KBR

KEMPER COUNTY IGCC UNIT 1 PROJECT

SOUTHERN COMPANY

MECHANICAL STRENGTH CALCULATION

ITEM NAME : AGR FLASH GAS KO DRUM

(ITEM NO : DR1065 / 2065)

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

Rev No.	PURPOSE OF ISSUE	PREPARED	CHECKED	APPROVED	ISSUE DATE
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

CLIENT	:	Southern Company Services, Inc.
VENDOR	:	SUNGJIN GEOTEC CO., LTD.
PLANT	:	Kemper County
Doc. Title	:	AGR FLASH GAS KO DRUM
PO No.	:	MPC17984-0001
SCS No.	:	MM78159
SGT No.	:	SGT11-SP11-DR1065/2065-CAL

MM78159 B

Plant: Kemper County SUNGJIN GEOTECH
Southern Company Generation
SGT11-SP11-DR1065-2065-CAL Rev: 2
PO: MPC17984-0001

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ITEM NO. DR 1065 / 2065

DESIGN DATA

ITEM NO. : DR 1065 / 2065

CODE		**ASME Section VIII Division 1 2007 Edition, A09 Addenda**					
CODE STAMP		YES					
NATIONAL BOARD		YES					
CORROSION ALLOWANCE		0.063	inch	(	1.6	mm)	
JOINT EFFICIENCY	(SHELL/HEAD)	0.85 / 1.0					
POST WELD HEAT TREATMENT		NO					
RADIOGRAPHY	(SHELL/HEAD)	SPOT / FULL					
PNEUMATIC TEST PRESS		--	[psi G]	(	--	[kg/㎠ G])	
HYDRO. TEST PRESSURE (AT SHOP & TOP)		234.00	[psi G]	(	16.46	[kg/㎠ G])	
HYDRO. TEST PRESSURE (AT FIELD & TOP)		234.00	[psi G]	(	16.46	[kg/㎠ G])	
DESIGN INTERNAL TEMPERATURE		250	°F	(	121.12	℃)	
DESIGN EXTERNAL TEMPERATURE		-	°F	(	-	℃)	
MIN. DESIGN METAL TEMPERATURE		10	°F	(	-12.23	℃)	
DESIGN INTERNAL PRESSURE		180.0	[psi G]	(	12.66	[kg/㎠ G])	
DESIGN EXTERNAL PRESSURE		-	[psi G]	(	-	[kg/㎠ G])	
OPERATING TEMPERATURE		110	°F	(	43.34	℃)	
OPERATING PRESSURE		-	[psi G]	(	-	[kg/㎠ G])	
CONTENTS		***					
LIQUID SPECIFIC GRAVITY		1.024					
LENGTH BETWEEN TANGENT LINE		102	inch	(	2591.0	mm)	
SHELL INSIDE DIAMETER		36	inch	(	915.0	mm)	
TYPE OF HEADS		2:1 ELLIP.					
WIND LOAD		100 mph (ASCE 7-05)					
SEISMIC LOAD		CLASS C (ASCE 7-05)					
INSULATION THICKNESS	(HOT)	2.0	inch	(	50.0	mm)	
FIRE PROOFING THICKNESS		NONE	inch	(	NONE	mm)	
VOLUME		503.0	US gal	(	1.9	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 $\alpha > 30$ 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:	RT4
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	180	250	-320		Note 1	No
Straight Flange on TOP HEAD	180	250	-320		Note 2	No
SHELL	180	250	-320		Note 2	No
Straight Flange on BTM HEAD	180	250	-320		Note 2	No
BTM HEAD	180	250	-320		Note 1	No
6" (AO)	180	250	-320	Nozzle	Note 2	No
				Pad	Note 2	No
2" (AV)	180	250	-320		Note 2	No
18" (BB)	180	250	-320		Note 2	No
6" (BE)	180	250	-320	Nozzle	Note 2	No
				Pad	Note 2	No
8" (BJ)	180	250	-320	Nozzle	Note 2	No
				Pad	Note 2	No
2" (BS)	180	250	-320		Note 2	No
2" (CW)	180	250	-320	Nozzle	Note 2	No
				Pad	Note 2	No
2" (LB1A/B)	180	250	-320		Note 2	No
2" (LT2A/B, LT3A/B, LT4A/B)	180	250	-320		Note 2	No
1 1/2" (TT1)	180	250	-320		Note 2	No

Chamber design MDMT is 10 °F
Chamber rated MDMT is -320 °F @ 180 psi

Chamber Design MAWP hot & corroded is 180 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	36.0236 ID	9.4075	0.4016*	0.2572	0.063	1.00	Internal
Straight Flange on TOP HEAD	SA-240 304L	36.0236 ID	1.9685	0.4724	0.2591	0.063	1.00	Internal
SHELL	SA-240 304L	36.0236 ID	98.0709	0.4724	0.2949	0.063	0.85	Internal
Straight Flange on BTM HEAD	SA-240 304L	36.0236 ID	1.9685	0.4724	0.2599	0.063	1.00	Internal
BTM HEAD	SA-240 304L	36.0236 ID	9.4075	0.4016*	0.2583	0.063	1.00	Internal
SKIRT	SA-240 304L	36.6142 OD	33.7165	0.3543	0.1043	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 150
AV	2"	2.07 IDx0.94	SA-182 F304L <= 5	No	No	No	N/A	N/A	N/A	N/A	Custom Integral Forging A182 F304L Class 150
BB	18"	18.00 IDx1.00	SA-182 F304L <= 5	No	No	No	N/A	N/A	N/A	N/A	LWN A182 F304L Class 150
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 150
BJ	8"	NPS 8 Sch 80S (XS)	SA-312 TP304L Wld & smls pipe	No	No	No	SA-240 304L	No	No	No	WN A182 F304L Class 150
BS	2"	2.00 IDx0.53	SA-182 F304L <= 5	No	No	No	N/A	N/A	N/A	N/A	LWN A182 F304L Class 150
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 150
LB1A/B	2"	2.00 IDx0.65	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"	2.00 IDx0.65	SA-182 F304L <= 5	No	No	No	N/A	N/A	N/A	N/A	LWN A182 F304L Class 300
TT1	1 1/2"	1.50 IDx0.63	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 234 psi at 68 °F (the chamber design P = 180 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)	235.72	1.72	1	1.30	9,515	22,500	No
Straight Flange on TOP HEAD	235.72	1.72	1	1.30	9,104	22,500	No
SHELL	235.72	1.72	1	1.30	9,104	22,500	No
Straight Flange on BTM HEAD	235.72	1.72	1	1.30	9,104	22,500	No
BTM HEAD	235.72	1.72	1	1.30	9,515	22,500	No
1 1/2" (TT1)	235.778	1.778	1	1.30	8,989	33,750	No
18" (BB)	234.654	0.654	1	1.30	17,268	33,750	No
2" (AV)	235.107	1.107	1	1.30	9,447	33,750	No
2" (BS)	235.727	1.728	1	1.30	9,269	33,750	No
2" (CW)	235.1	1.1	1	1.30	4,340	33,750	No
2" (LB1A/B)	234.623	0.623	1	1.30	8,945	33,750	No
2" (LT2A/B, LT3A/B, LT4A/B)	235.784	1.784	1	1.30	8,989	33,750	No
6" (AO)	235.173	1.174	1	1.30	6,216	33,750	No
6" (BE)	235.606	1.606	1	1.30	6,877	33,750	No
8" (BJ)	234.855	0.855	1	1.30	4,675	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 234 psi at 68 °F (the chamber design P = 180 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)	235.046	1.046	1	1.30	9,488	22,500	No
Straight Flange on TOP HEAD	235.046	1.046	1	1.30	9,078	22,500	No
SHELL	238.586	4.586	1	1.30	9,215	22,500	No
Straight Flange on BTM HEAD	238.657	4.657	1	1.30	9,218	22,500	No
BTM HEAD	238.982	4.982	1	1.30	9,647	22,500	No
1 1/2" (TT1)	235.435	1.435	1	1.30	8,976	33,750	No
18" (BB)	238.115	4.115	1	1.30	17,523	33,750	No
2" (AV)	234.654	0.654	1	1.30	9,429	33,750	No
2" (BS)	238.477	4.477	1	1.30	9,377	33,750	No
2" (CW)	239.307	5.307	1	1.30	4,418	33,750	No
2" (LB1A/B)	236.203	2.203	1	1.30	9,005	33,750	No
2" (LT2A/B, LT3A/B, LT4A/B)	237.177	3.177	1	1.30	9,042	33,750	No
6" (AO)	234.654	0.654	1	1.30	6,203	33,750	No
6" (BE)	237.029	3.029	1	1.30	6,919	33,750	No
8" (BJ)	237.206	3.206	1	1.30	4,721	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 234 psi at 68 °F (the chamber design P = 180 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)	235.046	1.046	1	1.30	11,293	22,500	No
Straight Flange on TOP HEAD	235.046	1.046	1	1.30	10,493	22,500	No
SHELL	238.586	4.586	1	1.30	10,651	22,500	No
Straight Flange on BTM HEAD	238.657	4.657	1	1.30	10,654	22,500	No
BTM HEAD	238.984	4.985	1	1.30	11,482	22,500	No
1 1/2" (TT1)	235.438	1.438	1	1.30	10,393	33,750	No
18" (BB)	238.117	4.117	1	1.30	19,837	33,750	No
2" (AV)	234.654	0.654	1	1.30	11,222	33,750	No
2" (BS)	238.479	4.48	1	1.30	10,819	33,750	No
2" (CW)	239.307	5.307	1	1.30	4,778	33,750	No
2" (LB1A/B)	236.205	2.205	1	1.30	10,427	33,750	No
2" (LT2A/B, LT3A/B, LT4A/B)	237.179	3.179	1	1.30	10,470	33,750	No
6" (AO)	234.654	0.654	1	1.30	6,337	33,750	No
6" (BE)	237.031	3.031	1	1.30	7,060	33,750	No
8" (BJ)	237.208	3.208	1	1.30	4,862	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	204.5	173.8	73.4	0	0	0	309.2
SHELL	1,480.6	1,285.5	231.8	0	0	736.8	3,711
BTM HEAD	209.4	178	73.4	0	0	303.8	293.8
SKIRT	394.7	323.9	0	0	0	0	0
BASE BLOCK	235	235	0	0	0	0	0
TOTAL:	**2,524.1**	**2,196.2**	**378.6**	**0**	**0**	**1,040.6**	**4,313.9**

* 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	0	0	122.1	114.3	0	1,791.4	0	0	0
SHELL	0	0	835.6	809.6	87	192.2	0	0	2,204.6
BTM HEAD	0	0	13.3	12.6	0	57.9	0	0	0
SKIRT	0	0	0	0	0	0	0	0	0
TOTAL:	**0**	**0**	**970.9**	**936.5**	**87**	**2,041.5**	**0**	**0**	**2,204.6**

Vessel operating weight, Corroded: 8,885 lb
Vessel operating weight, New: 9,239 lb
Vessel empty weight, Corroded: 7,844 lb
Vessel empty weight, New: 8,207 lb
Vessel test weight, New: 12,274 lb

Vessel center of gravity location - from datum - lift condition

Vessel Lift Weight, New: 8,207 lb
Center of Gravity: 59.1757"

Vessel Capacity

Vessel Capacity** (New): 503 US gal
Vessel Capacity** (Corroded): 507 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:	3.9370 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:	12.2833 ft
Vessel Minimum Diameter, b	
Operating, Corroded:	3.4088 ft
Empty, Corroded:	3.4088 ft
hydrotest, New, field:	3.0807 ft
Fundamental Frequency, n_1	
Operating, Corroded:	21.7262 Hz
Empty, Corroded:	22.2405 Hz
hydrotest, New, field:	20.6341 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	136.0236	7.34	27.3	*	839	949	1,048	0.0099
SHELL	37.9528	7.35	27.3	0.3789	839	1,983	14,495	0.0089
BTM HEAD (top)	33.7165	7.34	27.3	*	839	2,027	15,311	0.0011
SKIRT	0	6.99	27.3	0.2617	839	2,365	21,480	0.0009
*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	136.0236	7.34	28.3	*	839	949	1,048	0.0095
SHELL	37.9528	7.35	28.3	0.3789	839	1,983	14,495	0.0085
BTM HEAD (top)	33.7165	7.34	28.3	*	839	2,027	15,311	0.0011
SKIRT	0	6.99	28.3	0.2617	839	2,365	21,480	0.0009
*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	136.0236	7.34	28.3	*	277	338	366	0.0038
SHELL	37.9528	7.35	28.3	0.435	277	912	7,053	0.0034
BTM HEAD (top)	33.7165	7.34	28.3	*	277	936	7,414	0.0004
SKIRT	0	6.99	28.3	0.3199	277	1,133	10,321	0.0003
*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	17.21	17.21	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 = 21.7262 Hz $\geq$ 1 Hz.

$\bar{z}$ = 0.60 * h
= 0.60 * 12.2833
= 15.0000

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

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

$Q = Sqr(1 / (1 + 0.63 * ((b + h) / L_{\bar{z}})^{0.63}))$
$= Sqr(1 / (1 + 0.63 * ((3.4088 + 12.2833) / 427.0566)^{0.63}))$
$= 0.9629$

$G = 0.925 * (1 + 1.7 * g_Q * I_{\bar{z}} * Q) / (1 + 1.7 * g_v * I_{\bar{z}})$
$= 0.925 * (1 + 1.7 * 3.40 * 0.2281 * 0.9629) / (1 + 1.7 * 3.40 * 0.2281)$
$= 0.9055$

Gust Factor Calculations: Empty, Corroded

Vessel is considered a rigid structure as $n_1 = 22.2405$ Hz ≥ 1 Hz.

$\bar{z} = 0.60 * h$
$= 0.60 * 12.2833$
$= 15.0000$

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

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

$Q = Sqr(1 / (1 + 0.63 * ((b + h) / L_{\bar{z}})^{0.63}))$
$= Sqr(1 / (1 + 0.63 * ((3.4088 + 12.2833) / 427.0566)^{0.63}))$
$= 0.9629$

$G = 0.925 * (1 + 1.7 * g_Q * I_{\bar{z}} * Q) / (1 + 1.7 * g_v * I_{\bar{z}})$
$= 0.925 * (1 + 1.7 * 3.40 * 0.2281 * 0.9629) / (1 + 1.7 * 3.40 * 0.2281)$
$= 0.9055$

Gust Factor Calculations: hydrotest, New, field

Vessel is considered a rigid structure as $n_1 = 20.6341$ Hz ≥ 1 Hz.

$\bar{z} = 0.60 * h$
$= 0.60 * 12.2833$
$= 15.0000$

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

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

$Q = Sqr(1 / (1 + 0.63 * ((b + h) / L_{\bar{z}})^{0.63}))$
$= Sqr(1 / (1 + 0.63 * ((3.4088 + 12.2833) / 427.0566)^{0.63}))$
$= 0.9633$

$G = 0.925 * (1 + 1.7 * g_Q * I_{\bar{z}} * Q) / (1 + 1.7 * g_v * I_{\bar{z}})$
$= 0.925 * (1 + 1.7 * 3.40 * 0.2281 * 0.9633) / (1 + 1.7 * 3.40 * 0.2281)$
$= 0.9057$

Table Lookup Values

$\alpha = 9.5000$, 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. $D + P + P_s + 0.7E = (1.0 + V_{Accel})D + P + P_s + 0.7\rho Q_E$
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 $= \rho Q_E$
V_{Accel} = User defined vertical acceleration

Vessel Characteristics

Vessel height: 12.2833 ft
Vessel Weight:
Operating, Corroded: 8,885 lb
Empty, Corroded: 7,844 lb

Period of Vibration Calculation

Fundamental Period, T:
Operating, Corroded: 0.046 sec (f = 21.7 Hz)
Empty, Corroded: 0.045 sec (f = 22.2 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	136.0236	27.3	*	120	117
SHELL	37.9528	27.3	0.3789	293	3,415
BTM HEAD (top)	33.7165	27.3	*	297	3,519
SKIRT	0	27.3	0.3199	304	4,369
*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	136.0236	28.3	*	112	111
SHELL	37.9528	28.3	0.3789	262	3,286
BTM HEAD (top)	33.7165	28.3	*	264	3,378
SKIRT	0	28.3	0.3199	269	4,129
*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}

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

11.4.4: Design spectral response acceleration parameters

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

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

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	304	8,885.1	0.0114	0.2
Operating, New	316	9,239.2	0.0114	0.2
Empty, Corroded	269	7,844.4	0.0114	0.2
Empty, New	281	8,206.8	0.0114	0.2

Base Shear Calculations

Operating, Corroded
Empty, Corroded

Base Shear Calculations: Operating, Corroded

Paragraph 15.4.2: $T < 0.06$, so:

$V = 0.30 * S_{DS} * W * I$

$= 0.30 * 0.1304 * 8885.0703 * 1.2500$

$= 434.48$ 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)

$= 0.70 * 1.0000 * 434.48$

$= 304.14$ lb

Base Shear Calculations: Empty, Corroded

Paragraph 15.4.2: $T < 0.06$, so:

$V = 0.30 * S_{DS} * W * I$

$= 0.30 * 0.1304 * 7844.4272 * 1.2500$

$= 383.59$ 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)

$= 0.70 * 1.0000 * 383.59$

$= 268.51$ 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 = 180 psi @ 250 °F

Static liquid head:

P_s= 0 psi (SG=1.024, H_s=0" Operating head)
P_{th}= 1.7197 psi (SG=1, H_s=47.6402" Horizontal test head)
P_{tv}= 0.9749 psi (SG=1, H_s=27.0079" Vertical test head)

Corrosion allowance:	Inner C = 0.063"	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 -	Spot UW-11(a)(5)(b) Type 1

Estimated weight*:	new = 204.5 lb	corr = 173.8 lb
Capacity*:	new = 35.2 US gal	corr = 35.6 US gal

* includes straight flange

Inner diameter	=	36.0236"
Minimum head thickness	=	0.4016"
Head ratio D/2h	=	2 (new)
Head ratio D/2h	=	1.9931 (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: 29.3256 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" + 0.063" = 0.1255"
Design thickness due to internal pressure (t)	=	0.2572"

K (Corroded)

K = (1/6)*[2 + (D / (2*h))^2]
= (1/6)*[2 + (36.1496 / (2*9.0689))^2]
= 0.995377

K (New)

K = (1/6)*[2 + (D / (2*h))^2]
= (1/6)*[2 + (36.0236 / (2*9.0059))^2]
= 1

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

t = P*D*K / (2*S*E - 0.2*P) + Corrosion
= 180*36.1496*0.995377 / (2*16,700*1 - 0.2*180) + 0.063
= 0.2571"

The head internal pressure design thickness is 0.2572".

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

EFE = (75*t / R_f)*(1 - R_f / R_o)

= (75*0.4724 / 6.3602)*(1 - 6.3602 / ϒ⊆)

= 5.571%

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 = 180 psi @ 250 °F

Static liquid head:

P_s = 0.67 psi (SG = 1.024, H_s = 18.0315",Operating head)
P_{th} = 1.72 psi (SG = 1, H_s = 47.6402", Horizontal test head)
P_{tv} = 4.59 psi (SG = 1, H_s = 127.0472", Vertical test head)

Corrosion allowance   Inner C = 0.063"   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 -	Spot UW-11(b) Type 1
	Top circumferential joint -	Spot UW-11(a)(5)b Type 1
	Bottom circumferential joint -	Spot UW-11(a)(5)b Type 1

Estimated weight	New = 1,480.6 lb	corr = 1,285.5 lb
Capacity	New = 432.71 US gal	corr = 435.74 US gal

ID = 36.0236"
Length L_c = 98.0709"
t = 0.4724"

Insulation thk:	1.9685"	density:	13.73 lb/ft^3	Weight:	187.7 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
= 180.67*18.0748 / (16,700*0.85 - 0.60*180.67) + 0.063
= 0.2949"

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

EFE = (50*t / R_f)*(1 - R_f / R_o)
= (50*0.4724 / 18.248)*(1 - 18.248 / ϒ⊆)
= 1.2945%

Design thickness = 0.2949"

The governing condition is due to internal pressure.

The cylinder thickness of 0.4724" 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	180	16,700	8,381	250	0.063	Wind	0.1029	0.082
						Seismic	0.0962	0.0887
Operating, Hot & New	180	16,700	8,598	250	0	Wind	0.1025	0.0815
						Seismic	0.0959	0.0882

Hot Shut Down, Corroded	0	16,700	8,381	250	0.063	Wind	0.0076	0.0225
						Seismic	0.0009	0.0111
Hot Shut Down, New	0	16,700	8,598	250	0	Wind	0.0076	0.0223
						Seismic	0.0009	0.0112
Empty, Corroded	0	16,700	10,733	68	0.063	Wind	0.0076	0.0176
						Seismic	0.0008	0.0085
Empty, New	0	16,700	11,023	68	0	Wind	0.0076	0.0174
						Seismic	0.0008	0.0086
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0	16,700	8,381	250	0.063	Weight	0.0051	0.0094

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

A = 0.125 / (R_o / t)
= 0.125 / (18.4843 / 0.4094)
= 0.002769
B = 8,381 psi
S = 16,700 / 1.00 = 16,700 psi
S_{cHC} = min(B, S) = 8,381 psi

Allowable Compressive Stress, Hot and New- S_{cHN}, (table HA-3)

A = 0.125 / (R_o / t)
= 0.125 / (18.4843 / 0.4724)
= 0.003195
B = 8,598 psi
S = 16,700 / 1.00 = 16,700 psi
S_{cHN} = min(B, S) = 8,598 psi

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

A = 0.125 / (R_o / t)
= 0.125 / (18.4843 / 0.4724)
= 0.003195
B = 11,023 psi
S = 16,700 / 1.00 = 16,700 psi
S_{cCN} = min(B, S) = 11,023 psi

Allowable Compressive Stress, Cold and Corroded- S_{cCC}, (table HA-3)

A = 0.125 / (R_o / t)
= 0.125 / (18.4843 / 0.4094)
= 0.002769
B = 10,733 psi
S = 16,700 / 1.00 = 16,700 psi
S_{cCC} = min(B, S) = 10,733 psi

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

A = 0.125 / (R_o / t)
= 0.125 / (18.4843 / 0.4094)
= 0.002769
B = 10,733 psi
S = 16,700 / 1.00 = 16,700 psi
S_{cVC} = min(B, S) = 10,733 psi

Operating, Hot & Corroded, Wind, Bottom Seam

$t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
$= 180*18.0748 / (2*16{,}700*1.20*0.85 + 0.40*|180|)$
$= 0.0953"$

$t_m = M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
$= 173{,}945 / (\pi*18.2795^2*16{,}700*1.20*0.85)$
$= 0.0097"$

$t_w = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.60*6{,}959.4 / (2*\pi*18.2795*16{,}700*1.20*0.85)$
$= 0.0021"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0.0953 + 0.0097 - (0.0021)$
$= 0.1029"$

$t_{wc} = W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 6{,}959.4 / (2*\pi*18.2795*16{,}700*1.20*0.85)$
$= 0.0036"$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0.0097 + (0.0036) - (0.0953)|$
$= 0.082"$

Operating, Hot & New, Wind, Bottom Seam

$t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
$= 180*18.0118 / (2*16{,}700*1.20*0.85 + 0.40*|180|)$
$= 0.095"$

$t_m = M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
$= 174{,}467 / (\pi*18.248^2*16{,}700*1.20*0.85)$
$= 0.0098"$

$t_w = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.60*7{,}218.9 / (2*\pi*18.248*16{,}700*1.20*0.85)$
$= 0.0022"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0.095 + 0.0098 - (0.0022)$
$= 0.1025"$

$t_{wc} = W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 7{,}218.9 / (2*\pi*18.248*16{,}700*1.20*0.85)$
$= 0.0037"$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0.0098 + (0.0037) - (0.095)|$
$= 0.0815"$

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)
$= 173{,}945 / (\pi*18.2795^2*16{,}700*1.20*0.85)$
$= 0.0097"$

$t_w = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.60*6{,}959.4 / (2*\pi*18.2795*16{,}700*1.20*0.85)$
$= 0.0021"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0 + 0.0097 - (0.0021)$
$= 0.0076"$

$t_{mc} = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 173{,}945 / (\pi*18.2795^2*8{,}381.16*1.20)$

$= 0.0165"$

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

$= 6,959.4 / (2*\pi*18.2795*8,381.16*1.20)$

$= 0.006"$

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

$= 0.0165 + (0.006) - (0)$

$= 0.0225"$

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)

$= 174,467 / (\pi*18.248^2*16,700*1.20*0.85)$

$= 0.0098"$

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

$= 0.60*7,218.9 / (2*\pi*18.248*16,700*1.20*0.85)$

$= 0.0022"$

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

$= 0 + 0.0098 - (0.0022)$

$= 0.0076"$

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

$= 174,467 / (\pi*18.248^2*8,598.36*1.20)$

$= 0.0162"$

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

$= 7,218.9 / (2*\pi*18.248*8,598.36*1.20)$

$= 0.0061"$

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

$= 0.0162 + (0.0061) - (0)$

$= 0.0223"$

Empty, Corroded, Wind, Bottom Seam

$t_p = 0"$ (Pressure)

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

$= 173,945 / (\pi*18.2795^2*16,700*1.20*0.85)$

$= 0.0097"$

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

$= 0.60*6,933.3 / (2*\pi*18.2795*16,700*1.20*0.85)$

$= 0.0021"$

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

$= 0 + 0.0097 - (0.0021)$

$= 0.0076"$

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

$= 173,945 / (\pi*18.2795^2*10,732.55*1.20)$

$= 0.0129"$

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

$= 6,933.3 / (2*\pi*18.2795*10,732.55*1.20)$

$= 0.0047"$

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

$= 0.0129 + (0.0047) - (0)$

$= 0.0176"$

Empty, New, Wind, Bottom Seam

$t_p = 0"$ (Pressure)

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

$= 174{,}467 / (\pi*18.248^2*16{,}700*1.20*0.85)$

$= 0.0098"$

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

$= 0.60*7{,}192.8 / (2*\pi*18.248*16{,}700*1.20*0.85)$

$= 0.0022"$

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

$= 0 + 0.0098 - (0.0022)$

$= 0.0076"$

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

$= 174{,}467 / (\pi*18.248^2*11{,}023.27*1.20)$

$= 0.0126"$

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

$= 7{,}192.8 / (2*\pi*18.248*11{,}023.27*1.20)$

$= 0.0047"$

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

$= 0.0126 + (0.0047) - (0)$

$= 0.0174"$

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)

$= 19{,}019 / (\pi*18.2795^2*8{,}381.16*1.00)$

$= 0.0022"$

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

$= 6{,}959.4 / (2*\pi*18.2795*8{,}381.16*1.00)$

$= 0.0072"$

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

$= |0 + 0.0022 - (0.0072)|$

$= 0.0051"$

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

$= 0.0022 + (0.0072) - (0)$

$= 0.0094"$

Operating, Hot & Corroded, Seismic, Bottom Seam

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

$= 180*18.0748 / (2*16{,}700*1.20*0.85 + 0.40*|180|)$

$= 0.0953"$

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

$= 40{,}980 / (\pi*18.2795^2*16{,}700*1.20*0.85)$

$= 0.0023"$

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

$= 0.40*6{,}959.4 / (2*\pi*18.2795*16{,}700*1.20*0.85)$

$= 0.0014"$

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

$= 0.0953 + 0.0023 - (0.0014)$

$= 0.0962"$

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

$= 1.20*6{,}959.4 / (2*\pi*18.2795*16{,}700*1.20*0.85)$

$= 0.0043"$

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

$= |0.0023 + (0.0043) - (0.0953)|$
$= 0.0887''$

Operating, Hot & New, Seismic, Bottom Seam

$t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
$= 180*18.0118 / (2*16{,}700*1.20*0.85 + 0.40*|180|)$
$= 0.095''$

$t_m = M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
$= 42{,}274 / (\pi*18.248^2*16{,}700*1.20*0.85)$
$= 0.0024''$

$t_w = (0.6 - VAccel)*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.40*7{,}218.9 / (2*\pi*18.248*16{,}700*1.20*0.85)$
$= 0.0015''$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0.095 + 0.0024 - (0.0015)$
$= 0.0959''$

$t_{wc} = (1 + VAccel)*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 1.20*7{,}218.9 / (2*\pi*18.248*16{,}700*1.20*0.85)$
$= 0.0044''$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0.0024 + (0.0044) - (0.095)|$
$= 0.0882''$

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)
$= 40{,}980 / (\pi*18.2795^2*16{,}700*1.20*0.85)$
$= 0.0023''$

$t_w = (0.6 - VAccel)*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.40*6{,}959.4 / (2*\pi*18.2795*16{,}700*1.20*0.85)$
$= 0.0014''$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0 + 0.0023 - (0.0014)$
$= 0.0009''$

$t_{mc} = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 40{,}980 / (\pi*18.2795^2*8{,}381.16*1.20)$
$= 0.0039''$

$t_{wc} = (1 + VAccel)*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 1.20*6{,}959.4 / (2*\pi*18.2795*8{,}381.16*1.20)$
$= 0.0072''$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0039 + (0.0072) - (0)$
$= 0.0111''$

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)
$= 42{,}274 / (\pi*18.248^2*16{,}700*1.20*0.85)$
$= 0.0024''$

$t_w = (0.6 - VAccel)*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.40*7{,}218.9 / (2*\pi*18.248*16{,}700*1.20*0.85)$

$= 0.0015''$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0 + 0.0024 - (0.0015)$
$= 0.0009''$

$t_{mc} = M / (\pi * R_m^2 * S_c * K_s)$ (bending)
$= 42,274 / (\pi * 18.248^2 * 8,598.36 * 1.20)$
$= 0.0039''$

$t_{wc} = (1 + VAccel) * W / (2 * \pi * R_m * S_c * K_s)$ (Weight)
$= 1.20 * 7,218.9 / (2 * \pi * 18.248 * 8,598.36 * 1.20)$
$= 0.0073''$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0039 + (0.0073) - (0)$
$= 0.0112''$

Empty, Corroded, Seismic, Bottom Seam

$t_p = 0''$ (Pressure)

$t_m = M / (\pi * R_m^2 * S_t * K_s * E_c)$ (bending)
$= 39,427 / (\pi * 18.2795^2 * 16,700 * 1.20 * 0.85)$
$= 0.0022''$

$t_w = (0.6 - VAccel) * W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)
$= 0.40 * 6,933.3 / (2 * \pi * 18.2795 * 16,700 * 1.20 * 0.85)$
$= 0.0014''$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0 + 0.0022 - (0.0014)$
$= 0.0008''$

$t_{mc} = M / (\pi * R_m^2 * S_c * K_s)$ (bending)
$= 39,427 / (\pi * 18.2795^2 * 10,732.55 * 1.20)$
$= 0.0029''$

$t_{wc} = (1 + VAccel) * W / (2 * \pi * R_m * S_c * K_s)$ (Weight)
$= 1.20 * 6,933.3 / (2 * \pi * 18.2795 * 10,732.55 * 1.20)$
$= 0.0056''$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0029 + (0.0056) - (0)$
$= 0.0085''$

Empty, New, Seismic, Bottom Seam

$t_p = 0''$ (Pressure)

$t_m = M / (\pi * R_m^2 * S_t * K_s * E_c)$ (bending)
$= 40,749 / (\pi * 18.248^2 * 16,700 * 1.20 * 0.85)$
$= 0.0023''$

$t_w = (0.6 - VAccel) * W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)
$= 0.40 * 7,192.8 / (2 * \pi * 18.248 * 16,700 * 1.20 * 0.85)$
$= 0.0015''$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0 + 0.0023 - (0.0015)$
$= 0.0008''$

$t_{mc} = M / (\pi * R_m^2 * S_c * K_s)$ (bending)
$= 40,749 / (\pi * 18.248^2 * 11,023.27 * 1.20)$
$= 0.0029''$

$t_{wc} = (1 + VAccel) * W / (2 * \pi * R_m * S_c * K_s)$ (Weight)
$= 1.20 * 7,192.8 / (2 * \pi * 18.248 * 11,023.27 * 1.20)$
$= 0.0057''$

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

$= 0.0029 + (0.0057) - (0)$

$= 0.0086''$

BTM HEAD

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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 = 180 psi @ 250 °F

Static liquid head:

P_s= 1.0745 psi (SG=1.024, H_s=29.0689" Operating head)
P_{th}= 1.7197 psi (SG=1, H_s=47.6402" Horizontal test head)
P_{tv}= 4.9822 psi (SG=1, H_s=138.0217" Vertical test head)

Corrosion allowance:	Inner C = 0.063"	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 -	Spot UW-11(a)(5)(b) Type 1

Estimated weight*:	new = 209.4 lb	corr = 178 lb
Capacity*:	new = 35.2 US gal	corr = 35.6 US gal

* includes straight flange

Inner diameter	=	36.0236"
Minimum head thickness	=	0.4016"
Head ratio D/2h	=	2 (new)
Head ratio D/2h	=	1.9931 (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: 29.3256 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" + 0.063" = 0.1255"
Design thickness due to internal pressure (t) = 0.2583"

K (Corroded)

K = (1/6)*[2 + (D / (2*h))^2]
= (1/6)*[2 + (36.1496 / (2*9.0689))^2]
= 0.995377

K (New)

K = (1/6)*[2 + (D / (2*h))^2]
= (1/6)*[2 + (36.0236 / (2*9.0059))^2]
= 1

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

t = P*D*K / (2*S*E - 0.2*P) + Corrosion
= 181.07*36.1496*0.995377 / (2*16,700*1 - 0.2*181.07) + 0.063
= 0.2583"

The head internal pressure design thickness is 0.2583".

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

EFE = (75*t / R_f)*(1 - R_f / R_o)

= (75*0.4724 / 6.3602)*(1 - 6.3602 / ϒ⊆)

= 5.571%

SKIRT

Material:	SA-240 304L (II-D p. 82, ln. 38)
Design temperature, operating:	250 °F
Inner diameter at top, new:	35.9055 in
Inner diameter at bottom, new:	35.9055 in
Overall length:	33.7165 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:	4.2362 in down from the top seam

Skirt design thickness, largest of the following + corrosion = 0.1043 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	1,005.39	0.0175
Wind	operating, corroded (-)	bottom	250	7,904.67	1,119.81	0.0413
Wind	operating, new (+)	bottom	250	16,700	818.02	0.0174
Wind	operating, new (-)	bottom	250	8,181.41	928.13	0.0402
Wind	empty, corroded (+)	bottom	68	16,700	1,032.32	0.018
Wind	empty, corroded (-)	bottom	68	10,095.67	1,088.4	0.0314
Wind	empty, new (+)	bottom	68	16,700	839.94	0.0178
Wind	empty, new (-)	bottom	68	10,465.49	902.55	0.0306
Wind	test, new (+)	bottom	68	16,700	228.63	0.0049
Wind	test, new (-)	bottom	68	10,465.49	635.89	0.0215
Seismic	operating, corroded (+)	bottom	250	16,700	101.25	0.0018
Seismic	operating, corroded (-)	bottom	250	7,904.67	486.91	0.0179
Seismic	operating, new (+)	bottom	250	16,700	84.54	0.0018
Seismic	operating, new (-)	bottom	250	8,181.41	414.69	0.018
Seismic	empty, corroded (+)	bottom	68	16,700	105.47	0.0018
Seismic	empty, corroded (-)	bottom	68	10,095.67	439.61	0.0127
Seismic	empty, new (+)	bottom	68	16,700	88.05	0.0019
Seismic	empty, new (-)	bottom	68	10,465.49	376.23	0.0127

Loading due to wind, operating & corroded

Windward side (tensile)

Required thickness, tensile stress at base:

$$t = -0.6*W / (\pi*D*S_t*E) + 48*M / (\pi*D^2*S_t*E)$$
$$= -0.6*8{,}614.49 / (\pi*36.1969*16{,}700*0.7) + 48*21{,}480.3 / (\pi*36.1969^2*16{,}700*0.7)$$
$$= 0.0175 \text{ in}$$

Required thickness, tensile stress at the top:

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

$= -0.6*8{,}290.56 / (\pi*36.1969*16{,}700*0.55) + 48*15{,}310.8 / (\pi*36.1969^2*16{,}700*0.55)$
$= 0.0147$ in

Leeward side (compressive)

Required thickness, compressive stress at base:

$t = W / (\pi*D*S_c*E_c) + 48*M / (\pi*D^2*S_c*E_c)$
$= 8{,}614.49 / (\pi*36.1969*7{,}905*1) + 48*21{,}480.3 / (\pi*36.1969^2*7{,}905*1)$
$= 0.0413$ in

Required thickness, compressive stress at the top:

$t = W_t / (\pi*D_t*S_c*E_c) + 48*M_t / (\pi*D_t^2*S_c*E_c)$
$= 8{,}290.56 / (\pi*36.1969*7{,}905*1) + 48*15{,}310.8 / (\pi*36.1969^2*7{,}905*1)$
$= 0.0318$ 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:	40.0787 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:	33.1496 in
Base plate outer diameter, D_o:	43.622 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	21,480.3	8,885.1	0.206	0.4641	124.68	0.4569	0.125
Wind	operating, new	21,524.5	9,239.2	0.2044	0.4657	125.53	0.453	0.1248
Wind	empty, corroded	21,480.3	7,844.4	0.2123	0.4604	122.7	0.4701	0.126
Wind	empty, new	21,524.5	8,206.8	0.2107	0.4622	123.63	0.4662	0.1257
Wind	test, new	10,320.7	12,274.8	0.0505	0.3266	61.74	0.1463	0.1113
Seismic	operating, corroded	4,369.2	8,885.1	0.017	0.2779	44.69	0.0902	0.1104
Seismic	operating, new	4,514.3	9,239.2	0.0173	0.2826	46.21	0.0906	0.1104
Seismic	empty, corroded	4,129.1	7,844.4	0.0183	0.269	41.88	0.0984	0.1105
Seismic	empty, new	4,277.4	8,206.8	0.0186	0.2739	43.43	0.0985	0.1105

Anchor bolt load (governing)

P = -0.6*W / N + 48 * M / (N*BC)
= -0.6*7,844.43 / 4 + 48 * 21,480.3 / (4*40.0787)
= 5,254.76 lb_f

Required area per bolt = P / S_b = 0.2123 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:	38.3858 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

$t_s = (N*A_b) / (\pi*d)$
$= (4*0.551) / (\pi*38.3858)$
$= 0.0183$ in

From table 12.4 for k = 0.171809:

$K_1 = 2.7234$, $K_2 = 1.1253$
$L_1 = 12.5992$, $L_2 = 24.4357$, $L_3 = 5.2471$

Total tensile force on bolting

$T = (12*M - 0.6*W*(L_1 + L_3)) / (L_2 + L_3)$
$= (12*21{,}524.5 - 0.6*9{,}239.2*(12.5992 + 5.2471)) / (24.4357 + 5.2471)$
$= 5{,}368.85\ lb_f$

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

$f_s = T / (t_s * (d / 2) * K_1)$
$= 5{,}368.85 / (0.0183 * (38.3858 / 2) * 2.7234)$
$= 5{,}620$ psi

Total compressive load on foundation

$C_c = T + W + \text{Bolt Preload}$
$= 5{,}368.85 + 9{,}239.2 + 0$
$= 14{,}608.05\ lb_f$

Foundation bearing stress

$f_c = C_c / (((t_c - t_s) + n*t_s)*(d / 2)*K_2)$
$= 14{,}608.05 / (((5.2362 - 0.0183) + 9.2872*0.0183)*(38.3858 / 2)*1.1253)$
$= 126$ psi

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

$k = 1 / (1 + f_s / (n*f_c))$
$= 1 / (1 + 5{,}620 / (9.2872*126))$
$= 0.171809$

Base plate required thickness (governing)

From Brownell & Young, Table 10.3:, l / b = 0.1432

$M_x = 0.0034*126*24.4699^2 = 251.8\ lb_f$

$M_y = -0.4691*126*3.5039^2 = -723\ lb_f$

$t_r = (6*M_{max} / S_p)^{0.5}$
$= (6*722.96 / 19{,}999)^{0.5}$
$= 0.4657$ in

The base plate thickness is satisfactory.

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

$t_{cr} = (3.91*F / (S_y*(2*b / w+w / (2*l)-d_b*(2 / w+1 / (2*l)))))^{0.5}$
$= (3.91*3{,}334.93 / (30{,}000*(2*3.5039 / 5.9843+5.9843 / (2*1.732)-1.4961*(2 / 5.9843+1 / (2*1.732)))))^{0.5}$
$= 0.4701$ 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

$S_g = F / (2 * A_g)$
= 3,334.93 / (2 * 1.6654)
= 1,001 psi

The gusset plate thickness is satisfactory.

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

$t = 1.76*(F*l / (M_b*h_c*S_s))^{2 / 3}*(OD_s / 2)^{1 / 3}$
$= 1.76*(3{,}334.93*1.7323 / (17.315*7.9921*25{,}050))^{2 / 3}*(36.6142 / 2)^{1 / 3}$
= 0.0652 in

The skirt thickness is satisfactory.

6" (AO)

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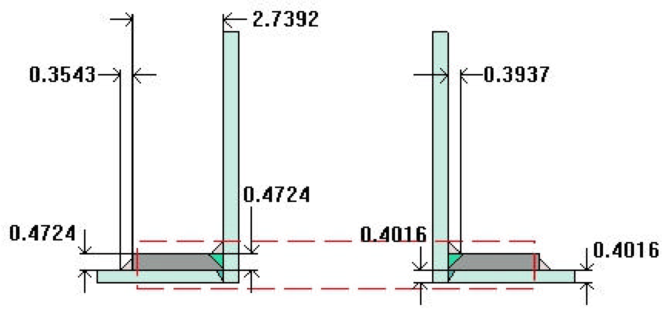

$t_{w(lower)}$ = 0.4016 in

Leg_{41} = 0.3937 in

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

Leg_{42} = 0.3543 in

D_p = 12.2045 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:	12.2045 in
Flange description:	6 inch Class 150 WN A182 F304L
Bolt Material:	SA-193 B8 1 Bolt (II-D p. 356, ln. 20)
Flange rated MDMT:	-320°F
(Per UHA-51(d)(1)(a))	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	185 psi @ 250°F
ASME B16.5 flange rating MAP:	230 psi @ 68°F
ASME B16.5 flange hydro test:	350 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:	270°
Calculated as hillside:	Yes
Local vessel minimum thickness:	0.4016 in
End of nozzle to datum line:	129.0157 in
Nozzle inside diameter, new:	5.761 in
Nozzle nominal wall thickness:	0.432 in
Nozzle corrosion allowance:	0.063 in
Opening chord length:	5.9803 in
Projection available outside vessel, Lpr:	14.2 in
Projection available outside vessel to flange face, Lf:	17.7 in
Distance to head center, R:	5.9843 in
Pad is split:	No

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 180 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}
1.0461	4.1769	0.9787	0.5707	--	2.4729	0.1546	0.338	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
3,142.17	53,410.69	97,975.95	16,285.4	137,825.97	57,583.57	99,127.69

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})	0.1693	0.248	weld size is adequate
Nozzle to pad groove (Upper)	0.2583	0.4724	weld size is adequate

Calculations for internal pressure 180 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(5.9803, 2.9902 + (0.432 - 0.063) + (0.4016 - 0.063))
= 5.9803 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 - 0.063), 2.5*(0.432 - 0.063) + 0.4724)
= 0.8464 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 180*2.9435 / (16,700*1 - 0.6*180)
= 0.0319 in

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

t_r = P*K_1*D / (2*S*E - 0.2*P)
= 180*0.8969*36.1496 / (2*16,700*1 - 0.2*180)
= 0.1749 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 = $d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
= 5.9803*0.1749*1 + 2*0.369*0.1749*1*(1 - 1)
= 1.0461 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.9787 in^2

= $d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= 5.9803*(1*0.3386 - 1*0.1749) - 2*0.369*(1*0.3386 - 1*0.1749)*(1 - 1)
= 0.9787 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*(0.3386 + 0.369)*(1*0.3386 - 1*0.1749) - 2*0.369*(1*0.3386 - 1*0.1749)*(1 - 1)
= 0.2316 in^2

A_2 = smaller of the following= 0.5707 in^2

= $5*(t_n - t_{rn})*f_{r2}*t$
= 5*(0.369 - 0.0319)*1*0.3386
= 0.5707 in^2

= $2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
= 2*(0.369 - 0.0319)*(2.5*0.369 + 0.4724)*1
= 0.9405 in^2

A_{41} = Leg^2*f_{r3}
= 0.3932^2*1
= 0.1546 in^2

(Part of the weld is outside of the limits)

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

(Part of the weld is outside of the limits)

A_5 = $(D_p - d - 2*t_n)*t_e*f_{r4}$
= (11.9606 - 6.7262)*0.4724*1
= 2.4729 in^2

Area = $A_1 + A_2 + A_{41} + A_{42} + A_5$
= 0.9787 + 0.5707 + 0.1546 + 0 + 2.4729
= 4.1769 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 = 0.369 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 = 0.3386 in
$t_{w(min)} = 0.5*t_{min}$ = 0.1693 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} = 0.338 in (E =1) (pressure plus external loads govern in longitudinal direction)
Wall thickness per UG-45(b)(1):	t_{r2} = 0.2571 in
Wall thickness per UG-16(b):	t_{r3} = 0.1255 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.308 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 0.2571 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.2571 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.338 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 = $(\pi / 2)$*12.2045*0.3543*8,183 = 55,585.67 lb_f

(3) Nozzle wall in shear
$(\pi / 2)$*Mean nozzle dia*t_n*S_n = $(\pi / 2)$*6.256*0.369*11,690 = 42,390.28 lb_f

(4) Groove weld in tension
$(\pi / 2)$*Nozzle OD*t_w*S_g = $(\pi / 2)$*6.625*0.3386*12,358 = 43,542.02 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)

$W = (A - A_1 + 2 * t_n * f_{r1} * (E_1 * t - F * t_r)) * S_v$
$= (1.0461 - 0.9787 + 2*0.369*1*(1*0.3386 - 1*0.1749))*16,700$
$= 3,142.17\ lb_f$

$W_{1-1} = (A_2 + A_5 + A_{41} + A_{42}) * S_v$
$= (0.5707 + 2.4729 + 0.1546 + 0)*16,700$
$= 53,410.69\ lb_f$

$W_{2-2} = (A_2 + A_3 + A_{41} + A_{43} + 2 * t_n * t * f_{r1}) * S_v$
$= (0.5707 + 0 + 0.1546 + 0 + 2*0.369*0.3386*1)*16,700$
$= 16,285.4\ lb_f$

$W_{3-3} = (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2 * t_n * t * f_{r1}) * S_v$
$= (0.5707 + 0 + 2.4729 + 0.1546 + 0 + 0 + 2*0.369*0.3386*1)*16,700$
$= 57,583.57\ lb_f$

Load for path 1-1 lesser of W or W_{1-1} = 3142.17 lb_f
Path 1-1 through (2) & (3) = 55,585.67 + 42,390.28 = 97,975.95 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} = 3142.17 lb_f
Path 2-2 through (1), (4), (6) = 33,526.22 + 43,542.02 + 60,757.72 = 137,825.97 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} = 3142.17 lb_f
Path 3-3 through (2), (4) = 55,585.67 + 43,542.02 = 99,127.69 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

Applied Loads

Radial load:	P_r =	-1,699.77 lb_f
Circumferential moment:	M_1 =	102,072.3 lb_f-in
Circumferential shear:	V_2 =	3,399.53 lb_f
Longitudinal moment:	M_2 =	102,072.3 lb_f-in
Longitudinal shear:	V_1 =	3,399.53 lb_f
Torsion moment:	M_t =	72,127.62 lb_f-in
Internal pressure:	P =	180 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 = 32.8157 in

U = r_o / Sqr(R_m*t) = 1.816
Pressure stress intensity factor, I = 1 (derived from PVP-Vol. 399, pages 77-82)

Local pressure stress = I*P*R_i / (2*t) =8,678 psi

Maximum combined stress (P_L+P_b+Q) = 45,755 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) = 16,076 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*	0.0287	426	426	426	426	426	426	426	426
SR-2	0.0138	1,228	-1,228	1,228	-1,228	1,228	-1,228	1,228	-1,228
SR-3*	0.0261	0	0	0	0	-6,972	-6,972	6,972	6,972
SR-3	0.0177	0	0	0	0	-28,370	28,370	28,370	-28,370
SR-3*	0.0261	-6,972	-6,972	6,972	6,972	0	0	0	0
SR-3	0.0177	-28,370	28,370	28,370	-28,370	0	0	0	0
Pressure stress*		8,678	8,678	8,678	8,678	8,678	8,678	8,678	8,678
Total O_x stress		-25,010	29,274	45,674	-13,522	-25,010	29,274	45,674	-13,522
Membrane O_x stress*		2,132	2,132	16,076	16,076	2,132	2,132	16,076	16,076
SR-2*	0.0085	126	126	126	126	126	126	126	126
SR-2	0.0041	365	-365	365	-365	365	-365	365	-365
SR-3*	0.0079	0	0	0	0	-2,110	-2,110	2,110	2,110
SR-3	0.0052	0	0	0	0	-8,335	8,335	8,335	-8,335
SR-3*	0.0079	-2,110	-2,110	2,110	2,110	0	0	0	0
SR-3	0.0052	-8,335	8,335	8,335	-8,335	0	0	0	0
Pressure stress*		8,678	8,678	8,678	8,678	8,678	8,678	8,678	8,678
Total O_y stress		-1,276	14,664	19,614	2,214	-1,276	14,664	19,614	2,214
Membrane O_y stress*		6,694	6,694	10,914	10,914	6,694	6,694	10,914	10,914
Shear from M_t		926	926	926	926	926	926	926	926
Shear from V_1		0	0	0	0	-528	-528	528	528
Shear from V_2		528	528	-528	-528	0	0	0	0
Total Shear stress		1,454	1,454	398	398	398	398	1,454	1,454
Combined stress (P_L+P_b+Q)		-25,099	29,417	45,680	15,756	-25,017	29,285	45,755	16,002

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 = 32.8157 in

U = r_o / Sqr(R_m*t) = 0.642
Pressure stress intensity factor, I = 0.28233 (derived from PVP-Vol. 399, pages 77-82)

Local pressure stress = I*P*R_i / (2*t) =2,450 psi

Maximum combined stress (P_L+P_b+Q) = 38,041 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) = 6,465 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*	0.1093	282	282	282	282	282	282	282	282
SR-2	0.0641	994	-994	994	-994	994	-994	994	-994
SR-3*	0.1241	0	0	0	0	-3,733	-3,733	3,733	3,733
SR-3	0.1688	0	0	0	0	-30,466	30,466	30,466	-30,466
SR-3*	0.1241	-3,733	-3,733	3,733	3,733	0	0	0	0
SR-3	0.1688	-30,466	30,466	30,466	-30,466	0	0	0	0
Pressure stress*		2,450	2,450	2,450	2,450	2,450	2,450	2,450	2,450
Total O_x stress		-30,473	28,471	37,925	-24,995	-30,473	28,471	37,925	-24,995
Membrane O_x stress*		-1,001	-1,001	6,465	6,465	-1,001	-1,001	6,465	6,465
SR-2*	0.0325	84	84	84	84	84	84	84	84
SR-2	0.0197	305	-305	305	-305	305	-305	305	-305
SR-3*	0.0373	0	0	0	0	-1,122	-1,122	1,122	1,122
SR-3	0.0519	0	0	0	0	-9,367	9,367	9,367	-9,367
SR-3*	0.0373	-1,122	-1,122	1,122	1,122	0	0	0	0
SR-3	0.0519	-9,367	9,367	9,367	-9,367	0	0	0	0
Pressure stress*		2,450	2,450	2,450	2,450	2,450	2,450	2,450	2,450
Total O_y stress		-7,650	10,474	13,328	-6,016	-7,650	10,474	13,328	-6,016
Membrane O_y stress*		1,412	1,412	3,656	3,656	1,412	1,412	3,656	3,656
Shear from M_t		1,290	1,290	1,290	1,290	1,290	1,290	1,290	1,290
Shear from V_1		0	0	0	0	-403	-403	403	403
Shear from V_2		403	403	-403	-403	0	0	0	0
Total Shear stress		1,693	1,693	887	887	887	887	1,693	1,693
Combined stress (P_L+P_b+Q)		-30,598	28,629	37,957	-25,036	-30,507	28,515	38,041	-25,145

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

$\sigma_{n\,(Pm)} = P*R_i / (2*t_n) - P_r / (\pi*(R_o^2 - R_i^2)) + M*R_o / I$
$= 180*2.9435 / (2*0.315) - -1{,}699.77 / (\pi*(3.3125^2 - 2.9435^2)) + 144{,}352*3.3125 / 35.6035$
$= 14{,}506$ 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

$\sigma_{shear} = (V_L^2 + V_c^2)^{0.5} / (\pi*R_i*t_n)$
$= (3{,}399.53^2 + 3{,}399.53^2)^{0.5} / (\pi*2.9435*0.369)$
$= 1{,}409$ psi

$\sigma_{torsion} = M_t / (2*\pi*R_i^2*t_n)$
$= 72{,}127.6 / (2*\pi*2.9435^2*0.369)$
$= 3{,}591$ psi

$\sigma_{total} = \sigma_{shear} + \sigma_{torsion}$
$= 1{,}409 + 3{,}591$
$= 4{,}999$ psi

UG-45(c): The total combined shear stress (4,999 psi) is below than the allowable ($0.7*S_n = 0.7*16{,}700 = 11{,}690$ psi)

2" (AV)

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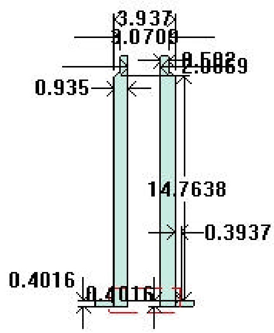

$t_{w(lower)}$ = 0.4016 in

Leg_{41} = 0.3937 in

Note: Per UW-16(b) minimum inside corner radius r_1 = min [1 / 4*t , 0.125 in] = 0.0846 in

Located on:	TOP HEAD
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 150 custom integral A182 F304L (Nut Relief)
Bolt Material:	SA-193 B8 1 Bolt (II-D p. 356, ln. 20)
Flange rated MDMT:	-320°F
(Per UHA-51(d)(1)(a))	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	185 psi @ 250°F
ASME B16.5 flange rating MAP:	230 psi @ 68°F
ASME B16.5 flange hydro test:	350 psi @ 68°F
Gasket Description:	Flexitallic Spiral Wound CG 304L S.S.
PWHT performed:	No
Nozzle orientation:	90°
Calculated as hillside:	Yes
Local vessel minimum thickness:	0.4016 in
End of nozzle to datum line:	129.0157 in
Nozzle inside diameter, new:	2.0669 in
Nozzle wall thickness, t_n:	0.935 in
Nozzle minimum wall thickness:	0.502 in
Nozzle corrosion allowance:	0.063 in
Opening chord length:	2.2267 in
Projection available outside vessel, Lpr:	17.0768 in
Projection available outside vessel to flange face, Lf:	17.8268 in
Distance to head center, R:	5.9843 in

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 180 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)							0.252	0.502

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.237	0.2756	weld size is adequate

Calculations for internal pressure 180 psi @ 250 °F

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

Parallel Limit of reinforcement per UG-40 and Fig. UG-40 sketch (e-2)

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(2.2267, 1.1134 + (0.935 - 0.063) + (0.4016 - 0.063))
= 2.324 in

Outer Normal Limit of reinforcement per UG-40 and Fig. UG-40 sketch (e-2)

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(0.4016 - 0.063), 2.5*(0.935 - 0.063) + 0)
= 0.8464 in

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

t_m = P*R_n / (S_n*E - 0.6*P)
= 180*1.0965 / (16,700*1 - 0.6*180)
= 0.0119 in

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

t_r = P*K_1*D / (2*S*E - 0.2*P)
= 180*0.8969*36.1496 / (2*16,700*1 - 0.2*180)
= 0.1749 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.3386 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.237 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

Interpretation VIII-1-83-66 has been applied.
Wall thickness per UG-45(a): t_{r1} = 0.2497 in (E =1) (pressure plus external loads govern in longitudinal direction)

Wall thickness per UG-45(b)(1):	t_{r2} = 0.2571 in
Wall thickness per UG-16(b):	t_{r3} = 0.1255 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.252 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 0.2571 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.252 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.252 in

Available nozzle wall thickness new, t_n = 0.502 in

The nozzle neck thickness is adequate.

Applied Loads

Radial load:	P_r =	-449.74 lb_f
Circumferential moment:	M_1 =	8,679.62 lb_f-in
Circumferential shear:	V_2 =	899.49 lb_f
Longitudinal moment:	M_2 =	8,679.62 lb_f-in
Longitudinal shear:	V_1 =	899.49 lb_f
Torsion moment:	M_t =	6,162.53 lb_f-in
Internal pressure:	P =	180 psi
Head yield stress:	S_y =	20,200 psi

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

Mean dish radius R_m = 32.8157 in

U = r_o / Sqr(R_m*t) = 0.591
Pressure stress intensity factor, I = 1 (derived from PVP-Vol. 399, pages 77-82)

Local pressure stress = I*P*R_i / (2*t) =8,678 psi

Maximum combined stress (P_L+P_b+Q) = 39,455 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) = 12,119 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*	0.1168	458	458	458	458	458	458	458	458
SR-2	0.0694	1,634	-1,634	1,634	-1,634	1,634	-1,634	1,634	-1,634
SR-3*	0.1313	0	0	0	0	-2,983	-2,983	2,983	2,983
SR-3	0.1881	0	0	0	0	-25,637	25,637	25,637	-25,637
SR-3*	0.1313	-2,983	-2,983	2,983	2,983	0	0	0	0
SR-3	0.1881	-25,637	25,637	25,637	-25,637	0	0	0	0
Pressure stress*		8,678	8,678	8,678	8,678	8,678	8,678	8,678	8,678
Total O_x stress		-17,850	30,156	39,390	-15,152	-17,850	30,156	39,390	-15,152
Membrane O_x stress*		6,153	6,153	12,119	12,119	6,153	6,153	12,119	12,119
SR-2*	0.0345	135	135	135	135	135	135	135	135
SR-2	0.0214	504	-504	504	-504	504	-504	504	-504
SR-3*	0.0395	0	0	0	0	-897	-897	897	897
SR-3	0.0576	0	0	0	0	-7,850	7,850	7,850	-7,850
SR-3*	0.0395	-897	-897	897	897	0	0	0	0
SR-3	0.0576	-7,850	7,850	7,850	-7,850	0	0	0	0
Pressure stress*		8,678	8,678	8,678	8,678	8,678	8,678	8,678	8,678
Total O_y stress		570	15,262	18,064	1,356	570	15,262	18,064	1,356
Membrane O_y stress*		7,916	7,916	9,710	9,710	7,916	7,916	9,710	9,710
Shear from M_t		748	748	748	748	748	748	748	748
Shear from V_1		0	0	0	0	-430	-430	430	430
Shear from V_2		430	430	-430	-430	0	0	0	0
Total Shear stress		1,178	1,178	318	318	318	318	1,178	1,178
Combined stress (P_L+P_b+Q)		18,570	30,249	39,395	16,520	18,431	30,163	39,455	16,675

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

$\sigma_{n\,(Pm)} = P*R_i / (2*t_n) - P_r / (\pi*(R_o^2 - R_i^2)) + M*R_o / I$
$= 180*1.0965 / (2*0.439) - -449.74 / (\pi*(1.5354^2 - 1.0965^2)) + 12{,}274.8*1.5354 / 3.2301$
= 6,184 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

$\sigma_{shear} = (V_L^2 + V_c^2)^{0.5} / (\pi*R_i*t_n)$
$= (899.49^2 + 899.49^2)^{0.5} / (\pi*1.0965*0.439)$
= 841 psi

$\sigma_{torsion} = M_t / (2*\pi*R_i^2*t_n)$
$= 6{,}162.5 / (2*\pi*1.0965^2*0.439)$
= 1,858 psi

$\sigma_{total} = \sigma_{shear} + \sigma_{torsion}$
= 841 + 1,858
= 2,700 psi

UG-45(c): The total combined shear stress (2,700 psi) is below than the allowable ($0.7*S_n = 0.7*16{,}700 = 11{,}690$ psi)

18" (BB)

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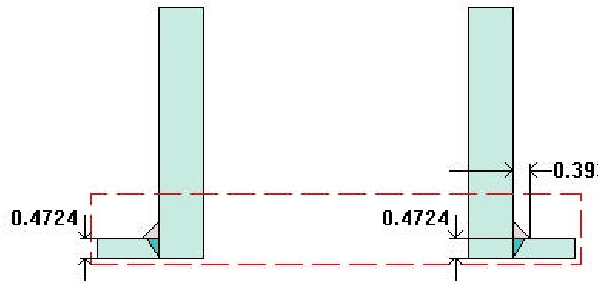
$t_{w(lower)}$ = 0.4724 in

Leg_{41} = 0.3937 in



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

Located on:	SHELL
Liquid static head included:	0.1842 psi
Nozzle material specification:	SA-182 F304L <= 5 (II-D p. 82, ln. 34)
Nozzle longitudinal joint efficiency:	1
Flange description:	18 inch Class 150 LWN A182 F304L
Bolt Material:	SA-193 B8 1 Bolt (II-D p. 356, ln. 20)
Flange rated MDMT:	-320°F
(Per UHA-51(d)(1)(a))	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	185 psi @ 250°F
ASME B16.5 flange rating MAP:	230 psi @ 68°F
ASME B16.5 flange hydro test:	350 psi @ 68°F
Gasket Description:	Flexitallic Spiral Wound CG 304L S.S.
PWHT performed:	No
Nozzle orientation:	330°
Local vessel minimum thickness:	0.4724 in
Nozzle center line offset to datum line:	24.0157 in
End of nozzle to shell center:	29.0157 in
Nozzle inside diameter, new:	18 in
Nozzle nominal wall thickness:	1 in
Nozzle corrosion allowance:	0.063 in
Projection available outside vessel, Lpr:	8.9715 in
Projection available outside vessel to flange face, Lf:	10.5315 in

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 180.18 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}
2.372	3.8036	1.9318	1.7168	--	--	0.155	0.1614	1

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 180.18 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(18.126, 9.063 + (1 - 0.063) + (0.4724 - 0.063))
= 18.126 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*(0.4724 - 0.063), 2.5*(1 - 0.063) + 0)
= 1.0236 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 180.1842*9.063 / (16,700*1 - 0.6*180.1842)
= 0.0984 in

Required thickness t_r from UG-37(a)

t_r = P*R / (S*E - 0.6*P)
= 180.1842*18.0748 / (16,700*1 - 0.6*180.1842)
= 0.1963 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})
= 18.126*0.1963*1 + 2*0.937*0.1963*1*(1 - 1)
= 3.558 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 3.8636 in^2

$= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
$= 18.126*(1*0.4094 - 1*0.1963) - 2*0.937*(1*0.4094 - 1*0.1963)*(1 - 1)$
$= 3.8636\ in^2$

$= 2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
$= 2*(0.4094 + 0.937)*(1*0.4094 - 1*0.1963) - 2*0.937*(1*0.4094 - 1*0.1963)*(1 - 1)$
$= 0.574\ in^2$

A_2 = smaller of the following= 1.7168 in^2

$= 5*(t_n - t_{rn})*f_{r2}*t$
$= 5*(0.937 - 0.0984)*1*0.4094$
$= 1.7168\ in^2$

$= 5*(t_n - t_{rn})*f_{r2}*t_n$
$= 5*(0.937 - 0.0984)*1*0.937$
$= 3.9289\ in^2$

$A_{41} = Leg^2*f_{r2}$
$= 0.3937^2*1$
$= 0.155\ in^2$

$Area = A_1 + A_2 + A_{41}$
$= 3.8636 + 1.7168 + 0.155$
$= 5.7354\ in^2$

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 = 0.4094 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 (Access Opening)

Wall thickness req'd per UG-45(a): t_{r1} = 0.1614 in (E =1)

Available nozzle wall thickness new, t_n = 1 in

The nozzle neck thickness is adequate.

Check the opening per Appendix 1-7

Area required within 75 percent of the limits of reinforcement
= 2 / 3*A = (2 / 3)*3.558 = 2.372 in^2

Area that is within 75 percent of the limits of reinforcement is:

A_1 = larger of 0.574 or

$= (2*limits - d)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
$= (2*13.5945 - 18.126)*(1*0.4094 - 1*0.1963) - 2*0.937*(1*0.4094 - 1*0.1963)*(1 - 1)$
$= 1.9318\ in^2$

$Area = A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$
$= 1.9318 + 1.7168 + 0 + 0.155 + 0 + 0 + 0$
$= 3.8036\ in^2$

The area placement requirements of Appendix 1-7 are satisfied.

The opening is not within the size range defined by 1-7(b)(1)(a) and (b) so it is exempt from the requirements of 1-7(b)(2),(3) and (4).

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

6" (BE)

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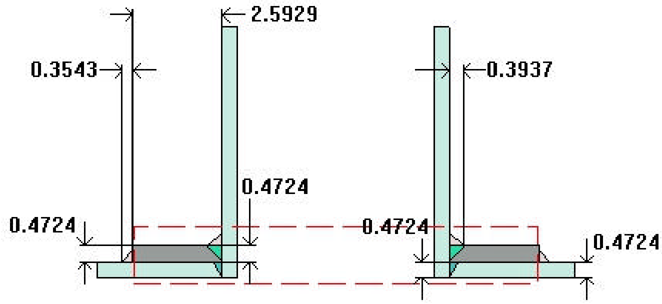

$t_{w(lower)}$ = 0.4724 in

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:	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 150 WN A182 F304L
Bolt Material:	SA-193 B8 1 Bolt (II-D p. 356, ln. 20)
Flange rated MDMT:	-320°F
(Per UHA-51(d)(1)(a))	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	185 psi @ 250°F
ASME B16.5 flange rating MAP:	230 psi @ 68°F
ASME B16.5 flange hydro test:	350 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:	245°
Local vessel minimum thickness:	0.4724 in
Nozzle center line offset to datum line:	47.9921 in
End of nozzle to shell center:	29 in
Nozzle inside diameter, new:	5.761 in
Nozzle nominal wall thickness:	0.432 in
Nozzle corrosion allowance:	0.063 in
Projection available outside vessel, Lpr:	7.0157 in
Projection available outside vessel to flange face, Lf:	10.5157 in
Pad is split:	No

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 180 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}
1.1544	4.5337	1.256	0.6901	--	2.4326	0.155	0.2591	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
932.45	54,737.32	96,182.76	19,159.47	146,939.63	59,783.63	106,448.16

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})	0.2047	0.248	weld size is adequate
Nozzle to pad groove (Upper)	0.2583	0.4724	weld size is adequate

Calculations for internal pressure 180 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(5.887, 2.9435 + (0.432 - 0.063) + (0.4724 - 0.063))
= 5.887 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*(0.4724 - 0.063), 2.5*(0.432 - 0.063) + 0.4724)
= 1.0236 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 180*2.9435 / (16,700*1 - 0.6*180)
= 0.0319 in

Required thickness t_r from UG-37(a)

t_r = P*R / (S*E - 0.6*P)
= 180*18.0748 / (16,700*1 - 0.6*180)
= 0.1961 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 $S_p / S_v = 1$

$A = d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
$= 5.887*0.1961*1 + 2*0.369*0.1961*1*(1 - 1)$
$= 1.1544\ in^2$

Area available from FIG. UG-37.1

A_1 = larger of the following= 1.256 in^2

$= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
$= 5.887*(1*0.4094 - 1*0.1961) - 2*0.369*(1*0.4094 - 1*0.1961)*(1 - 1)$
$= 1.256\ in^2$

$= 2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
$= 2*(0.4094 + 0.369)*(1*0.4094 - 1*0.1961) - 2*0.369*(1*0.4094 - 1*0.1961)*(1 - 1)$
$= 0.3322\ in^2$

A_2 = smaller of the following= 0.6901 in^2

$= 5*(t_n - t_{rn})*f_{r2}*t$
$= 5*(0.369 - 0.0319)*1*0.4094$
$= 0.6901\ in^2$

$= 2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
$= 2*(0.369 - 0.0319)*(2.5*0.369 + 0.4724)*1$
$= 0.9405\ in^2$

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

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

(Part of the weld is outside of the limits)

$A_5 = (D_p - d - 2*t_n)*t_e*f_{r4}$
$= (11.774 - 5.887 - 2*0.369)*0.4724*1$
$= 2.4326\ in^2$

$Area = A_1 + A_2 + A_{41} + A_{42} + A_5$
$= 1.256 + 0.6901 + 0.155 + 0 + 2.4326$
$= 4.5337\ in^2$

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 = 0.369 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 = 0.4094 in
$t_{w(min)} = 0.5*t_{min} = 0.2047$ 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): $t_{r1} = 0.2109$ in (E =1) (pressure plus external loads govern in longitudinal direction)
Wall thickness per UG-45(b)(1): $t_{r2} = 0.2591$ in
Wall thickness per UG-16(b): $t_{r3} = 0.1255$ in

Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.308 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 0.2591 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.2591 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.2591 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)*6.256*0.369*11,690 = 42,390.28 lb_f

(4) Groove weld in tension
(π / 2)*Nozzle OD*t_w*S_g = (π / 2)*6.625*0.4094*12,358 = 52,655.68 lb_f

(6) Upper groove weld in tension
(π / 2)*Nozzle OD*t_w*S_g = (π / 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
= (1.1544 - 1.256 + 2*0.369*1*(1*0.4094 - 1*0.1961))*16,700
= 932.45 lb_f

W_{1-1} = (A_2 + A_5 + A_{41} + A_{42})*S_v
= (0.6901 + 2.4326 + 0.155 + 0)*16,700
= 54,737.32 lb_f

W_{2-2} = (A_2 + A_3 + A_{41} + A_{43} + 2*t_n*t*f_{r1})*S_v
= (0.6901 + 0 + 0.155 + 0 + 2*0.369*0.4094*1)*16,700
= 19,159.47 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
= (0.6901 + 0 + 2.4326 + 0.155 + 0 + 0 + 2*0.369*0.4094*1)*16,700
= 59,783.63 lb_f

Load for path 1-1 lesser of W or W_{1-1} = 932.45 lb_f
Path 1-1 through (2) & (3) = 53,792.48 + 42,390.28 = 96,182.76 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} = 932.45 lb_f
Path 2-2 through (1), (4), (6) = 33,526.22 + 52,655.68 + 60,757.72 = 146,939.63 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} = 932.45 lb_f
Path 3-3 through (2), (4) = 53,792.48 + 52,655.68 = 106,448.16 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

Applied Loads

Radial load:	P_r =	-1,699.77 lb_f
Circumferential moment:	M_c =	50,949.34 lb_f-in
Circumferential shear:	V_c =	2,081.17 lb_f
Longitudinal moment:	M_L =	50,949.34 lb_f-in
Longitudinal shear:	V_L =	2,081.17 lb_f
Torsion moment:	M_t =	72,127.62 lb_f-in
Internal pressure:	P =	180 psi
Mean shell radius:	R_m =	18.2795 in
Local shell thickness:	t =	0.4094 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 = 18.2795 / 0.4094 = 44.6451

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

Local circumferential pressure stress = I*P*R_i / t =7,946 psi

Local longitudinal pressure stress = I*P*R_i / (2*t) =3,973 psi

Maximum combined stress (P_L+P_b+Q) = 37,328 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) = 13,576 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*	2.4947	0.2827	0	0	0	0	567	567	567	567
4C*	5.0412	0.2827	1,145	1,145	1,145	1,145	0	0	0	0
1C	0.0618	0.2827	0	0	0	0	3,760	-3,760	3,760	-3,760
2C-1	0.0178	0.2827	1,083	-1,083	1,083	-1,083	0	0	0	0
3A*	1.6002	0.2827	0	0	0	0	-2,108	-2,108	2,108	2,108
1A	0.0648	0.2827	0	0	0	0	-22,868	22,868	22,868	-22,868
3B*	3.4044	0.2827	-4,485	-4,485	4,485	4,485	0	0	0	0
1B-1	0.0157	0.2827	-5,540	5,540	5,540	-5,540	0	0	0	0
Pressure stress*			7,946	7,946	7,946	7,946	7,946	7,946	7,946	7,946
Total circumferential stress			149	9,063	20,199	6,953	-12,703	25,513	37,249	-16,007
Primary membrane circumferential stress*			4,606	4,606	13,576	13,576	6,405	6,405	10,621	10,621
3C*	2.4947	0.2827	567	567	567	567	0	0	0	0
4C*	5.0412	0.2827	0	0	0	0	1,145	1,145	1,145	1,145
1C-1	0.0408	0.2827	2,482	-2,482	2,482	-2,482	0	0	0	0
2C	0.0307	0.2827	0	0	0	0	1,868	-1,868	1,868	-1,868
4A*	4.245	0.2827	0	0	0	0	-5,592	-5,592	5,592	5,592
2A	0.0282	0.2827	0	0	0	0	-9,952	9,952	9,952	-9,952
4B*	1.6952	0.2827	-2,233	-2,233	2,233	2,233	0	0	0	0
2B-1	0.0277	0.2827	-9,775	9,775	9,775	-9,775	0	0	0	0
Pressure stress*			3,973	3,973	3,973	3,973	3,973	3,973	3,973	3,973
Total longitudinal stress			-4,986	9,600	19,030	-5,484	-8,558	7,610	22,530	-1,110
Primary membrane longitudinal stress*			2,307	2,307	6,773	6,773	-474	-474	10,710	10,710
Shear from M_t			804	804	804	804	804	804	804	804
Circ shear from V_c			274	274	-274	-274	0	0	0	0
Long shear from V_L			0	0	0	0	-274	-274	274	274
Total Shear stress			1,078	1,078	530	530	530	530	1,078	1,078
Combined stress (P_L+P_b+Q)			5,569	10,442	20,404	12,482	-12,770	25,529	37,328	-16,085

Note: * denotes primary stress.

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

R_m / t = 18.2795 / 0.8819 = 20.7279

Pressure stress intensity factor, I = 0.67473 (derived from PVP-Vol. 399, pages 77-82)

Local circumferential pressure stress = I*P*R_i / t =5,361 psi

Local longitudinal pressure stress = I*P*R_i / (2*t) =2,681 psi

Maximum combined stress (P_L+P_b+Q) = 23,491 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) = 9,017 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*	2.8688	0.1586	0	0	0	0	302	302	302	302
4C*	3.4658	0.1586	365	365	365	365	0	0	0	0
1C	0.1097	0.1586	0	0	0	0	1,439	-1,439	1,439	-1,439
2C-1	0.0759	0.1586	995	-995	995	-995	0	0	0	0
3A*	0.705	0.1586	0	0	0	0	-769	-769	769	769
1A	0.0948	0.1586	0	0	0	0	-12,856	12,856	12,856	-12,856
3B*	2.27	0.1586	-2,475	-2,475	2,475	2,475	0	0	0	0
1B-1	0.0435	0.1586	-5,899	5,899	5,899	-5,899	0	0	0	0
Pressure stress*			5,361	5,361	5,361	5,361	7,946	7,946	7,946	7,946
Total circumferential stress			-1,653	8,155	15,095	1,307	-3,938	18,896	23,312	-5,278
Primary membrane circumferential stress*			3,251	3,251	8,201	8,201	7,479	7,479	9,017	9,017
3C*	2.8688	0.1586	302	302	302	302	0	0	0	0
4C*	3.4658	0.1586	0	0	0	0	365	365	365	365
1C-1	0.1133	0.1586	1,486	-1,486	1,486	-1,486	0	0	0	0
2C	0.0759	0.1586	0	0	0	0	995	-995	995	-995
4A*	1.0619	0.1586	0	0	0	0	-1,158	-1,158	1,158	1,158
2A	0.0528	0.1586	0	0	0	0	-7,160	7,160	7,160	-7,160
4B*	0.6831	0.1586	-745	-745	745	745	0	0	0	0
2B-1	0.069	0.1586	-9,357	9,357	9,357	-9,357	0	0	0	0
Pressure stress*			3,973	3,973	3,973	3,973	2,681	2,681	2,681	2,681
Total longitudinal stress			-4,341	11,401	15,863	-5,823	-4,277	8,053	12,359	-3,951
Primary membrane longitudinal stress*			3,530	3,530	5,020	5,020	1,888	1,888	4,204	4,204
Shear from M_t			1,186	1,186	1,186	1,186	1,186	1,186	1,186	1,186
Circ shear from V_c			227	227	-227	-227	0	0	0	0
Long shear from V_L			0	0	0	0	-227	-227	227	227
Total Shear stress			1,413	1,413	959	959	959	959	1,413	1,413
Combined stress (P_L+P_b+Q)			-4,947	11,930	16,512	7,383	-5,081	18,980	23,491	-6,176

Note: * denotes primary stress.

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

$\sigma_{n\ (Pm)} = P*R_i / (2*t_n) - P_r / (\pi*(R_o^2 - R_i^2)) + M*R_o / I$
$= 180*2.9435 / (2*0.315) - -1{,}699.77 / (\pi*(3.3125^2 - 2.9435^2)) + 72{,}053.3*3.3125 / 35.6035$
= 7,779 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

$\sigma_{shear} = (V_L^2 + V_c^2)^{0.5} / (\pi*R_i*t_n)$
$= (2{,}081.17^2 + 2{,}081.17^2)^{0.5} / (\pi*2.9435*0.369)$
= 863 psi

$\sigma_{torsion} = M_t / (2*\pi*R_i^2*t_n)$
$= 72{,}127.6 / (2*\pi*2.9435^2*0.369)$
= 3,591 psi

$\sigma_{total} = \sigma_{shear} + \sigma_{torsion}$
= 863 + 3,591
= 4,453 psi

UG-45(c): The total combined shear stress (4,453 psi) is below than the allowable ($0.7*S_n$ = 0.7*16,700 = 11,690 psi)

8" (BJ)

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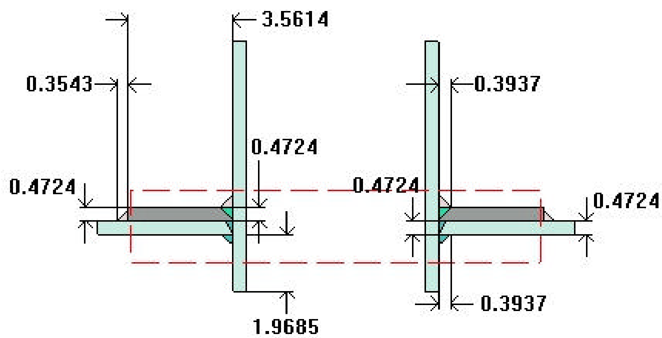

$t_{w(lower)}$ = 0.4724 in

Leg_{41} = 0.3937 in

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

Leg_{42} = 0.3543 in

Leg_{43} = 0.3937 in

h_{new} = 1.9685 in

D_p = 15.7478 in

t_e = 0.4724 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 8 Sch 80S (XS)
Pad material specification:	SA-240 304L (II-D p. 82, ln. 38)
Pad diameter:	15.7478 in
Flange description:	8 inch Class 150 WN A182 F304L
Bolt Material:	SA-193 B8 1 Bolt (II-D p. 356, ln. 20)
Flange rated MDMT:	-320°F
(Per UHA-51(d)(1)(a))	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	185 psi @ 250°F
ASME B16.5 flange rating MAP:	230 psi @ 68°F
ASME B16.5 flange hydro test:	350 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:	300°
Local vessel minimum thickness:	0.4724 in
Nozzle center line offset to datum line:	44.0157 in
End of nozzle to shell center:	29 in
Nozzle inside diameter, new:	7.625 in
Nozzle nominal wall thickness:	0.5 in
Nozzle corrosion allowance:	0.063 in
Projection available outside vessel, Lpr:	6.5157 in
Internal projection, h_{new}:	1.9685 in
Projection available outside vessel to flange face, Lf:	10.5157 in
Pad is split:	No

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 180 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}
1.5199	5.0043	--	0.8087	0.6994	3.249	0.2472	0.2591	0.4375

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
879.46	70,351.45	137,429	35,289.89	224,968.33	89,547.55	173,944.91

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})	0.2047	0.248	weld size is adequate
Nozzle to pad groove (Upper)	0.3059	0.4724	weld size is adequate

Calculations for internal pressure 180 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(7.751, 3.8755 + (0.5 - 0.063) + (0.4724 - 0.063))
= 7.751 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*(0.4724 - 0.063), 2.5*(0.5 - 0.063) + 0.4724)
= 1.0236 in

Inner Normal Limit of reinforcement per UG-40

L_I = MIN(2.5*(t - C), 2.5*(t_i - C_n - C))
= MIN(2.5*(0.4724 - 0.063), 2.5*(0.5 - 0.063 - 0.063))
= 0.935 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 180*3.8755 / (16,700*1 - 0.6*180)
= 0.042 in

Required thickness t_r from UG-37(a)

t_r = P*R / (S*E - 0.6*P)
= 180*18.0748 / (16,700*1 - 0.6*180)
= 0.1961 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 = $d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
= 7.751*0.1961*1 + 2*0.437*0.1961*1*(1 - 1)
= 1.5199 in^2

Area available from FIG. UG-37.1

Area A_1 is not included in these calculations.
A_2 = smaller of the following= 0.8087 in^2

= $5*(t_n - t_{rn})*f_{r2}*t$
= 5*(0.437 - 0.042)*1*0.4094
= 0.8087 in^2

= $2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
= 2*(0.437 - 0.042)*(2.5*0.437 + 0.4724)*1
= 1.2363 in^2

A_3 = smaller of the following= 0.6994 in^2

= $5*t*t_i*f_{r2}$
= 5*0.4094*0.374*1
= 0.7657 in^2

= $5*t_i*t_i*f_{r2}$
= 5*0.374*0.374*1
= 0.6994 in^2

= $2*h*t_i*f_{r2}$
= 2*1.9055*0.374*1
= 1.4253 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_{43} = Leg^2*f_{r2}
= 0.3037^2*1
= 0.0922 in^2

A_5 = $(D_p - d - 2*t_n)*t_e*f_{r4}$
= (15.502 - 7.751 - 2*0.437)*0.4724*1
= 3.249 in^2

Area = $A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$
= 0 + 0.8087 + 0.6994 + 0.155 + 0 + 0.0922 + 3.249
= 5.0043 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 = 0.437 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 = 0.4094 in
$t_{w(min)}$ = 0.5*t_{min} = 0.2047 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} = 0.2281 in (E =1) (pressure plus external loads govern in longitudinal direction)
Wall thickness per UG-45(b)(1):	t_{r2} = 0.2591 in
Wall thickness per UG-16(b):	t_{r3} = 0.1255 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.3447 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 0.2591 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.2591 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.2591 in

Available nozzle wall thickness new, t_n = 0.875*0.5 = 0.4375 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
Lower fillet weld in shear:	0.49*16,700 =	8,183 psi

Strength of welded joints:

(1) Inner fillet weld in shear
(π / 2)*Nozzle OD*Leg*S_i = (π / 2)*8.625*0.3937*8,183 = 43,647.34 lb_f

(2) Outer fillet weld in shear
(π / 2)*Pad OD*Leg*S_o = (π / 2)*15.7478*0.3543*8,183 = 71,723.6 lb_f

(3) Nozzle wall in shear
(π / 2)*Mean nozzle dia*t_n*S_n = (π / 2)*8.188*0.437*11,690 = 65,705.4 lb_f

(4) Groove weld in tension
(π / 2)*Nozzle OD*t_w*S_g = (π / 2)*8.625*0.4094*12,358 = 68,551.74 lb_f

(5) Lower fillet weld in shear
(π / 2)*Nozzle OD*Leg*S_l = (π / 2)*8.625*0.3037*8,183 = 33,669.56 lb_f

(6) Upper groove weld in tension
(π / 2)*Nozzle OD*t_w*S_g = (π / 2)*8.625*0.4724*12,358 = 79,099.68 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
= (1.5199 - 1.6537 + 2*0.437*1*(1*0.4094 - 1*0.1961))*16,700
= 879.46 lb_f

W_{1-1} = (A_2 + A_5 + A_{41} + A_{42})*S_v
= (0.8087 + 3.249 + 0.155 + 0)*16,700
= 70,351.45 lb_f

W_{2-2} = (A_2 + A_3 + A_{41} + A_{43} + 2*t_n*t*f_{r1})*S_v

$= (0.8087 + 0.6994 + 0.155 + 0.0922 + 2*0.437*0.4094*1)*16,700$
$= 35,289.89\ lb_f$

$W_{3-3} = (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2*t_n*t*f_{r1})*S_v$
$= (0.8087 + 0.6994 + 3.249 + 0.155 + 0 + 0.0922 + 2*0.437*0.4094*1)*16,700$
$= 89,547.55\ lb_f$

Load for path 1-1 lesser of W or W_{1-1} = 879.46 lb_f
Path 1-1 through (2) & (3) = 71,723.6 + 65,705.4 = 137,429 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} = 879.46 lb_f
Path 2-2 through (1), (4), (5), (6) = 43,647.34 + 68,551.74 + 33,669.56 + 79,099.68 = 224,968.33 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} = 879.46 lb_f
Path 3-3 through (2), (4), (5) = 71,723.6 + 68,551.74 + 33,669.56 = 173,944.91 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

Applied Loads

Radial load:	P_r =	-2,557.36 lb_f
Circumferential moment:	M_c =	95,302.19 lb_f-in
Circumferential shear:	V_c =	3,134.98 lb_f
Longitudinal moment:	M_L =	95,302.19 lb_f-in
Longitudinal shear:	V_L =	3,134.98 lb_f
Torsion moment:	M_t =	134,794.45 lb_f-in
Internal pressure:	P =	180 psi
Mean shell radius:	R_m =	18.2795 in
Local shell thickness:	t =	0.4094 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 = 18.2795 / 0.4094 = 44.6451

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

Local circumferential pressure stress = I*P*R_i / t =7,946 psi

Local longitudinal pressure stress = I*P*R_i / (2*t) =3,973 psi

Maximum combined stress (P_L+P_b+Q) = 47,095 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) = 13,685 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*	1.6324	0.3769	0	0	0	0	558	558	558	558
4C*	3.9073	0.3769	1,335	1,335	1,335	1,335	0	0	0	0
1C	0.0618	0.3769	0	0	0	0	5,657	-5,657	5,657	-5,657
2C-1	0.0101	0.3769	924	-924	924	-924	0	0	0	0
3A*	1.2789	0.3769	0	0	0	0	-2,364	-2,364	2,364	2,364
1A	0.0616	0.3769	0	0	0	0	-30,497	30,497	30,497	-30,497
3B*	2.3826	0.3769	-4,404	-4,404	4,404	4,404	0	0	0	0
1B-1	0.0108	0.3769	-5,347	5,347	5,347	-5,347	0	0	0	0
Pressure stress*			7,946	7,946	7,946	7,946	7,946	7,946	7,946	7,946
Total circumferential stress			454	9,300	19,956	7,414	-18,700	30,980	47,022	-25,286
Primary membrane circumferential stress*			4,877	4,877	13,685	13,685	6,140	6,140	10,868	10,868
3C*	1.6324	0.3769	558	558	558	558	0	0	0	0
4C*	3.9073	0.3769	0	0	0	0	1,335	1,335	1,335	1,335
1C-1	0.0251	0.3769	2,297	-2,297	2,297	-2,297	0	0	0	0
2C	0.03	0.3769	0	0	0	0	2,746	-2,746	2,746	-2,746
4A*	4.4123	0.3769	0	0	0	0	-8,155	-8,155	8,155	8,155
2A	0.0255	0.3769	0	0	0	0	-12,624	12,624	12,624	-12,624
4B*	1.3658	0.3769	-2,524	-2,524	2,524	2,524	0	0	0	0
2B-1	0.0209	0.3769	-10,347	10,347	10,347	-10,347	0	0	0	0
Pressure stress*			3,973	3,973	3,973	3,973	3,973	3,973	3,973	3,973
Total longitudinal stress			-6,043	10,057	19,699	-5,589	-12,725	7,031	28,833	-1,907
Primary membrane longitudinal stress*			2,007	2,007	7,055	7,055	-2,847	-2,847	13,463	13,463
Shear from M_t			845	845	845	845	845	845	845	845
Circ shear from V_c			310	310	-310	-310	0	0	0	0
Long shear from V_L			0	0	0	0	-310	-310	310	310
Total Shear stress			1,155	1,155	535	535	535	535	1,155	1,155
Combined stress (P_L+P_b+Q)			6,895	10,894	20,378	13,047	-18,748	30,992	47,095	-25,343

Note: * denotes primary stress.

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

R_m / t = 18.2795 / 0.8819 = 20.7279

Pressure stress intensity factor, I = 0.46428 (derived from PVP-Vol. 399, pages 77-82)

Local circumferential pressure stress = I*P*R_i / t =3,689 psi

Local longitudinal pressure stress = I*P*R_i / (2*t) =1,845 psi

Maximum combined stress (P_L+P_b+Q) = 28,600 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) = 9,630 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*	2.3904	0.2064	0	0	0	0	379	379	379	379
4C*	3.1823	0.2064	505	505	505	505	0	0	0	0
1C	0.0844	0.2064	0	0	0	0	1,665	-1,665	1,665	-1,665
2C-1	0.0536	0.2064	1,058	-1,058	1,058	-1,058	0	0	0	0
3A*	0.8327	0.2064	0	0	0	0	-1,305	-1,305	1,305	1,305
1A	0.0879	0.2064	0	0	0	0	-17,127	17,127	17,127	-17,127
3B*	2.3584	0.2064	-3,695	-3,695	3,695	3,695	0	0	0	0
1B-1	0.0355	0.2064	-6,917	6,917	6,917	-6,917	0	0	0	0
Pressure stress*			3,689	3,689	3,689	3,689	7,946	7,946	7,946	7,946
Total circumferential stress			-5,360	6,358	15,864	-86	-8,442	22,482	28,422	-9,162
Primary membrane circumferential stress*			499	499	7,889	7,889	7,020	7,020	9,630	9,630
3C*	2.3904	0.2064	379	379	379	379	0	0	0	0
4C*	3.1823	0.2064	0	0	0	0	505	505	505	505
1C-1	0.0891	0.2064	1,758	-1,758	1,758	-1,758	0	0	0	0
2C	0.0535	0.2064	0	0	0	0	1,056	-1,056	1,056	-1,056
4A*	1.3466	0.2064	0	0	0	0	-2,110	-2,110	2,110	2,110
2A	0.0475	0.2064	0	0	0	0	-9,255	9,255	9,255	-9,255
4B*	0.801	0.2064	-1,255	-1,255	1,255	1,255	0	0	0	0
2B-1	0.0573	0.2064	-11,165	11,165	11,165	-11,165	0	0	0	0
Pressure stress*			3,973	3,973	3,973	3,973	1,845	1,845	1,845	1,845
Total longitudinal stress			-6,310	12,504	18,530	-7,316	-7,959	8,439	14,771	-5,851
Primary membrane longitudinal stress*			3,097	3,097	5,607	5,607	240	240	4,460	4,460
Shear from M_t			1,308	1,308	1,308	1,308	1,308	1,308	1,308	1,308
Circ shear from V_c			262	262	-262	-262	0	0	0	0
Long shear from V_L			0	0	0	0	-262	-262	262	262
Total Shear stress			1,570	1,570	1,046	1,046	1,046	1,046	1,570	1,570
Combined stress (P_L+P_b+Q)			-7,475	12,882	18,891	7,527	-9,274	22,559	28,600	-9,788

Note: * denotes primary stress.

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

$\sigma_{n\ (Pm)} = P*R_i / (2*t_n) - P_r / (\pi*(R_o^2 - R_i^2)) + M*R_o / I$
$= 180*3.8755 / (2*0.3745) - -2{,}557.36 / (\pi*(4.3125^2 - 3.8755^2)) + 134{,}777.6*4.3125 / 94.475$
= 7,311 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

$\sigma_{shear} = (V_L^2 + V_c^2)^{0.5} / (\pi*R_i*t_n)$
$= (3{,}134.98^2 + 3{,}134.98^2)^{0.5} / (\pi*3.8755*0.437)$
= 833 psi

$\sigma_{torsion} = M_t / (2*\pi*R_i^2*t_n)$
$= 134{,}794.5 / (2*\pi*3.8755^2*0.437)$
= 3,269 psi

$\sigma_{total} = \sigma_{shear} + \sigma_{torsion}$
= 833 + 3,269
= 4,102 psi

UG-45(c): The total combined shear stress (4,102 psi) is below than the allowable ($0.7*S_n = 0.7*16{,}700 = 11{,}690$ psi)

2" (BS)

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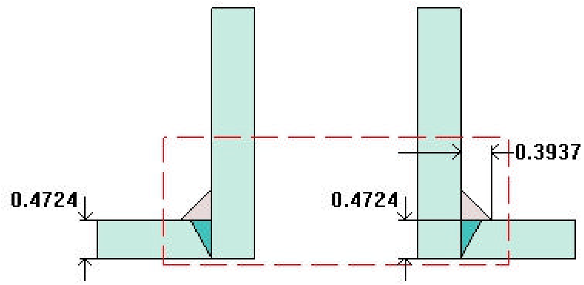
$t_{w(lower)}$ = 0.4724 in

Leg_{41} = 0.3937 in



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

Located on:	SHELL
Liquid static head included:	0.555 psi
Nozzle material specification:	SA-182 F304L <= 5 (II-D p. 82, ln. 34)
Nozzle longitudinal joint efficiency:	1
Flange description:	2 inch Class 150 LWN A182 F304L
Bolt Material:	SA-193 B8 1 Bolt (II-D p. 356, ln. 20)
Flange rated MDMT:	-320°F
(Per UHA-51(d)(1)(a))	
Liquid static head on flange:	0.5181 psi
ASME B16.5 flange rating MAWP:	185 psi @ 250°F
ASME B16.5 flange rating MAP:	230 psi @ 68°F
ASME B16.5 flange hydro test:	350 psi @ 68°F
Gasket Description:	Flexitallic Spiral Wound CG 304L S.S.
PWHT performed:	No
Nozzle orientation:	230°
Local vessel minimum thickness:	0.4724 in
Nozzle center line offset to datum line:	5.9843 in
End of nozzle to shell center:	27.1654 in
Nozzle inside diameter, new:	2 in
Nozzle nominal wall thickness:	0.53 in
Nozzle corrosion allowance:	0.063 in
Projection available outside vessel, Lpr:	7.9311 in
Projection available outside vessel to flange face, Lf:	8.6811 in

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 180.56 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)							0.252	0.53

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.25	0.2756	weld size is adequate

Calculations for internal pressure 180.56 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(2.126, 1.063 + (0.53 - 0.063) + (0.4724 - 0.063))
= 2.126 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*(0.4724 - 0.063), 2.5*(0.53 - 0.063) + 0)
= 1.0236 in

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

t_m = P*R_n / (S_n*E - 0.6*P)
= 180.555*1.063 / (16,700*1 - 0.6*180.555)
= 0.0116 in

Required thickness t_r from UG-37(a)

t_r = P*R / (S*E - 0.6*P)
= 180.555*18.0748 / (16,700*1 - 0.6*180.555)
= 0.1967 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.4094 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} = 0.1725 in (E =1) (pressure plus external loads govern in longitudinal direction)
Wall thickness per UG-45(b)(1): t_{r2} = 0.2597 in

Wall thickness per UG-16(b):	$t_{r3} = 0.1255$ in
Standard wall pipe per UG-45(b)(4):	$t_{r4} = 0.252$ in
The greater of t_{r2} or t_{r3}:	$t_{r5} = 0.2597$ in
The lesser of t_{r4} or t_{r5}:	$t_{r6} = 0.252$ in

Required per UG-45 is the larger of t_{r1} or $t_{r6} = 0.252$ in

Available nozzle wall thickness new, $t_n = 0.53$ in

The nozzle neck thickness is adequate.

Applied Loads

Radial load:	P_r =	-449.74 lb_f
Circumferential moment:	M_c =	4,426.6 lb_f-in
Circumferential shear:	V_c =	551.16 lb_f
Longitudinal moment:	M_L =	4,426.6 lb_f-in
Longitudinal shear:	V_L =	551.16 lb_f
Torsion moment:	M_t =	6,162.53 lb_f-in
Internal pressure:	P =	180.555 psi
Mean shell radius:	R_m =	18.2795 in
Local shell thickness:	t =	0.4094 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 = 18.2795 / 0.4094 = 44.6451

Pressure stress intensity factor, I = 1.0277 (derived from PVP-Vol. 399, pages 77-82)

Local circumferential pressure stress = I*P*R_i / t =8,192 psi

Local longitudinal pressure stress = I*P*R_i / (2*t) =4,096 psi

Maximum combined stress (P_L+P_b+Q) = 23,480 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) = 10,437 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*	7.5192	0.0732	0	0	0	0	452	452	452	452
4C*	8.118	0.0732	488	488	488	488	0	0	0	0
1C	0.1501	0.0732	0	0	0	0	2,416	-2,416	2,416	-2,416
2C-1	0.1136	0.0732	1,829	-1,829	1,829	-1,829	0	0	0	0
3A*	1.0785	0.0732	0	0	0	0	-476	-476	476	476
1A	0.1013	0.0732	0	0	0	0	-11,988	11,988	11,988	-11,988
3B*	3.9763	0.0732	-1,757	-1,757	1,757	1,757	0	0	0	0
1B-1	0.052	0.0732	-6,154	6,154	6,154	-6,154	0	0	0	0
Pressure stress*			8,192	8,192	8,192	8,192	7,971	7,971	7,971	7,971
Total circumferential stress			2,598	11,248	18,420	2,454	-1,625	17,519	23,303	-5,505
Primary membrane circumferential stress*			6,923	6,923	10,437	10,437	7,947	7,947	8,899	8,899
3C*	7.5192	0.0732	452	452	452	452	0	0	0	0
4C*	8.118	0.0732	0	0	0	0	488	488	488	488
1C-1	0.1519	0.0732	2,445	-2,445	2,445	-2,445	0	0	0	0
2C	0.1106	0.0732	0	0	0	0	1,780	-1,780	1,780	-1,780
4A*	1.442	0.0732	0	0	0	0	-637	-637	637	637
2A	0.0581	0.0732	0	0	0	0	-6,876	6,876	6,876	-6,876
4B*	1.0534	0.0732	-465	-465	465	465	0	0	0	0
2B-1	0.0844	0.0732	-9,988	9,988	9,988	-9,988	0	0	0	0
Pressure stress*			3,986	3,986	3,986	3,986	4,096	4,096	4,096	4,096
Total longitudinal stress			-3,570	11,516	17,336	-7,530	-1,149	9,043	13,877	-3,435
Primary membrane longitudinal stress*			3,973	3,973	4,903	4,903	3,947	3,947	5,221	5,221
Shear from M_t			1,023	1,023	1,023	1,023	1,023	1,023	1,023	1,023
Circ shear from V_c			280	280	-280	-280	0	0	0	0
Long shear from V_L			0	0	0	0	-280	-280	280	280
Total Shear stress			1,303	1,303	743	743	743	743	1,303	1,303
Combined stress (P_L+P_b+Q)			6,696	12,692	18,798	10,094	-2,167	17,584	23,480	-6,134

Note: * denotes primary stress.

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

$\sigma_{n\ (Pm)} = P*R_i / (2*t_n) - P_r / (\pi*(R_o^2 - R_i^2)) + M*R_o / I$
$= 180.56*1.063 / (2*0.467) - -449.74 / (\pi*(1.53^2 - 1.063^2)) + 6{,}260.2*1.53 / 3.301$
= 3,225 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

$\sigma_{shear} = (V_L^2 + V_c^2)^{0.5} / (\pi*R_i*t_n)$
$= (551.16^2 + 551.16^2)^{0.5} / (\pi*1.063*0.467)$
= 500 psi

$\sigma_{torsion} = M_t / (2*\pi*R_i^2*t_n)$
$= 6{,}162.5 / (2*\pi*1.063^2*0.467)$
= 1,859 psi

$\sigma_{total} = \sigma_{shear} + \sigma_{torsion}$
= 500 + 1,859
= 2,358 psi

UG-45(c): The total combined shear stress (2,358 psi) is below than the allowable ($0.7*S_n$ = 0.7*16,700 = 11,690 psi)

2" (CW)

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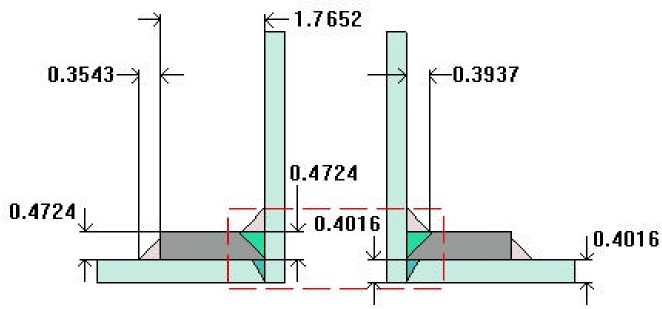

$t_{w(lower)}$ = 0.4016 in

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:	1.3895 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 150 WN A182 F304L
Bolt Material:	SA-193 B8 1 Bolt (II-D p. 356, ln. 20)
Flange rated MDMT:	-320°F
(Per UHA-51(d)(1)(a))	
Liquid static head on flange:	1.4043 psi
ASME B16.5 flange rating MAWP:	185 psi @ 250°F
ASME B16.5 flange rating MAP:	230 psi @ 68°F
ASME B16.5 flange hydro test:	350 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:	0.063 in
Projection available outside vessel, Lpr:	6.1042 in
Projection available outside vessel to flange face, Lf:	8.6042 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 = 181.39 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)							0.2761	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})	0.1967	0.2756	weld size is adequate
Pad to shell fillet (Leg_{42})	0.1693	0.248	weld size is adequate
Nozzle to pad groove (Upper)	0.1967	0.4724	weld size is adequate

Calculations for internal pressure 181.39 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(1.813, 0.9065 + (0.344 - 0.063) + (0.4016 - 0.063))
= 1.813 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 - 0.063), 2.5*(0.344 - 0.063) + 0.4724)
= 0.8464 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 181.3895*0.9065 / (16,700*1 - 0.6*181.3895)
= 0.0099 in

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

t_r = P*K_1*D / (2*S*E - 0.2*P)
= 181.3895*0.8969*36.1496 / (2*16,700*1 - 0.2*181.3895)
= 0.1763 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 = 0.281 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.1967 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 = 0.3386 in
$t_{w(min)}$ = 0.5*t_{min} = 0.1693 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} = 0.2761 in (E =1) (pressure plus external loads govern in longitudinal direction)
Wall thickness per UG-45(b)(1):	t_{r2} = 0.2586 in
Wall thickness per UG-16(b):	t_{r3} = 0.1255 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.1977 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 0.2586 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.1977 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.2761 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 =	-449.74 lb_f
Circumferential moment:	M_1 =	8,679.62 lb_f-in
Circumferential shear:	V_2 =	899.49 lb_f
Longitudinal moment:	M_2 =	8,679.62 lb_f-in
Longitudinal shear:	V_1 =	899.49 lb_f
Torsion moment:	M_t =	6,162.53 lb_f-in
Internal pressure:	P =	181.39 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 = 32.8157 in

U = r_o / Sqr(R_m*t) = 0.886
Pressure stress intensity factor, I = 1 (derived from PVP-Vol. 399, pages 77-82)

Local pressure stress = I*P*R_i / (2*t) =8,745 psi

Maximum combined stress (P_L+P_b+Q) = 24,687 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) = 11,087 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*	0.0759	298	298	298	298	298	298	298	298
SR-2	0.0413	972	-972	972	-972	972	-972	972	-972
SR-3*	0.09	0	0	0	0	-2,044	-2,044	2,044	2,044
SR-3	0.0924	0	0	0	0	-12,594	12,594	12,594	-12,594
SR-3*	0.09	-2,044	-2,044	2,044	2,044	0	0	0	0
SR-3	0.0924	-12,594	12,594	12,594	-12,594	0	0	0	0
Pressure stress*		8,745	8,745	8,745	8,745	8,745	8,745	8,745	8,745
Total O_x stress		-4,623	18,621	24,653	-2,479	-4,623	18,621	24,653	-2,479
Membrane O_x stress*		6,999	6,999	11,087	11,087	6,999	6,999	11,087	11,087
SR-2*	0.0235	92	92	92	92	92	92	92	92
SR-2	0.0124	292	-292	292	-292	292	-292	292	-292
SR-3*	0.0271	0	0	0	0	-616	-616	616	616
SR-3	0.0279	0	0	0	0	-3,803	3,803	3,803	-3,803
SR-3*	0.0271	-616	-616	616	616	0	0	0	0
SR-3	0.0279	-3,803	3,803	3,803	-3,803	0	0	0	0
Pressure stress*		8,745	8,745	8,745	8,745	8,745	8,745	8,745	8,745
Total O_y stress		4,710	11,732	13,548	5,358	4,710	11,732	13,548	5,358
Membrane O_y stress*		8,221	8,221	9,453	9,453	8,221	8,221	9,453	9,453
Shear from M_t		332	332	332	332	332	332	332	332
Shear from V_1		0	0	0	0	-286	-286	286	286
Shear from V_2		286	286	-286	-286	0	0	0	0
Total Shear stress		618	618	46	46	46	46	618	618
Combined stress (P_L+P_b+Q)		9,414	18,676	24,653	7,838	9,333	18,621	24,687	7,934

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 = 32.8157 in

U = r_o / Sqr(R_m*t) = 0.23
Pressure stress intensity factor, I = 0.20874 (derived from PVP-Vol. 399, pages 77-82)

Local pressure stress = I*P*R_i / (2*t) =1,825 psi

Maximum combined stress (P_L+P_b+Q) = 13,271 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) = 2,386 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*	0.213	146	146	146	146	146	146	146	146
SR-2	0.174	714	-714	714	-714	714	-714	714	-714
SR-3*	0.1624	0	0	0	0	-415	-415	415	415
SR-3	0.652	0	0	0	0	-10,007	10,007	10,007	-10,007
SR-3*	0.1624	-415	-415	415	415	0	0	0	0
SR-3	0.652	-10,007	10,007	10,007	-10,007	0	0	0	0
Pressure stress*		1,825	1,825	1,825	1,825	1,825	1,825	1,825	1,825
Total O_x stress		-7,737	10,849	13,107	-8,335	-7,737	10,849	13,107	-8,335
Membrane O_x stress*		1,556	1,556	2,386	2,386	1,556	1,556	2,386	2,386
SR-2*	0.0658	45	45	45	45	45	45	45	45
SR-2	0.052	213	-213	213	-213	213	-213	213	-213
SR-3*	0.0492	0	0	0	0	-126	-126	126	126
SR-3	0.19	0	0	0	0	-2,916	2,916	2,916	-2,916
SR-3*	0.0492	-126	-126	126	126	0	0	0	0
SR-3	0.19	-2,916	2,916	2,916	-2,916	0	0	0	0
Pressure stress*		1,825	1,825	1,825	1,825	1,825	1,825	1,825	1,825
Total O_y stress		-959	4,447	5,125	-1,133	-959	4,447	5,125	-1,133
Membrane O_y stress*		1,744	1,744	1,996	1,996	1,744	1,744	1,996	1,996
Shear from M_t		858	858	858	858	858	858	858	858
Shear from V_1		0	0	0	0	-297	-297	297	297
Shear from V_2		297	297	-297	-297	0	0	0	0
Total Shear stress		1,155	1,155	561	561	561	561	1,155	1,155
Combined stress (P_L+P_b+Q)		-7,928	11,051	13,146	-8,378	-7,783	10,898	13,271	-8,516

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

$\sigma_{n\ (Pm)} = P*R_i / (2*t_n) - P_r / (\pi*(R_o^2 - R_i^2)) + M*R_o / I$
$= 181.39*0.9065 / (2*0.238) - -449.74 / (\pi*(1.1875^2 - 0.9065^2)) + 12,274.8*1.1875 / 1.0315$
= 14,720 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

$\sigma_{shear} = (V_L^2 + V_c^2)^{0.5} / (\pi*R_i*t_n)$
$= (899.49^2 + 899.49^2)^{0.5} / (\pi*0.9065*0.281)$
= 1,590 psi

$\sigma_{torsion} = M_t / (2*\pi*R_i^2*t_n)$
$= 6,162.5 / (2*\pi*0.9065^2*0.281)$
= 4,247 psi

$\sigma_{total} = \sigma_{shear} + \sigma_{torsion}$
= 1,590 + 4,247
= 5,837 psi

UG-45(c): The total combined shear stress (5,837 psi) is below than the allowable ($0.7*S_n$ = 0.7*16,700 = 11,690 psi)

2" (LB1A/B)

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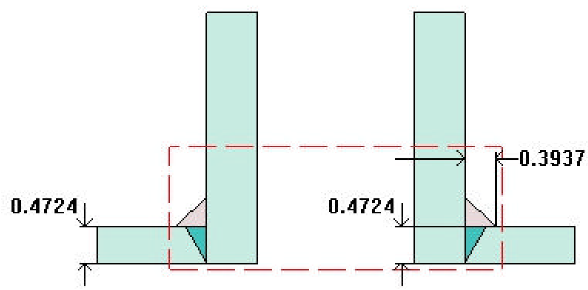
$t_{w(lower)}$ = 0.4724 in

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 B8 1 Bolt (II-D p. 356, ln. 20)
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:	0.4724 in
Nozzle center line offset to datum line:	68.9843 in
End of nozzle to shell center:	27 in
Nozzle inside diameter, new:	2 in
Nozzle nominal wall thickness:	0.655 in
Nozzle corrosion allowance:	0.063 in
Projection available outside vessel, Lpr:	7.6357 in
Projection available outside vessel to flange face, Lf:	8.5157 in

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 180 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)							0.252	0.655

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.25	0.2756	weld size is adequate

Calculations for internal pressure 180 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(2.126, 1.063 + (0.655 - 0.063) + (0.4724 - 0.063))
= 2.126 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*(0.4724 - 0.063), 2.5*(0.655 - 0.063) + 0)
= 1.0236 in

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

t_m = P*R_n / (S_n*E - 0.6*P)
= 180*1.063 / (16,700*1 - 0.6*180)
= 0.0115 in

Required thickness t_r from UG-37(a)

t_r = P*R / (S*E - 0.6*P)
= 180*18.0748 / (16,700*1 - 0.6*180)
= 0.1961 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.4094 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} = 0.0745 in (E =1)
Wall thickness per UG-45(b)(1): t_{r2} = 0.2591 in

Wall thickness per UG-16(b):	t_{r3} = 0.1255 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.252 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 0.2591 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.252 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.252 in

Available nozzle wall thickness new, t_n = 0.655 in

The nozzle neck thickness is adequate.

2" (LT2A/B, LT3A/B, LT4A/B)

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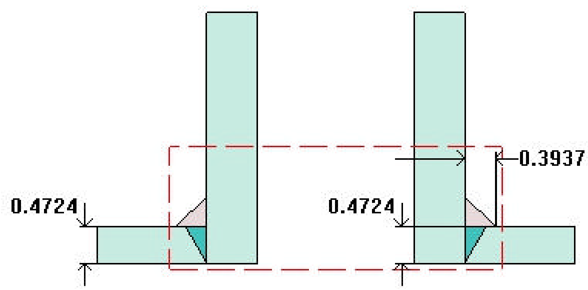

$t_{w(lower)}$ = 0.4724 in

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 B8 1 Bolt (II-D p. 356, ln. 20)
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:	135°
Local vessel minimum thickness:	0.4724 in
Nozzle center line offset to datum line:	42 in
End of nozzle to shell center:	27 in
Nozzle inside diameter, new:	2 in
Nozzle nominal wall thickness:	0.655 in
Nozzle corrosion allowance:	0.063 in
Projection available outside vessel, Lpr:	7.6357 in
Projection available outside vessel to flange face, Lf:	8.5157 in

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 180 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)							0.252	0.655

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

UW-16 Weld Sizing Summary			
Weld description	**Required weld throat size (in)**	**Actual weld throat size (in)**	**Status**
Nozzle to shell fillet (Leg_{41})	0.25	0.2756	weld size is adequate

Calculations for internal pressure 180 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(2.126, 1.063 + (0.655 - 0.063) + (0.4724 - 0.063))
= 2.126 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*(0.4724 - 0.063), 2.5*(0.655 - 0.063) + 0)
= 1.0236 in

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

t_m = P*R_n / (S_n*E - 0.6*P)
= 180*1.063 / (16,700*1 - 0.6*180)
= 0.0115 in

Required thickness t_r from UG-37(a)

t_r = P*R / (S*E - 0.6*P)
= 180*18.0748 / (16,700*1 - 0.6*180)
= 0.1961 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.4094 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} = 0.0745 in (E =1)
Wall thickness per UG-45(b)(1): t_{r2} = 0.2591 in

Wall thickness per UG-16(b):	t_{r3} = 0.1255 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.252 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 0.2591 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.252 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.252 in

Available nozzle wall thickness new, t_n = 0.655 in

The nozzle neck thickness is adequate.

1 1/2" (TT1)

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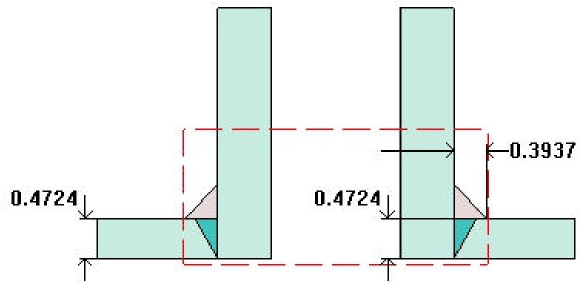


$t_{w(lower)}$ = 0.4724 in

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:	1.5 inch Class 300 LWN A182 F304L
Bolt Material:	SA-193 B8 1 Bolt (II-D p. 356, ln. 20)
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:	135°
Local vessel minimum thickness:	0.4724 in
Nozzle center line offset to datum line:	90 in
End of nozzle to shell center:	27 in
Nozzle inside diameter, new:	1.5 in
Nozzle nominal wall thickness:	0.625 in
Nozzle corrosion allowance:	0.063 in
Projection available outside vessel, Lpr:	7.7057 in
Projection available outside vessel to flange face, Lf:	8.5157 in

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2) For P = 180 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)							0.2406	0.625

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.25	0.2756	weld size is adequate

Calculations for internal pressure 180 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(1.626, 0.813 + (0.625 - 0.063) + (0.4724 - 0.063))
= 1.7844 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*(0.4724 - 0.063), 2.5*(0.625 - 0.063) + 0)
= 1.0236 in

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

t_m = P*R_n / (S_n*E - 0.6*P)
= 180*0.813 / (16,700*1 - 0.6*180)
= 0.0088 in

Required thickness t_r from UG-37(a)

t_r = P*R / (S*E - 0.6*P)
= 180*18.0748 / (16,700*1 - 0.6*180)
= 0.1961 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.4094 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} = 0.0718 in (E =1)
Wall thickness per UG-45(b)(1): t_{r2} = 0.2591 in

Wall thickness per UG-16(b):	t_{r3} = 0.1255 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.2406 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 0.2591 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.2406 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.2406 in

Available nozzle wall thickness new, t_n = 0.625 in

The nozzle neck thickness is adequate.

CALCULATION OF BASEBLOCK UNDER LIFTING CONDITION

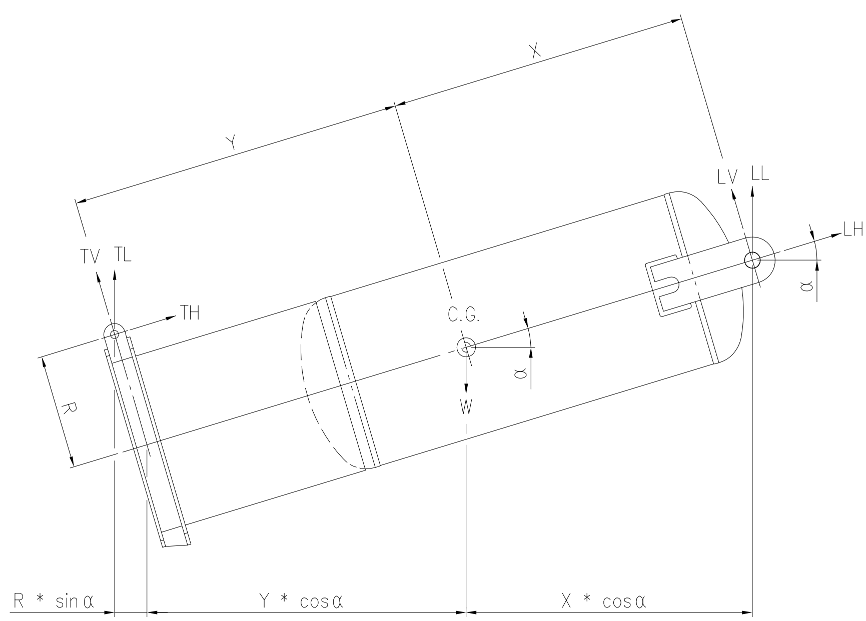
1. CALCULATION OF LIFTING FORCES

a) ERECTION WEIGHT	We =	3800	kg
b) DYNAMIC LOAD FACTOR	F =	1.5	--
c) LIFTING WEIGHT	W = We x F =	5700	kg
d) DIMENSIONS ;	X =	1278.0	mm
	Y =	2341.0	mm
	R =	629.0	mm

* LL = W x (Y x cos α+ R x sin α) / ((X + Y) x cos α+ R x sin α)
* TL = W x (X x cos α) / ((X + Y) x cos α+ R x sin α)
* LV = LL x cos α, LH = LL x sin α
* TV = TL x cos α, TH = TL x sin α

2. SUMMARY OF LIFTING FORCES IN VARIOUS ANGLES OF LIFTING

Max. Loads ;	LL =	5700.0	kg	(at α =	90.00 Deg.)
	LV =	3703.1	kg	(at α =	5.00 Deg.)
	LH =	5700.0	kg	(at α =	90.00 Deg.)
	TL =	2012.9	kg	(at α =	0.00 Deg.)
	TV =	2012.9	kg	(at α =	0.00 Deg.)
	TH =	1340.3	kg	(at α =	61.00 Deg.)



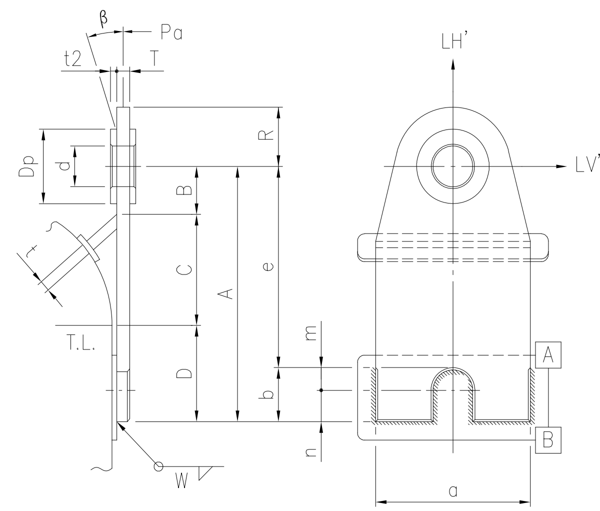
α	LL	TL	LV	LH	TV	TH
0.0	3687.1	2012.9	3687.1	0.0	2012.9	0.0
5.0	3717.3	1982.7	3703.1	324.0	1975.2	172.8
15.0	3776.7	1923.3	3648.0	977.5	1857.8	497.8
30.0	3870.7	1829.3	3352.1	1935.3	1584.2	914.7
45.0	3985.2	1714.8	2817.9	2817.9	1212.6	1212.6
60.0	4152.9	1547.1	2076.4	3596.5	773.6	1339.9
75.0	4479.1	1220.9	1159.3	4326.5	316.0	1179.3
85.0	5026.0	674.0	438.0	5006.9	58.7	671.4
90.0	5700.0	0.0	0.0	5700.0	0.0	0.0

3. STRENGTH OF LIFTING LUG

MATERIAL AT LUG			:	SA 516-70	
ALLOWABLE STRESS IN TENSION		Sa	=	14.06	kg/㎟
YIELD STRESS		Sy	=	26.72	kg/㎟
Q'TY OF LIFTING LUG		N	=	2	ea
VERTICAL FORCE PER 1 LUG	LV'= LV / N		=	1851.56	kg
HORIZONTAL FORCE PER 1 LUG	LH'= LH / N		=	2850	kg
LIFTING HALF ANGLE		ß	=	15	deg.
AXIAL FORCE PER 1 LUG	Pa = LH' * tan ß		=	763.66	kg

* DIMENSIONS

T =	20	㎜	A =	415	㎜
t =	10	㎜	B =	80	㎜
R =	50	㎜	C =	110	㎜
d =	27	㎜	D =	225	㎜
a =	150	㎜	W =	10	㎜
b =	125	㎜	e =	290	㎜
Dp =	0	㎜	t2 =	0	㎜



3-1. CHECK OF LUG

a) SHEAR STRESS DUE TO LH'

S1 = 2*LH'/{(2*R-d)*T + 1/2 * (Dp-d) * t2 * 2}

= 3.904 kg/㎟ < 0.4*Sy= 10.688 kg/㎟ ; O.K. !

b) TENSION DUE TO LH'

S2 = LH'/{(2*R-d)*T + (Dp-d) * t2 * 2}

= 1.952 kg/㎟ < 0.6*Sy= 16.032 kg/㎟ ; O.K. !

c) SHEAR STRESS DUE TO LV'

S3 = 2*LV'/{(2*R-d)*T + 1/2 * (Dp-d) * t2 * 2}

= 2.536 kg/㎟ < 0.4*Sy= 10.688 kg/㎟ ; O.K. !

d) TENSION DUE TO LV'

S4 = LV'/{(2*R-d)*T + (Dp-d) * t2 * 2}

= 1.268 kg/㎟ < 0.6*Sy= 16.032 kg/㎟ ; O.K. !

e) BENDING STRESS DUE TO LV'

S5 = 6 * LV' * B / [(2 * R)²* T]

= 4.444 kg/㎟ < 0.66*Sy= 17.6352 kg/㎟ ; O.K. !

3-2. STRESS OF GUIDE POINT

a) BENDING STRESS DUE TO Pa

$S6 = 6*Pa*B/(2*R*T^2) = 6 * 763.66 * 80 / (2 * 50 * 20^2)$

$= 9.164$ ㎏/㎟ $<$ $0.66*Sy=$ 17.6352 ㎏/㎟ ; O.K. !

b) TENSION DUE TO LH'

$S7 = LH'/ (2*R*T) = 2850.00 / \{(2 * 50 * 20)$

$= 1.425$ ㎏/㎟ $<$ $0.6*Sy=$ 16.032 ㎏/㎟ ; O.K. !

c) COMBINED STRESS

$S8 = (S6/0.66Sy) + (S7/0.6Sy) < 1$

$= 0.609 < 1$ O.K. !

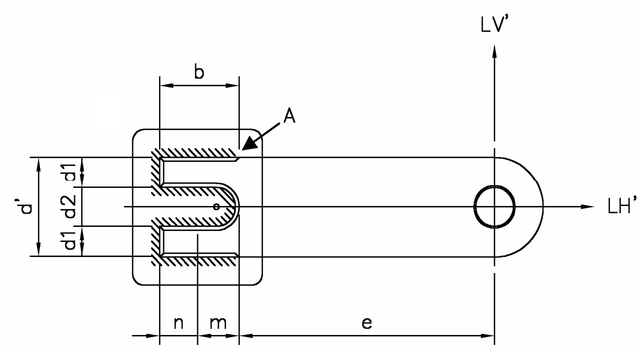
d) AXIAL STRESS DUE TO Pa

$S9 = Pa / (2 * R * t)$

$= 0.764$ ㎏/㎟ $<$ $0.6*Sy=$ 16.032 ㎏/㎟ ; O.K. !

3-3. LIFTING LUG WELD CALCULATION - LUG TO PAD WELD

b =	125.00	mm
d1 =	75.00	mm
d2 =	0.00	mm
d' =	150.00	mm
e =	290.00	mm
LV' =	1851.6	kg
LH' =	2850	kg



(A) HORIZONTAL POSITION WITH LOAD LV'

1) Lug Weld Check Per Unit Width of Weld Throat

* Centroid , $n = 2b^2 / (4 * b + 2d1) =$ 48.077 mm

$m = b - n$ = 76.923 mm

* Twisting Moment , T =(b+e-n)*LV'= 679381 kg-mm

* The polar moment of inertia of weld , Jw

$Jw = 4*[b^3/12+b*(b/2-n)] + 2*d1*n^2 + 2*b*(d1+d2/2)^2 + 2*b*(d2/2)^2 + 2*[d1^3/12+d1*(d1/2+d2/2)^2]$

= 2692462 mm^3

* Distance from c.g to point being analyzed, $C = \sqrt{[m^2 + (0.5d')^2]} =$ 107.43 mm

Analyzed point is A

* Weld length, L = 2 * b + d1 = 325.00 mm

a) Direct shear force, fs = LV' / L = 5.697 kg/mm

b) Max. Load from twisting, f = T * C / Jw = 27.109 kg/mm

Vertical component , fv = m * f / C = 19.410 kg/mm
Horizontal component , fh=0.5d'* f/C = 18.925 kg/mm

c) Combined load per mm , $F = \sqrt{[fh^2 + (fs + fv)^2]} =$ 31.440 kg/mm

d) Weld size check

Allowable stress S = 0.4 * Sy = 10.688 kg/㎟

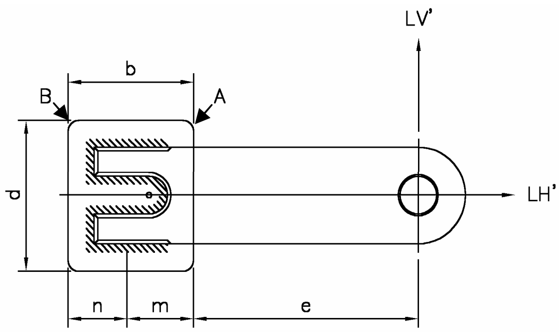
leg size, W = F / 0.707S = 4.161 mm < Min. Size = 10.00 mm O.K !

(B) VERTICAL POSITION WITH LOAD LH'

Weld area , A = L * (0.707 * W) = 2297.75 ㎟

fs' = LH' / A = 1.240 kg/㎟ < 0.4 * Sy = 10.688 kg/㎟ O.K !

3-4. LIFTING LUG WELD CALCULATION - PAD TO SHELL WELD



MATERIAL AT PAD =	SA 516-70	
YIELD STRESS =	26.72	kg/㎟
b =	150.00	mm
d =	200.00	mm
e =	290.00	mm
LV' =	1851.6	kg
LH' =	2850.0	kg

(A) HORIZONTAL POSITION WITH LOAD LV'

1) Lug Weld Check Per Unit Width of Weld Throat

* Centroid , n = m = b / 2 = 75.000 mm

* Twisting Moment , T =(b+e-n)*LV'= 675821 kg-mm

* The polar moment of inertia of weld , Jw
  $Jw = (b + d)^3 / 6$ = 7145833 mm^3

* Distance from c.g to point being analyzed, $C = \sqrt{[m^2+(0.5d')^2]}$= 125.00 mm

Analyzed point is A or B

* Weld length, L = 2 * b + 2 * d = 700.00 mm

a) Direct shear force, fs = LV' / L = 2.645 kg/mm

b) Max. Load from twisting, f = T * C / Jw = 11.822 kg/mm

Vertical component , fv = m * f / C = 7.093 kg/mm
Horizontal component , fh = 0.5d'*f/C= 9.458 kg/mm

c) Combined load per mm , $F = \sqrt{[fh^2 + (fs + fv)^2]}$ = 13.575 kg/mm

d) Weld size check

Allowable stress S = 0.4 * Sy = 10.688 kg/㎟

leg size, W = F / 0.707S = 1.796 mm < Min. Size = 9.00 mm O.K !

(B) VERTICAL POSITION WITH LOAD LH'

Weld area , A = L * (0.707 * W) = 4454.1 ㎟

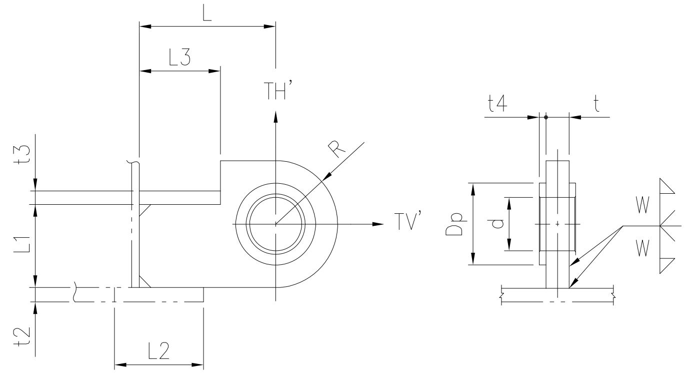
fs' = LH' / A = 0.640 kg/㎟ < 0.4 * Sy = 10.688 kg/㎟ O.K !

4. STRENGTH OF TAILING LUG

USED MATERIAL	=	SA 516-70	
YIELD STRESS OF TAILING LUG	Sy =	26.72	kg/㎟
ALLOWABLE SHEAR STRESS (0.4 * Sy)	Ssa =	10.688	kg/㎟
ALLOWABLE BENDING STRESS (0.66 * Sy)	Sba =	17.635	kg/㎟
ALLOWABLE TENSILE STRESS (0.6 * Sy)	Sta =	16.032	kg/㎟
TAILING LUG Q'TY.	N =	1	EA
LIFTING LOAD (MAX. AT HORIZONTAL COND.)	TV =	2012.88	kg
LIFTING LOAD PER TAILING LUG (VERTICAL FORCE)	TV' = TV/N =	2012.88	kg
LIFTING LOAD (MAX. AT VERTICAL COND.) AT 61.00 deg.	TH =	1340.26	kg
LIFTING LOAD PER TAILING LUG (HORIZONTAL FORCE)	TH' = TH/N =	1340.26	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 **

4-1) SHEAR STRESS AT HORIZONTAL STATE

S1 = 2TV' / [(2R - d) * t + 1/2 * (Dp - d) * 2t4] = 2.757 kg/㎟

∴ S1 = 2.757 kg/㎟ < Ssa = 10.69 kg/㎟

O.K. !

4-2) TENSION STRESS AT HORIZONTAL STATE

S2 = TV' / [(2R - d) * t + (Dp - d) * 2t4] = 1.379 kg/㎟

∴ S2 = 1.379 kg/㎟ < Sta = 16.032 kg/㎟

O.K. !

4-3) BENDING STRESS AT MAX. SLOPED LOAD STATE , AT 61.00 deg.

S3 = 6 * TH' * L / [(2 * R)²*t] = 6.594 kg/㎟

∴ S3 = 6.594 kg/㎟ < Sba = 17.635 kg/㎟

O.K. !

4-4) TENSION STRESS AT MAX. SLOPED LOAD STATE , AT 61.00 deg.

S4 = TH' / [(2 * R - d) * t] = 0.918 ㎏/㎟

∴ S4 = 0.918 ㎏/㎟ < Sta = 16.032 ㎏/㎟

O.K. !

4-5) COMBINE STRESS AT MAX. SLOPED STATE, AT 61.00 deg.

Scomb = S3 / Sba + S4 / Sta = 0.431 < 1.0

O.K. !

4-6) CHECK OF WELDMENT

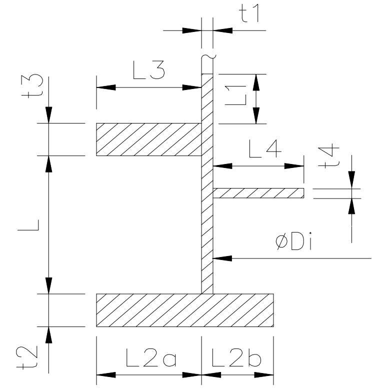
Sw = TV' / (2 * L4 * W) = 0.517 ㎏/㎟

∴ Sw = 0.517 ㎏/㎟ < 0.49 * Sba = 7.856 ㎏/㎟

O.K. !

5. BASE BLOCK UNDER ERECTION CONDITION

5-1. 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 =	912.00	mm

5-2. EFFECTIVE LENGTH OF SKIRT

Rm = (Di + t1) / 2 = 460.50 mm

L1 = Min.(0.78 * $\sqrt{}$(Rm * t1), 16*t1) = 50.21 mm

5-3. SECTION AREA , A

A1 = t1 * (L + L1 + t3) = 2044.9 ㎟

A2 = t2 * (L2a + L2b) = 3458.0 ㎟

A3 = t3 * L3 = 2314.0 ㎟

A4 = t4 * L4 = 0.0 ㎟

TOTAL AREA, A = 7816.9 ㎟

5-4. 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 = 67.05 mm

Y = (L2a + L2b) - C = 65.95 mm

5-5. MOMENT OF INERTIA OF AREA, I (ABOUT NEUTRAL AXIS)

I1 = (L + L1 + t3) * t1^3 / 12 + A1 * (h1 - C)^2 = 1444362 mm^4

I2 = t2 * (L2a + L2b)^3 / 12 + A2 * (h2 - C)^2 = 5098429 mm^4

I3 = t3 * L3^3 / 12 + A3 * (h3 - C)^2 = 2704186 mm^4

I4 = t4 * L4^3 / 12 + A4 * (h4 - C)^2 = 0 mm^4

TOTAL I = I1 + I2 + I3 + I4 = 9246977 mm^4

5-6. MIN. SECTION MODULUS, Z

Z1 = I / C = 137910 mm^3

Z2 = I / Y = 140214 mm^3

Z = Min.(Z1, Z2) = 137910 mm^3

5-7. STRESS IN BASE BLOCK DUE TO TV

TV = 2012.9 kg (Max. Force at Tailing Lug)
R = 486.95 mm (Radius to neutral axis)
Sy = 26.72 kg/㎟ (Yield Strength of Base)
Z = 137910 kg/mm^3 (Section Modulus of Base)
A = 7816.9 ㎟ (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 = 233966 kg-mm
Ta = 0.2387 * TV = 480.5 kg

σ = Ma / Z + Ta / A = 1.758 kg/㎟ < 0.66Sy = 17.635 kg/㎟

THEREFORE, BRACING IS NOT REQUIRED !!

6. LOCAL STRESS CALCULATION (LIFTING LUG)

Geometry

Height(radial):	1.2598"	Pad Thickness:	0.4724"
Width (circumferential):	5.9055"	Pad Width:	7.874"
Length	4.9213"	Pad Length:	5.9055"
Fillet Weld Size:	0.3937"	Pad Weld Size:	0.3543"
Location Angle:	45.00°		

Applied Loads

Radial load:	P_r =	0 lb_f
Circumferential moment:	M_c =	5,207.77 lb_f-in
Circumferential shear:	V_c =	4,100.6 lb_f
Longitudinal moment:	M_L =	8,679.62 lb_f-in
Longitudinal shear:	V_L =	6,283.18 lb_f
Torsion moment:	M_t =	0 lb_f-in
Internal pressure:	P =	0 psi
Mean shell radius:	R_m =	18.248 in
Shell yield stress:	S_y =	25,000 psi

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

R_m / t = 18.248 / 0.9449 = 19.3125

C_1 = 3.3465, C_2 = 2.8543 in

Local circumferential pressure stress = P*R_i / t =0 psi

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

Maximum combined stress (P_L+P_b+Q) = -1,548 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) = -314 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 lug edge per WRC Bulletin 107										
Figure	**value**	**β**	**A_u**	**A_l**	**B_u**	**B_l**	**C_u**	**C_l**	**D_u**	**D_l**
3C*	2.6504	0.1685	0	0	0	0	0	0	0	0
4C*	3.1719	0.176	0	0	0	0	0	0	0	0
1C	0.1018	0.1768	0	0	0	0	0	0	0	0
2C-1	0.0697	0.1768	0	0	0	0	0	0	0	0
3A*	0.6868	0.1739	0	0	0	0	-82	-82	82	82
1A	0.0893	0.2008	0	0	0	0	-853	853	853	-853
3B*	2.1022	0.1649	-314	-314	314	314	0	0	0	0
1B-1	0.0426	0.1698	-802	802	802	-802	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total circumferential stress			-1,116	488	1,116	-488	-935	771	935	-771
Primary membrane circumferential stress*			-314	-314	314	314	-82	-82	82	82
3C*	2.581	0.176	0	0	0	0	0	0	0	0
4C*	3.2135	0.1685	0	0	0	0	0	0	0	0
1C-1	0.1084	0.1713	0	0	0	0	0	0	0	0
2C	0.0723	0.1713	0	0	0	0	0	0	0	0
4A*	1.0541	0.1739	0	0	0	0	-111	-111	111	111
2A	0.0492	0.1969	0	0	0	0	-479	479	479	-479
4B*	0.6396	0.1649	-99	-99	99	99	0	0	0	0
2B-1	0.0664	0.176	-1,206	1,206	1,206	-1,206	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total longitudinal stress			-1,305	1,107	1,305	-1,107	-590	368	590	-368
Primary membrane longitudinal stress*			-99	-99	99	99	-111	-111	111	111
Shear from M_t			0	0	0	0	0	0	0	0
Circ shear from V_c			324	324	-324	-324	0	0	0	0
Long shear from V_L			0	0	0	0	-582	-582	582	582
Total Shear stress			324	324	-324	-324	-582	-582	582	582
Combined stress (P_L+P_b+Q)			-1,548	1,246	1,548	-1,246	-1,370	1,232	1,370	1,232

Note: * denotes primary stress.

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

R_m / t = 18.248 / 0.4724 = 38.625

C_1 = 4.2913, C_2 = 3.3071 in

Local circumferential pressure stress = P*R_i / t =0 psi

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

Maximum combined stress (P_L+P_b+Q) = -3,296 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) = -1,024 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*	3.4408	0.2046	0	0	0	0	0	0	0	0
4C*	5.1699	0.2204	0	0	0	0	0	0	0	0
1C	0.0664	0.222	0	0	0	0	0	0	0	0
2C-1	0.0322	0.222	0	0	0	0	0	0	0	0
3A*	1.5859	0.2156	0	0	0	0	-309	-309	309	309
1A	0.0719	0.2464	0	0	0	0	-2,239	2,239	2,239	-2,239
3B*	4.058	0.1977	-1,024	-1,024	1,024	1,024	0	0	0	0
1B-1	0.0264	0.2047	-1,649	1,649	1,649	-1,649	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total circumferential stress			-2,673	625	2,673	-625	-2,548	1,930	2,548	-1,930
Primary membrane circumferential stress*			-1,024	-1,024	1,024	1,024	-309	-309	309	309
3C*	3.1779	0.2204	0	0	0	0	0	0	0	0
4C*	5.3525	0.2046	0	0	0	0	0	0	0	0
1C-1	0.0684	0.2105	0	0	0	0	0	0	0	0
2C	0.0386	0.2105	0	0	0	0	0	0	0	0
4A*	3.1572	0.2156	0	0	0	0	-537	-537	537	537
2A	0.035	0.2359	0	0	0	0	-1,138	1,138	1,138	-1,138
4B*	1.5849	0.1977	-383	-383	383	383	0	0	0	0
2B-1	0.0408	0.2085	-2,502	2,502	2,502	-2,502	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total longitudinal stress			-2,885	2,119	2,885	-2,119	-1,675	601	1,675	-601
Primary membrane longitudinal stress*			-383	-383	383	383	-537	-537	537	537
Shear from M_t			0	0	0	0	0	0	0	0
Circ shear from V_c			506	506	-506	-506	0	0	0	0
Long shear from V_L			0	0	0	0	-1,005	-1,005	1,005	1,005
Total Shear stress			506	506	-506	-506	-1,005	-1,005	1,005	1,005
Combined stress (P_L+P_b+Q)			-3,296	2,274	3,296	-2,274	-3,207	2,470	3,207	-2,470

Note: * denotes primary stress.