# DOCUMENT PACKAGE

78” ID ACA After Reactor

Item No: R-2210

PO No: 4700984380

Serial No: 293-03

National Board: 2

Evonik Corporation

Mobile, Alabama Plant

ACA Project

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**Carolina Integrated Solutions**

**157 Derrick Road**

**Spartanburg, South Carolina 29303**

**864-308-8281**

National Board Number: 2
Mfg. Representative: RM Date: 2-17-16
Authorized Inspector: N.A Date: 2-17-16

# 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: Carolina Integrated Solutions, 157 Derrick Road, Spartanburg, South Carolina 29303, USA (Name and address of Manufacturer)

2. Manufactured for: Dominion Tank and Vessel, 1501 Valley Road, Richmond, VA 23222, USA (Name and address of Purchaser)

3. Location of installation: Evonik, 4201 Degussa Rd, Mobile County, AL 36582, USA (Name and address)

4. Type: Vertical (Horizontal or vertical, tank) | 293-03 (Manufacturer's serial number) | N/A (CRN) | 15515-03-1 R1 (Drawing number) | 2 (National Board number) | 2015 (Year built)

5. ASME Code, Section VIII, Division 1: 2013 Edition [Edition and Addenda, if applicable (date)] | N/A (Code Case numbers) | Lethal Service [Special service per UG-120(d)]

6. Shell: SA-240 316L (Material spec. number, grade) | 0.3125" (Nominal thickness) | 0" (Corr. allow.) | 6'-6" (Inner diameter) | 13'-9" [Length (overall)]

**Body Flanges on Shells**

| No. | Type | ID | OD | Flange Thk | Min Hub Thk | Material | How Attached | Location | Bolting: Num & Size | Bolting: Bolting Material | Bolting: Washer (OD, ID, thk) | Bolting: Washer Material |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |

7. Seams: Type 1 [Long. (welded, dbl., sngl., lap, butt)] | Full [R.T. (spot or full)] | 100% (Eff., %) | N/A (H.T. temp.) | N/A (Time, hr) | Type 1 [Girth (welded, dbl., sngl., lap, butt)] | Full [R.T.(Spot or Full)] | 100% (Eff., %) | 2 (No. of courses)

8. Heads: (a) Material: SA-240 316L (Spec. no., grade) (b) Material: SA-240 316L (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 | 0.4" | 0" | 78" IR | 4.75" IR | N/A | N/A | N/A | N/A | Concave |
| (b) | BOTTOM | 0.4" | 0" | 78" IR | 4.75" IR | N/A | N/A | N/A | N/A | Concave |

**Body Flanges on Heads**

| | Location | Type | ID | OD | Flange Thk | Min Hub Thk | Material | How Attached | Bolting: Num & Size | Bolting: Bolting Material | Bolting: Washer (OD, ID, thk) | Bolting: Washer Material |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (a) | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| (b) | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |

9. MAWP: 45 psi (Internal) | -14.7 psi (External) at max. temp. 338.00 °F (Internal) | 338.00 °F (External).

Min. design metal temp. -20.00 °F at 45 psi. Hydro., pneu., or comb. test pressure Hydro. at 60 psi.
Proof test N/A.

10. Nozzles, inspection, and safety valve openings:

| Purpose (Inlet, Outlet, Drain, etc.) | No. | Diameter or Size | Type | Material: Nozzle | Material: Flange | Nozzle Thickness: Nom. | Nozzle Thickness: Corr. | Reinforcement Material | Attachment Details: Nozzle | Attachment Details: Flange | Location (Insp. Open.) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A2,S1 | 2 | NPS 2 | Cl. 150 WN | SA-312 TP316L | SA-182 F316L | 0.154" | 0" | N/A | UW-16.1(e) | APP 2-4(6) | Top Head |
| A4,A6,T1,V1 | 4 | NPS 1.5 | Cl. 150 WN | SA-312 TP316L | SA-182 F316L | 0.145" | 0" | N/A | UW-16.1(e) | APP 2-4(6) | Top Head,Shell |
| Sight Glass (G1) | 1 | 6" ID | N/A | SA-182 F316L | N/A | 2.5" | 0" | N/A | UW-16.1(e) | N/A | Top Head |
| L2,R1 | 2 | NPS 4 | Cl. 150 WN | SA-312 TP316L | SA-182 F316L | 0.237" | 0" | N/A | UW-16.1(e) | APP 2-4(6) | Top Head |
| Level Switch - High (L4) | 1 | NPS 3 | Cl. 150 WN | SA-312 TP316L | SA-182 F316L | 0.216" | 0" | N/A | UW-16.1(e) | APP 2-4(6) | Top Head |
| Manway w/Davit (M1) | 1 | 23.25" ID | Cl. 150 WN | SA-240 316L | SA-182 F316L | 0.375" | 0" | SA-240 316L | UW-16.1(h) | APP 2-4(6) | Top Head |

*Additional Nozzles - See attached ...*

11. Supports: Skirt No (Yes or no) Lugs 4 (Number) Legs N/A (Number) Other N/A (Describe) Attached Shell -02 - 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: NONE (Name of part, item number, Manufacturer's name and identifying stamp)

Shop test performed in the horizontal position.
Safety Relief by others.
See attached U-4 form.

National Board Number: 2
Mfg. Representative: Rm Date: 2-17-16
Authorized Inspector: JA Date: 2-17-16

**Form U-1A (Back)**

## 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 51,098 expires July 1, 2018.

Date 2-17-16 Co. name Carolina Integrated Solutions (Manufacturer) Signed Ricky McRobie (Representative)

## CERTIFICATE OF SHOP/FIELD INSPECTION

Vessel constructed by Carolina Integrated Solutions at 157 Derrick Road Spartanburg, South Carolina 29303.
I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and employed by OneCIS Insurance Company have inspected the component described in this Manufacturer's Data Report on 12-22-15, 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 2-17-16 Signed (Authorized Inspector) Commissions NB-14016A [National Board (incl. endorsements)]

(04/14)

## FORM U-4 MANUFACTURER'S DATA REPORT SUPPLEMENTARY SHEET
### As Required by the Provisions of the ASME Boiler and Pressure Vessel Code Rules, Section VIII, Division 1

1. Manufactured and certified by: Carolina Integrated Solutions 157 Derrick Road Spartanburg, South Carolina 29303 USA (Name and address of Manufacturer)

2. Manufactured for: Dominion Tank and Vessel 1501 Valley Road Richmond, VA 23222 USA (Name and address of Purchaser)

3. Location of installation: Evonik 4201 Degussa Rd Mobile County, AL 36582 USA (Name and address)

4. Type: Vertical (Horizontal, vertical, or sphere) | Reactor (Tank, separator, heat exch., etc.) | 293-03 (Manufacturer's serial number)

N/A (CRN) | 15515-03-1 R1 (Drawing Number) | 2 (National Board number) | 2015 (Year built)

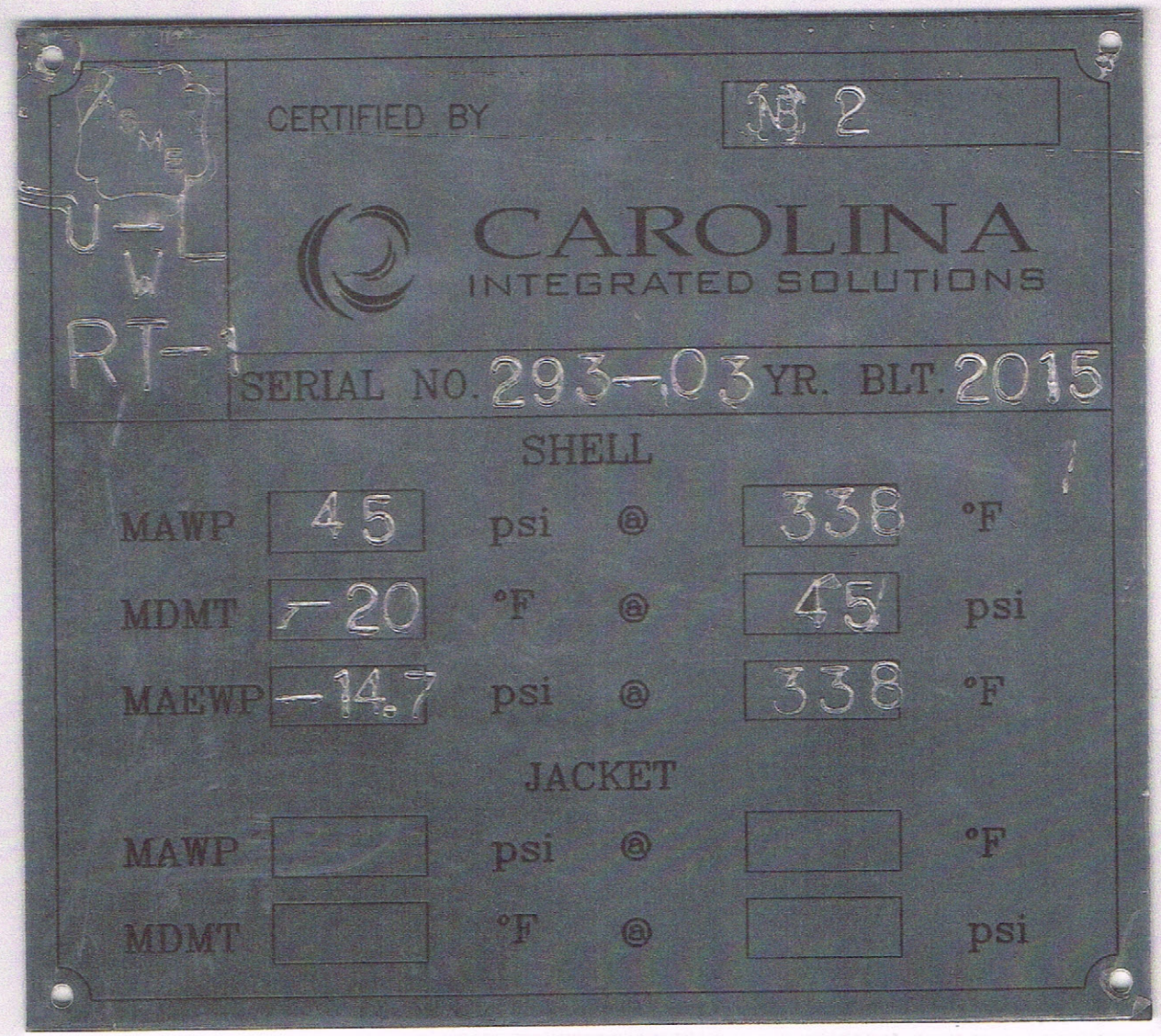
**Additional Nozzles:**

| Purpose (Inlet, Outlet, Drain, etc) | No. | Diameter or Size | Type | Material | | Nozzle Thickness | | Reinforcement Material | Attachment Details | | Location (Insp. Open.) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Nozzle | Flange | Nom. | Corr. | | Nozzle | Flange | |
| Off Gas Vent (V2) | 1 | NPS 1 | Cl. 150 WN | SA-312 TP316L | SA-182 F316L | 0.133" | 0" | N/A | UW-16.1(e) | APP 2-4(6) | Top Head |
| A7,S2 | 2 | NPS 3 | Cl. 150 WN | SA-312 TP316L | SA-182 F316L | 0.216" | 0" | SA-240 316L | UW-16.1(h) | APP 2-4(6) | Top Head,Shell |
| Liquid Outlet (B1) | 1 | NPS 4 | Cl. 150 WN | SA-312 TP316L | SA-182 F316L | 0.237" | 0" | SA-240 316L | UW-16.1(h) | APP 2-4(6) | BTM Head |

Certificate of Authorization: Type U No. 51,098 Expires July 1, 2018

Date 2-17-16 Name Carolina Integrated Solutions (Manufacturer) Signed Ricky McRae (Representative)

Date 2-17-16 Name (Authorized Inspector) Commissions NB-14016A [National Board (incl. endorsements)]


CERTIFIED BY
NB 2
U
W
RT-1
CAROLINA
INTEGRATED SOLUTIONS
SERIAL NO. 293-03 YR. BLT. 2015
SHELL
MAWP 45 psi @ 338 °F
MDMT -20 °F @ 45 psi
MAEWP -14.7 psi @ 338 °F
JACKET
MAWP psi @ °F
MDMT °F @ psi

TANK 3

| | | | | | |
|---|---|---|---|---|---|
| MAWP | 3.1 BARG | PSIG @ | 170 °C | °F |
| MDMT | −29°C | °F @ | 3.1 BARG | PSIG |
| MAEWP | −1.013 BARG | PSIG @ | 170 °C | °F |
| JKT MAWP | | PSIG @ | | °F |
| JKT MDMT | | °F @ | | PSIG |

INSPECTOR

PLANT MOBILE ALABAMA

| | |
|---|---|
| WEIGHT | 7600 LBS |
| MATERIAL | SA-240 316 / 316L |
| P.O. No. | 4500984380 |
| EQUIP No. | R-2210 |
| PROC. No. | 142-00940 |

CAROLINA INTEGRATED SOLUTIONS

**CUSTOMER:**

**Job#** 293-03 **DATE:** 8/5/2015

**DESCRIPTION:** 78" ID ACA AFTER REACTOR R-2210 **DRAWING NO.** 15515-03-1,2,3 REV. 01

**QC MANAGER APPROVED:** Rick McRobie **DATE:** 08/05/15

**DATE:**

**AI REVIEWED:** **DATE:** 8-19-15

| OPERATION NUMBERS | DESCRIPTION<br>ITEMS BELOW HAVE TO FOLLOW IN NUMERICAL ORDER GIVEN.<br>A = ACTUAL R = REVIEW W = WITNESS H = HOLD | DATE AND SIGNATURE | | | |
|---|---|---|---|---|---|
| | | Weld Map | CIS INSPECTOR | Welder I.D. | AUTHORIZED INSPECTOR |
| | | | | | |
| 1 | Verify WPS | | | | |
| 2 | Review Calculations and Drawings | | | | N.A 8-19-15 |
| 3 | Review Material Test Reports | | | | |
| | GS=Girth Seam LS= Long Seam | | | | |
| | | | | | |
| | Fit-Up Bottom Head to Shell Course 1 (GS 1) | 1 | 11-17-15 Rm | | |
| | Weld Inside | | 12-1-15 Rm | CI3 | |
| | Pt Backgrind | | PT GOOD 12-4-15 Rm | | N.A 12-4-15 |
| | Weld Outside | | | CI3 | |
| | | | | | |
| | Fit-Up Shell Course 1 Long Seam (LS 1) | 1 | 11-17-15 Rm | | |
| | Weld Inside | | 12-1-15 Rm | CI3 | |
| | PT Backgrind | | PT GOOD 12-4-15 Rm | | N.A 12-4-15 |
| | Weld Outside | | | CI3 | |
| | | | | | |
| | Fit-Up Shell Course 1 to Shell Course 2 (GS 2) | 1 | 11-17-15 Rm | | |
| | Weld Inside | | 12-1-15 Rm | CI3 | |
| | PT Backgrind | | PT GOOD 12-4-15 Rm | | N.A 12-4-15 |
| | Weld Outside | | | CI3 | |
| | | | | | |
| | Fit-Up Shell Course 2 Long Seam (LS 2) | 1 | 11-17-15 Rm | | |
| | Weld Inside | | 12-1-15 Rm | CI3 | |
| | PT Backgrind | | PT GOOD 12-4-15 Rm | | N.A 12-4-15 |

CAROLINA INTEGRATED SOLUTIONS

**CUSTOMER:**

**Job#** 293-03 **DATE:** 8/5/2015

**DESCRIPTION:** 78" ID ACA AFTER REACTOR R-2210 **DRAWING NO.** 15515-03-1,2,3 REV. 0

**QC MANAGER APPROVED:** Rick McRobie **DATE:** 08/05/15

**DATE:**

**AI REVIEWED:** N.A **DATE:** 8-19-15

| OPERATION NUMBERS | DESCRIPTION<br>ITEMS BELOW HAVE TO FOLLOW IN NUMERICAL ORDER GIVEN.<br>A = ACTUAL R = REVIEW W = WITNESS H = HOLD | DATE AND SIGNATURE | | | |
|---|---|---|---|---|---|
| | | Weld Map | CIS INSPECTOR | Welder I.D. | AUTHORIZED INSPECTOR |
| | **Weld Outside** | | | | |
| | | | | | |
| | **Fit-Up Shell Course 2 to Top Head (GS 3)** | 1 | 12-3-15 Rm | | |
| | **Weld Inside** | | 12-3-15 Rm | CI3 | |
| | **PT Backgrind** | | PT Good 12-4-15 Rm | | N.A 12-4-15 |
| | **Weld Outside** | | | CI3 | |
| | | | | | |
| | **Schedule Of Openings** | | | | |
| | **A1** | | | | |
| | **W1** | 5 | 11-9-15 Rm | CI12 | |
| | **W2** | 5 | 11-9-15 Rm | CI12 | |
| | **W3** | 5 | 12-16-15 Rm | CI16 | |
| | **Completed Nozzle** | | 12-22-15 Rm | | |
| | | | | | |
| | **A2** | | | | |
| | **W1** | 5 | 10-22-15 Rm | CI12 | |
| | **W2** | 5 | 10-30-15 Rm | CI12 | 10-30-15 N.A |
| | **Comlpeted Nozzle** | | 12-22-15 Rm | | |
| | | | | | |
| | **A3** | | | | |
| | **W1** | 2 | 11-10-15 Rm | CI12 | |
| | **W2** | 2 | 11-10-15 Rm | CI12 | |
| | **W3** | 2 | 12-16-15 Rm | CI16 | |

CAROLINA INTEGRATED SOLUTIONS

**CUSTOMER:** | **Job#** 293-03 | **DATE:** 8/5/2015

**DESCRIPTION:** 78" ID ACA AFTER REACTOR R-2210 | **DRAWING NO.** 15515-03-1,2,3 REV. 0 1

**QC MANAGER APPROVED:** Rick McRobie | **DATE:** 08/05/15

**DATE:**

**AI REVIEWED:** N.A | **DATE:** 8-19-15

| OPERATION NUMBERS | DESCRIPTION<br>ITEMS BELOW HAVE TO FOLLOW IN NUMERICAL ORDER GIVEN.<br>A = ACTUAL R = REVIEW W = WITNESS H = HOLD | DATE AND SIGNATURE | | | |
|---|---|---|---|---|---|
| | | Weld Map | CIS INSPECTOR | Welder I.D. | AUTHORIZED INSPECTOR |
| | Completed Nozzle | | 12-22-15 Rm | | |
| | | | | | |
| | A4 | | | | |
| | W1 | 2 | 10-22-15 Rm | CI12 | |
| | W2 | 2 | 10-30-15 Rm | CI12 | 10-30-15 N.A |
| | W3 | 2 | 11-17-15 Rm | CI12 | |
| | W4 | 2 | 11-17-15 Rm | CI12 | |
| | Completed Nozzle | | 12-22-15 Rm | | |
| | | | | | |
| | A5 / | | | | |
| | W1 | 3 | 11-9-15 Rm | CI2 | |
| | W2 | 3 | 11-9-15 Rm | CI2 | |
| | W3 | 3 | 12-16-15 Rm | CI16 | |
| | Completed Nozzle | | 12-22-15 Rm | | |
| | | | | | |
| | A6 | | | | |
| | W1 | 3 | 10-22-15 Rm | CI12 | |
| | W2 | 3 | 10-30-15 Rm | CI12 | 10-30-15 N.A |
| | W3 | 3 | 11-17-15 Rm | CI12 | |
| | W4 | 3 | 11-17-15 Rm | CI12 | |
| | Completed Nozzle | | 12-22-15 Rm | | |
| | | | | | |
| | A7 | | | | |
| | W1 | 6 | 11-10-15 Rm | CI12 | |
| | W2 | 6 | 12-14-15 Rm | CI16 | |

CAROLINA INTEGRATED SOLUTIONS

**CUSTOMER:**

**Job#** 293-03 **DATE:** 8/5/2015

**DESCRIPTION:** 78" ID ACA AFTER REACTOR R-2210 **DRAWING NO.** 15515-03-1,2,3 REV. 8 1

**QC MANAGER APPROVED:** Rick McRobie **DATE:** 08/05/15

**DATE:**

**AI REVIEWED:** N.A **DATE:** 8-19-15

| OPERATION NUMBERS | DESCRIPTION<br>ITEMS BELOW HAVE TO FOLLOW IN NUMERICAL ORDER GIVEN.<br>A = ACTUAL R = REVIEW W = WITNESS H = HOLD | DATE AND SIGNATURE | | | |
|---|---|---|---|---|---|
| | | Weld Map | CIS INSPECTOR | Welder I.D. | AUTHORIZED INSPECTOR |
| | W3 | 6 | 12-14-15 Rm | CI16 | |
| | W4 | 6 | 12-14-15 Rm | CI16 | |
| | W5 | 6 | 11-10-15 Rm | CI12 | |
| | W6 | 6 | 11-10-15 Rm | CI12 | |
| | Completed Nozzle | | 12-22-15 Rm | | |
| | | | | | |
| | B1 | | | | |
| | W1 | 7 | 10-26-15 Rm | CI12 | |
| | W2 | 7 | 10-30-15 Rm | CI12 | 10-30-15 N.A |
| | W3 | 7 | 10-30-15 Rm | CI12 | |
| | W4 | 7 | 10-30-15 Rm | CI12 | |
| | W5 | 7 | 11-13-15 Rm | CI12 | |
| | W6 | 7 | 11-13-15 Rm | CI12 | |
| | W7 | 7 | 11-13-15 Rm | CI12 | |
| | Completed Nozzle | | 12-22-15 Rm | | |
| | | | | | |
| | G1 | | | | |
| | W1 | 8 | 11-18-15 Rm | CI1 | |
| | ~~W2~~ | ~~8~~ | | | |
| | Completed Nozzle | | 12-22-15 Rm | | |
| | | | | | |
| | L1 | | | | |
| | W1 | 4 | 11-10-15 Rm | CI1 | |
| | W2 | 4 | 11-10-15 Rm | CI1 | |
| | Completed Nozzle | | 12-22-15 Rm | | |

CAROLINA INTEGRATED SOLUTIONS

**CUSTOMER:**

**Job#** 293-03 **DATE:** 8/5/2015

**DESCRIPTION:** 78" ID ACA AFTER REACTOR R-2210 **DRAWING NO.** 15515-03-1,2,3 REV. 01

**QC MANAGER APPROVED:** Rick McRobie **DATE:** 08/05/15

**DATE:**

**AI REVIEWED:** N.A **DATE:** 8-19-15

| OPERATION NUMBERS | DESCRIPTION<br>ITEMS BELOW HAVE TO FOLLOW IN NUMERICAL ORDER GIVEN.<br>A = ACTUAL R = REVIEW W = WITNESS H = HOLD | DATE AND SIGNATURE | | | |
|---|---|---|---|---|---|
| | | Weld Map | CIS INSPECTOR | Welder I.D. | AUTHORIZED INSPECTOR |
| | | | | | |
| | L2 | | | | |
| | W1 | 4 | 10-26-15 Rm | CI12 | |
| | W2 | 4 | 10-30-15 Rm | CI12 | 10-30-15 N.A |
| | Completed Nozzle | | 12-22-15 Rm | | |
| | | | | | |
| | L4 | | | | |
| | W1 | 9 | 10-26-15 Rm | CI12 | |
| | W2 | 9 | 10-30-15 Rm | CI12 | 10-30-15 N.A |
| | Completed Nozzle | | 12-22-15 Rm | | |
| | | | | | |
| | M1 | | | | |
| | W1 | 10A | 10-27-15 Rm | CI12 R+H CI3 F+C | |
| | W2 | 10A | 10-27-15 Rm | CI12 R+H CI3 F+C | |
| | W3 | 10A | 10-30-15 Rm | CI12 R+C CI3 F+C | 10-30-15 N.A |
| | W4 | 10A | 10-30-15 Rm | CI3 | |
| | W5 | 10A | 10-30-15 Rm | CI3 | |
| | W6 | 10B | 12-18-15 Rm | CI16 | |
| | W7 | 10B | 12-18-15 Rm | CI16 | |
| | W8 | 10B | 12-18-15 Rm | CI16 | |
| | W9 | 10B | 12-22-15 Rm | CI3 | |
| | W10 | 10B | 12-22-15 Rm | CI3 | |
| | W11 | 10B | 12-22-15 Rm | CI3 | |
| | Completed Manway | | 12-22-15 Rm | | |
| | | | | | |

CAROLINA INTEGRATED SOLUTIONS

**CUSTOMER:**

**Job#** 293-03 **DATE:** 8/5/2015

**DESCRIPTION:** 78" ID ACA AFTER REACTOR R-2210 **DRAWING NO.** 15515-03-1,2,3 REV. 01

**QC MANAGER APPROVED:** Rick McRobie **DATE:** 08/05/15

**DATE:**

**AI REVIEWED:** N.A **DATE:** 8-19-15

| OPERATION NUMBERS | DESCRIPTION<br>ITEMS BELOW HAVE TO FOLLOW IN NUMERICAL ORDER GIVEN.<br>A = ACTUAL R = REVIEW W = WITNESS H = HOLD | DATE AND SIGNATURE | | | |
|---|---|---|---|---|---|
| | | Weld Map | CIS INSPECTOR | Welder I.D. | AUTHORIZED INSPECTOR |
| | R1 | | | | |
| | W1 | 11 | 10-26-15 Rm | CI12 | |
| | W2 | 11 | 10-30-15 Rm | CI12 | 10-30-15 N.A |
| | Completed Nozzle | | 12-22-15 Rm | | |
| | | | | | |
| | S1 | | | | |
| | W1 | 12 | 10-26-15 Rm | CI12 | |
| | W2 | 12 | 10-30-15 Rm | CI12 | 10-30-15 N.A |
| | Completed Nozzle | | 12-22-15 Rm | | |
| | | | | | |
| | S2 | | | | |
| | W1 | 13 | 10-26-15 Rm | CI12 | |
| | W2 | 13 | 10-30-15 Rm | CI12 | 10-30-15 N.A |
| | W3 | 13 | 10-30-15 Rm | CI12 | |
| | W4 | 13 | 10-30-15 Rm | CI12 | |
| | Completed Nozzle | | 12-22-15 Rm | | |
| | | | | | |
| | T1 | | | | |
| | W1 | 14 | 11-13-15 Rm | CI1 | |
| | W2 | 14 | 12-14-15 Rm | CI16 | |
| | W3 | 14 | 12-14-15 Rm | CI16 | |
| | W4 | 14 | 12-14-15 Rm | CI16 | |
| | Completed Nozzle | | 12-22-15 Rm | | |
| | | | | | |
| | V1 | | | | |

CAROLINA INTEGRATED SOLUTIONS

**CUSTOMER:** _____ **Job#** 293-03 **DATE:** 8/5/2015

**DESCRIPTION:** 78" ID ACA AFTER REACTOR R-2210 **DRAWING NO.** 15515-03-1,2,3 REV. 01

**QC MANAGER APPROVED:** Rick McRobie **DATE:** 08/05/15

_____ **DATE:** _____

**AI REVIEWED:** N.A **DATE:** 8-19-15

| OPERATION NUMBERS | DESCRIPTION<br>ITEMS BELOW HAVE TO FOLLOW IN NUMERICAL ORDER GIVEN.<br>A = ACTUAL R = REVIEW W = WITNESS H = HOLD | DATE AND SIGNATURE | | | |
|---|---|---|---|---|---|
| | | Weld Map | CIS INSPECTOR | Welder I.D. | AUTHORIZED INSPECTOR |
| | **W1** | 15 | 10-26-15 Rm | CI12 | |
| | **W2** | 15 | 10-30-15 Rm | CI12 | 10-30-15 N.A |
| | **W3** | 15 | 11-17-15 Rm | CI12 | |
| | **W4** | 15 | 11-17-15 Rm | CI12 | |
| | **Completed Nozzle** | | 12-22-15 Rm | | |
| | | | | | |
| | **V2** | | | | |
| | **W1** | 16 | 10-26-15 Rm | CI12 | |
| | W2 | 16 | 10-30-15 Rm | CI12 | 10-30-15 N.A |
| | **W3** | 16 | 11-17-15 Rm | CI12 | |
| | **W4** | 16 | 11-17-15 Rm | CI12 | |
| | **Completed Nozzle** | | 12-22-15 Rm | | |
| | | | | | |
| | **Attachments** | | | | |
| | | | | | |
| | **Lifting Lug A** | | | | |
| | **W1** | 17 | 12-18-15 Rm | CI3 | |
| | **W2** | 17 | 12-18-15 Rm | CI3 | |
| | **W3** | 17 | 12-18-15 Rm | CI3 | |
| | **W4** | 17 | 12-18-15 Rm | CI3 | |
| | **Completed Weld** | | 12-22-15 Rm | | |
| | | | | | |
| | **Lifting Lug B** | | | | |
| | **W1** | 17 | 12-18-15 Rm | CI3 | |
| | **W2** | 17 | 12-18-15 Rm | CI3 | |

CAROLINA INTEGRATED SOLUTIONS

**CUSTOMER:** | **Job#** 293-03 | **DATE:** 8/5/2015

**DESCRIPTION:** 78" ID ACA AFTER REACTOR R-2210 | **DRAWING NO.** 15515-03-1,2,3 REV. 0 1

**QC MANAGER APPROVED:** Rick McRobie | **DATE:** 08/05/15

**DATE:**

**AI REVIEWED:** N.A | **DATE:** 8-19-15

| OPERATION NUMBERS | DESCRIPTION<br>ITEMS BELOW HAVE TO FOLLOW IN NUMERICAL ORDER GIVEN.<br>A = ACTUAL R = REVIEW W = WITNESS H = HOLD | DATE AND SIGNATURE | | | |
|---|---|---|---|---|---|
| | | Weld Map | CIS INSPECTOR | Welder I.D. | AUTHORIZED INSPECTOR |
| | W3 | 17 | 12-18-15 Rm | CI3 | |
| | W4 | 17 | 12-18-15 Rm | CI3 | |
| | Completed Weld | | 12-22-15 Rm | | |
| | | | | | |
| | Trailing Lug | | | | |
| | W1 | 18 | 12-18-15 Rm | CI3 | |
| | W2 | 18 | 12-18-15 Rm | CI3 | |
| | Completed Weld | | 12-22-15 Rm | | |
| | | | | | |
| | Dip Pipe Support Bracket A3 | | | | |
| | W1 | 19 | 12-16-15 Rm | CI16 | |
| | W2 | 19 | 12-16-15 Rm | CI16 | |
| | W3 | 19 | 12-16-15 Rm | CI16 | |
| | W4 | 19 | 12-16-15 Rm | CI16 | |
| | Completed Weld | | 12-22-15 Rm | | |
| | | | | | |
| | Dip Pipe Support Bracket A5 | | | | |
| | W1 | 19 | 12-16-15 Rm | CI16 | |
| | W2 | 19 | 12-16-15 Rm | CI16 | |
| | W3 | 19 | 12-16-15 Rm | CI16 | |
| | W4 | 19 | 12-16-15 Rm | CI16 | |
| | Completed Weld | | 12-22-15 Rm | | |
| | | | | | |
| | Dip Pipe Support Bracket A1 | | | | |

CAROLINA INTEGRATED SOLUTIONS

**CUSTOMER:**

**Job#** 293-03 **DATE:** 8/5/2015

**DESCRIPTION:** 78" ID ACA AFTER REACTOR R-2210 **DRAWING NO.** 15515-03-1,2,3 REV. 0*1

**QC MANAGER APPROVED:** Rick McRobie **DATE:** 08/05/15

**DATE:**

**AI REVIEWED:** N.A **DATE:** 8-15-15

| OPERATION NUMBERS | DESCRIPTION<br>ITEMS BELOW HAVE TO FOLLOW IN NUMERICAL ORDER GIVEN.<br>A = ACTUAL R = REVIEW W = WITNESS H = HOLD | DATE AND SIGNATURE | | | |
|---|---|---|---|---|---|
| | | Weld Map | CIS INSPECTOR | Welder I.D. | AUTHORIZED INSPECTOR |
| | W1 | 19 | 12-16-15 Rm | CI16 | |
| | W2 | 19 | 12-16-15 Rm | CI16 | |
| | W3 | 19 | 12-16-15 Rm | CI16 | |
| | W4 | 19 | 12-16-15 Rm | CI16 | |
| | Completed Weld | | 12-22-15 Rm | | |
| | | | | | |
| | Dip Pipe Support Bracket L1 | | | | |
| | W1 | 19 | 12-16-15 Rm | CI16 | |
| | W2 | 19 | 12-16-15 Rm | CI16 | |
| | W3 | 19 | 12-16-15 Rm | CI16 | |
| | W4 | 19 | 12-16-15 Rm | CI16 | |
| | Completed Weld | | 12-22-15 Rm | | |
| | | | | | |
| | Support Lug A | | | | |
| | W1 | 20 | 12-18-15 Rm | CI3 | |
| | W2 | 20 | 11-30-15 Rm | CI5 | |
| | W3 | 20 | 11-30-15 Rm | CI5 | |
| | W4 | 20 | 11-30-15 Rm | CI5 | |
| | W5 | 20 | 12-18-15 Rm | CI12 | |
| | W6 | 20 | 11-30-15 Rm | CI5 | |
| | Completed Weld | | 12-22-15 Rm | | |
| | | | | | |
| | Support Lug B | | | | |
| | W1 | 20 | 12-18-15 Rm | CI3 | |

CAROLINA INTEGRATED SOLUTIONS

**CUSTOMER:**

**Job#** 293-03 **DATE:** 8/5/2015

**DESCRIPTION:** 78" ID ACA AFTER REACTOR R-2210 **DRAWING NO.** 15515-03-1,2,3 REV. 8

**QC MANAGER APPROVED:** Rick McRobie **DATE:** 08/05/15

**DATE:**

**AI REVIEWED:** N.A **DATE:** 8-19-15

| OPERATION NUMBERS | DESCRIPTION<br>ITEMS BELOW HAVE TO FOLLOW IN NUMERICAL ORDER GIVEN.<br>A = ACTUAL R = REVIEW W = WITNESS H = HOLD | DATE AND SIGNATURE | | | |
|---|---|---|---|---|---|
| | | Weld Map | CIS INSPECTOR | Welder I.D. | AUTHORIZED INSPECTOR |
| | W2 | 20 | 11-30-15 Rm | CI5 | |
| | W3 | 20 | 11-30-15 Rm | CI5 | |
| | W4 | 20 | 11-30-15 Rm | CI5 | |
| | W5 | 20 | 12-18-15 Rm | CI12 | |
| | Completed Weld | | 12-22-15 Rm | | |
| | | | | | |
| | Support Lug C | | | | |
| | W1 | 20 | 12-18-15 Rm | CI3 | |
| | W2 | 20 | 11-30-15 Rm | CI5 | |
| | W3 | 20 | 11-30-15 Rm | CI5 | |
| | W4 | 20 | 11-30-15 Rm | CI5 | |
| | W5 | 20 | 12-18-15 Rm | CI12 | |
| | W6 | 20 | 11-30-15 Rm | CI5 | |
| | Completed Weld | | 12-22-15 Rm | | |
| | | | | | |
| | Support Lug D | | | | |
| | W1 | 20 | 12-18-15 Rm | CI3 | |
| | W2 | 20 | 11-30-15 Rm | CI5 | |
| | W3 | 20 | 11-30-15 Rm | CI5 | |
| | W4 | 20 | 11-30-15 Rm | CI5 | |
| | W5 | 20 | 12-18-15 Rm | CI12 | |
| | Completed Weld | | 12-22-15 Rm | | |
| | | | | | |
| | Top Ring W1 | | | | |

CAROLINA INTEGRATED SOLUTIONS

**CUSTOMER:**

**Job#** 293-03 **DATE:** 8/5/2015

**DESCRIPTION:** 78" ID ACA AFTER REACTOR R-2210 **DRAWING NO.** 15515-03-1,2,3 REV. 8 I

**QC MANAGER APPROVED:** Rick McRobie **DATE:** 08/05/15

**DATE:**

**AI REVIEWED:** N.A **DATE:** 8-19-15

| OPERATION NUMBERS | DESCRIPTION<br>ITEMS BELOW HAVE TO FOLLOW IN NUMERICAL ORDER GIVEN.<br>A = ACTUAL R = REVIEW W = WITNESS H = HOLD | DATE AND SIGNATURE | | | | |
|---|---|---|---|---|---|---|
| | | Weld Map | CIS INSPECTOR | Welder I.D. | AUTHORIZED INSPECTOR | |
| | 0-90 | 21 | 12-18-15 Rm | CI3 | | |
| | 90-180 | 21 | 12-18-15 Rm | CI3 | | |
| | 180-270 | 21 | 12-18-15 Rm | CI3 | | |
| | 270-0 | 21 | 12-18-15 Rm | CI3 | | |
| | Completed Weld | | 12-22-15 Rm | | | |
| | | | | | | |
| | Shell Clips 1-8 | | | | | |
| | W1 | 22 | 12-18-15 Rm | CI16 | | |
| | Completed Weld | | 12-22-15 Rm | | | |
| | | | | | | |
| | Head Clips 1-4 | | | | | |
| | W1 | 22 | 11-13-15 Rm | CI2 | | |
| | Completed Weld | | 12-22-15 Rm | | | |
| | | | | | | |
| | Stiffener Ring W1 | | | | | |
| | 0-90 | 1 | 12-18-15 Rm | CI3 | | |
| | 90-180 | 1 | 12-18-15 Rm | CI3 | | |
| | 180-270 | 1 | 12-18-15 Rm | CI3 | | |
| | 270-0 | 1 | 12-18-15 Rm | CI3 | | |
| | | | | | | |
| | FINAL INTERNAL INSPECTION | | 12-22-15 Rm | | 12-22-15 | H |
| | FINAL EXTERNAL INSPECTION | | 12-22-15 Rm | | 12-22-15 | H |
| | REVIEW RT FILM | | 12-28-15 Rm | | N.A 12-28-15 | H |
| | REVIEW NAMEPLATE / ATTACHMENT | | 12-28-15 Rm | | N.A 12-28-15 | H |
| | HYDRO AT 60 PSIG | | HYDRO COMP 12-22-15 Rm | | N.A 12-22-15 | H |

CAROLINA INTEGRATED SOLUTIONS

**CUSTOMER:**

**Job#** 293-03 **DATE:** 8/5/2015

**DESCRIPTION:** 78" ID ACA AFTER REACTOR R-2210 **DRAWING NO.** 15515-03-1,2,3 REV. 01

**QC MANAGER APPROVED:** Rick McRobie **DATE:** 08/05/15

**DATE:**

**AI REVIEWED:** N.A **DATE:** 8-19-15

| OPERATION NUMBERS | DESCRIPTION<br>ITEMS BELOW HAVE TO FOLLOW IN NUMERICAL ORDER GIVEN.<br>A = ACTUAL R = REVIEW W = WITNESS H = HOLD | DATE AND SIGNATURE | | | |
|---|---|---|---|---|---|
| | | Weld Map | CIS INSPECTOR | Welder I.D. | AUTHORIZED INSPECTOR |
| | REVIEW AND SIGN DATA REPORT | | 12-28-15 RM | | NA 12-28-15 H |
| | | | | | |
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CAROLINA
INTEGRATED SOLUTIONS

# CERTIFICATION OF DYE-PENETRANT TEST INSPECTION

IAF JOB NO 293-03 CUSTOMER Evonik

CUSTOMER REFERENCE PO. IAF DRAWING NO.

PROCEDURE NO. 124, REV. 3 METHOD: VISIBLE

ACCEPTANCE CRITERIA: SECTION V, ARTICLE 6 & SECTION VIII, DIV. 1, APPENDIX 8

MATERIALS: MAGNAFLUX SPOTCHEK SKL-SPI BATCH # 15G01K

MAGNAFLUX SPOTCHECK SKC-S BATCH # 15F15K

MAGNAFLUX SPOTCHECK SKD-S2 BATCH # 15F11K

LIGHTING: MINIMUM 100 fc

TYPE AND LOCATION OF WELD

| ROOT | BACKCHIP | COVER | FILLET | MATL | THKNESS | ACCEPT REJECT | WELD LOCATION |
|---|---|---|---|---|---|---|---|
| X | | | X | 316 ss | Sch 40 | ACC | A6 1-1/2" W2 |
| X | | | X | 316 ss | Sch 40 | ACC | V1 1-1/2" W2 |
| X | | | X | 316 ss | Sch 40 | ACC | S1 2" W2 |
| X | | | X | 316 ss | Sch 40 | ACC | R1 4" W2 |
| X | | | X | 316 ss | Sch 40 | ACC | A2 2" W2 |
| X | | | X | 316 ss | Sch 40 | ACC | L2 4" W2 |
| X | | | X | 316 ss | Sch 40 | ACC | A4 1-1/2" W2 |
| X | | | X | 316 ss | Sch 40 | ACC | V2 1" W2 |
| X | | | X | 316 ss | Sch 40 | ACC | L4 3" W2 |
| X | | | X | 316 ss | Sch 40 | ACC | S2 3" W2 |
| X | | | X | 316 ss | 3/8" PL | ACC | M1 24" W3 |

I HAVE WITNESSED THIS TEST AND CERTIFY THAT THE WELDS ARE FREE OF ANY SURFACE DEFECTS

Ricky McRobie — INSPECTOR

Level II — QUALIFICATION LEVEL

Ricky McRobie

QUALITY CONTROL MANAGER

CUSTOMER REPRESENTATIVE

DATE 11-10-15

DATE

CAROLINA
INTEGRATED SOLUTIONS

# CERTIFICATION OF DYE-PENETRANT TEST INSPECTION

IAF JOB NO 293-03 CUSTOMER Evonik

CUSTOMER REFERENCE PO. IAF DRAWING NO.

PROCEDURE NO. 124, REV. 3 METHOD: VISIBLE

ACCEPTANCE CRITERIA: SECTION V, ARTICLE 6 & SECTION VIII, DIV. 1, APPENDIX 8

MATERIALS: MAGNAFLUX SPOTCHEK SKL-SPI BATCH # 15G01K

MAGNAFLUX SPOTCHECK SKC-S BATCH # 15F15K

MAGNAFLUX SPOTCHECK SKD-S2 BATCH # 15F11K

LIGHTING: MINIMUM 100 fc

TYPE AND LOCATION OF WELD

| ROOT | BACKCHIP | COVER | FILLET | MATL | THKNESS | ACCEPT REJECT | WELD LOCATION |
|---|---|---|---|---|---|---|---|
| | | | X | 316 ss | 3/16 PL | ACC | A4 1-1/2 W3 W4 |
| | | | X | 316 ss | 3/16 PL | ACC | A6 1-1/2 W3 W4 |
| | | | X | 316 ss | 3/16 PL | ACC | V1 1-1/2 W3 W4 |
| | | | X | 316 ss | 3/16 PL | ACC | V2 1" W3 W4 |
| | | | X | 316 ss | 5/16 PL | ACC | M1 24" W4 W5 |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

I HAVE WITNESSED THIS TEST AND CERTIFY THAT THE WELDS ARE FREE OF ANY SURFACE DEFECTS

Ricky McRobie
INSPECTOR

Level II
QUALIFICATION LEVEL

Ricky McRobie
QUALITY CONTROL MANAGER

CUSTOMER REPRESENTATIVE

DATE 11-18-15

DATE

CAROLINA
INTEGRATED SOLUTIONS

# CERTIFICATION OF DYE-PENETRANT TEST INSPECTION

IAF JOB NO 293-03 CUSTOMER Evonik

CUSTOMER REFERENCE PO. _____ IAF DRAWING NO. _____

PROCEDURE NO. 124, REV. 3 METHOD: VISIBLE

ACCEPTANCE CRITERIA: SECTION V, ARTICLE 6 & SECTION VIII, DIV. 1, APPENDIX 8

MATERIALS: MAGNAFLUX SPOTCHEK SKL-SPI BATCH # 15G01K

MAGNAFLUX SPOTCHECK SKC-S BATCH # 15F15K

MAGNAFLUX SPOTCHECK SKD-S2 BATCH # 15F11K

LIGHTING: MINIMUM 100 fc

TYPE AND LOCATION OF WELD

| ROOT | BACKCHIP | COVER | FILLET | MATL | THKNESS | ACCEPT REJECT | WELD LOCATION |
|---|---|---|---|---|---|---|---|
| X | | | X | 316 ss | Sch 40 | ACC | B1 4" W2 |
| | | | X | 316 ss | 5/16 PL | ACC | B1 4" W3 |
| | | | X | 316 ss | 5/16 PL | ACC | B1 4" W4 |
| | | | X | 316 ss | 3/16 PL | ACC | B1 4" W5 |
| | | | X | 316 ss | 3/16 PL | ACC | B1 4" W6 |
| | | | X | 316 ss | 3/16 PL | ACC | B1 4" W7 |
| | | | | | | | |
| | | | | | | | |
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| | | | | | | | |

I HAVE WITNESSED THIS TEST AND CERTIFY THAT THE WELDS ARE FREE OF ANY SURFACE DEFECTS

Ricky McRobie
INSPECTOR

Level II
QUALIFICATION LEVEL

Ricky McRobie
QUALITY CONTROL MANAGER

CUSTOMER REPRESENTATIVE

DATE 11-10-15

DATE _____

CAROLINA
INTEGRATED SOLUTIONS

# CERTIFICATION OF DYE-PENETRANT TEST INSPECTION

IAF JOB NO 293-03 CUSTOMER Evonik

CUSTOMER REFERENCE PO. _____ IAF DRAWING NO. _____

PROCEDURE NO. 124, REV. 3 METHOD: VISIBLE

ACCEPTANCE CRITERIA: SECTION V, ARTICLE 6 & SECTION VIII, DIV. 1, APPENDIX 8

MATERIALS: MAGNAFLUX SPOTCHEK SKL-SPI BATCH # 15G01K

MAGNAFLUX SPOTCHECK SKC-S BATCH # 15F15K

MAGNAFLUX SPOTCHECK SKD-S2 BATCH # 15F11K

LIGHTING: MINIMUM 100 fc

TYPE AND LOCATION OF WELD

| ROOT | BACKCHIP | COVER | FILLET | MATL | THKNESS | ACCEPT REJECT | WELD LOCATION |
|---|---|---|---|---|---|---|---|
| | X | | | 316 ss | 5/16 ss | ACC | GS1 |
| | X | | | 316 ss | 5/16 ss | ACC | LS1 |
| | X | | | 316 ss | 5/16 ss | ACC | GS2 |
| | X | | | 316 ss | 5/16 ss | ACC | LS2 |
| | X | | | 316 ss | 5/16 ss | ACC | GS3 |
| | | | | | | | |
| | | | | | | | |
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| | | | | | | | |
| | | | | | | | |

I HAVE WITNESSED THIS TEST AND CERTIFY THAT THE WELDS ARE FREE OF ANY SURFACE DEFECTS

Ricky McRoberts
INSPECTOR

Level II
QUALIFICATION LEVEL

Ricky McRoberts
QUALITY CONTROL MANAGER

CUSTOMER REPRESENTATIVE

DATE 12-7-15

DATE _____

CAROLINA
INTEGRATED SOLUTIONS

# CERTIFICATION OF DYE-PENETRANT TEST INSPECTION

IAF JOB NO 293-03 CUSTOMER Evonik

CUSTOMER REFERENCE PO. IAF DRAWING NO.

PROCEDURE NO. 124, REV. 3 METHOD: VISIBLE

ACCEPTANCE CRITERIA: SECTION V, ARTICLE 6 & SECTION VIII, DIV. 1, APPENDIX 8

MATERIALS: MAGNAFLUX SPOTCHEK SKL-SPI BATCH # 15G01K

MAGNAFLUX SPOTCHECK SKC-S BATCH # 15F15K

MAGNAFLUX SPOTCHECK SKD-S2 BATCH # 15F11K

LIGHTING: MINIMUM 100 fc

TYPE AND LOCATION OF WELD

| ROOT | BACKCHIP | COVER | FILLET | MATL | THKNESS | ACCEPT REJECT | WELD LOCATION |
|---|---|---|---|---|---|---|---|
| | | | X | 316 ss | sch 40 | ACC | A1 1-1/2" W2,3 |
| | | | X | 316 ss | sch 40 | ACC | A3 1" W2,3 |
| | | | X | 316 ss | sch 40 | ACC | A5 1" W2,3 |
| X | | | X | 316 ss | sch 40 | ACC | A7 3" W2,3,4 |
| X | | | X | 316 ss | sch 40 | ACC | B1 4" W5,6,7 |
| | | | X | 316 ss | 3/8 ss | ACC | M1w6,7,8,9,10,11 |
| X | | | X | 316 ss | sch 40 | ACC | T1 1-1/2" W2,3,4 |
| | | | X | 316 ss | 5/8 ss | ACC | Lug A W1,2,3,4 |
| | | | X | 316 ss | 5/8 ss | ACC | Lug B W1,2,3,4 |
| | | | X | 316 ss | 5/8 ss | ACC | T Lug W1,2 |
| | | | X | 316 ss | 1/4 ss | ACC | dpsb A3 w1,2,3,4 |

I HAVE WITNESSED THIS TEST AND CERTIFY THAT THE WELDS ARE FREE OF ANY SURFACE DEFECTS

Ricky mc Rolin
INSPECTOR

Level II
QUALIFICATION LEVEL

Ricky mc Rolin
QUALITY CONTROL MANAGER

CUSTOMER REPRESENTATIVE

DATE 12-18-15

DATE

CAROLINA
INTEGRATED SOLUTIONS

# CERTIFICATION OF DYE-PENETRANT TEST INSPECTION

IAF JOB NO 293-03 CUSTOMER Evonik

CUSTOMER REFERENCE PO. IAF DRAWING NO.

PROCEDURE NO. 124, REV. 3 METHOD: VISIBLE

ACCEPTANCE CRITERIA: SECTION V, ARTICLE 6 & SECTION VIII, DIV. 1, APPENDIX 8

MATERIALS: MAGNAFLUX SPOTCHEK SKL-SPI BATCH # 15G01K

MAGNAFLUX SPOTCHECK SKC-S BATCH # 15F15K

MAGNAFLUX SPOTCHECK SKD-S2 BATCH # 15F11K

LIGHTING: MINIMUM 100 fc

TYPE AND LOCATION OF WELD

| ROOT | BACKCHIP | COVER | FILLET | MATL | THKNESS | ACCEPT REJECT | WELD LOCATION |
|---|---|---|---|---|---|---|---|
| | | | X | 316 ss | 1/4 ss | ACC | dpsb A5 w1,2,3,4 |
| | | | X | 316 ss | 1/4 ss | ACC | dpsb A1 w1,2,3,4 |
| | | | X | 316 ss | 1/4 ss | ACC | dpsb L1 w1,2,3,4 |
| | | | X | 316 ss | 1/2 ss | ACC | SLA w1,2,3,4,5,6 |
| | | | X | 316 ss | 1/2 ss | ACC | SLB w1,2,3,4,5 |
| | | | X | 316 ss | 1/2 ss | ACC | SLC w1,2,3,4,5,6 |
| | | | X | 316 ss | 1/2 ss | ACC | SLD w1,2,3,4,5 |
| | | | X | 316 ss | 3/16 ss | ACC | Tring W1 0-360 |
| | | | X | 316 ss | 3/16 ss | ACC | SClips 1-8 W1 |
| | | | X | 316 ss | 3/16 ss | ACC | HClips 1-4 W1 |
| | | | X | 316 ss | 3/8 ss | ACC | Sring W1 0-360 |

I HAVE WITNESSED THIS TEST AND CERTIFY THAT THE WELDS ARE FREE OF ANY SURFACE DEFECTS

Ricky McRobie
INSPECTOR

Level II
QUALIFICATION LEVEL

Ricky McRobie
QUALITY CONTROL MANAGER

CUSTOMER REPRESENTATIVE

DATE 12-18-15

DATE

CAROLINA
INTEGRATED SOLUTIONS

157 Derrick Road - Spartanburg, SC 29303 - 864-308-8281

# HYDROSTATIC/PRESSURE TEST DATA

SOP 1.9 FORM 101 HDQC PAGE 1 of 1

| CONTRACT NO. | DIV. | PURCHASER | LOCATION | TYPE VESSEL |
|---|---|---|---|---|
| 293 | 3 | EVONIK | SPARTANBURG | PRESSURE LS |

| TYPE TEST | TEST CONDUCTED BY | LEVEL CERT. |
|---|---|---|
| WATER | RICKY MCROBIE | 2 |

| DESIGN PRESSURE | DESIGN VACUUM | TIME PERIOD TEST WAS HELD |
|---|---|---|
| 45 PSIG | TEST VACUUM | 1 HRS __ MINUTES |
| TEST PRESSURE 60 PSIG | | |

| HEIGHT OF WATER LEVEL | TYPE OF LEAK CHECKING PERFORMED |
|---|---|
| FULL | VISUAL |

| GAUGE NO. | GAUGE CALIBRATION DATE | GAUGE MANUFACTURER | GAUGE RANGE |
|---|---|---|---|
| CIS-1 | 12/22/2015 | dynamic fluid comp | 0-300 |

| EXAMINATION TIME | MATERIAL TYPE | TEMPERATURE | TEMPERATURE GAUGE NO. |
|---|---|---|---|
| AM | 316L | SELECT GRADE | |

DESCRIBE ANY REPAIRS MADE NONE

COMMENTS

AS A DULY AUTHORIZED REPRESENTATIVE OF CAROLINA INTEGRATED SOLUTIONS, I HEREBY CERTIFY THAT THE ABOVE TANK AND/OR VESSEL HAS BEEN TESTED IN ACCORDANCE WITH CIS PROCEDURE 1.9, AND APPLICABLE CODE REQUIREMENTS. THIS CERTIFICATION DOES NOT RELIEVE CIS OF ANY WARRANTIES EXPRESSED IN THE CONTRACT.

| CIS REPRESENTATIVE | DATE | DISPOSITION |
|---|---|---|
| Ricky McRobie | 12/22/2015 | ACCEPTED |
| CUSTOMER REPRESENTATIVE | DATE | DISPOSITION |
| Larry Teale | 12/22/2015 | ACCEPTED |
| AUTHORIZED INSPECTOR | DATE | DISPOSITION |
| | 12/22/2015 | ACCEPTED |

CAROLINA
INTEGRATED SOLUTIONS

157 Derrick Road - Spartanburg, SC 29303 - 864-308-8281

# VISUAL INSPECTION REPORT



| REPORT NO. | CONTRACT | DIV. | REFERENCE | DRAWING REV. | PIECE MARK NO. |
|---|---|---|---|---|---|
| 1 | 293 | 3 | 15515-03-1 | 1 | 293-03 |

| MAT'L TYPE | MAT'L THICKNESS | PROCEDURE NO. | EQUIPMENT FOR WHITE LIGHT |
|---|---|---|---|
| 316L | 5/16", SCH40 | S.O.P. 2.1 | FLASH LIGHT (LED) |

| SURFACE CONDITION | JOINT TYPE | STAGE OF MFG. |
|---|---|---|
| AS WELDED | BUTT | FINAL |

| EXAMINATION TIME | DURATION EXAMINATION TIME |
|---|---|
| AM | 1 HRS. MINUTES |

| DESCRIPTION/IDENTIFICATION | STATUS (ACCEPTED\REJECTED) | INSPECTED BY |
|---|---|---|
| GS1 | ACCEPTED | RM |
| LS1 | ACCEPTED | RM |
| GS2 | ACCEPTED | RM |
| LS2 | ACCEPTED | RM |
| GS3 | ACCEPTED | RM |
| NOZZLE A1 | ACCEPTED | RM |
| NOZZLE A2 | ACCEPTED | RM |
| NOZZLE A3 | ACCEPTED | RM |
| NOZZLE A4 | ACCEPTED | RM |
| NOZZLE A5 | ACCEPTED | RM |

REFERENCE SKETCH (or PHOTOGRAPH) – ***IF REQUIRED***

| CERTIFIED BY | DATE | CERT. LEVEL | DISPOSITION |
|---|---|---|---|
| RICK MCROBIE | 12/22/2015 | 2 | ACCEPTED |

| CUSTOMER REP. | DATE | CODE INSPECTOR REVIEW | DATE |
|---|---|---|---|
| LARRY TEAL | 12/22/2015 | NICK AMADOR | 12/22/2015 |

CAROLINA
INTEGRATED SOLUTIONS
157 Derrick Road - Spartanburg, SC 29303 - 864-308-8281

# VISUAL INSPECTION REPORT



| REPORT NO. | CONTRACT | DIV. | REFERENCE | DRAWING REV. | PIECE MARK NO. |
|---|---|---|---|---|---|
| 2 | 293 | 3 | 15515-03-1 | 1 | 293-03 |

| MAT'L TYPE | MAT'L THICKNESS | PROCEDURE NO. | EQUIPMENT FOR WHITE LIGHT |
|---|---|---|---|
| 316L | 5/16", SCH40 | S.O.P. 2.1 | FLASH LIGHT (LED) |

| SURFACE CONDITION | JOINT TYPE | STAGE OF MFG. |
|---|---|---|
| AS WELDED | BUTT | FINAL |

| EXAMINATION TIME | DURATION EXAMINATION TIME |
|---|---|
| AM | 1 HRS. MINUTES |

| DESCRIPTION/IDENTIFICATION | STATUS (ACCEPTED\REJECTED) | INSPECTED BY |
|---|---|---|
| NOZZLE A6 | ACCEPTED | RM |
| NOZZLE A7 | ACCEPTED | RM |
| NOZZLE B1 | ACCEPTED | RM |
| NOZZLE G1 | ACCEPTED | RM |
| NOZZLE L1 | ACCEPTED | RM |
| NOZZLE L2 | ACCEPTED | RM |
| NOZZLE L4 | ACCEPTED | RM |
| NOZZLE M1 | ACCEPTED | RM |
| NOZZLE R1 | ACCEPTED | RM |
| NOZZLE S1 | ACCEPTED | RM |

REFERENCE SKETCH (or PHOTOGRAPH) – *IF REQUIRED*

| CERTIFIED BY | DATE | CERT. LEVEL | DISPOSITION |
|---|---|---|---|
| RICK MCROBIE | 12/22/2015 | 2 | ACCEPTED |

| CUSTOMER REP. | DATE | CODE INSPECTOR REVIEW | DATE |
|---|---|---|---|
| LARRY TEAL | 12/22/2015 | NICK AMADOR | 12/22/2015 |

CAROLINA
INTEGRATED SOLUTIONS
157 Derrick Road - Spartanburg, SC 29303 - 864-308-8281

# VISUAL INSPECTION REPORT



| REPORT NO. | CONTRACT | DIV. | REFERENCE | DRAWING REV. | PIECE MARK NO. |
|---|---|---|---|---|---|
| 3 | 293 | 3 | 15515-03-1 | 1 | 293-03 |

| MAT'L TYPE | MAT'L THICKNESS | PROCEDURE NO. | EQUIPMENT FOR WHITE LIGHT |
|---|---|---|---|
| 316L | 5/16", SCH40 | S.O.P. 2.1 | FLASH LIGHT (LED) |

| SURFACE CONDITION | JOINT TYPE | STAGE OF MFG. |
|---|---|---|
| AS WELDED | BUTT | FINAL |

| EXAMINATION TIME | DURATION EXAMINATION TIME |
|---|---|
| AM | 1 HRS. MINUTES |

| DESCRIPTION/IDENTIFICATION | STATUS (ACCEPTED\REJECTED) | INSPECTED BY |
|---|---|---|
| NOZZLE S2 | ACCEPTED | RM |
| NOZZLE T1 | ACCEPTED | RM |
| NOZZLE V1 | ACCEPTED | RM |
| NOZZLE V2 | ACCEPTED | RM |
| LIFTING LUG A | ACCEPTED | RM |
| LIFTING LUG B | ACCEPTED | RM |
| TAILING LUG | ACCEPTED | RM |
| DIP PIPE SUPPORT BRACKET A3 | ACCEPTED | RM |
| DIP PIPE SUPPORT BRACKET A5 | ACCEPTED | RM |
| DIP PIPE SUPPORT BRACKET A1 | ACCEPTED | RM |

REFERENCE SKETCH (or PHOTOGRAPH) – *IF REQUIRED*

| CERTIFIED BY | DATE | CERT. LEVEL | DISPOSITION |
|---|---|---|---|
| RICK MCROBIE | 12/22/2015 | 2 | ACCEPTED |

| CUSTOMER REP. | DATE | CODE INSPECTOR REVIEW | DATE |
|---|---|---|---|
| LARRY TEAL | 12/22/2015 | NICK AMADOR | 12/22/2015 |

CAROLINA
INTEGRATED SOLUTIONS

157 Derrick Road - Spartanburg, SC 29303 - 864-308-8281

# VISUAL INSPECTION REPORT



| REPORT NO. | CONTRACT | DIV. | REFERENCE | DRAWING REV. | PIECE MARK NO. |
|---|---|---|---|---|---|
| 4 | 293 | 3 | 15515-03-1 | 1 | 293-03 |

| MAT'L TYPE | MAT'L THICKNESS | PROCEDURE NO. | EQUIPMENT FOR WHITE LIGHT |
|---|---|---|---|
| 316L | 5/16", SCH40 | S.O.P. 2.1 | FLASH LIGHT (LED) |

| SURFACE CONDITION | JOINT TYPE | STAGE OF MFG. |
|---|---|---|
| AS WELDED | BUTT | FINAL |

| EXAMINATION TIME | DURATION EXAMINATION TIME |
|---|---|
| AM | 1 HRS. MINUTES |

| DESCRIPTION/IDENTIFICATION | STATUS (ACCEPTED\REJECTED) | INSPECTED BY |
|---|---|---|
| DIP PIPE SUPPORT BRACKET L1 | ACCEPTED | RM |
| SUPPORT LUG A | ACCEPTED | RM |
| SUPPORT LUG B | ACCEPTED | RM |
| SUPPORT LUG C | ACCEPTED | RM |
| SUPPORT LUG D | ACCEPTED | RM |
| TOP RING | ACCEPTED | RM |
| SHELL CLIPS | ACCEPTED | RM |
| HEAD CLIPS | ACCEPTED | RM |
| STIFFENER RING | ACCEPTED | RM |
| | SELECT OPTION | |

REFERENCE SKETCH (or PHOTOGRAPH) – *IF REQUIRED*

| CERTIFIED BY | DATE | CERT. LEVEL | DISPOSITION |
|---|---|---|---|
| RICK MCROBIE | 12/22/2015 | 2 | ACCEPTED |

| CUSTOMER REP. | DATE | CODE INSPECTOR REVIEW | DATE |
|---|---|---|---|
| LARRY TEAL | 12/22/2015 | NICK AMADOR | 12/22/2015 |

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# RADIOGRAPHIC INSPECTION REPORT

Job # P243513 PO # 293-2782 WO # N/A Date: 10/29/2015 Page 1 of 1

CLIENT: **CAROLINA INTERGRATED SOLUTIONS**
LOCATION: **100 B Southwest Dr.**
**Spartanburg, South Carolina 29303**

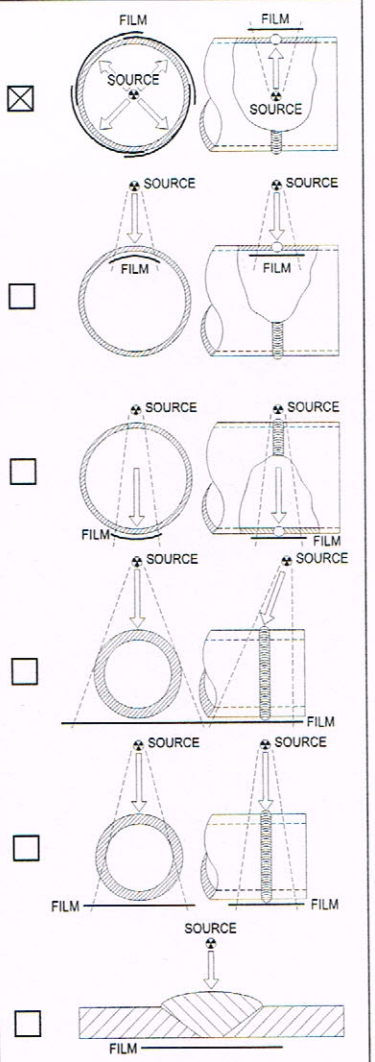
PART NO.: TANK 293-03
PART NAME: TANK #3 MANWAY
MATERIAL: STAINLESS STEEL
THICKNESS: .437"
TYPE WELD: Butt

## RADIOGRAPHIC INSPECTION TECHNIQUE

Specification(s): ATS 120.1 REV 25 IAW ASME SECTION VIII

| | | | |
|---|---|---|---|
| Isotope | Ir192 | Film Size | 4.5" X 17" |
| Curies | 44.1 | Film Type | Fuji 50 |
| KV | N/A | Sensitivity | #7 WIRE .013" |
| MA | N/A | Penetrameter | 1 ASTM B |
| Time | 110 SECONDS | Shim(s) | N/A |
| SFD | 11.9 INCHES | Develop: Temp: | Auto Time: Auto |
| SOD | 11.5 INCHES | Screen(s) | .002 PB F&B |
| OFD | .437 INCHES | Source Size (Effective) | .127" |
| Source Size (Physical) | .1"x.1" | Films Per Cassette | 1 |
| Geometric Unsharpness | .004" | Weld Reinforcement | +/- .060" |

## SETUP




☒ ☐ ☐ ☐ ☐ ☐ ☐ SEE ATTACHED SKETCH

## INTERPRETATION

| PART I.D./ FILM VIEW | Accept | Reject | Crack | Slag Inclusion | Tungsten Inclusion | Porosity | Undercut | Incomplete Fusion | Incomplete | Root Concavity | Root Convexity | DENSITY Penetrameter | DENSITY Area of Interest | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Horizontal Seam | | | | | | | | | | | | | | |
| 0-1 | ✔ | | | | / | / | / | | | | | 3.0 | 2.9 | |
| 1-2 | ✔ | | | | | | | | | | | 3.0 | 3.1 | |
| 2-3 | ✔ | | | | / | / | / | | | | | 2.8 | 2.8 | |
| 3-4 | ✔ | | | | | / | | | | | | 2.8 | 2.9 | |
| 4-0 | ✔ | | | | / | / | / | | | | | 3.0 | 2.9 | Artifacts |
| | | | | | | | | | | | | | | |
| Vertical Seam | | | | | | | | | | | | | | |
| 0-1 | ✔ | | | | / | / | | | | | | 3.0 | 2.7 | (V1) |

RADIOGRAPHER(S): Jerry L Dillard for Brett Powell Level II R.T.

INTERPRETER: Jerry L. Dillard Jerry L Dillard for Brett Powell Level II R.T.

CLIENT APPROVAL: Ricky McBride Lab work

APPLIED TECHNICAL SERVICES, INCORPORATED

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# RADIOGRAPHIC INSPECTION REPORT

Job # P245625 PO # 293-2828 WO # N/A Date: 12/12/2015 Page 1 of 1

CLIENT: **CAROLINA INTERGRATED SOLUTIONS**
LOCATION: **157 DERRICK RD**
**SPARTANBURG, SC. 29303**

PART NO.: TANK 293-03
PART NAME: SEE BELOW
MATERIAL: STAINLESS STEEL
THICKNESS: .312" ROLLED STEEL
TYPE WELD: SAW

## RADIOGRAPHIC INSPECTION TECHNIQUE

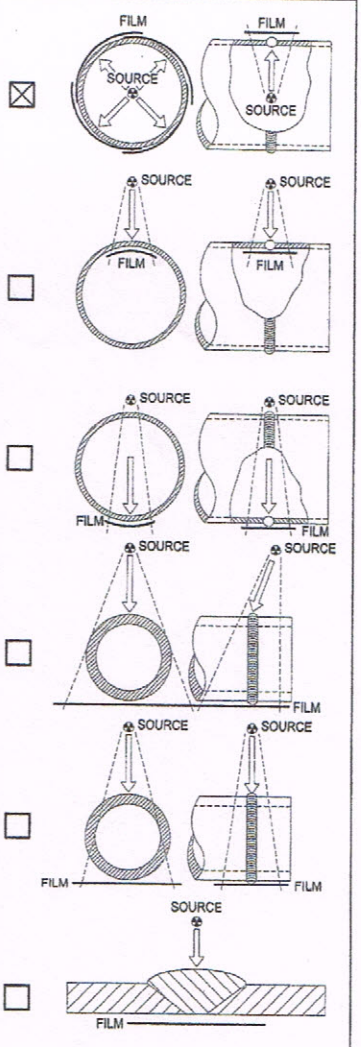
Specification(s): ATS 120.1 REV 25 IAW ASME SECTION VIII

| | | | |
|---|---|---|---|
| Isotope | IR 192 D1240 | Film Size | 4.5" X 17" |
| Curies | 94 | Film Type | Fuji 80 |
| KV | N/A | Sensitivity | #6 WIRE .0100" |
| MA | N/A | Penetrameter | 1 ASTM B |
| Time | 320 SECONDS | Shim(s) | N/A |
| SFD | 39.1 INCHES | Develop: Temp: | 70° F Time: 4.5 MIN |
| SOD | 39 INCHES | Screen(s) | .002 PB F&B |
| OFD | .312 INCHES | Source Size (Effective) | .143 |
| Source Size (Physical) | .1"x.1" | Films Per Cassette | 1 |
| Geometric Unsharpness | .001" | Weld Reinforcement | .090" |

## INTERPRETATION

| PART I.D./ FILM VIEW | Accept | Reject | Crack | Slag Inclusion | Tungsten Inclusion | Porosity | Undercut | Incomplete Fusion | Incomplete | Root Concavity | Root Convexity | DENSITY Penetrameter | DENSITY Area of Interest | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W GS1 | | | | | | | | | | | | | | WELDER ID CI3 |
| 0 TO 1 | ✓ | | | | | | | | | | | 3.2 | 3.2 | |
| 1 TO 2 | ✓ | | | | | | | | | | | 3.2 | 3.2 | |
| 2 TO 3 | ✓ | | | | | | | | | | | 3.3 | 3.3 | |
| 3 TO 4 | ✓ | | | | | | / | | | | | 3.3 | 3.3 | |
| 4 TO 5 | ✓ | | | | | | / | | | | | 3.3 | 3.3 | |
| 5 TO 6 | ✓ | | | | | | | | | | | 3.3 | 3.3 | |
| 6 TO 7 | ✓ | | | / | | | | | | | | 3.2 | 3.2 | |
| 7 TO 8 | ✓ | | | | | | | | | | | 3.2 | 3.2 | |
| 8 TO 9 | ✓ | | | | | | | | | | | 3.3 | 3.3 | |
| 9 TO 10 | ✓ | | | | | | | | | | | 3.3 | 3.3 | |
| 10 TO 11 | ✓ | | | | | | | | | | | 3.3 | 3.3 | |
| 11 TO 12 | ✓ | | | | | | | | | | | 3.3 | 3.3 | |
| 12 TO 13 | ✓ | | | | | | | | | | | 3.3 | 3.3 | |
| 13 TO 14 | ✓ | | | | | | | | | | | 3.3 | 3.3 | |
| 14 TO 15 | ✓ | | | | | | | | | | | 3.3 | 3.3 | |
| 15 TO 16 | ✓ | | | | | | | | | | | 3.3 | 3.3 | CRIMP |
| 16 TO 17 | ✓ | | | | | | | | | | | 3.8 | 3.8 | |
| 17 TO 18 | ✓ | | | | | | / | | | | | 3.5 | 3.5 | |
| 18 TO 19 | ✓ | | | | | | / | | | | | 3.6 | 3.6 | |
| 19 TO 20 | ✓ | | | | | | | | | | | 3.3 | 3.3 | |
| 20 TO 0 | ✓ | | | | | | | | | | | 3.3 | 3.3 | |

## SETUP




☐ SEE ATTACHED SKETCH

RADIOGRAPHER(S): Jerry L Dillard Level II R.T.

INTERPRETER: Jerry L Dillard Level II R.T.

CLIENT APPROVAL: Ricky McBride

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# RADIOGRAPHIC INSPECTION REPORT

Job # P245625 PO # 293-2828 WO # N/A Date: 12/12/2015 Page 1 of 1

CLIENT: **CAROLINA INTERGRATED SOLUTIONS**
LOCATION: **157 DERRICK RD**
**SPARTANBURG, SC. 29303**

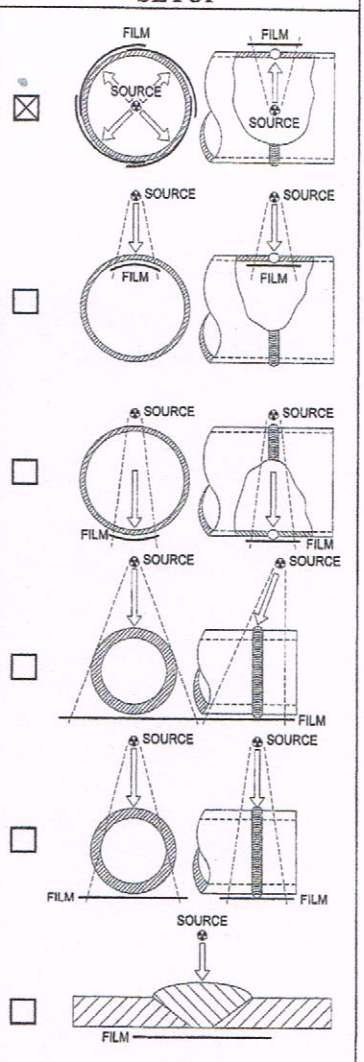
PART NO.: TANK 293-03
PART NAME: SEE BELOW
MATERIAL: STAINLESS STEEL
THICKNESS: .312" ROLLED STEEL
TYPE WELD: SAW

## RADIOGRAPHIC INSPECTION TECHNIQUE

Specification(s): ATS 120.1 REV 25 IAW ASME SECTION VIII

| | | | |
|---|---|---|---|
| Isotope | IR 192 D1240 | Film Size | 4.5" X 17" |
| Curies | 94 | Film Type | Fuji 80 |
| KV | N/A | Sensitivity | #6 WIRE .0100" |
| MA | N/A | Penetrameter | 1 ASTM B |
| Time | 320 SECONDS | Shim(s) | N/A |
| SFD | 39.1 INCHES | Develop: Temp: | 70° F Time: 4.5 MIN |
| SOD | 39 INCHES | Screen(s) | .002 PB F&B |
| OFD | .312 INCHES | Source Size (Effective) | .143 |
| Source Size (Physical) | .1"x.1" | Films Per Cassette | 1 |
| Geometric Unsharpness | .001" | Weld Reinforcement | .090" |

## SETUP




☒ ☐ ☐ ☐ ☐ ☐ ☐ SEE ATTACHED SKETCH

## INTERPRETATION

| PART I.D./ FILM VIEW | Accept | Reject | Crack | Slag Inclusion | Tungsten Inclusion | Porosity | Undercut | Incomplete Fusion | Incomplete | Root Concavity | Root Convexity | DENSITY Penetrameter | DENSITY Area of Interest | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W GS2 | | | | | | | | | | | | | | WELDER ID CI3 |
| 0 TO 1 | ✓ | | | | | | | | | | | 2.7 | 2.7 | |
| 1 TO 2 | ✓ | | | | | | | | | | | 2.8 | 2.8 | CRIMP |
| 2 TO 3 | ✓ | | | | | | | | | | | 2.6 | 2.6 | |
| 3 TO 4 | ✓ | | | | | | | | | | | 2.8 | 2.8 | |
| 4 TO 5 | ✓ | | | / | | / | | | | | | 2.7 | 2.7 | |
| 5 TO 6 | ✓ | | | | | | | | | | | 2.8 | 2.8 | EDGE OF CAP |
| 6 TO 7 | ✓ | | | / | | / | | | | | | 2.7 | 2.7 | |
| 7 TO 8 | ✓ | | | | | | | | | | | 2.8 | 2.8 | ROOT EDGE |
| 8 TO 9 | ✓ | | | | | | | | | | | 2.6 | 2.6 | |
| 9 TO 10 | ✓ | | | | | | | | | | | 2.8 | 2.8 | |
| 10 TO 11 | ✓ | | | | | | | | | | | 2.7 | 2.7 | |
| 11 TO 12 | ✓ | | | | | | | | | | | 3.0 | 3.0 | |
| 12 TO 13 | ✓ | | | | | | | | | | | 3.1 | 3.1 | |
| 13 TO 14 | ✓ | | | | | | | | | | | 3.0 | 3.0 | |
| 14 TO 15 | ✓ | | | | | / | | | | | | 3.2 | 3.2 | |
| 15 TO 16 | ✓ | | | | | / | | | | | | 3.2 | 3.2 | |
| 16 TO 17 | ✓ | | | | | / | | | | | | 3.0 | 3.0 | |
| 17 TO 18 | ✓ | | | | | | | | | | | 3.3 | 3.3 | |
| 18 TO 19 | ✓ | | | | | | | | | | | 3.2 | 3.2 | |
| 19 TO 20 | ✓ | | | | | | | | | | | 3.1 | 3.1 | |
| 20 TO 0 | ✓ | | | | | | | | | | | 3.3 | 3.3 | |

RADIOGRAPHER(S): Jerry L Dillard Level II R.T.

INTERPRETER: Jerry L Dillard Level II R.T.

CLIENT APPROVAL:

APPLIED TECHNICAL SERVICES, INCORPORATED

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# RADIOGRAPHIC INSPECTION REPORT

Job # P245625 PO # 293-2828 WO # N/A Date: 12/12/2015 Page 1 of 1

CLIENT: **CAROLINA INTERGRATED SOLUTIONS**
LOCATION: **157 DERRICK RD**
**SPARTANBURG, SC. 29303**

PART NO.: TANK 293-03
PART NAME: SEE BELOW
MATERIAL: STAINLESS STEEL
THICKNESS: .312" ROLLED STEEL
TYPE WELD: SAW

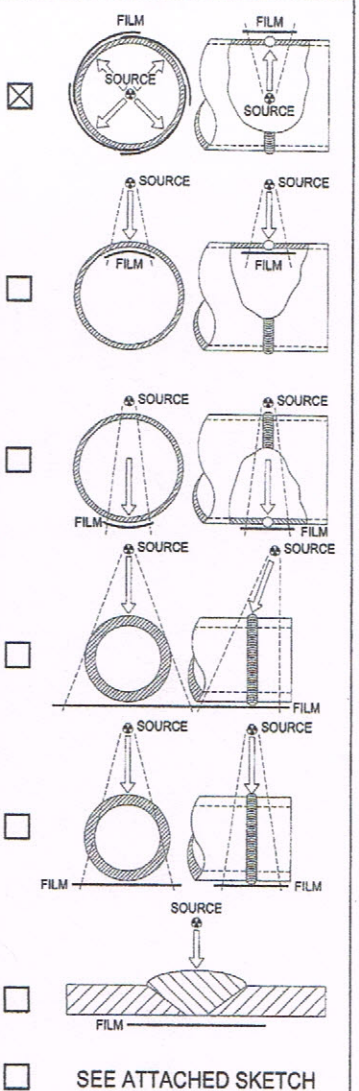
## RADIOGRAPHIC INSPECTION TECHNIQUE

| | | | |
|---|---|---|---|
| Specification(s) | ATS 120.1 REV 25 IAW ASME SECTION VIII | | |
| Isotope | IR 192 D1240 | Film Size | 4.5" X 17" |
| Curies | 94 | Film Type | Fuji 80 |
| KV | N/A | Sensitivity | #6 WIRE .0100" |
| MA | N/A | Penetrameter | 1 ASTM B |
| Time | 320 SECONDS | Shim(s) | N/A |
| SFD | 39.1 INCHES | Develop: Temp: | 70° F Time: 4.5 MIN |
| SOD | 39 INCHES | Screen(s) | .002 PB F&B |
| OFD | .312 INCHES | Source Size (Effective) | .143 |
| Source Size (Physical) | .1"x.1" | Films Per Cassette | 1 |
| Geometric Unsharpness | .001" | Weld Reinforcement | .090" |

## INTERPRETATION

| PART I.D./ FILM VIEW | Accept | Reject | Crack | Slag Inclusion | Tungsten Inclusion | Porosity | Undercut | Incomplete Fusion | Incomplete | Root Concavity | Root Convexity | DENSITY Penetrameter | DENSITY Area of Interest | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W GS3 | | | | | | | | | | | | | | WELDER ID CI3 |
| 0 TO 1 | ✓ | | | | | / | | | | | | 3.5 | 3.5 | |
| 1 TO 2 | ✓ | | | | | | | | | | | 3.6 | 3.6 | |
| 2 TO 3 | ✓ | | | | | | | | | | | 3.5 | 3.5 | |
| 3 TO 4 | ✓ | | | | | | | | | | | 3.4 | 3.4 | |
| 4 TO 5 | ✓ | | | | | | | | | | | 3.8 | 3.8 | |
| 5 TO 6 | ✓ | | | | | | / | | | | | 3.7 | 3.7 | |
| 6 TO 7 | ✓ | | | | | | | | | | | 3.6 | 3.6 | |
| 7 TO 8 | ✓ | | | | | / | / | | | | | 3.5 | 3.5 | |
| 8 TO 9 | ✓ | | | | | / | | | | | | 3.6 | 3.6 | |
| 9 TO 10 | ✓ | | | | | | | | | | | 3.5 | 3.5 | |
| 10 TO 11 | ✓ | | | | | | | | | | | 3.4 | 3.4 | |
| 11 TO 12 | ✓ | | | | | | | | | | | 3.5 | 3.5 | |
| 12 TO 13 | ✓ | | | | | | | | | | | 3.6 | 3.6 | |
| 13 TO 14 | ✓ | | | | | / | | | | | | 3.6 | 3.6 | |
| 14 TO 15 | ✓ | | | | | | | | | | | 3.7 | 3.7 | |
| 15 TO 16 | ✓ | | | | | | | | | | | 3.5 | 3.5 | |
| 16 TO 17 | ✓ | | | | | | | | | | | 3.4 | 3.4 | |
| 17 TO 18 | ✓ | | | | | | | | | | | 3.5 | 3.5 | |
| 18 TO 19 | ✓ | | | | | | | | | | | 3.7 | 3.7 | |
| 19 TO 20 | ✓ | | | | | | | | | | | 3.8 | 3.8 | |
| 20 TO 0 | ✓ | | | | | | | | | | | 3.3 | 3.3 | |

## SETUP




☒ ☐ ☐ ☐ ☐ ☐ SEE ATTACHED SKETCH

RADIOGRAPHER(S): Jerry L Dillard Level II R.T.

INTERPRETER: Jerry L Dillard Level II R.T.

CLIENT APPROVAL: Ricky McRobert

APPLIED TECHNICAL SERVICES, INCORPORATED

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# RADIOGRAPHIC INSPECTION REPORT

Job # P245625 PO # 293-2828 WO # N/A Date: 12/12/2015 Page 1 of 1

CLIENT: **CAROLINA INTERGRATED SOLUTIONS**
LOCATION: **157 DERRICK RD**
**SPARTANBURG, SC. 29303**

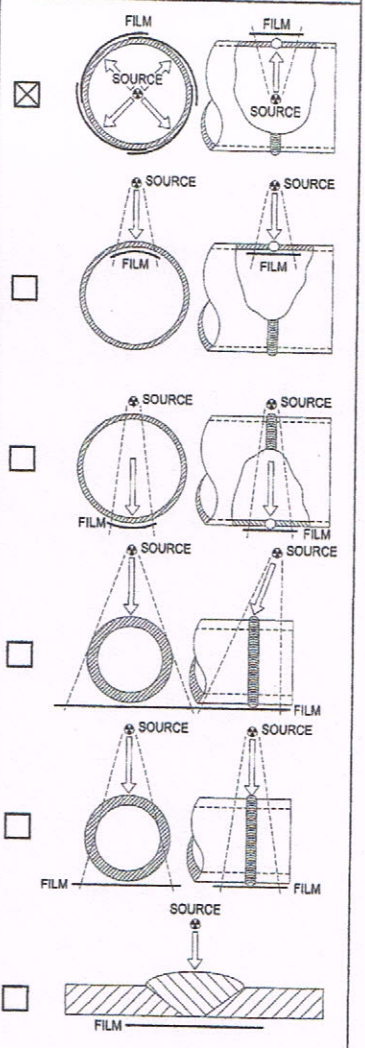
PART NO.: TANK 293-03
PART NAME: SEE BELOW
MATERIAL: STAINLESS STEEL
THICKNESS: .312" ROLLED STEEL
TYPE WELD: SAW

## RADIOGRAPHIC INSPECTION TECHNIQUE

Specification(s) ATS 120.1 REV 25 IAW ASME SECTION VIII

| | | | |
|---|---|---|---|
| Isotope | IR 192 D1240 | Film Size | 4.5" X 17" |
| Curies | 94 | Film Type | Fuji 80 |
| KV | N/A | Sensitivity | #6 WIRE .0100" |
| MA | N/A | Penetrameter | 1 ASTM B |
| Time | 320 SECONDS | Shim(s) | N/A |
| SFD | 39.1 INCHES | Develop: Temp: | 70° F Time: 4.5 MIN |
| SOD | 39 INCHES | Screen(s) | .002 PB F&B |
| OFD | .312 INCHES | Source Size (Effective) | .143 |
| Source Size (Physical) | .1"x.1" | Films Per Cassette | 1 |
| Geometric Unsharpness | .001" | Weld Reinforcement | .090" |

## SETUP




## INTERPRETATION

| PART I.D./ FILM VIEW | Accept | Reject | Crack | Slag Inclusion | Tungsten Inclusion | Porosity | Undercut | Incomplete Fusion | Incomplete | Root Concavity | Root Convexity | DENSITY Penetrameter | DENSITY Area of Interest | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W LS1 | | | | | | | | | | | | | | WELDER ID CI3 |
| 0 TO 1 | ✓ | | | | | | | | | | | 2.1 | 2.1 | |
| 1 TO 2 | ✓ | | | | | | | | | | | 2.3 | 2.3 | |
| 2 TO 3 | ✓ | | | | | | | | | | | 2.6 | 2.6 | |
| 3 TO 4 | ✓ | | | | | | | | | | | 2.8 | 2.8 | |
| 4 TO 5 | ✓ | | | | | | | | | | | 2.4 | 2.4 | |
| 5 TO 6 | ✓ | | | | | | | | | | | 2.3 | 2.3 | |
| 6 TO 7 | ✓ | | | | | | | | | | | 2.1 | 2.1 | |
| W LS2 | | | | | | | | | | | | | | WELDER ID CI3 |
| 0 TO 1 | ✓ | | | | | | | | | | | 2.1 | 2.1 | |
| 1 TO 2 | ✓ | | | | | | | | | | | 2.3 | 2.3 | |
| 2 TO 3 | ✓ | | | | | | | | | | | 2.6 | 2.6 | |
| 3 TO 4 | ✓ | | | | | | | | | | | 2.8 | 2.8 | |
| 4 TO 5 | | X | | X | | | | | | | | 2.4 | 2.4 | |
| 5 TO 6 | ✓ | | | | | | | | | | | 2.3 | 2.3 | |
| 6 TO 7 | | X | | X | | | | | | | | 2..3 | 2.1 | |
| 7 TO 8 | ✓ | | | | | | | | | | | 2.1 | 2.1 | |

RADIOGRAPHER(S): Jerry L Dillard Level II R.T.

INTERPRETER: Jerry L Dillard Level II R.T.

CLIENT APPROVAL: Bucky McRobert

APPLIED TECHNICAL SERVICES, INCORPORATED

214 Pelham Davis Circle, Greenville, South Carolina 29615 •(864) 675-6060 Fax (864) 675-6040 • www.atslab.com

# RADIOGRAPHIC INSPECTION REPORT

Job # P245625 PO # 293-2828 WO # N/A Date: 12/12/2015 Page 1 of 1

CLIENT: **CAROLINA INTERGRATED SOLUTIONS**
LOCATION: **157 DERRICK RD**
**SPARTANBURG, SC. 29303**

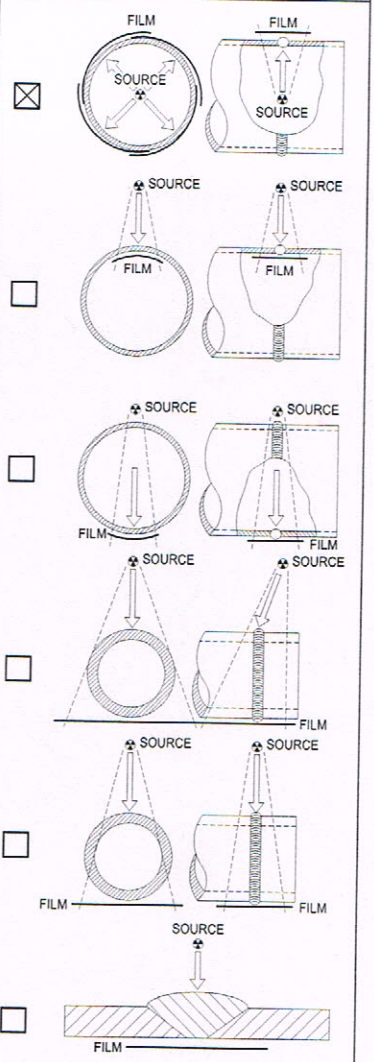
PART NO.: TANK 293-03
PART NAME: SEE BELOW
MATERIAL: STAINLESS STEEL
THICKNESS: .312" ROLLED STEEL
TYPE WELD: SAW

## RADIOGRAPHIC INSPECTION TECHNIQUE

Specification(s) ATS 120.1 REV 25 IAW ASME SECTION VIII
Isotope IR 192 D1240
Curies 94
KV N/A
MA N/A
Time 320 SECONDS
SFD 39.1 INCHES
SOD 39 INCHES
OFD .312 INCHES
Source Size (Physical) .1"x.1"
Geometric Unsharpness .001"

Film Size 4.5" X 17"
Film Type Fuji 80
Sensitivity #6 WIRE .0100"
Penetrameter 1 ASTM B
Shim(s) N/A
Develop: Temp: 70° F Time: 4.5 MIN
Screen(s) .002 PB F&B
Source Size (Effective) .143
Films Per Cassette 1
Weld Reinforcement .090"

## SETUP




☒ ☐ ☐ ☐ ☐ ☐ ☐ SEE ATTACHED SKETCH

## INTERPRETATION

| PART I.D./ FILM VIEW | Accept | Reject | Crack | Slag Inclusion | Tungsten Inclusion | Porosity | Undercut | Incomplete Fusion | Incomplete | Root Concavity | Root Convexity | DENSITY Penetrameter | DENSITY Area of Interest | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W1 | | | | | | | | | | | | | | WELDER ID CI2 |
| 0 TO 1 | ✔ | | | | | | | | | | | 3.5 | 3.5 | |
| 1 TO 2 | ✔ | | | | | | | | | | | 3.6 | 3.6 | |
| 2 TO 3 | ✔ | | | | | | | | | | | 3.6 | 3.5 | |
| 3 TO 0 | ✔ | | | | | | | | | | | 3.8 | 3.6 | |
| W2 | | | | | | | | | | | | | | |
| 0 TO 1 | | X | | | | X | | | | | | 3.0 | 3.3 | |
| 1 TO 2 | ✔ | | | | | | | | | | | 3.1 | 3.1 | |
| 2 TO 3 | ✔ | | | | | | | | | | | 3.2 | 3.2 | |
| 3 TO 0 | | X | | | | X | | | | | | 3.3 | 3.3 | |

RADIOGRAPHER(S): Jerry L Dillard Level II R.T.
INTERPRETER: Jerry L Dillard Level II R.T.
CLIENT APPROVAL:

# APPLIED TECHNICAL SERVICES, INCORPORATED

214 Pelham Davis Circle, Greenville, South Carolina 29615 • (864) 675-6060 Fax (864) 675-6040 • www.atslab.com

# RADIOGRAPHIC INSPECTION REPORT

Job # P245625 PO # 293-2828 WO # N/A Date: 12/14/2015 Page 1 of 1

CLIENT: **CAROLINA INTERGRATED SOLUTIONS**
LOCATION: **157 DERRICK RD**
**SPARTANBURG, SC. 29303**

PART NO.: TANK 293-03
PART NAME: SEE BELOW
MATERIAL: STAINLESS STEEL
THICKNESS: .312" ROLLED STEEL
TYPE WELD: SAW

## RADIOGRAPHIC INSPECTION TECHNIQUE

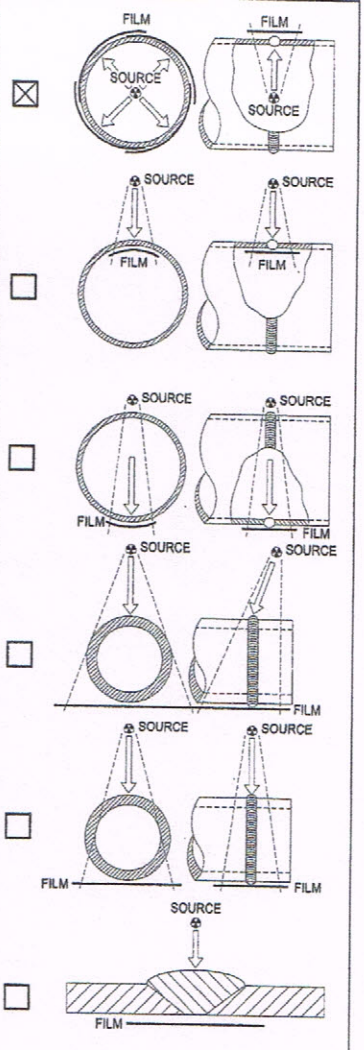
Specification(s) ATS 120.1 REV 25 IAW ASME SECTION VIII

| | | | |
|---|---|---|---|
| Isotope | IR 192 D1240 | Film Size | 4.5" X 17" |
| Curies | 94 | Film Type | Fuji 80 |
| KV | N/A | Sensitivity | #6 WIRE .0100" |
| MA | N/A | Penetrameter | 1 ASTM B |
| Time | 320 SECONDS | Shim(s) | N/A |
| SFD | 39.1 INCHES | Develop: Temp: | 70° F Time: 4.5 MIN |
| SOD | 39 INCHES | Screen(s) | .002 PB F&B |
| OFD | .312 INCHES | Source Size (Effective) | .143 |
| Source Size (Physical) | .1"x.1" | Films Per Cassette | 1 |
| Geometric Unsharpness | .001" | Weld Reinforcement | .090" |

## INTERPRETATION

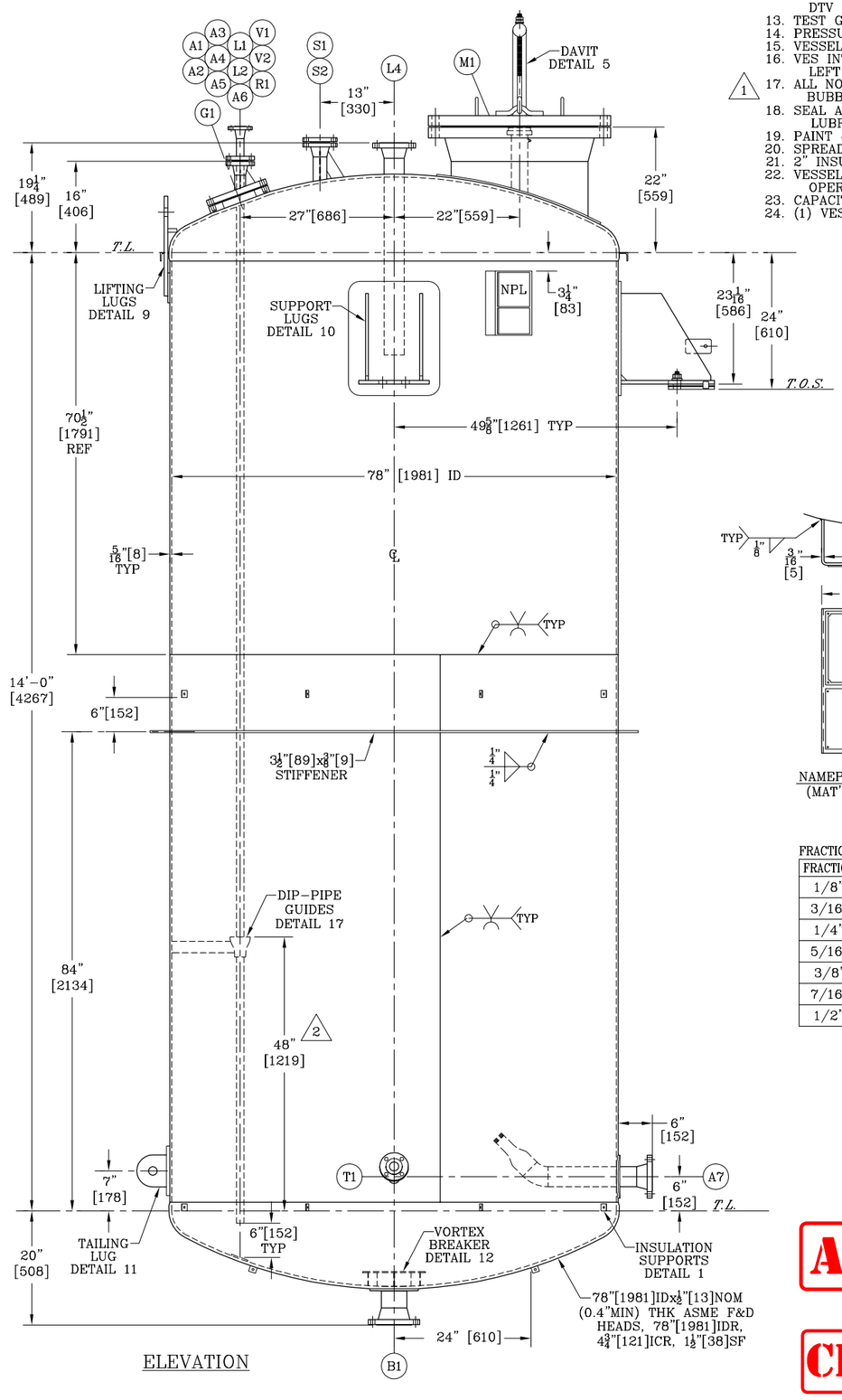
| PART I.D./ FILM VIEW | Accept | Reject | Crack | Slag Inclusion | Tungsten Inclusion | Porosity | Undercut | Incomplete Fusion | Incomplete | Root Concavity | Root Convexity | DENSITY Penetrameter | DENSITY Area of Interest | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W2R1 | | | | | | | | | | | | | | |
| 0 TO 1 | ✔ | | | | | | | | | | | 3.0 | 3.0 | |
| 1 TO 2 | ✔ | | | | | | | | | | | 3.1 | 3.1 | |
| 2 TO 3 | ✔ | | | | | | | | | | | 3.0 | 3.0 | |
| 3 TO 0 | ✔ | | | | | | | | | | | 2.9 | 2.9 | |

## SETUP




☐ SEE ATTACHED SKETCH

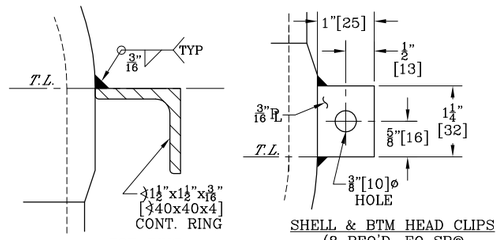
RADIOGRAPHER(S): Jerry L Dillard Level II R.T.
INTERPRETER: Jerry L Dillard Level II R.T.
CLIENT APPROVAL: Ricky McRobue




ELEVATION

PAINT, DISCOLORATION & GENERAL SHOP SOIL TO PROVIDE A MUTUALLY ACCEPTABLE WORKMANLIKE PRODUCT.

12. GASKET DIMENSIONS FOR CLASS 150# FLGS TO BE PER ANSI B16.5 TABLE E3. DTV TO SUPPLY (3) SPARE GASKET FOR MANWAY & ALL BLIND CONNECTIONS.
13. TEST GASKETS TO BE SAME DIMENSIONS & COMPRESSIBILITY AS SERVICE.
14. PRESSURE BOLTING SUPPLIED W/VESSEL TO BE USED FOR TESTING.
15. VESSEL EXT: PICKLE & PASSIVATE WELDS PER NOTE 8; ACID WASH REMAINDER.
16. VES INTERIOR: PICKLE & PASSIVATE PER STD TS 25-0205-2. ANY WATER LEFT AFTER HYDROTEST TO BE REMOVED BY BLOWING AIR OR SWABBING.
17. ALL NOZZLE REPADS TO HAVE 1/8" NPT WEEP HOLES @ LOW POINT; AIR-SOAP BUBBLE TEST @15 PSI. ALL OTHER EXT. PADS TO HAVE 1/4"ø VENT HOLES.
18. SEAL ALL MACH. FACES & THREADS W/PLASTIC PROTECTORS BEFORE SHIPPING. LUBRICATE ALL BOLT THREADS W/ANTI-SEIZE.
19. PAINT 45°,135°,225°& 315° ABOVE SUPPORT LUGS USING 4" TALL LETTERING.
20. SPREADER BAR REQUIRED WHEN LIFTING VESSEL; SHACKLE SIZE= 9 1/2 TON
21. 2" INSULATION REQ'D (BY OTHERS).
22. VESSEL WEIGHTS: EMPTY= 7,600 lbs; FLOODED (WATER)= 39,000 lbs; OPERATING= 32,200 lbs.
23. CAPACITY: 3,810 gals; HEADS= 209 gals; SHELL= 3,403 gal.
24. (1) VESSEL REQ'D.




TOP RING




SHELL & BTM HEAD CLIPS
(8 REQ'D, EQ SP@
(2) ELEVS; 4 REQ'D,
EQ SP ON HEAD)

## DETAIL 1
INSULATION SUPPORTS

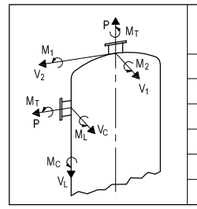



NAMEPLATE BRACKET
(MAT'L: 304 S/S)

FRACTION TO MILLIMETER CONVERSION

| FRACTION | MM | FRACTION | MM |
|---|---|---|---|
| 1/8" | [3] | 9/16" | [14] |
| 3/16" | [5] | 5/8" | [16] |
| 1/4" | [6] | 11/16" | [17] |
| 5/16" | [8] | 3/4" | [19] |
| 3/8" | [10] | 13/16" | [21] |
| 7/16" | [11] | 7/8" | [22] |
| 1/2" | [13] | 15/16" | [24] |

NOZZLE LOAD TABLE




| NOZ MARK | lbf | | | lbf ft | | |
|---|---|---|---|---|---|---|
| | P | $V_L$ $V_1$ | $V_C$ $V_2$ | $M_L$ $M_1$ | $M_C$ $M_2$ | $M_T$ |
| A7 | 787 | 922 | 674 | 1032 | 664 | 1328 |
| B1 | 967 | 1079 | 787 | 1549 | 1033 | 1918 |
| S1 | 517 | 697 | 517 | 369 | 295 | 590 |
| S2 | 787 | 922 | 674 | 1032 | 664 | 1328 |
| | | | | | | |
| | | | | | | |

| | | | |
|---|---|---|---|
| ○ MAWP | 3.1 BARG | PSIG @ | 170°C °F ○ |
| MDMT | -29°C | °F @ | 3.1 BARG PSIG |
| MAEWP | -1.013 BARG | PSIG @ | 170°C °F |
| JKT MAWP | | PSIG @ | °F |
| JKT MDMT | | °F @ | PSIG |
| INSPECTOR | | | |
| PLANT | MOBILE, ALABAMA | | |
| WEIGHT | 7,600 LBS | | |
| MATERIAL | SA-240 316/316L | | |
| P.O. No. | 4700984380 | | |
| EQUIP No. | R-2210 | | |
| ○ PROJ No. | 4142-00940 | | ○ |

NAMEPLATE DETAIL

AS-BUILT

CERTIFIED

CERTIFIED BY NB LATER

U-L W RT-1

CAROLINA INTEGRATED SOLUTIONS
157 Derrick Rd, Spartanburg, SC 29303

SERIAL NO. 293-03 YR BUILT 2015

| | | | | |
|---|---|---|---|---|
| | | SHELL | | |
| MAWP | 45 | psi @ | 338 | °F |
| MDMT | -20 | °F @ | 45 | psi |
| MAEWP | -14.7 | psi @ | 338 | °F |
| | | JACKET | | |
| MAWP | | psi @ | | °F |
| MDMT | | °F @ | | psi |

NOZZLE SCHEDULE

| REPADS | MARK | SIZE | SCH | NO. | DESCRIPTION | SERVICE | DETAIL |
|---|---|---|---|---|---|---|---|
| | A1 | 1½" | 40S | 1 | 150# ANSI RFWN FLG | CRUDE ACA INLET DIP-PIPE | 13 |
| | A2 | 2" | 40S | 1 | 150# ANSI RFWN W/RED. RFSO FLG | MOUNT FOR A1 | 13 |
| | A3 | 1" | 40S | 1 | 150# ANSI RFWN FLG | ACETIC ACID INLET DIP-PIPE | 6 |
| | A4 | 1½" | 40S | 1 | 150# ANSI RFWN W/RED. SO & GUSSETS | MOUNT FOR A3 | 2,6 |
| | A5 | 1" | 40S | 1 | 150# ANSI RFWN FLG | LIQUID INLET DIP-PIPE | 6 |
| | A6 | 1½" | 40S | 1 | 150# ANSI RFWN W/RED. SO & GUSSETS | MOUNT FOR A5 | 2,6 |
| 7½"ODx5/16"THK | A7 | 3" | 40S | 1 | 150# ANSI RFWN FLG | IN TANK EDUCTOR INLET | 16 |
| 8½"ODx5/16"THK | B1 | 4" | 40S | 1 | 150# ANSI RFWN FLG | PRODUCT OUTLET | 12 |
| | G1 | 6" | – | 1 | 150# ANSI RF STUD PAD | SIGHT GLASS | 8 |
| | L1 | 3" | 40S | 1 | 150# ANSI RFWN FLG | LEVEL INDICATION STILLING WELL | 7 |
| | L2 | 4" | 40S | 1 | 150# ANSI RFWN FLG W/RED. SO FLG | MOUNT FOR L1 | 7 |
| | L4 | 3" | 40S | 1 | 150# ANSI RFWN FLG | LEVEL SWITCH- HIGH | 14 |
| 29 1/16"ODx5/16"THK | M1 | 24" | 3/8" | 1 | 150# ANSI RFWN FLG W/BF | MANWAY W/DAVIT | 4,5 |
| | R1 | 4" | 40S | 1 | 150# ANSI RFWN FLG | EMERGENCY PRESSURE RELIEF | 3 |
| | S1 | 2" | 40S | 1 | 150# ANSI RFWN FLG W/BF | SPARE | 3 |
| 8"ODx5/16"THK | S2 | 3" | 40S | 1 | 150# ANSI RFWN FLG W/BF | SPARE | 3 |
| | T1 | 1½" | 40S | 1 | 150# ANSI RFWN FLG W/GUSSETS | TEMPERATURE INDICATION | 15 |
| | V1 | 1½" | 40S | 1 | 150# ANSI RFWN FLG W/GUSSETS | VAPOR EQUALIZATION | 2 |
| | V2 | 1" | 40S | 1 | 150# ANSI RFWN FLG W/GUSSETS | OFF GAS VENT | 2 |

DESIGN DATA

1. DESIGN PRESS & TEMP: VESSEL- (-14.7) +45 PSIG @338°F [(-1.013) +3.1 BARG @170°C]
   OPERATING PRESS & TEMP: VESSEL- 1 PSIG @158°F [.06 BARG @-70°C]
2. CORROSION ALLOWANCE- NONE
3. SPECIFIC GRAVITY OF CONTENTS- 0.993 (61.98 lb/cf)
4. HYDROTEST- 60 PSIG [4.1 BARG] (USE WATER W/A CHLORIDE CONTENT <50 ppm).
5. FULL RADIOGRAPH REQ'D.
6. WIND LOAD- PER IBC 2009; 140 MPH, I=1.15, EXP C, 62 FT ELEVATION.
7. SEISMIC LOAD- PER IBC 2009; Ss=11%, S1=5.1%, I=1.5, CLASS D
8. VESSEL TO BE DESIGNED FOR LETHAL SERVICE.

MATERIAL

HEADS & SHELL- SA-240 316/316L
NOZ NECKS- SA-312 TP 316/316L (SMLS)
FLANGES- SA-182 F 316/316L
MANWAY NECK- SA-240 316/316L
SIGHT GLASS- SA-240 316/316L
FITTINGS- SA-403 WP 316/316L
REINF PADS- SA-240 316/316L
INTERNAL ATTACH- SA-240 316/316L
LIFT & TAIL LUGS- SA-240 304/304L
EXTERNAL ATTACH- SA-240 304/304L
SUPPORT LUGS- SA-240 304/304L
BOLTING- SA-193 B7/SA-194 2H (GALV)
GASKETS: VES- SP WD CGI 316/GRAPHITE
SIGHT GLASS- 1/8" GRAPHITE

WELDING PROCEDURES

| No. | PROCESS | ROD | NOTES | No. | PROCESS | ROD | NOTES |
|---|---|---|---|---|---|---|---|
| 8-8-2 | (GTAW) | ER308L | 304 to 304 | 8-8-4 | (GMAW) | ER316L | 316 ROOT ONLY |
| 8-8-3 | (FCAW) | ER308LT1-1 | 304 to 304 | 8-8-5 | (SAW) | ER316L | 316 to 316 |
| 8-8-4 | (GMAW) | ER308L | 304 ROOT ONLY | 8-8-2 | (GTAW) | ER316L | 304 to 316 |
| 8-8-5 | (SAW) | ER308L | 304 to 304 | 8-8-3 | (FCAW) | ER316LT1-1 | 304 to 316 |
| 8-8-2 | (GTAW) | ER316L | 316 to 316 | 8-8-4 | (GMAW) | ER316L | 304/316 ROOT ONLY |
| 8-8-3 | (FCAW) | ER316LT1-1 | 316 to 316 | 8-8-5 | (SAW) | ER316L | 304 to 316 |

CONSTRUCTION NOTES

1. VESSEL TO BE DESIGNED & CONSTRUCTED PER ASME CODE, SEC VIII, DIV 1, 2013 EDITION; ALSO PER SPECS LISTED BELOW.
2. ASME CODE STAMP & NATIONAL BOARD REGISTRATION REQ'D.
3. FLANGE FACE FINISH= 125AA
4. NOZZLE BOLT HOLES TO STRADDLE 0-180° CENTERLINE OR ITS PARALLEL.
5. INSIDE NOZZLE PROJECTION= 0, UNLESS NOTED OTHERWISE.
6. NOZZLE "B1" TO BE GROUND FLUSH.
7. SHELL & HEAD JOINTS TO BE FULL PENETRATION BUTT JOINTS; NOZZLE NECK TO SHELL OR HEAD JOINTS TO BE FULL PENETRATION.
8. ALL WELDS TO BE PASTED PER EC PT&E SPEC 25-0205, PARAGRAPH 5.2. PICKLING PASTE MATERIAL TO BE METINOX 71E OR EQUIVALENT.
9. HOLD FOR AUTH ASME & CUSTOMER INSPECTORS AT: a) FIT-UP & COMPLETION OF BACKGOUGING; b) FIT-UP OF MANWAY; c) HYDROTEST.
10. INTERNAL WELDS TO BE REASONABLY SMOOTH, BUT NOT NECESSARILY RIPPLE FREE OR GROUND SMOOTH.
11. INSIDE SURFACE OF COMPLETED VESSEL TO BE FREE OF RUST, SCALE, SLAG, GREASE. WELD FLUX, SPATTER, ARC BURNS, GOUGES, TOOL MARKS, OIL, INK, MILL MARKINGS,

LETHAL SERVICE

DTV REF DWGS: 15515-03-2, 15515-03-3

DESTINATION: THEODORE, AL

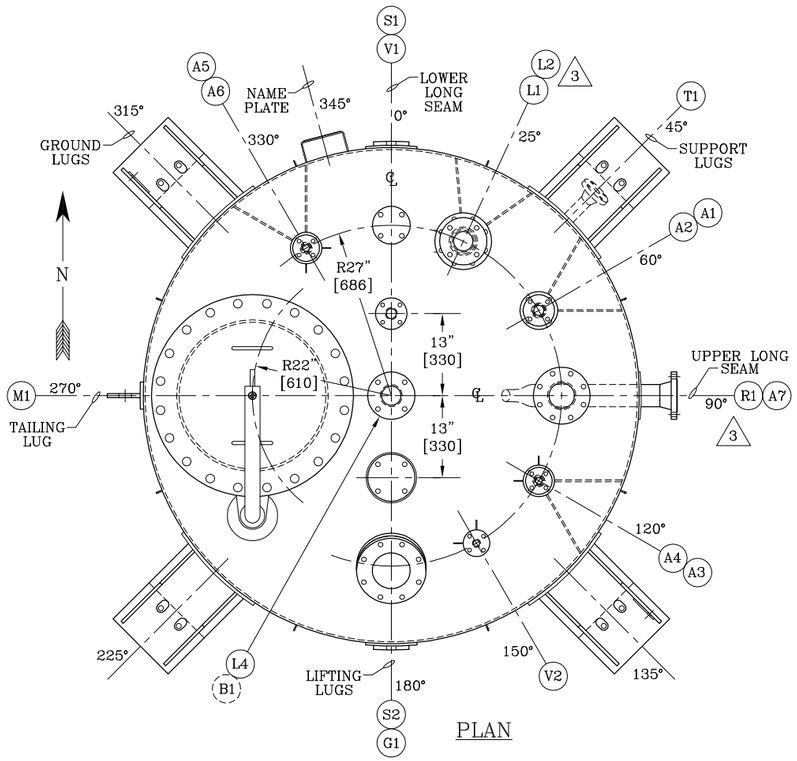
REFERENCE:
CUST PO No: 4700984380
ITEM No: R-2210
PROJ No: 4142-00940
SPEC Nos: R-2210, REV 2; 20.230.013, REV 2; 20.230.030, REV 2; 20.230.036, R2; 20.230.032
CUST STDS: 25-0101-3; 25-0205-2; 25-0801-2; 25-0807; 25-0901; 25-0902; 25-0903; 25-0108; 25-0303

| MARK | REVISION DESCRIPTION | BY | CK'D | DATE |
|---|---|---|---|---|
| 2 | ADD DIP-PIPE GUIDE ELEVS | RTC | BT | 12-7-15 |
| 1 | ADD CONSTRUCTION NOTE 17 | RTC | BT | 11-3-15 |
| 0 | REV PER CUSTOMER APPROVAL | RTC | BT | 7-7-15 |
| A | REV PER CUSTOMER COMMENTS | RTC | BT | 5-5-15 |

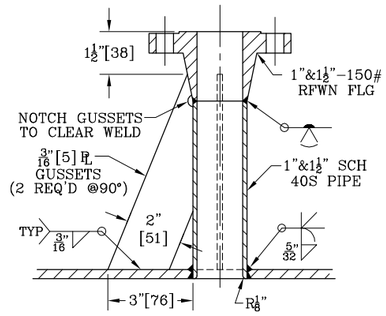
DOMINION
Tank & Vessel Company, Inc.
1501 Valley Road, Richmond, VA 23222

78"ID ACA AFTER REACTOR R-2210
EVONIK CORPORATION
MOBILE ALABAMA PLANT
ACA PROJECT

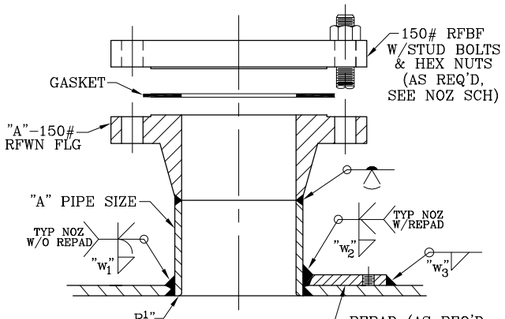
DRAWN RTC 2-10-15
CHECKED BT 2-18-15
CERTIFIED
SCALE 1"=12"
JOB NO. 293-03
15515-03-1
REV. 2



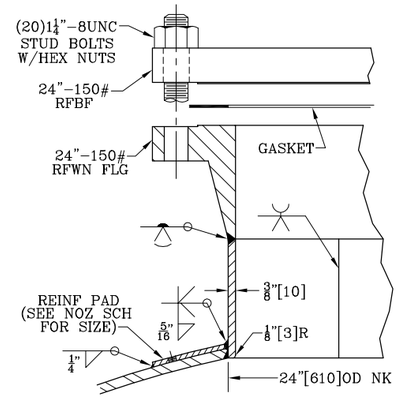

PLAN




DETAIL 2
1"&1½"–150# NOZZLES W/GUSSETS



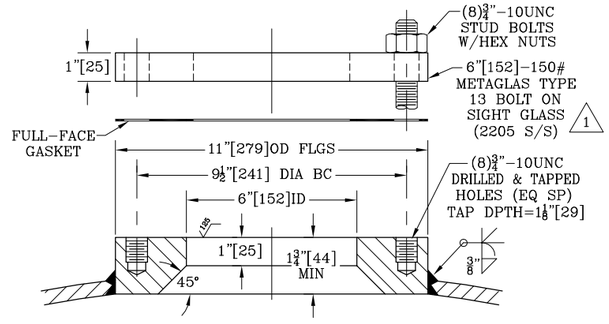

DETAIL 3
150# WELD NECK FLANGES
SEE TABLE 3 FOR DIMENSIONS.
SEE NOZZLE SCHEDULE FOR "A."




DETAIL 4
MANWAY

TABLE 3

| NOM PIPE SIZE "A" | WELD SIZE "w1" | "w2" | "w3" | STUD BOLTS NO. | SIZE |
|---|---|---|---|---|---|
| 2" | 5/32" | – | – | 4 | 5/8"–11UNC |
| 3" | 7/32" | 1/4" | 1/4" | 4 | 5/8"–11UNC |
| 4" | 1/4" | – | – | 8 | 5/8"–11UNC |




DETAIL 8
NOZZLE "G1"

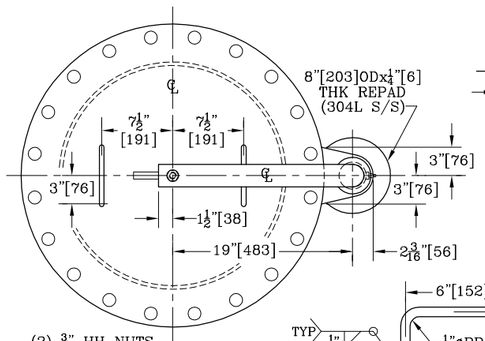


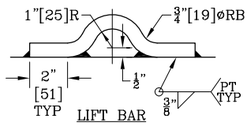


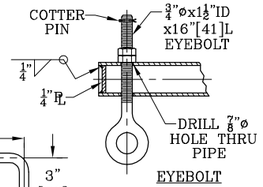


DETAIL 9
LIFTING LUGS
(2 REQ'D, EQ SP)
SEE PLAN FOR ORIENTATION

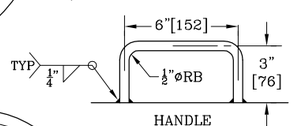
**AS-BUILT**



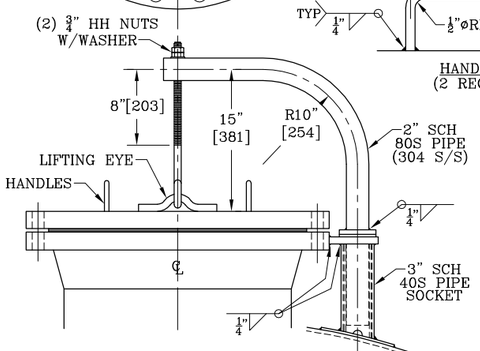



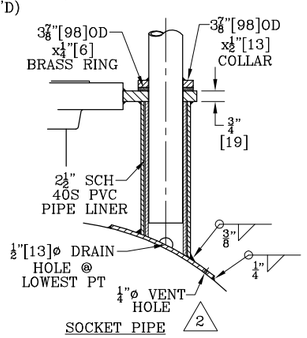

EYEBOLT



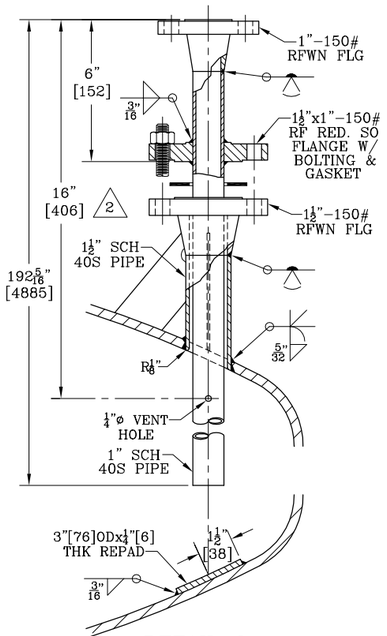

HANDLE
(2 REQ'D)



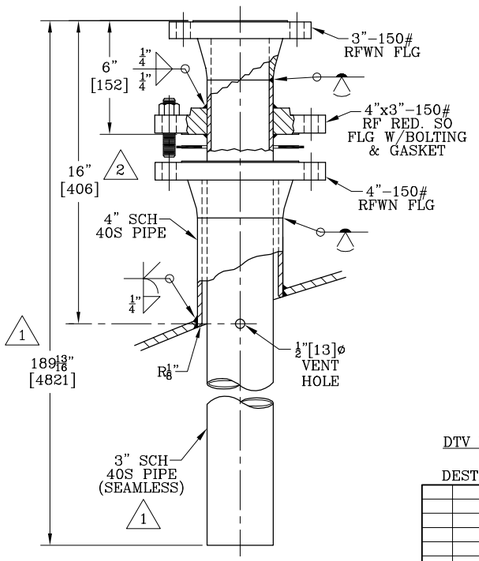

DETAIL 5
DAVIT FOR 24"–150# RFWN FLANGE
NOTES: ALL MAT'L TO BE S/S EXCEPT AS NOTED.
SEE PLAN FOR TRUE DAVIT ORIENTATION.




SOCKET PIPE




DETAIL 6
DIP–PIPES "A3&A5 ON A4&A6"
SEE DETAIL 2 FOR GUSSETS.
SEE DETAIL 17 FOR DIP–PIPE GUIDES.




DETAIL 7
NOZZLE "L1 ON L2"
SEE DTL 17 FOR DIP–PIPE GUIDE.

FRACTION TO MILLIMETER CONVERSION

| FRACTION | MM | FRACTION | MM |
|---|---|---|---|
| 1/8" | [3] | 9/16" | [14] |
| 3/16" | [5] | 5/8" | [16] |
| 1/4" | [6] | 11/16" | [17] |
| 5/16" | [8] | 3/4" | [19] |
| 3/8" | [10] | 13/16" | [21] |
| 7/16" | [11] | 7/8" | [22] |
| 1/2" | [13] | 15/16" | [24] |

**CERTIFIED**

LETHAL SERVICE

REFERENCE:
CUST PO No: 4700984380
ITEM No: R–2210
PROJ No: 4142–00940
SPEC Nos: R–2210, REV 2; 20.230.013, REV 2; 20.230.030, REV 2; 20.230.036, R1; 20.230.032
CUST STDS: 25–0101–3; 25–0205–2; 25–0801–2; 25–0807; 25–0901 thru 25–0903; 25–0108; 25–0303

DTV MAIN DWG: 15515–03–1

DESTINATION: THEODORE, AL

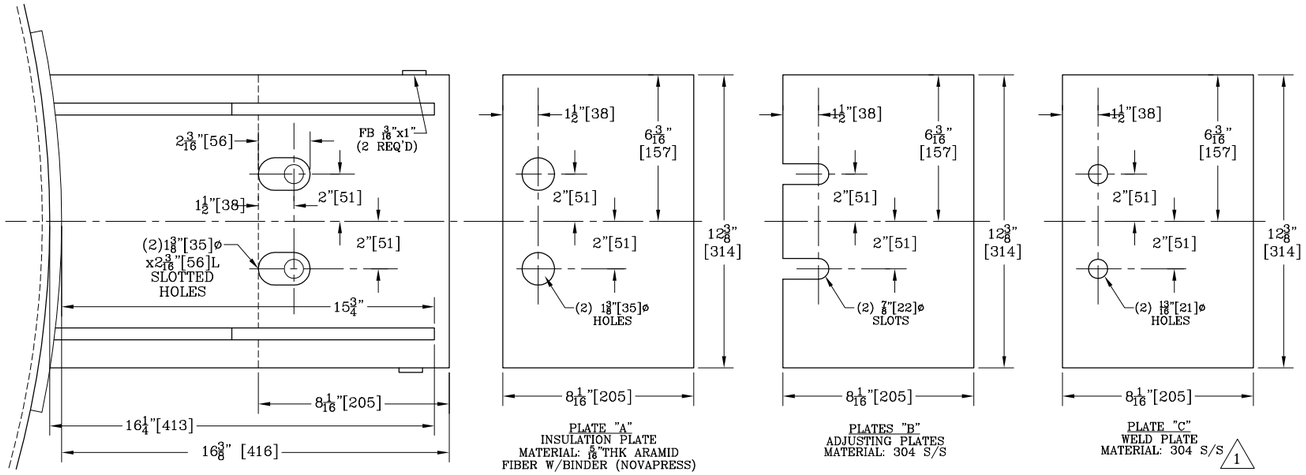
| MARK | REVISION DESCRIPTION | BY | CK'D | DATE |
|---|---|---|---|---|
| 3 | REORIENT R1,L1&L2 | RTC | EW | 12-17-15 |
| 2 | ADD VENT HOLE LOCATIONS | RTC | BT | 11-3-15 |
| 1 | REV L1 LGTH; REMOVE HOLD DTL 8 | RTC | BT | 8-12-15 |
| 0 | REV PER CUSTOMER APPROVAL | RTC | BT | 7-9-15 |
| A | REV PER CUSTOMER COMMENTS | RTC | BT | 5-5-15 |

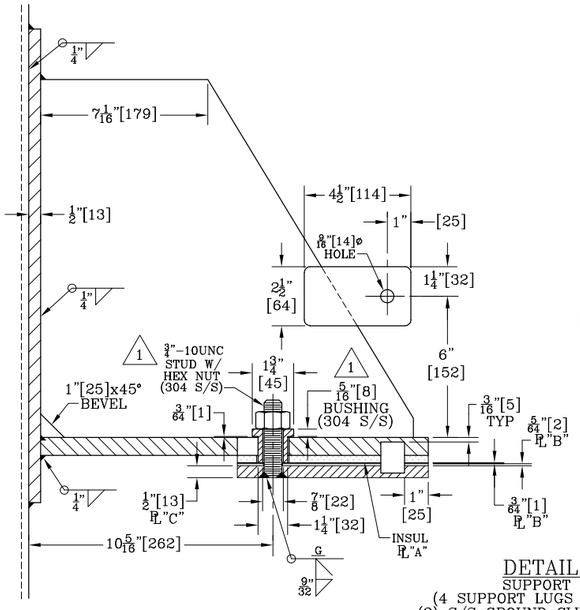
DOMINION
Tank & Vessel Company, Inc.
1501 Valley Road, Richmond, VA 23222

78"ID ACA AFTER REACTOR R–2210
EVONIK CORPORATION
MOBILE ALABAMA PLANT
ACA PROJECT

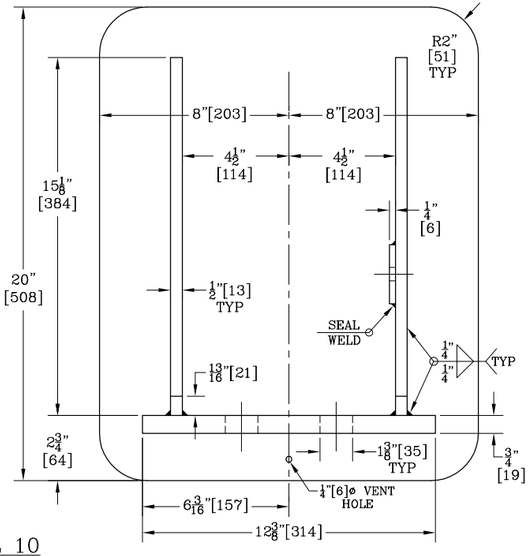
| | | | |
|---|---|---|---|
| DRAWN | RTC | 2–10–15 | |
| CHECKED | BT | 2–18–15 | |
| CERTIFIED | | | |
| SCALE | | | |

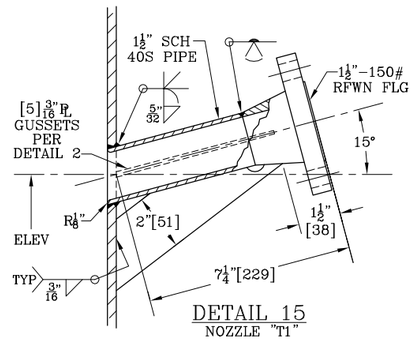
JOB NO. 293–03
15515–03–2
REV. 3



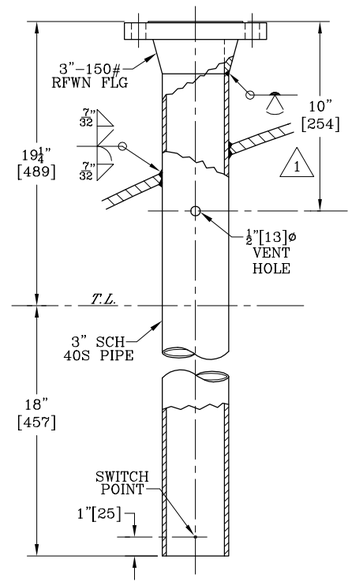




DETAIL 10
SUPPORT LUGS
(4 SUPPORT LUGS REQ'D, EQ SP)
(2) S/S GROUND CLIPS REQ'D, EQ SP.
SEE ELEV & PLAN FOR LOCATION.



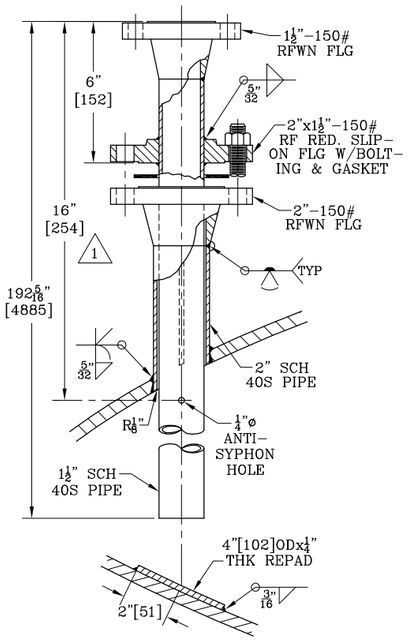




DETAIL 15
NOZZLE "T1"



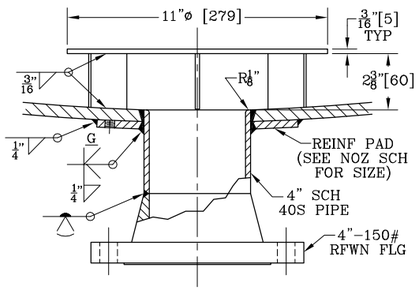

DETAIL 14
NOZZLE "L4"

AS-BUILT

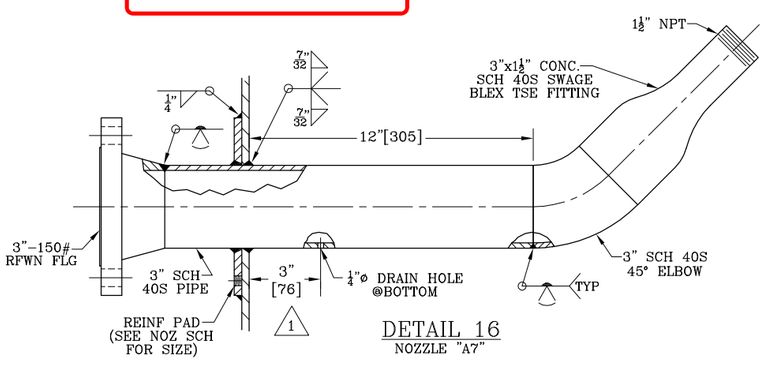



DETAIL 13
DIP-PIPE "A1 ON A2"

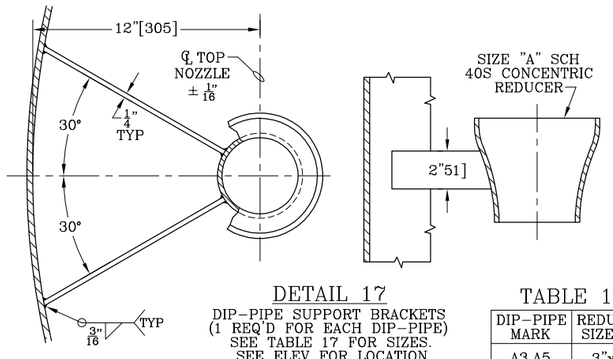



DETAIL 12
VORTEX BREAKER
@NOZZLE "B1"



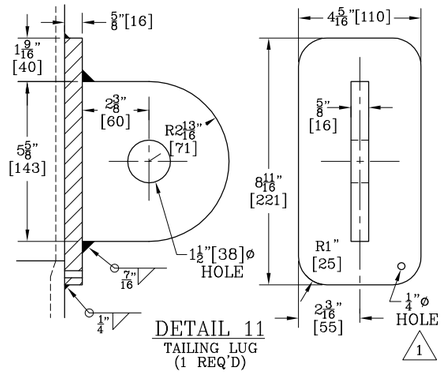

DETAIL 16
NOZZLE "A7"




DETAIL 17
DIP-PIPE SUPPORT BRACKETS
(1 REQ'D FOR EACH DIP-PIPE)
SEE TABLE 17 FOR SIZES.
SEE ELEV FOR LOCATION.

TABLE 17

| DIP-PIPE MARK | REDUCER SIZE "A" |
|---|---|
| A3,A5 | 3"x1 1/2" |
| A1 | 4"x2" |
| L1 | 6"x4" |




DETAIL 11
TAILING LUG
(1 REQ'D)

FRACTION TO MILLIMETER CONVERSION

| FRACTION | MM | FRACTION | MM |
|---|---|---|---|
| 1/8" | [3] | 9/16" | [14] |
| 3/16" | [5] | 5/8" | [16] |
| 1/4" | [6] | 11/16" | [17] |
| 5/16" | [8] | 3/4" | [19] |
| 3/8" | [10] | 13/16" | [21] |
| 7/16" | [11] | 7/8" | [22] |
| 1/2" | [13] | 15/16" | [24] |

DTV MAIN DWG: 15515-03-1

DESTINATION: THEODORE, AL

CERTIFIED

LETHAL SERVICE

REFERENCE:
CUST PO No: 4700984380
ITEM No: R-2210
PROJ No: 4142-00940
SPEC Nos: R-2210, REV 2; 20.230.013, REV 2; 20.230.030, REV 2; 20.230.036, R1; 20.230.032
CUST STDS: 25-0101-3; 25-0205-2; 25-0801-2; 25-0807; 25-0901 thru 25-0903; 25-0108; 25-0303

| MARK | REVISION DESCRIPTION | BY | CK'D | DATE |
|---|---|---|---|---|
| 1 | ADD VENT HOLE LOCATIONS; REV MATERIAL DTL 10 | RTC | BT | 11-3-15 |
| 0 | REV PER CUSTOMER APPROVAL | RTC | BT | 7-9-15 |
| A | REV PER CUSTOMER COMMENTS | RTC | BT | 5-5-15 |

DOMINION
Tank & Vessel Company, Inc.
1501 Valley Road, Richmond, VA 23222

78"ID ACA AFTER REACTOR R-2210
EVONIK CORPORATION
MOBILE ALABAMA PLANT
ACA PROJECT

DRAWN RTC 2-10-15
CHECKED BT 2-18-15
CERTIFIED
SCALE

JOB NO. 293-03
15515-03-3
REV. 1


# ASME Pressure Vessel Design Calculations

| | |
|---|---|
| **Item:** | ACA After Reactor |
| **Vessel No:** | R-2210 |
| **Customer:** | Evonik Corporation (Theodore, AL) |
| **Contract:** | 293-03 (DTV #15515-03) |
| **Designer:** | bturner |
| **Rev - Date:** | 2 - 07/20/2015 |

# Table of Contents

# Table of Contents

## Revision History

| Revisions | | | |
|---|---|---|---|
| **No.** | **Date** | **Operator** | **Notes** |
| 0 | 2/11/2015 | bturner | Customer Approval |
| 1 | 5/ 5/2015 | bturner | Revised per customer comments |
| 2 | 7/20/2015 | bturner | Revised per customer comments. Released for fabrication. |

## Pressure Summary

| Component Summary | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Identifier | P Design (psi) | T Design (°F) | MAWP (psi) | MAP (psi) | MAEP (psi) | $T_e$ external (°F) | MDMT (°F) | MDMT Exemption | Impact Tested |
| F&D Head (top) | 45 | 338 | 94.77 | 97.09 | 32.18 | 338 | -320 | Note 1 | No |
| Straight Flange on F&D Head (top) | 45 | 338 | 207.38 | 212.47 | 52.69 | 338 | -320 | Note 2 | No |
| Shell -02 | 45 | 338 | 128.62 | 133.17 | 20.36 | 338 | -320 | Note 3 | No |
| Shell -01 | 45 | 338 | 125.18 | 133.17 | 20.36 | 338 | -320 | Note 4 | No |
| Straight Flange on F&D Head (btm) | 45 | 338 | 202.52 | 212.47 | 52.81 | 338 | -320 | Note 6 | No |
| F&D Head (btm) | 45 | 338 | 89.44 | 97.09 | 32.18 | 338 | -320 | Note 5 | No |
| Support Lugs | 45 | 338 | 45 | N/A | N/A | N/A | N/A | N/A | N/A |
| Vacuum Ring | N/A | N/A | N/A | N/A | 17.92 | 338 | N/A | N/A | No |
| Mount for A1 (A2) | 45 | 338 | 167.01 | 171.11 | 32.18 | 338 | -55 | Note 7 | No |
| Mount for A3 (A4) | 45 | 338 | 167.01 | 171.11 | 32.18 | 338 | -55 | Note 7 | No |
| Mount for A5 (A6) | 45 | 338 | 167.01 | 171.11 | 32.18 | 338 | -55 | Note 7 | No |
| InTank Eductor Inlet (A7) | 45 | 338 | 125.29 | 133.17 | 20.36 | 338 | -55 | Nozzle / Note 7 | No |
| | | | | | | | | Pad / Note 4 | No |
| Liquid Outlet (B1) | 45 | 338 | 159.06 | 168.66 | 32.18 | 338 | -55 | Nozzle / Note 7 | No |
| | | | | | | | | Pad / Note 8 | No |
| Sight Glass (G1) | 45 | 338 | 138.31 | 171.11 | 32.18 | 338 | -55 | Note 9 | No |
| Mount for L1 (L2) | 45 | 338 | 99.53 | 101.97 | 24.29 | 338 | -55 | Note 7 | No |
| Level Switch - High (L4) | 45 | 338 | 120.97 | 123.93 | 30.62 | 338 | -55 | Note 7 | No |
| Manway w/Davit (M1) | 45 | 338 | 45.4 | 46.51 | 20.16 | 338 | -55 | Nozzle / Note 7 | No |
| | | | | | | | | Pad / Note 4 | No |
| Emergency Pressure Relief (R1) | 45 | 338 | 99.53 | 101.97 | 24.29 | 338 | -55 | Note 7 | No |
| Spare (S1) | 45 | 338 | 167.01 | 171.11 | 32.18 | 338 | -55 | Note 7 | No |
| Spare (S2) | 45 | 338 | 165.69 | 169.75 | 32.18 | 338 | -55 | Nozzle / Note 7 | No |
| | | | | | | | | Pad / Note 1 | No |
| Temperature Indicator (T1) | 45 | 338 | 125.31 | 133.17 | 20.36 | 338 | -55 | Note 7 | No |
| Vent (V1) | 45 | 338 | 167.01 | 171.11 | 32.18 | 338 | -55 | Note 7 | No |
| Off Gas Vent (V2) | 45 | 338 | 167.01 | 171.11 | 32.18 | 338 | -55 | Note 7 | No |

| Chamber Summary | |
|---|---|
| Design MDMT | -20 °F |
| Rated MDMT | -55 °F @ 45 psi |
| MAWP hot & corroded | 45 psi @ 338 °F |
| MAP cold & new | 46.51 psi @ 70 °F |
| MAEP | 17.92 psi @ 338 °F |
| (1) The MAWP is limited due to the MAWP limit set in the Calculations tab of the Set Mode dialog. | |

| Notes for MDMT Rating | | |
|---|---|---|
| **Note #** | **Exemption** | **Details** |
| 1. | Impact test exempt per UHA-51(g) (coincident ratio = 0.2628) | |
| 2. | Impact test exempt per UHA-51(g) (coincident ratio = 0.2105) | |
| 3. | Impact test exempt per UHA-51(g) (coincident ratio = 0.347) | |
| 4. | Rated MDMT per UHA-51(d)(1)(a), (carbon content does not exceed 0.10%) = -320°F | |
| 5. | Impact test exempt per UHA-51(g) (coincident ratio = 0.2939) | |
| 6. | Impact test exempt per UHA-51(g) (coincident ratio = 0.2333) | |
| 7. | Flange rating governs:<br>Flange rated MDMT per UHA-51(d)(1)(a) = -320°F<br>Bolts rated MDMT per Fig UCS-66 note (c) = -55°F | |
| 8. | Impact test exempt per UHA-51(g) (coincident ratio = 0.2953) | |
| 9. | Impact test exempt per UHA-51(g) (coincident ratio = 0.2628) | Bolts rated MDMT per Fig UCS-66 note (c) = -55°F |

## Vacuum Summary

| Largest Unsupported Length Le | | | |
|---|---|---|---|
| **Component** | **Line of Support** | **Elevation above Datum (in)** | **Length Le (in)** |
| F&D Head (top) | - | 181.6505 | N/A |
| - | 1/3 depth of F&D Head (top) | 172.4168 | N/A |
| Straight Flange on F&D Head (top) Top | - | 168 | 88.9168 |
| Straight Flange on F&D Head (top) Bottom | - | 166.5 | 88.9168 |
| Shell -02 Top | - | 166.5 | 88.9168 |
| Shell -02 Bottom | - | 97.5 | 88.9168 |
| Shell -01 Top | - | 97.5 | 88.9168 |
| - | Vacuum Ring | 83.5 | 88.4168 |
| Shell -01 Bottom | - | 1.5 | 88.9168 |
| Straight Flange on F&D Head (btm) Top | - | 1.5 | 87.9168 |
| Straight Flange on F&D Head (btm) Bottom | - | 0 | 87.9168 |
| - | 1/3 depth of F&D Head (btm) | -4.4168 | N/A |
| F&D Head (btm) | - | -13.6505 | N/A |
| For Rings, the listed value of 'Le' is Ls per UG-29. | | | |

## Thickness Summary

| Component Data | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Component Identifier | Material | Diameter (in) | Length (in) | Nominal t (in) | Design t (in) | Total Corrosion (in) | Joint E | Load |
| F&D Head (top) | SA-240 316L | 78 ID | 13.6505 | 0.4* | 0.2346 | 0 | 1.00 | External |
| Straight Flange on F&D Head (top) | SA-240 316L | 78 ID | 1.5 | 0.5 | 0.2743 | 0 | 1.00 | External |
| Shell -02 | SA-240 316L | 78 ID | 69 | 0.3125 | 0.2735 | 0 | 1.00 | External |
| Shell -01 | SA-240 316L | 78 ID | 96 | 0.3125 | 0.2735 | 0 | 1.00 | External |
| Straight Flange on F&D Head (btm) | SA-240 316L | 78 ID | 1.5 | 0.5 | 0.2731 | 0 | 1.00 | External |
| F&D Head (btm) | SA-240 316L | 78 ID | 13.6505 | 0.4* | 0.2346 | 0 | 1.00 | External |
| *Head minimum thickness after forming | | | | | | | | |

| Definitions | |
|---|---|
| Nominal t | Vessel wall nominal thickness |
| Design t | Required vessel thickness due to governing loading + corrosion |
| Joint E | Longitudinal seam joint efficiency |
| **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

| Weight (lb) Contributed by Vessel Elements | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Component | Metal New* | Metal Corroded | Insulation | Insulation Supports | Lining | Piping + Liquid | Operating Liquid | | Test Liquid | | Surface Area ft² |
| | | | | | | | New | Corroded | New | Corroded | |
| F&D Head (top) | 649.1 | 649.1 | 92 | 0 | 0 | 0 | 0 | 0 | 1,747.3 | 1,747.3 | 40 |
| Shell -02 | 1,538.4 | 1,538.4 | 242.7 | 0 | 0 | 0 | 6,508.5 | 6,508.5 | 11,901.5 | 11,901.5 | 118 |
| Shell -01 | 2,139.3 | 2,139.3 | 337.7 | 0 | 0 | 0 | 16,443.9 | 16,443.9 | 16,559.8 | 16,559.8 | 165 |
| F&D Head (btm) | 718.8 | 718.8 | 92 | 0 | 0 | 0 | 1,643.1 | 1,643.1 | 1,654.7 | 1,654.7 | 44 |
| Support Lugs | 493.3 | 493.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 27 |
| **TOTAL:** | **5,538.9** | **5,538.9** | **764.5** | **0** | **0** | **0** | **24,595.5** | **24,595.5** | **31,863.2** | **31,863.2** | **394** |
| *Shells with attached nozzles have weight reduced by material cut out for opening. | | | | | | | | | | | |

| Weight (lb) Contributed by Attachments | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Component | Body Flanges | | Nozzles & Flanges | | Packed Beds | Ladders & Platforms | Trays | Tray Supports | Rings & Clips | Vertical Loads | Surface Area ft² |
| | New | Corroded | New | Corroded | | | | | | | |
| F&D Head (top) | 0 | 0 | 1,065.5 | 1,065.5 | 0 | 0 | 0 | 0 | 0 | 0 | 28 |
| Shell -02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 49.8 | 0 | 2 |
| Shell -01 | 0 | 0 | 24.6 | 24.6 | 0 | 0 | 0 | 0 | 110.5 | 0 | 15 |
| F&D Head (btm) | 0 | 0 | 22.2 | 22.2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| **TOTAL:** | **0** | **0** | **1,112.3** | **1,112.3** | **0** | **0** | **0** | **0** | **160.3** | **0** | **46** |

| Vessel Totals | | |
|---|---|---|
| | New | Corroded |
| Operating Weight (lb) | 32,172 | 32,172 |
| Empty Weight (lb) | 7,576 | 7,576 |
| Test Weight (lb) | 38,675 | 38,675 |
| Surface Area (ft²) | 440 | - |
| Capacity** (US gal) | 3,810 | 3,810 |
| **The vessel capacity does not include volume of nozzle, piping or other attachments. | | |

| Vessel Lift Condition | |
|---|---|
| Vessel Lift Weight, New (lb) | 7,576 |
| Center of Gravity from Datum (in) | 100.9732 |

## Nozzle Schedule

| Specifications | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Nozzle mark** | **Identifier** | **Size** | **Materials** | | **Impact Tested** | **Normalized** | **Fine Grain** | **Flange** | **Blind** |
| A2 | Mount for A1 | NPS 2 Sch 40S (Std) | Nozzle | SA-312 TP316L Wld & smls pipe | No | No | No | NPS 2 Class 150 WN A182 F316L | NPS 2 Class 150 A182 F316L |
| A4 | Mount for A3 | NPS 1.5 Sch 40S (Std) | Nozzle | SA-312 TP316L Wld & smls pipe | No | No | No | NPS 1 1/2 Class 150 WN A182 F316L | NPS 1 1/2 Class 150 A182 F316L |
| A6 | Mount for A5 | NPS 1.5 Sch 40S (Std) | Nozzle | SA-312 TP316L Wld & smls pipe | No | No | No | NPS 1 1/2 Class 150 WN A182 F316L | NPS 1 1/2 Class 150 A182 F316L |
| A7 | InTank Eductor Inlet | NPS 3 Sch 40S (Std) | Nozzle | SA-312 TP316L Wld & smls pipe | No | No | No | NPS 3 Class 150 WN A182 F316L | No |
| | | | Pad | SA-240 316L | No | No | No | | |
| B1 | Liquid Outlet | NPS 4 Sch 40S (Std) | Nozzle | SA-312 TP316L Wld & smls pipe | No | No | No | NPS 4 Class 150 WN A182 F316L | No |
| | | | Pad | SA-240 316L | No | No | No | | |
| G1 | Sight Glass | 11 OD x 2.5 | Nozzle | SA-182 F316L <= 5 (low stress) | No | No | No | N/A | NPS 6 Class 150 A182 F316L |
| L2 | Mount for L1 | NPS 4 Sch 40S (Std) | Nozzle | SA-312 TP316L Wld & smls pipe | No | No | No | NPS 4 Class 150 WN A182 F316L | NPS 4 Class 150 A182 F316L |
| L4 | Level Switch - High | NPS 3 Sch 40S (Std) | Nozzle | SA-312 TP316L Wld & smls pipe | No | No | No | NPS 3 Class 150 WN A182 F316L | No |
| M1 | Manway w/Davit | 24 OD x 0.375 | Nozzle | SA-240 316L | No | No | No | NPS 24 Class 150 WN A182 F316L | NPS 24 Class 150 A182 F316L |
| | | | Pad | SA-240 316L | No | No | No | | |
| R1 | Emergency Pressure Relief | NPS 4 Sch 40S (Std) | Nozzle | SA-312 TP316L Wld & smls pipe | No | No | No | NPS 4 Class 150 WN A182 F316L | No |
| S1 | Spare | NPS 2 Sch 40S (Std) | Nozzle | SA-312 TP316L Wld & smls pipe | No | No | No | NPS 2 Class 150 WN A182 F316L | NPS 2 Class 150 A182 F316L |
| S2 | Spare | NPS 3 Sch 40S (Std) | Nozzle | SA-312 TP316L Wld & smls pipe | No | No | No | NPS 3 Class 150 WN A182 F316L | NPS 3 Class 150 A182 F316L |
| | | | Pad | SA-240 316L | No | No | No | | |
| T1 | Temperature Indicator | NPS 1.5 Sch 40S (Std) | Nozzle | SA-312 TP316L Wld & smls pipe | No | No | No | NPS 1 1/2 Class 150 WN A182 F316L | No |
| V1 | Vent | NPS 1.5 Sch 40S (Std) | Nozzle | SA-312 TP316L Wld & smls pipe | No | No | No | NPS 1 1/2 Class 150 WN A182 F316L | No |
| V2 | Off Gas Vent | NPS 1 Sch 40S (Std) | Nozzle | SA-312 TP316L Wld & smls pipe | No | No | No | NPS 1 Class 150 WN A182 F316L | No |

## Nozzle Summary

| Dimensions | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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) | | |
| A2 | 2.375 | 0.154 | 0.154 | Yes | Yes | 0.4* | N/A | | N/A | N/A | 0 | Exempt |
| A4 | 1.9 | 0.145 | 0.145 | Yes | Yes | 0.4* | N/A | | N/A | N/A | 0 | Exempt |
| A6 | 1.9 | 0.145 | 0.145 | Yes | Yes | 0.4* | N/A | | N/A | N/A | 0 | Exempt |
| A7 | 3.5 | 0.216 | 0.216 | Yes | Yes | 0.3125 | N/A | | 2 | 0.3125 | 0 | Exempt |
| B1 | 4.5 | 0.237 | 0.237 | Yes | Yes | 0.4* | 0.3943 | | 2 | 0.3125 | 0 | 100.0 |
| G1 | 11 | 2.5 | 0.3281 | Yes | Yes | 0.4* | 0.1077 | | N/A | N/A | 0 | 100.0 |
| L2 | 4.5 | 0.237 | 0.237 | Yes | Yes | 0.4* | 0.3158 | | N/A | N/A | 0 | 100.0 |
| L4 | 3.5 | 0.216 | 0.216 | Yes | Yes | 0.4* | 0.2897 | | N/A | N/A | 0 | 100.0 |
| M1 | 24 | 0.375 | 0.076 | Yes | Yes | 0.4* | 0.278 | | 2 | 0.3125 | 0 | 100.0 |
| R1 | 4.5 | 0.237 | 0.237 | Yes | Yes | 0.4* | 0.3158 | | N/A | N/A | 0 | 100.0 |
| S1 | 2.375 | 0.154 | 0.154 | Yes | Yes | 0.4* | N/A | | N/A | N/A | 0 | Exempt |
| S2 | 3.5 | 0.216 | 0.216 | Yes | Yes | 0.4* | 0.3968 | | 2 | 0.3125 | 0 | 100.0 |
| T1 | 1.9 | 0.145 | 0.145 | Yes | Yes | 0.3125 | N/A | | N/A | N/A | 0 | Exempt |
| V1 | 1.9 | 0.145 | 0.145 | Yes | Yes | 0.4* | N/A | | N/A | N/A | 0 | Exempt |
| V2 | 1.315 | 0.133 | 0.133 | Yes | Yes | 0.4* | N/A | | N/A | N/A | 0 | Exempt |
| *Head minimum thickness after forming | | | | | | | | | | | | |

| Definitions | |
|---|---|
| tn | Nozzle thickness |
| Req tn | 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 |

## Radiography Summary

| UG-116 Radiography | | | | | | | |
|---|---|---|---|---|---|---|---|
| Component | Longitudinal Seam | | Top Circumferential Seam | | Bottom Circumferential Seam | | Mark |
| | Category (Fig UW-3) | Radiography / Joint Type | Category (Fig UW-3) | Radiography / Joint Type | Category (Fig UW-3) | Radiography / Joint Type | |
| F&D Head (top) | A | Full UW-11(a) / Type 1 | N/A | N/A | B | Full UW-11(a) / Type 1 | RT1 |
| Shell -02 | A | Full UW-11(a) / Type 1 | B | Full UW-11(a) / Type 1 | B | Full UW-11(a) / Type 1 | RT1 |
| Shell -01 | A | Full UW-11(a) / Type 1 | B | Full UW-11(a) / Type 1 | B | Full UW-11(a) / Type 1 | RT1 |
| F&D Head (btm) | A | Full UW-11(a) / Type 1 | B | Full UW-11(a) / Type 1 | N/A | N/A | RT1 |
| **Nozzle** | **Longitudinal Seam** | | **Nozzle to Vessel Circumferential Seam** | | **Nozzle free end Circumferential Seam** | | |
| Mount for A1 (A2) | N/A | Seamless No RT | D | N/A / Type 7 | C | UW-11(a)(4) exempt / Type 1 | N/A |
| Mount for A3 (A4) | N/A | Seamless No RT | D | N/A / Type 7 | C | UW-11(a)(4) exempt / Type 1 | N/A |
| Mount for A5 (A6) | N/A | Seamless No RT | D | N/A / Type 7 | C | UW-11(a)(4) exempt / Type 1 | N/A |
| Sight Glass (G1) | N/A | Seamless No RT | D | N/A / Type 7 | N/A | N/A | N/A |
| Mount for L1 (L2) | N/A | Seamless No RT | D | N/A / Type 7 | C | UW-11(a)(4) exempt / Type 1 | N/A |
| Level Switch - High (L4) | N/A | Seamless No RT | D | N/A / Type 7 | C | UW-11(a)(4) exempt / Type 1 | N/A |
| Manway w/Davit (M1) | A | User Defined (E = 1.00) | D | N/A / Type 7 | C | Full UW-11(a) / Type 1 | RT1 |
| Off Gas Vent (V2) | N/A | Seamless No RT | D | N/A / Type 7 | C | UW-11(a)(4) exempt / Type 1 | N/A |
| Emergency Pressure Relief (R1) | N/A | Seamless No RT | D | N/A / Type 7 | C | UW-11(a)(4) exempt / Type 1 | N/A |
| Spare (S1) | N/A | Seamless No RT | D | N/A / Type 7 | C | UW-11(a)(4) exempt / Type 1 | N/A |
| Spare (S2) | N/A | Seamless No RT | D | N/A / Type 7 | C | UW-11(a)(4) exempt / Type 1 | N/A |
| Vent (V1) | N/A | Seamless No RT | D | N/A / Type 7 | C | UW-11(a)(4) exempt / Type 1 | N/A |
| InTank Eductor Inlet (A7) | N/A | Seamless No RT | D | N/A / Type 7 | C | UW-11(a)(4) exempt / Type 1 | N/A |
| Temperature Indicator (T1) | N/A | Seamless No RT | D | N/A / Type 7 | C | UW-11(a)(4) exempt / Type 1 | N/A |
| Liquid Outlet (B1) | N/A | Seamless No RT | D | N/A / Type 7 | C | UW-11(a)(4) exempt / Type 1 | N/A |
| **Nozzle Flange** | **Longitudinal Seam** | | **Flange Face** | | **Nozzle to Flange Circumferential Seam** | | |
| ASME B16.5/16.47 flange attached to Mount for A1 (A2) | N/A | Seamless No RT | N/A | N/A / Gasketed | C | UW-11(a)(4) exempt / Type 1 | N/A |
| ASME B16.5/16.47 flange attached to Mount for A3 (A4) | N/A | Seamless No RT | N/A | N/A / Gasketed | C | UW-11(a)(4) exempt / Type 1 | N/A |
| ASME B16.5/16.47 flange attached to Mount for A5 (A6) | N/A | Seamless No RT | N/A | N/A / Gasketed | C | UW-11(a)(4) exempt / Type 1 | N/A |
| ASME B16.5/16.47 flange attached to Mount for L1 (L2) | N/A | Seamless No RT | N/A | N/A / Gasketed | C | UW-11(a)(4) exempt / Type 1 | N/A |
| ASME B16.5/16.47 flange attached to Level Switch - High (L4) | N/A | Seamless No RT | N/A | N/A / Gasketed | C | UW-11(a)(4) exempt / Type 1 | N/A |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| ASME B16.5/16.47 flange attached to Manway w/Davit (M1) | N/A | Seamless No RT | N/A | N/A / Gasketed | C | Full UW-11(a) / Type 1 | RT1 |
| ASME B16.5/16.47 flange attached to Off Gas Vent (V2) | N/A | Seamless No RT | N/A | N/A / Gasketed | C | UW-11(a)(4) exempt / Type 1 | N/A |
| ASME B16.5/16.47 flange attached to Emergency Pressure Relief (R1) | N/A | Seamless No RT | N/A | N/A / Gasketed | C | UW-11(a)(4) exempt / Type 1 | N/A |
| ASME B16.5/16.47 flange attached to Spare (S1) | N/A | Seamless No RT | N/A | N/A / Gasketed | C | UW-11(a)(4) exempt / Type 1 | N/A |
| ASME B16.5/16.47 flange attached to Spare (S2) | N/A | Seamless No RT | N/A | N/A / Gasketed | C | UW-11(a)(4) exempt / Type 1 | N/A |
| ASME B16.5/16.47 flange attached to Vent (V1) | N/A | Seamless No RT | N/A | N/A / Gasketed | C | UW-11(a)(4) exempt / Type 1 | N/A |
| ASME B16.5/16.47 flange attached to InTank Eductor Inlet (A7) | N/A | Seamless No RT | N/A | N/A / Gasketed | C | UW-11(a)(4) exempt / Type 1 | N/A |
| ASME B16.5/16.47 flange attached to Temperature Indicator (T1) | N/A | Seamless No RT | N/A | N/A / Gasketed | C | UW-11(a)(4) exempt / Type 1 | N/A |
| ASME B16.5/16.47 flange attached to Liquid Outlet (B1) | N/A | Seamless No RT | N/A | N/A / Gasketed | C | UW-11(a)(4) exempt / Type 1 | N/A |
| UG-116(e) Required Marking: **RT1** | | | | | | | |

## Hydrostatic Test

**Horizontal shop hydrostatic test based on MAWP per UG-99(b)**

Gauge pressure at 70°F =
1.3*MAWP*LSR
= 1.3*45*1.0245
= 59.93 psi

| Horizontal shop hydrostatic test | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Identifier** | **Local test pressure (psi)** | **Test liquid static head (psi)** | **UG-99(b) stress ratio** | **UG-99(b) pressure factor** | **Stress during test (psi)** | **Allowable test stress (psi)** | **Stress excessive?** |
| F&D Head (top) (1) | 62.749 | 2.816 | 1.0245 | 1.30 | 6,118 | 22,500 | No |
| Straight Flange on F&D Head (top) | 62.749 | 2.816 | 1.0245 | 1.30 | 4,926 | 22,500 | No |
| Shell -02 | 62.749 | 2.816 | 1.0245 | 1.30 | 7,862 | 22,500 | No |
| Shell -01 | 62.749 | 2.816 | 1.0245 | 1.30 | 7,862 | 22,500 | No |
| Straight Flange on F&D Head (btm) | 62.749 | 2.816 | 1.0245 | 1.30 | 4,926 | 22,500 | No |
| F&D Head (btm) | 62.749 | 2.816 | 1.0245 | 1.30 | 6,118 | 22,500 | No |
| Emergency Pressure Relief (R1) | 60.53 | 0.597 | 1.0245 | 1.30 | 10,777 | 33,750 | No |
| InTank Eductor Inlet (A7) | 61.396 | 1.463 | 1.0245 | 1.30 | 6,798 | 33,750 | No |
| Level Switch - High (L4) | 61.396 | 1.463 | 1.0245 | 1.30 | 8,487 | 33,750 | No |
| Liquid Outlet (B1) | 61.414 | 1.481 | 1.0245 | 1.30 | 7,280 | 33,750 | No |
| Manway w/Davit (M1) | 61.761 | 1.827 | 1.0245 | 1.30 | 21,324 | 33,750 | No |
| Mount for A1 (A2) | 60.891 | 0.958 | 1.0245 | 1.30 | 10,834 | 33,750 | No |
| Mount for A3 (A4) | 61.857 | 1.924 | 1.0245 | 1.30 | 10,785 | 33,750 | No |
| Mount for A5 (A6) | 60.526 | 0.593 | 1.0245 | 1.30 | 10,552 | 33,750 | No |
| Mount for L1 (L2) | 61.414 | 1.481 | 1.0245 | 1.30 | 10,934 | 33,750 | No |
| Off Gas Vent (V2) | 62.204 | 2.271 | 1.0245 | 1.30 | 10,397 | 33,750 | No |
| Sight Glass (G1) | 62.33 | 2.397 | 1.3577 | 1.30 | 8,520 | 33,750 | No |
| Spare (S1) | 60.909 | 0.976 | 1.0245 | 1.30 | 10,344 | 33,750 | No |
| Spare (S2) | 61.866 | 1.932 | 1.0245 | 1.30 | 6,834 | 33,750 | No |
| Temperature Indicator (T1) | 60.358 | 0.425 | 1.0245 | 1.30 | 12,852 | 33,750 | No |
| Vent (V1) | 60.395 | 0.462 | 1.0245 | 1.30 | 10,530 | 33,750 | No |

(1) F&D Head (top) limits the UG-99(b) stress ratio.
(2) $P_L$ stresses at nozzle openings have been estimated using the method described in Division 2 Part 4.5.
(3) $1.5*0.9*S_y$ used as the basis for the maximum local primary membrane stress at the nozzle intersection $P_L$.
(4) The zero degree angular position is assumed to be up, and the test liquid height is assumed to the top-most flange.

The field test condition has not been investigated.

| Building Code: IBC 2009<br>(Wind loads determined in accordance with ASCE 7-05) | | |
|---|---|---|
| **Elevation of base above grade** | | 62.0000 ft |
| **Increase effective outer diameter by** | | 1.0000 ft |
| **Wind Force Coefficient, Cf** | | 0.7000 |
| **Occupancy Category (Table 1-1)** | | III |
| **Basic Wind Speed, V** | | 140.0000 mph |
| **Importance Factor, I** | | 1.1500 |
| **Exposure category** | | C |
| **Wind Directionality Factor, Kd** | | 0.9500 |
| **Topographic Factor, Kzt** | | 1.0000 |
| **Enforce min. loading of 10 psf** | | Yes |
| **Vessel Characteristics** | | |
| **Height, h** | | 3.0594 ft |
| **Minimum Diameter, b** | Operating, Corroded | 6.8854 ft |
| | Empty, Corroded | 6.8854 ft |
| | Hydrotest, Corroded, Field | 6.5521 ft |
| **Fundamental Frequency, $n_1$** | Operating, Corroded | 40.5263 Hz |
| | Empty, Corroded | 94.3023 Hz |
| | Hydrotest, Corroded, Field | 41.8902 Hz |
| | Vacuum, Corroded | 40.5263 Hz |
| **Damping coefficient, $\beta$** | Operating, Corroded | 0.0255 |
| | Empty, Corroded | 0.0210 |
| | Hydrotest, Corroded, Field | 0.0260 |
| | Vacuum, Corroded | 0.0255 |

Table Lookup Values

| 2.4.1 Basic Load Combinations for Allowable Stress Design | |
|---|---|
| **Load combinations considered in accordance with ASCE section 2.4.1:** | |
| 5. | $D + P + P_s + W$ |
| 7. | $0.6D + P + P_s + W$ |
| **Parameter Description** | |
| $D$ | = Dead load |
| $P$ | = Internal or external pressure load |
| $P_s$ | = Static head load |
| $W$ | = Wind load |

**Wind Deflection Reports:**



| Wind Deflection Report: Operating, Corroded | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Component** | **Elevation of Bottom above Base (in)** | **Effective OD (ft)** | **Elastic Modulus E ($10^6$ psi)** | **Inertia I ($ft^4$)** | **Platform Wind Shear at Bottom ($lb_f$)** | **Total Wind Shear at Bottom ($lb_f$)** | **Bending Moment at Bottom ($lb_f$-ft)** | **Deflection at Top (in)** |
| F&D Head (top) | 21.5625 | 7.91 | 26.8 | * | 0 | 331 | 1,576 | 0 |
| Shell -02 (top) | 0 | 7.89 | 26.8 | 2.842 | 0 | 912 | 2,693 | 0 |
| Shell -02 (bottom) | 0 | 7.89 | 26.8 | 2.842 | 0 | 4,070 | 26,328 | 0.0002 |
| Shell -01 | -47.4375 | 7.89 | 26.8 | 2.842 | 0 | 2,813 | 12,744 | 0.0011 |
| F&D Head (btm) | -143.4375 | 7.91 | 26.8 | * | 0 | 309 | 168 | 0.0012 |
| *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 ($lb_f$) | Total Wind Shear at Bottom ($lb_f$) | Bending Moment at Bottom ($lb_f$-ft) | Deflection at Top (in) |
| F&D Head (top) | 21.5625 | 7.91 | 28.3 | * | 0 | 331 | 1,576 | 0 |
| Shell -02 (top) | 0 | 7.89 | 28.3 | 2.842 | 0 | 912 | 2,693 | 0 |
| Shell -02 (bottom) | 0 | 7.89 | 28.3 | 2.842 | 0 | 4,070 | 26,328 | 0.0002 |
| Shell -01 | -47.4375 | 7.89 | 28.3 | 2.842 | 0 | 2,813 | 12,744 | 0.001 |
| F&D Head (btm) | -143.4375 | 7.91 | 28.3 | * | 0 | 309 | 168 | 0.0012 |
| *Moment of Inertia I varies over the length of the component | | | | | | | | |

| Wind Deflection Report: Vacuum, 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 ($lb_f$) | Total Wind Shear at Bottom ($lb_f$) | Bending Moment at Bottom ($lb_f$-ft) | Deflection at Top (in) |
| F&D Head (top) | 21.5625 | 7.91 | 26.8 | * | 0 | 331 | 1,576 | 0 |
| Shell -02 (top) | 0 | 7.89 | 26.8 | 2.842 | 0 | 912 | 2,693 | 0 |
| Shell -02 (bottom) | 0 | 7.89 | 26.8 | 2.842 | 0 | 4,070 | 26,328 | 0.0002 |
| Shell -01 | -47.4375 | 7.89 | 26.8 | 2.842 | 0 | 2,813 | 12,744 | 0.0011 |
| F&D Head (btm) | -143.4375 | 7.91 | 26.8 | * | 0 | 309 | 168 | 0.0012 |
| *Moment of Inertia I varies over the length of the component | | | | | | | | |

| Wind Deflection Report: Field Hydrotest, 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 ($lb_f$) | Total Wind Shear at Bottom ($lb_f$) | Bending Moment at Bottom ($lb_f$-ft) | Deflection at Top (in) |
| F&D Head (top) | 21.5625 | 7.91 | 28.3 | * | 0 | 104 | 1,452 | 0 |
| Shell -02 (top) | 0 | 7.89 | 28.3 | 2.842 | 0 | 287 | 1,803 | 0 |
| Shell -02 (bottom) | 0 | 7.89 | 28.3 | 2.842 | 0 | 1,286 | 8,371 | 0.0001 |
| Shell -01 | -47.4375 | 7.89 | 28.3 | 2.842 | 0 | 888 | 4,080 | 0.0003 |
| F&D Head (btm) | -143.4375 | 7.91 | 28.3 | * | 0 | 97 | 52 | 0.0004 |
| *Moment of Inertia I varies over the length of the component | | | | | | | | |

### Wind Pressure (WP) Calculations

Gust Factor ($G^-$) Calculations

$Kz = 2.01 * (Z/Zg)^{2/\alpha}$

$= 2.01 * (Z/900.0000)^{0.2105}$

$qz = 0.00256 * Kz * Kzt * Kd * V^2 * I$

$= 0.00256 * Kz * 1.0000 * 0.9500 * 140.0000^2 * 1.1500$

$= 54.8173 * Kz$

$WP = qz * G * Cf$ (Minimum 10 $lb/ft^2$)

$= qz * G * 0.7000$ (Minimum 10 $lb/ft^2$)

| Design Wind Pressures | | | | | | | |
|---|---|---|---|---|---|---|---|
| Height Z (') | Kz | qz (psf) | WP (psf) | | | | |
| | | | Operating | Empty | Hydrotest New | Hydrotest Corroded | Vacuum |
| 15.0 | 0.8489 | 46.53 | 29.65 | 29.65 | N.A. | 10.00 | 29.65 |
| 20.0 | 0.9019 | 49.44 | 31.50 | 31.50 | N.A. | 10.40 | 31.50 |
| 25.0 | 0.9453 | 51.82 | 33.01 | 33.01 | N.A. | 10.90 | 33.01 |
| 30.0 | 0.9823 | 53.84 | 34.30 | 34.30 | N.A. | 11.32 | 34.30 |
| 40.0 | 1.0436 | 57.21 | 36.45 | 36.45 | N.A. | 12.03 | 36.45 |
| 50.0 | 1.0938 | 59.96 | 38.20 | 38.20 | N.A. | 12.61 | 38.20 |
| 60.0 | 1.1366 | 62.30 | 39.69 | 39.69 | N.A. | 13.10 | 39.69 |
| 70.0 | 1.1741 | 64.36 | 41.00 | 41.00 | N.A. | 13.54 | 41.00 |
| Design Wind Force determined from: F = Pressure * Af , where Af is the projected area. | | | | | | | |

**Gust Factor Calculations**

Operating, Corroded
Empty, Corroded
Vacuum, Corroded
Hydrotest, Corroded, field

**Gust Factor Calculations: Operating, Corroded**

Vessel is considered a rigid structure as $n_1$ = 40.5263 Hz ≥ 1 Hz.

$z^-$ = max ( 0.60 * h , $z_{min}$ )
= max ( 0.60 * 3.0594 , 15.0000 )
= 15.0000

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

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

Q = Sqr(1 / (1 + 0.63 * ((b + h) / $L_{z^-}$)$^{0.63}$))
= Sqr(1 / (1 + 0.63 * ((6.8854 + 3.0594) / 427.0566)$^{0.63}$))
= 0.9718

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* 0.2281 * 0.9718) / (1 + 1.7 * 3.40 * 0.2281)
= 0.9101

**Gust Factor Calculations: Empty, Corroded**

Vessel is considered a rigid structure as $n_1$ = 94.3023 Hz ≥ 1 Hz.

$z^- = \max ( 0.60 * h , z_{min} )$
$= \max ( 0.60 * 3.0594 , 15.0000 )$
$= 15.0000$
$I_{z^-} = c * (33 / z^-)^{1/6}$
$= 0.2000 * (33 / 15.0000)^{1/6}$
$= 0.2281$
$L_{z^-} = l * (z^- / 33)^{ep}$
$= 500.0000 * (15.0000 / 33)^{0.2000}$
$= 427.0566$
$Q = Sqr(1 / (1 + 0.63 * ((b + h) / L_{z^-})^{0.63}))$
$= Sqr(1 / (1 + 0.63 * ((6.8854 + 3.0594) / 427.0566)^{0.63}))$
$= 0.9718$
$G = 0.925 * (1 + 1.7 * g_Q * I_{z^-} * Q) / (1 + 1.7 * g_v * I_{z^-})$
$= 0.925 * (1 + 1.7 * 3.40* 0.2281 * 0.9718) / (1 + 1.7 * 3.40 * 0.2281)$
$= 0.9101$

**Gust Factor Calculations: Vacuum, Corroded**

Vessel is considered a rigid structure as $n_1 = 40.5263$ Hz ≥ 1 Hz.

$z^- = \max ( 0.60 * h , z_{min} )$
$= \max ( 0.60 * 3.0594 , 15.0000 )$
$= 15.0000$
$I_{z^-} = c * (33 / z^-)^{1/6}$
$= 0.2000 * (33 / 15.0000)^{1/6}$
$= 0.2281$
$L_{z^-} = l * (z^- / 33)^{ep}$
$= 500.0000 * (15.0000 / 33)^{0.2000}$
$= 427.0566$
$Q = Sqr(1 / (1 + 0.63 * ((b + h) / L_{z^-})^{0.63}))$
$= Sqr(1 / (1 + 0.63 * ((6.8854 + 3.0594) / 427.0566)^{0.63}))$
$= 0.9718$
$G = 0.925 * (1 + 1.7 * g_Q * I_{z^-} * Q) / (1 + 1.7 * g_v * I_{z^-})$
$= 0.925 * (1 + 1.7 * 3.40* 0.2281 * 0.9718) / (1 + 1.7 * 3.40 * 0.2281)$
$= 0.9101$

**Gust Factor Calculations: Hydrotest, Corroded, field**

Vessel is considered a rigid structure as $n_1 = 41.8902$ Hz ≥ 1 Hz.

$z^- = \max ( 0.60 * h , z_{min} )$
$= \max ( 0.60 * 3.0594 , 15.0000 )$
$= 15.0000$
$I_{z^-} = c * (33 / z^-)^{1/6}$
$= 0.2000 * (33 / 15.0000)^{1/6}$
$= 0.2281$
$L_{z^-} = l * (z^- / 33)^{ep}$

$= 500.0000 * (15.0000 / 33)^{0.2000}$

$= 427.0566$

$Q = Sqr(1 / (1 + 0.63 * ((b + h) / L_{z^-})^{0.63}))$

$= Sqr(1 / (1 + 0.63 * ((6.8854 + 3.0594) / 427.0566)^{0.63}))$

$= 0.9723$

$G = 0.925 * (1 + 1.7 * g_Q * I_{z^-} * Q) / (1 + 1.7 * g_v * I_{z^-})$

$= 0.925 * (1 + 1.7 * 3.40* 0.2281 * 0.9723) / (1 + 1.7 * 3.40 * 0.2281)$

$= 0.9104$

| Table Lookup Values | |
|---|---|
| $\alpha = 9.5000$, $z_g = 900.0000$ ft | [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] |
| $z_{min} = 15.0000$ ft | [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] |

| Building Code: IBC 2009 building mounted (Seismic loads determined in accordance with ASCE 7-05) | | |
|---|---|---|
| **Site Class** | | D |
| **Spectral Response Acceleration at short period (% g), $S_s$** | | 11.00% |
| **Spectral Response Acceleration at period of 1 sec (% g), $S_1$** | | 5.10% |
| **Response Modification Factor from Table 13.6-1, $R_p$** | | 3.0000 |
| **Importance Factor, $I_p$** | | 1.5000 |
| **Amplification factor from Table 13.6-1, $a_p$** | | 1.0000 |
| **z/h Ratio** | | 0.8600 |
| **Acceleration-based Site Coefficient, $F_a$** | | 1.6000 |
| **Velocity-based Site Coefficient, $F_v$** | | 2.4000 |
| **Redundancy factor, ρ** | | 1.0000 |
| **Occupancy Category (Table 1-1)** | | III |
| **User Defined Vertical Accelerations Considered** | | No |
| **Vessel Characteristics** | | |
| **Height** | | 3.0594 ft |
| **Weight** | Operating, Corroded | 32,172 lb |
| | Empty, Corroded | 7,576 lb |
| | Vacuum, Corroded | 32,172 lb |
| **Period of Vibration Calculation** | | |
| **Fundamental Period, T** | Operating, Corroded | 0.025 sec (f = 40.5 Hz) |
| | Empty, Corroded | 0.011 sec (f = 94.3 Hz) |
| | Vacuum, Corroded | 0.025 sec (f = 40.5 Hz) |

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

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

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

| 12.4.2.3 Basic Load Combinations for Allowable Stress Design | | | |
|---|---|---|---|
| **Load combinations considered in accordance with ASCE section 2.4.1:** | | | |
| 5. | $D + P + P_s + 0.7E$ | $= (1.0 + 0.14S_{DS})D + P + P_s + 0.7\rho Q_E$ | |
| 8. | $0.6D + P + P_s + 0.7E$ | $= (0.6 - 0.14S_{DS})D + P + P_s + 0.7\rho Q_E$ | |
| **Parameter description** | | | |
| $D$ | = Dead load | | |
| $P$ | = Internal or external pressure load | | |
| $P_s$ | = Static head load | | |
| $E$ | = Seismic load | $= E_h$ +/- $E_v$ | $= \rho Q_E$ +/- $0.2S_{DS}D$ |

**Seismic Shear Reports:**

Operating, Corroded
Empty, Corroded
Vacuum, 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 ($lb_f$)** | **Bending Moment at Bottom ($lb_f$-ft)** |
| F&D Head (top) | 21.5625 | 26.8 | * | 35 | 1,432 |
| Shell -02 (top) | 0 | 26.8 | 2.8424 | 39 | 1,500 |
| Shell -02 (bottom) | 0 | 26.8 | 2.8424 | 1,397 | 12,221 |
| Shell -01 | -47.4375 | 26.8 | 2.8424 | 1,272 | 6,855 |
| F&D Head (btm) | -143.4375 | 26.8 | * | 215 | 112 |
| *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 ($lb_f$)** | **Bending Moment at Bottom ($lb_f$-ft)** |
| F&D Head (top) | 21.5625 | 28.3 | * | 44 | 1,440 |
| Shell -02 (top) | 0 | 28.3 | 2.8424 | 48 | 1,524 |
| Shell -02 (bottom) | 0 | 28.3 | 2.8424 | 288 | 2,804 |
| Shell -01 | -47.4375 | 28.3 | 2.8424 | 267 | 1,692 |
| F&D Head (btm) | -143.4375 | 28.3 | * | 90 | 59 |
| *Moment of Inertia I varies over the length of the component | | | | | |

| Seismic Shear Report: Vacuum, Corroded | | | | | |
|---|---|---|---|---|---|
| Component | Elevation of Bottom above Base (in) | Elastic Modulus E ($10^6$ psi) | Inertia I ($ft^4$) | Seismic Shear at Bottom ($lb_f$) | Bending Moment at Bottom ($lb_f$-ft) |
| F&D Head (top) | 21.5625 | 26.8 | * | 35 | 1,432 |
| Shell -02 (top) | 0 | 26.8 | 2.8424 | 39 | 1,500 |
| Shell -02 (bottom) | 0 | 26.8 | 2.8424 | 1,397 | 12,221 |
| Shell -01 | -47.4375 | 26.8 | 2.8424 | 1,272 | 6,855 |
| F&D Head (btm) | -143.4375 | 26.8 | * | 215 | 112 |
| *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, $S_{MS}$
$S_{MS} = F_a * S_s = 1.6000 * 11.00 / 100 = 0.1760$
The maximum considered earthquake spectral response acceleration at 1 s period, $S_{M1}$
$S_{M1} = F_v * S_1 = 2.4000 * 5.10 / 100 = 0.1224$

### 11.4.4: Design spectral response acceleration parameters

Design earthquake spectral response acceleration at short period, $S_{DS}$
$S_{DS} = 2 / 3 * S_{MS} = 2 / 3 * 0.1760 = 0.1173$
Design earthquake spectral response acceleration at 1 s period, $S_{D1}$
$S_{D1} = 2 / 3 * S_{M1} = 2 / 3 * 0.1224 = 0.0816$

### 11.6 Seismic Design Category

The Occupancy Category is III.
From Table 11.6-1, the Seismic Design Category based on $S_{Ds} = 0.1173$ is A.
From Table 11.6-2, the Seismic Design Category based on $S_{D1} = 0.0816$ is B.
This vessel is assigned to Seismic Design Category B.

### 12.4.2.3: Seismic Load Combinations: Vertical Term

Factor is applied to dead load.

Compressive Side: $= 1.0 + 0.14 * S_{DS}$
$= 1.0 + 0.14 * 0.1173$
$= 1.0164$
Tensile Side: $= 0.6 - 0.14 * S_{DS}$
$= 0.6 - 0.14 * 0.1173$
$= 0.5836$

### Base Shear Calculations

Operating, Corroded
Empty, Corroded
Vacuum, Corroded

**Base Shear Calculations: Operating, Corroded**

The base shear $F_p$ is as per Equation 13.3-1 below, provided its value is between $F_{pMin}$ and $F_{pMax}$

$F_p$ = 0.40 * $a_p$ * $S_{DS}$ * $W_p$ / ($R_p$ / $I_p$) * (1 + 2 * z / h)
= 0.40 * 1.0000 * 0.1173 * 32,171.5586/ (3.0000 / 1.5000) * (1 + 2 * 0.8600)
= 2,053.4890 lb

$F_{pMin}$ = 0.30 * $S_{DS}$ * $I_p$ * $W_p$
= 0.30 * 0.1173 * 1.5000 * 32,171.5586
= 1,698.66 lb

$F_{pMax}$ = 1.60 * $S_{DS}$ * $I_p$ * $W_p$
= 1.60 * 0.1173 * 1.5000 * 32,171.5586
= 9,059.51 lb

$F_p$ = 2,053.49 lb

**12.4.2.1 Seismic Load Combinations: Horizontal Seismic Load Effect, $E_h$**

$Q_E$ = $F_p$
$E_h$ = 0.7 * ρ * $Q_E$ (Only 70% of seismic load considered as per Section 2.4.1)
= 0.70 * 1.0000 * 2,053.49
= 1,437.44 lb

**Base Shear Calculations: Empty, Corroded**

The base shear $F_p$ is as per Equation 13.3-1 below, provided its value is between $F_{pMin}$ and $F_{pMax}$

$F_p$ = 0.40 * $a_p$ * $S_{DS}$ * $W_p$ / ($R_p$ / $I_p$) * (1 + 2 * z / h)
= 0.40 * 1.0000 * 0.1173 * 7,576.0244/ (3.0000 / 1.5000) * (1 + 2 * 0.8600)
= 483.5726 lb

$F_{pMin}$ = 0.30 * $S_{DS}$ * $I_p$ * $W_p$
= 0.30 * 0.1173 * 1.5000 * 7,576.0244
= 400.01 lb

$F_{pMax}$ = 1.60 * $S_{DS}$ * $I_p$ * $W_p$
= 1.60 * 0.1173 * 1.5000 * 7,576.0244
= 2,133.41 lb

$F_p$ = 483.57 lb

**12.4.2.1 Seismic Load Combinations: Horizontal Seismic Load Effect, $E_h$**

$Q_E$ = $F_p$
$E_h$ = 0.7 * ρ * $Q_E$ (Only 70% of seismic load considered as per Section 2.4.1)
= 0.70 * 1.0000 * 483.57
= 338.50 lb

**Base Shear Calculations: Vacuum, Corroded**

The base shear $F_p$ is as per Equation 13.3-1 below, provided its value is between $F_{pMin}$ and $F_{pMax}$

$F_p$ = 0.40 * $a_p$ * $S_{DS}$ * $W_p$ / ($R_p$ / $I_p$) * (1 + 2 * z / h)
= 0.40 * 1.0000 * 0.1173 * 32,171.5586/ (3.0000 / 1.5000) * (1 + 2 * 0.8600)
= 2,053.4890 lb

$F_{pMin}$ = 0.30 * $S_{DS}$ * $I_p$ * $W_p$
= 0.30 * 0.1173 * 1.5000 * 32,171.5586
= 1,698.66 lb

$F_{pMax}$ = 1.60 * $S_{DS}$ * $I_p$ * $W_p$
= 1.60 * 0.1173 * 1.5000 * 32,171.5586
= 9,059.5107 lb

$F_p$ = 2,053.49 lb

**12.4.2.1 Seismic Load Combinations: Horizontal Seismic Load Effect, $E_h$**

$Q_E$ = $F_p$
$E_h$ = 0.7 * ρ * $Q_E$ (Only 70% of seismic load considered as per Section 2.4.1)
= 0.70 * 1.0000 * 2,053.49
= 1,437.44 lb

## Liquid Level

| ASME Section VIII Division 1, 2013 Edition | |
|---|---|
| **Location from Datum (in)** | 135.5 |
| **Operating Liquid Specific Gravity** | 0.993 |

## Support Lugs

| Inputs | |
|---|---|
| **Support material** | SA-240 304L |
| **This support is attached to** | Shell -02 |
| **Distance from baseplate to datum** | 144.9375" |
| **Lug allowable stress, $S_b$** | 16,700 psi |
| **Shell to center of load bearing area, d** | 10.3125" |
| **Lug length, circumferential direction, L** | 12.375" |
| **Lug attachment fillet weld size** | 0.25" |
| **Radial/bending lug stiffness ratio** | 2 |
| **Number of support lugs** | 4 |
| **Local Shell** | |
| **Outer Diameter** | 78.625" |
| **Thickness** | 0.3125" |
| **Inner Corrosion** | 0" |
| **Outer Corrosion** | 0" |
| **Base Plate** | |
| **Width, b** | 16.375" |
| **Thickness, $t_b$** | 0.75" |
| **Load Bearing Width, $L_b$** | 8.0625" |
| **Gusset** | |
| **Height, h** | 15.125" |
| **Thickness, $t_g$** | 0.5" |
| **Separation, $L_g$** | 9" |
| **Reinforcing Pad** | |
| **Width, Circumferential Direction** | 16" |
| **Length, Longitudinal Direction** | 20" |
| **Thickness, $t_e$** | 0.5" |
| **Attachment Fillet Weld Size** | 0.25" |

## Stresses in Shell at Lug Supports

| Condition | Total Weight (lb) | Shear V ($lb_f$) | Moment M ($lb_f$-ft) | Lug orient | Lug Loading | | | | | | Stress in Shell (psi) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | W (lb) | $P_r$ ($lb_f$) | $V_L$ ($lb_f$) | $M_L$ ($lb_f$-ft) | $V_c$ ($lb_f$) | $M_c$ ($lb_f$-ft) | Primary Circ ($P_L$) | Primary Long ($P_L$) | Combined $P_L+P_b+Q$ |
| **Wind, operating Attack angle = 0°** | 32,172 | 4,982 | 23,635 | 0° | 4,826 | -1,661 | 1,968 | 1,691.36 | 0 | 0.00 | 8,191 | 4,212 | 13,220 |
| | | | | 90° | 8,043 | 0 | 8,043 | 6,911.86 | 830 | 713.59 | 10,032 | 5,292 | 29,414 |
| | | | | 180° | 8,043 | 1,661 | 10,901 | 9,367.61 | 0 | 0.00 | 10,107 | 5,628 | 38,846 |
| | | | | 270° | 8,043 | 0 | 8,043 | 6,911.86 | -830 | -713.59 | 10,032 | 5,292 | 29,414 |
| **Wind, operating Attack angle = 45°** | 32,172 | 4,982 | 23,635 | 0° | 4,826 | -881 | 2,805 | 2,410.63 | -881 | -756.88 | 7,948 | 4,370 | 14,730 |
| | | | | 90° | 4,826 | -881 | 2,805 | 2,410.63 | 881 | 756.88 | 7,948 | 4,370 | 14,730 |
| | | | | 180° | 8,043 | 881 | 10,064 | 8,648.34 | 881 | 756.88 | 10,349 | 5,627 | 35,523 |
| | | | | 270° | 8,043 | 881 | 10,064 | 8,648.34 | -881 | -756.88 | 10,349 | 5,627 | 35,523 |
| **Wind, operating, new Attack angle = 0°** | 32,172 | 4,982 | 23,635 | 0° | 4,826 | -1,661 | 1,968 | 1,691.36 | 0 | 0.00 | 8,191 | 4,212 | 13,220 |
| | | | | 90° | 8,043 | 0 | 8,043 | 6,911.86 | 830 | 713.59 | 10,032 | 5,292 | 29,414 |
| | | | | 180° | 8,043 | 1,661 | 10,901 | 9,367.61 | 0 | 0.00 | 10,107 | 5,628 | 38,846 |
| | | | | 270° | 8,043 | 0 | 8,043 | 6,911.86 | -830 | -713.59 | 10,032 | 5,292 | 29,414 |
| **Wind, operating, new Attack angle = 45°** | 32,172 | 4,982 | 23,635 | 0° | 4,826 | -881 | 2,805 | 2,410.63 | -881 | -756.88 | 7,948 | 4,370 | 14,730 |
| | | | | 90° | 4,826 | -881 | 2,805 | 2,410.63 | 881 | 756.88 | 7,948 | 4,370 | 14,730 |
| | | | | 180° | 8,043 | 881 | 10,064 | 8,648.34 | 881 | 756.88 | 10,349 | 5,627 | 35,523 |
| | | | | 270° | 8,043 | 881 | 10,064 | 8,648.34 | -881 | -756.88 | 10,349 | 5,627 | 35,523 |
| **Wind, empty, new Attack angle = 0°** | 7,576 | 4,982 | 23,635 | 0° | 1,136 | -1,661 | -1,721 | -1,479.16 | 0 | 0.00 | 2,439 | 1,404 | 7,646 |
| | | | | 90° | 1,894 | 0 | 1,894 | 1,627.66 | 830 | 713.59 | -1,040 | -770 | 6,319 |
| | | | | 180° | 1,894 | 1,661 | 4,752 | 4,083.42 | 0 | 0.00 | -4,103 | -2,013 | -17,639 |
| | | | | 270° | 1,894 | 0 | 1,894 | 1,627.66 | -830 | -713.59 | -1,040 | 770 | 6,319 |
| **Wind, empty, new Attack angle = 45°** | 7,576 | 4,982 | 23,635 | 0° | 1,136 | -881 | -884 | -759.88 | -881 | -756.88 | 1,277 | 1,562 | 7,018 |
| | | | | 90° | 1,136 | -881 | -884 | -759.88 | 881 | 756.88 | 1,277 | 1,562 | 7,018 |
| | | | | 180° | 1,894 | 881 | 3,915 | 3,364.14 | 881 | 756.88 | -2,941 | -1,562 | -13,997 |
| | | | | 270° | 1,894 | 881 | 3,915 | 3,364.14 | -881 | -756.88 | -2,941 | -1,562 | -13,997 |
| **Wind, vacuum Attack angle = 0°** | 32,172 | 4,982 | 23,635 | 0° | 4,826 | -1,661 | 1,968 | 1,691.36 | 0 | 0.00 | -1,849 | -980 | -8,635 |
| | | | | 90° | 8,043 | 0 | 8,043 | 6,911.86 | 830 | 713.59 | -6,251 | -3,402 | -27,468 |
| | | | | 180° | 8,043 | 1,661 | 10,901 | 9,367.61 | 0 | 0.00 | -9,314 | -4,830 | -38,836 |
| | | | | 270° | 8,043 | 0 | 8,043 | 6,911.86 | -830 | -713.59 | -6,251 | -3,402 | -27,468 |
| **Wind, vacuum Attack angle = 45°** | 32,172 | 4,982 | 23,635 | 0° | 4,826 | -881 | 2,805 | 2,410.63 | -881 | -756.88 | -2,583 | -1,495 | -10,687 |
| | | | | 90° | 4,826 | -881 | 2,805 | 2,410.63 | 881 | 756.88 | -2,583 | -1,495 | -10,687 |
| | | | | 180° | 8,043 | 881 | 10,064 | 8,648.34 | 881 | 756.88 | -8,152 | -4,315 | -35,172 |
| | | | | 270° | 8,043 | 881 | 10,064 | 8,648.34 | -881 | -756.88 | -8,152 | -4,315 | -35,172 |
| **Seismic, operating, new Attack angle = 0°** | 32,172 | 1,437 | 10,721 | 0° | 4,694 | -479 | 3,397 | 2,919.58 | 0 | 0.00 | 7,912 | 4,014 | 15,899 |
| | | | | 90° | 8,175 | 0 | 8,175 | 7,025.40 | 240 | 205.88 | 10,104 | 5,333 | 29,775 |
| | | | | 180° | 8,175 | 479 | 9,471 | 8,139.39 | 0 | 0.00 | 10,385 | 5,576 | 33,475 |
| | | | | 270° | 8,175 | 0 | 8,175 | 7,025.40 | -240 | -205.88 | 10,104 | 5,333 | 29,775 |
| **Seismic, operating, new Attack angle = 45°** | 32,172 | 1,437 | 10,721 | 0° | 4,694 | -254 | 3,777 | 3,245.86 | -254 | -218.37 | 7,919 | 4,058 | 16,723 |
| | | | | 90° | 4,694 | -254 | 3,777 | 3,245.86 | 254 | 218.37 | 7,919 | 4,058 | 16,723 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 180° | 8,175 | 254 | 9,092 | 7,813.11 | 254 | 218.37 | 10,379 | 5,532 | 32,494 |
| | | | | 270° | 8,175 | 254 | 9,092 | 7,813.11 | -254 | -218.37 | 10,379 | 5,532 | 32,494 |
| **Seismic, empty, new Attack angle = 0°** | 7,576 | 339 | 1,280 | 0° | 1,105 | -113 | 951 | 816.86 | 0 | 0.00 | 623 | 331 | 3,268 |
| | | | | 90° | 1,925 | 0 | 1,925 | 1,654.40 | 56 | 48.48 | -1,057 | -595 | 6,349 |
| | | | | 180° | 1,925 | 113 | 2,080 | 1,787.40 | 0 | 0.00 | -1,243 | -679 | -6,993 |
| | | | | 270° | 1,925 | 0 | 1,925 | 1,654.40 | -56 | -48.48 | -1,057 | -595 | 6,349 |
| **Seismic, empty, new Attack angle = 45°** | 7,576 | 339 | 1,280 | 0° | 1,105 | -60 | 996 | 855.82 | -60 | -51.42 | 601 | 328 | 3,356 |
| | | | | 90° | 1,105 | -60 | 996 | 855.82 | 60 | 51.42 | 601 | 328 | 3,356 |
| | | | | 180° | 1,925 | 60 | 2,035 | 1,748.44 | 60 | 51.42 | -1,171 | -648 | -6,780 |
| | | | | 270° | 1,925 | 60 | 2,035 | 1,748.44 | -60 | -51.42 | -1,171 | -648 | -6,780 |
| **Seismic, vacuum Attack angle = 0°** | 32,172 | 1,437 | 10,721 | 0° | 4,694 | -479 | 3,397 | 2,919.58 | 0 | 0.00 | -3,269 | -1,810 | -12,116 |
| | | | | 90° | 8,175 | 0 | 8,175 | 7,025.40 | 240 | 205.88 | -6,323 | -3,443 | -27,880 |
| | | | | 180° | 8,175 | 479 | 9,471 | 8,139.39 | 0 | 0.00 | -7,466 | -4,000 | -32,721 |
| | | | | 270° | 8,175 | 0 | 8,175 | 7,025.40 | -240 | -205.88 | -6,323 | -3,443 | -27,880 |
| **Seismic, vacuum Attack angle = 45°** | 32,172 | 1,437 | 10,721 | 0° | 4,694 | -254 | 3,777 | 3,245.86 | -254 | -218.37 | -3,680 | -2,000 | -13,125 |
| | | | | 90° | 4,694 | -254 | 3,777 | 3,245.86 | 254 | 218.37 | -3,680 | -2,000 | -13,125 |
| | | | | 180° | 8,175 | 254 | 9,092 | 7,813.11 | 254 | 218.37 | -7,056 | -3,810 | -31,205 |
| | | | | 270° | 8,175 | 254 | 9,092 | 7,813.11 | -254 | -218.37 | -7,056 | -3,810 | -31,205 |

| Applied Loads (Seismic, operating, new, Attack angle = 0°, lug orientation = 180°) | |
|---|---|
| **Radial load, $P_r$** | 479.15 $lb_f$ |
| **Circumferential moment, $M_c$** | 0 $lb_f$-in |
| **Circumferential shear, $V_c$** | 0 $lb_f$ |
| **Longitudinal moment, $M_L$** | 97,672.7 $lb_f$-in |
| **Longitudinal shear, $V_L$** | 9,471.29 $lb_f$ |
| **Torsion moment, $M_t$** | 0 $lb_f$-in |
| **Internal pressure, P** | 45 psi |
| **Mean shell radius, $R_m$** | 39.1563" |
| **Local shell thickness, T** | 0.3125" |
| **Design factor** | 3 |

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

$\gamma = R_m / T = 39.1563 / 0.3125 = 125.3$

$C_1 = 8$, $C_2 = 10$ in

Local circumferential pressure stress = $P*R_i / T$ =5,616 psi

Local longitudinal pressure stress = $P*R_i / (2*T)$ =2,808 psi

Maximum combined stress ($P_L+P_b+Q$) = 17,154 psi
Allowable combined stress ($P_L+P_b+Q$) = ±3*S = ±48,900 psi

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

Maximum local primary membrane stress ($P_L$) = 10,385 psi
Allowable local primary membrane stress ($P_L$) = ±1.5*S = ±24,450 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* | 3.5638 | 0.2577 | 0 | 0 | 0 | 0 | -140 | -140 | -140 | -140 |
| 4C* | 11.0052 | 0.2406 | -431 | -431 | -431 | -431 | 0 | 0 | 0 | 0 |
| 1C | 0.06 | 0.2211 | 0 | 0 | 0 | 0 | -1,766 | 1,766 | -1,766 | 1,766 |
| 2C-1 | 0.0131 | 0.2211 | -386 | 386 | -386 | 386 | 0 | 0 | 0 | 0 |
| 3A* | 3.5533 | 0.2201 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1A | 0.0532 | 0.2314 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3B* | 6.9564 | 0.2371 | -5,200 | -5,200 | 5,200 | 5,200 | 0 | 0 | 0 | 0 |
| 1B-1 | 0.0105 | 0.2249 | -7,155 | 7,155 | 7,155 | -7,155 | 0 | 0 | 0 | 0 |
| **Pressure stress*** | | | 5,616 | 5,616 | 5,616 | 5,616 | 5,616 | 5,616 | 5,616 | 5,616 |
| **Total circumferential stress** | | | -7,556 | 7,526 | 17,154 | 3,616 | 3,710 | 7,242 | 3,710 | 7,242 |
| **Primary membrane circumferential stress*** | | | -15 | -15 | 10,385 | 10,385 | 5,476 | 5,476 | 5,476 | 5,476 |
| 3C* | 4.021 | 0.2406 | -157 | -157 | -157 | -157 | 0 | 0 | 0 | 0 |
| 4C* | 10.3463 | 0.2577 | 0 | 0 | 0 | 0 | -405 | -405 | -405 | -405 |
| 1C-1 | 0.0285 | 0.2437 | -839 | 839 | -839 | 839 | 0 | 0 | 0 | 0 |
| 2C | 0.0323 | 0.2437 | 0 | 0 | 0 | 0 | -951 | 951 | -951 | 951 |
| 4A* | 10.9824 | 0.2201 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2A | 0.0212 | 0.2535 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4B* | 3.3944 | 0.2371 | -2,925 | -2,925 | 2,925 | 2,925 | 0 | 0 | 0 | 0 |
| 2B-1 | 0.0138 | 0.2471 | -8,558 | 8,558 | 8,558 | -8,558 | 0 | 0 | 0 | 0 |
| **Pressure stress*** | | | 2,808 | 2,808 | 2,808 | 2,808 | 2,808 | 2,808 | 2,808 | 2,808 |
| **Total longitudinal stress** | | | -9,671 | 9,123 | 13,295 | -2,143 | 1,452 | 3,354 | 1,452 | 3,354 |
| **Primary membrane longitudinal stress*** | | | -274 | -274 | 5,576 | 5,576 | 2,403 | 2,403 | 2,403 | 2,403 |
| **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 | -758 | -758 | 758 | 758 |
| **Total Shear stress** | | | 0 | 0 | 0 | 0 | -758 | -758 | 758 | 758 |
| **Combined stress ($P_L$+$P_b$+Q)** | | | -9,671 | 9,123 | 17,154 | -5,759 | 3,941 | 7,385 | 3,941 | 7,385 |

* denotes primary stress.

| Applied Loads (Seismic, operating, new, Attack angle = 0°, lug orientation = 180°) | |
|---|---|
| **Radial load, $P_r$** | 239.57 $lb_f$ |
| **Circumferential moment, $M_c$** | 0 $lb_f$-in |
| **Circumferential shear, $V_c$** | 0 $lb_f$ |
| **Longitudinal moment, $M_L$** | 48,836.4 $lb_f$-in |
| **Longitudinal shear, $V_L$** | 4,735.65 $lb_f$ |
| **Torsion moment, $M_t$** | 0 $lb_f$-in |
| **Internal pressure, P** | 45 psi |
| **Mean shell radius, $R_m$** | 39.1563" |
| **Local shell thickness, T** | 0.8125" |
| **Design factor** | 3 |

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

$\gamma = R_m / T = 39.1563 / 0.8125 = 48.1923$

$C_1 = 0.5$, $C_2 = 2$ in

Note: Actual lug $C_1 / C_2 < 1 / 4$, $C_1 / C_2 = 1 / 4$ used as this is the minimum ratio covered by WRC 107.

Local circumferential pressure stress = $P*R_i / T$ =5,616 psi

Local longitudinal pressure stress = $P*R_i / (2*T)$ =2,808 psi

Maximum combined stress ($P_L+P_b+Q$) = 33,475 psi
Allowable combined stress ($P_L+P_b+Q$) = $\pm 3*S$ = ±48,900 psi

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

Maximum local primary membrane stress ($P_L$) = 6,798 psi
Allowable local primary membrane stress ($P_L$) = $\pm 1.5*S$ = ±24,450 psi

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

| Stresses at the lug edge per WRC Bulletin 107 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Figure** | **value** | β | **$A_u$** | **$A_l$** | **$B_u$** | **$B_l$** | **$C_u$** | **$C_l$** | **$D_u$** | **$D_l$** |
| 3C* | 9.2315 | 0.0378 | 0 | 0 | 0 | 0 | -70 | -70 | -70 | -70 |
| 4C* | 9.4401 | 0.0306 | -71 | -71 | -71 | -71 | 0 | 0 | 0 | 0 |
| 1C | 0.2688 | 0.0225 | 0 | 0 | 0 | 0 | -585 | 585 | -585 | 585 |
| 2C-1 | 0.2293 | 0.0225 | -499 | 499 | -499 | 499 | 0 | 0 | 0 | 0 |
| 3A* | 0.236 | 0.0203 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1A | 0.1052 | 0.0252 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3B* | 1.6759 | 0.0322 | -1,253 | -1,253 | 1,253 | 1,253 | 0 | 0 | 0 | 0 |
| 1B-1 | 0.0632 | 0.0277 | -25,827 | 25,827 | 25,827 | -25,827 | 0 | 0 | 0 | 0 |
| **Pressure stress*** | | | 5,616 | 5,616 | 5,616 | 5,616 | 5,616 | 5,616 | 5,616 | 5,616 |
| **Total circumferential stress** | | | -22,034 | 30,618 | 32,126 | -18,530 | 4,961 | 6,131 | 4,961 | 6,131 |
| **Primary membrane circumferential stress*** | | | 4,292 | 4,292 | 6,798 | 6,798 | 5,546 | 5,546 | 5,546 | 5,546 |
| 3C* | 9.4365 | 0.0306 | -71 | -71 | -71 | -71 | 0 | 0 | 0 | 0 |
| 4C* | 9.3382 | 0.0378 | 0 | 0 | 0 | 0 | -70 | -70 | -70 | -70 |
| 1C-1 | 0.2283 | 0.0319 | -497 | 497 | -497 | 497 | 0 | 0 | 0 | 0 |
| 2C | 0.179 | 0.0319 | 0 | 0 | 0 | 0 | -390 | 390 | -390 | 390 |
| 4A* | 0.2807 | 0.0203 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2A | 0.0633 | 0.0331 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4B* | 0.4364 | 0.0322 | -603 | -603 | 603 | 603 | 0 | 0 | 0 | 0 |
| 2B-1 | 0.1037 | 0.0384 | -30,632 | 30,632 | 30,632 | -30,632 | 0 | 0 | 0 | 0 |
| **Pressure stress*** | | | 2,808 | 2,808 | 2,808 | 2,808 | 2,808 | 2,808 | 2,808 | 2,808 |
| **Total longitudinal stress** | | | -28,995 | 33,263 | 33,475 | -26,795 | 2,348 | 3,128 | 2,348 | 3,128 |
| **Primary membrane longitudinal stress*** | | | 2,134 | 2,134 | 3,340 | 3,340 | 2,738 | 2,738 | 2,738 | 2,738 |
| **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 | -729 | -729 | 729 | 729 |
| **Total Shear stress** | | | 0 | 0 | 0 | 0 | -729 | -729 | 729 | 729 |
| **Combined stress ($P_L$+$P_b$+Q)** | | | -28,995 | 33,263 | 33,475 | -26,795 | 5,151 | 6,299 | 5,151 | 6,299 |
| * denotes primary stress. | | | | | | | | | | |

| Applied Loads (Wind, operating, Attack angle = 0°, lug orientation = 180°) | |
|---|---|
| **Radial load, $P_r$** | 1,660.73 $lb_f$ |
| **Circumferential moment, $M_c$** | 0 $lb_f$-in |
| **Circumferential shear, $V_c$** | 0 $lb_f$ |
| **Longitudinal moment, $M_L$** | 112,411.4 $lb_f$-in |
| **Longitudinal shear, $V_L$** | 10,900.5 $lb_f$ |
| **Torsion moment, $M_t$** | 0 $lb_f$-in |
| **Internal pressure, P** | 45 psi |
| **Mean shell radius, $R_m$** | 39.1563" |
| **Local shell thickness, T** | 0.3125" |
| **Design factor** | 3 |

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

$\gamma = R_m / T = 39.1563 / 0.3125 = 125.3$

$C_1 = 8$, $C_2 = 10$ in

Local circumferential pressure stress = $P*R_i / T$ =5,616 psi

Local longitudinal pressure stress = $P*R_i / (2*T)$ =2,808 psi

Maximum combined stress ($P_L+P_b+Q$) = 17,005 psi
Allowable combined stress ($P_L+P_b+Q$) = ±3*S = ±48,900 psi

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

Maximum local primary membrane stress ($P_L$) = 10,107 psi
Allowable local primary membrane stress ($P_L$) = ±1.5*S = ±24,450 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* | 3.5638 | 0.2577 | 0 | 0 | 0 | 0 | -484 | -484 | -484 | -484 |
| 4C* | 11.0052 | 0.2406 | -1,494 | -1,494 | -1,494 | -1,494 | 0 | 0 | 0 | 0 |
| 1C | 0.06 | 0.2211 | 0 | 0 | 0 | 0 | -6,122 | 6,122 | -6,122 | 6,122 |
| 2C-1 | 0.0131 | 0.2211 | -1,337 | 1,337 | -1,337 | 1,337 | 0 | 0 | 0 | 0 |
| 3A* | 3.5533 | 0.2201 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1A | 0.0532 | 0.2314 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3B* | 6.9564 | 0.2371 | -5,985 | -5,985 | 5,985 | 5,985 | 0 | 0 | 0 | 0 |
| 1B-1 | 0.0105 | 0.2249 | -8,235 | 8,235 | 8,235 | -8,235 | 0 | 0 | 0 | 0 |
| **Pressure stress*** | | | 5,616 | 5,616 | 5,616 | 5,616 | 5,616 | 5,616 | 5,616 | 5,616 |
| **Total circumferential stress** | | | -11,435 | 7,709 | 17,005 | 3,209 | -990 | 11,254 | -990 | 11,254 |
| **Primary membrane circumferential stress*** | | | -1,863 | -1,863 | 10,107 | 10,107 | 5,132 | 5,132 | 5,132 | 5,132 |
| 3C* | 4.021 | 0.2406 | -546 | -546 | -546 | -546 | 0 | 0 | 0 | 0 |
| 4C* | 10.3463 | 0.2577 | 0 | 0 | 0 | 0 | -1,404 | -1,404 | -1,404 | -1,404 |
| 1C-1 | 0.0285 | 0.2437 | -2,908 | 2,908 | -2,908 | 2,908 | 0 | 0 | 0 | 0 |
| 2C | 0.0323 | 0.2437 | 0 | 0 | 0 | 0 | -3,296 | 3,296 | -3,296 | 3,296 |
| 4A* | 10.9824 | 0.2201 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2A | 0.0212 | 0.2535 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4B* | 3.3944 | 0.2371 | -3,366 | -3,366 | 3,366 | 3,366 | 0 | 0 | 0 | 0 |
| 2B-1 | 0.0138 | 0.2471 | -9,850 | 9,850 | 9,850 | -9,850 | 0 | 0 | 0 | 0 |
| **Pressure stress*** | | | 2,808 | 2,808 | 2,808 | 2,808 | 2,808 | 2,808 | 2,808 | 2,808 |
| **Total longitudinal stress** | | | -13,862 | 11,654 | 12,570 | -1,314 | -1,892 | 4,700 | -1,892 | 4,700 |
| **Primary membrane longitudinal stress*** | | | -1,104 | -1,104 | 5,628 | 5,628 | 1,404 | 1,404 | 1,404 | 1,404 |
| **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 | -872 | -872 | 872 | 872 |
| **Total Shear stress** | | | 0 | 0 | 0 | 0 | -872 | -872 | 872 | 872 |
| **Combined stress ($P_L$+$P_b$+Q)** | | | -13,862 | 11,654 | 17,005 | -4,523 | -2,423 | 11,368 | -2,423 | 11,368 |

* denotes primary stress.

| Applied Loads (Wind, operating, Attack angle = 0°, lug orientation = 180°) | |
|---|---|
| **Radial load, $P_r$** | 830.37 $lb_f$ |
| **Circumferential moment, $M_c$** | 0 $lb_f$-in |
| **Circumferential shear, $V_c$** | 0 $lb_f$ |
| **Longitudinal moment, $M_L$** | 56,205.7 $lb_f$-in |
| **Longitudinal shear, $V_L$** | 5,450.25 $lb_f$ |
| **Torsion moment, $M_t$** | 0 $lb_f$-in |
| **Internal pressure, P** | 45 psi |
| **Mean shell radius, $R_m$** | 39.1563" |
| **Local shell thickness, T** | 0.8125" |
| **Design factor** | 3 |

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

$\gamma = R_m / T = 39.1563 / 0.8125 = 48.1923$

$C_1 = 0.5$, $C_2 = 2$ in

Note: Actual lug $C_1 / C_2 < 1 / 4$, $C_1 / C_2 = 1 / 4$ used as this is the minimum ratio covered by WRC 107.

Local circumferential pressure stress = $P*R_i / T$ =5,616 psi

Local longitudinal pressure stress = $P*R_i / (2*T)$ =2,808 psi

Maximum combined stress ($P_L+P_b+Q$) = 38,846 psi
Allowable combined stress ($P_L+P_b+Q$) = $\pm 3*S$ = ±48,900 psi

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

Maximum local primary membrane stress ($P_L$) = 6,812 psi
Allowable local primary membrane stress ($P_L$) = $\pm 1.5*S$ = ±24,450 psi

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

| Stresses at the lug edge per WRC Bulletin 107 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Figure** | **value** | β | **$A_u$** | **$A_l$** | **$B_u$** | **$B_l$** | **$C_u$** | **$C_l$** | **$D_u$** | **$D_l$** |
| 3C* | 9.2315 | 0.0378 | 0 | 0 | 0 | 0 | -241 | -241 | -241 | -241 |
| 4C* | 9.4401 | 0.0306 | -246 | -246 | -246 | -246 | 0 | 0 | 0 | 0 |
| 1C | 0.2688 | 0.0225 | 0 | 0 | 0 | 0 | -2,029 | 2,029 | -2,029 | 2,029 |
| 2C-1 | 0.2293 | 0.0225 | -1,731 | 1,731 | -1,731 | 1,731 | 0 | 0 | 0 | 0 |
| 3A* | 0.236 | 0.0203 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1A | 0.1052 | 0.0252 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3B* | 1.6759 | 0.0322 | -1,442 | -1,442 | 1,442 | 1,442 | 0 | 0 | 0 | 0 |
| 1B-1 | 0.0632 | 0.0277 | -29,724 | 29,724 | 29,724 | -29,724 | 0 | 0 | 0 | 0 |
| **Pressure stress*** | | | 5,616 | 5,616 | 5,616 | 5,616 | 5,616 | 5,616 | 5,616 | 5,616 |
| **Total circumferential stress** | | | -27,527 | 35,383 | 34,805 | -21,181 | 3,346 | 7,404 | 3,346 | 7,404 |
| **Primary membrane circumferential stress*** | | | 3,928 | 3,928 | 6,812 | 6,812 | 5,375 | 5,375 | 5,375 | 5,375 |
| 3C* | 9.4365 | 0.0306 | -246 | -246 | -246 | -246 | 0 | 0 | 0 | 0 |
| 4C* | 9.3382 | 0.0378 | 0 | 0 | 0 | 0 | -244 | -244 | -244 | -244 |
| 1C-1 | 0.2283 | 0.0319 | -1,723 | 1,723 | -1,723 | 1,723 | 0 | 0 | 0 | 0 |
| 2C | 0.179 | 0.0319 | 0 | 0 | 0 | 0 | -1,351 | 1,351 | -1,351 | 1,351 |
| 4A* | 0.2807 | 0.0203 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2A | 0.0633 | 0.0331 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4B* | 0.4364 | 0.0322 | -694 | -694 | 694 | 694 | 0 | 0 | 0 | 0 |
| 2B-1 | 0.1037 | 0.0384 | -35,255 | 35,255 | 35,255 | -35,255 | 0 | 0 | 0 | 0 |
| **Pressure stress*** | | | 2,808 | 2,808 | 2,808 | 2,808 | 2,808 | 2,808 | 2,808 | 2,808 |
| **Total longitudinal stress** | | | -35,110 | 38,846 | 36,788 | -30,276 | 1,213 | 3,915 | 1,213 | 3,915 |
| **Primary membrane longitudinal stress*** | | | 1,868 | 1,868 | 3,256 | 3,256 | 2,564 | 2,564 | 2,564 | 2,564 |
| **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 | -838 | -838 | 838 | 838 |
| **Total Shear stress** | | | 0 | 0 | 0 | 0 | -838 | -838 | 838 | 838 |
| **Combined stress ($P_L$+$P_b$+Q)** | | | -35,110 | 38,846 | 36,788 | -30,276 | 3,636 | 7,595 | 3,636 | 7,595 |
| * denotes primary stress. | | | | | | | | | | |

**Gusset plate required thickness, Bednar 5.2**

$S_c = 12{,}525 / (1 + (1/12{,}525)*(h/(0.289*t_g))^2)$
$= 12{,}525 / (1 + (1/12{,}525)*(15.125/(0.289*0.5))^2)$
$= 6{,}681$ psi

$t_g = V_L*(3*d - b)/(S_c*b^2*\text{Sin}(\alpha)^2)$
$= 10{,}900.5*(3*10.3125 - 16.375)/(6{,}681*16.375^2*\text{Sin}(42.728)^2)$
$= 0.1925$ in

The gusset thickness of 0.5 in is adequate.

**Lug base plate required thickness**

From Escoe table 4-8 (l/b = 1.8194)

$C_x = 0.12811$, $C_y = -0.12464$

$f_c = V_L/(L_b*L)$
$= 10{,}900.5/(8.0625*12.375)$
$= 109$ psi

$M_x = C_x*f_c*L_g^2$
$= 0.12811*109*9^2$
$= 1{,}133.7$ in-lb$_f$/in

$M_y = C_y*f_c*L_b^2$
$= -0.12464*109*8.0625^2$
$= -885.17$ in-lb$_f$/in

$M = \text{Max}[\text{Abs}(M_x), \text{Abs}(M_y)]$
$= \text{Max}[\text{Abs}(1{,}133.7), \text{Abs}(-885.17)]$
$= 1{,}133.7$ in-lb$_f$/in

$t_b = \text{Sqr}(6*M / S_b)$
$= \text{Sqr}(6*1{,}133.7 / 16{,}700)$
$= 0.6382$ in

The base plate thickness of 0.75 in is adequate.

**Support Lug to Pad Fillet Weld Sizing - Bednar chapters 5.2 and 10.3**

Note: continuous welding on both sides of the gusset is assumed for all support lug fillet welds.

$d_h = t_a + h + t_b$

$L_w = b + 2*d_h = 12.375 + 2*15.875 = 44.125$ in
$Z_w = (2*b*d_h + d_h^2)/3 = (2*12.375*15.875 + 15.875^2)/3 = 214.97$ in$^2$
$Z_z = (2*d_h*b + b^2)/3 = (2*15.875*12.375 + 12.375^2)/3 = 182.02$ in$^2$

Shear $f_1 = V_L/L_w = 10{,}900.5/44.125 = 247$ lb$_f$/in
Shear $f_2 = V_c/L_w = 0/44.125 = 0$ lb$_f$/in
Bending $f_3$ = larger absolute value of $M_L/Z_w$ or $M_c/Z_z$
$= M_L/Z_w$
$= 112{,}411.4/214.97$
$= 522.91$ lb$_f$/in

Resultant load $f = (f_1^2 + f_2^2 + f_3^2)^{1/2}$

$= (247.04^2 + 0^2 + 522.91^2)^{1/2}$
$= 578.32$ $lb_f/in$

Required weld size $w = F/(0.707*0.55*S_a)$

$= 578.32/(0.707*0.55*16{,}300)$
$= 0.0912$ in

The support lug fillet weld size of 0.25 in is adequate.

**Support Lug Pad to Shell Fillet Weld Sizing - Bednar chapters 5.2 and 10.3**

$L_w = 2*(b + d_h) = 2*(16 + 20) = 72$ in
$Z_w = b*d_h + d_h^2/3 = 16*16 + 20^2/3 = 453.33$ $in^2$
$Z_z = d_h*b + b^2/3 = 20*16 + 16^2/3 = 405.33$ $in^2$

Shear $f_1 = V_L/L_w = 10{,}900.5/72 = 151$ $lb_f/in$
Shear $f_2 = V_c/L_w = 0/72 = 0$ $lb_f/in$
Bending $f_3$ = larger absolute value of $M_L/Z_w$ or $M_c/Z_z$
$= M_L/Z_w$
$= 112{,}411.4/453.33$
$= 247.97$ $lb_f/in$

Resultant load $f = (f_1^2 + f_2^2 + f_3^2)^{1/2}$

$= (151.4^2 + 0^2 + 247.97^2)^{1/2}$
$= 290.53$ $lb_f/in$

Required weld size $w = F/(0.707*0.55*S_a)$

$= 290.53/(0.707*0.55*16{,}300)$
$= 0.0458$ in

The support lug pad fillet weld size of 0.25 in is adequate.

## Vacuum Ring

| ASME Section VIII Division 1, 2013 Edition | |
|---|---|
| **Attached to** | Shell -01 |
| **Ring type** | Flat bar |
| **Description** | 3/8x3.5 Flat Bar |
| **Material** | SA-240 304L (II-D p. 86, ln. 43) |
| **External design pressure** | 14.7 psi |
| **External design temperature** | 338°F |
| **Corrosion allowance** | 0" |
| **Distance from ring neutral axis to datum** | 83.5" |
| **Distance to previous support** | 88.9168" |
| **Distance to next support** | 87.9168" |
| **Internal ring** | No |
| **Welds** | |
| **Weld configuration** | Continuous both sides |
| **Fillet weld leg size** | 0.25" |
| **Vessel thickness at weld location, new** | 0.3125" |
| **Vessel corrosion allowance at weld location** | 0" |
| **Stiffener thickness at weld location** | 0.375" |
| **Ring Properties** | |
| **Max depth to thickness ratio** | 12 |
| **Ring distance to centroid** | 1.75" |
| **Ring area** | 1.3125 $in^2$ |
| **Ring inertia** | 1.3398 $in^4$ |

**External Pressure, (Corroded & at 338°F) UG-29(a)**

$L / D_o$ = 88.9168 / 78.625 = 1.1309
$D_o / t$ = 78.625 / 0.2736 = 287.3773
From Table G: A = 2.4161E-04
From Table HA-4: B = 3,171.23 psi

$P_a$ = 4*B / (3*($D_o$ / t))
= 4*3,171.23 / (3*(78.625 / 0.273595))
= 14.71 psi

B = 0.75*P*$D_o$ / (t + $A_s$ / $L_s$)
= 0.75*14.7*78.625 / (0.2736 + 1.3125 / 88.4168)
= 3,005 psi

From Table HA-3: A = 0.00022966 (ring, 338°F)

From Table HA-4: A = 0.00022899 (shell, 338°F)

$I_s'$ = $[D_o^2 * L_s * (t + A_s / L_s) * A] / 10.9$
= $[78.625^2 * 88.4168 * (0.2736 + 1.3125 / 88.4168) * 0.00022966] / 10.9$
= 3.3219 $in^4$

$I'$ for the composite corroded shell-ring cross section is 4.0478 $in^4$

As $I' >= I_s'$ a 3/8x3.5 Flat Bar stiffener is adequate for an external pressure of 14.7 psi.

**Check the stiffener ring attachment welds per UG-30**
Per UG-30(f)(1) the minimum attachment weld size is 0.25 in

The fillet weld size of 0.25 in is adequate per UG-30(f)(1).

Radial pressure load, $P * L_s$ = 14.7*88.4168 = 1,299.73 $lb_f/in$
Radial shear load, $V = 0.01 * P * L_s * D_o$ = 0.01*14.7*88.4168*78.625 = 1,021.91 $lb_f$
First moment of area, Q = 1.7*0.8294 = 1.4133 $in^3$

Weld shear flow, $q = V * Q / I'$ = 356.8059 $lb_f/in$
Combined weld load, $f_w$ = Sqr(1,299.7274$^2$ + 356.8059$^2$) = 1,347.81 $lb_f/in$

Allowable weld stress per UW-18(d) $S_w = 0.55 * S$ = 0.55*16,300 = 8,965 psi

**Fillet weld size required to resist radial pressure and shear**

$t_w$ = $f_w * (d_{weld\ segment} + d_{toe}) / (S_w * d_{weld\ total})$ + corrosion
= 1,347.81*(1 + 0) / (8,965*2) + 0
= 0.0752 in

The fillet weld size of 0.25 in is adequate to resist radial pressure and shear.

**Maximum Allowable External Pressure, (Corroded & at 338°F) UG-29(a)**

$L / D_o$ = 88.9168 / 78.625 = 1.1309
$D_o / t$ = 78.625 / 0.2958 = 265.8082
From Table G: A = 2.723E-04
From Table HA-4: B = 3,575.1 psi

$P_a$ = $4 * B / (3 * (D_o / t))$
= 4*3,575.1 / (3*(78.625 / 0.295796))
= 17.93 psi

B = $0.75 * P * D_o / (t + A_s / L_s)$
= 0.75*17.92*78.625 / (0.2958 + 1.3125 / 88.4168)
= 3,401 psi

From Table HA-3: A = 0.00025985 (ring, 338°F)
From Table HA-4: A = 0.00025908 (shell, 338°F)

$I_s'$ = $[D_o^2 * L_s * (t + A_s / L_s) * A] / 10.9$
= $[78.625^2 * 88.4168 * (0.2958 + 1.3125 / 88.4168) * 0.00025985] / 10.9$
= 4.0478 $in^4$

$I'$ for the composite corroded shell-ring cross section is 4.0478 $in^4$

As $I' >= I_s'$ a 3/8x3.5 Flat Bar stiffener is adequate for an external pressure of 17.92 psi.

**Check the stiffener ring attachment welds per UG-30**
Per UG-30(f)(1) the minimum attachment weld size is 0.25 in

The fillet weld size of 0.25 in is adequate per UG-30(f)(1).

Radial pressure load, $P*L_s = 17.92*88.4168 = 1,584.14$ $lb_f/in$
Radial shear load, $V = 0.01*P*L_s*D_o = 0.01*17.92*88.4168*78.625 = 1,245.53$ $lb_f$
First moment of area, $Q = 1.7*0.8294 = 1.4133$ $in^3$

Weld shear flow, $q = V*Q / I' = 434.8852$ $lb_f/in$
Combined weld load, $f_w = Sqr(1,584.1447^2 + 434.8852^2) = 1,642.75$ $lb_f/in$

Allowable weld stress per UW-18(d) $S_w = 0.55*S = 0.55*16,300 = 8,965$ psi

**Fillet weld size required to resist radial pressure and shear**

$$\begin{aligned} t_w &= f_w*(d_{\text{weld segment}} + d_{toe}) / (S_w*d_{\text{weld total}}) + \text{corrosion} \\ &= 1,642.75*(1 + 0) / (8,965*2) + 0 \\ &= 0.0916 \text{ in} \end{aligned}$$

The fillet weld size of 0.25 in is adequate to resist radial pressure and shear.

**F&D Head (top)**

| ASME Section VIII Division 1, 2013 Edition | | | | |
|---|---|---|---|---|
| **Component** | | F&D Head | | |
| **Material** | | SA-240 316L (II-D p. 74, ln. 9) | | |
| **Attached To** | | Shell -02 | | |
| **Impact Tested** | **Normalized** | **Fine Grain Practice** | **PWHT** | **Optimize MDMT/ Find MAWP** |
| No | No | No | No | No |
| | | **Design Pressure (psi)** | **Design Temperature (°F)** | **Design MDMT (°F)** |
| **Internal** | | 45 | 338 | -20 |
| **External** | | 14.7 | 338 | |
| **Static Liquid Head** | | | | |
| **Condition** | | **$P_s$ (psi)** | **$H_s$ (in)** | **SG** |
| **Test horizontal** | | 2.82 | 78 | 1 |
| **Dimensions** | | | | |
| **Inner Diameter** | | 78" | | |
| **Crown Radius L** | | 78" | | |
| **Knuckle Radius r** | | 4.75" | | |
| **Minimum Thickness** | | 0.4" | | |
| **Corrosion** | **Inner** | 0" | | |
| | **Outer** | 0" | | |
| **Length $L_{sf}$** | | 1.5" | | |
| **Nominal Thickness $t_{sf}$** | | 0.5" | | |
| **Weight and Capacity** | | | | |
| | | **Weight (lb)[1]** | | **Capacity (US gal)[1]** |
| **New** | | 649.05 | | 198.26 |
| **Corroded** | | 649.05 | | 198.26 |
| **Insulation** | | | | |
| | | **Thickness (in)** | **Density (lb/ft$^3$)** | **Weight (lb)** |
| **Insulation** | | 2 | 12 | 92.01 |
| | | **Spacing(in)** | **Individual Weight (lb)** | **Total Weight (lb)** |
| **Insulation Supports** | | 0 | 0 | 0 |
| **Radiography** | | | | |
| **Category A joints** | | Full UW-11(a) Type 1 | | |

| Head to shell seam | Full UW-11(a) Type 1 |
|---|---|

[1] includes straight flange

| Results Summary | |
|---|---|
| Governing condition | external pressure |
| Minimum thickness per UG-16 | 0.0625" + 0" = 0.0625" |
| Design thickness due to internal pressure (t) | 0.1899" |
| Design thickness due to external pressure ($t_e$) | 0.2346" |
| Maximum allowable working pressure (MAWP) | 94.77 psi |
| Maximum allowable pressure (MAP) | 97.09 psi |
| Maximum allowable external pressure (MAEP) | 32.18 psi |
| Rated MDMT | -320°F |

| UHA-51 Material Toughness Requirements | |
|---|---|
| $t_r$ = 45*78*1 / (2*16,700*1 - 0.2*45) = | 0.1051" |
| Stress ratio = $t_r$*E* / ($t_n$ - c) = 0.1051*1 / (0.4 - 0) = | 0.2628 |
| Impact test exempt per UHA-51(g) (coincident ratio = 0.2628) | |
| Rated MDMT = | -320°F |
| Material is exempt from impact testing at the Design MDMT of -20°F. | |

| Factor M | | |
|---|---|---|
| M = 1/4*[3 + (L / r)$^{1/2}$] | | |
| Corroded | M = 1/4*[3 + (78 / 4.75)$^{1/2}$] | 1.7631 |
| New | M = 1/4*[3 + (78 / 4.75)$^{1/2}$] | 1.7631 |

**Design thickness for internal pressure, (Corroded at 338 °F) Appendix 1-4(d)**

t = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 45*78*1.7631 / (2*16,300*1 - 0.2*45) + 0
= 0.1899"

**Maximum allowable working pressure, (Corroded at 338 °F) Appendix 1-4(d)**

P = 2*S*E*t / (L*M + 0.2*t) - $P_s$
= 2*16,300*1*0.4 / (78*1.7631 + 0.2*0.4) - 0
= 94.77 psi

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

P = 2*S*E*t / (L*M + 0.2*t) - $P_s$
= 2*16,700*1*0.4 / (78*1.7631 + 0.2*0.4) - 0
= 97.09 psi

**Design thickness for external pressure, (Corroded at 338 °F) UG-33(e)**

Equivalent outside spherical radius ($R_o$)
= Outside crown radius
= 78.4 in

A = 0.125 / ($R_o$ / t)
= 0.125 / (78.4 / 0.234551)
= 0.000374

From Table HA-4: B = 4,913.5547 psi

$P_a$ = B / ($R_o$ / t)
= 4,913.5547 / (78.4 / 0.2346)
= 14.7 psi

t = 0.2346" + Corrosion = 0.2346" + 0" = 0.2346"
Check the external pressure per UG-33(a)(1) Appendix 1-4(d)

t = 1.67*$P_e$*L*M / (2*S*E - 0.2*1.67*$P_e$) + Corrosion
= 1.67*14.7*78*1.7631 / (2*16,300*1 - 0.2*1.67*14.7) + 0
= 0.1036"

The head external pressure design thickness ($t_e$) is 0.2346".

**Maximum Allowable External Pressure, (Corroded at 338 °F) UG-33(e)**

Equivalent outside spherical radius ($R_o$)
= Outside crown radius
= 78.4 in

A = 0.125 / ($R_o$ / t)
= 0.125 / (78.4 / 0.4)
= 0.000638

From Table HA-4: B = 6,308.0192 psi

$P_a$ = B / ($R_o$ / t)
= 6,308.0192 / (78.4 / 0.4)
= 32.1838 psi

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

P = 2*S*E*t / ((L*M + 0.2*t)*1.67)
= 2*16,300*1*0.4 / ((78*1.7631 + 0.2*0.4)*1.67)
= 56.75 psi

The maximum allowable external pressure (MAEP) is 32.18 psi.

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

$$
\begin{aligned}
EFE &= (75*t / R_f)*(1 - R_f / R_o) \\
&= (75*0.5 / 5)*(1 - 5 / \infty) \\
&= 7.5\%
\end{aligned}
$$

## Straight Flange on F&D Head (top)

| ASME Section VIII Division 1, 2013 Edition | | | | |
|---|---|---|---|---|
| **Component** | | Cylinder | | |
| **Material** | | SA-240 316L (II-D p. 74, ln. 9) | | |
| **Impact Tested** | **Normalized** | **Fine Grain Practice** | **PWHT** | **Optimize MDMT/ Find MAWP** |
| No | No | No | No | No |
| | | **Design Pressure (psi)** | **Design Temperature (°F)** | **Design MDMT (°F)** |
| **Internal** | | 45 | 338 | -20 |
| **External** | | 14.7 | 338 | |
| **Static Liquid Head** | | | | |
| **Condition** | | **$P_s$ (psi)** | **$H_s$ (in)** | **SG** |
| **Test horizontal** | | 2.82 | 78 | 1 |
| **Dimensions** | | | | |
| **Inner Diameter** | | 78" | | |
| **Length** | | 1.5" | | |
| **Nominal Thickness** | | 0.5" | | |
| **Corrosion** | **Inner** | 0" | | |
| | **Outer** | 0" | | |
| **Weight and Capacity** | | | | |
| | | **Weight (lb)** | | **Capacity (US gal)** |
| **New** | | 53.64 | | 31.03 |
| **Corroded** | | 53.64 | | 31.03 |
| **Insulation** | | | | |
| | | **Thickness (in)** | **Density (lb/ft$^3$)** | **Weight (lb)** |
| **Insulation** | | 2 | 12 | 0 |
| | | **Spacing(in)** | **Individual Weight (lb)** | **Total Weight (lb)** |
| **Insulation Supports** | | 0 | 0 | 0 |
| **Radiography** | | | | |
| **Longitudinal seam** | | Full UW-11(a) Type 1 | | |
| **Bottom Circumferential seam** | | Full UW-11(a) Type 1 | | |

| Results Summary | |
|---|---|
| Governing condition | External pressure |
| Minimum thickness per UG-16 | 0.0625" + 0" = 0.0625" |
| Design thickness due to internal pressure (t) | 0.1079" |
| Design thickness due to external pressure ($t_e$) | 0.2743" |
| Design thickness due to combined loadings + corrosion | 0.0448" |
| Maximum allowable working pressure (MAWP) | 207.38 psi |
| Maximum allowable pressure (MAP) | 212.47 psi |
| Maximum allowable external pressure (MAEP) | 52.69 psi |
| Rated MDMT | -320 °F |

| UHA-51 Material Toughness Requirements | |
|---|---|
| $t_r$ = 45*39 / (16,700*1 - 0.6*45) = | 0.1053" |
| Stress ratio = $t_r$*E* / ($t_n$ - c) = 0.1053*1 / (0.5 - 0) = | 0.2105 |
| Impact test exempt per UHA-51(g) (coincident ratio = 0.2105) | |
| Rated MDMT = | -320°F |
| Material is exempt from impact testing at the Design MDMT of -20°F. | |

**Design thickness, (at 338 °F) UG-27(c)(1)**

t = P*R / (S*E - 0.60*P) + Corrosion
= 45*39 / (16,300*1.00 - 0.60*45) + 0
= 0.1079"

**Maximum allowable working pressure, (at 338 °F) UG-27(c)(1)**

P = S*E*t / (R + 0.60*t) - $P_s$
= 16,300*1.00*0.5 / (39 + 0.60*0.5) - 0
= 207.38 psi

**Maximum allowable pressure, (at 70 °F) UG-27(c)(1)**

P = S*E*t / (R + 0.60*t)
= 16,700*1.00*0.5 / (39 + 0.60*0.5)
= 212.47 psi

**External Pressure, (Corroded & at 338 °F) UG-28(c)**

$L / D_o$ = 88.9168 / 79 = 1.1255
$D_o / t$ = 79 / 0.2743 = 288.0010
From table G: A = 0.000242
From table HA-4: B = 3,175.2138 psi

$P_a$ = 4*B / (3*($D_o$ / t))
= 4*3,175.21 / (3*(79 / 0.2743))
= 14.7 psi

**Design thickness for external pressure $P_a$ = 14.7 psi**

$t_a$ = t + Corrosion = 0.2743 + 0 = 0.2743"

**Maximum Allowable External Pressure, (Corroded & at 338 °F) UG-28(c)**

$L / D_o$ = 88.9168 / 79 = 1.1255
$D_o / t$ = 79 / 0.5 = 158.0000
From table G: A = 0.000605
From table HA-4: B = 6,243.9546 psi

$P_a$ = 4*B / (3*($D_o$ / t))
= 4*6,243.95 / (3*(79 / 0.5))
= 52.69 psi

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

EFE = (50*t / $R_f$)*(1 - $R_f$ / $R_o$)
= (50*0.5 / 39.25)*(1 - 39.25 / ∞)
= 0.6369%

| 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 | 45 | 16,300 | 7,501 | 338 | 0 | Wind | 0.0448 | 0.0443 |
| | | | | | | Seismic | 0.0448 | 0.0443 |
| Operating, Hot & New | 45 | 16,300 | 7,501 | 338 | 0 | Wind | 0.0448 | 0.0443 |
| | | | | | | Seismic | 0.0448 | 0.0443 |
| Hot Shut Down, Corroded | 0 | 16,300 | 7,501 | 338 | 0 | Wind | 0.0001 | 0.0012 |
| | | | | | | Seismic | 0.0001 | 0.0012 |
| Hot Shut Down, New | 0 | 16,300 | 7,501 | 338 | 0 | Wind | 0.0001 | 0.0012 |
| | | | | | | Seismic | 0.0001 | 0.0012 |
| Empty, Corroded | 0 | 16,700 | 10,071 | 70 | 0 | Wind | 0 | 0.0009 |
| | | | | | | Seismic | 0.0001 | 0.0009 |
| Empty, New | 0 | 16,700 | 10,071 | 70 | 0 | Wind | 0 | 0.0009 |
| | | | | | | Seismic | 0.0001 | 0.0009 |
| Vacuum | -14.7 | 16,300 | 7,501 | 338 | 0 | Wind | 0.0319 | 0.0331 |
| | | | | | | Seismic | 0.0319 | 0.0331 |
| Hot Shut Down, Corroded, Weight & Eccentric Moments Only | 0 | 16,300 | 7,501 | 338 | 0 | Weight | 0.0005 | 0.0014 |

| ASME Section VIII Division 1, 2013 Edition | | | | |
|---|---|---|---|---|
| **Component** | | Cylinder | | |
| **Material** | | SA-240 316L (II-D p. 74, ln. 9) | | |
| **Impact Tested** | **Normalized** | **Fine Grain Practice** | **PWHT** | **Optimize MDMT/ Find MAWP** |
| No | No | No | No | No |
| | | **Design Pressure (psi)** | **Design Temperature (°F)** | **Design MDMT (°F)** |
| **Internal** | | 45 | 338 | -20 |
| **External** | | 14.7 | 338 | |
| **Static Liquid Head** | | | | |
| **Condition** | | **$P_s$ (psi)** | **$H_s$ (in)** | **SG** |
| **Operating** | | 1.36 | 38 | 0.993 |
| **Test horizontal** | | 2.82 | 78 | 1 |
| **Dimensions** | | | | |
| **Inner Diameter** | | 78" | | |
| **Length** | | 69" | | |
| **Nominal Thickness** | | 0.3125" | | |
| **Corrosion** | **Inner** | 0" | | |
| | **Outer** | 0" | | |
| **Weight and Capacity** | | | | |
| | | **Weight (lb)** | | **Capacity (US gal)** |
| **New** | | 1,538.43 | | 1,427.3 |
| **Corroded** | | 1,538.43 | | 1,427.3 |
| **Insulation** | | | | |
| | | **Thickness (in)** | **Density (lb/ft$^3$)** | **Weight (lb)** |
| **Insulation** | | 2 | 12 | 242.74 |
| | | **Spacing(in)** | **Individual Weight (lb)** | **Total Weight (lb)** |
| **Insulation Supports** | | 0 | 0 | 0 |
| **Radiography** | | | | |
| **Longitudinal seam** | | Full UW-11(a) Type 1 | | |
| **Top Circumferential seam** | | Full UW-11(a) Type 1 | | |
| | | Full UW-11(a) Type 1 | | |

| Bottom Circumferential seam | |
|---|---|

| Results Summary | |
|---|---|
| Governing condition | External pressure |
| Minimum thickness per UG-16 | 0.0625" + 0" = 0.0625" |
| Design thickness due to internal pressure (t) | 0.1112" |
| Design thickness due to external pressure ($t_e$) | 0.2735" |
| Design thickness due to combined loadings + corrosion | 0.0542" |
| Maximum allowable working pressure (MAWP) | 128.62 psi |
| Maximum allowable pressure (MAP) | 133.17 psi |
| Maximum allowable external pressure (MAEP) | 20.36 psi |
| Rated MDMT | -320 °F |

| UHA-51 Material Toughness Requirements | |
|---|---|
| $t_r$ = 46.36*39 / (16,700*1 - 0.6*46.36) = | 0.1085" |
| Stress ratio = $t_r$*$E^*$ / ($t_n$ - c) = 0.1085*1 / (0.3125 - 0) = | 0.347 |
| Impact test exempt per UHA-51(g) (coincident ratio = 0.347) | |
| Rated MDMT = | -320°F |
| Material is exempt from impact testing at the Design MDMT of -20°F. | |

**Design thickness, (at 338 °F) UG-27(c)(1)**

t = P*R / (S*E - 0.60*P) + Corrosion
= 46.36*39 / (16,300*1.00 - 0.60*46.36) + 0
= 0.1112"

**Maximum allowable working pressure, (at 338 °F) UG-27(c)(1)**

P = S*E*t / (R + 0.60*t) - $P_s$
= 16,300*1.00*0.3125 / (39 + 0.60*0.3125) - 1.36
= 128.62 psi

**Maximum allowable pressure, (at 70 °F) UG-27(c)(1)**

P = S*E*t / (R + 0.60*t)
= 16,700*1.00*0.3125 / (39 + 0.60*0.3125)
= 133.17 psi

**External Pressure, (Corroded & at 338 °F) UG-28(c)**

$L / D_o$ = 88.9168 / 78.625 = 1.1309
$D_o / t$ = 78.625 / 0.2735 = 287.4751
From table G: A = 0.000241
From table HA-4: B = 3,169.4091 psi

$P_a$ = 4*B / (3*($D_o$ / t))
= 4*3,169.41 / (3*(78.625 / 0.2735))
= 14.7 psi

**Design thickness for external pressure $P_a$ = 14.7 psi**

$t_a$ = t + Corrosion = 0.2735 + 0 = 0.2735"

**Maximum Allowable External Pressure, (Corroded & at 338 °F) UG-28(c)**

L / $D_o$ = 88.9168 / 78.625 = 1.1309
$D_o$ / t = 78.625 / 0.3125 = 251.6000
From table G: A = 0.000293
From table HA-4: B = 3,841.19 psi

$P_a$ = 4*B / (3*($D_o$ / t))
= 4*3,841.19 / (3*(78.625 / 0.3125))
= 20.36 psi

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

EFE = (50*t / $R_f$)*(1 - $R_f$ / $R_o$)
= (50*0.3125 / 39.1563)*(1 - 39.1563 / ∞)
= 0.399%

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

$P_v$ = W / (2*π*$R_m$) + M / (π*$R_m^2$)
= 2,337.1 / (2*π*39.1563) + 32,316 / (π*$39.1563^2$)
= 16.2087 lb/in
α = $P_v$ / ($P_e$*$D_o$)
= 16.2087 / (14.7*78.625)
= 0.014
n = 6
m = 1.23 / (L / $D_o$)$^2$
= 1.23 / (88.9168 / 78.625)$^2$
= 0.9617
Ratio $P_e$ = ($n^2$ - 1 + m + m*α) / ($n^2$ - 1 + m)
= ($6^2$ - 1 + 0.9617 + 0.9617*0.014) / ($6^2$ - 1 + 0.9617)
= 1.0004
Ratio $P_e$ * $P_e$ ≤ MAEP
(1.0004 * 14.7 = 14.71) ≤ 20.36
Cylinder design thickness is satisfactory.

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

$P_v$ = 0.6*W / (2*π*$R_m$) + M / (π*$R_m^2$)
= 0.60*-29,096.8 / (2*π*39.1563) + 315,939 / (π*$39.1563^2$)
= -5.3682 lb/in
α = $P_v$ / ($P_e$*$D_o$)
= -5.3682 / (14.7*78.625)
= -0.0046
n = 6

$$
\begin{aligned}
m &= 1.23 / (L / D_o)^2 \\
&= 1.23 / (88.9168 / 78.625)^2 \\
&= 0.9617 \\
\text{Ratio } P_e &= (n^2 - 1 + m + m*\alpha) / (n^2 - 1 + m) \\
&= (6^2 - 1 + 0.9617 + 0.9617*-0.0046) / (6^2 - 1 + 0.9617) \\
&= 1 \\
\text{Ratio } P_e * P_e &\leq \text{MAEP} \\
(1 * 14.7 = 14.7) &\leq 20.36
\end{aligned}
$$

Cylinder design thickness is satisfactory.

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

$$
\begin{aligned}
P_v &= (1 + 0.14*S_{DS})*W / (2*\pi*R_m) + M / (\pi*R_m^2) \\
&= 1.02*2,337.1 / (2*\pi*39.1563) + 17,998 / (\pi*39.1563^2) \\
&= 13.3921 \text{ lb/in} \\
\alpha &= P_v / (P_e*D_o) \\
&= 13.3921 / (14.7*78.625) \\
&= 0.0116 \\
n &= 6 \\
m &= 1.23 / (L / D_o)^2 \\
&= 1.23 / (88.9168 / 78.625)^2 \\
&= 0.9617 \\
\text{Ratio } P_e &= (n^2 - 1 + m + m*\alpha) / (n^2 - 1 + m) \\
&= (6^2 - 1 + 0.9617 + 0.9617*0.0116) / (6^2 - 1 + 0.9617) \\
&= 1.0003 \\
\text{Ratio } P_e * P_e &\leq \text{MAEP} \\
(1.0003 * 14.7 = 14.7) &\leq 20.36
\end{aligned}
$$

Cylinder design thickness is satisfactory.

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

$$
\begin{aligned}
P_v &= (0.6 - 0.14*S_{DS})*W / (2*\pi*R_m) + M / (\pi*R_m^2) \\
&= 0.58*-29,096.8 / (2*\pi*39.1563) + 146,654 / (\pi*39.1563^2) \\
&= -38.5707 \text{ lb/in} \\
\alpha &= P_v / (P_e*D_o) \\
&= -38.5707 / (14.7*78.625) \\
&= -0.0334 \\
n &= 6 \\
m &= 1.23 / (L / D_o)^2 \\
&= 1.23 / (88.9168 / 78.625)^2 \\
&= 0.9617 \\
\text{Ratio } P_e &= (n^2 - 1 + m + m*\alpha) / (n^2 - 1 + m) \\
&= (6^2 - 1 + 0.9617 + 0.9617*-0.0334) / (6^2 - 1 + 0.9617) \\
&= 1 \\
\text{Ratio } P_e * P_e &\leq \text{MAEP} \\
(1 * 14.7 = 14.7) &\leq 20.36
\end{aligned}
$$

Cylinder design thickness is satisfactory.

| 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 | 45 | 16,300 | 6,864 | 338 | 0 | Top | Wind | 0.0449 | 0.044 |
| | | | | | | | Seismic | 0.0447 | 0.0442 |
| | | | | | | Bottom | Wind | 0.0542 | 0.0451 |
| | | | | | | | Seismic | 0.0525 | 0.0468 |
| Operating, Hot & New | 45 | 16,300 | 6,864 | 338 | 0 | Top | Wind | 0.0449 | 0.044 |
| | | | | | | | Seismic | 0.0447 | 0.0442 |
| | | | | | | Bottom | Wind | 0.0542 | 0.0451 |
| | | | | | | | Seismic | 0.0525 | 0.0468 |
| Hot Shut Down, Corroded | 0 | 16,300 | 6,864 | 338 | 0 | Top | Wind | 0.0001 | 0.002 |
| | | | | | | | Seismic | 0.0002 | 0.0016 |
| | | | | | | Bottom | Wind | 0.0094 | 0.0003 |
| | | | | | | | Seismic | 0.0077 | 0.002 |
| Hot Shut Down, New | 0 | 16,300 | 6,864 | 338 | 0 | Top | Wind | 0.0001 | 0.002 |
| | | | | | | | Seismic | 0.0002 | 0.0016 |
| | | | | | | Bottom | Wind | 0.0094 | 0.0003 |
| | | | | | | | Seismic | 0.0077 | 0.002 |
| Empty, Corroded | 0 | 16,700 | 9,231 | 70 | 0 | Top | Wind | 0.0001 | 0.0015 |
| | | | | | | | Seismic | 0.0002 | 0.0012 |
| | | | | | | Bottom | Wind | 0.0042 | 0.0049 |
| | | | | | | | Seismic | 0.0013 | 0.0002 |
| Empty, New | 0 | 16,700 | 9,231 | 70 | 0 | Top | Wind | 0.0001 | 0.0015 |
| | | | | | | | Seismic | 0.0002 | 0.0012 |
| | | | | | | Bottom | Wind | 0.0042 | 0.0049 |
| | | | | | | | Seismic | 0.0013 | 0.0002 |
| Vacuum | -14.7 | 16,300 | 6,864 | 338 | 0 | Top | Wind | 0.0347 | 0.0368 |
| | | | | | | | Seismic | 0.035 | 0.0364 |
| | | | | | | Bottom | Wind | 0.0125 | 0.0341 |
| | | | | | | | Seismic | 0.0165 | 0.0301 |
| Hot Shut Down, Corroded, Weight & Eccentric Moments Only | 0 | 16,300 | 6,864 | 338 | 0 | Top | Weight | 0.0009 | 0.0019 |
| | | | | | | Bottom | Weight | 0.0073 | 0.0072 |

## Shell -01

| ASME Section VIII Division 1, 2013 Edition | | | | |
|---|---|---|---|---|
| **Component** | | Cylinder | | |
| **Material** | | SA-240 316L (II-D p. 74, ln. 9) | | |
| **Impact Tested** | **Normalized** | **Fine Grain Practice** | **PWHT** | **Optimize MDMT/ Find MAWP** |
| No | No | No | No | No |
| | | **Design Pressure (psi)** | **Design Temperature (°F)** | **Design MDMT (°F)** |
| **Internal** | | 45 | 338 | -20 |
| **External** | | 14.7 | 338 | |
| **Static Liquid Head** | | | | |
| **Condition** | | **$P_s$ (psi)** | **$H_s$ (in)** | **SG** |
| **Operating** | | 4.8 | 134 | 0.993 |
| **Test horizontal** | | 2.82 | 78 | 1 |
| **Dimensions** | | | | |
| **Inner Diameter** | | 78" | | |
| **Length** | | 96" | | |
| **Nominal Thickness** | | 0.3125" | | |
| **Corrosion** | **Inner** | 0" | | |
| | **Outer** | 0" | | |
| **Weight and Capacity** | | | | |
| | | **Weight (lb)** | | **Capacity (US gal)** |
| **New** | | 2,139.3 | | 1,985.81 |
| **Corroded** | | 2,139.3 | | 1,985.81 |
| **Insulation** | | | | |
| | | **Thickness (in)** | **Density (lb/ft$^3$)** | **Weight (lb)** |
| **Insulation** | | 2 | 12 | 337.72 |
| | | **Spacing(in)** | **Individual Weight (lb)** | **Total Weight (lb)** |
| **Insulation Supports** | | 0 | 0 | 0 |
| **Radiography** | | | | |
| **Longitudinal seam** | | Full UW-11(a) Type 1 | | |
| **Top Circumferential seam** | | Full UW-11(a) Type 1 | | |
| | | Full UW-11(a) Type 1 | | |

| Bottom Circumferential seam | |
|---|---|

| Results Summary | |
|---|---|
| Governing condition | External pressure |
| Minimum thickness per UG-16 | 0.0625" + 0" = 0.0625" |
| Design thickness due to internal pressure (t) | 0.1194" |
| Design thickness due to external pressure ($t_e$) | 0.2735" |
| Design thickness due to combined loadings + corrosion | 0.0523" |
| Maximum allowable working pressure (MAWP) | 125.18 psi |
| Maximum allowable pressure (MAP) | 133.17 psi |
| Maximum allowable external pressure (MAEP) | 20.36 psi |
| Rated MDMT | -320 °F |

| UHA-51 Material Toughness Requirements |
|---|
| Rated MDMT per UHA-51(d)(1)(a), (carbon content does not exceed 0.10%) = -320°F |
| Material is exempt from impact testing at the Design MDMT of -20°F. |

**Design thickness, (at 338 °F) UG-27(c)(1)**

t = P*R / (S*E - 0.60*P) + Corrosion
= 49.8*39 / (16,300*1.00 - 0.60*49.8) + 0
= 0.1194"

**Maximum allowable working pressure, (at 338 °F) UG-27(c)(1)**

P = S*E*t / (R + 0.60*t) - $P_s$
= 16,300*1.00*0.3125 / (39 + 0.60*0.3125) - 4.8
= 125.18 psi

**Maximum allowable pressure, (at 70 °F) UG-27(c)(1)**

P = S*E*t / (R + 0.60*t)
= 16,700*1.00*0.3125 / (39 + 0.60*0.3125)
= 133.17 psi

**External Pressure, (Corroded & at 338 °F) UG-28(c)**

$L / D_o$ = 88.9168 / 78.625 = 1.1309
$D_o / t$ = 78.625 / 0.2735 = 287.4751
From table G: A = 0.000241
From table HA-4: B = 3,169.4091 psi

$P_a$ = 4*B / (3*($D_o$ / t))
= 4*3,169.41 / (3*(78.625 / 0.2735))
= 14.7 psi

**Design thickness for external pressure $P_a$ = 14.7 psi**

$t_a$ = t + Corrosion = 0.2735 + 0 = 0.2735"

**Maximum Allowable External Pressure, (Corroded & at 338 °F) UG-28(c)**

$L / D_o$ = 88.9168 / 78.625 = 1.1309
$D_o / t$ = 78.625 / 0.3125 = 251.6000
From table G: A = 0.000293
From table HA-4: B = 3,841.19 psi

$P_a$ = 4*B / (3*($D_o$ / t))
= 4*3,841.19 / (3*(78.625 / 0.3125))
= 20.36 psi

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

EFE = (50*t / $R_f$)*(1 - $R_f$ / $R_o$)
= (50*0.3125 / 39.1563)*(1 - 39.1563 / ∞)
= 0.399%

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

$P_v$ = 0.6*W / (2*π*$R_m$) + M / (π*$R_m^2$)
= 0.60*-28,037.9 / (2*π*39.1563) + 152,923 / (π*$39.1563^2$)
= -36.6297 lb/in
α = $P_v$ / ($P_e$*$D_o$)
= -36.6297 / (14.7*78.625)
= -0.0317
n = 6
m = 1.23 / ($L / D_o$)$^2$
= 1.23 / (88.9168 / 78.625)$^2$
= 0.9617
Ratio $P_e$ = ($n^2$ - 1 + m + m*α) / ($n^2$ - 1 + m)
= ($6^2$ - 1 + 0.9617 + 0.9617*-0.0317) / ($6^2$ - 1 + 0.9617)
= 1
Ratio $P_e$ * $P_e$ ≤ MAEP
(1 * 14.7 = 14.7) ≤ 20.36
Cylinder design thickness is satisfactory.

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

$P_v$ = (0.6 - 0.14*$S_{DS}$)*W / (2*π*$R_m$) + M / (π*$R_m^2$)
= 0.58*-28,037.9 / (2*π*39.1563) + 82,261 / (π*$39.1563^2$)
= -49.4277 lb/in
α = $P_v$ / ($P_e$*$D_o$)
= -49.4277 / (14.7*78.625)
= -0.0428
n = 6
m = 1.23 / ($L / D_o$)$^2$
= 1.23 / (88.9168 / 78.625)$^2$
= 0.9617

Ratio $P_e$ = $(n^2 - 1 + m + m*\alpha) / (n^2 - 1 + m)$
= $(6^2 - 1 + 0.9617 + 0.9617*-0.0428) / (6^2 - 1 + 0.9617)$
= 1

Ratio $P_e$ * $P_e$ ≤ MAEP

(1 * 14.7 = 14.7) ≤ 20.36

Cylinder design thickness is satisfactory.

| 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 | 45 | 16,300 | 6,864 | 338 | 0 | Wind | 0.0523 | 0.0467 |
| | | | | | | Seismic | 0.0516 | 0.0474 |
| Operating, Hot & New | 45 | 16,300 | 6,864 | 338 | 0 | Wind | 0.0523 | 0.0467 |
| | | | | | | Seismic | 0.0516 | 0.0474 |
| Hot Shut Down, Corroded | 0 | 16,300 | 6,864 | 338 | 0 | Wind | 0.0074 | 0.0019 |
| | | | | | | Seismic | 0.0068 | 0.0025 |
| Hot Shut Down, New | 0 | 16,300 | 6,864 | 338 | 0 | Wind | 0.0074 | 0.0019 |
| | | | | | | Seismic | 0.0068 | 0.0025 |
| Empty, Corroded | 0 | 16,700 | 9,231 | 70 | 0 | Wind | 0.0023 | 0.0021 |
| | | | | | | Seismic | 0.0009 | 0.0002 |
| Empty, New | 0 | 16,700 | 9,231 | 70 | 0 | Wind | 0.0023 | 0.0021 |
| | | | | | | Seismic | 0.0009 | 0.0002 |
| Vacuum | -14.7 | 16,300 | 6,864 | 338 | 0 | Wind | 0.0171 | 0.0303 |
| | | | | | | Seismic | 0.0187 | 0.0288 |
| Hot Shut Down, Corroded, Weight & Eccentric Moments Only | 0 | 16,300 | 6,864 | 338 | 0 | Weight | 0.007 | 0.007 |

## Straight Flange on F&D Head (btm)

| ASME Section VIII Division 1, 2013 Edition | | | | |
|---|---|---|---|---|
| **Component** | | Cylinder | | |
| **Material** | | SA-240 316L (II-D p. 74, ln. 9) | | |
| **Impact Tested** | **Normalized** | **Fine Grain Practice** | **PWHT** | **Optimize MDMT/ Find MAWP** |
| No | No | No | No | No |
| | | **Design Pressure (psi)** | **Design Temperature (°F)** | **Design MDMT (°F)** |
| **Internal** | | 45 | 338 | -20 |
| **External** | | 14.7 | 338 | |
| **Static Liquid Head** | | | | |
| **Condition** | | **$P_s$ (psi)** | **$H_s$ (in)** | **SG** |
| **Operating** | | 4.86 | 135.5 | 0.993 |
| **Test horizontal** | | 2.82 | 78 | 1 |
| **Dimensions** | | | | |
| **Inner Diameter** | | 78" | | |
| **Length** | | 1.5" | | |
| **Nominal Thickness** | | 0.5" | | |
| **Corrosion** | **Inner** | 0" | | |
| | **Outer** | 0" | | |
| **Weight and Capacity** | | | | |
| | | **Weight (lb)** | | **Capacity (US gal)** |
| **New** | | 53.64 | | 31.03 |
| **Corroded** | | 53.64 | | 31.03 |
| **Insulation** | | | | |
| | | **Thickness (in)** | **Density (lb/ft$^3$)** | **Weight (lb)** |
| **Insulation** | | 2 | 12 | 0 |
| | | **Spacing(in)** | **Individual Weight (lb)** | **Total Weight (lb)** |
| **Insulation Supports** | | 0 | 0 | 0 |
| **Radiography** | | | | |
| **Longitudinal seam** | | Full UW-11(a) Type 1 | | |
| **Top Circumferential seam** | | Full UW-11(a) Type 1 | | |

| Results Summary | |
|---|---|
| Governing condition | External pressure |
| Minimum thickness per UG-16 | 0.0625" + 0" = 0.0625" |
| Design thickness due to internal pressure (t) | 0.1196" |
| Design thickness due to external pressure ($t_e$) | 0.2731" |
| Design thickness due to combined loadings + corrosion | 0.0502" |
| Maximum allowable working pressure (MAWP) | 202.52 psi |
| Maximum allowable pressure (MAP) | 212.47 psi |
| Maximum allowable external pressure (MAEP) | 52.81 psi |
| Rated MDMT | -320 °F |

| UHA-51 Material Toughness Requirements | |
|---|---|
| $t_r$ = 49.86*39 / (16,700*1 - 0.6*49.86) = | 0.1166" |
| Stress ratio = $t_r$*$E^*$ / ($t_n$ - c) = 0.1166*1 / (0.5 - 0) = | 0.2333 |
| Impact test exempt per UHA-51(g) (coincident ratio = 0.2333) | |
| Rated MDMT = | -320°F |
| Material is exempt from impact testing at the Design MDMT of -20°F. | |

**Design thickness, (at 338 °F) UG-27(c)(1)**

t = P*R / (S*E - 0.60*P) + Corrosion
= 49.86*39 / (16,300*1.00 - 0.60*49.86) + 0
= 0.1196"

**Maximum allowable working pressure, (at 338 °F) UG-27(c)(1)**

P = S*E*t / (R + 0.60*t) - $P_s$
= 16,300*1.00*0.5 / (39 + 0.60*0.5) - 4.86
= 202.52 psi

**Maximum allowable pressure, (at 70 °F) UG-27(c)(1)**

P = S*E*t / (R + 0.60*t)
= 16,700*1.00*0.5 / (39 + 0.60*0.5)
= 212.47 psi

**External Pressure, (Corroded & at 338 °F) UG-28(c)**

$L / D_o$ = 87.9168 / 79 = 1.1129
$D_o / t$ = 79 / 0.2731 = 289.2485
From table G: A = 0.000243
From table HA-4: B = 3,188.9677 psi

$P_a$ = 4*B / (3*($D_o$ / t))
= 4*3,188.97 / (3*(79 / 0.2731))
= 14.7 psi

**Design thickness for external pressure $P_a$ = 14.7 psi**

$t_a$ = t + Corrosion = 0.2731 + 0 = 0.2731"

**Maximum Allowable External Pressure, (Corroded & at 338 °F) UG-28(c)**

$L / D_o$ = 87.9168 / 79 = 1.1129
$D_o / t$ = 79 / 0.5 = 158.0000
From table G: A = 0.000612
From table HA-4: B = 6,258.183 psi

$P_a$ = 4*B / (3*($D_o$ / t))
= 4*6,258.18 / (3*(79 / 0.5))
= 52.81 psi

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

EFE = (50*t / $R_f$)*(1 - $R_f$ / $R_o$)
= (50*0.5 / 39.25)*(1 - 39.25 / ∞)
= 0.6369%

| 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 | 45 | 16,300 | 7,501 | 338 | 0 | Wind | 0.0501 | 0.048 |
| | | | | | | Seismic | 0.0502 | 0.0479 |
| Operating, Hot & New | 45 | 16,300 | 7,501 | 338 | 0 | Wind | 0.0501 | 0.048 |
| | | | | | | Seismic | 0.0502 | 0.0479 |
| Hot Shut Down, Corroded | 0 | 16,300 | 7,501 | 338 | 0 | Wind | 0.0053 | 0.0031 |
| | | | | | | Seismic | 0.0054 | 0.0031 |
| Hot Shut Down, New | 0 | 16,300 | 7,501 | 338 | 0 | Wind | 0.0053 | 0.0031 |
| | | | | | | Seismic | 0.0054 | 0.0031 |
| Empty, Corroded | 0 | 16,700 | 10,071 | 70 | 0 | Wind | 0.0002 | 0.0001 |
| | | | | | | Seismic | 0.0002 | 0.0001 |
| Empty, New | 0 | 16,700 | 10,071 | 70 | 0 | Wind | 0.0002 | 0.0001 |
| | | | | | | Seismic | 0.0002 | 0.0001 |
| Vacuum | -14.7 | 16,300 | 7,501 | 338 | 0 | Wind | 0.0203 | 0.025 |
| | | | | | | Seismic | 0.0202 | 0.0252 |
| Hot Shut Down, Corroded, Weight & Eccentric Moments Only | 0 | 16,300 | 7,501 | 338 | 0 | Weight | 0.0063 | 0.0063 |

## F&D Head (btm)

| ASME Section VIII Division 1, 2013 Edition | | | | |
|---|---|---|---|---|
| **Component** | | F&D Head | | |
| **Material** | | SA-240 316L (II-D p. 74, ln. 9) | | |
| **Attached To** | | Shell -01 | | |
| **Impact Tested** | **Normalized** | **Fine Grain Practice** | **PWHT** | **Optimize MDMT/ Find MAWP** |
| No | No | No | No | No |
| | | **Design Pressure (psi)** | **Design Temperature (°F)** | **Design MDMT (°F)** |
| **Internal** | | 45 | 338 | -20 |
| **External** | | 14.7 | 338 | |
| **Static Liquid Head** | | | | |
| **Condition** | | **$P_s$ (psi)** | **$H_s$ (in)** | **SG** |
| **Operating** | | 5.33 | 148.7505 | 0.993 |
| **Test horizontal** | | 2.82 | 78 | 1 |
| **Dimensions** | | | | |
| **Inner Diameter** | | 78" | | |
| **Crown Radius L** | | 78" | | |
| **Knuckle Radius r** | | 4.75" | | |
| **Minimum Thickness** | | 0.4" | | |
| **Corrosion** | **Inner** | 0" | | |
| | **Outer** | 0" | | |
| **Length $L_{sf}$** | | 1.5" | | |
| **Nominal Thickness $t_{sf}$** | | 0.5" | | |
| **Weight and Capacity** | | | | |
| | | **Weight (lb)[1]** | | **Capacity (US gal)[1]** |
| **New** | | 718.8 | | 198.26 |
| **Corroded** | | 718.8 | | 198.26 |
| **Insulation** | | | | |
| | | **Thickness (in)** | **Density (lb/ft$^3$)** | **Weight (lb)** |
| **Insulation** | | 2 | 12 | 92.01 |
| | | **Spacing(in)** | **Individual Weight (lb)** | **Total Weight (lb)** |
| **Insulation Supports** | | 0 | 0 | 0 |
| **Radiography** | | | | |

| | |
|---|---|
| **Category A joints** | Full UW-11(a) Type 1 |
| **Head to shell seam** | Full UW-11(a) Type 1 |

[1] includes straight flange

| Results Summary | |
|---|---|
| Governing condition | external pressure |
| Minimum thickness per UG-16 | 0.0625" + 0" = 0.0625" |
| Design thickness due to internal pressure (t) | 0.2124" |
| Design thickness due to external pressure ($t_e$) | 0.2346" |
| Maximum allowable working pressure (MAWP) | 89.44 psi |
| Maximum allowable pressure (MAP) | 97.09 psi |
| Maximum allowable external pressure (MAEP) | 32.18 psi |
| Rated MDMT | -320°F |

| UHA-51 Material Toughness Requirements | |
|---|---|
| $t_r$ = 50.33*78*1 / (2*16,700*1 - 0.2*50.33) = | 0.1176" |
| Stress ratio = $t_r$*$E^*$ / ($t_n$ - c) = 0.1176*1 / (0.4 - 0) = | 0.2939 |
| Impact test exempt per UHA-51(g) (coincident ratio = 0.2939) | |
| Rated MDMT = | -320°F |
| Material is exempt from impact testing at the Design MDMT of -20°F. | |

| Factor M | | |
|---|---|---|
| M = 1/4*[3 + (L / r)$^{1/2}$] | | |
| Corroded | M = 1/4*[3 + (78 / 4.75)$^{1/2}$] | 1.7631 |
| New | M = 1/4*[3 + (78 / 4.75)$^{1/2}$] | 1.7631 |

**Design thickness for internal pressure, (Corroded at 338 °F) Appendix 1-4(d)**

t = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 50.33*78*1.7631 / (2*16,300*1 - 0.2*50.33) + 0
= 0.2124"

**Maximum allowable working pressure, (Corroded at 338 °F) Appendix 1-4(d)**

P = 2*S*E*t / (L*M + 0.2*t) - $P_s$
= 2*16,300*1*0.4 / (78*1.7631 + 0.2*0.4) - 5.33
= 89.44 psi

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

P = 2*S*E*t / (L*M + 0.2*t) - $P_s$
= 2*16,700*1*0.4 / (78*1.7631 + 0.2*0.4) - 0
= 97.09 psi

**Design thickness for external pressure, (Corroded at 338 °F) UG-33(e)**

Equivalent outside spherical radius ($R_o$)
= Outside crown radius
= 78.4 in

A = 0.125 / ($R_o$ / t)
= 0.125 / (78.4 / 0.234551)
= 0.000374

From Table HA-4: B = 4,913.5547 psi

$P_a$ = B / ($R_o$ / t)
= 4,913.5547 / (78.4 / 0.2346)
= 14.7 psi

t = 0.2346" + Corrosion = 0.2346" + 0" = 0.2346"
Check the external pressure per UG-33(a)(1) Appendix 1-4(d)

t = 1.67*$P_e$*L*M / (2*S*E - 0.2*1.67*$P_e$) + Corrosion
= 1.67*14.7*78*1.7631 / (2*16,300*1 - 0.2*1.67*14.7) + 0
= 0.1036"

The head external pressure design thickness ($t_e$) is 0.2346".

**Maximum Allowable External Pressure, (Corroded at 338 °F) UG-33(e)**

Equivalent outside spherical radius ($R_o$)
= Outside crown radius
= 78.4 in

A = 0.125 / ($R_o$ / t)
= 0.125 / (78.4 / 0.4)
= 0.000638

From Table HA-4: B = 6,308.0192 psi

$P_a$ = B / ($R_o$ / t)
= 6,308.0192 / (78.4 / 0.4)
= 32.1838 psi

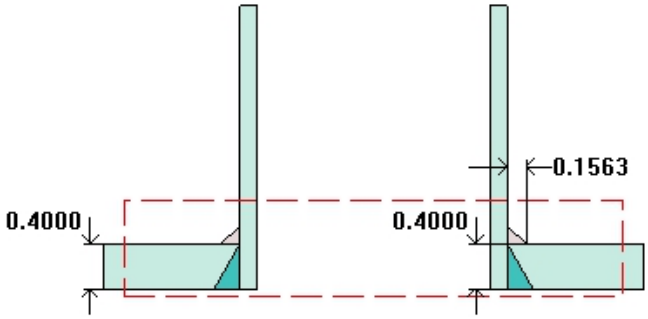
**Check the Maximum External Pressure, UG-33(a)(1) Appendix 1-4(d)**

P = 2*S*E*t / ((L*M + 0.2*t)*1.67)
= 2*16,300*1*0.4 / ((78*1.7631 + 0.2*0.4)*1.67)
= 56.75 psi

The maximum allowable external pressure (MAEP) is 32.18 psi.

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

$$
\begin{aligned}
EFE &= (75*t / R_f)*(1 - R_f / R_o) \\
&= (75*0.5 / 5)*(1 - 5 / \infty) \\
&= 7.5\%
\end{aligned}
$$

| ASME Section VIII Division 1, 2013 Edition | |
|---|---|
|  | |
| Note: round inside edges per UG-76(c) | |
| **Location and Orientation** | |
| **Located on** | F&D Head (top) |
| **Orientation** | 60° |
| **End of nozzle to datum line** | 184" |
| **Calculated as hillside** | Yes |
| **Distance to head center, R** | 27" |
| **Passes through a Category A joint** | No |
| **Nozzle** | |
| **Description** | NPS 2 Sch 40S (Std) |
| **Access opening** | No |
| **Material specification** | SA-312 TP316L Wld & smls pipe (II-D p. 74, ln. 14) |
| **Inside diameter, new** | 2.067" |
| **Nominal wall thickness** | 0.154" |
| **Corrosion allowance** | 0" |
| **Opening chord length** | 2.203" |
| **Projection available outside vessel, Lpr** | 4.2206" |
| **Projection available outside vessel to flange face, Lf** | 6.7206" |
| **Local vessel minimum thickness** | 0.4" |
| **Liquid static head included** | 0 psi |
| **Longitudinal joint efficiency** | 1 |
| **Welds** | |
| **Inner Fillet, $Leg_{41}$** | 0.1563" |

| | |
|---|---|
| **Nozzle to vessel groove weld** | 0.4" |

| ASME B16.5-2009 Flange | |
|---|---|
| **Description** | NPS 2 Class 150 WN A182 F316L |
| **Bolt Material** | SA-193 B7 Bolt <= 2 1/2 (II-D p. 352, ln. 31) |
| **Blind included** | Yes |
| **Rated MDMT** | -55°F |
| **Liquid static head** | 0 psi |
| **MAWP rating** | 169.3 psi @ 338°F |
| **MAP rating** | 230 psi @ 70°F |
| **Hydrotest rating** | 350 psi @ 70°F |
| **PWHT performed** | No |
| **Impact Tested** | No |
| **Circumferential joint radiography** | None UW-11(c) Type 1 |
| **Gasket** | |
| **Description** | Flexitallic Spiral Wound CGI 316L S.S. |
| **Notes** | |
| Flange rated MDMT per UHA-51(d)(1)(a) = -320°F<br>Bolts rated MDMT per Fig UCS-66 note (c) = -55°F | |

| UHA-51 Material Toughness Requirements Nozzle | |
|---|---|
| $t_r$ = 45*1.0335 / (16,700*1 - 0.6*45) = | 0.0028" |
| Stress ratio = $t_r$*$E^*$ / ($t_n$ - c) = 0.0028*1 / (0.1348 - 0) = | 0.0207 |
| Impact test exempt per UHA-51(g) (coincident ratio = 0.0207) | |
| Rated MDMT = | -320°F |
| Material is exempt from impact testing at the Design MDMT of -20°F. | |

**Reinforcement Calculations for MAWP**

The vessel wall thickness governs the MAWP of this nozzle.

| UG-37 Area Calculation Summary ($in^2$) | UG-45 Summary (in) |
|---|---|
| For P = 167.01 psi @ 338 °F | 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 | 0.1348 |

| 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 ($Leg_{41}$) | 0.1078 | 0.1094 | weld size is adequate |

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

**Reinforcement Calculations for MAP**

The vessel wall thickness governs the MAP of this nozzle.

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For P = 171.11 psi @ 70 °F | | | | | | | 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 | 0.1348 |

| 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 ($Leg_{41}$) | 0.1078 | 0.1094 | weld size is adequate |

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

**Reinforcement Calculations for MAEP**

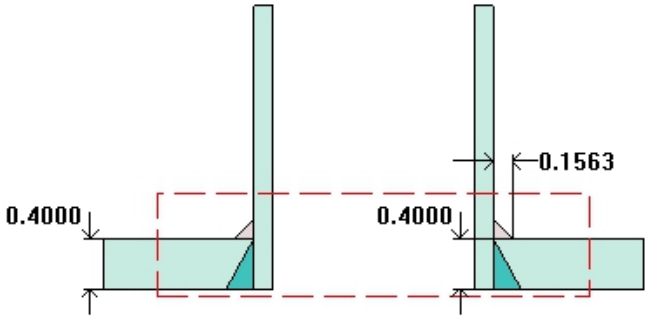
| UG-37 Area Calculation Summary ($in^2$) | UG-45 Summary (in) |
|---|---|
| For Pe = 32.18 psi @ 338 °F | |

| | | | | | | | 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 | 0.1348 |

| UG-41 Weld Failure Path Analysis Summary |
|---|
| Weld strength calculations are not required for external pressure |

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| Weld description | Required weld throat size (in) | Actual weld throat size (in) | Status |
| Nozzle to shell fillet ($Leg_{41}$) | 0.1078 | 0.1094 | weld size is adequate |

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

| ASME Section VIII Division 1, 2013 Edition | |
|---|---|
|  | |
| Note: round inside edges per UG-76(c) | |
| **Location and Orientation** | |
| **Located on** | F&D Head (top) |
| **Orientation** | 120° |
| **End of nozzle to datum line** | 184" |
| **Calculated as hillside** | Yes |
| **Distance to head center, R** | 27" |
| **Passes through a Category A joint** | No |
| **Nozzle** | |
| **Description** | NPS 1.5 Sch 40S (Std) |
| **Access opening** | No |
| **Material specification** | SA-312 TP316L Wld & smls pipe (II-D p. 74, ln. 14) |
| **Inside diameter, new** | 1.61" |
| **Nominal wall thickness** | 0.145" |
| **Corrosion allowance** | 0" |
| **Opening chord length** | 1.7159" |
| **Projection available outside vessel, Lpr** | 4.3639" |
| **Projection available outside vessel to flange face, Lf** | 6.8039" |
| **Local vessel minimum thickness** | 0.4" |
| **Liquid static head included** | 0 psi |
| **Longitudinal joint efficiency** | 1 |
| **Welds** | |
| **Inner Fillet, $Leg_{41}$** | 0.1563" |

| | |
|---|---|
| **Nozzle to vessel groove weld** | 0.4" |

| ASME B16.5-2009 Flange | |
|---|---|
| **Description** | NPS 1.5 Class 150 WN A182 F316L |
| **Bolt Material** | SA-193 B7 Bolt <= 2 1/2 (II-D p. 352, ln. 31) |
| **Blind included** | Yes |
| **Rated MDMT** | -55°F |
| **Liquid static head** | 0 psi |
| **MAWP rating** | 169.3 psi @ 338°F |
| **MAP rating** | 230 psi @ 70°F |
| **Hydrotest rating** | 350 psi @ 70°F |
| **PWHT performed** | No |
| **Impact Tested** | No |
| **Circumferential joint radiography** | None UW-11(c) Type 1 |
| **Gasket** | |
| **Description** | Flexitallic Spiral Wound CGI 316L S.S. |
| **Notes** | |
| Flange rated MDMT per UHA-51(d)(1)(a) = -320°F<br>Bolts rated MDMT per Fig UCS-66 note (c) = -55°F | |

| UHA-51 Material Toughness Requirements Nozzle | |
|---|---|
| $t_r$ = 45*0.805 / (16,700*1 - 0.6*45) = | 0.0022" |
| Stress ratio = $t_r$*$E^*$ / ($t_n$ - c) = 0.0022*1 / (0.1269 - 0) = | 0.0171 |
| Impact test exempt per UHA-51(g) (coincident ratio = 0.0171) | |
| Rated MDMT = | -320°F |
| Material is exempt from impact testing at the Design MDMT of -20°F. | |

**Reinforcement Calculations for MAWP**

The vessel wall thickness governs the MAWP of this nozzle.

| UG-37 Area Calculation Summary ($in^2$) | UG-45 Summary (in) |
|---|---|

| For P = 167.01 psi @ 338 °F | | | | | | | The nozzle passes UG-45 | |
|---|---|---|---|---|---|---|---|---|
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| This nozzle is exempt from area calculations per UG-36(c)(3)(a) | | | | | | | 0.1269 | 0.1269 |

| 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 ($Leg_{41}$) | 0.1015 | 0.1094 | weld size is adequate |

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

**Reinforcement Calculations for MAP**

The vessel wall thickness governs the MAP of this nozzle.

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For P = 171.11 psi @ 70 °F | | | | | | | The nozzle passes UG-45 | |
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| This nozzle is exempt from area calculations per UG-36(c)(3)(a) | | | | | | | 0.1269 | 0.1269 |

| 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 ($Leg_{41}$) | 0.1015 | 0.1094 | weld size is adequate |

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

**Reinforcement Calculations for MAEP**

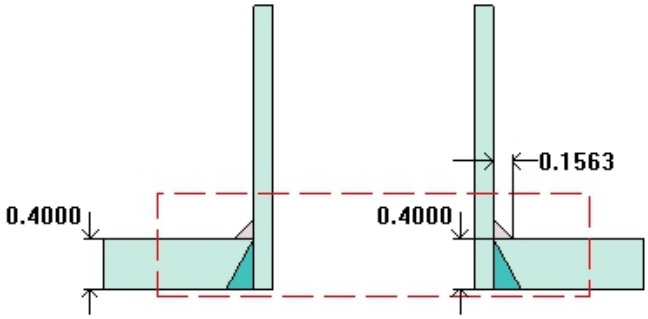
| UG-37 Area Calculation Summary | UG-45 |
|---|---|

| ($in^2$) | | | | | | | Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For Pe = 32.18 psi @ 338 °F | | | | | | | The nozzle passes UG-45 | |
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| This nozzle is exempt from area calculations per UG-36(c)(3)(a) | | | | | | | 0.1269 | 0.1269 |

| UG-41 Weld Failure Path Analysis Summary |
|---|
| Weld strength calculations are not required for external pressure |

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| Weld description | Required weld throat size (in) | Actual weld throat size (in) | Status |
| Nozzle to shell fillet ($Leg_{41}$) | 0.1015 | 0.1094 | weld size is adequate |

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

| ASME Section VIII Division 1, 2013 Edition | |
|---|---|
|  | |
| Note: round inside edges per UG-76(c) | |
| **Location and Orientation** | |
| **Located on** | F&D Head (top) |
| **Orientation** | 330° |
| **End of nozzle to datum line** | 184" |
| **Calculated as hillside** | Yes |
| **Distance to head center, R** | 27" |
| **Passes through a Category A joint** | No |
| **Nozzle** | |
| **Description** | NPS 1.5 Sch 40S (Std) |
| **Access opening** | No |
| **Material specification** | SA-312 TP316L Wld & smls pipe (II-D p. 74, ln. 14) |
| **Inside diameter, new** | 1.61" |
| **Nominal wall thickness** | 0.145" |
| **Corrosion allowance** | 0" |
| **Opening chord length** | 1.7159" |
| **Projection available outside vessel, Lpr** | 4.3639" |
| **Projection available outside vessel to flange face, Lf** | 6.8039" |
| **Local vessel minimum thickness** | 0.4" |
| **Liquid static head included** | 0 psi |
| **Longitudinal joint efficiency** | 1 |
| **Welds** | |
| **Inner Fillet, $Leg_{41}$** | 0.1563" |

| | |
|---|---|
| **Nozzle to vessel groove weld** | 0.4" |

| ASME B16.5-2009 Flange | |
|---|---|
| **Description** | NPS 1.5 Class 150 WN A182 F316L |
| **Bolt Material** | SA-193 B7 Bolt <= 2 1/2 (II-D p. 352, ln. 31) |
| **Blind included** | Yes |
| **Rated MDMT** | -55°F |
| **Liquid static head** | 0 psi |
| **MAWP rating** | 169.3 psi @ 338°F |
| **MAP rating** | 230 psi @ 70°F |
| **Hydrotest rating** | 350 psi @ 70°F |
| **PWHT performed** | No |
| **Impact Tested** | No |
| **Circumferential joint radiography** | None UW-11(c) Type 1 |
| **Gasket** | |
| **Description** | Flexitallic Spiral Wound CGI 316L S.S. |
| **Notes** | |
| Flange rated MDMT per UHA-51(d)(1)(a) = -320°F<br>Bolts rated MDMT per Fig UCS-66 note (c) = -55°F | |

| UHA-51 Material Toughness Requirements Nozzle | |
|---|---|
| $t_r$ = 45*0.805 / (16,700*1 - 0.6*45) = | 0.0022" |
| Stress ratio = $t_r$*$E^*$ / ($t_n$ - c) = 0.0022*1 / (0.1269 - 0) = | 0.0171 |
| Impact test exempt per UHA-51(g) (coincident ratio = 0.0171) | |
| Rated MDMT = | -320°F |
| Material is exempt from impact testing at the Design MDMT of -20°F. | |

**Reinforcement Calculations for MAWP**

The vessel wall thickness governs the MAWP of this nozzle.

| UG-37 Area Calculation Summary ($in^2$) | UG-45 Summary (in) |
|---|---|

| For P = 167.01 psi @ 338 °F | | | | | | | The nozzle passes UG-45 | |
|---|---|---|---|---|---|---|---|---|
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| This nozzle is exempt from area calculations per UG-36(c)(3)(a) | | | | | | | 0.1269 | 0.1269 |

| 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 ($Leg_{41}$) | 0.1015 | 0.1094 | weld size is adequate |

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

**Reinforcement Calculations for MAP**

The vessel wall thickness governs the MAP of this nozzle.

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For P = 171.11 psi @ 70 °F | | | | | | | The nozzle passes UG-45 | |
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| This nozzle is exempt from area calculations per UG-36(c)(3)(a) | | | | | | | 0.1269 | 0.1269 |

| 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 ($Leg_{41}$) | 0.1015 | 0.1094 | weld size is adequate |

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

**Reinforcement Calculations for MAEP**

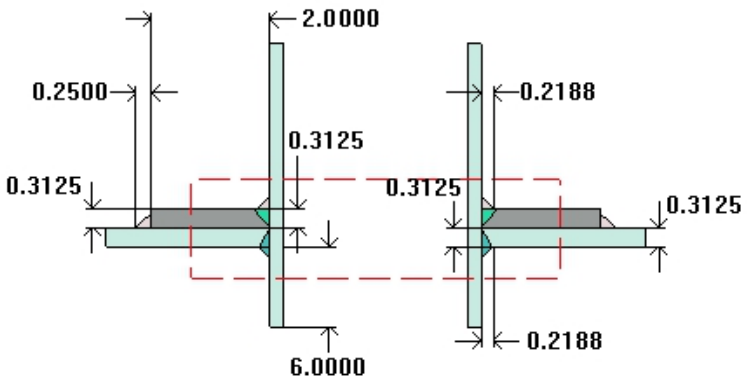
| UG-37 Area Calculation Summary | UG-45 |
|---|---|

| ($in^2$) | | | | | | | Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For Pe = 32.18 psi @ 338 °F | | | | | | | The nozzle passes UG-45 | |
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| This nozzle is exempt from area calculations per UG-36(c)(3)(a) | | | | | | | 0.1269 | 0.1269 |

| UG-41 Weld Failure Path Analysis Summary |
|---|
| Weld strength calculations are not required for external pressure |

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| Weld description | Required weld throat size (in) | Actual weld throat size (in) | Status |
| Nozzle to shell fillet ($Leg_{41}$) | 0.1015 | 0.1094 | weld size is adequate |

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

| ASME Section VIII Division 1, 2013 Edition |
|---|
|  |
| Note: round inside edges per UG-76(c) |

| Location and Orientation | |
|---|---|
| **Located on** | Shell -01 |
| **Orientation** | 90° |
| **Nozzle center line offset to datum line** | 6" |
| **End of nozzle to shell center** | 45.3125" |
| **Passes through a Category A joint** | No |

| Nozzle | |
|---|---|
| **Description** | NPS 3 Sch 40S (Std) |
| **Access opening** | No |
| **Material specification** | SA-312 TP316L Wld & smls pipe (II-D p. 74, ln. 14) |
| **Inside diameter, new** | 3.068" |
| **Nominal wall thickness** | 0.216" |
| **Corrosion allowance** | 0" |
| **Projection available outside vessel, Lpr** | 3.25" |
| **Internal projection, $h_{new}$** | 6" |
| **Projection available outside vessel to flange face, Lf** | 6" |
| **Local vessel minimum thickness** | 0.3125" |
| **Liquid static head included** | 4.7 psi |
| **Longitudinal joint efficiency** | 1 |

| Reinforcing Pad | |
|---|---|
| **Material specification** | SA-240 316L (II-D p. 74, ln. 9) |
| **Diameter, $D_p$** | 7.5" |

| | |
|---|---|
| **Thickness, $t_e$** | 0.3125" |
| **Is split** | No |
| **Welds** | |
| **Inner Fillet, $Leg_{41}$** | 0.2188" |
| **Outer Fillet, $Leg_{42}$** | 0.25" |
| **Lower Fillet, $Leg_{43}$** | 0.2188" |
| **Nozzle to vessel groove weld** | 0.3125" |
| **Pad groove weld** | 0.3125" |

| ASME B16.5-2009 Flange | |
|---|---|
| **Description** | NPS 3 Class 150 WN A182 F316L |
| **Bolt Material** | SA-193 B7 Bolt <= 2 1/2 (II-D p. 352, ln. 31) |
| **Blind included** | No |
| **Rated MDMT** | -55°F |
| **Liquid static head** | 4.64 psi |
| **Consider External Loads on Flange MAWP Rating** | No |
| **MAWP rating** | 169.3 psi @ 338°F |
| **MAP rating** | 230 psi @ 70°F |
| **Hydrotest rating** | 350 psi @ 70°F |
| **PWHT performed** | No |
| **Impact Tested** | No |
| **Circumferential joint radiography** | None UW-11(c) Type 1 |
| **Notes** | |
| Flange rated MDMT per UHA-51(d)(1)(a) = -320°F<br>Bolts rated MDMT per Fig UCS-66 note (c) = -55°F | |

| UHA-51 Material Toughness Requirements Nozzle |
|---|
| Rated MDMT per UHA-51(d)(1)(a), (carbon content does not exceed 0.10%) = -320°F |
| Material is exempt from impact testing at the Design MDMT of -20°F. |

| UHA-51 Material Toughness Requirements Pad |
|---|
| Rated MDMT per UHA-51(d)(1)(a), (carbon content does not exceed 0.10%) = -320°F |
| Material is exempt from impact testing at the Design MDMT of -20°F. |

### Reinforcement Calculations for MAWP

The vessel wall thickness governs the MAWP of this nozzle.

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For P = 129.99 psi @ 338 °F | | | | | | | 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 | 0.189 |

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

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| Weld description | Required weld size (in) | Actual weld size (in) | Status |
| Nozzle to pad fillet ($Leg_{41}$) | 0.1512 | 0.1531 | weld size is adequate |
| Pad to shell fillet ($Leg_{42}$) | 0.1562 | 0.175 | weld size is adequate |

| WRC 107 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Load Case | P (psi) | $P_r$ ($lb_f$) | $M_c$ ($lb_f$-in) | $V_c$ ($lb_f$) | $M_L$ ($lb_f$-in) | $V_L$ ($lb_f$) | $M_t$ ($lb_f$-in) | Max Comb Stress (psi) | Allow Comb Stress (psi) | Max Local Primary Stress (psi) | Allow Local Primary Stress (psi) | Over stressed |
| Load case 1 | 129.99 | 787 | 7,968 | 674 | 12,384 | 922 | 15,936 | 31,789 | 48,900 | 19,117 | 24,450 | No |
| Load case 1 (Hot Shut Down) | 0 | 787 | 7,968 | 674 | 12,384 | 922 | 15,936 | -19,617 | 48,900 | -5,399 | 24,450 | No |
| Load case 1 (Pr Reversed) | 129.99 | -787 | 7,968 | 674 | 12,384 | 922 | 15,936 | **35,611** | **48,900** | **21,621** | **24,450** | No |
| Load case 1 (Pr Reversed) (Hot Shut Down) | 0 | -787 | 7,968 | 674 | 12,384 | 922 | 15,936 | 19,479 | 48,900 | 5,399 | 24,450 | No |

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

### Reinforcement Calculations for MAP

The vessel wall thickness governs the MAP of this nozzle.

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For P = 133.17 psi @ 70 °F | | | | | | | 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 | 0.189 |

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

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| Weld description | Required weld size (in) | Actual weld size (in) | Status |
| Nozzle to pad fillet ($Leg_{41}$) | 0.1512 | 0.1531 | weld size is adequate |
| Pad to shell fillet ($Leg_{42}$) | 0.1562 | 0.175 | weld size is adequate |

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

### Reinforcement Calculations for MAEP

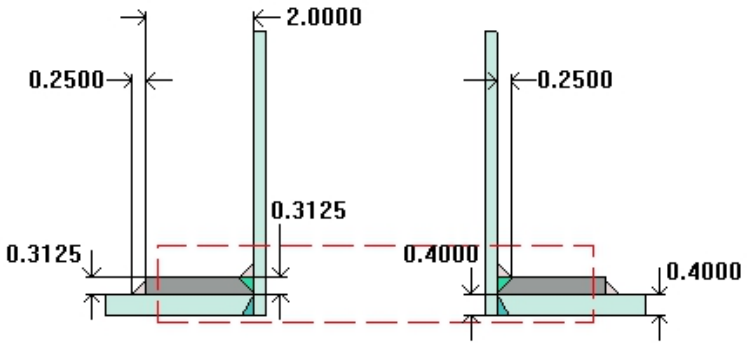
| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For Pe = 20.36 psi @ 338 °F | | | | | | | The nozzle passes UG-45 | |
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| This nozzle is exempt from area calculations per UG-36(c)(3)(a) | | | | | | | 0.0952 | 0.189 |

| UG-41 Weld Failure Path Analysis Summary |
|---|
| Weld strength calculations are not required for external pressure |

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| **Weld description** | **Required weld size (in)** | **Actual weld size (in)** | **Status** |
| Nozzle to pad fillet ($Leg_{41}$) | 0.1512 | 0.1531 | weld size is adequate |
| Pad to shell fillet ($Leg_{42}$) | 0.1562 | 0.175 | weld size is adequate |

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

## Liquid Outlet (B1)

| ASME Section VIII Division 1, 2013 Edition |
|---|
|   |
| Note: round inside edges per UG-76(c) |

| Location and Orientation | |
|---|---|
| **Located on** | F&D Head (btm) |
| **Orientation** | 0° |
| **End of nozzle to datum line** | -20" |
| **Calculated as hillside** | No |
| **Distance to head center, R** | 0" |
| **Passes through a Category A joint** | No |

| Nozzle | |
|---|---|
| **Description** | NPS 4 Sch 40S (Std) |
| **Access opening** | No |
| **Material specification** | SA-312 TP316L Wld & smls pipe (II-D p. 74, ln. 14) |
| **Inside diameter, new** | 4.026" |
| **Nominal wall thickness** | 0.237" |
| **Corrosion allowance** | 0" |
| **Projection available outside vessel, Lpr** | 3.3818" |
| **Projection available outside vessel to flange face, Lf** | 6.3818" |
| **Local vessel minimum thickness** | 0.4" |
| **Liquid static head included** | 5.56 psi |
| **Longitudinal joint efficiency** | 1 |

| Reinforcing Pad | |
|---|---|
| **Material specification** | SA-240 316L (II-D p. 74, ln. 9) |
| **Diameter, $D_p$** | 8.5" |

| | |
|---|---|
| **Thickness, $t_e$** | 0.3125" |
| **Is split** | No |
| **Welds** | |
| **Inner Fillet, $Leg_{41}$** | 0.25" |
| **Outer Fillet, $Leg_{42}$** | 0.25" |
| **Nozzle to vessel groove weld** | 0.4" |
| **Pad groove weld** | 0.3125" |

| **ASME B16.5-2009 Flange** | |
|---|---|
| **Description** | NPS 4 Class 150 WN A182 F316L |
| **Bolt Material** | SA-193 B7 Bolt <= 2 1/2 (II-D p. 352, ln. 31) |
| **Blind included** | No |
| **Rated MDMT** | -55°F |
| **Liquid static head** | 5.57 psi |
| **Consider External Loads on Flange MAWP Rating** | No |
| **MAWP rating** | 169.3 psi @ 338°F |
| **MAP rating** | 230 psi @ 70°F |
| **Hydrotest rating** | 350 psi @ 70°F |
| **PWHT performed** | No |
| **Impact Tested** | No |
| **Circumferential joint radiography** | None UW-11(c) Type 1 |
| **Notes** | |
| Flange rated MDMT per UHA-51(d)(1)(a) = -320°F<br>Bolts rated MDMT per Fig UCS-66 note (c) = -55°F | |

| **UHA-51 Material Toughness Requirements Nozzle** |
|---|
| Rated MDMT per UHA-51(d)(1)(a), (carbon content does not exceed 0.10%) = -320°F |
| Material is exempt from impact testing at the Design MDMT of -20°F. |

| **UHA-51 Material Toughness Requirements Pad** | |
|---|---|
| $t_r$ = 50.56*78*1 / (2*16,700*1 - 0.2*50.56) = | 0.1181" |
| Stress ratio = $t_r$*$E^*$ / ($t_n$ - c) = 0.1181*1 / (0.4 - 0) = | 0.2953 |
| Impact test exempt per UHA-51(g) (coincident ratio = 0.2953) | |
| Rated MDMT = | -320°F |
| Material is exempt from impact testing at the Design MDMT of -20°F. | |

### Reinforcement Calculations for MAWP

Available reinforcement per UG-37 governs the MAWP of this nozzle.

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For P = 164.62 psi @ 338 °F<br>The opening is adequately reinforced | | | | | | | The nozzle passes UG-45 | |
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| 1.5873 | 1.5875 | 0.0231 | 0.3919 | -- | 1.11 | 0.0625 | 0.2074 | 0.2074 |

| 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 |
| 25,541.24 | 25,499.72 | 44,768.09 | 10,497.2 | 74,862.84 | 28,590.2 | 60,764.65 |

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| Weld description | Required weld size (in) | Actual weld size (in) | Status |
| Nozzle to pad fillet ($Leg_{41}$) | 0.1659 | 0.175 | weld size is adequate |
| Pad to shell fillet ($Leg_{42}$) | 0.1562 | 0.175 | weld size is adequate |

| WRC 107 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Load Case | P (psi) | $P_r$ ($lb_f$) | $M_1$ ($lb_f$-in) | $V_2$ ($lb_f$) | $M_2$ ($lb_f$-in) | $V_1$ ($lb_f$) | $M_t$ ($lb_f$-in) | Max Comb Stress (psi) | Allow Comb Stress (psi) | Max Local Primary Stress (psi) | Allow Local Primary Stress (psi) | Over stressed |
| Load case 1 | 164.62 | 967 | 18,588 | 787 | 12,396 | 1,079 | 23,016 | 32,280 | 48,900 | 17,722 | 24,450 | No |
| Load case 1 (Hot Shut Down) | 0 | 967 | 18,588 | 787 | 12,396 | 1,079 | 23,016 | -21,169 | 48,900 | -2,798 | 24,450 | No |
| Load case 1 (Pr Reversed) | 164.62 | -967 | 18,588 | 787 | 12,396 | 1,079 | 23,016 | **37,247** | **48,900** | **18,848** | **24,450** | No |
| Load case 1 (Pr Reversed) (Hot Shut Down) | 0 | -967 | 18,588 | 787 | 12,396 | 1,079 | 23,016 | 21,197 | 48,900 | 2,798 | 24,450 | No |

### Reinforcement Calculations for MAP

Available reinforcement per UG-37 governs the MAP of this nozzle.

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For P = 168.66 psi @ 70 °F<br>The opening is adequately reinforced | | | | | | | The nozzle passes UG-45 | |
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| 1.5873 | 1.5875 | 0.0231 | 0.3919 | -- | 1.11 | 0.0625 | 0.2074 | 0.2074 |

| 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 |
| 26,168.02 | 26,125.48 | 45,866.69 | 10,754.8 | 76,699.96 | 29,291.8 | 62,255.8 |

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| Weld description | Required weld size (in) | Actual weld size (in) | Status |
| Nozzle to pad fillet ($Leg_{41}$) | 0.1659 | 0.175 | weld size is adequate |
| Pad to shell fillet ($Leg_{42}$) | 0.1562 | 0.175 | weld size is adequate |

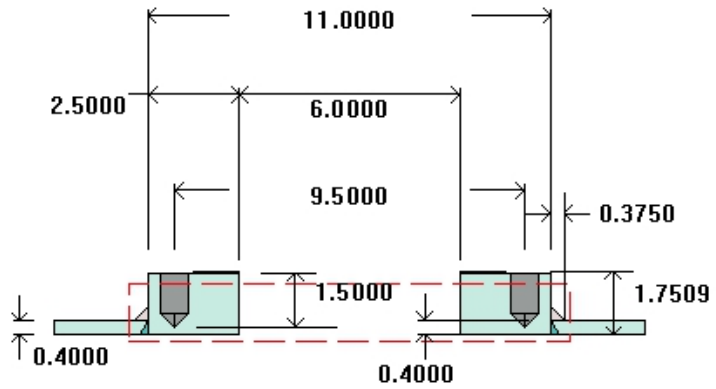
### Reinforcement Calculations for MAEP

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For Pe = 32.18 psi @ 338 °F<br>The opening is adequately reinforced | | | | | | | The nozzle passes UG-45 | |
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| 0.8052 | 1.5591 | -- | 0.3866 | -- | 1.11 | 0.0625 | 0.1358 | 0.2074 |

| UG-41 Weld Failure Path Analysis Summary |
|---|
| Weld strength calculations are not required for external pressure |

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| **Weld description** | **Required weld size (in)** | **Actual weld size (in)** | **Status** |
| Nozzle to pad fillet ($Leg_{41}$) | 0.1659 | 0.175 | weld size is adequate |
| Pad to shell fillet ($Leg_{42}$) | 0.1562 | 0.175 | weld size is adequate |

## Sight Glass (G1)

| ASME Section VIII Division 1, 2013 Edition |
|---|
|  |
| Note: round inside edges per UG-76(c) |
| Note: Thread engagement shall comply with the requirements of UG-43(g). |

| Location and Orientation | |
|---|---|
| **Located on** | F&D Head (top) |
| **Orientation** | 180° |
| **End of nozzle to datum line** | 177.9415" |
| **Calculated as hillside** | No |
| **Distance to head center, R** | 27" |
| **Passes through a Category A joint** | No |

| Nozzle | |
|---|---|
| **Access opening** | No |
| **Material specification** | SA-182 F316L <= 5 (low stress) (II-D p. 74, ln. 6) |
| **Bolt material specification** | SA-193 B7 Bolt <= 2 1/2 (II-D p. 352, ln. 31) |
| **Bolt rated MDMT** | -55°F |
| **Pad inner diameter** | 6" |
| **Pad outer diameter, $D_p$** | 11" |
| **Pad thickness** | 1.7509" |
| **Figure UG-40 thickness, $t_e$** | 1.2909" |
| **Tapped hole diameter** | 0.75" |
| **Tapped hole depth** | 1.5" |
| **Tapped hole bolt circle** | 9.5" |
| **Raised face height** | 0.06" |
| **Raised face outer diameter** | 8.5" |

| | |
|---|---|
| **Corrosion allowance** | 0" |
| **Projection available outside vessel, Lpr** | 1.2909" |
| **Projection available outside vessel to flange face, Lf** | 1.3509" |
| **Local vessel minimum thickness** | 0.4" |
| **Liquid static head included** | 0 psi |
| **Longitudinal joint efficiency** | 1 |
| **Welds** | |
| **Inner Fillet, $Leg_{42}$** | 0.375" |
| **Nozzle to vessel groove weld** | 0.4" |

| **ASME B16.5-2009 Blind** | |
|---|---|
| **Description** | NPS 6 Class 150 Blind A182 F316L |
| **Rated MDMT** | -55°F |
| **Liquid static head** | 0 psi |
| **MAWP rating** | 169.3 psi @ 338°F |
| **MAP rating** | 230 psi @ 70°F |
| **Hydrotest rating** | 350 psi @ 70°F |
| **Impact Tested** | No |
| **Notes** | |
| Blind rated MDMT per UHA-51(d)(1)(a) = -320°F<br>Bolts rated MDMT per Fig UCS-66 note (c) = -55°F | |

| **UHA-51 Material Toughness Requirements Pad** | |
|---|---|
| $t_r$ = 45*78*1 / (2*16,700*1 - 0.2*45) = | 0.1051" |
| Stress ratio = $t_r$*$E^*$ / ($t_n$ - c) = 0.1051*1 / (0.4 - 0) = | 0.2628 |
| Impact test exempt per UHA-51(g) (coincident ratio = 0.2628) | |
| Rated MDMT = | -320°F |
| Material is exempt from impact testing at the Design MDMT of -20°F. | |

**Reinforcement Calculations for MAWP**

Available reinforcement per UG-37 governs the MAWP of this nozzle.

| **UG-37 Area Calculation Summary ($in^2$)** | **UG-45 Summary (in)** |
|---|---|

| For P = 138.31 psi @ 338 °F<br>The opening is adequately reinforced | | | | | | | The nozzle passes UG-45 | |
|---|---|---|---|---|---|---|---|---|
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| 4.2073 | 4.2074 | 0.3283 | -- | -- | 3.773 | 0.1061 | 0.3281 | 2.5 |

| 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 |
| Pad to shell fillet ($Leg_{42}$) | 0.25 | 0.2625 | weld size is adequate |

**Reinforcement Calculations for MAP**

The vessel wall thickness governs the MAP of this nozzle.

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For P = 171.11 psi @ 70 °F<br>The opening is adequately reinforced | | | | | | | The nozzle passes UG-45 | |
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| 4.2136 | 5.1406 | -- | -- | -- | 5 | 0.1406 | 0.3281 | 2.5 |

| 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 |
| Pad to shell fillet ($Leg_{42}$) | 0.25 | 0.2625 | weld size is adequate |

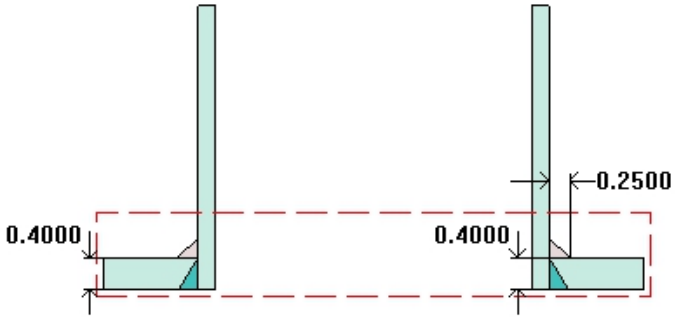
**Reinforcement Calculations for MAEP**

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For Pe = 32.18 psi @ 338 °F<br>The opening is adequately reinforced | | | | | | | The nozzle passes UG-45 | |
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| 3.259 | 3.8791 | -- | -- | -- | 3.773 | 0.1061 | 0.1358 | 2.5 |

| UG-41 Weld Failure Path Analysis Summary |
|---|
| Weld strength calculations are not required for external pressure |

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| **Weld description** | **Required weld throat size (in)** | **Actual weld throat size (in)** | **Status** |
| Pad to shell fillet ($Leg_{42}$) | 0.25 | 0.2625 | weld size is adequate |

## Mount for L1 (L2)

| ASME Section VIII Division 1, 2013 Edition |
|---|
|  |
| Note: round inside edges per UG-76(c) |

| Location and Orientation | |
|---|---|
| **Located on** | F&D Head (top) |
| **Orientation** | 90° |
| **End of nozzle to datum line** | 184" |
| **Calculated as hillside** | Yes |
| **Distance to head center, R** | 27" |
| **Passes through a Category A joint** | No |
| **Nozzle** | |
| **Description** | NPS 4 Sch 40S (Std) |
| **Access opening** | No |
| **Material specification** | SA-312 TP316L Wld & smls pipe (II-D p. 74, ln. 14) |
| **Inside diameter, new** | 4.026" |
| **Nominal wall thickness** | 0.237" |
| **Corrosion allowance** | 0" |
| **Opening chord length** | 4.2911" |
| **Projection available outside vessel, Lpr** | 3.3587" |
| **Projection available outside vessel to flange face, Lf** | 6.3587" |
| **Local vessel minimum thickness** | 0.4" |
| **Liquid static head included** | 0 psi |
| **Longitudinal joint efficiency** | 1 |
| **Welds** | |
| **Inner Fillet, $Leg_{41}$** | 0.25" |

| | |
|---|---|
| **Nozzle to vessel groove weld** | 0.4" |

| ASME B16.5-2009 Flange | |
|---|---|
| **Description** | NPS 4 Class 150 WN A182 F316L |
| **Bolt Material** | SA-193 B7 Bolt <= 2 1/2 (II-D p. 352, ln. 31) |
| **Blind included** | Yes |
| **Rated MDMT** | -55°F |
| **Liquid static head** | 0 psi |
| **MAWP rating** | 169.3 psi @ 338°F |
| **MAP rating** | 230 psi @ 70°F |
| **Hydrotest rating** | 350 psi @ 70°F |
| **PWHT performed** | No |
| **Impact Tested** | No |
| **Circumferential joint radiography** | None UW-11(c) Type 1 |
| **Gasket** | |
| **Description** | Flexitallic Spiral Wound CGI 316L S.S. |
| **Notes** | |
| Flange rated MDMT per UHA-51(d)(1)(a) = -320°F<br>Bolts rated MDMT per Fig UCS-66 note (c) = -55°F | |

| UHA-51 Material Toughness Requirements Nozzle | |
|---|---|
| $t_r$ = 45*2.013 / (16,700*1 - 0.6*45) = | 0.0054" |
| Stress ratio = $t_r$*E* / ($t_n$ - c) = 0.0054*1 / (0.2074 - 0) = | 0.0262 |
| Impact test exempt per UHA-51(g) (coincident ratio = 0.0262) | |
| Rated MDMT = | -320°F |
| Material is exempt from impact testing at the Design MDMT of -20°F. | |

**Reinforcement Calculations for MAWP**

Available reinforcement per UG-37 governs the MAWP of this nozzle.

| UG-37 Area Calculation Summary ($in^2$) | UG-45 Summary (in) |
|---|---|
| | The nozzle passes UG-45 |

| For P = 99.53 psi @ 338 °F<br>The opening is adequately reinforced | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| 1.0225 | 1.0227 | 0.6939 | 0.2663 | -- | -- | 0.0625 | 0.2074 | 0.2074 |

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

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

**Reinforcement Calculations for MAP**

Available reinforcement per UG-37 governs the MAP of this nozzle.

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For P = 101.97 psi @ 70 °F<br>The opening is adequately reinforced | | | | | | | The nozzle passes UG-45 | |
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| 1.0225 | 1.0228 | 0.694 | 0.2663 | -- | -- | 0.0625 | 0.2074 | 0.2074 |

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

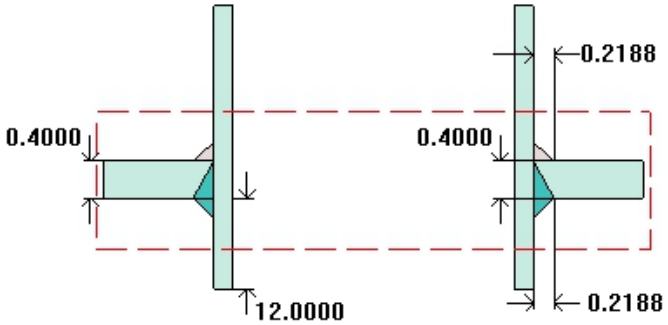
| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| Weld description | Required weld throat size (in) | Actual weld throat size (in) | Status |
| Nozzle to shell fillet ($Leg_{41}$) | 0.1659 | 0.175 | weld size is adequate |

**Reinforcement Calculations for MAEP**

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For Pe = 24.29 psi @ 338 °F<br>The opening is adequately reinforced | | | | | | | The nozzle passes UG-45 | |
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| 0.6774 | 0.6774 | 0.3614 | 0.2535 | -- | -- | 0.0625 | 0.1025 | 0.2074 |

| UG-41 Weld Failure Path Analysis Summary |
|---|
| Weld strength calculations are not required for external pressure |

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

| ASME Section VIII Division 1, 2013 Edition |
|---|
|  |
| Note: round inside edges per UG-76(c) |

| Location and Orientation | |
|---|---|
| **Located on** | F&D Head (top) |
| **Orientation** | 0° |
| **End of nozzle to datum line** | 190" |
| **Calculated as hillside** | No |
| **Distance to head center, R** | 0" |
| **Passes through a Category A joint** | No |

| Nozzle | |
|---|---|
| **Description** | NPS 3 Sch 40S (Std) |
| **Access opening** | No |
| **Material specification** | SA-312 TP316L Wld & smls pipe (II-D p. 74, ln. 14) |
| **Inside diameter, new** | 3.068" |
| **Nominal wall thickness** | 0.216" |
| **Corrosion allowance** | 0" |
| **Projection available outside vessel, Lpr** | 5.6191" |
| **Internal projection, $h_{new}$** | 12" |
| **Projection available outside vessel to flange face, Lf** | 8.3691" |
| **Local vessel minimum thickness** | 0.4" |
| **Liquid static head included** | 0 psi |
| **Longitudinal joint efficiency** | 1 |

| Welds | |
|---|---|
| **Inner Fillet, $Leg_{41}$** | 0.2188" |

| | |
|---|---|
| **Lower Fillet, $Leg_{43}$** | 0.2188" |
| **Nozzle to vessel groove weld** | 0.4" |

| ASME B16.5-2009 Flange | |
|---|---|
| **Description** | NPS 3 Class 150 WN A182 F316L |
| **Bolt Material** | SA-193 B7 Bolt <= 2 1/2 (II-D p. 352, ln. 31) |
| **Blind included** | No |
| **Rated MDMT** | -55°F |
| **Liquid static head** | 0 psi |
| **MAWP rating** | 169.3 psi @ 338°F |
| **MAP rating** | 230 psi @ 70°F |
| **Hydrotest rating** | 350 psi @ 70°F |
| **PWHT performed** | No |
| **Impact Tested** | No |
| **Circumferential joint radiography** | None UW-11(c) Type 1 |
| **Notes** | |
| Flange rated MDMT per UHA-51(d)(1)(a) = -320°F<br>Bolts rated MDMT per Fig UCS-66 note (c) = -55°F | |

| UHA-51 Material Toughness Requirements Nozzle | |
|---|---|
| $t_r$ = 45*1.534 / (16,700*1 - 0.6*45) = | 0.0041" |
| Stress ratio = $t_r$*$E^*$ / ($t_n$ - c) = 0.0041*1 / (0.189 - 0) = | 0.0219 |
| Impact test exempt per UHA-51(g) (coincident ratio = 0.0219) | |
| Rated MDMT = | -320°F |
| Material is exempt from impact testing at the Design MDMT of -20°F. | |

**Reinforcement Calculations for MAWP**

Available reinforcement per UG-37 governs the MAWP of this nozzle.

| UG-37 Area Calculation Summary ($in^2$) | UG-45 Summary (in) |
|---|---|
| **For P = 120.97 psi @ 338 °F<br>The opening is adequately reinforced** | **The nozzle passes UG-45** |

| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
|---|---|---|---|---|---|---|---|---|
| 0.8886 | 0.8887 | 0.3386 | 0.221 | 0.2333 | -- | 0.0958 | 0.189 | 0.189 |

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

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| Weld description | Required weld throat size (in) | Actual weld throat size (in) | Status |
| Nozzle to shell fillet ($Leg_{41}$) | 0.1512 | 0.1531 | weld size is adequate |

**Reinforcement Calculations for MAP**

Available reinforcement per UG-37 governs the MAP of this nozzle.

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For P = 123.93 psi @ 70 °F<br>The opening is adequately reinforced | | | | | | | The nozzle passes UG-45 | |
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| 0.8886 | 0.8887 | 0.3386 | 0.221 | 0.2333 | -- | 0.0958 | 0.189 | 0.189 |

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

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| Weld description | Required weld throat size (in) | Actual weld throat size (in) | Status |
| Nozzle to shell fillet ($Leg_{41}$) | 0.1512 | 0.1531 | weld size is adequate |

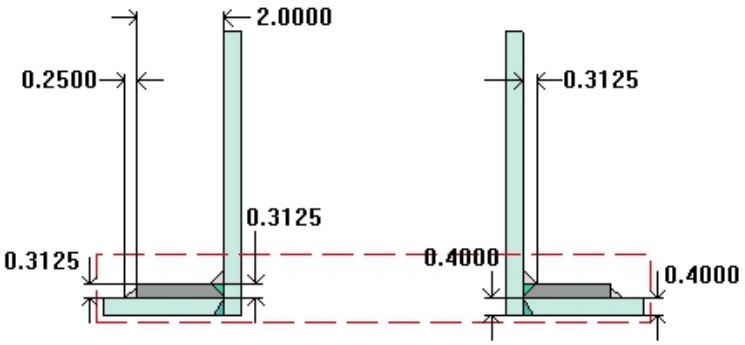
**Reinforcement Calculations for MAEP**

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For Pe = 30.62 psi @ 338 °F<br>The opening is adequately reinforced | | | | | | | The nozzle passes UG-45 | |
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| 0.5885 | 0.5886 | 0.0503 | 0.2092 | 0.2333 | -- | 0.0958 | 0.1292 | 0.189 |

| UG-41 Weld Failure Path Analysis Summary |
|---|
| Weld strength calculations are not required for external pressure |

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| **Weld description** | **Required weld throat size (in)** | **Actual weld throat size (in)** | **Status** |
| Nozzle to shell fillet ($Leg_{41}$) | 0.1512 | 0.1531 | weld size is adequate |

## Manway w/Davit (M1)

| ASME Section VIII Division 1, 2013 Edition | |
|---|---|
|  | |
| Note: round inside edges per UG-76(c) | |
| **Location and Orientation** | |
| **Located on** | F&D Head (top) |
| **Orientation** | 270° |
| **End of nozzle to datum line** | 190" |
| **Calculated as hillside** | Yes |
| **Distance to head center, R** | 22" |
| **Passes through a Category A joint** | No |
| **Nozzle** | |
| **Access opening** | Yes |
| **Material specification** | SA-240 316L (II-D p. 74, ln. 9) |
| **Inside diameter, new** | 23.25" |
| **Nominal wall thickness** | 0.375" |
| **Corrosion allowance** | 0" |
| **Opening chord length** | 24.2572" |
| **Projection available outside vessel, Lpr** | 2.9899" |
| **Projection available outside vessel to flange face, Lf** | 8.9899" |
| **Local vessel minimum thickness** | 0.4" |
| **User input radial limit of reinforcement** | 19" |
| **Liquid static head included** | 0 psi |
| **Longitudinal joint efficiency** | 1 |
| **Reinforcing Pad** | |
| **Material specification** | SA-240 316L (II-D p. 74, ln. 9) |

| | |
|---|---|
| **Diameter, $D_p$** | 29.0327" |
| **Thickness, $t_e$** | 0.3125" |
| **Is split** | Yes |
| **Butt welds tested to confirm full penetration** | No |
| **Joint efficiency** | 0.75 |
| **Welds** | |
| **Inner Fillet, $Leg_{41}$** | 0.3125" |
| **Outer Fillet, $Leg_{42}$** | 0.25" |
| **Nozzle to vessel groove weld** | 0.4" |
| **Pad groove weld** | 0.3125" |

| ASME B16.5-2009 Flange | |
|---|---|
| **Description** | NPS 24 Class 150 WN A182 F316L |
| **Bolt Material** | SA-193 B7 Bolt <= 2 1/2 (II-D p. 352, ln. 31) |
| **Blind included** | Yes |
| **Rated MDMT** | -55°F |
| **Liquid static head** | 0 psi |
| **MAWP rating** | 169.3 psi @ 338°F |
| **MAP rating** | 230 psi @ 70°F |
| **Hydrotest rating** | 350 psi @ 70°F |
| **PWHT performed** | No |
| **Impact Tested** | No |
| **Circumferential joint radiography** | Full UW-11(a) Type 1 |
| **Gasket** | |
| **Description** | Flexitallic Spiral Wound CGI 316L S.S. |
| **Notes** | |
| Flange rated MDMT per UHA-51(d)(1)(a) = -320°F<br>Bolts rated MDMT per Fig UCS-66 note (c) = -55°F | |

| UHA-51 Material Toughness Requirements Nozzle | |
|---|---|
| $t_r$ = 45*11.625 / (16,700*1 - 0.6*45) = | 0.0314" |
| Stress ratio = $t_r$*E* / ($t_n$ - c) = 0.0314*1 / (0.375 - 0) = | 0.0837 |
| Impact test exempt per UHA-51(g) (coincident ratio = 0.0837) | |
| Rated MDMT = | -320°F |
| Material is exempt from impact testing at the Design MDMT of -20°F. | |

| UHA-51 Material Toughness Requirements Pad |
|---|
| Rated MDMT per UHA-51(d)(1)(a), (carbon content does not exceed 0.10%) = -320°F |
| Material is exempt from impact testing at the Design MDMT of -20°F. |

**Reinforcement Calculations for MAWP**

Available reinforcement per UG-37 governs the MAWP of this nozzle.

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For P = 45.4 psi @ 338 °F<br>The opening is adequately reinforced | | | | | | | The nozzle passes UG-45 | |
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| 4.6467 | 4.6474 | 2.8645 | 0.6852 | -- | 0.9375 | 0.1602 | 0.0324 | 0.375 |

| UG-41 Weld Failure Path Analysis Summary ($lb_f$) | | | | | | |
|---|---|---|---|---|---|---|
| All failure paths are stronger than the applicable weld loads | | | | | | |
| Weld load W | Weld load $W_{1-1}$ | Path 1-1 strength | Weld load $W_{2-2}$ | Path 2-2 strength | Weld load $W_{3-3}$ | Path 3-3 strength |
| 31,598.19 | 29,061.27 | 249,845.23 | 17,651.27 | 418,087.39 | 33,951.27 | 272,951.23 |

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| Weld description | Required weld size (in) | Actual weld size (in) | Status |
| Nozzle to pad fillet ($Leg_{41}$) | 0.2188 | 0.2188 | weld size is adequate |
| Pad to shell fillet ($Leg_{42}$) | 0.1562 | 0.175 | weld size is adequate |

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

EFE = $(50*t / R_f)*(1 - R_f / R_o)$

= $(50*0.375 / 11.8125)*(1 - 11.8125 / \infty)$

= 1.5873%

### Reinforcement Calculations for MAP

Available reinforcement per UG-37 governs the MAP of this nozzle.

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For P = 46.51 psi @ 70 °F<br>The opening is adequately reinforced | | | | | | | The nozzle passes UG-45 | |
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| 4.6465 | 4.6476 | 2.8647 | 0.6852 | -- | 0.9375 | 0.1602 | 0.0324 | 0.375 |

| UG-41 Weld Failure Path Analysis Summary ($lb_f$) | | | | | | |
|---|---|---|---|---|---|---|
| All failure paths are stronger than the applicable weld loads | | | | | | |
| Weld load W | Weld load $W_{1-1}$ | Path 1-1 strength | Weld load $W_{2-2}$ | Path 2-2 strength | Weld load $W_{3-3}$ | Path 3-3 strength |
| 32,366.66 | 29,774.43 | 255,976.41 | 18,084.43 | 428,347.2 | 34,784.43 | 279,649.42 |

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| Weld description | Required weld size (in) | Actual weld size (in) | Status |
| Nozzle to pad fillet ($Leg_{41}$) | 0.2188 | 0.2188 | weld size is adequate |
| Pad to shell fillet ($Leg_{42}$) | 0.1562 | 0.175 | weld size is adequate |

### Reinforcement Calculations for MAEP

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For Pe = 20.16 psi @ 338 °F<br>The opening is adequately reinforced | | | | | | | The nozzle passes UG-45 | |
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| 3.3719 | 3.3722 | 1.6764 | 0.5981 | -- | 0.9375 | 0.1602 | 0.076 | 0.375 |

| UG-41 Weld Failure Path Analysis Summary |
|---|
| Weld strength calculations are not required for external pressure |

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| **Weld description** | **Required weld size (in)** | **Actual weld size (in)** | **Status** |
| Nozzle to pad fillet ($Leg_{41}$) | 0.2188 | 0.2188 | weld size is adequate |
| Pad to shell fillet ($Leg_{42}$) | 0.1562 | 0.175 | weld size is adequate |

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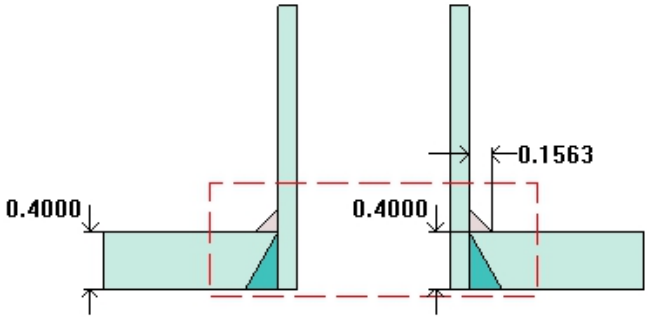
|---|---|
|  | |
| Note: round inside edges per UG-76(c) | |
| **Location and Orientation** | |
| **Located on** | F&D Head (top) |
| **Orientation** | 150° |
| **End of nozzle to datum line** | 184" |
| **Calculated as hillside** | Yes |
| **Distance to head center, R** | 27" |
| **Passes through a Category A joint** | No |
| **Nozzle** | |
| **Description** | NPS 1 Sch 40S (Std) |
| **Access opening** | No |
| **Material specification** | SA-312 TP316L Wld & smls pipe (II-D p. 74, ln. 14) |
| **Inside diameter, new** | 1.049" |
| **Nominal wall thickness** | 0.133" |
| **Corrosion allowance** | 0" |
| **Opening chord length** | 1.118" |
| **Projection available outside vessel, Lpr** | 4.7176" |
| **Projection available outside vessel to flange face, Lf** | 6.9076" |
| **Local vessel minimum thickness** | 0.4" |
| **Liquid static head included** | 0 psi |
| **Longitudinal joint efficiency** | 1 |
| **Welds** | |
| **Inner Fillet, $Leg_{41}$** | 0.1563" |

| | |
|---|---|
| **Nozzle to vessel groove weld** | 0.4" |

| ASME B16.5-2009 Flange | |
|---|---|
| **Description** | NPS 1 Class 150 WN A182 F316L |
| **Bolt Material** | SA-193 B7 Bolt <= 2 1/2 (II-D p. 352, ln. 31) |
| **Blind included** | No |
| **Rated MDMT** | -55°F |
| **Liquid static head** | 0 psi |
| **MAWP rating** | 169.3 psi @ 338°F |
| **MAP rating** | 230 psi @ 70°F |
| **Hydrotest rating** | 350 psi @ 70°F |
| **PWHT performed** | No |
| **Impact Tested** | No |
| **Circumferential joint radiography** | None UW-11(c) Type 1 |
| **Notes** | |
| Flange rated MDMT per UHA-51(d)(1)(a) = -320°F<br>Bolts rated MDMT per Fig UCS-66 note (c) = -55°F | |

| UHA-51 Material Toughness Requirements Nozzle | |
|---|---|
| $t_r$ = 45*0.5245 / (16,700*1 - 0.6*45) = | 0.0014" |
| Stress ratio = $t_r$*E* / ($t_n$ - c) = 0.0014*1 / (0.1164 - 0) = | 0.0122 |
| Impact test exempt per UHA-51(g) (coincident ratio = 0.0122) | |
| Rated MDMT = | -320°F |
| Material is exempt from impact testing at the Design MDMT of -20°F. | |

**Reinforcement Calculations for MAWP**

The vessel wall thickness governs the MAWP of this nozzle.

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For P = 167.01 psi @ 338 °F | | | | | | | 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 | | | | | | | 0.1164 | 0.1164 |

| | | |
|---|---|---|
| calculations per UG-36(c)(3)(a) | | |

| 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 ($Leg_{41}$) | 0.0931 | 0.1094 | weld size is adequate |

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

**Reinforcement Calculations for MAP**

The vessel wall thickness governs the MAP of this nozzle.

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For P = 171.11 psi @ 70 °F | | | | | | | The nozzle passes UG-45 | |
| **A required** | **A available** | **$A_1$** | **$A_2$** | **$A_3$** | **$A_5$** | **A welds** | **$t_{req}$** | **$t_{min}$** |
| This nozzle is exempt from area calculations per UG-36(c)(3)(a) | | | | | | | 0.1164 | 0.1164 |

| 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 ($Leg_{41}$) | 0.0931 | 0.1094 | weld size is adequate |

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

**Reinforcement Calculations for MAEP**

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For Pe = 32.18 psi @ 338 °F | | | | | | | The nozzle passes UG-45 | |
| **A required** | **A available** | **$A_1$** | **$A_2$** | **$A_3$** | **$A_5$** | **A welds** | **$t_{req}$** | **$t_{min}$** |

| | | |
|---|---|---|
| This nozzle is exempt from area calculations per UG-36(c)(3)(a) | 0.1164 | 0.1164 |

| UG-41 Weld Failure Path Analysis Summary |
|---|
| Weld strength calculations are not required for external pressure |

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| **Weld description** | **Required weld throat size (in)** | **Actual weld throat size (in)** | **Status** |
| Nozzle to shell fillet ($Leg_{41}$) | 0.0931 | 0.1094 | weld size is adequate |

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

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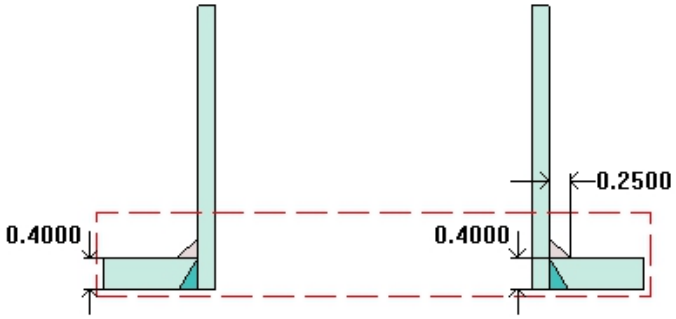
|---|---|
|  | |
| Note: round inside edges per UG-76(c) | |
| **Location and Orientation** | |
| **Located on** | F&D Head (top) |
| **Orientation** | 25° |
| **End of nozzle to datum line** | 184" |
| **Calculated as hillside** | Yes |
| **Distance to head center, R** | 27" |
| **Passes through a Category A joint** | No |
| **Nozzle** | |
| **Description** | NPS 4 Sch 40S (Std) |
| **Access opening** | No |
| **Material specification** | SA-312 TP316L Wld & smls pipe (II-D p. 74, ln. 14) |
| **Inside diameter, new** | 4.026" |
| **Nominal wall thickness** | 0.237" |
| **Corrosion allowance** | 0" |
| **Opening chord length** | 4.2911" |
| **Projection available outside vessel, Lpr** | 3.3587" |
| **Projection available outside vessel to flange face, Lf** | 6.3587" |
| **Local vessel minimum thickness** | 0.4" |
| **Liquid static head included** | 0 psi |
| **Longitudinal joint efficiency** | 1 |
| **Welds** | |
| **Inner Fillet, $Leg_{41}$** | 0.25" |

| | |
|---|---|
| **Nozzle to vessel groove weld** | 0.4" |

| ASME B16.5-2009 Flange | |
|---|---|
| **Description** | NPS 4 Class 150 WN A182 F316L |
| **Bolt Material** | SA-193 B7 Bolt <= 2 1/2 (II-D p. 352, ln. 31) |
| **Blind included** | No |
| **Rated MDMT** | -55°F |
| **Liquid static head** | 0 psi |
| **MAWP rating** | 169.3 psi @ 338°F |
| **MAP rating** | 230 psi @ 70°F |
| **Hydrotest rating** | 350 psi @ 70°F |
| **PWHT performed** | No |
| **Impact Tested** | No |
| **Circumferential joint radiography** | None UW-11(c) Type 1 |
| **Notes** | |
| Flange rated MDMT per UHA-51(d)(1)(a) = -320°F<br>Bolts rated MDMT per Fig UCS-66 note (c) = -55°F | |

| UHA-51 Material Toughness Requirements Nozzle | |
|---|---|
| $t_r$ = 45*2.013 / (16,700*1 - 0.6*45) = | 0.0054" |
| Stress ratio = $t_r$*$E^*$ / ($t_n$ - c) = 0.0054*1 / (0.2074 - 0) = | 0.0262 |
| Impact test exempt per UHA-51(g) (coincident ratio = 0.0262) | |
| Rated MDMT = | -320°F |
| Material is exempt from impact testing at the Design MDMT of -20°F. | |

**Reinforcement Calculations for MAWP**

Available reinforcement per UG-37 governs the MAWP of this nozzle.

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For P = 99.53 psi @ 338 °F<br>The opening is adequately reinforced | | | | | | | The nozzle passes UG-45 | |
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| 1.0225 | 1.0227 | 0.6939 | 0.2663 | -- | -- | 0.0625 | 0.2074 | 0.2074 |

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

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

**Reinforcement Calculations for MAP**

Available reinforcement per UG-37 governs the MAP of this nozzle.

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For P = 101.97 psi @ 70 °F<br>The opening is adequately reinforced | | | | | | | The nozzle passes UG-45 | |
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| 1.0225 | 1.0228 | 0.694 | 0.2663 | -- | -- | 0.0625 | 0.2074 | 0.2074 |

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

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

**Reinforcement Calculations for MAEP**

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For Pe = 24.29 psi @ 338 °F<br>The opening is adequately reinforced | | | | | | | The nozzle passes UG-45 | |
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| 0.6774 | 0.6774 | 0.3614 | 0.2535 | -- | -- | 0.0625 | 0.1025 | 0.2074 |

| UG-41 Weld Failure Path Analysis Summary |
|---|
| Weld strength calculations are not required for external pressure |

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

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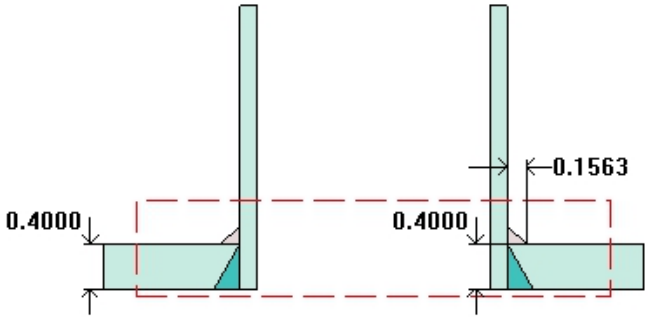
|---|---|
|  | |
| Note: round inside edges per UG-76(c) | |
| **Location and Orientation** | |
| **Located on** | F&D Head (top) |
| **Orientation** | 0° |
| **End of nozzle to datum line** | 187.25" |
| **Calculated as hillside** | Yes |
| **Distance to head center, R** | 13" |
| **Passes through a Category A joint** | No |
| **Nozzle** | |
| **Description** | NPS 2 Sch 40S (Std) |
| **Access opening** | No |
| **Material specification** | SA-312 TP316L Wld & smls pipe (II-D p. 74, ln. 14) |
| **Inside diameter, new** | 2.067" |
| **Nominal wall thickness** | 0.154" |
| **Corrosion allowance** | 0" |
| **Opening chord length** | 2.0963" |
| **Projection available outside vessel, Lpr** | 3.9945" |
| **Projection available outside vessel to flange face, Lf** | 6.4945" |
| **Local vessel minimum thickness** | 0.4" |
| **Liquid static head included** | 0 psi |
| **Longitudinal joint efficiency** | 1 |
| **Welds** | |
| **Inner Fillet, $Leg_{41}$** | 0.1563" |

| | |
|---|---|
| **Nozzle to vessel groove weld** | 0.4" |

| ASME B16.5-2009 Flange | |
|---|---|
| **Description** | NPS 2 Class 150 WN A182 F316L |
| **Bolt Material** | SA-193 B7 Bolt <= 2 1/2 (II-D p. 352, ln. 31) |
| **Blind included** | Yes |
| **Rated MDMT** | -55°F |
| **Liquid static head** | 0 psi |
| **Consider External Loads on Flange MAWP Rating** | No |
| **MAWP rating** | 169.3 psi @ 338°F |
| **MAP rating** | 230 psi @ 70°F |
| **Hydrotest rating** | 350 psi @ 70°F |
| **PWHT performed** | No |
| **Impact Tested** | No |
| **Circumferential joint radiography** | None UW-11(c) Type 1 |
| **Gasket** | |
| **Description** | Flexitallic Spiral Wound CGI 316L S.S. |
| **Notes** | |
| Flange rated MDMT per UHA-51(d)(1)(a) = -320°F<br>Bolts rated MDMT per Fig UCS-66 note (c) = -55°F | |

| UHA-51 Material Toughness Requirements Nozzle |
|---|
| Rated MDMT per UHA-51(d)(1)(a), (carbon content does not exceed 0.10%) = -320°F |
| Material is exempt from impact testing at the Design MDMT of -20°F. |

**Reinforcement Calculations for MAWP**

The vessel wall thickness governs the MAWP of this nozzle.

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For P = 167.01 psi @ 338 °F | | | | | | | 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 | 0.1348 |

| 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 ($Leg_{41}$) | 0.1078 | 0.1094 | weld size is adequate |

| WRC 107 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Load Case** | **P (psi)** | **$P_r$ ($lb_f$)** | **$M_1$ ($lb_f$-in)** | **$V_2$ ($lb_f$)** | **$M_2$ ($lb_f$-in)** | **$V_1$ ($lb_f$)** | **$M_t$ ($lb_f$-in)** | **Max Comb Stress (psi)** | **Allow Comb Stress (psi)** | **Max Local Primary Stress (psi)** | **Allow Local Primary Stress (psi)** | **Over stressed** |
| Load case 1 | 167.01 | 517 | 4,428 | 697 | 3,540 | 517 | 7,080 | 39,837 | 48,900 | 16,368 | 24,450 | No |
| Load case 1 (Hot Shut Down) | 0 | 517 | 4,428 | 697 | 3,540 | 517 | 7,080 | -26,554 | 48,900 | -1,509 | 24,450 | No |
| Load case 1 (Pr Reversed) | 167.01 | -517 | 4,428 | 697 | 3,540 | 517 | 7,080 | **42,981** | **48,900** | **17,792** | **24,450** | No |
| Load case 1 (Pr Reversed) (Hot Shut Down) | 0 | -517 | 4,428 | 697 | 3,540 | 517 | 7,080 | 26,698 | 48,900 | 1,509 | 24,450 | No |

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

**Reinforcement Calculations for MAP**

The vessel wall thickness governs the MAP of this nozzle.

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For P = 171.11 psi @ 70 °F | | | | | | | 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 | 0.1348 |

| 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 ($Leg_{41}$) | 0.1078 | 0.1094 | weld size is adequate |

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

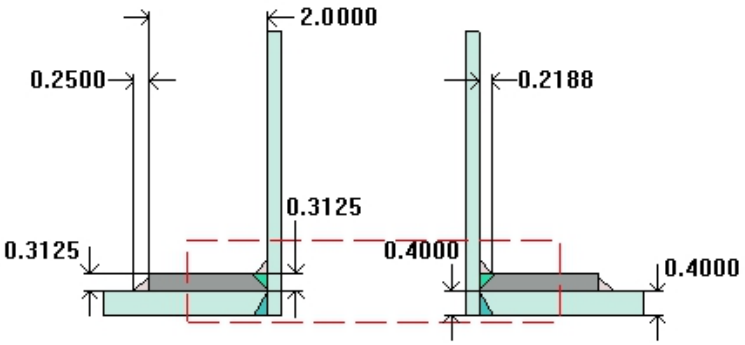
**Reinforcement Calculations for MAEP**

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For Pe = 32.18 psi @ 338 °F | | | | | | | 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 | 0.1348 |

| UG-41 Weld Failure Path Analysis Summary |
|---|
| Weld strength calculations are not required for external pressure |

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| **Weld description** | **Required weld throat size (in)** | **Actual weld throat size (in)** | **Status** |
| Nozzle to shell fillet ($Leg_{41}$) | 0.1078 | 0.1094 | weld size is adequate |

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

| ASME Section VIII Division 1, 2013 Edition |
|---|
|   |
| Note: round inside edges per UG-76(c) |

| Location and Orientation | |
|---|---|
| **Located on** | F&D Head (top) |
| **Orientation** | 180° |
| **End of nozzle to datum line** | 187.25" |
| **Calculated as hillside** | Yes |
| **Distance to head center, R** | 13" |
| **Passes through a Category A joint** | No |
| **Nozzle** | |
| **Description** | NPS 3 Sch 40S (Std) |
| **Access opening** | No |
| **Material specification** | SA-312 TP316L Wld & smls pipe (II-D p. 74, ln. 14) |
| **Inside diameter, new** | 3.068" |
| **Nominal wall thickness** | 0.216" |
| **Corrosion allowance** | 0" |
| **Opening chord length** | 3.1115" |
| **Projection available outside vessel, Lpr** | 3.6609" |
| **Projection available outside vessel to flange face, Lf** | 6.4109" |
| **Local vessel minimum thickness** | 0.4" |
| **Liquid static head included** | 0 psi |
| **Longitudinal joint efficiency** | 1 |
| **Reinforcing Pad** | |
| **Material specification** | SA-240 316L (II-D p. 74, ln. 9) |

| | |
|---|---|
| **Diameter, $D_p$** | 7.5492" |
| **Thickness, $t_e$** | 0.3125" |
| **Is split** | No |
| **Welds** | |
| **Inner Fillet, $Leg_{41}$** | 0.2188" |
| **Outer Fillet, $Leg_{42}$** | 0.25" |
| **Nozzle to vessel groove weld** | 0.4" |
| **Pad groove weld** | 0.3125" |

| **ASME B16.5-2009 Flange** | |
|---|---|
| **Description** | NPS 3 Class 150 WN A182 F316L |
| **Bolt Material** | SA-193 B7 Bolt <= 2 1/2 (II-D p. 352, ln. 31) |
| **Blind included** | Yes |
| **Rated MDMT** | -55°F |
| **Liquid static head** | 0 psi |
| **Consider External Loads on Flange MAWP Rating** | No |
| **MAWP rating** | 169.3 psi @ 338°F |
| **MAP rating** | 230 psi @ 70°F |
| **Hydrotest rating** | 350 psi @ 70°F |
| **PWHT performed** | No |
| **Impact Tested** | No |
| **Circumferential joint radiography** | None UW-11(c) Type 1 |
| **Gasket** | |
| **Description** | Flexitallic Spiral Wound CGI 316L S.S. |
| **Notes** | |
| Flange rated MDMT per UHA-51(d)(1)(a) = -320°F<br>Bolts rated MDMT per Fig UCS-66 note (c) = -55°F | |

| **UHA-51 Material Toughness Requirements Nozzle** |
|---|
| Rated MDMT per UHA-51(d)(1)(a), (carbon content does not exceed 0.10%) = -320°F |
| Material is exempt from impact testing at the Design MDMT of -20°F. |

| UHA-51 Material Toughness Requirements Pad | |
|---|---|
| $t_r$ = 45*78*1 / (2*16,700*1 - 0.2*45) = | 0.1051" |
| Stress ratio = $t_r$*E* / ($t_n$ - c) = 0.1051*1 / (0.4 - 0) = | 0.2628 |
| Impact test exempt per UHA-51(g) (coincident ratio = 0.2628) | |
| Rated MDMT = | -320°F |
| Material is exempt from impact testing at the Design MDMT of -20°F. | |

**Reinforcement Calculations for MAWP**

Available reinforcement per UG-37 governs the MAWP of this nozzle.

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For P = 165.69 psi @ 338 °F<br>The opening is adequately reinforced | | | | | | | The nozzle passes UG-45 | |
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| 1.2347 | 1.2349 | 0.0099 | 0.3415 | -- | 0.8356 | 0.0479 | 0.189 | 0.189 |

| 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 |
| 19,987.16 | 19,967.1 | 36,391.26 | 9,163.86 | 56,854.44 | 22,783.74 | 50,203.56 |

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| Weld description | Required weld size (in) | Actual weld size (in) | Status |
| Nozzle to pad fillet ($Leg_{41}$) | 0.1512 | 0.1531 | weld size is adequate |
| Pad to shell fillet ($Leg_{42}$) | 0.1562 | 0.175 | weld size is adequate |

| WRC 107 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Load Case | P (psi) | $P_r$ ($lb_f$) | $M_1$ ($lb_f$-in) | $V_2$ ($lb_f$) | $M_2$ ($lb_f$-in) | $V_1$ ($lb_f$) | $M_t$ ($lb_f$-in) | Max Comb Stress (psi) | Allow Comb Stress (psi) | Max Local Primary Stress (psi) | Allow Local Primary Stress (psi) | Over stressed |
| Load case 1 | 165.69 | 787 | 12,384 | 922 | 7,968 | 674 | 15,936 | 29,093 | 48,900 | 17,299 | 24,450 | No |
| Load case 1 (Hot Shut Down) | 0 | 787 | 12,384 | 922 | 7,968 | 674 | 15,936 | -17,298 | 48,900 | -2,181 | 24,450 | No |
| Load case 1 (Pr Reversed) | 165.69 | -787 | 12,384 | 922 | 7,968 | 674 | 15,936 | **33,473** | **48,900** | **18,335** | **24,450** | No |
| Load case 1 (Pr Reversed) (Hot Shut Down) | 0 | -787 | 12,384 | 922 | 7,968 | 674 | 15,936 | 17,319 | 48,900 | 2,181 | 24,450 | No |

### Reinforcement Calculations for MAP

Available reinforcement per UG-37 governs the MAP of this nozzle.

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For P = 169.75 psi @ 70 °F<br>The opening is adequately reinforced | | | | | | | The nozzle passes UG-45 | |
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| 1.2347 | 1.2349 | 0.0099 | 0.3415 | -- | 0.8356 | 0.0479 | 0.189 | 0.189 |

| 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 |
| 20,477.19 | 20,457.1 | 37,284.3 | 9,388.74 | 58,249.64 | 23,342.86 | 51,435.55 |

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| Weld description | Required weld size (in) | Actual weld size (in) | Status |
| Nozzle to pad fillet ($Leg_{41}$) | 0.1512 | 0.1531 | weld size is adequate |
| Pad to shell fillet ($Leg_{42}$) | 0.1562 | 0.175 | weld size is adequate |

### Reinforcement Calculations for MAEP

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For Pe = 32.18 psi @ 338 °F<br>The opening is adequately reinforced | | | | | | | The nozzle passes UG-45 | |
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| 0.6223 | 1.216 | -- | 0.3326 | -- | 0.8355 | 0.0479 | 0.1358 | 0.189 |

| UG-41 Weld Failure Path Analysis Summary |
|---|
| Weld strength calculations are not required for external pressure |

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| **Weld description** | **Required weld size (in)** | **Actual weld size (in)** | **Status** |
| Nozzle to pad fillet ($Leg_{41}$) | 0.1512 | 0.1531 | weld size is adequate |
| Pad to shell fillet ($Leg_{42}$) | 0.1562 | 0.175 | weld size is adequate |

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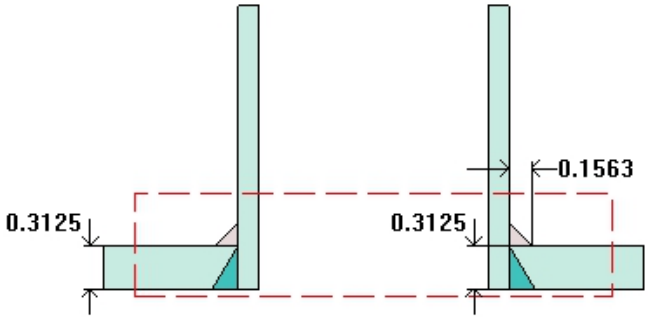
|  | |
| Note: round inside edges per UG-76(c) | |
| **Location and Orientation** | |
| **Located on** | Shell -01 |
| **Orientation** | 45° |
| **Nozzle center/shell outer surface intersection to datum** | 6" |
| **End of nozzle to shell center** | 46.3199" |
| **Tilted** | 15° from radial |
| **Passes through a Category A joint** | No |
| **Nozzle** | |
| **Description** | NPS 1.5 Sch 40S (Std) |
| **Access opening** | No |
| **Material specification** | SA-312 TP316L Wld & smls pipe (II-D p. 74, ln. 14) |
| **Inside diameter, new** | 1.61" |
| **Nominal wall thickness** | 0.145" |
| **Corrosion allowance** | 0" |
| **Opening chord length** | 1.6668" |
| **Projection available outside vessel, Lpr** | 4.56" |
| **Projection available outside vessel to flange face, Lf** | 7" |
| **Local vessel minimum thickness** | 0.3125" |
| **Liquid static head included** | 4.67 psi |
| **Longitudinal joint efficiency** | 1 |
| **Welds** | |
| **Inner Fillet, $Leg_{41}$** | 0.1563" |

| | |
|---|---|
| **Nozzle to vessel groove weld** | 0.3125" |

| ASME B16.5-2009 Flange | |
|---|---|
| **Description** | NPS 1.5 Class 150 WN A182 F316L |
| **Bolt Material** | SA-193 B7 Bolt <= 2 1/2 (II-D p. 352, ln. 31) |
| **Blind included** | No |
| **Rated MDMT** | -55°F |
| **Liquid static head** | 4.57 psi |
| **MAWP rating** | 169.3 psi @ 338°F |
| **MAP rating** | 230 psi @ 70°F |
| **Hydrotest rating** | 350 psi @ 70°F |
| **PWHT performed** | No |
| **Impact Tested** | No |
| **Circumferential joint radiography** | None UW-11(c) Type 1 |
| **Notes** | |
| Flange rated MDMT per UHA-51(d)(1)(a) = -320°F<br>Bolts rated MDMT per Fig UCS-66 note (c) = -55°F | |

| UHA-51 Material Toughness Requirements Nozzle | |
|---|---|
| $t_r$ = 49.67*0.805 / (16,700*1 - 0.6*49.67) = | 0.0024" |
| Stress ratio = $t_r$*E* / ($t_n$ - c) = 0.0024*1 / (0.1269 - 0) = | 0.0189 |
| Impact test exempt per UHA-51(g) (coincident ratio = 0.0189) | |
| Rated MDMT = | -320°F |
| Material is exempt from impact testing at the Design MDMT of -20°F. | |

**Reinforcement Calculations for MAWP**

The vessel wall thickness governs the MAWP of this nozzle.

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For P = 129.98 psi @ 338 °F | | | | | | | The nozzle passes UG-45 | |
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |

| | | |
|---|---|---|
| This nozzle is exempt from area calculations per UG-36(c)(3)(a) | 0.1269 | 0.1269 |

| 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 ($Leg_{41}$) | 0.1015 | 0.1094 | weld size is adequate |

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

**Reinforcement Calculations for MAP**

The vessel wall thickness governs the MAP of this nozzle.

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For P = 133.17 psi @ 70 °F | | | | | | | The nozzle passes UG-45 | |
| **A required** | **A available** | **$A_1$** | **$A_2$** | **$A_3$** | **$A_5$** | **A welds** | **$t_{req}$** | **$t_{min}$** |
| This nozzle is exempt from area calculations per UG-36(c)(3)(a) | | | | | | | 0.1269 | 0.1269 |

| 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 ($Leg_{41}$) | 0.1015 | 0.1094 | weld size is adequate |

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

**Reinforcement Calculations for MAEP**

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For Pe = 20.36 psi @ 338 °F | | | | | | | The nozzle passes UG-45 | |
| | | **$A_1$** | **$A_2$** | **$A_3$** | **$A_5$** | | **$t_{req}$** | **$t_{min}$** |

| A required | A available | | | | | A welds | | |
|---|---|---|---|---|---|---|---|---|
| This nozzle is exempt from area calculations per UG-36(c)(3)(a) | | | | | | | 0.0625 | 0.1269 |

| UG-41 Weld Failure Path Analysis Summary |
|---|
| Weld strength calculations are not required for external pressure |

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| Weld description | Required weld throat size (in) | Actual weld throat size (in) | Status |
| Nozzle to shell fillet ($Leg_{41}$) | 0.1015 | 0.1094 | weld size is adequate |

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

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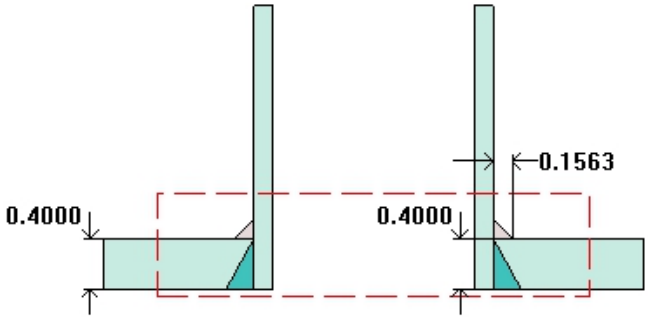
|---|---|
|  | |
| Note: round inside edges per UG-76(c) | |
| **Location and Orientation** | |
| **Located on** | F&D Head (top) |
| **Orientation** | 0° |
| **End of nozzle to datum line** | 184" |
| **Calculated as hillside** | Yes |
| **Distance to head center, R** | 27" |
| **Passes through a Category A joint** | No |
| **Nozzle** | |
| **Description** | NPS 1.5 Sch 40S (Std) |
| **Access opening** | No |
| **Material specification** | SA-312 TP316L Wld & smls pipe (II-D p. 74, ln. 14) |
| **Inside diameter, new** | 1.61" |
| **Nominal wall thickness** | 0.145" |
| **Corrosion allowance** | 0" |
| **Opening chord length** | 1.7159" |
| **Projection available outside vessel, Lpr** | 4.3639" |
| **Projection available outside vessel to flange face, Lf** | 6.8039" |
| **Local vessel minimum thickness** | 0.4" |
| **Liquid static head included** | 0 psi |
| **Longitudinal joint efficiency** | 1 |
| **Welds** | |
| **Inner Fillet, $Leg_{41}$** | 0.1563" |

| | |
|---|---|
| **Nozzle to vessel groove weld** | 0.4" |

| ASME B16.5-2009 Flange | |
|---|---|
| **Description** | NPS 1.5 Class 150 WN A182 F316L |
| **Bolt Material** | SA-193 B7 Bolt <= 2 1/2 (II-D p. 352, ln. 31) |
| **Blind included** | No |
| **Rated MDMT** | -55°F |
| **Liquid static head** | 0 psi |
| **MAWP rating** | 169.3 psi @ 338°F |
| **MAP rating** | 230 psi @ 70°F |
| **Hydrotest rating** | 350 psi @ 70°F |
| **PWHT performed** | No |
| **Impact Tested** | No |
| **Circumferential joint radiography** | None UW-11(c) Type 1 |
| **Notes** | |
| Flange rated MDMT per UHA-51(d)(1)(a) = -320°F<br>Bolts rated MDMT per Fig UCS-66 note (c) = -55°F | |

| UHA-51 Material Toughness Requirements Nozzle | |
|---|---|
| $t_r$ = 45*0.805 / (16,700*1 - 0.6*45) = | 0.0022" |
| Stress ratio = $t_r$*E* / ($t_n$ - c) = 0.0022*1 / (0.1269 - 0) = | 0.0171 |
| Impact test exempt per UHA-51(g) (coincident ratio = 0.0171) | |
| Rated MDMT = | -320°F |
| Material is exempt from impact testing at the Design MDMT of -20°F. | |

**Reinforcement Calculations for MAWP**

The vessel wall thickness governs the MAWP of this nozzle.

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For P = 167.01 psi @ 338 °F | | | | | | | The nozzle passes UG-45 | |
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |

| | | |
|---|---|---|
| This nozzle is exempt from area calculations per UG-36(c)(3)(a) | 0.1269 | 0.1269 |

| 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 ($Leg_{41}$) | 0.1015 | 0.1094 | weld size is adequate |

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

**Reinforcement Calculations for MAP**

The vessel wall thickness governs the MAP of this nozzle.

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For P = 171.11 psi @ 70 °F | | | | | | | The nozzle passes UG-45 | |
| **A required** | **A available** | **$A_1$** | **$A_2$** | **$A_3$** | **$A_5$** | **A welds** | **$t_{req}$** | **$t_{min}$** |
| This nozzle is exempt from area calculations per UG-36(c)(3)(a) | | | | | | | 0.1269 | 0.1269 |

| 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 ($Leg_{41}$) | 0.1015 | 0.1094 | weld size is adequate |

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

**Reinforcement Calculations for MAEP**

| UG-37 Area Calculation Summary ($in^2$) | | | | | | | UG-45 Summary (in) | |
|---|---|---|---|---|---|---|---|---|
| For Pe = 32.18 psi @ 338 °F | | | | | | | The nozzle passes UG-45 | |
| | | **$A_1$** | **$A_2$** | **$A_3$** | **$A_5$** | | **$t_{req}$** | **$t_{min}$** |

| A required | A available | | | | | A welds | | |
|---|---|---|---|---|---|---|---|---|
| This nozzle is exempt from area calculations per UG-36(c)(3)(a) | | | | | | | 0.1269 | 0.1269 |

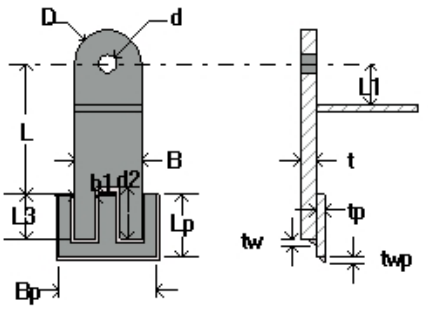
| UG-41 Weld Failure Path Analysis Summary |
|---|
| Weld strength calculations are not required for external pressure |

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| Weld description | Required weld throat size (in) | Actual weld throat size (in) | Status |
| Nozzle to shell fillet ($Leg_{41}$) | 0.1015 | 0.1094 | weld size is adequate |

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

## Lifting Lugs (Evonik Type 2)

**Minimum report**

| Geometry Inputs | |
|---|---|
|  | |
| **Attached To** | Shell -02 |
| **Material** | SA-240 304L |
| **Distance of Lift Point From Datum** | 177.1875" |
| **Angular Position** | 180 deg and 0 deg |
| **Length, L** | 10.6875" |
| **Width, B** | 5.625" |
| **Thickness, t** | 0.625" |
| **Hole Diameter, d** | 1.5" |
| **Pin Diameter, Dp** | 1.25" |
| **Diameter at Pin, D** | 5.625" |
| **Length to Brace Plate, $L_1$** | 3.375" |
| **Load Angle from Vertical, $\phi$** | 0 deg |
| **Has Brace Plate** | Yes |
| **Welds** | |
| **Size, $t_w$** | 0.3125" |
| **Length, $b_1$** | 1.8125" |
| **Length, $d_2$** | 4" |
| **Reinforcement Pad** | |
| **Width, $B_p$** | 8.125" |
| **Length, $L_p$** | 5.25" |
| **Thickness, $t_p$** | 0.375" |
| **Weld Size, $t_{wp}$** | 0.25" |
| **Weld Length, $L_3$** | 4" |

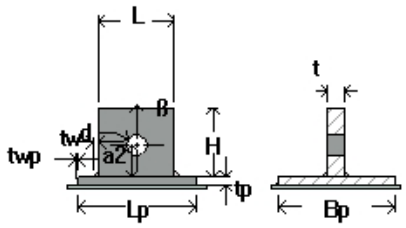
| Intermediate Values | |
|---|---|
| Load Factor | 1.5000 |
| Vessel Weight (new, incl. Load Factor), W | 11,364 lb |
| Lug Weight (new), $W_{lug}$ | 49.8 lb (Qty=2) |
| Distance from Center of Gravity to Top Lug, $l_1$ | 76.2143" |
| Distance from Center of Gravity to Tail Lug, $l_2$ | 93.4732" |
| Distance from Vessel Center Line to Tail Lug, $l_3$ | 42.3125" |
| Allowable Stress, Tensile, $\sigma_t$ | 19,980 psi |
| Allowable Stress, Shear, $\sigma_s$ | 13,320 psi |
| Allowable Stress, Bearing, $\sigma_p$ | 29,970 psi |
| Allowable Stress, Bending, $\sigma_b$ | 22,201 psi |
| Allowable Stress, Weld Shear, $\tau_{allowable}$ | 13,320 psi |
| Allowable Stress set to 1/3 Sy per ASME B30.20 | No |

| Summary Values | |
|---|---|
| Required Lift Pin Diameter, $d_{reqd}$ | 0.5211" |
| Required Lug Thickness, $t_{reqd}$ | 0.1517" |
| Estimated Brace Plate Length | 4.2562" |
| Lug Stress Ratio, $\sigma_{ratio}$ | 0.48 |
| Weld Shear Stress Ratio, $\tau_{ratio}$ | 0.21 |
| Lug Design | Acceptable |
| Local Stresses WRC 107 | Acceptable |
| Maximum Out of Plane Lift Angle - Weak Axis Bending | 22.98 deg |

COMPRESS recommends a spreader beam be used to prevent weak axis bending of the top lugs.
Ear lug brace plate should be removed before vessel is put in service.

## Tailing Lug (Evonik Type 2)

**Minimum report**

| Geometry Inputs | |
|---|---|
|  | |
| **Attached To** | Shell -01 |
| **Material** | SA-240<br>304L |
| **Orientation** | Longitudinal |
| **Distance of Lift Point From Datum** | 7.5" |
| **Angular Position** | 270 deg |
| **Length, L** | 5.625" |
| **Height, H** | 5.1875" |
| **Thickness, t** | 0.625" |
| **Hole Diameter, d** | 1.5" |
| **Pin Diameter, Dp** | 1.25" |
| **Load Eccentricity, $a_1$** | 0" |
| **Distance from Load to Shell or Pad, $a_2$** | 2.375" |
| **Load Angle Normal to Vessel, $\beta$** | 0 deg |
| **Load Angle from Vertical, $\phi$** | -90 deg |
| **Welds** | |
| **Size, $t_w$** | 0.4375" |
| **Reinforcement Pad** | |
| **Width, $B_p$** | 4.3125" |
| **Length, $L_p$** | 8.6875" |
| **Thickness, $t_p$** | 0.625" |
| **Weld Size, $t_{wp}$** | 0.25" |

| Intermediate Values | |
|---|---|
| Load Factor | 1.5000 |
| Vessel Weight (new, incl. Load Factor), W | 11,364 lb |
| Lug Weight (new), $W_{lug}$ | 12.3 lb |
| Distance from Center of Gravity to Top Lug, $l_1$ | 76.2143" |
| Distance from Center of Gravity to Tail Lug, $l_2$ | 93.4732" |
| Distance from Vessel Center Line to Tail Lug, $l_3$ | 42.3125" |
| Allowable Stress, Tensile, $\sigma_t$ | 19,980 psi |
| Allowable Stress, Shear, $\sigma_s$ | 13,320 psi |
| Allowable Stress, Bearing, $\sigma_p$ | 29,970 psi |
| Allowable Stress, Bending, $\sigma_b$ | 22,201 psi |
| Allowable Stress, Weld Shear, $\tau_{allowable}$ | 13,320 psi |
| Allowable Stress set to 1/3 Sy per ASME B30.20 | No |

| Summary Values | |
|---|---|
| Required Lift Pin Diameter, $d_{reqd}$ | 0.4939" |
| Required Lug Thickness, $t_{reqd}$ | 0.1362" |
| Lug Stress Ratio, $\sigma_{ratio}$ | 0.13 |
| Weld Shear Stress Ratio, $\tau_{ratio}$ | 0.18 |
| Lug Design | Acceptable |
| Local Stresses WRC 107 | Acceptable |