WILTEW

QUALITY WORK FOR INDUSTRY

2650 Schillinger Road North
P.O. Box 6
Semmes, Alabama 36575
Phone: (251) 661-9770 Fax: (251) 661-8707
www.wiltew.com

Document Title: 3592 UA-DR-0091 IP Condensate Drum Documentation Package
Document #: CDP-3592-35
Vendor: JWWTEW, LLC dba Wiltew
SoCo PO# MPC 10037829
SoCo Project: Kemper County IGCC Unit 1

UA-DR-0091 IP Condensate Drum

Documentation Package

Wiltew Job #3592

WILTEW

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Quality Record

Approved

WILTEW

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U1A DATA REPORTS

FORM U-1A MANUFACTURER'S DATA REPORT FOR PRESSURE VESSELS
(Alternative Form for Single Chamber, Completely Shop or Field Fabricated Vessels Only)
As Required by the Provisions of the ASME Boiler and Pressure Vessel Code Rules, Section VIII, Division 1

1. Manufactured and certified by WILTEW 2650 SCHILLINGER ROAD NORTH SEMMES ALABAMA 36575 USA
(Name and address of Manufacturer)

2. Manufactured for Mississippi Power Company 2992 West Beach Blvd. Gulfport, MS. 39501
(Name and address of Purchaser)

3. Location of installation Mississippi Power Company 2992 West Beach Blvd. Gulfport, MS. 39501
(Name and address)

4. Type Vertical (Horizontal or vertical, tank) 3592-1 (Manufacturer's serial number) - (CRN) 3592 (Drawing number) 021 (National Board number) 2012 (Year built)

5. The chemical and physical properties of all parts meet the requirements of material specifications of the ASME BOILER AND PRESSURE VESSEL CODE. The design, construction, and workmanship conform to ASME Rules, Section VIII, Division 1 2010 Edition (Year)
to 2011 Addenda [Addenda (date)] NA (Code Case numbers) None [Special service per UG-120(d)]

6. Shell SA-516 70 (Material spec. number, grade) .375 (Nominal thickness) 0.125 (Corr. allow.) 8'-11 1/4" (Inner diameter) 27'-0" SM/SM [Length (overall)]

7. Seams Type 1 [Long. (welded, dbl., sngl., lap, butt)] Spot [R. T. (spot or full)] 85 (Eff., %) NA (H. T. temp.) NA (Time, hr) Type 1 [Girth (welded, dbl., sngl., lap, butt)] Spot [R. T. (spot or full)] 85 (Eff., %) 4 (No. of courses)

8. Heads: (a) Material SA-516 70 (Spec. no., grade) (b) Material SA-515 70 (Spec. no., grade)

	Location (Top, Bottom, Ends)	Minimum Thickness	Corrosion Allowance	Crown Radius	Knuckle Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side To Pressure (Convex or Concave)
(a)	TOP	.283	.125	-	-	2:1	-	-	-	convex
(b)	BOTTOM	.3119	.125	-	-	2:1	-	-	-	convex

If removable, bolts used (describe other fastenings) NA
(Material spec. number, grade, size, number)

9. MAWP 50 (Internal) - (External) at max. temp. 400 (Internal) - (External)
Min. design metal temp. 10 at - Hydro., ~~pneu., or comb.~~ test pressure 65

10. Nozzles, inspection, and safety valve openings:

Purpose (Inlet, Outlet, Drain)	Number	Diameter or Size	Type	Material	Nominal Thickness	Reinforcement Material	How Attached	Location
Manway	1	24"	RFSO	SA-516 70	.500	SA-516 70	UW16.1	-
Inlet	1	16"	RFWN	SA-106B	.375	Integral	UW16.1	-
Outlet	1	12"	RFWN	SA-106B	.500	Integral	UW16.1	-
Outlet	1	8"	RFWN	SA-106B	.500	SA-516 70	UW16.1	-
Inlet	1	3"	RFWN	SA-106B	.300	Integral	UW16.1	-
Instrument	2	2"	RFWN	SA-106B	.344	Integral	UW16.1	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-

11. Supports: Skirt No (Yes or no) Lugs None (Number) Legs 4 (Number) Other NA (Describe) Attached shell / welded (Where and how)

12. Remarks: Manufacturer's Partial Data Reports properly identified and signed by Commissioned Inspectors have been furnished for the following items of the report: NA
(Name of part, item number, Manufacturer's name and identifying stamp)

Materials are exempt from code impacts per UG 20 (f). Pressure relief device provided by others.

CERTIFICATE OF SHOP / FIELD COMPLIANCE

We certify that the statements made in this report are correct and that all details of design, material, construction, and workmanship of this vessel conform to the ASME BOILER AND PRESSURE VESSEL CODE, Section VIII, Division 1. "U" Certificate of Authorization Number 34282
expires 12/10/12
Date 4/12/12 Co. name WILTEW (Manufacturer) Signed [signature] (Representative)

CERTIFICATE OF SHOP / FIELD INSPECTION

Vessel constructed by WILTEW at 2650 SCHILLINGER ROAD NORTH SEMMES, ALABAMA 36575 USA

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province of AL and employed by One Beacon America Insurance Company have inspected the component described in this Manufacturer's Data Report on 4-12-12, and state that, to the best of my knowledge and belief, the Manufacturer has constructed this pressure vessel in accordance with ASME BOILER AND PRESSURE VESSEL CODE, Section VIII, Division 1. By Signing this certificate neither the Inspector nor his/her employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his/her employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.
Date 4-12-12 Signed [signature] (Authorized Inspector) Commissions 11289IS,A; AL10233BL [National Board (incl. endorsements), State, Province, and number]

CEI - FP03-SB-04358-001 - U1A Ext - Revision 15 - FP 5.0.1

Quality Record

MM188078

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UA-DR-0091 IP Condensate Drum

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HYDROSTATIC TEST RECORD

Quality Record

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WILTEW

HYDROSTATIC TEST RECORD

Customer:	Southern Company	Test Temp:	75F
Serial No:	3592-1	Hold Time:	1hr
Test Pressure:	65psig	Test Fluid:	Potable Water
Test Gage SN:	109039-1	Calibration Due Date:	4.12.13

A.I Acceptance:	Richard B. Hill	Date:	4-12-12
Wiltew Representative Acceptance:	[signature]	Date:	4.12.12
Customer Acceptance:	[signature]	Date:	4/12/12

Comments:

Quality Record

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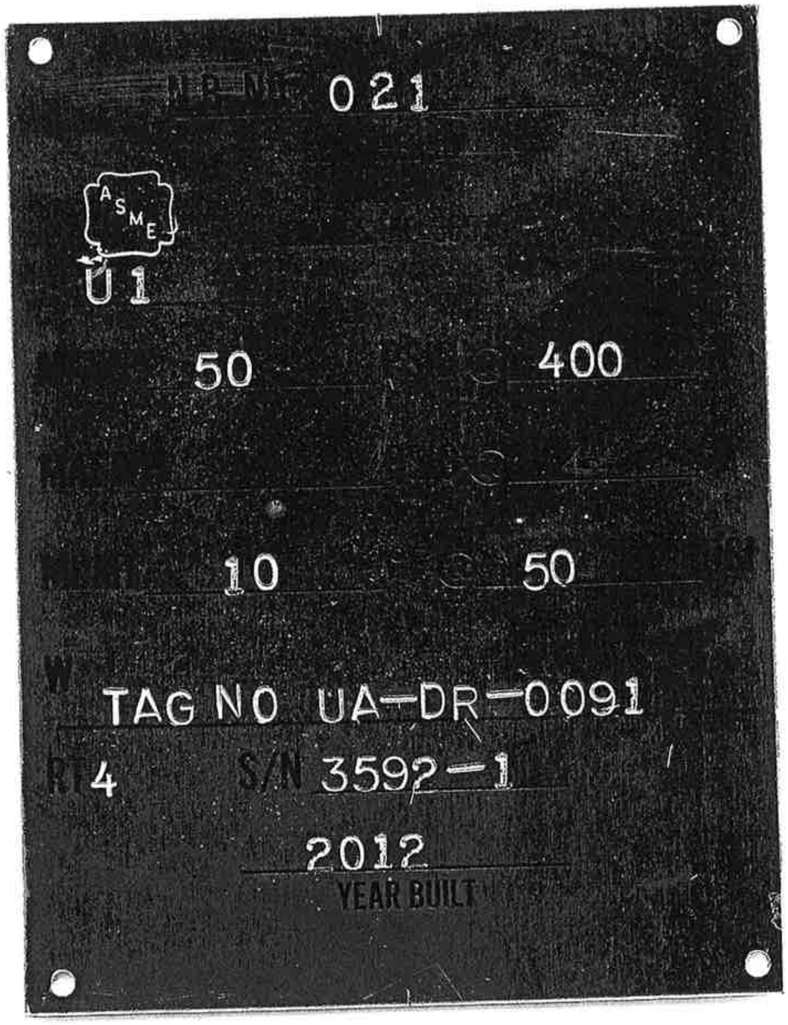
DATA PLATE PHOTO COPY



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NDE TEST REPORTS

Quality Record

MM188078

Approved

SPECIALIZING IN SOILS EXPLORATION, PHYSICAL TESTING, ENGINEERING AND NDT EXAMINATION SERVICES

CHALLENGE
ENGINEERING & TESTING, INC.

P.O. BOX 91537
4234 HALLS MILL ROAD
MOBILE, ALABAMA 36691
PHONE: (251) 666-1435
FAX: (251) 666-1438
EMAIL: CHALLENGETESTING@AOL.COM

REPORT OF RADIOGRAPHIC EXAMINATION

REPORT TO: Wiltew L.L.C.
Job# 3592

PROJECT Tank Spot X-Ray For Southern Company

CLIENT'S NO.:
ORDER NO.: N12-087
REPORT NO.:
DATE:

Acceptance Standard: ASME Sec. VIII UW-52 (Spot)

Date of Examination: 4-2-12

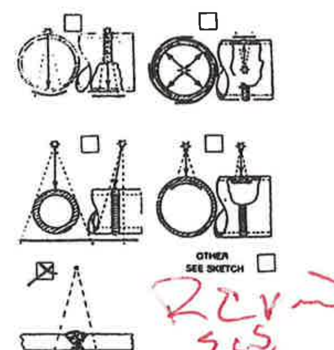
WELD NO.	FILM VIEW	WELDER NOS.	RECOMMENDATIONS ACCEPT	RECOMMENDATIONS REJECT	DENSITY / REMARKS	
Circ.-1	A-B	54/63	✓		Note: S.L.	2.81
Circ.-2	A-B	54/63	✓			3.07
Circ.-3	A-B	54/63	✓		Note: Stop+Start I.U.	3.18
Circ.-4	A-B	54/93	✓		Note: Gouge on inside of Tank	2.84
Circ.-5	A-B	54/93	✓			2.91
Long Seam-1	A-B	54/63	✓			2.93
Long Seam-2	A-B	54/93	✓			3.08
Long Seam-3	A-B	54/93	✓			2.81
Long Seam-4	A-B	54/93	✓			2.97

4.2.12

Reviewed RC
AI OBAI
4-3-12

EXPOSURE DATA

Iridium ☒	Curies: 63
X-Ray ☐	MA: KV:
Radiographic Proc.	ASME Sec. V
Material Type:	C/S
Component:	Pipe ☐ Plate ☒ Other ☐
Material Thickness:	.375"
Reinforcement:	.125"
Total Thickness:	.500"
Source to Object:	18"
Source Side of Obj. to Film:	.500"
Source Size: .1X.1	U.G. ≤ 0.02
Exposure Time:	1 min. 50 Sec.
IQI Size: 17	MT'L: S/S
IQI Type:	ASME
Sensitivity: 2-2T	S.S. ☒ F.S. ☐
Screen Thickness:	F. .001 B. .001
Film Type:	AGFA D-4
Film Size:	10X24cm
S. or D. Wall Viewing:	Single
Film Per Cassette:	1
Total Film Used:	9



RCV
SCS
4/2/12

ABBREVIATIONS AND TERMS

SI • Slag Inclusion
IP • Incomplete Penetration
RC • Root Concavity
RI • Rounded Indication
SL • Slag Lines
TI • Tungsten Inclusion
IU • Internal Undercut
EU • External Undercut
P • Porosity
LI • Linear Indication
CR • Crack
IF • Incomplete Fusion

RADIOGRAPHER Daniel Heathco LEVEL II INTERPRETER [signature] LEVEL II

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TRACE DRAWINGS

Quality Record

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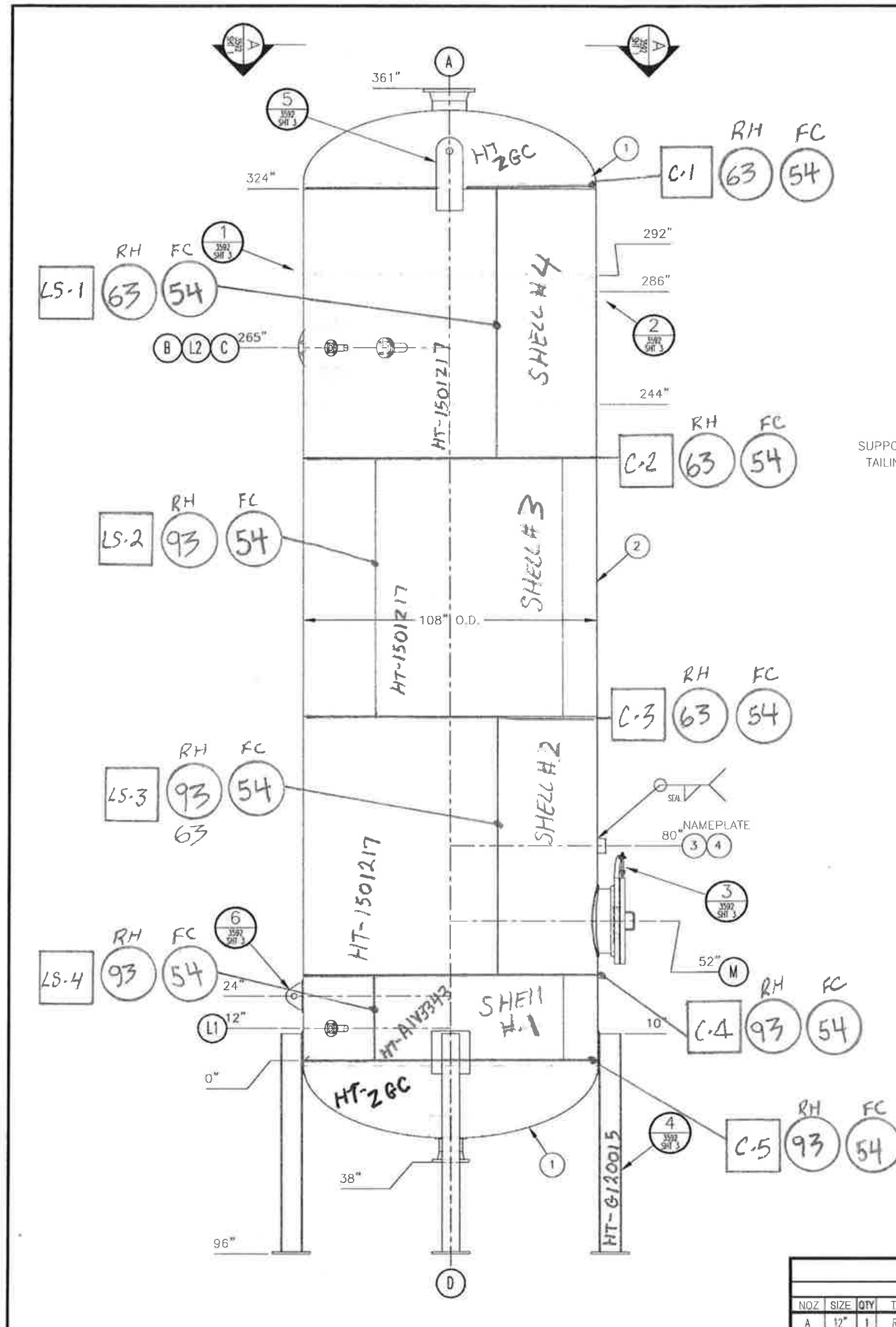
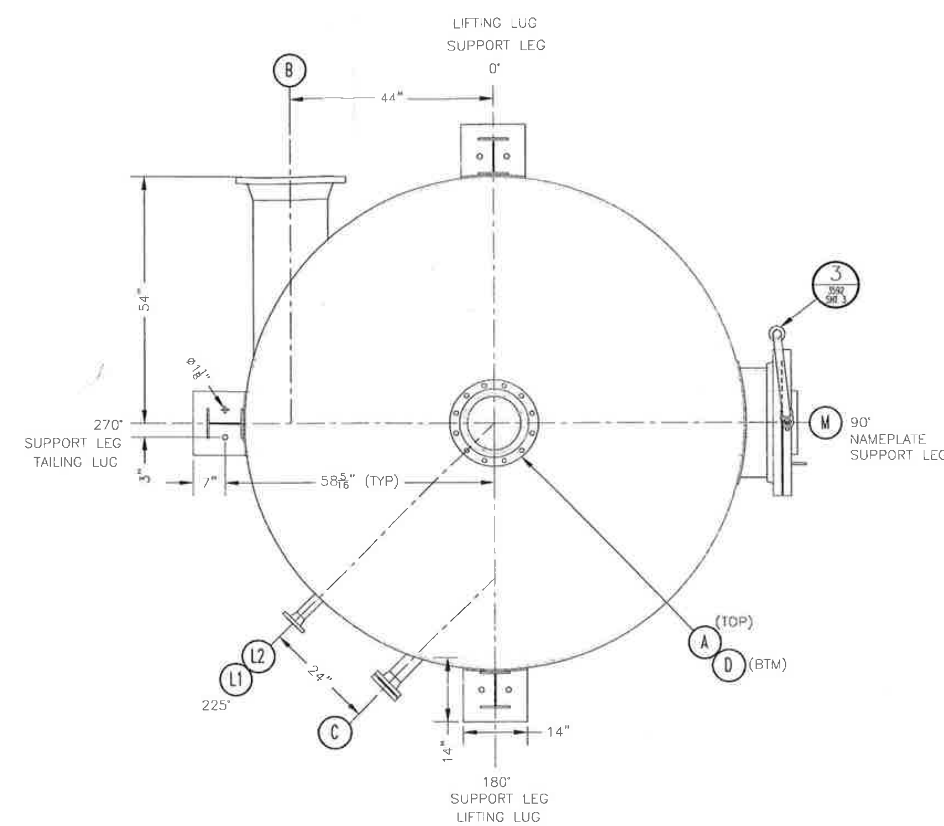


ELEVATION
SCALE: 1 1/2" = 1'-0"



A VIEW – NOZZLE ORIENTATION
SCALE: 1 1/2" = 1'-0"
NOTE: TOP INSULATION RING NOT SHOWN FOR CLARITY

DESIGN DATA

DESIGN CODE: ASME SECTION VIII, DIV. 1

DESIGN CONDITIONS	SHELL SIDE
MAX. ALLOW. INT. WORKING PRESSURE	50 PSIG
MAX. ALLOW. EXT. WORKING PRESSURE	NONE
DESIGN TEMPERATURE	400°F
TEST PRESSURE(HYDROSTATIC)	65 PSIG
CORROSION ALLOWANCE	.125"
RADIOGRAPHY (RT)	SPOT
LIQUID PENETRANT EXAMINATION (PT)	N/A
POST WELD HEAT TREAT	N/A
STAMP	"U"

SURFACE PREP & PAINTING-EXTERIOR: "LATER"

WEIGHT: 16700 #EMPTY 135601 #FLOODED

MATERIALS:

SHELL: SA-516 GR70	BODY FLG'S: N/A
NOZ. FLG'S: SA-105	BOLTING: SA-193 B7/SA-194 2H
GASKETS: "LATER"	STIFFENERS: N/A
SUPPORTS: C.S.	HEADS: SA-516 GR70
INTERNALS: N/A	

NOTES:
1. PROTECT ALL STAINLESS STEEL SURFACES TO AVOID CARBON CONTAMINATION.
2. ALL FLANGE BOLT HOLES TO STRADDLE VESSEL CENTERLINES.
3. PROTECT ALL OPENINGS FOR SHIPMENT.
4. ALL REINFORCING PADS TO HAVE A ¼" NPT TEST TAP.
5. REMOVE ALL BURRS, WELD SPATTERS, AND SHARP EDGES.

ITEM	QTY	DESCRIPTION	MATERIAL	HEAT No.
1	2	HEAD, 3/8" MIN THK X 108" O.D. W/ 2" S.F., 2:1 ELLIPTICAL HEAD	SA-516 GR70	
2	1	PL., 3/8" THK X 108" O.D. X 324" LONG, SHELL	SA-516 GR70	
3	1	NB NP, STANDARD NATIONAL BOARD NAMEPLATE, W/ 3" STAND OFF	S.S.	
4	1	NP BRKT, STANDARD NAMEPLATE BRACKET, W/ 3" STAND OFF	S.S.	
5				

NATIONAL BD. NO. 021

U
W
RT4

CERTIFIED BY:
WILTEW
2650 SCHILLINGER RD. N.
SEMMES, AL.

SHELL MAWP 50 PSI AT 400°F
MDMT 10° F AT 50 PSI
MFG. SERIAL NO. 3592
YEAR BUILT 2011
EQUIPMENT TAG# UA-DR-0091

N.B. NAMEPLATE
SCALE: NTS
NOTE: 3" STANDOFF

WELDER ID MAP

NOZZLE SCHEDULE

					THICKNESS/SCHEDULE				REPAD	MATERIAL					PROJ.	
NOZ	SIZE	QTY	TYPE	RATING	NECK	FLANGE	F.R./STUB	REPAD	O.D./WIDTH	NECK	FLANGE	F.R./STUB	REPAD	HEAT No.	FROM O.D.	SERVICE
A	12"	1	RFWN	150#	XH(.500")	XH BORE	-	-	-	SA-106 B	SA-105	-	-		SEE DETAIL	LP STEAM OUTLET
B	16"	1	RFWN	150#	STD(.375")	STD BORE	-	-	-	SA-106 B	SA-105	-	-		SEE DETAIL	IP CONDENSATE INLET
C	3"	1	RFWN	150#	80(.300")	80 BORE	-	-	-	SA-106 B	SA-105	-	-		8"	INITIAL FILL INLET
D	8"	1	RFWN	150#	80(.500")	80 BORE	-	.375"	11.625" O.D.	SA-106 B	SA-105	-	SA-516 GR70		SEE DETAIL	LP CONDENSATE OUTLET
L1	2"	1	RFWN	150#	160(.344")	160 BORE	-	-	-	SA-106 B	SA-105	-	-		8"	LEVEL
L2	2"	1	RFWN	150#	160(.344")	160 BORE	-	-	-	SA-106 B	SA-105	-	-		8"	LEVEL
M	24"	1	RFSO	150#	.500"	STD	-	.375"	27" O.D.	SA-516 GR70	SA-105	-	SA-516 GR70		8"	MANWAY W/ HINGED COVER

No.	DESCRIPTION	BY	DATE
1	REVISED PER CUSTOMER COMMENTS	GAM	11/04/2011
0	FOR APPROVAL	GAM	08/30/2011

REVISIONS

WILTEW
2650 SCHILLINGER RD N.
SEMMES, AL. 36575

108" O.D. IP CONDENSATE DRUM
ELEVATION, NOZZLE ORIENTATION, AND FABRICATION DETAILS
SOUTHERN COMPANY

JOB No.	DRAWING No.	SHEET	REV.
3592	3592	1/3	1

SCALE: AS NOTED | DRAWN BY: GAM | DATE: 08/30/2011

SOUTHERN COMPANY TAG# 01G-UA-DR-0091 | PO# MPC10037829

Quality Record

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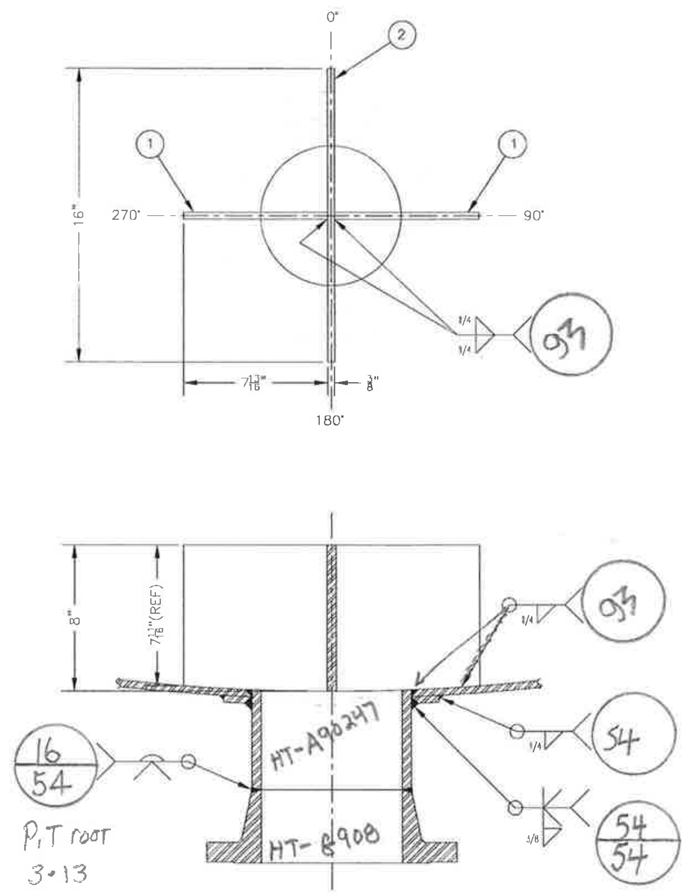
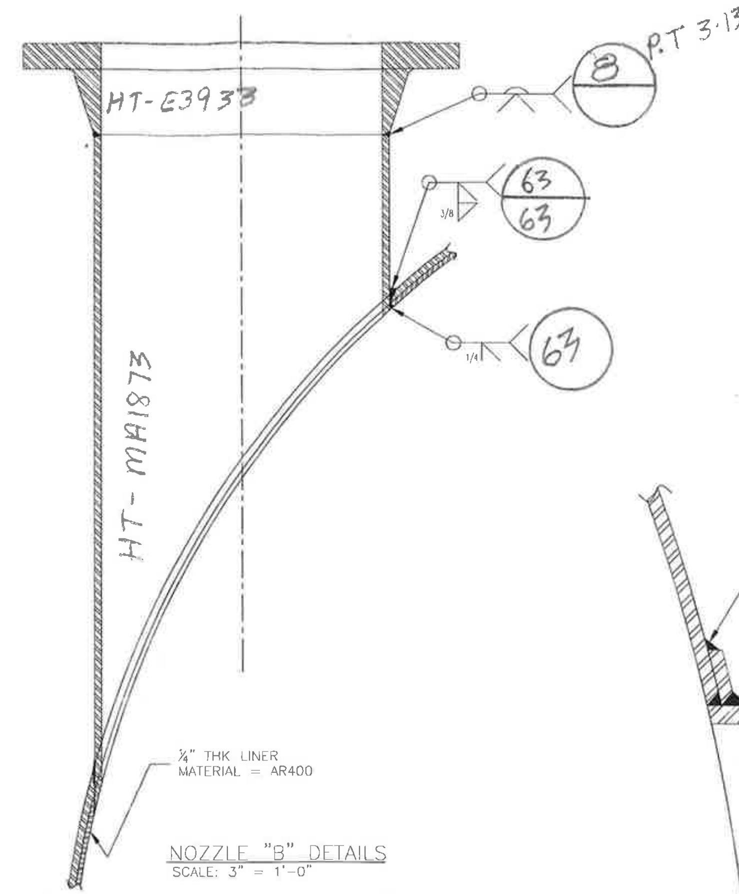
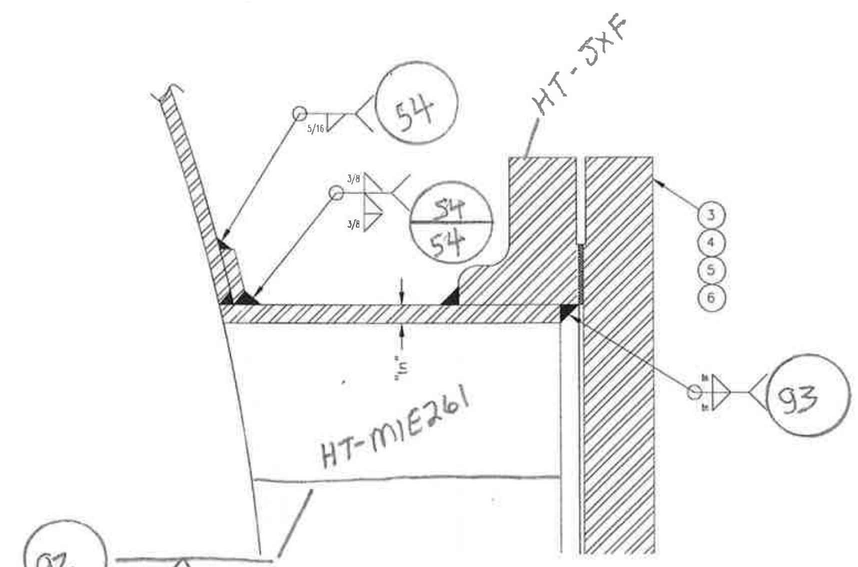
ITEM	QTY	DESCRIPTION	MATERIAL	HEAT No.
1	2	PL., 3/8" THK X 7 13/16" X 8" VORTEX BREAKER	SA-36	
2	1	PL., 3/8" THK X 8" X 16" VORTEX BREAKER	SA-36	
3	1	BLIND FLANGE, 24" 150# BLIND FLANGE FOR MANWAY COVER	SA-105	
4	1	GASKET, 1/8" THK 24" 150# FLANGE GASKET	GARLOCK	
5	20	STUDS, 1 1/4" DIA X 7 1/2" LONG @ MANWAY COVER	SA-193 B7	
6	40	NUTS, 1 1/4" HVY HEX NUTS @ MANWAY COVER	SA-194 2H	
7	1	BLIND FLANGE, 3" 150# BLIND FLANGE FOR MANWAY COVER	SA-105	
8	1	GASKET, 1/8" THK 3" 150# FLANGE GASKET	GARLOCK	
9	4	STUDS, 5/8" DIA X 4" LONG @ MANWAY COVER	SA-193 B7	
10	8	NUTS, 5/8" HVY HEX NUTS @ MANWAY COVER	SA-194 2H	
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				



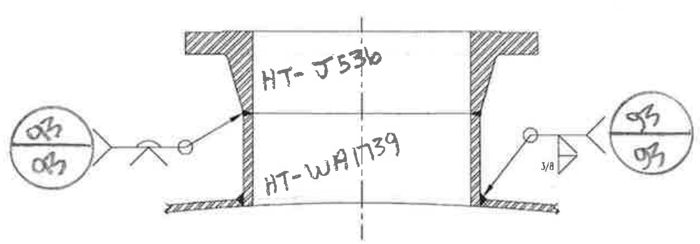
NOZZLE "D" & VORTEX BREAKER DETAILS
SCALE: 3" = 1'-0"



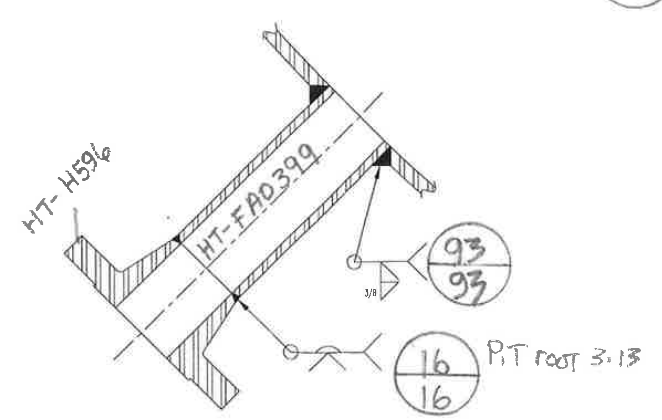
NOZZLE "B" DETAILS
SCALE: 3" = 1'-0"



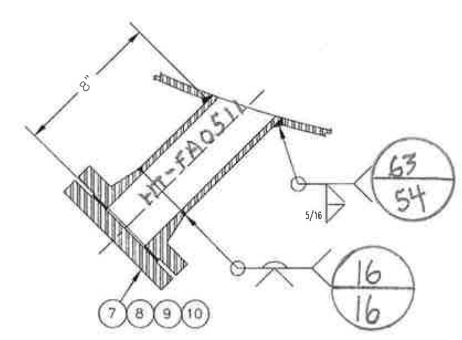
NOZZLE "M" - MANWAY DETAILS
SCALE: 6" = 1'-0"
NOTE: SEE SHEET 3 FOR MANWAY DAVIT DETAILS



NOZZLE "A" DETAILS
SCALE: 3" = 1'-0"



NOZZLE "L1" & "L2" DETAILS
SCALE: 3" = 1'-0"



NOZZLE "C" DETAILS
SCALE: 3" = 1'-0"

WELDER ID MAP

No	DESCRIPTION	BY	DATE
0	FOR APPROVAL	GAM	08/30/2011

REVISIONS

WILTEW
2650 SCHILLINGER RD N.
SEMMES, AL. 36575

108" O.D. IP CONDENSATE DRUM
NOZZLE FABRICATION DETAILS
AND VORTEX BREAKER DETAILS
SOUTHERN COMPANY

JOB No.	DRAWING No.	SHEET	REV.
3592	3592	2/3	0
SCALE: AS NOTED	DRAWN BY: GAM	DATE: 08/30/2011	
SOUTHERN COMPANY TAG#: 01G-UA-DR-0091	PO#: MPC10037829		

Quality Record

Approved

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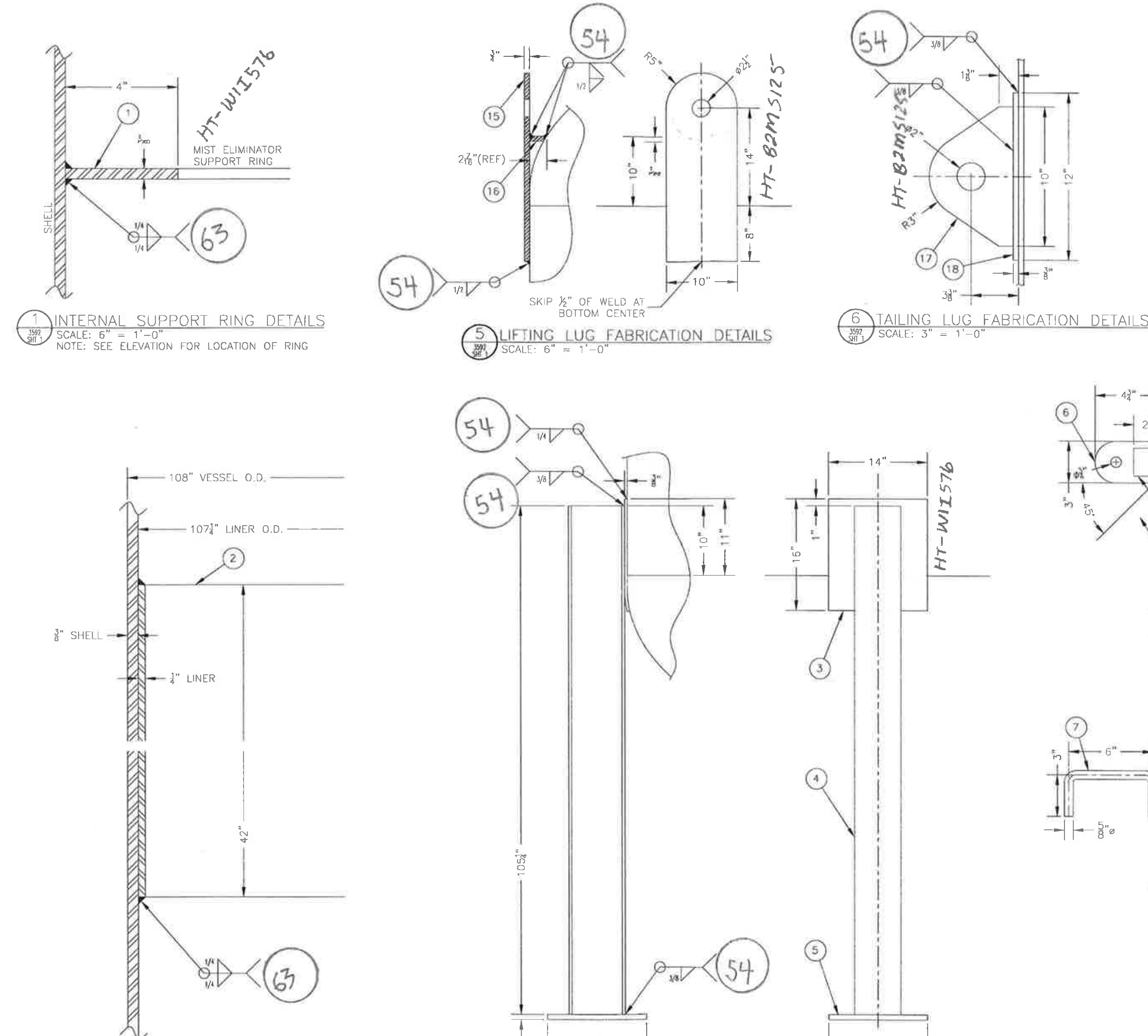
ITEM	QTY	DESCRIPTION	MATERIAL	HEAT No.
1	1	PL., 3/8" THK X 107 1/4" O.D. X 99 1/4" I.D. SUPPORT RING	SA-36	
2	1	PL., 1/4" THK X 107 1/4" O.D. X 42" TALL, LINER	AR-400	
3	4	PL., 3/8" THK X 14" X 16" SUPPORT LEG REPAD	SA-36	
4	4	BEAM, W8x24 X 105 1/4" LONG SUPPORT LEGS	SA-36	
5	4	PL., 3/4" THK X 14" X 14" BASE PLATE	SA-36	
6	1	PL.,1/2" THK X 3" WIDE X 4 3/4" LONG	SA-36	
7	1	RB., 5/8" DIA X 12" LONG	SA-36	
8	1	EYE-BOLT, 5/8" DIA X 7 1/8" LONG	SA-36	
9	1	RB., 5/8" DIA X 6" LONG	SA-36	
10	1	RB., 2" DIA X 46" LONG	SA-36	
11	1	PL.,1/2" THK X 2 5/16" WIDE X 8" LONG	SA-36	
12	2	PL., 1/4" THK X 4" O.D. X 2 1/8" I.D.	SA-36	
13	1	PIPE, 2" SCH 40 X 9" LONG	SA-106 B	
14	1	COTTER PIN, 1/8" DIA	S.S.	
15	2	PL., 3/4" THK X 10" X 27" LONG LIFTING LUG	SA-36	
16	2	PL., 3/4" THK X 2 7/16"(REF) X 10" BRACE PLATE	SA-36	
17	1	PL., 3/4" THK X 6 3/8" X 10"	SA-36	
18	1	PL., 3/8" THK X 4" X 12" BRACE PLATE	SA-36	
19				
20				



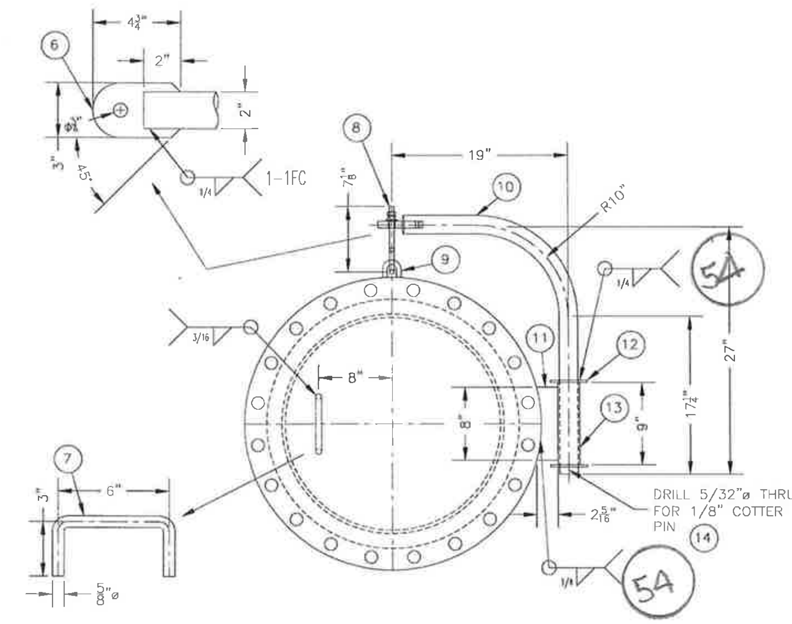
1 INTERNAL SUPPORT RING DETAILS
SCALE: 6" = 1'-0"
NOTE: SEE ELEVATION FOR LOCATION OF RING

5 LIFTING LUG FABRICATION DETAILS
SCALE: 6" = 1'-0"

6 TAILING LUG FABRICATION DETAILS
SCALE: 3" = 1'-0"

2 INTERNAL LINER FABRICATION DETAILS
SCALE: 6" = 1'-0"
NOTE: SEE SHEET 1, ELEVATION FOR LOCATION OF LINER

4 SUPPORT LEG FABRICATION DETAILS
SCALE: 1 1/2" = 1'-0"
NOTE: SEE SHEET 1, ORIENTATION FOR LOCATION OF LEGS



3 MANWAY DAVIT ARM FABRICATION DETAILS
SCALE: 6" = 1'-0"
NOTE: SEE SHEET 1, ORIENTATION FOR LOCATION OF DAVIT

WELDER ID MAP

No	DESCRIPTION	BY	DATE
1	REVISED SUPPORT LEG LENGTH	GAM	11/04/2011
0	FOR APPROVAL	GAM	08/30/2011

REVISIONS

WILTEW
2650 SCHILLINGER RD N.
SEMMES, AL. 36575

108" O.D. IP CONDENSATE DRUM
INTERNAL LINER, LIFTING LUGS,
SUPPORT LEGS, & MISC. DETAILS
SOUTHERN COMPANY

JOB No.	DRAWING No.	SHEET	REV
3592	3592	3/3	1

SCALE: AS NOTED
DRAWN BY: GAM
DATE: 08/30/2011
SOUTHERN COMPANY TAG#: 01G-UA-DR-0091
PO#: MPC10037829

Quality Record

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WILTEW

Document Title: 3592 UA-DR-0091 IP Condensate Drum Documentation Package
Document #: CDP-3592-35
Vendor: JWWTEW, LLC dba Wiltew
SoCo PO# MPC 10037829
SoCo Project: Kemper County IGCC Unit 1

UA-DR-0091 IP Condensate Drum

Documentation Package

MATERIAL TEST REPORTS

Quality Record

MM188078

Approved

BAKER TANKHEAD INCORPORATED

BAKER TANKHEAD, INC.
P.O. BOX 77021
10405 NORTH FREEWAY
FORT WORTH, TX 76177
USA
Ph: 866-232-8030
Fax: 817-847-7244

Material Certification

Date: 02-Mar-12

To

WILTEW, LLC.
P.O. BOX 6
SEMMES, AL 36575

Ship To

WILTEW, LLC.
2650 SCHILLINGER ROAD NORTH
SEMMES, AL 36575

Ph: 251-661-9770 Fax: 251-661-8707

Job Customer PO	Qty	Code/Lot	Material	Mill*	Heat No*	SLab / Pc No*
122337 8463-3591	2	ZGC	1323960375516	* See Mill Test Report		

108"OD X 3/8"NOM 2:1 ELLIP
.320"MIN - SA516-70 - 2"SF
28 13/16"IOH -- 28' 3 5/16"OSC
30 DEG QS BEVEL
126 1/2"DIA B 1326#

* The items listed above were formed in strict accordance with all applicable requirements of the ASME Boiler and Pressure Vessel Code Section VIII, Div. 1.

* We hereby certify that these parts comply with tolerances of UG-81 of ASME Section VIII, Div. 1.

* We hereby certify that these heads were cold formed in compliance with the ASME Boiler and Pressure Vessel Code, Section VIII, Div. 1 Paragraph UCS-79 (d).

* These heads were not heat treated.

3.6.12

Quality Record

MM188078

Approved

P.O.# 34652 (1pc) 132 x 396 x 3/8 SA516-70 ZGC

JSW STEEL (USA) INC.

5200 East McKinney Road,
BAYTOWN, TX 77523

MET-04
TC No.: BR139421-3225-01

METALLURGICAL TEST REPORT

HEADS

Sold To: DELTA STEEL INC. CORPORATE OFFICE 5599 SAN FELIPE, SUITE 600 HOUSTON, TX 77056	**Ship To:** FORT WORTH SO.FRWY PRIMARY STOCK C/O DELTA STEEL, INC. 9217 SOUTH FREEWAY FORT WORTH, TX 76140	This is to certify that the product described herein was manufactured, sampled, and tested in accordance with the specifications and requirements in such specifications. Fine Grain, Si-AL Fully Killed Steel	**Bulletin Num.** 139421
Plates Manufactured in the USA	**Order No:** JUS6014-04	**Approved By:**	
TEST NORMALIZED 1650 DEG F @ 30 MINS	**Date:** 4/27/2011 **P.O.:** OFW-231423	**Shipping Mode:** CUSTOMER TRUCK DIN EN 10204 2004 3.1	
Specifications: HOT ROLLED PLATE CUT EDGE ASTM/ASME A/SA516-07 GR 70 AS ROLLED & TEST NORMALIZED PRESSURE VESSEL QUALITY	**Marking Instructions:** Each plate stenciled with, Mfr name, PO, Heat No., length, width, thickness, weight, grade, Plate no.	**Insp.**	

Item No.	Material Dimensions (in) Gauge	Width	Length	Qty	Wgt. (Lbs)	Heat No.	Gauge Tested	Test/ Plate Identity	Test Direc.	Test Cond	Yield Point (KSI)	Tensile Str. (KSI)	YS/UTS Ratio	Elongation in 8"	Elongation in 2"	Yield Strength Determined at	Plates
04	3750	132.00	396.00	2	11,118	S13225	0.3750	01C-A	TRAN	TN	52	80	0.65	18%		0.2%	00747275A
							0.3750	01C-A	TRAN	AR	52	83	0.63	26%		0.2%	00747275A
							0.3750	01C-B	TRAN	TN	52	80	0.65	18%		0.2%	00747275B
							0.3750	01C-B	TRAN	AR	52	83	0.63	26%		0.2%	00747275B

Wiltew 3592

Accepted
Q.C. Dept.
Initials 7 Hu
Date 3-6-12

Quality Record

REW 505 4/12/12

Test	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Sn	Al	N	V	B	Ti	Nb	Ca	CE
LADLE	0.24	1.10	0.013	0.003	0.27	0.007	0.032	0.011	0.002	0.000	0.034	0.004	0.001	0.0000	0.002	0.000	0.0030	0.43

Approved By: ____________

Checked By: RG. 12/21/11

MM188078

Approved

68062293 SI 804172

SHELL #1

NUCOR

NUCOR STEEL TUSCALOOSA, INC.

MILL TEST CERTIFICATE

1700 HOLT RD N.E.
Tuscaloosa, AL 35404-1000
800-827-8872

Load Number	Tally	Mill Order Number	P.O. Number	Part Number	Certificate Number	Date
393354	00000000425063	N-108323-006	56000995		L341608-1	09/30/2011 11:06

Grade

Order Description:
A516 70, 0.3750 IN x 96.000 IN x 480.000 IN

Quality Plan Description:
A/SA516-70: ASTM A516-70-10/ASME SA516-70 2009 ADDENDA

Customer:
Sold TO:
MACSTEEL SERVICE CENTERS USA Alpharetta GA
Ship TO:
MACSTEEL SERVICE CENTERS USA Alpharetta GA

Shipped Item	Heat/Slab Number	Certified By	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Cb	V	Al	Ti	N2	B	Ca	Sn	CEV
1I2587E	A1V3343-02 ***	A1V3343	0.21	1.10	0.007	0.004	0.20	0.20	0.08	0.06	0.016	0.002	0.002	0.033	0.001	0.008	0.0002	0.0038	0.010	0.43
1I2589B	A1V3343-03 ***	A1V3343	0.21	1.10	0.007	0.004	0.20	0.20	0.08	0.06	0.016	0.002	0.002	0.033	0.001	0.008	0.0002	0.0038	0.010	0.43
1I2589CA	A1V3343-03 ***	A1V3343	0.21	1.10	0.007	0.004	0.20	0.20	0.08	0.06	0.016	0.002	0.002	0.033	0.001	0.008	0.0002	0.0038	0.010	0.43

Shipped Item	Certified By	Heat Number	Yield ksi	Tensile ksi	Y/T %	ELONGATION %		Bend OK?	Hard HB	Charpy Impacts (ft-lbf)					Shear %				Test Temp
						2"	8"			Size mm	1	2	3	Avg	1	2	3	Avg	
1I2587E	S1I2587BTT	A1V3343 ***	57.9	80.1	72.3	34.4													
1I2587E	S1I2587FTT	A1V3343 ***	61.8	85.2	72.5	30.2													
1I2587E	S1I2587MTT	A1V3343 ***	58.1	79.0	73.5	30.4													
1I2589B	S1I2589BTT	A1V3343 ***	56.7	78.0	72.7	34.7													
1I2589B	S1I2589FTT	A1V3343 ***	61.9	80.8	76.6	30.6													
1I2589B	S1I2589MTT	A1V3343 ***	55.9	76.9	72.7	26.2													
1I2589CA	S1I2589BTT	A1V3343 ***	56.7	78.0	72.7	34.7													
1I2589CA	S1I2589FTT	A1V3343 ***	61.9	80.8	76.6	30.6													
1I2589CA	S1I2589MTT	A1V3343 ***	55.9	76.9	72.7	26.2													

Wiltew
Accepted 3592
Q.C. Dept.
Initials [illegible]
Date 2.29.12

Items: 3 PCS: 10 Weight: 49006 LBS

Mercury has not come in contact with this product during the manufacturing process not has any mercury been used by the manufacturing process. Certified in accordance with EN 10204 3.1. No weld repair has been performed on this material.
Manufactured to a fully killed fine grain practice. ** Produced from Coil **
ISO 9001:2008 Registered, PED Certified

**** indicates Heats melted and Manufactured in the U.S.A.

We hereby certify that the product described above passed all of the tests required by the specifications.

April Pitts

April Pitts - QA Engineer

[illegible] 4/12/12

6

Quality Record

MM188078

Approved

68062293 SI 804375

SHELL 2, 3, 4

NUCOR PLATE MILL

P.O.Box 279
Winton, NC 27986
(252) 356-3700

Mill Test Report

Page 2

NUCOR It's our Nature.

Issuing Date : 02/16/2011 B/L No. : 285815 Load No. : 287567 Our Order No. : 88870/17 Cust. Order No. : 56000477

Vehicle No: 9296

Specification : 0.3750" x 120.000" x 480.000"
ASTM A516 70-10/ASME SA516 70 SA516-485 PVQ 2009 Addenda

Sold To : Macsteel Service Centers USA Inc
2005 GRASSLAND PARKWAY
ALPHARETTA,GA 30004

Ship To : FERRO UNION SOUTHEAST, INC.
2005 GRASSLAND PARKWAY
ALPHARETTA,GA 30004

Marking :

Heat No	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Al(tot)	V	Nb	Ti	N	Ca	B	Sn	CEQ	PCM
1501217	0.18	1.02	0.011	0.001	0.18	0.27	0.09	0.09	0.02	0.025	0.007	0.002	0.001		0.0027	0.0002	0.013	0.40	0.26

Tensile Test								Charpy Impacts											
Plate Serial No	Pieces	Tons	Dir.	(psi) Yield	(psi) Tensile	Elongation % in 2"	Elongation % in 8"	Dir.	1	(%) shear	2	(%) shear	3	(%) shear	Ave.	(%) shear	Size	Temp	Min Ave.
1501217-04	1	3.06	T	53,900	78,000		21.2												

3592
Wiltew
Accepted
Q.C. Dept.
Initials [signature]
Date 2.29.12

Manufactured to fully killed fine grain practice by Electric Arc Furnace. Welding or weld repair was not performed on this material. Mercury has not been used in the direct manufacturing of this material. Produced as continuous cast discrete plate as-rolled, unless otherwise noted in Specification.
Yield by 0.5EUL method unless otherwise specified. Ceq = C+(Mn/6)+((Cr+Mo+V)/5)+((Cu+Ni)/15)
Pcm = C+(Si/30)+(Mn/20)+(Cu/20)+(Ni/60)+(Cr/20)+(Mo/15)+(V/10)+5B
Melted and manufactured in the USA. ISO 9001:2008 certified (#008063) by SRI Quality System Registrar (#0985-09). PED 97/23/EC 7/2 Annex 1, Para. 4.3 Compliant. DIN 50049 3.1.B/EN 10204 3.1B(2004), DIN EN 10204 3.1(2005) compliant. For ABS grades only, Quality Assurance certificate 09-MMPQA-546

We hereby certify that the contents of this report are accurate and correct. All test results and operations performed by the material manufacturer are in compliance with the applicable specifications, including customer specifications.

T. A. Depretis [signature]
T. A. Depretis, Metallurgist

02/17/2011 4:22:21 PM

REVD SCS 4/12/12

7

Quality Record

MM188078

Approved

68034323 SI 793928

81

NUCOR PLATE MILL

P. O. Box 279
Winton, NC 27986
(252) 356-3700

Mill Test Report

Page 5

NUCOR It's our Nature.

Issuing Date: 10/11/2011 B/L No.: 307367 Load No.: 309148 Our Order No.: 93936/2 Cust. Order No.: 1173

Vehicle No: WTI 3720

Specification: 0.250" x 96.000" x 288.000"
NUHEAT AR400 F

Sold To: TASSCO, LLC
PO Box 101447
25 West Park Circle
BIRMINGHAM, AL 35211

Ship To: TASSCO, LLC - BHAM
CHRIS HALLMARK
25 WEST PARK CIRCLE
BIRMINGHAM, AL 35211

Marking:

Test Note:

Heat No.	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Alz	V	Nb	Ti	N	Ca	B	Sn	Ceq	pcm
1200078	0.15	1.32	0.010	0.004	0.27	0.17	0.06	0.07	0.05	0.026	0.005	0.000	0.025	0.0000	0.0029	0.0023	0.007	0.411	0.254

			Tensile Test					Heat Treat				Charpy Impacts												
													---Absorbed Energy (ft-lbs)---					---Lateral Expansion (in.)---						
Plate Serial No.	Pieces	Tons	Dir.	Yield (psi)	Tensile (psi)	Elong. % in 2"	R.A. %	Quench deg F	Time (min)	Temper deg F	Time (min)	Dir.	1	2	3	Ave	Min	1	2	3	Ave	Min	Temp deg F	BHN
1200078 - 04 - 6	2	1.98						1665	14	400	18													362
1200078 - 06 - 2	2	1.96						1665	15	400	18													365

Wiltew
Accepted
Q.C. Dept
Initials [illegible]
Date 2/29/12

Manufactured to fully killed fine grain practice by Electric Arc Furnace. Welding or weld repair was not performed on this material. Mercury has not been used in the direct manufacturing of this material. Produced as continuous cast discrete plate. Yield by 0.5EUL on rectangular specimens. Ceq = C+(Mn/6)+((Cr+Mo+V)/5)+((Cu+Ni)/15)
Pcm = C+(Si/30)+(Mn/20)+(Cu/20)+(Ni/60)+(Cr/20)+(Mo/15)+(V/10)+5B
Melted and manufactured in the USA. ISO 9001-2008 certified (#008063) by SRI Quality System Registrar (#0985-09). PED 97/23/EC 7/2 Annex 1, Para. 4.3 Compliant. DIN 50049 3.1.B/EN 10204 3.1.B(2004), DIN EN 10204 3.1(2005) compliant. For ABS grades only, Quality Assurance certificate No. 09-MMPQA-546.

We hereby certify that the contents of this report are accurate and correct. All test results and operations performed by the material manufacturer are in compliance with the applicable specifications.

T. A. Depreis
T. A. Depreis, Metallurgist

[illegible] SCS 1/12/12

Quality Record

MM188078

Approved

T.T.
CC

WILSON 49491-REV 08/08

Line #1

UNITED STATES STEEL

TUBULAR PRODUCTS
CERTIFIED TEST REPORT
(IN ACCORDANCE WITH ISO 10474/EN10204/DIN50049 "type 3.1")

DATE: 12/05/10
TIME: 04:03:06
SERIAL NO: L0034208

MILL ORDER/ITEM NO	SHIPPERS NO.	P.O. NUMBER	VEHICLE I.D
DR49950 05		018692	

SOLD TO ADDRESS	MAIL TO ADDRESS	VENDOR
TUBULAR STEEL INC ATTN ACCTS PAYABLE 1031 EXECUTIVE PARKWAY DR SAINT LOUIS MO 63141-6351	TUBULAR STEEL INC ATTN ACCTS PAYABLE 1031 EXECUTIVE PARKWAY DR SAINT LOUIS MO 63141-6351	USS TUBULAR PRODUCTS 2199 EAST 28TH ST. LORAIN, OH 44055

SPECIFICATION AND GRADE

PIPE CARBON SMLS LINE PIPE ASTM A106-*08 ASME SA106-*2010 EDITION GRADE B/C SPECIAL OD TOLERANCE TO TSI/USS 003 REV 10 DTD 9/22/09 API 5L-*44TH ED DTD OCT 2007 AND ISO 3183:2007 MOD PSL-2 GRADE X42 Q BLK REG MILL COAT PE BEV 30 DEG MEETING ALL THE APPLICABLE REQUIREMENTS OF NACE STANDARD MR-01-75
*:2003/COR.1:2005 AND MR0103-2007

16" STD.

NOZZLE B

MATERIAL COND: QUENCH AND TEMPER — O.D.: 16.000(406.400) in (mm) — WALL: 0.375 (9.525) in (mm)

TENSILE

PRODUCT IDENTIFICATION	TEST TYPE/ ORIENTATION	TEST COND.	GAUGE WIDTH IN	YIELD PSI	EXT% .50	TENSILE PSI	Y/T	ELONG% (IN 2")	HARDNESS SCALE: HRB	MIN HYDRO PSI	DWELL(SEC)
				MIN: 52200		MIN: 70000	MAX:	MIN:	MIN:	2080	5
				MAX: 71800		MAX: 110200	0.93	30.0	MAX: 99.0		
MA1873 R818QA	STRIP/L/B	QT	1.500	69000	.50	83500	0.82	39.0	B 87.1	2080	5
MA1873 R818QA	STRIP/L/B	QT	1.500	66500	.50	82500	0.81	39.0			
		**	END OF	DATA THIS	SHEET	**					

LEGEND: L - LONGITUDINAL, U - UPSET, T - TRANSVERSE, NM - NORMALIZED, QT - QUENCH & TEMPERED, SR - STRESS RELIEVED, AR - AS ROLLED, TR - THERMOMECHANICAL ROLLED, B - BODY, W - WELD

PRODUCT IDENTIFICATION	TYPE	C	MN	P	S	SI	CU	NI	CR	MO	AL	N	V	B	TI	CB	CO	C.E.* MAX .43
MA1873	HEAT	16	103	009	005	21	15	09	10	03	025		021	0002	001	002		.38
MA1873 R818QA	PROD	16	103	010	005	22	15	09	11	04	029		019	0003	002	002		.38
MA1873 R818QA	PROD	16	103	010	005	22	15	09	11	04	029		019	0003	002	001		.38
			** END	OF DATA	THIS	SHEET	**											

*C.E. IS BASED ON THE FOLLOWING EQUATION(S): CE=C+MN/6+(CR+MO+V)/5+(NI+CU)/15

DECIMAL POSITIONS FOR ELEMENTS ARE INDICATED BY THE LEFT MARGIN, VERTICAL DOTTED LINE OR DECIMAL POINT.

RECEIVED
MAR 08 REC'D

RRW
SOS
4/12/12

Wiltew
Accepted
Q.C. Dept.
Initials
Date

3592

A Schlumberger Company
Main Office 1302 Conti, P.O. Box 1492
Houston, TX 77251-1492 Phone (713) 237-3700
WILSON

Quality Record

MM188078

Approved

WILSON 49491-REV 08/08

UNITED STATES STEEL

TUBULAR PRODUCTS
CERTIFIED TEST REPORT
(IN ACCORDANCE WITH ISO 10474/EN10204/DIN50049 "type 3.1")

DATE: 12/05/10
TIME: 04:03:06
SERIAL NO: L0034208

MILL ORDER/ITEM NO	SHIPPERS NO.	P.O. NUMBER	
DR49950 05		018692	
MATERIAL COND: QUENCH AND TEMPER		O.D.: 16.000(406.400) in (mm)	WALL: 0.375 (9.525) in (mm)

CHARPY V-NOTCH IMPACT TESTING

PRODUCT IDENTIFICATION	FLAT	BEND	GRAIN SIZE	MIN COLLAPSE	DIR	TEST LOC.	TEMP DEG F	SIZE	TEST COND.	FT-LBS 1	FT-LBS 2	FT-LBS 3	FT-LBS AVG	% SHEAR 1	% SHEAR 2	% SHEAR 3	% SHEAR AVG
MA1873 R818QA	OK				T	B	+ 32	2/3	QT	114	124	138	125	100	100	100	100
MA1873 R818QA					L	B	- 60	2/3	QT	111	109	120	113	100	100	100	100

** END OF DATA THIS SHEET **

LEGEND L - LONGITUDINAL T - TRANSVERSE B - BODY W - WELD HAZ - HEAT AFFECTED ZONE

TESTING / INSPECTION INFORMATION

TEST / INSPECTION	YES	RESULTS / COMMENTS
FULL LENGTH VISUAL	X	
FULL LENGTH EM	X	OD X ODID ___ L ___ LT X 10.0% NOTCH
FULL LENGTH MPI		
FULL LENGTH UT	X	ID X OD/ID ___ L X LT ___ 10.0% NOTCH
END AREA INSPECTION (PLAIN END)	X	MPI X UT ___
SPECIAL END AREA (SEA) INSP		MPI ___ UT ___
FULL LENGTH DRIFT		DRIFT MANDREL SIZE:

ADDITIONAL NOTES/COMMENTS

MELTED AND MANUFACTURED IN THE USA. NO REPAIRS BY WELDING. NO MERCURY OR MERCURY COMPOUNDS ARE ADDED TO THE STEEL AND ALL MERCURY BEARING EQUIPMENT IS PROTECTED BY A DOUBLE BOUNDARY OF CONTAINMENT.
MINIMUM TEMPERING TEMPERATURE 1050 DEG F.
MATERIAL ALSO MEETS THE REQUIREMENTS OF A53/SA53 GRADE B. THIS MULTIPLE CERTIFIED PRODUCT,(ASTM A53/AND OR A106 GRADE B, AND/OR ASTM A333 GRADE 6, AND API 5L X52Q) HAS HIGHER YIELD STRENGTH PROPERTIES THAN MATERIAL ORDERED AS ASTM A53 AND/OR A106 GRADE B AND/OR ASTM A333 GRADE 6

3592

THIS IS TO CERTIFY THAT THE PRODUCT DESCRIBED HEREIN WAS MANUFACTURED, SAMPLED, TESTED AND/OR INSPECTED IN ACCORDANCE WITH THE SPECIFICATION AND FULFILLS THE REQUIREMENTS IN SUCH RESPECTS.

PREPARED BY THE OFFICE OF: R. HARRIS - MANAGER, Q.A.

DATE 12/05/10

PAGE 2 OF 3

RECEIVED
MAR 08 2011

TT
CC

RQW
5C5
4/12/12

Quality Record

WILSON
A Schlumberger Company
Main Office 1302 Conti, P.O. Box 1492
Houston, TX 77251-1492 Phone (713) 237-3700

Approved

MM188078

Line #2

UNITED STATES STEEL

TUBULAR PRODUCTS
CERTIFIED TEST REPORT
(IN ACCORDANCE WITH ISO 10474/EN10204/DIN50049 "type 3.1")

DATE: 07/29/11
TIME: 13:20:58
SERIAL NO: L0036914

MILL ORDER/ITEM NO	SHIPPERS NO.	P.O. NUMBER	VEHICLE I.D
DR01378 07		022173	

SOLD TO ADDRESS	MAIL TO ADDRESS	VENDOR
TUBULAR STEEL INC ATTN ACCTS PAYABLE 1031 EXECUTIVE PARKWAY DR SAINT LOUIS MO 63141-6339	TUBULAR STEEL INC ATTN ACCTS PAYABLE 1031 EXECUTIVE PARKWAY DR SAINT LOUIS MO 63141-6339	USS TUBULAR PRODUCTS 2199 EAST 28TH ST. LORAIN, OH 44055

SPECIFICATION AND GRADE

PIPE CARBON SMLS LINE PIPE ASTM A106-*08 ASME SA106-*2010 EDITION GRADE B/C SPECIAL OD TOLERANCE TO TSI/USS 003 REV 10 DTD 9/22/09 API 5L-*44TH ED DTD OCT 2007 AND ISO 3183:2007 MOD PSL-2 GRADE X42 Q BLK REG MILL COAT PE BEV 30 DEG MEETING ALL THE APPLICABLE REQUIREMENTS OF NACE STANDARD MR-01-75 *:2003/COR.1:2005 AND MR0103-2007

12" XH

NOZZLE/A

MATERIAL COND: QUENCH AND TEMPER

O.D.: 12.750(323.850) In (mm) WALL: 0.500 (12.700) In (mm)

TENSILE

PRODUCT IDENTIFICATION	TEST TYPE/ ORIENTATION	TEST COND.	GAUGE WIDTH IN	YIELD PSI	EXT % .50	TENSILE PSI	Y/T	ELONG % (IN 2 ")	HARDNESS SCALE: HRB	MIN HYDRO PSI	DWELL(SEC)
				MIN: 52200		MIN: 70000	MAX:	MIN:	MIN: 70.0	2970	5
				MAX: 71800		MAX: 110200	0.93	30.0	MAX: 99.5		
WA1739 T947QA	STRIP/L/B	QT	1.500	69500	.50	83500	0.83	42.9	B 93.7	2970	5
WA1739 T947QA	STRIP/L/B	QT	1.500	70000	.50	84000	0.83	41.7			

** END OF DATA THIS SHEET **

LEGEND: L - LONGITUDINAL, U - UPSET, T - TRANSVERSE, NM - NORMALIZED, QT - QUENCH & TEMPERED, SR - STRESS RELIEVED, AR - AS ROLLED, TR - THERMOMECHANICAL ROLLED, B - BODY, W - WELD

PRODUCT IDENTIFICATION	TYPE	C	MN	P	S	SI	CU	NI	CR	MO	AL	N	V	B	TI	CB	CO	C.E.* MAX *
WA1739	HEAT	13	102	009	002	25	10	05	09	05	020		028	0001	001	000		.34
WA1739 T947QA	PROD	15	106	011	002	25	10	06	09	05	020		032	0003	003	005		.37
WA1739 T947QA	PROD	13	104	010	001	25	10	06	09	04	019		030	0003	003	004		.35

** END OF DATA THIS SHEET **

*C.E. IS BASED ON THE FOLLOWING EQUATION(S): * SEE ADDITIONAL NOTES

DECIMAL POSITIONS FOR ELEMENTS ARE INDICATED BY THE LEFT MARGIN, VERTICAL DOTTED LINE OR DECIMAL POINT. ELEMENTS REPORTED IN MASS FRACTION (%)

PAGE 1 OF 6

Wiltew Accepted Q.C. Dept.
Initials [signature]
Date 3.12.12

3592

RECEIVED MAR 08 2011

COTT

REM S:3 4/12/12

Quality Record

MM188078

Approved

WILSON 49491-REV. 08/08

UNITED STATES STEEL

TUBULAR PRODUCTS
CERTIFIED TEST REPORT
(IN ACCORDANCE WITH ISO 10474/EN10204/DIN50049 "type 3.1")

DATE: 07/29/11
TIME: 13:20:58
SERIAL NO: L0036914

MILL ORDER/ITEM NO	SHIPPERS NO.	P.O. NUMBER
DR01378 07		022173

MATERIAL COND: QUENCH AND TEMPER

O.D.: 12.750(323.850) in (mm) WALL: 0.500 (12.700) in (mm)

PRODUCT IDENTIFICATION	FLAT	BEND	GRAIN SIZE	MIN COLLAPSE	DIR	TEST LOC.	TEMP DEG F	SIZE	TEST COND.	FT-LBS 1	FT-LBS 2	FT-LBS 3	FT-LBS AVG	% SHEAR 1	% SHEAR 2	% SHEAR 3	% SHEAR AVG
WA1739 T947QA	OK				T	B	+ 32	2/3	QT	165	171	169	168	100	100	100	100
WA1739 T947QA					L	B	- 50	FULL	QT	241	219	210	223	100	100	100	100

(CHARPY V-NOTCH IMPACT TESTING)

** END OF DATA THIS SHEET **

LEGEND L-LONGITUDINAL T-TRANSVERSE B-BODY W-WELD HAZ-HEAT AFFECTED ZONE

TESTING / INSPECTION INFORMATION

TEST / INSPECTION	YES	RESULTS / COMMENTS
FULL LENGTH VISUAL	X	
FULL LENGTH EMI	X	OD X OD/ID ___ L ___ L/T X 10.0% NOTCH
FULL LENGTH MPI		
FULL LENGTH UT	X	ID X OD/ID ___ L X L/T ___ 10.0% NOTCH
END AREA INSPECTION (PLAIN END)	X	MPI X UT ___
SPECIAL END AREA (SEA) INSP		MPI ___ UT ___
FULL LENGTH DRIFT		DRIFT MANDREL SIZE:

ADDITIONAL NOTES/COMMENTS

MELTED AND MANUFACTURED IN THE USA. NO REPAIRS BY WELDING. NO MERCURY OR MERCURY COMPOUNDS ARE ADDED TO THE STEEL AND ALL MERCURY BEARING EQUIPMENT IS PROTECTED BY A DOUBLE BOUNDARY OF CONTAINMENT.
*C.E. IS BASED ON THE FOLLOWING EQUATION(S):
FOR CARBON MIN: .01 TO MAX: .12, CE=C+SI/30+(MN+CU+CR)/20+NI/60+MO/15+V/10+5B WITH .25 MAX C.E.
FOR CARBON MIN: .13 TO MAX: .30, CE=C+MN/6+(CR+MO+V)/5+(NI+CU)/15 WITH .43 MAX C.E.
MINIMUM TEMPERING TEMPERATURE 1050 DEG F.
MATERIAL ALSO MEETS THE REQUIREMENTS OF A53/SA53 GRADE B. THIS MULTIPLE CERTIFIED PRODUCT,(ASTM A53/AND OR A106 GRADE B, AND/OR ASTM A333 GRADE 6, AND API 5L X52Q) HAS HIGHER YIELD STRENGTH PROPERTIES THAN MATERIAL ORDERED AS ASTM A53 AND/OR A106 GRADE B AND/OR ASTM A333 GRADE 6

THIS IS TO CERTIFY THAT THE PRODUCT DESCRIBED HEREIN WAS MANUFACTURED, SAMPLED, TESTED AND/OR INSPECTED IN ACCORDANCE WITH THE SPECIFICATION AND FULFILLS THE REQUIREMENTS IN SUCH RESPECTS.

PREPARED BY THE OFFICE OF: R. HARRIS - MANAGER, Q.A.

DATE 07/29/11

3592

RECEIVED

ccTT

5L5
4/12/12

Quality Record

WILSON
A Schlumberger Company
Main Office 1302 Conti, P.O. Box 1492
Houston, TX 77251-1492 Phone (713) 237-3700

MM188078

Approved

Line 5

UNITED STATES STEEL

TUBULAR PRODUCTS
CERTIFIED TEST REPORT
(IN ACCORDANCE WITH ISO 10474/EN10204/DIN50049 "type 3.1")

DATE: 07/27/10
TIME: 04:06:53
SERIAL NO: L0032739

MILL ORDER/ITEM NO	SHIPPERS NO.	P.O. NUMBER	VEHICLE I.D.
DR48949 05	R82193	106576-00	GRW88757

SOLD TO ADDRESS	MAIL TO ADDRESS	VENDOR
TEXAS PIPE & SUPPLY CO INC 2330 HOLMES RD HOUSTON TX 77051-1098	TEXAS PIPE & SUPPLY CO INC 2330 HOLMES RD HOUSTON TX 77051-1098	USS TUBULAR PRODUCTS 2199 EAST 28TH ST. LORAIN, OH 44055

SPECIFICATION AND GRADE

PIPE CARBON SMLS STD PIPE API 5L-*44TH ED DTD OCT 2007 AND ISO 3183:2007 MOD PSL-1 GRADE B AND GRADE X42 R N OR Q ASTM A53-*07 ASTM A106-*08 GRADE B QUAD STENCIL ASME SA53-*2007 EDITION ASME SA106-*2007 EDITION GRADE B BLK REG MILL COAT PE BEV 30 DEG MEETING ALL THE APPLICABLE REQUIREMENTS OF NACE STANDARD MR-01-75 *:2003/COR.1:2005 AND MR0103-2007

Z" SCH 160

NOZZLE L1 + L2

MATERIAL COND: AS ROLLED — O.D.: 2.375 (60.325) in (mm) — WALL: 0.344 (8.737) in (mm)

PRODUCT IDENTIFICATION	TENSILE TEST TYPE/ ORIENTATION	TEST COND.	GAUGE WIDTH IN	YIELD PSI	EXT % .50	TENSILE PSI	Y/T	ELONG % (IN 2")	HARDNESS SCALE: HRB	MIN HYDRO PSI	DWELL(SEC)
				MIN: 42100 MAX:		MIN: 70000 MAX:	MAX:	MIN: 24.0	MIN: MAX: 99.0	2970	5
FA0399	STRIP/L/B	AR	0.750	47100	.50	75000	0.63	35.9	B 77.0	2970	5
FA0429	STRIP/L/B	AR	0.750	47200	.50	75000	0.63	35.9	B 75.8	2970	5
		**	END OF DATA THIS SHEET **								

LEGEND: L - LONGITUDINAL, U - UPSET; T - TRANSVERSE, NM - NORMALIZED; QT - QUENCH & TEMPERED, SR - STRESS RELIEVED; AR - AS ROLLED, TR - THERMOMECHANICAL ROLLED; B - BODY; W - WELD

PRODUCT IDENTIFICATION	TYPE	C	MN	P	S	SI	CU	NI	CR	MO	AL	N	V	B	TI	CB	CO	C.E.* MAX .50
FA0399	HEAT	19	104	011	005	18	13	09	07	02	028		00	0002	001	000		.40
FA0399	PROD	19	103	014	005	20	13	10	08	01	035		00	0004	003	008		.40
FA0399	PROD	19	103	014	005	21	13	10	08	01	036		00	0005	003	010		.40
FA0429	HEAT	19	105	012	003	18	14	10	09	03	036		00	0000	001	000		.41
FA0429	PROD	19	105	015	004	19	14	12	10	01	037		00	0003	003	009		.40
FA0429	PROD	19	106	015	004	19	14	12	10	01	037		00	0003	003	009		.41
			** END OF DATA THIS SHEET **															

*C.E. IS BASED ON THE FOLLOWING EQUATION(S): CE=C+ (MN/6)+(CR+MO+V)/5+ (NI+CU)/15

DECIMAL POSITIONS FOR ELEMENTS ARE INDICATED BY THE LEFT MARGIN, VERTICAL DOTTED LINE OR DECIMAL POINT.

RECEIVED
MAR 08 REC'D

REW SCS 4/12/12

Wiltew
Accepted
Q.C. Dept.
Initials [signature]
Date 3.12.12
3592

CCT

Quality Record

MM188078

Approved

UNITED STATES STEEL

TUBULAR PRODUCTS
CERTIFIED TEST REPORT
(IN ACCORDANCE WITH ISO 10474/EN10204/DIN50049 "type 3.1")

DATE: 07/27/10
TIME: 04:06:53
SERIAL NO: L0032739

MILL ORDER/ITEM NO	SHIPPERS NO.	P.O. NUMBER	
DR48949 05	R82193	106576-00	0017079

MATERIAL COND: AS ROLLED

O.D.: 2.375 (60.325) in (mm) WALL: 0.344 (8.737) in (mm)

PRODUCT IDENTIFICATION	FLAT	BEND	GRAIN SIZE	MIN COLLAPSE	DIR	TEST LOC.	TEMP	SIZE	TEST COND.	CHARPY V-NOTCH IMPACT TESTING FT-LBS 1	2	3	AVG	% SHEAR 1	2	3	AVG
							DEG										
FA0399		OK															
FA0429		OK															

** END OF DATA THIS SHEET **

LEGEND L - LONGITUDINAL T - TRANSVERSE B - BODY W - WELD HAZ - HEAT AFFECTED ZONE

TESTING / INSPECTION INFORMATION

TEST / INSPECTION	YES	RESULTS / COMMENTS
FULL LENGTH VISUAL	X	OD ____ OD/ID ____ L ____ L/T ____
FULL LENGTH EMI		
FULL LENGTH MPI		ID ____ OD/ID ____ L ____ L/T ____
FULL LENGTH UT		MPI ____ UT ____
END AREA INSPECTION (PLAIN END)		MPI ____ UT ____
SPECIAL END AREA (SEA) INSP		DRIFT MANDREL SIZE:
FULL LENGTH DRIFT		

ADDITIONAL NOTES/COMMENTS

MELTED AND MANUFACTURED IN THE USA. NO REPAIRS BY WELDING. NO MERCURY OR MERCURY COMPOUNDS ARE ADDED TO THE STEEL AND ALL MERCURY BEARING EQUIPMENT IS PROTECTED BY A DOUBLE BOUNDARY OF CONTAINMENT.
PRODUCT WAS HOT ROLLED AND HOT FINISHED
ALL MELTING AND MANUFACTURING TOOK PLACE IN THE USA
PIPE ALSO MEET THE REQUIREMENTS OF ASTM A106 GRADE C & ASME SA106 GRADE C

3592

THIS IS TO CERTIFY THAT THE PRODUCT DESCRIBED HEREIN WAS MANUFACTURED, SAMPLED, TESTED AND/OR INSPECTED IN ACCORDANCE WITH THE SPECIFICATION AND FULFILLS THE REQUIREMENTS IN SUCH RESPECTS.

PREPARED BY THE OFFICE OF: R. HARRIS - MANAGER, Q.A.

DATE 07/27/10

SCS 4/12/12

RECEIVED
MAR 08 REC'D

CCH

Quality Record

MM188078

Approved

Line #4

UNITED STATES STEEL

TUBULAR PRODUCTS
CERTIFIED TEST REPORT
(IN ACCORDANCE WITH ISO 10474/EN10204/DIN50049 "type 3.1")

DATE: 08/19/10
TIME: 04:05:52
SERIAL NO: L0032997

MILL ORDER/ITEM NO	SHIPPERS NO	P.O. NUMBER	VEHICLE I.D	
DR49406 05	R82349	107497-00	LT8301	

SOLD TO ADDRESS	MAIL TO ADDRESS	VENDOR
TEXAS PIPE & SUPPLY CO INC 2330 HOLMES RD HOUSTON TX 77051-1098	TEXAS PIPE & SUPPLY CO INC 2330 HOLMES RD HOUSTON TX 77051-1098	USS TUBULAR PRODUCTS 2199 EAST 28TH ST. LORAIN, OH 44055

SPECIFICATION AND GRADE

PIPE CARBON SMLS STD PIPE API 5L-*44TH ED DTD OCT 2007 AND ISO 3183:2007 MOD PSL-1 GRADE B AND GRADE X42 R N OR Q ASTM A53-*07 ASTM A106-*08 GRADE B QUAD STENCIL ASME SA53-*2010 EDITION ASME SA106-*2010 EDITION GRADE B BLK REG MILL COAT PE BEV 30 DEG MEETING ALL THE APPLICABLE REQUIREMENTS OF NACE STANDARD MR-01-75 *:2003/COR.1:2005 AND MR0103-2007

3" SCH 80

NOZZLE C

MATERIAL COND: AS ROLLED

O.D.: 3.500 (88.900) in (mm)

WALL: 0.300 (7.620) in (mm)

TENSILE

PRODUCT IDENTIFICATION	TEST TYPE/ ORIENTATION	TEST COND.	GAUGE WIDTH IN	YIELD PSI	EXT % .50	TENSILE PSI	Y/T	ELONG % (IN 2")	HARDNESS SCALE: HRB	MIN HYDRO PSI	DWELL(SEC)
				MIN: 42100 MAX:		MIN: 70000 MAX:	MAX:	MIN: 23.0	MIN: MAX: 99.0	2970	5
FA0508	STRIP/L/B	AR	0.750	49000	.50	78000	0.63	35.0	B 77.4	2970	5
FA0511	STRIP/L/B	AR	0.750	46400	.50	75500	0.62	31.6	B 77.4	2970	5

** END OF DATA THIS SHEET **

LEGEND: L - LONGITUDINAL U - UPSET T - TRANSVERSE NM - NORMALIZED QT - QUENCH & TEMPERED SR - STRESS RELIEVED AR - AS ROLLED TR - THERMOMECHANICAL ROLLED B - BODY W - WELD

PRODUCT IDENTIFICATION	TYPE		C	MN	P	S	SI	CU	NI	CR	MO	AL	N	V	B	TI	CB	CO				C.E.* MAX .50
FA0508	HEAT		20	105	012	007	20	13	08	08	02	030		00	0001	002	000					.41
FA0508	PROD		21	108	015	007	21	13	08	08	01	038		00	0004	004	010					.42
FA0508	PROD		22	108	015	007	21	13	08	08	01	039		00	0004	004	010					.43
FA0511	HEAT		19	103	011	008	20	14	11	08	01	035		00	0001	002	000					.40
FA0511	PROD		21	105	013	008	21	14	11	08	01	037		00	0004	004	009					.42
FA0511	PROD		21	105	013	008	21	14	11	08	01	037		00	0004	004	010					.42

** END OF DATA THIS SHEET **

*C.E. IS BASED ON THE FOLLOWING EQUATION(S): CE=C+(MN/6)+(CR+MO+V)/5+ (NI+CU)/15

DECIMAL POSITIONS FOR ELEMENTS ARE INDICATED BY THE LEFT MARGIN, VERTICAL DOTTED LINE OR DECIMAL POINT.

PAGE 1 OF 2

Wiltew
Accepted
Q.C. Dept.
Initials
Date 3.12.12
3592

RCS 4/12/12

RECEIVED

Quality Record

MM188078

Approved

UNITED STATES STEEL

TUBULAR PRODUCTS
CERTIFIED TEST REPORT
(IN ACCORDANCE WITH ISO 10474/EN10204/DIN50049 "type 3.1")

DATE: 08/19/10
TIME: 04:05:52
SERIAL NO: L0032997

MILL ORDER/ITEM NO	SHIPPERS NO.	P.O. NUMBER	
DR49406 05	R82349	107497-00	0017458

MATERIAL COND: AS ROLLED

O.D.: 3.500 (88.900) in (mm)   WALL: 0.300 (7.620) in (mm)

PRODUCT IDENTIFICATION	FLAT	BEND	GRAIN SIZE	MIN COLLAPSE	CHARPY V-NOTCH IMPACT TESTING DIR	TEST LOC.	TEMP	SIZE	TEST COND.	FT-LBS 1	FT-LBS 2	FT-LBS 3	FT-LBS AVG	% SHEAR 1	% SHEAR 2	% SHEAR 3	% SHEAR AVG
							DEG										
FA0508	OK																
FA0511	OK																

** END OF DATA THIS SHEET **

LEGEND L - LONGITUDINAL T - TRANSVERSE B - BODY W - WELD HAZ - HEAT AFFECTED ZONE

TESTING / INSPECTION INFORMATION

TEST / INSPECTION	YES	RESULTS / COMMENTS
FULL LENGTH VISUAL	X	
FULL LENGTH EMI		OD ____ OD/ID ____ L ____ L/T ____
FULL LENGTH MPI		
FULL LENGTH UT		ID ____ OD/ID ____ L ____ L/T ____
END AREA INSPECTION (PLAIN END)		MPI ____ UT ____
SPECIAL END AREA (SEA) INSP		MPI ____ UT ____
FULL LENGTH DRIFT		DRIFT MANDREL SIZE:

ADDITIONAL NOTES/COMMENTS

MELTED AND MANUFACTURED IN THE USA. NO REPAIRS BY WELDING. NO MERCURY OR MERCURY COMPOUNDS ARE ADDED TO THE STEEL AND ALL MERCURY BEARING EQUIPMENT IS PROTECTED BY A DOUBLE BOUNDARY OF CONTAINMENT.
PRODUCT WAS HOT ROLLED AND HOT FINISHED
PIPE ALSO MEET THE REQUIREMENTS OF ASTM A106 GRADE C & ASME SA106 GRADE C

3592

THIS IS TO CERTIFY THAT THE PRODUCT DESCRIBED HEREIN WAS MANUFACTURED, SAMPLED, TESTED AND/OR INSPECTED IN ACCORDANCE WITH THE SPECIFICATION AND FULFILLS THE REQUIREMENTS IN SUCH RESPECTS.

PREPARED BY THE OFFICE OF R. HARRIS - MANAGER, Q.A.

DATE 08/19/10

RECEIVED
MAR 08 REC'D

TJT
CC

Rcvd
5C3
4/12/12

Quality Record

MM188078

Approved

Page 1 of 1

2669 MARTIN LUTHER KING BLVD
YOUNGSTOWN, OH 44510

Line #3

8" XH

V&M STAR LP.
Seamless Tubular Products

8970-3592

Certified Test Report
10/26/2011

CUSTOMER: TUBULAR STEEL INC.
SLN: A90247 **GRADE:** API 5L X42/B PSL 2 Rev. October 1, 2008
OD: 8.625 **WALL:** 0.500 **LBS/FT:** 43.43
DESC: SEAMLESS HOT ROLLED
PEB DRL LP
CUSTOMER ORDER NUMBER: 24732
ORDER LINE #: Y-93440-001
W/O NO:
LOT NUMBER:

COMMENT: Melted and Manufactured in the U.S.A.
This pipe is also manufactured to: ASTM A106B/C-10 ASTM A53B-10 ASME SA106B/C-2011 ASME SA53B-2011 V&M Star s QA program meets the requirements of DIN EN 10204-2004 Type 3.1. Satisfies NACE MR0103-2010.
No repair welding has been conducted. Material is free from Mercury. ISO 9001:2008 Certified.

MECHANICAL PROPERTIES:

	SPECIMEN CROSS SECTION			STRENGTH KSI		ELONGATION		
JT-POS	WIDTH(IN)	THICK(IN)	AREA(SQIN)	YIELD	TENSILE	GAGE LENGTH	%ELONG	%RA
1)	1.510	0.459	0.6971	55.1	85.6	2	29.0	
2)								
3)								
4)								
5)								

SUPPLEMENTAL REQUIREMENT
HARDNESS: 79.6-HRBW-AVG
FLATTENING:
NACE TEST:
GRAIN SIZE:
OTHER:
COLLAPSE:
MIN:
AS QUENCHED:

INSPECTION: **Q/T:** **AF:** 0 **AT:** 0 **TF:** 0 **TT:** 0
HYDROSTATIC TEST (psi): 3650for a 5 second minimum **DRIFT PLUG SIZE:** INCHES Required CE Max of 0.43
MAX INTERNAL YIELD (psi): 5590

CHEMICAL ANALYSIS: 61 Electromagnetic Inspected. Reference Standard was a test joint with 10% OD Longitudinal and Transverse notches.

	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Sn	Nb	V	Al	Ca	B	Ti	N	CE
HEAT	0.22	0.79	0.011	0.004	0.22	0.19	0.07	0.09	0.03	0.009	0.000	0.002	0.028	0.0015	0.0003	0.001	0.0090	0.39
PRODUCT 1)	0.21	0.77	0.010	0.004	0.22	0.18	0.07	0.09	0.02			0.002	0.027	0.0019	0.0003	0.001	0.0091	0.38
PRODUCT 2)	0.22	0.78	0.010	0.004	0.22	0.19	0.07	0.09	0.02			0.002	0.027	0.0016	0.0003	0.001		0.39
PRODUCT 3)																		
PRODUCT 4)																		

CHARPY IMPACT TESTING NOTCH: V

	DIRECTION	SIZE	TEMP(Deg.F)	FTLBS 1	FTLBS 2	FTLBS 3	AVG	SHEAR 1	SHEAR 2	SHEAR 3	AVG
TEST #1	TRANS	FULL	32	20	28	27	25.00	25	20	20	22
TEST #2											
TEST #3											

This material has been produced and tested in accordance with the requirements of applicable specifications unless otherwise listed below. We hereby certify that the above test results are representative of those contained in the records of the company. Any modification to this certification as provided by V & M TUBES; without the expressed written consent of V & M TUBES negates the validity of the test report. V & M TUBES is not responsible for the inability of the material to meet specific applications.

SIGNED: Joe E. Dolak
NAME: JOE DOLAK **TITLE:** PRODUCT METALLURGIST
DATE APPROVED: 10/26/2011

NOZZLE D

Wiltew
Accepted
Q.C. Dept.
Initials
Date 3-12-12
3592

11/2/2011 10:03:32 AM
RECEIVED

CGT

RJ 5C5 4/11/12

Quality Record

WILSON 49491-REV 08/08

A Schlumberger Company
Main Office 1302 Conti, P.O. Box 1492
Houston, TX 77251-1492 Phone (713) 237-3700
WILSON

MM188078

Approved

44

SSAB

Test Certificate

Form TC1: Revision 1: Date 31 Oct 2000

12400 Highway 43 North, Axis, Alabama 36505

Customer: O'NEAL STEEL INC. P.O. BOX 98 ATTN: SHAUN KELLEY BIRMINGHAM AL 35201-0098	Customer P.O. No.: 2269060OP108	Mill Order No.: 41-310655-03	Shipping Manifest: AT125199
	Product Description: ABS (2011) GR A ASTM A36(08)/A709(09A)36/ASME SA36(10)	Ship Date: 13 Sep 11 Cert Date: 13 Sep 11	Cert No: 081300421 (Page 1 of 1)
	Size: 0.375 X 120.0 X 480.0 (IN)		

Tested Pieces			Tensiles								Charpy Impact Tests													BDWTT	
Heat Id	Piece Id	Piece Dimensions	Tst Loc	YS (KSI)	UTS (KSI)	%RA	Elong % 2in	Elong % 8in	Tst Dir	Average Hardness	Abs. Energy(FTLB) 1	2	3	Avg	% Shear 1	2	3	Avg	Tst Tmp	Tst Dir	Tst Siz (mm)			Tmp	%Shr
W11576	A04	0.400 (DISCRT)	L	48	61			29	T																

Chemical Analysis

Heat Id	C	Mn	P	S	Si	Tot Al	Cu	Ni	Cr	Mo	Cb	V	Ti	CEV	ORGN
W11576	.05	1.15	.010	.003	.29	.028	.29	.13	.21	.04	.004	.006	.022	.25	USA

MERCURY IS NOT A METALLURGICAL COMPONENT OF THE STEEL AND NO MERCURY WAS INTENTIONALLY ADDED DURING THE MANUFACTURE OF THIS PRODUCT
WE HEREBY CERTIFY THAT MATERIAL DESCRIBED HEREIN HAS BEEN MADE BY SSAB AMERICAS BY THE ELECTRIC FURNACE / STRAND CAST PROCESS AND TESTED IN ACCORDANCE WITH THE REQUIREMENTS OF THE AMERICAN BUREAU OF SHIPPING RULES WITH SATISFACTORY RESULTS.
CEV = C + MN/6
MTR EN 10204:2004 INSPECTION CERTIFICATE 3.1 COMPLIANT
100% MELTED AND MANUFACTURED IN THE USA.
PRODUCTS SHIPPED:
W11576 A04 PCES: 3, WGT: 18400

LEG REPAD
TAIL LUG REPAD
MIST ELIM RING
Vortex Breaker

3592
Wiltew
Accepted
Q.C. Dept.
Initials
Date 4.4.12

ABS AMERICAS
SURVEYOR
(SIGNED) BANDER AL-RESHIDI
MOBILE, AL-DATE 09/26/2011

ABS
MOBILE

M2044625

RCVD
SCS
4/12/12

SEP 14 2011

(U) Cust Part # : 804359

WE HEREBY CERTIFY THAT THIS MATERIAL WAS TESTED IN ACCORDANCE WITH, AND MEETS THE REQUIREMENTS OF, THE APPROPRIATE SPECIFICATION

Justin Ward
SENIOR METALLURGIST

Quality Record

MM188078

Approved

68062293 SI 804375

NUCOR P.O.Box 279
Winton, NC 27986
(252) 356-3700

PLATE MILL

Mill Test Report
Page 2

NUCOR It's our Nature:

Issuing Date : 02/16/2011 B/L No. : 285815 Load No. : 287567 Our Order No. : 88870/17 Cust. Order No. : 56000477

Vehicle No: 9296

Specification : 0.3750" x 120.000" x 480.000"
ASTM A516 70-10/ASME SA516 70 SA516-485 PVQ 2009 Addenda

Sold To : Macsteel Service Centers USA Inc
2005 GRASSLAND PARKWAY
ALPHARETTA,GA 30004

Ship To : FERRO UNION SOUTHEAST, INC.
2005 GRASSLAND PARKWAY
ALPHARETTA,GA 30004

Marking :

Heat No	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Al(tot)	V	Nb	Ti	N	Ca	B	Sn	CEQ	PCM
1501217	0.18	1.02	0.011	0.001	0.18	0.27	0.09	0.09	0.02	0.025	0.007	0.002	0.001		0.0027	0.0002	0.013	0.40	0.26

		Tensile Test						Charpy Impacts											
Plate Serial No	Pieces	Tons	Dir.	(psi) Yield	(psi) Tensile	Elongation % in 2"	Elongation % in 8"	Dir.	1	(%) shear	2	(%) shear	3	(%) shear	Ave.	(%) shear	Size	Temp	Min Ave.
1501217-04	1	3.06	T	53,900	78,000		21.2												

Nozzle Repads

3592
Wiltew
Accepted
Q.C. Dept.
Initials [signature]
Date 4.4.12

Rom
SCS
4/12/12

Manufactured to fully killed fine grain practice by Electric Arc Furnace. Welding or weld repair was not performed on this material. Mercury has not been used in the direct manufacturing of this material. Produced as continuous cast discrete plate as-rolled, unless otherwise noted in Specification.
Yield by 0.5EUL method unless otherwise specified. Ceq = C+(Mn/6)+((Cr+Mo+V)/5)+((Cu+Ni)/15)
Pcm = C+(Si/30)+(Mn/20)+(Cu/20)+(Ni/60)+(Cr/20)+(Mo/15)+(V/10)+5B
Melted and manufactured in the USA. ISO 9001:2008 certified (#008063) by SRI Quality System Registrar (#985-09). PED 97/23/EC 7/2 Annex 1, Para. 4.3 Compliant. DIN 50049 3.1.B/EN 10204 3.1B(2004), DIN EN 10204 3.1(2005) compliant. For ABS grades only, Quality Assurance certificate 09-MMPQA-546

We hereby certify that the contents of this report are accurate and correct. All test results and operations performed by the material manufacturer are in compliance with the applicable specifications, including customer specifications.

T. A. Depretis
T. A. Depretis, Metallurgist

02/17/2011 4:22:21 PM

4

Quality Record

MM188078

Approved

22

GERDAU
CARTERSVILLE STEEL MILL
384 OLD GRASSDALE RD NE
CARTERSVILLE GA 30121 USA
(770) 387-3300

Chemical and Physical Test Report
Made and Melted In USA

G-193465

SHIP TO	INVOICE TO	SHIP DATE
O'NEAL STEEL INC ONE O'NEAL LN BOX 508, CHICKASAW BRANCH MOBILE, AL 36611	O'NEAL STEEL INC. ATTN: MIKE STANFORD PO BOX 2623 BIRMINGHAM, AL 35202-2623	02/09/12 **CUST. ACCOUNT NO** 36791606

PRODUCED IN: CARTERSVILLE

SHAPE + SIZE	GRADE	SPECIFICATION	SALES ORDER	CUST P.O. NUMBER
W8 X 24#	A57250/992	ASTM A572 GR50-07, ASTM A992-06A, ASTM A709 GR50-10	2703970-02	0719384-108

HEAT I.D.	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Nb	B	N	Sn	Al	Ti	Ca	Zn	C Eqv
G120015	.07	1.13	.013	.021	.28	.24	.08	.04	.018	.025	.001	.0000	.0090	.010	.000	.00100	.00400	.00200	.34

Mechanical Test: Yield 53800 PSI, 370.94 MPA Tensile: 70500 PSI, 486.08 MPA %El: 22.0/8in, 22.0/200MM
Customer Requirements CASTING: STRAND CAST
Comment: NO WELD REPAIRMENT PERFORMED. STEEL NOT EXPOSED TO MERCURY.
Mechanical Test: Yield 53700 PSI, 370.25 MPA Tensile: 70300 PSI, 484.7 MPA %El: 23.7/8in, 23.7/200MM
Customer Requirements CASTING: STRAND CAST
Comment: NO WELD REPAIRMENT PERFORMED. STEEL NOT EXPOSED TO MERCURY.
CUST ITEM NUMBER: 00878278

LEGS

3592

Wiltew
Accepted
Q.C. Dept.
Initials
Date 4.3.12

Customer Notes
NO WELD REPAIRMENT PERFORMED. STEEL NOT EXPOSED TO MERCURY.
All manufacturing processes including melt and cast, occurred in USA. MTR complies with EN10204 3.1B

SCS 4/12/12

THE ABOVE FIGURES ARE CERTIFIED CHEMICAL AND PHYSICAL TEST RECORDS AS CONTAINED IN THE PERMANENT RECORDS OF COMPANY.

Bhaskar Yalamanchili
Quality Director
Gerdau

Metallurgical Services Manager
CARTERSVILLE STEEL MILL

Seller warrants that all material furnished shall comply with specifications subject to standard published manufacturing variations. NO OTHER WARRANTIES, EXPRESSED OR IMPLIED, ARE MADE BY THE SELLER, AND SPECIFICALLY EXCLUDED ARE WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.
In no event shall seller be liable for indirect, consequential or punitive damages arising out of or related to the materials furnished by seller.
Any claim for damages for materials that do not conform to specifications must be made from buyer to seller immediately after delivery of same in order to allow the seller the opportunity to inspect the material in question.

Quality Record

MM188078

Approved

NUCOR
NUCOR STEEL TUSCALOOSA, INC.

MILL TEST CERTIFICATE

1700 HOLT RD N.E.
Tuscaloosa, AL 35404-1000
800-827-8872

Load Number	Tally	Mill Order Number	P.O. Number	Part Number	Certificate Number	Date
397626	00000000436194	N-109998-001	2278229 OP	807365	L353293-1	01/18/2012 20:51

Grade

Order Description:
A36, 0.7500 IN x 72.000 IN x 240.000 IN

Quality Plan Description:
A36/SA36/A70936: ASTM A36-08/ASME SA36-03/A709-36-10

Customer:

Sold TO:
ONEAL BIRMINGHAM AL

Ship TO:
O'NEAL BIRMINGHAM AL

Shipped Item	Heat/Slab Number	Certified By	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Cb	V	Al	Ti	N2	B	Ca	Sn	CEV
2A0711C	B2M5125-05 ***	B2M5125	0.19	0.89	0.012	0.005	0.04	0.20	0.05	0.06	0.018	0.000	0.001	0.031	0.001	0.010	0.0001	0.0017	0.008	0.38
2A0711D	B2M5125-05 ***	B2M5125	0.19	0.89	0.012	0.005	0.04	0.20	0.05	0.06	0.018	0.000	0.001	0.031	0.001	0.010	0.0001	0.0017	0.008	0.38
2A0711E	B2M5125-05 ***	B2M5125	0.19	0.89	0.012	0.005	0.04	0.20	0.05	0.06	0.018	0.000	0.001	0.031	0.001	0.010	0.0001	0.0017	0.008	0.38

Shipped Item	Certified By	Heat Number	Yield ksi	Tensile ksi	Y/T %	ELONGATION %		Bend OK?	Hard HB	Charpy Impacts (ft-lbf)					Shear %				Test Temp
						2"	8"			Size mm	1	2	3	Avg	1	2	3	Avg	
2A0711C	S2A0711FTT	B2M5125 ***	46.5	69.2	67.2	39.4													
2A0711C	S2A0711MTT	B2M5125 ***	46.3	66.0	70.2	38.7													
2A0711D	S2A0711FTT	B2M5125 ***	46.5	69.2	67.2	39.4													
2A0711D	S2A0711MTT	B2M5125 ***	46.3	66.0	70.2	38.7													
2A0711E	S2A0711FTT	B2M5125 ***	46.5	69.2	67.2	39.4													
2A0711E	S2A0711MTT	B2M5125 ***	46.3	66.0	70.2	38.7													

Items: 3 PCS: 12 Weight: 44105 LBS

Mercury has not come in contact with this product during the manufacturing process not has any mercury been used by the manufacturing process. Certified in accordance with EN 10204 3.1. No weld repair has been performed on this material. CERTIFIED IN ACCORDANCE WITH "EN 10204 3.1.B" Manufactured to a fully killed fine grain practice. NUTEMPER TEMPER PASSED plate from coil
ISO 9001:2008 Registered, PED Certified

We hereby certify that the product described above passed all of the tests required by the specifications.

April Pitts

April Pitts - QA Engineer

"***" indicates Heats melted and Manufactured in the U.S.A.

3592

LIFT LUG
TAIL LUG
Base Plates

Wiltew
Accepted
Q.C. Dept.
Initials
Date 4.4.12

SCS
4/12/12

Quality Record

MM188078

Approved

Approved

MM188078

NUCOR

NUCOR CORPORATION
NUCOR STEEL SOUTH CAROLINA

Mill Certification
1/12/2012

300 Steel Mill Road
DARLINGTON, SC 29540
(843) 393-5841
Fax: (843) 395-8701

Sold To: ONEAL STEEL INC
PO BOX 98
BIRMINGHAM, AL 35202
(205) 599-8000
Fax: (205) 599-8132

Ship To: ONEAL STEEL INC
2975 DUSS AVE
AMBRIDGE, PA 15003-0000
(724) 251-2023
Fax: (205) 599-8151

Customer P.O.	2279907	Sales Order	151292.26
Product Group	Merchant Bar Quality	Part Number	300020002403600
Grade	ASTM A36/A36M-08, A709/A709M-11 GR36, ASME SA36-07 Ed 09 Ad	Lot #	DL1110731303
Size	2" (2.0000) Round	Heat #	DL11107313
Product	2" (2.0000) Round 20 A36	B.L. Number	C1-570522
Description	A36	Load Number	C1-253548
Customer Spec		Customer Part #	00835489

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed above and that it satisfies those requirements.

C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Cb
0.18%	0.82%	0.014%	0.04%	0.22%	0.36%	0.09%	0.12%	0.020%	0.005%	0.003%

Yield 1: 47,000psi (324MPa) Tensile 1: 72000psi (496MPa) Elongation: 27% In 8"(% in 203.3mm)
Yield 2: 46,000psi (317MPa) Tensile 2: 71000psi (490MPa) Elongation 28% In 8"(% In 203.3mm)
Reduction Ratio 16 :1

1. WELDING OR WELD REPAIR WAS NOT PERFORMED ON THIS MATERIAL
2. MELTED AND MANUFACTURED IN THE USA
3. MERCURY, RADIUM, OR ALPHA SOURCE MATERIALS IN ANY FORM HAVE NOT BEEN USED IN THE PRODUCTION OF THIS MATERIAL

Davit ARM

3592

Wiltew
Accepted
Q.C. Dept.
Initials [signature]
Date 4.4.12

Quality Record

[signature] SCG 4/12/12

[signature]
James H. Blew
Division Metallurgist

NBMG-10 January 1, 2012

08Mar12 7:47 T E S T C E R T I F I C A T E No: PC 126101

13

Sold By:
CARGILL STEEL SERVICE CENTERS
DEPARTMENT OF CARGILL, INCORPORATED
1800 INDUSTRIAL DR
PANAMA CITY FL 32405-6029
Tel: 850-784-6721 Fax: 850 784-9472

P/O No SEE LINE ITEMS
Rel MOBILE
S/O No PC 54974-003
B/L No PC 52056-003 Shp 08Mar12
Inv No Inv

Sold To: (20234)
ONEAL STEEL INC
PO BOX 98
BIRMINGHAM AL 35202

Ship To: (10)
O'NEAL STEEL INC
ONE O'NEAL LANE
CHICKASAW AL 36611

Tel: 205-599-8000 Fax: 205 599-8131

CERTIFICATE of ANALYSIS and TESTS Cert. No: PC 126101
08Mar12

Part No 2284149/805538
HR PLATE SHEET ASTMA-36/ASME SA-36
1/2 X 72.0000" X 240.0000"

		Pcs	Wgt
		8	19,604
Heat Number	Tag No	Pcs	Wgt
37760C	841692 YIELD=42.6-46.6/TENS=75.5-76/ELONG=33/MILL=<USS> VESSL=<NYC608742>/MELT=<USA>/MFG=<USA>	4	9,802
37760C	841693 YIELD=42.6-46.6/TENS=75.5-76/ELONG=33/MILL=<USS> VESSL=<NYC608742>/MELT=<USA>/MFG=<USA>	4	9,802

Heat Number *** Chemical Analysis ***
37760C *=<*> C=0.2500 Mn=1.0300 P=0.0090 S=0.0080 Si=0.0150 Cu=0.0400
Al=0.0470 Ti=0.0010 Cb=0.0020 Cr=0.0500 Ni=0.0200 B=0.0003
N=0.0040

ELEMENTS NOT LISTED TEST BELOW DETECTABLE LEVELS
ALL ASTM PLATE PRODUCTS ARE PRODUCED FROM COIL

THIS IS TO CERTIFY THAT THE PRODUCT DESCRIBED
HEREIN WAS SAMPLED AND TESTED IN ACCORDANCE
WITH THE SPECIFICATION, TO OUR KNOWLEDGE,
AND FULFILLS REQUIREMENTS IN SUCH RESPECT.

3592 Davit Arm assembly

Wiltew
Accepted
Q.C. Dept.
Initials
Date 4.4.12

REND
SCO
4/12/12

Quality Record

MM188078

Approved

15Mar12 14:39 T E S T C E R T I F I C A T E No: PC 126413

12

Sold By:
CARGILL STEEL SERVICE CENTERS
DEPARTMENT OF CARGILL, INCORPORATED
1800 INDUSTRIAL DR
PANAMA CITY FL 32405-6029
Tel: 850-784-6721 Fax: 850 784-9472

P/O No SEE ITEMS
Rel MOBILE
S/O No PC 55044-004
B/L No PC 52133-004 Shp 15Mar12
Inv No Inv

Sold To: (20234)
ONEAL STEEL INC
PO BOX 98
BIRMINGHAM AL 35202

Ship To: (10)
O'NEAL STEEL INC
ONE O'NEAL LANE
CHICKASAW AL 36611

Tel: 205-599-8000 Fax: 205 599-8131

CERTIFICATE of ANALYSIS and TESTS Cert. No: PC 126413
15Mar12

Part No 2286727-800201
HR PLATE SHEET ASTMA-36/ASME SA-36
1/4 X 72.0000" X 240.0000"

		Pcs	Wgt
		12	14,702

Heat Number	Tag No	Pcs	Wgt
049897	841994	6	7,351
	YIELD=47.6/TENS=74.5/ELONG=30.9/MILL=<THYSSENKRU> VESSL=<LTD224>/CNTRY=<USA>		
049897	841995	6	7,351
	YIELD=47.6/TENS=74.5/ELONG=30.9/MILL=<THYSSENKRU> VESSL=<LTD224>/CNTRY=<USA>		

Heat Number *** Chemical Analysis ***
049897 *=<*> C=0.2020 Mn=0.8810 P=0.0130 S=0.0061 Si=0.0190 Cu=0.0180
Al=0.0500 Ti=0.0010 V=0.0030 Mo=0.0010 Cr=0.0230 Ni=0.0130
B=0.0001 N=0.0041

ELEMENTS NOT LISTED TEST BELOW DETECTABLE LEVELS
ALL ASTM PLATE PRODUCTS ARE PRODUCED FROM COIL

THIS IS TO CERTIFY THAT THE PRODUCT DESCRIBED
HEREIN WAS SAMPLED AND TESTED IN ACCORDANCE
WITH THE SPECIFICATION, TO OUR KNOWLEDGE,
AND FULFILLS REQUIREMENTS IN SUCH RESPECT.

3592 Davit ARM assembly

Wiltew
Accepted
Q.C. Dept.
Initials
Date 4.4.12

REm SCS 4/12/12

Page: 1 .... Last

Quality Record

MM188078

Approved

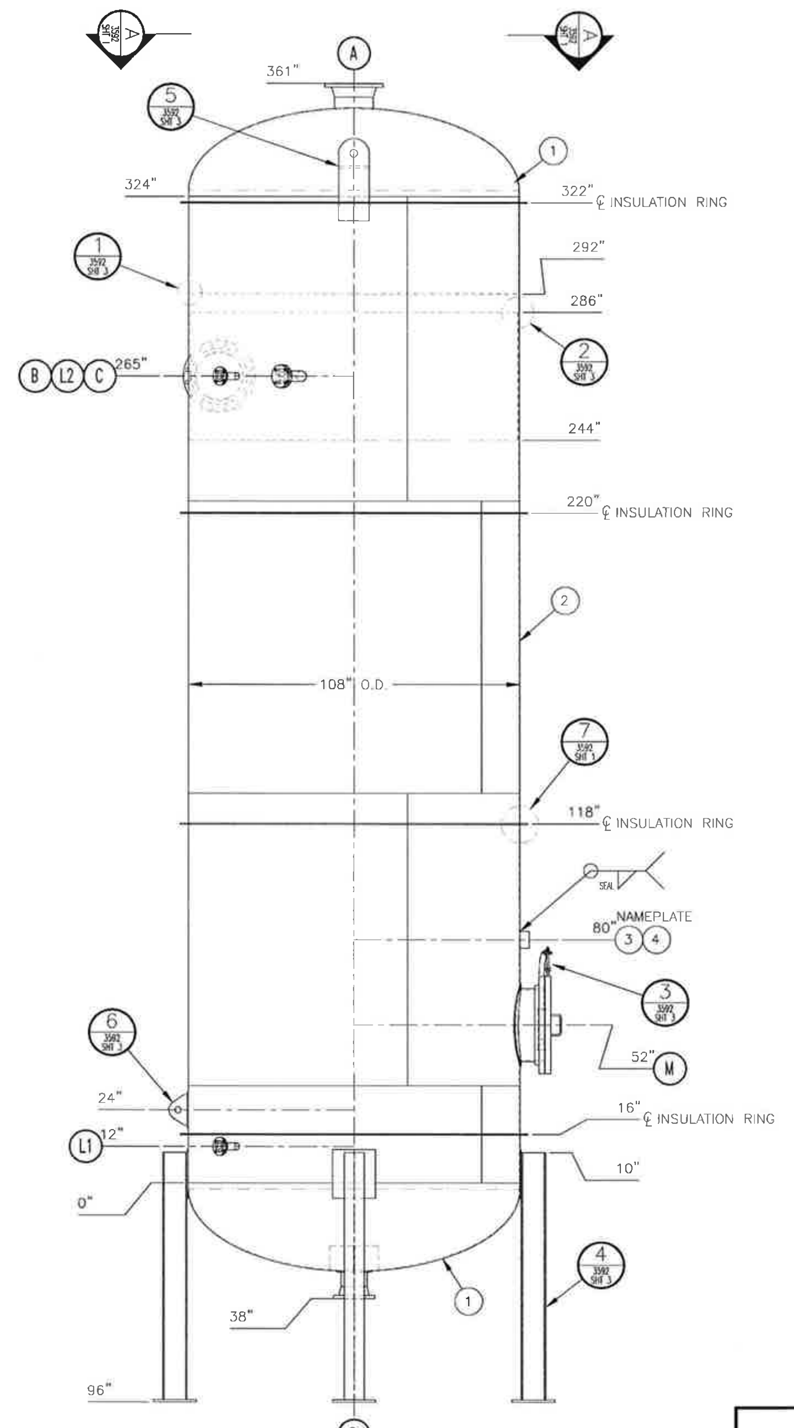
WILTEW

Document Title: 3592 UA-DR-0091 IP Condensate Drum Documentation Package
Document #: CDP-3592-35
Vendor: JWWTEW, LLC dba Wiltew
SoCo PO# MPC 10037829
SoCo Project: Kemper County IGCC Unit 1

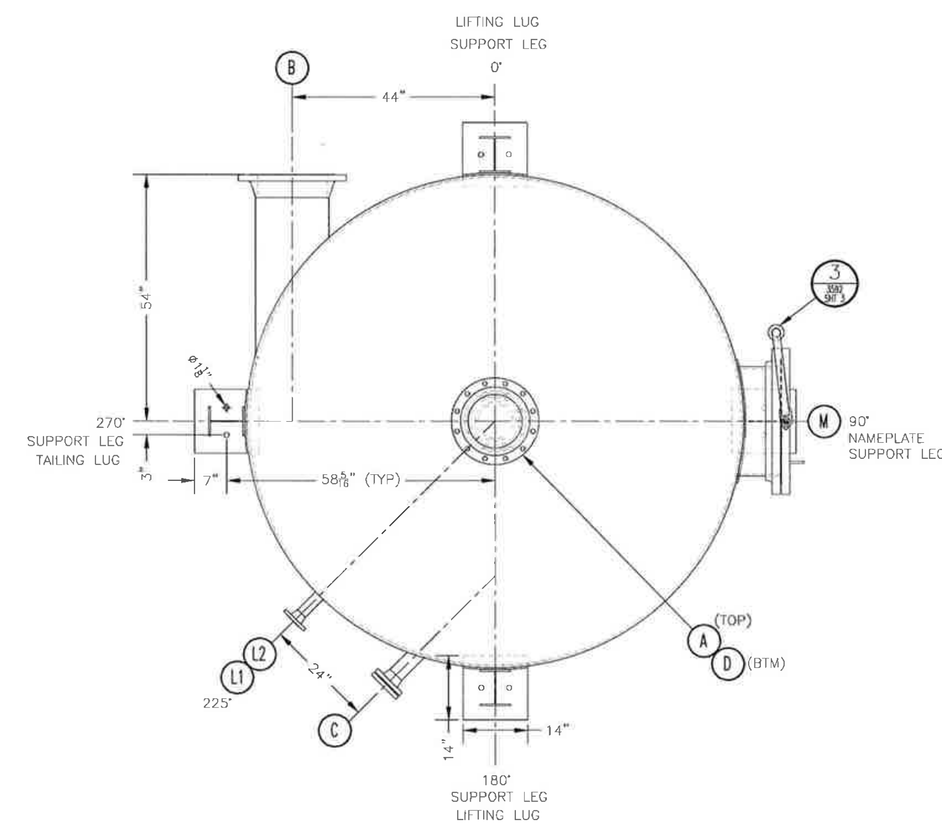
UA-DR-0091 IP Condensate Drum

Documentation Package

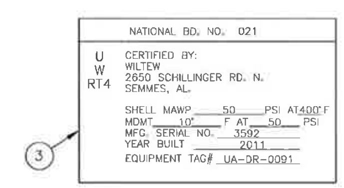
AS-BUILT DRAWINGS



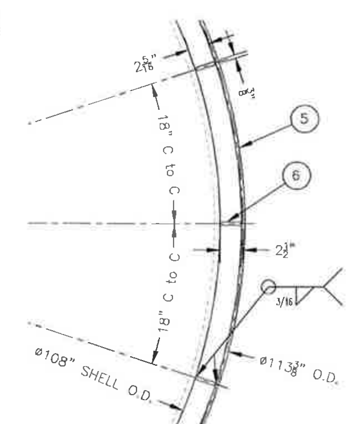
ELEVATION
SCALE: 1 1/2" = 1'-0"



A VIEW – NOZZLE ORIENTATION
SCALE: 1 1/2" = 1'-0"
NOTE: INSULATION RINGS NOT SHOWN FOR CLARITY



N.B. NAMEPLATE
SCALE: NTS
NOTE: 3" STANDOFF



7 INSULATION FABRICATION DETAILS
SCALE: 1 1/2" = 1'-0"
NOTE: DIMENSIONS ARE TYPICAL

DESIGN DATA

DESIGN CODE: ASME SECTION VIII, DIV. 1

DESIGN CONDITIONS	SHELL SIDE
MAX. ALLOW. INT. WORKING PRESSURE	50 PSIG
MAX. ALLOW. EXT. WORKING PRESSURE	NONE
DESIGN TEMPERATURE	400°F
TEST PRESSURE(HYDROSTATIC)	65 PSIG
CORROSION ALLOWANCE	.125"
RADIOGRAPHY (RT)	SPOT
LIQUID PENETRANT EXAMINATION (PT)	N/A
POST WELD HEAT TREAT	N/A
STAMP	"U"

SURFACE PREP & PAINTING–EXTERIOR: "LATER"

WEIGHT: 17500 #EMPTY 135601 #FLOODED

MATERIALS:

SHELL: SA-516 GR70	BODY FLG'S: N/A
NOZ. FLG'S. SA-105	BOLTING: SA-193 B7/SA-194 2H
GASKETS: "LATER"	STIFFENERS: N/A
SUPPORTS: C.S.	HEADS: SA-516 GR70
INTERNALS: N/A	

NOTES:
1. PROTECT ALL STAINLESS STEEL SURFACES TO AVOID CARBON CONTAMINATION.
2. ALL FLANGE BOLT HOLES TO STRADDLE VESSEL CENTERLINES.
3. PROTECT ALL OPENINGS FOR SHIPMENT.
4. ALL REINFORCING PADS TO HAVE A ¼" NPT TEST TAP.
5. REMOVE ALL BURRS, WELD SPATTERS, AND SHARP EDGES.

ITEM	QTY	DESCRIPTION	MATERIAL	HEAT No.
1	2	HEAD, 3/8" MIN THK X 108" O.D. W/ 2" S.F., 2:1 ELLIPTICAL HEAD	SA-516 GR70	
2	1	PL., 3/8" THK X 108" O.D. X 324" LONG, SHELL	SA-516 GR70	
3	1	NB NP, STANDARD NATIONAL BOARD NAMEPLATE, W/ 3" STAND OFF	S.S.	
4	1	NP BRKT, STANDARD NAMEPLATE BRACKET, W/ 3" STAND OFF	S.S.	
5	4	RB., 3/8" DIA ROLLED TO 113-3/8" O.D. INSULATION RING	SA-36	
6	80	RB., 3/8" DIA X 2-5/16"(REF) INSULATION RING STAND OFF	SA-36	

NOZZLE SCHEDULE

					THICKNESS/SCHEDULE				REPAD	MATERIAL					PROJ.	
NOZ	SIZE	QTY	TYPE	RATING	NECK	FLANGE	F.R./STUB	REPAD	O.D./WIDTH	NECK	FLANGE	F.R./STUB	REPAD	HEAT No.	FROM O.D.	SERVICE
A	12"	1	RFWN	150#	XH(.500")	XH BORE	–	–	–	SA-106 B	SA-105	–	–		SEE DETAIL	LP STEAM OUTLET
B	16"	1	RFWN	150#	STD(.375")	STD BORE	–	–	–	SA-106 B	SA-105	–	–		SEE DETAIL	IP CONDENSATE INLET
C	3"	1	RFWN	150#	80(.300")	80 BORE	–	–	–	SA-106 B	SA-105	–	–		8"	INITIAL FILL INLET
D	8"	1	RFWN	150#	80(.500")	80 BORE	–	.375"	11.625" O.D.	SA-106 B	SA-105	–	SA-516 GR70		SEE DETAIL	LP CONDENSATE OUTLET
L1	2"	1	RFWN	150#	160(.344")	160 BORE	–	–	–	SA-106 B	SA-105	–	–		8"	LEVEL
L2	2"	1	RFWN	150#	160(.344")	160 BORE	–	–	–	SA-106 B	SA-105	–	–		8"	LEVEL
M	24"	1	RFSO	150#	.500"	STD	–	.375"	27" O.D.	SA-516 GR70	SA-105	–	SA-516 GR70		8"	MANWAY W/ HINGED COVER

No	DESCRIPTION	BY	DATE
3	AS BUILT	GAM	6/1/2012
2	ADDED INSULATION RING DETAILS	GAM	3/14/2012
1	REVISED PER CUSTOMER COMMENTS	GAM	11/04/2011
0	FOR APPROVAL	GAM	08/30/2011

REVISIONS

WILTEW
2650 SCHILLINGER RD N.
SEMMES, AL 36575

108" O.D. IP CONDENSATE DRUM ELEVATION, NOZZLE ORIENTATION, AND FABRICATION DETAILS

SOUTHERN COMPANY

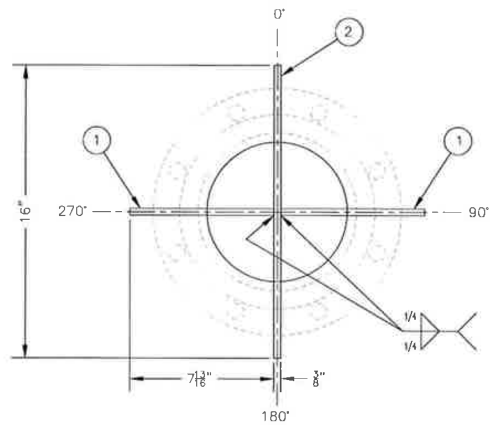
JOB No.	DRAWING No.	SHEET	REV.
3592	3592	1/3	3
SCALE: AS NOTED	DRAWN BY: GAM	DATE: 08/30/2011	
SOUTHERN COMPANY TAG#: 01G-UA-DR-0091	PO#: MPC10037829		

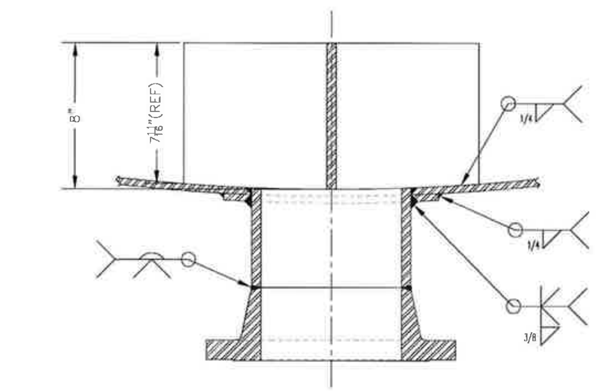
Quality Record

Approved

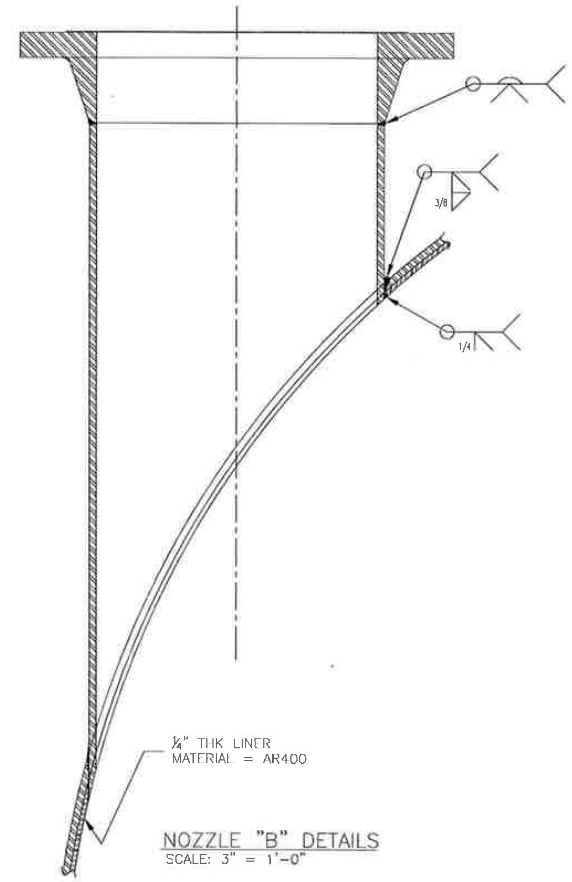
MM188078

ITEM	QTY	DESCRIPTION	MATERIAL	HEAT No.
1	2	PL., 3/8" THK X 7 13/16" X 8" VORTEX BREAKER	SA-36	
2	1	PL., 3/8" THK X 8" X 16" VORTEX BREAKER	SA-36	
3	1	BLIND FLANGE, 24" 150# BLIND FLANGE FOR MANWAY COVER	SA-105	
4	1	GASKET, 1/8" THK 24" 150# FLANGE GASKET	GARLOCK	
5	20	STUDS, 1 1/4" DIA X 7 1/2" LONG @ MANWAY COVER	SA-193 B7	
6	40	NUTS, 1 1/4" HVY HEX NUTS @ MANWAY COVER	SA-194 2H	
7	1	BLIND FLANGE, 3" 150# BLIND FLANGE FOR MANWAY COVER	SA-105	
8	1	GASKET, 1/8" THK 3" 150# FLANGE GASKET	GARLOCK	
9	4	STUDS, 5/8" DIA X 4" LONG @ MANWAY COVER	SA-193 B7	
10	8	NUTS, 5/8" HVY HEX NUTS @ MANWAY COVER	SA-194 2H	
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

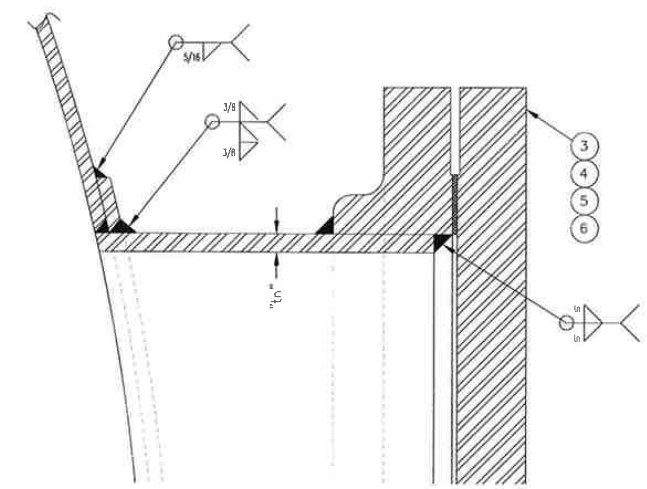




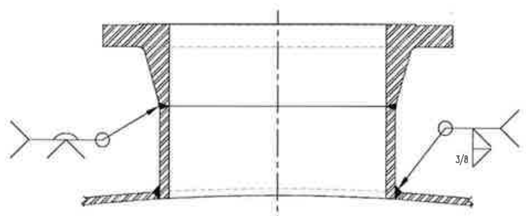
NOZZLE "D" & VORTEX BREAKER DETAILS
SCALE: 3" = 1'-0"



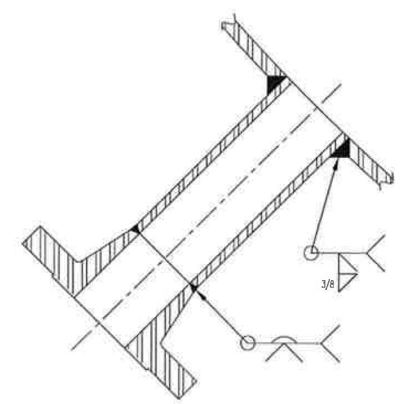
NOZZLE "B" DETAILS
SCALE: 3" = 1'-0"



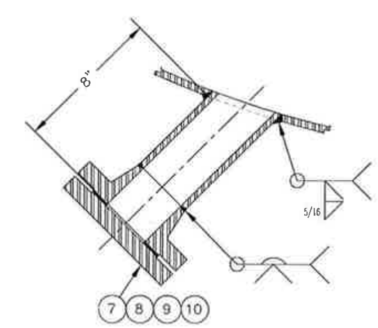
NOZZLE "M" – MANWAY DETAILS
SCALE: 6" = 1'-0"
NOTE: SEE SHEET 3 FOR MANWAY DAVIT DETAILS



NOZZLE "A" DETAILS
SCALE: 3" = 1'-0"



NOZZLE "L1" & "L2" DETAILS
SCALE: 3" = 1'-0"



NOZZLE "C" DETAILS
SCALE: 3" = 1'-0"

No.	DESCRIPTION	BY	DATE
1	AS BUILT	GAM	06/1/12
0	FOR APPROVAL	GAM	08/30/2011

REVISIONS

WILTEW
2650 SCHILLINGER RD N.
SEMMES, AL. 36575

108" O.D. IP CONDENSATE DRUM
NOZZLE FABRICATION DETAILS
AND VORTEX BREAKER DETAILS
SOUTHERN COMPANY

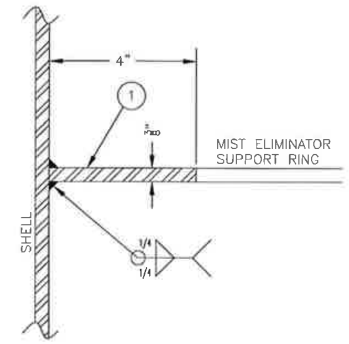
JOB No.	DRAWING No.	SHEET	REV.
3592	3592	2/3	1
SCALE: AS NOTED	DRAWN BY: GAM	DATE: 08/30/2011	
SOUTHERN COMPANY TAG#: 01G-UA-DR-0091	PO#: MPC10037829		

Quality Record

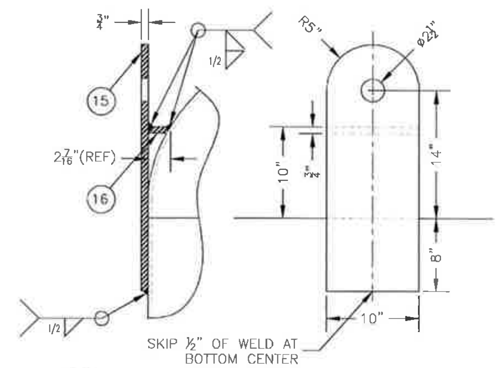
Approved

MM188078

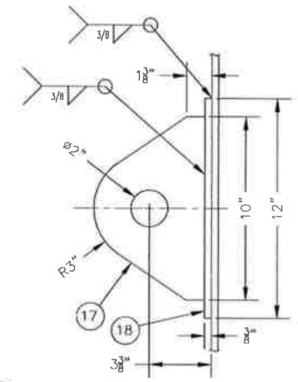
ITEM	QTY	DESCRIPTION	MATERIAL	HEAT No.
1	1	PL., 3/8" THK X 107 1/4" O.D. X 99 1/4" I.D. SUPPORT RING	SA-36	
2	1	PL., 1/4" THK X 107 1/4" O.D. X 42" TALL, LINER	AR-400	
3	4	PL., 3/8" THK X 14" X 16" SUPPORT LEG REPAD	SA-36	
4	4	BEAM, W8x24 X 105 1/4" LONG SUPPORT LEGS	SA-36	
5	4	PL., 3/4" THK X 14" X 14" BASE PLATE	SA-36	
6	1	PL.,1/2" THK X 3" WIDE X 4 3/4" LONG	SA-36	
7	1	RB., 5/8" DIA X 12" LONG	SA-36	
8	1	EYE-BOLT, 5/8" DIA X 7 1/8" LONG	SA-36	
9	1	RB., 5/8" DIA X 6" LONG	SA-36	
10	1	RB., 2" DIA X 46" LONG	SA-36	
11	1	PL.,1/2" THK X 2 5/16" WIDE X 8" LONG	SA-36	
12	2	PL., 1/4" THK X 4" O.D. X 2 1/8" I.D.	SA-36	
13	1	PIPE, 2" SCH 40 X 9" LONG	SA-106 B	
14	1	COTTER PIN, 1/8" DIA	S.S.	
15	2	PL., 3/4" THK X 10" X 27" LONG LIFTING LUG	SA-36	
16	2	PL., 3/4" THK X 2 7/16"(REF) X 10" BRACE PLATE	SA-36	
17	1	PL., 3/4" THK X 6 3/8" X 10"	SA-36	
18	1	PL., 3/8" THK X 4" X 12" BRACE PLATE	SA-36	
19				
20				



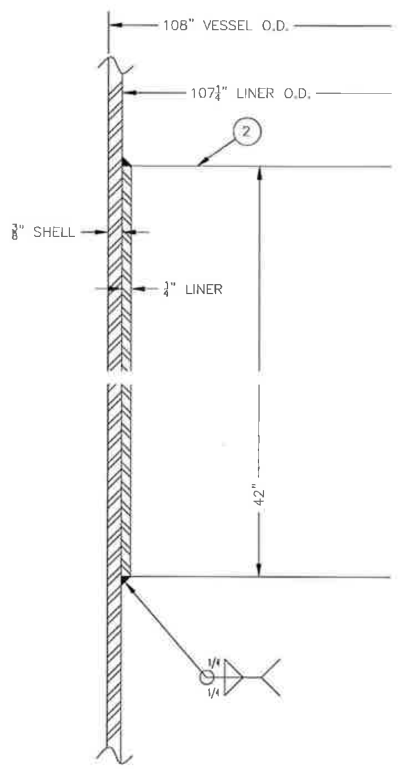
1 INTERNAL SUPPORT RING DETAILS
SCALE: 6" = 1'-0"
NOTE: SEE ELEVATION FOR LOCATION OF RING



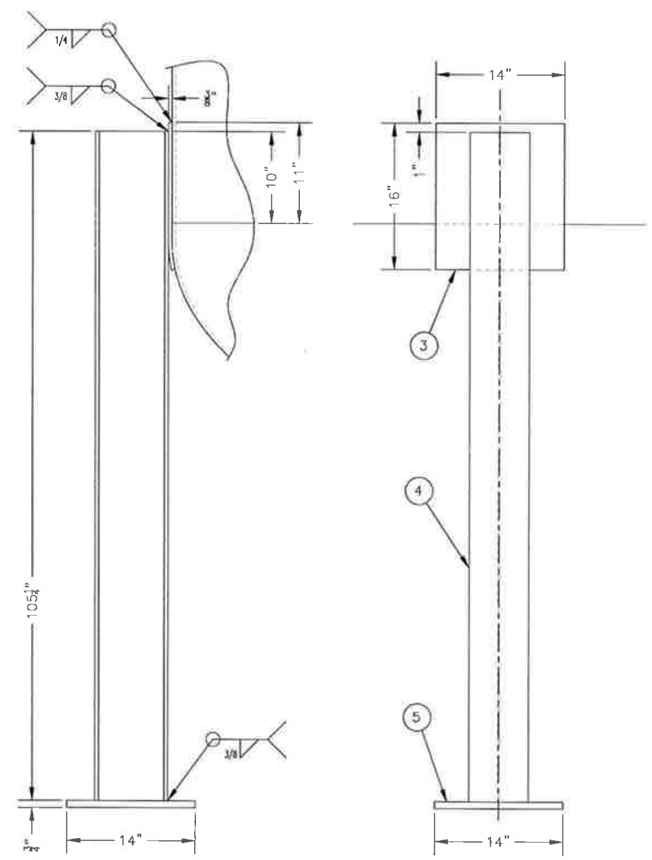
5 LIFTING LUG FABRICATION DETAILS
SCALE: 6" = 1'-0"



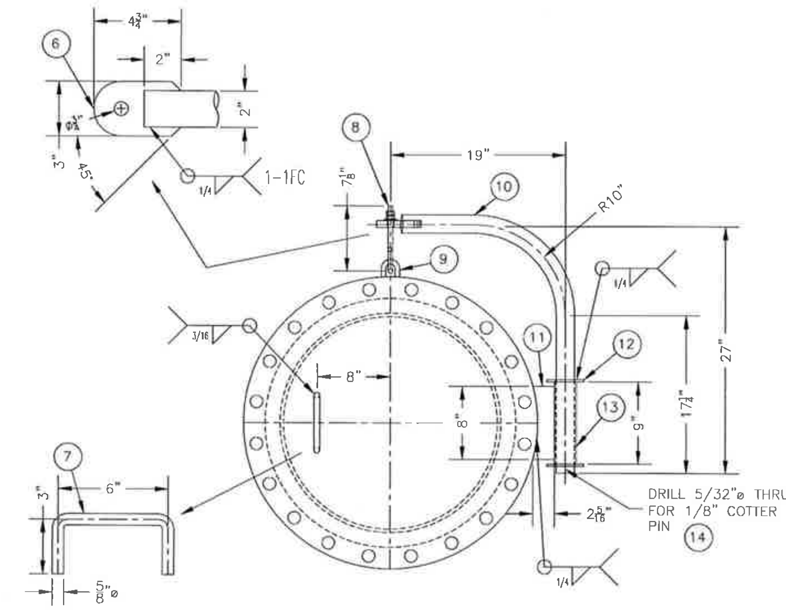
6 TAILING LUG FABRICATION DETAILS
SCALE: 3" = 1'-0"



2 INTERNAL LINER FABRICATION DETAILS
SCALE: 6" = 1'-0"
NOTE: SEE SHEET 1, ELEVATION FOR LOCATION OF LINER



4 SUPPORT LEG FABRICATION DETAILS
SCALE: 1 1/2" = 1'-0"
NOTE: SEE SHEET 1, ORIENTATION FOR LOCATION OF LEGS



3 MANWAY DAVIT ARM FABRICATION DETAILS
SCALE: 6" = 1'-0"
NOTE: SEE SHEET 1, ORIENTATION FOR LOCATION OF DAVIT

No.	DESCRIPTION	BY	DATE
2	AS BUILT	GAM	6/1/2012
1	REVISED SUPPORT LEG LENGTH	GAM	11/04/2011
0	FOR APPROVAL	GAM	08/30/2011

REVISIONS

WILTEW
2650 SCHILLINGER RD N.
SEMMES, AL 36575

108" O.D. IP CONDENSATE DRUM
INTERNAL LINER, LIFTING LUGS,
SUPPORT LEGS, & MISC. DETAILS
SOUTHERN COMPANY

JOB No.	DRAWING No.	SHEET	REV.
3592	3592	3/3	2
SCALE: AS NOTED	DRAWN BY GAM	DATE 08/30/2011	
SOUTHERN COMPANY TAG# 01G-UA-DR-0091	PO# MPC10037829		

Quality Record

Approved

WILTEW

Document Title: 3592 UA-DR-0091 IP Condensate Drum Documentation Package
Document #: CDP-3592-35
Vendor: JWWTEW, LLC dba Wiltew
SoCo PO# MPC 10037829
SoCo Project: Kemper County IGCC Unit 1

UA-DR-0091 IP Condensate Drum

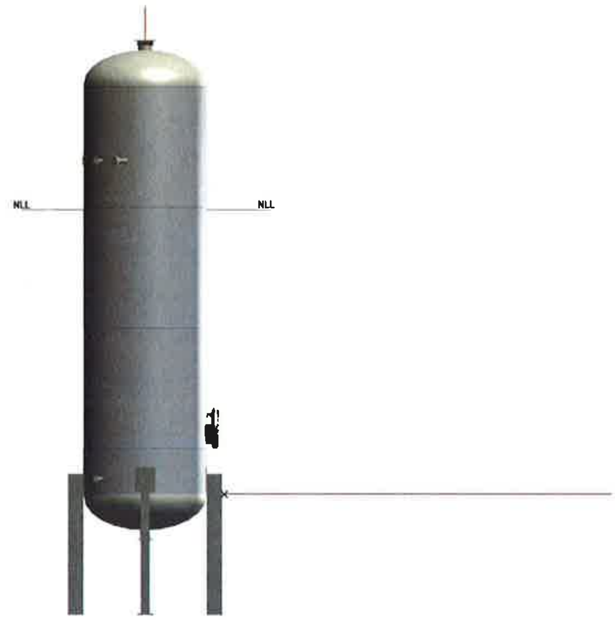
Documentation Package

CODE CALCULATIONS

FMS Engineering, LLC

2509 Commercial Park Dr.

Mobile, AL 36606



COMPRESS Pressure Vessel Design Calculations

Item no.: UA-DR-0091
Customer: Wiltew
Job No.: 3592
Contract: 11089
Designer: D Roberts
Date: May 31, 2011

Wiltew
Accepted
Q.C. Dept.
Initials [illegible]
Date 5/31/11

ALABAMA
LICENSED
No. 30879
PROFESSIONAL
ENGINEER
DAVID J. ROBERTS

David J. Roberts
2011.06.29 08:35:31 -05'00'

R. Hill
OBAI
3-15-12

Quality
Record

MM188078

Approved

Deficiencies Summary

No deficiencies found.

Nozzle Schedule

Nozzle mark	Service	Size	Materials								
			Nozzle	Impact	Norm	Fine Grain	Pad	Impact	Norm	Fine Grain	Flange
A	Nozzle A	NPS 12 X Heavy	SA-106 B Smls pipe	No	No	No	SA-516 70	No	No	No	WN A105 Class 150
B	Nozzle B	NPS 16 Sch 40 (XS)	SA-106 B Smls pipe	No	No	No	N/A	N/A	N/A	N/A	WN A105 Class 150
C	Nozzle C	NPS 3 Sch 80 (XS)	SA-106 B Smls pipe	No	No	No	N/A	N/A	N/A	N/A	WN A105 Class 150
D	Nozzle D	NPS 8 Sch 80 (XS)	SA-106 B Smls pipe	No	No	No	SA-516 70	No	No	No	WN A105 Class 150
L1	Nozzle L1	NPS 2 Sch 160	SA-106 B Smls pipe	No	No	No	N/A	N/A	N/A	N/A	WN A105 Class 150
L2	Nozzle L2	NPS 2 Sch 80 (XS)	SA-106 B Smls pipe	No	No	No	N/A	N/A	N/A	N/A	WN A105 Class 150
M	Nozzle M	24.00 IDx0.50	SA-516 70	No	No	No	SA-516 70	No	No	No	SO A516 70 Class 150

Nozzle Summary

Nozzle mark	OD (in)	t_n (in)	Req t_n (in)	A_1?	A_2?	Shell			Reinforcement Pad		Corr (in)	A_a/A_r (%)
						Nom t (in)	Design t (in)	User t (in)	Width (in)	t_{pad} (in)		
A	12.75	0.5	0.3377	Yes	Yes	0.283*	0.2788		2	0.375	0.125	100.0
B	16	0.5	0.3033	Yes	Yes	0.375	0.2145		N/A	N/A	0.125	100.0
C	3.5	0.3	0.216	Yes	Yes	0.375	N/A		N/A	N/A	0	Exempt
D	8.625	0.5	0.3898	Yes	Yes	0.32*	0.3096		2	0.375	0.125	100.0
L1	2.375	0.344	0.2969	Yes	Yes	0.375	N/A		N/A	N/A	0.125	Exempt
L2	2.375	0.218	0.154	Yes	Yes	0.375	N/A		N/A	N/A	0	Exempt
M	25	0.5	0.2942	Yes	Yes	0.375	0.2411		2	0.375	0.125	100.0

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

Pressure Summary

Pressure Summary for Chamber bounded by Ellipsoidal Head #2 and Ellipsoidal Head #1

Identifier	P Design (psi)	T Design (°F)	MAWP (psi)	MAP (psi)	MDMT (°F)	MDMT Exemption		Impact Tested
Ellipsoidal Head #1	50	400	50.03	89.51	-55	Note 1		No
Straight Flange on Ellipsoidal Head #1	50	400	78.85	118.38	-55	Note 2		No
Cylinder #1	50	400	78.85	118.38	-55	Note 2		No
Cylinder #2	50	400	75.46	118.38	-55	Note 3		No
Cylinder #3	50	400	71.99	118.38	-55	Note 4		No
Cylinder #4	50	400	70.69	118.38	-55	Note 5		No
Straight Flange on Ellipsoidal Head #2	50	400	70.62	118.38	-55	Note 7		No
Ellipsoidal Head #2	50	400	52.58	101.28	-55	Note 6		No
Legs #1	50	400	50	N/A	N/A	N/A		N/A
Nozzle A (A)	50	400	63.53	97.02	-43.4	Nozzle	Note 8	No
						Pad	Note 9	No
Nozzle B (B)	50	400	52.04	79.58	-55	Note 10		No
Nozzle C (C)	50	400	92.76	139.27	-55	Note 11		No
Nozzle D (D)	50	400	71.08	127.72	-46.1	Nozzle	Note 12	No
						Pad	Note 13	No
Nozzle L1 (L1)	50	400	85.01	139.27	-55	Note 14		No
Nozzle L2 (L2)	50	400	92.76	139.27	-55	Note 15		No
Nozzle M (M)	50	400	56.03	89.47	-55	Nozzle	Note 16	No
						Pad	Note 17	No

Chamber design MDMT is 10 °F
Chamber rated MDMT is -43.4 °F @ 50 psi

Chamber MAWP hot & corroded is 50 psi @ 400 °F

Chamber MAP cold & new is 79.58 psi @ 70 °F

This pressure chamber is not designed for external pressure.

Notes for MDMT Rating:

Note #	Exemption	Details
1.	Straight Flange governs MDMT	
2.	Material impact test exemption temperature from Fig UCS-66 Curve B = -20 °F Fig UCS-66.1 MDMT reduction = 50.3 °F, (coincident ratio = 0.5393655) Rated MDMT is governed by UCS-66(b)(2)	UCS-66 governing thickness = 0.375 in
3.	Material impact test exemption temperature from Fig UCS-66 Curve B = -20 °F Fig UCS-66.1 MDMT reduction = 43.4 °F, (coincident ratio = 0.5759223) Rated MDMT is governed by UCS-66(b)(2)	UCS-66 governing thickness = 0.375 in
4.	Material impact test exemption temperature from Fig UCS-66 Curve B = -20 °F Fig UCS-66.1 MDMT reduction = 38.7 °F, (coincident ratio = 0.6132509) Rated MDMT is governed by UCS-66(b)(2)	UCS-66 governing thickness = 0.375 in
5.	Material impact test exemption temperature from Fig UCS-66 Curve B = -20 °F Fig UCS-66.1 MDMT reduction = 37.3 °F, (coincident ratio = 0.6272475) Rated MDMT is governed by UCS-66(b)(2)	UCS-66 governing thickness = 0.375 in

6.	Straight Flange governs MDMT	
7.	Material impact test exemption temperature from Fig UCS-66 Curve B = -20 °F Fig UCS-66.1 MDMT reduction = 37.2 °F, (coincident ratio = 0.6280251) Rated MDMT is governed by UCS-66(b)(2)	UCS-66 governing thickness = 0.375 in
8.	Nozzle impact test exemption temperature from Fig UCS-66 Curve B = -20 °F Fig UCS-66.1 MDMT reduction = 23.4 °F, (coincident ratio = 0.76646)	UCS-66 governing thickness = 0.375 in.
9.	Pad impact test exemption temperature from Fig UCS-66 Curve B = -20 °F Fig UCS-66.1 MDMT reduction = 23.4 °F, (coincident ratio = 0.76646)	UCS-66 governing thickness = 0.375 in.
10.	Nozzle impact test exemption temperature from Fig UCS-66 Curve B = -20 °F Fig UCS-66.1 MDMT reduction = 50.3 °F, (coincident ratio = 0.53948) Rated MDMT is governed by UCS-66(b)(2)	UCS-66 governing thickness = 0.375 in.
11.	Nozzle impact test exemption temperature from Fig UCS-66 Curve B = -20 °F Fig UCS-66.1 MDMT reduction = 50.3 °F, (coincident ratio = 0.53948) Rated MDMT is governed by UCS-66(b)(2)	UCS-66 governing thickness = 0.2625 in.
12.	Nozzle impact test exemption temperature from Fig UCS-66 Curve B = -20 °F Fig UCS-66.1 MDMT reduction = 26.1 °F, (coincident ratio = 0.73862)	UCS-66 governing thickness = 0.375 in.
13.	Pad impact test exemption temperature from Fig UCS-66 Curve B = -20 °F Fig UCS-66.1 MDMT reduction = 26.1 °F, (coincident ratio = 0.73862)	UCS-66 governing thickness = 0.375 in.
14.	Flange rating governs: Flange rated MDMT = -155 °F Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F	UCS-66(b)(3): Coincident ratio = 0.2025432
15.	Flange rating governs: Flange rated MDMT = -155 °F Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F	UCS-66(b)(3): Coincident ratio = 0.1754386
16.	Nozzle impact test exemption temperature from Fig UCS-66 Curve B = -20 °F Fig UCS-66.1 MDMT reduction = 38.8 °F, (coincident ratio = 0.6118) Rated MDMT is governed by UCS-66(b)(2)	UCS-66 governing thickness = 0.375 in.
17.	Pad impact test exemption temperature from Fig UCS-66 Curve B = -20 °F Fig UCS-66.1 MDMT reduction = 38.8 °F, (coincident ratio = 0.6118) Rated MDMT is governed by UCS-66(b)(2)	UCS-66 governing thickness = 0.375 in.

Design notes are available on the Settings Summary page.

Revision History

No.	Date	Operator	Notes
0	5/27/2011	droberts	New vessel created ASME Section VIII Division 1 [COMPRESS Build 7110]
1	6/29/2011	droberts	Revised Leg length from 76 to 112", Enlarged repad from 18"x16" to 20"x18"

Settings Summary

COMPRESS Build 7110

Units: U.S. Customary

Datum Line Location: 0.00" from bottom seam

Design

ASME Section VIII Division 1, 2010 Edition

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, find nozzle MAWP and MAP
Corrosion weight loss:	100% of theoretical loss
UG-23 Stress Increase:	1.20
Skirt/legs stress increase:	1.0
Minimum nozzle projection:	6"
Juncture calculations for α > 30 only:	Yes
Preheat P-No 1 Materials > 1.25&#34 and <= 1.50" thick:	No
UG-37(a) shell tr calculation considers longitudinal stress:	No

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

Hydro/Pneumatic Test

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

Required Marking - UG-116

UG-116(e) Radiography:	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):	No
UG-22(d)(2) Vessel supports such as lugs, rings, skirts, saddles and legs:	Yes
UG-22(f) Wind reactions:	Yes
UG-22(f) Seismic reactions:	Yes
UG-22(j) Test pressure and coincident static head acting during the test:	No

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

Thickness Summary

Component Identifier	Material	Diameter (in)	Length (in)	Nominal t (in)	Design t (in)	Total Corrosion (in)	Joint E	Load
Ellipsoidal Head #1	SA-516 70	108 OD	27.1415	0.283*	0.283	0.125	0.85	Internal
Straight Flange on Ellipsoidal Head #1	SA-516 70	108 OD	2	0.375	0.2837	0.125	0.85	Internal
Cylinder #1	SA-516 70	108 OD	96	0.375	0.2837	0.125	0.85	Internal
Cylinder #2	SA-516 70	108 OD	96	0.375	0.2944	0.125	0.85	Internal
Cylinder #3	SA-516 70	108 OD	96	0.375	0.3054	0.125	0.85	Internal
Cylinder #4	SA-516 70	108 OD	36	0.375	0.3095	0.125	0.85	Internal
Straight Flange on Ellipsoidal Head #2	SA-516 70	108 OD	2	0.375	0.3098	0.125	0.85	Internal
Ellipsoidal Head #2	SA-516 70	108 OD	27.16	0.32*	0.3119	0.125	0.85	Internal

Nominal t: Vessel wall nominal thickness

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

Joint E: Longitudinal seam joint efficiency

* Head minimum thickness after forming

Load

internal: Circumferential stress due to internal pressure governs

external: External pressure governs

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

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

Weight Summary

Component	Weight (lb) Contributed by Vessel Elements							Surface Area ft²
	Metal New*	Metal Corroded*	Insulation & Supports	Lining	Piping + Liquid	Operating Liquid	Test Liquid	
Ellipsoidal Head #1	1,133.4	642.3	0	0	0	0	6,524.5	102
Cylinder #1	3,421.9	2,283.9	0	0	0	0	31,473.1	225
Cylinder #2	3,444.7	2,299.1	0	0	0	30,796.9	31,306	226
Cylinder #3	3,392.6	2,264.4	0	0	0	31,577.2	31,428.5	223
Cylinder #4	1,291.3	861.9	0	0	0	11,795.1	11,740.2	85
Ellipsoidal Head #2	1,277.8	785	0	0	0	6,550	6,505.6	102
Legs #1	1,972.2	1,972.2	0	0	0	0	0	188
TOTAL:	**15,933.9**	**11,108.8**	**0**	**0**	**0**	**80,719.3**	**118,978**	**1,151**

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

Component	Weight (lb) Contributed by Attachments										Surface Area ft²
	Body Flanges		Nozzles & Flanges		Packed Beds	Ladders & Platforms	Trays & Supports	Rings & Clips	Vertical Loads		
	New	Corroded	New	Corroded							
Ellipsoidal Head #1	0	0	110.7	105.1	0	0	0	0	0		4
Cylinder #1	0	0	473.8	401.1	0	0	0	0	0		16
Cylinder #2	0	0	0	0	0	0	0	0	0		0
Cylinder #3	0	0	819.7	793.7	0	0	0	0	0		14
Cylinder #4	0	0	9.7	8.4	0	0	0	0	0		1
Ellipsoidal Head #2	0	0	61.4	57.4	0	0	0	0	0		3
Legs #1	0	0	0	0	0	0	0	0	0		0
TOTAL:	**0**	**0**	**1,475.4**	**1,365.7**	**0**	**0**	**0**	**0**	**0**		**37**

Vessel operating weight, Corroded:	93,194 lb
Vessel operating weight, New:	97,737 lb
Vessel empty weight, Corroded:	12,475 lb
Vessel empty weight, New:	17,409 lb
Vessel test weight, New:	136,387 lb
Vessel surface area:	1,188 ft²

Vessel center of gravity location - from datum - lift condition

Vessel Lift Weight, New:	17,409 lb
Center of Gravity:	135.7399"

Vessel Capacity

Vessel Capacity** (New):	14,232 US gal
Vessel Capacity** (Corroded):	14,305 US gal

**The vessel capacity does not include volume of nozzle, piping or other attachments.

Long Seam Summary

Shell Long Seam Angles	
Component	**Seam 1**
Cylinder #1	155.8503°
Cylinder #2	185.8503°
Cylinder #3	155.8503°
Cylinder #4	185.8503°

Shell Plate Lengths		
Component	**Starting Angle**	**Plate 1**
Cylinder #1	155.8503°	338.1139"
Cylinder #2	185.8503°	338.1139"
Cylinder #3	155.8503°	338.1139"
Cylinder #4	185.8503°	338.1139"

*North is located at 0°
*Plate Lengths use the circumfrence of the vessel based on the mid diameter of the components

Hydrostatic Test

Shop test pressure determination for Chamber bounded by Ellipsoidal Head #2 and Ellipsoidal Head #1 based on MAWP per UG-99(b)

Shop hydrostatic test gauge pressure is 65 psi at 70 °F (the chamber MAWP = 50 psi)

The shop 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
Ellipsoidal Head #1 (1)	66.336	1.336	1	1.30
Straight Flange on Ellipsoidal Head #1	66.336	1.336	1	1.30
Cylinder #1	69.801	4.801	1	1.30
Cylinder #2	73.266	8.266	1	1.30
Cylinder #3	76.732	11.732	1	1.30
Cylinder #4	78.031	13.031	1	1.30
Straight Flange on Ellipsoidal Head #2	78.103	13.103	1	1.30
Ellipsoidal Head #2	79.072	14.072	1	1.30
Nozzle A (A)	65.284	0.284	1	1.30
Nozzle B (B)	68.736	3.736	1	1.30
Nozzle C (C)	68.518	3.518	1	1.30
Nozzle D (D)	79.367	14.367	1	1.30
Nozzle L1 (L1)	77.628	12.628	1	1.30
Nozzle L2 (L2)	68.5	3.5	1	1.30
Nozzle M (M)	76.587	11.587	1	1.30

Notes:
(1) Ellipsoidal Head #1 limits the UG-99 stress ratio.

The field test condition has not been investigated for the Chamber bounded by Ellipsoidal Head #2 and Ellipsoidal Head #1.

The test temperature of 70 °F is warmer than the minimum recommended temperature of -13.4 °F so the brittle fracture provision of UG-99(h) has been met.

Cylinder #1

ASME Section VIII Division 1, 2010 Edition

Component: Cylinder
Material specification: SA-516 70 (II-D p. 18
Material impact test exemption temperature from Fig UCS-66 Curve B = -20 °F
Fig UCS-66.1 MDMT reduction = 50.3 °F, (coincident ratio = 0.5393655)
Rated MDMT is governed by UCS-66(b)(2)
UCS-66 governing thickness = 0.375 in

Internal design pressure: P = 50 psi @ 400 °F

Static liquid head:

P_s = 0 psi (SG = 1, H_s = 0",Operating head)
P_{tv} = 4.8 psi (SG = 1, H_s = 133", Vertical test head)

Corrosion allowance Inner C = 0.125" Outer C = 0"

Design MDMT = 10 °F
Rated MDMT = -55 °F

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

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

Estimated weight	New = 3,421.9 lb	corr = 2,283.9 lb
Capacity	New = 3,754.43 US gal	corr = 3,771.95 US gal

OD = 108"
Length L_c = 96"
t = 0.375"

Design thickness, (at 400 °F) Appendix 1-1

t = $P*R_o$ / (S*E + 0.40*P) + Corrosion
= 50*54 / (20,000*0.85 + 0.40*50) + 0.125
= 0.2837"

Maximum allowable working pressure, (at 400 °F) Appendix 1-1

P = S*E*t / (R_o - 0.40*t) - P_s
= 20,000*0.85*0.25 / (54 - 0.40*0.25) - 0
= 78.85 psi

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

P = S*E*t / (R_o - 0.40*t)
= 20,000*0.85*0.375 / (54 - 0.40*0.375)
= 118.38 psi

% Extreme fiber elongation - UCS-79(d)

EFE = $(50*t / R_f)*(1 - R_f / R_o)$
= $(50*0.375 / 53.8125)*(1 - 53.8125 / \infty)$
= 0.3484%

The extreme fiber elongation does not exceed 5%.

Design thickness = 0.2837"

The governing condition is due to internal pressure.

The cylinder thickness of 0.375" is adequate.

Thickness Required Due to Pressure + External Loads

Condition	Pressure P (psi)	Allowable Stress Before UG-23 Stress Increase (psi)		Temperature (°F)	Corrosion C (in)	Load	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
		S_t	S_c					
Operating, Hot & Corroded	50	20,000	8,017	400	0.125	Wind	0.0663	0.0645
						Seismic	0.0657	0.0651
Operating, Hot & New	50	20,000	10,568	400	0	Wind	0.0661	0.0641
						Seismic	0.0655	0.0647
Hot Shut Down, Corroded	0	20,000	8,017	400	0.125	Wind	0.0005	0.0028
						Seismic	0.0002	0.0015
Hot Shut Down, New	0	20,000	10,568	400	0	Wind	0.0004	0.0025
						Seismic	0.0003	0.0016
Empty, Corroded	0	20,000	8,341	70	0.125	Wind	0.0005	0.0027
						Seismic	0.0002	0.0014
Empty, New	0	20,000	11,676	70	0	Wind	0.0004	0.0023
						Seismic	0.0003	0.0015
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0	20,000	8,017	400	0.125	Weight	0.001	0.0015

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

A = $0.125 / (R_o / t)$
= 0.125 / (54 / 0.25)
= 0.000579

B = 8,017 psi

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

S_{cHC} = min(B, S) = 8,017 psi

Allowable Compressive Stress, Hot and New- S_{cHN}, (table CS-2)

A = $0.125 / (R_o / t)$
= 0.125 / (54 / 0.375)
= 0.000868

B = 10,568 psi

Quality Record

Approved

MM188078

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

S_{cHN} = min(B, S) = 10,568 psi

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

A = 0.125 / (R_o / t)
= 0.125 / (54 / 0.375)
= 0.000868

B = 11,676 psi

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

S_{cCN} = min(B, S) = 11,676 psi

Allowable Compressive Stress, Cold and Corroded- S_{cCC}, (table CS-2)

A = 0.125 / (R_o / t)
= 0.125 / (54 / 0.25)
= 0.000579

B = 8,341 psi

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

S_{cCC} = min(B, S) = 8,341 psi

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

A = 0.125 / (R_o / t)
= 0.125 / (54 / 0.25)
= 0.000579

B = 8,017 psi

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

S_{cVC} = min(B, S) = 8,017 psi

Operating, Hot & Corroded, Wind, Bottom Seam

t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|) (Pressure)
= 50*53.75 / (2*20,000*1.20*0.85 + 0.40*|50|)
= 0.0658"

t_m = M / (π*R_m^2*S_t*K_s*E_c) (bending)
= 149,833 / (π*53.875^2*20,000*1.20*0.85)
= 0.0008"

t_w = 0.6*W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 0.60*3,432.5 / (2*π*53.875*20,000*1.20*0.85)
= 0.0003"

t_t = t_p + t_m - t_w (total required, tensile)
= 0.0658 + 0.0008 - (0.0003)
= 0.0663"

t_{wc} = W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 3,432.5 / (2*π*53.875*20,000*1.20*0.85)
= 0.0005"

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0.0008 + (0.0005) - (0.0658)|$
$= \underline{0.0645"}$

Maximum allowable working pressure, Longitudinal Stress

$P = 2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w))$
$= 2*20,000*1.20*0.85*(0.25 - 0.0008 + (0.0003)) / (53.75 - 0.40*(0.25 - 0.0008 + (0.0003)))$
$= 189.73$ psi

Operating, Hot & New, Wind, Bottom Seam

$t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
$= 50*53.625 / (2*20,000*1.20*0.85 + 0.40*|50|)$
$= 0.0657"$

$t_m = M / (\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
$= 154,317 / (\pi*53.8125^2*20,000*1.20*0.85)$
$= 0.0008"$

$t_w = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.60*5,139.8 / (2*\pi*53.8125*20,000*1.20*0.85)$
$= 0.0004"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0.0657 + 0.0008 - (0.0004)$
$= \underline{0.0661"}$

$t_{wc} = W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 5,139.8 / (2*\pi*53.8125*20,000*1.20*0.85)$
$= 0.0007"$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0.0008 + (0.0007) - (0.0657)|$
$= \underline{0.0641"}$

Maximum allowable working pressure, Longitudinal Stress

$P = 2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w))$
$= 2*20,000*1.20*0.85*(0.375 - 0.0008 + (0.0004)) / (53.625 - 0.40*(0.375 - 0.0008 + (0.0004)))$
$= 285.82$ psi

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)
$= 149,833 / (\pi*53.875^2*20,000*1.20*0.85)$
$= 0.0008"$

$t_w = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.60*3,432.5 / (2*\pi*53.875*20,000*1.20*0.85)$
$= 0.0003"$

t_t $= t_p + t_m - t_w$ (total required, tensile)
$= 0 + 0.0008 - (0.0003)$
$= \underline{0.0005"}$

$t_{mc} = M / (\pi * R_m^2 * S_c * K_s)$ (bending)
$= 149{,}833 / (\pi * 53.875^2 * 8{,}016.58 * 1.20)$
$= 0.0017"$

$t_{wc} = W / (2 * \pi * R_m * S_c * K_s)$ (Weight)
$= 3{,}432.5 / (2 * \pi * 53.875 * 8{,}016.58 * 1.20)$
$= 0.0011"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0017 + (0.0011) - (0)$
$= \underline{0.0028"}$

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)
$= 154{,}317 / (\pi * 53.8125^2 * 20{,}000 * 1.20 * 0.85)$
$= 0.0008"$

$t_w = 0.6 * W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)
$= 0.60 * 5{,}139.8 / (2 * \pi * 53.8125 * 20{,}000 * 1.20 * 0.85)$
$= 0.0004"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0 + 0.0008 - (0.0004)$
$= \underline{0.0004"}$

$t_{mc} = M / (\pi * R_m^2 * S_c * K_s)$ (bending)
$= 154{,}317 / (\pi * 53.8125^2 * 10{,}568.3 * 1.20)$
$= 0.0013"$

$t_{wc} = W / (2 * \pi * R_m * S_c * K_s)$ (Weight)
$= 5{,}139.8 / (2 * \pi * 53.8125 * 10{,}568.3 * 1.20)$
$= 0.0012"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0013 + (0.0012) - (0)$
$= \underline{0.0025"}$

Empty, Corroded, Wind, Bottom Seam

$t_p = 0"$ (Pressure)
$t_m = M / (\pi * R_m^2 * S_t * K_s * E_c)$ (bending)
$= 149{,}833 / (\pi * 53.875^2 * 20{,}000 * 1.20 * 0.85)$
$= 0.0008"$

$t_w = 0.6 * W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)
$= 0.60 * 3{,}432.5 / (2 * \pi * 53.875 * 20{,}000 * 1.20 * 0.85)$
$= 0.0003"$

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

$= 0 + 0.0008 - (0.0003)$

$= \underline{0.0005"}$

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

$= 149{,}833 / (\pi^*53.875^{2*}8{,}341.12^*1.20)$

$= 0.0016"$

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

$= 3{,}432.5 / (2^*\pi^*53.875^*8{,}341.12^*1.20)$

$= 0.001"$

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

$= 0.0016 + (0.001) - (0)$

$= \underline{0.0027"}$

Empty, New, Wind, Bottom Seam

$t_p = 0"$ (Pressure)

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

$= 154{,}317 / (\pi^*53.8125^{2*}20{,}000^*1.20^*0.85)$

$= 0.0008"$

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

$= 0.60^*5{,}139.8 / (2^*\pi^*53.8125^*20{,}000^*1.20^*0.85)$

$= 0.0004"$

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

$= 0 + 0.0008 - (0.0004)$

$= \underline{0.0004"}$

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

$= 154{,}317 / (\pi^*53.8125^{2*}11{,}675.8^*1.20)$

$= 0.0012"$

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

$= 5{,}139.8 / (2^*\pi^*53.8125^*11{,}675.8^*1.20)$

$= 0.0011"$

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

$= 0.0012 + (0.0011) - (0)$

$= \underline{0.0023"}$

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)

$= 20{,}841 / (\pi^*53.875^{2*}8{,}016.58^*1.00)$

$= 0.0003"$

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

$= 3{,}432.5 / (2^*\pi^*53.875^*8{,}016.58^*1.00)$

$= 0.0013"$

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

$= |0 + 0.0003 - (0.0013)|$

$= \underline{0.001"}$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0003 + (0.0013) - (0)$
$= \underline{0.0015"}$

Operating, Hot & Corroded, Seismic, Bottom Seam

$t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
$= 50*53.75 / (2*20{,}000*1.20*0.85 + 0.40*|50|)$
$= 0.0658"$

$t_m = M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
$= 36{,}712 / (\pi*53.875^2*20{,}000*1.20*0.85)$
$= 0.0002"$

$t_w = (0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.58*3{,}432.5 / (2*\pi*53.875*20{,}000*1.20*0.85)$
$= 0.0003"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0.0658 + 0.0002 - (0.0003)$
$= \underline{0.0657"}$

$t_{wc} = (1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 1.02*3{,}432.5 / (2*\pi*53.875*20{,}000*1.20*0.85)$
$= 0.0005"$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0.0002 + (0.0005) - (0.0658)|$
$= \underline{0.0651"}$

Maximum allowable working pressure, Longitudinal Stress

$P = 2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w))$
$= 2*20{,}000*1.20*0.85*(0.25 - 0.0002 + (0.0003)) / (53.75 - 0.40*(0.25 - 0.0002 + (0.0003)))$
$= 190.19$ psi

Operating, Hot & New, Seismic, Bottom Seam

$t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
$= 50*53.625 / (2*20{,}000*1.20*0.85 + 0.40*|50|)$
$= 0.0657"$

$t_m = M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
$= 49{,}473 / (\pi*53.8125^2*20{,}000*1.20*0.85)$
$= 0.0003"$

$t_w = (0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.58*5{,}139.8 / (2*\pi*53.8125*20{,}000*1.20*0.85)$
$= 0.0004"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0.0657 + 0.0003 - (0.0004)$
$= \underline{0.0655"}$

t_{wc} = $(1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $1.02*5{,}139.8 / (2*\pi*53.8125*20{,}000*1.20*0.85)$
= 0.0008"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= $|0.0003 + (0.0008) - (0.0657)|$
= 0.0647"

Maximum allowable working pressure, Longitudinal Stress

$P = 2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w))$
= $2*20{,}000*1.20*0.85*(0.375 - 0.0003 + (0.0004)) / (53.625 - 0.40*(0.375 - 0.0003 + (0.0004)))$
= 286.24 psi

Hot Shut Down, Corroded, Seismic, Bottom Seam

t_p = 0" (Pressure)
t_m = $M / (\pi*R_m^2*S_c*K_s)$ (bending)
= $36{,}712 / (\pi*53.875^2*8{,}016.58*1.20)$
= 0.0004"

t_w = $(0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
= $0.58*3{,}432.5 / (2*\pi*53.875*8{,}016.58*1.20)$
= 0.0006"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= $|0 + 0.0004 - (0.0006)|$
= 0.0002"

t_{wc} = $(1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
= $1.02*3{,}432.5 / (2*\pi*53.875*8{,}016.58*1.20)$
= 0.0011"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= $0.0004 + (0.0011) - (0)$
= 0.0015"

Hot Shut Down, New, Seismic, Bottom Seam

t_p = 0" (Pressure)
t_m = $M / (\pi*R_m^2*S_c*K_s)$ (bending)
= $49{,}473 / (\pi*53.8125^2*10{,}568.3*1.20)$
= 0.0004"

t_w = $(0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
= $0.58*5{,}139.8 / (2*\pi*53.8125*10{,}568.3*1.20)$
= 0.0007"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= $|0 + 0.0004 - (0.0007)|$
= 0.0003"

t_{wc} = $(1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
= $1.02*5{,}139.8 / (2*\pi*53.8125*10{,}568.3*1.20)$

$= 0.0012"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0004 + (0.0012) - (0)$
$= \underline{0.0016"}$

Empty, Corroded, Seismic, Bottom Seam

$t_p = 0"$ (Pressure)
$t_m = M / (\pi * R_m{}^2 * S_c * K_s)$ (bending)
$= 35{,}379 / (\pi * 53.875^2 * 8{,}341.12 * 1.20)$
$= 0.0004"$

$t_w = (0.6 - 0.14 * S_{DS}) * W / (2 * \pi * R_m * S_c * K_s)$ (Weight)
$= 0.58 * 3{,}432.5 / (2 * \pi * 53.875 * 8{,}341.12 * 1.20)$
$= 0.0006"$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
$= |0 + 0.0004 - (0.0006)|$
$= \underline{0.0002"}$

$t_{wc} = (1 + 0.14 * S_{DS}) * W / (2 * \pi * R_m * S_c * K_s)$ (Weight)
$= 1.02 * 3{,}432.5 / (2 * \pi * 53.875 * 8{,}341.12 * 1.20)$
$= 0.001"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0004 + (0.001) - (0)$
$= \underline{0.0014"}$

Empty, New, Seismic, Bottom Seam

$t_p = 0"$ (Pressure)
$t_m = M / (\pi * R_m{}^2 * S_c * K_s)$ (bending)
$= 46{,}675 / (\pi * 53.8125^2 * 11{,}675.8 * 1.20)$
$= 0.0004"$

$t_w = (0.6 - 0.14 * S_{DS}) * W / (2 * \pi * R_m * S_c * K_s)$ (Weight)
$= 0.58 * 5{,}139.8 / (2 * \pi * 53.8125 * 11{,}675.8 * 1.20)$
$= 0.0006"$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
$= |0 + 0.0004 - (0.0006)|$
$= \underline{0.0003"}$

$t_{wc} = (1 + 0.14 * S_{DS}) * W / (2 * \pi * R_m * S_c * K_s)$ (Weight)
$= 1.02 * 5{,}139.8 / (2 * \pi * 53.8125 * 11{,}675.8 * 1.20)$
$= 0.0011"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0004 + (0.0011) - (0)$
$= \underline{0.0015"}$

Cylinder #2

ASME Section VIII Division 1, 2010 Edition

Component: Cylinder
Material specification: SA-516 70 (II-D p. 18
Material impact test exemption temperature from Fig UCS-66 Curve B = -20 °F
Fig UCS-66.1 MDMT reduction = 43.4 °F, (coincident ratio = 0.5759223)
Rated MDMT is governed by UCS-66(b)(2)
UCS-66 governing thickness = 0.375 in

Internal design pressure: P = 50 psi @ 400 °F

Static liquid head:

P_s	=	3.39 psi	(SG = 1, H_s = 94",Operating head)
P_{tv}	=	8.27 psi	(SG = 1, H_s = 229", Vertical test head)

Corrosion allowance Inner C = 0.125" Outer C = 0"

Design MDMT = 10 °F
Rated MDMT = -55 °F

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

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

Estimated weight	New = 3,444.7 lb	corr = 2,299.1 lb
Capacity	New = 3,754.43 US gal	corr = 3,771.95 US gal

OD	=	108"
Length L_c	=	96"
t	=	0.375"

Design thickness, (at 400 °F) Appendix 1-1

t = $P*R_o$ / (S*E + 0.40*P) + Corrosion
= 53.39*54 / (20,000*0.85 + 0.40*53.39) + 0.125
= 0.2944"

Maximum allowable working pressure, (at 400 °F) Appendix 1-1

P = S*E*t / (R_o - 0.40*t) - P_s
= 20,000*0.85*0.25 / (54 - 0.40*0.25) - 3.39
= 75.46 psi

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

P = S*E*t / (R_o - 0.40*t)
= 20,000*0.85*0.375 / (54 - 0.40*0.375)
= 118.38 psi

% Extreme fiber elongation - UCS-79(d)

EFE = $(50*t / R_f)*(1 - R_f / R_o)$
= $(50*0.375 / 53.8125)*(1 - 53.8125 / \infty)$
= 0.3484%

The extreme fiber elongation does not exceed 5%.

Design thickness = 0.2944"

The governing condition is due to internal pressure.

The cylinder thickness of 0.375" is adequate.

Thickness Required Due to Pressure + External Loads

Condition	Pressure P (psi)	Allowable Stress Before UG-23 Stress Increase (psi)		Temperature (°F)	Corrosion C (in)	Load	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
		S_t	S_c					
Operating, Hot & Corroded	50	20,000	8,017	400	0.125	Wind	0.0676	0.0627
						Seismic	0.0661	0.0642
Operating, Hot & New	50	20,000	10,568	400	0	Wind	0.0673	0.0621
						Seismic	0.0659	0.0635
Hot Shut Down, Corroded	0	20,000	8,017	400	0.125	Wind	0.0018	0.0066
						Seismic	0.0003	0.0034
Hot Shut Down, New	0	20,000	10,568	400	0	Wind	0.0016	0.0057
						Seismic	0.0002	0.0035
Empty, Corroded	0	20,000	8,341	70	0.125	Wind	0.0018	0.0064
						Seismic	0.0003	0.0024
Empty, New	0	20,000	11,676	70	0	Wind	0.0016	0.0052
						Seismic	0.0004	0.0025
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0	20,000	8,017	400	0.125	Weight	0.0018	0.0024

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

A = $0.125 / (R_o / t)$
= 0.125 / (54 / 0.25)
= 0.000579

B = 8,017 psi

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

S_{cHC} = min(B, S) = 8,017 psi

Allowable Compressive Stress, Hot and New- S_{cHN}, (table CS-2)

A = $0.125 / (R_o / t)$
= 0.125 / (54 / 0.375)
= 0.000868

B = 10,568 psi

Quality Record

Approved

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

S_{cHN} = min(B, S) = 10,568 psi

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

A = $0.125 / (R_o / t)$
= 0.125 / (54 / 0.375)
= 0.000868

B = 11,676 psi

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

S_{cCN} = min(B, S) = 11,676 psi

Allowable Compressive Stress, Cold and Corroded- S_{cCC}, (table CS-2)

A = $0.125 / (R_o / t)$
= 0.125 / (54 / 0.25)
= 0.000579

B = 8,341 psi

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

S_{cCC} = min(B, S) = 8,341 psi

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

A = $0.125 / (R_o / t)$
= 0.125 / (54 / 0.25)
= 0.000579

B = 8,017 psi

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

S_{cVC} = min(B, S) = 8,017 psi

Operating, Hot & Corroded, Wind, Bottom Seam

$t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
= 50*53.75 / (2*20,000*1.20*0.85 + 0.40*|50|)
= 0.0658"

$t_m = M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
= $425,382 / (\pi*53.875^2*20,000*1.20*0.85)$
= 0.0023"

$t_w = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $0.60*5,731.6 / (2*\pi*53.875*20,000*1.20*0.85)$
= 0.0005"

$t_t = t_p + t_m - t_w$ (total required, tensile)
= 0.0658 + 0.0023 - (0.0005)
= 0.0676"

$t_{wc} = W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $5,731.6 / (2*\pi*53.875*20,000*1.20*0.85)$
= 0.0008"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0.0023 + (0.0008) - (0.0658)|
= 0.0627"

Maximum allowable working pressure, Longitudinal Stress

P = $2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w))$
= 2*20,000*1.20*0.85*(0.25 - 0.0023 + (0.0005)) / (53.75 - 0.40*(0.25 - 0.0023 + (0.0005)))
= 188.76 psi

Operating, Hot & New, Wind, Bottom Seam

t_p = $P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
= 50*53.625 / (2*20,000*1.20*0.85 + 0.40*|50|)
= 0.0657"

t_m = $M / (\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
= $429{,}866 / (\pi*53.8125^2*20{,}000*1.20*0.85)$
= 0.0023"

t_w = $0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $0.60*8{,}584.5 / (2*\pi*53.8125*20{,}000*1.20*0.85)$
= 0.0007"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0.0657 + 0.0023 - (0.0007)
= 0.0673"

t_{wc} = $W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $8{,}584.5 / (2*\pi*53.8125*20{,}000*1.20*0.85)$
= 0.0012"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0.0023 + (0.0012) - (0.0657)|
= 0.0621"

Maximum allowable working pressure, Longitudinal Stress

P = $2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w))$
= 2*20,000*1.20*0.85*(0.375 - 0.0023 + (0.0007)) / (53.625 - 0.40*(0.375 - 0.0023 + (0.0007)))
= 284.91 psi

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)
= $425{,}382 / (\pi*53.875^2*20{,}000*1.20*0.85)$
= 0.0023"

t_w = $0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $0.60*5{,}731.6 / (2*\pi*53.875*20{,}000*1.20*0.85)$
= 0.0005"

t_t $= t_p + t_m - t_w$ (total required, tensile)
$= 0 + 0.0023 - (0.0005)$
$=$ <u>0.0018"</u>

t_{mc} $= M / (\pi * R_m{}^2 * S_c * K_s)$ (bending)
$= 425{,}382 / (\pi * 53.875^2 * 8{,}016.58 * 1.20)$
$= 0.0048"$

t_{wc} $= W / (2 * \pi * R_m * S_c * K_s)$ (Weight)
$= 5{,}731.6 / (2 * \pi * 53.875 * 8{,}016.58 * 1.20)$
$= 0.0018"$

t_c $= t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0048 + (0.0018) - (0)$
$=$ <u>0.0066"</u>

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)
$= 429{,}866 / (\pi * 53.8125^2 * 20{,}000 * 1.20 * 0.85)$
$= 0.0023"$

t_w $= 0.6 * W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)
$= 0.60 * 8{,}584.5 / (2 * \pi * 53.8125 * 20{,}000 * 1.20 * 0.85)$
$= 0.0007"$

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

t_{mc} $= M / (\pi * R_m{}^2 * S_c * K_s)$ (bending)
$= 429{,}866 / (\pi * 53.8125^2 * 10{,}568.3 * 1.20)$
$= 0.0037"$

t_{wc} $= W / (2 * \pi * R_m * S_c * K_s)$ (Weight)
$= 8{,}584.5 / (2 * \pi * 53.8125 * 10{,}568.3 * 1.20)$
$= 0.002"$

t_c $= t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0037 + (0.002) - (0)$
$=$ <u>0.0057"</u>

Empty, Corroded, Wind, Bottom Seam

t_p $= 0"$ (Pressure)
t_m $= M / (\pi * R_m{}^2 * S_t * K_s * E_c)$ (bending)
$= 425{,}382 / (\pi * 53.875^2 * 20{,}000 * 1.20 * 0.85)$
$= 0.0023"$

t_w $= 0.6 * W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)
$= 0.60 * 5{,}731.6 / (2 * \pi * 53.875 * 20{,}000 * 1.20 * 0.85)$
$= 0.0005"$

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

$= 0 + 0.0023 - (0.0005)$

$= \underline{0.0018"}$

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

$= 425{,}382 / (\pi * 53.875^2 * 8{,}341.12 * 1.20)$

$= 0.0047"$

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

$= 5{,}731.6 / (2 * \pi * 53.875 * 8{,}341.12 * 1.20)$

$= 0.0017"$

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

$= 0.0047 + (0.0017) - (0)$

$= \underline{0.0064"}$

Empty, New, Wind, Bottom Seam

$t_p = 0"$ (Pressure)

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

$= 429{,}866 / (\pi * 53.8125^2 * 20{,}000 * 1.20 * 0.85)$

$= 0.0023"$

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

$= 0.60 * 8{,}584.5 / (2 * \pi * 53.8125 * 20{,}000 * 1.20 * 0.85)$

$= 0.0007"$

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

$= 0 + 0.0023 - (0.0007)$

$= \underline{0.0016"}$

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

$= 429{,}866 / (\pi * 53.8125^2 * 11{,}675.8 * 1.20)$

$= 0.0034"$

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

$= 8{,}584.5 / (2 * \pi * 53.8125 * 11{,}675.8 * 1.20)$

$= 0.0018"$

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

$= 0.0034 + (0.0018) - (0)$

$= \underline{0.0052"}$

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)

$= 20{,}841 / (\pi * 53.875^2 * 8{,}016.58 * 1.00)$

$= 0.0003"$

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

$= 5{,}731.6 / (2 * \pi * 53.875 * 8{,}016.58 * 1.00)$

$= 0.0021"$

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

$= |0 + 0.0003 - (0.0021)|$

$= \underline{0.0018"}$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0003 + (0.0021) - (0)$
$= \underline{0.0024"}$

Operating, Hot & Corroded, Seismic, Bottom Seam

$t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
$= 50*53.75 / (2*20{,}000*1.20*0.85 + 0.40*|50|)$
$= 0.0658"$

$t_m = M / (\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
$= 145{,}163 / (\pi*53.875^2*20{,}000*1.20*0.85)$
$= 0.0008"$

$t_w = (0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.58*5{,}731.6 / (2*\pi*53.875*20{,}000*1.20*0.85)$
$= 0.0005"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0.0658 + 0.0008 - (0.0005)$
$= \underline{0.0661"}$

$t_{wc} = (1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 1.02*5{,}731.6 / (2*\pi*53.875*20{,}000*1.20*0.85)$
$= 0.0008"$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0.0008 + (0.0008) - (0.0658)|$
$= \underline{0.0642"}$

Maximum allowable working pressure, Longitudinal Stress

$P = 2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w))$
$= 2*20{,}000*1.20*0.85*(0.25 - 0.0008 + (0.0005)) / (53.75 - 0.40*(0.25 - 0.0008 + (0.0005)))$
$= 189.89$ psi

Operating, Hot & New, Seismic, Bottom Seam

$t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
$= 50*53.625 / (2*20{,}000*1.20*0.85 + 0.40*|50|)$
$= 0.0657"$

$t_m = M / (\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
$= 170{,}735 / (\pi*53.8125^2*20{,}000*1.20*0.85)$
$= 0.0009"$

$t_w = (0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.58*8{,}584.5 / (2*\pi*53.8125*20{,}000*1.20*0.85)$
$= 0.0007"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0.0657 + 0.0009 - (0.0007)$
$= \underline{0.0659"}$

t_{wc} = $(1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $1.02*8,584.5 / (2*\pi*53.8125*20,000*1.20*0.85)$
= 0.0013"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0.0009 + (0.0013) - (0.0657)|
= 0.0635"

Maximum allowable working pressure, Longitudinal Stress

P = $2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w))$
= 2*20,000*1.20*0.85*(0.375 - 0.0009 + (0.0007)) / (53.625 - 0.40*(0.375 - 0.0009 + (0.0007)))
= 285.97 psi

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)
= $145,163 / (\pi*53.875^2*20,000*1.20*0.85)$
= 0.0008"

t_w = $(0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $0.58*5,731.6 / (2*\pi*53.875*20,000*1.20*0.85)$
= 0.0005"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0 + 0.0008 - (0.0005)
= 0.0003"

t_{mc} = $M / (\pi*R_m^2*S_c*K_s)$ (bending)
= $145,163 / (\pi*53.875^2*8,016.58*1.20)$
= 0.0017"

t_{wc} = $(1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
= $1.02*5,731.6 / (2*\pi*53.875*8,016.58*1.20)$
= 0.0018"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0.0017 + (0.0018) - (0)
= 0.0034"

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)
= $170,735 / (\pi*53.8125^2*20,000*1.20*0.85)$
= 0.0009"

t_w = $(0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $0.58*8,584.5 / (2*\pi*53.8125*20,000*1.20*0.85)$
= 0.0007"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0 + 0.0009 - (0.0007)

$= \underline{0.0002"}$

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

$= 170{,}735 / (\pi*53.8125^2*10{,}568.3*1.20)$

$= 0.0015"$

$t_{wc} = (1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)

$= 1.02*8{,}584.5 / (2*\pi*53.8125*10{,}568.3*1.20)$

$= 0.002"$

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

$= 0.0015 + (0.002) - (0)$

$= \underline{0.0035"}$

Empty, Corroded, Seismic, Bottom Seam

$t_p = 0"$ (Pressure)

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

$= 62{,}641 / (\pi*53.875^2*8{,}341.12*1.20)$

$= 0.0007"$

$t_w = (0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)

$= 0.58*5{,}731.6 / (2*\pi*53.875*8{,}341.12*1.20)$

$= 0.001"$

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

$= |0 + 0.0007 - (0.001)|$

$= \underline{0.0003"}$

$t_{wc} = (1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)

$= 1.02*5{,}731.6 / (2*\pi*53.875*8{,}341.12*1.20)$

$= 0.0017"$

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

$= 0.0007 + (0.0017) - (0)$

$= \underline{0.0024"}$

Empty, New, Seismic, Bottom Seam

$t_p = 0"$ (Pressure)

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

$= 85{,}644 / (\pi*53.8125^2*11{,}675.8*1.20)$

$= 0.0007"$

$t_w = (0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)

$= 0.58*8{,}584.5 / (2*\pi*53.8125*11{,}675.8*1.20)$

$= 0.0011"$

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

$= |0 + 0.0007 - (0.0011)|$

$= \underline{0.0004"}$

$t_{wc} = (1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)

$= 1.02*8{,}584.5 / (2*\pi*53.8125*11{,}675.8*1.20)$

$= 0.0018"$

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

$= 0.0007 + (0.0018) - (0)$

$= \underline{0.0025''}$

Cylinder #3

ASME Section VIII Division 1, 2010 Edition

Component: Cylinder
Material specification: SA-516 70 (II-D p. 18
Material impact test exemption temperature from Fig UCS-66 Curve B = -20 °F
Fig UCS-66.1 MDMT reduction = 38.7 °F, (coincident ratio = 0.6132509)
Rated MDMT is governed by UCS-66(b)(2)
UCS-66 governing thickness = 0.375 in

Internal design pressure: P = 50 psi @ 400 °F

Static liquid head:

P_s	=	6.86 psi	(SG = 1, H_s = 190",Operating head)
P_{tv}	=	11.73 psi	(SG = 1, H_s = 325", Vertical test head)

Corrosion allowance Inner C = 0.125" Outer C = 0"

Design MDMT = 10 °F No impact test performed
Rated MDMT = -55 °F Material is not normalized
Material is not produced to Fine Grain Practice
PWHT is not performed

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

Estimated weight	New = 3,392.6 lb	corr = 2,264.4 lb
Capacity	New = 3,754.43 US gal	corr = 3,771.95 US gal

OD	=	108"
Length L_c	=	96"
t	=	0.375"

Design thickness, (at 400 °F) Appendix 1-1

t = $P*R_o$ / (S*E + 0.40*P) + Corrosion
= 56.86*54 / (20,000*0.85 + 0.40*56.86) + 0.125
= 0.3054"

Maximum allowable working pressure, (at 400 °F) Appendix 1-1

P = S*E*t / (R_o - 0.40*t) - P_s
= 20,000*0.85*0.25 / (54 - 0.40*0.25) - 6.86
= 71.99 psi

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

P = S*E*t / (R_o - 0.40*t)
= 20,000*0.85*0.375 / (54 - 0.40*0.375)
= 118.38 psi

% Extreme fiber elongation - UCS-79(d)

EFE = $(50^*t / R_f)^*(1 - R_f / R_o)$
= $(50^*0.375 / 53.8125)^*(1 - 53.8125 / \infty)$
= 0.3484%

The extreme fiber elongation does not exceed 5%.

Design thickness = 0.3054"

The governing condition is due to internal pressure.

The cylinder thickness of 0.375" is adequate.

Thickness Required Due to Pressure + External Loads

Condition	Pressure P (psi)	Allowable Stress Before UG-23 Stress Increase (psi)		Temperature (°F)	Corrosion C (in)	Load	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
		S_t	S_c					
Operating, Hot & Corroded	50	20,000	8,017	400	0.125	Wind	0.0698	0.0599
						Seismic	0.0674	0.0623
Operating, Hot & New	50	20,000	10,568	400	0	Wind	0.0693	0.0591
						Seismic	0.0671	0.0613
Hot Shut Down, Corroded	0	20,000	8,017	400	0.125	Wind	0.0039	0.0127
						Seismic	0.0015	0.0076
Hot Shut Down, New	0	20,000	10,568	400	0	Wind	0.0036	0.0106
						Seismic	0.0014	0.007
Empty, Corroded	0	20,000	8,341	70	0.125	Wind	0.0039	0.0122
						Seismic	0.0001	0.0041
Empty, New	0	20,000	11,676	70	0	Wind	0.0036	0.0096
						Seismic	0.0003	0.0041
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0	20,000	8,017	400	0.125	Weight	0.0025	0.0039

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

A = $0.125 / (R_o / t)$
= 0.125 / (54 / 0.25)
= 0.000579

B = 8,017 psi

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

S_{cHC} = min(B, S) = 8,017 psi

Allowable Compressive Stress, Hot and New- S_{cHN}, (table CS-2)

A = $0.125 / (R_o / t)$
= 0.125 / (54 / 0.375)
= 0.000868

B = 10,568 psi

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

S_{cHN} = min(B, S) = 10,568 psi

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

$A = 0.125 / (R_o / t)$
$= 0.125 / (54 / 0.375)$
$= 0.000868$

B = 11,676 psi

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

S_{cCN} = min(B, S) = 11,676 psi

Allowable Compressive Stress, Cold and Corroded- S_{cCC}, (table CS-2)

$A = 0.125 / (R_o / t)$
$= 0.125 / (54 / 0.25)$
$= 0.000579$

B = 8,341 psi

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

S_{cCC} = min(B, S) = 8,341 psi

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

$A = 0.125 / (R_o / t)$
$= 0.125 / (54 / 0.25)$
$= 0.000579$

B = 8,017 psi

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

S_{cVC} = min(B, S) = 8,017 psi

Operating, Hot & Corroded, Wind, Bottom Seam

$t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
$= 50*53.75 / (2*20{,}000*1.20*0.85 + 0.40*|50|)$
$= 0.0658"$

$t_m = M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
$= 873{,}517 / (\pi*53.875^2*20{,}000*1.20*0.85)$
$= 0.0047"$

$t_w = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.60*8{,}789.7 / (2*\pi*53.875*20{,}000*1.20*0.85)$
$= 0.0008"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0.0658 + 0.0047 - (0.0008)$
$= 0.0698"$

$t_{wc} = W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 8{,}789.7 / (2*\pi*53.875*20{,}000*1.20*0.85)$
$= 0.0013"$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0.0047 + (0.0013) - (0.0658)|$
$= \underline{0.0599"}$

Maximum allowable working pressure, Longitudinal Stress

$P = 2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w))$
$= 2*20{,}000*1.20*0.85*(0.25 - 0.0047 + (0.0008)) / (53.75 - 0.40*(0.25 - 0.0047 + (0.0008)))$
$= 187.13$ psi

Operating, Hot & New, Wind, Bottom Seam

$t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
$= 50*53.625 / (2*20{,}000*1.20*0.85 + 0.40*|50|)$
$= 0.0657"$

$t_m = M / (\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
$= 876{,}902 / (\pi*53.8125^2*20{,}000*1.20*0.85)$
$= 0.0047"$

$t_w = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.60*12{,}796.9 / (2*\pi*53.8125*20{,}000*1.20*0.85)$
$= 0.0011"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0.0657 + 0.0047 - (0.0011)$
$= \underline{0.0693"}$

$t_{wc} = W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 12{,}796.9 / (2*\pi*53.8125*20{,}000*1.20*0.85)$
$= 0.0019"$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0.0047 + (0.0019) - (0.0657)|$
$= \underline{0.0591"}$

Maximum allowable working pressure, Longitudinal Stress

$P = 2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w))$
$= 2*20{,}000*1.20*0.85*(0.375 - 0.0047 + (0.0011)) / (53.625 - 0.40*(0.375 - 0.0047 + (0.0011)))$
$= 283.35$ psi

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)
$= 873{,}517 / (\pi*53.875^2*20{,}000*1.20*0.85)$
$= 0.0047"$

$t_w = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.60*8{,}789.7 / (2*\pi*53.875*20{,}000*1.20*0.85)$
$= 0.0008"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0 + 0.0047 - (0.0008)$
$= \underline{0.0039"}$

$t_{mc} = M / (\pi^*R_m{}^2{}^*S_c{}^*K_s)$ (bending)
$= 873{,}517 / (\pi^*53.875^2{}^*8{,}016.58^*1.20)$
$= 0.01"$

$t_{wc} = W / (2^*\pi^*R_m{}^*S_c{}^*K_s)$ (Weight)
$= 8{,}789.7 / (2^*\pi^*53.875^*8{,}016.58^*1.20)$
$= 0.0027"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.01 + (0.0027) - (0)$
$= \underline{0.0127"}$

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)
$= 876{,}902 / (\pi^*53.8125^2{}^*20{,}000^*1.20^*0.85)$
$= 0.0047"$

$t_w = 0.6^*W / (2^*\pi^*R_m{}^*S_t{}^*K_s{}^*E_c)$ (Weight)
$= 0.60^*12{,}796.9 / (2^*\pi^*53.8125^*20{,}000^*1.20^*0.85)$
$= 0.0011"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0 + 0.0047 - (0.0011)$
$= \underline{0.0036"}$

$t_{mc} = M / (\pi^*R_m{}^2{}^*S_c{}^*K_s)$ (bending)
$= 876{,}902 / (\pi^*53.8125^2{}^*10{,}568.3^*1.20)$
$= 0.0076"$

$t_{wc} = W / (2^*\pi^*R_m{}^*S_c{}^*K_s)$ (Weight)
$= 12{,}796.9 / (2^*\pi^*53.8125^*10{,}568.3^*1.20)$
$= 0.003"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0076 + (0.003) - (0)$
$= \underline{0.0106"}$

Empty, Corroded, Wind, Bottom Seam

$t_p = 0"$ (Pressure)
$t_m = M / (\pi^*R_m{}^2{}^*S_t{}^*K_s{}^*E_c)$ (bending)
$= 873{,}517 / (\pi^*53.875^2{}^*20{,}000^*1.20^*0.85)$
$= 0.0047"$

$t_w = 0.6^*W / (2^*\pi^*R_m{}^*S_t{}^*K_s{}^*E_c)$ (Weight)
$= 0.60^*8{,}789.7 / (2^*\pi^*53.875^*20{,}000^*1.20^*0.85)$
$= 0.0008"$

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

$= 0 + 0.0047 - (0.0008)$
$= \underline{0.0039"}$

$t_{mc} = M / (\pi * R_m^2 * S_c * K_s)$ (bending)
$= 873{,}517 / (\pi * 53.875^2 * 8{,}341.12 * 1.20)$
$= 0.0096"$

$t_{wc} = W / (2 * \pi * R_m * S_c * K_s)$ (Weight)
$= 8{,}789.7 / (2 * \pi * 53.875 * 8{,}341.12 * 1.20)$
$= 0.0026"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0096 + (0.0026) - (0)$
$= \underline{0.0122"}$

Empty, New, Wind, Bottom Seam

$t_p = 0"$ (Pressure)
$t_m = M / (\pi * R_m^2 * S_t * K_s * E_c)$ (bending)
$= 876{,}902 / (\pi * 53.8125^2 * 20{,}000 * 1.20 * 0.85)$
$= 0.0047"$

$t_w = 0.6 * W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)
$= 0.60 * 12{,}796.9 / (2 * \pi * 53.8125 * 20{,}000 * 1.20 * 0.85)$
$= 0.0011"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0 + 0.0047 - (0.0011)$
$= \underline{0.0036"}$

$t_{mc} = M / (\pi * R_m^2 * S_c * K_s)$ (bending)
$= 876{,}902 / (\pi * 53.8125^2 * 11{,}675.8 * 1.20)$
$= 0.0069"$

$t_{wc} = W / (2 * \pi * R_m * S_c * K_s)$ (Weight)
$= 12{,}796.9 / (2 * \pi * 53.8125 * 11{,}675.8 * 1.20)$
$= 0.0027"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0069 + (0.0027) - (0)$
$= \underline{0.0096"}$

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)
$= 51{,}854 / (\pi * 53.875^2 * 8{,}016.58 * 1.00)$
$= 0.0007"$

$t_w = W / (2 * \pi * R_m * S_c * K_s)$ (Weight)
$= 8{,}789.7 / (2 * \pi * 53.875 * 8{,}016.58 * 1.00)$
$= 0.0032"$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
$= |0 + 0.0007 - (0.0032)|$

= <u>0.0025"</u>

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0.0007 + (0.0032) - (0)
= <u>0.0039"</u>

Operating, Hot & Corroded, Seismic, Bottom Seam

t_p = $P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
= 50*53.75 / (2*20,000*1.20*0.85 + 0.40*|50|)
= 0.0658"

t_m = $M / (\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
= 422,985 / (π*53.875²*20,000*1.20*0.85)
= 0.0023"

t_w = $(0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= 0.58*8,789.7 / (2*π*53.875*20,000*1.20*0.85)
= 0.0007"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0.0658 + 0.0023 - (0.0007)
= <u>0.0674"</u>

t_{wc} = $(1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= 1.02*8,789.7 / (2*π*53.875*20,000*1.20*0.85)
= 0.0013"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0.0023 + (0.0013) - (0.0658)|
= <u>0.0623"</u>

Maximum allowable working pressure, Longitudinal Stress

P = $2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w))$
= 2*20,000*1.20*0.85*(0.25 - 0.0023 + (0.0007)) / (53.75 - 0.40*(0.25 - 0.0023 + (0.0007)))
= 188.95 psi

Operating, Hot & New, Seismic, Bottom Seam

t_p = $P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
= 50*53.625 / (2*20,000*1.20*0.85 + 0.40*|50|)
= 0.0657"

t_m = $M / (\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
= 462,293 / (π*53.8125²*20,000*1.20*0.85)
= 0.0025"

t_w = $(0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= 0.58*12,796.9 / (2*π*53.8125*20,000*1.20*0.85)
= 0.0011"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0.0657 + 0.0025 - (0.0011)
= <u>0.0671"</u>

t_{wc} = $(1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $1.02*12,796.9 / (2*\pi*53.8125*20,000*1.20*0.85)$
= 0.0019"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0.0025 + (0.0019) - (0.0657)|
= 0.0613"

Maximum allowable working pressure, Longitudinal Stress

P = $2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w))$
= 2*20,000*1.20*0.85*(0.375 - 0.0025 + (0.0011)) / (53.625 - 0.40*(0.375 - 0.0025 + (0.0011)))
= 285.03 psi

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)
= $422,985 / (\pi*53.875^2*20,000*1.20*0.85)$
= 0.0023"

t_w = $(0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $0.58*8,789.7 / (2*\pi*53.875*20,000*1.20*0.85)$
= 0.0007"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0 + 0.0023 - (0.0007)
= 0.0015"

t_{mc} = $M / (\pi*R_m^2*S_c*K_s)$ (bending)
= $422,985 / (\pi*53.875^2*8,016.58*1.20)$
= 0.0048"

t_{wc} = $(1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
= $1.02*8,789.7 / (2*\pi*53.875*8,016.58*1.20)$
= 0.0027"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0.0048 + (0.0027) - (0)
= 0.0076"

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)
= $462,293 / (\pi*53.8125^2*20,000*1.20*0.85)$
= 0.0025"

t_w = $(0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $0.58*12,796.9 / (2*\pi*53.8125*20,000*1.20*0.85)$
= 0.0011"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0 + 0.0025 - (0.0011)

$= \underline{0.0014"}$

$t_{mc} = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 462{,}293 / (\pi*53.8125^2*10{,}568.3*1.20)$
$= 0.004"$

$t_{wc} = (1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 1.02*12{,}796.9 / (2*\pi*53.8125*10{,}568.3*1.20)$
$= 0.003"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.004 + (0.003) - (0)$
$= \underline{0.007"}$

Empty, Corroded, Seismic, Bottom Seam

$t_p = 0"$ (Pressure)
$t_m = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 129{,}820 / (\pi*53.875^2*8{,}341.12*1.20)$
$= 0.0014"$

$t_w = (0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 0.58*8{,}789.7 / (2*\pi*53.875*8{,}341.12*1.20)$
$= 0.0015"$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
$= |0 + 0.0014 - (0.0015)|$
$= \underline{0.0001"}$

$t_{wc} = (1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 1.02*8{,}789.7 / (2*\pi*53.875*8{,}341.12*1.20)$
$= 0.0026"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0014 + (0.0026) - (0)$
$= \underline{0.0041"}$

Empty, New, Seismic, Bottom Seam

$t_p = 0"$ (Pressure)
$t_m = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 167{,}083 / (\pi*53.8125^2*11{,}675.8*1.20)$
$= 0.0013"$

$t_w = (0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 0.58*12{,}796.9 / (2*\pi*53.8125*11{,}675.8*1.20)$
$= 0.0016"$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
$= |0 + 0.0013 - (0.0016)|$
$= \underline{0.0003"}$

$t_{wc} = (1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 1.02*12{,}796.9 / (2*\pi*53.8125*11{,}675.8*1.20)$
$= 0.0028"$

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

$= 0.0013 + (0.0028) - (0)$

$= \underline{0.0041"}$

Cylinder #4

ASME Section VIII Division 1, 2010 Edition

Component: Cylinder
Material specification: SA-516 70 (II-D p. 18
Material impact test exemption temperature from Fig UCS-66 Curve B = -20 °F
Fig UCS-66.1 MDMT reduction = 37.3 °F, (coincident ratio = 0.6272475)
Rated MDMT is governed by UCS-66(b)(2)
UCS-66 governing thickness = 0.375 in

Internal design pressure: P = 50 psi @ 400 °F

Static liquid head:

P_s = 8.16 psi (SG = 1, H_s = 226",Operating head)

P_{tv} = 13.03 psi (SG = 1, H_s = 361", Vertical test head)

Corrosion allowance Inner C = 0.125" Outer C = 0"

Design MDMT = 10 °F
Rated MDMT = -55 °F

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

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

Estimated weight	New = 1,291.3 lb	corr = 861.9 lb
Capacity	New = 1,407.91 US gal	corr = 1,414.48 US gal

OD = 108"
Length L_c = 36"
t = 0.375"

Design thickness, (at 400 °F) Appendix 1-1

$$t = P*R_o / (S*E + 0.40*P) + Corrosion$$
$$= 58.16*54 / (20{,}000*0.85 + 0.40*58.16) + 0.125$$
$$= 0.3095"$$

Maximum allowable working pressure, (at 400 °F) Appendix 1-1

$$P = S*E*t / (R_o - 0.40*t) - P_s$$
$$= 20{,}000*0.85*0.25 / (54 - 0.40*0.25) - 8.16$$
$$= 70.69 \text{ psi}$$

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

$$P = S*E*t / (R_o - 0.40*t)$$
$$= 20{,}000*0.85*0.375 / (54 - 0.40*0.375)$$
$$= 118.38 \text{ psi}$$

% Extreme fiber elongation - UCS-79(d)

$$EFE = (50*t / R_f)*(1 - R_f / R_o)$$
$$= (50*0.375 / 53.8125)*(1 - 53.8125 / \infty)$$
$$= 0.3484\%$$

The extreme fiber elongation does not exceed 5%.

Design thickness = 0.3095"

The governing condition is due to internal pressure.

The cylinder thickness of 0.375" is adequate.

Thickness Required Due to Pressure + External Loads

Condition	Pressure P (psi)	Allowable Stress Before UG-23 Stress Increase (psi)		Temperature (°F)	Corrosion C (in)	Location	Load	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
		S_t	S_c						
Operating, Hot & Corroded	50	20,000	8,017	400	0.125	Top	Wind	0.0601	0.0499
							Seismic	0.0577	0.0523
						Bottom	Wind	0.066	0.062
							Seismic	0.0662	0.0618
Operating, Hot & New	50	20,000	10,568	400	0	Top	Wind	0.0597	0.0492
							Seismic	0.0575	0.0514
						Bottom	Wind	0.0659	0.0619
							Seismic	0.0661	0.0617
Hot Shut Down, Corroded	0	20,000	8,017	400	0.125	Top	Wind	0.0041	0.015
							Seismic	0.0018	0.0091
						Bottom	Wind	0.0101	0.006
							Seismic	0.0102	0.0058
Hot Shut Down, New	0	20,000	10,568	400	0	Top	Wind	0.0038	0.0125
							Seismic	0.0017	0.0084
						Bottom	Wind	0.0101	0.006
							Seismic	0.0103	0.0058
Empty, Corroded	0	20,000	8,341	70	0.125	Top	Wind	0.0041	0.0144
							Seismic	0.0001	0.0045
						Bottom	Wind	0.0001	0
							Seismic	0.0001	0.0001
Empty, New	0	20,000	11,676	70	0	Top	Wind	0.0038	0.0113
							Seismic	0.0003	0.0045
						Bottom	Wind	0.0002	0.0001
							Seismic	0.0002	0.0001
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0	20,000	8,017	400	0.125	Top	Weight	0.0028	0.0043
						Bottom	Weight	0.012	0.012

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

A	=	0.125 / (R_o / t)
	=	0.125 / (54 / 0.25)
	=	0.000579
B	=	8,017 psi
S	=	20,000 / 1.00 = 20,000 psi
S_{cHC}	=	min(B, S) = 8,017 psi

Allowable Compressive Stress, Hot and New- S_{cHN}, (table CS-2)

A	=	0.125 / (R_o / t)
	=	0.125 / (54 / 0.375)
	=	0.000868
B	=	10,568 psi
S	=	20,000 / 1.00 = 20,000 psi
S_{cHN}	=	min(B, S) = 10,568 psi

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

A	=	0.125 / (R_o / t)
	=	0.125 / (54 / 0.375)
	=	0.000868
B	=	11,676 psi
S	=	20,000 / 1.00 = 20,000 psi
S_{cCN}	=	min(B, S) = 11,676 psi

Allowable Compressive Stress, Cold and Corroded- S_{cCC}, (table CS-2)

A	=	0.125 / (R_o / t)
	=	0.125 / (54 / 0.25)
	=	0.000579
B	=	8,341 psi
S	=	20,000 / 1.00 = 20,000 psi
S_{cCC}	=	min(B, S) = 8,341 psi

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

A	=	0.125 / (R_o / t)
	=	0.125 / (54 / 0.25)
	=	0.000579
B	=	8,017 psi
S	=	20,000 / 1.00 = 20,000 psi
S_{cVC}	=	min(B, S) = 8,017 psi

Operating, Hot & Corroded, Wind, Above Support Point

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

= 50*53.75 / (2*20,000*1.20*1.00 + 0.40*|50|)

$= 0.056"$

$t_m = M / (\pi * R_m^2 * S_t * K_s * E_c)$ (bending)
$= 1{,}058{,}235 / (\pi * 53.875^2 * 20{,}000 * 1.20 * 1.00)$
$= 0.0048"$

$t_w = 0.6 * W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)
$= 0.60 * 9{,}636 / (2 * \pi * 53.875 * 20{,}000 * 1.20 * 1.00)$
$= 0.0007"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0.056 + 0.0048 - (0.0007)$
$=$ <u>0.0601"</u>

$t_{wc} = W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)
$= 9{,}636 / (2 * \pi * 53.875 * 20{,}000 * 1.20 * 1.00)$
$= 0.0012"$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0.0048 + (0.0012) - (0.056)|$
$=$ <u>0.0499"</u>

Maximum allowable working pressure, Longitudinal Stress

$P = 2 * S_t * K_s * E_c * (t - t_m + t_w) / (R - 0.40 * (t - t_m + t_w))$
$= 2 * 20{,}000 * 1.20 * 1.00 * (0.25 - 0.0048 + (0.0007)) / (53.75 - 0.40 * (0.25 - 0.0048 + (0.0007)))$
$= 219.98$ psi

<u>Operating, Hot & New, Wind, Above Support Point</u>

$t_p = P * R / (2 * S_t * K_s * E_c + 0.40 * |P|)$ (Pressure)
$= 50 * 53.625 / (2 * 20{,}000 * 1.20 * 1.00 + 0.40 * |50|)$
$= 0.0558"$

$t_m = M / (\pi * R_m^2 * S_t * K_s * E_c)$ (bending)
$= 1{,}061{,}536 / (\pi * 53.8125^2 * 20{,}000 * 1.20 * 1.00)$
$= 0.0049"$

$t_w = 0.6 * W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)
$= 0.60 * 14{,}061.9 / (2 * \pi * 53.8125 * 20{,}000 * 1.20 * 1.00)$
$= 0.001"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0.0558 + 0.0049 - (0.001)$
$=$ <u>0.0597"</u>

$t_{wc} = W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)
$= 14{,}061.9 / (2 * \pi * 53.8125 * 20{,}000 * 1.20 * 1.00)$
$= 0.0017"$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0.0049 + (0.0017) - (0.0558)|$
$=$ <u>0.0492"</u>

Maximum allowable working pressure, Longitudinal Stress

$P = 2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w))$
$= 2*20{,}000*1.20*1.00*(0.375 - 0.0049 + (0.001)) / (53.625 - 0.40*(0.375 - 0.0049 + (0.001)))$
$= 333.17$ psi

Hot Shut Down, Corroded, Wind, Above Support Point

$t_p = 0"$ (Pressure)
$t_m = M / (\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
$= 1{,}058{,}235 / (\pi*53.875^2*20{,}000*1.20*1.00)$
$= 0.0048"$

$t_w = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.60*9{,}636 / (2*\pi*53.875*20{,}000*1.20*1.00)$
$= 0.0007"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0 + 0.0048 - (0.0007)$
$= \underline{0.0041"}$

$t_{mc} = M / (\pi*R_m{}^2*S_c*K_s)$ (bending)
$= 1{,}058{,}235 / (\pi*53.875^2*8{,}016.58*1.20)$
$= 0.0121"$

$t_{wc} = W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 9{,}636 / (2*\pi*53.875*8{,}016.58*1.20)$
$= 0.003"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0121 + (0.003) - (0)$
$= \underline{0.015"}$

Hot Shut Down, New, Wind, Above Support Point

$t_p = 0"$ (Pressure)
$t_m = M / (\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
$= 1{,}061{,}536 / (\pi*53.8125^2*20{,}000*1.20*1.00)$
$= 0.0049"$

$t_w = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.60*14{,}061.9 / (2*\pi*53.8125*20{,}000*1.20*1.00)$
$= 0.001"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0 + 0.0049 - (0.001)$
$= \underline{0.0038"}$

$t_{mc} = M / (\pi*R_m{}^2*S_c*K_s)$ (bending)
$= 1{,}061{,}536 / (\pi*53.8125^2*10{,}568.3*1.20)$
$= 0.0092"$

$t_{wc} = W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 14{,}061.9 / (2*\pi*53.8125*10{,}568.3*1.20)$

$= 0.0033"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0092 + (0.0033) - (0)$
$= \underline{0.0125"}$

Empty, Corroded, Wind, Above Support Point

$t_p = 0"$ (Pressure)
$t_m = M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
$= 1,058,235 / (\pi*53.875^2*20,000*1.20*1.00)$
$= 0.0048"$

$t_w = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.60*9,636 / (2*\pi*53.875*20,000*1.20*1.00)$
$= 0.0007"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0 + 0.0048 - (0.0007)$
$= \underline{0.0041"}$

$t_{mc} = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 1,058,235 / (\pi*53.875^2*8,341.12*1.20)$
$= 0.0116"$

$t_{wc} = W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 9,636 / (2*\pi*53.875*8,341.12*1.20)$
$= 0.0028"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0116 + (0.0028) - (0)$
$= \underline{0.0144"}$

Empty, New, Wind, Above Support Point

$t_p = 0"$ (Pressure)
$t_m = M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
$= 1,061,536 / (\pi*53.8125^2*20,000*1.20*1.00)$
$= 0.0049"$

$t_w = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.60*14,061.9 / (2*\pi*53.8125*20,000*1.20*1.00)$
$= 0.001"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0 + 0.0049 - (0.001)$
$= \underline{0.0038"}$

$t_{mc} = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 1,061,536 / (\pi*53.8125^2*11,675.8*1.20)$
$= 0.0083"$

$t_{wc} = W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 14,061.9 / (2*\pi*53.8125*11,675.8*1.20)$
$= 0.003"$

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0.0083 + (0.003) - (0)
= 0.0113"

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

t_p = 0" (Pressure)

t_m = M / (π*R_m^2*S_c*K_s) (bending)
= 51,369 / (π*53.875²*8,016.58*1.00)
= 0.0007"

t_w = W / (2*π*R_m*S_c*K_s) (Weight)
= 9,636 / (2*π*53.875*8,016.58*1.00)
= 0.0036"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= |0 + 0.0007 - (0.0036)|
= 0.0028"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0.0007 + (0.0036) - (0)
= 0.0043"

Operating, Hot & Corroded, Wind, Below Support Point

t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|) (Pressure)
= 50*53.75 / (2*20,000*1.20*1.00 + 0.40*|50|)
= 0.056"

t_m = M / (π*R_m^2*S_t*K_s*E_c) (bending)
= 5,206 / (π*53.875²*20,000*1.20*1.00)
= 0"

t_w = W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= -81,579.1 / (2*π*53.875*20,000*1.20*1.00)
= -0.01"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0.056 + 0 - (-0.01)
= 0.066"

t_{wc} = 0.6*W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 0.60*-81,579.1 / (2*π*53.875*20,000*1.20*1.00)
= -0.006"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0 + (-0.006) - (0.056)|
= 0.062"

Maximum allowable working pressure, Longitudinal Stress

$P = 2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w))$
$= 2*20{,}000*1.20*1.00*(0.25 - 0 + (-0.01)) / (53.75 - 0.40*(0.25 - 0 + (-0.01)))$
$= 214.65$ psi

Operating, Hot & New, Wind, Below Support Point

t_p	=	$P*R / (2*S_t*K_s*E_c + 0.40*\|P\|)$	(Pressure)
	=	$50*53.625 / (2*20{,}000*1.20*1.00 + 0.40*\|50\|)$	
	=	0.0558"	
t_m	=	$M / (\pi*R_m{}^2*S_t*K_s*E_c)$	(bending)
	=	$5{,}206 / (\pi*53.8125^2*20{,}000*1.20*1.00)$	
	=	0"	
t_w	=	$W / (2*\pi*R_m*S_t*K_s*E_c)$	(Weight)
	=	$-81{,}697.1 / (2*\pi*53.8125*20{,}000*1.20*1.00)$	
	=	-0.0101"	
t_t	=	$t_p + t_m - t_w$	(total required, tensile)
	=	0.0558 + 0 - (-0.0101)	
	=	<u>0.0659"</u>	
t_{wc}	=	$0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$	(Weight)
	=	$0.60*-81{,}697.1 / (2*\pi*53.8125*20{,}000*1.20*1.00)$	
	=	-0.006"	
t_c	=	$\|t_{mc} + t_{wc} - t_{pc}\|$	(total, net tensile)
	=	|0 + (-0.006) - (0.0558)|	
	=	<u>0.0619"</u>	

Maximum allowable working pressure, Longitudinal Stress

$P = 2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w))$
$= 2*20{,}000*1.20*1.00*(0.375 - 0 + (-0.0101)) / (53.625 - 0.40*(0.375 - 0 + (-0.0101)))$
$= 327.52$ psi

Hot Shut Down, Corroded, Wind, Below Support Point

t_p	=	0"	(Pressure)
t_m	=	$M / (\pi*R_m{}^2*S_t*K_s*E_c)$	(bending)
	=	$5{,}206 / (\pi*53.875^2*20{,}000*1.20*1.00)$	
	=	0"	
t_w	=	$W / (2*\pi*R_m*S_t*K_s*E_c)$	(Weight)
	=	$-81{,}579.1 / (2*\pi*53.875*20{,}000*1.20*1.00)$	
	=	-0.01"	
t_t	=	$t_p + t_m - t_w$	(total required, tensile)
	=	0 + 0 - (-0.01)	

= <u>0.0101"</u>

t_{wc} = $0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $0.60*-81{,}579.1 / (2*\pi*53.875*20{,}000*1.20*1.00)$
= -0.006"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= $|0 + (-0.006) - (0)|$
= <u>0.006"</u>

Hot Shut Down, New, Wind, Below Support Point

t_p = 0" (Pressure)
t_m = $M / (\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
= $5{,}206 / (\pi*53.8125^2*20{,}000*1.20*1.00)$
= 0"

t_w = $W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $-81{,}697.1 / (2*\pi*53.8125*20{,}000*1.20*1.00)$
= -0.0101"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0 + 0 - (-0.0101)
= <u>0.0101"</u>

t_{wc} = $0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $0.60*-81{,}697.1 / (2*\pi*53.8125*20{,}000*1.20*1.00)$
= -0.006"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= $|0 + (-0.006) - (0)|$
= <u>0.006"</u>

Empty, Corroded, Wind, Below Support Point

t_p = 0" (Pressure)
t_m = $M / (\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
= $5{,}206 / (\pi*53.875^2*20{,}000*1.20*1.00)$
= 0"

t_w = $W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $-866.4 / (2*\pi*53.875*20{,}000*1.20*1.00)$
= -0.0001"

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

t_{wc} = $0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $0.60*-866.4 / (2*\pi*53.875*20{,}000*1.20*1.00)$
= -0.0001"

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

Empty, New, Wind, Below Support Point

t_p = 0" (Pressure)
t_m = $M / (\pi * R_m^2 * S_t * K_s * E_c)$ (bending)
= $5{,}206 / (\pi * 53.8125^2 * 20{,}000 * 1.20 * 1.00)$
= 0"

t_w = $W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)
= $-1{,}375.1 / (2 * \pi * 53.8125 * 20{,}000 * 1.20 * 1.00)$
= -0.0002"

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

t_{wc} = $0.6 * W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)
= $0.60 * -1{,}375.1 / (2 * \pi * 53.8125 * 20{,}000 * 1.20 * 1.00)$
= -0.0001"

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

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

t_p = 0" (Pressure)
t_m = $M / (\pi * R_m^2 * S_t * K_s * E_c)$ (bending)
= $0 / (\pi * 53.875^2 * 20{,}000 * 1.00 * 1.00)$
= 0"

t_w = $W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)
= $-81{,}579.1 / (2 * \pi * 53.875 * 20{,}000 * 1.00 * 1.00)$
= -0.012"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= $0 + 0 - (-0.012)$
= 0.012"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= $|0 + (-0.012) - (0)|$
= 0.012"

Operating, Hot & Corroded, Seismic, Above Support Point

t_p = $P * R / (2 * S_t * K_s * E_c + 0.40 * |P|)$ (Pressure)
= $50 * 53.75 / (2 * 20{,}000 * 1.20 * 1.00 + 0.40 * |50|)$
= 0.056"

t_m = $M / (\pi^*R_m{}^2{}^*S_t{}^*K_s{}^*E_c)$ (bending)
= $536{,}087 / (\pi^*53.875^2{}^*20{,}000^*1.20^*1.00)$
= 0.0024"

t_w = $(0.6 - 0.14^*S_{DS})^*W / (2^*\pi^*R_m{}^*S_t{}^*K_s{}^*E_c)$ (Weight)
= $0.58^*9{,}636 / (2^*\pi^*53.875^*20{,}000^*1.20^*1.00)$
= 0.0007"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0.056 + 0.0024 - (0.0007)
= 0.0577"

t_{wc} = $(1 + 0.14^*S_{DS})^*W / (2^*\pi^*R_m{}^*S_t{}^*K_s{}^*E_c)$ (Weight)
= $1.02^*9{,}636 / (2^*\pi^*53.875^*20{,}000^*1.20^*1.00)$
= 0.0012"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0.0024 + (0.0012) - (0.056)|
= 0.0523"

Maximum allowable working pressure, Longitudinal Stress

$P = 2^*S_t{}^*K_s{}^*E_c{}^*(t - t_m + t_w) / (R - 0.40^*(t - t_m + t_w))$
= 2*20,000*1.20*1.00*(0.25 - 0.0024 + (0.0007)) / (53.75 - 0.40*(0.25 - 0.0024 + (0.0007)))
= 222.09 psi

Operating, Hot & New, Seismic, Above Support Point

t_p = $P^*R / (2^*S_t{}^*K_s{}^*E_c + 0.40^*|P|)$ (Pressure)
= 50*53.625 / (2*20,000*1.20*1.00 + 0.40*|50|)
= 0.0558"

t_m = $M / (\pi^*R_m{}^2{}^*S_t{}^*K_s{}^*E_c)$ (bending)
= $581{,}050 / (\pi^*53.8125^2{}^*20{,}000^*1.20^*1.00)$
= 0.0027"

t_w = $(0.6 - 0.14^*S_{DS})^*W / (2^*\pi^*R_m{}^*S_t{}^*K_s{}^*E_c)$ (Weight)
= $0.58^*14{,}061.9 / (2^*\pi^*53.8125^*20{,}000^*1.20^*1.00)$
= 0.001"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0.0558 + 0.0027 - (0.001)
= 0.0575"

t_{wc} = $(1 + 0.14^*S_{DS})^*W / (2^*\pi^*R_m{}^*S_t{}^*K_s{}^*E_c)$ (Weight)
= $1.02^*14{,}061.9 / (2^*\pi^*53.8125^*20{,}000^*1.20^*1.00)$
= 0.0018"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0.0027 + (0.0018) - (0.0558)|
= 0.0514"

Maximum allowable working pressure, Longitudinal Stress

$P = 2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w))$
$= 2*20{,}000*1.20*1.00*(0.375 - 0.0027 + (0.001)) / (53.625 - 0.40*(0.375 - 0.0027 + (0.001)))$
$= 335.12$ psi

Hot Shut Down, Corroded, Seismic, Above Support Point

$t_p = 0"$ (Pressure)
$t_m = M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
$= 536{,}087 / (\pi*53.875^2*20{,}000*1.20*1.00)$
$= 0.0024"$

$t_w = (0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.58*9{,}636 / (2*\pi*53.875*20{,}000*1.20*1.00)$
$= 0.0007"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0 + 0.0024 - (0.0007)$
$= \underline{0.0018"}$

$t_{mc} = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 536{,}087 / (\pi*53.875^2*8{,}016.58*1.20)$
$= 0.0061"$

$t_{wc} = (1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 1.02*9{,}636 / (2*\pi*53.875*8{,}016.58*1.20)$
$= 0.003"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0061 + (0.003) - (0)$
$= \underline{0.0091"}$

Hot Shut Down, New, Seismic, Above Support Point

$t_p = 0"$ (Pressure)
$t_m = M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
$= 581{,}050 / (\pi*53.8125^2*20{,}000*1.20*1.00)$
$= 0.0027"$

$t_w = (0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.58*14{,}061.9 / (2*\pi*53.8125*20{,}000*1.20*1.00)$
$= 0.001"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0 + 0.0027 - (0.001)$
$= \underline{0.0017"}$

$t_{mc} = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 581{,}050 / (\pi*53.8125^2*10{,}568.3*1.20)$
$= 0.005"$

$t_{wc} = (1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 1.02*14{,}061.9 / (2*\pi*53.8125*10{,}568.3*1.20)$

$= 0.0033"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.005 + (0.0033) - (0)$
$= \underline{0.0084"}$

Empty, Corroded, Seismic, Above Support Point

$t_p = 0"$ (Pressure)
$t_m = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 144{,}511 / (\pi*53.875^2*8{,}341.12*1.20)$
$= 0.0016"$

$t_w = (0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 0.58*9{,}636 / (2*\pi*53.875*8{,}341.12*1.20)$
$= 0.0017"$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
$= |0 + 0.0016 - (0.0017)|$
$= \underline{0.0001"}$

$t_{wc} = (1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 1.02*9{,}636 / (2*\pi*53.875*8{,}341.12*1.20)$
$= 0.0029"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0016 + (0.0029) - (0)$
$= \underline{0.0045"}$

Empty, New, Seismic, Above Support Point

$t_p = 0"$ (Pressure)
$t_m = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 187{,}875 / (\pi*53.8125^2*11{,}675.8*1.20)$
$= 0.0015"$

$t_w = (0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 0.58*14{,}061.9 / (2*\pi*53.8125*11{,}675.8*1.20)$
$= 0.0017"$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
$= |0 + 0.0015 - (0.0017)|$
$= \underline{0.0003"}$

$t_{wc} = (1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 1.02*14{,}061.9 / (2*\pi*53.8125*11{,}675.8*1.20)$
$= 0.003"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0015 + (0.003) - (0)$
$= \underline{0.0045"}$

Operating, Hot & Corroded, Seismic, Below Support Point

t_p = $P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
= $50*53.75 / (2*20{,}000*1.20*1.00 + 0.40*|50|)$
= 0.056"

t_m = $M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
= $1{,}963 / (\pi*53.875^2*20{,}000*1.20*1.00)$
= 0"

t_w = $(1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $1.02*-81{,}579.1 / (2*\pi*53.875*20{,}000*1.20*1.00)$
= -0.0102"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= $0.056 + 0 - (-0.0102)$
= <u>0.0662"</u>

t_{wc} = $(0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $0.58*-81{,}579.1 / (2*\pi*53.875*20{,}000*1.20*1.00)$
= -0.0058"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= $|0 + (-0.0058) - (0.056)|$
= <u>0.0618"</u>

Maximum allowable working pressure, Longitudinal Stress

P = $2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w))$
= $2*20{,}000*1.20*1.00*(0.25 - 0 + (-0.0102)) / (53.75 - 0.40*(0.25 - 0 + (-0.0102)))$
= 214.5 psi

Operating, Hot & New, Seismic, Below Support Point

t_p = $P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
= $50*53.625 / (2*20{,}000*1.20*1.00 + 0.40*|50|)$
= 0.0558"

t_m = $M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
= $2{,}087 / (\pi*53.8125^2*20{,}000*1.20*1.00)$
= 0"

t_w = $(1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $1.02*-81{,}697.1 / (2*\pi*53.8125*20{,}000*1.20*1.00)$
= -0.0103"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= $0.0558 + 0 - (-0.0103)$
= <u>0.0661"</u>

t_{wc} = $(0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $0.58*-81{,}697.1 / (2*\pi*53.8125*20{,}000*1.20*1.00)$

$= -0.0059"$

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

$= |0 + (-0.0059) - (0.0558)|$

$= \underline{0.0617"}$

Maximum allowable working pressure, Longitudinal Stress

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

$= 2*20{,}000*1.20*1.00*(0.375 - 0 + (-0.0103)) / (53.625 - 0.40*(0.375 - 0 + (-0.0103)))$

$= 327.37$ psi

Hot Shut Down, Corroded, Seismic, Below Support Point

$t_p = 0"$ (Pressure)

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

$= 1{,}963 / (\pi*53.875^{2}*20{,}000*1.20*1.00)$

$= 0"$

$t_w = (1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)

$= 1.02*-81{,}579.1 / (2*\pi*53.875*20{,}000*1.20*1.00)$

$= -0.0102"$

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

$= 0 + 0 - (-0.0102)$

$= \underline{0.0102"}$

$t_{wc} = (0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)

$= 0.58*-81{,}579.1 / (2*\pi*53.875*20{,}000*1.20*1.00)$

$= -0.0058"$

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

$= |0 + (-0.0058) - (0)|$

$= \underline{0.0058"}$

Hot Shut Down, New, Seismic, Below Support Point

$t_p = 0"$ (Pressure)

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

$= 2{,}087 / (\pi*53.8125^{2}*20{,}000*1.20*1.00)$

$= 0"$

$t_w = (1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)

$= 1.02*-81{,}697.1 / (2*\pi*53.8125*20{,}000*1.20*1.00)$

$= -0.0103"$

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

$= 0 + 0 - (-0.0103)$

$= \underline{0.0103"}$

$t_{wc} = (0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)

$= 0.58*-81,697.1 / (2*\pi*53.8125*20,000*1.20*1.00)$
$= -0.0059"$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0 + (-0.0059) - (0)|$
$= \underline{0.0058"}$

Empty, Corroded, Seismic, Below Support Point

$t_p = 0"$ (Pressure)
$t_m = M / (\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
$= 281 / (\pi*53.875^2*20,000*1.20*1.00)$
$= 0"$

$t_w = (1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 1.02*-866.4 / (2*\pi*53.875*20,000*1.20*1.00)$
$= -0.0001"$

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

$t_{wc} = (0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.58*-866.4 / (2*\pi*53.875*20,000*1.20*1.00)$
$= -0.0001"$

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

Empty, New, Seismic, Below Support Point

$t_p = 0"$ (Pressure)
$t_m = M / (\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
$= 415 / (\pi*53.8125^2*20,000*1.20*1.00)$
$= 0"$

$t_w = (1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 1.02*-1,375.1 / (2*\pi*53.8125*20,000*1.20*1.00)$
$= -0.0002"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0 + 0 - (-0.0002)$
$= \underline{0.0002"}$

$t_{wc} = (0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.58*-1,375.1 / (2*\pi*53.8125*20,000*1.20*1.00)$
$= -0.0001"$

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

Ellipsoidal Head #1

ASME Section VIII, Division 1, 2010 Edition

Component:	Ellipsoidal Head
Material Specification:	SA-516 70 (II-D p.18, ln. 19)

Straight Flange governs MDMT

Internal design pressure: P = 50 psi @ 400 °F

Static liquid head:

P_s= 0 psi (SG=1, H_s=0" Operating head)
P_{tv}= 1.2634 psi (SG=1, H_s=35" Vertical test head)

Corrosion allowance: Inner C = 0.125" Outer C = 0"

Design MDMT = 10°F
Rated MDMT = -55°F

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

Radiography:	Category A joints -	Seamless No RT
	Head to shell seam -	Spot UW-11(b) Type 1

Estimated weight*:	new = 1,133.4 lb	corr = 642.3 lb
Capacity*:	new = 780.9 US gal	corr = 787.8 US gal

* includes straight flange

Outer diameter	=	108"
Minimum head thickness	=	0.283"
Head ratio D/2h	=	2 (new)
Head ratio D/2h	=	1.9954 (corroded)
Straight flange length L_{sf}	=	2"
Nominal straight flange thickness t_{sf}	=	0.375"

Results Summary

The governing condition is internal pressure.

Minimum thickness per UG-16	=	0.0625" + 0.125" = 0.1875"
Design thickness due to internal pressure (t)	=	0.283"
Maximum allowable working pressure (MAWP)	=	50.03 psi
Maximum allowable pressure (MAP)	=	89.51 psi

K (Corroded)

$K=(1/6)*[2 + (D / (2*h))^2]=(1/6)*[2 + (107.684 / (2*26.9835))^2]=0.996915$

K (New)

$K=(1/6)*[2 + (D / (2*h))^2]=(1/6)*[2 + (107.434 / (2*26.8585))^2]=1$

Design thickness for internal pressure, (Corroded at 400 °F) Appendix 1-4(c)

$t = P*D_o*K / (2*S*E + 2*P*(K - 0.1)) + Corrosion$
$= 50*108*0.996915 / (2*20,000*0.85 + 2*50*(0.996915 - 0.1)) + 0.125$
$= 0.2829"$

Design thickness for internal pressure, (Corroded at 400 °F) Appendix 1-4(f)(2)

From Table UG-37, L = 96.8156 in.
From Table 1-4.4, r / D = 0.1708.
r = 0.1708*107.684 = 18.3888 in

$0.0005 \leq (t_{min\ head} - Corrosion) / L = 0.158 / 96.8156 = 0.0016 < 0.002$

$C_1 = 0.692*r / D + 0.605$
$= 0.692*0.1708 + 0.605$
$= 0.7232$

$S_e = C_1*E_T*(t / r)$
$= 0.7232*27,900,000*(0.1409 / 18.3888)$
$= 154,644$ psi

$C_2 = 1.46 - 2.6*r / D$
$= 1.46 - 2.6*0.1708$
$= 1.016$

$\phi = (L*t)^{0.5} / r$
$= (96.8156*0.1409)^{0.5} / 18.3888$
$= 0.200881$ radians

$a = 0.5*D - r$
$= 0.5*107.684 -18.3888$
$= 35.4532"$

$b = L - r$
$= 96.8156 - 18.3888$
$= 78.4268"$

$\beta = arc\ cos(a / b)$
$= arc\ cos(35.4532 / 78.4268)$
$= 1.101729$ radians

$\phi = 0.2009 < \beta = 1.1017$

$c = a / (cos(\beta - \phi))$
$= 35.4532 / (cos(1.1017 - 0.2009))$
$= 57.0955"$

$R_e = c + r$
$= 57.0955 + 18.3888$
$= 75.48428"$

$P_e = S_e*t / (C_2*R_e*(0.5*R_e / r - 1))$
$= 154,644*0.1409 / (1.016*75.4843*(0.5*75.4843 / 18.3888 - 1))$
$= 270.03$ psi

P_y = $S_y*t / (C_2*R_e*(0.5*R_e / r - 1))$
= 32,500*0.1409 / (1.016*75.4843*(0.5*75.4843 / 18.3888 - 1))
= 56.75 psi

$1 \le P_e / P_y = 270.03 / 56.75 = 4.76 \le 8.29$

P_{ck} = $0.408*P_y + 0.192*P_e$
= 0.408*56.75 + 0.192*270.03
= 75 psi

P_{ck} / 1.5 = 50 psi ≥ Internal design pressure P = 50 psi

t = t_r + Corrosion
= 0.140942 + 0.125
= 0.265942"

Design thickness is acceptable per Appendix 1-4(f) for a design pressure of 50 psi.

The head internal pressure design thickness is 0.283".

Maximum allowable working pressure, (Corroded at 400 °F) Appendix 1-4(c)

P = $2*S*E*t / (K*D_o - 2*t*(K - 0.1)) - P_s$
= 2*20,000*0.85*0.158 / (0.996915*108 - 2*0.158*(0.996915 - 0.1)) - 0
= 50.03 psi

Maximum allowable working pressure, (Corroded at 400 °F) Appendix 1-4(f)(2)

From Table UG-37, L = 96.8156 in.
From Table 1-4.4, r / D = 0.1708.
r = 0.1708*107.684 = 18.3888 in

$0.0005 \le (t_{min\ head}$ - Corrosion) / L = 0.158 / 96.8156 = 0.0016 < 0.002

C_1 = 0.692*r / D + 0.605
= 0.692*0.1708 + 0.605
= 0.7232

S_e = $C_1*E_T*(t / r)$
= 0.7232*27,900,000*(0.158 / 18.3888)
= 173,360 psi

C_2 = 1.46 - 2.6*r / D
= 1.46 - 2.6*0.1708
= 1.016

ϕ = $(L*t)^{0.5} / r$
= $(96.8156*0.158)^{0.5}$ / 18.3888
= 0.212691 radians

a = 0.5*D - r
= 0.5*107.684 -18.3888
= 35.4532"

b = L - r
= 96.8156 - 18.3888

$= 78.4268"$

$\beta = \text{arc cos}(a / b)$
$= \text{arc cos}(35.4532 / 78.4268)$
$= 1.101729$ radians

$\phi = 0.2127 < \beta = 1.1017$

$c = a / (\cos(\beta - \phi))$
$= 35.4532 / (\cos(1.1017 - 0.2127))$
$= 56.26074"$

$R_e = c + r$
$= 56.2607 + 18.3888$
$= 74.64952"$

$P_e = S_e*t / (C_2*R_e*(0.5*R_e / r - 1))$
$= 173{,}360*0.158 / (1.016*74.6495*(0.5*74.6495 / 18.3888 - 1))$
$= 350.71$ psi

$P_y = S_y*t / (C_2*R_e*(0.5*R_e / r - 1))$
$= 32{,}500*0.158 / (1.016*74.6495*(0.5*74.6495 / 18.3888 - 1))$
$= 65.75$ psi

$1 \le P_e / P_y = 350.71 / 65.75 = 5.33 \le 8.29$

$P_{ck} = 0.408*P_y + 0.192*P_e$
$= 0.408*65.75 + 0.192*350.71$
$= 94.16$ psi

$P_{ck} / 1.5 = 62.77$ psi

$P = P_{ck} / 1.5 - P_s$
$= 94.16 / 1.5 - 0$
$= 62.77$ psi

The maximum allowable working pressure (MAWP) is <u>50.03</u> psi.

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

$P = 2*S*E*t / (K*D_o - 2*t*(K - 0.1)) - P_s$
$= 2*20{,}000*0.85*0.283 / (1*108 - 2*0.283*(1 - 0.1)) - 0$
$= 89.51$ psi

The maximum allowable pressure (MAP) is <u>89.51</u> psi.

% Extreme fiber elongation - UCS-79(d)

$EFE = (75*t / R_f)*(1 - R_f / R_o)$
$= (75*0.375 / 18.4513)*(1 - 18.4513 / \infty)$
$= 1.5243\%$

The extreme fiber elongation does not exceed 5%.

Straight Flange on Ellipsoidal Head #1

ASME Section VIII Division 1, 2010 Edition

Component: Straight Flange
Material specification: SA-516 70 (II-D p. 18
Material impact test exemption temperature from Fig UCS-66 Curve B = -20 °F
Fig UCS-66.1 MDMT reduction = 50.3 °F, (coincident ratio = 0.5393655)
Rated MDMT is governed by UCS-66(b)(2)
UCS-66 governing thickness = 0.375 in

Internal design pressure: P = 50 psi @ 400 °F

Static liquid head:

P_s = 0 psi (SG = 1, H_s = 0",Operating head)
P_{tv} = 1.34 psi (SG = 1, H_s = 37", Vertical test head)

Corrosion allowance Inner C = 0.125" Outer C = 0"

Design MDMT = 10 °F
Rated MDMT = -55 °F

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

Radiography: Longitudinal joint - Seamless No RT
Circumferential joint - Spot UW-11(b) Type 1

Estimated weight New = 71.8 lb corr = 47.9 lb
Capacity New = 78.22 US gal corr = 78.58 US gal

OD = 108"
Length L_c = 2"
t = 0.375"

Design thickness, (at 400 °F) Appendix 1-1

t = $P*R_o$ / (S*E + 0.40*P) + Corrosion
= 50*54 / (20,000*0.85 + 0.40*50) + 0.125
= 0.2837"

Maximum allowable working pressure, (at 400 °F) Appendix 1-1

P = S*E*t / (R_o - 0.40*t) - P_s
= 20,000*0.85*0.25 / (54 - 0.40*0.25) - 0
= 78.85 psi

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

P = S*E*t / (R_o - 0.40*t)
= 20,000*0.85*0.375 / (54 - 0.40*0.375)
= 118.38 psi

% Extreme fiber elongation - UCS-79(d)

EFE = $(50*t / R_f)*(1 - R_f / R_o)$
= $(50*0.375 / 53.8125)*(1 - 53.8125 / \infty)$
= 0.3484%

The extreme fiber elongation does not exceed 5%.

Design thickness = 0.2837"

The governing condition is due to internal pressure.

The cylinder thickness of 0.375" is adequate.

Thickness Required Due to Pressure + External Loads

Condition	Pressure P (psi)	Allowable Stress Before UG-23 Stress Increase (psi)		Temperature (°F)	Corrosion C (in)	Load	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
		S_t	S_c					
Operating, Hot & Corroded	50	20,000	8,017	400	0.125	Wind	0.0658	0.0657
						Seismic	0.0658	0.0657
Operating, Hot & New	50	20,000	10,568	400	0	Wind	0.0656	0.0655
						Seismic	0.0656	0.0655
Hot Shut Down, Corroded	0	20,000	8,017	400	0.125	Wind	0.0001	0.0003
						Seismic	0.0001	0.0002
Hot Shut Down, New	0	20,000	10,568	400	0	Wind	0.0001	0.0003
						Seismic	0.0002	0.0003
Empty, Corroded	0	20,000	8,341	70	0.125	Wind	0.0001	0.0003
						Seismic	0.0001	0.0002
Empty, New	0	20,000	11,676	70	0	Wind	0.0001	0.0003
						Seismic	0.0001	0.0003
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0	20,000	8,017	400	0.125	Weight	0.0003	0.0003

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

A = $0.125 / (R_o / t)$
= 0.125 / (54 / 0.25)
= 0.000579

B = 8,017 psi

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

S_{cHC} = min(B, S) = 8,017 psi

Allowable Compressive Stress, Hot and New- S_{cHN}, (table CS-2)

A = $0.125 / (R_o / t)$
= 0.125 / (54 / 0.375)
= 0.000868

B = 10,568 psi

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

S_{cHN} = min(B, S) = 10,568 psi

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

A = 0.125 / (R_o / t)
= 0.125 / (54 / 0.375)
= 0.000868

B = 11,676 psi

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

S_{cCN} = min(B, S) = 11,676 psi

Allowable Compressive Stress, Cold and Corroded- S_{cCC}, (table CS-2)

A = 0.125 / (R_o / t)
= 0.125 / (54 / 0.25)
= 0.000579

B = 8,341 psi

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

S_{cCC} = min(B, S) = 8,341 psi

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

A = 0.125 / (R_o / t)
= 0.125 / (54 / 0.25)
= 0.000579

B = 8,017 psi

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

S_{cVC} = min(B, S) = 8,017 psi

Operating, Hot & Corroded, Wind, Bottom Seam

t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|) (Pressure)
= 50*53.75 / (2*20,000*1.20*0.85 + 0.40*|50|)
= 0.0658"

t_m = M / (π*R_m^2*S_t*K_s*E_c) (bending)
= 5,938 / (π*53.875²*20,000*1.20*0.85)
= 0"

t_w = 0.6*W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 0.60*747.5 / (2*π*53.875*20,000*1.20*0.85)
= 0.0001"

t_t = t_p + t_m - t_w (total required, tensile)
= 0.0658 + 0 - (0.0001)
= 0.0658"

t_{wc} = W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 747.5 / (2*π*53.875*20,000*1.20*0.85)

$= 0.0001"$

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

$= |0 + (0.0001) - (0.0658)|$

$= \underline{0.0657"}$

Maximum allowable working pressure, Longitudinal Stress

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

$= 2*20,000*1.20*0.85*(0.25 - 0 + (0.0001)) / (53.75 - 0.40*(0.25 - 0 + (0.0001)))$

$= 190.15$ psi

Operating, Hot & New, Wind, Bottom Seam

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

$= 50*53.625 / (2*20,000*1.20*0.85 + 0.40*|50|)$

$= 0.0657"$

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

$= 5,938 / (\pi*53.8125^2*20,000*1.20*0.85)$

$= 0"$

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

$= 0.60*1,244.1 / (2*\pi*53.8125*20,000*1.20*0.85)$

$= 0.0001"$

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

$= 0.0657 + 0 - (0.0001)$

$= \underline{0.0656"}$

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

$= 1,244.1 / (2*\pi*53.8125*20,000*1.20*0.85)$

$= 0.0002"$

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

$= |0 + (0.0002) - (0.0657)|$

$= \underline{0.0655"}$

Maximum allowable working pressure, Longitudinal Stress

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

$= 2*20,000*1.20*0.85*(0.375 - 0 + (0.0001)) / (53.625 - 0.40*(0.375 - 0 + (0.0001)))$

$= 286.17$ psi

Hot Shut Down, Corroded, Wind, Bottom Seam

$t_p = 0"$ (Pressure)

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

$= 5,938 / (\pi*53.875^2*8,016.58*1.20)$

$= 0.0001"$

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

$= 0.60*747.5 / (2*\pi*53.875*8,016.58*1.20)$

$= 0.0001"$

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

$t_{wc} = W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 747.5 / (2*\pi*53.875*8,016.58*1.20)$
$= 0.0002"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0001 + (0.0002) - (0)$
$= \underline{0.0003"}$

Hot Shut Down, New, Wind, Bottom Seam

$t_p = 0"$ (Pressure)
$t_m = M / (\pi*R_m{}^2*S_c*K_s)$ (bending)
$= 5,938 / (\pi*53.8125^2*10,568.3*1.20)$
$= 0.0001"$

$t_w = 0.6*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 0.60*1,244.1 / (2*\pi*53.8125*10,568.3*1.20)$
$= 0.0002"$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
$= |0 + 0.0001 - (0.0002)|$
$= \underline{0.0001"}$

$t_{wc} = W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 1,244.1 / (2*\pi*53.8125*10,568.3*1.20)$
$= 0.0003"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0001 + (0.0003) - (0)$
$= \underline{0.0003"}$

Empty, Corroded, Wind, Bottom Seam

$t_p = 0"$ (Pressure)
$t_m = M / (\pi*R_m{}^2*S_c*K_s)$ (bending)
$= 5,938 / (\pi*53.875^2*8,341.12*1.20)$
$= 0.0001"$

$t_w = 0.6*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 0.60*747.5 / (2*\pi*53.875*8,341.12*1.20)$
$= 0.0001"$

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

$t_{wc} = W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 747.5 / (2*\pi*53.875*8,341.12*1.20)$
$= 0.0002"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0001 + (0.0002) - (0)$
$= \underline{0.0003"}$

Empty, New, Wind, Bottom Seam

$t_p = 0"$ (Pressure)
$t_m = M / (\pi*R_m{}^2*S_c*K_s)$ (bending)
$= 5,938 / (\pi*53.8125^2*11,675.8*1.20)$
$= 0"$

$t_w = 0.6*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 0.60*1,244.1 / (2*\pi*53.8125*11,675.8*1.20)$
$= 0.0002"$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
$= |0 + 0 - (0.0002)|$
$= \underline{0.0001"}$

$t_{wc} = W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 1,244.1 / (2*\pi*53.8125*11,675.8*1.20)$
$= 0.0003"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0 + (0.0003) - (0)$
$= \underline{0.0003"}$

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)
$= 0 / (\pi*53.875^2*8,016.58*1.00)$
$= 0"$

$t_w = W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 747.5 / (2*\pi*53.875*8,016.58*1.00)$
$= 0.0003"$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
$= |0 + 0 - (0.0003)|$
$= \underline{0.0003"}$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0 + (0.0003) - (0)$
$= \underline{0.0003"}$

Operating, Hot & Corroded, Seismic, Bottom Seam

$t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
$= 50*53.75 / (2*20,000*1.20*0.85 + 0.40*|50|)$
$= 0.0658"$

$t_m = M / (\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
$= 1,019 / (\pi*53.875^2*20,000*1.20*0.85)$

$= 0"$

$t_w = (0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)

$= 0.58*747.5 / (2*\pi*53.875*20,000*1.20*0.85)$

$= 0.0001"$

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

$= 0.0658 + 0 - (0.0001)$

$=$ <u>0.0658"</u>

$t_{wc} = (1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)

$= 1.02*747.5 / (2*\pi*53.875*20,000*1.20*0.85)$

$= 0.0001"$

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

$= |0 + (0.0001) - (0.0658)|$

$=$ <u>0.0657"</u>

Maximum allowable working pressure, Longitudinal Stress

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

$= 2*20,000*1.20*0.85*(0.25 - 0 + (0.0001)) / (53.75 - 0.40*(0.25 - 0 + (0.0001)))$

$= 190.16$ psi

<u>**Operating, Hot & New, Seismic, Bottom Seam**</u>

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

$= 50*53.625 / (2*20,000*1.20*0.85 + 0.40*|50|)$

$= 0.0657"$

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

$= 1,593 / (\pi*53.8125^2*20,000*1.20*0.85)$

$= 0"$

$t_w = (0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)

$= 0.58*1,244.1 / (2*\pi*53.8125*20,000*1.20*0.85)$

$= 0.0001"$

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

$= 0.0657 + 0 - (0.0001)$

$=$ <u>0.0656"</u>

$t_{wc} = (1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)

$= 1.02*1,244.1 / (2*\pi*53.8125*20,000*1.20*0.85)$

$= 0.0002"$

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

$= |0 + (0.0002) - (0.0657)|$

$=$ <u>0.0655"</u>

Maximum allowable working pressure, Longitudinal Stress

$P = 2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w))$
$= 2*20{,}000*1.20*0.85*(0.375 - 0 + (0.0001)) / (53.625 - 0.40*(0.375 - 0 + (0.0001)))$
$= 286.19$ psi

Hot Shut Down, Corroded, Seismic, Bottom Seam

$t_p = 0"$ (Pressure)
$t_m = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 1{,}019 / (\pi*53.875^2*8{,}016.58*1.20)$
$= 0"$

$t_w = (0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 0.58*747.5 / (2*\pi*53.875*8{,}016.58*1.20)$
$= 0.0001"$

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

$t_{wc} = (1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 1.02*747.5 / (2*\pi*53.875*8{,}016.58*1.20)$
$= 0.0002"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0 + (0.0002) - (0)$
$=$ 0.0002"

Hot Shut Down, New, Seismic, Bottom Seam

$t_p = 0"$ (Pressure)
$t_m = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 1{,}593 / (\pi*53.8125^2*10{,}568.3*1.20)$
$= 0"$

$t_w = (0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 0.58*1{,}244.1 / (2*\pi*53.8125*10{,}568.3*1.20)$
$= 0.0002"$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
$= |0 + 0 - (0.0002)|$
$=$ 0.0002"

$t_{wc} = (1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 1.02*1{,}244.1 / (2*\pi*53.8125*10{,}568.3*1.20)$
$= 0.0003"$

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

Empty, Corroded, Seismic, Bottom Seam

t_p = 0" (Pressure)
t_m = $M / (\pi * R_m{}^2 * S_c * K_s)$ (bending)
= $934 / (\pi * 53.875^2 * 8{,}341.12 * 1.20)$
= 0"
t_w = $(0.6 - 0.14 * S_{DS}) * W / (2 * \pi * R_m * S_c * K_s)$ (Weight)
= $0.58 * 747.5 / (2 * \pi * 53.875 * 8{,}341.12 * 1.20)$
= 0.0001"
t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= |0 + 0 - (0.0001)|
= 0.0001"
t_{wc} = $(1 + 0.14 * S_{DS}) * W / (2 * \pi * R_m * S_c * K_s)$ (Weight)
= $1.02 * 747.5 / (2 * \pi * 53.875 * 8{,}341.12 * 1.20)$
= 0.0002"
t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0 + (0.0002) - (0)
= 0.0002"

Empty, New, Seismic, Bottom Seam

t_p = 0" (Pressure)
t_m = $M / (\pi * R_m{}^2 * S_c * K_s)$ (bending)
= $1{,}408 / (\pi * 53.8125^2 * 11{,}675.8 * 1.20)$
= 0"
t_w = $(0.6 - 0.14 * S_{DS}) * W / (2 * \pi * R_m * S_c * K_s)$ (Weight)
= $0.58 * 1{,}244.1 / (2 * \pi * 53.8125 * 11{,}675.8 * 1.20)$
= 0.0002"
t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= |0 + 0 - (0.0002)|
= 0.0001"
t_{wc} = $(1 + 0.14 * S_{DS}) * W / (2 * \pi * R_m * S_c * K_s)$ (Weight)
= $1.02 * 1{,}244.1 / (2 * \pi * 53.8125 * 11{,}675.8 * 1.20)$
= 0.0003"
t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0 + (0.0003) - (0)
= 0.0003"

Straight Flange on Ellipsoidal Head #2

ASME Section VIII Division 1, 2010 Edition

Component: Straight Flange
Material specification: SA-516 70 (II-D p. 18
Material impact test exemption temperature from Fig UCS-66 Curve B = -20 °F
Fig UCS-66.1 MDMT reduction = 37.2 °F, (coincident ratio = 0.6280251)
Rated MDMT is governed by UCS-66(b)(2)
UCS-66 governing thickness = 0.375 in

Internal design pressure: P = 50 psi @ 400 °F

Static liquid head:

P_s = 8.23 psi (SG = 1, H_s = 228",Operating head)
P_{tv} = 13.1 psi (SG = 1, H_s = 363", Vertical test head)

Corrosion allowance Inner C = 0.125" Outer C = 0"

Design MDMT = 10 °F
Rated MDMT = -55 °F

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

Radiography:	Longitudinal joint -	Seamless No RT
	Circumferential joint -	Spot UW-11(b) Type 1

Estimated weight	New = 71.8 lb	corr = 47.9 lb
Capacity	New = 78.22 US gal	corr = 78.58 US gal

OD = 108"
Length L_c = 2"
t = 0.375"

Design thickness, (at 400 °F) Appendix 1-1

$$t = P*R_o / (S*E + 0.40*P) + \text{Corrosion}$$
$$= 58.23*54 / (20{,}000*0.85 + 0.40*58.23) + 0.125$$
$$= 0.3098"$$

Maximum allowable working pressure, (at 400 °F) Appendix 1-1

$$P = S*E*t / (R_o - 0.40*t) - P_s$$
$$= 20{,}000*0.85*0.25 / (54 - 0.40*0.25) - 8.23$$
$$= 70.62 \text{ psi}$$

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

$$P = S*E*t / (R_o - 0.40*t)$$
$$= 20{,}000*0.85*0.375 / (54 - 0.40*0.375)$$
$$= 118.38 \text{ psi}$$

% Extreme fiber elongation - UCS-79(d)

EFE	=	$(50^*t / R_f)^*(1 - R_f / R_o)$
	=	$(50^*0.375 / 53.8125)^*(1 - 53.8125 / \infty)$
	=	0.3484%

The extreme fiber elongation does not exceed 5%.

Design thickness = 0.3098"

The governing condition is due to internal pressure.

The cylinder thickness of 0.375" is adequate.

Thickness Required Due to Pressure + External Loads

Condition	Pressure P (psi)	Allowable Stress Before UG-23 Stress Increase (psi)		Temperature (°F)	Corrosion C (in)	Load	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
		S_t	S_c					
Operating, Hot & Corroded	50	20,000	8,017	400	0.125	Wind	0.0777	0.0729
						Seismic	0.0779	0.0727
Operating, Hot & New	50	20,000	10,568	400	0	Wind	0.0775	0.0728
						Seismic	0.0777	0.0726
Hot Shut Down, Corroded	0	20,000	8,017	400	0.125	Wind	0.0118	0.007
						Seismic	0.012	0.0069
Hot Shut Down, New	0	20,000	10,568	400	0	Wind	0.0118	0.0071
						Seismic	0.012	0.0069
Empty, Corroded	0	20,000	8,341	70	0.125	Wind	0.0001	0
						Seismic	0.0001	0.0001
Empty, New	0	20,000	11,676	70	0	Wind	0.0002	0.0001
						Seismic	0.0002	0.0001
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0	20,000	8,017	400	0.125	Weight	0.0142	0.0142

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

A	=	$0.125 / (R_o / t)$
	=	$0.125 / (54 / 0.25)$
	=	0.000579
B	=	8,017 psi
S	=	20,000 / 1.00 = 20,000 psi
S_{cHC}	=	min(B, S) = 8,017 psi

Allowable Compressive Stress, Hot and New- S_{cHN}, (table CS-2)

A	=	$0.125 / (R_o / t)$
	=	$0.125 / (54 / 0.375)$
	=	0.000868
B	=	10,568 psi

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

S_{cHN} = min(B, S) = 10,568 psi

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

A = $0.125 / (R_o / t)$
= 0.125 / (54 / 0.375)
= 0.000868

B = 11,676 psi

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

S_{cCN} = min(B, S) = 11,676 psi

Allowable Compressive Stress, Cold and Corroded- S_{cCC}, (table CS-2)

A = $0.125 / (R_o / t)$
= 0.125 / (54 / 0.25)
= 0.000579

B = 8,341 psi

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

S_{cCC} = min(B, S) = 8,341 psi

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

A = $0.125 / (R_o / t)$
= 0.125 / (54 / 0.25)
= 0.000579

B = 8,017 psi

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

S_{cVC} = min(B, S) = 8,017 psi

Operating, Hot & Corroded, Wind, Top Seam

t_p	=	$P*R / (2*S_t*K_s*E_c + 0.40*\|P\|)$	(Pressure)
	=	$50*53.75 / (2*20{,}000*1.20*0.85 + 0.40*\|50\|)$	
	=	0.0658"	
t_m	=	$M / (\pi*R_m{}^2*S_t*K_s*E_c)$	(bending)
	=	$4{,}836 / (\pi*53.875^2*20{,}000*1.20*0.85)$	
	=	0"	
t_w	=	$W / (2*\pi*R_m*S_t*K_s*E_c)$	(Weight)
	=	$-81{,}427.8 / (2*\pi*53.875*20{,}000*1.20*0.85)$	
	=	-0.0118"	
t_t	=	$t_p + t_m - t_w$	(total required, tensile)
	=	0.0658 + 0 - (-0.0118)	
	=	0.0777"	
t_{wc}	=	$0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$	(Weight)
	=	$0.60*-81{,}427.8 / (2*\pi*53.875*20{,}000*1.20*0.85)$	

= -0.0071"

t_c	=	$\lvert t_{mc} + t_{wc} - t_{pc} \rvert$	(total, net tensile)
	=	$\lvert 0 + (-0.0071) - (0.0658) \rvert$	
	=	0.0729"	

Maximum allowable working pressure, Longitudinal Stress

$$P = 2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w))$$
$$= 2*20,000*1.20*0.85*(0.25 - 0 + (-0.0118)) / (53.75 - 0.40*(0.25 - 0 + (-0.0118)))$$
$$= 181.12 \text{ psi}$$

Operating, Hot & New, Wind, Top Seam

t_p	=	$P*R / (2*S_t*K_s*E_c + 0.40*\lvert P \rvert)$	(Pressure)
	=	$50*53.625 / (2*20,000*1.20*0.85 + 0.40*\lvert 50 \rvert)$	
	=	0.0657"	
t_m	=	$M / (\pi*R_m{}^2*S_t*K_s*E_c)$	(bending)
	=	$4,836 / (\pi*53.8125^2*20,000*1.20*0.85)$	
	=	0"	
t_w	=	$W / (2*\pi*R_m*S_t*K_s*E_c)$	(Weight)
	=	$-81,538.4 / (2*\pi*53.8125*20,000*1.20*0.85)$	
	=	-0.0118"	
t_t	=	$t_p + t_m - t_w$	(total required, tensile)
	=	0.0657 + 0 - (-0.0118)	
	=	0.0775"	
t_{wc}	=	$0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$	(Weight)
	=	$0.60*-81,538.4 / (2*\pi*53.8125*20,000*1.20*0.85)$	
	=	-0.0071"	
t_c	=	$\lvert t_{mc} + t_{wc} - t_{pc} \rvert$	(total, net tensile)
	=	$\lvert 0 + (-0.0071) - (0.0657) \rvert$	
	=	0.0728"	

Maximum allowable working pressure, Longitudinal Stress

$$P = 2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w))$$
$$= 2*20,000*1.20*0.85*(0.375 - 0 + (-0.0118)) / (53.625 - 0.40*(0.375 - 0 + (-0.0118)))$$
$$= 277.05 \text{ psi}$$

Hot Shut Down, Corroded, Wind, Top Seam

t_p	=	0"	(Pressure)
t_m	=	$M / (\pi*R_m{}^2*S_t*K_s*E_c)$	(bending)
	=	$4,836 / (\pi*53.875^2*20,000*1.20*0.85)$	
	=	0"	

t_w = $W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $-81{,}427.8 / (2*\pi*53.875*20{,}000*1.20*0.85)$
= -0.0118"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0 + 0 - (-0.0118)
= 0.0118"

t_{wc} = $0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $0.60*-81{,}427.8 / (2*\pi*53.875*20{,}000*1.20*0.85)$
= -0.0071"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0 + (-0.0071) - (0)|
= 0.007"

Hot Shut Down, New, Wind, Top Seam

t_p = 0" (Pressure)
t_m = $M / (\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
= $4{,}836 / (\pi*53.8125^2*20{,}000*1.20*0.85)$
= 0"

t_w = $W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $-81{,}538.4 / (2*\pi*53.8125*20{,}000*1.20*0.85)$
= -0.0118"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0 + 0 - (-0.0118)
= 0.0118"

t_{wc} = $0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $0.60*-81{,}538.4 / (2*\pi*53.8125*20{,}000*1.20*0.85)$
= -0.0071"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0 + (-0.0071) - (0)|
= 0.0071"

Empty, Corroded, Wind, Top Seam

t_p = 0" (Pressure)
t_m = $M / (\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
= $4{,}836 / (\pi*53.875^2*20{,}000*1.20*0.85)$
= 0"

t_w = $W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $-842.4 / (2*\pi*53.875*20{,}000*1.20*0.85)$
= -0.0001"

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

$= 0 + 0 - (-0.0001)$

$= \underline{0.0001"}$

$t_{wc} = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)

$= 0.60*-842.4 / (2*\pi*53.875*20{,}000*1.20*0.85)$

$= -0.0001"$

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

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

$= \underline{0"}$

Empty, New, Wind, Top Seam

$t_p = 0"$ (Pressure)

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

$= 4{,}836 / (\pi*53.8125^2*20{,}000*1.20*0.85)$

$= 0"$

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

$= -1{,}339.3 / (2*\pi*53.8125*20{,}000*1.20*0.85)$

$= -0.0002"$

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

$= 0 + 0 - (-0.0002)$

$= \underline{0.0002"}$

$t_{wc} = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)

$= 0.60*-1{,}339.3 / (2*\pi*53.8125*20{,}000*1.20*0.85)$

$= -0.0001"$

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

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

$= \underline{0.0001"}$

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

$t_p = 0"$ (Pressure)

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

$= 0 / (\pi*53.875^2*20{,}000*1.00*0.85)$

$= 0"$

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

$= -81{,}427.8 / (2*\pi*53.875*20{,}000*1.00*0.85)$

$= -0.0142"$

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

$= 0 + 0 - (-0.0142)$

$= \underline{0.0142"}$

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

$= |0 + (-0.0142) - (0)|$

$= \underline{0.0142"}$

Operating, Hot & Corroded, Seismic, Top Seam

t_p = $P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
= $50*53.75 / (2*20{,}000*1.20*0.85 + 0.40*|50|)$
= 0.0658"

t_m = $M / (\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
= $1{,}810 / (\pi*53.875^2*20{,}000*1.20*0.85)$
= 0"

t_w = $(1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $1.02*\text{-}81{,}427.8 / (2*\pi*53.875*20{,}000*1.20*0.85)$
= -0.012"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0.0658 + 0 - (-0.012)
= <u>0.0779"</u>

t_{wc} = $(0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $0.58*\text{-}81{,}427.8 / (2*\pi*53.875*20{,}000*1.20*0.85)$
= -0.0069"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0 + (-0.0069) - (0.0658)|
= <u>0.0727"</u>

Maximum allowable working pressure, Longitudinal Stress

$P = 2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w))$
= 2*20,000*1.20*0.85*(0.25 - 0 + (-0.012)) / (53.75 - 0.40*(0.25 - 0 + (-0.012)))
= 180.97 psi

Operating, Hot & New, Seismic, Top Seam

t_p = $P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
= $50*53.625 / (2*20{,}000*1.20*0.85 + 0.40*|50|)$
= 0.0657"

t_m = $M / (\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
= $1{,}926 / (\pi*53.8125^2*20{,}000*1.20*0.85)$
= 0"

t_w = $(1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $1.02*\text{-}81{,}538.4 / (2*\pi*53.8125*20{,}000*1.20*0.85)$
= -0.012"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0.0657 + 0 - (-0.012)
= <u>0.0777"</u>

t_{wc} = $(0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $0.58*\text{-}81{,}538.4 / (2*\pi*53.8125*20{,}000*1.20*0.85)$

$= -0.0069"$

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

$= |0 + (-0.0069) - (0.0657)|$

$= \underline{0.0726"}$

Maximum allowable working pressure, Longitudinal Stress

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

$= 2*20{,}000*1.20*0.85*(0.375 - 0 + (-0.012)) / (53.625 - 0.40*(0.375 - 0 + (-0.012)))$

$= 276.9$ psi

Hot Shut Down, Corroded, Seismic, Top Seam

$t_p = 0"$ (Pressure)

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

$= 1{,}810 / (\pi*53.875^2*20{,}000*1.20*0.85)$

$= 0"$

$t_w = (1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)

$= 1.02*-81{,}427.8 / (2*\pi*53.875*20{,}000*1.20*0.85)$

$= -0.012"$

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

$= 0 + 0 - (-0.012)$

$= \underline{0.012"}$

$t_{wc} = (0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)

$= 0.58*-81{,}427.8 / (2*\pi*53.875*20{,}000*1.20*0.85)$

$= -0.0069"$

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

$= |0 + (-0.0069) - (0)|$

$= \underline{0.0069"}$

Hot Shut Down, New, Seismic, Top Seam

$t_p = 0"$ (Pressure)

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

$= 1{,}926 / (\pi*53.8125^2*20{,}000*1.20*0.85)$

$= 0"$

$t_w = (1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)

$= 1.02*-81{,}538.4 / (2*\pi*53.8125*20{,}000*1.20*0.85)$

$= -0.012"$

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

$= 0 + 0 - (-0.012)$

$= \underline{0.012"}$

$t_{wc} = (0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)

= $0.58*-81{,}538.4 / (2*\pi*53.8125*20{,}000*1.20*0.85)$
= -0.0069"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= $|0 + (-0.0069) - (0)|$
= 0.0069"

Empty, Corroded, Seismic, Top Seam

t_p = 0" (Pressure)
t_m = $M / (\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
= $264 / (\pi*53.875^2*20{,}000*1.20*0.85)$
= 0"

t_w = $(1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $1.02*-842.4 / (2*\pi*53.875*20{,}000*1.20*0.85)$
= -0.0001"

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

t_{wc} = $(0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $0.58*-842.4 / (2*\pi*53.875*20{,}000*1.20*0.85)$
= -0.0001"

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

Empty, New, Seismic, Top Seam

t_p = 0" (Pressure)
t_m = $M / (\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
= $390 / (\pi*53.8125^2*20{,}000*1.20*0.85)$
= 0"

t_w = $(1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $1.02*-1{,}339.3 / (2*\pi*53.8125*20{,}000*1.20*0.85)$
= -0.0002"

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

t_{wc} = $(0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $0.58*-1{,}339.3 / (2*\pi*53.8125*20{,}000*1.20*0.85)$
= -0.0001"

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

Ellipsoidal Head #2

ASME Section VIII, Division 1, 2010 Edition

Component:	Ellipsoidal Head
Material Specification:	SA-516 70 (II-D p.18, ln. 19)

Straight Flange governs MDMT

Internal design pressure: P = 50 psi @ 400 °F

Static liquid head:

P_s= 9.2035 psi (SG=1, H_s=254.965" Operating head)
P_{tv}= 14.0721 psi (SG=1, H_s=389.84" Vertical test head)

Corrosion allowance: Inner C = 0.125" Outer C = 0"

Design MDMT = 10°F	No impact test performed
Rated MDMT = -55°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 -	Seamless No RT
	Head to shell seam -	Spot UW-11(b) Type 1

Estimated weight*:	new = 1,277.8 lb	corr = 785 lb
Capacity*:	new = 779.4 US gal	corr = 786.4 US gal

* includes straight flange

Outer diameter	=	108"
Minimum head thickness	=	0.32"
Head ratio D/2h	=	2 (new)
Head ratio D/2h	=	1.9954 (corroded)
Straight flange length L_{sf}	=	2"
Nominal straight flange thickness t_{sf}	=	0.375"

Results Summary

The governing condition is internal pressure.

Minimum thickness per UG-16	=	0.0625" + 0.125" = 0.1875"
Design thickness due to internal pressure (t)	=	0.3119"
Maximum allowable working pressure (MAWP)	=	52.58 psi
Maximum allowable pressure (MAP)	=	101.28 psi

K (Corroded)

$K=(1/6)*[2 + (D / (2*h))^2]=(1/6)*[2 + (107.61 / (2*26.965))^2]=0.996913$

K (New)

$K=(1/6)*[2 + (D / (2*h))^2]=(1/6)*[2 + (107.36 / (2*26.84))^2]=1$

Design thickness for internal pressure, (Corroded at 400 °F) Appendix 1-4(c)

$$
\begin{aligned}
t &= P*D_o*K / (2*S*E + 2*P*(K - 0.1)) + \text{Corrosion} \\
&= 59.2*108*0.996913 / (2*20{,}000*0.85 + 2*59.2*(0.996913 - 0.1)) + 0.125 \\
&= 0.3119''
\end{aligned}
$$

The head internal pressure design thickness is 0.3119".

Maximum allowable working pressure, (Corroded at 400 °F) Appendix 1-4(c)

$$
\begin{aligned}
P &= 2*S*E*t / (K*D_o - 2*t*(K - 0.1)) - P_s \\
&= 2*20{,}000*0.85*0.195 / (0.996913*108 - 2*0.195*(0.996913 - 0.1)) - 9.2 \\
&= 52.58 \text{ psi}
\end{aligned}
$$

The maximum allowable working pressure (MAWP) is 52.58 psi.

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

$$
\begin{aligned}
P &= 2*S*E*t / (K*D_o - 2*t*(K - 0.1)) - P_s \\
&= 2*20{,}000*0.85*0.32 / (1*108 - 2*0.32*(1 - 0.1)) - 0 \\
&= 101.28 \text{ psi}
\end{aligned}
$$

The maximum allowable pressure (MAP) is 101.28 psi.

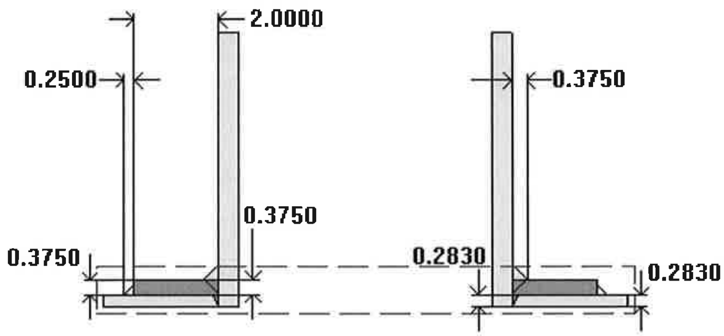
% Extreme fiber elongation - UCS-79(d)

$$
\begin{aligned}
EFE &= (75*t / R_f)*(1 - R_f / R_o) \\
&= (75*0.375 / 18.4387)*(1 - 18.4387 / \infty) \\
&= 1.5253\%
\end{aligned}
$$

The extreme fiber elongation does not exceed 5%.

Nozzle A (A)

ASME Section VIII Division 1, 2010 Edition



$t_{w(lower)}$ = 0.283 in
Leg_{41} = 0.375 in
$t_{w(upper)}$ = 0.375 in
Leg_{42} = 0.25 in
D_p = 16.75 in
t_e = 0.375 in

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

Located on:	Ellipsoidal Head #1
Liquid static head included:	0 psi
Nozzle material specification:	SA-106 B Smls pipe (II-D p. 10
Nozzle longitudinal joint efficiency:	1
Nozzle description:	NPS 12 X Heavy
Pad material specification:	SA-516 70 (II-D p. 18
Pad diameter:	16.75 in
Flange description:	12 inch Class 150 WN A105
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 334
Flange rated MDMT:	-55°F
(UCS-66(b)(3): Coincident ratio = 0.1754386)	
(Flange rated MDMT = -155 °F Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F)	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	200 psi @ 400°F
ASME B16.5 flange rating MAP:	285 psi @ 70°F
ASME B16.5 flange hydro test:	450 psi @ 70°F
PWHT performed:	No
Circumferential joint radiography:	Spot UW-11(b) Type 1
Nozzle orientation:	0°
Calculated as hillside:	No
Local vessel minimum thickness:	0.283 in
End of nozzle to datum line:	361 in
Nozzle inside diameter, new:	11.75 in
Nozzle nominal wall thickness:	0.5 in
Nozzle corrosion allowance:	0.125 in
Projection available outside vessel, Lpr:	3.5483 in

Projection available outside vessel to flange face, Lf:	8.0483 in
Distance to head center, R:	0 in
Pad is split:	No

Reinforcement Calculations for Internal Pressure

Available reinforcement per UG-37 governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 63.53 psi @ 400 °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}
1.8627	1.8628	0.0496	0.2382	--	1.5	0.075	0.2955	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
36,315.26	36,264	151,716.59	7,040.35	220,915.55	38,290.35	111,294.22

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.25	0.2625	weld size is adequate
Pad to shell fillet (Leg_{42})	0.079	0.175	weld size is adequate
Nozzle to pad groove (Upper)	0.2625	0.375	weld size is adequate

Calculations for internal pressure 63.53 psi @ 400 °F

Fig UCS-66.2 general note (1) applies.

Nozzle impact test exemption temperature from Fig UCS-66 Curve B = -20 °F
Fig UCS-66.1 MDMT reduction = 23.4 °F, (coincident ratio = 0.76646).

Pad impact test exemption temperature from Fig UCS-66 Curve B = -20 °F
Fig UCS-66.1 MDMT reduction = 23.4 °F, (coincident ratio = 0.76646).

Nozzle UCS-66 governing thk:	0.375 in
Nozzle rated MDMT:	-43.4 °F
Pad UCS-66 governing thickness:	0.375 in
Pad rated MDMT:	-43.4 °F

Parallel Limit of reinforcement per UG-40

$$L_R = MAX(d, R_n + (t_n - C_n) + (t - C))$$
$$= MAX(12, 6 + (0.5 - 0.125) + (0.283 - 0.125))$$
$$= 12 \text{ in}$$

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*(0.283 - 0.125), 2.5*(0.5 - 0.125) + 0.375)
= 0.395 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 63.5314*6 / (17,100*1 - 0.6*63.5314)
= 0.0223 in

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

t_r = P*K_1*D_o / (2*S*E + 0.8*P)
= 63.5314*0.8979*108 / (2*20,000*1 + 0.8*63.5314)
= 0.1538 in

Area required per UG-37(c)

Allowable stresses: S_n = 17,100, S_v = 20,000, S_p = 20,000 psi

f_{r1} = lesser of 1 or S_n / S_v = 0.855

f_{r2} = lesser of 1 or S_n / S_v = 0.855

f_{r3} = lesser of f_{r2} or S_p / S_v = 0.855

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})
= 12*0.1538*1 + 2*0.375*0.1538*1*(1 - 0.855)
= 1.8627 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.0496 in^2

= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})
= 12*(1*0.158 - 1*0.1538) - 2*0.375*(1*0.158 - 1*0.1538)*(1 - 0.855)
= 0.0496 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*(0.158 + 0.375)*(1*0.158 - 1*0.1538) - 2*0.375*(1*0.158 - 1*0.1538)*(1 - 0.855)
= 0.004 in^2

A_2 = smaller of the following= 0.2382 in^2

= 5*(t_n - t_{rn})*f_{r2}*t

= $5*(0.375 - 0.0223)*0.855*0.158$
= 0.2382 in^2

= $2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
= $2*(0.375 - 0.0223)*(2.5*0.375 + 0.375)*0.855$
= 0.7916 in^2

A_{41} = Leg^2*f_{r3}
= $0.1208^2*0.855$
= <u>0.0125</u> in^2

(Part of the weld is outside of the limits)

A_{42} = Leg^2*f_{r4}
= 0.25^2*1
= <u>0.0625</u> in^2

A_5 = $(D_p - d - 2*t_n)*t_e*f_{r4}$
= $(16.75 - 12 - 2*0.375)*0.375*1$
= <u>1.5</u> in^2

Area = $A_1 + A_2 + A_{41} + A_{42} + A_5$
= $0.0496 + 0.2382 + 0.0125 + 0.0625 + 1.5$
= <u>1.8628</u> 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 = 0.375 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = <u>0.25</u> in
$t_{c(actual)}$ = $0.7*Leg = 0.7*0.375 = 0.2625$ in

Outer fillet: t_{min} = lesser of 0.75 or t_e or t = 0.158 in
$t_{w(min)}$ = $0.5*t_{min}$ = <u>0.079</u> in
$t_{w(actual)}$ = $0.7*Leg = 0.7*0.25 = 0.175$ in

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG\text{-}27}$ = $P*R / (S*E - 0.6*P) + Corrosion$
= $63.5314*6 / (17{,}100*1 - 0.6*63.5314) + 0.125$
= 0.1473 in

t_a = max[$t_{a\ UG\text{-}27}$, $t_{a\ UG\text{-}22}$]

	=	max[0.1473 , 0]
	=	0.1473 in

t_{b1}	=	0.2955 in

t_{b1}	=	max[t_{b1} , $t_{b\ UG16}$]
	=	max[0.2955 , 0.1875]
	=	0.2955 in

t_b	=	min[t_{b3} , t_{b1}]
	=	min[0.4531 , 0.2955]
	=	0.2955 in

t_{UG-45}	=	max[t_a , t_b]
	=	max[0.1473 , 0.2955]
	=	0.2955 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*20,000 =	14,800 psi
Nozzle wall in shear:	0.7*17,100 =	11,970 psi
Inner fillet weld in shear:	0.49*17,100 =	8,379 psi
Outer fillet weld in shear:	0.49*20,000 =	9,800 psi
Upper groove weld in tension:	0.74*20,000 =	14,800 psi

Strength of welded joints:

(1) Inner fillet weld in shear
(π / 2)*Nozzle OD*Leg*S_i = (π / 2)*12.75*0.375*8,379 = 62,929.39 lb_f

(2) Outer fillet weld in shear
(π / 2)*Pad OD*Leg*S_o = (π / 2)*16.75*0.25*9,800 = 64,461.55 lb_f

(3) Nozzle wall in shear
(π / 2)*Mean nozzle dia*t_n*S_n = (π / 2)*12.375*0.375*11,970 = 87,255.04 lb_f

(4) Groove weld in tension
(π / 2)*Nozzle OD*t_w*S_g = (π / 2)*12.75*0.158*14,800 = 46,832.66 lb_f

(6) Upper groove weld in tension
(π / 2)*Nozzle OD*t_w*S_g = (π / 2)*12.75*0.375*14,800 = 111,153.48 lb_f

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

W	=	($A - A_1 + 2*t_n*f_{r1}*(E_1*t - F*t_r)$)*$S_v$
	=	(1.8627 - 0.0496 + 2*0.375*0.855*(1*0.158 - 1*0.1538))*20,000
	=	<u>36,315.26</u> lb_f

$$W_{1\text{-}1} = (A_2 + A_5 + A_{41} + A_{42})*S_v$$
$$= (0.2382 + 1.5 + 0.0125 + 0.0625)*20{,}000$$
$$= \underline{36{,}264}\ lb_f$$

$$W_{2\text{-}2} = (A_2 + A_3 + A_{41} + A_{43} + 2*t_n*t*f_{r1})*S_v$$
$$= (0.2382 + 0 + 0.0125 + 0 + 2*0.375*0.158*0.855)*20{,}000$$
$$= \underline{7{,}040.35}\ lb_f$$

$$W_{3\text{-}3} = (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2*t_n*t*f_{r1})*S_v$$
$$= (0.2382 + 0 + 1.5 + 0.0125 + 0.0625 + 0 + 2*0.375*0.158*0.855)*20{,}000$$
$$= \underline{38{,}290.35}\ lb_f$$

Load for path 1-1 lesser of W or W_{1-1} = 36264 lb_f
Path 1-1 through (2) & (3) = 64,461.55 + 87,255.04 = 151,716.59 lb_f
Path 1-1 is stronger than W_{1-1} so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or W_{2-2} = 7040.35 lb_f
Path 2-2 through (1), (4), (6) = 62,929.39 + 46,832.66 + 111,153.5 = 220,915.55 lb_f
Path 2-2 is stronger than W_{2-2} so it is acceptable per UG-41(b)(1).

Load for path 3-3 lesser of W or W_{3-3} = 36315.26 lb_f
Path 3-3 through (2), (4) = 64,461.55 + 46,832.66 = 111,294.22 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

Reinforcement Calculations for MAP

Available reinforcement per UG-37 governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 97.02 psi @ 70 °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}
2.7989	2.7993	0.5536	0.5645	--	1.5	0.1812	0.2608	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
45,721.54	44,914	179,626.45	18,503.3	257,966.7	49,753.3	148,345.38

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.25	0.2625	weld size is adequate
Pad to shell fillet (Leg_{42})	0.1415	0.175	weld size is adequate
Nozzle to pad groove (Upper)	0.2625	0.375	weld size is adequate

Calculations for internal pressure 97.02 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

$$L_R = MAX(d, R_n + (t_n - C_n) + (t - C))$$
$$= MAX(11.75, 5.875 + (0.5 - 0) + (0.283 - 0))$$
$$= 11.75 \text{ in}$$

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*(0.283 - 0), 2.5*(0.5 - 0) + 0.375)
= 0.7075 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 97.0183*5.875 / (17,100*1 - 0.6*97.0183)
= 0.0334 in

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

t_r = P*K_1*D_o / (2*S*E + 0.8*P)
= 97.0183*0.9*108 / (2*20,000*1 + 0.8*97.0183)
= 0.2353 in

Area required per UG-37(c)

Allowable stresses: S_n = 17,100, S_v = 20,000, S_p = 20,000 psi

f_{r1} = lesser of 1 or S_n / S_v = 0.855

f_{r2} = lesser of 1 or S_n / S_v = 0.855

f_{r3} = lesser of f_{r2} or S_p / S_v = 0.855

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})
= 11.75*0.2353*1 + 2*0.5*0.2353*1*(1 - 0.855)
= 2.7989 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.5536 in^2

= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})
= 11.75*(1*0.283 - 1*0.2353) - 2*0.5*(1*0.283 - 1*0.2353)*(1 - 0.855)
= 0.5536 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*(0.283 + 0.5)*(1*0.283 - 1*0.2353) - 2*0.5*(1*0.283 - 1*0.2353)*(1 - 0.855)
= 0.0678 in^2

A_2 = smaller of the following= 0.5645 in^2

= 5*(t_n - t_{rn})*f_{r2}*t

$= 5*(0.5 - 0.0334)*0.855*0.283$

$= 0.5645\ in^2$

$= 2*(t_n - t_m)*(2.5*t_n + t_e)*f_{r2}$

$= 2*(0.5 - 0.0334)*(2.5*0.5 + 0.375)*0.855$

$= 1.2966\ in^2$

$A_{41} = Leg^2*f_{r3}$

$= 0.3726^2*0.855$

$= \underline{0.1187}\ in^2$

(Part of the weld is outside of the limits)

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

$= 0.25^2*1$

$= \underline{0.0625}\ in^2$

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

$= (16.75 - 11.75 - 2*0.5)*0.375*1$

$= \underline{1.5}\ in^2$

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

$= 0.5536 + 0.5645 + 0.1187 + 0.0625 + 1.5$

$= \underline{2.7993}\ in^2$

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 = 0.375 in

$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = $\underline{0.25}$ in

$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 in

Outer fillet: t_{min} = lesser of 0.75 or t_e or t = 0.283 in

$t_{w(min)}$ = $0.5*t_{min}$ = $\underline{0.1415}$ in

$t_{w(actual)}$ = 0.7*Leg = 0.7*0.25 = 0.175 in

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG\text{-}27} = P*R / (S*E - 0.6*P) + Corrosion$

$= 97.0183*5.875 / (17{,}100*1 - 0.6*97.0183) + 0$

$= 0.0334\ in$

$t_a = max[\ t_{a\ UG\text{-}27}\ ,\ t_{a\ UG\text{-}22}\ ]$

$= \max[\ 0.0334\ ,\ 0\ ]$
$= 0.0334$ in

$t_{b1} = 0.2608$ in

$t_{b1} = \max[\ t_{b1}\ ,\ t_{b\ UG16}\ ]$
$= \max[\ 0.2608\ ,\ 0.0625\ ]$
$= 0.2608$ in

$t_b = \min[\ t_{b3}\ ,\ t_{b1}\ ]$
$= \min[\ 0.3281\ ,\ 0.2608\ ]$
$= 0.2608$ in

$t_{UG\text{-}45} = \max[\ t_a\ ,\ t_b\ ]$
$= \max[\ 0.0334\ ,\ 0.2608\ ]$
$= 0.2608$ 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*20,000 =	14,800 psi
Nozzle wall in shear:	0.7*17,100 =	11,970 psi
Inner fillet weld in shear:	0.49*17,100 =	8,379 psi
Outer fillet weld in shear:	0.49*20,000 =	9,800 psi
Upper groove weld in tension:	0.74*20,000 =	14,800 psi

Strength of welded joints:

(1) Inner fillet weld in shear
$(\pi / 2)$*Nozzle OD*Leg*$S_i = (\pi / 2)*12.75*0.375*8,379 = 62,929.39\ lb_f$

(2) Outer fillet weld in shear
$(\pi / 2)$*Pad OD*Leg*$S_o = (\pi / 2)*16.75*0.25*9,800 = 64,461.55\ lb_f$

(3) Nozzle wall in shear
$(\pi / 2)$*Mean nozzle dia*$t_n*S_n = (\pi / 2)*12.25*0.5*11,970 = 115,164.9\ lb_f$

(4) Groove weld in tension
$(\pi / 2)$*Nozzle OD*$t_w*S_g = (\pi / 2)*12.75*0.283*14,800 = 83,883.83\ lb_f$

(6) Upper groove weld in tension
$(\pi / 2)$*Nozzle OD*$t_w*S_g = (\pi / 2)*12.75*0.375*14,800 = 111,153.48\ lb_f$

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

$W = (A - A_1 + 2*t_n*f_{r1}*(E_1*t - F*t_r))*S_v$
$= (2.7989 - 0.5536 + 2*0.5*0.855*(1*0.283 - 1*0.2353))*20,000$
$= \underline{45,721.54}\ lb_f$

$$W_{1\text{-}1} = (A_2 + A_5 + A_{41} + A_{42})*S_v$$
$$= (0.5645 + 1.5 + 0.1187 + 0.0625)*20{,}000$$
$$= \underline{44{,}914}\ lb_f$$

$$W_{2\text{-}2} = (A_2 + A_3 + A_{41} + A_{43} + 2*t_n*t*f_{r1})*S_v$$
$$= (0.5645 + 0 + 0.1187 + 0 + 2*0.5*0.283*0.855)*20{,}000$$
$$= \underline{18{,}503.3}\ lb_f$$

$$W_{3\text{-}3} = (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2*t_n*t*f_{r1})*S_v$$
$$= (0.5645 + 0 + 1.5 + 0.1187 + 0.0625 + 0 + 2*0.5*0.283*0.855)*20{,}000$$
$$= \underline{49{,}753.3}\ lb_f$$

Load for path 1-1 lesser of W or $W_{1\text{-}1}$ = 44914 lb_f
Path 1-1 through (2) & (3) = 64,461.55 + 115,164.9 = <u>179,626.45</u> lb_f
Path 1-1 is stronger than $W_{1\text{-}1}$ so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or $W_{2\text{-}2}$ = 18503.3 lb_f
Path 2-2 through (1), (4), (6) = 62,929.39 + 83,883.83 + 111,153.5 = <u>257,966.7</u> lb_f
Path 2-2 is stronger than $W_{2\text{-}2}$ so it is acceptable per UG-41(b)(1).

Load for path 3-3 lesser of W or $W_{3\text{-}3}$ = 45721.54 lb_f
Path 3-3 through (2), (4) = 64,461.55 + 83,883.83 = <u>148,345.38</u> lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

Nozzle B (B)

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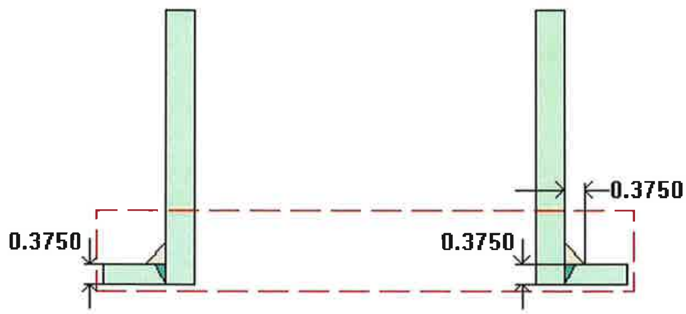
$t_{w(lower)}$ = 0.375 in
Leg_{41} = 0.375 in



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

Located on:	Cylinder #1
Liquid static head included:	0 psi
Nozzle material specification:	SA-106 B Smls pipe (II-D p. 10
Nozzle longitudinal joint efficiency:	1
Nozzle description:	NPS 16 Sch 40 (XS)
Flange description:	16 inch Class 150 WN A105
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 334
Flange rated MDMT:	-55°F
(UCS-66(b)(3): Coincident ratio = 0.1754386)	
(Flange rated MDMT = -155 °F Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F)	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	200 psi @ 400°F
ASME B16.5 flange rating MAP:	285 psi @ 70°F
ASME B16.5 flange hydro test:	450 psi @ 70°F
PWHT performed:	No
Circumferential joint radiography:	Spot UW-11(b) Type 1
Nozzle orientation:	270°
Local vessel minimum thickness:	0.375 in
Nozzle center line offset to datum line:	265 in
End of nozzle to shell center:	62 in
Offset from center, Lo:	-44 in
Nozzle inside diameter, new:	15 in
Nozzle nominal wall thickness:	0.5 in
Nozzle corrosion allowance:	0.125 in
Opening chord length:	28.8235 in
Projection available outside vessel, Lpr:	16.7508 in

Projection available outside vessel to flange face, Lf: 21.7508 in

Reinforcement Calculations for Internal Pressure

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 92.76 psi @ 400 °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}
3.6162	4.0662	3.5896	0.3564	--	--	0.1202	0.375	0.4375

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})	0.175	0.2625	weld size is adequate

Calculations for internal pressure 92.76 psi @ 400 °F

Fig UCS-66.2 general note (1) applies.

Nozzle impact test exemption temperature from Fig UCS-66 Curve B = -20 °F
Fig UCS-66.1 MDMT reduction = 50.3 °F, (coincident ratio = 0.53948)
Rated MDMT is governed by UCS-66(b)(2).

Nozzle UCS-66 governing thk:	0.375 in
Nozzle rated MDMT:	-55 °F

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(28.8235, 14.4118 + (0.5 - 0.125) + (0.375 - 0.125))
= 28.8235 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*(0.375 - 0.125), 2.5*(0.5 - 0.125) + 0)
= 0.625 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 92.7577*7.625 / (17,100*1 - 0.6*92.7577)

$= \quad 0.0415$ in

Required thickness t_r from UG-37(a)

$t_r \quad = \quad P*R_o / (S*E + 0.4*P)$
$= \quad 92.7577*54 / (20{,}000*1 + 0.4*92.7577)$
$= \quad 0.25$ in

Area required per UG-37(c)

Allowable stresses: $S_n = 17{,}100$, $S_v = 20{,}000$ psi

f_{r1} = lesser of 1 or $S_n / S_v = 0.855$

f_{r2} = lesser of 1 or $S_n / S_v = 0.855$

$A \quad = \quad d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
$= \quad 28.8235*0.25*0.5 + 2*0.375*0.25*0.5*(1 - 0.855)$
$= \quad \underline{3.6162}\ in^2$

Area available from FIG. UG-37.1

A_1 = larger of the following= $\underline{3.5896}\ in^2$

$= \quad d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
$= \quad 28.8235*(1*0.25 - 0.5*0.25) - 2*0.375*(1*0.25 - 0.5*0.25)*(1 - 0.855)$
$= \quad 3.5896\ in^2$

$= \quad 2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
$= \quad 2*(0.25 + 0.375)*(1*0.25 - 0.5*0.25) - 2*0.375*(1*0.25 - 0.5*0.25)*(1 - 0.855)$
$= \quad 0.1427\ in^2$

A_2 = smaller of the following= $\underline{0.3564}\ in^2$

$= \quad 5*(t_n - t_{rn})*f_{r2}*t$
$= \quad 5*(0.375 - 0.0415)*0.855*0.25$
$= \quad 0.3564\ in^2$

$= \quad 5*(t_n - t_{rn})*f_{r2}*t_n$
$= \quad 5*(0.375 - 0.0415)*0.855*0.375$
$= \quad 0.5346\ in^2$

$A_{41} \quad = \quad Leg^2*f_{r2}$
$= \quad 0.375^2*0.855$
$= \quad \underline{0.1202}\ in^2$

Area = $A_1 + A_2 + A_{41}$
= 3.5896 + 0.3564 + 0.1202
= <u>4.0662</u> 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 = 0.25 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = <u>0.175</u> in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 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

$t_{a\ UG\text{-}27}$ = P*R / (S*E - 0.6*P) + Corrosion
= 92.7577*7.625 / (17,100*1 - 0.6*92.7577) + 0.125
= 0.1665 in

t_a = max[$t_{a\ UG\text{-}27}$, $t_{a\ UG\text{-}22}$]
= max[0.1665 , 0]
= 0.1665 in

t_{b1} = P*R_o / (S*E + 0.4*P) + Corrosion
= 92.7577*54 / (20,000*1 + 0.4*92.7577) + 0.125
= 0.375 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.375 , 0.1875]
= 0.375 in

t_b = min[t_{b3} , t_{b1}]
= min[0.4531 , 0.375]
= 0.375 in

$t_{UG\text{-}45}$ = max[t_a , t_b]
= max[0.1665 , 0.375]
= 0.375 in

Available nozzle wall thickness new, t_n = 0.875*0.5 = 0.4375 in

The nozzle neck thickness is adequate.

Reinforcement check in the plane parallel to the longitudinal axis

Reinforcement Calculations for Internal Pressure

Available reinforcement per UG-37 governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 52.04 psi @ 400 °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}
2.1558	2.1563	1.6601	0.376	--	--	0.1202	0.2654	0.4375

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})	0.175	0.2625	weld size is adequate

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(15.25, 7.625 + (0.5 - 0.125) + (0.375 - 0.125))
= 15.25 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*(0.375 - 0.125), 2.5*(0.5 - 0.125) + 0)
= 0.625 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 52.0403*7.625 / (17,100*1 - 0.6*52.0403)
= 0.0232 in

Required thickness t_r from UG-37(a)

t_r = P*R_o / (S*E + 0.4*P)
= 52.0403*54 / (20,000*1 + 0.4*52.0403)

$= \quad 0.1404$ in

Area required per UG-37(c)

Allowable stresses: S_n = 17,100, S_v = 20,000 psi

f_{r1} = lesser of 1 or S_n / S_v = 0.855

f_{r2} = lesser of 1 or S_n / S_v = 0.855

$$\begin{aligned} A &= d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1}) \\ &= 15.25*0.1404*1 + 2*0.375*0.1404*1*(1 - 0.855) \\ &= \underline{2.1558}\ in^2 \end{aligned}$$

Area available from FIG. UG-37.1

A_1 = larger of the following= $\underline{1.6601}$ in^2

$$\begin{aligned} &= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1}) \\ &= 15.25*(1*0.25 - 1*0.1404) - 2*0.375*(1*0.25 - 1*0.1404)*(1 - 0.855) \\ &= 1.6601\ in^2 \end{aligned}$$

$$\begin{aligned} &= 2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1}) \\ &= 2*(0.25 + 0.375)*(1*0.25 - 1*0.1404) - 2*0.375*(1*0.25 - 1*0.1404)*(1 - 0.855) \\ &= 0.1251\ in^2 \end{aligned}$$

A_2 = smaller of the following= $\underline{0.376}$ in^2

$$\begin{aligned} &= 5*(t_n - t_{rn})*f_{r2}*t \\ &= 5*(0.375 - 0.0232)*0.855*0.25 \\ &= 0.376\ in^2 \end{aligned}$$

$$\begin{aligned} &= 5*(t_n - t_{rn})*f_{r2}*t_n \\ &= 5*(0.375 - 0.0232)*0.855*0.375 \\ &= 0.564\ in^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= Leg^2*f_{r2} \\ &= 0.375^2*0.855 \\ &= \underline{0.1202}\ in^2 \end{aligned}$$

$$\begin{aligned} Area &= A_1 + A_2 + A_{41} \\ &= 1.6601 + 0.376 + 0.1202 \\ &= \underline{2.1563}\ in^2 \end{aligned}$$

As Area >= A the reinforcement is adequate.

UG-45 Nozzle Neck Thickness Check

$t_{a\ UG\text{-}27}$ = P*R / (S*E - 0.6*P) + Corrosion
= 52.0403*7.625 / (17,100*1 - 0.6*52.0403) + 0.125
= 0.1482 in

t_a = max[$t_{a\ UG\text{-}27}$, $t_{a\ UG\text{-}22}$]
= max[0.1482 , 0]
= 0.1482 in

t_{b1} = P*R_o / (S*E + 0.4*P) + Corrosion
= 52.0403*54 / (20,000*1 + 0.4*52.0403) + 0.125
= 0.2654 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.2654 , 0.1875]
= 0.2654 in

t_b = min[t_{b3} , t_{b1}]
= min[0.4531 , 0.2654]
= 0.2654 in

$t_{UG\text{-}45}$ = max[t_a , t_b]
= max[0.1482 , 0.2654]
= 0.2654 in

Available nozzle wall thickness new, t_n = 0.875*0.5 = 0.4375 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

The vessel wall thickness governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in²) For P = 139.27 psi @ 70 °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}
5.3642	6.1334	5.3101	0.7031	--	--	0.1202	0.3281	0.4375

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.25	0.2625	weld size is adequate

Calculations for internal pressure 139.27 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(28.4646, 14.2323 + (0.5 - 0) + (0.375 - 0))
= 28.4646 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*(0.375 - 0), 2.5*(0.5 - 0) + 0)
= 0.9375 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 139.2731*7.5 / (17,100*1 - 0.6*139.2731)
= 0.0614 in

Required thickness t_r from UG-37(a)

t_r = P*R_o / (S*E + 0.4*P)
= 139.2731*54 / (20,000*1 + 0.4*139.2731)

$= \quad 0.375$ in

Area required per UG-37(c)

Allowable stresses: $S_n = 17{,}100$, $S_v = 20{,}000$ psi

f_{r1} = lesser of 1 or $S_n / S_v = 0.855$

f_{r2} = lesser of 1 or $S_n / S_v = 0.855$

$$
\begin{aligned}
A &= d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1}) \\
&= 28.4646*0.375*0.5 + 2*0.5*0.375*0.5*(1 - 0.855) \\
&= \underline{5.3642}\ \text{in}^2
\end{aligned}
$$

Area available from FIG. UG-37.1

A_1 = larger of the following= $\underline{5.3101}$ in^2

$$
\begin{aligned}
&= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1}) \\
&= 28.4646*(1*0.375 - 0.5*0.375) - 2*0.5*(1*0.375 - 0.5*0.375)*(1 - 0.855) \\
&= 5.3101\ \text{in}^2
\end{aligned}
$$

$$
\begin{aligned}
&= 2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1}) \\
&= 2*(0.375 + 0.5)*(1*0.375 - 0.5*0.375) - 2*0.5*(1*0.375 - 0.5*0.375)*(1 - 0.855) \\
&= 0.3009\ \text{in}^2
\end{aligned}
$$

A_2 = smaller of the following= $\underline{0.7031}$ in^2

$$
\begin{aligned}
&= 5*(t_n - t_{rn})*f_{r2}*t \\
&= 5*(0.5 - 0.0614)*0.855*0.375 \\
&= 0.7031\ \text{in}^2
\end{aligned}
$$

$$
\begin{aligned}
&= 5*(t_n - t_{rn})*f_{r2}*t_n \\
&= 5*(0.5 - 0.0614)*0.855*0.5 \\
&= 0.9375\ \text{in}^2
\end{aligned}
$$

$$
\begin{aligned}
A_{41} &= Leg^2*f_{r2} \\
&= 0.375^2*0.855 \\
&= \underline{0.1202}\ \text{in}^2
\end{aligned}
$$

$$
\begin{aligned}
\text{Area} &= A_1 + A_2 + A_{41} \\
&= 5.3101 + 0.7031 + 0.1202 \\
&= \underline{6.1334}\ \text{in}^2
\end{aligned}
$$

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 = 0.375 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 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

$t_{a\ UG\text{-}27}$	=	P*R / (S*E - 0.6*P) + Corrosion
	=	139.2731*7.5 / (17,100*1 - 0.6*139.2731) + 0
	=	0.0614 in
t_a	=	max[$t_{a\ UG\text{-}27}$, $t_{a\ UG\text{-}22}$]
	=	max[0.0614 , 0]
	=	0.0614 in
t_{b1}	=	P*R_o / (S*E + 0.4*P) + Corrosion
	=	139.2731*54 / (20,000*1 + 0.4*139.2731) + 0
	=	0.375 in
t_{b1}	=	max[t_{b1} , $t_{b\ UG16}$]
	=	max[0.375 , 0.0625]
	=	0.375 in
t_b	=	min[t_{b3} , t_{b1}]
	=	min[0.3281 , 0.375]
	=	0.3281 in
$t_{UG\text{-}45}$	=	max[t_a , t_b]
	=	max[0.0614 , 0.3281]
	=	0.3281 in

Available nozzle wall thickness new, t_n = 0.875*0.5 = 0.4375 in

The nozzle neck thickness is adequate.

Reinforcement check in the plane parallel to the longitudinal axis

Reinforcement Calculations for MAP

Available reinforcement per UG-37 governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 79.58 psi @ 70 °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}
3.2491	3.2495	2.3838	0.7455	--	--	0.1202	0.2145	0.4375

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.25	0.2625	weld size is adequate

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(15, 7.5 + (0.5 - 0) + (0.375 - 0))
= 15 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*(0.375 - 0), 2.5*(0.5 - 0) + 0)
= 0.9375 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 79.5822*7.5 / (17,100*1 - 0.6*79.5822)
= 0.035 in

Required thickness t_r from UG-37(a)

t_r = P*R_o / (S*E + 0.4*P)
= 79.5822*54 / (20,000*1 + 0.4*79.5822)

$= \quad 0.2145$ in

Area required per UG-37(c)

Allowable stresses: S_n = 17,100, S_v = 20,000 psi

f_{r1} = lesser of 1 or S_n / S_v = 0.855

f_{r2} = lesser of 1 or S_n / S_v = 0.855

$$\begin{aligned} A &= d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1}) \\ &= 15*0.2145*1 + 2*0.5*0.2145*1*(1 - 0.855) \\ &= \underline{3.2491} \text{ in}^2 \end{aligned}$$

Area available from FIG. UG-37.1

A_1 = larger of the following= 2.3838 in^2

$$\begin{aligned} &= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1}) \\ &= 15*(1*0.375 - 1*0.2145) - 2*0.5*(1*0.375 - 1*0.2145)*(1 - 0.855) \\ &= 2.3838 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} &= 2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1}) \\ &= 2*(0.375 + 0.5)*(1*0.375 - 1*0.2145) - 2*0.5*(1*0.375 - 1*0.2145)*(1 - 0.855) \\ &= 0.2576 \text{ in}^2 \end{aligned}$$

A_2 = smaller of the following= 0.7455 in^2

$$\begin{aligned} &= 5*(t_n - t_m)*f_{r2}*t \\ &= 5*(0.5 - 0.035)*0.855*0.375 \\ &= 0.7455 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} &= 5*(t_n - t_m)*f_{r2}*t_n \\ &= 5*(0.5 - 0.035)*0.855*0.5 \\ &= 0.9939 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= Leg^2*f_{r2} \\ &= 0.375^2*0.855 \\ &= \underline{0.1202} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} \\ &= 2.3838 + 0.7455 + 0.1202 \\ &= \underline{3.2495} \text{ in}^2 \end{aligned}$$

As Area >= A the reinforcement is adequate.

UG-45 Nozzle Neck Thickness Check

$t_{a\ UG\text{-}27}$ = P*R / (S*E - 0.6*P) + Corrosion
= 79.5822*7.5 / (17,100*1 - 0.6*79.5822) + 0
= 0.035 in

t_a = max[$t_{a\ UG\text{-}27}$, $t_{a\ UG\text{-}22}$]
= max[0.035 , 0]
= 0.035 in

t_{b1} = P*R_o / (S*E + 0.4*P) + Corrosion
= 79.5822*54 / (20,000*1 + 0.4*79.5822) + 0
= 0.2145 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.2145 , 0.0625]
= 0.2145 in

t_b = min[t_{b3} , t_{b1}]
= min[0.3281 , 0.2145]
= 0.2145 in

$t_{UG\text{-}45}$ = max[t_a , t_b]
= max[0.035 , 0.2145]
= 0.2145 in

Available nozzle wall thickness new, t_n = 0.875*0.5 = 0.4375 in

The nozzle neck thickness is adequate.

Nozzle C (C)

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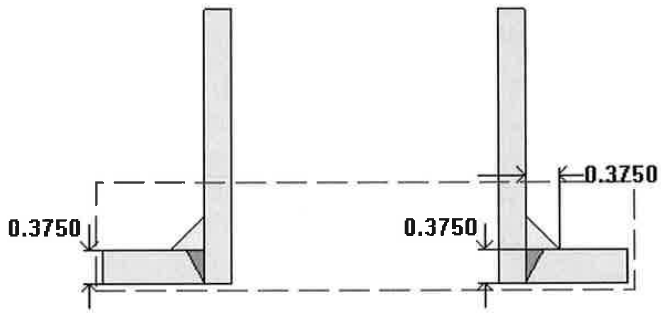
$t_{w(lower)}$ = 0.375 in
Leg_{41} = 0.375 in



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

Located on:	Cylinder #1
Liquid static head included:	0 psi
Nozzle material specification:	SA-106 B Smls pipe (II-D p. 10
Nozzle longitudinal joint efficiency:	1
Nozzle description:	NPS 3 Sch 80 (XS)
Flange description:	3 inch Class 150 WN A105
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 334
Flange rated MDMT:	-55°F
(UCS-66(b)(3): Coincident ratio = 0.1754386)	
(Flange rated MDMT = -155 °F Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F)	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	200 psi @ 400°F
ASME B16.5 flange rating MAP:	285 psi @ 70°F
ASME B16.5 flange hydro test:	450 psi @ 70°F
Gasket Description:	Flexitallic Spiral Wound CG 304L S.S.
PWHT performed:	No
Circumferential joint radiography:	Spot UW-11(b) Type 1
Nozzle orientation:	135°
Local vessel minimum thickness:	0.375 in
Nozzle center line offset to datum line:	265 in
End of nozzle to shell center:	62 in
Offset from center, Lo:	-24 in
Nozzle inside diameter, new:	2.9 in
Nozzle nominal wall thickness:	0.3 in
Nozzle corrosion allowance:	0 in
Opening chord length:	3.2404 in

Projection available outside vessel, Lpr:	10.047 in
Projection available outside vessel to flange face, Lf:	12.797 in

Reinforcement Calculations for Internal Pressure

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 92.76 psi @ 400 °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)							0.189	0.2625

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})	0.175	0.2625	weld size is adequate

Calculations for internal pressure 92.76 psi @ 400 °F

Fig UCS-66.2 general note (1) applies.

Nozzle impact test exemption temperature from Fig UCS-66 Curve B = -20 °F
Fig UCS-66.1 MDMT reduction = 50.3 °F, (coincident ratio = 0.53948)
Rated MDMT is governed by UCS-66(b)(2).

Nozzle UCS-66 governing thk:	0.2625 in
Nozzle rated MDMT:	-55 °F

Parallel Limit of reinforcement per UG-40

$$L_R = MAX(d, R_n + (t_n - C_n) + (t - C))$$
$$= MAX(3.2404, 1.6202 + (0.3 - 0) + (0.375 - 0.125))$$
$$= 3.2404 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)$$
$$= MIN(2.5*(0.375 - 0.125), 2.5*(0.3 - 0) + 0)$$
$$= 0.625 \text{ in}$$

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

t_{rn} = $P*R_n / (S_n*E - 0.6*P)$
= 92.7577*1.45 / (17,100*1 - 0.6*92.7577)
= 0.0079 in

Required thickness t_r from UG-37(a)

t_r = $P*R_o / (S*E + 0.4*P)$
= 92.7577*54 / (20,000*1 + 0.4*92.7577)
= 0.25 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 = 0.25 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = <u>0.175</u> in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 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

$t_{a\ UG\text{-}27}$ = P*R / (S*E - 0.6*P) + Corrosion
= 92.7577*1.45 / (17,100*1 - 0.6*92.7577) + 0
= 0.0079 in

t_a = max[$t_{a\ UG\text{-}27}$, $t_{a\ UG\text{-}22}$]
= max[0.0079 , 0]
= 0.0079 in

t_{b1} = $P*R_o / (S*E + 0.4*P)$ + Corrosion
= 92.7577*54 / (20,000*1 + 0.4*92.7577) + 0.125
= 0.375 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.375 , 0.0625]
= 0.375 in

t_b = min[t_{b3} , t_{b1}]
= min[0.189 , 0.375]
= 0.189 in

$t_{UG\text{-}45}$ = max[t_a , t_b]
= max[0.0079 , 0.189]

= 0.189 in

Available nozzle wall thickness new, t_n = 0.875*0.3 = 0.2625 in

The nozzle neck thickness is adequate.

Reinforcement check in the plane parallel to the longitudinal axis

Reinforcement Calculations for Internal Pressure

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 92.76 psi @ 400 °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)							0.189	0.2625

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})	0.175	0.2625	weld size is adequate

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(2.9, 1.45 + (0.3 - 0) + (0.375 - 0.125))
= 2.9 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*(0.375 - 0.125), 2.5*(0.3 - 0) + 0)
= 0.625 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 92.7577*1.45 / (17,100*1 - 0.6*92.7577)
= 0.0079 in

Required thickness t_r from UG-37(a)

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

$= \quad 92.7577*54 / (20{,}000*1 + 0.4*92.7577)$

$= \quad 0.25$ in

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

UG-45 Nozzle Neck Thickness Check

$t_{a\ UG\text{-}27} = P*R / (S*E - 0.6*P) + \text{Corrosion}$
$= 92.7577*1.45 / (17{,}100*1 - 0.6*92.7577) + 0$
$= 0.0079$ in

$t_a = \max[\ t_{a\ UG\text{-}27} , t_{a\ UG\text{-}22}\ ]$
$= \max[\ 0.0079 , 0\ ]$
$= 0.0079$ in

$t_{b1} = P*R_o / (S*E + 0.4*P) + \text{Corrosion}$
$= 92.7577*54 / (20{,}000*1 + 0.4*92.7577) + 0.125$
$= 0.375$ in

$t_{b1} = \max[\ t_{b1} , t_{b\ UG16}\ ]$
$= \max[\ 0.375 , 0.0625\ ]$
$= 0.375$ in

$t_b = \min[\ t_{b3} , t_{b1}\ ]$
$= \min[\ 0.189 , 0.375\ ]$
$= 0.189$ in

$t_{UG\text{-}45} = \max[\ t_a , t_b\ ]$
$= \max[\ 0.0079 , 0.189\ ]$
$= 0.189$ in

Available nozzle wall thickness new, $t_n = 0.875*0.3 = 0.2625$ in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

The vessel wall thickness governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 139.27 psi @ 70 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.189	0.2625

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})	0.21	0.2625	weld size is adequate

Calculations for internal pressure 139.27 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

$$L_R = MAX(d, R_n + (t_n - C_n) + (t - C))$$
$$= MAX(3.2423, 1.6212 + (0.3 - 0) + (0.375 - 0))$$
$$= 3.2423 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)$$
$$= MIN(2.5*(0.375 - 0), 2.5*(0.3 - 0) + 0)$$
$$= 0.75 \text{ in}$$

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

$$t_{rn} = P*R_n / (S_n*E - 0.6*P)$$
$$= 139.2731*1.45 / (17{,}100*1 - 0.6*139.2731)$$
$$= 0.0119 \text{ in}$$

Required thickness t_r from UG-37(a)

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

$= 139.2731*54 / (20,000*1 + 0.4*139.2731)$
$= 0.375$ 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 = 0.3 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = <u>0.21</u> in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 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

$$
\begin{aligned}
t_{a\ UG\text{-}27} &= P*R / (S*E - 0.6*P) + Corrosion \\
&= 139.2731*1.45 / (17{,}100*1 - 0.6*139.2731) + 0 \\
&= 0.0119 \text{ in}
\end{aligned}
$$

$$
\begin{aligned}
t_a &= \max[\, t_{a\ UG\text{-}27} ,\ t_{a\ UG\text{-}22} \,] \\
&= \max[\, 0.0119 ,\ 0 \,] \\
&= 0.0119 \text{ in}
\end{aligned}
$$

$$
\begin{aligned}
t_{b1} &= P*R_o / (S*E + 0.4*P) + Corrosion \\
&= 139.2731*54 / (20{,}000*1 + 0.4*139.2731) + 0 \\
&= 0.375 \text{ in}
\end{aligned}
$$

$$
\begin{aligned}
t_{b1} &= \max[\, t_{b1} ,\ t_{b\ UG16} \,] \\
&= \max[\, 0.375 ,\ 0.0625 \,] \\
&= 0.375 \text{ in}
\end{aligned}
$$

$$
\begin{aligned}
t_b &= \min[\, t_{b3} ,\ t_{b1} \,] \\
&= \min[\, 0.189 ,\ 0.375 \,] \\
&= 0.189 \text{ in}
\end{aligned}
$$

$$
\begin{aligned}
t_{UG\text{-}45} &= \max[\, t_a ,\ t_b \,] \\
&= \max[\, 0.0119 ,\ 0.189 \,] \\
&= 0.189 \text{ in}
\end{aligned}
$$

Available nozzle wall thickness new, t_n = 0.875*0.3 = 0.2625 in

The nozzle neck thickness is adequate.

Reinforcement check in the plane parallel to the longitudinal axis

Reinforcement Calculations for MAP

Available reinforcement per UG-37 governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 139.27 psi @ 70 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.189	0.2625

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})	0.21	0.2625	weld size is adequate

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(2.9, 1.45 + (0.3 - 0) + (0.375 - 0))
= 2.9 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*(0.375 - 0), 2.5*(0.3 - 0) + 0)
= 0.75 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 139.2731*1.45 / (17,100*1 - 0.6*139.2731)
= 0.0119 in

Required thickness t_r from UG-37(a)

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

$= 139.2731*54 / (20{,}000*1 + 0.4*139.2731)$
$= 0.375$ in

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

UG-45 Nozzle Neck Thickness Check

$t_{a\ UG\text{-}27} = P*R / (S*E - 0.6*P) + \text{Corrosion}$
$= 139.2731*1.45 / (17{,}100*1 - 0.6*139.2731) + 0$
$= 0.0119$ in

$t_a = \max[\ t_{a\ UG\text{-}27}\ ,\ t_{a\ UG\text{-}22}\ ]$
$= \max[\ 0.0119\ ,\ 0\ ]$
$= 0.0119$ in

$t_{b1} = P*R_o / (S*E + 0.4*P) + \text{Corrosion}$
$= 139.2731*54 / (20{,}000*1 + 0.4*139.2731) + 0$
$= 0.375$ in

$t_{b1} = \max[\ t_{b1}\ ,\ t_{b\ UG16}\ ]$
$= \max[\ 0.375\ ,\ 0.0625\ ]$
$= 0.375$ in

$t_b = \min[\ t_{b3}\ ,\ t_{b1}\ ]$
$= \min[\ 0.189\ ,\ 0.375\ ]$
$= 0.189$ in

$t_{UG\text{-}45} = \max[\ t_a\ ,\ t_b\ ]$
$= \max[\ 0.0119\ ,\ 0.189\ ]$
$= 0.189$ in

Available nozzle wall thickness new, $t_n = 0.875*0.3 = 0.2625$ in

The nozzle neck thickness is adequate.

Nozzle D (D)

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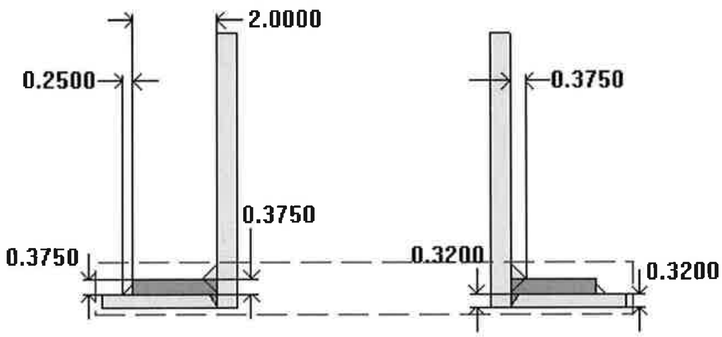

$t_{w(lower)}$ = 0.32 in
Leg_{41} = 0.375 in
$t_{w(upper)}$ = 0.375 in
Leg_{42} = 0.25 in
D_p = 12.625 in
t_e = 0.375 in

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

Located on:	Ellipsoidal Head #2
Liquid static head included:	9.482 psi
Nozzle material specification:	SA-106 B Smls pipe (II-D p. 10
Nozzle longitudinal joint efficiency:	1
Nozzle description:	NPS 8 Sch 80 (XS)
Pad material specification:	SA-516 70 (II-D p. 18
Pad diameter:	12.625 in
Flange description:	8 inch Class 150 WN A105
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 334
Flange rated MDMT:	-55°F
(UCS-66(b)(3): Coincident ratio = 0.2087491)	
(Flange rated MDMT = -155 °F Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F)	
Liquid static head on flange:	9.4935 psi
ASME B16.5 flange rating MAWP:	200 psi @ 400°F
ASME B16.5 flange rating MAP:	285 psi @ 70°F
ASME B16.5 flange hydro test:	450 psi @ 70°F
PWHT performed:	No
Circumferential joint radiography:	Spot UW-11(b) Type 1
Nozzle orientation:	0°
Calculated as hillside:	No
Local vessel minimum thickness:	0.32 in
End of nozzle to datum line:	-37 in
Nozzle inside diameter, new:	7.625 in
Nozzle nominal wall thickness:	0.5 in
Nozzle corrosion allowance:	0.125 in
Projection available outside vessel, Lpr:	3.9268 in

Projection available outside vessel to flange face, Lf:	7.9268 in
Distance to head center, R:	0 in
Pad is split:	No

Reinforcement Calculations for Internal Pressure

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 80.56 psi @ 400 °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}
1.5567	1.9211	0.0002	0.2971	--	1.5	0.1238	0.3411	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
31,129.69	38,418	106,756.72	9,668.88	156,861.81	40,918.88	87,686.56

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.25	0.2625	weld size is adequate
Pad to shell fillet (Leg_{42})	0.0975	0.175	weld size is adequate
Nozzle to pad groove (Upper)	0.2625	0.375	weld size is adequate

Calculations for internal pressure 80.56 psi @ 400 °F

Fig UCS-66.2 general note (1) applies.

Nozzle impact test exemption temperature from Fig UCS-66 Curve B = -20 °F
Fig UCS-66.1 MDMT reduction = 26.1 °F, (coincident ratio = 0.73862).

Pad impact test exemption temperature from Fig UCS-66 Curve B = -20 °F
Fig UCS-66.1 MDMT reduction = 26.1 °F, (coincident ratio = 0.73862).

Nozzle UCS-66 governing thk:	0.375 in
Nozzle rated MDMT:	-46.1 °F
Pad UCS-66 governing thickness:	0.375 in
Pad rated MDMT:	-46.1 °F

Parallel Limit of reinforcement per UG-40

$$L_R = MAX(d, R_n + (t_n - C_n) + (t - C))$$
$$= MAX(7.875, 3.9375 + (0.5 - 0.125) + (0.32 - 0.125))$$
$$= 7.875 \text{ in}$$

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*(0.32 - 0.125), 2.5*(0.5 - 0.125) + 0.375)
= 0.4875 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 80.5572*3.9375 / (17,100*1 - 0.6*80.5572)
= 0.0186 in

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

t_r = P*K_1*D_o / (2*S*E + 0.8*P)
= 80.5572*0.8979*108 / (2*20,000*1 + 0.8*80.5572)
= 0.195 in

Area required per UG-37(c)

Allowable stresses: S_n = 17,100, S_v = 20,000, S_p = 20,000 psi

f_{r1} = lesser of 1 or S_n / S_v = 0.855

f_{r2} = lesser of 1 or S_n / S_v = 0.855

f_{r3} = lesser of f_{r2} or S_p / S_v = 0.855

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})
= 7.875*0.195*1 + 2*0.375*0.195*1*(1 - 0.855)
= <u>1.5567</u> in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= <u>0.0002</u> in^2

= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})
= 7.875*(1*0.195 - 1*0.195) - 2*0.375*(1*0.195 - 1*0.195)*(1 - 0.855)
= 0.0002 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*(0.195 + 0.375)*(1*0.195 - 1*0.195) - 2*0.375*(1*0.195 - 1*0.195)*(1 - 0.855)
= 0 in^2

A_2 = smaller of the following= <u>0.2971</u> in^2

= 5*(t_n - t_{rn})*f_{r2}*t

$= 5*(0.375 - 0.0186)*0.855*0.195$
$= 0.2971\ in^2$

$= 2*(t_n - t_m)*(2.5*t_n + t_e)*f_{r2}$
$= 2*(0.375 - 0.0186)*(2.5*0.375 + 0.375)*0.855$
$= 0.7999\ in^2$

$A_{41} = Leg^2*f_{r3}$
$= 0.2678^2*0.855$
$= 0.0613\ in^2$

(Part of the weld is outside of the limits)

$A_{42} = Leg^2*f_{r4}$
$= 0.25^2*1$
$= 0.0625\ in^2$

$A_5 = (D_p - d - 2*t_n)*t_e*f_{r4}$
$= (12.625 - 7.875 - 2*0.375)*0.375*1$
$= 1.5\ in^2$

$Area = A_1 + A_2 + A_{41} + A_{42} + A_5$
$= 0.0002 + 0.2971 + 0.0613 + 0.0625 + 1.5$
$= 1.9211\ in^2$

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 = 0.375 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 in

Outer fillet: t_{min} = lesser of 0.75 or t_e or t = 0.195 in
$t_{w(min)}$ = $0.5*t_{min}$ = 0.0975 in
$t_{w(actual)}$ = 0.7*Leg = 0.7*0.25 = 0.175 in

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG\text{-}27} = P*R / (S*E - 0.6*P) + Corrosion$
$= 80.5687*3.9375 / (17,100*1 - 0.6*80.5687) + 0.125$
$= 0.1436\ in$

$t_a = max[\ t_{a\ UG\text{-}27}\ ,\ t_{a\ UG\text{-}22}\ ]$

$= \max[0.1436, 0]$
$= 0.1436$ in

$t_{b1} = 0.3411$ in

$t_{b1} = \max[t_{b1}, t_{b\,UG16}]$
$= \max[0.3411, 0.1875]$
$= 0.3411$ in

$t_b = \min[t_{b3}, t_{b1}]$
$= \min[0.4068, 0.3411]$
$= 0.3411$ in

$t_{UG\text{-}45} = \max[t_a, t_b]$
$= \max[0.1436, 0.3411]$
$= 0.3411$ 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*20,000 =	14,800 psi
Nozzle wall in shear:	0.7*17,100 =	11,970 psi
Inner fillet weld in shear:	0.49*17,100 =	8,379 psi
Outer fillet weld in shear:	0.49*20,000 =	9,800 psi
Upper groove weld in tension:	0.74*20,000 =	14,800 psi

Strength of welded joints:

(1) Inner fillet weld in shear
$(\pi / 2)$*Nozzle OD*Leg*S_i = $(\pi / 2)$*8.625*0.375*8,379 = 42,569.88 lb_f

(2) Outer fillet weld in shear
$(\pi / 2)$*Pad OD*Leg*S_o = $(\pi / 2)$*12.625*0.25*9,800 = 48,586.7 lb_f

(3) Nozzle wall in shear
$(\pi / 2)$*Mean nozzle dia*t_n*S_n = $(\pi / 2)$*8.25*0.375*11,970 = 58,170.03 lb_f

(4) Groove weld in tension
$(\pi / 2)$*Nozzle OD*t_w*S_g = $(\pi / 2)$*8.625*0.195*14,800 = 39,099.87 lb_f

(6) Upper groove weld in tension
$(\pi / 2)$*Nozzle OD*t_w*S_g = $(\pi / 2)$*8.625*0.375*14,800 = 75,192.05 lb_f

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

$W = (A - A_1 + 2*t_n*f_{r1}*(E_1*t - F*t_r))*S_v$
$= (1.5567 - 0.0002 + 2*0.375*0.855*(1*0.195 - 1*0.195))*20,000$
$= \underline{31,129.69}$ lb_f

$$W_{1\text{-}1} = (A_2 + A_5 + A_{41} + A_{42})*S_v$$
$$= (0.2971 + 1.5 + 0.0613 + 0.0625)*20{,}000$$
$$= \underline{38{,}418}\ lb_f$$

$$W_{2\text{-}2} = (A_2 + A_3 + A_{41} + A_{43} + 2*t_n*t*f_{r1})*S_v$$
$$= (0.2971 + 0 + 0.0613 + 0 + 2*0.375*0.195*0.855)*20{,}000$$
$$= \underline{9{,}668.88}\ lb_f$$

$$W_{3\text{-}3} = (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2*t_n*t*f_{r1})*S_v$$
$$= (0.2971 + 0 + 1.5 + 0.0613 + 0.0625 + 0 + 2*0.375*0.195*0.855)*20{,}000$$
$$= \underline{40{,}918.88}\ lb_f$$

Load for path 1-1 lesser of W or W_{1-1} = 31129.69 lb_f
Path 1-1 through (2) & (3) = 48,586.7 + 58,170.03 = 106,756.72 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} = 9668.88 lb_f
Path 2-2 through (1), (4), (6) = 42,569.88 + 39,099.87 + 75,192.05 = 156,861.81 lb_f
Path 2-2 is stronger than W_{2-2} so it is acceptable per UG-41(b)(1).

Load for path 3-3 lesser of W or W_{3-3} = 31129.69 lb_f
Path 3-3 through (2), (4) = 48,586.7 + 39,099.87 = 87,686.56 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

Reinforcement Calculations for MAP

Available reinforcement per UG-37 governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 127.72 psi @ 70 °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}
2.4054	2.4055	0.0779	0.6449	--	1.5	0.1827	0.2818	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
46,728.91	46,552	124,971.58	20,774	181,925.83	52,024	112,750.58

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.25	0.2625	weld size is adequate
Pad to shell fillet (Leg_{42})	0.16	0.175	weld size is adequate
Nozzle to pad groove (Upper)	0.2625	0.375	weld size is adequate

Calculations for internal pressure 127.72 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

$$L_R = MAX(d, R_n + (t_n - C_n) + (t - C))$$
$$= MAX(7.625, 3.8125 + (0.5 - 0) + (0.32 - 0))$$
$$= 7.625 \text{ in}$$

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*(0.32 - 0), 2.5*(0.5 - 0) + 0.375)
= 0.8 in

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

t_{rn} = $P*R_n / (S_n*E - 0.6*P)$
= 127.7249*3.8125 / (17,100*1 - 0.6*127.7249)
= 0.0286 in

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

t_r = $P*K_1*D_o / (2*S*E + 0.8*P)$
= 127.7249*0.9*108 / (2*20,000*1 + 0.8*127.7249)
= 0.3096 in

Area required per UG-37(c)

Allowable stresses: S_n = 17,100, S_v = 20,000, S_p = 20,000 psi

f_{r1} = lesser of 1 or S_n / S_v = 0.855

f_{r2} = lesser of 1 or S_n / S_v = 0.855

f_{r3} = lesser of f_{r2} or S_p / S_v = 0.855

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

A = $d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
= 7.625*0.3096*1 + 2*0.5*0.3096*1*(1 - 0.855)
= 2.4054 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.0779 in^2

= $d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= 7.625*(1*0.32 - 1*0.3096) - 2*0.5*(1*0.32 - 1*0.3096)*(1 - 0.855)
= 0.0779 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*(0.32 + 0.5)*(1*0.32 - 1*0.3096) - 2*0.5*(1*0.32 - 1*0.3096)*(1 - 0.855)
= 0.0156 in^2

A_2 = smaller of the following= 0.6449 in^2

= $5*(t_n - t_{rn})*f_{r2}*t$

$= 5*(0.5 - 0.0286)*0.855*0.32$
$= 0.6449\ in^2$

$= 2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
$= 2*(0.5 - 0.0286)*(2.5*0.5 + 0.375)*0.855$
$= 1.3099\ in^2$

$A_{41} = Leg^2*f_{r3}$
$= 0.375^2*0.855$
$= \underline{0.1202}\ in^2$

$A_{42} = Leg^2*f_{r4}$
$= 0.25^2*1$
$= \underline{0.0625}\ in^2$

$A_5 = (D_p - d - 2*t_n)*t_e*f_{r4}$
$= (12.625 - 7.625 - 2*0.5)*0.375*1$
$= \underline{1.5}\ in^2$

$Area = A_1 + A_2 + A_{41} + A_{42} + A_5$
$= 0.0779 + 0.6449 + 0.1202 + 0.0625 + 1.5$
$= \underline{2.4055}\ in^2$

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 = 0.375 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = $\underline{0.25}$ in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 in

Outer fillet: t_{min} = lesser of 0.75 or t_e or t = 0.32 in
$t_{w(min)}$ = $0.5*t_{min}$ = $\underline{0.16}$ in
$t_{w(actual)}$ = 0.7*Leg = 0.7*0.25 = 0.175 in

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG\text{-}27} = P*R / (S*E - 0.6*P) + Corrosion$
$= 127.7249*3.8125 / (17{,}100*1 - 0.6*127.7249) + 0$
$= 0.0286\ in$

$t_a = max[\ t_{a\ UG\text{-}27}\ ,\ t_{a\ UG\text{-}22}\ ]$
$= max[\ 0.0286\ ,\ 0\ ]$

$= 0.0286$ in

$t_{b1} = 0.3429$ in

$t_{b1} = \max[t_{b1}, t_{b\,UG16}]$
$= \max[0.3429, 0.0625]$
$= 0.3429$ in

$t_b = \min[t_{b3}, t_{b1}]$
$= \min[0.2818, 0.3429]$
$= 0.2818$ in

$t_{UG\text{-}45} = \max[t_a, t_b]$
$= \max[0.0286, 0.2818]$
$= 0.2818$ 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*20,000 =	14,800 psi
Nozzle wall in shear:	0.7*17,100 =	11,970 psi
Inner fillet weld in shear:	0.49*17,100 =	8,379 psi
Outer fillet weld in shear:	0.49*20,000 =	9,800 psi
Upper groove weld in tension:	0.74*20,000 =	14,800 psi

Strength of welded joints:

(1) Inner fillet weld in shear
$(\pi / 2)*\text{Nozzle OD}*\text{Leg}*S_i = (\pi / 2)*8.625*0.375*8,379 = 42,569.88\ lb_f$

(2) Outer fillet weld in shear
$(\pi / 2)*\text{Pad OD}*\text{Leg}*S_o = (\pi / 2)*12.625*0.25*9,800 = 48,586.7\ lb_f$

(3) Nozzle wall in shear
$(\pi / 2)*\text{Mean nozzle dia}*t_n*S_n = (\pi / 2)*8.125*0.5*11,970 = 76,384.88\ lb_f$

(4) Groove weld in tension
$(\pi / 2)*\text{Nozzle OD}*t_w*S_g = (\pi / 2)*8.625*0.32*14,800 = 64,163.89\ lb_f$

(6) Upper groove weld in tension
$(\pi / 2)*\text{Nozzle OD}*t_w*S_g = (\pi / 2)*8.625*0.375*14,800 = 75,192.05\ lb_f$

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

$W = (A - A_1 + 2*t_n*f_{r1}*(E_1*t - F*t_r))*S_v$
$= (2.4054 - 0.0779 + 2*0.5*0.855*(1*0.32 - 1*0.3096))*20,000$
$= \underline{46,728.91}\ lb_f$

$$W_{1-1} = (A_2 + A_5 + A_{41} + A_{42})*S_v$$
$$= (0.6449 + 1.5 + 0.1202 + 0.0625)*20,000$$
$$= \underline{46.552}\ lb_f$$

$$W_{2-2} = (A_2 + A_3 + A_{41} + A_{43} + 2*t_n*t*f_{r1})*S_v$$
$$= (0.6449 + 0 + 0.1202 + 0 + 2*0.5*0.32*0.855)*20,000$$
$$= \underline{20.774}\ lb_f$$

$$W_{3-3} = (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2*t_n*t*f_{r1})*S_v$$
$$= (0.6449 + 0 + 1.5 + 0.1202 + 0.0625 + 0 + 2*0.5*0.32*0.855)*20,000$$
$$= \underline{52.024}\ lb_f$$

Load for path 1-1 lesser of W or W_{1-1} = 46552 lb_f
Path 1-1 through (2) & (3) = 48,586.7 + 76,384.88 = 124.971.58 lb_f
Path 1-1 is stronger than W_{1-1} so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or W_{2-2} = 20774 lb_f
Path 2-2 through (1), (4), (6) = 42,569.88 + 64,163.89 + 75,192.05 = 181.925.83 lb_f
Path 2-2 is stronger than W_{2-2} so it is acceptable per UG-41(b)(1).

Load for path 3-3 lesser of W or W_{3-3} = 46728.91 lb_f
Path 3-3 through (2), (4) = 48,586.7 + 64,163.89 = 112.750.58 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

Nozzle L1 (L1)

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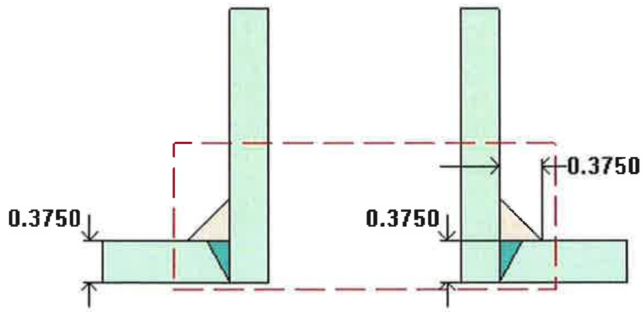
$t_{w(lower)}$ = 0.375 in
Leg_{41} = 0.375 in



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

Located on:	Cylinder #4
Liquid static head included:	7.7552 psi
Nozzle material specification:	SA-106 B Smls pipe (II-D p. 10
Nozzle longitudinal joint efficiency:	1
Nozzle description:	NPS 2 Sch 160
Flange description:	2 inch Class 150 WN A105
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 334
Flange rated MDMT:	-55°F
(UCS-66(b)(3): Coincident ratio = 0.2025432)	
(Flange rated MDMT = -155 °F Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F)	
Liquid static head on flange:	7.7248 psi
ASME B16.5 flange rating MAWP:	200 psi @ 400°F
ASME B16.5 flange rating MAP:	285 psi @ 70°F
ASME B16.5 flange hydro test:	450 psi @ 70°F
PWHT performed:	No
Circumferential joint radiography:	Spot UW-11(b) Type 1
Nozzle orientation:	135°
Local vessel minimum thickness:	0.375 in
Nozzle center line offset to datum line:	12 in
End of nozzle to shell center:	62 in
Nozzle inside diameter, new:	1.687 in
Nozzle nominal wall thickness:	0.344 in
Nozzle corrosion allowance:	0.125 in
Projection available outside vessel, Lpr:	5.5 in
Projection available outside vessel to flange face, Lf:	8 in

Reinforcement Calculations for Internal Pressure

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 92.76 psi @ 400 °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)							0.2598	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 throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1533	0.2625	weld size is adequate

Calculations for internal pressure 92.76 psi @ 400 °F

Fig UCS-66.2 general note (1) applies.

Nozzle is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.01862).

Nozzle UCS-66 governing thk: 0.301 in
Nozzle rated MDMT: -155 °F

Parallel Limit of reinforcement per UG-40

$$
\begin{aligned}
L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
&= \text{MAX}(1.937, 0.9685 + (0.344 - 0.125) + (0.375 - 0.125)) \\
&= 1.937 \text{ in}
\end{aligned}
$$

Outer Normal Limit of reinforcement per UG-40

$$
\begin{aligned}
L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
&= \text{MIN}(2.5*(0.375 - 0.125), 2.5*(0.344 - 0.125) + 0) \\
&= 0.5475 \text{ in}
\end{aligned}
$$

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

$$
\begin{aligned}
t_{rn} &= P*R_n / (S_n*E - 0.6*P) \\
&= 92.7603*0.9685 / (17{,}100*1 - 0.6*92.7603) \\
&= 0.0053 \text{ in}
\end{aligned}
$$

Required thickness t_r from UG-37(a)

t_r = $P*R_o / (S*E + 0.4*P)$
= 92.7603*54 / (20,000*1 + 0.4*92.7603)
= 0.25 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 = 0.219 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.1533 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 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

$t_{a\ UG\text{-}27}$ = P*R / (S*E - 0.6*P) + Corrosion
= 92.7603*0.9685 / (17,100*1 - 0.6*92.7603) + 0.125
= 0.1303 in

t_a = max[$t_{a\ UG\text{-}27}$, $t_{a\ UG\text{-}22}$]
= max[0.1303 , 0]
= 0.1303 in

t_{b1} = $P*R_o / (S*E + 0.4*P)$ + Corrosion
= 92.7603*54 / (20,000*1 + 0.4*92.7603) + 0.125
= 0.375 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.375 , 0.1875]
= 0.375 in

t_b = min[t_{b3} , t_{b1}]
= min[0.2598 , 0.375]
= 0.2598 in

$t_{UG\text{-}45}$ = max[t_a , t_b]
= max[0.1303 , 0.2598]
= 0.2598 in

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

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

The vessel wall thickness governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 139.27 psi @ 70 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1348	0.301

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 throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2408	0.2625	weld size is adequate

Calculations for internal pressure 139.27 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

$$
\begin{aligned}
L_R &= \mathrm{MAX}(d,\ R_n + (t_n - C_n) + (t - C)) \\
&= \mathrm{MAX}(1.687,\ 0.8435 + (0.344 - 0) + (0.375 - 0)) \\
&= 1.687 \text{ in}
\end{aligned}
$$

Outer Normal Limit of reinforcement per UG-40

$$
\begin{aligned}
L_H &= \mathrm{MIN}(2.5*(t - C),\ 2.5*(t_n - C_n) + t_e) \\
&= \mathrm{MIN}(2.5*(0.375 - 0),\ 2.5*(0.344 - 0) + 0) \\
&= 0.86 \text{ in}
\end{aligned}
$$

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

$$
\begin{aligned}
t_{rn} &= P*R_n / (S_n*E - 0.6*P) \\
&= 139.2731*0.8435 / (17{,}100*1 - 0.6*139.2731) \\
&= 0.0069 \text{ in}
\end{aligned}
$$

Required thickness t_r from UG-37(a)

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

= 139.2731*54 / (20,000*1 + 0.4*139.2731)
= 0.375 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 = 0.344 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.2408 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 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

$t_{a\ UG\text{-}27}$ = P*R / (S*E - 0.6*P) + Corrosion
= 139.2731*0.8435 / (17,100*1 - 0.6*139.2731) + 0
= 0.0069 in

t_a = max[$t_{a\ UG\text{-}27}$, $t_{a\ UG\text{-}22}$]
= max[0.0069 , 0]
= 0.0069 in

t_{b1} = P*R_o / (S*E + 0.4*P) + Corrosion
= 139.2731*54 / (20,000*1 + 0.4*139.2731) + 0
= 0.375 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.375 , 0.0625]
= 0.375 in

t_b = min[t_{b3} , t_{b1}]
= min[0.1348 , 0.375]
= 0.1348 in

$t_{UG\text{-}45}$ = max[t_a , t_b]
= max[0.0069 , 0.1348]
= 0.1348 in

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

The nozzle neck thickness is adequate.

Nozzle L2 (L2)

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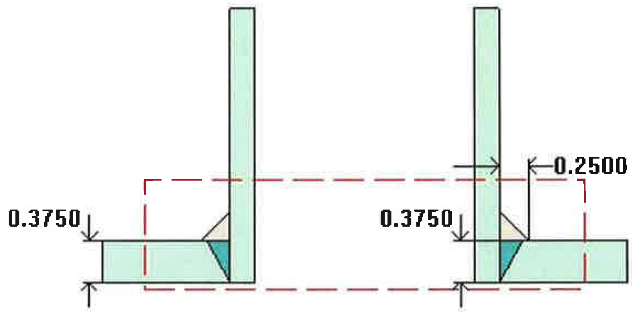
$t_{w(lower)}$ = 0.375 in
Leg_{41} = 0.25 in



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

Located on:	Cylinder #1
Liquid static head included:	0 psi
Nozzle material specification:	SA-106 B Smls pipe (II-D p. 10
Nozzle longitudinal joint efficiency:	1
Nozzle description:	NPS 2 Sch 80 (XS)
Flange description:	2 inch Class 150 WN A105
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 334
Flange rated MDMT:	-55°F
(UCS-66(b)(3): Coincident ratio = 0.1754386)	
(Flange rated MDMT = -155 °F Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F)	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	200 psi @ 400°F
ASME B16.5 flange rating MAP:	285 psi @ 70°F
ASME B16.5 flange hydro test:	450 psi @ 70°F
PWHT performed:	No
Circumferential joint radiography:	Spot UW-11(b) Type 1
Nozzle orientation:	135°
Local vessel minimum thickness:	0.375 in
Nozzle center line offset to datum line:	265 in
End of nozzle to shell center:	62 in
Nozzle inside diameter, new:	1.939 in
Nozzle nominal wall thickness:	0.218 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	5.5 in
Projection available outside vessel to flange face, Lf:	8 in

Quality Record

Approved

MM188078

Reinforcement Calculations for Internal Pressure

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 92.76 psi @ 400 °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)							<u>0.1348</u>	0.1908

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	<u>0.1526</u>	0.175	weld size is adequate

Calculations for internal pressure 92.76 psi @ 400 °F

Fig UCS-66.2 general note (1) applies.

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

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

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(1.939, 0.9695 + (0.218 - 0) + (0.375 - 0.125))
= 1.939 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*(0.375 - 0.125), 2.5*(0.218 - 0) + 0)
= 0.545 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 92.7577*0.9695 / (17,100*1 - 0.6*92.7577)
= 0.0053 in

Required thickness t_r from UG-37(a)

t_r = $P*R_o / (S*E + 0.4*P)$
= 92.7577*54 / (20,000*1 + 0.4*92.7577)
= 0.25 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 = 0.218 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = <u>0.1526</u> in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.25 = 0.175 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

$t_{a\ UG\text{-}27}$ = P*R / (S*E - 0.6*P) + Corrosion
= 92.7577*0.9695 / (17,100*1 - 0.6*92.7577) + 0
= 0.0053 in

t_a = max[$t_{a\ UG\text{-}27}$, $t_{a\ UG\text{-}22}$]
= max[0.0053 , 0]
= 0.0053 in

t_{b1} = $P*R_o$ / (S*E + 0.4*P) + Corrosion
= 92.7577*54 / (20,000*1 + 0.4*92.7577) + 0.125
= 0.375 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.375 , 0.0625]
= 0.375 in

t_b = min[t_{b3} , t_{b1}]
= min[0.1348 , 0.375]
= 0.1348 in

$t_{UG\text{-}45}$ = max[t_a , t_b]
= max[0.0053 , 0.1348]
= 0.1348 in

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

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

The vessel wall thickness governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 139.27 psi @ 70 °F							**UG-45 Nozzle Wall Thickness Summary (in)** The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1348	0.1908

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1526	0.175	weld size is adequate

Calculations for internal pressure 139.27 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(1.939, 0.9695 + (0.218 - 0) + (0.375 - 0))
= 1.939 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*(0.375 - 0), 2.5*(0.218 - 0) + 0)
= 0.545 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 139.2731*0.9695 / (17,100*1 - 0.6*139.2731)
= 0.0079 in

Required thickness t_r from UG-37(a)

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

= 139.2731*54 / (20,000*1 + 0.4*139.2731)
= 0.375 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 = 0.218 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = <u>0.1526</u> in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.25 = 0.175 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

$t_{a\ UG\text{-}27}$	=	P*R / (S*E - 0.6*P) + Corrosion
	=	139.2731*0.9695 / (17,100*1 - 0.6*139.2731) + 0
	=	0.0079 in
t_a	=	max[$t_{a\ UG\text{-}27}$, $t_{a\ UG\text{-}22}$]
	=	max[0.0079 , 0]
	=	0.0079 in
t_{b1}	=	P*R_o / (S*E + 0.4*P) + Corrosion
	=	139.2731*54 / (20,000*1 + 0.4*139.2731) + 0
	=	0.375 in
t_{b1}	=	max[t_{b1} , $t_{b\ UG16}$]
	=	max[0.375 , 0.0625]
	=	0.375 in
t_b	=	min[t_{b3} , t_{b1}]
	=	min[0.1348 , 0.375]
	=	0.1348 in
$t_{UG\text{-}45}$	=	max[t_a , t_b]
	=	max[0.0079 , 0.1348]
	=	0.1348 in

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

The nozzle neck thickness is adequate.

Nozzle M (M)

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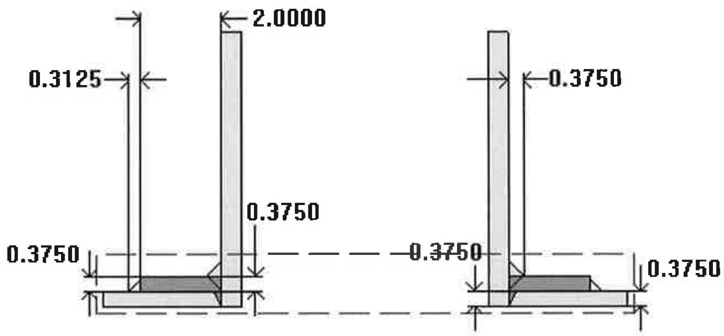

$t_{w(lower)}$ = 0.375 in
Leg_{41} = 0.375 in
$t_{w(upper)}$ = 0.375 in
Leg_{42} = 0.3125 in
D_p = 29 in
t_e = 0.375 in

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

Located on:	Cylinder #3
Liquid static head included:	6.7141 psi
Nozzle material specification:	SA-516 70 (II-D p. 18
Nozzle longitudinal joint efficiency:	1
Pad material specification:	SA-516 70 (II-D p. 18
Pad diameter:	29 in
Flange description:	24 inch Class 150 SO A516 70
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 334
Flange rated MDMT:	-55°F
(UCS-66(b)(3): Coincident ratio = 0.1974768)	
(Flange rated MDMT = -155 °F Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F)	
Liquid static head on flange:	6.2809 psi
ASME B16.5 flange rating MAWP:	200 psi @ 400°F
ASME B16.5 flange rating MAP:	285 psi @ 70°F
ASME B16.5 flange hydro test:	450 psi @ 70°F
Gasket Description:	Flexitallic Spiral Wound CG 304L S.S.
Flange external fillet weld leg (UW-21):	0.7 in (0.7 in min)
Flange internal fillet weld leg (UW-21):	0.4286 in (0.4286 in min)
PWHT performed:	No
Nozzle orientation:	0°
Local vessel minimum thickness:	0.375 in
Nozzle center line offset to datum line:	52 in
End of nozzle to shell center:	62 in
Nozzle inside diameter, new:	24 in
Nozzle nominal wall thickness:	0.5 in
Nozzle corrosion allowance:	0.125 in

Projection available outside vessel, Lpr:	7.5 in
Projection available outside vessel to flange face, Lf:	8 in
Pad is split:	No

Reinforcement Calculations for Internal Pressure

Available reinforcement per UG-37 governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 62.74 psi @ 400 °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}
4.1026	4.1037	1.9599	0.4211	--	1.5	0.2227	0.2942	0.5

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
44,066.61	42,876	342,580.88	14,672	507,563.56	46,626	284,805

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.25	0.2625	weld size is adequate
Pad to shell fillet (Leg_{42})	0.125	0.2188	weld size is adequate
Nozzle to pad groove (Upper)	0.2625	0.375	weld size is adequate

Calculations for internal pressure 62.74 psi @ 400 °F

Nozzle impact test exemption temperature from Fig UCS-66 Curve B = -20 °F
Fig UCS-66.1 MDMT reduction = 38.8 °F, (coincident ratio = 0.6118)
Rated MDMT is governed by UCS-66(b)(2).

Pad impact test exemption temperature from Fig UCS-66 Curve B = -20 °F
Fig UCS-66.1 MDMT reduction = 38.8 °F, (coincident ratio = 0.6118)
Rated MDMT is governed by UCS-66(b)(2).

Nozzle UCS-66 governing thk:	0.375 in
Nozzle rated MDMT:	-55 °F
Pad UCS-66 governing thickness:	0.375 in
Pad rated MDMT:	-55 °F

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, $R_n + (t_n - C_n) + (t - C)$)
= MAX(24.25, 12.125 + (0.5 - 0.125) + (0.375 - 0.125))
= 24.25 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*(0.375 - 0.125), 2.5*(0.5 - 0.125) + 0.375)
= 0.625 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 62.7397*12.125 / (20,000*1 - 0.6*62.7397)
= 0.0381 in

Required thickness t_r from UG-37(a)

t_r = P*R_o / (S*E + 0.4*P)
= 62.7397*54 / (20,000*1 + 0.4*62.7397)
= 0.1692 in

Area required per UG-37(c)

Allowable stresses: S_n = 20,000, S_v = 20,000, S_p = 20,000 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})
= 24.25*0.1692*1 + 2*0.375*0.1692*1*(1 - 1)
= <u>4.1026</u> in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= <u>1.9599</u> in^2

= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})
= 24.25*(1*0.25 - 1*0.1692) - 2*0.375*(1*0.25 - 1*0.1692)*(1 - 1)
= 1.9599 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*(0.25 + 0.375)*(1*0.25 - 1*0.1692) - 2*0.375*(1*0.25 - 1*0.1692)*(1 - 1)
= 0.101 in^2

A_2 = smaller of the following= <u>0.4211</u> in^2

= 5*(t_n - t_{rn})*f_{r2}*t

= $5*(0.375 - 0.0381)*1*0.25$
= 0.4211 in^2

= $2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
= $2*(0.375 - 0.0381)*(2.5*0.375 + 0.375)*1$
= 0.8844 in^2

A_{41} = Leg^2*f_{r3}
= 0.3536^2*1
= $\underline{0.125}$ in^2

(Part of the weld is outside of the limits)

A_{42} = Leg^2*f_{r4}
= 0.3125^2*1
= $\underline{0.0977}$ in^2

A_5 = $(D_p - d - 2*t_n)*t_e*f_{r4}$
= $(29 - 24.25 - 2*0.375)*0.375*1$
= $\underline{1.5}$ in^2

Area = $A_1 + A_2 + A_{41} + A_{42} + A_5$
= $1.9599 + 0.4211 + 0.125 + 0.0977 + 1.5$
= $\underline{4.1037}$ 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 = 0.375 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = $\underline{0.25}$ in
$t_{c(actual)}$ = $0.7*Leg = 0.7*0.375 = 0.2625$ in

Outer fillet: t_{min} = lesser of 0.75 or t_e or t = 0.25 in
$t_{w(min)}$ = $0.5*t_{min}$ = $\underline{0.125}$ in
$t_{w(actual)}$ = $0.7*Leg = 0.7*0.3125 = 0.2188$ in

UG-45 Nozzle Neck Thickness Check

$t_{a\ UG\text{-}27}$ = $P*R / (S*E - 0.6*P)$ + Corrosion
= $62.7397*12.125 / (20{,}000*1 - 0.6*62.7397) + 0.125$
= 0.1631 in

t_a = $\max[\, t_{a\ UG\text{-}27} , t_{a\ UG\text{-}22} \,]$
= $\max[\, 0.1631 , 0 \,]$
= 0.1631 in

t_{b1}	=	$P*R_o$ / (S*E + 0.4*P) + Corrosion
	=	62.7397*54 / (20,000*1 + 0.4*62.7397) + 0.125
	=	0.2942 in

t_{b1}	=	max[t_{b1} , $t_{b\ UG16}$]
	=	max[0.2942 , 0.1875]
	=	0.2942 in

t_b	=	min[t_{b3} , t_{b1}]
	=	min[0.4531 , 0.2942]
	=	0.2942 in

$t_{UG\text{-}45}$	=	max[t_a , t_b]
	=	max[0.1631 , 0.2942]
	=	0.2942 in

Available nozzle wall thickness new, t_n = 0.5 in

The nozzle neck thickness is adequate.

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

Groove weld in tension:	0.74*20,000 =	14,800 psi
Nozzle wall in shear:	0.7*20,000 =	14,000 psi
Inner fillet weld in shear:	0.49*20,000 =	9,800 psi
Outer fillet weld in shear:	0.49*20,000 =	9,800 psi
Upper groove weld in tension:	0.74*20,000 =	14,800 psi

Strength of welded joints:

(1) Inner fillet weld in shear
(π / 2)*Nozzle OD*Leg*S_i = (π / 2)*25*0.375*9,800 = 144,316.92 lb_f

(2) Outer fillet weld in shear
(π / 2)*Pad OD*Leg*S_o = (π / 2)*29*0.3125*9,800 = 139,506.36 lb_f

(3) Nozzle wall in shear
(π / 2)*Mean nozzle dia*t_n*S_n = (π / 2)*24.625*0.375*14,000 = 203,074.52 lb_f

(4) Groove weld in tension
(π / 2)*Nozzle OD*t_w*S_g = (π / 2)*25*0.25*14,800 = 145,298.66 lb_f

(6) Upper groove weld in tension
(π / 2)*Nozzle OD*t_w*S_g = (π / 2)*25*0.375*14,800 = 217,948 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
	=	(4.1026 - 1.9599 + 2*0.375*1*(1*0.25 - 1*0.1692))*20,000
	=	<u>44,066.61</u> lb_f

$W_{1\text{-}1}$ = $(A_2 + A_5 + A_{41} + A_{42})*S_v$
= $(0.4211 + 1.5 + 0.125 + 0.0977)*20{,}000$
= 42,876 lb_f

$W_{2\text{-}2}$ = $(A_2 + A_3 + A_{41} + A_{43} + 2*t_n*t*f_{r1})*S_v$
= $(0.4211 + 0 + 0.125 + 0 + 2*0.375*0.25*1)*20{,}000$
= 14,672 lb_f

$W_{3\text{-}3}$ = $(A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2*t_n*t*f_{r1})*S_v$
= $(0.4211 + 0 + 1.5 + 0.125 + 0.0977 + 0 + 2*0.375*0.25*1)*20{,}000$
= 46,626 lb_f

Load for path 1-1 lesser of W or $W_{1\text{-}1}$ = 42876 lb_f
Path 1-1 through (2) & (3) = 139,506.4 + 203,074.5 = 342,580.88 lb_f
Path 1-1 is stronger than $W_{1\text{-}1}$ so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or $W_{2\text{-}2}$ = 14672 lb_f
Path 2-2 through (1), (4), (6) = 144,316.9 + 145,298.7 + 217,948 = 507,563.56 lb_f
Path 2-2 is stronger than $W_{2\text{-}2}$ so it is acceptable per UG-41(b)(1).

Load for path 3-3 lesser of W or $W_{3\text{-}3}$ = 44066.61 lb_f
Path 3-3 through (2), (4) = 139,506.4 + 145,298.7 = 284,805 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

% Extreme fiber elongation - UCS-79(d)

EFE = $(50*t / R_f)*(1 - R_f / R_o)$
= $(50*0.5 / 12.25)*(1 - 12.25 / \infty)$
= 2.0408%

The extreme fiber elongation does not exceed 5%.

Reinforcement Calculations for MAP

Available reinforcement per UG-37 governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 89.47 psi @ 70 °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}
5.7869	5.788	3.2131	0.8366	--	1.5	0.2383	0.2411	0.5

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
54,153.2	51,498	408,897.94	27,044	580,212.94	58,998	357,454.38

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.25	0.2625	weld size is adequate
Pad to shell fillet (Leg_{42})	0.1875	0.2188	weld size is adequate
Nozzle to pad groove (Upper)	0.2625	0.375	weld size is adequate

Calculations for internal pressure 89.47 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(24, 12 + (0.5 - 0) + (0.375 - 0))
= 24 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*(0.375 - 0), 2.5*(0.5 - 0) + 0.375)
= 0.9375 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 89.465*12 / (20,000*1 - 0.6*89.465)
= 0.0538 in

Required thickness t_r from UG-37(a)

t_r = $P*R_o / (S*E + 0.4*P)$
= 89.465*54 / (20,000*1 + 0.4*89.465)
= 0.2411 in

Area required per UG-37(c)

Allowable stresses: S_n = 20,000, S_v = 20,000, S_p = 20,000 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 = $d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
= 24*0.2411*1 + 2*0.5*0.2411*1*(1 - 1)
= 5.7869 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 3.2131 in^2

= $d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= 24*(1*0.375 - 1*0.2411) - 2*0.5*(1*0.375 - 1*0.2411)*(1 - 1)
= 3.2131 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*(0.375 + 0.5)*(1*0.375 - 1*0.2411) - 2*0.5*(1*0.375 - 1*0.2411)*(1 - 1)
= 0.2343 in^2

A_2 = smaller of the following= 0.8366 in^2

= $5*(t_n - t_{rn})*f_{r2}*t$
= 5*(0.5 - 0.0538)*1*0.375
= 0.8366 in^2

= $2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
= 2*(0.5 - 0.0538)*(2.5*0.5 + 0.375)*1
= 1.4502 in^2

A_{41} = Leg^2*f_{r3}
= 0.375^2*1
= 0.1406 in^2

A_{42} = Leg^2*f_{r4}
= 0.3125^2*1
= $\underline{0.0977}$ in^2

A_5 = $(D_p - d - 2*t_n)*t_e*f_{r4}$
= $(29 - 24 - 2*0.5)*0.375*1$
= $\underline{1.5}$ in^2

Area = $A_1 + A_2 + A_{41} + A_{42} + A_5$
= $3.2131 + 0.8366 + 0.1406 + 0.0977 + 1.5$
= $\underline{5.788}$ 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 = 0.375 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = $\underline{0.25}$ in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 in

Outer fillet: t_{min} = lesser of 0.75 or t_e or t = 0.375 in
$t_{w(min)}$ = $0.5*t_{min}$ = $\underline{0.1875}$ in
$t_{w(actual)}$ = 0.7*Leg = 0.7*0.3125 = 0.2188 in

UG-45 Nozzle Neck Thickness Check

$t_{a\ UG\text{-}27}$ = P*R / (S*E - 0.6*P) + Corrosion
= 89.465*12 / (20,000*1 - 0.6*89.465) + 0
= 0.0538 in

t_a = max[$t_{a\ UG\text{-}27}$, $t_{a\ UG\text{-}22}$]
= max[0.0538 , 0]
= 0.0538 in

t_{b1} = $P*R_o$ / (S*E + 0.4*P) + Corrosion
= 89.465*54 / (20,000*1 + 0.4*89.465) + 0
= 0.2411 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.2411 , 0.0625]
= 0.2411 in

t_b = min[t_{b3} , t_{b1}]
= min[0.3281 , 0.2411]
= 0.2411 in

t_{UG-45} = max[t_a , t_b]
= max[0.0538 , 0.2411]
= 0.2411 in

Available nozzle wall thickness new, t_n = 0.5 in

The nozzle neck thickness is adequate.

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

Groove weld in tension:	0.74*20,000 =	14,800 psi
Nozzle wall in shear:	0.7*20,000 =	14,000 psi
Inner fillet weld in shear:	0.49*20,000 =	9,800 psi
Outer fillet weld in shear:	0.49*20,000 =	9,800 psi
Upper groove weld in tension:	0.74*20,000 =	14,800 psi

Strength of welded joints:

(1) Inner fillet weld in shear
(π / 2)*Nozzle OD*Leg*S_i = (π / 2)*25*0.375*9,800 = 144,316.92 lb_f

(2) Outer fillet weld in shear
(π / 2)*Pad OD*Leg*S_o = (π / 2)*29*0.3125*9,800 = 139,506.36 lb_f

(3) Nozzle wall in shear
(π / 2)*Mean nozzle dia*t_n*S_n = (π / 2)*24.5*0.5*14,000 = 269,391.56 lb_f

(4) Groove weld in tension
(π / 2)*Nozzle OD*t_w*S_g = (π / 2)*25*0.375*14,800 = 217,948 lb_f

(6) Upper groove weld in tension
(π / 2)*Nozzle OD*t_w*S_g = (π / 2)*25*0.375*14,800 = 217,948 lb_f

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

W = $(A - A_1 + 2*t_n*f_{r1}*(E_1*t - F*t_r))*S_v$
= (5.7869 - 3.2131 + 2*0.5*1*(1*0.375 - 1*0.2411))*20,000
= <u>54,153.2</u> lb_f

W_{1-1} = $(A_2 + A_5 + A_{41} + A_{42})*S_v$
= (0.8366 + 1.5 + 0.1406 + 0.0977)*20,000
= <u>51,498</u> lb_f

W_{2-2} = $(A_2 + A_3 + A_{41} + A_{43} + 2*t_n*t*f_{r1})*S_v$
= (0.8366 + 0 + 0.1406 + 0 + 2*0.5*0.375*1)*20,000
= <u>27,044</u> lb_f

W_{3-3} = $(A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2*t_n*t*f_{r1})*S_v$
= (0.8366 + 0 + 1.5 + 0.1406 + 0.0977 + 0 + 2*0.5*0.375*1)*20,000

= $\underline{58.998}$ lb_f

Load for path 1-1 lesser of W or W_{1-1} = 51498 lb_f
Path 1-1 through (2) & (3) = 139,506.4 + 269,391.6 = $\underline{408.897.94}$ lb_f
Path 1-1 is stronger than W_{1-1} so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or W_{2-2} = 27044 lb_f
Path 2-2 through (1), (4), (6) = 144,316.9 + 217,948 + 217,948 = $\underline{580.212.94}$ lb_f
Path 2-2 is stronger than W_{2-2} so it is acceptable per UG-41(b)(1).

Load for path 3-3 lesser of W or W_{3-3} = 54153.2 lb_f
Path 3-3 through (2), (4) = 139,506.4 + 217,948 = $\underline{357.454.38}$ lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

Legs #1

Leg material:			A992
Leg description:			W 14x43 (Flange out)
Number of legs:	N =	4	
Overall length:		112	in
Base to girth seam length:		96	in
Pad length:		20	in
Pad width:		18	in
Pad thickness:		0.375	in
Bolt circle:		110	in
Anchor bolt size:		1	inch series 8 threaded
Anchor bolt material:			SA-193 B7
Anchor bolts/leg:		2	
Anchor bolt allowable stress:	S_b =	20,000	psi
Anchor bolt corrosion allowance:		0	in
Anchor bolt hole clearance:		0.375	in
Base plate width:		14	in
Base plate length:		14	in
Base plate thickness:		1	in (0.6012 in required)
Base plate allowable stress:		24,000	psi
Foundation allowable bearing stress:		1,658	psi
Effective length coefficient:	K =	1.2	
Coefficient:	C_m =	0.85	
Leg yield stress:	F_y =	50,000	psi
Leg elastic modulus:	E =	29,000,000	psi
Leg to pad fillet weld:		0.625	in (0.4416 in required)
Pad to shell fillet weld:		0.25	in (0.144 in required)
Legs braced:		No	

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

Loading	Force attack angle °	Leg position °	Axial end load lb_f	Shear resisted lb_f	Axial f_a psi	Bending f_{bx} psi	Bending f_{by} psi	Ratio H_{1-1}	Ratio H_{1-2}
Wind operating corroded Moment = 87,752.4 lb_f-ft	0	0	4,000.2	2,676.8	317	4,590	0	0.1325	0.1497
		90	22,805.4	282.7	1,810	2,486	2,431	0.2106	0.2093
		180	32,488.4	2,676.8	2,578	7,695	0	0.3145	0.3191
		270	22,805.4	282.7	1,810	2,486	2,431	0.2106	0.2093
	45	0	4,000.2	1,479.7	317	2,060	8,999	0.3009	0.3457
		90	4,000.2	1,479.7	317	2,060	8,999	0.3009	0.3457
		180	32,488.4	1,479.7	2,578	5,165	8,999	0.4969	0.5152
		270	32,488.4	1,479.7	2,578	5,165	8,999	0.4969	0.5152
	32	0	4,000.2	2,004.5	317	3,074	9,136	0.3306	0.3806
		90	4,000.2	955.0	317	1,221	6,966	0.2265	0.2587
		180	32,488.4	2,004.5	2,578	6,179	9,136	0.5270	0.5500
		270	32,488.4	955.0	2,578	4,326	6,966	0.4191	0.4281

Loading	Force attack angle °	Leg position °	Axial end load lb_f	Shear resisted lb_f	Axial f_a psi	Bending f_{bx} psi	Bending f_{by} psi	Ratio H_{1-1}	Ratio H_{1-2}
Governing Condition Wind operating new Moment = 88,027.4 lb_f-ft	0	0	4,651.4	2,676.8	369	4,661	0	0.1366	0.1535
		90	23,941.3	282.7	1,900	2,609	2,431	0.2180	0.2161
		180	33,654.7	2,676.8	2,671	7,822	0	0.3220	0.3261
		270	23,941.3	282.7	1,900	2,609	2,431	0.2180	0.2161
	45	0	4,651.4	1,479.7	369	2,131	8,999	0.3054	0.3496
		90	4,651.4	1,479.7	369	2,131	8,999	0.3054	0.3496
		180	33,654.7	1,479.7	2,671	5,292	8,999	0.5050	0.5221
		270	33,654.7	1,479.7	2,671	5,292	8,999	0.5050	0.5221
	32	0	4,651.4	2,004.5	369	3,145	9,136	0.3351	0.3845
		90	4,651.4	955.0	369	1,292	6,966	0.2309	0.2625
		180	33,654.7	2,004.5	2,671	6,306	9,136	0.5351	0.5570
		270	33,654.7	955.0	2,671	4,453	6,966	0.4271	0.4351

Loading	Force attack angle °	Leg position °	Axial end load lb_f	Shear resisted lb_f	Axial f_a psi	Bending f_{bx} psi	Bending f_{by} psi	Ratio H_{1-1}	Ratio H_{1-2}
Wind empty corroded Moment = 87,752.4 lb_f-ft	0	0	-8,107.7	2,676.8	-643	5,038	0	0.1009	0.1312
		90	2,625.6	282.7	208	286	2,431	0.0796	0.0893
		180	12,308.6	2,676.8	977	5,496	0	0.1855	0.1991
		270	2,625.6	282.7	208	286	2,431	0.0796	0.0893
	45	0	-8,107.7	1,479.7	-643	2,507	8,999	0.2639	0.3272
		90	-8,107.7	1,479.7	-643	2,507	8,999	0.2639	0.3272
		180	12,308.6	1,479.7	977	2,965	8,999	0.3578	0.3951
		270	12,308.6	1,479.7	977	2,965	8,999	0.3578	0.3951
	32	0	-8,107.7	2,004.5	-643	3,522	9,136	0.2934	0.3621
		90	-8,107.7	955.0	-643	1,669	6,966	0.1908	0.2402
		180	12,308.6	2,004.5	977	3,980	9,136	0.3876	0.4300
		270	12,308.6	955.0	977	2,127	6,966	0.2824	0.3081

Loading	Force attack angle °	Leg position °	Axial end load lb_f	Shear resisted lb_f	Axial f_a psi	Bending f_{bx} psi	Bending f_{by} psi	Ratio H_{1-1}	Ratio H_{1-2}
Wind empty new Moment = 88,027.4 lb_f-ft	0	0	-7,397.8	2,676.8	-587	4,960	0	0.1014	0.1307
		90	3,859.3	282.7	306	421	2,431	0.0876	0.0966
		180	13,572.6	2,676.8	1,077	5,633	0	0.1935	0.2066
		270	3,859.3	282.7	306	421	2,431	0.0876	0.0966
	45	0	-7,397.8	1,479.7	-587	2,430	8,999	0.2647	0.3268
		90	-7,397.8	1,479.7	-587	2,430	8,999	0.2647	0.3268
		180	13,572.6	1,479.7	1,077	3,103	8,999	0.3665	0.4026
		270	13,572.6	1,479.7	1,077	3,103	8,999	0.3665	0.4026
	32	0	-7,397.8	2,004.5	-587	3,444	9,136	0.2943	0.3616
		90	-7,397.8	955.0	-587	1,592	6,966	0.1915	0.2397
		180	13,572.6	2,004.5	1,077	4,117	9,136	0.3963	0.4375
		270	13,572.6	955.0	1,077	2,265	6,966	0.2910	0.3156

Loading	Force attack angle °	Leg position °	Axial end load lb_f	Shear resisted lb_f	Axial f_a psi	Bending f_{bx} psi	Bending f_{by} psi	Ratio H_{1-1}	Ratio H_{1-2}
Wind test new Moment = 4,555.8 lb_f-ft	0	0	19,956.3	0.0	1,584	2,175	0	0.1268	0.1187
		90	34,098.4	0.0	2,706	3,716	0	0.2170	0.2028
		180	34,601.1	0.0	2,746	3,771	0	0.2202	0.2058
		270	34,098.4	0.0	2,706	3,716	0	0.2170	0.2028
	45	0	19,956.3	0.0	1,584	2,175	0	0.1268	0.1187
		90	19,956.3	0.0	1,584	2,175	0	0.1268	0.1187
		180	34,601.1	0.0	2,746	3,771	0	0.2202	0.2058
		270	34,601.1	0.0	2,746	3,771	0	0.2202	0.2058

Loading	Force attack angle °	Leg position °	Axial end load lb_f	Shear resisted lb_f	Axial f_a psi	Bending f_{bx} psi	Bending f_{by} psi	Ratio H_{1-1}	Ratio H_{1-2}
Seismic operating corroded Moment = 44,510.3 lb_f-ft	0	0	8,355.4	1,603.0	663	3,398	0	0.1172	0.1251
		90	23,221.7	169.3	1,843	2,531	1,456	0.1870	0.1823
		180	28,133.2	1,603.0	2,233	5,554	0	0.2434	0.2427
		270	23,221.7	169.3	1,843	2,531	1,456	0.1870	0.1823
	45	0	8,355.4	886.1	663	1,883	5,389	0.2193	0.2425
		90	8,355.4	886.1	663	1,883	5,389	0.2193	0.2425
		180	28,133.2	886.1	2,233	4,039	5,389	0.3513	0.3601
		270	28,133.2	886.1	2,233	4,039	5,389	0.3513	0.3601
	32	0	8,355.4	1,200.4	663	2,490	5,471	0.2371	0.2634
		90	8,355.4	571.9	663	1,381	4,171	0.1745	0.1904
		180	28,133.2	1,200.4	2,233	4,646	5,471	0.3693	0.3810
		270	28,133.2	571.9	2,233	3,537	4,171	0.3051	0.3080

Loading	Force attack angle °	Leg position °	Axial end load lb_f	Shear resisted lb_f	Axial f_a psi	Bending f_{bx} psi	Bending f_{by} psi	Ratio H_{1-1}	Ratio H_{1-2}
Seismic operating new Moment = 48,246.9 lb_f-ft	0	0	8,603.9	1,681.1	683	3,547	0	0.1220	0.1302
		90	24,378.4	177.5	1,935	2,657	1,527	0.1964	0.1913
		180	29,702.2	1,681.1	2,357	5,846	0	0.2566	0.2557
		270	24,378.4	177.5	1,935	2,657	1,527	0.1964	0.1913
	45	0	8,603.9	929.3	683	1,958	5,652	0.2291	0.2534
		90	8,603.9	929.3	683	1,958	5,652	0.2291	0.2534
		180	29,702.2	929.3	2,357	4,257	5,652	0.3703	0.3788
		270	29,702.2	929.3	2,357	4,257	5,652	0.3703	0.3788
	32	0	8,603.9	1,258.9	683	2,595	5,738	0.2478	0.2753
		90	8,603.9	599.8	683	1,431	4,375	0.1820	0.1987
		180	29,702.2	1,258.9	2,357	4,894	5,738	0.3891	0.4008
		270	29,702.2	599.8	2,357	3,731	4,375	0.3216	0.3242

Loading	Force attack angle °	Leg position °	Axial end load lb_f	Shear resisted lb_f	Axial f_a psi	Bending f_{bx} psi	Bending f_{by} psi	Ratio H_{1-1}	Ratio H_{1-2}
Seismic empty corroded Moment = 12,019.2 lb_f-ft	0	0	201.2	214.6	16	355	0	0.0099	0.0113
		90	2,673.5	22.7	212	291	195	0.0220	0.0218
		180	3,999.8	214.6	317	769	0	0.0340	0.0339
		270	2,673.5	22.7	212	291	195	0.0220	0.0218
	45	0	201.2	118.6	16	152	721	0.0232	0.0270
		90	201.2	118.6	16	152	721	0.0232	0.0270
		180	3,999.8	118.6	317	566	721	0.0475	0.0496
		270	3,999.8	118.6	317	566	721	0.0475	0.0496
	32	0	201.2	160.7	16	233	732	0.0256	0.0298
		90	201.2	76.5	16	85	558	0.0173	0.0200
		180	3,999.8	160.7	317	647	732	0.0499	0.0524
		270	3,999.8	76.5	317	499	558	0.0415	0.0426

Loading	Force attack angle °	Leg position °	Axial end load lb_f	Shear resisted lb_f	Axial f_a psi	Bending f_{bx} psi	Bending f_{by} psi	Ratio H_{1-1}	Ratio H_{1-2}
Seismic empty new Moment = 15,621.7 lb_f-ft	0	0	521.3	299.4	41	522	0	0.0153	0.0172
		90	3,929.7	31.6	312	428	272	0.0320	0.0316
		180	5,653.5	299.4	449	1,081	0	0.0479	0.0477
		270	3,929.7	31.6	312	428	272	0.0320	0.0316
	45	0	521.3	165.5	41	238	1,007	0.0339	0.0391
		90	521.3	165.5	41	238	1,007	0.0339	0.0391
		180	5,653.5	165.5	449	798	1,007	0.0668	0.0696
		270	5,653.5	165.5	449	798	1,007	0.0668	0.0696
	32	0	521.3	224.2	41	352	1,022	0.0373	0.0430
		90	521.3	106.8	41	145	779	0.0257	0.0294
		180	5,653.5	224.2	449	911	1,022	0.0701	0.0735
		270	5,653.5	106.8	449	704	779	0.0585	0.0599

Leg Calculations (AISC manual ninth edition)

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

$P_1 = W_t / N + 48*M_t / (N*D)$
$= 95,765.24 / 4 + 48*88,027.4 / (4*108.75)$
$=$ 33,654.68 lb_f

Allowable axial compressive stress, F_a (AISC chapter E)

$C_c = Sqr(2*\pi^2*E / F_y)$
$= Sqr(2*\pi^2*29,000,000 / 50,000)$
$= 106.9988$

$K*l / r = 1.2*97.25 / 1.894 = 61.6151$

$F_a = 1 * (1 - (K*l / r)^2 / (2*C_c^2))*F_y / (5 / 3 + 3*(K*l / r) / (8*C_c)-(K*l / r)^3 / (8*C_c^3))$
$= 1 * (1 - (61.6151)^2 / (2*106.9988^2))*50,000 / (5 / 3 + 3*(61.6151) / (8*106.9988)-(61.6151)^3 / (8*106.9988^3))$
$= 22,440$ psi

Allowable axial compression and bending (AISC chapter H)

$F'_{ex} = 1*12*\pi^2*E / (23*(K*l / r)^2)$
$= 1*12*\pi^2*29,000,000 / (23*(20.0232)^2)$
$= 372,463$ psi

$F'_{ey} = 1*12*\pi^2*E / (23*(K*l / r)^2)$
$= 1*12*\pi^2*29,000,000 / (23*(61.6151)^2)$
$= 39,335$ psi

$F_b = 1*0.66*F_y$
$= 1*0.66*50,000$
$= 33,000$ psi

Compressive axial stress

$f_a = P_1 / A$
$= 33,654.68 / 12.6$
$=$ 2,671 psi

Bending stresses

$f_{bx} = F*\cos(\alpha)*L / (I_x / C_x) + P_1*E_{cc} / (I_x / C_x)$
$= 2,004.47*\cos(32)*97.25 / (428 / 6.83) + 33,654.68*6.83 / (428 / 6.83)$
$=$ 6,306 psi

$f_{by} = F*\sin(\alpha)*L / (I_y / C_y)$
$= 2,004.47*\sin(32)*97.25 / (45.2 / 4)$
$=$ 9,136 psi

AISC equation H_{1-1}

$H_{1-1} = f_a / F_a + C_{mx}*f_{bx} / ((1 - f_a / F'_{ex})*F_{bx}) + C_{my}*f_{by} / ((1 - f_a / F'_{ey})*F_{by})$
$= 2,671 / 22,440 + 0.85*6,306 / ((1 - 2,671 / 372,463)*33,000) + 0.85*9,136 / ((1 - 2,671 / 39,335)*33,000)$
$=$ 0.5351

AISC equation H_{1-2}

$H_{1-2} = f_a / (0.6*1*F_y) + f_{bx} / F_{bx} + f_{by} / F_{by}$
$= 2,671 / (0.6*1*50,000) + 6,306 / 33,000 + 9,136 / 33,000$
$=$ 0.557

4, W 14x43 legs are adequate.

Anchor bolts - Wind empty corroded condition governs

Tensile loading per leg (2 bolts per leg)

R = 48*M / (N*BC) - 0.6*W / N
= 48*135,103.4 / (4*110) - 0.6*12,474.54 / 4
= 12,867.38 lb_f

Required area per bolt

A_b = R / (S_b*n)
= 12,867.38 / (20,000*2)
= 0.3217 in^2

Area of a 1 inch series 8 threaded bolt (corroded) = 0.551 in^2

1 inch series 8 threaded bolts are satisfactory.

Check the leg to pad fillet weld, Bednar 10.3, Wind operating new governs

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

Z_w = (2*b*d + d^2) / 3
= (2*7.995*14.75 + 14.75^2) / 3
= 151.1383 in^2

J_w = (b + 2*d)^3 / 12 - d^2*(b + d)^2 / (b + 2*d)
= (7.995 + 2*14.75)^3 / 12 - 14.75^2*(7.995 + 14.75)^2 / (7.995 + 2*14.75)
= 1,390.968 in^3

E = d^2 / (b + 2*d)
= 14.75^2 / (7.995 + 2*14.75)
= 5.80244 in

Governing weld load f_x = Cos(0)*2,676.76 = 2,676.76 lb_f
Governing weld load f_y = Sin(0)*2,676.76 = 0 lb_f

f_1 = P_1 / L_{weld}
= 33,654.68 / 37.495
= 897.58 lb_f/in (V_L direct shear)

f_2= f_y*L_{leg}*0.5*b / J_w
= 0*97.25*0.5*7.995 / 1,390.968
= 0 lb_f/in (V_L torsion shear)

f_3 = f_y / L_{weld}
= 0 / 37.495
= 0 lb_f/in (V_c direct shear)

f_4 = f_y*L_{leg}*E / J_w
= 0*97.25*5.8024 / 1,390.968
= 0 lb_f/in (V_c torsion shear)

f_5 = (f_x*L_{leg} + P_1*E_{cc}) / Z_w

$= (2,676.76*97.25 + 33,654.68*6.83) / 151.1383$
$= 3,243.23\ lb_f/in$ (M_L bending)

$f_6 = f_x / L_{weld}$
$= 2,676.76 / 37.495$
$= 71.39\ lb_f/in$ (Direct outward radial shear)

$f = Sqr((f_1 + f_2)^2 + (f_3 + f_4)^2 + (f_5 + f_6)^2)$
$= Sqr((897.58 + 0)^2 + (0 + 0)^2 + (3,243.23 + 71.39)^2)$
$= 3,434\ lb_f/in$ (Resultant shear load)

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

$t_w = f / (0.707*0.55*S_a)$
$= 3,434 / (0.707*0.55*20,000)$
$= \underline{0.4416}$ in

The 0.625 in leg to pad attachment fillet weld size is adequate.

Check the pad to vessel fillet weld, Bednar 10.3, Wind operating new governs

$Z_w = b*d + d^2 / 3$
$= 18*20 + 20^2 / 3$
$= 493.3333\ in^2$

$J_w = (b + d)^3 / 6$
$= (18 + 20)^3 / 6$
$= 9,145.333\ in^3$

$f_1 = P_1 / L_{weld}$
$= 33,654.68 / 76$
$= 442.82\ lb_f/in$ (V_L direct shear)

$f_2 = f_y*L_{leg}*0.5*b / J_w$
$= 0*97.25*0.5*18 / 9,145.333$
$= 0\ lb_f/in$ (V_L torsion shear)

$f_3 = f_y / L_{weld}$
$= 0 / 76$
$= 0\ lb_f/in$ (V_c direct shear)

$f_4 = f_y*L_{leg}*0.5*d / J_w$
$= 0*97.25*0.5*20 / 9,145.333$
$= 0\ lb_f/in$ (V_c torsion shear)

$f_5 = (f_x*L_{leg} + P_1*E_{cc}) / Z_w$
$= (2,676.76*97.25 + 33,654.68*6.83) / 493.3333$
$= 993.6\ lb_f/in$ (M_L bending)

$f_6 = f_x / L_{weld}$
$= 2,676.76 / 76$
$= 35.22\ lb_f/in$ (Direct outward radial shear)

$f = Sqr((f_1 + f_2)^2 + (f_3 + f_4)^2 + (f_5 + f_6)^2)$
$= Sqr((442.82 + 0)^2 + (0 + 0)^2 + (993.6 + 35.22)^2)$
$= 1,120.07\ lb_f/in$ (Resultant shear load)

Required pad to vessel fillet weld leg size (welded all around the pad edge)

$t_w = f / (0.707*0.55*S_a)$
= 1,120.07 / (0.707*0.55*20,000)
= <u>0.144</u> in

0.25 in pad to vessel attachment fillet weld size is adequate.

Base plate thickness check, AISC 3-106

$f_p = P / (B*N)$
= 39,202.91 / (14*14)
= 200 psi

m = (N - 0.95*d) / 2
= (14 - 0.95*13.66) / 2
= 0.5115 in

n = (B - 0.8*b) / 2
= (14 - 0.8*7.995) / 2
= 3.802 in

$L = 0.5*(d + b) / 2 - Sqr((0.5*(d + b))^2 / 4 - P / (4*F_p))$
$= 0.5*(13.66 + 7.995) / 2 - Sqr((0.5*(13.66 + 7.995))^2 / 4 - 39,202.91 / (4*1,658))$
= 0.5767 in

$t_b = Largest(m, n, L)*Sqr(3*f_p / S_b)$
= 3.802*Sqr(3*200 / 24,000)
= <u>0.6012</u> in

The base plate thickness is adequate.

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

Applied Loads

Radial load:	P_r =	2,676.76	lb_f
Circumferential moment:	M_c =	0	lb_f-in
Circumferential shear:	V_c =	0	lb_f
Longitudinal moment:	M_L =	482,210.41	lb_f-in
Longitudinal shear:	V_L =	32,488.43	lb_f
Torsion moment:	M_t =	0	lb_f-in
Internal pressure:	P =	58.158	psi
Mean shell radius:	R_m =	53.9375	in
Local shell thickness:	t =	0.25	in
Shell yield stress:	S_y =	32,500	psi

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

R_m / t = 53.9375 / 0.25 = 215.75

C_1 = 9, C_2 = 15.874 in

Local circumferential pressure stress = P*R_i / t =12,518 psi

Local longitudinal pressure stress = P*R_i / (2*t) =6,259 psi

Maximum combined stress (P_L+P_b+Q) = 57,031 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-60,000 psi

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

Maximum local primary membrane stress (P_L) = 28,807 psi
Allowable local primary membrane (P_L) = +-1.5*S = +-30,000 psi

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

Stresses at the 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*	3.2356	0.283	0	0	0	0	-642	-642	-642	-642
4C*	14.9584	0.2472	-2,969	-2,969	-2,969	-2,969	0	0	0	0
1C	0.0592	0.2062	0	0	0	0	-15,213	15,213	-15,213	15,213
2C-1	0.0099	0.2062	-2,544	2,544	-2,544	2,544	0	0	0	0
3A*	5.4099	0.2016	0	0	0	0	0	0	0	0
1A	0.0501	0.2051	0	0	0	0	0	0	0	0
3B*	8.5921	0.2436	-19,258	-19,258	19,258	19,258	0	0	0	0
1B-1	0.0075	0.2092	-30,768	30,768	30,768	-30,768	0	0	0	0
Pressure stress*			12,518	12,518	12,518	12,518	12,518	12,518	12,518	12,518
Total circumferential stress			-43,021	23,603	57,031	583	-3,337	27,089	-3,337	27,089
Primary membrane circumferential stress*			-9,709	-9,709	28,807	28,807	11,876	11,876	11,876	11,876
3C*	4.0492	0.2472	-804	-804	-804	-804	0	0	0	0
4C*	12.7886	0.283	0	0	0	0	-2,539	-2,539	-2,539	-2,539
1C-1	0.0199	0.2536	-5,114	5,114	-5,114	5,114	0	0	0	0
2C	0.0319	0.2536	0	0	0	0	-8,197	8,197	-8,197	8,197
4A*	18.0653	0.2016	0	0	0	0	0	0	0	0
2A	0.019	0.2361	0	0	0	0	0	0	0	0
4B*	3.8975	0.2436	-13,498	-13,498	13,498	13,498	0	0	0	0
2B-1	0.0103	0.2395	-36,910	36,910	36,910	-36,910	0	0	0	0
Pressure stress*			6,259	6,259	6,259	6,259	6,259	6,259	6,259	6,259
Total longitudinal stress			-50,067	33,981	50,749	-12,843	-4,477	11,917	-4,477	11,917
Primary membrane longitudinal stress*			-8,043	-8,043	18,953	18,953	3,720	3,720	3,720	3,720
Shear from M_t			0	0	0	0	0	0	0	0
Circ shear from V_c			0	0	0	0	0	0	0	0

Long shear from V_L	0	0	0	0	-2,047	-2,047	2,047	2,047
Total Shear stress	0	0	0	0	-2,047	-2,047	2,047	2,047
Combined stress (P_L+P_b+Q)	-50,067	33,981	57,031	-13,426	-6,032	27,360	-6,032	27,360

Note: * denotes primary stress.

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

R_m / t = 53.9375 / 0.625 = 86.3

C_1 = 3.9975, C_2 = 11.7071 in

Local circumferential pressure stress = P*R_i / t =12,518 psi

Local longitudinal pressure stress = P*R_i / (2*t) =6,259 psi

Maximum combined stress (P_L+P_b+Q) = 48,709 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-60,000 psi

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

Maximum local primary membrane stress (P_L) = 21,743 psi
Allowable local primary membrane (P_L) = +-1.5*S = +-30,000 psi

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

Stresses at the leg edge per WRC Bulletin 107

Figure	value	β	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	5.809	0.1803	0	0	0	0	-461	-461	-461	-461
4C*	11.7197	0.1491	-931	-931	-931	-931	0	0	0	0
1C	0.0858	0.1135	0	0	0	0	-3,528	3,528	-3,528	3,528
2C-1	0.0528	0.1135	-2,171	2,171	-2,171	2,171	0	0	0	0
3A*	3.3247	0.106	0	0	0	0	0	0	0	0
1A	0.0803	0.1202	0	0	0	0	0	0	0	0
3B*	8.4463	0.1517	-10,156	-10,156	10,156	10,156	0	0	0	0
1B-1	0.0278	0.131	-29,137	29,137	29,137	-29,137	0	0	0	0
Pressure stress*			12,518	12,518	12,518	12,518	12,518	12,518	12,518	12,518
Total circumferential stress			-29,877	32,739	48,709	-5,223	8,529	15,585	8,529	15,585
Primary membrane circumferential stress*			1,431	1,431	21,743	21,743	12,057	12,057	12,057	12,057
3C*	7.2302	0.1491	-574	-574	-574	-574	0	0	0	0
4C*	10.6061	0.1803	0	0	0	0	-842	-842	-842	-842
1C-1	0.0622	0.1547	-2,557	2,557	-2,557	2,557	0	0	0	0
2C	0.0385	0.1547	0	0	0	0	-1,583	1,583	-1,583	1,583
4A*	5.5796	0.106	0	0	0	0	0	0	0	0
2A	0.0347	0.15	0	0	0	0	0	0	0	0
4B*	3.4418	0.1517	-6,731	-6,731	6,731	6,731	0	0	0	0
2B-1	0.028	0.1679	-22,905	22,905	22,905	-22,905	0	0	0	0
Pressure stress*			6,259	6,259	6,259	6,259	6,259	6,259	6,259	6,259
Total longitudinal stress			-26,508	24,416	32,764	-7,932	3,834	7,000	3,834	7,000
Primary membrane longitudinal stress*			-1,046	-1,046	12,416	12,416	5,417	5,417	5,417	5,417
Shear from M_t			0	0	0	0	0	0	0	0

Circ shear from V_c	0	0	0	0	0	0	0	0
Long shear from V_L	0	0	0	0	-1,110	-1,110	1,110	1,110
Total Shear stress	0	0	0	0	-1,110	-1,110	1,110	1,110
Combined stress (P_L+P_b+Q)	-29,877	32,739	48,709	-7,932	8,778	15,726	8,778	15,726

Note: * denotes primary stress.

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:	No

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

5. $D + P + P_s + 0.7E \quad = (1.0 + 0.14S_{DS})D + P + P_s + 0.7\rho Q_E$
8. $0.6D + P + P_s + 0.7E \quad = (0.6 - 0.14S_{DS})D + P + P_s + 0.7\rho Q_E$

Where

D = Dead load
P = Internal or external pressure load
P_s = Static head load
E = Seismic load $= E_h$ +/- E_v $= \rho Q_E$ +/- $0.2S_{DS}D$

Vessel Characteristics

Vessel height: 37.4285 ft
Vessel Weight:
Operating, Corroded: 93,194 lb
Empty, Corroded: 12,475 lb

Period of Vibration Calculation

Fundamental Period, T:
Operating, Corroded: 0.319 sec (f = 3.1 Hz)
Empty, Corroded: 0.110 sec (f = 9.0 Hz)

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

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

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

Seismic Shear Reports:

Operating, Corroded
Empty, Corroded
Base Shear Calculations

Seismic Shear Report: Operating, Corroded

Component	Elevation of bottom above base (in)	Elastic modulus E (10^6 psi)	Inertia I (ft^4)	Seismic shear at Bottom (lbf)	Bending Moment at Bottom (lbf-ft)
Ellipsoidal Head #1	420	27.9	*	61	85
Cylinder #1	324	27.9	5.9228	247	3,059
Cylinder #2	228	27.9	5.9228	1,949	12,097
Cylinder #3	132	27.9	5.9228	3,108	35,249
Cylinder #4 (top)	96	27.9	5.9228	3,370	44,674
Legs #1	0	29.0	0.0456	3,544	72,795
Cylinder #4 (bottom)	96	27.9	5.9228	157	164
Ellipsoidal Head #2	96	27.9	*	151	151
*Moment of Inertia I varies over the length of the component					

Seismic Shear Report: Empty, Corroded

Component	Elevation of bottom above base (in)	Elastic modulus E (10^6 psi)	Inertia I (ft^4)	Seismic shear at Bottom (lbf)	Bending Moment at Bottom (lbf-ft)
Ellipsoidal Head #1	420	29.4	*	56	78
Cylinder #1	324	29.4	5.9228	226	2,948
Cylinder #2	228	29.4	5.9228	335	5,220
Cylinder #3	132	29.4	5.9228	425	10,818
Cylinder #4 (top)	96	29.4	5.9228	441	12,043
Legs #1	0	29.0	0.0456	474	15,750
Cylinder #4 (bottom)	96	29.4	5.9228	17	23
Ellipsoidal Head #2	96	29.4	*	16	22
*Moment of Inertia I varies over the length of the component					

11.4.3: Maximum considered earthquake spectral response acceleration

The maximum considered earthquake spectral response acceleration at short period, S_{MS}
S_{MS} = F_a * S_s = 1.2000 * 16.30 / 100 = 0.1956
The maximum considered earthquake spectral response acceleration at 1 s period, S_{M1}
S_{M1} = F_v * S_1 = 1.7000 * 9.90 / 100 = 0.1683

11.4.4: Design spectral response acceleration parameters

Design earthquake spectral response acceleration at short period, S_{DS}
S_{DS} = 2 / 3 * S_{MS} = 2 / 3 * 0.1956 = 0.1304
Design earthquake spectral response acceleration at 1 s period, S_{D1}
S_{D1} = 2 / 3 * S_{M1} = 2 / 3 * 0.1683 = 0.1122

12.4.2.3: Seismic Load Combinations: Vertical Term

Factor is applied to dead load.

Compressive Side: $= 1.0 + 0.14 * S_{DS}$
$= 1.0 + 0.14 * 0.1304$
$= 1.0183$

Tensile Side: $= 0.6 - 0.14 * S_{DS}$
$= 0.6 - 0.14 * 0.1304$
$= 0.5817$

Base Shear Calculations

Operating, Corroded
Empty, Corroded

Base Shear Calculations: Operating, Corroded

Paragraph 15.4.4: Period Determination

Fundamental Period is taken from the Rayleigh method listed previously in this report.

T = 0.3193 sec.

12.8.1: Calculation of Seismic Response Coefficient

C_s is the value computed below, bounded by C_sMin and C_sMax:
C_sMin is 0.03; in addition, if S_1 >= 0.6g, C_sMin shall not be less than eqn 15.4-2.
C_sMax calculated with 12.8-3 because (T = 0.3193) <= (T_L = 12.0000)

$C_s = S_{DS} / (R / I)$ = 0.1304 / (3.0000 / 1.2500) = 0.0543
C_sMin = 0.03
C_sMax = S_{D1} / (T * (R / I)) = 0.1122 / (0.3193 * (3.0000 / 1.2500)) = 0.1464
C_s = 0.0543

12.8.1: Calculation of Base Shear

$V = C_s * W$
= 0.0543 * 93193.8047
= 5,063.53 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 * 5,063.53
= 3,544.47 lb

Base Shear Calculations: Empty, Corroded

Paragraph 15.4.4: Period Determination

Fundamental Period is taken from the Rayleigh method listed previously in this report.

T = 0.1105 sec.

12.8.1: Calculation of Seismic Response Coefficient

C_s is the value computed below, bounded by C_sMin and C_sMax:
C_sMin is 0.03; in addition, if S_1 >= 0.6g, C_sMin shall not be less than eqn 15.4-2.
C_sMax calculated with 12.8-3 because (T = 0.1105) <= (T_L = 12.0000)

$C_s = \underline{S_{DS}} / (\underline{R} / \underline{I})$ = 0.1304 / (3.0000 / 1.2500) = 0.0543
C_sMin = 0.03
C_sMax = $\underline{S_{D1}} / (T * (\underline{R} / \underline{I}))$ = 0.1122 / (0.1105 * (3.0000 / 1.2500)) = 0.4231
C_s = 0.0543

12.8.1: Calculation of Base Shear

V = C_s * $\underline{W}$
= 0.0543 * 12474.5371
= 677.78 lb

12.4.2.1 Seismic Load Combinations: Horizontal Seismic Load Effect, E_h
Q_E = V
E_h = 0.7 * ρ * Q_E (Only 70% of seismic load considered as per Section 2.4.1)
= 0.70 * 1.0000 * 677.78
= 474.45 lb

Wind Code

Building Code:	**ASCE 7-05**
Elevation of base above grade:	0.0000 ft
Increase effective outer diameter by:	5.0000 ft
Wind Force Coefficient Cf:	0.5500
Basic Wind Speed:, V:	100.0000 mph
Importance Factor:, I:	1.1500
Exposure category:	C
Wind Directionality Factor, Kd:	1.0000
Topographic Factor, Kzt:	1.0000
Enforce min. loading of 10 psf:	Yes

Vessel Characteristics

Vessel height, h: 37.4285 ft

Vessel Minimum Diameter, b

Operating, Corroded: 9.0000 ft

Empty, Corroded: 9.0000 ft

Fundamental Frequency, n_1

Operating, Corroded: 3.1319 Hz

Empty, Corroded: 9.0498 Hz

Damping coefficient, β

Operating, Corroded: 0.0246

Empty, Corroded: 0.0200

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
Wind Pressure Calculations

Wind Deflection Report: Operating, Corroded

Component	Elevation of bottom above	Effective OD (ft)	Elastic modulus E (10^6 psi)	Inertia I (ft^4)	Platform wind shear at	Total wind shear at	bending moment at	Deflection at top (in)

	base (in)				Bottom (lbf)	Bottom (lbf)	Bottom (lbf-ft)	
Ellipsoidal Head #1	420	14.00	27.9	*	0	446	495	0.0733
Cylinder #1	324	14.00	27.9	5.923	0	2,094	12,486	0.0722
Cylinder #2	228	14.00	27.9	5.923	0	3,627	35,449	0.0687
Cylinder #3	132	14.00	27.9	5.923	0	5,042	72,793	0.0657
Cylinder #4 (top)	96	14.00	27.9	5.923	0	5,542	88,186	0.0638
Legs #1	0	0	29.0	0.04564	0	5,919	135,103	0.0636
Cylinder #4 (bottom)	96	14.00	27.9	5.923	0	377	434	0.0636
Ellipsoidal Head #2	96	14.00	27.9	*	0	363	403	0.0636
*Moment of Inertia I varies over the length of the component								

Wind Deflection Report: Empty, Corroded

Component	Elevation of bottom above base (in)	Effective OD (ft)	Elastic modulus E (10^6 psi)	Inertia I (ft^4)	Platform wind shear at Bottom (lbf)	Total wind shear at Bottom (lbf)	bending moment at Bottom (lbf-ft)	Deflection at top (in)
Ellipsoidal Head #1	420	14.00	29.4	*	0	446	495	0.0728
Cylinder #1	324	14.00	29.4	5.923	0	2,094	12,486	0.0718
Cylinder #2	228	14.00	29.4	5.923	0	3,627	35,449	0.0685
Cylinder #3	132	14.00	29.4	5.923	0	5,042	72,793	0.0656
Cylinder #4 (top)	96	14.00	29.4	5.923	0	5,542	88,186	0.0638
Legs #1	0	0	29.0	0.04564	0	5,919	135,103	0.0636
Cylinder #4 (bottom)	96	14.00	29.4	5.923	0	377	434	0.0636
Ellipsoidal Head #2	96	14.00	29.4	*	0	363	403	0.0636
*Moment of Inertia I varies over the length of the component								

Wind Pressure (WP) Calculations

Gust Factor (G¯) Calculations

$$Kz = 2.01 * (Z/Zg)^{2/\alpha}$$
$$= 2.01 * (Z/900.0000)^{0.2105}$$
$$qz = 0.00256 * Kz * Kzt * Kd * V^2 * I \text{ psf}$$
$$= 0.00256 * Kz * 1.0000 * 1.0000 * 100.0000^2 * 1.1500$$
$$= 29.4400 * Kz$$
$$WP = qz * G * Cf \text{ (Minimum 10 lb/ft}^2\text{)}$$
$$= qz * G * 0.5500 \text{ (Minimum 10 lb/ft}^2\text{)}$$

Design Wind Pressures

Height Z (')	Kz	qz (psf)	WP: Operating (psf)	WP: Empty (psf)	WP: hydrotest (psf)	WP: Vacuum (psf)
15.0	0.8489	24.99	12.25	12.25	N.A.	N.A.
20.0	0.9019	26.55	13.01	13.01	N.A.	N.A.
25.0	0.9453	27.83	13.64	13.64	N.A.	N.A.
30.0	0.9823	28.92	14.17	14.17	N.A.	N.A.

40.0	1.0436	30.72	15.06	15.06	N.A.	N.A.

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

Gust Factor Calculations

Operating, Corroded
Empty, Corroded

Gust Factor Calculations: Operating, Corroded

Vessel is considered a rigid structure as n_1 = 3.1319 Hz ≥ 1 Hz.

z^- = 0.60 * h
= 0.60 * 37.4285
= 22.4571

I_{z^-} = c * (33 / z^-)$^{1/6}$
= 0.2000 * (33 / 22.4571)$^{1/6}$
= 0.2133

L_{z^-} = l * (z^- / 33)^{ep}
= 500.0000 * (22.4571 / 33)$^{0.2000}$
= 462.9540

Q = Sqr(1 / (1 + 0.63 * ((b + h) / L_{z^-})$^{0.63}$))
= Sqr(1 / (1 + 0.63 * ((9.0000 + 37.4285) / 462.9540)$^{0.63}$))
= 0.9333

G = 0.925 * (1 + 1.7 * g_Q * I_{z^-} * Q) / (1 + 1.7 * g_v * I_{z^-})
= 0.925 * (1 + 1.7 * 3.40* 0.2133 * 0.9333) / (1 + 1.7 * 3.40 * 0.2133)
= 0.8910

Gust Factor Calculations: Empty, Corroded

Vessel is considered a rigid structure as n_1 = 9.0498 Hz ≥ 1 Hz.

z^- = 0.60 * h
= 0.60 * 37.4285
= 22.4571

I_{z^-} = c * (33 / z^-)$^{1/6}$
= 0.2000 * (33 / 22.4571)$^{1/6}$
= 0.2133

L_{z^-} = l * (z^- / 33)^{ep}
= 500.0000 * (22.4571 / 33)$^{0.2000}$
= 462.9540

Q = Sqr(1 / (1 + 0.63 * ((b + h) / L_{z^-})$^{0.63}$))
= Sqr(1 / (1 + 0.63 * ((9.0000 + 37.4285) / 462.9540)$^{0.63}$))
= 0.9333

G = 0.925 * (1 + 1.7 * g_Q * I_{z^-} * Q) / (1 + 1.7 * g_v * I_{z^-})

$= 0.925 * (1 + 1.7 * 3.40 * 0.2133 * 0.9333) / (1 + 1.7 * 3.40 * 0.2133)$

$= 0.8910$

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]
$a^{-} = 0.1538$, $b^{-} = 0.6500$	[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]

Liquid Level bounded by Ellipsoidal Head #2

Location from datum	226"
Operating Liquid Specific Gravity	1
Test liquid specific gravity	1