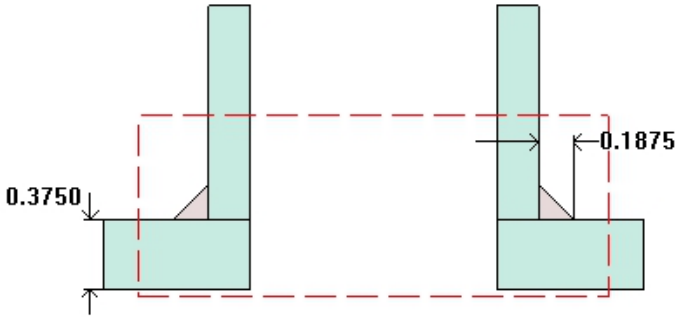
$t_{w(lower)}$ = 0 in
Leg_{41} = 0.1875 in



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

Location and Orientation

Located on:	Shell
Orientation:	300°
Nozzle center line offset to datum line:	1.25 in
End of nozzle to shell center:	19 in
Passes through a Category A joint:	No

Nozzle

Access opening:	No
Material specification:	SA-105 (II-D p. 18, ln. 5)
Description:	NPS 1 Class 3000 - threaded
Inside diameter, new:	1.315 in
Nominal wall thickness:	0.2175 in
Corrosion allowance:	0 in
Projection available outside vessel, Lpr:	1 in
Local vessel minimum thickness:	0.375 in
User input radial limit of reinforcement:	1.25 in
Liquid static head included:	3.8359 psi
Longitudinal joint efficiency:	1

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 203.84 psi @ 250 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
0.2246	0.2749	0.242	--	--	--	0.0329	0.0938	0.2175

UG-41 Weld Failure Path Analysis Summary (lb_f) All failure paths are stronger than the applicable weld loads				
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength
1,528.58	704.06	12,381.15	4,194.93	5,051.09

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1268	0.1312	weld size is adequate

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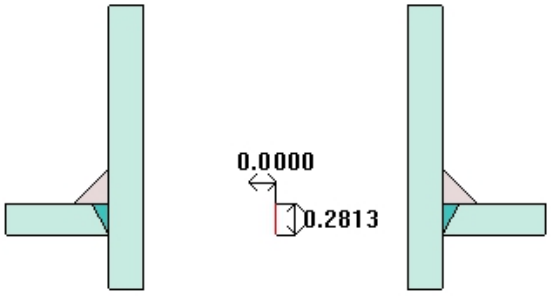
$t_{w(lower)}$ = 0.2813 in
Leg_{41} = 0.3125 in
Leg_{43} = 0 in
h_{new} = 0.5 in



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

Location and Orientation

Located on:	Ellipsoidal Head, Bottom
Orientation:	270°
End of nozzle to datum line:	-8.7452 in
Calculated as hillside:	Yes
Distance to head center, R:	15.5 in
Passes through a Category A joint:	No

Nozzle

Access opening:	No
Material specification:	SA-105 (II-D p. 18, ln. 5)
Description:	NPS 2 Class 3000 - threaded
Inside diameter, new:	2.375 in
Nominal wall thickness:	0.3125 in
Corrosion allowance:	0 in
Opening chord length:	3.2247 in
Projection available outside vessel, Lpr:	1 in
Internal projection, h_{new}:	0.5 in
Local vessel minimum thickness:	0.2813 in
Liquid static head included:	4.1628 psi
Longitudinal joint efficiency:	1

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 204.16 psi @ 250 °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)							0.0938	0.3125

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})	0.1968	0.2188	weld size is adequate

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

1.5" CL 3000 (N3)

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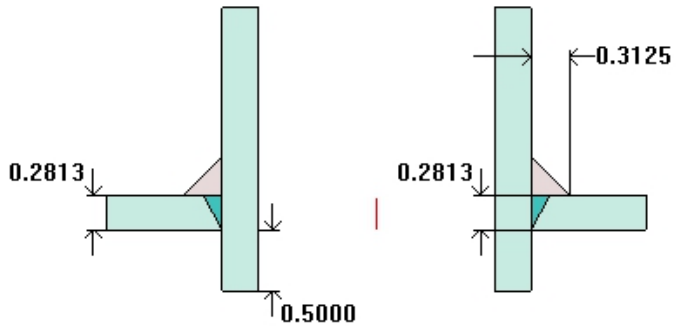

$t_{w(lower)}$ = 0.2813 in
Leg_{41} = 0.3125 in
Leg_{43} = 0 in
h_{new} = 0.5 in

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

Location and Orientation

Located on:	Ellipsoidal Head, Bottom
Orientation:	0°
End of nozzle to datum line:	-8.5845 in
Calculated as hillside:	Yes
Distance to head center, R:	15.5 in
Passes through a Category A joint:	No

Nozzle

Access opening:	No
Material specification:	SA-105 (II-D p. 18, ln. 5)
Description:	NPS 1.5 Class 3000 - threaded
Inside diameter, new:	1.9 in
Nominal wall thickness:	0.3 in
Corrosion allowance:	0 in
Opening chord length:	2.5617 in
Projection available outside vessel, Lpr:	1 in
Internal projection, h_{new}:	0.5 in
Local vessel minimum thickness:	0.2813 in
Liquid static head included:	4.157 psi
Longitudinal joint efficiency:	1

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 204.16 psi @ 250 °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)							0.0938	0.3

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})	0.1968	0.2188	weld size is adequate

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

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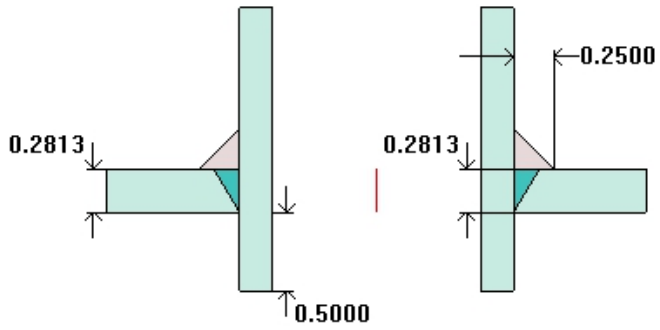


$t_{w(lower)}$ = 0.2813 in
Leg_{41} = 0.25 in
Leg_{43} = 0 in
h_{new} = 0.5 in

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

Location and Orientation

Located on:	Ellipsoidal Head, Bottom
Orientation:	180°
End of nozzle to datum line:	-8.3286 in
Calculated as hillside:	Yes
Distance to head center, R:	15.5 in
Passes through a Category A joint:	No

Nozzle

Access opening:	No
Material specification:	SA-105 (II-D p. 18, ln. 5)
Description:	NPS 1 Class 3000 - threaded
Inside diameter, new:	1.315 in
Nominal wall thickness:	0.2175 in
Corrosion allowance:	0 in
Opening chord length:	1.7625 in
Projection available outside vessel, Lpr:	1 in
Internal projection, h_{new}:	0.5 in
Local vessel minimum thickness:	0.2813 in
Liquid static head included:	4.1478 psi
Longitudinal joint efficiency:	1

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 204.15 psi @ 250 °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)							0.0938	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})	0.1522	0.175	weld size is adequate

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

Wind Code
Seismic Code

Commentary for Wind Code:
Wind calculated for highest location value.
Back to top

Commentary for Seismic Code:
Seismic calculated for highest location value.
Back to top

Wind Code

Building Code:	**NBC Canada 2005**
Elevation of base above grade:	0.0000 ft (0.0000 m)
Increase effective outer diameter by:	0.0000 ft (0.0000 m)
Pressure Coefficient, C_p:	0.5400
Reference Wind Pressure, q:	0.1523 psi (1.0500 kPa)
Exposure category:	B
Importance Factor, Iw:	1.0000
Location:	Cape Race, NewFoundLand

Vessel Characteristics

Vessel height, H:	11.0959 ft (3.3820 m)
Vessel Minimum Diameter, w	
Operating, Corroded:	3.0000 ft (0.9144 m)
Empty, Corroded:	3.0000 ft (0.9144 m)
Fundamental Frequency, N_0	
Operating, Corroded:	33.1581 Hz
Empty, Corroded:	64.6481 Hz
Critical damping ratio, β	
Operating, Corroded:	0.0248
Empty, Corroded:	0.0200

See Component Commentary

Wind Deflection Reports:

Operating, Corroded
Empty, Corroded
Wind Pressure Calculations

Wind Deflection Report: Operating, Corroded

Component	Elevation of bottom above base (in)	Effective OD (ft)	Elastic modulus E (10^6 psi)	Inertia I (ft^4)	Platform wind shear at Bottom (lbf)	Total wind shear at Bottom (lbf)	bending moment at Bottom (lbf-ft)	Deflection at top (in)
Ellipsoidal Head, Top	122.01	3.00	28.3	*	0	48	19	0.0016
Shell	26.01	3.00	28.3	0.3211	0	548	2,489	0.0014
Ellipsoidal Head, Bottom (top)	24	3.00	28.3	*	0	559	2,581	0.0001
Support Skirt	0	3.03	28.5	0.1683	0	685	3,821	0.0001
*Moment of Inertia I varies over the length of the component								

Wind Deflection Report: Empty, Corroded

Component	Elevation of bottom above base (in)	Effective OD (ft)	Elastic modulus E (10^6 psi)	Inertia I (ft^4)	Platform wind shear at Bottom (lbf)	Total wind shear at Bottom (lbf)	bending moment at Bottom (lbf-ft)	Deflection at top (in)
Ellipsoidal Head, Top	122.01	3.00	29.2	*	0	48	19	0.0015
Shell	26.01	3.00	29.2	0.3211	0	546	2,481	0.0014
Ellipsoidal Head, Bottom (top)	24	3.00	29.2	*	0	557	2,573	0.0001
Support Skirt	0	3.03	29.4	0.1683	0	683	3,809	0.0001
*Moment of Inertia I varies over the length of the component								

Wind Pressure (WP) Calculations

Gust Factor (Cg) Calculations

$WP = I_w * q * C_e * C_g * C_p$
$= 1.0000 * 0.5670 * C_e * C_g$
For computation of C_e, see NBC 2005 Structural Commentaries (Part 4 of Div. B), Dynamic Procedure, Exposure Factor, C_e (page I-24, (7)-(9)).

Design Wind Pressures

Height Z (m)	C_e	WP: Operating (psf)	WP: Empty (psf)	WP: Hydrotest New (psf)	WP: Hydrotest Corroded (psf)	WP: Vacuum (psf)
3	0.5000	20.8485	20.7806	N.A.	N.A.	20.8485
6	0.5000	20.8485	20.7806	N.A.	N.A.	20.8485

Gust Factor (Cg) Calculations

Operating, Corroded
Empty, Corroded

Gust Factor Calculations: Operating, Corroded

Background Turbulence Factor:	B = 1.7643	[Commentary, Figure I-18]
Surface Roughness Factor:	K = 0.1000	
Factor C_e at vessel top:	C_{eH} = 0.5000	[Commentary, Figure I-17]

$V^- = Sqr(q / 0.00065) = 40.1919$

$V_H = V^- * Sqr(C_{eH})$ = 28.4200

Size Reduction Factor s from Commentary, Figure I-19:

$s = pi / [3 * \{1 + (8 * N_\theta * H)/(3 * V_H)\} * \{1 + (10 * N_\theta * w)/V_H\}]$
$= pi / [3 * \{1 + (8 * 33.1581 * 3.3820)/(3 * 28.4200)\} * \{1 + (10 * 33.1581 * 0.9144)/28.4200\}]$
$= 0.0078$

Gust Energy Ratio from Commentary, Figure I-20:

$X_0 = 1220 * N_\theta / V_H$
$= 1220 * 33.1581 / 28.4200$
$= 1,423.3954$

$F = X_0^2 / (1 + X_0^2)^{4/3}$
$= 0.0079$

$sigma/mu = Sqr((K / C_{eH}) * (B + s * F / \beta))$
$= Sqr((0.1000 / 0.5000) * (1.7643 + 0.0078 * 0.0079 / 0.0248))$
$= 0.5944$

$nu = N_\theta * Sqr(s*F / (s*F + \beta*B))$
$= 33.1581 * Sqr(0.0078*0.0079 / (0.0078*0.0079 + 0.0248*1.7643))$
$= 1.2434$

$g_p = Sqr(2*ln(3600 * nu)) + 0.577 / Sqr(2*ln(3600 * nu))$
$= Sqr(2*ln(3600 * 1.2434)) + 0.577 / Sqr(2*ln(3600 * 1.2434))$
$= 4.2411$

$C_g = 1 + g_p * sigma/mu$
$= 1 + 4.2411 * 0.5944$
$= 3.5211$

Gust Factor Calculations: Empty, Corroded

Background Turbulence Factor:	B = 1.7643	[Commentary, Figure I-18]
Surface Roughness Factor:	K = 0.1000	
Factor C_e at vessel top:	C_{eH} = 0.5000	[Commentary, Figure I-17]

$V^- = Sqr(q / 0.00065)$ = 40.1919
$V_H = V^- * Sqr(C_{eH})$ = 28.4200

Size Reduction Factor s from Commentary, Figure I-19:

$s = pi / [3 * \{1 + (8 * N_\theta * H)/(3 * V_H)\} * \{1 + (10 * N_\theta * w)/V_H\}]$
$= pi / [3 * \{1 + (8 * 64.6481 * 3.3820)/(3 * 28.4200)\} * \{1 + (10 * 64.6481 * 0.9144)/28.4200\}]$
$= 0.0022$

Gust Energy Ratio from Commentary, Figure I-20:

$X_0 = 1220 * N_\theta / V_H$
$= 1220 * 64.6481 / 28.4200$
$= 2,775.1865$

$F = X_0^2 / (1 + X_0^2)^{4/3}$
$= 0.0051$

$sigma/mu = Sqr((K / C_{eH}) * (B + s * F / \beta))$
$= Sqr((0.1000 / 0.5000) * (1.7643 + 0.0022 * 0.0051 / 0.0200))$

= 0.5941

nu = N_o * Sqr(s*F / (s*F + β*B))

= 64.6481 * Sqr(0.0022*0.0051 / (0.0022*0.0051 + 0.0200*1.7643))

= 1.1570

g_p = Sqr(2*ln(3600 * nu)) + 0.577 / Sqr(2*ln(3600 * nu))

= Sqr(2*ln(3600 * 1.1570)) + 0.577 / Sqr(2*ln(3600 * 1.1570))

= 4.2241

C_g = 1 + g_p * sigma/mu

= 1 + 4.2241 * 0.5941

= 3.5096

Seismic Code

Method of seismic analysis:	**NBC Canada 2005**
Importance Factor:	$I_E = 1.0000$
Location:	La-Malbaie, Quebec
5% Damped Spectral Response Accel. at T = 0.2s	$S_a(0.2) = 2.3000$
5% Damped Spectral Response Accel. at T = 0.5s	$S_a(0.5) = 1.2000$
5% Damped Spectral Response Accel. at T = 1.0s	$S_a(1.0) = 0.6000$
5% Damped Spectral Response Accel. at T = 2.0s	$S_a(2.0) = 0.1900$
Site Class:	C
Acceleration-based Site Coefficient:	$F_a = 1.0000$
Velocity-based Site Coefficient:	$F_v = 1.0000$
Ductility-related force modification factor:	$R_d = 1.0000$
Overstrength-related force modification factor:	$R_o = 1.0000$
Vertical Accelerations Considered:	No

See Component Commentary

Vessel Characteristics

Vessel height: 11.0959 ft
Vessel Weight:
Operating, Corroded: 5,568 lb
Empty, Corroded: 1,617 lb

Period of Vibration Calculation

Fundamental Period, T:
Operating, Corroded: 0.030 sec (f = 33.2 Hz)
Empty, Corroded: 0.015 sec (f = 64.6 Hz)

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

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

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

Seismic Shear Reports:

Operating, Corroded
Empty, Corroded
Base Shear Calculations

Seismic Shear Report: Operating, Corroded

Component	Elevation of bottom above base (in)	Elastic modulus E (10^6 psi)	Inertia I (ft^4)	Seismic shear at Bottom (lbf)	Bending Moment at Bottom (lbf-ft)
Ellipsoidal Head, Top	122.01	28.3	*	1,124	444
Shell	26.01	28.3	0.3211	8,256	44,051
Ellipsoidal Head, Bottom (top)	24	28.3	*	8,307	45,438
Support Skirt	0	28.5	0.1683	8,538	62,409
*Moment of Inertia I varies over the length of the component					

Seismic Shear Report: Empty, Corroded

Component	Elevation of bottom above base (in)	Elastic modulus E (10^6 psi)	Inertia I (ft^4)	Seismic shear at Bottom (lbf)	Bending Moment at Bottom (lbf-ft)
Ellipsoidal Head, Top	122.01	29.2	*	398	187
Shell	26.01	29.2	0.3211	2,350	12,790
Ellipsoidal Head, Bottom (top)	24	29.2	*	2,364	13,184
Support Skirt	0	29.4	0.1683	2,480	18,070
*Moment of Inertia I varies over the length of the component					

Base Shear Calculations

Operating, Corroded
Empty, Corroded

Base Shear Calculations: Operating, Corroded

Fundamental Period computed by Rayleigh approximation: 0.030
The design spectral response acceleration, $S(T_a)$ per 4.1.8.4.(6): 2.3000
Higher mode factor, M_v per 4.1.8.11.(5): 1.0000

$V = 2/3 * S(T_a) * M_v * I_E * W / (R_d * R_o)$
$= 2/3 * 2.3000 * 1.0000 * 1.0000 * 5,568.4429 / (1.0000 * 1.0000)$
$= 8,538.2793$ lb

Per 4.1.8.11.(2), the minimum lateral earthquake force, V, shall be no less than V_{min}:

$V_{min} = 2/3 * S(2.0) * M_v * I_E * W / (R_d * R_o)$
$= 2/3 * 0.1900 * 1.0000 * 1.0000 * 5,568.4429 / (1.0000 * 1.0000)$
$= 705.34$ lb

$V = 8,538.28$ lb

Base Shear Calculations: Empty, Corroded

Fundamental Period computed by Rayleigh approximation: 0.015
The design spectral response acceleration, $S(T_a)$ per 4.1.8.4.(6): 2.3000
Higher mode factor, M_v per 4.1.8.11.(5): 1.0000

$V = 2/3 * S(T_a) * M_v * I_E * W / (R_d * R_o)$
$= 2/3 * 2.3000 * 1.0000 * 1.0000 * 1,617.2814 / (1.0000 * 1.0000)$

= 2,479.8315 lb

Per 4.1.8.11.(2), the minimum lateral earthquake force, V, shall be no less than V_{min}:

V_{min} = 2/3 * S(2.0) * M_v * I_E * W / (R_d * R_o)
= 2/3 * 0.1900 * 1.0000 * 1.0000 * 1,617.2814 / (1.0000 * 1.0000)
= 204.8557 lb

V = 2,479.83 lb

Support Skirt

Material:		SA-36 (II-D p. 10, ln. 15)
Design temperature, operating:	250	°F
Inner diameter at top, new:	36	in
Inner diameter at bottom, new:	36	in
Overall length (includes base ring thickness):	24	in
Corrosion allowance inside:	0	in
Corrosion allowance outside:	0	in
Weld joint efficiency top:	0.55	
Weld joint efficiency bottom:	0.8	
Nominal thickness, new:	0.1875	in
Skirt is attached to:		Ellipsoidal Head, Bottom
Skirt attachment offset:	2.01	in down from the top seam

Skirt design thickness, largest of the following + corrosion = 0.0588 in

The governing condition is due to earthquake, compressive stress at the base, operating & corroded.

The skirt thickness of 0.1875 in is adequate.

Loading	Vessel Condition (Stress)	Governing Skirt Location	Temperature (°F)	Allowable Stress (psi)	Calculated Stress/E (psi)	Required thickness (in)
Wind	operating, corroded (+)	top	250	13,226.29	-94.02	0.0013
Wind	operating, corroded (-)	bottom	250	13,226.29	499	0.0071
Wind	empty, corroded (+)	bottom	70	16,600	201.45	0.0023
Wind	empty, corroded (-)	bottom	70	13,226.29	312.9	0.0044
Seismic	operating, corroded (+)	top	250	16,600	4,670.52	0.0528
Seismic	operating, corroded (-)	bottom	250	13,226.29	4,144.66	0.0588
Seismic	empty, corroded (+)	top	70	16,600	1,362.16	0.0154
Seismic	empty, corroded (-)	bottom	70	13,226.29	1,200.31	0.017

Loading due to earthquake, operating & corroded

Tensile side

Required thickness, tensile stress at base:

$$t = -W / (\pi * D * S_t * E) + 48 * M / (\pi * D^2 * S_t * E)$$
$$= -5{,}568.07 / (\pi * 36.1875 * 16{,}600 * 0.8) + 48 * 62{,}408.7 / (\pi * 36.1875^2 * 16{,}600 * 0.8)$$
$$= 0.0511 \text{ in}$$

Required thickness, tensile stress at the top:

$$t = -W_t / (\pi * D_t * S_t * E) + 48 * M_t / (\pi * D_t^2 * S_t * E)$$
$$= -5{,}423.29 / (\pi * 36.1875 * 16{,}600 * 0.55) + 48 * 45{,}370.1 / (\pi * 36.1875^2 * 16{,}600 * 0.55)$$
$$= 0.0528 \text{ in}$$

Compressive side

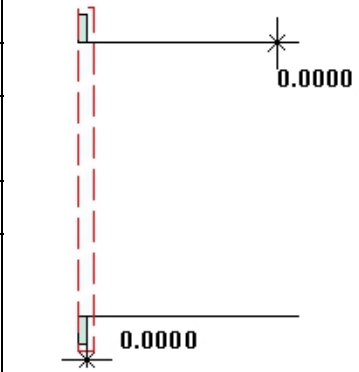
Required thickness, compressive stress at base:

$t = W / (\pi * D * S_c * E_c) + 48 * M / (\pi * D^2 * S_c * E_c)$
$= 5{,}568.07 / (\pi * 36.1875 * 13{,}226 * 1) + 48 * 62{,}408.7 / (\pi * 36.1875^2 * 13{,}226 * 1)$
$= 0.0588$ in

Required thickness, compressive stress at the top:

$t = W_t / (\pi * D_t * S_c * E_c) + 48 * M_t / (\pi * D_t^2 * S_c * E_c)$
$= 5{,}423.29 / (\pi * 36.1875 * 13{,}226 * 1) + 48 * 45{,}370.1 / (\pi * 36.1875^2 * 13{,}226 * 1)$
$= 0.0436$ in

Skirt Opening 1 (SO 1)

ASME Section VIII, Division 2, 2010 Edition, A11 Addenda			
Component		Skirt Opening	
Description		Skirt Opening 1	
Drawing Mark		SO 1	
Sleeve Material		SA-106 B Smls pipe (II-D p. 10, ln. 40)	
Location and Orientation			
Attached to		Support Skirt	
Orientation		radial	
Offset, L		6"	
Angle, θ		0°	
Distance, r		18.2"	
Through a Category B Joint		No	
Dimensions			
Inside Diameter		6"	
Nominal Wall Thickness		0.0625"	
Skirt Thickness		0.1875"	
External Projection Available, L_{pr1}		0.1875"	
Corrosion	**Inner**	0"	
	Outer	0"	

Skirt Opening Reinforcement Summary							
			Required Thickness t_r (in)	A_T (in^2)	A_r (in^2)	Ratio	Status
Operating Hot & Corroded	Wind	Tensile	0	0.5362	0	N/A	OK
		Compressive	0.0068	0.5175	0.0407	12.7307	OK
	Seismic	Tensile	0.0379	0.5917	0.2276	2.5992	OK
		Compressive	0.055	0.3847	0.3298	1.1664	OK
Empty Cold & Corroded	Wind	Tensile	0.0016	0.7296	0.0097	74.9875	OK
		Compressive	0.0041	0.5248	0.0248	21.1365	OK
	Seismic	Tensile	0.011	0.694	0.066	10.5169	OK
		Compressive	0.0159	0.4924	0.0954	5.1591	OK

Note: Skirt required thickness of zero on tensile side indicates load is compressive.

Saddle

Saddle material:			SA-36
Saddle construction is:			Web at edge of rib
Saddle allowable stress:	S_s =	16,600	psi
Saddle yield stress:	S_y =	36,000	psi
Saddle distance to datum:		6.625	in
Tangent to tangent length:	L =	100	in
Saddle separation:	L_s =	82.75	in
Vessel radius:	R =	18	in
Tangent distance left:	A_l =	8.625	in
Tangent distance right:	A_r =	8.625	in
Saddle height:	H_s =	30	in
Saddle contact angle:	θ =	120	°
Wind pressure:		21.9297	psf
Web plate thickness:	t_s =	0.375	in
Base plate length:	E =	31.18	in
Base plate width:	F =	4	in
Base plate thickness:	t_b =	0.375	in
Number of stiffener ribs:	n =	4	
Largest stiffener rib spacing:	d_i =	9.9767	in
Stiffener rib thickness:	t_w =	0.25	in
Saddle width:	B =	4	in
Anchor bolt size & type:			0.625 inch series 8 threaded
Anchor bolt material:			
Anchor bolt allowable shear:		15,000	psi
Anchor bolt corrosion allowance:		0	in
Anchor bolts per saddle:		2	
Base coefficient of friction:	μ =	0.45	

Weight on left saddle: operating corr = 2,680 lb, test new = 2,680 lb
Weight on right saddle: operating corr = 2,680 lb, test new = 2,680 lb
Weight of saddle pair = 156 lb

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

Seismic base shear on vessel

Vessel is assumed to be a rigid structure.

Method of seismic analysis:		NBC Canada 2005
Vertical seismic accelerations considered:		No
Importance factor:	I_E =	1
Spectral response acceleration value at 0.2 s:	$S_a(0.2)$ =	2.3
Acceleration based site coefficient:	F_a =	1
Response modification factor:	R_p =	1
Seismic coefficient:	C_p =	1
Response factor:	A_r =	1
Vessel elevation:	h_x =	0 in
Structure total height:	h_n =	0 in

Weight on Saddle: W_p = 5,360 lb_f

Vessel is at $h_x = 0$ therefore $A_x = 1$

$S_p = \min[C_p*A_r*A_x / R_p , 4]$
$= \min[1*1*1 / 1 , 4]$
$= 1$

$V_p = 0.3*F_a*S_a(0.2)*I_E*S_p*W_p$
$= 0.3*1*2.3*1*1*5,360$
$= 3,698.4\ lb_f$

Saddle reactions due to weight + seismic

V_v = vertical seismic force acting on right saddle
V = horizontal seismic shear acting on right saddle (worst case if not slotted)

Seismic longitudinal reaction, Q_l (right saddle):

$Q_l = V*H_s / L_s + V_v$
$= 3,698.4*30 / 82.75 + 0$
$= 1,340.81\ lb_f$

Seismic transverse reaction, Q_t (right saddle):

$Q_t = V*H_s / (R_o*\text{Sin}(\theta / 2)) + V_v$
$= 1,849.2*30 / (18*\text{Sin}(120 / 2)) + 0$
$= 3,558.79\ lb_f$

Q = Weight on saddle + larger of Q_t or Q_l
$Q = W + Q_t = 2,680 + 3,558.79 = 6,238.79\ lb_f$

Transverse wind shear on vessel

$V_{wt} = P_w*G*(C_{f(shell)}*(\text{Projected shell area}) + C_{f(saddle)}*(\text{Projected saddle area}))$
$= 21.93*0.85*(0.54*28.5343 + 2*0.6667)$
$= 312.07\ lb_f$

End wind shear on vessel

$V_{we} = P_w*G*(C_{f(shell)}*\pi*R_o^2 / 144 + C_{f(saddle)}*(\text{Projected saddle area}))$
$= 21.93*0.85*(0.5*\pi*18^2 / 144 + 2*3.25)$
$= 186.9\ lb_f$

Load	Vessel condition	Bending + pressure between saddles (psi)				Bending + pressure at the saddle (psi)			
		S_1 (+)	allow (+)	S_1 (-)	allow (-)	S_2 (+)	allow (+)	S_2 (-)	allow (-)
Seismic	Operating	7,020	25,680	246	22,430	6,778	25,680	4	22,430
Wind	Operating	6,892	25,680	117	22,430	6,778	25,680	4	22,430
Wind	Test	8,809	40,500	110	22,430	8,703	40,500	4	22,430

Load	Vessel condition	Tangential shear (psi)		Circumferential stress (psi)		Stress over saddle (psi)		Splitting (psi)	
		S_3	allow	S_4 (horns)	allow (+/-)	S_5	allow	S_6	allow
Seismic	Operating	1,096	17,120	-1,768	32,100	2,857	18,000	564	11,067
Wind	Operating	523	17,120	-845	32,100	1,365	18,000	270	11,067
Wind	Test	488	32,400	-788	40,500	1,272	32,400	251	32,400

Longitudinal stress between saddles (Seismic ,Operating, right saddle loading and geometry govern)

$S_1 = +- 3*K_1*Q*(L / 12) / (\pi*R^2*t)$
$= 3*0.5892*6,238.79*(100 / 12) / (\pi*17.8125^2*0.375)$
$= 246$ psi

$S_p = P*R / (2*t)$
$= 288.27*17.625 / (2*0.375)$
$= 6,774$ psi

Maximum tensile stress $S_{1t} = S_1 + S_p = 7,020$ psi
Maximum compressive stress (shut down) $S_{1c} = S_1 = 246$ psi

Tensile stress is acceptable (<=1.2*S*E = 25,680 psi)
Compressive stress is acceptable (<=1.2*S_c = 22,430 psi)

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

$S_3 = K_{2.3}*Q / (R*(t))$
$= 0.8799*6,238.79 / (17.8125*(0.375))$
$= 822$ psi

Tangential shear stress is acceptable (<= 0.8*S = 17,120 psi)

Tangential shear stress in the right head (Seismic ,Operating)

$S_3 = K_{2.3}*Q / (R*t_h)$
$= 0.8799*6,238.79 / (17.8125*0.2813)$
$= 1,096$ psi

Tangential shear stress is acceptable (<= 0.8*S = 17,120 psi)

Additional stress in the head used as a stiffener

$S_{3h} = K_{2.4}*Q / (R*t_h)$
$= 0.4011*6{,}238.79 / (17.8125*0.2813)$
$= 500$ psi

$S_p = P*(K*D_i + 0.2*t_h) / (2*t_h)$
$= 288.27*(1*35.4374 + 0.2*0.2813) / (2*0.2813)$
$= 18{,}187$ psi

Total stress in the head = $S_{3h} + S_p = 18{,}689$ psi

Stress in the head is acceptable (<= $1.25*S_h = 26{,}750$ psi)

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

$S_4 = -Q / (4*t*(b+1.56*Sqr(R_o*t))) - 12*K_3*Q*R / (L*t^2)$
$= -6{,}238.79 / (4*0.375*(4+1.56*Sqr(18*0.375))) - 12*0.0132*6{,}238.79*17.8125 / (100*0.375^2)$
$= -1{,}768$ psi

Circumferential stress at saddle horns is acceptable (<=$1.5*S_a = 32{,}100$ psi)

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

$S_5 = K_5*Q / ((t)*(t_s + 1.56*Sqr(R_o*t_c)))$
$= 0.7603*6{,}238.79 / ((0.375)*(0.375 + 1.56*Sqr(18*0.375)))$
$= 2{,}857$ psi

Ring compression in shell is acceptable (<= $0.5*S_y = 18{,}000$ psi)

Saddle splitting load (right, Seismic ,Operating)

Area resisting splitting force = Web area + wear plate area

$A_e = H_{eff}*t_s + t_p*W_p$
$= 6*0.375 + 0*0$
$= 2.25$ in^2

$S_6 = K_8*Q / A_e$
$= 0.2035*6{,}238.79 / 2.25$
$= 564$ psi

Stress in saddle is acceptable (<= $(2 / 3)*S_s = 11{,}067$ psi)

Longitudinal stress at the left saddle (Wind ,Operating)

L_e = 2*(Left head depth) / 3 + L + 2*(Right head depth) / 3
$= 2*9.1407 / 3 + 100 + 2*9.1406 / 3$
$= 112.1875$ in

$w = W_t / L_e = 5{,}360 / 112.1875 = 47.78$ lb$_f$/in

Bending moment at the left saddle:

$M_q = w*(2*H*A_l / 3 + A_l^2 / 2 - (R^2 - H^2) / 4)$
$= 47.78*(2*9.1407*8.625 / 3 + 8.625^2 / 2 - (18^2 - 9.1407^2) / 4)$
$= 1{,}416.2$ lb$_f$-in

S_2 = +- M_q*K_1' / (π*R^2*t)
= 1,416.2*1 / (π*17.8125^2*0.375)
= 4 psi

S_p = P*R / (2*t)
= 288.27*17.625 / (2*0.375)
= 6,774 psi

Maximum tensile stress S_{2t} = S_2 + S_p = 6,778 psi
Maximum compressive stress (shut down) S_{2c} = S_2 = 4 psi

Tensile stress is acceptable (<=1.2*S = 25,680 psi)
Compressive stress is acceptable (<=1.2*S_c = 22,430 psi)

Shear stress in anchor bolting, one end slotted

Maximum seismic or wind base shear = 3,698.4 lb_f

Thermal expansion base shear = W*μ = 2,758*0.45 = 1,241.1 lb_f
Corroded root area for a 0.625 inch series 8 threaded bolt = 0.202 in^2 (2 per saddle)

Bolt shear stress = 3,698.4 / (0.202*1*2) = 9,154 psi

Anchor bolt stress is acceptable (<= 15,000 psi)

Shear stress in anchor bolting, transverse

Maximum seismic or wind base shear = 3,698.4 lb_f
Corroded root area for a 0.625 inch series 8 threaded bolt = 0.202 in^2 (2 per saddle)

Bolt shear stress = 3,698.4 / (0.202*2*2) = 4,577 psi

Anchor bolt stress is acceptable (<= 15,000 psi)

Web plate buckling check (Escoe pg 251)

Allowable compressive stress S_c is the lesser of 16,600 or 47,400 psi: (16,600)

S_c = K_i*π^2*E / (12*(1 - 0.3^2)*(d_i / t_s)^2)
= 1.28*π^2*29E+06 / (12*(1 - 0.3^2)*(9.9767 / 0.375)^2)
= 47,400 psi

Allowable compressive load on the saddle

b_e = d_i*t_s / (d_i*t_s + 2*t_w*(b - 1))
= 9.9767*0.375 / (9.9767*0.375 + 2*0.25*(4 - 1))
= 0.7138

F_b = n*(A_s + 2*b_e*t_s)*S_c
= 4*(0.9063 + 2*0.7138*0.375)*16,600
= 95,722.67 lb_f

Saddle loading of 6,316.79 lb_f is <= F_b; satisfactory.

Primary bending + axial stress in the saddle due to end loads (assumes one saddle slotted)
σ_b = V*(H_s - x_o)*y / I + Q / A

= 3,698.4*(30 - 14.8859)*3.0593 / 13.08 + 6,238.79 / 15.3163
= 13,482 psi

The primary bending + axial stress in the saddle <= 16,600 psi; satisfactory.

Secondary bending + axial stress in the saddle due to end loads (includes thermal expansion, assumes one saddle slotted)

$\sigma_b = V*(H_s - x_o)*y / I + Q / A$
= 4,939.5*(30 - 14.8859)*3.0593 / 13.08 + 6,238.79 / 15.3163
= 17,870 psi

The secondary bending + axial stress in the saddle < $2*S_y$= 72,000 psi; satisfactory.

Saddle base plate thickness check (Roark sixth edition, Table 26, case 7a)

where a = 9.9767, b = 3.625 in

$t_b = (\beta_1*q*b^2 / (1.5*S_a))^{0.5}$
$= (2.2899*51*3.625^2 / (1.5*16,600))^{0.5}$
= 0.2474 in

The base plate thickness of 0.375 in is adequate.

Foundation bearing check

$S_f = Q_{max} / (F*E)$
= 6,316.79 / (4*31.18)
= 51 psi

Concrete bearing stress ≤ 1,658 psi ; satisfactory.