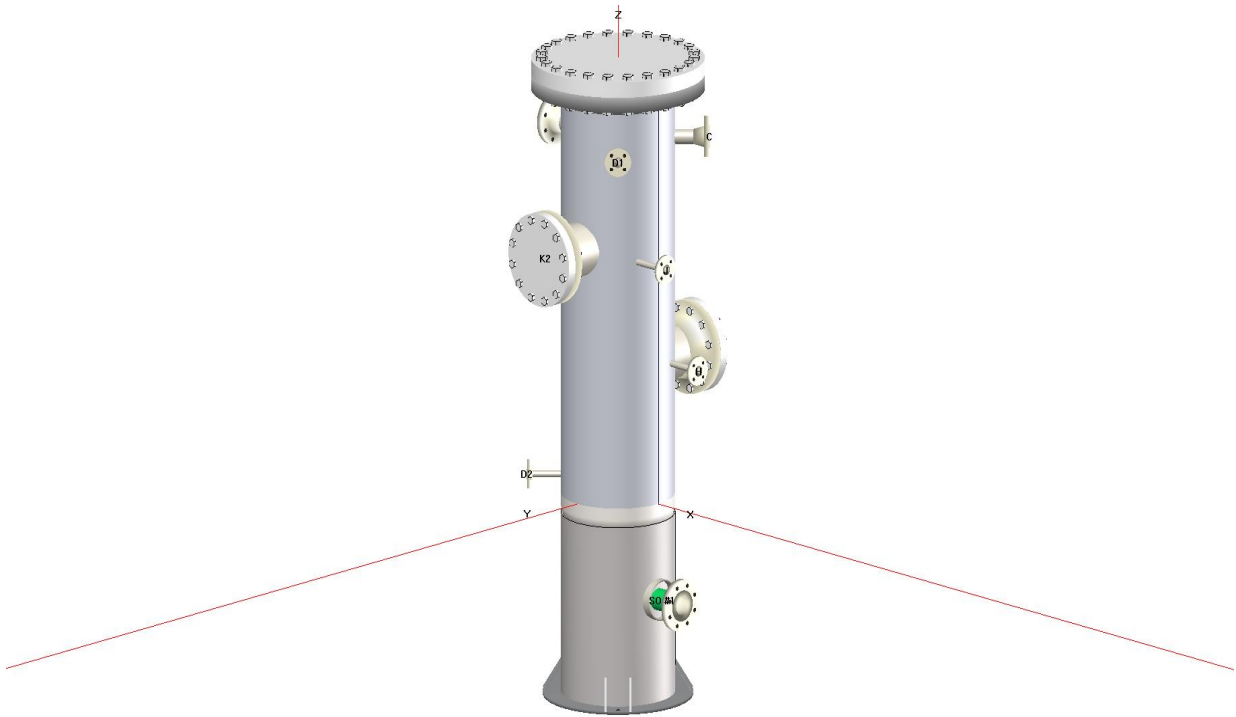


# Houston Vessel Manufacturing, LLC

16250 Tomball Parkway

Houston, TX 77086



## COMPRESS Pressure Vessel Design Calculations

**Item:** HT SHIFT REACTOR

**PO#:** 110862

**Customer:** BAYOTECH

**Job#:** HVM2112003B

**Designer:** Kevin Griffith

**Date:** Friday, January 14, 2022

REV 0

RELEASED FOR FABRICATION

TAG # 600-R-1001

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## Deficiencies Summary

***No deficiencies found.***

## Nozzle Schedule

| Specifications     |                                    |                        |             |                              |               |            |            |                                  |                           |
|--------------------|------------------------------------|------------------------|-------------|------------------------------|---------------|------------|------------|----------------------------------|---------------------------|
| Nozzle mark        | Identifier                         | Size                   | Materials   |                              | Impact Tested | Normalized | Fine Grain | Flange                           | Blind                     |
| <a href="#">A</a>  | GAS INLET                          | NPS 3 Sch 40S (Std)    | Nozzle      | SA-312 TP316 Wld pipe        | No            | No         | No         | NPS 3 Class 300 WN A182 F316     | No                        |
| <a href="#">B</a>  | GAS OUTLET                         | NPS 3 Sch 40S (Std)    | Nozzle      | SA-312 TP316 Wld & smls pipe | No            | No         | No         | N/A                              | No                        |
|                    | <a href="#">B16.9 Elbow #1 (B)</a> | NPS 3 Sch 40S (Std)    | B16.9 Elbow | SA-403 316                   | No            | No         | No         | N/A                              | No                        |
|                    | <a href="#">Nozzle Pipe #1 (B)</a> | NPS 3 Sch 40S (Std)    | Nozzle Pipe | SA-312 TP316 Wld & smls pipe | No            | No         | No         | NPS 3 Class 300 WN A182 F316     | No                        |
| <a href="#">C</a>  | PSV                                | NPS 2 Sch 40S (Std)    | Nozzle      | SA-312 TP316 Wld pipe        | No            | No         | No         | NPS 2 Class 300 WN A182 F316     | No                        |
| <a href="#">D1</a> | CATALYST ACTIVATION                | NPS 0.75 Sch 40S (Std) | Nozzle      | SA-312 TP316 Wld pipe        | No            | No         | No         | NPS 3/4 Class 300 SW A182 F316   | No                        |
| <a href="#">D2</a> | CATALYST ACTIVATION                | NPS 0.75 Sch 40S (Std) | Nozzle      | SA-312 TP316 Wld pipe        | No            | No         | No         | NPS 3/4 Class 300 SW A182 F316   | No                        |
| <a href="#">E1</a> | TE CONNECTIONS                     | NPS 1.5 Sch 40S (Std)  | Nozzle      | SA-312 TP316 Wld pipe        | No            | No         | No         | NPS 1 1/2 Class 300 WN A182 F316 | No                        |
| <a href="#">E2</a> | TE CONNECTIONS                     | NPS 1.5 Sch 40S (Std)  | Nozzle      | SA-312 TP316 Wld pipe        | No            | No         | No         | NPS 1 1/2 Class 300 WN A182 F316 | No                        |
| <a href="#">E3</a> | TE CONNECTIONS                     | NPS 1.5 Sch 40S (Std)  | Nozzle      | SA-312 TP316 Wld pipe        | No            | No         | No         | NPS 1 1/2 Class 300 WN A182 F316 | No                        |
| <a href="#">E4</a> | TE CONNECTIONS                     | NPS 1.5 Sch 40S (Std)  | Nozzle      | SA-312 TP316 Wld pipe        | No            | No         | No         | NPS 1 1/2 Class 300 WN A182 F316 | No                        |
| <a href="#">H</a>  | COIL INLET                         | NPS 0.75 Sch 40S (Std) | Nozzle      | SA-312 TP316 Wld & smls pipe | No            | No         | No         | NPS 3/4 Class 300 WN A182 F316   | No                        |
| <a href="#">J</a>  | COIL OUTLET                        | NPS 0.75 Sch 40S (Std) | Nozzle      | SA-312 TP316 Wld & smls pipe | No            | No         | No         | NPS 3/4 Class 300 WN A182 F316   | No                        |
| <a href="#">K1</a> | HANDHOLE                           | NPS 8 Sch 40S (Std)    | Nozzle      | SA-312 TP316 Wld pipe        | No            | No         | No         | NPS 8 Class 300 WN A182 F316     | NPS 8 Class 300 A182 F316 |
| <a href="#">K2</a> | HANDHOLE                           | NPS 8 Sch 40S (Std)    | Nozzle      | SA-312 TP316 Wld pipe        | No            | No         | No         | NPS 8 Class 300 WN A182 F316     | NPS 8 Class 300 A182 F316 |

## Nozzle Summary

| Dimensions                            |         |                     |                         |                  |                  |            |               |             |                   |                       |           |                                    |
|---------------------------------------|---------|---------------------|-------------------------|------------------|------------------|------------|---------------|-------------|-------------------|-----------------------|-----------|------------------------------------|
| Nozzle mark                           | OD (in) | t <sub>n</sub> (in) | Req t <sub>n</sub> (in) | A <sub>1</sub> ? | A <sub>2</sub> ? | Shell      |               |             | Reinforcement Pad |                       | Corr (in) | A <sub>a</sub> /A <sub>r</sub> (%) |
|                                       |         |                     |                         |                  |                  | Nom t (in) | Design t (in) | User t (in) | Width (in)        | t <sub>pad</sub> (in) |           |                                    |
| <a href="#">A</a>                     | 3.5     | 0.216               | 0.1629                  | Yes              | Yes              | 0.25       | N/A           |             | N/A               | N/A                   | 0         | Exempt                             |
| <a href="#">B</a>                     | 3.5     | 0.216               | 0.1617                  | Yes              | Yes              | 0.1661*    | N/A           |             | N/A               | N/A                   | 0         | Exempt                             |
| <a href="#">C</a>                     | 2.375   | 0.154               | 0.154                   | Yes              | Yes              | 0.25       | N/A           |             | N/A               | N/A                   | 0         | Exempt                             |
| <a href="#">D1</a>                    | 1.05    | 0.113               | 0.113                   | Yes              | Yes              | 0.25       | N/A           |             | N/A               | N/A                   | 0         | Exempt                             |
| <a href="#">D2</a>                    | 1.05    | 0.113               | 0.113                   | Yes              | Yes              | 0.25       | N/A           |             | N/A               | N/A                   | 0         | Exempt                             |
| <a href="#">E1</a>                    | 1.9     | 0.145               | 0.145                   | Yes              | Yes              | 0.25       | N/A           |             | N/A               | N/A                   | 0         | Exempt                             |
| <a href="#">E2</a>                    | 1.9     | 0.145               | 0.145                   | Yes              | Yes              | 0.25       | N/A           |             | N/A               | N/A                   | 0         | Exempt                             |
| <a href="#">E3</a>                    | 1.9     | 0.145               | 0.145                   | Yes              | Yes              | 0.25       | N/A           |             | N/A               | N/A                   | 0         | Exempt                             |
| <a href="#">E4</a>                    | 1.9     | 0.145               | 0.145                   | Yes              | Yes              | 0.25       | N/A           |             | N/A               | N/A                   | 0         | Exempt                             |
| <a href="#">H</a>                     | 1.05    | 0.113               | 0.113                   | Yes              | Yes              | 0.25       | N/A           |             | N/A               | N/A                   | 0         | Exempt                             |
| <a href="#">J</a>                     | 1.05    | 0.113               | 0.113                   | Yes              | Yes              | 0.25       | N/A           |             | N/A               | N/A                   | 0         | Exempt                             |
| <a href="#">K1</a>                    | 8.625   | 0.322               | 0.0774                  | Yes              | Yes              | 0.25       | 0.1425        |             | N/A               | N/A                   | 0         | 106.5                              |
| <a href="#">K2</a>                    | 8.625   | 0.322               | 0.0774                  | Yes              | Yes              | 0.25       | 0.1425        |             | N/A               | N/A                   | 0         | 106.5                              |
| *Head minimum thickness after forming |         |                     |                         |                  |                  |            |               |             |                   |                       |           |                                    |

| Definitions        |                                                                                                               |
|--------------------|---------------------------------------------------------------------------------------------------------------|
| t <sub>n</sub>     | Nozzle thickness                                                                                              |
| Req t <sub>n</sub> | Nozzle thickness required per UG-45/UG-16<br>Increased for pipe to account for 12.5% pipe thickness tolerance |
| 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 <sub>a</sub>     | Area available per UG-37, governing condition                                                                 |
| A <sub>r</sub>     | Area required per UG-37, governing condition                                                                  |
| Corr               | Corrosion allowance on nozzle wall                                                                            |

## Pressure Summary

| Component Summary                                      |                      |                     |               |              |                   |                  |
|--------------------------------------------------------|----------------------|---------------------|---------------|--------------|-------------------|------------------|
| Identifier                                             | P<br>Design<br>(psi) | T<br>Design<br>(°F) | MAWP<br>(psi) | MDMT<br>(°F) | MDMT<br>Exemption | Impact<br>Tested |
| <a href="#">ASME B16.5/16.47 Blind on Flange #1</a>    | 225                  | 840                 | 420           | -55          | Note 1            | No               |
| <a href="#">Cylinder #1</a>                            | 225                  | 840                 | 251.36        | -320         | Note 2            | No               |
| <a href="#">Straight Flange on Ellipsoidal Head #1</a> | 225                  | 840                 | 336.99        | -320         | Note 2            | No               |
| <a href="#">Ellipsoidal Head #1</a>                    | 225                  | 840                 | 225.02        | -320         | Note 3            | No               |
| <a href="#">Flange #1</a>                              | 225                  | 840                 | 420           | -55          | Note 1            | No               |
| <a href="#">GAS INLET (A)</a>                          | 225                  | 840                 | 346.55        | -55          | Note 4            | No               |
| <a href="#">GAS OUTLET (B)</a>                         | 225                  | 840                 | 291.91        | -320         | Note 2            | No               |
| <a href="#">B16.9 Elbow #1 (B)</a>                     | 225                  | 840                 | 1,732.7       | -320         | Note 5            | No               |
| <a href="#">Nozzle Pipe #1 (B)</a>                     | 225                  | 840                 | 420           | -55          | Note 6, 7         | No               |
| <a href="#">PSV (C)</a>                                | 225                  | 840                 | 346.55        | -55          | Note 4            | No               |
| <a href="#">CATALYST ACTIVATION (D1)</a>               | 225                  | 840                 | 346.55        | -55          | Note 4            | No               |
| <a href="#">CATALYST ACTIVATION (D2)</a>               | 225                  | 840                 | 346.55        | -55          | Note 4            | No               |
| <a href="#">TE CONNECTIONS (E1)</a>                    | 225                  | 840                 | 346.55        | -55          | Note 4            | No               |
| <a href="#">TE CONNECTIONS (E2)</a>                    | 225                  | 840                 | 346.55        | -55          | Note 4            | No               |
| <a href="#">TE CONNECTIONS (E3)</a>                    | 225                  | 840                 | 346.55        | -55          | Note 4            | No               |
| <a href="#">TE CONNECTIONS (E4)</a>                    | 225                  | 840                 | 346.55        | -55          | Note 4            | No               |
| <a href="#">COIL INLET (H)</a>                         | 225                  | 840                 | 346.55        | -55          | Note 4            | No               |
| <a href="#">COIL OUTLET (J)</a>                        | 225                  | 840                 | 346.55        | -55          | Note 4            | No               |
| <a href="#">HANDHOLE (K1)</a>                          | 225                  | 840                 | 233.11        | -55          | Note 4            | No               |
| <a href="#">HANDHOLE (K2)</a>                          | 225                  | 840                 | 233.11        | -55          | Note 4            | No               |

| Chamber Summary                                                                                                                                                       |                  |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|
| Design MDMT                                                                                                                                                           | -20 °F           |
| Rated MDMT                                                                                                                                                            | -55 °F @ 225 psi |
| MAWP hot & corroded                                                                                                                                                   | 225 psi @ 840 °F |
| (1) The MAWP is limited due to the MAWP limit set in the Calculations tab of the Set Mode dialog.<br>(2) This pressure chamber is not designed for external pressure. |                  |

| Notes for Maximum Pressure Rating |                                                                                                    |
|-----------------------------------|----------------------------------------------------------------------------------------------------|
| Note #                            | Details                                                                                            |
| 1.                                | Option to calculate MAP was not selected. See the Calculation->General tab of the Set Mode dialog. |



| Notes for MDMT Rating |                                                                                                                              |                                                  |
|-----------------------|------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------|
| Note #                | Exemption                                                                                                                    | Details                                          |
| 1.                    | Flange rated MDMT per UHA-51(d)(1)(a) = -320°F                                                                               | Bolts rated MDMT per Fig UCS-66 note (c) = -55°F |
| 2.                    | Rated MDMT per UHA-51(d)(1)(a), (carbon content does not exceed 0.10%) = -320°F                                              |                                                  |
| 3.                    | <a href="#">Straight Flange</a> governs MDMT                                                                                 |                                                  |
| 4.                    | 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 |                                                  |
| 5.                    | Impact test exempt per UHA-51(g) (coincident ratio = 0.0907)                                                                 |                                                  |
| 6.                    | Impact test exempt per UHA-51(g) (coincident ratio = 0.1036)                                                                 |                                                  |
| 7.                    | Flange rating governs:<br>Flange rated MDMT per UHA-51(d)(1)(a) = -320°F                                                     | Bolts rated MDMT per Fig UCS-66 note (c) = -55°F |

### Revision History

| Revisions |           |          |                                                                            |
|-----------|-----------|----------|----------------------------------------------------------------------------|
| No.       | Date      | Operator | Notes                                                                      |
| 0         | 6/ 8/2021 | gcasco   | New vessel created ASME Section VIII Division 1 [COMPRESS 2020 Build 8010] |

## Settings Summary

| COMPRESS 2021 Build 8110                                           |                                  |
|--------------------------------------------------------------------|----------------------------------|
| ASME Section VIII Division 1, 2019 Edition                         |                                  |
| Units                                                              | U.S. Customary                   |
| Datum Line Location                                                | 0.00" from bottom seam           |
| Vessel Design Mode                                                 | Design Mode                      |
| Minimum thickness                                                  | 0.0625" per UG-16(b)             |
| Design for cold shut down only                                     | No                               |
| Design for lethal service (full radiography required)              | No                               |
| User has limited MAWP to                                           | 225 psi                          |
| Design nozzles for                                                 | Design P only                    |
| Corrosion weight loss                                              | 100% of theoretical loss         |
| UG-23 Stress Increase                                              | 1.20                             |
| Skirt/legs stress increase                                         | 1.0                              |
| Minimum nozzle projection                                          | 1"                               |
| Juncture calculations for $\alpha > 30$ only                       | Yes                              |
| Preheat P-No 1 Materials > 1.25" and $\leq 1.50$ " thick           | No                               |
| UG-37(a) shell tr calculation considers longitudinal stress        | No                               |
| Cylindrical shells made from pipe are entered as minimum thickness | No                               |
| Nozzles made from pipe are entered as minimum thickness            | No                               |
| ASME B16.9 fittings are entered as minimum thickness               | Yes                              |
| Butt welds                                                         | Tapered per Figure UCS-66.3(a)   |
| Disallow Appendix 1-5, 1-8 calculations under 15 psi               | No                               |
| Hydro/Pneumatic Test                                               |                                  |
| Shop Hydrotest Pressure                                            | 1.3 times vessel MAWP [UG-99(b)] |
| Test liquid specific gravity                                       | 1.00                             |
| Maximum stress during test                                         | 90% of yield                     |
| Required Marking - UG-116                                          |                                  |
| UG-116(e) Radiography                                              | RT3                              |
| UG-116(f) Postweld heat treatment                                  | None                             |
| Code Cases\Interpretations                                         |                                  |
| Use Appendix 46                                                    | No                               |
| Use UG-44(b)                                                       | No                               |
| Use Code Case 2955                                                 | No                               |

|                                                                                                                                         |     |
|-----------------------------------------------------------------------------------------------------------------------------------------|-----|
| Apply interpretation VIII-1-83-66                                                                                                       | Yes |
| Apply interpretation VIII-1-86-175                                                                                                      | Yes |
| Apply interpretation VIII-1-01-37                                                                                                       | Yes |
| Apply interpretation VIII-1-01-150                                                                                                      | Yes |
| Apply interpretation VIII-1-07-50                                                                                                       | Yes |
| Apply interpretation VIII-1-16-85                                                                                                       | No  |
| No UCS-66.1 MDMT reduction                                                                                                              | No  |
| No UCS-68(c) MDMT reduction                                                                                                             | No  |
| Disallow UG-20(f) exemptions                                                                                                            | No  |
| <b>UG-22 Loadings</b>                                                                                                                   |     |
| UG-22(a) Internal or External Design Pressure                                                                                           | Yes |
| UG-22(b) Weight of the vessel and normal contents under operating or test conditions                                                    | Yes |
| UG-22(c) Superimposed static reactions from weight of attached equipment (external loads)                                               | No  |
| UG-22(d)(2) Vessel supports such as lugs, rings, skirts, saddles and legs                                                               | Yes |
| UG-22(f) Wind reactions                                                                                                                 | No  |
| UG-22(f) Seismic reactions                                                                                                              | No  |
| UG-22(j) Test pressure and coincident static head acting during the test:                                                               | No  |
| Note: UG-22(b),(c) and (f) loads only considered when supports are present.                                                             |     |
| Note 2: UG-22(d)(1),(e),(f)-snow,(g),(h),(i) are not considered. If these loads are present, additional calculations must be performed. |     |

| License Information |               |
|---------------------|---------------|
| Company Name        | Generon IGS   |
| License             | Commercial    |
| License Key ID      | 23148         |
| Support Expires     | July 27, 2022 |

## Radiography Summary

| UG-116 Radiography                                                               |                        |                             |                                          |                             |                                          |                             |      |
|----------------------------------------------------------------------------------|------------------------|-----------------------------|------------------------------------------|-----------------------------|------------------------------------------|-----------------------------|------|
| Component                                                                        | Longitudinal Seam      |                             | Top Circumferential Seam                 |                             | Bottom Circumferential Seam              |                             | Mark |
|                                                                                  | Category<br>(Fig UW-3) | Radiography / Joint<br>Type | Category<br>(Fig UW-3)                   | Radiography / Joint<br>Type | Category<br>(Fig UW-3)                   | Radiography / Joint<br>Type |      |
| <a href="#">ASME B16.5/16.47 Blind on Flange #1</a>                              | N/A                    | Seamless No RT              | N/A                                      | N/A                         | N/A                                      | N/A / Gasketed              | N/A  |
| <a href="#">Cylinder #1</a>                                                      | N/A                    | Welded pipe                 | C                                        | N/A                         | B                                        | Spot UW-11(b) /<br>Type 1   | RT3  |
| <a href="#">Flange #1</a>                                                        | N/A                    | Seamless No RT              | N/A                                      | N/A / Gasketed              | C                                        | N/A                         | N/A  |
| <a href="#">Ellipsoidal Head #1</a>                                              | N/A                    | Seamless No RT              | B                                        | Spot UW-11(b) /<br>Type 1   | N/A                                      | N/A                         | RT3  |
| Nozzle                                                                           | Longitudinal Seam      |                             | Nozzle to Vessel Circumferential<br>Seam |                             | Nozzle free end Circumferential<br>Seam  |                             |      |
| <a href="#">GAS INLET (A)</a>                                                    | N/A                    | Welded pipe                 | D                                        | N/A / Type 7                | C                                        | UW-11(b) exempt /<br>Type 1 | N/A  |
| <a href="#">PSV (C)</a>                                                          | N/A                    | Welded pipe                 | D                                        | N/A / Type 7                | C                                        | UW-11(b) exempt /<br>Type 1 | N/A  |
| <a href="#">CATALYST ACTIVATION (D1)</a>                                         | N/A                    | Welded pipe                 | D                                        | N/A / Type 7                | C                                        | N/A / Type 6                | N/A  |
| <a href="#">TE CONNECTIONS (E1)</a>                                              | N/A                    | Welded pipe                 | D                                        | N/A / Type 7                | C                                        | UW-11(b) exempt /<br>Type 1 | N/A  |
| <a href="#">TE CONNECTIONS (E2)</a>                                              | N/A                    | Welded pipe                 | D                                        | N/A / Type 7                | C                                        | UW-11(b) exempt /<br>Type 1 | N/A  |
| <a href="#">TE CONNECTIONS (E3)</a>                                              | N/A                    | Welded pipe                 | D                                        | N/A / Type 7                | C                                        | UW-11(b) exempt /<br>Type 1 | N/A  |
| <a href="#">TE CONNECTIONS (E4)</a>                                              | N/A                    | Welded pipe                 | D                                        | N/A / Type 7                | C                                        | UW-11(b) exempt /<br>Type 1 | N/A  |
| <a href="#">HANDHOLE (K1)</a>                                                    | N/A                    | Welded pipe                 | D                                        | N/A / Type 7                | C                                        | UW-11(b) exempt /<br>Type 1 | N/A  |
| <a href="#">COIL OUTLET (J)</a>                                                  | N/A                    | Welded pipe                 | D                                        | N/A / Type 7                | C                                        | UW-11(b) exempt /<br>Type 1 | N/A  |
| <a href="#">COIL INLET (H)</a>                                                   | N/A                    | Welded pipe                 | D                                        | N/A / Type 7                | C                                        | UW-11(b) exempt /<br>Type 1 | N/A  |
| <a href="#">CATALYST ACTIVATION (D2)</a>                                         | N/A                    | Welded pipe                 | D                                        | N/A / Type 7                | C                                        | N/A / Type 6                | N/A  |
| <a href="#">HANDHOLE (K2)</a>                                                    | N/A                    | Welded pipe                 | D                                        | N/A / Type 7                | C                                        | UW-11(b) exempt /<br>Type 1 | N/A  |
| <a href="#">GAS OUTLET (B)</a>                                                   | N/A                    | Seamless No RT              | D                                        | N/A / Type 7                | B                                        | UW-11(b) exempt /<br>Type 1 | N/A  |
| <a href="#">B16.9 Elbow #1 (B)</a>                                               | N/A                    | Seamless No RT              | B                                        | UW-11(b) exempt /<br>Type 1 | B                                        | UW-11(b) exempt /<br>Type 1 | N/A  |
| <a href="#">Nozzle Pipe #1 (B)</a>                                               | N/A                    | Seamless No RT              | B                                        | UW-11(b) exempt /<br>Type 1 | C                                        | UW-11(b) exempt /<br>Type 1 | N/A  |
| Nozzle Flange                                                                    | Longitudinal Seam      |                             | Flange Face                              |                             | Nozzle to Flange Circumferential<br>Seam |                             |      |
| <a href="#">ASME B16.5/16.47 flange attached to GAS<br/>INLET (A)</a>            | N/A                    | Seamless No RT              | N/A                                      | N/A / Gasketed              | C                                        | UW-11(b) exempt /<br>Type 1 | N/A  |
| <a href="#">ASME B16.5/16.47 flange attached to PSV (C)</a>                      | N/A                    | Seamless No RT              | N/A                                      | N/A / Gasketed              | C                                        | UW-11(b) exempt /<br>Type 1 | N/A  |
| <a href="#">ASME B16.5/16.47 flange attached to<br/>CATALYST ACTIVATION (D1)</a> | N/A                    | Seamless No RT              | N/A                                      | N/A / Gasketed              | C                                        | N/A / Type 6                | N/A  |
| <a href="#">ASME B16.5/16.47 flange attached to TE<br/>CONNECTIONS (E1)</a>      | N/A                    | Seamless No RT              | N/A                                      | N/A / Gasketed              | C                                        | UW-11(b) exempt /<br>Type 1 | N/A  |
| <a href="#">ASME B16.5/16.47 flange attached to TE<br/>CONNECTIONS (E2)</a>      | N/A                    | Seamless No RT              | N/A                                      | N/A / Gasketed              | C                                        | UW-11(b) exempt /<br>Type 1 | N/A  |
| <a href="#">ASME B16.5/16.47 flange attached to TE<br/>CONNECTIONS (E3)</a>      | N/A                    | Seamless No RT              | N/A                                      | N/A / Gasketed              | C                                        | UW-11(b) exempt /<br>Type 1 | N/A  |

|                                                                                     |     |                |     |                |   |                          |     |
|-------------------------------------------------------------------------------------|-----|----------------|-----|----------------|---|--------------------------|-----|
| <a href="#">ASME B16.5/16.47 flange attached to TE CONNECTIONS (E4)</a>             | N/A | Seamless No RT | N/A | N/A / Gasketed | C | UW-11(b) exempt / Type 1 | N/A |
| <a href="#">ASME B16.5/16.47 flange attached to HANDHOLE (K1)</a>                   | N/A | Seamless No RT | N/A | N/A / Gasketed | C | UW-11(b) exempt / Type 1 | N/A |
| <a href="#">ASME B16.5/16.47 flange attached to COIL OUTLET (J)</a>                 | N/A | Seamless No RT | N/A | N/A / Gasketed | C | UW-11(b) exempt / Type 1 | N/A |
| <a href="#">ASME B16.5/16.47 flange attached to COIL INLET (H)</a>                  | N/A | Seamless No RT | N/A | N/A / Gasketed | C | UW-11(b) exempt / Type 1 | N/A |
| <a href="#">ASME B16.5/16.47 flange attached to CATALYST ACTIVATION (D2)</a>        | N/A | Seamless No RT | N/A | N/A / Gasketed | C | N/A / Type 6             | N/A |
| <a href="#">ASME B16.5/16.47 flange attached to HANDHOLE (K2)</a>                   | N/A | Seamless No RT | N/A | N/A / Gasketed | C | UW-11(b) exempt / Type 1 | N/A |
| <a href="#">ASME B16.5/16.47 flange attached to right end of Nozzle Pipe #1 (B)</a> | N/A | Seamless No RT | N/A | N/A / Gasketed | C | UW-11(b) exempt / Type 1 | N/A |
| Interpretation VIII-1 01-150 has been applied.                                      |     |                |     |                |   |                          |     |
| UG-116(e) Required Marking: <b>RT3</b>                                              |     |                |     |                |   |                          |     |

## Thickness Summary

| Component Data                                         |                       |               |             |                |               |                      |         |          |
|--------------------------------------------------------|-----------------------|---------------|-------------|----------------|---------------|----------------------|---------|----------|
| Component Identifier                                   | Material              | Diameter (in) | Length (in) | Nominal t (in) | Design t (in) | Total Corrosion (in) | Joint E | Load     |
| <a href="#">Cylinder #1</a>                            | SA-312 TP316 Wld pipe | 20 OD         | 68.125      | 0.25           | 0.196         | 0                    | 0.85    | Internal |
| <a href="#">Straight Flange on Ellipsoidal Head #1</a> | SA-240 316            | 20 OD         | 2           | 0.25           | 0.1675        | 0                    | 0.85    | Internal |
| <a href="#">Ellipsoidal Head #1</a>                    | SA-240 316            | 20 OD         | 5.0831      | 0.1661*        | 0.1661        | 0                    | 0.85    | Internal |
| <a href="#">Support Skirt #1</a>                       | SA-312 TP316 Wld pipe | 20 OD         | 29.629      | 0.25           | 0.0026        | 0                    | 0.55    | Weight   |
| *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 ft <sup>2</sup> |
|                                                                                    |                |                |            |                     |          |                 | New              | Corroded | New          | Corroded     |                              |
| <a href="#">ASME B16.5/16.47 Blind on Flange #1</a>                                | 575            | 575            | 0          | 0                   | 0        | 0               | 0                | 0        | 0            | 0            | 7                            |
| <a href="#">Cylinder #1</a>                                                        | 295.9          | 295.9          | 0          | 0                   | 0        | 0               | 0                | 0        | 750          | 750          | 29                           |
| <a href="#">Ellipsoidal Head #1</a>                                                | 30.5           | 30.5           | 0          | 0                   | 0        | 0               | 0                | 0        | 62.7         | 62.7         | 4                            |
| <a href="#">Support Skirt #1</a>                                                   | 131            | 131            | 0          | 0                   | 0        | 0               | 0                | 0        | 0            | 0            | 26                           |
| <a href="#">Skirt Base Ring #1</a>                                                 | 61             | 61             | 0          | 0                   | 0        | 0               | 0                | 0        | 0            | 0            | 7                            |
| <b>TOTAL:</b>                                                                      | <b>1,093.4</b> | <b>1,093.4</b> | <b>0</b>   | <b>0</b>            | <b>0</b> | <b>0</b>        | <b>0</b>         | <b>0</b> | <b>812.7</b> | <b>812.7</b> | <b>73</b>                    |
| *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 ft <sup>2</sup> |
|                                                     | New          | Corroded   | New               | Corroded     |             |                     |          |               |               |                |                              |
| <a href="#">ASME B16.5/16.47 Blind on Flange #1</a> | 0            | 0          | 0                 | 0            | 0           | 0                   | 0        | 0             | 0             | 0              | 0                            |
| <a href="#">Cylinder #1</a>                         | 315          | 315        | 417               | 417          | 0           | 0                   | 0        | 0             | 0             | 0              | 24                           |
| <a href="#">Ellipsoidal Head #1</a>                 | 0            | 0          | 27.7              | 27.7         | 0           | 0                   | 0        | 0             | 0             | 0              | 2                            |
| <a href="#">Support Skirt #1</a>                    | 0            | 0          | 4.6               | 4.6          | 0           | 0                   | 0        | 0             | 0             | 0              | 0                            |
| <b>TOTAL:</b>                                       | <b>315</b>   | <b>315</b> | <b>449.2</b>      | <b>449.2</b> | <b>0</b>    | <b>0</b>            | <b>0</b> | <b>0</b>      | <b>0</b>      | <b>0</b>       | <b>19</b>                    |

| Vessel Totals                                                                         |       |          |
|---------------------------------------------------------------------------------------|-------|----------|
|                                                                                       | New   | Corroded |
| Operating Weight (lb)                                                                 | 1,858 | 1,858    |
| Empty Weight (lb)                                                                     | 1,858 | 1,858    |
| Test Weight (lb)                                                                      | 2,677 | 2,677    |
| Surface Area (ft <sup>2</sup> )                                                       | 92    | -        |
| Capacity** (US gal)                                                                   | 95    | 95       |
| **The vessel capacity does not include volume of nozzle, piping or other attachments. |       |          |

| Vessel Lift Condition             |         |
|-----------------------------------|---------|
| Vessel Lift Weight, New (lb)      | 1,858   |
| Center of Gravity from Datum (in) | 43.0494 |

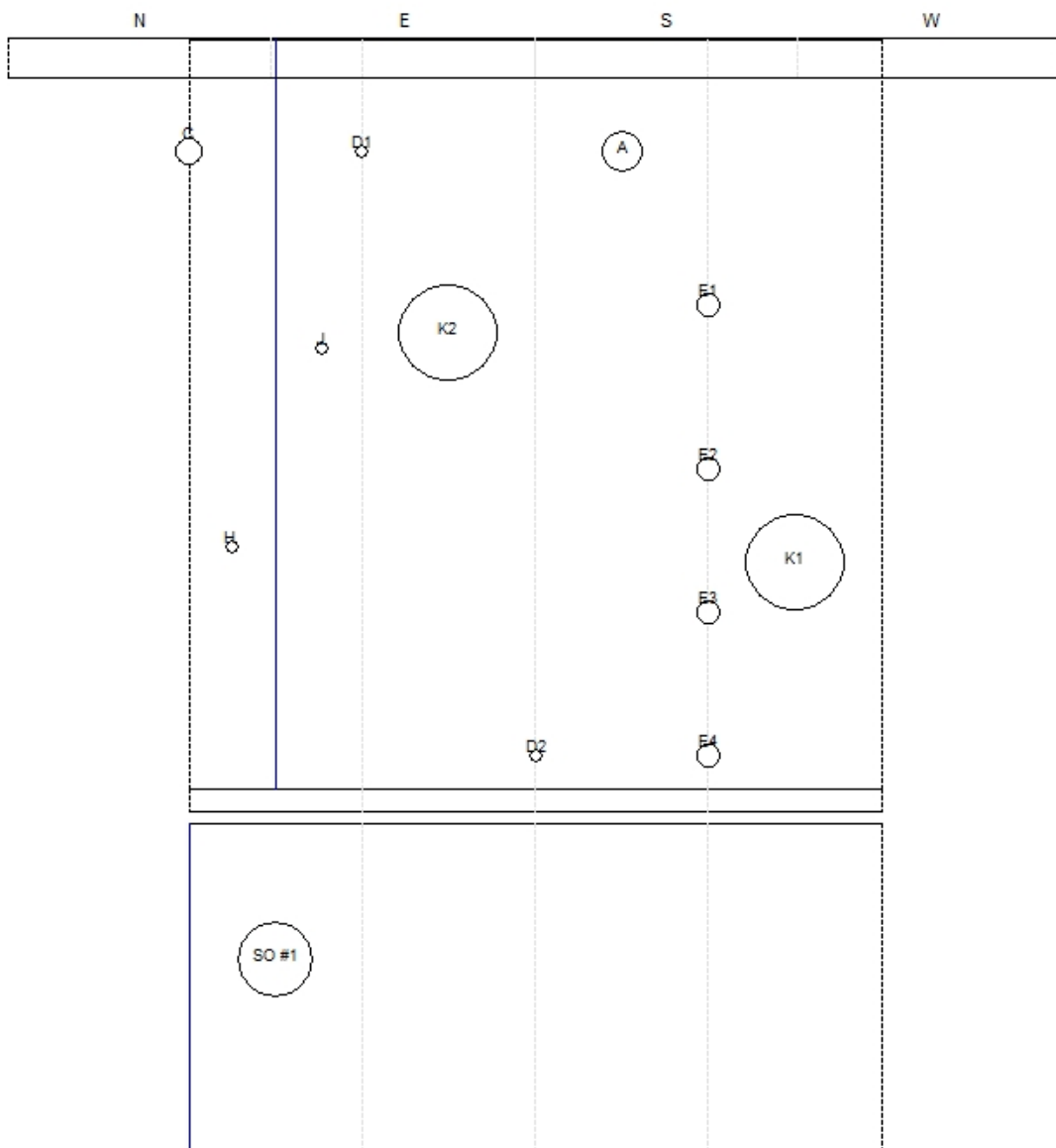


## Long Seam Summary

| Shell Long Seam Angles           |        |
|----------------------------------|--------|
| Component                        | Seam 1 |
| <a href="#">Cylinder #1</a>      | 0°     |
| <a href="#">Support Skirt #1</a> | 315°   |

| Shell Plate Lengths              |                |          |
|----------------------------------|----------------|----------|
| Component                        | Starting Angle | Plate 1  |
| <a href="#">Cylinder #1</a>      | 0°             | 62.0465" |
| <a href="#">Support Skirt #1</a> | 315°           | 62.0465" |

| Notes                                                                                                                          |
|--------------------------------------------------------------------------------------------------------------------------------|
| 1) Plate Lengths use the circumference of the vessel based on the mid diameter of the components.<br>2) North is located at 0° |



Shell Rollout

## Hydrostatic Test

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

$$\begin{aligned}
 \text{Gauge pressure at } 70^{\circ}\text{F} &= \\
 &= 1.3 \cdot \text{MAWP} \cdot \text{LSR} \\
 &= 1.3 \cdot 225 \cdot 1.2687 \\
 &= 371.09 \text{ psi}
 \end{aligned}$$

| Horizontal shop hydrostatic test                                                                                                                                             |                           |                               |                       |                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|-------------------------------|-----------------------|--------------------------|
| Identifier                                                                                                                                                                   | Local test pressure (psi) | Test liquid static head (psi) | UG-99(b) stress ratio | UG-99(b) pressure factor |
| Flange #1                                                                                                                                                                    | 372.037                   | 0.942                         | N/A                   | 1.30                     |
| Cylinder #1 (1)                                                                                                                                                              | 372.024                   | 0.93                          | 1.2687                | 1.30                     |
| Straight Flange on Ellipsoidal Head #1                                                                                                                                       | 372.024                   | 0.93                          | 1.2739                | 1.30                     |
| Ellipsoidal Head #1                                                                                                                                                          | 372.027                   | 0.933                         | 1.2739                | 1.30                     |
| B16.9 Elbow #1 (B)                                                                                                                                                           | 371.728                   | 0.633                         | 1.2739                | 1.30                     |
| CATALYST ACTIVATION (D1)                                                                                                                                                     | 371.428                   | 0.333                         | 1.2687                | 1.30                     |
| CATALYST ACTIVATION (D2)                                                                                                                                                     | 372.091                   | 0.997                         | 1.2687                | 1.30                     |
| COIL INLET (H)                                                                                                                                                               | 371.341                   | 0.247                         | 1.2739                | 1.30                     |
| COIL OUTLET (J)                                                                                                                                                              | 371.341                   | 0.247                         | 1.2739                | 1.30                     |
| GAS INLET (A)                                                                                                                                                                | 372.25                    | 1.155                         | 1.2687                | 1.30                     |
| GAS OUTLET (B)                                                                                                                                                               | 371.728                   | 0.633                         | 1.2739                | 1.30                     |
| HANDHOLE (K1)                                                                                                                                                                | 371.816                   | 0.722                         | 1.2687                | 1.30                     |
| HANDHOLE (K2)                                                                                                                                                                | 371.816                   | 0.722                         | 1.2687                | 1.30                     |
| Nozzle Pipe #1 (B)                                                                                                                                                           | 371.51                    | 0.415                         | 1.2739                | 1.30                     |
| PSV (C)                                                                                                                                                                      | 371.443                   | 0.349                         | 1.2687                | 1.30                     |
| TE CONNECTIONS (E1)                                                                                                                                                          | 372.101                   | 1.007                         | 1.2687                | 1.30                     |
| TE CONNECTIONS (E2)                                                                                                                                                          | 372.101                   | 1.007                         | 1.2687                | 1.30                     |
| TE CONNECTIONS (E3)                                                                                                                                                          | 372.101                   | 1.007                         | 1.2687                | 1.30                     |
| TE CONNECTIONS (E4)                                                                                                                                                          | 372.101                   | 1.007                         | 1.2687                | 1.30                     |
| (1) Cylinder #1 limits the UG-99(b) stress ratio.<br>(2) 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.

## Foundation Load Summary

| Skirt Base Ring #1: Total Loading at Base |                     |                                   |                                        |                                       |
|-------------------------------------------|---------------------|-----------------------------------|----------------------------------------|---------------------------------------|
| Load                                      | Vessel Condition    | Base Shear<br>( lb <sub>f</sub> ) | Base Moment<br>( lb <sub>f</sub> -ft ) | Vertical Force<br>( lb <sub>f</sub> ) |
| Weight                                    | Operating, Corroded | 0                                 | 47                                     | 1,858                                 |
| Weight                                    | Operating, New      | 0                                 | 47                                     | 1,858                                 |

Shear and moment values reported above are presented without applicable load combination factors.

| Support Information                            |                  |
|------------------------------------------------|------------------|
| Support Type                                   | Skirt Base Ring  |
| Base Ring Inner Diameter                       | 14.375"          |
| Base Ring Outer Diameter                       | 26.375"          |
| Base Ring Thickness                            | 0.5"             |
| Number of Anchor Bolts                         | 4                |
| Bolt Circle Diameter                           | 24.125"          |
| Bolt Size and Type                             | 3/8" coarse bolt |
| Bolt Hole Clearance                            | 0.375"           |
| Center of Gravity (Distance from Support Base) | 75.7994"         |

## Bill of Materials

| Heads / Covers |                                          |            |               |           |                |     |
|----------------|------------------------------------------|------------|---------------|-----------|----------------|-----|
| Item #         | Type                                     | Material   | Thk [in]      | Dia. [in] | Wt. [lb] (ea.) | Qty |
| H1             | Ellipsoidal Head                         | SA-240 316 | 0.1661 (min.) | 20 OD     | 30.9           | 1   |
| H2             | ASME B16.5/B16.47 Blind NPS 20 Class 300 | A182 F316  | 2.5           | 30.5 OD   | 575            | 1   |
| H3             | ASME B16.5/B16.47 Blind NPS 8 Class 300  | A182 F316  | 1.62          | 15 OD     | 92             | 2   |

| Shells / Skirts |               |                                      |          |           |             |                |     |
|-----------------|---------------|--------------------------------------|----------|-----------|-------------|----------------|-----|
| Item #          | Type          | Material                             | Thk [in] | Dia. [in] | Length [in] | Wt. [lb] (ea.) | Qty |
| S1              | Cylinder      | SA-312 TP316 Wld pipe; NPS 20 Sch 10 | 0.25     | 20 OD     | 68.1        | 306.5          | 1   |
| S2              | Support Skirt | SA-312 TP316 Wld pipe; NPS 20 Sch 10 | 0.25     | 20 OD     | 29.1        | 131            | 1   |

| Base Ring |                               |            |          |             |          |     |
|-----------|-------------------------------|------------|----------|-------------|----------|-----|
| Item #    | Type                          | Material   | Thk [in] | Length [in] | Wt. [lb] | Qty |
| BR1       | Base ring - single base plate | SA-240-316 | 0.5      | 64          | 54.3     | 1   |

| Nozzles / Nozzle Piping / Skirt Opening |               |                              |                        |          |           |             |          |
|-----------------------------------------|---------------|------------------------------|------------------------|----------|-----------|-------------|----------|
| Item #                                  | Type          | Material                     | NPS                    | Thk [in] | Dia. [in] | Length [in] | Wt. [lb] |
| P1                                      | Skirt Opening | SA-312 TP316 Wld & smls pipe | NPS 6 Sch 40 (Std)     | 0.28     | 6.625 OD  | 2.8         | 2.3      |
| Noz1                                    | Nozzle        | SA-312 TP316 Wld pipe        | NPS 3 Sch 40S (Std)    | 0.216    | 3.5 OD    | 3.3         | 2.1      |
| Noz2                                    | Nozzle        | SA-312 TP316 Wld pipe        | NPS 2 Sch 40S (Std)    | 0.154    | 2.375 OD  | 3.6         | 1.1      |
| Noz3                                    | Nozzle        | SA-312 TP316 Wld pipe        | NPS 0.75 Sch 40S (Std) | 0.113    | 1.05 OD   | 11.4        | 1.1      |
| Noz4                                    | Nozzle        | SA-312 TP316 Wld pipe        | NPS 1.5 Sch 40S (Std)  | 0.145    | 1.9 OD    | 14.4        | 3.3      |
| Noz5                                    | Nozzle        | SA-312 TP316 Wld pipe        | NPS 8 Sch 40S (Std)    | 0.322    | 8.625 OD  | 10.8        | 26.2     |
| Noz6                                    | Nozzle        | SA-312 TP316 Wld & smls pipe | NPS 0.75 Sch 40S (Std) | 0.113    | 1.05 OD   | 11.2        | 1.1      |
| Noz7                                    | Nozzle        | SA-312 TP316 Wld & smls pipe | NPS 3 Sch 40S (Std)    | 0.216    | 3.5 OD    | 4.2         | 2.7      |
| P1                                      | Nozzle Pipe   | SA-312 TP316 Wld & smls pipe | NPS 3 Sch 40S (Std)    | 0.216    | 3.5 OD    | 8.4         | 5.4      |

| ASME B16.9 Fittings |                         |            |                     |     |
|---------------------|-------------------------|------------|---------------------|-----|
| Item #              | Type                    | Material   | Size [in]           | Qty |
| EB1                 | B16.9 Elbow Long Radius | SA-403 316 | NPS 3 Sch 40S (Std) | 1   |

| Flanges |                                      |           |       |             |                |     |
|---------|--------------------------------------|-----------|-------|-------------|----------------|-----|
| Item #  | Type                                 | Material  | NPS   | Dia. [in]   | Wt. [lb] (ea.) | Qty |
| AF1     | ASME B16.5 Slip On - Class 300       | A182 F316 | 20    | 30.5 x 20.2 | 315            | 1   |
| AF2     | ASME B16.5 Welding Neck - Class 300  | A182 F316 | 3     | 8.25 x 3.07 | 15             | 2   |
| AF3     | ASME B16.5 Welding Neck - Class 300  | A182 F316 | 2     | 6.5 x 2.07  | 9              | 1   |
| AF4     | ASME B16.5 Socket Welded - Class 300 | A182 F316 | 3/4   | 4.62 x 0.82 | 3              | 2   |
| AF5     | ASME B16.5 Welding Neck - Class 300  | A182 F316 | 1 1/2 | 6.12 x 1.61 | 7              | 4   |
| AF6     | ASME B16.5 Welding Neck - Class 300  | A182 F316 | 8     | 15 x 7.98   | 67             | 2   |
| AF7     | ASME B16.5 Welding Neck - Class 300  | A182 F316 | 3/4   | 4.62 x 0.82 | 3              | 2   |

| Fasteners |                      |                         |             |     |
|-----------|----------------------|-------------------------|-------------|-----|
| Item #    | Description          | Material                | Length [in] | Qty |
| FB1       | 1-1/4" series 8 bolt | SA-193 B7 Bolt <= 2 1/2 | 7           | 24  |
| FB2       | 3/4" coarse bolt     | SA-193 B7 Bolt <= 2 1/2 | 3.5         | 16  |
| FB3       | 5/8" coarse bolt     | SA-193 B7 Bolt <= 2 1/2 | 3           | 8   |
| FB4       | 5/8" coarse bolt     | SA-193 B7 Bolt <= 2 1/2 | 2.5         | 16  |
| FB5       | 3/4" coarse bolt     | SA-193 B7 Bolt <= 2 1/2 | 3           | 16  |
| FB6       | 7/8" coarse bolt     | SA-193 B7 Bolt <= 2 1/2 | 4.8         | 24  |
| SB1       | 3/8" coarse bolt     | Base Ring bolt material | -           | 4   |

All listed flange bolts require associated nuts and washers in accordance with Division 1, UCS-11.

| Plates |            |          |          |            |
|--------|------------|----------|----------|------------|
| Item # | Material   | Thk [in] | Wt. [lb] | Qty [ ft²] |
| Plate1 | SA-240-316 | 0.375    | 6.4      | 0.0526     |

Plate1 - Note: Applies to base ring gussets

**ASME B16.5/16.47 Blind on Flange #1**

| ASME B16.5-2013 Blind                                                                             |                                               |
|---------------------------------------------------------------------------------------------------|-----------------------------------------------|
| <b>Description</b>                                                                                | NPS 20 Class 300 Blind A182 F316              |
| <b>Attached to</b>                                                                                | Flange #1                                     |
| <b>Bolt Material</b>                                                                              | SA-193 B7 Bolt <= 2 1/2 (II-D p. 398, In. 32) |
| <b>Rated MDMT</b>                                                                                 | -55°F                                         |
| <b>Liquid static head</b>                                                                         | 0 psi                                         |
| <b>Consider External Loads on Blind MAWP Rating</b>                                               | Yes                                           |
| <b>MAWP reduction due to external loads</b>                                                       | 0 psi                                         |
| <b>MAWP rating</b>                                                                                | 420 psi @ 840°F                               |
| <b>MAP rating</b>                                                                                 | 720 psi @ 70°F                                |
| <b>Hydrotest rating</b>                                                                           | 1,100 psi @ 70°F                              |
| <b>External fillet weld leg (UW-21)</b>                                                           | 0.35" (0.35" min)                             |
| <b>Internal fillet weld leg (UW-21)</b>                                                           | 0.25" (0.25" min)                             |
| <b>Produced to Fine Grain Practice and Supplied in Heat Treated Condition</b>                     | No                                            |
| <b>Impact Tested</b>                                                                              | No                                            |
| MAWP Reduction Due to External Loads                                                              |                                               |
| $P_m = 16 \cdot M / (\pi \cdot G^3) = 16 \cdot 0 / (\pi \cdot 21.6^3) =$                          | 0 psi                                         |
| $P_r = -4 \cdot W / (\pi \cdot G^2) = -4 \cdot 575 / (\pi \cdot 21.6^2) =$                        | -1.57 psi                                     |
| $MAWP_{reduction} = \max[P_m + P_r, 0] = \max[0 + -1.57, 0] =$                                    | 0 psi                                         |
| $MAWP = MAWP - MAWP_{reduction} - P_s = 420 - 0 - 0 =$                                            | 420 psi                                       |
| UW-21 Flange Welds                                                                                |                                               |
| $X_{min} = \min[1.4 \cdot t_n, g_0] = [1.4 \cdot 0.25, 1.46] =$                                   | 0.35"                                         |
| $External\ Leg_{min} = X_{min} + C_o / 0.7 = 0.35 + 0 / 0.7 =$                                    | 0.35"                                         |
| $Internal\ Leg_{min} = \min[t_n, 0.25" + C_i / 0.7] = \min[0.25, 0.25 + 0 / 0.7] =$               | 0.25"                                         |
| Notes                                                                                             |                                               |
| Blind rated MDMT per UHA-51(d)(1)(a) = -320°F<br>Bolts rated MDMT per Fig UCS-66 note (c) = -55°F |                                               |

## Flange #1

| ASME B16.5-2013 Flange                                                                             |                                                           |
|----------------------------------------------------------------------------------------------------|-----------------------------------------------------------|
| Description                                                                                        | NPS 20 Class 300 SO A182 F316                             |
| Attached to                                                                                        | Top end of Cylinder #1                                    |
| Bolt Material                                                                                      | SA-193 B7 Bolt $\leq 2 \frac{1}{2}$ (II-D p. 398, In. 32) |
| Blind included                                                                                     | Yes                                                       |
| Rated MDMT                                                                                         | -55°F                                                     |
| Liquid static head                                                                                 | 0 psi                                                     |
| Consider External Loads on Flange MAWP Rating                                                      | Yes                                                       |
| MAWP reduction due to external loads                                                               | 0 psi                                                     |
| MAWP rating                                                                                        | 420 psi @ 840°F                                           |
| MAP rating                                                                                         | 720 psi @ 70°F                                            |
| Hydrotest rating                                                                                   | 1,100 psi @ 70°F                                          |
| External fillet weld leg (UW-21)                                                                   | 0.35" (0.35" min)                                         |
| Internal fillet weld leg (UW-21)                                                                   | 0.25" (0.25" min)                                         |
| PWHT performed                                                                                     | No                                                        |
| Produced to Fine Grain Practice and Supplied in Heat Treated Condition                             | No                                                        |
| Impact Tested                                                                                      | No                                                        |
| MAWP Reduction Due to External Loads                                                               |                                                           |
| $P_m = 16 \cdot M / (\pi \cdot G^3) = 16 \cdot 0 / (\pi \cdot 21.6^3) =$                           | 0 psi                                                     |
| $P_r = -4 \cdot W / (\pi \cdot G^2) = -4 \cdot 575 / (\pi \cdot 21.6^2) =$                         | -1.57 psi                                                 |
| $MAWP_{reduction} = \max[P_m + P_r, 0] = \max[0 + -1.57, 0] =$                                     | 0 psi                                                     |
| $MAWP = MAWP - MAWP_{reduction} - P_s = 420 - 0 - 0 =$                                             | 420 psi                                                   |
| UW-21 Flange Welds                                                                                 |                                                           |
| $X_{min} = \min[1.4 \cdot t_n, g_0] = [1.4 \cdot 0.25, 1.46] =$                                    | 0.35"                                                     |
| $External\ Leg_{min} = X_{min} + C_o / 0.7 = 0.35 + 0 / 0.7 =$                                     | 0.35"                                                     |
| $Internal\ Leg_{min} = \min[t_n, 0.25" + C_i / 0.7] = \min[0.25, 0.25 + 0 / 0.7] =$                | 0.25"                                                     |
| Notes                                                                                              |                                                           |
| Flange rated MDMT per UHA-51(d)(1)(a) = -320°F<br>Bolts rated MDMT per Fig UCS-66 note (c) = -55°F |                                                           |



## Cylinder #1

| ASME Section VIII Division 1, 2019 Edition |            |                                           |                           |                        |
|--------------------------------------------|------------|-------------------------------------------|---------------------------|------------------------|
| Component                                  |            | Cylinder                                  |                           |                        |
| Material                                   |            | SA-312 TP316 Wld pipe (II-D p. 76, ln. 7) |                           |                        |
| Pipe NPS and Schedule                      |            | NPS 20 Sch 10                             |                           |                        |
| Impact Tested                              | Normalized | Fine Grain Practice                       | PWHT                      | Maximize MDMT/ No MAWP |
| No                                         | No         | No                                        | No                        | No                     |
|                                            |            | Design Pressure (psi)                     | Design Temperature ( ° F) | Design MDMT ( ° F)     |
| Internal                                   |            | 225                                       | 840                       | -20                    |
| Static Liquid Head                         |            |                                           |                           |                        |
| Condition                                  |            | P <sub>s</sub> (psi)                      | H <sub>s</sub> (in)       | SG                     |
| Test horizontal                            |            | 0.93                                      | 25.75                     | 1                      |
| Dimensions                                 |            |                                           |                           |                        |
| Outer Diameter                             |            | 20"                                       |                           |                        |
| Length                                     |            | 68.125"                                   |                           |                        |
| Pipe Nominal Thickness                     |            | 0.25"                                     |                           |                        |
| Pipe Minimum Thickness <sup>1</sup>        |            | 0.2188"                                   |                           |                        |
| Corrosion                                  | Inner      | 0"                                        |                           |                        |
|                                            | Outer      | 0"                                        |                           |                        |
| Weight and Capacity                        |            |                                           |                           |                        |
|                                            |            | Weight (lb)                               |                           | Capacity (US gal)      |
| New                                        |            | 295.89                                    |                           | 88.08                  |
| Corroded                                   |            | 295.89                                    |                           | 88.08                  |
| Radiography                                |            |                                           |                           |                        |
| Longitudinal seam                          |            | Welded pipe                               |                           |                        |
| Bottom Circumferential seam                |            | Spot UW-11(b) Type 1                      |                           |                        |

<sup>1</sup>Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

| Results Summary                                       |                            |
|-------------------------------------------------------|----------------------------|
| Governing condition                                   | Internal pressure          |
| Minimum thickness per UG-16                           | $0.0625" + 0" = 0.0625"$   |
| Design thickness due to internal pressure (t)         | <a href="#">0.196"</a>     |
| Design thickness due to combined loadings + corrosion | <a href="#">0.0798"</a>    |
| Maximum allowable working pressure (MAWP)             | <a href="#">251.36 psi</a> |
| Rated MDMT                                            | -320 °F                    |

| UHA-51 Material Toughness Requirements                                            |         |
|-----------------------------------------------------------------------------------|---------|
| $t_r = 225 \times 10 / (17,000 \times 0.85 + 0.4 \times 225) =$                   | 0.1547" |
| Stress ratio = $t_r \times E^* / (t_n - c) = 0.1547 \times 0.85 / (0.2188 - 0) =$ | 0.6013  |
| 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 840 °F) Appendix 1-1

$$\begin{aligned}
 t &= P \times R_o / (S \times E + 0.40 \times P) + \text{Corrosion} \\
 &= 225 \times 10 / (13,400 \times 0.85 + 0.40 \times 225) + 0 \\
 &= \a href="#">0.196"
 \end{aligned}$$

#### Maximum allowable working pressure, (at 840 °F) Appendix 1-1

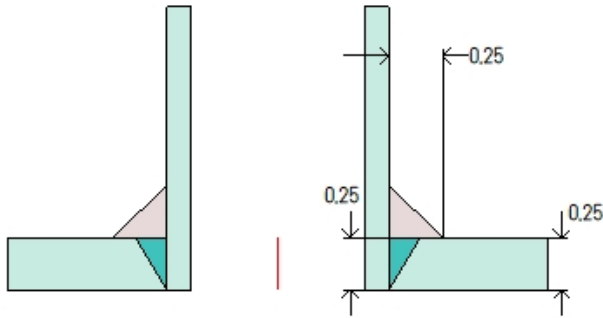
$$\begin{aligned}
 P &= S \times E \times t / (R_o - 0.40 \times t) - P_s \\
 &= 13,400 \times 0.85 \times (0.25 \times 0.875) / (10 - 0.40 \times (0.25 \times 0.875)) - 0 \\
 &= \a href="#">251.36 \text{ psi}
 \end{aligned}$$

| 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 <sub>t</sub>                                      | S <sub>c</sub> |                  |                  |        |                               |                                   |
| Operating, Hot & Corroded                                | 225              | 15,765                                              | 9,142          | 840              | 0                | Weight | 0.0798                        | 0.0795                            |
| Operating, Hot & New                                     | 225              | 15,765                                              | 9,142          | 840              | 0                | Weight | 0.0798                        | 0.0795                            |
| Hot Shut Down, Corroded                                  | 0                | 15,765                                              | 9,142          | 840              | 0                | Weight | 0.0026                        | 0.003                             |
| Hot Shut Down, New                                       | 0                | 15,765                                              | 9,142          | 840              | 0                | Weight | 0.0026                        | 0.003                             |
| Empty, Corroded                                          | 0                | 20,000                                              | 12,395         | 70               | 0                | Weight | 0.0019                        | 0.0022                            |
| Empty, New                                               | 0                | 20,000                                              | 12,395         | 70               | 0                | Weight | 0.0019                        | 0.0022                            |
| Hot Shut Down, Corroded, Weight & Eccentric Moments Only | 0                | 15,765                                              | 9,142          | 840              | 0                | Weight | 0.0026                        | 0.003                             |

| ASME Section VIII Division 1 UG-80(a) Out-of-Roundness                                                                                                                           |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $(D_{\max} - D_{\min})$ shall not exceed 1% of D                                                                                                                                 |
| When the cross section passes through an opening or within 1 I.D. of the opening,<br>$(D_{\max} - D_{\min})$ shall not exceed 1% of D + 2% of the inside diameter of the opening |

## CATALYST ACTIVATION (D1)

### ASME Section VIII Division 1, 2019 Edition



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

#### Location and Orientation

|                                         |             |
|-----------------------------------------|-------------|
| Located on                              | Cylinder #1 |
| Orientation                             | 45°         |
| Nozzle center line offset to datum line | 58"         |
| End of nozzle to shell center           | 16"         |
| Passes through a Category A joint       | No          |

#### Nozzle

|                                                                    |                                           |
|--------------------------------------------------------------------|-------------------------------------------|
| Description                                                        | NPS 0.75 Sch 40S (Std)                    |
| Access opening                                                     | No                                        |
| Material specification                                             | SA-312 TP316 Wld pipe (II-D p. 76, In. 7) |
| Inside diameter, new                                               | 0.824"                                    |
| Pipe nominal wall thickness                                        | 0.113"                                    |
| Pipe minimum wall thickness <sup>1</sup>                           | 0.0989"                                   |
| Corrosion allowance                                                | 0"                                        |
| Projection available outside vessel, L <sub>pr</sub>               | 5.44"                                     |
| Projection available outside vessel to flange face, L <sub>f</sub> | 6"                                        |
| Local vessel minimum thickness                                     | 0.2188"                                   |
| Liquid static head included                                        | 0 psi                                     |

#### Welds

|                                 |       |
|---------------------------------|-------|
| Inner fillet, Leg <sub>41</sub> | 0.25" |
| Nozzle to vessel groove weld    | 0.25" |

#### Radiography

|                          |             |
|--------------------------|-------------|
| <b>Longitudinal seam</b> | Welded pipe |
|--------------------------|-------------|

<sup>1</sup> Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

| ASME B16.5-2013 Flange                                                                             |                                                           |
|----------------------------------------------------------------------------------------------------|-----------------------------------------------------------|
| <b>Description</b>                                                                                 | NPS 0.75 Class 300 SW A182 F316                           |
| <b>Bolt Material</b>                                                                               | SA-193 B7 Bolt $\leq 2 \frac{1}{2}$ (II-D p. 398, ln. 32) |
| <b>Blind included</b>                                                                              | No                                                        |
| <b>Rated MDMT</b>                                                                                  | -55°F                                                     |
| <b>Liquid static head</b>                                                                          | 0 psi                                                     |
| <b>MAWP rating</b>                                                                                 | 420 psi @ 840°F                                           |
| <b>MAP rating</b>                                                                                  | 720 psi @ 70°F                                            |
| <b>Hydrotest rating</b>                                                                            | 1,100 psi @ 70°F                                          |
| <b>External fillet weld leg (UW-21)</b>                                                            | 0.1582" (0.1582" min)                                     |
| <b>PWHT performed</b>                                                                              | No                                                        |
| <b>Produced to Fine Grain Practice and Supplied in Heat Treated Condition</b>                      | No                                                        |
| <b>Impact Tested</b>                                                                               | No                                                        |
| UW-21 Flange Welds                                                                                 |                                                           |
| $X_{\min} = \min[1.4 \cdot t_n, g_0] = [1.4 \cdot 0.113, 0.395] =$                                 | 0.1582"                                                   |
| External Leg <sub>min</sub> = $X_{\min} + C_o / 0.7 = 0.1582 + 0 / 0.7 =$                          | 0.1582"                                                   |
| 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                                |         |
|------------------------------------------------------------------------------|---------|
| $t_r = 225 \cdot 0.412 / (17,000 \cdot 1 - 0.6 \cdot 225) =$                 | 0.0055" |
| Stress ratio = $t_r \cdot E^* / (t_n - c) = 0.0055 \cdot 1 / (0.0989 - 0) =$ | 0.0556  |
| Impact test exempt per UHA-51(g) (coincident ratio = 0.0556)                 |         |
| Rated MDMT =                                                                 | -320°F  |
| Material is exempt from impact testing at the Design MDMT of -20°F.          |         |

## Reinforcement Calculations for Internal Pressure

| UG-37 Area Calculation Summary<br>(in <sup>2</sup> )               |                |                |                |                |                |            | UG-45<br>Summary (in)      |                  |
|--------------------------------------------------------------------|----------------|----------------|----------------|----------------|----------------|------------|----------------------------|------------------|
| For P = 225 psi @ 840 °F                                           |                |                |                |                |                |            | The nozzle passes<br>UG-45 |                  |
| A<br>required                                                      | A<br>available | A <sub>1</sub> | A <sub>2</sub> | A <sub>3</sub> | A <sub>5</sub> | A<br>welds | t <sub>req</sub>           | t <sub>min</sub> |
| This nozzle is exempt from area<br>calculations per UG-36(c)(3)(a) |                |                |                |                |                |            | 0.0989                     | 0.0989           |

| 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<br>throat size (in) | Actual weld<br>throat size (in) | Status                |
| Nozzle to shell fillet (Leg <sub>41</sub> ) | 0.0791                            | 0.175                           | weld size is adequate |

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

## Reinforcement Calculations for MAWP

The vessel wall thickness governs the MAWP of this nozzle.

| UG-37 Area Calculation Summary<br>(in <sup>2</sup> )               |                |                |                |                |                |            | UG-45<br>Summary (in)      |                  |
|--------------------------------------------------------------------|----------------|----------------|----------------|----------------|----------------|------------|----------------------------|------------------|
| For P = 346.55 psi @ 840 °F                                        |                |                |                |                |                |            | The nozzle passes<br>UG-45 |                  |
| A<br>required                                                      | A<br>available | A <sub>1</sub> | A <sub>2</sub> | A <sub>3</sub> | A <sub>5</sub> | A<br>welds | t <sub>req</sub>           | t <sub>min</sub> |
| This nozzle is exempt from area<br>calculations per UG-36(c)(3)(a) |                |                |                |                |                |            | 0.0989                     | 0.0989           |

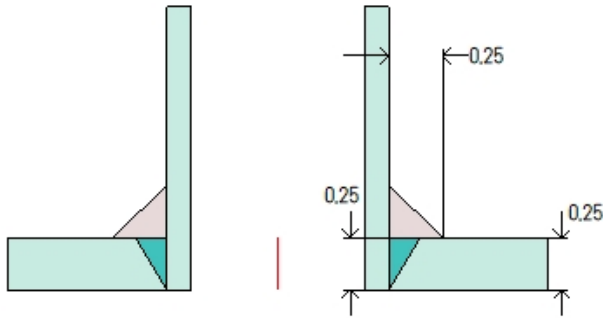
| UG-41 Weld Failure Path Analysis Summary                             |
|----------------------------------------------------------------------|
| The nozzle is exempt from weld strength calculations per UW-15(b)(2) |

| UW-16 Weld Sizing Summary                   |                                |                              |                       |
|---------------------------------------------|--------------------------------|------------------------------|-----------------------|
| Weld description                            | Required weld throat size (in) | Actual weld throat size (in) | Status                |
| Nozzle to shell fillet (Leg <sub>41</sub> ) | 0.0791                         | 0.175                        | weld size is adequate |

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

## CATALYST ACTIVATION (D2)

### ASME Section VIII Division 1, 2019 Edition



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

#### Location and Orientation

|                                         |             |
|-----------------------------------------|-------------|
| Located on                              | Cylinder #1 |
| Orientation                             | 135°        |
| Nozzle center line offset to datum line | 3"          |
| End of nozzle to shell center           | 16"         |
| Passes through a Category A joint       | No          |

#### Nozzle

|                                                                    |                                           |
|--------------------------------------------------------------------|-------------------------------------------|
| Description                                                        | NPS 0.75 Sch 40S (Std)                    |
| Access opening                                                     | No                                        |
| Material specification                                             | SA-312 TP316 Wld pipe (II-D p. 76, In. 7) |
| Inside diameter, new                                               | 0.824"                                    |
| Pipe nominal wall thickness                                        | 0.113"                                    |
| Pipe minimum wall thickness <sup>1</sup>                           | 0.0989"                                   |
| Corrosion allowance                                                | 0"                                        |
| Projection available outside vessel, L <sub>pr</sub>               | 5.44"                                     |
| Projection available outside vessel to flange face, L <sub>f</sub> | 6"                                        |
| Local vessel minimum thickness                                     | 0.2188"                                   |
| User input radial limit of reinforcement                           | 0.75"                                     |
| Liquid static head included                                        | 0 psi                                     |

#### Welds

|                                 |       |
|---------------------------------|-------|
| Inner fillet, Leg <sub>41</sub> | 0.25" |
| Nozzle to vessel groove weld    | 0.25" |



| Radiography       |             |
|-------------------|-------------|
| Longitudinal seam | Welded pipe |

<sup>1</sup>Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

| ASME B16.5-2013 Flange                                                                             |                                               |
|----------------------------------------------------------------------------------------------------|-----------------------------------------------|
| Description                                                                                        | NPS 0.75 Class 300 SW A182 F316               |
| Bolt Material                                                                                      | SA-193 B7 Bolt <= 2 1/2 (II-D p. 398, ln. 32) |
| Blind included                                                                                     | No                                            |
| Rated MDMT                                                                                         | -55°F                                         |
| Liquid static head                                                                                 | 0 psi                                         |
| MAWP rating                                                                                        | 420 psi @ 840°F                               |
| MAP rating                                                                                         | 720 psi @ 70°F                                |
| Hydrotest rating                                                                                   | 1,100 psi @ 70°F                              |
| External fillet weld leg (UW-21)                                                                   | 0.1582" (0.1582" min)                         |
| PWHT performed                                                                                     | No                                            |
| Produced to Fine Grain Practice and Supplied in Heat Treated Condition                             | No                                            |
| Impact Tested                                                                                      | No                                            |
| UW-21 Flange Welds                                                                                 |                                               |
| $X_{min} = \min[1.4 \cdot t_n, g_0] = [1.4 \cdot 0.113, 0.395] =$                                  | 0.1582"                                       |
| External Leg <sub>min</sub> = $X_{min} + C_o / 0.7 = 0.1582 + 0 / 0.7 =$                           | 0.1582"                                       |
| 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                                |         |
|------------------------------------------------------------------------------|---------|
| $t_r = 225 \cdot 0.412 / (17,000 \cdot 1 - 0.6 \cdot 225) =$                 | 0.0055" |
| Stress ratio = $t_r \cdot E^* / (t_n - c) = 0.0055 \cdot 1 / (0.0989 - 0) =$ | 0.0556  |
| Impact test exempt per UHA-51(g) (coincident ratio = 0.0556)                 |         |
| Rated MDMT =                                                                 | -320°F  |
| Material is exempt from impact testing at the Design MDMT of -20°F.          |         |

## Reinforcement Calculations for Internal Pressure

| UG-37 Area Calculation Summary (in <sup>2</sup> )               |             |                |                |                |                |         | UG-45 Summary (in)      |                  |
|-----------------------------------------------------------------|-------------|----------------|----------------|----------------|----------------|---------|-------------------------|------------------|
| For P = 225 psi @ 840 °F                                        |             |                |                |                |                |         | The nozzle passes UG-45 |                  |
| A required                                                      | A available | A <sub>1</sub> | A <sub>2</sub> | A <sub>3</sub> | A <sub>5</sub> | A welds | t <sub>req</sub>        | t <sub>min</sub> |
| This nozzle is exempt from area calculations per UG-36(c)(3)(a) |             |                |                |                |                |         | 0.0989                  | 0.0989           |

| 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 <sub>41</sub> ) | 0.0791                         | 0.175                        | weld size is adequate |

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

## Reinforcement Calculations for MAWP

The vessel wall thickness governs the MAWP of this nozzle.

| UG-37 Area Calculation Summary (in <sup>2</sup> )               |             |                |                |                |                |         | UG-45 Summary (in)      |                  |
|-----------------------------------------------------------------|-------------|----------------|----------------|----------------|----------------|---------|-------------------------|------------------|
| For P = 346.55 psi @ 840 °F                                     |             |                |                |                |                |         | The nozzle passes UG-45 |                  |
| A required                                                      | A available | A <sub>1</sub> | A <sub>2</sub> | A <sub>3</sub> | A <sub>5</sub> | A welds | t <sub>req</sub>        | t <sub>min</sub> |
| This nozzle is exempt from area calculations per UG-36(c)(3)(a) |             |                |                |                |                |         | 0.0989                  | 0.0989           |

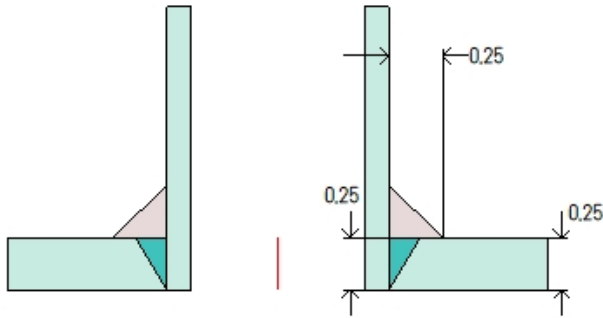
| UG-41 Weld Failure Path Analysis Summary                             |
|----------------------------------------------------------------------|
| The nozzle is exempt from weld strength calculations per UW-15(b)(2) |

| UW-16 Weld Sizing Summary                   |                                |                              |                       |
|---------------------------------------------|--------------------------------|------------------------------|-----------------------|
| Weld description                            | Required weld throat size (in) | Actual weld throat size (in) | Status                |
| Nozzle to shell fillet (Leg <sub>41</sub> ) | 0.0791                         | 0.175                        | weld size is adequate |

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

## COIL INLET (H)

### ASME Section VIII Division 1, 2019 Edition



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

| Location and Orientation                               |                                                  |
|--------------------------------------------------------|--------------------------------------------------|
| Located on                                             | Cylinder #1                                      |
| Orientation                                            | 0°                                               |
| Nozzle center line offset to datum line                | 22"                                              |
| End of nozzle to shell center                          | 16"                                              |
| Offset from center, Lo                                 | -4"                                              |
| Passes through a Category A joint                      | No                                               |
| Nozzle                                                 |                                                  |
| Description                                            | NPS 0.75 Sch 40S (Std)                           |
| Access opening                                         | No                                               |
| Material specification                                 | SA-312 TP316 Wld & smls pipe (II-D p. 76, ln. 5) |
| Inside diameter, new                                   | 0.824"                                           |
| Pipe nominal wall thickness                            | 0.113"                                           |
| Pipe minimum wall thickness <sup>1</sup>               | 0.0989"                                          |
| Corrosion allowance                                    | 0"                                               |
| Opening chord length                                   | 0.9024"                                          |
| Projection available outside vessel, Lpr               | 4.3732"                                          |
| Projection available outside vessel to flange face, Lf | 6.6232"                                          |
| Local vessel minimum thickness                         | 0.2188"                                          |
| Liquid static head included                            | 0 psi                                            |
| Welds                                                  |                                                  |
| Inner fillet, Leg <sub>41</sub>                        | 0.25"                                            |

|                              |                      |
|------------------------------|----------------------|
| Nozzle to vessel groove weld | 0.25"                |
| Radiography                  |                      |
| Longitudinal seam            | Welded pipe          |
| Circumferential seam         | Full UW-11(a) Type 1 |

<sup>1</sup>Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

| ASME B16.5-2013 Flange                                                                             |                                               |
|----------------------------------------------------------------------------------------------------|-----------------------------------------------|
| Description                                                                                        | NPS 0.75 Class 300 WN A182 F316               |
| Bolt Material                                                                                      | SA-193 B7 Bolt <= 2 1/2 (II-D p. 398, ln. 32) |
| Blind included                                                                                     | No                                            |
| Rated MDMT                                                                                         | -55°F                                         |
| Liquid static head                                                                                 | 0 psi                                         |
| MAWP rating                                                                                        | 420 psi @ 840°F                               |
| MAP rating                                                                                         | 720 psi @ 70°F                                |
| Hydrotest rating                                                                                   | 1,100 psi @ 70°F                              |
| PWHT performed                                                                                     | No                                            |
| Produced to Fine Grain Practice and Supplied in Heat Treated Condition                             | No                                            |
| Impact Tested                                                                                      | No                                            |
| Circumferential joint radiography                                                                  | Full UW-11(a) 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                                |         |
|------------------------------------------------------------------------------|---------|
| $t_r = 225 \cdot 0.412 / (17,000 \cdot 1 - 0.6 \cdot 225) =$                 | 0.0055" |
| Stress ratio = $t_r \cdot E^* / (t_n - c) = 0.0055 \cdot 1 / (0.0989 - 0) =$ | 0.0556  |
| Impact test exempt per UHA-51(g) (coincident ratio = 0.0556)                 |         |
| Rated MDMT =                                                                 | -320°F  |
| Material is exempt from impact testing at the Design MDMT of -20°F.          |         |

## Reinforcement Calculations for Internal Pressure

| UG-37 Area Calculation Summary<br>(in <sup>2</sup> )               |                |                |                |                |                |            | UG-45<br>Summary (in)      |                  |
|--------------------------------------------------------------------|----------------|----------------|----------------|----------------|----------------|------------|----------------------------|------------------|
| For P = 225 psi @ 840 °F                                           |                |                |                |                |                |            | The nozzle passes<br>UG-45 |                  |
| A<br>required                                                      | A<br>available | A <sub>1</sub> | A <sub>2</sub> | A <sub>3</sub> | A <sub>5</sub> | A<br>welds | t <sub>req</sub>           | t <sub>min</sub> |
| This nozzle is exempt from area<br>calculations per UG-36(c)(3)(a) |                |                |                |                |                |            | 0.0989                     | 0.0989           |

| 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<br>throat size (in) | Actual weld<br>throat size (in) | Status                |
| Nozzle to shell fillet (Leg <sub>41</sub> ) | 0.0791                            | 0.175                           | weld size is adequate |

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

## Reinforcement Calculations for MAWP

The vessel wall thickness governs the MAWP of this nozzle.

| UG-37 Area Calculation Summary<br>(in <sup>2</sup> )               |                |                |                |                |                |            | UG-45<br>Summary (in)      |                  |
|--------------------------------------------------------------------|----------------|----------------|----------------|----------------|----------------|------------|----------------------------|------------------|
| For P = 346.55 psi @ 840 °F                                        |                |                |                |                |                |            | The nozzle passes<br>UG-45 |                  |
| A<br>required                                                      | A<br>available | A <sub>1</sub> | A <sub>2</sub> | A <sub>3</sub> | A <sub>5</sub> | A<br>welds | t <sub>req</sub>           | t <sub>min</sub> |
| This nozzle is exempt from area<br>calculations per UG-36(c)(3)(a) |                |                |                |                |                |            | 0.0989                     | 0.0989           |

| 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 <sub>41</sub> ) | 0.0791                         | 0.175                        | weld size is adequate |

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

**Reinforcement check in the plane parallel to the longitudinal axis**

**Reinforcement Calculations for Internal Pressure**

| UG-37 Area Calculation Summary (in <sup>2</sup> )               |             |                |                |                |                |         | UG-45 Summary (in)      |                  |
|-----------------------------------------------------------------|-------------|----------------|----------------|----------------|----------------|---------|-------------------------|------------------|
| For P = 225 psi @ 840 °F                                        |             |                |                |                |                |         | The nozzle passes UG-45 |                  |
| A required                                                      | A available | A <sub>1</sub> | A <sub>2</sub> | A <sub>3</sub> | A <sub>5</sub> | A welds | t <sub>req</sub>        | t <sub>min</sub> |
| This nozzle is exempt from area calculations per UG-36(c)(3)(a) |             |                |                |                |                |         | 0.0989                  | 0.0989           |

| 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 <sub>41</sub> ) | 0.0791                         | 0.175                        | weld size is adequate |

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

**Reinforcement check in the plane parallel to the longitudinal axis**

## Reinforcement Calculations for MAWP

The vessel wall thickness governs the MAWP of this nozzle.

| UG-37 Area Calculation Summary<br>(in <sup>2</sup> )               |                |                |                |                |                |            | UG-45<br>Summary (in)      |                  |
|--------------------------------------------------------------------|----------------|----------------|----------------|----------------|----------------|------------|----------------------------|------------------|
| For P = 346.55 psi @ 840 °F                                        |                |                |                |                |                |            | The nozzle passes<br>UG-45 |                  |
| A<br>required                                                      | A<br>available | A <sub>1</sub> | A <sub>2</sub> | A <sub>3</sub> | A <sub>5</sub> | A<br>welds | t <sub>req</sub>           | t <sub>min</sub> |
| This nozzle is exempt from area<br>calculations per UG-36(c)(3)(a) |                |                |                |                |                |            | 0.0989                     | 0.0989           |

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

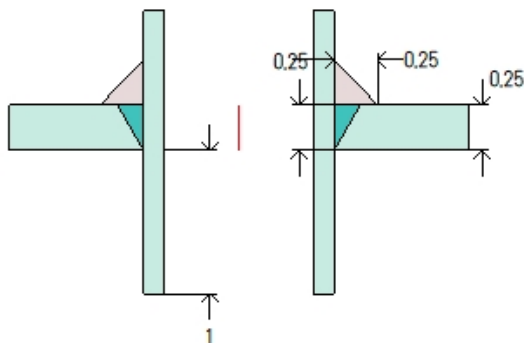
| UW-16 Weld Sizing Summary                   |                                   |                                 |                       |
|---------------------------------------------|-----------------------------------|---------------------------------|-----------------------|
| Weld description                            | Required weld<br>throat size (in) | Actual weld<br>throat size (in) | Status                |
| Nozzle to shell fillet (Leg <sub>41</sub> ) | 0.0791                            | 0.175                           | weld size is adequate |

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



## COIL OUTLET (J)

### ASME Section VIII Division 1, 2019 Edition



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

| Location and Orientation                               |                                                  |
|--------------------------------------------------------|--------------------------------------------------|
| Located on                                             | Cylinder #1                                      |
| Orientation                                            | 0°                                               |
| Nozzle center line offset to datum line                | 40"                                              |
| End of nozzle to shell center                          | 16"                                              |
| Offset from center, Lo                                 | 4"                                               |
| Passes through a Category A joint                      | No                                               |
| Nozzle                                                 |                                                  |
| Description                                            | NPS 0.75 Sch 40S (Std)                           |
| Access opening                                         | No                                               |
| Material specification                                 | SA-312 TP316 Wld & smls pipe (II-D p. 76, ln. 5) |
| Inside diameter, new                                   | 0.824"                                           |
| Pipe nominal wall thickness                            | 0.113"                                           |
| Pipe minimum wall thickness <sup>1</sup>               | 0.0989"                                          |
| Corrosion allowance                                    | 0"                                               |
| Opening chord length                                   | 0.9024"                                          |
| Projection available outside vessel, Lpr               | 4.3732"                                          |
| Internal projection, h <sub>new</sub>                  | 1"                                               |
| Projection available outside vessel to flange face, Lf | 6.6232"                                          |
| Local vessel minimum thickness                         | 0.2188"                                          |
| Liquid static head included                            | 0 psi                                            |
| Welds                                                  |                                                  |

|                                 |                      |
|---------------------------------|----------------------|
| Inner fillet, Leg <sub>41</sub> | 0.25"                |
| Lower fillet, Leg <sub>43</sub> | 0"                   |
| Nozzle to vessel groove weld    | 0.25"                |
| <b>Radiography</b>              |                      |
| Longitudinal seam               | Welded pipe          |
| Circumferential seam            | None UW-11(c) Type 1 |

<sup>1</sup> Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

| <b>ASME B16.5-2013 Flange</b>                                                                      |                                               |
|----------------------------------------------------------------------------------------------------|-----------------------------------------------|
| <b>Description</b>                                                                                 | NPS 0.75 Class 300 WN A182 F316               |
| <b>Bolt Material</b>                                                                               | SA-193 B7 Bolt <= 2 1/2 (II-D p. 398, ln. 32) |
| <b>Blind included</b>                                                                              | No                                            |
| <b>Rated MDMT</b>                                                                                  | -55°F                                         |
| <b>Liquid static head</b>                                                                          | 0 psi                                         |
| <b>MAWP rating</b>                                                                                 | 420 psi @ 840°F                               |
| <b>MAP rating</b>                                                                                  | 720 psi @ 70°F                                |
| <b>Hydrotest rating</b>                                                                            | 1,100 psi @ 70°F                              |
| <b>PWHT performed</b>                                                                              | No                                            |
| <b>Produced to Fine Grain Practice and Supplied in Heat Treated Condition</b>                      | No                                            |
| <b>Impact Tested</b>                                                                               | No                                            |
| <b>Circumferential joint radiography</b>                                                           | None UW-11(c) Type 1                          |
| <b>Notes</b>                                                                                       |                                               |
| Flange rated MDMT per UHA-51(d)(1)(a) = -320°F<br>Bolts rated MDMT per Fig UCS-66 note (c) = -55°F |                                               |

| <b>UHA-51 Material Toughness Requirements Nozzle</b>                                |         |
|-------------------------------------------------------------------------------------|---------|
| $t_r = 225 \cdot 0.412 / (17,000 \cdot 1 - 0.6 \cdot 225) =$                        | 0.0055" |
| $\text{Stress ratio} = t_r \cdot E^* / (t_n - c) = 0.0055 \cdot 1 / (0.0989 - 0) =$ | 0.0556  |
| Impact test exempt per UHA-51(g) (coincident ratio = 0.0556)                        |         |
| Rated MDMT =                                                                        | -320°F  |
| Material is exempt from impact testing at the Design MDMT of -20°F.                 |         |

## Reinforcement Calculations for Internal Pressure

| UG-37 Area Calculation Summary (in <sup>2</sup> )               |             |                |                |                |                |         | UG-45 Summary (in)      |                  |
|-----------------------------------------------------------------|-------------|----------------|----------------|----------------|----------------|---------|-------------------------|------------------|
| For P = 225 psi @ 840 °F                                        |             |                |                |                |                |         | The nozzle passes UG-45 |                  |
| A required                                                      | A available | A <sub>1</sub> | A <sub>2</sub> | A <sub>3</sub> | A <sub>5</sub> | A welds | t <sub>req</sub>        | t <sub>min</sub> |
| This nozzle is exempt from area calculations per UG-36(c)(3)(a) |             |                |                |                |                |         | 0.0989                  | 0.0989           |

| 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 <sub>41</sub> ) | 0.0791                         | 0.175                        | weld size is adequate |

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

## Reinforcement Calculations for MAWP

The vessel wall thickness governs the MAWP of this nozzle.

| UG-37 Area Calculation Summary (in <sup>2</sup> )               |             |                |                |                |                |         | UG-45 Summary (in)      |                  |
|-----------------------------------------------------------------|-------------|----------------|----------------|----------------|----------------|---------|-------------------------|------------------|
| For P = 346.55 psi @ 840 °F                                     |             |                |                |                |                |         | The nozzle passes UG-45 |                  |
| A required                                                      | A available | A <sub>1</sub> | A <sub>2</sub> | A <sub>3</sub> | A <sub>5</sub> | A welds | t <sub>req</sub>        | t <sub>min</sub> |
| This nozzle is exempt from area calculations per UG-36(c)(3)(a) |             |                |                |                |                |         | 0.0989                  | 0.0989           |

| 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 <sub>41</sub> ) | 0.0791                         | 0.175                        | weld size is adequate |

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

**Reinforcement check in the plane parallel to the longitudinal axis**

**Reinforcement Calculations for Internal Pressure**

| UG-37 Area Calculation Summary (in <sup>2</sup> )               |             |                |                |                |                |         | UG-45 Summary (in)      |                  |
|-----------------------------------------------------------------|-------------|----------------|----------------|----------------|----------------|---------|-------------------------|------------------|
| For P = 225 psi @ 840 °F                                        |             |                |                |                |                |         | The nozzle passes UG-45 |                  |
| A required                                                      | A available | A <sub>1</sub> | A <sub>2</sub> | A <sub>3</sub> | A <sub>5</sub> | A welds | t <sub>req</sub>        | t <sub>min</sub> |
| This nozzle is exempt from area calculations per UG-36(c)(3)(a) |             |                |                |                |                |         | 0.0989                  | 0.0989           |

| 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 <sub>41</sub> ) | 0.0791                         | 0.175                        | weld size is adequate |

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

**Reinforcement check in the plane parallel to the longitudinal axis**

## Reinforcement Calculations for MAWP

The vessel wall thickness governs the MAWP of this nozzle.

| UG-37 Area Calculation Summary<br>(in <sup>2</sup> )               |                |                |                |                |                |            | UG-45<br>Summary (in)      |                  |
|--------------------------------------------------------------------|----------------|----------------|----------------|----------------|----------------|------------|----------------------------|------------------|
| For P = 346.55 psi @ 840 °F                                        |                |                |                |                |                |            | The nozzle passes<br>UG-45 |                  |
| A<br>required                                                      | A<br>available | A <sub>1</sub> | A <sub>2</sub> | A <sub>3</sub> | A <sub>5</sub> | A<br>welds | t <sub>req</sub>           | t <sub>min</sub> |
| This nozzle is exempt from area<br>calculations per UG-36(c)(3)(a) |                |                |                |                |                |            | 0.0989                     | 0.0989           |

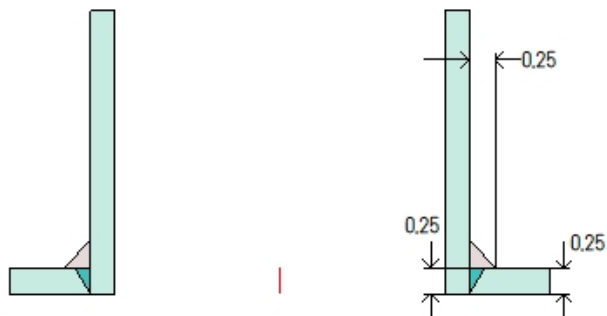
| UG-41 Weld Failure Path Analysis Summary                             |  |
|----------------------------------------------------------------------|--|
| The nozzle is exempt from weld strength calculations per UW-15(b)(2) |  |

| UW-16 Weld Sizing Summary                   |                                   |                                 |                       |
|---------------------------------------------|-----------------------------------|---------------------------------|-----------------------|
| Weld description                            | Required weld<br>throat size (in) | Actual weld<br>throat size (in) | Status                |
| Nozzle to shell fillet (Leg <sub>41</sub> ) | 0.0791                            | 0.175                           | weld size is adequate |

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

## GAS INLET (A)

### ASME Section VIII Division 1, 2019 Edition



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

#### Location and Orientation

|                                         |             |
|-----------------------------------------|-------------|
| Located on                              | Cylinder #1 |
| Orientation                             | 180°        |
| Nozzle center line offset to datum line | 58"         |
| End of nozzle to shell center           | 16"         |
| Passes through a Category A joint       | No          |

#### Nozzle

|                                                                    |                                           |
|--------------------------------------------------------------------|-------------------------------------------|
| Description                                                        | NPS 3 Sch 40S (Std)                       |
| Access opening                                                     | No                                        |
| Material specification                                             | SA-312 TP316 Wld pipe (II-D p. 76, In. 7) |
| Inside diameter, new                                               | 3.068"                                    |
| Pipe nominal wall thickness                                        | 0.216"                                    |
| Pipe minimum wall thickness <sup>1</sup>                           | 0.189"                                    |
| Corrosion allowance                                                | 0"                                        |
| Projection available outside vessel, L <sub>pr</sub>               | 2.88"                                     |
| Projection available outside vessel to flange face, L <sub>f</sub> | 6"                                        |
| Local vessel minimum thickness                                     | 0.2188"                                   |
| Liquid static head included                                        | 0 psi                                     |

#### Welds

|                                 |       |
|---------------------------------|-------|
| Inner fillet, Leg <sub>41</sub> | 0.25" |
| Nozzle to vessel groove weld    | 0.25" |

#### Radiography

|                             |                      |
|-----------------------------|----------------------|
| <b>Longitudinal seam</b>    | Welded pipe          |
| <b>Circumferential seam</b> | None UW-11(c) Type 1 |

<sup>1</sup>Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

| ASME B16.5-2013 Flange                                                                               |                                                           |
|------------------------------------------------------------------------------------------------------|-----------------------------------------------------------|
| <b>Description</b>                                                                                   | NPS 3 Class 300 WN A182 F316                              |
| <b>Bolt Material</b>                                                                                 | SA-193 B7 Bolt $\leq 2 \frac{1}{2}$ (II-D p. 398, ln. 32) |
| <b>Blind included</b>                                                                                | No                                                        |
| <b>Rated MDMT</b>                                                                                    | -55 °F                                                    |
| <b>Liquid static head</b>                                                                            | 0 psi                                                     |
| <b>MAWP rating</b>                                                                                   | 420 psi @ 840 °F                                          |
| <b>MAP rating</b>                                                                                    | 720 psi @ 70 °F                                           |
| <b>Hydrotest rating</b>                                                                              | 1,100 psi @ 70 °F                                         |
| <b>PWHT performed</b>                                                                                | No                                                        |
| <b>Produced to Fine Grain Practice and Supplied in Heat Treated Condition</b>                        | No                                                        |
| <b>Impact Tested</b>                                                                                 | No                                                        |
| <b>Circumferential joint radiography</b>                                                             | 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                        |         |
|----------------------------------------------------------------------|---------|
| $t_r = 225 * 1.534 / (17,000 * 1 - 0.6 * 225) =$                     | 0.0205" |
| Stress ratio = $t_r * E^* / (t_n - c) = 0.0205 * 1 / (0.189 - 0) =$  | 0.1083  |
| Impact test exempt per UHA-51(g) (coincident ratio = 0.1083)         |         |
| Rated MDMT =                                                         | -320 °F |
| Material is exempt from impact testing at the Design MDMT of -20 °F. |         |

## Reinforcement Calculations for Internal Pressure

| UG-37 Area Calculation Summary (in <sup>2</sup> )               |             |                |                |                |                |         | UG-45 Summary (in)      |                  |
|-----------------------------------------------------------------|-------------|----------------|----------------|----------------|----------------|---------|-------------------------|------------------|
| For P = 225 psi @ 840 °F                                        |             |                |                |                |                |         | The nozzle passes UG-45 |                  |
| A required                                                      | A available | A <sub>1</sub> | A <sub>2</sub> | A <sub>3</sub> | A <sub>5</sub> | A welds | t <sub>req</sub>        | t <sub>min</sub> |
| This nozzle is exempt from area calculations per UG-36(c)(3)(a) |             |                |                |                |                |         | 0.1425                  | 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 throat size (in) | Actual weld throat size (in) | Status                |
| Nozzle to shell fillet (Leg <sub>41</sub> ) | 0.1512                         | 0.175                        | weld size is adequate |

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

## Reinforcement Calculations for MAWP

The vessel wall thickness governs the MAWP of this nozzle.

| UG-37 Area Calculation Summary (in <sup>2</sup> )               |             |                |                |                |                |         | UG-45 Summary (in)      |                  |
|-----------------------------------------------------------------|-------------|----------------|----------------|----------------|----------------|---------|-------------------------|------------------|
| For P = 346.55 psi @ 840 °F                                     |             |                |                |                |                |         | The nozzle passes UG-45 |                  |
| A required                                                      | A available | A <sub>1</sub> | A <sub>2</sub> | A <sub>3</sub> | A <sub>5</sub> | A welds | t <sub>req</sub>        | t <sub>min</sub> |
| 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) |

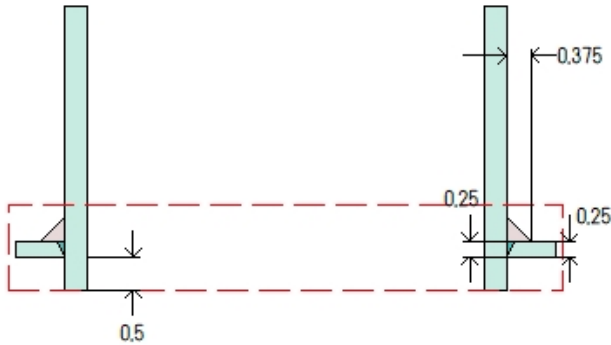


| UW-16 Weld Sizing Summary                   |                                |                              |                       |
|---------------------------------------------|--------------------------------|------------------------------|-----------------------|
| Weld description                            | Required weld throat size (in) | Actual weld throat size (in) | Status                |
| Nozzle to shell fillet (Leg <sub>41</sub> ) | 0.1512                         | 0.175                        | weld size is adequate |

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

## HANDHOLE (K1)

### ASME Section VIII Division 1, 2019 Edition



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

#### Location and Orientation

|                                         |             |
|-----------------------------------------|-------------|
| Located on                              | Cylinder #1 |
| Orientation                             | 270°        |
| Nozzle center line offset to datum line | 20.5"       |
| End of nozzle to shell center           | 18"         |
| Passes through a Category A joint       | No          |

#### Nozzle

|                                                                    |                                           |
|--------------------------------------------------------------------|-------------------------------------------|
| Description                                                        | NPS 8 Sch 40S (Std)                       |
| Access opening                                                     | Yes                                       |
| Material specification                                             | SA-312 TP316 Wld pipe (II-D p. 76, In. 7) |
| Inside diameter, new                                               | 7.981"                                    |
| Pipe nominal wall thickness                                        | 0.322"                                    |
| Pipe minimum wall thickness <sup>1</sup>                           | 0.2818"                                   |
| Corrosion allowance                                                | 0"                                        |
| Projection available outside vessel, L <sub>pr</sub>               | 3.62"                                     |
| Internal projection, h <sub>new</sub>                              | 0.5"                                      |
| Projection available outside vessel to flange face, L <sub>f</sub> | 8"                                        |
| Local vessel minimum thickness                                     | 0.2188"                                   |
| User input radial limit of reinforcement                           | 7"                                        |
| Liquid static head included                                        | 0 psi                                     |

#### Welds

|                                 |        |
|---------------------------------|--------|
| Inner fillet, Leg <sub>41</sub> | 0.375" |
|---------------------------------|--------|

|                                 |                      |
|---------------------------------|----------------------|
| Lower fillet, Leg <sub>43</sub> | 0"                   |
| Nozzle to vessel groove weld    | 0.25"                |
| <b>Radiography</b>              |                      |
| Longitudinal seam               | Welded pipe          |
| Circumferential seam            | Full UW-11(a) Type 1 |

<sup>1</sup> Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

| <b>ASME B16.5-2013 Flange</b>                                                                        |                                               |
|------------------------------------------------------------------------------------------------------|-----------------------------------------------|
| Description                                                                                          | NPS 8 Class 300 WN A182 F316                  |
| Bolt Material                                                                                        | SA-193 B7 Bolt <= 2 1/2 (II-D p. 398, ln. 32) |
| Blind included                                                                                       | Yes                                           |
| Rated MDMT                                                                                           | -55 °F                                        |
| Liquid static head                                                                                   | 0 psi                                         |
| MAWP rating                                                                                          | 420 psi @ 840 °F                              |
| MAP rating                                                                                           | 720 psi @ 70 °F                               |
| Hydrotest rating                                                                                     | 1,100 psi @ 70 °F                             |
| PWHT performed                                                                                       | No                                            |
| Produced to Fine Grain Practice and Supplied in Heat Treated Condition                               | No                                            |
| Impact Tested                                                                                        | No                                            |
| Circumferential joint radiography                                                                    | Full UW-11(a) Type 1                          |
| <b>Notes</b>                                                                                         |                                               |
| Flange rated MDMT per UHA-51(d)(1)(a) = -320 °F<br>Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F |                                               |

| <b>UHA-51 Material Toughness Requirements Nozzle</b>                                |         |
|-------------------------------------------------------------------------------------|---------|
| $t_r = 225 \cdot 10 / (17,000 \cdot 1 + 0.4 \cdot 225) =$                           | 0.1317" |
| $\text{Stress ratio} = t_r \cdot E^* / (t_n - c) = 0.1317 \cdot 1 / (0.2188 - 0) =$ | 0.6017  |
| 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 Internal Pressure

| UG-37 Area Calculation Summary (in <sup>2</sup> )                |             |                |                |                |                |         | UG-45 Summary (in)      |                  |
|------------------------------------------------------------------|-------------|----------------|----------------|----------------|----------------|---------|-------------------------|------------------|
| For P = 225 psi @ 840 °F<br>The opening is adequately reinforced |             |                |                |                |                |         | The nozzle passes UG-45 |                  |
| A required                                                       | A available | A <sub>1</sub> | A <sub>2</sub> | A <sub>3</sub> | A <sub>5</sub> | A welds | t <sub>req</sub>        | t <sub>min</sub> |
| 1.1373                                                           | 1.2109      | 0.4592         | 0.2891         | 0.322          | --             | 0.1406  | 0.0677                  | 0.2818           |

| 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 <sub>41</sub> ) | 0.1532                         | 0.2625                       | weld size is adequate |

## Reinforcement Calculations for MAWP

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

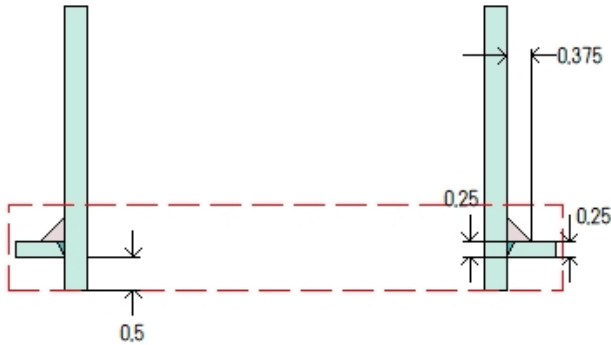
| UG-37 Area Calculation Summary (in <sup>2</sup> )                   |             |                |                |                |                |         | UG-45 Summary (in)      |                  |
|---------------------------------------------------------------------|-------------|----------------|----------------|----------------|----------------|---------|-------------------------|------------------|
| For P = 233.11 psi @ 840 °F<br>The opening is adequately reinforced |             |                |                |                |                |         | The nozzle passes UG-45 |                  |
| A required                                                          | A available | A <sub>1</sub> | A <sub>2</sub> | A <sub>3</sub> | A <sub>5</sub> | A welds | t <sub>req</sub>        | t <sub>min</sub> |
| 1.178                                                               | 1.178       | 0.4286         | 0.2868         | 0.322          | --             | 0.1406  | 0.0702                  | 0.2818           |

| 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 <sub>41</sub> ) | 0.1532                         | 0.2625                       | weld size is adequate |

## HANDHOLE (K2)

### ASME Section VIII Division 1, 2019 Edition



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

#### Location and Orientation

|                                         |             |
|-----------------------------------------|-------------|
| Located on                              | Cylinder #1 |
| Orientation                             | 90°         |
| Nozzle center line offset to datum line | 41.5"       |
| End of nozzle to shell center           | 18"         |
| Passes through a Category A joint       | No          |

#### Nozzle

|                                                                    |                                           |
|--------------------------------------------------------------------|-------------------------------------------|
| Description                                                        | NPS 8 Sch 40S (Std)                       |
| Access opening                                                     | Yes                                       |
| Material specification                                             | SA-312 TP316 Wld pipe (II-D p. 76, In. 7) |
| Inside diameter, new                                               | 7.981"                                    |
| Pipe nominal wall thickness                                        | 0.322"                                    |
| Pipe minimum wall thickness <sup>1</sup>                           | 0.2818"                                   |
| Corrosion allowance                                                | 0"                                        |
| Projection available outside vessel, L <sub>pr</sub>               | 3.62"                                     |
| Internal projection, h <sub>new</sub>                              | 0.5"                                      |
| Projection available outside vessel to flange face, L <sub>f</sub> | 8"                                        |
| Local vessel minimum thickness                                     | 0.2188"                                   |
| User input radial limit of reinforcement                           | 7"                                        |
| Liquid static head included                                        | 0 psi                                     |

#### Welds

|                                 |        |
|---------------------------------|--------|
| Inner fillet, Leg <sub>41</sub> | 0.375" |
|---------------------------------|--------|

|                                 |                      |
|---------------------------------|----------------------|
| Lower fillet, Leg <sub>43</sub> | 0"                   |
| Nozzle to vessel groove weld    | 0.25"                |
| <b>Radiography</b>              |                      |
| Longitudinal seam               | Welded pipe          |
| Circumferential seam            | Full UW-11(a) Type 1 |

<sup>1</sup> Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

| <b>ASME B16.5-2013 Flange</b>                                                                        |                                               |
|------------------------------------------------------------------------------------------------------|-----------------------------------------------|
| Description                                                                                          | NPS 8 Class 300 WN A182 F316                  |
| Bolt Material                                                                                        | SA-193 B7 Bolt <= 2 1/2 (II-D p. 398, ln. 32) |
| Blind included                                                                                       | Yes                                           |
| Rated MDMT                                                                                           | -55 °F                                        |
| Liquid static head                                                                                   | 0 psi                                         |
| MAWP rating                                                                                          | 420 psi @ 840 °F                              |
| MAP rating                                                                                           | 720 psi @ 70 °F                               |
| Hydrotest rating                                                                                     | 1,100 psi @ 70 °F                             |
| PWHT performed                                                                                       | No                                            |
| Produced to Fine Grain Practice and Supplied in Heat Treated Condition                               | No                                            |
| Impact Tested                                                                                        | No                                            |
| Circumferential joint radiography                                                                    | Full UW-11(a) Type 1                          |
| <b>Notes</b>                                                                                         |                                               |
| Flange rated MDMT per UHA-51(d)(1)(a) = -320 °F<br>Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F |                                               |

| <b>UHA-51 Material Toughness Requirements Nozzle</b>                                |         |
|-------------------------------------------------------------------------------------|---------|
| $t_r = 225 \cdot 10 / (17,000 \cdot 1 + 0.4 \cdot 225) =$                           | 0.1317" |
| $\text{Stress ratio} = t_r \cdot E^* / (t_n - c) = 0.1317 \cdot 1 / (0.2188 - 0) =$ | 0.6017  |
| 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 Internal Pressure

| UG-37 Area Calculation Summary (in <sup>2</sup> )                |             |                |                |                |                |         | UG-45 Summary (in)      |                  |
|------------------------------------------------------------------|-------------|----------------|----------------|----------------|----------------|---------|-------------------------|------------------|
| For P = 225 psi @ 840 °F<br>The opening is adequately reinforced |             |                |                |                |                |         | The nozzle passes UG-45 |                  |
| A required                                                       | A available | A <sub>1</sub> | A <sub>2</sub> | A <sub>3</sub> | A <sub>5</sub> | A welds | t <sub>req</sub>        | t <sub>min</sub> |
| 1.1373                                                           | 1.2109      | 0.4592         | 0.2891         | 0.322          | --             | 0.1406  | 0.0677                  | 0.2818           |

| 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 <sub>41</sub> ) | 0.1532                         | 0.2625                       | weld size is adequate |

## Reinforcement Calculations for MAWP

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

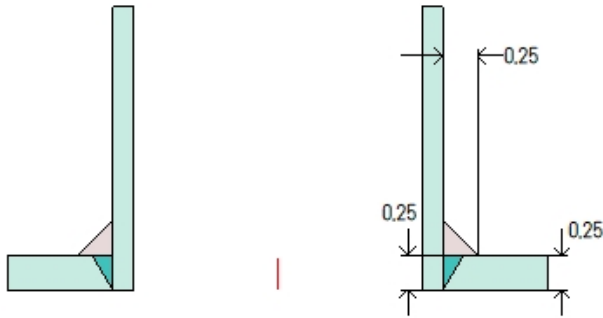
| UG-37 Area Calculation Summary (in <sup>2</sup> )                   |             |                |                |                |                |         | UG-45 Summary (in)      |                  |
|---------------------------------------------------------------------|-------------|----------------|----------------|----------------|----------------|---------|-------------------------|------------------|
| For P = 233.11 psi @ 840 °F<br>The opening is adequately reinforced |             |                |                |                |                |         | The nozzle passes UG-45 |                  |
| A required                                                          | A available | A <sub>1</sub> | A <sub>2</sub> | A <sub>3</sub> | A <sub>5</sub> | A welds | t <sub>req</sub>        | t <sub>min</sub> |
| 1.178                                                               | 1.178       | 0.4286         | 0.2868         | 0.322          | --             | 0.1406  | 0.0702                  | 0.2818           |

| 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 <sub>41</sub> ) | 0.1532                         | 0.2625                       | weld size is adequate |

PSV (C)

ASME Section VIII Division 1, 2019 Edition



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

Location and Orientation

|                                         |             |
|-----------------------------------------|-------------|
| Located on                              | Cylinder #1 |
| Orientation                             | 315°        |
| Nozzle center line offset to datum line | 58"         |
| End of nozzle to shell center           | 16"         |
| Passes through a Category A joint       | No          |

Nozzle

|                                                                    |                                           |
|--------------------------------------------------------------------|-------------------------------------------|
| Description                                                        | NPS 2 Sch 40S (Std)                       |
| Access opening                                                     | No                                        |
| Material specification                                             | SA-312 TP316 Wld pipe (II-D p. 76, In. 7) |
| Inside diameter, new                                               | 2.067"                                    |
| Pipe nominal wall thickness                                        | 0.154"                                    |
| Pipe minimum wall thickness <sup>1</sup>                           | 0.1348"                                   |
| Corrosion allowance                                                | 0"                                        |
| Projection available outside vessel, L <sub>pr</sub>               | 3.25"                                     |
| Projection available outside vessel to flange face, L <sub>f</sub> | 6"                                        |
| Local vessel minimum thickness                                     | 0.2188"                                   |
| Liquid static head included                                        | 0 psi                                     |

Welds

|                                 |       |
|---------------------------------|-------|
| Inner fillet, Leg <sub>41</sub> | 0.25" |
| Nozzle to vessel groove weld    | 0.25" |

Radiography



|                             |                      |
|-----------------------------|----------------------|
| <b>Longitudinal seam</b>    | Welded pipe          |
| <b>Circumferential seam</b> | None UW-11(c) Type 1 |

<sup>1</sup>Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

| ASME B16.5-2013 Flange                                                                               |                                                           |
|------------------------------------------------------------------------------------------------------|-----------------------------------------------------------|
| <b>Description</b>                                                                                   | NPS 2 Class 300 WN A182 F316                              |
| <b>Bolt Material</b>                                                                                 | SA-193 B7 Bolt $\leq 2 \frac{1}{2}$ (II-D p. 398, ln. 32) |
| <b>Blind included</b>                                                                                | No                                                        |
| <b>Rated MDMT</b>                                                                                    | -55 °F                                                    |
| <b>Liquid static head</b>                                                                            | 0 psi                                                     |
| <b>MAWP rating</b>                                                                                   | 420 psi @ 840 °F                                          |
| <b>MAP rating</b>                                                                                    | 720 psi @ 70 °F                                           |
| <b>Hydrotest rating</b>                                                                              | 1,100 psi @ 70 °F                                         |
| <b>PWHT performed</b>                                                                                | No                                                        |
| <b>Produced to Fine Grain Practice and Supplied in Heat Treated Condition</b>                        | No                                                        |
| <b>Impact Tested</b>                                                                                 | No                                                        |
| <b>Circumferential joint radiography</b>                                                             | 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                                |         |
|------------------------------------------------------------------------------|---------|
| $t_r = 225 \cdot 1.0335 / (17,000 \cdot 1 - 0.6 \cdot 225) =$                | 0.0138" |
| Stress ratio = $t_r \cdot E^* / (t_n - c) = 0.0138 \cdot 1 / (0.1348 - 0) =$ | 0.1023  |
| Impact test exempt per UHA-51(g) (coincident ratio = 0.1023)                 |         |
| Rated MDMT =                                                                 | -320 °F |
| Material is exempt from impact testing at the Design MDMT of -20 °F.         |         |

## Reinforcement Calculations for Internal Pressure

| UG-37 Area Calculation Summary (in <sup>2</sup> )               |             |                |                |                |                |         | UG-45 Summary (in)      |                  |
|-----------------------------------------------------------------|-------------|----------------|----------------|----------------|----------------|---------|-------------------------|------------------|
| For P = 225 psi @ 840 °F                                        |             |                |                |                |                |         | The nozzle passes UG-45 |                  |
| A required                                                      | A available | A <sub>1</sub> | A <sub>2</sub> | A <sub>3</sub> | A <sub>5</sub> | A welds | t <sub>req</sub>        | t <sub>min</sub> |
| 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 <sub>41</sub> ) | 0.1078                         | 0.175                        | weld size is adequate |

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

## Reinforcement Calculations for MAWP

The vessel wall thickness governs the MAWP of this nozzle.

| UG-37 Area Calculation Summary (in <sup>2</sup> )               |             |                |                |                |                |         | UG-45 Summary (in)      |                  |
|-----------------------------------------------------------------|-------------|----------------|----------------|----------------|----------------|---------|-------------------------|------------------|
| For P = 346.55 psi @ 840 °F                                     |             |                |                |                |                |         | The nozzle passes UG-45 |                  |
| A required                                                      | A available | A <sub>1</sub> | A <sub>2</sub> | A <sub>3</sub> | A <sub>5</sub> | A welds | t <sub>req</sub>        | t <sub>min</sub> |
| This nozzle is exempt from area calculations per UG-36(c)(3)(a) |             |                |                |                |                |         | 0.1348                  | 0.1348           |

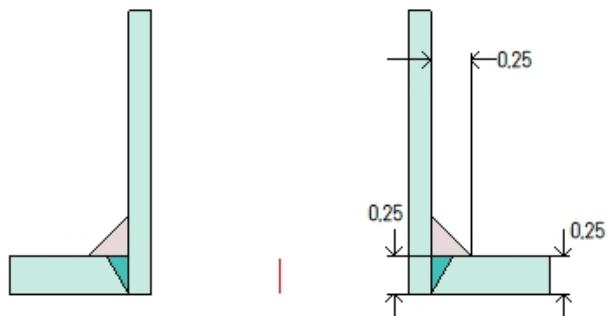
| UG-41 Weld Failure Path Analysis Summary                             |
|----------------------------------------------------------------------|
| The nozzle is exempt from weld strength calculations per UW-15(b)(2) |

| UW-16 Weld Sizing Summary                   |                                |                              |                       |
|---------------------------------------------|--------------------------------|------------------------------|-----------------------|
| Weld description                            | Required weld throat size (in) | Actual weld throat size (in) | Status                |
| Nozzle to shell fillet (Leg <sub>41</sub> ) | 0.1078                         | 0.175                        | weld size is adequate |

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

## TE CONNECTIONS (E1)

### ASME Section VIII Division 1, 2019 Edition



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

#### Location and Orientation

|                                         |             |
|-----------------------------------------|-------------|
| Located on                              | Cylinder #1 |
| Orientation                             | 225°        |
| Nozzle center line offset to datum line | 44"         |
| End of nozzle to shell center           | 16"         |
| Passes through a Category A joint       | No          |

#### Nozzle

|                                                                    |                                           |
|--------------------------------------------------------------------|-------------------------------------------|
| Description                                                        | NPS 1.5 Sch 40S (Std)                     |
| Access opening                                                     | No                                        |
| Material specification                                             | SA-312 TP316 Wld pipe (II-D p. 76, In. 7) |
| Inside diameter, new                                               | 1.61"                                     |
| Pipe nominal wall thickness                                        | 0.145"                                    |
| Pipe minimum wall thickness <sup>1</sup>                           | 0.1269"                                   |
| Corrosion allowance                                                | 0"                                        |
| Projection available outside vessel, L <sub>pr</sub>               | 3.31"                                     |
| Projection available outside vessel to flange face, L <sub>f</sub> | 6"                                        |
| Local vessel minimum thickness                                     | 0.2188"                                   |
| Liquid static head included                                        | 0 psi                                     |

#### Welds

|                                 |       |
|---------------------------------|-------|
| Inner fillet, Leg <sub>41</sub> | 0.25" |
| Nozzle to vessel groove weld    | 0.25" |

#### Radiography

|                             |                      |
|-----------------------------|----------------------|
| <b>Longitudinal seam</b>    | Welded pipe          |
| <b>Circumferential seam</b> | Full UW-11(a) Type 1 |

<sup>1</sup>Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

| ASME B16.5-2013 Flange                                                                               |                                                           |
|------------------------------------------------------------------------------------------------------|-----------------------------------------------------------|
| <b>Description</b>                                                                                   | NPS 1.5 Class 300 WN A182 F316                            |
| <b>Bolt Material</b>                                                                                 | SA-193 B7 Bolt $\leq 2 \frac{1}{2}$ (II-D p. 398, ln. 32) |
| <b>Blind included</b>                                                                                | No                                                        |
| <b>Rated MDMT</b>                                                                                    | -55 °F                                                    |
| <b>Liquid static head</b>                                                                            | 0 psi                                                     |
| <b>MAWP rating</b>                                                                                   | 420 psi @ 840 °F                                          |
| <b>MAP rating</b>                                                                                    | 720 psi @ 70 °F                                           |
| <b>Hydrotest rating</b>                                                                              | 1,100 psi @ 70 °F                                         |
| <b>PWHT performed</b>                                                                                | No                                                        |
| <b>Produced to Fine Grain Practice and Supplied in Heat Treated Condition</b>                        | No                                                        |
| <b>Impact Tested</b>                                                                                 | No                                                        |
| <b>Circumferential joint radiography</b>                                                             | Full UW-11(a) 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                                |         |
|------------------------------------------------------------------------------|---------|
| $t_r = 225 \cdot 0.805 / (17,000 \cdot 1 - 0.6 \cdot 225) =$                 | 0.0107" |
| Stress ratio = $t_r \cdot E^* / (t_n - c) = 0.0107 \cdot 1 / (0.1269 - 0) =$ | 0.0847  |
| Impact test exempt per UHA-51(g) (coincident ratio = 0.0847)                 |         |
| Rated MDMT =                                                                 | -320 °F |
| Material is exempt from impact testing at the Design MDMT of -20 °F.         |         |

## Reinforcement Calculations for Internal Pressure

| UG-37 Area Calculation Summary (in <sup>2</sup> )               |             |                |                |                |                |         | UG-45 Summary (in)      |                  |
|-----------------------------------------------------------------|-------------|----------------|----------------|----------------|----------------|---------|-------------------------|------------------|
| For P = 225 psi @ 840 °F                                        |             |                |                |                |                |         | The nozzle passes UG-45 |                  |
| A required                                                      | A available | A <sub>1</sub> | A <sub>2</sub> | A <sub>3</sub> | A <sub>5</sub> | A welds | t <sub>req</sub>        | t <sub>min</sub> |
| 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 <sub>41</sub> ) | 0.1015                         | 0.175                        | weld size is adequate |

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

## Reinforcement Calculations for MAWP

The vessel wall thickness governs the MAWP of this nozzle.

| UG-37 Area Calculation Summary (in <sup>2</sup> )               |             |                |                |                |                |         | UG-45 Summary (in)      |                  |
|-----------------------------------------------------------------|-------------|----------------|----------------|----------------|----------------|---------|-------------------------|------------------|
| For P = 346.55 psi @ 840 °F                                     |             |                |                |                |                |         | The nozzle passes UG-45 |                  |
| A required                                                      | A available | A <sub>1</sub> | A <sub>2</sub> | A <sub>3</sub> | A <sub>5</sub> | A welds | t <sub>req</sub>        | t <sub>min</sub> |
| This nozzle is exempt from area calculations per UG-36(c)(3)(a) |             |                |                |                |                |         | 0.1269                  | 0.1269           |

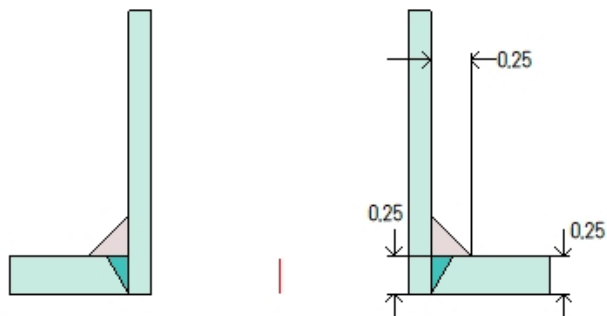
| UG-41 Weld Failure Path Analysis Summary                             |
|----------------------------------------------------------------------|
| The nozzle is exempt from weld strength calculations per UW-15(b)(2) |

| UW-16 Weld Sizing Summary                   |                                |                              |                       |
|---------------------------------------------|--------------------------------|------------------------------|-----------------------|
| Weld description                            | Required weld throat size (in) | Actual weld throat size (in) | Status                |
| Nozzle to shell fillet (Leg <sub>41</sub> ) | 0.1015                         | 0.175                        | weld size is adequate |

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

## TE CONNECTIONS (E2)

### ASME Section VIII Division 1, 2019 Edition



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

#### Location and Orientation

|                                         |             |
|-----------------------------------------|-------------|
| Located on                              | Cylinder #1 |
| Orientation                             | 225°        |
| Nozzle center line offset to datum line | 29"         |
| End of nozzle to shell center           | 16"         |
| Passes through a Category A joint       | No          |

#### Nozzle

|                                                                    |                                           |
|--------------------------------------------------------------------|-------------------------------------------|
| Description                                                        | NPS 1.5 Sch 40S (Std)                     |
| Access opening                                                     | No                                        |
| Material specification                                             | SA-312 TP316 Wld pipe (II-D p. 76, In. 7) |
| Inside diameter, new                                               | 1.61"                                     |
| Pipe nominal wall thickness                                        | 0.145"                                    |
| Pipe minimum wall thickness <sup>1</sup>                           | 0.1269"                                   |
| Corrosion allowance                                                | 0"                                        |
| Projection available outside vessel, L <sub>pr</sub>               | 3.31"                                     |
| Projection available outside vessel to flange face, L <sub>f</sub> | 6"                                        |
| Local vessel minimum thickness                                     | 0.2188"                                   |
| User input radial limit of reinforcement                           | 1.28"                                     |
| Liquid static head included                                        | 0 psi                                     |

#### Welds

|                                 |       |
|---------------------------------|-------|
| Inner fillet, Leg <sub>41</sub> | 0.25" |
| Nozzle to vessel groove weld    | 0.25" |



| Radiography          |                      |
|----------------------|----------------------|
| Longitudinal seam    | Welded pipe          |
| Circumferential seam | Full UW-11(a) Type 1 |

<sup>1</sup> Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

| ASME B16.5-2013 Flange                                                                             |                                               |
|----------------------------------------------------------------------------------------------------|-----------------------------------------------|
| Description                                                                                        | NPS 1.5 Class 300 WN A182 F316                |
| Bolt Material                                                                                      | SA-193 B7 Bolt <= 2 1/2 (II-D p. 398, ln. 32) |
| Blind included                                                                                     | No                                            |
| Rated MDMT                                                                                         | -55°F                                         |
| Liquid static head                                                                                 | 0 psi                                         |
| MAWP rating                                                                                        | 420 psi @ 840°F                               |
| MAP rating                                                                                         | 720 psi @ 70°F                                |
| Hydrotest rating                                                                                   | 1,100 psi @ 70°F                              |
| PWHT performed                                                                                     | No                                            |
| Produced to Fine Grain Practice and Supplied in Heat Treated Condition                             | No                                            |
| Impact Tested                                                                                      | No                                            |
| Circumferential joint radiography                                                                  | Full UW-11(a) 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                                       |         |
|-------------------------------------------------------------------------------------|---------|
| $t_r = 225 \cdot 0.805 / (17,000 \cdot 1 - 0.6 \cdot 225) =$                        | 0.0107" |
| $\text{Stress ratio} = t_r \cdot E^* / (t_n - c) = 0.0107 \cdot 1 / (0.1269 - 0) =$ | 0.0847  |
| Impact test exempt per UHA-51(g) (coincident ratio = 0.0847)                        |         |
| Rated MDMT =                                                                        | -320°F  |
| Material is exempt from impact testing at the Design MDMT of -20°F.                 |         |

## Reinforcement Calculations for Internal Pressure

| UG-37 Area Calculation Summary (in <sup>2</sup> )               |             |                |                |                |                |         | UG-45 Summary (in)      |                  |
|-----------------------------------------------------------------|-------------|----------------|----------------|----------------|----------------|---------|-------------------------|------------------|
| For P = 225 psi @ 840 °F                                        |             |                |                |                |                |         | The nozzle passes UG-45 |                  |
| A required                                                      | A available | A <sub>1</sub> | A <sub>2</sub> | A <sub>3</sub> | A <sub>5</sub> | A welds | t <sub>req</sub>        | t <sub>min</sub> |
| 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 <sub>41</sub> ) | 0.1015                         | 0.175                        | weld size is adequate |

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

## Reinforcement Calculations for MAWP

The vessel wall thickness governs the MAWP of this nozzle.

| UG-37 Area Calculation Summary (in <sup>2</sup> )               |             |                |                |                |                |         | UG-45 Summary (in)      |                  |
|-----------------------------------------------------------------|-------------|----------------|----------------|----------------|----------------|---------|-------------------------|------------------|
| For P = 346.55 psi @ 840 °F                                     |             |                |                |                |                |         | The nozzle passes UG-45 |                  |
| A required                                                      | A available | A <sub>1</sub> | A <sub>2</sub> | A <sub>3</sub> | A <sub>5</sub> | A welds | t <sub>req</sub>        | t <sub>min</sub> |
| This nozzle is exempt from area calculations per UG-36(c)(3)(a) |             |                |                |                |                |         | 0.1269                  | 0.1269           |

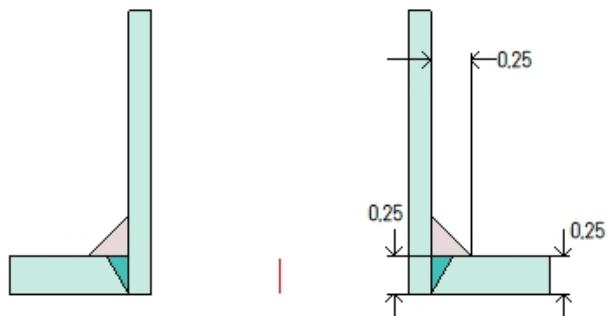
| UG-41 Weld Failure Path Analysis Summary                             |
|----------------------------------------------------------------------|
| The nozzle is exempt from weld strength calculations per UW-15(b)(2) |

| UW-16 Weld Sizing Summary                   |                                |                              |                       |
|---------------------------------------------|--------------------------------|------------------------------|-----------------------|
| Weld description                            | Required weld throat size (in) | Actual weld throat size (in) | Status                |
| Nozzle to shell fillet (Leg <sub>41</sub> ) | 0.1015                         | 0.175                        | weld size is adequate |

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

## TE CONNECTIONS (E3)

### ASME Section VIII Division 1, 2019 Edition



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

#### Location and Orientation

|                                         |             |
|-----------------------------------------|-------------|
| Located on                              | Cylinder #1 |
| Orientation                             | 225°        |
| Nozzle center line offset to datum line | 16"         |
| End of nozzle to shell center           | 16"         |
| Passes through a Category A joint       | No          |

#### Nozzle

|                                                                    |                                           |
|--------------------------------------------------------------------|-------------------------------------------|
| Description                                                        | NPS 1.5 Sch 40S (Std)                     |
| Access opening                                                     | No                                        |
| Material specification                                             | SA-312 TP316 Wld pipe (II-D p. 76, In. 7) |
| Inside diameter, new                                               | 1.61"                                     |
| Pipe nominal wall thickness                                        | 0.145"                                    |
| Pipe minimum wall thickness <sup>1</sup>                           | 0.1269"                                   |
| Corrosion allowance                                                | 0"                                        |
| Projection available outside vessel, L <sub>pr</sub>               | 3.31"                                     |
| Projection available outside vessel to flange face, L <sub>f</sub> | 6"                                        |
| Local vessel minimum thickness                                     | 0.2188"                                   |
| Liquid static head included                                        | 0 psi                                     |

#### Welds

|                                 |       |
|---------------------------------|-------|
| Inner fillet, Leg <sub>41</sub> | 0.25" |
| Nozzle to vessel groove weld    | 0.25" |

#### Radiography

|                             |                      |
|-----------------------------|----------------------|
| <b>Longitudinal seam</b>    | Welded pipe          |
| <b>Circumferential seam</b> | Full UW-11(a) Type 1 |

<sup>1</sup>Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

| ASME B16.5-2013 Flange                                                                               |                                                           |
|------------------------------------------------------------------------------------------------------|-----------------------------------------------------------|
| <b>Description</b>                                                                                   | NPS 1.5 Class 300 WN A182 F316                            |
| <b>Bolt Material</b>                                                                                 | SA-193 B7 Bolt $\leq 2 \frac{1}{2}$ (II-D p. 398, ln. 32) |
| <b>Blind included</b>                                                                                | No                                                        |
| <b>Rated MDMT</b>                                                                                    | -55 °F                                                    |
| <b>Liquid static head</b>                                                                            | 0 psi                                                     |
| <b>MAWP rating</b>                                                                                   | 420 psi @ 840 °F                                          |
| <b>MAP rating</b>                                                                                    | 720 psi @ 70 °F                                           |
| <b>Hydrotest rating</b>                                                                              | 1,100 psi @ 70 °F                                         |
| <b>PWHT performed</b>                                                                                | No                                                        |
| <b>Produced to Fine Grain Practice and Supplied in Heat Treated Condition</b>                        | No                                                        |
| <b>Impact Tested</b>                                                                                 | No                                                        |
| <b>Circumferential joint radiography</b>                                                             | Full UW-11(a) 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                                       |         |
|-------------------------------------------------------------------------------------|---------|
| $t_r = 225 \cdot 0.805 / (17,000 \cdot 1 - 0.6 \cdot 225) =$                        | 0.0107" |
| $\text{Stress ratio} = t_r \cdot E^* / (t_n - c) = 0.0107 \cdot 1 / (0.1269 - 0) =$ | 0.0847  |
| Impact test exempt per UHA-51(g) (coincident ratio = 0.0847)                        |         |
| Rated MDMT =                                                                        | -320 °F |
| Material is exempt from impact testing at the Design MDMT of -20 °F.                |         |

## Reinforcement Calculations for Internal Pressure

| UG-37 Area Calculation Summary (in <sup>2</sup> )               |             |                |                |                |                |         | UG-45 Summary (in)      |                  |
|-----------------------------------------------------------------|-------------|----------------|----------------|----------------|----------------|---------|-------------------------|------------------|
| For P = 225 psi @ 840 °F                                        |             |                |                |                |                |         | The nozzle passes UG-45 |                  |
| A required                                                      | A available | A <sub>1</sub> | A <sub>2</sub> | A <sub>3</sub> | A <sub>5</sub> | A welds | t <sub>req</sub>        | t <sub>min</sub> |
| 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 <sub>41</sub> ) | 0.1015                         | 0.175                        | weld size is adequate |

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

## Reinforcement Calculations for MAWP

The vessel wall thickness governs the MAWP of this nozzle.

| UG-37 Area Calculation Summary (in <sup>2</sup> )               |             |                |                |                |                |         | UG-45 Summary (in)      |                  |
|-----------------------------------------------------------------|-------------|----------------|----------------|----------------|----------------|---------|-------------------------|------------------|
| For P = 346.55 psi @ 840 °F                                     |             |                |                |                |                |         | The nozzle passes UG-45 |                  |
| A required                                                      | A available | A <sub>1</sub> | A <sub>2</sub> | A <sub>3</sub> | A <sub>5</sub> | A welds | t <sub>req</sub>        | t <sub>min</sub> |
| This nozzle is exempt from area calculations per UG-36(c)(3)(a) |             |                |                |                |                |         | 0.1269                  | 0.1269           |

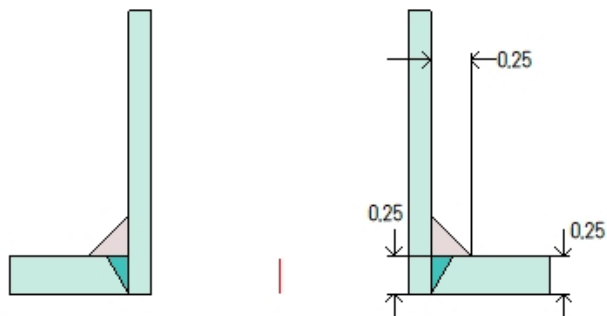
| UG-41 Weld Failure Path Analysis Summary                             |
|----------------------------------------------------------------------|
| The nozzle is exempt from weld strength calculations per UW-15(b)(2) |

| UW-16 Weld Sizing Summary                   |                                |                              |                       |
|---------------------------------------------|--------------------------------|------------------------------|-----------------------|
| Weld description                            | Required weld throat size (in) | Actual weld throat size (in) | Status                |
| Nozzle to shell fillet (Leg <sub>41</sub> ) | 0.1015                         | 0.175                        | weld size is adequate |

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

## TE CONNECTIONS (E4)

### ASME Section VIII Division 1, 2019 Edition



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

#### Location and Orientation

|                                         |             |
|-----------------------------------------|-------------|
| Located on                              | Cylinder #1 |
| Orientation                             | 225°        |
| Nozzle center line offset to datum line | 3"          |
| End of nozzle to shell center           | 16"         |
| Passes through a Category A joint       | No          |

#### Nozzle

|                                                                    |                                           |
|--------------------------------------------------------------------|-------------------------------------------|
| Description                                                        | NPS 1.5 Sch 40S (Std)                     |
| Access opening                                                     | No                                        |
| Material specification                                             | SA-312 TP316 Wld pipe (II-D p. 76, In. 7) |
| Inside diameter, new                                               | 1.61"                                     |
| Pipe nominal wall thickness                                        | 0.145"                                    |
| Pipe minimum wall thickness <sup>1</sup>                           | 0.1269"                                   |
| Corrosion allowance                                                | 0"                                        |
| Projection available outside vessel, L <sub>pr</sub>               | 3.31"                                     |
| Projection available outside vessel to flange face, L <sub>f</sub> | 6"                                        |
| Local vessel minimum thickness                                     | 0.2188"                                   |
| Liquid static head included                                        | 0 psi                                     |

#### Welds

|                                 |       |
|---------------------------------|-------|
| Inner fillet, Leg <sub>41</sub> | 0.25" |
| Nozzle to vessel groove weld    | 0.25" |

#### Radiography



|                             |                      |
|-----------------------------|----------------------|
| <b>Longitudinal seam</b>    | Welded pipe          |
| <b>Circumferential seam</b> | Full UW-11(a) Type 1 |

<sup>1</sup>Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

| ASME B16.5-2013 Flange                                                                               |                                                           |
|------------------------------------------------------------------------------------------------------|-----------------------------------------------------------|
| <b>Description</b>                                                                                   | NPS 1.5 Class 300 WN A182 F316                            |
| <b>Bolt Material</b>                                                                                 | SA-193 B7 Bolt $\leq 2 \frac{1}{2}$ (II-D p. 398, ln. 32) |
| <b>Blind included</b>                                                                                | No                                                        |
| <b>Rated MDMT</b>                                                                                    | -55 °F                                                    |
| <b>Liquid static head</b>                                                                            | 0 psi                                                     |
| <b>MAWP rating</b>                                                                                   | 420 psi @ 840 °F                                          |
| <b>MAP rating</b>                                                                                    | 720 psi @ 70 °F                                           |
| <b>Hydrotest rating</b>                                                                              | 1,100 psi @ 70 °F                                         |
| <b>PWHT performed</b>                                                                                | No                                                        |
| <b>Produced to Fine Grain Practice and Supplied in Heat Treated Condition</b>                        | No                                                        |
| <b>Impact Tested</b>                                                                                 | No                                                        |
| <b>Circumferential joint radiography</b>                                                             | Full UW-11(a) 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                                |         |
|------------------------------------------------------------------------------|---------|
| $t_r = 225 \cdot 0.805 / (17,000 \cdot 1 - 0.6 \cdot 225) =$                 | 0.0107" |
| Stress ratio = $t_r \cdot E^* / (t_n - c) = 0.0107 \cdot 1 / (0.1269 - 0) =$ | 0.0847  |
| Impact test exempt per UHA-51(g) (coincident ratio = 0.0847)                 |         |
| Rated MDMT =                                                                 | -320 °F |
| Material is exempt from impact testing at the Design MDMT of -20 °F.         |         |

## Reinforcement Calculations for Internal Pressure

| UG-37 Area Calculation Summary (in <sup>2</sup> )               |             |                |                |                |                |         | UG-45 Summary (in)      |                  |
|-----------------------------------------------------------------|-------------|----------------|----------------|----------------|----------------|---------|-------------------------|------------------|
| For P = 225 psi @ 840 °F                                        |             |                |                |                |                |         | The nozzle passes UG-45 |                  |
| A required                                                      | A available | A <sub>1</sub> | A <sub>2</sub> | A <sub>3</sub> | A <sub>5</sub> | A welds | t <sub>req</sub>        | t <sub>min</sub> |
| 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 <sub>41</sub> ) | 0.1015                         | 0.175                        | weld size is adequate |

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

## Reinforcement Calculations for MAWP

The vessel wall thickness governs the MAWP of this nozzle.

| UG-37 Area Calculation Summary (in <sup>2</sup> )               |             |                |                |                |                |         | UG-45 Summary (in)      |                  |
|-----------------------------------------------------------------|-------------|----------------|----------------|----------------|----------------|---------|-------------------------|------------------|
| For P = 346.55 psi @ 840 °F                                     |             |                |                |                |                |         | The nozzle passes UG-45 |                  |
| A required                                                      | A available | A <sub>1</sub> | A <sub>2</sub> | A <sub>3</sub> | A <sub>5</sub> | A welds | t <sub>req</sub>        | t <sub>min</sub> |
| 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 <sub>41</sub> ) | 0.1015                         | 0.175                        | weld size is adequate |

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

### Straight Flange on Ellipsoidal Head #1

| ASME Section VIII Division 1, 2019 Edition |            |                                 |                           |                        |
|--------------------------------------------|------------|---------------------------------|---------------------------|------------------------|
| Component                                  |            | Cylinder                        |                           |                        |
| Material                                   |            | SA-240 316 (II-D p. 72, ln. 43) |                           |                        |
| Impact Tested                              | Normalized | Fine Grain Practice             | PWHT                      | Maximize MDMT/ No MAWP |
| No                                         | No         | No                              | No                        | No                     |
|                                            |            | Design Pressure (psi)           | Design Temperature ( ° F) | Design MDMT ( ° F)     |
| Internal                                   |            | 225                             | 840                       | -20                    |
| Static Liquid Head                         |            |                                 |                           |                        |
| Condition                                  |            | P <sub>s</sub> (psi)            | H <sub>s</sub> (in)       | SG                     |
| Test horizontal                            |            | 0.93                            | 25.75                     | 1                      |
| Dimensions                                 |            |                                 |                           |                        |
| Outer Diameter                             |            | 20"                             |                           |                        |
| Length                                     |            | 2"                              |                           |                        |
| Nominal Thickness                          |            | 0.25"                           |                           |                        |
| Corrosion                                  | Inner      | 0"                              |                           |                        |
|                                            | Outer      | 0"                              |                           |                        |
| Weight and Capacity                        |            |                                 |                           |                        |
|                                            |            | Weight (lb)                     |                           | Capacity (US gal)      |
| New                                        |            | 9                               |                           | 2.59                   |
| Corroded                                   |            | 9                               |                           | 2.59                   |
| Radiography                                |            |                                 |                           |                        |
| Longitudinal seam                          |            | Seamless No RT                  |                           |                        |
| Top Circumferential seam                   |            | Spot UW-11(b) Type 1            |                           |                        |

| Results Summary                                       |                            |
|-------------------------------------------------------|----------------------------|
| Governing condition                                   | Internal pressure          |
| Minimum thickness per UG-16                           | $0.0625" + 0" = 0.0625"$   |
| Design thickness due to internal pressure (t)         | <a href="#">0.1675"</a>    |
| Design thickness due to combined loadings + corrosion | <a href="#">0.0801"</a>    |
| Maximum allowable working pressure (MAWP)             | <a href="#">336.99 psi</a> |
| Rated MDMT                                            | -320 °F                    |

| UHA-51 Material Toughness Requirements                                           |         |
|----------------------------------------------------------------------------------|---------|
| $t_r = 225 \cdot 10 / (20,000 \cdot 0.85 + 0.4 \cdot 225) =$                     | 0.1317" |
| Stress ratio $= t_r \cdot E^* / (t_n - c) = 0.1317 \cdot 0.85 / (0.25 - 0) =$    | 0.4476  |
| 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 840 °F) Appendix 1-1

$$\begin{aligned}
 t &= P \cdot R_o / (S \cdot E + 0.40 \cdot P) + \text{Corrosion} \\
 &= 225 \cdot 10 / (15,700 \cdot 0.85 + 0.40 \cdot 225) + 0 \\
 &= \a href="#">0.1675"
 \end{aligned}$$

#### Maximum allowable working pressure, (at 840 °F) Appendix 1-1

$$\begin{aligned}
 P &= S \cdot E \cdot t / (R_o - 0.40 \cdot t) - P_s \\
 &= 15,700 \cdot 0.85 \cdot 0.25 / (10 - 0.40 \cdot 0.25) - 0 \\
 &= \a href="#">336.99 \text{ psi}
 \end{aligned}$$

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

$$\begin{aligned}
 EFE &= (50 \cdot t / R_f) \cdot (1 - R_f / R_o) \\
 &= (50 \cdot 0.25 / 9.875) \cdot (1 - 9.875 / \infty) \\
 &= 1.2658\%
 \end{aligned}$$

| 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 <sub>t</sub>                                      | S <sub>c</sub> |                  |                  |        |                               |                                   |
| Operating, Hot & Corroded                                | 225              | 15,700                                              | 9,380          | 840              | 0                | Weight | 0.0801                        | 0.0798                            |
| Operating, Hot & New                                     | 225              | 15,700                                              | 9,380          | 840              | 0                | Weight | 0.0801                        | 0.0798                            |
| Hot Shut Down, Corroded                                  | 0                | 15,700                                              | 9,380          | 840              | 0                | Weight | 0.0026                        | 0.003                             |
| Hot Shut Down, New                                       | 0                | 15,700                                              | 9,380          | 840              | 0                | Weight | 0.0026                        | 0.003                             |
| Empty, Corroded                                          | 0                | 20,000                                              | 12,656         | 70               | 0                | Weight | 0.0019                        | 0.0022                            |
| Empty, New                                               | 0                | 20,000                                              | 12,656         | 70               | 0                | Weight | 0.0019                        | 0.0022                            |
| Hot Shut Down, Corroded, Weight & Eccentric Moments Only | 0                | 15,700                                              | 9,380          | 840              | 0                | Weight | 0.0026                        | 0.003                             |

| ASME Section VIII Division 1 UG-80(a) Out-of-Roundness                                                                                                                           |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $(D_{\max} - D_{\min})$ shall not exceed 1% of D                                                                                                                                 |
| When the cross section passes through an opening or within 1 I.D. of the opening,<br>$(D_{\max} - D_{\min})$ shall not exceed 1% of D + 2% of the inside diameter of the opening |

# Ellipsoidal Head #1

| ASME Section VIII Division 1, 2019 Edition |            |                                 |                          |                                |
|--------------------------------------------|------------|---------------------------------|--------------------------|--------------------------------|
| Component                                  |            | Ellipsoidal Head                |                          |                                |
| Material                                   |            | SA-240 316 (II-D p. 72, ln. 43) |                          |                                |
| Attached To                                |            | Cylinder #1                     |                          |                                |
| Impact Tested                              | Normalized | Fine Grain Practice             | PWHT                     | Maximize MDMT/<br>No MAWP      |
| No                                         | No         | No                              | No                       | No                             |
|                                            |            | Design Pressure (psi)           | Design Temperature (° F) | Design MDMT (° F)              |
| Internal                                   |            | 225                             | 840                      | -20                            |
| Static Liquid Head                         |            |                                 |                          |                                |
| Condition                                  |            | P <sub>s</sub> (psi)            | H <sub>s</sub> (in)      | SG                             |
| Test horizontal                            |            | 0.93                            | 25.8339                  | 1                              |
| Dimensions                                 |            |                                 |                          |                                |
| Outer Diameter                             |            | 20"                             |                          |                                |
| Head Ratio                                 |            | 2                               |                          |                                |
| Minimum Thickness                          |            | 0.1661"                         |                          |                                |
| Corrosion                                  | Inner      | 0"                              |                          |                                |
|                                            | Outer      | 0"                              |                          |                                |
| Length L <sub>sf</sub>                     |            | 2"                              |                          |                                |
| Nominal Thickness t <sub>sf</sub>          |            | 0.25"                           |                          |                                |
| Weight and Capacity                        |            |                                 |                          |                                |
|                                            |            | Weight (lb) <sup>1</sup>        |                          | Capacity (US gal) <sup>1</sup> |
| New                                        |            | 30.45                           |                          | 6.9                            |
| Corroded                                   |            | 30.45                           |                          | 6.9                            |
| Radiography                                |            |                                 |                          |                                |
| Category A joints                          |            | Seamless No RT                  |                          |                                |
| Head to shell seam                         |            | Spot UW-11(b) Type 1            |                          |                                |

<sup>1</sup> includes straight flange

| Results Summary                               |                            |
|-----------------------------------------------|----------------------------|
| Governing condition                           | internal pressure          |
| Minimum thickness per UG-16                   | 0.0625" + 0" = 0.0625"     |
| Design thickness due to internal pressure (t) | <a href="#">0.1661"</a>    |
| Maximum allowable working pressure (MAWP)     | <a href="#">225.02</a> psi |
| <a href="#">Straight Flange</a> governs MDMT  | -320 °F                    |

| Factor K                            |                                               |   |
|-------------------------------------|-----------------------------------------------|---|
| $K = (1/6) * [2 + (D / (2 * h))^2]$ |                                               |   |
| Corroded                            | $K = (1/6) * [2 + (19.6678 / (2 * 4.917))^2]$ | 1 |
| New                                 | $K = (1/6) * [2 + (19.6678 / (2 * 4.917))^2]$ | 1 |

**Design thickness for internal pressure, (Corroded at 840 °F) Appendix 1-4(c)**

$$\begin{aligned}
 t &= P * D_o * K / (2 * S * E + 2 * P * (K - 0.1)) + \text{Corrosion} \\
 &= 225 * 20 * 1 / (2 * 15,700 * 0.85 + 2 * 225 * (1 - 0.1)) + 0 \\
 &= \a href="#">0.1661"
 \end{aligned}$$

**Maximum allowable working pressure, (Corroded at 840 °F) Appendix 1-4(c)**

$$\begin{aligned}
 P &= 2 * S * E * t / (K * D_o - 2 * t * (K - 0.1)) - P_s \\
 &= 2 * 15,700 * 0.85 * 0.1661 / (1 * 20 - 2 * 0.1661 * (1 - 0.1)) - 0 \\
 &= \a href="#">225.02 \text{ psi}
 \end{aligned}$$

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

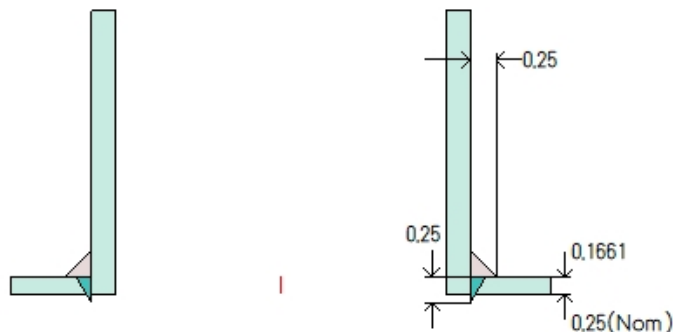
$$\begin{aligned}
 EFE &= (75 * t / R_f) * (1 - R_f / R_o) \\
 &= (75 * 0.25 / 3.4685) * (1 - 3.4685 / \infty) \\
 &= 5.4058\%
 \end{aligned}$$

| ASME Section VIII Division 1 UG-81(a) Out-of-Roundness                     |
|----------------------------------------------------------------------------|
| Inside surface shall not deviate outside the shape by more than 1.25% of D |
| Inside surface shall not deviate inside the shape by more than 0.625% of D |



## GAS OUTLET (B)

### ASME Section VIII Division 1, 2019 Edition



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

#### Location and Orientation

|                                   |                     |
|-----------------------------------|---------------------|
| Located on                        | Ellipsoidal Head #1 |
| Orientation                       | 0°                  |
| End of nozzle to datum line       | -11"                |
| 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 TP316 Wld & smls pipe (II-D p. 76, ln. 5) |
| Inside diameter, new                                 | 3.068"                                           |
| Pipe nominal wall thickness                          | 0.216"                                           |
| Pipe minimum wall thickness <sup>1</sup>             | 0.189"                                           |
| Corrosion allowance                                  | 0"                                               |
| Projection available outside vessel, L <sub>pr</sub> | 3.9954"                                          |
| Local vessel minimum thickness                       | 0.1661"                                          |
| Liquid static head included                          | 0 psi                                            |

#### Welds

|                                 |       |
|---------------------------------|-------|
| Inner fillet, Leg <sub>41</sub> | 0.25" |
| Nozzle to vessel groove weld    | 0.25" |

#### Radiography

|                             |                      |
|-----------------------------|----------------------|
| <b>Longitudinal seam</b>    | Seamless No RT       |
| <b>Circumferential seam</b> | None UW-11(c) Type 1 |

<sup>1</sup>Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

| UHA-51 Material Toughness Requirements Nozzle                                   |         |
|---------------------------------------------------------------------------------|---------|
| $t_r = 225 \cdot 0.9 \cdot 20 / (2 \cdot 20,000 \cdot 1 + 0.8 \cdot 225) =$     | 0.1008" |
| Stress ratio = $t_r \cdot E^* / (t_n - c) = 0.1008 \cdot 1 / (0.1661 - 0) =$    | 0.6069  |
| 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 Internal Pressure

| UG-37 Area Calculation Summary (in <sup>2</sup> )               |             |                |                |                |                |         | UG-45 Summary (in)      |                  |
|-----------------------------------------------------------------|-------------|----------------|----------------|----------------|----------------|---------|-------------------------|------------------|
| For P = 225 psi @ 840 °F                                        |             |                |                |                |                |         | The nozzle passes UG-45 |                  |
| A required                                                      | A available | A <sub>1</sub> | A <sub>2</sub> | A <sub>3</sub> | A <sub>5</sub> | A welds | t <sub>req</sub>        | t <sub>min</sub> |
| This nozzle is exempt from area calculations per UG-36(c)(3)(a) |             |                |                |                |                |         | 0.1415                  | 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 throat size (in) | Actual weld throat size (in) | Status                |
| Nozzle to shell fillet (Leg <sub>41</sub> ) | 0.1512                         | 0.175                        | weld size is adequate |

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

## Reinforcement Calculations for MAWP

The vessel wall thickness governs the MAWP of this nozzle.

| UG-37 Area Calculation Summary<br>(in <sup>2</sup> )               |                |                |                |                |                |            | UG-45<br>Summary (in)      |                  |
|--------------------------------------------------------------------|----------------|----------------|----------------|----------------|----------------|------------|----------------------------|------------------|
| For P = 291.91 psi @ 840 °F                                        |                |                |                |                |                |            | The nozzle passes<br>UG-45 |                  |
| A<br>required                                                      | A<br>available | A <sub>1</sub> | A <sub>2</sub> | A <sub>3</sub> | A <sub>5</sub> | A<br>welds | t <sub>req</sub>           | t <sub>min</sub> |
| This nozzle is exempt from area<br>calculations per UG-36(c)(3)(a) |                |                |                |                |                |            | 0.1829                     | 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<br>throat size (in) | Actual weld<br>throat size (in) | Status                |
| Nozzle to shell fillet (Leg <sub>41</sub> ) | 0.1512                            | 0.175                           | weld size is adequate |

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

**B16.9 Elbow #1 (B)**

| ASME Section VIII Division 1, 2019 Edition |            |                                 |                           |                           |
|--------------------------------------------|------------|---------------------------------|---------------------------|---------------------------|
| Component                                  |            | ASME B16.9 Elbow                |                           |                           |
| Type                                       |            | Long Radius 90-deg              |                           |                           |
| Material                                   |            | SA-403 316 (II-D p. 76, ln. 12) |                           |                           |
| Pipe NPS and Schedule                      |            | NPS 3 Sch 40S (Std)             |                           |                           |
| Attached To                                |            | GAS OUTLET (B)                  |                           |                           |
| Impact Tested                              | Normalized | Fine Grain Practice             | PWHT                      | Maximize MDMT/<br>No MAWP |
| No                                         | No         | No                              | No                        | No                        |
|                                            |            | Design Pressure (psi)           | Design Temperature ( ° F) | Design MDMT ( ° F)        |
| Internal                                   |            | 225                             | 840                       | -20                       |
| Static Liquid Head                         |            |                                 |                           |                           |
| Condition                                  |            | P <sub>s</sub> (psi)            | H <sub>s</sub> (in)       | SG                        |
| Test horizontal                            |            | 0.63                            | 17.534                    | 1                         |
| Dimensions                                 |            |                                 |                           |                           |
| Outer Diameter                             |            | 3.5"                            |                           |                           |
| Minimum Thickness                          |            | 0.216"                          |                           |                           |
| Center-to-End, A                           |            | 4.5"                            |                           |                           |
| Corrosion                                  | Inner      | 0"                              |                           |                           |
|                                            | Outer      | 0"                              |                           |                           |
| Weight and Capacity                        |            |                                 |                           |                           |
|                                            |            | Weight (lb)                     |                           | Capacity (US gal)         |
| New                                        |            | 4.57                            |                           | 0.23                      |
| Corroded                                   |            | 4.57                            |                           | 0.23                      |
| Radiography                                |            |                                 |                           |                           |
| Longitudinal seam                          |            | Seamless No RT                  |                           |                           |
| Left Circumferential seam                  |            | None UW-11(c) Type 1            |                           |                           |
| Right Circumferential seam                 |            | None UW-11(c) Type 1            |                           |                           |

| Results Summary                               |                             |
|-----------------------------------------------|-----------------------------|
| Governing condition                           | UG-16                       |
| Minimum thickness per UG-16                   | $0.0625" + 0" = 0.0625"$    |
| Design thickness due to internal pressure (t) | <a href="#">0.0294"</a>     |
| Maximum allowable working pressure (MAWP)     | <a href="#">1.732.7 psi</a> |
| Rated MDMT                                    | -320 °F                     |

| UHA-51 Material Toughness Requirements                                              |         |
|-------------------------------------------------------------------------------------|---------|
| $t_r = 225 \cdot 1.75 / (20,000 \cdot 0.85 + 0.4 \cdot 225) =$                      | 0.023"  |
| $\text{Stress ratio} = t_r \cdot E' / (t_n - c) = 0.023 \cdot 0.85 / (0.216 - 0) =$ | 0.0907  |
| Impact test exempt per UHA-51(g) (coincident ratio = 0.0907)                        |         |
| Rated MDMT =                                                                        | -320 °F |
| Material is exempt from impact testing at the Design MDMT of -20 °F.                |         |

#### Design thickness, (at 840 °F) Appendix 1-1

$$\begin{aligned}
 t &= P \cdot R_o / (S \cdot E + 0.40 \cdot P) + \text{Corrosion} \\
 &= 225 \cdot 1.75 / (15,700 \cdot 0.85 + 0.40 \cdot 225) + 0 \\
 &= \a href="#">0.0294"
 \end{aligned}$$

#### Maximum allowable working pressure, (at 840 °F) Appendix 1-1

$$\begin{aligned}
 P &= S \cdot E \cdot t / (R_o - 0.40 \cdot t) - P_s \\
 &= 15,700 \cdot 0.85 \cdot 0.216 / (1.75 - 0.40 \cdot 0.216) - 0 \\
 &= \a href="#">1.732.7 \text{ psi}
 \end{aligned}$$

### Nozzle Pipe #1 (B)

| ASME Section VIII Division 1, 2019 Edition |            |                                                  |                          |                        |
|--------------------------------------------|------------|--------------------------------------------------|--------------------------|------------------------|
| Component                                  |            | Nozzle Pipe                                      |                          |                        |
| Material                                   |            | SA-312 TP316 Wld & smls pipe (II-D p. 76, ln. 5) |                          |                        |
| Pipe NPS and Schedule                      |            | NPS 3 Sch 40S (Std)                              |                          |                        |
| Attached To                                |            | B16.9 Elbow #1 (B)                               |                          |                        |
| Impact Tested                              | Normalized | Fine Grain Practice                              | PWHT                     | Maximize MDMT/ No MAWP |
| No                                         | No         | No                                               | No                       | No                     |
|                                            |            | Design Pressure (psi)                            | Design Temperature ( °F) | Design MDMT ( °F)      |
| Internal                                   |            | 225                                              | 840                      | -20                    |
| Static Liquid Head                         |            |                                                  |                          |                        |
| Condition                                  |            | P <sub>s</sub> (psi)                             | H <sub>s</sub> (in)      | SG                     |
| Test horizontal                            |            | 0.42                                             | 11.5                     | 1                      |
| Dimensions                                 |            |                                                  |                          |                        |
| Outer Diameter                             |            | 3.5"                                             |                          |                        |
| Length                                     |            | 8.375"                                           |                          |                        |
| Pipe Nominal Thickness                     |            | 0.216"                                           |                          |                        |
| Pipe Minimum Thickness <sup>1</sup>        |            | 0.189"                                           |                          |                        |
| Corrosion                                  | Inner      | 0"                                               |                          |                        |
|                                            | Outer      | 0"                                               |                          |                        |
| Weight and Capacity                        |            |                                                  |                          |                        |
|                                            |            | Weight (lb)                                      |                          | Capacity (US gal)      |
| New                                        |            | 5.41                                             |                          | 0.27                   |
| Corroded                                   |            | 5.41                                             |                          | 0.27                   |
| Radiography                                |            |                                                  |                          |                        |
| Longitudinal seam                          |            | Seamless No RT                                   |                          |                        |
| Left Circumferential seam                  |            | None UW-11(c) Type 1                             |                          |                        |
| Right Circumferential seam                 |            | None UW-11(c) Type 1                             |                          |                        |

<sup>1</sup>Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

| ASME B16.5-2013 Flange                                                                               |                                               |
|------------------------------------------------------------------------------------------------------|-----------------------------------------------|
| Description                                                                                          | NPS 3 Class 300 WN A182 F316                  |
| Bolt Material                                                                                        | SA-193 B7 Bolt <= 2 1/2 (II-D p. 398, ln. 32) |
| Blind included                                                                                       | No                                            |
| Rated MDMT                                                                                           | -55 °F                                        |
| Liquid static head                                                                                   | 0 psi                                         |
| MAWP rating                                                                                          | 420 psi @ 840 °F                              |
| MAP rating                                                                                           | 720 psi @ 70 °F                               |
| Hydrotest rating                                                                                     | 1,100 psi @ 70 °F                             |
| PWHT performed                                                                                       | No                                            |
| Produced to Fine Grain Practice and Supplied in Heat Treated Condition                               | 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 |                                               |

| Results Summary                               |                              |
|-----------------------------------------------|------------------------------|
| Governing condition                           | UG-16                        |
| Minimum thickness per UG-16                   | 0.0625" + 0" = 0.0625"       |
| Design thickness due to internal pressure (t) | <a href="#">0.0294"</a>      |
| Maximum allowable working pressure (MAWP)     | <a href="#">1,506.33 psi</a> |
| Rated MDMT                                    | -320 °F                      |

| UHA-51 Material Toughness Requirements                                              |         |
|-------------------------------------------------------------------------------------|---------|
| $t_r = 225 \cdot 1.75 / (20,000 \cdot 0.85 + 0.4 \cdot 225) =$                      | 0.023"  |
| $\text{Stress ratio} = t_r \cdot E' / (t_n - c) = 0.023 \cdot 0.85 / (0.189 - 0) =$ | 0.1036  |
| Impact test exempt per UHA-51(g) (coincident ratio = 0.1036)                        |         |
| Rated MDMT =                                                                        | -320 °F |
| Material is exempt from impact testing at the Design MDMT of -20 °F.                |         |

#### Design thickness, (at 840 °F) Appendix 1-1

$$\begin{aligned}
 t &= P \cdot R_o / (S \cdot E + 0.40 \cdot P) + \text{Corrosion} \\
 &= 225 \cdot 1.75 / (15,700 \cdot 0.85 + 0.40 \cdot 225) + 0 \\
 &= \text{0.0294"}
 \end{aligned}$$

**Maximum allowable working pressure, (at 840 °F) Appendix 1-1**

$$\begin{aligned} P &= S \cdot E \cdot t / (R_o - 0.40 \cdot t) - P_s \\ &= 15,700 \cdot 0.85 \cdot (0.216 \cdot 0.875) / (1.75 - 0.40 \cdot (0.216 \cdot 0.875)) - 0 \\ &= \underline{1.506.33} \text{ psi} \end{aligned}$$



### Support Skirt #1

| ASME Section VIII Division 1, 2019 Edition |         |                                           |            |                     |
|--------------------------------------------|---------|-------------------------------------------|------------|---------------------|
| Component                                  |         | Support Skirt                             |            |                     |
| Skirt is Attached To                       |         | Ellipsoidal Head #1                       |            |                     |
| Skirt Attachment Offset                    |         | 3.121" down from the top seam             |            |                     |
| Material                                   |         | SA-312 TP316 Wld pipe (II-D p. 76, ln. 7) |            |                     |
|                                            |         | Impact Tested <sup>1</sup>                | Normalized | Fine Grain Practice |
|                                            |         | No                                        | No         | No                  |
| Design Temperature                         |         |                                           |            |                     |
| Internal                                   |         | 650 °F                                    |            |                     |
| Dimensions                                 |         |                                           |            |                     |
| Inner Diameter                             | Top     | 19.5"                                     |            |                     |
|                                            | Botttom | 19.5"                                     |            |                     |
| Length (includes base ring thickness)      |         | 29.629"                                   |            |                     |
| Nominal Thickness                          |         | 0.25"                                     |            |                     |
| Corrosion                                  | Inner   | 0"                                        |            |                     |
|                                            | Outer   | 0"                                        |            |                     |
| Weight                                     |         |                                           |            |                     |
| New                                        |         | 131.03 lb                                 |            |                     |
| Corroded                                   |         | 131.03 lb                                 |            |                     |
| Joint Efficiency                           |         |                                           |            |                     |
| Top                                        |         | 0.55                                      |            |                     |
| Bottom                                     |         | 0.7                                       |            |                     |

<sup>1</sup>Impact testing requirements are not checked for supports

**Skirt design thickness, largest of the following + corrosion = 0.0026 in**

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

The skirt thickness of 0.2188 in is adequate.

| Results Summary |                     |                             |                          |                  |                        |                           |                         |
|-----------------|---------------------|-----------------------------|--------------------------|------------------|------------------------|---------------------------|-------------------------|
| Loading         | Condition           | Tensile or Compressive Side | Governing Skirt Location | Temperature (°F) | Allowable Stress (psi) | Calculated Stress/E (psi) | Required thickness (in) |
| Weight          | operating, corroded | Tensile                     | bottom                   | 650              | 11,748.15              | -108.53                   | <a href="#">0.0023</a>  |
|                 |                     | Compressive                 |                          |                  |                        | 123.11                    | <a href="#">0.0026</a>  |
|                 | empty, corroded     | Tensile                     | bottom                   | 70               | 14,582.34              | -108.53                   | 0.0019                  |
|                 |                     | Compressive                 |                          |                  |                        | 123.11                    | 0.0021                  |

## Loading due to weight, operating & corroded

### Windward side (tensile)

Required thickness, tensile stress at base:

$$\begin{aligned}
 t &= -W / (\pi \cdot D_t \cdot S_t \cdot E) + 48 \cdot M / (\pi \cdot D_t^2 \cdot S_t \cdot E) \\
 &= -1,796.58 / (\pi \cdot 19.75 \cdot 11,748 \cdot 1) + 48 \cdot 46.5 / (\pi \cdot 19.75^2 \cdot 11,748 \cdot 1) \\
 &= 0.0023 \text{ in}
 \end{aligned}$$

Required thickness, tensile stress at the top:

$$\begin{aligned}
 t &= -W_t / (\pi \cdot D_t \cdot S_t \cdot E) + 48 \cdot M_t / (\pi \cdot D_t^2 \cdot S_t \cdot E) \\
 &= -1,660.96 / (\pi \cdot 19.75 \cdot 11,748 \cdot 1) + 48 \cdot 46.5 / (\pi \cdot 19.75^2 \cdot 11,748 \cdot 1) \\
 &= 0.0021 \text{ in}
 \end{aligned}$$

### Leeward side (compressive)

Required thickness, compressive stress at base:

$$\begin{aligned}
 t &= W / (\pi \cdot D_c \cdot S_c \cdot E_c) + 48 \cdot M / (\pi \cdot D_c^2 \cdot S_c \cdot E_c) \\
 &= 1,796.58 / (\pi \cdot 19.75 \cdot 11,748 \cdot 1) + 48 \cdot 46.5 / (\pi \cdot 19.75^2 \cdot 11,748 \cdot 1) \\
 &= 0.0026 \text{ in}
 \end{aligned}$$

Required thickness, compressive stress at the top:

$$\begin{aligned}
 t &= W_t / (\pi \cdot D_t \cdot S_c \cdot E_c) + 48 \cdot M_t / (\pi \cdot D_t^2 \cdot S_c \cdot E_c) \\
 &= 1,660.96 / (\pi \cdot 19.75 \cdot 11,748 \cdot 1) + 48 \cdot 46.5 / (\pi \cdot 19.75^2 \cdot 11,748 \cdot 1) \\
 &= 0.0024 \text{ in}
 \end{aligned}$$

### Skirt Base Ring #1

| Inputs                                       |                        |
|----------------------------------------------|------------------------|
| Base configuration                           | single base plate      |
| Base plate material                          | SA-240-316             |
| Base plate allowable stress, $S_p$           | 20,000 psi             |
| Foundation compressive strength              | 1,658 psi              |
| Concrete ultimate 28-day strength            | 3,000 psi              |
| Bolt circle, BC                              | 24.125"                |
| Base plate inner diameter, $D_i$             | 14.375"                |
| Base plate outer diameter, $D_o$             | 26.375"                |
| Base plate thickness, $t_b$                  | 0.5"                   |
| Gusset separation, $w$                       | 4"                     |
| Gusset height, $h$                           | 4.75"                  |
| Gusset thickness, $t_g$                      | 0.375"                 |
| Anchor Bolts                                 |                        |
| Material                                     |                        |
| Allowable stress, $S_b$                      | 20,000 psi             |
| Bolt size and type                           | 0.375" coarse threaded |
| Number of bolts, $N$                         | 4                      |
| Corrosion allowance (applied to root radius) | 0"                     |
| Anchor bolt clearance                        | 0.375"                 |
| Bolt root area (corroded), $A_b$             | 0.07 in <sup>2</sup>   |
| Diameter of anchor bolt holes, $d_b$         | 0.75"                  |
| Initial bolt preload                         | 0% (0 psi)             |
| Bolt at 0°                                   | No                     |

| Results Summary |                     |                           |                              |         |                                       |                          |                                 |
|-----------------|---------------------|---------------------------|------------------------------|---------|---------------------------------------|--------------------------|---------------------------------|
| Load            | Vessel condition    | Base V (lb <sub>f</sub> ) | Base M (lb <sub>f</sub> -ft) | W (lb)  | Required bolt area (in <sup>2</sup> ) | t <sub>r</sub> Base (in) | Foundation bearing stress (psi) |
| Weight          | operating, corroded | 0                         | 46.5                         | 1,857.6 | 0                                     | 0.0846                   | 5.2                             |
| Weight          | operating, new      | 0                         | 46.5                         | 1,857.6 | 0                                     | 0.0846                   | 5.2                             |
| Weight          | empty, corroded     | 0                         | 46.5                         | 1,857.6 | 0                                     | 0.0846                   | 5.2                             |
| Weight          | empty, new          | 0                         | 46.5                         | 1,857.6 | 0                                     | 0.0846                   | 5.2                             |

#### Anchor bolt load (governing)

$$\begin{aligned}
 P &= -W / N + 48 * M / (N * BC) \\
 &= -1,857.58 / 4 + 48 * 46.5 / (4 * 24.125) \\
 &= -441.26 \text{ lb}_f
 \end{aligned}$$

The anchor bolts are satisfactory (no net uplift on anchor bolt)

#### Foundation bearing stress (governing)

$$\begin{aligned}
 A_c &= \pi * (D_o^2 - D_i^2) / 4 - N * \pi * d_b^2 / 4 \\
 &= \pi * (26.375^2 - 14.375^2) / 4 - 4 * \pi * 0.75^2 / 4 \\
 &= 382.2926 \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 I_c &= \pi * (D_o^4 - D_i^4) / 64 \\
 &= \pi * (26.375^4 - 14.375^4) / 64 \\
 &= 21,658.12 \text{ in}^4
 \end{aligned}$$

$$\begin{aligned}
 f_c &= N * A_b * \text{Preload} / A_c + W / A_c + 6 * M * D_o / I_c \\
 &= 4 * 0.0678 * 0 / 382.2926 + 1,857.58 / 382.2926 + 6 * 46.5 * 26.375 / 21,658.12 \\
 &= 5 \text{ psi}
 \end{aligned}$$

As  $f_c \leq 1,658$  psi the base plate width is satisfactory.

#### Base plate required thickness (governing)

From Brownell & Young, Table 10.3;  $l / b = 0.2245$

$$M_x = 0.0053 * 5 * 14.1977^2 = 5.5 \text{ lb}_f$$

$$M_y = -0.4515 * 5 * 3.1875^2 = -23.9 \text{ lb}_f$$

$$\begin{aligned}
 t_r &= (6 * M_{\max} / S_p)^{0.5} \\
 &= (6 * 23.85 / 20,000)^{0.5} \\
 &= 0.0846 \text{ in}
 \end{aligned}$$

The base plate thickness is satisfactory.

#### Base plate bolt load (Jawad & Farr eq. 12.13, governing)

$$\text{Bolt load} = A_b * f_s = 0.0678 * 0 = 0 \text{ lb}_f$$

$$\begin{aligned}
 t_r &= (3.91 * F / (S_y * (2 * b / w + w / (2 * l) - d_b * (2 / w + 1 / (2 * l))))))^{0.5} \\
 &= (3.91 * 0 / (36,000 * (2 * 3.1875 / 4 + 4 / (2 * 2.0625) - 0.75 * (2 / 4 + 1 / (2 * 2.0625))))))^{0.5} \\
 &= 0 \text{ in}
 \end{aligned}$$

The base plate thickness is satisfactory.

**Check skirt for gusset reaction (Jawad & Farr eq. 12.14)**

$$\begin{aligned} S_r &= 1.5 \cdot F \cdot b / (\text{gussets} \cdot \pi \cdot t_{sk}^2 \cdot h) \\ &= 1.5 \cdot 0 \cdot 3.1875 / (2 \cdot \pi \cdot 0.25^2 \cdot 4.75) \\ &= 0 \text{ psi} \end{aligned}$$

As  $S_r \leq 24,882$  psi the skirt thickness is adequate to resist the gusset reaction.

### Skirt Opening #1 (SO #1)

| ASME Section VIII Division 1, 2019 Edition      |                                                  |  |    |
|-------------------------------------------------|--------------------------------------------------|--|----|
| Component                                       | Skirt Opening                                    |  |    |
| Description                                     | Skirt Opening #1                                 |  |    |
| Drawing Mark                                    | SO #1                                            |  |    |
| Opening for Nozzle                              | GAS OUTLET (B)                                   |  |    |
| Sleeve Material                                 | SA-312 TP316 Wld & smls pipe (II-D p. 76, ln. 5) |  |    |
| Location and Orientation                        |                                                  |  |    |
| Attached to                                     | Support Skirt #1                                 |  |    |
| Orientation                                     | radial                                           |  |    |
| Offset, L                                       | 17.25"                                           |  |    |
| Angle, $\theta$                                 | 0°                                               |  |    |
| Distance, r                                     | 11"                                              |  |    |
| Through a Category B Joint                      | No                                               |  |    |
| Dimensions                                      |                                                  |  |    |
| Pipe NPS and Schedule                           | NPS 6 Sch 40S (Std)                              |  |    |
| Inside Diameter                                 | 6.065"                                           |  |    |
| Nominal Wall Thickness                          | 0.28"                                            |  |    |
| Skirt Thickness                                 | 0.25"                                            |  |    |
| Leg <sub>41</sub>                               | 0.25"                                            |  |    |
| Leg <sub>43</sub>                               | 0"                                               |  |    |
| External Projection Available, L <sub>pr1</sub> | 1"                                               |  |    |
| Internal Projection, L <sub>pr2</sub>           | 1"                                               |  |    |
| Corrosion                                       | Inner                                            |  | 0" |
|                                                 | Outer                                            |  | 0" |

| Skirt Opening Reinforcement Summary |        |             |                                     |                             |                             |          |        |
|-------------------------------------|--------|-------------|-------------------------------------|-----------------------------|-----------------------------|----------|--------|
|                                     |        |             | Required Thickness<br>$t_r$<br>(in) | $A_T$<br>(in <sup>2</sup> ) | $A_r$<br>(in <sup>2</sup> ) | Ratio    | Status |
| Operating Hot & Corroded            | Weight | Tensile     | 0                                   | 2.0152                      | 0                           | N/A      | OK     |
|                                     |        | Compressive | 0.0025                              | 2.0059                      | 0.0152                      | 131.7589 | OK     |
| Empty Cold & Corroded               | Weight | Tensile     | 0                                   | 2.0152                      | 0                           | N/A      | OK     |
|                                     |        | Compressive | 0.002                               | 2.0077                      | 0.0123                      | 163.6917 | OK     |

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