KBR

KEMPER COUNTY IGCC UNIT 1 PROJECT

SOUTHERN COMPANY

MECHANICAL STRENGTH CALCULATION

ITEM NAME : AGR FLASH GAS COMPRESSOR KO DRUM

(ITEM NO : DR1080 / 2080)

KBR
ACCEPTANCE
FOR ENGINEERING USE

THIS DOCUMENT IS:
ACCEPTED (Code 1) X
ACCEPTED WITH COMMENTS (Code 2)
NOT ACCEPTED (Code 3)
NOT REVIEWED (Code 4)

ACCEPTANCE DOES NOT RELIEVE SUPPLIER FROM FURNISHING MATERIAL IN CONFORMANCE WITH ORDER. REFER TO SDR-1 FOR FULL DEFINITION OF ACCEPTANCE CONDITIONS.

DISCIPLINE VM BY DN
DATE 19-Sep-11

FOR APPROVAL
2011.09.05
SUNG JIN GEOTEC CO., LTD.

ASME

03					
02	REVISED AS COMMENTS	J.S.PARK	~~D.H.HYUN~~	H.C.JUNG	05-Sep-2011
01	REVISED AS COMMENTS	J.S.PARK	J.K.KIM	H.C.JUNG	15-Jun-2011
00	ISSUED FOR APPROVAL	J.S.PARK	J.K.KIM	H.C.JUNG	11-Apr-2011
Rev No.	PURPOSE OF ISSUE	PREPARED	CHECKED	APPROVED	ISSUE DATE

CLIENT	:	Southern Company Services, Inc.
VENDOR	:	SUNGJIN GEOTEC CO., LTD.
PLANT	:	Kemper County
Doc. Title	:	AGR FLASH GAS COMPRESSOR KO DRUM
PO No.	:	MPC17984-0001
SCS No.	:	MM78162
SGT No.	:	SGT11-SP11-DR1080/2080-CAL

MM78162 B

Plant: Kemper County SUNGJIN GEOTECH
Southern Company Generation
SGT11-SP11-DR1080-2080-CAL Rev: 2
PO: MPC17984-0001

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ITEM NO. DR 1080 / 2080

DESIGN DATA

ITEM NO. : DR 1080 / 2080

CODE		**ASME Section VIII Division 1 2007 Edition, A09 Addenda**				
CODE STAMP		YES				
NATIONAL BOARD		YES				
CORROSION ALLOWANCE		0.000	inch	(	0.0	mm)
JOINT EFFICIENCY	(SHELL/HEAD)	1.0 / 1.0				
POST WELD HEAT TREATMENT		NO				
RADIOGRAPHY	(SHELL/HEAD)	FULL / FULL				
PNEUMATIC TEST PRESS		--	[psi G]	(	--	[kg/㎠ G])
HYDRO. TEST PRESSURE (AT SHOP & TOP)		396.50	[psi G]	(	27.88	[kg/㎠ G])
HYDRO. TEST PRESSURE (AT FIELD & TOP)		396.50	[psi G]	(	27.88	[kg/㎠ G])
DESIGN INTERNAL TEMPERATURE		250	°F	(	121.12	℃)
DESIGN EXTERNAL TEMPERATURE		-	°F	(	-	℃)
MIN. DESIGN METAL TEMPERATURE		10	°F	(	-12.23	℃)
DESIGN INTERNAL PRESSURE		305.0	[psi G]	(	21.45	[kg/㎠ G])
DESIGN EXTERNAL PRESSURE		-	[psi G]	(	-	[kg/㎠ G])
OPERATING TEMPERATURE		115	°F	(	46.12	℃)
OPERATING PRESSURE		-	[psi G]	(	-	[kg/㎠ G])
CONTENTS		***				
LIQUID SPECIFIC GRAVITY		1.018				
LENGTH BETWEEN TANGENT LINE		106	inch	(	2692.0	mm)
SHELL INSIDE DIAMETER		29	inch	(	743.0	mm)
TYPE OF HEADS		2:1 ELLIP.				
WIND LOAD		100 mph (ASCE 7-05)				
SEISMIC LOAD		CLASS C (ASCE 7-05)				
INSULATION THICKNESS		2.0	inch	(	50	mm)
FIRE PROOFING THICKNESS		NONE	inch	(	NONE	mm)
VOLUME		337.0	US gal	(	1.28	M^3)

Settings Summary

COMPRESS Build 7110

Units: U.S. Customary

Datum Line Location: -1.97" from bottom seam

Design

ASME Section VIII Division 1, 2007 Edition, A09 Addenda

Design or Rating:	Get Thickness from Pressure
Minimum thickness:	0.0625" per UG-16(b)
Design for cold shut down only:	No
Design for lethal service (full radiography required):	No
Design nozzles for:	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:	5.9055"
Juncture calculations for α > 30 only:	Yes
Preheat P-No 1 Materials > 1.25" and <= 1.50" thick:	Yes
UG-37(a) shell tr calculation considers longitudinal stress:	No

Pipe under-tolerance is not applied to cylindrical shell thicknesses.
Butt welds are tapered per Figure UCS-66.3(a).

Hydro/Pneumatic Test

Shop Hydrotest Pressure:	1.3 times design P
Test liquid specific gravity:	1.00
Field Hydrotest Pressure:	1.3 times design P
Wind load present @ field:	33% of design
Maximum stress during test:	90% of yield

Required Marking - UG-116

UG-116(e) Radiography:	RT1 (user specified, automatic determination deactivated)
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):	Yes
UG-22(d)(2) Vessel supports such as lugs, rings, skirts, saddles and legs:	Yes
UG-22(f) Wind reactions:	Yes
UG-22(f) Seismic reactions:	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.

Pressure Summary

Pressure Summary for Chamber bounded by BTM HEAD and TOP HEAD

Identifier	P Design (psi)	T Design (°F)	MDMT (°F)	MDMT Exemption		Impact Tested
TOP HEAD	305	250	-320		Note 1	No
Straight Flange on TOP HEAD	305	250	-320		Note 2	No
SHELL	305	250	-320		Note 2	No
Straight Flange on BTM HEAD	305	250	-320		Note 2	No
BTM HEAD	305	250	-320		Note 1	No
UPPER SHELL FLANGE	305	250	-320		Note 2	No
UPPER SHELL FLANGE - Flange Hub	305	250	-320		Note 2	No
LOWER SHELL FLANGE	305	250	-320		Note 2	No
LOWER SHELL FLANGE - Flange Hub	305	250	-320		Note 2	No
6" (AO)	305	250	-320	Nozzle	Note 2	No
				Pad	Note 2	No
2" (AV)	305	250	-320		Note 2	No
6" (BE)	305	250	-320	Nozzle	Note 2	No
				Pad	Note 2	No
6" (BJ)	305	250	-320	Nozzle	Note 2	No
				Pad	Note 2	No
2" (BS)	305	250	-320		Note 2	No
2" (CW)	305	250	-320	Nozzle	Note 2	No
				Pad	Note 2	No
2" (LB1A/B)	305	250	-320		Note 2	No
2" (LT2A/B, LT3A/B, LT4A/B)	305	250	-320		Note 2	No
2" (TT1)	305	250	-320		Note 2	No

Chamber design MDMT is 10 °F
Chamber rated MDMT is -320 °F @ 305 psi

Chamber Design MAWP hot & corroded is 305 psi

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.
2.	Option to calculate MAWP was not selected. See the Calculation->General tab of the Set Mode dialog.

Notes for MDMT Rating:

Note #	Exemption	Details
1.	Material Rated MDMT per UHA-51(d)(1)(a) = -320 °F	
2.	Rated MDMT per UHA-51(d)(1)(a) = -320 °F	

Design notes are available on the Settings Summary page.

Thickness Summary

Component Identifier	Material	Diameter (in)	Length (in)	Nominal t (in)	Design t (in)	Total Corrosion (in)	Joint E	Load
TOP HEAD	SA-240 304L	29.252 ID	7.7146	0.4016*	0.2677	0	1.00	Internal
Straight Flange on TOP HEAD	SA-240 304L	29.252 ID	1.9685	0.4724	0.2701	0	1.00	Internal
SHELL	SA-240 304L	29.252 ID	85.422	0.3937	0.2707	0	1.00	Internal
Straight Flange on BTM HEAD	SA-240 304L	29.252 ID	1.9685	0.4724	0.2708	0	1.00	Internal
BTM HEAD	SA-240 304L	29.252 ID	7.7146	0.4016*	0.2685	0	1.00	Internal
SKIRT	SA-240 304L	30 OD	34.0669	0.3543	0.1153	0.063	0.55	Wind

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

Nozzle Schedule

Nozzle mark	Service	Size	Materials								
			Nozzle	Impact	Norm	Fine Grain	Pad	Impact	Norm	Fine Grain	Flange
AO	6"	NPS 6 Sch 80S (XS)	SA-312 TP304L Wld & smls pipe	No	No	No	SA-240 304L	No	No	No	WN A182 F304L Class 300
AV	2"	NPS 2 Sch 160	SA-312 TP304L Wld & smls pipe	No	No	No	N/A	N/A	N/A	N/A	WN A182 F304L Class 300
BE	6"	NPS 6 Sch 80S (XS)	SA-312 TP304L Wld & smls pipe	No	No	No	SA-240 304L	No	No	No	WN A182 F304L Class 300
BJ	6"	NPS 6 Sch 80S (XS)	SA-312 TP304L Wld & smls pipe	No	No	No	SA-240 304L	No	No	No	WN A182 F304L Class 300
BS	2"	2.07 IDx0.62	SA-182 F304L <= 5	No	No	No	N/A	N/A	N/A	N/A	LWN A182 F304L Class 300
CW	2"	NPS 2 Sch 160	SA-312 TP304L Wld & smls pipe	No	No	No	SA-240 304L	No	No	No	WN A182 F304L Class 300
LB1A/B	2"	2.07 IDx0.62	SA-182 F304L <= 5	No	No	No	N/A	N/A	N/A	N/A	LWN A182 F304L Class 300
LT2A/B, LT3A/B, LT4A/B	2"	2.07 IDx0.62	SA-182 F304L <= 5	No	No	No	N/A	N/A	N/A	N/A	LWN A182 F304L Class 300
TT1	2"	2.07 IDx0.62	SA-182 F304L <= 5	No	No	No	N/A	N/A	N/A	N/A	LWN A182 F304L Class 300

Hydrostatic Test

Shop test pressure determination for Chamber bounded by BTM HEAD and TOP HEAD based on design P per UG-99(b)

Shop hydrostatic test gauge pressure is 396.5 psi at 68 °F (the chamber design P = 305 psi)

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

Identifier	Local test pressure psi	Test liquid static head psi	UG-99 stress ratio	UG-99 pressure factor	Stress during test psi	Allowable test stress psi	Stress excessive?
TOP HEAD (1)	397.953	1.453	1	1.30	13,045	22,500	No
Straight Flange on TOP HEAD	397.953	1.453	1	1.30	12,518	22,500	No
SHELL	397.953	1.453	1	1.30	14,982	22,500	No
Straight Flange on BTM HEAD	397.953	1.453	1	1.30	12,518	22,500	No
BTM HEAD	397.953	1.453	1	1.30	13,045	22,500	No
2" (AV)	397.306	0.806	1	1.30	3,226	33,750	No
2" (BS)	397.186	0.686	1	1.30	14,755	33,750	No
2" (CW)	397.456	0.956	1	1.30	5,986	33,750	No
2" (LB1A/B)	397.068	0.568	1	1.30	14,751	33,750	No
2" (LT2A/B, LT3A/B, LT4A/B)	397.682	1.182	1	1.30	14,774	33,750	No
2" (TT1)	397.462	0.963	1	1.30	14,766	33,750	No
6" (AO)	397.529	1.029	1	1.30	8,636	33,750	No
6" (BE)	396.883	0.383	1	1.30	10,170	33,750	No
6" (BJ)	397.115	0.615	1	1.30	10,176	33,750	No

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

Field test pressure determination for Chamber bounded by BTM HEAD and TOP HEAD based on design P per UG-99(b)

Field hydrostatic test gauge pressure is 396.5 psi at 68 °F (the chamber design P = 305 psi)

The field test is performed with the vessel in the vertical position.

Identifier	Local test pressure psi	Test liquid static head psi	UG-99 stress ratio	UG-99 pressure factor	Stress during test psi	Allowable test stress psi	Stress excessive?
TOP HEAD (1)	397.438	0.938	1	1.30	13,028	22,500	No
Straight Flange on TOP HEAD	397.438	0.938	1	1.30	12,502	22,500	No
SHELL	401.122	4.622	1	1.30	15,101	22,500	No
Straight Flange on BTM HEAD	401.193	4.693	1	1.30	12,620	22,500	No
BTM HEAD	401.457	4.957	1	1.30	13,160	22,500	No
2" (AV)	396.891	0.391	1	1.30	3,223	33,750	No
2" (BS)	401.014	4.514	1	1.30	14,898	33,750	No
2" (CW)	401.842	5.342	1	1.30	6,052	33,750	No
2" (LB1A/B)	399.173	2.674	1	1.30	14,829	33,750	No
2" (LT2A/B, LT3A/B, LT4A/B)	399.57	3.07	1	1.30	14,844	33,750	No
2" (TT1)	398.234	1.734	1	1.30	14,794	33,750	No
6" (AO)	397.088	0.588	1	1.30	8,626	33,750	No
6" (BE)	399.564	3.064	1	1.30	10,239	33,750	No
6" (BJ)	399.853	3.353	1	1.30	10,246	33,750	No

Notes:
(1) TOP HEAD limits the UG-99 stress ratio.
(2) P_L stresses at nozzle openings have been estimated using the method described in PVP-Vol. 399, pages 77-82.
(3) $1.5*0.9*S_y$ used as the basis for the maximum local primary membrane stress at the nozzle intersection P_L.

Corroded Hydrostatic Test

The shop test condition has not been investigated for the Chamber bounded by BTM HEAD and TOP HEAD.

Field test pressure determination for Chamber bounded by BTM HEAD and TOP HEAD based on design P per UG-99(b)

Field hydrostatic test gauge pressure is 396.5 psi at 68 °F (the chamber design P = 305 psi)

The field test is performed with the vessel in the vertical position.

Identifier	Local test pressure psi	Test liquid static head psi	UG-99 stress ratio	UG-99 pressure factor	Stress during test psi	Allowable test stress psi	Stress excessive?
TOP HEAD (1)	397.438	0.938	1	1.30	13,028	22,500	No
Straight Flange on TOP HEAD	397.438	0.938	1	1.30	12,502	22,500	No
SHELL	401.122	4.622	1	1.30	15,101	22,500	No
Straight Flange on BTM HEAD	401.193	4.693	1	1.30	12,620	22,500	No
BTM HEAD	401.457	4.957	1	1.30	13,160	22,500	No
2" (AV)	396.891	0.391	1	1.30	3,223	33,750	No
2" (BS)	401.014	4.514	1	1.30	14,898	33,750	No
2" (CW)	401.842	5.342	1	1.30	6,052	33,750	No
2" (LB1A/B)	399.173	2.674	1	1.30	14,829	33,750	No
2" (LT2A/B, LT3A/B, LT4A/B)	399.57	3.07	1	1.30	14,844	33,750	No
2" (TT1)	398.234	1.734	1	1.30	14,794	33,750	No
6" (AO)	397.088	0.588	1	1.30	8,626	33,750	No
6" (BE)	399.564	3.064	1	1.30	10,239	33,750	No
6" (BJ)	399.853	3.353	1	1.30	10,246	33,750	No

Notes:
(1) TOP HEAD limits the UG-99 stress ratio.
(2) P_L stresses at nozzle openings have been estimated using the method described in PVP-Vol. 399, pages 77-82.
(3) $1.5*0.9*S_y$ used as the basis for the maximum local primary membrane stress at the nozzle intersection P_L.

Weight Summary

Component	Weight (lb) Contributed by Vessel Elements						
	Metal New*	Metal Corroded*	Insulation & Supports	Lining	Piping + Liquid	Operating Liquid	Test Liquid
TOP HEAD	139.9	139.9	64.8	0	0	0	178.3
SHELL	896.5	896.5	178.5	0	0	463.5	2,088.7
BTM HEAD	143.4	143.4	64.8	0	0	169.6	166.6
SKIRT	326	267.5	0	0	0	0	0
BASE BLOCK	204	204	0	0	0	0	0
TOTAL:	**1,709.9**	**1,651.4**	**308**	**0**	**0**	**633.1**	**2,433.6**

* 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					
TOP HEAD	940.4	940.4	97.3	97.3	0	1,799.9	0	0	0
SHELL	940.4	940.4	223.5	223.5	57.4	183.7	0	0	2,204.6
BTM HEAD	0	0	17.2	17.2	0	57.9	0	0	0
SKIRT	0	0	0	0	0	0	0	0	0
TOTAL:	**1,880.9**	**1,880.9**	**338**	**338**	**57.4**	**2,041.5**	**0**	**0**	**2,204.6**

Vessel operating weight, Corroded: 9,115 lb
Vessel operating weight, New: 9,173 lb
Vessel empty weight, Corroded: 8,482 lb
Vessel empty weight, New: 8,540 lb
Vessel test weight, New: 10,798 lb

Vessel center of gravity location - from datum - lift condition

Vessel Lift Weight, New: 8,540 lb
Center of Gravity: 74.9674"

Vessel Capacity

Vessel Capacity** (New): 337 US gal
Vessel Capacity** (Corroded): 337 US gal
**The vessel capacity does not include volume of nozzle, piping or other attachments.

Wind Code

Building Code:	**ASCE 7-05**
Elevation of base above grade:	0.9843 ft
Increase effective outer diameter by:	3.2808 ft
Wind Force Coefficient Cf:	0.8000
Basic Wind Speed:, V:	100.0408 mph
Importance Factor:, I:	1.1500
Exposure category:	C
Wind Directionality Factor, Kd:	0.9500
Top Deflection Limit:	6 in. per 100 ft.
Topographic Factor, Kzt:	1.0000
Enforce min. loading of 10 psf:	Yes

Vessel Characteristics

Vessel height, h:	12.4736 ft
Vessel Minimum Diameter, b	
Operating, Corroded:	2.8314 ft
Empty, Corroded:	2.8314 ft
hydrotest, New, field:	2.5033 ft
Fundamental Frequency, n_1	
Operating, Corroded:	13.1836 Hz
Empty, Corroded:	13.4619 Hz
hydrotest, New, field:	13.5444 Hz
Damping coefficient, β	
Operating, Corroded:	0.0256
Empty, Corroded:	0.0210
hydrotest, New, field:	0.0210

Table Lookup Values

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

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

Where

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

Wind Deflection Reports:

Operating, Corroded
Empty, Corroded
hydrotest, New, field

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)
TOP HEAD	131.6874	6.12	27.3	*	839	1,004	1,421	0.0168
SHELL	37.9528	6.11	27.3	0.1943	839	1,826	12,719	0.014
BTM HEAD (top)	34.0669	6.12	27.3	*	839	1,860	13,419	0.0018
SKIRT	0	5.78	27.3	0.1429	839	2,142	19,099	0.0015
*Moment of Inertia I varies over the length of the component								

Wind Deflection Report: Empty, Corroded

Component	Elevation of bottom above base (in)	Effective OD (ft)	Elastic modulus E (10^6 psi)	Inertia I (ft^4)	Platform wind shear at Bottom (lbf)	Total wind shear at Bottom (lbf)	bending moment at Bottom (lbf-ft)	Deflection at top (in)
TOP HEAD	131.6874	6.12	28.3	*	839	1,004	1,421	0.0162
SHELL	37.9528	6.11	28.3	0.1943	839	1,826	12,719	0.0135
BTM HEAD (top)	34.0669	6.12	28.3	*	839	1,860	13,419	0.0017
SKIRT	0	5.78	28.3	0.1429	839	2,142	19,099	0.0014
*Moment of Inertia I varies over the length of the component								

Wind Deflection Report: hydrotest, New, field

Component	Elevation of bottom above base (in)	Effective OD (ft)	Elastic modulus E (10^6 psi)	Inertia I (ft^4)	Platform wind shear at Bottom (lbf)	Total wind shear at Bottom (lbf)	bending moment at Bottom (lbf-ft)	Deflection at top (in)
TOP HEAD	131.6874	6.12	28.3	*	277	368	504	0.0061
SHELL	37.9528	6.11	28.3	0.1943	277	819	5,455	0.0051
BTM HEAD (top)	34.0669	6.12	28.3	*	277	838	5,758	0.0006
SKIRT	0	5.78	28.3	0.1749	277	1,002	8,370	0.0005
*Moment of Inertia I varies over the length of the component								

Wind Pressure (WP) Calculations

Gust Factor ($\bar{G}$) Calculations

$Kz = 2.01 * (Z/Zg)^{2/\alpha}$
$= 2.01 * (Z/900.0000)^{0.2105}$
$qz = 0.00256 * Kz * Kzt * Kd * V^2 * I$ psf
$= 0.00256 * Kz * 1.0000 * 0.9500 * 100.0408^2 * 1.1500$
$= 27.9908 * Kz$
$WP = qz * G * Cf$ (Minimum 10 lb/ft^2)
$= qz * G * 0.8000$ (Minimum 10 lb/ft^2)

Design Wind Pressures

Height Z (')	Kz	qz (psf)	WP: Operating (psf)	WP: Empty (psf)	WP: hydrotest (psf)	WP: Vacuum (psf)
15.0	0.8489	23.76	17.22	17.22	10.00	N.A.

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

Gust Factor Calculations

Operating, Corroded
Empty, Corroded
hydrotest, New, field

Gust Factor Calculations: Operating, Corroded

Vessel is considered a rigid structure as $n_1 = 13.1836$ Hz $\geq$ 1 Hz.

$\bar{z} = 0.60 * h$
$= 0.60 * 12.4736$
$= 15.0000$
$I_{\bar{z}} = c * (33 / \bar{z})^{1/6}$
$= 0.2000 * (33 / 15.0000)^{1/6}$
$= 0.2281$

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

$Q = Sqr(1 / (1 + 0.63 * ((b + h) / L_{\bar{z}})^{0.63}))$
$= Sqr(1 / (1 + 0.63 * ((2.8314 + 12.4736) / 427.0566)^{0.63}))$
$= 0.9634$

$G = 0.925 * (1 + 1.7 * g_Q * I_{\bar{z}} * Q) / (1 + 1.7 * g_v * I_{\bar{z}})$
$= 0.925 * (1 + 1.7 * 3.40 * 0.2281 * 0.9634) / (1 + 1.7 * 3.40 * 0.2281)$
$= 0.9058$

Gust Factor Calculations: Empty, Corroded

Vessel is considered a rigid structure as n_1 = 13.4619 Hz ≥ 1 Hz.

$\bar{z} = 0.60 * h$
$= 0.60 * 12.4736$
$= 15.0000$

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

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

$Q = Sqr(1 / (1 + 0.63 * ((b + h) / L_{\bar{z}})^{0.63}))$
$= Sqr(1 / (1 + 0.63 * ((2.8314 + 12.4736) / 427.0566)^{0.63}))$
$= 0.9634$

$G = 0.925 * (1 + 1.7 * g_Q * I_{\bar{z}} * Q) / (1 + 1.7 * g_v * I_{\bar{z}})$
$= 0.925 * (1 + 1.7 * 3.40 * 0.2281 * 0.9634) / (1 + 1.7 * 3.40 * 0.2281)$
$= 0.9058$

Gust Factor Calculations: hydrotest, New, field

Vessel is considered a rigid structure as n_1 = 13.5444 Hz ≥ 1 Hz.

$\bar{z} = 0.60 * h$
$= 0.60 * 12.4736$
$= 15.0000$

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

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

$Q = Sqr(1 / (1 + 0.63 * ((b + h) / L_{\bar{z}})^{0.63}))$
$= Sqr(1 / (1 + 0.63 * ((2.8314 + 12.4736) / 427.0566)^{0.63}))$
$= 0.9639$

$G = 0.925 * (1 + 1.7 * g_Q * I_{\bar{z}} * Q) / (1 + 1.7 * g_v * I_{\bar{z}})$
$= 0.925 * (1 + 1.7 * 3.40 * 0.2281 * 0.9639) / (1 + 1.7 * 3.40 * 0.2281)$
$= 0.9060$

Table Lookup Values

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

Seismic Code

Method of seismic analysis:	**ASCE 7-05 ground supported**
Site Class	C
Importance Factor:	I = 1.2500
Spectral Response Acceleration at short period (% g)	S_s = 16.30%
Spectral Response Acceleration at period of 1 sec (% g)	S_1 = 9.90%
Response Modification Coeficient from Table 15.4-2	R = 3.0000
Acceleration based site co-efficient:	F_a = 1.2000
Velocity based site co-efficient:	F_v = 1.7000
Long-period transition period:	T_L = 12.0000
Redundancy factor:	ρ = 1.0000
User Defined Vertical Accelerations Considered:	Yes
Force Multiplier:	= 0.3333
Minimum Weight Multiplier:	= 0.2000

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

5. $D + P + P_s + 0.7E \quad = (1.0 + V_{Accel})D + P + P_s + 0.7\rho Q_E$

8. $0.6D + P + P_s + 0.7E = (0.6 - V_{Accel})D + P + P_s + 0.7\rho Q_E$

Where

D = Dead load

P = Internal or external pressure load

P_s = Static head load

E = Seismic load = ρQ_E

V_{Accel} = User defined vertical acceleration

Vessel Characteristics

Vessel height: 12.4736 ft
Vessel Weight:
Operating, Corroded: 9,115 lb
Empty, Corroded: 8,482 lb

Period of Vibration Calculation

Fundamental Period, T:
Operating, Corroded: 0.076 sec (f = 13.2 Hz)
Empty, Corroded: 0.074 sec (f = 13.5 Hz)

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

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

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

Seismic Shear Reports:

Operating, Corroded
Empty, Corroded

Base Shear Calculations

Seismic Shear Report: Operating, Corroded

Component	Elevation of bottom above base (in)	Elastic modulus E (10^6 psi)	Inertia I (ft^4)	Seismic shear at Bottom (lbf)	Bending Moment at Bottom (lbf-ft)

TOP HEAD	131.6874	27.3	*	156	187
SHELL	37.9528	27.3	0.1943	339	2,817
BTM HEAD (top)	34.0669	27.3	*	342	2,927
SKIRT	0	27.3	0.1749	347	3,908
*Moment of Inertia I varies over the length of the component					

Seismic Shear Report: Empty, Corroded

Component	Elevation of bottom above base (in)	Elastic modulus E (10^6 psi)	Inertia I (ft^4)	Seismic shear at Bottom (lbf)	Bending Moment at Bottom (lbf-ft)
TOP HEAD	131.6874	28.3	*	150	180
SHELL	37.9528	28.3	0.1943	318	2,707
BTM HEAD (top)	34.0669	28.3	*	319	2,810
SKIRT	0	28.3	0.1749	323	3,722
*Moment of Inertia I varies over the length of the component					

11.4.3: Maximum considered earthquake spectral response acceleration

The maximum considered earthquake spectral response acceleration at short period, S_{MS}

$S_{MS} = F_a * S_s = 1.2000 * 16.30 / 100 = 0.1956$

The maximum considered earthquake spectral response acceleration at 1 s period, S_{M1}

$S_{M1} = F_v * S_1 = 1.7000 * 9.90 / 100 = 0.1683$

11.4.4: Design spectral response acceleration parameters

Design earthquake spectral response acceleration at short period, S_{DS}

$S_{DS} = 2 / 3 * S_{MS} = 2 / 3 * 0.1956 = 0.1304$

Design earthquake spectral response acceleration at 1 s period, S_{D1}

$S_{D1} = 2 / 3 * S_{M1} = 2 / 3 * 0.1683 = 0.1122$

User Defined Vertical Acceleration Term, V_{Accel}

Factor is applied to dead load.

Compressive Side: $= 1.0 + V_{Accel}$

Tensile Side: $= 0.6 - V_{Accel}$

V_{Accel} Term is: greater of (Force Mult * Base Shear / Weight) or (Min. Weight Mult.)				
Force multiplier = 0.3333		Minimum Weight Multiplier = 0.2000		
Condition	Base Shear (lbf)	Weight (lb)	Force Mult * Shear / Weight	V_{Accel}
Operating, Corroded	347	9,114.8	0.0127	0.2
Operating, New	349	9,173.3	0.0127	0.2
Empty, Corroded	323	8,481.7	0.0127	0.2
Empty, New	325	8,540.3	0.0127	0.2

Base Shear Calculations

Operating, Corroded
Empty, Corroded

Base Shear Calculations: Operating, Corroded

Paragraph 15.4.4: Period Determination

Fundamental Period is taken from the Rayleigh method listed previously in this report.
$T = 0.0759$ sec.

12.8.1: Calculation of Seismic Response Coefficient

C_s is the value computed below, bounded by C_sMin and C_sMax:
C_sMin is 0.03; in addition, if $S_1 >= 0.6g$, C_sMin shall not be less than eqn 15.4-2.
C_sMax calculated with 12.8-3 because $(T = 0.0759) <= (T_L = 12.0000)$

$C_s = S_{DS} / (R / I) = 0.1304 / (3.0000 / 1.2500) = 0.0543$

$C_s Min = 0.03$

$C_s Max = S_{D1} / (T * (R / I)) = 0.1122 / (0.0759 * (3.0000 / 1.2500)) = 0.6163$

$C_s = 0.0543$

12.8.1: Calculation of Base Shear

$V = C_s * W$
$= 0.0543 * 9114.8125$
$= 495.24$ lb

12.4.2.1 Seismic Load Combinations: Horizontal Seismic Load Effect, E_h

$Q_E = V$

$E_h = 0.7 * \rho * Q_E$ (Only 70% of seismic load considered as per Section 2.4.1)
$= 0.70 * 1.0000 * 495.24$
$= 346.67$ lb

Base Shear Calculations: Empty, Corroded

Paragraph 15.4.4: Period Determination

Fundamental Period is taken from the Rayleigh method listed previously in this report.
$T = 0.0743$ sec.

12.8.1: Calculation of Seismic Response Coefficient

C_s is the value computed below, bounded by C_sMin and C_sMax:
C_sMin is 0.03; in addition, if $S_1 >= 0.6g$, C_sMin shall not be less than eqn 15.4-2.
C_sMax calculated with 12.8-3 because $(T = 0.0743) <= (T_L = 12.0000)$

$C_s = S_{DS} / (R / I) = 0.1304 / (3.0000 / 1.2500) = 0.0543$

$C_s Min = 0.03$

$C_s Max = S_{D1} / (T * (R / I)) = 0.1122 / (0.0743 * (3.0000 / 1.2500)) = 0.6293$

$C_s = 0.0543$

12.8.1: Calculation of Base Shear

$V = C_s * W$
$= 0.0543 * 8481.7246$
$= 460.84$ lb

12.4.2.1 Seismic Load Combinations: Horizontal Seismic Load Effect, E_h

$Q_E = V$

$E_h = 0.7 * \rho * Q_E$ (Only 70% of seismic load considered as per Section 2.4.1)
$= 0.70 * 1.0000 * 460.84$
$= 322.59$ lb

TOP HEAD

ASME Section VIII, Division 1, 2007 Edition, A09 Addenda

Component:	Ellipsoidal Head
Material Specification:	SA-240 304L (II-D p.82, ln. 38)

Material Rated MDMT per UHA-51(d)(1)(a) = -320 °F

Internal design pressure: P = 305 psi @ 250 °F

Static liquid head:

P_s= 0 psi (SG=1.018, H_s=0" Operating head)
P_{th}= 1.4531 psi (SG=1, H_s=40.256" Horizontal test head)
P_{tv}= 0.8669 psi (SG=1, H_s=24.0157" Vertical test head)

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

Design MDMT = 10°F	No impact test performed
Rated MDMT = -320°F	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 -	Full UW-11(a) Type 1
	Head to shell seam -	Full UW-11(a) Type 1

Estimated weight*:	new = 139.9 lb	corr = 139.9 lb
Capacity*:	new = 19.9 US gal	corr = 19.9 US gal

* includes straight flange

Inner diameter	=	29.252"
Minimum head thickness	=	0.4016"
Head ratio D/2h	=	2 (new)
Head ratio D/2h	=	2 (corroded)
Straight flange length L_{sf}	=	1.9685"
Nominal straight flange thickness t_{sf}	=	0.4724"

Insulation thk*:	1.9685"	density: 13.7342 lb/ft^3	weight: 20.6595 lb
Insulation support ring spacing:	141.7323"	individual weight: 44.0925 lb	total weight: 44.0925 lb

* includes straight flange if applicable

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)	=	0.2677"

Design thickness for internal pressure, (Corroded at 250 °F) UG-32(d)(1)

t = P*D / (2*S*E - 0.2*P) + Corrosion
= 305*29.252 / (2*16,700*1 - 0.2*305) + 0
= 0.2676"

The head internal pressure design thickness is 0.2677".

% Forming strain - UHA-44(a)(2)(b)

EFE = (75*t / R_f)*(1 - R_f / R_o)
= (75*0.4724 / 5.2091)*(1 - 5.2091 / ϒ⊆)
= 6.8022%

SHELL

ASME Section VIII Division 1, 2007 Edition, A09 Addenda

Component: Cylinder
Material specification: SA-240 304L (II-D p. 82, ln. 38)
Rated MDMT per UHA-51(d)(1)(a) = -320 °F

Internal design pressure: P = 305 psi @ 250 °F

Static liquid head:

P_s = 0.66 psi (SG = 1.018, H_s = 18.0315",Operating head)
P_{th} = 1.45 psi (SG = 1, H_s = 40.256", Horizontal test head)
P_{tv} = 4.62 psi (SG = 1, H_s = 128.0315", Vertical test head)

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

Design MDMT = 10 °F
Rated MDMT = -320 °F

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

Radiography:		
	Longitudinal joint -	Full UW-11(a) Type 1
	Top circumferential joint -	Full UW-11(a) Type 1
	Bottom circumferential joint -	Full UW-11(a) Type 1

Estimated weight New = 896.5 lb corr = 896.5 lb
Capacity New = 248.52 US gal corr = 248.52 US gal

ID = 29.252"
Length L_c = 85.422"
t = 0.3937"

Insulation thk:	1.9685"	density:	13.73 lb/ft^3	Weight:	134.4 lb
Insulation Support Spacing:	141.7323"	Individual Support Weight:	44.1 lb	Total Support Weight:	44.1 lb

Design thickness, (at 250 °F) UG-27(c)(1)

t = P*R / (S*E - 0.60*P) + Corrosion
= 305.66*14.626 / (16,700*1.00 - 0.60*305.66) + 0
= 0.2707"

% Forming strain - UHA-44(a)(2)(a)

EFE = $(50*t / R_f)*(1 - R_f / R_o)$
= (50*0.3937 / 14.8228)*(1 - 14.8228 / ϒ⊆)
= 1.328%

Design thickness = 0.2707"

The governing condition is due to internal pressure.

The cylinder thickness of 0.3937" 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	305	16,700	8,637	250	0	Wind	0.1195	0.0958
						Seismic	0.1118	0.1036
Operating, Hot & New	305	16,700	8,637	250	0	Wind	0.1195	0.0958
						Seismic	0.1118	0.1035

Hot Shut Down, Corroded	0	16,700	8,637	250	0	Wind	0.0086	0.0293
						Seismic	0.0008	0.0143
Hot Shut Down, New	0	16,700	8,637	250	0	Wind	0.0086	0.0293
						Seismic	0.0008	0.0143
Empty, Corroded	0	16,700	11,075	68	0	Wind	0.0086	0.0229
						Seismic	0.0007	0.011
Empty, New	0	16,700	11,075	68	0	Wind	0.0086	0.0229
						Seismic	0.0007	0.011
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0	16,700	8,637	250	0	Weight	0.0089	0.0103

Allowable Compressive Stress, Hot and Corroded- S_{cHC}, (table HA-3)

A = 0.125 / (R_o / t)
= 0.125 / (15.0197 / 0.3937)
= 0.003277
B = 8,637 psi
S = 16,700 / 1.00 = 16,700 psi
S_{cHC} = min(B, S) = 8,637 psi

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

S_{cHN} = S_{cHC}
= 8,637 psi

Allowable Compressive Stress, Cold and New- S_{cCN}, (table HA-3)

A = 0.125 / (R_o / t)
= 0.125 / (15.0197 / 0.3937)
= 0.003277
B = 11,075 psi
S = 16,700 / 1.00 = 16,700 psi
S_{cCN} = min(B, S) = 11,075 psi

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

S_{cCC} = S_{cCN}
= 11,075 psi

Allowable Compressive Stress, Vacuum and Corroded- S_{cVC}, (table HA-3)

A = 0.125 / (R_o / t)
= 0.125 / (15.0197 / 0.3937)
= 0.003277
B = 11,075 psi
S = 16,700 / 1.00 = 16,700 psi
S_{cVC} = min(B, S) = 11,075 psi

Operating, Hot & Corroded, Wind, Bottom Seam

t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|) (Pressure)
= 305*14.626 / (2*16,700*1.20*1.00 + 0.40*|305|)
= 0.111"

t_m = M / (π*R_m^2*S_t*K_s*E_c) (bending)
= 152,625 / (π*14.8228^2*16,700*1.20*1.00)
= 0.011"

t_w = 0.6*W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 0.60*7,713.9 / (2*π*14.8228*16,700*1.20*1.00)

$= 0.0025"$

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

$= 0.111 + 0.011 - (0.0025)$

$= 0.1195"$

$t_{wc} = W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)

$= 7{,}713.9 / (2*\pi*14.8228*16{,}700*1.20*1.00)$

$= 0.0041"$

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

$= |0.011 + (0.0041) - (0.111)|$

$= 0.0958"$

Operating, Hot & New, Wind, Bottom Seam

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

$= 305*14.626 / (2*16{,}700*1.20*1.00 + 0.40*|305|)$

$= 0.111"$

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

$= 152{,}625 / (\pi*14.8228^2*16{,}700*1.20*1.00)$

$= 0.011"$

$t_w = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)

$= 0.60*7{,}713.9 / (2*\pi*14.8228*16{,}700*1.20*1.00)$

$= 0.0025"$

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

$= 0.111 + 0.011 - (0.0025)$

$= 0.1195"$

$t_{wc} = W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)

$= 7{,}713.9 / (2*\pi*14.8228*16{,}700*1.20*1.00)$

$= 0.0041"$

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

$= |0.011 + (0.0041) - (0.111)|$

$= 0.0958"$

Hot Shut Down, Corroded, Wind, Bottom Seam

$t_p = 0"$ (Pressure)

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

$= 152{,}625 / (\pi*14.8228^2*16{,}700*1.20*1.00)$

$= 0.011"$

$t_w = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)

$= 0.60*7{,}713.9 / (2*\pi*14.8228*16{,}700*1.20*1.00)$

$= 0.0025"$

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

$= 0 + 0.011 - (0.0025)$

$= 0.0086"$

$t_{mc} = M / (\pi*R_m^2*S_c*K_s)$ (bending)

$= 152{,}625 / (\pi*14.8228^2*8{,}637.24*1.20)$

$= 0.0213"$

$t_{wc} = W / (2*\pi*R_m*S_c*K_s)$ (Weight)

$= 7{,}713.9 / (2*\pi*14.8228*8{,}637.24*1.20)$

$= 0.008"$

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

$= 0.0213 + (0.008) - (0)$

$= 0.0293"$

Hot Shut Down, New, Wind, Bottom Seam

t_p = 0" (Pressure)

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

$= 152{,}625 / (\pi*14.8228^2*16{,}700*1.20*1.00)$

= 0.011"

$t_w = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)

$= 0.60*7{,}713.9 / (2*\pi*14.8228*16{,}700*1.20*1.00)$

= 0.0025"

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

= 0 + 0.011 - (0.0025)

= 0.0086"

$t_{mc} = M / (\pi*R_m^2*S_c*K_s)$ (bending)

$= 152{,}625 / (\pi*14.8228^2*8{,}637.24*1.20)$

= 0.0213"

$t_{wc} = W / (2*\pi*R_m*S_c*K_s)$ (Weight)

$= 7{,}713.9 / (2*\pi*14.8228*8{,}637.24*1.20)$

= 0.008"

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

= 0.0213 + (0.008) - (0)

= 0.0293"

Empty, Corroded, Wind, Bottom Seam

t_p = 0" (Pressure)

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

$= 152{,}625 / (\pi*14.8228^2*16{,}700*1.20*1.00)$

= 0.011"

$t_w = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)

$= 0.60*7{,}696.6 / (2*\pi*14.8228*16{,}700*1.20*1.00)$

= 0.0025"

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

= 0 + 0.011 - (0.0025)

= 0.0086"

$t_{mc} = M / (\pi*R_m^2*S_c*K_s)$ (bending)

$= 152{,}625 / (\pi*14.8228^2*11{,}075.34*1.20)$

= 0.0166"

$t_{wc} = W / (2*\pi*R_m*S_c*K_s)$ (Weight)

$= 7{,}696.6 / (2*\pi*14.8228*11{,}075.34*1.20)$

= 0.0062"

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

= 0.0166 + (0.0062) - (0)

= 0.0229"

Empty, New, Wind, Bottom Seam

t_p = 0" (Pressure)

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

$= 152{,}625 / (\pi*14.8228^2*16{,}700*1.20*1.00)$

= 0.011"

$t_w = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)

$= 0.60*7{,}696.6 / (2*\pi*14.8228*16{,}700*1.20*1.00)$

= 0.0025"

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

$= 0 + 0.011 - (0.0025)$
$= 0.0086"$

$t_{mc} = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 152{,}625 / (\pi*14.8228^2*11{,}075.34*1.20)$
$= 0.0166"$

$t_{wc} = W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 7{,}696.6 / (2*\pi*14.8228*11{,}075.34*1.20)$
$= 0.0062"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0166 + (0.0062) - (0)$
$= 0.0229"$

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)
$= 4{,}346 / (\pi*14.8228^2*8{,}637.24*1.00)$
$= 0.0007"$

$t_w = W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 7{,}713.9 / (2*\pi*14.8228*8{,}637.24*1.00)$
$= 0.0096"$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
$= |0 + 0.0007 - (0.0096)|$
$= 0.0089"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0007 + (0.0096) - (0)$
$= 0.0103"$

Operating, Hot & Corroded, Seismic, Bottom Seam

$t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
$= 305*14.626 / (2*16{,}700*1.20*1.00 + 0.40*|305|)$
$= 0.111"$

$t_m = M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
$= 33{,}802 / (\pi*14.8228^2*16{,}700*1.20*1.00)$
$= 0.0024"$

$t_w = (0.6 - VAccel)*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.40*7{,}713.9 / (2*\pi*14.8228*16{,}700*1.20*1.00)$
$= 0.0017"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0.111 + 0.0024 - (0.0017)$
$= 0.1118"$

$t_{wc} = (1 + VAccel)*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 1.20*7{,}713.9 / (2*\pi*14.8228*16{,}700*1.20*1.00)$
$= 0.005"$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0.0024 + (0.005) - (0.111)|$
$= 0.1036"$

Operating, Hot & New, Seismic, Bottom Seam

$t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
$= 305*14.626 / (2*16{,}700*1.20*1.00 + 0.40*|305|)$
$= 0.111"$

$t_m = M / (\pi * R_m^2 * S_t * K_s * E_c)$ (bending)
$= 33{,}961 / (\pi * 14.8228^2 * 16{,}700 * 1.20 * 1.00)$
$= 0.0025"$

$t_w = (0.6 - VAccel) * W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)
$= 0.40 * 7{,}713.9 / (2 * \pi * 14.8228 * 16{,}700 * 1.20 * 1.00)$
$= 0.0017"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0.111 + 0.0025 - (0.0017)$
$= 0.1118"$

$t_{wc} = (1 + VAccel) * W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)
$= 1.20 * 7{,}713.9 / (2 * \pi * 14.8228 * 16{,}700 * 1.20 * 1.00)$
$= 0.005"$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0.0025 + (0.005) - (0.111)|$
$= 0.1035"$

Hot Shut Down, Corroded, Seismic, Bottom Seam

$t_p = 0"$ (Pressure)

$t_m = M / (\pi * R_m^2 * S_t * K_s * E_c)$ (bending)
$= 33{,}802 / (\pi * 14.8228^2 * 16{,}700 * 1.20 * 1.00)$
$= 0.0024"$

$t_w = (0.6 - VAccel) * W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)
$= 0.40 * 7{,}713.9 / (2 * \pi * 14.8228 * 16{,}700 * 1.20 * 1.00)$
$= 0.0017"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0 + 0.0024 - (0.0017)$
$= 0.0008"$

$t_{mc} = M / (\pi * R_m^2 * S_c * K_s)$ (bending)
$= 33{,}802 / (\pi * 14.8228^2 * 8{,}637.24 * 1.20)$
$= 0.0047"$

$t_{wc} = (1 + VAccel) * W / (2 * \pi * R_m * S_c * K_s)$ (Weight)
$= 1.20 * 7{,}713.9 / (2 * \pi * 14.8228 * 8{,}637.24 * 1.20)$
$= 0.0096"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0047 + (0.0096) - (0)$
$= 0.0143"$

Hot Shut Down, New, Seismic, Bottom Seam

$t_p = 0"$ (Pressure)

$t_m = M / (\pi * R_m^2 * S_t * K_s * E_c)$ (bending)
$= 33{,}961 / (\pi * 14.8228^2 * 16{,}700 * 1.20 * 1.00)$
$= 0.0025"$

$t_w = (0.6 - VAccel) * W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)
$= 0.40 * 7{,}713.9 / (2 * \pi * 14.8228 * 16{,}700 * 1.20 * 1.00)$
$= 0.0017"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0 + 0.0025 - (0.0017)$
$= 0.0008"$

$t_{mc} = M / (\pi * R_m^2 * S_c * K_s)$ (bending)
$= 33{,}961 / (\pi * 14.8228^2 * 8{,}637.24 * 1.20)$
$= 0.0047"$

$t_{wc} = (1 + VAccel)*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 1.20*7{,}713.9 / (2*\pi*14.8228*8{,}637.24*1.20)$
$= 0.0096"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0047 + (0.0096) - (0)$
$= 0.0143"$

Empty, Corroded, Seismic, Bottom Seam

$t_p = 0"$ (Pressure)

$t_m = M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
$= 32{,}478 / (\pi*14.8228^2*16{,}700*1.20*1.00)$
$= 0.0023"$

$t_w = (0.6 - VAccel)*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.40*7{,}696.6 / (2*\pi*14.8228*16{,}700*1.20*1.00)$
$= 0.0016"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0 + 0.0023 - (0.0016)$
$= 0.0007"$

$t_{mc} = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 32{,}478 / (\pi*14.8228^2*11{,}075.34*1.20)$
$= 0.0035"$

$t_{wc} = (1 + VAccel)*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 1.20*7{,}696.6 / (2*\pi*14.8228*11{,}075.34*1.20)$
$= 0.0075"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0035 + (0.0075) - (0)$
$= 0.011"$

Empty, New, Seismic, Bottom Seam

$t_p = 0"$ (Pressure)

$t_m = M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
$= 32{,}643 / (\pi*14.8228^2*16{,}700*1.20*1.00)$
$= 0.0024"$

$t_w = (0.6 - VAccel)*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.40*7{,}696.6 / (2*\pi*14.8228*16{,}700*1.20*1.00)$
$= 0.0016"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0 + 0.0024 - (0.0016)$
$= 0.0007"$

$t_{mc} = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 32{,}643 / (\pi*14.8228^2*11{,}075.34*1.20)$
$= 0.0036"$

$t_{wc} = (1 + VAccel)*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 1.20*7{,}696.6 / (2*\pi*14.8228*11{,}075.34*1.20)$
$= 0.0075"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0036 + (0.0075) - (0)$
$= 0.011"$

BTM HEAD

ASME Section VIII, Division 1, 2007 Edition, A09 Addenda

Component:	Ellipsoidal Head
Material Specification:	SA-240 304L (II-D p.82, ln. 38)

Material Rated MDMT per UHA-51(d)(1)(a) = -320 °F

Internal design pressure: P = 305 psi @ 250 °F

Static liquid head:

P_s= 1.0037 psi (SG=1.018, H_s=27.313" Operating head)
P_{th}= 1.4531 psi (SG=1, H_s=40.256" Horizontal test head)
P_{tv}= 4.9566 psi (SG=1, H_s=137.313" Vertical test head)

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

Design MDMT = 10°F	No impact test performed
Rated MDMT = -320°F	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 -	Full UW-11(a) Type 1
	Head to shell seam -	Full UW-11(a) Type 1

Estimated weight*:	new = 143.4 lb	corr = 143.4 lb
Capacity*:	new = 19.9 US gal	corr = 19.9 US gal

* includes straight flange

Inner diameter	=	29.252"
Minimum head thickness	=	0.4016"
Head ratio D/2h	=	2 (new)
Head ratio D/2h	=	2 (corroded)
Straight flange length L_{sf}	=	1.9685"
Nominal straight flange thickness t_{sf}	=	0.4724"

Insulation thk*:	1.9685"	density: 13.7342 lb/ft^3	weight: 20.6595 lb
Insulation support ring spacing:	141.7323"	individual weight: 44.0925 lb	total weight: 44.0925 lb

* includes straight flange if applicable

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)	=	0.2685"

Design thickness for internal pressure, (Corroded at 250 °F) UG-32(d)(1)

t = P*D / (2*S*E - 0.2*P) + Corrosion
= 306*29.252 / (2*16,700*1 - 0.2*306) + 0
= 0.2685"

The head internal pressure design thickness is 0.2685".

% Forming strain - UHA-44(a)(2)(b)

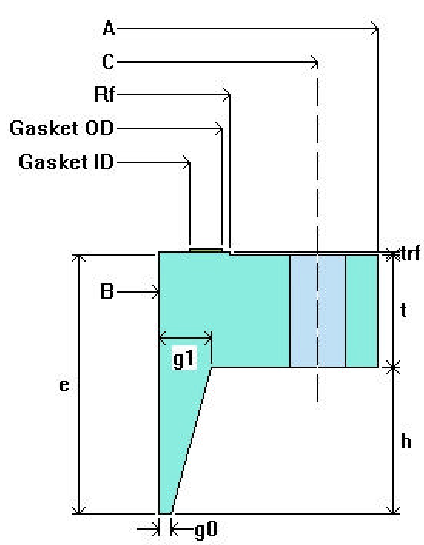
EFE = (75*t / R_f)*(1 - R_f / R_o)
= (75*0.4724 / 5.2091)*(1 - 5.2091 / ϒ⊆)
= 6.8022%

UPPER SHELL FLANGE

ASME VIII-1, 2007 Edition, A09 Addenda, Appendix 2 Flange Calculations

Flange is attached to:	TOP HEAD	
Flange type:	Weld neck integral	
Flange material specification:	SA-182 F304L <= 5 (low stress) (II-D p. 82, ln. 35)	
Bolt material specification:	SA-193 B8T 1 Bolt (II-D p. 360, ln. 9)	
Bolt Description:	1.75 in Series 8 Thread	
Internal design pressure, P:	305 psi @ 250 °F	
Required flange thickness: t_r=	3.3475 in	
Corrosion allowance:	Bore = 0 in	Flange = 0 in
Bolt corrosion (root), C_{bolt}:	0 in	
Design MDMT:	10 °F	No impact test performed
Rated MDMT:	-320 °F	Flange material is normalized
		Material is produced to fine grain practice
		PWHT is not performed
Estimated weight:	New = 940.4 lb	corroded = 940.4 lb

Flange dimensions, new



flange OD A	= 43 in
bolt circle C	= 39.25 in
raised face OD Rf	= 33.75 in
gasket OD	= 33.252 in
gasket ID	= 31.252 in
flange ID B	= 29.252 in
facing height t_{rf}	= 0.0598 in
thickness t	= 3.5598 in
bolting	= 28- 1.75 in dia
hub thickness g_1	= 1.6539 in
hub thickness g_0	= 0.374 in
hub length h	= 4.6299 in
length e	= 8.1898 in
gasket factor m	= 3
seating stress y	= 10,000 psi
Gasket thickness T	= 0.126 in

gasket description Spiral-wound

Note: this flange is calculated as an integral type.

Flange calculations for Internal Pressure + Wind

Longitudinal bending moment on flange

$P_m = 16*M_b/(\pi*G^3)$
$= 16*16,985.8/(\pi*32.5448^3)$
$= 2.5096$ psi

Axial load on flange

$P_r = -4*0.6*F/(\pi*G^2)$
$= -4*0.6*3,239.79/(\pi*32.5448^2)$

= -2.3368 psi

Total design load on flange (used for H - ref. III-1 NC-3658.1)

$= P + P_s + P_m + P_r$
= 305 + 0 + 2.5096 + -2.3368
= 305.1728 psi

The static head of liquid has not been included in the total design load because the vessel is supported below the flange.

Gasket details from facing sketch 1(a) or (b), Column II

Gasket width N = 1 in

$b_0 = N/2 = 0.5$ in

Effective gasket seating width, $b = 0.5*b_0^{1/2} = 0.3536$ in

G = OD of contact face - 2*b = 33.252 - 2*0.3536 = 32.5448 in

$h_G = (C - G)/2 = (39.25 - 32.5448)/2 = 3.3526$ in

$h_D = R + g_1/2 = 3.3451 + 1.6539/2 = 4.172$ in

$h_T = (R + g_1 + h_G)/2 = (3.3451 + 1.6539 + 3.3526)/2 = 4.1758$ in

$H_p = 2*b*3.14*G*m*P$
= 2*0.3536*3.14*32.5448*3*305
= 66,126.3 lb_f

$H = 0.785*G^2*P$
$= 0.785*32.5448^2*305.1728$
= 253,733.55 lb_f

$H_D = 0.785*B^2*P$
$= 0.785*29.252^2*305$
= 204,870.63 lb_f

$H_T = H - H_D$
= 253,733.5 - 204,870.6
= 48,862.92 lb_f

$W_{m1} = H + H_p$
= 253,733.5 + 66,126.3
= 319,859.84 lb_f

$W_{m2} = 3.14*b*G*y$
= 3.14*0.3536*32.5448*10,000
= 361,345.88 lb_f

Required bolt area, A_m = greater of A_{m1}, A_{m2} = 19.22053 in^2

$A_{m1} = W_{m1}/S_b$ = 319,859.8/17,200 = 18.5965 in^2

$A_{m2} = W_{m2}/S_a$ = 361,345.9/18,800 = 19.2205 in^2

Total area for 28- 1.75 in dia bolts, corroded, A_b = 55.44 in^2

$W = (A_m + A_b)*S_a/2$
= (19.2205 + 55.44)*18,800/2
= 701,808.94 lb_f

$M_D = H_D*h_D$ = 204,870.6*4.172 = 854,730 lb_f-in
$M_T = H_T*h_T$ = 48,862.92*4.1758 = 204,042.5 lb_f-in

$H_G = W_{m1} - H$ = 319,859.8 - 253,733.5 = 66,126.3 lb_f

$M_G = H_G*h_G$ = 66,126.3*3.3526 = 221,696 lb_f-in

$M_o = M_D + M_T + M_G$ = 854,730 + 204,042.5 + 221,696 = 1,280,469 lb_f-in

$M_g = W*h_G$ = 701,808.9*3.3526 = 2,352,896 lb_f-in

Hub and Flange Factors

$h_0 = (B*g_0)^{1/2} = (29.252*0.374)^{1/2} = 3.3077$ in

From FIG. 2-7.1, where K = A/B = 43/29.252 = 1.47

T = 1.7237   Z = 2.7229   Y = 5.2106   U = 5.726

$h/h_0 = 1.3998$ $g_1/g_0 = 4.4221$

F = 0.5858   V = 0.0327 $e = F/h_0 = 0.1771$

$d = (U/V)*h_0*g_0^2 = (5.725972/0.0327)*3.3077*0.374^2$
$= 80.9571$ in^3

Stresses at operating conditions - VIII-1, Appendix 2-7

f = 1

$L = (t*e + 1)/T + t^3/d$
$= (3.5598*0.1771 + 1)/1.723743 + 3.5598^3/80.9571$
$= 1.503142$

$S_H = f*M_o/(L*g_1{}^2*B)$
$= 1*1,280,469/(1.503142*1.6539^2*29.252)$
= 10,646 psi

$S_R = (1.33*t*e + 1)*M_o/(L*t^2*B)$
$= (1.33*3.5598*0.1771 + 1)*1,280,469/(1.503142*3.5598^2*29.252)$
= 4,225 psi

$S_T = Y*M_o/(t^2*B) - Z*S_R$
$= 5.2106*1,280,469/(3.5598^2*29.252) - 2.7229*4,225$
= 6,495 psi

Allowable stress S_{fo} = 13,600 psi
Allowable stress S_{no} = 16,700 psi

S_T does not exceed S_{fo}
S_H does not exceed Min[$1.5*S_{fo}$, $2.5*S_{no}$] = 20,400 psi
S_R does not exceed S_{fo}
$0.5(S_H + S_R)$ = 7,435 psi does not exceed S_{fo}
$0.5(S_H + S_T)$ = 8,570 psi does not exceed S_{fo}

Stresses at gasket seating - VIII-1, Appendix 2-7

$S_H = f*M_g/(L*g_1{}^2*B)$
$= 1*2,352,896/(1.503142*1.6539^2*29.252)$
= 19,562 psi

$S_R = (1.33*t*e + 1)*M_g/(L*t^2*B)$
$= (1.33*3.5598*0.1771 + 1)*2,352,896/(1.503142*3.5598^2*29.252)$
= 7,764 psi

$S_T = Y*M_g/(t^2*B) - Z*S_R$
$= 5.2106*2,352,896/(3.5598^2*29.252) - 2.7229*7,764$
= 11,934 psi

Allowable stress S_{fa} = 16,700 psi
Allowable stress S_{na} = 16,700 psi

S_T does not exceed S_{fa}
S_H does not exceed Min[$1.5*S_{fa}$, $2.5*S_{na}$] = 25,050 psi
S_R does not exceed S_{fa}
$0.5(S_H + S_R)$ = 13,663 psi does not exceed S_{fa}
$0.5(S_H + S_T)$ = 15,748 psi does not exceed S_{fa}

Flange rigidity per VIII-1, Appendix 2-14

$J = 52.14*V*M_o/(L*E*g_0{}^2*K_I*h_0)$
$= 52.14*0.0327*2,352,896/(1.5031*28,310,588*0.374^2*0.3*3.3077)$

= 0.6796694

The flange rigidity index J does not exceed 1; satisfactory.

Flange calculations for Internal Pressure + Seismic

Longitudinal bending moment on flange

$P_m = 16*M_b/(\pi*G^3)$
$= 16*2{,}236.8/(\pi*32.5448^3)$
$= 0.3305$ psi

Axial load on flange

$P_r = -4*(0.6 - VAccel)*F/(\pi*G^2)$
$= -4*(0.6 - 0.2)*3{,}239.79/(\pi*32.5448^2)$
$= -1.5578$ psi

Total design load on flange (used for H - ref. III-1 NC-3658.1)

$= P + P_s + P_m + P_r$
$= 305 + 0 + 0.3305 + -1.5578$
$= 305$ psi

When the sum of equivalent pressures due to external loads (Pm + Pr) is a negative value, it is conservatively ignored.

The static head of liquid has not been included in the total design load because the vessel is supported below the flange.

This load combination does not govern the flange design.

UPPER SHELL FLANGE - Flange hub

ASME Section VIII Division 1, 2007 Edition, A09 Addenda

Component:	Flange hub
Material specification:	SA-182 F304L <= 5 (low stress) (II-D p. 82, ln. 35)
Rated MDMT per UHA-51(d)(1)(a) = -320 °F	

Internal design pressure: P = 305 psi @ 250 °F

Static liquid head:

P_s = 0 psi (SG = 1.018, H_s = 0",Operating head)
P_{th} = 1.45 psi (SG = 1, H_s = 40.256", Horizontal test head)
P_{tv} = 1.24 psi (SG = 1, H_s = 34.2339", Vertical test head)

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

Design MDMT = 10 °F	No impact test performed
Rated MDMT = -320 °F	Material is normalized
	Material is produced to Fine Grain Practice
	PWHT is not performed

Radiography:	Longitudinal joint -	Seamless No RT
	Top circumferential joint -	Full UW-11(a) Type 1
	Bottom circumferential joint -	N/A

Estimated weight	New = 46.1 lb	corr = 46.1 lb
Capacity	New = 13.47 US gal	corr = 13.47 US gal

ID = 29.252"
Length L_c = 4.6299"
t = 0.374"

Design thickness, (at 250 °F) UG-27(c)(1)

t = P*R / (S*E - 0.60*P) + Corrosion
= 305*14.626 / (13,600*1.00 - 0.60*305) + 0
= 0.3325"

Design thickness = 0.3325"

The governing condition is due to internal pressure.

The cylinder thickness of 0.374" 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	305	13,600	8,560	250	0	Wind	0.1364	0.1325
						Seismic	0.1355	0.1334
Operating, Hot & New	305	13,600	8,560	250	0	Wind	0.1364	0.1325
						Seismic	0.1355	0.1334
Hot Shut Down, Corroded	0	13,600	8,560	250	0	Wind	0.0002	0.0058
						Seismic	0.001	0.0044
Hot Shut Down, New	0	13,600	8,560	250	0	Wind	0.0002	0.0058
						Seismic	0.001	0.0044
Empty, Corroded	0	16,700	10,972	68	0	Wind	0.0002	0.0045
						Seismic	0.0008	0.0034
Empty, New	0	16,700	10,972	68	0	Wind	0.0002	0.0045
						Seismic	0.0008	0.0034
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0	13,600	8,560	250	0	Weight	0.004	0.0041

Allowable Compressive Stress, Hot and Corroded- S_{cHC}, (table HA-3)

A = $0.125 / (R_o / t)$
= 0.125 / (15 / 0.374)
= 0.003117
B = 8,560 psi
S = 13,600 / 1.00 = 13,600 psi
S_{cHC} = min(B, S) = 8,560 psi

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

S_{cHN} = S_{cHC}
= 8,560 psi

Allowable Compressive Stress, Cold and New- S_{cCN}, (table HA-3)

A = $0.125 / (R_o / t)$
= 0.125 / (15 / 0.374)
= 0.003117
B = 10,972 psi
S = 16,700 / 1.00 = 16,700 psi
S_{cCN} = min(B, S) = 10,972 psi

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

S_{cCC} = S_{cCN}
= 10,972 psi

Allowable Compressive Stress, Vacuum and Corroded- S_{cVC}, (table HA-3)

A = $0.125 / (R_o / t)$
= 0.125 / (15 / 0.374)
= 0.003117

$B = 10{,}972$ psi

$S = 16{,}700 / 1.00 = 16{,}700$ psi

$S_{cVC} = \min(B, S) = 10{,}972$ psi

Operating, Hot & Corroded, Wind, Bottom Seam

$t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
$= 305*14.626 / (2*13{,}600*1.20*1.00 + 0.40*|305|)$
$= 0.1362"$

$t_m = M / (\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
$= 17{,}049 / (\pi*14.813^2*13{,}600*1.20*1.00)$
$= 0.0015"$

$t_w = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.60*3{,}239.8 / (2*\pi*14.813*13{,}600*1.20*1.00)$
$= 0.0013"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0.1362 + 0.0015 - (0.0013)$
$= 0.1364"$

$t_{wc} = W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 3{,}239.8 / (2*\pi*14.813*13{,}600*1.20*1.00)$
$= 0.0021"$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0.0015 + (0.0021) - (0.1362)|$
$= 0.1325"$

Operating, Hot & New, Wind, Bottom Seam

$t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
$= 305*14.626 / (2*13{,}600*1.20*1.00 + 0.40*|305|)$
$= 0.1362"$

$t_m = M / (\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
$= 17{,}049 / (\pi*14.813^2*13{,}600*1.20*1.00)$
$= 0.0015"$

$t_w = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.60*3{,}239.8 / (2*\pi*14.813*13{,}600*1.20*1.00)$
$= 0.0013"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0.1362 + 0.0015 - (0.0013)$
$= 0.1364"$

$t_{wc} = W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 3{,}239.8 / (2*\pi*14.813*13{,}600*1.20*1.00)$
$= 0.0021"$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0.0015 + (0.0021) - (0.1362)|$
$= 0.1325"$

Hot Shut Down, Corroded, Wind, Bottom Seam

$t_p = 0"$ (Pressure)

$t_m = M / (\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
$= 17{,}049 / (\pi*14.813^2*13{,}600*1.20*1.00)$
$= 0.0015"$

$t_w = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.60*3{,}239.8 / (2*\pi*14.813*13{,}600*1.20*1.00)$

$= 0.0013"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0 + 0.0015 - (0.0013)$
$= 0.0002"$

$t_{mc} = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 17{,}049 / (\pi*14.813^2*8{,}560.41*1.20)$
$= 0.0024"$

$t_{wc} = W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 3{,}239.8 / (2*\pi*14.813*8{,}560.41*1.20)$
$= 0.0034"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0024 + (0.0034) - (0)$
$= 0.0058"$

Hot Shut Down, New, Wind, Bottom Seam

$t_p = 0"$ (Pressure)

$t_m = M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
$= 17{,}049 / (\pi*14.813^2*13{,}600*1.20*1.00)$
$= 0.0015"$

$t_w = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.60*3{,}239.8 / (2*\pi*14.813*13{,}600*1.20*1.00)$
$= 0.0013"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0 + 0.0015 - (0.0013)$
$= 0.0002"$

$t_{mc} = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 17{,}049 / (\pi*14.813^2*8{,}560.41*1.20)$
$= 0.0024"$

$t_{wc} = W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 3{,}239.8 / (2*\pi*14.813*8{,}560.41*1.20)$
$= 0.0034"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0024 + (0.0034) - (0)$
$= 0.0058"$

Empty, Corroded, Wind, Bottom Seam

$t_p = 0"$ (Pressure)

$t_m = M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
$= 17{,}049 / (\pi*14.813^2*16{,}700*1.20*1.00)$
$= 0.0012"$

$t_w = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.60*3{,}239.8 / (2*\pi*14.813*16{,}700*1.20*1.00)$
$= 0.001"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0 + 0.0012 - (0.001)$
$= 0.0002"$

$t_{mc} = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 17{,}049 / (\pi*14.813^2*10{,}972.44*1.20)$
$= 0.0019"$

$t_{wc} = W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 3{,}239.8 / (2*\pi*14.813*10{,}972.44*1.20)$
$= 0.0026"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0019 + (0.0026) - (0)$
$= 0.0045''$

Empty, New, Wind, Bottom Seam

$t_p = 0''$ (Pressure)

$t_m = M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
$= 17{,}049 / (\pi*14.813^2*16{,}700*1.20*1.00)$
$= 0.0012''$

$t_w = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.60*3{,}239.8 / (2*\pi*14.813*16{,}700*1.20*1.00)$
$= 0.001''$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0 + 0.0012 - (0.001)$
$= 0.0002''$

$t_{mc} = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 17{,}049 / (\pi*14.813^2*10{,}972.44*1.20)$
$= 0.0019''$

$t_{wc} = W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 3{,}239.8 / (2*\pi*14.813*10{,}972.44*1.20)$
$= 0.0026''$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0019 + (0.0026) - (0)$
$= 0.0045''$

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)
$= 180 / (\pi*14.813^2*8{,}560.41*1.00)$
$= 0''$

$t_w = W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 3{,}239.8 / (2*\pi*14.813*8{,}560.41*1.00)$
$= 0.0041''$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
$= |0 + 0 - (0.0041)|$
$= 0.004''$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0 + (0.0041) - (0)$
$= 0.0041''$

Operating, Hot & Corroded, Seismic, Bottom Seam

$t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
$= 305*14.626 / (2*13{,}600*1.20*1.00 + 0.40*|305|)$
$= 0.1362''$

$t_m = M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
$= 2{,}247 / (\pi*14.813^2*13{,}600*1.20*1.00)$
$= 0.0002''$

$t_w = (0.6 - VAccel)*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.40*3{,}239.8 / (2*\pi*14.813*13{,}600*1.20*1.00)$
$= 0.0009''$

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

$= 0.1362 + 0.0002 - (0.0009)$
$= 0.1355''$

$t_{wc} = (1 + VAccel)*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 1.20*3{,}239.8 / (2*\pi*14.813*13{,}600*1.20*1.00)$
$= 0.0026''$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0.0002 + (0.0026) - (0.1362)|$
$= 0.1334''$

Operating, Hot & New, Seismic, Bottom Seam

$t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
$= 305*14.626 / (2*13{,}600*1.20*1.00 + 0.40*|305|)$
$= 0.1362''$

$t_m = M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
$= 2{,}258 / (\pi*14.813^2*13{,}600*1.20*1.00)$
$= 0.0002''$

$t_w = (0.6 - VAccel)*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.40*3{,}239.8 / (2*\pi*14.813*13{,}600*1.20*1.00)$
$= 0.0009''$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0.1362 + 0.0002 - (0.0009)$
$= 0.1355''$

$t_{wc} = (1 + VAccel)*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 1.20*3{,}239.8 / (2*\pi*14.813*13{,}600*1.20*1.00)$
$= 0.0026''$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0.0002 + (0.0026) - (0.1362)|$
$= 0.1334''$

Hot Shut Down, Corroded, Seismic, Bottom Seam

$t_p = 0''$ (Pressure)

$t_m = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 2{,}247 / (\pi*14.813^2*8{,}560.41*1.20)$
$= 0.0003''$

$t_w = (0.6 - VAccel)*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 0.40*3{,}239.8 / (2*\pi*14.813*8{,}560.41*1.20)$
$= 0.0014''$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
$= |0 + 0.0003 - (0.0014)|$
$= 0.001''$

$t_{wc} = (1 + VAccel)*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 1.20*3{,}239.8 / (2*\pi*14.813*8{,}560.41*1.20)$
$= 0.0041''$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0003 + (0.0041) - (0)$
$= 0.0044''$

Hot Shut Down, New, Seismic, Bottom Seam

$t_p = 0''$ (Pressure)

$t_m = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 2{,}258 / (\pi*14.813^2*8{,}560.41*1.20)$

$= 0.0003"$

$t_w = (0.6 - VAccel)*W / (2*\pi*R_m*S_c*K_s)$ (Weight)

$= 0.40*3,239.8 / (2*\pi*14.813*8,560.41*1.20)$

$= 0.0014"$

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

$= |0 + 0.0003 - (0.0014)|$

$= 0.001"$

$t_{wc} = (1 + VAccel)*W / (2*\pi*R_m*S_c*K_s)$ (Weight)

$= 1.20*3,239.8 / (2*\pi*14.813*8,560.41*1.20)$

$= 0.0041"$

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

$= 0.0003 + (0.0041) - (0)$

$= 0.0044"$

Empty, Corroded, Seismic, Bottom Seam

$t_p = 0"$ (Pressure)

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

$= 2,162 / (\pi*14.813^2*10,972.44*1.20)$

$= 0.0002"$

$t_w = (0.6 - VAccel)*W / (2*\pi*R_m*S_c*K_s)$ (Weight)

$= 0.40*3,239.8 / (2*\pi*14.813*10,972.44*1.20)$

$= 0.0011"$

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

$= |0 + 0.0002 - (0.0011)|$

$= 0.0008"$

$t_{wc} = (1 + VAccel)*W / (2*\pi*R_m*S_c*K_s)$ (Weight)

$= 1.20*3,239.8 / (2*\pi*14.813*10,972.44*1.20)$

$= 0.0032"$

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

$= 0.0002 + (0.0032) - (0)$

$= 0.0034"$

Empty, New, Seismic, Bottom Seam

$t_p = 0"$ (Pressure)

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

$= 2,173 / (\pi*14.813^2*10,972.44*1.20)$

$= 0.0002"$

$t_w = (0.6 - VAccel)*W / (2*\pi*R_m*S_c*K_s)$ (Weight)

$= 0.40*3,239.8 / (2*\pi*14.813*10,972.44*1.20)$

$= 0.0011"$

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

$= |0 + 0.0002 - (0.0011)|$

$= 0.0008"$

$t_{wc} = (1 + VAccel)*W / (2*\pi*R_m*S_c*K_s)$ (Weight)

$= 1.20*3,239.8 / (2*\pi*14.813*10,972.44*1.20)$

$= 0.0032"$

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

$= 0.0002 + (0.0032) - (0)$

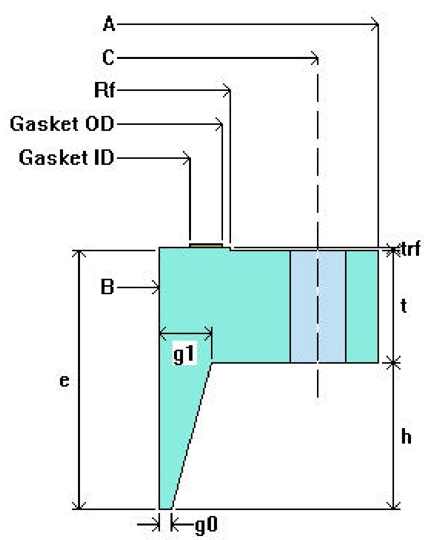
$= 0.0034"$

LOWER SHELL FLANGE

ASME VIII-1, 2007 Edition, A09 Addenda, Appendix 2 Flange Calculations

Flange is attached to:	SHELL (Top)	
Flange type:	Weld neck integral	
Flange material specification:	SA-182 F304L <= 5 (low stress) (II-D p. 82, ln. 35)	
Bolt material specification:	SA-193 B8T 1 Bolt (II-D p. 360, ln. 9)	
Bolt Description:	1.75 in Series 8 Thread	
Internal design pressure, P:	305 psi @ 250 °F	
Required flange thickness: t_r=	3.3475 in	
Corrosion allowance:	Bore = 0 in	Flange = 0 in
Bolt corrosion (root), C_{bolt}:	0 in	
Design MDMT:	10 °F	No impact test performed
Rated MDMT:	-320 °F	Flange material is normalized
		Material is produced to fine grain practice
		PWHT is not performed
Estimated weight:	New = 940.4 lb	corroded = 940.4 lb

Flange dimensions, new



flange OD A	= 43 in
bolt circle C	= 39.25 in
raised face OD Rf	= 33.75 in
gasket OD	= 33.252 in
gasket ID	= 31.252 in
flange ID B	= 29.252 in
facing height t_{rf}	= 0.0598 in
thickness t	= 3.5598 in
bolting	= 28- 1.75 in dia
hub thickness g_1	= 1.6539 in
hub thickness g_0	= 0.374 in
hub length h	= 4.6299 in
length e	= 8.1898 in
gasket factor m	= 3
seating stress y	= 10,000 psi
Gasket thickness T	= 0.126 in

gasket description Spiral-wound

Note: this flange is calculated as an integral type.

Flange calculations for Internal Pressure + Wind

Longitudinal bending moment on flange

$P_m = 16*M_b/(\pi*G^3)$
$= 16*17,064.9/(\pi*32.5448^3)$
$= 2.5213$ psi

Axial load on flange

$P_r = -4*0.6*F/(\pi*G^2)$
$= -4*0.6*3,239.79/(\pi*32.5448^2)$

$= -2.3368$ psi

Total design load on flange (used for H - ref. III-1 NC-3658.1)

$= P + P_s + P_m + P_r$
$= 305 + 0 + 2.5213 + -2.3368$
$= 305.1845$ psi

The static head of liquid has not been included in the total design load because the vessel is supported below the flange.

Gasket details from facing sketch 1(a) or (b), Column II

Gasket width N = 1 in

$b_0 = N/2 = 0.5$ in

Effective gasket seating width, $b = 0.5*b_0^{1/2} = 0.3536$ in

G = OD of contact face - 2*b = 33.252 - 2*0.3536 = 32.5448 in

$h_G = (C - G)/2 = (39.25 - 32.5448)/2 = 3.3526$ in

$h_D = R + g_1/2 = 3.3451 + 1.6539/2 = 4.172$ in

$h_T = (R + g_1 + h_G)/2 = (3.3451 + 1.6539 + 3.3526)/2 = 4.1758$ in

$H_p = 2*b*3.14*G*m*P$
$= 2*0.3536*3.14*32.5448*3*305$
$= 66{,}126.3\ lb_f$

$H = 0.785*G^2*P$
$= 0.785*32.5448^2*305.1845$
$= 253{,}743.27\ lb_f$

$H_D = 0.785*B^2*P$
$= 0.785*29.252^2*305$
$= 204{,}870.63\ lb_f$

$H_T = H - H_D$
$= 253{,}743.3 - 204{,}870.6$
$= 48{,}872.64\ lb_f$

$W_{m1} = H + H_p$
$= 253{,}743.3 + 66{,}126.3$
$= 319{,}869.56\ lb_f$

$W_{m2} = 3.14*b*G*y$
$= 3.14*0.3536*32.5448*10{,}000$
$= 361{,}345.88\ lb_f$

Required bolt area, A_m = greater of A_{m1}, A_{m2} = 19.22053 in^2

$A_{m1} = W_{m1}/S_b = 319{,}869.6/17{,}200 = 18.5971\ in^2$

$A_{m2} = W_{m2}/S_a = 361{,}345.9/18{,}800 = 19.2205\ in^2$

Total area for 28- 1.75 in dia bolts, corroded, $A_b = 55.44\ in^2$

$W = (A_m + A_b)*S_a/2$
$= (19.2205 + 55.44)*18{,}800/2$
$= 701{,}808.94\ lb_f$

$M_D = H_D*h_D = 204{,}870.6*4.172 = 854{,}730\ lb_f$-in
$M_T = H_T*h_T = 48{,}872.64*4.1758 = 204{,}083.1\ lb_f$-in

$H_G = W_{m1} - H = 319{,}869.6 - 253{,}743.3 = 66{,}126.3\ lb_f$

$M_G = H_G*h_G = 66{,}126.3*3.3526 = 221{,}696\ lb_f$-in

$M_o = M_D + M_T + M_G = 854{,}730 + 204{,}083.1 + 221{,}696 = 1{,}280{,}509\ lb_f$-in

$M_g = W*h_G = 701{,}808.9*3.3526 = 2{,}352{,}896\ lb_f$-in

Hub and Flange Factors

$h_0 = (B*g_0)^{1/2} = (29.252*0.374)^{1/2} = 3.3077$ in

From FIG. 2-7.1, where $K = A/B = 43/29.252 = 1.47$

$T = 1.7237$ $Z = 2.7229$ $Y = 5.2106$ $U = 5.726$

$h/h_0 = 1.3998$ $g_1/g_0 = 4.4221$

$F = 0.5858$ $V = 0.0327$ $e = F/h_0 = 0.1771$

$d = (U/V)*h_0*g_0^2 = (5.725972/0.0327)*3.3077*0.374^2$
$= 80.9571$ in^3

Stresses at operating conditions - VIII-1, Appendix 2-7

$f = 1$

$L = (t*e + 1)/T + t^3/d$
$= (3.5598*0.1771 + 1)/1.723743 + 3.5598^3/80.9571$
$= 1.503142$

$S_H = f*M_o/(L*g_1^2*B)$
$= 1*1{,}280{,}509/(1.503142*1.6539^2*29.252)$
$= 10{,}646$ psi

$S_R = (1.33*t*e + 1)*M_o/(L*t^2*B)$
$= (1.33*3.5598*0.1771 + 1)*1{,}280{,}509/(1.503142*3.5598^2*29.252)$
$= 4{,}225$ psi

$S_T = Y*M_o/(t^2*B) - Z*S_R$
$= 5.2106*1{,}280{,}509/(3.5598^2*29.252) - 2.7229*4{,}225$
$= 6{,}495$ psi

Allowable stress $S_{fo} = 13{,}600$ psi
Allowable stress $S_{no} = 16{,}700$ psi

S_T does not exceed S_{fo}
S_H does not exceed Min[$1.5*S_{fo}$, $2.5*S_{no}$] = 20,400 psi
S_R does not exceed S_{fo}
$0.5(S_H + S_R) = 7{,}436$ psi does not exceed S_{fo}
$0.5(S_H + S_T) = 8{,}570$ psi does not exceed S_{fo}

Stresses at gasket seating - VIII-1, Appendix 2-7

$S_H = f*M_g/(L*g_1^2*B)$
$= 1*2{,}352{,}896/(1.503142*1.6539^2*29.252)$
$= 19{,}562$ psi

$S_R = (1.33*t*e + 1)*M_g/(L*t^2*B)$
$= (1.33*3.5598*0.1771 + 1)*2{,}352{,}896/(1.503142*3.5598^2*29.252)$
$= 7{,}764$ psi

$S_T = Y*M_g/(t^2*B) - Z*S_R$
$= 5.2106*2{,}352{,}896/(3.5598^2*29.252) - 2.7229*7{,}764$
$= 11{,}934$ psi

Allowable stress $S_{fa} = 16{,}700$ psi
Allowable stress $S_{na} = 16{,}700$ psi

S_T does not exceed S_{fa}
S_H does not exceed Min[$1.5*S_{fa}$, $2.5*S_{na}$] = 25,050 psi
S_R does not exceed S_{fa}
$0.5(S_H + S_R) = 13{,}663$ psi does not exceed S_{fa}
$0.5(S_H + S_T) = 15{,}748$ psi does not exceed S_{fa}

Flange rigidity per VIII-1, Appendix 2-14

$J = 52.14*V*M_o/(L*E*g_0^2*K_I*h_0)$
$= 52.14*0.0327*2{,}352{,}896/(1.5031*28{,}310{,}588*0.374^2*0.3*3.3077)$

= 0.6796694

The flange rigidity index J does not exceed 1; satisfactory.

Flange calculations for Internal Pressure + Seismic

Longitudinal bending moment on flange

$P_m = 16*M_b/(\pi*G^3)$
$= 16*2,256.7/(\pi*32.5448^3)$
$= 0.3334$ psi

Axial load on flange

$P_r = -4*(0.6 - VAccel)*F/(\pi*G^2)$
$= -4*(0.6 - 0.2)*3,239.79/(\pi*32.5448^2)$
$= -1.5578$ psi

Total design load on flange (used for H - ref. III-1 NC-3658.1)

$= P + P_s + P_m + P_r$
$= 305 + 0 + 0.3334 + -1.5578$
$= 305$ psi

When the sum of equivalent pressures due to external loads (Pm + Pr) is a negative value, it is conservatively ignored.

The static head of liquid has not been included in the total design load because the vessel is supported below the flange.

This load combination does not govern the flange design.

LOWER SHELL FLANGE - Flange hub

ASME Section VIII Division 1, 2007 Edition, A09 Addenda

Component:	Flange hub
Material specification:	SA-182 F304L <= 5 (low stress) (II-D p. 82, ln. 35)
Rated MDMT per UHA-51(d)(1)(a) = -320 °F	

Internal design pressure: P = 305 psi @ 250 °F

Static liquid head:

P_s = 0 psi (SG = 1.018, H_s = 0",Operating head)
P_{th} = 1.45 psi (SG = 1, H_s = 40.256", Horizontal test head)
P_{tv} = 1.54 psi (SG = 1, H_s = 42.5496", Vertical test head)

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

Design MDMT = 10 °F	No impact test performed
Rated MDMT = -320 °F	Material is normalized
	Material is produced to Fine Grain Practice
	PWHT is not performed

Radiography:	Longitudinal joint -	Seamless No RT
	Top circumferential joint -	N/A
	Bottom circumferential joint -	Full UW-11(a) Type 1

Estimated weight	New = 46.1 lb	corr = 46.1 lb
Capacity	New = 13.47 US gal	corr = 13.47 US gal

ID = 29.252"
Length L_c = 4.6299"
t = 0.374"

Design thickness, (at 250 °F) UG-27(c)(1)

t = P*R / (S*E - 0.60*P) + Corrosion
= 305*14.626 / (13,600*1.00 - 0.60*305) + 0
= 0.3325"

Design thickness = 0.3325"

The governing condition is due to internal pressure.

The cylinder thickness of 0.374" 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	305	13,600	8,560	250	0	Wind	0.1372	0.1317
						Seismic	0.1357	0.1333
Operating, Hot & New	305	13,600	8,560	250	0	Wind	0.1372	0.1317
						Seismic	0.1357	0.1332
Hot Shut Down, Corroded	0	13,600	8,560	250	0	Wind	0.001	0.007
						Seismic	0.0008	0.0046
Hot Shut Down, New	0	13,600	8,560	250	0	Wind	0.001	0.007
						Seismic	0.0008	0.0046
Empty, Corroded	0	16,700	10,972	68	0	Wind	0.0008	0.0055
						Seismic	0.0006	0.0036
Empty, New	0	16,700	10,972	68	0	Wind	0.0008	0.0055
						Seismic	0.0006	0.0036
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0	13,600	8,560	250	0	Weight	0.004	0.0041

Allowable Compressive Stress, Hot and Corroded- S_{cHC}, (table HA-3)

A = $0.125 / (R_o / t)$
= 0.125 / (15 / 0.374)
= 0.003117
B = 8,560 psi
S = 13,600 / 1.00 = 13,600 psi
S_{cHC} = min(B, S) = 8,560 psi

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

S_{cHN} = S_{cHC}
= 8,560 psi

Allowable Compressive Stress, Cold and New- S_{cCN}, (table HA-3)

A = $0.125 / (R_o / t)$
= 0.125 / (15 / 0.374)
= 0.003117
B = 10,972 psi
S = 16,700 / 1.00 = 16,700 psi
S_{cCN} = min(B, S) = 10,972 psi

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

S_{cCC} = S_{cCN}
= 10,972 psi

Allowable Compressive Stress, Vacuum and Corroded- S_{cVC}, (table HA-3)

A = $0.125 / (R_o / t)$
= 0.125 / (15 / 0.374)
= 0.003117

$B = 10{,}972$ psi

$S = 16{,}700 / 1.00 = 16{,}700$ psi

$S_{cVC} = \min(B, S) = 10{,}972$ psi

Operating, Hot & Corroded, Wind, Bottom Seam

$t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
$= 305*14.626 / (2*13{,}600*1.20*1.00 + 0.40*|305|)$
$= 0.1362"$

$t_m = M / (\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
$= 25{,}656 / (\pi*14.813^2*13{,}600*1.20*1.00)$
$= 0.0023"$

$t_w = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.60*3{,}239.8 / (2*\pi*14.813*13{,}600*1.20*1.00)$
$= 0.0013"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0.1362 + 0.0023 - (0.0013)$
$= 0.1372"$

$t_{wc} = W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 3{,}239.8 / (2*\pi*14.813*13{,}600*1.20*1.00)$
$= 0.0021"$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0.0023 + (0.0021) - (0.1362)|$
$= 0.1317"$

Operating, Hot & New, Wind, Bottom Seam

$t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
$= 305*14.626 / (2*13{,}600*1.20*1.00 + 0.40*|305|)$
$= 0.1362"$

$t_m = M / (\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
$= 25{,}656 / (\pi*14.813^2*13{,}600*1.20*1.00)$
$= 0.0023"$

$t_w = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.60*3{,}239.8 / (2*\pi*14.813*13{,}600*1.20*1.00)$
$= 0.0013"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0.1362 + 0.0023 - (0.0013)$
$= 0.1372"$

$t_{wc} = W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 3{,}239.8 / (2*\pi*14.813*13{,}600*1.20*1.00)$
$= 0.0021"$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0.0023 + (0.0021) - (0.1362)|$
$= 0.1317"$

Hot Shut Down, Corroded, Wind, Bottom Seam

$t_p = 0"$ (Pressure)

$t_m = M / (\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
$= 25{,}656 / (\pi*14.813^2*13{,}600*1.20*1.00)$
$= 0.0023"$

$t_w = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.60*3{,}239.8 / (2*\pi*14.813*13{,}600*1.20*1.00)$

$= 0.0013''$

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

$= 0 + 0.0023 - (0.0013)$

$= 0.001''$

$t_{mc} = M / (\pi * R_m^2 * S_c * K_s)$ (bending)

$= 25,656 / (\pi * 14.813^2 * 8,560.41 * 1.20)$

$= 0.0036''$

$t_{wc} = W / (2 * \pi * R_m * S_c * K_s)$ (Weight)

$= 3,239.8 / (2 * \pi * 14.813 * 8,560.41 * 1.20)$

$= 0.0034''$

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

$= 0.0036 + (0.0034) - (0)$

$= 0.007''$

Hot Shut Down, New, Wind, Bottom Seam

$t_p = 0''$ (Pressure)

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

$= 25,656 / (\pi * 14.813^2 * 13,600 * 1.20 * 1.00)$

$= 0.0023''$

$t_w = 0.6 * W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)

$= 0.60 * 3,239.8 / (2 * \pi * 14.813 * 13,600 * 1.20 * 1.00)$

$= 0.0013''$

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

$= 0 + 0.0023 - (0.0013)$

$= 0.001''$

$t_{mc} = M / (\pi * R_m^2 * S_c * K_s)$ (bending)

$= 25,656 / (\pi * 14.813^2 * 8,560.41 * 1.20)$

$= 0.0036''$

$t_{wc} = W / (2 * \pi * R_m * S_c * K_s)$ (Weight)

$= 3,239.8 / (2 * \pi * 14.813 * 8,560.41 * 1.20)$

$= 0.0034''$

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

$= 0.0036 + (0.0034) - (0)$

$= 0.007''$

Empty, Corroded, Wind, Bottom Seam

$t_p = 0''$ (Pressure)

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

$= 25,656 / (\pi * 14.813^2 * 16,700 * 1.20 * 1.00)$

$= 0.0019''$

$t_w = 0.6 * W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)

$= 0.60 * 3,239.8 / (2 * \pi * 14.813 * 16,700 * 1.20 * 1.00)$

$= 0.001''$

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

$= 0 + 0.0019 - (0.001)$

$= 0.0008''$

$t_{mc} = M / (\pi * R_m^2 * S_c * K_s)$ (bending)

$= 25,656 / (\pi * 14.813^2 * 10,972.44 * 1.20)$

$= 0.0028''$

$t_{wc} = W / (2 * \pi * R_m * S_c * K_s)$ (Weight)

$= 3,239.8 / (2 * \pi * 14.813 * 10,972.44 * 1.20)$

$= 0.0026''$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0028 + (0.0026) - (0)$
$= 0.0055"$

Empty, New, Wind, Bottom Seam

$t_p = 0"$ (Pressure)
$t_m = M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
$= 25{,}656 / (\pi*14.813^2*16{,}700*1.20*1.00)$
$= 0.0019"$
$t_w = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.60*3{,}239.8 / (2*\pi*14.813*16{,}700*1.20*1.00)$
$= 0.001"$
$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0 + 0.0019 - (0.001)$
$= 0.0008"$
$t_{mc} = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 25{,}656 / (\pi*14.813^2*10{,}972.44*1.20)$
$= 0.0028"$
$t_{wc} = W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 3{,}239.8 / (2*\pi*14.813*10{,}972.44*1.20)$
$= 0.0026"$
$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0028 + (0.0026) - (0)$
$= 0.0055"$

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)
$= 180 / (\pi*14.813^2*8{,}560.41*1.00)$
$= 0"$
$t_w = W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 3{,}239.8 / (2*\pi*14.813*8{,}560.41*1.00)$
$= 0.0041"$
$t_t = |t_p + t_m - t_w|$ (total, net compressive)
$= |0 + 0 - (0.0041)|$
$= 0.004"$
$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0 + (0.0041) - (0)$
$= 0.0041"$

Operating, Hot & Corroded, Seismic, Bottom Seam

$t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
$= 305*14.626 / (2*13{,}600*1.20*1.00 + 0.40*|305|)$
$= 0.1362"$
$t_m = M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
$= 3{,}958 / (\pi*14.813^2*13{,}600*1.20*1.00)$
$= 0.0004"$
$t_w = (0.6 - VAccel)*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.40*3{,}239.8 / (2*\pi*14.813*13{,}600*1.20*1.00)$
$= 0.0009"$
$t_t = t_p + t_m - t_w$ (total required, tensile)

$= 0.1362 + 0.0004 - (0.0009)$
$= 0.1357''$

$t_{wc} = (1 + VAccel)*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 1.20*3{,}239.8 / (2*\pi*14.813*13{,}600*1.20*1.00)$
$= 0.0026''$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0.0004 + (0.0026) - (0.1362)|$
$= 0.1333''$

Operating, Hot & New, Seismic, Bottom Seam

$t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
$= 305*14.626 / (2*13{,}600*1.20*1.00 + 0.40*|305|)$
$= 0.1362''$

$t_m = M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
$= 3{,}978 / (\pi*14.813^2*13{,}600*1.20*1.00)$
$= 0.0004''$

$t_w = (0.6 - VAccel)*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.40*3{,}239.8 / (2*\pi*14.813*13{,}600*1.20*1.00)$
$= 0.0009''$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0.1362 + 0.0004 - (0.0009)$
$= 0.1357''$

$t_{wc} = (1 + VAccel)*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 1.20*3{,}239.8 / (2*\pi*14.813*13{,}600*1.20*1.00)$
$= 0.0026''$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0.0004 + (0.0026) - (0.1362)|$
$= 0.1332''$

Hot Shut Down, Corroded, Seismic, Bottom Seam

$t_p = 0''$ (Pressure)

$t_m = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 3{,}958 / (\pi*14.813^2*8{,}560.41*1.20)$
$= 0.0006''$

$t_w = (0.6 - VAccel)*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 0.40*3{,}239.8 / (2*\pi*14.813*8{,}560.41*1.20)$
$= 0.0014''$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
$= |0 + 0.0006 - (0.0014)|$
$= 0.0008''$

$t_{wc} = (1 + VAccel)*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 1.20*3{,}239.8 / (2*\pi*14.813*8{,}560.41*1.20)$
$= 0.0041''$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0006 + (0.0041) - (0)$
$= 0.0046''$

Hot Shut Down, New, Seismic, Bottom Seam

$t_p = 0''$ (Pressure)

$t_m = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 3{,}978 / (\pi*14.813^2*8{,}560.41*1.20)$

= 0.0006"

t_w = (0.6 - VAccel)*W / (2*π*R_m*S_c*K_s) (Weight)
= 0.40*3,239.8 / (2*π*14.813*8,560.41*1.20)
= 0.0014"

t_t = |t_p + t_m - t_w| (total, net compressive)
= |0 + 0.0006 - (0.0014)|
= 0.0008"

t_{wc} = (1 + VAccel)*W / (2*π*R_m*S_c*K_s) (Weight)
= 1.20*3,239.8 / (2*π*14.813*8,560.41*1.20)
= 0.0041"

t_c = t_{mc} + t_{wc} - t_{pc} (total required, compressive)
= 0.0006 + (0.0041) - (0)
= 0.0046"

Empty, Corroded, Seismic, Bottom Seam

t_p = 0" (Pressure)

t_m = M / (π*R_m^2*S_c*K_s) (bending)
= 3,803 / (π*14.813^2*10,972.44*1.20)
= 0.0004"

t_w = (0.6 - VAccel)*W / (2*π*R_m*S_c*K_s) (Weight)
= 0.40*3,239.8 / (2*π*14.813*10,972.44*1.20)
= 0.0011"

t_t = |t_p + t_m - t_w| (total, net compressive)
= |0 + 0.0004 - (0.0011)|
= 0.0006"

t_{wc} = (1 + VAccel)*W / (2*π*R_m*S_c*K_s) (Weight)
= 1.20*3,239.8 / (2*π*14.813*10,972.44*1.20)
= 0.0032"

t_c = t_{mc} + t_{wc} - t_{pc} (total required, compressive)
= 0.0004 + (0.0032) - (0)
= 0.0036"

Empty, New, Seismic, Bottom Seam

t_p = 0" (Pressure)

t_m = M / (π*R_m^2*S_c*K_s) (bending)
= 3,824 / (π*14.813^2*10,972.44*1.20)
= 0.0004"

t_w = (0.6 - VAccel)*W / (2*π*R_m*S_c*K_s) (Weight)
= 0.40*3,239.8 / (2*π*14.813*10,972.44*1.20)
= 0.0011"

t_t = |t_p + t_m - t_w| (total, net compressive)
= |0 + 0.0004 - (0.0011)|
= 0.0006"

t_{wc} = (1 + VAccel)*W / (2*π*R_m*S_c*K_s) (Weight)
= 1.20*3,239.8 / (2*π*14.813*10,972.44*1.20)
= 0.0032"

t_c = t_{mc} + t_{wc} - t_{pc} (total required, compressive)
= 0.0004 + (0.0032) - (0)
= 0.0036"

SKIRT

Material:	SA-240 304L (II-D p. 82, ln. 38)
Design temperature, operating:	250 °F
Inner diameter at top, new:	29.2913 in
Inner diameter at bottom, new:	29.2913 in
Overall length:	34.0669 in
Corrosion allowance inside:	0 in
Corrosion allowance outside:	0.063 in
Weld joint efficiency top:	0.55
Weld joint efficiency bottom:	0.7
Nominal thickness, new:	0.3543 in
Skirt is attached to:	BTM HEAD
Skirt attachment offset:	3.8858 in down from the top seam

Skirt design thickness, largest of the following + corrosion = 0.1153 in

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

The skirt thickness of 0.3543 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 (+)	bottom	250	16,700	1,354.16	0.0236
Wind	operating, corroded (-)	bottom	250	8,192.68	1,472.17	0.0524
Wind	operating, new (+)	bottom	250	16,700	1,106.73	0.0235
Wind	operating, new (-)	bottom	250	8,478.06	1,207.7	0.0505
Wind	empty, corroded (+)	bottom	68	16,700	1,374.2	0.024
Wind	empty, corroded (-)	bottom	68	10,480.55	1,448.79	0.0403
Wind	empty, new (+)	bottom	68	16,700	1,123.17	0.0238
Wind	empty, new (-)	bottom	68	10,862.21	1,188.51	0.0388
Wind	test, new (+)	bottom	68	16,700	312.49	0.0066
Wind	test, new (-)	bottom	68	10,862.21	730.54	0.0238
Seismic	operating, corroded (+)	bottom	250	16,700	147.32	0.0026
Seismic	operating, corroded (-)	bottom	250	8,192.68	627.39	0.0223
Seismic	operating, new (+)	bottom	250	16,700	120.65	0.0026
Seismic	operating, new (-)	bottom	250	8,478.06	517.44	0.0216
Seismic	empty, corroded (+)	bottom	68	16,700	144.79	0.0025
Seismic	empty, corroded (-)	bottom	68	10,480.55	588.21	0.0164
Seismic	empty, new (+)	bottom	68	16,700	118.64	0.0025
Seismic	empty, new (-)	bottom	68	10,862.21	485.34	0.0158

Loading due to wind, operating & corroded

Windward side (tensile)

Required thickness, tensile stress at base:

$t = -0.6*W / (\pi*D*S_t*E) + 48*M / (\pi*D^2*S_t*E)$

$= -0.6*8,871.91 / (\pi*29.5827*16,700*0.7) + 48*19,098.6 / (\pi*29.5827^2*16,700*0.7)$

$= 0.0236$ in

Required thickness, tensile stress at the top:

$t = -0.6*W_t / (\pi*D_t*S_t*E) + 48*M_t / (\pi*D_t^2*S_t*E)$

$= -0.6*8{,}604.41 / (\pi*29.5827*16{,}700*0.55) + 48*13{,}419 / (\pi*29.5827^2*16{,}700*0.55)$
$= 0.0195$ in

Leeward side (compressive)

Required thickness, compressive stress at base:

$t = W / (\pi*D*S_c*E_c) + 48*M / (\pi*D^2*S_c*E_c)$
$= 8{,}871.91 / (\pi*29.5827*8{,}193*1) + 48*19{,}098.6 / (\pi*29.5827^2*8{,}193*1)$
$= 0.0524$ in

Required thickness, compressive stress at the top:

$t = W_t / (\pi*D_t*S_c*E_c) + 48*M_t / (\pi*D_t^2*S_c*E_c)$
$= 8{,}604.41 / (\pi*29.5827*8{,}193*1) + 48*13{,}419 / (\pi*29.5827^2*8{,}193*1)$
$= 0.0399$ in

BASE BLOCK

Base configuration:	external bolt chairs
Foundation compressive strength:	1,664 psi
Concrete ultimate 28-day strength:	3,001 psi
Anchor bolt material:	ASTM F1554 GR.55
Anchor bolt allowable stress, S_b:	24,750 psi
Bolt circle, BC:	33.5433 in
Anchor bolt corrosion allowance (applied to root radius):	0 in
Anchor bolt clearance:	0.4961 in
Base plate material:	SA 516-70
Base plate allowable stress, S_p:	19,999 psi
Base plate inner diameter, D_i:	26.5354 in
Base plate outer diameter, D_o:	37.0079 in
Base plate thickness, t_b:	1.0236 in
Gusset separation, w:	5.9843 in
Gusset height, h:	5.9449 in
Gusset thickness, t_g:	0.5118 in
Compression plate width:	3.5039 in
Compression plate length:	7.9921 in
Compression plate thickness, t_c:	1.0236 in
Initial bolt preload:	0 % (0 psi)
Number of bolts, N:	4
Bolt size and type:	1 inch series 8 threaded
Bolt root area (corroded), A_b:	0.551 in^2
Diameter of anchor bolt holes, d_b:	1.4961 in

Load	Vessel condition	Base M (lb_f-ft)	W (lb)	Required bolt area (in^2)	t_r Base (in)	Foundation bearing stress (psi)	$t_r$comp plate (in)	t_r gusset (in)
Wind	operating, corroded	19,098.6	9,114.8	0.2208	0.5083	152.2	0.4863	0.1269
Wind	operating, new	19,099.3	9,173.3	0.2205	0.5085	152.34	0.4856	0.1269
Wind	empty, corroded	19,098.6	8,481.7	0.2247	0.5058	150.7	0.494	0.1275
Wind	empty, new	19,099.3	8,540.2	0.2243	0.506	150.85	0.4933	0.1274
Wind	test, new	8,370.1	10,798.7	0.0555	0.3499	72.12	0.1801	0.1121
Seismic	operating, corroded	3,908	9,114.8	0.0197	0.3108	56.91	0.1092	0.1107
Seismic	operating, new	3,927.6	9,173.3	0.0197	0.3116	57.21	0.1092	0.1107
Seismic	empty, corroded	3,722.3	8,481.7	0.0195	0.3027	53.99	0.1103	0.1107
Seismic	empty, new	3,742.5	8,540.2	0.0196	0.3036	54.29	0.1104	0.1107

Anchor bolt load (governing)

P = -0.6*W / N + 48 * M / (N*BC)
= -0.6*8,481.71 / 4 + 48 * 19,098.6 / (4*33.5433)
= 5,560.18 lb_f

Required area per bolt = P / S_b = 0.2247 in^2

The area provided (0.551 in^2) by the specified anchor bolt is adequate.

Support calculations (Jawad & Farr chapter 12, governing)

Base plate width, t_c:	5.2362 in
Average base plate diameter, d:	31.7717 in
Base plate elastic modulus, E_s:	29,000,000 psi
Base plate yield stress, S_y:	30,000 psi

E_c = 57,000.00*Sqr(3,001) = 3,122,591 psi

n = E_s/E_c = 29,000,000 / 3,122,591 = 9.2872

$t_s = (N*A_b) / (\pi*d)$
$= (4*0.551) / (\pi*31.7717)$
$= 0.0221$ in

From table 12.4 for k = 0.181908:

$K_1 = 2.701, \quad K_2 = 1.1591$
$L_1 = 10.1084, L_2 = 19.9978, L_3 = 4.596$

Total tensile force on bolting

$T = (12*M - 0.6*W *(L_1 + L_3)) / (L_2 + L_3)$
$= (12*19{,}099.3 - 0.6*9{,}173.33 *(10.1084 + 4.596)) / (19.9978 + 4.596)$
$= 6{,}028.27\ lb_f$

Tensile stress in bolts use the larger of f_s or bolt preload = 0 psi

$f_s = T / (t_s * (d / 2) * K_1)$
$= 6{,}028.27 / (0.0221 * (31.7717 / 2) * 2.701)$
$= 6{,}363$ psi

Total compressive load on foundation

$C_c = T + W + \text{Bolt Preload}$
$= 6{,}028.27 + 9{,}173.33 + 0$
$= 15{,}201.6\ lb_f$

Foundation bearing stress

$f_c = C_c / (((t_c - t_s) + n*t_s)*(d / 2)*K_2)$
$= 15{,}201.6 / (((5.2362 - 0.0221) + 9.2872*0.0221)*(31.7717 / 2)*1.1591)$
$= 152$ psi

As $f_c <= 1{,}664$ psi the base plate width is satisfactory.

$k = 1 / (1 + f_s / (n*f_c))$
$= 1 / (1 + 6{,}363 / (9.2872*152))$
$= 0.181908$

Base plate required thickness (governing)

From Brownell & Young, Table 10.3:, l / b = 0.1812

$M_x = 0.0042*152*19.337^2 = 241.5\ lb_f$

$M_y = -0.4609*152*3.5039^2 = -862\ lb_f$

$t_r = (6*M_{max} / S_p)^{0.5}$
$= (6*861.96 / 19{,}999)^{0.5}$
$= 0.5085$ in

The base plate thickness is satisfactory.

Check the compression plate for bolt load (Jawad & Farr equation 12.13)

$t_{cr} = (3.91*F / (S_y*(2*b / w+w / (2*l)-d_b*(2 / w+1 / (2*l)))))^{0.5}$
$= (3.91*3{,}627.43 / (30{,}000*(2*3.5039 / 5.9843+5.9843 / (2*1.772)-1.4961*(2 / 5.9843+1 / (2*1.772)))))^{0.5}$
$= 0.494$ in

The compression plate thickness is satisfactory.

Check gusset plate thickness (Bednar chapter 4.3)

Radius of gyration of gusset

$r = 0.289*t_g$
$= 0.289*0.5118$
$= 0.1479$ in

Cross sectional area of one gusset

$A_g = t_g*(b - 0.25)$
$= 0.5118*(3.5039 - 0.25)$
$= 1.6654\ in^2$

Gusset allowable stress

$S_a = 17000 - 0.485*(h / r)^2$
$= 17000 - 0.485*(5.9449 / 0.1479)^2$
$= 16{,}217$ psi

Gusset axial stress due to bolt load

$S_g = F / (2 * A_g)$
$= 3{,}627.43 / (2 * 1.6654)$
$= 1{,}089$ psi

The gusset plate thickness is satisfactory.

Check skirt thickness for bolt load reaction (Brownell & Young eq. 10.59)

$t = 1.76*(F*l / (M_b*h_c*S_s))^{2/3}*(OD_s / 2)^{1/3}$
$= 1.76*(3{,}627.43*1.7717 / (17.315*7.9921*25{,}050))^{2/3}*(30 / 2)^{1/3}$
$= 0.0655$ in

The skirt thickness is satisfactory.

6" (AO)

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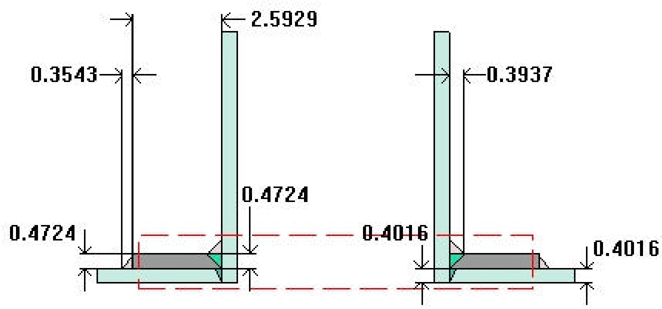

$t_{w(lower)}$ = 0.4016 in

Leg_{41} = 0.3937 in

$t_{w(upper)}$ = 0.4724 in

Leg_{42} = 0.3543 in

D_p = 11.8108 in

t_e = 0.4724 in

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

Located on:	TOP HEAD
Liquid static head included:	0 psi
Nozzle material specification:	SA-312 TP304L Wld & smls pipe (II-D p. 86, ln. 1)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	NPS 6 Sch 80S (XS)
Pad material specification:	SA-240 304L (II-D p. 82, ln. 38)
Pad diameter:	11.8108 in
Flange description:	6 inch Class 300 WN A182 F304L
Bolt Material:	SA-193 B8T 2 Bolt (3/4 < t <= 1) (II-D p. 360, ln. 16)
Flange rated MDMT:	-320°F
(Per UHA-51(d)(1)(a))	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	482.5 psi @ 250°F
ASME B16.5 flange rating MAP:	600 psi @ 68°F
ASME B16.5 flange hydro test:	925 psi @ 68°F
Gasket Description:	Flexitallic Spiral Wound CG 304L S.S.
PWHT performed:	No
Circumferential joint radiography:	None UW-11(c) Type 1
Nozzle orientation:	0°
Calculated as hillside:	No
Local vessel minimum thickness:	0.4016 in
End of nozzle to datum line:	130 in
Nozzle inside diameter, new:	5.761 in
Nozzle nominal wall thickness:	0.432 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	12.6109 in
Projection available outside vessel to flange face, Lf:	16.4909 in
Distance to head center, R:	0 in
Pad is split:	No

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 305 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}
1.3875	4.155	0.9259	0.7606	--	2.3135	0.155	0.3527	0.378

UG-41 Weld Failure Path Analysis Summary (lb_f) All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength	Weld load W_{3-3}	Path 3-3 strength
10,028.4	53,926.7	102,919.37	21,084.76	145,928	59,720.94	105,436.55

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.25	0.2756	weld size is adequate
Pad to shell fillet (Leg_{42})	0.2008	0.248	weld size is adequate
Nozzle to pad groove (Upper)	0.3024	0.4724	weld size is adequate

Calculations for internal pressure 305 psi @ 250 °F

Nozzle rated MDMT per UHA-51(d)(1)(a) = -320 °F.
Pad rated MDMT per UHA-51(d)(1)(a) = -320 °F.

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(5.761, 2.8805 + (0.432 - 0) + (0.4016 - 0))
= 5.761 in

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(0.4016 - 0), 2.5*(0.432 - 0) + 0.4724)
= 1.0039 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 305*2.8805 / (16,700*1 - 0.6*305)
= 0.0532 in

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

t_r = P*K_1*D / (2*S*E - 0.2*P)
= 305*0.9*29.252 / (2*16,700*1 - 0.2*305)
= 0.2409 in

Area required per UG-37(c)

Allowable stresses: S_n = 16,700, S_v = 16,700, S_p = 16,700 psi

f_{r1} = lesser of 1 or S_n / S_v = 1

f_{r2} = lesser of 1 or S_n / S_v = 1

f_{r3} = lesser of f_{r2} or S_p / S_v = 1

f_{r4} = lesser of 1 or S_p / S_v = 1

A	=	$d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
	=	5.761*0.2409*1 + 2*0.432*0.2409*1*(1 - 1)
	=	1.3875 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.9259 in^2

=	$d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
=	5.761*(1*0.4016 - 1*0.2409) - 2*0.432*(1*0.4016 - 1*0.2409)*(1 - 1)
=	0.9259 in^2
=	$2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
=	2*(0.4016 + 0.432)*(1*0.4016 - 1*0.2409) - 2*0.432*(1*0.4016 - 1*0.2409)*(1 - 1)
=	0.268 in^2

A_2 = smaller of the following= 0.7606 in^2

=	$5*(t_n - t_{rn})*f_{r2}*t$
=	5*(0.432 - 0.0532)*1*0.4016
=	0.7606 in^2
=	$2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
=	2*(0.432 - 0.0532)*(2.5*0.432 + 0.4724)*1
=	1.1761 in^2

A_{41}	=	Leg^2*f_{r3}
	=	0.3937^2*1
	=	0.155 in^2
A_{42}	=	Leg^2*f_{r4}
	=	0^2*1
	=	0 in^2

(Part of the weld is outside of the limits)

A_5	=	$(D_p - d - 2*t_n)*t_e*f_{r4}$
	=	(11.522 - 5.761 - 2*0.432)*0.4724*1
	=	2.3135 in^2
Area	=	$A_1 + A_2 + A_{41} + A_{42} + A_5$
	=	0.9259 + 0.7606 + 0.155 + 0 + 2.3135
	=	4.155 in^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: t_{min} = lesser of 0.75 or t_n or t_e = 0.432 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.3937 = 0.2756 in

Outer fillet: t_{min} = lesser of 0.75 or t_e or t = 0.4016 in
$t_{w(min)}$ = $0.5*t_{min}$ = 0.2008 in
$t_{w(actual)}$ = 0.7*Leg = 0.7*0.3543 = 0.248 in

UG-45 Nozzle Neck Thickness Check

Interpretation VIII-1-83-66 has been applied.
Wall thickness per UG-45(a): t_{r1} = 0.3527 in (E =1) (pressure plus external loads govern in longitudinal direction)

Wall thickness per UG-45(b)(1):	t_{r2} = 0.2676 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.245 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 0.2676 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.245 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.3527 in

Available nozzle wall thickness new, t_n = 0.875*0.432 = 0.378 in

The nozzle neck thickness is adequate.

Allowable stresses in joints UG-45(c) and UW-15(c)

Groove weld in tension:	0.74*16,700 =	12,358 psi
Nozzle wall in shear:	0.7*16,700 =	11,690 psi
Inner fillet weld in shear:	0.49*16,700 =	8,183 psi
Outer fillet weld in shear:	0.49*16,700 =	8,183 psi
Upper groove weld in tension:	0.74*16,700 =	12,358 psi

Strength of welded joints:

(1) Inner fillet weld in shear
$(\pi / 2)$*Nozzle OD*Leg*S_i = $(\pi / 2)$*6.625*0.3937*8,183 = 33,526.22 lb_f

(2) Outer fillet weld in shear
$(\pi / 2)$*Pad OD*Leg*S_o = $(\pi / 2)$*11.8108*0.3543*8,183 = 53,792.48 lb_f

(3) Nozzle wall in shear
$(\pi / 2)$*Mean nozzle dia*t_n*S_n = $(\pi / 2)$*6.193*0.432*11,690 = 49,126.89 lb_f

(4) Groove weld in tension
$(\pi / 2)$*Nozzle OD*t_w*S_g = $(\pi / 2)$*6.625*0.4016*12,358 = 51,644.06 lb_f

(6) Upper groove weld in tension
$(\pi / 2)$*Nozzle OD*t_w*S_g = $(\pi / 2)$*6.625*0.4724*12,358 = 60,757.72 lb_f

Loading on welds per UG-41(b)(1)

$$W = (A - A_1 + 2*t_n*f_{r1}*(E_1*t - F*t_r))*S_v$$
$$= (1.3875 - 0.9259 + 2*0.432*1*(1*0.4016 - 1*0.2409))*16,700$$
$$= 10,028.4\ lb_f$$

$$W_{1\text{-}1} = (A_2 + A_5 + A_{41} + A_{42})*S_v$$
$$= (0.7606 + 2.3135 + 0.155 + 0)*16,700$$
$$= 53,926.7\ lb_f$$

$$W_{2\text{-}2} = (A_2 + A_3 + A_{41} + A_{43} + 2*t_n*t*f_{r1})*S_v$$
$$= (0.7606 + 0 + 0.155 + 0 + 2*0.432*0.4016*1)*16,700$$
$$= 21,084.76\ lb_f$$

$$W_{3\text{-}3} = (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2*t_n*t*f_{r1})*S_v$$
$$= (0.7606 + 0 + 2.3135 + 0.155 + 0 + 0 + 2*0.432*0.4016*1)*16,700$$
$$= 59,720.94\ lb_f$$

Load for path 1-1 lesser of W or $W_{1\text{-}1}$ = 10028.4 lb_f
Path 1-1 through (2) & (3) = 53,792.48 + 49,126.89 = 102,919.37 lb_f
Path 1-1 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 2-2 lesser of W or $W_{2\text{-}2}$ = 10028.4 lb_f
Path 2-2 through (1), (4), (6) = 33,526.22 + 51,644.06 + 60,757.72 = 145,928 lb_f
Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 3-3 lesser of W or $W_{3\text{-}3}$ = 10028.4 lb_f

Path 3-3 through (2), (4) = 53,792.48 + 51,644.06 = 105,436.55 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

Applied Loads

Radial load:	P_r =	-2,067.94 lb_f
Circumferential moment:	M_1 =	121,783.7 lb_f-in
Circumferential shear:	V_2 =	4,136.1 lb_f
Longitudinal moment:	M_2 =	121,783.7 lb_f-in
Longitudinal shear:	V_1 =	4,136.1 lb_f
Torsion moment:	M_t =	86,032.36 lb_f-in
Internal pressure:	P =	305 psi
Head yield stress:	S_y =	20,200 psi

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

Mean dish radius R_m = 26.6592 in

U = r_o / Sqr(R_m*t) = 1.805
Pressure stress intensity factor, I = 1 (derived from PVP-Vol. 399, pages 77-82)

Local pressure stress = I*P*R_i / (2*t) =10,048 psi

Maximum combined stress (P_L+P_b+Q) = 42,473 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-50,100 psi

Note: The allowable combined stress (P_L+P_b+Q) is based on the strain hardening characteristics of this material.
The maximum combined stress (P_L+P_b+Q) is within allowable limits.

Maximum local primary membrane stress (P_L) = 16,512 psi
Allowable local primary membrane stress (P_L) = +-1.5*S = +-25,050 psi

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

Stresses at the pad edge per WRC Bulletin 107									
Figure	**value**	**A_u**	**A_l**	**B_u**	**B_l**	**C_u**	**C_l**	**D_u**	**D_l**
SR-2*	0.0289	371	371	371	371	371	371	371	371
SR-2	0.0139	1,069	-1,069	1,069	-1,069	1,069	-1,069	1,069	-1,069
SR-3*	0.0264	0	0	0	0	-6,093	-6,093	6,093	6,093
SR-3	0.0179	0	0	0	0	-24,789	24,789	24,789	-24,789
SR-3*	0.0264	-6,093	-6,093	6,093	6,093	0	0	0	0
SR-3	0.0179	-24,789	24,789	24,789	-24,789	0	0	0	0
Pressure stress*		10,048	10,048	10,048	10,048	10,048	10,048	10,048	10,048
Total O_x stress		-19,394	28,046	42,370	-9,346	-19,394	28,046	42,370	-9,346
Membrane O_x stress*		4,326	4,326	16,512	16,512	4,326	4,326	16,512	16,512
SR-2*	0.0086	110	110	110	110	110	110	110	110
SR-2	0.0042	323	-323	323	-323	323	-323	323	-323
SR-3*	0.008	0	0	0	0	-1,846	-1,846	1,846	1,846
SR-3	0.0053	0	0	0	0	-7,340	7,340	7,340	-7,340
SR-3*	0.008	-1,846	-1,846	1,846	1,846	0	0	0	0
SR-3	0.0053	-7,340	7,340	7,340	-7,340	0	0	0	0
Pressure stress*		10,048	10,048	10,048	10,048	10,048	10,048	10,048	10,048
Total O_y stress		1,295	15,329	19,667	4,341	1,295	15,329	19,667	4,341
Membrane O_y stress*		8,312	8,312	12,004	12,004	8,312	8,312	12,004	12,004
Shear from M_t		978	978	978	978	978	978	978	978
Shear from V_1		0	0	0	0	-555	-555	555	555
Shear from V_2		555	555	-555	-555	0	0	0	0
Total Shear stress		1,533	1,533	423	423	423	423	1,533	1,533
Combined stress (P_L+P_b+Q)		20,915	28,228	42,378	13,713	20,706	28,060	42,473	14,026

Notes: (1) * denotes primary stress.

(2) The nozzle is assumed to be a rigid (solid) attachment.

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

Mean dish radius R_m = 26.6592 in

U = r_o / Sqr(R_m*t) = 0.686
Pressure stress intensity factor, I = 0.33137 (derived from PVP-Vol. 399, pages 77-82)

Local pressure stress = I*P*R_i / (2*t) =3,330 psi

Maximum combined stress (P_L+P_b+Q) = 39,357 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-50,100 psi

Note: The allowable combined stress (P_L+P_b+Q) is based on the strain hardening characteristics of this material.
The maximum combined stress (P_L+P_b+Q) is within allowable limits.

Maximum local primary membrane stress (P_L) = 7,506 psi
Allowable local primary membrane stress (P_L) = +-1.5*S = +-25,050 psi

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

Stresses at the nozzle OD per WRC Bulletin 107									
Figure	**value**	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
SR-2*	0.1032	279	279	279	279	279	279	279	279
SR-2	0.06	975	-975	975	-975	975	-975	975	-975
SR-3*	0.118	0	0	0	0	-3,897	-3,897	3,897	3,897
SR-3	0.1551	0	0	0	0	-30,735	30,735	30,735	-30,735
SR-3*	0.118	-3,897	-3,897	3,897	3,897	0	0	0	0
SR-3	0.1551	-30,735	30,735	30,735	-30,735	0	0	0	0
Pressure stress*		3,330	3,330	3,330	3,330	3,330	3,330	3,330	3,330
Total O_x stress		-30,048	29,472	39,216	-24,204	-30,048	29,472	39,216	-24,204
Membrane O_x stress*		-288	-288	7,506	7,506	-288	-288	7,506	7,506
SR-2*	0.0308	83	83	83	83	83	83	83	83
SR-2	0.0184	299	-299	299	-299	299	-299	299	-299
SR-3*	0.0354	0	0	0	0	-1,169	-1,169	1,169	1,169
SR-3	0.0475	0	0	0	0	-9,413	9,413	9,413	-9,413
SR-3*	0.0354	-1,169	-1,169	1,169	1,169	0	0	0	0
SR-3	0.0475	-9,413	9,413	9,413	-9,413	0	0	0	0
Pressure stress*		3,330	3,330	3,330	3,330	3,330	3,330	3,330	3,330
Total O_y stress		-6,870	11,358	14,294	-5,130	-6,870	11,358	14,294	-5,130
Membrane O_y stress*		2,244	2,244	4,582	4,582	2,244	2,244	4,582	4,582
Shear from M_t		1,428	1,428	1,428	1,428	1,428	1,428	1,428	1,428
Shear from V_1		0	0	0	0	-455	-455	455	455
Shear from V_2		455	455	-455	-455	0	0	0	0
Total Shear stress		1,883	1,883	973	973	973	973	1,883	1,883
Combined stress (P_L+P_b+Q)		-30,200	29,666	39,254	-24,254	-30,089	29,524	39,357	-24,388

Notes: (1) * denotes primary stress.

(2) The nozzle is assumed to be a rigid (solid) attachment.

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$\sigma_{n\,(Pm)} = P*R_i / (2*t_n) - P_r / (\pi*(R_o^2 - R_i^2)) + M*R_o / I$
$= 305*2.8805 / (2*0.378) - -2{,}067.94 / (\pi*(3.3125^2 - 2.8805^2)) + 172{,}228.2*3.3125 / 40.4907$
$= 15{,}498$ psi

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable ($\leq S = 16{,}700$ psi)

Shear stress in the nozzle wall due to external loads

$\sigma_{shear} = (V_L^2 + V_c^2)^{0.5} / (\pi*R_i*t_n)$
$= (4{,}136.1^2 + 4{,}136.1^2)^{0.5} / (\pi*2.8805*0.432)$
$= 1{,}496$ psi

$\sigma_{torsion} = M_t / (2*\pi*R_i^2*t_n)$
$= 86{,}032.4 / (2*\pi*2.8805^2*0.432)$
$= 3{,}820$ psi

$\sigma_{total} = \sigma_{shear} + \sigma_{torsion}$
$= 1{,}496 + 3{,}820$
$= 5{,}316$ psi

UG-45(c): The total combined shear stress (5,316 psi) is below than the allowable ($0.7*S_n = 0.7*16{,}700 = 11{,}690$ psi)

2" (AV)

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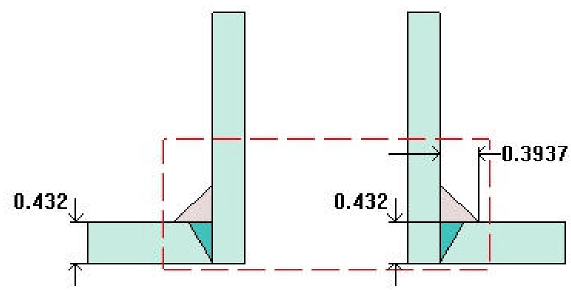
$t_{w(lower)}$ = 0.432 in

Leg_{41} = 0.3937 in



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

Located on:	6" (AO)
Liquid static head included:	0 psi
Nozzle material specification:	SA-312 TP304L Wld & smls pipe (II-D p. 86, ln. 1)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	NPS 2 Sch 160
Flange description:	2 inch Class 300 WN A182 F304L
Bolt Material:	SA-193 B8T 2 Bolt <= 3/4 (II-D p. 360, ln. 18)
Flange rated MDMT:	-320°F
(Per UHA-51(d)(1)(a))	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	482.5 psi @ 250°F
ASME B16.5 flange rating MAP:	600 psi @ 68°F
ASME B16.5 flange hydro test:	925 psi @ 68°F
Gasket Description:	Flexitallic Spiral Wound CG 304L S.S.
PWHT performed:	No
Circumferential joint radiography:	None UW-11(c) Type 1
Nozzle orientation:	0°
Local vessel minimum thickness:	0.432 in
Nozzle center line offset to face of parent nozzle:	10 in
End of nozzle to shell center:	12.9921 in
Nozzle inside diameter, new:	1.687 in
Nozzle nominal wall thickness:	0.344 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	6.9296 in
Projection available outside vessel to flange face, Lf:	9.6796 in

This nozzle passes through a Category A joint.

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 305 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}
0.0897	1.2495	0.5297	0.5648	--	--	0.155	0.1434	0.301

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})	0.2408	0.2756	weld size is adequate

Calculations for internal pressure 305 psi @ 250 °F

Nozzle rated MDMT per UHA-51(d)(1)(a) = -320 °F.

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(1.687, 0.8435 + (0.344 - 0) + (0.432 - 0))
= 1.687 in

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(0.432 - 0), 2.5*(0.344 - 0) + 0)
= 0.86 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 305*0.8435 / (16,700*1 - 0.6*305)
= 0.0156 in

Required thickness t_r from UG-37(a)

t_r = P*R / (S*E - 0.6*P)
= 305*2.8805 / (16,700*1 - 0.6*305)
= 0.0532 in

Area required per UG-37(c)

Allowable stresses: S_n = 16,700, S_v = 16,700 psi

f_{r1} = lesser of 1 or S_n / S_v = 1

f_{r2} = lesser of 1 or S_n / S_v = 1

A = d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})
= 1.687*0.0532*1 + 2*0.344*0.0532*1*(1 - 1)
= 0.0897 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.5297 in^2

	=	$d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
	=	$1.687*(0.85*0.432 - 1*0.0532) - 2*0.344*(0.85*0.432 - 1*0.0532)*(1 - 1)$
	=	0.5297 in^2
	=	$2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
	=	$2*(0.432 + 0.344)*(0.85*0.432 - 1*0.0532) - 2*0.344*(0.85*0.432 - 1*0.0532)*(1 - 1)$
	=	0.4873 in^2

A_2 = smaller of the following= 0.5648 in^2

	=	$5*(t_n - t_{rn})*f_{r2}*t$
	=	$5*(0.344 - 0.0156)*1*0.432$
	=	0.7093 in^2
	=	$5*(t_n - t_{rn})*f_{r2}*t_n$
	=	$5*(0.344 - 0.0156)*1*0.344$
	=	0.5648 in^2
A_{41}	=	Leg^2*f_{r2}
	=	0.3937^2*1
	=	0.155 in^2
Area	=	$A_1 + A_2 + A_{41}$
	=	0.5297 + 0.5648 + 0.155
	=	1.2495 in^2

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.344 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.2408 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.3937 = 0.2756 in

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	t_{r1} = 0.1434 in (E =1) (pressure plus external loads govern in longitudinal direction)
Wall thickness per UG-45(b)(1):	t_{r2} = 0.0532 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} = 0.0625 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.0625 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.1434 in

Available nozzle wall thickness new, t_n = 0.875*0.344 = 0.301 in

The nozzle neck thickness is adequate.

Applied Loads

Radial load:	P_r =	-449.96 lb_f
Circumferential moment:	M_c =	4,426.6 lb_f-in
Circumferential shear:	V_c =	550.94 lb_f
Longitudinal moment:	M_L =	4,426.6 lb_f-in
Longitudinal shear:	V_L =	550.94 lb_f
Torsion moment:	M_t =	6,188.57 lb_f-in
Internal pressure:	P =	305 psi
Mean shell radius:	R_m =	3.0965 in
Local shell thickness:	t =	0.432 in
Shell yield stress:	S_y =	20,200 psi

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

R_m / t = 3.0965 / 0.432 = 7.1678

Pressure stress intensity factor, I = 1.2178 (derived from PVP-Vol. 399, pages 77-82)

Local circumferential pressure stress = I*P*R_i / t =2,477 psi

Local longitudinal pressure stress = I*P*R_i / (2*t) =1,239 psi

Maximum combined stress (P_L+P_b+Q) = 17,667 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-50,100 psi

Note: The allowable combined stress (P_L+P_b+Q) is based on the strain hardening characteristics of this material.

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

Maximum local primary membrane stress (P_L) = 5,609 psi
Allowable local primary membrane (P_L) = +-1.5*S = +-25,050 psi

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

Stresses at the nozzle OD per WRC Bulletin 107										
Figure	**value**	**β**	**A_u**	**A_l**	**B_u**	**B_l**	**C_u**	**C_l**	**D_u**	**D_l**
3C*	0.9172	0.3356	0	0	0	0	309	309	309	309
4C*	1.1402	0.3356	384	384	384	384	0	0	0	0
1C	0.0864	0.3356	0	0	0	0	1,250	-1,250	1,250	-1,250
2C-1	0.0581	0.3356	840	-840	840	-840	0	0	0	0
3A*	0.2917	0.3356	0	0	0	0	-929	-929	929	929
1A	0.0915	0.3356	0	0	0	0	-12,532	12,532	12,532	-12,532
3B*	0.8629	0.3356	-2,748	-2,748	2,748	2,748	0	0	0	0
1B-1	0.0371	0.3356	-5,081	5,081	5,081	-5,081	0	0	0	0
Pressure stress*			2,477	2,477	2,477	2,477	2,034	2,034	2,034	2,034
Total circumferential stress			-4,128	4,354	11,530	-312	-9,868	12,696	17,054	-10,510
Primary membrane circumferential stress*			113	113	5,609	5,609	1,414	1,414	3,272	3,272
3C*	0.9172	0.3356	309	309	309	309	0	0	0	0
4C*	1.1402	0.3356	0	0	0	0	384	384	384	384
1C-1	0.0855	0.3356	1,237	-1,237	1,237	-1,237	0	0	0	0
2C	0.0576	0.3356	0	0	0	0	833	-833	833	-833
4A*	0.5427	0.3356	0	0	0	0	-1,728	-1,728	1,728	1,728
2A	0.0527	0.3356	0	0	0	0	-7,218	7,218	7,218	-7,218
4B*	0.2855	0.3356	-909	-909	909	909	0	0	0	0
2B-1	0.0627	0.3356	-8,588	8,588	8,588	-8,588	0	0	0	0
Pressure stress*			1,017	1,017	1,017	1,017	1,239	1,239	1,239	1,239
Total longitudinal stress			-6,934	7,768	12,060	-7,590	-6,490	6,280	11,402	-4,700
Primary membrane longitudinal stress*			417	417	2,235	2,235	-105	-105	3,351	3,351
Shear from M_t			1,617	1,617	1,617	1,617	1,617	1,617	1,617	1,617
Circ shear from V_c			342	342	-342	-342	0	0	0	0
Long shear from V_L			0	0	0	0	-342	-342	342	342
Total Shear stress			1,959	1,959	1,275	1,275	1,275	1,275	1,959	1,959
Combined stress (P_L+P_b+Q)			-7,941	8,659	13,097	-7,807	-10,295	12,940	17,667	-11,109

Note: * denotes primary stress.

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$\sigma_{n\,(Pm)} = P*R_i / (2*t_n) - P_r / (\pi*(R_o^2 - R_i^2)) + M*R_o / I$
$= 305*0.8435 / (2*0.301) - -449.96 / (\pi*(1.1875^2 - 0.8435^2)) + 6{,}260.2*1.1875 / 1.1642$
$= 7{,}018$ psi

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable ($\leq S = 16{,}700$ psi)

Shear stress in the nozzle wall due to external loads

$\sigma_{shear} = (V_L^2 + V_c^2)^{0.5} / (\pi*R_i*t_n)$
$= (550.94^2 + 550.94^2)^{0.5} / (\pi*0.8435*0.344)$
$= 855$ psi

$\sigma_{torsion} = M_t / (2*\pi*R_i^2*t_n)$
$= 6{,}188.6 / (2*\pi*0.8435^2*0.344)$
$= 4{,}024$ psi

$\sigma_{total} = \sigma_{shear} + \sigma_{torsion}$
$= 855 + 4{,}024$
$= 4{,}879$ psi

UG-45(c): The total combined shear stress (4,879 psi) is below than the allowable ($0.7*S_n$ = 0.7*16,700 = 11,690 psi)

6" (BE)

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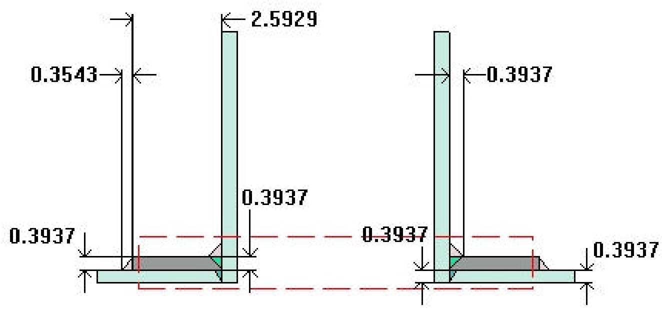

$t_{w(lower)}$ = 0.3937 in

Leg_{41} = 0.3937 in

$t_{w(upper)}$ = 0.3937 in

Leg_{42} = 0.3543 in

D_p = 11.8108 in

t_e = 0.3937 in

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

Located on:	SHELL
Liquid static head included:	0 psi
Nozzle material specification:	SA-312 TP304L Wld & smls pipe (II-D p. 86, ln. 1)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	NPS 6 Sch 80S (XS)
Pad material specification:	SA-240 304L (II-D p. 82, ln. 38)
Pad diameter:	11.8108 in
Flange description:	6 inch Class 300 WN A182 F304L
Bolt Material:	SA-193 B8T 2 Bolt (3/4 < t <= 1) (II-D p. 360, ln. 16)
Flange rated MDMT:	-320°F
(Per UHA-51(d)(1)(a))	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	482.5 psi @ 250°F
ASME B16.5 flange rating MAP:	600 psi @ 68°F
ASME B16.5 flange hydro test:	925 psi @ 68°F
Gasket Description:	Flexitallic Spiral Wound CG 304L S.S.
PWHT performed:	No
Circumferential joint radiography:	None UW-11(c) Type 1
Nozzle orientation:	0°
Local vessel minimum thickness:	0.3937 in
Nozzle center line offset to datum line:	47.9921 in
End of nozzle to shell center:	25.63 in
Nozzle inside diameter, new:	5.761 in
Nozzle nominal wall thickness:	0.432 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	6.7303 in
Projection available outside vessel to flange face, Lf:	10.6103 in
Pad is split:	No

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) **For P = 305 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}**
1.5559	3.5409	0.7122	0.7457	--	1.928	0.155	0.245	0.378

UG-41 Weld Failure Path Analysis Summary (lb_f) **All failure paths are stronger than the applicable weld loads**						
Weld load W	**Weld load W_{1-1}**	**Path 1-1 strength**	**Weld load W_{2-2}**	**Path 2-2 strength**	**Weld load W_{3-3}**	**Path 3-3 strength**
15,874.01	47,238.5	102,919.37	20,722.32	134,789.09	52,919.13	104,423.91

UW-16 Weld Sizing Summary			
Weld description	**Required weld size (in)**	**Actual weld size (in)**	**Status**
Nozzle to pad fillet (Leg_{41})	0.25	0.2756	weld size is adequate
Pad to shell fillet (Leg_{42})	0.1968	0.248	weld size is adequate
Nozzle to pad groove (Upper)	0.2756	0.3937	weld size is adequate

Calculations for internal pressure 305 psi @ 250 °F

Nozzle rated MDMT per UHA-51(d)(1)(a) = -320 °F.
Pad rated MDMT per UHA-51(d)(1)(a) = -320 °F.

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(5.761, 2.8805 + (0.432 - 0) + (0.3937 - 0))
= 5.761 in

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(0.3937 - 0), 2.5*(0.432 - 0) + 0.3937)
= 0.9843 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 305*2.8805 / (16,700*1 - 0.6*305)
= 0.0532 in

Required thickness t_r from UG-37(a)

t_r = P*R / (S*E - 0.6*P)
= 305*14.626 / (16,700*1 - 0.6*305)
= 0.2701 in

Area required per UG-37(c)

Allowable stresses: S_n = 16,700, S_v = 16,700, S_p = 16,700 psi

f_{r1} = lesser of 1 or S_n / S_v = 1

f_{r2} = lesser of 1 or S_n / S_v = 1

f_{r3} = lesser of f_{r2} or S_p / S_v = 1

f_{r4} = lesser of 1 or $S_p / S_v = 1$

$A = d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
$= 5.761*0.2701*1 + 2*0.432*0.2701*1*(1 - 1)$
$= 1.5559$ in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.7122 in^2

$= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
$= 5.761*(1*0.3937 - 1*0.2701) - 2*0.432*(1*0.3937 - 1*0.2701)*(1 - 1)$
$= 0.7122$ in^2

$= 2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
$= 2*(0.3937 + 0.432)*(1*0.3937 - 1*0.2701) - 2*0.432*(1*0.3937 - 1*0.2701)*(1 - 1)$
$= 0.2041$ in^2

A_2 = smaller of the following= 0.7457 in^2

$= 5*(t_n - t_{rn})*f_{r2}*t$
$= 5*(0.432 - 0.0532)*1*0.3937$
$= 0.7457$ in^2

$= 2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
$= 2*(0.432 - 0.0532)*(2.5*0.432 + 0.3937)*1$
$= 1.1165$ in^2

$A_{41} = Leg^2*f_{r3}$
$= 0.3937^2*1$
$= 0.155$ in^2

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

(Part of the weld is outside of the limits)

$A_5 = (D_p - d - 2*t_n)*t_e*f_{r4}$
$= (11.522 - 5.761 - 2*0.432)*0.3937*1$
$= 1.928$ in^2

$Area = A_1 + A_2 + A_{41} + A_{42} + A_5$
$= 0.7122 + 0.7457 + 0.155 + 0 + 1.928$
$= 3.5409$ in^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: t_{min} = lesser of 0.75 or t_n or t_e = 0.3937 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.25 in
$t_{c(actual)} = 0.7*Leg = 0.7*0.3937 = 0.2756$ in

Outer fillet: t_{min} = lesser of 0.75 or t_e or t = 0.3937 in
$t_{w(min)} = 0.5*t_{min} = 0.1969$ in
$t_{w(actual)} = 0.7*Leg = 0.7*0.3543 = 0.248$ in

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a): $t_{r1} = 0.1981$ in (E =1) (pressure plus external loads govern in longitudinal direction)
Wall thickness per UG-45(b)(1): $t_{r2} = 0.2701$ in
Wall thickness per UG-16(b): $t_{r3} = 0.0625$ in

Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.245 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 0.2701 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.245 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.245 in

Available nozzle wall thickness new, t_n = 0.875*0.432 = 0.378 in

The nozzle neck thickness is adequate.

Allowable stresses in joints UG-45(c) and UW-15(c)

Groove weld in tension:	0.74*16,700 = 12,358 psi
Nozzle wall in shear:	0.7*16,700 = 11,690 psi
Inner fillet weld in shear:	0.49*16,700 = 8,183 psi
Outer fillet weld in shear:	0.49*16,700 = 8,183 psi
Upper groove weld in tension:	0.74*16,700 = 12,358 psi

Strength of welded joints:

(1) Inner fillet weld in shear
(π / 2)*Nozzle OD*Leg*S_i = (π / 2)*6.625*0.3937*8,183 = 33,526.22 lb_f

(2) Outer fillet weld in shear
(π / 2)*Pad OD*Leg*S_o = (π / 2)*11.8108*0.3543*8,183 = 53,792.48 lb_f

(3) Nozzle wall in shear
(π / 2)*Mean nozzle dia*t_n*S_n = (π / 2)*6.193*0.432*11,690 = 49,126.89 lb_f

(4) Groove weld in tension
(π / 2)*Nozzle OD*t_w*S_g = (π / 2)*6.625*0.3937*12,358 = 50,631.43 lb_f

(6) Upper groove weld in tension
(π / 2)*Nozzle OD*t_w*S_g = (π / 2)*6.625*0.3937*12,358 = 50,631.43 lb_f

Loading on welds per UG-41(b)(1)

W = (A - A_1 + 2*t_n*f_{r1}*(E_1*t - F*t_r))*S_v
= (1.5559 - 0.7122 + 2*0.432*1*(1*0.3937 - 1*0.2701))*16,700
= 15,874.01 lb_f

W_{1-1} = (A_2 + A_5 + A_{41} + A_{42})*S_v
= (0.7457 + 1.928 + 0.155 + 0)*16,700
= 47,238.5 lb_f

W_{2-2} = (A_2 + A_3 + A_{41} + A_{43} + 2*t_n*t*f_{r1})*S_v
= (0.7457 + 0 + 0.155 + 0 + 2*0.432*0.3937*1)*16,700
= 20,722.32 lb_f

W_{3-3} = (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2*t_n*t*f_{r1})*S_v
= (0.7457 + 0 + 1.928 + 0.155 + 0 + 0 + 2*0.432*0.3937*1)*16,700
= 52,919.13 lb_f

Load for path 1-1 lesser of W or W_{1-1} = 15874.01 lb_f
Path 1-1 through (2) & (3) = 53,792.48 + 49,126.89 = 102,919.37 lb_f
Path 1-1 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 2-2 lesser of W or W_{2-2} = 15874.01 lb_f
Path 2-2 through (1), (4), (6) = 33,526.22 + 50,631.43 + 50,631.43 = 134,789.09 lb_f
Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 3-3 lesser of W or W_{3-3} = 15874.01 lb_f
Path 3-3 through (2), (4) = 53,792.48 + 50,631.43 = 104,423.91 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

Applied Loads

Radial load:	P_r =	-2,067.94 lb_f
Circumferential moment:	M_c =	60,896.19 lb_f-in
Circumferential shear:	V_c =	2,530.91 lb_f
Longitudinal moment:	M_L =	60,896.19 lb_f-in
Longitudinal shear:	V_L =	2,530.91 lb_f
Torsion moment:	M_t =	86,032.36 lb_f-in
Internal pressure:	P =	305 psi
Mean shell radius:	R_m =	14.8228 in
Local shell thickness:	t =	0.3937 in
Shell yield stress:	S_y =	20,200 psi

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

R_m / t = 14.8228 / 0.3937 = 37.65

Pressure stress intensity factor, I = 1 (derived from PVP-Vol. 399, pages 77-82)

Local circumferential pressure stress = I*P*R_i / t =11,331 psi

Local longitudinal pressure stress = I*P*R_i / (2*t) =5,666 psi

Maximum combined stress (P_L+P_b+Q) = 49,493 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-50,100 psi

Note: The allowable combined stress (P_L+P_b+Q) is based on the strain hardening characteristics of this material.

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

Maximum local primary membrane stress (P_L) = 17,523 psi
Allowable local primary membrane (P_L) = +-1.5*S = +-25,050 psi

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

Stresses at the pad edge per WRC Bulletin 107										
Figure	**value**	**β**	**A_u**	**A_l**	**B_u**	**B_l**	**C_u**	**C_l**	**D_u**	**D_l**
3C*	1.7277	0.3486	0	0	0	0	612	612	612	612
4C*	3.6967	0.3486	1,310	1,310	1,310	1,310	0	0	0	0
1C	0.0615	0.3486	0	0	0	0	4,923	-4,923	4,923	-4,923
2C-1	0.014	0.3486	1,121	-1,121	1,121	-1,121	0	0	0	0
3A*	1.2463	0.3486	0	0	0	0	-2,517	-2,517	2,517	2,517
1A	0.0658	0.3486	0	0	0	0	-30,018	30,018	30,018	-30,018
3B*	2.4175	0.3486	-4,882	-4,882	4,882	4,882	0	0	0	0
1B-1	0.0137	0.3486	-6,250	6,250	6,250	-6,250	0	0	0	0
Pressure stress*			11,331	11,331	11,331	11,331	11,331	11,331	11,331	11,331
Total circumferential stress			2,630	12,888	24,894	10,152	-15,669	34,521	49,401	-20,481
Primary membrane circumferential stress*			7,759	7,759	17,523	17,523	9,426	9,426	14,460	14,460
3C*	1.7277	0.3486	612	612	612	612	0	0	0	0
4C*	3.6967	0.3486	0	0	0	0	1,310	1,310	1,310	1,310
1C-1	0.0341	0.3486	2,730	-2,730	2,730	-2,730	0	0	0	0
2C	0.03	0.3486	0	0	0	0	2,401	-2,401	2,401	-2,401
4A*	3.7114	0.3486	0	0	0	0	-7,495	-7,495	7,495	7,495
2A	0.0287	0.3486	0	0	0	0	-13,093	13,093	13,093	-13,093
4B*	1.3073	0.3486	-2,640	-2,640	2,640	2,640	0	0	0	0
2B-1	0.0261	0.3486	-11,907	11,907	11,907	-11,907	0	0	0	0
Pressure stress*			5,666	5,666	5,666	5,666	5,666	5,666	5,666	5,666
Total longitudinal stress			-5,539	12,815	23,555	-5,719	-11,211	10,173	29,965	-1,023
Primary membrane longitudinal stress*			3,638	3,638	8,918	8,918	-519	-519	14,471	14,471
Shear from M_t			997	997	997	997	997	997	997	997
Circ shear from V_c			347	347	-347	-347	0	0	0	0
Long shear from V_L			0	0	0	0	-347	-347	347	347
Total Shear stress			1,344	1,344	650	650	650	650	1,344	1,344
Combined stress (P_L+P_b+Q)			8,600	14,196	25,158	15,924	-15,762	34,538	49,493	-20,573

Note: * denotes primary stress.

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

R_m / t = 14.8228 / 0.7874 = 18.825

Pressure stress intensity factor, I = 0.68977 (derived from PVP-Vol. 399, pages 77-82)

Local circumferential pressure stress = I*P*R_i / t =7,816 psi

Local longitudinal pressure stress = I*P*R_i / (2*t) =3,908 psi

Maximum combined stress (P_L+P_b+Q) = 33,510 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-50,100 psi

Note: The allowable combined stress (P_L+P_b+Q) is based on the strain hardening characteristics of this material.

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

Maximum local primary membrane stress (P_L) = 13,054 psi
Allowable local primary membrane (P_L) = +-1.5*S = +-25,050 psi

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

Stresses at the nozzle OD per WRC Bulletin 107										
Figure	value	β	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	2.3693	0.1955	0	0	0	0	420	420	420	420
4C*	3.0027	0.1955	532	532	532	532	0	0	0	0
1C	0.0923	0.1955	0	0	0	0	1,847	-1,847	1,847	-1,847
2C-1	0.0613	0.1955	1,227	-1,227	1,227	-1,227	0	0	0	0
3A*	0.7239	0.1955	0	0	0	0	-1,303	-1,303	1,303	1,303
1A	0.0904	0.1955	0	0	0	0	-18,380	18,380	18,380	-18,380
3B*	2.1329	0.1955	-3,839	-3,839	3,839	3,839	0	0	0	0
1B-1	0.0387	0.1955	-7,869	7,869	7,869	-7,869	0	0	0	0
Pressure stress*			7,816	7,816	7,816	7,816	11,331	11,331	11,331	11,331
Total circumferential stress			-2,133	11,151	21,283	3,091	-6,085	26,981	33,281	-7,173
Primary membrane circumferential stress*			4,509	4,509	12,187	12,187	10,448	10,448	13,054	13,054
3C*	2.3693	0.1955	420	420	420	420	0	0	0	0
4C*	3.0027	0.1955	0	0	0	0	532	532	532	532
1C-1	0.0962	0.1955	1,925	-1,925	1,925	-1,925	0	0	0	0
2C	0.0613	0.1955	0	0	0	0	1,227	-1,227	1,227	-1,227
4A*	1.1448	0.1955	0	0	0	0	-2,061	-2,061	2,061	2,061
2A	0.0496	0.1955	0	0	0	0	-10,085	10,085	10,085	-10,085
4B*	0.6969	0.1955	-1,254	-1,254	1,254	1,254	0	0	0	0
2B-1	0.0621	0.1955	-12,626	12,626	12,626	-12,626	0	0	0	0
Pressure stress*			5,666	5,666	5,666	5,666	3,908	3,908	3,908	3,908
Total longitudinal stress			-5,869	15,533	21,891	-7,211	-6,479	11,237	17,813	-4,811
Primary membrane longitudinal stress*			4,832	4,832	7,340	7,340	2,379	2,379	6,501	6,501
Shear from M_t			1,585	1,585	1,585	1,585	1,585	1,585	1,585	1,585
Circ shear from V_c			309	309	-309	-309	0	0	0	0
Long shear from V_L			0	0	0	0	-309	-309	309	309
Total Shear stress			1,894	1,894	1,276	1,276	1,276	1,276	1,894	1,894
Combined stress (P_L+P_b+Q)			-6,661	16,238	22,899	10,613	-7,573	27,084	33,510	-8,224

Note: * denotes primary stress.

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$\sigma_{n\ (Pm)} = P*R_i / (2*t_n) - P_r / (\pi*(R_o^2 - R_i^2)) + M*R_o / I$
$= 305*2.8805 / (2*0.378) - -2{,}067.94 / (\pi*(3.3125^2 - 2.8805^2)) + 86{,}120.2*3.3125 / 40.4907$
= 8,454 psi

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable ($\leq S$ = 16,700 psi)

Shear stress in the nozzle wall due to external loads

$\sigma_{shear} = (V_L^2 + V_c^2)^{0.5} / (\pi*R_i*t_n)$
$= (2{,}530.91^2 + 2{,}530.91^2)^{0.5} / (\pi*2.8805*0.432)$
= 916 psi

$\sigma_{torsion} = M_t / (2*\pi*R_i^2*t_n)$
$= 86{,}032.4 / (2*\pi*2.8805^2*0.432)$
= 3,820 psi

$\sigma_{total} = \sigma_{shear} + \sigma_{torsion}$
= 916 + 3,820
= 4,736 psi

UG-45(c): The total combined shear stress (4,736 psi) is below than the allowable ($0.7*S_n$ = 0.7*16,700 = 11,690 psi)

6" (BJ)

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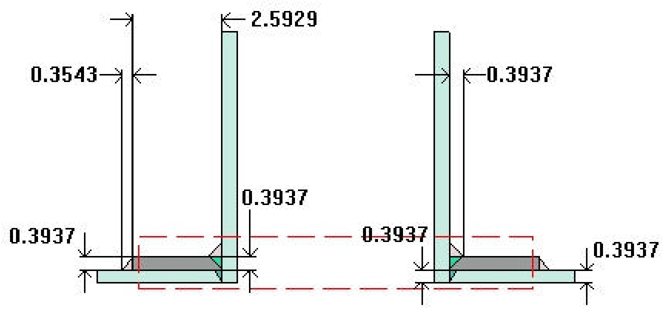

$t_{w(lower)}$ = 0.3937 in

Leg_{41} = 0.3937 in

$t_{w(upper)}$ = 0.3937 in

Leg_{42} = 0.3543 in

D_p = 11.8108 in

t_e = 0.3937 in

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

Located on:	SHELL
Liquid static head included:	0 psi
Nozzle material specification:	SA-312 TP304L Wld & smls pipe (II-D p. 86, ln. 1)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	NPS 6 Sch 80S (XS)
Pad material specification:	SA-240 304L (II-D p. 82, ln. 38)
Pad diameter:	11.8108 in
Flange description:	6 inch Class 300 WN A182 F304L
Bolt Material:	SA-193 B8T 2 Bolt (3/4 < t <= 1) (II-D p. 360, ln. 16)
Flange rated MDMT:	-320°F
(Per UHA-51(d)(1)(a))	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	482.5 psi @ 250°F
ASME B16.5 flange rating MAP:	600 psi @ 68°F
ASME B16.5 flange hydro test:	925 psi @ 68°F
Gasket Description:	Flexitallic Spiral Wound CG 304L S.S.
PWHT performed:	No
Circumferential joint radiography:	None UW-11(c) Type 1
Nozzle orientation:	315°
Local vessel minimum thickness:	0.3937 in
Nozzle center line offset to datum line:	40 in
End of nozzle to shell center:	25.63 in
Nozzle inside diameter, new:	5.761 in
Nozzle nominal wall thickness:	0.432 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	6.7303 in
Projection available outside vessel to flange face, Lf:	10.6103 in
Pad is split:	No

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 305 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}
1.5559	3.5409	0.7122	0.7457	--	1.928	0.155	0.245	0.378

UG-41 Weld Failure Path Analysis Summary (lb_f) All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength	Weld load W_{3-3}	Path 3-3 strength
15,874.01	47,238.5	102,919.37	20,722.32	134,789.09	52,919.13	104,423.91

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.25	0.2756	weld size is adequate
Pad to shell fillet (Leg_{42})	0.1968	0.248	weld size is adequate
Nozzle to pad groove (Upper)	0.2756	0.3937	weld size is adequate

Calculations for internal pressure 305 psi @ 250 °F

Nozzle rated MDMT per UHA-51(d)(1)(a) = -320 °F.
Pad rated MDMT per UHA-51(d)(1)(a) = -320 °F.

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(5.761, 2.8805 + (0.432 - 0) + (0.3937 - 0))
= 5.761 in

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(0.3937 - 0), 2.5*(0.432 - 0) + 0.3937)
= 0.9843 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 305*2.8805 / (16,700*1 - 0.6*305)
= 0.0532 in

Required thickness t_r from UG-37(a)

t_r = P*R / (S*E - 0.6*P)
= 305*14.626 / (16,700*1 - 0.6*305)
= 0.2701 in

Area required per UG-37(c)

Allowable stresses: S_n = 16,700, S_v = 16,700, S_p = 16,700 psi

f_{r1} = lesser of 1 or S_n / S_v = 1

f_{r2} = lesser of 1 or S_n / S_v = 1

f_{r3} = lesser of f_{r2} or S_p / S_v = 1

f_{r4} = lesser of 1 or $S_p / S_v = 1$

A	=	$d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
	=	$5.761*0.2701*1 + 2*0.432*0.2701*1*(1 - 1)$
	=	1.5559 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.7122 in^2

	=	$d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
	=	$5.761*(1*0.3937 - 1*0.2701) - 2*0.432*(1*0.3937 - 1*0.2701)*(1 - 1)$
	=	0.7122 in^2
	=	$2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
	=	$2*(0.3937 + 0.432)*(1*0.3937 - 1*0.2701) - 2*0.432*(1*0.3937 - 1*0.2701)*(1 - 1)$
	=	0.2041 in^2

A_2 = smaller of the following= 0.7457 in^2

	=	$5*(t_n - t_{rn})*f_{r2}*t$
	=	$5*(0.432 - 0.0532)*1*0.3937$
	=	0.7457 in^2
	=	$2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
	=	$2*(0.432 - 0.0532)*(2.5*0.432 + 0.3937)*1$
	=	1.1165 in^2

A_{41}	=	Leg^2*f_{r3}
	=	0.3937^2*1
	=	0.155 in^2
A_{42}	=	Leg^2*f_{r4}
	=	0^2*1
	=	0 in^2

(Part of the weld is outside of the limits)

A_5	=	$(D_p - d - 2*t_n)*t_e*f_{r4}$
	=	$(11.522 - 5.761 - 2*0.432)*0.3937*1$
	=	1.928 in^2
Area	=	$A_1 + A_2 + A_{41} + A_{42} + A_5$
	=	$0.7122 + 0.7457 + 0.155 + 0 + 1.928$
	=	3.5409 in^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: t_{min} = lesser of 0.75 or t_n or t_e = 0.3937 in

$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.25 in

$t_{c(actual)}$ = 0.7*Leg = 0.7*0.3937 = 0.2756 in

Outer fillet: t_{min} = lesser of 0.75 or t_e or t = 0.3937 in

$t_{w(min)} = 0.5*t_{min}$ = 0.1969 in

$t_{w(actual)}$ = 0.7*Leg = 0.7*0.3543 = 0.248 in

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	t_{r1} = 0.1981 in (E =1) (pressure plus external loads govern in longitudinal direction)
Wall thickness per UG-45(b)(1):	t_{r2} = 0.2701 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in

Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.245 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 0.2701 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.245 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.245 in

Available nozzle wall thickness new, t_n = 0.875*0.432 = 0.378 in

The nozzle neck thickness is adequate.

Allowable stresses in joints UG-45(c) and UW-15(c)

Groove weld in tension:	0.74*16,700 = 12,358 psi
Nozzle wall in shear:	0.7*16,700 = 11,690 psi
Inner fillet weld in shear:	0.49*16,700 = 8,183 psi
Outer fillet weld in shear:	0.49*16,700 = 8,183 psi
Upper groove weld in tension:	0.74*16,700 = 12,358 psi

Strength of welded joints:

(1) Inner fillet weld in shear
$(\pi / 2)$*Nozzle OD*Leg*S_i = $(\pi / 2)$*6.625*0.3937*8,183 = 33,526.22 lb_f

(2) Outer fillet weld in shear
$(\pi / 2)$*Pad OD*Leg*S_o = $(\pi / 2)$*11.8108*0.3543*8,183 = 53,792.48 lb_f

(3) Nozzle wall in shear
$(\pi / 2)$*Mean nozzle dia*t_n*S_n = $(\pi / 2)$*6.193*0.432*11,690 = 49,126.89 lb_f

(4) Groove weld in tension
$(\pi / 2)$*Nozzle OD*t_w*S_g = $(\pi / 2)$*6.625*0.3937*12,358 = 50,631.43 lb_f

(6) Upper groove weld in tension
$(\pi / 2)$*Nozzle OD*t_w*S_g = $(\pi / 2)$*6.625*0.3937*12,358 = 50,631.43 lb_f

Loading on welds per UG-41(b)(1)

$$W = (A - A_1 + 2*t_n*f_{r1}*(E_1*t - F*t_r))*S_v$$
$$= (1.5559 - 0.7122 + 2*0.432*1*(1*0.3937 - 1*0.2701))*16{,}700$$
$$= 15{,}874.01\ lb_f$$

$$W_{1\text{-}1} = (A_2 + A_5 + A_{41} + A_{42})*S_v$$
$$= (0.7457 + 1.928 + 0.155 + 0)*16{,}700$$
$$= 47{,}238.5\ lb_f$$

$$W_{2\text{-}2} = (A_2 + A_3 + A_{41} + A_{43} + 2*t_n*t*f_{r1})*S_v$$
$$= (0.7457 + 0 + 0.155 + 0 + 2*0.432*0.3937*1)*16{,}700$$
$$= 20{,}722.32\ lb_f$$

$$W_{3\text{-}3} = (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2*t_n*t*f_{r1})*S_v$$
$$= (0.7457 + 0 + 1.928 + 0.155 + 0 + 0 + 2*0.432*0.3937*1)*16{,}700$$
$$= 52{,}919.13\ lb_f$$

Load for path 1-1 lesser of W or $W_{1\text{-}1}$ = 15874.01 lb_f
Path 1-1 through (2) & (3) = 53,792.48 + 49,126.89 = 102,919.37 lb_f
Path 1-1 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 2-2 lesser of W or $W_{2\text{-}2}$ = 15874.01 lb_f
Path 2-2 through (1), (4), (6) = 33,526.22 + 50,631.43 + 50,631.43 = 134,789.09 lb_f
Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 3-3 lesser of W or $W_{3\text{-}3}$ = 15874.01 lb_f
Path 3-3 through (2), (4) = 53,792.48 + 50,631.43 = 104,423.91 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

Applied Loads

Radial load:	P_r =	-2,067.94 lb_f
Circumferential moment:	M_c =	60,896.19 lb_f-in
Circumferential shear:	V_c =	2,530.91 lb_f
Longitudinal moment:	M_L =	60,896.19 lb_f-in
Longitudinal shear:	V_L =	2,530.91 lb_f
Torsion moment:	M_t =	86,032.36 lb_f-in
Internal pressure:	P =	305 psi
Mean shell radius:	R_m =	14.8228 in
Local shell thickness:	t =	0.3937 in
Shell yield stress:	S_y =	20,200 psi

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

R_m / t = 14.8228 / 0.3937 = 37.65

Pressure stress intensity factor, I = 1 (derived from PVP-Vol. 399, pages 77-82)

Local circumferential pressure stress = I*P*R_i / t =11,331 psi

Local longitudinal pressure stress = I*P*R_i / (2*t) =5,666 psi

Maximum combined stress (P_L+P_b+Q) = 49,493 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-50,100 psi

Note: The allowable combined stress (P_L+P_b+Q) is based on the strain hardening characteristics of this material.

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

Maximum local primary membrane stress (P_L) = 17,523 psi
Allowable local primary membrane (P_L) = +-1.5*S = +-25,050 psi

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

Stresses at the pad edge per WRC Bulletin 107										
Figure	value	β	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	1.7277	0.3486	0	0	0	0	612	612	612	612
4C*	3.6967	0.3486	1,310	1,310	1,310	1,310	0	0	0	0
1C	0.0615	0.3486	0	0	0	0	4,923	-4,923	4,923	-4,923
2C-1	0.014	0.3486	1,121	-1,121	1,121	-1,121	0	0	0	0
3A*	1.2463	0.3486	0	0	0	0	-2,517	-2,517	2,517	2,517
1A	0.0658	0.3486	0	0	0	0	-30,018	30,018	30,018	-30,018
3B*	2.4175	0.3486	-4,882	-4,882	4,882	4,882	0	0	0	0
1B-1	0.0137	0.3486	-6,250	6,250	6,250	-6,250	0	0	0	0
Pressure stress*			11,331	11,331	11,331	11,331	11,331	11,331	11,331	11,331
Total circumferential stress			2,630	12,888	24,894	10,152	-15,669	34,521	49,401	-20,481
Primary membrane circumferential stress*			7,759	7,759	17,523	17,523	9,426	9,426	14,460	14,460
3C*	1.7277	0.3486	612	612	612	612	0	0	0	0
4C*	3.6967	0.3486	0	0	0	0	1,310	1,310	1,310	1,310
1C-1	0.0341	0.3486	2,730	-2,730	2,730	-2,730	0	0	0	0
2C	0.03	0.3486	0	0	0	0	2,401	-2,401	2,401	-2,401
4A*	3.7114	0.3486	0	0	0	0	-7,495	-7,495	7,495	7,495
2A	0.0287	0.3486	0	0	0	0	-13,093	13,093	13,093	-13,093
4B*	1.3073	0.3486	-2,640	-2,640	2,640	2,640	0	0	0	0
2B-1	0.0261	0.3486	-11,907	11,907	11,907	-11,907	0	0	0	0
Pressure stress*			5,666	5,666	5,666	5,666	5,666	5,666	5,666	5,666
Total longitudinal stress			-5,539	12,815	23,555	-5,719	-11,211	10,173	29,965	-1,023
Primary membrane longitudinal stress*			3,638	3,638	8,918	8,918	-519	-519	14,471	14,471
Shear from M_t			997	997	997	997	997	997	997	997
Circ shear from V_c			347	347	-347	-347	0	0	0	0
Long shear from V_L			0	0	0	0	-347	-347	347	347
Total Shear stress			1,344	1,344	650	650	650	650	1,344	1,344
Combined stress (P_L+P_b+Q)			8,600	14,196	25,158	15,924	-15,762	34,538	49,493	-20,573

Note: * denotes primary stress.

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

R_m / t = 14.8228 / 0.7874 = 18.825

Pressure stress intensity factor, I = 0.68977 (derived from PVP-Vol. 399, pages 77-82)

Local circumferential pressure stress = I*P*R_i / t =7,816 psi

Local longitudinal pressure stress = I*P*R_i / (2*t) =3,908 psi

Maximum combined stress (P_L+P_b+Q) = 33,510 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-50,100 psi

Note: The allowable combined stress (P_L+P_b+Q) is based on the strain hardening characteristics of this material.

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

Maximum local primary membrane stress (P_L) = 13,054 psi
Allowable local primary membrane (P_L) = +-1.5*S = +-25,050 psi

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

Stresses at the nozzle OD per WRC Bulletin 107										
Figure	**value**	**β**	**A_u**	**A_l**	**B_u**	**B_l**	**C_u**	**C_l**	**D_u**	**D_l**
3C*	2.3693	0.1955	0	0	0	0	420	420	420	420
4C*	3.0027	0.1955	532	532	532	532	0	0	0	0
1C	0.0923	0.1955	0	0	0	0	1,847	-1,847	1,847	-1,847
2C-1	0.0613	0.1955	1,227	-1,227	1,227	-1,227	0	0	0	0
3A*	0.7239	0.1955	0	0	0	0	-1,303	-1,303	1,303	1,303
1A	0.0904	0.1955	0	0	0	0	-18,380	18,380	18,380	-18,380
3B*	2.1329	0.1955	-3,839	-3,839	3,839	3,839	0	0	0	0
1B-1	0.0387	0.1955	-7,869	7,869	7,869	-7,869	0	0	0	0
Pressure stress*			7,816	7,816	7,816	7,816	11,331	11,331	11,331	11,331
Total circumferential stress			-2,133	11,151	21,283	3,091	-6,085	26,981	33,281	-7,173
Primary membrane circumferential stress*			4,509	4,509	12,187	12,187	10,448	10,448	13,054	13,054
3C*	2.3693	0.1955	420	420	420	420	0	0	0	0
4C*	3.0027	0.1955	0	0	0	0	532	532	532	532
1C-1	0.0962	0.1955	1,925	-1,925	1,925	-1,925	0	0	0	0
2C	0.0613	0.1955	0	0	0	0	1,227	-1,227	1,227	-1,227
4A*	1.1448	0.1955	0	0	0	0	-2,061	-2,061	2,061	2,061
2A	0.0496	0.1955	0	0	0	0	-10,085	10,085	10,085	-10,085
4B*	0.6969	0.1955	-1,254	-1,254	1,254	1,254	0	0	0	0
2B-1	0.0621	0.1955	-12,626	12,626	12,626	-12,626	0	0	0	0
Pressure stress*			5,666	5,666	5,666	5,666	3,908	3,908	3,908	3,908
Total longitudinal stress			-5,869	15,533	21,891	-7,211	-6,479	11,237	17,813	-4,811
Primary membrane longitudinal stress*			4,832	4,832	7,340	7,340	2,379	2,379	6,501	6,501
Shear from M_t			1,585	1,585	1,585	1,585	1,585	1,585	1,585	1,585
Circ shear from V_c			309	309	-309	-309	0	0	0	0
Long shear from V_L			0	0	0	0	-309	-309	309	309
Total Shear stress			1,894	1,894	1,276	1,276	1,276	1,276	1,894	1,894
Combined stress (P_L+P_b+Q)			-6,661	16,238	22,899	10,613	-7,573	27,084	33,510	-8,224

Note: * denotes primary stress.

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$\sigma_{n\,(Pm)} = P*R_i / (2*t_n) - P_r / (\pi*(R_o^2 - R_i^2)) + M*R_o / I$
$= 305*2.8805 / (2*0.378) - -2{,}067.94 / (\pi*(3.3125^2 - 2.8805^2)) + 86{,}120.2*3.3125 / 40.4907$
$= 8{,}454$ psi

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable ($\leq S = 16{,}700$ psi)

Shear stress in the nozzle wall due to external loads

$\sigma_{shear} = (V_L^2 + V_c^2)^{0.5} / (\pi*R_i*t_n)$
$= (2{,}530.91^2 + 2{,}530.91^2)^{0.5} / (\pi*2.8805*0.432)$
$= 916$ psi

$\sigma_{torsion} = M_t / (2*\pi*R_i^2*t_n)$
$= 86{,}032.4 / (2*\pi*2.8805^2*0.432)$
$= 3{,}820$ psi

$\sigma_{total} = \sigma_{shear} + \sigma_{torsion}$
$= 916 + 3{,}820$
$= 4{,}736$ psi

UG-45(c): The total combined shear stress (4,736 psi) is below than the allowable ($0.7*S_n$ = 0.7*16,700 = 11,690 psi)

2" (BS)

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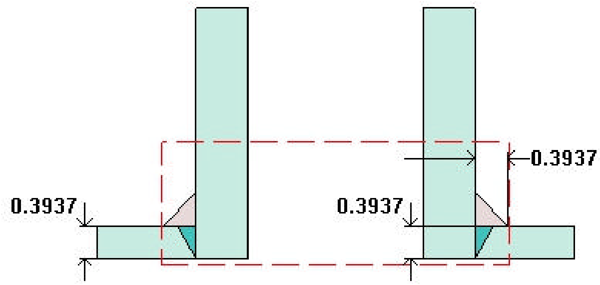
$t_{w(lower)}$ = 0.3937 in

Leg_{41} = 0.3937 in



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

Located on:	SHELL
Liquid static head included:	0.553 psi
Nozzle material specification:	SA-182 F304L <= 5 (II-D p. 82, ln. 34)
Nozzle longitudinal joint efficiency:	1
Flange description:	2 inch Class 300 LWN A182 F304L
Bolt Material:	SA-193 B8T 2 Bolt <= 3/4 (II-D p. 360, ln. 18)
Flange rated MDMT:	-320°F
(Per UHA-51(d)(1)(a))	
Liquid static head on flange:	0.515 psi
ASME B16.5 flange rating MAWP:	482.5 psi @ 250°F
ASME B16.5 flange rating MAP:	600 psi @ 68°F
ASME B16.5 flange hydro test:	925 psi @ 68°F
Gasket Description:	Flexitallic Spiral Wound CG 304L S.S.
PWHT performed:	No
Nozzle orientation:	300°
Local vessel minimum thickness:	0.3937 in
Nozzle center line offset to datum line:	5.9843 in
End of nozzle to shell center:	23.622 in
Nozzle inside diameter, new:	2.0669 in
Nozzle nominal wall thickness:	0.6201 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	7.7224 in
Projection available outside vessel to flange face, Lf:	8.6024 in

This nozzle passes through a Category A joint.

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 305.55 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}
0.5593	1.5925	0.2545	1.183	--	--	0.155	0.189	0.6201

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.25	0.2756	weld size is adequate

Calculations for internal pressure 305.55 psi @ 250 °F

Nozzle rated MDMT per UHA-51(d)(1)(a) = -320 °F.

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(2.0669, 1.0335 + (0.6201 - 0) + (0.3937 - 0))
= 2.0669 in

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(0.3937 - 0), 2.5*(0.6201 - 0) + 0)
= 0.9843 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 305.553*1.0335 / (16,700*1 - 0.6*305.553)
= 0.0191 in

Required thickness t_r from UG-37(a)

t_r = P*R / (S*E - 0.6*P)
= 305.553*14.626 / (16,700*1 - 0.6*305.553)
= 0.2706 in

Area required per UG-37(c)

Allowable stresses: S_n = 16,700, S_v = 16,700 psi

f_{r1} = lesser of 1 or S_n / S_v = 1

f_{r2} = lesser of 1 or S_n / S_v = 1

A = d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})
= 2.0669*0.2706*1 + 2*0.6201*0.2706*1*(1 - 1)
= 0.5593 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.2545 in^2

$= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
$= 2.0669*(1*0.3937 - 1*0.2706) - 2*0.6201*(1*0.3937 - 1*0.2706)*(1 - 1)$
$= 0.2545\ in^2$

$= 2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
$= 2*(0.3937 + 0.6201)*(1*0.3937 - 1*0.2706) - 2*0.6201*(1*0.3937 - 1*0.2706)*(1 - 1)$
$= 0.2496\ in^2$

A_2 = smaller of the following= 1.183 in^2

$= 5*(t_n - t_{rn})*f_{r2}*t$
$= 5*(0.6201 - 0.0191)*1*0.3937$
$= 1.183\ in^2$

$= 5*(t_n - t_{rn})*f_{r2}*t_n$
$= 5*(0.6201 - 0.0191)*1*0.6201$
$= 1.8633\ in^2$

$A_{41} = Leg^2*f_{r2}$
$= 0.3937^2*1$
$= 0.155\ in^2$

$Area = A_1 + A_2 + A_{41}$
$= 0.2545 + 1.183 + 0.155$
$= 1.5925\ in^2$

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.3937 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.3937 = 0.2756 in

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	t_{r1} = 0.1184 in (E =1) (pressure plus external loads govern in longitudinal direction)
Wall thickness per UG-45(b)(1):	t_{r2} = 0.2706 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.189 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 0.2706 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.189 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.189 in

Available nozzle wall thickness new, t_n = 0.6201 in

The nozzle neck thickness is adequate.

Applied Loads

Radial load:	P_r =	-449.96 lb_f
Circumferential moment:	M_c =	4,426.6 lb_f-in
Circumferential shear:	V_c =	550.94 lb_f
Longitudinal moment:	M_L =	4,426.6 lb_f-in
Longitudinal shear:	V_L =	550.94 lb_f
Torsion moment:	M_t =	6,188.57 lb_f-in
Internal pressure:	P =	305.553 psi
Mean shell radius:	R_m =	14.8228 in
Local shell thickness:	t =	0.3937 in
Shell yield stress:	S_y =	20,200 psi

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

R_m / t = 14.8228 / 0.3937 = 37.65

Pressure stress intensity factor, I = 1 (derived from PVP-Vol. 399, pages 77-82)

Local circumferential pressure stress = I*P*R_i / t =11,351 psi

Local longitudinal pressure stress = I*P*R_i / (2*t) =5,676 psi

Maximum combined stress (P_L+P_b+Q) = 26,485 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-50,100 psi

Note: The allowable combined stress (P_L+P_b+Q) is based on the strain hardening characteristics of this material.

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

Maximum local primary membrane stress (P_L) = 13,913 psi
Allowable local primary membrane (P_L) = +-1.5*S = +-25,050 psi

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

Stresses at the nozzle OD per WRC Bulletin 107										
Figure	value	β	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	5.8948	0.0976	0	0	0	0	455	455	455	455
4C*	6.617	0.0976	510	510	510	510	0	0	0	0
1C	0.1334	0.0976	0	0	0	0	2,324	-2,324	2,324	-2,324
2C-1	0.0964	0.0976	1,679	-1,679	1,679	-1,679	0	0	0	0
3A*	1.1471	0.0976	0	0	0	0	-601	-601	601	601
1A	0.0982	0.0976	0	0	0	0	-11,630	11,630	11,630	-11,630
3B*	3.9132	0.0976	-2,052	-2,052	2,052	2,052	0	0	0	0
1B-1	0.048	0.0976	-5,685	5,685	5,685	-5,685	0	0	0	0
Pressure stress*			11,351	11,351	11,351	11,351	11,351	11,351	11,351	11,351
Total circumferential stress			5,803	13,815	21,277	6,549	1,899	20,511	26,361	-1,547
Primary membrane circumferential stress*			9,809	9,809	13,913	13,913	11,205	11,205	12,407	12,407
3C*	5.8948	0.0976	455	455	455	455	0	0	0	0
4C*	6.617	0.0976	0	0	0	0	510	510	510	510
1C-1	0.1363	0.0976	2,374	-2,374	2,374	-2,374	0	0	0	0
2C	0.0962	0.0976	0	0	0	0	1,676	-1,676	1,676	-1,676
4A*	1.5841	0.0976	0	0	0	0	-830	-830	830	830
2A	0.0546	0.0976	0	0	0	0	-6,466	6,466	6,466	-6,466
4B*	1.0857	0.0976	-569	-569	569	569	0	0	0	0
2B-1	0.0756	0.0976	-8,953	8,953	8,953	-8,953	0	0	0	0
Pressure stress*			5,676	5,676	5,676	5,676	5,676	5,676	5,676	5,676
Total longitudinal stress			-1,017	12,141	18,027	-4,627	566	10,146	15,158	-1,126
Primary membrane longitudinal stress*			5,562	5,562	6,700	6,700	5,356	5,356	7,016	7,016
Shear from M_t			915	915	915	915	915	915	915	915
Circ shear from V_c			269	269	-269	-269	0	0	0	0
Long shear from V_L			0	0	0	0	-269	-269	269	269
Total Shear stress			1,184	1,184	646	646	646	646	1,184	1,184
Combined stress (P_L+P_b+Q)			7,219	14,428	21,401	11,250	2,161	20,551	26,485	-2,539

Note: * denotes primary stress.

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$\sigma_{n\ (Pm)} = P*R_i / (2*t_n) - P_r / (\pi*(R_o^2 - R_i^2)) + M*R_o / I$
$= 305.55*1.0335 / (2*0.6201) - -449.96 / (\pi*(1.6535^2 - 1.0335^2)) + 6{,}260.2*1.6535 / 4.9756$
$= 2{,}421$ psi

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable ($\leq S = 16{,}700$ psi)

Shear stress in the nozzle wall due to external loads

$\sigma_{shear} = (V_L^2 + V_c^2)^{0.5} / (\pi*R_i*t_n)$
$= (550.94^2 + 550.94^2)^{0.5} / (\pi*1.0335*0.6201)$
$= 387$ psi

$\sigma_{torsion} = M_t / (2*\pi*R_i^2*t_n)$
$= 6{,}188.6 / (2*\pi*1.0335^2*0.6201)$
$= 1{,}487$ psi

$\sigma_{total} = \sigma_{shear} + \sigma_{torsion}$
$= 387 + 1{,}487$
$= 1{,}874$ psi

UG-45(c): The total combined shear stress (1,874 psi) is below than the allowable ($0.7*S_n = 0.7*16,700 = 11,690$ psi)

2" (CW)

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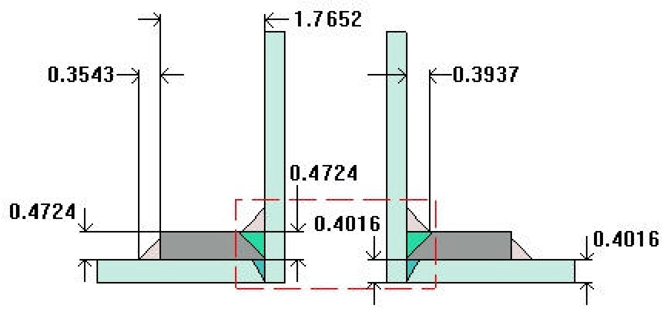

$t_{w(lower)}$ = 0.4016 in

Leg_{41} = 0.3937 in

$t_{w(upper)}$ = 0.4724 in

Leg_{42} = 0.3543 in

D_p = 5.9053 in

t_e = 0.4724 in

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

Located on:	BTM HEAD
Liquid static head included:	1.3813 psi
Nozzle material specification:	SA-312 TP304L Wld & smls pipe (II-D p. 86, ln. 1)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	NPS 2 Sch 160
Pad material specification:	SA-240 304L (II-D p. 82, ln. 38)
Pad diameter:	5.9053 in
Flange description:	2 inch Class 300 WN A182 F304L
Bolt Material:	SA-193 B8T 2 Bolt <= 3/4 (II-D p. 360, ln. 18)
Flange rated MDMT:	-320°F
(Per UHA-51(d)(1)(a))	
Liquid static head on flange:	1.3961 psi
ASME B16.5 flange rating MAWP:	482.5 psi @ 250°F
ASME B16.5 flange rating MAP:	600 psi @ 68°F
ASME B16.5 flange hydro test:	925 psi @ 68°F
Gasket Description:	Flexitallic Spiral Wound CG 304L S.S.
PWHT performed:	No
Circumferential joint radiography:	None UW-11(c) Type 1
Nozzle orientation:	0°
Calculated as hillside:	No
Local vessel minimum thickness:	0.4016 in
End of nozzle to datum line:	-17.9921 in
Nozzle inside diameter, new:	1.687 in
Nozzle nominal wall thickness:	0.344 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	7.5517 in
Projection available outside vessel to flange face, Lf:	10.3017 in
Distance to head center, R:	0 in
Pad is split:	No

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 306.38 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)							0.2479	0.301

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 pad fillet (Leg_{41})	0.2408	0.2756	weld size is adequate
Pad to shell fillet (Leg_{42})	0.2008	0.248	weld size is adequate
Nozzle to pad groove (Upper)	0.2408	0.4724	weld size is adequate

Calculations for internal pressure 306.38 psi @ 250 °F

Nozzle rated MDMT per UHA-51(d)(1)(a) = -320 °F.
Pad rated MDMT per UHA-51(d)(1)(a) = -320 °F.

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(1.687, 0.8435 + (0.344 - 0) + (0.4016 - 0))
= 1.687 in

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(0.4016 - 0), 2.5*(0.344 - 0) + 0.4724)
= 1.0039 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 306.3813*0.8435 / (16,700*1 - 0.6*306.3813)
= 0.0156 in

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

t_r = P*K_1*D / (2*S*E - 0.2*P)
= 306.3813*0.9*29.252 / (2*16,700*1 - 0.2*306.3813)
= 0.2419 in

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

UW-16(c)(2) Weld Check

Inner fillet: t_{min} = lesser of 0.75 or t_n or t_e = 0.344 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.2408 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.3937 = 0.2756 in

Outer fillet: t_{min} = lesser of 0.75 or t_e or t = 0.4016 in
$t_{w(min)}$ = 0.5*t_{min} = 0.2008 in
$t_{w(actual)}$ = 0.7*Leg = 0.7*0.3543 = 0.248 in

UG-45 Nozzle Neck Thickness Check

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

Wall thickness per UG-45(a):	t_{r1} = 0.2479 in (E =1) (pressure plus external loads govern in longitudinal direction)
Wall thickness per UG-45(b)(1):	t_{r2} = 0.2688 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} = 0.2688 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} = 0.2479 in

Available nozzle wall thickness new, t_n = 0.875*0.344 = 0.301 in

The nozzle neck thickness is adequate.

Applied Loads

Radial load:	P_r =	-449.96 lb_f
Circumferential moment:	M_1 =	8,679.62 lb_f-in
Circumferential shear:	V_2 =	899.05 lb_f
Longitudinal moment:	M_2 =	8,679.62 lb_f-in
Longitudinal shear:	V_1 =	899.05 lb_f
Torsion moment:	M_t =	6,188.57 lb_f-in
Internal pressure:	P =	306.381 psi
Head yield stress:	S_y =	20,200 psi

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

Mean dish radius R_m = 26.6592 in

U = r_o / Sqr(R_m*t) = 0.902
Pressure stress intensity factor, I = 1 (derived from PVP-Vol. 399, pages 77-82)

Local pressure stress = I*P*R_i / (2*t) =10,093 psi

Maximum combined stress (P_L+P_b+Q) = 21,102 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-50,100 psi

Note: The allowable combined stress (P_L+P_b+Q) is based on the strain hardening characteristics of this material.
The maximum combined stress (P_L+P_b+Q) is within allowable limits.

Maximum local primary membrane stress (P_L) = 11,743 psi
Allowable local primary membrane stress (P_L) = +-1.5*S = +-25,050 psi

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

Stresses at the pad edge per WRC Bulletin 107									
Figure	**value**	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
SR-2*	0.0739	206	206	206	206	206	206	206	206
SR-2	0.0399	668	-668	668	-668	668	-668	668	-668
SR-3*	0.0878	0	0	0	0	-1,444	-1,444	1,444	1,444
SR-3	0.0877	0	0	0	0	-8,656	8,656	8,656	-8,656
SR-3*	0.0878	-1,444	-1,444	1,444	1,444	0	0	0	0
SR-3	0.0877	-8,656	8,656	8,656	-8,656	0	0	0	0
Pressure stress*		10,093	10,093	10,093	10,093	10,093	10,093	10,093	10,093
Total O_x stress		867	16,843	21,067	2,419	867	16,843	21,067	2,419
Membrane O_x stress*		8,855	8,855	11,743	11,743	8,855	8,855	11,743	11,743
SR-2*	0.023	64	64	64	64	64	64	64	64
SR-2	0.012	201	-201	201	-201	201	-201	201	-201
SR-3*	0.0264	0	0	0	0	-434	-434	434	434
SR-3	0.0264	0	0	0	0	-2,606	2,606	2,606	-2,606
SR-3*	0.0264	-434	-434	434	434	0	0	0	0
SR-3	0.0264	-2,606	2,606	2,606	-2,606	0	0	0	0
Pressure stress*		10,093	10,093	10,093	10,093	10,093	10,093	10,093	10,093
Total O_y stress		7,318	12,128	13,398	7,784	7,318	12,128	13,398	7,784
Membrane O_y stress*		9,723	9,723	10,591	10,591	9,723	9,723	10,591	10,591
Shear from M_t		281	281	281	281	281	281	281	281
Shear from V_1		0	0	0	0	-241	-241	241	241
Shear from V_2		241	241	-241	-241	0	0	0	0
Total Shear stress		522	522	40	40	40	40	522	522
Combined stress (P_L+P_b+Q)		7,360	16,900	21,067	7,784	7,318	16,843	21,102	7,834

Notes: (1) * denotes primary stress.

(2) The nozzle is assumed to be a rigid (solid) attachment.

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

Mean dish radius R_m = 26.6592 in

U = r_o / Sqr(R_m*t) = 0.246
Pressure stress intensity factor, I = 0.22973 (derived from PVP-Vol. 399, pages 77-82)

Local pressure stress = I*P*R_i / (2*t) =2,319 psi

Maximum combined stress (P_L+P_b+Q) = 11,964 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-50,100 psi

Note: The allowable combined stress (P_L+P_b+Q) is based on the strain hardening characteristics of this material.
The maximum combined stress (P_L+P_b+Q) is within allowable limits.

Maximum local primary membrane stress (P_L) = 2,826 psi
Allowable local primary membrane stress (P_L) = +-1.5*S = +-25,050 psi

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

Stresses at the nozzle OD per WRC Bulletin 107									
Figure	**value**	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
SR-2*	0.2066	122	122	122	122	122	122	122	122
SR-2	0.1628	575	-575	575	-575	575	-575	575	-575
SR-3*	0.1637	0	0	0	0	-385	-385	385	385
SR-3	0.5944	0	0	0	0	-8,395	8,395	8,395	-8,395
SR-3*	0.1637	-385	-385	385	385	0	0	0	0
SR-3	0.5944	-8,395	8,395	8,395	-8,395	0	0	0	0
Pressure stress*		2,319	2,319	2,319	2,319	2,319	2,319	2,319	2,319
Total O_x stress		-5,764	9,876	11,796	-6,144	-5,764	9,876	11,796	-6,144
Membrane O_x stress*		2,056	2,056	2,826	2,826	2,056	2,056	2,826	2,826
SR-2*	0.0636	37	37	37	37	37	37	37	37
SR-2	0.0488	172	-172	172	-172	172	-172	172	-172
SR-3*	0.0498	0	0	0	0	-117	-117	117	117
SR-3	0.174	0	0	0	0	-2,457	2,457	2,457	-2,457
SR-3*	0.0498	-117	-117	117	117	0	0	0	0
SR-3	0.174	-2,457	2,457	2,457	-2,457	0	0	0	0
Pressure stress*		2,319	2,319	2,319	2,319	2,319	2,319	2,319	2,319
Total O_y stress		-46	4,524	5,102	-156	-46	4,524	5,102	-156
Membrane O_y stress*		2,239	2,239	2,473	2,473	2,239	2,239	2,473	2,473
Shear from M_t		799	799	799	799	799	799	799	799
Shear from V_1		0	0	0	0	-276	-276	276	276
Shear from V_2		276	276	-276	-276	0	0	0	0
Total Shear stress		1,075	1,075	523	523	523	523	1,075	1,075
Combined stress (P_L+P_b+Q)		6,109	10,084	11,837	-6,189	5,813	9,927	11,964	6,362

Notes: (1) * denotes primary stress.

(2) The nozzle is assumed to be a rigid (solid) attachment.

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$\sigma_{n\,(Pm)} = P*R_i / (2*t_n) - P_r / (\pi*(R_o^2 - R_i^2)) + M*R_o / I$
$= 306.38*0.8435 / (2*0.301) - -449.96 / (\pi*(1.1875^2 - 0.8435^2)) + 12,274.8*1.1875 / 1.1642$
$= 13,155$ psi

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable ($\leq S = 16,700$ psi)

Shear stress in the nozzle wall due to external loads

$\sigma_{shear} = (V_L^2 + V_c^2)^{0.5} / (\pi*R_i*t_n)$
$= (899.05^2 + 899.05^2)^{0.5} / (\pi*0.8435*0.344)$
$= 1,395$ psi

$\sigma_{torsion} = M_t / (2*\pi*R_i^2*t_n)$
$= 6,188.6 / (2*\pi*0.8435^2*0.344)$
$= 4,024$ psi

$\sigma_{total} = \sigma_{shear} + \sigma_{torsion}$
$= 1,395 + 4,024$
$= 5,419$ psi

UG-45(c): The total combined shear stress (5,419 psi) is below than the allowable ($0.7*S_n = 0.7*16,700 = 11,690$ psi)

2" (LB1A/B)

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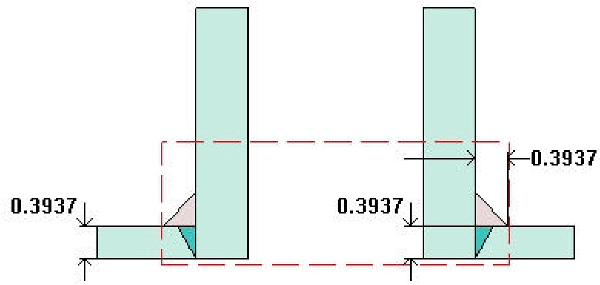
$t_{w(lower)}$ = 0.3937 in

Leg_{41} = 0.3937 in



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

Located on:	SHELL
Liquid static head included:	0 psi
Nozzle material specification:	SA-182 F304L <= 5 (II-D p. 82, ln. 34)
Nozzle longitudinal joint efficiency:	1
Flange description:	2 inch Class 300 LWN A182 F304L
Bolt Material:	SA-193 B8T 2 Bolt <= 3/4 (II-D p. 360, ln. 18)
Flange rated MDMT:	-320°F
(Per UHA-51(d)(1)(a))	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	482.5 psi @ 250°F
ASME B16.5 flange rating MAP:	600 psi @ 68°F
ASME B16.5 flange hydro test:	925 psi @ 68°F
Gasket Description:	Flexitallic Spiral Wound CG 304L S.S.
PWHT performed:	No
Nozzle orientation:	45°
Local vessel minimum thickness:	0.3937 in
Nozzle center line offset to datum line:	56.9685 in
End of nozzle to shell center:	23.622 in
Nozzle inside diameter, new:	2.0669 in
Nozzle nominal wall thickness:	0.6201 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	7.7224 in
Projection available outside vessel to flange face, Lf:	8.6024 in

This nozzle passes through a Category A joint.

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 305 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}
0.5582	1.5935	0.2555	1.183	--	--	0.155	0.189	0.6201

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.25	0.2756	weld size is adequate

Calculations for internal pressure 305 psi @ 250 °F

Nozzle rated MDMT per UHA-51(d)(1)(a) = -320 °F.

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(2.0669, 1.0335 + (0.6201 - 0) + (0.3937 - 0))
= 2.0669 in

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(0.3937 - 0), 2.5*(0.6201 - 0) + 0)
= 0.9843 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 305*1.0335 / (16,700*1 - 0.6*305)
= 0.0191 in

Required thickness t_r from UG-37(a)

t_r = P*R / (S*E - 0.6*P)
= 305*14.626 / (16,700*1 - 0.6*305)
= 0.2701 in

Area required per UG-37(c)

Allowable stresses: S_n = 16,700, S_v = 16,700 psi

f_{r1} = lesser of 1 or S_n / S_v = 1

f_{r2} = lesser of 1 or S_n / S_v = 1

A = d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})
= 2.0669*0.2701*1 + 2*0.6201*0.2701*1*(1 - 1)
= 0.5582 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.2555 in^2

$= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
$= 2.0669*(1*0.3937 - 1*0.2701) - 2*0.6201*(1*0.3937 - 1*0.2701)*(1 - 1)$
$= 0.2555\ in^2$

$= 2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
$= 2*(0.3937 + 0.6201)*(1*0.3937 - 1*0.2701) - 2*0.6201*(1*0.3937 - 1*0.2701)*(1 - 1)$
$= 0.2506\ in^2$

A_2 = smaller of the following= 1.183 in^2

$= 5*(t_n - t_{rn})*f_{r2}*t$
$= 5*(0.6201 - 0.0191)*1*0.3937$
$= 1.183\ in^2$

$= 5*(t_n - t_{rn})*f_{r2}*t_n$
$= 5*(0.6201 - 0.0191)*1*0.6201$
$= 1.8633\ in^2$

$A_{41} = Leg^2*f_{r2}$
$= 0.3937^2*1$
$= 0.155\ in^2$

Area $= A_1 + A_2 + A_{41}$
$= 0.2555 + 1.183 + 0.155$
$= 1.5935\ in^2$

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.3937 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.3937 = 0.2756 in

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	t_{r1} = 0.0191 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 0.2701 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.189 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 0.2701 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.189 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.189 in

Available nozzle wall thickness new, t_n = 0.6201 in

The nozzle neck thickness is adequate.

2" (LT2A/B, LT3A/B, LT4A/B)

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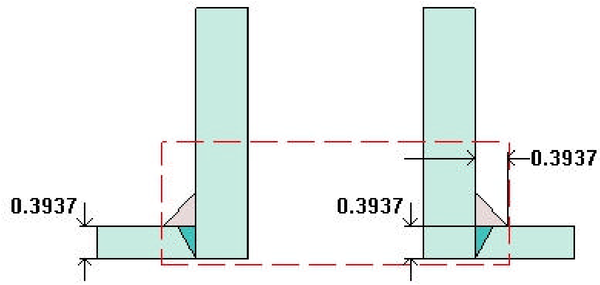
$t_{w(lower)}$ = 0.3937 in

Leg_{41} = 0.3937 in



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

Located on:	SHELL
Liquid static head included:	0 psi
Nozzle material specification:	SA-182 F304L <= 5 (II-D p. 82, ln. 34)
Nozzle longitudinal joint efficiency:	1
Flange description:	2 inch Class 300 LWN A182 F304L
Bolt Material:	SA-193 B8T 2 Bolt <= 3/4 (II-D p. 360, ln. 18)
Flange rated MDMT:	-320°F
(Per UHA-51(d)(1)(a))	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	482.5 psi @ 250°F
ASME B16.5 flange rating MAP:	600 psi @ 68°F
ASME B16.5 flange hydro test:	925 psi @ 68°F
Gasket Description:	Flexitallic Spiral Wound CG 304L S.S.
PWHT performed:	No
Nozzle orientation:	255°
Local vessel minimum thickness:	0.3937 in
Nozzle center line offset to datum line:	45.9843 in
End of nozzle to shell center:	23.622 in
Nozzle inside diameter, new:	2.0669 in
Nozzle nominal wall thickness:	0.6201 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	7.7224 in
Projection available outside vessel to flange face, Lf:	8.6024 in

This nozzle passes through a Category A joint.

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 305 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}
0.5582	1.5935	0.2555	1.183	--	--	0.155	0.189	0.6201

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.25	0.2756	weld size is adequate

Calculations for internal pressure 305 psi @ 250 °F

Nozzle rated MDMT per UHA-51(d)(1)(a) = -320 °F.

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(2.0669, 1.0335 + (0.6201 - 0) + (0.3937 - 0))
= 2.0669 in

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(0.3937 - 0), 2.5*(0.6201 - 0) + 0)
= 0.9843 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 305*1.0335 / (16,700*1 - 0.6*305)
= 0.0191 in

Required thickness t_r from UG-37(a)

t_r = P*R / (S*E - 0.6*P)
= 305*14.626 / (16,700*1 - 0.6*305)
= 0.2701 in

Area required per UG-37(c)

Allowable stresses: S_n = 16,700, S_v = 16,700 psi

f_{r1} = lesser of 1 or S_n / S_v = 1

f_{r2} = lesser of 1 or S_n / S_v = 1

A = d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})
= 2.0669*0.2701*1 + 2*0.6201*0.2701*1*(1 - 1)
= 0.5582 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.2555 in^2

$= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
$= 2.0669*(1*0.3937 - 1*0.2701) - 2*0.6201*(1*0.3937 - 1*0.2701)*(1 - 1)$
$= 0.2555\ in^2$

$= 2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
$= 2*(0.3937 + 0.6201)*(1*0.3937 - 1*0.2701) - 2*0.6201*(1*0.3937 - 1*0.2701)*(1 - 1)$
$= 0.2506\ in^2$

A_2 = smaller of the following= 1.183 in^2

$= 5*(t_n - t_{rn})*f_{r2}*t$
$= 5*(0.6201 - 0.0191)*1*0.3937$
$= 1.183\ in^2$

$= 5*(t_n - t_{rn})*f_{r2}*t_n$
$= 5*(0.6201 - 0.0191)*1*0.6201$
$= 1.8633\ in^2$

$A_{41} = Leg^2*f_{r2}$
$= 0.3937^2*1$
$= 0.155\ in^2$

$Area = A_1 + A_2 + A_{41}$
$= 0.2555 + 1.183 + 0.155$
$= 1.5935\ in^2$

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.3937 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.3937 = 0.2756 in

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	t_{r1} = 0.0191 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 0.2701 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.189 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 0.2701 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.189 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.189 in

Available nozzle wall thickness new, t_n = 0.6201 in

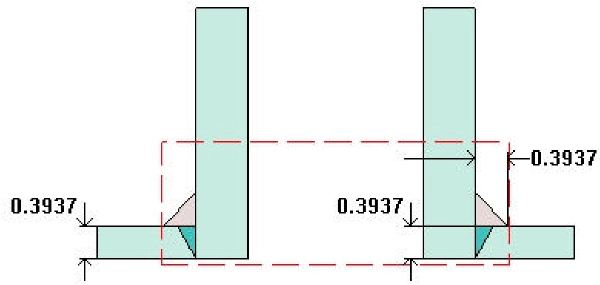
The nozzle neck thickness is adequate.

2" (TT1)

ASME Section VIII Division 1, 2007 Edition, A09 Addenda

$t_{w(lower)}$ = 0.3937 in

Leg_{41} = 0.3937 in



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

Located on:	SHELL
Liquid static head included:	0 psi
Nozzle material specification:	SA-182 F304L <= 5 (II-D p. 82, ln. 34)
Nozzle longitudinal joint efficiency:	1
Flange description:	2 inch Class 300 LWN A182 F304L
Bolt Material:	SA-193 B8T 2 Bolt <= 3/4 (II-D p. 360, ln. 18)
Flange rated MDMT:	-320°F
(Per UHA-51(d)(1)(a))	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	482.5 psi @ 250°F
ASME B16.5 flange rating MAP:	600 psi @ 68°F
ASME B16.5 flange hydro test:	925 psi @ 68°F
Gasket Description:	Flexitallic Spiral Wound CG 304L S.S.
PWHT performed:	No
Nozzle orientation:	270°
Local vessel minimum thickness:	0.3937 in
Nozzle center line offset to datum line:	82.9843 in
End of nozzle to shell center:	23.622 in
Nozzle inside diameter, new:	2.0669 in
Nozzle nominal wall thickness:	0.6201 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	7.7224 in
Projection available outside vessel to flange face, Lf:	8.6024 in

This nozzle passes through a Category A joint.

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 305 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}
0.5582	1.5935	0.2555	1.183	--	--	0.155	0.189	0.6201

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.25	0.2756	weld size is adequate

Calculations for internal pressure 305 psi @ 250 °F

Nozzle rated MDMT per UHA-51(d)(1)(a) = -320 °F.

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(2.0669, 1.0335 + (0.6201 - 0) + (0.3937 - 0))
= 2.0669 in

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(0.3937 - 0), 2.5*(0.6201 - 0) + 0)
= 0.9843 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 305*1.0335 / (16,700*1 - 0.6*305)
= 0.0191 in

Required thickness t_r from UG-37(a)

t_r = P*R / (S*E - 0.6*P)
= 305*14.626 / (16,700*1 - 0.6*305)
= 0.2701 in

Area required per UG-37(c)

Allowable stresses: S_n = 16,700, S_v = 16,700 psi

f_{r1} = lesser of 1 or S_n / S_v = 1

f_{r2} = lesser of 1 or S_n / S_v = 1

A = d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})
= 2.0669*0.2701*1 + 2*0.6201*0.2701*1*(1 - 1)
= 0.5582 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.2555 in^2

$= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
$= 2.0669*(1*0.3937 - 1*0.2701) - 2*0.6201*(1*0.3937 - 1*0.2701)*(1 - 1)$
$= 0.2555\ in^2$

$= 2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
$= 2*(0.3937 + 0.6201)*(1*0.3937 - 1*0.2701) - 2*0.6201*(1*0.3937 - 1*0.2701)*(1 - 1)$
$= 0.2506\ in^2$

A_2 = smaller of the following= 1.183 in^2

$= 5*(t_n - t_{rn})*f_{r2}*t$
$= 5*(0.6201 - 0.0191)*1*0.3937$
$= 1.183\ in^2$

$= 5*(t_n - t_{rn})*f_{r2}*t_n$
$= 5*(0.6201 - 0.0191)*1*0.6201$
$= 1.8633\ in^2$

$A_{41} = Leg^2*f_{r2}$
$= 0.3937^2*1$
$= 0.155\ in^2$

Area $= A_1 + A_2 + A_{41}$
$= 0.2555 + 1.183 + 0.155$
$= 1.5935\ in^2$

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.3937 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.3937 = 0.2756 in

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

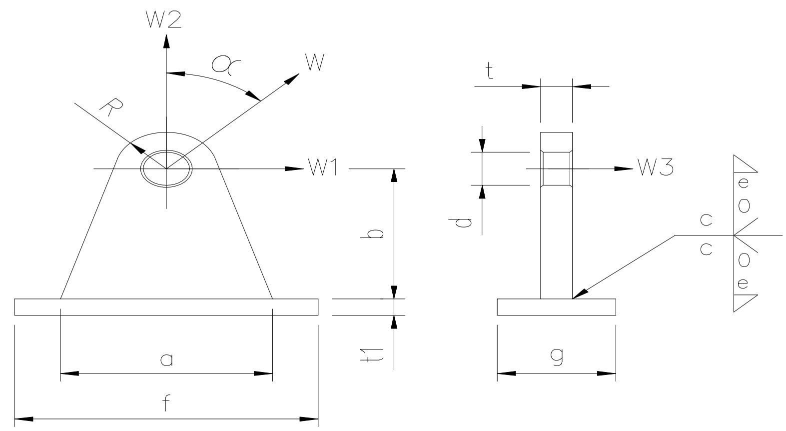
Wall thickness per UG-45(a):	t_{r1} = 0.0191 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 0.2701 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.189 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 0.2701 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.189 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.189 in

Available nozzle wall thickness new, t_n = 0.6201 in

The nozzle neck thickness is adequate.

1. CALCULATION OF LIFTING LUG



DIMENSIONS

a =	150 mm,	d =	27 mm,	R =	50 mm,	b =	170 mm,
c =	7 mm,	t =	20 mm,	α=	45 °,	e =	45 °
f =	200 mm,	g =	70 mm,	t1 =	18 mm,	ts =	10 mm, (HEAD or SHELL TH'K.)
Rs =	371.5 mm, (SHELL or HEAD INSIDE RADIUS)						

1) DESIGN CONDITION

LIFTING LUG Q'TY.	:	2	EA
MATERIAL OF LIFTING LUG	:	SA 240-304L	
YIELD STRESS OF LIFTING LUG	Sy =	17.58	kg/mm^2
MATERIAL OF SHELL or HEAD	:	SA 240-304L	
ALOWABLE STRESS AT AMB.	Ss =	11.74	kg/mm^2
VESSEL or H/EX ERECTION WEIGHT	We =	3900	kg
LOAD IMPACT FACTOR	C1 =	1.5	
LOAD PER ONE LUG	W =	2925	kg

W1 = W * COS α= 2069.0 kg

W2 = W * SIN α = 2069.0 kg

W3 = W * 0.1 = 293.0 kg (10% ASSUMED)

2) STRENGTH CALCULATION

(2-1) TENSILE STRESS OF SECTION 'I - I' PORTION DUE TO "W2"

ST = W2 / [(2 * R - d) * t)] = 2069.00 / [(2 * 50.00 - 27.00) * 20.00)]

= 1.417 kg/mm^2 < 0.6Sy = 10.548 kg/mm^2

(2-2) BENDING STRESS DUE TO "W1"

M1 = W1 * b =	2069.00	*	170	=	351730.0	kg-mm
Z1 = t * a^2 / 6 =	20 * (		150)^2 /6	=	75000.00	mm^3
Sb1 = M1 / Z1 =	4.690	kg/mm^2		<	11.6028	kg/mm^2 (0.66*Sy)

(2-3) BENDING STRESS DUE TO "W3"

M2 = W3 * b =	293.00	*	170	=	49810.0	kg-mm
Z2 = a * t^2 / 6 =	150 * (		20)^2 /6	=	10000.00	mm^3
Sb2 = M2 / Z2 =	4.981	kg/mm^2		<	11.6028	kg/mm^2 (0.66*Sy)

(2-4) SHEAR STRESS DUE TO "W"

SS = W / [(R - d/2) * t] = 2925.00 / [(50.00 - 27.00 / 2) * 20.00]

= 4.007 kg/mm^2 < 0.4*Sy = 7.032 kg/mm^2

(2-5) SHEAR STRESS OF WELDMENT

SWS = W / (2 * a *c) = 2925.00 / (2 * 150.00 * 7.00)

= 1.393 kg/mm^2 < 0.28*Sy = 4.9224 kg/mm^2

(2-6) SHELL STRESS

1) LINE LOADS

f1 = 6 ML / a2 = 93.79 kg/mm Where, ML= W1 * b = M1

f2 = W2 / a = 13.79 kg/mm

2) LOCAL STRESS DUE TO W2 & ML

S5 = 1.17 * v[Rs * (ts + t1)] * (f1 + 1.5f2) / (ts + t1)2

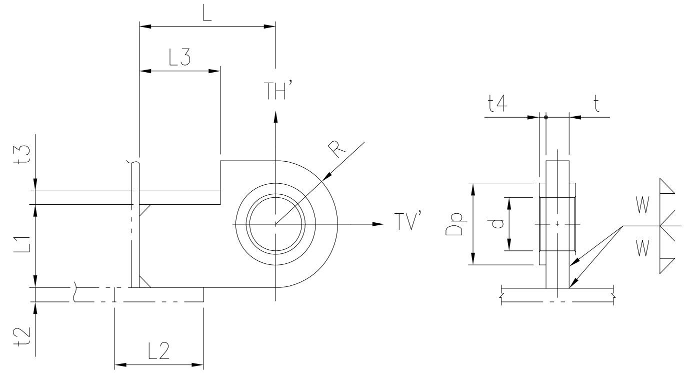
= 17.425 kg/mm2 < 2*Ss = 23.48 kg/mm2

2. STRENGTH OF TAILING LUG

USED MATERIAL	=	SA 240-304L	
YIELD STRESS OF TAILING LUG	Sy =	17.58	kg/㎟
ALLOWABLE SHEAR STRESS (0.4 * Sy)	Ssa =	7.032	kg/㎟
ALLOWABLE BENDING STRESS (0.66 * Sy)	Sba =	11.603	kg/㎟
ALLOWABLE TENSILE STRESS (0.6 * Sy)	Sta =	10.548	kg/㎟
TAILING LUG Q'TY.	N =	1	EA
LIFTING LOAD (MAX. AT HORIZONTAL COND.)	TV =	993.60	kg
LIFTING LOAD PER TAILING LUG (VERTICAL FORCE)	TV' = TV/N =	993.60	kg
LIFTING LOAD (MAX. AT VERTICAL COND.) AT 61.00 deg.	TH =	669.68	kg
LIFTING LOAD PER TAILING LUG (HORIZONTAL FORCE)	TH' = TH/N =	669.68	kg

* DIMENSIONS

t =	20.0	mm	t2 =	26.00	mm
L =	164.0	mm	t3 =	26.00	mm
R =	50.0	mm	L1 =	151.00	mm
d =	27.0	mm	L2 =	133.00	mm
W =	7.0	mm (WELD LEG)	L3 =	89.00	mm
Dp =	0.0	mm	TOTAL WELD LENGTH L4 =	278.00	mm
t4 =	0.0	mm			



** STRENGTH CALCULATION **

2-1) SHEAR STRESS AT HORIZONTAL STATE

S1 = 2TV' / [(2R - d) * t + 1/2 * (Dp - d) * 2t4] = 1.361 kg/㎟

∴ S1 = 1.361 kg/㎟ < Ssa = 7.03 kg/㎟

O.K. !

2-2) TENSION STRESS AT HORIZONTAL STATE

S2 = TV' / [(2R - d) * t + (Dp - d) * 2t4] = 0.681 kg/㎟

∴ S2 = 0.681 kg/㎟ < Sta = 10.548 kg/㎟

O.K. !

2-3) BENDING STRESS AT MAX. SLOPED LOAD STATE , AT 61.00 deg.

S3 = 6 * TH' * L / [(2 * R)²*t] = 3.295 kg/㎟

∴ S3 = 3.295 kg/㎟ < Sba = 11.603 kg/㎟

O.K. !

2-4) TENSION STRESS AT MAX. SLOPED LOAD STATE , AT 61.00 deg.

S4 = TH' / [(2 * R - d) * t] = 0.459 ㎏/㎟

∴ S4 = 0.459 ㎏/㎟ < Sta = 10.548 ㎏/㎟

O.K. !

2-5) COMBINE STRESS AT MAX. SLOPED STATE, AT 61.00 deg.

Scomb = S3 / Sba + S4 / Sta = 0.327 < 1.0

O.K. !

2-6) CHECK OF WELDMENT

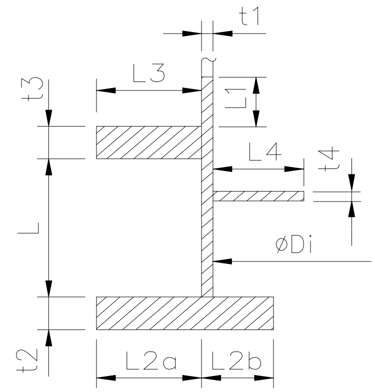
Sw = TV' / (2 * L4 * W) = 0.255 ㎏/㎟

∴ Sw = 0.255 ㎏/㎟ < 0.49 * Sba = 5.169 ㎏/㎟

O.K. !

3. BASE BLOCK UNDER ERECTION CONDITION

3-1. SECTIONAL PROPERTIES OF BASE BLOCK



t1 =	9.00	mm
t2 =	26.00	mm
t3 =	26.00	mm
t4 =	0.00	mm
L2a =	89.00	mm
L2b =	44.00	mm
L3 =	89.00	mm
L4 =	0.00	mm
L =	151.00	mm
Di =	744.00	mm

3-2. EFFECTIVE LENGTH OF SKIRT

Rm = (Di + t1) / 2 = 376.50 mm

L1 = Min.(0.78 * $\sqrt{}$(Rm * t1), 16*t1) = 45.40 mm

3-3. SECTION AREA , A

A1 = t1 * (L + L1 + t3) = 2001.6 ㎟

A2 = t2 * (L2a + L2b) = 3458.0 ㎟

A3 = t3 * L3 = 2314.0 ㎟

A4 = t4 * L4 = 0.0 ㎟

TOTAL AREA, A = 7773.6 ㎟

3-4. CENTROID, C

h1 = L2a + t1 / 2 = 93.5 mm

h2 = (L2a + L2b) / 2 = 66.5 mm

h3 = L3 / 2 - (L3 - L2a) = 44.5 mm

h4 = L2a + t1 + L4 / 2 = 98.0 mm

C = [(A1 * h1) + (A2 * h2) + (A3 * h3) + (A4 * h4)] / A = 66.90 mm

Y = (L2a + L2b) - C = 66.10 mm

3-5. MOMENT OF INERTIA OF AREA, I (ABOUT NEUTRAL AXIS)

I1 = (L + L1 + t3) * t1^3 / 12 + A1 * (h1 - C)^2 = 1429424 mm^4

I2 = t2 * (L2a + L2b)^3 / 12 + A2 * (h2 - C)^2 = 5097943 mm^4

I3 = t3 * L3^3 / 12 + A3 * (h3 - C)^2 = 2688863 mm^4

I4 = t4 * L4^3 / 12 + A4 * (h4 - C)^2 = 0 mm^4

TOTAL I = I1 + I2 + I3 + I4 = 9216230 mm^4

3-6. MIN. SECTION MODULUS, Z

Z1 = I / C = 137754 mm^3

Z2 = I / Y = 139436 mm^3

Z = Min.(Z1, Z2) = 137754 mm^3

3-7. STRESS IN BASE BLOCK DUE TO TV

TV = 993.6 kg (Max. Force at Tailing Lug)
R = 403.10 mm (Radius to neutral axis)
Sy = 17.58 kg/㎟ (Yield Strength of Base)
Z = 137754 kg/mm^3 (Section Modulus of Base)
A = 7773.6 ㎟ (Section Area of Base)

a) BENDING MOMENT (Ma) & TANGENTIAL FORCE (Ta) AT BASE BLOCK

CASE ; NO BRACING : ROARK 4th ED. CASE 25

Ma = 0.2387 * TV * R = 95603 kg-mm
Ta = 0.2387 * TV = 237.2 kg

σ = Ma / Z + Ta / A = 0.725 kg/㎟ < 0.66Sy = 11.603 kg/㎟

THEREFORE, BRACING IS NOT REQUIRED !!