COMPRESS Pressure Vessel Design Calculations

Item:
Vessel No:
Customer:
Contract:
Designer:
Date:
STRENGTH CALCULATION SHEET

| PROJECT : | A1 PROJECT |
| CLIENT : | HS E&C |
| VENDOR : | HS ENGINEERING |

| MANUFACTURER : |

| W/O No. | CLIENT P.O. No. |
| DOCUMENT No. | |
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### DESIGN DATA

**ITEM NO.**

**SERVICE**

<table>
<thead>
<tr>
<th>CODE</th>
<th>ASME SEC. VIII DIV.1 2010 EDITION</th>
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<td>CODE STAMP</td>
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<td>CORROSION ALLOWANCE</td>
<td>1.6 mm</td>
</tr>
<tr>
<td>JOINT EFFICIENCY (SHELL/HEAD)</td>
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<td>POST WELD HEAT TREATMENT</td>
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<td>RADIOGRAPHY (SHELL/HEAD)</td>
<td>FULL/FULL</td>
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<td>PNEUMATIC TEST PRESS</td>
<td>--- [psi g] = --- [MPa g]</td>
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<tr>
<td>HYDROSTATIC TEST PRESSURE (AT SHOP)</td>
<td>306.8 [psi g] = 2.116 [MPa g]</td>
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<tr>
<td>M.A.W.P. (CORR. &amp; HOT)</td>
<td>244.9 [psi g] = 1.688 [MPa g]</td>
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<tr>
<td>M.A.P. (NEW &amp; COLD)</td>
<td>279.8 [psi g] = 1.929 [MPa g]</td>
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<tr>
<td>DESIGN TEMPERATURE</td>
<td>190 [°F] = 87.8 [°C]</td>
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<tr>
<td>MIN. DESIGN METAL TEMPERATURE</td>
<td>50.0 [°F] = 10.0 [°C]</td>
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<td>DESIGN EXTERNAL PRESSURE</td>
<td>--- [psi g] = --- [MPa g]</td>
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<td>OPERATING TEMPERATURE</td>
<td>140 [°F] = 60.0 [°C]</td>
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<td>OPERATING PRESSURE</td>
<td>135.0 [psi g] = 0.931 [MPa g]</td>
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<td>PRESSURE DROP</td>
<td>--- [psi g] = --- [MPa g]</td>
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<tr>
<td>SP. &amp; GR.</td>
<td></td>
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<tr>
<td>SHELL OUTSIDE DIAMETER</td>
<td>mm</td>
</tr>
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<td>LENGTH BETWEEN T.L</td>
<td>mm</td>
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<td>TYPE OF HEADS</td>
<td>2:1 ELLIP.</td>
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<td>WIND LOAD</td>
<td>ASCE 7-05, 155 km/hr, Exp. = “C”, I=1.15</td>
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<td>ASCE 7-05, “D”; Ss=8.1%g, S1=2.3%g, I=1.25</td>
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<td>INSULATION THICKNESS</td>
<td>--- mm</td>
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<td>FIRE PROOFING THICKNESS</td>
<td>--- mm</td>
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<td>VOLUME</td>
<td>m³</td>
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<td>SHELL &amp; HEAD S.R. AFTER COLD FORMING</td>
<td>YES</td>
</tr>
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<td>LETHAL/TOXIC</td>
<td>NO</td>
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**NOTES**

1. THE THERMAL OR MECHANICAL SHOCK LOADINGS : NO
2. CYCLIC LOADING : NO
3. CYCLIC & DYNAMIC REACTION DUE TO PRESSURE OR THERMAL VARIATIONS, OR FROM EQUIPMENT MOUNTED ON A VESSEL, & MECHANICAL LOADING; NO
4. IMPACT REACTIONS DUE TO FLUID SHOCK ; NO
Settings Summary
COMPRESS 2012 Build 7200

Units: U.S. Customary

Datum Line Location: -1.97" from bottom seam

Design

ASME Section VIII Division 1, 2010 Edition, A11 Addenda

- Design or Rating: Get Thickness from Pressure
- Minimum thickness: 0.0625" per UG-16(b)
- Design for cold shut down only: No
- Design for lethal service (full radiography required): No
- Design nozzles for: Larger of MAWP or MAP
- Corrosion weight loss: 100% of theoretical loss
- UG-23 Stress Increase: 1.20
- Skirt/legs stress increase: 1.0
- Minimum nozzle projection: 5.9055"
- Juncture calculations for $\alpha > 30$ only: Yes
- Preheat P-No 1 Materials > 1.25" and <= 1.50" thick: Yes
- UG-37(a) shell tr calculation considers longitudinal stress: No

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

Hydro/Pneumatic Test

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

Required Marking - UG-116

- UG-116(e) Radiography: RT1
- UG-116(f) Postweld heat treatment: None

Code Cases/Interpretations

- Use Code Case 2547: No
- Apply interpretation VIII-1-83-66: Yes
- Apply interpretation VIII-1-86-175: Yes
- Apply interpretation VIII-1-83-115: Yes
- Apply interpretation VIII-1-01-37: Yes
- No UCS-66.1 MDMT reduction: No
- No UCS-68(c) MDMT reduction: No
- Disallow UG-20(f) exemptions: No

UG-22 Loadings

- UG-22(a) Internal or External Design Pressure: Yes
- UG-22(b) Weight of the vessel and normal contents under operating or test conditions: Yes
- UG-22(c) Superimposed static reactions from weight of attached equipment (external loads): Yes
- UG-22(d)(2) Vessel supports such as lugs, rings, skirts, saddles and legs: Yes
- UG-22(f) Wind reactions: Yes
- UG-22(f) Seismic reactions: Yes
- UG-22(j) Test pressure and coincident static head acting during the test: Yes

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

Pressure Summary for Chamber bounded by Bottom Ellipsoidal Head and Top Ellipsoidal Head

<table>
<thead>
<tr>
<th>Identifier</th>
<th>P Design (psi)</th>
<th>T Design (°F)</th>
<th>MAWP (psi)</th>
<th>MAP (psi)</th>
<th>MDMT (°F)</th>
<th>MDMT Exemption</th>
<th>Impact Tested</th>
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<tr>
<td>Top Ellipsoidal Head</td>
<td>150</td>
<td>190</td>
<td>248.37</td>
<td>283.8</td>
<td>-20</td>
<td>Note 1</td>
<td>No</td>
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<tr>
<td>Straight Flange on Top Ellipsoidal Head</td>
<td>150</td>
<td>190</td>
<td>296.25</td>
<td>331.86</td>
<td>-20</td>
<td>Note 2</td>
<td>No</td>
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<td>Shell</td>
<td>150</td>
<td>190</td>
<td>296.25</td>
<td>331.86</td>
<td>-20</td>
<td>Note 2</td>
<td>No</td>
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<tr>
<td>Straight Flange on Bottom Ellipsoidal Head</td>
<td>150</td>
<td>190</td>
<td>291.41</td>
<td>326.44</td>
<td>-20</td>
<td>Note 2</td>
<td>No</td>
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<tr>
<td>Bottom Ellipsoidal Head</td>
<td>150</td>
<td>190</td>
<td>244.89</td>
<td>279.83</td>
<td>-20</td>
<td>Note 3</td>
<td>No</td>
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<tr>
<td>Legs</td>
<td>150</td>
<td>190</td>
<td>244.89</td>
<td>279.83</td>
<td>-20</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Manhole (M1 (20″))</td>
<td>150</td>
<td>190</td>
<td>244.89</td>
<td>279.83</td>
<td>-20</td>
<td>No</td>
<td>Note 4</td>
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<td>Inlet (N1 (8″))</td>
<td>150</td>
<td>190</td>
<td>244.89</td>
<td>279.83</td>
<td>-20</td>
<td>No</td>
<td>Note 5</td>
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<td>Outlet (N2 (8″))</td>
<td>150</td>
<td>190</td>
<td>244.89</td>
<td>279.83</td>
<td>-20</td>
<td>No</td>
<td>Note 6</td>
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<tr>
<td>Desiccant fill (N3 (4″))</td>
<td>150</td>
<td>190</td>
<td>244.89</td>
<td>279.83</td>
<td>-20</td>
<td>No</td>
<td>Note 8</td>
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<tr>
<td>Desiccant discharge (N4 (4″))</td>
<td>150</td>
<td>190</td>
<td>244.89</td>
<td>279.83</td>
<td>-20</td>
<td>No</td>
<td>Note 9</td>
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<tr>
<td>Safety relief V/V comm. (N5 (4″))</td>
<td>150</td>
<td>190</td>
<td>244.89</td>
<td>279.83</td>
<td>-20</td>
<td>No</td>
<td>Note 10</td>
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<tr>
<td>P.I (N6 (2″))</td>
<td>150</td>
<td>190</td>
<td>244.89</td>
<td>279.83</td>
<td>-20</td>
<td>No</td>
<td>Note 5</td>
</tr>
</tbody>
</table>

Chamber design MDMT is 50 °F
Chamber rated MDMT is -20 °F @ 244.89 psi
Chamber MAWP hot & corroded is 244.89 psi @ 190 °F
Chamber MAP cold & new is 279.83 psi @ 62.6 °F
This pressure chamber is not designed for external pressure.

Notes for MDMT Rating:

<table>
<thead>
<tr>
<th>Note #</th>
<th>Exemption</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Straight Flange governs MDMT</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Material is impact test exempt per UG-20(f)</td>
<td>UCS-66 governing thickness = 0.5906 in</td>
</tr>
<tr>
<td>3.</td>
<td>Straight Flange governs MDMT</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Nozzle is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.2889).</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Pad is impact test exempt per UG-20(f)</td>
<td>UCS-66 governing thickness = 0.5906 in</td>
</tr>
<tr>
<td>6.</td>
<td>Nozzle is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.2916).</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Pad is impact test exempt per UG-20(f)</td>
<td>UCS-66 governing thickness = 0.502 in.</td>
</tr>
<tr>
<td>8.</td>
<td>Nozzle is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.1231).</td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>Nozzle is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.317).</td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>Nozzle is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.055).</td>
<td></td>
</tr>
</tbody>
</table>

Design notes are available on the Settings Summary page.
## Nozzle Summary

<table>
<thead>
<tr>
<th>Nozzle mark</th>
<th>OD (in)</th>
<th>$t_n$ (in)</th>
<th>Req $t_n$ (in)</th>
<th>$A_1$?</th>
<th>$A_2$?</th>
<th>Shell</th>
<th>Reinforcement Pad</th>
<th>Corr (in)</th>
<th>$A_1/A_e$ (%)</th>
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<tr>
<td>M1 (20&quot;)</td>
<td>20</td>
<td>0.4724</td>
<td>0.3911</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td>6.5354</td>
<td>0.5906</td>
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<tr>
<td>N1 (8&quot;)</td>
<td>8.625</td>
<td>0.5</td>
<td>0.394</td>
<td>Yes</td>
<td>Yes</td>
<td>0.502*</td>
<td>0.4518</td>
<td>3.5614</td>
<td>0.5906</td>
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<tr>
<td>N2 (8&quot;)</td>
<td>8.625</td>
<td>0.5</td>
<td>0.394</td>
<td>Yes</td>
<td>Yes</td>
<td>0.502*</td>
<td>0.4486</td>
<td>3.5614</td>
<td>0.5906</td>
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<tr>
<td>N3 (4&quot;)</td>
<td>4.5</td>
<td>0.337</td>
<td>0.1046</td>
<td>Yes</td>
<td>Yes</td>
<td>0.502*</td>
<td>0.495</td>
<td>1.8839</td>
<td>0.5906</td>
</tr>
<tr>
<td>N4 (4&quot;)</td>
<td>4.5</td>
<td>0.337</td>
<td>0.1046</td>
<td>Yes</td>
<td>Yes</td>
<td>0.502*</td>
<td>0.4518</td>
<td>1.8839</td>
<td>0.5906</td>
</tr>
<tr>
<td>N5 (4&quot;)</td>
<td>4.5</td>
<td>0.337</td>
<td>0.156</td>
<td>Yes</td>
<td>Yes</td>
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<td>0.495</td>
<td>1.5732</td>
<td>0.5906</td>
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<td>N6 (2&quot;)</td>
<td>2.375</td>
<td>0.344</td>
<td>0.226</td>
<td>Yes</td>
<td>Yes</td>
<td>0.5906</td>
<td>N/A</td>
<td>1.7652</td>
<td>0.5906</td>
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</table>

- $t_n$: Nozzle thickness
- Req $t_n$: Nozzle thickness required per UG-45/UG-16
- Nom $t$: Vessel wall thickness
- Design $t$: Required vessel wall thickness due to pressure + corrosion allowance per UG-37
- User $t$: Local vessel wall thickness (near opening)
- $A_1$: Area available per UG-37, governing condition
- $A_2$: Area required per UG-37, governing condition
- Corr: Corrosion allowance on nozzle wall
- *: Head minimum thickness after forming
<table>
<thead>
<tr>
<th>Nozzle mark</th>
<th>Service</th>
<th>Size</th>
<th>Nozzle</th>
<th>Impact</th>
<th>Norm</th>
<th>Fine Grain</th>
<th>Pad</th>
<th>Impact</th>
<th>Norm</th>
<th>Fine Grain</th>
<th>Flange</th>
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<tbody>
<tr>
<td>M1 (20&quot;)</td>
<td>Manhole</td>
<td>19.06 IDx0.47</td>
<td>SA-516 70</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>SA-516 70</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>WN A105 Class 150</td>
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<tr>
<td>N1 (8&quot;)</td>
<td>Inlet</td>
<td>NPS 8 Sch 80 (XS)</td>
<td>SA-106 B Smls pipe</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>SA-516 70</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>WN A105 Class 150</td>
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<tr>
<td>N2 (8&quot;)</td>
<td>Outlet</td>
<td>NPS 8 Sch 80 (XS)</td>
<td>SA-106 B Smls pipe</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>SA-516 70</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>WN A105 Class 150</td>
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<tr>
<td>N3 (4&quot;)</td>
<td>Desiccant fill</td>
<td>NPS 4 Sch 80 (XS)</td>
<td>SA-106 B Smls pipe</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>SA-516 70</td>
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<td>No</td>
<td>Yes</td>
<td>WN A105 Class 150</td>
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<tr>
<td>N4 (4&quot;)</td>
<td>Desiccant discharge</td>
<td>NPS 4 Sch 80 (XS)</td>
<td>SA-106 B Smls pipe</td>
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<td>No</td>
<td>No</td>
<td>SA-516 70</td>
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<td>No</td>
<td>Yes</td>
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<tr>
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<td>Safety relief V/V conn.</td>
<td>NPS 4 Sch 80 (XS)</td>
<td>SA-106 B Smls pipe</td>
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<td>No</td>
<td>SA-516 70</td>
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<td>Yes</td>
<td>WN A105 Class 300</td>
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<td>N6 (2&quot;)</td>
<td>P.I</td>
<td>NPS 2 Sch 160</td>
<td>SA-106 B Smls pipe</td>
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<td>No</td>
<td>No</td>
<td>SA-516 70</td>
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<td>Yes</td>
<td>WN A105 Class 150</td>
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<tr>
<td>Component Identifier</td>
<td>Material</td>
<td>Diameter (in)</td>
<td>Length (in)</td>
<td>Nominal t (in)</td>
<td>Design t (in)</td>
<td>Total Corrosion (in)</td>
<td>Joint E</td>
<td>Load</td>
<td></td>
<td></td>
<td></td>
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<td>-----------------------------------------------</td>
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<tr>
<td>Top Ellipsoidal Head</td>
<td>SA-516 70</td>
<td>71.6535 OD</td>
<td>18.1644</td>
<td>0.502*</td>
<td>0.3293</td>
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<td>1.00</td>
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<tr>
<td>Straight Flange on Top Ellipsoidal Head</td>
<td>SA-516 70</td>
<td>71.6535 OD</td>
<td>1.9685</td>
<td>0.5906</td>
<td>0.3309</td>
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<td>0.3309</td>
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<td>Straight Flange on Bottom Ellipsoidal Head</td>
<td>SA-516 70</td>
<td>71.6535 ID</td>
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<td>0.5906</td>
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</tr>
<tr>
<td>Bottom Ellipsoidal Head</td>
<td>SA-516 70</td>
<td>71.6535 ID</td>
<td>18.4154</td>
<td>0.502*</td>
<td>0.3318</td>
<td>0.063</td>
<td>1.00</td>
<td>Internal</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Nominal t: Vessel wall nominal thickness  
Design t: Required vessel thickness due to governing loading + corrosion  
Joint E: Longitudinal seam joint efficiency  
* Head minimum thickness after forming  
Load  
internal: Circumferential stress due to internal pressure governs  
external: External pressure governs  
Wind: Combined longitudinal stress of pressure + weight + wind governs  
Seismic: Combined longitudinal stress of pressure + weight + seismic governs
### Weight Summary

#### Weight (lb) Contributed by Vessel Elements

<table>
<thead>
<tr>
<th>Component</th>
<th>Metal New</th>
<th>Metal Corroded</th>
<th>Insulation</th>
<th>Insulation Supports</th>
<th>Lining</th>
<th>Piping + Liquid</th>
<th>Operating Liquid</th>
<th>Test Liquid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Ellipsoidal Head</td>
<td>892</td>
<td>783.1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1,954.5</td>
<td>1,967.9</td>
</tr>
<tr>
<td>Shell</td>
<td>2,479.2</td>
<td>2,216.7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>9,599.8</td>
<td>9,634.6</td>
</tr>
<tr>
<td>Bottom Ellipsoidal Head</td>
<td>919.1</td>
<td>806.8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2,032.9</td>
<td>2,046.5</td>
</tr>
<tr>
<td>Legs</td>
<td>659.1</td>
<td>659.1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>TOTAL:</strong></td>
<td><strong>4,949.4</strong></td>
<td><strong>4,465.7</strong></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td><strong>13,587.2</strong></td>
<td><strong>13,649.1</strong></td>
</tr>
</tbody>
</table>

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

#### Weight (lb) Contributed by Attachments

<table>
<thead>
<tr>
<th>Component</th>
<th>Body Flanges</th>
<th>Nozzles &amp; Flanges</th>
<th>Packed Beds</th>
<th>Ladders &amp; Platforms</th>
<th>Trays</th>
<th>Tray Supports</th>
<th>Rings &amp; Clips</th>
<th>Vertical Loads</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Ellipsoidal Head</td>
<td>0</td>
<td>165.3</td>
<td>160.1</td>
<td>213.3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Shell</td>
<td>0</td>
<td>656.2</td>
<td>648.5</td>
<td>7,355.2</td>
<td>0</td>
<td>0</td>
<td>103.9</td>
<td>352.7</td>
</tr>
<tr>
<td>Bottom Ellipsoidal Head</td>
<td>0</td>
<td>124.5</td>
<td>121.2</td>
<td>213.3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Legs</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>TOTAL:</strong></td>
<td>0</td>
<td>946</td>
<td>929.8</td>
<td>7,781.8</td>
<td>0</td>
<td>0</td>
<td>103.9</td>
<td>352.7</td>
</tr>
</tbody>
</table>

Vessel operating weight, Corroded: 13,634 lb  
Vessel operating weight, New: 14,134 lb  
Vessel empty weight, Corroded: 13,634 lb  
Vessel empty weight, New: 14,134 lb  
Vessel test weight, New: 19,939 lb  
Vessel test weight, Corroded: 19,501 lb

Vessel center of gravity location - from datum - lift condition

Vessel Lift Weight, New: 6,352 lb  
Center of Gravity: 29.1363"

### Vessel Capacity

Vessel Capacity** (New): 1,622 US gal  
Vessel Capacity** (Corroded): 1,629 US gal  
**The vessel capacity does not include volume of nozzle, piping or other attachments.
Hydrostatic Test

Shop test pressure determination for Chamber bounded by Bottom Ellipsoidal Head and Top Ellipsoidal Head based on MAP per UG-99(c)

Shop hydrostatic test gauge pressure is 360.834 psi at 62.6 °F

The shop test is performed with the vessel in the horizontal position.

<table>
<thead>
<tr>
<th>Identifier</th>
<th>MAP psi</th>
<th>Test pressure psi</th>
<th>Test liquid static head psi</th>
<th>UG-99(c) pressure factor</th>
<th>Stress during test psi</th>
<th>Allowable test stress psi</th>
<th>Stress excessive?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Ellipsoidal Head</td>
<td>283.798</td>
<td>363.403</td>
<td>2.568</td>
<td>1.30</td>
<td>23,016</td>
<td>34,200</td>
<td>No</td>
</tr>
<tr>
<td>Straight Flange on Top Ellipsoidal Head</td>
<td>331.858</td>
<td>363.399</td>
<td>2.565</td>
<td>1.30</td>
<td>21,864</td>
<td>34,200</td>
<td>No</td>
</tr>
<tr>
<td>Shell</td>
<td>331.858</td>
<td>363.399</td>
<td>2.565</td>
<td>1.30</td>
<td>21,864</td>
<td>34,200</td>
<td>No</td>
</tr>
<tr>
<td>Straight Flange on Bottom Ellipsoidal Head</td>
<td>326.442</td>
<td>363.421</td>
<td>2.587</td>
<td>1.30</td>
<td>22,229</td>
<td>34,200</td>
<td>No</td>
</tr>
<tr>
<td>Bottom Ellipsoidal Head</td>
<td>279.828</td>
<td>363.421</td>
<td>2.587</td>
<td>1.30</td>
<td>23,344</td>
<td>34,200</td>
<td>No</td>
</tr>
<tr>
<td>Desiccant discharge (N4 (4&quot;))</td>
<td>279.828</td>
<td>363.004</td>
<td>2.169</td>
<td>1.30</td>
<td>17,134</td>
<td>51,300</td>
<td>No</td>
</tr>
<tr>
<td>Desiccant fill (N3 (4&quot;))</td>
<td>279.828</td>
<td>363.193</td>
<td>2.359</td>
<td>1.30</td>
<td>17,176</td>
<td>51,300</td>
<td>No</td>
</tr>
<tr>
<td>Inlet (N1 (8&quot;))</td>
<td>279.828</td>
<td>362.265</td>
<td>1.431</td>
<td>1.30</td>
<td>16,365</td>
<td>51,300</td>
<td>No</td>
</tr>
<tr>
<td>Manhole (M1 (20&quot;)) (2)</td>
<td>279.828</td>
<td>363.776</td>
<td>2.942</td>
<td>1.30</td>
<td>28,405</td>
<td>51,300</td>
<td>No</td>
</tr>
<tr>
<td>Outlet (N2 (8&quot;))</td>
<td>279.828</td>
<td>362.696</td>
<td>1.861</td>
<td>1.30</td>
<td>12,715</td>
<td>51,300</td>
<td>No</td>
</tr>
<tr>
<td>P.I (N6 (2&quot;))</td>
<td>279.828</td>
<td>362.804</td>
<td>1.97</td>
<td>1.30</td>
<td>19,787</td>
<td>51,300</td>
<td>No</td>
</tr>
</tbody>
</table>

Notes:
(1) PL stresses at nozzle openings have been estimated using the method described in PVP-Vol. 399, pages 77-82.
(2) Manhole (M1 (20")) is the component that determines the test pressure.
(3) 1.5*S_n used as the basis for the maximum local primary membrane stress at the nozzle intersection P_L.
(4) The zero degree angular position is assumed to be up, and the test liquid height is assumed to the top-most flange.

The field test condition has not been investigated for the Chamber bounded by Bottom Ellipsoidal Head and Top Ellipsoidal Head.

The test temperature of 62.6 °F is warmer than the minimum recommended temperature of 30 °F so the brittle fracture provision of UG-99(h) has been met.

NOTE: Figure UCS 66.2 general note (6) has been applied.
Corroded Hydrostatic Test

The shop test condition has not been investigated for the Chamber bounded by Bottom Ellipsoidal Head and Top Ellipsoidal Head.

Field test pressure determination for Chamber bounded by Bottom Ellipsoidal Head and Top Ellipsoidal Head based on MAWP per UG-99(b)

Field hydrostatic test gauge pressure is 318.36 psi at 62.6 °F (the chamber MAWP = 244.893 psi)

The field test is performed with the vessel in the vertical position.

<table>
<thead>
<tr>
<th>Identifier</th>
<th>Local test pressure psi</th>
<th>Test liquid static head psi</th>
<th>UG-99(b) stress ratio</th>
<th>UG-99(b) pressure factor</th>
<th>Stress during test psi</th>
<th>Allowable test stress psi</th>
<th>Stress excessive?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Ellipsoidal Head (1)</td>
<td>319.375</td>
<td>1.014</td>
<td>1</td>
<td>1.30</td>
<td>23,172</td>
<td>34,200</td>
<td>No</td>
</tr>
<tr>
<td>Straight Flange on Top Ellipsoidal Head</td>
<td>319.375</td>
<td>1.014</td>
<td>1</td>
<td>1.30</td>
<td>21,529</td>
<td>34,200</td>
<td>No</td>
</tr>
<tr>
<td>Shell</td>
<td>321.825</td>
<td>3.465</td>
<td>1</td>
<td>1.30</td>
<td>21,694</td>
<td>34,200</td>
<td>No</td>
</tr>
<tr>
<td>Straight Flange on Bottom Ellipsoidal Head</td>
<td>321.896</td>
<td>3.536</td>
<td>1</td>
<td>1.30</td>
<td>22,059</td>
<td>34,200</td>
<td>No</td>
</tr>
<tr>
<td>Bottom Ellipsoidal Head</td>
<td>322.545</td>
<td>4.184</td>
<td>1</td>
<td>1.30</td>
<td>23,734</td>
<td>34,200</td>
<td>No</td>
</tr>
<tr>
<td>Desiccant discharge (N4 (4&quot;))</td>
<td>322.691</td>
<td>4.331</td>
<td>1</td>
<td>1.30</td>
<td>16,194</td>
<td>51,300</td>
<td>No</td>
</tr>
<tr>
<td>Desiccant fill (N3 (4&quot;))</td>
<td>318.875</td>
<td>0.515</td>
<td>1</td>
<td>1.30</td>
<td>16,037</td>
<td>51,300</td>
<td>No</td>
</tr>
<tr>
<td>Inlet (N1 (8&quot;))</td>
<td>322.839</td>
<td>4.478</td>
<td>1</td>
<td>1.30</td>
<td>15,050</td>
<td>51,300</td>
<td>No</td>
</tr>
<tr>
<td>Manhole (M1 (20&quot;))</td>
<td>321.503</td>
<td>3.143</td>
<td>1</td>
<td>1.30</td>
<td>29,081</td>
<td>51,300</td>
<td>No</td>
</tr>
<tr>
<td>Outlet (N2 (8&quot;))</td>
<td>318.648</td>
<td>0.288</td>
<td>1</td>
<td>1.30</td>
<td>14,583</td>
<td>51,300</td>
<td>No</td>
</tr>
<tr>
<td>P.I (N6 (2&quot;))</td>
<td>321.661</td>
<td>3.301</td>
<td>1</td>
<td>1.30</td>
<td>11,561</td>
<td>51,300</td>
<td>No</td>
</tr>
<tr>
<td>Safety relief V/V conn. (N5 (4&quot;))</td>
<td>318.856</td>
<td>0.496</td>
<td>1</td>
<td>1.30</td>
<td>18,991</td>
<td>51,300</td>
<td>No</td>
</tr>
</tbody>
</table>

Notes:
(1) Top Ellipsoidal Head limits the UG-99(b) stress ratio.
(2) \( P_L \) stresses at nozzle openings have been estimated using the method described in PVP-Vol. 399, pages 77-82.
(3) \( 1.5 \times 0.9 \times S_Y \) used as the basis for the maximum local primary membrane stress at the nozzle intersection \( P_L \).

The test temperature of 62.6 °F is warmer than the minimum recommended temperature of 10 °F so the brittle fracture provision of UG-99(h) has been met.
Wind Code

Table Lookup Values

2.4.1 Basic Load Combinations for Allowable Stress Design
The following load combinations are considered in accordance with ASCE section 2.4.1:

5. \( D + P + P_s + W \)

7. \( 0.6D + P + P_s + W \)

Where

\( D \) = Dead load

\( P \) = Internal or external pressure load

\( P_s \) = Static head load

\( W \) = Wind load

Wind Deflection Reports:

Operating, Corroded
Empty, Corroded
Hydrotest, Corroded, field

Wind Pressure Calculations

Wind Deflection Report: Operating, Corroded

<table>
<thead>
<tr>
<th>Component</th>
<th>Elevation of bottom above base (in)</th>
<th>Effective OD (ft)</th>
<th>Elastic modulus E (10^6 psi)</th>
<th>Inertia I (ft^4)</th>
<th>Platform wind shear at Bottom (lbf)</th>
<th>Total wind shear at Bottom (lbf)</th>
<th>Bending moment at Bottom (lbf-ft)</th>
<th>Deflection at top (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Ellipsoidal Head</td>
<td>121.7717</td>
<td>7.94</td>
<td>28.8</td>
<td>*</td>
<td>0</td>
<td>159</td>
<td>293</td>
<td>0.0132</td>
</tr>
<tr>
<td>Shell (top)</td>
<td>53.8976</td>
<td>7.94</td>
<td>28.8</td>
<td>3.595</td>
<td>0</td>
<td>775</td>
<td>5,310</td>
<td>0.0132</td>
</tr>
<tr>
<td>Legs</td>
<td>0</td>
<td>0</td>
<td>29.0</td>
<td>0.005105</td>
<td>0</td>
<td>775</td>
<td>8,874</td>
<td>0.0132</td>
</tr>
<tr>
<td>Shell (bottom)</td>
<td>53.8976</td>
<td>7.94</td>
<td>28.8</td>
<td>3.595</td>
<td>0</td>
<td>0</td>
<td>83</td>
<td>0.0132</td>
</tr>
<tr>
<td>Bottom Ellipsoidal Head</td>
<td>53.8976</td>
<td>8.03</td>
<td>28.8</td>
<td>*</td>
<td>0</td>
<td>0</td>
<td>83</td>
<td>0.0132</td>
</tr>
</tbody>
</table>

* Moment of Inertia I varies over the length of the component
Wind Deflection Report: Empty, Corroded

<table>
<thead>
<tr>
<th>Component</th>
<th>Elevation of bottom above base (in)</th>
<th>Effective OD (ft)</th>
<th>Elastic modulus E (10^6 psi)</th>
<th>Inertia I (ft^4)</th>
<th>Platform wind shear at Bottom (lbf)</th>
<th>Total wind shear at Bottom (lbf)</th>
<th>bending moment at Bottom (lbf-ft)</th>
<th>Deflection at top (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Ellipsoidal Head</td>
<td>121.7717</td>
<td>7.94</td>
<td>29.4</td>
<td>*</td>
<td>0</td>
<td>114</td>
<td>259</td>
<td>0.0095</td>
</tr>
<tr>
<td>Shell (top)</td>
<td>53.8976</td>
<td>7.94</td>
<td>29.4</td>
<td>3.595</td>
<td>0</td>
<td>556</td>
<td>4,542</td>
<td>0.0095</td>
</tr>
<tr>
<td>Legs</td>
<td>0</td>
<td>0</td>
<td>29.0</td>
<td>0.005105</td>
<td>0</td>
<td>556</td>
<td>7,122</td>
<td>0.0095</td>
</tr>
<tr>
<td>Shell (bottom)</td>
<td>53.8976</td>
<td>7.94</td>
<td>29.4</td>
<td>3.595</td>
<td>0</td>
<td>0</td>
<td>83</td>
<td>0.0095</td>
</tr>
<tr>
<td>Bottom Ellipsoidal Head</td>
<td>53.8976</td>
<td>8.03</td>
<td>29.4</td>
<td>*</td>
<td>0</td>
<td>0</td>
<td>83</td>
<td>0.0095</td>
</tr>
</tbody>
</table>

*Moment of Inertia I varies over the length of the component

Wind Deflection Report: Hydrotest, Corroded, field

<table>
<thead>
<tr>
<th>Component</th>
<th>Elevation of bottom above base (in)</th>
<th>Effective OD (ft)</th>
<th>Elastic modulus E (10^6 psi)</th>
<th>Inertia I (ft^4)</th>
<th>Platform wind shear at Bottom (lbf)</th>
<th>Total wind shear at Bottom (lbf)</th>
<th>bending moment at Bottom (lbf-ft)</th>
<th>Deflection at top (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Ellipsoidal Head</td>
<td>121.7717</td>
<td>7.94</td>
<td>29.4</td>
<td>*</td>
<td>0</td>
<td>159</td>
<td>293</td>
<td>0.0132</td>
</tr>
<tr>
<td>Shell (top)</td>
<td>53.8976</td>
<td>7.94</td>
<td>29.4</td>
<td>3.595</td>
<td>0</td>
<td>775</td>
<td>5,310</td>
<td>0.0132</td>
</tr>
<tr>
<td>Legs</td>
<td>0</td>
<td>0</td>
<td>29.0</td>
<td>0.005105</td>
<td>0</td>
<td>775</td>
<td>8,874</td>
<td>0.0132</td>
</tr>
<tr>
<td>Shell (bottom)</td>
<td>53.8976</td>
<td>7.94</td>
<td>29.4</td>
<td>3.595</td>
<td>0</td>
<td>0</td>
<td>83</td>
<td>0.0132</td>
</tr>
<tr>
<td>Bottom Ellipsoidal Head</td>
<td>53.8976</td>
<td>8.03</td>
<td>29.4</td>
<td>*</td>
<td>0</td>
<td>0</td>
<td>83</td>
<td>0.0132</td>
</tr>
</tbody>
</table>

*Moment of Inertia I varies over the length of the component

Wind Pressure (WP) Calculations

**Gust Factor (G)** Calculations

\[
K_z = 2.01 \times (Z/Z_0)^{2/3}
\]

\[
q_z = 0.00256 \times K_z \times K_{zt} \times K_d \times V^2 \times I
\]

\[
WP = q_z \times G \times C_f \times (\text{Minimum 10 lb/ft}^2)
\]

Design Wind Pressures

<table>
<thead>
<tr>
<th>Height Z (')</th>
<th>Kz</th>
<th>qz (psf)</th>
<th>WP: Operating (psf)</th>
<th>WP: Empty (psf)</th>
<th>WP: Hydrotest New (psf)</th>
<th>WP: Hydrotest Corroded (psf)</th>
<th>WP: Vacuum (psf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15.0</td>
<td>0.8489</td>
<td>22.02</td>
<td>13.94</td>
<td>13.94</td>
<td>N.A.</td>
<td>10.00</td>
<td>N.A.</td>
</tr>
</tbody>
</table>

Design Wind Force determined from: \( F = \text{Pressure} \times A_f \), where \( A_f \) is the projected area.

**Gust Factor Calculations**

- Operating, Corroded
- Empty, Corroded
- Hydrotest, Corroded, field

**Gust Factor Calculations: Operating, Corroded**

Vessel is considered a rigid structure as \( n_1 = 6.6494 \text{ Hz} \geq 1 \text{ Hz} \).

\[
z^- = \max \left( 0.60 \times \frac{h}{z_{min}} \right)
\]

\[
z^- = \max \left( 0.60 \times 11.8254 , 15.0000 \right)
\]

\[
I_{z^-} = \left( \frac{33}{z^2} \right)^{1/6}
\]

\[
I_{z^-} = 0.2000 \times \left( \frac{33}{15.0000} \right)^{1/6}
\]
Gust Factor Calculations: Empty, Corroded

Vessel is considered a rigid structure as \( n_1 = 6.6494 \text{ Hz} \geq 1 \text{ Hz} \).

\[
\bar{z} = \max \left( 0.60 \times \frac{h}{z_{\min}} \right) = \max \left( 0.60 \times \frac{11.8254}{15.0000} \right) = 15.0000
\]

\[
\bar{L}_z = \frac{1}{c} \left( \frac{\bar{z}}{33} \right)^{1/6}
\]

\[
= 0.2000 \times \left( \frac{33}{15.0000} \right)^{1/6}
= 0.2281
\]

\[
\bar{L}_{z_{\bar{z}}} = \frac{1}{c} \left( \frac{\bar{z}}{33} \right)^{1/6}
\]

\[
= 500.0000 \times \left( \frac{15.0000}{33} \right)^{0.2000}
= 427.0566
\]

\[
Q = \sqrt{\frac{1}{1 + 0.63 \times \left( \frac{h + h}{L_z} \right)^{0.63}}}
\]

\[
= \sqrt{\frac{1}{1 + 0.63 \times \left( \frac{(5.9711 + 11.8254)}{427.0566} \right)^{0.63}}}
= 0.9600
\]

\[
G = 0.925 \times \frac{(1 + 1.7 \times \tilde{E}_Q \times I_{\bar{z}} - Q) / (1 + 1.7 \times \tilde{E}_Q \times I_{\bar{z}})}{0.925 \times (1 + 1.7 \times 3.40 \times 0.2281 \times 0.9600) / (1 + 1.7 \times 3.40 \times 0.2281)}
= 0.9040
\]

Gust Factor Calculations: Hydrotest, Corroded, field

Vessel is considered a rigid structure as \( n_1 = 5.5184 \text{ Hz} \geq 1 \text{ Hz} \).

\[
\bar{z} = \max \left( 0.60 \times \frac{h}{z_{\min}} \right) = \max \left( 0.60 \times \frac{11.8254}{15.0000} \right) = 15.0000
\]

\[
\bar{L}_z = \frac{1}{c} \left( \frac{\bar{z}}{33} \right)^{1/6}
\]

\[
= 0.2000 \times \left( \frac{33}{15.0000} \right)^{1/6}
= 0.2281
\]

\[
\bar{L}_{z_{\bar{z}}} = \frac{1}{c} \left( \frac{\bar{z}}{33} \right)^{1/6}
\]

\[
= 500.0000 \times \left( \frac{15.0000}{33} \right)^{0.2000}
= 427.0566
\]

\[
Q = \sqrt{\frac{1}{1 + 0.63 \times \left( \frac{h + h}{L_z} \right)^{0.63}}}
\]

\[
= \sqrt{\frac{1}{1 + 0.63 \times \left( \frac{(5.9711 + 11.8254)}{427.0566} \right)^{0.63}}}
= 0.9600
\]

\[
G = 0.925 \times \frac{(1 + 1.7 \times \tilde{E}_Q \times I_{\bar{z}} - Q) / (1 + 1.7 \times \tilde{E}_Q \times I_{\bar{z}})}{0.925 \times (1 + 1.7 \times 3.40 \times 0.2281 \times 0.9600) / (1 + 1.7 \times 3.40 \times 0.2281)}
= 0.9040
\]

Table Lookup Values

\[
\alpha = 9.5000, z_g = 900.0000 \text{ ft} \quad [\text{Table 6-2, page 78}] \\
\epsilon = 0.2000, l = 500.0000, \epsilon p = 0.2000 \quad [\text{Table 6-2, page 78}] \\
a = 0.1538, b = 0.6500 \quad [\text{Table 6-2, page 78}] \\
\gamma_{\text{min}} = 15.0000 \text{ ft} \quad [\text{Table 6-2, page 78}] \\
\tilde{E}_Q = 3.40 \quad [6.5.8.1 \text{ page 26}]
$g_v = 3.40$
Seismic Code

12.4.2.3 Basic Load Combinations for Allowable Stress Design

The following load combinations are considered in accordance with ASCE section 2.4.1:

5. \[ D + P + P_s + 0.7E = (1.0 + 0.14\times SDS)D + P + P_s + 0.7\rho QE \]

8. \[ 0.6D + P + P_s + 0.7E = (0.6 - 0.14\times SDS)D + P + P_s + 0.7\rho QE \]

Where

- \( D \) = Dead load
- \( P \) = Internal or external pressure load
- \( P_s \) = Static head load
- \( E \) = Seismic load

\[ = E_h +/- E_v = \rho QE +/- 0.2SDS D \]

Vessel Characteristics

Vessel height: 11.8254 ft
Vessel Weight:
- Operating, Corroded: 13,634 lb
- Empty, Corroded: 13,634 lb

Period of Vibration Calculation

Fundamental Period, \( T \):

- Operating, Corroded: 0.150 sec (f = 6.6 Hz)
- Empty, Corroded: 0.150 sec (f = 6.6 Hz)

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

\[ T = 2 \times PI \times Sqr\left( \frac{\text{Sum}(W_i \times y_i^2)}{g \times \text{Sum}(W_i \times y_i)} \right) \]

\( W_i \) is the weight of the \( i \)th lumped mass, and \( y_i \) is its deflection when the system is treated as a cantilever beam.

Seismic Shear Reports:

- Operating, Corroded
- Empty, Corroded

Base Shear Calculations

Seismic Shear Report: Operating, Corroded

<table>
<thead>
<tr>
<th>Component</th>
<th>Elevation of bottom above base (in)</th>
<th>Elastic modulus E (10^6 psi)</th>
<th>Inertia I (ft^4)</th>
<th>Seismic shear at Bottom (lbf)</th>
<th>Bending Moment at Bottom (lbf-ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Ellipsoidal Head</td>
<td>121.7717</td>
<td>28.8</td>
<td>*</td>
<td>72</td>
<td>233</td>
</tr>
<tr>
<td>Shell (top)</td>
<td>53.8976</td>
<td>28.8</td>
<td>3.5951</td>
<td>471</td>
<td>4,263</td>
</tr>
<tr>
<td>Legs</td>
<td>0</td>
<td>29.0</td>
<td>0.0051</td>
<td>515</td>
<td>6,611</td>
</tr>
<tr>
<td>Shell (bottom)</td>
<td>53.8976</td>
<td>28.8</td>
<td>3.5951</td>
<td>36</td>
<td>114</td>
</tr>
</tbody>
</table>
### Seismic Shear Report: Empty, Corroded

<table>
<thead>
<tr>
<th>Component</th>
<th>Elevation of bottom above base (in)</th>
<th>Elastic modulus E (10^5 psi)</th>
<th>Inertia I (ft^4)</th>
<th>Seismic shear at Bottom (lbf)</th>
<th>Bending Moment at Bottom (lbf-ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bottom Ellipsoidal Head</td>
<td>53.8976</td>
<td>28.8</td>
<td>*</td>
<td>33</td>
<td>111</td>
</tr>
</tbody>
</table>

*Moment of Inertia I varies over the length of the component

### 11.4.3: Maximum considered earthquake spectral response acceleration

The maximum considered earthquake spectral response acceleration at short period, \( S_{MS} \)

\[
S_{MS} = F_a * S_s = 1.6000 * 8.10 / 100 = 0.1296
\]

The maximum considered earthquake spectral response acceleration at 1 s period, \( S_{M1} \)

\[
S_{M1} = F_v * S_1 = 2.4000 * 2.30 / 100 = 0.0552
\]

### 11.4.4: Design spectral response acceleration parameters

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

\[
S_{DS} = 2 / 3 * S_{MS} = 2 / 3 * 0.1296 = 0.0864
\]

Design earthquake spectral response acceleration at 1 s period, \( S_{D1} \)

\[
S_{D1} = 2 / 3 * S_{M1} = 2 / 3 * 0.0552 = 0.0368
\]

### 12.4.2.3: Seismic Load Combinations: Vertical Term

Factor is applied to dead load.

Compressive Side: \( = 1.0 + 0.14 * S_{DS} \)

\[
= 1.0 + 0.14 * 0.0864 = 1.0121
\]

Tensile Side: \( = 0.6 - 0.14 * S_{DS} \)

\[
= 0.6 - 0.14 * 0.0864 = 0.5879
\]

### Base Shear Calculations

* Operating, Corroded
  * Empty, Corroded

### Base Shear Calculations: Operating, Corroded

#### Paragraph 15.4.4: Period Determination

Fundamental Period is taken from the Rayleigh method listed previously in this report.

\( T = 0.1504 \) sec.

### 12.8.1: Calculation of Seismic Response Coefficient

\( C_s \) is the value computed below, bounded by \( C_{sMin} \) and \( C_{sMax} \):

\( C_{sMin} \) is 0.03; and in addition, if \( S_1 >= 0.6g \), \( C_{sMin} \) shall not be less than eqn 15.4-2.

\( C_{sMax} \) calculated with 12.8-3 because \( (T = 0.1504) <= (T_L = 12.0000) \)

\[
C_s = \frac{S_{DS}}{(R/L)} = 0.0864 / (2.0000 / 1.2500) = 0.0540
\]

\( C_{sMin} = 0.03 \)

\( C_{sMax} = \frac{S_{D1}}{(T * (R/L))} = 0.0368 / (0.1504 * (2.0000 / 1.2500)) = 0.1529 \)
12.4.2.1 Seismic Load Combinations: Horizontal Seismic Load Effect, $E_h$

**Physical Calculations**

- $C_s = 0.0540$

**Calculation of Base Shear**

$$V = C_s \times \frac{W}{\rho}$$

$$= 0.0540 \times 13,634.0000 = 736.24 \text{ lb}$$

**12.8.1: Calculation of Seismic Response Coefficient**

$C_s$ is the value computed below, bounded by $C_s_{\text{Min}}$ and $C_s_{\text{Max}}$:

- $C_s_{\text{Min}}$ is 0.03; in addition, if $S_1 \geq 0.6g$, $C_s_{\text{Min}}$ shall not be less than eqn 15.4-2.
- $C_s_{\text{Max}}$ calculated with 12.8-3 because $(T = 0.1504) \leq (T_L = 12.0000)$

$$C_s = \frac{S_{DS}}{(R / I)} = \frac{0.0864}{(2.0000 / 1.2500)} = 0.0540$$

$$C_{s_{\text{Min}}} = 0.03$$

$$C_{s_{\text{Max}}} = \frac{S_{DS}}{(T * (R / I))} = \frac{0.0368}{(0.1504 * (2.0000 / 1.2500))} = 0.1529$$

$$C_s = 0.0540$$

**Paragraph 15.4.4: Period Determination**

Fundamental Period is taken from the Rayleigh method listed previously in this report.

$T = 0.1504 \text{ sec.}$

**12.8.1: Calculation of Seismic Response Coefficient**

$$QE = V$$

$$E_h = 0.7 * \rho * QE \text{ (Only 70% of seismic load considered as per Section 2.4.1)}$$

$$= 0.70 * 1.0000 * 736.24$$

$$= 515.37 \text{ lb}$$

**Base Shear Calculations: Empty, Corroded**

**12.8.1: Calculation of Base Shear**

$$V = C_s \times \frac{W}{\rho}$$

$$= 0.0540 \times 13,634.0000 = 736.24 \text{ lb}$$

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

$$QE = V$$

$$E_h = 0.7 * \rho * QE \text{ (Only 70% of seismic load considered as per Section 2.4.1)}$$

$$= 0.70 * 1.0000 * 736.24$$

$$= 515.37 \text{ lb}$$
ASME Section VIII, Division 1, 2010 Edition, τ11 Addenda

Component: Ellipsoidal Head
Material Specification: SA-516 70 (II-D p.18, ln. 19)
Straight Flange governs MDMT

Internal design pressure: \( P = 150 \text{ psi @ 190 °F} \)

Static liquid head:

- \( P_s = 0 \text{ psi (SG=1, } H_s=0'' \text{ Operating head)} \)
- \( P_{th} = 2.57 \text{ psi (SG=1, } H_s=71.1516'' \text{ Horizontal test head)} \)

Corrosion allowance:

- Inner C = 0.063''
- Outer C = 0''

Design MDMT = 50°F
Rated MDMT = -20°F

Material is produced to fine grain practice
PWHT is not performed
Do not Optimize MDMT / Find MAWP

Radiography:
- Category A joints - Seamless No RT
- Head to shell seam - Full UW-11(a) Type 1

Estimated weight*:
- new = 892 lb
- corr = 783.1 lb
Capacity*:
- new = 233.1 US gal
- corr = 234.6 US gal

* includes straight flange

Outer diameter = 71.6535''
Minimum head thickness = 0.502''
Head ratio \( D/2h \) = 2 (new)
Head ratio \( D/2h \) = 1.9964 (corroded)
Straight flange length \( L_{sf} \) = 1.9685''
Nominal straight flange thickness \( t_{sf} \) = 0.5906''

Results Summary

The governing condition is internal pressure.
Minimum thickness per UG-16 = 0.0625'' + 0.063'' = 0.1255''
Design thickness due to internal pressure \( (t) \) = 0.3293''
Maximum allowable working pressure (MAWP) = 248.37 psi
Maximum allowable pressure (MAP) = 283.8 psi

K (Corroded)

\[
K = \frac{(1/6)\left[2 + (D / (2*h))\right]^2}{(1/6)\left[2 + (70.7756 / (2*17.7254))\right]^2}
\]
= 0.997633

K (New)

\[
K = \frac{(1/6)\left[2 + (D / (2*h))\right]^2}{(1/6)\left[2 + (70.6496 / (2*17.6624))\right]^2}
\]
= 1

Design thickness for internal pressure, (Corroded at 190 °F) Appendix 1-4(c)

\[
t = \frac{P*D_0*K / (2*S*E + 2*P*(K - 0.1)) + Corrosion}{150*71.6535*0.997633 / (2*20,000*1 + 2*150*(0.997633 - 0.1)) + 0.063}
\]
= 0.3293''

The head internal pressure design thickness is 0.3293''.

Maximum allowable working pressure, (Corroded at 190 °F) Appendix 1-4(c)

\[
P = \frac{2*S*E*t / (K*D_0 - 2*t*(K - 0.1)) - P_s}{2*20,000*1*0.439 / (0.997633*71.6535 - 2*0.439*(0.997633 - 0.1)) - 0}
\]
= 248.37 psi

The maximum allowable working pressure (MAWP) is 248.37 psi.

Maximum allowable pressure, (New at 62.6 °F) Appendix 1-4(c)
The maximum allowable pressure (MAP) is 283.8 psi.

% Extreme fiber elongation - UCS-79(d)

\[
P = \frac{2S^*E^*t}{(K^*D_0 - 2^*t^*(K - 0.1))} - P_s
\]
\[
= \frac{2*20,000*1*0.502}{(1*71.6535 - 2*0.502*(1 - 0.1))} - 0
\]
\[
= 283.8 \text{ psi}
\]

\[
EFE = \frac{(75^t / R_f)^*(1 - R_f / R_0)}{Y_{\text{eq}}}
\]
\[
= \frac{(75*0.5906 / 12.3057)^*(1 - 12.3057 / Y_{\text{eq}})}{Y_{\text{eq}}}
\]
\[
= 3.5993\%
\]

The extreme fiber elongation does not exceed 5%.
Straight Flange on Top Ellipsoidal Head

ASME Section VIII Division 1, 2010 Edition, A11 Addenda

Component: Straight Flange
Material specification: SA-516 70 (II-D p. 18, ln. 19)
Material is impact test exempt per UG-20(f)
UCS-66 governing thickness = 0.5906 in

Internal design pressure: \( P = 150 \text{ psi} @ 190 \degree F \)

**Static liquid head:**

\[ P_{th} = 2.57 \text{ psi} \quad \left( \text{SG} = 1, H_s = 71.063", \text{Horizontal test head} \right) \]

Corrosion allowance

Design MDMT = 50 °F
Rated MDMT = -20 °F

Radiography:

Longitudinal joint - Seamless No RT
Circumferential joint - Full UW-11(a) Type I

Estimated weight

New = 73.4 lb  
corr = 65.7 lb

Capacity

New = 33.24 US gal  
corr = 33.36 US gal

OD = 71.6535"
Length \( L_c = 1.9685" \)
\( t = 0.5906" \)

**Design thickness, (at 190 °F) Appendix 1-1**

\[
t = \frac{P R_o}{(S E + 0.40 * P)} + \text{Corrosion}
= \frac{150 * 35.8268}{(20,000 * 1.00 + 0.40 * 150) + 0.063}
= 0.3309"\]

**Maximum allowable working pressure, (at 190 °F) Appendix 1-1**

\[
P = \frac{S E * t}{(R_o - 0.40 * t)} - P_s
= \frac{20,000 * 1.00 * 0.5276}{(35.8268 - 0.40 * 0.5276) - 0}
= 296.25 \text{ psi}\]

**Maximum allowable pressure, (at 62.6 °F) Appendix 1-1**

\[
P = \frac{S E * t}{(R_o - 0.40 * t)}
= \frac{20,000 * 1.00 * 0.5906}{(35.8268 - 0.40 * 0.5906)}
= 331.86 \text{ psi}\]

% Extreme fiber elongation - UCS-79(d)

\[
\text{EFE} = \frac{50 * t / R_f}{(1 - R_f / R_0)}
= \frac{50 * 0.5906 / 35.5315}{(1 - 35.5315 / Y_{\infty})}
= 0.831\%
\]

The extreme fiber elongation does not exceed 5%.

**Design thickness = 0.3309"**

The governing condition is due to internal pressure.

The cylinder thickness of 0.5906" is adequate.

**Thickness Required Due to Pressure + External Loads**
<table>
<thead>
<tr>
<th>Condition</th>
<th>Pressure P (psi)</th>
<th>$S_t$</th>
<th>$S_c$</th>
<th>Temperature (°F)</th>
<th>Corrosion C (in)</th>
<th>Load</th>
<th>Req'd Thk Due to Tension (in)</th>
<th>Req'd Thk Due to Compression (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating, Hot &amp; Corroded</td>
<td>150</td>
<td>20,000</td>
<td>14,648</td>
<td>190</td>
<td>0.063</td>
<td>Wind</td>
<td>0.1101</td>
<td>0.11</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>Seismic</td>
<td>0.11</td>
<td></td>
</tr>
<tr>
<td>Operating, Hot &amp; New</td>
<td>150</td>
<td>20,000</td>
<td>15,085</td>
<td>190</td>
<td>0</td>
<td>Wind</td>
<td>0.1099</td>
<td>0.1097</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Seismic</td>
<td>0.1099</td>
<td></td>
</tr>
<tr>
<td>Hot Shut Down, Corroded</td>
<td>0</td>
<td>20,000</td>
<td>14,648</td>
<td>190</td>
<td>0.063</td>
<td>Wind</td>
<td>0.0001</td>
<td>0.0003</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>Seismic</td>
<td>0.0001</td>
<td></td>
</tr>
<tr>
<td>Hot Shut Down, New</td>
<td>0</td>
<td>20,000</td>
<td>15,085</td>
<td>190</td>
<td>0</td>
<td>Wind</td>
<td>0.0001</td>
<td>0.0003</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Seismic</td>
<td>0.0001</td>
<td></td>
</tr>
<tr>
<td>Empty, Corroded</td>
<td>0</td>
<td>20,000</td>
<td>14,648</td>
<td>70</td>
<td>0.063</td>
<td>Wind</td>
<td>0.0001</td>
<td>0.0003</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Seismic</td>
<td>0.0001</td>
<td></td>
</tr>
<tr>
<td>Empty, New</td>
<td>0</td>
<td>20,000</td>
<td>15,085</td>
<td>70</td>
<td>0</td>
<td>Wind</td>
<td>0.0001</td>
<td>0.0003</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Seismic</td>
<td>0.0001</td>
<td></td>
</tr>
<tr>
<td>Hot Shut Down, Corroded, Weight &amp; Eccentric</td>
<td>0</td>
<td>20,000</td>
<td>14,648</td>
<td>190</td>
<td>0.063</td>
<td>Weight</td>
<td>0.0003</td>
<td>0.0003</td>
</tr>
</tbody>
</table>

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Component: Cylinder
Material specification: SA-516 70 (II-D p. 18, ln. 19)
Material is impact test exempt per UG-20(f)
UCS-66 governing thickness = 0.5906 in

Internal design pressure: \( P = 150 \text{ psi @ 190 °F} \)

**Static liquid head:**

\[ P_{th} = 2.57 \text{ psi (SG = 1, } H_k = 71.063", \text{ Horizontal test head)} \]

Corrosion allowance
- Inner \( C = 0.063" \)
- Outer \( C = 0" \)

Design MDMT = 50 °F
Rated MDMT = -20 °F

Material is not normalized
Material is produced to Fine Grain Practice
PWHT is not performed

Radiography:
- Longitudinal joint - Full UW-11(a) Type 1
- Top circumferential joint - Full UW-11(a) Type 1
- Bottom circumferential joint - Full UW-11(a) Type 1

Estimated weight
- New = 2,479.2 lb
corr = 2,216.7 lb

Capacity
- New = 1,146.09 US gal
corr = 1,150.2 US gal

OD = 71.6535"
Length \( L_c = 67.874" \)
t = 0.5906"

**Design thickness, (at 190 °F) Appendix 1-1**

\[
t = \frac{P \cdot R_o}{(S \cdot E + 0.40 \cdot P) + \text{Corrosion}}
\]

\[
= \frac{150 \cdot 35.8268}{(20,000 \cdot 1.00 + 0.40 \cdot 150)} + 0.063
\]

\[
= 0.3309" \]

**Maximum allowable working pressure, (at 190 °F) Appendix 1-1**

\[
P = \frac{S \cdot E \cdot t}{(R_o - 0.40 \cdot t) - P_o}
\]

\[
= \frac{20,000 \cdot 1.00 \cdot 0.5276}{(35.8268 - 0.40 \cdot 0.5276) - 0}
\]

\[
= 296.25 \text{ psi} \]

**Maximum allowable pressure, (at 62.6 °F) Appendix 1-1**

\[
P = \frac{S \cdot E \cdot t}{(R_o - 0.40 \cdot t)}
\]

\[
= \frac{20,000 \cdot 1.00 \cdot 0.5906}{35.8268 - 0.40 \cdot 0.5906}
\]

\[
= 331.86 \text{ psi} \]

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

\[
EFE = \left(\frac{50 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right)
\]

\[
= \left(\frac{50 \cdot 0.5906}{35.5315}\right) \cdot \left(1 - \frac{35.5315}{R_o}\right)
\]

\[
= 0.831\%
\]

The extreme fiber elongation does not exceed 5%.

**Design thickness = 0.3309"**

The governing condition is due to internal pressure.

The cylinder thickness of 0.5906" is adequate.

**Thickness Required Due to Pressure + External Loads**
<table>
<thead>
<tr>
<th>Condition</th>
<th>Pressure P (psi)</th>
<th>UG-23 Stress Increase (psi)</th>
<th>Temperature (°F)</th>
<th>Corrosion C (in)</th>
<th>Location</th>
<th>Load</th>
<th>Req'd Thk Due to Tension (in)</th>
<th>Req'd Thk Due to Compression (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating, Hot &amp; Corroded</td>
<td>150</td>
<td>20,000</td>
<td>14,648</td>
<td>190</td>
<td>Top</td>
<td>Wind</td>
<td>0.1104</td>
<td>0.1087</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Bottom</td>
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Straight Flange on Bottom Ellipsoidal Head

ASME Section VIII Division 1, 2010 Edition, A11 Addenda

Component: Straight Flange
Material specification: SA-516 70 (II-D p. 18, ln. 19)
Material is impact test exempt per UG-20(f)
UCS-66 governing thickness = 0.5906 in

Internal design pressure: \( P = 150 \text{ psi} \) @ 190 °F

**Static liquid head:**

\[ P_{th} = 2.59 \text{ psi} \quad (SG = 1, H_s = 71.6535", \text{ Horizontal test head}) \]

Corrosion allowance

<table>
<thead>
<tr>
<th>Inner C</th>
<th>Outer C</th>
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<tr>
<td>0.063&quot;</td>
<td>0&quot;</td>
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</tbody>
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Design MDMT = 50 °F
Rated MDMT = -20 °F

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

Radiography:
- Longitudinal joint - Seamless No RT
- Circumferential joint - Full UW-11(a) Type 1

Estimated weight
- New = 74.7 lb
corr = 66.8 lb

Capacity
- New = 34.36 US gal
corr = 34.48 US gal

ID = 71.6535"
Length \( L_C \) = 1.9685"
t = 0.5906"

**Design thickness, (at 190 °F) UG-27(c)(1)**

\[
t = \frac{P \times R}{S \times E \times t} + \text{Corrosion}
\]

\[
t = 150 \times 35.8898 / (20,000 \times 1.00 - 0.60 \times 150) + 0.063
\]

\[= 0.3334" \]

**Maximum allowable working pressure, (at 190 °F) UG-27(c)(1)**

\[
P = \frac{S \times E \times t}{R + 0.60 \times t - P_s}
\]

\[
P = 20,000 \times 1.00 \times 0.5276 / (35.8898 + 0.60 \times 0.5276) - 0
\]

\[= 291.41 \text{ psi} \]

**Maximum allowable pressure, (at 62.6 °F) UG-27(c)(1)**

\[
P = \frac{S \times E \times t}{R + 0.60 \times t}
\]

\[
P = 20,000 \times 1.00 \times 0.5906 / (35.8268 + 0.60 \times 0.5906)
\]

\[= 326.44 \text{ psi} \]

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

\[
EFE = \left( \frac{50 \times t}{R_f} \right) \times (1 - \frac{R_f}{R_o})
\]

\[
EFE = (50 \times 0.5906 / 36.122) \times (1 - 36.122 / 36.122)
\]

\[= 0.8174% \]

The extreme fiber elongation does not exceed 5%.

**Design thickness = 0.3334"**

The governing condition is due to internal pressure.

The cylinder thickness of 0.5906" is adequate.

**Thickness Required Due to Pressure + External Loads**

<table>
<thead>
<tr>
<th>Pressure P</th>
<th>Allowable Stress Before UG-23 Stress Increase</th>
<th>Temperature</th>
<th>Corrosion</th>
<th>Req’d Thk Due</th>
<th>Req’d Thk Due to</th>
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<td>( psi)</td>
<td>( °F)</td>
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<td>to Tension (in)</td>
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ASME Section VIII, Division 1, 2010 Edition, A11 Addenda

Component: Ellipsoidal Head
Material Specification: SA-516 70 (II-D p.18, ln. 19)
Straight Flange governs MDMT

Internal design pressure: P = 150 psi @ 190 °F

Static liquid head:

\[ P_s = 0 \text{ psi (SG}=1, \ H_s=0'' \text{ Operating head)} \]
\[ P_{th}= 2.59 \text{ psi (SG}=1, \ H_s=71.6535'' \text{ Horizontal test head)} \]

Corrosion allowance: Inner C = 0.063'' Outer C = 0''

Design MDMT = 50°F
Rated MDMT = -20°F

No impact test performed
Material is not normalized
Material is produced to fine grain practice
PWHT is not performed
Do not Optimize MDMT / Find MAWP

Radiography: Category A joints - Seamless No RT
Head to shell seam - Full UW-11(a) Type 1

Estimated weight*: new = 919.1 lb corr = 806.8 lb
Capacity*: new = 242.8 US gal corr = 244.4 US gal
* includes straight flange

Inner diameter = 71.6535''
Minimum head thickness = 0.502''
Head ratio D/2h = 2 (new)
Head ratio D/2h = 1.9965 (corroded)
Straight flange length L_{sf} = 1.9685''
Nominal straight flange thickness t_{sf} = 0.5906''

Results Summary

The governing condition is internal pressure.
Minimum thickness per UG-16 = 0.0625'' + 0.063'' = 0.1255''
Design thickness due to internal pressure (t) = 0.3318''
Maximum allowable working pressure (MAWP) = 244.89 psi
Maximum allowable pressure (MAP) = 279.83 psi

K (Corroded)
\[ K = \frac{1}{6}* \left[ 2 + \left( \frac{D}{2h} \right)^2 \right] \]
\[ = \frac{1}{6}* \left[ 2 + \left( \frac{71.7795}{2*17.9764} \right)^2 \right] \]
\[ = 0.997666 \]

K (New)
\[ K = \frac{1}{6}* \left[ 2 + \left( \frac{D}{2h} \right)^2 \right] \]
\[ = \frac{1}{6}* \left[ 2 + \left( \frac{71.6535}{2*17.9134} \right)^2 \right] \]
\[ = 1 \]

Design thickness for internal pressure, (Corroded at 190 °F) Appendix 1-4(c)
\[ t = \frac{P*D*K}{(2*S*E - 0.2*P) + \text{Corrosion}} \]
\[ = 150*71.7795*0.997666 / (2*20,000*1 - 0.2*150) + 0.063 \]
\[ = 0.3317'' \]

The head internal pressure design thickness is 0.3318''.

Maximum allowable working pressure, (Corroded at 190 °F) Appendix 1-4(c)
\[ P = \frac{2*S*E*t}{(K*D + 0.2*t)} - P_s \]
\[ = 2*20,000*1*0.439 / (0.997666*71.7795 +0.2*0.439) - 0 \]
\[ = 244.89 \text{ psi} \]

The maximum allowable working pressure (MAWP) is 244.89 psi.

Maximum allowable pressure, (New at 62.6 °F) Appendix 1-4(c)
The maximum allowable pressure (MAP) is $279.83$ psi.

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

\[
P = \frac{2SEt}{(KD + 0.2t) - Ps}
\]

\[
P = \frac{2 \times 20,000 \times 1 \times 0.502}{(1 \times 71.6535 + 0.2 \times 0.502) - 0} = 279.83 \text{ psi}
\]

\[
EFE = \frac{75t}{Rf}(1 - \frac{Rf}{Ro})
\]

\[
EFE = \frac{75 \times 0.5906}{12.4764}(1 - \frac{12.4764}{12.4764}) = 3.55\%
\]

The extreme fiber elongation does not exceed 5%.
Legs

Leg material: A 36
Leg description: H-150*150*7/10 (Flange in)
Number of legs: N = 4
Overall length: 69.185 in
Base to girth seam length: 53.8976 in
Pad length: 14.9606 in
Pad width: 8.2677 in
Pad thickness: 0.5906 in
Bolt circle: 73.5591 in
Anchor bolt size: 1 inch series 8 threaded
Anchor bolt material: A 307-B
Anchor bolts/leg: 2
Anchor bolt allowable stress: $S_b = 20,000$ psi
Anchor bolt corrosion allowance: 0 in
Anchor bolt hole clearance: 0.2559 in
Base plate width: 10 in
Base plate length: 10 in
Base plate thickness: 0.7874 in ($0.2292$ in required)
Base plate allowable stress: 24,000 psi
Foundation allowable bearing stress: 1,653 psi
Effective length coefficient: $K = 1.2$
Coefficient: $C_m = 0.85$
Leg yield stress: $F_y = 36,000$ psi
Leg elastic modulus: $E = 29,000,000$ psi
Leg to pad fillet weld: 0.3543 in ($0.0341$ in required)
Pad to shell fillet weld: 0.4331 in ($0.0224$ in required)
Legs braced: No

Note: The support attachment point is assumed to be 1 in up from the cylinder circumferential seam.

Conditions Investigated (Only Governing Condition Reported)

Wind operating corroded
Wind operating new
Wind empty corroded
Wind empty new
Wind test corroded
Seismic operating corroded
Seismic operating new
Seismic empty corroded
Seismic empty new
Axial end load, $P_1$ (Based on vessel total bending moment acting at leg attachment elevation)

$$P_1 = \frac{W_t}{N} + \frac{48M_t}{(N*D)}$$

$$= \frac{18,850.58}{4} + \frac{48*4,623.4}{(4*72.8346)}$$

$$= 5,474.39 \text{ lbf}$$

Allowable axial compressive stress, $F_a$ (AISC chapter E)

$$C_c = \sqrt{2*\pi^2*E / F_y}$$

$$= \sqrt{2*\pi^2*29,000,000 / 36,000}$$

$$= 126.0993$$

$$K^3/r = 1.2*55.3307 / 1.4745 = 45.0314$$

$$F_a = 1\frac{1}{(1 - (K^3 / r)^2 / (2*C_c^2)^2)*F_y / (5 / 3 + 3*(K^3 / r) / (8*C_c^3) - (K^3 / r)^3 / (8*C_c^3))}$$

$$= 18,778 \text{ psi}$$

Allowable axial compression and bending (AISC chapter H)

$$F'_{ex} = 1\frac{12*\pi^2*E / (23*(K^3 / r)^2)}$$

$$= 73,641 \text{ psi}$$

$$F'_{ey} = 1\frac{12*\pi^2*E / (23*(K^3 / r)^2)}$$

$$= 214,514 \text{ psi}$$

$$F_b = 1\frac{0.66*F_y}{1*0.66*36,000}$$

$$= 23,760 \text{ psi}$$

Compressive axial stress

$$f_a = \frac{P_1}{A}$$

$$= 5,474.39 / 6.2217$$

$$= 880 \text{ psi}$$

Bending stresses

$$f_{bx} = F*cos(\alpha)*L / (I_y / C_{x}) + P_1*E_{cc} / (I_y / C_y)$$

$$= 164.53*cos(56)*55.3307 / (13.5261 / 2.9528) + 5,474.39*2.9528 / (13.5261 / 2.9528)$$

$$= 4,640 \text{ psi}$$

$$f_{by} = F*sin(\alpha)*L / (I_y / C_y)$$

$$= 164.53*sin(56)*55.3307 / (39.4 / 2.95)$$

$$= 566 \text{ psi}$$

AISC equation $H_{1-1}$
H_{1-1} = f_a / (F_a + C_{mx} * f_bx / ((1 - f_a / F_{cx}) * F_{bx}) + C_{my} * f_by / ((1 - f_a / F_{cy}) * F_{by})
= 880 / 18,778 + 0.85 * 4,640 / ((1 - 880 / 73,641) * 23,760) + 0.85 * 566 / ((1 - 880 / 214,514) * 23,760)
= 0.2352

AISC equation H_{1-2}

H_{1-2} = f_a / (0.6 * 1 * F_y) + f_{bx} / F_{bx} + f_{by} / F_{by}
= 880 / (0.6 * 1 * 36,000) + 4,640 / 23,760 + 566 / 23,760
= 0.2598

4, H-150*150*7/10 legs are adequate.

**Anchor bolts - Wind operating corroded condition governs**

Tensile loading per leg (2 bolts per leg)

R = \frac{48 * M}{(N \times BC)} - 0.6 * \frac{W}{N}
= \frac{48 * 8,735.5}{(4 * 73.5591)} - 0.6 * \frac{13,634}{4}
= -597.53 \text{ lb}

There is no net uplift (R is negative).

1 inch series 8 threaded bolts are satisfactory.

**Check the leg to pad fillet weld, Bednar 10.3, Wind test corroded governs**

Note: continuous welding is assumed for all support leg fillet welds.

The following leg attachment weld analysis assumes the fillet weld is present on three sides (leg top closure plate is used).

\[ Z_w = \frac{(2 * b * d + d^2)}{3} \]
= \frac{(2 * 5.9055 * 13.8543 + 13.8543^2)}{3}
= 118.5254 \text{ in}^2

\[ J_w = \frac{(b + 2 * d)^3}{12} - d^2 \frac{(b + d)^2}{(b + 2 * d)} \]
= \frac{(5.9055 + 2 * 13.8543)^3}{12} - 13.8543^2 \frac{(5.9055 + 13.8543)^2}{(5.9055 + 2 * 13.8543)}
= 935.5481 \text{ in}^3

\[ E = d^2 / (b + 2 * d) \]
= 13.8543^2 / (5.9055 + 2 * 13.8543)
= 5.710165 \text{ in}

Governing weld load \( f_x = \cos(56) * 164.53 = 92 \text{ lb} \)

Governing weld load \( f_y = \sin(56) * 164.53 = 136.4 \text{ lb} \)

\[ f_1 = \frac{P_1}{L_{\text{weld}}} \]
= 5,474.39 / 33.6142
= 162.86 \text{ lb/in (V_t direct shear)}

\[ f_2 = f_y \times L_{\text{leg}} \times 0.5 * b / J_w \]
= 136.4 * 55.3307 * 0.5 * 5.9055 / 935.5481
= 23.82 \text{ lb/in (V_t torsion shear)}

\[ f_3 = f_y / L_{\text{weld}} \]
= 136.4 / 33.6142
= 4.06 \text{ lb/in (V_c direct shear)}

\[ f_4 = f_y \times L_{\text{leg}} \times E / J_w \]
= 136.4 * 55.3307 * 5.7102 / 935.5481
= 46.06 \text{ lb/in (V_c torsion shear)}

\[ f_5 = (f_x \times L_{\text{leg}} + P_1 \times F_{cc}) / Z_w \]
= (92 * 55.3307 + 5,474.39 * 2.9528) / 118.5254
= 179.33 \text{ lb/in (M_t bending)}

\[ f_6 = f_x / L_{\text{weld}} \]
= 92 / 33.6142
= 2.74 \text{ lb/in (Direct outward radial shear)}

\[ f = \sqrt{(f_1 + f_2)^2 + (f_3 + f_4)^2 + (f_5 + f_6)^2} \]
= \sqrt{(162.86 + 23.82)^2 + (4.06 + 46.06)^2 + (179.33 + 2.74)^2}
= 265.54 \text{ lb/in (Resultant shear load)}

Required leg to pad fillet weld leg size (welded both sides + top)
\[ t_w = \frac{f}{(0.707*0.55*S_w)} \]
\[ = \frac{265.54}{(0.707*0.55*20,000)} \]
\[ = 0.0341 \text{ in} \]

The 0.3543 in leg to pad attachment fillet weld size is adequate.

**Check the pad to vessel fillet weld, Bednar 10.3, Wind test corroded governs**

\[ Z_w = b*d + d^2 / 3 \]
\[ = 8.2677*14.9606 + 14.9606^2 / 3 \]
\[ = 198.2971 \text{ in}^2 \]

\[ J_w = (b + d)^3 / 6 \]
\[ = (8.2677 + 14.9606)^3 / 6 \]
\[ = 2,088.8326 \text{ in}^3 \]

\[ f_1 = \frac{P_1}{L_{weld}} \]
\[ = 5,474.39 / 46.4567 \]
\[ = 117.84 \text{ lb/in} (V_t, \text{direct shear}) \]

\[ f_2 = \frac{f_y * L_{leg} * 0.5*b}{J_w} \]
\[ = 136.4*55.3307*0.5*8.2677 / 2,088.8326 \]
\[ = 14.94 \text{ lb/in} (V_t, \text{torsion shear}) \]

\[ f_3 = \frac{f_y}{L_{weld}} \]
\[ = 136.4 / 46.4567 \]
\[ = 2.94 \text{ lb/in} (V_c, \text{direct shear}) \]

\[ f_4 = \frac{f_y * L_{leg} * 0.5*d}{J_w} \]
\[ = 136.4*55.3307*0.5*14.9606 / 2,088.8326 \]
\[ = 27.03 \text{ lb/in} (V_c, \text{torsion shear}) \]

\[ f_5 = \frac{f_x * L_{leg} + P_1 E_{cc}}{Z_w} \]
\[ = (92*55.3307 + 5,474.39*2.9528) / 198.2971 \]
\[ = 107.19 \text{ lb/in} (M, \text{bending}) \]

\[ f_6 = \frac{f_x}{L_{weld}} \]
\[ = 92 / 46.4567 \]
\[ = 1.98 \text{ lb/in} (\text{Direct outward radial shear}) \]

\[ f = \sqrt{(f_1 + f_2)^2 + (f_3 + f_4)^2 + (f_5 + f_6)^2} \]
\[ = \sqrt{((117.84 + 14.94)^2 + (2.94 + 27.03)^2 + (107.19 + 1.98)^2)} \]
\[ = 174.48 \text{ lb/in} (\text{Resultant shear load}) \]

**Required pad to vessel fillet weld leg size (welded all around the pad edge)**

\[ t_w = \frac{f}{(0.707*0.55*S_w)} \]
\[ = \frac{174.48}{(0.707*0.55*20,000)} \]
\[ = 0.0224 \text{ in} \]

0.4331 in pad to vessel attachment fillet weld size is adequate.

**Base plate thickness check, AISC 3-106**

\[ f_p = \frac{P}{(B*N)} \]
\[ = 6,039.23 / (10*10) \]
\[ = 60 \text{ psi} \]

\[ m = \frac{N - 0.95*d}{2} \]
\[ = (10 - 0.95*5.9055) / 2 \]
\[ = 2.1949 \text{ in} \]

\[ n = \frac{(B - 0.8*b)}{2} \]
\[ = (10 - 0.8*5.9055) / 2 \]
\[ = 2.6378 \text{ in} \]

\[ L = 0.5*(d + b) / 2 - \sqrt{(0.5*(d + b)^2 / 4 - P / (4*F_p))} \]
\[ = 0.5*(5.9055 + 5.9055) / 2 - \sqrt{(0.5*(5.9055 + 5.9055)^2 / 4 - 6,039.23 / (4*1,653))} \]
\[ = 0.1589 \text{ in} \]

\[ t_b = \text{Largest}(m, n, L) * \sqrt{(3*f_p / S_b)} \]
\[ = 2.6378 * \sqrt{3*60 / 24,000} \]
\[ = 0.2292 \text{ in} \]

The base plate thickness is adequate.
Check the leg to vessel attachment stresses, WRC-107 (Wind test corroded governs)

Applied Loads

Radial load: \( P_r = -98.33 \text{ lbf} \)
Circumferential moment: \( M_c = 0 \text{ lb}\text{-f in} \)
Circumferential shear: \( V_c = 0 \text{ lbf} \)
Longitudinal moment: \( M_L = 21,605.29 \text{ lb}\text{-f in} \)
Longitudinal shear: \( V_L = 5,474.39 \text{ lbf} \)
Torsion moment: \( M_t = 0 \text{ lb}\text{-f in} \)
Internal pressure: \( P = 360.834 \text{ psi} \)
Mean shell radius: \( R_m = 35.5945 \text{ in} \)
Local shell thickness: \( t = 0.5276 \text{ in} \)
Shell yield stress: \( S_y = 38,000 \text{ psi} \)

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

\[ R_m / t = 35.5945 / 0.5276 = 67.4712 \]

\[ C_1 = 4.1339, C_2 = 11.8743 \text{ in} \]

Local circumferential pressure stress = \( P \cdot R_i / t = 24,165 \text{ psi} \)
Local longitudinal pressure stress = \( P \cdot R_i / (2 \cdot t) = 12,082 \text{ psi} \)
Maximum combined stress (\( P_L+P_b+Q \)) = 25,942 psi
Allowable combined stress (\( P_L+P_b+Q \)) = \( \pm 3 \cdot S = \pm 68,400 \text{ psi} \)
The maximum combined stress (\( P_L+P_b+Q \)) is within allowable limits.

Maximum local primary membrane stress (\( P_L \)) = 24,715 psi
Allowable local primary membrane (\( P_L \)) = \( \pm 1.5 \cdot S = \pm 34,200 \text{ psi} \)
The maximum local primary membrane stress (\( P_L \)) is within allowable limits.

Stresses at the pad edge per WRC Bulletin 107

<table>
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<th>Figure</th>
<th>value</th>
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<th>( A_l )</th>
<th>( B_u )</th>
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<th>( C_u )</th>
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</table>
Note: * denotes primary stress.

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

\[ R_{m} / t = 35.5945 / 1.1181 = 31.8347 \]

\[ C_1 = 2.9528, \quad C_2 = 10.9962 \text{ in} \]

Local circumferential pressure stress = \( P \times R_i / t = 24,165 \text{ psi} \)

Local longitudinal pressure stress = \( P \times R_i / (2 \times t) = 12,082 \text{ psi} \)

Maximum combined stress (\( P_L + P_b + Q \)) = 24,953 psi

Allowable combined stress (\( P_L + P_b + Q \)) = \( +3 \times S = +68,400 \text{ psi} \)

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

Maximum local primary membrane stress (\( P_L \)) = 24,357 psi

Allowable local primary membrane (\( P_L \)) = \( +1.5 \times S = +34,200 \text{ psi} \)

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

| Shear from \( M_i \) | \( 0 \) | \( 0 \) | \( 0 \) | \( 0 \) | \( 0 \) | \( 0 \) | \( 0 \) | \( 0 \) | \( 0 \) | \( 0 \) |
| Long shear from \( V_L \) | \( 0 \) | \( 0 \) | \( 0 \) | \( -218 \) | \( -218 \) | \( 218 \) | \( 218 \) | \( 0 \) | \( 0 \) | \( 0 \) |
| Total Shear stress | \( 0 \) | \( 0 \) | \( 0 \) | \( -218 \) | \( -218 \) | \( 218 \) | \( 218 \) | \( 0 \) | \( 0 \) | \( 0 \) |
| Combined stress (\( P_i + P_b + Q \)) | 22,604 | 24,786 | 25,942 | 23,488 | 24,330 | 24,038 | 24,330 | 24,038 | 0 | 0 |

Stresses at the leg edge per WRC Bulletin 107

<table>
<thead>
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<td>0</td>
</tr>
<tr>
<td>Shear from ( M_i )</td>
<td>( 0 )</td>
<td>( 0 )</td>
<td>( 0 )</td>
<td>( 0 )</td>
<td>( 0 )</td>
<td>( 0 )</td>
<td>( 0 )</td>
<td>( 0 )</td>
<td>( 0 )</td>
<td>( 0 )</td>
</tr>
<tr>
<td>Circ shear from ( V_c )</td>
<td>( 0 )</td>
<td>( 0 )</td>
<td>( 0 )</td>
<td>( 0 )</td>
<td>( 0 )</td>
<td>( 0 )</td>
<td>( 0 )</td>
<td>( 0 )</td>
<td>( 0 )</td>
<td>( 0 )</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-111</td>
<td>-111</td>
<td>111</td>
<td>111</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------------------</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>------</td>
<td>------</td>
<td>-----</td>
<td>-----</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long shear from $V_L$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Shear stress</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Combined stress ($P_a+P_b+Q$)</td>
<td>23,469</td>
<td>24,525</td>
<td>24,953</td>
<td>23,761</td>
<td>24,224</td>
<td>24,122</td>
<td>24,224</td>
<td>24,122</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: * denotes primary stress.
ASME Section VIII Division 1, 2010 Edition, A11 Addenda

Located on: Bottom Ellipsoidal Head
Liquid static head included: 0 psi
Nozzle material specification: SA-106 B Smls pipe (II-D p. 10, ln. 40)
Nozzle longitudinal joint efficiency: 1
Nozzle description: NPS 8 Sch 80 (XS)
Pad material specification: SA-516 70 (II-D p. 18, ln. 19)
Pad diameter: 15.7478 in
Flange description: NPS 8 Class 150 WN A105
Bolt Material: SA-193 B7 Bolt <= 2 1/2 (II-D p. 334, ln. 32)
Flange rated MDMT: -34.1°F
(UCS-66(b)(1)(b))
Liquid static head on flange: 0 psi
ASME B16.5-2009 flange rating MAWP: 262.5 psi @ 190°F
ASME B16.5-2009 flange rating MAP: 285 psi @ 62.6°F
ASME B16.5-2009 flange hydro test: 450 psi @ 62.6°F
PWHT performed: No
Circumferential joint radiography: Full UW-11(a) Type 1
Nozzle orientation: 0°
Calculated as hillside: No
Local vessel minimum thickness: 0.502 in
End of nozzle to datum line: 26.1181 in
Nozzle inside diameter, new: 7.625 in
Nozzle nominal wall thickness: 0.5 in
Nozzle corrosion allowance: 0.063 in
Projection available outside vessel, Lp: 3.833 in
Projection available outside vessel to flange face, Lf: 7.833 in
Distance to head center, R: 0 in
Pad is split: No

Reinforcement Calculations for Internal Pressure

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

- \( t_{w(\text{lower})} = 0.502 \) in
- \( \text{Leg}_{41} = 0.375 \) in
- \( t_{w(\text{upper})} = 0.5906 \) in
- \( \text{Leg}_{42} = 0.4331 \) in
- \( D_p = 15.7478 \) in
- \( t_e = 0.5906 \) in

<table>
<thead>
<tr>
<th>UG-37 Area Calculation Summary (in²)</th>
<th>UG-45 Nozzle Wall Thickness Summary (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>For ( P = 244.89 ) psi @ 190°F</td>
<td>The nozzle passes UG-45</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>A required</th>
<th>A available</th>
<th>( A_1 )</th>
<th>( A_2 )</th>
<th>( A_3 )</th>
<th>( A_5 )</th>
<th>A welds</th>
<th>( t_{\text{req}} )</th>
<th>( t_{\text{min}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.114</td>
<td>5.2294</td>
<td>0.333</td>
<td>0.715</td>
<td>--</td>
<td>4.0612</td>
<td>0.1202</td>
<td>0.3447</td>
<td>0.4375</td>
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</table>

UG-41 Weld Failure Path Analysis Summary (lb)
All failure paths are stronger than the applicable weld loads
<table>
<thead>
<tr>
<th>Weld load W</th>
<th>Weld load $W_{1,1}$</th>
<th>Path 1-1 strength</th>
<th>Weld load $W_{2,2}$</th>
<th>Path 2-2 strength</th>
<th>Weld load $W_{3,3}$</th>
<th>Path 3-3 strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>56,272.46</td>
<td>97,928.04</td>
<td>172,263.82</td>
<td>23,264.68</td>
<td>249,001.09</td>
<td>104,488.72</td>
<td>193,003.16</td>
</tr>
</tbody>
</table>

**UW-16 Weld Sizing Summary**

<table>
<thead>
<tr>
<th>Weld description</th>
<th>Required weld size (in)</th>
<th>Actual weld size (in)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nozzle to pad fillet (Leg41)</td>
<td>0.25</td>
<td>0.2625</td>
<td>weld size is adequate</td>
</tr>
<tr>
<td>Pad to shell fillet (Leg42)</td>
<td>0.2194</td>
<td>0.3031</td>
<td>weld size is adequate</td>
</tr>
<tr>
<td>Nozzle to pad groove (Upper)</td>
<td>0.3059</td>
<td>0.5906</td>
<td>weld size is adequate</td>
</tr>
</tbody>
</table>
Maximum stresses due to the applied loads at the pad edge (includes pressure)

Mean dish radius \( R_m = 65.0931 \) in

U = \( r_0 / \sqrt{R_m*t} \) = 1.473

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

Local pressure stress = \( I*P*R_i / (2*t) \) = 18,096 psi

Maximum combined stress \( (P_L+P_b+Q) \) = 37,672 psi

Allowable combined stress \( (P_L+P_b+Q) \) = \( \pm 3*S \) = \( \pm 60,000 \) psi

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

Maximum local primary membrane stress \( (P_L) \) = 21,602 psi

Allowable local primary membrane stress \( (P_L) \) = \( \pm 1.5*S \) = \( \pm 30,000 \) psi

The local maximum primary membrane stress \( (P_L) \) is within allowable limits.
Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

Mean dish radius $R_m = 65.0931$ in

$U = \frac{r_0}{\text{Sqr}(R_m \cdot t)} = 0.527$

Pressure stress intensity factor, $I = 0.3175$ (derived from PVP-Vol. 399, pages 77-82)

Local pressure stress $= I \cdot P \cdot R_i / (2 \cdot t) = 5,745$ psi

Maximum combined stress $(P_L+P_b+Q) = 21,860$ psi

Allowable combined stress $(P_L+P_b+Q) = \pm 3 \cdot S = \pm 60,000$ psi

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

Maximum local primary membrane stress $(P_L) = 7,138$ psi

Allowable local primary membrane stress $(P_L) = \pm 1.5 \cdot S = \pm 30,000$ psi

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

### Stresses at the pad edge per WRC Bulletin 107

<table>
<thead>
<tr>
<th>Figure</th>
<th>value</th>
<th>$A_u$</th>
<th>$A_l$</th>
<th>$B_u$</th>
<th>$B_l$</th>
<th>$C_u$</th>
<th>$C_l$</th>
<th>$D_u$</th>
<th>$D_l$</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR-2</td>
<td>0.0192</td>
<td>-765</td>
<td>765</td>
<td>-765</td>
<td>765</td>
<td>-765</td>
<td>765</td>
<td>-765</td>
<td>765</td>
</tr>
<tr>
<td>SR-3*</td>
<td>0.0407</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-3,767</td>
<td>-3,767</td>
<td>3,767</td>
<td>3,767</td>
</tr>
<tr>
<td>SR-3</td>
<td>0.0303</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-16,824</td>
<td>16,824</td>
<td>16,824</td>
<td>-16,824</td>
</tr>
<tr>
<td>SR-3*</td>
<td>0.0407</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>SR-3</td>
<td>0.0303</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Notes: (1) * denotes primary stress.

(2) The nozzle is assumed to be a rigid (solid) attachment.

### Stresses at the nozzle OD per WRC Bulletin 107

<table>
<thead>
<tr>
<th>Figure</th>
<th>value</th>
<th>$A_u$</th>
<th>$A_l$</th>
<th>$B_u$</th>
<th>$B_l$</th>
<th>$C_u$</th>
<th>$C_l$</th>
<th>$D_u$</th>
<th>$D_l$</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR-2</td>
<td>0.0192</td>
<td>-765</td>
<td>765</td>
<td>-765</td>
<td>765</td>
<td>-765</td>
<td>765</td>
<td>-765</td>
<td>765</td>
</tr>
<tr>
<td>SR-3*</td>
<td>0.0407</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-3,767</td>
<td>-3,767</td>
<td>3,767</td>
<td>3,767</td>
</tr>
<tr>
<td>SR-3</td>
<td>0.0303</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-16,824</td>
<td>16,824</td>
<td>16,824</td>
<td>-16,824</td>
</tr>
<tr>
<td>SR-3*</td>
<td>0.0407</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>SR-3</td>
<td>0.0303</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Pressure stress* $= 18,096$ psi

Total $O_x$ stress $= 17,070$ psi

Membrane $O_x$ stress* $= 17,835$ psi

Shear from $M_1$ $= 394$ psi

Shear from $V_1$ $= 0$ psi

Shear from $V_2$ $= 236$ psi

Combined stress $(P_L+P_b+Q) = 18,153$ psi

Notes: (1) * denotes primary stress.

(2) The nozzle is assumed to be a rigid (solid) attachment.
Longitudinal stress in the nozzle wall due to internal pressure + external loads

\[ \sigma_n (P_m) = \frac{P \cdot R_i}{2 \cdot t_n} - \frac{P_r}{\pi (R_o^2 - R_i^2)} + \frac{M \cdot R_o}{I} \]

\[ = \frac{244.89 \cdot 3.8755}{2 \cdot 0.3745} - \frac{1,279.16}{\pi (4.3125^2 - 3.8755^2)} + \frac{95,322.5 \cdot 4.3125}{94.475} \]

\[ = 5,505 \text{ psi} \]

The average primary stress \( P_m \) (see Division 2.5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable (\( \leq S = 17,100 \text{ psi} \))

Shear stress in the nozzle wall due to external loads

\[ \sigma_{\text{shear}} = \frac{(V_L^2 + V_c^2)^{0.5}}{\pi (R_i^2 + t_n^2)} \]

\[ = \frac{(0^2 + 2,558.332)^{0.5}}{\pi (3.8755^2 + 0.437)} \]

\[ = 481 \text{ psi} \]

\[ \sigma_{\text{torsion}} = \frac{M_t}{2 \pi R_i^2 t_n} \]

\[ = \frac{67,398.4}{2 \pi (3.8755^2 \cdot 0.437)} \]

\[ = 1,634 \text{ psi} \]

\[ \sigma_{\text{total}} = \sigma_{\text{shear}} + \sigma_{\text{torsion}} \]

\[ = 481 + 1,634 \]

\[ = 2,115 \text{ psi} \]

UG-45: The total combined shear stress (2,115 psi) is below than the allowable (0.7*S_n = 0.7*17,100 = 11,970 psi)

Reinforcement Calculations for MAP

<table>
<thead>
<tr>
<th>SR-3*</th>
<th>0.141</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR-3</td>
<td>0.2316</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pressure stress*</td>
<td>5,745</td>
<td>5,745</td>
<td>5,745</td>
<td>5,745</td>
<td>5,745</td>
<td>5,745</td>
<td>5,745</td>
<td></td>
</tr>
<tr>
<td>Total ( O_1 ) stress</td>
<td>5,017</td>
<td>6,161</td>
<td>5,017</td>
<td>6,161</td>
<td>-11,798</td>
<td>19,878</td>
<td>21,832</td>
<td>-7,556</td>
</tr>
<tr>
<td>Membrane ( O_2 ) stress*</td>
<td>5,589</td>
<td>5,589</td>
<td>5,589</td>
<td>5,589</td>
<td>4,040</td>
<td>4,040</td>
<td>7,138</td>
<td>7,138</td>
</tr>
<tr>
<td>SR-2</td>
<td>0.0239</td>
<td>-173</td>
<td>-173</td>
<td>-173</td>
<td>-173</td>
<td>173</td>
<td>-173</td>
<td>173</td>
</tr>
<tr>
<td>SR-3*</td>
<td>0.0426</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-468</td>
<td>-468</td>
<td>468</td>
</tr>
<tr>
<td>SR-3</td>
<td>0.0691</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-4,555</td>
<td>4,555</td>
<td>4,555</td>
</tr>
<tr>
<td>SR-3*</td>
<td>0.0426</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>0</td>
<td>0</td>
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<tr>
<td>SR-3</td>
<td>0.0691</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pressure stress*</td>
<td>5,745</td>
<td>5,745</td>
<td>5,745</td>
<td>5,745</td>
<td>5,745</td>
<td>5,745</td>
<td>5,745</td>
<td></td>
</tr>
<tr>
<td>Total ( O_1 ) stress</td>
<td>5,526</td>
<td>5,872</td>
<td>5,526</td>
<td>5,872</td>
<td>503</td>
<td>9,959</td>
<td>10,549</td>
<td>1,785</td>
</tr>
<tr>
<td>Membrane ( O_2 ) stress*</td>
<td>5,699</td>
<td>5,699</td>
<td>5,699</td>
<td>5,699</td>
<td>5,231</td>
<td>5,231</td>
<td>6,167</td>
<td>6,167</td>
</tr>
<tr>
<td>Shear from ( M_t )</td>
<td>560</td>
<td>560</td>
<td>560</td>
<td>560</td>
<td>560</td>
<td>560</td>
<td>560</td>
<td>560</td>
</tr>
<tr>
<td>Shear from ( V_1 )</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Shear from ( V_2 )</td>
<td>183</td>
<td>183</td>
<td>-183</td>
<td>-183</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total shear stress</td>
<td>743</td>
<td>743</td>
<td>377</td>
<td>377</td>
<td>560</td>
<td>560</td>
<td>560</td>
<td>560</td>
</tr>
<tr>
<td>Combined stress (( P_m + P_r + Q ))</td>
<td>6,057</td>
<td>6,773</td>
<td>5,726</td>
<td>6,420</td>
<td>12,352</td>
<td>19,910</td>
<td>21,860</td>
<td>9,408</td>
</tr>
</tbody>
</table>

Notes: (1) * denotes primary stress.
(2) The nozzle is assumed to be a rigid (solid) attachment.

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

\[ \sigma_n (P_m) = \frac{P \cdot R_i}{(2 \cdot t_n)} - \frac{P_r}{(\pi (R_o^2 - R_i^2))} + \frac{M \cdot R_o}{I} \]

\[ = 244.89 \cdot 3.8755 / (2 \cdot 0.3745) - 1,279.16 / (\pi (4.3125^2 - 3.8755^2)) + 95,322.5 \cdot 4.3125 / 94.475 \]

\[ = 5,505 \text{ psi} \]

The average primary stress \( P_m \) (see Division 2.5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable (\( \leq S = 17,100 \text{ psi} \))

Shear stress in the nozzle wall due to external loads

\[ \sigma_{\text{shear}} = \frac{(V_L^2 + V_c^2)^{0.5}}{\pi (R_i^2 + t_n^2)} \]

\[ = (0^2 + 2,558.332)^{0.5} / (\pi (3.8755^2 + 0.437)) \]

\[ = 481 \text{ psi} \]

\[ \sigma_{\text{torsion}} = \frac{M_t}{2 \pi R_i^2 t_n} \]

\[ = 67,398.4 / (2 \pi (3.8755^2 \cdot 0.437)) \]

\[ = 1,634 \text{ psi} \]

\[ \sigma_{\text{total}} = \sigma_{\text{shear}} + \sigma_{\text{torsion}} \]

\[ = 481 + 1,634 \]

\[ = 2,115 \text{ psi} \]

UG-45: The total combined shear stress (2,115 psi) is below than the allowable (0.7*S_n = 0.7*17,100 = 11,970 psi)

Reinforcement Calculations for MAP

<table>
<thead>
<tr>
<th>A required</th>
<th>A available</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>A5</th>
<th>A welds</th>
<th>treq</th>
<th>tmin</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.5103</td>
<td>5.3459</td>
<td>0.3755</td>
<td>0.9378</td>
<td>--</td>
<td>3.9124</td>
<td>0.1202</td>
<td>0.2818</td>
<td>0.4375</td>
</tr>
</tbody>
</table>
All failure paths are stronger than the applicable weld loads

<table>
<thead>
<tr>
<th>Weld load ( W )</th>
<th>Weld load ( W_{1,1} )</th>
<th>Path 1-1 strength</th>
<th>Weld load ( W_{2,2} )</th>
<th>Path 2-2 strength</th>
<th>Weld load ( W_{3,3} )</th>
<th>Path 3-3 strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>63,553.45</td>
<td>99,408.03</td>
<td>181,369.52</td>
<td>29,743.66</td>
<td>261,633.35</td>
<td>107,991.69</td>
<td>205,635.42</td>
</tr>
</tbody>
</table>

**UW-16 Weld Sizing Summary**

<table>
<thead>
<tr>
<th>Weld description</th>
<th>Required weld size (in)</th>
<th>Actual weld size (in)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nozzle to pad fillet (Leg41)</td>
<td>0.25</td>
<td>0.2625</td>
<td>weld size is adequate</td>
</tr>
<tr>
<td>Pad to shell fillet (Leg42)</td>
<td>0.2509</td>
<td>0.3031</td>
<td>weld size is adequate</td>
</tr>
<tr>
<td>Nozzle to pad groove (Upper)</td>
<td>0.35</td>
<td>0.5906</td>
<td>weld size is adequate</td>
</tr>
</tbody>
</table>
Reinforcement Calculations for Internal Pressure

Located on: Top Ellipsoidal Head
Liquid static head included: 0 psi
Nozzle material specification: SA-106 B Smls pipe (II-D p. 10, ln. 40)
Nozzle longitudinal joint efficiency: 1
Nozzle description: NPS 8 Sch 80 (XS)
Pad material specification: SA-516 70 (II-D p. 18, ln. 19)
Pad diameter: 15.7478 in
Flange description: NPS 8 Class 150 WN A105
Bolt Material: SA-193 B7 Bolt <= 2 1/2 (II-D p. 334, ln. 32)
Flange rated MDMT: -34.1°F
Liquid static head on flange: 0 psi
ASME B16.5-2009 flange rating MAWP: 262.5 psi @ 190°F
ASME B16.5-2009 flange rating MAP: 285 psi @ 62.6°F
ASME B16.5-2009 flange hydro test: 450 psi @ 62.6°F
PWHT performed: No
Circumferential joint radiography: Full UW-11(a) Type 1
Nozzle orientation: 0°
Calculated as hillside: No
Local vessel minimum thickness: 0.502 in
End of nozzle to datum line: 97.9449 in
Nozzle inside diameter, new: 7.625 in
Nozzle nominal wall thickness: 0.5 in
Nozzle corrosion allowance: 0.063 in
Projection available outside vessel, Lpr: 4.1016 in
Projection available outside vessel to flange face, Lf: 8.1016 in
Distance to head center, R: 0 in
Pad is split: No

Reinforcement Calculations for Internal Pressure

<table>
<thead>
<tr>
<th>A</th>
<th>A available</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>A5</th>
<th>A welds</th>
<th>treq</th>
<th>tmin</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0896</td>
<td>5.2531</td>
<td>0.3567</td>
<td>0.715</td>
<td>--</td>
<td>4.0612</td>
<td>0.1202</td>
<td>0.3447</td>
<td>0.4375</td>
</tr>
</tbody>
</table>

UG-41 Weld Failure Path Analysis Summary (lb)
All failure paths are stronger than the applicable weld loads
### UW-16 Weld Sizing Summary

<table>
<thead>
<tr>
<th>Weld description</th>
<th>Required weld size (in)</th>
<th>Actual weld size (in)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nozzle to pad fillet (Leg41)</td>
<td>0.25</td>
<td>0.2625</td>
<td>weld size is adequate</td>
</tr>
<tr>
<td>Pad to shell fillet (Leg42)</td>
<td>0.2194</td>
<td>0.3031</td>
<td>weld size is adequate</td>
</tr>
<tr>
<td>Nozzle to pad groove (Upper)</td>
<td>0.3059</td>
<td>0.5906</td>
<td>weld size is adequate</td>
</tr>
</tbody>
</table>
Applied Loads

Radial load: \( P_r = 1,279.16 \text{ lb} \)
Circumferential moment: \( M_1 = 95,322.53 \text{ lb}\cdot\text{in} \)
Circumferential shear: \( V_2 = 2,558.33 \text{ lb} \)
Longitudinal moment: \( M_2 = 0 \text{ lb}\cdot\text{in} \)
Longitudinal shear: \( V_1 = 0 \text{ lb} \)
Torsion moment: \( M_t = 67,398.43 \text{ lb}\cdot\text{in} \)
Internal pressure: \( P = 244.893 \text{ psi} \)
Head yield stress: \( S_y = 35,000 \text{ psi} \)

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

Mean dish radius \( R_m = 64.0248 \text{ in} \)

\[ U = \frac{r_o}{\sqrt{R_m^2t}} = 1.485 \]
Pressure stress intensity factor, \( I = 1 \) (derived from PVP-Vol. 399, pages 77-82)

Local pressure stress = \( 1*P*R_1 / (2*t) = 17,798 \text{ psi} \)

Maximum combined stress \( (P_L+P_b+Q) = 37,048 \text{ psi} \)
Allowable combined stress \( (P_L+P_b+Q) = +3*S = +60,000 \text{ psi} \)

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

Maximum local primary membrane stress \( (P_L) = 21,273 \text{ psi} \)
Allowable local primary membrane stress \( (P_L) = +1.5*S = +30,000 \text{ psi} \)

The local maximum primary membrane stress \( (P_L) \) is within allowable limits.
Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

Mean dish radius \( R_m = 64.0248 \text{ in} \)

\[ U = \frac{r_0}{\sqrt{R_m t}} = 0.531 \]

Pressure stress intensity factor, \( I = 0.31693 \) (derived from PVP-Vol. 399, pages 77-82)

Local pressure stress = \( I \times P \times R_i / (2 \times t) = 5,641 \text{ psi} \)

Maximum combined stress \( (P_L + P_b + Q) = 21,715 \text{ psi} \)

Allowable combined stress \( (P_L + P_b + Q) = \pm 3 \times S = \pm 60,000 \text{ psi} \)

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

Maximum local primary membrane stress \( (P_L) = 7,041 \text{ psi} \)

Allowable local primary membrane stress \( (P_L) = \pm 1.5 \times S = \pm 30,000 \text{ psi} \)

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

<table>
<thead>
<tr>
<th>Figure</th>
<th>value</th>
<th>( A_u )</th>
<th>( A_l )</th>
<th>( B_u )</th>
<th>( B_l )</th>
<th>( C_u )</th>
<th>( C_l )</th>
<th>( D_u )</th>
<th>( D_l )</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR-2*</td>
<td>0.0387</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SR-2</td>
<td>0.0189</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SR-3*</td>
<td>0.04</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SR-3</td>
<td>0.0295</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: (1) * denotes primary stress.

(2) The nozzle is assumed to be a rigid (solid) attachment.
Longitudinal stress in the nozzle wall due to internal pressure + external loads

\[ \sigma_{n}(P_m) = \frac{P \times R_i}{2 \times t_n} - \frac{P_r}{\pi (R_o^2 - R_i^2)} + \frac{M \times R_o}{I} \]
\[ = \frac{244.89 \times 3.8755}{2 \times 0.3745} - \frac{1,279.16}{\pi (4.3125^2 - 3.8755^2)} + \frac{95,322.5 \times 4.3125}{94.475} \]
\[ = 5,505 \text{ psi} \]

The average primary stress \( P_m \) (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable (\( \leq S = 17,100 \text{ psi} \)).

Shear stress in the nozzle wall due to external loads

\[ \sigma_{\text{shear}} = \frac{(V_1^2 + V_c^2)^{0.5}}{(\pi \times R_i^2 \times t_n)} \]
\[ = (0^2 + 2,558.33)^{0.5} / (\pi \times 3.8755^2 \times 0.437) \]
\[ = 481 \text{ psi} \]

\[ \sigma_{\text{torsion}} = \frac{M_t}{(2 \pi R_i^2 \times t_n)} \]
\[ = 67,398.4 / (2 \pi \times 3.8755^2 \times 0.437) \]
\[ = 1,634 \text{ psi} \]

\[ \sigma_{\text{total}} = \sigma_{\text{shear}} + \sigma_{\text{torsion}} \]
\[ = 481 + 1,634 \]
\[ = 2,115 \text{ psi} \]

UG-45: The total combined shear stress (2,115 psi) is below the allowable (0.7\( S_n \) = 0.7\( 17,100 = 11,970 \text{ psi} \)).

Reinforcement Calculations for MAP

<table>
<thead>
<tr>
<th>Pressure stress*</th>
<th>Total ( O_y ) stress</th>
<th>Membrane ( O_y ) stress*</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR-3* 0.1404</td>
<td>5,641 5,641 5,641</td>
<td>5,486 5,486 5,486</td>
</tr>
<tr>
<td>SR-3 0.2289</td>
<td>0 0 0 0 0 0</td>
<td>0 0 0 0 0 0</td>
</tr>
<tr>
<td>Pressure stress*</td>
<td>5,641 5,641 5,641</td>
<td>5,486 5,486 5,486</td>
</tr>
<tr>
<td>Total ( O_y ) stress</td>
<td>5,423 5,767 5,423</td>
<td>5,767 5,423 5,767</td>
</tr>
<tr>
<td>Membrane ( O_y ) stress*</td>
<td>5,595 5,595 5,595</td>
<td>5,595 5,595 5,595</td>
</tr>
</tbody>
</table>

Notes:
1. * denotes primary stress.
2. The nozzle is assumed to be a rigid (solid) attachment.

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

\[ \sigma_{n}(P_m) = \frac{P \times R_i}{(2 \times t_n)} - \frac{P_r}{(\pi \times (R_o^2 - R_i^2))} + \frac{M \times R_o}{I} \]
\[ = 244.89 \times 3.8755 / (2 \times 0.3745) - 1,279.16 / (\pi (4.3125^2 - 3.8755^2)) + 95,322.5 \times 4.3125 / 94.475 \]
\[ = 5,505 \text{ psi} \]

The average primary stress \( P_m \) (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable (\( \leq S = 17,100 \text{ psi} \)).

Shear stress in the nozzle wall due to external loads

\[ \sigma_{\text{shear}} = (V_1^2 + V_c^2)^{0.5} / (\pi \times R_i^2 \times t_n) \]
\[ = (0^2 + 2,558.33)^{0.5} / (\pi \times 3.8755^2 \times 0.437) \]
\[ = 481 \text{ psi} \]

\[ \sigma_{\text{torsion}} = M_t / (2 \pi R_i^2 \times t_n) \]
\[ = 67,398.4 / (2 \pi \times 3.8755^2 \times 0.437) \]
\[ = 1,634 \text{ psi} \]

\[ \sigma_{\text{total}} = \sigma_{\text{shear}} + \sigma_{\text{torsion}} \]
\[ = 481 + 1,634 \]
\[ = 2,115 \text{ psi} \]

UG-45: The total combined shear stress (2,115 psi) is below the allowable (0.7\( S_n \) = 0.7\( 17,100 = 11,970 \text{ psi} \)).

Reinforcement Calculations for MAP
All failure paths are stronger than the applicable weld loads

<table>
<thead>
<tr>
<th>Weld load $W$</th>
<th>Weld load $W_{1,1}$</th>
<th>Path 1-1 strength</th>
<th>Weld load $W_{2,2}$</th>
<th>Path 2-2 strength</th>
<th>Weld load $W_{3,3}$</th>
<th>Path 3-3 strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>62,649.19</td>
<td>99,408.03</td>
<td>181,369.52</td>
<td>29,743.66</td>
<td>261,633.35</td>
<td>107,991.69</td>
<td>205,635.42</td>
</tr>
</tbody>
</table>

**UW-16 Weld Sizing Summary**

<table>
<thead>
<tr>
<th>Weld description</th>
<th>Required weld size (in)</th>
<th>Actual weld size (in)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nozzle to pad fillet (Leg41)</td>
<td>0.25</td>
<td>0.2625</td>
<td>weld size is adequate</td>
</tr>
<tr>
<td>Pad to shell fillet (Leg42)</td>
<td>0.2509</td>
<td>0.3031</td>
<td>weld size is adequate</td>
</tr>
<tr>
<td>Nozzle to pad groove (Upper)</td>
<td>0.35</td>
<td>0.5906</td>
<td>weld size is adequate</td>
</tr>
</tbody>
</table>
Note: round inside edges per UG-76(c)

Located on: Top Ellipsoidal Head
Liquid static head included: 0 psi
Nozzle material specification: SA-106 B Smls pipe (II-D p. 10, ln. 40)
Nozzle longitudinal joint efficiency: 1
Nozzle description: NPS 4 Sch 80 (XS)
Pad material specification: SA-516 70 (II-D p. 18, ln. 19)
Pad diameter: 8.2677 in
Flange description: NPS 4 Class 150 WN A105
Bolt Material: SA-193 B7 Bolt <= 2 1/2 (II-D p. 334, ln. 32)
Flange rated MDMT: -34.1°F
(UCS-66(b)(1)(b))
Liquid static head on flange: 0 psi
ASME B16.5-2009 flange rating MAWP: 262.5 psi @ 190°F
ASME B16.5-2009 flange rating MAP: 285 psi @ 62.6°F
ASME B16.5-2009 flange hydro test: 450 psi @ 62.6°F
PWHT performed: No
Circumferential joint radiography: Full UW-11(a) Type 1
Nozzle orientation: 193°
Calculated as hillside: No
Local vessel minimum thickness: 0.502 in
End of nozzle to datum line: 91.0666 in
Nozzle inside diameter, new: 3.826 in
Nozzle nominal wall thickness: 0.337 in
Nozzle corrosion allowance: 0.063 in
Projection available outside vessel, Lpr: 4.8739 in
Projection available outside vessel to flange face, Lf: 7.8739 in
Distance to head center, R: 26.1811 in
Pad is split: No

Reinforcement Calculations for Internal Pressure

<table>
<thead>
<tr>
<th>A</th>
<th>A</th>
<th>A</th>
<th>A</th>
<th>A</th>
<th>t_{req}</th>
<th>t_{min}</th>
</tr>
</thead>
<tbody>
<tr>
<td>required</td>
<td>available</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>welds</td>
</tr>
<tr>
<td>1.7452</td>
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<td>0.0235</td>
<td>0.4607</td>
<td>--</td>
<td>2.0102</td>
<td>0.1073</td>
</tr>
</tbody>
</table>

UG-37 Area Calculation Summary (in^2)
For P = 244.89 psi @ 190 °F
The opening is adequately reinforced

UG-41 Weld Failure Path Analysis Summary (lb f)
All failure paths are stronger than the applicable weld loads

UG-45 Nozzle Wall Thickness Summary (in)
The nozzle passes UG-45
Reinforcement Calculations for MAP

UW-16 Weld Sizing Summary

<table>
<thead>
<tr>
<th>Weld load $W_{1-1}$</th>
<th>Path 1-1 strength</th>
<th>Weld load $W_{2-2}$</th>
<th>Path 2-2 strength</th>
<th>Weld load $W_{3-3}$</th>
<th>Path 3-3 strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>34,490.42</td>
<td>51,564.35</td>
<td>76,890</td>
<td>15,473.6</td>
<td>128,689.42</td>
<td>55,677.96</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>101,040.33</td>
<td></td>
</tr>
</tbody>
</table>

UG-37 Area Calculation Summary (in²)
For $P = 279.83$ psi @ 62.6 °F
The opening is adequately reinforced

<table>
<thead>
<tr>
<th>$A_{required}$</th>
<th>$A_{available}$</th>
<th>$A_1$</th>
<th>$A_2$</th>
<th>$A_3$</th>
<th>$A_5$</th>
<th>$A_{welds}$</th>
<th>$t_{req}$</th>
<th>$t_{min}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.9424</td>
<td>2.65</td>
<td>0.0259</td>
<td>0.6554</td>
<td>1.8614</td>
<td>0.1073</td>
<td>0.0316</td>
<td>0.2949</td>
<td></td>
</tr>
</tbody>
</table>

UG-45 Nozzle Wall Thickness Summary (in)
The nozzle passes UG-45

UG-41 Weld Failure Path Analysis Summary (lb)
All failure paths are stronger than the applicable weld loads

<table>
<thead>
<tr>
<th>Weld load $W_{1-1}$</th>
<th>Path 1-1 strength</th>
<th>Weld load $W_{2-2}$</th>
<th>Path 2-2 strength</th>
<th>Weld load $W_{3-3}$</th>
<th>Path 3-3 strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>38,409.25</td>
<td>52,482.35</td>
<td>81,496.14</td>
<td>21,039.39</td>
<td>135,280.16</td>
<td>58,267.73</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>107,631.08</td>
</tr>
</tbody>
</table>

UG-16 Weld Sizing Summary

<table>
<thead>
<tr>
<th>Weld description</th>
<th>Required weld size (in)</th>
<th>Actual weld size (in)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nozzle to pad fillet (Leg41)</td>
<td>0.2359</td>
<td>0.248</td>
<td>weld size is adequate</td>
</tr>
<tr>
<td>Pad to shell fillet (Leg42)</td>
<td>0.2509</td>
<td>0.3031</td>
<td>weld size is adequate</td>
</tr>
<tr>
<td>Nozzle to pad groove (Upper)</td>
<td>0.2359</td>
<td>0.5906</td>
<td>weld size is adequate</td>
</tr>
</tbody>
</table>
Reinforcement Calculations for Internal Pressure

Located on: Bottom Ellipsoidal Head

Liquid static head included: 0 psi
Nozzle material specification: SA-106 B Smls pipe (II-D p. 10, ln. 40)
Nozzle longitudinal joint efficiency: 1
Nozzle description: NPS 4 Sch 80 (XS)
Pad material specification: SA-516 70 (II-D p. 18, ln. 19)
Pad diameter: 8.2677 in
Flange description: NPS 4 Class 150 WN A105
Bolt Material: SA-193 B7 Bolt <= 2 1/2 (II-D p. 334, ln. 32)
Flange rated MDMT: -34.1°F

Liquid static head on flange: 0 psi
ASME B16.5-2009 flange rating MAWP: 262.5 psi @ 190°F
ASME B16.5-2009 flange rating MAP: 285 psi @ 62.6°F
ASME B16.5-2009 flange hydro test: 450 psi @ 62.6°F
PWHT performed: No
Circumferential joint radiography: Full UW-11(a) Type 1
Nozzle orientation: 193°
Calculated as hillside: No
Local vessel minimum thickness: 0.502 in
End of nozzle to datum line: -22.0705 in
Nozzle inside diameter, new: 3.826 in
Nozzle nominal wall thickness: 0.337 in
Nozzle corrosion allowance: 0.063 in
Projection available outside vessel, Lpr: 4.874 in
Projection available outside vessel to flange face, Lf: 7.874 in
Distance to head center, R: 21.7323 in
Pad is split: No

Reinforcement Calculations for Internal Pressure

<table>
<thead>
<tr>
<th>UG-37 Area Calculation Summary (in²)</th>
<th>UG-45 Nozzle Wall Thickness Summary (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>For P = 244.89 psi @ 190°F</td>
<td>The nozzle passes UG-45</td>
</tr>
<tr>
<td>The opening is adequately reinforced</td>
<td></td>
</tr>
<tr>
<td>A required</td>
<td>A available</td>
</tr>
<tr>
<td>1.5936</td>
<td>2.7473</td>
</tr>
</tbody>
</table>

UG-41 Weld Failure Path Analysis Summary (lbf)
All failure paths are stronger than the applicable weld loads.
## Reinforcement Calculations for MAP

<table>
<thead>
<tr>
<th>Weld load W</th>
<th>Weld load W_{1-1}</th>
<th>Path 1-1 strength</th>
<th>Weld load W_{2-2}</th>
<th>Path 2-2 strength</th>
<th>Weld load W_{3-3}</th>
<th>Path 3-3 strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>28,899.12</td>
<td>51,564.35</td>
<td>76,890</td>
<td>15,473.6</td>
<td>128,689.42</td>
<td>55,677.96</td>
<td>101,040.33</td>
</tr>
</tbody>
</table>

### UW-16 Weld Sizing Summary

<table>
<thead>
<tr>
<th>Weld description</th>
<th>Required weld size (in)</th>
<th>Actual weld size (in)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nozzle to pad fillet (Leg41)</td>
<td>0.1918</td>
<td>0.248</td>
<td>weld size is adequate</td>
</tr>
<tr>
<td>Pad to shell fillet (Leg42)</td>
<td>0.2194</td>
<td>0.3031</td>
<td>weld size is adequate</td>
</tr>
<tr>
<td>Nozzle to pad groove (Upper)</td>
<td>0.1918</td>
<td>0.5906</td>
<td>weld size is adequate</td>
</tr>
</tbody>
</table>

### UG-41 Weld Failure Path Analysis Summary (lbf)

All failure paths are stronger than the applicable weld loads

<table>
<thead>
<tr>
<th>Weld load W</th>
<th>Weld load W_{1-1}</th>
<th>Path 1-1 strength</th>
<th>Weld load W_{2-2}</th>
<th>Path 2-2 strength</th>
<th>Weld load W_{3-3}</th>
<th>Path 3-3 strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>32,287.03</td>
<td>52,482.35</td>
<td>81,496.14</td>
<td>21,039.39</td>
<td>135,280.16</td>
<td>58,267.73</td>
<td>107,631.08</td>
</tr>
</tbody>
</table>

### UG-37 Area Calculation Summary (in²)

For \( P = 279.83 \text{ psi} \) @ 62.6 °F
The opening is adequately reinforced

<table>
<thead>
<tr>
<th>( A ) required</th>
<th>( A ) available</th>
<th>( A_1 )</th>
<th>( A_2 )</th>
<th>( A_3 )</th>
<th>( A_5 )</th>
<th>( A ) welds</th>
<th>( t_{req} )</th>
<th>( t_{min} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.7726</td>
<td>2.8113</td>
<td>0.1872</td>
<td>0.6554</td>
<td>1.8614</td>
<td>0.1073</td>
<td>1.8614</td>
<td>0.0316</td>
<td>0.2949</td>
</tr>
</tbody>
</table>

### UG-45 Nozzle Wall Thickness Summary (in)
The nozzle passes UG-45

All failure paths are stronger than the applicable weld loads

<table>
<thead>
<tr>
<th>Weld load W</th>
<th>Weld load W_{1-1}</th>
<th>Path 1-1 strength</th>
<th>Weld load W_{2-2}</th>
<th>Path 2-2 strength</th>
<th>Weld load W_{3-3}</th>
<th>Path 3-3 strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>32,287.03</td>
<td>52,482.35</td>
<td>81,496.14</td>
<td>21,039.39</td>
<td>135,280.16</td>
<td>58,267.73</td>
<td>107,631.08</td>
</tr>
</tbody>
</table>

### UW-16 Weld Sizing Summary

<table>
<thead>
<tr>
<th>Weld description</th>
<th>Required weld size (in)</th>
<th>Actual weld size (in)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nozzle to pad fillet (Leg41)</td>
<td>0.2359</td>
<td>0.248</td>
<td>weld size is adequate</td>
</tr>
<tr>
<td>Pad to shell fillet (Leg42)</td>
<td>0.2509</td>
<td>0.3031</td>
<td>weld size is adequate</td>
</tr>
<tr>
<td>Nozzle to pad groove (Upper)</td>
<td>0.2359</td>
<td>0.5906</td>
<td>weld size is adequate</td>
</tr>
</tbody>
</table>
Reinforcement Calculations for Internal Pressure

\[ t_{\text{w(lower)}} = 0.502 \text{ in} \]
\[ \text{Leg}_{41} = 0.3543 \text{ in} \]
\[ t_{\text{w(upper)}} = 0.5906 \text{ in} \]
\[ \text{Leg}_{42} = 0.4331 \text{ in} \]
\[ D_p = 8.2676 \text{ in} \]
\[ t_e = 0.5906 \text{ in} \]

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

Located on: Top Ellipsoidal Head
Liquid static head included: 0 psi
Nozzle material specification: SA-106 B SMLS pipe (II-D p. 10, ln. 40)
Nozzle longitudinal joint efficiency: 1
Nozzle description: NPS 4 Sch 80 (XS)
Pad material specification: SA-516 70 (II-D p. 18, ln. 19)
Pad diameter: 8.2676 in
Flange description: NPS 4 Class 300 WN A105
Bolt Material: SA-193 B7 Bolt <= 2 1/2 (II-D p. 334, ln. 32)
Flange rated MDMT:

(UCS-66(b)(3): Coincident ratio = 0.3309)
(Flange rated MDMT = -155 °F)
Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F

Liquid static head on flange: 0 psi
ASME B16.5-2009 flange rating MAWP: 686 psi @ 190°F
ASME B16.5-2009 flange rating MAP: 740 psi @ 62.6°F
ASME B16.5-2009 flange hydro test: 1,125 psi @ 62.6°F
PWHT performed: No
Circumferential joint radiography: Full UW-11(a) Type I
Nozzle orientation: 230°
Calculated as hillside: Yes
Local vessel minimum thickness: 0.502 in
End of nozzle to datum line: 93.6378 in
Nozzle inside diameter, new: 3.826 in
Nozzle nominal wall thickness: 0.337 in
Nozzle corrosion allowance: 0.063 in
Opening chord length: 4.5098 in
Projection available outside vessel, Lpr: 4.929 in
Projection available outside vessel to flange face, Lf: 8.309 in
Distance to head center, R: 26.1811 in
Pad is split: No

Reinforcement Calculations for Internal Pressure

\[
\begin{array}{cccccccc}
\text{A required} & \text{A available} & A_1 & A_2 & A_3 & A_5 & A_{\text{welds}} & t_{\text{req}} & t_{\text{min}} \\
1.9866 & 2.6373 & 0.0269 & 0.4607 & -- & 1.8581 & 0.2916 & 0.1365 & 0.2949
\end{array}
\]

UG-37 Area Calculation Summary (in²)
For \( P = 244.89 \text{ psi at } 190 \text{ °F} \)
The opening is adequately reinforced
UG-45 Nozzle Wall Thickness Summary (in)
The nozzle passes UG-45
### UG-41 Weld Failure Path Analysis Summary (lb f)

All failure paths are stronger than the applicable weld loads

<table>
<thead>
<tr>
<th>Weld load W</th>
<th>Weld load W_{1-1} strength</th>
<th>Weld load W_{2-2} strength</th>
<th>Weld load W_{3-3} strength</th>
<th>Path 1-1 strength</th>
<th>Path 2-2 strength</th>
<th>Path 3-3 strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>39,251.88</td>
<td>52,208.87</td>
<td>76,888.93</td>
<td>15,473.6</td>
<td>128,689.42</td>
<td>56,322.48</td>
<td>101,039.26</td>
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</tbody>
</table>

### UW-16 Weld Sizing Summary

<table>
<thead>
<tr>
<th>Weld description</th>
<th>Required weld size (in)</th>
<th>Actual weld size (in)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nozzle to pad fillet (Leg41)</td>
<td>0.1918</td>
<td>0.248</td>
<td>weld size is adequate</td>
</tr>
<tr>
<td>Pad to shell fillet (Leg42)</td>
<td>0.2194</td>
<td>0.3031</td>
<td>weld size is adequate</td>
</tr>
<tr>
<td>Nozzle to pad groove (Upper)</td>
<td>0.1918</td>
<td>0.5906</td>
<td>weld size is adequate</td>
</tr>
</tbody>
</table>
Applied Loads

Radial load: \( P_r = 483.34 \text{ lb}_f \)
Circumferential moment: \( M_1 = 19,294.63 \text{ lb}_f \text{-in} \)
Circumferential shear: \( V_2 = 966.68 \text{ lb}_f \)
Longitudinal moment: \( M_2 = 0 \text{ lb}_f \text{-in} \)
Longitudinal shear: \( V_1 = 0 \text{ lb}_f \)
Torsion moment: \( M_t = 13,630.15 \text{ lb}_f \text{-in} \)
Internal pressure: \( P = 244.893 \text{ psi} \)
Head yield stress: \( S_y = 35,000 \text{ psi} \)

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

Mean dish radius \( R_m = 64.0248 \text{ in} \)

\[ U = \frac{r_o}{\sqrt{R_m \cdot t}} = 0.721 \]

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

Local pressure stress = \( I \cdot P \cdot R_i / (2 \cdot t) = 17,798 \text{ psi} \)

Maximum combined stress \( (P_L + P_b + Q) = 35,173 \text{ psi} \)
Allowable combined stress \( (P_L + P_b + Q) = \pm 3 \cdot S = \pm 60,000 \text{ psi} \)

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

Maximum local primary membrane stress \( (P_L) = 19,687 \text{ psi} \)
Allowable local primary membrane stress \( (P_L) = \pm 1.5 \cdot S = \pm 30,000 \text{ psi} \)

The local maximum primary membrane stress \( (P_L) \) is within allowable limits.
Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

Mean dish radius $R_m = 64.0248$ in

$U = \frac{r_o}{\sqrt{R_m*t}} = 0.277$

Pressure stress intensity factor, $I = 0.41245$ (derived from PVP-Vol. 399, pages 77-82)

Local pressure stress = $I*P*R_i / (2*t) = 7,341$ psi

Maximum combined stress ($P_L+P_b+Q$) = 14,400 psi

Allowable combined stress ($P_L+P_b+Q$) = $\pm 3*S = \pm 60,000$ psi

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

Maximum local primary membrane stress ($P_L$) = 7,621 psi

Allowable local primary membrane stress ($P_L$) = $\pm 1.5*S = \pm 30,000$ psi

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

Notes:
1) * denotes primary stress.
2) The nozzle is assumed to be a rigid (solid) attachment.

Stresses at the pad edge per WRC Bulletin 107

<table>
<thead>
<tr>
<th>Figure</th>
<th>value</th>
<th>$A_u$</th>
<th>$A_l$</th>
<th>$B_u$</th>
<th>$B_l$</th>
<th>$C_u$</th>
<th>$C_l$</th>
<th>$D_u$</th>
<th>$D_l$</th>
</tr>
</thead>
<tbody>
<tr>
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<td>853</td>
<td>-853</td>
<td>853</td>
<td>-853</td>
<td>853</td>
<td>-853</td>
<td>853</td>
</tr>
<tr>
<td>SR-3*</td>
<td>0.1131</td>
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<td>0</td>
<td>0</td>
<td>-2,136</td>
<td>-2,136</td>
<td>2,136</td>
<td>2,136</td>
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<tr>
<td>SR-3*</td>
<td>0.1131</td>
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<tr>
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</tr>
<tr>
<td>Pressure stress*</td>
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<td>17,798</td>
<td>17,798</td>
<td>17,798</td>
<td>17,798</td>
<td>17,798</td>
<td>17,798</td>
<td>17,798</td>
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<tr>
<td>Total $O_x$ stress</td>
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<td>18,404</td>
<td>16,698</td>
<td>18,404</td>
<td>-1,768</td>
<td>32,598</td>
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<td>4,210</td>
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</tr>
<tr>
<td>Membrane $O_x$ stress*</td>
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<td>17,551</td>
<td>17,551</td>
<td>17,551</td>
<td>15,415</td>
<td>15,415</td>
<td>19,687</td>
<td>19,687</td>
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</tr>
<tr>
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<td>-74</td>
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<td>SR-2</td>
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<td>-262</td>
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<td>262</td>
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<tr>
<td>SR-3*</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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<td>-642</td>
<td>-642</td>
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<td>SR-3</td>
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<td>-4,998</td>
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<td>0</td>
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</tr>
<tr>
<td>Pressure stress*</td>
<td>17,798</td>
<td>17,798</td>
<td>17,798</td>
<td>17,798</td>
<td>17,798</td>
<td>17,798</td>
<td>17,798</td>
<td>17,798</td>
<td>17,798</td>
</tr>
<tr>
<td>Total $O_x$ stress</td>
<td>17,462</td>
<td>17,986</td>
<td>17,462</td>
<td>17,986</td>
<td>11,822</td>
<td>22,342</td>
<td>23,102</td>
<td>13,630</td>
<td></td>
</tr>
<tr>
<td>Membrane $O_x$ stress*</td>
<td>17,724</td>
<td>17,724</td>
<td>17,724</td>
<td>17,724</td>
<td>17,082</td>
<td>17,082</td>
<td>18,366</td>
<td>18,366</td>
<td></td>
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<tr>
<td>Shear from $M_t$</td>
<td>338</td>
<td>338</td>
<td>338</td>
<td>338</td>
<td>338</td>
<td>338</td>
<td>338</td>
<td>338</td>
<td>338</td>
</tr>
<tr>
<td>Shear from $V_1$</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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</tr>
<tr>
<td>Shear from $V_2$</td>
<td>183</td>
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<td>-183</td>
<td>-183</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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</tr>
<tr>
<td>Total Shear stress</td>
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<td>521</td>
<td>155</td>
<td>155</td>
<td>338</td>
<td>338</td>
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</tr>
<tr>
<td>Combined stress ($P_L+P_b+Q$)</td>
<td>17,726</td>
<td>18,756</td>
<td>17,492</td>
<td>18,455</td>
<td>13,607</td>
<td>32,609</td>
<td>35,173</td>
<td>13,642</td>
<td></td>
</tr>
</tbody>
</table>
Longitudinal stress in the nozzle wall due to internal pressure + external loads

\[ \sigma_{n}(Pm) = \frac{P \cdot R_i}{2 \cdot t_n} - \frac{P}{(\pi \cdot (R_o^2 - R_i^2))} + \frac{M \cdot R_o}{I} \]

\[ = \frac{244.89 \cdot 1.976}{2 \cdot 0.2319} - \frac{483.34}{(\pi \cdot (2.252 - 1.976^2))} + 19,294.6 \cdot 2.25 \div 8.1551 \]

\[ = 6,234 \text{ psi} \]

The average primary stress \( P_m \) (see Division 2.5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable \( \leq S = 17,100 \text{ psi} \)

Shear stress in the nozzle wall due to external loads

\[ \sigma_{\text{shear}} = \sqrt{(V_1^2 + V_c^2)} \cdot 0.5 \div (\pi \cdot R_i^2 \cdot t_n) \]

\[ = (02 + 966.682) \cdot 0.5 \div (\pi \cdot 1.976^2 \cdot 0.274) \]

\[ = 568 \text{ psi} \]

\[ \sigma_{\text{torsion}} = M_t \div (2 \cdot \pi \cdot R_i^2 \cdot t_n) \]

\[ = 13,630.1 \div (2 \cdot \pi \cdot 1.976^2 \cdot 0.274) \]

\[ = 2,028 \text{ psi} \]

\[ \sigma_{\text{total}} = \sigma_{\text{shear}} + \sigma_{\text{torsion}} \]

\[ = 568 + 2,028 \]

\[ = 2,596 \text{ psi} \]

UG-45: The total combined shear stress (2,596 psi) is below than the allowable \( 0.7 \cdot S_n = 0.7 \cdot 17,100 = 11,970 \text{ psi} \)

Reinforcement Calculations for MAP

<table>
<thead>
<tr>
<th>SR-3*</th>
<th>0.1651</th>
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<th>0</th>
<th>0</th>
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<th>0</th>
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</tr>
</thead>
<tbody>
<tr>
<td>SR-3</td>
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</tr>
<tr>
<td>Total ( O_x ) stress</td>
<td>7.191</td>
<td>7.437</td>
<td>7.191</td>
<td>7.437</td>
<td>5.009</td>
<td>9.393</td>
<td>9.373</td>
<td>5.481</td>
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<tr>
<td>Shear from ( M_t )</td>
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<td>416</td>
<td>416</td>
<td>416</td>
<td>416</td>
<td>416</td>
<td>416</td>
<td>416</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shear from ( V_1 )</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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</tr>
<tr>
<td>Shear from ( V_2 )</td>
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<td>-133</td>
<td>-133</td>
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<td>0</td>
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<td>0</td>
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<td></td>
</tr>
<tr>
<td>Total Shear stress</td>
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<td>549</td>
<td>283</td>
<td>283</td>
<td>416</td>
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<td>416</td>
<td>416</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Combined stress ( (P_r + P_n + Q) )</td>
<td>7,593</td>
<td>8,108</td>
<td>7,349</td>
<td>7,852</td>
<td>5,673</td>
<td>14,400</td>
<td>14,324</td>
<td>5,519</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: (1) * denotes primary stress.
(2) The nozzle is assumed to be a rigid (solid) attachment.

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

\[ \sigma_{n}(Pm) = \frac{P \cdot R_i}{(2 \cdot t_n)} - \frac{P}{(\pi \cdot (R_o^2 - R_i^2))} + \frac{M \cdot R_o}{I} \]

\[ = 244.89 \cdot 1.976 / (2 \cdot 0.2319) - 483.34 / (\pi \cdot (2.252 - 1.976^2)) + 19,294.6 \cdot 2.25 / 8.1551 \]

\[ = 6,234 \text{ psi} \]

The average primary stress \( P_m \) (see Division 2.5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable \( \leq S = 17,100 \text{ psi} \)

Shear stress in the nozzle wall due to external loads

\[ \sigma_{\text{shear}} = \sqrt{(V_1^2 + V_c^2)} \cdot 0.5 / (\pi \cdot R_i^2 \cdot t_n) \]

\[ = (02 + 966.682) \cdot 0.5 / (\pi \cdot 1.976^2 \cdot 0.274) \]

\[ = 568 \text{ psi} \]

\[ \sigma_{\text{torsion}} = M_t / (2 \cdot \pi \cdot R_i^2 \cdot t_n) \]

\[ = 13,630.1 / (2 \cdot \pi \cdot 1.976^2 \cdot 0.274) \]

\[ = 2,028 \text{ psi} \]

\[ \sigma_{\text{total}} = \sigma_{\text{shear}} + \sigma_{\text{torsion}} \]

\[ = 568 + 2,028 \]

\[ = 2,596 \text{ psi} \]

UG-45: The total combined shear stress (2,596 psi) is below than the allowable \( 0.7 \cdot S_n = 0.7 \cdot 17,100 = 11,970 \text{ psi} \)

Reinforcement Calculations for MAP

| ITEM NO. : B01-K-0156A/B/C/D |  |
|-------------------------------|--|---|---|---|---|---|---|---|---|---|---|---|
| A required | A available | A1 | A2 | A3 | A5 | A welds | treq | nmin |
| 2.2095 | 2.7974 | 0.0296 | 0.6554 | -- | 1.8581 | 0.2543 | 0.0819 | 0.2949 |  |

UG-41 Weld Failure Path Analysis Summary (lbf)
All failure paths are stronger than the applicable weld loads

<table>
<thead>
<tr>
<th>Weld load</th>
<th>Weld load</th>
<th>Path 1-1 strength</th>
<th>Weld load</th>
<th>Path 2-2 strength</th>
<th>Weld load</th>
<th>Path 3-3 strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>W₁₁</td>
<td>43,677.61</td>
<td>W₂₂</td>
<td>55,356.87</td>
<td>W₃₃</td>
<td>81,495.08</td>
</tr>
<tr>
<td></td>
<td></td>
<td>81,495.08</td>
<td></td>
<td>21,039.39</td>
<td></td>
<td>135,280.16</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>61,142.26</td>
<td></td>
<td>107,630.01</td>
</tr>
</tbody>
</table>

UW-16 Weld Sizing Summary

<table>
<thead>
<tr>
<th>Weld description</th>
<th>Required weld size (in)</th>
<th>Actual weld size (in)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nozzle to pad fillet (Leg₄₁)</td>
<td>0.2359</td>
<td>0.248</td>
<td>weld size is adequate</td>
</tr>
<tr>
<td>Pad to shell fillet (Leg₄₂)</td>
<td>0.2509</td>
<td>0.3031</td>
<td>weld size is adequate</td>
</tr>
<tr>
<td>Nozzle to pad groove (Upper)</td>
<td>0.2359</td>
<td>0.5906</td>
<td>weld size is adequate</td>
</tr>
</tbody>
</table>
P.I (N6 (2"))

ASME Section VIII Division 1, 2010 Edition, A11 Addenda

Located on: Shell
Liquid static head included: 0 psi
Nozzle material specification: SA-106 B Smls pipe (II-D p. 10, ln. 40)
Nozzle longitudinal joint efficiency: 1
Nozzle description: NPS 2 Sch 160
Pad material specification: SA-516 70 (II-D p. 18, ln. 19)
Pad diameter: 5.9053 in
Flange description: NPS 2 Class 150 WN A105
Bolt Material: SA-193 B7 Bolt <= 2 1/2 (II-D p. 334, ln. 32)
Flange rated MDMT: -34.1°F (UCS-66(b)(1)(b))
Liquid static head on flange: 0 psi
ASME B16.5-2009 flange rating MAWP: 262.5 psi @ 190°F
ASME B16.5-2009 flange rating MAP: 285 psi @ 62.6°F
ASME B16.5-2009 flange hydro test: 450 psi @ 62.6°F
PWHT performed: No
Circumferential joint radiography: Full UW-11(a) Type 1
Nozzle orientation: 250°
Local vessel minimum thickness: 0.5906 in
Nozzle center line offset to datum line: 7.4016 in
End of nozzle to shell center: 43.7008 in
Nozzle inside diameter, new: 1.687 in
Nozzle nominal wall thickness: 0.344 in
Nozzle corrosion allowance: 0.063 in
Projection available outside vessel, Lpr: 5.374 in
Projection available outside vessel to flange face, Lf: 7.874 in
Pad is split: No

Reinforcement Calculations for Internal Pressure

<table>
<thead>
<tr>
<th>UG-37 Area Calculation Summary (in²)</th>
<th>UG-41 Weld Failure Path Analysis Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>For P = 244.89 psi @ 190°F</td>
<td>The nozzle is exempt from weld strength calculations per UW-15(b)(2)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>A required</th>
<th>A available</th>
<th>A₁</th>
<th>A₂</th>
<th>A₃</th>
<th>A₅</th>
<th>A welds</th>
<th>tₕₚ</th>
<th>tₘᵢᵣ</th>
</tr>
</thead>
<tbody>
<tr>
<td>This nozzle is exempt from area calculations per UG-36(c)(3)(a)</td>
<td>0.1977</td>
<td>0.301</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: round inside edges per UG-76(c)
This opening does not require reinforcement per UG-36(c)(3)(a)

Reinforcement Calculations for MAP

<table>
<thead>
<tr>
<th>Weld description</th>
<th>Required weld size (in)</th>
<th>Actual weld size (in)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nozzle to pad fillet (Leg41)</td>
<td>0.1967</td>
<td>0.248</td>
<td>weld size is adequate</td>
</tr>
<tr>
<td>Pad to shell fillet (Leg42)</td>
<td>0.2638</td>
<td>0.3031</td>
<td>weld size is adequate</td>
</tr>
<tr>
<td>Nozzle to pad groove (Upper)</td>
<td>0.1967</td>
<td>0.5906</td>
<td>weld size is adequate</td>
</tr>
</tbody>
</table>

UG-37 Area Calculation Summary (in²)
For P = 279.83 psi @ 62.6 °F

<table>
<thead>
<tr>
<th>A required</th>
<th>A available</th>
<th>A₁</th>
<th>A₂</th>
<th>A₃</th>
<th>A₅</th>
<th>A welds</th>
<th>tₐ₀₀</th>
<th>tₐ₁₀₁</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This nozzle is exempt from area calculations per UG-36(c)(3)(a) 0.1348 0.301

The nozzle passes UG-45

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

UG-16 Weld Sizing Summary

<table>
<thead>
<tr>
<th>Weld description</th>
<th>Required weld size (in)</th>
<th>Actual weld size (in)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nozzle to pad fillet (Leg41)</td>
<td>0.2408</td>
<td>0.248</td>
<td>weld size is adequate</td>
</tr>
<tr>
<td>Pad to shell fillet (Leg42)</td>
<td>0.2953</td>
<td>0.3031</td>
<td>weld size is adequate</td>
</tr>
<tr>
<td>Nozzle to pad groove (Upper)</td>
<td>0.2408</td>
<td>0.5906</td>
<td>weld size is adequate</td>
</tr>
</tbody>
</table>

This opening does not require reinforcement per UG-36(c)(3)(a)
Reinforcement Calculations for Internal Pressure

Located on: Shell
Liquid static head included: 0 psi
Nozzle material specification: SA-516 70 (II-D p. 18, ln. 19)
Nozzle longitudinal joint efficiency: 1
Pad material specification: SA-516 70 (II-D p. 18, ln. 19)
Pad diameter: 33.0709 in
Flange description: NPS 20 Class 150 WN A105
Bolt Material: SA-193 B7 Bolt <= 2 1/2 (II-D p. 334, ln. 32)
Flange rated MDMT: -34.1°F
(UCS-66(b)(1(b))
Liquid static head on flange: 0 psi
ASME B16.5-2009 flange rating MAWP: 262.5 psi @ 190°F
ASME B16.5-2009 flange rating MAP: 285 psi @ 62.6°F
ASME B16.5-2009 flange hydro test: 450 psi @ 62.6°F
PWHT performed: No
Circumferential joint radiography: Full UW-11(a) Type 1
Nozzle orientation: 180°
Local vessel minimum thickness: 0.5906 in
Nozzle center line offset to datum line: 20.4724 in
End of nozzle to shell center: 45.6693 in
Nozzle inside diameter, new: 19.0551 in
Nozzle nominal wall thickness: 0.4724 in
Nozzle corrosion allowance: 0.063 in
Projection available outside vessel, Lpr: 4.1525 in
Projection available outside vessel to flange face, Lf: 9.8425 in
Pad is split: No

Reinforcement Calculations for Internal Pressure

<table>
<thead>
<tr>
<th>UG-37 Area Calculation Summary (in²)</th>
<th>UG-45 Nozzle Wall Thickness Summary (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>For P = 244.89 psi @ 190°F</td>
<td>The nozzle passes UG-45</td>
</tr>
<tr>
<td>The opening is adequately reinforced</td>
<td></td>
</tr>
<tr>
<td>A required</td>
<td>A available</td>
</tr>
<tr>
<td>------------</td>
<td>-------------</td>
</tr>
<tr>
<td>8.3735</td>
<td>10.5607</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>UG-41 Weld Failure Path Analysis Summary (lbₚ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All failure paths are stronger than the applicable weld loads</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Weld load W</th>
<th>Weld load W₁₋₁ strength</th>
<th>Weld load W₂₋₂ strength</th>
<th>Weld load W₃₋₃ strength</th>
</tr>
</thead>
</table>
% Extreme fiber elongation - UCS-79(d)

\[
EFE = \frac{50 \times t}{R_f} \times \left(1 - \frac{R_f}{R_o}\right)
\]
\[
= \left(\frac{50 \times 0.4724}{9.7638}\right) \times \left(1 - \frac{9.7638}{Y_{\infty}}\right)
\]
\[
= 2.4194\%
\]

The extreme fiber elongation does not exceed 5%.

Reinforcement Calculations for MAP

### UG-37 Area Calculation Summary (in²)
For P = 279.83 psi @ 62.6 °F
The opening is adequately reinforced

<table>
<thead>
<tr>
<th>A</th>
<th>A available</th>
<th>A₁</th>
<th>A₂</th>
<th>A₅</th>
<th>treq</th>
<th>tmin</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.4986</td>
<td>10.7998</td>
<td>1.7544</td>
<td>0.9982</td>
<td>--</td>
<td>7.719</td>
<td>0.3281</td>
</tr>
</tbody>
</table>

### UG-45 Nozzle Wall Thickness Summary (in)
The nozzle passes UG-45

### UG-41 Weld Failure Path Analysis Summary (lb)
All failure paths are stronger than the applicable weld loads

<table>
<thead>
<tr>
<th>Weld load W</th>
<th>Weld load W₁⁺</th>
<th>Path 1-1 strength</th>
<th>Weld load W₂⁺</th>
<th>Path 2-2 strength</th>
<th>Weld load W₃⁺</th>
<th>Path 3-3 strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>156,623.83</td>
<td>180,908.31</td>
<td>423,352.45</td>
<td>33,936.02</td>
<td>664,613.82</td>
<td>192,068.33</td>
<td>495,050.65</td>
</tr>
</tbody>
</table>

### UW-16 Weld Sizing Summary

<table>
<thead>
<tr>
<th>Weld description</th>
<th>Required weld size (in)</th>
<th>Actual weld size (in)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nozzle to pad fillet (Leg₄₁)</td>
<td>0.25</td>
<td>0.2625</td>
<td>weld size is adequate</td>
</tr>
<tr>
<td>Pad to shell fillet (Leg₄₂)</td>
<td>0.2638</td>
<td>0.3031</td>
<td>weld size is adequate</td>
</tr>
<tr>
<td>Nozzle to pad groove (Upper)</td>
<td>0.2866</td>
<td>0.5906</td>
<td>weld size is adequate</td>
</tr>
</tbody>
</table>
### Geometry Inputs

<table>
<thead>
<tr>
<th>Attached To</th>
<th>Shell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>A 516-70</td>
</tr>
<tr>
<td>Distance of Lift Point From Datum</td>
<td>87.5591&quot;</td>
</tr>
<tr>
<td>Angular Position</td>
<td>0.00 deg and 180.00 deg</td>
</tr>
<tr>
<td>Length of Lug, L</td>
<td>17.7165&quot;</td>
</tr>
<tr>
<td>Width of Lug, B</td>
<td>5.1181&quot;</td>
</tr>
<tr>
<td>Thickness of Lug, t</td>
<td>0.8661&quot;</td>
</tr>
<tr>
<td>Hole Diameter, d</td>
<td>1.9685&quot;</td>
</tr>
<tr>
<td>Pin Diameter, Dp</td>
<td>1.5748&quot;</td>
</tr>
<tr>
<td>Lug Diameter at Pin, D</td>
<td>5.1181&quot;</td>
</tr>
<tr>
<td>Weld Size, tw</td>
<td>0.3937&quot;</td>
</tr>
<tr>
<td>Weld Length, b₁</td>
<td>1.5748&quot;</td>
</tr>
<tr>
<td>Weld Length, d₂</td>
<td>2.7559&quot;</td>
</tr>
<tr>
<td>Width of Pad, Bₚ</td>
<td>9.0551&quot;</td>
</tr>
<tr>
<td>Length of Pad, Lₚ</td>
<td>6.6929&quot;</td>
</tr>
<tr>
<td>Pad Thickness, tₚ</td>
<td>0.5906&quot;</td>
</tr>
<tr>
<td>Pad Weld Size, twp</td>
<td>0.4331&quot;</td>
</tr>
<tr>
<td>Weld Length, L₃</td>
<td>4.7244&quot;</td>
</tr>
<tr>
<td>Length to Brace Plate, L₁</td>
<td>2.7559&quot;</td>
</tr>
<tr>
<td>Load Angle from Vertical, φ</td>
<td>0.0000 °</td>
</tr>
<tr>
<td>Has Brace Plate</td>
<td>Yes</td>
</tr>
</tbody>
</table>

### Intermediate Values

<table>
<thead>
<tr>
<th>Load Factor</th>
<th>1.5000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vessel Weight (new, incl. Load Factor), W</td>
<td>9528 lb</td>
</tr>
<tr>
<td>Lug Weight (new), Wₘₙₙ</td>
<td>104 lb (Qty=2)</td>
</tr>
<tr>
<td>Allowable Stress, Tensile, σₜ</td>
<td>19980 psi</td>
</tr>
<tr>
<td>Allowable Stress, Shear, σₕ</td>
<td>13320 psi</td>
</tr>
<tr>
<td>Allowable Stress, Bearing, σₚ</td>
<td>29970 psi</td>
</tr>
<tr>
<td>Allowable Stress, Bending, σₛ</td>
<td>22201 psi</td>
</tr>
<tr>
<td>Allowable Stress, Weld Shear, τₘₙₙₙₙ allowabe</td>
<td>13320 psi</td>
</tr>
</tbody>
</table>
Summary Values

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required Lift Pin Diameter, (d_{\text{reqd}})</td>
<td>0.4772&quot;</td>
</tr>
<tr>
<td>Required Lug Thickness, (t_{\text{reqd}})</td>
<td>0.103&quot;</td>
</tr>
<tr>
<td>Estimated Brace Plate Length</td>
<td>9.7426&quot;</td>
</tr>
<tr>
<td>Lug Stress Ratio, (\sigma_{\text{ratio}})</td>
<td>0.05</td>
</tr>
<tr>
<td>Weld Shear Stress Ratio, (\tau_{\text{ratio}})</td>
<td>0.05</td>
</tr>
<tr>
<td>Lug Design</td>
<td>Acceptable</td>
</tr>
<tr>
<td>Local Stresses</td>
<td>Acceptable</td>
</tr>
<tr>
<td>Maximum Out of Plane Lift Angle - Weak Axis Bending</td>
<td>47.26 deg</td>
</tr>
</tbody>
</table>

COMPRESS recommends a spreader beam be used to prevent weak axis bending of the top lugs. Ear lug brace plate should be removed before vessel is put in service.

Lift Forces

\[
F_r = \text{force on vessel at lug}
\]

\[
F_r = \frac{W}{\cos(\phi_1)}(1 \times \frac{x_1}{x_1 + x_2})
\]

\[
= \left(\frac{9,528}{\cos(0.0000)}\right) \left(1 \times \frac{35.8268}{35.8268 + 35.8268}\right)
\]

\[
= 4,764 \text{ lbf}
\]

where 'x_1' is the distance between this lug and the center of gravity

'x_2' is the distance between the second lift lug and the center of gravity

Lug Pin Diameter - Shear stress

\[
d_{\text{reqd}} &= \left(\frac{2 \times F_v}{(\pi \times \sigma_s)}\right)^{0.5}
\]

\[
= \left(\frac{2 \times 4,764}{(\pi \times 13,320)}\right)^{0.5} = 0.4772"
\]

\[
d_{\text{reqd}} / D_p = 0.4772 / 1.5748 = 0.30 \text{ Acceptable}
\]

\[
\sigma = \frac{F_v}{A}
\]

\[
= \frac{4,764}{(2 \times (0.25 \times \pi \times 1.5748^2))} = 1,223 \text{ psi}
\]

\[
\sigma / \sigma_s = 1,223 / 13,320 = 0.09 \text{ Acceptable}
\]

Lug Thickness - Tensile stress

\[
t_{\text{reqd}} = \frac{F_v}{(D - d) \times \sigma_t}
\]

\[
= \frac{4,764}{(5.1181 - 1.9685) \times 19,980} = 0.0757"
\]

\[
t_{\text{reqd}} / t = 0.0757 / 0.8661 = 0.09 \text{ Acceptable}
\]

\[
\sigma = F_v / A
\]

\[
= \frac{4,764}{(5.1181 - 1.9685) \times 0.8661} = 1,746 \text{ psi}
\]

\[
\sigma / \sigma_t = 1,746 / 19,980 = 0.09 \text{ Acceptable}
\]

Lug Thickness - Bearing stress

\[
t_{\text{reqd}} = \frac{F_v}{(D_p \times \sigma_p)}
\]

\[
= \frac{4,764}{(1.5748 \times 29,970)} = 0.1009"
\]

\[
t_{\text{reqd}} / t = 0.1009 / 0.8661 = 0.12 \text{ Acceptable}
\]

\[
\sigma = F_v / A_{\text{bearing}}
\]
Lug Thickness - Shear stress

\[ \tau = \frac{F_v}{A_{\text{shear}}} = \frac{F_v}{(2*t*L_{\text{shear}})} = \frac{4,764}{(2*0.8661*1.7367)} = 1,584 \text{ psi} \]

\[ \frac{\tau}{\sigma_s} = \frac{1,584}{13,320} = 0.12 \text{ Acceptable} \]

\[ \phi = \frac{55*D_p}{d} = \frac{55*1.5748}{1.9685} = 44^\circ \]

\[ Z = 0.5*(D - d) + 0.5*D_p*(1 - \cos(\phi)) = 0.5*(5.1181 - 1.9685) + 0.5*1.5748*(1 - \cos(44)) = 1.7958^\circ \]

\[ Z_1 = 0.5*D - \sqrt{0.25*D^2 - (0.5*D_p*\sin(\phi))^2} = 0.5*5.1181 - \sqrt{0.25*5.1181^2 - (0.5*1.5748*\sin(44))^2} = 0.0591^\circ \]

\[ L_{\text{shear}} = Z - Z_1 = 1.7367^\circ \]

Lug Plate Stress

Lug stress, tensile + bending, during rotational lift:

\[ \sigma_{\text{ratio}} = \left[ \frac{F_{\text{ten}}}{(t_{\text{ten}}*\sigma_t)} \right] + \left[ \frac{M_{\text{bend}}}{(Z_{\text{bend}}*\sigma_b)} \right] \leq 1 \]

\[ = \left[ \frac{F_{\text{top}}*(\alpha)*\sin(\alpha)}{(t*B^2*\sigma_t)} \right] + \left[ \frac{(6*F_{\text{top}})*(L)*\cos(\alpha)}{(t*B^2 * \sigma_b)} \right] \leq 1 \]

\[ = \frac{4,764*\sin(90.0)}{(0.8661*5.1181*19,980) + 6*(4,764)*17.7165*\cos(90.0)} / (0.8661*5.1181^2*22,201) = 0.05 \text{ Acceptable} \]

Weak Axis Bending Stress

Maximum lift cable angle from vertical \( \theta = 47.26 \text{ deg} \)

\[ \sigma_b = \frac{M}{Z} = (F*\sin(\theta)*L_1) / Z \]

\[ F*\cos(\theta) = 0.5*W \Rightarrow F = 0.5*W / \cos(\theta) \]

\[ \theta = \arctan\left(\frac{2*\sigma_b*Z}{(W*L_1)}\right) \]

\[ = \arctan\left(\frac{2*22,201*(5.1181*0.8661^2)}{(9,528*2.7559)}\right) = 47.26 \text{ deg} \]

Loading on brace plate and head are not considered.

Weld Stress
Weld stress, direct and torsional shear, during rotational lift:

**Direct shear:**

Maximum weld shear stress occurs at lift angle 90.00 deg; lift force = 4,764 lbf

\[ \tau_{weld} = \frac{F_r \cos(\alpha)}{A_{weld}} \]

\[ = \frac{4,764 \cos(90.0)}{7.0135} = 0 \text{ psi} \]

\[ \tau_{s} = \frac{F_r \sin(\alpha)}{A_{weld}} \]

\[ = \frac{4,764 \sin(90.0)}{7.0135} = 679 \text{ psi} \]

\[ \tau = \sqrt{\tau_t^2 + \tau_s^2} \]

\[ = \sqrt{0^2 + 679^2} = 679 \text{ psi} \]

\[ \frac{\tau}{\tau_{allowable}} = \frac{679}{13,320} = 0.05 \leq 1 \text{ Acceptable} \]

**Pad Weld Stress**

**Direct shear:**

Maximum weld shear stress occurs at lift angle 90.00 deg; lift force = 4,764 lbf

\[ A_{weld} = 0.707 \times t_{wp} (2L_p + B_p) = 0.707 \times 0.4331 (2 \times 6.6929 + 9.0551) = 6.871 \text{ in}^2 \]

\[ \tau_t = \frac{F_r \cos(\alpha)}{A_{weld}} \]

\[ = \frac{4,764 \cos(90.0)}{6.871} = 0 \text{ psi} \]

\[ \tau_s = \frac{F_r \sin(\alpha)}{A_{weld}} \]

\[ = \frac{4,764 \sin(90.0)}{6.871} = 693 \text{ psi} \]

\[ \tau = \sqrt{\tau_t^2 + \tau_s^2} \]

\[ = \sqrt{0^2 + 693^2} = 693 \text{ psi} \]

\[ \frac{\tau}{\tau_{allowable}} = \frac{693}{13,320} = 0.05 \leq 1 \text{ Acceptable} \]

**WRC 107 Analysis**

**Geometry**

- Height (radial): 0.8661"  
  Pad Thickness: 0.5906"
- Width (circumferential): 5.1181"  
  Pad Width: 9.0551"
- Length: 4.7244"  
  Pad Length: 6.6929"
- Fillet Weld Size: 0.3937"  
  Pad Weld Size: 0.4331"
Located on: Shell (4.7244" from top end)
Location Angle: 0.00° and 180.00°

Applied Loads

Radial load: \( P_r = 0 \) lb
Circumferential moment: \( M_c = 0 \) lb·in
Circumferential shear: \( V_c = 0 \) lb
Longitudinal moment: \( M_L = 4,876.53 \) lb·in
Longitudinal shear: \( V_L = 4,764 \) lb
Torsion moment: \( M_t = 0 \) lb·in
Internal pressure: \( P = 0 \) psi
Mean shell radius: \( R_m = 35.5315 \) in
Shell yield stress: \( S_y = 38,000 \) psi

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

\[ R_m / t = 35.5315 / 1.1811 = 30.0833 \]
\[ C_1 = 2.9528, \ C_2 = 2.7559 \ \text{in} \]

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

Maximum combined stress \( (P_L+P_b+Q) \) = 732 psi
Allowable combined stress \( (P_L+P_b+Q) \) = \( \pm 3*S = \pm 60,000 \) psi

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

Maximum local primary membrane stress \( (P_L) \) = -87 psi
Allowable local primary membrane \( (P_L) \) = \( \pm 1.5*S = \pm 30,000 \) psi

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

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<tr>
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<th>( \beta )</th>
<th>( A_u )</th>
<th>( A_l )</th>
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Pressure stress* 0 0 0 0 0 0 0 0 0
Total circumferential stress -478 304 478 -304 0 0 0 0
Primary membrane circumferential stress* -87 -87 87 87 0 0 0 0

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Pressure stress* 0 0 0 0 0 0 0 0 0
Total longitudinal stress -619 569 619 -569 0 0 0 0
Primary membrane longitudinal stress* -25 -25 25 25 0 0 0 0
Note: * denotes primary stress.

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

\[
\frac{R_m}{t} = \frac{35.5315}{0.5906} = 60.1667
\]

\[C_1 = 4.9606, \ C_2 = 3.7795 \text{ in}\]

Local circumferential pressure stress = \(P \cdot R_i / t = 0\) psi

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

Maximum combined stress \((P_L + P_b + Q)\) = -1,132 psi

Allowable combined stress \((P_L + P_b + Q)\) = \(\pm 3\cdot S = \pm 60,000\) psi

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

Maximum local primary membrane stress \((P_L)\) = -343 psi

Allowable local primary membrane \((P_L)\) = \(\pm 1.5\cdot S = \pm 30,000\) psi

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

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### Stresses at the pad edge per WRC Bulletin 107

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Pressure stress*  

Total circumferential stress  

Primary membrane circumferential stress*  

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<th>value</th>
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<th>(A_u)</th>
<th>(A_1)</th>
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<th>(C_1)</th>
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Pressure stress*  

Total longitudinal stress  

Primary membrane longitudinal stress*  

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Note: * denotes primary stress.