| KBR | KEMPER COUNTY<br>IGCC UNIT 1 PROJECT | SOUTHERN COMPANY |
|---|---|---|

# MECHANICAL STRENGTH CALCULATION

## ITEM NAME : AGR REGENERATOR REFLUX DRUM

## ( ITEM NO : DR1064 / 2064)

KBR
ACCEPTANCE
FOR ENGINEERING USE

THIS DOCUMENT IS:
ACCEPTED (Code 1) X
ACCEPTED WITH COMMENTS (Code 2)
NOT ACCEPTED (Code 3)
NOT REVIEWED (Code 4)

ACCEPTANCE DOES NOT RELIEVE SUPPLIER FROM FURNISHING MATERIAL IN CONFORMANCE WITH ORDER. REFER TO SDR-1 FOR FULL DEFINITION OF ACCEPTANCE CONDITIONS.

DISCIPLINE VM BY SR DATE 07JUL11

FOR APPROVAL
2011.06.15
SUNG JIN GEOTEC CO., LTD.

ASME

| | | | | | |
|---|---|---|---|---|---|
| 03 | | | | | |
| 02 | | | | | |
| 01 | ISSUED FOR APPROVAL | J.S.PARK | J.K.KIM | H.C.JUNG | 15-Jun-2011 |
| 00 | ISSUED FOR APPROVAL | J.S.PARK | J.K.KIM | H.C.JUNG | 11-Apr-2011 |
| Rev No. | PURPOSE OF ISSUE | PREPARED | CHECKED | APPROVED | ISSUE DATE |

| | | |
|---|---|---|
| CLIENT | : | Southern Company Services, Inc. |
| VENDOR | : | SUNGJIN GEOTEC CO., LTD. |
| PLANT | : | Kemper County |
| Doc. Title | : | AGR REGENERATOR REFLUX DRUM |
| PO No. | : | MPC17984-0001 |
| SCS No. | : | LATER |
| SGT No. | : | SGT11-SP11-DR1064/2064-CAL |

MM78156 A

Plant: Kemper County SUNGJIN GEOTECH
Southern Company Generation
SGT11-SP11-DR1064-2064-CAL Rev: 1
PO: MPC17984-0001

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**ITEM NO. DR 1064 / 2064**

# DESIGN DATA

**ITEM NO. : DR 1064 / 2064**

| | | | | | |
|---|---|---|---|---|---|
| CODE | **ASME Section VIII Division 1 2007 Edition, A09 Addenda** | | | | |
| CODE STAMP | YES | | | | |
| NATIONAL BOARD | YES | | | | |
| CORROSION ALLOWANCE | 0.063 | inch | ( | 1.6 | mm) |
| JOINT EFFICIENCY (SHELL/HEAD) | 0.85 / 1.0 | | | | |
| POST WELD HEAT TREATMENT | NO | | | | |
| RADIOGRAPHY (SHELL/HEAD) | SPOT / FULL | | | | |
| PNEUMATIC TEST PRESS | -- | [psi G] | ( | -- | [kg/§ ² G]) |
| HYDRO. TEST PRESSURE (AT SHOP & TOP) | 65.00 | [psi G] | ( | 4.57 | [kg/§ ² G]) |
| HYDRO. TEST PRESSURE (AT FIELD & TOP) | 65.00 | [psi G] | ( | 4.57 | [kg/§ ² G]) |
| DESIGN INTERNAL TEMPERATURE | 250 | ¢ µ | ( | 121.12 | ¡ É) |
| DESIGN EXTERNAL TEMPERATURE | 115 | ¢ µ | ( | 46.12 | ¡ É) |
| MIN. DESIGN METAL TEMPERATURE | 10 | ¢ µ | ( | -12.23 | ¡ É) |
| DESIGN INTERNAL PRESSURE | 50.0 | [psi G] | ( | 3.52 | [kg/§ ² G]) |
| DESIGN EXTERNAL PRESSURE | F.V. | [psi G] | ( | F.V. | [kg/§ ² G]) |
| OPERATING TEMPERATURE | 115 | ¢ µ | ( | 46.12 | ¡ É) |
| OPERATING PRESSURE | - | [psi G] | ( | - | [kg/§ ² G]) |
| CONTENTS | *** | | | | |
| LIQUID SPECIFIC GRAVITY | 1.015 | | | | |
| LENGTH BETWEEN TANGENT LINE | 144 | inch | ( | 3658.0 | mm) |
| SHELL INSIDE DIAMETER | 48 | inch | ( | 1219.0 | mm) |
| TYPE OF HEADS | 2:1 ELLIP. | | | | |
| WIND LOAD | 100 mph (ASCE 7-05) | | | | |
| SEISMIC LOAD | CLASS C (ASCE 7-05) | | | | |
| INSULATION THICKNESS | NONE | inch | ( | NONE | mm) |
| FIRE PROOFING THICKNESS | NONE | inch | ( | NONE | mm) |
| VOLUME | 1253.0 | US gal | ( | 4.74 | M^3) |
| | | | | | |

## Settings Summary

## COMPRESS Build 7110

**Units: U.S. Customary**

**Datum Line Location: -1.97" from bottom seam**

**Design**

ASME Section VIII Division 1, 2007 Edition, A09 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: | Design P only |
| Corrosion weight loss: | 100% of theoretical loss |
| UG-23 Stress Increase: | 1.20 |
| Skirt/legs stress increase: | 1.0 |
| Minimum nozzle projection: | 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 |

Pipe under-tolerance is not applied to cylindrical shell thicknesses.
Butt welds are tapered per Figure UCS-66.3(a).

**Hydro/Pneumatic Test**

| | |
|---|---|
| Shop Hydrotest Pressure: | 1.3 times design P |
| Test liquid specific gravity: | 1.00 |
| Field Hydrotest Pressure: | 1.3 times design P |
| Wind load present @ field: | 33% of design |
| Maximum stress during test: | 90% of yield |

**Required Marking - UG-116**

| | |
|---|---|
| UG-116(e) Radiography: | RT4 |
| UG-116(f) Postweld heat treatment: | None |

**Code Cases\Interpretations**

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

**UG-22 Loadings**

| | |
|---|---|
| UG-22(a) Internal or External Design Pressure : | Yes |
| UG-22(b) Weight of the vessel and normal contents under operating or test conditions: | Yes |
| UG-22(c) Superimposed static reactions from weight of attached equipment (external loads): | 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 BTM HEAD and TOP HEAD**

| Identifier | P Design ( psi) | T Design ( °F) | MAEP ( psi) | $T_e$ external ( °F) | MDMT ( °F) | MDMT Exemption | | Impact Tested |
|---|---|---|---|---|---|---|---|---|
| TOP HEAD | 50 | 250 | 82.33 | 115 | -320 | | Note 1 | No |
| Straight Flange on TOP HEAD | 50 | 250 | 74.03 | 115 | -320 | | Note 2 | No |
| SHELL | 50 | 250 | 74.03 | 115 | -320 | | Note 3 | No |
| Straight Flange on BTM HEAD | 50 | 250 | 74.03 | 115 | -320 | | Note 5 | No |
| BTM HEAD | 50 | 250 | 82.33 | 115 | -320 | | Note 4 | No |
| 4" (AM) | 50 | 250 | 15 | 115 | -55 | Nozzle | Note 6 | No |
| | | | | | | Pad | Note 7 | No |
| 14" (AO) | 50 | 250 | 15 | 115 | -55 | Nozzle | Note 6 | No |
| | | | | | | Pad | Note 7 | No |
| 24" (BB) | 50 | 250 | 15 | 115 | -55 | | Note 6 | No |
| 1 1/2" (BH) | 50 | 250 | 15 | 115 | -55 | | Note 6 | No |
| 18" (BJ) | 50 | 250 | 15 | 115 | -55 | Nozzle | Note 6 | No |
| | | | | | | Pad | Note 8 | No |
| 2" (BS) | 50 | 250 | 15 | 115 | -55 | | Note 6 | No |
| 4" (CW) | 50 | 250 | 15 | 115 | -55 | Nozzle | Note 6 | No |
| | | | | | | Pad | Note 9 | No |
| 2" (LB1A/B, LT3A/B, LT5A/B, LT7A/B) | 50 | 250 | 15 | 115 | -55 | | Note 6 | No |
| 2" (LT2A/B, LT4A/B, LT6A/B) | 50 | 250 | 15 | 115 | -55 | | Note 6 | No |

Chamber design MDMT is 10 °F
Chamber rated MDMT is -55 °F @ 50 psi

Chamber Design MAWP hot & corroded is 50 psi

Chamber MAEP is 15 psi @ 115 °F
Vacuum rings did not govern the external pressure rating.

**Notes for Maximum Pressure Rating:**

| Note # | Details |
|---|---|
| 1. | Option to calculate MAP was not selected. See the Calculation->General tab of the Set Mode dialog. |
| 2. | Option to calculate MAWP was not selected. See the Calculation->General tab of the Set Mode dialog. |

**Notes for MDMT Rating:**

| Note # | Exemption | Details |
|---|---|---|
| 1. | Material Impact test exempt per UHA-51(g)(coincident ratio = 0.17707) | |
| 2. | Impact test exempt per UHA-51(g)(coincident ratio = 0.14782) | |
| 3. | Impact test exempt per UHA-51(g)(coincident ratio = 0.15623) | |
| 4. | Material Impact test exempt per UHA-51(g)(coincident ratio = 0.18889) | |
| 5. | Impact test exempt per UHA-51(g)(coincident ratio = 0.15639) | |
| 6. | Flange rating governs:<br>Flange rated MDMT = -320 °F<br>Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F | Per UHA-51(d)(1)(a) |
| 7. | Impact test exempt per UHA-51(g)(coincident ratio = 0.15951) | |
| 8. | Impact test exempt per UHA-51(g)(coincident ratio = 0.14841) | |
| 9. | Impact test exempt per UHA-51(g)(coincident ratio = 0.17218) | |

Design notes are available on the Settings Summary page.

## Thickness Summary

| Component Identifier | Material | Diameter (in) | Length (in) | Nominal t (in) | Design t (in) | Total Corrosion (in) | Joint E | Load |
|---|---|---|---|---|---|---|---|---|
| TOP HEAD | SA-240 304L | 47.9921 ID | 12.4665 | 0.4685* | 0.1893 | 0.063 | 1.00 | External |
| Straight Flange on TOP HEAD | SA-240 304L | 47.9921 ID | 1.9685 | 0.5512 | 0.317 | 0.063 | 1.00 | External |
| SHELL | SA-240 304L | 47.9921 ID | 140.0787 | 0.5512 | 0.317 | 0.063 | 0.85 | External |
| Straight Flange on BTM HEAD | SA-240 304L | 47.9921 ID | 1.9685 | 0.5512 | 0.317 | 0.063 | 1.00 | External |
| BTM HEAD | SA-240 304L | 47.9921 ID | 12.4665 | 0.4685* | 0.1893 | 0.063 | 1.00 | External |
| UPPER SKIRT | SA-240 304L | 48.5039 OD | 34.4173 | 0.3937 | 0.1288 | 0.063 | 0.55 | Wind |
| LOWER SKIRT | SA-516 70 | 48.5039 OD | 124.6063 | 0.3937 | 0.1184 | 0.063 | 0.70 | Wind |

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

**Nozzle Schedule**

| Nozzle mark | Service | Size | Materials | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Nozzle | Impact | Norm | Fine Grain | Pad | Impact | Norm | Fine Grain | Flange |
| AM | 4" | NPS 4 Sch 80S (XS) | SA-312 TP304L Wld & smls pipe | No | No | No | SA-240 304L | No | No | No | WN A182 F304L Class 150 |
| AO | 14" | 12.90 IDx0.55 | SA-240 304L | No | No | No | SA-240 304L | No | No | No | WN A182 F304L Class 150 |
| BB | 24" | 24.00 IDx1.13 | SA-182 F304L <= 5 | No | No | No | N/A | N/A | N/A | N/A | LWN A182 F304L Class 150 |
| BH | 1 1/2" | 1.61 IDx0.47 | SA-182 F304L <= 5 | No | No | No | N/A | N/A | N/A | N/A | LWN A182 F304L Class 150 |
| BJ | 18" | 16.90 IDx0.55 | SA-240 304L | No | No | No | SA-240 304L | No | No | No | WN A182 F304L Class 150 |
| BS | 2" | 2.07 IDx0.50 | SA-182 F304L <= 5 | No | No | No | N/A | N/A | N/A | N/A | LWN A182 F304L Class 150 |
| CW | 4" | NPS 4 Sch 80S (XS) | SA-312 TP304L Wld & smls pipe | No | No | No | SA-240 304L | No | No | No | WN A182 F304L Class 150 |
| LB1A/B, LT3A/B, LT5A/B, LT7A/B | 2" | 2.07 IDx0.62 | SA-182 F304L <= 5 | No | No | No | N/A | N/A | N/A | N/A | LWN A182 F304L Class 300 |
| LT2A/B, LT4A/B, LT6A/B | 2" | 2.07 IDx0.62 | SA-182 F304L <= 5 | No | No | No | N/A | N/A | N/A | N/A | LWN A182 F304L Class 300 |

## Hydrostatic Test

**Shop test pressure determination for Chamber bounded by BTM HEAD and TOP HEAD based on design P per UG-99(b)**

Shop hydrostatic test gauge pressure is 65 psi at 68 °F (the chamber design P = 50 psi)

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

| Identifier | Local test pressure psi | Test liquid static head psi | UG-99 stress ratio | UG-99 pressure factor | Stress during test psi | Allowable test stress psi | Stress excessive? |
|---|---|---|---|---|---|---|---|
| TOP HEAD (1) | 67.041 | 2.041 | 1 | 1.30 | 3,090 | 22,500 | No |
| Straight Flange on TOP HEAD | 67.041 | 2.041 | 1 | 1.30 | 2,952 | 22,500 | No |
| SHELL | 67.041 | 2.041 | 1 | 1.30 | 2,952 | 22,500 | No |
| Straight Flange on BTM HEAD | 67.041 | 2.041 | 1 | 1.30 | 2,952 | 22,500 | No |
| BTM HEAD | 67.041 | 2.041 | 1 | 1.30 | 3,090 | 22,500 | No |
| 1 1/2" (BH) | 66.964 | 1.964 | 1 | 1.30 | 3,088 | 33,750 | No |
| 14" (AO) | 66.525 | 1.525 | 1 | 1.30 | 3,553 | 33,750 | No |
| 18" (BJ) | 67.51 | 2.51 | 1 | 1.30 | 3,473 | 33,750 | No |
| 2" (BS) | 67.368 | 2.368 | 1 | 1.30 | 3,237 | 33,750 | No |
| 2" (LB1A/B, LT3A/B, LT5A/B, LT7A/B) | 67.207 | 2.207 | 1 | 1.30 | 2,991 | 33,750 | No |
| 2" (LT2A/B, LT4A/B, LT6A/B) | 65.907 | 0.907 | 1 | 1.30 | 2,933 | 33,750 | No |
| 24" (BB) | 65.854 | 0.854 | 1 | 1.30 | 6,330 | 33,750 | No |
| 4" (AM) | 66.11 | 1.11 | 1 | 1.30 | 2,198 | 33,750 | No |
| 4" (CW) | 66.244 | 1.244 | 1 | 1.30 | 2,112 | 33,750 | No |

Notes:
(1) TOP HEAD limits the UG-99 stress ratio.
(2) $P_L$ stresses at nozzle openings have been estimated using the method described in PVP-Vol. 399, pages 77-82.
(3) $1.5*0.9*S_y$ used as the basis for the maximum local primary membrane stress at the nozzle intersection $P_L$.
(4) The zero degree angular position is assumed to be up, and the test liquid height is assumed to the top-most flange.

**Field test pressure determination for Chamber bounded by BTM HEAD and TOP HEAD based on design P per UG-99(b)**

Field hydrostatic test gauge pressure is 65 psi at 68 °F (the chamber design P = 50 psi)

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

| Identifier | Local test pressure psi | Test liquid static head psi | UG-99 stress ratio | UG-99 pressure factor | Stress during test psi | Allowable test stress psi | Stress excessive? |
|---|---|---|---|---|---|---|---|
| TOP HEAD (1) | 66.154 | 1.154 | 1 | 1.30 | 3,049 | 22,500 | No |
| Straight Flange on TOP HEAD | 66.154 | 1.154 | 1 | 1.30 | 2,913 | 22,500 | No |
| SHELL | 71.21 | 6.21 | 1 | 1.30 | 3,136 | 22,500 | No |
| Straight Flange on BTM HEAD | 71.282 | 6.282 | 1 | 1.30 | 3,139 | 22,500 | No |
| BTM HEAD | 71.715 | 6.715 | 1 | 1.30 | 3,306 | 22,500 | No |
| 1 1/2" (BH) | 68.784 | 3.784 | 1 | 1.30 | 3,172 | 33,750 | No |
| 14" (AO) | 65.645 | 0.645 | 1 | 1.30 | 3,506 | 33,750 | No |
| 18" (BJ) | 68.626 | 3.626 | 1 | 1.30 | 3,530 | 33,750 | No |
| 2" (BS) | 71.103 | 6.103 | 1 | 1.30 | 3,416 | 33,750 | No |
| 2" (LB1A/B, LT3A/B, LT5A/B, LT7A/B) | 68.07 | 3.07 | 1 | 1.30 | 3,029 | 33,750 | No |
| 2" (LT2A/B, LT4A/B, LT6A/B) | 71.103 | 6.103 | 1 | 1.30 | 3,164 | 33,750 | No |
| 24" (BB) | 70.632 | 5.632 | 1 | 1.30 | 6,789 | 33,750 | No |
| 4" (AM) | 65.679 | 0.679 | 1 | 1.30 | 2,183 | 33,750 | No |
| 4" (CW) | 72.364 | 7.364 | 1 | 1.30 | 2,308 | 33,750 | No |

Notes:
(1) TOP HEAD limits the UG-99 stress ratio.
(2) $P_L$ stresses at nozzle openings have been estimated using the method described in PVP-Vol. 399, pages 77-82.
(3) $1.5*0.9*S_y$ used as the basis for the maximum local primary membrane stress at the nozzle intersection $P_L$.

### Corroded Hydrostatic Test

The shop test condition has not been investigated for the Chamber bounded by BTM HEAD and TOP HEAD.

**Field test pressure determination for Chamber bounded by BTM HEAD and TOP HEAD based on design P per UG-99(b)**

Field hydrostatic test gauge pressure is 65 psi at 68 °F (the chamber design P = 50 psi)

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

| Identifier | Local test pressure psi | Test liquid static head psi | UG-99 stress ratio | UG-99 pressure factor | Stress during test psi | Allowable test stress psi | Stress excessive? |
|---|---|---|---|---|---|---|---|
| TOP HEAD (1) | 66.154 | 1.154 | 1 | 1.30 | 3,533 | 22,500 | No |
| Straight Flange on TOP HEAD | 66.154 | 1.154 | 1 | 1.30 | 3,293 | 22,500 | No |
| SHELL | 71.21 | 6.21 | 1 | 1.30 | 3,545 | 22,500 | No |
| Straight Flange on BTM HEAD | 71.282 | 6.282 | 1 | 1.30 | 3,548 | 22,500 | No |
| BTM HEAD | 71.717 | 6.717 | 1 | 1.30 | 3,830 | 22,500 | No |
| 1 1/2" (BH) | 68.786 | 3.786 | 1 | 1.30 | 3,625 | 33,750 | No |
| 14" (AO) | 65.645 | 0.645 | 1 | 1.30 | 3,831 | 33,750 | No |
| 18" (BJ) | 68.629 | 3.629 | 1 | 1.30 | 4,055 | 33,750 | No |
| 2" (BS) | 71.105 | 6.105 | 1 | 1.30 | 3,922 | 33,750 | No |
| 2" (LB1A/B, LT3A/B, LT5A/B, LT7A/B) | 68.072 | 3.072 | 1 | 1.30 | 3,420 | 33,750 | No |
| 2" (LT2A/B, LT4A/B, LT6A/B) | 71.105 | 6.105 | 1 | 1.30 | 3,573 | 33,750 | No |
| 24" (BB) | 70.634 | 5.634 | 1 | 1.30 | 7,613 | 33,750 | No |
| 4" (AM) | 65.679 | 0.679 | 1 | 1.30 | 2,326 | 33,750 | No |
| 4" (CW) | 72.364 | 7.364 | 1 | 1.30 | 2,437 | 33,750 | No |

Notes:
(1) TOP HEAD limits the UG-99 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*0.9*$S_y$ used as the basis for the maximum local primary membrane stress at the nozzle intersection $P_L$.

## Weight Summary

| Component | Weight ( lb) Contributed by Vessel Elements | | | | | | |
|---|---|---|---|---|---|---|---|
| | Metal New* | Metal Corroded* | Insulation & Supports | Lining | Piping + Liquid | Operating Liquid | Test Liquid |
| TOP HEAD | 394.2 | 343.3 | 0 | 0 | 0 | 0 | 718.1 |
| SHELL | 3,282.7 | 2,911.4 | 0 | 0 | 0 | 5,327.9 | 9,330.5 |
| BTM HEAD | 415.2 | 361.4 | 0 | 0 | 0 | 672 | 656.9 |
| UPPER SKIRT | 593.9 | 498.2 | 0 | 0 | 0 | 0 | 0 |
| LOWER SKIRT | 2,098.3 | 1,760.2 | 0 | 0 | 0 | 0 | 0 |
| BASE BLOCK | 345 | 345 | 0 | 0 | 0 | 0 | 0 |
| **TOTAL:** | **7,129.3** | **6,219.5** | **0** | **0** | **0** | **5,999.9** | **10,705.5** |

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

| Component | Weight ( lb) Contributed by Attachments | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Body Flanges | | Nozzles & Flanges | | Packed Beds | Ladders & Platforms | Trays & Supports | Rings & Clips | Vertical Loads |
| | New | Corroded | New | Corroded | | | | | |
| TOP HEAD | 0 | 0 | 275.9 | 260.6 | 0 | 2,648.2 | 0 | 0 | 0 |
| SHELL | 0 | 0 | 1,455.4 | 1,423.8 | 154.4 | 960 | 0 | 0 | 4,409.2 |
| BTM HEAD | 0 | 0 | 40.3 | 36.9 | 0 | 4,067.4 | 0 | 0 | 0 |
| UPPER SKIRT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| LOWER SKIRT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **TOTAL:** | **0** | **0** | **1,771.6** | **1,721.3** | **154.4** | **7,675.7** | **0** | **0** | **4,409.2** |

Vessel operating weight, Corroded: 26,180 lb
Vessel operating weight, New: 27,106 lb
Vessel empty weight, Corroded: 20,180 lb
Vessel empty weight, New: 21,140 lb
Vessel test weight, New: 31,846 lb

**Vessel center of gravity location - from datum - lift condition**

Vessel Lift Weight, New: 21,140 lb
Center of Gravity: 34.9864"

**Vessel Capacity**

Vessel Capacity** (New): 1,253 US gal
Vessel Capacity** (Corroded): 1,260 US gal
**The vessel capacity does not include volume of nozzle, piping or other attachments.

## Wind Code

| | |
|---|---|
| **Building Code:** | **ASCE 7-05** |
| Elevation of base above grade: | 0.9843 ft |
| Increase effective outer diameter by: | 3.4121 ft |
| Wind Force Coefficient Cf: | 0.8000 |
| Basic Wind Speed:, V: | 100.0408 mph |
| Importance Factor:, I: | 1.1500 |
| Exposure category: | C |
| Wind Directionality Factor, Kd: | 0.9500 |
| Top Deflection Limit: | 6 in. per 100 ft. |
| Topographic Factor, Kzt: | 1.0000 |
| Enforce min. loading of 10 psf: | Yes |

**Vessel Characteristics**

| | |
|---|---|
| Vessel height, h: | 26.5408 ft |
| Vessel Minimum Diameter, b | |
| Operating, Corroded: | 4.0912 ft |
| Empty, Corroded: | 4.0912 ft |
| hydrotest, New, field: | 4.0912 ft |
| Fundamental Frequency, $n_1$ | |
| Operating, Corroded: | 6.9116 Hz |
| Empty, Corroded: | 7.6650 Hz |
| hydrotest, New, field: | 6.3385 Hz |
| Vacuum, Corroded: | 6.9213 Hz |
| Damping coefficient, β | |
| Operating, Corroded: | 0.0246 |
| Empty, Corroded: | 0.0200 |
| hydrotest, New, field: | 0.0200 |
| Vacuum, Corroded: | 0.0249 |

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
Vacuum, Corroded
hydrotest, New, field

Wind Pressure Calculations

**Wind Deflection Report: Operating, Corroded**

| Component | Elevation of bottom above base (in) | Effective OD (ft) | Elastic modulus E ($10^6$ psi) | Inertia I ($ft^4$) | Platform wind shear at Bottom (lbf) | Total wind shear at Bottom (lbf) | bending moment at Bottom (lbf-ft) | Deflection at top (in) |
|---|---|---|---|---|---|---|---|---|
| TOP HEAD | 304.0551 | 7.50 | 27.3 | * | 1,180 | 1,340 | 1,679 | 0.0806 |
| SHELL | 163.9764 | 7.50 | 27.3 | 1.062 | 1,180 | 2,969 | 28,911 | 0.0756 |
| BTM HEAD (top) | 159.0236 | 7.50 | 27.3 | * | 1,180 | 3,022 | 43,261 | 0.0286 |
| | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| UPPER SKIRT | 124.6063 | 7.45 | 27.3 | 0.6947 | 1,180 | 3,386 | 52,449 | 0.0271 |
| LOWER SKIRT | 0 | 7.45 | 29.4 | 0.6947 | 1,180 | 4,703 | 94,442 | 0.0174 |
| *Moment of Inertia I varies over the length of the component | | | | | | | | |

**Wind Deflection Report: Empty, Corroded**

| Component | Elevation of bottom above base (in) | Effective OD (ft) | Elastic modulus E ($10^6$ psi) | Inertia I ($ft^4$) | Platform wind shear at Bottom (lbf) | Total wind shear at Bottom (lbf) | bending moment at Bottom (lbf-ft) | Deflection at top (in) |
|---|---|---|---|---|---|---|---|---|
| TOP HEAD | 304.0551 | 7.50 | 28.3 | * | 1,180 | 1,340 | 1,679 | 0.0801 |
| SHELL | 163.9764 | 7.50 | 28.3 | 1.062 | 1,180 | 2,969 | 28,911 | 0.0751 |
| BTM HEAD (top) | 159.0236 | 7.50 | 28.3 | * | 1,180 | 3,022 | 43,261 | 0.0286 |
| UPPER SKIRT | 124.6063 | 7.45 | 28.3 | 0.6947 | 1,180 | 3,386 | 52,449 | 0.0271 |
| LOWER SKIRT | 0 | 7.45 | 29.4 | 0.6947 | 1,180 | 4,703 | 94,442 | 0.0174 |
| *Moment of Inertia I varies over the length of the component | | | | | | | | |

**Wind Deflection Report: Vacuum, Corroded**

| Component | Elevation of bottom above base (in) | Effective OD (ft) | Elastic modulus E ($10^6$ psi) | Inertia I ($ft^4$) | Platform wind shear at Bottom (lbf) | Total wind shear at Bottom (lbf) | bending moment at Bottom (lbf-ft) | Deflection at top (in) |
|---|---|---|---|---|---|---|---|---|
| TOP HEAD | 304.0551 | 7.50 | 28.0 | * | 1,180 | 1,340 | 1,679 | 0.0802 |
| SHELL | 163.9764 | 7.50 | 28.0 | 1.062 | 1,180 | 2,969 | 28,911 | 0.0752 |
| BTM HEAD (top) | 159.0236 | 7.50 | 28.0 | * | 1,180 | 3,022 | 43,261 | 0.0286 |
| UPPER SKIRT | 124.6063 | 7.45 | 28.0 | 0.6947 | 1,180 | 3,386 | 52,449 | 0.0271 |
| LOWER SKIRT | 0 | 7.45 | 29.4 | 0.6947 | 1,180 | 4,703 | 94,442 | 0.0174 |
| *Moment of Inertia I varies over the length of the component | | | | | | | | |

**Wind Deflection Report: hydrotest, New, field**

| Component | Elevation of bottom above base (in) | Effective OD (ft) | Elastic modulus E ($10^6$ psi) | Inertia I ($ft^4$) | Platform wind shear at Bottom (lbf) | Total wind shear at Bottom (lbf) | bending moment at Bottom (lbf-ft) | Deflection at top (in) |
|---|---|---|---|---|---|---|---|---|
| TOP HEAD | 304.0551 | 7.50 | 28.3 | * | 389 | 470 | 620 | 0.0377 |
| SHELL | 163.9764 | 7.50 | 28.3 | 1.194 | 389 | 1,346 | 13,315 | 0.0353 |
| BTM HEAD (top) | 159.0236 | 7.50 | 28.3 | * | 389 | 1,377 | 26,846 | 0.0134 |
| UPPER SKIRT | 124.6063 | 7.45 | 28.3 | 0.8303 | 389 | 1,591 | 31,102 | 0.0127 |
| LOWER SKIRT | 0 | 7.45 | 29.4 | 0.8303 | 389 | 2,365 | 51,640 | 0.0081 |
| *Moment of Inertia I varies over the length of the component | | | | | | | | |

**Wind Pressure (WP) Calculations**

Gust Factor ($\bar{G}$) Calculations

Kz $= 2.01 * (Z/Zg)^{2/\alpha}$
$= 2.01 * (Z/900.0000)^{0.2105}$
qz $= 0.00256 * Kz * Kzt * Kd * V^2 * I$ psf
$= 0.00256 * Kz * 1.0000 * 0.9500 * 100.0408^2 * 1.1500$
$= 27.9908 * Kz$
WP $= qz * G * Cf$ (Minimum 10 lb/ft$^2$)
$= qz * G * 0.8000$ (Minimum 10 lb/ft$^2$)

**Design Wind Pressures**

| Height Z (') | Kz | qz (psf) | WP: Operating (psf) | WP: Empty (psf) | WP: hydrotest (psf) | WP: Vacuum (psf) |
|---|---|---|---|---|---|---|
| 15.0 | 0.8489 | 23.76 | 17.04 | 17.04 | 10.00 | 17.04 |
| 20.0 | 0.9019 | 25.24 | 18.10 | 18.10 | 10.00 | 18.10 |
| 25.0 | 0.9453 | 26.46 | 18.97 | 18.97 | 10.00 | 18.97 |
| 30.0 | 0.9823 | 27.49 | 19.72 | 19.72 | 10.00 | 19.72 |

Design Wind Force determined from: F = Pressure * Af , where Af is the projected area.

**Gust Factor Calculations**

Operating, Corroded
Empty, Corroded
Vacuum, Corroded
hydrotest, New, field

**Gust Factor Calculations: Operating, Corroded**

Vessel is considered a rigid structure as $n_1$ = 6.9116 Hz ¡ Ã1 Hz.

$\bar{z} = 0.60 * h$
$= 0.60 * 26.5408$
$= 15.9245$
$I_{\bar{z}} = c * (33 / \bar{z})^{1/6}$
$= 0.2000 * (33 / 15.9245)^{1/6}$
$= 0.2258$
$L_{\bar{z}} = l * (\bar{z} / 33)^{ep}$
$= 500.0000 * (15.9245 / 33)^{0.2000}$
$= 432.1957$
$Q = Sqr(1 / (1 + 0.63 * ((b + h) / L_{\bar{z}})^{0.63}))$
$= Sqr(1 / (1 + 0.63 * ((4.0912 + 26.5408) / 432.1957)^{0.63}))$
$= 0.9454$
$G = 0.925 * (1 + 1.7 * g_Q * I_{\bar{z}} * Q) / (1 + 1.7 * g_v * I_{\bar{z}})$
$= 0.925 * (1 + 1.7 * 3.40 * 0.2258 * 0.9454) / (1 + 1.7 * 3.40 * 0.2258)$
$= 0.8964$

**Gust Factor Calculations: Empty, Corroded**

Vessel is considered a rigid structure as $n_1$ = 7.6650 Hz ¡ Ã1 Hz.

$\bar{z} = 0.60 * h$
$= 0.60 * 26.5408$
$= 15.9245$
$I_{\bar{z}} = c * (33 / \bar{z})^{1/6}$
$= 0.2000 * (33 / 15.9245)^{1/6}$
$= 0.2258$
$L_{\bar{z}} = l * (\bar{z} / 33)^{ep}$
$= 500.0000 * (15.9245 / 33)^{0.2000}$
$= 432.1957$
$Q = Sqr(1 / (1 + 0.63 * ((b + h) / L_{\bar{z}})^{0.63}))$
$= Sqr(1 / (1 + 0.63 * ((4.0912 + 26.5408) / 432.1957)^{0.63}))$
$= 0.9454$
$G = 0.925 * (1 + 1.7 * g_Q * I_{\bar{z}} * Q) / (1 + 1.7 * g_v * I_{\bar{z}})$
$= 0.925 * (1 + 1.7 * 3.40 * 0.2258 * 0.9454) / (1 + 1.7 * 3.40 * 0.2258)$
$= 0.8964$

**Gust Factor Calculations: Vacuum, Corroded**

Vessel is considered a rigid structure as $n_1$ = 6.9213 Hz ¡ Å1 Hz.

$\bar{z}$ = 0.60 * h
= 0.60 * 26.5408
= 15.9245

$I_{\bar{z}}$ = c * (33 / $\bar{z}$)$^{1/6}$
= 0.2000 * (33 / 15.9245)$^{1/6}$
= 0.2258

$L_{\bar{z}}$ = l * ($\bar{z}$ / 33)$^{ep}$
= 500.0000 * (15.9245 / 33)$^{0.2000}$
= 432.1957

Q = Sqr(1 / (1 + 0.63 * ((b + h) / $L_{\bar{z}}$)$^{0.63}$))
= Sqr(1 / (1 + 0.63 * ((4.0912 + 26.5408) / 432.1957)$^{0.63}$))
= 0.9454

G = 0.925 * (1 + 1.7 * $g_Q$ * $I_{\bar{z}}$ * Q) / (1 + 1.7 * $g_v$ * $I_{\bar{z}}$)
= 0.925 * (1 + 1.7 * 3.40* 0.2258 * 0.9454) / (1 + 1.7 * 3.40 * 0.2258)
= 0.8964

**Gust Factor Calculations: hydrotest, New, field**

Vessel is considered a rigid structure as $n_1$ = 6.3385 Hz ¡ Å1 Hz.

$\bar{z}$ = 0.60 * h
= 0.60 * 26.5408
= 15.9245

$I_{\bar{z}}$ = c * (33 / $\bar{z}$)$^{1/6}$
= 0.2000 * (33 / 15.9245)$^{1/6}$
= 0.2258

$L_{\bar{z}}$ = l * ($\bar{z}$ / 33)$^{ep}$
= 500.0000 * (15.9245 / 33)$^{0.2000}$
= 432.1957

Q = Sqr(1 / (1 + 0.63 * ((b + h) / $L_{\bar{z}}$)$^{0.63}$))
= Sqr(1 / (1 + 0.63 * ((4.0912 + 26.5408) / 432.1957)$^{0.63}$))
= 0.9454

G = 0.925 * (1 + 1.7 * $g_Q$ * $I_{\bar{z}}$ * Q) / (1 + 1.7 * $g_v$ * $I_{\bar{z}}$)
= 0.925 * (1 + 1.7 * 3.40* 0.2258 * 0.9454) / (1 + 1.7 * 3.40 * 0.2258)
= 0.8964

**Table Lookup Values**

| | |
|---|---|
| $\alpha$ = 9.5000, Zg = 900.0000 ' | [Table 6-2, page 78] |
| c = 0.2000, l = 500.0000, ep = 0.2000 | [Table 6-2, page 78] |
| $\bar{a}$ = 0.1538, $\bar{b}$ = 0.6500 | [Table 6-2, page 78] |
| $g_Q$ = 3.40 | [6.5.8.1 page 26] |
| $g_v$ = 3.40 | [6.5.8.1 page 26] |

## Seismic Code

| **Method of seismic analysis:** | **ASCE 7-05 ground supported** |
|---|---|
| Site Class | C |
| Importance Factor: | I = 1.2500 |
| Spectral Response Acceleration at short period (% g) | $S_s$ = 16.30% |
| Spectral Response Acceleration at period of 1 sec (% g) | $S_1$ = 9.90% |
| Response Modification Coeficient from Table 15.4-2 | R = 3.0000 |
| Acceleration based site co-efficient: | $F_a$ = 1.2000 |
| Velocity based site co-efficient: | $F_v$ = 1.7000 |
| Long-period transition period: | $T_L$ = 12.0000 |
| Redundancy factor: | $\rho$ = 1.0000 |
| User Defined Vertical Accelerations Considered: | Yes |
| Force Multiplier: | = 0.3333 |
| Minimum Weight Multiplier: | = 0.2000 |

**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. $D + P + P_s + 0.7E = (1.0 + V_{Accel})D + P + P_s + 0.7\rho Q_E$
8. $0.6D + P + P_s + 0.7E = (0.6 - V_{Accel})D + P + P_s + 0.7\rho Q_E$

Where
$D$ = Dead load
$P$ = Internal or external pressure load
$P_s$ = Static head load
$E$ = Seismic load = $\rho Q_E$
$V_{Accel}$ = User defined vertical acceleration

**Vessel Characteristics**

Vessel height: 26.5408 ft
Vessel Weight:
Operating, Corroded: 26,180 lb
Empty, Corroded: 20,180 lb
Vacuum, Corroded: 26,180 lb

**Period of Vibration Calculation**

Fundamental Period, T:
Operating, Corroded: 0.145 sec (f = 6.9 Hz)
Empty, Corroded: 0.130 sec (f = 7.7 Hz)
Vacuum, Corroded: 0.144 sec (f = 6.9 Hz)

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

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

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

**Seismic Shear Reports:**

Operating, Corroded
Empty, Corroded
Vacuum, Corroded

Base Shear Calculations

**Seismic Shear Report: Operating, Corroded**

| Component | Elevation of bottom above base (in) | Elastic modulus E ($10^6$ psi) | Inertia I ($ft^4$) | Seismic shear at Bottom (lbf) | Bending Moment at Bottom (lbf-ft) |
|---|---|---|---|---|---|
| TOP HEAD | 304.0551 | 27.3 | * | 198 | 295 |
| SHELL | 163.9764 | 27.3 | 1.0618 | 804 | 7,188 |
| BTM HEAD (top) | 159.0236 | 27.3 | * | 935 | 20,448 |
| UPPER SKIRT | 124.6063 | 27.3 | 0.8303 | 975 | 23,150 |
| LOWER SKIRT | 0 | 29.4 | 0.8303 | 996 | 33,380 |
| *Moment of Inertia I varies over the length of the component | | | | | |

**Seismic Shear Report: Empty, Corroded**

| Component | Elevation of bottom above base (in) | Elastic modulus E ($10^6$ psi) | Inertia I ($ft^4$) | Seismic shear at Bottom (lbf) | Bending Moment at Bottom (lbf-ft) |
|---|---|---|---|---|---|
| TOP HEAD | 304.0551 | 28.3 | * | 198 | 295 |
| SHELL | 163.9764 | 28.3 | 1.0618 | 597 | 6,469 |
| BTM HEAD (top) | 159.0236 | 28.3 | * | 718 | 19,641 |
| UPPER SKIRT | 124.6063 | 28.3 | 0.8303 | 747 | 21,692 |
| LOWER SKIRT | 0 | 29.4 | 0.8303 | 768 | 29,552 |
| *Moment of Inertia I varies over the length of the component | | | | | |

**Seismic Shear Report: Vacuum, Corroded**

| Component | Elevation of bottom above base (in) | Elastic modulus E ($10^6$ psi) | Inertia I ($ft^4$) | Seismic shear at Bottom (lbf) | Bending Moment at Bottom (lbf-ft) |
|---|---|---|---|---|---|
| TOP HEAD | 304.0551 | 28.0 | * | 198 | 295 |
| SHELL | 163.9764 | 28.0 | 1.0618 | 804 | 7,188 |
| BTM HEAD (top) | 159.0236 | 28.0 | * | 935 | 20,448 |
| UPPER SKIRT | 124.6063 | 28.0 | 0.8303 | 975 | 23,150 |
| LOWER SKIRT | 0 | 29.4 | 0.8303 | 996 | 33,380 |
| *Moment of Inertia I varies over the length of the component | | | | | |

**11.4.3: Maximum considered earthquake spectral response acceleration**

The maximum considered earthquake spectral response acceleration at short period, $S_{MS}$

$S_{MS} = F_a * S_s = 1.2000 * 16.30 / 100 = 0.1956$

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

$S_{M1} = F_v * S_1 = 1.7000 * 9.90 / 100 = 0.1683$

**11.4.4: Design spectral response acceleration parameters**

Design earthquake spectral response acceleration at short period, $S_{DS}$

$S_{DS} = 2 / 3 * S_{MS} = 2 / 3 * 0.1956 = 0.1304$

Design earthquake spectral response acceleration at 1 s period, $S_{D1}$

$S_{D1} = 2 / 3 * S_{M1} = 2 / 3 * 0.1683 = 0.1122$

**User Defined Vertical Acceleration Term, $V_{Accel}$**

Factor is applied to dead load.

Compressive Side: $= 1.0 + V_{Accel}$

Tensile Side: $= 0.6 - V_{Accel}$

| **$V_{Accel}$ Term is: greater of (Force Mult * Base Shear / Weight) or (Min. Weight Mult.)** | |
|---|---|
| Force multiplier = 0.3333 | Minimum Weight Multiplier = 0.2000 |

| Condition | Base Shear ( lbf) | Weight ( lb) | Force Mult * Shear / Weight | $V_{Accel}$ |
|---|---|---|---|---|
| Operating, Corroded | 996 | 26,180 | 0.0127 | 0.2 |
| Operating, New | 1,031 | 27,106 | 0.0127 | 0.2 |
| Empty, Corroded | 768 | 20,180.1 | 0.0127 | 0.2 |
| Empty, New | 804 | 21,140.2 | 0.0127 | 0.2 |
| Vacuum, Corroded | 996 | 26,180 | 0.0127 | 0.2 |

**Base Shear Calculations**

Operating, Corroded
Empty, Corroded
Vacuum, 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 = 0.1447 sec.

**12.8.1: Calculation of Seismic Response Coefficient**

$C_s$ is the value computed below, bounded by $C_s$Min and $C_s$Max:
$C_s$Min is 0.03; in addition, if $S_1$ >= 0.6g, $C_s$Min shall not be less than eqn 15.4-2.
$C_s$Max calculated with 12.8-3 because (T = 0.1447) <= ($T_L$ = 12.0000)

$C_s = S_{DS} / (R / I) = 0.1304 / (3.0000 / 1.2500) = 0.0543$

$C_s$Min = 0.03

$C_s$Max = $S_{D1} / (T * (R / I)) = 0.1122 / (0.1447 * (3.0000 / 1.2500)) = 0.3231$

$C_s = 0.0543$

**12.8.1: Calculation of Base Shear**

$V = C_s * W$
= 0.0543 * 26179.9922
= 1,422.45 lb

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

$Q_E = V$

$E_h = 0.7 * \rho * Q_E$ (Only 70% of seismic load considered as per Section 2.4.1)
= 0.70 * 1.0000 * 1,422.45
= 995.71 lb

**Base Shear Calculations: Empty, Corroded**

**Paragraph 15.4.4: Period Determination**

Fundamental Period is taken from the Rayleigh method listed previously in this report.
T = 0.1305 sec.

**12.8.1: Calculation of Seismic Response Coefficient**

$C_s$ is the value computed below, bounded by $C_s$Min and $C_s$Max:
$C_s$Min is 0.03; in addition, if $S_1$ >= 0.6g, $C_s$Min shall not be less than eqn 15.4-2.
$C_s$Max calculated with 12.8-3 because (T = 0.1305) <= ($T_L$ = 12.0000)

$C_s = S_{DS} / (R / I) = 0.1304 / (3.0000 / 1.2500) = 0.0543$

$C_s$Min = 0.03

$C_s$Max = $S_{D1} / (T * (R / I)) = 0.1122 / (0.1305 * (3.0000 / 1.2500)) = 0.3583$

$C_s$ = 0.0543

**12.8.1: Calculation of Base Shear**

$V = C_s * W$
= 0.0543 * 20180.1094
= 1,096.45 lb

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

$Q_E = V$
$E_h = 0.7 * \rho * Q_E$ (Only 70% of seismic load considered as per Section 2.4.1)
= 0.70 * 1.0000 * 1,096.45
= 767.52 lb

**Base Shear Calculations: Vacuum, Corroded**

**Paragraph 15.4.4: Period Determination**

Fundamental Period is taken from the Rayleigh method listed previously in this report.
T = 0.1445 sec.

**12.8.1: Calculation of Seismic Response Coefficient**

$C_s$ is the value computed below, bounded by $C_s$Min and $C_s$Max:
$C_s$Min is 0.03; in addition, if $S_1$ >= 0.6g, $C_s$Min shall not be less than eqn 15.4-2.
$C_s$Max calculated with 12.8-3 because (T = 0.1445) <= ($T_L$ = 12.0000)

$C_s = S_{DS} / (R / I)$ = 0.1304 / (3.0000 / 1.2500) = 0.0543

$C_s$Min = 0.03

$C_s$Max = $S_{D1} / (T * (R / I))$ = 0.1122 / (0.1445 * (3.0000 / 1.2500)) = 0.3236

$C_s$ = 0.0543

**12.8.1: Calculation of Base Shear**

$V = C_s * W$
= 0.0543 * 26179.9922
= 1,422.45 lb

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

$Q_E = V$
$E_h = 0.7 * \rho * Q_E$ (Only 70% of seismic load considered as per Section 2.4.1)
= 0.70 * 1.0000 * 1,422.45
= 995.71 lb

## TOP HEAD

**ASME Section VIII, Division 1, 2007 Edition, A09 Addenda**

| | |
|---|---|
| Component: | Ellipsoidal Head |
| Material Specification: | SA-240 304L (II-D p.82, ln. 38) |

Material Impact test exempt per UHA-51(g)(coincident ratio = 0.17707)

Internal design pressure: P = 50 psi @ 250 °F
External design pressure: $P_e$ = 15 psi @ 115 °F

**Static liquid head:**

$P_s$= 0 psi (SG=1.015, $H_s$=0" Operating head)
$P_{th}$= 2.0407 psi (SG=1, $H_s$=56.5341" Horizontal test head)
$P_{tv}$= 1.0829 psi (SG=1, $H_s$=30" Vertical test head)

| | | |
|---|---|---|
| Corrosion allowance: | Inner C = 0.063" | Outer C = 0" |

| | |
|---|---|
| Design MDMT = 10°F | No impact test performed |
| Rated MDMT = -320°F | Material is not normalized |
| | Material is not produced to fine grain practice |
| | PWHT is not performed |
| | Do not Optimize MDMT / Find MAWP |

| | | |
|---|---|---|
| Radiography: | Category A joints - | Full UW-11(a) Type 1 |
| | Head to shell seam - | Spot UW-11(a)(5)(b) Type 1 |

| | | |
|---|---|---|
| Estimated weight*: | new = 394.2 lb | corr = 343.3 lb |
| Capacity*: | new = 78.1 US gal | corr = 78.8 US gal |

* includes straight flange

| | | |
|---|---|---|
| Inner diameter | = | 47.9921" |
| Minimum head thickness | = | 0.4685" |
| Head ratio D/2h | = | 2 (new) |
| Head ratio D/2h | = | 1.9948 (corroded) |
| Straight flange length $L_{sf}$ | = | 1.9685" |
| Nominal straight flange thickness $t_{sf}$ | = | 0.5512" |

**Results Summary**

The governing condition is external pressure.

| | | |
|---|---|---|
| Minimum thickness per UG-16 | = | 0.0625" + 0.063" = 0.1255" |
| Design thickness due to internal pressure (t) | = | 0.1349" |
| Design thickness due to external pressure ($t_e$) | = | 0.1893" |
| Maximum allowable external pressure (MAEP) | = | 82.33 psi |

**K (Corroded)**

K = $(1/6)*[2 + (D / (2*h))^2]$
= $(1/6)*[2 + (48.1181 / (2*12.061))^2]$
= 0.996522

**K (New)**

K = $(1/6)*[2 + (D / (2*h))^2]$
= $(1/6)*[2 + (47.9921 / (2*11.998))^2]$
= 1

**Design thickness for internal pressure, (Corroded at 250 °F) Appendix 1-4(c)**

t = P*D*K / (2*S*E - 0.2*P) + Corrosion
= 50*48.1181*0.996522 / (2*16,700*1 - 0.2*50) + 0.063
= 0.1348"

The head internal pressure design thickness is 0.1349".

**Design thickness for external pressure, (Corroded at 115 °F) UG-33(d)**

Equivalent outside spherical radius ($R_o$)

$R_o$ = $K_o*D_o$
= 0.8831*48.9291

= 43.2088 in

A = $0.125 / (R_o / t)$
= 0.125 / (43.2088 / 0.126208)
= 0.000365

From Table HA-3:B = 5,135.418 psi

$P_a$ = $B / (R_o / t)$
= 5,135.418 / (43.2088 / 0.1262)
= 15 psi

t = 0.1262" + Corrosion = 0.1262" + 0.063" = 0.1892"

Check the external pressure per UG-33(a)(1) Appendix 1-4(c)

t = $1.67*P_e*D*K / (2*S*E - 0.2*1.67*P_e)$ + Corrosion
= 1.67*15*48.1181*0.996522 / (2*16,700*1 - 0.2*1.67*15) + 0.063
= 0.099"

The head external pressure design thickness ($t_e$) is 0.1892".

**Maximum Allowable External Pressure, (Corroded at 115 °F) UG-33(d)**

Equivalent outside spherical radius ($R_o$)
$R_o$ = $K_o*D_o$
= 0.8831*48.9291
= 43.2088 in

A = $0.125 / (R_o / t)$
= 0.125 / (43.2088 / 0.405504)
= 0.001173

From Table HA-3:B = 8,772.8906 psi

$P_a$ = $B / (R_o / t)$
= 8,772.891 / (43.2088 / 0.4055)
= 82.3315 psi

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

P = $2*S*E*t / ((K*D + 0.2*t)*1.67) - P_{s2}$
= 2*16,700*1*0.4055 / ((0.996522*48.1181 +0.2*0.4055)*1.67) - 0
= 168.85 psi

The maximum allowable external pressure (MAEP) is 82.33 psi.

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

EFE = $(75*t / R_f)*(1 - R_f / R_o)$
= (75*0.5512 / 8.4343)*(1 - 8.4343 / ϒ⊆)
= 4.9013%

## SHELL

**ASME Section VIII Division 1, 2007 Edition, A09 Addenda**

| | |
|---|---|
| Component: | Cylinder |
| Material specification: | SA-240 304L (II-D p. 82, ln. 38) |

Impact test exempt per UHA-51(g)(coincident ratio = 0.15623)

Internal design pressure: P = 50 psi @ 250 °F
External design pressure: $P_e$ = 15 psi @ 115 °F

**Static liquid head:**

$P_s$ = 2.82 psi (SG = 1.015, $H_s$ = 77.0315",Operating head)
$P_{th}$ = 2.04 psi (SG = 1, $H_s$ = 56.5341", Horizontal test head)
$P_{tv}$ = 6.21 psi (SG = 1, $H_s$ = 172.0472", Vertical test head)

Corrosion allowance    Inner C = 0.063"    Outer C = 0"

| | |
|---|---|
| Design MDMT = 10 °F | No impact test performed |
| Rated MDMT = -320 °F | Material is not normalized |
| | Material is not produced to Fine Grain Practice |
| | PWHT is not performed |

| | | |
|---|---|---|
| Radiography: | Longitudinal joint - | Spot UW-11(b) Type 1 |
| | Top circumferential joint - | Spot UW-11(a)(5)b Type 1 |
| | Bottom circumferential joint - | Spot UW-11(a)(5)b Type 1 |

| | | |
|---|---|---|
| Estimated weight | New = 3,282.7 lb | corr = 2,911.4 lb |
| Capacity | New = 1,096.96 US gal | corr = 1,102.73 US gal |

ID = 47.9921"
Length $L_c$ = 140.0787"
t = 0.5512"

**Design thickness, (at 250 °F) UG-27(c)(1)**

t = P*R / (S*E - 0.60*P) + Corrosion
= 52.82*24.0591 / (16,700*0.85 - 0.60*52.82) + 0.063
= 0.1528"

**External Pressure, (Corroded & at 115 °F) UG-28(c)**

$L / D_o$ = 152.0564 / 49.0945 = 3.0972
$D_o / t$ = 49.0945 / 0.254 = 193.3211
From table G: A = 0.000154
From table HA-3: B = 2,174.8667 psi

$P_a$ = 4*B / (3*($D_o$ / t))
= 4*2,174.87 / (3*(49.0945 / 0.254))
= 15 psi

**Design thickness for external pressure $P_a$ = 15 psi**

$t_a$ = t + Corrosion = 0.254 + 0.063 = 0.317"

**Maximum Allowable External Pressure, (Corroded & at 115 °F) UG-28(c)**

$L / D_o$ = 152.0564 / 49.0945 = 3.0972
$D_o / t$ = 49.0945 / 0.4882 = 100.5661
From table G: A = 0.000399
From table HA-3: B = 5,583.8892 psi

$P_a$ = 4*B / (3*($D_o$ / t))
= 4*5,583.89 / (3*(49.0945 / 0.4882))
= 74.03 psi

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

EFE = $(50*t / R_f)*(1 - R_f / R_o)$
= $(50*0.5512 / 24.2717)*(1 - 24.2717 / ϒ⊆)$
= 1.1354%

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

$P_v = W / (2*\pi*R_m) + M / (\pi*R_m^2)$
$= 12{,}460.3 / (2*\pi*24.3032) + 346{,}930 / (\pi*24.3032^2)$
= 268.5665 lb/in

$\alpha = P_v / (P_e*D_o)$
= 268.5665 / (15*49.0945)
= 0.3647

n = 3

$m = 1.23 / (L / D_o)^2$
$= 1.23 / (152.0564 / 49.0945)^2$
= 0.1282

Ratio $P_e = (n^2 - 1 + m + m*\alpha) / (n^2 - 1 + m)$
$= (3^2 - 1 + 0.1282 + 0.1282*0.3647) / (3^2 - 1 + 0.1282)$
= 1.0058

Ratio $P_e$ * $P_e$ ¡ ÂMAEP design cylinder thickness is satisfactory.

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

$P_v = (1 + VAccel)*W / (2*\pi*R_m) + M / (\pi*R_m^2)$
$= 1.20*12{,}460.3 / (2*\pi*24.3032) + 86{,}256 / (\pi*24.3032^2)$
= 144.4038 lb/in

$\alpha = P_v / (P_e*D_o)$
= 144.4038 / (15*49.0945)
= 0.1961

n = 3

$m = 1.23 / (L / D_o)^2$
$= 1.23 / (152.0564 / 49.0945)^2$
= 0.1282

Ratio $P_e = (n^2 - 1 + m + m*\alpha) / (n^2 - 1 + m)$
$= (3^2 - 1 + 0.1282 + 0.1282*0.1961) / (3^2 - 1 + 0.1282)$
= 1.0031

Ratio $P_e$ * $P_e$ ¡ ÂMAEP design cylinder thickness is satisfactory.

**Design thickness = 0.317"**

The governing condition is due to external pressure.

The cylinder thickness of 0.5512" is adequate.

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

| Condition | Pressure P ( psi) | Allowable Stress Before UG-23 Stress Increase ( psi) | | Temperature ( °F) | Corrosion C (in) | Load | Req'd Thk Due to Tension (in) | Req'd Thk Due to Compression (in) |
|---|---|---|---|---|---|---|---|---|
| | | $S_t$ | $S_c$ | | | | | |
| Operating, Hot & Corroded | 50 | 16,700 | 8,221 | 250 | 0.063 | Wind | 0.0434 | 0.0195 |
| | | | | | | Seismic | 0.0361 | 0.0268 |
| Operating, Hot & New | 50 | 16,700 | 8,402 | 250 | 0 | Wind | 0.0432 | 0.0192 |
| | | | | | | Seismic | 0.036 | 0.0264 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Hot Shut Down, Corroded | 0 | 16,700 | 8,221 | 250 | 0.063 | Wind | 0.0081 | 0.0272 |
| | | | | | | Seismic | 0.0008 | 0.0146 |
| Hot Shut Down, New | 0 | 16,700 | 8,402 | 250 | 0 | Wind | 0.008 | 0.027 |
| | | | | | | Seismic | 0.0008 | 0.0149 |
| Empty, Corroded | 0 | 16,700 | 10,519 | 68 | 0.063 | Wind | 0.0081 | 0.0213 |
| | | | | | | Seismic | 0.0005 | 0.011 |
| Empty, New | 0 | 16,700 | 10,760 | 68 | 0 | Wind | 0.008 | 0.0211 |
| | | | | | | Seismic | 0.0006 | 0.0112 |
| Vacuum | -15 | 16,700 | 10,263 | 115 | 0.063 | Wind | 0.0034 | 0.0365 |
| | | | | | | Seismic | 0.0135 | 0.0264 |
| Hot Shut Down, Corroded, Weight & Eccentric Moments Only | 0 | 16,700 | 8,221 | 250 | 0.063 | Weight | 0.0082 | 0.0117 |

**Allowable Compressive Stress, Hot and Corroded- $S_{cHC}$, (table HA-3)**

A = 0.125 / ($R_o$ / t)
= 0.125 / (24.5472 / 0.4882)
= 0.002486
B = 8,221 psi
S = 16,700 / 1.00 = 16,700 psi
$S_{cHC}$ = min(B, S) = 8,221 psi

**Allowable Compressive Stress, Hot and New- $S_{cHN}$, (table HA-3)**

A = 0.125 / ($R_o$ / t)
= 0.125 / (24.5472 / 0.5512)
= 0.002807
B = 8,402 psi
S = 16,700 / 1.00 = 16,700 psi
$S_{cHN}$ = min(B, S) = 8,402 psi

**Allowable Compressive Stress, Cold and New- $S_{cCN}$, (table HA-3)**

A = 0.125 / ($R_o$ / t)
= 0.125 / (24.5472 / 0.5512)
= 0.002807
B = 10,760 psi
S = 16,700 / 1.00 = 16,700 psi
$S_{cCN}$ = min(B, S) = 10,760 psi

**Allowable Compressive Stress, Cold and Corroded- $S_{cCC}$, (table HA-3)**

A = 0.125 / ($R_o$ / t)
= 0.125 / (24.5472 / 0.4882)
= 0.002486
B = 10,519 psi
S = 16,700 / 1.00 = 16,700 psi
$S_{cCC}$ = min(B, S) = 10,519 psi

**Allowable Compressive Stress, Vacuum and Corroded- $S_{cVC}$, (table HA-3)**

A = 0.125 / ($R_o$ / t)
= 0.125 / (24.5472 / 0.4882)
= 0.002486
B = 10,263 psi
S = 16,700 / 1.00 = 16,700 psi
$S_{cVC}$ = min(B, S) = 10,263 psi

**Operating, Hot & Corroded, Wind, Bottom Seam**

$t_p$ = $P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
= 50*24.0591 / (2*16,700*1.20*0.85 + 0.40*|50|)
= 0.0353"

$t_m$ = $M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
= $346{,}930 / (\pi*24.3032^2*16{,}700*1.20*0.85)$
= 0.011"

$t_w$ = $0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= 0.60*12,460.3 / (2*π*24.3032*16,700*1.20*0.85)
= 0.0029"

$t_t$ = $t_p + t_m - t_w$ (total required, tensile)
= 0.0353 + 0.011 - (0.0029)
= 0.0434"

$t_{wc}$ = $W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= 12,460.3 / (2*π*24.3032*16,700*1.20*0.85)
= 0.0048"

$t_c$ = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0.011 + (0.0048) - (0.0353)|
= 0.0195"

**Operating, Hot & New, Wind, Bottom Seam**

$t_p$ = $P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
= 50*23.9961 / (2*16,700*1.20*0.85 + 0.40*|50|)
= 0.0352"

$t_m$ = $M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
= $347{,}264 / (\pi*24.2717^2*16{,}700*1.20*0.85)$
= 0.011"

$t_w$ = $0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= 0.60*12,929.4 / (2*π*24.2717*16,700*1.20*0.85)
= 0.003"

$t_t$ = $t_p + t_m - t_w$ (total required, tensile)
= 0.0352 + 0.011 - (0.003)
= 0.0432"

$t_{wc}$ = $W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= 12,929.4 / (2*π*24.2717*16,700*1.20*0.85)
= 0.005"

$t_c$ = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0.011 + (0.005) - (0.0352)|
= 0.0192"

**Hot Shut Down, Corroded, Wind, Bottom Seam**

$t_p$ = 0" (Pressure)

$t_m$ = $M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
= $346{,}930 / (\pi*24.3032^2*16{,}700*1.20*0.85)$
= 0.011"

$t_w$ = $0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= 0.60*12,460.3 / (2*π*24.3032*16,700*1.20*0.85)
= 0.0029"

$t_t$ = $t_p + t_m - t_w$ (total required, tensile)
= 0 + 0.011 - (0.0029)
= 0.0081"

$t_{mc}$ = M / (π*$R_m^2$*$S_c$*$K_s$) (bending)
= 346,930 / (π*24.3032²*8,221.21*1.20)
= 0.019"

$t_{wc}$ = W / (2*π*$R_m$*$S_c$*$K_s$) (Weight)
= 12,460.3 / (2*π*24.3032*8,221.21*1.20)
= 0.0083"

$t_c$ = $t_{mc}$ + $t_{wc}$ - $t_{pc}$ (total required, compressive)
= 0.019 + (0.0083) - (0)
= 0.0272"

**Hot Shut Down, New, Wind, Bottom Seam**

$t_p$ = 0" (Pressure)

$t_m$ = M / (π*$R_m^2$*$S_t$*$K_s$*$E_c$) (bending)
= 347,264 / (π*24.2717²*16,700*1.20*0.85)
= 0.011"

$t_w$ = 0.6*W / (2*π*$R_m$*$S_t$*$K_s$*$E_c$) (Weight)
= 0.60*12,929.4 / (2*π*24.2717*16,700*1.20*0.85)
= 0.003"

$t_t$ = $t_p$ + $t_m$ - $t_w$ (total required, tensile)
= 0 + 0.011 - (0.003)
= 0.008"

$t_{mc}$ = M / (π*$R_m^2$*$S_c$*$K_s$) (bending)
= 347,264 / (π*24.2717²*8,401.54*1.20)
= 0.0186"

$t_{wc}$ = W / (2*π*$R_m$*$S_c$*$K_s$) (Weight)
= 12,929.4 / (2*π*24.2717*8,401.54*1.20)
= 0.0084"

$t_c$ = $t_{mc}$ + $t_{wc}$ - $t_{pc}$ (total required, compressive)
= 0.0186 + (0.0084) - (0)
= 0.027"

**Empty, Corroded, Wind, Bottom Seam**

$t_p$ = 0" (Pressure)

$t_m$ = M / (π*$R_m^2$*$S_t$*$K_s$*$E_c$) (bending)
= 346,930 / (π*24.3032²*16,700*1.20*0.85)
= 0.011"

$t_w$ = 0.6*W / (2*π*$R_m$*$S_t$*$K_s$*$E_c$) (Weight)
= 0.60*12,414 / (2*π*24.3032*16,700*1.20*0.85)
= 0.0029"

$t_t$ = $t_p$ + $t_m$ - $t_w$ (total required, tensile)
= 0 + 0.011 - (0.0029)
= 0.0081"

$t_{mc}$ = M / (π*$R_m^2$*$S_c$*$K_s$) (bending)
= 346,930 / (π*24.3032²*10,518.68*1.20)
= 0.0148"

$t_{wc}$ = W / (2*π*$R_m$*$S_c$*$K_s$) (Weight)
= 12,414 / (2*π*24.3032*10,518.68*1.20)
= 0.0064"

$t_c$ = $t_{mc}$ + $t_{wc}$ - $t_{pc}$ (total required, compressive)
= 0.0148 + (0.0064) - (0)
= 0.0213"

**Empty, New, Wind, Bottom Seam**

$t_p$ = 0" (Pressure)

$t_m$ = M / (π*$R_m^2$*$S_t$*$K_s$*$E_c$) (bending)

= 347,264 / (π*24.2717$^2$*16,700*1.20*0.85)

= 0.011"

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

= 0.60*12,883.1 / (2*π*24.2717*16,700*1.20*0.85)

= 0.003"

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

= 0 + 0.011 - (0.003)

= 0.008"

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

= 347,264 / (π*24.2717$^2$*10,759.82*1.20)

= 0.0145"

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

= 12,883.1 / (2*π*24.2717*10,759.82*1.20)

= 0.0065"

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

= 0.0145 + (0.0065) - (0)

= 0.0211"

**Vacuum, Wind, Bottom Seam**

$t_p$ = P*R / (2*$S_c$*$K_s$ + 0.40*|P|) (Pressure)

= -15*24.0591 / (2*10,262.63*1.20 + 0.40*|15|)

= -0.0146"

$t_m$ = M / (π*$R_m^2$*$S_c$*$K_s$) (bending)

= 346,930 / (π*24.3032$^2$*10,262.63*1.20)

= 0.0152"

$t_w$ = 0.6*W / (2*π*$R_m$*$S_c$*$K_s$) (Weight)

= 0.60*12,460.3 / (2*π*24.3032*10,262.63*1.20)

= 0.004"

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

= |-0.0146 + 0.0152 - (0.004)|

= 0.0034"

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

= 12,460.3 / (2*π*24.3032*10,262.63*1.20)

= 0.0066"

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

= 0.0152 + (0.0066) - (-0.0146)

= 0.0365"

**Hot Shut Down, Corroded, Weight & Eccentric Moments Only, Bottom Seam**

$t_p$ = 0" (Pressure)

$t_m$ = M / (π*$R_m^2$*$S_c$*$K_s$) (bending)

= 26,523 / (π*24.3032$^2$*8,221.21*1.00)

= 0.0017"

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

= 12,460.3 / (2*π*24.3032*8,221.21*1.00)

= 0.0099"

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

= |0 + 0.0017 - (0.0099)|

$= 0.0082"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0017 + (0.0099) - (0)$
$= 0.0117"$

**Operating, Hot & Corroded, Seismic, Bottom Seam**

$t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
$= 50*24.0591 / (2*16{,}700*1.20*0.85 + 0.40*|50|)$
$= 0.0353"$

$t_m = M / (\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
$= 86{,}256 / (\pi*24.3032^2*16{,}700*1.20*0.85)$
$= 0.0027"$

$t_w = (0.6 - VAccel)*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.40*12{,}460.3 / (2*\pi*24.3032*16{,}700*1.20*0.85)$
$= 0.0019"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0.0353 + 0.0027 - (0.0019)$
$= 0.0361"$

$t_{wc} = (1 + VAccel)*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 1.20*12{,}460.3 / (2*\pi*24.3032*16{,}700*1.20*0.85)$
$= 0.0057"$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0.0027 + (0.0057) - (0.0353)|$
$= 0.0268"$

**Operating, Hot & New, Seismic, Bottom Seam**

$t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
$= 50*23.9961 / (2*16{,}700*1.20*0.85 + 0.40*|50|)$
$= 0.0352"$

$t_m = M / (\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
$= 88{,}852 / (\pi*24.2717^2*16{,}700*1.20*0.85)$
$= 0.0028"$

$t_w = (0.6 - VAccel)*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.40*12{,}929.4 / (2*\pi*24.2717*16{,}700*1.20*0.85)$
$= 0.002"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0.0352 + 0.0028 - (0.002)$
$= 0.036"$

$t_{wc} = (1 + VAccel)*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 1.20*12{,}929.4 / (2*\pi*24.2717*16{,}700*1.20*0.85)$
$= 0.006"$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0.0028 + (0.006) - (0.0352)|$
$= 0.0264"$

**Hot Shut Down, Corroded, Seismic, Bottom Seam**

$t_p = 0"$ (Pressure)

$t_m = M / (\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
$= 86{,}256 / (\pi*24.3032^2*16{,}700*1.20*0.85)$
$= 0.0027"$

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

= $0.40*12,460.3 / (2*\pi*24.3032*16,700*1.20*0.85)$
= 0.0019"

$t_t$ = $t_p + t_m - t_w$ (total required, tensile)
= 0 + 0.0027 - (0.0019)
= 0.0008"

$t_{mc}$ = $M / (\pi*R_m{}^2*S_c*K_s)$ (bending)
= $86,256 / (\pi*24.3032^2*8,221.21*1.20)$
= 0.0047"

$t_{wc}$ = $(1 + VAccel)*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
= $1.20*12,460.3 / (2*\pi*24.3032*8,221.21*1.20)$
= 0.0099"

$t_c$ = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0.0047 + (0.0099) - (0)
= 0.0146"

**Hot Shut Down, New, Seismic, Bottom Seam**

$t_p$ = 0" (Pressure)

$t_m$ = $M / (\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
= $88,852 / (\pi*24.2717^2*16,700*1.20*0.85)$
= 0.0028"

$t_w$ = $(0.6 - VAccel)*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $0.40*12,929.4 / (2*\pi*24.2717*16,700*1.20*0.85)$
= 0.002"

$t_t$ = $t_p + t_m - t_w$ (total required, tensile)
= 0 + 0.0028 - (0.002)
= 0.0008"

$t_{mc}$ = $M / (\pi*R_m{}^2*S_c*K_s)$ (bending)
= $88,852 / (\pi*24.2717^2*8,401.54*1.20)$
= 0.0048"

$t_{wc}$ = $(1 + VAccel)*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
= $1.20*12,929.4 / (2*\pi*24.2717*8,401.54*1.20)$
= 0.0101"

$t_c$ = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0.0048 + (0.0101) - (0)
= 0.0149"

**Empty, Corroded, Seismic, Bottom Seam**

$t_p$ = 0" (Pressure)

$t_m$ = $M / (\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
= $77,628 / (\pi*24.3032^2*16,700*1.20*0.85)$
= 0.0025"

$t_w$ = $(0.6 - VAccel)*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $0.40*12,414 / (2*\pi*24.3032*16,700*1.20*0.85)$
= 0.0019"

$t_t$ = $t_p + t_m - t_w$ (total required, tensile)
= 0 + 0.0025 - (0.0019)
= 0.0005"

$t_{mc}$ = $M / (\pi*R_m{}^2*S_c*K_s)$ (bending)
= $77,628 / (\pi*24.3032^2*10,518.68*1.20)$
= 0.0033"

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

= 1.20*12,414 / (2*π*24.3032*10,518.68*1.20)
= 0.0077"

$t_c$ = $t_{mc}$ + $t_{wc}$ - $t_{pc}$ (total required, compressive)
= 0.0033 + (0.0077) - (0)
= 0.011"

**Empty, New, Seismic, Bottom Seam**

$t_p$ = 0" (Pressure)

$t_m$ = M / (π*$R_m^2$*$S_t$*$K_s$*$E_c$) (bending)
= 80,308 / (π*24.2717$^2$*16,700*1.20*0.85)
= 0.0025"

$t_w$ = (0.6 - VAccel)*W / (2*π*$R_m$*$S_t$*$K_s$*$E_c$) (Weight)
= 0.40*12,883.1 / (2*π*24.2717*16,700*1.20*0.85)
= 0.002"

$t_t$ = $t_p$ + $t_m$ - $t_w$ (total required, tensile)
= 0 + 0.0025 - (0.002)
= 0.0006"

$t_{mc}$ = M / (π*$R_m^2$*$S_c$*$K_s$) (bending)
= 80,308 / (π*24.2717$^2$*10,759.82*1.20)
= 0.0034"

$t_{wc}$ = (1 + VAccel)*W / (2*π*$R_m$*$S_c$*$K_s$) (Weight)
= 1.20*12,883.1 / (2*π*24.2717*10,759.82*1.20)
= 0.0079"

$t_c$ = $t_{mc}$ + $t_{wc}$ - $t_{pc}$ (total required, compressive)
= 0.0034 + (0.0079) - (0)
= 0.0112"

**Vacuum, Seismic, Bottom Seam**

$t_p$ = P*R / (2*$S_c$*$K_s$ + 0.40*|P|) (Pressure)
= -15*24.0591 / (2*10,262.63*1.20 + 0.40*|15|)
= -0.0146"

$t_m$ = M / (π*$R_m^2$*$S_c$*$K_s$) (bending)
= 86,256 / (π*24.3032$^2$*10,262.63*1.20)
= 0.0038"

$t_w$ = (0.6 - VAccel)*W / (2*π*$R_m$*$S_c$*$K_s$) (Weight)
= 0.40*12,460.3 / (2*π*24.3032*10,262.63*1.20)
= 0.0027"

$t_t$ = |$t_p$ + $t_m$ - $t_w$| (total, net compressive)
= |-0.0146 + 0.0038 - (0.0027)|
= 0.0135"

$t_{wc}$ = (1 + VAccel)*W / (2*π*$R_m$*$S_c$*$K_s$) (Weight)
= 1.20*12,460.3 / (2*π*24.3032*10,262.63*1.20)
= 0.008"

$t_c$ = $t_{mc}$ + $t_{wc}$ - $t_{pc}$ (total required, compressive)
= 0.0038 + (0.008) - (-0.0146)
= 0.0264"

## BTM HEAD

**ASME Section VIII, Division 1, 2007 Edition, A09 Addenda**

| | |
|---|---|
| Component: | Ellipsoidal Head |
| Material Specification: | SA-240 304L (II-D p.82, ln. 38) |

Material Impact test exempt per UHA-51(g)(coincident ratio = 0.18889)

Internal design pressure: P = 50 psi @ 250 °F
External design pressure: $P_e$ = 15 psi @ 115 °F

**Static liquid head:**

$P_s$= 3.3363 psi (SG=1.015, $H_s$=91.061" Operating head)
$P_{th}$= 2.0407 psi (SG=1, $H_s$=56.5341" Horizontal test head)
$P_{tv}$= 6.7146 psi (SG=1, $H_s$=186.0138" Vertical test head)

| | | |
|---|---|---|
| Corrosion allowance: | Inner C = 0.063" | Outer C = 0" |

| | |
|---|---|
| Design MDMT = 10°F | No impact test performed |
| Rated MDMT = -320°F | Material is not normalized |
| | Material is not produced to fine grain practice |
| | PWHT is not performed |
| | Do not Optimize MDMT / Find MAWP |

| | | |
|---|---|---|
| Radiography: | Category A joints - | Full UW-11(a) Type 1 |
| | Head to shell seam - | Spot UW-11(a)(5)(b) Type 1 |

| | | |
|---|---|---|
| Estimated weight*: | new = 415.2 lb | corr = 361.4 lb |
| Capacity*: | new = 78.1 US gal | corr = 78.8 US gal |

* includes straight flange

| | | |
|---|---|---|
| Inner diameter | = | 47.9921" |
| Minimum head thickness | = | 0.4685" |
| Head ratio D/2h | = | 2 (new) |
| Head ratio D/2h | = | 1.9948 (corroded) |
| Straight flange length $L_{sf}$ | = | 1.9685" |
| Nominal straight flange thickness $t_{sf}$ | = | 0.5512" |

**Results Summary**

The governing condition is external pressure.

| | | |
|---|---|---|
| Minimum thickness per UG-16 | = | 0.0625" + 0.063" = 0.1255" |
| Design thickness due to internal pressure (t) | = | 0.1396" |
| Design thickness due to external pressure ($t_e$) | = | 0.1893" |
| Maximum allowable external pressure (MAEP) | = | 82.33 psi |

**K (Corroded)**

K = $(1/6)*[2 + (D / (2*h))^2]$
= $(1/6)*[2 + (48.1181 / (2*12.061))^2]$
= 0.996522

**K (New)**

K = $(1/6)*[2 + (D / (2*h))^2]$
= $(1/6)*[2 + (47.9921 / (2*11.998))^2]$
= 1

**Design thickness for internal pressure, (Corroded at 250 °F) Appendix 1-4(c)**

t = P*D*K / (2*S*E - 0.2*P) + Corrosion
= 53.34*48.1181*0.996522 / (2*16,700*1 - 0.2*53.34) + 0.063
= 0.1396"

The head internal pressure design thickness is 0.1396".

**Design thickness for external pressure, (Corroded at 115 °F) UG-33(d)**

Equivalent outside spherical radius ($R_o$)

$R_o$ = $K_o*D_o$
= 0.8831*48.9291

= 43.2088 in

A = 0.125 / ($R_o$ / t)
= 0.125 / (43.2088 / 0.126208)
= 0.000365

From Table HA-3:B = 5,135.418 psi

$P_a$ = B / ($R_o$ / t)
= 5,135.418 / (43.2088 / 0.1262)
= 15 psi

t = 0.1262" + Corrosion = 0.1262" + 0.063" = 0.1892"

Check the external pressure per UG-33(a)(1) Appendix 1-4(c)

t = 1.67*$P_e$*D*K / (2*S*E - 0.2*1.67*$P_e$) + Corrosion
= 1.67*15*48.1181*0.996522 / (2*16,700*1 - 0.2*1.67*15) + 0.063
= 0.099"

The head external pressure design thickness ($t_e$) is 0.1892".

**Maximum Allowable External Pressure, (Corroded at 115 °F) UG-33(d)**

Equivalent outside spherical radius ($R_o$)
$R_o$ = $K_o$*$D_o$
= 0.8831*48.9291
= 43.2088 in

A = 0.125 / ($R_o$ / t)
= 0.125 / (43.2088 / 0.405504)
= 0.001173

From Table HA-3:B = 8,772.8906 psi

$P_a$ = B / ($R_o$ / t)
= 8,772.891 / (43.2088 / 0.4055)
= 82.3315 psi

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

P = 2*S*E*t / ((K*D + 0.2*t)*1.67) - $P_{s2}$
= 2*16,700*1*0.4055 / ((0.996522*48.1181 +0.2*0.4055)*1.67) - 0
= 168.85 psi

The maximum allowable external pressure (MAEP) is 82.33 psi.

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

EFE = (75*t / $R_f$)*(1 - $R_f$ / $R_o$)
= (75*0.5512 / 8.4343)*(1 - 8.4343 / ϒ⊆)
= 4.9013%

**UPPER SKIRT**

| | |
|---|---|
| Material: | SA-240 304L (II-D p. 82, ln. 38) |
| Design temperature, operating: | 250 °F |
| Design temperature, vacuum: | 115 °F |
| Inner diameter at top, new: | 47.7165 in |
| Inner diameter at bottom, new: | 47.7165 in |
| Overall length: | 34.4173 in |
| Corrosion allowance inside: | 0 in |
| Corrosion allowance outside: | 0.063 in |
| Weld joint efficiency top: | 0.55 |
| Weld joint efficiency bottom: | 0.7 |
| Nominal thickness, new: | 0.3937 in |
| Skirt is attached to: | BTM HEAD |
| Skirt attachment offset: | 4.9528 in down from the top seam |

**Skirt design thickness, largest of the following + corrosion = 0.1288 in**

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

The skirt thickness of 0.3937 in is adequate.

| Loading | Vessel Condition (Stress) | Governing Skirt Location | Temperature (°F) | Allowable Stress (psi) | Calculated Stress/E (psi) | Required thickness (in) |
|---|---|---|---|---|---|---|
| Wind | operating, corroded (+) | bottom | 250 | 16,700 | 1,090.88 | 0.0216 |
| Wind | operating, corroded (-) | bottom | 250 | 7,668 | 1,526.4 | 0.0658 |
| Wind | operating, new (+) | bottom | 250 | 16,700 | 905.75 | 0.0214 |
| Wind | operating, new (-) | bottom | 250 | 7,928.21 | 1,289.73 | 0.064 |
| Wind | empty, corroded (+) | top | 68 | 16,700 | 1,196.06 | 0.0237 |
| Wind | empty, corroded (-) | bottom | 68 | 9,755.54 | 1,406.21 | 0.0477 |
| Wind | empty, new (+) | top | 68 | 16,700 | 992.89 | 0.0234 |
| Wind | empty, new (-) | bottom | 68 | 10,127.39 | 1,189.47 | 0.0462 |
| Wind | test, new (+) | bottom | 68 | 16,700 | 325.35 | 0.0077 |
| Wind | test, new (-) | bottom | 68 | 10,127.39 | 1,011.06 | 0.0393 |
| Wind | vacuum, corroded (+) | bottom | 115 | 16,700 | 1,090.88 | 0.0216 |
| Wind | vacuum, corroded (-) | bottom | 115 | 9,523.45 | 1,526.4 | 0.053 |
| Seismic | operating, corroded (+) | top | 250 | 16,700 | 404.31 | 0.008 |
| Seismic | operating, corroded (-) | bottom | 250 | 7,668 | 1,035.38 | 0.0447 |
| Seismic | operating, new (+) | top | 250 | 16,700 | 339.3 | 0.008 |
| Seismic | operating, new (-) | bottom | 250 | 7,928.21 | 885.05 | 0.044 |
| Seismic | empty, corroded (+) | top | 68 | 16,700 | 462.49 | 0.0092 |
| Seismic | empty, corroded (-) | bottom | 68 | 9,755.54 | 861.97 | 0.0292 |
| Seismic | empty, new (+) | top | 68 | 16,700 | 387.94 | 0.0091 |
| Seismic | empty, new (-) | bottom | 68 | 10,127.39 | 740.47 | 0.0288 |
| Seismic | vacuum, corroded (+) | top | 115 | 16,700 | 404.31 | 0.008 |
| Seismic | vacuum, corroded (-) | bottom | 115 | 9,523.45 | 1,035.38 | 0.036 |

## Loading due to wind, operating & corroded

### Windward side (tensile)

**Required thickness, tensile stress at base:**

t = $-0.6*W / (\pi*D*S_t*E) + 48*M / (\pi*D^2*S_t*E)$

= $-0.6*23{,}798.26 / (\pi*48.0472*16{,}700*0.7) + 48*52{,}449.4 / (\pi*48.0472^2*16{,}700*0.7)$
= 0.0216 in

**Required thickness, tensile stress at the top:**

t = $-0.6*W_t / (\pi*D_t*S_t*E) + 48*M_t / (\pi*D_t^2*S_t*E)$
= $-0.6*23{,}300.05 / (\pi*48.0472*16{,}700*0.55) + 48*43{,}260.9 / (\pi*48.0472^2*16{,}700*0.55)$
= 0.0211 in

### Leeward side (compressive)

**Required thickness, compressive stress at base:**

t = $W / (\pi*D*S_c*E_c) + 48*M / (\pi*D^2*S_c*E_c)$
= $23{,}798.26 / (\pi*48.0472*7{,}668*1) + 48*52{,}449.4 / (\pi*48.0472^2*7{,}668*1)$
= 0.0658 in

**Required thickness, compressive stress at the top:**

t = $W_t / (\pi*D_t*S_c*E_c) + 48*M_t / (\pi*D_t^2*S_c*E_c)$
= $23{,}300.05 / (\pi*48.0472*7{,}668*1) + 48*43{,}260.9 / (\pi*48.0472^2*7{,}668*1)$
= 0.0575 in

**LOWER SKIRT**

| | |
|---|---|
| Material: | SA-516 70 (II-D p. 18, ln. 24) |
| Design temperature, operating: | 68 °F |
| Design temperature, vacuum: | 68 °F |
| Inner diameter at top, new: | 47.7165 in |
| Inner diameter at bottom, new: | 47.7165 in |
| Overall length: | 124.6063 in |
| Corrosion allowance inside: | 0 in |
| Corrosion allowance outside: | 0.063 in |
| Weld joint efficiency top: | 0.7 |
| Weld joint efficiency bottom: | 0.7 |
| Nominal thickness, new: | 0.3937 in |
| Skirt is attached to: | UPPER SKIRT |
| Skirt attachment offset: | 0 in up from the bottom seam |

**Skirt design thickness, largest of the following + corrosion = 0.1184 in**

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

The skirt thickness of 0.3937 in is adequate.

| Loading | Vessel Condition (Stress) | Governing Skirt Location | Temperature (°F) | Allowable Stress (psi) | Calculated Stress/E (psi) | Required thickness (in) |
|---|---|---|---|---|---|---|
| Wind | operating, corroded (+) | bottom | 68 | 20,000 | 2,261.23 | 0.0374 |
| Wind | operating, corroded (-) | bottom | 68 | 14,339.67 | 2,402.06 | 0.0554 |
| Wind | operating, new (+) | bottom | 68 | 20,000 | 1,881.72 | 0.037 |
| Wind | operating, new (-) | bottom | 68 | 15,041.35 | 2,029.33 | 0.0531 |
| Wind | empty, corroded (+) | bottom | 68 | 20,000 | 2,364.25 | 0.0391 |
| Wind | empty, corroded (-) | bottom | 68 | 14,339.67 | 2,281.87 | 0.0526 |
| Wind | empty, new (+) | bottom | 68 | 20,000 | 1,967.65 | 0.0387 |
| Wind | empty, new (-) | bottom | 68 | 15,041.35 | 1,929.07 | 0.0505 |
| Wind | test, new (+) | bottom | 68 | 20,000 | 787.05 | 0.0155 |
| Wind | test, new (-) | bottom | 68 | 15,041.35 | 1,390.67 | 0.0364 |
| Wind | vacuum, corroded (+) | bottom | 68 | 20,000 | 2,261.23 | 0.0374 |
| Wind | vacuum, corroded (-) | bottom | 68 | 14,339.67 | 2,402.06 | 0.0554 |
| Seismic | operating, corroded (+) | bottom | 68 | 20,000 | 661.75 | 0.0109 |
| Seismic | operating, corroded (-) | bottom | 68 | 14,339.67 | 1,282.43 | 0.0296 |
| Seismic | operating, new (+) | bottom | 68 | 20,000 | 560.76 | 0.011 |
| Seismic | operating, new (-) | bottom | 68 | 15,041.35 | 1,104.66 | 0.0289 |
| Seismic | empty, corroded (+) | bottom | 68 | 20,000 | 621 | 0.0103 |
| Seismic | empty, corroded (-) | bottom | 68 | 14,339.67 | 1,061.6 | 0.0245 |
| Seismic | empty, new (+) | bottom | 68 | 20,000 | 526.94 | 0.0104 |
| Seismic | empty, new (-) | bottom | 68 | 15,041.35 | 920.58 | 0.0241 |
| Seismic | vacuum, corroded (+) | bottom | 68 | 20,000 | 661.75 | 0.0109 |
| Seismic | vacuum, corroded (-) | bottom | 68 | 14,339.67 | 1,282.43 | 0.0296 |

## Loading due to wind, operating & corroded

### Windward side (tensile)

**Required thickness, tensile stress at base:**

$$t = -0.6*W / (\pi*D*S_t*E) + 48*M / (\pi*D^2*S_t*E)$$

$= -0.6*25{,}558.49 / (\pi*48.0472*20{,}000*0.7) + 48*94{,}442.3 / (\pi*48.0472^2*20{,}000*0.7)$
$= 0.0374$ in

**Required thickness, tensile stress at the top:**

$t = -0.6*W_t / (\pi*D_t*S_t*E) + 48*M_t / (\pi*D_t^2*S_t*E)$
$= -0.6*23{,}798.26 / (\pi*48.0472*20{,}000*0.7) + 48*52{,}449.4 / (\pi*48.0472^2*20{,}000*0.7)$
$= 0.018$ in

### Leeward side (compressive)

**Required thickness, compressive stress at base:**

$t = W / (\pi*D*S_c*E_c) + 48*M / (\pi*D^2*S_c*E_c)$
$= 25{,}558.49 / (\pi*48.0472*14{,}340*1) + 48*94{,}442.3 / (\pi*48.0472^2*14{,}340*1)$
$= 0.0554$ in

**Required thickness, compressive stress at the top:**

$t = W_t / (\pi*D_t*S_c*E_c) + 48*M_t / (\pi*D_t^2*S_c*E_c)$
$= 23{,}798.26 / (\pi*48.0472*14{,}340*1) + 48*52{,}449.4 / (\pi*48.0472^2*14{,}340*1)$
$= 0.0352$ in

## BASE BLOCK

| | |
|---|---|
| Base configuration: | external bolt chairs |
| Foundation compressive strength: | 1,664 psi |
| Concrete ultimate 28-day strength: | 3,001 psi |
| Anchor bolt material: | ASTM F1554 GR. 55 |
| Anchor bolt allowable stress, $S_b$: | 24,750 psi |
| Bolt circle, BC: | 51.9685 in |
| Anchor bolt corrosion allowance (applied to root radius): | 0 in |
| Anchor bolt clearance: | 0.4961 in |
| Base plate material: | SA 516-70 |
| Base plate allowable stress, $S_p$: | 19,999 psi |
| Base plate inner diameter, $D_i$: | 45.0394 in |
| Base plate outer diameter, $D_o$: | 55.5118 in |
| Base plate thickness, $t_b$: | 1.0236 in |
| Gusset separation, w: | 5.9843 in |
| Gusset height, h: | 5.9449 in |
| Gusset thickness, $t_g$: | 0.5118 in |
| Compression plate width: | 3.5039 in |
| Compression plate length: | 7.9921 in |
| Compression plate thickness, $t_c$: | 1.0236 in |
| Initial bolt preload: | 0 % (0 psi) |
| Number of bolts, N: | 8 |
| Bolt size and type: | 1 inch series 8 threaded |
| Bolt root area (corroded), $A_b$: | 0.551 $in^2$ |
| Diameter of anchor bolt holes, $d_b$: | 1.4961 in |

| Load | Vessel condition | Base M ($lb_f$-ft) | W (lb) | Required bolt area ($in^2$) | $t_r$ Base (in) | Foundation bearing stress (psi) | $t_r$comp plate (in) | $t_r$ gusset (in) |
|---|---|---|---|---|---|---|---|---|
| Wind | operating, corroded | 94,442.3 | 26,180 | 0.3612 | 0.673 | 277.24 | 0.6208 | 0.1393 |
| Wind | operating, new | 94,487.4 | 27,106 | 0.3586 | 0.6749 | 278.81 | 0.6166 | 0.1388 |
| Wind | empty, corroded | 94,442.3 | 20,180.1 | 0.3794 | 0.6609 | 267.37 | 0.6481 | 0.1422 |
| Wind | empty, new | 94,487.4 | 21,140.1 | 0.3767 | 0.6631 | 269.15 | 0.644 | 0.1417 |
| Wind | test, new | 51,639.9 | 31,851.7 | 0.1444 | 0.5256 | 169.08 | 0.3391 | 0.118 |
| Wind | vacuum, corroded | 94,442.3 | 26,180 | 0.3612 | 0.673 | 277.24 | 0.6208 | 0.1393 |
| Seismic | operating, corroded | 33,379.9 | 26,180 | 0.1028 | 0.5097 | 159 | 0.3159 | 0.1169 |
| Seismic | operating, new | 34,029.3 | 27,106 | 0.104 | 0.5159 | 162.9 | 0.3168 | 0.1169 |
| Seismic | empty, corroded | 29,552.3 | 20,180.1 | 0.0971 | 0.4689 | 134.58 | 0.3135 | 0.1168 |
| Seismic | empty, new | 30,225.7 | 21,140.1 | 0.0983 | 0.4761 | 138.73 | 0.3144 | 0.1168 |
| Seismic | vacuum, corroded | 33,379.9 | 26,180 | 0.1028 | 0.5097 | 159 | 0.3159 | 0.1169 |

**Anchor bolt load (governing)**

P = -0.6*W / N + 48 * M / (N*BC)
= -0.6*20,180.1 / 8 + 48 * 94,442.3 / (8*51.9685)
= 9,390.29 $lb_f$

Required area per bolt = P / $S_b$ = 0.3794 $in^2$

The area provided (0.551 $in^2$) by the specified anchor bolt is adequate.

**Support calculations (Jawad & Farr chapter 12, governing)**

| | |
|---|---|
| Base plate width, $t_c$: | 5.2362 in |
| Average base plate diameter, d: | 50.2756 in |
| Base plate elastic modulus, $E_s$: | 29,000,000 psi |
| Base plate yield stress, $S_y$: | 30,000 psi |

$E_c$ = 57,000.00*Sqr(3,001) = 3,122,539 psi

$n = E_s/E_c$ = 29,000,000 / 3,122,539 = 9.2873

$t_s = (N*A_b) / (\pi*d)$
= (8*0.551) / (π*50.2756)
= 0.0279 in

**From table 12.4 for k = 0.199136:**

$K_1$ = 2.6629, $K_2$ = 1.215
$L_1$ = 15.1311, $L_2$ = 31.0268, $L_3$ = 7.9558

**Total tensile force on bolting**

$T = (12*M - 0.6*W *(L_1 + L_3)) / (L_2 + L_3)$
= (12*94,487.4 - 0.6*27,105.96 *(15.1311 + 7.9558)) / (31.0268 + 7.9558)
= 19,454.17 $lb_f$

Tensile stress in bolts use the larger of $f_s$ or bolt preload = 0 psi

$f_s = T / (t_s * (d / 2) * K_1)$
= 19,454.17 / (0.0279 * (50.2756 / 2) * 2.6629)
= 10,414 psi

**Total compressive load on foundation**

$C_c$ = T + W + Bolt Preload
= 19,454.17 + 27,105.96 + 0
= 46,560.13 $lb_f$

**Foundation bearing stress**

$f_c = C_c / (((t_c - t_s) + n*t_s)*(d / 2)*K_2)$
= 46,560.13 / (((5.2362 - 0.0279) + 9.2873*0.0279)*(50.2756 / 2)*1.215)
= 279 psi

As $f_c$ <= 1,664 psi the base plate width is satisfactory.

$k = 1 / (1 + f_s / (n*f_c))$
= 1 / (1 + 10,414 / (9.2873*279))
= 0.199136

**Base plate required thickness (governing)**

From Brownell & Young, Table 10.3:, l / b = 0.2615

$M_x = 0.0061*279*13.4001^2$ = 306.4 $lb_f$

$M_y = -0.4435*279*3.5039^2$ = -1,518.2 $lb_f$

$t_r = (6*M_{max} / S_p)^{0.5}$
$= (6*1{,}518.21 / 19{,}999)^{0.5}$
= 0.6749 in

The base plate thickness is satisfactory.

**Check the compression plate for bolt load (Jawad & Farr equation 12.13)**

$t_{cr} = (3.91*F / (S_y*(2*b / w+w / (2*l)-d_b*(2 / w+1 / (2*l)))))^{0.5}$
$= (3.91*6{,}338.46 / (30{,}000*(2*3.5039 / 5.9843+5.9843 / (2*1.732)-1.4961*(2 / 5.9843+1 / (2*1.732)))))^{0.5}$
= 0.6481 in

The compression plate thickness is satisfactory.

**Check gusset plate thickness (Bednar chapter 4.3)**

Radius of gyration of gusset

$r = 0.289*t_g$
= 0.289*0.5118
= 0.1479 in

Cross sectional area of one gusset

$A_g = t_g*(b - 0.25)$
$= 0.5118*(3.5039 - 0.25)$
$= 1.6654\ in^2$

Gusset allowable stress

$S_a = 17000 - 0.485*(h / r)^2$
$= 17000 - 0.485*(5.9449 / 0.1479)^2$
$= 16,217$ psi

Gusset axial stress due to bolt load

$S_g = F / (2 * A_g)$
$= 6,338.46 / (2 * 1.6654)$
$= 1,903$ psi

The gusset plate thickness is satisfactory.

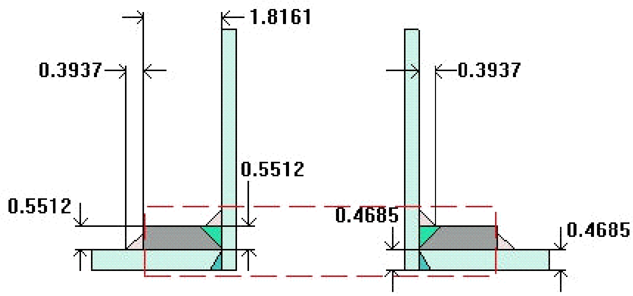
**Check skirt thickness for bolt load reaction (Brownell & Young eq. 10.59)**

$t = 1.76*(F*l / (M_b*h_c*S_s))^{2 / 3}*(OD_s / 2)^{1 / 3}$
$= 1.76*(6,338.46*1.7323 / (18.5748*7.9921*30,000))^{2 / 3}*(48.5039 / 2)^{1 / 3}$
$= 0.093$ in

The skirt thickness is satisfactory.

**4" (AM)**

**ASME Section VIII Division 1, 2007 Edition, A09 Addenda**




$t_{w(lower)}$ = 0.4685 in

$Leg_{41}$ = 0.3937 in

$t_{w(upper)}$ = 0.5512 in

$Leg_{42}$ = 0.3937 in

$D_p$ = 8.2678 in

$t_e$ = 0.5512 in

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

| | |
|---|---|
| Located on: | TOP HEAD |
| Liquid static head included: | 0 psi |
| Nozzle material specification: | SA-312 TP304L Wld & smls pipe (II-D p. 86, ln. 1) |
| Nozzle longitudinal joint efficiency: | 1 |
| Nozzle description: | NPS 4 Sch 80S (XS) |
| Pad material specification: | SA-240 304L (II-D p. 82, ln. 38) |
| Pad diameter: | 8.2678 in |
| Flange description: | 4 inch Class 150 WN A182 F304L |
| Bolt Material: | SA-193 B7 Bolt <= 2 1/2 (II-D p. 348, ln. 33) |
| Flange rated MDMT: | -55°F |
| (Per UHA-51(d)(1)(a)) | |
| (Flange rated MDMT = -320 °F<br>Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F) | |
| Liquid static head on flange: | 0 psi |
| ASME B16.5 flange rating MAWP: | 185 psi @ 250°F |
| ASME B16.5 flange rating MAP: | 230 psi @ 68°F |
| ASME B16.5 flange hydro test: | 350 psi @ 68°F |
| Gasket Description: | Flexitallic Spiral Wound CG 304L S.S. |
| PWHT performed: | No |
| Circumferential joint radiography: | None UW-11(c) Type 1 |
| Nozzle orientation: | 290° |
| Calculated as hillside: | Yes |
| Local vessel minimum thickness: | 0.4685 in |
| End of nozzle to datum line: | 174.0157 in |
| Nozzle inside diameter, new: | 3.826 in |
| Nozzle nominal wall thickness: | 0.337 in |
| Nozzle corrosion allowance: | 0.063 in |
| Opening chord length: | 4.0761 in |
| Projection available outside vessel, Lpr: | 15.3172 in |
| Projection available outside vessel to flange face, Lf: | 18.3172 in |
| Distance to head center, R: | 10.7874 in |
| Pad is split: | No |

**Reinforcement Calculations for Internal Pressure**

| UG-37 Area Calculation Summary ($in^2$) For P = 50 psi @ 250 °F The opening is adequately reinforced | | | | | | | UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45 | |
|---|---|---|---|---|---|---|---|---|
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| 0.2636 | 4.0261 | 1.3892 | 0.5436 | -- | 1.9383 | 0.155 | 0.2795 | 0.2949 |

| UG-41 Weld Failure Path Analysis Summary ($lb_f$) All failure paths are stronger than the applicable weld loads | | | | | | |
|---|---|---|---|---|---|---|
| Weld load W | Weld load $W_{1-1}$ | Path 1-1 strength | Weld load $W_{2-2}$ | Path 2-2 strength | Weld load $W_{3-3}$ | Path 3-3 strength |
| -15,677.64 | 44,036.87 | 63,102.7 | 15,377.74 | 106,342.36 | 47,747.99 | 77,261.84 |

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| Weld description | Required weld size (in) | Actual weld size (in) | Status |
| Nozzle to pad fillet ($Leg_{41}$) | 0.1918 | 0.2756 | weld size is adequate |
| Pad to shell fillet ($Leg_{42}$) | 0.2027 | 0.2756 | weld size is adequate |
| Nozzle to pad groove (Upper) | 0.1918 | 0.5512 | weld size is adequate |

**Calculations for internal pressure 50 psi @ 250 °F**

Nozzle rated MDMT per UHA-51(d)(1)(a) = -320 °F.
Pad Impact test exempt per UHA-51(g)(coincident ratio = 0.15951).

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

$L_R$ = MAX(d, $R_n$ + ($t_n$ - $C_n$) + (t - C))
= MAX(4.0761, 2.0381 + (0.337 - 0.063) + (0.4685 - 0.063))
= 4.0761 in

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

$L_H$ = MIN(2.5*(t - C), 2.5*($t_n$ - $C_n$) + $t_e$)
= MIN(2.5*(0.4685 - 0.063), 2.5*(0.337 - 0.063) + 0.5512)
= 1.0138 in

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

$t_{rn}$ = P*$R_n$ / ($S_n$*E - 0.6*P)
= 50*1.976 / (16,700*1 - 0.6*50)
= 0.0059 in

**Required thickness $t_r$ from UG-37(a)(c)**

$t_r$ = P*$K_1$*D / (2*S*E - 0.2*P)
= 50*0.8976*48.1181 / (2*16,700*1 - 0.2*50)
= 0.0647 in

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

Allowable stresses: $S_n$ = 16,700, $S_v$ = 16,700, $S_p$ = 16,700 psi

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

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

$f_{r3}$ = lesser of $f_{r2}$ or $S_p$ / $S_v$ = 1

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

| | | |
|---|---|---|
| A | = | $d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$ |
| | = | 4.0761*0.0647*1 + 2*0.274*0.0647*1*(1 - 1) |
| | = | 0.2636 $in^2$ |

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

$A_1$ = larger of the following= 1.3892 $in^2$

| | | |
|---|---|---|
| | = | $d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$ |
| | = | 4.0761*(1*0.4055 - 1*0.0647) - 2*0.274*(1*0.4055 - 1*0.0647)*(1 - 1) |
| | = | 1.3892 $in^2$ |
| | = | $2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$ |
| | = | 2*(0.4055 + 0.274)*(1*0.4055 - 1*0.0647) - 2*0.274*(1*0.4055 - 1*0.0647)*(1 - 1) |
| | = | 0.4632 $in^2$ |

$A_2$ = smaller of the following= 0.5436 $in^2$

| | | |
|---|---|---|
| | = | $5*(t_n - t_{rn})*f_{r2}*t$ |
| | = | 5*(0.274 - 0.0059)*1*0.4055 |
| | = | 0.5436 $in^2$ |
| | = | $2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$ |
| | = | 2*(0.274 - 0.0059)*(2.5*0.274 + 0.5512)*1 |
| | = | 0.6629 $in^2$ |

| | | |
|---|---|---|
| $A_{41}$ | = | $Leg^2*f_{r3}$ |
| | = | $0.3937^2*1$ |
| | = | 0.155 $in^2$ |
| $A_{42}$ | = | $Leg^2*f_{r4}$ |
| | = | $0^2*1$ |
| | = | 0 $in^2$ |

(Part of the weld is outside of the limits)

| | | |
|---|---|---|
| $A_5$ | = | $(D_p - d - 2*t_n)*t_e*f_{r4}$ |
| | = | (8.1522 - 4.6355)*0.5512*1 |
| | = | 1.9383 $in^2$ |
| Area | = | $A_1 + A_2 + A_{41} + A_{42} + A_5$ |
| | = | 1.3892 + 0.5436 + 0.155 + 0 + 1.9383 |
| | = | 4.0261 $in^2$ |

As Area >= A the reinforcement is adequate.

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

Inner fillet: $t_{min}$ = lesser of 0.75 or $t_n$ or $t_e$ = 0.274 in

$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.1918 in

$t_{c(actual)}$ = 0.7*Leg = 0.7*0.3937 = 0.2756 in

Outer fillet: $t_{min}$ = lesser of 0.75 or $t_e$ or t = 0.4055 in

$t_{w(min)}$ = $0.5*t_{min}$ = 0.2028 in

$t_{w(actual)}$ = 0.7*Leg = 0.7*0.3937 = 0.2756 in

**UG-45 Nozzle Neck Thickness Check**

Interpretation VIII-1-83-66 has been applied.

Wall thickness per UG-45(a): $t_{r1}$ = 0.2795 in (E =1) (pressure plus external loads govern in longitudinal direction)

| | |
|---|---|
| Wall thickness per UG-45(b)(1): | $t_{r2}$ = 0.1348 in |
| Wall thickness per UG-16(b): | $t_{r3}$ = 0.1255 in |
| Standard wall pipe per UG-45(b)(4): | $t_{r4}$ = 0.2704 in |
| The greater of $t_{r2}$ or $t_{r3}$: | $t_{r5}$ = 0.1348 in |
| The lesser of $t_{r4}$ or $t_{r5}$: | $t_{r6}$ = 0.1348 in |

Required per UG-45 is the larger of $t_{r1}$ or $t_{r6}$ = 0.2795 in

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

The nozzle neck thickness is adequate.

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

| | | |
|---|---|---|
| Groove weld in tension: | 0.74*16,700 = | 12,358 psi |
| Nozzle wall in shear: | 0.7*16,700 = | 11,690 psi |
| Inner fillet weld in shear: | 0.49*16,700 = | 8,183 psi |
| Outer fillet weld in shear: | 0.49*16,700 = | 8,183 psi |
| Upper groove weld in tension: | 0.74*16,700 = | 12,358 psi |

**Strength of welded joints:**

(1) Inner fillet weld in shear
$(\pi / 2)$*Nozzle OD*Leg*$S_i$ = $(\pi / 2)$*4.5*0.3937*8,183 = 22,772.53 $lb_f$

(2) Outer fillet weld in shear
$(\pi / 2)$*Pad OD*Leg*$S_o$ = $(\pi / 2)$*8.2678*0.3937*8,183 = 41,839.63 $lb_f$

(3) Nozzle wall in shear
$(\pi / 2)$*Mean nozzle dia*$t_n$*$S_n$ = $(\pi / 2)$*4.226*0.274*11,690 = 21,263.08 $lb_f$

(4) Groove weld in tension
$(\pi / 2)$*Nozzle OD*$t_w$*$S_g$ = $(\pi / 2)$*4.5*0.4055*12,358 = 35,422.21 $lb_f$

(6) Upper groove weld in tension
$(\pi / 2)$*Nozzle OD*$t_w$*$S_g$ = $(\pi / 2)$*4.5*0.5512*12,358 = 48,147.63 $lb_f$

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

$$
\begin{aligned}
W &= (A - A_1 + 2 * t_n * f_{r1} * (E_1 * t - F * t_r)) * S_v \\
&= (0.2636 - 1.3892 + 2*0.274*1*(1*0.4055 - 1*0.0647))*16{,}700 \\
&= -15{,}677.64\ lb_f
\end{aligned}
$$

$$
\begin{aligned}
W_{1\text{-}1} &= (A_2 + A_5 + A_{41} + A_{42}) * S_v \\
&= (0.5436 + 1.9383 + 0.155 + 0)*16{,}700 \\
&= 44{,}036.87\ lb_f
\end{aligned}
$$

$$
\begin{aligned}
W_{2\text{-}2} &= (A_2 + A_3 + A_{41} + A_{43} + 2 * t_n * t * f_{r1}) * S_v \\
&= (0.5436 + 0 + 0.155 + 0 + 2*0.274*0.4055*1)*16{,}700 \\
&= 15{,}377.74\ lb_f
\end{aligned}
$$

$$
\begin{aligned}
W_{3\text{-}3} &= (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2 * t_n * t * f_{r1}) * S_v \\
&= (0.5436 + 0 + 1.9383 + 0.155 + 0 + 0 + 2*0.274*0.4055*1)*16{,}700 \\
&= 47{,}747.99\ lb_f
\end{aligned}
$$

Load for path 1-1 lesser of W or $W_{1\text{-}1}$ = -15677.64 $lb_f$
Path 1-1 through (2) & (3) = 41,839.63 + 21,263.08 = 63,102.7 $lb_f$
Path 1-1 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 2-2 lesser of W or $W_{2\text{-}2}$ = -15677.64 $lb_f$
Path 2-2 through (1), (4), (6) = 22,772.53 + 35,422.21 + 48,147.63 = 106,342.36 $lb_f$
Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 3-3 lesser of W or $W_{3\text{-}3}$ = -15677.64 $lb_f$

Path 3-3 through (2), (4) = 41,839.63 + 35,422.21 = 77,261.84 $lb_f$
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

**Applied Loads**

| | | |
|---|---|---|
| Radial load: | $P_r$ = | -967.83 $lb_f$ |
| Circumferential moment: | $M_1$ = | 38,624.29 $lb_f$-in |
| Circumferential shear: | $V_2$ = | 1,933.46 $lb_f$ |
| Longitudinal moment: | $M_2$ = | 38,624.29 $lb_f$-in |
| Longitudinal shear: | $V_1$ = | 1,933.46 $lb_f$ |
| Torsion moment: | $M_t$ = | 27,254 $lb_f$-in |
| Internal pressure: | P = | 50 psi |
| Head yield stress: | $S_y$ = | 20,200 psi |

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

Mean dish radius $R_m$ = 43.6746 in

U = $r_o$ / Sqr($R_m$*t) = 0.966
Pressure stress intensity factor, I = 1 (derived from PVP-Vol. 399, pages 77-82)

Local pressure stress = I*P*$R_i$ / (2*t) =2,680 psi

Maximum combined stress ($P_L$+$P_b$+Q) = 35,573 psi
Allowable combined stress ($P_L$+$P_b$+Q ) = +-3*S = +-50,100 psi

Note: The allowable combined stress ($P_L$+$P_b$+Q) is based on the strain hardening characteristics of this material.
The maximum combined stress ($P_L$+$P_b$+Q) is within allowable limits.

Maximum local primary membrane stress ($P_L$) = 7,630 psi
Allowable local primary membrane stress ($P_L$) = +-1.5*S = +-25,050 psi

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

| Stresses at the pad edge per WRC Bulletin 107 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Figure** | **value** | $A_u$ | $A_l$ | $B_u$ | $B_l$ | $C_u$ | $C_l$ | $D_u$ | $D_l$ |
| SR-2* | 0.0692 | 407 | 407 | 407 | 407 | 407 | 407 | 407 | 407 |
| SR-2 | 0.037 | 1,307 | -1,307 | 1,307 | -1,307 | 1,307 | -1,307 | 1,307 | -1,307 |
| SR-3* | 0.0814 | 0 | 0 | 0 | 0 | -4,543 | -4,543 | 4,543 | 4,543 |
| SR-3 | 0.0794 | 0 | 0 | 0 | 0 | -26,591 | 26,591 | 26,591 | -26,591 |
| SR-3* | 0.0814 | -4,543 | -4,543 | 4,543 | 4,543 | 0 | 0 | 0 | 0 |
| SR-3 | 0.0794 | -26,591 | 26,591 | 26,591 | -26,591 | 0 | 0 | 0 | 0 |
| **Pressure stress*** | | 2,680 | 2,680 | 2,680 | 2,680 | 2,680 | 2,680 | 2,680 | 2,680 |
| **Total $O_x$ stress** | | -26,740 | 23,828 | 35,528 | -20,268 | -26,740 | 23,828 | 35,528 | -20,268 |
| **Membrane $O_x$ stress*** | | -1,456 | -1,456 | 7,630 | 7,630 | -1,456 | -1,456 | 7,630 | 7,630 |
| SR-2* | 0.0215 | 127 | 127 | 127 | 127 | 127 | 127 | 127 | 127 |
| SR-2 | 0.0111 | 392 | -392 | 392 | -392 | 392 | -392 | 392 | -392 |
| SR-3* | 0.0245 | 0 | 0 | 0 | 0 | -1,367 | -1,367 | 1,367 | 1,367 |
| SR-3 | 0.0239 | 0 | 0 | 0 | 0 | -8,004 | 8,004 | 8,004 | -8,004 |
| SR-3* | 0.0245 | -1,367 | -1,367 | 1,367 | 1,367 | 0 | 0 | 0 | 0 |
| SR-3 | 0.0239 | -8,004 | 8,004 | 8,004 | -8,004 | 0 | 0 | 0 | 0 |
| **Pressure stress*** | | 2,680 | 2,680 | 2,680 | 2,680 | 2,680 | 2,680 | 2,680 | 2,680 |
| **Total $O_y$ stress** | | -6,172 | 9,052 | 12,570 | -4,222 | -6,172 | 9,052 | 12,570 | -4,222 |
| **Membrane $O_y$ stress*** | | 1,440 | 1,440 | 4,174 | 4,174 | 1,440 | 1,440 | 4,174 | 4,174 |
| **Shear from $M_t$** | | 647 | 647 | 647 | 647 | 647 | 647 | 647 | 647 |
| **Shear from $V_1$** | | 0 | 0 | 0 | 0 | -373 | -373 | 373 | 373 |
| **Shear from $V_2$** | | 373 | 373 | -373 | -373 | 0 | 0 | 0 | 0 |
| **Total Shear stress** | | 1,020 | 1,020 | 274 | 274 | 274 | 274 | 1,020 | 1,020 |
| **Combined stress ($P_L$+$P_b$+Q)** | | -26,790 | 23,898 | 35,531 | -20,273 | -26,744 | 23,833 | 35,573 | -20,333 |

Notes: (1) * denotes primary stress.

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

**Maximum stresses due to the applied loads at the nozzle OD (includes pressure)**

Mean dish radius $R_m$ = 43.6746 in

U = $r_o$ / Sqr($R_m$*t) = 0.348
Pressure stress intensity factor, I = 0.33279 (derived from PVP-Vol. 399, pages 77-82)

Local pressure stress = I*P*$R_i$ / (2*t) =892 psi

Maximum combined stress ($P_L$+$P_b$+Q) = 18,439 psi
Allowable combined stress ($P_L$+$P_b$+Q ) = +-3*S = +-50,100 psi

Note: The allowable combined stress ($P_L$+$P_b$+Q) is based on the strain hardening characteristics of this material.
The maximum combined stress ($P_L$+$P_b$+Q) is within allowable limits.

Maximum local primary membrane stress ($P_L$) = 2,141 psi
Allowable local primary membrane stress ($P_L$) = +-1.5*S = +-25,050 psi

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

| Stresses at the nozzle OD per WRC Bulletin 107 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Figure** | **value** | **$A_u$** | **$A_l$** | **$B_u$** | **$B_l$** | **$C_u$** | **$C_l$** | **$D_u$** | **$D_l$** |
| SR-2* | 0.1737 | 184 | 184 | 184 | 184 | 184 | 184 | 184 | 184 |
| SR-2 | 0.1208 | 766 | -766 | 766 | -766 | 766 | -766 | 766 | -766 |
| SR-3* | 0.1631 | 0 | 0 | 0 | 0 | -1,065 | -1,065 | 1,065 | 1,065 |
| SR-3 | 0.3936 | 0 | 0 | 0 | 0 | -15,418 | 15,418 | 15,418 | -15,418 |
| SR-3* | 0.1631 | -1,065 | -1,065 | 1,065 | 1,065 | 0 | 0 | 0 | 0 |
| SR-3 | 0.3936 | -15,418 | 15,418 | 15,418 | -15,418 | 0 | 0 | 0 | 0 |
| **Pressure stress*** | | 892 | 892 | 892 | 892 | 892 | 892 | 892 | 892 |
| **Total $O_x$ stress** | | -14,641 | 14,663 | 18,325 | -14,043 | -14,641 | 14,663 | 18,325 | -14,043 |
| **Membrane $O_x$ stress*** | | 11 | 11 | 2,141 | 2,141 | 11 | 11 | 2,141 | 2,141 |
| SR-2* | 0.0522 | 55 | 55 | 55 | 55 | 55 | 55 | 55 | 55 |
| SR-2 | 0.0372 | 236 | -236 | 236 | -236 | 236 | -236 | 236 | -236 |
| SR-3* | 0.05 | 0 | 0 | 0 | 0 | -326 | -326 | 326 | 326 |
| SR-3 | 0.1189 | 0 | 0 | 0 | 0 | -4,658 | 4,658 | 4,658 | -4,658 |
| SR-3* | 0.05 | -326 | -326 | 326 | 326 | 0 | 0 | 0 | 0 |
| SR-3 | 0.1189 | -4,658 | 4,658 | 4,658 | -4,658 | 0 | 0 | 0 | 0 |
| **Pressure stress*** | | 892 | 892 | 892 | 892 | 892 | 892 | 892 | 892 |
| **Total $O_y$ stress** | | -3,801 | 5,043 | 6,167 | -3,621 | -3,801 | 5,043 | 6,167 | -3,621 |
| **Membrane $O_y$ stress*** | | 621 | 621 | 1,273 | 1,273 | 621 | 621 | 1,273 | 1,273 |
| **Shear from $M_t$** | | 896 | 896 | 896 | 896 | 896 | 896 | 896 | 896 |
| **Shear from $V_1$** | | 0 | 0 | 0 | 0 | -286 | -286 | 286 | 286 |
| **Shear from $V_2$** | | 286 | 286 | -286 | -286 | 0 | 0 | 0 | 0 |
| **Total Shear stress** | | 1,182 | 1,182 | 610 | 610 | 610 | 610 | 1,182 | 1,182 |
| **Combined stress ($P_L$+$P_b$+Q)** | | -14,768 | 14,806 | 18,356 | -14,079 | -14,675 | 14,702 | 18,439 | -14,175 |

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**

$\sigma_{n\ (Pm)} = P*R_i / (2*t_n) - P_r / (\pi*(R_o^2 - R_i^2)) + M*R_o / I$
= 50*1.976 / (2*0.2319) - -967.83 / (π*(2.25² - 1.976²)) + 54,623*2.25 / 8.1551
= 15,550 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 ( i  ≤S = 16,700 psi)

**Shear stress in the nozzle wall due to external loads**

$\sigma_{shear} = (V_L^2 + V_c^2)^{0.5} / (\pi*R_i*t_n)$
$= (1{,}933.46^2 + 1{,}933.46^2)^{0.5} / (\pi*1.976*0.274)$
= 1,608 psi

$\sigma_{torsion} = M_t / (2*\pi*R_i^2*t_n)$
$= 27{,}254 / (2*\pi*1.976^2*0.274)$
= 4,054 psi

$\sigma_{total} = \sigma_{shear} + \sigma_{torsion}$
= 1,608 + 4,054
= 5,662 psi

UG-45(c): The total combined shear stress (5,662 psi) is below than the allowable ($0.7*S_n$ = 0.7*16,700 = 11,690 psi)

**Reinforcement Calculations for External Pressure**

| UG-37 Area Calculation Summary ($in^2$) For Pe = 15 psi @ 115 °F The opening is adequately reinforced | | | | | | | UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45 | |
|---|---|---|---|---|---|---|---|---|
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| 0.2572 | 3.7331 | 1.1384 | 0.5015 | -- | 1.9382 | 0.155 | 0.2766 | 0.2949 |

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

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| Weld description | Required weld size (in) | Actual weld size (in) | Status |
| Nozzle to pad fillet ($Leg_{41}$) | 0.1918 | 0.2756 | weld size is adequate |
| Pad to shell fillet ($Leg_{42}$) | 0.2027 | 0.2756 | weld size is adequate |
| Nozzle to pad groove (Upper) | 0.1918 | 0.5512 | weld size is adequate |

**Calculations for external pressure 15 psi @ 115 °F**

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

$L_R$ = MAX(d, $R_n$ + ($t_n$ - $C_n$) + (t - C))
= MAX(4.076, 2.038 + (0.337 - 0.063) + (0.4685 - 0.063))
= 4.076 in

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

$L_H$ = MIN(2.5*(t - C), 2.5*($t_n$ - $C_n$) + $t_e$)
= MIN(2.5*(0.4685 - 0.063), 2.5*(0.337 - 0.063) + 0.5512)
= 1.0138 in

**Nozzle required thickness per UG-28 $t_{rn}$ = 0.0267 in**

**From UG-37(d)(1) required thickness $t_r$ = 0.1262 in**

**Area required per UG-37(d)(1)**

Allowable stresses: $S_n$ = 16,700, $S_v$ = 16,700, $S_p$ = 16,700 psi

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

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

$f_{r3}$ = lesser of $f_{r2}$ or $S_p$ / $S_v$ = 1

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

A = 0.5*(d*$t_r$*F + 2*$t_n$*$t_r$*F*(1 - $f_{r1}$))
= 0.5*(4.076*0.1262*1 + 2*0.274*0.1262*1*(1 - 1))
= 0.2572 $in^2$

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

$A_1$ = larger of the following= 1.1384 $in^2$

= d*($E_1$*t - F*$t_r$) - 2*$t_n$*($E_1$*t - F*$t_r$)*(1 - $f_{r1}$)
= 4.076*(1*0.4055 - 1*0.1262) - 2*0.274*(1*0.4055 - 1*0.1262)*(1 - 1)
= 1.1384 $in^2$

= $2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= $2*(0.4055 + 0.274)*(1*0.4055 - 1*0.1262) - 2*0.274*(1*0.4055 - 1*0.1262)*(1 - 1)$
= 0.3796 $in^2$

$A_2$ = smaller of the following= 0.5015 $in^2$

= $5*(t_n - t_{rn})*f_{r2}*t$
= $5*(0.274 - 0.0267)*1*0.4055$
= 0.5015 $in^2$

= $2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
= $2*(0.274 - 0.0267)*(2.5*0.274 + 0.5512)*1$
= 0.6116 $in^2$

$A_{41}$ = $Leg^2*f_{r3}$
= $0.3937^2*1$
= 0.155 $in^2$

$A_{42}$ = $Leg^2*f_{r4}$
= $0^2*1$
= 0 $in^2$

(Part of the weld is outside of the limits)

$A_5$ = $(D_p - d - 2*t_n)*t_e*f_{r4}$
= $(8.152 - 4.6355)*0.5512*1$
= 1.9382 $in^2$

Area = $A_1 + A_2 + A_{41} + A_{42} + A_5$
= $1.1384 + 0.5015 + 0.155 + 0 + 1.9382$
= 3.7331 $in^2$

As Area >= A the reinforcement is adequate.

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

Inner fillet: $t_{min}$ = lesser of 0.75 or $t_n$ or $t_e$ = 0.274 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.1918 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.3937 = 0.2756 in

Outer fillet: $t_{min}$ = lesser of 0.75 or $t_e$ or t = 0.4055 in
$t_{w(min)}$ = $0.5*t_{min}$ = 0.2028 in
$t_{w(actual)}$ = 0.7*Leg = 0.7*0.3937 = 0.2756 in

**UG-45 Nozzle Neck Thickness Check**

Interpretation VIII-1-83-66 has been applied.

| | |
|---|---|
| Wall thickness per UG-45(a): | $t_{r1}$ = 0.2766 in (pressure plus external loads govern in longitudinal direction) |
| Wall thickness per UG-45(b)(2): | $t_{r2}$ = 0.0845 in |
| Wall thickness per UG-16(b): | $t_{r3}$ = 0.1255 in |
| Standard wall pipe per UG-45(b)(4): | $t_{r4}$ = 0.2704 in |
| The greater of $t_{r2}$ or $t_{r3}$: | $t_{r5}$ = 0.1255 in |
| The lesser of $t_{r4}$ or $t_{r5}$: | $t_{r6}$ = 0.1255 in |

Required per UG-45 is the larger of $t_{r1}$ or $t_{r6}$ = 0.2766 in

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

The nozzle neck thickness is adequate.

**External Pressure, (Corroded & at 115 °F) UG-28(c)**

$L / D_o$ = 19.4512 / 4.5 = 4.3225
$D_o / t$ = 4.5 / 0.0267 = 168.8481
From table G: A = 0.000134
From table HA-3: B = 1,899.5408 psi

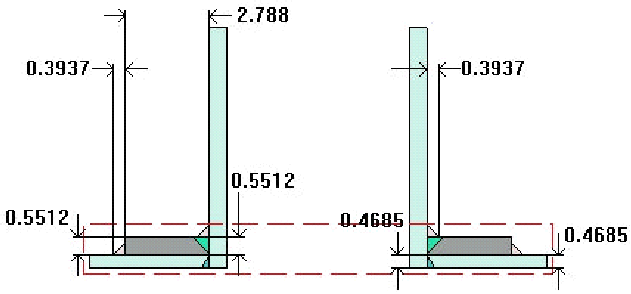
$P_a$ = 4*B / (3*($D_o$ / t))
= 4*1,899.54 / (3*(4.5 / 0.0267))
= 15 psi

**Design thickness for external pressure $P_a$ = 15 psi**

$t_a$ = t + Corrosion = 0.0267 + 0.063 = 0.0896"

**14" (AO)**

**ASME Section VIII Division 1, 2007 Edition, A09 Addenda**




$t_{w(lower)}$ = 0.4685 in

$Leg_{41}$ = 0.3937 in

$t_{w(upper)}$ = 0.5512 in

$Leg_{42}$ = 0.3937 in

$D_p$ = 19.6849 in

$t_e$ = 0.5512 in

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

| | |
|---|---|
| Located on: | TOP HEAD |
| Liquid static head included: | 0 psi |
| Nozzle material specification: | SA-240 304L (II-D p. 82, ln. 38) |
| Nozzle longitudinal joint efficiency: | 1 |
| Pad material specification: | SA-240 304L (II-D p. 82, ln. 38) |
| Pad diameter: | 19.6849 in |
| Flange description: | 14 inch Class 150 WN A182 F304L |
| Bolt Material: | SA-193 B7 Bolt <= 2 1/2 (II-D p. 348, ln. 33) |
| Flange rated MDMT: | -55°F |
| (Per UHA-51(d)(1)(a)) | |
| (Flange rated MDMT = -320 °F<br>Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F) | |
| Liquid static head on flange: | 0 psi |
| ASME B16.5 flange rating MAWP: | 185 psi @ 250°F |
| ASME B16.5 flange rating MAP: | 230 psi @ 68°F |
| ASME B16.5 flange hydro test: | 350 psi @ 68°F |
| Gasket Description: | Flexitallic Spiral Wound CG 304L S.S. |
| PWHT performed: | No |
| Circumferential joint radiography: | Spot UW-11(b) Type 1 |
| Nozzle orientation: | 125° |
| Calculated as hillside: | Yes |
| Local vessel minimum thickness: | 0.4685 in |
| End of nozzle to datum line: | 174.0157 in |
| Nozzle inside diameter, new: | 12.8976 in |
| Nozzle nominal wall thickness: | 0.5512 in |
| Nozzle corrosion allowance: | 0.063 in |
| Opening chord length: | 13.128 in |
| Projection available outside vessel, Lpr: | 12.5519 in |
| Projection available outside vessel to flange face, Lf: | 17.5519 in |
| Distance to head center, R: | 5.6693 in |
| Pad is split: | No |

**Reinforcement Calculations for Internal Pressure**

| UG-37 Area Calculation Summary ($in^2$) For P = 50 psi @ 250 °F The opening is adequately reinforced | | | | | | | UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45 | |
|---|---|---|---|---|---|---|---|---|
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| 0.8491 | 8.808 | 4.4743 | 0.9503 | -- | 3.0734 | 0.31 | 0.3106 | 0.5512 |

| UG-41 Weld Failure Path Analysis Summary ($lb_f$) All failure paths are stronger than the applicable weld loads | | | | | | |
|---|---|---|---|---|---|---|
| Weld load W | Weld load $W_{1-1}$ | Path 1-1 strength | Weld load $W_{2-2}$ | Path 2-2 strength | Weld load $W_{3-3}$ | Path 3-3 strength |
| -54,983.21 | 72,372.41 | 220,742.16 | 25,070.46 | 330,842.94 | 78,984.36 | 209,819 |

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| Weld description | Required weld size (in) | Actual weld size (in) | Status |
| Nozzle to pad fillet ($Leg_{41}$) | 0.25 | 0.2756 | weld size is adequate |
| Pad to shell fillet ($Leg_{42}$) | 0.2027 | 0.2756 | weld size is adequate |
| Nozzle to pad groove (Upper) | 0.3417 | 0.5512 | weld size is adequate |

**Calculations for internal pressure 50 psi @ 250 °F**

Nozzle Impact test exempt per UHA-51(g)(coincident ratio = 0.15951).
Pad Impact test exempt per UHA-51(g)(coincident ratio = 0.15951).

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

$L_R$ = MAX(d, $R_n$ + ($t_n$ - $C_n$) + (t - C))
= MAX(13.128, 6.564 + (0.5512 - 0.063) + (0.4685 - 0.063))
= 13.128 in

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

$L_H$ = MIN(2.5*(t - C), 2.5*($t_n$ - $C_n$) + $t_e$)
= MIN(2.5*(0.4685 - 0.063), 2.5*(0.5512 - 0.063) + 0.5512)
= 1.0138 in

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

$t_{rn}$ = P*$R_n$ / ($S_n$*E - 0.6*P)
= 50*6.5118 / (16,700*1 - 0.6*50)
= 0.0195 in

**Required thickness $t_r$ from UG-37(a)(c)**

$t_r$ = P*$K_1$*D / (2*S*E - 0.2*P)
= 50*0.8976*48.1181 / (2*16,700*1 - 0.2*50)
= 0.0647 in

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

Allowable stresses: $S_n$ = 16,700, $S_v$ = 16,700, $S_p$ = 16,700 psi

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

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

$f_{r3}$ = lesser of $f_{r2}$ or $S_p$ / $S_v$ = 1

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

| | | |
|---|---|---|
| A | = | $d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$ |
| | = | 13.128*0.0647*1 + 2*0.4882*0.0647*1*(1 - 1) |
| | = | 0.8491 $in^2$ |

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

$A_1$ = larger of the following= 4.4743 $in^2$

| | |
|---|---|
| = | $d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$ |
| = | 13.128*(1*0.4055 - 1*0.0647) - 2*0.4882*(1*0.4055 - 1*0.0647)*(1 - 1) |
| = | 4.4743 $in^2$ |
| = | $2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$ |
| = | 2*(0.4055 + 0.4882)*(1*0.4055 - 1*0.0647) - 2*0.4882*(1*0.4055 - 1*0.0647)*(1 - 1) |
| = | 0.6092 $in^2$ |

$A_2$ = smaller of the following= 0.9503 $in^2$

| | |
|---|---|
| = | $5*(t_n - t_{rn})*f_{r2}*t$ |
| = | 5*(0.4882 - 0.0195)*1*0.4055 |
| = | 0.9503 $in^2$ |
| = | $2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$ |
| = | 2*(0.4882 - 0.0195)*(2.5*0.4882 + 0.5512)*1 |
| = | 1.6607 $in^2$ |

| | | |
|---|---|---|
| $A_{41}$ | = | $Leg^2*f_{r3}$ |
| | = | $0.3937^2*1$ |
| | = | 0.155 $in^2$ |
| $A_{42}$ | = | $Leg^2*f_{r4}$ |
| | = | $0.3937^2*1$ |
| | = | 0.155 $in^2$ |
| $A_5$ | = | $(D_p - d - 2*t_n)*t_e*f_{r4}$ |
| | = | (19.6849 - 14.1089)*0.5512*1 |
| | = | 3.0734 $in^2$ |
| Area | = | $A_1 + A_2 + A_{41} + A_{42} + A_5$ |
| | = | 4.4743 + 0.9503 + 0.155 + 0.155 + 3.0734 |
| | = | 8.808 $in^2$ |

As Area >= A the reinforcement is adequate.

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

Inner fillet: $t_{min}$ = lesser of 0.75 or $t_n$ or $t_e$ = 0.4882 in

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

$t_{c(actual)}$ = 0.7*Leg = 0.7*0.3937 = 0.2756 in

Outer fillet: $t_{min}$ = lesser of 0.75 or $t_e$ or t = 0.4055 in

$t_{w(min)}$ = $0.5*t_{min}$ = 0.2028 in

$t_{w(actual)}$ = 0.7*Leg = 0.7*0.3937 = 0.2756 in

**UG-45 Nozzle Neck Thickness Check**

Interpretation VIII-1-83-66 has been applied.

Wall thickness per UG-45(a): $t_{r1}$ = 0.3106 in (E =1) (pressure plus external loads govern in longitudinal direction)

Wall thickness per UG-45(b)(1): $t_{r2}$ = 0.1348 in

Wall thickness per UG-16(b): $t_{r3}$ = 0.1255 in

| | |
|---|---|
| Standard wall pipe per UG-45(b)(4): | $t_{r4}$ = 0.3911 in |
| The greater of $t_{r2}$ or $t_{r3}$: | $t_{r5}$ = 0.1348 in |
| The lesser of $t_{r4}$ or $t_{r5}$: | $t_{r6}$ = 0.1348 in |

Required per UG-45 is the larger of $t_{r1}$ or $t_{r6}$ = 0.3106 in

Available nozzle wall thickness new, $t_n$ = 0.5512 in

The nozzle neck thickness is adequate.

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

| | | |
|---|---|---|
| Groove weld in tension: | 0.74*16,700 = | 12,358 psi |
| Nozzle wall in shear: | 0.7*16,700 = | 11,690 psi |
| Inner fillet weld in shear: | 0.49*16,700 = | 8,183 psi |
| Outer fillet weld in shear: | 0.49*16,700 = | 8,183 psi |
| Upper groove weld in tension: | 0.74*16,700 = | 12,358 psi |

**Strength of welded joints:**

(1) Inner fillet weld in shear
$(\pi / 2)$*Nozzle OD*Leg*$S_i$ = $(\pi / 2)$*14*0.3937*8,183 = 70,847.87 $lb_f$

(2) Outer fillet weld in shear
$(\pi / 2)$*Pad OD*Leg*$S_o$ = $(\pi / 2)$*19.6849*0.3937*8,183 = 99,616.57 $lb_f$

(3) Nozzle wall in shear
$(\pi / 2)$*Mean nozzle dia*$t_n$*$S_n$ = $(\pi / 2)$*13.5118*0.4882*11,690 = 121,125.59 $lb_f$

(4) Groove weld in tension
$(\pi / 2)$*Nozzle OD*$t_w$*$S_g$ = $(\pi / 2)$*14*0.4055*12,358 = 110,202.44 $lb_f$

(6) Upper groove weld in tension
$(\pi / 2)$*Nozzle OD*$t_w$*$S_g$ = $(\pi / 2)$*14*0.5512*12,358 = 149,792.63 $lb_f$

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

$$
\begin{aligned}
W &= (A - A_1 + 2*t_n*f_{r1}*(E_1*t - F*t_r))*S_v \\
&= (0.8491 - 4.4743 + 2*0.4882*1*(1*0.4055 - 1*0.0647))*16{,}700 \\
&= -54{,}983.21\ lb_f
\end{aligned}
$$

$$
\begin{aligned}
W_{1-1} &= (A_2 + A_5 + A_{41} + A_{42})*S_v \\
&= (0.9503 + 3.0734 + 0.155 + 0.155)*16{,}700 \\
&= 72{,}372.41\ lb_f
\end{aligned}
$$

$$
\begin{aligned}
W_{2-2} &= (A_2 + A_3 + A_{41} + A_{43} + 2*t_n*t*f_{r1})*S_v \\
&= (0.9503 + 0 + 0.155 + 0 + 2*0.4882*0.4055*1)*16{,}700 \\
&= 25{,}070.46\ lb_f
\end{aligned}
$$

$$
\begin{aligned}
W_{3-3} &= (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2*t_n*t*f_{r1})*S_v \\
&= (0.9503 + 0 + 3.0734 + 0.155 + 0.155 + 0 + 2*0.4882*0.4055*1)*16{,}700 \\
&= 78{,}984.36\ lb_f
\end{aligned}
$$

Load for path 1-1 lesser of W or $W_{1-1}$ = -54983.21 $lb_f$
Path 1-1 through (2) & (3) = 99,616.57 + 121,125.6 = 220,742.16 $lb_f$
Path 1-1 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 2-2 lesser of W or $W_{2-2}$ = -54983.21 $lb_f$
Path 2-2 through (1), (4), (6) = 70,847.87 + 110,202.4 + 149,792.6 = 330,842.94 $lb_f$
Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 3-3 lesser of W or $W_{3-3}$ = -54983.21 $lb_f$
Path 3-3 through (2), (4) = 99,616.57 + 110,202.4 = 209,819 $lb_f$
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

**Applied Loads**

| | | |
|---|---|---|
| Radial load: | $P_r$ = | -3,668.5 $lb_f$ |
| Circumferential moment: | $M_1$ = | 373,049.91 $lb_f$-in |
| Circumferential shear: | $V_2$ = | 7,350.22 $lb_f$ |
| Longitudinal moment: | $M_2$ = | 373,049.91 $lb_f$-in |
| Longitudinal shear: | $V_1$ = | 7,350.22 $lb_f$ |
| Torsion moment: | $M_t$ = | 263,773.56 $lb_f$-in |
| Internal pressure: | P = | 50 psi |
| Head yield stress: | $S_y$ = | 20,200 psi |

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

Mean dish radius $R_m$ = 43.6746 in

U = $r_o$ / Sqr($R_m$*t) = 2.326 > 2.2 so let U = 2.2
Pressure stress intensity factor, I = 1 (derived from PVP-Vol. 399, pages 77-82)

Local pressure stress = I*P*$R_i$ / (2*t) =2,680 psi

Maximum combined stress ($P_L$+$P_b$+Q) = 47,727 psi
Allowable combined stress ($P_L$+$P_b$+Q ) = +-3*S = +-50,100 psi

Note: The allowable combined stress ($P_L$+$P_b$+Q) is based on the strain hardening characteristics of this material.
The maximum combined stress ($P_L$+$P_b$+Q) is within allowable limits.

Maximum local primary membrane stress ($P_L$) = 12,336 psi
Allowable local primary membrane stress ($P_L$) = +-1.5*S = +-25,050 psi

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

| Stresses at the pad edge per WRC Bulletin 107 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Figure** | **value** | **$A_u$** | **$A_l$** | **$B_u$** | **$B_l$** | **$C_u$** | **$C_l$** | **$D_u$** | **$D_l$** |
| SR-2* | 0.022 | 491 | 491 | 491 | 491 | 491 | 491 | 491 | 491 |
| SR-2 | 0.01 | 1,339 | -1,339 | 1,339 | -1,339 | 1,339 | -1,339 | 1,339 | -1,339 |
| SR-3* | 0.017 | 0 | 0 | 0 | 0 | -9,165 | -9,165 | 9,165 | 9,165 |
| SR-3 | 0.0105 | 0 | 0 | 0 | 0 | -33,963 | 33,963 | 33,963 | -33,963 |
| SR-3* | 0.017 | -9,165 | -9,165 | 9,165 | 9,165 | 0 | 0 | 0 | 0 |
| SR-3 | 0.0105 | -33,963 | 33,963 | 33,963 | -33,963 | 0 | 0 | 0 | 0 |
| **Pressure stress*** | | 2,680 | 2,680 | 2,680 | 2,680 | 2,680 | 2,680 | 2,680 | 2,680 |
| **Total $O_x$ stress** | | -38,618 | 26,630 | 47,638 | -22,966 | -38,618 | 26,630 | 47,638 | -22,966 |
| **Membrane $O_x$ stress*** | | -5,994 | -5,994 | 12,336 | 12,336 | -5,994 | -5,994 | 12,336 | 12,336 |
| SR-2* | 0.0066 | 147 | 147 | 147 | 147 | 147 | 147 | 147 | 147 |
| SR-2 | 0.003 | 402 | -402 | 402 | -402 | 402 | -402 | 402 | -402 |
| SR-3* | 0.005 | 0 | 0 | 0 | 0 | -2,695 | -2,695 | 2,695 | 2,695 |
| SR-3 | 0.0032 | 0 | 0 | 0 | 0 | -10,351 | 10,351 | 10,351 | -10,351 |
| SR-3* | 0.005 | -2,695 | -2,695 | 2,695 | 2,695 | 0 | 0 | 0 | 0 |
| SR-3 | 0.0032 | -10,351 | 10,351 | 10,351 | -10,351 | 0 | 0 | 0 | 0 |
| **Pressure stress*** | | 2,680 | 2,680 | 2,680 | 2,680 | 2,680 | 2,680 | 2,680 | 2,680 |
| **Total $O_y$ stress** | | -9,817 | 10,081 | 16,275 | -5,231 | -9,817 | 10,081 | 16,275 | -5,231 |
| **Membrane $O_y$ stress*** | | 132 | 132 | 5,522 | 5,522 | 132 | 132 | 5,522 | 5,522 |
| **Shear from $M_t$** | | 1,081 | 1,081 | 1,081 | 1,081 | 1,081 | 1,081 | 1,081 | 1,081 |
| **Shear from $V_1$** | | 0 | 0 | 0 | 0 | -589 | -589 | 589 | 589 |
| **Shear from $V_2$** | | 589 | 589 | -589 | -589 | 0 | 0 | 0 | 0 |
| **Total Shear stress** | | 1,670 | 1,670 | 492 | 492 | 492 | 492 | 1,670 | 1,670 |
| **Combined stress ($P_L$+$P_b$+Q)** | | -38,715 | 26,797 | 47,646 | -22,980 | -38,626 | 26,645 | 47,727 | -23,122 |

Notes: (1) * denotes primary stress.

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

**Maximum stresses due to the applied loads at the nozzle OD (includes pressure)**

Mean dish radius $R_m$ = 43.6746 in

U = $r_o$ / Sqr($R_m$*t) = 1.083
Pressure stress intensity factor, I = 0.54842 (derived from PVP-Vol. 399, pages 77-82)

Local pressure stress = I*P*$R_i$ / (2*t) =1,470 psi

Maximum combined stress ($P_L$+$P_b$+Q) = 31,237 psi
Allowable combined stress ($P_L$+$P_b$+Q ) = +-3*S = +-50,100 psi

Note: The allowable combined stress ($P_L$+$P_b$+Q) is based on the strain hardening characteristics of this material.
The maximum combined stress ($P_L$+$P_b$+Q) is within allowable limits.

Maximum local primary membrane stress ($P_L$) = 6,108 psi
Allowable local primary membrane stress ($P_L$) = +-1.5*S = +-25,050 psi

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

| Stresses at the nozzle OD per WRC Bulletin 107 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Figure | value | $A_u$ | $A_l$ | $B_u$ | $B_l$ | $C_u$ | $C_l$ | $D_u$ | $D_l$ |
| SR-2* | 0.0606 | 243 | 243 | 243 | 243 | 243 | 243 | 243 | 243 |
| SR-2 | 0.0318 | 765 | -765 | 765 | -765 | 765 | -765 | 765 | -765 |
| SR-3* | 0.0697 | 0 | 0 | 0 | 0 | -4,395 | -4,395 | 4,395 | 4,395 |
| SR-3 | 0.0642 | 0 | 0 | 0 | 0 | -24,289 | 24,289 | 24,289 | -24,289 |
| SR-3* | 0.0697 | -4,395 | -4,395 | 4,395 | 4,395 | 0 | 0 | 0 | 0 |
| SR-3 | 0.0642 | -24,289 | 24,289 | 24,289 | -24,289 | 0 | 0 | 0 | 0 |
| **Pressure stress*** | | 1,470 | 1,470 | 1,470 | 1,470 | 1,470 | 1,470 | 1,470 | 1,470 |
| **Total $O_x$ stress** | | -26,206 | 20,842 | 31,162 | -18,946 | -26,206 | 20,842 | 31,162 | -18,946 |
| **Membrane $O_x$ stress*** | | -2,682 | -2,682 | 6,108 | 6,108 | -2,682 | -2,682 | 6,108 | 6,108 |
| SR-2* | 0.0187 | 75 | 75 | 75 | 75 | 75 | 75 | 75 | 75 |
| SR-2 | 0.0096 | 231 | -231 | 231 | -231 | 231 | -231 | 231 | -231 |
| SR-3* | 0.021 | 0 | 0 | 0 | 0 | -1,324 | -1,324 | 1,324 | 1,324 |
| SR-3 | 0.0194 | 0 | 0 | 0 | 0 | -7,340 | 7,340 | 7,340 | -7,340 |
| SR-3* | 0.021 | -1,324 | -1,324 | 1,324 | 1,324 | 0 | 0 | 0 | 0 |
| SR-3 | 0.0194 | -7,340 | 7,340 | 7,340 | -7,340 | 0 | 0 | 0 | 0 |
| **Pressure stress*** | | 1,470 | 1,470 | 1,470 | 1,470 | 1,470 | 1,470 | 1,470 | 1,470 |
| **Total $O_y$ stress** | | -6,888 | 7,330 | 10,440 | -4,702 | -6,888 | 7,330 | 10,440 | -4,702 |
| **Membrane $O_y$ stress*** | | 221 | 221 | 2,869 | 2,869 | 221 | 221 | 2,869 | 2,869 |
| **Shear from $M_t$** | | 896 | 896 | 896 | 896 | 896 | 896 | 896 | 896 |
| **Shear from $V_1$** | | 0 | 0 | 0 | 0 | -349 | -349 | 349 | 349 |
| **Shear from $V_2$** | | 349 | 349 | -349 | -349 | 0 | 0 | 0 | 0 |
| **Total Shear stress** | | 1,245 | 1,245 | 547 | 547 | 547 | 547 | 1,245 | 1,245 |
| **Combined stress ($P_L+P_b+Q$)** | | -26,286 | 20,956 | 31,176 | -18,967 | -26,221 | 20,864 | 31,237 | -19,054 |

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**

$\sigma_{n\ (Pm)} = P*R_i / (2*t_n) - P_r / (\pi*(R_o^2 - R_i^2)) + M*R_o / I$
$= 50*6.5118 / (2*0.4882) - -3{,}668.5 / (\pi*(7^2 - 6.5118^2)) + 527{,}572.3*7 / 473.5381$
$= 8{,}309$ 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 ( ¡ ÂS = 16,700 psi)

**Shear stress in the nozzle wall due to external loads**

$\sigma_{shear} = (V_L^2 + V_c^2)^{0.5} / (\pi*R_i*t_n)$
$= (7{,}350.22^2 + 7{,}350.22^2)^{0.5} / (\pi*6.5118*0.4882)$
$= 1{,}041$ psi

$\sigma_{torsion} = M_t / (2*\pi*R_i^2*t_n)$
$= 263{,}773.6 / (2*\pi*6.5118^2*0.4882)$
$= 2{,}028$ psi

$\sigma_{total} = \sigma_{shear} + \sigma_{torsion}$
$= 1{,}041 + 2{,}028$
$= 3{,}069$ psi

UG-45(c): The total combined shear stress (3,069 psi) is below than the allowable ($0.7*S_n = 0.7*16{,}700 = 11{,}690$ psi)

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

$$
\begin{aligned}
EFE &= (50 * t / R_f) * (1 - R_f / R_o) \\
&= (50 * 0.5512 / 6.7244) * (1 - 6.7244 / \Upsilon\subseteq) \\
&= 4.0984\%
\end{aligned}
$$

**Reinforcement Calculations for External Pressure**

| UG-37 Area Calculation Summary ($in^2$) For Pe = 15 psi @ 115 °F The opening is adequately reinforced | | | | | | | UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45 | |
|---|---|---|---|---|---|---|---|---|
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| 0.8284 | 7.9348 | 3.6665 | 0.8849 | -- | 3.0734 | 0.31 | 0.301 | 0.5512 |

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

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| Weld description | Required weld size (in) | Actual weld size (in) | Status |
| Nozzle to pad fillet ($Leg_{41}$) | 0.25 | 0.2756 | weld size is adequate |
| Pad to shell fillet ($Leg_{42}$) | 0.2027 | 0.2756 | weld size is adequate |
| Nozzle to pad groove (Upper) | 0.3417 | 0.5512 | weld size is adequate |

**Calculations for external pressure 15 psi @ 115 °F**

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

$L_R$ = MAX(d, $R_n$ + ($t_n$ - $C_n$) + (t - C))
= MAX(13.1279, 6.564 + (0.5512 - 0.063) + (0.4685 - 0.063))
= 13.1279 in

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

$L_H$ = MIN(2.5*(t - C), 2.5*($t_n$ - $C_n$) + $t_e$)
= MIN(2.5*(0.4685 - 0.063), 2.5*(0.5512 - 0.063) + 0.5512)
= 1.0138 in

**Nozzle required thickness per UG-28 $t_{rn}$ = 0.0517 in**

**From UG-37(d)(1) required thickness $t_r$ = 0.1262 in**

**Area required per UG-37(d)(1)**

Allowable stresses: $S_n$ = 16,700, $S_v$ = 16,700, $S_p$ = 16,700 psi

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

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

$f_{r3}$ = lesser of $f_{r2}$ or $S_p$ / $S_v$ = 1

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

A = 0.5*(d*$t_r$*F + 2*$t_n$*$t_r$*F*(1 - $f_{r1}$))
= 0.5*(13.1279*0.1262*1 + 2*0.4882*0.1262*1*(1 - 1))
= 0.8284 $in^2$

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

$A_1$ = larger of the following= 3.6665 $in^2$

= d*($E_1$*t - F*$t_r$) - 2*$t_n$*($E_1$*t - F*$t_r$)*(1 - $f_{r1}$)
= 13.1279*(1*0.4055 - 1*0.1262) - 2*0.4882*(1*0.4055 - 1*0.1262)*(1 - 1)
= 3.6665 $in^2$

$= 2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
$= 2*(0.4055 + 0.4882)*(1*0.4055 - 1*0.1262) - 2*0.4882*(1*0.4055 - 1*0.1262)*(1 - 1)$
$= 0.4992$ in$^2$

$A_2$ = smaller of the following= 0.8849 in$^2$

$= 5*(t_n - t_{rn})*f_{r2}*t$
$= 5*(0.4882 - 0.0517)*1*0.4055$
$= 0.8849$ in$^2$

$= 2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
$= 2*(0.4882 - 0.0517)*(2.5*0.4882 + 0.5512)*1$
$= 1.5465$ in$^2$

$A_{41} = Leg^2*f_{r3}$
$= 0.3937^2*1$
$= 0.155$ in$^2$

$A_{42} = Leg^2*f_{r4}$
$= 0.3937^2*1$
$= 0.155$ in$^2$

$A_5 = (D_p - d - 2*t_n)*t_e*f_{r4}$
$= (19.6849 - 14.1089)*0.5512*1$
$= 3.0734$ in$^2$

Area $= A_1 + A_2 + A_{41} + A_{42} + A_5$
$= 3.6665 + 0.8849 + 0.155 + 0.155 + 3.0734$
$= 7.9348$ in$^2$

As Area >= A the reinforcement is adequate.

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

Inner fillet: $t_{min}$ = lesser of 0.75 or $t_n$ or $t_e$ = 0.4882 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.3937 = 0.2756 in

Outer fillet: $t_{min}$ = lesser of 0.75 or $t_e$ or t = 0.4055 in
$t_{w(min)} = 0.5*t_{min}$ = 0.2028 in
$t_{w(actual)}$ = 0.7*Leg = 0.7*0.3937 = 0.2756 in

**UG-45 Nozzle Neck Thickness Check**

Interpretation VIII-1-83-66 has been applied.

| | |
|---|---|
| Wall thickness per UG-45(a): | $t_{r1}$ = 0.301 in (pressure plus external loads govern in longitudinal direction) |
| Wall thickness per UG-45(b)(2): | $t_{r2}$ = 0.0845 in |
| Wall thickness per UG-16(b): | $t_{r3}$ = 0.1255 in |
| Standard wall pipe per UG-45(b)(4): | $t_{r4}$ = 0.3911 in |
| The greater of $t_{r2}$ or $t_{r3}$: | $t_{r5}$ = 0.1255 in |
| The lesser of $t_{r4}$ or $t_{r5}$: | $t_{r6}$ = 0.1255 in |

Required per UG-45 is the larger of $t_{r1}$ or $t_{r6}$ = 0.301 in

Available nozzle wall thickness new, $t_n$ = 0.5512 in

The nozzle neck thickness is adequate.

**External Pressure, (Corroded & at 115 °F) UG-28(c)**

$L / D_o = 19.3353 / 14 = 1.3811$

$D_o$ / t = 14 / 0.0517 = 270.5865
From table G: A = 0.000216
From table HA-3: B = 3,044.1375 psi

$P_a$ = 4*B / (3*($D_o$ / t))
= 4*3,044.14 / (3*(14 / 0.0517))
= 15 psi

**Design thickness for external pressure $P_a$ = 15 psi**

$t_a$ = t + Corrosion = 0.0517 + 0.063 = 0.1147"

**24" (BB)**

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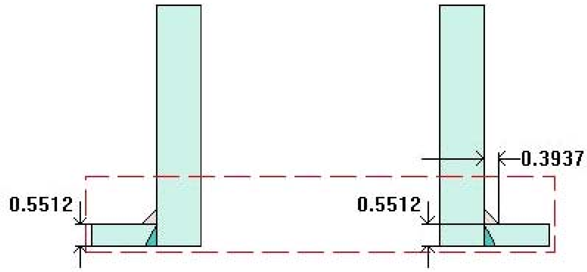
$t_{w(lower)}$ = 0.5512 in

$Leg_{41}$ = 0.3937 in




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

| | |
|---|---|
| Located on: | SHELL |
| Liquid static head included: | 2.235 psi |
| Nozzle material specification: | SA-182 F304L <= 5 (II-D p. 82, ln. 34) |
| Nozzle longitudinal joint efficiency: | 1 |
| Flange description: | 24 inch Class 150 LWN A182 F304L |
| Bolt Material: | SA-193 B7 Bolt <= 2 1/2 (II-D p. 348, ln. 33) |
| Flange rated MDMT: | -55°F |
| (Per UHA-51(d)(1)(a)) | |
| (Flange rated MDMT = -320 °F<br>Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F) | |
| Liquid static head on flange: | 1.7953 psi |
| ASME B16.5 flange rating MAWP: | 185 psi @ 250°F |
| ASME B16.5 flange rating MAP: | 230 psi @ 68°F |
| ASME B16.5 flange hydro test: | 350 psi @ 68°F |
| Gasket Description: | Flexitallic Spiral Wound CG 304L S.S. |
| PWHT performed: | No |
| Nozzle orientation: | 45° |
| Local vessel minimum thickness: | 0.5512 in |
| Nozzle center line offset to datum line: | 30 in |
| End of nozzle to shell center: | 34.0157 in |
| Nozzle inside diameter, new: | 24 in |
| Nozzle nominal wall thickness: | 1.125 in |
| Nozzle corrosion allowance: | 0.063 in |
| Projection available outside vessel, Lpr: | 7.5885 in |
| Projection available outside vessel to flange face, Lf: | 9.4685 in |

**Reinforcement Calculations for Internal Pressure**

| UG-37 Area Calculation Summary ($in^2$) For P = 52.24 psi @ 250 °F The opening is adequately reinforced | | | | | | | UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45 | |
|---|---|---|---|---|---|---|---|---|
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| 1.2126 | 7.6345 | 4.9795 | 2.5 | -- | -- | 0.155 | 0.1008 | 1.125 |

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

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| Weld description | Required weld throat size (in) | Actual weld throat size (in) | Status |
| Nozzle to shell fillet ($Leg_{41}$) | 0.25 | 0.2756 | weld size is adequate |

**Calculations for internal pressure 52.24 psi @ 250 °F**

Nozzle Impact test exempt per UHA-51(g)(coincident ratio = 0.15443).

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

$L_R$ = MAX(d, $R_n$ + ($t_n$ - $C_n$) + (t - C))
= MAX(24.126, 12.063 + (1.125 - 0.063) + (0.5512 - 0.063))
= 24.126 in

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

$L_H$ = MIN(2.5*(t - C), 2.5*($t_n$ - $C_n$) + $t_e$)
= MIN(2.5*(0.5512 - 0.063), 2.5*(1.125 - 0.063) + 0)
= 1.2205 in

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

$t_{rn}$ = P*$R_n$ / ($S_n$*E - 0.6*P)
= 52.235*12.063 / (16,700*1 - 0.6*52.235)
= 0.0378 in

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

$t_r$ = P*R / (S*E - 0.6*P)
= 52.235*24.0591 / (16,700*1 - 0.6*52.235)
= 0.0754 in

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

Allowable stresses: $S_n$ = 16,700, $S_v$ = 16,700 psi

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

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

A = d*$t_r$*F + 2*$t_n$*$t_r$*F*(1 - $f_{r1}$)
= 24.126*0.0754*1 + 2*1.062*0.0754*1*(1 - 1)
= 1.8189 $in^2$

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

$A_1$ = larger of the following= 9.959 $in^2$

$= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
$= 24.126*(1*0.4882 - 1*0.0754) - 2*1.062*(1*0.4882 - 1*0.0754)*(1 - 1)$
$= 9.959\ in^2$

$= 2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
$= 2*(0.4882 + 1.062)*(1*0.4882 - 1*0.0754) - 2*1.062*(1*0.4882 - 1*0.0754)*(1 - 1)$
$= 1.2798\ in^2$

$A_2$ = smaller of the following= 2.5 $in^2$

$= 5*(t_n - t_{rn})*f_{r2}*t$
$= 5*(1.062 - 0.0378)*1*0.4882$
$= 2.5\ in^2$

$= 5*(t_n - t_{rn})*f_{r2}*t_n$
$= 5*(1.062 - 0.0378)*1*1.062$
$= 5.4386\ in^2$

$A_{41} = Leg^2*f_{r2}$
$= 0.3937^2*1$
$= 0.155\ in^2$

$Area = A_1 + A_2 + A_{41}$
$= 9.959 + 2.5 + 0.155$
$= 12.614\ in^2$

As Area >= A the reinforcement is adequate.

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

Fillet weld: $t_{min}$ = lesser of 0.75 or $t_n$ or t = 0.4882 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.3937 = 0.2756 in

The fillet weld size is satisfactory.

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

**UG-45 Nozzle Neck Thickness Check (Access Opening)**

Wall thickness req'd per UG-45(a): $t_{r1}$ = 0.1008 in (E =1)

Available nozzle wall thickness new, $t_n$ = 1.125 in

The nozzle neck thickness is adequate.

**Check the opening per Appendix 1-7**

Area required within 75 percent of the limits of reinforcement
= 2 / 3*A = (2 / 3)*1.8189 = 1.2126 $in^2$

Area that is within 75 percent of the limits of reinforcement is:

$A_1$ = larger of 1.2798 or

$= (2*limits - d)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
$= (2*18.0945 - 24.126)*(1*0.4882 - 1*0.0754) - 2*1.062*(1*0.4882 - 1*0.0754)*(1 - 1)$
$= 4.9795\ in^2$

$Area = A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$
$= 4.9795 + 2.5 + 0 + 0.155 + 0 + 0 + 0$
$= 7.6345\ in^2$

The area placement requirements of Appendix 1-7 are satisfied.

The opening is not within the size range defined by 1-7(b)(1)(a) and (b) so it is exempt from the requirements of 1-7(b)(2),(3) and (4).

$R_n$ / R ratio does not exceed 0.7 so a U-2(g) analysis is not required per 1-7(b)(1)(c).

**Reinforcement Calculations for External Pressure**

| UG-37 Area Calculation Summary ($in^2$) For Pe = 15 psi @ 115 °F The opening is adequately reinforced | | | | | | | UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45 | |
|---|---|---|---|---|---|---|---|---|
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| 2.0423 | 5.416 | 2.8255 | 2.4355 | -- | -- | 0.155 | 0.1272 | 1.125 |

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

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| Weld description | Required weld throat size (in) | Actual weld throat size (in) | Status |
| Nozzle to shell fillet ($Leg_{41}$) | 0.25 | 0.2756 | weld size is adequate |

**Calculations for external pressure 15 psi @ 115 °F**

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

$L_R$ = MAX(d, $R_n$ + ($t_n$ - $C_n$) + (t - C))
= MAX(24.126, 12.063 + (1.125 - 0.063) + (0.5512 - 0.063))
= 24.126 in

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

$L_H$ = MIN(2.5*(t - C), 2.5*($t_n$ - $C_n$) + $t_e$)
= MIN(2.5*(0.5512 - 0.063), 2.5*(1.125 - 0.063) + 0)
= 1.2205 in

**Nozzle required thickness per UG-28 $t_{rn}$ = 0.0642 in**

**From UG-37(d)(1) required thickness $t_r$ = 0.254 in**

**Area required per UG-37(d)(1)**

Allowable stresses: $S_n$ = 16,700, $S_v$ = 16,700 psi

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

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

A = 0.5*(d*$t_r$*F + 2*$t_n$*$t_r$*F*(1 - $f_{r1}$))
= 0.5*(24.126*0.254*1 + 2*1.062*0.254*1*(1 - 1))
= 3.0634 $in^2$

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

$A_1$ = larger of the following= 5.6511 $in^2$

= d*($E_1$*t - F*$t_r$) - 2*$t_n$*($E_1$*t - F*$t_r$)*(1 - $f_{r1}$)
= 24.126*(1*0.4882 - 1*0.254) - 2*1.062*(1*0.4882 - 1*0.254)*(1 - 1)
= 5.6511 $in^2$

= 2*(t + $t_n$)*($E_1$*t - F*$t_r$) - 2*$t_n$*($E_1$*t - F*$t_r$)*(1 - $f_{r1}$)
= 2*(0.4882 + 1.062)*(1*0.4882 - 1*0.254) - 2*1.062*(1*0.4882 - 1*0.254)*(1 - 1)
= 0.7262 $in^2$

$A_2$ = smaller of the following= 2.4355 $in^2$

$= 5*(t_n - t_{rn})*f_{r2}*t$
$= 5*(1.062 - 0.0642)*1*0.4882$
$= 2.4355\ in^2$

$= 5*(t_n - t_{rn})*f_{r2}*t_n$
$= 5*(1.062 - 0.0642)*1*1.062$
$= 5.2984\ in^2$

$A_{41} = Leg^2*f_{r2}$
$= 0.3937^2*1$
$= 0.155\ in^2$

$Area = A_1 + A_2 + A_{41}$
$= 5.6511 + 2.4355 + 0.155$
$= 8.2416\ in^2$

As Area >= A the reinforcement is adequate.

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

Fillet weld: $t_{min}$ = lesser of 0.75 or $t_n$ or t = 0.4882 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.3937 = 0.2756 in

The fillet weld size is satisfactory.

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

**UG-45 Nozzle Neck Thickness Check (Access Opening)**

Wall thickness req'd per UG-45(a): $t_{r1}$ = 0.1272 in

Available nozzle wall thickness new, $t_n$ = 1.125 in

The nozzle neck thickness is adequate.

**Check the opening per Appendix 1-7**

Area required within 75 percent of the limits of reinforcement
= 2 / 3*A = (2 / 3)*3.0634 = 2.0423 $in^2$

Area that is within 75 percent of the limits of reinforcement is:

$A_1$ = larger of 0.7262 or

$= (2*limits - d)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
$= (2*18.0945 - 24.126)*(1*0.4882 - 1*0.254) - 2*1.062*(1*0.4882 - 1*0.254)*(1 - 1)$
$= 2.8255\ in^2$

$Area = A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$
$= 2.8255 + 2.4355 + 0 + 0.155 + 0 + 0 + 0$
$= 5.416\ in^2$

The area placement requirements of Appendix 1-7 are satisfied.

**External Pressure, (Corroded & at 115 °F) UG-28(c)**

$L / D_o$ = 13.272 / 26.25 = 0.5056
$D_o / t$ = 26.25 / 0.0642 = 408.8524
From table G: A = 0.000327
From table HA-3: B = 4,599.5483 psi

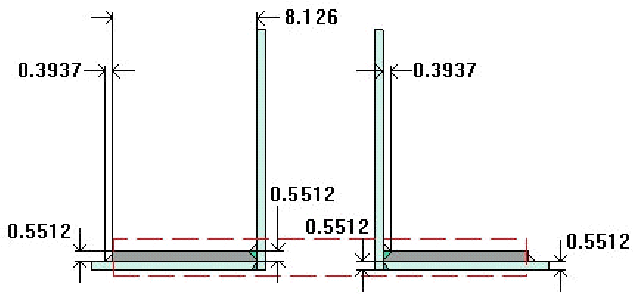
$P_a = 4*B / (3*(D_o / t))$
$= 4*4{,}599.55 / (3*(26.25 / 0.0642))$
$= 15\ psi$

**Design thickness for external pressure $P_a$ = 15 psi**

$t_a$ = t + Corrosion = 0.0642 + 0.063 = 0.1272"

**18" (BJ)**

**ASME Section VIII Division 1, 2007 Edition, A09 Addenda**




$t_{w(lower)}$ = 0.5512 in

$Leg_{41}$ = 0.3937 in

$t_{w(upper)}$ = 0.5512 in

$Leg_{42}$ = 0.3937 in

$D_p$ = 34.252 in

$t_e$ = 0.5512 in

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

| | |
|---|---|
| Located on: | SHELL |
| Liquid static head included: | 0.1993 psi |
| Nozzle material specification: | SA-240 304L (II-D p. 82, ln. 38) |
| Nozzle longitudinal joint efficiency: | 1 |
| Pad material specification: | SA-240 304L (II-D p. 82, ln. 38) |
| Pad diameter: | 34.252 in |
| Flange description: | 18 inch Class 150 WN A182 F304L |
| Bolt Material: | SA-193 B7 Bolt <= 2 1/2 (II-D p. 348, ln. 33) |
| Flange rated MDMT: | -55°F |
| (Per UHA-51(d)(1)(a)) | |
| (Flange rated MDMT = -320 °F<br>Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F) | |
| Liquid static head on flange: | 0 psi |
| ASME B16.5 flange rating MAWP: | 185 psi @ 250°F |
| ASME B16.5 flange rating MAP: | 230 psi @ 68°F |
| ASME B16.5 flange hydro test: | 350 psi @ 68°F |
| Gasket Description: | Flexitallic Spiral Wound CG 304L S.S. |
| PWHT performed: | No |
| Circumferential joint radiography: | Spot UW-11(b) Type 1 |
| Nozzle orientation: | 180° |
| Local vessel minimum thickness: | 0.5512 in |
| Nozzle center line offset to datum line: | 82.0079 in |
| End of nozzle to shell center: | 37.0079 in |
| Nozzle inside diameter, new: | 16.8976 in |
| Nozzle nominal wall thickness: | 0.5512 in |
| Nozzle corrosion allowance: | 0.063 in |
| Projection available outside vessel, Lpr: | 6.9606 in |
| Projection available outside vessel to flange face, Lf: | 12.4606 in |
| Pad is split: | No |

**Reinforcement Calculations for Internal Pressure**

| UG-37 Area Calculation Summary ($in^2$) For P = 50.2 psi @ 250 °F The opening is adequately reinforced | | | | | | | UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45 | |
|---|---|---|---|---|---|---|---|---|
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| 1.2334 | 17.2062 | 7.0772 | 1.1291 | -- | 8.8449 | 0.155 | 0.1805 | 0.5512 |

| UG-41 Weld Failure Path Analysis Summary ($lb_f$) All failure paths are stronger than the applicable weld loads | | | | | | |
|---|---|---|---|---|---|---|
| Weld load W | Weld load $W_{1-1}$ | Path 1-1 strength | Weld load $W_{2-2}$ | Path 2-2 strength | Weld load $W_{3-3}$ | Path 3-3 strength |
| -90,813.4 | 169,154.94 | 330,317.47 | 29,404.51 | 454,258 | 177,114.98 | 343,911.59 |

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| Weld description | Required weld size (in) | Actual weld size (in) | Status |
| Nozzle to pad fillet ($Leg_{41}$) | 0.25 | 0.2756 | weld size is adequate |
| Pad to shell fillet ($Leg_{42}$) | 0.2441 | 0.2756 | weld size is adequate |
| Nozzle to pad groove (Upper) | 0.3417 | 0.5512 | weld size is adequate |

**Calculations for internal pressure 50.2 psi @ 250 °F**

Nozzle Impact test exempt per UHA-51(g)(coincident ratio = 0.14841).
Pad Impact test exempt per UHA-51(g)(coincident ratio = 0.14841).

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

$L_R$ = MAX(d, $R_n$ + ($t_n$ - $C_n$) + (t - C))
= MAX(17.0236, 8.5118 + (0.5512 - 0.063) + (0.5512 - 0.063))
= 17.0236 in

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

$L_H$ = MIN(2.5*(t - C), 2.5*($t_n$ - $C_n$) + $t_e$)
= MIN(2.5*(0.5512 - 0.063), 2.5*(0.5512 - 0.063) + 0.5512)
= 1.2205 in

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

$t_{rn}$ = P*$R_n$ / ($S_n$*E - 0.6*P)
= 50.1993*8.5118 / (16,700*1 - 0.6*50.1993)
= 0.0256 in

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

$t_r$ = P*R / (S*E - 0.6*P)
= 50.1993*24.0591 / (16,700*1 - 0.6*50.1993)
= 0.0725 in

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

Allowable stresses: $S_n$ = 16,700, $S_v$ = 16,700, $S_p$ = 16,700 psi

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

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

$f_{r3}$ = lesser of $f_{r2}$ or $S_p$ / $S_v$ = 1

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

$A = d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
$= 17.0236*0.0725*1 + 2*0.4882*0.0725*1*(1 - 1)$
$= 1.2334$ in$^2$

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

$A_1$ = larger of the following= 7.0772 in$^2$

$= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
$= 17.0236*(1*0.4882 - 1*0.0725) - 2*0.4882*(1*0.4882 - 1*0.0725)*(1 - 1)$
$= 7.0772$ in$^2$

$= 2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
$= 2*(0.4882 + 0.4882)*(1*0.4882 - 1*0.0725) - 2*0.4882*(1*0.4882 - 1*0.0725)*(1 - 1)$
$= 0.8118$ in$^2$

$A_2$ = smaller of the following= 1.1291 in$^2$

$= 5*(t_n - t_{rn})*f_{r2}*t$
$= 5*(0.4882 - 0.0256)*1*0.4882$
$= 1.1291$ in$^2$

$= 2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
$= 2*(0.4882 - 0.0256)*(2.5*0.4882 + 0.5512)*1$
$= 1.6391$ in$^2$

$A_{41} = Leg^2*f_{r3}$
$= 0.3937^2*1$
$= 0.155$ in$^2$

$A_{42} = Leg^2*f_{r4}$
$= 0^2*1$
$= 0$ in$^2$

(Part of the weld is outside of the limits)

$A_5 = (D_p - d - 2*t_n)*t_e*f_{r4}$
$= (34.0472 - 17.0236 - 2*0.4882)*0.5512*1$
$= 8.8449$ in$^2$

$Area = A_1 + A_2 + A_{41} + A_{42} + A_5$
$= 7.0772 + 1.1291 + 0.155 + 0 + 8.8449$
$= 17.2062$ in$^2$

As Area >= A the reinforcement is adequate.

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

Inner fillet: $t_{min}$ = lesser of 0.75 or $t_n$ or $t_e$ = 0.4882 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.3937 = 0.2756 in

Outer fillet: $t_{min}$ = lesser of 0.75 or $t_e$ or t = 0.4882 in
$t_{w(min)} = 0.5*t_{min}$ = 0.2441 in
$t_{w(actual)}$ = 0.7*Leg = 0.7*0.3937 = 0.2756 in

**UG-45 Nozzle Neck Thickness Check**

Wall thickness per UG-45(a): $t_{r1}$ = 0.1805 in (E =1) (pressure plus external loads govern in longitudinal direction)
Wall thickness per UG-45(b)(1): $t_{r2}$ = 0.1355 in
Wall thickness per UG-16(b): $t_{r3}$ = 0.1255 in

| | |
|---|---|
| Standard wall pipe per UG-45(b)(4): | $t_{r4}$ = 0.3911 in |
| The greater of $t_{r2}$ or $t_{r3}$: | $t_{r5}$ = 0.1355 in |
| The lesser of $t_{r4}$ or $t_{r5}$: | $t_{r6}$ = 0.1355 in |

Required per UG-45 is the larger of $t_{r1}$ or $t_{r6}$ = 0.1805 in

Available nozzle wall thickness new, $t_n$ = 0.5512 in

The nozzle neck thickness is adequate.

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

| | | |
|---|---|---|
| Groove weld in tension: | 0.74*16,700 = | 12,358 psi |
| Nozzle wall in shear: | 0.7*16,700 = | 11,690 psi |
| Inner fillet weld in shear: | 0.49*16,700 = | 8,183 psi |
| Outer fillet weld in shear: | 0.49*16,700 = | 8,183 psi |
| Upper groove weld in tension: | 0.74*16,700 = | 12,358 psi |

**Strength of welded joints:**

(1) Inner fillet weld in shear
$(\pi / 2)$*Nozzle OD*Leg*$S_i$ = $(\pi / 2)$*18*0.3937*8,183 = 91,090.11 $lb_f$

(2) Outer fillet weld in shear
$(\pi / 2)$*Pad OD*Leg*$S_o$ = $(\pi / 2)$*34.252*0.3937*8,183 = 173,334.19 $lb_f$

(3) Nozzle wall in shear
$(\pi / 2)$*Mean nozzle dia*$t_n$*$S_n$ = $(\pi / 2)$*17.5118*0.4882*11,690 = 156,983.28 $lb_f$

(4) Groove weld in tension
$(\pi / 2)$*Nozzle OD*$t_w$*$S_g$ = $(\pi / 2)$*18*0.4882*12,358 = 170,577.41 $lb_f$

(6) Upper groove weld in tension
$(\pi / 2)$*Nozzle OD*$t_w$*$S_g$ = $(\pi / 2)$*18*0.5512*12,358 = 192,590.5 $lb_f$

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

$$\begin{aligned} W &= (A - A_1 + 2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)) \cdot S_v \\ &= (1.2334 - 7.0772 + 2 \cdot 0.4882 \cdot 1 \cdot (1 \cdot 0.4882 - 1 \cdot 0.0725)) \cdot 16{,}700 \\ &= -90{,}813.4\ lb_f \end{aligned}$$

$$\begin{aligned} W_{1\text{-}1} &= (A_2 + A_5 + A_{41} + A_{42}) \cdot S_v \\ &= (1.1291 + 8.8449 + 0.155 + 0) \cdot 16{,}700 \\ &= 169{,}154.9\ lb_f \end{aligned}$$

$$\begin{aligned} W_{2\text{-}2} &= (A_2 + A_3 + A_{41} + A_{43} + 2 \cdot t_n \cdot t \cdot f_{r1}) \cdot S_v \\ &= (1.1291 + 0 + 0.155 + 0 + 2 \cdot 0.4882 \cdot 0.4882 \cdot 1) \cdot 16{,}700 \\ &= 29{,}404.51\ lb_f \end{aligned}$$

$$\begin{aligned} W_{3\text{-}3} &= (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2 \cdot t_n \cdot t \cdot f_{r1}) \cdot S_v \\ &= (1.1291 + 0 + 8.8449 + 0.155 + 0 + 0 + 2 \cdot 0.4882 \cdot 0.4882 \cdot 1) \cdot 16{,}700 \\ &= 177{,}115\ lb_f \end{aligned}$$

Load for path 1-1 lesser of W or $W_{1-1}$ = -90813.4 $lb_f$
Path 1-1 through (2) & (3) = 173,334.2 + 156,983.3 = 330,317.47 $lb_f$
Path 1-1 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 2-2 lesser of W or $W_{2-2}$ = -90813.4 $lb_f$
Path 2-2 through (1), (4), (6) = 91,090.11 + 170,577.4 + 192,590.5 = 454,258 $lb_f$
Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 3-3 lesser of W or $W_{3-3}$ = -90813.4 $lb_f$
Path 3-3 through (2), (4) = 173,334.2 + 170,577.4 = 343,911.59 $lb_f$
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

**Applied Loads**

| | | |
|---|---|---|
| Radial load: | $P_r$ = | -4,742.15 $lb_f$ |
| Circumferential moment: | $M_c$ = | 269,154.91 $lb_f$-in |
| Circumferential shear: | $V_c$ = | 5,809.19 $lb_f$ |
| Longitudinal moment: | $M_L$ = | 269,154.91 $lb_f$-in |
| Longitudinal shear: | $V_L$ = | 5,809.19 $lb_f$ |
| Torsion moment: | $M_t$ = | 380,514.41 $lb_f$-in |
| Internal pressure: | P = | 50.199 psi |
| Mean shell radius: | $R_m$ = | 24.3032 in |
| Local shell thickness: | t = | 0.4882 in |
| Shell yield stress: | $S_y$ = | 20,200 psi |

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

$R_m$ / t = 24.3032 / 0.4882 = 49.7831

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

Local circumferential pressure stress = I*P*$R_i$ / t =2,474 psi

Local longitudinal pressure stress = I*P*$R_i$ / (2*t) =1,237 psi

Maximum combined stress ($P_L$+$P_b$+Q) = 38,476 psi
Allowable combined stress ($P_L$+$P_b$+Q) = +-3*S = +-50,100 psi

Note: The allowable combined stress ($P_L$+$P_b$+Q) is based on the strain hardening characteristics of this material.

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

Maximum local primary membrane stress ($P_L$) = 9,221 psi
Allowable local primary membrane ($P_L$) = +-1.5*S = +-25,050 psi

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

| Stresses at the pad edge per WRC Bulletin 107 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Figure** | **value** | **β** | **$A_u$** | **$A_l$** | **$B_u$** | **$B_l$** | **$C_u$** | **$C_l$** | **$D_u$** | **$D_l$** |
| 3C* | 1.0291 | 0.6166 | 0 | 0 | 0 | 0 | 411 | 411 | 411 | 411 |
| 4C* | 2.9914 | 0.6166 | 1,196 | 1,196 | 1,196 | 1,196 | 0 | 0 | 0 | 0 |
| 1C | 0.062 | 0.6166 | 0 | 0 | 0 | 0 | 7,402 | -7,402 | 7,402 | -7,402 |
| 2C-1 | 0.0049 | 0.6166 | 585 | -585 | 585 | -585 | 0 | 0 | 0 | 0 |
| 3A* | 0.978 | 0.6166 | 0 | 0 | 0 | 0 | -1,481 | -1,481 | 1,481 | 1,481 |
| 1A | 0.059 | 0.6166 | 0 | 0 | 0 | 0 | -26,680 | 26,680 | 26,680 | -26,680 |
| 3B* | 1.5968 | 0.6166 | -2,417 | -2,417 | 2,417 | 2,417 | 0 | 0 | 0 | 0 |
| 1B-1 | 0.0068 | 0.6166 | -3,075 | 3,075 | 3,075 | -3,075 | 0 | 0 | 0 | 0 |
| **Pressure stress*** | | | 2,474 | 2,474 | 2,474 | 2,474 | 2,474 | 2,474 | 2,474 | 2,474 |
| **Total circumferential stress** | | | -1,237 | 3,743 | 9,747 | 2,427 | -17,874 | 20,682 | 38,448 | -29,716 |
| **Primary membrane circumferential stress*** | | | 1,253 | 1,253 | 6,087 | 6,087 | 1,404 | 1,404 | 4,366 | 4,366 |
| 3C* | 1.0291 | 0.6166 | 411 | 411 | 411 | 411 | 0 | 0 | 0 | 0 |
| 4C* | 2.9914 | 0.6166 | 0 | 0 | 0 | 0 | 1,196 | 1,196 | 1,196 | 1,196 |
| 1C-1 | 0.0107 | 0.6166 | 1,277 | -1,277 | 1,277 | -1,277 | 0 | 0 | 0 | 0 |
| 2C | 0.03 | 0.6166 | 0 | 0 | 0 | 0 | 3,582 | -3,582 | 3,582 | -3,582 |
| 4A* | 4.4837 | 0.6166 | 0 | 0 | 0 | 0 | -6,788 | -6,788 | 6,788 | 6,788 |
| 2A | 0.0236 | 0.6166 | 0 | 0 | 0 | 0 | -10,672 | 10,672 | 10,672 | -10,672 |
| 4B* | 0.9971 | 0.6166 | -1,510 | -1,510 | 1,510 | 1,510 | 0 | 0 | 0 | 0 |
| 2B-1 | 0.0138 | 0.6166 | -6,240 | 6,240 | 6,240 | -6,240 | 0 | 0 | 0 | 0 |
| **Pressure stress*** | | | 1,237 | 1,237 | 1,237 | 1,237 | 1,237 | 1,237 | 1,237 | 1,237 |
| **Total longitudinal stress** | | | -4,825 | 5,101 | 10,675 | -4,359 | -11,445 | 2,735 | 23,475 | -5,033 |
| **Primary membrane longitudinal stress*** | | | 138 | 138 | 3,158 | 3,158 | -4,355 | -4,355 | 9,221 | 9,221 |
| **Shear from $M_t$** | | | 423 | 423 | 423 | 423 | 423 | 423 | 423 | 423 |
| **Circ shear from $V_c$** | | | 221 | 221 | -221 | -221 | 0 | 0 | 0 | 0 |
| **Long shear from $V_L$** | | | 0 | 0 | 0 | 0 | -221 | -221 | 221 | 221 |
| **Total Shear stress** | | | 644 | 644 | 202 | 202 | 202 | 202 | 644 | 644 |
| **Combined stress ($P_L$+$P_b$+Q)** | | | -4,937 | 5,358 | 10,717 | 6,798 | -17,880 | 20,684 | 38,476 | -29,733 |

Note: * denotes primary stress.

**Maximum stresses due to the applied loads at the nozzle OD (includes pressure)**

$R_m$ / t = 24.3032 / 1.0394 = 23.3828

Pressure stress intensity factor, I = 1.19888 (derived from PVP-Vol. 399, pages 77-82)

Local circumferential pressure stress = I*P*$R_i$ / t =2,966 psi

Local longitudinal pressure stress = I*P*$R_i$ / (2*t) =1,483 psi

Maximum combined stress ($P_L$+$P_b$+Q) = 20,126 psi
Allowable combined stress ($P_L$+$P_b$+Q) = +-3*S = +-50,100 psi

Note: The allowable combined stress ($P_L$+$P_b$+Q) is based on the strain hardening characteristics of this material.

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

Maximum local primary membrane stress ($P_L$) = 6,298 psi
Allowable local primary membrane ($P_L$) = +-1.5*S = +-25,050 psi

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

| Stresses at the nozzle OD per WRC Bulletin 107 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Figure** | **value** | $\beta$ | $A_u$ | $A_l$ | $B_u$ | $B_l$ | $C_u$ | $C_l$ | $D_u$ | $D_l$ |
| 3C* | 1.6536 | 0.324 | 0 | 0 | 0 | 0 | 310 | 310 | 310 | 310 |
| 4C* | 2.8159 | 0.324 | 529 | 529 | 529 | 529 | 0 | 0 | 0 | 0 |
| 1C | 0.0608 | 0.324 | 0 | 0 | 0 | 0 | 1,601 | -1,601 | 1,601 | -1,601 |
| 2C-1 | 0.0231 | 0.324 | 608 | -608 | 608 | -608 | 0 | 0 | 0 | 0 |
| 3A* | 1.0014 | 0.324 | 0 | 0 | 0 | 0 | -1,355 | -1,355 | 1,355 | 1,355 |
| 1A | 0.0752 | 0.324 | 0 | 0 | 0 | 0 | -14,275 | 14,275 | 14,275 | -14,275 |
| 3B* | 2.0719 | 0.324 | -2,803 | -2,803 | 2,803 | 2,803 | 0 | 0 | 0 | 0 |
| 1B-1 | 0.02 | 0.324 | -3,797 | 3,797 | 3,797 | -3,797 | 0 | 0 | 0 | 0 |
| **Pressure stress*** | | | 2,966 | 2,966 | 2,966 | 2,966 | 2,474 | 2,474 | 2,474 | 2,474 |
| **Total circumferential stress** | | | -2,497 | 3,881 | 10,703 | 1,893 | -11,245 | 14,103 | 20,015 | -11,737 |
| **Primary membrane circumferential stress*** | | | 692 | 692 | 6,298 | 6,298 | 1,429 | 1,429 | 4,139 | 4,139 |
| 3C* | 1.6536 | 0.324 | 310 | 310 | 310 | 310 | 0 | 0 | 0 | 0 |
| 4C* | 2.8159 | 0.324 | 0 | 0 | 0 | 0 | 529 | 529 | 529 | 529 |
| 1C-1 | 0.051 | 0.324 | 1,343 | -1,343 | 1,343 | -1,343 | 0 | 0 | 0 | 0 |
| 2C | 0.0306 | 0.324 | 0 | 0 | 0 | 0 | 806 | -806 | 806 | -806 |
| 4A* | 2.1427 | 0.324 | 0 | 0 | 0 | 0 | -2,899 | -2,899 | 2,899 | 2,899 |
| 2A | 0.0359 | 0.324 | 0 | 0 | 0 | 0 | -6,815 | 6,815 | 6,815 | -6,815 |
| 4B* | 0.9687 | 0.324 | -1,311 | -1,311 | 1,311 | 1,311 | 0 | 0 | 0 | 0 |
| 2B-1 | 0.0365 | 0.324 | -6,929 | 6,929 | 6,929 | -6,929 | 0 | 0 | 0 | 0 |
| **Pressure stress*** | | | 1,237 | 1,237 | 1,237 | 1,237 | 1,483 | 1,483 | 1,483 | 1,483 |
| **Total longitudinal stress** | | | -5,350 | 5,822 | 11,130 | -5,414 | -6,896 | 5,122 | 12,532 | -2,710 |
| **Primary membrane longitudinal stress*** | | | 236 | 236 | 2,858 | 2,858 | -887 | -887 | 4,911 | 4,911 |
| **Shear from $M_t$** | | | 719 | 719 | 719 | 719 | 719 | 719 | 719 | 719 |
| **Circ shear from $V_c$** | | | 198 | 198 | -198 | -198 | 0 | 0 | 0 | 0 |
| **Long shear from $V_L$** | | | 0 | 0 | 0 | 0 | -198 | -198 | 198 | 198 |
| **Total Shear stress** | | | 917 | 917 | 521 | 521 | 521 | 521 | 917 | 917 |
| **Combined stress ($P_L$+$P_b$+Q)** | | | -5,619 | 6,187 | 11,480 | 7,381 | -11,307 | 14,133 | 20,126 | -11,829 |

Note: * denotes primary stress.

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

$\sigma_{n\ (Pm)} = P*R_i / (2*t_n) - P_r / (\pi*(R_o^2 - R_i^2)) + M*R_o / I$
= 50.2*8.5118 / (2*0.4882) - -4,742.15 / ($\pi$*($9^2$ - $8.5118^2$)) + 380,642.5*9 / 1,030.334
= 3,939 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 ( ≤ S = 16,700 psi)

**Shear stress in the nozzle wall due to external loads**

$\sigma_{shear} = (V_L^2 + V_c^2)^{0.5} / (\pi*R_i*t_n)$
= ($5,809.19^2$ + $5,809.19^2$)$^{0.5}$ / ($\pi$*8.5118*0.4882)
= 629 psi

$\sigma_{torsion} = M_t / (2*\pi*R_i^2*t_n)$
= 380,514.4 / (2*$\pi$*$8.5118^2$*0.4882)
= 1,712 psi

$\sigma_{total} = \sigma_{shear} + \sigma_{torsion}$
= 629 + 1,712
= 2,342 psi

UG-45(c): The total combined shear stress (2,342 psi) is below than the allowable ($0.7*S_n$ = 0.7*16,700 = 11,690 psi)

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

| | | |
|---|---|---|
| EFE | = | $(50*t / R_f)*(1 - R_f / R_o)$ |
| | = | (50*0.5512 / 8.7244)*(1 - 8.7244 / ϒ⊆) |
| | = | 3.1588% |

**Reinforcement Calculations for External Pressure**

| UG-37 Area Calculation Summary ($in^2$) For Pe = 15 psi @ 115 °F The opening is adequately reinforced | | | | | | | UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45 | |
|---|---|---|---|---|---|---|---|---|
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| 2.1616 | 14.0515 | 3.9875 | 1.0641 | -- | 8.8449 | 0.155 | 0.1678 | 0.5512 |

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

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| Weld description | Required weld size (in) | Actual weld size (in) | Status |
| Nozzle to pad fillet ($Leg_{41}$) | 0.25 | 0.2756 | weld size is adequate |
| Pad to shell fillet ($Leg_{42}$) | 0.2441 | 0.2756 | weld size is adequate |
| Nozzle to pad groove (Upper) | 0.3417 | 0.5512 | weld size is adequate |

**Calculations for external pressure 15 psi @ 115 °F**

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

$L_R$ = MAX(d, $R_n$ + ($t_n$ - $C_n$) + (t - C))
= MAX(17.0236, 8.5118 + (0.5512 - 0.063) + (0.5512 - 0.063))
= 17.0236 in

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

$L_H$ = MIN(2.5*(t - C), 2.5*($t_n$ - $C_n$) + $t_e$)
= MIN(2.5*(0.5512 - 0.063), 2.5*(0.5512 - 0.063) + 0.5512)
= 1.2205 in

**Nozzle required thickness per UG-28 $t_{rn}$ = 0.0523 in**

**From UG-37(d)(1) required thickness $t_r$ = 0.254 in**

**Area required per UG-37(d)(1)**

Allowable stresses: $S_n$ = 16,700, $S_v$ = 16,700, $S_p$ = 16,700 psi

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

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

$f_{r3}$ = lesser of $f_{r2}$ or $S_p$ / $S_v$ = 1

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

A = 0.5*(d*$t_r$*F + 2*$t_n$*$t_r$*F*(1 - $f_{r1}$))
= 0.5*(17.0236*0.254*1 + 2*0.4882*0.254*1*(1 - 1))
= 2.1616 $in^2$

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

$A_1$ = larger of the following= 3.9875 $in^2$

= d*($E_1$*t - F*$t_r$) - 2*$t_n$*($E_1$*t - F*$t_r$)*(1 - $f_{r1}$)
= 17.0236*(1*0.4882 - 1*0.254) - 2*0.4882*(1*0.4882 - 1*0.254)*(1 - 1)
= 3.9875 $in^2$

= $2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= $2*(0.4882 + 0.4882)*(1*0.4882 - 1*0.254) - 2*0.4882*(1*0.4882 - 1*0.254)*(1 - 1)$
= 0.4574 $in^2$

$A_2$ = smaller of the following= 1.0641 $in^2$

= $5*(t_n - t_rn)*f_{r2}*t$
= $5*(0.4882 - 0.0523)*1*0.4882$
= 1.0641 $in^2$

= $2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
= $2*(0.4882 - 0.0523)*(2.5*0.4882 + 0.5512)*1$
= 1.5446 $in^2$

$A_{41}$ = $Leg^2*f_{r3}$
= $0.3937^2*1$
= 0.155 $in^2$

$A_{42}$ = $Leg^2*f_{r4}$
= $0^2*1$
= 0 $in^2$

(Part of the weld is outside of the limits)

$A_5$ = $(D_p - d - 2*t_n)*t_e*f_{r4}$
= $(34.0472 - 17.0236 - 2*0.4882)*0.5512*1$
= 8.8449 $in^2$

Area = $A_1 + A_2 + A_{41} + A_{42} + A_5$
= $3.9875 + 1.0641 + 0.155 + 0 + 8.8449$
= 14.0515 $in^2$

As Area >= A the reinforcement is adequate.

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

Inner fillet: $t_{min}$ = lesser of 0.75 or $t_n$ or $t_e$ = 0.4882 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.3937 = 0.2756 in

Outer fillet: $t_{min}$ = lesser of 0.75 or $t_e$ or t = 0.4882 in
$t_{w(min)}$ = $0.5*t_{min}$ = 0.2441 in
$t_{w(actual)}$ = 0.7*Leg = 0.7*0.3937 = 0.2756 in

**UG-45 Nozzle Neck Thickness Check**

| | |
|---|---|
| Wall thickness per UG-45(a): | $t_{r1}$ = 0.1678 in (pressure plus external loads govern in longitudinal direction) |
| Wall thickness per UG-45(b)(2): | $t_{r2}$ = 0.0846 in |
| Wall thickness per UG-16(b): | $t_{r3}$ = 0.1255 in |
| Standard wall pipe per UG-45(b)(4): | $t_{r4}$ = 0.3911 in |
| The greater of $t_{r2}$ or $t_{r3}$: | $t_{r5}$ = 0.1255 in |
| The lesser of $t_{r4}$ or $t_{r5}$: | $t_{r6}$ = 0.1255 in |

Required per UG-45 is the larger of $t_{r1}$ or $t_{r6}$ = 0.1678 in

Available nozzle wall thickness new, $t_n$ = 0.5512 in

The nozzle neck thickness is adequate.

**External Pressure, (Corroded & at 115 °F) UG-28(c)**

$L / D_o$ = 14.17 / 18 = 0.7872

$D_o / t$ = 18 / 0.0523 = 344.4051
From table G: A = 0.000275
From table HA-3: B = 3,874.5396 psi

$P_a$ = 4*B / (3*($D_o$ / t))
= 4*3,874.54 / (3*(18 / 0.0523))
= 15 psi

**Design thickness for external pressure $P_a$ = 15 psi**

$t_a$ = t + Corrosion = 0.0523 + 0.063 = 0.1153"

**1 1/2" (BH)**

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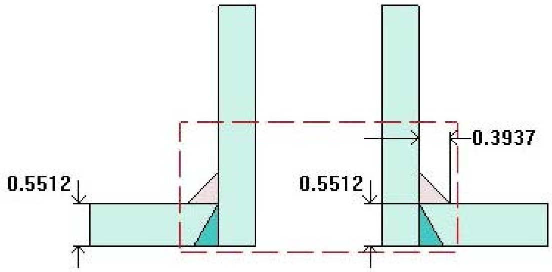
$t_{w(lower)}$ = 0.5512 in

$Leg_{41}$ = 0.3937 in

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

| | |
|---|---|
| Located on: | SHELL |
| Liquid static head included: | 0.3592 psi |
| Nozzle material specification: | SA-182 F304L <= 5 (II-D p. 82, ln. 34) |
| Nozzle longitudinal joint efficiency: | 1 |
| Flange description: | 1.5 inch Class 150 LWN A182 F304L |
| Bolt Material: | SA-193 B7 Bolt <= 2 1/2 (II-D p. 348, ln. 33) |
| Flange rated MDMT: | -55°F |
| (Per UHA-51(d)(1)(a)) | |
| (Flange rated MDMT = -320 °F<br>Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F) | |
| Liquid static head on flange: | 0.3297 psi |
| ASME B16.5 flange rating MAWP: | 185 psi @ 250°F |
| ASME B16.5 flange rating MAP: | 230 psi @ 68°F |
| ASME B16.5 flange hydro test: | 350 psi @ 68°F |
| Gasket Description: | Flexitallic Spiral Wound CG 304L S.S. |
| PWHT performed: | No |
| Nozzle orientation: | 230° |
| Local vessel minimum thickness: | 0.5512 in |
| Nozzle center line offset to datum line: | 70 in |
| End of nozzle to shell center: | 33.0709 in |
| Nozzle inside diameter, new: | 1.6102 in |
| Nozzle nominal wall thickness: | 0.4744 in |
| Nozzle corrosion allowance: | 0.063 in |
| Projection available outside vessel, Lpr: | 7.8336 in |
| Projection available outside vessel to flange face, Lf: | 8.5236 in |

**Reinforcement Calculations for Internal Pressure**

| UG-37 Area Calculation Summary ($in^2$) For P = 50.36 psi @ 250 °F | | | | | | | UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45 | |
|---|---|---|---|---|---|---|---|---|
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| This nozzle is exempt from area calculations per UG-36(c)(3)(a) | | | | | | | 0.1529 | 0.4744 |

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

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| Weld description | Required weld throat size (in) | Actual weld throat size (in) | Status |
| Nozzle to shell fillet ($Leg_{41}$) | 0.25 | 0.2756 | weld size is adequate |

**Calculations for internal pressure 50.36 psi @ 250 °F**

Nozzle Impact test exempt per UHA-51(g)(coincident ratio = 0.21851).

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

$L_R$ = MAX(d, $R_n$ + ($t_n$ - $C_n$) + (t - C))
= MAX(1.7362, 0.8681 + (0.4744 - 0.063) + (0.5512 - 0.063))
= 1.7677 in

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

$L_H$ = MIN(2.5*(t - C), 2.5*($t_n$ - $C_n$) + $t_e$)
= MIN(2.5*(0.5512 - 0.063), 2.5*(0.4744 - 0.063) + 0)
= 1.0285 in

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

$t_{rn}$ = P*$R_n$ / ($S_n$*E - 0.6*P)
= 50.3592*0.8681 / (16,700*1 - 0.6*50.3592)
= 0.0026 in

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

$t_r$ = P*R / (S*E - 0.6*P)
= 50.3592*24.0591 / (16,700*1 - 0.6*50.3592)
= 0.0727 in

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

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

Fillet weld: $t_{min}$ = lesser of 0.75 or $t_n$ or t = 0.4114 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*$t_{min}$ = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.3937 = 0.2756 in

The fillet weld size is satisfactory.

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

**UG-45 Nozzle Neck Thickness Check**

| | |
|---|---|
| Wall thickness per UG-45(a): | $t_{r1}$ = 0.1529 in (E =1) (pressure plus external loads govern in longitudinal direction) |
| Wall thickness per UG-45(b)(1): | $t_{r2}$ = 0.1357 in |

| | |
|---|---|
| Wall thickness per UG-16(b): | $t_{r3}$ = 0.1255 in |
| Standard wall pipe per UG-45(b)(4): | $t_{r4}$ = 0.2406 in |
| The greater of $t_{r2}$ or $t_{r3}$: | $t_{r5}$ = 0.1357 in |
| The lesser of $t_{r4}$ or $t_{r5}$: | $t_{r6}$ = 0.1357 in |

Required per UG-45 is the larger of $t_{r1}$ or $t_{r6}$ = 0.1529 in

Available nozzle wall thickness new, $t_n$ = 0.4744 in

The nozzle neck thickness is adequate.

**Applied Loads**

| | | |
|---|---|---|
| Radial load: | $P_r$ = | -326.28 $lb_f$ |
| Circumferential moment: | $M_c$ = | 2,517.09 $lb_f$-in |
| Circumferential shear: | $V_c$ = | 399.04 $lb_f$ |
| Longitudinal moment: | $M_L$ = | 2,517.09 $lb_f$-in |
| Longitudinal shear: | $V_L$ = | 399.04 $lb_f$ |
| Torsion moment: | $M_t$ = | 3,558.64 $lb_f$-in |
| Internal pressure: | P = | 50.359 psi |
| Mean shell radius: | $R_m$ = | 24.3032 in |
| Local shell thickness: | t = | 0.4882 in |
| Shell yield stress: | $S_y$ = | 20,200 psi |

**Maximum stresses due to the applied loads at the nozzle OD (includes pressure)**

$R_m$ / t = 24.3032 / 0.4882 = 49.7831

Pressure stress intensity factor, I = 1.06934 (derived from PVP-Vol. 399, pages 77-82)

Local circumferential pressure stress = I*P*$R_i$ / t =2,654 psi

Local longitudinal pressure stress = I*P*$R_i$ / (2*t) =1,327 psi

Maximum combined stress ($P_L$+$P_b$+Q) = 10,580 psi
Allowable combined stress ($P_L$+$P_b$+Q) = +-3*S = +-50,100 psi

Note: The allowable combined stress ($P_L$+$P_b$+Q) is based on the strain hardening characteristics of this material.

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

Maximum local primary membrane stress ($P_L$) = 3,444 psi
Allowable local primary membrane ($P_L$) = +-1.5*S = +-25,050 psi

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

| Stresses at the nozzle OD per WRC Bulletin 107 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Figure** | **value** | $\beta$ | $A_u$ | $A_l$ | $B_u$ | $B_l$ | $C_u$ | $C_l$ | $D_u$ | $D_l$ |
| 3C* | 9.2792 | 0.0461 | 0 | 0 | 0 | 0 | 255 | 255 | 255 | 255 |
| 4C* | 9.5184 | 0.0461 | 262 | 262 | 262 | 262 | 0 | 0 | 0 | 0 |
| 1C | 0.1911 | 0.0461 | 0 | 0 | 0 | 0 | 1,570 | -1,570 | 1,570 | -1,570 |
| 2C-1 | 0.1501 | 0.0461 | 1,233 | -1,233 | 1,233 | -1,233 | 0 | 0 | 0 | 0 |
| 3A* | 0.6772 | 0.0461 | 0 | 0 | 0 | 0 | -128 | -128 | 128 | 128 |
| 1A | 0.105 | 0.0461 | 0 | 0 | 0 | 0 | -5,943 | 5,943 | 5,943 | -5,943 |
| 3B* | 2.7886 | 0.0461 | -528 | -528 | 528 | 528 | 0 | 0 | 0 | 0 |
| 1B-1 | 0.059 | 0.0461 | -3,340 | 3,340 | 3,340 | -3,340 | 0 | 0 | 0 | 0 |
| **Pressure stress*** | | | 2,654 | 2,654 | 2,654 | 2,654 | 2,482 | 2,482 | 2,482 | 2,482 |
| **Total circumferential stress** | | | 281 | 4,495 | 8,017 | -1,129 | -1,764 | 6,982 | 10,378 | -4,648 |
| **Primary membrane circumferential stress*** | | | 2,388 | 2,388 | 3,444 | 3,444 | 2,609 | 2,609 | 2,865 | 2,865 |
| 3C* | 9.2792 | 0.0461 | 255 | 255 | 255 | 255 | 0 | 0 | 0 | 0 |
| 4C* | 9.5184 | 0.0461 | 0 | 0 | 0 | 0 | 262 | 262 | 262 | 262 |
| 1C-1 | 0.1902 | 0.0461 | 1,562 | -1,562 | 1,562 | -1,562 | 0 | 0 | 0 | 0 |
| 2C | 0.1481 | 0.0461 | 0 | 0 | 0 | 0 | 1,217 | -1,217 | 1,217 | -1,217 |
| 4A* | 0.9282 | 0.0461 | 0 | 0 | 0 | 0 | -176 | -176 | 176 | 176 |
| 2A | 0.0615 | 0.0461 | 0 | 0 | 0 | 0 | -3,481 | 3,481 | 3,481 | -3,481 |
| 4B* | 0.7208 | 0.0461 | -137 | -137 | 137 | 137 | 0 | 0 | 0 | 0 |
| 2B-1 | 0.1012 | 0.0461 | -5,728 | 5,728 | 5,728 | -5,728 | 0 | 0 | 0 | 0 |
| **Pressure stress*** | | | 1,241 | 1,241 | 1,241 | 1,241 | 1,327 | 1,327 | 1,327 | 1,327 |
| **Total longitudinal stress** | | | -2,807 | 5,525 | 8,923 | -5,657 | -851 | 3,677 | 6,463 | -2,933 |
| **Primary membrane longitudinal stress*** | | | 1,359 | 1,359 | 1,633 | 1,633 | 1,413 | 1,413 | 1,765 | 1,765 |
| **Shear from $M_t$** | | | 709 | 709 | 709 | 709 | 709 | 709 | 709 | 709 |
| **Circ shear from $V_c$** | | | 203 | 203 | -203 | -203 | 0 | 0 | 0 | 0 |
| **Long shear from $V_L$** | | | 0 | 0 | 0 | 0 | -203 | -203 | 203 | 203 |
| **Total Shear stress** | | | 912 | 912 | 506 | 506 | 506 | 506 | 912 | 912 |
| **Combined stress ($P_L$+$P_b$+Q)** | | | 3,586 | 6,057 | 9,149 | -5,713 | -1,989 | 7,058 | 10,580 | -5,042 |

Note: * denotes primary stress.

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

$\sigma_{n\ (Pm)} = P*R_i / (2*t_n) - P_r / (\pi*(R_o^2 - R_i^2)) + M*R_o / I$
$= 50.36*0.8681 / (2*0.4114) - -326.28 / (\pi*(1.2795^2 - 0.8681^2)) + 3{,}559.7*1.2795 / 1.6591$
$= 2{,}916$ 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 ( ≤ S = 16,700 psi)

**Shear stress in the nozzle wall due to external loads**

$\sigma_{shear} = (V_L^2 + V_c^2)^{0.5} / (\pi*R_i*t_n)$
$= (399.04^2 + 399.04^2)^{0.5} / (\pi*0.8681*0.4114)$
$= 503$ psi

$\sigma_{torsion} = M_t / (2*\pi*R_i^2*t_n)$
$= 3{,}558.6 / (2*\pi*0.8681^2*0.4114)$
$= 1{,}827$ psi

$\sigma_{total} = \sigma_{shear} + \sigma_{torsion}$
$= 503 + 1{,}827$
$= 2{,}330$ psi

UG-45(c): The total combined shear stress (2,330 psi) is below than the allowable ($0.7*S_n = 0.7*16,700 = 11,690$ psi)

**Reinforcement Calculations for External Pressure**

| UG-37 Area Calculation Summary ($in^2$) For Pe = 15 psi @ 115 °F | | | | | | | UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45 | |
|---|---|---|---|---|---|---|---|---|
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| This nozzle is exempt from area calculations per UG-36(c)(3)(a) | | | | | | | 0.1517 | 0.4744 |

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

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| Weld description | Required weld throat size (in) | Actual weld throat size (in) | Status |
| Nozzle to shell fillet ($Leg_{41}$) | 0.25 | 0.2756 | weld size is adequate |

**Calculations for external pressure 15 psi @ 115 °F**

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

$L_R$ = MAX(d, $R_n$ + ($t_n$ - $C_n$) + (t - C))
= MAX(1.7362, 0.8681 + (0.4744 - 0.063) + (0.5512 - 0.063))
= 1.7677 in

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

$L_H$ = MIN(2.5*(t - C), 2.5*($t_n$ - $C_n$) + $t_e$)
= MIN(2.5*(0.5512 - 0.063), 2.5*(0.4744 - 0.063) + 0)
= 1.0285 in

**Nozzle required thickness per UG-28 $t_{rn}$ = 0.0136 in**

**From UG-37(d)(1) required thickness $t_r$ = 0.254 in**

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

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

Fillet weld: $t_{min}$ = lesser of 0.75 or $t_n$ or t = 0.4114 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*$t_{min}$ = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.3937 = 0.2756 in

The fillet weld size is satisfactory.

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

**UG-45 Nozzle Neck Thickness Check**

| | |
|---|---|
| Wall thickness per UG-45(a): | $t_{r1}$ = 0.1517 in (pressure plus external loads govern in longitudinal direction) |
| Wall thickness per UG-45(b)(2): | $t_{r2}$ = 0.0846 in |
| Wall thickness per UG-16(b): | $t_{r3}$ = 0.1255 in |
| Standard wall pipe per UG-45(b)(4): | $t_{r4}$ = 0.2406 in |
| The greater of $t_{r2}$ or $t_{r3}$: | $t_{r5}$ = 0.1255 in |
| The lesser of $t_{r4}$ or $t_{r5}$: | $t_{r6}$ = 0.1255 in |

Required per UG-45 is the larger of $t_{r1}$ or $t_{r6}$ = 0.1517 in

Available nozzle wall thickness new, $t_n$ = 0.4744 in

The nozzle neck thickness is adequate.

**External Pressure, (Corroded & at 115 °F) UG-28(c)**

$L / D_o$ = 8.557 / 2.5591 = 3.3438
$D_o / t$ = 2.5591 / 0.0136 = 187.9461
From table G: A = 0.000150
From table HA-3: B = 2,114.3132 psi

$P_a$ = 4*B / (3*($D_o$ / t))
= 4*2,114.31 / (3*(2.5591 / 0.0136))
= 15 psi

**Design thickness for external pressure $P_a$ = 15 psi**

$t_a$ = t + Corrosion = 0.0136 + 0.063 = 0.0766"

**2" (BS)**

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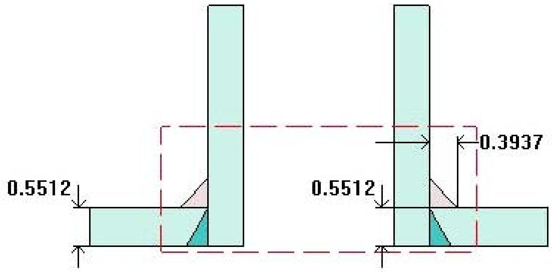
$t_{w(lower)}$ = 0.5512 in

$Leg_{41}$ = 0.3937 in




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

| | |
|---|---|
| Located on: | SHELL |
| Liquid static head included: | 2.7131 psi |
| Nozzle material specification: | SA-182 F304L <= 5 (II-D p. 82, ln. 34) |
| Nozzle longitudinal joint efficiency: | 1 |
| Flange description: | 2 inch Class 150 LWN A182 F304L |
| Bolt Material: | SA-193 B7 Bolt <= 2 1/2 (II-D p. 348, ln. 33) |
| Flange rated MDMT: | -55°F |
| (Per UHA-51(d)(1)(a)) | |
| (Flange rated MDMT = -320 °F<br>Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F) | |
| Liquid static head on flange: | 2.6752 psi |
| ASME B16.5 flange rating MAWP: | 185 psi @ 250°F |
| ASME B16.5 flange rating MAP: | 230 psi @ 68°F |
| ASME B16.5 flange hydro test: | 350 psi @ 68°F |
| Gasket Description: | Flexitallic Spiral Wound CG 304L S.S. |
| PWHT performed: | No |
| Nozzle orientation: | 180° |
| Local vessel minimum thickness: | 0.5512 in |
| Nozzle center line offset to datum line: | 5.9843 in |
| End of nozzle to shell center: | 33.0709 in |
| Nozzle inside diameter, new: | 2.0669 in |
| Nozzle nominal wall thickness: | 0.502 in |
| Nozzle corrosion allowance: | 0.063 in |
| Projection available outside vessel, Lpr: | 7.7736 in |
| Projection available outside vessel to flange face, Lf: | 8.5236 in |

**Reinforcement Calculations for Internal Pressure**

| UG-37 Area Calculation Summary ($in^2$) For P = 52.71 psi @ 250 °F | | | | | | | UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45 | |
|---|---|---|---|---|---|---|---|---|
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| This nozzle is exempt from area calculations per UG-36(c)(3)(a) | | | | | | | 0.163 | 0.502 |

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

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| Weld description | Required weld throat size (in) | Actual weld throat size (in) | Status |
| Nozzle to shell fillet ($Leg_{41}$) | 0.25 | 0.2756 | weld size is adequate |

**Calculations for internal pressure 52.71 psi @ 250 °F**

Nozzle Impact test exempt per UHA-51(g)(coincident ratio = 0.22787).

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

$L_R$ = $MAX(d, R_n + (t_n - C_n) + (t - C))$
= MAX(2.1929, 1.0965 + (0.502 - 0.063) + (0.5512 - 0.063))
= 2.1929 in

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

$L_H$ = $MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)$
= MIN(2.5*(0.5512 - 0.063), 2.5*(0.502 - 0.063) + 0)
= 1.0974 in

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

$t_{rn}$ = $P*R_n / (S_n*E - 0.6*P)$
= 52.7131*1.0965 / (16,700*1 - 0.6*52.7131)
= 0.0035 in

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

$t_r$ = P*R / (S*E - 0.6*P)
= 52.7131*24.0591 / (16,700*1 - 0.6*52.7131)
= 0.0761 in

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

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

Fillet weld: $t_{min}$ = lesser of 0.75 or $t_n$ or t = 0.439 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*$t_{min}$ = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.3937 = 0.2756 in

The fillet weld size is satisfactory.

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

**UG-45 Nozzle Neck Thickness Check**

| | |
|---|---|
| Wall thickness per UG-45(a): | $t_{r1}$ = 0.163 in (E =1) (pressure plus external loads govern in longitudinal direction) |
| Wall thickness per UG-45(b)(1): | $t_{r2}$ = 0.1391 in |

| | |
|---|---|
| Wall thickness per UG-16(b): | $t_{r3}$ = 0.1255 in |
| Standard wall pipe per UG-45(b)(4): | $t_{r4}$ = 0.252 in |
| The greater of $t_{r2}$ or $t_{r3}$: | $t_{r5}$ = 0.1391 in |
| The lesser of $t_{r4}$ or $t_{r5}$: | $t_{r6}$ = 0.1391 in |

Required per UG-45 is the larger of $t_{r1}$ or $t_{r6}$ = 0.163 in

Available nozzle wall thickness new, $t_n$ = 0.502 in

The nozzle neck thickness is adequate.

**Applied Loads**

| | | |
|---|---|---|
| Radial load: | $P_r$ = | -449.74 $lb_f$ |
| Circumferential moment: | $M_c$ = | 4,426.6 $lb_f$-in |
| Circumferential shear: | $V_c$ = | 551.16 $lb_f$ |
| Longitudinal moment: | $M_L$ = | 4,426.6 $lb_f$-in |
| Longitudinal shear: | $V_L$ = | 551.16 $lb_f$ |
| Torsion moment: | $M_t$ = | 6,162.53 $lb_f$-in |
| Internal pressure: | P = | 52.713 psi |
| Mean shell radius: | $R_m$ = | 24.3032 in |
| Local shell thickness: | t = | 0.4882 in |
| Shell yield stress: | $S_y$ = | 20,200 psi |

**Maximum stresses due to the applied loads at the nozzle OD (includes pressure)**

$R_m$ / t = 24.3032 / 0.4882 = 49.7831

Pressure stress intensity factor, I = 1.11912 (derived from PVP-Vol. 399, pages 77-82)

Local circumferential pressure stress = I*P*$R_i$ / t =2,907 psi

Local longitudinal pressure stress = I*P*$R_i$ / (2*t) =1,454 psi

Maximum combined stress ($P_L$+$P_b$+Q) = 13,966 psi
Allowable combined stress ($P_L$+$P_b$+Q) = +-3*S = +-50,100 psi

Note: The allowable combined stress ($P_L$+$P_b$+Q) is based on the strain hardening characteristics of this material.

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

Maximum local primary membrane stress ($P_L$) = 4,220 psi
Allowable local primary membrane ($P_L$) = +-1.5*S = +-25,050 psi

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

| Stresses at the nozzle OD per WRC Bulletin 107 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Figure | value | β | $A_u$ | $A_l$ | $B_u$ | $B_l$ | $C_u$ | $C_l$ | $D_u$ | $D_l$ |
| 3C* | 8.9649 | 0.0553 | 0 | 0 | 0 | 0 | 340 | 340 | 340 | 340 |
| 4C* | 9.3547 | 0.0553 | 355 | 355 | 355 | 355 | 0 | 0 | 0 | 0 |
| 1C | 0.1713 | 0.0553 | 0 | 0 | 0 | 0 | 1,940 | -1,940 | 1,940 | -1,940 |
| 2C-1 | 0.1323 | 0.0553 | 1,498 | -1,498 | 1,498 | -1,498 | 0 | 0 | 0 | 0 |
| 3A* | 0.8638 | 0.0553 | 0 | 0 | 0 | 0 | -240 | -240 | 240 | 240 |
| 1A | 0.104 | 0.0553 | 0 | 0 | 0 | 0 | -8,627 | 8,627 | 8,627 | -8,627 |
| 3B* | 3.4494 | 0.0553 | -958 | -958 | 958 | 958 | 0 | 0 | 0 | 0 |
| 1B-1 | 0.0564 | 0.0553 | -4,678 | 4,678 | 4,678 | -4,678 | 0 | 0 | 0 | 0 |
| **Pressure stress*** | | | 2,907 | 2,907 | 2,907 | 2,907 | 2,598 | 2,598 | 2,598 | 2,598 |
| **Total circumferential stress** | | | -876 | 5,484 | 10,396 | -1,956 | -3,989 | 9,385 | 13,745 | -7,389 |
| **Primary membrane circumferential stress*** | | | 2,304 | 2,304 | 4,220 | 4,220 | 2,698 | 2,698 | 3,178 | 3,178 |
| 3C* | 8.9649 | 0.0553 | 340 | 340 | 340 | 340 | 0 | 0 | 0 | 0 |
| 4C* | 9.3547 | 0.0553 | 0 | 0 | 0 | 0 | 355 | 355 | 355 | 355 |
| 1C-1 | 0.1716 | 0.0553 | 1,943 | -1,943 | 1,943 | -1,943 | 0 | 0 | 0 | 0 |
| 2C | 0.1313 | 0.0553 | 0 | 0 | 0 | 0 | 1,487 | -1,487 | 1,487 | -1,487 |
| 4A* | 1.1808 | 0.0553 | 0 | 0 | 0 | 0 | -328 | -328 | 328 | 328 |
| 2A | 0.0602 | 0.0553 | 0 | 0 | 0 | 0 | -4,994 | 4,994 | 4,994 | -4,994 |
| 4B* | 0.895 | 0.0553 | -249 | -249 | 249 | 249 | 0 | 0 | 0 | 0 |
| 2B-1 | 0.0958 | 0.0553 | -7,947 | 7,947 | 7,947 | -7,947 | 0 | 0 | 0 | 0 |
| **Pressure stress*** | | | 1,299 | 1,299 | 1,299 | 1,299 | 1,454 | 1,454 | 1,454 | 1,454 |
| **Total longitudinal stress** | | | -4,614 | 7,394 | 11,778 | -8,002 | -2,026 | 4,988 | 8,618 | -4,344 |
| **Primary membrane longitudinal stress*** | | | 1,390 | 1,390 | 1,888 | 1,888 | 1,481 | 1,481 | 2,137 | 2,137 |
| **Shear from $M_t$** | | | 852 | 852 | 852 | 852 | 852 | 852 | 852 | 852 |
| **Circ shear from $V_c$** | | | 234 | 234 | -234 | -234 | 0 | 0 | 0 | 0 |
| **Long shear from $V_L$** | | | 0 | 0 | 0 | 0 | -234 | -234 | 234 | 234 |
| **Total Shear stress** | | | 1,086 | 1,086 | 618 | 618 | 618 | 618 | 1,086 | 1,086 |
| **Combined stress ($P_L$+$P_b$+Q)** | | | -4,907 | 7,885 | 12,014 | -8,065 | -4,167 | 9,470 | 13,966 | -7,737 |

Note: * denotes primary stress.

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

$\sigma_{n\ (Pm)} = P*R_i / (2*t_n) - P_r / (\pi*(R_o^2 - R_i^2)) + M*R_o / I$
= 52.71*1.0965 / (2*0.439) - -449.74 / (π*(1.5354$^2$ - 1.0965$^2$)) + 6,260.2*1.5354 / 3.2301
= 3,165 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 ( ¡ ÂS = 16,700 psi)

**Shear stress in the nozzle wall due to external loads**

$\sigma_{shear} = (V_L^2 + V_c^2)^{0.5} / (\pi*R_i*t_n)$
= (551.16$^2$ + 551.16$^2$)$^{0.5}$ / (π*1.0965*0.439)
= 515 psi

$\sigma_{torsion} = M_t / (2*\pi*R_i^2*t_n)$
= 6,162.5 / (2*π*1.0965$^2$*0.439)
= 1,858 psi

$\sigma_{total} = \sigma_{shear} + \sigma_{torsion}$
= 515 + 1,858
= 2,374 psi

UG-45(c): The total combined shear stress (2,374 psi) is below than the allowable ($0.7*S_n = 0.7*16,700 = 11,690$ psi)

**Reinforcement Calculations for External Pressure**

| UG-37 Area Calculation Summary ($in^2$) For Pe = 15 psi @ 115 °F | | | | | | | UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45 | |
|---|---|---|---|---|---|---|---|---|
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| This nozzle is exempt from area calculations per UG-36(c)(3)(a) | | | | | | | 0.1614 | 0.502 |

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

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| Weld description | Required weld throat size (in) | Actual weld throat size (in) | Status |
| Nozzle to shell fillet ($Leg_{41}$) | 0.25 | 0.2756 | weld size is adequate |

**Calculations for external pressure 15 psi @ 115 °F**

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

$$
\begin{aligned}
L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
&= \text{MAX}(2.1929, 1.0965 + (0.502 - 0.063) + (0.5512 - 0.063)) \\
&= 2.1929 \text{ in}
\end{aligned}
$$

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

$$
\begin{aligned}
L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
&= \text{MIN}(2.5*(0.5512 - 0.063), 2.5*(0.502 - 0.063) + 0) \\
&= 1.0974 \text{ in}
\end{aligned}
$$

**Nozzle required thickness per UG-28 $t_{rn}$ = 0.0153 in**

**From UG-37(d)(1) required thickness $t_r$ = 0.254 in**

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

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

Fillet weld: $t_{min}$ = lesser of 0.75 or $t_n$ or t = 0.439 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*$t_{min}$ = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.3937 = 0.2756 in

The fillet weld size is satisfactory.

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

**UG-45 Nozzle Neck Thickness Check**

| | |
|---|---|
| Wall thickness per UG-45(a): | $t_{r1}$ = 0.1614 in (pressure plus external loads govern in longitudinal direction) |
| Wall thickness per UG-45(b)(2): | $t_{r2}$ = 0.0846 in |
| Wall thickness per UG-16(b): | $t_{r3}$ = 0.1255 in |
| Standard wall pipe per UG-45(b)(4): | $t_{r4}$ = 0.252 in |
| The greater of $t_{r2}$ or $t_{r3}$: | $t_{r5}$ = 0.1255 in |
| The lesser of $t_{r4}$ or $t_{r5}$: | $t_{r6}$ = 0.1255 in |

Required per UG-45 is the larger of $t_{r1}$ or $t_{r6}$ = 0.1614 in

Available nozzle wall thickness new, $t_n$ = 0.502 in

The nozzle neck thickness is adequate.

**External Pressure, (Corroded & at 115 °F) UG-28(c)**

$L / D_o$ = 8.5717 / 3.0709 = 2.7913
$D_o / t$ = 3.0709 / 0.0153 = 200.5648
From table G: A = 0.000160
From table HA-3: B = 2,256.3857 psi

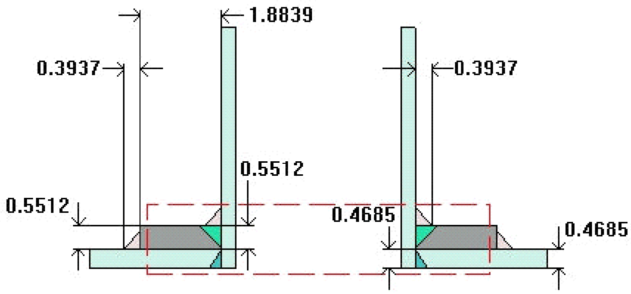
$P_a$ = $4*B / (3*(D_o / t))$
= 4*2,256.39 / (3*(3.0709 / 0.0153))
= 15 psi

**Design thickness for external pressure $P_a$ = 15 psi**

$t_a$ = t + Corrosion = 0.0153 + 0.063 = 0.0783"

**4" (CW)**

**ASME Section VIII Division 1, 2007 Edition, A09 Addenda**




$t_{w(lower)}$ = 0.4685 in

$Leg_{41}$ = 0.3937 in

$t_{w(upper)}$ = 0.5512 in

$Leg_{42}$ = 0.3937 in

$D_p$ = 8.2677 in

$t_e$ = 0.5512 in

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

| | |
|---|---|
| Located on: | BTM HEAD |
| Liquid static head included: | 3.9764 psi |
| Nozzle material specification: | SA-312 TP304L Wld & smls pipe (II-D p. 86, ln. 1) |
| Nozzle longitudinal joint efficiency: | 1 |
| Nozzle description: | NPS 4 Sch 80S (XS) |
| Pad material specification: | SA-240 304L (II-D p. 82, ln. 38) |
| Pad diameter: | 8.2677 in |
| Flange description: | 4 inch Class 150 WN A182 F304L |
| Bolt Material: | SA-193 B7 Bolt <= 2 1/2 (II-D p. 348, ln. 33) |
| Flange rated MDMT: | -55°F |
| (Per UHA-51(d)(1)(a)) | |
| (Flange rated MDMT = -320 °F<br>Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F) | |
| Liquid static head on flange: | 3.9936 psi |
| ASME B16.5 flange rating MAWP: | 185 psi @ 250°F |
| ASME B16.5 flange rating MAP: | 230 psi @ 68°F |
| ASME B16.5 flange hydro test: | 350 psi @ 68°F |
| Gasket Description: | Flexitallic Spiral Wound CG 304L S.S. |
| PWHT performed: | No |
| Circumferential joint radiography: | None UW-11(c) Type 1 |
| Nozzle orientation: | 0° |
| Calculated as hillside: | No |
| Local vessel minimum thickness: | 0.4685 in |
| End of nozzle to datum line: | -30 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: | 14.5863 in |
| Projection available outside vessel to flange face, Lf: | 17.5863 in |
| Distance to head center, R: | 0 in |
| Pad is split: | No |

**Reinforcement Calculations for Internal Pressure**

| UG-37 Area Calculation Summary ($in^2$)<br>For P = 53.98 psi @ 250 °F<br>The opening is adequately reinforced | | | | | | | UG-45 Nozzle Wall Thickness Summary (in)<br>The nozzle passes UG-45 | |
|---|---|---|---|---|---|---|---|---|
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| 0.2759 | 3.9004 | 1.3266 | 0.5426 | -- | 1.8762 | 0.155 | 0.2797 | 0.2949 |

| UG-41 Weld Failure Path Analysis Summary ($lb_f$)<br>All failure paths are stronger than the applicable weld loads | | | | | | |
|---|---|---|---|---|---|---|
| Weld load W | Weld load $W_{1-1}$ | Path 1-1 strength | Weld load $W_{2-2}$ | Path 2-2 strength | Weld load $W_{3-3}$ | Path 3-3 strength |
| -14,474.1 | 42,982.51 | 63,102.37 | 15,361.04 | 106,342.36 | 46,693.63 | 77,261.5 |

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| Weld description | Required weld size (in) | Actual weld size (in) | Status |
| Nozzle to pad fillet ($Leg_{41}$) | 0.1918 | 0.2756 | weld size is adequate |
| Pad to shell fillet ($Leg_{42}$) | 0.2027 | 0.2756 | weld size is adequate |
| Nozzle to pad groove (Upper) | 0.1918 | 0.5512 | weld size is adequate |

**Calculations for internal pressure 53.98 psi @ 250 °F**

Nozzle rated MDMT per UHA-51(d)(1)(a) = -320 °F.
Pad Impact test exempt per UHA-51(g)(coincident ratio = 0.17218).

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

$L_R$ = MAX(d, $R_n + (t_n - C_n) + (t - C)$)
= MAX(3.952, 1.976 + (0.337 - 0.063) + (0.4685 - 0.063))
= 3.952 in

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

$L_H$ = MIN(2.5*(t - C), 2.5*($t_n - C_n$) + $t_e$)
= MIN(2.5*(0.4685 - 0.063), 2.5*(0.337 - 0.063) + 0.5512)
= 1.0138 in

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

$t_{rn}$ = $P*R_n / (S_n*E - 0.6*P)$
= 53.9764*1.976 / (16,700*1 - 0.6*53.9764)
= 0.0064 in

**Required thickness $t_r$ from UG-37(a)(c)**

$t_r$ = $P*K_1*D / (2*S*E - 0.2*P)$
= 53.9764*0.8976*48.1181 / (2*16,700*1 - 0.2*53.9764)
= 0.0698 in

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

Allowable stresses: $S_n$ = 16,700, $S_v$ = 16,700, $S_p$ = 16,700 psi

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

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

$f_{r3}$ = lesser of $f_{r2}$ or $S_p / S_v$ = 1

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

$A = d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
$= 3.952*0.0698*1 + 2*0.274*0.0698*1*(1 - 1)$
$= 0.2759\ in^2$

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

$A_1$ = larger of the following= 1.3266 $in^2$

$= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
$= 3.952*(1*0.4055 - 1*0.0698) - 2*0.274*(1*0.4055 - 1*0.0698)*(1 - 1)$
$= 1.3266\ in^2$

$= 2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
$= 2*(0.4055 + 0.274)*(1*0.4055 - 1*0.0698) - 2*0.274*(1*0.4055 - 1*0.0698)*(1 - 1)$
$= 0.4562\ in^2$

$A_2$ = smaller of the following= 0.5426 $in^2$

$= 5*(t_n - t_{rn})*f_{r2}*t$
$= 5*(0.274 - 0.0064)*1*0.4055$
$= 0.5426\ in^2$

$= 2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
$= 2*(0.274 - 0.0064)*(2.5*0.274 + 0.5512)*1$
$= 0.6616\ in^2$

$A_{41} = Leg^2*f_{r3}$
$= 0.3937^2*1$
$= 0.155\ in^2$

$A_{42} = Leg^2*f_{r4}$
$= 0^2*1$
$= 0\ in^2$

(Part of the weld is outside of the limits)

$A_5 = (D_p - d - 2*t_n)*t_e*f_{r4}$
$= (7.904 - 3.952 - 2*0.274)*0.5512*1$
$= 1.8762\ in^2$

$Area = A_1 + A_2 + A_{41} + A_{42} + A_5$
$= 1.3266 + 0.5426 + 0.155 + 0 + 1.8762$
$= 3.9004\ in^2$

As Area >= A the reinforcement is adequate.

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

Inner fillet: $t_{min}$ = lesser of 0.75 or $t_n$ or $t_e$ = 0.274 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.1918 in
$t_{c(actual)} = 0.7*Leg = 0.7*0.3937 = 0.2756$ in

Outer fillet: $t_{min}$ = lesser of 0.75 or $t_e$ or t = 0.4055 in
$t_{w(min)} = 0.5*t_{min} = 0.2028$ in
$t_{w(actual)} = 0.7*Leg = 0.7*0.3937 = 0.2756$ in

**UG-45 Nozzle Neck Thickness Check**

Interpretation VIII-1-83-66 has been applied.
Wall thickness per UG-45(a): $t_{r1}$ = 0.2797 in (E =1) (pressure plus external loads govern in longitudinal direction)

| | |
|---|---|
| Wall thickness per UG-45(b)(1): | $t_{r2}$ = 0.1405 in |
| Wall thickness per UG-16(b): | $t_{r3}$ = 0.1255 in |
| Standard wall pipe per UG-45(b)(4): | $t_{r4}$ = 0.2704 in |
| The greater of $t_{r2}$ or $t_{r3}$: | $t_{r5}$ = 0.1405 in |
| The lesser of $t_{r4}$ or $t_{r5}$: | $t_{r6}$ = 0.1405 in |

Required per UG-45 is the larger of $t_{r1}$ or $t_{r6}$ = 0.2797 in

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

The nozzle neck thickness is adequate.

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

| | | |
|---|---|---|
| Groove weld in tension: | 0.74*16,700 = | 12,358 psi |
| Nozzle wall in shear: | 0.7*16,700 = | 11,690 psi |
| Inner fillet weld in shear: | 0.49*16,700 = | 8,183 psi |
| Outer fillet weld in shear: | 0.49*16,700 = | 8,183 psi |
| Upper groove weld in tension: | 0.74*16,700 = | 12,358 psi |

**Strength of welded joints:**

(1) Inner fillet weld in shear
$(\pi / 2)$*Nozzle OD*Leg*$S_i$ = $(\pi / 2)$*4.5*0.3937*8,183 = 22,772.53 $lb_f$

(2) Outer fillet weld in shear
$(\pi / 2)$*Pad OD*Leg*$S_o$ = $(\pi / 2)$*8.2677*0.3937*8,183 = 41,839.29 $lb_f$

(3) Nozzle wall in shear
$(\pi / 2)$*Mean nozzle dia*$t_n$*$S_n$ = $(\pi / 2)$*4.226*0.274*11,690 = 21,263.08 $lb_f$

(4) Groove weld in tension
$(\pi / 2)$*Nozzle OD*$t_w$*$S_g$ = $(\pi / 2)$*4.5*0.4055*12,358 = 35,422.21 $lb_f$

(6) Upper groove weld in tension
$(\pi / 2)$*Nozzle OD*$t_w$*$S_g$ = $(\pi / 2)$*4.5*0.5512*12,358 = 48,147.63 $lb_f$

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

$$W = (A - A_1 + 2*t_n*f_{r1}*(E_1*t - F*t_r))*S_v$$
$$= (0.2759 - 1.3266 + 2*0.274*1*(1*0.4055 - 1*0.0698))*16{,}700$$
$$= -14{,}474.1\ lb_f$$

$$W_{1-1} = (A_2 + A_5 + A_{41} + A_{42})*S_v$$
$$= (0.5426 + 1.8762 + 0.155 + 0)*16{,}700$$
$$= 42{,}982.51\ lb_f$$

$$W_{2-2} = (A_2 + A_3 + A_{41} + A_{43} + 2*t_n*t*f_{r1})*S_v$$
$$= (0.5426 + 0 + 0.155 + 0 + 2*0.274*0.4055*1)*16{,}700$$
$$= 15{,}361.04\ lb_f$$

$$W_{3-3} = (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2*t_n*t*f_{r1})*S_v$$
$$= (0.5426 + 0 + 1.8762 + 0.155 + 0 + 0 + 2*0.274*0.4055*1)*16{,}700$$
$$= 46{,}693.63\ lb_f$$

Load for path 1-1 lesser of W or $W_{1-1}$ = -14474.1 $lb_f$
Path 1-1 through (2) & (3) = 41,839.29 + 21,263.08 = 63,102.37 $lb_f$
Path 1-1 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 2-2 lesser of W or $W_{2-2}$ = -14474.1 $lb_f$
Path 2-2 through (1), (4), (6) = 22,772.53 + 35,422.21 + 48,147.63 = 106,342.36 $lb_f$
Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 3-3 lesser of W or $W_{3-3}$ = -14474.1 $lb_f$

Path 3-3 through (2), (4) = 41,839.29 + 35,422.21 = 77,261.5 $lb_f$
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

**Applied Loads**

| | | |
|---|---|---|
| Radial load: | $P_r$ = | -967.83 $lb_f$ |
| Circumferential moment: | $M_1$ = | 38,624.29 $lb_f$-in |
| Circumferential shear: | $V_2$ = | 1,933.46 $lb_f$ |
| Longitudinal moment: | $M_2$ = | 38,624.29 $lb_f$-in |
| Longitudinal shear: | $V_1$ = | 1,933.46 $lb_f$ |
| Torsion moment: | $M_t$ = | 27,254 $lb_f$-in |
| Internal pressure: | P = | 53.976 psi |
| Head yield stress: | $S_y$ = | 20,200 psi |

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

Mean dish radius $R_m$ = 43.6746 in

U = $r_o$ / Sqr($R_m$*t) = 0.982
Pressure stress intensity factor, I = 1 (derived from PVP-Vol. 399, pages 77-82)

Local pressure stress = I*P*$R_i$ / (2*t) =2,893 psi

Maximum combined stress ($P_L$+$P_b$+Q) = 34,960 psi
Allowable combined stress ($P_L$+$P_b$+Q ) = +-3*S = +-50,100 psi

Note: The allowable combined stress ($P_L$+$P_b$+Q) is based on the strain hardening characteristics of this material.
The maximum combined stress ($P_L$+$P_b$+Q) is within allowable limits.

Maximum local primary membrane stress ($P_L$) = 7,747 psi
Allowable local primary membrane stress ($P_L$) = +-1.5*S = +-25,050 psi

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

| Stresses at the pad edge per WRC Bulletin 107 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Figure** | **value** | **$A_u$** | **$A_l$** | **$B_u$** | **$B_l$** | **$C_u$** | **$C_l$** | **$D_u$** | **$D_l$** |
| SR-2* | 0.068 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 |
| SR-2 | 0.0363 | 1,282 | -1,282 | 1,282 | -1,282 | 1,282 | -1,282 | 1,282 | -1,282 |
| SR-3* | 0.0798 | 0 | 0 | 0 | 0 | -4,454 | -4,454 | 4,454 | 4,454 |
| SR-3 | 0.0773 | 0 | 0 | 0 | 0 | -25,887 | 25,887 | 25,887 | -25,887 |
| SR-3* | 0.0798 | -4,454 | -4,454 | 4,454 | 4,454 | 0 | 0 | 0 | 0 |
| SR-3 | 0.0773 | -25,887 | 25,887 | 25,887 | -25,887 | 0 | 0 | 0 | 0 |
| **Pressure stress*** | | 2,893 | 2,893 | 2,893 | 2,893 | 2,893 | 2,893 | 2,893 | 2,893 |
| **Total $O_x$ stress** | | -25,766 | 23,444 | 34,916 | -19,422 | -25,766 | 23,444 | 34,916 | -19,422 |
| **Membrane $O_x$ stress*** | | -1,161 | -1,161 | 7,747 | 7,747 | -1,161 | -1,161 | 7,747 | 7,747 |
| SR-2* | 0.0211 | 124 | 124 | 124 | 124 | 124 | 124 | 124 | 124 |
| SR-2 | 0.0109 | 385 | -385 | 385 | -385 | 385 | -385 | 385 | -385 |
| SR-3* | 0.024 | 0 | 0 | 0 | 0 | -1,340 | -1,340 | 1,340 | 1,340 |
| SR-3 | 0.0233 | 0 | 0 | 0 | 0 | -7,803 | 7,803 | 7,803 | -7,803 |
| SR-3* | 0.024 | -1,340 | -1,340 | 1,340 | 1,340 | 0 | 0 | 0 | 0 |
| SR-3 | 0.0233 | -7,803 | 7,803 | 7,803 | -7,803 | 0 | 0 | 0 | 0 |
| **Pressure stress*** | | 2,893 | 2,893 | 2,893 | 2,893 | 2,893 | 2,893 | 2,893 | 2,893 |
| **Total $O_y$ stress** | | -5,741 | 9,095 | 12,545 | -3,831 | -5,741 | 9,095 | 12,545 | -3,831 |
| **Membrane $O_y$ stress*** | | 1,677 | 1,677 | 4,357 | 4,357 | 1,677 | 1,677 | 4,357 | 4,357 |
| **Shear from $M_t$** | | 626 | 626 | 626 | 626 | 626 | 626 | 626 | 626 |
| **Shear from $V_1$** | | 0 | 0 | 0 | 0 | -367 | -367 | 367 | 367 |
| **Shear from $V_2$** | | 367 | 367 | -367 | -367 | 0 | 0 | 0 | 0 |
| **Total Shear stress** | | 993 | 993 | 259 | 259 | 259 | 259 | 993 | 993 |
| **Combined stress ($P_L+P_b+Q$)** | | -25,815 | 23,512 | 34,919 | -19,426 | -25,769 | 23,449 | 34,960 | -19,485 |

Notes: (1) * denotes primary stress.

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

**Maximum stresses due to the applied loads at the nozzle OD (includes pressure)**

Mean dish radius $R_m$ = 43.6746 in

U = $r_o$ / Sqr($R_m$*t) = 0.348
Pressure stress intensity factor, I = 0.31645 (derived from PVP-Vol. 399, pages 77-82)

Local pressure stress = I*P*$R_i$ / (2*t) =916 psi

Maximum combined stress ($P_L+P_b+Q$) = 18,463 psi
Allowable combined stress ($P_L+P_b+Q$ ) = +-3*S = +-50,100 psi

Note: The allowable combined stress ($P_L+P_b+Q$) is based on the strain hardening characteristics of this material.
The maximum combined stress ($P_L+P_b+Q$) is within allowable limits.

Maximum local primary membrane stress ($P_L$) = 2,165 psi
Allowable local primary membrane stress ($P_L$) = +-1.5*S = +-25,050 psi

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

| Stresses at the nozzle OD per WRC Bulletin 107 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Figure** | **value** | **$A_u$** | **$A_l$** | **$B_u$** | **$B_l$** | **$C_u$** | **$C_l$** | **$D_u$** | **$D_l$** |
| SR-2* | 0.1737 | 184 | 184 | 184 | 184 | 184 | 184 | 184 | 184 |
| SR-2 | 0.1208 | 766 | -766 | 766 | -766 | 766 | -766 | 766 | -766 |
| SR-3* | 0.1631 | 0 | 0 | 0 | 0 | -1,065 | -1,065 | 1,065 | 1,065 |
| SR-3 | 0.3936 | 0 | 0 | 0 | 0 | -15,418 | 15,418 | 15,418 | -15,418 |
| SR-3* | 0.1631 | -1,065 | -1,065 | 1,065 | 1,065 | 0 | 0 | 0 | 0 |
| SR-3 | 0.3936 | -15,418 | 15,418 | 15,418 | -15,418 | 0 | 0 | 0 | 0 |
| **Pressure stress*** | | 916 | 916 | 916 | 916 | 916 | 916 | 916 | 916 |
| **Total $O_x$ stress** | | -14,617 | 14,687 | 18,349 | -14,019 | -14,617 | 14,687 | 18,349 | -14,019 |
| **Membrane $O_x$ stress*** | | 35 | 35 | 2,165 | 2,165 | 35 | 35 | 2,165 | 2,165 |
| SR-2* | 0.0522 | 55 | 55 | 55 | 55 | 55 | 55 | 55 | 55 |
| SR-2 | 0.0372 | 236 | -236 | 236 | -236 | 236 | -236 | 236 | -236 |
| SR-3* | 0.05 | 0 | 0 | 0 | 0 | -326 | -326 | 326 | 326 |
| SR-3 | 0.1189 | 0 | 0 | 0 | 0 | -4,658 | 4,658 | 4,658 | -4,658 |
| SR-3* | 0.05 | -326 | -326 | 326 | 326 | 0 | 0 | 0 | 0 |
| SR-3 | 0.1189 | -4,658 | 4,658 | 4,658 | -4,658 | 0 | 0 | 0 | 0 |
| **Pressure stress*** | | 916 | 916 | 916 | 916 | 916 | 916 | 916 | 916 |
| **Total $O_y$ stress** | | -3,777 | 5,067 | 6,191 | -3,597 | -3,777 | 5,067 | 6,191 | -3,597 |
| **Membrane $O_y$ stress*** | | 645 | 645 | 1,297 | 1,297 | 645 | 645 | 1,297 | 1,297 |
| **Shear from $M_t$** | | 896 | 896 | 896 | 896 | 896 | 896 | 896 | 896 |
| **Shear from $V_1$** | | 0 | 0 | 0 | 0 | -286 | -286 | 286 | 286 |
| **Shear from $V_2$** | | 286 | 286 | -286 | -286 | 0 | 0 | 0 | 0 |
| **Total Shear stress** | | 1,182 | 1,182 | 610 | 610 | 610 | 610 | 1,182 | 1,182 |
| **Combined stress ($P_L+P_b+Q$)** | | -14,744 | 14,830 | 18,380 | -14,055 | -14,651 | 14,726 | 18,463 | -14,151 |

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**

$\sigma_{n\ (Pm)} = P*R_i / (2*t_n) - P_r / (\pi*(R_o^2 - R_i^2)) + M*R_o / I$
= 53.98*1.976 / (2*0.2319) - -967.83 / (π*(2.25$^2$ - 1.976$^2$)) + 54,623*2.25 / 8.1551
= 15,567 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 ( ¡ ÂS = 16,700 psi)

**Shear stress in the nozzle wall due to external loads**

$\sigma_{shear} = (V_L^2 + V_c^2)^{0.5} / (\pi*R_i*t_n)$
= (1,933.46$^2$ + 1,933.46$^2$)$^{0.5}$ / (π*1.976*0.274)
= 1,608 psi

$\sigma_{torsion} = M_t / (2*\pi*R_i^2*t_n)$
= 27,254 / (2*π*1.976$^2$*0.274)
= 4,054 psi

$\sigma_{total} = \sigma_{shear} + \sigma_{torsion}$
= 1,608 + 4,054
= 5,662 psi

UG-45(c): The total combined shear stress (5,662 psi) is below than the allowable (0.7*$S_n$ = 0.7*16,700 = 11,690 psi)

**Reinforcement Calculations for External Pressure**

| UG-37 Area Calculation Summary ($in^2$) For Pe = 15 psi @ 115 °F The opening is adequately reinforced | | | | | | | UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45 | |
|---|---|---|---|---|---|---|---|---|
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| 0.2494 | 3.6389 | 1.1038 | 0.5039 | -- | 1.8762 | 0.155 | 0.2766 | 0.2949 |

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

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| Weld description | Required weld size (in) | Actual weld size (in) | Status |
| Nozzle to pad fillet ($Leg_{41}$) | 0.1918 | 0.2756 | weld size is adequate |
| Pad to shell fillet ($Leg_{42}$) | 0.2027 | 0.2756 | weld size is adequate |
| Nozzle to pad groove (Upper) | 0.1918 | 0.5512 | weld size is adequate |

**Calculations for external pressure 15 psi @ 115 °F**

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

$L_R$ = MAX(d, $R_n$ + ($t_n$ - $C_n$) + (t - C))
= MAX(3.952, 1.976 + (0.337 - 0.063) + (0.4685 - 0.063))
= 3.952 in

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

$L_H$ = MIN(2.5*(t - C), 2.5*($t_n$ - $C_n$) + $t_e$)
= MIN(2.5*(0.4685 - 0.063), 2.5*(0.337 - 0.063) + 0.5512)
= 1.0138 in

**Nozzle required thickness per UG-28 $t_{rn}$ = 0.0255 in**

**From UG-37(d)(1) required thickness $t_r$ = 0.1262 in**

**Area required per UG-37(d)(1)**

Allowable stresses: $S_n$ = 16,700, $S_v$ = 16,700, $S_p$ = 16,700 psi

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

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

$f_{r3}$ = lesser of $f_{r2}$ or $S_p$ / $S_v$ = 1

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

A = 0.5*(d*$t_r$*F + 2*$t_n$*$t_r$*F*(1 - $f_{r1}$))
= 0.5*(3.952*0.1262*1 + 2*0.274*0.1262*1*(1 - 1))
= 0.2494 $in^2$

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

$A_1$ = larger of the following= 1.1038 $in^2$

= d*($E_1$*t - F*$t_r$) - 2*$t_n$*($E_1$*t - F*$t_r$)*(1 - $f_{r1}$)
= 3.952*(1*0.4055 - 1*0.1262) - 2*0.274*(1*0.4055 - 1*0.1262)*(1 - 1)
= 1.1038 $in^2$

= $2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= $2*(0.4055 + 0.274)*(1*0.4055 - 1*0.1262) - 2*0.274*(1*0.4055 - 1*0.1262)*(1 - 1)$
= 0.3796 $in^2$

$A_2$ = smaller of the following= 0.5039 $in^2$

= $5*(t_n - t_{rn})*f_{r2}*t$
= $5*(0.274 - 0.0255)*1*0.4055$
= 0.5039 $in^2$

= $2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
= $2*(0.274 - 0.0255)*(2.5*0.274 + 0.5512)*1$
= 0.6145 $in^2$

$A_{41}$ = $Leg^2*f_{r3}$
= $0.3937^2*1$
= 0.155 $in^2$

$A_{42}$ = $Leg^2*f_{r4}$
= $0^2*1$
= 0 $in^2$

(Part of the weld is outside of the limits)

$A_5$ = $(D_p - d - 2*t_n)*t_e*f_{r4}$
= $(7.904 - 3.952 - 2*0.274)*0.5512*1$
= 1.8762 $in^2$

Area = $A_1 + A_2 + A_{41} + A_{42} + A_5$
= $1.1038 + 0.5039 + 0.155 + 0 + 1.8762$
= 3.6389 $in^2$

As Area >= A the reinforcement is adequate.

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

Inner fillet: $t_{min}$ = lesser of 0.75 or $t_n$ or $t_e$ = 0.274 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.1918 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.3937 = 0.2756 in

Outer fillet: $t_{min}$ = lesser of 0.75 or $t_e$ or t = 0.4055 in
$t_{w(min)}$ = $0.5*t_{min}$ = 0.2028 in
$t_{w(actual)}$ = 0.7*Leg = 0.7*0.3937 = 0.2756 in

**UG-45 Nozzle Neck Thickness Check**

Interpretation VIII-1-83-66 has been applied.

| | |
|---|---|
| Wall thickness per UG-45(a): | $t_{r1}$ = 0.2766 in (pressure plus external loads govern in longitudinal direction) |
| Wall thickness per UG-45(b)(2): | $t_{r2}$ = 0.0845 in |
| Wall thickness per UG-16(b): | $t_{r3}$ = 0.1255 in |
| Standard wall pipe per UG-45(b)(4): | $t_{r4}$ = 0.2704 in |
| The greater of $t_{r2}$ or $t_{r3}$: | $t_{r5}$ = 0.1255 in |
| The lesser of $t_{r4}$ or $t_{r5}$: | $t_{r6}$ = 0.1255 in |

Required per UG-45 is the larger of $t_{r1}$ or $t_{r6}$ = 0.2766 in

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

The nozzle neck thickness is adequate.

**External Pressure, (Corroded & at 115 °F) UG-28(c)**

$L / D_o$ = 17.5863 / 4.5 = 3.9081
$D_o / t$ = 4.5 / 0.0255 = 176.5999
From table G: A = 0.000141
From table HA-3: B = 1,986.7726 psi

$P_a$ = $4*B / (3*(D_o / t))$
= 4*1,986.77 / (3*(4.5 / 0.0255))
= 15 psi

**Design thickness for external pressure $P_a$ = 15 psi**

$t_a$ = t + Corrosion = 0.0255 + 0.063 = 0.0885"

**2" (LB1A/B, LT3A/B, LT5A/B, LT7A/B)**

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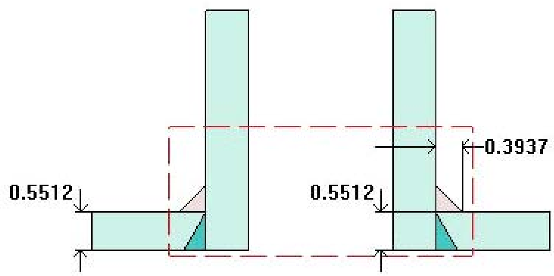
$t_{w(lower)}$ = 0.5512 in

$Leg_{41}$ = 0.3937 in




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

| | |
|---|---|
| Located on: | SHELL |
| Liquid static head included: | 0 psi |
| Nozzle material specification: | SA-182 F304L <= 5 (II-D p. 82, ln. 34) |
| Nozzle longitudinal joint efficiency: | 1 |
| Flange description: | 2 inch Class 300 LWN A182 F304L |
| Bolt Material: | SA-193 B7 Bolt <= 2 1/2 (II-D p. 348, ln. 33) |
| Flange rated MDMT: | -55°F |
| (Per UHA-51(d)(1)(a)) | |
| (Flange rated MDMT = -320 °F<br>Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F) | |
| Liquid static head on flange: | 0 psi |
| ASME B16.5 flange rating MAWP: | 482.5 psi @ 250°F |
| ASME B16.5 flange rating MAP: | 600 psi @ 68°F |
| ASME B16.5 flange hydro test: | 925 psi @ 68°F |
| Gasket Description: | Flexitallic Spiral Wound CG 304L S.S. |
| PWHT performed: | No |
| Nozzle orientation: | 212° |
| Local vessel minimum thickness: | 0.5512 in |
| Nozzle center line offset to datum line: | 90 in |
| End of nozzle to shell center: | 33.0709 in |
| Nozzle inside diameter, new: | 2.0669 in |
| Nozzle nominal wall thickness: | 0.6201 in |
| Nozzle corrosion allowance: | 0.063 in |
| Projection available outside vessel, Lpr: | 7.6436 in |
| Projection available outside vessel to flange face, Lf: | 8.5236 in |

**Reinforcement Calculations for Internal Pressure**

| UG-37 Area Calculation Summary ($in^2$) For P = 50 psi @ 250 °F The opening is adequately reinforced | | | | | | | UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45 | |
|---|---|---|---|---|---|---|---|---|
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| 0.1582 | 2.419 | 0.9123 | 1.3517 | -- | -- | 0.155 | 0.1352 | 0.6201 |

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

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| Weld description | Required weld throat size (in) | Actual weld throat size (in) | Status |
| Nozzle to shell fillet ($Leg_{41}$) | 0.25 | 0.2756 | weld size is adequate |

**Calculations for internal pressure 50 psi @ 250 °F**

Nozzle Impact test exempt per UHA-51(g)(coincident ratio = 0.14781).

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

$$
\begin{aligned}
L_R &= MAX(d, R_n + (t_n - C_n) + (t - C)) \\
&= MAX(2.1929, 1.0965 + (0.6201 - 0.063) + (0.5512 - 0.063)) \\
&= 2.1929 \text{ in}
\end{aligned}
$$

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

$$
\begin{aligned}
L_H &= MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
&= MIN(2.5*(0.5512 - 0.063), 2.5*(0.6201 - 0.063) + 0) \\
&= 1.2205 \text{ in}
\end{aligned}
$$

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

$$
\begin{aligned}
t_{rn} &= P*R_n / (S_n*E - 0.6*P) \\
&= 50*1.0965 / (16{,}700*1 - 0.6*50) \\
&= 0.0033 \text{ in}
\end{aligned}
$$

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

$$
\begin{aligned}
t_r &= P*R / (S*E - 0.6*P) \\
&= 50*24.0591 / (16{,}700*1 - 0.6*50) \\
&= 0.0722 \text{ in}
\end{aligned}
$$

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

Allowable stresses: $S_n$ = 16,700, $S_v$ = 16,700 psi

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

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

$$
\begin{aligned}
A &= d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1}) \\
&= 2.1929*0.0722*1 + 2*0.5571*0.0722*1*(1 - 1) \\
&= 0.1582 \text{ in}^2
\end{aligned}
$$

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

$A_1$ = larger of the following= 0.9123 $in^2$

= $d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= 2.1929*(1*0.4882 - 1*0.0722) - 2*0.5571*(1*0.4882 - 1*0.0722)*(1 - 1)
= 0.9123 $in^2$

= $2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= 2*(0.4882 + 0.5571)*(1*0.4882 - 1*0.0722) - 2*0.5571*(1*0.4882 - 1*0.0722)*(1 - 1)
= 0.8697 $in^2$

$A_2$ = smaller of the following= 1.3517 $in^2$

= $5*(t_n - t_{rn})*f_{r2}*t$
= 5*(0.5571 - 0.0033)*1*0.4882
= 1.3517 $in^2$

= $5*(t_n - t_{rn})*f_{r2}*t_n$
= 5*(0.5571 - 0.0033)*1*0.5571
= 1.5425 $in^2$

$A_{41}$ = $Leg^2*f_{r2}$
= $0.3937^2*1$
= 0.155 $in^2$

Area = $A_1 + A_2 + A_{41}$
= 0.9123 + 1.3517 + 0.155
= 2.419 $in^2$

As Area >= A the reinforcement is adequate.

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

Fillet weld: $t_{min}$ = lesser of 0.75 or $t_n$ or t = 0.4882 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.3937 = 0.2756 in

The fillet weld size is satisfactory.

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

**UG-45 Nozzle Neck Thickness Check**

| | |
|---|---|
| Wall thickness per UG-45(a): | $t_{r1}$ = 0.0663 in (E =1) |
| Wall thickness per UG-45(b)(1): | $t_{r2}$ = 0.1352 in |
| Wall thickness per UG-16(b): | $t_{r3}$ = 0.1255 in |
| Standard wall pipe per UG-45(b)(4): | $t_{r4}$ = 0.252 in |
| The greater of $t_{r2}$ or $t_{r3}$: | $t_{r5}$ = 0.1352 in |
| The lesser of $t_{r4}$ or $t_{r5}$: | $t_{r6}$ = 0.1352 in |

Required per UG-45 is the larger of $t_{r1}$ or $t_{r6}$ = 0.1352 in

Available nozzle wall thickness new, $t_n$ = 0.6201 in

The nozzle neck thickness is adequate.

**Reinforcement Calculations for External Pressure**

| UG-37 Area Calculation Summary ($in^2$) For Pe = 15 psi @ 115 °F The opening is adequately reinforced | | | | | | | UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45 | |
|---|---|---|---|---|---|---|---|---|
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| 0.2784 | 1.9895 | 0.5136 | 1.3209 | -- | -- | 0.155 | 0.1255 | 0.6201 |

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

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| Weld description | Required weld throat size (in) | Actual weld throat size (in) | Status |
| Nozzle to shell fillet ($Leg_{41}$) | 0.25 | 0.2756 | weld size is adequate |

**Calculations for external pressure 15 psi @ 115 °F**

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

$L_R$ = MAX(d, $R_n$ + ($t_n$ - $C_n$) + (t - C))
= MAX(2.1929, 1.0965 + (0.6201 - 0.063) + (0.5512 - 0.063))
= 2.1929 in

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

$L_H$ = MIN(2.5*(t - C), 2.5*($t_n$ - $C_n$) + $t_e$)
= MIN(2.5*(0.5512 - 0.063), 2.5*(0.6201 - 0.063) + 0)
= 1.2205 in

**Nozzle required thickness per UG-28 $t_{rn}$ = 0.0159 in**

**From UG-37(d)(1) required thickness $t_r$ = 0.254 in**

**Area required per UG-37(d)(1)**

Allowable stresses: $S_n$ = 16,700, $S_v$ = 16,700 psi

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

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

A = 0.5*(d*$t_r$*F + 2*$t_n$*$t_r$*F*(1 - $f_{r1}$))
= 0.5*(2.1929*0.254*1 + 2*0.5571*0.254*1*(1 - 1))
= 0.2784 $in^2$

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

$A_1$ = larger of the following= 0.5136 $in^2$

= d*($E_1$*t - F*$t_r$) - 2*$t_n$*($E_1$*t - F*$t_r$)*(1 - $f_{r1}$)
= 2.1929*(1*0.4882 - 1*0.254) - 2*0.5571*(1*0.4882 - 1*0.254)*(1 - 1)
= 0.5136 $in^2$

= 2*(t + $t_n$)*($E_1$*t - F*$t_r$) - 2*$t_n$*($E_1$*t - F*$t_r$)*(1 - $f_{r1}$)
= 2*(0.4882 + 0.5571)*(1*0.4882 - 1*0.254) - 2*0.5571*(1*0.4882 - 1*0.254)*(1 - 1)
= 0.4897 $in^2$

$A_2$ = smaller of the following= 1.3209 $in^2$

$= 5*(t_n - t_{rn})*f_{r2}*t$
$= 5*(0.5571 - 0.0159)*1*0.4882$
$= 1.3209\ in^2$

$= 5*(t_n - t_{rn})*f_{r2}*t_n$
$= 5*(0.5571 - 0.0159)*1*0.5571$
$= 1.5074\ in^2$

$A_{41} = Leg^2*f_{r2}$
$= 0.3937^2*1$
$= 0.155\ in^2$

Area $= A_1 + A_2 + A_{41}$
$= 0.5136 + 1.3209 + 0.155$
$= 1.9895\ in^2$

As Area >= A the reinforcement is adequate.

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

Fillet weld: $t_{min}$ = lesser of 0.75 or $t_n$ or t = 0.4882 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.3937 = 0.2756 in

The fillet weld size is satisfactory.

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

**UG-45 Nozzle Neck Thickness Check**

| | |
|---|---|
| Wall thickness per UG-45(a): | $t_{r1}$ = 0.0789 in |
| Wall thickness per UG-45(b)(2): | $t_{r2}$ = 0.0846 in |
| Wall thickness per UG-16(b): | $t_{r3}$ = 0.1255 in |
| Standard wall pipe per UG-45(b)(4): | $t_{r4}$ = 0.252 in |
| The greater of $t_{r2}$ or $t_{r3}$: | $t_{r5}$ = 0.1255 in |
| The lesser of $t_{r4}$ or $t_{r5}$: | $t_{r6}$ = 0.1255 in |

Required per UG-45 is the larger of $t_{r1}$ or $t_{r6}$ = 0.1255 in

Available nozzle wall thickness new, $t_n$ = 0.6201 in

The nozzle neck thickness is adequate.

**External Pressure, (Corroded & at 115 °F) UG-28(c)**

$L / D_o$ = 8.5794 / 3.3071 = 2.5942
$D_o / t$ = 3.3071 / 0.0159 = 207.7180
From table G: A = 0.000165
From table HA-3: B = 2,336.7605 psi

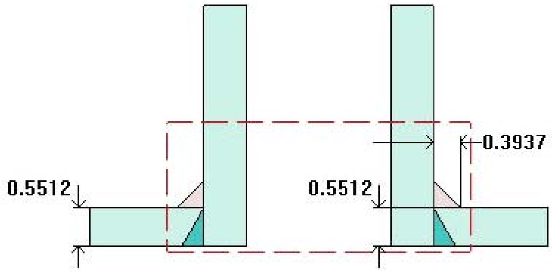
$P_a = 4*B / (3*(D_o / t))$
$= 4*2{,}336.76 / (3*(3.3071 / 0.0159))$
$= 15$ psi

**Design thickness for external pressure $P_a$ = 15 psi**

$t_a$ = t + Corrosion = 0.0159 + 0.063 = 0.0789"

**2" (LT2A/B, LT4A/B, LT6A/B)**

**ASME Section VIII Division 1, 2007 Edition, A09 Addenda**




$t_{w(lower)}$ = 0.5512 in

$Leg_{41}$ = 0.3937 in

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

| | |
|---|---|
| Located on: | SHELL |
| Liquid static head included: | 2.7131 psi |
| Nozzle material specification: | SA-182 F304L <= 5 (II-D p. 82, ln. 34) |
| Nozzle longitudinal joint efficiency: | 1 |
| Flange description: | 2 inch Class 300 LWN A182 F304L |
| Bolt Material: | SA-193 B7 Bolt <= 2 1/2 (II-D p. 348, ln. 33) |
| Flange rated MDMT: | -55°F |
| (Per UHA-51(d)(1)(a)) | |
| (Flange rated MDMT = -320 °F<br>Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F) | |
| Liquid static head on flange: | 2.6752 psi |
| ASME B16.5 flange rating MAWP: | 482.5 psi @ 250°F |
| ASME B16.5 flange rating MAP: | 600 psi @ 68°F |
| ASME B16.5 flange hydro test: | 925 psi @ 68°F |
| Gasket Description: | Flexitallic Spiral Wound CG 304L S.S. |
| PWHT performed: | No |
| Nozzle orientation: | 290° |
| Local vessel minimum thickness: | 0.5512 in |
| Nozzle center line offset to datum line: | 5.9843 in |
| End of nozzle to shell center: | 33.0709 in |
| Nozzle inside diameter, new: | 2.0669 in |
| Nozzle nominal wall thickness: | 0.6201 in |
| Nozzle corrosion allowance: | 0.063 in |
| Projection available outside vessel, Lpr: | 7.6436 in |
| Projection available outside vessel to flange face, Lf: | 8.5236 in |

**Reinforcement Calculations for Internal Pressure**

| UG-37 Area Calculation Summary ($in^2$) For P = 52.71 psi @ 250 °F | | | | | | | UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45 | |
|---|---|---|---|---|---|---|---|---|
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| This nozzle is exempt from area calculations per UG-36(c)(3)(a) | | | | | | | 0.1391 | 0.6201 |

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

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| Weld description | Required weld throat size (in) | Actual weld throat size (in) | Status |
| Nozzle to shell fillet ($Leg_{41}$) | 0.25 | 0.2756 | weld size is adequate |

**Calculations for internal pressure 52.71 psi @ 250 °F**

Nozzle Impact test exempt per UHA-51(g)(coincident ratio = 0.15586).

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

$L_R$ = MAX(d, $R_n$ + ($t_n$ - $C_n$) + (t - C))
= MAX(2.1929, 1.0965 + (0.6201 - 0.063) + (0.5512 - 0.063))
= 2.1929 in

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

$L_H$ = MIN(2.5*(t - C), 2.5*($t_n$ - $C_n$) + $t_e$)
= MIN(2.5*(0.5512 - 0.063), 2.5*(0.6201 - 0.063) + 0)
= 1.2205 in

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

$t_{rn}$ = P*$R_n$ / ($S_n$*E - 0.6*P)
= 52.7131*1.0965 / (16,700*1 - 0.6*52.7131)
= 0.0035 in

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

$t_r$ = P*R / (S*E - 0.6*P)
= 52.7131*24.0591 / (16,700*1 - 0.6*52.7131)
= 0.0761 in

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

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

Fillet weld: $t_{min}$ = lesser of 0.75 or $t_n$ or t = 0.4882 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*$t_{min}$ = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.3937 = 0.2756 in

The fillet weld size is satisfactory.

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

**UG-45 Nozzle Neck Thickness Check**

| | |
|---|---|
| Wall thickness per UG-45(a): | $t_{r1}$ = 0.0665 in (E =1) |
| Wall thickness per UG-45(b)(1): | $t_{r2}$ = 0.1391 in |

| | |
|---|---|
| Wall thickness per UG-16(b): | $t_{r3}$ = 0.1255 in |
| Standard wall pipe per UG-45(b)(4): | $t_{r4}$ = 0.252 in |
| The greater of $t_{r2}$ or $t_{r3}$: | $t_{r5}$ = 0.1391 in |
| The lesser of $t_{r4}$ or $t_{r5}$: | $t_{r6}$ = 0.1391 in |

Required per UG-45 is the larger of $t_{r1}$ or $t_{r6}$ = 0.1391 in

Available nozzle wall thickness new, $t_n$ = 0.6201 in

The nozzle neck thickness is adequate.

**Reinforcement Calculations for External Pressure**

| UG-37 Area Calculation Summary ($in^2$) For Pe = 15 psi @ 115 °F | | | | | | | UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45 | |
|---|---|---|---|---|---|---|---|---|
| A required | A available | $A_1$ | $A_2$ | $A_3$ | $A_5$ | A welds | $t_{req}$ | $t_{min}$ |
| This nozzle is exempt from area calculations per UG-36(c)(3)(a) | | | | | | | 0.1255 | 0.6201 |

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

| UW-16 Weld Sizing Summary | | | |
|---|---|---|---|
| Weld description | Required weld throat size (in) | Actual weld throat size (in) | Status |
| Nozzle to shell fillet ($Leg_{41}$) | 0.25 | 0.2756 | weld size is adequate |

**Calculations for external pressure 15 psi @ 115 °F**

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

$$
\begin{aligned}
L_R &= MAX(d, R_n + (t_n - C_n) + (t - C)) \\
&= MAX(2.1929, 1.0965 + (0.6201 - 0.063) + (0.5512 - 0.063)) \\
&= 2.1929 \text{ in}
\end{aligned}
$$

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

$$
\begin{aligned}
L_H &= MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
&= MIN(2.5*(0.5512 - 0.063), 2.5*(0.6201 - 0.063) + 0) \\
&= 1.2205 \text{ in}
\end{aligned}
$$

**Nozzle required thickness per UG-28 $t_{rn}$ = 0.0159 in**

**From UG-37(d)(1) required thickness $t_r$ = 0.254 in**

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

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

Fillet weld: $t_{min}$ = lesser of 0.75 or $t_n$ or t = 0.4882 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*$t_{min}$ = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.3937 = 0.2756 in

The fillet weld size is satisfactory.

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

**UG-45 Nozzle Neck Thickness Check**

| | |
|---|---|
| Wall thickness per UG-45(a): | $t_{r1}$ = 0.0789 in |
| Wall thickness per UG-45(b)(2): | $t_{r2}$ = 0.0846 in |
| Wall thickness per UG-16(b): | $t_{r3}$ = 0.1255 in |
| Standard wall pipe per UG-45(b)(4): | $t_{r4}$ = 0.252 in |
| The greater of $t_{r2}$ or $t_{r3}$: | $t_{r5}$ = 0.1255 in |
| The lesser of $t_{r4}$ or $t_{r5}$: | $t_{r6}$ = 0.1255 in |

Required per UG-45 is the larger of $t_{r1}$ or $t_{r6}$ = 0.1255 in

Available nozzle wall thickness new, $t_n$ = 0.6201 in

The nozzle neck thickness is adequate.

**External Pressure, (Corroded & at 115 °F) UG-28(c)**

$L / D_o$ = 8.5794 / 3.3071 = 2.5942
$D_o / t$ = 3.3071 / 0.0159 = 207.7180
From table G: A = 0.000165
From table HA-3: B = 2,336.7605 psi

$P_a$ = $4*B / (3*(D_o / t))$
= 4*2,336.76 / (3*(3.3071 / 0.0159))
= 15 psi

**Design thickness for external pressure $P_a$ = 15 psi**

$t_a$ = t + Corrosion = 0.0159 + 0.063 = 0.0789"

## CALCULATION OF BASEBLOCK UNDER LIFTING CONDITION

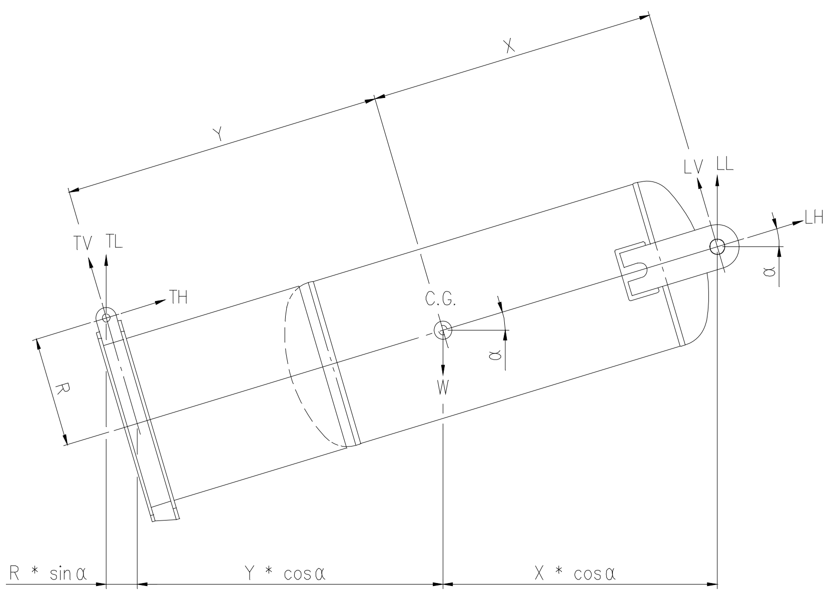
### 1. CALCULATION OF LIFTING FORCES

| | | | |
|---|---|---|---|
| a) ERECTION WEIGHT | We = | 9600 | kg |
| b) DYNAMIC LOAD FACTOR | F = | 1.5 | -- |
| c) LIFTING WEIGHT | W = We x F = | 14400 | kg |
| d) DIMENSIONS ; | X = | 2959.0 | mm |
| | Y = | 4918.0 | mm |
| | R = | 780.0 | mm |

* LL = W x ( Y x cosα + R x sinα ) / ( ( X + Y ) x cosα + R x sinα )
* TL = W x ( X x cosα ) / ( ( X + Y ) x cosα + R x sinα )
* LV = LL x cosα , LH = LL x sinα
* TV = TL x cosα , TH = TL x sinα

### 2. SUMMARY OF LIFTING FORCES IN VARIOUS ANGLES OF LIFTING

| Max. Loads ; | | | | |
|---|---|---|---|---|
| | LL = | 14400.0 | kg | ( at α = 90.00 Deg.) |
| | LV = | 9006.2 | kg | ( at α = 3.00 Deg.) |
| | LH = | 14400.0 | kg | ( at α = 90.00 Deg.) |
| | TL = | 5409.4 | kg | ( at α = 0.00 Deg.) |
| | TV = | 5409.4 | kg | ( at α = 0.00 Deg.) |
| | TH = | 4043.8 | kg | ( at α = 65.00 Deg.) |



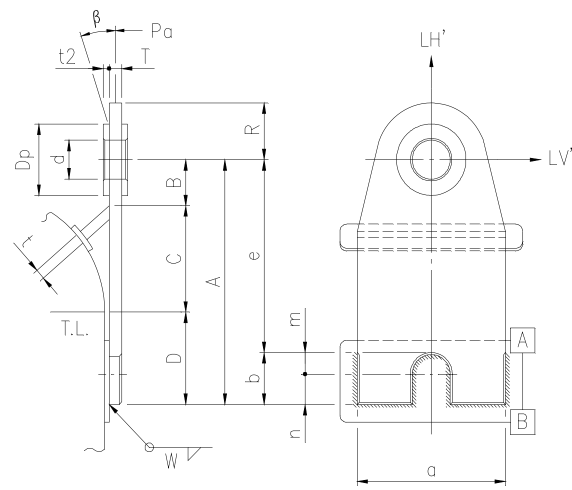

| α | LL | TL | LV | LH | TV | TH |
|---|---|---|---|---|---|---|
| 0.0 | 8990.6 | 5409.4 | 8990.6 | 0.0 | 5409.4 | 0.0 |
| 5.0 | 9037.1 | 5362.9 | 9002.7 | 787.6 | 5342.5 | 467.4 |
| 15.0 | 9130.4 | 5269.6 | 8819.3 | 2363.1 | 5090.0 | 1363.9 |
| 30.0 | 9283.2 | 5116.8 | 8039.5 | 4641.6 | 4431.3 | 2558.4 |
| 45.0 | 9478.0 | 4922.0 | 6702.0 | 6702.0 | 3480.4 | 3480.4 |
| 60.0 | 9782.6 | 4617.4 | 4891.3 | 8472.0 | 2308.7 | 3998.8 |
| 75.0 | 10450.3 | 3949.7 | 2704.7 | 10094.2 | 1022.3 | 3815.1 |
| 85.0 | 11862.6 | 2537.4 | 1033.9 | 11817.4 | 221.2 | 2527.8 |
| 90.0 | 14400.0 | 0.0 | 0.0 | 14400.0 | 0.0 | 0.0 |

### 3. STRENGTH OF LIFTING LUG

| | | | | | |
|---|---|---|---|---|---|
| MATERIAL AT LUG | | | : | SA 516-70 | |
| ALLOWABLE STRESS IN TENSION | | Sa | = | 14.06 | § ,/§ ± |
| YIELD STRESS | | Sy | = | 26.72 | § ,/§ ± |
| Q'TY OF LIFTING LUG | | N | = | 2 | ea |
| VERTICAL FORCE PER 1 LUG | LV'= LV / N | | = | 4503.10 | § , |
| HORIZONTAL FORCE PER 1 LUG | LH'= LH / N | | = | 7200 | § , |
| LIFTING HALF ANGLE | | ß | = | 15 | deg. |
| AXIAL FORCE PER 1 LUG | Pa = LH' * tan ß | | = | 1929.23 | § , |

* DIMENSIONS

| | | | | | |
|---|---|---|---|---|---|
| T = | 20 | § ® | A = | 415 | § ® |
| t = | 10 | § ® | B = | 80 | § ® |
| R = | 80 | § ® | C = | 110 | § ® |
| d = | 27 | § ® | D = | 225 | § ® |
| a = | 210 | § ® | W = | 10 | § ® |
| b = | 125 | § ® | e = | 290 | § ® |
| Dp = | 0 | § ® | t2 = | 0 | § ® |




3-1. CHECK OF LUG

a) SHEAR STRESS DUE TO LH'

S1 = 2*LH'/{(2*R-d)*T + 1/2 * (Dp-d) * t2 * 2}

= 5.414 § ,/§ ± < 0.4*Sy= 10.688 § ,/§ ±; O.K. !

b) TENSION DUE TO LH'

S2 = LH'/{(2*R-d)*T + (Dp-d) * t2 * 2}

= 2.707 § ,/§ ± < 0.6*Sy= 16.032 § ,/§ ±; O.K. !

c) SHEAR STRESS DUE TO LV'

S3 = 2*LV'/{(2*R-d)*T + 1/2 * (Dp-d) * t2 * 2}

= 3.386 § ,/§ ± < 0.4*Sy= 10.688 § ,/§ ±; O.K. !

d) TENSION DUE TO LV'

S4 = LV'/{(2*R-d)*T + (Dp-d) * t2 * 2}

= 1.693 § ,/§ ± < 0.6*Sy= 16.032 § ,/§ ±; O.K. !

e) BENDING STRESS DUE TO LV'

S5 = 6 * LV' * B / [(2 * R)² * T]

= 4.222 § ,/§ ± < 0.66*Sy= 17.6352 § ,/§ ±; O.K. !

3-2. STRESS OF GUIDE POINT

a) BENDING STRESS DUE TO Pa

S6 = 6*Pa*B/(2*R*T²) = 6 * 1929.23 * 80 / (2 * 80 * 20²)

= 14.469 § ¸/§ ± < 0.66*Sy= 17.6352 § ¸/§ ±; O.K. !

b) TENSION DUE TO LH'

S7 = LH'/ (2*R*T) = 7200.00 / {(2 * 80 * 20)

= 2.250 § ¸/§ ± < 0.6*Sy= 16.032 § ¸/§ ±; O.K. !

c) COMBINED STRESS

S8 = (S6/0.66Sy) + (S7/0.6Sy) < 1

= 0.961 < 1 O.K. !

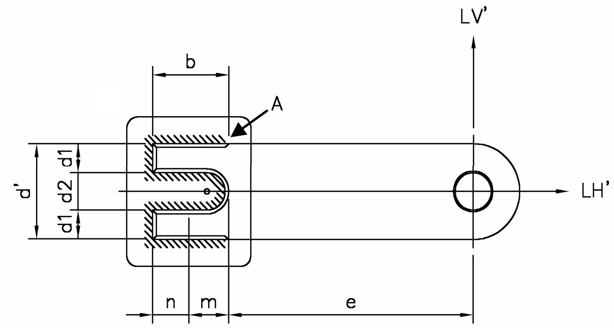
d) AXIAL STRESS DUE TO Pa

S9 = Pa / (2 * R * t)

= 1.206 § ¸/§ ± < 0.6*Sy= 16.032 § ¸/§ ±; O.K. !

3-3. LIFTING LUG WELD CALCULATION - LUG TO PAD WELD

| | | |
|---|---|---|
| b = | 125.00 | mm |
| d1 = | 105.00 | mm |
| d2 = | 0.00 | mm |
| d' = | 210.00 | mm |
| e = | 290.00 | mm |
| LV' = | 4503.1 | kg |
| LH' = | 7200 | kg |




(A) HORIZONTAL POSITION WITH LOAD LV'

1) Lug Weld Check Per Unit Width of Weld Throat

* Centroid , $n = 2b^2 / (4 * b + 2d1) =$ 44.014 mm
  $m = b - n$ = 80.986 mm

* Twisting Moment , T =(b+e-n)*LV'= 1670586 kg-mm

* The polar moment of inertia of weld , Jw
  $Jw = 4*[b^3/12+b*(b/2-n)] + 2*d1*n^2 + 2*b*(d1+d2/2)^2 + 2*b*(d2/2)^2 + 2*[d1^3/12+d1*(d1/2+d2/2)^2]$
  = 4595105 $mm^3$

* Distance from c.g to point being analyzed, C = ¡ ¡$[m^2 + (0.5d')^2]$ = 132.60 mm

Analyzed point is A

* Weld length, L = 2 * b + d1 = 355.00 mm

a) Direct shear force, fs = LV' / L = 12.685 kg/mm

b) Max. Load from twisting, f = T * C / Jw = 48.209 kg/mm

Vertical component , fv = m * f / C = 29.443 kg/mm
Horizontal component , fh=0.5d'* f/C = 38.174 kg/mm

c) Combined load per mm , F = ¡ ¡ $[fh^2 + (fs + fv)^2]$ = 56.850 kg/mm

d) Weld size check

Allowable stress S = 0.4 * Sy = 10.688 kg/§ ±

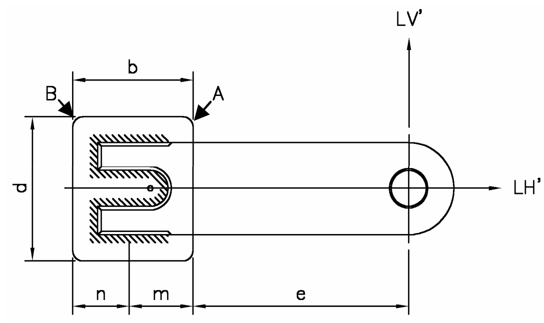
leg size, W = F / 0.707S = 7.523 mm < Min. Size = 10.00 mm O.K !

(B) VERTICAL POSITION WITH LOAD LH'

Weld area , A = L * (0.707 * W) = 2509.85 § ±

fs' = LH' / A = 2.869 kg/§ ± < 0.4 * Sy = 10.688 kg/§ ± O.K !

## 3-4. LIFTING LUG WELD CALCULATION - PAD TO SHELL WELD




| | | |
|---|---|---|
| MATERIAL AT PAD = | SA 516-70 | |
| YIELD STRESS = | 26.72 | § /§ ± |
| b = | 150.00 | mm |
| d = | 260.00 | mm |
| e = | 290.00 | mm |
| LV' = | 4503.1 | kg |
| LH' = | 7200.0 | kg |

(A) HORIZONTAL POSITION WITH LOAD LV'

1) Lug Weld Check Per Unit Width of Weld Throat

* Centroid , n = m = b / 2 = 75.000 mm

* Twisting Moment , T =(b+e-n)*LV'= 1643631 kg-mm

* The polar moment of inertia of weld , Jw
  $Jw = (b + d)^3 / 6$ = 11486833 $mm^3$

* Distance from c.g to point being analyzed, C = ¡ ¡$[m^2+(0.5d')^2]$= 150.08 mm

Analyzed point is A or B

* Weld length, L = 2 * b + 2 * d = 820.00 mm

a) Direct shear force, fs = LV' / L = 5.492 kg/mm

b) Max. Load from twisting, f = T * C / Jw = 21.475 kg/mm

Vertical component , fv = m * f / C = 10.732 kg/mm
Horizontal component , fh = 0.5d'*f/C= 18.601 kg/mm

c) Combined load per mm , F = ¡ ¡ $[fh^2 + (fs + fv)^2]$ = 24.682 kg/mm

d) Weld size check

Allowable stress S = 0.4 * Sy = 10.688 kg/§ ±

leg size, W = F / 0.707S = 3.266 mm < Min. Size = 10.00 mm O.K !

(B) VERTICAL POSITION WITH LOAD LH'

Weld area , A = L * (0.707 * W) = 5797.4 § ±

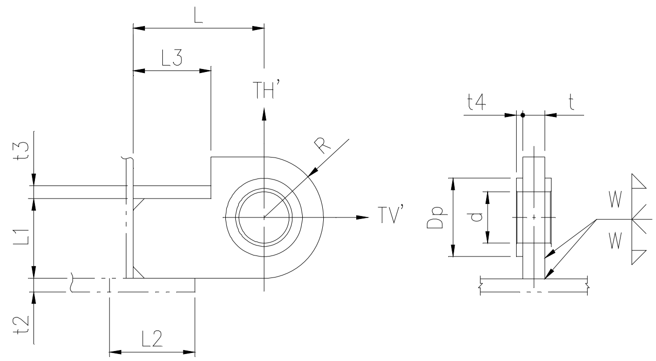
fs' = LH' / A = 1.242 kg/§ ± < 0.4 * Sy = 10.688 kg/§ ± O.K !

**4. STRENGTH OF TAILING LUG**

| | | | |
|---|---|---|---|
| USED MATERIAL | = | SA 516-70 | |
| YIELD STRESS OF TAILING LUG | Sy = | 26.72 | § /§ ± |
| ALLOWABLE SHEAR STRESS (0.4 * Sy) | Ssa = | 10.688 | § /§ ± |
| ALLOWABLE BENDING STRESS (0.66 * Sy) | Sba = | 17.635 | § /§ ± |
| ALLOWABLE TENSILE STRESS (0.6 * Sy) | Sta = | 16.032 | § /§ ± |
| TAILING LUG Q'TY. | N = | 1 | EA |
| LIFTING LOAD (MAX. AT HORIZONTAL COND.) | TV = | 5409.37 | kg |
| LIFTING LOAD PER TAILING LUG (VERTICAL FORCE) | TV' = TV/N = | 5409.37 | kg |
| LIFTING LOAD (MAX. AT VERTICAL COND.) AT 65.00 deg. | TH = | 4043.83 | kg |
| LIFTING LOAD PER TAILING LUG (HORIZONTAL FORCE) | TH' = TH/N = | 4043.83 | kg |

* DIMENSIONS

| | | | | | |
|---|---|---|---|---|---|
| t = | 20.0 | mm | t2 = | 26.00 | mm |
| L = | 164.0 | mm | t3 = | 26.00 | mm |
| R = | 60.0 | mm | L1 = | 151.00 | mm |
| d = | 27.0 | mm | L2 = | 133.00 | mm |
| W = | 7.0 | mm (WELD LEG) | L3 = | 89.00 | mm |
| Dp = | 0.0 | mm | TOTAL WELD LENGTH L4 = | 298.00 | mm |
| t4 = | 0.0 | mm | | | |




** STRENGTH CALCULATION **

4-1) SHEAR STRESS AT HORIZONTAL STATE

S1 = 2TV' / [(2R - d) * t + 1/2 * (Dp - d) * 2t4] = 5.817 § /§ ±

¡ ÅS1 = 5.817 § /§ ± < Ssa = 10.69 § /§ ±

O.K. !

4-2) TENSION STRESS AT HORIZONTAL STATE

S2 = TV' / [(2R - d) * t + (Dp - d) * 2t4] = 2.908 § /§ ±

¡ ÅS2 = 2.908 § /§ ± < Sta = 16.032 § /§ ±

O.K. !

4-3) BENDING STRESS AT MAX. SLOPED LOAD STATE , AT 65.00 deg.

S3 = 6 * TH' * L / [(2 * R)²*t] = 13.816 § /§ ±

¡ ÅS3 = 13.816 § /§ ± < Sba = 17.635 § /§ ±

O.K. !

4-4) TENSION STRESS AT MAX. SLOPED LOAD STATE , AT 65.00 deg.

S4 = TH' / [(2 * R - d) * t ] = 2.174 § ¸/§ ±

¡ ÅS4 = 2.174 § ¸/§ ± < Sta = 16.032 § ¸/§ ±

O.K. !

4-5) COMBINE STRESS AT MAX. SLOPED STATE, AT 65.00 deg.

Scomb = S3 / Sba + S4 / Sta = 0.919 < 1.0

O.K. !

4-6) CHECK OF WELDMENT

Sw = TV' / (2 * L4 * W) = 1.297 § ¸/§ ±

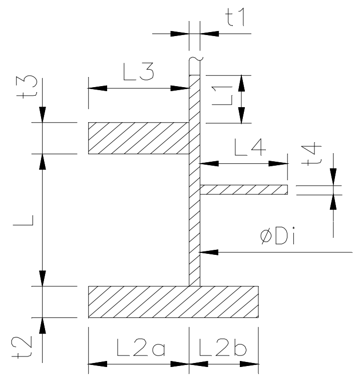
¡ ÅSw = 1.297 § ¸/§ ± < 0.49 * Sba = 7.856 § ¸/§ ±

O.K. !

**5. BASE BLOCK UNDER ERECTION CONDITION**

5-1. SECTIONAL PROPERTIES OF BASE BLOCK

| | | |
|---|---|---|
| t1 = | 10.00 | mm |
| t2 = | 26.00 | mm |
| t3 = | 26.00 | mm |
| t4 = | 0.00 | mm |
| L2a = | 89.00 | mm |
| L2b = | 44.00 | mm |
| L3 = | 89.00 | mm |
| L4 = | 0.00 | mm |
| L = | 151.00 | mm |
| Di = | 1212.00 | mm |




5-2. EFFECTIVE LENGTH OF SKIRT

| | | |
|---|---|---|
| Rm = (Di + t1) / 2 = | 611.00 | mm |
| L1 = Min.( 0.78 * ¡ ì (Rm * t1), 16*t1) = | 60.97 | mm |

5-3. SECTION AREA , A

| | | |
|---|---|---|
| A1 = t1 * (L + L1 + t3) = | 2379.7 | § ± |
| A2 = t2 * (L2a + L2b) = | 3458.0 | § ± |
| A3 = t3 * L3 = | 2314.0 | § ± |
| A4 = t4 * L4 = | 0.0 | § ± |
| TOTAL AREA, A = | 8151.7 | § ± |

5-4. CENTROID, C

| | | |
|---|---|---|
| h1 = L2a + t1 / 2 = | 94.0 | mm |
| h2 = (L2a + L2b) / 2 = | 66.5 | mm |
| h3 = L3 / 2 - (L3 - L2a) = | 44.5 | mm |
| h4 = L2a + t1 + L4 / 2 = | 99.0 | mm |

| | | |
|---|---|---|
| C = [(A1 * h1) + (A2 * h2) + (A3 * h3) + (A4 * h4)] / A = | 68.28 | mm |
| Y = (L2a + L2b) - C = | 64.72 | mm |

5-5. MOMENT OF INERTIA OF AREA, I (ABOUT NEUTRAL AXIS)

| | | |
|---|---|---|
| I1 = (L + L1 + t3) * t1^3 / 12 + A1 * (h1 - C)^2 = | 1593690 | mm^4 |
| I2 = t2 * (L2a + L2b)^3 / 12 + A2 * (h2 - C)^2 = | 5108372 | mm^4 |
| I3 = t3 * L3^3 / 12 + A3 * (h3 - C)^2 = | 2836293 | mm^4 |
| I4 = t4 * L4^3 / 12 + A4 * (h4 - C)^2 = | 0 | mm^4 |
| TOTAL I = I1 + I2 + I3 + I4 = | 9538355 | mm^4 |

5-6. MIN. SECTION MODULUS, Z

| | | |
|---|---|---|
| Z1 = I / C = | 139689 | mm^3 |
| Z2 = I / Y = | 147385 | mm^3 |
| Z = Min.(Z1, Z2) = | 139689 | mm^3 |

5-7. STRESS IN BASE BLOCK DUE TO TV

| | | |
|---|---|---|
| TV = | 5409.4 kg | (Max. Force at Tailing Lug) |
| R = | 636.72 mm | (Radius to neutral axis) |
| Sy = | 26.72 kg/§ ± | (Yield Strength of Base) |
| Z = | 139689 kg/mm^3 | (Section Modulus of Base) |
| A = | 8151.7 § ± | (Section Area of Base) |

a) BENDING MOMENT (Ma) & TANGENTIAL FORCE (Ta) AT BASE BLOCK

CASE ; NO BRACING : ROARK 4th ED. CASE 25

Ma = 0.2387 * TV * R = 822140 kg-mm
Ta = 0.2387 * TV = 1291.2 kg

¥ è= Ma / Z + Ta / A = 6.044 kg/§ ± < 0.66Sy = 17.635 kg/§ ±

THEREFORE, BRACING IS NOT REQUIRED !!

## 6. LOCAL STRESS CALCULATION (LIFTING LUG)

**Geometry**

| | | | |
|---|---|---|---|
| Height(radial): | 1.3386" | Pad Thickness: | 0.5512" |
| Width (circumferential): | 8.2677" | Pad Width: | 10.2362" |
| Length | 4.9213" | Pad Length: | 5.9055" |
| Fillet Weld Size: | 0.3937" | Pad Weld Size: | 0.3937" |
| Location Angle: | 45.00° | | |

**Applied Loads**

| | | | |
|---|---|---|---|
| Radial load: | $P_r$ = | 0 | $lb_f$ |
| Circumferential moment: | $M_c$ = | 13,887.39 | $lb_f$-in |
| Circumferential shear: | $V_c$ = | 9,942.86 | $lb_f$ |
| Longitudinal moment: | $M_L$ = | 21,699.04 | $lb_f$-in |
| Longitudinal shear: | $V_L$ = | 15,873.3 | $lb_f$ |
| Torsion moment: | $M_t$ = | 0 | $lb_f$-in |
| Internal pressure: | P = | 0 | psi |
| Mean shell radius: | $R_m$ = | 24.2717 | in |
| Shell yield stress: | $S_y$ = | 25,000 | psi |

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

$R_m$ / t = 24.2717 / 1.1024 = 22.0179

$C_1$ = 4.5276, $C_2$ = 2.8543 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) = 2,645 psi
Allowable combined stress ($P_L$+$P_b$+Q) = +-3*S = +-50,100 psi

Note: The allowable combined stress ($P_L$+$P_b$+Q) is based on the strain hardening characteristics of this material.

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

Maximum local primary membrane stress ($P_L$) = -502 psi
Allowable local primary membrane ($P_L$) = +-1.5*S = +-25,050 psi

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

| Stresses at the lug edge per WRC Bulletin 107 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Figure | value | β | $A_u$ | $A_l$ | $B_u$ | $B_l$ | $C_u$ | $C_l$ | $D_u$ | $D_l$ |
| 3C* | 3.1393 | 0.1455 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4C* | 3.5843 | 0.1678 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1C | 0.1013 | 0.1701 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2C-1 | 0.0679 | 0.1701 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3A* | 0.7642 | 0.16 | 0 | 0 | 0 | 0 | -149 | -149 | 149 | 149 |
| 1A | 0.0897 | 0.1875 | 0 | 0 | 0 | 0 | -1,352 | 1,352 | 1,352 | -1,352 |
| 3B* | 2.2836 | 0.1372 | -502 | -502 | 502 | 502 | 0 | 0 | 0 | 0 |
| 1B-1 | 0.0449 | 0.1453 | -1,364 | 1,364 | 1,364 | -1,364 | 0 | 0 | 0 | 0 |
| Pressure stress* | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total circumferential stress | | | -1,866 | 862 | 1,866 | -862 | -1,501 | 1,203 | 1,501 | -1,203 |
| Primary membrane circumferential stress* | | | -502 | -502 | 502 | 502 | -149 | -149 | 149 | 149 |
| 3C* | 2.8809 | 0.1678 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4C* | 3.7332 | 0.1455 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1C-1 | 0.1142 | 0.1539 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2C | 0.0758 | 0.1539 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4A* | 1.1601 | 0.16 | 0 | 0 | 0 | 0 | -186 | -186 | 186 | 186 |
| 2A | 0.0512 | 0.1678 | 0 | 0 | 0 | 0 | -862 | 862 | 862 | -862 |
| 4B* | 0.6622 | 0.1372 | -132 | -132 | 132 | 132 | 0 | 0 | 0 | 0 |
| 2B-1 | 0.0715 | 0.1438 | -2,195 | 2,195 | 2,195 | -2,195 | 0 | 0 | 0 | 0 |
| Pressure stress* | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total longitudinal stress | | | -2,327 | 2,063 | 2,327 | -2,063 | -1,048 | 676 | 1,048 | -676 |
| Primary membrane longitudinal stress* | | | -132 | -132 | 132 | 132 | -186 | -186 | 186 | 186 |
| Shear from $M_t$ | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Circ shear from $V_c$ | | | 498 | 498 | -498 | -498 | 0 | 0 | 0 | 0 |
| Long shear from $V_L$ | | | 0 | 0 | 0 | 0 | -1,261 | -1,261 | 1,261 | 1,261 |
| Total Shear stress | | | 498 | 498 | -498 | -498 | -1,261 | -1,261 | 1,261 | 1,261 |
| Combined stress ($P_L$+$P_b$+Q) | | | -2,645 | 2,243 | 2,645 | -2,243 | 2,562 | 2,576 | 2,562 | 2,576 |

Note: * denotes primary stress.

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

$R_m$ / t = 24.2717 / 0.5512 = 44.0357

$C_1$ = 5.5118, $C_2$ = 3.3465 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) = -5,920 psi
Allowable combined stress ($P_L$+$P_b$+Q) = +-3*S = +-50,100 psi

Note: The allowable combined stress ($P_L$+$P_b$+Q) is based on the strain hardening characteristics of this material.

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

Maximum local primary membrane stress ($P_L$) = -1,816 psi
Allowable local primary membrane ($P_L$) = +-1.5*S = +-25,050 psi

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

| Stresses at the pad edge per WRC Bulletin 107 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Figure** | **value** | $\beta$ | $A_u$ | $A_l$ | $B_u$ | $B_l$ | $C_u$ | $C_l$ | $D_u$ | $D_l$ |
| 3C* | 4.5514 | 0.1735 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4C* | 6.0293 | 0.2029 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1C | 0.0658 | 0.206 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2C-1 | 0.0322 | 0.206 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3A* | 1.8247 | 0.1923 | 0 | 0 | 0 | 0 | -581 | -581 | 581 | 581 |
| 1A | 0.0717 | 0.2215 | 0 | 0 | 0 | 0 | -3,657 | 3,657 | 3,657 | -3,657 |
| 3B* | 4.8245 | 0.1628 | -1,816 | -1,816 | 1,816 | 1,816 | 0 | 0 | 0 | 0 |
| 1B-1 | 0.0297 | 0.1721 | -3,048 | 3,048 | 3,048 | -3,048 | 0 | 0 | 0 | 0 |
| **Pressure stress*** | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total circumferential stress** | | | -4,864 | 1,232 | 4,864 | -1,232 | -4,238 | 3,076 | 4,238 | -3,076 |
| **Primary membrane circumferential stress*** | | | -1,816 | -1,816 | 1,816 | 1,816 | -581 | -581 | 581 | 581 |
| 3C* | 3.7865 | 0.2029 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4C* | 6.4817 | 0.1735 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1C-1 | 0.0733 | 0.1846 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2C | 0.0422 | 0.1846 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4A* | 3.4946 | 0.1923 | 0 | 0 | 0 | 0 | -909 | -909 | 909 | 909 |
| 2A | 0.0373 | 0.1974 | 0 | 0 | 0 | 0 | -2,135 | 2,135 | 2,135 | -2,135 |
| 4B* | 1.7514 | 0.1628 | -564 | -564 | 564 | 564 | 0 | 0 | 0 | 0 |
| 2B-1 | 0.0453 | 0.1694 | -4,722 | 4,722 | 4,722 | -4,722 | 0 | 0 | 0 | 0 |
| **Pressure stress*** | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total longitudinal stress** | | | -5,286 | 4,158 | 5,286 | -4,158 | -3,044 | 1,226 | 3,044 | -1,226 |
| **Primary membrane longitudinal stress*** | | | -564 | -564 | 564 | 564 | -909 | -909 | 909 | 909 |
| **Shear from $M_t$** | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Circ shear from $V_c$** | | | 818 | 818 | -818 | -818 | 0 | 0 | 0 | 0 |
| **Long shear from $V_L$** | | | 0 | 0 | 0 | 0 | -2,151 | -2,151 | 2,151 | 2,151 |
| **Total Shear stress** | | | 818 | 818 | -818 | -818 | -2,151 | -2,151 | 2,151 | 2,151 |
| **Combined stress ($P_L$+$P_b$+Q)** | | | -5,920 | 4,371 | 5,920 | -4,371 | -5,873 | 4,683 | 5,873 | 4,683 |

Note: * denotes primary stress.