

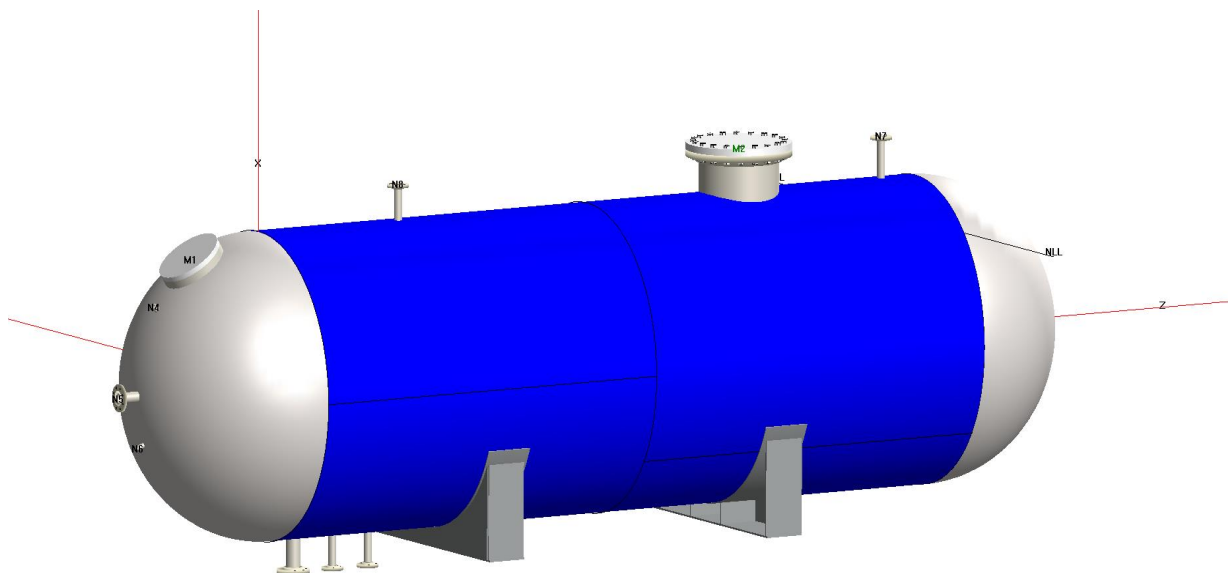
# INSPECTRA S.R.L.

Calle Sandía 2500

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Santa Cruz de la Sierra

Bolivia



## N. Trabajo 116-18-T-C

**Vessel N°** GLP-V-09

**Número Documento** MC-V-09/01

**Revisión:** 0

**Cliente:** YPFB TRANSPORTE S.A.

**Diseñado por:** Ingeniería Inspectra S.R.L.

**Fecha:** jueves, abril 04, 2019

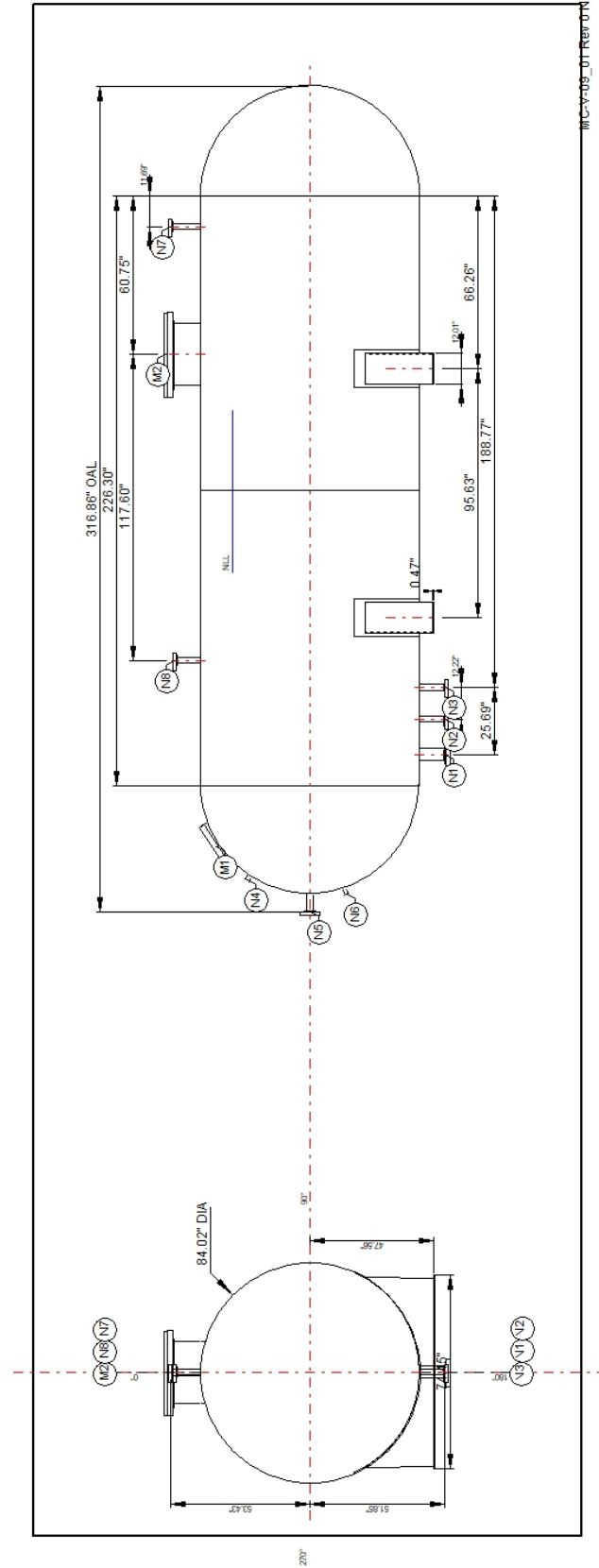
Con Nueva Entrada de Hombre de 24" estándar  
Con todas las boquillas mayores a 3/4" con tubo Sch 80 y Bridas SORF  
Con cambio de  $\varnothing$  3" a  $\varnothing$  4" en la entrada de producto

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MC-V09\_01 Rev D11N CW7

## Deficiencies Summary

### Deficiencies for [C-01](#)

The nominal thickness (0.328") is less than the design thickness (0.3285").

### Deficiencies for [C-02](#)

The nominal thickness (0.328") is less than the design thickness (0.3285").

### Deficiencies for [Entrada de Inspección \(M1\)](#)

UG-37: Not adequately reinforced (Chamber MAWP)

The inner fillet weld ( $Leg_{41} = 0.315$  in) is less than the minimum of 0.328 in.

SA-105: PWHT is mandatory for thicknesses over 1.25 in. (nozzle circumferential seam).

### Deficiencies for [PT \(Cuna 1 y 2\)](#)

The base plate thickness is not adequate.

Anchor bolting is not adequate.

### Deficiencies for [V-01](#)

The nominal thickness (0.573") is less than the design thickness (0.5741").

### Deficiencies for [V-02](#)

The nominal thickness (0.573") is less than the design thickness (0.5741").

### Deficiencies for [Welded Cover #1](#)

Figure UW-13.2: Weld bevel depth ( $b = 1.2016$  in) is less than minimum of 2.3425 in.

The flat head thickness (1.4516") is not sufficient to accommodate the minimum weld bevel  $b$  (2.3425") plus the minimum  $t_p$  (0.25").

SA-105: PWHT is mandatory for thicknesses over 1.25 in.

## Nozzle Schedule

| Specifications     |                                 |  |              |                    |               |            |            |                             |                       |
|--------------------|---------------------------------|--|--------------|--------------------|---------------|------------|------------|-----------------------------|-----------------------|
| Nozzle mark        | Identifier                      | Size   | Materials    |                    | Impact Tested | Normalized | Fine Grain | Flange                      | Blind                 |
| <a href="#">M1</a> | Entrada de Inspección           | 19.685 OD x 2.3425                           | Nozzle       | SA-105             | No            | No         | No         | N/A                         | No                    |
|                    | <a href="#">Welded Cover #1</a> | ID = 15" x Thk = 1.4516"                     | Welded Cover | SA-105             | No            | No         | No         | N/A                         | N/A                   |
| <a href="#">M2</a> | Entrada Hombre                  | NPS 24 Sch 20 (Std)                          | Nozzle       | SA-106 B Smls pipe | No            | No         | No         | NPS 24 Class 150 SO A105    | NPS 24 Class 150 A105 |
|                    |                                 |  | Pad          | SA-516 70          | No            | No         | No         |                             |                       |
| <a href="#">N1</a> | Entrada PVT                     | NPS 4 Sch 80 (XS)                            | Nozzle       | SA-106 B Smls pipe | No            | No         | No         | NPS 4 Class 300 SO A105     | No                    |
|                    |                                 |  | Pad          | SA-516 70          | No            | No         | No         |                             |                       |
| <a href="#">N2</a> | Salida                          | NPS 2 Sch 80 (XS)                            | Nozzle       | SA-106 B Smls pipe | No            | No         | No         | NPS 2 Class 300 SO A105     | No                    |
| <a href="#">N3</a> | Compensación                    | NPS 2 Sch 80 (XS)                            | Nozzle       | SA-106 B Smls pipe | No            | No         | No         | NPS 2 Class 300 SO A105     | No                    |
| <a href="#">N4</a> | Indicador de Presión            | NPS 0.75 Class 6000 - Threaded Full Coupling | Nozzle       | SA-105             | No            | No         | No         | N/A                         | No                    |
| <a href="#">N5</a> | Indicador de Nivel              | NPS 2.5 Sch 80 (XS)                          | Nozzle       | SA-106 B Smls pipe | No            | No         | No         | NPS 2 1/2 Class 300 SO A105 | No                    |
| <a href="#">N6</a> | Indicador de Temperatura        | NPS 0.75 Class 3000 - Threaded Full Coupling | Nozzle       | SA-105             | No            | No         | No         | N/A                         | No                    |
| <a href="#">N7</a> | Alivio de presión               | NPS 2 Sch 80 (XS)                            | Nozzle       | SA-106 B Smls pipe | No            | No         | No         | NPS 2 Class 300 SO A105     | No                    |
| <a href="#">N8</a> | Alivio de presión               | NPS 2 Sch 80 (XS)                            | Nozzle       | SA-106 B Smls pipe | No            | No         | No         | NPS 2 Class 300 SO A105     | No                    |

## 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="#">M1</a>                    | 19.685  | 2.3425              | 0.2773                  | Yes              | Yes              | 0.328*     | 0.2773        |             | N/A               | N/A                   | 0         | 100.0                              |
| <a href="#">M2</a>                    | 24      | 0.375               | 0.375                   | Yes              | Yes              | 0.573      | 0.573         |             | 11.0315           | 0.75                  | 0         | 123.3                              |
| <a href="#">N1</a>                    | 4.5     | 0.337               | 0.237                   | Yes              | Yes              | 0.573      | 0.573         |             | 1.6476            | 0.75                  | 0         | 136.7                              |
| <a href="#">N2</a>                    | 2.375   | 0.218               | 0.154                   | Yes              | Yes              | 0.573      | N/A           |             | N/A               | N/A                   | 0         | Exempt                             |
| <a href="#">N3</a>                    | 2.375   | 0.218               | 0.154                   | Yes              | Yes              | 0.573      | N/A           |             | N/A               | N/A                   | 0         | Exempt                             |
| <a href="#">N4</a>                    | 1.75    | 0.345               | 0.0625                  | Yes              | Yes              | 0.328*     | N/A           |             | N/A               | N/A                   | 0         | Exempt                             |
| <a href="#">N5</a>                    | 2.875   | 0.276               | 0.203                   | Yes              | Yes              | 0.328*     | N/A           |             | N/A               | N/A                   | 0         | Exempt                             |
| <a href="#">N6</a>                    | 1.38    | 0.16                | 0.0625                  | Yes              | Yes              | 0.328*     | N/A           |             | N/A               | N/A                   | 0         | Exempt                             |
| <a href="#">N7</a>                    | 2.375   | 0.218               | 0.154                   | Yes              | Yes              | 0.573      | N/A           |             | N/A               | N/A                   | 0         | Exempt                             |
| <a href="#">N8</a>                    | 2.375   | 0.218               | 0.154                   | Yes              | Yes              | 0.573      | N/A           |             | N/A               | N/A                   | 0         | Exempt                             |
| *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="#">C-01</a>                          | 250                  | 125                 | 249.66        | -20          | Note 1            |        | No               |
| <a href="#">V-01</a>                          | 250                  | 125                 | 249.54        | 38.01        | Note 2            |        | No               |
| <a href="#">V-02</a>                          | 250                  | 125                 | 249.54        | 38.01        | Note 2            |        | No               |
| <a href="#">C-02</a>                          | 250                  | 125                 | 249.66        | -20          | Note 1            |        | No               |
| <a href="#">PT (Cuna 1 y 2)</a>               | 250                  | 125                 | 249.48        | N/A          | N/A               |        | N/A              |
| <a href="#">Entrada de Inspección (M1)</a>    | 250                  | 125                 | 249.48        | -150         | Note 3            |        | No               |
| <a href="#">Welded Cover #1</a>               | 250                  | 125                 | 496.62        | -9.75        | Note 4            |        | No               |
| <a href="#">Entrada Hombre (M2)</a>           | 250                  | 125                 | 250.98        | -20          | Nozzle            | Note 5 | No               |
|   |                      |                     |               |              | Pad               | Note 6 | No               |
| <a href="#">Entrada PVT (N1)</a>              | 250                  | 125                 | 249.53        | -20          | Nozzle            | Note 7 | No               |
|   |                      |                     |               |              | Pad               | Note 6 | No               |
| <a href="#">Salida (N2)</a>                   | 250                  | 125                 | 249.53        | -20          | Note 8            |        | No               |
| <a href="#">Compensación (N3)</a>             | 250                  | 125                 | 249.53        | -20          | Note 8            |        | No               |
| <a href="#">Indicador de Presión (N4)</a>     | 250                  | 125                 | 295.29        | -150         | Note 9            |        | No               |
| <a href="#">Indicador de Nivel (N5)</a>       | 250                  | 125                 | 294.83        | -20          | Note 8            |        | No               |
| <a href="#">Indicador de Temperatura (N6)</a> | 250                  | 125                 | 294.56        | -150         | Note 10           |        | No               |
| <a href="#">Alivio de presión (N7)</a>        | 250                  | 125                 | 250.98        | -20          | Note 8            |        | No               |
| <a href="#">Alivio de presión (N8)</a>        | 250                  | 125                 | 250.98        | -20          | Note 8            |        | No               |

| Chamber Summary  |                       |
|--|-----------------------|
| Design MDMT  | 38 °F                 |
| Rated MDMT   | 38.01 °F @ 249.48 psi |
| MAWP hot & corroded  | 249.48 psi @ 125 °F   |
| (1) 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.                    | Material is impact test exempt per UG-20(f)  | UCS-66 governing thickness = 0.328 in   |
| 2.                    | Material impact test exemption temperature from Fig UCS-66 Curve A = 38.01 °F  | UCS-66 governing thickness = 0.573 in   |
| 3.                    | Nozzle is impact test exempt to -150 °F per UCS-66(b)(3) (coincident ratio = 0.046).   |   |
| 4.                    | Head impact test exemption temperature from Fig UCS-66 Curve B = 49.45 °F<br>Fig UCS-66.1 MDMT reduction = 59.2 °F, (coincident ratio = 0.5024)  | UCS-66 governing thickness = 1.4516 in  |
| 5.                    | Nozzle impact test exemption temperature from Fig UCS-66 Curve B = -20 °F<br>Fig UCS-66.1 MDMT reduction = 40.3 °F, (coincident ratio = 0.5952)<br>Rated MDMT of -60.3 °F is limited to -50 °F by UCS-66(b)(2) | UCS-66 governing thickness = 0.3281 in. |
| 6.                    | Pad is impact test exempt per UG-20(f)   | UCS-66 governing thickness = 0.573 in.  |
| 7.                    | Nozzle is impact test exempt to -150 °F per UCS-66(b)(3) (coincident ratio = 0.1096).  |   |
| 8.                    | Flange rating governs:<br>Flange rated MDMT per UCS-66(c) = -20 °F<br>Bolts rated MDMT per Fig UCS-66 note (e) = -40 °F  |   |
| 9.                    | Nozzle is impact test exempt to -150 °F per UCS-66(b)(3) (coincident ratio = 0.0221).  |   |
| 10.                   | Nozzle is impact test exempt to -150 °F per UCS-66(b)(3) (coincident ratio = 0.0478).  |   |

### Revision History

| Revisions |           |          |   |
|-----------|-----------|----------|---|
| No.       | Date      | Operator | Notes   |
| 0         | 2/ 8/2019 | Antonio  | New vessel created ASME Section VIII Division 1 [INSPECT 2019 Build 7900]   |
| 1         | 3/28/2019 | Antonio  | Converted from ASME Section VIII Division 1, 2017 Edition to ASME Section VIII Division 1, 1995 Edition. During the conversion, changes may have been made to your vessel (some may be listed above). Please check your vessel carefully. |

## Settings Summary

| INSPECT 2019 Build 7900  |                                  |
|--|----------------------------------|
| ASME Section VIII Division 1, 1995 Edition                         |                                  |
| Units  | U.S. Customary                   |
| Datum Line Location  | 0.00" from left seam             |
| Vessel Design Mode   | Rating Mode (Analysis)           |
| 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   | 250 psi                          |
| Design nozzles for   | Chamber MAWP                     |
| Corrosion weight loss  | 100% of theoretical loss         |
| UG-23 Stress Increase  | 1.20                             |
| Skirt/legs stress increase   | 1.0                              |
| Minimum nozzle projection  | 0.25"                            |
| 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               | No                               |
| 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  | 1.5 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  | RT4                              |
| UG-116(f) Postweld heat treatment                                  | None                             |
| Code Cases\Interpretations   |                                  |
| Use Code Case 2901   | No                               |
| Apply interpretation VIII-1-83-66                                  | No                               |
| Apply interpretation VIII-1-86-175                                 | No                               |

|   |     |
|---|-----|
| Apply interpretation VIII-1-83-115  | No  |
| Use Code Case 2236 if opening fails 1-7(b)  | No  |
| Apply interpretation VIII-1-01-37   | No  |
| Apply interpretation VIII-1-04-08   | No  |
| Apply interpretation VIII-1-01-150  | No  |
| 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  |
| Note: UG-22(b),(c) and (f) loads only considered when supports are present.               |     |

| License Information |                  |
|---------------------|------------------|
| Company Name        | Inspectra S.r.l. |
| License             | Enterprise       |
| License Key ID      | 38243            |
| Support Expires     | October 15, 2019 |

## Radiography Summary

| UG-116 Radiography  |                     |                          |                                       |                          |                                       |                          |      |
|---|---------------------|--------------------------|---------------------------------------|--------------------------|---------------------------------------|--------------------------|------|
| Component   | Longitudinal Seam   |                          | Left Circumferential Seam             |                          | Right Circumferential Seam            |                          | Mark |
|   | Category (Fig UW-3) | Radiography / Joint Type | Category (Fig UW-3)                   | Radiography / Joint Type | Category (Fig UW-3)                   | Radiography / Joint Type |      |
| <a href="#">C-01</a>  | A                   | Spot UW-11(b) / Type 1   | N/A                                   | N/A                      | A                                     | Full UW-11(a) / Type 1   | RT4  |
| <a href="#">Welded Cover #1</a>   | N/A                 | Seamless No RT           | N/A                                   | N/A                      | N/A                                   | N/A                      | N/A  |
| <a href="#">V-01</a>  | A                   | Full UW-11(a) / Type 1   | A                                     | Full UW-11(a) / Type 1   | B                                     | Full UW-11(a) / Type 1   | RT1  |
| <a href="#">V-02</a>  | A                   | Full UW-11(a) / Type 1   | B                                     | Full UW-11(a) / Type 1   | A                                     | Full UW-11(a) / Type 1   | RT1  |
| <a href="#">C-02</a>  | A                   | Spot UW-11(b) / Type 1   | A                                     | Full UW-11(a) / Type 1   | N/A                                   | N/A                      | RT4  |
| Nozzle  | Longitudinal Seam   |                          | Nozzle to Vessel Circumferential Seam |                          | Nozzle free end Circumferential Seam  |                          |      |
| <a href="#">Entrada de Inspección (M1)</a>                                  | N/A                 | Seamless No RT           | D                                     | N/A / Type 7             | B                                     | N/A                      | N/A  |
| <a href="#">Indicador de Presión (N4)</a>                                   | N/A                 | Seamless No RT           | D                                     | N/A / Type 7             | N/A                                   | N/A                      | N/A  |
| <a href="#">Indicador de Nivel (N5)</a>                                     | N/A                 | Seamless No RT           | D                                     | N/A / Type 7             | C                                     | N/A                      | N/A  |
| <a href="#">Indicador de Temperatura (N6)</a>                               | N/A                 | Seamless No RT           | D                                     | N/A / Type 7             | N/A                                   | N/A                      | N/A  |
| <a href="#">Compensación (N3)</a>   | N/A                 | Seamless No RT           | D                                     | N/A / Type 7             | C                                     | N/A                      | N/A  |
| <a href="#">Alivio de presión (N8)</a>                                      | N/A                 | Seamless No RT           | D                                     | N/A / Type 7             | C                                     | N/A                      | N/A  |
| <a href="#">Entrada PVT (N1)</a>  | N/A                 | Seamless No RT           | D                                     | N/A / Type 7             | C                                     | N/A                      | N/A  |
| <a href="#">Salida (N2)</a>   | N/A                 | Seamless No RT           | D                                     | N/A / Type 7             | C                                     | N/A                      | N/A  |
| <a href="#">Alivio de presión (N7)</a>                                      | N/A                 | Seamless No RT           | D                                     | N/A / Type 7             | C                                     | N/A                      | N/A  |
| <a href="#">Entrada Hombre (M2)</a>   | N/A                 | Seamless No RT           | D                                     | N/A / Type 7             | C                                     | N/A                      | N/A  |
| Nozzle Flange   | Longitudinal Seam   |                          | Flange Face                           |                          | Nozzle to Flange Circumferential Seam |                          |      |
| <a href="#">ASME B16.5/16.47 flange attached to Indicador de Nivel (N5)</a> | N/A                 | Seamless No RT           | N/A                                   | N/A / Gasketed           | C                                     | N/A                      | N/A  |
| <a href="#">ASME B16.5/16.47 flange attached to Compensación (N3)</a>       | N/A                 | Seamless No RT           | N/A                                   | N/A / Gasketed           | C                                     | N/A                      | N/A  |
| <a href="#">ASME B16.5/16.47 flange attached to Alivio de presión (N8)</a>  | N/A                 | Seamless No RT           | N/A                                   | N/A / Gasketed           | C                                     | N/A                      | N/A  |
| <a href="#">ASME B16.5/16.47 flange attached to Entrada PVT (N1)</a>        | N/A                 | Seamless No RT           | N/A                                   | N/A / Gasketed           | C                                     | N/A                      | N/A  |
| <a href="#">ASME B16.5/16.47 flange attached to Salida (N2)</a>             | N/A                 | Seamless No RT           | N/A                                   | N/A / Gasketed           | C                                     | N/A                      | N/A  |
| <a href="#">ASME B16.5/16.47 flange attached to Alivio de presión (N7)</a>  | N/A                 | Seamless No RT           | N/A                                   | N/A / Gasketed           | C                                     | N/A                      | N/A  |
| <a href="#">ASME B16.5/16.47 flange attached to Entrada Hombre (M2)</a>     | N/A                 | Seamless No RT           | N/A                                   | N/A / Gasketed           | C                                     | N/A                      | N/A  |
| UG-116(e) Required Marking: <b>RT4</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="#">C-01</a>                  | SA-455 <= 3/8            | 84.0157 OD    | 42.0079     | 0.328*         | 0.3285        | 0                    | 0.85    | Internal |
| <a href="#">V-01</a>                  | SA-455 ( 3/8 < t <= 5/8) | 84.0157 OD    | 113.1496    | 0.573          | 0.5741        | 0                    | 1.00    | Internal |
| <a href="#">V-02</a>                  | SA-455 ( 3/8 < t <= 5/8) | 84.0157 OD    | 113.1496    | 0.573          | 0.5741        | 0                    | 1.00    | Internal |
| <a href="#">C-02</a>                  | SA-455 <= 3/8            | 84.0157 OD    | 42.0079     | 0.328*         | 0.3285        | 0                    | 0.85    | Internal |
| <a href="#">Welded Cover #1</a>       | SA-105                   | 15 ID         | 1.4516      | 1.4516         | 1.0299        | 0                    | 1.00    | Internal |
| *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="#">C-01</a>                       | 992             | 992             | 0          | 0                   | 0        | 0               | 2,906.6          | 2,906.6         | 5,482           | 5,482           | 75                           |
| <a href="#">V-01</a>                       | 4,805.1         | 4,805.1         | 0          | 0                   | 0        | 0               | 11,321.6         | 11,321.6        | 22,036.7        | 22,036.7        | 207                          |
| <a href="#">V-02</a>                       | 4,735.8         | 4,735.8         | 0          | 0                   | 0        | 0               | 11,318.2         | 11,318.2        | 22,200.1        | 22,200.1        | 204                          |
| <a href="#">C-02</a>                       | 1,021.2         | 1,021.2         | 0          | 0                   | 0        | 0               | 2,906            | 2,906           | 5,474.1         | 5,474.1         | 77                           |
| <a href="#">PT (Cuna 1 y 2)</a>            | 886             | 886             | 0          | 0                   | 0        | 0               | 0                | 0               | 0               | 0               | 77                           |
| <b>TOTAL:</b>                              | <b>12,440.1</b> | <b>12,440.1</b> | <b>0</b>   | <b>0</b>            | <b>0</b> | <b>0</b>        | <b>28,452.4</b>  | <b>28,452.4</b> | <b>55,192.8</b> | <b>55,192.8</b> | <b>641</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 | Trays    | Tray Supports | Rings & Clips | Vertical Loads | Surface Area ft <sup>2</sup> |
|  | New          | Corroded | New               | Corroded       |             |          |               |               |                |                              |
| <a href="#">C-01</a>                   | 0            | 0        | 233.6             | 233.6          | 0           | 0        | 0             | 0             | 0              | 4                            |
| <a href="#">V-01</a>                   | 0            | 0        | 75.2              | 75.2           | 0           | 0        | 0             | 0             | 0              | 3                            |
| <a href="#">V-02</a>                   | 0            | 0        | 1,075.1           | 1,075.1        | 0           | 0        | 0             | 0             | 0              | 16                           |
| <a href="#">C-02</a>                   | 0            | 0        | 0                 | 0              | 0           | 0        | 0             | 0             | 0              | 0                            |
| <b>TOTAL:</b>                          | <b>0</b>     | <b>0</b> | <b>1,383.9</b>    | <b>1,383.9</b> | <b>0</b>    | <b>0</b> | <b>0</b>      | <b>0</b>      | <b>0</b>       | <b>23</b>                    |

| Vessel Totals   |        |          |
|---|--------|----------|
|   | New    | Corroded |
| Operating Weight (lb)   | 42,276 | 42,276   |
| Empty Weight (lb)   | 13,824 | 13,824   |
| Test Weight (lb)  | 69,017 | 69,017   |
| Surface Area (ft <sup>2</sup> )   | 664    | -        |
| Capacity** (US gal)   | 6,597  | 6,597    |
| **The vessel capacity does not include volume of nozzle, piping or other attachments. |        |          |

| Vessel Lift Condition             |          |
|-----------------------------------|----------|
| Vessel Lift Weight, New (lb)      | 13,824   |
| Center of Gravity from Datum (in) | 114.3136 |

## Long Seam Summary

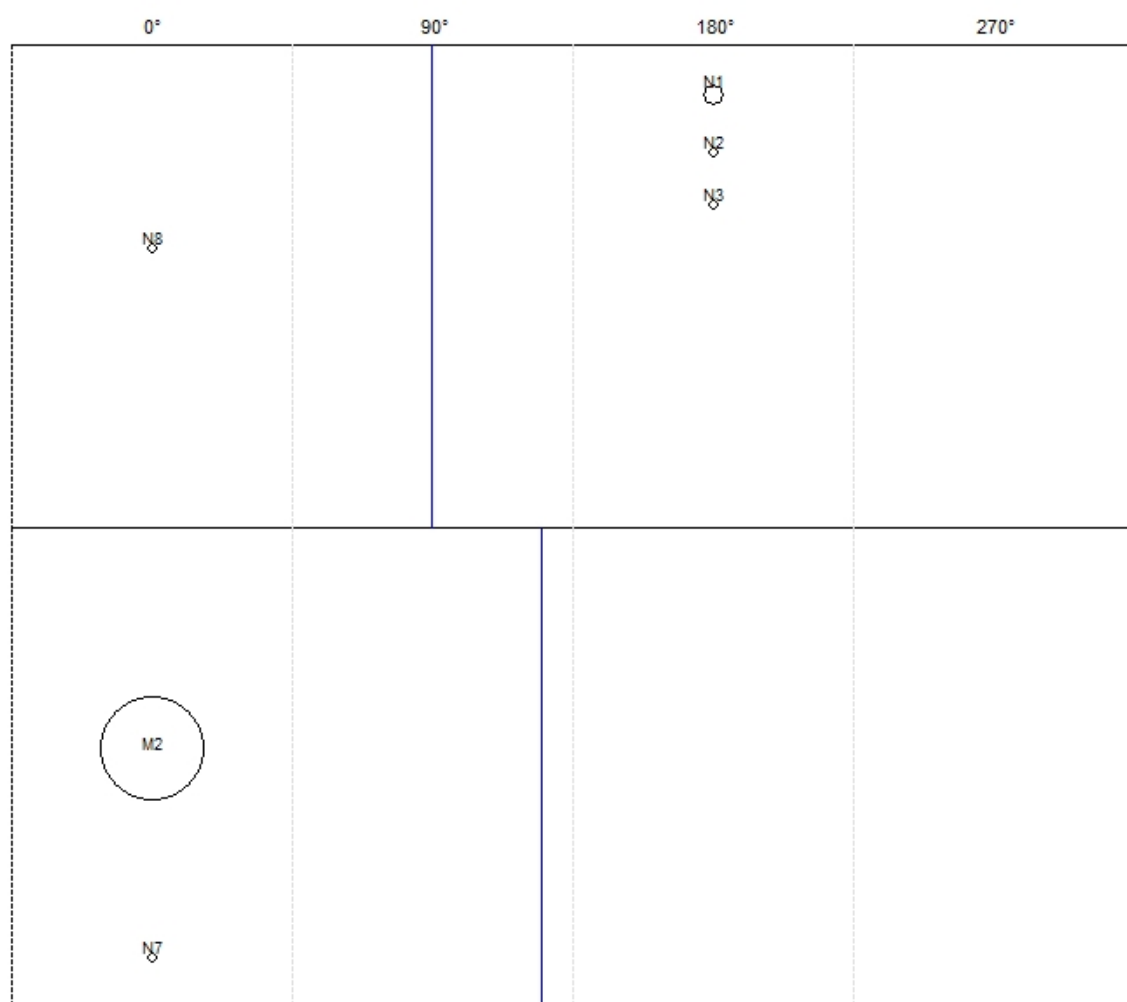
| Shell Long Seam Angles |         |
|------------------------|---------|
| Component              | Seam 1  |
| <a href="#">V-01</a>   | 90 deg  |
| <a href="#">V-02</a>   | 125 deg |

| Shell Plate Lengths  |                |           |
|----------------------|----------------|-----------|
| Component            | Starting Angle | Plate 1   |
| <a href="#">V-01</a> | 90 deg         | 262.1431" |
| <a href="#">V-02</a> | 125 deg        | 262.1431" |

### Note

1) Plate Lengths use the circumference of the vessel based on the mid diameter of the components.





Shell Rollout

## Hydrostatic Test

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

$$\begin{aligned}
 \text{Gauge pressure at } 70^{\circ}\text{F} &= \\
 &= 1.5 \cdot \text{MAWP} \cdot \text{LSR} \\
 &= 1.5 \cdot 249.48 \cdot 1 \\
 &= 374.22 \text{ psi}
 \end{aligned}$$

| Horizontal shop hydrostatic test  |                           |                               |                       |                          |
|---|---------------------------|-------------------------------|-----------------------|--------------------------|
| Identifier  | Local test pressure (psi) | Test liquid static head (psi) | UG-99(b) stress ratio | UG-99(b) pressure factor |
| C-01 (1)  | 377.656                   | 3.433                         | 1                     | 1.50                     |
| V-01  | 377.647                   | 3.424                         | 1                     | 1.50                     |
| V-02  | 377.647                   | 3.424                         | 1                     | 1.50                     |
| C-02  | 377.656                   | 3.433                         | 1                     | 1.50                     |
| Welded Cover #1   | 374.849                   | 0.627                         | 1                     | 1.50                     |
| Alivio de presión (N7)  | 374.635                   | 0.412                         | 1                     | 1.50                     |
| Alivio de presión (N8)  | 374.635                   | 0.412                         | 1                     | 1.50                     |
| Compensación (N3)   | 378.023                   | 3.8                           | 1                     | 1.50                     |
| Entrada Hombre (M2)   | 374.635                   | 0.412                         | 1                     | 1.50                     |
| Entrada PVT (N1)  | 378.023                   | 3.8                           | 1                     | 1.50                     |
| Entrada de Inspección (M1)  | 374.882                   | 0.66                          | 1                     | 1.50                     |
| Indicador de Nivel (N5)   | 376.193                   | 1.971                         | 1                     | 1.50                     |
| Indicador de Presión (N4)   | 375.313                   | 1.09                          | 1                     | 1.50                     |
| Indicador de Temperatura (N6)   | 376.658                   | 2.435                         | 1                     | 1.50                     |
| Salida (N2)   | 378.023                   | 3.8                           | 1                     | 1.50                     |
| (1) C-01 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.

The test temperature of 70 °F is warmer than the minimum recommended temperature of 68.01 °F so the brittle fracture provision of UG-99(h) has been met.

## **Engineering Notes**

1. Dado que la entrada de hombre no es de tamaño estandar, se ha modelado con un cuello de las mismas dimensiones de la instalada y una tapa soldada con aceros SA-105. El software no acepta tapas tipo studbolt noestandar, debido a es esto se presentan los errores en la lista de deficiencias en el Welded Cover # 1.
2. No es posible con el software espaciar los refuerzos de las cunas de forma que no sea regular.
3. No es posible modelar placas de soporte que no sean rectangulares con el software.
4. La deficiencia que se presenta sobre la entrada de inspección M1 donde obliga realizar PWHT, no es válido dado que se ha colocado esta entrada de inspección hecha de tubo, manulamente, porque las dimensiones no son estándar, y este tipo de accesorios forjados se fabrican sin costura.
5. Debe reforzarse la placa base de las cunas y la placa de refuerzo.

## Bill of Materials

| Heads / Covers |  |               |              |            |                |     |
|----------------|--|---------------|--------------|------------|----------------|-----|
| Item #         | Type                                     | Material      | Thk [in]     | Dia. [in]  | Wt. [lb] (ea.) | Qty |
| H1             | Hemi Head                                | SA-455 <= 3/8 | 0.328 (min.) | 84.0157 OD | 1,021.2        | 2   |
| H2             | Welded Cover                             | SA-105        | 1.4516       | 15 ID      | 125            | 1   |
| H3             | ASME B16.5/B16.47 Blind NPS 24 Class 150 | A105          | 1.88         | 32 OD      | 480            | 1   |

| Shells |          |                          |          |            |             |                |     |
|--------|----------|--------------------------|----------|------------|-------------|----------------|-----|
| Item # | Type     | Material                 | Thk [in] | Dia. [in]  | Length [in] | Wt. [lb] (ea.) | Qty |
| S1     | Cylinder | SA-455 ( 3/8 < t <= 5/8) | 0.573    | 84.0157 OD | 113.1       | 4,809.9        | 2   |

| Nozzles |        |                    |                     |          |           |             |          |
|---------|--------|--------------------|---------------------|----------|-----------|-------------|----------|
| Item #  | Type   | Material           | NPS                 | Thk [in] | Dia. [in] | Length [in] | Wt. [lb] |
| Noz1    | Nozzle | SA-105             | -                   | 2.3425   | 19.685 OD | 2.6         | 93.1     |
| Noz2    | Nozzle | SA-106 B Smls pipe | NPS 2.5 Sch 80 (XS) | 0.276    | 2.875 OD  | 6.6         | 4.2      |
| Noz3    | Nozzle | SA-106 B Smls pipe | NPS 2 Sch 80 (XS)   | 0.218    | 2.375 OD  | 42.4        | 17.7     |
| Noz4    | Nozzle | SA-106 B Smls pipe | NPS 4 Sch 80 (XS)   | 0.337    | 4.5 OD    | 10.1        | 19.4     |
| Noz5    | Nozzle | SA-106 B Smls pipe | NPS 24 Sch 20 (Std) | 0.375    | 24 OD     | 13.4        | 363.2    |

| Nozzles - Couplings |  |          |           |             |     |
|---------------------|--|----------|-----------|-------------|-----|
| Item #              | Type   | Material | Dia. [in] | Length [in] | Qty |
| C1                  | NPS 0.75 Class 6000 - Threaded Full Coupling | SA-105   | 1.75 OD   | 2           | 1   |
| C2                  | NPS 0.75 Class 3000 - Threaded Full Coupling | SA-105   | 1.38 OD   | 2.3576      | 1   |

| Flanges |                                |          |     |            |                |     |
|---------|--------------------------------|----------|-----|------------|----------------|-----|
| Item #  | Type                           | Material | NPS | Dia. [in]  | Wt. [lb] (ea.) | Qty |
| AF1     | ASME B16.5 Slip On - Class 300 | A105     | 2.5 | 7.5 x 2.94 | 10             | 1   |
| AF2     | ASME B16.5 Slip On - Class 300 | A105     | 2.0 | 6.5 x 2.44 | 7              | 4   |
| AF3     | ASME B16.5 Slip On - Class 300 | A105     | 4   | 10 x 4.57  | 22             | 1   |
| AF4     | ASME B16.5 Slip On - Class 150 | A105     | 24  | 32 x 24.25 | 220            | 1   |

| Fasteners |                      |                         |             |     |
|-----------|----------------------|-------------------------|-------------|-----|
| Item #    | Description          | Material                | Length [in] | Qty |
| FB1       | 3/4" coarse bolt     | SA-193 B7 Bolt <= 2 1/2 | 3.3         | 8   |
| FB2       | 5/8" coarse bolt     | SA-193 B7 Bolt <= 2 1/2 | 3           | 32  |
| FB3       | 3/4" coarse bolt     | SA-193 B7 Bolt <= 2 1/2 | 3.8         | 8   |
| FB4       | 1-1/4" series 8 bolt | SA-193 B7 Bolt <= 2 1/2 | 5.8         | 20  |
| SB1       | 5/8" coarse bolt     | SA-193 B8               | -           | 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 [ ft^2] |
| Plate1  | SA-516 70 | 0.75     | 485.1    | 11.9        |
| Plate1 - Note: Applies to nozzle pad                          |           |          |          |             |
| Plate2  | A283 GR C | 0.2756   | 214.6    | 19.17       |
| Plate2 - Note: Applies to saddle wear plate                   |           |          |          |             |
| Plate3  | A283 GR C | 0.4724   | 670.7    | 34.84       |
| Plate3 - Note: Applies to saddle base plate, saddle web plate |           |          |          |             |

**Liquid Level bounded by C-02**

| ASME Section VIII Division 1, 1995 Edition |         |
|--|---------|
| Location from Center Line (in)             | 29.7507 |
| Operating Liquid Specific Gravity          | 0.5621  |

| ASME Section VIII Division 1, 1995 Edition |            |                                    |                         |                           |
|--|------------|------------------------------------|-------------------------|---------------------------|
| Component                                  |            | Hemispherical Head                 |                         |                           |
| Material                                   |            | SA-455 <= 3/8 (II-D p. 22, ln. 21) |                         |                           |
| Attached To                                |            | V-01                               |                         |                           |
| 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                                   |            | 250                                | 125                     | 38                        |
| Static Liquid Head                         |            |                                    |                         |                           |
| Condition                                  |            | P <sub>s</sub> (psi)               | H <sub>s</sub> (in)     | SG                        |
| Operating                                  |            | 1.45                               | 71.4306                 | 0.5621                    |
| Test horizontal                            |            | 3.43                               | 95.1077                 | 1                         |
| Dimensions                                 |            |                                    |                         |                           |
| Outer Diameter                             |            | 84.0157"                           |                         |                           |
| Minimum Thickness                          |            | 0.328"                             |                         |                           |
| Corrosion                                  | Inner      | 0"                                 |                         |                           |
|  | Outer      | 0"                                 |                         |                           |
| Weight and Capacity                        |            |                                    |                         |                           |
|  |            | Weight (lb)                        |                         | Capacity (US gal)         |
| New  |            | 991.97                             |                         | 656.49                    |
| Corroded                                   |            | 991.97                             |                         | 656.49                    |
| Radiography                                |            |                                    |                         |                           |
| Category A joints - Long Seam              |            | Spot UW-11(b) Type 1               |                         |                           |
| Category A joints - Circ Seam              |            | Full UW-11(a) 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="#">0.3285"</a>    |
| Maximum allowable working pressure (MAWP)     | <a href="#">249.66 psi</a> |
| Rated MDMT                                    | -20 °F                     |

| UCS-66 Material Toughness Requirements   |        |
|--|--------|
| Governing thickness, $t_g =$   | 0.328" |
| MDMT =   | -20 °F |
| Material is exempt from impact testing per UG-20(f) at the Design MDMT of 38 °F. |        |

#### Design thickness, (at 125 °F) Appendix 1-1

$$\begin{aligned}
 t &= P \cdot R_o / (2 \cdot S \cdot E + 0.80 \cdot P) + \text{Corrosion} \\
 &= 251.45 \cdot 42.0079 / (2 \cdot 18,800 \cdot 0.85 + 0.80 \cdot 251.45) + 0 \\
 &= \underline{0.3285"}
 \end{aligned}$$

#### Maximum allowable working pressure, (at 125 °F) Appendix 1-1

$$\begin{aligned}
 P &= 2 \cdot S \cdot E \cdot t / (R_o - 0.80 \cdot t) - P_s \\
 &= 2 \cdot 18,800 \cdot 0.85 \cdot 0.328 / (42.0079 - 0.80 \cdot 0.328) - 1.45 \\
 &= \underline{249.66} \text{ psi}
 \end{aligned}$$

#### % Extreme fiber elongation - UCS-79(d)

$$\begin{aligned}
 \text{EFE} &= (75 \cdot t / R_f) \cdot (1 - R_f / R_o) \\
 &= (75 \cdot 0.328 / 41.8439) \cdot (1 - 41.8439 / \text{infinity}) \\
 &= 0.5879\%
 \end{aligned}$$

The extreme fiber elongation does not exceed 5%.

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

$$\begin{aligned}
 A &= 0.125 / (R_o / t) \\
 &= 0.125 / (42.0079 / 0.328) \\
 &= 0.000976 \\
 B &= 12,183 \text{ psi} \\
 S &= 18,800 / 1.00 = 18,800 \text{ psi} \\
 S_{cHC} &= \min(B, S) = 12,183 \text{ psi}
 \end{aligned}$$

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

$$\begin{aligned}
 S_{cHN} &= S_{cHC} \\
 &= 12,183 \text{ psi}
 \end{aligned}$$

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

$$\begin{aligned}
 A &= 0.125 / (R_o / t) \\
 &= 0.125 / (42.0079 / 0.328) \\
 &= 0.000976 \\
 B &= 12,183 \text{ psi} \\
 S &= 18,800 / 1.00 = 18,800 \text{ psi} \\
 S_{cCN} &= \min(B, S) = 12,183 \text{ psi}
 \end{aligned}$$



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

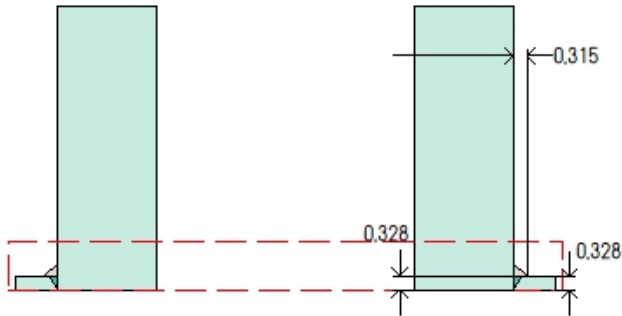
$$\begin{aligned} S_{cCC} &= S_{cCN} \\ &= 12,183 \text{ psi} \end{aligned}$$

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

$$\begin{aligned} A &= 0.125 / (R_o / t) \\ &= 0.125 / (42.0079 / 0.328) \\ &= 0.000976 \\ B &= 12,183 \text{ psi} \\ S &= 18,800 / 1.00 = 18,800 \text{ psi} \\ S_{cVC} &= \min(B, S) = 12,183 \text{ psi} \end{aligned}$$

# Entrada de Inspección (M1)

## ASME Section VIII Division 1, 1995 Edition



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

### Location and Orientation

|                                   |          |
|-----------------------------------|----------|
| Located on                        | C-01     |
| Orientation                       | 0°       |
| End of nozzle to datum line       | -23.583" |
| Calculated as hillside            | No       |
| Distance to head center, R        | 35.1575" |
| Passes through a Category A joint | No       |

### Nozzle

|  |                            |
|--|----------------------------|
| Access opening                           | No                         |
| Material specification                   | SA-105 (II-D p. 18, ln. 6) |
| Inside diameter, new                     | 15"                        |
| Nominal wall thickness                   | 2.3425"                    |
| Corrosion allowance                      | 0"                         |
| Projection available outside vessel, Lpr | 2.25"                      |
| Local vessel minimum thickness           | 0.328"                     |
| Liquid static head included              | 0 psi                      |
| Longitudinal joint efficiency            | 1                          |

### Welds

|                                 |        |
|---------------------------------|--------|
| Inner fillet, Leg <sub>41</sub> | 0.315" |
| Nozzle to vessel groove weld    | 0.328" |

| UCS-66 Material Toughness Requirements Nozzle                                  |         |
|--|---------|
| $t_r = 249.48 \times 7.5 / (17,500 \times 1 - 0.6 \times 249.48) =$            | 0.1078" |
| Stress ratio $= t_r \times E^* / (t_n - c) = 0.1078 \times 1 / (2.3425 - 0) =$ | 0.046   |
| Stress ratio $\leq 0.4$ , MDMT per UCS-66(b)(3) =                              | -150°F  |
| Material is exempt from impact testing at the Design MDMT of 38°F.             |         |

## Reinforcement Calculations for Chamber MAWP

| UG-37 Area Calculation Summary (in <sup>2</sup> )                              |                        |                        |                        |                |                |                        | UG-45 Summary (in)      |                  |
|--|------------------------|------------------------|------------------------|----------------|----------------|------------------------|-------------------------|------------------|
| For P = 249.54 psi @ 125 °F<br><i>The opening is NOT adequately reinforced</i> |                        |                        |                        |                |                |                        | 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> |
| <a href="#">4.2496</a>   | <a href="#">4.2476</a> | <a href="#">0.7438</a> | <a href="#">3.4115</a> | --             | --             | <a href="#">0.0923</a> | <a href="#">0.2773</a>  | 2.3425           |

| 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> ) | <a href="#">0.2296</a>         | 0.2205                       | weld size is NOT adequate |

Calculations for internal pressure 249.54 psi @ 125 °F

### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(15, 7.5 + (2.3425 - 0) + (0.328 - 0)) \\
 &= 15 \text{ in}
 \end{aligned}$$

### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.328 - 0), 2.5*(2.3425 - 0) + 0) \\
 &= 0.82 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_m &= P*R_n / (S_n*E - 0.6*P) \\
 &= 249.5425*7.5 / (17,500*1 - 0.6*249.5425) \\
 &= 0.1079 \text{ in}
 \end{aligned}$$

### Required thickness t<sub>r</sub> from UG-37(a)

$$\begin{aligned}
 t_r &= P*R_o / (2*S*E + 0.8*P) \\
 &= 249.5425*42.0079 / (2*18,800*1 + 0.8*249.5425) \\
 &= 0.2773 \text{ in}
 \end{aligned}$$

### Required thickness t<sub>r</sub> per Interpretation VIII-1-07-50

$$\begin{aligned}
 t_r &= P*R_o / (2*S*E + 0.8*P) \\
 &= 249.5425*42.0079 / (2*18,800*0.85 + 0.8*249.5425) \\
 &= 0.326 \text{ in}
 \end{aligned}$$

### Area required per UG-37(c)

Allowable stresses:  $S_n = 17,500$ ,  $S_v = 18,800$  psi

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.9309$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.9309$$

$$\begin{aligned} A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\ &= 15 \cdot 0.2773 \cdot 1 + 2 \cdot 2.3425 \cdot 0.2773 \cdot 1 \cdot (1 - 0.9309) \\ &= \underline{4.2496} \text{ in}^2 \end{aligned}$$

### Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{0.7438} \text{ in}^2$$

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 15 \cdot (1 \cdot 0.328 - 1 \cdot 0.2773) - 2 \cdot 2.3425 \cdot (1 \cdot 0.328 - 1 \cdot 0.2773) \cdot (1 - 0.9309) \\ &= 0.7438 \text{ in}^2 \\ &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2 \cdot (0.328 + 2.3425) \cdot (1 \cdot 0.328 - 1 \cdot 0.2773) - 2 \cdot 2.3425 \cdot (1 \cdot 0.328 - 1 \cdot 0.2773) \cdot (1 - 0.9309) \\ &= 0.2543 \text{ in}^2 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{3.4115} \text{ in}^2$$

$$\begin{aligned} &= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t \\ &= 5 \cdot (2.3425 - 0.1079) \cdot 0.9309 \cdot 0.328 \\ &= 3.4115 \text{ in}^2 \\ &= 2 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot L_{pr} \\ &= 2 \cdot (2.3425 - 0.1079) \cdot 0.9309 \cdot 2.25 \\ &= 9.361 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 \cdot f_{r2} \\ &= 0.315^2 \cdot 0.9309 \\ &= \underline{0.0923} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} \\ &= 0.7438 + 3.4115 + 0.0923 \\ &= \underline{4.2476} \text{ in}^2 \end{aligned}$$

**\*\* As Area < A the reinforcement is NOT adequate. \*\***

### UW-16(c) Weld Check

Fillet weld:  $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.328 \text{ in}$

$t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7 * t_{\min} = 0.2296 \text{ in}$

$t_{c(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 0.315 = 0.2205 \text{ in}$

**\*\* The fillet weld size IS NOT satisfactory. \*\***

### UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):  $t_{r1} = 0.1079 \text{ in (E = 1)}$

Wall thickness per UG-45(b)(1):  $t_{r2} = 0.2773 \text{ in}$

Wall thickness per UG-16(b):  $t_{r3} = 0.0625 \text{ in}$

Standard wall pipe per UG-45(b)(4):  $t_{r4} = 0.3281 \text{ in}$

The greater of  $t_{r2}$  or  $t_{r3}$ :  $t_{r5} = 0.2773 \text{ in}$

The lesser of  $t_{r4}$  or  $t_{r5}$ :  $t_{r6} = 0.2773 \text{ in}$

Required per UG-45 is the larger of  $t_{r1}$  or  $t_{r6} = 0.2773 \text{ in}$

Available nozzle wall thickness new,  $t_n = 2.3425 \text{ in}$

The nozzle neck thickness 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 = 249.48 psi @ 125 °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> |
| <a href="#">4.2487</a>  | <a href="#">4.2487</a> | <a href="#">0.7447</a> | <a href="#">3.4117</a> | --             | --             | <a href="#">0.0923</a> | <a href="#">0.2773</a>  | 2.3425           |

| 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> ) | <a href="#">0.2296</a>         | 0.2205                       | weld size is NOT adequate |

### Calculations for internal pressure 249.48 psi @ 125 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(15, 7.5 + (2.3425 - 0) + (0.328 - 0)) \\
 &= 15 \text{ in}
 \end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.328 - 0), 2.5*(2.3425 - 0) + 0) \\
 &= 0.82 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_{rn} &= P*R_n / (S_n*E - 0.6*P) \\
 &= 249.4816*7.5 / (17,500*1 - 0.6*249.4816) \\
 &= 0.1078 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> from UG-37(a)

$$\begin{aligned}
 t_r &= P*R_o / (2*S*E + 0.8*P) \\
 &= 249.4816*42.0079 / (2*18,800*1 + 0.8*249.4816) \\
 &= 0.2773 \text{ in}
 \end{aligned}$$

**Required thickness  $t_r$  per Interpretation VIII-1-07-50**

$$\begin{aligned}
 t_r &= P \cdot R_o / (2 \cdot S \cdot E + 0.8 \cdot P) \\
 &= 249.4816 \cdot 42.0079 / (2 \cdot 18,800 \cdot 0.85 + 0.8 \cdot 249.4816) \\
 &= 0.3259 \text{ in}
 \end{aligned}$$

**Area required per UG-37(c)**

Allowable stresses:  $S_n = 17,500$ ,  $S_v = 18,800$  psi

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.9309$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.9309$$

$$\begin{aligned}
 A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\
 &= 15 \cdot 0.2773 \cdot 1 + 2 \cdot 2.3425 \cdot 0.2773 \cdot 1 \cdot (1 - 0.9309) \\
 &= \underline{4.2487} \text{ in}^2
 \end{aligned}$$

**Area available from FIG. UG-37.1**

$A_1$  = larger of the following = 0.7447 in<sup>2</sup>

$$\begin{aligned}
 &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= 15 \cdot (1 \cdot 0.328 - 1 \cdot 0.2773) - 2 \cdot 2.3425 \cdot (1 \cdot 0.328 - 1 \cdot 0.2773) \cdot (1 - 0.9309) \\
 &= 0.7447 \text{ in}^2 \\
 &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= 2 \cdot (0.328 + 2.3425) \cdot (1 \cdot 0.328 - 1 \cdot 0.2773) - 2 \cdot 2.3425 \cdot (1 \cdot 0.328 - 1 \cdot 0.2773) \cdot (1 - 0.9309) \\
 &= 0.2546 \text{ in}^2
 \end{aligned}$$

$A_2$  = smaller of the following = 3.4117 in<sup>2</sup>

$$\begin{aligned}
 &= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t \\
 &= 5 \cdot (2.3425 - 0.1078) \cdot 0.9309 \cdot 0.328 \\
 &= 3.4117 \text{ in}^2 \\
 &= 2 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot L_{pr} \\
 &= 2 \cdot (2.3425 - 0.1078) \cdot 0.9309 \cdot 2.25 \\
 &= 9.3615 \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2 \cdot f_{r2} \\
 &= 0.315^2 \cdot 0.9309 \\
 &= \underline{0.0923} \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_{41} \\
 &= 0.7447 + 3.4117 + 0.0923
 \end{aligned}$$



$$= 4.2487 \text{ in}^2$$

As Area  $\geq$  A the reinforcement is adequate.

#### UW-16(c) Weld Check

Fillet weld:  $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.328 \text{ in}$

$t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7 * t_{\min} = 0.2296 \text{ in}$

$t_{c(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 0.315 = 0.2205 \text{ in}$

**\*\* The fillet weld size IS NOT satisfactory. \*\***

#### UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):  $t_{r1} = 0.1078 \text{ in (E = 1)}$

Wall thickness per UG-45(b)(1):  $t_{r2} = 0.2773 \text{ in}$

Wall thickness per UG-16(b):  $t_{r3} = 0.0625 \text{ in}$

Standard wall pipe per UG-45(b)(4):  $t_{r4} = 0.3281 \text{ in}$

The greater of  $t_{r2}$  or  $t_{r3}$ :  $t_{r5} = 0.2773 \text{ in}$

The lesser of  $t_{r4}$  or  $t_{r5}$ :  $t_{r6} = 0.2773 \text{ in}$

Required per UG-45 is the larger of  $t_{r1}$  or  $t_{r6} = 0.2773 \text{ in}$

Available nozzle wall thickness new,  $t_n = 2.3425 \text{ in}$

The nozzle neck thickness is adequate.

### Welded Cover #1

| ASME Section VIII Division 1, 1995 Edition      |            |                            |                           |                           |
|---|------------|----------------------------|---------------------------|---------------------------|
| Component                                       |            | Welded Cover               |                           |                           |
| Configuration                                   |            | Figure UG-34 Sketch (h)    |                           |                           |
| Weld Detail                                     |            | Figure UW-13.2 Sketch (c)  |                           |                           |
| Material  |            | SA-105 (II-D p. 18, In. 6) |                           |                           |
| Attached To                                     |            | Entrada de Inspección (M1) |                           |                           |
| 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  |            | 250                        | 125                       | 38                        |
| Static Liquid Head                              |            |                            |                           |                           |
| Condition                                       |            | P <sub>s</sub> (psi)       | H <sub>s</sub> (in)       | SG                        |
| Test horizontal                                 |            | 0.63                       | 17.366                    | 1                         |
| Dimensions                                      |            |                            |                           |                           |
| Inner Diameter                                  |            | 15"                        |                           |                           |
| Nominal Thickness                               |            | 1.4516"                    |                           |                           |
| Weld Bevel Depth (a)                            |            | 2.3425"                    |                           |                           |
| Weld Bevel Depth (b)                            |            | 1.2016"                    |                           |                           |
| Outer Surface to Edge of Weld (t <sub>p</sub> ) |            | 0.25"                      |                           |                           |
| Corrosion                                       | Inner      | 0"                         |                           |                           |
|   | Outer      | 0"                         |                           |                           |
| Weight and Capacity                             |            |                            |                           |                           |
|   |            | Weight (lb)                |                           | Capacity (US gal)         |
| New   |            | 125.02                     |                           | 0                         |
| Corroded  |            | 125.02                     |                           | 0                         |
| Radiography                                     |            |                            |                           |                           |
| Category A joints                               |            | Seamless No RT             |                           |                           |

| 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="#">1.0299"</a>    |
| Maximum allowable working pressure (MAWP)     | <a href="#">496.62</a> psi |
| Rated MDMT                                    | -9.75 °F                   |

| UCS-66 Material Toughness Requirements                                |          |
|---|----------|
| Governing thickness, $t_g =$  | 1.4516"  |
| Exemption temperature from Fig UCS-66 Curve B =                       | 49.45 °F |
| Stress ratio per UCS-66(b)(1)(b) = $249.48 / 496.62 =$                | 0.5024   |
| Reduction in MDMT, $T_R$ from Fig UCS-66.1 =                          | 59.2 °F  |
| MDMT = $\max[ \text{MDMT} - T_R, -50 ] = \max[ 49.45 - 59.2, -50 ] =$ | -9.75 °F |
| Material is exempt from impact testing at the Design MDMT of 38 °F.   |          |

| Figure UW-13.2 Weld Sizing                           |         |   |                              |        |               |
|--|---------|---|------------------------------|--------|---------------|
| $a + b \geq 2*t_s + C_{i,shell} + C_{o,shell} + C_i$ |         |   |                              |        |               |
| $t_p \geq \min[ t_s, 0.25 ] + C_o$                   |         |   |                              |        |               |
| Results  |         |   |                              |        |               |
| $a + b =$  | 3.5441" | < | $2*2.3425 + 0 + 0 =$         | 4.685" | <b>Not OK</b> |
| $t_p =$  | 0.25"   | ≥ | $\min[ 2.3425, 0.25 ] + 0 =$ | 0.25"  | OK            |

#### UG-34(d) Dimensional Checks

$$t_s (2.3425") \geq 1.25*t_r (1.25*0.1081 = 0.1351") \quad \text{OK}$$

#### Factor C from Figure UG-34 Sketch (h)

$$\text{Factor C} = 0.33$$

#### Design thickness, (at 125 °F) UG-34(c)(2)

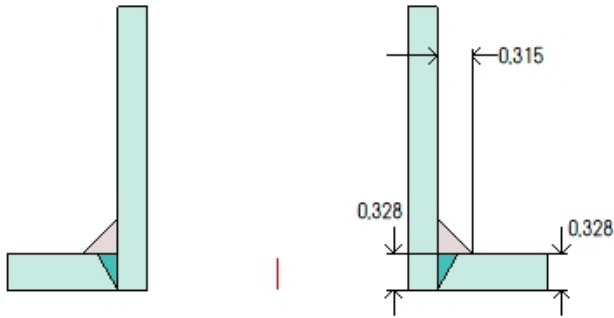
$$\begin{aligned}
 t &= d*\text{Sqr}(C*P / (S*E)) + \text{Corrosion} \\
 &= 15*\text{Sqr}(0.33*250 / (17,500*1)) + 0 \\
 &= \a href="#">1.0299"
 \end{aligned}$$

#### Maximum allowable working pressure, (at 125 °F )

$$\begin{aligned}
 \text{MAWP} &= (S*E / C)*(t / d)^2 - P_s \\
 &= (17,500*1 / 0.33)*(1.4516 / 15)^2 - 0 \\
 &= \a href="#">496.62 \text{ psi}
 \end{aligned}$$

# Indicador de Nivel (N5)

## ASME Section VIII Division 1, 1995 Edition



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

### Location and Orientation

|                                   |         |
|-----------------------------------|---------|
| Located on                        | C-01    |
| Orientation                       | 0°      |
| End of nozzle to datum line       | -48.55" |
| Calculated as hillside            | No      |
| Distance to head center, R        | 0"      |
| Passes through a Category A joint | No      |

### Nozzle

|  |   |
|--|---|
| Description  | NPS 2.5 Sch 80 (XS)                     |
| Access opening   | No                                      |
| Material specification   | SA-106 B Smls pipe (II-D p. 10, ln. 31) |
| Inside diameter, new   | 2.323"                                  |
| Pipe nominal wall thickness  | 0.276"                                  |
| Pipe minimum wall thickness <sup>1</sup>                           | 0.2415"                                 |
| Corrosion allowance  | 0"                                      |
| Projection available outside vessel, L <sub>pr</sub>               | 6.2908"                                 |
| Projection available outside vessel to flange face, L <sub>f</sub> | 6.5668"                                 |
| Local vessel minimum thickness                                     | 0.328"                                  |
| Liquid static head included  | 0.6 psi                                 |
| Longitudinal joint efficiency                                      | 1                                       |

### Welds

|                                 |        |
|---------------------------------|--------|
| Inner fillet, Leg <sub>41</sub> | 0.315" |
|---------------------------------|--------|

|                                     |        |
|-------------------------------------|--------|
| <b>Nozzle to vessel groove weld</b> | 0.328" |
|-------------------------------------|--------|

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

| ASME B16.5-1988 Flange  |  |
|---|--|
| <b>Description</b>  | NPS 2.5 Class 300 SO A105                                |
| <b>Bolt Material</b>  | SA-193 B7 Bolt $\leq 2 \frac{1}{2}$ (II-D p. 386, ln. 2) |
| <b>Blind included</b>   | No   |
| <b>Rated MDMT</b>   | -20 °F   |
| <b>Liquid static head</b>   | 0.6 psi  |
| <b>MAWP rating</b>  | 723.75 psi @ 125 °F                                      |
| <b>MAP rating</b>   | 740 psi @ 70 °F  |
| <b>Hydrotest rating</b>   | 1,125 psi @ 70 °F  |
| <b>External fillet weld leg (UW-21)</b>   | 0.28" (0.276" min)                                       |
| <b>Internal fillet weld leg (UW-21)</b>   | 0.276" (0.276" min)                                      |
| <b>PWHT performed</b>   | No   |
| <b>Impact Tested</b>  | No   |
| UW-21 Flange Welds  |  |
| External Leg <sub>min</sub> = $t_n + C_o / 0.7 = 0.276 + 0 / 0.7 =$                           | 0.276"   |
| Internal Leg <sub>min</sub> = $t_n = 0.276 =$   | 0.276"   |
| Notes   |  |
| Flange rated MDMT per UCS-66(c) = -20 °F<br>Bolts rated MDMT per Fig UCS-66 note (e) = -40 °F |  |

| UCS-66 Material Toughness Requirements Nozzle                        |         |
|--|---------|
| $t_r = 250.09 * 1.1615 / (15,000 * 1 - 0.6 * 250.09) =$              | 0.0196" |
| Stress ratio = $t_r * E^* / (t_n - c) = 0.0196 * 1 / (0.2415 - 0) =$ | 0.081   |
| Stress ratio $\leq 0.4$ , MDMT per UCS-66(b)(3) =                    | -150 °F |
| Material is exempt from impact testing at the Design MDMT of 38 °F.  |         |

## Reinforcement Calculations for Chamber MAWP

| UG-37 Area Calculation Summary (in <sup>2</sup> )               |             |                |                |                |                |         | UG-45 Summary (in)      |                  |
|---|-------------|----------------|----------------|----------------|----------------|---------|-------------------------|------------------|
| For P = 250.15 psi @ 125 °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) |             |                |                |                |                |         | <a href="#">0.1776</a>  | 0.2415           |

| 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> ) | <a href="#">0.1932</a>         | 0.2205                       | weld size is adequate |

### Calculations for internal pressure 250.15 psi @ 125 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(2.323, 1.1615 + (0.276 - 0) + (0.328 - 0)) \\
 &= 2.323 \text{ in}
 \end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.328 - 0), 2.5*(0.276 - 0) + 0) \\
 &= 0.69 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_m &= P*R_n / (S_n*E - 0.6*P) \\
 &= 250.1461*1.1615 / (15,000*1 - 0.6*250.1461) \\
 &= 0.0196 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> from UG-37(a)

$$\begin{aligned}
 t_r &= P*R_o / (2*S*E + 0.8*P) \\
 &= 250.1461*42.0079 / (2*18,800*1 + 0.8*250.1461) \\
 &= 0.278 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> per Interpretation VIII-1-07-50

$$\begin{aligned}
 t_r &= P*R_o / (2*S*E + 0.8*P) \\
 &= 250.1461*42.0079 / (2*18,800*0.85 + 0.8*250.1461)
 \end{aligned}$$

$$= 0.3267 \text{ in}$$

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

### **UW-16(c) Weld Check**

Fillet weld:  $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.276 \text{ in}$

$t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7 * t_{\min} = 0.1932 \text{ in}$

$t_{c(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 0.315 = 0.2205 \text{ in}$

The fillet weld size is satisfactory.

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

### **UG-45 Nozzle Neck Thickness Check**

Wall thickness per UG-45(a):  $t_{r1} = 0.0196 \text{ in } (E = 1)$

Wall thickness per UG-45(b)(1):  $t_{r2} = 0.278 \text{ in}$

Wall thickness per UG-16(b):  $t_{r3} = 0.0625 \text{ in}$

Standard wall pipe per UG-45(b)(4):  $t_{r4} = 0.1776 \text{ in}$

The greater of  $t_{r2}$  or  $t_{r3}$ :  $t_{r5} = 0.278 \text{ in}$

The lesser of  $t_{r4}$  or  $t_{r5}$ :  $t_{r6} = 0.1776 \text{ in}$

Required per UG-45 is the larger of  $t_{r1}$  or  $t_{r6} = 0.1776 \text{ in}$

Available nozzle wall thickness new,  $t_n = 0.875 * 0.276 = 0.2415 \text{ in}$

The nozzle neck thickness is adequate.

## 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 = 295.43 psi @ 125 °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) |                |                |                |                |                |            | <a href="#">0.1776</a>     | 0.2415           |

| 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> ) | <a href="#">0.1932</a>            | 0.2205                          | weld size is adequate |

### Calculations for internal pressure 295.43 psi @ 125 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\&= \text{MAX}(2.323, 1.1615 + (0.276 - 0) + (0.328 - 0)) \\&= 2.323 \text{ in}\end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\&= \text{MIN}(2.5*(0.328 - 0), 2.5*(0.276 - 0) + 0) \\&= 0.69 \text{ in}\end{aligned}$$

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

$$\begin{aligned}t_{rn} &= P*R_n / (S_n*E - 0.6*P) \\&= 295.4311*1.1615 / (15,000*1 - 0.6*295.4311) \\&= 0.0231 \text{ in}\end{aligned}$$

#### Required thickness $t_r$ from UG-37(a)

$$\begin{aligned}t_r &= P*R_o / (2*S*E + 0.8*P) \\&= 295.4311*42.0079 / (2*18,800*1 + 0.8*295.4311) \\&= 0.328 \text{ in}\end{aligned}$$



#### Required thickness $t_r$ per Interpretation VIII-1-07-50

$$\begin{aligned}t_r &= P \cdot R_o / (2 \cdot S \cdot E + 0.8 \cdot P) \\&= 295.4311 \cdot 42.0079 / (2 \cdot 18,800 \cdot 0.85 + 0.8 \cdot 295.4311) \\&= 0.3855 \text{ in}\end{aligned}$$

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

#### UW-16(c) Weld Check

Fillet weld:  $t_{\min}$  = lesser of 0.75 or  $t_n$  or  $t = 0.276$  in

$t_{c(\min)}$  = lesser of 0.25 or  $0.7 \cdot t_{\min} = 0.1932$  in

$t_{c(\text{actual})} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.315 = 0.2205$  in

The fillet weld size is satisfactory.

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

#### UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):  $t_{r1} = 0.0231$  in ( $E = 1$ )

Wall thickness per UG-45(b)(1):  $t_{r2} = 0.328$  in

Wall thickness per UG-16(b):  $t_{r3} = 0.0625$  in

Standard wall pipe per UG-45(b)(4):  $t_{r4} = 0.1776$  in

The greater of  $t_{r2}$  or  $t_{r3}$ :  $t_{r5} = 0.328$  in

The lesser of  $t_{r4}$  or  $t_{r5}$ :  $t_{r6} = 0.1776$  in

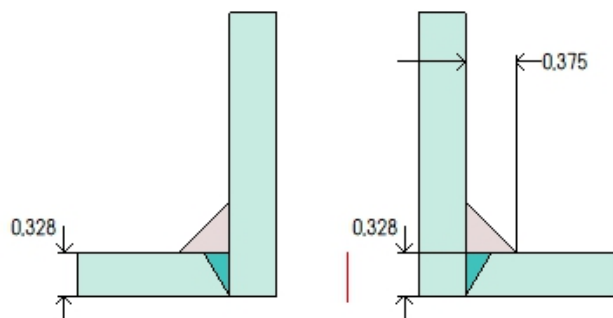
Required per UG-45 is the larger of  $t_{r1}$  or  $t_{r6} = 0.1776$  in

Available nozzle wall thickness new,  $t_n = 0.875 \cdot 0.276 = 0.2415$  in

The nozzle neck thickness is adequate.

# Indicador de Presión (N4)

## ASME Section VIII Division 1, 1995 Edition



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

### Location and Orientation

|                                   |          |
|-----------------------------------|----------|
| Located on                        | C-01     |
| Orientation                       | 0°       |
| End of nozzle to datum line       | -36.387" |
| Calculated as hillside            | No       |
| Distance to head center, R        | 23.2283" |
| Passes through a Category A joint | No       |

### Nozzle

|  |  |
|--|--|
| Description  | NPS 0.75 Class 6000 - Threaded Full Coupling |
| Access opening                                       | No   |
| Material specification                               | SA-105 (II-D p. 18, ln. 6)                   |
| Inside diameter, new                                 | 1.06"  |
| Nominal wall thickness                               | 0.345"                                       |
| Corrosion allowance                                  | 0"   |
| Projection available outside vessel, L <sub>pr</sub> | 1.672"                                       |
| Local vessel minimum thickness                       | 0.328"                                       |
| Liquid static head included                          | 0.13 psi                                     |
| Longitudinal joint efficiency                        | 1  |

### Welds

|                                 |        |
|---------------------------------|--------|
| Inner fillet, Leg <sub>41</sub> | 0.375" |
| Nozzle to vessel groove weld    | 0.328" |

| UCS-66 Material Toughness Requirements Nozzle                               |         |
|---|---------|
| $t_r = 249.61 \cdot 0.53 / (17,500 \cdot 1 - 0.6 \cdot 249.61) =$           | 0.0076" |
| Stress ratio $= t_r \cdot E^* / (t_n - c) = 0.0076 \cdot 1 / (0.345 - 0) =$ | 0.0221  |
| Stress ratio $\leq 0.4$ , MDMT per UCS-66(b)(3) =                           | -150°F  |
| Material is exempt from impact testing at the Design MDMT of 38°F.          |         |

## Reinforcement Calculations for Chamber MAWP

| UG-37 Area Calculation Summary<br>(in <sup>2</sup> )               |                |                |                |                |                |            | UG-44<br>Summary (in)      |                  |
|--|----------------|----------------|----------------|----------------|----------------|------------|----------------------------|------------------|
| For P = 249.67 psi @ 125 °F  |                |                |                |                |                |            | The nozzle passes<br>UG-44 |                  |
| 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) |                |                |                |                |                |            | <a href="#">0.0625</a>     | 0.345            |

| 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> ) | <a href="#">0.2296</a>            | 0.2625                          | weld size is adequate |

### Calculations for internal pressure 249.67 psi @ 125 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(1.06, 0.53 + (0.345 - 0) + (0.328 - 0)) \\
 &= 1.203 \text{ in}
 \end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.328 - 0), 2.5*(0.345 - 0) + 0) \\
 &= 0.82 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_{rn} &= P*R_n / (S_n*E - 0.6*P) \\
 &= 249.6748*0.53 / (17,500*1 - 0.6*249.6748) \\
 &= 0.0076 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> from UG-37(a)

$$\begin{aligned}
 t_r &= P*R_o / (2*S*E + 0.8*P) \\
 &= 249.6748*42.0079 / (2*18,800*1 + 0.8*249.6748) \\
 &= 0.2775 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> per Interpretation VIII-1-07-50

$$\begin{aligned}
 t_r &= P*R_o / (2*S*E + 0.8*P) \\
 &= 249.6748*42.0079 / (2*18,800*0.85 + 0.8*249.6748)
 \end{aligned}$$

$$= 0.3261 \text{ in}$$

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

### **UW-16(c) Weld Check**

Fillet weld:  $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.328 \text{ in}$

$t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7 * t_{\min} = 0.2296 \text{ in}$

$t_{c(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 0.375 = 0.2625 \text{ in}$

The fillet weld size is satisfactory.

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

### **UG-44 Thickness Check - ASME B16.11 Coupling**

$$\begin{aligned} t_{a \text{ App 1-1}} &= P * R_o / (S_n * E + 0.4 * P) + \text{Corrosion} \\ &= 249.6748 * 0.875 / (17,500 * 1 + 0.4 * 249.6748) + 0 \\ &= 0.0124 \text{ in} \end{aligned}$$

$$\begin{aligned} t_{a \text{ UG-44}} &= \max[ t_{a \text{ App 1-1}} , t_{b \text{ UG16}} ] \\ &= \max[ 0.0124 , 0.0625 ] \\ &= 0.0625 \text{ in} \end{aligned}$$

Available nozzle wall thickness new,  $t_n = 0.345 \text{ in}$

The nozzle neck thickness is adequate.

## 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-44<br>Summary (in)      |                  |
|--|----------------|----------------|----------------|----------------|----------------|------------|----------------------------|------------------|
| For P = 295.42 psi @ 125 °F  |                |                |                |                |                |            | The nozzle passes<br>UG-44 |                  |
| 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) |                |                |                |                |                |            | <a href="#">0.0625</a>     | 0.345            |

| 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> ) | <a href="#">0.2296</a>            | 0.2625                          | weld size is adequate |

### Calculations for internal pressure 295.42 psi @ 125 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\&= \text{MAX}(1.06, 0.53 + (0.345 - 0) + (0.328 - 0)) \\&= 1.203 \text{ in}\end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\&= \text{MIN}(2.5*(0.328 - 0), 2.5*(0.345 - 0) + 0) \\&= 0.82 \text{ in}\end{aligned}$$

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

$$\begin{aligned}t_{rn} &= P*R_n / (S_n*E - 0.6*P) \\&= 295.4247*0.53 / (17,500*1 - 0.6*295.4247) \\&= 0.009 \text{ in}\end{aligned}$$

#### Required thickness $t_r$ from UG-37(a)

$$\begin{aligned}t_r &= P*R_o / (2*S*E + 0.8*P) \\&= 295.4247*42.0079 / (2*18,800*1 + 0.8*295.4247) \\&= 0.328 \text{ in}\end{aligned}$$

#### Required thickness $t_r$ per Interpretation VIII-1-07-50

$$\begin{aligned}t_r &= P \cdot R_o / (2 \cdot S \cdot E + 0.8 \cdot P) \\&= 295.4247 \cdot 42.0079 / (2 \cdot 18,800 \cdot 0.85 + 0.8 \cdot 295.4247) \\&= 0.3855 \text{ in}\end{aligned}$$

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

#### UW-16(c) Weld Check

Fillet weld:  $t_{\min}$  = lesser of 0.75 or  $t_n$  or  $t = 0.328$  in

$t_{c(\min)}$  = lesser of 0.25 or  $0.7 \cdot t_{\min} = 0.2296$  in

$t_{c(\text{actual})} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.375 = 0.2625$  in

The fillet weld size is satisfactory.

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

#### UG-44 Thickness Check - ASME B16.11 Coupling

$$\begin{aligned}t_{a \text{ App 1-1}} &= P \cdot R_o / (S_n \cdot E + 0.4 \cdot P) + \text{Corrosion} \\&= 295.4247 \cdot 0.875 / (17,500 \cdot 1 + 0.4 \cdot 295.4247) + 0 \\&= 0.0147 \text{ in}\end{aligned}$$

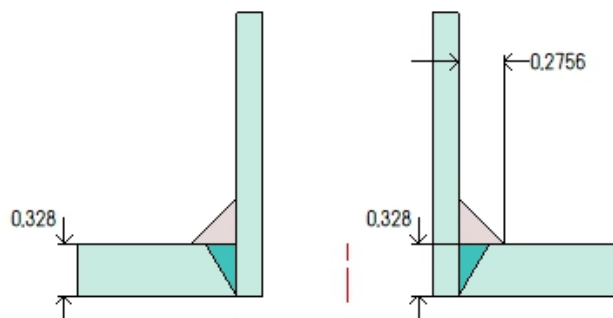
$$\begin{aligned}t_{a \text{ UG-44}} &= \max[ t_{a \text{ App 1-1}}, t_{b \text{ UG16}} ] \\&= \max[ 0.0147, 0.0625 ] \\&= 0.0625 \text{ in}\end{aligned}$$

Available nozzle wall thickness new,  $t_n = 0.345$  in

The nozzle neck thickness is adequate.

# Indicador de Temperatura (N6)

## ASME Section VIII Division 1, 1995 Edition



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

### Location and Orientation

|                                   |           |
|-----------------------------------|-----------|
| Located on                        | C-01      |
| Orientation                       | 180°      |
| End of nozzle to datum line       | -41.7365" |
| Calculated as hillside            | No        |
| Distance to head center, R        | 13.3858"  |
| Passes through a Category A joint | No        |

### Nozzle

|  |  |
|--|--|
| Description  | NPS 0.75 Class 3000 - Threaded Full Coupling |
| Access opening                                       | No   |
| Material specification                               | SA-105 (II-D p. 18, ln. 6)                   |
| Inside diameter, new                                 | 1.06"  |
| Nominal wall thickness                               | 0.16"  |
| Corrosion allowance                                  | 0"   |
| Projection available outside vessel, L <sub>pr</sub> | 2.0296"                                      |
| Local vessel minimum thickness                       | 0.328"                                       |
| Liquid static head included                          | 0.88 psi                                     |
| Longitudinal joint efficiency                        | 1  |

### Welds

|                                 |         |
|---------------------------------|---------|
| Inner fillet, Leg <sub>41</sub> | 0.2756" |
| Nozzle to vessel groove weld    | 0.328"  |



| UCS-66 Material Toughness Requirements Nozzle                              |         |
|--|---------|
| $t_r = 250.36 \cdot 0.53 / (17,500 \cdot 1 - 0.6 \cdot 250.36) =$          | 0.0076" |
| Stress ratio $= t_r \cdot E^* / (t_n - c) = 0.0076 \cdot 1 / (0.16 - 0) =$ | 0.0478  |
| Stress ratio $\leq 0.4$ , MDMT per UCS-66(b)(3) =                          | -150 °F |
| Material is exempt from impact testing at the Design MDMT of 38 °F.        |         |

## Reinforcement Calculations for Chamber MAWP

| UG-37 Area Calculation Summary (in <sup>2</sup> )               |             |                |                |                |                |         | UG-44 Summary (in)      |                  |
|---|-------------|----------------|----------------|----------------|----------------|---------|-------------------------|------------------|
| For P = 250.42 psi @ 125 °F                                     |             |                |                |                |                |         | The nozzle passes UG-44 |                  |
| 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) |             |                |                |                |                |         | <a href="#">0.0625</a>  | 0.16             |

| 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> ) | <a href="#">0.112</a>          | 0.1929                       | weld size is adequate |

### Calculations for internal pressure 250.42 psi @ 125 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(1.06, 0.53 + (0.16 - 0) + (0.328 - 0)) \\
 &= 1.06 \text{ in}
 \end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.328 - 0), 2.5*(0.16 - 0) + 0) \\
 &= 0.4 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_{rn} &= P*R_n / (S_n*E - 0.6*P) \\
 &= 250.4177*0.53 / (17,500*1 - 0.6*250.4177) \\
 &= 0.0076 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> from UG-37(a)

$$\begin{aligned}
 t_r &= P*R_o / (2*S*E + 0.8*P) \\
 &= 250.4177*42.0079 / (2*18,800*1 + 0.8*250.4177) \\
 &= 0.2783 \text{ in}
 \end{aligned}$$

**Required thickness  $t_r$  per Interpretation VIII-1-07-50**

$$\begin{aligned}
 t_r &= P \cdot R_o / (2 \cdot S \cdot E + 0.8 \cdot P) \\
 &= 250.4177 \cdot 42.0079 / (2 \cdot 18,800 \cdot 0.85 + 0.8 \cdot 250.4177) \\
 &= 0.3271 \text{ in}
 \end{aligned}$$

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

**UW-16(c) Weld Check**

Fillet weld:  $t_{\min}$  = lesser of 0.75 or  $t_n$  or  $t = 0.16$  in

$t_{c(\min)}$  = lesser of 0.25 or  $0.7 \cdot t_{\min} = 0.112$  in

$t_{c(\text{actual})} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.2756 = 0.1929$  in

The fillet weld size is satisfactory.

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

**UG-44 Thickness Check - ASME B16.11 Coupling**

$$\begin{aligned}
 t_{a \text{ App 1-1}} &= P \cdot R_o / (S_n \cdot E + 0.4 \cdot P) + \text{Corrosion} \\
 &= 250.4308 \cdot 0.69 / (17,500 \cdot 1 + 0.4 \cdot 250.4308) + 0 \\
 &= 0.0098 \text{ in}
 \end{aligned}$$

$$\begin{aligned}
 t_{a \text{ UG-44}} &= \max[ t_{a \text{ App 1-1}}, t_{b \text{ UG16}} ] \\
 &= \max[ 0.0098, 0.0625 ] \\
 &= 0.0625 \text{ in}
 \end{aligned}$$

Available nozzle wall thickness new,  $t_n = 0.16$  in

The nozzle neck thickness is adequate.

## 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-44<br>Summary<br>(in)   |                  |
|--|----------------|----------------|----------------|----------------|----------------|------------|----------------------------|------------------|
| For P = 295.43 psi @ 125 °F  |                |                |                |                |                |            | The nozzle<br>passes UG-44 |                  |
| 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) |                |                |                |                |                |            | <a href="#">0.0625</a>     | 0.16             |

| 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> ) | <a href="#">0.112</a>             | 0.1929                          | weld size is adequate |

### Calculations for internal pressure 295.43 psi @ 125 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\&= \text{MAX}(1.06, 0.53 + (0.16 - 0) + (0.328 - 0)) \\&= 1.06 \text{ in}\end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\&= \text{MIN}(2.5*(0.328 - 0), 2.5*(0.16 - 0) + 0) \\&= 0.4 \text{ in}\end{aligned}$$

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

$$\begin{aligned}t_{rn} &= P*R_n / (S_n*E - 0.6*P) \\&= 295.4331*0.53 / (17,500*1 - 0.6*295.4331) \\&= 0.009 \text{ in}\end{aligned}$$

#### Required thickness t<sub>r</sub> from UG-37(a)

$$\begin{aligned}t_r &= P*R_o / (2*S*E + 0.8*P) \\&= 295.4331*42.0079 / (2*18,800*1 + 0.8*295.4331) \\&= 0.328 \text{ in}\end{aligned}$$

#### Required thickness $t_r$ per Interpretation VIII-1-07-50

$$\begin{aligned}t_r &= P \cdot R_o / (2 \cdot S \cdot E + 0.8 \cdot P) \\&= 295.4331 \cdot 42.0079 / (2 \cdot 18,800 \cdot 0.85 + 0.8 \cdot 295.4331) \\&= 0.3855 \text{ in}\end{aligned}$$

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

#### UW-16(c) Weld Check

Fillet weld:  $t_{\min}$  = lesser of 0.75 or  $t_n$  or  $t = 0.16$  in

$t_{c(\min)}$  = lesser of 0.25 or  $0.7 \cdot t_{\min} = 0.112$  in

$t_{c(\text{actual})} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.2756 = 0.1929$  in

The fillet weld size is satisfactory.

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

#### UG-44 Thickness Check - ASME B16.11 Coupling

$$\begin{aligned}t_{a \text{ App 1-1}} &= P \cdot R_o / (S_n \cdot E + 0.4 \cdot P) + \text{Corrosion} \\&= 295.4462 \cdot 0.69 / (17,500 \cdot 1 + 0.4 \cdot 295.4462) + 0 \\&= 0.0116 \text{ in}\end{aligned}$$

$$\begin{aligned}t_{a \text{ UG-44}} &= \max[ t_{a \text{ App 1-1}}, t_{b \text{ UG16}} ] \\&= \max[ 0.0116, 0.0625 ] \\&= 0.0625 \text{ in}\end{aligned}$$

Available nozzle wall thickness new,  $t_n = 0.16$  in

The nozzle neck thickness is adequate.

| ASME Section VIII Division 1, 1995 Edition |            |   |                           |                        |
|--|------------|---|---------------------------|------------------------|
| Component                                  |            | Cylinder                                      |                           |                        |
| Material                                   |            | SA-455 ( 3/8 < t <= 5/8) (II-D p. 22, ln. 16) |                           |                        |
| 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                                   |            | 250   | 125                       | 38                     |
| Static Liquid Head                         |            |   |                           |                        |
| Condition                                  |            | P <sub>s</sub> (psi)                          | H <sub>s</sub> (in)       | SG                     |
| Operating                                  |            | 1.44  | 71.1856                   | 0.5621                 |
| Test horizontal                            |            | 3.42  | 94.8628                   | 1                      |
| Dimensions                                 |            |   |                           |                        |
| Outer Diameter                             |            | 84.0157"                                      |                           |                        |
| Length                                     |            | 113.1496"                                     |                           |                        |
| Nominal Thickness                          |            | 0.573"  |                           |                        |
| Corrosion                                  | Inner      | 0"  |                           |                        |
|  | Outer      | 0"  |                           |                        |
| Weight and Capacity                        |            |   |                           |                        |
|  |            | Weight (lb)                                   |                           | Capacity (US gal)      |
| New  |            | 4,805.13                                      |                           | 2,641.94               |
| Corroded                                   |            | 4,805.13                                      |                           | 2,641.94               |
| Radiography                                |            |   |                           |                        |
| Longitudinal seam                          |            | Full UW-11(a) Type 1                          |                           |                        |
| Left Circumferential seam                  |            | Full UW-11(a) Type 1                          |                           |                        |
| Right Circumferential seam                 |            | Full UW-11(a) 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="#">0.5741"</a>    |
| Maximum allowable working pressure (MAWP)     | <a href="#">249.54 psi</a> |
| Rated MDMT                                    | 38.01 °F                   |

| UCS-66 Material Toughness Requirements                                     |          |
|--|----------|
| Governing thickness, $t_g =$   | 0.573"   |
| Exemption temperature from Fig UCS-66 Curve A =                            | 38.01 °F |
| $t_r = 250.93 \cdot 42.0079 / (18,300 \cdot 1 + 0.4 \cdot 250.93) =$       | 0.5729"  |
| Stress ratio $= t_r \cdot E' / (t_g - c) = 0.5729 \cdot 1 / (0.573 - 0) =$ | 0.9998   |
| Reduction in MDMT, $T_R$ from Fig UCS-66.1 =                               | 0 °F     |
| MDMT $= \max[ \text{MDMT} - T_R, -50 ] = \max[ 38.01 - 0, -50 ] =$         | 38.01 °F |
| <b>Rated MDMT of 38.01 °F &gt; Design MDMT of 38 °F.</b>                   |          |

#### Design thickness, (at 125 °F) Appendix 1-1

$$\begin{aligned}
 t &= P \cdot R_o / (S \cdot E + 0.40 \cdot P) + \text{Corrosion} \\
 &= 251.44 \cdot 42.0079 / (18,300 \cdot 1.00 + 0.40 \cdot 251.44) + 0 \\
 &= \text{0.5741"}
 \end{aligned}$$

#### Maximum allowable working pressure, (at 125 °F) Appendix 1-1

$$\begin{aligned}
 P &= S \cdot E \cdot t / (R_o - 0.40 \cdot t) - P_s \\
 &= 18,300 \cdot 1.00 \cdot 0.573 / (42.0079 - 0.40 \cdot 0.573) - 1.44 \\
 &= \text{249.54 psi}
 \end{aligned}$$

#### % Extreme fiber elongation - UCS-79(d)

$$\begin{aligned}
 \text{EFE} &= (50 \cdot t / R_f) \cdot (1 - R_f / R_o) \\
 &= (50 \cdot 0.573 / 41.7214) \cdot (1 - 41.7214 / \text{infinity}) \\
 &= 0.6867\%
 \end{aligned}$$

The extreme fiber elongation does not exceed 5%.

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

$$\begin{aligned}
 A &= 0.125 / (R_o / t) \\
 &= 0.125 / (42.0079 / 0.573) \\
 &= 0.001705 \\
 B &= 14,330 \text{ psi} \\
 S &= 18,300 / 1.00 = 18,300 \text{ psi} \\
 S_{cHC} &= \min(B, S) = 14,330 \text{ psi}
 \end{aligned}$$

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

$$\begin{aligned} S_{cHN} &= S_{cHC} \\ &= 14,330 \text{ psi} \end{aligned}$$

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

$$\begin{aligned} A &= 0.125 / (R_o / t) \\ &= 0.125 / (42.0079 / 0.573) \\ &= 0.001705 \\ B &= 14,330 \text{ psi} \\ S &= 18,300 / 1.00 = 18,300 \text{ psi} \\ S_{cCN} &= \min(B, S) = 14,330 \text{ psi} \end{aligned}$$

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

$$\begin{aligned} S_{cCC} &= S_{cCN} \\ &= 14,330 \text{ psi} \end{aligned}$$

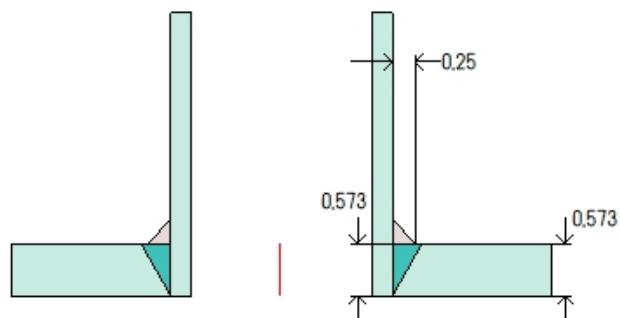
**Allowable Compressive Stress, Vacuum and Corroded-  $S_{cVC}$ , (table CS-2)**

$$\begin{aligned} A &= 0.125 / (R_o / t) \\ &= 0.125 / (42.0079 / 0.573) \\ &= 0.001705 \\ B &= 14,330 \text{ psi} \\ S &= 18,300 / 1.00 = 18,300 \text{ psi} \\ S_{cVC} &= \min(B, S) = 14,330 \text{ psi} \end{aligned}$$



# Alivio de presión (N8)

## ASME Section VIII Division 1, 1995 Edition



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

### Location and Orientation

|   |          |
|---|----------|
| Located on                              | V-01     |
| Orientation                             | 0°       |
| Nozzle center line offset to datum line | 47.95"   |
| End of nozzle to shell center           | 51.8479" |
| Passes through a Category A joint       | No       |

### Nozzle

|  |   |
|--|---|
| Description  | NPS 2 Sch 80 (XS)                       |
| Access opening   | No                                      |
| Material specification   | SA-106 B Smls pipe (II-D p. 10, ln. 31) |
| Inside diameter, new   | 1.939"                                  |
| Pipe nominal wall thickness  | 0.218"                                  |
| Pipe minimum wall thickness <sup>1</sup>                           | 0.1908"                                 |
| Corrosion allowance  | 0"                                      |
| Projection available outside vessel, L <sub>pr</sub>               | 9.622"                                  |
| Projection available outside vessel to flange face, L <sub>f</sub> | 9.84"                                   |
| Local vessel minimum thickness                                     | 0.573"                                  |
| Liquid static head included  | 0 psi                                   |
| Longitudinal joint efficiency                                      | 1                                       |

### Welds

|                                 |        |
|---------------------------------|--------|
| Inner fillet, Leg <sub>41</sub> | 0.25"  |
| Nozzle to vessel groove weld    | 0.573" |

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

| ASME B16.5-1988 Flange  |  |
|---|--|
| <b>Description</b>  | NPS 2 Class 300 SO A105                      |
| <b>Bolt Material</b>  | SA-193 B7 Bolt <= 2 1/2 (II-D p. 386, ln. 2) |
| <b>Blind included</b>   | No   |
| <b>Rated MDMT</b>   | -20°F  |
| <b>Liquid static head</b>   | 0 psi  |
| <b>MAWP rating</b>  | 723.75 psi @ 125°F                           |
| <b>MAP rating</b>   | 740 psi @ 70°F                               |
| <b>Hydrotest rating</b>   | 1,125 psi @ 70°F                             |
| <b>External fillet weld leg (UW-21)</b>   | 0.22" (0.218" min)                           |
| <b>Internal fillet weld leg (UW-21)</b>   | 0.218" (0.218" min)                          |
| <b>PWHT performed</b>   | No   |
| <b>Impact Tested</b>  | No   |
| UW-21 Flange Welds  |  |
| External $Leg_{min} = t_n + C_o / 0.7 = 0.218 + 0 / 0.7 =$                                  | 0.218"                                       |
| Internal $Leg_{min} = t_n = 0.218 =$  | 0.218"                                       |
| Notes   |  |
| Flange rated MDMT per UCS-66(c) = -20°F<br>Bolts rated MDMT per Fig UCS-66 note (e) = -40°F |  |

| UCS-66 Material Toughness Requirements Nozzle                         |         |
|---|---------|
| $t_r = 249.48 * 0.9695 / (15,000 * 1 - 0.6 * 249.48) =$               | 0.0163" |
| $Stress\ ratio = t_r * E^* / (t_n - c) = 0.0163 * 1 / (0.1908 - 0) =$ | 0.0854  |
| $Stress\ ratio \leq 0.4, MDMT\ per\ UCS-66(b)(3) =$                   | -150°F  |
| Material is exempt from impact testing at the Design MDMT of 38°F.    |         |

## Reinforcement Calculations for Chamber MAWP

| UG-37 Area Calculation Summary (in <sup>2</sup> )               |             |                |                |                |                |         | UG-45 Summary (in)      |                  |
|---|-------------|----------------|----------------|----------------|----------------|---------|-------------------------|------------------|
| For P = 249.54 psi @ 125 °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) |             |                |                |                |                |         | <a href="#">0.1348</a>  | 0.1908           |

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

| UW-16 Weld Sizing Summary                   |                                |                              |                       |
|---|--------------------------------|------------------------------|-----------------------|
| Weld description                            | Required weld throat size (in) | Actual weld throat size (in) | Status                |
| Nozzle to shell fillet (Leg <sub>41</sub> ) | <a href="#">0.1526</a>         | 0.175                        | weld size is adequate |

### Calculations for internal pressure 249.54 psi @ 125 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(1.939, 0.9695 + (0.218 - 0) + (0.573 - 0)) \\
 &= 1.939 \text{ in}
 \end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.573 - 0), 2.5*(0.218 - 0) + 0) \\
 &= 0.545 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_{rn} &= P*R_n / (S_n*E - 0.6*P) \\
 &= 249.5425*0.9695 / (15,000*1 - 0.6*249.5425) \\
 &= 0.0163 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> from UG-37(a)

$$\begin{aligned}
 t_r &= P*R_o / (S*E + 0.4*P) \\
 &= 249.5425*42.0079 / (18,300*1 + 0.4*249.5425) \\
 &= 0.5697 \text{ in}
 \end{aligned}$$

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

### UW-16(c) Weld Check

Fillet weld:  $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.218 \text{ in}$

$t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7 * t_{\min} = 0.1526 \text{ in}$

$t_{c(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 0.25 = 0.175 \text{ in}$

The fillet weld size is satisfactory.

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

### UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):  $t_{r1} = 0.0163 \text{ in (E = 1)}$

Wall thickness per UG-45(b)(1):  $t_{r2} = 0.5697 \text{ in}$

Wall thickness per UG-16(b):  $t_{r3} = 0.0625 \text{ in}$

Standard wall pipe per UG-45(b)(4):  $t_{r4} = 0.1348 \text{ in}$

The greater of  $t_{r2}$  or  $t_{r3}$ :  $t_{r5} = 0.5697 \text{ in}$

The lesser of  $t_{r4}$  or  $t_{r5}$ :  $t_{r6} = 0.1348 \text{ in}$

Required per UG-45 is the larger of  $t_{r1}$  or  $t_{r6} = 0.1348 \text{ in}$

Available nozzle wall thickness new,  $t_n = 0.875 * 0.218 = 0.1908 \text{ in}$

The nozzle neck thickness is adequate.

## 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 = 250.98 psi @ 125 °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) |                |                |                |                |                |            | <a href="#">0.1348</a>     | 0.1908           |

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

| UW-16 Weld Sizing Summary                   |                                   |                                 |                       |
|---|-----------------------------------|---------------------------------|-----------------------|
| Weld description                            | Required weld<br>throat size (in) | Actual weld<br>throat size (in) | Status                |
| Nozzle to shell fillet (Leg <sub>41</sub> ) | <a href="#">0.1526</a>            | 0.175                           | weld size is adequate |

### Calculations for internal pressure 250.98 psi @ 125 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(1.939, 0.9695 + (0.218 - 0) + (0.573 - 0)) \\
 &= 1.939 \text{ in}
 \end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.573 - 0), 2.5*(0.218 - 0) + 0) \\
 &= 0.545 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_{rn} &= P*R_n / (S_n*E - 0.6*P) \\
 &= 250.9838*0.9695 / (15,000*1 - 0.6*250.9838) \\
 &= 0.0164 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> from UG-37(a)

$$\begin{aligned}
 t_r &= P*R_o / (S*E + 0.4*P) \\
 &= 250.9838*42.0079 / (18,300*1 + 0.4*250.9838) \\
 &= 0.573 \text{ in}
 \end{aligned}$$

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

### UW-16(c) Weld Check

Fillet weld:  $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.218 \text{ in}$

$t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7 * t_{\min} = 0.1526 \text{ in}$

$t_{c(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 0.25 = 0.175 \text{ in}$

The fillet weld size is satisfactory.

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

### UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):  $t_{r1} = 0.0164 \text{ in (E = 1)}$

Wall thickness per UG-45(b)(1):  $t_{r2} = 0.573 \text{ in}$

Wall thickness per UG-16(b):  $t_{r3} = 0.0625 \text{ in}$

Standard wall pipe per UG-45(b)(4):  $t_{r4} = 0.1348 \text{ in}$

The greater of  $t_{r2}$  or  $t_{r3}$ :  $t_{r5} = 0.573 \text{ in}$

The lesser of  $t_{r4}$  or  $t_{r5}$ :  $t_{r6} = 0.1348 \text{ in}$

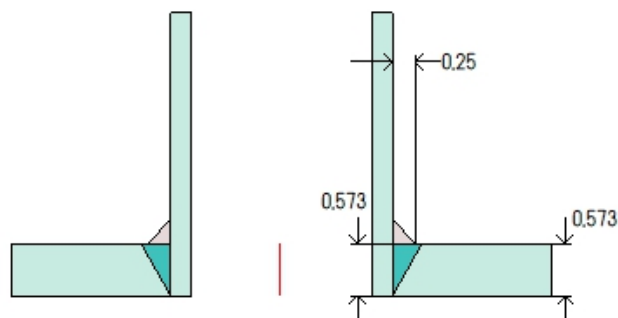
Required per UG-45 is the larger of  $t_{r1}$  or  $t_{r6} = 0.1348 \text{ in}$

Available nozzle wall thickness new,  $t_n = 0.875 * 0.218 = 0.1908 \text{ in}$

The nozzle neck thickness is adequate.

### Compensación (N3)

#### ASME Section VIII Division 1, 1995 Edition



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

#### Location and Orientation

|   |          |
|---|----------|
| Located on                              | V-01     |
| Orientation                             | 180°     |
| Nozzle center line offset to datum line | 37.53"   |
| End of nozzle to shell center           | 51.8479" |
| Passes through a Category A joint       | No       |

#### Nozzle

|  |   |
|--|---|
| Description  | NPS 2 Sch 80 (XS)                       |
| Access opening   | No                                      |
| Material specification   | SA-106 B Smls pipe (II-D p. 10, ln. 31) |
| Inside diameter, new   | 1.939"                                  |
| Pipe nominal wall thickness  | 0.218"                                  |
| Pipe minimum wall thickness <sup>1</sup>                           | 0.1908"                                 |
| Corrosion allowance  | 0"                                      |
| Projection available outside vessel, L <sub>pr</sub>               | 9.622"                                  |
| Projection available outside vessel to flange face, L <sub>f</sub> | 9.84"                                   |
| Local vessel minimum thickness                                     | 0.573"                                  |
| Liquid static head included  | 1.46 psi                                |
| Longitudinal joint efficiency                                      | 1                                       |

#### Welds

|                                 |        |
|---------------------------------|--------|
| Inner fillet, Leg <sub>41</sub> | 0.25"  |
| Nozzle to vessel groove weld    | 0.573" |

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

| ASME B16.5-1988 Flange  |   |
|---|---|
| Description   | NPS 2 Class 300 SO A105                     |
| Bolt Material   | SA-193 B7 Bolt ≤ 2 1/2 (II-D p. 386, ln. 2) |
| Blind included  | No  |
| Rated MDMT  | -20°F                                       |
| Liquid static head  | 1.66 psi                                    |
| MAWP rating   | 723.75 psi @ 125°F                          |
| MAP rating  | 740 psi @ 70°F                              |
| Hydrotest rating  | 1,125 psi @ 70°F                            |
| External fillet weld leg (UW-21)  | 0.22" (0.218" min)                          |
| Internal fillet weld leg (UW-21)  | 0.218" (0.218" min)                         |
| PWHT performed  | No  |
| Impact Tested   | No  |
| UW-21 Flange Welds  |   |
| External $Leg_{min} = t_n + C_o / 0.7 = 0.218 + 0 / 0.7 =$                                  | 0.218"                                      |
| Internal $Leg_{min} = t_n = 0.218 =$  | 0.218"                                      |
| Notes   |   |
| Flange rated MDMT per UCS-66(c) = -20°F<br>Bolts rated MDMT per Fig UCS-66 note (e) = -40°F |   |

| UCS-66 Material Toughness Requirements Nozzle                        |         |
|--|---------|
| $t_r = 250.94 * 0.9695 / (15,000 * 1 - 0.6 * 250.94) =$              | 0.0164" |
| Stress ratio = $t_r * E^* / (t_n - c) = 0.0164 * 1 / (0.1908 - 0) =$ | 0.0859  |
| Stress ratio ≤ 0.4, MDMT per UCS-66(b)(3) =                          | -150°F  |
| Material is exempt from impact testing at the Design MDMT of 38°F.   |         |



## Reinforcement Calculations for Chamber MAWP

| UG-37 Area Calculation Summary<br>(in <sup>2</sup> )               |                |                |                |                |                |            | UG-45<br>Summary (in)      |                  |
|--|----------------|----------------|----------------|----------------|----------------|------------|----------------------------|------------------|
| For P = 251 psi @ 125 °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) |                |                |                |                |                |            | <a href="#">0.1348</a>     | 0.1908           |

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

| UW-16 Weld Sizing Summary                   |                                   |                                 |                       |
|---|-----------------------------------|---------------------------------|-----------------------|
| Weld description                            | Required weld<br>throat size (in) | Actual weld<br>throat size (in) | Status                |
| Nozzle to shell fillet (Leg <sub>41</sub> ) | <a href="#">0.1526</a>            | 0.175                           | weld size is adequate |

### Calculations for internal pressure 251 psi @ 125 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(1.939, 0.9695 + (0.218 - 0) + (0.573 - 0)) \\
 &= 1.939 \text{ in}
 \end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.573 - 0), 2.5*(0.218 - 0) + 0) \\
 &= 0.545 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_{rn} &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 250.9985 \cdot 0.9695 / (15,000 \cdot 1 - 0.6 \cdot 250.9985) \\
 &= 0.0164 \text{ in}
 \end{aligned}$$

#### Required thickness $t_r$ from UG-37(a)

$$\begin{aligned}
 t_r &= P \cdot R_o / (S \cdot E + 0.4 \cdot P) \\
 &= 250.9985 \cdot 42.0079 / (18,300 \cdot 1 + 0.4 \cdot 250.9985) \\
 &= 0.573 \text{ in}
 \end{aligned}$$

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

### UW-16(c) Weld Check

Fillet weld:  $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.218 \text{ in}$

$t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7 * t_{\min} = 0.1526 \text{ in}$

$t_{c(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 0.25 = 0.175 \text{ in}$

The fillet weld size is satisfactory.

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

### UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):  $t_{r1} = 0.0164 \text{ in (E = 1)}$

Wall thickness per UG-45(b)(1):  $t_{r2} = 0.573 \text{ in}$

Wall thickness per UG-16(b):  $t_{r3} = 0.0625 \text{ in}$

Standard wall pipe per UG-45(b)(4):  $t_{r4} = 0.1348 \text{ in}$

The greater of  $t_{r2}$  or  $t_{r3}$ :  $t_{r5} = 0.573 \text{ in}$

The lesser of  $t_{r4}$  or  $t_{r5}$ :  $t_{r6} = 0.1348 \text{ in}$

Required per UG-45 is the larger of  $t_{r1}$  or  $t_{r6} = 0.1348 \text{ in}$

Available nozzle wall thickness new,  $t_n = 0.875 * 0.218 = 0.1908 \text{ in}$

The nozzle neck thickness is adequate.

## 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 = 250.98 psi @ 125 °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) |                |                |                |                |                |            | <a href="#">0.1348</a>     | 0.1908           |

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

| UW-16 Weld Sizing Summary                   |                                   |                                 |                       |
|---|-----------------------------------|---------------------------------|-----------------------|
| Weld description                            | Required weld<br>throat size (in) | Actual weld<br>throat size (in) | Status                |
| Nozzle to shell fillet (Leg <sub>41</sub> ) | <a href="#">0.1526</a>            | 0.175                           | weld size is adequate |

### Calculations for internal pressure 250.98 psi @ 125 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\&= \text{MAX}(1.939, 0.9695 + (0.218 - 0) + (0.573 - 0)) \\&= 1.939 \text{ in}\end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\&= \text{MIN}(2.5*(0.573 - 0), 2.5*(0.218 - 0) + 0) \\&= 0.545 \text{ in}\end{aligned}$$

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

$$\begin{aligned}t_{rn} &= P*R_n / (S_n*E - 0.6*P) \\&= 250.9833*0.9695 / (15,000*1 - 0.6*250.9833) \\&= 0.0164 \text{ in}\end{aligned}$$

#### Required thickness $t_r$ from UG-37(a)

$$\begin{aligned}t_r &= P*R_o / (S*E + 0.4*P) \\&= 250.9833*42.0079 / (18,300*1 + 0.4*250.9833) \\&= 0.573 \text{ in}\end{aligned}$$

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

### UW-16(c) Weld Check

Fillet weld:  $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.218 \text{ in}$

$t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7 * t_{\min} = 0.1526 \text{ in}$

$t_{c(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 0.25 = 0.175 \text{ in}$

The fillet weld size is satisfactory.

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

### UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):  $t_{r1} = 0.0164 \text{ in (E = 1)}$

Wall thickness per UG-45(b)(1):  $t_{r2} = 0.573 \text{ in}$

Wall thickness per UG-16(b):  $t_{r3} = 0.0625 \text{ in}$

Standard wall pipe per UG-45(b)(4):  $t_{r4} = 0.1348 \text{ in}$

The greater of  $t_{r2}$  or  $t_{r3}$ :  $t_{r5} = 0.573 \text{ in}$

The lesser of  $t_{r4}$  or  $t_{r5}$ :  $t_{r6} = 0.1348 \text{ in}$

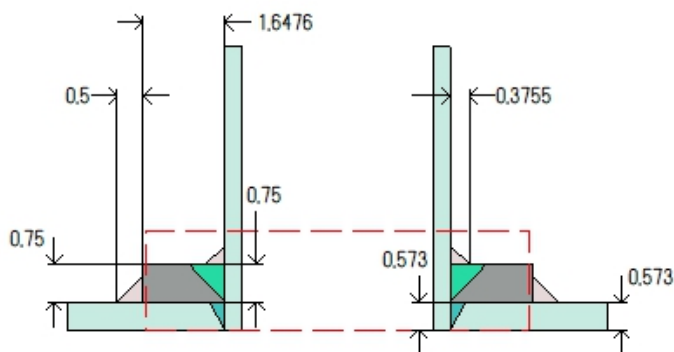
Required per UG-45 is the larger of  $t_{r1}$  or  $t_{r6} = 0.1348 \text{ in}$

Available nozzle wall thickness new,  $t_n = 0.875 * 0.218 = 0.1908 \text{ in}$

The nozzle neck thickness is adequate.

# Entrada PVT (N1)

## ASME Section VIII Division 1, 1995 Edition



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

### Location and Orientation

|   |          |
|---|----------|
| Located on                              | V-01     |
| Orientation                             | 180°     |
| Nozzle center line offset to datum line | 11.84"   |
| End of nozzle to shell center           | 51.8479" |
| Passes through a Category A joint       | No       |

### Nozzle

|  |   |
|--|---|
| Description  | NPS 4 Sch 80 (XS)                       |
| Access opening   | No                                      |
| Material specification   | SA-106 B Smls pipe (II-D p. 10, ln. 31) |
| Inside diameter, new   | 3.826"                                  |
| Pipe nominal wall thickness  | 0.337"                                  |
| Pipe minimum wall thickness <sup>1</sup>                           | 0.2949"                                 |
| Corrosion allowance  | 0"                                      |
| Projection available outside vessel, L <sub>pr</sub>               | 9.503"                                  |
| Projection available outside vessel to flange face, L <sub>f</sub> | 9.84"                                   |
| Local vessel minimum thickness                                     | 0.573"                                  |
| Liquid static head included  | 1.46 psi                                |
| Longitudinal joint efficiency                                      | 1                                       |

### Reinforcing Pad

|                          |                                |
|--------------------------|--------------------------------|
| Material specification   | SA-516 70 (II-D p. 18, ln. 23) |
| Diameter, D <sub>p</sub> | 7.7953"                        |

|                                 |         |
|---------------------------------|---------|
| Thickness, $t_e$                | 0.75"   |
| Is split                        | No      |
| <b>Welds</b>                    |         |
| Inner fillet, Leg <sub>41</sub> | 0.3755" |
| Outer fillet, Leg <sub>42</sub> | 0.5"    |
| Nozzle to vessel groove weld    | 0.573"  |
| Pad groove weld                 | 0.75"   |

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

| ASME B16.5-1988 Flange  |  |
|---|--|
| Description   | NPS 4 Class 300 SO A105                                  |
| Bolt Material   | SA-193 B7 Bolt $\leq 2 \frac{1}{2}$ (II-D p. 386, ln. 2) |
| Blind included  | No   |
| Rated MDMT  | -20°F  |
| Liquid static head  | 1.66 psi   |
| MAWP rating   | 723.75 psi @ 125°F                                       |
| MAP rating  | 740 psi @ 70°F   |
| Hydrotest rating  | 1,125 psi @ 70°F   |
| External fillet weld leg (UW-21)  | 0.337" (0.337" min)                                      |
| Internal fillet weld leg (UW-21)  | 0.337" (0.337" min)                                      |
| PWHT performed  | No   |
| Impact Tested   | No   |
| UW-21 Flange Welds  |  |
| External Leg <sub>min</sub> = $t_n + C_o / 0.7 = 0.337 + 0 / 0.7 =$                         | 0.337"   |
| Internal Leg <sub>min</sub> = $t_n = 0.337 =$   | 0.337"   |
| Notes   |  |
| Flange rated MDMT per UCS-66(c) = -20°F<br>Bolts rated MDMT per Fig UCS-66 note (e) = -40°F |  |

| UCS-66 Material Toughness Requirements Nozzle                        |         |
|--|---------|
| $t_r = 250.94 * 1.913 / (15,000 * 1 - 0.6 * 250.94) =$               | 0.0323" |
| Stress ratio = $t_r * E^* / (t_n - c) = 0.0323 * 1 / (0.2949 - 0) =$ | 0.1096  |
| Stress ratio $\leq 0.4$ , MDMT per UCS-66(b)(3) =                    | -150°F  |
| Material is exempt from impact testing at the Design MDMT of 38°F.   |         |

| UCS-66 Material Toughness Requirements Pad                                       |        |
|--|--------|
| Governing thickness, $t_g$ =   | 0.573" |
| MDMT =   | -20 °F |
| Material is exempt from impact testing per UG-20(f) at the Design MDMT of 38 °F. |        |

## Reinforcement Calculations for Chamber MAWP

| UG-37 Area Calculation Summary (in <sup>2</sup> )                |                        |                |                        |                |                        |                        | UG-45 Summary (in)      |                  |
|--|------------------------|----------------|------------------------|----------------|------------------------|------------------------|-------------------------|------------------|
| For P = 251 psi @ 125 °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> |
| <a href="#">2.262</a>  | <a href="#">3.0919</a> | --             | <a href="#">0.7156</a> | --             | <a href="#">2.2607</a> | <a href="#">0.1156</a> | <a href="#">0.2074</a>  | 0.2949           |

| UG-41 Weld Failure Path Analysis Summary (lb <sub>f</sub> )   |                            |                           |                            |                            |                            |                            |
|---|----------------------------|---------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| All failure paths are stronger than the applicable weld loads |                            |                           |                            |                            |                            |                            |
| Weld load W   | Weld load W <sub>1-1</sub> | Path 1-1 strength         | Weld load W <sub>2-2</sub> | Path 2-2 strength          | Weld load W <sub>3-3</sub> | Path 3-3 strength          |
| <a href="#">41,397.22</a>                                     | <a href="#">56,581.65</a>  | <a href="#">75,638.59</a> | <a href="#">21,004.19</a>  | <a href="#">143,011.52</a> | <a href="#">62,374.87</a>  | <a href="#">107,348.68</a> |

| UW-16 Weld Sizing Summary                 |                         |                       |                       |
|---|-------------------------|-----------------------|-----------------------|
| Weld description                          | Required weld size (in) | Actual weld size (in) | Status                |
| Nozzle to pad fillet (Leg <sub>41</sub> ) | <a href="#">0.2359</a>  | 0.2628                | weld size is adequate |
| Pad to shell fillet (Leg <sub>42</sub> )  | <a href="#">0.2865</a>  | 0.35                  | weld size is adequate |

### Calculations for internal pressure 251 psi @ 125 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(3.826, 1.913 + (0.337 - 0) + (0.573 - 0)) \\
 &= 3.826 \text{ in}
 \end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.573 - 0), 2.5*(0.337 - 0) + 0.75) \\
 &= 1.4325 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_{rn} &= P*R_n / (S_n*E - 0.6*P) \\
 &= 250.9985*1.913 / (15,000*1 - 0.6*250.9985) \\
 &= 0.0323 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> from UG-37(a)

$$\begin{aligned}
 t_r &= P*R_o / (S*E + 0.4*P) \\
 &= 250.9985*42.0079 / (18,300*1 + 0.4*250.9985) \\
 &= 0.573 \text{ in}
 \end{aligned}$$



### Area required per UG-37(c)

Allowable stresses:  $S_n = 15,000$ ,  $S_v = 18,300$ ,  $S_p = 17,500$  psi

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.8197$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.8197$$

$$f_{r3} = \text{lesser of } f_{r2} \text{ or } S_p / S_v = 0.8197$$

$$f_{r4} = \text{lesser of } 1 \text{ or } S_p / S_v = 0.9563$$

$$\begin{aligned} A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\ &= 3.826 \cdot 0.573 \cdot 1 + 2 \cdot 0.337 \cdot 0.573 \cdot 1 \cdot (1 - 0.8197) \\ &= \underline{2.262} \text{ in}^2 \end{aligned}$$

### Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{0} \text{ in}^2$$

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 3.826 \cdot (1 \cdot 0.573 - 1 \cdot 0.573) - 2 \cdot 0.337 \cdot (1 \cdot 0.573 - 1 \cdot 0.573) \cdot (1 - 0.8197) \\ &= -0.0001 \text{ in}^2 \\ &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2 \cdot (0.573 + 0.337) \cdot (1 \cdot 0.573 - 1 \cdot 0.573) - 2 \cdot 0.337 \cdot (1 \cdot 0.573 - 1 \cdot 0.573) \cdot (1 - 0.8197) \\ &= -0.0001 \text{ in}^2 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{0.7156} \text{ in}^2$$

$$\begin{aligned} &= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t \\ &= 5 \cdot (0.337 - 0.0323) \cdot 0.8197 \cdot 0.573 \\ &= 0.7156 \text{ in}^2 \\ &= 2 \cdot (t_n - t_{rn}) \cdot (2.5 \cdot t_n + t_e) \cdot f_{r2} \\ &= 2 \cdot (0.337 - 0.0323) \cdot (2.5 \cdot 0.337 + 0.75) \cdot 0.8197 \\ &= 0.7955 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 \cdot f_{r3} \\ &= 0.3755^2 \cdot 0.8197 \\ &= \underline{0.1156} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{42} &= \text{Leg}^2 \cdot f_{r4} \\ &= 0^2 \cdot 0.9563 \\ &= \underline{0} \text{ in}^2 \end{aligned}$$

(Part of the weld is outside of the limits)

$$\begin{aligned}
 A_5 &= (D_p - d - 2*t_n)*t_e*f_{r4} \\
 &= (7.652 - 3.826 - 2*0.337)*0.75*0.9563 \\
 &= \underline{2.2607} \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_{41} + A_{42} + A_5 \\
 &= 0 + 0.7156 + 0.1156 + 0 + 2.2607 \\
 &= \underline{3.0919} \text{ in}^2
 \end{aligned}$$

As Area >= A the reinforcement is adequate.

### UW-16(c)(2) Weld Check

$$\begin{aligned}
 \text{Inner fillet: } t_{\min} &= \text{lesser of } 0.75 \text{ or } t_n \text{ or } t_e = 0.337 \text{ in} \\
 t_{c(\min)} &= \text{lesser of } 0.25 \text{ or } 0.7*t_{\min} = \underline{0.2359} \text{ in} \\
 t_{c(\text{actual})} &= 0.7*\text{Leg} = 0.7*0.3755 = 0.2629 \text{ in}
 \end{aligned}$$

$$\begin{aligned}
 \text{Outer fillet: } t_{\min} &= \text{lesser of } 0.75 \text{ or } t_e \text{ or } t = 0.573 \text{ in} \\
 t_{w(\min)} &= 0.5*t_{\min} = \underline{0.2865} \text{ in} \\
 t_{w(\text{actual})} &= 0.7*\text{Leg} = 0.7*0.5 = 0.35 \text{ in}
 \end{aligned}$$

### UG-45 Nozzle Neck Thickness Check

$$\begin{aligned}
 \text{Wall thickness per UG-45(a):} & \quad t_{r1} = 0.0324 \text{ in (E =1)} \\
 \text{Wall thickness per UG-45(b)(1):} & \quad t_{r2} = 0.573 \text{ in} \\
 \text{Wall thickness per UG-16(b):} & \quad t_{r3} = 0.0625 \text{ in} \\
 \text{Standard wall pipe per UG-45(b)(4):} & \quad t_{r4} = 0.2074 \text{ in} \\
 \text{The greater of } t_{r2} \text{ or } t_{r3}: & \quad t_{r5} = 0.573 \text{ in} \\
 \text{The lesser of } t_{r4} \text{ or } t_{r5}: & \quad t_{r6} = 0.2074 \text{ in}
 \end{aligned}$$

Required per UG-45 is the larger of  $t_{r1}$  or  $t_{r6} = \underline{0.2074}$  in

Available nozzle wall thickness new,  $t_n = 0.875*0.337 = 0.2949$  in

The nozzle neck thickness is adequate.

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

$$\begin{aligned}
 \text{Groove weld in tension:} & \quad 0.74*18,300 = 13,542 \text{ psi} \\
 \text{Nozzle wall in shear:} & \quad 0.7*15,000 = 10,500 \text{ psi} \\
 \text{Inner fillet weld in shear:} & \quad 0.49*15,000 = 7,350 \text{ psi} \\
 \text{Outer fillet weld in shear:} & \quad 0.49*17,500 = 8,575 \text{ psi} \\
 \text{Upper groove weld in tension:} & \quad 0.74*17,500 = 12,950 \text{ psi}
 \end{aligned}$$

### Strength of welded joints:

$$\begin{aligned}
 (1) \text{ Inner fillet weld in shear} \\
 (\pi / 2)*\text{Nozzle OD}*\text{Leg}*S_i &= (\pi / 2)*4.5*0.3755*7,350 = 19,508.76 \text{ lb}_f
 \end{aligned}$$

$$(2) \text{ Outer fillet weld in shear}$$

$$(\pi / 2) * \text{Pad OD} * \text{Leg} * S_o = (\pi / 2) * 7.7953 * 0.5 * 8,575 = 52,499.54 \text{ lb}_f$$

(3) Nozzle wall in shear

$$(\pi / 2) * \text{Mean nozzle dia} * t_n * S_n = (\pi / 2) * 4.163 * 0.337 * 10,500 = 23,139.05 \text{ lb}_f$$

(4) Groove weld in tension

$$(\pi / 2) * \text{Nozzle OD} * t_w * S_g = (\pi / 2) * 4.5 * 0.573 * 13,542 = 54,849.14 \text{ lb}_f$$

(6) Upper groove weld in tension

$$(\pi / 2) * \text{Nozzle OD} * t_w * S_g = (\pi / 2) * 4.5 * 0.75 * 12,950 = 68,653.62 \text{ lb}_f$$

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

$$\begin{aligned} W &= (A - (d - 2 * t_n) * (E_1 * t - F * t_r)) * S_v \\ &= (2.262 - (3.826 - 2 * 0.337) * (1 * 0.573 - 1 * 0.573)) * 18,300 \\ &= \underline{41,397.22} \text{ lb}_f \end{aligned}$$

$$\begin{aligned} W_{1-1} &= (A_2 + A_5 + A_{41} + A_{42}) * S_v \\ &= (0.7156 + 2.2607 + 0.1156 + 0) * 18,300 \\ &= \underline{56,581.65} \text{ lb}_f \end{aligned}$$

$$\begin{aligned} W_{2-2} &= (A_2 + A_3 + A_{41} + A_{43} + 2 * t_n * t * f_{r1}) * S_v \\ &= (0.7156 + 0 + 0.1156 + 0 + 2 * 0.337 * 0.573 * 0.8197) * 18,300 \\ &= \underline{21,004.19} \text{ lb}_f \end{aligned}$$

$$\begin{aligned} W_{3-3} &= (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2 * t_n * t * f_{r1}) * S_v \\ &= (0.7156 + 0 + 2.2607 + 0.1156 + 0 + 0 + 2 * 0.337 * 0.573 * 0.8197) * 18,300 \\ &= \underline{62,374.87} \text{ lb}_f \end{aligned}$$

Load for path 1-1 lesser of W or  $W_{1-1} = 41,397.22 \text{ lb}_f$

Path 1-1 through (2) & (3) = 52,499.54 + 23,139.05 = 75,638.59  $\text{lb}_f$

Path 1-1 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 2-2 lesser of W or  $W_{2-2} = 21,004.19 \text{ lb}_f$

Path 2-2 through (1), (4), (6) = 19,508.76 + 54,849.14 + 68,653.62 = 143,011.52  $\text{lb}_f$

Path 2-2 is stronger than  $W_{2-2}$  so it is acceptable per UG-41(b)(1).

Load for path 3-3 lesser of W or  $W_{3-3} = 41,397.22 \text{ lb}_f$

Path 3-3 through (2), (4) = 52,499.54 + 54,849.14 = 107,348.68  $\text{lb}_f$

Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

## 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 = 250.98 psi @ 125 °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> |
| <a href="#">2.2619</a>  | <a href="#">3.0919</a> | --             | <a href="#">0.7156</a> | --             | <a href="#">2.2607</a> | <a href="#">0.1156</a> | <a href="#">0.2074</a>  | 0.2949           |

| UG-41 Weld Failure Path Analysis Summary (lb <sub>f</sub> )   |                            |                           |                            |                            |                            |                            |
|---|----------------------------|---------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| All failure paths are stronger than the applicable weld loads |                            |                           |                            |                            |                            |                            |
| Weld load W   | Weld load W <sub>1-1</sub> | Path 1-1 strength         | Weld load W <sub>2-2</sub> | Path 2-2 strength          | Weld load W <sub>3-3</sub> | Path 3-3 strength          |
| <a href="#">41,392.02</a>                                     | <a href="#">56,581.65</a>  | <a href="#">75,638.59</a> | <a href="#">21,004.19</a>  | <a href="#">143,011.52</a> | <a href="#">62,374.87</a>  | <a href="#">107,348.68</a> |

| UW-16 Weld Sizing Summary                 |                         |                       |                       |
|---|-------------------------|-----------------------|-----------------------|
| Weld description                          | Required weld size (in) | Actual weld size (in) | Status                |
| Nozzle to pad fillet (Leg <sub>41</sub> ) | <a href="#">0.2359</a>  | 0.2628                | weld size is adequate |
| Pad to shell fillet (Leg <sub>42</sub> )  | <a href="#">0.2865</a>  | 0.35                  | weld size is adequate |

### Calculations for internal pressure 250.98 psi @ 125 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(3.826, 1.913 + (0.337 - 0) + (0.573 - 0)) \\
 &= 3.826 \text{ in}
 \end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.573 - 0), 2.5*(0.337 - 0) + 0.75) \\
 &= 1.4325 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_{rn} &= P*R_n / (S_n*E - 0.6*P) \\
 &= 250.9833*1.913 / (15,000*1 - 0.6*250.9833) \\
 &= 0.0323 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> from UG-37(a)

$$\begin{aligned}
 t_r &= P*R_o / (S*E + 0.4*P) \\
 &= 250.9833*42.0079 / (18,300*1 + 0.4*250.9833)
 \end{aligned}$$

$$= 0.573 \text{ in}$$

### Area required per UG-37(c)

Allowable stresses:  $S_n = 15,000$ ,  $S_v = 18,300$ ,  $S_p = 17,500$  psi

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.8197$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.8197$$

$$f_{r3} = \text{lesser of } f_{r2} \text{ or } S_p / S_v = 0.8197$$

$$f_{r4} = \text{lesser of } 1 \text{ or } S_p / S_v = 0.9563$$

$$\begin{aligned} A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\ &= 3.826 \cdot 0.573 \cdot 1 + 2 \cdot 0.337 \cdot 0.573 \cdot 1 \cdot (1 - 0.8197) \\ &= 2.2619 \text{ in}^2 \end{aligned}$$

### Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = 0 \text{ in}^2$$

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 3.826 \cdot (1 \cdot 0.573 - 1 \cdot 0.573) - 2 \cdot 0.337 \cdot (1 \cdot 0.573 - 1 \cdot 0.573) \cdot (1 - 0.8197) \\ &= 0 \text{ in}^2 \\ &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2 \cdot (0.573 + 0.337) \cdot (1 \cdot 0.573 - 1 \cdot 0.573) - 2 \cdot 0.337 \cdot (1 \cdot 0.573 - 1 \cdot 0.573) \cdot (1 - 0.8197) \\ &= 0 \text{ in}^2 \end{aligned}$$

$$A_2 = \text{smaller of the following} = 0.7156 \text{ in}^2$$

$$\begin{aligned} &= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t \\ &= 5 \cdot (0.337 - 0.0323) \cdot 0.8197 \cdot 0.573 \\ &= 0.7156 \text{ in}^2 \\ &= 2 \cdot (t_n - t_{rn}) \cdot (2.5 \cdot t_n + t_e) \cdot f_{r2} \\ &= 2 \cdot (0.337 - 0.0323) \cdot (2.5 \cdot 0.337 + 0.75) \cdot 0.8197 \\ &= 0.7955 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 \cdot f_{r3} \\ &= 0.3755^2 \cdot 0.8197 \\ &= 0.1156 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{42} &= \text{Leg}^2 \cdot f_{r4} \\ &= 0^2 \cdot 0.9563 \\ &= 0 \text{ in}^2 \end{aligned}$$

(Part of the weld is outside of the limits)

$$\begin{aligned} A_5 &= (D_p - d - 2*t_n)*t_e*f_{r4} \\ &= (7.652 - 3.826 - 2*0.337)*0.75*0.9563 \\ &= \underline{2.2607} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} + A_{42} + A_5 \\ &= 0 + 0.7156 + 0.1156 + 0 + 2.2607 \\ &= \underline{3.0919} \text{ in}^2 \end{aligned}$$

As Area  $\geq$  A the reinforcement is adequate.

### UW-16(c)(2) Weld Check

$$\begin{aligned} \text{Inner fillet: } t_{\min} &= \text{lesser of } 0.75 \text{ or } t_n \text{ or } t_e = 0.337 \text{ in} \\ t_{c(\min)} &= \text{lesser of } 0.25 \text{ or } 0.7*t_{\min} = \underline{0.2359} \text{ in} \\ t_{c(\text{actual})} &= 0.7*\text{Leg} = 0.7*0.3755 = 0.2629 \text{ in} \end{aligned}$$

$$\begin{aligned} \text{Outer fillet: } t_{\min} &= \text{lesser of } 0.75 \text{ or } t_e \text{ or } t = 0.573 \text{ in} \\ t_{w(\min)} &= 0.5*t_{\min} = \underline{0.2865} \text{ in} \\ t_{w(\text{actual})} &= 0.7*\text{Leg} = 0.7*0.5 = 0.35 \text{ in} \end{aligned}$$

### UG-45 Nozzle Neck Thickness Check

$$\begin{aligned} \text{Wall thickness per UG-45(a):} & \quad t_{r1} = 0.0324 \text{ in (E =1)} \\ \text{Wall thickness per UG-45(b)(1):} & \quad t_{r2} = 0.573 \text{ in} \\ \text{Wall thickness per UG-16(b):} & \quad t_{r3} = 0.0625 \text{ in} \\ \text{Standard wall pipe per UG-45(b)(4):} & \quad t_{r4} = 0.2074 \text{ in} \\ \text{The greater of } t_{r2} \text{ or } t_{r3}: & \quad t_{r5} = 0.573 \text{ in} \\ \text{The lesser of } t_{r4} \text{ or } t_{r5}: & \quad t_{r6} = 0.2074 \text{ in} \end{aligned}$$

Required per UG-45 is the larger of  $t_{r1}$  or  $t_{r6} = \underline{0.2074}$  in

Available nozzle wall thickness new,  $t_n = 0.875*0.337 = 0.2949$  in

The nozzle neck thickness is adequate.

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

$$\begin{aligned} \text{Groove weld in tension:} & \quad 0.74*18,300 = 13,542 \text{ psi} \\ \text{Nozzle wall in shear:} & \quad 0.7*15,000 = 10,500 \text{ psi} \\ \text{Inner fillet weld in shear:} & \quad 0.49*15,000 = 7,350 \text{ psi} \\ \text{Outer fillet weld in shear:} & \quad 0.49*17,500 = 8,575 \text{ psi} \\ \text{Upper groove weld in tension:} & \quad 0.74*17,500 = 12,950 \text{ psi} \end{aligned}$$

### Strength of welded joints:

(1) Inner fillet weld in shear

$$(\pi / 2) * \text{Nozzle OD} * \text{Leg} * S_i = (\pi / 2) * 4.5 * 0.3755 * 7,350 = 19,508.76 \text{ lb}_f$$

(2) Outer fillet weld in shear

$$(\pi / 2) * \text{Pad OD} * \text{Leg} * S_o = (\pi / 2) * 7.7953 * 0.5 * 8,575 = 52,499.54 \text{ lb}_f$$

(3) Nozzle wall in shear

$$(\pi / 2) * \text{Mean nozzle dia} * t_n * S_n = (\pi / 2) * 4.163 * 0.337 * 10,500 = 23,139.05 \text{ lb}_f$$

(4) Groove weld in tension

$$(\pi / 2) * \text{Nozzle OD} * t_w * S_g = (\pi / 2) * 4.5 * 0.573 * 13,542 = 54,849.14 \text{ lb}_f$$

(6) Upper groove weld in tension

$$(\pi / 2) * \text{Nozzle OD} * t_w * S_g = (\pi / 2) * 4.5 * 0.75 * 12,950 = 68,653.62 \text{ lb}_f$$

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

$$\begin{aligned} W &= (A - (d - 2 * t_n) * (E_1 * t - F * t_r)) * S_v \\ &= (2.2619 - (3.826 - 2 * 0.337) * (1 * 0.573 - 1 * 0.573)) * 18,300 \\ &= \underline{41.392.02} \text{ lb}_f \end{aligned}$$

$$\begin{aligned} W_{1-1} &= (A_2 + A_5 + A_{41} + A_{42}) * S_v \\ &= (0.7156 + 2.2607 + 0.1156 + 0) * 18,300 \\ &= \underline{56.581.65} \text{ lb}_f \end{aligned}$$

$$\begin{aligned} W_{2-2} &= (A_2 + A_3 + A_{41} + A_{43} + 2 * t_n * t * f_{r1}) * S_v \\ &= (0.7156 + 0 + 0.1156 + 0 + 2 * 0.337 * 0.573 * 0.8197) * 18,300 \\ &= \underline{21.004.19} \text{ lb}_f \end{aligned}$$

$$\begin{aligned} W_{3-3} &= (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2 * t_n * t * f_{r1}) * S_v \\ &= (0.7156 + 0 + 2.2607 + 0.1156 + 0 + 0 + 2 * 0.337 * 0.573 * 0.8197) * 18,300 \\ &= \underline{62.374.87} \text{ lb}_f \end{aligned}$$

Load for path 1-1 lesser of W or  $W_{1-1} = 41,392.02 \text{ lb}_f$

Path 1-1 through (2) & (3) =  $52,499.54 + 23,139.05 = \underline{75.638.59} \text{ lb}_f$

Path 1-1 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 2-2 lesser of W or  $W_{2-2} = 21,004.19 \text{ lb}_f$

Path 2-2 through (1), (4), (6) =  $19,508.76 + 54,849.14 + 68,653.62 = \underline{143.011.52} \text{ lb}_f$

Path 2-2 is stronger than  $W_{2-2}$  so it is acceptable per UG-41(b)(1).

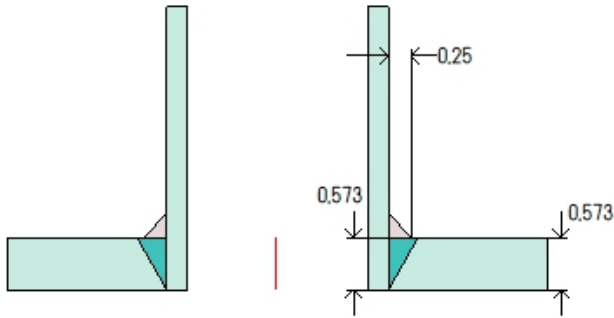
Load for path 3-3 lesser of W or  $W_{3-3} = 41,392.02 \text{ lb}_f$

Path 3-3 through (2), (4) =  $52,499.54 + 54,849.14 = \underline{107.348.68} \text{ lb}_f$

Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

Salida (N2)

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

Location and Orientation

|   |          |
|---|----------|
| Located on                              | V-01     |
| Orientation                             | 180°     |
| Nozzle center line offset to datum line | 25.31"   |
| End of nozzle to shell center           | 51.8479" |
| Passes through a Category A joint       | No       |

Nozzle

|  |   |
|--|---|
| Description  | NPS 2 Sch 80 (XS)                       |
| Access opening   | No                                      |
| Material specification   | SA-106 B Smls pipe (II-D p. 10, ln. 31) |
| Inside diameter, new   | 1.939"                                  |
| Pipe nominal wall thickness  | 0.218"                                  |
| Pipe minimum wall thickness <sup>1</sup>                           | 0.1908"                                 |
| Corrosion allowance  | 0"                                      |
| Projection available outside vessel, L <sub>pr</sub>               | 9.622"                                  |
| Projection available outside vessel to flange face, L <sub>f</sub> | 9.84"                                   |
| Local vessel minimum thickness                                     | 0.573"                                  |
| Liquid static head included  | 1.46 psi                                |
| Longitudinal joint efficiency                                      | 1                                       |

Welds

|                                 |        |
|---------------------------------|--------|
| Inner fillet, Leg <sub>41</sub> | 0.25"  |
| Nozzle to vessel groove weld    | 0.573" |



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

| ASME B16.5-1988 Flange  |   |
|---|---|
| <b>Description</b>  | NPS 2 Class 300 SO A105                     |
| <b>Bolt Material</b>  | SA-193 B7 Bolt ≤ 2 1/2 (II-D p. 386, ln. 2) |
| <b>Blind included</b>   | No  |
| <b>Rated MDMT</b>   | -20°F                                       |
| <b>Liquid static head</b>   | 1.66 psi                                    |
| <b>MAWP rating</b>  | 723.75 psi @ 125°F                          |
| <b>MAP rating</b>   | 740 psi @ 70°F                              |
| <b>Hydrotest rating</b>   | 1,125 psi @ 70°F                            |
| <b>External fillet weld leg (UW-21)</b>   | 0.22" (0.218" min)                          |
| <b>Internal fillet weld leg (UW-21)</b>   | 0.218" (0.218" min)                         |
| <b>PWHT performed</b>   | No  |
| <b>Impact Tested</b>  | No  |
| UW-21 Flange Welds  |   |
| External $Leg_{min} = t_n + C_o / 0.7 = 0.218 + 0 / 0.7 =$                                  | 0.218"                                      |
| Internal $Leg_{min} = t_n = 0.218 =$  | 0.218"                                      |
| Notes   |   |
| Flange rated MDMT per UCS-66(c) = -20°F<br>Bolts rated MDMT per Fig UCS-66 note (e) = -40°F |   |

| UCS-66 Material Toughness Requirements Nozzle                         |         |
|---|---------|
| $t_r = 250.94 * 0.9695 / (15,000 * 1 - 0.6 * 250.94) =$               | 0.0164" |
| $Stress\ ratio = t_r * E^* / (t_n - c) = 0.0164 * 1 / (0.1908 - 0) =$ | 0.0859  |
| $Stress\ ratio \leq 0.4, MDMT\ per\ UCS-66(b)(3) =$                   | -150°F  |
| Material is exempt from impact testing at the Design MDMT of 38°F.    |         |

## Reinforcement Calculations for Chamber MAWP

| UG-37 Area Calculation Summary<br>(in <sup>2</sup> )               |                |                |                |                |                |            | UG-45<br>Summary (in)      |                  |
|--|----------------|----------------|----------------|----------------|----------------|------------|----------------------------|------------------|
| For P = 251 psi @ 125 °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) |                |                |                |                |                |            | <a href="#">0.1348</a>     | 0.1908           |

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

| UW-16 Weld Sizing Summary                   |                                   |                                 |                       |
|---|-----------------------------------|---------------------------------|-----------------------|
| Weld description                            | Required weld<br>throat size (in) | Actual weld<br>throat size (in) | Status                |
| Nozzle to shell fillet (Leg <sub>41</sub> ) | <a href="#">0.1526</a>            | 0.175                           | weld size is adequate |

### Calculations for internal pressure 251 psi @ 125 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(1.939, 0.9695 + (0.218 - 0) + (0.573 - 0)) \\
 &= 1.939 \text{ in}
 \end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.573 - 0), 2.5*(0.218 - 0) + 0) \\
 &= 0.545 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_m &= P*R_n / (S_n*E - 0.6*P) \\
 &= 250.9985*0.9695 / (15,000*1 - 0.6*250.9985) \\
 &= 0.0164 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> from UG-37(a)

$$\begin{aligned}
 t_r &= P*R_o / (S*E + 0.4*P) \\
 &= 250.9985*42.0079 / (18,300*1 + 0.4*250.9985) \\
 &= 0.573 \text{ in}
 \end{aligned}$$

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

### UW-16(c) Weld Check

Fillet weld:  $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.218 \text{ in}$

$t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7 * t_{\min} = 0.1526 \text{ in}$

$t_{c(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 0.25 = 0.175 \text{ in}$

The fillet weld size is satisfactory.

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

### UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):  $t_{r1} = 0.0164 \text{ in (E = 1)}$

Wall thickness per UG-45(b)(1):  $t_{r2} = 0.573 \text{ in}$

Wall thickness per UG-16(b):  $t_{r3} = 0.0625 \text{ in}$

Standard wall pipe per UG-45(b)(4):  $t_{r4} = 0.1348 \text{ in}$

The greater of  $t_{r2}$  or  $t_{r3}$ :  $t_{r5} = 0.573 \text{ in}$

The lesser of  $t_{r4}$  or  $t_{r5}$ :  $t_{r6} = 0.1348 \text{ in}$

Required per UG-45 is the larger of  $t_{r1}$  or  $t_{r6} = 0.1348 \text{ in}$

Available nozzle wall thickness new,  $t_n = 0.875 * 0.218 = 0.1908 \text{ in}$

The nozzle neck thickness is adequate.

## 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 = 250.98 psi @ 125 °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) |                |                |                |                |                |            | <a href="#">0.1348</a>     | 0.1908           |

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

| UW-16 Weld Sizing Summary                   |                                   |                                 |                       |
|---|-----------------------------------|---------------------------------|-----------------------|
| Weld description                            | Required weld<br>throat size (in) | Actual weld<br>throat size (in) | Status                |
| Nozzle to shell fillet (Leg <sub>41</sub> ) | <a href="#">0.1526</a>            | 0.175                           | weld size is adequate |

### Calculations for internal pressure 250.98 psi @ 125 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\&= \text{MAX}(1.939, 0.9695 + (0.218 - 0) + (0.573 - 0)) \\&= 1.939 \text{ in}\end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\&= \text{MIN}(2.5*(0.573 - 0), 2.5*(0.218 - 0) + 0) \\&= 0.545 \text{ in}\end{aligned}$$

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

$$\begin{aligned}t_{rn} &= P*R_n / (S_n*E - 0.6*P) \\&= 250.9833*0.9695 / (15,000*1 - 0.6*250.9833) \\&= 0.0164 \text{ in}\end{aligned}$$

#### Required thickness $t_r$ from UG-37(a)

$$\begin{aligned}t_r &= P*R_o / (S*E + 0.4*P) \\&= 250.9833*42.0079 / (18,300*1 + 0.4*250.9833) \\&= 0.573 \text{ in}\end{aligned}$$

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

### UW-16(c) Weld Check

Fillet weld:  $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.218 \text{ in}$

$t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7 * t_{\min} = 0.1526 \text{ in}$

$t_{c(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 0.25 = 0.175 \text{ in}$

The fillet weld size is satisfactory.

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

### UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):  $t_{r1} = 0.0164 \text{ in (E = 1)}$

Wall thickness per UG-45(b)(1):  $t_{r2} = 0.573 \text{ in}$

Wall thickness per UG-16(b):  $t_{r3} = 0.0625 \text{ in}$

Standard wall pipe per UG-45(b)(4):  $t_{r4} = 0.1348 \text{ in}$

The greater of  $t_{r2}$  or  $t_{r3}$ :  $t_{r5} = 0.573 \text{ in}$

The lesser of  $t_{r4}$  or  $t_{r5}$ :  $t_{r6} = 0.1348 \text{ in}$

Required per UG-45 is the larger of  $t_{r1}$  or  $t_{r6} = 0.1348 \text{ in}$

Available nozzle wall thickness new,  $t_n = 0.875 * 0.218 = 0.1908 \text{ in}$

The nozzle neck thickness is adequate.

| ASME Section VIII Division 1, 1995 Edition |            |   |                          |                        |
|--|------------|---|--------------------------|------------------------|
| Component                                  |            | Cylinder                                      |                          |                        |
| Material                                   |            | SA-455 ( 3/8 < t <= 5/8) (II-D p. 22, ln. 16) |                          |                        |
| 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                                   |            | 250   | 125                      | 38                     |
| Static Liquid Head                         |            |   |                          |                        |
| Condition                                  |            | P <sub>s</sub> (psi)                          | H <sub>s</sub> (in)      | SG                     |
| Operating                                  |            | 1.44  | 71.1856                  | 0.5621                 |
| Test horizontal                            |            | 3.42  | 94.8628                  | 1                      |
| Dimensions                                 |            |   |                          |                        |
| Outer Diameter                             |            | 84.0157"                                      |                          |                        |
| Length                                     |            | 113.1496"                                     |                          |                        |
| Nominal Thickness                          |            | 0.573"  |                          |                        |
| Corrosion                                  | Inner      | 0"  |                          |                        |
|  | Outer      | 0"  |                          |                        |
| Weight and Capacity                        |            |   |                          |                        |
|  |            | Weight (lb)                                   |                          | Capacity (US gal)      |
| New  |            | 4,735.78                                      |                          | 2,641.94               |
| Corroded                                   |            | 4,735.78                                      |                          | 2,641.94               |
| Radiography                                |            |   |                          |                        |
| Longitudinal seam                          |            | Full UW-11(a) Type 1                          |                          |                        |
| Left Circumferential seam                  |            | Full UW-11(a) Type 1                          |                          |                        |
| Right Circumferential seam                 |            | Full UW-11(a) 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="#">0.5741"</a>    |
| Maximum allowable working pressure (MAWP)     | <a href="#">249.54 psi</a> |
| Rated MDMT                                    | 38.01 °F                   |

| UCS-66 Material Toughness Requirements                                     |          |
|--|----------|
| Governing thickness, $t_g =$   | 0.573"   |
| Exemption temperature from Fig UCS-66 Curve A =                            | 38.01 °F |
| $t_r = 250.93 \cdot 42.0079 / (18,300 \cdot 1 + 0.4 \cdot 250.93) =$       | 0.5729"  |
| Stress ratio $= t_r \cdot E' / (t_n - c) = 0.5729 \cdot 1 / (0.573 - 0) =$ | 0.9998   |
| Reduction in MDMT, $T_R$ from Fig UCS-66.1 =                               | 0 °F     |
| MDMT $= \max[ \text{MDMT} - T_R, -50 ] = \max[ 38.01 - 0, -50 ] =$         | 38.01 °F |
| <b>Rated MDMT of 38.01 °F &gt; Design MDMT of 38 °F.</b>                   |          |

#### Design thickness, (at 125 °F) Appendix 1-1

$$\begin{aligned}
 t &= P \cdot R_o / (S \cdot E + 0.40 \cdot P) + \text{Corrosion} \\
 &= 251.44 \cdot 42.0079 / (18,300 \cdot 1.00 + 0.40 \cdot 251.44) + 0 \\
 &= \text{0.5741"}
 \end{aligned}$$

#### Maximum allowable working pressure, (at 125 °F) Appendix 1-1

$$\begin{aligned}
 P &= S \cdot E \cdot t / (R_o - 0.40 \cdot t) - P_s \\
 &= 18,300 \cdot 1.00 \cdot 0.573 / (42.0079 - 0.40 \cdot 0.573) - 1.44 \\
 &= \text{249.54 psi}
 \end{aligned}$$

#### % Extreme fiber elongation - UCS-79(d)

$$\begin{aligned}
 \text{EFE} &= (50 \cdot t / R_f) \cdot (1 - R_f / R_o) \\
 &= (50 \cdot 0.573 / 41.7214) \cdot (1 - 41.7214 / \text{infinity}) \\
 &= 0.6867\%
 \end{aligned}$$

The extreme fiber elongation does not exceed 5%.

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

$$\begin{aligned}
 A &= 0.125 / (R_o / t) \\
 &= 0.125 / (42.0079 / 0.573) \\
 &= 0.001705 \\
 B &= 14,330 \text{ psi} \\
 S &= 18,300 / 1.00 = 18,300 \text{ psi} \\
 S_{cHC} &= \min(B, S) = 14,330 \text{ psi}
 \end{aligned}$$

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

$$\begin{aligned} S_{cHN} &= S_{cHC} \\ &= 14,330 \text{ psi} \end{aligned}$$

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

$$\begin{aligned} A &= 0.125 / (R_o / t) \\ &= 0.125 / (42.0079 / 0.573) \\ &= 0.001705 \\ B &= 14,330 \text{ psi} \\ S &= 18,300 / 1.00 = 18,300 \text{ psi} \\ S_{cCN} &= \min(B, S) = 14,330 \text{ psi} \end{aligned}$$

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

$$\begin{aligned} S_{cCC} &= S_{cCN} \\ &= 14,330 \text{ psi} \end{aligned}$$

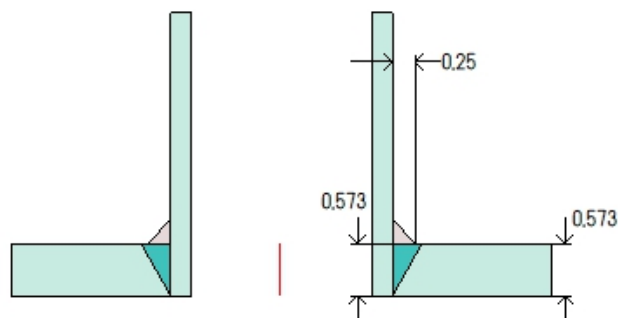
**Allowable Compressive Stress, Vacuum and Corroded-  $S_{cVC}$ , (table CS-2)**

$$\begin{aligned} A &= 0.125 / (R_o / t) \\ &= 0.125 / (42.0079 / 0.573) \\ &= 0.001705 \\ B &= 14,330 \text{ psi} \\ S &= 18,300 / 1.00 = 18,300 \text{ psi} \\ S_{cVC} &= \min(B, S) = 14,330 \text{ psi} \end{aligned}$$



# Alivio de presión (N7)

## ASME Section VIII Division 1, 1995 Edition



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

### Location and Orientation

|   |           |
|---|-----------|
| Located on                              | V-02      |
| Orientation                             | 0°        |
| Nozzle center line offset to datum line | 214.6063" |
| End of nozzle to shell center           | 53.4279"  |
| Passes through a Category A joint       | No        |

### Nozzle

|  |   |
|--|---|
| Description  | NPS 2 Sch 80 (XS)                       |
| Access opening   | No                                      |
| Material specification   | SA-106 B Smls pipe (II-D p. 10, ln. 31) |
| Inside diameter, new   | 1.939"                                  |
| Pipe nominal wall thickness  | 0.218"                                  |
| Pipe minimum wall thickness <sup>1</sup>                           | 0.1908"                                 |
| Corrosion allowance  | 0"                                      |
| Projection available outside vessel, L <sub>pr</sub>               | 11.202"                                 |
| Projection available outside vessel to flange face, L <sub>f</sub> | 11.42"                                  |
| Local vessel minimum thickness                                     | 0.573"                                  |
| Liquid static head included  | 0 psi                                   |
| Longitudinal joint efficiency                                      | 1                                       |

### Welds

|                                 |        |
|---------------------------------|--------|
| Inner fillet, Leg <sub>41</sub> | 0.25"  |
| Nozzle to vessel groove weld    | 0.573" |

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

| ASME B16.5-1988 Flange  |  |
|---|--|
| <b>Description</b>  | NPS 2 Class 300 SO A105                                  |
| <b>Bolt Material</b>  | SA-193 B7 Bolt $\leq 2 \frac{1}{2}$ (II-D p. 386, ln. 2) |
| <b>Blind included</b>   | No   |
| <b>Rated MDMT</b>   | -20°F  |
| <b>Liquid static head</b>   | 0 psi  |
| <b>MAWP rating</b>  | 723.75 psi @ 125°F                                       |
| <b>MAP rating</b>   | 740 psi @ 70°F   |
| <b>Hydrotest rating</b>   | 1,125 psi @ 70°F   |
| <b>External fillet weld leg (UW-21)</b>   | 0.22" (0.218" min)                                       |
| <b>Internal fillet weld leg (UW-21)</b>   | 0.218" (0.218" min)                                      |
| <b>PWHT performed</b>   | No   |
| <b>Impact Tested</b>  | No   |
| UW-21 Flange Welds  |  |
| External $\text{Leg}_{\min} = t_n + C_o / 0.7 = 0.218 + 0 / 0.7 =$                          | 0.218"   |
| Internal $\text{Leg}_{\min} = t_n = 0.218 =$  | 0.218"   |
| Notes   |  |
| Flange rated MDMT per UCS-66(c) = -20°F<br>Bolts rated MDMT per Fig UCS-66 note (e) = -40°F |  |

| UCS-66 Material Toughness Requirements Nozzle                               |         |
|---|---------|
| $t_r = 249.48 * 0.9695 / (15,000 * 1 - 0.6 * 249.48) =$                     | 0.0163" |
| $\text{Stress ratio} = t_r * E^* / (t_n - c) = 0.0163 * 1 / (0.1908 - 0) =$ | 0.0854  |
| $\text{Stress ratio} \leq 0.4$ , MDMT per UCS-66(b)(3) =                    | -150°F  |
| Material is exempt from impact testing at the Design MDMT of 38°F.          |         |

## Reinforcement Calculations for Chamber MAWP

| UG-37 Area Calculation Summary (in <sup>2</sup> )               |             |                |                |                |                |         | UG-45 Summary (in)      |                  |
|---|-------------|----------------|----------------|----------------|----------------|---------|-------------------------|------------------|
| For P = 249.54 psi @ 125 °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) |             |                |                |                |                |         | <a href="#">0.1348</a>  | 0.1908           |

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

| UW-16 Weld Sizing Summary                   |                                |                              |                       |
|---|--------------------------------|------------------------------|-----------------------|
| Weld description                            | Required weld throat size (in) | Actual weld throat size (in) | Status                |
| Nozzle to shell fillet (Leg <sub>41</sub> ) | <a href="#">0.1526</a>         | 0.175                        | weld size is adequate |

### Calculations for internal pressure 249.54 psi @ 125 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(1.939, 0.9695 + (0.218 - 0) + (0.573 - 0)) \\
 &= 1.939 \text{ in}
 \end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.573 - 0), 2.5*(0.218 - 0) + 0) \\
 &= 0.545 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_{rn} &= P*R_n / (S_n*E - 0.6*P) \\
 &= 249.5425*0.9695 / (15,000*1 - 0.6*249.5425) \\
 &= 0.0163 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> from UG-37(a)

$$\begin{aligned}
 t_r &= P*R_o / (S*E + 0.4*P) \\
 &= 249.5425*42.0079 / (18,300*1 + 0.4*249.5425) \\
 &= 0.5697 \text{ in}
 \end{aligned}$$

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

### UW-16(c) Weld Check

Fillet weld:  $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.218 \text{ in}$

$t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7 \cdot t_{\min} = 0.1526 \text{ in}$

$t_{c(\text{actual})} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.25 = 0.175 \text{ in}$

The fillet weld size is satisfactory.

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

### UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):  $t_{r1} = 0.0163 \text{ in (E = 1)}$

Wall thickness per UG-45(b)(1):  $t_{r2} = 0.5697 \text{ in}$

Wall thickness per UG-16(b):  $t_{r3} = 0.0625 \text{ in}$

Standard wall pipe per UG-45(b)(4):  $t_{r4} = 0.1348 \text{ in}$

The greater of  $t_{r2}$  or  $t_{r3}$ :  $t_{r5} = 0.5697 \text{ in}$

The lesser of  $t_{r4}$  or  $t_{r5}$ :  $t_{r6} = 0.1348 \text{ in}$

Required per UG-45 is the larger of  $t_{r1}$  or  $t_{r6} = 0.1348 \text{ in}$

Available nozzle wall thickness new,  $t_n = 0.875 \cdot 0.218 = 0.1908 \text{ in}$

The nozzle neck thickness is adequate.

## 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 = 250.98 psi @ 125 °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) |                |                |                |                |                |            | <a href="#">0.1348</a>     | 0.1908           |

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

| UW-16 Weld Sizing Summary                   |                                   |                                 |                       |
|---|-----------------------------------|---------------------------------|-----------------------|
| Weld description                            | Required weld<br>throat size (in) | Actual weld<br>throat size (in) | Status                |
| Nozzle to shell fillet (Leg <sub>41</sub> ) | <a href="#">0.1526</a>            | 0.175                           | weld size is adequate |

### Calculations for internal pressure 250.98 psi @ 125 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(1.939, 0.9695 + (0.218 - 0) + (0.573 - 0)) \\
 &= 1.939 \text{ in}
 \end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.573 - 0), 2.5*(0.218 - 0) + 0) \\
 &= 0.545 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_{rn} &= P*R_n / (S_n*E - 0.6*P) \\
 &= 250.9838*0.9695 / (15,000*1 - 0.6*250.9838) \\
 &= 0.0164 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> from UG-37(a)

$$\begin{aligned}
 t_r &= P*R_o / (S*E + 0.4*P) \\
 &= 250.9838*42.0079 / (18,300*1 + 0.4*250.9838) \\
 &= 0.573 \text{ in}
 \end{aligned}$$

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

### UW-16(c) Weld Check

Fillet weld:  $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.218 \text{ in}$

$t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7 * t_{\min} = 0.1526 \text{ in}$

$t_{c(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 0.25 = 0.175 \text{ in}$

The fillet weld size is satisfactory.

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

### UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):  $t_{r1} = 0.0164 \text{ in (E = 1)}$

Wall thickness per UG-45(b)(1):  $t_{r2} = 0.573 \text{ in}$

Wall thickness per UG-16(b):  $t_{r3} = 0.0625 \text{ in}$

Standard wall pipe per UG-45(b)(4):  $t_{r4} = 0.1348 \text{ in}$

The greater of  $t_{r2}$  or  $t_{r3}$ :  $t_{r5} = 0.573 \text{ in}$

The lesser of  $t_{r4}$  or  $t_{r5}$ :  $t_{r6} = 0.1348 \text{ in}$

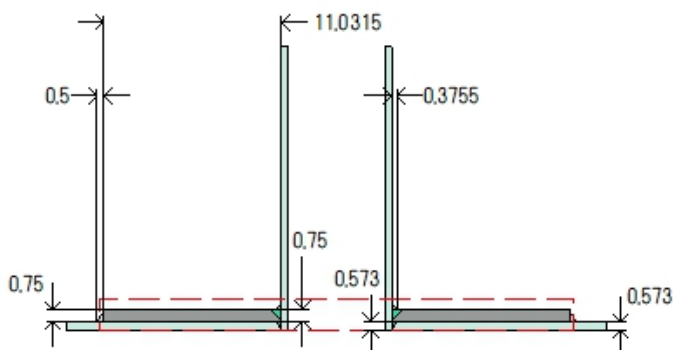
Required per UG-45 is the larger of  $t_{r1}$  or  $t_{r6} = 0.1348 \text{ in}$

Available nozzle wall thickness new,  $t_n = 0.875 * 0.218 = 0.1908 \text{ in}$

The nozzle neck thickness is adequate.

## Entrada Hombre (M2)

### ASME Section VIII Division 1, 1995 Edition



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

#### Location and Orientation

|   |          |
|---|----------|
| Located on                              | V-02     |
| Orientation                             | 0°       |
| Nozzle center line offset to datum line | 165.55"  |
| End of nozzle to shell center           | 53.4279" |
| Passes through a Category A joint       | No       |

#### Nozzle

|  |   |
|--|---|
| Description  | NPS 24 Sch 20 (Std)                     |
| Access opening   | No                                      |
| Material specification   | SA-106 B Smls pipe (II-D p. 10, ln. 31) |
| Inside diameter, new   | 23.25"                                  |
| Pipe nominal wall thickness  | 0.375"                                  |
| Pipe minimum wall thickness <sup>1</sup>                           | 0.3281"                                 |
| Corrosion allowance  | 0"                                      |
| Projection available outside vessel, L <sub>pr</sub>               | 11.045"                                 |
| Projection available outside vessel to flange face, L <sub>f</sub> | 11.42"                                  |
| Local vessel minimum thickness                                     | 0.573"                                  |
| Liquid static head included  | 0 psi                                   |
| Longitudinal joint efficiency                                      | 1                                       |

#### Reinforcing Pad

|                          |                                |
|--------------------------|--------------------------------|
| Material specification   | SA-516 70 (II-D p. 18, ln. 23) |
| Diameter, D <sub>p</sub> | 46.063"                        |

|                                 |         |
|---------------------------------|---------|
| Thickness, $t_e$                | 0.75"   |
| Is split                        | No      |
| <b>Welds</b>                    |         |
| Inner fillet, Leg <sub>41</sub> | 0.3755" |
| Outer fillet, Leg <sub>42</sub> | 0.5"    |
| Nozzle to vessel groove weld    | 0.573"  |
| Pad groove weld                 | 0.75"   |

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

| <b>ASME B16.5-1988 Flange</b>   |  |
|---|--|
| <b>Description</b>  | NPS 24 Class 150 SO A105                                 |
| <b>Bolt Material</b>  | SA-193 B7 Bolt $\leq 2 \frac{1}{2}$ (II-D p. 386, ln. 2) |
| <b>Blind included</b>   | Yes  |
| <b>Rated MDMT</b>   | -20°F  |
| <b>Liquid static head</b>   | 0 psi  |
| <b>MAWP rating</b>  | 278.75 psi @ 125°F                                       |
| <b>MAP rating</b>   | 285 psi @ 70°F   |
| <b>Hydrotest rating</b>   | 450 psi @ 70°F   |
| <b>External fillet weld leg (UW-21)</b>   | 0.375" (0.375" min)                                      |
| <b>Internal fillet weld leg (UW-21)</b>   | 0.375" (0.375" min)                                      |
| <b>PWHT performed</b>   | No   |
| <b>Impact Tested</b>  | No   |
| <b>UW-21 Flange Welds</b>   |  |
| External Leg <sub>min</sub> = $t_n + C_o / 0.7 = 0.375 + 0 / 0.7 =$                         | 0.375"   |
| Internal Leg <sub>min</sub> = $t_n = 0.375 =$   | 0.375"   |
| <b>Notes</b>  |  |
| Flange rated MDMT per UCS-66(c) = -20°F<br>Bolts rated MDMT per Fig UCS-66 note (e) = -40°F |  |



| UCS-66 Material Toughness Requirements Nozzle                                  |         |
|--|---------|
| Governing thickness, $t_g =$   | 0.3281" |
| Exemption temperature from Fig UCS-66 Curve B =                                | -20°F   |
| $t_r = 249.48 \times 11.625 / (15,000 \times 1 - 0.6 \times 249.48) =$         | 0.1953" |
| Stress ratio = $t_r \times E^* / (t_n - c) = 0.1953 \times 1 / (0.3281 - 0) =$ | 0.5952  |
| Reduction in MDMT, $T_R$ from Fig UCS-66.1 =                                   | 40.3°F  |
| MDMT = $\max[\text{MDMT} - T_R, -50] = \max[-20 - 40.3, -50] =$                | -50°F   |
| Material is exempt from impact testing at the Design MDMT of 38°F.             |         |

| UCS-66 Material Toughness Requirements Pad                                      |        |
|---|--------|
| Governing thickness, $t_g =$  | 0.573" |
| MDMT =  | -20°F  |
| Material is exempt from impact testing per UG-20(f) at the Design MDMT of 38°F. |        |

## Reinforcement Calculations for Chamber MAWP

| UG-37 Area Calculation Summary (in <sup>2</sup> )                   |                         |                        |                       |                |                         |                        | UG-45 Summary (in)      |                  |
|---|-------------------------|------------------------|-----------------------|----------------|-------------------------|------------------------|-------------------------|------------------|
| For P = 249.54 psi @ 125 °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> |
| <a href="#">13.323</a>  | <a href="#">16.6008</a> | <a href="#">0.0758</a> | <a href="#">0.422</a> | --             | <a href="#">15.8241</a> | <a href="#">0.2789</a> | <a href="#">0.3281</a>  | 0.3281           |

| UG-41 Weld Failure Path Analysis Summary (lb <sub>f</sub> )   |                            |                            |                            |                            |                            |                            |
|---|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| All failure paths are stronger than the applicable weld loads |                            |                            |                            |                            |                            |                            |
| Weld load W   | Weld load W <sub>1-1</sub> | Path 1-1 strength          | Weld load W <sub>2-2</sub> | Path 2-2 strength          | Weld load W <sub>3-3</sub> | Path 3-3 strength          |
| <a href="#">242.460.92</a>                                    | <a href="#">302.408.04</a> | <a href="#">456.345.42</a> | <a href="#">16.284.55</a>  | <a href="#">762.728.09</a> | <a href="#">308.854.51</a> | <a href="#">602.753.29</a> |

| UW-16 Weld Sizing Summary                 |                         |                       |                       |
|---|-------------------------|-----------------------|-----------------------|
| Weld description                          | Required weld size (in) | Actual weld size (in) | Status                |
| Nozzle to pad fillet (Leg <sub>41</sub> ) | <a href="#">0.25</a>    | 0.2628                | weld size is adequate |
| Pad to shell fillet (Leg <sub>42</sub> )  | <a href="#">0.2865</a>  | 0.35                  | weld size is adequate |

### Calculations for internal pressure 249.54 psi @ 125 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(23.25, 11.625 + (0.375 - 0) + (0.573 - 0)) \\
 &= 23.25 \text{ in}
 \end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.573 - 0), 2.5*(0.375 - 0) + 0.75) \\
 &= 1.4325 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_{rn} &= P*R_n / (S_n*E - 0.6*P) \\
 &= 249.5425*11.625 / (15,000*1 - 0.6*249.5425) \\
 &= 0.1953 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> from UG-37(a)

$$\begin{aligned}
 t_r &= P*R_o / (S*E + 0.4*P) \\
 &= 249.5425*42.0079 / (18,300*1 + 0.4*249.5425) \\
 &= 0.5697 \text{ in}
 \end{aligned}$$

### Area required per UG-37(c)

Allowable stresses:  $S_n = 15,000$ ,  $S_v = 18,300$ ,  $S_p = 17,500$  psi

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.8197$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.8197$$

$$f_{r3} = \text{lesser of } f_{r2} \text{ or } S_p / S_v = 0.8197$$

$$f_{r4} = \text{lesser of } 1 \text{ or } S_p / S_v = 0.9563$$

$$\begin{aligned} A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\ &= 23.25 \cdot 0.5697 \cdot 1 + 2 \cdot 0.375 \cdot 0.5697 \cdot 1 \cdot (1 - 0.8197) \\ &= \underline{13.323} \text{ in}^2 \end{aligned}$$

### Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{0.0758} \text{ in}^2$$

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 23.25 \cdot (1 \cdot 0.573 - 1 \cdot 0.5697) - 2 \cdot 0.375 \cdot (1 \cdot 0.573 - 1 \cdot 0.5697) \cdot (1 - 0.8197) \\ &= 0.0758 \text{ in}^2 \\ &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2 \cdot (0.573 + 0.375) \cdot (1 \cdot 0.573 - 1 \cdot 0.5697) - 2 \cdot 0.375 \cdot (1 \cdot 0.573 - 1 \cdot 0.5697) \cdot (1 - 0.8197) \\ &= 0.0058 \text{ in}^2 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{0.422} \text{ in}^2$$

$$\begin{aligned} &= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t \\ &= 5 \cdot (0.375 - 0.1953) \cdot 0.8197 \cdot 0.573 \\ &= 0.422 \text{ in}^2 \\ &= 2 \cdot (t_n - t_{rn}) \cdot (2.5 \cdot t_n + t_e) \cdot f_{r2} \\ &= 2 \cdot (0.375 - 0.1953) \cdot (2.5 \cdot 0.375 + 0.75) \cdot 0.8197 \\ &= 0.4971 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 \cdot f_{r3} \\ &= 0.3755^2 \cdot 0.8197 \\ &= \underline{0.1156} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{42} &= \text{Leg}^2 \cdot f_{r4} \\ &= 0.4132^2 \cdot 0.9563 \\ &= \underline{0.1633} \text{ in}^2 \end{aligned}$$

(Part of the weld is outside of the limits)

$$\begin{aligned}
 A_5 &= (D_p - d - 2t_n) \cdot t_e \cdot f_{r4} \\
 &= (46.063 - 23.25 - 2 \cdot 0.375) \cdot 0.75 \cdot 0.9563 \\
 &= \underline{15.8241} \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_{41} + A_{42} + A_5 \\
 &= 0.0758 + 0.422 + 0.1156 + 0.1633 + 15.8241 \\
 &= \underline{16.6008} \text{ in}^2
 \end{aligned}$$

As Area  $\geq$  A the reinforcement is adequate.

### UW-16(c)(2) Weld Check

$$\begin{aligned}
 \text{Inner fillet: } t_{\min} &= \text{lesser of } 0.75 \text{ or } t_n \text{ or } t_e = 0.375 \text{ in} \\
 t_{c(\min)} &= \text{lesser of } 0.25 \text{ or } 0.7 \cdot t_{\min} = \underline{0.25} \text{ in} \\
 t_{c(\text{actual})} &= 0.7 \cdot \text{Leg} = 0.7 \cdot 0.375 = 0.2629 \text{ in}
 \end{aligned}$$

$$\begin{aligned}
 \text{Outer fillet: } t_{\min} &= \text{lesser of } 0.75 \text{ or } t_e \text{ or } t = 0.573 \text{ in} \\
 t_{w(\min)} &= 0.5 \cdot t_{\min} = \underline{0.2865} \text{ in} \\
 t_{w(\text{actual})} &= 0.7 \cdot \text{Leg} = 0.7 \cdot 0.5 = 0.35 \text{ in}
 \end{aligned}$$

### UG-45 Nozzle Neck Thickness Check

$$\begin{aligned}
 \text{Wall thickness per UG-45(a):} & \quad t_{r1} = 0.1953 \text{ in (E = 1)} \\
 \text{Wall thickness per UG-45(b)(1):} & \quad t_{r2} = 0.5697 \text{ in} \\
 \text{Wall thickness per UG-16(b):} & \quad t_{r3} = 0.0625 \text{ in} \\
 \text{Standard wall pipe per UG-45(b)(4):} & \quad t_{r4} = 0.3281 \text{ in} \\
 \text{The greater of } t_{r2} \text{ or } t_{r3}: & \quad t_{r5} = 0.5697 \text{ in} \\
 \text{The lesser of } t_{r4} \text{ or } t_{r5}: & \quad t_{r6} = 0.3281 \text{ in}
 \end{aligned}$$

Required per UG-45 is the larger of  $t_{r1}$  or  $t_{r6} = \underline{0.3281}$  in

Available nozzle wall thickness new,  $t_n = 0.875 \cdot 0.375 = 0.3281$  in

The nozzle neck thickness is adequate.

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

$$\begin{aligned}
 \text{Groove weld in tension:} & \quad 0.74 \cdot 18,300 = 13,542 \text{ psi} \\
 \text{Nozzle wall in shear:} & \quad 0.7 \cdot 15,000 = 10,500 \text{ psi} \\
 \text{Inner fillet weld in shear:} & \quad 0.49 \cdot 15,000 = 7,350 \text{ psi} \\
 \text{Outer fillet weld in shear:} & \quad 0.49 \cdot 17,500 = 8,575 \text{ psi} \\
 \text{Upper groove weld in tension:} & \quad 0.74 \cdot 17,500 = 12,950 \text{ psi}
 \end{aligned}$$

### Strength of welded joints:

$$\begin{aligned}
 (1) \text{ Inner fillet weld in shear} \\
 (\pi / 2) \cdot \text{Nozzle OD} \cdot \text{Leg} \cdot S_i &= (\pi / 2) \cdot 24 \cdot 0.375 \cdot 7,350 = 104,046.72 \text{ lb}_f
 \end{aligned}$$

$$(2) \text{ Outer fillet weld in shear}$$

$$(\pi / 2) * \text{Pad OD} * \text{Leg} * S_o = (\pi / 2) * 46.063 * 0.5 * 8,575 = 310,224.54 \text{ lb}_f$$

(3) Nozzle wall in shear

$$(\pi / 2) * \text{Mean nozzle dia} * t_n * S_n = (\pi / 2) * 23.625 * 0.375 * 10,500 = 146,120.87 \text{ lb}_f$$

(4) Groove weld in tension

$$(\pi / 2) * \text{Nozzle OD} * t_w * S_g = (\pi / 2) * 24 * 0.573 * 13,542 = 292,528.75 \text{ lb}_f$$

(6) Upper groove weld in tension

$$(\pi / 2) * \text{Nozzle OD} * t_w * S_g = (\pi / 2) * 24 * 0.75 * 12,950 = 366,152.62 \text{ lb}_f$$

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

$$\begin{aligned} W &= (A - (d - 2 * t_n) * (E_1 * t - F * t_r)) * S_v \\ &= (13.323 - (23.25 - 2 * 0.375) * (1 * 0.573 - 1 * 0.5697)) * 18,300 \\ &= \underline{242,460.92} \text{ lb}_f \end{aligned}$$

$$\begin{aligned} W_{1-1} &= (A_2 + A_5 + A_{41} + A_{42}) * S_v \\ &= (0.422 + 15.8241 + 0.1156 + 0.1633) * 18,300 \\ &= \underline{302,408.04} \text{ lb}_f \end{aligned}$$

$$\begin{aligned} W_{2-2} &= (A_2 + A_3 + A_{41} + A_{43} + 2 * t_n * t * f_{r1}) * S_v \\ &= (0.422 + 0 + 0.1156 + 0 + 2 * 0.375 * 0.573 * 0.8197) * 18,300 \\ &= \underline{16,284.55} \text{ lb}_f \end{aligned}$$

$$\begin{aligned} W_{3-3} &= (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2 * t_n * t * f_{r1}) * S_v \\ &= (0.422 + 0 + 15.8241 + 0.1156 + 0.1633 + 0 + 2 * 0.375 * 0.573 * 0.8197) * 18,300 \\ &= \underline{308,854.51} \text{ lb}_f \end{aligned}$$

Load for path 1-1 lesser of W or  $W_{1-1} = 242,460.92 \text{ lb}_f$

Path 1-1 through (2) & (3) =  $310,224.54 + 146,120.87 = \underline{456,345.42} \text{ lb}_f$

Path 1-1 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 2-2 lesser of W or  $W_{2-2} = 16,284.55 \text{ lb}_f$

Path 2-2 through (1), (4), (6) =  $104,046.72 + 292,528.75 + 366,152.62 = \underline{762,728.09} \text{ lb}_f$

Path 2-2 is stronger than  $W_{2-2}$  so it is acceptable per UG-41(b)(1).

Load for path 3-3 lesser of W or  $W_{3-3} = 242,460.92 \text{ lb}_f$

Path 3-3 through (2), (4) =  $310,224.54 + 292,528.75 = \underline{602,753.29} \text{ lb}_f$

Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

## 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 = 250.98 psi @ 125 °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> |
| <a href="#">13.3995</a>   | <a href="#">16.5224</a> | <a href="#">0.0002</a> | <a href="#">0.4192</a> | --             | <a href="#">15.8241</a> | <a href="#">0.2789</a> | <a href="#">0.3281</a>  | 0.3281           |

| UG-41 Weld Failure Path Analysis Summary (lb <sub>f</sub> )   |                            |                            |                            |                            |                            |                            |
|---|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| All failure paths are stronger than the applicable weld loads |                            |                            |                            |                            |                            |                            |
| Weld load W   | Weld load W <sub>1-1</sub> | Path 1-1 strength          | Weld load W <sub>2-2</sub> | Path 2-2 strength          | Weld load W <sub>3-3</sub> | Path 3-3 strength          |
| <a href="#">245,206.73</a>                                    | <a href="#">302,356.8</a>  | <a href="#">456,345.42</a> | <a href="#">16,233.31</a>  | <a href="#">762,728.09</a> | <a href="#">308,803.27</a> | <a href="#">602,753.29</a> |

| UW-16 Weld Sizing Summary                 |                         |                       |                       |
|---|-------------------------|-----------------------|-----------------------|
| Weld description                          | Required weld size (in) | Actual weld size (in) | Status                |
| Nozzle to pad fillet (Leg <sub>41</sub> ) | <a href="#">0.25</a>    | 0.2628                | weld size is adequate |
| Pad to shell fillet (Leg <sub>42</sub> )  | <a href="#">0.2865</a>  | 0.35                  | weld size is adequate |

### Calculations for internal pressure 250.98 psi @ 125 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(23.25, 11.625 + (0.375 - 0) + (0.573 - 0)) \\
 &= 23.25 \text{ in}
 \end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.573 - 0), 2.5*(0.375 - 0) + 0.75) \\
 &= 1.4325 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_{rn} &= P*R_n / (S_n*E - 0.6*P) \\
 &= 250.9838*11.625 / (15,000*1 - 0.6*250.9838) \\
 &= 0.1965 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> from UG-37(a)

$$\begin{aligned}
 t_r &= P*R_o / (S*E + 0.4*P) \\
 &= 250.9838*42.0079 / (18,300*1 + 0.4*250.9838)
 \end{aligned}$$

$$= 0.573 \text{ in}$$

### Area required per UG-37(c)

Allowable stresses:  $S_n = 15,000$ ,  $S_v = 18,300$ ,  $S_p = 17,500$  psi

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.8197$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.8197$$

$$f_{r3} = \text{lesser of } f_{r2} \text{ or } S_p / S_v = 0.8197$$

$$f_{r4} = \text{lesser of } 1 \text{ or } S_p / S_v = 0.9563$$

$$\begin{aligned} A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\ &= 23.25 \cdot 0.573 \cdot 1 + 2 \cdot 0.375 \cdot 0.573 \cdot 1 \cdot (1 - 0.8197) \\ &= \underline{13.3995} \text{ in}^2 \end{aligned}$$

### Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{0.0002} \text{ in}^2$$

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 23.25 \cdot (1 \cdot 0.573 - 1 \cdot 0.573) - 2 \cdot 0.375 \cdot (1 \cdot 0.573 - 1 \cdot 0.573) \cdot (1 - 0.8197) \\ &= 0.0002 \text{ in}^2 \\ &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2 \cdot (0.573 + 0.375) \cdot (1 \cdot 0.573 - 1 \cdot 0.573) - 2 \cdot 0.375 \cdot (1 \cdot 0.573 - 1 \cdot 0.573) \cdot (1 - 0.8197) \\ &= 0 \text{ in}^2 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{0.4192} \text{ in}^2$$

$$\begin{aligned} &= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t \\ &= 5 \cdot (0.375 - 0.1965) \cdot 0.8197 \cdot 0.573 \\ &= 0.4192 \text{ in}^2 \\ &= 2 \cdot (t_n - t_{rn}) \cdot (2.5 \cdot t_n + t_e) \cdot f_{r2} \\ &= 2 \cdot (0.375 - 0.1965) \cdot (2.5 \cdot 0.375 + 0.75) \cdot 0.8197 \\ &= 0.4938 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 \cdot f_{r3} \\ &= 0.375^2 \cdot 0.8197 \\ &= \underline{0.1156} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{42} &= \text{Leg}^2 \cdot f_{r4} \\ &= 0.4132^2 \cdot 0.9563 \\ &= \underline{0.1633} \text{ in}^2 \end{aligned}$$

(Part of the weld is outside of the limits)

$$\begin{aligned} A_5 &= (D_p - d - 2*t_n)*t_e*f_{r4} \\ &= (46.063 - 23.25 - 2*0.375)*0.75*0.9563 \\ &= \underline{15.8241} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} + A_{42} + A_5 \\ &= 0.0002 + 0.4192 + 0.1156 + 0.1633 + 15.8241 \\ &= \underline{16.5224} \text{ in}^2 \end{aligned}$$

As Area  $\geq$  A the reinforcement is adequate.

### UW-16(c)(2) Weld Check

$$\begin{aligned} \text{Inner fillet: } t_{\min} &= \text{lesser of } 0.75 \text{ or } t_n \text{ or } t_e = 0.375 \text{ in} \\ t_{c(\min)} &= \text{lesser of } 0.25 \text{ or } 0.7*t_{\min} = \underline{0.25} \text{ in} \\ t_{c(\text{actual})} &= 0.7*\text{Leg} = 0.7*0.3755 = 0.2629 \text{ in} \end{aligned}$$

$$\begin{aligned} \text{Outer fillet: } t_{\min} &= \text{lesser of } 0.75 \text{ or } t_e \text{ or } t = 0.573 \text{ in} \\ t_{w(\min)} &= 0.5*t_{\min} = \underline{0.2865} \text{ in} \\ t_{w(\text{actual})} &= 0.7*\text{Leg} = 0.7*0.5 = 0.35 \text{ in} \end{aligned}$$

### UG-45 Nozzle Neck Thickness Check

$$\begin{aligned} \text{Wall thickness per UG-45(a):} & \quad t_{r1} = 0.1965 \text{ in (E =1)} \\ \text{Wall thickness per UG-45(b)(1):} & \quad t_{r2} = 0.573 \text{ in} \\ \text{Wall thickness per UG-16(b):} & \quad t_{r3} = 0.0625 \text{ in} \\ \text{Standard wall pipe per UG-45(b)(4):} & \quad t_{r4} = 0.3281 \text{ in} \\ \text{The greater of } t_{r2} \text{ or } t_{r3}: & \quad t_{r5} = 0.573 \text{ in} \\ \text{The lesser of } t_{r4} \text{ or } t_{r5}: & \quad t_{r6} = 0.3281 \text{ in} \end{aligned}$$

Required per UG-45 is the larger of  $t_{r1}$  or  $t_{r6} = \underline{0.3281}$  in

Available nozzle wall thickness new,  $t_n = 0.875*0.375 = 0.3281$  in

The nozzle neck thickness is adequate.

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

$$\begin{aligned} \text{Groove weld in tension:} & \quad 0.74*18,300 = 13,542 \text{ psi} \\ \text{Nozzle wall in shear:} & \quad 0.7*15,000 = 10,500 \text{ psi} \\ \text{Inner fillet weld in shear:} & \quad 0.49*15,000 = 7,350 \text{ psi} \\ \text{Outer fillet weld in shear:} & \quad 0.49*17,500 = 8,575 \text{ psi} \\ \text{Upper groove weld in tension:} & \quad 0.74*17,500 = 12,950 \text{ psi} \end{aligned}$$



### Strength of welded joints:

(1) Inner fillet weld in shear

$$(\pi / 2) * \text{Nozzle OD} * \text{Leg} * S_i = (\pi / 2) * 24 * 0.375 * 7,350 = 104,046.72 \text{ lb}_f$$

(2) Outer fillet weld in shear

$$(\pi / 2) * \text{Pad OD} * \text{Leg} * S_o = (\pi / 2) * 46.063 * 0.5 * 8,575 = 310,224.54 \text{ lb}_f$$

(3) Nozzle wall in shear

$$(\pi / 2) * \text{Mean nozzle dia} * t_n * S_n = (\pi / 2) * 23.625 * 0.375 * 10,500 = 146,120.87 \text{ lb}_f$$

(4) Groove weld in tension

$$(\pi / 2) * \text{Nozzle OD} * t_w * S_g = (\pi / 2) * 24 * 0.573 * 13,542 = 292,528.75 \text{ lb}_f$$

(6) Upper groove weld in tension

$$(\pi / 2) * \text{Nozzle OD} * t_w * S_g = (\pi / 2) * 24 * 0.75 * 12,950 = 366,152.62 \text{ lb}_f$$

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

$$\begin{aligned} W &= (A - (d - 2 * t_n) * (E_1 * t - F * t_r)) * S_v \\ &= (13.3995 - (23.25 - 2 * 0.375) * (1 * 0.573 - 1 * 0.573)) * 18,300 \\ &= \underline{245,206.73} \text{ lb}_f \end{aligned}$$

$$\begin{aligned} W_{1-1} &= (A_2 + A_5 + A_{41} + A_{42}) * S_v \\ &= (0.4192 + 15.8241 + 0.1156 + 0.1633) * 18,300 \\ &= \underline{302,356.8} \text{ lb}_f \end{aligned}$$

$$\begin{aligned} W_{2-2} &= (A_2 + A_3 + A_{41} + A_{43} + 2 * t_n * t * f_{r1}) * S_v \\ &= (0.4192 + 0 + 0.1156 + 0 + 2 * 0.375 * 0.573 * 0.8197) * 18,300 \\ &= \underline{16,233.31} \text{ lb}_f \end{aligned}$$

$$\begin{aligned} W_{3-3} &= (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2 * t_n * t * f_{r1}) * S_v \\ &= (0.4192 + 0 + 15.8241 + 0.1156 + 0.1633 + 0 + 2 * 0.375 * 0.573 * 0.8197) * 18,300 \\ &= \underline{308,803.27} \text{ lb}_f \end{aligned}$$

Load for path 1-1 lesser of W or  $W_{1-1} = 245,206.73 \text{ lb}_f$

Path 1-1 through (2) & (3) =  $310,224.54 + 146,120.87 = \underline{456,345.42} \text{ lb}_f$

Path 1-1 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 2-2 lesser of W or  $W_{2-2} = 16,233.31 \text{ lb}_f$

Path 2-2 through (1), (4), (6) =  $104,046.72 + 292,528.75 + 366,152.62 = \underline{762,728.09} \text{ lb}_f$

Path 2-2 is stronger than  $W_{2-2}$  so it is acceptable per UG-41(b)(1).

Load for path 3-3 lesser of W or  $W_{3-3} = 245,206.73 \text{ lb}_f$

Path 3-3 through (2), (4) =  $310,224.54 + 292,528.75 = \underline{602,753.29} \text{ lb}_f$

Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

| ASME Section VIII Division 1, 1995 Edition |            |                                    |                         |                           |
|--|------------|------------------------------------|-------------------------|---------------------------|
| Component                                  |            | Hemispherical Head                 |                         |                           |
| Material                                   |            | SA-455 <= 3/8 (II-D p. 22, ln. 21) |                         |                           |
| Attached To                                |            | V-02                               |                         |                           |
| 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                                   |            | 250                                | 125                     | 38                        |
| Static Liquid Head                         |            |                                    |                         |                           |
| Condition                                  |            | P <sub>s</sub> (psi)               | H <sub>s</sub> (in)     | SG                        |
| Operating                                  |            | 1.45                               | 71.4306                 | 0.5621                    |
| Test horizontal                            |            | 3.43                               | 95.1077                 | 1                         |
| Dimensions                                 |            |                                    |                         |                           |
| Outer Diameter                             |            | 84.0157"                           |                         |                           |
| Minimum Thickness                          |            | 0.328"                             |                         |                           |
| Corrosion                                  | Inner      | 0"                                 |                         |                           |
|  | Outer      | 0"                                 |                         |                           |
| Weight and Capacity                        |            |                                    |                         |                           |
|  |            | Weight (lb)                        |                         | Capacity (US gal)         |
| New  |            | 1,021.19                           |                         | 656.49                    |
| Corroded                                   |            | 1,021.19                           |                         | 656.49                    |
| Radiography                                |            |                                    |                         |                           |
| Category A joints - Long Seam              |            | Spot UW-11(b) Type 1               |                         |                           |
| Category A joints - Circ Seam              |            | Full UW-11(a) 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="#">0.3285"</a>    |
| Maximum allowable working pressure (MAWP)     | <a href="#">249.66 psi</a> |
| Rated MDMT                                    | -20 °F                     |

| UCS-66 Material Toughness Requirements   |        |
|--|--------|
| Governing thickness, $t_g =$   | 0.328" |
| MDMT =   | -20 °F |
| Material is exempt from impact testing per UG-20(f) at the Design MDMT of 38 °F. |        |

#### Design thickness, (at 125 °F) Appendix 1-1

$$\begin{aligned}
 t &= P \cdot R_o / (2 \cdot S \cdot E + 0.80 \cdot P) + \text{Corrosion} \\
 &= 251.45 \cdot 42.0079 / (2 \cdot 18,800 \cdot 0.85 + 0.80 \cdot 251.45) + 0 \\
 &= \underline{0.3285"}
 \end{aligned}$$

#### Maximum allowable working pressure, (at 125 °F) Appendix 1-1

$$\begin{aligned}
 P &= 2 \cdot S \cdot E \cdot t / (R_o - 0.80 \cdot t) - P_s \\
 &= 2 \cdot 18,800 \cdot 0.85 \cdot 0.328 / (42.0079 - 0.80 \cdot 0.328) - 1.45 \\
 &= \underline{249.66} \text{ psi}
 \end{aligned}$$

#### % Extreme fiber elongation - UCS-79(d)

$$\begin{aligned}
 EFE &= (75 \cdot t / R_f) \cdot (1 - R_f / R_o) \\
 &= (75 \cdot 0.328 / 41.8439) \cdot (1 - 41.8439 / \text{infinity}) \\
 &= 0.5879\%
 \end{aligned}$$

The extreme fiber elongation does not exceed 5%.

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

$$\begin{aligned}
 A &= 0.125 / (R_o / t) \\
 &= 0.125 / (42.0079 / 0.328) \\
 &= 0.000976 \\
 B &= 12,183 \text{ psi} \\
 S &= 18,800 / 1.00 = 18,800 \text{ psi} \\
 S_{cHC} &= \min(B, S) = 12,183 \text{ psi}
 \end{aligned}$$

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

$$\begin{aligned}
 S_{cHN} &= S_{cHC} \\
 &= 12,183 \text{ psi}
 \end{aligned}$$

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

$$\begin{aligned}
 A &= 0.125 / (R_o / t) \\
 &= 0.125 / (42.0079 / 0.328) \\
 &= 0.000976 \\
 B &= 12,183 \text{ psi} \\
 S &= 18,800 / 1.00 = 18,800 \text{ psi} \\
 S_{cCN} &= \min(B, S) = 12,183 \text{ psi}
 \end{aligned}$$

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

$$\begin{aligned} S_{cCC} &= S_{cCN} \\ &= 12,183 \text{ psi} \end{aligned}$$

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

$$\begin{aligned} A &= 0.125 / (R_o / t) \\ &= 0.125 / (42.0079 / 0.328) \\ &= 0.000976 \\ B &= 12,183 \text{ psi} \\ S &= 18,800 / 1.00 = 18,800 \text{ psi} \\ S_{cVC} &= \min(B, S) = 12,183 \text{ psi} \end{aligned}$$

PT (Cuna 1 y 2)

| ASME Section VIII Division 1, 1995 Edition     |                    |              |
|--|--------------------|--------------|
| Saddle Material                                | A283 GR C          |              |
| Saddle Construction                            | Web at edge of rib |              |
| Welded to Vessel                               | Yes                |              |
| Saddle Allowable Stress, S <sub>s</sub>        | 20,624 psi         |              |
| Saddle Yield Stress, S <sub>y</sub>            | 36,000 psi         |              |
| Foundation Allowable Stress                    | 1,658 psi          |              |
| Design Pressure                                | Left Saddle        | Right Saddle |
| Operating                                      | 250.93 psi         |              |
| Test   | 377.65 psi         |              |
| Dimensions                                     |                    |              |
| Right saddle distance to datum                 | 160.0394"          |              |
| Tangent To Tangent Length, L                   | 226.2992"          |              |
| Saddle separation, L <sub>s</sub>              | 95.6299"           |              |
| Vessel Radius, R                               | 42.0079"           |              |
| Tangent Distance Left, A <sub>l</sub>          | 64.4094"           |              |
| Tangent Distance Right, A <sub>r</sub>         | 66.2598"           |              |
| Saddle Height, H <sub>s</sub>                  | 47.5591"           |              |
| Saddle Contact Angle, θ                        | 120°               |              |
| Web Plate Thickness, t <sub>s</sub>            | 0.4724"            |              |
| Base Plate Length, E                           | 74.4488"           |              |
| Base Plate Width, F                            | 12.0079"           |              |
| Base Plate Thickness, t <sub>b</sub>           | 0.4724"            |              |
| Number of Stiffening Ribs, n                   | 4                  |              |
| Largest Stiffening Rib Spacing, d <sub>i</sub> | 26.9414"           |              |
| Stiffening Rib Thickness, t <sub>w</sub>       | 0.4724"            |              |
| Saddle Width, b                                | 12.0079"           |              |
| Reinforcing Plate                              |                    |              |
| Thickness, t <sub>p</sub>                      | 0.2756"            |              |
| Width, W <sub>p</sub>                          | 14.2126"           |              |
| Contact Angle, θ <sub>w</sub>                  | 132°               |              |
| Bolting  |                    |              |
| Material                                       | SA-193 B8          |              |

|                                     |                        |           |
|-------------------------------------|------------------------|-----------|
| Bolt Allowable Shear                | 18,800 psi             |           |
| Description                         | 0.625" coarse threaded |           |
| Corrosion on root                   | 0"                     |           |
| Anchor Bolts per Saddle             | 2                      |           |
| Base coefficient of friction, $\mu$ | 0.45                   |           |
| Weight                              |                        |           |
|                                     | Operating,<br>Corroded | Hydrotest |
| Weight on Left Saddle               | 20,104 lb              | 33,130 lb |
| Weight on Right Saddle              | 21,286 lb              | 35,001 lb |
| Weight of Saddle Pair               | 886 lb                 |           |

| Notes  |  |
|--|--|
| (1) Saddle calculations are based on the method presented in "Stresses in Large Cylindrical Pressure Vessels on Two Saddle Supports" by L.P. Zick. |  |

| Stress Summary |           |              |  |              |                       |              |  |              |                       |              |
|----------------|-----------|--------------|--|--------------|-----------------------|--------------|--|--------------|-----------------------|--------------|
| Load           | Condition | Saddle       | Bending + pressure between saddles (psi) |              |                       |              | Bending + pressure at the saddle (psi) |              |                       |              |
|                |           |              | S <sub>1</sub><br>(+)                    | allow<br>(+) | S <sub>1</sub><br>(-) | allow<br>(-) | S <sub>2</sub><br>(+)                  | allow<br>(+) | S <sub>2</sub><br>(-) | allow<br>(-) |
| Weight         | Operating | Right Saddle | <a href="#">8.950</a>                    | 18,300       | <a href="#">-122</a>  | 14,330       | <a href="#">10.850</a>                 | 18,300       | <a href="#">1.778</a> | 14,330       |
|                |           | Left Saddle  |  |              |                       |              | <a href="#">10.775</a>                 | 18,300       | <a href="#">1.702</a> | 14,330       |
|                | Test      | Right Saddle | <a href="#">13.453</a>                   | 33,300       | <a href="#">-202</a>  | 14,330       | <a href="#">16.581</a>                 | 33,300       | <a href="#">2.926</a> | 14,330       |
|                |           | Left Saddle  |  |              |                       |              | <a href="#">16.456</a>                 | 33,300       | <a href="#">2.802</a> | 14,330       |

| Stress Summary |           |              |                        |        |                              |             |                          |        |                       |        |
|----------------|-----------|--------------|------------------------|--------|------------------------------|-------------|--------------------------|--------|-----------------------|--------|
| Load           | Condition | Saddle       | Tangential shear (psi) |        | Circumferential stress (psi) |             | Stress over saddle (psi) |        | Splitting (psi)       |        |
|                |           |              | S <sub>3</sub>         | allow  | S <sub>4</sub> (horns)       | allow (+/-) | S <sub>5</sub>           | allow  | S <sub>6</sub>        | allow  |
| Weight         | Operating | Right Saddle | <a href="#">366</a>    | 14,640 | <a href="#">-8,060</a>       | 27,450      | <a href="#">1,949</a>    | 18,000 | <a href="#">700</a>   | 13,749 |
|                |           | Left Saddle  | <a href="#">321</a>    | 14,640 | <a href="#">-7,612</a>       | 27,450      | <a href="#">1,841</a>    | 18,000 | <a href="#">661</a>   | 13,749 |
|                | Test      | Right Saddle | <a href="#">600</a>    | 26,640 | <a href="#">-13,253</a>      | 33,300      | <a href="#">3,204</a>    | 32,400 | <a href="#">1,151</a> | 32,400 |
|                |           | Left Saddle  | <a href="#">530</a>    | 26,640 | <a href="#">-12,544</a>      | 33,300      | <a href="#">3,033</a>    | 32,400 | <a href="#">1,090</a> | 32,400 |

## Load Case 1: Weight, Operating

**Longitudinal stress between saddles (Weight, Operating, left saddle loading and geometry govern)**

$$\begin{aligned}
 S_1 &= \pm 3K_1 Q^*(L/12) / (\pi R^2 t) \\
 &= 3 \cdot 0.3369 \cdot 20,104 \cdot (226.2992 / 12) / (\pi \cdot 41.7214^2 \cdot 0.573) \\
 &= -122 \text{ psi}
 \end{aligned}$$

$$\begin{aligned}
 S_p &= P \cdot R / (2 \cdot t) \\
 &= 250.93 \cdot 41.4349 / (2 \cdot 0.573) \\
 &= 9,073 \text{ psi}
 \end{aligned}$$

Maximum tensile stress  $S_{1t} = S_1 + S_p = \text{8,950 psi}$   
Maximum compressive stress (shut down)  $S_{1c} = S_1 = \text{-122 psi}$

Tensile stress is acceptable ( $\leq S \cdot E = 18,300 \text{ psi}$ )  
Compressive stress is acceptable ( $\leq S_c = 14,330 \text{ psi}$ )

**Longitudinal stress at the right saddle (Weight, Operating)**

$$\begin{aligned}
 L_e &= 2 \cdot (\text{Left head depth}) / 3 + L + 2 \cdot (\text{Right head depth}) / 3 \\
 &= 2 \cdot 42.0079 / 3 + 226.2992 + 2 \cdot 42.0079 / 3 \\
 &= 282.3097 \text{ in}
 \end{aligned}$$

$$w = W_t / L_e = 41,390 / 282.3097 = 146.61 \text{ lb}_f/\text{in}$$

Bending moment at the right saddle:

$$\begin{aligned}
 M_q &= w \cdot (2 \cdot H \cdot A_r / 3 + A_r^2 / 2 - (R^2 - H^2) / 4) \\
 &= 146.61 \cdot (2 \cdot 42.0079 \cdot 66.2598 / 3 + 66.2598^2 / 2 - (42.0079^2 - 42.0079^2) / 4) \\
 &= 593,896.8 \text{ lb}_f\text{-in}
 \end{aligned}$$

$$\begin{aligned}
 S_2 &= \pm M_q \cdot K_1' / (\pi R^2 t) \\
 &= 593,896.8 \cdot 9.3799 / (\pi \cdot 41.7214^2 \cdot 0.573) \\
 &= 1,778 \text{ psi}
 \end{aligned}$$

$$\begin{aligned}
 S_p &= P \cdot R / (2 \cdot t) \\
 &= 250.93 \cdot 41.4349 / (2 \cdot 0.573) \\
 &= 9,073 \text{ psi}
 \end{aligned}$$

Maximum tensile stress  $S_{2t} = S_2 + S_p = \text{10,850 psi}$   
Maximum compressive stress (shut down)  $S_{2c} = S_2 = \text{1,778 psi}$

Tensile stress is acceptable ( $\leq S = 18,300 \text{ psi}$ )

Compressive stress is acceptable ( $\leq S_c = 14,330$  psi)

#### Tangential shear stress in the shell (right saddle, Weight, Operating)

$$\begin{aligned} Q_{\text{shear}} &= Q - w \cdot (a + 2 \cdot H / 3) \\ &= 21,286 - 146.61 \cdot (66.2598 + 2 \cdot 42.0079 / 3) \\ &= 7,465.6 \text{ lb}_f \end{aligned}$$

$$\begin{aligned} S_3 &= K_{2.2} \cdot Q_{\text{shear}} / (R \cdot t) \\ &= 1.1707 \cdot 7,465.6 / (41.7214 \cdot 0.573) \\ &= \underline{366} \text{ psi} \end{aligned}$$

Tangential shear stress is acceptable ( $\leq 0.8 \cdot S = 14,640$  psi)

#### Circumferential stress at the right saddle horns (Weight, Operating)

$$\begin{aligned} S_4 &= -Q / (4 \cdot t \cdot (b + 1.56 \cdot \text{Sqr}(R_o \cdot t))) - 12 \cdot K_3 \cdot Q \cdot R / (L \cdot t^2) \\ &= -21,286 / (4 \cdot 0.573 \cdot (12.0079 + 1.56 \cdot \text{Sqr}(42.0079 \cdot 0.573))) - 12 \cdot 0.0529 \cdot 21,286 \cdot 41.7214 / (226.2992 \cdot 0.573^2) \\ &= \underline{-8.060} \text{ psi} \end{aligned}$$

Circumferential stress at saddle horns is acceptable ( $\leq 1.5 \cdot S_a = 27,450$  psi)

The wear plate was not considered in the calculation of  $S_4$  because the wear plate width is not at least  $\{b + 1.56 \cdot (R_o \cdot t)^{0.5}\} = 19.6615$  in

#### Ring compression in shell over right saddle (Weight, Operating)

$$\begin{aligned} S_5 &= K_5 \cdot Q / ((t + t_p) \cdot (t_s + 1.56 \cdot \text{Sqr}(R_o \cdot t_c))) \\ &= 0.7603 \cdot 21,286 / ((0.573 + 0.2756) \cdot (0.4724 + 1.56 \cdot \text{Sqr}(42.0079 \cdot 0.8486))) \\ &= \underline{1.949} \text{ psi} \end{aligned}$$

Ring compression in shell is acceptable ( $\leq 0.5 \cdot S_y = 18,000$  psi)

#### Saddle splitting load (right, Weight, Operating)

Area resisting splitting force = Web area + wear plate area

$$\begin{aligned} A_e &= H_{\text{eff}} \cdot t_s + t_p \cdot W_p \\ &= 4.8031 \cdot 0.4724 + 0.2756 \cdot 14.2126 \\ &= 6.1861 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} S_6 &= K_8 \cdot Q / A_e \\ &= 0.2035 \cdot 21,286 / 6.1861 \\ &= \underline{700} \text{ psi} \end{aligned}$$

Stress in saddle is acceptable ( $\leq (2 / 3) \cdot S_s = 13,749$  psi)

#### Longitudinal stress at the left saddle (Weight, Operating)

$$\begin{aligned} L_e &= 2 \cdot (\text{Left head depth}) / 3 + L + 2 \cdot (\text{Right head depth}) / 3 \\ &= 2 \cdot 42.0079 / 3 + 226.2992 + 2 \cdot 42.0079 / 3 \\ &= 282.3097 \text{ in} \end{aligned}$$

$$w = W_t / L_e = 41,390 / 282.3097 = 146.61 \text{ lb}_f/\text{in}$$

Bending moment at the left saddle:

$$M_q = w \cdot (2 \cdot H \cdot A_l / 3 + A_l^2 / 2 - (R^2 - H^2) / 4)$$



$$= 146.61 * (2 * 42.0079 * 64.4094 / 3 + 64.4094^2 / 2 - (42.0079^2 - 42.0079^2) / 4)$$

$$= 568,574.7 \text{ lb}_f\text{-in}$$

$$S_2 = \pm M_0 * K_1' / (\pi * R^2 * t)$$

$$= 568,574.7 * 9.3799 / (\pi * 41.7214^2 * 0.573)$$

$$= 1,702 \text{ psi}$$

$$S_p = P * R / (2 * t)$$

$$= 250.93 * 41.4349 / (2 * 0.573)$$

$$= 9,073 \text{ psi}$$

Maximum tensile stress  $S_{2t} = S_2 + S_p = 10.775 \text{ psi}$   
 Maximum compressive stress (shut down)  $S_{2c} = S_2 = 1.702 \text{ psi}$

Tensile stress is acceptable ( $\leq S = 18,300 \text{ psi}$ )  
 Compressive stress is acceptable ( $\leq S_c = 14,330 \text{ psi}$ )

### Tangential shear stress in the shell (left saddle, Weight, Operating)

$$Q_{\text{shear}} = Q - w * (a + 2 * H / 3)$$

$$= 20,104 - 146.61 * (64.4094 + 2 * 42.0079 / 3)$$

$$= 6,554.89 \text{ lb}_f$$

$$S_3 = K_{2.2} * Q_{\text{shear}} / (R * t)$$

$$= 1.1707 * 6,554.89 / (41.7214 * 0.573)$$

$$= 321 \text{ psi}$$

Tangential shear stress is acceptable ( $\leq 0.8 * S = 14,640 \text{ psi}$ )

### Circumferential stress at the left saddle horns (Weight, Operating)

$$S_4 = -Q / (4 * t * (b + 1.56 * \text{Sqr}(R_o * t))) - 12 * K_3 * Q * R / (L * t^2)$$

$$= -20,104 / (4 * 0.573 * (12.0079 + 1.56 * \text{Sqr}(42.0079 * 0.573))) - 12 * 0.0529 * 20,104 * 41.7214 / (226.2992 * 0.573^2)$$

$$= -7.612 \text{ psi}$$

Circumferential stress at saddle horns is acceptable ( $\leq 1.5 * S_a = 27,450 \text{ psi}$ )  
 The wear plate was not considered in the calculation of  $S_4$  because the wear plate width is not at least  $\{b + 1.56 * (R_o * t)^{0.5}\} = 19.6615 \text{ in}$

### Ring compression in shell over left saddle (Weight, Operating)

$$S_5 = K_5 * Q / ((t + t_p) * (t_s + 1.56 * \text{Sqr}(R_o * t_c)))$$

$$= 0.7603 * 20,104 / ((0.573 + 0.2756) * (0.4724 + 1.56 * \text{Sqr}(42.0079 * 0.8486)))$$

$$= 1.841 \text{ psi}$$

Ring compression in shell is acceptable ( $\leq 0.5 * S_y = 18,000 \text{ psi}$ )

### Saddle splitting load (left, Weight, Operating)

Area resisting splitting force = Web area + wear plate area

$$A_e = H_{\text{eff}} * t_s + t_p * W_p$$

$$= 4.8031 * 0.4724 + 0.2756 * 14.2126$$

$$= 6.1861 \text{ in}^2$$

$$S_6 = K_8 * Q / A_e$$

$$= 0.2035 * 20,104 / 6.1861$$

$$= 661 \text{ psi}$$

Stress in saddle is acceptable ( $\leq (2/3) \cdot S_s = 13,749 \text{ psi}$ )

## Load Case 2: Weight, Test

**Longitudinal stress between saddles (Weight, Test, left saddle loading and geometry govern)**

$$\begin{aligned} S_1 &= \pm 3 \cdot K_1 \cdot Q \cdot (L / 12) / (\pi \cdot R^2 \cdot t) \\ &= 3 \cdot -0.3369 \cdot 33,130 \cdot (226.2992 / 12) / (\pi \cdot 41.7214^2 \cdot 0.573) \\ &= -202 \text{ psi} \end{aligned}$$

$$\begin{aligned} S_p &= P \cdot R / (2 \cdot t) \\ &= 377.65 \cdot 41.4349 / (2 \cdot 0.573) \\ &= 13,654 \text{ psi} \end{aligned}$$

Maximum tensile stress  $S_{1t} = S_1 + S_p = 13,453 \text{ psi}$   
Maximum compressive stress (shut down)  $S_{1c} = S_1 = -202 \text{ psi}$

Tensile stress is acceptable ( $\leq 0.9 \cdot S_y \cdot E = 33,300 \text{ psi}$ )  
Compressive stress is acceptable ( $\leq S_c = 14,330 \text{ psi}$ )

**Longitudinal stress at the right saddle (Weight, Test)**

$$\begin{aligned} L_e &= 2 \cdot (\text{Left head depth}) / 3 + L + 2 \cdot (\text{Right head depth}) / 3 \\ &= 2 \cdot 42.0079 / 3 + 226.2992 + 2 \cdot 42.0079 / 3 \\ &= 282.3097 \text{ in} \end{aligned}$$

$$w = W_t / L_e = 68,131 / 282.3097 = 241.33 \text{ lb}_f/\text{in}$$

Bending moment at the right saddle:

$$\begin{aligned} M_q &= w \cdot (2 \cdot H \cdot A_r / 3 + A_r^2 / 2 - (R^2 - H^2) / 4) \\ &= 241.33 \cdot (2 \cdot 42.0079 \cdot 66.2598 / 3 + 66.2598^2 / 2 - (42.0079^2 - 42.0079^2) / 4) \\ &= 977,598.1 \text{ lb}_f\text{-in} \end{aligned}$$

$$\begin{aligned} S_2 &= \pm M_q \cdot K_1' / (\pi \cdot R^2 \cdot t) \\ &= 977,598.1 \cdot 9.3799 / (\pi \cdot 41.7214^2 \cdot 0.573) \\ &= 2,926 \text{ psi} \end{aligned}$$

$$\begin{aligned} S_p &= P \cdot R / (2 \cdot t) \\ &= 377.65 \cdot 41.4349 / (2 \cdot 0.573) \\ &= 13,654 \text{ psi} \end{aligned}$$

Maximum tensile stress  $S_{2t} = S_2 + S_p = 16,581 \text{ psi}$   
Maximum compressive stress (shut down)  $S_{2c} = S_2 = 2,926 \text{ psi}$

Tensile stress is acceptable ( $\leq 0.9 \cdot S_y = 33,300 \text{ psi}$ )  
Compressive stress is acceptable ( $\leq S_c = 14,330 \text{ psi}$ )

**Tangential shear stress in the shell (right saddle, Weight, Test)**

$$\begin{aligned} Q_{\text{shear}} &= Q - w \cdot (a + 2 \cdot H / 3) \\ &= 35,001 - 241.33 \cdot (66.2598 + 2 \cdot 42.0079 / 3) \\ &= 12,251.61 \text{ lb}_f \end{aligned}$$

$$S_3 = K_{2.2} \cdot Q_{\text{shear}} / (R \cdot t)$$

$$= 1.1707 * 12,251.61 / (41.7214 * 0.573)$$

$$= 600 \text{ psi}$$

Tangential shear stress is acceptable ( $\leq 0.8 * (0.9 * S_y) = 26,640 \text{ psi}$ )

#### Circumferential stress at the right saddle horns (Weight, Test)

$$S_4 = -Q / (4 * t * (b + 1.56 * \text{Sqr}(R_o * t))) - 12 * K_3 * Q * R / (L * t^2)$$

$$= -35,001 / (4 * 0.573 * (12.0079 + 1.56 * \text{Sqr}(42.0079 * 0.573))) - 12 * 0.0529 * 35,001 * 41.7214 / (226.2992 * 0.573^2)$$

$$= -13.253 \text{ psi}$$

Circumferential stress at saddle horns is acceptable ( $\leq 0.9 * S_y = 33,300 \text{ psi}$ )

The wear plate was not considered in the calculation of  $S_4$  because the wear plate width is not at least  $\{b + 1.56 * (R_o * t)^{0.5}\} = 19.6615 \text{ in}$

#### Ring compression in shell over right saddle (Weight, Test)

$$S_5 = K_5 * Q / ((t + t_p) * (t_s + 1.56 * \text{Sqr}(R_o * t_c)))$$

$$= 0.7603 * 35,001 / ((0.573 + 0.2756) * (0.4724 + 1.56 * \text{Sqr}(42.0079 * 0.8486)))$$

$$= 3.204 \text{ psi}$$

Ring compression in shell is acceptable ( $\leq 0.9 * S_y = 32,400 \text{ psi}$ )

#### Saddle splitting load (right, Weight, Test)

Area resisting splitting force = Web area + wear plate area

$$A_e = H_{eff} * t_s + t_p * W_p$$

$$= 4.8031 * 0.4724 + 0.2756 * 14.2126$$

$$= 6.1861 \text{ in}^2$$

$$S_6 = K_8 * Q / A_e$$

$$= 0.2035 * 35,001 / 6.1861$$

$$= 1.151 \text{ psi}$$

Stress in saddle is acceptable ( $\leq 0.9 * S_y = 32,400 \text{ psi}$ )

#### Longitudinal stress at the left saddle (Weight, Test)

$$L_e = 2 * (\text{Left head depth}) / 3 + L + 2 * (\text{Right head depth}) / 3$$

$$= 2 * 42.0079 / 3 + 226.2992 + 2 * 42.0079 / 3$$

$$= 282.3097 \text{ in}$$

$$w = W_t / L_e = 68,131 / 282.3097 = 241.33 \text{ lb/in}$$

Bending moment at the left saddle:

$$M_q = w * (2 * H * A_l / 3 + A_l^2 / 2 - (R^2 - H^2) / 4)$$

$$= 241.33 * (2 * 42.0079 * 64.4094 / 3 + 64.4094^2 / 2 - (42.0079^2 - 42.0079^2) / 4)$$

$$= 935,915.9 \text{ lb-in}$$

$$S_2 = \pm M_q * K_1' / (\pi * R^2 * t)$$

$$= 935,915.9 * 9.3799 / (\pi * 41.7214^2 * 0.573)$$

$$= 2,802 \text{ psi}$$

$$S_p = P * R / (2 * t)$$

$$= 377.65 * 41.4349 / (2 * 0.573)$$

$$= 13,654 \text{ psi}$$

$$\text{Maximum tensile stress } S_{2t} = S_2 + S_p = 16.456 \text{ psi}$$

$$\text{Maximum compressive stress (shut down) } S_{2c} = S_2 = 2.802 \text{ psi}$$

$$\text{Tensile stress is acceptable (} \leq 0.9 \cdot S_y = 33,300 \text{ psi)}$$

$$\text{Compressive stress is acceptable (} \leq S_c = 14,330 \text{ psi)}$$

### **Tangential shear stress in the shell (left saddle, Weight, Test)**

$$\begin{aligned} Q_{\text{shear}} &= Q - w \cdot (a + 2 \cdot H / 3) \\ &= 33,130 - 241.33 \cdot (64.4094 + 2 \cdot 42.0079 / 3) \\ &= 10,827.17 \text{ lb}_f \end{aligned}$$

$$\begin{aligned} S_3 &= K_{2.2} \cdot Q_{\text{shear}} / (R \cdot t) \\ &= 1.1707 \cdot 10,827.17 / (41.7214 \cdot 0.573) \\ &= 530 \text{ psi} \end{aligned}$$

$$\text{Tangential shear stress is acceptable (} \leq 0.8 \cdot (0.9 \cdot S_y) = 26,640 \text{ psi)}$$

### **Circumferential stress at the left saddle horns (Weight, Test)**

$$\begin{aligned} S_4 &= -Q / (4 \cdot t \cdot (b + 1.56 \cdot \text{Sqr}(R_o \cdot t))) - 12 \cdot K_3 \cdot Q \cdot R / (L \cdot t^2) \\ &= -33,130 / (4 \cdot 0.573 \cdot (12.0079 + 1.56 \cdot \text{Sqr}(42.0079 \cdot 0.573))) - 12 \cdot 0.0529 \cdot 33,130 \cdot 41.7214 / (226.2992 \cdot 0.573^2) \\ &= -12,544 \text{ psi} \end{aligned}$$

$$\text{Circumferential stress at saddle horns is acceptable (} \leq 0.9 \cdot S_y = 33,300 \text{ psi)}$$

The wear plate was not considered in the calculation of  $S_4$  because the wear plate width is not at least  $\{b + 1.56 \cdot (R_o \cdot t)^{0.5}\} = 19.6615 \text{ in}$

### **Ring compression in shell over left saddle (Weight, Test)**

$$\begin{aligned} S_5 &= K_5 \cdot Q / ((t + t_p) \cdot (t_s + 1.56 \cdot \text{Sqr}(R_o \cdot t_c))) \\ &= 0.7603 \cdot 33,130 / ((0.573 + 0.2756) \cdot (0.4724 + 1.56 \cdot \text{Sqr}(42.0079 \cdot 0.8486))) \\ &= 3.033 \text{ psi} \end{aligned}$$

$$\text{Ring compression in shell is acceptable (} \leq 0.9 \cdot S_y = 32,400 \text{ psi)}$$

### **Saddle splitting load (left, Weight, Test)**

Area resisting splitting force = Web area + wear plate area

$$\begin{aligned} A_e &= H_{\text{eff}} \cdot t_s + t_p \cdot W_p \\ &= 4.8031 \cdot 0.4724 + 0.2756 \cdot 14.2126 \\ &= 6.1861 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} S_6 &= K_8 \cdot Q / A_e \\ &= 0.2035 \cdot 33,130 / 6.1861 \\ &= 1.090 \text{ psi} \end{aligned}$$

$$\text{Stress in saddle is acceptable (} \leq 0.9 \cdot S_y = 32,400 \text{ psi)}$$

### **Shear stress in anchor bolting, one end slotted**

$$\text{Maximum seismic or wind base shear} = 0 \text{ lb}_f$$

$$\text{Thermal expansion base shear} = W \cdot \mu = 21,729 \cdot 0.45 = 9,778.05 \text{ lb}_f$$

Corroded root area for a 0.625" coarse threaded bolt = 0.202 in<sup>2</sup> ( 2 per saddle )

Bolt shear stress = 9,778.05 / (0.202\*1\*2) = 24,203 psi

**\*\* Anchor bolt stress is excessive ( > 18,800 psi)\*\***

#### Shear stress in anchor bolting, transverse

Maximum seismic or wind base shear = 0 lb<sub>f</sub>

Corroded root area for a 0.625" coarse threaded bolt = 0.202 in<sup>2</sup> ( 2 per saddle )

Bolt shear stress = 0 / (0.202\*2\*2) = 0 psi

Anchor bolt stress is acceptable ( ≤ 18,800 psi)

#### Web plate buckling check (Escoe pg 251)

Allowable compressive stress  $S_c$  is the lesser of 20,624 or 10,317 psi: (10,317)

$$\begin{aligned} S_c &= K_i \pi^2 E / (12(1 - 0.3^2)(d_i / t_s)^2) \\ &= 1.28 \pi^2 29E+06 / (12(1 - 0.3^2)(26.9414 / 0.4724)^2) \\ &= 10,317 \text{ psi} \end{aligned}$$

Allowable compressive load on the saddle

$$\begin{aligned} b_e &= d_i t_s / (d_i t_s + 2 t_w (b - 1)) \\ &= 26.9414 * 0.4724 / (26.9414 * 0.4724 + 2 * 0.4724 * (12.0079 - 1)) \\ &= 0.5503 \end{aligned}$$

$$\begin{aligned} F_b &= n(A_s + 2 b_e t_s) S_c \\ &= 4(5.4498 + 2 * 0.5503 * 0.4724) * 10,317 \\ &= 246,352.69 \text{ lb}_f \end{aligned}$$

Saddle loading of 35,444 lb<sub>f</sub> is ≤  $F_b$ ; satisfactory.

#### Primary bending + axial stress in the saddle due to end loads (assumes one saddle slotted)

$$\begin{aligned} \sigma_b &= V(H_s - x_o)y / I + Q / A \\ &= 0(47.5591 - 34.7402) * 7.6325 / 485.97 + 21,286 / 56.1739 \\ &= 379 \text{ psi} \end{aligned}$$

The primary bending + axial stress in the saddle ≤  $S_s = 20,624$  psi; satisfactory.

#### Secondary bending + axial stress in the saddle due to end loads (includes thermal expansion, assumes one saddle slotted)

$$\begin{aligned} \sigma_b &= V(H_s - x_o)y / I + Q / A \\ &= 9,778.05(47.5591 - 34.7402) * 7.6325 / 485.97 + 21,286 / 56.1739 \\ &= 2,348 \text{ psi} \end{aligned}$$

The secondary bending + axial stress in the saddle ≤  $2S_y = 72,000$  psi; satisfactory.

#### Saddle base plate thickness check (Roark sixth edition, Table 26, case 7a)

where  $a = 26.9414$ ,  $b = 11.5354$  in

$$\begin{aligned} t_b &= (\beta_1 q b^2 / (1.5 S_a))^{0.5} \\ &= (2.0208 * 40 * 11.5354^2 / (1.5 * 20,624))^{0.5} \\ &= 0.5871 \text{ in} \end{aligned}$$

**\*\* WARNING The base plate thickness is not adequate \*\***

**Foundation bearing check**

$$\begin{aligned} S_f &= Q_{\max} / (F \cdot E) \\ &= 35,444 / (12.0079 \cdot 74.4488) \\ &= 40 \text{ psi} \end{aligned}$$

Concrete bearing stress  $\leq 1,658$  psi ; satisfactory.