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18-D-272
R06
V-1264

**DESIGN CALCULATION**

*In Accordance with ASME Section VIII Division 1*

```
ASME Code Version     : 2021

Analysis Performed by : THE ANUP ENGINEERING LIMITED.

Job File              : ...\V-1264_R06.pvdb

Date of Analysis      : Dec 21,2022   4:21pm
```

**PV Elite 24, January 2022**

### Vessel Design Summary:

### ASME Code, Section VIII Division 1, 2021

| | | |
|---|---|---|
| Diameter Spec : 29.250 in ID | | |
| Vessel Design Length, Tangent to Tangent | 10.25 | ft |
| Distance of Bottom Tangent above Grade | 16.75 | ft |
| Distance of Base above Grade | 0.00 | ft |
| Specified Datum Line Distance | 16.91 | ft |
| Internal Design Temperature | 500 | °F |
| Internal Design Pressure | 105.000 | psig |
| External Design Temperature | 300 | °F |
| External Design Pressure | 15.000 | psig |
| Maximum Allowable Working Pressure | 150 | psig |
| External Max. Allowable Working Pressure | 82 | psig |
| Shop Test Pressure | 312.913 | psig |
| Required Minimum Design Metal Temperature | 32.0 | °F |
| Warmest Computed Minimum Design Metal Temperature | -55.0 | °F |
| Wind Design Code | ASCE/SEI 7-16 | |
| Earthquake Design Code | ASCE/SEI 7-16 | |

### Materials of Construction:

| Component Type | Material | Class | Thickness | UNS # | Normalized | Impact Tested |
|---|---|---|---|---|---|---|
| Shell | SA-240 316L | ... | ... | S31603 | No | No |
| Head | SA-240 316L | ... | ... | S31603 | No | No |
| Flange | SA-182 F316L | ... | > 5 | S31603 | No | No |
| Skirt | SA-516 70 | ... | ... | K02700 | No | No |
| Skirt | SA-240 316L | ... | ... | S31603 | No | No |
| Nozzle | SA-312 TP316L | ... | ... | S31603 | No | No |
| Nozzle | SA-182 F316L | ... | <= 5 | S31603 | No | No |
| Nozzle Flg | SA-182 F316L | ... | <= 5 | S31603 | No | No |
| Basering | SA-516 70 | ... | ... | K02700 | No | No |
| Flg Bolting | SA-193 B7M | ... | <= 2 1/2 | G41400 | No | No |
| Base Bolting | SA-193 B7M | ... | <= 2 1/2 | G41400 | No | No |

Normalized is determined based on the UCS-66 material curve selection and Figure UCS-66.
Impact Tested is based on material selection and material data properties.

### Element Pressures and MAWP (psig & in):

| Element Description or Type | Design Pressure + Stat. head | Ext. Press. | Element M.A.W.P | Total Corrosion Allowance | Str. Flg. Gov. | In Creep Range |
|---|---|---|---|---|---|---|
| BTM D-END | 106.619 | 15.00 | 285.000 | 0.0315 | No | N/S |
| SHELL-1 | 106.288 | 15.00 | 359.000 | 0.0315 | N/A | N/S |
| SHELL-2 | 105.000 | 15.00 | 360.000 | 0.0315 | N/A | N/S |
| NOZZLE M FLANGE | 105.000 | 15.00 | 150.000 | 0.0315 | N/A | N/S |
| NOZZLE M BLIND | 105.000 | 15.00 | 230.000 | 0.0315 | N/A | N/S |

*N/S in the Creep Range column specifies that the Creep Range Temperature was not specified in the ASME Code Section II Part D for this material.*

Liquid Level: 3.77 ft Dens.: 61.776 lb/ft^3 Sp. Gr.: 0.990

**Element Types and Properties:**

| Element Type | "To" Elev ft | Element Length ft | Nominal Thickness in | Finished Thickness in | Reqd Thk Internal in | Reqd Thk External in | Long Eff | Circ Eff |
|---|---|---|---|---|---|---|---|---|
| Skirt | -8.71 | 8.202 | 0.394 | 0.394 | ... | ... | 0.60 | 0.60 |
| Skirt | -3.28 | 5.430 | 0.394 | 0.394 | ... | ... | 0.60 | 0.60 |
| Skirt | -0.16 | 3.117 | 0.394 | 0.394 | ... | ... | 0.60 | 0.60 |
| Ellipse | 0.00 | 0.164 | 0.394 | 0.315 | 0.137 | 0.113 | 1.00 | 1.00 |
| Cylinder | 4.92 | 4.921 | 0.394 | 0.394 | 0.137 | 0.208 | 1.00 | 1.00 |
| Cylinder | 9.51 | 4.587 | 0.394 | 0.394 | 0.136 | 0.208 | 1.00 | 1.00 |
| Body Flg | 9.83 | 0.318 | ... | 1.690 | ... | ... | 1.00 | 1.00 |
| Body Flg | 10.09 | 0.230 | 2.756 | 2.756 | 1.873 | 1.071 | 1.00 | 1.00 |

**Wind/Earthquake Shear, Bending:**

| From | To | Distance to Support ft | Cumulative Wind Shear lbf | Earthquake Shear lbf | Wind Bending ft-lbf | Earthquake Bending ft-lbf |
|---|---|---|---|---|---|---|
| 10 | 20 | 4.10105 | 1533.32 | 3575.17 | 26863.9 | 71804.7 |
| 20 | 30 | 10.917 | 1360.34 | 3456.15 | 14996.9 | 42968.9 |
| 30 | 40 | 15.1903 | 1041.42 | 2949.35 | 8476.37 | 25578.7 |
| 40 | 50 | 16.8307 | 975.514 | 2826.24 | 5333.18 | 16578 |
| 50 | 60 | 19.3733 | 971.986 | 2716.04 | 5173.49 | 16123.5 |
| 60 | 80 | 24.1273 | 577.65 | 1663.97 | 1360.41 | 5345.92 |
| 80 | 90 | 26.5797 | 13.7538 | 565.396 | 4.13497 | 233.283 |
| 90 | 100 | 26.885 | 6.3746 | 469.429 | 0.732 | 53.9045 |

Abs Max of the all of the Stress Ratio's : 0.2973

**Basering Data : Basering W/Gussets & Chair Cap**

| | | |
|---|---|---|
| Thickness of Basering | 1.2598 | in |
| Inside Diameter of Basering | 25.2362 | in |
| Outside Diameter of Basering | 40.2756 | in |
| Nominal Diameter of Bolts | 1.7500 | in |
| Diameter of Bolt Circle | 35.5000 | in |
| Number of Bolts | 4 | |
| Thickness of Gusset Plates | 0.7874 | in |
| Average Width of Gusset Plates | 5.2360 | in |
| Height of Gussets | 8.1880 | in |
| Distance between Gussets | 4.0157 | in |
| Thickness of Top Plate or Ring | 1.5748 | in |
| Circumferential Width of the Top Plate | 7.0079 | in |
| Radial Width of the Top Plate | 5.2362 | in |

**Basering Sketch for Cylindrical Skirts:**

```
                 ----->| |<----- 0.3937 in
   30.00 in   ----------->|
```

```
                                        _
           29.21 in   --------->| |
                                | |_____________   _
                                |  _____________|  _ 1.5748 in
                                | |        |
                                | |        |
                                | |        |
                                | |        |
                                | |        |
                                | |        |
                          ______| |__ _ ___|____   _
           25.24 in  --->|___________|_|________|  _ 1.2598 in
           35.50 in  ---------------->|         |
           40.28 in  -------------------------->|
```

**Basering Cross Section View**

**Loads for Foundation/Support Design:**

**Factored Loads:**

| | | |
|---|---|---|
| Total Wind Shear on Support | 1533. | lbf |
| Total Earthquake Shear on Support | 3575. | lbf |
| Wind Moment on Support | 26864. | ft-lbf |
| Earthquake Moment on Support | 71805. | ft-lbf |
| Maximum Initial Bolt Load | 22090. | lbf |

**Un-Factored Loads:**

| | | |
|---|---|---|
| Wind Shear on Support | 2556. | lbf |
| Earthquake Shear on Support | 5107. | lbf |
| Wind Moment on Support | 44773. | ft-lbf |
| Earthquake Moment on Support | 102578. | ft-lbf |
| Maximum Initial Bolt Load | 36817. | lbf |

Note:
Wind and Earthquake moments include the effects of user defined forces and moments if any exist in the job and were specified to act (compute loads and stresses) during these cases. Also included are moment effects due to eccentric weights if any are present in the input.

**Local Stress Analysis Results:**

| Description | Analysis Type | Max Stress Ratio | High Stress Location | Pass Fail |
|---|---|---|---|---|
| Lift Lug | WRC-107/537 | 0.956 | n/a | Passed |
| Local Skirt | Jawad & Farr | 0.274 | n/a | Passed |
| Type-1 | WRC-107/537 | 0.563 | n/a | Passed |
| Nozzle B2 2" | WRC-107/537 | 0.700 | n/a | Passed |
| Nozzle LT2 2" | WRC-297 | 0.541 | Shell | Passed |
| Nozzle L2 2" | WRC-297 | 0.541 | Shell | Passed |
| Nozzle S 2" | WRC-297 | 0.541 | Shell | Passed |
| Nozzle LT1 2" | WRC-297 | 0.540 | Shell | Passed |
| Nozzle L1 2" | WRC-297 | 0.540 | Shell | Passed |
| Nozzle B4 2" | WRC-297 | 0.538 | Shell | Passed |
| Nozzle B3 2" | WRC-297 | 0.538 | Shell | Passed |
| Nozzle LT3 | WRC-297 | 0.540 | Shell | Passed |
| Nozzle LT4 | WRC-297 | 0.541 | Shell | Passed |
| Nozzle A 3" | WRC-297 | 0.760 | Shell | Passed |

**18-D-272**
**R06**
**V-1264**
**PV Elite 24        Licensee: THE ANUP ENGINEERING LIMITED.**
**FileName : V-1264_R06    -----------------------------------**
**Vessel Design Summary:              Step:  119   4:21pm  Dec 21,2022**

**Weights:**

| | | | |
|---|---|---|---|
| Fabricated | - Bare W/O Removable Internals | 5976.4 | lbm |
| Shop Test | - Fabricated + Water ( Full ) | 9031.8 | lbm |
| Shipping | - Fab. + Rem. Intls.+ Shipping App. | 5976.4 | lbm |
| Erected | - Fab. + Rem. Intls.+ Insul. (etc) | 10351.6 | lbm |
| Empty | - Fab. + Intls. + Details + Wghts. | 10351.6 | lbm |
| Operating | - Empty + Operating Liquid (No CA) | 11381.3 | lbm |
| Field Test | - Empty Weight + Water (Full) | 13180.6 | lbm |

**Nozzle Calculation Summary (psig & in):**

| Description | MAWP | Ext | MAPNC | UG-45 | [tr] | Weld Path | Areas or Stresses |
|---|---|---|---|---|---|---|---|
| Nozzle B2 2" | 183 | OK | ... | OK | 0.166 | OK | Passed |
| Nozzle LT2 2" | 359 | OK | ... | OK | 0.182 | OK | Passed |
| Nozzle L2 2" | 359 | OK | ... | OK | 0.182 | OK | Passed |
| Nozzle S 2" | 359 | OK | ... | OK | 0.182 | OK | Passed |
| Nozzle LT1 2" | 359 | OK | ... | OK | 0.181 | OK | Passed |
| Nozzle L1 2" | 359 | OK | ... | OK | 0.181 | OK | Passed |
| Nozzle B4 2" | 359 | OK | ... | OK | 0.181 | OK | Passed |
| Nozzle B3 2" | 359 | OK | ... | OK | 0.181 | OK | Passed |
| Nozzle LT3 | 359 | OK | ... | OK | 0.181 | OK | Passed |
| Nozzle LT4 | 359 | OK | ... | OK | 0.182 | OK | Passed |
| Nozzle A 3" | 298 | OK | ... | OK | 0.181 | OK | Passed |
| Nozzle B1 6in. | 157 | OK | ... | OK | 0.276 | OK | Passed |
| Nozzle V 2" | 213 | OK | ... | OK | 0.220 | OK | Passed |

**Nozzle MAWP Summary:**

```
Minimum MAWP Nozzles          :          157 Nozzle  : Nozzle B1 6in.
Minimum MAWP Shells/Flanges   :          150 Element : NOZZLE M FLANGE
Minimum MAPnc Shells/Flanges  :            0 Element : NOZZLE M FLANGE
---------------------------------------------------------------------
Computed Vessel M.A.W.P.      :          150 psig
```

*Multiple output lines for the same nozzle indicates required Code calculations in both the longitudinal and circumferential planes of reinforcement where applicable.*

**Check the Spatial Relationship between the Nozzles:**

| From Node | Nozzle Description | Y Coordinate in | Layout Angle deg | Dia. Limit in |
|---|---|---|---|---|
| 40 | Nozzle B2 2" | 0.000 | 0.000 | 4.113 |
| 50 | Nozzle LT2 2" | 7.968 | 330.000 | 4.037 |
| 50 | Nozzle L2 2" | 7.968 | 225.000 | 4.037 |
| 50 | Nozzle S 2" | 7.968 | 270.000 | 4.037 |
| 50 | Nozzle LT1 2" | 49.968 | 330.000 | 4.037 |
| 50 | Nozzle L1 2" | 49.968 | 225.000 | 4.037 |
| 50 | Nozzle B4 2" | 43.968 | 300.000 | 4.126 |
| 50 | Nozzle B3 2" | 37.968 | 225.000 | 4.126 |
| 50 | Nozzle LT3 | 49.968 | 0.000 | 4.037 |
| 50 | Nozzle LT4 | 7.968 | 0.000 | 4.037 |
| 60 | Nozzle A 3" | 70.968 | 270.000 | 5.026 |
| 90 | Nozzle B1 6in. | 0.000 | 180.000 | 12.074 |
| 90 | Nozzle V 2" | 0.000 | 305.000 | 8.761 |

**The nozzle spacing is computed by the following:**

= sqrt( $ll^2$ + $lc^2$ ) where

ll - Arc length along the inside vessel surface in the long. direction.
lc - Arc length along the inside vessel surface in the circ. direction

If any interferences/violations are found, they will be noted below.

No interference violations have been detected!

**Checking Multiple Nozzles on Flat Head per ASME Sec. VIII Div. 1 UG-39**

Comparing Nozzles on Element: NOZZLE M BLIND

**UG-39 Average Nozzle Diameter and Ligament Checks:**

| Nozzle Pair Description | Avg. dia. in | Head Dia. /4 in | Ligament Width in | Min. dn /4 in |
|---|---|---|---|---|
| Nozzle B1 6in. & Nozz | 3.6195 | 7.75 | 12.771 | 0.5157 |

**UG-39 Nozzle Spacing and Average Area Checks:**

| Nozzle Pair Description | Center Spacing in | Avg. dia. * 1.25 in | Avg. Area Available in^2 | Avg. Area Reqd. in^2 |
|---|---|---|---|---|
| Nozzle B1 6in. & Nozz | 17.74 | 4.5244 | No Calc | No Calc |

**UG-39 Nozzle Diameter and Distance to Edge Checks:**

| Nozzle Description | Nozzle dia. in | Head Dia. /2 in | Distance from Edge in | Nozzle dia./4 in |
|---|---|---|---|---|
| Nozzle B1 6in. | 5.176 | 15.5 | 4.1575 | 1.294 |
| Nozzle V 2" | 2.063 | 15.5 | 5.8137 | 0.5157 |

No Multiple Nozzle spacing violations detected!

### Nozzle Schedule:

| Description | Nominal or Actual Size | Schd or FVC Type | Flg Type | Nozzle O/Dia in | Wall Thk in | Reinforcing Pad Diameter | Pad Thk in | Cut Length in | Flg Class |
|---|---|---|---|---|---|---|---|---|---|
| Nozzle B2 2" | 2.000 in | 80S | WNF | 2.375 | 0.218 | ... | ... | 6.3 | 600 |
| Nozzle LT2 2" | 2.000 in | Actual | LWN | 3.313 | 0.656 | ... | ... | 7.5 | 300 |
| Nozzle L2 2" | 2.000 in | Actual | LWN | 3.313 | 0.656 | ... | ... | 7.5 | 600 |
| Nozzle S 2" | 2.000 in | Actual | LWN | 3.313 | 0.656 | ... | ... | 7.6 | 600 |
| Nozzle LT1 2" | 2.000 in | Actual | LWN | 3.313 | 0.656 | ... | ... | 7.5 | 300 |
| Nozzle L1 2" | 2.000 in | Actual | LWN | 3.313 | 0.656 | ... | ... | 7.5 | 600 |
| Nozzle B4 2" | 2.000 in | Actual | LWN | 3.313 | 0.656 | ... | ... | 7.6 | 600 |
| Nozzle B3 2" | 2.000 in | Actual | LWN | 3.313 | 0.656 | ... | ... | 7.6 | 600 |
| Nozzle LT3 | 2.000 in | Actual | LWN | 3.313 | 0.656 | ... | ... | 7.5 | 300 |
| Nozzle LT4 | 2.000 in | Actual | LWN | 3.313 | 0.656 | ... | ... | 7.5 | 300 |
| Nozzle V 2" | 2.000 in | Actual | LWN | 3.313 | 0.656 | ... | ... | 9.6 | 300 |
| Nozzle A 3" | 3.000 in | XXS | WNF | 3.500 | 0.600 | ... | ... | 5.3 | 600 |
| Nozzle B1 6in. | 6.000 in | XXS | WNF | 6.625 | 0.864 | ... | ... | 6.2 | 300 |

*General Notes for the above table:*

The Cut Length is the Outside Projection + Inside Projection + Drop + In Plane Shell Thickness. This value does not include weld gaps, nor does it account for shrinkage.

In the case of Oblique Nozzles, the Outside Diameter must be increased. The Re-Pad WIDTH around the nozzle is calculated as follows: Width of Pad = (Pad Outside Dia. (per above) - Nozzle Outside Dia.)/2

For hub nozzles, the thickness and diameter shown are those of the smaller and thinner section.

### Nozzle Material and Weld Fillet Leg Size Details (in):

| Description | Material | Shl Grve Weld | Noz Shl/Pad Weld | Pad OD Weld | Pad Grve Weld | Inside Weld |
|---|---|---|---|---|---|---|
| Nozzle B2 2 | SA-312 TP316L | 0.314 | 0.196 | ... | ... | ... |
| Nozzle LT2 | SA-182 F316L | 0.390 | 0.354 | ... | ... | ... |
| Nozzle L2 2 | SA-182 F316L | 0.390 | 0.354 | ... | ... | ... |
| Nozzle S 2" | SA-182 F316L | 0.390 | 0.354 | ... | ... | ... |
| Nozzle LT1 | SA-182 F316L | 0.390 | 0.354 | ... | ... | ... |
| Nozzle L1 2 | SA-182 F316L | 0.390 | 0.354 | ... | ... | ... |
| Nozzle B4 2 | SA-182 F316L | 0.390 | 0.354 | ... | ... | ... |
| Nozzle B3 2 | SA-182 F316L | 0.390 | 0.354 | ... | ... | ... |
| Nozzle LT3 | SA-182 F316L | 0.390 | 0.354 | ... | ... | ... |
| Nozzle LT4 | SA-182 F316L | 0.390 | 0.354 | ... | ... | ... |
| Nozzle V 2" | SA-182 F316L | 2.000 | 0.354 | ... | ... | ... |
| Nozzle A 3" | SA-312 TP316L | 0.390 | 0.354 | ... | ... | ... |
| Nozzle B1 6 | SA-312 TP316L | 1.941 | 0.354 | ... | ... | ... |

Note: The Outside projections below do not include the flange thickness.

### Nozzle Miscellaneous Data:

| Description | Elev/Distance From Datum ft | Layout Angle deg | Proj Outside in | Proj Inside in | Installed in Component |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Nozzle B2 2" | ... | 0.0 | 6.00 | 0.00 | BTM D-END |
| Nozzle LT2 2" | 0.500 | 330.0 | 7.11 | 0.00 | SHELL-1 |
| Nozzle L2 2" | 0.500 | 225.0 | 7.11 | 0.00 | SHELL-1 |
| Nozzle S 2" | 0.500 | 270.0 | 7.11 | 0.00 | SHELL-1 |
| Nozzle LT1 2" | 4.000 | 330.0 | 7.11 | 0.00 | SHELL-1 |
| Nozzle L1 2" | 4.000 | 225.0 | 7.11 | 0.00 | SHELL-1 |
| Nozzle B4 2" | 3.500 | 300.0 | 7.11 | 0.00 | SHELL-1 |
| Nozzle B3 2" | 3.000 | 225.0 | 7.11 | 0.00 | SHELL-1 |
| Nozzle LT3 | 4.000 | 0.0 | 7.11 | 0.00 | SHELL-1 |
| Nozzle LT4 | 0.500 | 0.0 | 7.11 | 0.00 | SHELL-1 |
| Nozzle V 2" | ... | 305.0 | 6.89 | 0.00 | NOZZLE M BLIND |
| Nozzle A 3" | 5.750 | 270.0 | 4.86 | 0.00 | SHELL-2 |
| Nozzle B1 6in. | ... | 180.0 | 3.47 | 0.00 | NOZZLE M BLIND |

**Bill of Materials:**

| QTY | DESCRIPTION | MATERIAL |
|---|---|---|
| 1 | SKIRT: 0.394" THK X 29.250" ID X 8'-2.43" | SA-516 70 |
| 1 | SKIRT: 0.394" THK X 29.250" ID X 5'-5.16" | SA-516 70 |
| 1 | SKIRT: 0.394" THK X 29.250" ID X 3'-1.40" | SA-240 316L |
| 1 | ELLIPTICAL HEAD: 2.0 X 1, 0.394" THK X 29.250" ID X 1.97" | SA-240 316L |
| 1 | CYLINDER: 0.394" THK X 29.250" ID X 4'-11.06" | SA-240 316L |
| 1 | CYLINDER: 0.394" THK X 29.250" ID X 4'-7.04" | SA-240 316L |
| 1 | BODY FLANGE: 1.690" THK X 34.940" OD | SA-182 F316L |
| 1 | BODY FLANGE: 2.756" THK X 34.940" OD | SA-182 F316L |
| 1 | PLATFORM: 42.00" HEIGHT X 45.00" WIDE | |
| 1 | PLATFORM: 42.00" HEIGHT X 51.00" WIDE | |
| 2 | PACKING: 0.000" | ... |
| 1 | PLATFORM: 42.00" HEIGHT X 38.00" WIDE | |
| 1 | RECTANGULAR CLIP: 0.551" X 15.500" X 8.071" THK | SA-240 316L |
| 1 | RECTANGULAR CLIP PAD: 3.268" X 18.268" X 0.394" THK | SA-240 316L |
| 2 | LIFTING LUGS: | SA-516 70 |
| 2 | LIFTING LUG PADS: 6.693" X 8.661" X 0.394" THK | |
| 1 | BASERING TOP PLATES: 7.008" X 5.236" X 1.575" | SA-182 F316L |
| 1 | BASERING: 40.276" OD X 25.236 ID X 1.260" | SA-516 70 |
| 4 | BASERING BOLTS: 1.750" DIA | SA-193 B7M |
| 4 | NUTS FOR BODY BASERING BOLTS: 1.750" DIA | ... |
| 8 | BASERING GUSSET PLATES: 5.236" X 5.236" X 8.188" X 0.787" | ... |
| 1 | GASKET: 31.500" OD X 30.500" ID | ... |
| 44 | BODY FLANGE BOLTS: 0.750" DIA | SA-193 B7M |
| 88 | NUTS FOR BODY FLANGE BOLTS: 0.750" DIA | ... |
| 1 | NAMEPLATE | ... |

**Minimum Design Metal Temperature Results Summary (°F):**

| Description Notes | Curve | Basic MDMT | Reduced MDMT | UG-20(f) MDMT | Thickness ratio | Gov Thk in | E* | PWHT reqd |
|---|---|---|---|---|---|---|---|---|
| NOZZLE M BLIN[11] | | -320 | | | | | | |
| BTM D-END [16] | | -320 | | | | | | |
| SHELL-1 [16] | | -320 | | | | | | |
| SHELL-2 [16] | | -320 | | | | | | |
| Nozzle B2 2" [15] | | -320 | | | | | | |
| Nozzle LT2 2"[15] | | -320 | | | | | | |
| Nozzle L2 2" [15] | | -320 | | | | | | |
| Nozzle S 2" [15] | | -320 | | | | | | |
| Nozzle LT1 2"[15] | | -320 | | | | | | |
| Nozzle L1 2" [15] | | -320 | | | | | | |
| Nozzle B4 2" [15] | | -320 | | | | | | |
| Nozzle B3 2" [15] | | -320 | | | | | | |
| Nozzle LT3 [15] | | -320 | | | | | | |
| Nozzle LT4 [15] | | -320 | | | | | | |
| Nozzle A 3" [15] | | -320 | | | | | | |
| Nozzle B1 6in[15] | | -320 | | | | | | |
| Nozzle V 2" [15] | | -320 | | | | | | |
| Bolting [21] | | -55 | | | | | | |
| Warmest MDMT: | | -55 | | | | | | |

| | | |
|---|---|---|
| Required Minimum Design Metal Temperature | 32.0 | °F |
| Warmest Computed Minimum Design Metal Temperature | -55.0 | °F |

**Notes:**
[ ! ] - This was an impact tested material.
[ 1] - Governing Nozzle Weld.
[ 4] - ASME Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(-c).
[ 5] - ASME Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(-b).
[ 6] - MDMT Calculations at the Shell/Head Joint.
[ 7] - MDMT Calculations for the Straight Flange.
[ 8] - Cylinder/Cone/Flange Junction MDMT.
[ 9] - Calculations in the Spherical Portion of the Head.
[10] - Calculations in the Knuckle Portion of the Head.
[11] - Calculated (Body Flange) Flange MDMT.
[12] - Calculated Flat Head MDMT per UCS-66.3
[13] - Tubesheet MDMT, shell side, if applicable
[14] - Tubesheet MDMT, tube side, if applicable
[15] - Nozzle Material
[16] - Shell or Head Material
[17] - Impact Testing required
[18] - Impact Testing not required, see UCS-66(b)(3)
[20] - Cylinder/Cone Junction MDMT based on Longitudinal Stress considerations
[21] - Body Flange Bolting Material
[22] - Nozzle Flange Bolting Material
[23] - Stiffening Ring to Shell Weld
[24] - Saddle to Shell Weld

UG-84(b)(2) was not considered.
UCS-66(g) was not considered.
UCS-66(i) was not considered.

Notes:
Impact test temps were not entered in and not considered in the analysis.

UCS-66(i) applies to impact tested materials not by specification and
UCS-66(g) applies to materials impact tested per UG-84.1 General Note (c).
The Basic MDMT includes the (30F) PWHT credit if applicable.

Class From To : Basic Element Checks.

```
--------------------------------------------------------------------------
Note  30   50    There is a high jump in the Joint Eff.
Warn. 10   20    Skirt diameter at base is < at the top
Warn. 20   30    Skirt diameter at base is < at the top
Warn. 30   40    Skirt diameter at base is < at the top
```

Class From To: Check of Additional Element Data

```
--------------------------------------------------------------------------
```

**Units used in this Analysis (ENGLISH_UniCode):**

| Name | System Unit | Constant | User Unit |
|---|---|---|---|
| Length | Feet | 1.0000 | ft |
| Force | Pounds | 1.0000 | lbf |
| Mass | Pounds | 1.0000 | lbm |
| Area | sq. inches | 1.0000 | in^2 |
| Moment | ft. lbs. | 1.0000 | ft-lbf |
| Stress | lbs./sq.in. | 1.0000 | psi |
| Temperature | Degrees F | 1.0000 | °F |
| Pressure | psig | 1.0000 | psig |
| Elast. Modulus | lbs./sq.in. | 1.0000 | psi |
| Pipe Density | lbs./cu.in. | 1.0000 | lb/in^3 |
| Ins. Density | lbs./cu.ft. | 1.0000 | lb/ft^3 |
| Fluid Density | lbs./cu.ft. | 1.0000 | lb/ft^3 |
| Wind Speed | miles/hr | 1.0000 | mile/hr |
| Tray Weight | lbs./sq.ft. | 1.0000 | lb/ft^2 |
| Inertia | in.**4 | 1.0000 | in**4 |
| G Load | G's | 1.0000 | g's |
| Wind Load | lbs./sq.ft. | 1.0000 | psf |
| Elevation | Feet | 1.0000 | ft |
| Volume | in.**3 | 1.0000 | in3 |
| Diameter | inches | 1.0000 | in |
| Thickness | inches | 1.0000 | in |

**PV Elite Vessel Analysis Program: Input Data**

18-D-272
R06
V-1264

| | | |
|---|---|---|
| Design Internal Pressure (for Hydrotest) | 105 | psig |
| Design Internal Temperature | 500.0 | °F |
| Projection of Nozzle from Vessel Top | 0 | in |
| Projection of Nozzle from Vessel Bottom | 0 | in |
| Minimum Design Metal Temperature | 32.0 | °F |
| Type of Construction | Welded | |
| Special Service | Sour | |
| Degree of Radiography | RT-1 | |
| Use Higher Longitudinal Stresses (Flag) | Y | |
| Select t for Internal Pressure (Flag) | N | |
| Select t for External Pressure (Flag) | N | |
| Select t for Axial Stress (Flag) | N | |
| Select Location for Stiff. Rings (Flag) | N | |
| Consider Vortex Shedding | Y | |

**Shop Pressure Test:**

| | |
|---|---|
| Type of Pressure Test | User Entered Pressure |
| Pressure Test Position | Horizontal |

| | |
|---|---|
| Load Case 1 | NP+EW+1.5WI+FW+BW |
| Load Case 2 | NP+EW+EE+FS+BS |
| Load Case 3 | NP+OW+1.5WI+FW+BW |
| Load Case 4 | NP+OW+EQ+FS+BS |
| Load Case 5 | NP+HW+HI |
| Load Case 6 | NP+HW+HE |
| Load Case 7 | IP+OW+1.5WI+FW+BW |
| Load Case 8 | IP+OW+EQ+FS+BS |

```
Load Case 9                           EP+OW+1.5WI+FW+BW
Load Case 10                            EP+OW+EQ+FS+BS
Load Case 11                                  HP+HW+HI
Load Case 12                                  HP+HW+HE
Load Case 13                                  IP+WE+EW
Load Case 14                                  IP+WF+CW
Load Case 15                                  IP+VO+OW
Load Case 16                                  IP+VE+EW
Load Case 17                                  NP+VO+OW
Load Case 18                               FS+BS+IP+OW
Load Case 19                               FS+BS+EP+OW

Wind Design Code                             ASCE/SEI 7-16
Wind Load Reduction Scale Factor                     0.600
Basic Wind Speed                     [V]               101  mile/hr
Surface Roughness Category                 C: Open Terrain
Importance Factor                                      1.0
Type of Surface                          Moderately Smooth
Base Elevation                                           0  ft
Percent Wind for Hydrotest                            33.0
Using User defined Wind Press. Vs Elev.                  N
Height of Hill or Escarpment     H or Hh                 0  ft
Distance Upwind of Crest              Lh                 0  ft
Distance from Crest to the Vessel      x                 0  ft
Type of Terrain ( Hill, Escarpment )                  Flat
Damping Factor (Beta) for Wind (Ope)                0.0100
Damping Factor (Beta) for Wind (Empty)              0.0000
Damping Factor (Beta) for Wind (Filled)             0.0000
Site Elevation above Sea Level                           0  ft

Seismic Design Code                          ASCE/SEI 7-16
Seismic Load Reduction Scale Factor                  0.700
Importance Factor                                    1.250
Table Value Fa                                       1.000
Table Value Fv                                       1.721
Max. Mapped Res. Acceleration       [Ss]             1.616
Max. Eff. Ground Acceleration        [S]             0.869
Force Modification Factor R                          3.000
Site Class                                               D
Component Elevation Ratio            z/h             0.000
Amplification Factor                  Ap             0.000
Force Factor                                         0.000
Consider Vertical Acceleration                         Yes
Minimum Acceleration Multiplier                      0.333
User Value of Sds (used if > 0 )                     1.077
User Value of Sd1 (used if > 0 )                     0.996
Moment Reduction Factor Tau                          1.000

M.A.W.P + Static Head to Nozzle                          Y
Consider MAP New and Cold in Noz. Design                 N
Consider External Loads for Nozzle Des.                  Y
Use ASME VIII-1 Appendix 1-9                             N

Perform Blast Load Analysis                             No
Material Database Year       Current w/Addenda or Code Year
```

**Configuration Directives:**

```
Do not use Nozzle MDMT Interpretation VIII-1 01-37        No
Use Table G instead of exact equation for "A"            Yes
Shell Head Joints are Tapered                            Yes
```

| | |
|---|---|
| Compute "K" in corroded condition | Yes |
| Use Code Case 2286 | No |
| Use the MAWP to compute the MDMT | Yes |
| For thickness ratios <= 0.35, MDMT will be -155F (-104C) | Yes |
| For PWHT & P1 Materials the MDMT can be < -55F (-48C) | No |
| Using Metric Material Databases, ASME II D | No |
| Calculate B31.3 type stress for Nozzles with Loads | Yes |
| Reduce the MDMT due to lower membrane stress | Yes |
| Consider Longitudinal Stress in MDMT Calculations | Yes |

**Complete Listing of Vessel Elements and Details:**

| | | |
|---|---|---|
| Element From Node | 10 | |
| Element To Node | 20 | |
| Element Type | Skirt Sup. | |
| Description | BTM SKIRT-2 | |
| Distance "FROM" to "TO" | 8.2021 | ft |
| Skirt Inside Diameter | 29.25 | in |
| Diameter of Skirt at Base | 29.21 | in |
| Skirt Thickness | 0.3937 | in |
| Internal Corrosion Allowance | 0.0315 | in |
| Nominal Thickness | 0.3937 | in |
| External Corrosion Allowance | 0 | in |
| Design Temperature Internal Pressure | 500 | °F |
| Design Temperature External Pressure | 300 | °F |
| Effective Diameter Multiplier | 1.2 | |
| Material Name | SA-516 70 | |
| Allowable Stress, Ambient | 20000 | psi |
| Allowable Stress, Operating | 20000 | psi |
| Allowable Stress, Hydrotest | 34200 | psi |
| Material Density | 0.28 | lb/in^3 |
| P Number Thickness | 1.25 | in |
| Yield Stress, Operating | 31000 | psi |
| UCS-66 Chart Curve Designation | B | |
| External Pressure Chart Name | CS-2 | |
| UNS Number | K02700 | |
| Product Form | Plate | |
| Efficiency, Longitudinal Seam | 0.6 | |
| Efficiency, Head-to-Skirt or Circ. Seam | 0.6 | |
| Weld is pre-Heated | No | |

--------------------------------------------------------------------

| | | |
|---|---|---|
| Element From Node | 20 | |
| Element To Node | 30 | |
| Element Type | Skirt Sup. | |
| Description | BTM SKIRT-1 | |
| Distance "FROM" to "TO" | 5.4298 | ft |
| Skirt Inside Diameter | 29.25 | in |
| Diameter of Skirt at Base | 29.21 | in |
| Skirt Thickness | 0.3937 | in |
| Internal Corrosion Allowance | 0.0315 | in |
| Nominal Thickness | 0.3937 | in |
| External Corrosion Allowance | 0 | in |
| Design Temperature Internal Pressure | 500 | °F |
| Design Temperature External Pressure | 300 | °F |
| Effective Diameter Multiplier | 1.2 | |
| Material Name | SA-516 70 | |
| Efficiency, Longitudinal Seam | 0.6 | |
| Efficiency, Head-to-Skirt or Circ. Seam | 0.6 | |

| | | |
|---|---|---|
| Weld is pre-Heated | No | |
| Element From Node | 20 | |
| Detail Type | Platform | |
| Detail ID | PLATFORM 1 | |
| Dist. from "FROM" Node / Offset dist | 0.32 | ft |
| Platform Start Angle (degrees) | 14.03 | |
| Platform End Angle (degrees) | 195.0 | |
| Platform Wind Area | 2835 | in^2 |
| Platform Weight | 1607.9 | lbf |
| Platform Railing Weight | 22 | lbf/ft |
| Platform Grating Weight | 30 | lb/ft^2 |
| Platform Width | 45 | in |
| Platform Height | 42 | in |
| Platform Clearance or End Offset | 0 | in |
| Platform Force Coefficient | 1.5 | |
| Ladder Layout Angle | 0.0 | |
| Ladder Start Elevation | 0 | ft |
| Ladder End Elevation | 0 | ft |
| Unit Weight of Ladder | 30 | lbf/ft |
| Platform Length (top head platform) | 0 | in |

---------------------------------------------------------------------

| | | |
|---|---|---|
| Element From Node | 30 | |
| Element To Node | 40 | |
| Element Type | Skirt Sup. | |
| Description | TOP SKIRT | |
| Distance "FROM" to "TO" | 3.1168 | ft |
| Skirt Inside Diameter | 29.25 | in |
| Diameter of Skirt at Base | 29.21 | in |
| Skirt Thickness | 0.3937 | in |
| Internal Corrosion Allowance | 0.0315 | in |
| Nominal Thickness | 0.3937 | in |
| External Corrosion Allowance | 0 | in |
| Design Temperature Internal Pressure | 500 | °F |
| Design Temperature External Pressure | 300 | °F |
| Effective Diameter Multiplier | 1.2 | |
| Material Name | SA-240 316L | |
| Allowable Stress, Ambient | 16700 | psi |
| Allowable Stress, Operating | 14800 | psi |
| Allowable Stress, Hydrotest | 22500 | psi |
| Material Density | 0.29 | lb/in^3 |
| P Number Thickness | 0 | in |
| Yield Stress, Operating | 16400 | psi |
| External Pressure Chart Name | HA-4 | |
| UNS Number | S31603 | |
| Product Form | Plate | |
| Efficiency, Longitudinal Seam | 0.6 | |
| Efficiency, Head-to-Skirt or Circ. Seam | 0.6 | |
| Weld is pre-Heated | No | |

---------------------------------------------------------------------

| | | |
|---|---|---|
| Element From Node | 40 | |
| Element To Node | 50 | |
| Element Type | Elliptical | |
| Description | BTM D-END | |
| Distance "FROM" to "TO" | 0.164 | ft |
| Inside Diameter | 29.25 | in |
| Element Thickness | 0.315 | in |

```
Internal Corrosion Allowance                         0.0315  in
Nominal Thickness                                    0.3937  in
External Corrosion Allowance                              0  in
Design Internal Pressure                                105  psig
Design Temperature Internal Pressure                    500  °F
Design External Pressure                                 15  psig
Design Temperature External Pressure                    300  °F
Effective Diameter Multiplier                           1.2
Material Name                                   SA-240 316L
Efficiency, Longitudinal Seam                           1.0
Efficiency, Circumferential Seam                        1.0
Elliptical Head Factor                                  2.0
Weld is pre-Heated                                       No

    Element From Node                                    40
    Detail Type                                      Liquid
    Detail ID                                     Liquid 30
    Dist. from "FROM" Node / Offset dist            -0.6085  ft
    Height/Length of Liquid                          0.7725  ft
    Liquid Density                                   61.776  lb/ft^3

    Element From Node                                    40
    Detail Type                                      Nozzle
    Detail ID                                  Nozzle B2 2"
    Dist. from "FROM" Node / Offset dist                  0  in
    Nozzle Diameter                                       2  in.
    Nozzle Schedule                                     80S
    Nozzle Class                                        600
    Layout Angle                                        0.0
    Blind Flange (Y/N)                                    N
    Weight of Nozzle ( Used if > 0 )                 30.615  lbf
    Grade of Attached Flange                         GR 2.3
    Nozzle Matl                                SA-312 TP316L

--------------------------------------------------------------------

Element From Node                                        50
Element To Node                                          60
Element Type           Cylinder                     ! Atype
Description                                         SHELL-1
Distance "FROM" to "TO"                              4.9213  ft
Inside Diameter                                       29.25  in
Element Thickness                                    0.3937  in
Internal Corrosion Allowance                         0.0315  in
Nominal Thickness                                    0.3937  in
External Corrosion Allowance                              0  in
Design Internal Pressure                                105  psig
Design Temperature Internal Pressure                    500  °F
Design External Pressure                                 15  psig
Design Temperature External Pressure                    300  °F
Effective Diameter Multiplier                           1.2
Material Name                                   SA-240 316L
Efficiency, Longitudinal Seam                           1.0
Efficiency, Circumferential Seam                        1.0
Weld is pre-Heated                                       No

    Element From Node                                    50
    Detail Type                                    Platform
    Detail ID                                    PLATFORM 2
    Dist. from "FROM" Node / Offset dist                  1  ft
    Platform Start Angle (degrees)                     77.0
```

| | | |
|---|---|---|
| Platform End Angle (degrees) | 347.0 | |
| Platform Wind Area | 3213 | in^2 |
| Platform Weight | 1053.4 | lbf |
| Platform Railing Weight | 22 | lbf/ft |
| Platform Grating Weight | 30 | lb/ft^2 |
| Platform Width | 51 | in |
| Platform Height | 42 | in |
| Platform Clearance or End Offset | 0 | in |
| Platform Force Coefficient | 1.5 | |
| Ladder Layout Angle | 90.0 | |
| Ladder Start Elevation | 0 | ft |
| Ladder End Elevation | 0 | ft |
| Unit Weight of Ladder | 30 | lbf/ft |
| Platform Length (top head platform) | 0 | in |

| | | |
|---|---|---|
| Element From Node | 50 | |
| Detail Type | Packing | |
| Detail ID | Pack: [1 of 1] | |
| Dist. from "FROM" Node / Offset dist | 0 | ft |
| Height of Packed Section | 0 | ft |
| Density | 0 | lb/ft^3 |
| Percent Volume Holdup | 0.0 | |
| Specific Gravity of Packing Liquid | 0.0 | |

| | | |
|---|---|---|
| Element From Node | 50 | |
| Detail Type | Liquid | |
| Detail ID | H2S | |
| Dist. from "FROM" Node / Offset dist | 0 | ft |
| Height/Length of Liquid | 3.002 | ft |
| Liquid Density | 61.776 | lb/ft^3 |

| | | |
|---|---|---|
| Element From Node | 50 | |
| Detail Type | Nozzle | |
| Detail ID | Nozzle LT2 2" | |
| Dist. from "FROM" Node / Offset dist | 0.5 | ft |
| Nozzle Diameter | 2 | in. |
| Nozzle Schedule | None | |
| Nozzle Class | 300 | |
| Layout Angle | 330.0 | |
| Blind Flange (Y/N) | N | |
| Weight of Nozzle ( Used if > 0 ) | 21.65 | lbf |
| Grade of Attached Flange | GR 2.3 | |
| Nozzle Matl | SA-182 F316L | |

| | | |
|---|---|---|
| Element From Node | 50 | |
| Detail Type | Nozzle | |
| Detail ID | Nozzle L2 2" | |
| Dist. from "FROM" Node / Offset dist | 0.5 | ft |
| Nozzle Diameter | 2 | in. |
| Nozzle Schedule | None | |
| Nozzle Class | 600 | |
| Layout Angle | 225.0 | |
| Blind Flange (Y/N) | N | |
| Weight of Nozzle ( Used if > 0 ) | 21.65 | lbf |
| Grade of Attached Flange | GR 2.3 | |
| Nozzle Matl | SA-182 F316L | |

| | | |
|---|---|---|
| Element From Node | 50 | |
| Detail Type | Nozzle | |
| Detail ID | Nozzle S 2" | |
| Dist. from "FROM" Node / Offset dist | 0.5 | ft |

| | | |
|---|---|---|
| Nozzle Diameter | 2 | in. |
| Nozzle Schedule | None | |
| Nozzle Class | 600 | |
| Layout Angle | 270.0 | |
| Blind Flange (Y/N) | N | |
| Weight of Nozzle ( Used if > 0 ) | 21.654 | lbf |
| Grade of Attached Flange | GR 2.3 | |
| Nozzle Matl | SA-182 F316L | |

| | | |
|---|---|---|
| Element From Node | 50 | |
| Detail Type | Nozzle | |
| Detail ID | Nozzle LT1 2" | |
| Dist. from "FROM" Node / Offset dist | 4 | ft |
| Nozzle Diameter | 2 | in. |
| Nozzle Schedule | None | |
| Nozzle Class | 300 | |
| Layout Angle | 330.0 | |
| Blind Flange (Y/N) | N | |
| Weight of Nozzle ( Used if > 0 ) | 21.644 | lbf |
| Grade of Attached Flange | GR 2.3 | |
| Nozzle Matl | SA-182 F316L | |

| | | |
|---|---|---|
| Element From Node | 50 | |
| Detail Type | Nozzle | |
| Detail ID | Nozzle L1 2" | |
| Dist. from "FROM" Node / Offset dist | 4 | ft |
| Nozzle Diameter | 2 | in. |
| Nozzle Schedule | None | |
| Nozzle Class | 600 | |
| Layout Angle | 225.0 | |
| Blind Flange (Y/N) | N | |
| Weight of Nozzle ( Used if > 0 ) | 21.65 | lbf |
| Grade of Attached Flange | GR 2.3 | |
| Nozzle Matl | SA-182 F316L | |

| | | |
|---|---|---|
| Element From Node | 50 | |
| Detail Type | Nozzle | |
| Detail ID | Nozzle B4 2" | |
| Dist. from "FROM" Node / Offset dist | 3.5 | ft |
| Nozzle Diameter | 2 | in. |
| Nozzle Schedule | None | |
| Nozzle Class | 600 | |
| Layout Angle | 300.0 | |
| Blind Flange (Y/N) | Y | |
| Weight of Nozzle ( Used if > 0 ) | 21.654 | lbf |
| Grade of Attached Flange | GR 2.3 | |
| Nozzle Matl | SA-182 F316L | |

| | | |
|---|---|---|
| Element From Node | 50 | |
| Detail Type | Nozzle | |
| Detail ID | Nozzle B3 2" | |
| Dist. from "FROM" Node / Offset dist | 3 | ft |
| Nozzle Diameter | 2 | in. |
| Nozzle Schedule | None | |
| Nozzle Class | 600 | |
| Layout Angle | 225.0 | |
| Blind Flange (Y/N) | N | |
| Weight of Nozzle ( Used if > 0 ) | 21.654 | lbf |
| Grade of Attached Flange | GR 2.3 | |
| Nozzle Matl | SA-182 F316L | |

| | | |
|---|---|---|
| Element From Node | 50 | |
| Detail Type | Nozzle | |
| Detail ID | Nozzle LT3 | |
| Dist. from "FROM" Node / Offset dist | 4 | ft |
| Nozzle Diameter | 2 | in. |
| Nozzle Schedule | None | |
| Nozzle Class | 300 | |
| Layout Angle | 0.0 | |
| Blind Flange (Y/N) | N | |
| Weight of Nozzle ( Used if > 0 ) | 21.65 | lbf |
| Grade of Attached Flange | GR 2.3 | |
| Nozzle Matl | SA-182 F316L | |

| | | |
|---|---|---|
| Element From Node | 50 | |
| Detail Type | Nozzle | |
| Detail ID | Nozzle LT4 | |
| Dist. from "FROM" Node / Offset dist | 0.5 | ft |
| Nozzle Diameter | 2 | in. |
| Nozzle Schedule | None | |
| Nozzle Class | 300 | |
| Layout Angle | 0.0 | |
| Blind Flange (Y/N) | N | |
| Weight of Nozzle ( Used if > 0 ) | 21.65 | lbf |
| Grade of Attached Flange | GR 2.3 | |
| Nozzle Matl | SA-182 F316L | |

--------------------------------------------------------------------

| | | | |
|---|---|---|---|
| Element From Node | | 60 | |
| Element To Node | | 80 | |
| Element Type | Cylinder | ! Atype | |
| Description | | SHELL-2 | |
| Distance "FROM" to "TO" | | 4.5866 | ft |
| Inside Diameter | | 29.25 | in |
| Element Thickness | | 0.3937 | in |
| Internal Corrosion Allowance | | 0.0315 | in |
| Nominal Thickness | | 0.3937 | in |
| External Corrosion Allowance | | 0 | in |
| Design Internal Pressure | | 105 | psig |
| Design Temperature Internal Pressure | | 500 | °F |
| Design External Pressure | | 15 | psig |
| Design Temperature External Pressure | | 300 | °F |
| Effective Diameter Multiplier | | 1.2 | |
| Material Name | | SA-240 316L | |
| Efficiency, Longitudinal Seam | | 1.0 | |
| Efficiency, Circumferential Seam | | 1.0 | |
| Weld is pre-Heated | | No | |

| | | |
|---|---|---|
| Element From Node | 60 | |
| Detail Type | Platform | |
| Detail ID | PLATFORM 3 | |
| Dist. from "FROM" Node / Offset dist | 1 | ft |
| Platform Start Angle (degrees) | 270.0 | |
| Platform End Angle (degrees) | 90.0 | |
| Platform Wind Area | 4788 | in^2 |
| Platform Weight | 1290.8 | lbf |
| Platform Railing Weight | 22 | lbf/ft |
| Platform Grating Weight | 30 | lb/ft^2 |
| Platform Width | 38 | in |
| Platform Height | 42 | in |
| Platform Clearance or End Offset | 0 | in |

```
     Platform Force Coefficient                            1.5
     Ladder Layout Angle                                  90.0
     Ladder Start Elevation                                  0  ft
     Ladder End Elevation                                    0  ft
     Unit Weight of Ladder                                  30  lbf/ft
     Platform Length (top head platform)                     0  in

     Element From Node                                      60
     Detail Type                                       Packing
     Detail ID                                  Pack: [1 of 1]
     Dist. from "FROM" Node / Offset dist                    0  ft
     Height of Packed Section                                0  ft
     Density                                                 0  lb/ft^3
     Percent Volume Holdup                                 0.0
     Specific Gravity of Packing Liquid                    0.0

     Element From Node                                      60
     Detail Type                                        Nozzle
     Detail ID                                     Nozzle A 3"
     Dist. from "FROM" Node / Offset dist               0.8287  ft
     Nozzle Diameter                                         3  in.
     Nozzle Schedule                                       XXS
     Nozzle Class                                          600
     Layout Angle                                        270.0
     Blind Flange (Y/N)                                      N
     Weight of Nozzle ( Used if > 0 )                   29.633  lbf
     Grade of Attached Flange                           GR 2.3
     Nozzle Matl                                  SA-312 TP316L

     Element From Node                                      60
     Detail Type                                        Weight
     Detail ID                                 MIST ELIMINATOR
     Dist. from "FROM" Node / Offset dist               3.6253  ft
     Miscellaneous Weight                                  303  lbf
     Offset from Element Centerline                          0  in

     Element From Node                                      60
     Detail Type                                        Weight
     Detail ID                                          MISC.0
     Dist. from "FROM" Node / Offset dist               3.6253  ft
     Miscellaneous Weight                                   28  lbf
     Offset from Element Centerline                          0  in

 --------------------------------------------------------------------

 Element From Node                                          80
 Element To Node                                            90
 Element Type                                           Flange
 Description                                   NOZZLE M FLANGE
 Distance "FROM" to "TO"                                0.3183  ft
 Flange Inside Diameter                                  29.25  in
 Element Thickness                                        1.69  in
 Internal Corrosion Allowance                           0.0315  in
 Nominal Thickness                                           0  in
 External Corrosion Allowance                                0  in
 Design Internal Pressure                                  105  psig
 Design Temperature Internal Pressure                      500  °F
 Design External Pressure                                   15  psig
 Design Temperature External Pressure                      300  °F
 Effective Diameter Multiplier                             1.2
 Material Name                                    SA-182 F316L
```

```
     Allowable Stress, Ambient                           16700  psi
     Allowable Stress, Operating                         10900  psi
     Allowable Stress, Hydrotest                         22500  psi
     Material Density                                     0.29  lb/in^3
     P Number Thickness                                      0  in
     Yield Stress, Operating                             16400  psi
     External Pressure Chart Name                         HA-4
     UNS Number                                         S31603
     Class / Thickness / Grade                          :: > 5
     Product Form                                     Forgings
 Perform Flange Stress Calculation (Y/N)                     Y
 Weld is pre-Heated                                         No

 --------------------------------------------------------------------

 Element From Node                                          90
 Element To Node                                           100
 Element Type                                           Flange
 Description                                   NOZZLE M BLIND
 Distance "FROM" to "TO"                                0.2297  ft
 Flange Outside Diameter                                 34.94  in
 Element Thickness                                      2.7559  in
 Internal Corrosion Allowance                           0.0315  in
 Nominal Thickness                                      2.7559  in
 External Corrosion Allowance                                0  in
 Design Internal Pressure                                  105  psig
 Design Temperature Internal Pressure                      500  °F
 Design External Pressure                                   15  psig
 Design Temperature External Pressure                      300  °F
 Effective Diameter Multiplier                             1.2
 Material Name                                    SA-182 F316L
 Perform Flange Stress Calculation (Y/N)                     Y
 Weld is pre-Heated                                         No

     Element From Node                                      90
     Detail Type                                        Nozzle
     Detail ID                                 Nozzle B1 6in.0
     Dist. from "FROM" Node / Offset dist                   10  in
     Nozzle Diameter                                         6  in.
     Nozzle Schedule                                       XXS
     Nozzle Class                                          300
     Layout Angle                                        180.0
     Blind Flange (Y/N)                                      N
     Weight of Nozzle ( Used if > 0 )                    63.52  lbf
     Grade of Attached Flange                           GR 2.3
     Nozzle Matl                                 SA-312 TP316L

     Element From Node                                      90
     Detail Type                                        Nozzle
     Detail ID                                     Nozzle V 2"
     Dist. from "FROM" Node / Offset dist                   10  in
     Nozzle Diameter                                         2  in.
     Nozzle Schedule                                      None
     Nozzle Class                                          300
     Layout Angle                                        305.0
     Blind Flange (Y/N)                                      N
     Weight of Nozzle ( Used if > 0 )                   26.367  lbf
     Grade of Attached Flange                           GR 2.3
     Nozzle Matl                                  SA-182 F316L
```

**XY Coordinate Calculations:**

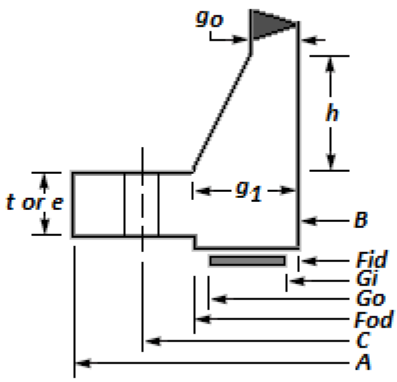
| From | To | X (Horiz.) ft | Y (Vert.) ft | DX (Horiz.) ft | DY (Vert.) ft |
|---|---|---|---|---|---|
| BTM SKIRT-2 | | ... | 8.2021 | ... | 8.2021 |
| BTM SKIRT-1 | | ... | 13.6319 | ... | 5.42979 |
| TOP SKIRT | | ... | 16.7487 | ... | 3.1168 |
| BTM D-END | | ... | 16.9127 | ... | 0.164 |
| SHELL-1 | | ... | 21.8339 | ... | 4.92126 |
| SHELL-2 | | ... | 26.4206 | ... | 4.58661 |
| NOZZLE M FLANGE | | ... | 26.7389 | ... | 0.31833 |
| NOZZLE M BLIND | | ... | 26.9998 | ... | 0.22966 |

PV Elite includes an 1/8 inch (3.175mm) raised face and gasket thicknesses for girth flanges and tubesheet thicknesses where applicable in the Tangent to Tangent length calculation. The calculated dimensions are based on the given element lengths. Due to variability in manufacturing (weld gaps etc.), the Tangent to Tangent length may not be exact.

**Flange Input Data Values** **Description: FLANGE :**

NOZZLE M FLANGE

| | | | |
|---|---|---|---|
| Flange Type | | Integral Weld Neck | |
| Design Pressure | P | 105.00 | psig |
| Design Temperature | | 500 | °F |
| Internal Corrosion Allowance | ci | 0.0315 | in |
| External Corrosion Allowance | ce | 0.0000 | in |
| Use Corrosion Allowance in Thickness Calcs. | | No | |
| Flange Inside Diameter | B | 29.250 | in |
| Flange Outside Diameter | A | 34.940 | in |
| Flange Thickness | t | 1.6900 | in |
| Thickness of Hub at Small End | go | 0.3937 | in |
| Thickness of Hub at Large End | g1 | 0.8637 | in |
| Length of Hub | h | 2.1300 | in |
| Flange Material | | SA-182 F316L | |
| Flange Material UNS number | | S31603 | |
| Flange Allowable Stress At Temperature | Sfo | 10900.00 | psi |
| Flange Allowable Stress At Ambient | Sfa | 16700.00 | psi |
| Bolt Material | | SA-193 B7M | |
| Bolt Allowable Stress At Temperature | Sb | 20000.00 | psi |
| Bolt Allowable Stress At Ambient | Sa | 20000.00 | psi |
| Diameter of Bolt Circle | C | 33.310 | in |
| Nominal Bolt Diameter | a | 0.7500 | in |
| Type of Threads | | TEMA Thread Series | |
| Number of Bolts | | 44 | |
| Flange Face Outside Diameter | Fod | 32.000 | in |
| Flange Face Inside Diameter | Fid | 29.250 | in |
| Flange Facing Sketch | | 1, Code Sketch 1a | |
| Gasket Outside Diameter | Go | 31.500 | in |
| Gasket Inside Diameter | Gi | 30.500 | in |
| Gasket Factor | m | 3.0000 | |
| Gasket Design Seating Stress | y | 10000.00 | psi |
| Column for Gasket Seating | | 2, Code Column II | |
| Gasket Thickness | tg | 0.1250 | in |
| Flange Class | | 150 | |
| Flange Grade | | GR 2.3 | |
| Flange Series | Series | A | |




**ASME Code, Section VIII Division 1, 2021**

Hub Small End Required Thickness due to Internal Pressure:
```
  = (P*(D/2+Ca))/(S*E-0.6*P) per UG-27 (c)(1)
  = (105.0*(29.25/2+0.0315))/(10900.0*1.0-0.6*105.0)+Ca
  = 0.1735 in
```

Hub Small End Hub MAWP:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (10900.0 * 1.0 * 0.3622)/(14.6565 + 0.6 * 0.3622 )
  = 265.435 psig
```

| | | | |
|---|---|---|---|
| Corroded Flange ID, | Bcor = B+2*Fcor | 29.313 | in |
| Corroded Large Hub, | g1Cor = g1-ci | 0.832 | in |
| Corroded Small Hub, | g0Cor = go-ci | 0.362 | in |
| Code R Dimension, | R = ((C-Bcor)/2)-g1cor | 1.166 | in |
| Gasket Contact Width, | N = (Go - Gi) / 2 | 0.500 | in |
| Basic Gasket Width, | bo = N / 2 | 0.250 | in |
| Effective Gasket Width, | b = bo | 0.250 | in |
| Gasket Reaction Diameter, | G = (Go + Gi) / 2 | 31.000 | in |

**Basic Flange and Bolt Loads:**

Hydrostatic End Load due to Pressure [H]:
```
  = 0.785 * G² * Peq
  = 0.785 * 31.0² * 105.0
  = 79250.602 lbf
```

Contact Load on Gasket Surfaces [Hp]:
```
  = 2 * b * pi * G * m * P
  = 2 * 0.25 * pi * 31.0 * 3.0 * 105.0
  = 15338.826 lbf
```

Hydrostatic End Load at Flange ID [Hd]:
```
  = pi * Bcor² * P  / 4
  = pi * 29.313² *105.0/4
  = 70859.734 lbf
```

Pressure Force on Flange Face [Ht]:
```
  = H - Hd
  = 79251 - 70860
  = 8390.867 lbf
```

Operating Bolt Load [Wm1]:
```
  = max( H + Hp + H'p, 0 )
  = max( 79251 + 15339 + 0, 0 )
  = 94589.430 lbf
```

Gasket Seating Bolt Load [Wm2]:
```
  = y * b * pi * G  + yPart * bPart * lp
  = 10000.0*0.25*pi*31.0+0.0*0.0*0.0
  = 243473.438 lbf
```

Required Bolt Area [Am]:
```
  = max( Wm1/Sb, Wm2/Sa )
  = max( 94589/20000, 243473/20000 )
  = 12.174 in^2
```

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:
```
  = Ab * Sa/( y * pi(Go + Gi) )
  = 13.288 * 20000.0/(10000.0 * pi(31.5 + 30.5) )
  = 0.136 in
```

Note: Recommended Min. Width for Sheet and Composite Gaskets per table 2-4 :
```
 = 1.000 in[Note: Exceeds actual gasket width, 0.500  ]
```

Flange Design Bolt Load, Gasket Seating [W]:
```
  = Sa( Am + Ab ) / 2
  = 20000.0( 12.1737 + 13.288 )/2
  = 254616.70 lbf
```

Gasket Load for the Operating Condition [HG]:
```
  = Wm1 - H
  = 94589 - 79251
  = 15338.83 lbf
```

**Moment Arm Calculations:**

Distance to Gasket Load Reaction [hg]:
```
  = (C - G ) / 2
  = ( 33.31 - 31.0 )/2
  = 1.1550 in
```

Distance to Face Pressure Reaction [ht]:
```
  = ( R + g1 + hg ) / 2
  = ( 1.1663 + 0.8322 + 1.155 )/2
  = 1.5768 in
```

Distance to End Pressure Reaction [hd]:
```
  = R + ( g1 / 2 )
  = 1.1663 +( 0.8322/2.0 )
  = 1.5824 in
```

**Summary of Moments for Internal Pressure: (ft-lbf)**

| Loading | | Force | Distance | Bolt Corr | Moment |
|---|---|---|---|---|---|
| End Pressure, | Md | 70860. | 1.5824 | 1.0000 | 9344. |
| Face Pressure, | Mt | 8391. | 1.5768 | 1.0000 | 1103. |
| Gasket Load, | Mg | 15339. | 1.1550 | 1.0000 | 1476. |
| Gasket Seating, | Matm | 254617. | 1.1550 | 1.0000 | 24507. |

Total Moment for Operation, Mop 11923. ft-lbf

```
 Total Moment for Gasket seating, Matm                          24507. ft-lbf
```

*You chose not to perform Stress Calculations on this Standard Flange.*
*The pressure rating of the flange will be used to check code compliance.*

```
 Estimated Finished Weight of Flange at given Thk.      177.0 lbm
 Estimated Unfinished Weight of Forging at given Thk    317.8 lbm
```

**Flange Input Data Values**   **Description: BLIND FLANGE :**

NOZZLE M BLIND

```
Flange Type                                               Blind

Design Pressure                           P             105.00  psig
Design Temperature                                        500   °F
Internal Corrosion Allowance             ci             0.0315  in
External Corrosion Allowance             ce             0.0000  in
Use Corrosion Allowance in Thickness Calcs.                Yes

Flange Outside Diameter                   A             34.940  in
Flange Thickness                          t             2.7559  in

Flange Material                                   SA-182 F316L
Flange Material UNS number                              S31603
Flange Allowable Stress At Temperature  Sfo           10900.00  psi
Flange Allowable Stress At Ambient      Sfa           16700.00  psi

Bolt Material                                       SA-193 B7M
Bolt Allowable Stress At Temperature     Sb           20000.00  psi
Bolt Allowable Stress At Ambient         Sa           20000.00  psi

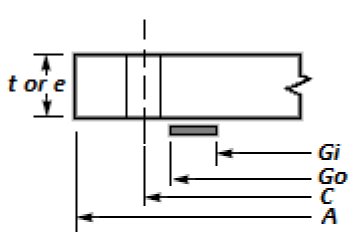
Diameter of the Load Reaction, Long  Span  D             0.000  in
Diameter of the Load Reaction, Short Span  d             0.000  in
Perimeter along the Center of the Bolts    L           104.646  in

Diameter of Bolt Circle                   C             33.310  in
Nominal Bolt Diameter                     a             0.7500  in
Type of Threads                          TEMA Thread Series
Number of Bolts                                             44

Flange Face Outside Diameter            Fod             32.000  in
Flange Face Inside Diameter             Fid             29.250  in
Flange Facing Sketch                      1, Code Sketch 1a

Gasket Outside Diameter                  Go             31.500  in
Gasket Inside Diameter                   Gi             30.500  in
Gasket Factor                             m             3.0000
Gasket Design Seating Stress              y           10000.00  psi

Column for Gasket Seating                 2, Code Column II
Gasket Thickness                         tg             0.1250  in
```

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```
Gasket Contact Width,       N = (Go - Gi) / 2             0.500   in
```

```
Basic Gasket Width,         bo = N / 2                    0.250  in
Effective Gasket Width,      b = bo                       0.250  in
Gasket Reaction Diameter,    G = (Go + Gi) / 2           31.000  in
```

**Basic Flange and Bolt Loads:**

Hydrostatic End Load due to Pressure [H]:
```
= 0.785 * G² * Peq
= 0.785 * 31.0² * 105.0
= 79250.602 lbf
```

Contact Load on Gasket Surfaces [Hp]:
```
= 2 * b * pi * G * m * P
= 2 * 0.25 * pi * 31.0 * 3.0 * 105.0
= 15338.826 lbf
```

Operating Bolt Load [Wm1]:
```
= max( H + Hp + H'p, 0 )
= max( 79251 + 15339 + 0, 0 )
= 94589.430 lbf
```

Gasket Seating Bolt Load [Wm2]:
```
= y * b * pi * G  + yPart * bPart * lp
= 10000.0*0.25*pi*31.0+0.0*0.0*0.0
= 243473.438 lbf
```

Required Bolt Area [Am]:
```
= max( Wm1/Sb, Wm2/Sa )
= max( 94589/20000, 243473/20000 )
= 12.174 in^2
```

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
```
= 2a + 6t/(m + 0.5)
= 2 * 0.75 + 6 * 2.724/(3.0 + 0.5)
= 6.170 in
```

Actual Circumferential Bolt Spacing [Bs]:
```
= C * sin( pi / n )
= 33.31 * sin( pi/44 )
= 2.376 in
```

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:
```
= max( sqrt( Bs/( 2a + t )), 1 )
= max( sqrt( 2.376/( 2 * 0.75 + 2.724 )), 1 )
= 1.0000
```

**Bolting Information for TEMA Imperial Thread Series (Non Mandatory):**

| | Minimum | Actual | Maximum |
|---|---|---|---|
| Bolt Area: | 12.174 | 13.288 | |
| Radial Distance between Bolts and Edge: | 0.812 | 0.815 | |
| Circ. Spacing between the Bolts: | 1.750 | 2.376 | 6.170 |

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:
```
= Ab * Sa/( y * pi(Go + Gi) )
= 13.288 * 20000.0/(10000.0 * pi(31.5 + 30.5) )
= 0.136 in
```

Flange Design Bolt Load, Gasket Seating [W]:

```
  = Sa( Am + Ab ) / 2
  = 20000.0( 12.1737 + 13.288 )/2
  = 254616.70 lbf
```

Gasket Load for the Operating Condition [HG]:

```
  = Wm1
  = 94589.43 lbf
```

**Moment Arm Calculations:**

Distance to Gasket Load Reaction [hg]:

```
  = (C - G ) / 2
  = ( 33.31 - 31.0 )/2
  = 1.1550 in
```

Tangential Flange Stress, Flat Head (UG-34), Operating [STo]:

```
  = 1.9 * Wm1 * hG * Bsc/(t² * G) + C * Z * Peq * G²/t²
  = 1.9*94589*1.155*1.0/(2.7244²*31.0)+0.3*1.0*105.0*31.0²/2.7244²
  = 4980.51 psi
```

Tangential Flange Stress, Flat Head (UG-34), Seating [STa]:

```
  = 1.9 * W * hG * Bsc/ (t² * G)
  = 1.9*254617*1.155*1.0/(2.7244²*31.0)
  = 2428.37 psi
```

Bolt Stress, Operating [BSo]:

```
  = Wm1 / Ab
  = 94589/13.288
  = 7118.41 psi
```

Bolt Stress, Seating [BSa]:

```
  = ( Wm2 / Ab )
  = (243473/13.288)
  = 18322.81 psi
```

**Flange Stress Analysis Results: psi**

| | Operating Actual | Operating Allowed | Gasket Seating Actual | Gasket Seating Allowed |
|---|---|---|---|---|
| Tangential Flange | 4980.51 | 10900.00 | 2428.37 | 16700.00 |
| Bolting | 7118.41 | 20000.00 | 18322.81 | 20000.00 |

```
Reqd. Blind Flange Thickness at Center              1.873 in
Reqd. Blind Flange Thickness at Gasket              1.070 in
Estimated M.A.W.P. ( Operating )                      230 psig
Estimated Finished Weight of Flange at given Thk.   766.3 lbm
Estimated Unfinished Weight of Forging at given Thk 766.3 lbm
```

*SA-182 F316L, Min Metal Temp without impact per UHA-51: -320 °F*

**Internal Pressure Results Summary:**

**Element Thickness, Pressure, Diameter and Allowable Stress :**

| From | To | Int. Press + Liq. Hd psig | Nominal Thickness in | Total Corr Allowance in | Element Diameter in | Allowable Stress(SE) psi |
|---|---|---|---|---|---|---|
| BTM SKIRT-2 | | ... | 0.3937 | 0.031496 | 29.25 | ... |
| BTM SKIRT-1 | | ... | 0.3937 | 0.031496 | 29.25 | ... |
| TOP SKIRT | | ... | 0.3937 | 0.031496 | 29.25 | ... |
| BTM D-END | | 106.619 | 0.3937 | 0.031496 | 29.25 | 14800 |
| SHELL-1 | | 106.288 | 0.3937 | 0.031496 | 29.25 | 14800 |
| SHELL-2 | | 105 | 0.3937 | 0.031496 | 29.25 | 14800 |
| NOZZLE M FLANGE | | 105 | ... | 0.031496 | 29.25 | 10900 |
| NOZZLE M BLIND | | 105 | 2.75591 | 0.031496 | 34.94 | 10900 |

**Element Required Thickness and MAWP :**

| From | To | Design Pressure psig | M.A.W.P. Corroded psig | M.A.P. New & Cold psig | Minimum Thickness in | Required Thickness in |
|---|---|---|---|---|---|---|
| BTM SKIRT-2 | | ... | No Calc | No Calc | 0.3937 | No Calc |
| BTM SKIRT-1 | | ... | No Calc | No Calc | 0.3937 | No Calc |
| TOP SKIRT | | ... | No Calc | No Calc | 0.3937 | No Calc |
| BTM D-END | | 105 | 284.885 | 358.874 | 0.31496 | 0.13686 |
| SHELL-1 | | 105 | 359.119 | 442.414 | 0.3937 | 0.13721 |
| SHELL-2 | | 105 | 360.407 | 442.413 | 0.3937 | 0.13592 |
| NOZZLE M FLANGE | | 105 | 150 | 230 | 1.69 | No Calc |
| NOZZLE M BLIND | | 105 | 229.79 | 295 | 2.75591 | 1.8731 |
| Minimum | | | 150 | 230 | | |

MAWP: 150 psig, limited by: NOZZLE M FLANGE.

Elements Suitable for Design Internal Pressure.

**<u>Internal Pressure Calculation Results:</u>**

**ASME Code, Section VIII Division 1, 2021**

**<u>Elliptical Head From 40 To 50 SA-240 316L at 500 °F</u>**

BTM D-END

Longitudinal Joint: User Defined

Material UNS Number: S31603

Required Thickness due to Internal Pressure [tr]:
```
  = (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
  = (106.619*29.313*0.997)/(2*14800.0*1.0-0.2*106.619)
  = 0.1054 + 0.0315 = 0.1369 in
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 1.619 psig
```
  = (2*S*E*t)/(Kcor*D+0.2*t) per Appendix 1-4 (c)
  = (2*14800.0*1.0*0.2835)/(0.997*29.313+0.2*0.2835)
```

```
  = 287 - 2 = 285  psig
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
  = (2*S*E*t)/(K*D+0.2*t) per Appendix 1-4 (c)
  = (2*16700.0*1.0*0.315)/(1.0*29.25+0.2*0.315)
  = 359 psig
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(Kcor*D+0.2*t))/(2*E*t)
  = (106.619*(0.997*29.313+0.2*0.2835))/(2*1.0*0.2835)
  = 5507.651 psi
```

Straight Flange Required Thickness:
```
  = (P*R)/(S*E-0.6*P) + c    per UG-27 (c)(1)
  = (106.619*14.6565)/(14800.0*1.0-0.6*106.619)+0.031
  = 0.138 in
```

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 1.358 psig
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (14800.0 * 1.0 * 0.3622)/(14.6565 + 0.6 * 0.3622 )
  = 360 - 1 = 359  psig
```

Factor K, corroded condition [Kcor]:
```
  = ( 2 + ( Inside Diameter/( 2 * Inside Head Depth ))²)/6
  = ( 2 +( 29.313/( 2 * 7.344 ))²)/6
  = 0.997144
```

% Elongation per Table UG-79-1 (75*tnom/Rf)*(1-Rf/Ro)  5.712 %
Note: Please Check Requirements of Table UHA-44 for Elongation limits.

*SA-240 316L, Min Metal Temp without impact per UHA-51:  -320 °F*

**Cylindrical Shell From 50 To 60 SA-240 316L at 500 °F**

SHELL-1

Longitudinal    Joint:   User Defined

Material UNS Number:    S31603

Required Thickness due to Internal Pressure [tr]:
```
  = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
  = (106.288*14.6565)/(14800.0*1.0-0.6*106.288)
  = 0.1057 + 0.0315 = 0.1372 in
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 1.288 psig
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (14800.0*1.0*0.3622)/(14.6565+0.6*0.3622)
  = 360 - 1 = 359  psig
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (16700.0*1.0*0.3937)/(14.625+0.6*0.3937)
  = 442 psig
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(R+0.6*t))/(E*t)
  = (106.288*(14.6565+0.6*0.3622))/(1.0*0.3622)
  = 4364.673 psi
```

% Elongation per Table UG-79-1 (50*tnom/Rf)*(1-Rf/Ro) 1.328 %
Note: Please Check Requirements of Table UHA-44 for Elongation limits.

*SA-240 316L, Min Metal Temp without impact per UHA-51: -320 °F*

**Cylindrical Shell From 60 To 80 SA-240 316L at 500 °F**

SHELL-2

Longitudinal Joint: User Defined

Material UNS Number: S31603

Required Thickness due to Internal Pressure [tr]:
```
  = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
  = (105.0*14.6565)/(14800.0*1.0-0.6*105.0)
  = 0.1044 + 0.0315 = 0.1359 in
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (14800.0*1.0*0.3622)/(14.6565+0.6*0.3622)
  = 360 psig
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (16700.0*1.0*0.3937)/(14.625+0.6*0.3937)
  = 442 psig
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(R+0.6*t))/(E*t)
  = (105.0*(14.6565+0.6*0.3622))/(1.0*0.3622)
  = 4311.791 psi
```

% Elongation per Table UG-79-1 (50*tnom/Rf)*(1-Rf/Ro) 1.328 %
Note: Please Check Requirements of Table UHA-44 for Elongation limits.

*SA-240 316L, Min Metal Temp without impact per UHA-51: -320 °F*

**Hydrostatic Test Pressure Results:**

```
 Pressure per UG99b     = 1.30 * M.A.W.P. * Sa/S        220.034  psig
 Pressure per UG99b[35] = 1.30 * Design Pres * Sa/S     154.024  psig
 Pressure per UG99c     = 1.30 * M.A.P. - Head(Hyd)     297.737  psig
 Pressure per UG100     = 1.10 * M.A.W.P. * Sa/S        186.182  psig
 Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)   150.150  psig
 Pressure per App 27-4  = M.A.W.P.                      150.000  psig

 User Defined Hydrostatic Test Pressure at High Point   312.913  psig
```

**Horizontal Test performed per: User Hydro Pressure**

*Please note that Nozzle, Shell, Head, Flange, etc MAWPs are all considered when determining the hydrotest pressure for those test types that are based on the MAWP of the vessel.*

**Stresses on Elements due to Test Pressure (psi & psig):**

| From To | Stress | Allowable | Ratio | Pressure |
|---|---|---|---|---|
| BTM D-END | 16218.8 | 22500.0 | 0.721 | 313.97 |

| | | | | |
|---|---|---|---|---|
| SHELL-1 | 12893.1 | 22500.0 | 0.573 | 313.97 |
| SHELL-2 | 12893.1 | 22500.0 | 0.573 | 313.97 |

**Stress ratios for Nozzle and Pad Materials (psi):**

| Description | Pad/Nozzle | Ambient | Operating | Ratio |
|---|---|---|---|---|
| Nozzle B2 2" | Nozzle | 16700.00 | 10900.00 | 1.532 |
| Nozzle LT2 2" | Nozzle | 16700.00 | 10900.00 | 1.532 |
| Nozzle L2 2" | Nozzle | 16700.00 | 10900.00 | 1.532 |
| Nozzle S 2" | Nozzle | 16700.00 | 10900.00 | 1.532 |
| Nozzle LT1 2" | Nozzle | 16700.00 | 10900.00 | 1.532 |
| Nozzle L1 2" | Nozzle | 16700.00 | 10900.00 | 1.532 |
| Nozzle B4 2" | Nozzle | 16700.00 | 10900.00 | 1.532 |
| Nozzle B3 2" | Nozzle | 16700.00 | 10900.00 | 1.532 |
| Nozzle LT3 | Nozzle | 16700.00 | 10900.00 | 1.532 |
| Nozzle LT4 | Nozzle | 16700.00 | 10900.00 | 1.532 |
| Nozzle A 3" | Nozzle | 16700.00 | 10900.00 | 1.532 |
| Nozzle B1 6in. | Nozzle | 16700.00 | 10900.00 | 1.532 |
| Nozzle V 2" | Nozzle | 16700.00 | 10900.00 | 1.532 |
| Minimum | | | | 1.532 |

**Stress ratios for Pressurized Vessel Elements (psi):**

| Description | Ambient | Operating | Ratio |
|---|---|---|---|
| BTM D-END | 16700.00 | 14800.00 | 1.128 |
| SHELL-1 | 16700.00 | 14800.00 | 1.128 |
| SHELL-2 | 16700.00 | 14800.00 | 1.128 |
| NOZZLE M FLANGE | 16700.00 | 10900.00 | 1.532 |
| NOZZLE M BLIND | 16700.00 | 10900.00 | 1.532 |
| Minimum | | | 1.128 |

**Hoop Stress in Nozzle Wall during Pressure Test (psi):**

| Description | Ambient | Operating | Ratio |
|---|---|---|---|
| Nozzle B2 2" | 2215.57 | 21710.00 | 0.102 |
| Nozzle LT2 2" | 666.78 | 21710.00 | 0.031 |
| Nozzle L2 2" | 666.78 | 21710.00 | 0.031 |
| Nozzle S 2" | 666.78 | 21710.00 | 0.031 |
| Nozzle LT1 2" | 666.78 | 21710.00 | 0.031 |
| Nozzle L1 2" | 666.78 | 21710.00 | 0.031 |
| Nozzle B4 2" | 706.72 | 21710.00 | 0.033 |
| Nozzle B3 2" | 706.72 | 21710.00 | 0.033 |
| Nozzle LT3 | 666.78 | 21710.00 | 0.031 |
| Nozzle LT4 | 666.78 | 21710.00 | 0.031 |
| Nozzle A 3" | 987.77 | 21710.00 | 0.045 |
| Nozzle B1 6in. | 1310.77 | 21710.00 | 0.060 |
| Nozzle V 2" | 707.18 | 21710.00 | 0.033 |

Elements Suitable for Test Pressure.

## External Pressure Calculation Results :

### External Pressure Calculations:

| From | To | Section Length ft | Outside Diameter in | Corroded Thickness in | Factor A | Factor B psi |
|---|---|---|---|---|---|---|
| 10 | 20 | 16.7487 | ... | ... | No Calc | No Calc |
| 20 | 30 | 16.7487 | ... | ... | No Calc | No Calc |
| 30 | 40 | 16.7487 | ... | ... | No Calc | No Calc |
| 40 | 50 | No Calc | 29.8799 | 0.28346 | 0.0013176 | 7815.78 |
| 50 | 60 | 9.875 | 30.0374 | 0.3622 | 0.00041039 | 5417.14 |
| 60 | 80 | 9.875 | 30.0374 | 0.3622 | 0.00041039 | 5417.13 |
| 80 | 90 | No Calc | ... | 1.6585 | No Calc | No Calc |
| 90 | 100 | No Calc | ... | 2.72441 | No Calc | No Calc |

### External Pressure Calculations:

| From | To | External Actual T. in | External Required T. in | External Design Pressure psig | External M.A.W.P. psig |
|---|---|---|---|---|---|
| 10 | 20 | ... | No Calc | ... | No Calc |
| 20 | 30 | ... | No Calc | ... | No Calc |
| 30 | 40 | ... | No Calc | ... | No Calc |
| 40 | 50 | 0.31496 | 0.11258 | 15 | 82.3852 |
| 50 | 60 | 0.3937 | 0.20846 | 15 | 87.0964 |
| 60 | 80 | 0.3937 | 0.20846 | 15 | 87.0963 |
| 80 | 90 | 1.69 | No Calc | 15 | No Calc |
| 90 | 100 | 2.75591 | 1.071 | 15 | No Calc |
| Minimum | | | | | 82 |

### External Pressure Calculations:

| From | To | Actual Length Bet. Stiffeners ft | Allowable Length Bet. Stiffeners ft | Ring Inertia Required in**4 | Ring Inertia Available in**4 |
|---|---|---|---|---|---|
| 10 | 20 | 16.7487 | No Calc | No Calc | No Calc |
| 20 | 30 | 16.7487 | No Calc | No Calc | No Calc |
| 30 | 40 | 16.7487 | No Calc | No Calc | No Calc |
| 40 | 50 | No Calc | No Calc | No Calc | No Calc |
| 50 | 60 | 9.875 | 200.986 | No Calc | No Calc |
| 60 | 80 | 9.875 | 200.985 | No Calc | No Calc |
| 80 | 90 | No Calc | No Calc | No Calc | No Calc |
| 90 | 100 | No Calc | No Calc | No Calc | No Calc |

Elements Suitable for External Pressure.

**ASME Code, Section VIII Division 1, 2021**

## Elliptical Head From 40 to 50 Ext. Chart: HA-4 at 300 °F

BTM D-END
Elastic Modulus from Chart: HA-4 at 300 °F: 26400000 psi

| Results for Maximum Allowable Ext. Pressure | | | | MAEP |
|---|---|---|---|---|
| Tca | Outer Dia | Do/t | Factor A | Factor B |
| 0.283 | 29.88 | 105.41 | 0.0013176 | 7815.78 |

MAEP = B/(K0*Do/t) = 7815.7837/( 0.9 *105.4097 ) = 82.3852 psig

| Results for Required Thickness | | | | Tca |
|---|---|---|---|---|
| Tca | Outer Dia | Do/t | Factor A | Factor B |
| 0.081 | 29.88 | 368.50 | 0.0003769 | 4975.13 |

MAEP = B/(K0*Do/t) = 4975.126/( 0.9 *368.4999 ) = 15.0011 psig

---

**Cylindrical Shell From 50 to 60 Ext. Chart: HA-4 at 300 °F**

SHELL-1
Elastic Modulus from Chart: HA-4 at 300 °F: 26400000 psi

| Results for Maximum Allowable Ext. Pressure | | | | | | MAEP |
|---|---|---|---|---|---|---|
| Tca | Outer Dia | Slen | Do/t | L/D | Factor A | Factor B |
| 0.362 | 30.04 | 118.50 | 82.93 | 3.9451 | 0.0004104 | 5417.14 |

MAEP = (4*B)/(3*(Do/t)) = (4*5417.1353)/(3*82.9293) = 87.0964 psig

| Results for Required Thickness | | | | | | Tca |
|---|---|---|---|---|---|---|
| Tca | Outer Dia | Slen | Do/t | L/D | Factor A | Factor B |
| 0.177 | 30.04 | 118.50 | 169.73 | 3.9451 | 0.0001447 | 1909.62 |

MAEP = (4*B)/(3*(Do/t)) = (4*1909.6219)/(3*169.7339) = 15.0009 psig

| Results for Maximum Stiffened Length | | | | | | Slen |
|---|---|---|---|---|---|---|
| Tca | Outer Dia | Slen | Do/t | L/D | Factor A | Factor B |
| 0.362 | 30.04 | 2411.83 | 82.93 | 50.0000 | 0.0001615 | 2131.56 |

MAEP = (4*B)/(3*(Do/t)) = (4*2131.563)/(3*82.9293) = 34.2712 psig

---

**Cylindrical Shell From 60 to 80 Ext. Chart: HA-4 at 300 °F**

SHELL-2
Elastic Modulus from Chart: HA-4 at 300 °F: 26400000 psi

| Results for Maximum Allowable Ext. Pressure | | | | | | MAEP |
|---|---|---|---|---|---|---|
| Tca | Outer Dia | Slen | Do/t | L/D | Factor A | Factor B |
| 0.362 | 30.04 | 118.50 | 82.93 | 3.9451 | 0.0004104 | 5417.13 |

MAEP = (4*B)/(3*(Do/t)) = (4*5417.1299)/(3*82.9293) = 87.0963 psig

Results for Required Thickness | Tca |

| Tca | Outer Dia | Slen | Do/t | L/D | Factor A | Factor B |
|---|---|---|---|---|---|---|
| 0.177 | 30.04 | 118.50 | 169.73 | 3.9451 | 0.0001447 | 1909.62 |

MAEP = (4*B)/(3*(Do/t)) = (4*1909.6219)/(3*169.7339) = 15.0009 psig

Results for Maximum Stiffened Length | Slen |

| Tca | Outer Dia | Slen | Do/t | L/D | Factor A | Factor B |
|---|---|---|---|---|---|---|
| 0.362 | 30.04 | 2411.82 | 82.93 | 50.0000 | 0.0001615 | 2131.56 |

MAEP = (4*B)/(3*(Do/t)) = (4*2131.5608)/(3*82.9293) = 34.2711 psig

---

**Element and Detail Weights:**

| From | To | Element Metal Wgt. lbf | Element ID Volume in3 | Corroded Metal Wgt. lbf | Corroded ID Volume in3 | Extra due Misc % lbf |
|---|---|---|---|---|---|---|
| 10 | 20 | 1423.07 | ... | 1383.2 | ... | 142.307 |
| 20 | 30 | 668.463 | ... | 642.066 | ... | 66.8463 |
| 30 | 40 | 397.414 | ... | 381.72 | ... | 39.7414 |
| 40 | 50 | 141.005 | 4598.2 | 129.725 | 4625.12 | 14.1005 |
| 50 | 60 | 627.92 | 39682.5 | 578.299 | 39853.6 | 62.792 |
| 60 | 80 | 585.221 | 36984.1 | 538.975 | 37143.6 | 58.5221 |
| 80 | 90 | 177.043 | 2571.77 | 173.833 | 2577.94 | 17.7043 |
| 90 | 100 | 766.3 | ... | 766.3 | ... | 76.63 |
| Total | | 4786 | 83836 | 4594 | 84200 | 478 |

**Weight of Details:**

| From | Type | Weight of Detail lbf | X Offset, Dtl. Cent. ft | Y Offset, Dtl. Cent. ft | Z Offset Dtl. Cent. ft | Description |
|---|---|---|---|---|---|---|
| 20 | Plat | 1768.67 | -2.15164 | 0.32 | -0.55705 | PLATFORM 1 |
| 40 | Liqd | 164.385 | ... | -0.30427 | ... | Liquid 30 |
| 40 | Nozl | 33.6769 | ... | -1.01025 | ... | Nozzle B2 2" |
| 50 | Plat | 1158.71 | 1.81005 | 1 | -2.89669 | PLATFORM 2 |
| 50 | Pack | ... | ... | ... | ... | Pack: [1 of 1] |
| 50 | Liqd | 865.376 | ... | 1.50098 | ... | H2S |
| 50 | Nozl | 23.815 | -0.7574 | 0.5 | -1.31185 | Nozzle LT2 2" |
| 50 | Nozl | 23.815 | -1.07112 | 0.5 | 1.07112 | Nozzle L2 2" |
| 50 | Nozl | 23.8198 | -1.51492 | 0.5 | ... | Nozzle S 2" |
| 50 | Nozl | 23.808 | -0.7574 | 4 | -1.31185 | Nozzle LT1 2" |
| 50 | Nozl | 23.815 | -1.07112 | 4 | 1.07112 | Nozzle L1 2" |
| 50 | Nozl | 23.8198 | -1.31196 | 3.5 | -0.75746 | Nozzle B4 2" |
| 50 | Nozl | 23.8198 | -1.07121 | 3 | 1.07121 | Nozzle B3 2" |
| 50 | Nozl | 23.815 | ... | 4 | -1.51479 | Nozzle LT3 |
| 50 | Nozl | 23.815 | ... | 0.5 | -1.51479 | Nozzle LT4 |
| 60 | Plat | 1419.86 | ... | 1 | 1.97372 | PLATFORM 3 |
| 60 | Pack | ... | ... | ... | ... | Pack: [1 of 1] |
| 60 | Nozl | 32.5969 | -1.42129 | 0.82874 | ... | Nozzle A 3" |
| 60 | Wght | 303 | ... | 3.62533 | ... | MIST ELIMINATOR |
| 60 | Wght | 28 | ... | 3.62533 | ... | MISC. |
| 60 | Clip | 28.7807 | 1.21875 | 1.88025 | ... | Type-1 |
| 90 | Nozl | 69.8721 | ... | 0.37433 | 0.83333 | Nozzle B1 6in. |
| 90 | Nozl | 29.0038 | -0.68263 | 0.51674 | -0.47798 | Nozzle V 2" |

**Total Weight of Each Detail Type:**

| | |
|---|---|
| Platforms | 4347.2 |
| Liquid | 1029.8 |
| Nozzles | 379.5 |
| Weights | 331.0 |
| Clips | 28.8 |
| Sum of the Detail Weights | 6116.3 lbf |

**Weight Summation Results: (lbf)**

| | Fabricated | Shop Test | Shipping | Erected | Empty | Operating |
|---|---|---|---|---|---|---|
| Main Elements | 5265.1 | 5265.1 | 5265.1 | 5265.1 | 5265.1 | 5265.1 |
| Nozzles | 379.5 | 379.5 | 379.5 | 379.5 | 379.5 | 379.5 |
| Wld Weights | 303.0 | 303.0 | 303.0 | 303.0 | 303.0 | 303.0 |
| Clips | 28.8 | 28.8 | 28.8 | 28.8 | 28.8 | 28.8 |
| Platforms | ... | ... | ... | 4347.2 | 4347.2 | 4347.2 |
| Empty Weights | ... | ... | ... | 28.0 | 28.0 | ... |
| Test Weights | ... | 28.0 | ... | ... | ... | ... |
| Ope Weights | ... | ... | ... | ... | ... | 28.0 |
| Ope. Liquid | ... | ... | ... | ... | ... | 1029.8 |
| Test Liquid | ... | 3027.4 | ... | ... | ... | ... |
| Totals | 5976.4 | 9031.8 | 5976.4 | 10351.6 | 10351.6 | 11381.3 |

**Field Installation Options:**
Platforms installed before lifting.

**Miscellaneous Weight Percent: 10.0 %**

*Note that the above value for the miscellaneous weight percent has been applied to the shells/heads/flange/tubesheets/tubes etc. in the weight calculations for metallic components.*

**Weight Summary:**

| | | |
|---|---|---|
| Fabricated Wt. | - Bare Weight without Removable Internals | 5976.4 lbf |
| Shop Test Wt. | - Fabricated Weight + Water ( Full ) | 9031.8 lbf |
| Shipping Wt. | - Fab. Weight + removable Intls.+ Shipping App. | 5976.4 lbf |
| Erected Wt. | - Fab. Wt + or - loose items (trays,platforms etc.) | 10351.6 lbf |
| Ope. Wt. no Liq | - Fab. Weight + Internals. + Details + Weights | 10351.6 lbf |
| Operating Wt. | - Empty Weight + Operating Liq. Uncorroded | 11381.3 lbf |
| Field Test Wt. | - Empty Weight + Water (Full) | 13180.6 lbf |

Weights used in Vortex Shedding Calculations:

| | |
|---|---|
| Mass of the Upper 1/3 of the Vertical Vessel (operating) | 4676.0 lbf |
| Mass of the Upper 1/3 of the Vertical Vessel (filled w/water) | 6232.4 lbf |
| Mass of the Upper 1/3 of the Vertical Vessel (empty) | 4221.0 lbf |

Note: The Field Test weight as computed in the corroded condition.

**Outside Surface Areas of Elements:**

| From | To | Surface Area in^2 |
|---|---|---|
| 10 | 20 | 9287.92 |
| 20 | 30 | 6148.6 |
| 30 | 40 | 3529.41 |
| 40 | 50 | 1163.73 |
| 50 | 60 | 5572.75 |
| 60 | 80 | 5193.81 |
| 80 | 90 | 679.654 |
| 90 | 100 | 1261.33 |

Total 32837.207 in^2 [228.0 Square Feet ]

**Element and Detail Weights:**

**18-D-272**
**R06**
**V-1264**
**PV Elite 24 Licensee: THE ANUP ENGINEERING LIMITED.**
**FileName : V-1264_R06 -----------------------------------**
**Element and Detail Weights: Step: 7 4:21pm Dec 21,2022**

| From | To | Total Ele. Empty Wgt. lbm | Total. Ele. Oper. Wgt. lbm | Total. Ele. Hydro. Wgt. lbm | Total Dtl. Offset Mom. ft-lbf | Oper. Wgt. No Liquid lbm |
|---|---|---|---|---|---|---|
| 10 | 20 | 1565.38 | 1565.38 | 1521.52 | ... | 1565.38 |
| 20 | 30 | 735.309 | 2503.98 | 2474.94 | 3805.54 | 2503.98 |
| 30 | 40 | 437.155 | 437.155 | 419.892 | ... | 437.155 |
| 40 | 50 | 188.782 | 353.168 | 343.392 | ... | 188.782 |
| 50 | 60 | 905.055 | 2929.14 | 3448.34 | 1917.38 | 2063.76 |
| 60 | 80 | 1036.12 | 2455.98 | 3746.4 | 11.2531 | 2455.98 |
| 80 | 90 | 194.747 | 194.747 | 284.309 | ... | 194.747 |
| 90 | 100 | 941.806 | 941.806 | 941.806 | 19.7988 | 941.806 |

**Cumulative Vessel Weight**

| From | To | Cumulative Ope Wgt. No Liquid lbm | Cumulative Oper. Wgt. lbm | Cumulative Hydro. Wgt. lbm |
|---|---|---|---|---|
| 10 | 20 | 10351.6 | 11381.3 | 13180.6 |
| 20 | 30 | 8786.21 | 9815.97 | 11659.1 |
| 30 | 40 | 6282.23 | 7311.99 | 9184.14 |
| 40 | 50 | 5845.08 | 6874.84 | 8764.25 |
| 50 | 60 | 5656.29 | 6521.67 | 8420.85 |
| 60 | 80 | 3592.53 | 3592.53 | 4972.52 |
| 80 | 90 | 1136.55 | 1136.55 | 1226.11 |
| 90 | 100 | 941.806 | 941.806 | 941.806 |

The cumulative operating weights no liquid in the column above are the cumulative operating weights minus the operating liquid weight minus any weights absent in the empty condition.

**Cumulative Vessel Moment**

| From | To | Cumulative Empty Mom. ft-lbf | Cumulative Oper. Mom. ft-lbf | Cumulative Hydro. Mom. ft-lbf |
|---|---|---|---|---|
| 10 | 20 | 5753.98 | 5753.98 | 5753.98 |
| 20 | 30 | 5753.98 | 5753.98 | 5753.98 |
| 30 | 40 | 1948.44 | 1948.44 | 1948.44 |
| 40 | 50 | 1948.44 | 1948.44 | 1948.44 |
| 50 | 60 | 1948.44 | 1948.44 | 1948.44 |
| 60 | 80 | 31.0519 | 31.0519 | 31.0519 |
| 80 | 90 | 19.7988 | 19.7988 | 19.7988 |
| 90 | 100 | 19.7988 | 19.7988 | 19.7988 |

**Nozzle Flange MAWP Results: (psig & °F)**

| Nozzle Description | Flange Rating Ope. | Ambient | Design Temp | Class | Grade/ Group | Equiv. Press | - - - - - - Max Pressure UG-44(b) | 50% | DNV |
|---|---|---|---|---|---|---|---|---|---|
| Nozzle B2 2" | 785.0 | 1200.0 | 500 | 600 | GR 2.3 | ... | ... | ... | ... |
| Nozzle LT2 2" | 395.0 | 600.0 | 500 | 300 | GR 2.3 | ... | ... | ... | ... |
| Nozzle L2 2" | 785.0 | 1200.0 | 500 | 600 | GR 2.3 | ... | ... | ... | ... |
| Nozzle S 2" | 785.0 | 1200.0 | 500 | 600 | GR 2.3 | ... | ... | ... | ... |
| Nozzle LT1 2" | 395.0 | 600.0 | 500 | 300 | GR 2.3 | ... | ... | ... | ... |
| Nozzle L1 2" | 785.0 | 1200.0 | 500 | 600 | GR 2.3 | ... | ... | ... | ... |
| Nozzle B4 2" | 785.0 | 1200.0 | 500 | 600 | GR 2.3 | ... | ... | ... | ... |
| Nozzle B3 2" | 785.0 | 1200.0 | 500 | 600 | GR 2.3 | ... | ... | ... | ... |
| Nozzle LT3 | 395.0 | 600.0 | 500 | 300 | GR 2.3 | ... | ... | ... | ... |
| Nozzle LT4 | 395.0 | 600.0 | 500 | 300 | GR 2.3 | ... | ... | ... | ... |
| Nozzle A 3" | 785.0 | 1200.0 | 500 | 600 | GR 2.3 | ... | ... | ... | ... |
| Nozzle B1 6in. | 395.0 | 600.0 | 500 | 300 | GR 2.3 | ... | ... | ... | ... |
| Nozzle V 2" | 395.0 | 600.0 | 500 | 300 | GR 2.3 | ... | ... | ... | ... |
| Min Rating | 395.0 | 600.0 psig [for Core Elements] | | | | | ... | ... | ... |

Pressure Ratings are per ASME B16.5 2017 Edition

***Warning:***
*There are nozzles in this model, but no flange MAWPs were de-rated. Be sure this is what you intended. There is a check box in the nozzle dialog that instructs PV Elite to perform the de-rating for each nozzle flange. See ASME VIII-1, UG-44(b) for more information.*

The Natural Frequencies for the vessel have been computed iteratively by solving a system of matrices. These matrices describe the mass and the stiffness of the vessel. This is the generalized eigenvalue/ eigenvector problem and is referenced in some mathematical texts.

The Natural Frequency for the Vessel (Empty.) is 4.64009 Hz.

The Natural Frequency for the Vessel (Ope...) is 4.43877 Hz.

**Wind Load Calculation Results:**

**Input Values:**

| | | | |
|---|---|---|---|
| Wind Design Code | | ASCE/SEI 7-16 | |
| Wind Load Reduction Scale Factor | | 0.600 | |
| Basic Wind Speed | [V] | 101 | mile/hr |
| Surface Roughness Category | | C: Open Terrain | |
| Importance Factor | | 1.0 | |
| Type of Surface | | Moderately Smooth | |
| Base Elevation | | 0 | ft |
| Percent Wind for Hydrotest | | 33.0 | |
| Using User defined Wind Press. Vs Elev. | | N | |
| Height of Hill or Escarpment | H or Hh | 0 | ft |
| Distance Upwind of Crest | Lh | 0 | ft |
| Distance from Crest to the Vessel | x | 0 | ft |
| Type of Terrain ( Hill, Escarpment ) | | Flat | |
| Damping Factor (Beta) for Wind (Ope) | | 0.0100 | |
| Damping Factor (Beta) for Wind (Empty) | | 0.0000 | |
| Damping Factor (Beta) for Wind (Filled) | | 0.0000 | |
| Site Elevation above Sea Level | | 0 | ft |

**Wind Analysis Results**

Static Gust-Effect Factor, Operating Case [G]:
= min(0.85, 0.925((1 + 1.7 * gQ * Izbar * Q )/( 1 + 1.7 * gV * Izbar)))
= min(0.85,0.925((1+1.7*3.4*0.225*0.947)/(1+1.7*3.4*0.225)))
= min(0.85, 0.897 )
= 0.850

Note: Vortex shedding loads have been applied at the analyst's request, even though the vessel was determined to be stable and not susceptible to vortex shedding.

**Vortex Shedding Loads, per NBC 1990 Supplement, pages 149-150**

Compute the critical wind speed using the weighted average diameter of the top one-third of the vessel [Vh(ope)]
= Fn(ope) * Davg / 0.2 * 0.6818
= 4.4388 * 2.533/0.2 * 0.6818
= 38.33 mile/hr

Compute the aspect ratio (gamma) for the entire structure [Gamma]
= $(\text{Total Height})^2$ / Sum of the Wind Area
= $27.0^2/9668 = 10.8578$

Determine the Velocity Pressure Qh(ope) (English Units only)
= $0.5 * 0.0668 * \text{Rho} * \text{Vh(ope)}^2$
= $0.5 * 0.0668 * 0.0749 * 38.3299^2 = 3.6786$ psf

Compute the equivalent force per unit area which will act on the top one-third of the vessel [F/area]:
= $(\text{qh(ope)}*\text{C1})/((\text{Gamma}*(\text{Beta(ope)}-(\text{C2}*\text{Rho}*\text{Davg}^2/\text{M3}))))^{0.5}$ [English Units]
= $(3.679*2.5)/((10.86*(0.01-(0.6*0.0749*2.533^2/519.6))))^{0.5}$
= 28.388630 psf

**18-D-272**
**R06**
**V-1264**
**PV Elite 24        Licensee: THE ANUP ENGINEERING LIMITED.**
**FileName : V-1264_R06    -------------------------------------**
**Wind Load Calculation:                Step:   10   4:21pm  Dec 21,2022**

## Platform Load Calculations

| ID | Wind Area in^2 | Elevation ft | Pressure psf | Force lbf | Cf |
|---|---|---|---|---|---|
| PLATFORM 1 | 2835.00 | 8.52 | 0.00 | 0.00 | 1.50 |
| PLATFORM 2 | 3213.00 | 17.91 | 27.00 | 602.51 | 1.50 |
| PLATFORM 3 | 4788.00 | 22.83 | 28.01 | 931.39 | 1.50 |

## Wind Loads on Masses/Equipment/Piping

| ID | Wind Area in^2 | Elevation ft | Pressure psf | Force lbf |
|---|---|---|---|---|
| MIST ELIMINAT | 0.00 | 25.46 | 28.39 | 0.00 |
| MISC. | 0.00 | 25.46 | 28.39 | 0.00 |

The following table contains results for Vortex Shedding Case (Ope).

**Wind Load Calculation:**

| From | To | Wind Height ft | Wind Diameter ft | Wind Area in^2 | Wind Pressure psf | Element Wind Load lbf |
|---|---|---|---|---|---|---|
| 10 | 20 | 4.10199 | 3.00174 | 3545.36 | ... | ... |
| 20 | 30 | 10.9176 | 3.00174 | 2347.03 | ... | ... |
| 30 | 40 | 15.1906 | 3.00174 | 1347.24 | ... | ... |
| 40 | 50 | 16.8307 | 2.98799 | 70.5644 | ... | ... |
| 50 | 60 | 19.3733 | 3.00374 | 2128.63 | 27.0032 | 805.137 |
| 60 | 80 | 24.1273 | 3.00374 | 1983.89 | 28.3886 | 1124.51 |
| 80 | 90 | 26.5797 | 2.925 | 134.082 | 28.3886 | 16.4265 |
| 90 | 100 | 26.885 | 3.494 | 115.55 | 28.3886 | 14.1561 |

End of Vortex Shedding Calculations

```
Natural Frequency of Vessel (Operating)              4.439 Hz
Natural Frequency of Vessel (Empty)                  4.640 Hz
Natural Frequency of Vessel (Test)                   4.064 Hz

User Entered Importance Factor is                    1.000
Force Coefficient                               [Cf] 0.621
Structure Height to Diameter ratio                   10.858
Height to top of Structure                           27.000 ft
```

*This is classified as a rigid structure. Static analysis performed.*

**Sample Calculation for the First Element:**

The ASCE code performs all calculations in Imperial Units
only.  The wind pressure is therefore computed in these units.

Value of [Alpha] and [Zg]:
Exposure Category: C from Table 26.11-1
Alpha = 9.5: Zg = 900.0 ft

Effective Height [z]:
= Centroid Height + Vessel Base Elevation
= 4.102 + 0.0 = 4.102 ft

Velocity Pressure coefficient evaluated at height z [Kz]:
Because z(4.102 ft.) < 15 ft.
= 2.01( 15 / Zg )$^{2/Alpha}$
= 2.01( 15/900.0 )$^{2/9.5}$
= 0.849

Type of Hill: No Hill

Wind Directionality Factor [Kd]:
= 1, per Table 26.6-1

As there is No Hill Present: [Kzt]:
K1 = 0, K2 = 0, K3 = 0

Topographical Factor [Kzt]:
= ( 1 + K1 * K2 * K3 )$^2$
= ( 1 + 0.0* 0.0* 0.0 )$^2$
= 1.0

Velocity Pressure evaluated at height z, Imperial Units [qz]:
= max( 16, 0.00256 * Kz * Kzt * Kd * Ke * V(mph)$^2$ )
= max( 16, 0.00256 * 0.849 * 1.0 * 1.0 * 1.0 * 101.0$^2$ )
= 22.2 psf

Force on the first element [F]:
= qz * G * Cf * WindArea
= 22.168 * 0.85 * 0.621 * 24.621
= 288.3 lbf

| Element | Hgt (z) ft | K1 | K2 | K3 | Kz | Kzt | qz psf |
|---|---|---|---|---|---|---|---|
| BTM SKIRT-2 | 4.1 | 0.000 | 0.000 | 0.000 | 0.849 | 1.000 | 22.168 |
| BTM SKIRT-1 | 10.9 | 0.000 | 0.000 | 0.000 | 0.849 | 1.000 | 22.168 |
| TOP SKIRT | 15.2 | 0.000 | 0.000 | 0.000 | 0.851 | 1.000 | 22.227 |
| BTM D-END | 16.8 | 0.000 | 0.000 | 0.000 | 0.870 | 1.000 | 22.712 |
| SHELL-1 | 19.4 | 0.000 | 0.000 | 0.000 | 0.896 | 1.000 | 23.395 |
| SHELL-2 | 24.1 | 0.000 | 0.000 | 0.000 | 0.938 | 1.000 | 24.501 |
| NOZZLE M FLANGE | 26.6 | 0.000 | 0.000 | 0.000 | 0.958 | 1.000 | 25.006 |
| NOZZLE M BLIND | 26.9 | 0.000 | 0.000 | 0.000 | 0.960 | 1.000 | 25.066 |

## Wind Vibration Calculations

This evaluation is based on work by Kanti Mahajan and Ed Zorilla

### Nomenclature

Cf - Correction factor for natural frequency
D - Average outer insulated diameter of vessel, ft
Df - Damping Factor < 0.75 Unstable, > 0.95 Stable
Dr - Average outer insulated of top half of vessel, ft
f - Natural frequency of vibration (Hertz)
f1 - Natural frequency of bare vessel based on a unit value of $(D/L^2)(10^4)$
L - Total height of structure ft
Lc - Total length of conical section(s) of vessel, ft
tb - Uncorroded plate thickness at bottom of vessel, in
V30 - Design Wind Speed provided by user, mile/hr
Vc - Critical wind velocity, mile/hr
Vw - Maximum wind speed at top of structure, mile/hr

```
 W   - Total corroded weight of structure, lbf
 Ws  - Cor. vessel weight excl. weight of parts which do not effect stiff. lbf
  Z  - Maximum amplitude of vibration at top of vessel, in
 Dl  - Logarithmic decrement ( taken as 0.03 for Welded Structures )
 Vp  - Vib. Chance, <= 0.200E+02(High); 0.200E+02 < 0.250E+02(Probable)
 P30 - wind pressure 30 feet above the base
```

Check other Conditions and Basic Assumptions:

```
 :: Total Cone Length / Total Length < 0.5
 :: 0.0/27.0 = 0.0

 :: [ D / L² ] * 10⁴ < 8 (English Units, ft.)
 :: [ 2.5/27.0² ] * 10⁴ = 34.319 [Geometry Violation]
```

Compute the vibration possibility. If Vp > 0.250E+02 no chance. [Vp]:

```
  = W / ( L * Dr²)
  = 11170/( 27.0 * 2.523² )
  = 0.64998E+02
```

Since Vp is > 0.250E+02 no further vibration analysis is required !

## Platform Load Calculations

| ID | Wind Area in^2 | Elevation ft | Pressure psf | Force lbf | Cf |
|---|---|---|---|---|---|
| PLATFORM 1 | 2835.00 | 8.52 | 22.17 | 436.44 | 1.50 |
| PLATFORM 2 | 3213.00 | 17.91 | 23.00 | 513.25 | 1.50 |
| PLATFORM 3 | 4788.00 | 22.83 | 24.20 | 804.66 | 1.50 |

## Wind Loads on Masses/Equipment/Piping

| ID | Wind Area in^2 | Elevation ft | Pressure psf | Force lbf |
|---|---|---|---|---|
| MIST ELIMINAT | 0.00 | 25.46 | 24.78 | 0.00 |
| MISC. | 0.00 | 25.46 | 24.78 | 0.00 |

The Natural Frequency for the Vessel (Ope...) is 4.43877 Hz.

**Wind Load Calculation:**

| From | To | Wind Height ft | Wind Diameter ft | Wind Area in^2 | Wind Pressure psf | Element Wind Load lbf |
|---|---|---|---|---|---|---|
| 10 | 20 | 4.10199 | 3.00174 | 3545.36 | 22.1682 | 172.979 |
| 20 | 30 | 10.9176 | 3.00174 | 2347.03 | 22.1682 | 318.917 |
| 30 | 40 | 15.1906 | 3.00174 | 1347.24 | 22.2273 | 65.907 |
| 40 | 50 | 16.8307 | 2.98799 | 70.5644 | 22.7122 | 3.52734 |
| 50 | 60 | 19.3733 | 3.00374 | 2128.63 | 23.395 | 394.336 |
| 60 | 80 | 24.1273 | 3.00374 | 1983.89 | 24.5012 | 563.896 |
| 80 | 90 | 26.5797 | 2.925 | 134.082 | 25.0057 | 7.37922 |
| 90 | 100 | 26.885 | 3.494 | 115.55 | 25.0658 | 6.3746 |

Note:
The Wind Loads calculated and printed in the Wind Load
calculation report have been factored by the input

scalar/load reduction factor of: 0.600.

*Be sure the wind speed is in accordance with the specified wind design code.*

## Earthquake Load Calculation Results:

## Earthquake Load Calculation:

### Input Values:

```
Seismic Design Code                                      ASCE/SEI 7-16
Seismic Load Reduction Scale Factor                              0.700
Importance Factor                                                1.250
Table Value Fa                                                   1.000
Table Value Fv                                                   1.721
Max. Mapped Res. Acceleration        [Ss]                        1.616
Max. Eff. Ground Acceleration         [S]                        0.869
Force Modification Factor R                                      3.000
Site Class                                                           D
Component Elevation Ratio             z/h                        0.000
Amplification Factor                   Ap                        0.000
Force Factor                                                     0.000
Consider Vertical Acceleration                                     Yes
Minimum Acceleration Multiplier                                  0.333
User Value of Sds (used if > 0 )                                 1.077
User Value of Sd1 (used if > 0 )                                 0.996
Moment Reduction Factor Tau                                      1.000
```

## Seismic Analysis Results:

```
Sms = Fa * Ss = 1.0 * 1.616 = 1.616
Sm1 = Fv * S1 = 1.721 * 0.869 = 1.496
Sds = 2/3 * Sms = 2/3 * 1.616 = 1.077

Sds = Max( 0.8*Sds, SdsUser )
    = Max( 0.862, 1.077 )
    = 1.077

Sd1 = 2/3 * Sm1 = 2/3 * 1.496 = 0.997

Sd1 = Max( 0.8*Sd1, Sd1User )
    = Max( 0.798, 0.996 )
    = 0.996
```

Check Approximate Fundamental Period from 12.8-7 [Ta]:
= Ct * $hn^x$ where Ct = 0.020, x = 0.75 and hn = Structural Height (ft.)
= 0.020 *( $27.0^{0.75}$)
= 0.237 seconds

The Coefficient Cu from Table 12.8-1 is : 1.400

Fundamental Period (1/Frequency) [T]:
= ( 1/Natural Frequency ) = ( 1/4.439 )
= 0.225

Check the Value of T which is the smaller of Cu*Ta and T:
= Minimum Value of(1.4 * 0.237, 0.225 ) per 12.8.2
= 0.225

Compute the Seismic Response Coefficient per equation 12.8-2 [Cs]:
= Sds / ( R / I )
= 1.077/( 3.0/1.25 )
= 0.449

Check the Maximum value of Cs per equation 12.8-3 [Cs]:
```
  = Sd1 / ( T * ( R / Ie ) )
  = 0.996/( 0.225 *( 3.0/1.25 ) )
  = 1.842
```

Check the Minimum value of Cs per equation 15.4-1 [Cs]:
```
  = max( ( 0.044 * SDS * Ie ), 0.030 )
  = max(( 0.044 * 1.077 * 1.25 ), 0.030 )
  = 0.059
```

Because S1 >= 0.6, check Minimum value of Cs per 15.4-2:
```
  = 0.8 * S1 / ( R / Ie )
  = 0.8 * 0.87/( 3.0/1.25 )
  = 0.290
```

Total Base Shear [V]:
```
  = Cs * W (Equation 12.8-1):
  =  0.4487 * 11381.3
  = 5107.379 lbf
```

Vertical load per 12.4-4, [Ev]:
```
  = 0.2 * Sds * W
  = 0.2 * 1.077 * 11381
  = 2451.5 lbf

 Minimum Vertical load YEq = Gy * Total Weight, [YEq]:
  = 0.333 * 11381 = 3789.99 lbf

 Final Base Shear,       V = 3575.17 lbf
 Final Vertical Load, Ev = 2652.99 lbf
```

Distribute the Base shear force to each element according to the equations
Fx = Cvx * V (eqn. 12.8-11 ) and the vertical distribution factor
Cvx = Wx*hx$^k$/( Sum of Wi*hi$^k$ ) and k is an exponent which is related
to the period of Vibration.

In this case, the value of k was 1.0

The Natural Frequency for the Vessel (Ope...) is 4.43877 Hz.

**Earthquake Load Calculation:**

| From | To | Earthquake Height ft | Earthquake Weight lbf | Element Ope Load lbf | Element Emp Load lbf | Element Vertical Load lbf |
|---|---|---|---|---|---|---|
| 10 | 20 | 4.10105 | 1565.38 | 119.018 | 124.45 | 2652.99 |
| 20 | 30 | 10.917 | 2503.98 | 506.795 | 155.616 | 2288.1 |
| 30 | 40 | 15.1903 | 437.155 | 123.112 | 128.731 | 1704.43 |
| 40 | 50 | 16.8307 | 353.168 | 110.2 | 61.5949 | 1602.52 |
| 50 | 60 | 19.3733 | 2929.14 | 1052.07 | 339.907 | 1520.2 |
| 60 | 80 | 24.1273 | 2455.98 | 1098.58 | 484.618 | 837.419 |
| 80 | 90 | 26.5797 | 194.747 | 95.9667 | 100.347 | 264.93 |
| 90 | 100 | 26.885 | 941.806 | 469.429 | 490.854 | 219.535 |

Note:
The Earthquake Loads calculated and printed in the Earthquake
Load calculation report have been factored by the input
scalar/load reduction factor of: 0.700.

**The following table is for the Operating Case + Vortex Shedding.**

**Wind/Earthquake Shear, Bending:**

| From | To | Distance to Support ft | Cumulative Wind Shear lbf | Earthquake Shear lbf | Wind Bending ft-lbf | Earthquake Bending ft-lbf |
|---|---|---|---|---|---|---|
| 10 | 20 | 4.10105 | 1533.32 | 3575.17 | 43546.8 | 71804.7 |
| 20 | 30 | 10.917 | 1360.34 | 3456.15 | 27468.7 | 42968.9 |
| 30 | 40 | 15.1903 | 1041.42 | 2949.35 | 16825.1 | 25578.7 |
| 40 | 50 | 16.8307 | 975.514 | 2826.24 | 10715.5 | 16578 |
| 50 | 60 | 19.3733 | 971.986 | 2716.04 | 10394 | 16123.5 |
| 60 | 80 | 24.1273 | 577.65 | 1663.97 | 2728.31 | 5345.92 |
| 80 | 90 | 26.5797 | 13.7538 | 565.396 | 9.18884 | 233.283 |
| 90 | 100 | 26.885 | 6.3746 | 469.429 | 1.62555 | 53.9045 |

**The following table is for the Operating Case.**

**Wind/Earthquake Shear, Bending:**

| From | To | Distance to Support ft | Cumulative Wind Shear lbf | Earthquake Shear lbf | Wind Bending ft-lbf | Earthquake Bending ft-lbf |
|---|---|---|---|---|---|---|
| 10 | 20 | 4.10105 | 1533.32 | 3575.17 | 26863.9 | 71804.7 |
| 20 | 30 | 10.917 | 1360.34 | 3456.15 | 14996.9 | 42968.9 |
| 30 | 40 | 15.1903 | 1041.42 | 2949.35 | 8476.37 | 25578.7 |
| 40 | 50 | 16.8307 | 975.514 | 2826.24 | 5333.18 | 16578 |
| 50 | 60 | 19.3733 | 971.986 | 2716.04 | 5173.49 | 16123.5 |
| 60 | 80 | 24.1273 | 577.65 | 1663.97 | 1360.41 | 5345.92 |
| 80 | 90 | 26.5797 | 13.7538 | 565.396 | 4.13497 | 233.283 |
| 90 | 100 | 26.885 | 6.3746 | 469.429 | 0.732 | 53.9045 |

Note:
The Wind Shears/Moments and the Earthquake Shears/Moments calculated and printed in the Wind/Earthquake Shear and Bending report have been factored by the input Scalar/Load reductions factors of;
Wind: 0.600; Earthquake: 0.700.

## Wind and Earthquake Deflection Calculations:

The following table is for Earthquake Deflection; Operating Case.

### Earthquake Load Deflection:

| From | To | Cumulative Shear lbf | Centroid Deflection in | Elem. End Deflection in | Elem. Ang. Rotation |
|---|---|---|---|---|---|
| 10 | 20 | 3575.17 | 0.0086 | 0.03192 | 0.00059842 |
| 20 | 30 | 3456.15 | 0.053662 | 0.079232 | 0.00083377 |
| 30 | 40 | 2949.35 | 0.095289 | 0.11216 | 0.00092069 |
| 40 | 50 | 2826.24 | 0.11306 | 0.11397 | 0.00092545 |
| 50 | 60 | 2716.04 | 0.142 | 0.17105 | 0.00099531 |
| 60 | 80 | 1663.97 | 0.19862 | 0.22639 | 0.0010103 |
| 80 | 90 | 565.396 | 0.22832 | 0.23025 | 0.0010103 |
| 90 | 100 | 469.429 | 0.23164 | 0.23303 | 0.0010103 |

Allowable deflection at the Tower Top (Ope)(6.000"/100ft. Criteria)
Allowable deflection : 1.620 Actual deflection : 0.233 in

The following table is for Wind Deflection; Operating Case + Vortex Shedding.

### Wind Load Deflection:

| From | To | Cumulative Shear lbf | Centroid Deflection in | Elem. End Deflection in | Elem. Ang. Rotation |
|---|---|---|---|---|---|
| 10 | 20 | 1960.23 | 0.0056278 | 0.021035 | 0.00039744 |
| 20 | 30 | 1960.23 | 0.035534 | 0.052706 | 0.00056154 |
| 30 | 40 | 1960.23 | 0.063538 | 0.074948 | 0.00062328 |
| 40 | 50 | 1960.23 | 0.075562 | 0.076178 | 0.00062661 |
| 50 | 60 | 1960.23 | 0.095162 | 0.11481 | 0.00067247 |
| 60 | 80 | 1155.09 | 0.13341 | 0.15209 | 0.00067891 |
| 80 | 90 | 30.5827 | 0.15339 | 0.15468 | 0.00067891 |
| 90 | 100 | 14.1561 | 0.15562 | 0.15655 | 0.00067891 |

Allowable deflection at the Tower Top (Emp)(6.000"/100ft. Criteria)
Allowable deflection : 1.620 Actual deflection : 0.157 in

The following table is for Wind Deflection; Operating Case.

### Wind Load Deflection:

| From | To | Cumulative Shear lbf | Centroid Deflection in | Elem. End Deflection in | Elem. Ang. Rotation |
|---|---|---|---|---|---|
| 10 | 20 | 1533.32 | 0.0034148 | 0.012554 | 0.00023295 |
| 20 | 30 | 1360.34 | 0.020976 | 0.030793 | 0.00031885 |
| 30 | 40 | 1041.42 | 0.036922 | 0.04334 | 0.00034973 |
| 40 | 50 | 975.514 | 0.043684 | 0.04403 | 0.00035139 |
| 50 | 60 | 971.986 | 0.054645 | 0.065594 | 0.00037424 |
| 60 | 80 | 577.65 | 0.075939 | 0.086323 | 0.00037744 |
| 80 | 90 | 13.7538 | 0.087043 | 0.087764 | 0.00037744 |
| 90 | 100 | 6.3746 | 0.088284 | 0.088805 | 0.00037744 |

---

**Critical Wind Velocity for Tower Vibration:**

| From | To | 1st Crit. Wind Speed mile/hr | 2nd Crit. Wind Speed mile/hr |
|---|---|---|---|
| 10 | 20 | 45.3017 | 283.136 |
| 20 | 30 | 45.3017 | 283.136 |
| 30 | 40 | 45.3017 | 283.136 |
| 40 | 50 | 45.0943 | 281.839 |
| 50 | 60 | 45.3319 | 283.325 |
| 60 | 80 | 45.3319 | 283.325 |
| 80 | 90 | 44.1436 | 275.897 |
| 90 | 100 | 52.7308 | 329.568 |

Allowable deflection at the Tower Top (Ope)(6.000"/100ft. Criteria)
Allowable deflection : 1.620    Actual deflection : 0.089 in

**Longitudinal Stress Constants:**

| From | To | Metal Area New in^2 | Metal Area Corroded in^2 | Section Modulus New in³ | Section Modulus Corroded in³ |
|---|---|---|---|---|---|
| 10 | 20 | 36.6152 | 33.7218 | 267.477 | 246.859 |
| 20 | 30 | 36.6152 | 33.7218 | 267.477 | 246.859 |
| 30 | 40 | 36.6152 | 33.7218 | 267.477 | 246.859 |
| 40 | 50 | 29.2539 | 26.3565 | 213.967 | 193.183 |
| 50 | 60 | 36.6647 | 33.7674 | 268.205 | 247.53 |
| 60 | 80 | 36.6647 | 33.7674 | 268.205 | 247.53 |
| 80 | 90 | 36.6647 | 33.7674 | 268.205 | 247.53 |
| 90 | 100 | 36.6647 | 33.7674 | 268.205 | 247.53 |

**Longitudinal Allowable Stresses:**

| From | To | Tensile psi | Hydrotest Tensile psi | Compressive psi | Hydrotest Compressive psi |
|---|---|---|---|---|---|
| 10 | 20 | 14400 | 24624 | -14808.1 | -19495 |
| 20 | 30 | 14400 | 24624 | -14808.1 | -19495 |
| 30 | 40 | 10656 | 16200 | -8705.73 | -14001.6 |
| 40 | 50 | 17760 | 27000 | -8382.42 | -13430.6 |
| 50 | 60 | 17760 | 27000 | -8703.96 | -13998.5 |
| 60 | 80 | 17760 | 27000 | -8703.96 | -13998.5 |
| 80 | 90 | 13080 | 27000 | -8703.96 | -13998.5 |
| 90 | 100 | 13080 | 27000 | -8703.96 | -13998.5 |

## Longitudinal Stress Report

Longitudinal Operating and Empty Stresses are computed in the corroded condition. Stresses due to loads in the hydrostatic test cases have also been computed in the corroded condition.

### Longitudinal Pressure Stresses due to:

| From | To | Longitudinal Stress Internal Pressure psi | Longitudinal Stress External Pressure psi | Longitudinal Stress Hydrotest Pressure psi |
|---|---|---|---|---|
| 10 | 20 | ... | ... | ... |
| 20 | 30 | ... | ... | ... |
| 30 | 40 | ... | ... | ... |
| 40 | 50 | 2693.5 | -399.073 | 8026.99 |
| 50 | 60 | 2103.39 | -314.781 | 6268.38 |
| 60 | 80 | 2103.4 | -314.781 | 6268.39 |
| 80 | 90 | ... | ... | ... |
| 90 | 100 | ... | ... | ... |

### Longitudinal Stresses due to Weight Loads for these Conditions:

| From | To | Wght. Str. Empty psi | Wght. Str. Operating psi | Wght. Str. Hydrotest psi | Wght. Str. Emp. Mom. psi | Wght. Str. Opr. Mom. psi |
|---|---|---|---|---|---|---|
| 10 | 20 | -306.97 | -337.507 | ... | 279.706 | 279.706 |
| 20 | 30 | -260.549 | -291.086 | ... | 279.706 | 279.706 |
| 30 | 40 | -186.296 | -216.833 | ... | 94.715 | 94.715 |
| 40 | 50 | -221.77 | -221.77 | ... | 121.032 | 121.032 |
| 50 | 60 | -167.508 | -167.508 | ... | 94.4583 | 94.4583 |
| 60 | 80 | -106.391 | -106.391 | ... | 1.50537 | 1.50537 |
| 80 | 90 | -33.6583 | -33.6583 | ... | 0.95983 | 0.95983 |
| 90 | 100 | -27.891 | -27.891 | ... | 0.95983 | 0.95983 |

### Longitudinal Stresses due to Weight Loads and Bending for these Conditions:

| From | To | Wght. Str. Hyd. Mom. psi | Bend. Str. Oper. Wind psi | Bend. Str. Oper. Equ. psi | Bend. Str. Hyd. Wind psi | Bend. Str. Hyd. Equ. psi |
|---|---|---|---|---|---|---|
| 10 | 20 | ... | 1305.88 | 3490.48 | ... | ... |
| 20 | 30 | ... | 729.011 | 2088.75 | ... | ... |
| 30 | 40 | ... | 412.043 | 1243.4 | ... | ... |
| 40 | 50 | ... | 331.283 | 1029.78 | ... | ... |
| 50 | 60 | ... | 250.806 | 781.653 | ... | ... |
| 60 | 80 | ... | 65.9512 | 259.165 | ... | ... |
| 80 | 90 | ... | 0.20046 | 11.3094 | ... | ... |
| 90 | 100 | ... | 0.035486 | 2.61324 | ... | ... |

### Longitudinal Stresses due to these Conditions:

| | | Vortex Shedding | Vortex Shedding | Vortex Shedding | Earthquake |
|---|---|---|---|---|---|

**18-D-272**
**R06**
**V-1264**
**PV Elite 24 Licensee: THE ANUP ENGINEERING LIMITED.**
**FileName : V-1264_R06 -----------------------------------**
**Longitudinal Stresses due to: Step: 16 4:21pm Dec 21,2022**

| From | To | Operating Case psi | Empty Case psi | Test Case psi | Empty Case psi |
|---|---|---|---|---|---|
| 10 | 20 | 2116.84 | ... | ... | 1912.48 |
| 20 | 30 | 1335.28 | ... | ... | 1185.28 |
| 30 | 40 | 817.881 | ... | ... | 740.83 |
| 40 | 50 | 665.616 | ... | ... | 648.189 |
| 50 | 60 | 503.89 | ... | ... | 494.374 |
| 60 | 80 | 132.266 | ... | ... | 197.16 |
| 80 | 90 | 0.44547 | ... | ... | 11.8255 |
| 90 | 100 | 0.078805 | ... | ... | 2.73251 |

**Longitudinal Stresses due to Applied Axial Forces:**

| From | To | Longitudinal Stress Y Forces Wind psi | Longitudinal Stress Y Forces Seismic psi |
|---|---|---|---|
| 10 | 20 | ... | 78.6728 |
| 20 | 30 | ... | 67.8522 |
| 30 | 40 | ... | 50.5437 |
| 40 | 50 | ... | 60.8018 |
| 50 | 60 | ... | 45.0198 |
| 60 | 80 | ... | 24.7997 |
| 80 | 90 | ... | 7.84575 |
| 90 | 100 | ... | 6.50139 |

**Longitudinal Stresses due to User Forces and Moments:**

| From | To | Wind For/Mom Corroded psi | Earthquake For/Mom Corroded psi | Wind For/Mom No Corrosion psi | Earthquake For/Mom No Corrosion psi |
|---|---|---|---|---|---|
| 10 | 20 | ... | ... | ... | ... |
| 20 | 30 | ... | ... | ... | ... |
| 30 | 40 | ... | ... | ... | ... |
| 40 | 50 | ... | ... | ... | ... |
| 50 | 60 | ... | ... | ... | ... |
| 60 | 80 | ... | ... | ... | ... |
| 80 | 90 | ... | ... | ... | ... |
| 90 | 100 | ... | ... | ... | ... |

**Bending Stresses due to Blast Load:**

| From | To | Bending Stress psi |
|---|---|---|
| 10 | 20 | ... |
| 20 | 30 | ... |
| 30 | 40 | ... |
| 40 | 50 | ... |
| 50 | 60 | ... |
| 60 | 80 | ... |
| 80 | 90 | ... |
| 90 | 100 | ... |

**Stress Combination Load Cases for Vertical Vessels:**

**Load Case Definition Key**

IP = Longitudinal Stress due to Internal Pressure
EP = Longitudinal Stress due to External Pressure
HP = Longitudinal Stress due to Hydrotest Pressure
NP = No Pressure
EW = Longitudinal Stress due to Weight (No Liquid)
OW = Longitudinal Stress due to Weight (Operating)
HW = Longitudinal Stress due to Weight (Hydrotest)
WI = Bending Stress due to Wind Moment (Operating)
EQ = Bending Stress due to Earthquake Moment (Operating)
EE = Bending Stress due to Earthquake Moment (Empty)
HI = Bending Stress due to Wind Moment (Hydrotest)
HE = Bending Stress due to Earthquake Moment (Hydrotest)
WE = Bending Stress due to Wind Moment (Empty) (no CA)
WF = Bending Stress due to Wind Moment (Filled) (no CA)
CW = Longitudinal Stress due to Weight (Empty) (no CA)
VO = Bending Stress due to Vortex Shedding Loads ( Ope )
VE = Bending Stress due to Vortex Shedding Loads ( Emp )
VF = Bending Stress due to Vortex Shedding Loads ( Test No CA. )
FW = Axial Stress due to Vertical Forces for the Wind Case
FS = Axial Stress due to Vertical Forces for the Seismic Case
BW = Bending Stress due to Lat. Forces for the Wind Case, Corroded
BS = Bending Stress due to Lat. Forces for the Seismic Case, Corroded
BN = Bending Stress due to Lat. Forces for the Wind Case, UnCorroded
BU = Bending Stress due to Lat. Forces for the Seismic Case, UnCorroded
BL = Bending Stress due to Blast Loads, Corroded

**General Notes:**

Case types HI and HE are in the Corroded condition.

Case types WE, WF, and CW are in the Un-Corroded condition.

A blank stress and stress ratio indicates that the corresponding stress comprising those components that did not contribute to that type of stress.

An asterisk (*) in the final column denotes overstress.

Analysis of Load Case 1 : NP+EW+WI+FW+BW

| From Node | Tensile Stress | All. Tens. Stress | Comp. Stress | All. Comp. Stress | Tens. Ratio | Comp. Ratio |
|---|---|---|---|---|---|---|
| 10 | 1278.61 | 14400.00 | -1892.55 | 14808.10 | 0.0888 | 0.1278 |
| 20 | 748.17 | 14400.00 | -1269.27 | 14808.10 | 0.0520 | 0.0857 |
| 30 | 320.46 | 10656.00 | -693.05 | 8705.73 | 0.0301 | 0.0796 |
| 40 | 230.55 | 17760.00 | -674.08 | 8382.42 | 0.0130 | 0.0804 |
| 50 | 177.76 | 17760.00 | -512.77 | 8703.96 | 0.0100 | 0.0589 |
| 60 | | 17760.00 | -173.85 | 8703.96 | | 0.0200 |

Analysis of Load Case 2 : NP+EW+EE+FS+BS

| From Node | Tensile Stress | All. Tens. Stress | Comp. Stress | All. Comp. Stress | Tens. Ratio | Comp. Ratio |
|---|---|---|---|---|---|---|
| 10 | 1963.89 | 14400.00 | -2420.49 | 14808.10 | 0.1364 | 0.1635 |
| 20 | 1272.29 | 14400.00 | -1657.68 | 14808.10 | 0.0884 | 0.1119 |
| 30 | 699.79 | 10656.00 | -971.30 | 8705.73 | 0.0657 | 0.1116 |
| 40 | 608.25 | 17760.00 | -930.19 | 8382.42 | 0.0342 | 0.1110 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 50 | 466.34 | 17760.00 | -711.32 | 8703.96 | 0.0263 | 0.0817 |
| 60 | 117.07 | 17760.00 | -280.26 | 8703.96 | 0.0066 | 0.0322 |

Analysis of Load Case 3 : NP+OW+WI+FW+BW

| From Node | Tensile Stress | All. Tens. Stress | Comp. Stress | All. Comp. Stress | Tens. Ratio | Comp. Ratio |
|---|---|---|---|---|---|---|
| 10 | 1248.07 | 14400.00 | -1923.09 | 14808.10 | 0.0867 | 0.1299 |
| 20 | 717.63 | 14400.00 | -1299.80 | 14808.10 | 0.0498 | 0.0878 |
| 30 | 289.93 | 10656.00 | -723.59 | 8705.73 | 0.0272 | 0.0831 |
| 40 | 230.55 | 17760.00 | -674.08 | 8382.42 | 0.0130 | 0.0804 |
| 50 | 177.76 | 17760.00 | -512.77 | 8703.96 | 0.0100 | 0.0589 |
| 60 | | 17760.00 | -173.85 | 8703.96 | | 0.0200 |

Analysis of Load Case 4 : NP+OW+EQ+FS+BS

| From Node | Tensile Stress | All. Tens. Stress | Comp. Stress | All. Comp. Stress | Tens. Ratio | Comp. Ratio |
|---|---|---|---|---|---|---|
| 10 | 3511.35 | 14400.00 | -4029.02 | 14808.10 | 0.2438 | 0.2721 |
| 20 | 2145.22 | 14400.00 | -2591.69 | 14808.10 | 0.1490 | 0.1750 |
| 30 | 1171.82 | 10656.00 | -1504.40 | 8705.73 | 0.1100 | 0.1728 |
| 40 | 989.84 | 17760.00 | -1311.78 | 8382.42 | 0.0557 | 0.1565 |
| 50 | 753.62 | 17760.00 | -998.60 | 8703.96 | 0.0424 | 0.1147 |
| 60 | 179.08 | 17760.00 | -342.26 | 8703.96 | 0.0101 | 0.0393 |

Analysis of Load Case 5 : NP+HW+HI

| From Node | Tensile Stress | All. Tens. Stress | Comp. Stress | All. Comp. Stress | Tens. Ratio | Comp. Ratio |
|---|---|---|---|---|---|---|
| 10 | 0.00 | 24624.00 | 0.00 | 19495.02 | 0.0000 | 0.0000 |
| 20 | 0.00 | 24624.00 | 0.00 | 19495.02 | 0.0000 | 0.0000 |
| 30 | 0.00 | 16200.00 | 0.00 | 14001.60 | 0.0000 | 0.0000 |
| 40 | 0.00 | 27000.00 | 0.00 | 13430.58 | 0.0000 | 0.0000 |
| 50 | 0.00 | 27000.00 | 0.00 | 13998.49 | 0.0000 | 0.0000 |
| 60 | 0.00 | 27000.00 | 0.00 | 13998.48 | 0.0000 | 0.0000 |

Analysis of Load Case 6 : NP+HW+HE

| From Node | Tensile Stress | All. Tens. Stress | Comp. Stress | All. Comp. Stress | Tens. Ratio | Comp. Ratio |
|---|---|---|---|---|---|---|
| 10 | 0.00 | 24624.00 | 0.00 | 19495.02 | 0.0000 | 0.0000 |
| 20 | 0.00 | 24624.00 | 0.00 | 19495.02 | 0.0000 | 0.0000 |
| 30 | 0.00 | 16200.00 | 0.00 | 14001.60 | 0.0000 | 0.0000 |
| 40 | 0.00 | 27000.00 | 0.00 | 13430.58 | 0.0000 | 0.0000 |
| 50 | 0.00 | 27000.00 | 0.00 | 13998.49 | 0.0000 | 0.0000 |
| 60 | 0.00 | 27000.00 | 0.00 | 13998.48 | 0.0000 | 0.0000 |

Analysis of Load Case 7 : IP+OW+WI+FW+BW

| From Node | Tensile Stress | All. Tens. Stress | Comp. Stress | All. Comp. Stress | Tens. Ratio | Comp. Ratio |
|---|---|---|---|---|---|---|
| 10 | 1248.07 | 14400.00 | -1923.09 | 14808.10 | 0.0867 | 0.1299 |
| 20 | 717.63 | 14400.00 | -1299.80 | 14808.10 | 0.0498 | 0.0878 |
| 30 | 289.93 | 10656.00 | -723.59 | 8705.73 | 0.0272 | 0.0831 |
| 40 | 2924.05 | 17760.00 | | 8382.42 | 0.1646 | |
| 50 | 2281.15 | 17760.00 | | 8703.96 | 0.1284 | |
| 60 | 2064.46 | 17760.00 | | 8703.96 | 0.1162 | |

Analysis of Load Case 8 : IP+OW+EQ+FS+BS

| From Node | Tensile Stress | All. Tens. Stress | Comp. Stress | All. Comp. Stress | Tens. Ratio | Comp. Ratio |
|---|---|---|---|---|---|---|

| | | | | | | |
|---|---|---|---|---|---|---|
| 10 | 3511.35 | 14400.00 | -4029.02 | 14808.10 | 0.2438 | 0.2721 |
| 20 | 2145.22 | 14400.00 | -2591.69 | 14808.10 | 0.1490 | 0.1750 |
| 30 | 1171.82 | 10656.00 | -1504.40 | 8705.73 | 0.1100 | 0.1728 |
| 40 | 3683.35 | 17760.00 | | 8382.42 | 0.2074 | |
| 50 | 2857.02 | 17760.00 | | 8703.96 | 0.1609 | |
| 60 | 2282.47 | 17760.00 | | 8703.96 | 0.1285 | |

Analysis of Load Case 9 : EP+OW+WI+FW+BW

| From Node | Tensile Stress | All. Tens. Stress | Comp. Stress | All. Comp. Stress | Tens. Ratio | Comp. Ratio |
|---|---|---|---|---|---|---|
| 10 | 1248.07 | 14400.00 | -1923.09 | 14808.10 | 0.0867 | 0.1299 |
| 20 | 717.63 | 14400.00 | -1299.80 | 14808.10 | 0.0498 | 0.0878 |
| 30 | 289.93 | 10656.00 | -723.59 | 8705.73 | 0.0272 | 0.0831 |
| 40 | | 17760.00 | -1073.16 | 8382.42 | | 0.1280 |
| 50 | | 17760.00 | -827.55 | 8703.96 | | 0.0951 |
| 60 | | 17760.00 | -488.63 | 8703.96 | | 0.0561 |

Analysis of Load Case 10 : EP+OW+EQ+FS+BS

| From Node | Tensile Stress | All. Tens. Stress | Comp. Stress | All. Comp. Stress | Tens. Ratio | Comp. Ratio |
|---|---|---|---|---|---|---|
| 10 | 3511.35 | 14400.00 | -4029.02 | 14808.10 | 0.2438 | 0.2721 |
| 20 | 2145.22 | 14400.00 | -2591.69 | 14808.10 | 0.1490 | 0.1750 |
| 30 | 1171.82 | 10656.00 | -1504.40 | 8705.73 | 0.1100 | 0.1728 |
| 40 | 590.77 | 17760.00 | -1710.85 | 8382.42 | 0.0333 | 0.2041 |
| 50 | 438.84 | 17760.00 | -1313.38 | 8703.96 | 0.0247 | 0.1509 |
| 60 | | 17760.00 | -657.04 | 8703.96 | | 0.0755 |

Analysis of Load Case 11 : HP+HW+HI

| From Node | Tensile Stress | All. Tens. Stress | Comp. Stress | All. Comp. Stress | Tens. Ratio | Comp. Ratio |
|---|---|---|---|---|---|---|
| 10 | 0.00 | 24624.00 | 0.00 | 19495.02 | 0.0000 | 0.0000 |
| 20 | 0.00 | 24624.00 | 0.00 | 19495.02 | 0.0000 | 0.0000 |
| 30 | 0.00 | 16200.00 | 0.00 | 14001.60 | 0.0000 | 0.0000 |
| 40 | 8026.99 | 27000.00 | | 13430.58 | 0.2973 | |
| 50 | 6268.38 | 27000.00 | | 13998.49 | 0.2322 | |
| 60 | 6268.39 | 27000.00 | | 13998.48 | 0.2322 | |

Analysis of Load Case 12 : HP+HW+HE

| From Node | Tensile Stress | All. Tens. Stress | Comp. Stress | All. Comp. Stress | Tens. Ratio | Comp. Ratio |
|---|---|---|---|---|---|---|
| 10 | 0.00 | 24624.00 | 0.00 | 19495.02 | 0.0000 | 0.0000 |
| 20 | 0.00 | 24624.00 | 0.00 | 19495.02 | 0.0000 | 0.0000 |
| 30 | 0.00 | 16200.00 | 0.00 | 14001.60 | 0.0000 | 0.0000 |
| 40 | 8026.99 | 27000.00 | | 13430.58 | 0.2973 | |
| 50 | 6268.38 | 27000.00 | | 13998.49 | 0.2322 | |
| 60 | 6268.39 | 27000.00 | | 13998.48 | 0.2322 | |

Analysis of Load Case 13 : IP+WE+EW

| From Node | Tensile Stress | All. Tens. Stress | Comp. Stress | All. Comp. Stress | Tens. Ratio | Comp. Ratio |
|---|---|---|---|---|---|---|
| 10 | | 14400.00 | -586.68 | 14808.10 | | 0.0396 |
| 20 | 19.16 | 14400.00 | -540.26 | 14808.10 | 0.0013 | 0.0365 |
| 30 | | 10656.00 | -281.01 | 8705.73 | | 0.0323 |
| 40 | 2592.77 | 17760.00 | | 8382.42 | 0.1460 | |
| 50 | 2030.34 | 17760.00 | | 8703.96 | 0.1143 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 60 | 1998.51 | 17760.00 | | 8703.96 | 0.1125 | |

Analysis of Load Case 14 : IP+WF+CW

| From Node | Tensile Stress | All. Tens. Stress | Comp. Stress | All. Comp. Stress | Tens. Ratio | Comp. Ratio |
|---|---|---|---|---|---|---|
| 10 | | 14400.00 | -310.84 | 14808.10 | | 0.0210 |
| 20 | | 14400.00 | -268.08 | 14808.10 | | 0.0181 |
| 30 | | 10656.00 | -199.70 | 8705.73 | | 0.0229 |
| 40 | 2493.70 | 17760.00 | | 8382.42 | 0.1404 | |
| 50 | 1949.12 | 17760.00 | | 8703.96 | 0.1097 | |
| 60 | 2005.41 | 17760.00 | | 8703.96 | 0.1129 | |

Analysis of Load Case 15 : IP+VO+OW

| From Node | Tensile Stress | All. Tens. Stress | Comp. Stress | All. Comp. Stress | Tens. Ratio | Comp. Ratio |
|---|---|---|---|---|---|---|
| 10 | 2059.04 | 14400.00 | -2734.05 | 14808.10 | 0.1430 | 0.1846 |
| 20 | 1323.90 | 14400.00 | -1906.07 | 14808.10 | 0.0919 | 0.1287 |
| 30 | 695.76 | 10656.00 | -1129.43 | 8705.73 | 0.0653 | 0.1297 |
| 40 | 3258.38 | 17760.00 | | 8382.42 | 0.1835 | |
| 50 | 2534.24 | 17760.00 | | 8703.96 | 0.1427 | |
| 60 | 2130.78 | 17760.00 | | 8703.96 | 0.1200 | |

Analysis of Load Case 16 : IP+VE+EW

| From Node | Tensile Stress | All. Tens. Stress | Comp. Stress | All. Comp. Stress | Tens. Ratio | Comp. Ratio |
|---|---|---|---|---|---|---|
| 10 | | 14400.00 | -586.68 | 14808.10 | | 0.0396 |
| 20 | 19.16 | 14400.00 | -540.26 | 14808.10 | 0.0013 | 0.0365 |
| 30 | | 10656.00 | -281.01 | 8705.73 | | 0.0323 |
| 40 | 2592.77 | 17760.00 | | 8382.42 | 0.1460 | |
| 50 | 2030.34 | 17760.00 | | 8703.96 | 0.1143 | |
| 60 | 1998.51 | 17760.00 | | 8703.96 | 0.1125 | |

Analysis of Load Case 17 : NP+VO+OW

| From Node | Tensile Stress | All. Tens. Stress | Comp. Stress | All. Comp. Stress | Tens. Ratio | Comp. Ratio |
|---|---|---|---|---|---|---|
| 10 | 2059.04 | 14400.00 | -2734.05 | 14808.10 | 0.1430 | 0.1846 |
| 20 | 1323.90 | 14400.00 | -1906.07 | 14808.10 | 0.0919 | 0.1287 |
| 30 | 695.76 | 10656.00 | -1129.43 | 8705.73 | 0.0653 | 0.1297 |
| 40 | 564.88 | 17760.00 | -1008.42 | 8382.42 | 0.0318 | 0.1203 |
| 50 | 430.84 | 17760.00 | -765.86 | 8703.96 | 0.0243 | 0.0880 |
| 60 | 27.38 | 17760.00 | -240.16 | 8703.96 | 0.0015 | 0.0276 |

Analysis of Load Case 18 : FS+BS+IP+OW

| From Node | Tensile Stress | All. Tens. Stress | Comp. Stress | All. Comp. Stress | Tens. Ratio | Comp. Ratio |
|---|---|---|---|---|---|---|
| 10 | 20.87 | 14400.00 | -538.54 | 14808.10 | 0.0014 | 0.0364 |
| 20 | 56.47 | 14400.00 | -502.94 | 14808.10 | 0.0039 | 0.0340 |
| 30 | | 10656.00 | -261.00 | 8705.73 | | 0.0300 |
| 40 | 2653.57 | 17760.00 | | 8382.42 | 0.1494 | |
| 50 | 2075.36 | 17760.00 | | 8703.96 | 0.1169 | |
| 60 | 2023.31 | 17760.00 | | 8703.96 | 0.1139 | |

Analysis of Load Case 19 : FS+BS+EP+OW

| From Node | Tensile Stress | All. Tens. Stress | Comp. Stress | All. Comp. Stress | Tens. Ratio | Comp. Ratio |
|---|---|---|---|---|---|---|

| | | | | | | |
|---|---|---|---|---|---|---|
| 10 | 20.87 | 14400.00 | -538.54 | 14808.10 | 0.0014 | 0.0364 |
| 20 | 56.47 | 14400.00 | -502.94 | 14808.10 | 0.0039 | 0.0340 |
| 30 | | 10656.00 | -261.00 | 8705.73 | | 0.0300 |
| 40 | | 17760.00 | -681.07 | 8382.42 | | 0.0813 |
| 50 | | 17760.00 | -531.73 | 8703.96 | | 0.0611 |
| 60 | | 17760.00 | -397.88 | 8703.96 | | 0.0457 |

Absolute Maximum of the all of the Stress Ratio's 0.2973

Governing Element: BTM D-END
Governing Load Case 11 : HP+HW+HI

| Element Description | Long Pressure Stress | Weight + Axial Load Stress | Eccentric Moment Stress | Wind or Earthquake Stress | Combined Stress | Which Side |
|---|---|---|---|---|---|---|
| BTM SKIRT-2 | ... | ... | ... | ... | ... | + Tens |
| BTM SKIRT-2 | ... | ... | ... | ... | ... | - Comp |
| BTM SKIRT-1 | ... | ... | ... | ... | ... | + Tens |
| BTM SKIRT-1 | ... | ... | ... | ... | ... | - Comp |
| TOP SKIRT | ... | ... | ... | ... | ... | + Tens |
| TOP SKIRT | ... | ... | ... | ... | ... | - Comp |
| BTM D-END | 8027.0 | ... | ... | ... | 8027.0 | + Tens |
| BTM D-END | 8027.0 | ... | ... | ... | ... | - Comp |
| SHELL-1 | 6268.4 | ... | ... | ... | 6268.4 | + Tens |
| SHELL-1 | 6268.4 | ... | ... | ... | ... | - Comp |
| SHELL-2 | 6268.4 | ... | ... | ... | 6268.4 | + Tens |
| SHELL-2 | 6268.4 | ... | ... | ... | ... | - Comp |

## Fatigue Stress Calculations due to Wind Induced Vortex Shedding Loads

| From | Elevation | Alternating Stress | Sif | Number of Cycles | Hours of Total Vibration |
|---|---|---|---|---|---|
| 10 | 8.20 | 4652.40 | 2.0 | 1000000 | 62.58 |
| 20 | 13.63 | 2934.68 | 2.0 | 1000000 | 62.58 |
| 30 | 16.75 | 2842.06 | 3.0 | 1000000 | 62.58 |
| 40 | 16.91 | 1541.97 | 2.0 | 1000000 | 62.58 |
| 50 | 21.83 | 1167.31 | 2.0 | 1000000 | 62.58 |
| 60 | 26.42 | 306.41 | 2.0 | 1000000 | 62.58 |
| 80 | 26.74 | 1.03 | 2.0 | 1000000 | 62.58 |
| 90 | 27.00 | 0.18 | 2.0 | 1000000 | 62.58 |

Cycle Life Determination based on ASME Div. II, Table 5-110.1

**Skirt Support Analysis Per EN 13445-3 Section 16.12:**

NOTE:
The skirt comprises more than one piece. If this is the case,
the Openings will only be considered in this Section of the
Skirt! Otherwise, make the whole skirt all one piece.

Item: BTM SKIRT-1

**Type B Skirt per EN-13445 Figure 16.12-2:**

| | | | |
|---|---|---|---|
| Total vessel (empty) weight | Fg | 6004.354 | lbf |
| Weight of vessel contents (liquid) | Ff | 1029.762 | lbf |
| Vessel Gross Weight | Fg + Ff = F4 | 7034.115 | lbf |
| Skirt Mean Diameter | Dz | 29.635 | in |
| Skirt Analysis Thickness (Corroded) | ez | 0.362 | in |
| Skirt Height | H | 65.157 | in |
| Force at section 1-1 | F1 | 7034.115 | lbf |
| Moment at section 1-1 | M1 | 25578.650 | ft-lbf |
| Applied Moment - Bottom of Skirt | Mb | 42968.914 | ft-lbf |
| Weight Above the Skirt | W | 9815.970 | lbf |

**Frame Input Data:**

| Access # | Diameter in | Layout Angle deg | Cntr. Dist. From Bottom in | Obround Cntr-Cntr in | Frame Width in | Frame Thickness in |
|---|---|---|---|---|---|---|
| 1 | 10.7480 | 135.0 | 58.31 | 0.00 | 5.354 | 0.354 |
| 2 | 4.4882 | 180.0 | 23.03 | 0.00 | 4.528 | 0.236 |

Interference check:

| Access | Access | Pitch in | Ligament in |
|---|---|---|---|
| 1 | 2 | 16.5603 | 8.9422 |
| 1 | 2 | 16.5603 | 8.9422 |

INTERFERENCE CHECK: No Interference Detected between Openings

Minimum Pitch between openings is: 16.5603 in
Minimum Ligament between Openings is: 8.9422 in

Recommended minimum Ligament:
= 2 * Sqrt( D * t )
= 2 * Sqrt( 29.635 * 0.362 ) = 6.553 in
Please evaluate the suitability of this result

Section properties at least metal area [A]:

Number of Openings At Critical Height = 1

| Access No | Layout Angle 1 Deg. | Layout Angle 2 Deg. |
|---|---|---|
| 1 | 113.7353 | 156.2647 |

The points for integrating Ixx, Iyy is as follows:

| FROM THETA1 Deg | TO THETA2 Deg |
|---|---|
| -203.735 | 113.735 |

| | | | |
|---|---|---|---|
| Height of Weakest Section | H | 58.308 | in |
| Rotation of Principle Axes | a | 0.000 | Deg. |
| Centroid Position in X direction | g | 0.112 | in |
| Centroid Position in Y direction | h | -0.112 | in |
| Principle Moment of Inertia | Ixx | 3681.798 | in**4 |
| Principle Moment of Inertia | Iyy | 3681.798 | in**4 |
| Distance to Extreme Fiber | ybar | 15.110 | in |
| Distance to Extreme Fiber | xbar | 15.110 | in |
| Minimum Section Modulus | W4 | 243.663 | in ^3 |
| Metal Area at the Cutting Plane | A4 | 33.532 | in^2 |

Half Opening Width Subtended Angle at Weakest Section: [delta]:
= $\sin^{-1}$ ( Largest Opening Width / Dz )
= $\sin^{-1}$ ( 10.748/29.635 ) = 0.3711 rad(21.2647 deg)

Skirt Mean Radius at Section 4-4 [r]:
= Dz/2 = 29.635/2 = 14.8176 in

Opening Ratio At Weakest Section: EN 13445 Equation 16.12-76 [ratio]:
= delta * sqrt(r/ez)
= 0.371 * sqrt(14.818/0.362) = 2.3738

*WARNING: ratio Exceeds 2 - See EN 13445 16.12.76(a).*
*This equation is a precaution against radial bucking at the opening.*
*The frame (if there is one), may prevent this. The code does not*
*say what size this frame should be. Your judgement is required.*

**Analysis of the Section at Weakest Section Modulus [Section 4-4]:**

Skirt Corroded Thickness [ez]:
= ex(new) - ci - cext = 0.394 - 0.031 - 0.0 = 0.3622 in

Please note:
There is more than one opening in the skirt
EN-13445 and AD-2000 considers only one opening per Figure 16.12-4
this skirt has 2 openings. Please check results

Note: Sometimes the moments are expressed in ft-lbf
and other times in in-lbf. Please be aware of this.

Find the moment acting at the Critical Height [M4]:
= (Mbottom - Mtop)*(H - CutHeight)/H + Mtop
= (42968.914 - 25578.65)*(65.157 - 58.308)/65.157 + 25578.65
= 27406.834 ft-lbf

Compute the section modulus [Zxx and Zyy]:
Zxx = Ixx/ybar = 3681.798/15.11 = 243.6627 in $^3$
Zyy = Iyy/xbar = 3681.798/15.11 = 243.6627 in $^3$
Z = min(Zxx, Zyy) = min(243.663,243.663) = 243.6627 in $^3$

The balance of the calculations are per EN-13445, and
they may be treated as academic if the designated code
is not EN-13445

Radius of Gyration of Skirt at 4-4 [rg]:

```
  = sqrt( min( Ixx, Iyy ) / Area(A4) )
  = sqrt( min( 3681.798, 3681.798 )/33.532 ) )
  = 10.478 in
```

Note: rg is not included in the analysis of EN 13445

Skirt Slenderness Ratio [r/L]:

```
  = 10.478/65.157 = 0.161
```

Location of the Skirt Centroid at critical height [e]:

```
  = sqrt(ex² + ey²) = sqrt( 0.112²+-0.112²)
  = 0.000 in
```

*Where ex = 0.112 : ey = -0.112*

Note: Moment Converted to ft-lbf units

Moment Increment at Centroid [DeltaM4]:

```
  = ( Fg + Ff ) * e = F4 * e
  = ( 6004.35 + 1029.76 ) * 0.15772 = 92.451 ft-lbf
```

Nomenclature per EN-13445:

Note: Moments are displayed as in-lbf units.

**Check of the Skirt in Regions with Openings, per 16.12.4.3:**

Weakening Factor, 16.12-70(b) [psi_1]:

```
  = min( 1; A4/( pi * D_3 * e_(a3) )
  = min( 1; 33.532/( pi * 29.675 * 0.362 )
  = 0.993
```

Weakening Factor, 16.12-70(c) [psi_2]:

```
  = min( 1; 4 * W4 /( pi * D^2_3/( pi * D_3 * e_(a3) )
  = min( 1; 4.0 * 243.663/( pi * 29.675^2 * 0.362 ) )
  = 0.973
```

Maximum Bending Moment [M_(max)]:

```
  = pi/4 * d3^2 * e_(a3) * sigmac_(all)
  = pi/4 * 29.675^2 * 0.362 * 14808.1
  = 309135.9 ft-lbf
```

Maximum Compressive Force [Fc_(,max)]:

```
  = pi * d3 * e_(a3) * sigmac_(all)
  = pi * 29.675 * 0.362 * 14808.1
  = 500031.1 lbf
```

Unity Check of Weakened Section, 16.12-70 [UC_1]:

```
  = F_4/( psi_1 * F_(c,max) ) + ( abs( M_4 ) + F_4 * abs( y_g ) )/( psi_2 * M_(max) ) )
  = 7034.1/(0.993*500031)+(abs(27406.8)+7034.1*abs(0.158))/(0.973*309135.9))
  = 0.106  must be <= to 1, Passed
```

**The stresses are satisfactory in the region with the opening(s).**

**Skirt Support Analysis Per EN 13445-3 Section 16.12:**

Item: TOP SKIRT

**Type B Skirt per EN-13445 Figure 16.12-2:**

```
Total vessel (empty) weight            Fg          6004.354  lbf
Head Weight below section 2-2      DeltaFg          188.782  lbf
Weight of vessel contents (liquid)      Ff         1029.762  lbf
Vessel Gross Weight           Fg + Ff = F4         7034.115  lbf

Skirt Mean Diameter                     Dz           29.635  in
Skirt Analysis Thickness (Corroded)     ez            0.362  in
Skirt Height                             H           37.402  in

Force  at section 1-1                   F1         6845.333  lbf
Moment at section 1-1                   M1        16577.975  ft-lbf
Applied Moment - Bottom of Skirt        Mb        25578.650  ft-lbf
Weight Above the Skirt                   W         7311.992  lbf
```

**Frame Input Data:**

| Access # | Diameter in | Layout Angle deg | Cntr. Dist. From Bottom in | Obround Cntr-Cntr in | Frame Width in | Frame Thickness in |
|---|---|---|---|---|---|---|
| 1 | 2.8740 | 90.0 | 29.41 | 0.00 | 2.362 | 0.203 |
| 2 | 2.8740 | 270.0 | 29.41 | 0.00 | 2.362 | 0.203 |

Interference check:

| Access | Access | Pitch in | Ligament in |
|---|---|---|---|
| 1 | 2 | 46.5509 | 43.6723 |
| 1 | 2 | 46.5509 | 43.6723 |

INTERFERENCE CHECK: No Interference Detected between Openings

```
Minimum Pitch between openings    is:     46.5509 in
Minimum Ligament between Openings is:     43.6723 in
```

Recommended minimum Ligament:

```
= 2 * Sqrt( D * t )
= 2 * Sqrt( 29.635 * 0.362 ) = 6.553 in
  Please evaluate the suitability of this result
```

Section properties at least metal area [A]:

Number of Openings At Critical Height = 2

| Access No | Layout Angle 1 Deg. | Layout Angle 2 Deg. |
|---|---|---|
| 1 | 84.4347 | 95.5653 |
| 2 | 264.4347 | 275.5653 |

The points for integrating Ixx, Iyy is as follows:

| FROM THETA1 Deg | TO THETA2 Deg |
|---|---|

```
    95.565        264.435
   -84.435         84.435

 Height of Weakest Section          H              29.406  in
 Rotation of Principle Axes         a              -0.000  Deg.
 Centroid Position in X direction   g               0.000  in
 Centroid Position in Y direction   h               0.000  in
 Principle Moment of Inertia      Ixx            3663.991  in**4
 Principle Moment of Inertia      Iyy            3704.002  in**4
 Distance to Extreme Fiber       ybar              14.999  in
 Distance to Extreme Fiber       xbar              14.999  in
 Minimum Section Modulus           W4             244.287  in ^3
 Metal Area at the Cutting Plane   A4              33.556  in^2
```

Half Opening Width Subtended Angle at Weakest Section: [delta]:
= $\sin^{-1}$ ( Largest Opening Width / Dz )
= $\sin^{-1}$ ( 2.874/29.635 ) = 0.0971 rad(5.5653 deg)

Skirt Mean Radius at Section 4-4 [r]:
= Dz/2 = 29.635/2 = 14.8176 in

Opening Ratio At Weakest Section: EN 13445 Equation 16.12-76 [ratio]:
= delta * sqrt(r/ez)
= 0.097 * sqrt(14.818/0.362) = 0.6213

Ok as the ratio is < 2 - See EN 13445 16.12.76(a).

**Analysis of the Section at Weakest Section Modulus [Section 4-4]:**

Skirt Corroded Thickness [ez]:
= ex(new) - ci - cext = 0.394 - 0.031 - 0.0 = 0.3622 in

Please note:
There is more than one opening in the skirt
EN-13445 and AD-2000 considers only one opening per Figure 16.12-4
this skirt has 2 openings. Please check results

Note: Sometimes the moments are expressed in ft-lbf
and other times in in-lbf. Please be aware of this.

Find the moment acting at the Critical Height [M4]:
= (Mbottom - Mtop)*(H - CutHeight)/H + Mtop
= (25578.65 - 16577.975)*(37.402 - 29.406)/37.402 + 16577.975
= 18502.078 ft-lbf

Compute the section modulus [Zxx and Zyy]:
Zxx = Ixx/ybar = 3663.991/15.0 = 244.2872 in$^3$
Zyy = Iyy/xbar = 3704.002/15.0 = 246.9548 in$^3$
Z = min(Zxx, Zyy) = min(244.287,246.955) = 244.2872 in$^3$

The balance of the calculations are per EN-13445, and
they may be treated as academic if the designated code
is not EN-13445

Radius of Gyration of Skirt at 4-4 [rg]:
= sqrt( min( Ixx, Iyy ) / Area(A4) )
= sqrt( min( 3663.991, 3704.002 )/33.556 ) )
= 10.449 in

Note: rg is not included in the analysis of EN 13445

Skirt Slenderness Ratio [r/L]:
```
  = 10.449/37.402 = 0.279
```

Location of the Skirt Centroid at critical height [e]:
```
  = sqrt(ex² + ey²) = sqrt(0.0²+0.0²)
  = 0.158 in
```

*Where ex = 0.0 : ey = 0.0*

Note: Moment Converted to ft-lbf units

Moment Increment at Centroid [DeltaM4]:
```
  = ( Fg + Ff ) * e = F4 * e
  = ( 6004.35 + 1029.76 ) * 0. = 0.0 ft-lbf
```

Nomenclature per EN-13445:

Note: Moments are displayed as in-lbf units.

**Check of the Skirt in Regions with Openings, per 16.12.4.3:**

Weakening Factor, 16.12-70(b) [psi_1]:
```
  = min( 1; A4/( pi * D_3 * e_(a3) )
  = min( 1; 33.556/( pi * 29.675 * 0.362 )
  = 0.994
```

Weakening Factor, 16.12-70(c) [psi_2]:
```
  = min( 1; 4 * W4 /( pi * D^2_3/( pi * D_3 * e_(a3) )
  = min( 1; 4.0 * 246.955/( pi * 29.675^2 * 0.362 ) )
  = 0.986
```

Maximum Bending Moment [M_(max)]:
```
  = pi/4 * d3^2 * e_(a3) * sigmac_(all)
  = pi/4 * 29.675^2 * 0.362 * 14808.1
  = 309135.9 ft-lbf
```

Maximum Compressive Force [Fc_(,max)]:
```
  = pi * d3 * e_(a3) * sigmac_(all)
  = pi * 29.675 * 0.362 * 14808.1
  = 500031.1 lbf
```

Unity Check of Weakened Section, 16.12-70 [UC_1]:
```
  = F_4/( psi_1 * F_(c,max) ) + ( abs( M_4 ) + F_4 * abs( y_g ) )/( psi_2 * M_(max) ) )
  = 7034.1/(0.994*500031)+(abs(18502.1)+7034.1*abs(0.0))/(0.986*309135.9))
  = 0.075  must be <= to 1, Passed
```

**The stresses are satisfactory in the region with the opening(s).**

**Shop/Field Installation Options :**

Platform(s) installed in the Field before being lifted.

Note : The CG is computed from the first Element From Node

```
Center of Gravity of the Platforms                          15.699 ft
Center of Gravity of the Liquid                             18.099 ft
Center of Gravity of the Nozzles                            21.266 ft
Center of Gravity of the Added Weights (Operating)          25.459 ft
Center of Gravity of the Added Weights (Empty)              25.459 ft

Center of Gravity of Bare Shell New and Cold                15.271 ft
Center of Gravity of Bare Shell Corroded                    15.249 ft

Vessel CG in the Operating Condition                        16.197 ft
Vessel CG in the Fabricated (Shop/Empty) Condition          16.216 ft
Vessel CG in the Test Condition                             18.005 ft
```

**Rigging Analysis Results:**

Lifting Weight based the calculated Erected Weight.

```
Total Effective Length of Vessel for this analysis            26.97 ft
Total vessel weight (No Liquid)                  Twt       10351.59 lbf
Impact weight multiplication factor              Imp           1.35
Design lifting weight,  DWT = Imp * Twt                    13974.64 lbf
Elevation of the Tailing Lug (bottom)                          0.45 ft
Elevation of the Lifting Lug (top   )                         25.75 ft
Design Reaction force at the tailing lug                    5264.58 lbf
Design Reaction force at the lifting lug                    8710.06 lbf

CG Distance from Tailing Lug                                  15.77 ft
CG Distance from the Nearer Lifting Lug/Trunnion               9.53 ft

Compressive Allowable Increase Factor                          1.00
```

**Critical Values:**

| | Max Stress psi | Elevation ft | Allowables psi | |
|---|---|---|---|---|
| Bending | 1558.12 | 16.75 | 11401.38 | (UG-23) |
| Shear | 149.74 | 25.50 | 11690.00 | (0.7*S) |

The compressive bending allowable stress is the minimum of the tensile allowable and the compressive allowable times the specified compressive allowable increase factor.

Forces and Moments at selected elevations (not all analysis points shown):

| Distance ft | Bending Moment ft-lbf | Bending Stress psi | Shear Force lbf | Shear Stress psi |
|---|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 374.3 | 10.2 |
| 10.37 | 28406.3 | 1273.0 | 655.0 | 17.9 |
| 16.13 | 28422.7 | 1272.4 | 1185.9 | 32.4 |
| 17.90 | 25748.5 | 1152.0 | 1875.9 | 51.2 |
| 24.59 | 3255.0 | 145.6 | 5008.0 | 136.6 |
| 26.74 | 251.7 | 7.9 | 2192.0 | 50.2 |

**Unity Check (Actual Stress / Allowable Stress):**

Maximum Unity Check is 0.1367 at elevation 16.7487 ft - Must be <=1

Note: The rigging analysis is performed using a uniformly distributed load.

--- Plot data successfully generated ...----

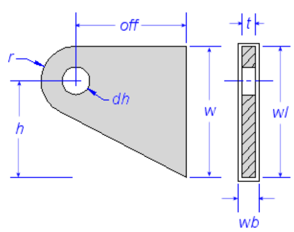
 

### Lifting Lug Calculations:

#### Input Values:

| | | |
|---|---|---|
| Lifting Lug Material | | SA-516 70 |
| Lifting Lug Yield Stress | Yield | 38000.00 psi |
| | | |
| Total Height of Lifting Lug | w | 5.9055 in |
| Thickness of Lifting Lug | t | 1.7717 in |
| Diameter of Hole in Lifting Lug | dh | 0.9055 in |
| Radius of Semi-Circular Arc of Lifting Lug | r | 2.9528 in |
| Height of Lug from bottom to Center of Hole | h | 2.9528 in |
| Offset from Vessel OD to Center of Hole | off | 10.2362 in |
| Lug Fillet Weld Size | tw | 0.7874 in |
| Length of weld along side of Lifting Lug | wl | 5.9055 in |
| Length of Weld along Bottom of Lifting Lug | wb | 4.1339 in |
| Thickness of Collar (if any) | tc | 0.0000 in |
| Diameter of Collar (if any) | dc | 0.0000 in |
| Impact Factor | Impfac | 1.35 |
| Sling Angle from Horizontal | | 90.0 deg |
| Number of Lugs in Group | | 2 |

Lifting Lug Orientation to Vessel: Perpendicular
Lift Orientation : From Horizontal to Vertical




#### Lifting Lug and Weld Stresses at various Angles: psi

| Angle | Weld Stresses Primary | Weld Stresses Secondary | Weld Stresses Allowable | Lug Stresses Combined | Lug Stresses Allowable | Maximum Ratio |
|---|---|---|---|---|---|---|
| 0 | 4502.5 | ... | 15200.0 | 14430.0 | 25080.0 | 0.575 |
| 5 | 4701.4 | ... | 15200.0 | 14789.8 | 25080.0 | 0.590 |
| 10 | 4868.4 | ... | 15200.0 | 15038.6 | 25080.0 | 0.600 |
| 15 | 5002.4 | ... | 15200.0 | 15174.6 | 25080.0 | 0.605 |
| 20 | 5102.3 | ... | 15200.0 | 15196.8 | 25080.0 | 0.606 |
| 25 | 5167.5 | ... | 15200.0 | 15105.2 | 25080.0 | 0.602 |
| 30 | 5197.7 | ... | 15200.0 | 14900.7 | 25080.0 | 0.594 |
| 35 | 5192.7 | ... | 15200.0 | 14585.1 | 25080.0 | 0.582 |
| 40 | 5153.0 | ... | 15200.0 | 14161.1 | 25080.0 | 0.565 |
| 45 | 5079.2 | ... | 15200.0 | 13632.6 | 25080.0 | 0.544 |
| 50 | 4972.4 | ... | 15200.0 | 13004.3 | 25080.0 | 0.519 |
| 55 | 4834.3 | ... | 15200.0 | 12282.2 | 25080.0 | 0.490 |
| 60 | 4667.2 | ... | 15200.0 | 11473.7 | 25080.0 | 0.457 |
| 65 | 4474.7 | ... | 15200.0 | 10588.2 | 25080.0 | 0.422 |
| 70 | 4262.3 | ... | 15200.0 | 9638.5 | 25080.0 | 0.384 |
| 75 | 4040.6 | ... | 15200.0 | 8644.5 | 25080.0 | 0.345 |
| 80 | 3833.5 | ... | 15200.0 | 7645.9 | 25080.0 | 0.305 |
| 85 | 3721.7 | ... | 15200.0 | 6764.6 | 25080.0 | 0.270 |
| 90 | 4356.0 | ... | 15200.0 | 6945.6 | 25080.0 | 0.287 |

**Computed Results:**

| | |
|---|---|
| Total vessel weight (No Liquid) | 10351.59 lbf |
| Design Reaction force at the tailing lug | 5264.58 lbf |
| Design Reaction force at the lifting lug | 8710.06 lbf |
| | |
| Worst Case Lift Angle for Primary Weld Stresses | 32 deg |
| Tangential Force at this Angle | 3758.4 lbf |
| Axial Force at this Angle | 2348.5 lbf |
| | |
| Worst Case Lift Angle for Secondary Weld Stresses | 0 deg |
| Tangential Force at this Angle | 4355.0 lbf |
| Axial Force at this Angle | 0.0 lbf |
| | |
| Worst Case Lift Angle for Lug Stresses | 18 deg |
| Tangential Force at this Angle | 4180.4 lbf |
| Axial Force at this Angle | 1358.3 lbf |

*Converting the weld leg dimension (tw) to the weld throat dimension.*

**Weld Group Inertia Calculations:**

| | | |
|---|---|---|
| Weld Group Inertia about the Circumferential Axis | Ilc | 67.279 in**4 |
| Weld Group Centroid distance in the Long. Direction | Yll | 3.509 in |
| Dist. of Weld Group Centroid from Lug bottom | Yll_b | 2.953 in |
| Weld Group Inertia about the Longitudinal Axis | Ill | 15.635 in**4 |
| Weld Group Centroid Distance in the Circ. Direction | Ylc | 1.443 in |

*Note: The Impact Factor is applied to the Forces acting on the Lug.*

Primary Shear Stress in the Welds due to Shear Loads [Ssll]:
$= \mathrm{sqrt}( Fax^2 + Ft^2 + Fn^2 )/(( 2 * (wl + wb) ) * tw )$
$= \mathrm{sqrt}(2349^2+3758^2+0^2)/((2*(5.9+4.1))*0.5567)$
= 396.49 psi

Shear Stress in the Welds due to Bending Loads [Sblf]:
= (Fn(h-Yll_b))Yll/Ilc + (Fax * off * Yll/Ilc) + (Ft * off * Ylc/Ill)
= (0(2.953-2.953))3.509/67.279 +
(2349 * 10.236 * 3.509/67.279) +
(3758 * 10.236 * 1.443/15.635)
= 4803.40 psi

Total Shear Stress for Combined Loads [St]:
= Ssll + Sblf
= 396.49 + 4803.402
= 5199.89 psi

Allowable Shear Stress for Combined Loads [Sta]:
= 0.4 * Yield * Occfac (AISC Shear Allowable)
= 0.4 * 38000 * 1.0
= 15200.00 psi

Shear Stress in Lug above Hole [Shs]:
$= \mathrm{sqrt}( Pl^2 + Fax^2 ) / Sha$
$= \mathrm{sqrt}( 6987^2 + 2349^2 )/8.858$
= 832.15 psi

Allowable Shear Stress in Lug above Hole [Sas]:
= 0.4 * Yield * Occfac

```
  = 0.4 * 38000 * 1.0
  = 15200.00 psi
```

Pin Hole Bearing Width [Pbw]:
```
  = Lug Thickness + 2 * Collar Thickness
  = 1.772 + 2 * 0.0
  = 1.772 in
```

Pin Hole Bearing Stress [Pbs]:
```
  = sqrt( Pl² + Faxial² ) / ( Pbw * dh )
  = sqrt( 6987² + 2349² )/( 1.772 * 0.906 )
  = 4594.94 psi
```

Allowable Bearing Stress [Pba]:
```
  = min( 0.75 * Yield * Occfac, 0.9 * Yield ) AISC Bearing All.
  = min( 0.75 * 38000 * 1.0, 34200.0 )
  = 28500.00 psi
```

Bending Stress at the Base of the Lug [Fbs]:
```
  = Ft * off/(w * t²/6) + Fax * off/(w² * t/6)
  = 4180 * 10.236/(5.906 * 1.772²/6) +
    1358 * 10.236/(5.906² * 1.772/6)
  = 14787.67 psi
```

Tensile Stress at the Base of the Lug [Fa]:
```
  = Fn / (w * t)
  = 0/(5.906 * 1.772)
  = 0.00 psi
```

Total Combined Stress at the Base of the Lug:
```
  = Fbs + Fa
  = 14787.7 + 0.0
  = 14787.67 psi
```

Lug Allowable Stress for Bending and Tension:
```
  = min( 0.66 * Yield * Occfac, 0.75 * Yield )
  = min( 0.66 * 38000 * 1.0, 28500.0 )
  = 25080.00 psi
```

Required Shackle Pin Diameter [Spd]:
```
  = sqrt((2(Fn² + Fax²)⁰·⁵/( pi * Sta)))
  = sqrt(2(6987² + 2349²)⁰·⁵/( pi * 15200))
  = 0.5556 in
```

**WRC 107/537 Stress Analysis for the Lifting Lug to Shell Junction in the new and Cold Condition (no corrosion applied).**

*Note: The full lug load is applied in both the circumferential and longitudinal directions simultaneously.*

*Note: Attachment dimensions (C11P, C22P etc.) may be modified accounting for attachment welds where applicable.*

**Input Echo, WRC107/537 Item 1, Description: Lift Lug**

```
 Diameter Basis for Vessel                 Vbasis      ID
 Cylindrical or Spherical Vessel           Cylsph      Cylindrical
 Internal Corrosion Allowance                 Cas      0.0000   in
 Vessel Diameter                               Dv      29.250   in
 Vessel Thickness                              Tv       0.394   in
```

Note: Lifting lug calculations are performed at ambient temperature conditions.

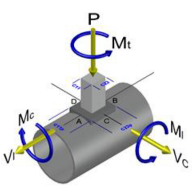
| | | | |
|---|---|---|---|
| Attachment Type | Type | Rectangular | |
| Parameter C11 | C11 | 4.13 | in |
| Parameter C22 | C22 | 5.91 | in |
| Thickness of Reinforcing Pad | Tpad | 0.394 | in |
| Pad Parameter C11P | C11p | 7.244 | in |
| Pad Parameter C22P | C22p | 8.937 | in |
| Design Internal Pressure | Dp | 0.000 | psig |
| Include Pressure Thrust | | No | |

External Forces and Moments in WRC 107/537 Convention:

| | | | | |
|---|---|---|---|---|
| Radial Load | (SUS) | P | 0.0 | lbf |
| Longitudinal Shear | (SUS) | Vl | 6987.3 | lbf |
| Circumferential Shear | (SUS) | Vc | 6987.3 | lbf |
| Circumferential Moment | (SUS) | Mc | 5960.3 | ft-lbf |
| Longitudinal Moment | (SUS) | Ml | 0.0 | ft-lbf |
| Torsional Moment | (SUS) | Mt | 0.0 | ft-lbf |

| | | |
|---|---|---|
| Use Interactive Control | | No |
| WRC107 Version | Version | March 1979 |
| Include Pressure Stress Indices per Div. 2 | | No |
| Compute Pressure Stress per WRC-368 | | No |
| Local Loads applied at end of Nozzle/Attachment | | No |

*WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".*




*WRC 107/537 has dimensional limitations that can be found in the bulletin's Foreword and which can also be inferred by review of the non-dimensional curve limits.*

WRC 107 Stress Calculation for SUStained loads:

| | | | |
|---|---|---|---|
| Radial Load | P | 0.0 | lbf |
| Circumferential Shear | VC | 6987.3 | lbf |
| Longitudinal Shear | VL | 6987.3 | lbf |
| Circumferential Moment | MC | 5960.3 | ft-lbf |
| Longitudinal Moment | ML | 0.0 | ft-lbf |
| Torsional Moment | MT | 0.0 | ft-lbf |

Dimensionless Parameters used : Gamma = 19.07

**Dimensionless Loads for Cylindrical Shells at Attachment Junction:**

| Curves read for 1979 | Beta | Figure | Value | Location |
|---|---|---|---|---|
| N(PHI) / ( P/Rm ) | 0.196 | 4C | 3.035 | (A,B) |
| N(PHI) / ( P/Rm ) | 0.196 | 3C | 2.356 | (C,D) |
| M(PHI) / ( P ) | 0.157 | 2C1 | 0.079 | (A,B) |
| M(PHI) / ( P ) | 0.157 | 1C | 0.111 | (C,D) |

| | | | | |
|---|---|---|---|---|
| N(PHI) / ( MC/(Rm**2 * Beta) ) | 0.155 | 3A | 0.620 | (A,B,C,D) |
| M(PHI) / ( MC/(Rm * Beta) ) | 0.171 | 1A | 0.094 | (A,B,C,D) |
| N(PHI) / ( ML/(Rm**2 * Beta) ) | 0.175 | 3B | 2.089 | (A,B,C,D) |
| M(PHI) / ( ML/(Rm * Beta) ) | 0.173 | 1B | 0.042 | (A,B,C,D) |
| N(x) / ( P/Rm ) | 0.178 | 3C | 2.522 | (A,B) |
| N(x) / ( P/Rm ) | 0.178 | 4C | 3.121 | (C,D) |
| M(x) / ( P ) | 0.181 | 1C1 | 0.101 | (A,B) |
| M(x) / ( P ) | 0.181 | 2C | 0.067 | (C,D) |
| N(x) / ( MC/(Rm**2 * Beta) ) | 0.155 | 4A | 0.928 | (A,B,C,D) |
| M(x) / ( MC/(Rm * Beta) ) | 0.202 | 2A | 0.047 | (A,B,C,D) |
| N(x) / ( ML/(Rm**2 * Beta) ) | 0.175 | 4B | 0.643 | (A,B,C,D) |
| M(x) / ( ML/(Rm * Beta) ) | 0.190 | 2B | 0.061 | (A,B,C,D) |

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Attachment Junction (psi)**

| Type of Stress Load | Stress Intensity Values at Au | Al | Bu | Bl | Cu | Cl | Du | Dl |
|---|---|---|---|---|---|---|---|---|
| Circ. Memb. P | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Circ. Bend. P | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Circ. Memb. MC | 0 | 0 | 0 | 0 | -1243 | -1243 | 1243 | 1243 |
| Circ. Bend. MC | 0 | 0 | 0 | 0 | -25246 | 25246 | 25246 | -25246 |
| Circ. Memb. ML | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Circ. Bend. ML | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tot. Circ. Str. | 0 | 0 | 0 | 0 | -26490 | 24003 | 26490 | -24003 |
| Long. Memb. P | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Long. Bend. P | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Long. Memb. MC | 0 | 0 | 0 | 0 | -1982 | -1982 | 1982 | 1982 |
| Long. Bend. MC | 0 | 0 | 0 | 0 | -10752 | 10752 | 10752 | -10752 |
| Long. Memb. ML | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Long. Bend. ML | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tot. Long. Str. | 0 | 0 | 0 | 0 | -12735 | 8770 | 12735 | -8770 |
| Shear VC | 1073 | 1073 | -1073 | -1073 | 0 | 0 | 0 | 0 |
| Shear VL | 0 | 0 | 0 | 0 | -751 | -751 | 751 | 751 |
| Shear MT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tot. Shear | 1073 | 1073 | -1073 | -1073 | -751 | -751 | 751 | 751 |
| Str. Int. | 2146 | 2146 | 2146 | 2146 | 26531 | 24040 | 26531 | 24040 |

Dimensionless Parameters used : Gamma = 37.65

**Dimensionless Loads for Cylindrical Shells at Pad Edge:**

| Curves read for 1979 | Beta | Figure | Value | Location |
|---|---|---|---|---|
| N(PHI) / ( P/Rm ) | 0.304 | 4C | 4.215 | (A,B) |
| N(PHI) / ( P/Rm ) | 0.304 | 3C | 2.061 | (C,D) |
| M(PHI) / ( P ) | 0.263 | 2C1 | 0.022 | (A,B) |
| M(PHI) / ( P ) | 0.263 | 1C ! | 0.062 | (C,D) |
| N(PHI) / ( MC/(Rm**2 * Beta) ) | 0.262 | 3A | 1.466 | (A,B,C,D) |
| M(PHI) / ( MC/(Rm * Beta) ) | 0.289 | 1A | 0.068 | (A,B,C,D) |

```
 N(PHI) / ( ML/(Rm**2 * Beta) )   0.281   3B        3.017   (A,B,C,D)
 M(PHI) / ( ML/(Rm    * Beta) )   0.283   1B        0.015   (A,B,C,D)

 N(x)   / ( P/Rm )                0.285   3C        2.248   (A,B)
 N(x)   / ( P/Rm )                0.285   4C        4.394   (C,D)
 M(x)   / ( P )                   0.289   1C1       0.042   (A,B)
 M(x)   / ( P )                   0.289   2C  !     0.032   (C,D)
 N(x)   / ( MC/(Rm**2 * Beta) )   0.262   4A        3.327   (A,B,C,D)
 M(x)   / ( MC/(Rm    * Beta) )   0.328   2A        0.027   (A,B,C,D)
 N(x)   / ( ML/(Rm**2 * Beta) )   0.281   4B        1.467   (A,B,C,D)
 M(x)   / ( ML/(Rm    * Beta) )   0.301   2B        0.022   (A,B,C,D)
```

Note - The ! mark next to the figure name denotes curve value exceeded.

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Edge of Reinforcing Pad (psi)**

| Type of Stress Load | Stress Intensity Values at Au | Al | Bu | Bl | Cu | Cl | Du | Dl |
|---|---|---|---|---|---|---|---|---|
| Circ. Memb. P | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Circ. Bend. P | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Circ. Memb. MC | 0 | 0 | 0 | 0 | -3741 | -3741 | 3741 | 3741 |
| Circ. Bend. MC | 0 | 0 | 0 | 0 | -44118 | 44118 | 44118 | -44118 |
| Circ. Memb. ML | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Circ. Bend. ML | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tot. Circ. Str. | 0 | 0 | 0 | 0 | -47859 | 40376 | 47859 | -40376 |
| Long. Memb. P | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Long. Bend. P | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Long. Memb. MC | 0 | 0 | 0 | 0 | -8970 | -8970 | 8970 | 8970 |
| Long. Bend. MC | 0 | 0 | 0 | 0 | -15246 | 15246 | 15246 | -15246 |
| Long. Memb. ML | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Long. Bend. ML | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tot. Long. Str. | 0 | 0 | 0 | 0 | -24216 | 6275 | 24216 | -6275 |
| Shear VC | 1224 | 1224 | -1224 | -1224 | 0 | 0 | 0 | 0 |
| Shear VL | 0 | 0 | 0 | 0 | -992 | -992 | 992 | 992 |
| Shear MT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tot. Shear | 1224 | 1224 | -1224 | -1224 | -992 | -992 | 992 | 992 |
| Str. Int. | 2449 | 2449 | 2449 | 2449 | 47901 | 40405 | 47901 | 40405 |

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (psi)**

| Type of Stress Load | Stress Intensity Values at Au | Al | Bu | Bl | Cu | Cl | Du | Dl |
|---|---|---|---|---|---|---|---|---|
| Circ. Pm (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Circ. Pl (SUS) | 0 | 0 | 0 | 0 | -1243 | -1243 | 1243 | 1243 |
| Circ. Q (SUS) | 0 | 0 | 0 | 0 | -25246 | 25246 | 25246 | -25246 |
| Long. Pm (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Long. Pl (SUS) | 0 | 0 | 0 | 0 | -1982 | -1982 | 1982 | 1982 |
| Long. Q (SUS) | 0 | 0 | 0 | 0 | -10752 | 10752 | 10752 | -10752 |
| Shear Pm (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Shear Pl (SUS) | 1073 | 1073 | -1073 | -1073 | -751 | -751 | 751 | 751 |
| Shear Q (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pm (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pm+Pl (SUS) | 2146 | 2146 | 2146 | 2146 | 2450 | 2450 | 2450 | 2450 |
| Pm+Pl+Q (Total) | 2146 | 2146 | 2146 | 2146 | 26531 | 24040 | 26531 | 24040 |

**Vessel Stress Summation Comparison (psi):**

| Type of Stress Int. | Max. S.I. | S.I. Allowable | Result |
|---|---|---|---|
| Pm (SUS) | 0 | 16700 | Passed |
| Pm+Pl (SUS) | 2450 | 25050 | Passed |
| Pm+Pl+Q (TOTAL) | 26531 | 50100 | Passed |

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

---

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Reinforcing Pad Edge (psi)**

| Type of Stress Load | Stress Intensity Values at Au | Al | Bu | Bl | Cu | Cl | Du | Dl |
|---|---|---|---|---|---|---|---|---|
| Circ. Pm (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Circ. Pl (SUS) | 0 | 0 | 0 | 0 | -3741 | -3741 | 3741 | 3741 |
| Circ. Q (SUS) | 0 | 0 | 0 | 0 | -44118 | 44118 | 44118 | -44118 |
| Long. Pm (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Long. Pl (SUS) | 0 | 0 | 0 | 0 | -8970 | -8970 | 8970 | 8970 |
| Long. Q (SUS) | 0 | 0 | 0 | 0 | -15246 | 15246 | 15246 | -15246 |
| Shear Pm (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Shear Pl (SUS) | 1224 | 1224 | -1224 | -1224 | -992 | -992 | 992 | 992 |
| Shear Q (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pm (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pm+Pl (SUS) | 2449 | 2449 | 2449 | 2449 | 9152 | 9152 | 9152 | 9152 |
| Pm+Pl+Q (Total) | 2449 | 2449 | 2449 | 2449 | 47901 | 40405 | 47901 | 40405 |

**Vessel Stress Summation Comparison (psi):**

| Type of Stress Int. | Max. S.I. | S.I. Allowable | Result |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Pm (SUS) | 0 | 16700 | Passed |
| Pm+Pl (SUS) | 9152 | 25050 | Passed |
| Pm+Pl+Q (TOTAL) | 47901 | 50100 | Passed |

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

**Skirt Data :**

```
 Skirt Outside Diameter at Base      SOD, D6          29.9974  in
 Skirt Thickness                        STHK           0.3937  in
 Skirt Internal Corrosion Allowance      SCA           0.0315  in
 Skirt External Corrosion Allowance                    0.0000  in
 Skirt Material                                    SA-516 70
```

**Basering Input: Type of Geometry: Basering W/Gussets & Chair Cap**

```
 Thickness of Basering            TBA,  ea4           1.2598  in
 Design Temperature of the Basering                   100.00  °F
 Basering Material                                 SA-516 70
 Basering Ope. All. Stress        BASOPE, f4        20000.00  psi
 Basering Yield Stress                              38000.00  psi
 Inside Diameter of Basering           DI, D4        25.2362  in
 Outside Diameter of Basering         DOU, D5        40.2756  in

 Nominal Diameter of Bolts        BND, d(b0)          1.7500  in
 Bolt Corrosion Allowance                BCA          0.0000  in
 Bolt Material                                   SA-193 B7M
 Bolt Material Class/Thickness Range               <= 2 1/2
 Bolt Operating Allowable Stress      SA, fB        20000.00  psi
 Number of Bolts                      RN, nb               4
 Diameter of Bolt Circle             DC, DBC         35.5000  in
 Bolt Allowable Shear Stress                       13050.000  psi

 Ultimate Comp. Strength of Concrete     FPC          3000.0  psi
 Allowable Comp. Strength of Concrete     FC          4000.0  psi
 Modular ratio Steel/Concrete                          9.833

 Thickness of Gusset Plates          TGA, e7          0.7874  in
 Width of Gussets at Top Plate          TWDT          5.2360  in
 Width of Gussets at Base Plate         BWDT          5.2360  in
 Gusset Plate Elastic Modulus              E      29000000.0  psi
 Gusset Plate Yield Stress                SY         38000.0  psi
 Height of Gussets                    HG, h1          8.1880  in
 Distance between Gussets             RG, b6          4.0157  in
 Dist. from Bolt Center to Gusset (Rg/2)  CG          2.0079  in
 Number of Gussets per bolt               NG               2

 Thickness of Top Plate or Ring      TTA, e5          1.5748  in
 Radial Width of the Top Plate    TOPWTH, b5          5.2362  in
 Circum. Width of the Top Plate    CMWTH, b4          7.0079  in
 Anchor Bolt Hole Dia. in Top Plate    BHOLE          2.1250  in

 External Corrosion Allowance             CA          0.0630  in

 Dead Weight of Vessel                    DW         10351.6  lbf
 Operating Weight of Vessel              ROW         11381.3  lbf
 Earthquake Moment on Basering         EQMOM         71804.7  ft-lbf
 Wind Moment on Basering               WIMOM         26863.9  ft-lbf
 Vortex Shedding Moment on Basering   Vormom         43546.8  ft-lbf
 Percent Bolt Preload                    ppl           100.0

 Use AISC A5.2 Increase in Fc and Bolt Stress             No
 Use Allowable Weld Stress per AISC J2.5                  No

 Factor for Increase of Allowables     Fact          1.0000
```

**Results for Basering Analysis : Analyze Option**

Basering Thickness Calculation method used : Neutral Axis Shift

**Calculation of Bolt Loads for Multiple Loading Conditions:**

Bolt Load, Earthquake Operating Case [F_(B,e)]:
```
  = (( 4 * M/DC ) - abs( W - vertical force ))/nb     per Jawad & Farr, Eq. 12.3
  = (( 4 * 861656/35.5) - 8728 )/4
  = 22089.9 lbf
```

Bolt Load, Windload Empty Case [F_(B,w)]:
```
  = (( 4 * M/DC ) - W )/nb     per Jawad & Farr, Eq. 12.3
  = (( 4 * 322367/35.5) - 10352 )/4
  = 6492.9 lbf
```

Bolt Load, Windload Vortex Shedding Case [F_(B,v)]:
```
  = (( 4 * M/DC ) - W )/nb     per Jawad & Farr, Eq. 12.3
  = (( 4 * 522561/35.5) - 11381 )/4
  = 11874.7 lbf
```

Calculation of Maximum Load per Bolt [W/Bolt], Earthquake + Operating Condition:
where: W = ROW - Yforce (from gy Accleration or user force), M = EQMOM

```
  = (( 4 * M/DC ) - W )/nb     per Jawad & Farr, Eq. 12.3
  = (( 4 * 861656/35.5) - 8728 )/4
  = 22089.9 lbf

 Area Available in all the Bolts (Corr)               7.9200  in^2
```

Shear Stress in a Single Bolt [taub]:
```
  = Shear Force / ( Bolt Area * Number of Bolts )
  = 3575/( 1.98 * 4 )
  = 451.4 psi.  Must be less than 13050.0 psi.

 Concrete Contact Area of Base Ring             CCA     773.82  in^2
 Concrete Contact Section Modulus of Base Ring         5425.28  in³
```

Concrete Load (Simplified method), Earthquake in Operating Condition [Sc]:
```
  = ((ppl/100*(Abt*Sa)+W)/Cca) + M/CZ per Jawad & Farr Eq. 12.1
  = (1.0(7.92*20000+14034)/773.82) + 861656/5425.28
  = 381.66 psi
```

Neutral Axis Shift Method Per Singh and Soler:

| Trial# | Alpha | k | Rho1 | Rho2 | Rho3 | Rho4 | Ftstr | Fcstr |
|---|---|---|---|---|---|---|---|---|
| 0 | 60.226 | 0.252 | 1.375 | 2.547 | 0.779 | 0.448 | 7192.4 | 204.3 |
| 2 | 58.529 | 0.619 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 4 | 58.529 | 0.334 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 6 | 58.529 | 0.263 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 8 | 58.529 | 0.245 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 10 | 58.529 | 0.240 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 12 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 14 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 16 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 18 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 20 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 22 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 24 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 26 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 28 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 30 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 32 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 34 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 36 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 38 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 40 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 42 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 44 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 46 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 48 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 50 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 52 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 54 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 56 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 58 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 60 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 62 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 64 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 66 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 68 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 70 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 72 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 74 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 76 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 78 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 80 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 82 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 84 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 86 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 88 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 90 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 92 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 94 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 96 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| 98 | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |
| ** | 58.529 | 0.239 | 1.337 | 2.575 | 0.778 | 0.451 | 7106.2 | 209.8 |

Results of Neutral Axis Shift Calculation:

| | | | |
|---|---|---|---|
| Bearing Pressure on Concrete | | 209.81 | psi |
| Concrete Allowable Stress | | 4000.00 | psi |
| Stress developed in Bolt | | 7106.23 | psi |
| Allowable Bolt Stress | 20000.0 [Fact] | 20000.00 | psi |

Calculation of Basering Thickness, (N.A. Shift) [Tbna]:

```
  = Rw * sqrt( 3 * Scna / S) + CA per Jawad & Farr Eq. 12.12
  = 5.1391 * sqrt( 3 * 209.814/30000.0 ) + 0.063
  = 0.807 in
```

Required Thickness of Top Plate in Tension:
(Calculated as a fixed beam per Megyesy)

```
Ft = (Sa*Abss),        Bolt Allowable Stress * Area
Rm = (Ft * 2 * Cg)/8,  Bending Moment
Sb                     Allowable Bending Stress
Wt = (Topwth  -  Bnd), Width of Section
```

Required Thickness of Top Plate [T]:

```
  = sqrt( 6 * Rm / ( Sb * Wt )) + CA
  = sqrt( 6 * 19878/( 30000 * 3.4862 )) + 0.063
  = 1.131 in
```

Required Thickness of Top Chair Cap Plate per Moss:

```
   P  = (Sa*Abss)           Bolt Allowable Stress * Area
   e  = (Topwth-Bhole)/2    Distance to Edge of Hole
   Sb                       Allowable Bending Stress
   b  = Cg                  Gusset Plate Dimension
   db = Bhole               Bolt Hole Diameter
```

Top Chair Cap Plate Required Thickness [Tc]

```
  = ( P /( Sb * e ) * sqrt( 0.375 * b - 0.22 * db )) + CA
  = (39600/(30000*1.422)*sqrt(0.375*4.02-0.22*2.125))+0.063
  = 1.0446 in
```

Stress in the Top Plate at given Thickness [Stpl]:

```
  = P( 0.375 * b - 0.22 * db ) / e / ( Tta - Ca )²
  = 39600( 0.375 * 4.016 - 0.22 * 2.125)/1.422/( 1.575 - 0.063 )²
  = 12648.564 psi, must be less than 30000.0 psi
```

<u>Required Thickness of Gusset in Compression, per AISC E2-1:</u>

1. Allowed Compression at Given Thickness:

```
    Factor Kl/r Per E2-1                            36.0217
    Factor Cc Per E2-1                             122.7360
    Allowable Buckling Str. per E2-1               20503.00  psi
    Actual Buckling Str. at Given Thickness         4802.52  psi

 Required Gusset/Support Plate thickness, + CA       0.3467  in
```

2. Allowed Compression at Calculated Thickness:

```
    Factor Kl/r Per E2-1                            99.9898
    Factor Cc Per E2-1                             122.7360
    Allowable Buckling Str. per E2-1               13330.92  psi
    Act. Buckling Str. at Calculated Thickness     13330.92  psi
```

**Summary of Basering Thickness Calculations:**

```
 Required Basering Thickness (N.A. Shift)            0.8074  in
 Actual Basering Thickness                           1.2598  in

 Required Top Ring/Plate Thickness as a Fixed Beam   1.1309  in
 Required Thickness of Chair Cap per Moss/AISI       1.0446  in
 Actual Top Plate/Ring Thickness                     1.5748  in

 Required Gusset/Support Plate thickness, + CA       0.3467  in
 Actual Gusset/Support Plate Thickness               0.7874  in
```

<u>Local Stress at the Top Plate per AISI, including axial Stress [S]:</u>

```
  = Wmax*e/t²[1.32*Z/(1.43*Cmwth*(Hg+Tta)²/(R*Tskirt)
    + (4(Cmwth)(Hg+Tta)²)^.333 + 0.031 /sqrt(R*Tskirt)
  = 14070*2.75/0.36²[1.32*0.11/(1.43*7.01*(8.98)²/(14.64*0.36)
    +(4*7.01(8.19+ 0.79)²)^.333 + 0.031/sqrt(14.64* 0.36)
  = 4190.752 psi
```

Where [Z]:

```
  = 1/[(0.177*Wgp*Tba/sqrt(R*t))*(Tba/t)² + 1]
  = 1/[(0.177*7.008*1.26/sqrt(14.636*0.362))*(1.26/0.362)²+1]
  = 0.109
```

Where [e]:
```
  = ( Dc - Ds ) / 2
  = ( 35.5 - 29.997 )/2
  = 2.751 in
```

```
 Local Stress in the Skirt due to the Gussets            4190  psi
 Weight plus Bending Stress in the Skirt (Highest)       4029  psi
 Comb. loc. + bending stress  Worst Load Case            8219  psi
 Allowed membrane+bending stress( 1.5* Skirt All.)      30000  psi
```

**Weld Size Calculations per Steel Plate Engineering Data - Vol. 2**

Compute the Weld load at the Skirt/Base Junction [W]
```
  = SkirtStress * ( SkirtThickness - CA )
  = 4029.021 *( 0.394 - 0.031 )
  = 1459.33 lbf/in
```

Results for Computed Minimum Basering Weld Size [BWeld]
```
  = W / [( 0.4 * Yield ) * 2 * 0.707]
  = 1459/[( 0.4 * 31000 ) * 2 * 0.707]
  = 0.083 in
```

<u>Results for Computed Minimum Gusset and Top Plate to Skirt Weld Size</u>

Vertical Plate Load [Wv]
```
  = Bolt Load / ( Cmwth + 2 * ( Hg + Tta ) )
  = 39600.0/( 5.591 + 2 *( 8.188 + 1.575 ) )
  = 1576.675 lbf/in
```

Horizontal Plate Load [Wh]
```
  = Bolt Load * e / ( Cmwth * (Hg+Tta) + 0.6667 * (Hg+Tta)² )
  = 39600.0 * 2.751/(5.591 *(9.763) + 0.6667 *(9.763)² )
  = 922.37 lbf/in
```

Resultant Weld Load [Wr]
```
  = sqrt( Wv² + Wh²)
  = sqrt( 1576.67² + 922.37²)
  = 1826.655 lbf/in
```

Results for Computed Min Gusset and Top Plate to Skirt Weld Size [GsWeld]
```
  = Wr / [( 0.4 * Yield ) * 2 * 0.707]
  = 1826.65/[( 0.4 * 31000 ) * 2 * 0.707]
  = 0.104 in
```

<u>Results for Computed Minimum Gusset to Top Plate Weld Size</u>

Weld Load [Wv]
```
  = Bolt Load / ( 2 * TopWth )
  = 39600.0/( 2 * 5.236 )
  = 3781.512 lbf/in
```

Weld Load [Wh]
```
  = Bolt Load * e / ( 2 * Hgt * TopWth )
  = 39600.0 * 2.75/( 2 * 9.763 * 5.236 )
  = 1065.686 lbf/in
```

Resultant Weld Load [Wr]
```
  = sqrt( Wv² + Wh²)
  = sqrt( 3781.51² + 1065.69²)
  = 3928.807 lbf/in
```

Results for Computed Min Gusset to Top Plate Weld Size [GtpWeld]

```
  = Wr / [( 0.4 * Yield ) * 2 * 0.707]
  = 3928.81/[( 0.4 * 31000 ) * 2 * 0.707]
  = 0.224 in
```

Note: The calculated weld sizes need not exceed the component thickness framing into the weld. At the same time, the weld must meet a minimum size specification which is 3/16 in. (4.76 mm) or 1/4 in. (6.35 mm), depending on the component thickness.

**Summary of Required Weld Sizes:**

```
 Required Basering to Skirt Double Fillet Weld Size       0.1875  in
 Required Gusset to Skirt Double Fillet Weld Size         0.2500  in
 Required Top Plate to Skirt Weld Size                    0.2500  in
 Required Gusset to Top Plate Double Fillet Weld Size     0.2241  in
```

*Warning:*
*Please note that nozzle loadings, if included, are assumed to be local in nature and will not contribute to or create a net section bending moment. Therefore, the addition of nozzle loads will not affect the support load calculation. If you wish to create a load on the legs/lugs etc. from forces or moments, use the Force/Moment dialog and add the appropriate forces and moments at the correct locations in the model. Ensure that all supports are designed to take into account all possible loading conditions.*

**Input Echo, WRC107/537 Item 1, Description: Type-1 :**

| | | | |
|---|---|---|---|
| Diameter Basis for Vessel | Vbasis | ID | |
| Cylindrical or Spherical Vessel | Cylsph | Cylindrical | |
| Internal Corrosion Allowance | Cas | 0.0315 | in |
| Vessel Diameter | Dv | 29.250 | in |
| Vessel Thickness | Tv | 0.394 | in |
| Design Temperature | T1 | 500.0 | F |
| Vessel Material | | SA-240 316L | |
| Vessel UNS Number | | S31603 | |
| Vessel Cold S.I. Allowable | Smc | 16700.00 | psi |
| Vessel Hot S.I. Allowable | Smh | 14800.00 | psi |
| Attachment Type | Type | Rectangular | |
| Parameter C11 | C11 | 0.55 | in |
| Parameter C22 | C22 | 15.50 | in |
| Thickness of Reinforcing Pad | Tpad | 0.394 | in |
| Pad Parameter C11P | C11p | 3.268 | in |
| Pad Parameter C22P | C22p | 18.268 | in |
| Design Internal Pressure | Dp | 150.000 | psig |
| Include Pressure Thrust | | No | |

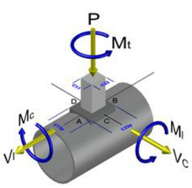
External Forces and Moments in WRC 107/537 Convention:

| | | | | |
|---|---|---|---|---|
| Radial Load | (SUS) | P | 500.0 | lbf |
| Longitudinal Shear | (SUS) | Vl | 3000.0 | lbf |
| Circumferential Shear | (SUS) | Vc | 500.0 | lbf |
| Circumferential Moment | (SUS) | Mc | 1000.0 | ft-lbf |
| Longitudinal Moment | (SUS) | Ml | 7500.0 | ft-lbf |
| Torsional Moment | (SUS) | Mt | 0.0 | ft-lbf |

| | | |
|---|---|---|
| Use Interactive Control | | No |
| WRC107 Version | Version | March 1979 |

| | |
|---|---|
| Include Pressure Stress Indices per Div. 2 | No |
| Compute Pressure Stress per WRC-368 | No |
| Local Loads applied at end of Nozzle/Attachment | No |

*WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".*




*WRC 107/537 has dimensional limitations that can be found in the bulletin's Foreword and which can also be inferred by review of the non-dimensional curve limits.*

WRC 107 Stress Calculation for SUStained loads:

| | | | |
|---|---|---|---|
| Radial Load | P | 500.0 | lbf |
| Circumferential Shear | VC | 500.0 | lbf |
| Longitudinal Shear | VL | 3000.0 | lbf |
| Circumferential Moment | MC | 1000.0 | ft-lbf |

**18-D-272**
**R06**
**V-1264**
**PV Elite 24        Licensee: THE ANUP ENGINEERING LIMITED.**
**FileName : V-1264_R06    -----------------------------------**
**WRC Clip Analysis: Type-1            Step:   23   4:21pm  Dec 21,2022**

```
Longitudinal Moment                        ML       7500.0   ft-lbf
Torsional Moment                           MT          0.0   ft-lbf

Dimensionless Parameters used :   Gamma = 19.89
```

**Dimensionless Loads for Cylindrical Shells at Attachment Junction:**

```
-------------------------------------------------------------------
Curves read for 1979             Beta  Figure    Value   Location
-------------------------------------------------------------------
N(PHI) / ( P/Rm )               0.157   4C        3.335   (A,B)
N(PHI) / ( P/Rm )               0.157   3C        2.808   (C,D)
M(PHI) / ( P )                  0.082   2C1       0.139   (A,B)
M(PHI) / ( P )                  0.082   1C        0.175   (C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )  0.056   3A  !     0.199   (A,B,C,D)
M(PHI) / ( MC/(Rm    * Beta) )  0.072   1A        0.103   (A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )  0.170   3B  !     2.167   (A,B,C,D)
M(PHI) / ( ML/(Rm    * Beta) )  0.152   1B        0.045   (A,B,C,D)

N(x)   / ( P/Rm )               0.122   3C        3.185   (A,B)
N(x)   / ( P/Rm )               0.122   4C        3.574   (C,D)
M(x)   / ( P )                  0.128   1C1       0.133   (A,B)
M(x)   / ( P )                  0.128   2C        0.096   (C,D)
N(x)   / ( MC/(Rm**2 * Beta) )  0.056   4A  !     0.255   (A,B,C,D)
M(x)   / ( MC/(Rm    * Beta) )  0.101   2A        0.058   (A,B,C,D)
N(x)   / ( ML/(Rm**2 * Beta) )  0.170   4B  !     0.666   (A,B,C,D)
M(x)   / ( ML/(Rm    * Beta) )  0.209   2B        0.056   (A,B,C,D)
```

Note - The ! mark next to the figure name denotes curve value exceeded.

Stress Concentration Factors: Kn = 1.00,   Kb = 1.00

**Stresses in the Vessel at the Attachment Junction (psi)**

| Type of Stress Load | Au | Al | Bu | Bl | Cu | Cl | Du | Dl |
|---|---|---|---|---|---|---|---|---|
| Circ. Memb. P | -146 | -146 | -146 | -146 | -123 | -123 | -123 | -123 |
| Circ. Bend. P | -729 | 729 | -729 | 729 | -917 | 917 | -917 | 917 |
| Circ. Memb. MC | 0 | 0 | 0 | 0 | -74 | -74 | 74 | 74 |
| Circ. Bend. MC | 0 | 0 | 0 | 0 | -11926 | 11926 | 11926 | -11926 |
| Circ. Memb. ML | -4513 | -4513 | 4513 | 4513 | 0 | 0 | 0 | 0 |
| Circ. Bend. ML | -18476 | 18476 | 18476 | -18476 | 0 | 0 | 0 | 0 |
| Tot. Circ. Str. | -23866 | 14545 | 22113 | -13379 | -13041 | 12646 | 10960 | -11058 |
| Long. Memb. P | -140 | -140 | -140 | -140 | -157 | -157 | -157 | -157 |
| Long. Bend. P | -699 | 699 | -699 | 699 | -502 | 502 | -502 | 502 |
| Long. Memb. MC | 0 | 0 | 0 | 0 | -156 | -156 | 156 | 156 |
| Long. Bend. MC | 0 | 0 | 0 | 0 | -4833 | 4833 | 4833 | -4833 |
| Long. Memb. ML | -2462 | -2462 | 2462 | 2462 | 0 | 0 | 0 | 0 |
| Long. Bend. ML | -16858 | 16858 | 16858 | -16858 | 0 | 0 | 0 | 0 |
| Tot. Long. Str. | -20160 | 14954 | 18480 | -13836 | -5649 | 5022 | 4330 | -4332 |
| Shear VC | 600 | 600 | -600 | -600 | 0 | 0 | 0 | 0 |
| Shear VL | 0 | 0 | 0 | 0 | -128 | -128 | 128 | 128 |
| Shear MT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

(Column group heading: Stress Intensity Values at)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Tot. Shear | 600 | 600 | -600 | -600 | -128 | -128 | 128 | 128 |
| Str. Int. | 23961 | 15384 | 22210 | 14249 | 13044 | 12648 | 10962 | 11061 |

Dimensionless Parameters used : Gamma = 40.96

### Dimensionless Loads for Cylindrical Shells at Pad Edge:

| Curves read for 1979 | Beta | Figure | Value | Location |
|---|---|---|---|---|
| N(PHI) / ( P/Rm ) | 0.397 | 4C | 3.547 | (A,B) |
| N(PHI) / ( P/Rm ) | 0.397 | 3C | 1.438 | (C,D) |
| M(PHI) / ( P ) | 0.226 | 2C1 | 0.028 | (A,B) |
| M(PHI) / ( P ) | 0.226 | 1C ! | 0.063 | (C,D) |
| N(PHI) / ( MC/(Rm**2 * Beta) ) | 0.195 | 3A ! | 1.656 | (A,B,C,D) |
| M(PHI) / ( MC/(Rm * Beta) ) | 0.246 | 1A | 0.070 | (A,B,C,D) |
| N(PHI) / ( ML/(Rm**2 * Beta) ) | 0.347 | 3B ! | 2.488 | (A,B,C,D) |
| M(PHI) / ( ML/(Rm * Beta) ) | 0.302 | 1B | 0.012 | (A,B,C,D) |
| N(x) / ( P/Rm ) | 0.317 | 3C | 2.017 | (A,B) |
| N(x) / ( P/Rm ) | 0.317 | 4C | 4.315 | (C,D) |
| M(x) / ( P ) | 0.332 | 1C1 | 0.032 | (A,B) |
| M(x) / ( P ) | 0.332 | 2C ! | 0.032 | (C,D) |
| N(x) / ( MC/(Rm**2 * Beta) ) | 0.195 | 4A ! | 3.151 | (A,B,C,D) |
| M(x) / ( MC/(Rm * Beta) ) | 0.328 | 2A | 0.026 | (A,B,C,D) |
| N(x) / ( ML/(Rm**2 * Beta) ) | 0.347 | 4B ! | 1.365 | (A,B,C,D) |
| M(x) / ( ML/(Rm * Beta) ) | 0.417 | 2B | 0.011 | (A,B,C,D) |

Note - The ! mark next to the figure name denotes curve value exceeded.

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

### Stresses in the Vessel at the Edge of Reinforcing Pad (psi)

| Type of Stress Load | Au | Al | Bu | Bl | Cu | Cl | Du | Dl |
|---|---|---|---|---|---|---|---|---|
| | Stress Intensity Values at | | | | | | | |
| Circ. Memb. P | -330 | -330 | -330 | -330 | -133 | -133 | -133 | -133 |
| Circ. Bend. P | -629 | 629 | -629 | 629 | -1435 | 1435 | -1435 | 1435 |
| Circ. Memb. MC | 0 | 0 | 0 | 0 | -300 | -300 | 300 | 300 |
| Circ. Bend. MC | 0 | 0 | 0 | 0 | -10461 | 10461 | 10461 | -10461 |
| Circ. Memb. ML | -5084 | -5084 | 5084 | 5084 | 0 | 0 | 0 | 0 |
| Circ. Bend. ML | -11338 | 11338 | 11338 | -11338 | 0 | 0 | 0 | 0 |
| Tot. Circ. Str. | -17381 | 6553 | 15462 | -5954 | -12331 | 11462 | 9192 | -8858 |
| Long. Memb. P | -187 | -187 | -187 | -187 | -401 | -401 | -401 | -401 |
| Long. Bend. P | -729 | 729 | -729 | 729 | -738 | 738 | -738 | 738 |
| Long. Memb. MC | 0 | 0 | 0 | 0 | -1134 | -1134 | 1134 | 1134 |
| Long. Bend. MC | 0 | 0 | 0 | 0 | -2923 | 2923 | 2923 | -2923 |
| Long. Memb. ML | -5100 | -5100 | 5100 | 5100 | 0 | 0 | 0 | 0 |
| Long. Bend. ML | -7579 | 7579 | 7579 | -7579 | 0 | 0 | 0 | 0 |
| Tot. Long. Str. | -13597 | 3021 | 11762 | -1937 | -5198 | 2126 | 2918 | -1451 |
| Shear VC | 211 | 211 | -211 | -211 | 0 | 0 | 0 | 0 |
| Shear VL | 0 | 0 | 0 | 0 | -226 | -226 | 226 | 226 |
| Shear MT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Tot. Shear | 211 | 211 | -211 | -211 | -226 | -226 | 226 | 226 |
| Str. Int. | 17393 | 6566 | 15474 | 5965 | 12338 | 11467 | 9200 | 8865 |

Note : The ratio Beta1/Beta2 for rectangular attachments was outside the range of values in tables 7 & 8 and was set to be an acceptable (maximum or minimum) value.

---

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (psi)**

| Type of Stress Load | Stress Intensity Values at Au | Al | Bu | Bl | Cu | Cl | Du | Dl |
|---|---|---|---|---|---|---|---|---|
| Circ. Pm (SUS) | 2835 | 2985 | 2835 | 2985 | 2835 | 2985 | 2835 | 2985 |
| Circ. Pl (SUS) | -4660 | -4660 | 4367 | 4367 | -197 | -197 | -49 | -49 |
| Circ. Q (SUS) | -19206 | 19206 | 17746 | -17746 | -12844 | 12844 | 11009 | -11009 |
| Long. Pm (SUS) | 1417 | 1417 | 1417 | 1417 | 1417 | 1417 | 1417 | 1417 |
| Long. Pl (SUS) | -2602 | -2602 | 2322 | 2322 | -313 | -313 | -1 | -1 |
| Long. Q (SUS) | -17557 | 17557 | 16158 | -16158 | -5335 | 5335 | 4331 | -4331 |
| Shear Pm (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Shear Pl (SUS) | 600 | 600 | -600 | -600 | -128 | -128 | 128 | 128 |
| Shear Q (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pm (SUS) | 2835 | 2985 | 2835 | 2985 | 2835 | 2985 | 2835 | 2985 |
| Pm+Pl (SUS) | 2185 | 2078 | 7303 | 7449 | 2648 | 2797 | 2797 | 2946 |
| Pm+Pl+Q (Total) | 21179 | 17785 | 25019 | 12582 | 10209 | 15633 | 13797 | 8076 |

**Vessel Stress Summation Comparison (psi):**

| Type of Stress Int. | Max. S.I. | S.I. Allowable | Result |
|---|---|---|---|
| Pm (SUS) | 2985 | 14800 | Passed |
| Pm+Pl (SUS) | 7449 | 22200 | Passed |
| Pm+Pl+Q (TOTAL) | 25019 | 44400 | Passed |

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

---

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Reinforcing Pad Edge (psi)**

| Type of Stress Load | Stress Intensity Values at Au | Al | Bu | Bl | Cu | Cl | Du | Dl |
|---|---|---|---|---|---|---|---|---|
| Circ. Pm (SUS) | 5995 | 6145 | 5995 | 6145 | 5995 | 6145 | 5995 | 6145 |
| Circ. Pl (SUS) | -5414 | -5414 | 4754 | 4754 | -434 | -434 | 166 | 166 |
| Circ. Q (SUS) | -11967 | 11967 | 10708 | -10708 | -11896 | 11896 | 9025 | -9025 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Long. Pm (SUS) | 2997 | 2997 | 2997 | 2997 | 2997 | 2997 | 2997 | 2997 |
| Long. Pl (SUS) | -5287 | -5287 | 4912 | 4912 | -1536 | -1536 | 733 | 733 |
| Long. Q (SUS) | -8309 | 8309 | 6850 | -6850 | -3662 | 3662 | 2185 | -2185 |
| Shear Pm (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Shear Pl (SUS) | 211 | 211 | -211 | -211 | -226 | -226 | 226 | 226 |
| Shear Q (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pm (SUS) | 5995 | 6145 | 5995 | 6145 | 5995 | 6145 | 5995 | 6145 |
| Pm+Pl (SUS) | 2902 | 3051 | 10765 | 10914 | 5573 | 5723 | 6183 | 6332 |
| Pm+Pl+Q (Total) | 11439 | 12706 | 21464 | 1108 | 6348 | 17612 | 15193 | 4282 |

**Vessel Stress Summation Comparison (psi):**

| Type of Stress Int. | Max. S.I. | S.I. Allowable | Result |
|---|---|---|---|
| Pm (SUS) | 6145 | 14800 | Passed |
| Pm+Pl (SUS) | 10914 | 22200 | Passed |
| Pm+Pl+Q (TOTAL) | 21464 | 44400 | Passed |

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

**Input, Nozzle Desc: Nozzle B2 2" From: 40**

| | | | |
|---|---|---|---|
| Pressure for Reinforcement Calculations | P | 151.619 | psig |
| Temperature for Internal Pressure | Temp | 500 | °F |
| Design External Pressure | Pext | 15.00 | psig |
| Temperature for External Pressure | Tempex | 300 | °F |
| | | | |
| Parent Material | | SA-240 316L | |
| Parent Allowable Stress at Temperature | Sv | 14800.00 | psi |
| Parent Allowable Stress At Ambient | Sva | 16700.00 | psi |
| | | | |
| Inside Diameter of Elliptical Head | D | 29.2500 | in |
| Aspect Ratio of Elliptical Head | Ar | 2.00 | |
| Head Finished (Minimum) Thickness | t | 0.3150 | in |
| Head Internal Corrosion Allowance | c | 0.0315 | in |
| Head External Corrosion Allowance | co | 0.0000 | in |
| | | | |
| Distance from Head Centerline | L1 | 0.0000 | in |
| | | | |
| User Entered Minimum Design Metal Temperature | | 32.00 | °F |

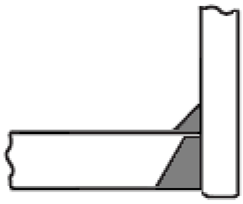
***Type of Element Connected to the Parent : Nozzle***

| | | | |
|---|---|---|---|
| Material | | SA-312 TP316L | |
| Material UNS Number | | S31603 | |
| Material Specification/Type | | Smls. pipe | |
| Allowable Stress at Temperature | Sn | 10900.00 | psi |
| Allowable Stress At Ambient | Sna | 16700.00 | psi |
| | | | |
| Diameter Basis (for tr calc only) | | Outside | |
| Layout Angle | | 0.00 | deg |
| Diameter | | 2.0000 | in. |
| | | | |
| Size and Thickness Basis | | Minimum | |
| Nominal Thickness | | 80S | |
| | | | |
| Flange Type | | Weld Neck Flange | |
| | | | |
| Corrosion Allowance | can | 0.0315 | in |
| Joint Efficiency of Shell Seam at Nozzle | E1 | 1.00 | |
| Joint Efficiency of Nozzle Neck | En | 1.00 | |
| | | | |
| Outside Projection | ho | 6.0000 | in |
| Weld leg size between Nozzle and Pad/Shell | Wo | 0.1960 | in |
| Groove weld depth between Nozzle and Vessel | Wgnv | 0.3140 | in |
| Inside Projection | h | 0.0000 | in |
| Weld leg size, Inside Element to Shell | Wi | 0.0000 | in |
| | | | |
| Flange Class | | 600 | |
| Flange Grade | | GR 2.3 | |
| | | | |
| Piping Exit Angle [North Clockwise reference] | | 90.0 | deg |
| Bend Radius Multiplier | | 1.50 | |
| Horizontal Run Length | | 28.0 | in |
| Centerline Distance to Tangent | | 77.0 | in |

The Pressure Design option was MAWP + static head (to the nozzle).

**Nozzle Sketch (may not represent actual weld type/configuration)**

**18-D-272**
**R06**
**V-1264**
**PV Elite 24        Licensee: THE ANUP ENGINEERING LIMITED.**
**FileName : V-1264_R06     -----------------------------------**
**Nozzle Calcs.: Nozzle B2 2"            Nozl:    27    4:21pm   Dec 21,2022**



**Insert/Set-in Nozzle No Pad, no Inside projection**

**Reinforcement CALCULATION, Description: Nozzle B2 2"**

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
Actual Outside Diameter Used in Calculation            2.375  in.
Actual Thickness Used in Calculation                   0.191  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Elliptical Head, tr [Int. Press]
```
  = P*D*K1/(2*Sv*E-0.2*P) per Appendix 1-4(c)
  = 0.9*151.619*29.313/(2*14800.0*1.0-0.2*151.62)
  = 0.1350 in
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Int. Press]
```
  = P*Ro/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = 151.62*1.1875/(10900*1.0+0.4*151.62)
  = 0.0164 in
```

Required Nozzle thickness under External Pressure per UG-28 :  0.0117  in

**UG-40, Limits of Reinforcement : [Internal Pressure]**
```
Parallel to Vessel Wall (Diameter Limit)            Dl     4.1130  in
Parallel to Vessel Wall, opening length              d     2.0565  in
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     0.3981  in
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 10900.0/14800.0 )
  = 0.736
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 10900.0/14800.0 )
  = 0.736
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 0.736, 1.0 )
  = 0.736
```

**Results of Nozzle Reinforcement Area Calculations: (in^2)**

| AREA AVAILABLE, A1 to A5 | | MAWP | External | Mapnc |
|---|---|---|---|---|
| Area Required | Ar | 0.289 | 0.087 | NA |
| Area in Shell | A1 | 0.293 | 0.399 | NA |

| | | | | |
|---|---|---|---|---|
| Area in Nozzle Wall | A2 | 0.084 | 0.087 | NA |
| Area in Inward Nozzle | A3 | 0.000 | 0.000 | NA |
| Area in Welds | A41+A42+A43 | 0.028 | 0.028 | NA |
| Area in Element | A5 | 0.000 | 0.000 | NA |
| TOTAL AREA AVAILABLE | Atot | 0.405 | 0.514 | NA |

The MAWP Case Governs the Analysis.

Nozzle Angle Used in Area Calculations    90.00  Degs.

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (2.0565*0.135*1.0+2*0.1593*0.135*1.0*(1-0.74))
  = 0.289 in^2
```

**Reinforcement Areas per Figure UG-37.1**

Area Available in Shell [A1]:
```
  = d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
  = 2.056( 1.0 * 0.2835 - 1.0 * 0.135 ) - 2 * 0.159
    ( 1.0 * 0.2835 - 1.0 * 0.135 ) *( 1 - 0.736 )
  = 0.293 in^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 0.398 )( 0.1593 - 0.0164 ) 0.7365
  = 0.084 in^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  =  0.196² * 0.7365 +( 0.0 )² * 0.7365
  = 0.028 in^2
```

**UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]**
```
 Wall Thickness for Internal/External pressures       ta = 0.0479 in
 Wall Thickness per UG16(b),                       tr16b = 0.0940 in
 Wall Thickness, shell/head, internal pressure      trb1 = 0.1814 in
 Wall Thickness                 tb1 = max(trb1, tr16b) = 0.1814 in
 Wall Thickness, shell/head, external pressure      trb2 = 0.0463 in
 Wall Thickness                 tb2 = max(trb2, tr16b) = 0.0940 in
 Wall Thickness per table UG-45                      tb3 = 0.1661 in
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.166, max( 0.1814, 0.094 ) ]
  = 0.1661 in
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 0.0479, 0.1661 )
  = 0.1661 in
```

Available Nozzle Neck Thickness = 0.1908 in --> OK

***Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):***
```
 Sustained  :    7013.9,  Allowable :  10900.0 psi   Passed
 Expansion  :       0.0,  Allowable :  27486.1 psi   Passed
 Occasional :     454.3,  Allowable :  14497.0 psi   Passed
```

```
 Shear      :   5044.1,  Allowable :   7630.0 psi  Passed
```

*The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

*SA-240 316L, Min Metal Temp without impact per UHA-51: -320 °F*

*SA-312 TP316L, Min Metal Temp without impact per UHA-51: -320 °F*

Note:
The flange pressure ratio is less than 0.35. Impact testing is not required due to low stress per UHA-51(g).

*Design Pressure/Ambient Rating = 151.62/1200.00 = 0.126*

Weld Size Calculations, Description: Nozzle B2 2"

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      0.1593  in
```

**Results Per UW-16.1:**

```
                           Required Thickness    Actual Thickness
 Nozzle Weld             0.1115 = 0.7 * tmin.   0.1386 = 0.7 * Wo in
```

**Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)**

Weld Load [W]:
```
  = max( 0,  (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0,( 0.2889 - 0.2929 + 2 * 0.1593 * 0.7365 *
    (1.0 * 0.2835 - 0.135 ) )14800)
  = 457.49 lbf
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 0.0838 + 0.0 + 0.0283 - 0.0 * 0.74 ) * 14800
  = 1658.38 lbf
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 0.0838 + 0.0 + 0.0283 +( 0.0665 ) ) * 14800
  = 2642.49 lbf
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = (  0.0838 + 0.0 + 0.0283 + 0.0 +( 0.0665 ) ) * 14800
  = 2642.49 lbf
```

**Strength of Connection Elements for Failure Path Analysis**

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 2.375 * 0.196 * 0.49 * 10900
  = 3905. lbf
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 1.1079) *( 0.1908 - 0.0315 ) * 0.7 * 10900
  = 4229. lbf
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 2.375 *( 0.315 - 0.0315 ) * 0.74 * 14800
  = 11582. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

**Strength of Failure Paths:**

Failure Path [Path 1-1]:

```
  = ( SONW + SNW ) = ( 3905 + 4229 ) = 8135 lbf
```

Failure Path [Path 2-2]:

```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 3905 + 0 + 11582 + 0 ) = 15487 lbf
```

Failure Path [Path 3-3]:

```
  = ( Sonw + Tngw + Sinw )
  = ( 3905 + 11582 + 0 ) = 15487 lbf
```

**Summary of Failure Path Calculations:**

```
 Path 1-1 = 8134    lbf, must exceed W = 457 lbf      or W1 = 1658 lbf
 Path 2-2 = 15487   lbf, must exceed W = 457 lbf      or W2 = 2642 lbf
 Path 3-3 = 15487   lbf, must exceed W = 457 lbf      or W3 = 2642 lbf
```

**Maximum Allowable Pressure for this Nozzle at this Location:**

```
 Converged Maximum Allowable Pressure in the Operating case: 183 psig

 Nozzle is O.K. for the External Pressure: 15 psig
```

The Drop for this Nozzle is : 0.0265 in
The Cut Length for this Nozzle is, Drop + Ho + H + T : 6.3415 in

**Input Echo, WRC107/537 Item    1,     Description: Nozzle B2 2"  :**

```
 Diameter Basis for Vessel                  Vbasis      ID
 Cylindrical or Spherical Vessel            Cylsph      Spherical
 Internal Corrosion Allowance                  Cas      0.0315  in
 Vessel Diameter                                Dv      52.650  in
 Vessel Thickness                               Tv       0.315  in

 Design Temperature                             T1       500.0  F
 Vessel Material                                   SA-240 316L
 Vessel UNS Number                                      S31603
 Vessel Cold S.I. Allowable                    Smc    16700.00  psi
 Vessel Hot  S.I. Allowable                    Smh    14800.00  psi

 Attachment Type                              Type      Round
 WRC107 Attachment Classification           Holsol      Hollow

 Diameter Basis for Nozzle                  Nbasis      OD
 Corrosion Allowance for Nozzle                Can      0.0315  in
 Nozzle Diameter                                Dn       2.375  in
 Nozzle Thickness                               Tn       0.191  in
 Nozzle Material                                 SA-312 TP316L
 Nozzle UNS Number                                      S31603
 Nozzle Cold S.I. Allowable                   SNmc    16700.00  psi
 Nozzle Hot  S.I. Allowable                   SNmh    10900.00  psi

 Design Internal Pressure                       Dp     151.619  psig
 Include Pressure Thrust                                    No
```

**18-D-272**
**R06**
**V-1264**
**PV Elite 24        Licensee: THE ANUP ENGINEERING LIMITED.**
**FileName : V-1264_R06    -----------------------------------**
**Nozzle Calcs.: Nozzle B2 2"           Nozl:    27    4:21pm  Dec 21,2022**

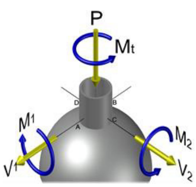
External Forces and Moments in WRC 107/537 Convention:

```
 Radial Load              (SUS)                  P      -630.0  lbf
 Longitudinal Shear       (SUS)           (Vl)  V1       630.0  lbf
 Circumferential Shear    (SUS)           (Vc)  V2       470.0  lbf
 Circumferential Moment   (SUS)           (Mc)  M1       210.0  ft-lbf
 Longitudinal Moment      (SUS)           (Ml)  M2       270.0  ft-lbf
 Torsional Moment         (SUS)                 Mt       310.0  ft-lbf


 Use Interactive Control                            No
 WRC107 Version                         Version  March   1979

 Include Pressure Stress Indices per Div. 2                 No
 Compute Pressure Stress per WRC-368                        No
 Local Loads applied at end of Nozzle/Attachment            No
```

*WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".*




*WRC 107/537 has dimensional limitations that can be found in the bulletin's Foreword and which can also be inferred by review of the non-dimensional curve limits.*

Stress Attenuation Diameter (for Insert Plates) per WRC 297:

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 2.375 + 2 * 1.65 * sqrt( 26.498 ( 0.315 - 0.031 ) )
  = 11.419 in
```

WRC 107 Stress Calculation for SUStained loads:

```
 Radial Load                                   P      -630.0  lbf
 Circumferential Shear                   (VC)  V2       470.0  lbf
 Longitudinal Shear                      (VL)  V1       630.0  lbf
 Circumferential Moment                  (MC)  M1       210.0  ft-lbf
 Longitudinal Moment                     (ML)  M2       270.0  ft-lbf
 Torsional Moment                              MT       310.0  ft-lbf

 Dimensionless Parameters: U =    0.43 TAU =    6.96 RHO =    1.78
```

**Dimensionless Loads for Spherical Shells at Attachment Junction:**

```
 -------------------------------------------------------------
 Curves read for 1979             Figure     Value    Location
 -------------------------------------------------------------
 N(x)  * T / P                     SP 2    0.07982   (A,B,C,D)
 M(x)      / P                     SP 2    0.06844   (A,B,C,D)
 N(x)  * T * SQRT(Rm * T ) / MC    SM 2    0.18588   (A,B,C,D)
 M(x)      * SQRT(Rm * T ) / MC    SM 2    0.18317   (A,B,C,D)
 N(x)  * T * SQRT(Rm * T ) / ML    SM 2    0.18588   (A,B,C,D)
 M(x)      * SQRT(Rm * T ) / ML    SM 2    0.18317   (A,B,C,D)

 N(y)  * T / P                     SP 2    0.20039   (A,B,C,D)
 M(y)      / P                     SP 2    0.05294   (A,B,C,D)
 N(y)  * T * SQRT(Rm * T ) / MC    SM 2    0.14008   (A,B,C,D)
 M(y)      * SQRT(Rm * T ) / MC    SM 2    0.19369   (A,B,C,D)
 N(y)  * T * SQRT(Rm * T ) / ML    SM 2    0.14008   (A,B,C,D)
```

M(y) * SQRT(Rm * T ) / ML SM 2 0.19369 (A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Attachment Junction (psi)**

| Type of Stress Load | Au | Al | Bu | Bl | Cu | Cl | Du | Dl |
|---|---|---|---|---|---|---|---|---|
| Rad. Memb. P | 625 | 625 | 625 | 625 | 625 | 625 | 625 | 625 |
| Rad. Bend. P | 3219 | -3219 | 3219 | -3219 | 3219 | -3219 | 3219 | -3219 |
| Rad. Memb. MC | 0 | 0 | 0 | 0 | -2127 | -2127 | 2127 | 2127 |
| Rad. Bend. MC | 0 | 0 | 0 | 0 | -12576 | 12576 | 12576 | -12576 |
| Rad. Memb. ML | -2734 | -2734 | 2734 | 2734 | 0 | 0 | 0 | 0 |
| Rad. Bend. ML | -16169 | 16169 | 16169 | -16169 | 0 | 0 | 0 | 0 |
| Tot. Rad. Str. | -15059 | 10841 | 22750 | -16028 | -10858 | 7855 | 18549 | -13043 |
| Tang. Memb. P | 1571 | 1571 | 1571 | 1571 | 1571 | 1571 | 1571 | 1571 |
| Tang. Bend. P | 2490 | -2490 | 2490 | -2490 | 2490 | -2490 | 2490 | -2490 |
| Tang. Memb. MC | 0 | 0 | 0 | 0 | -1602 | -1602 | 1602 | 1602 |
| Tang. Bend. MC | 0 | 0 | 0 | 0 | -13298 | 13298 | 13298 | -13298 |
| Tang. Memb. ML | -2060 | -2060 | 2060 | 2060 | 0 | 0 | 0 | 0 |
| Tang. Bend. ML | -17098 | 17098 | 17098 | -17098 | 0 | 0 | 0 | 0 |
| Tot. Tang. Str. | -15097 | 14118 | 23220 | -15956 | -10840 | 10776 | 18963 | -12615 |
| Shear VC | 444 | 444 | -444 | -444 | 0 | 0 | 0 | 0 |
| Shear VL | 0 | 0 | 0 | 0 | -595 | -595 | 595 | 595 |
| Shear MT | 1481 | 1481 | 1481 | 1481 | 1481 | 1481 | 1481 | 1481 |
| Tot. Shear | 1925 | 1925 | 1036 | 1036 | 885 | 885 | 2076 | 2076 |
| Str. Int. | 17004 | 15007 | 24048 | 17030 | 11734 | 11023 | 20843 | 14916 |

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (psi)**

| Type of Stress Load | Au | Al | Bu | Bl | Cu | Cl | Du | Dl |
|---|---|---|---|---|---|---|---|---|
| Rad. Pm (SUS) | 7049 | 7049 | 7049 | 7049 | 7049 | 7049 | 7049 | 7049 |
| Rad. Pl (SUS) | -2108 | -2108 | 3360 | 3360 | -1501 | -1501 | 2752 | 2752 |
| Rad. Q (SUS) | -12950 | 12950 | 19389 | -19389 | -9356 | 9356 | 15796 | -15796 |
| Long. Pm (SUS) | 7049 | 7049 | 7049 | 7049 | 7049 | 7049 | 7049 | 7049 |
| Long. Pl (SUS) | -489 | -489 | 3632 | 3632 | -31 | -31 | 3174 | 3174 |
| Long. Q (SUS) | -14607 | 14607 | 19588 | -19588 | -10808 | 10808 | 15789 | -15789 |
| Shear Pm (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Shear Pl (SUS) | 444 | 444 | -444 | -444 | -595 | -595 | 595 | 595 |
| Shear Q (SUS) | 1481 | 1481 | 1481 | 1481 | 1481 | 1481 | 1481 | 1481 |
| Pm (SUS) | 7049 | 7049 | 7049 | 7049 | 7049 | 7049 | 7049 | 7049 |
| Pm+Pl (SUS) | 6673 | 6673 | 11010 | 11010 | 7228 | 7228 | 10644 | 10644 |

```
Pm+Pl+Q (Total)|     9954|    22057|    31097|     9980|     4685|    18073|    27892|     7867|
```

**Vessel Stress Summation Comparison (psi):**

| Type of Stress Int. | Max. S.I. | S.I. Allowable | Result |
|---|---|---|---|
| Pm (SUS) | 7049 | 14800 | Passed |
| Pm+Pl (SUS) | 11010 | 22200 | Passed |
| Pm+Pl+Q (TOTAL) | 31097 | 44400 | Passed |

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

**Input, Nozzle Desc: Nozzle LT2 2"    From: 50**

| | | | |
|---|---|---|---|
| Pressure for Reinforcement Calculations | P | 151.073 | psig |
| Temperature for Internal Pressure | Temp | 500 | °F |
| Design External Pressure | Pext | 15.00 | psig |
| Temperature for External Pressure | Tempex | 300 | °F |
| Parent Material | | SA-240 316L | |
| Parent Allowable Stress at Temperature | Sv | 14800.00 | psi |
| Parent Allowable Stress At Ambient | Sva | 16700.00 | psi |
| Inside Diameter of Cylindrical Shell | D | 29.2500 | in |
| Design Length of Section | L | 118.5000 | in |
| Shell Finished (Minimum) Thickness | t | 0.3937 | in |
| Shell Internal Corrosion Allowance | c | 0.0315 | in |
| Shell External Corrosion Allowance | co | 0.0000 | in |
| Distance from Bottom/Left Tangent | | 0.66 | ft |
| User Entered Minimum Design Metal Temperature | | 32.00 | °F |

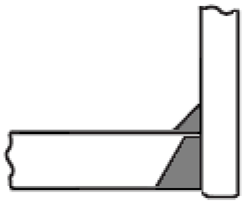
***Type of Element Connected to the Parent : Nozzle***

| | | | |
|---|---|---|---|
| Material | | SA-182 F316L | |
| Material UNS Number | | S31603 | |
| Material Specification/Type | | Forgings | |
| Allowable Stress at Temperature | Sn | 10900.00 | psi |
| Allowable Stress At Ambient | Sna | 16700.00 | psi |
| Diameter Basis (for tr calc only) | | Inside | |
| Layout Angle | | 330.00 | deg |
| Diameter | | 2.0000 | in. |
| Size and Thickness Basis | | Actual | |
| Actual Thickness | tn | 0.6563 | in |
| Flange Type | | Long Weld Neck | |
| Corrosion Allowance | can | 0.0000 | in |
| Joint Efficiency of Shell Seam at Nozzle | E1 | 1.00 | |
| Joint Efficiency of Nozzle Neck | En | 1.00 | |
| Outside Projection | ho | 7.1050 | in |
| Weld leg size between Nozzle and Pad/Shell | Wo | 0.3543 | in |
| Groove weld depth between Nozzle and Vessel | Wgnv | 0.3900 | in |
| Inside Projection | h | 0.0000 | in |
| Weld leg size, Inside Element to Shell | Wi | 0.0000 | in |
| Flange Class | | 300 | |
| Flange Grade | | GR 2.3 | |

The Pressure Design option was MAWP + static head (to the nozzle).

**Nozzle Sketch (may not represent actual weld type/configuration)**

**18-D-272**
**R06**
**V-1264**
**PV Elite 24        Licensee: THE ANUP ENGINEERING LIMITED.**
**FileName : V-1264_R06    -----------------------------------**
**Nozzle Calcs.: Nozzle LT2 2"          Nozl:    28    4:21pm   Dec 21,2022**



**Insert/Set-in Nozzle No Pad, no Inside projection**

**Reinforcement CALCULATION, Description: Nozzle LT2 2"**

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
 Actual Inside Diameter Used in Calculation              2.000  in.
 Actual Thickness Used in Calculation                    0.656  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Int. Press]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 151.07*14.6565/(14800*1.0-0.6*151.07)
  = 0.1505 in
```

Reqd thk per App. 1 of Nozzle Wall, trn [Int. Press]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 1.0(exp([151.07/(10900.0*1.0]-1)
  = 0.0140 in
```

Required Nozzle thickness under External Pressure per UG-28 :  0.0151  in

**UG-40, Limits of Reinforcement : [Internal Pressure]**
```
 Parallel to Vessel Wall (Diameter Limit)            Dl     4.0370  in
 Parallel to Vessel Wall                        Rn+tn+t     2.0185  in
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     0.9055  in
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 10900.0/14800.0 )
  = 0.736
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 10900.0/14800.0 )
  = 0.736
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 0.736, 1.0 )
  = 0.736
```

**Results of Nozzle Reinforcement Area Calculations: (in^2)**

| AREA AVAILABLE, A1 to A5 | | MAWP | External | Mapnc |
|---|---|---|---|---|
| Area Required | Ar | 0.353 | 0.208 | NA |
| Area in Shell | A1 | 0.358 | 0.313 | NA |

```
 Area in Nozzle Wall          A2 |      0.857|      0.855|        NA|
 Area in Inward Nozzle        A3 |      0.000|      0.000|        NA|
 Area in Welds      A41+A42+A43 |      0.092|      0.092|        NA|
 Area in Element              A5 |      0.000|      0.000|        NA|
 TOTAL AREA AVAILABLE       Atot |      1.307|      1.261|        NA|
```

The MAWP Case Governs the Analysis.

```
 Nozzle Angle Used in Area Calculations                  90.00  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (2.0*0.1505*1.0+2*0.6563*0.1505*1.0*(1-0.74))
  = 0.353 in^2
```

**Reinforcement Areas per Figure UG-37.1**

Area Available in Shell [A1]:
```
  = d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
  = 2.037( 1.0 * 0.3622 - 1.0 * 0.151 ) - 2 * 0.656
    ( 1.0 * 0.3622 - 1.0 * 0.1505 ) *( 1 - 0.736 )
  = 0.358 in^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 0.906 )( 0.6563 - 0.014 ) 0.7365
  = 0.857 in^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  =  0.3543² * 0.7365 +( 0.0 )² * 0.7365
  = 0.092 in^2
```

**UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]**
```
 Wall Thickness for Internal/External pressures       ta = 0.0151 in
 Wall Thickness per UG16(b),                       tr16b = 0.0940 in
 Wall Thickness, shell/head, internal pressure      trb1 = 0.1820 in
 Wall Thickness                 tb1 = max(trb1, tr16b) = 0.1820 in
 Wall Thickness, shell/head, external pressure      trb2 = 0.0464 in
 Wall Thickness                 tb2 = max(trb2, tr16b) = 0.0940 in
 Wall Thickness per table UG-45                      tb3 = 0.1890 in
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.189, max( 0.182, 0.094 ) ]
  = 0.1820 in
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 0.0151, 0.182 )
  = 0.1820 in
```

Available Nozzle Neck Thickness = 0.6563 in --> OK

***Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):***
```
 Sustained  :   1298.1,  Allowable :  10900.0 psi   Passed
 Expansion  :      0.0,  Allowable :  33201.9 psi   Passed
 Occasional :     86.7,  Allowable :  14497.0 psi   Passed
```

```
 Shear      :   1283.3,  Allowable :   7630.0 psi  Passed
```

*The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

*SA-240 316L, Min Metal Temp without impact per UHA-51:  -320 °F*

*SA-182 F316L, Min Metal Temp without impact per UHA-51:  -320 °F*

Note:
The flange pressure ratio is less than 0.35.  Impact testing is not required due to low stress per UHA-51(g).

*Design Pressure/Ambient Rating = 151.07/600.00 = 0.252*

Weld Size Calculations, Description: Nozzle LT2 2"

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      0.3622  in
```

**Results Per UW-16.1:**

```
                          Required Thickness    Actual Thickness
 Nozzle Weld            0.2500 = Min per Code 0.2505 = 0.7 * Wo in
```

**Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)**

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0,( 0.3531 - 0.358 + 2 * 0.6563 * 0.7365 *
    (1.0 * 0.3622 - 0.1505 ) )14800)
  = 2956.87 lbf
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 0.8568 + 0.0 + 0.0925 - 0.0 * 0.74 ) * 14800
  = 14048.45 lbf
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 0.8568 + 0.0 + 0.0925 +( 0.3501 ) ) * 14800
  = 19230.63 lbf
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = (  0.8568 + 0.0 + 0.0925 + 0.0 +( 0.3501 ) ) * 14800
  = 19230.63 lbf
```

**Strength of Connection Elements for Failure Path Analysis**

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 3.3126 * 0.3543 * 0.49 * 10900
  = 9847. lbf
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 1.3281) *( 0.6563 - 0.0 ) * 0.7 * 10900
  = 20894. lbf
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 3.3126 *( 0.3937 - 0.0315 ) * 0.74 * 14800
  = 20641. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

**Strength of Failure Paths:**

Failure Path [Path 1-1]:

```
  = ( SONW + SNW ) = ( 9847 + 20894 ) = 30741 lbf
```

Failure Path [Path 2-2]:

```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 9847 + 0 + 20641 + 0 ) = 30489 lbf
```

Failure Path [Path 3-3]:

```
  = ( Sonw + Tngw + Sinw )
  = ( 9847 + 20641 + 0 ) = 30489 lbf
```

**Summary of Failure Path Calculations:**

```
 Path 1-1 = 30741   lbf, must exceed W = 2956 lbf     or W1 = 14048 lbf
 Path 2-2 = 30488   lbf, must exceed W = 2956 lbf     or W2 = 19230 lbf
 Path 3-3 = 30488   lbf, must exceed W = 2956 lbf     or W3 = 19230 lbf
```

**Maximum Allowable Pressure for this Nozzle at this Location:**

Converged Maximum Allowable Pressure in the Operating case: 359 psig

Note: The MAWP of this junction was limited by the parent Shell/Head.

Nozzle is O.K. for the External Pressure: 15 psig

The Drop for this Nozzle is : 0.0941 in
The Cut Length for this Nozzle is, Drop + Ho + H + T : 7.5928 in

**Input Echo, WRC297 Item 1, Description: Nozzle LT2 2" :**

```
 Diameter Basis for Cylindrical Shell                        ID
 Shell Corrosion Allowance                                   0.0315  in
 Shell Diameter                                              29.250  in
 Shell Thickness                                             0.3937  in
 Shell Stress Concentration Factor                            1.000
 Vessel Material                                        SA-240 316L
 Vessel Cold S.I. Allowable                     Smc     16700.00  psi
 Vessel Hot  S.I. Allowable                     Smh     14800.00  psi

 Diameter Basis for Nozzle                                   ID
 Nozzle Corrosion Allowance                                  0.0000  in
 Nozzle Diameter                                              2.000  in
 Nozzle Thickness                                            0.6563  in
 Nozzle Stress Concentration Factor                           1.000
 Nozzle Material                                       SA-182 F316L
 Nozzle Cold S.I. Allowable                    SNmc     16700.00  psi
 Nozzle Hot  S.I. Allowable                    SNmh     10900.00  psi
```

Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-182 F316L

*Note:*
*External Forces and Moments in WRC 107/537 Convention:*

*These loads are assumed to be SUStained loads.*

| | | | |
|---|---|---|---|
| Design Internal Pressure | Dp | 151.07 | psig |
| Radial Load | P | -630.00 | lbf |
| Circumferential Shear | Vc | 470.00 | lbf |
| Longitudinal Shear | Vl | 630.00 | lbf |
| Circumferential Moment | Mc | 210.00 | ft-lbf |
| Longitudinal Moment | Ml | 270.00 | ft-lbf |
| Torsional Moment | Mt | 310.00 | ft-lbf |

| | |
|---|---|
| Include Axial Pressure Thrust | No |
| Include Pressure Stress Indices per Div. 2 | No |
| Local Loads applied at end of Nozzle/Attachment | No |

*Warning - The ratio, Dn/Tn (5.047) is < 10*
*check the limitations of WRC bulletin 297.*

**Stress Computations at the Edge of the Nozzle:**

Stress Attenuation Diameter (for Insert Plates) per WRC 297:
= NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
= 3.313 + 2 * 1.65 * sqrt( 14.838( 0.394 - 0.031 ) )
= 10.963 in

WRC 297 Curve Access Parameters:

| | | | |
|---|---|---|---|
| Vessel Mean Diameter | (D) = | 29.675 | in |
| Nozzle Outside Diameter | (d) = | 3.313 | in |
| Vessel Thickness used | (T) = | 0.362 | in |
| Nozzle Thickness used | (t) = | 0.656 | in |
| T / t | = | 0.552 | |
| d / t | = | 10.000 | |

Lambda = [(d/D) * sqrt(D/T)]  = 1.010

| | | |
|---|---|---|
| Nr/P | = | 0.106 |
| Mr/P | = | 0.218 |
| M0/P | = | 0.065 |
| N0/P | = | 0.132 |
| MrD/Mc | = | 0.304 |
| NrDL/Mc | = | 0.097 |
| M0d/Mc | = | 0.097 |
| N0DL/Mc | = | 0.031 |
| MrD/Ml | = | 0.195 |
| NrDL/Ml | = | 0.090 |
| M0D/Ml | = | 0.064 |
| N0DL/Ml | = | 0.120 |

***Vessel Stresses (psi):***

| LONGITUDINAL PLANE (Stresses Normal to longitudinal plane) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Outplane Membrane (P ) | 634 | 634 | 634 | 634 |
| Outplane Bending (P ) | 1877 | -1877 | 1877 | -1877 |
| Outplane Membrane (Mc) | 0 | 0 | 0 | 0 |
| Outplane Bending (Mc) | 0 | 0 | 0 | 0 |
| Outplane Membrane (ML) | -891 | -891 | 891 | 891 |
| Outplane Bending (ML) | -2871 | 2871 | 2871 | -2871 |
| Normal Pressure Stress | 6038 | 6189 | 6038 | 6189 |

| | | | | |
|---|---|---|---|---|
| Outplane Stress Summary | 4787 | 6926 | 12311 | 2966 |

***Vessel Stresses (psi):***

| LONGITUDINAL PLANE (Stresses parallel to longitudinal plane) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Inplane Membrane (P ) | 510 | 510 | 510 | 510 |
| Inplane Bending (P ) | 6293 | -6293 | 6293 | -6293 |
| Inplane Membrane (Mc) | 0 | 0 | 0 | 0 |
| Inplane Bending (Mc) | 0 | 0 | 0 | 0 |
| Inplane Membrane (ML) | -669 | -669 | 669 | 669 |
| Inplane Bending (ML) | -8720 | 8720 | 8720 | -8720 |
| Inplane Pressure Stress | 3019 | 3019 | 3019 | 3019 |
| Inplane Stress Summary | 433 | 5287 | 19211 | -10815 |

***Vessel Stresses (psi):***

| LONGITUDINAL PLANE (Shear stress normal to longitudinal plane) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Outplane Shear (Vc) | 249 | 249 | -249 | -249 |
| Outplane Shear (Vl) | 0 | 0 | 0 | 0 |
| Outplane Shear (Mt) | 595 | 595 | 595 | 595 |
| Shear Stress Summary | 844 | 844 | 346 | 346 |

***Vessel Stresses (psi):***

| LONGITUDINAL PLANE (Stress Intensities | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 4944 | 7282 | 19228 | 13798 |

***Vessel Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stresses Normal to circumferential plane) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Outplane Membrane (P ) | 634 | 634 | 634 | 634 |
| Outplane Bending (P ) | 1877 | -1877 | 1877 | -1877 |
| Outplane Membrane (Mc) | -181 | -181 | 181 | 181 |
| Outplane Bending (Mc) | -3389 | 3389 | 3389 | -3389 |
| Outplane Membrane (ML) | 0 | 0 | 0 | 0 |
| Outplane Bending (ML) | 0 | 0 | 0 | 0 |
| Normal Pressure Stress | 3019 | 3019 | 3019 | 3019 |
| Outplane Stress Summary | 1960 | 4984 | 9100 | -1432 |

***Vessel Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stresses parallel to circumferential plane) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Inplane Membrane (P ) | 510 | 510 | 510 | 510 |
| Inplane Bending (P ) | 6293 | -6293 | 6293 | -6293 |
| Inplane Membrane (Mc) | -562 | -562 | 562 | 562 |
| Inplane Bending (Mc) | -10562 | 10562 | 10562 | -10562 |
| Inplane Membrane (ML) | 0 | 0 | 0 | 0 |
| Inplane Bending (ML) | 0 | 0 | 0 | 0 |

| | | | | |
|---|---|---|---|---|
| Inplane Pressure Stress | 6038 | 6189 | 6038 | 6189 |
| Inplane Stress Summary | 1717 | 10406 | 23965 | -9594 |

***Vessel Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Shear stress normal to circumferential plane) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Outplane Shear (Vc) | 0 | 0 | 0 | 0 |
| Outplane Shear (Vl) | -334 | -334 | 334 | 334 |
| Torsional Shear (Mt) | 595 | 595 | 595 | 595 |
| Shear Stress Summary | 261 | 261 | 929 | 929 |

***Vessel Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stress Intensities | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 2126 | 10418 | 24022 | 9698 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Stresses in the hoop direction) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Hoop Membrane (P ) | 634 | 634 | 634 | 634 |
| Hoop Bending (P ) | 0 | 0 | 0 | 0 |
| Hoop Membrane (Mc) | 0 | 0 | 0 | 0 |
| Hoop Bending (Mc) | 0 | 0 | 0 | 0 |
| Hoop Membrane (ML) | -891 | -891 | 891 | 891 |
| Hoop Bending (ML) | 0 | 0 | 0 | 0 |
| Hoop Pressure Stress | 207 | 389 | 207 | 389 |
| Hoop Stress Summary | -50 | 132 | 1732 | 1914 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Stresses Normal to pipe cross-section) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Axial Membrane (P ) | 115 | 115 | 115 | 115 |
| Axial Bending (P ) | 1450 | -1450 | 1450 | -1450 |
| Axial Membrane (Mc) | 0 | 0 | 0 | 0 |
| Axial Bending (Mc) | 0 | 0 | 0 | 0 |
| Axial Membrane (ML) | -1047 | -1047 | 1047 | 1047 |
| Axial Bending (ML) | -2044 | 2044 | 2044 | -2044 |
| Axial Pressure Stress | 103 | 103 | 103 | 103 |
| Axial Stress Summary | -1423 | -235 | 4759 | -2229 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Shear stress) | Au Outside | Al Inside | Bu Outside | Bl Inside |
|---|---|---|---|---|
| Shear due to (Vc) | 137 | 137 | -137 | -137 |
| Shear due to (Vl) | 0 | 0 | 0 | 0 |
| Shear due to Torsion | 328 | 328 | 328 | 328 |
| Shear Stress Summary | 465 | 465 | 191 | 191 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Stress Intensities | Au Outside | Al Inside | Bu Outside | Bl Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 1658 | 999 | 4771 | 4160 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stresses in the hoop direction) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Hoop Membrane (P ) | 634 | 634 | 634 | 634 |
| Hoop Bending (P ) | 0 | 0 | 0 | 0 |
| Hoop Membrane (Mc) | -181 | -181 | 181 | 181 |
| Hoop Bending (Mc) | 0 | 0 | 0 | 0 |
| Hoop Membrane (ML) | 0 | 0 | 0 | 0 |
| Hoop Bending (ML) | 0 | 0 | 0 | 0 |
| Hoop Pressure Stress | 207 | 389 | 207 | 389 |
| Hoop Stress Summary | 660 | 842 | 1022 | 1204 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stresses Normal to pipe cross-section) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Axial Membrane (P ) | 115 | 115 | 115 | 115 |
| Axial Bending (P ) | 1450 | -1450 | 1450 | -1450 |
| Axial Membrane (Mc) | -814 | -814 | 814 | 814 |
| Axial Bending (Mc) | -2703 | 2703 | 2703 | -2703 |
| Axial Membrane (ML) | 0 | 0 | 0 | 0 |
| Axial Bending (ML) | 0 | 0 | 0 | 0 |
| Axial Pressure Stress | 103 | 103 | 103 | 103 |
| Axial Stress Summary | -1849 | 657 | 5185 | -3121 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Shear stress) | Cu Outside | Cl Inside | Du Outside | Dl Inside |
|---|---|---|---|---|
| Shear due to (Vc) | 0 | 0 | 0 | 0 |
| Shear due to (Vl) | -184 | -184 | 184 | 184 |
| Shear due to Torsion | 328 | 328 | 328 | 328 |
| Shear Stress Summary | 144 | 144 | 512 | 512 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stress Intensities | Cu Outside | Cl Inside | Du Outside | Dl Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 2525 | 920 | 5247 | 4444 |

**WRC 297 Stress Summations per ASME Sec. VIII Div. 2:**

**Vessel Stress Summation at Vessel-Nozzle Junction (psi):**

| Type of Stress Int. Location | Stress Values at Au | Al | Bu | Bl | Cu | Cl | Du | Dl |
|---|---|---|---|---|---|---|---|---|

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Circ. Pm (SUS) | 6038 | 6189 | 6038 | 6189 | 6038 | 6189 | 6038 | 6189 |
| Circ. Pl (SUS) | -257 | -257 | 1525 | 1525 | -52 | -52 | 1072 | 1072 |
| Circ. Q (SUS) | -994 | 994 | 4748 | -4748 | -4269 | 4269 | 16855 | -16855 |
| Long. Pm (SUS) | 3019 | 3019 | 3019 | 3019 | 3019 | 3019 | 3019 | 3019 |
| Long. Pl (SUS) | -159 | -159 | 1179 | 1179 | 453 | 453 | 815 | 815 |
| Long. Q (SUS) | -2427 | 2427 | 15013 | -15013 | -1512 | 1512 | 5266 | -5266 |
| Shear Pm (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Shear Pl (SUS) | 249 | 249 | -249 | -249 | -334 | -334 | 334 | 334 |
| Shear Q (SUS) | 595 | 595 | 595 | 595 | 595 | 595 | 595 | 595 |
| Pm (SUS) | 6038 | 6189 | 6038 | 6189 | 6038 | 6189 | 6038 | 6189 |
| Pm+Pl (SUS) | 5802 | 5952 | 7581 | 7731 | 6029 | 6178 | 7143 | 7293 |
| Pm+Pl+Q (Total) | 4944 | 7282 | 19228 | 13798 | 2126 | 10418 | 24022 | 9698 |

**Vessel Stress Summation Comparison (psi):**

| Type of Stress Int. | Max. S.I. | S.I. Allowable | Result |
|---|---|---|---|
| Pm (SUS) | 6189 | 14800 | Passed |
| Pm+Pl (SUS) | 7731 | 22200 | Passed |
| Pm+Pl+Q (TOTAL) | 24022 | 44400 | Passed |

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

**WRC 297 Stress Summations per ASME Sec. VIII Div. 2:**

**Nozzle Stress Summation at Vessel-Nozzle Junction (psi):**

| Type of Stress Int. Location | Au | Al | Bu | Bl | Cu | Cl | Du | Dl |
|---|---|---|---|---|---|---|---|---|
| Circ. Pm (SUS) | 207 | 389 | 207 | 389 | 207 | 389 | 207 | 389 |
| Circ. Pl (SUS) | -257 | -257 | 1525 | 1525 | 453 | 453 | 815 | 815 |
| Circ. Q (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Long. Pm (SUS) | 103 | 103 | 103 | 103 | 103 | 103 | 103 | 103 |
| Long. Pl (SUS) | -932 | -932 | 1162 | 1162 | -699 | -699 | 929 | 929 |
| Long. Q (SUS) | -594 | 594 | 3494 | -3494 | -1253 | 1253 | 4153 | -4153 |
| Shear Pm (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Shear Pl (SUS) | 137 | 137 | -137 | -137 | -184 | -184 | 184 | 184 |
| Shear Q (SUS) | 328 | 328 | 328 | 328 | 328 | 328 | 328 | 328 |
| Pm (SUS) | 207 | 389 | 207 | 389 | 207 | 389 | 207 | 389 |
| Pm+Pl (SUS) | 852 | 999 | 1769 | 1941 | 1308 | 1484 | 1211 | 1321 |
| Pm+Pl+Q (Total) | 1658 | 999 | 4771 | 4160 | 2525 | 920 | 5247 | 4444 |

**Nozzle Stress Summation Comparison (psi):**

| Type of Stress Int. | Max. S.I. | S.I. Allowable | Result |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Pm (SUS) | 389 | 10900 | Passed |
| Pm+Pl (SUS) | 1941 | 16350 | Passed |
| Pm+Pl+Q (TOTAL) | 5247 | 32700 | Passed |

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

**Input, Nozzle Desc: Nozzle L2 2" From: 50**

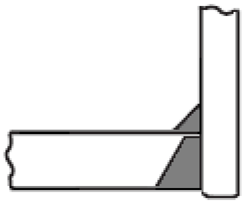
| | | | |
|---|---|---|---|
| Pressure for Reinforcement Calculations | P | 151.073 | psig |
| Temperature for Internal Pressure | Temp | 500 | °F |
| Design External Pressure | Pext | 15.00 | psig |
| Temperature for External Pressure | Tempex | 300 | °F |
| | | | |
| Parent Material | | SA-240 316L | |
| Parent Allowable Stress at Temperature | Sv | 14800.00 | psi |
| Parent Allowable Stress At Ambient | Sva | 16700.00 | psi |
| | | | |
| Inside Diameter of Cylindrical Shell | D | 29.2500 | in |
| Design Length of Section | L | 118.5000 | in |
| Shell Finished (Minimum) Thickness | t | 0.3937 | in |
| Shell Internal Corrosion Allowance | c | 0.0315 | in |
| Shell External Corrosion Allowance | co | 0.0000 | in |
| | | | |
| Distance from Bottom/Left Tangent | | 0.66 | ft |
| | | | |
| User Entered Minimum Design Metal Temperature | | 32.00 | °F |

***Type of Element Connected to the Parent : Nozzle***

| | | | |
|---|---|---|---|
| Material | | SA-182 F316L | |
| Material UNS Number | | S31603 | |
| Material Specification/Type | | Forgings | |
| Allowable Stress at Temperature | Sn | 10900.00 | psi |
| Allowable Stress At Ambient | Sna | 16700.00 | psi |
| | | | |
| Diameter Basis (for tr calc only) | | Inside | |
| Layout Angle | | 225.00 | deg |
| Diameter | | 2.0000 | in. |
| | | | |
| Size and Thickness Basis | | Actual | |
| Actual Thickness | tn | 0.6563 | in |
| | | | |
| Flange Type | | Long Weld Neck | |
| | | | |
| Corrosion Allowance | can | 0.0000 | in |
| Joint Efficiency of Shell Seam at Nozzle | E1 | 1.00 | |
| Joint Efficiency of Nozzle Neck | En | 1.00 | |
| | | | |
| Outside Projection | ho | 7.1050 | in |
| Weld leg size between Nozzle and Pad/Shell | Wo | 0.3540 | in |
| Groove weld depth between Nozzle and Vessel | Wgnv | 0.3900 | in |
| Inside Projection | h | 0.0000 | in |
| Weld leg size, Inside Element to Shell | Wi | 0.0000 | in |
| | | | |
| Flange Class | | 600 | |
| Flange Grade | | GR 2.3 | |

The Pressure Design option was MAWP + static head (to the nozzle).

**Nozzle Sketch (may not represent actual weld type/configuration)**



**Insert/Set-in Nozzle No Pad, no Inside projection**

**Reinforcement CALCULATION, Description: Nozzle L2 2"**

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
 Actual Inside Diameter Used in Calculation              2.000  in.
 Actual Thickness Used in Calculation                    0.656  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Int. Press]

```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 151.07*14.6565/(14800*1.0-0.6*151.07)
  = 0.1505 in
```

Reqd thk per App. 1 of Nozzle Wall, trn [Int. Press]

```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 1.0(exp([151.07/(10900.0*1.0]-1)
  = 0.0140 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0151 in

**UG-40, Limits of Reinforcement : [Internal Pressure]**

```
 Parallel to Vessel Wall (Diameter Limit)            Dl     4.0370  in
 Parallel to Vessel Wall                       Rn+tn+t     2.0185  in
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     0.9055  in
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 10900.0/14800.0 )
  = 0.736
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 10900.0/14800.0 )
  = 0.736
```

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 0.736, 1.0 )
  = 0.736
```

**Results of Nozzle Reinforcement Area Calculations: (in^2)**

| AREA AVAILABLE, A1 to A5 | | MAWP | External | Mapnc |
|---|---|---|---|---|
| Area Required | Ar | 0.353 | 0.208 | NA |
| Area in Shell | A1 | 0.358 | 0.313 | NA |

```
 Area in Nozzle Wall       A2 |     0.857|     0.855|        NA|
 Area in Inward Nozzle     A3 |     0.000|     0.000|        NA|
 Area in Welds    A41+A42+A43 |     0.092|     0.092|        NA|
 Area in Element           A5 |     0.000|     0.000|        NA|
 TOTAL AREA AVAILABLE    Atot |     1.307|     1.261|        NA|
```

The MAWP Case Governs the Analysis.

```
 Nozzle Angle Used in Area Calculations                  90.00  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (2.0*0.1505*1.0+2*0.6563*0.1505*1.0*(1-0.74))
  = 0.353 in^2
```

**Reinforcement Areas per Figure UG-37.1**

Area Available in Shell [A1]:
```
  = d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
  = 2.037( 1.0 * 0.3622 - 1.0 * 0.151 ) - 2 * 0.656
    ( 1.0 * 0.3622 - 1.0 * 0.1505 ) *( 1 - 0.736 )
  = 0.358 in^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 0.906 )( 0.6563 - 0.014 ) 0.7365
  = 0.857 in^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  =  0.354² * 0.7365 +( 0.0 )² * 0.7365
  = 0.092 in^2
```

**UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]**
```
 Wall Thickness for Internal/External pressures      ta = 0.0151 in
 Wall Thickness per UG16(b),                      tr16b = 0.0940 in
 Wall Thickness, shell/head, internal pressure     trb1 = 0.1820 in
 Wall Thickness                tb1 = max(trb1, tr16b) = 0.1820 in
 Wall Thickness, shell/head, external pressure     trb2 = 0.0464 in
 Wall Thickness                tb2 = max(trb2, tr16b) = 0.0940 in
 Wall Thickness per table UG-45                     tb3 = 0.1890 in
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.189, max( 0.182, 0.094 ) ]
  = 0.1820 in
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 0.0151, 0.182 )
  = 0.1820 in
```

Available Nozzle Neck Thickness = 0.6563 in --> OK

***Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):***
```
 Sustained  :   1298.1,  Allowable :  10900.0 psi  Passed
 Expansion  :      0.0,  Allowable :  33201.9 psi  Passed
 Occasional :     86.7,  Allowable :  14497.0 psi  Passed
```

```
 Shear      :   1283.3,  Allowable :   7630.0 psi  Passed
```

*The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

*SA-240 316L, Min Metal Temp without impact per UHA-51: -320 °F*

*SA-182 F316L, Min Metal Temp without impact per UHA-51: -320 °F*

Note:
The flange pressure ratio is less than 0.35. Impact testing is not required due to low stress per UHA-51(g).

*Design Pressure/Ambient Rating = 151.07/1200.00 = 0.126*

Weld Size Calculations, Description: Nozzle L2 2"

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      0.3622  in
```

**Results Per UW-16.1:**

```
                          Required Thickness    Actual Thickness
 Nozzle Weld             0.2500 = Min per Code 0.2503 = 0.7 * Wo in
```

**Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)**

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0,( 0.3531 - 0.358 + 2 * 0.6563 * 0.7365 *
    (1.0 * 0.3622 - 0.1505 ) )14800)
  = 2956.87 lbf
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 0.8568 + 0.0 + 0.0923 - 0.0 * 0.74 ) * 14800
  = 14045.90 lbf
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 0.8568 + 0.0 + 0.0923 +( 0.3501 ) ) * 14800
  = 19228.08 lbf
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = (  0.8568 + 0.0 + 0.0923 + 0.0 +( 0.3501 ) ) * 14800
  = 19228.08 lbf
```

**Strength of Connection Elements for Failure Path Analysis**

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 3.3126 * 0.354 * 0.49 * 10900
  = 9838. lbf
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 1.3281) *( 0.6563 - 0.0 ) * 0.7 * 10900
  = 20894. lbf
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 3.3126 *( 0.3937 - 0.0315 ) * 0.74 * 14800
  = 20641. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

**Strength of Failure Paths:**

Failure Path [Path 1-1]:
```
  = ( SONW + SNW ) = ( 9838 + 20894 ) = 30732 lbf
```

Failure Path [Path 2-2]:
```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 9838 + 0 + 20641 + 0 ) = 30479 lbf
```

Failure Path [Path 3-3]:
```
  = ( Sonw + Tngw + Sinw )
  = ( 9838 + 20641 + 0 ) = 30479 lbf
```

**Summary of Failure Path Calculations:**
```
 Path 1-1 = 30732   lbf, must exceed W = 2956 lbf     or W1 = 14045 lbf
 Path 2-2 = 30479   lbf, must exceed W = 2956 lbf     or W2 = 19228 lbf
 Path 3-3 = 30479   lbf, must exceed W = 2956 lbf     or W3 = 19228 lbf
```

**Maximum Allowable Pressure for this Nozzle at this Location:**
```
 Converged Maximum Allowable Pressure in the Operating case: 359 psig
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

```
 Nozzle is O.K. for the External Pressure: 15 psig
```

The Drop for this Nozzle is : 0.0941 in
The Cut Length for this Nozzle is, Drop + Ho + H + T : 7.5928 in

**Input Echo, WRC297 Item 1, Description: Nozzle L2 2" :**

```
 Diameter Basis for Cylindrical Shell                    ID
 Shell Corrosion Allowance                               0.0315  in
 Shell Diameter                                          29.250  in
 Shell Thickness                                         0.3937  in
 Shell Stress Concentration Factor                        1.000
 Vessel Material                                    SA-240 316L
 Vessel Cold S.I. Allowable                  Smc     16700.00  psi
 Vessel Hot  S.I. Allowable                  Smh     14800.00  psi

 Diameter Basis for Nozzle                               ID
 Nozzle Corrosion Allowance                              0.0000  in
 Nozzle Diameter                                          2.000  in
 Nozzle Thickness                                        0.6563  in
 Nozzle Stress Concentration Factor                       1.000
 Nozzle Material                                   SA-182 F316L
 Nozzle Cold S.I. Allowable                 SNmc     16700.00  psi
 Nozzle Hot  S.I. Allowable                 SNmh     10900.00  psi
```

Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-182 F316L

*Note:*
*External Forces and Moments in WRC 107/537 Convention:*

*These loads are assumed to be SUStained loads.*

| | | | |
|---|---|---|---|
| Design Internal Pressure | Dp | 151.07 | psig |
| Radial Load | P | -630.00 | lbf |
| Circumferential Shear | Vc | 470.00 | lbf |
| Longitudinal Shear | Vl | 630.00 | lbf |
| Circumferential Moment | Mc | 210.00 | ft-lbf |
| Longitudinal Moment | Ml | 270.00 | ft-lbf |
| Torsional Moment | Mt | 310.00 | ft-lbf |

| | |
|---|---|
| Include Axial Pressure Thrust | No |
| Include Pressure Stress Indices per Div. 2 | No |
| Local Loads applied at end of Nozzle/Attachment | No |

*Warning - The ratio, Dn/Tn (5.047) is < 10
check the limitations of WRC bulletin 297.*

**Stress Computations at the Edge of the Nozzle:**

Stress Attenuation Diameter (for Insert Plates) per WRC 297:
= NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
= 3.313 + 2 * 1.65 * sqrt( 14.838( 0.394 - 0.031 ) )
= 10.963 in

WRC 297 Curve Access Parameters:

| | | | |
|---|---|---|---|
| Vessel Mean Diameter | (D) = | 29.675 | in |
| Nozzle Outside Diameter | (d) = | 3.313 | in |
| Vessel Thickness used | (T) = | 0.362 | in |
| Nozzle Thickness used | (t) = | 0.656 | in |
| T / t | = | 0.552 | |
| d / t | = | 10.000 | |

Lambda = [(d/D) * sqrt(D/T)] = 1.010

| | | |
|---|---|---|
| Nr/P | = | 0.106 |
| Mr/P | = | 0.218 |
| M0/P | = | 0.065 |
| N0/P | = | 0.132 |
| MrD/Mc | = | 0.304 |
| NrDL/Mc | = | 0.097 |
| M0d/Mc | = | 0.097 |
| N0DL/Mc | = | 0.031 |
| MrD/Ml | = | 0.195 |
| NrDL/Ml | = | 0.090 |
| M0D/Ml | = | 0.064 |
| N0DL/Ml | = | 0.120 |

***Vessel Stresses (psi):***

| LONGITUDINAL PLANE (Stresses Normal to longitudinal plane) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Outplane Membrane (P ) | 634 | 634 | 634 | 634 |
| Outplane Bending (P ) | 1877 | -1877 | 1877 | -1877 |
| Outplane Membrane (Mc) | 0 | 0 | 0 | 0 |
| Outplane Bending (Mc) | 0 | 0 | 0 | 0 |
| Outplane Membrane (ML) | -891 | -891 | 891 | 891 |
| Outplane Bending (ML) | -2871 | 2871 | 2871 | -2871 |
| Normal Pressure Stress | 6038 | 6189 | 6038 | 6189 |

| | | | | |
|---|---|---|---|---|
| Outplane Stress Summary | 4787 | 6926 | 12311 | 2966 |

***Vessel Stresses (psi):***

| LONGITUDINAL PLANE (Stresses parallel to longitudinal plane) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Inplane Membrane (P ) | 510 | 510 | 510 | 510 |
| Inplane Bending (P ) | 6293 | -6293 | 6293 | -6293 |
| Inplane Membrane (Mc) | 0 | 0 | 0 | 0 |
| Inplane Bending (Mc) | 0 | 0 | 0 | 0 |
| Inplane Membrane (ML) | -669 | -669 | 669 | 669 |
| Inplane Bending (ML) | -8720 | 8720 | 8720 | -8720 |
| Inplane Pressure Stress | 3019 | 3019 | 3019 | 3019 |
| Inplane Stress Summary | 433 | 5287 | 19211 | -10815 |

***Vessel Stresses (psi):***

| LONGITUDINAL PLANE (Shear stress normal to longitudinal plane) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Outplane Shear (Vc) | 249 | 249 | -249 | -249 |
| Outplane Shear (Vl) | 0 | 0 | 0 | 0 |
| Outplane Shear (Mt) | 595 | 595 | 595 | 595 |
| Shear Stress Summary | 844 | 844 | 346 | 346 |

***Vessel Stresses (psi):***

| LONGITUDINAL PLANE (Stress Intensities | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 4944 | 7282 | 19228 | 13798 |

***Vessel Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stresses Normal to circumferential plane) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Outplane Membrane (P ) | 634 | 634 | 634 | 634 |
| Outplane Bending (P ) | 1877 | -1877 | 1877 | -1877 |
| Outplane Membrane (Mc) | -181 | -181 | 181 | 181 |
| Outplane Bending (Mc) | -3389 | 3389 | 3389 | -3389 |
| Outplane Membrane (ML) | 0 | 0 | 0 | 0 |
| Outplane Bending (ML) | 0 | 0 | 0 | 0 |
| Normal Pressure Stress | 3019 | 3019 | 3019 | 3019 |
| Outplane Stress Summary | 1960 | 4984 | 9100 | -1432 |

***Vessel Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stresses parallel to circumferential plane) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Inplane Membrane (P ) | 510 | 510 | 510 | 510 |
| Inplane Bending (P ) | 6293 | -6293 | 6293 | -6293 |
| Inplane Membrane (Mc) | -562 | -562 | 562 | 562 |
| Inplane Bending (Mc) | -10562 | 10562 | 10562 | -10562 |
| Inplane Membrane (ML) | 0 | 0 | 0 | 0 |
| Inplane Bending (ML) | 0 | 0 | 0 | 0 |

| | | | | |
|---|---|---|---|---|
| Inplane Pressure Stress | 6038 | 6189 | 6038 | 6189 |
| Inplane Stress Summary | 1717 | 10406 | 23965 | -9594 |

***Vessel Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Shear stress normal to circumferential plane) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Outplane Shear (Vc) | 0 | 0 | 0 | 0 |
| Outplane Shear (Vl) | -334 | -334 | 334 | 334 |
| Torsional Shear (Mt) | 595 | 595 | 595 | 595 |
| Shear Stress Summary | 261 | 261 | 929 | 929 |

***Vessel Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stress Intensities | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 2126 | 10418 | 24022 | 9698 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Stresses in the hoop direction) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Hoop Membrane (P ) | 634 | 634 | 634 | 634 |
| Hoop Bending (P ) | 0 | 0 | 0 | 0 |
| Hoop Membrane (Mc) | 0 | 0 | 0 | 0 |
| Hoop Bending (Mc) | 0 | 0 | 0 | 0 |
| Hoop Membrane (ML) | -891 | -891 | 891 | 891 |
| Hoop Bending (ML) | 0 | 0 | 0 | 0 |
| Hoop Pressure Stress | 207 | 389 | 207 | 389 |
| Hoop Stress Summary | -50 | 132 | 1732 | 1914 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Stresses Normal to pipe cross-section) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Axial Membrane (P ) | 115 | 115 | 115 | 115 |
| Axial Bending (P ) | 1450 | -1450 | 1450 | -1450 |
| Axial Membrane (Mc) | 0 | 0 | 0 | 0 |
| Axial Bending (Mc) | 0 | 0 | 0 | 0 |
| Axial Membrane (ML) | -1047 | -1047 | 1047 | 1047 |
| Axial Bending (ML) | -2044 | 2044 | 2044 | -2044 |
| Axial Pressure Stress | 103 | 103 | 103 | 103 |
| Axial Stress Summary | -1423 | -235 | 4759 | -2229 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Shear stress) | Au Outside | Al Inside | Bu Outside | Bl Inside |
|---|---|---|---|---|
| Shear due to (Vc) | 137 | 137 | -137 | -137 |
| Shear due to (Vl) | 0 | 0 | 0 | 0 |
| Shear due to Torsion | 328 | 328 | 328 | 328 |
| Shear Stress Summary | 465 | 465 | 191 | 191 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Stress Intensities | Au Outside | Al Inside | Bu Outside | Bl Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 1658 | 999 | 4771 | 4160 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stresses in the hoop direction) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Hoop Membrane (P ) | 634 | 634 | 634 | 634 |
| Hoop Bending (P ) | 0 | 0 | 0 | 0 |
| Hoop Membrane (Mc) | -181 | -181 | 181 | 181 |
| Hoop Bending (Mc) | 0 | 0 | 0 | 0 |
| Hoop Membrane (ML) | 0 | 0 | 0 | 0 |
| Hoop Bending (ML) | 0 | 0 | 0 | 0 |
| Hoop Pressure Stress | 207 | 389 | 207 | 389 |
| Hoop Stress Summary | 660 | 842 | 1022 | 1204 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stresses Normal to pipe cross-section) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Axial Membrane (P ) | 115 | 115 | 115 | 115 |
| Axial Bending (P ) | 1450 | -1450 | 1450 | -1450 |
| Axial Membrane (Mc) | -814 | -814 | 814 | 814 |
| Axial Bending (Mc) | -2703 | 2703 | 2703 | -2703 |
| Axial Membrane (ML) | 0 | 0 | 0 | 0 |
| Axial Bending (ML) | 0 | 0 | 0 | 0 |
| Axial Pressure Stress | 103 | 103 | 103 | 103 |
| Axial Stress Summary | -1849 | 657 | 5185 | -3121 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Shear stress) | Cu Outside | Cl Inside | Du Outside | Dl Inside |
|---|---|---|---|---|
| Shear due to (Vc) | 0 | 0 | 0 | 0 |
| Shear due to (Vl) | -184 | -184 | 184 | 184 |
| Shear due to Torsion | 328 | 328 | 328 | 328 |
| Shear Stress Summary | 144 | 144 | 512 | 512 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stress Intensities | Cu Outside | Cl Inside | Du Outside | Dl Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 2525 | 920 | 5247 | 4444 |

**WRC 297 Stress Summations per ASME Sec. VIII Div. 2:**

**Vessel Stress Summation at Vessel-Nozzle Junction (psi):**

| Type of Stress Int. Location | Stress Values at Au | Al | Bu | Bl | Cu | Cl | Du | Dl |
|---|---|---|---|---|---|---|---|---|

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Circ. Pm (SUS) | 6038 | 6189 | 6038 | 6189 | 6038 | 6189 | 6038 | 6189 |
| Circ. Pl (SUS) | -257 | -257 | 1525 | 1525 | -52 | -52 | 1072 | 1072 |
| Circ. Q (SUS) | -994 | 994 | 4748 | -4748 | -4269 | 4269 | 16855 | -16855 |
| Long. Pm (SUS) | 3019 | 3019 | 3019 | 3019 | 3019 | 3019 | 3019 | 3019 |
| Long. Pl (SUS) | -159 | -159 | 1179 | 1179 | 453 | 453 | 815 | 815 |
| Long. Q (SUS) | -2427 | 2427 | 15013 | -15013 | -1512 | 1512 | 5266 | -5266 |
| Shear Pm (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Shear Pl (SUS) | 249 | 249 | -249 | -249 | -334 | -334 | 334 | 334 |
| Shear Q (SUS) | 595 | 595 | 595 | 595 | 595 | 595 | 595 | 595 |
| Pm (SUS) | 6038 | 6189 | 6038 | 6189 | 6038 | 6189 | 6038 | 6189 |
| Pm+Pl (SUS) | 5802 | 5952 | 7581 | 7731 | 6029 | 6178 | 7143 | 7293 |
| Pm+Pl+Q (Total) | 4944 | 7282 | 19228 | 13798 | 2126 | 10418 | 24022 | 9698 |

**Vessel Stress Summation Comparison (psi):**

| Type of Stress Int. | Max. S.I. | S.I. Allowable | Result |
|---|---|---|---|
| Pm (SUS) | 6189 | 14800 | Passed |
| Pm+Pl (SUS) | 7731 | 22200 | Passed |
| Pm+Pl+Q (TOTAL) | 24022 | 44400 | Passed |

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

**WRC 297 Stress Summations per ASME Sec. VIII Div. 2:**

**Nozzle Stress Summation at Vessel-Nozzle Junction (psi):**

| Type of Stress Int. | Stress Values at | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Location | Au | Al | Bu | Bl | Cu | Cl | Du | Dl |
| Circ. Pm (SUS) | 207 | 389 | 207 | 389 | 207 | 389 | 207 | 389 |
| Circ. Pl (SUS) | -257 | -257 | 1525 | 1525 | 453 | 453 | 815 | 815 |
| Circ. Q (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Long. Pm (SUS) | 103 | 103 | 103 | 103 | 103 | 103 | 103 | 103 |
| Long. Pl (SUS) | -932 | -932 | 1162 | 1162 | -699 | -699 | 929 | 929 |
| Long. Q (SUS) | -594 | 594 | 3494 | -3494 | -1253 | 1253 | 4153 | -4153 |
| Shear Pm (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Shear Pl (SUS) | 137 | 137 | -137 | -137 | -184 | -184 | 184 | 184 |
| Shear Q (SUS) | 328 | 328 | 328 | 328 | 328 | 328 | 328 | 328 |
| Pm (SUS) | 207 | 389 | 207 | 389 | 207 | 389 | 207 | 389 |
| Pm+Pl (SUS) | 852 | 999 | 1769 | 1941 | 1308 | 1484 | 1211 | 1321 |
| Pm+Pl+Q (Total) | 1658 | 999 | 4771 | 4160 | 2525 | 920 | 5247 | 4444 |

**Nozzle Stress Summation Comparison (psi):**

| Type of Stress Int. | Max. S.I. | S.I. Allowable | Result |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Pm (SUS) | 389 | 10900 | Passed |
| Pm+Pl (SUS) | 1941 | 16350 | Passed |
| Pm+Pl+Q (TOTAL) | 5247 | 32700 | Passed |

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

**Input, Nozzle Desc: Nozzle S 2" From: 50**

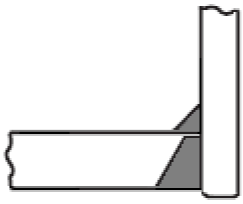
| | | | |
|---|---|---|---|
| Pressure for Reinforcement Calculations | P | 151.073 | psig |
| Temperature for Internal Pressure | Temp | 500 | °F |
| Design External Pressure | Pext | 15.00 | psig |
| Temperature for External Pressure | Tempex | 300 | °F |
| | | | |
| Parent Material | | SA-240 316L | |
| Parent Allowable Stress at Temperature | Sv | 14800.00 | psi |
| Parent Allowable Stress At Ambient | Sva | 16700.00 | psi |
| | | | |
| Inside Diameter of Cylindrical Shell | D | 29.2500 | in |
| Design Length of Section | L | 118.5000 | in |
| Shell Finished (Minimum) Thickness | t | 0.3937 | in |
| Shell Internal Corrosion Allowance | c | 0.0315 | in |
| Shell External Corrosion Allowance | co | 0.0000 | in |
| | | | |
| Distance from Bottom/Left Tangent | | 0.66 | ft |
| | | | |
| User Entered Minimum Design Metal Temperature | | 32.00 | °F |

***Type of Element Connected to the Parent : Nozzle***

| | | | |
|---|---|---|---|
| Material | | SA-182 F316L | |
| Material UNS Number | | S31603 | |
| Material Specification/Type | | Forgings | |
| Allowable Stress at Temperature | Sn | 10900.00 | psi |
| Allowable Stress At Ambient | Sna | 16700.00 | psi |
| | | | |
| Diameter Basis (for tr calc only) | | Inside | |
| Layout Angle | | 270.00 | deg |
| Diameter | | 2.0000 | in. |
| | | | |
| Size and Thickness Basis | | Actual | |
| Actual Thickness | tn | 0.6563 | in |
| | | | |
| Flange Type | | Long Weld Neck | |
| | | | |
| Corrosion Allowance | can | 0.0000 | in |
| Joint Efficiency of Shell Seam at Nozzle | E1 | 1.00 | |
| Joint Efficiency of Nozzle Neck | En | 1.00 | |
| | | | |
| Outside Projection | ho | 7.1078 | in |
| Weld leg size between Nozzle and Pad/Shell | Wo | 0.3543 | in |
| Groove weld depth between Nozzle and Vessel | Wgnv | 0.3900 | in |
| Inside Projection | h | 0.0000 | in |
| Weld leg size, Inside Element to Shell | Wi | 0.0000 | in |
| | | | |
| Flange Class | | 600 | |
| Flange Grade | | GR 2.3 | |

The Pressure Design option was MAWP + static head (to the nozzle).

**Nozzle Sketch (may not represent actual weld type/configuration)**



**Insert/Set-in Nozzle No Pad, no Inside projection**

**Reinforcement CALCULATION, Description: Nozzle S 2"**

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
 Actual Inside Diameter Used in Calculation              2.000  in.
 Actual Thickness Used in Calculation                    0.656  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Int. Press]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 151.07*14.6565/(14800*1.0-0.6*151.07)
  = 0.1505 in
```

Reqd thk per App. 1 of Nozzle Wall, trn [Int. Press]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 1.0(exp([151.07/(10900.0*1.0]-1)
  = 0.0140 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0151 in

**UG-40, Limits of Reinforcement : [Internal Pressure]**
```
 Parallel to Vessel Wall (Diameter Limit)            Dl     4.0370  in
 Parallel to Vessel Wall                       Rn+tn+t     2.0185  in
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     0.9055  in
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 10900.0/14800.0 )
  = 0.736
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 10900.0/14800.0 )
  = 0.736
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 0.736, 1.0 )
  = 0.736
```

**Results of Nozzle Reinforcement Area Calculations: (in^2)**

| AREA AVAILABLE, A1 to A5 | | MAWP | External | Mapnc |
|---|---|---|---|---|
| Area Required | Ar | 0.353 | 0.208 | NA |
| Area in Shell | A1 | 0.358 | 0.313 | NA |

```
 Area in Nozzle Wall          A2 |     0.857|     0.855|        NA|
 Area in Inward Nozzle        A3 |     0.000|     0.000|        NA|
 Area in Welds      A41+A42+A43 |     0.092|     0.092|        NA|
 Area in Element              A5 |     0.000|     0.000|        NA|
 TOTAL AREA AVAILABLE       Atot |     1.307|     1.261|        NA|
```

The MAWP Case Governs the Analysis.

```
 Nozzle Angle Used in Area Calculations                  90.00  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (2.0*0.1505*1.0+2*0.6563*0.1505*1.0*(1-0.74))
  = 0.353 in^2
```

**Reinforcement Areas per Figure UG-37.1**

Area Available in Shell [A1]:
```
  = d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
  = 2.037( 1.0 * 0.3622 - 1.0 * 0.151 ) - 2 * 0.656
    ( 1.0 * 0.3622 - 1.0 * 0.1505 ) *( 1 - 0.736 )
  = 0.358 in^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 0.906 )( 0.6563 - 0.014 ) 0.7365
  = 0.857 in^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  =  0.3543² * 0.7365 +( 0.0 )² * 0.7365
  = 0.092 in^2
```

**UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]**
```
 Wall Thickness for Internal/External pressures       ta = 0.0151 in
 Wall Thickness per UG16(b),                       tr16b = 0.0940 in
 Wall Thickness, shell/head, internal pressure      trb1 = 0.1820 in
 Wall Thickness                 tb1 = max(trb1, tr16b) = 0.1820 in
 Wall Thickness, shell/head, external pressure      trb2 = 0.0464 in
 Wall Thickness                 tb2 = max(trb2, tr16b) = 0.0940 in
 Wall Thickness per table UG-45                      tb3 = 0.1890 in
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.189, max( 0.182, 0.094 ) ]
  = 0.1820 in
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 0.0151, 0.182 )
  = 0.1820 in
```

Available Nozzle Neck Thickness = 0.6563 in --> OK

***Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):***
```
 Sustained  :    1298.1,  Allowable :  10900.0 psi   Passed
 Expansion  :       0.0,  Allowable :  33201.9 psi   Passed
 Occasional :      86.7,  Allowable :  14497.0 psi   Passed
```

```
 Shear      :   1283.3,  Allowable :   7630.0 psi  Passed
```

*The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

*SA-240 316L, Min Metal Temp without impact per UHA-51: -320 °F*

*SA-182 F316L, Min Metal Temp without impact per UHA-51: -320 °F*

Note:
The flange pressure ratio is less than 0.35. Impact testing is not required due to low stress per UHA-51(g).

*Design Pressure/Ambient Rating = 151.07/1200.00 = 0.126*

Weld Size Calculations, Description: Nozzle S 2"

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      0.3622  in
```

**Results Per UW-16.1:**

```
                          Required Thickness    Actual Thickness
 Nozzle Weld             0.2500 = Min per Code 0.2505 = 0.7 * Wo in
```

**Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)**

Weld Load [W]:
```
  = max( 0,  (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0,( 0.3531 - 0.358 + 2 * 0.6563 * 0.7365 *
    (1.0 * 0.3622 - 0.1505 ) )14800)
  = 2956.87 lbf
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 0.8568 + 0.0 + 0.0925 - 0.0 * 0.74 ) * 14800
  = 14048.45 lbf
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 0.8568 + 0.0 + 0.0925 +( 0.3501 ) ) * 14800
  = 19230.63 lbf
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = (  0.8568 + 0.0 + 0.0925 + 0.0 +( 0.3501 ) ) * 14800
  = 19230.63 lbf
```

**Strength of Connection Elements for Failure Path Analysis**

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 3.3126 * 0.3543 * 0.49 * 10900
  = 9847. lbf
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 1.3281) *( 0.6563 - 0.0 ) * 0.7 * 10900
  = 20894. lbf
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 3.3126 *( 0.3937 - 0.0315 ) * 0.74 * 14800
  = 20641. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

**Strength of Failure Paths:**

Failure Path [Path 1-1]:

```
  = ( SONW + SNW ) = ( 9847 + 20894 ) = 30741 lbf
```

Failure Path [Path 2-2]:

```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 9847 + 0 + 20641 + 0 ) = 30489 lbf
```

Failure Path [Path 3-3]:

```
  = ( Sonw + Tngw + Sinw )
  = ( 9847 + 20641 + 0 ) = 30489 lbf
```

**Summary of Failure Path Calculations:**

```
 Path 1-1 = 30741   lbf, must exceed W = 2956 lbf     or W1 = 14048 lbf
 Path 2-2 = 30488   lbf, must exceed W = 2956 lbf     or W2 = 19230 lbf
 Path 3-3 = 30488   lbf, must exceed W = 2956 lbf     or W3 = 19230 lbf
```

**Maximum Allowable Pressure for this Nozzle at this Location:**

```
 Converged Maximum Allowable Pressure in the Operating case: 359 psig
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

```
 Nozzle is O.K. for the External Pressure: 15 psig
```

The Drop for this Nozzle is : 0.0941 in
The Cut Length for this Nozzle is, Drop + Ho + H + T : 7.5956 in

**Input Echo, WRC297 Item    1,        Description: Nozzle S 2"   :**

```
 Diameter Basis for Cylindrical Shell                      ID
 Shell Corrosion Allowance                                 0.0315  in
 Shell Diameter                                            29.250  in
 Shell Thickness                                           0.3937  in
 Shell Stress Concentration Factor                          1.000
 Vessel Material                                      SA-240 316L
 Vessel Cold S.I. Allowable                     Smc     16700.00  psi
 Vessel Hot  S.I. Allowable                     Smh     14800.00  psi

 Diameter Basis for Nozzle                                 ID
 Nozzle Corrosion Allowance                                0.0000  in
 Nozzle Diameter                                            2.000  in
 Nozzle Thickness                                          0.6563  in
 Nozzle Stress Concentration Factor                         1.000
 Nozzle Material                                     SA-182 F316L
 Nozzle Cold S.I. Allowable                    SNmc     16700.00  psi
 Nozzle Hot  S.I. Allowable                    SNmh     10900.00  psi
```

Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-182 F316L

*Note:*
*External Forces and Moments in WRC 107/537 Convention:*

*These loads are assumed to be SUStained loads.*

| | | | |
|---|---|---|---|
| Design Internal Pressure | Dp | 151.07 | psig |
| Radial Load | P | -630.00 | lbf |
| Circumferential Shear | Vc | 470.00 | lbf |
| Longitudinal Shear | Vl | 630.00 | lbf |
| Circumferential Moment | Mc | 210.00 | ft-lbf |
| Longitudinal Moment | Ml | 270.00 | ft-lbf |
| Torsional Moment | Mt | 310.00 | ft-lbf |

| | |
|---|---|
| Include Axial Pressure Thrust | No |
| Include Pressure Stress Indices per Div. 2 | No |
| Local Loads applied at end of Nozzle/Attachment | No |

*Warning - The ratio, Dn/Tn (5.047) is < 10*
*check the limitations of WRC bulletin 297.*

**Stress Computations at the Edge of the Nozzle:**

Stress Attenuation Diameter (for Insert Plates) per WRC 297:

```
= NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
= 3.313 + 2 * 1.65 * sqrt( 14.838( 0.394 - 0.031 ) )
= 10.963 in
```

WRC 297 Curve Access Parameters:

```
Vessel Mean Diameter      (D) =     29.675 in
Nozzle Outside Diameter   (d) =      3.313 in
Vessel Thickness used     (T) =      0.362 in
Nozzle Thickness used     (t) =      0.656 in
T / t                         =      0.552
d / t                         =     10.000
```

Lambda = [(d/D) * sqrt(D/T)] = 1.010

```
Nr/P     =      0.106
Mr/P     =      0.218
M0/P     =      0.065
N0/P     =      0.132
MrD/Mc   =      0.304
NrDL/Mc  =      0.097
M0d/Mc   =      0.097
N0DL/Mc  =      0.031
MrD/Ml   =      0.195
NrDL/Ml  =      0.090
M0D/Ml   =      0.064
N0DL/Ml  =      0.120
```

***Vessel Stresses (psi):***

| LONGITUDINAL PLANE (Stresses Normal to longitudinal plane) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Outplane Membrane (P ) | 634 | 634 | 634 | 634 |
| Outplane Bending (P ) | 1877 | -1877 | 1877 | -1877 |
| Outplane Membrane (Mc) | 0 | 0 | 0 | 0 |
| Outplane Bending (Mc) | 0 | 0 | 0 | 0 |
| Outplane Membrane (ML) | -891 | -891 | 891 | 891 |
| Outplane Bending (ML) | -2871 | 2871 | 2871 | -2871 |
| Normal Pressure Stress | 6038 | 6189 | 6038 | 6189 |

| | | | | |
|---|---|---|---|---|
| Outplane Stress Summary | 4787 | 6926 | 12311 | 2966 |

***Vessel Stresses (psi):***

| LONGITUDINAL PLANE (Stresses parallel to longitudinal plane) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Inplane Membrane (P ) | 510 | 510 | 510 | 510 |
| Inplane Bending (P ) | 6293 | -6293 | 6293 | -6293 |
| Inplane Membrane (Mc) | 0 | 0 | 0 | 0 |
| Inplane Bending (Mc) | 0 | 0 | 0 | 0 |
| Inplane Membrane (ML) | -669 | -669 | 669 | 669 |
| Inplane Bending (ML) | -8720 | 8720 | 8720 | -8720 |
| Inplane Pressure Stress | 3019 | 3019 | 3019 | 3019 |
| Inplane Stress Summary | 433 | 5287 | 19211 | -10815 |

***Vessel Stresses (psi):***

| LONGITUDINAL PLANE (Shear stress normal to longitudinal plane) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Outplane Shear (Vc) | 249 | 249 | -249 | -249 |
| Outplane Shear (Vl) | 0 | 0 | 0 | 0 |
| Outplane Shear (Mt) | 595 | 595 | 595 | 595 |
| Shear Stress Summary | 844 | 844 | 346 | 346 |

***Vessel Stresses (psi):***

| LONGITUDINAL PLANE (Stress Intensities | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 4944 | 7282 | 19228 | 13798 |

***Vessel Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stresses Normal to circumferential plane) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Outplane Membrane (P ) | 634 | 634 | 634 | 634 |
| Outplane Bending (P ) | 1877 | -1877 | 1877 | -1877 |
| Outplane Membrane (Mc) | -181 | -181 | 181 | 181 |
| Outplane Bending (Mc) | -3389 | 3389 | 3389 | -3389 |
| Outplane Membrane (ML) | 0 | 0 | 0 | 0 |
| Outplane Bending (ML) | 0 | 0 | 0 | 0 |
| Normal Pressure Stress | 3019 | 3019 | 3019 | 3019 |
| Outplane Stress Summary | 1960 | 4984 | 9100 | -1432 |

***Vessel Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stresses parallel to circumferential plane) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Inplane Membrane (P ) | 510 | 510 | 510 | 510 |
| Inplane Bending (P ) | 6293 | -6293 | 6293 | -6293 |
| Inplane Membrane (Mc) | -562 | -562 | 562 | 562 |
| Inplane Bending (Mc) | -10562 | 10562 | 10562 | -10562 |
| Inplane Membrane (ML) | 0 | 0 | 0 | 0 |
| Inplane Bending (ML) | 0 | 0 | 0 | 0 |

| | | | | |
|---|---|---|---|---|
| Inplane Pressure Stress | 6038 | 6189 | 6038 | 6189 |
| Inplane Stress Summary | 1717 | 10406 | 23965 | -9594 |

***Vessel Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Shear stress normal to circumferential plane) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Outplane Shear (Vc) | 0 | 0 | 0 | 0 |
| Outplane Shear (Vl) | -334 | -334 | 334 | 334 |
| Torsional Shear (Mt) | 595 | 595 | 595 | 595 |
| Shear Stress Summary | 261 | 261 | 929 | 929 |

***Vessel Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stress Intensities | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 2126 | 10418 | 24022 | 9698 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Stresses in the hoop direction) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Hoop Membrane (P ) | 634 | 634 | 634 | 634 |
| Hoop Bending (P ) | 0 | 0 | 0 | 0 |
| Hoop Membrane (Mc) | 0 | 0 | 0 | 0 |
| Hoop Bending (Mc) | 0 | 0 | 0 | 0 |
| Hoop Membrane (ML) | -891 | -891 | 891 | 891 |
| Hoop Bending (ML) | 0 | 0 | 0 | 0 |
| Hoop Pressure Stress | 207 | 389 | 207 | 389 |
| Hoop Stress Summary | -50 | 132 | 1732 | 1914 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Stresses Normal to pipe cross-section) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Axial Membrane (P ) | 115 | 115 | 115 | 115 |
| Axial Bending (P ) | 1450 | -1450 | 1450 | -1450 |
| Axial Membrane (Mc) | 0 | 0 | 0 | 0 |
| Axial Bending (Mc) | 0 | 0 | 0 | 0 |
| Axial Membrane (ML) | -1047 | -1047 | 1047 | 1047 |
| Axial Bending (ML) | -2044 | 2044 | 2044 | -2044 |
| Axial Pressure Stress | 103 | 103 | 103 | 103 |
| Axial Stress Summary | -1423 | -235 | 4759 | -2229 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Shear stress) | Au Outside | Al Inside | Bu Outside | Bl Inside |
|---|---|---|---|---|
| Shear due to (Vc) | 137 | 137 | -137 | -137 |
| Shear due to (Vl) | 0 | 0 | 0 | 0 |
| Shear due to Torsion | 328 | 328 | 328 | 328 |
| Shear Stress Summary | 465 | 465 | 191 | 191 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Stress Intensities | Au Outside | Al Inside | Bu Outside | Bl Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 1658 | 999 | 4771 | 4160 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stresses in the hoop direction) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Hoop Membrane (P ) | 634 | 634 | 634 | 634 |
| Hoop Bending (P ) | 0 | 0 | 0 | 0 |
| Hoop Membrane (Mc) | -181 | -181 | 181 | 181 |
| Hoop Bending (Mc) | 0 | 0 | 0 | 0 |
| Hoop Membrane (ML) | 0 | 0 | 0 | 0 |
| Hoop Bending (ML) | 0 | 0 | 0 | 0 |
| Hoop Pressure Stress | 207 | 389 | 207 | 389 |
| Hoop Stress Summary | 660 | 842 | 1022 | 1204 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stresses Normal to pipe cross-section) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Axial Membrane (P ) | 115 | 115 | 115 | 115 |
| Axial Bending (P ) | 1450 | -1450 | 1450 | -1450 |
| Axial Membrane (Mc) | -814 | -814 | 814 | 814 |
| Axial Bending (Mc) | -2703 | 2703 | 2703 | -2703 |
| Axial Membrane (ML) | 0 | 0 | 0 | 0 |
| Axial Bending (ML) | 0 | 0 | 0 | 0 |
| Axial Pressure Stress | 103 | 103 | 103 | 103 |
| Axial Stress Summary | -1849 | 657 | 5185 | -3121 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Shear stress) | Cu Outside | Cl Inside | Du Outside | Dl Inside |
|---|---|---|---|---|
| Shear due to (Vc) | 0 | 0 | 0 | 0 |
| Shear due to (Vl) | -184 | -184 | 184 | 184 |
| Shear due to Torsion | 328 | 328 | 328 | 328 |
| Shear Stress Summary | 144 | 144 | 512 | 512 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stress Intensities | Cu Outside | Cl Inside | Du Outside | Dl Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 2525 | 920 | 5247 | 4444 |

**WRC 297 Stress Summations per ASME Sec. VIII Div. 2:**

**Vessel Stress Summation at Vessel-Nozzle Junction (psi):**

| Type of Stress Int. Location | Stress Values at Au | Al | Bu | Bl | Cu | Cl | Du | Dl |
|---|---|---|---|---|---|---|---|---|

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Circ. Pm (SUS) | 6038 | 6189 | 6038 | 6189 | 6038 | 6189 | 6038 | 6189 |
| Circ. Pl (SUS) | -257 | -257 | 1525 | 1525 | -52 | -52 | 1072 | 1072 |
| Circ. Q (SUS) | -994 | 994 | 4748 | -4748 | -4269 | 4269 | 16855 | -16855 |
| Long. Pm (SUS) | 3019 | 3019 | 3019 | 3019 | 3019 | 3019 | 3019 | 3019 |
| Long. Pl (SUS) | -159 | -159 | 1179 | 1179 | 453 | 453 | 815 | 815 |
| Long. Q (SUS) | -2427 | 2427 | 15013 | -15013 | -1512 | 1512 | 5266 | -5266 |
| Shear Pm (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Shear Pl (SUS) | 249 | 249 | -249 | -249 | -334 | -334 | 334 | 334 |
| Shear Q (SUS) | 595 | 595 | 595 | 595 | 595 | 595 | 595 | 595 |
| Pm (SUS) | 6038 | 6189 | 6038 | 6189 | 6038 | 6189 | 6038 | 6189 |
| Pm+Pl (SUS) | 5802 | 5952 | 7581 | 7731 | 6029 | 6178 | 7143 | 7293 |
| Pm+Pl+Q (Total) | 4944 | 7282 | 19228 | 13798 | 2126 | 10418 | 24022 | 9698 |

**Vessel Stress Summation Comparison (psi):**

| Type of Stress Int. | Max. S.I. | S.I. Allowable | Result |
|---|---|---|---|
| Pm (SUS) | 6189 | 14800 | Passed |
| Pm+Pl (SUS) | 7731 | 22200 | Passed |
| Pm+Pl+Q (TOTAL) | 24022 | 44400 | Passed |

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

**WRC 297 Stress Summations per ASME Sec. VIII Div. 2:**

**Nozzle Stress Summation at Vessel-Nozzle Junction (psi):**

| Type of Stress Int. Location | Stress Values at Au | Al | Bu | Bl | Cu | Cl | Du | Dl |
|---|---|---|---|---|---|---|---|---|
| Circ. Pm (SUS) | 207 | 389 | 207 | 389 | 207 | 389 | 207 | 389 |
| Circ. Pl (SUS) | -257 | -257 | 1525 | 1525 | 453 | 453 | 815 | 815 |
| Circ. Q (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Long. Pm (SUS) | 103 | 103 | 103 | 103 | 103 | 103 | 103 | 103 |
| Long. Pl (SUS) | -932 | -932 | 1162 | 1162 | -699 | -699 | 929 | 929 |
| Long. Q (SUS) | -594 | 594 | 3494 | -3494 | -1253 | 1253 | 4153 | -4153 |
| Shear Pm (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Shear Pl (SUS) | 137 | 137 | -137 | -137 | -184 | -184 | 184 | 184 |
| Shear Q (SUS) | 328 | 328 | 328 | 328 | 328 | 328 | 328 | 328 |
| Pm (SUS) | 207 | 389 | 207 | 389 | 207 | 389 | 207 | 389 |
| Pm+Pl (SUS) | 852 | 999 | 1769 | 1941 | 1308 | 1484 | 1211 | 1321 |
| Pm+Pl+Q (Total) | 1658 | 999 | 4771 | 4160 | 2525 | 920 | 5247 | 4444 |

**Nozzle Stress Summation Comparison (psi):**

| Type of Stress Int. | Max. S.I. | S.I. Allowable | Result |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Pm (SUS) | 389 | 10900 | Passed |
| Pm+Pl (SUS) | 1941 | 16350 | Passed |
| Pm+Pl+Q (TOTAL) | 5247 | 32700 | Passed |

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

**Input, Nozzle Desc: Nozzle LT1 2" From: 50**

| | | | |
|---|---|---|---|
| Pressure for Reinforcement Calculations | P | 150.000 | psig |
| Temperature for Internal Pressure | Temp | 500 | °F |
| Design External Pressure | Pext | 15.00 | psig |
| Temperature for External Pressure | Tempex | 300 | °F |
| Parent Material | | SA-240 316L | |
| Parent Allowable Stress at Temperature | Sv | 14800.00 | psi |
| Parent Allowable Stress At Ambient | Sva | 16700.00 | psi |
| Inside Diameter of Cylindrical Shell | D | 29.2500 | in |
| Design Length of Section | L | 118.5000 | in |
| Shell Finished (Minimum) Thickness | t | 0.3937 | in |
| Shell Internal Corrosion Allowance | c | 0.0315 | in |
| Shell External Corrosion Allowance | co | 0.0000 | in |
| Distance from Bottom/Left Tangent | | 4.16 | ft |
| User Entered Minimum Design Metal Temperature | | 32.00 | °F |

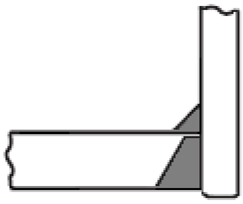
***Type of Element Connected to the Parent : Nozzle***

| | | | |
|---|---|---|---|
| Material | | SA-182 F316L | |
| Material UNS Number | | S31603 | |
| Material Specification/Type | | Forgings | |
| Allowable Stress at Temperature | Sn | 10900.00 | psi |
| Allowable Stress At Ambient | Sna | 16700.00 | psi |
| Diameter Basis (for tr calc only) | | Inside | |
| Layout Angle | | 330.00 | deg |
| Diameter | | 2.0000 | in. |
| Size and Thickness Basis | | Actual | |
| Actual Thickness | tn | 0.6563 | in |
| Flange Type | | Long Weld Neck | |
| Corrosion Allowance | can | 0.0000 | in |
| Joint Efficiency of Shell Seam at Nozzle | E1 | 1.00 | |
| Joint Efficiency of Nozzle Neck | En | 1.00 | |
| Outside Projection | ho | 7.1050 | in |
| Weld leg size between Nozzle and Pad/Shell | Wo | 0.3543 | in |
| Groove weld depth between Nozzle and Vessel | Wgnv | 0.3900 | in |
| Inside Projection | h | 0.0000 | in |
| Weld leg size, Inside Element to Shell | Wi | 0.0000 | in |
| Flange Class | | 300 | |
| Flange Grade | | GR 2.3 | |

The Pressure Design option was MAWP + static head (to the nozzle).

**Nozzle Sketch (may not represent actual weld type/configuration)**



**Insert/Set-in Nozzle No Pad, no Inside projection**

**Reinforcement CALCULATION, Description: Nozzle LT1 2"**

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
 Actual Inside Diameter Used in Calculation              2.000  in.
 Actual Thickness Used in Calculation                    0.656  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Int. Press]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 150.0*14.6565/(14800*1.0-0.6*150.0)
  = 0.1495 in
```

Reqd thk per App. 1 of Nozzle Wall, trn [Int. Press]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 1.0(exp([150.0/(10900.0*1.0]-1)
  = 0.0139 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0151 in

**UG-40, Limits of Reinforcement : [Internal Pressure]**
```
 Parallel to Vessel Wall (Diameter Limit)            Dl      4.0370  in
 Parallel to Vessel Wall                        Rn+tn+t      2.0185  in
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp      0.9055  in
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 10900.0/14800.0 )
  = 0.736
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 10900.0/14800.0 )
  = 0.736
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 0.736, 1.0 )
  = 0.736
```

**Results of Nozzle Reinforcement Area Calculations: (in^2)**

| AREA AVAILABLE, A1 to A5 | | MAWP | External | Mapnc |
|---|---|---|---|---|
| Area Required | Ar | 0.351 | 0.208 | NA |
| Area in Shell | A1 | 0.360 | 0.313 | NA |

| | | | | |
|---|---|---|---|---|
| Area in Nozzle Wall | A2 | 0.857 | 0.855 | NA |
| Area in Inward Nozzle | A3 | 0.000 | 0.000 | NA |
| Area in Welds | A41+A42+A43 | 0.092 | 0.092 | NA |
| Area in Element | A5 | 0.000 | 0.000 | NA |
| TOTAL AREA AVAILABLE | Atot | 1.309 | 1.261 | NA |

The MAWP Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (2.0*0.1495*1.0+2*0.6563*0.1495*1.0*(1-0.74))
  = 0.351 in^2
```

**Reinforcement Areas per Figure UG-37.1**

Area Available in Shell [A1]:
```
  = d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
  = 2.037( 1.0 * 0.3622 - 1.0 * 0.149 ) - 2 * 0.656
    ( 1.0 * 0.3622 - 1.0 * 0.1495 ) *( 1 - 0.736 )
  = 0.360 in^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 0.906 )( 0.6563 - 0.0139 ) 0.7365
  = 0.857 in^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  =  0.3543² * 0.7365 +( 0.0 )² * 0.7365
  = 0.092 in^2
```

**UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]**
```
 Wall Thickness for Internal/External pressures       ta = 0.0151 in
 Wall Thickness per UG16(b),                       tr16b = 0.0940 in
 Wall Thickness, shell/head, internal pressure      trb1 = 0.1810 in
 Wall Thickness                 tb1 = max(trb1, tr16b) = 0.1810 in
 Wall Thickness, shell/head, external pressure      trb2 = 0.0464 in
 Wall Thickness                 tb2 = max(trb2, tr16b) = 0.0940 in
 Wall Thickness per table UG-45                      tb3 = 0.1890 in
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.189, max( 0.181, 0.094 ) ]
  = 0.1810 in
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 0.0151, 0.181 )
  = 0.1810 in
```

Available Nozzle Neck Thickness = 0.6563 in --> OK

***Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):***
```
 Sustained  :   1297.4,  Allowable :  10900.0 psi  Passed
 Expansion  :      0.0,  Allowable :  33202.6 psi  Passed
 Occasional :     86.0,  Allowable :  14497.0 psi  Passed
```

```
 Shear      :   1283.3,  Allowable :   7630.0 psi  Passed
```

*The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

*SA-240 316L, Min Metal Temp without impact per UHA-51: -320 °F*

*SA-182 F316L, Min Metal Temp without impact per UHA-51: -320 °F*

Note:
The flange pressure ratio is less than 0.35. Impact testing is not required due to low stress per UHA-51(g).

*Design Pressure/Ambient Rating = 150.00/600.00 = 0.250*

Weld Size Calculations, Description: Nozzle LT1 2"

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      0.3622  in
```

**Results Per UW-16.1:**

```
                          Required Thickness    Actual Thickness
 Nozzle Weld            0.2500 = Min per Code 0.2505 = 0.7 * Wo in
```

**Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)**

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0,( 0.3506 - 0.3598 + 2 * 0.6563 * 0.7365 *
    (1.0 * 0.3622 - 0.1495 ) )14800)
  = 2907.97 lbf
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 0.8569 + 0.0 + 0.0925 - 0.0 * 0.74 ) * 14800
  = 14050.42 lbf
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 0.8569 + 0.0 + 0.0925 +( 0.3501 ) ) * 14800
  = 19232.60 lbf
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = (  0.8569 + 0.0 + 0.0925 + 0.0 +( 0.3501 ) ) * 14800
  = 19232.60 lbf
```

**Strength of Connection Elements for Failure Path Analysis**

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 3.3126 * 0.3543 * 0.49 * 10900
  = 9847. lbf
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 1.3281) *( 0.6563 - 0.0 ) * 0.7 * 10900
  = 20894. lbf
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 3.3126 *( 0.3937 - 0.0315 ) * 0.74 * 14800
  = 20641. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

**Strength of Failure Paths:**

Failure Path [Path 1-1]:

```
  = ( SONW + SNW ) = ( 9847 + 20894 ) = 30741 lbf
```

Failure Path [Path 2-2]:

```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 9847 + 0 + 20641 + 0 ) = 30489 lbf
```

Failure Path [Path 3-3]:

```
  = ( Sonw + Tngw + Sinw )
  = ( 9847 + 20641 + 0 ) = 30489 lbf
```

**Summary of Failure Path Calculations:**

```
 Path 1-1 = 30741   lbf, must exceed W = 2907 lbf     or W1 = 14050 lbf
 Path 2-2 = 30488   lbf, must exceed W = 2907 lbf     or W2 = 19232 lbf
 Path 3-3 = 30488   lbf, must exceed W = 2907 lbf     or W3 = 19232 lbf
```

**Maximum Allowable Pressure for this Nozzle at this Location:**

```
 Converged Maximum Allowable Pressure in the Operating case: 359 psig
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

```
 Nozzle is O.K. for the External Pressure: 15 psig
```

The Drop for this Nozzle is : 0.0941 in
The Cut Length for this Nozzle is, Drop + Ho + H + T : 7.5928 in

**Input Echo, WRC297 Item    1,        Description: Nozzle LT1 2" :**

```
 Diameter Basis for Cylindrical Shell                   ID
 Shell Corrosion Allowance                              0.0315  in
 Shell Diameter                                         29.250  in
 Shell Thickness                                        0.3937  in
 Shell Stress Concentration Factor                       1.000
 Vessel Material                                   SA-240 316L
 Vessel Cold S.I. Allowable                    Smc    16700.00  psi
 Vessel Hot  S.I. Allowable                    Smh    14800.00  psi

 Diameter Basis for Nozzle                              ID
 Nozzle Corrosion Allowance                             0.0000  in
 Nozzle Diameter                                         2.000  in
 Nozzle Thickness                                       0.6563  in
 Nozzle Stress Concentration Factor                      1.000
 Nozzle Material                                  SA-182 F316L
 Nozzle Cold S.I. Allowable                   SNmc    16700.00  psi
 Nozzle Hot  S.I. Allowable                   SNmh    10900.00  psi
```

Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-182 F316L

*Note:*
*External Forces and Moments in WRC 107/537 Convention:*

```
18-D-272
R06
V-1264
PV Elite 24       Licensee: THE ANUP ENGINEERING LIMITED.
FileName : V-1264_R06    -----------------------------------
Nozzle Calcs.: Nozzle LT1 2"          Nozl:   31   4:21pm  Dec 21,2022
```

*These loads are assumed to be SUStained loads.*

```
 Design Internal Pressure                        Dp       150.00  psig
 Radial Load                                      P      -630.00  lbf
 Circumferential Shear                           Vc       470.00  lbf
 Longitudinal Shear                              Vl       630.00  lbf
 Circumferential Moment                          Mc       210.00  ft-lbf
 Longitudinal Moment                             Ml       270.00  ft-lbf
 Torsional Moment                                Mt       310.00  ft-lbf

 Include Axial Pressure Thrust                                No
 Include Pressure Stress Indices per Div. 2                   No
 Local Loads applied at end of Nozzle/Attachment              No
```

*Warning - The ratio, Dn/Tn (5.047) is < 10*
*check the limitations of WRC bulletin 297.*

**Stress Computations at the Edge of the Nozzle:**

Stress Attenuation Diameter (for Insert Plates) per WRC 297:

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 3.313 + 2 * 1.65 * sqrt( 14.838( 0.394 - 0.031 ) )
  = 10.963 in
```

WRC 297 Curve Access Parameters:

```
 Vessel Mean Diameter      (D) =     29.675 in
 Nozzle Outside Diameter   (d) =      3.313 in
 Vessel Thickness used     (T) =      0.362 in
 Nozzle Thickness used     (t) =      0.656 in
 T / t                         =      0.552
 d / t                         =     10.000

Lambda = [(d/D) * sqrt(D/T)]  = 1.010

 Nr/P    =      0.106
 Mr/P    =      0.218
 M0/P    =      0.065
 N0/P    =      0.132
 MrD/Mc  =      0.304
 NrDL/Mc =      0.097
 M0d/Mc  =      0.097
 N0DL/Mc =      0.031
 MrD/Ml  =      0.195
 NrDL/Ml =      0.090
 M0D/Ml  =      0.064
 N0DL/Ml =      0.120
```

***Vessel Stresses (psi):***

| LONGITUDINAL PLANE (Stresses Normal to longitudinal plane) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Outplane Membrane (P ) | 634 | 634 | 634 | 634 |
| Outplane Bending (P ) | 1877 | -1877 | 1877 | -1877 |
| Outplane Membrane (Mc) | 0 | 0 | 0 | 0 |
| Outplane Bending (Mc) | 0 | 0 | 0 | 0 |
| Outplane Membrane (ML) | -891 | -891 | 891 | 891 |
| Outplane Bending (ML) | -2871 | 2871 | 2871 | -2871 |
| Normal Pressure Stress | 5995 | 6145 | 5995 | 6145 |

| | | | | |
|---|---|---|---|---|
| Outplane Stress Summary | 4744 | 6882 | 12268 | 2922 |

***Vessel Stresses (psi):***

| LONGITUDINAL PLANE (Stresses parallel to longitudinal plane) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Inplane Membrane (P ) | 510 | 510 | 510 | 510 |
| Inplane Bending (P ) | 6293 | -6293 | 6293 | -6293 |
| Inplane Membrane (Mc) | 0 | 0 | 0 | 0 |
| Inplane Bending (Mc) | 0 | 0 | 0 | 0 |
| Inplane Membrane (ML) | -669 | -669 | 669 | 669 |
| Inplane Bending (ML) | -8720 | 8720 | 8720 | -8720 |
| Inplane Pressure Stress | 2997 | 2997 | 2997 | 2997 |
| Inplane Stress Summary | 411 | 5265 | 19189 | -10837 |

***Vessel Stresses (psi):***

| LONGITUDINAL PLANE (Shear stress normal to longitudinal plane) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Outplane Shear (Vc) | 249 | 249 | -249 | -249 |
| Outplane Shear (Vl) | 0 | 0 | 0 | 0 |
| Outplane Shear (Mt) | 595 | 595 | 595 | 595 |
| Shear Stress Summary | 844 | 844 | 346 | 346 |

***Vessel Stresses (psi):***

| LONGITUDINAL PLANE (Stress Intensities | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 4902 | 7242 | 19206 | 13776 |

***Vessel Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stresses Normal to circumferential plane) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Outplane Membrane (P ) | 634 | 634 | 634 | 634 |
| Outplane Bending (P ) | 1877 | -1877 | 1877 | -1877 |
| Outplane Membrane (Mc) | -181 | -181 | 181 | 181 |
| Outplane Bending (Mc) | -3389 | 3389 | 3389 | -3389 |
| Outplane Membrane (ML) | 0 | 0 | 0 | 0 |
| Outplane Bending (ML) | 0 | 0 | 0 | 0 |
| Normal Pressure Stress | 2997 | 2997 | 2997 | 2997 |
| Outplane Stress Summary | 1938 | 4962 | 9078 | -1454 |

***Vessel Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stresses parallel to circumferential plane) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Inplane Membrane (P ) | 510 | 510 | 510 | 510 |
| Inplane Bending (P ) | 6293 | -6293 | 6293 | -6293 |
| Inplane Membrane (Mc) | -562 | -562 | 562 | 562 |
| Inplane Bending (Mc) | -10562 | 10562 | 10562 | -10562 |
| Inplane Membrane (ML) | 0 | 0 | 0 | 0 |
| Inplane Bending (ML) | 0 | 0 | 0 | 0 |

| | | | | |
|---|---|---|---|---|
| Inplane Pressure Stress | 5995 | 6145 | 5995 | 6145 |
| Inplane Stress Summary | 1674 | 10362 | 23922 | -9638 |

***Vessel Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Shear stress normal to circumferential plane) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Outplane Shear (Vc) | 0 | 0 | 0 | 0 |
| Outplane Shear (Vl) | -334 | -334 | 334 | 334 |
| Torsional Shear (Mt) | 595 | 595 | 595 | 595 |
| Shear Stress Summary | 261 | 261 | 929 | 929 |

***Vessel Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stress Intensities | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 2098 | 10374 | 23979 | 9742 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Stresses in the hoop direction) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Hoop Membrane (P ) | 634 | 634 | 634 | 634 |
| Hoop Bending (P ) | 0 | 0 | 0 | 0 |
| Hoop Membrane (Mc) | 0 | 0 | 0 | 0 |
| Hoop Bending (Mc) | 0 | 0 | 0 | 0 |
| Hoop Membrane (ML) | -891 | -891 | 891 | 891 |
| Hoop Bending (ML) | 0 | 0 | 0 | 0 |
| Hoop Pressure Stress | 206 | 386 | 206 | 386 |
| Hoop Stress Summary | -51 | 129 | 1731 | 1911 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Stresses Normal to pipe cross-section) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Axial Membrane (P ) | 115 | 115 | 115 | 115 |
| Axial Bending (P ) | 1450 | -1450 | 1450 | -1450 |
| Axial Membrane (Mc) | 0 | 0 | 0 | 0 |
| Axial Bending (Mc) | 0 | 0 | 0 | 0 |
| Axial Membrane (ML) | -1047 | -1047 | 1047 | 1047 |
| Axial Bending (ML) | -2044 | 2044 | 2044 | -2044 |
| Axial Pressure Stress | 103 | 103 | 103 | 103 |
| Axial Stress Summary | -1423 | -235 | 4759 | -2229 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Shear stress) | Au Outside | Al Inside | Bu Outside | Bl Inside |
|---|---|---|---|---|
| Shear due to (Vc) | 137 | 137 | -137 | -137 |
| Shear due to (Vl) | 0 | 0 | 0 | 0 |
| Shear due to Torsion | 328 | 328 | 328 | 328 |
| Shear Stress Summary | 465 | 465 | 191 | 191 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Stress Intensities | Au Outside | Al Inside | Bu Outside | Bl Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 1657 | 998 | 4771 | 4157 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stresses in the hoop direction) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Hoop Membrane (P ) | 634 | 634 | 634 | 634 |
| Hoop Bending (P ) | 0 | 0 | 0 | 0 |
| Hoop Membrane (Mc) | -181 | -181 | 181 | 181 |
| Hoop Bending (Mc) | 0 | 0 | 0 | 0 |
| Hoop Membrane (ML) | 0 | 0 | 0 | 0 |
| Hoop Bending (ML) | 0 | 0 | 0 | 0 |
| Hoop Pressure Stress | 206 | 386 | 206 | 386 |
| Hoop Stress Summary | 659 | 839 | 1021 | 1201 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stresses Normal to pipe cross-section) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Axial Membrane (P ) | 115 | 115 | 115 | 115 |
| Axial Bending (P ) | 1450 | -1450 | 1450 | -1450 |
| Axial Membrane (Mc) | -814 | -814 | 814 | 814 |
| Axial Bending (Mc) | -2703 | 2703 | 2703 | -2703 |
| Axial Membrane (ML) | 0 | 0 | 0 | 0 |
| Axial Bending (ML) | 0 | 0 | 0 | 0 |
| Axial Pressure Stress | 103 | 103 | 103 | 103 |
| Axial Stress Summary | -1849 | 657 | 5185 | -3121 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Shear stress) | Cu Outside | Cl Inside | Du Outside | Dl Inside |
|---|---|---|---|---|
| Shear due to (Vc) | 0 | 0 | 0 | 0 |
| Shear due to (Vl) | -184 | -184 | 184 | 184 |
| Shear due to Torsion | 328 | 328 | 328 | 328 |
| Shear Stress Summary | 144 | 144 | 512 | 512 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stress Intensities | Cu Outside | Cl Inside | Du Outside | Dl Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 2524 | 918 | 5247 | 4441 |

**WRC 297 Stress Summations per ASME Sec. VIII Div. 2:**

**Vessel Stress Summation at Vessel-Nozzle Junction (psi):**

| Type of Stress Int. Location | Stress Values at Au | Al | Bu | Bl | Cu | Cl | Du | Dl |
|---|---|---|---|---|---|---|---|---|

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Circ. Pm (SUS) | 5995 | 6145 | 5995 | 6145 | 5995 | 6145 | 5995 | 6145 |
| Circ. Pl (SUS) | -257 | -257 | 1525 | 1525 | -52 | -52 | 1072 | 1072 |
| Circ. Q (SUS) | -994 | 994 | 4748 | -4748 | -4269 | 4269 | 16855 | -16855 |
| Long. Pm (SUS) | 2997 | 2997 | 2997 | 2997 | 2997 | 2997 | 2997 | 2997 |
| Long. Pl (SUS) | -159 | -159 | 1179 | 1179 | 453 | 453 | 815 | 815 |
| Long. Q (SUS) | -2427 | 2427 | 15013 | -15013 | -1512 | 1512 | 5266 | -5266 |
| Shear Pm (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Shear Pl (SUS) | 249 | 249 | -249 | -249 | -334 | -334 | 334 | 334 |
| Shear Q (SUS) | 595 | 595 | 595 | 595 | 595 | 595 | 595 | 595 |
| Pm (SUS) | 5995 | 6145 | 5995 | 6145 | 5995 | 6145 | 5995 | 6145 |
| Pm+Pl (SUS) | 5759 | 5908 | 7538 | 7687 | 5986 | 6134 | 7100 | 7249 |
| Pm+Pl+Q (Total) | 4902 | 7242 | 19206 | 13776 | 2098 | 10374 | 23979 | 9742 |

**Vessel Stress Summation Comparison (psi):**

| Type of Stress Int. | Max. S.I. | S.I. Allowable | Result |
|---|---|---|---|
| Pm (SUS) | 6145 | 14800 | Passed |
| Pm+Pl (SUS) | 7687 | 22200 | Passed |
| Pm+Pl+Q (TOTAL) | 23979 | 44400 | Passed |

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

**WRC 297 Stress Summations per ASME Sec. VIII Div. 2:**

**Nozzle Stress Summation at Vessel-Nozzle Junction (psi):**

| Type of Stress Int. Location | Au | Al | Bu | Bl | Cu | Cl | Du | Dl |
|---|---|---|---|---|---|---|---|---|
| Circ. Pm (SUS) | 206 | 386 | 206 | 386 | 206 | 386 | 206 | 386 |
| Circ. Pl (SUS) | -257 | -257 | 1525 | 1525 | 453 | 453 | 815 | 815 |
| Circ. Q (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Long. Pm (SUS) | 103 | 103 | 103 | 103 | 103 | 103 | 103 | 103 |
| Long. Pl (SUS) | -932 | -932 | 1162 | 1162 | -699 | -699 | 929 | 929 |
| Long. Q (SUS) | -594 | 594 | 3494 | -3494 | -1253 | 1253 | 4153 | -4153 |
| Shear Pm (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Shear Pl (SUS) | 137 | 137 | -137 | -137 | -184 | -184 | 184 | 184 |
| Shear Q (SUS) | 328 | 328 | 328 | 328 | 328 | 328 | 328 | 328 |
| Pm (SUS) | 206 | 386 | 206 | 386 | 206 | 386 | 206 | 386 |
| Pm+Pl (SUS) | 852 | 996 | 1768 | 1938 | 1307 | 1481 | 1210 | 1318 |
| Pm+Pl+Q (Total) | 1657 | 998 | 4771 | 4157 | 2524 | 918 | 5247 | 4441 |

**Nozzle Stress Summation Comparison (psi):**

| Type of Stress Int. | Max. S.I. | S.I. Allowable | Result |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Pm (SUS) | 386 | 10900 | Passed |
| Pm+Pl (SUS) | 1938 | 16350 | Passed |
| Pm+Pl+Q (TOTAL) | 5247 | 32700 | Passed |

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

**Input, Nozzle Desc: Nozzle L1 2"    From: 50**

| | | | |
|---|---|---|---|
| Pressure for Reinforcement Calculations | P | 150.000 | psig |
| Temperature for Internal Pressure | Temp | 500 | °F |
| Design External Pressure | Pext | 15.00 | psig |
| Temperature for External Pressure | Tempex | 300 | °F |
| | | | |
| Parent Material | | SA-240 316L | |
| Parent Allowable Stress at Temperature | Sv | 14800.00 | psi |
| Parent Allowable Stress At Ambient | Sva | 16700.00 | psi |
| | | | |
| Inside Diameter of Cylindrical Shell | D | 29.2500 | in |
| Design Length of Section | L | 118.5000 | in |
| Shell Finished (Minimum) Thickness | t | 0.3937 | in |
| Shell Internal Corrosion Allowance | c | 0.0315 | in |
| Shell External Corrosion Allowance | co | 0.0000 | in |
| | | | |
| Distance from Bottom/Left Tangent | | 4.16 | ft |
| | | | |
| User Entered Minimum Design Metal Temperature | | 32.00 | °F |

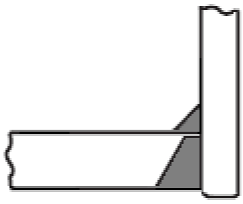
***Type of Element Connected to the Parent : Nozzle***

| | | | |
|---|---|---|---|
| Material | | SA-182 F316L | |
| Material UNS Number | | S31603 | |
| Material Specification/Type | | Forgings | |
| Allowable Stress at Temperature | Sn | 10900.00 | psi |
| Allowable Stress At Ambient | Sna | 16700.00 | psi |
| | | | |
| Diameter Basis (for tr calc only) | | Inside | |
| Layout Angle | | 225.00 | deg |
| Diameter | | 2.0000 | in. |
| | | | |
| Size and Thickness Basis | | Actual | |
| Actual Thickness | tn | 0.6563 | in |
| | | | |
| Flange Type | | Long Weld Neck | |
| | | | |
| Corrosion Allowance | can | 0.0000 | in |
| Joint Efficiency of Shell Seam at Nozzle | E1 | 1.00 | |
| Joint Efficiency of Nozzle Neck | En | 1.00 | |
| | | | |
| Outside Projection | ho | 7.1050 | in |
| Weld leg size between Nozzle and Pad/Shell | Wo | 0.3543 | in |
| Groove weld depth between Nozzle and Vessel | Wgnv | 0.3900 | in |
| Inside Projection | h | 0.0000 | in |
| Weld leg size, Inside Element to Shell | Wi | 0.0000 | in |
| | | | |
| Flange Class | | 600 | |
| Flange Grade | | GR 2.3 | |

The Pressure Design option was MAWP + static head (to the nozzle).

**Nozzle Sketch (may not represent actual weld type/configuration)**



**Insert/Set-in Nozzle No Pad, no Inside projection**

**Reinforcement CALCULATION, Description: Nozzle L1 2"**

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation              2.000  in.
Actual Thickness Used in Calculation                    0.656  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Int. Press]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 150.0*14.6565/(14800*1.0-0.6*150.0)
  = 0.1495 in
```

Reqd thk per App. 1 of Nozzle Wall, trn            [Int. Press]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 1.0(exp([150.0/(10900.0*1.0]-1)
  = 0.0139 in
```

Required Nozzle thickness under External Pressure per UG-28 :  0.0151  in

**UG-40, Limits of Reinforcement : [Internal Pressure]**
```
Parallel to Vessel Wall (Diameter Limit)            Dl      4.0370  in
Parallel to Vessel Wall                        Rn+tn+t      2.0185  in
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp      0.9055  in
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 10900.0/14800.0 )
  = 0.736
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 10900.0/14800.0 )
  = 0.736
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 0.736, 1.0 )
  = 0.736
```

**Results of Nozzle Reinforcement Area Calculations: (in^2)**

| AREA AVAILABLE, A1 to A5 | | MAWP | External | Mapnc |
|---|---|---|---|---|
| Area Required | Ar | 0.351 | 0.208 | NA |
| Area in Shell | A1 | 0.360 | 0.313 | NA |

| | | | | |
|---|---|---|---|---|
| Area in Nozzle Wall | A2 | 0.857 | 0.855 | NA |
| Area in Inward Nozzle | A3 | 0.000 | 0.000 | NA |
| Area in Welds | A41+A42+A43 | 0.092 | 0.092 | NA |
| Area in Element | A5 | 0.000 | 0.000 | NA |
| TOTAL AREA AVAILABLE | Atot | 1.309 | 1.261 | NA |

The MAWP Case Governs the Analysis.

```
 Nozzle Angle Used in Area Calculations                   90.00  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:

```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (2.0*0.1495*1.0+2*0.6563*0.1495*1.0*(1-0.74))
  = 0.351 in^2
```

**Reinforcement Areas per Figure UG-37.1**

Area Available in Shell [A1]:

```
  = d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
  = 2.037( 1.0 * 0.3622 - 1.0 * 0.149 ) - 2 * 0.656
    ( 1.0 * 0.3622 - 1.0 * 0.1495 ) *( 1 - 0.736 )
  = 0.360 in^2
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 0.906 )( 0.6563 - 0.0139 ) 0.7365
  = 0.857 in^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  =  0.3543² * 0.7365 +( 0.0 )² * 0.7365
  = 0.092 in^2
```

**UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]**

```
 Wall Thickness for Internal/External pressures      ta = 0.0151 in
 Wall Thickness per UG16(b),                      tr16b = 0.0940 in
 Wall Thickness, shell/head, internal pressure     trb1 = 0.1810 in
 Wall Thickness                tb1 = max(trb1, tr16b) = 0.1810 in
 Wall Thickness, shell/head, external pressure     trb2 = 0.0464 in
 Wall Thickness                tb2 = max(trb2, tr16b) = 0.0940 in
 Wall Thickness per table UG-45                     tb3 = 0.1890 in
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.189, max( 0.181, 0.094 ) ]
  = 0.1810 in
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

```
  = max( ta, tb )
  = max( 0.0151, 0.181 )
  = 0.1810 in
```

Available Nozzle Neck Thickness = 0.6563 in --> OK

***Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):***

```
 Sustained  :    1297.4,  Allowable :  10900.0 psi  Passed
 Expansion  :       0.0,  Allowable :  33202.6 psi  Passed
 Occasional :      86.0,  Allowable :  14497.0 psi  Passed
```

```
 Shear      :   1283.3,  Allowable :   7630.0 psi  Passed
```

*The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

*SA-240 316L, Min Metal Temp without impact per UHA-51:  -320 °F*

*SA-182 F316L, Min Metal Temp without impact per UHA-51:  -320 °F*

Note:
The flange pressure ratio is less than 0.35.  Impact testing is not required due to low stress per UHA-51(g).

*Design Pressure/Ambient Rating = 150.00/1200.00 = 0.125*

Weld Size Calculations, Description: Nozzle L1 2"

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      0.3622  in
```

**Results Per UW-16.1:**

```
                          Required Thickness    Actual Thickness
 Nozzle Weld             0.2500 = Min per Code 0.2505 = 0.7 * Wo in
```

**Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)**

Weld Load [W]:
```
  = max( 0,  (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0,( 0.3506 - 0.3598 + 2 * 0.6563 * 0.7365 *
    (1.0 * 0.3622 - 0.1495 ) )14800)
  = 2907.97 lbf
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 0.8569 + 0.0 + 0.0925 - 0.0 * 0.74 ) * 14800
  = 14050.42 lbf
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 0.8569 + 0.0 + 0.0925 +( 0.3501 ) ) * 14800
  = 19232.60 lbf
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = (  0.8569 + 0.0 + 0.0925 + 0.0 +( 0.3501 ) ) * 14800
  = 19232.60 lbf
```

**Strength of Connection Elements for Failure Path Analysis**

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 3.3126 * 0.3543 * 0.49 * 10900
  = 9847. lbf
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 1.3281) *( 0.6563 - 0.0 ) * 0.7 * 10900
  = 20894. lbf
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 3.3126 *( 0.3937 - 0.0315 ) * 0.74 * 14800
  = 20641. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

**Strength of Failure Paths:**

Failure Path [Path 1-1]:
```
  = ( SONW + SNW ) = ( 9847 + 20894 ) = 30741 lbf
```

Failure Path [Path 2-2]:
```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 9847 + 0 + 20641 + 0 ) = 30489 lbf
```

Failure Path [Path 3-3]:
```
  = ( Sonw + Tngw + Sinw )
  = ( 9847 + 20641 + 0 ) = 30489 lbf
```

**Summary of Failure Path Calculations:**
```
 Path 1-1 = 30741   lbf, must exceed W = 2907 lbf     or W1 = 14050 lbf
 Path 2-2 = 30488   lbf, must exceed W = 2907 lbf     or W2 = 19232 lbf
 Path 3-3 = 30488   lbf, must exceed W = 2907 lbf     or W3 = 19232 lbf
```

**Maximum Allowable Pressure for this Nozzle at this Location:**
```
 Converged Maximum Allowable Pressure in the Operating case: 359 psig
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

```
 Nozzle is O.K. for the External Pressure: 15 psig
```

The Drop for this Nozzle is : 0.0941 in
The Cut Length for this Nozzle is, Drop + Ho + H + T : 7.5928 in

**Input Echo, WRC297 Item 1, Description: Nozzle L1 2" :**

```
 Diameter Basis for Cylindrical Shell                   ID
 Shell Corrosion Allowance                            0.0315  in
 Shell Diameter                                       29.250  in
 Shell Thickness                                      0.3937  in
 Shell Stress Concentration Factor                     1.000
 Vessel Material                                 SA-240 316L
 Vessel Cold S.I. Allowable                  Smc    16700.00  psi
 Vessel Hot  S.I. Allowable                  Smh    14800.00  psi

 Diameter Basis for Nozzle                              ID
 Nozzle Corrosion Allowance                           0.0000  in
 Nozzle Diameter                                       2.000  in
 Nozzle Thickness                                     0.6563  in
 Nozzle Stress Concentration Factor                    1.000
 Nozzle Material                                SA-182 F316L
 Nozzle Cold S.I. Allowable                 SNmc    16700.00  psi
 Nozzle Hot  S.I. Allowable                 SNmh    10900.00  psi
```

Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-182 F316L

*Note:*
*External Forces and Moments in WRC 107/537 Convention:*

```
18-D-272
R06
V-1264
PV Elite 24       Licensee: THE ANUP ENGINEERING LIMITED.
FileName : V-1264_R06    -----------------------------------
Nozzle Calcs.: Nozzle L1 2"          Nozl:   32   4:21pm  Dec 21,2022
```

*These loads are assumed to be SUStained loads.*

```
 Design Internal Pressure                      Dp      150.00  psig
 Radial Load                                    P     -630.00  lbf
 Circumferential Shear                         Vc      470.00  lbf
 Longitudinal Shear                            Vl      630.00  lbf
 Circumferential Moment                        Mc      210.00  ft-lbf
 Longitudinal Moment                           Ml      270.00  ft-lbf
 Torsional Moment                              Mt      310.00  ft-lbf

 Include Axial Pressure Thrust                              No
 Include Pressure Stress Indices per Div. 2                 No
 Local Loads applied at end of Nozzle/Attachment            No
```

*Warning - The ratio, Dn/Tn (5.047) is < 10*
*check the limitations of WRC bulletin 297.*

**Stress Computations at the Edge of the Nozzle:**

Stress Attenuation Diameter (for Insert Plates) per WRC 297:

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 3.313 + 2 * 1.65 * sqrt( 14.838( 0.394 - 0.031 ) )
  = 10.963 in
```

WRC 297 Curve Access Parameters:

```
 Vessel Mean Diameter       (D) =     29.675 in
 Nozzle Outside Diameter    (d) =      3.313 in
 Vessel Thickness used      (T) =      0.362 in
 Nozzle Thickness used      (t) =      0.656 in
 T / t                          =      0.552
 d / t                          =     10.000

Lambda = [(d/D) * sqrt(D/T)]  = 1.010

 Nr/P     =      0.106
 Mr/P     =      0.218
 M0/P     =      0.065
 N0/P     =      0.132
 MrD/Mc   =      0.304
 NrDL/Mc  =      0.097
 M0d/Mc   =      0.097
 N0DL/Mc  =      0.031
 MrD/Ml   =      0.195
 NrDL/Ml  =      0.090
 M0D/Ml   =      0.064
 N0DL/Ml  =      0.120
```

***Vessel Stresses  (psi):***

```
 LONGITUDINAL PLANE             Au        Al        Bu        Bl
 (Stresses Normal to           Top       Top    Bottom    Bottom
 longitudinal plane)        Outside    Inside   Outside    Inside
 ------------------------------------------------------------------
 Outplane Membrane  (P )        634       634       634       634
 Outplane Bending   (P )       1877     -1877      1877     -1877
 Outplane Membrane  (Mc)          0         0         0         0
 Outplane Bending   (Mc)          0         0         0         0
 Outplane Membrane  (ML)       -891      -891       891       891
 Outplane Bending   (ML)      -2871      2871      2871     -2871
 Normal Pressure Stress        5995      6145      5995      6145
 ----------------------- -------- -------- -------- --------
```

```
 Outplane Stress Summary     4744     6882    12268     2922
```

***Vessel Stresses (psi):***

```
 LONGITUDINAL PLANE            Au       Al       Bu       Bl
 (Stresses parallel to        Top      Top   Bottom   Bottom
 longitudinal plane)      Outside   Inside  Outside   Inside
 -----------------------------------------------------------
 Inplane Membrane (P )        510      510      510      510
 Inplane Bending  (P )       6293    -6293     6293    -6293
 Inplane Membrane (Mc)          0        0        0        0
 Inplane Bending  (Mc)          0        0        0        0
 Inplane Membrane (ML)       -669     -669      669      669
 Inplane Bending  (ML)      -8720     8720     8720    -8720
 Inplane Pressure Stress     2997     2997     2997     2997
 ----------------------- -------- -------- -------- --------
 Inplane Stress Summary       411     5265    19189   -10837
```

***Vessel Stresses (psi):***

```
 LONGITUDINAL PLANE            Au       Al       Bu       Bl
 (Shear stress normal to      Top      Top   Bottom   Bottom
 longitudinal plane)      Outside   Inside  Outside   Inside
 -----------------------------------------------------------
 Outplane  Shear  (Vc)        249      249     -249     -249
 Outplane  Shear  (Vl)          0        0        0        0
 Outplane  Shear  (Mt)        595      595      595      595
 ----------------------- -------- -------- -------- --------
 Shear Stress Summary         844      844      346      346
```

***Vessel Stresses (psi):***

```
 LONGITUDINAL PLANE            Au       Al       Bu       Bl
 (Stress Intensities          Top      Top   Bottom   Bottom
                          Outside   Inside  Outside   Inside
 -----------------------------------------------------------
 Two * Max Shear Stress      4902     7242    19206    13776
```

***Vessel Stresses (psi):***

```
 CIRCUMFERENTIAL PLANE         Cu       Cl       Du       Dl
 (Stresses Normal to         Left     Left    Right    Right
 circumferential plane)   Outside   Inside  Outside   Inside
 -----------------------------------------------------------
 Outplane Membrane (P )       634      634      634      634
 Outplane Bending  (P )      1877    -1877     1877    -1877
 Outplane Membrane (Mc)      -181     -181      181      181
 Outplane Bending  (Mc)     -3389     3389     3389    -3389
 Outplane Membrane (ML)         0        0        0        0
 Outplane Bending  (ML)         0        0        0        0
 Normal Pressure Stress      2997     2997     2997     2997
 ----------------------- -------- -------- -------- --------
 Outplane Stress Summary     1938     4962     9078    -1454
```

***Vessel Stresses (psi):***

```
 CIRCUMFERENTIAL PLANE         Cu       Cl       Du       Dl
 (Stresses parallel to       Left     Left    Right    Right
 circumferential plane)   Outside   Inside  Outside   Inside
 -----------------------------------------------------------
 Inplane Membrane (P )        510      510      510      510
 Inplane Bending  (P )       6293    -6293     6293    -6293
 Inplane Membrane (Mc)       -562     -562      562      562
 Inplane Bending  (Mc)     -10562    10562    10562   -10562
 Inplane Membrane (ML)          0        0        0        0
 Inplane Bending  (ML)          0        0        0        0
```

| | | | | |
|---|---|---|---|---|
| Inplane Pressure Stress | 5995 | 6145 | 5995 | 6145 |
| Inplane Stress Summary | 1674 | 10362 | 23922 | -9638 |

***Vessel Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Shear stress normal to circumferential plane) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Outplane Shear (Vc) | 0 | 0 | 0 | 0 |
| Outplane Shear (Vl) | -334 | -334 | 334 | 334 |
| Torsional Shear (Mt) | 595 | 595 | 595 | 595 |
| Shear Stress Summary | 261 | 261 | 929 | 929 |

***Vessel Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stress Intensities | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 2098 | 10374 | 23979 | 9742 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Stresses in the hoop direction) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Hoop Membrane (P ) | 634 | 634 | 634 | 634 |
| Hoop Bending (P ) | 0 | 0 | 0 | 0 |
| Hoop Membrane (Mc) | 0 | 0 | 0 | 0 |
| Hoop Bending (Mc) | 0 | 0 | 0 | 0 |
| Hoop Membrane (ML) | -891 | -891 | 891 | 891 |
| Hoop Bending (ML) | 0 | 0 | 0 | 0 |
| Hoop Pressure Stress | 206 | 386 | 206 | 386 |
| Hoop Stress Summary | -51 | 129 | 1731 | 1911 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Stresses Normal to pipe cross-section) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Axial Membrane (P ) | 115 | 115 | 115 | 115 |
| Axial Bending (P ) | 1450 | -1450 | 1450 | -1450 |
| Axial Membrane (Mc) | 0 | 0 | 0 | 0 |
| Axial Bending (Mc) | 0 | 0 | 0 | 0 |
| Axial Membrane (ML) | -1047 | -1047 | 1047 | 1047 |
| Axial Bending (ML) | -2044 | 2044 | 2044 | -2044 |
| Axial Pressure Stress | 103 | 103 | 103 | 103 |
| Axial Stress Summary | -1423 | -235 | 4759 | -2229 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Shear stress) | Au Outside | Al Inside | Bu Outside | Bl Inside |
|---|---|---|---|---|
| Shear due to (Vc) | 137 | 137 | -137 | -137 |
| Shear due to (Vl) | 0 | 0 | 0 | 0 |
| Shear due to Torsion | 328 | 328 | 328 | 328 |
| Shear Stress Summary | 465 | 465 | 191 | 191 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Stress Intensities | Au Outside | Al Inside | Bu Outside | Bl Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 1657 | 998 | 4771 | 4157 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stresses in the hoop direction) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Hoop Membrane (P ) | 634 | 634 | 634 | 634 |
| Hoop Bending (P ) | 0 | 0 | 0 | 0 |
| Hoop Membrane (Mc) | -181 | -181 | 181 | 181 |
| Hoop Bending (Mc) | 0 | 0 | 0 | 0 |
| Hoop Membrane (ML) | 0 | 0 | 0 | 0 |
| Hoop Bending (ML) | 0 | 0 | 0 | 0 |
| Hoop Pressure Stress | 206 | 386 | 206 | 386 |
| Hoop Stress Summary | 659 | 839 | 1021 | 1201 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stresses Normal to pipe cross-section) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Axial Membrane (P ) | 115 | 115 | 115 | 115 |
| Axial Bending (P ) | 1450 | -1450 | 1450 | -1450 |
| Axial Membrane (Mc) | -814 | -814 | 814 | 814 |
| Axial Bending (Mc) | -2703 | 2703 | 2703 | -2703 |
| Axial Membrane (ML) | 0 | 0 | 0 | 0 |
| Axial Bending (ML) | 0 | 0 | 0 | 0 |
| Axial Pressure Stress | 103 | 103 | 103 | 103 |
| Axial Stress Summary | -1849 | 657 | 5185 | -3121 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Shear stress) | Cu Outside | Cl Inside | Du Outside | Dl Inside |
|---|---|---|---|---|
| Shear due to (Vc) | 0 | 0 | 0 | 0 |
| Shear due to (Vl) | -184 | -184 | 184 | 184 |
| Shear due to Torsion | 328 | 328 | 328 | 328 |
| Shear Stress Summary | 144 | 144 | 512 | 512 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stress Intensities | Cu Outside | Cl Inside | Du Outside | Dl Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 2524 | 918 | 5247 | 4441 |

**WRC 297 Stress Summations per ASME Sec. VIII Div. 2:**

**Vessel Stress Summation at Vessel-Nozzle Junction (psi):**

| Type of Stress Int. Location | Stress Values at Au | Al | Bu | Bl | Cu | Cl | Du | Dl |
|---|---|---|---|---|---|---|---|---|

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Circ. Pm (SUS) | 5995 | 6145 | 5995 | 6145 | 5995 | 6145 | 5995 | 6145 |
| Circ. Pl (SUS) | -257 | -257 | 1525 | 1525 | -52 | -52 | 1072 | 1072 |
| Circ. Q (SUS) | -994 | 994 | 4748 | -4748 | -4269 | 4269 | 16855 | -16855 |
| Long. Pm (SUS) | 2997 | 2997 | 2997 | 2997 | 2997 | 2997 | 2997 | 2997 |
| Long. Pl (SUS) | -159 | -159 | 1179 | 1179 | 453 | 453 | 815 | 815 |
| Long. Q (SUS) | -2427 | 2427 | 15013 | -15013 | -1512 | 1512 | 5266 | -5266 |
| Shear Pm (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Shear Pl (SUS) | 249 | 249 | -249 | -249 | -334 | -334 | 334 | 334 |
| Shear Q (SUS) | 595 | 595 | 595 | 595 | 595 | 595 | 595 | 595 |
| Pm (SUS) | 5995 | 6145 | 5995 | 6145 | 5995 | 6145 | 5995 | 6145 |
| Pm+Pl (SUS) | 5759 | 5908 | 7538 | 7687 | 5986 | 6134 | 7100 | 7249 |
| Pm+Pl+Q (Total) | 4902 | 7242 | 19206 | 13776 | 2098 | 10374 | 23979 | 9742 |

**Vessel Stress Summation Comparison (psi):**

| Type of Stress Int. | Max. S.I. | S.I. Allowable | Result |
|---|---|---|---|
| Pm (SUS) | 6145 | 14800 | Passed |
| Pm+Pl (SUS) | 7687 | 22200 | Passed |
| Pm+Pl+Q (TOTAL) | 23979 | 44400 | Passed |

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

**WRC 297 Stress Summations per ASME Sec. VIII Div. 2:**

**Nozzle Stress Summation at Vessel-Nozzle Junction (psi):**

| Type of Stress Int. Location | Stress Values at Au | Al | Bu | Bl | Cu | Cl | Du | Dl |
|---|---|---|---|---|---|---|---|---|
| Circ. Pm (SUS) | 206 | 386 | 206 | 386 | 206 | 386 | 206 | 386 |
| Circ. Pl (SUS) | -257 | -257 | 1525 | 1525 | 453 | 453 | 815 | 815 |
| Circ. Q (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Long. Pm (SUS) | 103 | 103 | 103 | 103 | 103 | 103 | 103 | 103 |
| Long. Pl (SUS) | -932 | -932 | 1162 | 1162 | -699 | -699 | 929 | 929 |
| Long. Q (SUS) | -594 | 594 | 3494 | -3494 | -1253 | 1253 | 4153 | -4153 |
| Shear Pm (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Shear Pl (SUS) | 137 | 137 | -137 | -137 | -184 | -184 | 184 | 184 |
| Shear Q (SUS) | 328 | 328 | 328 | 328 | 328 | 328 | 328 | 328 |
| Pm (SUS) | 206 | 386 | 206 | 386 | 206 | 386 | 206 | 386 |
| Pm+Pl (SUS) | 852 | 996 | 1768 | 1938 | 1307 | 1481 | 1210 | 1318 |
| Pm+Pl+Q (Total) | 1657 | 998 | 4771 | 4157 | 2524 | 918 | 5247 | 4441 |

**Nozzle Stress Summation Comparison (psi):**

| Type of Stress Int. | Max. S.I. | S.I. Allowable | Result |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Pm (SUS) | 386 | 10900 | Passed |
| Pm+Pl (SUS) | 1938 | 16350 | Passed |
| Pm+Pl+Q (TOTAL) | 5247 | 32700 | Passed |

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

**Input, Nozzle Desc: Nozzle B4 2" From: 50**

| | | | |
|---|---|---|---|
| Pressure for Reinforcement Calculations | P | 150.000 | psig |
| Temperature for Internal Pressure | Temp | 500 | °F |
| Design External Pressure | Pext | 15.00 | psig |
| Temperature for External Pressure | Tempex | 300 | °F |
| Parent Material | | SA-240 316L | |
| Parent Allowable Stress at Temperature | Sv | 14800.00 | psi |
| Parent Allowable Stress At Ambient | Sva | 16700.00 | psi |
| Inside Diameter of Cylindrical Shell | D | 29.2500 | in |
| Design Length of Section | L | 118.5000 | in |
| Shell Finished (Minimum) Thickness | t | 0.3937 | in |
| Shell Internal Corrosion Allowance | c | 0.0315 | in |
| Shell External Corrosion Allowance | co | 0.0000 | in |
| Distance from Bottom/Left Tangent | | 3.66 | ft |
| User Entered Minimum Design Metal Temperature | | 32.00 | °F |

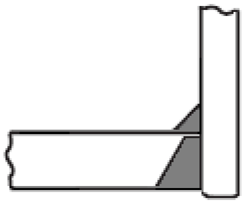
***Type of Element Connected to the Parent : Nozzle***

| | | | |
|---|---|---|---|
| Material | | SA-182 F316L | |
| Material UNS Number | | S31603 | |
| Material Specification/Type | | Forgings | |
| Allowable Stress at Temperature | Sn | 10900.00 | psi |
| Allowable Stress At Ambient | Sna | 16700.00 | psi |
| Diameter Basis (for tr calc only) | | Inside | |
| Layout Angle | | 300.00 | deg |
| Diameter | | 2.0000 | in. |
| Size and Thickness Basis | | Actual | |
| Actual Thickness | tn | 0.6563 | in |
| Flange Type | | Long Weld Neck | |
| Corrosion Allowance | can | 0.0315 | in |
| Joint Efficiency of Shell Seam at Nozzle | E1 | 1.00 | |
| Joint Efficiency of Nozzle Neck | En | 1.00 | |
| Outside Projection | ho | 7.1078 | in |
| Weld leg size between Nozzle and Pad/Shell | Wo | 0.3543 | in |
| Groove weld depth between Nozzle and Vessel | Wgnv | 0.3900 | in |
| Inside Projection | h | 0.0000 | in |
| Weld leg size, Inside Element to Shell | Wi | 0.0000 | in |
| Flange Class | | 600 | |
| Flange Grade | | GR 2.3 | |

The Pressure Design option was MAWP + static head (to the nozzle).

**Nozzle Sketch (may not represent actual weld type/configuration)**

```
18-D-272
R06
V-1264
PV Elite 24        Licensee: THE ANUP ENGINEERING LIMITED.
FileName : V-1264_R06    -----------------------------------
Nozzle Calcs.: Nozzle B4 2"          Nozl:    33   4:21pm  Dec 21,2022
```



**Insert/Set-in Nozzle No Pad, no Inside projection**

**Reinforcement CALCULATION, Description: Nozzle B4 2"**

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation              2.000  in.
Actual Thickness Used in Calculation                    0.656  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Int. Press]

```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 150.0*14.6565/(14800*1.0-0.6*150.0)
  = 0.1495 in
```

Reqd thk per App. 1 of Nozzle Wall, trn [Int. Press]

```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 1.031(exp([150.0/(10900.0*1.0]-1)
  = 0.0143 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0151 in

**UG-40, Limits of Reinforcement : [Internal Pressure]**

```
 Parallel to Vessel Wall (Diameter Limit)            Dl     4.1260  in
 Parallel to Vessel Wall, opening length              d     2.0630  in
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     0.9055  in
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 10900.0/14800.0 )
  = 0.736
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 10900.0/14800.0 )
  = 0.736
```

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 0.736, 1.0 )
  = 0.736
```

**Results of Nozzle Reinforcement Area Calculations: (in^2)**

| AREA AVAILABLE, A1 to A5 | | MAWP | External | Mapnc |
|---|---|---|---|---|
| Area Required | Ar | 0.358 | 0.212 | NA |
| Area in Shell | A1 | 0.369 | 0.321 | NA |

| | | | | |
|---|---|---|---|---|
| Area in Nozzle Wall | A2 | 0.814 | 0.813 | NA |
| Area in Inward Nozzle | A3 | 0.000 | 0.000 | NA |
| Area in Welds | A41+A42+A43 | 0.092 | 0.092 | NA |
| Area in Element | A5 | 0.000 | 0.000 | NA |
| TOTAL AREA AVAILABLE | Atot | 1.276 | 1.227 | NA |

The MAWP Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
```
= ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
= (2.063*0.1495*1.0+2*0.6248*0.1495*1.0*(1-0.74))
= 0.358 in^2
```

**Reinforcement Areas per Figure UG-37.1**

Area Available in Shell [A1]:
```
= d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
= 2.063( 1.0 * 0.3622 - 1.0 * 0.149 ) - 2 * 0.625
  ( 1.0 * 0.3622 - 1.0 * 0.1495 ) *( 1 - 0.736 )
= 0.369 in^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
= ( 2 * tlnp )( tn - trn )fr2
= ( 2 * 0.906 )( 0.6248 - 0.0143 ) 0.7365
= 0.814 in^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
= Wo² * fr2 + ( Wi-can/0.707 )² * fr2
=  0.3543² * 0.7365 +( 0.0 )² * 0.7365
= 0.092 in^2
```

**UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]**
```
Wall Thickness for Internal/External pressures        ta = 0.0466 in
Wall Thickness per UG16(b),                        tr16b = 0.0940 in
Wall Thickness, shell/head, internal pressure       trb1 = 0.1810 in
Wall Thickness                 tb1 = max(trb1, tr16b) = 0.1810 in
Wall Thickness, shell/head, external pressure       trb2 = 0.0464 in
Wall Thickness                 tb2 = max(trb2, tr16b) = 0.0940 in
Wall Thickness per table UG-45                       tb3 = 0.2205 in
```

Determine Nozzle Thickness candidate [tb]:
```
= min[ tb3, max( tb1,tb2) ]
= min[ 0.22, max( 0.181, 0.094 ) ]
= 0.1810 in
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
= max( ta, tb )
= max( 0.0466, 0.181 )
= 0.1810 in
```

Available Nozzle Neck Thickness = 0.6563 in --> OK

***Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):***
```
Sustained  :   1329.5,  Allowable :  10900.0 psi  Passed
Expansion  :      0.0,  Allowable :  33170.5 psi  Passed
Occasional :     95.0,  Allowable :  14497.0 psi  Passed
```

```
 Shear      :   1278.8,  Allowable :   7630.0 psi  Passed
```

*The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

*SA-240 316L, Min Metal Temp without impact per UHA-51: -320 °F*

*SA-182 F316L, Min Metal Temp without impact per UHA-51: -320 °F*

Note:
The flange pressure ratio is less than 0.35. Impact testing is not required due to low stress per UHA-51(g).

*Design Pressure/Ambient Rating = 150.00/1200.00 = 0.125*

Weld Size Calculations, Description: Nozzle B4 2"

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      0.3622  in
```

**Results Per UW-16.1:**

```
                        Required Thickness    Actual Thickness
 Nozzle Weld           0.2500 = Min per Code 0.2505 = 0.7 * Wo in
```

**Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)**

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0,( 0.3575 - 0.3688 + 2 * 0.6248 * 0.7365 *
    (1.0 * 0.3622 - 0.1495 ) )14800)
  = 2730.43 lbf
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 0.8143 + 0.0 + 0.0925 - 0.0 * 0.74 ) * 14800
  = 13420.07 lbf
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 0.8143 + 0.0 + 0.0925 +( 0.3333 ) ) * 14800
  = 18353.55 lbf
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = (  0.8143 + 0.0 + 0.0925 + 0.0 +( 0.3333 ) ) * 14800
  = 18353.55 lbf
```

**Strength of Connection Elements for Failure Path Analysis**

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 3.3126 * 0.3543 * 0.49 * 10900
  = 9847. lbf
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 1.3439) *( 0.6563 - 0.0315 ) * 0.7 * 10900
  = 20127. lbf
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 3.3126 *( 0.3937 - 0.0315 ) * 0.74 * 14800
  = 20641. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

**Strength of Failure Paths:**

Failure Path [Path 1-1]:
```
  = ( SONW + SNW ) = ( 9847 + 20127 ) = 29975 lbf
```

Failure Path [Path 2-2]:
```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 9847 + 0 + 20641 + 0 ) = 30489 lbf
```

Failure Path [Path 3-3]:
```
  = ( Sonw + Tngw + Sinw )
  = ( 9847 + 20641 + 0 ) = 30489 lbf
```

**Summary of Failure Path Calculations:**
```
 Path 1-1 = 29974   lbf, must exceed W = 2730 lbf     or W1 = 13420 lbf
 Path 2-2 = 30488   lbf, must exceed W = 2730 lbf     or W2 = 18353 lbf
 Path 3-3 = 30488   lbf, must exceed W = 2730 lbf     or W3 = 18353 lbf
```

**Maximum Allowable Pressure for this Nozzle at this Location:**
```
 Converged Maximum Allowable Pressure in the Operating case: 359 psig
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

```
 Nozzle is O.K. for the External Pressure: 15 psig
```

The Drop for this Nozzle is : 0.0941 in
The Cut Length for this Nozzle is, Drop + Ho + H + T : 7.5956 in

**Input Echo, WRC297 Item    1,        Description: Nozzle B4 2"  :**

```
 Diameter Basis for Cylindrical Shell                    ID
 Shell Corrosion Allowance                               0.0315  in
 Shell Diameter                                          29.250  in
 Shell Thickness                                         0.3937  in
 Shell Stress Concentration Factor                        1.000
 Vessel Material                                    SA-240 316L
 Vessel Cold S.I. Allowable                     Smc    16700.00  psi
 Vessel Hot  S.I. Allowable                     Smh    14800.00  psi

 Diameter Basis for Nozzle                               ID
 Nozzle Corrosion Allowance                              0.0315  in
 Nozzle Diameter                                          2.000  in
 Nozzle Thickness                                        0.6563  in
 Nozzle Stress Concentration Factor                       1.000
 Nozzle Material                                   SA-182 F316L
 Nozzle Cold S.I. Allowable                    SNmc    16700.00  psi
 Nozzle Hot  S.I. Allowable                    SNmh    10900.00  psi
```

Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-182 F316L

*Note:*
*External Forces and Moments in WRC 107/537 Convention:*

*These loads are assumed to be SUStained loads.*

| | | | |
|---|---|---|---|
| Design Internal Pressure | Dp | 150.00 | psig |
| Radial Load | P | -630.00 | lbf |
| Circumferential Shear | Vc | 470.00 | lbf |
| Longitudinal Shear | Vl | 630.00 | lbf |
| Circumferential Moment | Mc | 210.00 | ft-lbf |
| Longitudinal Moment | Ml | 270.00 | ft-lbf |
| Torsional Moment | Mt | 310.00 | ft-lbf |

| | |
|---|---|
| Include Axial Pressure Thrust | No |
| Include Pressure Stress Indices per Div. 2 | No |
| Local Loads applied at end of Nozzle/Attachment | No |

*Warning - The ratio, Dn/Tn (5.047) is < 10*
*check the limitations of WRC bulletin 297.*

**Stress Computations at the Edge of the Nozzle:**

Stress Attenuation Diameter (for Insert Plates) per WRC 297:
= NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
= 3.313 + 2 * 1.65 * sqrt( 14.838( 0.394 - 0.031 ) )
= 10.963 in

WRC 297 Curve Access Parameters:

| | | | |
|---|---|---|---|
| Vessel Mean Diameter | (D) = | 29.675 | in |
| Nozzle Outside Diameter | (d) = | 3.313 | in |
| Vessel Thickness used | (T) = | 0.362 | in |
| Nozzle Thickness used | (t) = | 0.625 | in |
| T / t | = | 0.580 | |
| d / t | = | 10.000 | |

Lambda = [(d/D) * sqrt(D/T)] = 1.010

| | | |
|---|---|---|
| Nr/P | = | 0.108 |
| Mr/P | = | 0.217 |
| M0/P | = | 0.065 |
| N0/P | = | 0.131 |
| MrD/Mc | = | 0.302 |
| NrDL/Mc | = | 0.100 |
| M0d/Mc | = | 0.098 |
| N0DL/Mc | = | 0.027 |
| MrD/Ml | = | 0.195 |
| NrDL/Ml | = | 0.091 |
| M0D/Ml | = | 0.065 |
| N0DL/Ml | = | 0.119 |

***Vessel Stresses (psi):***

| LONGITUDINAL PLANE (Stresses Normal to longitudinal plane) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Outplane Membrane (P ) | 630 | 630 | 630 | 630 |
| Outplane Bending (P ) | 1876 | -1876 | 1876 | -1876 |
| Outplane Membrane (Mc) | 0 | 0 | 0 | 0 |
| Outplane Bending (Mc) | 0 | 0 | 0 | 0 |
| Outplane Membrane (ML) | -889 | -889 | 889 | 889 |
| Outplane Bending (ML) | -2899 | 2899 | 2899 | -2899 |
| Normal Pressure Stress | 5995 | 6145 | 5995 | 6145 |

| | | | | |
|---|---|---|---|---|
| Outplane Stress Summary | 4713 | 6909 | 12289 | 2889 |

***Vessel Stresses (psi):***

| LONGITUDINAL PLANE (Stresses parallel to longitudinal plane) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Inplane Membrane (P ) | 516 | 516 | 516 | 516 |
| Inplane Bending (P ) | 6238 | -6238 | 6238 | -6238 |
| Inplane Membrane (Mc) | 0 | 0 | 0 | 0 |
| Inplane Bending (Mc) | 0 | 0 | 0 | 0 |
| Inplane Membrane (ML) | -679 | -679 | 679 | 679 |
| Inplane Bending (ML) | -8728 | 8728 | 8728 | -8728 |
| Inplane Pressure Stress | 2997 | 2997 | 2997 | 2997 |
| Inplane Stress Summary | 344 | 5324 | 19158 | -10774 |

***Vessel Stresses (psi):***

| LONGITUDINAL PLANE (Shear stress normal to longitudinal plane) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Outplane Shear (Vc) | 249 | 249 | -249 | -249 |
| Outplane Shear (Vl) | 0 | 0 | 0 | 0 |
| Outplane Shear (Mt) | 595 | 595 | 595 | 595 |
| Shear Stress Summary | 844 | 844 | 346 | 346 |

***Vessel Stresses (psi):***

| LONGITUDINAL PLANE (Stress Intensities | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 4870 | 7274 | 19175 | 13680 |

***Vessel Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stresses Normal to circumferential plane) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Outplane Membrane (P ) | 630 | 630 | 630 | 630 |
| Outplane Bending (P ) | 1876 | -1876 | 1876 | -1876 |
| Outplane Membrane (Mc) | -156 | -156 | 156 | 156 |
| Outplane Bending (Mc) | -3411 | 3411 | 3411 | -3411 |
| Outplane Membrane (ML) | 0 | 0 | 0 | 0 |
| Outplane Bending (ML) | 0 | 0 | 0 | 0 |
| Normal Pressure Stress | 2997 | 2997 | 2997 | 2997 |
| Outplane Stress Summary | 1936 | 5006 | 9070 | -1504 |

***Vessel Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stresses parallel to circumferential plane) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Inplane Membrane (P ) | 516 | 516 | 516 | 516 |
| Inplane Bending (P ) | 6238 | -6238 | 6238 | -6238 |
| Inplane Membrane (Mc) | -579 | -579 | 579 | 579 |
| Inplane Bending (Mc) | -10510 | 10510 | 10510 | -10510 |
| Inplane Membrane (ML) | 0 | 0 | 0 | 0 |
| Inplane Bending (ML) | 0 | 0 | 0 | 0 |

| | | | | |
|---|---|---|---|---|
| Inplane Pressure Stress | 5995 | 6145 | 5995 | 6145 |
| Inplane Stress Summary | 1660 | 10354 | 23838 | -9508 |

***Vessel Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Shear stress normal to circumferential plane) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Outplane Shear (Vc) | 0 | 0 | 0 | 0 |
| Outplane Shear (Vl) | -334 | -334 | 334 | 334 |
| Torsional Shear (Mt) | 595 | 595 | 595 | 595 |
| Shear Stress Summary | 261 | 261 | 929 | 929 |

***Vessel Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stress Intensities | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 2093 | 10366 | 23896 | 9614 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Stresses in the hoop direction) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Hoop Membrane (P ) | 630 | 630 | 630 | 630 |
| Hoop Bending (P ) | 0 | 0 | 0 | 0 |
| Hoop Membrane (Mc) | 0 | 0 | 0 | 0 |
| Hoop Bending (Mc) | 0 | 0 | 0 | 0 |
| Hoop Membrane (ML) | -889 | -889 | 889 | 889 |
| Hoop Bending (ML) | 0 | 0 | 0 | 0 |
| Hoop Pressure Stress | 228 | 408 | 228 | 408 |
| Hoop Stress Summary | -31 | 149 | 1747 | 1927 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Stresses Normal to pipe cross-section) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Axial Membrane (P ) | 119 | 119 | 119 | 119 |
| Axial Bending (P ) | 1575 | -1575 | 1575 | -1575 |
| Axial Membrane (Mc) | 0 | 0 | 0 | 0 |
| Axial Bending (Mc) | 0 | 0 | 0 | 0 |
| Axial Membrane (ML) | -1068 | -1068 | 1068 | 1068 |
| Axial Bending (ML) | -2247 | 2247 | 2247 | -2247 |
| Axial Pressure Stress | 114 | 114 | 114 | 114 |
| Axial Stress Summary | -1507 | -163 | 5123 | -2521 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Shear stress) | Au Outside | Al Inside | Bu Outside | Bl Inside |
|---|---|---|---|---|
| Shear due to (Vc) | 144 | 144 | -144 | -144 |
| Shear due to (Vl) | 0 | 0 | 0 | 0 |
| Shear due to Torsion | 345 | 345 | 345 | 345 |
| Shear Stress Summary | 489 | 489 | 201 | 201 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Stress Intensities | Au Outside | Al Inside | Bu Outside | Bl Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 1770 | 1026 | 5134 | 4466 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stresses in the hoop direction) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Hoop Membrane (P ) | 630 | 630 | 630 | 630 |
| Hoop Bending (P ) | 0 | 0 | 0 | 0 |
| Hoop Membrane (Mc) | -156 | -156 | 156 | 156 |
| Hoop Bending (Mc) | 0 | 0 | 0 | 0 |
| Hoop Membrane (ML) | 0 | 0 | 0 | 0 |
| Hoop Bending (ML) | 0 | 0 | 0 | 0 |
| Hoop Pressure Stress | 228 | 408 | 228 | 408 |
| Hoop Stress Summary | 702 | 882 | 1014 | 1194 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stresses Normal to pipe cross-section) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Axial Membrane (P ) | 119 | 119 | 119 | 119 |
| Axial Bending (P ) | 1575 | -1575 | 1575 | -1575 |
| Axial Membrane (Mc) | -831 | -831 | 831 | 831 |
| Axial Bending (Mc) | -2947 | 2947 | 2947 | -2947 |
| Axial Membrane (ML) | 0 | 0 | 0 | 0 |
| Axial Bending (ML) | 0 | 0 | 0 | 0 |
| Axial Pressure Stress | 114 | 114 | 114 | 114 |
| Axial Stress Summary | -1970 | 774 | 5586 | -3458 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Shear stress) | Cu Outside | Cl Inside | Du Outside | Dl Inside |
|---|---|---|---|---|
| Shear due to (Vc) | 0 | 0 | 0 | 0 |
| Shear due to (Vl) | -193 | -193 | 193 | 193 |
| Shear due to Torsion | 345 | 345 | 345 | 345 |
| Shear Stress Summary | 152 | 152 | 538 | 538 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stress Intensities | Cu Outside | Cl Inside | Du Outside | Dl Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 2689 | 989 | 5648 | 4774 |

**WRC 297 Stress Summations per ASME Sec. VIII Div. 2:**

**Vessel Stress Summation at Vessel-Nozzle Junction (psi):**

| Type of Stress Int. Location | Stress Values at Au | Al | Bu | Bl | Cu | Cl | Du | Dl |
|---|---|---|---|---|---|---|---|---|

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Circ. Pm (SUS) | 5995 | 6145 | 5995 | 6145 | 5995 | 6145 | 5995 | 6145 |
| Circ. Pl (SUS) | -259 | -259 | 1519 | 1519 | -63 | -63 | 1095 | 1095 |
| Circ. Q (SUS) | -1023 | 1023 | 4775 | -4775 | -4272 | 4272 | 16748 | -16748 |
| Long. Pm (SUS) | 2997 | 2997 | 2997 | 2997 | 2997 | 2997 | 2997 | 2997 |
| Long. Pl (SUS) | -163 | -163 | 1195 | 1195 | 474 | 474 | 786 | 786 |
| Long. Q (SUS) | -2490 | 2490 | 14966 | -14966 | -1535 | 1535 | 5287 | -5287 |
| Shear Pm (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Shear Pl (SUS) | 249 | 249 | -249 | -249 | -334 | -334 | 334 | 334 |
| Shear Q (SUS) | 595 | 595 | 595 | 595 | 595 | 595 | 595 | 595 |
| Pm (SUS) | 5995 | 6145 | 5995 | 6145 | 5995 | 6145 | 5995 | 6145 |
| Pm+Pl (SUS) | 5757 | 5906 | 7532 | 7681 | 5976 | 6124 | 7123 | 7271 |
| Pm+Pl+Q (Total) | 4870 | 7274 | 19175 | 13680 | 2093 | 10366 | 23896 | 9614 |

**Vessel Stress Summation Comparison (psi):**

| Type of Stress Int. | Max. S.I. | S.I. Allowable | Result |
|---|---|---|---|
| Pm (SUS) | 6145 | 14800 | Passed |
| Pm+Pl (SUS) | 7681 | 22200 | Passed |
| Pm+Pl+Q (TOTAL) | 23896 | 44400 | Passed |

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

**WRC 297 Stress Summations per ASME Sec. VIII Div. 2:**

**Nozzle Stress Summation at Vessel-Nozzle Junction (psi):**

| Type of Stress Int. Location | Stress Values at Au | Al | Bu | Bl | Cu | Cl | Du | Dl |
|---|---|---|---|---|---|---|---|---|
| Circ. Pm (SUS) | 228 | 408 | 228 | 408 | 228 | 408 | 228 | 408 |
| Circ. Pl (SUS) | -259 | -259 | 1519 | 1519 | 474 | 474 | 786 | 786 |
| Circ. Q (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Long. Pm (SUS) | 114 | 114 | 114 | 114 | 114 | 114 | 114 | 114 |
| Long. Pl (SUS) | -949 | -949 | 1187 | 1187 | -712 | -712 | 950 | 950 |
| Long. Q (SUS) | -672 | 672 | 3822 | -3822 | -1372 | 1372 | 4522 | -4522 |
| Shear Pm (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Shear Pl (SUS) | 144 | 144 | -144 | -144 | -193 | -193 | 193 | 193 |
| Shear Q (SUS) | 345 | 345 | 345 | 345 | 345 | 345 | 345 | 345 |
| Pm (SUS) | 228 | 408 | 228 | 408 | 228 | 408 | 228 | 408 |
| Pm+Pl (SUS) | 860 | 1025 | 1789 | 1958 | 1356 | 1529 | 1233 | 1332 |
| Pm+Pl+Q (Total) | 1770 | 1026 | 5134 | 4466 | 2689 | 989 | 5648 | 4774 |

**Nozzle Stress Summation Comparison (psi):**

| Type of Stress Int. | Max. S.I. | S.I. Allowable | Result |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Pm (SUS) | 408 | 10900 | Passed |
| Pm+Pl (SUS) | 1958 | 16350 | Passed |
| Pm+Pl+Q (TOTAL) | 5648 | 32700 | Passed |

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

**Input, Nozzle Desc: Nozzle B3 2" From: 50**

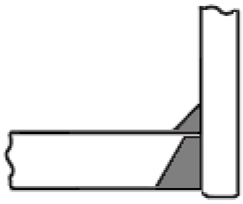
| | | | |
|---|---|---|---|
| Pressure for Reinforcement Calculations | P | 150.001 | psig |
| Temperature for Internal Pressure | Temp | 500 | °F |
| Design External Pressure | Pext | 15.00 | psig |
| Temperature for External Pressure | Tempex | 300 | °F |
| | | | |
| Parent Material | | SA-240 316L | |
| Parent Allowable Stress at Temperature | Sv | 14800.00 | psi |
| Parent Allowable Stress At Ambient | Sva | 16700.00 | psi |
| | | | |
| Inside Diameter of Cylindrical Shell | D | 29.2500 | in |
| Design Length of Section | L | 118.5000 | in |
| Shell Finished (Minimum) Thickness | t | 0.3937 | in |
| Shell Internal Corrosion Allowance | c | 0.0315 | in |
| Shell External Corrosion Allowance | co | 0.0000 | in |
| | | | |
| Distance from Bottom/Left Tangent | | 3.16 | ft |
| | | | |
| User Entered Minimum Design Metal Temperature | | 32.00 | °F |

***Type of Element Connected to the Parent : Nozzle***

| | | | |
|---|---|---|---|
| Material | | SA-182 F316L | |
| Material UNS Number | | S31603 | |
| Material Specification/Type | | Forgings | |
| Allowable Stress at Temperature | Sn | 10900.00 | psi |
| Allowable Stress At Ambient | Sna | 16700.00 | psi |
| | | | |
| Diameter Basis (for tr calc only) | | Inside | |
| Layout Angle | | 225.00 | deg |
| Diameter | | 2.0000 | in. |
| | | | |
| Size and Thickness Basis | | Actual | |
| Actual Thickness | tn | 0.6563 | in |
| | | | |
| Flange Type | | Long Weld Neck | |
| | | | |
| Corrosion Allowance | can | 0.0315 | in |
| Joint Efficiency of Shell Seam at Nozzle | E1 | 1.00 | |
| Joint Efficiency of Nozzle Neck | En | 1.00 | |
| | | | |
| Outside Projection | ho | 7.1078 | in |
| Weld leg size between Nozzle and Pad/Shell | Wo | 0.3540 | in |
| Groove weld depth between Nozzle and Vessel | Wgnv | 0.3900 | in |
| Inside Projection | h | 0.0000 | in |
| Weld leg size, Inside Element to Shell | Wi | 0.0000 | in |
| | | | |
| Flange Class | | 600 | |
| Flange Grade | | GR 2.3 | |

The Pressure Design option was MAWP + static head (to the nozzle).

**Nozzle Sketch (may not represent actual weld type/configuration)**



**Insert/Set-in Nozzle No Pad, no Inside projection**

**Reinforcement CALCULATION, Description: Nozzle B3 2"**

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation              2.000  in.
Actual Thickness Used in Calculation                    0.656  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Int. Press]

```
= P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
= 150.0*14.6565/(14800*1.0-0.6*150.0)
= 0.1495 in
```

Reqd thk per App. 1 of Nozzle Wall, trn [Int. Press]

```
= R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
= 1.031(exp([150.0/(10900.0*1.0]-1)
= 0.0143 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0151 in

**UG-40, Limits of Reinforcement : [Internal Pressure]**

```
Parallel to Vessel Wall (Diameter Limit)            Dl      4.1260  in
Parallel to Vessel Wall, opening length              d      2.0630  in
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp      0.9055  in
```

Weld Strength Reduction Factor [fr1]:

```
= min( 1, Sn/Sv )
= min( 1, 10900.0/14800.0 )
= 0.736
```

Weld Strength Reduction Factor [fr2]:

```
= min( 1, Sn/Sv )
= min( 1, 10900.0/14800.0 )
= 0.736
```

Weld Strength Reduction Factor [fr3]:

```
= min( fr2, fr4 )
= min( 0.736, 1.0 )
= 0.736
```

**Results of Nozzle Reinforcement Area Calculations: (in^2)**

| AREA AVAILABLE, A1 to A5 | | MAWP | External | Mapnc |
|---|---|---|---|---|
| Area Required | Ar | 0.358 | 0.212 | NA |
| Area in Shell | A1 | 0.369 | 0.321 | NA |

| | | | | |
|---|---|---|---|---|
| Area in Nozzle Wall | A2 | 0.814 | 0.813 | NA |
| Area in Inward Nozzle | A3 | 0.000 | 0.000 | NA |
| Area in Welds | A41+A42+A43 | 0.092 | 0.092 | NA |
| Area in Element | A5 | 0.000 | 0.000 | NA |
| TOTAL AREA AVAILABLE | Atot | 1.275 | 1.227 | NA |

The MAWP Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                  90.00  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (2.063*0.1495*1.0+2*0.6248*0.1495*1.0*(1-0.74))
  = 0.358 in^2
```

**Reinforcement Areas per Figure UG-37.1**

Area Available in Shell [A1]:
```
  = d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
  = 2.063( 1.0 * 0.3622 - 1.0 * 0.149 ) - 2 * 0.625
    ( 1.0 * 0.3622 - 1.0 * 0.1495 ) *( 1 - 0.736 )
  = 0.369 in^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 0.906 )( 0.6248 - 0.0143 ) 0.7365
  = 0.814 in^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  =  0.354² * 0.7365 +( 0.0 )² * 0.7365
  = 0.092 in^2
```

**UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]**
```
Wall Thickness for Internal/External pressures       ta = 0.0466 in
Wall Thickness per UG16(b),                       tr16b = 0.0940 in
Wall Thickness, shell/head, internal pressure      trb1 = 0.1810 in
Wall Thickness                 tb1 = max(trb1, tr16b) = 0.1810 in
Wall Thickness, shell/head, external pressure      trb2 = 0.0464 in
Wall Thickness                 tb2 = max(trb2, tr16b) = 0.0940 in
Wall Thickness per table UG-45                      tb3 = 0.2205 in
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.22, max( 0.181, 0.094 ) ]
  = 0.1810 in
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 0.0466, 0.181 )
  = 0.1810 in
```

Available Nozzle Neck Thickness = 0.6563 in --> OK

***Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):***
```
Sustained  :   1329.5,  Allowable :  10900.0 psi  Passed
Expansion  :      0.0,  Allowable :  33170.5 psi  Passed
Occasional :     95.0,  Allowable :  14497.0 psi  Passed
```

```
 Shear      :   1278.8,  Allowable :   7630.0 psi  Passed
```

*The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

*SA-240 316L, Min Metal Temp without impact per UHA-51: -320 °F*

*SA-182 F316L, Min Metal Temp without impact per UHA-51: -320 °F*

Note:
The flange pressure ratio is less than 0.35. Impact testing is not required due to low stress per UHA-51(g).

*Design Pressure/Ambient Rating = 150.00/1200.00 = 0.125*

Weld Size Calculations, Description: Nozzle B3 2"

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      0.3622  in
```

**Results Per UW-16.1:**

```
                           Required Thickness    Actual Thickness
 Nozzle Weld             0.2500 = Min per Code 0.2503 = 0.7 * Wo in
```

**Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)**

Weld Load [W]:
```
  = max( 0,  (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0,( 0.3575 - 0.3688 + 2 * 0.6248 * 0.7365 *
    (1.0 * 0.3622 - 0.1495 ) )14800)
  = 2730.47 lbf
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 0.8143 + 0.0 + 0.0923 - 0.0 * 0.74 ) * 14800
  = 13417.51 lbf
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 0.8143 + 0.0 + 0.0923 +( 0.3333 ) ) * 14800
  = 18351.00 lbf
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = (  0.8143 + 0.0 + 0.0923 + 0.0 +( 0.3333 ) ) * 14800
  = 18351.00 lbf
```

**Strength of Connection Elements for Failure Path Analysis**

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 3.3126 * 0.354 * 0.49 * 10900
  = 9838. lbf
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 1.3439) *( 0.6563 - 0.0315 ) * 0.7 * 10900
  = 20127. lbf
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 3.3126 *( 0.3937 - 0.0315 ) * 0.74 * 14800
  = 20641. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

**Strength of Failure Paths:**

Failure Path [Path 1-1]:
```
  = ( SONW + SNW ) = ( 9838 + 20127 ) = 29965 lbf
```

Failure Path [Path 2-2]:
```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 9838 + 0 + 20641 + 0 ) = 30479 lbf
```

Failure Path [Path 3-3]:
```
  = ( Sonw + Tngw + Sinw )
  = ( 9838 + 20641 + 0 ) = 30479 lbf
```

**Summary of Failure Path Calculations:**
```
 Path 1-1 = 29965   lbf, must exceed W = 2730 lbf     or W1 = 13417 lbf
 Path 2-2 = 30479   lbf, must exceed W = 2730 lbf     or W2 = 18350 lbf
 Path 3-3 = 30479   lbf, must exceed W = 2730 lbf     or W3 = 18350 lbf
```

**Maximum Allowable Pressure for this Nozzle at this Location:**
```
 Converged Maximum Allowable Pressure in the Operating case: 359 psig
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

```
 Nozzle is O.K. for the External Pressure: 15 psig
```

The Drop for this Nozzle is : 0.0941 in
The Cut Length for this Nozzle is, Drop + Ho + H + T : 7.5956 in

**Input Echo, WRC297 Item   1,     Description: Nozzle B3 2"  :**

```
 Diameter Basis for Cylindrical Shell                        ID
 Shell Corrosion Allowance                                   0.0315  in
 Shell Diameter                                              29.250  in
 Shell Thickness                                             0.3937  in
 Shell Stress Concentration Factor                            1.000
 Vessel Material                                        SA-240 316L
 Vessel Cold S.I. Allowable                    Smc     16700.00  psi
 Vessel Hot  S.I. Allowable                    Smh     14800.00  psi

 Diameter Basis for Nozzle                                   ID
 Nozzle Corrosion Allowance                                  0.0315  in
 Nozzle Diameter                                              2.000  in
 Nozzle Thickness                                            0.6563  in
 Nozzle Stress Concentration Factor                           1.000
 Nozzle Material                                       SA-182 F316L
 Nozzle Cold S.I. Allowable                   SNmc     16700.00  psi
 Nozzle Hot  S.I. Allowable                   SNmh     10900.00  psi
```

Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-182 F316L

*Note:*
*External Forces and Moments in WRC 107/537 Convention:*

*These loads are assumed to be SUStained loads.*

| | | | |
|---|---|---|---|
| Design Internal Pressure | Dp | 150.00 | psig |
| Radial Load | P | -630.00 | lbf |
| Circumferential Shear | Vc | 470.00 | lbf |
| Longitudinal Shear | Vl | 630.00 | lbf |
| Circumferential Moment | Mc | 210.00 | ft-lbf |
| Longitudinal Moment | Ml | 270.00 | ft-lbf |
| Torsional Moment | Mt | 310.00 | ft-lbf |

| | |
|---|---|
| Include Axial Pressure Thrust | No |
| Include Pressure Stress Indices per Div. 2 | No |
| Local Loads applied at end of Nozzle/Attachment | No |

*Warning - The ratio, Dn/Tn (5.047) is < 10*
*check the limitations of WRC bulletin 297.*

**Stress Computations at the Edge of the Nozzle:**

Stress Attenuation Diameter (for Insert Plates) per WRC 297:
= NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
= 3.313 + 2 * 1.65 * sqrt( 14.838( 0.394 - 0.031 ) )
= 10.963 in

WRC 297 Curve Access Parameters:

| | | | |
|---|---|---|---|
| Vessel Mean Diameter | (D) = | 29.675 | in |
| Nozzle Outside Diameter | (d) = | 3.313 | in |
| Vessel Thickness used | (T) = | 0.362 | in |
| Nozzle Thickness used | (t) = | 0.625 | in |
| T / t | = | 0.580 | |
| d / t | = | 10.000 | |

Lambda = [(d/D) * sqrt(D/T)] = 1.010

| | | |
|---|---|---|
| Nr/P | = | 0.108 |
| Mr/P | = | 0.217 |
| M0/P | = | 0.065 |
| N0/P | = | 0.131 |
| MrD/Mc | = | 0.302 |
| NrDL/Mc | = | 0.100 |
| M0d/Mc | = | 0.098 |
| N0DL/Mc | = | 0.027 |
| MrD/Ml | = | 0.195 |
| NrDL/Ml | = | 0.091 |
| M0D/Ml | = | 0.065 |
| N0DL/Ml | = | 0.119 |

***Vessel Stresses (psi):***

| LONGITUDINAL PLANE (Stresses Normal to longitudinal plane) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Outplane Membrane (P ) | 630 | 630 | 630 | 630 |
| Outplane Bending (P ) | 1876 | -1876 | 1876 | -1876 |
| Outplane Membrane (Mc) | 0 | 0 | 0 | 0 |
| Outplane Bending (Mc) | 0 | 0 | 0 | 0 |
| Outplane Membrane (ML) | -889 | -889 | 889 | 889 |
| Outplane Bending (ML) | -2899 | 2899 | 2899 | -2899 |
| Normal Pressure Stress | 5995 | 6145 | 5995 | 6145 |

```
 Outplane Stress Summary     4713     6909    12289     2889
```

***Vessel Stresses (psi):***

```
 LONGITUDINAL PLANE            Au       Al       Bu       Bl
 (Stresses parallel to        Top      Top   Bottom   Bottom
 longitudinal plane)      Outside   Inside  Outside   Inside
 ----------------------------------------------------------
 Inplane Membrane (P )        516      516      516      516
 Inplane Bending  (P )       6238    -6238     6238    -6238
 Inplane Membrane (Mc)          0        0        0        0
 Inplane Bending  (Mc)          0        0        0        0
 Inplane Membrane (ML)       -679     -679      679      679
 Inplane Bending  (ML)      -8728     8728     8728    -8728
 Inplane Pressure Stress     2997     2997     2997     2997
 ----------------------- -------- -------- -------- --------
 Inplane Stress Summary       344     5324    19158   -10774
```

***Vessel Stresses (psi):***

```
 LONGITUDINAL PLANE            Au       Al       Bu       Bl
 (Shear stress normal to      Top      Top   Bottom   Bottom
 longitudinal plane)      Outside   Inside  Outside   Inside
 ----------------------------------------------------------
 Outplane  Shear  (Vc)        249      249     -249     -249
 Outplane  Shear  (Vl)          0        0        0        0
 Outplane  Shear  (Mt)        595      595      595      595
 ----------------------- -------- -------- -------- --------
 Shear Stress Summary         844      844      346      346
```

***Vessel Stresses (psi):***

```
 LONGITUDINAL PLANE            Au       Al       Bu       Bl
 (Stress Intensities          Top      Top   Bottom   Bottom
                          Outside   Inside  Outside   Inside
 ----------------------------------------------------------
 Two * Max Shear Stress      4870     7274    19175    13680
```

***Vessel Stresses (psi):***

```
 CIRCUMFERENTIAL PLANE         Cu       Cl       Du       Dl
 (Stresses Normal to         Left     Left    Right    Right
 circumferential plane)   Outside   Inside  Outside   Inside
 ----------------------------------------------------------
 Outplane Membrane (P )       630      630      630      630
 Outplane Bending  (P )      1876    -1876     1876    -1876
 Outplane Membrane (Mc)      -156     -156      156      156
 Outplane Bending  (Mc)     -3411     3411     3411    -3411
 Outplane Membrane (ML)         0        0        0        0
 Outplane Bending  (ML)         0        0        0        0
 Normal Pressure Stress      2997     2997     2997     2997
 ----------------------- -------- -------- -------- --------
 Outplane Stress Summary     1936     5006     9070    -1504
```

***Vessel Stresses (psi):***

```
 CIRCUMFERENTIAL PLANE         Cu       Cl       Du       Dl
 (Stresses parallel to       Left     Left    Right    Right
 circumferential plane)   Outside   Inside  Outside   Inside
 ----------------------------------------------------------
 Inplane Membrane (P )        516      516      516      516
 Inplane Bending  (P )       6238    -6238     6238    -6238
 Inplane Membrane (Mc)       -579     -579      579      579
 Inplane Bending  (Mc)     -10510    10510    10510   -10510
 Inplane Membrane (ML)          0        0        0        0
 Inplane Bending  (ML)          0        0        0        0
```

| | | | | |
|---|---|---|---|---|
| Inplane Pressure Stress | 5995 | 6145 | 5995 | 6145 |
| Inplane Stress Summary | 1660 | 10354 | 23838 | -9508 |

***Vessel Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Shear stress normal to circumferential plane) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Outplane Shear (Vc) | 0 | 0 | 0 | 0 |
| Outplane Shear (Vl) | -334 | -334 | 334 | 334 |
| Torsional Shear (Mt) | 595 | 595 | 595 | 595 |
| Shear Stress Summary | 261 | 261 | 929 | 929 |

***Vessel Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stress Intensities | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 2093 | 10366 | 23896 | 9614 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Stresses in the hoop direction) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Hoop Membrane (P ) | 630 | 630 | 630 | 630 |
| Hoop Bending (P ) | 0 | 0 | 0 | 0 |
| Hoop Membrane (Mc) | 0 | 0 | 0 | 0 |
| Hoop Bending (Mc) | 0 | 0 | 0 | 0 |
| Hoop Membrane (ML) | -889 | -889 | 889 | 889 |
| Hoop Bending (ML) | 0 | 0 | 0 | 0 |
| Hoop Pressure Stress | 228 | 408 | 228 | 408 |
| Hoop Stress Summary | -31 | 149 | 1747 | 1927 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Stresses Normal to pipe cross-section) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Axial Membrane (P ) | 119 | 119 | 119 | 119 |
| Axial Bending (P ) | 1575 | -1575 | 1575 | -1575 |
| Axial Membrane (Mc) | 0 | 0 | 0 | 0 |
| Axial Bending (Mc) | 0 | 0 | 0 | 0 |
| Axial Membrane (ML) | -1068 | -1068 | 1068 | 1068 |
| Axial Bending (ML) | -2247 | 2247 | 2247 | -2247 |
| Axial Pressure Stress | 114 | 114 | 114 | 114 |
| Axial Stress Summary | -1507 | -163 | 5123 | -2521 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Shear stress) | Au Outside | Al Inside | Bu Outside | Bl Inside |
|---|---|---|---|---|
| Shear due to (Vc) | 144 | 144 | -144 | -144 |
| Shear due to (Vl) | 0 | 0 | 0 | 0 |
| Shear due to Torsion | 345 | 345 | 345 | 345 |
| Shear Stress Summary | 489 | 489 | 201 | 201 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Stress Intensities | Au Outside | Al Inside | Bu Outside | Bl Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 1770 | 1026 | 5134 | 4466 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stresses in the hoop direction) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Hoop Membrane (P ) | 630 | 630 | 630 | 630 |
| Hoop Bending (P ) | 0 | 0 | 0 | 0 |
| Hoop Membrane (Mc) | -156 | -156 | 156 | 156 |
| Hoop Bending (Mc) | 0 | 0 | 0 | 0 |
| Hoop Membrane (ML) | 0 | 0 | 0 | 0 |
| Hoop Bending (ML) | 0 | 0 | 0 | 0 |
| Hoop Pressure Stress | 228 | 408 | 228 | 408 |
| Hoop Stress Summary | 702 | 882 | 1014 | 1194 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stresses Normal to pipe cross-section) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Axial Membrane (P ) | 119 | 119 | 119 | 119 |
| Axial Bending (P ) | 1575 | -1575 | 1575 | -1575 |
| Axial Membrane (Mc) | -831 | -831 | 831 | 831 |
| Axial Bending (Mc) | -2947 | 2947 | 2947 | -2947 |
| Axial Membrane (ML) | 0 | 0 | 0 | 0 |
| Axial Bending (ML) | 0 | 0 | 0 | 0 |
| Axial Pressure Stress | 114 | 114 | 114 | 114 |
| Axial Stress Summary | -1970 | 774 | 5586 | -3458 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Shear stress) | Cu Outside | Cl Inside | Du Outside | Dl Inside |
|---|---|---|---|---|
| Shear due to (Vc) | 0 | 0 | 0 | 0 |
| Shear due to (Vl) | -193 | -193 | 193 | 193 |
| Shear due to Torsion | 345 | 345 | 345 | 345 |
| Shear Stress Summary | 152 | 152 | 538 | 538 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stress Intensities | Cu Outside | Cl Inside | Du Outside | Dl Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 2689 | 989 | 5648 | 4774 |

**WRC 297 Stress Summations per ASME Sec. VIII Div. 2:**

**Vessel Stress Summation at Vessel-Nozzle Junction (psi):**

| Type of Stress Int. Location | Stress Values at Au | Al | Bu | Bl | Cu | Cl | Du | Dl |
|---|---|---|---|---|---|---|---|---|

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Circ. Pm (SUS) | 5995 | 6145 | 5995 | 6145 | 5995 | 6145 | 5995 | 6145 |
| Circ. Pl (SUS) | -259 | -259 | 1519 | 1519 | -63 | -63 | 1095 | 1095 |
| Circ. Q (SUS) | -1023 | 1023 | 4775 | -4775 | -4272 | 4272 | 16748 | -16748 |
| Long. Pm (SUS) | 2997 | 2997 | 2997 | 2997 | 2997 | 2997 | 2997 | 2997 |
| Long. Pl (SUS) | -163 | -163 | 1195 | 1195 | 474 | 474 | 786 | 786 |
| Long. Q (SUS) | -2490 | 2490 | 14966 | -14966 | -1535 | 1535 | 5287 | -5287 |
| Shear Pm (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Shear Pl (SUS) | 249 | 249 | -249 | -249 | -334 | -334 | 334 | 334 |
| Shear Q (SUS) | 595 | 595 | 595 | 595 | 595 | 595 | 595 | 595 |
| Pm (SUS) | 5995 | 6145 | 5995 | 6145 | 5995 | 6145 | 5995 | 6145 |
| Pm+Pl (SUS) | 5757 | 5906 | 7532 | 7681 | 5976 | 6124 | 7123 | 7271 |
| Pm+Pl+Q (Total) | 4870 | 7274 | 19175 | 13680 | 2093 | 10366 | 23896 | 9614 |

**Vessel Stress Summation Comparison  (psi):**

| Type of Stress Int. | Max. S.I. | S.I. Allowable | Result |
|---|---|---|---|
| Pm (SUS) | 6145 | 14800 | Passed |
| Pm+Pl (SUS) | 7681 | 22200 | Passed |
| Pm+Pl+Q (TOTAL) | 23896 | 44400 | Passed |

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

**WRC 297 Stress Summations per ASME Sec. VIII Div. 2:**

**Nozzle Stress Summation at Vessel-Nozzle Junction  (psi):**

| Type of Stress Int. Location | Stress Values at Au | Al | Bu | Bl | Cu | Cl | Du | Dl |
|---|---|---|---|---|---|---|---|---|
| Circ. Pm (SUS) | 228 | 408 | 228 | 408 | 228 | 408 | 228 | 408 |
| Circ. Pl (SUS) | -259 | -259 | 1519 | 1519 | 474 | 474 | 786 | 786 |
| Circ. Q (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Long. Pm (SUS) | 114 | 114 | 114 | 114 | 114 | 114 | 114 | 114 |
| Long. Pl (SUS) | -949 | -949 | 1187 | 1187 | -712 | -712 | 950 | 950 |
| Long. Q (SUS) | -672 | 672 | 3822 | -3822 | -1372 | 1372 | 4522 | -4522 |
| Shear Pm (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Shear Pl (SUS) | 144 | 144 | -144 | -144 | -193 | -193 | 193 | 193 |
| Shear Q (SUS) | 345 | 345 | 345 | 345 | 345 | 345 | 345 | 345 |
| Pm (SUS) | 228 | 408 | 228 | 408 | 228 | 408 | 228 | 408 |
| Pm+Pl (SUS) | 860 | 1025 | 1789 | 1958 | 1356 | 1529 | 1233 | 1332 |
| Pm+Pl+Q (Total) | 1770 | 1026 | 5134 | 4466 | 2689 | 989 | 5648 | 4774 |

**Nozzle Stress Summation Comparison  (psi):**

| Type of Stress Int. | Max. S.I. | S.I. Allowable | Result |
|---|---|---|---|

```
 Pm (SUS)        |          408            10900      |      Passed     |
 Pm+Pl (SUS)     |         1958            16350      |      Passed     |
 Pm+Pl+Q (TOTAL)|         5648            32700      |      Passed     |
```

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

**Input, Nozzle Desc: Nozzle LT3 From: 50**

| | | | |
|---|---|---|---|
| Pressure for Reinforcement Calculations | P | 150.000 | psig |
| Temperature for Internal Pressure | Temp | 500 | °F |
| Design External Pressure | Pext | 15.00 | psig |
| Temperature for External Pressure | Tempex | 300 | °F |
| Parent Material | | SA-240 316L | |
| Parent Allowable Stress at Temperature | Sv | 14800.00 | psi |
| Parent Allowable Stress At Ambient | Sva | 16700.00 | psi |
| Inside Diameter of Cylindrical Shell | D | 29.2500 | in |
| Design Length of Section | L | 118.5000 | in |
| Shell Finished (Minimum) Thickness | t | 0.3937 | in |
| Shell Internal Corrosion Allowance | c | 0.0315 | in |
| Shell External Corrosion Allowance | co | 0.0000 | in |
| Distance from Bottom/Left Tangent | | 4.16 | ft |
| User Entered Minimum Design Metal Temperature | | 32.00 | °F |

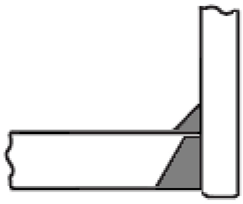
***Type of Element Connected to the Parent : Nozzle***

| | | | |
|---|---|---|---|
| Material | | SA-182 F316L | |
| Material UNS Number | | S31603 | |
| Material Specification/Type | | Forgings | |
| Allowable Stress at Temperature | Sn | 10900.00 | psi |
| Allowable Stress At Ambient | Sna | 16700.00 | psi |
| Diameter Basis (for tr calc only) | | Inside | |
| Layout Angle | | 0.00 | deg |
| Diameter | | 2.0000 | in. |
| Size and Thickness Basis | | Actual | |
| Actual Thickness | tn | 0.6563 | in |
| Flange Type | | Long Weld Neck | |
| Corrosion Allowance | can | 0.0000 | in |
| Joint Efficiency of Shell Seam at Nozzle | E1 | 1.00 | |
| Joint Efficiency of Nozzle Neck | En | 1.00 | |
| Outside Projection | ho | 7.1050 | in |
| Weld leg size between Nozzle and Pad/Shell | Wo | 0.3543 | in |
| Groove weld depth between Nozzle and Vessel | Wgnv | 0.3900 | in |
| Inside Projection | h | 0.0000 | in |
| Weld leg size, Inside Element to Shell | Wi | 0.0000 | in |
| Flange Class | | 300 | |
| Flange Grade | | GR 2.3 | |

The Pressure Design option was MAWP + static head (to the nozzle).

**Nozzle Sketch (may not represent actual weld type/configuration)**

```
18-D-272
R06
V-1264
PV Elite 24        Licensee: THE ANUP ENGINEERING LIMITED.
FileName : V-1264_R06    -----------------------------------
Nozzle Calcs.: Nozzle LT3             Nozl:    35    4:21pm  Dec 21,2022
```



**Insert/Set-in Nozzle No Pad, no Inside projection**

**Reinforcement CALCULATION, Description: Nozzle LT3**

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
 Actual Inside Diameter Used in Calculation              2.000  in.
 Actual Thickness Used in Calculation                    0.656  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Int. Press]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 150.0*14.6565/(14800*1.0-0.6*150.0)
  = 0.1495 in
```

Reqd thk per App. 1 of Nozzle Wall, trn [Int. Press]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 1.0(exp([150.0/(10900.0*1.0]-1)
  = 0.0139 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0151 in

**UG-40, Limits of Reinforcement : [Internal Pressure]**
```
 Parallel to Vessel Wall (Diameter Limit)            Dl     4.0370  in
 Parallel to Vessel Wall                       Rn+tn+t     2.0185  in
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     0.9055  in
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 10900.0/14800.0 )
  = 0.736
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 10900.0/14800.0 )
  = 0.736
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 0.736, 1.0 )
  = 0.736
```

**Results of Nozzle Reinforcement Area Calculations: (in^2)**

| AREA AVAILABLE, A1 to A5 | | MAWP | External | Mapnc |
|---|---|---|---|---|
| Area Required | Ar | 0.351 | 0.208 | NA |
| Area in Shell | A1 | 0.360 | 0.313 | NA |

| | | | | |
|---|---|---|---|---|
| Area in Nozzle Wall | A2 | 0.857 | 0.855 | NA |
| Area in Inward Nozzle | A3 | 0.000 | 0.000 | NA |
| Area in Welds | A41+A42+A43 | 0.092 | 0.092 | NA |
| Area in Element | A5 | 0.000 | 0.000 | NA |
| TOTAL AREA AVAILABLE | Atot | 1.309 | 1.261 | NA |

The MAWP Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (2.0*0.1495*1.0+2*0.6563*0.1495*1.0*(1-0.74))
  = 0.351 in^2
```

**Reinforcement Areas per Figure UG-37.1**

Area Available in Shell [A1]:
```
  = d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
  = 2.037( 1.0 * 0.3622 - 1.0 * 0.149 ) - 2 * 0.656
    ( 1.0 * 0.3622 - 1.0 * 0.1495 ) *( 1 - 0.736 )
  = 0.360 in^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 0.906 )( 0.6563 - 0.0139 ) 0.7365
  = 0.857 in^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  =  0.3543² * 0.7365 +( 0.0 )² * 0.7365
  = 0.092 in^2
```

**UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]**
```
 Wall Thickness for Internal/External pressures       ta = 0.0151 in
 Wall Thickness per UG16(b),                       tr16b = 0.0940 in
 Wall Thickness, shell/head, internal pressure      trb1 = 0.1810 in
 Wall Thickness               tb1 = max(trb1, tr16b) = 0.1810 in
 Wall Thickness, shell/head, external pressure      trb2 = 0.0464 in
 Wall Thickness               tb2 = max(trb2, tr16b) = 0.0940 in
 Wall Thickness per table UG-45                      tb3 = 0.1890 in
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.189, max( 0.181, 0.094 ) ]
  = 0.1810 in
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 0.0151, 0.181 )
  = 0.1810 in
```

Available Nozzle Neck Thickness = 0.6563 in --> OK

***Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):***
```
 Sustained  :   1297.4,  Allowable :  10900.0 psi  Passed
 Expansion  :      0.0,  Allowable :  33202.6 psi  Passed
 Occasional :     86.0,  Allowable :  14497.0 psi  Passed
```

```
 Shear      :   1283.3,  Allowable :   7630.0 psi  Passed
```

*The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

*SA-240 316L, Min Metal Temp without impact per UHA-51: -320 °F*

*SA-182 F316L, Min Metal Temp without impact per UHA-51: -320 °F*

Note:
The flange pressure ratio is less than 0.35. Impact testing is not required due to low stress per UHA-51(g).

*Design Pressure/Ambient Rating = 150.00/600.00 = 0.250*

Weld Size Calculations, Description: Nozzle LT3

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      0.3622  in
```

**Results Per UW-16.1:**

```
                          Required Thickness    Actual Thickness
 Nozzle Weld             0.2500 = Min per Code 0.2505 = 0.7 * Wo in
```

**Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)**

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0,( 0.3506 - 0.3598 + 2 * 0.6563 * 0.7365 *
    (1.0 * 0.3622 - 0.1495 ) )14800)
  = 2907.97 lbf
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 0.8569 + 0.0 + 0.0925 - 0.0 * 0.74 ) * 14800
  = 14050.42 lbf
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 0.8569 + 0.0 + 0.0925 +( 0.3501 ) ) * 14800
  = 19232.60 lbf
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = (  0.8569 + 0.0 + 0.0925 + 0.0 +( 0.3501 ) ) * 14800
  = 19232.60 lbf
```

**Strength of Connection Elements for Failure Path Analysis**

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 3.3126 * 0.3543 * 0.49 * 10900
  = 9847. lbf
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 1.3281) *( 0.6563 - 0.0 ) * 0.7 * 10900
  = 20894. lbf
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 3.3126 *( 0.3937 - 0.0315 ) * 0.74 * 14800
  = 20641. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

**Strength of Failure Paths:**

Failure Path [Path 1-1]:

```
  = ( SONW + SNW ) = ( 9847 + 20894 ) = 30741 lbf
```

Failure Path [Path 2-2]:

```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 9847 + 0 + 20641 + 0 ) = 30489 lbf
```

Failure Path [Path 3-3]:

```
  = ( Sonw + Tngw + Sinw )
  = ( 9847 + 20641 + 0 ) = 30489 lbf
```

**Summary of Failure Path Calculations:**

```
 Path 1-1 = 30741   lbf, must exceed W = 2907 lbf     or W1 = 14050 lbf
 Path 2-2 = 30488   lbf, must exceed W = 2907 lbf     or W2 = 19232 lbf
 Path 3-3 = 30488   lbf, must exceed W = 2907 lbf     or W3 = 19232 lbf
```

**Maximum Allowable Pressure for this Nozzle at this Location:**

```
 Converged Maximum Allowable Pressure in the Operating case: 359 psig
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

```
 Nozzle is O.K. for the External Pressure: 15 psig
```

The Drop for this Nozzle is : 0.0941 in
The Cut Length for this Nozzle is, Drop + Ho + H + T : 7.5928 in

**Input Echo, WRC297 Item 1, Description: Nozzle LT3 :**

```
 Diameter Basis for Cylindrical Shell                       ID
 Shell Corrosion Allowance                                  0.0315  in
 Shell Diameter                                             29.250  in
 Shell Thickness                                            0.3937  in
 Shell Stress Concentration Factor                           1.000
 Vessel Material                                       SA-240 316L
 Vessel Cold S.I. Allowable                     Smc     16700.00  psi
 Vessel Hot  S.I. Allowable                     Smh     14800.00  psi

 Diameter Basis for Nozzle                                  ID
 Nozzle Corrosion Allowance                                 0.0000  in
 Nozzle Diameter                                             2.000  in
 Nozzle Thickness                                           0.6563  in
 Nozzle Stress Concentration Factor                          1.000
 Nozzle Material                                      SA-182 F316L
 Nozzle Cold S.I. Allowable                    SNmc     16700.00  psi
 Nozzle Hot  S.I. Allowable                    SNmh     10900.00  psi
```

Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-182 F316L

*Note:*
*External Forces and Moments in WRC 107/537 Convention:*

*These loads are assumed to be SUStained loads.*

| | | | |
|---|---|---|---|
| Design Internal Pressure | Dp | 150.00 | psig |
| Radial Load | P | -630.00 | lbf |
| Circumferential Shear | Vc | 470.00 | lbf |
| Longitudinal Shear | Vl | 630.00 | lbf |
| Circumferential Moment | Mc | 210.00 | ft-lbf |
| Longitudinal Moment | Ml | 270.00 | ft-lbf |
| Torsional Moment | Mt | 310.00 | ft-lbf |

| | |
|---|---|
| Include Axial Pressure Thrust | No |
| Include Pressure Stress Indices per Div. 2 | No |
| Local Loads applied at end of Nozzle/Attachment | No |

*Warning - The ratio, Dn/Tn (5.047) is < 10*
*check the limitations of WRC bulletin 297.*

**Stress Computations at the Edge of the Nozzle:**

Stress Attenuation Diameter (for Insert Plates) per WRC 297:

```
= NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
= 3.313 + 2 * 1.65 * sqrt( 14.838( 0.394 - 0.031 ) )
= 10.963 in
```

WRC 297 Curve Access Parameters:

| | | | |
|---|---|---|---|
| Vessel Mean Diameter | (D) = | 29.675 | in |
| Nozzle Outside Diameter | (d) = | 3.313 | in |
| Vessel Thickness used | (T) = | 0.362 | in |
| Nozzle Thickness used | (t) = | 0.656 | in |
| T / t | = | 0.552 | |
| d / t | = | 10.000 | |

Lambda = [(d/D) * sqrt(D/T)]  = 1.010

| | |
|---|---|
| Nr/P = | 0.106 |
| Mr/P = | 0.218 |
| M0/P = | 0.065 |
| N0/P = | 0.132 |
| MrD/Mc = | 0.304 |
| NrDL/Mc = | 0.097 |
| M0d/Mc = | 0.097 |
| N0DL/Mc = | 0.031 |
| MrD/Ml = | 0.195 |
| NrDL/Ml = | 0.090 |
| M0D/Ml = | 0.064 |
| N0DL/Ml = | 0.120 |

***Vessel Stresses (psi):***

| LONGITUDINAL PLANE (Stresses Normal to longitudinal plane) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Outplane Membrane (P ) | 634 | 634 | 634 | 634 |
| Outplane Bending (P ) | 1877 | -1877 | 1877 | -1877 |
| Outplane Membrane (Mc) | 0 | 0 | 0 | 0 |
| Outplane Bending (Mc) | 0 | 0 | 0 | 0 |
| Outplane Membrane (ML) | -891 | -891 | 891 | 891 |
| Outplane Bending (ML) | -2871 | 2871 | 2871 | -2871 |
| Normal Pressure Stress | 5995 | 6145 | 5995 | 6145 |

```
 Outplane Stress Summary     4744     6882    12268     2922
```

***Vessel Stresses (psi):***

```
 LONGITUDINAL PLANE             Au       Al       Bu       Bl
 (Stresses parallel to         Top      Top   Bottom   Bottom
 longitudinal plane)       Outside   Inside  Outside   Inside
 -----------------------------------------------------------
 Inplane Membrane (P )         510      510      510      510
 Inplane Bending  (P )        6293    -6293     6293    -6293
 Inplane Membrane (Mc)           0        0        0        0
 Inplane Bending  (Mc)           0        0        0        0
 Inplane Membrane (ML)        -669     -669      669      669
 Inplane Bending  (ML)       -8720     8720     8720    -8720
 Inplane Pressure Stress      2997     2997     2997     2997
 ----------------------- -------- -------- -------- --------
 Inplane Stress Summary        411     5265    19189   -10837
```

***Vessel Stresses (psi):***

```
 LONGITUDINAL PLANE             Au       Al       Bu       Bl
 (Shear stress normal to       Top      Top   Bottom   Bottom
 longitudinal plane)       Outside   Inside  Outside   Inside
 -----------------------------------------------------------
 Outplane  Shear  (Vc)         249      249     -249     -249
 Outplane  Shear  (Vl)           0        0        0        0
 Outplane  Shear  (Mt)         595      595      595      595
 ----------------------- -------- -------- -------- --------
 Shear Stress Summary          844      844      346      346
```

***Vessel Stresses (psi):***

```
 LONGITUDINAL PLANE             Au       Al       Bu       Bl
 (Stress Intensities           Top      Top   Bottom   Bottom
                           Outside   Inside  Outside   Inside
 -----------------------------------------------------------
 Two * Max Shear Stress       4902     7242    19206    13776
```

***Vessel Stresses (psi):***

```
 CIRCUMFERENTIAL PLANE          Cu       Cl       Du       Dl
 (Stresses Normal to          Left     Left    Right    Right
 circumferential plane)    Outside   Inside  Outside   Inside
 -----------------------------------------------------------
 Outplane Membrane (P )        634      634      634      634
 Outplane Bending  (P )       1877    -1877     1877    -1877
 Outplane Membrane (Mc)       -181     -181      181      181
 Outplane Bending  (Mc)      -3389     3389     3389    -3389
 Outplane Membrane (ML)          0        0        0        0
 Outplane Bending  (ML)          0        0        0        0
 Normal Pressure Stress       2997     2997     2997     2997
 ----------------------- -------- -------- -------- --------
 Outplane Stress Summary      1938     4962     9078    -1454
```

***Vessel Stresses (psi):***

```
 CIRCUMFERENTIAL PLANE          Cu       Cl       Du       Dl
 (Stresses parallel to        Left     Left    Right    Right
 circumferential plane)    Outside   Inside  Outside   Inside
 -----------------------------------------------------------
 Inplane Membrane (P )         510      510      510      510
 Inplane Bending  (P )        6293    -6293     6293    -6293
 Inplane Membrane (Mc)        -562     -562      562      562
 Inplane Bending  (Mc)      -10562    10562    10562   -10562
 Inplane Membrane (ML)           0        0        0        0
 Inplane Bending  (ML)           0        0        0        0
```

| | | | | |
|---|---|---|---|---|
| Inplane Pressure Stress | 5995 | 6145 | 5995 | 6145 |
| Inplane Stress Summary | 1674 | 10362 | 23922 | -9638 |

***Vessel Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Shear stress normal to circumferential plane) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Outplane Shear (Vc) | 0 | 0 | 0 | 0 |
| Outplane Shear (Vl) | -334 | -334 | 334 | 334 |
| Torsional Shear (Mt) | 595 | 595 | 595 | 595 |
| Shear Stress Summary | 261 | 261 | 929 | 929 |

***Vessel Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stress Intensities | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 2098 | 10374 | 23979 | 9742 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Stresses in the hoop direction) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Hoop Membrane (P ) | 634 | 634 | 634 | 634 |
| Hoop Bending (P ) | 0 | 0 | 0 | 0 |
| Hoop Membrane (Mc) | 0 | 0 | 0 | 0 |
| Hoop Bending (Mc) | 0 | 0 | 0 | 0 |
| Hoop Membrane (ML) | -891 | -891 | 891 | 891 |
| Hoop Bending (ML) | 0 | 0 | 0 | 0 |
| Hoop Pressure Stress | 206 | 386 | 206 | 386 |
| Hoop Stress Summary | -51 | 129 | 1731 | 1911 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Stresses Normal to pipe cross-section) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Axial Membrane (P ) | 115 | 115 | 115 | 115 |
| Axial Bending (P ) | 1450 | -1450 | 1450 | -1450 |
| Axial Membrane (Mc) | 0 | 0 | 0 | 0 |
| Axial Bending (Mc) | 0 | 0 | 0 | 0 |
| Axial Membrane (ML) | -1047 | -1047 | 1047 | 1047 |
| Axial Bending (ML) | -2044 | 2044 | 2044 | -2044 |
| Axial Pressure Stress | 103 | 103 | 103 | 103 |
| Axial Stress Summary | -1423 | -235 | 4759 | -2229 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Shear stress) | Au Outside | Al Inside | Bu Outside | Bl Inside |
|---|---|---|---|---|
| Shear due to (Vc) | 137 | 137 | -137 | -137 |
| Shear due to (Vl) | 0 | 0 | 0 | 0 |
| Shear due to Torsion | 328 | 328 | 328 | 328 |
| Shear Stress Summary | 465 | 465 | 191 | 191 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Stress Intensities | Au Outside | Al Inside | Bu Outside | Bl Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 1657 | 998 | 4771 | 4157 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stresses in the hoop direction) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Hoop Membrane (P ) | 634 | 634 | 634 | 634 |
| Hoop Bending (P ) | 0 | 0 | 0 | 0 |
| Hoop Membrane (Mc) | -181 | -181 | 181 | 181 |
| Hoop Bending (Mc) | 0 | 0 | 0 | 0 |
| Hoop Membrane (ML) | 0 | 0 | 0 | 0 |
| Hoop Bending (ML) | 0 | 0 | 0 | 0 |
| Hoop Pressure Stress | 206 | 386 | 206 | 386 |
| Hoop Stress Summary | 659 | 839 | 1021 | 1201 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stresses Normal to pipe cross-section) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Axial Membrane (P ) | 115 | 115 | 115 | 115 |
| Axial Bending (P ) | 1450 | -1450 | 1450 | -1450 |
| Axial Membrane (Mc) | -814 | -814 | 814 | 814 |
| Axial Bending (Mc) | -2703 | 2703 | 2703 | -2703 |
| Axial Membrane (ML) | 0 | 0 | 0 | 0 |
| Axial Bending (ML) | 0 | 0 | 0 | 0 |
| Axial Pressure Stress | 103 | 103 | 103 | 103 |
| Axial Stress Summary | -1849 | 657 | 5185 | -3121 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Shear stress) | Cu Outside | Cl Inside | Du Outside | Dl Inside |
|---|---|---|---|---|
| Shear due to (Vc) | 0 | 0 | 0 | 0 |
| Shear due to (Vl) | -184 | -184 | 184 | 184 |
| Shear due to Torsion | 328 | 328 | 328 | 328 |
| Shear Stress Summary | 144 | 144 | 512 | 512 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stress Intensities | Cu Outside | Cl Inside | Du Outside | Dl Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 2524 | 918 | 5247 | 4441 |

**WRC 297 Stress Summations per ASME Sec. VIII Div. 2:**

**Vessel Stress Summation at Vessel-Nozzle Junction (psi):**

| Type of Stress Int. Location | Stress Values at Au | Al | Bu | Bl | Cu | Cl | Du | Dl |
|---|---|---|---|---|---|---|---|---|

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Circ. Pm (SUS) | 5995 | 6145 | 5995 | 6145 | 5995 | 6145 | 5995 | 6145 |
| Circ. Pl (SUS) | -257 | -257 | 1525 | 1525 | -52 | -52 | 1072 | 1072 |
| Circ. Q (SUS) | -994 | 994 | 4748 | -4748 | -4269 | 4269 | 16855 | -16855 |
| Long. Pm (SUS) | 2997 | 2997 | 2997 | 2997 | 2997 | 2997 | 2997 | 2997 |
| Long. Pl (SUS) | -159 | -159 | 1179 | 1179 | 453 | 453 | 815 | 815 |
| Long. Q (SUS) | -2427 | 2427 | 15013 | -15013 | -1512 | 1512 | 5266 | -5266 |
| Shear Pm (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Shear Pl (SUS) | 249 | 249 | -249 | -249 | -334 | -334 | 334 | 334 |
| Shear Q (SUS) | 595 | 595 | 595 | 595 | 595 | 595 | 595 | 595 |
| Pm (SUS) | 5995 | 6145 | 5995 | 6145 | 5995 | 6145 | 5995 | 6145 |
| Pm+Pl (SUS) | 5759 | 5908 | 7538 | 7687 | 5986 | 6134 | 7100 | 7249 |
| Pm+Pl+Q (Total) | 4902 | 7242 | 19206 | 13776 | 2098 | 10374 | 23979 | 9742 |

**Vessel Stress Summation Comparison (psi):**

| Type of Stress Int. | Max. S.I. | S.I. Allowable | Result |
|---|---|---|---|
| Pm (SUS) | 6145 | 14800 | Passed |
| Pm+Pl (SUS) | 7687 | 22200 | Passed |
| Pm+Pl+Q (TOTAL) | 23979 | 44400 | Passed |

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

**WRC 297 Stress Summations per ASME Sec. VIII Div. 2:**

**Nozzle Stress Summation at Vessel-Nozzle Junction (psi):**

| Type of Stress Int. Location | Au | Al | Bu | Bl | Cu | Cl | Du | Dl |
|---|---|---|---|---|---|---|---|---|
| Circ. Pm (SUS) | 206 | 386 | 206 | 386 | 206 | 386 | 206 | 386 |
| Circ. Pl (SUS) | -257 | -257 | 1525 | 1525 | 453 | 453 | 815 | 815 |
| Circ. Q (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Long. Pm (SUS) | 103 | 103 | 103 | 103 | 103 | 103 | 103 | 103 |
| Long. Pl (SUS) | -932 | -932 | 1162 | 1162 | -699 | -699 | 929 | 929 |
| Long. Q (SUS) | -594 | 594 | 3494 | -3494 | -1253 | 1253 | 4153 | -4153 |
| Shear Pm (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Shear Pl (SUS) | 137 | 137 | -137 | -137 | -184 | -184 | 184 | 184 |
| Shear Q (SUS) | 328 | 328 | 328 | 328 | 328 | 328 | 328 | 328 |
| Pm (SUS) | 206 | 386 | 206 | 386 | 206 | 386 | 206 | 386 |
| Pm+Pl (SUS) | 852 | 996 | 1768 | 1938 | 1307 | 1481 | 1210 | 1318 |
| Pm+Pl+Q (Total) | 1657 | 998 | 4771 | 4157 | 2524 | 918 | 5247 | 4441 |

**Nozzle Stress Summation Comparison (psi):**

| Type of Stress Int. | Max. S.I. | S.I. Allowable | Result |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Pm (SUS) | 386 | 10900 | Passed |
| Pm+Pl (SUS) | 1938 | 16350 | Passed |
| Pm+Pl+Q (TOTAL) | 5247 | 32700 | Passed |

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

**Input, Nozzle Desc: Nozzle LT4 From: 50**

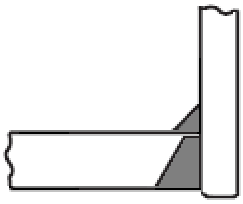
| | | | |
|---|---|---|---|
| Pressure for Reinforcement Calculations | P | 151.073 | psig |
| Temperature for Internal Pressure | Temp | 500 | °F |
| Design External Pressure | Pext | 15.00 | psig |
| Temperature for External Pressure | Tempex | 300 | °F |
| | | | |
| Parent Material | | SA-240 316L | |
| Parent Allowable Stress at Temperature | Sv | 14800.00 | psi |
| Parent Allowable Stress At Ambient | Sva | 16700.00 | psi |
| | | | |
| Inside Diameter of Cylindrical Shell | D | 29.2500 | in |
| Design Length of Section | L | 118.5000 | in |
| Shell Finished (Minimum) Thickness | t | 0.3937 | in |
| Shell Internal Corrosion Allowance | c | 0.0315 | in |
| Shell External Corrosion Allowance | co | 0.0000 | in |
| | | | |
| Distance from Bottom/Left Tangent | | 0.66 | ft |
| | | | |
| User Entered Minimum Design Metal Temperature | | 32.00 | °F |

***Type of Element Connected to the Parent : Nozzle***

| | | | |
|---|---|---|---|
| Material | | SA-182 F316L | |
| Material UNS Number | | S31603 | |
| Material Specification/Type | | Forgings | |
| Allowable Stress at Temperature | Sn | 10900.00 | psi |
| Allowable Stress At Ambient | Sna | 16700.00 | psi |
| | | | |
| Diameter Basis (for tr calc only) | | Inside | |
| Layout Angle | | 0.00 | deg |
| Diameter | | 2.0000 | in. |
| | | | |
| Size and Thickness Basis | | Actual | |
| Actual Thickness | tn | 0.6563 | in |
| | | | |
| Flange Type | | Long Weld Neck | |
| | | | |
| Corrosion Allowance | can | 0.0000 | in |
| Joint Efficiency of Shell Seam at Nozzle | E1 | 1.00 | |
| Joint Efficiency of Nozzle Neck | En | 1.00 | |
| | | | |
| Outside Projection | ho | 7.1050 | in |
| Weld leg size between Nozzle and Pad/Shell | Wo | 0.3543 | in |
| Groove weld depth between Nozzle and Vessel | Wgnv | 0.3900 | in |
| Inside Projection | h | 0.0000 | in |
| Weld leg size, Inside Element to Shell | Wi | 0.0000 | in |
| | | | |
| Flange Class | | 300 | |
| Flange Grade | | GR 2.3 | |

The Pressure Design option was MAWP + static head (to the nozzle).

**Nozzle Sketch (may not represent actual weld type/configuration)**



**Insert/Set-in Nozzle No Pad, no Inside projection**

**Reinforcement CALCULATION, Description: Nozzle LT4**

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation             2.000  in.
Actual Thickness Used in Calculation                   0.656  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Int. Press]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 151.07*14.6565/(14800*1.0-0.6*151.07)
  = 0.1505 in
```

Reqd thk per App. 1 of Nozzle Wall, trn [Int. Press]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 1.0(exp([151.07/(10900.0*1.0]-1)
  = 0.0140 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0151 in

**UG-40, Limits of Reinforcement : [Internal Pressure]**
```
Parallel to Vessel Wall (Diameter Limit)            Dl     4.0370  in
Parallel to Vessel Wall                        Rn+tn+t     2.0185  in
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     0.9055  in
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 10900.0/14800.0 )
  = 0.736
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 10900.0/14800.0 )
  = 0.736
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 0.736, 1.0 )
  = 0.736
```

**Results of Nozzle Reinforcement Area Calculations: (in^2)**

| AREA AVAILABLE, A1 to A5 | | MAWP | External | Mapnc |
|---|---|---|---|---|
| Area Required | Ar | 0.353 | 0.208 | NA |
| Area in Shell | A1 | 0.358 | 0.313 | NA |

| | | | | |
|---|---|---|---|---|
| Area in Nozzle Wall | A2 | 0.857 | 0.855 | NA |
| Area in Inward Nozzle | A3 | 0.000 | 0.000 | NA |
| Area in Welds | A41+A42+A43 | 0.092 | 0.092 | NA |
| Area in Element | A5 | 0.000 | 0.000 | NA |
| TOTAL AREA AVAILABLE | Atot | 1.307 | 1.261 | NA |

The MAWP Case Governs the Analysis.

```
 Nozzle Angle Used in Area Calculations                  90.00  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (2.0*0.1505*1.0+2*0.6563*0.1505*1.0*(1-0.74))
  = 0.353 in^2
```

**Reinforcement Areas per Figure UG-37.1**

Area Available in Shell [A1]:
```
  = d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
  = 2.037( 1.0 * 0.3622 - 1.0 * 0.151 ) - 2 * 0.656
    ( 1.0 * 0.3622 - 1.0 * 0.1505 ) *( 1 - 0.736 )
  = 0.358 in^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 0.906 )( 0.6563 - 0.014 ) 0.7365
  = 0.857 in^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  =  0.3543² * 0.7365 +( 0.0 )² * 0.7365
  = 0.092 in^2
```

**UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]**
```
 Wall Thickness for Internal/External pressures      ta = 0.0151 in
 Wall Thickness per UG16(b),                       tr16b = 0.0940 in
 Wall Thickness, shell/head, internal pressure     trb1 = 0.1820 in
 Wall Thickness                 tb1 = max(trb1, tr16b) = 0.1820 in
 Wall Thickness, shell/head, external pressure     trb2 = 0.0464 in
 Wall Thickness                 tb2 = max(trb2, tr16b) = 0.0940 in
 Wall Thickness per table UG-45                     tb3 = 0.1890 in
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.189, max( 0.182, 0.094 ) ]
  = 0.1820 in
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 0.0151, 0.182 )
  = 0.1820 in
```

Available Nozzle Neck Thickness = 0.6563 in --> OK

***Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):***
```
 Sustained  :   1298.1,  Allowable :  10900.0 psi  Passed
 Expansion  :      0.0,  Allowable :  33201.9 psi  Passed
 Occasional :     86.7,  Allowable :  14497.0 psi  Passed
```

```
 Shear      :   1283.3,  Allowable :   7630.0 psi  Passed
```

*The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

*SA-240 316L, Min Metal Temp without impact per UHA-51: -320 °F*

*SA-182 F316L, Min Metal Temp without impact per UHA-51: -320 °F*

Note:
The flange pressure ratio is less than 0.35. Impact testing is not required due to low stress per UHA-51(g).

*Design Pressure/Ambient Rating = 151.07/600.00 = 0.252*

Weld Size Calculations, Description: Nozzle LT4

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      0.3622  in
```

**Results Per UW-16.1:**

```
                          Required Thickness    Actual Thickness
 Nozzle Weld             0.2500 = Min per Code 0.2505 = 0.7 * Wo in
```

**Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)**

Weld Load [W]:
```
  = max( 0,  (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0,( 0.3531 - 0.358 + 2 * 0.6563 * 0.7365 *
    (1.0 * 0.3622 - 0.1505 ) )14800)
  = 2956.87 lbf
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 0.8568 + 0.0 + 0.0925 - 0.0 * 0.74 ) * 14800
  = 14048.45 lbf
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 0.8568 + 0.0 + 0.0925 +( 0.3501 ) ) * 14800
  = 19230.63 lbf
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = (  0.8568 + 0.0 + 0.0925 + 0.0 +( 0.3501 ) ) * 14800
  = 19230.63 lbf
```

**Strength of Connection Elements for Failure Path Analysis**

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 3.3126 * 0.3543 * 0.49 * 10900
  = 9847. lbf
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 1.3281) *( 0.6563 - 0.0 ) * 0.7 * 10900
  = 20894. lbf
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 3.3126 *( 0.3937 - 0.0315 ) * 0.74 * 14800
  = 20641. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

**Strength of Failure Paths:**

Failure Path [Path 1-1]:
```
  = ( SONW + SNW ) = ( 9847 + 20894 ) = 30741 lbf
```

Failure Path [Path 2-2]:
```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 9847 + 0 + 20641 + 0 ) = 30489 lbf
```

Failure Path [Path 3-3]:
```
  = ( Sonw + Tngw + Sinw )
  = ( 9847 + 20641 + 0 ) = 30489 lbf
```

**Summary of Failure Path Calculations:**
```
 Path 1-1 = 30741   lbf, must exceed W = 2956 lbf     or W1 = 14048 lbf
 Path 2-2 = 30488   lbf, must exceed W = 2956 lbf     or W2 = 19230 lbf
 Path 3-3 = 30488   lbf, must exceed W = 2956 lbf     or W3 = 19230 lbf
```

**Maximum Allowable Pressure for this Nozzle at this Location:**
```
 Converged Maximum Allowable Pressure in the Operating case: 359 psig
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

```
 Nozzle is O.K. for the External Pressure: 15 psig
```

The Drop for this Nozzle is : 0.0941 in
The Cut Length for this Nozzle is, Drop + Ho + H + T : 7.5928 in

**Input Echo, WRC297 Item 1, Description: Nozzle LT4 :**

```
 Diameter Basis for Cylindrical Shell                       ID
 Shell Corrosion Allowance                                  0.0315  in
 Shell Diameter                                             29.250  in
 Shell Thickness                                            0.3937  in
 Shell Stress Concentration Factor                           1.000
 Vessel Material                                       SA-240 316L
 Vessel Cold S.I. Allowable                   Smc     16700.00  psi
 Vessel Hot  S.I. Allowable                   Smh     14800.00  psi

 Diameter Basis for Nozzle                                  ID
 Nozzle Corrosion Allowance                                 0.0000  in
 Nozzle Diameter                                             2.000  in
 Nozzle Thickness                                           0.6563  in
 Nozzle Stress Concentration Factor                          1.000
 Nozzle Material                                      SA-182 F316L
 Nozzle Cold S.I. Allowable                  SNmc     16700.00  psi
 Nozzle Hot  S.I. Allowable                  SNmh     10900.00  psi
```

Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-182 F316L

*Note:*
*External Forces and Moments in WRC 107/537 Convention:*

*These loads are assumed to be SUStained loads.*

| | | | |
|---|---|---|---|
| Design Internal Pressure | Dp | 151.07 | psig |
| Radial Load | P | -630.00 | lbf |
| Circumferential Shear | Vc | 470.00 | lbf |
| Longitudinal Shear | Vl | 630.00 | lbf |
| Circumferential Moment | Mc | 210.00 | ft-lbf |
| Longitudinal Moment | Ml | 270.00 | ft-lbf |
| Torsional Moment | Mt | 310.00 | ft-lbf |

| | |
|---|---|
| Include Axial Pressure Thrust | No |
| Include Pressure Stress Indices per Div. 2 | No |
| Local Loads applied at end of Nozzle/Attachment | No |

*Warning - The ratio, Dn/Tn (5.047) is < 10*
*check the limitations of WRC bulletin 297.*

**Stress Computations at the Edge of the Nozzle:**

Stress Attenuation Diameter (for Insert Plates) per WRC 297:
= NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
= 3.313 + 2 * 1.65 * sqrt( 14.838( 0.394 - 0.031 ) )
= 10.963 in

WRC 297 Curve Access Parameters:

| | | | |
|---|---|---|---|
| Vessel Mean Diameter | (D) = | 29.675 | in |
| Nozzle Outside Diameter | (d) = | 3.313 | in |
| Vessel Thickness used | (T) = | 0.362 | in |
| Nozzle Thickness used | (t) = | 0.656 | in |
| T / t | = | 0.552 | |
| d / t | = | 10.000 | |

Lambda = [(d/D) * sqrt(D/T)] = 1.010

| | | |
|---|---|---|
| Nr/P | = | 0.106 |
| Mr/P | = | 0.218 |
| M0/P | = | 0.065 |
| N0/P | = | 0.132 |
| MrD/Mc | = | 0.304 |
| NrDL/Mc | = | 0.097 |
| M0d/Mc | = | 0.097 |
| N0DL/Mc | = | 0.031 |
| MrD/Ml | = | 0.195 |
| NrDL/Ml | = | 0.090 |
| M0D/Ml | = | 0.064 |
| N0DL/Ml | = | 0.120 |

***Vessel Stresses (psi):***

| LONGITUDINAL PLANE (Stresses Normal to longitudinal plane) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Outplane Membrane (P ) | 634 | 634 | 634 | 634 |
| Outplane Bending (P ) | 1877 | -1877 | 1877 | -1877 |
| Outplane Membrane (Mc) | 0 | 0 | 0 | 0 |
| Outplane Bending (Mc) | 0 | 0 | 0 | 0 |
| Outplane Membrane (ML) | -891 | -891 | 891 | 891 |
| Outplane Bending (ML) | -2871 | 2871 | 2871 | -2871 |
| Normal Pressure Stress | 6038 | 6189 | 6038 | 6189 |

| | | | | |
|---|---|---|---|---|
| Outplane Stress Summary | 4787 | 6926 | 12311 | 2966 |

***Vessel Stresses (psi):***

| LONGITUDINAL PLANE (Stresses parallel to longitudinal plane) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Inplane Membrane (P ) | 510 | 510 | 510 | 510 |
| Inplane Bending (P ) | 6293 | -6293 | 6293 | -6293 |
| Inplane Membrane (Mc) | 0 | 0 | 0 | 0 |
| Inplane Bending (Mc) | 0 | 0 | 0 | 0 |
| Inplane Membrane (ML) | -669 | -669 | 669 | 669 |
| Inplane Bending (ML) | -8720 | 8720 | 8720 | -8720 |
| Inplane Pressure Stress | 3019 | 3019 | 3019 | 3019 |
| Inplane Stress Summary | 433 | 5287 | 19211 | -10815 |

***Vessel Stresses (psi):***

| LONGITUDINAL PLANE (Shear stress normal to longitudinal plane) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Outplane Shear (Vc) | 249 | 249 | -249 | -249 |
| Outplane Shear (Vl) | 0 | 0 | 0 | 0 |
| Outplane Shear (Mt) | 595 | 595 | 595 | 595 |
| Shear Stress Summary | 844 | 844 | 346 | 346 |

***Vessel Stresses (psi):***

| LONGITUDINAL PLANE (Stress Intensities | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 4944 | 7282 | 19228 | 13798 |

***Vessel Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stresses Normal to circumferential plane) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Outplane Membrane (P ) | 634 | 634 | 634 | 634 |
| Outplane Bending (P ) | 1877 | -1877 | 1877 | -1877 |
| Outplane Membrane (Mc) | -181 | -181 | 181 | 181 |
| Outplane Bending (Mc) | -3389 | 3389 | 3389 | -3389 |
| Outplane Membrane (ML) | 0 | 0 | 0 | 0 |
| Outplane Bending (ML) | 0 | 0 | 0 | 0 |
| Normal Pressure Stress | 3019 | 3019 | 3019 | 3019 |
| Outplane Stress Summary | 1960 | 4984 | 9100 | -1432 |

***Vessel Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stresses parallel to circumferential plane) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Inplane Membrane (P ) | 510 | 510 | 510 | 510 |
| Inplane Bending (P ) | 6293 | -6293 | 6293 | -6293 |
| Inplane Membrane (Mc) | -562 | -562 | 562 | 562 |
| Inplane Bending (Mc) | -10562 | 10562 | 10562 | -10562 |
| Inplane Membrane (ML) | 0 | 0 | 0 | 0 |
| Inplane Bending (ML) | 0 | 0 | 0 | 0 |

| | | | | |
|---|---|---|---|---|
| Inplane Pressure Stress | 6038 | 6189 | 6038 | 6189 |
| Inplane Stress Summary | 1717 | 10406 | 23965 | -9594 |

***Vessel Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Shear stress normal to circumferential plane) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Outplane Shear (Vc) | 0 | 0 | 0 | 0 |
| Outplane Shear (Vl) | -334 | -334 | 334 | 334 |
| Torsional Shear (Mt) | 595 | 595 | 595 | 595 |
| Shear Stress Summary | 261 | 261 | 929 | 929 |

***Vessel Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stress Intensities | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 2126 | 10418 | 24022 | 9698 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Stresses in the hoop direction) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Hoop Membrane (P ) | 634 | 634 | 634 | 634 |
| Hoop Bending (P ) | 0 | 0 | 0 | 0 |
| Hoop Membrane (Mc) | 0 | 0 | 0 | 0 |
| Hoop Bending (Mc) | 0 | 0 | 0 | 0 |
| Hoop Membrane (ML) | -891 | -891 | 891 | 891 |
| Hoop Bending (ML) | 0 | 0 | 0 | 0 |
| Hoop Pressure Stress | 207 | 389 | 207 | 389 |
| Hoop Stress Summary | -50 | 132 | 1732 | 1914 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Stresses Normal to pipe cross-section) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Axial Membrane (P ) | 115 | 115 | 115 | 115 |
| Axial Bending (P ) | 1450 | -1450 | 1450 | -1450 |
| Axial Membrane (Mc) | 0 | 0 | 0 | 0 |
| Axial Bending (Mc) | 0 | 0 | 0 | 0 |
| Axial Membrane (ML) | -1047 | -1047 | 1047 | 1047 |
| Axial Bending (ML) | -2044 | 2044 | 2044 | -2044 |
| Axial Pressure Stress | 103 | 103 | 103 | 103 |
| Axial Stress Summary | -1423 | -235 | 4759 | -2229 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Shear stress) | Au Outside | Al Inside | Bu Outside | Bl Inside |
|---|---|---|---|---|
| Shear due to (Vc) | 137 | 137 | -137 | -137 |
| Shear due to (Vl) | 0 | 0 | 0 | 0 |
| Shear due to Torsion | 328 | 328 | 328 | 328 |
| Shear Stress Summary | 465 | 465 | 191 | 191 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Stress Intensities | Au Outside | Al Inside | Bu Outside | Bl Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 1658 | 999 | 4771 | 4160 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stresses in the hoop direction) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Hoop Membrane (P ) | 634 | 634 | 634 | 634 |
| Hoop Bending (P ) | 0 | 0 | 0 | 0 |
| Hoop Membrane (Mc) | -181 | -181 | 181 | 181 |
| Hoop Bending (Mc) | 0 | 0 | 0 | 0 |
| Hoop Membrane (ML) | 0 | 0 | 0 | 0 |
| Hoop Bending (ML) | 0 | 0 | 0 | 0 |
| Hoop Pressure Stress | 207 | 389 | 207 | 389 |
| Hoop Stress Summary | 660 | 842 | 1022 | 1204 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stresses Normal to pipe cross-section) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Axial Membrane (P ) | 115 | 115 | 115 | 115 |
| Axial Bending (P ) | 1450 | -1450 | 1450 | -1450 |
| Axial Membrane (Mc) | -814 | -814 | 814 | 814 |
| Axial Bending (Mc) | -2703 | 2703 | 2703 | -2703 |
| Axial Membrane (ML) | 0 | 0 | 0 | 0 |
| Axial Bending (ML) | 0 | 0 | 0 | 0 |
| Axial Pressure Stress | 103 | 103 | 103 | 103 |
| Axial Stress Summary | -1849 | 657 | 5185 | -3121 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Shear stress) | Cu Outside | Cl Inside | Du Outside | Dl Inside |
|---|---|---|---|---|
| Shear due to (Vc) | 0 | 0 | 0 | 0 |
| Shear due to (Vl) | -184 | -184 | 184 | 184 |
| Shear due to Torsion | 328 | 328 | 328 | 328 |
| Shear Stress Summary | 144 | 144 | 512 | 512 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stress Intensities | Cu Outside | Cl Inside | Du Outside | Dl Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 2525 | 920 | 5247 | 4444 |

**WRC 297 Stress Summations per ASME Sec. VIII Div. 2:**

**Vessel Stress Summation at Vessel-Nozzle Junction (psi):**

| Type of Stress Int. Location | Stress Values at Au | Al | Bu | Bl | Cu | Cl | Du | Dl |
|---|---|---|---|---|---|---|---|---|

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Circ. Pm (SUS) | 6038 | 6189 | 6038 | 6189 | 6038 | 6189 | 6038 | 6189 |
| Circ. Pl (SUS) | -257 | -257 | 1525 | 1525 | -52 | -52 | 1072 | 1072 |
| Circ. Q (SUS) | -994 | 994 | 4748 | -4748 | -4269 | 4269 | 16855 | -16855 |
| Long. Pm (SUS) | 3019 | 3019 | 3019 | 3019 | 3019 | 3019 | 3019 | 3019 |
| Long. Pl (SUS) | -159 | -159 | 1179 | 1179 | 453 | 453 | 815 | 815 |
| Long. Q (SUS) | -2427 | 2427 | 15013 | -15013 | -1512 | 1512 | 5266 | -5266 |
| Shear Pm (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Shear Pl (SUS) | 249 | 249 | -249 | -249 | -334 | -334 | 334 | 334 |
| Shear Q (SUS) | 595 | 595 | 595 | 595 | 595 | 595 | 595 | 595 |
| Pm (SUS) | 6038 | 6189 | 6038 | 6189 | 6038 | 6189 | 6038 | 6189 |
| Pm+Pl (SUS) | 5802 | 5952 | 7581 | 7731 | 6029 | 6178 | 7143 | 7293 |
| Pm+Pl+Q (Total) | 4944 | 7282 | 19228 | 13798 | 2126 | 10418 | 24022 | 9698 |

**Vessel Stress Summation Comparison (psi):**

| Type of Stress Int. | Max. S.I. | S.I. Allowable | Result |
|---|---|---|---|
| Pm (SUS) | 6189 | 14800 | Passed |
| Pm+Pl (SUS) | 7731 | 22200 | Passed |
| Pm+Pl+Q (TOTAL) | 24022 | 44400 | Passed |

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

**WRC 297 Stress Summations per ASME Sec. VIII Div. 2:**

**Nozzle Stress Summation at Vessel-Nozzle Junction (psi):**

| Type of Stress Int. Location | Stress Values at Au | Al | Bu | Bl | Cu | Cl | Du | Dl |
|---|---|---|---|---|---|---|---|---|
| Circ. Pm (SUS) | 207 | 389 | 207 | 389 | 207 | 389 | 207 | 389 |
| Circ. Pl (SUS) | -257 | -257 | 1525 | 1525 | 453 | 453 | 815 | 815 |
| Circ. Q (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Long. Pm (SUS) | 103 | 103 | 103 | 103 | 103 | 103 | 103 | 103 |
| Long. Pl (SUS) | -932 | -932 | 1162 | 1162 | -699 | -699 | 929 | 929 |
| Long. Q (SUS) | -594 | 594 | 3494 | -3494 | -1253 | 1253 | 4153 | -4153 |
| Shear Pm (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Shear Pl (SUS) | 137 | 137 | -137 | -137 | -184 | -184 | 184 | 184 |
| Shear Q (SUS) | 328 | 328 | 328 | 328 | 328 | 328 | 328 | 328 |
| Pm (SUS) | 207 | 389 | 207 | 389 | 207 | 389 | 207 | 389 |
| Pm+Pl (SUS) | 852 | 999 | 1769 | 1941 | 1308 | 1484 | 1211 | 1321 |
| Pm+Pl+Q (Total) | 1658 | 999 | 4771 | 4160 | 2525 | 920 | 5247 | 4444 |

**Nozzle Stress Summation Comparison (psi):**

| Type of Stress Int. | Max. S.I. | S.I. Allowable | Result |
|---|---|---|---|

 201

| | | | |
|---|---|---|---|
| Pm (SUS) | 389 | 10900 | Passed |
| Pm+Pl (SUS) | 1941 | 16350 | Passed |
| Pm+Pl+Q (TOTAL) | 5247 | 32700 | Passed |

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

**Input, Nozzle Desc: Nozzle A 3"          From: 60**

| | | | |
|---|---|---|---|
| Pressure for Reinforcement Calculations | P | 150.000 | psig |
| Temperature for Internal Pressure | Temp | 500 | °F |
| Design External Pressure | Pext | 15.00 | psig |
| Temperature for External Pressure | Tempex | 300 | °F |
| | | | |
| Parent Material | | SA-240 316L | |
| Parent Allowable Stress at Temperature | Sv | 14800.00 | psi |
| Parent Allowable Stress At Ambient | Sva | 16700.00 | psi |
| | | | |
| Inside Diameter of Cylindrical Shell | D | 29.2500 | in |
| Design Length of Section | L | 118.5000 | in |
| Shell Finished (Minimum) Thickness | t | 0.3937 | in |
| Shell Internal Corrosion Allowance | c | 0.0315 | in |
| Shell External Corrosion Allowance | co | 0.0000 | in |
| | | | |
| Distance from Bottom/Left Tangent | | 5.91 | ft |
| | | | |
| User Entered Minimum Design Metal Temperature | | 32.00 | °F |

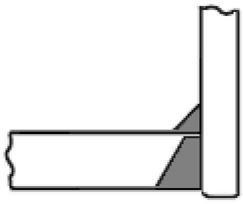
***Type of Element Connected to the Parent : Nozzle***

| | | | |
|---|---|---|---|
| Material | | SA-312 TP316L | |
| Material UNS Number | | S31603 | |
| Material Specification/Type | | Smls. pipe | |
| Allowable Stress at Temperature | Sn | 10900.00 | psi |
| Allowable Stress At Ambient | Sna | 16700.00 | psi |
| | | | |
| Diameter Basis (for tr calc only) | | Outside | |
| Layout Angle | | 270.00 | deg |
| Diameter | | 3.0000 | in. |
| | | | |
| Size and Thickness Basis | | Minimum | |
| Nominal Thickness | | XXS | |
| | | | |
| Flange Type | | Weld Neck Flange | |
| | | | |
| Corrosion Allowance | can | 0.0315 | in |
| Joint Efficiency of Shell Seam at Nozzle | E1 | 1.00 | |
| Joint Efficiency of Nozzle Neck | En | 1.00 | |
| | | | |
| Outside Projection | ho | 4.8613 | in |
| Weld leg size between Nozzle and Pad/Shell | Wo | 0.3543 | in |
| Groove weld depth between Nozzle and Vessel | Wgnv | 0.3900 | in |
| Inside Projection | h | 0.0000 | in |
| Weld leg size, Inside Element to Shell | Wi | 0.0000 | in |
| | | | |
| Flange Class | | 600 | |
| Flange Grade | | GR 2.3 | |

The Pressure Design option was MAWP + static head (to the nozzle).

**Nozzle Sketch (may not represent actual weld type/configuration)**



**Insert/Set-in Nozzle No Pad, no Inside projection**

**Reinforcement CALCULATION, Description: Nozzle A 3"**

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
 Actual Outside Diameter Used in Calculation            3.500  in.
 Actual Thickness Used in Calculation                   0.525  in.
```

*Error and Warning Messages for the Current Nozzle:*

*The nominal thickness selection seems to indicate that carbon steel was selected, but at the same time a stainless steel pipe material was selected. Please check the input to be sure this is what you intended.*

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Int. Press]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 150.0*14.6565/(14800*1.0-0.6*150.0)
  = 0.1495 in
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Int. Press]
```
  = P*Ro/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = 150.0*1.75/(10900*1.0+0.4*150.0)
  = 0.0240 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0134 in

**UG-40, Limits of Reinforcement : [Internal Pressure]**
```
 Parallel to Vessel Wall (Diameter Limit)            Dl     5.0260  in
 Parallel to Vessel Wall, opening length              d     2.5130  in
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     0.9055  in
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 10900.0/14800.0 )
  = 0.736
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 10900.0/14800.0 )
  = 0.736
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 0.736, 1.0 )
```

```
  = 0.736
```

**Results of Nozzle Reinforcement Area Calculations: (in^2)**

| AREA AVAILABLE, A1 to A5 | | MAWP | External | Mapnc |
|---|---|---|---|---|
| Area Required | Ar | 0.414 | 0.245 | NA |
| Area in Shell | A1 | 0.479 | 0.417 | NA |
| Area in Nozzle Wall | A2 | 0.626 | 0.640 | NA |
| Area in Inward Nozzle | A3 | 0.000 | 0.000 | NA |
| Area in Welds | A41+A42+A43 | 0.092 | 0.092 | NA |
| Area in Element | A5 | 0.000 | 0.000 | NA |
| TOTAL AREA AVAILABLE | Atot | 1.198 | 1.150 | NA |

The MAWP Case Governs the Analysis.

```
 Nozzle Angle Used in Area Calculations                 90.00  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:

```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (2.513*0.1495*1.0+2*0.4935*0.1495*1.0*(1-0.74))
  = 0.414 in^2
```

**Reinforcement Areas per Figure UG-37.1**

Area Available in Shell [A1]:

```
  = d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
  = 2.513( 1.0 * 0.3622 - 1.0 * 0.149 ) - 2 * 0.494
    ( 1.0 * 0.3622 - 1.0 * 0.1495 ) *( 1 - 0.736 )
  = 0.479 in^2
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 0.906 )( 0.4935 - 0.024 ) 0.7365
  = 0.626 in^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  =  0.3543² * 0.7365 +( 0.0 )² * 0.7365
  = 0.092 in^2
```

**UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]**

```
 Wall Thickness for Internal/External pressures      ta = 0.0554 in
 Wall Thickness per UG16(b),                      tr16b = 0.0940 in
 Wall Thickness, shell/head, internal pressure     trb1 = 0.1810 in
 Wall Thickness                 tb1 = max(trb1, tr16b) = 0.1810 in
 Wall Thickness, shell/head, external pressure     trb2 = 0.0464 in
 Wall Thickness                 tb2 = max(trb2, tr16b) = 0.0940 in
 Wall Thickness per table UG-45                     tb3 = 0.2205 in
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.22, max( 0.181, 0.094 ) ]
  = 0.1810 in
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

```
  = max( ta, tb )
  = max( 0.0554, 0.181 )
  = 0.1810 in
```

Available Nozzle Neck Thickness = 0.5250 in --> OK

***Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):***

```
 Sustained   :   2533.1,  Allowable :  10900.0 psi  Passed
 Expansion   :      0.0,  Allowable :  31966.9 psi  Passed
 Occasional  :    159.6,  Allowable :  14497.0 psi  Passed
 Shear       :   1991.3,  Allowable :   7630.0 psi  Passed
```

*The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

*SA-240 316L, Min Metal Temp without impact per UHA-51:  -320 °F*

*SA-312 TP316L, Min Metal Temp without impact per UHA-51:  -320 °F*

Note:
The flange pressure ratio is less than 0.35.  Impact testing is not required due to low stress per UHA-51(g).

*Design Pressure/Ambient Rating = 150.00/1200.00 = 0.125*

<u>Weld Size Calculations, Description: Nozzle A 3"</u>

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      0.3622  in
```

**Results Per UW-16.1:**

```
                          Required Thickness    Actual Thickness
 Nozzle Weld             0.2500 = Min per Code 0.2505 = 0.7 * Wo in
```

**Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)**

Weld Load [W]:
```
  = max( 0,  (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0,( 0.4144 - 0.4793 + 2 * 0.4935 * 0.7365 *
    (1.0 * 0.3622 - 0.1495 ) )14800)
  = 1328.98 lbf
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 0.6263 + 0.0 + 0.0925 - 0.0 * 0.74 ) * 14800
  = 10637.55 lbf
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 0.6263 + 0.0 + 0.0925 +( 0.2633 ) ) * 14800
  = 14534.29 lbf
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = (  0.6263 + 0.0 + 0.0925 + 0.0 +( 0.2633 ) ) * 14800
  = 14534.29 lbf
```

**Strength of Connection Elements for Failure Path Analysis**

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 3.5 * 0.3543 * 0.49 * 10900
```

```
  = 10404. lbf
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 1.5032) *( 0.525 - 0.0315 ) * 0.7 * 10900
  = 17783. lbf
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 3.5 *( 0.3937 - 0.0315 ) * 0.74 * 14800
  = 21809. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

**Strength of Failure Paths:**

Failure Path [Path 1-1]:

```
  = ( SONW + SNW ) = ( 10404 + 17783 ) = 28187 lbf
```

Failure Path [Path 2-2]:

```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 10404 + 0 + 21809 + 0 ) = 32213 lbf
```

Failure Path [Path 3-3]:

```
  = ( Sonw + Tngw + Sinw )
  = ( 10404 + 21809 + 0 ) = 32213 lbf
```

**Summary of Failure Path Calculations:**

```
 Path 1-1 = 28187   lbf, must exceed W = 1328 lbf     or W1 = 10637 lbf
 Path 2-2 = 32213   lbf, must exceed W = 1328 lbf     or W2 = 14534 lbf
 Path 3-3 = 32213   lbf, must exceed W = 1328 lbf     or W3 = 14534 lbf
```

**Maximum Allowable Pressure for this Nozzle at this Location:**

```
 Converged Maximum Allowable Pressure in the Operating case: 298 psig

 Nozzle is O.K. for the External Pressure: 15 psig
```

The Drop for this Nozzle is : 0.1051 in
The Cut Length for this Nozzle is, Drop + Ho + H + T : 5.3601 in

**Input Echo, WRC297 Item     1,        Description: Nozzle A 3"   :**

```
 Diameter Basis for Cylindrical Shell                       ID
 Shell Corrosion Allowance                                  0.0315  in
 Shell Diameter                                             29.250  in
 Shell Thickness                                            0.3937  in
 Shell Stress Concentration Factor                           1.000
 Vessel Material                                       SA-240 316L
 Vessel Cold S.I. Allowable                    Smc     16700.00  psi
 Vessel Hot  S.I. Allowable                    Smh     14800.00  psi

 Diameter Basis for Nozzle                                  OD
 Nozzle Corrosion Allowance                                 0.0315  in
 Nozzle Diameter                                             3.500  in
 Nozzle Thickness                                           0.5250  in
 Nozzle Stress Concentration Factor                          1.000
 Nozzle Material                                     SA-312 TP316L
 Nozzle Cold S.I. Allowable                   SNmc     16700.00  psi
 Nozzle Hot  S.I. Allowable                   SNmh     10900.00  psi
```

Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.

Make sure that material properties at this temperature are not
time-dependent for Material: SA-312 TP316L

*Note:*
*External Forces and Moments in WRC 107/537 Convention:*
*These loads are assumed to be SUStained loads.*

| | | | |
|---|---|---|---|
| Design Internal Pressure | Dp | 150.00 | psig |
| Radial Load | P | -810.00 | lbf |
| Circumferential Shear | Vc | 610.00 | lbf |
| Longitudinal Shear | Vl | 810.00 | lbf |
| Circumferential Moment | Mc | 400.00 | ft-lbf |
| Longitudinal Moment | Ml | 520.00 | ft-lbf |
| Torsional Moment | Mt | 600.00 | ft-lbf |

| | |
|---|---|
| Include Axial Pressure Thrust | No |
| Include Pressure Stress Indices per Div. 2 | No |
| Local Loads applied at end of Nozzle/Attachment | No |

*Warning - The ratio, Dn/Tn (6.667) is < 10*
*check the limitations of WRC bulletin 297.*

**Stress Computations at the Edge of the Nozzle:**

Stress Attenuation Diameter (for Insert Plates) per WRC 297:
= NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
= 3.5 + 2 * 1.65 * sqrt( 14.838( 0.394 - 0.031 ) )
= 11.150 in

WRC 297 Curve Access Parameters:

| | | | |
|---|---|---|---|
| Vessel Mean Diameter | (D) = | 29.675 | in |
| Nozzle Outside Diameter | (d) = | 3.500 | in |
| Vessel Thickness used | (T) = | 0.362 | in |
| Nozzle Thickness used | (t) = | 0.494 | in |
| T / t | = | 0.734 | |
| d / t | = | 10.000 | |

Lambda = [(d/D) * sqrt(D/T)] = 1.068

| | | |
|---|---|---|
| Nr/P | = | 0.111 |
| Mr/P | = | 0.199 |
| M0/P | = | 0.062 |
| N0/P | = | 0.125 |
| MrD/Mc | = | 0.293 |
| NrDL/Mc | = | 0.117 |
| M0d/Mc | = | 0.101 |
| N0DL/Mc | = | 0.040 |
| MrD/Ml | = | 0.189 |
| NrDL/Ml | = | 0.097 |
| M0D/Ml | = | 0.066 |
| N0DL/Ml | = | 0.121 |

***Vessel Stresses (psi):***

| LONGITUDINAL PLANE (Stresses Normal to longitudinal plane) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Outplane Membrane (P ) | 769 | 769 | 769 | 769 |
| Outplane Bending (P ) | 2313 | -2313 | 2313 | -2313 |

| | | | | |
|---|---|---|---|---|
| Outplane Membrane (Mc) | 0 | 0 | 0 | 0 |
| Outplane Bending (Mc) | 0 | 0 | 0 | 0 |
| Outplane Membrane (ML) | -1650 | -1650 | 1650 | 1650 |
| Outplane Bending (ML) | -5350 | 5350 | 5350 | -5350 |
| Normal Pressure Stress | 5995 | 6145 | 5995 | 6145 |
| Outplane Stress Summary | 2077 | 8301 | 16077 | 901 |

***Vessel Stresses (psi):***

| LONGITUDINAL PLANE (Stresses parallel to longitudinal plane) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Inplane Membrane (P ) | 687 | 687 | 687 | 687 |
| Inplane Bending (P ) | 7364 | -7364 | 7364 | -7364 |
| Inplane Membrane (Mc) | 0 | 0 | 0 | 0 |
| Inplane Bending (Mc) | 0 | 0 | 0 | 0 |
| Inplane Membrane (ML) | -1319 | -1319 | 1319 | 1319 |
| Inplane Bending (ML) | -15406 | 15406 | 15406 | -15406 |
| Inplane Pressure Stress | 2997 | 2997 | 2997 | 2997 |
| Inplane Stress Summary | -5677 | 10407 | 27773 | -17767 |

***Vessel Stresses (psi):***

| LONGITUDINAL PLANE (Shear stress normal to longitudinal plane) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Outplane Shear (Vc) | 306 | 306 | -306 | -306 |
| Outplane Shear (Vl) | 0 | 0 | 0 | 0 |
| Outplane Shear (Mt) | 1033 | 1033 | 1033 | 1033 |
| Shear Stress Summary | 1339 | 1339 | 727 | 727 |

***Vessel Stresses (psi):***

| LONGITUDINAL PLANE (Stress Intensities | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 8203 | 11057 | 27818 | 18724 |

***Vessel Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stresses Normal to circumferential plane) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Outplane Membrane (P ) | 769 | 769 | 769 | 769 |
| Outplane Bending (P ) | 2313 | -2313 | 2313 | -2313 |
| Outplane Membrane (Mc) | -415 | -415 | 415 | 415 |
| Outplane Bending (Mc) | -6317 | 6317 | 6317 | -6317 |
| Outplane Membrane (ML) | 0 | 0 | 0 | 0 |
| Outplane Bending (ML) | 0 | 0 | 0 | 0 |
| Normal Pressure Stress | 2997 | 2997 | 2997 | 2997 |
| Outplane Stress Summary | -653 | 7355 | 12811 | -4449 |

***Vessel Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stresses parallel to circumferential plane) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| Inplane Membrane (P ) | 687 | 687 | 687 | 687 |
| Inplane Bending (P ) | 7364 | -7364 | 7364 | -7364 |
| Inplane Membrane (Mc) | -1226 | -1226 | 1226 | 1226 |
| Inplane Bending (Mc) | -18362 | 18362 | 18362 | -18362 |
| Inplane Membrane (ML) | 0 | 0 | 0 | 0 |
| Inplane Bending (ML) | 0 | 0 | 0 | 0 |
| Inplane Pressure Stress | 5995 | 6145 | 5995 | 6145 |
| Inplane Stress Summary | -5542 | 16604 | 33634 | -17668 |

***Vessel Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Shear stress normal to circumferential plane) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Outplane Shear (Vc) | 0 | 0 | 0 | 0 |
| Outplane Shear (Vl) | -406 | -406 | 406 | 406 |
| Torsional Shear (Mt) | 1033 | 1033 | 1033 | 1033 |
| Shear Stress Summary | 627 | 627 | 1439 | 1439 |

***Vessel Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stress Intensities | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 5621 | 16646 | 33732 | 17822 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Stresses in the hoop direction) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Hoop Membrane (P ) | 769 | 769 | 769 | 769 |
| Hoop Bending (P ) | 0 | 0 | 0 | 0 |
| Hoop Membrane (Mc) | 0 | 0 | 0 | 0 |
| Hoop Bending (Mc) | 0 | 0 | 0 | 0 |
| Hoop Membrane (ML) | -1650 | -1650 | 1650 | 1650 |
| Hoop Bending (ML) | 0 | 0 | 0 | 0 |
| Hoop Pressure Stress | 383 | 563 | 383 | 563 |
| Hoop Stress Summary | -498 | -318 | 2802 | 2982 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Stresses Normal to pipe cross-section) | Au Top Outside | Al Top Inside | Bu Bottom Outside | Bl Bottom Inside |
|---|---|---|---|---|
| Axial Membrane (P ) | 173 | 173 | 173 | 173 |
| Axial Bending (P ) | 2856 | -2856 | 2856 | -2856 |
| Axial Membrane (Mc) | 0 | 0 | 0 | 0 |
| Axial Bending (Mc) | 0 | 0 | 0 | 0 |
| Axial Membrane (ML) | -2019 | -2019 | 2019 | 2019 |
| Axial Bending (ML) | -6167 | 6167 | 6167 | -6167 |
| Axial Pressure Stress | 191 | 191 | 191 | 191 |
| Axial Stress Summary | -4966 | 1656 | 11406 | -6640 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Shear stress) | Au Outside | Al Inside | Bu Outside | Bl Inside |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| Shear due to (Vc) | 224 | 224 | -224 | -224 |
| Shear due to (Vl) | 0 | 0 | 0 | 0 |
| Shear due to Torsion | 758 | 758 | 758 | 758 |
| Shear Stress Summary | 982 | 982 | 534 | 534 |

***Nozzle Stresses (psi):***

| LONGITUDINAL PLANE (Stress Intensities | Au Outside | Al Inside | Bu Outside | Bl Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 5172 | 2784 | 11439 | 9681 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stresses in the hoop direction) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Hoop Membrane (P ) | 769 | 769 | 769 | 769 |
| Hoop Bending (P ) | 0 | 0 | 0 | 0 |
| Hoop Membrane (Mc) | -415 | -415 | 415 | 415 |
| Hoop Bending (Mc) | 0 | 0 | 0 | 0 |
| Hoop Membrane (ML) | 0 | 0 | 0 | 0 |
| Hoop Bending (ML) | 0 | 0 | 0 | 0 |
| Hoop Pressure Stress | 383 | 563 | 383 | 563 |
| Hoop Stress Summary | 737 | 917 | 1567 | 1747 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stresses Normal to pipe cross-section) | Cu Left Outside | Cl Left Inside | Du Right Outside | Dl Right Inside |
|---|---|---|---|---|
| Axial Membrane (P ) | 173 | 173 | 173 | 173 |
| Axial Bending (P ) | 2856 | -2856 | 2856 | -2856 |
| Axial Membrane (Mc) | -1553 | -1553 | 1553 | 1553 |
| Axial Bending (Mc) | -7909 | 7909 | 7909 | -7909 |
| Axial Membrane (ML) | 0 | 0 | 0 | 0 |
| Axial Bending (ML) | 0 | 0 | 0 | 0 |
| Axial Pressure Stress | 191 | 191 | 191 | 191 |
| Axial Stress Summary | -6242 | 3864 | 12682 | -8848 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Shear stress) | Cu Outside | Cl Inside | Du Outside | Dl Inside |
|---|---|---|---|---|
| Shear due to (Vc) | 0 | 0 | 0 | 0 |
| Shear due to (Vl) | -298 | -298 | 298 | 298 |
| Shear due to Torsion | 758 | 758 | 758 | 758 |
| Shear Stress Summary | 460 | 460 | 1056 | 1056 |

***Nozzle Stresses (psi):***

| CIRCUMFERENTIAL PLANE (Stress Intensities | Cu Outside | Cl Inside | Du Outside | Dl Inside |
|---|---|---|---|---|
| Two * Max Shear Stress | 7039 | 3934 | 12781 | 10803 |

**WRC 297 Stress Summations per ASME Sec. VIII Div. 2:**

**Vessel Stress Summation at Vessel-Nozzle Junction (psi):**

| Type of Stress Int. Location | Au | Al | Bu | Bl | Cu | Cl | Du | Dl |
|---|---|---|---|---|---|---|---|---|
| Circ. Pm (SUS) | 5995 | 6145 | 5995 | 6145 | 5995 | 6145 | 5995 | 6145 |
| Circ. Pl (SUS) | -881 | -881 | 2419 | 2419 | -539 | -539 | 1913 | 1913 |
| Circ. Q (SUS) | -3037 | 3037 | 7663 | -7663 | -10998 | 10998 | 25726 | -25726 |
| Long. Pm (SUS) | 2997 | 2997 | 2997 | 2997 | 2997 | 2997 | 2997 | 2997 |
| Long. Pl (SUS) | -632 | -632 | 2006 | 2006 | 354 | 354 | 1184 | 1184 |
| Long. Q (SUS) | -8042 | 8042 | 22770 | -22770 | -4004 | 4004 | 8630 | -8630 |
| Shear Pm (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Shear Pl (SUS) | 306 | 306 | -306 | -306 | -406 | -406 | 406 | 406 |
| Shear Q (SUS) | 1033 | 1033 | 1033 | 1033 | 1033 | 1033 | 1033 | 1033 |
| Pm (SUS) | 5995 | 6145 | 5995 | 6145 | 5995 | 6145 | 5995 | 6145 |
| Pm+Pl (SUS) | 5147 | 5295 | 8441 | 8590 | 5531 | 5676 | 7951 | 8100 |
| Pm+Pl+Q (Total) | 8203 | 11057 | 27818 | 18724 | 5621 | 16646 | 33732 | 17822 |

**Vessel Stress Summation Comparison (psi):**

| Type of Stress Int. | Max. S.I. | S.I. Allowable | Result |
|---|---|---|---|
| Pm (SUS) | 6145 | 14800 | Passed |
| Pm+Pl (SUS) | 8590 | 22200 | Passed |
| Pm+Pl+Q (TOTAL) | 33732 | 44400 | Passed |

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

**WRC 297 Stress Summations per ASME Sec. VIII Div. 2:**

**Nozzle Stress Summation at Vessel-Nozzle Junction (psi):**

| Type of Stress Int. Location | Au | Al | Bu | Bl | Cu | Cl | Du | Dl |
|---|---|---|---|---|---|---|---|---|
| Circ. Pm (SUS) | 383 | 563 | 383 | 563 | 383 | 563 | 383 | 563 |
| Circ. Pl (SUS) | -881 | -881 | 2419 | 2419 | 354 | 354 | 1184 | 1184 |
| Circ. Q (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Long. Pm (SUS) | 191 | 191 | 191 | 191 | 191 | 191 | 191 | 191 |
| Long. Pl (SUS) | -1846 | -1846 | 2192 | 2192 | -1380 | -1380 | 1726 | 1726 |
| Long. Q (SUS) | -3311 | 3311 | 9023 | -9023 | -5053 | 5053 | 10765 | -10765 |
| Shear Pm (SUS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Shear Pl (SUS) | 224 | 224 | -224 | -224 | -298 | -298 | 298 | 298 |
| Shear Q (SUS) | 758 | 758 | 758 | 758 | 758 | 758 | 758 | 758 |
| Pm (SUS) | 383 | 563 | 383 | 563 | 383 | 563 | 383 | 563 |
| Pm+Pl (SUS) | 1696 | 1691 | 2899 | 3056 | 2016 | 2188 | 2087 | 2141 |
| Pm+Pl+Q (Total) | 5172 | 2784 | 11439 | 9681 | 7039 | 3934 | 12781 | 10803 |

**Nozzle Stress Summation Comparison (psi):**

| Type of Stress Int. | Max. S.I. | S.I. Allowable | Result |
|---|---|---|---|
| Pm (SUS) | 563 | 10900 | Passed |
| Pm+Pl (SUS) | 3056 | 16350 | Passed |
| Pm+Pl+Q (TOTAL) | 12781 | 32700 | Passed |

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

**Input, Nozzle Desc: Nozzle B1 6in. From: 90**

| | | | |
|---|---|---|---|
| Pressure for Reinforcement Calculations | P | 150.000 | psig |
| Temperature for Internal Pressure | Temp | 500 | °F |
| Design External Pressure | Pext | 15.00 | psig |
| Temperature for External Pressure | Tempex | 300 | °F |
| | | | |
| Parent Material | | SA-182 F316L | |
| Parent Allowable Stress at Temperature | Sv | 10900.00 | psi |
| Parent Allowable Stress At Ambient | Sva | 16700.00 | psi |
| | | | |
| Outside Diameter of Bolted Blind Flange | D | 34.9400 | in |
| Head Finished (Minimum) Thickness | t | 2.7559 | in |
| Head Internal Corrosion Allowance | c | 0.0315 | in |
| Head External Corrosion Allowance | co | 0.0000 | in |
| | | | |
| Distance from Head Centerline | L1 | 10.0000 | in |
| | | | |
| User Entered Minimum Design Metal Temperature | | 32.00 | °F |

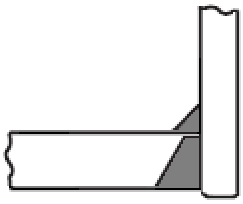
***Type of Element Connected to the Parent : Nozzle***

| | | | |
|---|---|---|---|
| Material | | SA-312 TP316L | |
| Material UNS Number | | S31603 | |
| Material Specification/Type | | Smls. pipe | |
| Allowable Stress at Temperature | Sn | 10900.00 | psi |
| Allowable Stress At Ambient | Sna | 16700.00 | psi |
| | | | |
| Diameter Basis (for tr calc only) | | Outside | |
| Layout Angle | | 180.00 | deg |
| Diameter | | 6.0000 | in. |
| | | | |
| Size and Thickness Basis | | Minimum | |
| Nominal Thickness | | XXS | |
| | | | |
| Flange Type | | Weld Neck Flange | |
| | | | |
| Corrosion Allowance | can | 0.0315 | in |
| Joint Efficiency of Shell Seam at Nozzle | E1 | 1.00 | |
| Joint Efficiency of Nozzle Neck | En | 1.00 | |
| | | | |
| Outside Projection | ho | 3.4724 | in |
| Weld leg size between Nozzle and Pad/Shell | Wo | 0.3543 | in |
| Groove weld depth between Nozzle and Vessel | Wgnv | 1.9409 | in |
| Inside Projection | h | 0.0000 | in |
| Weld leg size, Inside Element to Shell | Wi | 0.0000 | in |
| | | | |
| Flange Class | | 300 | |
| Flange Grade | | GR 2.3 | |

The Pressure Design option was MAWP + static head (to the nozzle).

**Nozzle Sketch (may not represent actual weld type/configuration)**



**Insert/Set-in Nozzle No Pad, no Inside projection**

**Reinforcement CALCULATION, Description: Nozzle B1 6in.**

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```
 Actual Outside Diameter Used in Calculation              6.625  in.
 Actual Thickness Used in Calculation                     0.756  in.
```

*Error and Warning Messages for the Current Nozzle:*

*The nominal thickness selection seems to indicate that carbon steel was selected, but at the same time a stainless steel pipe material was selected.  Please check the input to be sure this is what you intended.*

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Nozzle Wall, trn [Int. Press]

```
  = P*Ro/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = 150.0*3.3125/(10900*1.0+0.4*150.0)
  = 0.0453 in
```

Required Nozzle thickness under External Pressure per UG-28 :  0.0169  in

**UG-40, Limits of Reinforcement : [Internal Pressure]**

```
 Parallel to Vessel Wall (Diameter Limit)            Dl    12.0738  in
 Parallel to Vessel Wall                        Rn+tn+t     6.0369  in
 Normal to Vessel Wall (Thickness Limit), no pad    Tlnp     1.8113  in
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 10900.0/10900.0 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 10900.0/10900.0 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 1.0, 1.0 )
  = 1.000
```

**Results of Nozzle Reinforcement Area Calculations: (in^2)**

```
 AREA AVAILABLE, A1 to A5      |       MAWP|  External|      Mapnc|
```

| | | | | |
|---|---|---|---|---|
| Area Required | Ar | 5.697 | 2.690 | NA |
| Area in Shell | A1 | 3.609 | 11.622 | NA |
| Area in Nozzle Wall | A2 | 2.460 | 2.563 | NA |
| Area in Inward Nozzle | A3 | 0.000 | 0.000 | NA |
| Area in Welds | A41+A42+A43 | 0.126 | 0.126 | NA |
| Area in Element | A5 | 0.000 | 0.000 | NA |
| TOTAL AREA AVAILABLE | Atot | 6.195 | 14.311 | NA |

The MAWP Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
```
  = 0.5 * d * t + t * tn(1-fr1) per UG-39(a)(1)
  = 0.5*5.176*2.2011+2.2011*0.7245(1-1.0)
  = 5.697 in^2
```

**Reinforcement Areas per Figure UG-37.1**

Area Available in Shell [A1]:
```
  = d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
  = 6.898( 1.0 * 2.7244 - 1.0 * 2.201 ) - 2 * 0.725
    ( 1.0 * 2.7244 - 1.0 * 2.2011 ) *( 1 - 1.0 )
  = 3.609 in^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 1.811 )( 0.7245 - 0.0453 )1.0
  = 2.460 in^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  =  0.3543² * 1.0 +( 0.0 )² * 1.0
  = 0.126 in^2
```

**UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]**
```
 Wall Thickness for Internal/External pressures        ta = 0.0768 in
 Wall Thickness per UG16(b),                        tr16b = 0.0940 in
 Wall Thickness, shell/head, internal pressure       trb1 = 2.2326 in
 Wall Thickness               tb1 = max(trb1, tr16b) = 2.2326 in
 Wall Thickness, shell/head, external pressure       trb2 = 0.0464 in
 Wall Thickness               tb2 = max(trb2, tr16b) = 0.0940 in
 Wall Thickness per table UG-45                       tb3 = 0.2764 in
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.276, max( 2.2326, 0.094 ) ]
  = 0.2764 in
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 0.0768, 0.2764 )
  = 0.2764 in
```

Available Nozzle Neck Thickness = 0.7560 in --> OK

*SA-182 F316L, Min Metal Temp without impact per UHA-51: -320 °F*

*SA-312 TP316L, Min Metal Temp without impact per UHA-51:  -320 °F*

Note:
The flange pressure ratio is less than 0.35.  Impact testing is not
required due to low stress per UHA-51(g).

*Design Pressure/Ambient Rating = 150.00/600.00 = 0.250*

Weld Size Calculations, Description: Nozzle B1 6in.

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      0.7245  in
```

**Results Per UW-16.1:**

```
                          Required Thickness    Actual Thickness
 Nozzle Weld             0.2500 = Min per Code 0.2505 = 0.7 * Wo in
```

**Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)**

Weld Load [W]:
```
  = max( 0,  (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0,(5.6965 - 3.6094 + 2 * 0.7245 * 1.0 *
    (1.0 * 2.7244 - 2.2011 ) )10900)
  = 31014.01 lbf
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 2.4603 + 0.0 + 0.1256 - 0.0 * 1.0 ) * 10900
  = 28185.79 lbf
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 2.4603 + 0.0 + 0.1256 +( 3.9477 ) ) * 10900
  = 71215.69 lbf
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 2.4603 + 0.0 + 0.1256 + 0.0 +( 3.9477 ) ) * 10900
  = 71215.69 lbf
```

**Strength of Connection Elements for Failure Path Analysis**

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 6.625 * 0.3543 * 0.49 * 10900
  = 19694. lbf
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 2.9502) *( 0.756 - 0.0315 ) * 0.7 * 10900
  = 51236. lbf
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * Wgnvi * 0.74 * Sng
  = ( 3.1416/2.0 ) * 6.625 *( 1.9409 - 0.0 ) * 0.74 * 10900
  = 162921. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

**Strength of Failure Paths:**

Failure Path [Path 1-1]:
```
  = ( SONW + SNW ) = ( 19694 + 51236 ) = 70930 lbf
```

Failure Path [Path 2-2]:
```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 19694 + 0 + 162921 + 0 ) = 182615 lbf
```

Failure Path [Path 3-3]:
```
  = ( Sonw + Tngw + Sinw )
  = ( 19694 + 162921 + 0 ) = 182615 lbf
```

**Summary of Failure Path Calculations:**
```
 Path 1-1 = 70929   lbf, must exceed W = 31014 lbf    or W1 = 28185 lbf
 Path 2-2 = 182614  lbf, must exceed W = 31014 lbf    or W2 = 71215 lbf
 Path 3-3 = 182614  lbf, must exceed W = 31014 lbf    or W3 = 71215 lbf
```

**Maximum Allowable Pressure for this Nozzle at this Location:**
```
 Converged Maximum Allowable Pressure in the Operating case: 157 psig

 Nozzle is O.K. for the External Pressure: 15 psig
```

The Cut Length for this Nozzle is, Drop + Ho + H + T : 6.2303 in

**Input, Nozzle Desc: Nozzle V 2" From: 90**

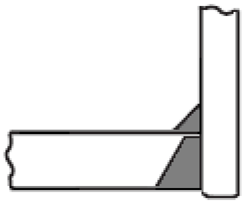
| | | | |
|---|---|---|---|
| Pressure for Reinforcement Calculations | P | 150.000 | psig |
| Temperature for Internal Pressure | Temp | 500 | °F |
| Design External Pressure | Pext | 15.00 | psig |
| Temperature for External Pressure | Tempex | 300 | °F |
| Parent Material | | SA-182 F316L | |
| Parent Allowable Stress at Temperature | Sv | 10900.00 | psi |
| Parent Allowable Stress At Ambient | Sva | 16700.00 | psi |
| Outside Diameter of Bolted Blind Flange | D | 34.9400 | in |
| Head Finished (Minimum) Thickness | t | 2.7559 | in |
| Head Internal Corrosion Allowance | c | 0.0315 | in |
| Head External Corrosion Allowance | co | 0.0000 | in |
| Distance from Head Centerline | L1 | 10.0000 | in |
| User Entered Minimum Design Metal Temperature | | 32.00 | °F |

***Type of Element Connected to the Parent : Nozzle***

| | | | |
|---|---|---|---|
| Material | | SA-182 F316L | |
| Material UNS Number | | S31603 | |
| Material Specification/Type | | Forgings | |
| Allowable Stress at Temperature | Sn | 10900.00 | psi |
| Allowable Stress At Ambient | Sna | 16700.00 | psi |
| Diameter Basis (for tr calc only) | | Inside | |
| Layout Angle | | 305.00 | deg |
| Diameter | | 2.0000 | in. |
| Size and Thickness Basis | | Actual | |
| Actual Thickness | tn | 0.6563 | in |
| Flange Type | | Long Weld Neck | |
| Corrosion Allowance | can | 0.0315 | in |
| Joint Efficiency of Shell Seam at Nozzle | E1 | 1.00 | |
| Joint Efficiency of Nozzle Neck | En | 1.00 | |
| Outside Projection | ho | 6.8898 | in |
| Weld leg size between Nozzle and Pad/Shell | Wo | 0.3543 | in |
| Groove weld depth between Nozzle and Vessel | Wgnv | 2.0000 | in |
| Inside Projection | h | 0.0000 | in |
| Weld leg size, Inside Element to Shell | Wi | 0.0000 | in |
| Flange Class | | 300 | |
| Flange Grade | | GR 2.3 | |

The Pressure Design option was MAWP + static head (to the nozzle).

**Nozzle Sketch (may not represent actual weld type/configuration)**



**Insert/Set-in Nozzle No Pad, no Inside projection**

**Reinforcement CALCULATION, Description: Nozzle V 2"**

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```
 Actual Inside Diameter Used in Calculation              2.000  in.
 Actual Thickness Used in Calculation                    0.656  in.
```

Nozzle input data check completed without errors.

Reqd thk per App. 1 of Nozzle Wall, trn            [Int. Press]

```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 1.031(exp([150.0/(10900.0*1.0]-1)
  = 0.0143 in
```

Required Nozzle thickness under External Pressure per UG-28 :  0.0149  in

**UG-40, Limits of Reinforcement : [Internal Pressure]**

```
 Parallel to Vessel Wall (Diameter Limit)            Dl      8.7614  in
 Parallel to Vessel Wall                        Rn+tn+t      4.3807  in
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp      1.5620  in
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 10900.0/10900.0 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 10900.0/10900.0 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 1.0, 1.0 )
  = 1.000
```

**Results of Nozzle Reinforcement Area Calculations: (in^2)**

| AREA AVAILABLE, A1 to A5 | | MAWP | External | Mapnc |
|---|---|---|---|---|
| Area Required | Ar | 2.270 | 1.072 | NA |
| Area in Shell | A1 | 3.505 | 11.286 | NA |
| Area in Nozzle Wall | A2 | 1.907 | 1.905 | NA |
| Area in Inward Nozzle | A3 | 0.000 | 0.000 | NA |
| Area in Welds | A41+A42+A43 | 0.126 | 0.126 | NA |
| Area in Element | A5 | 0.000 | 0.000 | NA |
| TOTAL AREA AVAILABLE | Atot | 5.538 | 13.317 | NA |

The MAWP Case Governs the Analysis.

```
 Nozzle Angle Used in Area Calculations                  90.00  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:

```
  = 0.5 * d * t + t * tn(1-fr1) per UG-39(a)(1)
  = 0.5*2.063*2.2011+2.2011*0.6248(1-1.0)
  = 2.270 in^2
```

**Reinforcement Areas per Figure UG-37.1**

Area Available in Shell [A1]:

```
  = d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
  = 6.698( 1.0 * 2.7244 - 1.0 * 2.201 ) - 2 * 0.625
    ( 1.0 * 2.7244 - 1.0 * 2.2011 ) *( 1 - 1.0 )
  = 3.505 in^2
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 1.562 )( 0.6248 - 0.0143 )1.0
  = 1.907 in^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  =  0.3543² * 1.0 +( 0.0 )² * 1.0
  = 0.126 in^2
```

**UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]**

```
 Wall Thickness for Internal/External pressures       ta = 0.0464 in
 Wall Thickness per UG16(b),                       tr16b = 0.0940 in
 Wall Thickness, shell/head, internal pressure      trb1 = 2.2326 in
 Wall Thickness                tb1 = max(trb1, tr16b) = 2.2326 in
 Wall Thickness, shell/head, external pressure      trb2 = 0.0464 in
 Wall Thickness                tb2 = max(trb2, tr16b) = 0.0940 in
 Wall Thickness per table UG-45                       tb3 = 0.2205 in
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.22, max( 2.2326, 0.094 ) ]
  = 0.2205 in
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

```
  = max( ta, tb )
  = max( 0.0464, 0.2205 )
  = 0.2205 in
```

Available Nozzle Neck Thickness = 0.6563 in --> OK

*SA-182 F316L, Min Metal Temp without impact per UHA-51: -320 °F*

Note:
The flange pressure ratio is less than 0.35. Impact testing is not required due to low stress per UHA-51(g).

*Design Pressure/Ambient Rating = 150.00/600.00 = 0.250*

Weld Size Calculations, Description: Nozzle V 2"

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      0.6248  in
```

**Results Per UW-16.1:**

```
                         Required Thickness    Actual Thickness
 Nozzle Weld           0.2500 = Min per Code 0.2505 = 0.7 * Wo in
```

**Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)**

Weld Load [W]:
```
  = max( 0,  (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0,(2.2705 - 3.5051 + 2 * 0.6248 * 1.0 *
     (1.0 * 2.7244 - 2.2011 ) )10900)
  = max( 0, -6330.23) lbf
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 1.9072 + 0.0 + 0.1256 - 0.0 * 1.0 ) * 10900
  = 22157.43 lbf
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.9072 + 0.0 + 0.1256 +( 3.4044 ) ) * 10900
  = 59265.86 lbf
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.9072 + 0.0 + 0.1256 + 0.0 +( 3.4044 ) ) * 10900
  = 59265.86 lbf
```

**Strength of Connection Elements for Failure Path Analysis**

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 3.3126 * 0.3543 * 0.49 * 10900
  = 9847. lbf
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 1.3439) *( 0.6563 - 0.0315 ) * 0.7 * 10900
  = 20127. lbf
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * Wgnvi * 0.74 * Sng
  = ( 3.1416/2.0 ) * 3.3126 *( 2.0 - 0.0 ) * 0.74 * 10900
  = 83942. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

**Strength of Failure Paths:**

Failure Path [Path 1-1]:
```
  = ( SONW + SNW ) = ( 9847 + 20127 ) = 29975 lbf
```

Failure Path [Path 2-2]:
```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 9847 + 0 + 83942 + 0 ) = 93789 lbf
```

Failure Path [Path 3-3]:
```
  = ( Sonw + Tngw + Sinw )
```

```
  = ( 9847 + 83942 + 0 ) = 93789 lbf
```

**Summary of Failure Path Calculations:**

```
 Path 1-1 = 29974   lbf, must exceed W = 0 lbf        or W1 = 22157 lbf
 Path 2-2 = 93788   lbf, must exceed W = 0 lbf        or W2 = 59265 lbf
 Path 3-3 = 93788   lbf, must exceed W = 0 lbf        or W3 = 59265 lbf
```

**Maximum Allowable Pressure for this Nozzle at this Location:**

```
 Converged Maximum Allowable Pressure in the Operating case: 213 psig

 Nozzle is O.K. for the External Pressure: 15 psig
```

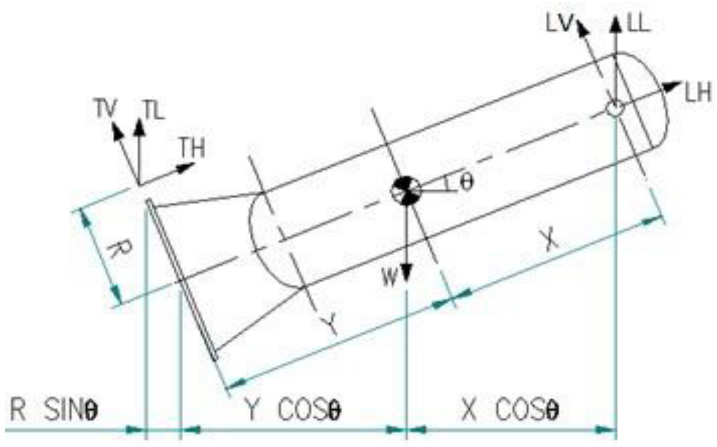
The Cut Length for this Nozzle is, Drop + Ho + H + T : 9.6477 in

| ANUP LALBHAI GROUP | | The Anup Engineering Limited | CALC PAGE NO. | 223 |
|---|---|---|---|---|
| | | | PREPD | KRK |
| Job No : | V-1264 | Adsorbent Chamber | CHKD | DMP |
| | | | APPD | BMP |
| Item No.: | 18-D-272 | Client : Airproducts | Revision No. | 6 |

## DESIGN CALCULATION FOR TAILING LUG & STIFFENING BEAM

**DESIGN OF TAIL BEAMS & LUGS AS PER " PRESSURE VESSEL DESIGN MANUAL " BY DENNIS R MOSS. (3rd ED) PAGE NO. 400 TO 415**

| | | | | |
|---|---|---|---|---|
| Center of gravity of vessel in erection condition (from C.L of Tailing Lug). | Y | = | 4942.65 | mm |
| Distance between Lifting Lug and Tailing Lug C.L | | | 7434 | mm |




CALCULATION OF BASE BLOCK UNDER ERECTION CONDITION

**Calculation Of Lifting Forces**

| | | | | | |
|---|---|---|---|---|---|
| Total Erection Weight | W | 6632 | kg | Quantity of lug | 1 |
| Wt.Acting On Each Lug | We | 6632 | kg | W=We x F | 8953 |
| Dynamic Load factor | F | 1.35 | | | |
| Dimensions | X | 2491.35 | mm | Z= X +Y | 7434 |
| | Y | 4942.65 | mm | | |
| | R | 582 | mm | | |

| Degree | LL | LV | LH | TL | TV | TH |
|---|---|---|---|---|---|---|
| 0 | 5952.72 | 5952.72 | 0.00 | 3000.48 | 3000.48 | 0.00 |
| 15 | 6014.37 | 5809.44 | 1556.63 | 2938.83 | 2838.69 | 760.62 |
| 30 | 6082.48 | 5267.58 | 3041.24 | 2870.72 | 2486.12 | 1435.36 |
| 45 | 6170.57 | 4363.25 | 4363.25 | 2782.63 | 1967.62 | 1967.62 |
| 60 | 6311.00 | 3155.50 | 5465.49 | 2642.20 | 1321.10 | 2288.21 |
| 75 | 6631.17 | 1716.27 | 6405.22 | 2322.03 | 600.99 | 2242.91 |
| 90 | 8953.20 | 0.00 | 8953.20 | 0.00 | 0.00 | 0.00 |
| Max Value | 8953.2 | 5952.72 | 8953.2 | 3000.48 | 3000.48 | 2288.21 |

Where,

$LL = \dfrac{W(Y\cos\theta + R\sin\theta)}{(X+Y)\cos\theta + R\sin\theta}$ **PAGE NO. 402**

$LV = LL\cos\theta$ **PAGE NO. 402**

$LH = LL\sin\theta$ **PAGE NO. 402**

$TL = \dfrac{W(X\cos\theta)}{(X+Y)\cos\theta + R\sin\theta}$ **PAGE NO. 402**

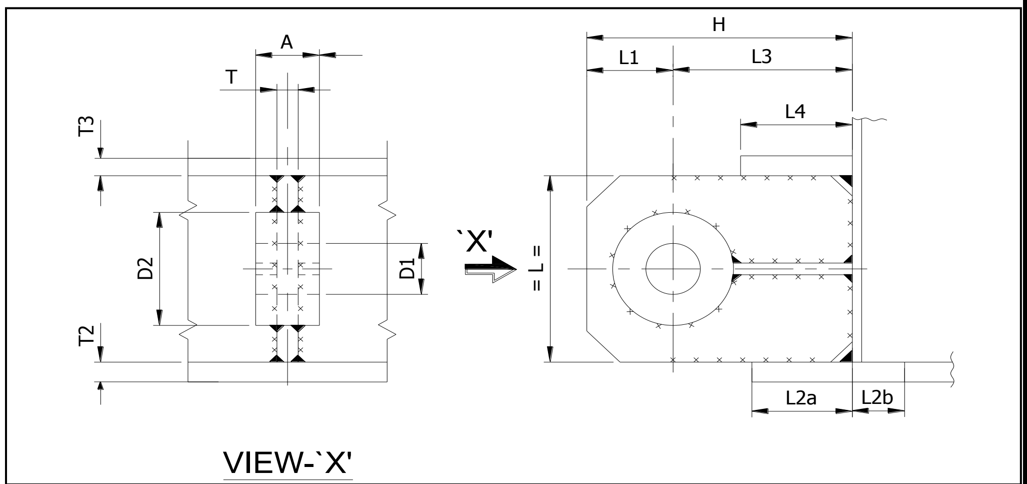
$TV = TL\cos\theta$ **PAGE NO. 402**

$TH = TL\sin\theta$ **PAGE NO. 402**

CALCULATION OF TAILING LUG

| | | | | | |
|---|---|---|---|---|---|
| Material of Construction | = | | | SA-516 Gr 70 | |
| Allowable Stress | = | Sa | = | 14.00 | kg/mm2 |
| Yield Stress | = | fy | = | 26.00 | kg/mm2 |
| Allowable Shear Stress | = | 0.40fy | = | 10.40 | kg/mm2 |
| Vertical Force | = | TV | = | 3000.48 | kg |
| Horizontal Force | = | TH | = | 2288.21 | kg |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| L | = | 208 | mm | L3 | = | 200 | mm |
| D2 | = | 115 | mm | L1=(H-L3) | = | 100 | mm |
| T | = | 14 | mm | D1 | = | 33 | mm |
| H | = | 300 | mm | A | = | 75 | mm |




**1) Shear Stress in lug due to vertical force**

$S1 = \dfrac{TV}{(L/2 - D1/2) \times T} = 2.45$ kg/mm2

Allowable Shear Stress = 0.40 x fy = 10.40 kg/mm2

HENCE ACTUAL IS LESS THAN ALLOWABLE ,DESIGN IS SAFE

**2) Shear Stress In Lug Due to Horizontal Force**

$S2 = \dfrac{TH}{(L1 - D1/2) \times T} = 1.96$ kg/mm2

Allowable Shear Stress = 0.40 x fy = 10.40 kg/mm2

HENCE ACTUAL IS LESS THAN ALLOWABLE,DESIGN IS SAFE

**3) TENSILE STRESS IN LUG DUE TO VERTICAL FORCE**

$S3 = \dfrac{TV}{(L-D1) \times T} = 1.22$ kg/mm2

Allowable tensile Stress = Sa = 14.00 kg/mm2

HENCE ACTUAL IS LESS THAN ALLOWABLE,DESIGN IS SAFE

**4) TENSILE STRESS IN LUG DUE TO HORIZONTAL FORCES**

$S4 = \dfrac{TH}{(H-D1) \times T} = 0.61$ kg/mm2

Allowable tensile Stress = Sa = 14.00 kg/mm2

HENCE ACTUAL IS LESS THAN ALLOWABLE, DESIGN IS SAFE

**5) BENDING STRESS IN LUG**

$S5 = \dfrac{TH \times L3}{(1/6) \times T \times L^2} = 4.53$ kg/mm2

**PAGE NO. 402** Allowable Bending Stress =0.66 x fy = 17.16 kg/mm2

HENCE ACTUAL IS LESS THAN ALLOWABLE,DESIGN IS SAFE

**6) CALCULATION OF PIN SIZE OF SHEAR**

$TV = 2 \times \pi/4 \times d^2 \times 0.45\ fy$

Hence $d2 = \dfrac{TV \times 4}{2x\ \pi \times 0.45fy} = 183.68\ mm^2$

| | | | |
|---|---|---|---|
| Hence d | = | 14 | mm |
| Taken Pin Diameter | = | 112 | mm |
| taken Pin Length | = | 75 | mm |

**7) Bearing Stress =**

$\dfrac{TV}{\text{Pin Dia x Pin Length}} = 0.36$ kg/mm2

Allowable Bearing Stress =0.80 x fy = 20.80 kg/mm2

HENCE ACTUAL STRESS IS LESS THAN ALLOWABLE,DESIGN IS SAFE

**8) Shear Force In Weld Ws=**

$\dfrac{TV}{2 \times (L+L4)} = 3.68$ kg/mm2

Fillet Weld Size, $W = \dfrac{Ws}{0.55 \times Sa} = 0.48$ mm

Provided Weld Size = 8 mm

**9) Sectional properties of base block.**

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Skirt Thk | t1 | = | 10 | mm | Di | = | 742 | mm | L2a | = | 70 | mm | L2a + L2b | = | 130.5 | mm |
| Skirt ID | Di | = | 742 | mm | t1 | = | 10 | mm | L2b | = | 60.5 | mm | Rm=(Di+t1)/2 | = | 376 | mm |
| Skirt OD | | = | 762 | mm | T2 | = | 14 | mm | L4 | = | 200 | mm | | | | |
| Base Ring ID | | = | 641 | mm | T3 | = | 14 | mm | L | = | 208 | mm | | | | |
| Base Ring OD | | = | 1023 | mm | | | | | | | | | | | | |

## DESIGN CALCULATION FOR TAILING LUG & STIFFENING BEAM

Effective Length of Skirt, Le = 0.78 x sqrt (Rm x t1) = 47.83 mm

HENCE Le<L, SO SECTION 3 IS NOT CONSIDERD AS STIFFNING SECTION

A1 = t1 x Le = 478.29 $mm^2$

A2 = t2 x (L2a + L2b) = 1827 $mm^2$

A = A1+A2 = 2305.29 $mm^2$

h1 = 75 mm

h2 = 65.25 mm

c = $\frac{(A1x\ h1)+(A2x\ h2)}{A}$ 67.273 mm

R = (Base pl.OD/2)-C = 444.227 mm

Moment Of Inertia Of Area

I1 = $(Le \times t1^3/12) + A1(h1\text{-}C)2$ = 32543.53 $mm^4$

I2 = $\frac{t2\ (L2a+L2b)^3 + A2(h2\text{-}C)^2}{12}$ = 2600332 $mm^4$

Total M.I = I1+I2 = 2632875 $mm^4$

Min Section Modulus, Z =I/C = 39137.25 $mm^3$

**Stresses in Base Block due to TV**

$\pi$ = 3.14159

TV = 3000.4782 kg

R = 444.227 mm

W = TV/(2 x π x R) 0.8205

KO = 1+ 0.5 cos x - 3.14 sin x + x sin *x*

M = W x $R^2$ x KO

| x(Deg) | KO | M (KG-mm) |
|---|---|---|
| 0 | 1.500 | 416893.59 |
| 15 | 0.738 | 205005.53 |
| 30 | 0.124 | 34467.89 |
| 45 | -0.313 | -86860.14 |
| 60 | -0.564 | -156695.80 |
| 75 | -0.641 | -178080.41 |
| 90 | -0.571 | -158640.52 |
| 120 | -0.157 | -43606.77 |
| 150 | 0.305 | 84820.65 |
| 180 | 0.500 | 138964.53 |

M max = 416893.59 kg-mm

Modulus Of Elasticity, E = 20510 kg/mm2

Total Moment OF Inertia I = 2632875.191 $mm^4$

Deflection, Dx = $\frac{(-)\ 0.4292 \times W \times R^4}{E \times I}$ = -0.748 mm

Z = 39137.25 $mm^4$

Stress In The Base Block = $\frac{Mmax\ at\ 0}{Z}$ = 10.65 kg/mm2

Allowable Stress 0.9 fy = 23.4 kg/mm2

Actual Stress Is Less Than Allowable. Design is Safe

**THE ANUP ENGINEERING LTD.**
Odhav Road,
Ahmedabad - 382 415

## HYDRO-TEST CALCULATION FOR HORIZONTAL CONDITION

| | | | |
|---|---|---|---|
| Description | : H2S RECOVERY UNIT | Calculation Page No. : | 225 |
| AEL WO No. | : V-1264 | Date : | 21-12-2022 |
| Document No. | : | Rev No. : | 6 |
| Item No. | : 18-D-272 | | |

| | | | | | |
|---|---|---|---|---|---|
| Hydrostatic Test Pressure in Vertical Position | | $P_V$ | = | 21.000 | kgf/cm² |
| Static Head in Vertical Position | | $H_1$ | = | 5411.00 | mm |
| Static Head in Horizontal Position (i.e. Inside Diameter of Equipment) | | $H_2$ | = | 742.95 | mm |
| Effective Static Head in Horizontal Positio | $(H = H_1 - H_2)$ | H | = | 4668.05 | mm |
| | | | = | 4.668 | m |
| Acceleration due to gravity | | g | = | 9.8067 | $m/s^2$ |
| Density of Water | | ρ | = | 1000.00 | $kg/m^3$ |

**Additional Static Head Pressure in Horizontal Position** P

= ρgH
= 1000 x 9.80665 x 4.66805
= 45777.933 $N/m^2$ = Pa
= 45.778 kPa
= 0.47 kgf/cm²

**Effective Static Head Pressure in Horizontal Position** $P_H$

= $P_V + P$
= 21 + 0.47
= 21.47 kgf/cm²

Roundup Value = 22.00 kgf/cm²

= 312.91 psig

# DESIGN OF CHANNEL COVER DAVIT

| | | |
|---|---|---|
| MDC NO : AEL/MDC/V-1264 | Client : Airproducts | Page : 226 |
| JOB NO : V-1264 | Consultant : Consultan | Rev. : 6 |
| Made By : The Anup Engineering Limited | Eqpt. No. : 18-D-272 | Date : 21-12-2022 |

**DESIGN OF COLUMN DAVIT AS PER " PRESSURE VESSEL DESIGN MANUAL " BY DENNIS R MOSS.**

| | | | |
|---|---|---|---|
| **Circumferencial moment at guide & support**<br>= Fr X L4 | Mo | [ lb-inch ] | 9,175.670 |
| **Axial load on Davit mast**<br>= fv + Wd | P | [ lb ] | 1,659.060 |
| **Longitudinal Moment at support**<br>= P X L4 | Mx | [ lb-inch ] | 7,315.810 |
| AXIAL STRESS (MAST) = P / A | fa | [ lb/ft^2 ] | 89,482.125 |
| BENDING STRESS (MAST) = M1 / Z | fb | [ lb/ft^2 ] | 14,54,081.976 |

## COMBINED STRESSES (MAST)

| | | | |
|---|---|---|---|
| Material of construction for mast | - | [ - ] | SA-106 Gr. B |
| Yield Stress of the Davit material | Sy | [ lb/ft^2 ] | 50,12,301.647 |
| Allowable axial stress in the mast=0.6XSy | Fa | [ lb/ft^2 ] | 30,07,380.980 |
| Allowable bending stress in the mast=0.66XSy | Fb | [ lb/ft^2 ] | 33,08,118.678 |
| Ratio fa / Fa | - | [ - ] | 0.030 |
| Ratio fb / Fb | - | [ - ] | 0.440 |
| fa / Fa + fb / Fb | - | [ - ] | 0.469 |

As fa/Fa+fb/Fb <=1, the design is adequate.

## BENDING STRESS (BOOM)

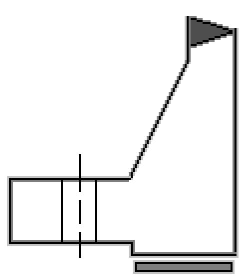
| | | | |
|---|---|---|---|
| fb = fv X L5 / Z | fb | [ lb/ft^2 ] | 10,68,974.372 |
| Allowable bending stress in the Boost=0.66XSy | Fb | [ lb/ft^2 ] | 33,08,118.678 |

**As actual stress < allowable, the design is adequate**

**Flange Input Data Values** **Description: FLANGE :**

Nozzle D 2" WNRFFlange

| | | | |
|---|---|---|---|
| Description of Flange Geometry (Type) | | Integral Weld Neck | |
| Design Pressure | P | 105.00 | psig |
| Design Temperature | | 500 | °F |
| Internal Corrosion Allowance | ci | 0.0315 | in |
| External Corrosion Allowance | ce | 0.0000 | in |
| Use Corrosion Allowance in Thickness Calcs. | | No | |
| | | | |
| Flange Inside Diameter | B | 2.070 | in |
| Flange Outside Diameter | A | 6.500 | in |
| Flange Thickness | t | 0.8800 | in |
| Thickness of Hub at Small End | go | 0.2063 | in |
| Thickness of Hub at Large End | g1 | 0.6713 | in |
| Length of Hub | h | 1.8700 | in |
| | | | |
| Flange Material | | SA-182 F316L | |
| Flange Material UNS number | | S31603 | |
| Flange Allowable Stress At Temperature | Sfo | 10900.00 | psi |
| Flange Allowable Stress At Ambient | Sfa | 16700.00 | psi |
| | | | |
| Bolt Material | | SA-193 B7M | |
| Bolt Allowable Stress At Temperature | Sb | 20000.00 | psi |
| Bolt Allowable Stress At Ambient | Sa | 20000.00 | psi |
| | | | |
| Diameter of Bolt Circle | C | 5.000 | in |
| Nominal Bolt Diameter | a | 0.6250 | in |
| Type of Threads | | TEMA Thread Series | |
| Number of Bolts | | 8 | |
| | | | |
| Flange Face Outside Diameter | Fod | 3.620 | in |
| Flange Face Inside Diameter | Fid | 2.070 | in |
| Flange Facing Sketch | | 1, Code Sketch 1a | |
| | | | |
| Gasket Outside Diameter | Go | 3.380 | in |
| Gasket Inside Diameter | Gi | 2.750 | in |
| Gasket Factor | m | 0.0000 | |
| Gasket Design Seating Stress | y | 0.00 | psi |
| | | | |
| Column for Gasket Seating | | 2, Code Column II | |
| Gasket Thickness | tg | 0.1250 | in |
| | | | |
| Flange Class | | 300 | |
| Flange Grade | | GR 2.3 | |



**ASME Code, Section VIII Division 1, 2019**

Hub Small End Required Thickness due to Internal Pressure:
= (P*(D/2+Ca))/(S*E-0.6*P) per UG-27 (c)(1)
= (105*(2.07/2+0.031))/(10900*1-0.6*105)+Ca
= 0.0418 in

Hub Small End Hub MAWP:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (10900 * 1 * 0.17 )/(1.07 + 0.6 * 0.17 )
  = 1626.590 psig

 Corroded Flange ID,      Bcor = B+2*Fcor                2.133  in
 Corroded Large Hub,     g1Cor = g1-ci                   0.640  in
 Corroded Small Hub,     g0Cor = go-ci                   0.175  in
 Code R Dimension,           R = ((C-Bcor)/2)-g1cor      0.794  in

 Gasket Contact Width,       N = (Go - Gi) / 2           0.315  in
 Basic Gasket Width,        bo = N / 2                   0.158  in
 Effective Gasket Width,     b = bo                      0.158  in
 Gasket Reaction Diameter,   G = Go (Self-Energizing)    3.380  in
```

**Basic Flange and Bolt Loads:**

Hydrostatic End Load due to Pressure [H]:
```
  = 0.785 * G² * Peq
  = 0.79 * 3.38² * 105
  = 942.134 lbf
```
Contact Load on Gasket Surfaces [Hp]:
```
  = 2 * b * Pi * G * m * P
  = 2 * 0.16 * 3.14 * 3.38 * 0 * 105
  = 0.000 lbf
```
Hydrostatic End Load at Flange ID [Hd]:
```
  = Pi * Bcor² * P  / 4
  = 3.14 * 2.13² *105/4
  = 375.196 lbf
```
Pressure Force on Flange Face [Ht]:
```
  = H - Hd
  = 942 - 375
  = 566.938 lbf
```
Operating Bolt Load [Wm1]:
```
  = max( H + Hp + H'p, 0 )
  = max( 942 + 0 + 0, 0 )
  = 942.134 lbf
```
Gasket Seating Bolt Load [Wm2]:
```
  = y * b * Pi * G  + yPart * bPart * lp
  = 0*0.16*3.141*3.38+0*0*0
  = 0.000 lbf
```
Required Bolt Area [Am]:
```
  = Maximum of Wm1/Sb, Wm2/Sa
  = Maximum of 942/20000, 0/20000
  = 0.047 in^2
```

Flange Design Bolt Load, Gasket Seating [W]:
```
  = Sa * ( Am + Ab ) / 2
  = 20000 * ( 0.047 + 1.62 )/2
  = 16631.07 lbf
```
Gasket Load for the Operating Condition [HG]:
```
  = Wm1 - H
  = 942 - 942
  = 0.00 lbf
```

**Moment Arm Calculations:**

Distance to Gasket Load Reaction [hg]:
```
  = (C - G ) / 2
  = ( 5  - 3.38 )/2
  = 0.8100 in
```
Distance to Face Pressure Reaction [ht]:
```
  = ( R + g1 + hg ) / 2
  = ( 0.79 + 0.64 + 0.81 )/2
  = 1.1218 in
```

Distance to End Pressure Reaction [hd]:

```
= R + ( g1 / 2 )
= 0.79 + ( 0.64/2.0 )
= 1.1136 in
```

**Summary of Moments for Internal Pressure: (ft-lbf)**

| Loading | Force | Distance | Bolt Corr | Moment |
|---|---|---|---|---|
| End Pressure, Md | 375. | 1.1136 | 1.0000 | 35. |
| Face Pressure, Mt | 567. | 1.1218 | 1.0000 | 53. |
| Gasket Load, Mg | 0. | 0.8100 | 1.0000 | 0. |
| Gasket Seating, Matm | 16631. | 0.8100 | 1.0000 | 1123. |

```
Total Moment for Operation,      Mop                               88. ft-lbf
Total Moment for Gasket seating, Matm                            1123. ft-lbf
```

*You chose not to perform Stress Calculations on this Standard Flange.*
*The pressure rating of the flange will be used to check code compliance.*

```
Estimated Finished Weight of Flange at given Thk.       9.5 lbm
Estimated Unfinished Weight of Forging at given Thk    23.8 lbm
```

Note:
The flange pressure ratio is less than 0.35. Impact testing is not required due to low stress per UHA-51(g).

*Design Pressure/Ambient Rating = 105.00/600.00 = 0.175*

**Internal Pressure Results Summary:**

**Element Thickness, Pressure, Diameter and Allowable Stress :**

| From | To | Int. Press + Liq. Hd psig | Nominal Thickness in | Total Corr Allowance in | Element Diameter in | Allowable Stress(SE) psi |
|---|---|---|---|---|---|---|
| Nozzle D 2" | Pipe | 105 | 0.2063 | 0.031496 | 1.93898 | 10900 |
| Nozzle D 2" | WNRF | 105 | 0.958 | 0.031496 | 2.07 | 10900 |

**Element Required Thickness and MAWP :**

| From | To | Design Pressure psig | M.A.W.P. Corroded psig | M.A.P. New & Cold psig | Minimum Thickness in | Required Thickness in |
|---|---|---|---|---|---|---|
| Nozzle D 2" | Pipe | 105 | 1723 | 3151 | 0.2063 | 0.093996 |
| Nozzle D 2" | WNRF | 105 | 395 | 600 | 0.88 | No Calc |
| Minimum | | | 395 | 600 | | |

MAWP: 395 psig, limited by: Nozzle D 2" WNRFFlange.

Elements Suitable for Design Internal Pressure.

**Internal Pressure Calculation Results:**

**ASME Code, Section VIII Division 1, 2019**

**Cylindrical Shell From 10 To 20 SA-312 TP316L at 500 °F**

Nozzle D 2" Pipe
Material UNS Number: S31603

Required Thickness due to Internal Pressure [tr]:
```
  = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
  = (105*1)/(10900*1-0.6*105)
  = 0.0097 + 0.0315 = 0.0412 in
```

*Note: The thickness required was less than the Code Minimum, therefore the Code Minimum value of 0.0625 in per UG-16 will be used.*

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (10900*1*0.17)/(1+0.6*0.17)
  = 1723 psig
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (16700*1*0.21)/(0.97+0.6*0.21)
  = 3151 psig
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(R+0.6*t))/(E*t)
  = (105*(1+0.6*0.17))/(1*0.17)
  = 664.267 psi
```

*SA-312 TP316L, Min Metal Temp without impact per UHA-51: -320 °F*

**Tabular Results**

Results were generated with the finite element program FE/Pipe®. Stress results are post-processed in accordance with the rules specified in ASME Section III and ASME Section VIII, Division 2.

Analysis Time Stamp: Sat Oct 23 14:10:05 2021.



---

```
Model Notes
Model Notes

  Input Echo:

  Description:

         V-1264
         Nozzle A 3"

  Model Type                    : Cylindrical Shell

  Parent Geometry
         Parent Outside Diam.   :      30.030 in.
         Thickness              :       0.394 in.

  Parent Properties:
         Cold Allowable         :     16700.0 psi
         Hot  Allowable         :     14800.0 psi
         Material DB # 1071122.
         Ultimate Tensile (Amb) :     70000.0 psi
         Yield Strength (Amb)   :     25000.0 psi
         Yield Strength (Hot)   :     16400.0 psi
         Elastic Modulus (Amb)  :  28300000.0 psi
         Poissons Ratio         :       0.300
         Expansion Coefficient  :  0.9700E-05 in./in./deg.
         Weight Density         :  0.0000E+00 lb./cu.in.(NOT USED)

  Nozzle Geometry
         Nozzle Outside Diam.   :       3.500 in.
         Thickness              :       0.438 in.
         Length                 :       5.590 in.
         Nozzle Tilt Angle      :       0.000 deg.
         Distance from Top      :      29.520 in.
         Distance from Bottom   :      30.480 in.

  Nozzle Properties
         Cold Allowable         :     16700.0 psi
         Hot  Allowable         :     14800.0 psi
         Material DB # 1071622.
         Ultimate Tensile (Amb) :     70000.0 psi
         Yield Strength (Amb)   :     25000.0 psi
         Yield Strength (Hot)   :     16400.0 psi
         Elastic Modulus (Amb)  :  28300000.0 psi
         Poissons Ratio         :       0.300
         Expansion Coefficient  :  0.9700E-05 in./in./deg.
         Weight Density         :  0.0000E+00 lb./cu.in. (NOT USED)
```

```
Design Operating Cycles      :       7000.
Ambient Temperature (Deg.)   :       70.00

Uniform thermal expansion produces no stress in this geometry.
Any thermal loads will come through operating forces and
moments applied through the nozzle.

Nozzle Inside  Temperature   :      500.00 deg.
Nozzle Outside Temperature   :      500.00 deg.
Vessel Inside  Temperature   :      500.00 deg.
Vessel Outside Temperature   :      500.00 deg.

Nozzle Pressure              :       105.0 psi
Vessel Pressure              :       105.0 psi

Operating Pressure           :       105.0 psi

The operating pressure is used for secondary and peak stress
cases. The design pressure is used for primary cases. The ratio
of the operating/design pressure = 1.000

User Defined Load Input Echo for the ATTACHMENT:
Loads are given at the End of Nozzle
Loads are defined in Local Coordinates

Forces( lb.)  Moments (ft-lb)

Load Case        FX         FY         FZ         MX         MY         MZ
---------------------------------------------------------------------------
   OPER:      810.0      810.0      610.0      600.0      400.0      520.0


FEA Model Loads:
These are the actual Attachment loads applied to
the FEA model.
These are the User Defined Loads translated to the
end of the nozzle and reported in global coordinates.

Forces( lb.)  Moments (ft-lb)

Load Case        FX         FY         FZ         MX         MY         MZ
---------------------------------------------------------------------------
   OPER:      810.0      810.0      610.0      600.0      400.0      520.0

The "top" or "positive" end of this model is "free" in
the axial and translational directions.

Stresses ARE nodally AVERAGED.

No weld dimensions have been given for the nozzle
connection to the shell. This will produce conservative
results for external loads and may tend to produce more
realistic inside surface pressure stresses.

Vessel Centerline  Vector     :  0.000   1.000   0.000
Nozzle Orientation Vector     :  1.000   0.000   0.000
```

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---

```
Load Case Report
FEPipe Version 15.0          Jobname: NOZZLE                 $P
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Load Case Report                                      $X

Inner and outer element temperatures are the same
throughout the model.  No thermal ratcheting
calculations will be performed.

THE   7  LOAD CASES ANALYZED ARE:

  1   SUSTAINED      (Pr Only)

      Sustained case run to satisfy local primary
      membrane and bending stress limits.
```

```
    /-------- Loads in Case   1
      Pressure Case    1

2   OPERATING      (Fatigue Calc Performed)

    Case run to compute the operating stresses used in
    secondary, peak and range calculations as needed.

    /-------- Loads in Case   2
      Pressure Case    1
      Loads from (Operating)

3   Program Generated -- Force Only

    Case run to compute sif's and flexibilities.
    /-------- Loads in Case   3
      Loads from (Axial)

4   Program Generated -- Force Only

    Case run to compute sif's and flexibilities.
    /-------- Loads in Case   4
      Loads from (Inplane)

5   Program Generated -- Force Only

    Case run to compute sif's and flexibilities.
    /-------- Loads in Case   5
      Loads from (Outplane)

6   Program Generated -- Force Only

    Case run to compute sif's and flexibilities.
    /-------- Loads in Case   6
      Loads from (Torsion)

7   Program Generated -- Force Only

    Case run to compute sif's and flexibilities.
    /-------- Loads in Case   7
      Pressure Case    1
```

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---

```
Solution Data
FEPipe Version 15.0          Jobname: NOZZLE              $P
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Solution Data


Maximum Solution Row Size =    1278
Number of Nodes           =    3318
Number of Elements        =    1098
Number of Solution Cases  =       7

Summation of Loads per Case
```

| Case # | FX | FY | FZ |
|---|---|---|---|
| 1 | -205. | 72438. | 0. |
| 2 | 605. | 73248. | 610. |
| 3 | 84267. | 0. | 0. |
| 4 | 0. | 0. | 0. |
| 5 | 0. | 0. | 0. |
| 6 | 0. | 0. | 0. |
| 7 | -205. | 72438. | 0. |

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---

```
ASME Code Stress Output Plots
FEPipe Version 15.0          Jobname: NOZZLE                 $P
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```

```
ASME Code Stress Output Plots                             $X
```

    1) Pl < SPL (SUS,Membrane) Case 1

    2) Qb < SPS (SUS,Bending) Case 1

    3) Pl+Pb+Q < SPS (SUS,Inside) Case 1

    4) Pl+Pb+Q < SPS (SUS,Outside) Case 1

    5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 1

    6) Pl+Pb+Q < SPS (OPE,Inside) Case 2

    7) Pl+Pb+Q < SPS (OPE,Outside) Case 2

    8) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 2

    9) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 2

    10) Membrane < User (OPE,Membrane) Case 2

    11) Bending < User (OPE,Bending) Case 2

    12) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 3

    13) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 4

    14) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 5

    15) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 6

    16) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 7

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---

```
Stress Results - Notes
FEPipe Version 15.0          Jobname: NOZZLE                 $P
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```

```
Stress Results - Notes


- Results  in  this  analysis  were  generated using the finite
  element solution method.

- Using 2019 ASME Section VIII Division 2

- Use Polished Bar fatigue curve.

- Ratio between Operating and Design Pressure =   1.000000
  Range cases use operating pressure. Primary cases
  use design pressure.

- Assume free end displacements of attached pipe
  (e.g. thermal loads) are secondary loads.

- Primary bending stresses at discontinuities
  are treated like secondary stresses. (Pb=0)

- Use Equivalent Stress (Von Mises).

- TRIAXIAL Stress Guidelines:
  S1+S2+S3 evaluation omitted from operating stress.
  Include S1+S2+S3 evaluation in primary case evaluation.
  Bending stress NOT included for all S1+S2+S3 calculations.
```

- Use local tensor values for averaged and not averaged stresses.

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---

```
ASME Overstressed Areas
FEPipe Version 15.0          Jobname: NOZZLE              $P
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```

```
ASME Overstressed Areas                                $X
```

```
             *** NO OVERSTRESSED NODES IN THIS MODEL ***
```

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---

```
Highest Primary Stress Ratios
FEPipe Version 15.0          Jobname: NOZZLE              $P
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```

```
Highest Primary Stress Ratios                          $X


Header Next to Nozzle Weld

       Pl            SPL     Primary Membrane Load Case 1
    5,501         22,200     Min Prin. Stress = -514. (24% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 1
            24%


Branch Next to Header Weld

       Pl            SPL     Primary Membrane Load Case 1
    4,734         22,200     Min Prin. Stress = -1187. (63% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 1
            21%


Branch Transition

       Pl            SPL     Primary Membrane Load Case 1
      545         22,200     Min Prin. Stress = -574. (22% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 1
             2%


Header away from Junction

       Pl            SPL     Primary Membrane Load Case 1
    4,028         22,200     Min Prin. Stress = -11. ( 0% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 1
            18%


Branch away from Junction

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 1
    1,404         47,250     Min Prin. Stress = -882. (43% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             4) Pl+Pb+Q < SPS (SUS,Outside) Case 1
             2%
```

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```
Highest Secondary Stress Ratios
FEPipe Version 15.0           Jobname: NOZZLE                 $P
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Highest Secondary Stress Ratios                        $X


Header Next to Nozzle Weld

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 2
   27,780         47,250     Min Prin. Stress = -5081. (72% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             7) Pl+Pb+Q < SPS (OPE,Outside) Case 2
            58%


Branch Next to Header Weld

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 2
   19,788         47,250     Min Prin. Stress = -7877. (86% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             6) Pl+Pb+Q < SPS (OPE,Inside) Case 2
            41%


Branch Transition

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 2
    4,270         47,250     Min Prin. Stress = -3491. (84% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             7) Pl+Pb+Q < SPS (OPE,Outside) Case 2
             9%


Header away from Junction

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 2
   12,736         47,250     Min Prin. Stress = -2107. (21% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             7) Pl+Pb+Q < SPS (OPE,Outside) Case 2
            26%


Branch away from Junction

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 2
    4,442         47,250     Min Prin. Stress = -3085. (97% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             6) Pl+Pb+Q < SPS (OPE,Inside) Case 2
             9%
```

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```
Highest Fatigue Stress Ratios
FEPipe Version 15.0           Jobname: NOZZLE                 $P
Released Jan. 2021             2:10pm   OCT 23,2021



Highest Fatigue Stress Ratios                          $X


Header Next to Nozzle Weld

Pl+Pb+Q+F     Damage Ratio   Primary+Secondary+Peak (Outer) Load Case 2
   18,752      0.008 Life    Stress Concentration Factor = 1.350
      psi      0.317 Stress  Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 861,644.
Allowable                    "B31" Fatigue Stress Allowable = 39375.0
```

```
   59,224                   Markl Fatigue Stress Allowable = 47828.5
      psi                   WRC 474 Mean Cycles to Failure = 786,456.
                            WRC 474 99% Probability Cycles = 182,704.
      31%                   WRC 474 95% Probability Cycles = 253,666.
                            BS5500 Allowed Cycles(Curve F) = 110,560.
                            Membrane-to-Bending Ratio = 0.415
                            Bending-to-PL+PB+Q Ratio = 0.707
                            Plot Reference:
                            9) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 2


Branch Next to Header Weld

Pl+Pb+Q+F    Damage Ratio   Primary+Secondary+Peak (Inner) Load Case 2
   13,357     0.000 Life    Stress Concentration Factor = 1.350
      psi     0.226 Stress  Strain Concentration Factor = 1.000
                            Cycles Allowed for this Stress = 1.0000E11
Allowable                   "B31" Fatigue Stress Allowable = 39375.0
   59,224                   Markl Fatigue Stress Allowable = 47828.5
      psi                   WRC 474 Mean Cycles to Failure = 2,094,036.
                            WRC 474 99% Probability Cycles = 486,473.
      22%                   WRC 474 95% Probability Cycles = 675,416.
                            BS5500 Allowed Cycles(Curve F) = 305,904.
                            Membrane-to-Bending Ratio = 0.667
                            Bending-to-PL+PB+Q Ratio = 0.600
                            Plot Reference:
                            8) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 2


Branch Transition

Pl+Pb+Q+F    Damage Ratio   Primary+Secondary+Peak (Outer) Load Case 2
    2,135     0.000 Life    Stress Concentration Factor = 1.000
      psi     0.036 Stress  Strain Concentration Factor = 1.000
                            Cycles Allowed for this Stress = 1.0000E11
Allowable                   "B31" Fatigue Stress Allowable = 39375.0
   59,224                   Markl Fatigue Stress Allowable = 47828.5
      psi                   WRC 474 Mean Cycles to Failure = 2.2386E8
                            WRC 474 99% Probability Cycles = 52,005,048.
       3%                   WRC 474 95% Probability Cycles = 72,203,488.
                            BS5500 Allowed Cycles(Curve F) = 64,868,344.
                            Membrane-to-Bending Ratio = 2.387
                            Bending-to-PL+PB+Q Ratio = 0.295
                            Plot Reference:
                            9) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 2


Header away from Junction

Pl+Pb+Q+F    Damage Ratio   Primary+Secondary+Peak (Outer) Load Case 2
    6,368     0.000 Life    Stress Concentration Factor = 1.000
      psi     0.108 Stress  Strain Concentration Factor = 1.000
                            Cycles Allowed for this Stress = 1.0000E11
Allowable                   "B31" Fatigue Stress Allowable = 39375.0
   59,224                   Markl Fatigue Stress Allowable = 47828.5
      psi                   WRC 474 Mean Cycles to Failure = 8,180,146.
                            WRC 474 99% Probability Cycles = 1,900,358.
      10%                   WRC 474 95% Probability Cycles = 2,638,446.
                            BS5500 Allowed Cycles(Curve F) = 1,147,386.
                            Membrane-to-Bending Ratio = 0.976
                            Bending-to-PL+PB+Q Ratio = 0.506
                            Plot Reference:
                            9) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 2


Branch away from Junction

Pl+Pb+Q+F    Damage Ratio   Primary+Secondary+Peak (Inner) Load Case 2
    2,221     0.000 Life    Stress Concentration Factor = 1.000
      psi     0.038 Stress  Strain Concentration Factor = 1.000
                            Cycles Allowed for this Stress = 1.0000E11
Allowable                   "B31" Fatigue Stress Allowable = 39375.0
   59,224                   Markl Fatigue Stress Allowable = 47828.5
      psi                   WRC 474 Mean Cycles to Failure = 1.9704E8
                            WRC 474 99% Probability Cycles = 45,775,296.
       3%                   WRC 474 95% Probability Cycles = 63,554,144.
                            BS5500 Allowed Cycles(Curve F) = 53,247,956.
                            Membrane-to-Bending Ratio = 2.985
                            Bending-to-PL+PB+Q Ratio = 0.251
                            Plot Reference:
                            8) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 2
```

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```
Highest Stress Ratios Per Region
FEPipe Version 15.0           Jobname: NOZZLE                $P
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Highest Stress Ratios Per Region                       $X


Header Next to Nozzle Weld

       Pl            SPL     Primary Membrane Load Case 1
    5,501         22,200     Min Prin. Stress = -514. (24% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 1
            24%

       Qb            SPS     Primary Bending Load Case 1
    1,877         47,250     Min Prin. Stress = -514. (24% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             2) Qb < SPS (SUS,Bending) Case 1
             3%

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 1
    6,562         47,250     Min Prin. Stress = -514. (24% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             3) Pl+Pb+Q < SPS (SUS,Inside) Case 1
            13%

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 1
    4,951         47,250     Min Prin. Stress = -514. (24% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             4) Pl+Pb+Q < SPS (SUS,Outside) Case 1
            10%

 S1+S2+S3             4S     Part 5 (5.3.2) Load Case 1
    8,311         59,200     Min Prin. Stress = -514. (24% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 1
            14%

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 2
   20,459         47,250     Min Prin. Stress = -5081. (72% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             6) Pl+Pb+Q < SPS (OPE,Inside) Case 2
            43%

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 2
   27,780         47,250     Min Prin. Stress = -5081. (72% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             7) Pl+Pb+Q < SPS (OPE,Outside) Case 2
            58%

Pl+Pb+Q+F   Damage Ratio     Primary+Secondary+Peak (Inner) Load Case 2
   13,810    0.000 Life      Stress Concentration Factor = 1.350
      psi    0.233 Stress    Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 2.8216E9
Allowable                    "B31" Fatigue Stress Allowable = 39375.0
   59,224                    Markl Fatigue Stress Allowable = 47828.5
      psi                    WRC 474 Mean Cycles to Failure = 2,454,090.
                             WRC 474 99% Probability Cycles = 570,118.
      23%                    WRC 474 95% Probability Cycles = 791,549.
                             BS5500 Allowed Cycles(Curve F) = 276,814.
                             Membrane-to-Bending Ratio = 0.449
                             Bending-to-PL+PB+Q Ratio = 0.690
                             Plot Reference:
                             8) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 2

Pl+Pb+Q+F   Damage Ratio     Primary+Secondary+Peak (Outer) Load Case 2
   18,752    0.008 Life      Stress Concentration Factor = 1.350
      psi    0.317 Stress    Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 861,644.
Allowable                    "B31" Fatigue Stress Allowable = 39375.0
   59,224                    Markl Fatigue Stress Allowable = 47828.5
      psi                    WRC 474 Mean Cycles to Failure = 786,456.
```

```
                                WRC 474 99% Probability Cycles = 182,704.
     31%                        WRC 474 95% Probability Cycles = 253,666.
                                BS5500 Allowed Cycles(Curve F) = 110,560.
                                Membrane-to-Bending Ratio = 0.415
                                Bending-to-PL+PB+Q Ratio = 0.707
                                Plot Reference:
                                9) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 2

 Membrane           User        Component Evaluation Load Case 2
   10,051         47,250        Min Prin. Stress = -5081. (72% Neg, 0% NegHi)
      psi            psi        Plot Reference:
                                10) Membrane < User (OPE,Membrane) Case 2
           21%

  Bending           User        Component Evaluation Load Case 2
   22,377         47,250        Min Prin. Stress = -5081. (72% Neg, 0% NegHi)
      psi            psi        Plot Reference:
                                11) Bending < User (OPE,Bending) Case 2
           47%


Branch Next to Header Weld

       Pl            SPL        Primary Membrane Load Case 1
    4,734         22,200        Min Prin. Stress = -1187. (63% Neg, 0% NegHi)
      psi            psi        Plot Reference:
                                1) Pl < SPL (SUS,Membrane) Case 1
           21%

       Qb            SPS        Primary Bending Load Case 1
    2,230         47,250        Min Prin. Stress = -1187. (63% Neg, 0% NegHi)
      psi            psi        Plot Reference:
                                2) Qb < SPS (SUS,Bending) Case 1
            4%

  Pl+Pb+Q            SPS        Primary+Secondary (Inner) Load Case 1
    6,505         47,250        Min Prin. Stress = -1187. (63% Neg, 0% NegHi)
      psi            psi        Plot Reference:
                                3) Pl+Pb+Q < SPS (SUS,Inside) Case 1
           13%

  Pl+Pb+Q            SPS        Primary+Secondary (Outer) Load Case 1
    3,255         47,250        Min Prin. Stress = -1187. (63% Neg, 0% NegHi)
      psi            psi        Plot Reference:
                                4) Pl+Pb+Q < SPS (SUS,Outside) Case 1
            6%

 S1+S2+S3             4S        Part 5 (5.3.2) Load Case 1
    5,499         59,200        Min Prin. Stress = -1187. (63% Neg, 0% NegHi)
      psi            psi        Plot Reference:
                                5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 1
            9%

  Pl+Pb+Q            SPS        Primary+Secondary (Inner) Load Case 2
   19,788         47,250        Min Prin. Stress = -7877. (86% Neg, 0% NegHi)
      psi            psi        Plot Reference:
                                6) Pl+Pb+Q < SPS (OPE,Inside) Case 2
           41%

  Pl+Pb+Q            SPS        Primary+Secondary (Outer) Load Case 2
   18,110         47,250        Min Prin. Stress = -7877. (86% Neg, 0% NegHi)
      psi            psi        Plot Reference:
                                7) Pl+Pb+Q < SPS (OPE,Outside) Case 2
           38%

Pl+Pb+Q+F    Damage Ratio       Primary+Secondary+Peak (Inner) Load Case 2
   13,357     0.000 Life        Stress Concentration Factor = 1.350
      psi     0.226 Stress      Strain Concentration Factor = 1.000
                                Cycles Allowed for this Stress = 1.0000E11
Allowable                       "B31" Fatigue Stress Allowable = 39375.0
   59,224                       Markl Fatigue Stress Allowable = 47828.5
      psi                       WRC 474 Mean Cycles to Failure = 2,094,036.
                                WRC 474 99% Probability Cycles = 486,473.
     22%                        WRC 474 95% Probability Cycles = 675,416.
                                BS5500 Allowed Cycles(Curve F) = 305,904.
                                Membrane-to-Bending Ratio = 0.667
                                Bending-to-PL+PB+Q Ratio = 0.600
                                Plot Reference:
                                8) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 2

Pl+Pb+Q+F    Damage Ratio       Primary+Secondary+Peak (Outer) Load Case 2
   12,224     0.000 Life        Stress Concentration Factor = 1.350
```

```
      psi     0.206 Stress    Strain Concentration Factor = 1.000
                              Cycles Allowed for this Stress = 1.0000E11
Allowable                     "B31" Fatigue Stress Allowable = 39375.0
   59,224                     Markl Fatigue Stress Allowable = 47828.5
      psi                     WRC 474 Mean Cycles to Failure = 2,861,285.
                              WRC 474 99% Probability Cycles = 664,715.
      20%                     WRC 474 95% Probability Cycles = 922,886.
                              BS5500 Allowed Cycles(Curve F) = 399,096.
                              Membrane-to-Bending Ratio = 0.656
                              Bending-to-PL+PB+Q Ratio = 0.604
                              Plot Reference:
                              9) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 2

 Membrane           User      Component Evaluation Load Case 2
   10,435         47,250      Min Prin. Stress = -7877. (86% Neg, 0% NegHi)
      psi            psi      Plot Reference:
                              10) Membrane < User (OPE,Membrane) Case 2
            22%

  Bending           User      Component Evaluation Load Case 2
   15,646         47,250      Min Prin. Stress = -7877. (86% Neg, 0% NegHi)
      psi            psi      Plot Reference:
                              11) Bending < User (OPE,Bending) Case 2
            33%


Branch Transition

       Pl            SPL      Primary Membrane Load Case 1
      545         22,200      Min Prin. Stress = -574. (22% Neg, 0% NegHi)
      psi            psi      Plot Reference:
                              1) Pl < SPL (SUS,Membrane) Case 1
             2%

       Qb            SPS      Primary Bending Load Case 1
      452         47,250      Min Prin. Stress = -574. (22% Neg, 0% NegHi)
      psi            psi      Plot Reference:
                              2) Qb < SPS (SUS,Bending) Case 1
             0%

  Pl+Pb+Q            SPS      Primary+Secondary (Inner) Load Case 1
      655         47,250      Min Prin. Stress = -574. (22% Neg, 0% NegHi)
      psi            psi      Plot Reference:
                              3) Pl+Pb+Q < SPS (SUS,Inside) Case 1
             1%

  Pl+Pb+Q            SPS      Primary+Secondary (Outer) Load Case 1
      950         47,250      Min Prin. Stress = -574. (22% Neg, 0% NegHi)
      psi            psi      Plot Reference:
                              4) Pl+Pb+Q < SPS (SUS,Outside) Case 1
             2%

 S1+S2+S3             4S      Part 5 (5.3.2) Load Case 1
      854         59,200      Min Prin. Stress = -574. (22% Neg, 0% NegHi)
      psi            psi      Plot Reference:
                              5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 1
             1%

  Pl+Pb+Q            SPS      Primary+Secondary (Inner) Load Case 2
    3,767         47,250      Min Prin. Stress = -3491. (84% Neg, 0% NegHi)
      psi            psi      Plot Reference:
                              6) Pl+Pb+Q < SPS (OPE,Inside) Case 2
             7%

  Pl+Pb+Q            SPS      Primary+Secondary (Outer) Load Case 2
    4,270         47,250      Min Prin. Stress = -3491. (84% Neg, 0% NegHi)
      psi            psi      Plot Reference:
                              7) Pl+Pb+Q < SPS (OPE,Outside) Case 2
             9%

Pl+Pb+Q+F    Damage Ratio     Primary+Secondary+Peak (Inner) Load Case 2
    1,883     0.000 Life      Stress Concentration Factor = 1.000
      psi     0.032 Stress    Strain Concentration Factor = 1.000
                              Cycles Allowed for this Stress = 1.0000E11
Allowable                     "B31" Fatigue Stress Allowable = 39375.0
   59,224                     Markl Fatigue Stress Allowable = 47828.5
      psi                     WRC 474 Mean Cycles to Failure = 3.2629E8
                              WRC 474 99% Probability Cycles = 75,801,496.
       3%                     WRC 474 95% Probability Cycles = 1.0524E8
                              BS5500 Allowed Cycles(Curve F) = 1.2144E8
                              Membrane-to-Bending Ratio = 6.790
                              Bending-to-PL+PB+Q Ratio = 0.128
```

```
                              Plot Reference:
                              8) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 2

Pl+Pb+Q+F    Damage Ratio     Primary+Secondary+Peak (Outer) Load Case 2
    2,135     0.000 Life      Stress Concentration Factor = 1.000
      psi     0.036 Stress    Strain Concentration Factor = 1.000
                              Cycles Allowed for this Stress = 1.0000E11
Allowable                     "B31" Fatigue Stress Allowable = 39375.0
   59,224                     Markl Fatigue Stress Allowable = 47828.5
      psi                     WRC 474 Mean Cycles to Failure = 2.2386E8
                              WRC 474 99% Probability Cycles = 52,005,048.
       3%                     WRC 474 95% Probability Cycles = 72,203,488.
                              BS5500 Allowed Cycles(Curve F) = 64,868,344.
                              Membrane-to-Bending Ratio = 2.387
                              Bending-to-PL+PB+Q Ratio = 0.295
                              Plot Reference:
                              9) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 2

 Membrane            User     Component Evaluation Load Case 2
    3,780          47,250     Min Prin. Stress = -3491. (84% Neg, 0% NegHi)
      psi             psi     Plot Reference:
                              10) Membrane < User (OPE,Membrane) Case 2
             8%

  Bending            User     Component Evaluation Load Case 2
    1,339          47,250     Min Prin. Stress = -3491. (84% Neg, 0% NegHi)
      psi             psi     Plot Reference:
                              11) Bending < User (OPE,Bending) Case 2
             2%


Header away from Junction

       Pl             SPL     Primary Membrane Load Case 1
    4,028          22,200     Min Prin. Stress = -11. ( 0% Neg, 0% NegHi)
      psi             psi     Plot Reference:
                              1) Pl < SPL (SUS,Membrane) Case 1
            18%

       Qb             SPS     Primary Bending Load Case 1
      681          47,250     Min Prin. Stress = -11. ( 0% Neg, 0% NegHi)
      psi             psi     Plot Reference:
                              2) Qb < SPS (SUS,Bending) Case 1
             1%

  Pl+Pb+Q             SPS     Primary+Secondary (Inner) Load Case 1
    4,567          47,250     Min Prin. Stress = -11. ( 0% Neg, 0% NegHi)
      psi             psi     Plot Reference:
                              3) Pl+Pb+Q < SPS (SUS,Inside) Case 1
             9%

  Pl+Pb+Q             SPS     Primary+Secondary (Outer) Load Case 1
    3,742          47,250     Min Prin. Stress = -11. ( 0% Neg, 0% NegHi)
      psi             psi     Plot Reference:
                              4) Pl+Pb+Q < SPS (SUS,Outside) Case 1
             7%

 S1+S2+S3              4S     Part 5 (5.3.2) Load Case 1
    6,732          59,200     Min Prin. Stress = -11. ( 0% Neg, 0% NegHi)
      psi             psi     Plot Reference:
                              5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 1
            11%

  Pl+Pb+Q             SPS     Primary+Secondary (Inner) Load Case 2
   11,112          47,250     Min Prin. Stress = -2107. (21% Neg, 0% NegHi)
      psi             psi     Plot Reference:
                              6) Pl+Pb+Q < SPS (OPE,Inside) Case 2
            23%

  Pl+Pb+Q             SPS     Primary+Secondary (Outer) Load Case 2
   12,736          47,250     Min Prin. Stress = -2107. (21% Neg, 0% NegHi)
      psi             psi     Plot Reference:
                              7) Pl+Pb+Q < SPS (OPE,Outside) Case 2
            26%

Pl+Pb+Q+F    Damage Ratio     Primary+Secondary+Peak (Inner) Load Case 2
    5,556     0.000 Life      Stress Concentration Factor = 1.000
      psi     0.094 Stress    Strain Concentration Factor = 1.000
                              Cycles Allowed for this Stress = 1.0000E11
Allowable                     "B31" Fatigue Stress Allowable = 39375.0
   59,224                     Markl Fatigue Stress Allowable = 47828.5
      psi                     WRC 474 Mean Cycles to Failure = 12,799,586.
```

```
                                WRC 474 99% Probability Cycles = 2,973,514.
       9%                       WRC 474 95% Probability Cycles = 4,128,408.
                                BS5500 Allowed Cycles(Curve F) = 1,727,606.
                                Membrane-to-Bending Ratio = 1.057
                                Bending-to-PL+PB+Q Ratio = 0.486
                                Plot Reference:
                                8) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 2

 Pl+Pb+Q+F    Damage Ratio      Primary+Secondary+Peak (Outer) Load Case 2
     6,368     0.000 Life       Stress Concentration Factor = 1.000
       psi     0.108 Stress     Strain Concentration Factor = 1.000
                                Cycles Allowed for this Stress = 1.0000E11
 Allowable                      "B31" Fatigue Stress Allowable = 39375.0
    59,224                      Markl Fatigue Stress Allowable = 47828.5
       psi                      WRC 474 Mean Cycles to Failure = 8,180,146.
                                WRC 474 99% Probability Cycles = 1,900,358.
       10%                      WRC 474 95% Probability Cycles = 2,638,446.
                                BS5500 Allowed Cycles(Curve F) = 1,147,386.
                                Membrane-to-Bending Ratio = 0.976
                                Bending-to-PL+PB+Q Ratio = 0.506
                                Plot Reference:
                                9) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 2

  Membrane           User       Component Evaluation Load Case 2
     7,195         47,250       Min Prin. Stress = -2107. (21% Neg, 0% NegHi)
       psi            psi       Plot Reference:
                                10) Membrane < User (OPE,Membrane) Case 2
            15%

   Bending           User       Component Evaluation Load Case 2
     7,383         47,250       Min Prin. Stress = -2107. (21% Neg, 0% NegHi)
       psi            psi       Plot Reference:
                                11) Bending < User (OPE,Bending) Case 2
            15%


 Branch away from Junction

        Pl            SPL       Primary Membrane Load Case 1
       656         22,200       Min Prin. Stress = -882. (43% Neg, 0% NegHi)
       psi            psi       Plot Reference:
                                1) Pl < SPL (SUS,Membrane) Case 1
             2%

        Qb            SPS       Primary Bending Load Case 1
       911         47,250       Min Prin. Stress = -882. (43% Neg, 0% NegHi)
       psi            psi       Plot Reference:
                                2) Qb < SPS (SUS,Bending) Case 1
             1%

   Pl+Pb+Q            SPS       Primary+Secondary (Inner) Load Case 1
     1,253         47,250       Min Prin. Stress = -882. (43% Neg, 0% NegHi)
       psi            psi       Plot Reference:
                                3) Pl+Pb+Q < SPS (SUS,Inside) Case 1
             2%

   Pl+Pb+Q            SPS       Primary+Secondary (Outer) Load Case 1
     1,404         47,250       Min Prin. Stress = -882. (43% Neg, 0% NegHi)
       psi            psi       Plot Reference:
                                4) Pl+Pb+Q < SPS (SUS,Outside) Case 1
             2%

  S1+S2+S3             4S       Part 5 (5.3.2) Load Case 1
       980         59,200       Min Prin. Stress = -882. (43% Neg, 0% NegHi)
       psi            psi       Plot Reference:
                                5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 1
             1%

   Pl+Pb+Q            SPS       Primary+Secondary (Inner) Load Case 2
     4,442         47,250       Min Prin. Stress = -3085. (97% Neg, 0% NegHi)
       psi            psi       Plot Reference:
                                6) Pl+Pb+Q < SPS (OPE,Inside) Case 2
             9%

   Pl+Pb+Q            SPS       Primary+Secondary (Outer) Load Case 2
     4,056         47,250       Min Prin. Stress = -3085. (97% Neg, 0% NegHi)
       psi            psi       Plot Reference:
                                7) Pl+Pb+Q < SPS (OPE,Outside) Case 2
             8%

 Pl+Pb+Q+F    Damage Ratio      Primary+Secondary+Peak (Inner) Load Case 2
     2,221     0.000 Life       Stress Concentration Factor = 1.000
```

```
      psi     0.038 Stress    Strain Concentration Factor = 1.000
                              Cycles Allowed for this Stress = 1.0000E11
Allowable                     "B31" Fatigue Stress Allowable = 39375.0
   59,224                     Markl Fatigue Stress Allowable = 47828.5
      psi                     WRC 474 Mean Cycles to Failure = 1.9704E8
                              WRC 474 99% Probability Cycles = 45,775,296.
       3%                     WRC 474 95% Probability Cycles = 63,554,144.
                              BS5500 Allowed Cycles(Curve F) = 53,247,956.
                              Membrane-to-Bending Ratio = 2.985
                              Bending-to-PL+PB+Q Ratio = 0.251
                              Plot Reference:
                              8) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 2

Pl+Pb+Q+F    Damage Ratio     Primary+Secondary+Peak (Outer) Load Case 2
    2,028     0.000 Life      Stress Concentration Factor = 1.000
      psi     0.034 Stress    Strain Concentration Factor = 1.000
                              Cycles Allowed for this Stress = 1.0000E11
Allowable                     "B31" Fatigue Stress Allowable = 39375.0
   59,224                     Markl Fatigue Stress Allowable = 47828.5
      psi                     WRC 474 Mean Cycles to Failure = 2.6254E8
                              WRC 474 99% Probability Cycles = 60,990,476.
       3%                     WRC 474 95% Probability Cycles = 84,678,808.
                              BS5500 Allowed Cycles(Curve F) = 83,939,232.
                              Membrane-to-Bending Ratio = 2.428
                              Bending-to-PL+PB+Q Ratio = 0.292
                              Plot Reference:
                              9) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 2

 Membrane           User      Component Evaluation Load Case 2
    3,841         47,250      Min Prin. Stress = -3085. (97% Neg, 0% NegHi)
      psi            psi      Plot Reference:
                              10) Membrane < User (OPE,Membrane) Case 2
             8%

  Bending           User      Component Evaluation Load Case 2
    1,524         47,250      Min Prin. Stress = -3085. (97% Neg, 0% NegHi)
      psi            psi      Plot Reference:
                              11) Bending < User (OPE,Bending) Case 2
             3%
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```
Stress Intensification Factors
FEPipe Version 15.0          Jobname: NOZZLE                 $P
Released Jan. 2021            2:10pm   OCT 23,2021



Stress Intensification Factors                        $X


Branch/Nozzle Sif Summary

                Peak       Primary     Secondary      SSI
Axial   :      13.575      10.056       20.111       2.027
Inplane :       3.748       2.776        5.552       1.727
Outplane:       5.164       3.825        7.650       1.623
Torsion :       0.638       0.810        0.946       0.889
Pressure:       1.106       1.374        1.639       1.139

The above stress intensification factors are to be used
in a beam-type analysis of the piping system.  Inplane,
Outplane and Torsional sif's should be used with the
matching branch pipe whose diameter and thickness is given
below.  The axial sif should be used to intensify the
axial stress in the branch pipe calculated by F/A.  The
pressure sif should be used to intensify the nominal
pressure stress in the PARENT or HEADER, calculated
from PDo/2T. B31 calculations use mean diameters and
Section VIII calculations use outside diameters. SSIs are
based on peak stress factors and correlated test results.

Pipe OD :        3.500  in.
Pipe Thk:        0.438  in.
Z approx:        3.225  cu.in.
Z exact :        2.879  cu.in.
```

```
  (SSI = SIF^x)        Axial   Inpl    Outpl   Tors    Pres
SIF/SSI Exponents:     0.885   0.773   0.817   0.471   3.148

SIF/SSI exponent based on relationship between primary and
peak stress factors from the finite element analysis.

B31.3 Branch Pressure i-factor =       24.138
      Header Pressure i-factor =        2.242

The B31.3 pressure i-factors should be used with with
F/A, where F is the axial force due to pressure, and
A is the area of the pipe wall. This is equivalent to
finding the pressure stress from (ip)(PD/4T).

B31.3   (Branch)
Peak Stress Sif ....    0.000         Axial
                        8.712         Inplane
                       11.245         Outplane
                        1.000         Torsional
B31.1  (Branch)
Peak Stress Sif ....    0.000         Axial
                        5.270         Inplane
                        5.270         Outplane
                        5.270         Torsional
WRC 330  (Branch)
Peak Stress Sif ....    0.000         Axial
                        3.558         Inplane
                        3.558         Outplane
                        1.000         Torsional
```

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```
Allowable Loads
FEPipe Version 15.0           Jobname: NOZZLE             $P
Released Jan. 2021              2:10pm   OCT 23,2021



Allowable Loads                                    $X
```

| SECONDARY<br>Load Type (Range): | Maximum<br>Individual<br>Occuring | Conservative<br>Simultaneous<br>Occuring | Realistic<br>Simultaneous<br>Occuring |
|---|---|---|---|
| Axial Force (lb. ) | 9899. | 2954. | 4431. |
| Inplane Moment (in. lb.) | 24505. | 5171. | 10969. |
| Outplane Moment (in. lb.) | 17784. | 3753. | 7960. |
| Torsional Moment (in. lb.) | 143841. | 44644. | 66966. |
| Pressure (psi ) | 756.01 | 105.00 | 105.00 |

| PRIMARY<br>Load Type: | Maximum<br>Individual<br>Occuring | Conservative<br>Simultaneous<br>Occuring | Realistic<br>Simultaneous<br>Occuring |
|---|---|---|---|
| Axial Force (lb. ) | 9302. | 2332. | 3498. |
| Inplane Moment (in. lb.) | 23027. | 4082. | 8660. |
| Outplane Moment (in. lb.) | 16711. | 2963. | 6285. |
| Torsional Moment (in. lb.) | 78954. | 20615. | 30922. |
| Pressure (psi ) | 423.71 | 105.00 | 105.00 |

NOTES:

1) Maximum Individual Occuring Loads are the maximum allowed values of the respective loads if all other load components are zero, i.e. the listed axial force may be applied if the inplane, outplane and torsional moments, and the pressure are zero.

2) The Conservative Allowable Simultaneous loads are the maximum loads that can be applied simultaneously. A conservative stress combination equation is used that typically produces stresses within 50-70% of the allowable stress.

3) The Realistic Allowable Simultaneous loads are the maximum loads that can be applied simultaneously. A more realistic stress combination equation is used

based on experience at Paulin Research. Stresses are typically produced within 80-105% of the allowable.

4) Secondary allowable loads are limits for expansion and operating piping loads.

5) Primary allowable loads are limits for weight, primary and sustained type piping loads.

6) High D/T low pressure systems may be subject to instability and should be checked when compressive stresses are present.

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```
Compressive Stress Summary
FEPipe Version 15.0          Jobname: NOZZLE             $P
Released Jan. 2021            2:10pm   OCT 23,2021
```

Compressive Stress Summary (psi)                        $X

Nomenclature:

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Min Stress        - Compressive Membrane and Bending Stress
Pts in Region     - No. of nodes in the model region
>5% Compression   - 5% or more of Compressive Stress Limit
>50% Compression  - 50% or more of Compressive Stress Limit
```

Compressive Stress Limit = -0.55 Min(Sy, kEt/R), Section slenderness ratio (elastic buckling) not considered.

| # | Load Type | Case | Min Stress | Pts in Region | >5% Compression and Bending | >50% Compression and Bending | Region |
|---|---|---|---|---|---|---|---|
| 1 | SUSTAINED | 1 | -514. | 696 | 24% | 0% | Header Next to Nozzle Weld |
| 2 | OPERATING | 2 | -5081. | 696 | 72% | 0% | Header Next to Nozzle Weld |
| 3 | EXPANSION | 2 | -5081. | 696 | 72% | 0% | Header Next to Nozzle Weld |
| 4 | OPERATING | 2 | -5081. | 696 | 72% | 0% | Header Next to Nozzle Weld |
| 5 | SUSTAINED | 1 | -11. | 1032 | 0% | 0% | Header away from Junction |
| 6 | OPERATING | 2 | -2107. | 1032 | 21% | 0% | Header away from Junction |
| 7 | EXPANSION | 2 | -2107. | 1032 | 21% | 0% | Header away from Junction |
| 8 | OPERATING | 2 | -2107. | 1032 | 21% | 0% | Header away from Junction |
| 9 | SUSTAINED | 1 | -1187. | 840 | 63% | 0% | Branch Next to Header Weld |
| 10 | OPERATING | 2 | -7877. | 840 | 86% | 0% | Branch Next to Header Weld |
| 11 | EXPANSION | 2 | -7877. | 840 | 86% | 0% | Branch Next to Header Weld |
| 12 | OPERATING | 2 | -7877. | 840 | 86% | 0% | Branch Next to Header Weld |
| 13 | SUSTAINED | 1 | -882. | 192 | 43% | 0% | Branch away from Junction |
| 14 | OPERATING | 2 | -3085. | 192 | 97% | 0% | Branch away from Junction |
| 15 | EXPANSION | 2 | -3085. | 192 | 97% | 0% | Branch away from Junction |
| 16 | OPERATING | 2 | -3085. | 192 | 97% | 0% | Branch away from Junction |
| 17 | SUSTAINED | 1 | -574. | 696 | 22% | 0% | Branch Transition |
| 18 | OPERATING | 2 | -3491. | 696 | 84% | 0% | Branch Transition |
| 19 | EXPANSION | 2 | -3491. | 696 | 84% | 0% | Branch Transition |
| 20 | OPERATING | 2 | -3491. | 696 | 84% | 0% | Branch Transition |

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Flexibilities
FEPipe Version 15.0          Jobname: NOZZLE             $P
Released Jan. 2021            2:10pm   OCT 23,2021
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Flexibilities                                           $X

The following stiffnesses should be used in a piping, "beam-type" analysis of the intersection. The stiff-

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nesses should be inserted at the surface of the
branch/header or nozzle/vessel junction.  The general
characteristics used for the branch pipe should be:

Outside Diameter =    3.500  in.
Wall Thickness   =    0.438  in.

Axial Translational Stiffness   =        297564.  lb./in.
Inplane Rotational Stiffness    =         71095.  in.lb./deg
Outplane Rotational Stiffness   =         35455.  in.lb./deg
Torsional Rotational Stiffness  =       1551009.  in.lb./deg


Estimated Radial Shell Displacement due to Allowable Loads
SECONDARY:
Axial (in.) =  0.033  In-Plane (in.) =  0.009  Out-Plane (in.) =  0.013

PRIMARY
Axial (in.) =  0.031  In-Plane (in.) =  0.009  Out-Plane (in.) =  0.013

Secondary Conservative Displacement =  0.015 in.
Secondary Realistic    Displacement =  0.025 in.

Primary Conservative Displacement =  0.012 in.
Primary Realistic Displacement    =  0.020 in.



Intersection Flexibility Factors for Branch/Nozzle
:

Find axial stiffness: K = 3EI/(kd)^3  lb./in.
Find bending and torsional stiffnesses: K = EI/(kd)  in.lb.per radian.
The EI product is    0.14260E+09    lb.in.^2
The value of (d) to use is:   3.062  in..
The resulting bending stiffness is in units of force x length per radian.

Axial Flexibility Factor     (k) =     3.686
Inplane Flexibility Factor   (k) =    11.433
Outplane Flexibility Factor  (k) =    22.926
Torsional Flexibility Factor (k) =     0.524
```

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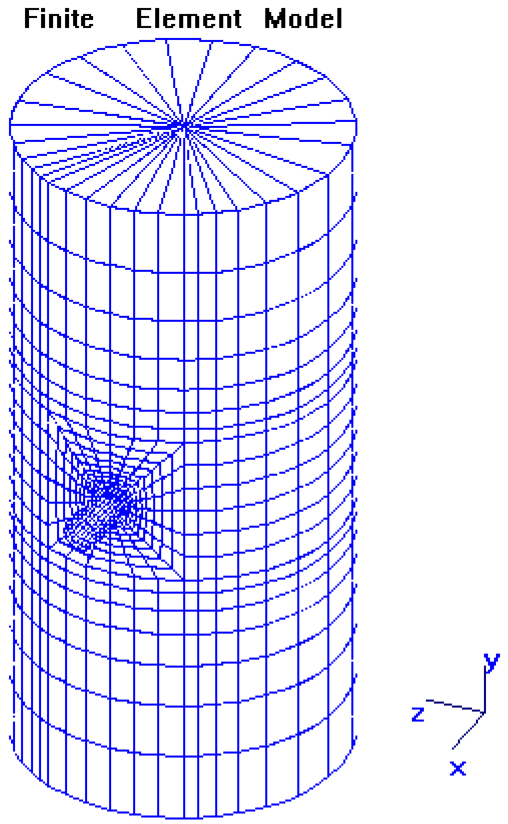
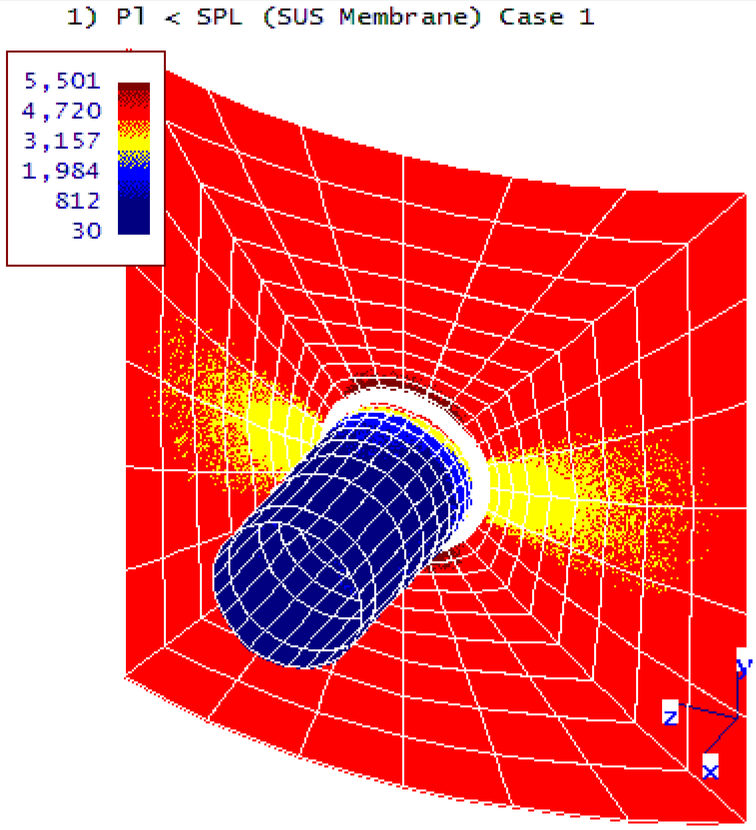
*Finite Element Model*



*Elements at Discontinuity*




- 3d
-

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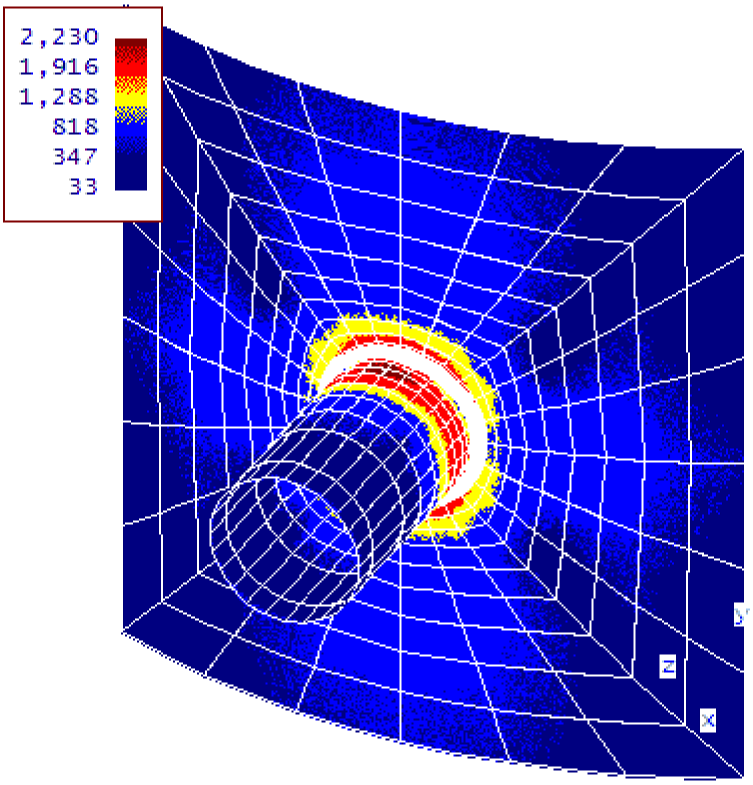
- 3d(Deformed)
-

2) Qb < SPS (SUS Bending) Case 1

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- 3d(Deformed)

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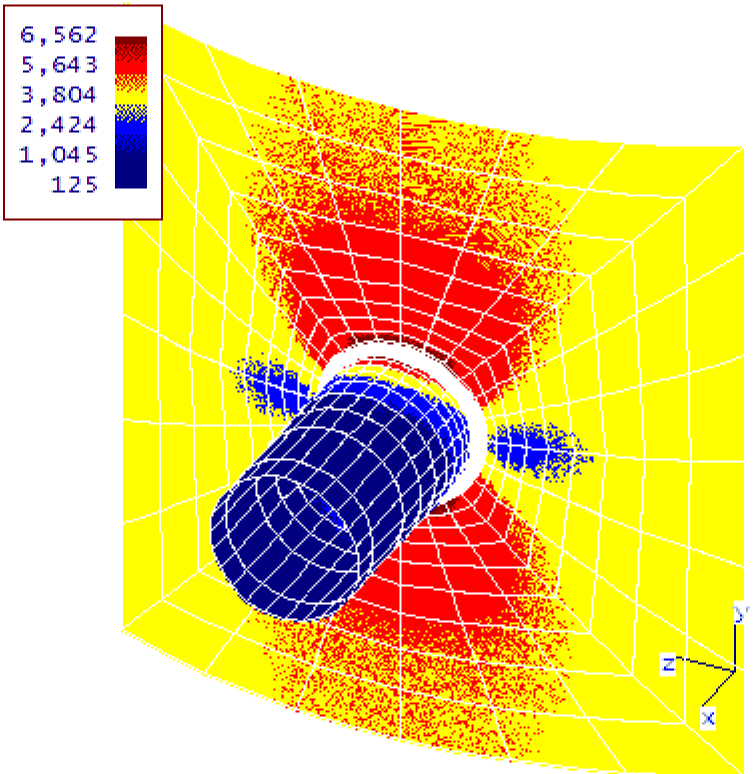
3) Pl+Pb+Q < SPS (SUS Inside) Case 1




3d(Small) 3d

- 3d(Deformed)

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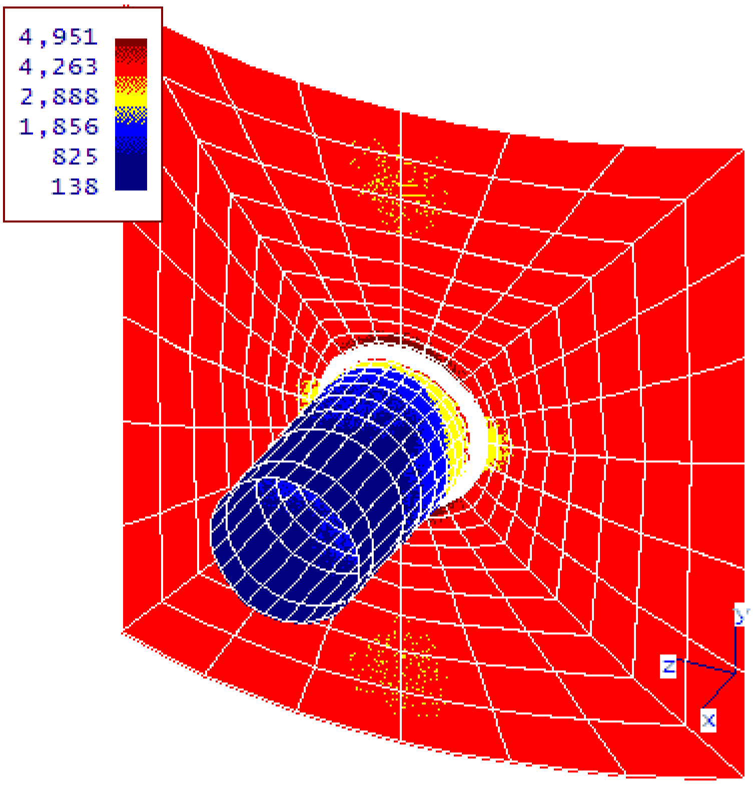
4) Pl+Pb+Q < SPS (SUS Outside) Case 1




3d(Small) 3d

- 3d(Deformed)

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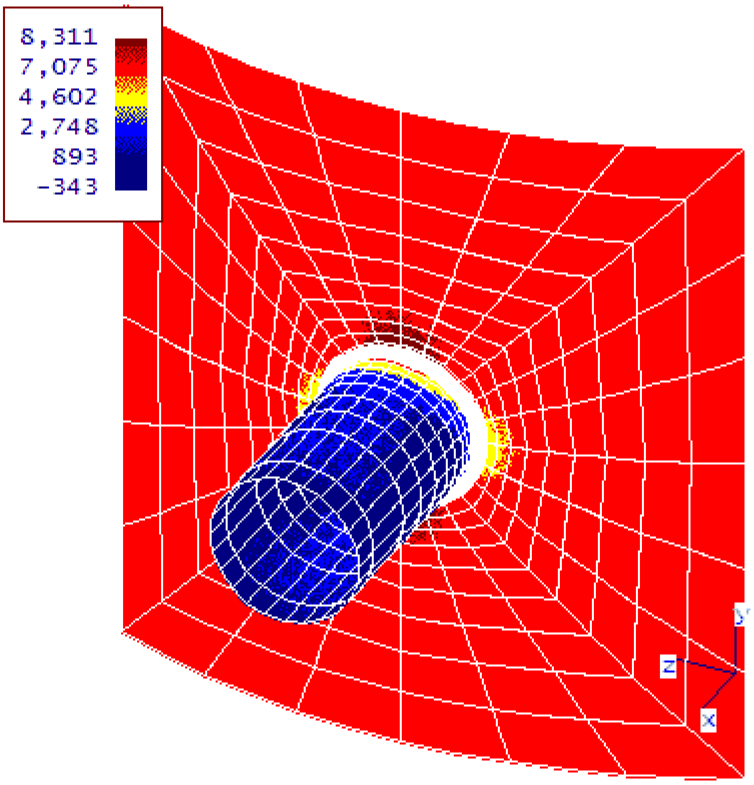
5) S1+S2+S3 < 4S (SUS S1+S2+S3) Case 1




3d(Small) 3d

- 3d(Deformed)

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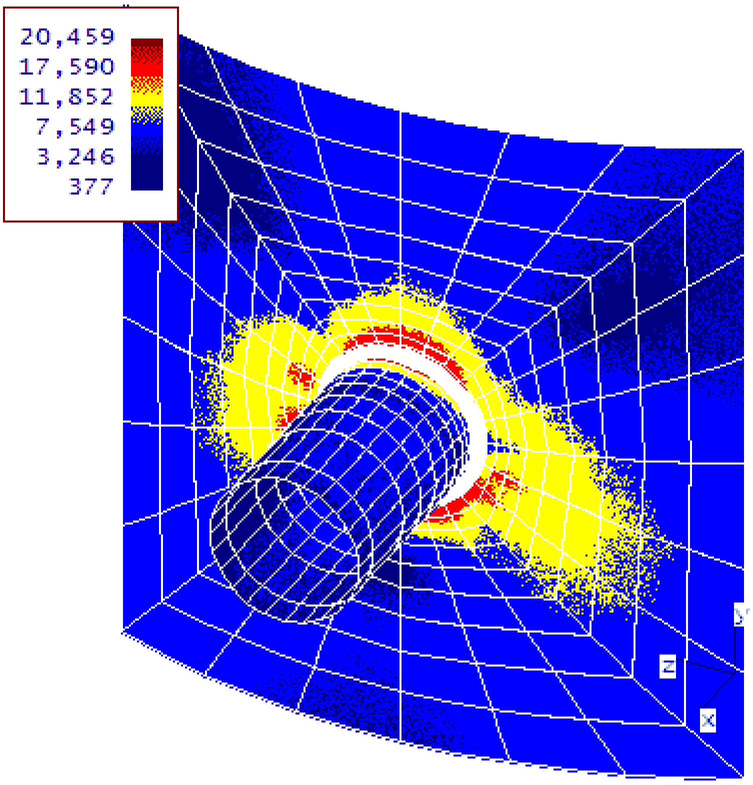
6) Pl+Pb+Q < SPS (OPE Inside) Case 2




3d(Small) 3d

- 3d(Deformed)

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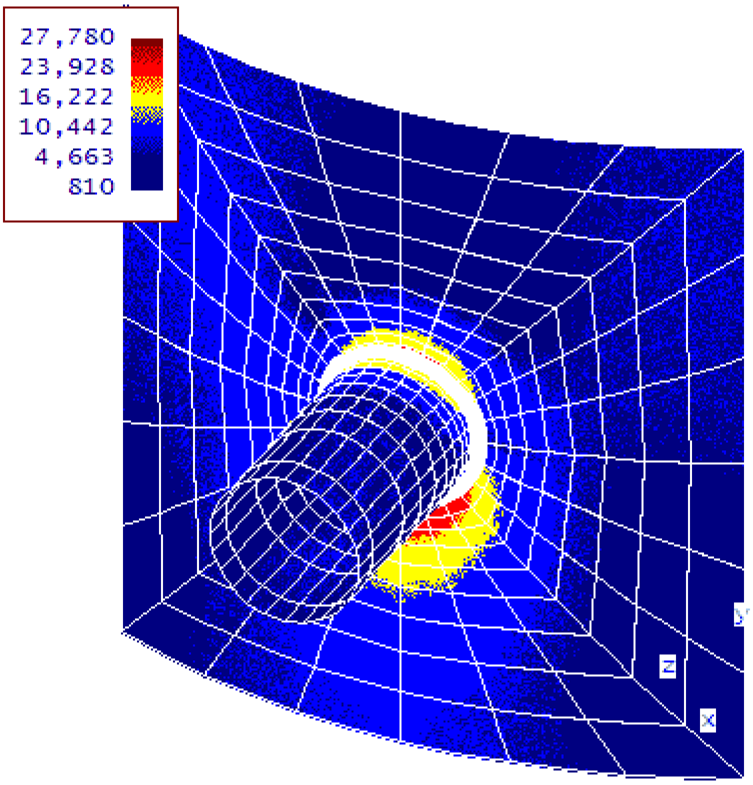
7) Pl+Pb+Q < SPS (OPE Outside) Case 2




3d(Small) 3d

- 3d(Deformed)

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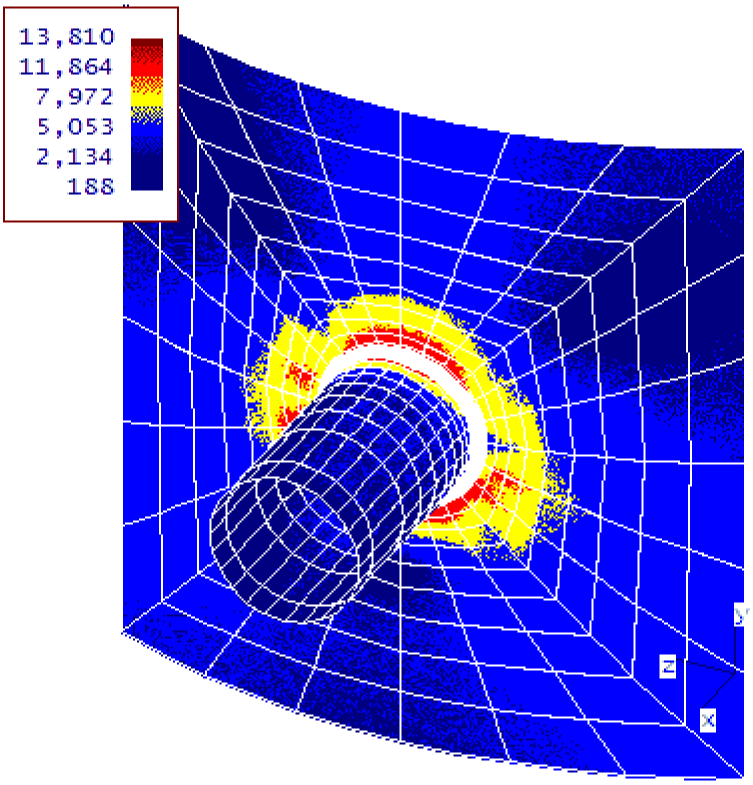
8) Pl+Pb+Q+F < 2Sa (EXP Inside) Case 2




3d(Small) 3d

- 3d(Deformed)

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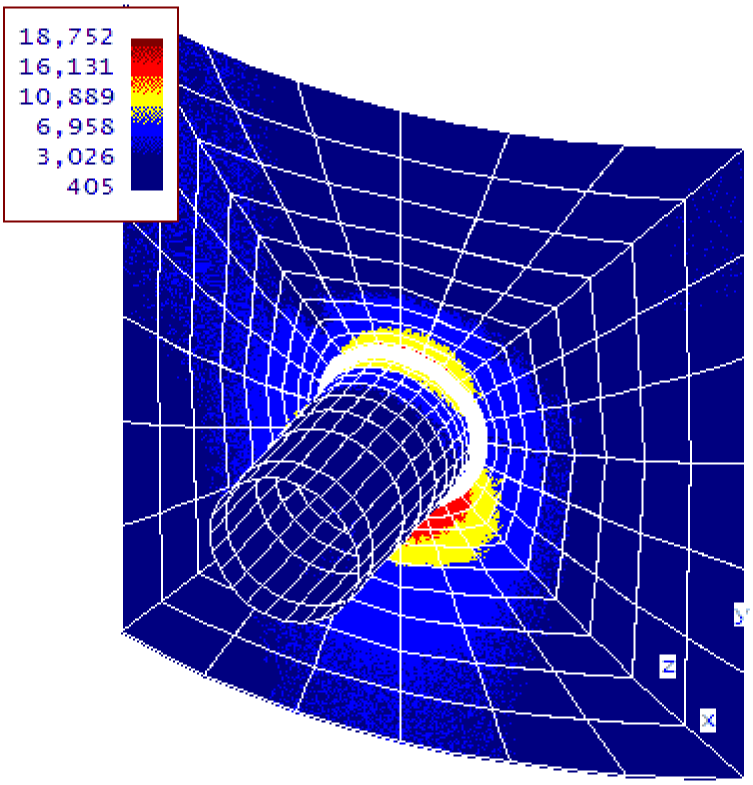
- 9) Pl+Pb+Q+F < 2Sa (EXP Outside) Case 2




3d(Small) 3d

- 3d(Deformed)

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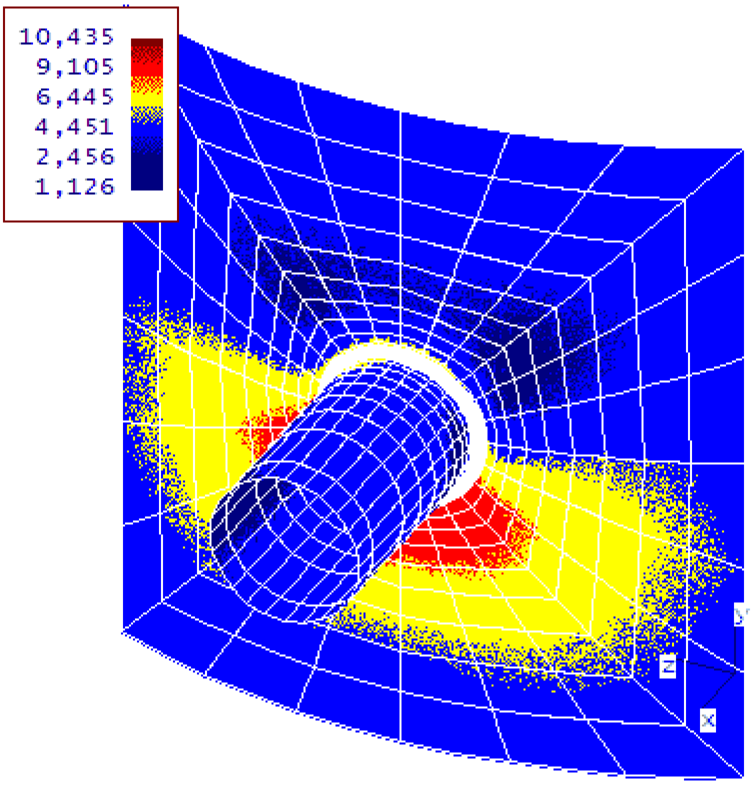
10) Membrane < User (OPE Membrane) Case 2




3d(Small) 3d

- 3d(Deformed)

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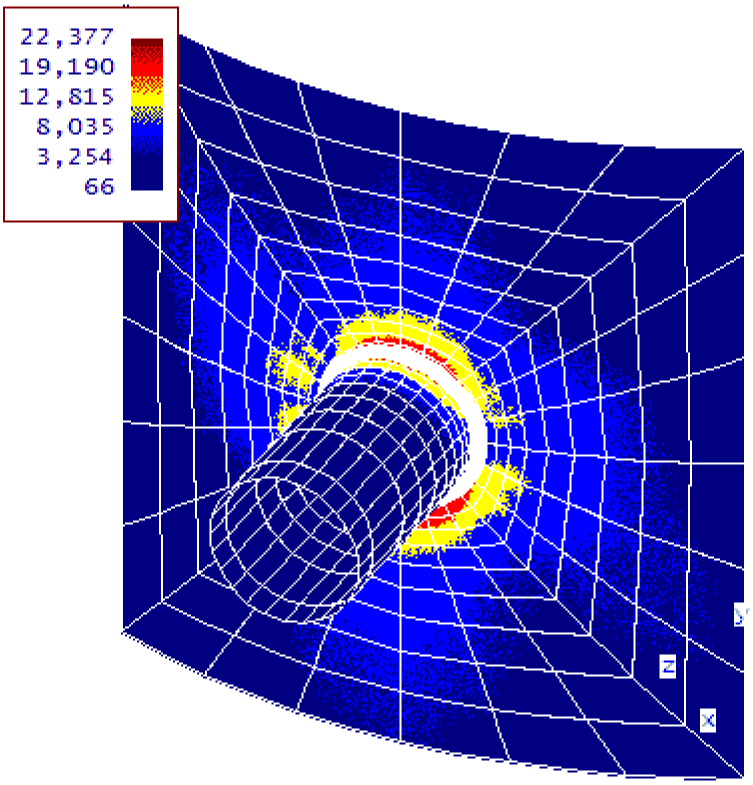
11) Bending < User (OPE Bending) Case 2

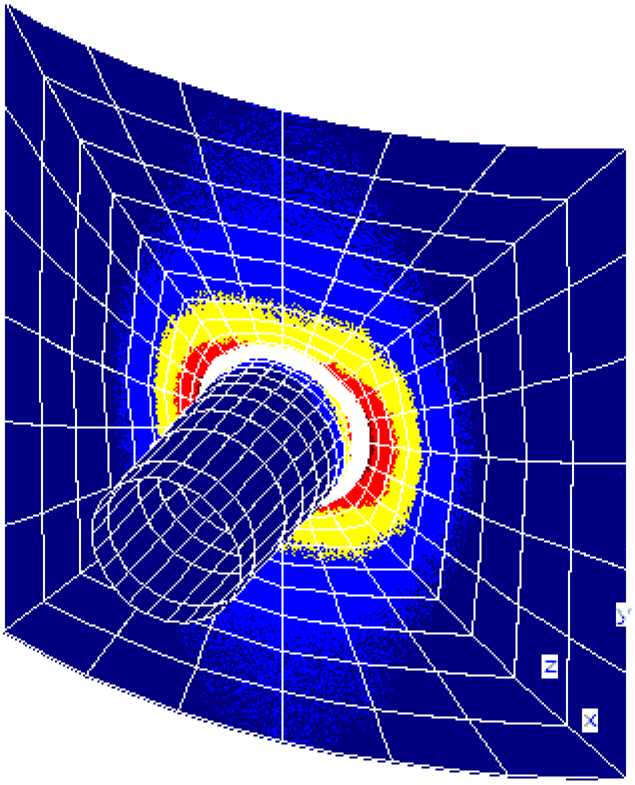



3d(Small) 3d

- 3d(Deformed)

---

12) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 3




3d(Small) 3d

- 3d(Deformed)
-

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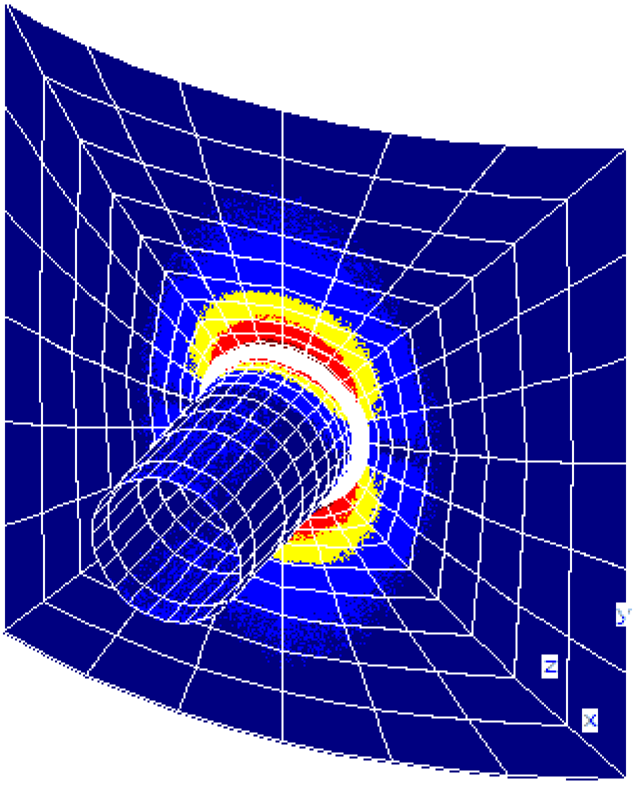
13) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 4




3d(Small) 3d

- 3d(Deformed)
-

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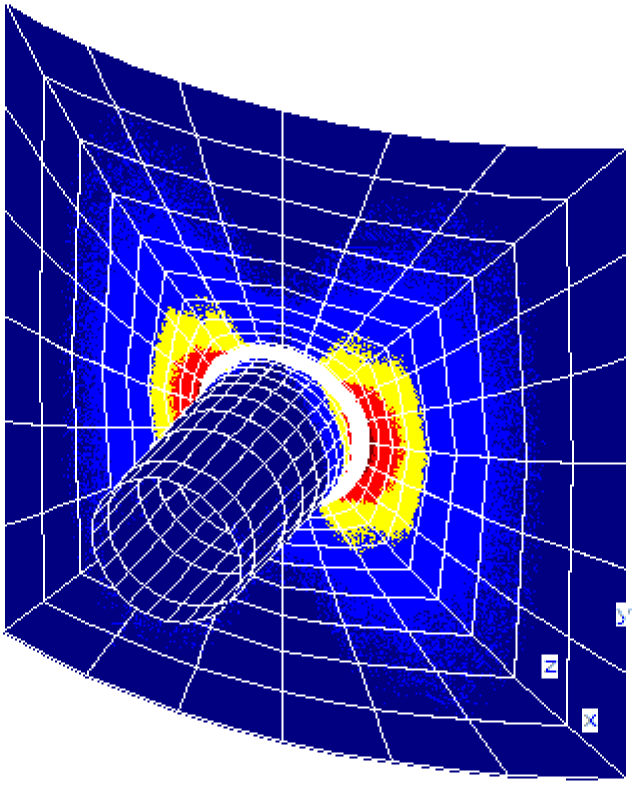
14) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 5

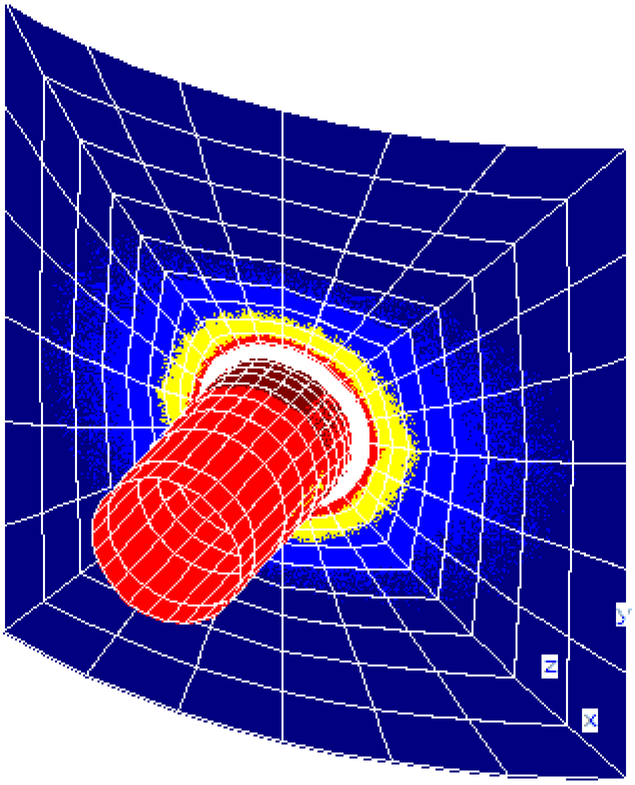



3d(Small) 3d

- 3d(Deformed)

---

15) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 6




3d(Small) 3d

- 3d(Deformed)

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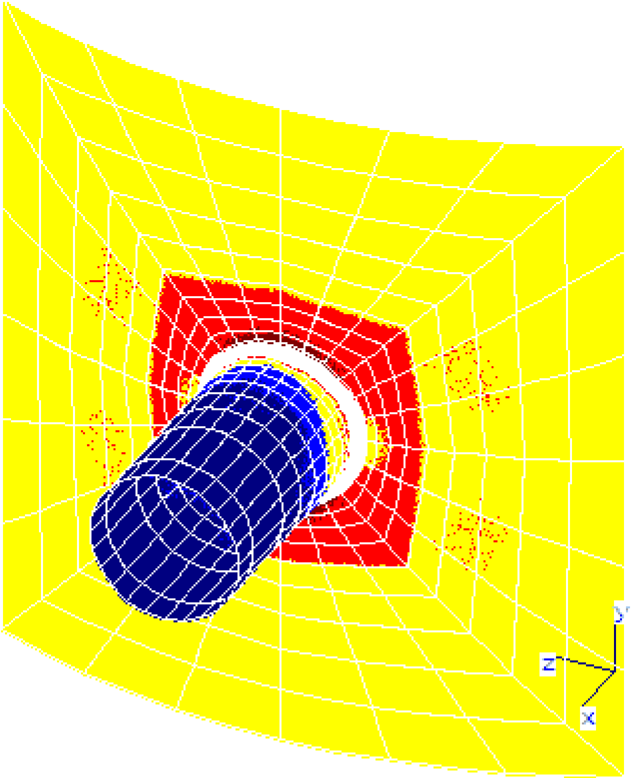
16) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 7




3d(Small) 3d

- 3d(Deformed)

**Tabular Results**

Results were generated with the finite element program FE/Pipe®. Stress results are post-processed in accordance with the rules specified in ASME Section III and ASME Section VIII, Division 2.

Analysis Time Stamp: Mon Oct 25 19:08:56 2021.



---

```
Model Notes
Model Notes

  Input Echo:

  Model Type                    : Flat Head

  Parent Geometry
         Parent Outside Diam.   :      34.900 in.
         Thickness              :       2.755 in.
         Attached Shell Length  :      33.320 in.
         Attached Shell Thick   :       0.394 in.
         Shell Transition Length:       5.230 in.
         Shell Transition SCF   :       1.350 in.

  Parent Properties:
         Cold Allowable         :     16700.0 psi
         Hot  Allowable         :     14800.0 psi
         Material DB # 1070322.
         Ultimate Tensile (Amb) :     65000.0 psi
         Yield Strength (Amb)   :     25000.0 psi
         Yield Strength (Hot)   :     16400.0 psi
         Elastic Modulus (Amb)  :  28300000.0 psi
         Poissons Ratio         :       0.300
         Expansion Coefficient  :  0.9700E-05 in./in./deg.
         Weight Density         :  0.0000E+00 lb./cu.in.(NOT USED)

  Nozzle Geometry
         Nozzle Outside Diam.   :       6.625 in.
         Thickness              :       0.864 in.
         Length                 :       6.500 in.
         Location perpendicular
         to the head centerline :       8.000 in.

         Nozzle Tilt Angle      :       0.000 deg.

  Nozzle Properties
         Cold Allowable         :     16700.0 psi
         Hot  Allowable         :     14800.0 psi
         Material DB # 1071622.
         Ultimate Tensile (Amb) :     70000.0 psi
         Yield Strength (Amb)   :     25000.0 psi
         Yield Strength (Hot)   :     16400.0 psi
         Elastic Modulus (Amb)  :  28300000.0 psi
         Poissons Ratio         :       0.300
         Expansion Coefficient  :  0.9700E-05 in./in./deg.
         Weight Density         :  0.0000E+00 lb./cu.in. (NOT USED)
```

```
Design Operating Cycles       :      7000.
Ambient Temperature (Deg.)    :      70.00

Uniform thermal expansion produces no stress in this geometry.
Any thermal loads will come through operating forces and
moments applied through the nozzle.

Nozzle Inside  Temperature    :     500.00 deg.
Nozzle Outside Temperature    :     500.00 deg.
Vessel Inside  Temperature    :     500.00 deg.
Vessel Outside Temperature    :     500.00 deg.

Nozzle Pressure               :      105.0 psi
Vessel Pressure               :      105.0 psi

User Defined Load Input Echo for the ATTACHMENT:
Loads are given at the End of Nozzle
Loads are defined in Local Coordinates

Forces( lb.)  Moments (ft-lb)

Load Case         FX          FY          FZ          MX          MY          MZ
---------------------------------------------------------------------------
   OPER:     1600.0      1600.0      1200.0      2400.0      1600.0      2100.0


FEA Model Loads:
These are the actual Attachment loads applied to
the FEA model.
These are the User Defined Loads translated to the
end of the nozzle and reported in global coordinates.

Forces( lb.)  Moments (ft-lb)

Load Case         FX          FY          FZ          MX          MY          MZ
---------------------------------------------------------------------------
   OPER:     1600.0      1600.0     -1200.0      1600.0      2400.0     -2100.0

Stresses ARE nodally AVERAGED.

No weld dimensions have been given for the nozzle
connection to the shell. This will produce conservative
results for external loads and may tend to produce more
realistic inside surface pressure stresses.

Vessel Centerline       Vector:  0.000    1.000    0.000
Nozzle Centerline       Vector:  0.000    1.000    0.000
Zero Degree Orientation Vector:  1.000    0.000    0.000
```

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---

```
Load Case Report
FEPipe Version 15.0          Jobname: NOZZLE              $P
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Load Case Report                                   $X

Inner and outer element temperatures are the same
throughout the model.  No thermal ratcheting
calculations will be performed.

THE   9  LOAD CASES ANALYZED ARE:

  1   WEIGHT ONLY     (Wgt Only)

      Weight ONLY case run to get the stress range
      between the installed and the operating states.

      /-------- Loads in Case   1
        Loads due to Weight

  2   SUSTAINED       (Wgt+Pr)

      Sustained case run to satisfy local primary
      membrane and bending stress limits.
```

```
    /-------- Loads in Case   2
      Loads due to Weight
      Pressure Case    1

3   OPERATING

    Case run to compute the operating stresses used in
    secondary, peak and range calculations as needed.

    /-------- Loads in Case   3
      Pressure Case    1
      Loads from (Operating)

4   RANGE          (Fatigue Calc Performed)

    Case run to get the RANGE of stresses.
    as described in NB-3222.2, 5.5.3.2, 5.5.5.2 or 5.5.6.1.

    /-------- Combinations in Range Case   4
      Plus  Stress Results from CASE   3
      Minus Stress Results from CASE   1

5   Program Generated -- Force Only

    Case run to compute sif's and flexibilities.
    /-------- Loads in Case   5
      Loads from (Axial)

6   Program Generated -- Force Only

    Case run to compute sif's and flexibilities.
    /-------- Loads in Case   6
      Loads from (Inplane)

7   Program Generated -- Force Only

    Case run to compute sif's and flexibilities.
    /-------- Loads in Case   7
      Loads from (Outplane)

8   Program Generated -- Force Only

    Case run to compute sif's and flexibilities.
    /-------- Loads in Case   8
      Loads from (Torsion)

9   Program Generated -- Force Only

    Case run to compute sif's and flexibilities.
    /-------- Loads in Case   9
      Pressure Case    1
```

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```
Solution Data
FEPipe Version 15.0          Jobname: NOZZLE              $P
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Solution Data


Maximum Solution Row Size =     816
Number of Nodes           =    2101
Number of Elements        =     708
Number of Solution Cases  =       8

Summation of Loads per Case

Case #               FX                  FY                  FZ

   1                  0.                  0.                  0.
   2                  0.              98192.                  0.
   3               1600.              99792.              -1200.
```

| | | | |
|---|---|---|---|
| 4 | 0. | 312746. | 0. |
| 5 | 0. | 0. | 0. |
| 6 | 0. | 0. | 0. |
| 7 | 0. | 0. | 0. |
| 8 | 0. | 98192. | 0. |

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---

ASME Code Stress Output Plots
FEPipe Version 15.0 Jobname: NOZZLE $P
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ASME Code Stress Output Plots $X

1) Pl < SPL (SUS,Membrane) Case 2

2) Qb < SPS (SUS,Bending) Case 2

3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2

6) Pl+Pb+Q < SPS (OPE,Inside) Case 3

7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

8) Membrane < User (OPE,Membrane) Case 3

9) Bending < User (OPE,Bending) Case 3

10) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 5

11) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 6

12) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 7

13) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 8

14) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 9

15) Pl+Pb+Q < SPS (EXP,Inside) Case 4

16) Pl+Pb+Q < SPS (EXP,Outside) Case 4

17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

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---

Stress Results - Notes
FEPipe Version 15.0 Jobname: NOZZLE $P
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Stress Results - Notes

- Results in this analysis were generated using the finite element solution method.

- Using 2019 ASME Section VIII Division 2

- Use Polished Bar fatigue curve.

- Ratio between Operating and Design Pressure = 1.000000
  Range cases use operating pressure. Primary cases

```
  use design pressure.

- Assume free end displacements of attached pipe
  (e.g. thermal loads) are secondary loads.

- Primary bending stresses at discontinuities
  are treated like secondary stresses. (Pb=0)

- Use Equivalent Stress (Von Mises).

- TRIAXIAL Stress Guidelines:
  S1+S2+S3 evaluation omitted from operating stress.
  Include S1+S2+S3 evaluation in primary case evaluation.
  Bending stress NOT included for all S1+S2+S3 calculations.

- Use local tensor values for averaged and not averaged stresses.
```

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---

```
ASME Overstressed Areas
FEPipe Version 15.0          Jobname: NOZZLE                 $P
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ASME Overstressed Areas                                 $X


             *** NO OVERSTRESSED NODES IN THIS MODEL ***
```

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---

```
Highest Primary Stress Ratios
FEPipe Version 15.0          Jobname: NOZZLE                 $P
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Highest Primary Stress Ratios                           $X


Shell Next to Nozzle 1

  Pl+Pb+Q          SPS     Primary+Secondary (Outer) Load Case 2
    3,304        47,250     Min Prin. Stress = -752. (88% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
             6%


Nozzle 1 Next to Shell

       Pl          SPL     Primary Membrane Load Case 2
    2,492        22,200     Min Prin. Stress = -1877. (58% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            1) Pl < SPL (SUS,Membrane) Case 2
            11%


Nozzle 1

       Pl          SPL     Primary Membrane Load Case 2
      350        22,200     Min Prin. Stress = -78. ( 0% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            1) Pl < SPL (SUS,Membrane) Case 2
             1%
```

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---

```
Highest Secondary Stress Ratios
FEPipe Version 15.0           Jobname: NOZZLE               $P
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Highest Secondary Stress Ratios                        $X

In combination case  4 the max range stress divided
by the max component stress is 1.00. The case tensor components
are NEVER additive and so the combination case will have
LOWER stresses than the largest of any of the individual
cases by between 1 and 20%.

Load      Combined/Max       Combined/Max
Case       (Inside)            (Outside)
------    -------------      -------------
   4         1.000              1.000


Shell Next to Nozzle 1

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 3
    4,415         47,250     Min Prin. Stress = -1532. (97% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
             9%

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 4
    4,415         47,250     Min Prin. Stress = -1532. (97% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
             9%


Nozzle 1 Next to Shell

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 3
    7,755         47,250     Min Prin. Stress = -1880. (76% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
            16%

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 4
    7,755         47,250     Min Prin. Stress = -1880. (76% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
            16%


Nozzle 1

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 3
    2,354         47,250     Min Prin. Stress = -1811. (76% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
             4%

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 4
    2,354         47,250     Min Prin. Stress = -1811. (76% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
             4%
```

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```
Highest Fatigue Stress Ratios
FEPipe Version 15.0           Jobname: NOZZLE               $P
Released Jan. 2021             7:08pm   OCT 25,2021



Highest Fatigue Stress Ratios                          $X
```

```
Shell Next to Nozzle 1

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 4
    5,961     0.000 Life     Stress Concentration Factor = 1.350
      psi     0.050 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 78750.0
  118,449                    Markl Fatigue Stress Allowable = 95657.0
      psi                    WRC 474 Mean Cycles to Failure = 70,354,992.
                             WRC 474 99% Probability Cycles = 16,344,413.
       5%                    WRC 474 95% Probability Cycles = 22,692,484.
                             BS5500 Allowed Cycles(Curve F) = 12,919,162.
                             Membrane-to-Bending Ratio = 0.190
                             Bending-to-PL+PB+Q Ratio = 0.840
                             Plot Reference:
                             18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4


Nozzle 1 Next to Shell

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 4
   10,469     0.000 Life     Stress Concentration Factor = 1.350
      psi     0.088 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 78750.0
  118,449                    Markl Fatigue Stress Allowable = 95657.0
      psi                    WRC 474 Mean Cycles to Failure = 24,950,874.
                             WRC 474 99% Probability Cycles = 5,796,419.
       8%                    WRC 474 95% Probability Cycles = 8,047,713.
                             BS5500 Allowed Cycles(Curve F) = 5,082,974.
                             Membrane-to-Bending Ratio = 0.559
                             Bending-to-PL+PB+Q Ratio = 0.642
                             Plot Reference:
                             18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4


Nozzle 1

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 4
    2,354     0.000 Life     Stress Concentration Factor = 1.000
      psi     0.020 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 78750.0
  118,449                    Markl Fatigue Stress Allowable = 95657.0
      psi                    WRC 474 Mean Cycles to Failure = 8.8296E8
                             WRC 474 99% Probability Cycles = 2.0512E8
       1%                    WRC 474 95% Probability Cycles = 2.8479E8
                             BS5500 Allowed Cycles(Curve F) = 1.2733E9
                             Membrane-to-Bending Ratio = 7.529
                             Bending-to-PL+PB+Q Ratio = 0.117
                             Plot Reference:
                             18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4
```

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```
Highest Stress Ratios Per Region
FEPipe Version 15.0           Jobname: NOZZLE                $P
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Highest Stress Ratios Per Region                      $X


Shell Next to Nozzle 1

       Pl            SPL     Primary Membrane Load Case 2
      678         22,200     Min Prin. Stress = -752. (88% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
             3%

       Qb            SPS     Primary Bending Load Case 2
    3,055         47,250     Min Prin. Stress = -752. (88% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             2) Qb < SPS (SUS,Bending) Case 2
```

```
             6%

  Pl+Pb+Q          SPS     Primary+Secondary (Inner) Load Case 2
    2,957       47,250     Min Prin. Stress = -752. (88% Neg, 0% NegHi)
      psi          psi     Plot Reference:
                           3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
             6%

  Pl+Pb+Q          SPS     Primary+Secondary (Outer) Load Case 2
    3,304       47,250     Min Prin. Stress = -752. (88% Neg, 0% NegHi)
      psi          psi     Plot Reference:
                           4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
             6%

 S1+S2+S3           4S     Part 5 (5.3.2) Load Case 2
      641       59,200     Min Prin. Stress = -752. (88% Neg, 0% NegHi)
      psi          psi     Plot Reference:
                           5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
             1%

  Pl+Pb+Q          SPS     Primary+Secondary (Inner) Load Case 3
    4,313       47,250     Min Prin. Stress = -1532. (97% Neg, 0% NegHi)
      psi          psi     Plot Reference:
                           6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
             9%

  Pl+Pb+Q          SPS     Primary+Secondary (Outer) Load Case 3
    4,415       47,250     Min Prin. Stress = -1532. (97% Neg, 0% NegHi)
      psi          psi     Plot Reference:
                           7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
             9%

 Membrane         User     Component Evaluation Load Case 3
    1,426       47,250     Min Prin. Stress = -1532. (97% Neg, 0% NegHi)
      psi          psi     Plot Reference:
                           8) Membrane < User (OPE,Membrane) Case 3
             3%

  Bending         User     Component Evaluation Load Case 3
    4,288       47,250     Min Prin. Stress = -1532. (97% Neg, 0% NegHi)
      psi          psi     Plot Reference:
                           9) Bending < User (OPE,Bending) Case 3
             9%

  Pl+Pb+Q          SPS     Primary+Secondary (Inner) Load Case 4
    4,313       47,250     Min Prin. Stress = -1532. (97% Neg, 0% NegHi)
      psi          psi     Plot Reference:
                           15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
             9%

  Pl+Pb+Q          SPS     Primary+Secondary (Outer) Load Case 4
    4,415       47,250     Min Prin. Stress = -1532. (97% Neg, 0% NegHi)
      psi          psi     Plot Reference:
                           16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
             9%

Pl+Pb+Q+F    Damage Ratio  Primary+Secondary+Peak (Inner) Load Case 4
    5,823     0.000 Life   Stress Concentration Factor = 1.350
      psi     0.049 Stress Strain Concentration Factor = 1.000
                           Cycles Allowed for this Stress = 1.0000E11
Allowable                  "B31" Fatigue Stress Allowable = 78750.0
  118,449                  Markl Fatigue Stress Allowable = 95657.0
      psi                  WRC 474 Mean Cycles to Failure = 77,036,216.
                           WRC 474 99% Probability Cycles = 17,896,554.
       4%                  WRC 474 95% Probability Cycles = 24,847,464.
                           BS5500 Allowed Cycles(Curve F) = 14,527,700.
                           Membrane-to-Bending Ratio = 0.190
                           Bending-to-PL+PB+Q Ratio = 0.840
                           Plot Reference:
                           17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Pl+Pb+Q+F    Damage Ratio  Primary+Secondary+Peak (Outer) Load Case 4
    5,961     0.000 Life   Stress Concentration Factor = 1.350
      psi     0.050 Stress Strain Concentration Factor = 1.000
                           Cycles Allowed for this Stress = 1.0000E11
Allowable                  "B31" Fatigue Stress Allowable = 78750.0
  118,449                  Markl Fatigue Stress Allowable = 95657.0
      psi                  WRC 474 Mean Cycles to Failure = 70,354,992.
                           WRC 474 99% Probability Cycles = 16,344,413.
       5%                  WRC 474 95% Probability Cycles = 22,692,484.
                           BS5500 Allowed Cycles(Curve F) = 12,919,162.
                           Membrane-to-Bending Ratio = 0.190
```

```
                              Bending-to-PL+PB+Q Ratio = 0.840
                              Plot Reference:
                              18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4


Nozzle 1 Next to Shell

       Pl          SPL        Primary Membrane Load Case 2
    2,492       22,200        Min Prin. Stress = -1877. (58% Neg, 0% NegHi)
      psi          psi        Plot Reference:
                              1) Pl < SPL (SUS,Membrane) Case 2
           11%

       Qb          SPS        Primary Bending Load Case 2
    3,718       47,250        Min Prin. Stress = -1877. (58% Neg, 0% NegHi)
      psi          psi        Plot Reference:
                              2) Qb < SPS (SUS,Bending) Case 2
            7%

  Pl+Pb+Q          SPS        Primary+Secondary (Inner) Load Case 2
    5,127       47,250        Min Prin. Stress = -1877. (58% Neg, 0% NegHi)
      psi          psi        Plot Reference:
                              3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
           10%

  Pl+Pb+Q          SPS        Primary+Secondary (Outer) Load Case 2
    3,858       47,250        Min Prin. Stress = -1877. (58% Neg, 0% NegHi)
      psi          psi        Plot Reference:
                              4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
            8%

 S1+S2+S3           4S        Part 5 (5.3.2) Load Case 2
    1,837       59,200        Min Prin. Stress = -1877. (58% Neg, 0% NegHi)
      psi          psi        Plot Reference:
                              5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
            3%

  Pl+Pb+Q          SPS        Primary+Secondary (Inner) Load Case 3
    7,150       47,250        Min Prin. Stress = -1880. (76% Neg, 0% NegHi)
      psi          psi        Plot Reference:
                              6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
           15%

  Pl+Pb+Q          SPS        Primary+Secondary (Outer) Load Case 3
    7,755       47,250        Min Prin. Stress = -1880. (76% Neg, 0% NegHi)
      psi          psi        Plot Reference:
                              7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
           16%

 Membrane         User        Component Evaluation Load Case 3
    3,642       47,250        Min Prin. Stress = -1880. (76% Neg, 0% NegHi)
      psi          psi        Plot Reference:
                              8) Membrane < User (OPE,Membrane) Case 3
            7%

  Bending         User        Component Evaluation Load Case 3
    6,492       47,250        Min Prin. Stress = -1880. (76% Neg, 0% NegHi)
      psi          psi        Plot Reference:
                              9) Bending < User (OPE,Bending) Case 3
           13%

  Pl+Pb+Q          SPS        Primary+Secondary (Inner) Load Case 4
    7,150       47,250        Min Prin. Stress = -1880. (76% Neg, 0% NegHi)
      psi          psi        Plot Reference:
                              15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
           15%

  Pl+Pb+Q          SPS        Primary+Secondary (Outer) Load Case 4
    7,755       47,250        Min Prin. Stress = -1880. (76% Neg, 0% NegHi)
      psi          psi        Plot Reference:
                              16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
           16%

Pl+Pb+Q+F   Damage Ratio      Primary+Secondary+Peak (Inner) Load Case 4
    9,653     0.000 Life      Stress Concentration Factor = 1.350
      psi     0.081 Stress    Strain Concentration Factor = 1.000
                              Cycles Allowed for this Stress = 1.0000E11
Allowable                     "B31" Fatigue Stress Allowable = 78750.0
  118,449                     Markl Fatigue Stress Allowable = 95657.0
      psi                     WRC 474 Mean Cycles to Failure = 33,323,274.
                              WRC 474 99% Probability Cycles = 7,741,438.
       8%                     WRC 474 95% Probability Cycles = 10,748,177.
```

```
                           BS5500 Allowed Cycles(Curve F) = 6,484,576.
                           Membrane-to-Bending Ratio = 0.553
                           Bending-to-PL+PB+Q Ratio = 0.644
                           Plot Reference:
                           17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Pl+Pb+Q+F   Damage Ratio   Primary+Secondary+Peak (Outer) Load Case 4
   10,469    0.000 Life    Stress Concentration Factor = 1.350
      psi    0.088 Stress  Strain Concentration Factor = 1.000
                           Cycles Allowed for this Stress = 1.0000E11
Allowable                  "B31" Fatigue Stress Allowable = 78750.0
  118,449                  Markl Fatigue Stress Allowable = 95657.0
      psi                  WRC 474 Mean Cycles to Failure = 24,950,874.
                           WRC 474 99% Probability Cycles = 5,796,419.
       8%                  WRC 474 95% Probability Cycles = 8,047,713.
                           BS5500 Allowed Cycles(Curve F) = 5,082,974.
                           Membrane-to-Bending Ratio = 0.559
                           Bending-to-PL+PB+Q Ratio = 0.642
                           Plot Reference:
                           18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4


Nozzle 1

       Pl           SPL    Primary Membrane Load Case 2
      350        22,200    Min Prin. Stress = -78. ( 0% Neg, 0% NegHi)
      psi           psi    Plot Reference:
                           1) Pl < SPL (SUS,Membrane) Case 2
             1%

       Qb           SPS    Primary Bending Load Case 2
      367        47,250    Min Prin. Stress = -78. ( 0% Neg, 0% NegHi)
      psi           psi    Plot Reference:
                           2) Qb < SPS (SUS,Bending) Case 2
             0%

  Pl+Pb+Q           SPS    Primary+Secondary (Inner) Load Case 2
      612        47,250    Min Prin. Stress = -78. ( 0% Neg, 0% NegHi)
      psi           psi    Plot Reference:
                           3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
             1%

  Pl+Pb+Q           SPS    Primary+Secondary (Outer) Load Case 2
      373        47,250    Min Prin. Stress = -78. ( 0% Neg, 0% NegHi)
      psi           psi    Plot Reference:
                           4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
             0%

 S1+S2+S3            4S    Part 5 (5.3.2) Load Case 2
      579        59,200    Min Prin. Stress = -78. ( 0% Neg, 0% NegHi)
      psi           psi    Plot Reference:
                           5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
             0%

  Pl+Pb+Q           SPS    Primary+Secondary (Inner) Load Case 3
    2,068        47,250    Min Prin. Stress = -1811. (76% Neg, 0% NegHi)
      psi           psi    Plot Reference:
                           6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
             4%

  Pl+Pb+Q           SPS    Primary+Secondary (Outer) Load Case 3
    2,354        47,250    Min Prin. Stress = -1811. (76% Neg, 0% NegHi)
      psi           psi    Plot Reference:
                           7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
             4%

 Membrane          User    Component Evaluation Load Case 3
    2,197        47,250    Min Prin. Stress = -1811. (76% Neg, 0% NegHi)
      psi           psi    Plot Reference:
                           8) Membrane < User (OPE,Membrane) Case 3
             4%

  Bending          User    Component Evaluation Load Case 3
      631        47,250    Min Prin. Stress = -1811. (76% Neg, 0% NegHi)
      psi           psi    Plot Reference:
                           9) Bending < User (OPE,Bending) Case 3
             1%

  Pl+Pb+Q           SPS    Primary+Secondary (Inner) Load Case 4
    2,068        47,250    Min Prin. Stress = -1811. (76% Neg, 0% NegHi)
      psi           psi    Plot Reference:
                           15) Pl+Pb+Q < SPS (EXP,Inside) Case 4
```

```
               4%

  Pl+Pb+Q           SPS      Primary+Secondary (Outer) Load Case 4
    2,354        47,250      Min Prin. Stress = -1811. (76% Neg, 0% NegHi)
      psi           psi      Plot Reference:
                             16) Pl+Pb+Q < SPS (EXP,Outside) Case 4
               4%

Pl+Pb+Q+F     Damage Ratio   Primary+Secondary+Peak (Inner) Load Case 4
    2,068      0.000 Life    Stress Concentration Factor = 1.000
      psi      0.017 Stress  Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 78750.0
  118,449                    Markl Fatigue Stress Allowable = 95657.0
      psi                    WRC 474 Mean Cycles to Failure = 1.3248E9
                             WRC 474 99% Probability Cycles = 3.0777E8
       1%                    WRC 474 95% Probability Cycles = 4.2730E8
                             BS5500 Allowed Cycles(Curve F) = 2.4330E9
                             Membrane-to-Bending Ratio = 7.529
                             Bending-to-PL+PB+Q Ratio = 0.117
                             Plot Reference:
                             17) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Pl+Pb+Q+F     Damage Ratio   Primary+Secondary+Peak (Outer) Load Case 4
    2,354      0.000 Life    Stress Concentration Factor = 1.000
      psi      0.020 Stress  Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 78750.0
  118,449                    Markl Fatigue Stress Allowable = 95657.0
      psi                    WRC 474 Mean Cycles to Failure = 8.8296E8
                             WRC 474 99% Probability Cycles = 2.0512E8
       1%                    WRC 474 95% Probability Cycles = 2.8479E8
                             BS5500 Allowed Cycles(Curve F) = 1.2733E9
                             Membrane-to-Bending Ratio = 7.529
                             Bending-to-PL+PB+Q Ratio = 0.117
                             Plot Reference:
                             18) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4
```

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```
Stress Intensification Factors
FEPipe Version 15.0            Jobname: NOZZLE                 $P
Released Jan. 2021              7:08pm   OCT 25,2021



Stress Intensification Factors                          $X


Branch/Nozzle Sif Summary

                  Peak      Primary    Secondary      SSI
Axial   :        2.588       1.917       3.833       1.244
Inplane :        1.273       0.943       1.886       1.084
Outplane:        1.248       0.924       1.848       1.052
Torsion :        0.628       0.760       0.931       0.793
Pressure:        5.203       3.854       7.708       1.461

The above stress intensification factors are to be used
in a beam-type analysis of the piping system.  Inplane,
Outplane and Torsional sif's should be used with the
matching branch pipe whose diameter and thickness is given
below.  The axial sif should be used to intensify the
axial stress in the branch pipe calculated by F/A.  The
pressure sif should be used to intensify the nominal
pressure stress in the PARENT or HEADER, calculated
from PDo/2T. B31 calculations use mean diameters and
Section VIII calculations use outside diameters. SSIs are
based on peak stress factors and correlated test results.

Pipe OD :        6.625  in.
Pipe Thk:        0.864  in.
Z approx:       22.522  cu.in.
Z exact :       20.025  cu.in.

  (SSI = SIF^x)        Axial   Inpl    Outpl   Tors    Pres
SIF/SSI Exponents:     0.684  -0.244  -0.357   0.590   0.818
```

```
SIF/SSI exponent based on relationship between primary and
peak stress factors from the finite element analysis.

B31.3 Branch Pressure i-factor =       19.771
      Header Pressure i-factor =       11.298

The B31.3 pressure i-factors should be used with with
F/A, where F is the axial force due to pressure, and
A is the area of the pipe wall. This is equivalent to
finding the pressure stress from (ip)(PD/4T).

B31.3   (Branch)
Peak Stress Sif ....    0.000         Axial
                        1.000         Inplane
                        1.000         Outplane
                        1.000         Torsional
B31.1  (Branch)
Peak Stress Sif ....    0.000         Axial
                        1.000         Inplane
                        1.000         Outplane
                        1.000         Torsional
WRC 330  (Branch)
Peak Stress Sif ....    0.000         Axial
                        1.000         Inplane
                        1.500         Outplane
                        1.000         Torsional
```



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```
Allowable Loads
FEPipe Version 15.0          Jobname: NOZZLE                 $P
Released Jan. 2021            7:08pm   OCT 25,2021



Allowable Loads                                       $X
```

| SECONDARY Load Type (Range): | | Maximum Individual Occuring | Conservative Simultaneous Occuring | Realistic Simultaneous Occuring |
|---|---|---|---|---|
| Axial Force | (lb. ) | 192746. | 59003. | 88504. |
| Inplane Moment | (in. lb.) | 501744. | 108606. | 230388. |
| Outplane Moment | (in. lb.) | 511925. | 110810. | 235063. |
| Torsional Moment | (in. lb.) | 1016267. | 311097. | 466645. |
| Pressure | (psi ) | 967.75 | 105.00 | 105.00 |

| PRIMARY Load Type: | | Maximum Individual Occuring | Conservative Simultaneous Occuring | Realistic Simultaneous Occuring |
|---|---|---|---|---|
| Axial Force | (lb. ) | 181120. | 53403. | 80104. |
| Inplane Moment | (in. lb.) | 471480. | 98298. | 208521. |
| Outplane Moment | (in. lb.) | 481047. | 100292. | 212752. |
| Torsional Moment | (in. lb.) | 584739. | 172408. | 258611. |
| Pressure | (psi ) | 909.38 | 105.00 | 105.00 |

NOTES:

1) Maximum Individual Occuring Loads are the maximum allowed values of the respective loads if all other load components are zero, i.e. the listed axial force may be applied if the inplane, outplane and torsional moments, and the pressure are zero.

2) The Conservative Allowable Simultaneous loads are the maximum loads that can be applied simultaneously. A conservative stress combination equation is used that typically produces stresses within 50-70% of the allowable stress.

3) The Realistic Allowable Simultaneous loads are the maximum loads that can be applied simultaneously. A more realistic stress combination equation is used based on experience at Paulin Research. Stresses are typically produced within 80-105% of the allowable.

4) Secondary allowable loads are limits for expansion and operating piping loads.

5) Primary allowable loads are limits for weight, primary and sustained type piping loads.

6) High D/T low pressure systems may be subject to instability and should be checked when compressive stresses are present.

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Compressive Stress Summary
FEPipe Version 15.0 Jobname: NOZZLE $P
Released Jan. 2021 7:08pm OCT 25,2021

Compressive Stress Summary (psi) $X

Nomenclature:
-------------
Min Stress - Compressive Membrane and Bending Stress
Pts in Region - No. of nodes in the model region
>5% Compression - 5% or more of Compressive Stress Limit
>50% Compression - 50% or more of Compressive Stress Limit

Compressive Stress Limit = -0.55 Min(Sy, kEt/R), Section slenderness ratio (elastic buckling) not considered.

| # | Load Type | Case | Min Stress | Pts in Region | >5% Compression and Bending | >50% Compression and Bending | Region |
|---|---|---|---|---|---|---|---|
| 1 | SUSTAINED | 2 | -1877. | 504 | 58% | 0% | Nozzle 1 Next to Shell |
| 2 | OPERATING | 3 | -1880. | 504 | 76% | 0% | Nozzle 1 Next to Shell |
| 3 | EXPANSION | 4 | -1880. | 504 | 76% | 0% | Nozzle 1 Next to Shell |
| 4 | SUSTAINED | 2 | -78. | 456 | 0% | 0% | Nozzle 1 |
| 5 | OPERATING | 3 | -1811. | 456 | 76% | 0% | Nozzle 1 |
| 6 | EXPANSION | 4 | -1811. | 456 | 76% | 0% | Nozzle 1 |
| 7 | SUSTAINED | 2 | -752. | 960 | 88% | 0% | Shell Next to Nozzle 1 |
| 8 | OPERATING | 3 | -1532. | 960 | 97% | 0% | Shell Next to Nozzle 1 |
| 9 | EXPANSION | 4 | -1532. | 960 | 97% | 0% | Shell Next to Nozzle 1 |

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Flexibilities
FEPipe Version 15.0 Jobname: NOZZLE $P
Released Jan. 2021 7:08pm OCT 25,2021

Flexibilities $X

The following stiffnesses should be used in a piping, "beam-type" analysis of the intersection. The stiff- nesses should be inserted at the surface of the branch/header or nozzle/vessel junction. The general characteristics used for the branch pipe should be:

Outside Diameter = 6.625 in.
Wall Thickness = 0.864 in.

Axial Translational Stiffness = 5670338. lb./in.
Inplane Rotational Stiffness = 5562630. in.lb./deg
Outplane Rotational Stiffness = 6171660. in.lb./deg
Torsional Rotational Stiffness = 360741056. in.lb./deg

Estimated Radial Shell Displacement due to Allowable Loads
SECONDARY:
Axial (in.) = 0.034 In-Plane (in.) = 0.005 Out-Plane (in.) = 0.004

```
PRIMARY
Axial (in.) =  0.032  In-Plane (in.) =  0.004  Out-Plane (in.) =  0.004

Secondary Conservative Displacement =  0.012 in.
Secondary Realistic    Displacement =  0.020 in.

Primary Conservative Displacement =  0.011 in.
Primary Realistic Displacement    =  0.018 in.


Intersection Flexibility Factors for Branch/Nozzle
:

Find axial stiffness: K = 3EI/(kd)^3  lb./in.
Find bending and torsional stiffnesses: K = EI/(kd)  in.lb.per radian.
The EI product is   0.18772E+10   lb.in.^2
The value of (d) to use is:   5.761  in..
The resulting bending stiffness is in units of force x length per radian.

Axial Flexibility Factor     (k) =     1.732
Inplane Flexibility Factor   (k) =     1.022
Outplane Flexibility Factor  (k) =     0.921
Torsional Flexibility Factor (k) =     0.016
```

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*Finite Element Model*

- Finite Element Model

*Area of Discontinuity at Nozzle*

- 1) Pl < SPL (SUS Membrane) Case 2
- 2) Qb < SPS (SUS Bending) Case 2
- 3) Pl+Pb+Q < SPS (SUS Inside) Case 2
- 4) Pl+Pb+Q < SPS (SUS Outside) Case 2
- 5) S1+S2+S3 < 4S (SUS S1+S2+S3) Case 2
- 6) Pl+Pb+Q < SPS (OPE Inside) Case 3
- 7) Pl+Pb+Q < SPS (OPE Outside) Case 3
- 8) Membrane < User (OPE Membrane) Case 3
- 9) Bending < User (OPE Bending) Case 3
- 15) Pl+Pb+Q < SPS (EXP Inside) Case 4
- 16) Pl+Pb+Q < SPS (EXP Outside) Case 4
- 17) Pl+Pb+Q+F < 2Sa (EXP Inside) Case 4
- 18) Pl+Pb+Q+F < 2Sa (EXP Outside) Case 4
- 10) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 5
- 11) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 6
- 12) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 7
- 13) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 8
- 14) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 9

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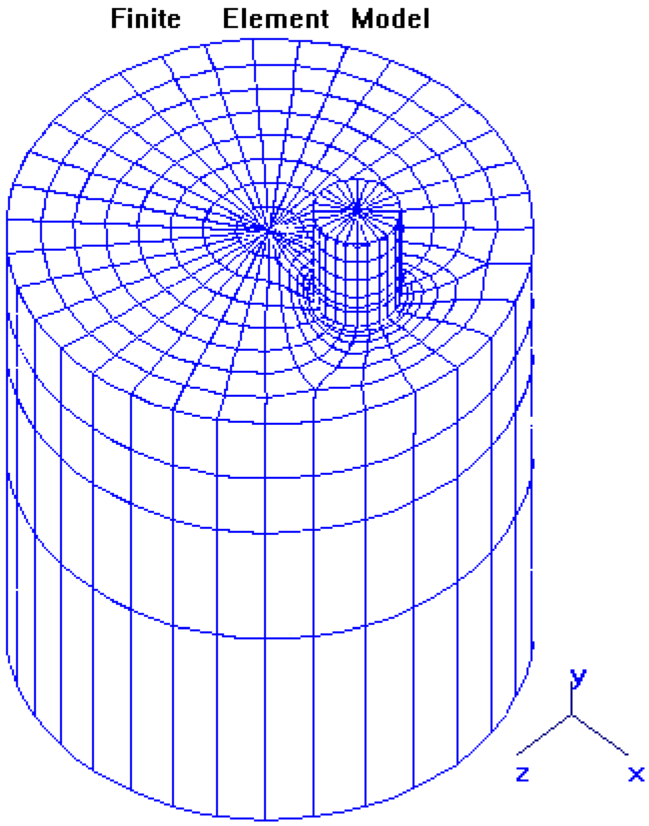


3d

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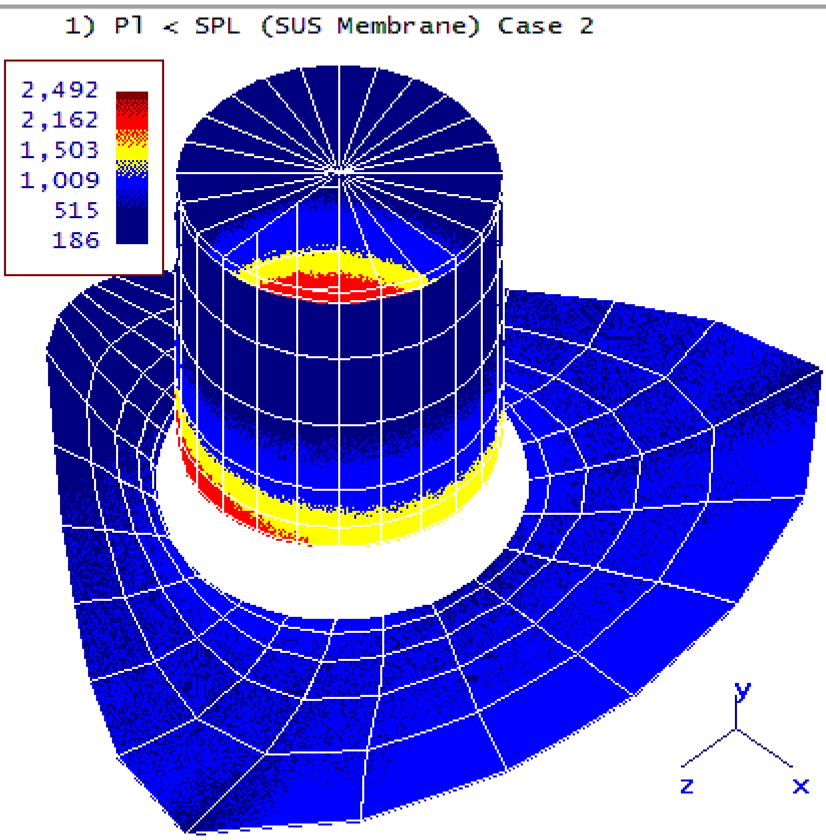


3d(Small) 3d

3d(Deformed)

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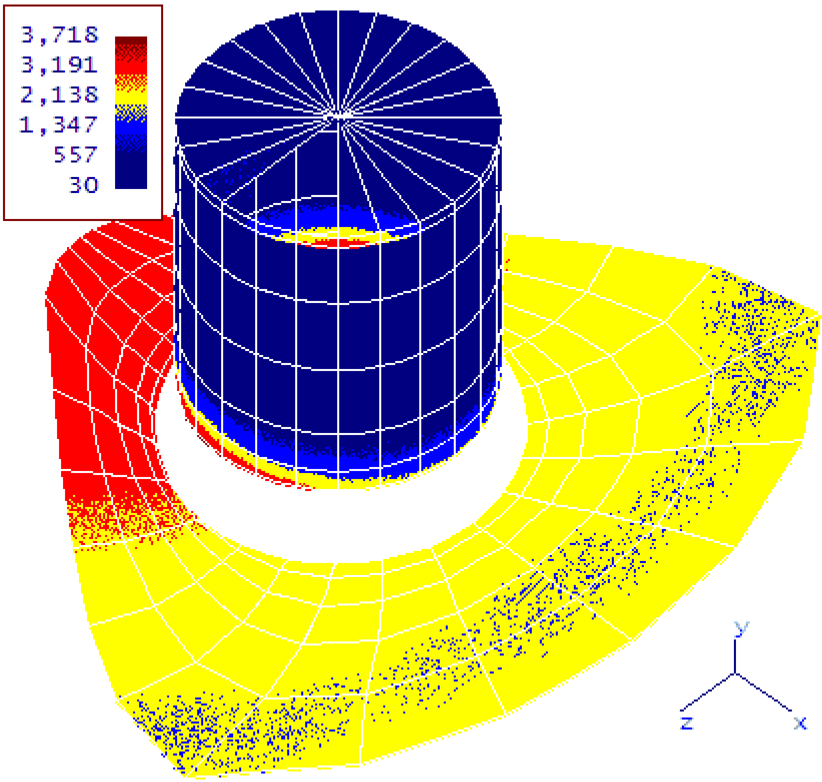
2) Qb < SPS (SUS Bending) Case 2




3d(Small) 3d

- 3d(Deformed)

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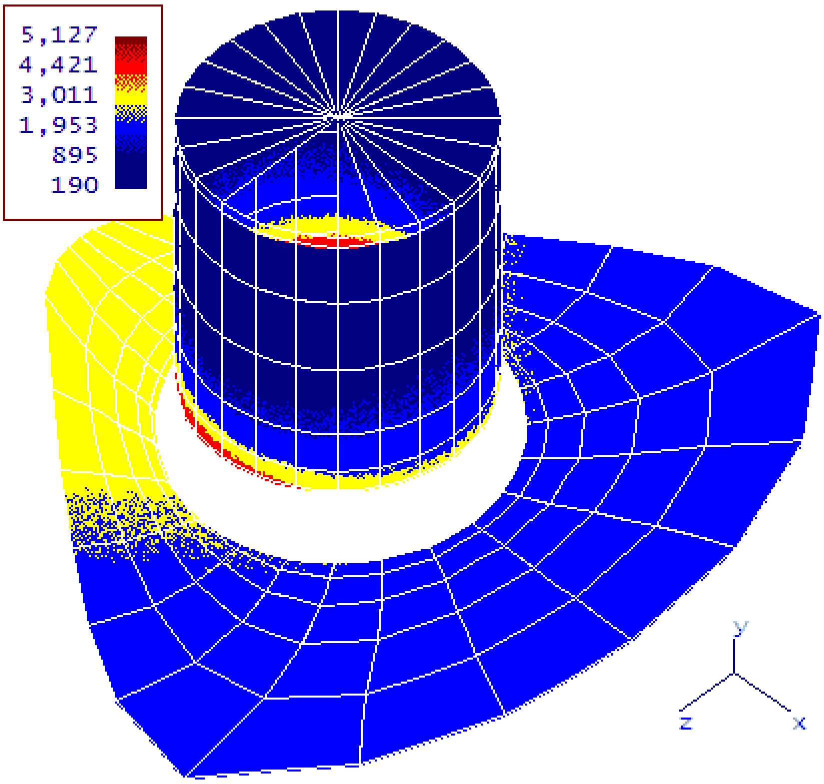
3) Pl+Pb+Q < SPS (SUS Inside) Case 2

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- 3d(Deformed)

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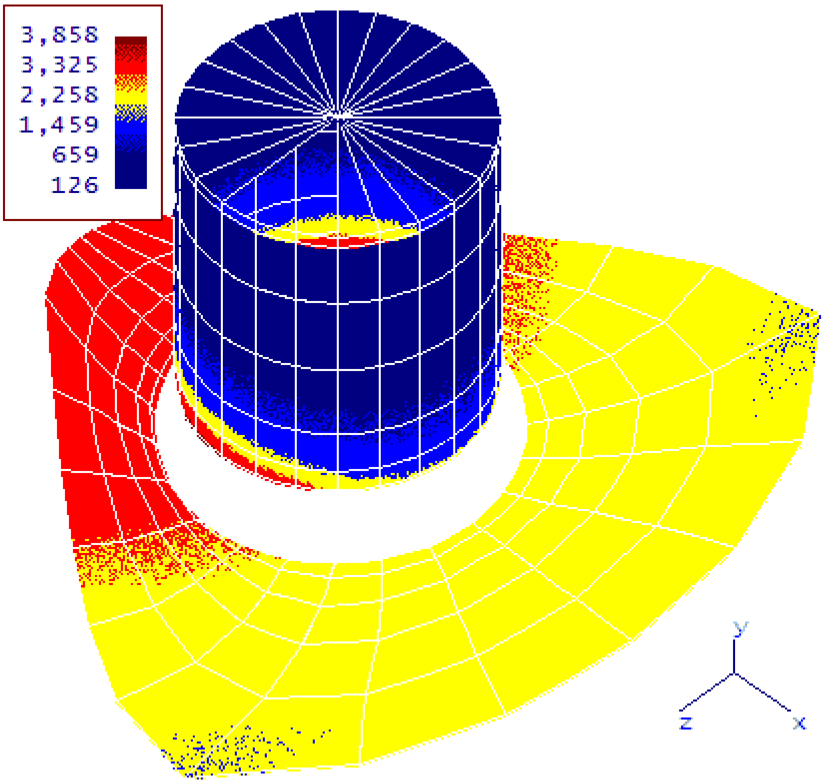
4) Pl+Pb+Q < SPS (SUS Outside) Case 2




3d(Small) 3d

- 3d(Deformed)
- 

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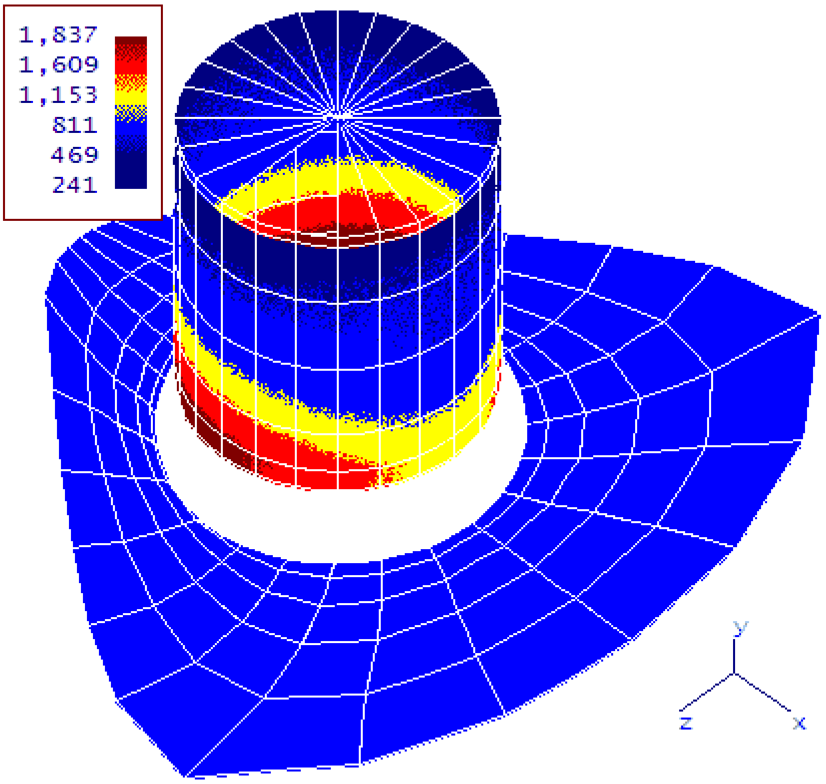
5) S1+S2+S3 < 4S (SUS S1+S2+S3) Case 2




3d(Small) 3d

- 3d(Deformed)
- 

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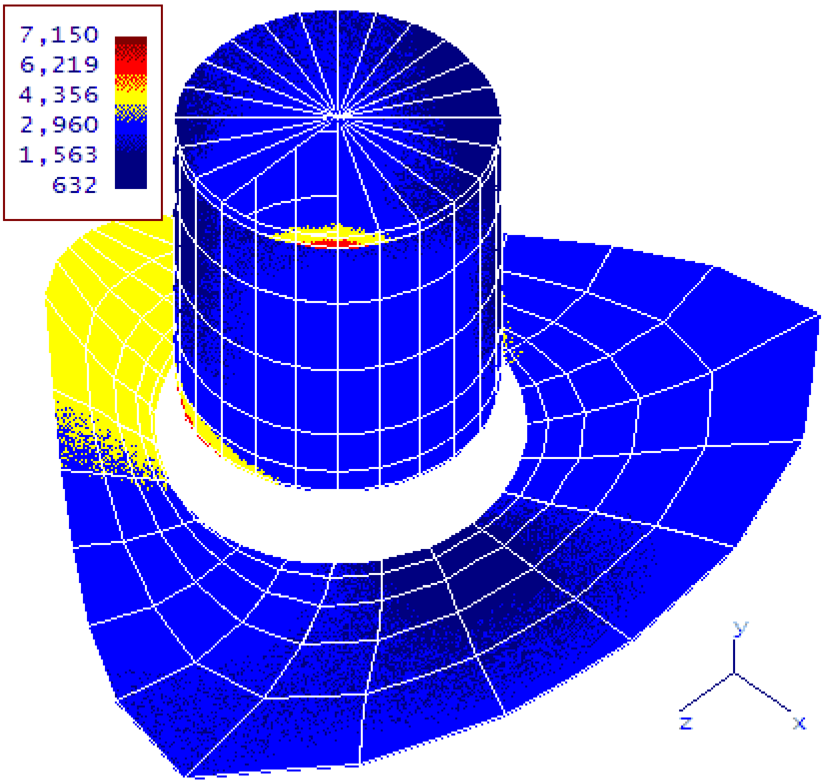
6) Pl+Pb+Q < SPS (OPE Inside) Case 3




- 3d(Small) 3d

  3d(Deformed)

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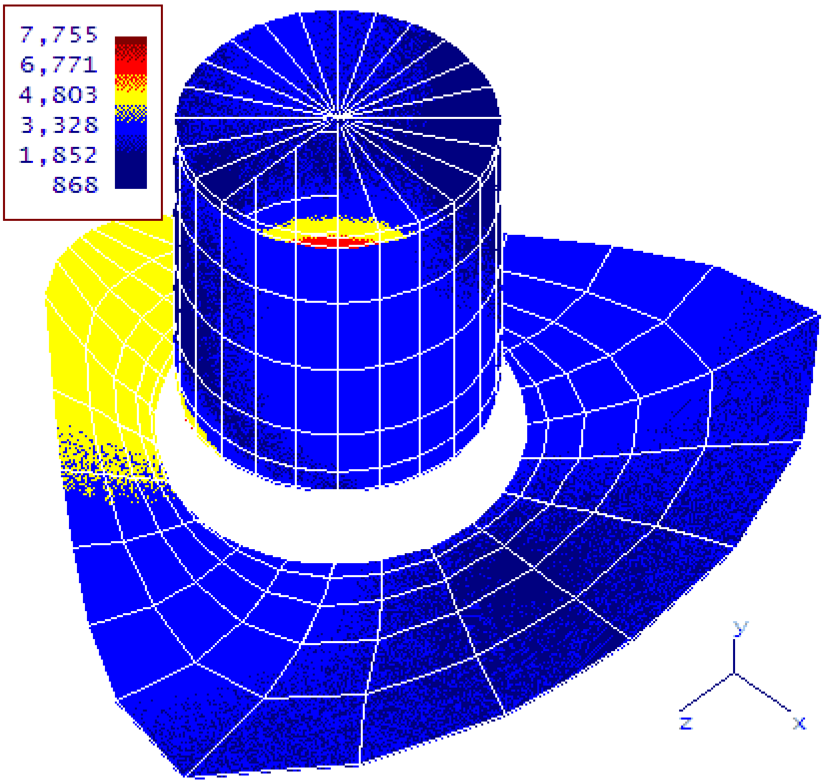
7) Pl+Pb+Q < SPS (OPE Outside) Case 3




- 3d(Small) 3d

  3d(Deformed)

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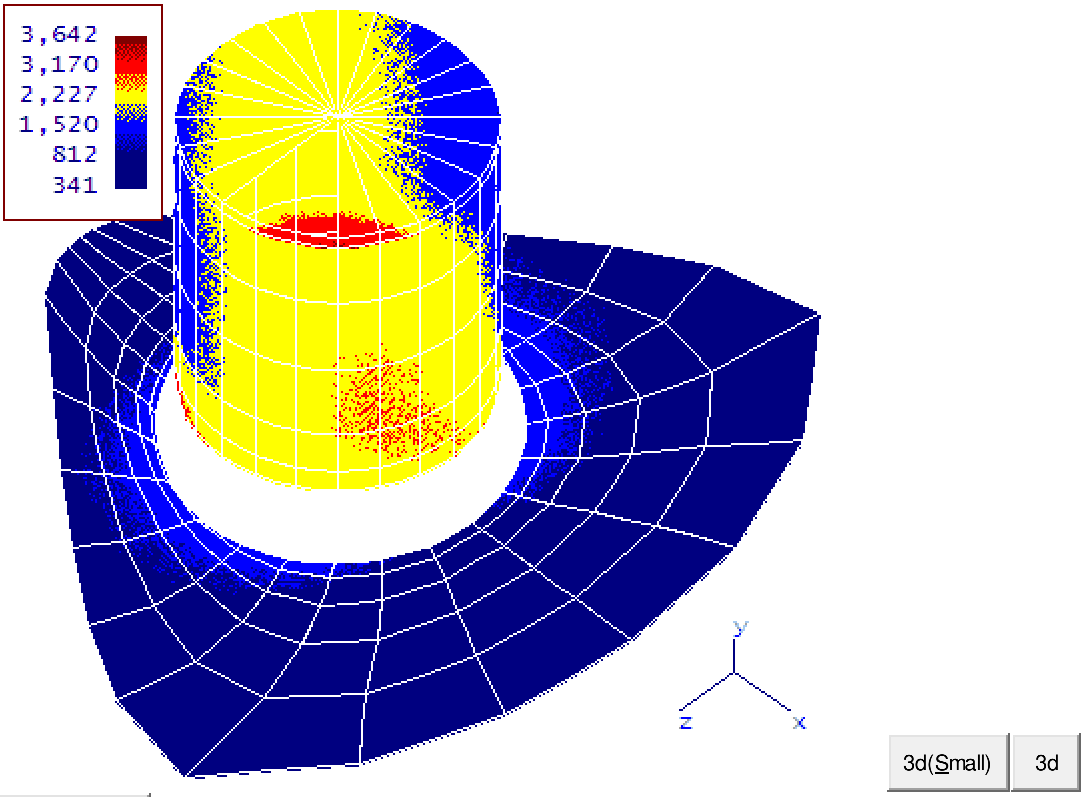
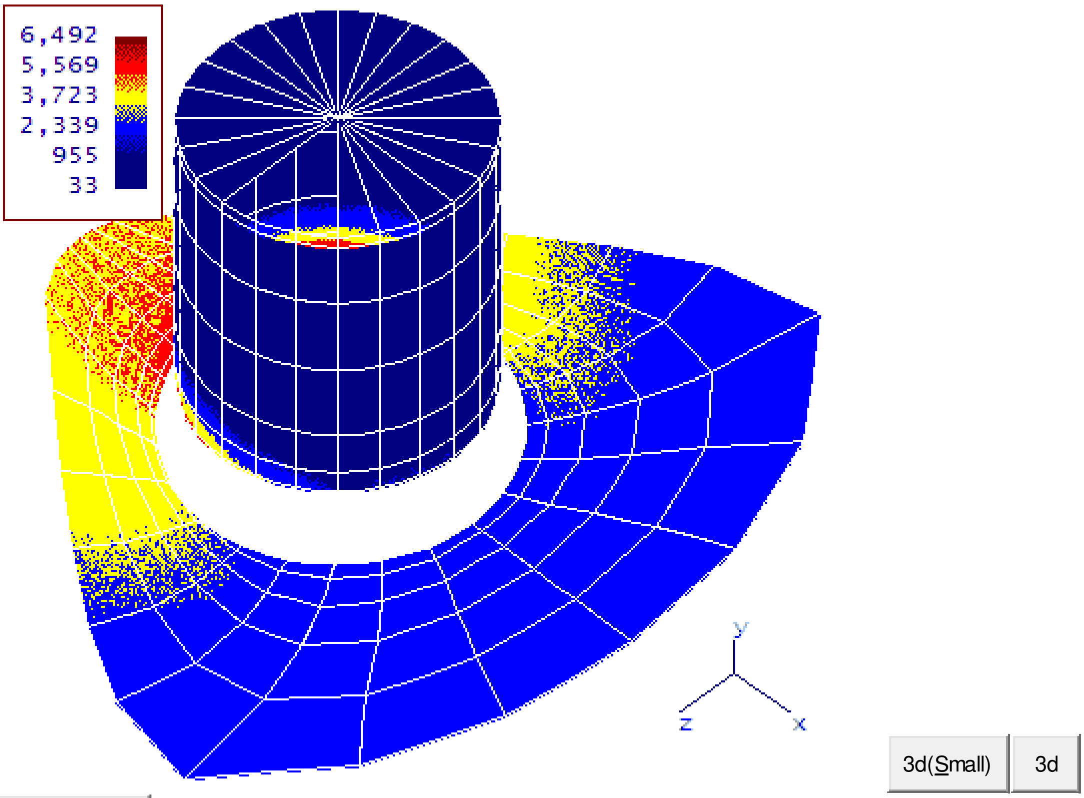
8) Membrane < User (OPE Membrane) Case 3



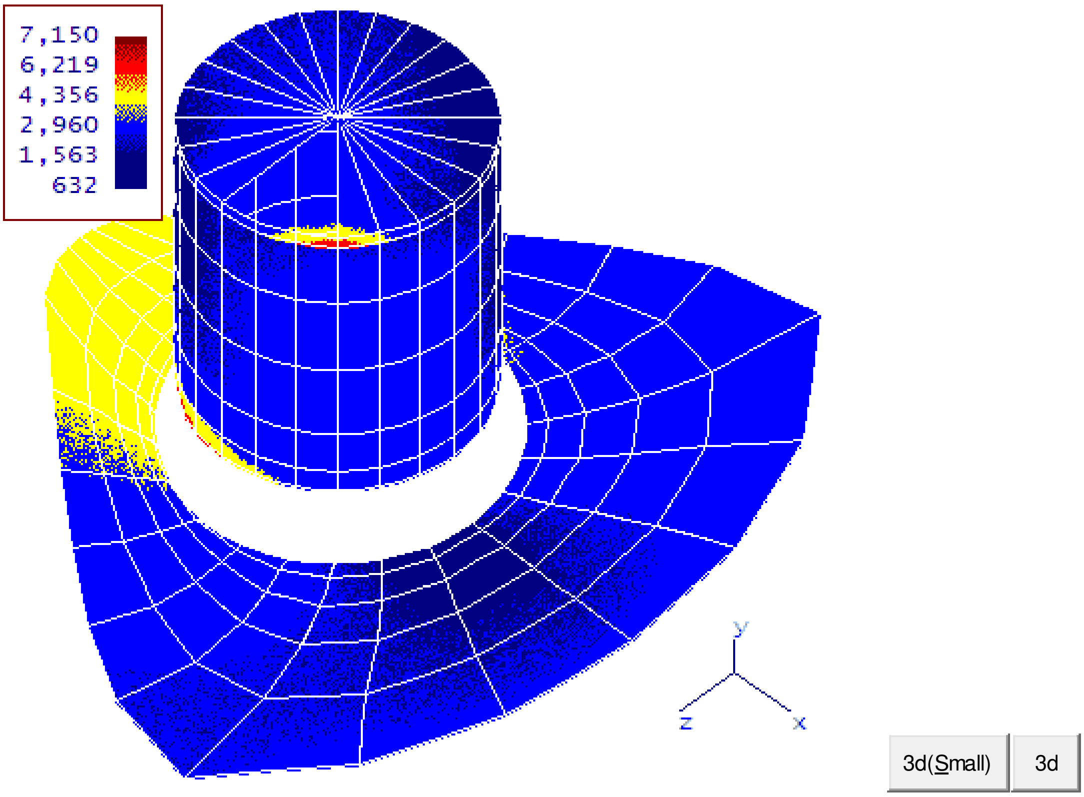

- 3d(Deformed)

- 9) Bending < User (OPE Bending) Case 3

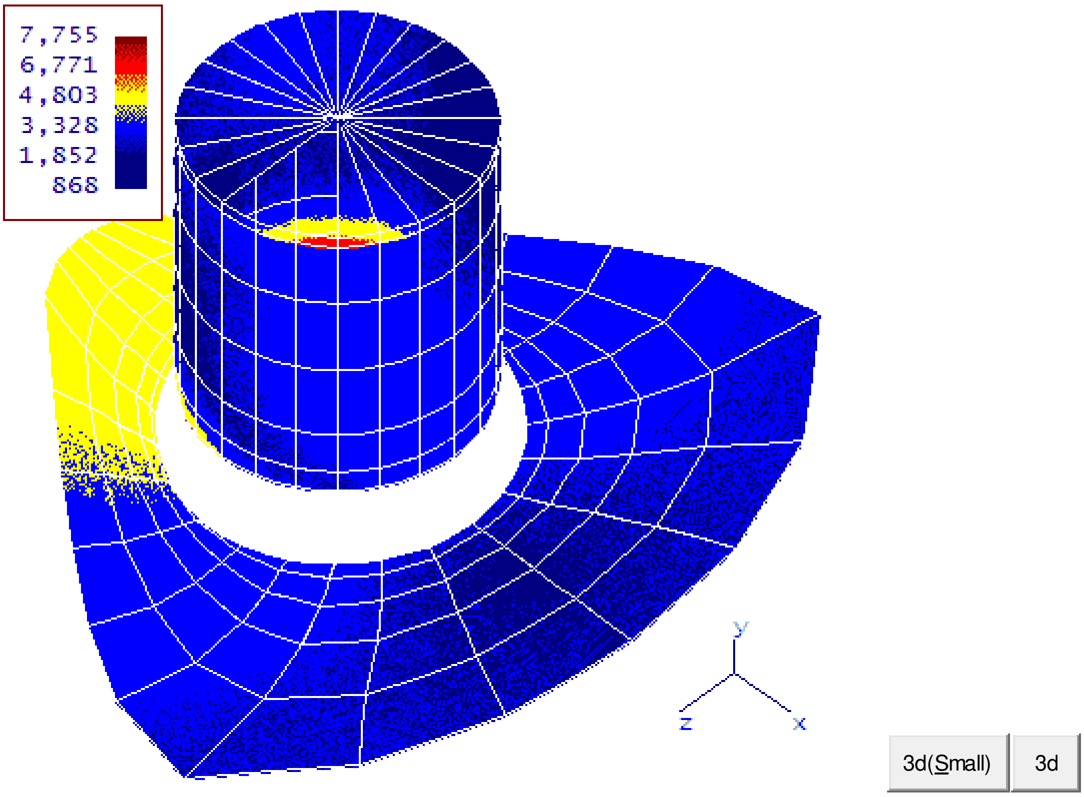



- 3d(Deformed)
- 

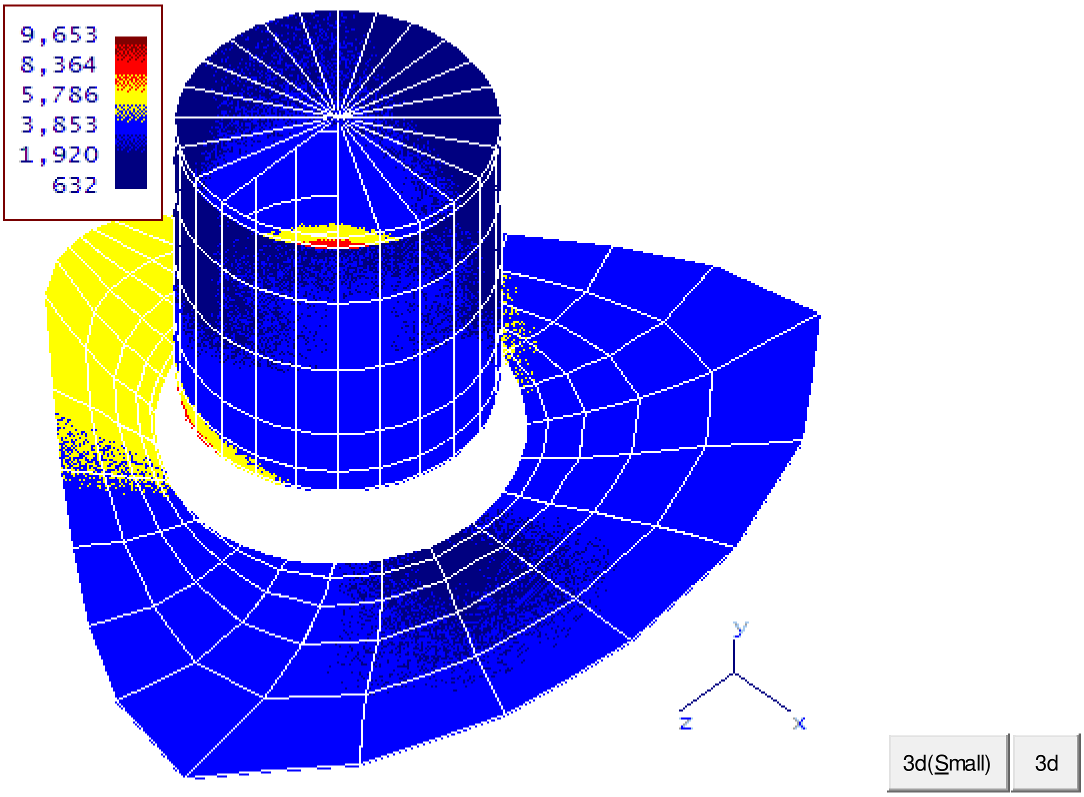
15) Pl+Pb+Q < SPS (EXP Inside) Case 4



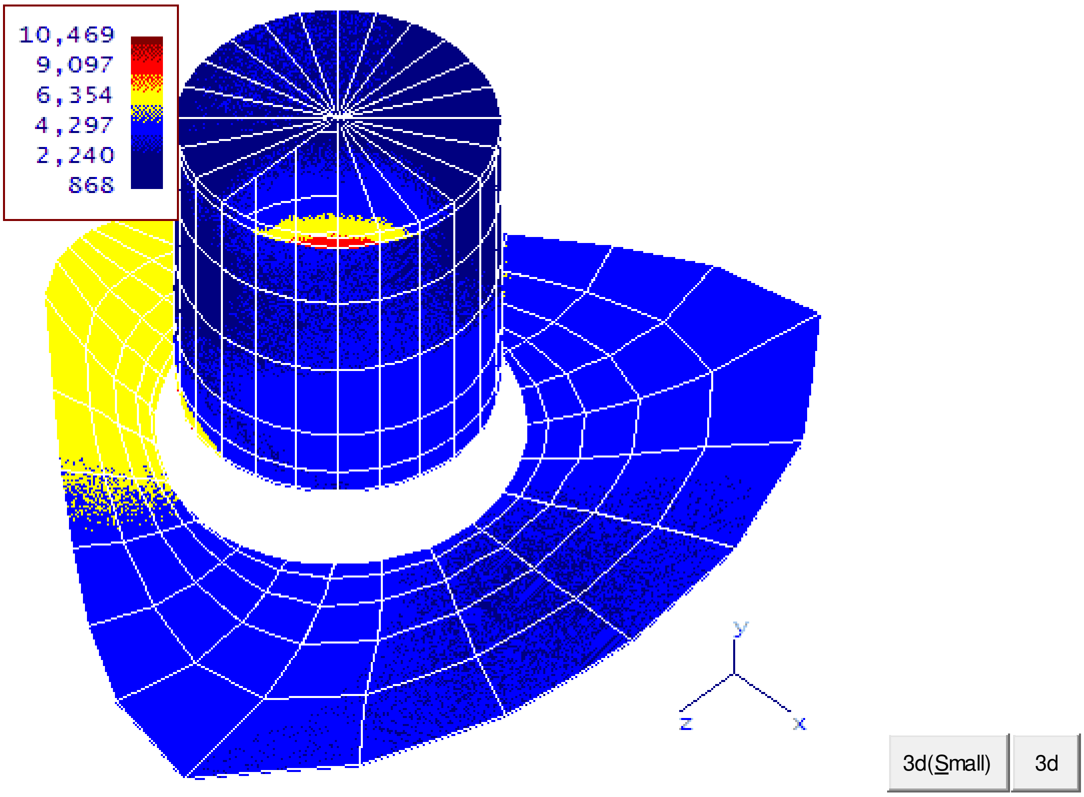

16) Pl+Pb+Q < SPS (EXP Outside) Case 4



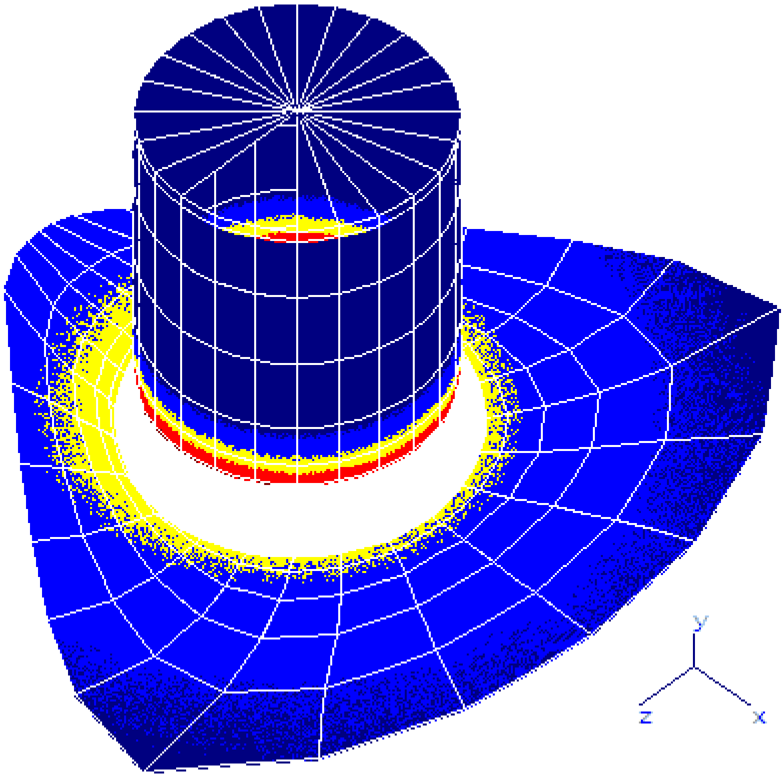
17) Pl+Pb+Q+F < 2Sa (EXP Inside) Case 4




18) Pl+Pb+Q+F < 2Sa (EXP Outside) Case 4



10) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 5




- 3d(Small) 3d
- 3d(Deformed)

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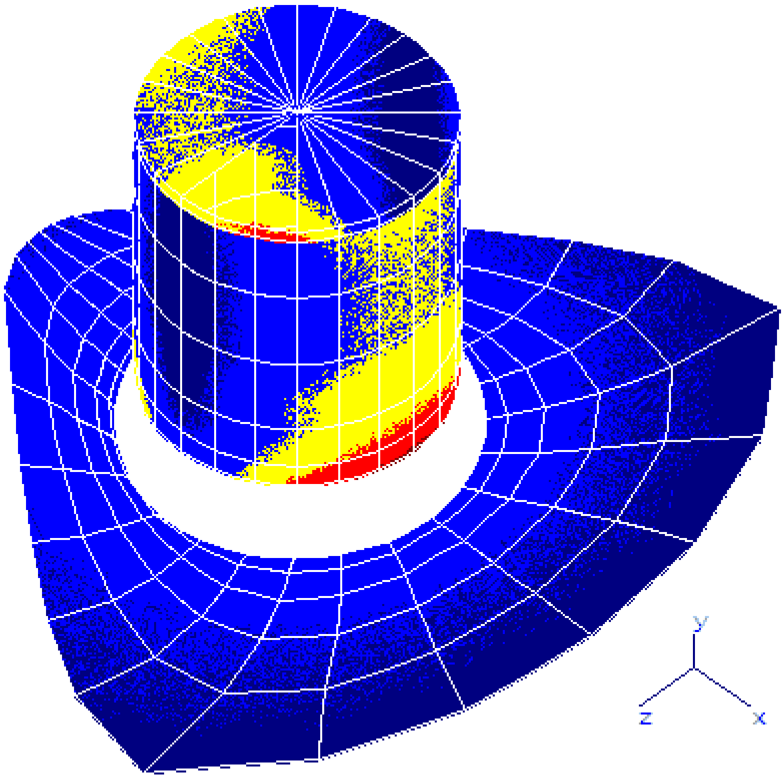
11) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 6




- 3d(Small) 3d
- 3d(Deformed)

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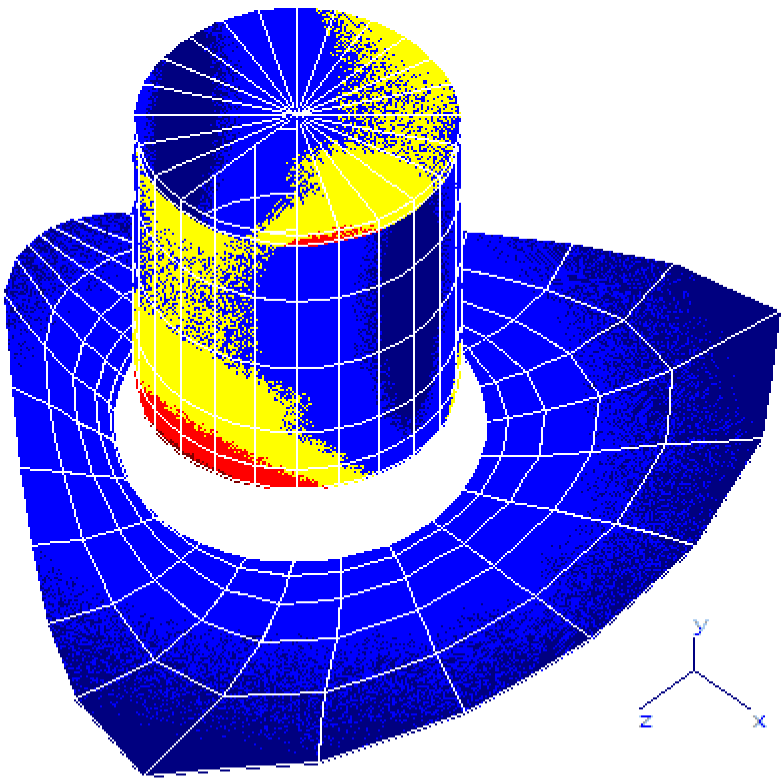
12) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 7




3d(Small) 3d

- 3d(Deformed)

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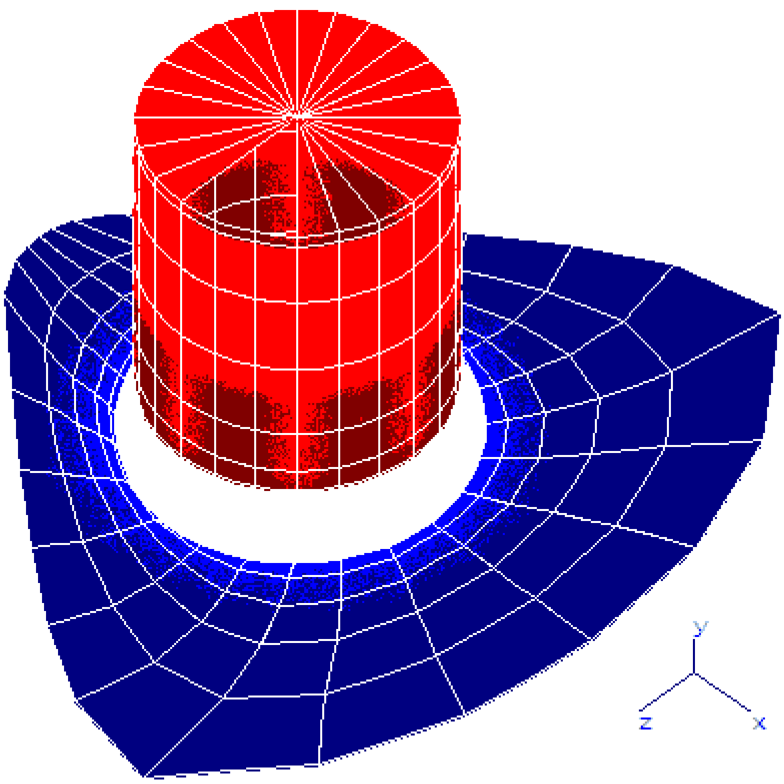
13) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 8




3d(Small) 3d

- 3d(Deformed)

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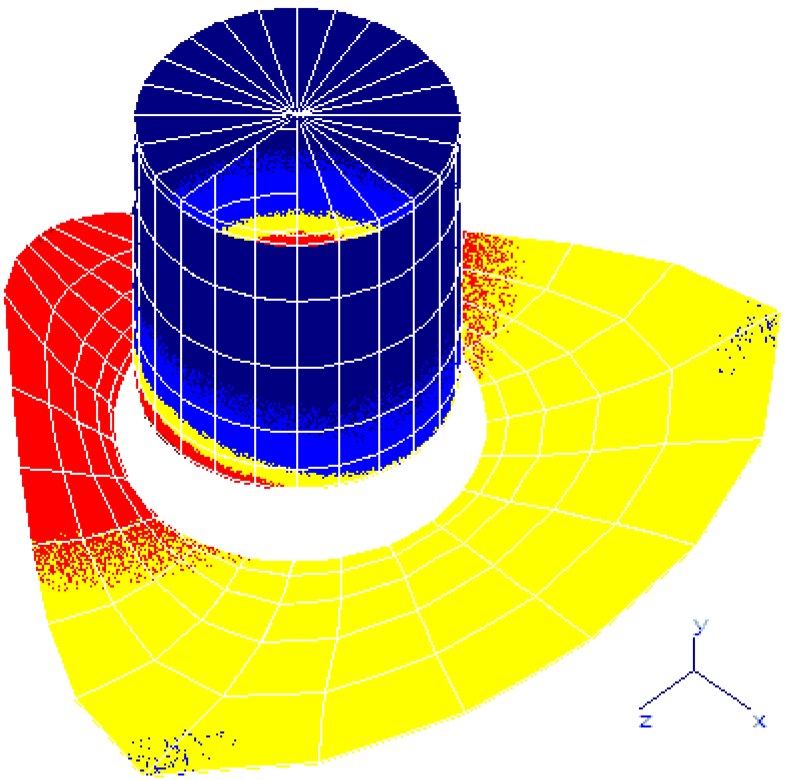
14) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 9




3d(Small) 3d

- 3d(Deformed)

**Tabular Results**

Results were generated with the finite element program FE/Pipe®. Stress results are post-processed in accordance with the rules specified in ASME Section III and ASME Section VIII, Division 2.

Analysis Time Stamp: Sat Oct 23 11:22:38 2021.



---

```
Model Notes
Model Notes

  Input Echo:

  Description:

         V-1264
         Nozzle B2

  Model Type                    : Cylindrical Shell

  Parent Geometry
         Parent Outside Diam.   :      30.030 in.
         Thickness              :       0.394 in.

  Parent Properties:
         Cold Allowable         :     16700.0 psi
         Hot  Allowable         :     14800.0 psi
         Material DB # 1071122.
         Ultimate Tensile (Amb) :     70000.0 psi
         Yield Strength (Amb)   :     25000.0 psi
         Yield Strength (Hot)   :     16400.0 psi
         Elastic Modulus (Amb)  :  28300000.0 psi
         Poissons Ratio         :       0.300
         Expansion Coefficient  :  0.9700E-05 in./in./deg.
         Weight Density         :  0.0000E+00 lb./cu.in.(NOT USED)

  Nozzle Geometry
         Nozzle Outside Diam.   :       2.375 in.
         Thickness              :       0.218 in.
         Length                 :       8.400 in.
         Nozzle Tilt Angle      :       0.000 deg.
         Distance from Top      :      29.520 in.
         Distance from Bottom   :      30.480 in.

  Nozzle Properties
         Cold Allowable         :     16700.0 psi
         Hot  Allowable         :     14800.0 psi
         Material DB # 1071622.
         Ultimate Tensile (Amb) :     70000.0 psi
         Yield Strength (Amb)   :     25000.0 psi
         Yield Strength (Hot)   :     16400.0 psi
         Elastic Modulus (Amb)  :  28300000.0 psi
         Poissons Ratio         :       0.300
         Expansion Coefficient  :  0.9700E-05 in./in./deg.
         Weight Density         :  0.0000E+00 lb./cu.in. (NOT USED)
```

```
Design Operating Cycles       :       7000.
Ambient Temperature (Deg.)    :       70.00

Uniform thermal expansion produces no stress in this geometry.
Any thermal loads will come through operating forces and
moments applied through the nozzle.

Nozzle Inside  Temperature    :      500.00 deg.
Nozzle Outside Temperature    :      500.00 deg.
Vessel Inside  Temperature    :      500.00 deg.
Vessel Outside Temperature    :      500.00 deg.

Nozzle Pressure               :       105.0 psi
Vessel Pressure               :       105.0 psi

Operating Pressure            :        10.0 psi

The operating pressure is used for secondary and peak stress
cases. The design pressure is used for primary cases. The ratio
of the operating/design pressure = 0.095

User Defined Load Input Echo for the ATTACHMENT:
Loads are given at the Nozzle/Header Junction
Loads are defined in Local Coordinatesc

Forces( lb.)  Moments (ft-lb)

Load Case        FX          FY          FZ          MX          MY          MZ
----------------------------------------------------------------------------
   OPER:      630.0       630.0       470.0       310.0       210.0       270.0


FEA Model Loads:
These are the actual Attachment loads applied to
the FEA model.
These are the User Defined Loads translated to the
end of the nozzle and reported in global coordinates.

Forces( lb.)  Moments (ft-lb)

Load Case        FX          FY          FZ          MX          MY          MZ
----------------------------------------------------------------------------
   OPER:      630.0       630.0       470.0       310.0       539.0      -171.0

The "top" or "positive" end of this model is "free" in
the axial and translational directions.

Stresses ARE nodally AVERAGED.

No weld dimensions have been given for the nozzle
connection to the shell. This will produce conservative
results for external loads and may tend to produce more
realistic inside surface pressure stresses.

Vessel Centerline  Vector     :  0.000   1.000   0.000
Nozzle Orientation Vector     :  1.000   0.000   0.000
```

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```
Load Case Report
FEPipe Version 15.0           Jobname: NOZZLE                 $P
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Load Case Report                                       $X

Inner and outer element temperatures are the same
throughout the model.  No thermal ratcheting
calculations will be performed.

THE   7  LOAD CASES ANALYZED ARE:

  1   SUSTAINED      (Pr Only)

      Sustained case run to satisfy local primary
      membrane and bending stress limits.
```

```
/-------- Loads in Case   1
  Pressure Case    1

2   OPERATING      (Fatigue Calc Performed)

    Case run to compute the operating stresses used in
    secondary, peak and range calculations as needed.

    /-------- Loads in Case   2
      Pressure Case    1
      Loads from (Operating)

3   Program Generated -- Force Only

    Case run to compute sif's and flexibilities.
    /-------- Loads in Case   3
      Loads from (Axial)

4   Program Generated -- Force Only

    Case run to compute sif's and flexibilities.
    /-------- Loads in Case   4
      Loads from (Inplane)

5   Program Generated -- Force Only

    Case run to compute sif's and flexibilities.
    /-------- Loads in Case   5
      Loads from (Outplane)

6   Program Generated -- Force Only

    Case run to compute sif's and flexibilities.
    /-------- Loads in Case   6
      Loads from (Torsion)

7   Program Generated -- Force Only

    Case run to compute sif's and flexibilities.
    /-------- Loads in Case   7
      Pressure Case    1
```

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```
Solution Data
FEPipe Version 15.0          Jobname: NOZZLE             $P
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```

Solution Data

```
Maximum Solution Row Size =     996
Number of Nodes           =    3378
Number of Elements        =    1118
Number of Solution Cases  =       7
```

Summation of Loads per Case

| Case # | FX | FY | FZ |
|---|---|---|---|
| 1 | -74. | 72441. | 0. |
| 2 | 556. | 73071. | 470. |
| 3 | 29557. | 0. | 0. |
| 4 | 0. | 0. | 0. |
| 5 | 0. | 0. | 0. |
| 6 | 0. | 0. | 0. |
| 7 | -74. | 72441. | 0. |

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```
ASME Code Stress Output Plots
FEPipe Version 15.0          Jobname: NOZZLE                 $P
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```

```
ASME Code Stress Output Plots                          $X
```

1) Pl < SPL (SUS,Membrane) Case 1

2) Qb < SPS (SUS,Bending) Case 1

3) Pl+Pb+Q < SPS (SUS,Inside) Case 1

4) Pl+Pb+Q < SPS (SUS,Outside) Case 1

5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 1

6) Pl+Pb+Q < SPS (OPE,Inside) Case 2

7) Pl+Pb+Q < SPS (OPE,Outside) Case 2

8) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 2

9) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 2

10) Membrane < User (OPE,Membrane) Case 2

11) Bending < User (OPE,Bending) Case 2

12) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 3

13) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 4

14) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 5

15) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 6

16) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 7

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---

```
Stress Results - Notes
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```

Stress Results - Notes

- Results in this analysis were generated using the finite element solution method.

- Using 2019 ASME Section VIII Division 2

- Use Polished Bar fatigue curve.

- Ratio between Operating and Design Pressure = 9.5238097E-02
  Range cases use operating pressure. Primary cases
  use design pressure.

- Assume free end displacements of attached pipe
  (e.g. thermal loads) are secondary loads.

- Primary bending stresses at discontinuities
  are treated like secondary stresses. (Pb=0)

- Use Equivalent Stress (Von Mises).

- TRIAXIAL Stress Guidelines:
  S1+S2+S3 evaluation omitted from operating stress.
  Include S1+S2+S3 evaluation in primary case evaluation.
  Bending stress NOT included for all S1+S2+S3 calculations.

- Use local tensor values for averaged and not averaged stresses.

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---

```
ASME Overstressed Areas
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ASME Overstressed Areas                            $X


             *** NO OVERSTRESSED NODES IN THIS MODEL ***
```

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---

```
Highest Primary Stress Ratios
FEPipe Version 15.0          Jobname: NOZZLE              $P
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Highest Primary Stress Ratios                      $X


Header Next to Nozzle Weld

       Pl            SPL     Primary Membrane Load Case 1
    6,340         22,200     Min Prin. Stress = -698. (31% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 1
            28%


Branch Next to Header Weld

       Pl            SPL     Primary Membrane Load Case 1
    4,692         22,200     Min Prin. Stress = -880. (58% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 1
            21%


Branch Transition

       Pl            SPL     Primary Membrane Load Case 1
      638         22,200     Min Prin. Stress = -359. (14% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 1
             2%


Header away from Junction

       Pl            SPL     Primary Membrane Load Case 1
    3,980         22,200     Min Prin. Stress = -17. ( 0% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 1
            17%


Branch away from Junction

       Pl            SPL     Primary Membrane Load Case 1
      713         22,200     Min Prin. Stress = -582. (43% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 1
             3%
```

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```
Highest Secondary Stress Ratios
FEPipe Version 15.0            Jobname: NOZZLE                 $P
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Highest Secondary Stress Ratios                        $X


Header Next to Nozzle Weld

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 2
   17,213          47,250    Min Prin. Stress = -7973. (96% Neg, 3% NegHi)
      psi             psi    Plot Reference:
                             7) Pl+Pb+Q < SPS (OPE,Outside) Case 2
            36%


Branch Next to Header Weld

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 2
   31,952          47,250    Min Prin. Stress = -17360. (89% Neg, 22% NegHi)
      psi             psi    Plot Reference:
                             7) Pl+Pb+Q < SPS (OPE,Outside) Case 2
            67%


Branch Transition

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 2
   12,020          47,250    Min Prin. Stress = -10665. (98% Neg, 9% NegHi)
      psi             psi    Plot Reference:
                             7) Pl+Pb+Q < SPS (OPE,Outside) Case 2
            25%


Header away from Junction

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 2
    7,793          47,250    Min Prin. Stress = -3297. (81% Neg, 0% NegHi)
      psi             psi    Plot Reference:
                             6) Pl+Pb+Q < SPS (OPE,Inside) Case 2
            16%


Branch away from Junction

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 2
    7,664          47,250    Min Prin. Stress = -6369. (98% Neg, 0% NegHi)
      psi             psi    Plot Reference:
                             6) Pl+Pb+Q < SPS (OPE,Inside) Case 2
            16%
```

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```
Highest Fatigue Stress Ratios
FEPipe Version 15.0            Jobname: NOZZLE                 $P
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Highest Fatigue Stress Ratios                          $X


Header Next to Nozzle Weld

Pl+Pb+Q+F     Damage Ratio   Primary+Secondary+Peak (Outer) Load Case 2
   11,619      0.000 Life    Stress Concentration Factor = 1.350
      psi      0.196 Stress  Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 39375.0
```

```
   59,224                    Markl Fatigue Stress Allowable = 47828.5
      psi                    WRC 474 Mean Cycles to Failure = 3,552,189.
                             WRC 474 99% Probability Cycles = 825,221.
      19%                    WRC 474 95% Probability Cycles = 1,145,732.
                             BS5500 Allowed Cycles(Curve F) = 464,763.
                             Membrane-to-Bending Ratio = 0.283
                             Bending-to-PL+PB+Q Ratio = 0.780
                             Plot Reference:
                             9) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 2


Branch Next to Header Weld

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 2
   21,568     0.018 Life     Stress Concentration Factor = 1.350
      psi     0.364 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 382,800.
Allowable                    "B31" Fatigue Stress Allowable = 39375.0
   59,224                    Markl Fatigue Stress Allowable = 47828.5
      psi                    WRC 474 Mean Cycles to Failure = 796,443.
                             WRC 474 99% Probability Cycles = 185,024.
      36%                    WRC 474 95% Probability Cycles = 256,887.
                             BS5500 Allowed Cycles(Curve F) = 72,664.
                             Membrane-to-Bending Ratio = 0.384
                             Bending-to-PL+PB+Q Ratio = 0.723
                             Plot Reference:
                             9) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 2


Branch Transition

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 2
    6,010     0.000 Life     Stress Concentration Factor = 1.000
      psi     0.101 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 39375.0
   59,224                    Markl Fatigue Stress Allowable = 47828.5
      psi                    WRC 474 Mean Cycles to Failure = 14,355,947.
                             WRC 474 99% Probability Cycles = 3,335,077.
      10%                    WRC 474 95% Probability Cycles = 4,630,400.
                             BS5500 Allowed Cycles(Curve F) = 1,365,009.
                             Membrane-to-Bending Ratio = 2.002
                             Bending-to-PL+PB+Q Ratio = 0.333
                             Plot Reference:
                             9) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 2


Header away from Junction

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 2
    3,896     0.000 Life     Stress Concentration Factor = 1.000
      psi     0.066 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 39375.0
   59,224                    Markl Fatigue Stress Allowable = 47828.5
      psi                    WRC 474 Mean Cycles to Failure = 41,808,800.
                             WRC 474 99% Probability Cycles = 9,712,739.
       6%                    WRC 474 95% Probability Cycles = 13,485,121.
                             BS5500 Allowed Cycles(Curve F) = 5,008,518.
                             Membrane-to-Bending Ratio = 0.344
                             Bending-to-PL+PB+Q Ratio = 0.744
                             Plot Reference:
                             8) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 2


Branch away from Junction

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 2
    3,832     0.000 Life     Stress Concentration Factor = 1.000
      psi     0.065 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 39375.0
   59,224                    Markl Fatigue Stress Allowable = 47828.5
      psi                    WRC 474 Mean Cycles to Failure = 57,315,124.
                             WRC 474 99% Probability Cycles = 13,315,077.
       6%                    WRC 474 95% Probability Cycles = 18,486,572.
                             BS5500 Allowed Cycles(Curve F) = 5,265,690.
                             Membrane-to-Bending Ratio = 12.001
                             Bending-to-PL+PB+Q Ratio = 0.077
                             Plot Reference:
                             8) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 2
```

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```
Highest Stress Ratios Per Region
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Highest Stress Ratios Per Region                      $X


Header Next to Nozzle Weld

       Pl           SPL     Primary Membrane Load Case 1
    6,340        22,200     Min Prin. Stress = -698. (31% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            1) Pl < SPL (SUS,Membrane) Case 1
            28%

       Qb           SPS     Primary Bending Load Case 1
    2,331        47,250     Min Prin. Stress = -698. (31% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            2) Qb < SPS (SUS,Bending) Case 1
             4%

  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 1
    7,990        47,250     Min Prin. Stress = -698. (31% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            3) Pl+Pb+Q < SPS (SUS,Inside) Case 1
            16%

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 1
    5,237        47,250     Min Prin. Stress = -698. (31% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            4) Pl+Pb+Q < SPS (SUS,Outside) Case 1
            11%

 S1+S2+S3            4S     Part 5 (5.3.2) Load Case 1
    8,834        59,200     Min Prin. Stress = -698. (31% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 1
            14%

  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 2
   14,447        47,250     Min Prin. Stress = -7973. (96% Neg, 3% NegHi)
      psi           psi     Plot Reference:
                            6) Pl+Pb+Q < SPS (OPE,Inside) Case 2
            30%

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 2
   17,213        47,250     Min Prin. Stress = -7973. (96% Neg, 3% NegHi)
      psi           psi     Plot Reference:
                            7) Pl+Pb+Q < SPS (OPE,Outside) Case 2
            36%

Pl+Pb+Q+F   Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 2
    9,752    0.000 Life     Stress Concentration Factor = 1.350
      psi    0.165 Stress   Strain Concentration Factor = 1.000
                            Cycles Allowed for this Stress = 1.0000E11
Allowable                   "B31" Fatigue Stress Allowable = 39375.0
   59,224                   Markl Fatigue Stress Allowable = 47828.5
      psi                   WRC 474 Mean Cycles to Failure = 5,942,654.
                            WRC 474 99% Probability Cycles = 1,380,559.
      16%                   WRC 474 95% Probability Cycles = 1,916,759.
                            BS5500 Allowed Cycles(Curve F) = 786,111.
                            Membrane-to-Bending Ratio = 0.368
                            Bending-to-PL+PB+Q Ratio = 0.731
                            Plot Reference:
                            8) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 2

Pl+Pb+Q+F   Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 2
   11,619    0.000 Life     Stress Concentration Factor = 1.350
      psi    0.196 Stress   Strain Concentration Factor = 1.000
                            Cycles Allowed for this Stress = 1.0000E11
Allowable                   "B31" Fatigue Stress Allowable = 39375.0
   59,224                   Markl Fatigue Stress Allowable = 47828.5
      psi                   WRC 474 Mean Cycles to Failure = 3,552,189.
```

```
                               WRC 474 99% Probability Cycles = 825,221.
     19%                       WRC 474 95% Probability Cycles = 1,145,732.
                               BS5500 Allowed Cycles(Curve F) = 464,763.
                               Membrane-to-Bending Ratio = 0.283
                               Bending-to-PL+PB+Q Ratio = 0.780
                               Plot Reference:
                               9) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 2

 Membrane           User       Component Evaluation Load Case 2
    6,310         47,250       Min Prin. Stress = -7973. (96% Neg, 3% NegHi)
      psi            psi       Plot Reference:
                               10) Membrane < User (OPE,Membrane) Case 2
           13%

  Bending           User       Component Evaluation Load Case 2
   14,294         47,250       Min Prin. Stress = -7973. (96% Neg, 3% NegHi)
      psi            psi       Plot Reference:
                               11) Bending < User (OPE,Bending) Case 2
           30%


Branch Next to Header Weld

       Pl            SPL       Primary Membrane Load Case 1
    4,692         22,200       Min Prin. Stress = -880. (58% Neg, 0% NegHi)
      psi            psi       Plot Reference:
                               1) Pl < SPL (SUS,Membrane) Case 1
           21%

       Qb            SPS       Primary Bending Load Case 1
    2,027         47,250       Min Prin. Stress = -880. (58% Neg, 0% NegHi)
      psi            psi       Plot Reference:
                               2) Qb < SPS (SUS,Bending) Case 1
            4%

  Pl+Pb+Q            SPS       Primary+Secondary (Inner) Load Case 1
    6,048         47,250       Min Prin. Stress = -880. (58% Neg, 0% NegHi)
      psi            psi       Plot Reference:
                               3) Pl+Pb+Q < SPS (SUS,Inside) Case 1
           12%

  Pl+Pb+Q            SPS       Primary+Secondary (Outer) Load Case 1
    3,511         47,250       Min Prin. Stress = -880. (58% Neg, 0% NegHi)
      psi            psi       Plot Reference:
                               4) Pl+Pb+Q < SPS (SUS,Outside) Case 1
            7%

 S1+S2+S3             4S       Part 5 (5.3.2) Load Case 1
    5,722         59,200       Min Prin. Stress = -880. (58% Neg, 0% NegHi)
      psi            psi       Plot Reference:
                               5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 1
            9%

  Pl+Pb+Q            SPS       Primary+Secondary (Inner) Load Case 2
   28,327         47,250       Min Prin. Stress = -17360. (89% Neg, 22% NegHi)
      psi            psi       Plot Reference:
                               6) Pl+Pb+Q < SPS (OPE,Inside) Case 2
           59%

  Pl+Pb+Q            SPS       Primary+Secondary (Outer) Load Case 2
   31,952         47,250       Min Prin. Stress = -17360. (89% Neg, 22% NegHi)
      psi            psi       Plot Reference:
                               7) Pl+Pb+Q < SPS (OPE,Outside) Case 2
           67%

Pl+Pb+Q+F   Damage Ratio       Primary+Secondary+Peak (Inner) Load Case 2
   19,121    0.009 Life        Stress Concentration Factor = 1.350
      psi    0.323 Stress      Strain Concentration Factor = 1.000
                               Cycles Allowed for this Stress = 765,018.
Allowable                      "B31" Fatigue Stress Allowable = 39375.0
   59,224                      Markl Fatigue Stress Allowable = 47828.5
      psi                      WRC 474 Mean Cycles to Failure = 1,251,701.
                               WRC 474 99% Probability Cycles = 290,787.
      32%                      WRC 474 95% Probability Cycles = 403,727.
                               BS5500 Allowed Cycles(Curve F) = 104,284.
                               Membrane-to-Bending Ratio = 0.384
                               Bending-to-PL+PB+Q Ratio = 0.723
                               Plot Reference:
                               8) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 2

Pl+Pb+Q+F   Damage Ratio       Primary+Secondary+Peak (Outer) Load Case 2
   21,568    0.018 Life        Stress Concentration Factor = 1.350
```

```
      psi     0.364 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 382,800.
Allowable                    "B31" Fatigue Stress Allowable = 39375.0
   59,224                    Markl Fatigue Stress Allowable = 47828.5
      psi                    WRC 474 Mean Cycles to Failure = 796,443.
                             WRC 474 99% Probability Cycles = 185,024.
      36%                    WRC 474 95% Probability Cycles = 256,887.
                             BS5500 Allowed Cycles(Curve F) = 72,664.
                             Membrane-to-Bending Ratio = 0.384
                             Bending-to-PL+PB+Q Ratio = 0.723
                             Plot Reference:
                             9) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 2

 Membrane           User     Component Evaluation Load Case 2
   10,831         47,250     Min Prin. Stress = -17360. (89% Neg, 22% NegHi)
      psi            psi     Plot Reference:
                             10) Membrane < User (OPE,Membrane) Case 2
            22%

  Bending           User     Component Evaluation Load Case 2
   28,187         47,250     Min Prin. Stress = -17360. (89% Neg, 22% NegHi)
      psi            psi     Plot Reference:
                             11) Bending < User (OPE,Bending) Case 2
            59%


Branch Transition

       Pl            SPL     Primary Membrane Load Case 1
      638         22,200     Min Prin. Stress = -359. (14% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 1
             2%

       Qb            SPS     Primary Bending Load Case 1
      536         47,250     Min Prin. Stress = -359. (14% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             2) Qb < SPS (SUS,Bending) Case 1
             1%

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 1
      836         47,250     Min Prin. Stress = -359. (14% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             3) Pl+Pb+Q < SPS (SUS,Inside) Case 1
             1%

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 1
    1,053         47,250     Min Prin. Stress = -359. (14% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             4) Pl+Pb+Q < SPS (SUS,Outside) Case 1
             2%

 S1+S2+S3             4S     Part 5 (5.3.2) Load Case 1
    1,116         59,200     Min Prin. Stress = -359. (14% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 1
             1%

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 2
    8,628         47,250     Min Prin. Stress = -10665. (98% Neg, 9% NegHi)
      psi            psi     Plot Reference:
                             6) Pl+Pb+Q < SPS (OPE,Inside) Case 2
            18%

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 2
   12,020         47,250     Min Prin. Stress = -10665. (98% Neg, 9% NegHi)
      psi            psi     Plot Reference:
                             7) Pl+Pb+Q < SPS (OPE,Outside) Case 2
            25%

Pl+Pb+Q+F   Damage Ratio     Primary+Secondary+Peak (Inner) Load Case 2
    4,314     0.000 Life     Stress Concentration Factor = 1.000
      psi     0.073 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 39375.0
   59,224                    Markl Fatigue Stress Allowable = 47828.5
      psi                    WRC 474 Mean Cycles to Failure = 39,475,240.
                             WRC 474 99% Probability Cycles = 9,170,622.
       7%                    WRC 474 95% Probability Cycles = 12,732,448.
                             BS5500 Allowed Cycles(Curve F) = 3,690,806.
                             Membrane-to-Bending Ratio = 59.092
                             Bending-to-PL+PB+Q Ratio = 0.017
```

```
                              Plot Reference:
                              8) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 2

Pl+Pb+Q+F    Damage Ratio     Primary+Secondary+Peak (Outer) Load Case 2
    6,010     0.000 Life      Stress Concentration Factor = 1.000
      psi     0.101 Stress    Strain Concentration Factor = 1.000
                              Cycles Allowed for this Stress = 1.0000E11
Allowable                     "B31" Fatigue Stress Allowable = 39375.0
   59,224                     Markl Fatigue Stress Allowable = 47828.5
      psi                     WRC 474 Mean Cycles to Failure = 14,355,947.
                              WRC 474 99% Probability Cycles = 3,335,077.
      10%                     WRC 474 95% Probability Cycles = 4,630,400.
                              BS5500 Allowed Cycles(Curve F) = 1,365,009.
                              Membrane-to-Bending Ratio = 2.002
                              Bending-to-PL+PB+Q Ratio = 0.333
                              Plot Reference:
                              9) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 2

 Membrane           User      Component Evaluation Load Case 2
    8,778         47,250      Min Prin. Stress = -10665. (98% Neg, 9% NegHi)
      psi            psi      Plot Reference:
                              10) Membrane < User (OPE,Membrane) Case 2
          18%

  Bending           User      Component Evaluation Load Case 2
    4,107         47,250      Min Prin. Stress = -10665. (98% Neg, 9% NegHi)
      psi            psi      Plot Reference:
                              11) Bending < User (OPE,Bending) Case 2
           8%


Header away from Junction

       Pl            SPL      Primary Membrane Load Case 1
    3,980         22,200      Min Prin. Stress = -17. ( 0% Neg, 0% NegHi)
      psi            psi      Plot Reference:
                              1) Pl < SPL (SUS,Membrane) Case 1
          17%

       Qb            SPS      Primary Bending Load Case 1
      634         47,250      Min Prin. Stress = -17. ( 0% Neg, 0% NegHi)
      psi            psi      Plot Reference:
                              2) Qb < SPS (SUS,Bending) Case 1
           1%

  Pl+Pb+Q            SPS      Primary+Secondary (Inner) Load Case 1
    4,385         47,250      Min Prin. Stress = -17. ( 0% Neg, 0% NegHi)
      psi            psi      Plot Reference:
                              3) Pl+Pb+Q < SPS (SUS,Inside) Case 1
           9%

  Pl+Pb+Q            SPS      Primary+Secondary (Outer) Load Case 1
    3,802         47,250      Min Prin. Stress = -17. ( 0% Neg, 0% NegHi)
      psi            psi      Plot Reference:
                              4) Pl+Pb+Q < SPS (SUS,Outside) Case 1
           8%

 S1+S2+S3             4S      Part 5 (5.3.2) Load Case 1
    6,717         59,200      Min Prin. Stress = -17. ( 0% Neg, 0% NegHi)
      psi            psi      Plot Reference:
                              5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 1
          11%

  Pl+Pb+Q            SPS      Primary+Secondary (Inner) Load Case 2
    7,793         47,250      Min Prin. Stress = -3297. (81% Neg, 0% NegHi)
      psi            psi      Plot Reference:
                              6) Pl+Pb+Q < SPS (OPE,Inside) Case 2
          16%

  Pl+Pb+Q            SPS      Primary+Secondary (Outer) Load Case 2
    7,262         47,250      Min Prin. Stress = -3297. (81% Neg, 0% NegHi)
      psi            psi      Plot Reference:
                              7) Pl+Pb+Q < SPS (OPE,Outside) Case 2
          15%

Pl+Pb+Q+F    Damage Ratio     Primary+Secondary+Peak (Inner) Load Case 2
    3,896     0.000 Life      Stress Concentration Factor = 1.000
      psi     0.066 Stress    Strain Concentration Factor = 1.000
                              Cycles Allowed for this Stress = 1.0000E11
Allowable                     "B31" Fatigue Stress Allowable = 39375.0
   59,224                     Markl Fatigue Stress Allowable = 47828.5
      psi                     WRC 474 Mean Cycles to Failure = 41,808,800.
```

```
                                WRC 474 99% Probability Cycles = 9,712,739.
      6%                        WRC 474 95% Probability Cycles = 13,485,121.
                                BS5500 Allowed Cycles(Curve F) = 5,008,518.
                                Membrane-to-Bending Ratio = 0.344
                                Bending-to-PL+PB+Q Ratio = 0.744
                                Plot Reference:
                                8) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 2

Pl+Pb+Q+F    Damage Ratio       Primary+Secondary+Peak (Outer) Load Case 2
    3,631     0.000 Life        Stress Concentration Factor = 1.000
      psi     0.061 Stress      Strain Concentration Factor = 1.000
                                Cycles Allowed for this Stress = 1.0000E11
Allowable                       "B31" Fatigue Stress Allowable = 39375.0
   59,224                       Markl Fatigue Stress Allowable = 47828.5
      psi                       WRC 474 Mean Cycles to Failure = 51,801,052.
                                WRC 474 99% Probability Cycles = 12,034,084.
       6%                       WRC 474 95% Probability Cycles = 16,708,049.
                                BS5500 Allowed Cycles(Curve F) = 6,190,345.
                                Membrane-to-Bending Ratio = 0.305
                                Bending-to-PL+PB+Q Ratio = 0.766
                                Plot Reference:
                                9) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 2

 Membrane           User        Component Evaluation Load Case 2
    2,631         47,250        Min Prin. Stress = -3297. (81% Neg, 0% NegHi)
      psi            psi        Plot Reference:
                                10) Membrane < User (OPE,Membrane) Case 2
             5%

  Bending           User        Component Evaluation Load Case 2
    6,296         47,250        Min Prin. Stress = -3297. (81% Neg, 0% NegHi)
      psi            psi        Plot Reference:
                                11) Bending < User (OPE,Bending) Case 2
            13%


Branch away from Junction

       Pl            SPL        Primary Membrane Load Case 1
      713         22,200        Min Prin. Stress = -582. (43% Neg, 0% NegHi)
      psi            psi        Plot Reference:
                                1) Pl < SPL (SUS,Membrane) Case 1
             3%

       Qb            SPS        Primary Bending Load Case 1
      804         47,250        Min Prin. Stress = -582. (43% Neg, 0% NegHi)
      psi            psi        Plot Reference:
                                2) Qb < SPS (SUS,Bending) Case 1
             1%

  Pl+Pb+Q            SPS        Primary+Secondary (Inner) Load Case 1
    1,415         47,250        Min Prin. Stress = -582. (43% Neg, 0% NegHi)
      psi            psi        Plot Reference:
                                3) Pl+Pb+Q < SPS (SUS,Inside) Case 1
             2%

  Pl+Pb+Q            SPS        Primary+Secondary (Outer) Load Case 1
    1,446         47,250        Min Prin. Stress = -582. (43% Neg, 0% NegHi)
      psi            psi        Plot Reference:
                                4) Pl+Pb+Q < SPS (SUS,Outside) Case 1
             3%

 S1+S2+S3             4S        Part 5 (5.3.2) Load Case 1
    1,229         59,200        Min Prin. Stress = -582. (43% Neg, 0% NegHi)
      psi            psi        Plot Reference:
                                5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 1
             2%

  Pl+Pb+Q            SPS        Primary+Secondary (Inner) Load Case 2
    7,664         47,250        Min Prin. Stress = -6369. (98% Neg, 0% NegHi)
      psi            psi        Plot Reference:
                                6) Pl+Pb+Q < SPS (OPE,Inside) Case 2
            16%

  Pl+Pb+Q            SPS        Primary+Secondary (Outer) Load Case 2
    7,187         47,250        Min Prin. Stress = -6369. (98% Neg, 0% NegHi)
      psi            psi        Plot Reference:
                                7) Pl+Pb+Q < SPS (OPE,Outside) Case 2
            15%

Pl+Pb+Q+F    Damage Ratio       Primary+Secondary+Peak (Inner) Load Case 2
    3,832     0.000 Life        Stress Concentration Factor = 1.000
```

```
      psi     0.065 Stress    Strain Concentration Factor = 1.000
                              Cycles Allowed for this Stress = 1.0000E11
Allowable                     "B31" Fatigue Stress Allowable = 39375.0
   59,224                     Markl Fatigue Stress Allowable = 47828.5
      psi                     WRC 474 Mean Cycles to Failure = 57,315,124.
                              WRC 474 99% Probability Cycles = 13,315,077.
       6%                     WRC 474 95% Probability Cycles = 18,486,572.
                              BS5500 Allowed Cycles(Curve F) = 5,265,690.
                              Membrane-to-Bending Ratio = 12.001
                              Bending-to-PL+PB+Q Ratio = 0.077
                              Plot Reference:
                              8) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 2

Pl+Pb+Q+F    Damage Ratio     Primary+Secondary+Peak (Outer) Load Case 2
    3,593     0.000 Life      Stress Concentration Factor = 1.000
      psi     0.061 Stress    Strain Concentration Factor = 1.000
                              Cycles Allowed for this Stress = 1.0000E11
Allowable                     "B31" Fatigue Stress Allowable = 39375.0
   59,224                     Markl Fatigue Stress Allowable = 47828.5
      psi                     WRC 474 Mean Cycles to Failure = 70,121,848.
                              WRC 474 99% Probability Cycles = 16,290,251.
       6%                     WRC 474 95% Probability Cycles = 22,617,284.
                              BS5500 Allowed Cycles(Curve F) = 6,385,288.
                              Membrane-to-Bending Ratio = 10.294
                              Bending-to-PL+PB+Q Ratio = 0.089
                              Plot Reference:
                              9) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 2

 Membrane           User      Component Evaluation Load Case 2
    7,386         47,250      Min Prin. Stress = -6369. (98% Neg, 0% NegHi)
      psi            psi      Plot Reference:
                              10) Membrane < User (OPE,Membrane) Case 2
            15%

  Bending           User      Component Evaluation Load Case 2
    1,549         47,250      Min Prin. Stress = -6369. (98% Neg, 0% NegHi)
      psi            psi      Plot Reference:
                              11) Bending < User (OPE,Bending) Case 2
             3%
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```
Stress Intensification Factors
FEPipe Version 15.0           Jobname: NOZZLE                 $P
Released Jan. 2021             11:22am  OCT 23,2021



Stress Intensification Factors                         $X


Branch/Nozzle Sif Summary

                  Peak      Primary    Secondary      SSI
Axial   :        8.652       6.409      12.817       1.643
Inplane :        2.914       2.159       4.318       1.428
Outplane:        3.449       2.555       5.110       1.329
Torsion :        0.630       0.816       0.933       0.794
Pressure:        1.347       1.583       1.995       1.071

The above stress intensification factors are to be used
in a beam-type analysis of the piping system.  Inplane,
Outplane and Torsional sif's should be used with the
matching branch pipe whose diameter and thickness is given
below.  The axial sif should be used to intensify the
axial stress in the branch pipe calculated by F/A.  The
pressure sif should be used to intensify the nominal
pressure stress in the PARENT or HEADER, calculated
from PDo/2T. B31 calculations use mean diameters and
Section VIII calculations use outside diameters. SSIs are
based on peak stress factors and correlated test results.

Pipe OD :        2.375  in.
Pipe Thk:        0.218  in.
Z approx:        0.797  cu.in.
Z exact :        0.731  cu.in.
```

```
  (SSI = SIF^x)        Axial   Inpl    Outpl   Tors    Pres
SIF/SSI Exponents:     0.861   0.719   0.758   0.439   1.543

SIF/SSI exponent based on relationship between primary and
peak stress factors from the finite element analysis.

B31.3 Branch Pressure i-factor =       20.774
      Header Pressure i-factor =        2.729

The B31.3 pressure i-factors should be used with with
F/A, where F is the axial force due to pressure, and
A is the area of the pipe wall. This is equivalent to
finding the pressure stress from (ip)(PD/4T).

B31.3   (Branch)
Peak Stress Sif ....     0.000         Axial
                         4.338         Inplane
                         5.600         Outplane
                         1.000         Torsional
B31.1  (Branch)
Peak Stress Sif ....     0.000         Axial
                         2.286         Inplane
                         2.286         Outplane
                         2.286         Torsional
WRC 330  (Branch)
Peak Stress Sif ....     0.000         Axial
                         1.543         Inplane
                         1.543         Outplane
                         1.000         Torsional
```

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```
Allowable Loads
FEPipe Version 15.0           Jobname: NOZZLE                $P
Released Jan. 2021             11:22am  OCT 23,2021



Allowable Loads                                       $X
```

| SECONDARY Load Type (Range): | Maximum Individual Occuring | Conservative Simultaneous Occuring | Realistic Simultaneous Occuring |
|---|---|---|---|
| Axial Force (lb. ) | 5448. | 1679. | 2518. |
| Inplane Moment (in. lb.) | 8001. | 1746. | 3703. |
| Outplane Moment (in. lb.) | 6760. | 1475. | 3129. |
| Torsional Moment (in. lb.) | 37019. | 11423. | 17134. |
| Pressure (psi ) | 620.97 | 105.00 | 105.00 |

| PRIMARY Load Type: | Maximum Individual Occuring | Conservative Simultaneous Occuring | Realistic Simultaneous Occuring |
|---|---|---|---|
| Axial Force (lb. ) | 5119. | 1346. | 2019. |
| Inplane Moment (in. lb.) | 7518. | 1398. | 2965. |
| Outplane Moment (in. lb.) | 6353. | 1181. | 2505. |
| Torsional Moment (in. lb.) | 19884. | 5227. | 7841. |
| Pressure (psi ) | 367.69 | 105.00 | 105.00 |

NOTES:

1) Maximum Individual Occuring Loads are the maximum allowed values of the respective loads if all other load components are zero, i.e. the listed axial force may be applied if the inplane, outplane and torsional moments, and the pressure are zero.

2) The Conservative Allowable Simultaneous loads are the maximum loads that can be applied simultaneously. A conservative stress combination equation is used that typically produces stresses within 50-70% of the allowable stress.

3) The Realistic Allowable Simultaneous loads are the maximum loads that can be applied simultaneously. A more realistic stress combination equation is used

based on experience at Paulin Research. Stresses are typically produced within 80-105% of the allowable.

4) Secondary allowable loads are limits for expansion and operating piping loads.

5) Primary allowable loads are limits for weight, primary and sustained type piping loads.

6) High D/T low pressure systems may be subject to instability and should be checked when compressive stresses are present.

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```
Compressive Stress Summary
FEPipe Version 15.0           Jobname: NOZZLE              $P
Released Jan. 2021             11:22am  OCT 23,2021
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```
Compressive Stress Summary (psi)                       $X

Nomenclature:
-------------
Min Stress        - Compressive Membrane and Bending Stress
Pts in Region     - No. of nodes in the model region
>5% Compression   - 5% or more of Compressive Stress Limit
>50% Compression  - 50% or more of Compressive Stress Limit

Compressive Stress Limit = -0.55 Min(Sy, kEt/R), Section
slenderness ratio (elastic buckling) not considered.
```

| # | Load Type | Case | Min Stress | Pts in Region | >5% Compression and Bending | >50% Compression and Bending | Region |
|---|---|---|---|---|---|---|---|
| 1 | SUSTAINED | 1 | -698. | 888 | 31% | 0% | Header Next to Nozzle Weld |
| 2 | OPERATING | 2 | -7973. | 888 | 96% | 3% | Header Next to Nozzle Weld |
| 3 | EXPANSION | 2 | -7973. | 888 | 96% | 3% | Header Next to Nozzle Weld |
| 4 | OPERATING | 2 | -7973. | 888 | 96% | 3% | Header Next to Nozzle Weld |
| 5 | SUSTAINED | 1 | -17. | 840 | 0% | 0% | Header away from Junction |
| 6 | OPERATING | 2 | -3297. | 840 | 81% | 0% | Header away from Junction |
| 7 | EXPANSION | 2 | -3297. | 840 | 81% | 0% | Header away from Junction |
| 8 | OPERATING | 2 | -3297. | 840 | 81% | 0% | Header away from Junction |
| 9 | SUSTAINED | 1 | -880. | 840 | 58% | 0% | Branch Next to Header Weld |
| 10 | OPERATING | 2 | -17360. | 840 | 89% | 22% | Branch Next to Header Weld |
| 11 | EXPANSION | 2 | -17360. | 840 | 89% | 22% | Branch Next to Header Weld |
| 12 | OPERATING | 2 | -17360. | 840 | 89% | 22% | Branch Next to Header Weld |
| 13 | SUSTAINED | 1 | -582. | 192 | 43% | 0% | Branch away from Junction |
| 14 | OPERATING | 2 | -6369. | 192 | 98% | 0% | Branch away from Junction |
| 15 | EXPANSION | 2 | -6369. | 192 | 98% | 0% | Branch away from Junction |
| 16 | OPERATING | 2 | -6369. | 192 | 98% | 0% | Branch away from Junction |
| 17 | SUSTAINED | 1 | -359. | 1272 | 14% | 0% | Branch Transition |
| 18 | OPERATING | 2 | -10665. | 1272 | 98% | 9% | Branch Transition |
| 19 | EXPANSION | 2 | -10665. | 1272 | 98% | 9% | Branch Transition |
| 20 | OPERATING | 2 | -10665. | 1272 | 98% | 9% | Branch Transition |

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Flexibilities
FEPipe Version 15.0           Jobname: NOZZLE              $P
Released Jan. 2021             11:22am  OCT 23,2021
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Flexibilities                                          $X
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The following stiffnesses should be used in a piping, "beam-type" analysis of the intersection. The stiff-

```
nesses should be inserted at the surface of the
branch/header or nozzle/vessel junction.  The general
characteristics used for the branch pipe should be:

Outside Diameter =    2.375  in.
Wall Thickness   =    0.218  in.

Axial Translational Stiffness   =        234689.  lb./in.
Inplane Rotational Stiffness    =         34219.  in.lb./deg
Outplane Rotational Stiffness   =         21211.  in.lb./deg
Torsional Rotational Stiffness  =        683221.  in.lb./deg


Estimated Radial Shell Displacement due to Allowable Loads
SECONDARY:
Axial (in.) =  0.023  In-Plane (in.) =  0.004  Out-Plane (in.) =  0.006

PRIMARY
Axial (in.) =  0.022  In-Plane (in.) =  0.004  Out-Plane (in.) =  0.006

Secondary Conservative Displacement =  0.009 in.
Secondary Realistic    Displacement =  0.016 in.

Primary Conservative Displacement =  0.008 in.
Primary Realistic Displacement    =  0.012 in.



Intersection Flexibility Factors for Branch/Nozzle
:

Find axial stiffness: K = 3EI/(kd)^3  lb./in.
Find bending and torsional stiffnesses: K = EI/(kd)  in.lb.per radian.
The EI product is    0.24570E+08    lb.in.^2
The value of (d) to use is:   2.157  in..
The resulting bending stiffness is in units of force x length per radian.

Axial Flexibility Factor     (k) =     3.151
Inplane Flexibility Factor   (k) =     5.810
Outplane Flexibility Factor  (k) =     9.373
Torsional Flexibility Factor (k) =     0.291
```

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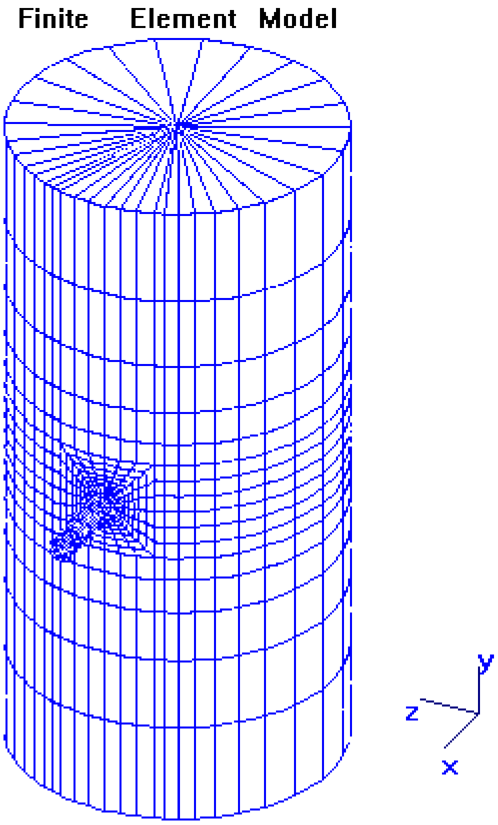
*Finite Element Model*


- Finite Element Model


*Elements at Discontinuity*


- 1) Pl < SPL (SUS Membrane) Case 1
- 2) Qb < SPS (SUS Bending) Case 1
- 3) Pl+Pb+Q < SPS (SUS Inside) Case 1
- 4) Pl+Pb+Q < SPS (SUS Outside) Case 1
- 5) S1+S2+S3 < 4S (SUS S1+S2+S3) Case 1
- 6) Pl+Pb+Q < SPS (OPE Inside) Case 2
- 7) Pl+Pb+Q < SPS (OPE Outside) Case 2
- 8) Pl+Pb+Q+F < 2Sa (EXP Inside) Case 2
- 9) Pl+Pb+Q+F < 2Sa (EXP Outside) Case 2
- 10) Membrane < User (OPE Membrane) Case 2
- 11) Bending < User (OPE Bending) Case 2
- 12) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 3
- 13) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 4
- 14) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 5
- 15) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 6
- 16) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 7




3d

- 

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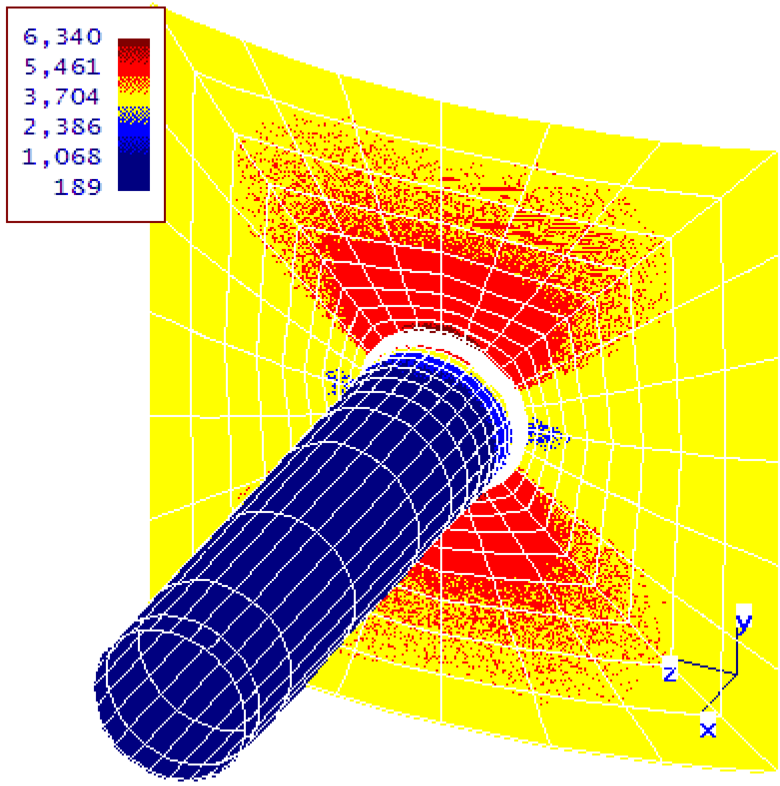
1) Pl < SPL (SUS Membrane) Case 1




3d(Small) 3d

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3d(Deformed)

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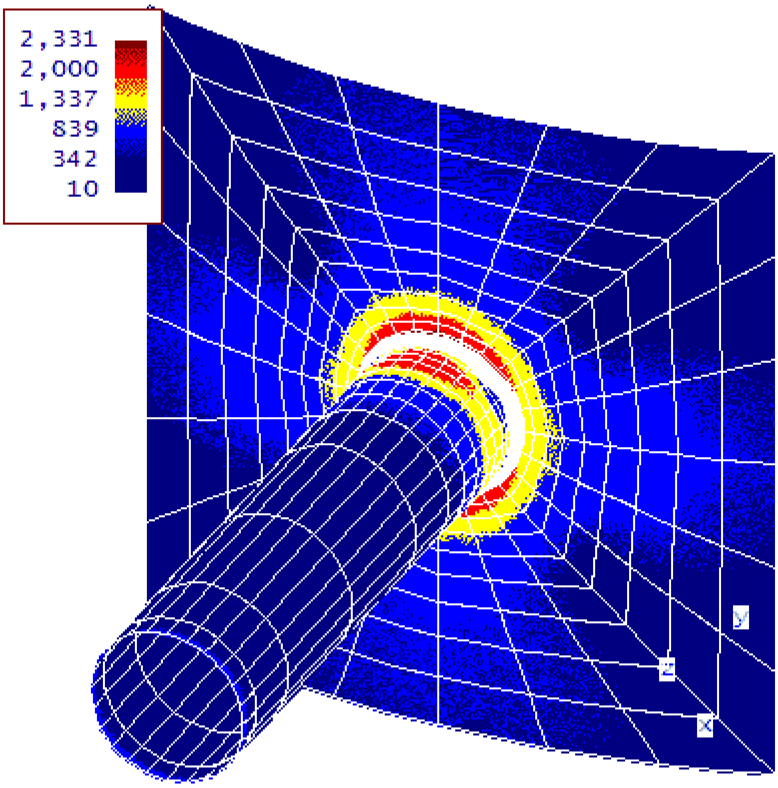
2) Qb < SPS (SUS Bending) Case 1




- 3d(Small) 3d
- 3d(Deformed)

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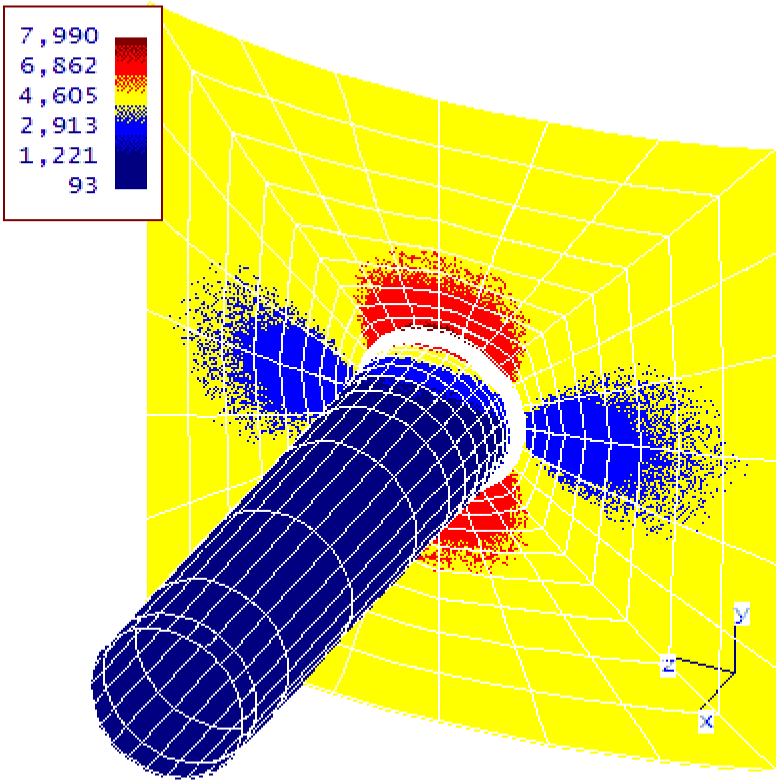
3) Pl+Pb+Q < SPS (SUS Inside) Case 1




- 3d(Small) 3d
- 3d(Deformed)

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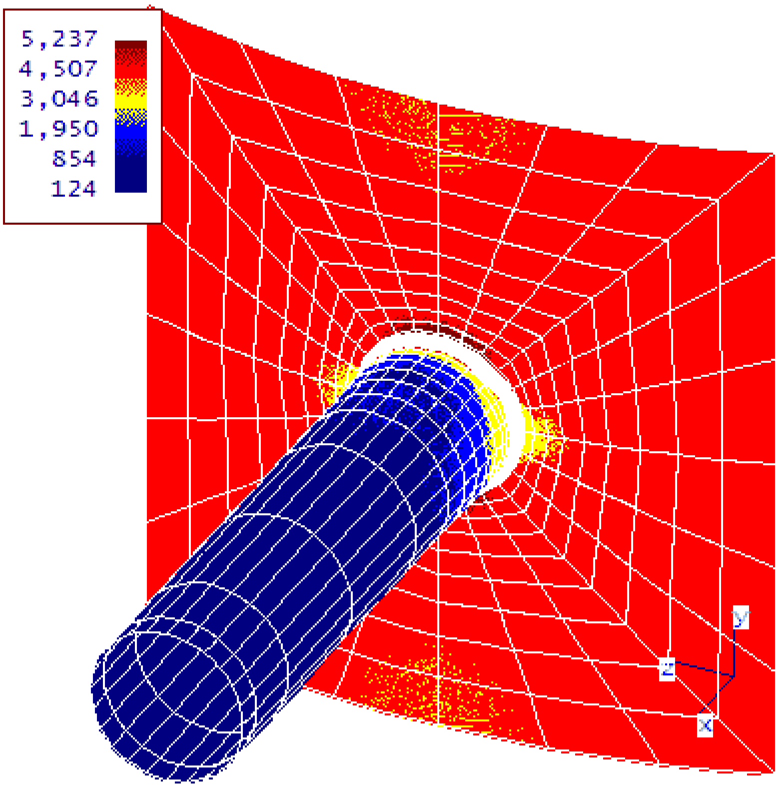
4) Pl+Pb+Q < SPS (SUS Outside) Case 1




- 3d(Small) 3d

3d(Deformed)

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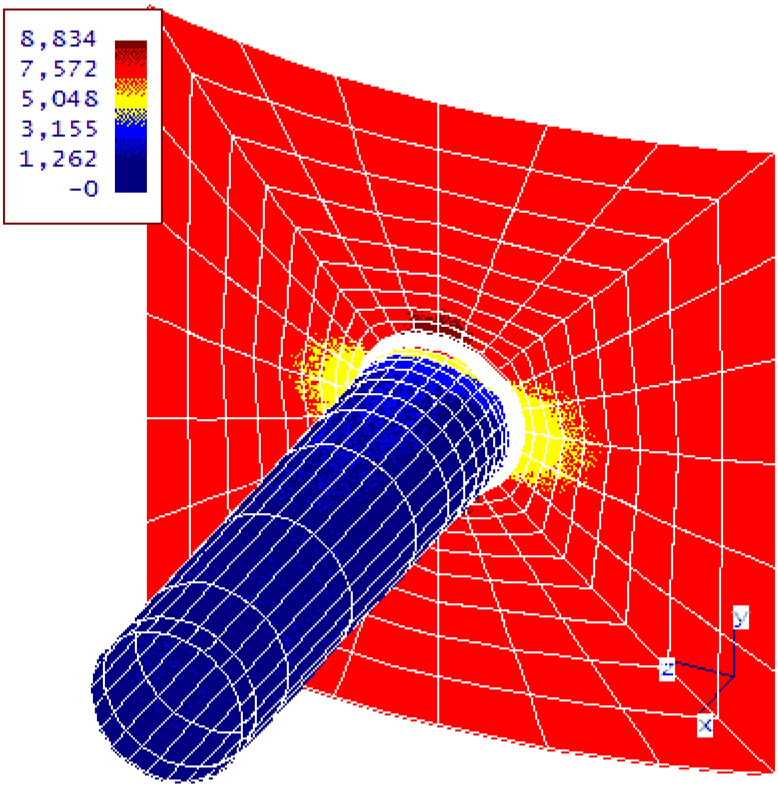
5) S1+S2+S3 < 4S (SUS S1+S2+S3) Case 1




- 3d(Small) 3d

3d(Deformed)

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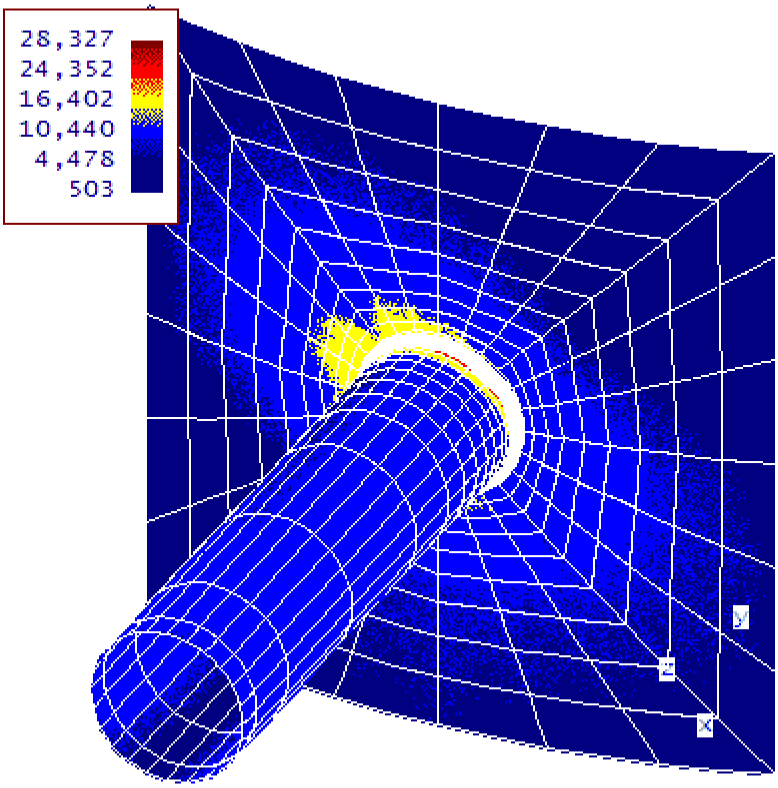
6) Pl+Pb+Q < SPS (OPE Inside) Case 2




- 3d(Small) 3d

3d(Deformed)

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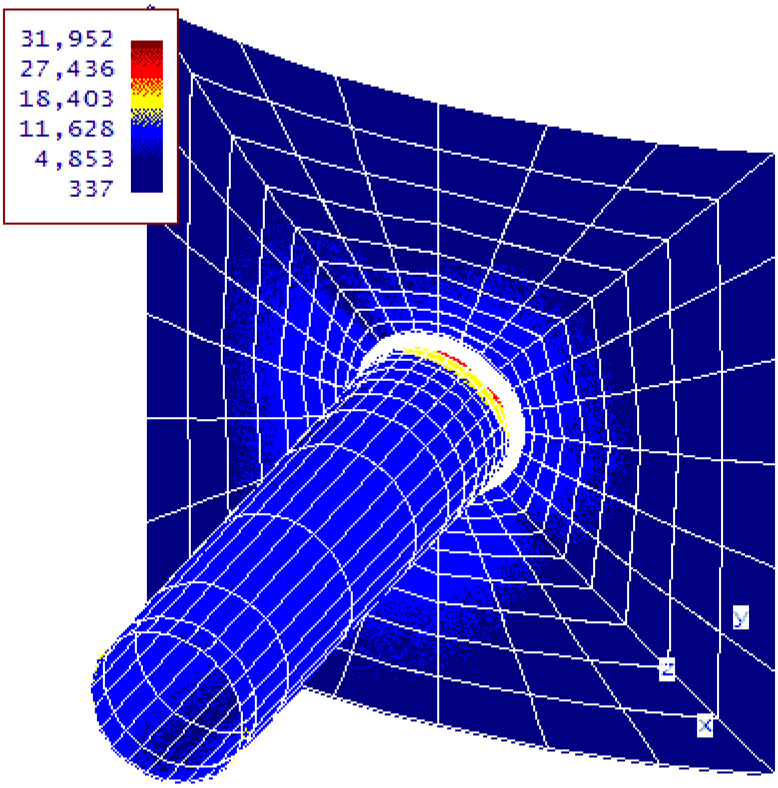
7) Pl+Pb+Q < SPS (OPE Outside) Case 2




- 3d(Small) 3d

3d(Deformed)

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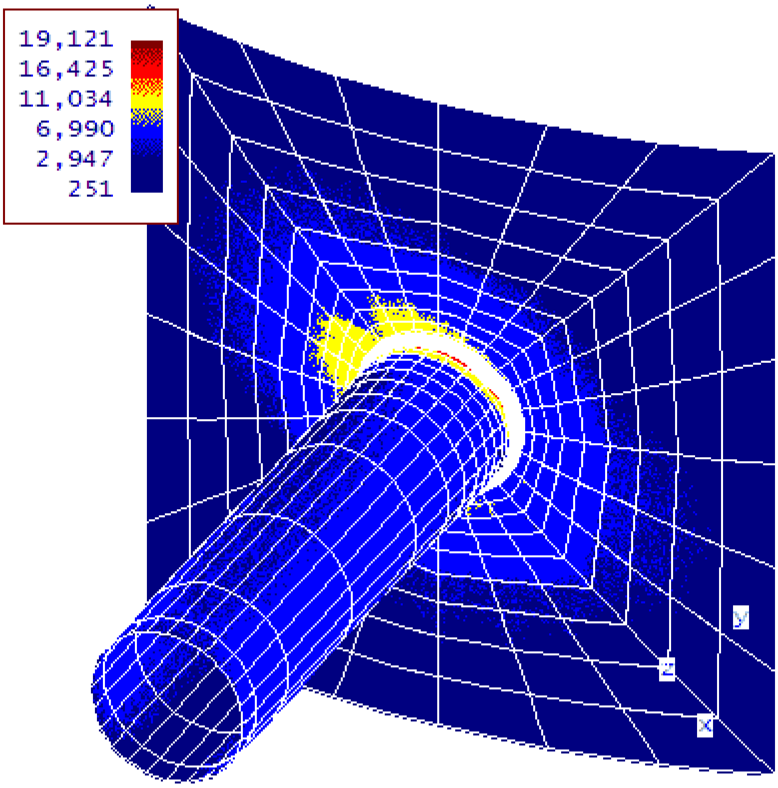
8) Pl+Pb+Q+F < 2Sa (EXP Inside) Case 2




- 3d(Small) 3d
- 3d(Deformed)

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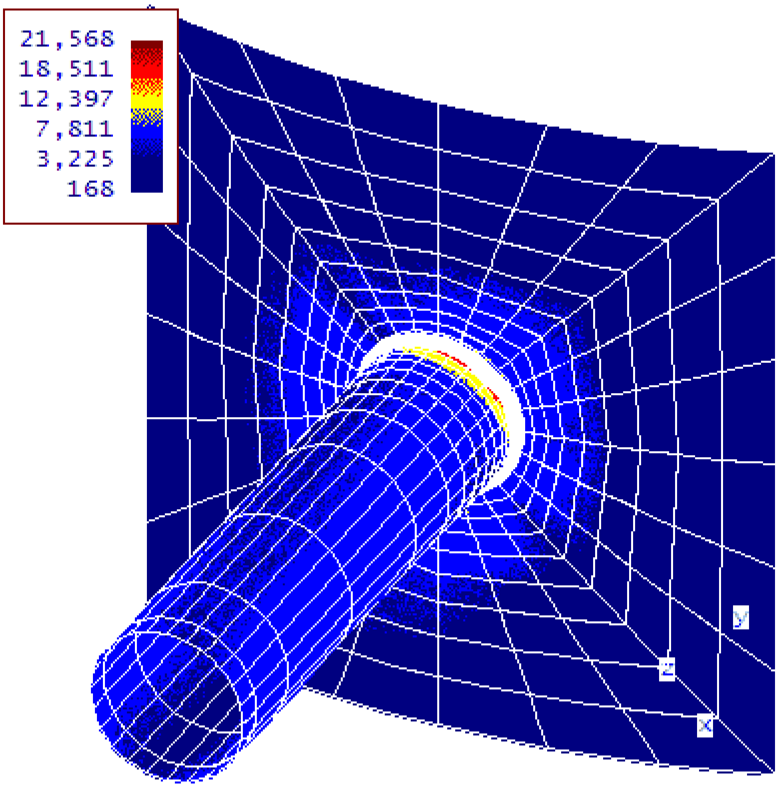
9) Pl+Pb+Q+F < 2Sa (EXP Outside) Case 2




- 3d(Small) 3d
- 3d(Deformed)

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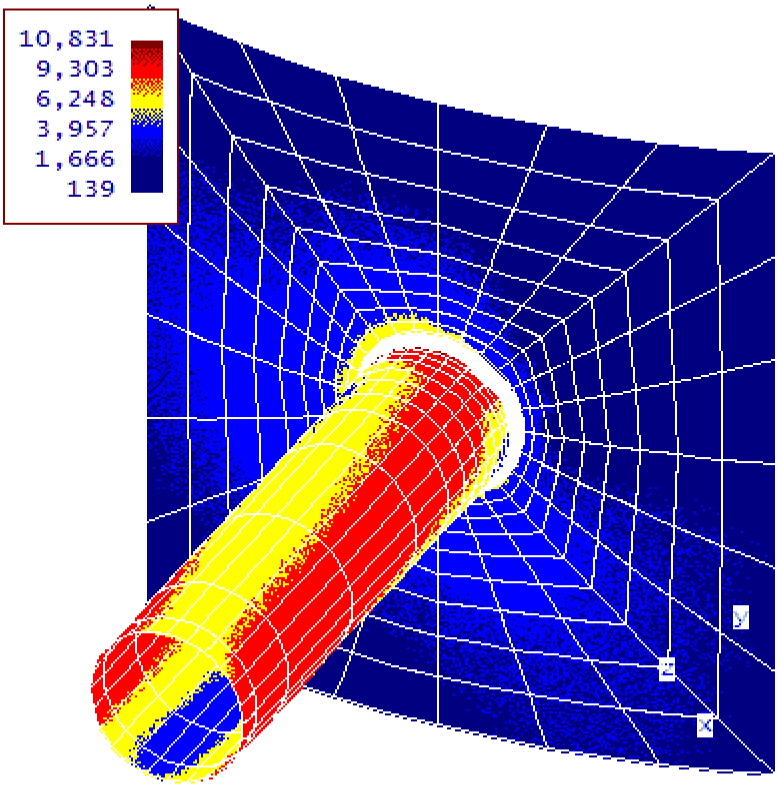
10) Membrane < User (OPE Membrane) Case 2




3d(Small) 3d

- 3d(Deformed)

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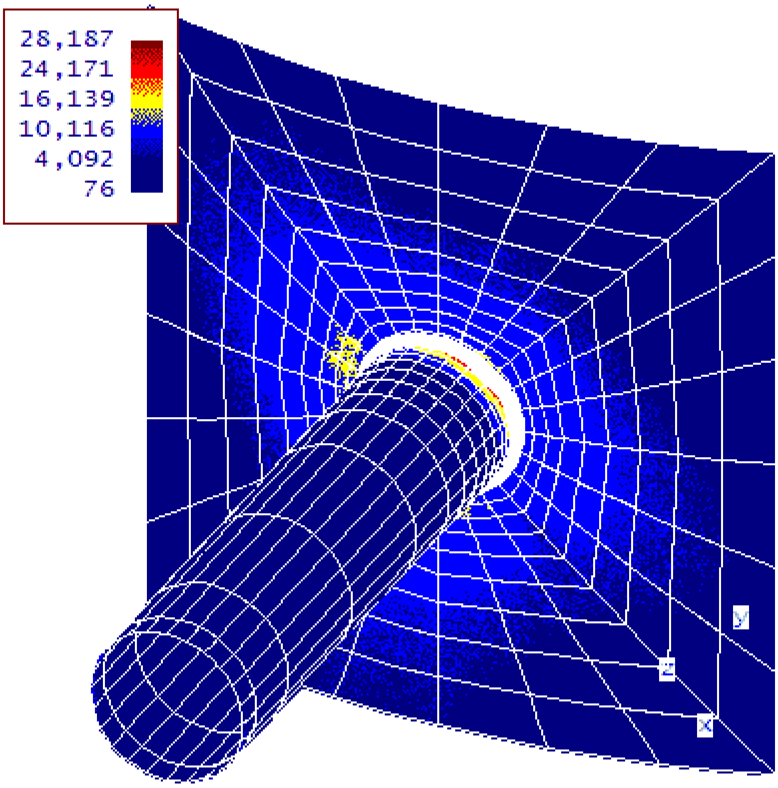
11) Bending < User (OPE Bending) Case 2




3d(Small) 3d

- 3d(Deformed)

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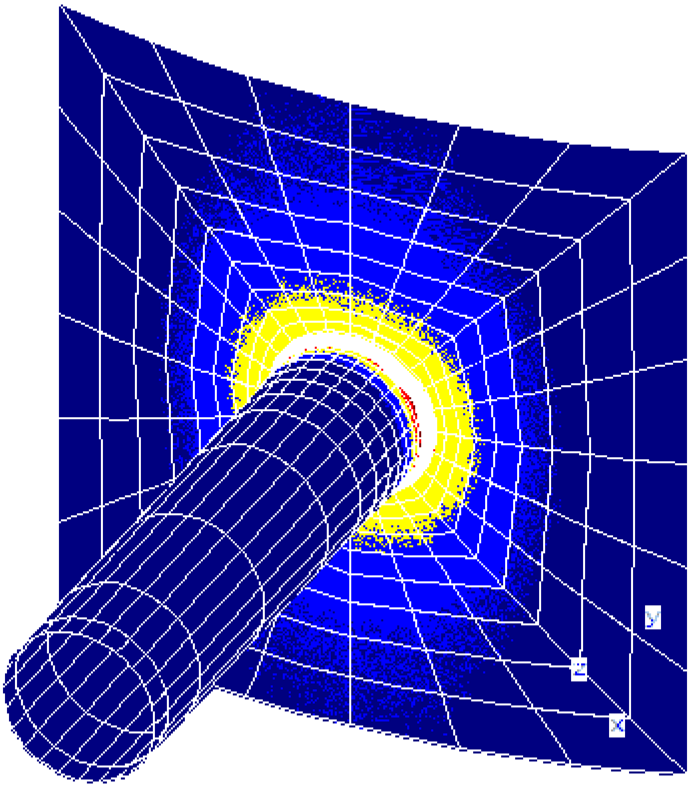
12) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 3




3d(Small) 3d

- 3d(Deformed)
- 

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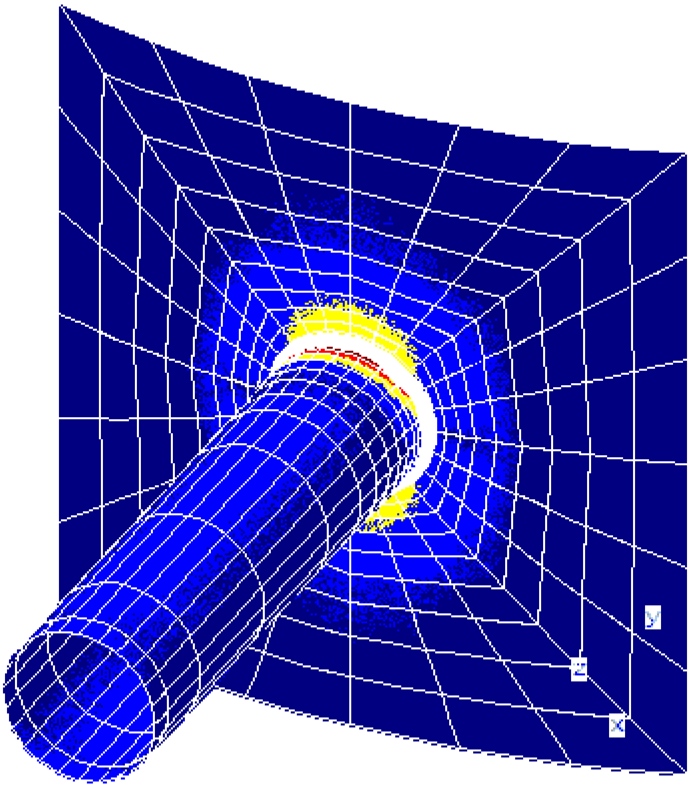
13) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 4




3d(Small) 3d

- 3d(Deformed)
- 

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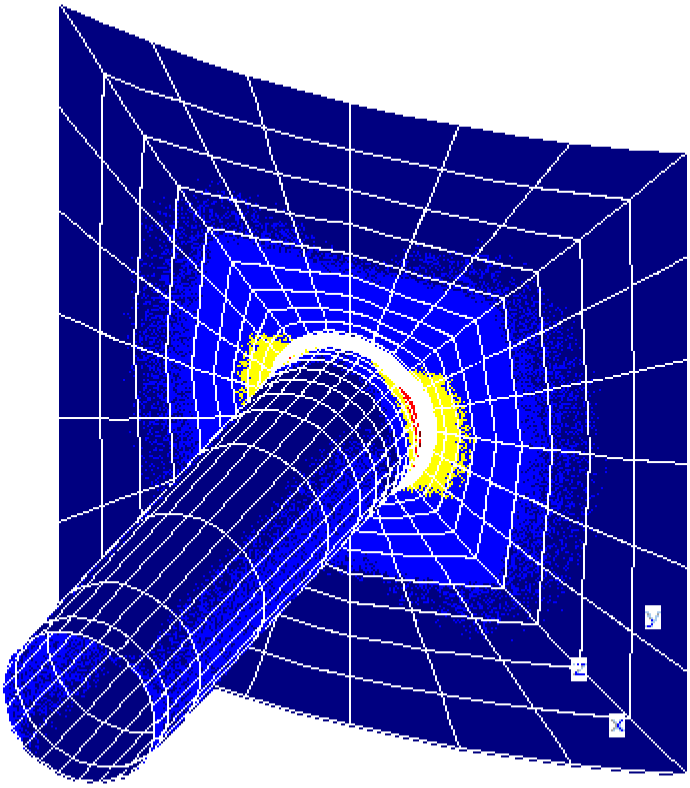
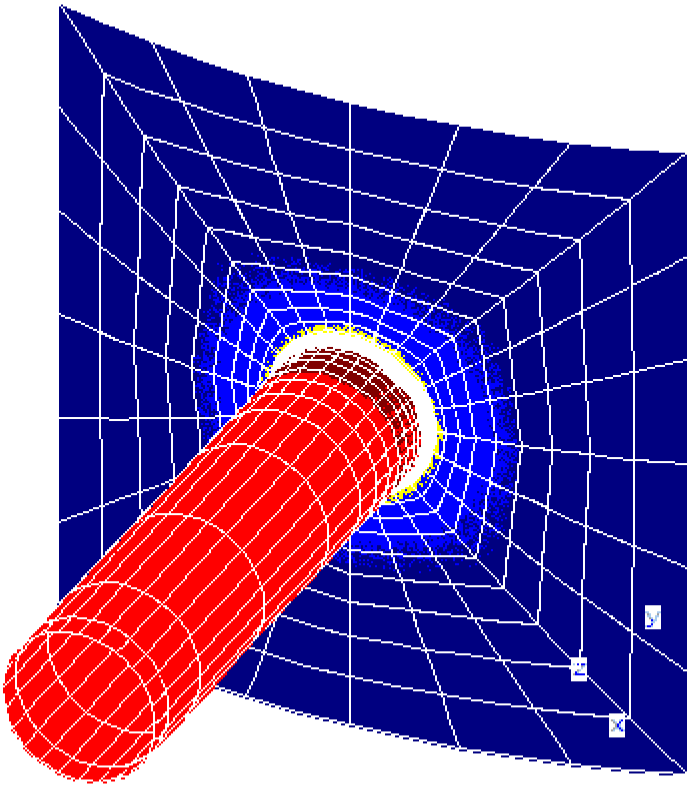
14) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 5



3d(Small) 3d

- 3d(Deformed)
- 

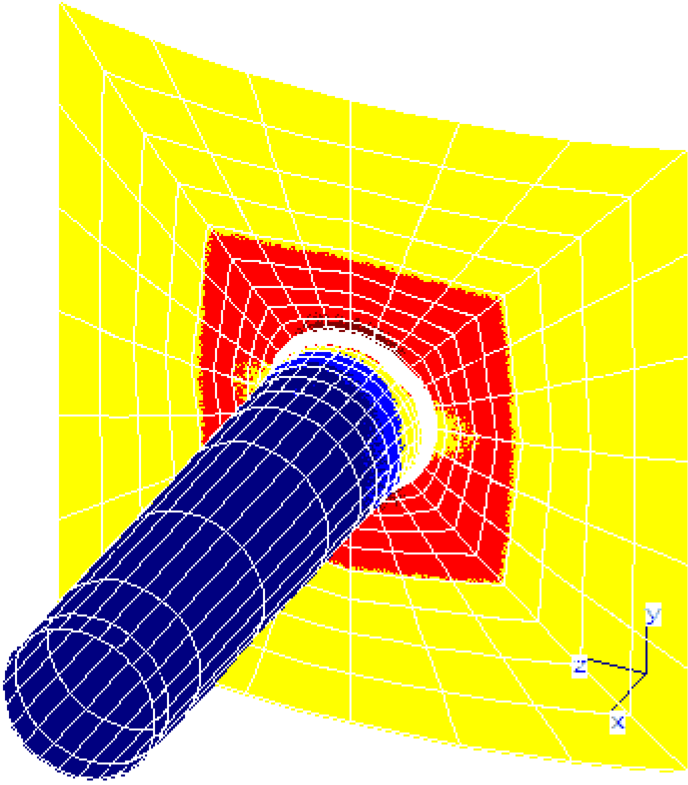
15) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 6



3d(Small) 3d

- 3d(Deformed)
- 

16) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 7




3d(Small) 3d

- 3d(Deformed)

**Tabular Results**

Results were generated with the finite element program FE/Pipe®. Stress results are post-processed in accordance with the rules specified in ASME Section III and ASME Section VIII, Division 2.

Analysis Time Stamp: Sat Oct 23 10:48:56 2021.



---

```
Model Notes
Model Notes

  Input Echo:

  Description:

         V-1264
         Nozzle B3,B4 and S

  Model Type                     : Cylindrical Shell

  Parent Geometry
         Parent Outside Diam.    :      30.030 in.
         Thickness               :       0.394 in.

  Parent Properties:
         Cold Allowable          :     16700.0 psi
         Hot  Allowable          :     14800.0 psi
         Material DB # 1071122.
         Ultimate Tensile (Amb)  :     70000.0 psi
         Yield Strength (Amb)    :     25000.0 psi
         Yield Strength (Hot)    :     16400.0 psi
         Elastic Modulus (Amb)   :  28300000.0 psi
         Poissons Ratio          :       0.300
         Expansion Coefficient   :  0.9700E-05 in./in./deg.
         Weight Density          :  0.0000E+00 lb./cu.in.(NOT USED)

  Nozzle Geometry
         Nozzle Outside Diam.    :       3.296 in.
         Thickness               :       0.656 in.
         Length                  :       8.400 in.
         Nozzle Tilt Angle       :       0.000 deg.
         Distance from Top       :      29.520 in.
         Distance from Bottom    :      30.480 in.

  Nozzle Properties
         Cold Allowable          :     16700.0 psi
         Hot  Allowable          :     14800.0 psi
         Material DB # 1070322.
         Ultimate Tensile (Amb)  :     65000.0 psi
         Yield Strength (Amb)    :     25000.0 psi
         Yield Strength (Hot)    :     16400.0 psi
         Elastic Modulus (Amb)   :  28300000.0 psi
         Poissons Ratio          :       0.300
         Expansion Coefficient   :  0.9700E-05 in./in./deg.
         Weight Density          :  0.0000E+00 lb./cu.in. (NOT USED)
```

```
Design Operating Cycles      :       7000.
Ambient Temperature (Deg.)   :       70.00

Uniform thermal expansion produces no stress in this geometry.
Any thermal loads will come through operating forces and
moments applied through the nozzle.

Nozzle Inside  Temperature   :      500.00 deg.
Nozzle Outside Temperature   :      500.00 deg.
Vessel Inside  Temperature   :      500.00 deg.
Vessel Outside Temperature   :      500.00 deg.

Nozzle Pressure              :       105.0 psi
Vessel Pressure              :       105.0 psi

Operating Pressure           :       105.0 psi

The operating pressure is used for secondary and peak stress
cases. The design pressure is used for primary cases. The ratio
of the operating/design pressure = 1.000

User Defined Load Input Echo for the ATTACHMENT:
Loads are given at the End of Nozzle
Loads are defined in Local Coordinates

Forces( lb.)  Moments (ft-lb)

Load Case        FX          FY          FZ          MX          MY          MZ
---------------------------------------------------------------------------
   OPER:      630.0       630.0       470.0       310.0       210.0       270.0


FEA Model Loads:
These are the actual Attachment loads applied to
the FEA model.
These are the User Defined Loads translated to the
end of the nozzle and reported in global coordinates.

Forces( lb.)  Moments (ft-lb)

Load Case        FX          FY          FZ          MX          MY          MZ
---------------------------------------------------------------------------
   OPER:      630.0       630.0       470.0       310.0       210.0       270.0

The "top" or "positive" end of this model is "free" in
the axial and translational directions.

Stresses ARE nodally AVERAGED.

No weld dimensions have been given for the nozzle
connection to the shell. This will produce conservative
results for external loads and may tend to produce more
realistic inside surface pressure stresses.

Vessel Centerline  Vector    :  0.000   1.000   0.000
Nozzle Orientation Vector    :  1.000   0.000   0.000
```

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---

```
Load Case Report
FEPipe Version 15.0           Jobname: NOZZLE                $P
Released Jan. 2021             10:47am  OCT 23,2021



Load Case Report                                      $X

Inner and outer element temperatures are the same
throughout the model.  No thermal ratcheting
calculations will be performed.

THE   7  LOAD CASES ANALYZED ARE:

  1   SUSTAINED      (Pr Only)

      Sustained case run to satisfy local primary
      membrane and bending stress limits.
```

```
/-------- Loads in Case   1
  Pressure Case    1

2   OPERATING      (Fatigue Calc Performed)

    Case run to compute the operating stresses used in
    secondary, peak and range calculations as needed.

    /-------- Loads in Case   2
      Pressure Case    1
      Loads from (Operating)

3   Program Generated -- Force Only

    Case run to compute sif's and flexibilities.
    /-------- Loads in Case   3
      Loads from (Axial)

4   Program Generated -- Force Only

    Case run to compute sif's and flexibilities.
    /-------- Loads in Case   4
      Loads from (Inplane)

5   Program Generated -- Force Only

    Case run to compute sif's and flexibilities.
    /-------- Loads in Case   5
      Loads from (Outplane)

6   Program Generated -- Force Only

    Case run to compute sif's and flexibilities.
    /-------- Loads in Case   6
      Loads from (Torsion)

7   Program Generated -- Force Only

    Case run to compute sif's and flexibilities.
    /-------- Loads in Case   7
      Pressure Case    1
```

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---

```
Solution Data
FEPipe Version 15.0          Jobname: NOZZLE               $P
Released Jan. 2021            10:48am  OCT 23,2021
```

Solution Data

```
Maximum Solution Row Size =    1440
Number of Nodes           =    3852
Number of Elements        =    1276
Number of Solution Cases  =       7
```

Summation of Loads per Case

| Case # | FX | FY | FZ |
|---|---|---|---|
| 1 | -250. | 72438. | 0. |
| 2 | 380. | 73068. | 470. |
| 3 | 108840. | 0. | 0. |
| 4 | 0. | 0. | 0. |
| 5 | 0. | 0. | 0. |
| 6 | 0. | 0. | 0. |
| 7 | -250. | 72438. | 0. |

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ASME Code Stress Output Plots $X

1) Pl < SPL (SUS,Membrane) Case 1

2) Qb < SPS (SUS,Bending) Case 1

3) Pl+Pb+Q < SPS (SUS,Inside) Case 1

4) Pl+Pb+Q < SPS (SUS,Outside) Case 1

5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 1

6) Pl+Pb+Q < SPS (OPE,Inside) Case 2

7) Pl+Pb+Q < SPS (OPE,Outside) Case 2

8) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 2

9) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 2

10) Membrane < User (OPE,Membrane) Case 2

11) Bending < User (OPE,Bending) Case 2

12) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 3

13) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 4

14) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 5

15) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 6

16) Pl+Pb+Q+F < 2Sa (SIF,Outside) Case 7

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---



Stress Results - Notes

- Results in this analysis were generated using the finite element solution method.

- Using 2019 ASME Section VIII Division 2

- Use Polished Bar fatigue curve.

- Ratio between Operating and Design Pressure = 1.000000
  Range cases use operating pressure. Primary cases use design pressure.

- Assume free end displacements of attached pipe (e.g. thermal loads) are secondary loads.

- Primary bending stresses at discontinuities are treated like secondary stresses. (Pb=0)

- Use Equivalent Stress (Von Mises).

- TRIAXIAL Stress Guidelines:
  S1+S2+S3 evaluation omitted from operating stress.
  Include S1+S2+S3 evaluation in primary case evaluation.
  Bending stress NOT included for all S1+S2+S3 calculations.

```
- Use local tensor values for averaged and not averaged stresses.
```

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---

```
ASME Overstressed Areas
FEPipe Version 15.0          Jobname: NOZZLE              $P
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ASME Overstressed Areas                             $X


             *** NO OVERSTRESSED NODES IN THIS MODEL ***
```

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---

```
Highest Primary Stress Ratios
FEPipe Version 15.0          Jobname: NOZZLE              $P
Released Jan. 2021            10:48am  OCT 23,2021



Highest Primary Stress Ratios                       $X


Header Next to Nozzle Weld

       Pl            SPL     Primary Membrane Load Case 1
    4,218         22,200     Min Prin. Stress = -127. ( 0% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 1
           18%


Branch Next to Header Weld

       Pl            SPL     Primary Membrane Load Case 1
    3,463         22,200     Min Prin. Stress = -1083. (76% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 1
           15%


Branch Transition

       Pl            SPL     Primary Membrane Load Case 1
      297         22,200     Min Prin. Stress = -338. ( 4% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 1
            1%


Header away from Junction

       Pl            SPL     Primary Membrane Load Case 1
    3,621         22,200     Min Prin. Stress = -11. ( 0% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 1
           16%


Branch away from Junction

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 1
    1,008         47,250     Min Prin. Stress = -637. (52% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             4) Pl+Pb+Q < SPS (SUS,Outside) Case 1
            2%
```

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```
Highest Secondary Stress Ratios
FEPipe Version 15.0          Jobname: NOZZLE                 $P
Released Jan. 2021            10:48am  OCT 23,2021



Highest Secondary Stress Ratios                        $X


Header Next to Nozzle Weld

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 2
   23,791          47,250    Min Prin. Stress = -2710. (54% Neg, 0% NegHi)
      psi             psi    Plot Reference:
                             7) Pl+Pb+Q < SPS (OPE,Outside) Case 2
            50%


Branch Next to Header Weld

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 2
   10,529          47,250    Min Prin. Stress = -3910. (80% Neg, 0% NegHi)
      psi             psi    Plot Reference:
                             6) Pl+Pb+Q < SPS (OPE,Inside) Case 2
            22%


Branch Transition

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 2
    2,769          47,250    Min Prin. Stress = -1783. (75% Neg, 0% NegHi)
      psi             psi    Plot Reference:
                             7) Pl+Pb+Q < SPS (OPE,Outside) Case 2
             5%


Header away from Junction

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 2
   10,962          47,250    Min Prin. Stress = -1291. (11% Neg, 0% NegHi)
      psi             psi    Plot Reference:
                             7) Pl+Pb+Q < SPS (OPE,Outside) Case 2
            23%


Branch away from Junction

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 2
    2,780          47,250    Min Prin. Stress = -2022. (81% Neg, 0% NegHi)
      psi             psi    Plot Reference:
                             7) Pl+Pb+Q < SPS (OPE,Outside) Case 2
             5%
```

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```
Highest Fatigue Stress Ratios
FEPipe Version 15.0          Jobname: NOZZLE                 $P
Released Jan. 2021            10:48am  OCT 23,2021



Highest Fatigue Stress Ratios                          $X


Header Next to Nozzle Weld

Pl+Pb+Q+F     Damage Ratio   Primary+Secondary+Peak (Outer) Load Case 2
   16,059      0.003 Life    Stress Concentration Factor = 1.350
      psi      0.271 Stress  Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 2,412,290.
Allowable                    "B31" Fatigue Stress Allowable = 39375.0
```

```
   59,224                    Markl Fatigue Stress Allowable = 47828.5
      psi                    WRC 474 Mean Cycles to Failure = 1,291,659.
                             WRC 474 99% Probability Cycles = 300,070.
      27%                    WRC 474 95% Probability Cycles = 416,615.
                             BS5500 Allowed Cycles(Curve F) = 176,016.
                             Membrane-to-Bending Ratio = 0.330
                             Bending-to-PL+PB+Q Ratio = 0.752
                             Plot Reference:
                             9) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 2


Branch Next to Header Weld

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 2
    7,107     0.000 Life     Stress Concentration Factor = 1.350
      psi     0.120 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 39375.0
   59,224                    Markl Fatigue Stress Allowable = 47828.5
      psi                    WRC 474 Mean Cycles to Failure = 10,998,750.
                             WRC 474 99% Probability Cycles = 2,555,156.
      12%                    WRC 474 95% Probability Cycles = 3,547,562.
                             BS5500 Allowed Cycles(Curve F) = 2,030,785.
                             Membrane-to-Bending Ratio = 0.769
                             Bending-to-PL+PB+Q Ratio = 0.565
                             Plot Reference:
                             8) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 2


Branch Transition

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 2
    1,385     0.000 Life     Stress Concentration Factor = 1.000
      psi     0.023 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 39375.0
   59,224                    Markl Fatigue Stress Allowable = 47828.5
      psi                    WRC 474 Mean Cycles to Failure = 6.4626E8
                             WRC 474 99% Probability Cycles = 1.5013E8
       2%                    WRC 474 95% Probability Cycles = 2.0845E8
                             BS5500 Allowed Cycles(Curve F) = 5.6546E8
                             Membrane-to-Bending Ratio = 4.451
                             Bending-to-PL+PB+Q Ratio = 0.183
                             Plot Reference:
                             9) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 2


Header away from Junction

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 2
    5,481     0.000 Life     Stress Concentration Factor = 1.000
      psi     0.093 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 39375.0
   59,224                    Markl Fatigue Stress Allowable = 47828.5
      psi                    WRC 474 Mean Cycles to Failure = 13,034,872.
                             WRC 474 99% Probability Cycles = 3,028,174.
       9%                    WRC 474 95% Probability Cycles = 4,204,298.
                             BS5500 Allowed Cycles(Curve F) = 1,799,367.
                             Membrane-to-Bending Ratio = 1.045
                             Bending-to-PL+PB+Q Ratio = 0.489
                             Plot Reference:
                             9) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 2


Branch away from Junction

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 2
    1,390     0.000 Life     Stress Concentration Factor = 1.000
      psi     0.023 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 39375.0
   59,224                    Markl Fatigue Stress Allowable = 47828.5
      psi                    WRC 474 Mean Cycles to Failure = 6.3878E8
                             WRC 474 99% Probability Cycles = 1.4840E8
       2%                    WRC 474 95% Probability Cycles = 2.0604E8
                             BS5500 Allowed Cycles(Curve F) = 5.5497E8
                             Membrane-to-Bending Ratio = 4.574
                             Bending-to-PL+PB+Q Ratio = 0.179
                             Plot Reference:
                             9) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 2
```

```
Highest Stress Ratios Per Region
FEPipe Version 15.0          Jobname: NOZZLE              $P
Released Jan. 2021            10:48am  OCT 23,2021



Highest Stress Ratios Per Region                      $X


Header Next to Nozzle Weld

       Pl            SPL     Primary Membrane Load Case 1
    4,218         22,200     Min Prin. Stress = -127. ( 0% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 1
            18%

       Qb            SPS     Primary Bending Load Case 1
      955         47,250     Min Prin. Stress = -127. ( 0% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             2) Qb < SPS (SUS,Bending) Case 1
             2%

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 1
    5,072         47,250     Min Prin. Stress = -127. ( 0% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             3) Pl+Pb+Q < SPS (SUS,Inside) Case 1
            10%

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 1
    3,757         47,250     Min Prin. Stress = -127. ( 0% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             4) Pl+Pb+Q < SPS (SUS,Outside) Case 1
             7%

 S1+S2+S3             4S     Part 5 (5.3.2) Load Case 1
    6,701         59,200     Min Prin. Stress = -127. ( 0% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 1
            11%

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 2
   17,676         47,250     Min Prin. Stress = -2710. (54% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             6) Pl+Pb+Q < SPS (OPE,Inside) Case 2
            37%

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 2
   23,791         47,250     Min Prin. Stress = -2710. (54% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             7) Pl+Pb+Q < SPS (OPE,Outside) Case 2
            50%

Pl+Pb+Q+F   Damage Ratio     Primary+Secondary+Peak (Inner) Load Case 2
   11,931    0.000 Life      Stress Concentration Factor = 1.350
      psi    0.201 Stress    Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 39375.0
   59,224                    Markl Fatigue Stress Allowable = 47828.5
      psi                    WRC 474 Mean Cycles to Failure = 3,537,844.
                             WRC 474 99% Probability Cycles = 821,889.
      20%                    WRC 474 95% Probability Cycles = 1,141,106.
                             BS5500 Allowed Cycles(Curve F) = 429,231.
                             Membrane-to-Bending Ratio = 0.197
                             Bending-to-PL+PB+Q Ratio = 0.836
                             Plot Reference:
                             8) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 2

Pl+Pb+Q+F   Damage Ratio     Primary+Secondary+Peak (Outer) Load Case 2
   16,059    0.003 Life      Stress Concentration Factor = 1.350
      psi    0.271 Stress    Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 2,412,290.
Allowable                    "B31" Fatigue Stress Allowable = 39375.0
   59,224                    Markl Fatigue Stress Allowable = 47828.5
      psi                    WRC 474 Mean Cycles to Failure = 1,291,659.
```

```
                                WRC 474 99% Probability Cycles = 300,070.
      27%                       WRC 474 95% Probability Cycles = 416,615.
                                BS5500 Allowed Cycles(Curve F) = 176,016.
                                Membrane-to-Bending Ratio = 0.330
                                Bending-to-PL+PB+Q Ratio = 0.752
                                Plot Reference:
                                9) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 2

  Membrane          User        Component Evaluation Load Case 2
     8,280        47,250        Min Prin. Stress = -2710. (54% Neg, 0% NegHi)
       psi           psi        Plot Reference:
                                10) Membrane < User (OPE,Membrane) Case 2
            17%

   Bending          User        Component Evaluation Load Case 2
    19,745        47,250        Min Prin. Stress = -2710. (54% Neg, 0% NegHi)
       psi           psi        Plot Reference:
                                11) Bending < User (OPE,Bending) Case 2
            41%


 Branch Next to Header Weld

        Pl           SPL        Primary Membrane Load Case 1
     3,463        22,200        Min Prin. Stress = -1083. (76% Neg, 0% NegHi)
       psi           psi        Plot Reference:
                                1) Pl < SPL (SUS,Membrane) Case 1
            15%

        Qb           SPS        Primary Bending Load Case 1
     2,041        47,250        Min Prin. Stress = -1083. (76% Neg, 0% NegHi)
       psi           psi        Plot Reference:
                                2) Qb < SPS (SUS,Bending) Case 1
             4%

   Pl+Pb+Q           SPS        Primary+Secondary (Inner) Load Case 1
     5,405        47,250        Min Prin. Stress = -1083. (76% Neg, 0% NegHi)
       psi           psi        Plot Reference:
                                3) Pl+Pb+Q < SPS (SUS,Inside) Case 1
            11%

   Pl+Pb+Q           SPS        Primary+Secondary (Outer) Load Case 1
     2,643        47,250        Min Prin. Stress = -1083. (76% Neg, 0% NegHi)
       psi           psi        Plot Reference:
                                4) Pl+Pb+Q < SPS (SUS,Outside) Case 1
             5%

  S1+S2+S3            4S        Part 5 (5.3.2) Load Case 1
     4,007        59,200        Min Prin. Stress = -1083. (76% Neg, 0% NegHi)
       psi           psi        Plot Reference:
                                5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 1
             6%

   Pl+Pb+Q           SPS        Primary+Secondary (Inner) Load Case 2
    10,529        47,250        Min Prin. Stress = -3910. (80% Neg, 0% NegHi)
       psi           psi        Plot Reference:
                                6) Pl+Pb+Q < SPS (OPE,Inside) Case 2
            22%

   Pl+Pb+Q           SPS        Primary+Secondary (Outer) Load Case 2
     8,905        47,250        Min Prin. Stress = -3910. (80% Neg, 0% NegHi)
       psi           psi        Plot Reference:
                                7) Pl+Pb+Q < SPS (OPE,Outside) Case 2
            18%

 Pl+Pb+Q+F    Damage Ratio      Primary+Secondary+Peak (Inner) Load Case 2
     7,107     0.000 Life       Stress Concentration Factor = 1.350
       psi     0.120 Stress     Strain Concentration Factor = 1.000
                                Cycles Allowed for this Stress = 1.0000E11
 Allowable                      "B31" Fatigue Stress Allowable = 39375.0
    59,224                      Markl Fatigue Stress Allowable = 47828.5
       psi                      WRC 474 Mean Cycles to Failure = 10,998,750.
                                WRC 474 99% Probability Cycles = 2,555,156.
       12%                      WRC 474 95% Probability Cycles = 3,547,562.
                                BS5500 Allowed Cycles(Curve F) = 2,030,785.
                                Membrane-to-Bending Ratio = 0.769
                                Bending-to-PL+PB+Q Ratio = 0.565
                                Plot Reference:
                                8) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 2

 Pl+Pb+Q+F    Damage Ratio      Primary+Secondary+Peak (Outer) Load Case 2
     6,011     0.000 Life       Stress Concentration Factor = 1.350
```

```
     psi     0.101 Stress    Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 39375.0
   59,224                    Markl Fatigue Stress Allowable = 47828.5
      psi                    WRC 474 Mean Cycles to Failure = 20,138,978.
                             WRC 474 99% Probability Cycles = 4,678,552.
      10%                    WRC 474 95% Probability Cycles = 6,495,673.
                             BS5500 Allowed Cycles(Curve F) = 3,356,506.
                             Membrane-to-Bending Ratio = 0.376
                             Bending-to-PL+PB+Q Ratio = 0.727
                             Plot Reference:
                             9) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 2

 Membrane          User      Component Evaluation Load Case 2
    6,117        47,250      Min Prin. Stress = -3910. (80% Neg, 0% NegHi)
      psi           psi      Plot Reference:
                             10) Membrane < User (OPE,Membrane) Case 2
            12%

  Bending          User      Component Evaluation Load Case 2
    7,897        47,250      Min Prin. Stress = -3910. (80% Neg, 0% NegHi)
      psi           psi      Plot Reference:
                             11) Bending < User (OPE,Bending) Case 2
            16%


Branch Transition

       Pl           SPL      Primary Membrane Load Case 1
      297        22,200      Min Prin. Stress = -338. ( 4% Neg, 0% NegHi)
      psi           psi      Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 1
             1%

       Qb           SPS      Primary Bending Load Case 1
      275        47,250      Min Prin. Stress = -338. ( 4% Neg, 0% NegHi)
      psi           psi      Plot Reference:
                             2) Qb < SPS (SUS,Bending) Case 1
             0%

  Pl+Pb+Q           SPS      Primary+Secondary (Inner) Load Case 1
      344        47,250      Min Prin. Stress = -338. ( 4% Neg, 0% NegHi)
      psi           psi      Plot Reference:
                             3) Pl+Pb+Q < SPS (SUS,Inside) Case 1
             0%

  Pl+Pb+Q           SPS      Primary+Secondary (Outer) Load Case 1
      557        47,250      Min Prin. Stress = -338. ( 4% Neg, 0% NegHi)
      psi           psi      Plot Reference:
                             4) Pl+Pb+Q < SPS (SUS,Outside) Case 1
             1%

 S1+S2+S3            4S      Part 5 (5.3.2) Load Case 1
      424        59,200      Min Prin. Stress = -338. ( 4% Neg, 0% NegHi)
      psi           psi      Plot Reference:
                             5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 1
             0%

  Pl+Pb+Q           SPS      Primary+Secondary (Inner) Load Case 2
    1,922        47,250      Min Prin. Stress = -1783. (75% Neg, 0% NegHi)
      psi           psi      Plot Reference:
                             6) Pl+Pb+Q < SPS (OPE,Inside) Case 2
             4%

  Pl+Pb+Q           SPS      Primary+Secondary (Outer) Load Case 2
    2,769        47,250      Min Prin. Stress = -1783. (75% Neg, 0% NegHi)
      psi           psi      Plot Reference:
                             7) Pl+Pb+Q < SPS (OPE,Outside) Case 2
             5%

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 2
      961     0.000 Life     Stress Concentration Factor = 1.000
      psi     0.016 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 39375.0
   59,224                    Markl Fatigue Stress Allowable = 47828.5
      psi                    WRC 474 Mean Cycles to Failure = 2.0320E9
                             WRC 474 99% Probability Cycles = 4.7206E8
       1%                    WRC 474 95% Probability Cycles = 6.5541E8
                             BS5500 Allowed Cycles(Curve F) = 3.5129E9
                             Membrane-to-Bending Ratio = 5.180
                             Bending-to-PL+PB+Q Ratio = 0.162
```

```
                               Plot Reference:
                               8) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 2

Pl+Pb+Q+F    Damage Ratio      Primary+Secondary+Peak (Outer) Load Case 2
    1,385     0.000 Life       Stress Concentration Factor = 1.000
      psi     0.023 Stress     Strain Concentration Factor = 1.000
                               Cycles Allowed for this Stress = 1.0000E11
Allowable                      "B31" Fatigue Stress Allowable = 39375.0
   59,224                      Markl Fatigue Stress Allowable = 47828.5
      psi                      WRC 474 Mean Cycles to Failure = 6.4626E8
                               WRC 474 99% Probability Cycles = 1.5013E8
       2%                      WRC 474 95% Probability Cycles = 2.0845E8
                               BS5500 Allowed Cycles(Curve F) = 5.6546E8
                               Membrane-to-Bending Ratio = 4.451
                               Bending-to-PL+PB+Q Ratio = 0.183
                               Plot Reference:
                               9) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 2

 Membrane           User       Component Evaluation Load Case 2
    2,330         47,250       Min Prin. Stress = -1783. (75% Neg, 0% NegHi)
      psi            psi       Plot Reference:
                               10) Membrane < User (OPE,Membrane) Case 2
             4%

  Bending           User       Component Evaluation Load Case 2
      684         47,250       Min Prin. Stress = -1783. (75% Neg, 0% NegHi)
      psi            psi       Plot Reference:
                               11) Bending < User (OPE,Bending) Case 2
             1%


Header away from Junction

       Pl            SPL       Primary Membrane Load Case 1
    3,621         22,200       Min Prin. Stress = -11. ( 0% Neg, 0% NegHi)
      psi            psi       Plot Reference:
                               1) Pl < SPL (SUS,Membrane) Case 1
            16%

       Qb            SPS       Primary Bending Load Case 1
      594         47,250       Min Prin. Stress = -11. ( 0% Neg, 0% NegHi)
      psi            psi       Plot Reference:
                               2) Qb < SPS (SUS,Bending) Case 1
             1%

  Pl+Pb+Q            SPS       Primary+Secondary (Inner) Load Case 1
    4,183         47,250       Min Prin. Stress = -11. ( 0% Neg, 0% NegHi)
      psi            psi       Plot Reference:
                               3) Pl+Pb+Q < SPS (SUS,Inside) Case 1
             8%

  Pl+Pb+Q            SPS       Primary+Secondary (Outer) Load Case 1
    3,593         47,250       Min Prin. Stress = -11. ( 0% Neg, 0% NegHi)
      psi            psi       Plot Reference:
                               4) Pl+Pb+Q < SPS (SUS,Outside) Case 1
             7%

 S1+S2+S3             4S       Part 5 (5.3.2) Load Case 1
    6,120         59,200       Min Prin. Stress = -11. ( 0% Neg, 0% NegHi)
      psi            psi       Plot Reference:
                               5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 1
            10%

  Pl+Pb+Q            SPS       Primary+Secondary (Inner) Load Case 2
   10,184         47,250       Min Prin. Stress = -1291. (11% Neg, 0% NegHi)
      psi            psi       Plot Reference:
                               6) Pl+Pb+Q < SPS (OPE,Inside) Case 2
            21%

  Pl+Pb+Q            SPS       Primary+Secondary (Outer) Load Case 2
   10,962         47,250       Min Prin. Stress = -1291. (11% Neg, 0% NegHi)
      psi            psi       Plot Reference:
                               7) Pl+Pb+Q < SPS (OPE,Outside) Case 2
            23%

Pl+Pb+Q+F    Damage Ratio      Primary+Secondary+Peak (Inner) Load Case 2
    5,092     0.000 Life       Stress Concentration Factor = 1.000
      psi     0.086 Stress     Strain Concentration Factor = 1.000
                               Cycles Allowed for this Stress = 1.0000E11
Allowable                      "B31" Fatigue Stress Allowable = 39375.0
   59,224                      Markl Fatigue Stress Allowable = 47828.5
      psi                      WRC 474 Mean Cycles to Failure = 16,572,259.
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                                  WRC 474 99% Probability Cycles = 3,849,956.
      8%                          WRC 474 95% Probability Cycles = 5,345,254.
                                  BS5500 Allowed Cycles(Curve F) = 2,244,170.
                                  Membrane-to-Bending Ratio = 1.030
                                  Bending-to-PL+PB+Q Ratio = 0.493
                                  Plot Reference:
                                  8) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 2

Pl+Pb+Q+F    Damage Ratio        Primary+Secondary+Peak (Outer) Load Case 2
    5,481     0.000 Life          Stress Concentration Factor = 1.000
      psi     0.093 Stress        Strain Concentration Factor = 1.000
                                  Cycles Allowed for this Stress = 1.0000E11
Allowable                         "B31" Fatigue Stress Allowable = 39375.0
   59,224                         Markl Fatigue Stress Allowable = 47828.5
      psi                         WRC 474 Mean Cycles to Failure = 13,034,872.
                                  WRC 474 99% Probability Cycles = 3,028,174.
      9%                          WRC 474 95% Probability Cycles = 4,204,298.
                                  BS5500 Allowed Cycles(Curve F) = 1,799,367.
                                  Membrane-to-Bending Ratio = 1.045
                                  Bending-to-PL+PB+Q Ratio = 0.489
                                  Plot Reference:
                                  9) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 2

 Membrane            User         Component Evaluation Load Case 2
    6,030          47,250         Min Prin. Stress = -1291. (11% Neg, 0% NegHi)
      psi             psi         Plot Reference:
                                  10) Membrane < User (OPE,Membrane) Case 2
            12%

  Bending            User         Component Evaluation Load Case 2
    5,876          47,250         Min Prin. Stress = -1291. (11% Neg, 0% NegHi)
      psi             psi         Plot Reference:
                                  11) Bending < User (OPE,Bending) Case 2
            12%


Branch away from Junction

       Pl             SPL         Primary Membrane Load Case 1
      383          22,200         Min Prin. Stress = -637. (52% Neg, 0% NegHi)
      psi             psi         Plot Reference:
                                  1) Pl < SPL (SUS,Membrane) Case 1
             1%

       Qb             SPS         Primary Bending Load Case 1
      733          47,250         Min Prin. Stress = -637. (52% Neg, 0% NegHi)
      psi             psi         Plot Reference:
                                  2) Qb < SPS (SUS,Bending) Case 1
             1%

  Pl+Pb+Q             SPS         Primary+Secondary (Inner) Load Case 1
      532          47,250         Min Prin. Stress = -637. (52% Neg, 0% NegHi)
      psi             psi         Plot Reference:
                                  3) Pl+Pb+Q < SPS (SUS,Inside) Case 1
             1%

  Pl+Pb+Q             SPS         Primary+Secondary (Outer) Load Case 1
    1,008          47,250         Min Prin. Stress = -637. (52% Neg, 0% NegHi)
      psi             psi         Plot Reference:
                                  4) Pl+Pb+Q < SPS (SUS,Outside) Case 1
             2%

 S1+S2+S3              4S         Part 5 (5.3.2) Load Case 1
      444          59,200         Min Prin. Stress = -637. (52% Neg, 0% NegHi)
      psi             psi         Plot Reference:
                                  5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 1
             0%

  Pl+Pb+Q             SPS         Primary+Secondary (Inner) Load Case 2
    2,115          47,250         Min Prin. Stress = -2022. (81% Neg, 0% NegHi)
      psi             psi         Plot Reference:
                                  6) Pl+Pb+Q < SPS (OPE,Inside) Case 2
             4%

  Pl+Pb+Q             SPS         Primary+Secondary (Outer) Load Case 2
    2,780          47,250         Min Prin. Stress = -2022. (81% Neg, 0% NegHi)
      psi             psi         Plot Reference:
                                  7) Pl+Pb+Q < SPS (OPE,Outside) Case 2
             5%

Pl+Pb+Q+F    Damage Ratio        Primary+Secondary+Peak (Inner) Load Case 2
    1,058     0.000 Life          Stress Concentration Factor = 1.000
```

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     psi     0.018 Stress    Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 39375.0
   59,224                    Markl Fatigue Stress Allowable = 47828.5
      psi                    WRC 474 Mean Cycles to Failure = 1.5023E9
                             WRC 474 99% Probability Cycles = 3.4901E8
       1%                    WRC 474 95% Probability Cycles = 4.8457E8
                             BS5500 Allowed Cycles(Curve F) = 2.1757E9
                             Membrane-to-Bending Ratio = 5.588
                             Bending-to-PL+PB+Q Ratio = 0.152
                             Plot Reference:
                             8) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 2

Pl+Pb+Q+F   Damage Ratio     Primary+Secondary+Peak (Outer) Load Case 2
    1,390    0.000 Life      Stress Concentration Factor = 1.000
      psi    0.023 Stress    Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 39375.0
   59,224                    Markl Fatigue Stress Allowable = 47828.5
      psi                    WRC 474 Mean Cycles to Failure = 6.3878E8
                             WRC 474 99% Probability Cycles = 1.4840E8
       2%                    WRC 474 95% Probability Cycles = 2.0604E8
                             BS5500 Allowed Cycles(Curve F) = 5.5497E8
                             Membrane-to-Bending Ratio = 4.574
                             Bending-to-PL+PB+Q Ratio = 0.179
                             Plot Reference:
                             9) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 2

 Membrane          User      Component Evaluation Load Case 2
    2,416        47,250      Min Prin. Stress = -2022. (81% Neg, 0% NegHi)
      psi           psi      Plot Reference:
                             10) Membrane < User (OPE,Membrane) Case 2
            5%

  Bending          User      Component Evaluation Load Case 2
    1,114        47,250      Min Prin. Stress = -2022. (81% Neg, 0% NegHi)
      psi           psi      Plot Reference:
                             11) Bending < User (OPE,Bending) Case 2
            2%
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```
Stress Intensification Factors
FEPipe Version 15.0          Jobname: NOZZLE                 $P
Released Jan. 2021            10:48am  OCT 23,2021
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```
Stress Intensification Factors                        $X
```

Branch/Nozzle Sif Summary

| | Peak | Primary | Secondary | SSI |
|---|---|---|---|---|
| Axial : | 20.708 | 15.339 | 30.679 | 3.346 |
| Inplane : | 4.584 | 3.395 | 6.791 | 2.767 |
| Outplane: | 6.332 | 4.690 | 9.380 | 2.548 |
| Torsion : | 0.651 | 0.936 | 0.965 | 1.345 |
| Pressure: | 0.911 | 1.053 | 1.350 | 1.631 |

The above stress intensification factors are to be used in a beam-type analysis of the piping system. Inplane, Outplane and Torsional sif's should be used with the matching branch pipe whose diameter and thickness is given below. The axial sif should be used to intensify the axial stress in the branch pipe calculated by F/A. The pressure sif should be used to intensify the nominal pressure stress in the PARENT or HEADER, calculated from PDo/2T. B31 calculations use mean diameters and Section VIII calculations use outside diameters. SSIs are based on peak stress factors and correlated test results.

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Pipe OD :        3.296  in.
Pipe Thk:        0.656  in.
Z approx:        3.591  cu.in.
Z exact :        3.054  cu.in.
```

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  (SSI = SIF^x)        Axial   Inpl    Outpl   Tors    Pres
SIF/SSI Exponents:     0.901   0.803   0.837   0.154  -0.557

SIF/SSI exponent based on relationship between primary and
peak stress factors from the finite element analysis.

B31.3 Branch Pressure i-factor =       34.547
      Header Pressure i-factor =        1.846

The B31.3 pressure i-factors should be used with with
F/A, where F is the axial force due to pressure, and
A is the area of the pipe wall. This is equivalent to
finding the pressure stress from (ip)(PD/4T).

B31.3   (Branch)
Peak Stress Sif ....    0.000         Axial
                       13.052         Inplane
                       16.847         Outplane
                        1.000         Torsional
B31.1  (Branch)
Peak Stress Sif ....    0.000         Axial
                        6.712         Inplane
                        6.712         Outplane
                        6.712         Torsional
WRC 330  (Branch)
Peak Stress Sif ....    0.000         Axial
                        4.530         Inplane
                        4.530         Outplane
                        1.000         Torsional
```

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Allowable Loads
FEPipe Version 15.0            Jobname: NOZZLE                $P
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Allowable Loads                                        $X
```

| SECONDARY Load Type (Range): | Maximum Individual Occuring | Conservative Simultaneous Occuring | Realistic Simultaneous Occuring |
|---|---|---|---|
| Axial Force (lb. ) | 8381. | 2572. | 3858. |
| Inplane Moment (in. lb.) | 21250. | 4611. | 9780. |
| Outplane Moment (in. lb.) | 15385. | 3338. | 7081. |
| Torsional Moment (in. lb.) | 149525. | 44491. | 66736. |
| Pressure (psi ) | 917.95 | 105.00 | 105.00 |

| PRIMARY Load Type: | Maximum Individual Occuring | Conservative Simultaneous Occuring | Realistic Simultaneous Occuring |
|---|---|---|---|
| Axial Force (lb. ) | 7876. | 2127. | 3190. |
| Inplane Moment (in. lb.) | 19969. | 3812. | 8087. |
| Outplane Moment (in. lb.) | 14457. | 2760. | 5855. |
| Torsional Moment (in. lb.) | 72432. | 19557. | 29335. |
| Pressure (psi ) | 552.64 | 105.00 | 105.00 |

NOTES:

1) Maximum Individual Occuring Loads are the maximum allowed values of the respective loads if all other load components are zero, i.e. the listed axial force may be applied if the inplane, outplane and torsional moments, and the pressure are zero.

2) The Conservative Allowable Simultaneous loads are the maximum loads that can be applied simultaneously. A conservative stress combination equation is used that typically produces stresses within 50-70% of the allowable stress.

3) The Realistic Allowable Simultaneous loads are the maximum loads that can be applied simultaneously. A more realistic stress combination equation is used

based on experience at Paulin Research. Stresses are typically produced within 80-105% of the allowable.

4) Secondary allowable loads are limits for expansion and operating piping loads.

5) Primary allowable loads are limits for weight, primary and sustained type piping loads.

6) High D/T low pressure systems may be subject to instability and should be checked when compressive stresses are present.

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Compressive Stress Summary
FEPipe Version 15.0 Jobname: NOZZLE $P
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Compressive Stress Summary (psi) $X

Nomenclature:
-------------
Min Stress - Compressive Membrane and Bending Stress
Pts in Region - No. of nodes in the model region
>5% Compression - 5% or more of Compressive Stress Limit
>50% Compression - 50% or more of Compressive Stress Limit

Compressive Stress Limit = -0.55 Min(Sy, kEt/R), Section slenderness ratio (elastic buckling) not considered.

| # | Load Type | Case | Min Stress | Pts in Region | >5% Compression and Bending | >50% Compression and Bending | Region |
|---|---|---|---|---|---|---|---|
| 1 | SUSTAINED | 1 | -127. | 840 | 0% | 0% | Header Next to Nozzle Weld |
| 2 | OPERATING | 2 | -2710. | 840 | 54% | 0% | Header Next to Nozzle Weld |
| 3 | EXPANSION | 2 | -2710. | 840 | 54% | 0% | Header Next to Nozzle Weld |
| 4 | OPERATING | 2 | -2710. | 840 | 54% | 0% | Header Next to Nozzle Weld |
| 5 | SUSTAINED | 1 | -11. | 1080 | 0% | 0% | Header away from Junction |
| 6 | OPERATING | 2 | -1291. | 1080 | 11% | 0% | Header away from Junction |
| 7 | EXPANSION | 2 | -1291. | 1080 | 11% | 0% | Header away from Junction |
| 8 | OPERATING | 2 | -1291. | 1080 | 11% | 0% | Header away from Junction |
| 9 | SUSTAINED | 1 | -1083. | 864 | 76% | 0% | Branch Next to Header Weld |
| 10 | OPERATING | 2 | -3910. | 864 | 80% | 0% | Branch Next to Header Weld |
| 11 | EXPANSION | 2 | -3910. | 864 | 80% | 0% | Branch Next to Header Weld |
| 12 | OPERATING | 2 | -3910. | 864 | 80% | 0% | Branch Next to Header Weld |
| 13 | SUSTAINED | 1 | -637. | 168 | 52% | 0% | Branch away from Junction |
| 14 | OPERATING | 2 | -2022. | 168 | 81% | 0% | Branch away from Junction |
| 15 | EXPANSION | 2 | -2022. | 168 | 81% | 0% | Branch away from Junction |
| 16 | OPERATING | 2 | -2022. | 168 | 81% | 0% | Branch away from Junction |
| 17 | SUSTAINED | 1 | -338. | 1080 | 4% | 0% | Branch Transition |
| 18 | OPERATING | 2 | -1783. | 1080 | 75% | 0% | Branch Transition |
| 19 | EXPANSION | 2 | -1783. | 1080 | 75% | 0% | Branch Transition |
| 20 | OPERATING | 2 | -1783. | 1080 | 75% | 0% | Branch Transition |

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Flexibilities
FEPipe Version 15.0 Jobname: NOZZLE $P
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Flexibilities $X

The following stiffnesses should be used in a piping, "beam-type" analysis of the intersection. The stiff-

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nesses should be inserted at the surface of the
branch/header or nozzle/vessel junction.  The general
characteristics used for the branch pipe should be:

Outside Diameter =    3.296  in.
Wall Thickness   =    0.656  in.

Axial Translational Stiffness   =        299488.  lb./in.
Inplane Rotational Stiffness    =         70892.  in.lb./deg
Outplane Rotational Stiffness   =         35919.  in.lb./deg
Torsional Rotational Stiffness  =       1308894.  in.lb./deg


Estimated Radial Shell Displacement due to Allowable Loads
SECONDARY:
Axial (in.) =  0.028  In-Plane (in.) =  0.007  Out-Plane (in.) =  0.010

PRIMARY
Axial (in.) =  0.026  In-Plane (in.) =  0.006  Out-Plane (in.) =  0.009

Secondary Conservative Displacement =  0.012 in.
Secondary Realistic    Displacement =  0.021 in.

Primary Conservative Displacement =  0.010 in.
Primary Realistic Displacement    =  0.017 in.



Intersection Flexibility Factors for Branch/Nozzle
:

Find axial stiffness: K = 3EI/(kd)^3  lb./in.
Find bending and torsional stiffnesses: K = EI/(kd)  in.lb.per radian.
The EI product is    0.14244E+09    lb.in.^2
The value of (d) to use is:   2.640  in..
The resulting bending stiffness is in units of force x length per radian.

Axial Flexibility Factor     (k) =     4.265
Inplane Flexibility Factor   (k) =    13.284
Outplane Flexibility Factor  (k) =    26.219
Torsional Flexibility Factor (k) =     0.720
```

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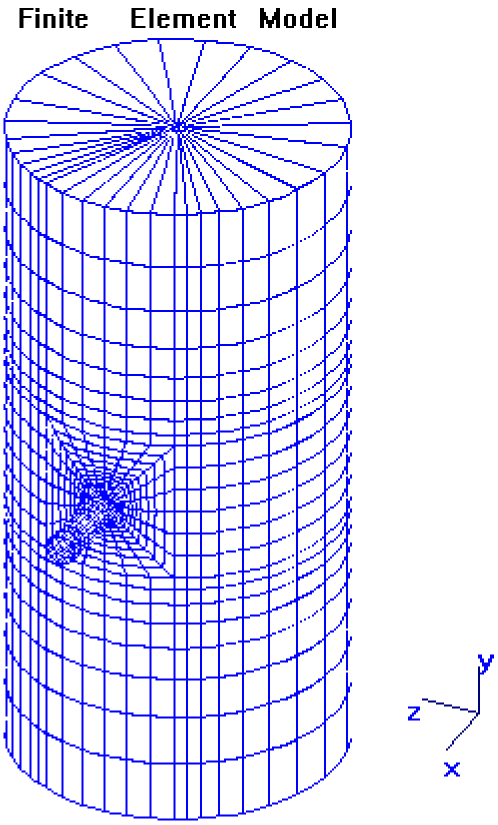
*Finite Element Model*

- Finite Element Model

*Elements at Discontinuity*

- 1) Pl < SPL (SUS Membrane) Case 1
- 2) Qb < SPS (SUS Bending) Case 1
- 3) Pl+Pb+Q < SPS (SUS Inside) Case 1
- 4) Pl+Pb+Q < SPS (SUS Outside) Case 1
- 5) S1+S2+S3 < 4S (SUS S1+S2+S3) Case 1
- 6) Pl+Pb+Q < SPS (OPE Inside) Case 2
- 7) Pl+Pb+Q < SPS (OPE Outside) Case 2
- 8) Pl+Pb+Q+F < 2Sa (EXP Inside) Case 2
- 9) Pl+Pb+Q+F < 2Sa (EXP Outside) Case 2
- 10) Membrane < User (OPE Membrane) Case 2
- 11) Bending < User (OPE Bending) Case 2
- 12) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 3
- 13) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 4
- 14) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 5
- 15) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 6
- 16) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 7




3d

- 

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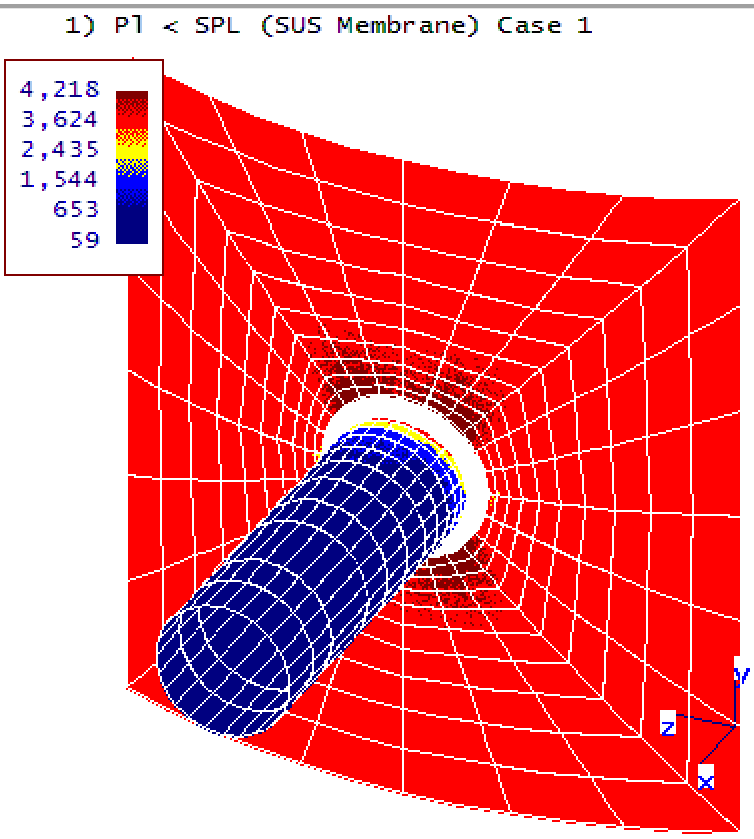


3d(Small) 3d

- 3d(Deformed)

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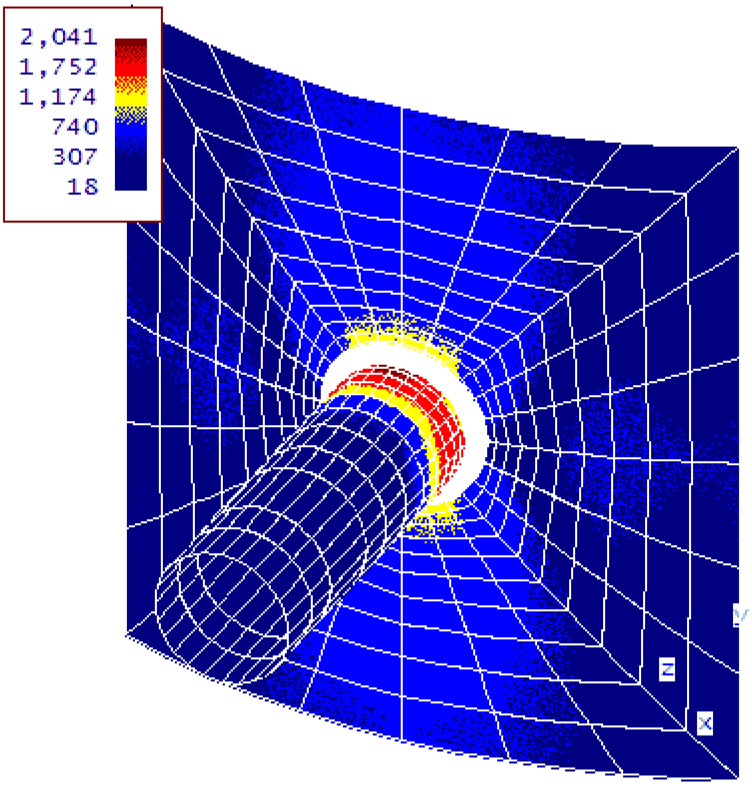
2) Qb < SPS (SUS Bending) Case 1




3d(Small) 3d

- 3d(Deformed)

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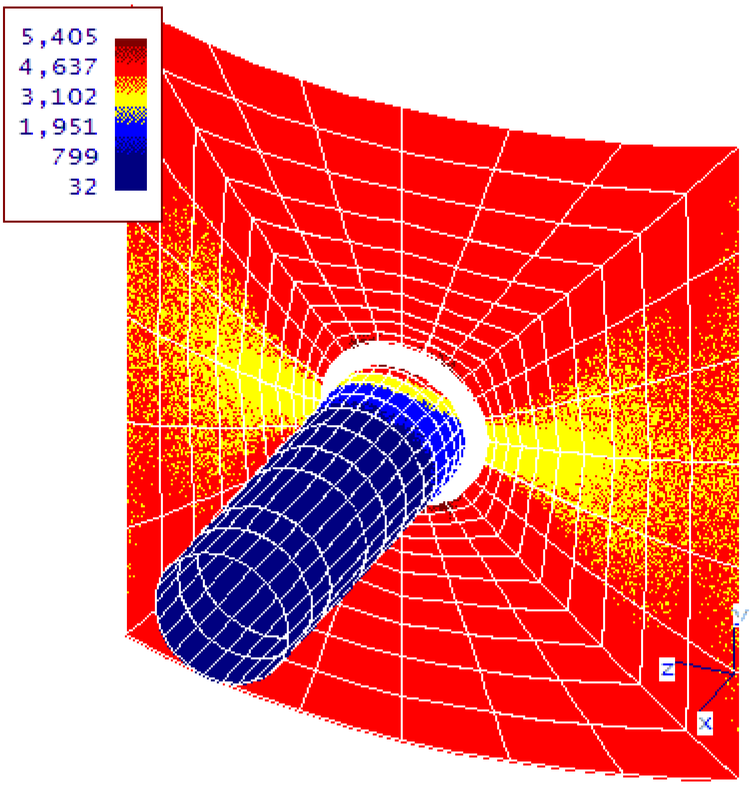
3) Pl+Pb+Q < SPS (SUS Inside) Case 1




3d(Small) 3d

- 3d(Deformed)

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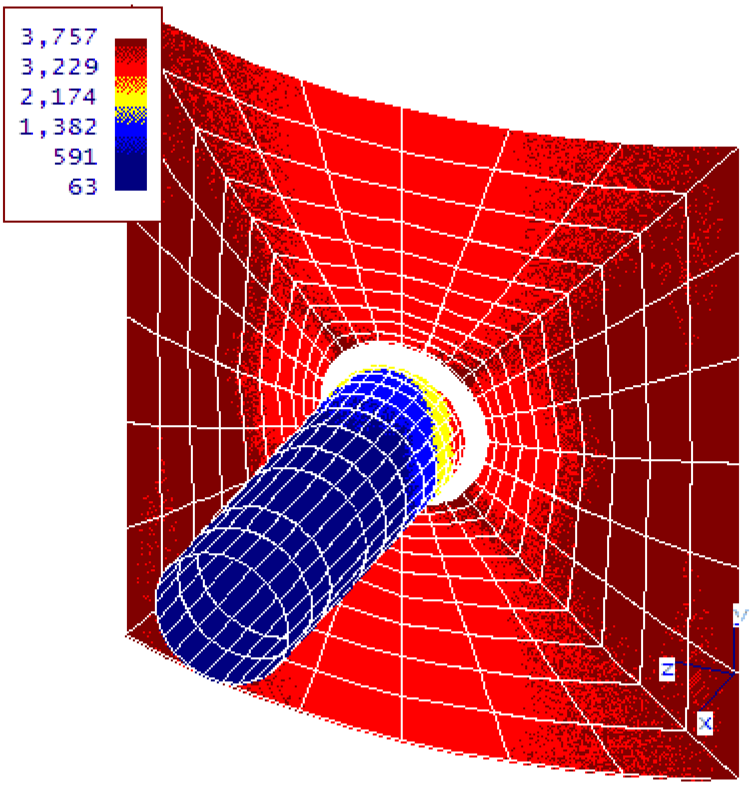
4) Pl+Pb+Q < SPS (SUS Outside) Case 1




3d(Small) 3d

- 3d(Deformed)

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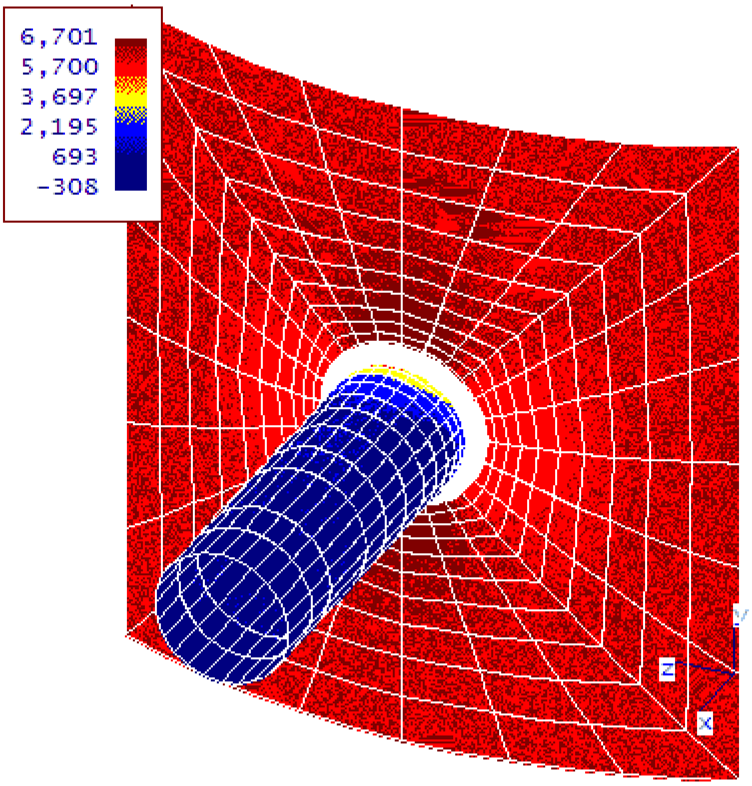
5) S1+S2+S3 < 4S (SUS S1+S2+S3) Case 1




3d(Small) 3d

- 3d(Deformed)

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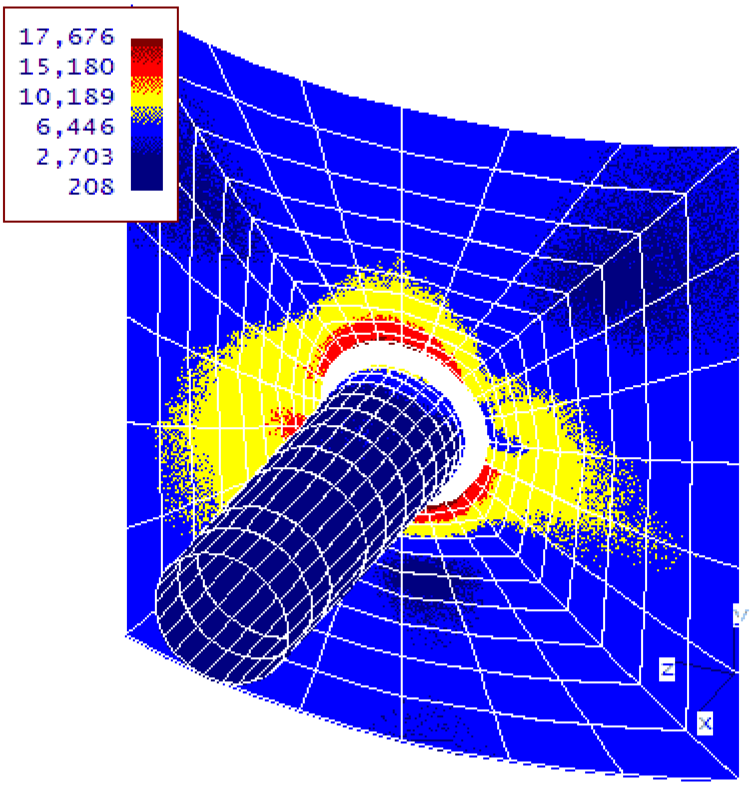
6) Pl+Pb+Q < SPS (OPE Inside) Case 2




3d(Small) 3d

- 3d(Deformed)

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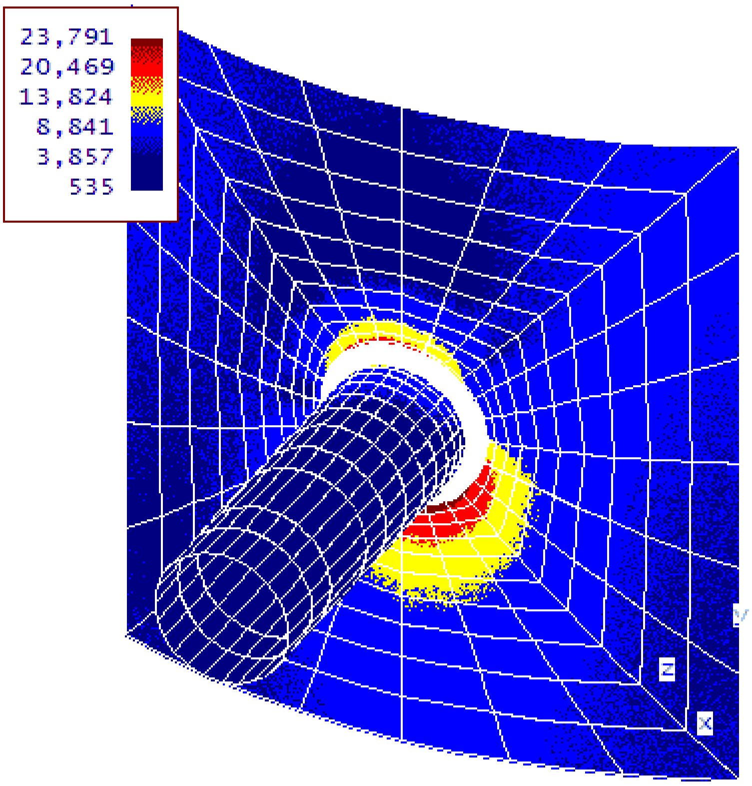
7) Pl+Pb+Q < SPS (OPE Outside) Case 2




3d(Small) 3d

- 3d(Deformed)

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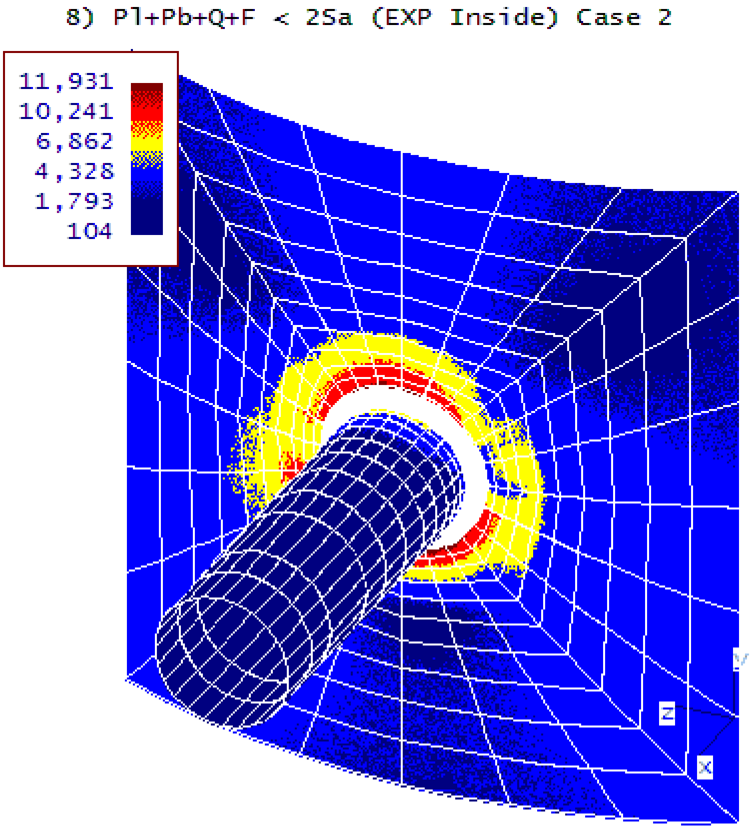
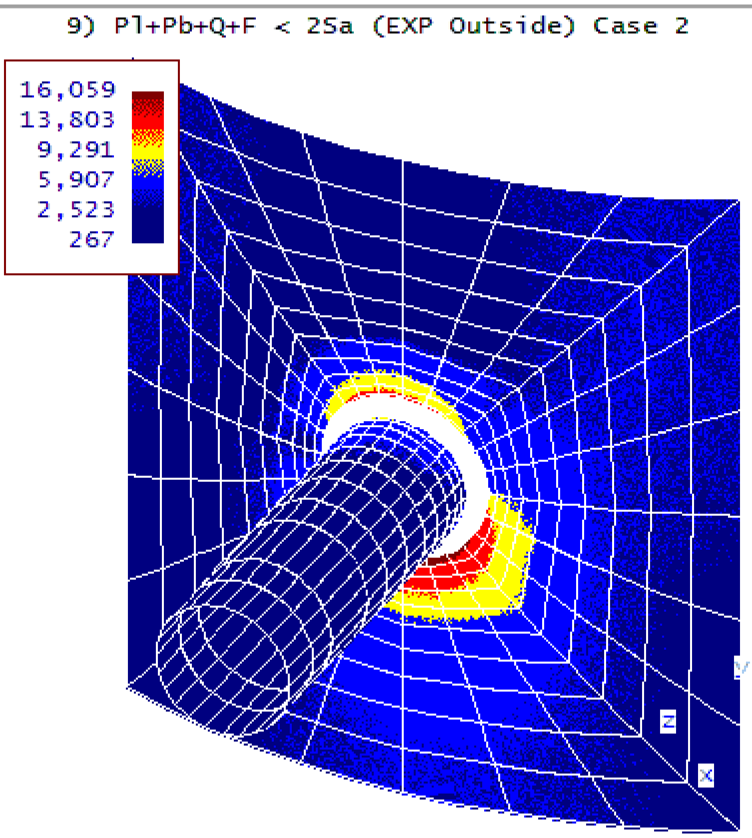



- 3d(Small) 3d
- 3d(Deformed)

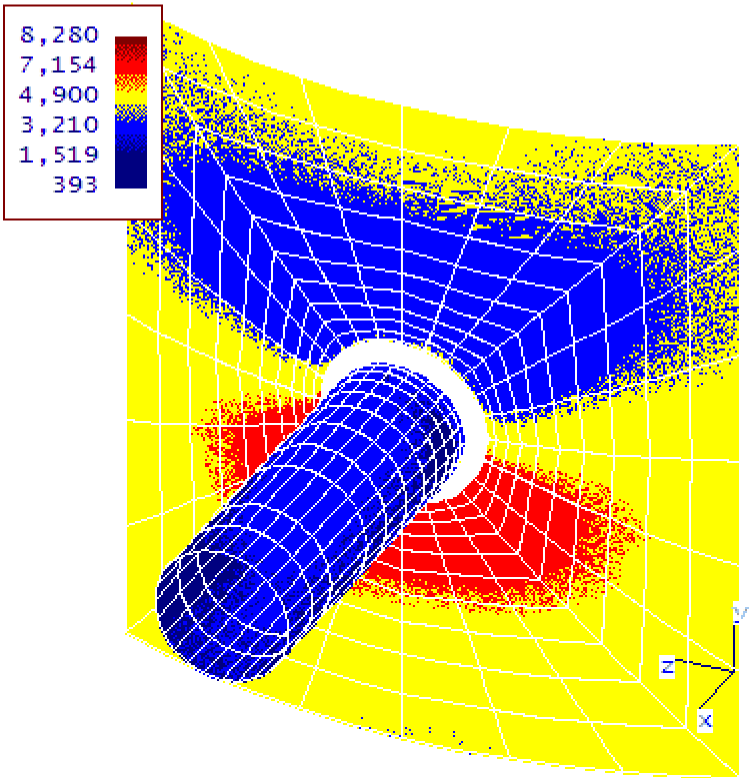
---




- 3d(Small) 3d
- 3d(Deformed)

---

10) Membrane < User (OPE Membrane) Case 2

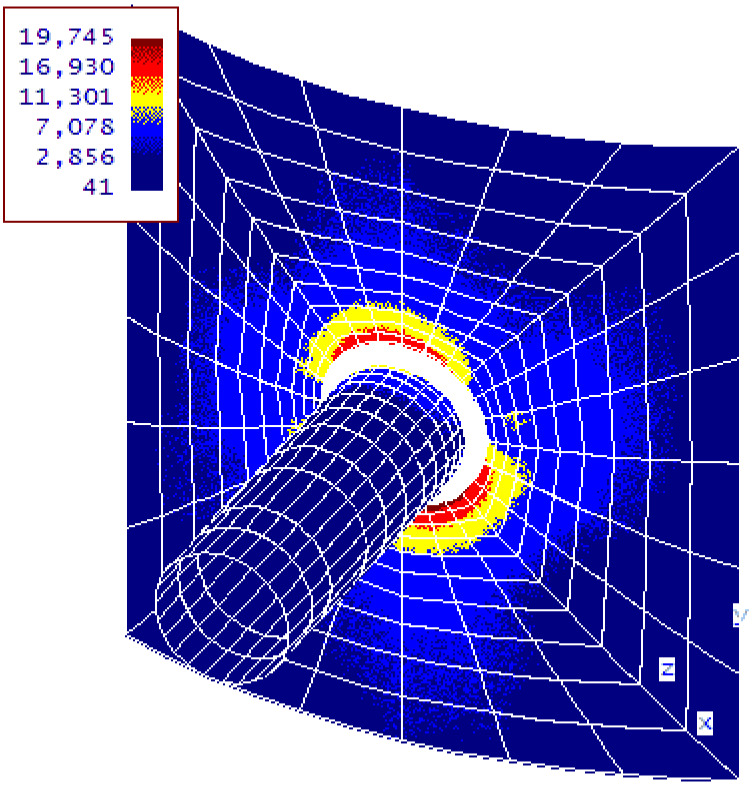



3d(Small) 3d

- 3d(Deformed)

---

11) Bending < User (OPE Bending) Case 2

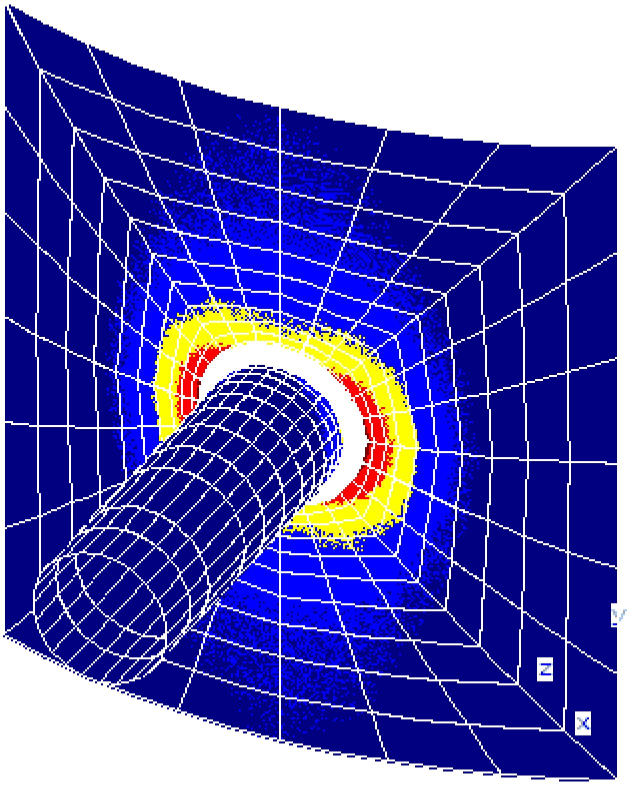



3d(Small) 3d

- 3d(Deformed)

---

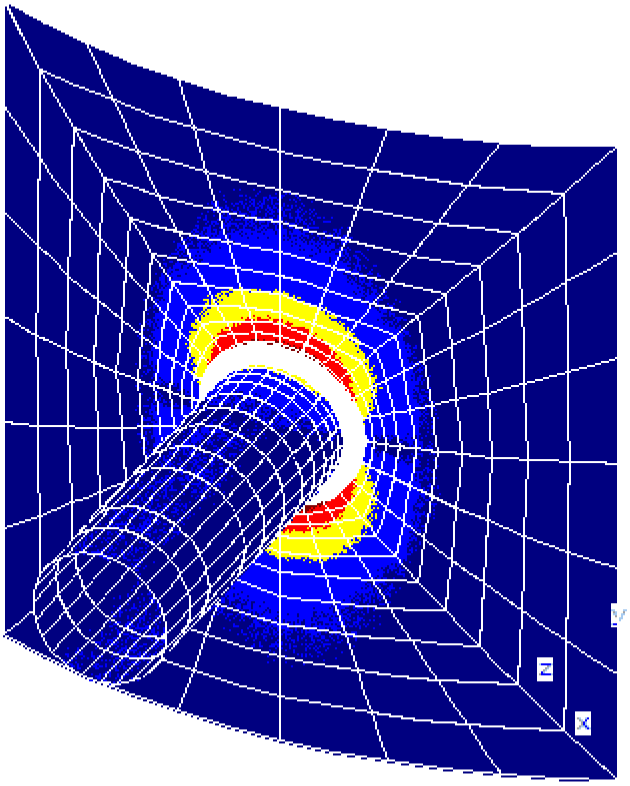
12) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 3



- 3d(Small) 3d
- 3d(Deformed)

---

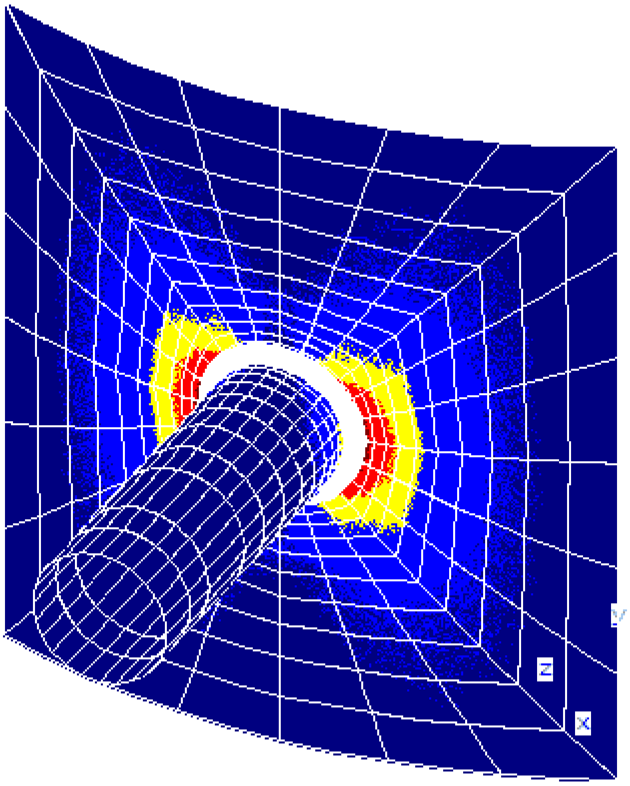
13) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 4



- 3d(Small) 3d
- 3d(Deformed)

---

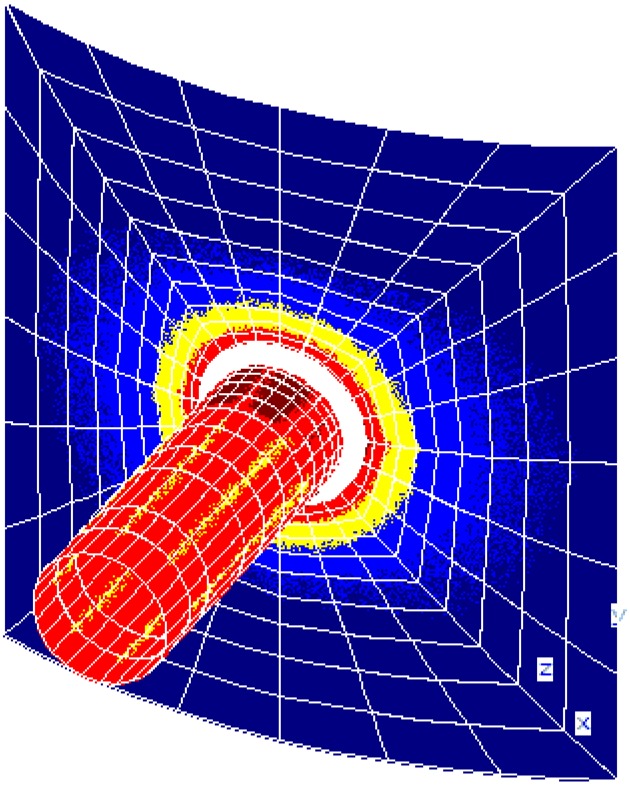
14) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 5




3d(Small) 3d

- 3d(Deformed)
- 

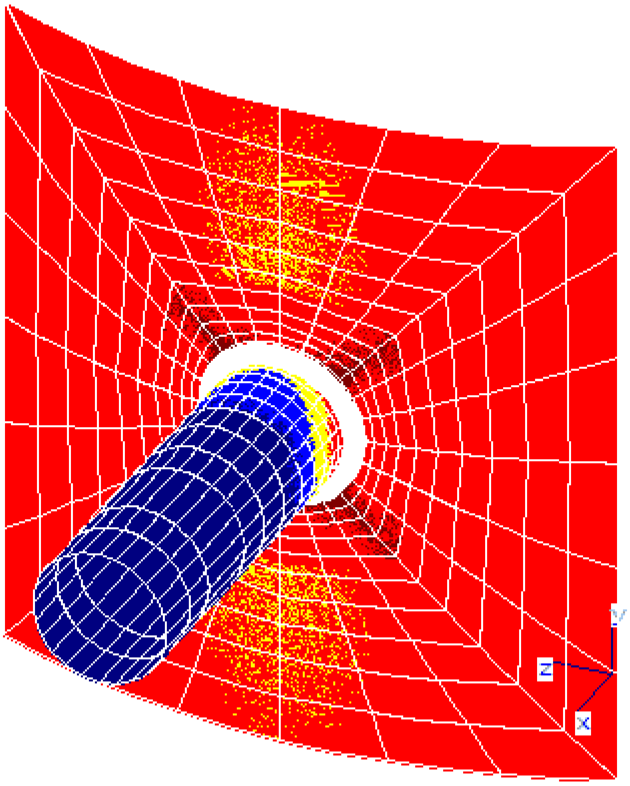
15) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 6




3d(Small) 3d

- 3d(Deformed)
- 

16) Pl+Pb+Q+F < 2Sa (SIF Outside) Case 7




3d(Small) 3d

- 3d(Deformed)

## B 16.5 FLANGE RATING CALCULATION BASED ON EXTERNAL LOADING(STATIC)

### NOZZLE B1

| SL NO | DESCRIPTION | | UNIT | VALUE | | |
|---|---|---|---|---|---|---|
| 1 | Internal design pressure | $P_D$ | barg | 7.24 | 105 psig | |
| 2 | Internal design temperature | T | $C^0$ | 260 | 500 deg F | |
| 3 | Nozzle flange size | | Inch | 6 | | |
| 4 | Flange class selected | # | | 300# | adequate | A 182 Gr. F316L |
| 5 | Flange rating as per B16.5 | $P_R$ | barg | 27.22 | 27.22 barg | |
| 6 | Static head | Ps | barg | 0 | | |
| 7 | Gasket MOC :- Spiral Wound | | | | | |
| 8 | Gasket outside diameter | God | mm | 209.55 | As per table 21 of ASME B-16.20 | |
| 9 | Gasket inside diameter | Gid | mm | 182.6 | | |
| 10 | Axial external load | F | N | 7117.5 | 725.8 | Kgf |
| 11 | Maximum external longitudinal moment | $M_L$ | N-m | 2847.1 | 290.3 | kgf-m |
| 12 | Maximum external circumferential moment | $M_C$ | N-m | 2169.2 | 221 | kgf-m |
| 13 | Maximum external torsional moment | $M_T$ | N-m | 3253.82 | 331.8 | kgf-m |
| 14 | Effective gasket width | b | mm | 6.5 | | |
| 15 | Gasket load reaction diameter | G | mm | 196.468 | | |
| 16 | Maximum external moment | $M_{fs}$ | N-mm | 3579314.7 | Resultant Moment | |
| | | $p_m$ | N/mm2 | 2.4 | | |
| | $MAWP_{Reduction}$ | $P_r$ | N/mm2 | 0.2 | | |
| 17 | $MAWP_{Reduction}$ | Peq | N/mm2 | 2.6 | | |
| 18 | $MAWP_{Reduction}$ | Peq | barg | 26.385 | | |
| 18 | Code Case 2901 Moment Factor | $F_M$ | - | 0.5 | As per Table 1 of Code Case 2901 | |
| 19 | $MAWP_{EXT\ LOAD}$ = Min. [ $P_R$, ($P_R$ x (1+$F_M$)-MAWP $_{REDUCTION}$)-$P_S$ | | **barg** | **14.44** | | |

**Provided nozzle flange is safe for external loadings**

| | | | | |
|---|---|---|---|---|
| 19 | 16 x MFS | | N-mm | 57269035.4 |
| 20 | 4 x F x G | | N-mm | 5593450.7 |
| 21 | PI X $G^3$ X ($P_R$- $P_D$) + $F_M$ X $P_R$ | | N-mm | 80027071.8 |
| 22 | $16M_E + 4F_E G \le \pi G^3\left[\left(P_R - P_D\right) + F_M P_R\right]$ | | **SAFE** | |

**B 16.5 FLANGE RATING CALCULATION BASED ON EXTERNAL LOADING(STATIC)**

**NOZZLE D 2"**

| SL NO | DESCRIPTION | | UNIT | VALUE | | |
|---|---|---|---|---|---|---|
| 1 | Internal design pressure | $P_D$ | barg | 7.24 | 105 psig | |
| 2 | Internal design temperature | T | $C^0$ | 260 | 500 deg F | |
| 3 | Nozzle flange size | | Inch | 2 | | |
| 4 | Flange class selected | # | | 600# | adequate | A 182 Gr. F316L |
| 5 | Flange rating as per B16.5 | $P_R$ | barg | 54.34 | 54.34 barg | |
| 6 | Static head | Ps | barg | 0.28559 | | |
| 7 | Gasket MOC :- Spiral Wound | | | | | |
| 8 | Gasket outside diameter | God | mm | 85.90 | As per table 21 of ASME B-16.20 | |
| 9 | Gasket inside diameter | Gid | mm | 69.9 | | |
| 10 | Axial external load | F | N | 2802.38 | 285.8 | Kgf |
| 11 | Maximum external longitudinal moment | $M_L$ | N-m | 366.055 | 37.3 | kgf-m |
| 12 | Maximum external circumferential moment | $M_C$ | N-m | 284.7 | 29 | kgf-m |
| 13 | Maximum external torsional moment | $M_T$ | N-m | 420.286 | 42.9 | kgf-m |
| 14 | Effective gasket width | b | mm | 4.0 | | |
| 15 | Gasket load reaction diameter | G | mm | 77.900 | | |
| 16 | Maximum external moment | $M_{fs}$ | N-mm | 463741.4 | Resultant Moment | |
| | | $p_m$ | N/mm2 | 5.0 | | |
| | $MAWP_{Reduction}$ | $P_r$ | N/mm2 | 0.6 | | |
| 17 | $MAWP_{Reduction}$ | Peq | N/mm2 | 5.6 | | |
| 18 | $MAWP_{Reduction}$ | Peq | barg | 55.841 | | |
| 18 | Code Case 2901 Moment Factor | $F_M$ | - | 0.5 | As per Table 1 of Code Case 2901 | |
| 19 | $MAWP_{EXT\ LOAD}$ = Min. [ $P_R$, ($P_R$ x (1+$F_M$)-MAWP $_{REDUCTION}$)-$P_S$ | | **barg** | **25.38** | | |

**Provided nozzle flange is safe for external loadings**

| | | | | |
|---|---|---|---|---|
| 19 | 16 x MFS | | N-mm | 7419861.7 |
| 20 | 4 x F x G | | N-mm | 873221.6 |
| 21 | PI X $G^3$ X ($P_R$- $P_D$) + $F_M$ X $P_R$ | | N-mm | 11030004.0 |
| 22 | $16M_E + 4F_E G \le \pi G^3\left[\left(P_R - P_D\right) + F_M P_R\right]$ | | **SAFE** | |

**Tabular Results**

Results were generated with the finite element program FE/Pipe®. Stress results are post-processed in accordance with the rules specified in ASME Section III and ASME Section VIII, Division 2.

Analysis Time Stamp: Fri Dec 16 11:57:18 2022.



---

```
Model Notes
Model Notes

  Input Echo:

  Description:

         PLC-1A,PLC-1B,PLC-1C For Platform #1
          PLC-2APLC-2B,PLC-2C,PLC-2D,PLC-2F,PLC-2I For Platform #2
          PLC-3A, PLC-3B, PLC-3C, PLC-3D, PLC-3E For Platform #3

  Model Type                    : Cylindrical Shell

  Parent Geometry
         Parent Outside Diam.   :      30.037 in.
         Thickness              :       0.394 in.
         Fillet Along Shell     :       0.394 in.

  Parent Properties:
         Cold Allowable         :     16693.8 psi
         Hot  Allowable         :     14793.9 psi
         Material DB # 1071122.
         Ultimate Tensile (Amb) :     69995.4 psi
         Yield Strength (Amb)   :     25004.6 psi
         Yield Strength (Hot)   :     16403.8 psi
         Elastic Modulus (Amb)  :  28301000.0 psi
         Poissons Ratio         :       0.300
         Expansion Coefficient  :  0.9700E-05 in./in./deg.
         Weight Density         :  0.0000E+00 lb./cu.in.(NOT USED)

  Structural Attachment Type    :  Longitudinal Lug

         Thickness              :       0.551 in.
         Height                 :      16.000 in.
         Length                 :       7.589 in.

         Rectangular Pad Width  :       3.268 in.
         Rectangular Pad Height :      18.756 in.
         Rectangular Pad Thick  :       0.394 in.
         Nozzle Tilt Angle      :       0.000 deg.
         Distance from Top      :      78.740 in.
         Distance from Bottom   :      19.685 in.

  Nozzle Properties
         Cold Allowable         :     20000.8 psi
         Hot  Allowable         :     20000.8 psi
         Material DB # 1016422.
         Ultimate Tensile (Amb) :     69995.4 psi
         Yield Strength (Amb)   :     37999.9 psi
         Yield Strength (Hot)   :     30994.6 psi
         Elastic Modulus (Amb)  :  29402000.0 psi
```

```
       Poissons Ratio          :       0.300
       Expansion Coefficient   :  0.7300E-05 in./in./deg.
       Weight Density          :  0.0000E+00 lb./cu.in. (NOT USED)

Design Operating Cycles        :       7000.
Ambient Temperature (Deg.)     :       69.98
```

Thermal Stresses will be introduced into this analysis due to the differences in temperature and/or thermal expansion coefficients. The following temperatures have been specified for the analysis:

```
Nozzle Inside  Temperature     :      500.00 deg.
Nozzle Outside Temperature     :      500.00 deg.
Vessel Inside  Temperature     :      500.00 deg.
Vessel Outside Temperature     :      500.00 deg.
Nozzle Pressure                :       105.2 psi
Vessel Pressure                :       105.2 psi

Operating Pressure             :        10.1 psi
```

The operating pressure is used for secondary and peak stress cases. The design pressure is used for primary cases. The ratio of the operating/design pressure = 0.097

User Defined Load Input Echo for the ATTACHMENT:
Loads are given at the End of Nozzle
Loads are defined in Global Coordinates

Forces( lb.)  Moments (ft-lb)

| Load Case | FX | FY | FZ | MX | MY | MZ |
|---|---|---|---|---|---|---|
| OPER: | 500.0 | -3000.0 | 500.0 | 0.0 | 1000.0 | 7500.0 |

FEA Model Loads:
These are the actual Attachment loads applied to the FEA model.
These are the User Defined Loads translated to the end of the nozzle and reported in global coordinates.

Forces( lb.)  Moments (ft-lb)

| Load Case | FX | FY | FZ | MX | MY | MZ |
|---|---|---|---|---|---|---|
| OPER: | 500.0 | -3000.0 | 500.0 | 0.0 | 1000.0 | 7500.0 |

The "top" or "positive" end of this model is "free" in the axial and translational directions.

Stresses ARE nodally AVERAGED.

```
Vessel Centerline  Vector      :  0.000    1.000    0.000
Nozzle Orientation Vector      :  1.000    0.000    0.000
```

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```
Load Case Report
FEPipe Version 15.0           Jobname: NOZZLE                 $P
Released Jan. 2021             11:56am  DEC 16,2022
```

Load Case Report $X

Inner and outer element temperatures are the same throughout the model.  No thermal ratcheting calculations will be performed.

THE   5  LOAD CASES ANALYZED ARE:

1  WEIGHT ONLY     (Wgt Only)

Weight ONLY case run to get the stress range between the installed and the operating states.

```
/-------- Loads in Case   1
  Loads due to Weight
```

```
2    SUSTAINED      (Wgt+Pr)

     Sustained case run to satisfy local primary
     membrane and bending stress limits.

     /-------- Loads in Case   2
       Loads due to Weight
       Pressure Case    1

3    Thermal ONLY

     Thermal ONLY case run in the event expansion
     stresses exceed the secondary stress allowable.

     /-------- Loads in Case   3
       Temperature Case    1
       Loads from (Thermal Only)

4    OPERATING

     Case run to compute the operating stresses used in
     secondary, peak and range calculations as needed.

     /-------- Loads in Case   4
       Pressure Case    1
       Temperature Case    1
       Loads from (Operating)

5    RANGE          (Fatigue Calc Performed)

     Case run to get the RANGE of stresses.
     as described in NB-3222.2, 5.5.3.2, 5.5.5.2 or 5.5.6.1.

     /-------- Combinations in Range Case    5
       Plus  Stress Results from CASE    4
       Minus Stress Results from CASE    1
```

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---

```
Solution Data
FEPipe Version 15.0          Jobname: NOZZLE              $P
Released Jan. 2021            11:56am  DEC 16,2022
```

Solution Data

```
Maximum Solution Row Size =    1482
Number of Nodes           =    3707
Number of Elements        =    1252
Number of Solution Cases  =       4
```

Summation of Loads per Case

| Case # | FX | FY | FZ |
|---|---|---|---|
| 1 | 0. | 0. | 0. |
| 2 | 0. | 72568. | 0. |
| 3 | 0. | 0. | 0. |
| 4 | 500. | 69568. | 500. |

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---

```
ASME Code Stress Output Plots
FEPipe Version 15.0          Jobname: NOZZLE              $P
Released Jan. 2021            11:57am  DEC 16,2022
```

ASME Code Stress Output Plots                          $X

1) Pl < SPL (SUS,Membrane) Case 2

2) Qb < SPS (SUS,Bending) Case 2

3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2

6) Pl+Pb+Q < SPS (OPE,Inside) Case 4

7) Pl+Pb+Q < SPS (OPE,Outside) Case 4

8) Membrane < User (OPE,Membrane) Case 4

9) Bending < User (OPE,Bending) Case 4

10) Pl+Pb+Q < SPS (EXP,Inside) Case 5

11) Pl+Pb+Q < SPS (EXP,Outside) Case 5

12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 5

13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5

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```
Stress Results - Notes
FEPipe Version 15.0          Jobname: NOZZLE                $P
Released Jan. 2021            11:57am  DEC 16,2022
```

Stress Results - Notes

- Results in this analysis were generated using the finite element solution method.

- Using 2019 ASME Section VIII Division 2

- Use Polished Bar fatigue curve.

- Ratio between Operating and Design Pressure = 9.6528761E-02
  Range cases use operating pressure. Primary cases use design pressure.

- Assume free end displacements of attached pipe (e.g. thermal loads) are secondary loads.

- Primary bending stresses at discontinuities are treated like secondary stresses. (Pb=0)

- Use Equivalent Stress (Von Mises).

- TRIAXIAL Stress Guidelines:
  S1+S2+S3 evaluation omitted from operating stress.
  Include S1+S2+S3 evaluation in primary case evaluation.
  Bending stress NOT included for all S1+S2+S3 calculations.

- Use local tensor values for averaged and not averaged stresses.

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---

```
ASME Overstressed Areas
FEPipe Version 15.0          Jobname: NOZZLE                $P
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```

ASME Overstressed Areas $X

*** NO OVERSTRESSED NODES IN THIS MODEL ***

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---

Highest Primary Stress Ratios
FEPipe Version 15.0 Jobname: NOZZLE $P
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Highest Primary Stress Ratios $X

Shell SCR at Plate # 1

| Pl | SPL | |
|---|---|---|
| 3,514 | 22,191 | Primary Membrane Load Case 2<br>Min Prin. Stress = -2. ( 0% Neg, 0% NegHi) |
| psi | psi | Plot Reference:<br>1) Pl < SPL (SUS,Membrane) Case 2 |
| 15% | | |

Long Plate SCR for Plate # 1

| Pl | SPL | |
|---|---|---|
| 458 | 30,995 | Primary Membrane Load Case 2<br>Min Prin. Stress = -319. (15% Neg, 0% NegHi) |
| psi | psi | Plot Reference:<br>1) Pl < SPL (SUS,Membrane) Case 2 |
| 1% | | |

Pad SCR for Plate # 1

| Pl | SPL | |
|---|---|---|
| 2,134 | 30,995 | Primary Membrane Load Case 2<br>Min Prin. Stress = -5. ( 0% Neg, 0% NegHi) |
| psi | psi | Plot Reference:<br>1) Pl < SPL (SUS,Membrane) Case 2 |
| 6% | | |

Shell in Plate # 1 Vicinity

| Pl | SPL | |
|---|---|---|
| 3,500 | 22,191 | Primary Membrane Load Case 2<br>Min Prin. Stress = -36. ( 1% Neg, 0% NegHi) |
| psi | psi | Plot Reference:<br>1) Pl < SPL (SUS,Membrane) Case 2 |
| 15% | | |

Long Plate for Plate # 1

| Pl | SPL | |
|---|---|---|
| 218 | 30,995 | Primary Membrane Load Case 2<br>Min Prin. Stress = -233. ( 7% Neg, 2% NegHi) |
| psi | psi | Plot Reference:<br>1) Pl < SPL (SUS,Membrane) Case 2 |
| 0% | | |

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Highest Secondary Stress Ratios
FEPipe Version 15.0 Jobname: NOZZLE $P
Released Jan. 2021 11:57am DEC 16,2022

Highest Secondary Stress Ratios $X

```
In combination case  5 the max range stress divided
by the max component stress is 1.00. The case tensor components
are NEVER additive and so the combination case will have
LOWER stresses than the largest of any of the individual
cases by between 1 and 20%.

Load      Combined/Max       Combined/Max
Case        (Inside)           (Outside)
------    -------------      -------------
   5         1.000               1.000


Shell SCR at Plate # 1

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 4
   15,746         47,232     Min Prin. Stress = -7404. (99% Neg, 20% NegHi)
     psi            psi     Plot Reference:
                            7) Pl+Pb+Q < SPS (OPE,Outside) Case 4
            33%

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 5
   15,746         47,232     Min Prin. Stress = -7404. (99% Neg, 20% NegHi)
     psi            psi     Plot Reference:
                            11) Pl+Pb+Q < SPS (EXP,Outside) Case 5
            33%


Long Plate SCR for Plate # 1

  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 4
   24,624         68,995     Min Prin. Stress = -20807. (78% Neg, 56% NegHi)
     psi            psi     Plot Reference:
                            6) Pl+Pb+Q < SPS (OPE,Inside) Case 4
            35%

  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 5
   24,624         68,995     Min Prin. Stress = -20807. (78% Neg, 56% NegHi)
     psi            psi     Plot Reference:
                            10) Pl+Pb+Q < SPS (EXP,Inside) Case 5
            35%


Pad SCR for Plate # 1

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 4
   13,955         68,995     Min Prin. Stress = -8477. (99% Neg, 6% NegHi)
     psi            psi     Plot Reference:
                            7) Pl+Pb+Q < SPS (OPE,Outside) Case 4
            20%

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 5
   13,955         68,995     Min Prin. Stress = -8477. (99% Neg, 6% NegHi)
     psi            psi     Plot Reference:
                            11) Pl+Pb+Q < SPS (EXP,Outside) Case 5
            20%


Shell in Plate # 1 Vicinity

  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 4
   10,418         47,232     Min Prin. Stress = -6676. (98% Neg, 29% NegHi)
     psi            psi     Plot Reference:
                            6) Pl+Pb+Q < SPS (OPE,Inside) Case 4
            22%

  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 5
   10,418         47,232     Min Prin. Stress = -6676. (98% Neg, 29% NegHi)
     psi            psi     Plot Reference:
                            10) Pl+Pb+Q < SPS (EXP,Inside) Case 5
            22%


Long Plate for Plate # 1

  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 4
   24,549         68,995     Min Prin. Stress = -18996. (82% Neg, 30% NegHi)
     psi            psi     Plot Reference:
                            6) Pl+Pb+Q < SPS (OPE,Inside) Case 4
            35%

  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 5
   24,549         68,995     Min Prin. Stress = -18996. (82% Neg, 30% NegHi)
```

```
      psi            psi      Plot Reference:
                              10) Pl+Pb+Q < SPS (EXP,Inside) Case 5
            35%
```

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---

```
Highest Fatigue Stress Ratios
FEPipe Version 15.0            Jobname: NOZZLE                 $P
Released Jan. 2021              11:57am  DEC 16,2022



Highest Fatigue Stress Ratios                          $X


Shell SCR at Plate # 1

Pl+Pb+Q+F     Damage Ratio     Primary+Secondary+Peak (Outer) Load Case 5
   21,257      0.000 Life      Stress Concentration Factor = 1.350
      psi      0.179 Stress    Strain Concentration Factor = 1.000
                               Cycles Allowed for this Stress = 1.0000E11
Allowable                      "B31" Fatigue Stress Allowable = 78719.4
  118,449                      Markl Fatigue Stress Allowable = 95657.0
      psi                      WRC 474 Mean Cycles to Failure = 4,399,098.
                               WRC 474 99% Probability Cycles = 1,021,970.
      17%                      WRC 474 95% Probability Cycles = 1,418,897.
                               BS5500 Allowed Cycles(Curve F) = 607,209.
                               Membrane-to-Bending Ratio = 0.561
                               Bending-to-PL+PB+Q Ratio = 0.641
                               Plot Reference:
                               13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5


Long Plate SCR for Plate # 1

Pl+Pb+Q+F     Damage Ratio     Primary+Secondary+Peak (Inner) Load Case 5
   33,243      0.039 Life      Stress Concentration Factor = 1.350
      psi      0.396 Stress    Strain Concentration Factor = 1.000
                               Cycles Allowed for this Stress = 181,117.
Allowable                      "B31" Fatigue Stress Allowable = 100003.8
   83,994                      Markl Fatigue Stress Allowable = 83402.0
      psi                      WRC 474 Mean Cycles to Failure = 913,129.
                               WRC 474 99% Probability Cycles = 212,132.
      39%                      WRC 474 95% Probability Cycles = 294,523.
                               BS5500 Allowed Cycles(Curve F) = 141,596.
                               Membrane-to-Bending Ratio = 2.014
                               Bending-to-PL+PB+Q Ratio = 0.332
                               Plot Reference:
                               12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 5


Pad SCR for Plate # 1

Pl+Pb+Q+F     Damage Ratio     Primary+Secondary+Peak (Outer) Load Case 5
   18,839      0.000 Life      Stress Concentration Factor = 1.350
      psi      0.224 Stress    Strain Concentration Factor = 1.000
                               Cycles Allowed for this Stress = 1.7818E8
Allowable                      "B31" Fatigue Stress Allowable = 100003.8
   83,994                      Markl Fatigue Stress Allowable = 83402.0
      psi                      WRC 474 Mean Cycles to Failure = 4,855,318.
                               WRC 474 99% Probability Cycles = 1,127,956.
      22%                      WRC 474 95% Probability Cycles = 1,566,047.
                               BS5500 Allowed Cycles(Curve F) = 777,958.
                               Membrane-to-Bending Ratio = 0.405
                               Bending-to-PL+PB+Q Ratio = 0.712
                               Plot Reference:
                               13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5


Shell in Plate # 1 Vicinity

Pl+Pb+Q+F     Damage Ratio     Primary+Secondary+Peak (Inner) Load Case 5
   10,418      0.000 Life      Stress Concentration Factor = 1.000
      psi      0.088 Stress    Strain Concentration Factor = 1.000
                               Cycles Allowed for this Stress = 1.0000E11
Allowable                      "B31" Fatigue Stress Allowable = 78719.4
  118,449                      Markl Fatigue Stress Allowable = 95657.0
```

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      psi                     WRC 474 Mean Cycles to Failure = 16,193,779.
                              WRC 474 99% Probability Cycles = 3,762,030.
       8%                     WRC 474 95% Probability Cycles = 5,223,179.
                              BS5500 Allowed Cycles(Curve F) = 2,096,205.
                              Membrane-to-Bending Ratio = 0.460
                              Bending-to-PL+PB+Q Ratio = 0.685
                              Plot Reference:
                              12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 5


Long Plate for Plate # 1

Pl+Pb+Q+F    Damage Ratio     Primary+Secondary+Peak (Inner) Load Case 5
   24,549     0.007 Life      Stress Concentration Factor = 1.000
      psi     0.292 Stress    Strain Concentration Factor = 1.000
                              Cycles Allowed for this Stress = 982,128.
Allowable                     "B31" Fatigue Stress Allowable = 100003.8
   83,994                     Markl Fatigue Stress Allowable = 83402.0
      psi                     WRC 474 Mean Cycles to Failure = 937,972.
                              WRC 474 99% Probability Cycles = 217,903.
      29%                     WRC 474 95% Probability Cycles = 302,536.
                              BS5500 Allowed Cycles(Curve F) = 142,898.
                              Membrane-to-Bending Ratio = 0.984
                              Bending-to-PL+PB+Q Ratio = 0.504
                              Plot Reference:
                              12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 5
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Highest Stress Ratios Per Region
FEPipe Version 15.0           Jobname: NOZZLE                  $P
Released Jan. 2021             11:57am  DEC 16,2022



Highest Stress Ratios Per Region                       $X


Shell SCR at Plate # 1

       Pl            SPL      Primary Membrane Load Case 2
    3,514         22,191      Min Prin. Stress = -2. ( 0% Neg, 0% NegHi)
      psi            psi      Plot Reference:
                              1) Pl < SPL (SUS,Membrane) Case 2
            15%

       Qb            SPS      Primary Bending Load Case 2
      183         47,232      Min Prin. Stress = -2. ( 0% Neg, 0% NegHi)
      psi            psi      Plot Reference:
                              2) Qb < SPS (SUS,Bending) Case 2
             0%

  Pl+Pb+Q            SPS      Primary+Secondary (Inner) Load Case 2
    3,643         47,232      Min Prin. Stress = -2. ( 0% Neg, 0% NegHi)
      psi            psi      Plot Reference:
                              3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
             7%

  Pl+Pb+Q            SPS      Primary+Secondary (Outer) Load Case 2
    3,407         47,232      Min Prin. Stress = -2. ( 0% Neg, 0% NegHi)
      psi            psi      Plot Reference:
                              4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
             7%

 S1+S2+S3             4S      Part 5 (5.3.2) Load Case 2
    5,987         59,176      Min Prin. Stress = -2. ( 0% Neg, 0% NegHi)
      psi            psi      Plot Reference:
                              5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
            10%

  Pl+Pb+Q            SPS      Primary+Secondary (Inner) Load Case 4
    8,860         47,232      Min Prin. Stress = -7404. (99% Neg, 20% NegHi)
      psi            psi      Plot Reference:
                              6) Pl+Pb+Q < SPS (OPE,Inside) Case 4
            18%

  Pl+Pb+Q            SPS      Primary+Secondary (Outer) Load Case 4
```

```
  15,746         47,232     Min Prin. Stress = -7404. (99% Neg, 20% NegHi)
     psi            psi     Plot Reference:
                            7) Pl+Pb+Q < SPS (OPE,Outside) Case 4
         33%

 Membrane          User     Component Evaluation Load Case 4
    6,349        47,232     Min Prin. Stress = -7404. (99% Neg, 20% NegHi)
     psi            psi     Plot Reference:
                            8) Membrane < User (OPE,Membrane) Case 4
         13%

  Bending          User     Component Evaluation Load Case 4
   10,642        47,232     Min Prin. Stress = -7404. (99% Neg, 20% NegHi)
     psi            psi     Plot Reference:
                            9) Bending < User (OPE,Bending) Case 4
         22%

  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 5
    8,860        47,232     Min Prin. Stress = -7404. (99% Neg, 20% NegHi)
     psi            psi     Plot Reference:
                            10) Pl+Pb+Q < SPS (EXP,Inside) Case 5
         18%

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 5
   15,746        47,232     Min Prin. Stress = -7404. (99% Neg, 20% NegHi)
     psi            psi     Plot Reference:
                            11) Pl+Pb+Q < SPS (EXP,Outside) Case 5
         33%

Pl+Pb+Q+F    Damage Ratio   Primary+Secondary+Peak (Inner) Load Case 5
   11,961     0.000 Life    Stress Concentration Factor = 1.350
      psi     0.101 Stress  Strain Concentration Factor = 1.000
                            Cycles Allowed for this Stress = 1.0000E11
Allowable                   "B31" Fatigue Stress Allowable = 78719.4
  118,449                   Markl Fatigue Stress Allowable = 95657.0
      psi                   WRC 474 Mean Cycles to Failure = 27,584,562.
                            WRC 474 99% Probability Cycles = 6,408,260.
      10%                   WRC 474 95% Probability Cycles = 8,897,189.
                            BS5500 Allowed Cycles(Curve F) = 3,407,947.
                            Membrane-to-Bending Ratio = 0.629
                            Bending-to-PL+PB+Q Ratio = 0.614
                            Plot Reference:
                            12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 5

Pl+Pb+Q+F    Damage Ratio   Primary+Secondary+Peak (Outer) Load Case 5
   21,257     0.000 Life    Stress Concentration Factor = 1.350
      psi     0.179 Stress  Strain Concentration Factor = 1.000
                            Cycles Allowed for this Stress = 1.0000E11
Allowable                   "B31" Fatigue Stress Allowable = 78719.4
  118,449                   Markl Fatigue Stress Allowable = 95657.0
      psi                   WRC 474 Mean Cycles to Failure = 4,399,098.
                            WRC 474 99% Probability Cycles = 1,021,970.
      17%                   WRC 474 95% Probability Cycles = 1,418,897.
                            BS5500 Allowed Cycles(Curve F) = 607,209.
                            Membrane-to-Bending Ratio = 0.561
                            Bending-to-PL+PB+Q Ratio = 0.641
                            Plot Reference:
                            13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5


Long Plate SCR for Plate # 1

       Pl           SPL     Primary Membrane Load Case 2
      458        30,995     Min Prin. Stress = -319. (15% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            1) Pl < SPL (SUS,Membrane) Case 2
          1%

       Qb           SPS     Primary Bending Load Case 2
        0        68,995     Min Prin. Stress = -319. (15% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            2) Qb < SPS (SUS,Bending) Case 2
          0%

  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 2
      458        68,995     Min Prin. Stress = -319. (15% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
          0%

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 2
      458        68,995     Min Prin. Stress = -319. (15% Neg, 0% NegHi)
```

```
     psi            psi     Plot Reference:
                            4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
             0%

 S1+S2+S3            4S     Part 5 (5.3.2) Load Case 2
      503        80,003     Min Prin. Stress = -319. (15% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
             0%

  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 4
   24,624        68,995     Min Prin. Stress = -20807. (78% Neg, 56% NegHi)
      psi           psi     Plot Reference:
                            6) Pl+Pb+Q < SPS (OPE,Inside) Case 4
            35%

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 4
   21,491        68,995     Min Prin. Stress = -20807. (78% Neg, 56% NegHi)
      psi           psi     Plot Reference:
                            7) Pl+Pb+Q < SPS (OPE,Outside) Case 4
            31%

 Membrane          User     Component Evaluation Load Case 4
   20,352        68,995     Min Prin. Stress = -20807. (78% Neg, 56% NegHi)
      psi           psi     Plot Reference:
                            8) Membrane < User (OPE,Membrane) Case 4
            29%

  Bending          User     Component Evaluation Load Case 4
   11,558        68,995     Min Prin. Stress = -20807. (78% Neg, 56% NegHi)
      psi           psi     Plot Reference:
                            9) Bending < User (OPE,Bending) Case 4
            16%

  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 5
   24,624        68,995     Min Prin. Stress = -20807. (78% Neg, 56% NegHi)
      psi           psi     Plot Reference:
                            10) Pl+Pb+Q < SPS (EXP,Inside) Case 5
            35%

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 5
   21,491        68,995     Min Prin. Stress = -20807. (78% Neg, 56% NegHi)
      psi           psi     Plot Reference:
                            11) Pl+Pb+Q < SPS (EXP,Outside) Case 5
            31%

Pl+Pb+Q+F   Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 5
   33,243    0.039 Life     Stress Concentration Factor = 1.350
      psi    0.396 Stress   Strain Concentration Factor = 1.000
                            Cycles Allowed for this Stress = 181,117.
Allowable                   "B31" Fatigue Stress Allowable = 100003.8
   83,994                   Markl Fatigue Stress Allowable = 83402.0
      psi                   WRC 474 Mean Cycles to Failure = 913,129.
                            WRC 474 99% Probability Cycles = 212,132.
      39%                   WRC 474 95% Probability Cycles = 294,523.
                            BS5500 Allowed Cycles(Curve F) = 141,596.
                            Membrane-to-Bending Ratio = 2.014
                            Bending-to-PL+PB+Q Ratio = 0.332
                            Plot Reference:
                            12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 5

Pl+Pb+Q+F   Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 5
   29,013    0.021 Life     Stress Concentration Factor = 1.350
      psi    0.345 Stress   Strain Concentration Factor = 1.000
                            Cycles Allowed for this Stress = 328,311.
Allowable                   "B31" Fatigue Stress Allowable = 100003.8
   83,994                   Markl Fatigue Stress Allowable = 83402.0
      psi                   WRC 474 Mean Cycles to Failure = 1,398,207.
                            WRC 474 99% Probability Cycles = 324,822.
      34%                   WRC 474 95% Probability Cycles = 450,982.
                            BS5500 Allowed Cycles(Curve F) = 212,980.
                            Membrane-to-Bending Ratio = 2.026
                            Bending-to-PL+PB+Q Ratio = 0.330
                            Plot Reference:
                            13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5


Pad SCR for Plate # 1

       Pl           SPL     Primary Membrane Load Case 2
    2,134        30,995     Min Prin. Stress = -5. ( 0% Neg, 0% NegHi)
      psi           psi     Plot Reference:
```

```
                               1) Pl < SPL (SUS,Membrane) Case 2
               6%

        Qb            SPS      Primary Bending Load Case 2
       238         68,995      Min Prin. Stress = -5. ( 0% Neg, 0% NegHi)
       psi            psi      Plot Reference:
                               2) Qb < SPS (SUS,Bending) Case 2
               0%

    Pl+Pb+Q           SPS      Primary+Secondary (Inner) Load Case 2
     2,218         68,995      Min Prin. Stress = -5. ( 0% Neg, 0% NegHi)
       psi            psi      Plot Reference:
                               3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
               3%

    Pl+Pb+Q           SPS      Primary+Secondary (Outer) Load Case 2
     2,100         68,995      Min Prin. Stress = -5. ( 0% Neg, 0% NegHi)
       psi            psi      Plot Reference:
                               4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
               3%

   S1+S2+S3            4S      Part 5 (5.3.2) Load Case 2
     3,648         80,003      Min Prin. Stress = -5. ( 0% Neg, 0% NegHi)
       psi            psi      Plot Reference:
                               5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
               4%

    Pl+Pb+Q           SPS      Primary+Secondary (Inner) Load Case 4
    13,034         68,995      Min Prin. Stress = -8477. (99% Neg, 6% NegHi)
       psi            psi      Plot Reference:
                               6) Pl+Pb+Q < SPS (OPE,Inside) Case 4
              18%

    Pl+Pb+Q           SPS      Primary+Secondary (Outer) Load Case 4
    13,955         68,995      Min Prin. Stress = -8477. (99% Neg, 6% NegHi)
       psi            psi      Plot Reference:
                               7) Pl+Pb+Q < SPS (OPE,Outside) Case 4
              20%

   Membrane          User      Component Evaluation Load Case 4
     5,958         68,995      Min Prin. Stress = -8477. (99% Neg, 6% NegHi)
       psi            psi      Plot Reference:
                               8) Membrane < User (OPE,Membrane) Case 4
               8%

    Bending          User      Component Evaluation Load Case 4
    12,305         68,995      Min Prin. Stress = -8477. (99% Neg, 6% NegHi)
       psi            psi      Plot Reference:
                               9) Bending < User (OPE,Bending) Case 4
              17%

    Pl+Pb+Q           SPS      Primary+Secondary (Inner) Load Case 5
    13,034         68,995      Min Prin. Stress = -8477. (99% Neg, 6% NegHi)
       psi            psi      Plot Reference:
                               10) Pl+Pb+Q < SPS (EXP,Inside) Case 5
              18%

    Pl+Pb+Q           SPS      Primary+Secondary (Outer) Load Case 5
    13,955         68,995      Min Prin. Stress = -8477. (99% Neg, 6% NegHi)
       psi            psi      Plot Reference:
                               11) Pl+Pb+Q < SPS (EXP,Outside) Case 5
              20%

  Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 5
    17,596      0.000 Life     Stress Concentration Factor = 1.350
       psi      0.209 Stress   Strain Concentration Factor = 1.000
                               Cycles Allowed for this Stress = 6.7690E8
  Allowable                    "B31" Fatigue Stress Allowable = 100003.8
    83,994                     Markl Fatigue Stress Allowable = 83402.0
       psi                     WRC 474 Mean Cycles to Failure = 6,298,671.
                               WRC 474 99% Probability Cycles = 1,463,266.
       20%                     WRC 474 95% Probability Cycles = 2,031,590.
                               BS5500 Allowed Cycles(Curve F) = 954,796.
                               Membrane-to-Bending Ratio = 0.422
                               Bending-to-PL+PB+Q Ratio = 0.703
                               Plot Reference:
                               12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 5

  Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 5
    18,839      0.000 Life     Stress Concentration Factor = 1.350
       psi      0.224 Stress   Strain Concentration Factor = 1.000
                               Cycles Allowed for this Stress = 1.7818E8
```

```
Allowable                    "B31" Fatigue Stress Allowable = 100003.8
   83,994                    Markl Fatigue Stress Allowable = 83402.0
      psi                    WRC 474 Mean Cycles to Failure = 4,855,318.
                             WRC 474 99% Probability Cycles = 1,127,956.
      22%                    WRC 474 95% Probability Cycles = 1,566,047.
                             BS5500 Allowed Cycles(Curve F) = 777,958.
                             Membrane-to-Bending Ratio = 0.405
                             Bending-to-PL+PB+Q Ratio = 0.712
                             Plot Reference:
                             13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5


Shell in Plate # 1 Vicinity

       Pl            SPL     Primary Membrane Load Case 2
    3,500         22,191     Min Prin. Stress = -36. ( 1% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
            15%

       Qb            SPS     Primary Bending Load Case 2
      205         47,232     Min Prin. Stress = -36. ( 1% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             2) Qb < SPS (SUS,Bending) Case 2
             0%

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 2
    3,589         47,232     Min Prin. Stress = -36. ( 1% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
             7%

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 2
    3,557         47,232     Min Prin. Stress = -36. ( 1% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
             7%

 S1+S2+S3             4S     Part 5 (5.3.2) Load Case 2
    5,994         59,176     Min Prin. Stress = -36. ( 1% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
            10%

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 4
   10,418         47,232     Min Prin. Stress = -6676. (98% Neg, 29% NegHi)
      psi            psi     Plot Reference:
                             6) Pl+Pb+Q < SPS (OPE,Inside) Case 4
            22%

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 4
   10,306         47,232     Min Prin. Stress = -6676. (98% Neg, 29% NegHi)
      psi            psi     Plot Reference:
                             7) Pl+Pb+Q < SPS (OPE,Outside) Case 4
            21%

 Membrane           User     Component Evaluation Load Case 4
    7,840         47,232     Min Prin. Stress = -6676. (98% Neg, 29% NegHi)
      psi            psi     Plot Reference:
                             8) Membrane < User (OPE,Membrane) Case 4
            16%

  Bending           User     Component Evaluation Load Case 4
    7,385         47,232     Min Prin. Stress = -6676. (98% Neg, 29% NegHi)
      psi            psi     Plot Reference:
                             9) Bending < User (OPE,Bending) Case 4
            15%

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 5
   10,418         47,232     Min Prin. Stress = -6676. (98% Neg, 29% NegHi)
      psi            psi     Plot Reference:
                             10) Pl+Pb+Q < SPS (EXP,Inside) Case 5
            22%

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 5
   10,306         47,232     Min Prin. Stress = -6676. (98% Neg, 29% NegHi)
      psi            psi     Plot Reference:
                             11) Pl+Pb+Q < SPS (EXP,Outside) Case 5
            21%

Pl+Pb+Q+F   Damage Ratio     Primary+Secondary+Peak (Inner) Load Case 5
   10,418     0.000 Life     Stress Concentration Factor = 1.000
```

```
     psi     0.088 Stress   Strain Concentration Factor = 1.000
                            Cycles Allowed for this Stress = 1.0000E11
Allowable                   "B31" Fatigue Stress Allowable = 78719.4
  118,449                   Markl Fatigue Stress Allowable = 95657.0
      psi                   WRC 474 Mean Cycles to Failure = 16,193,779.
                            WRC 474 99% Probability Cycles = 3,762,030.
       8%                   WRC 474 95% Probability Cycles = 5,223,179.
                            BS5500 Allowed Cycles(Curve F) = 2,096,205.
                            Membrane-to-Bending Ratio = 0.460
                            Bending-to-PL+PB+Q Ratio = 0.685
                            Plot Reference:
                            12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 5

Pl+Pb+Q+F    Damage Ratio   Primary+Secondary+Peak (Outer) Load Case 5
   10,306    0.000 Life     Stress Concentration Factor = 1.000
      psi    0.087 Stress   Strain Concentration Factor = 1.000
                            Cycles Allowed for this Stress = 1.0000E11
Allowable                   "B31" Fatigue Stress Allowable = 78719.4
  118,449                   Markl Fatigue Stress Allowable = 95657.0
      psi                   WRC 474 Mean Cycles to Failure = 16,079,411.
                            WRC 474 99% Probability Cycles = 3,735,460.
       8%                   WRC 474 95% Probability Cycles = 5,186,290.
                            BS5500 Allowed Cycles(Curve F) = 2,165,185.
                            Membrane-to-Bending Ratio = 0.902
                            Bending-to-PL+PB+Q Ratio = 0.526
                            Plot Reference:
                            13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5


Long Plate for Plate # 1

       Pl           SPL     Primary Membrane Load Case 2
      218        30,995     Min Prin. Stress = -233. ( 7% Neg, 2% NegHi)
      psi           psi     Plot Reference:
                            1) Pl < SPL (SUS,Membrane) Case 2
             0%

       Qb           SPS     Primary Bending Load Case 2
        0        68,995     Min Prin. Stress = -233. ( 7% Neg, 2% NegHi)
      psi           psi     Plot Reference:
                            2) Qb < SPS (SUS,Bending) Case 2
             0%

  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 2
      218        68,995     Min Prin. Stress = -233. ( 7% Neg, 2% NegHi)
      psi           psi     Plot Reference:
                            3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
             0%

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 2
      218        68,995     Min Prin. Stress = -233. ( 7% Neg, 2% NegHi)
      psi           psi     Plot Reference:
                            4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
             0%

 S1+S2+S3            4S     Part 5 (5.3.2) Load Case 2
     -265        80,003     Min Prin. Stress = -233. ( 7% Neg, 2% NegHi)
      psi           psi     Plot Reference:
                            5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
             0%

  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 4
   24,549        68,995     Min Prin. Stress = -18996. (82% Neg, 30% NegHi)
      psi           psi     Plot Reference:
                            6) Pl+Pb+Q < SPS (OPE,Inside) Case 4
            35%

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 4
   18,669        68,995     Min Prin. Stress = -18996. (82% Neg, 30% NegHi)
      psi           psi     Plot Reference:
                            7) Pl+Pb+Q < SPS (OPE,Outside) Case 4
            27%

 Membrane          User     Component Evaluation Load Case 4
   12,197        68,995     Min Prin. Stress = -18996. (82% Neg, 30% NegHi)
      psi           psi     Plot Reference:
                            8) Membrane < User (OPE,Membrane) Case 4
            17%

  Bending          User     Component Evaluation Load Case 4
   14,447        68,995     Min Prin. Stress = -18996. (82% Neg, 30% NegHi)
      psi           psi     Plot Reference:
```

```
                                9) Bending < User (OPE,Bending) Case 4
              20%

  Pl+Pb+Q            SPS        Primary+Secondary (Inner) Load Case 5
   24,549         68,995        Min Prin. Stress = -18996. (82% Neg, 30% NegHi)
      psi            psi        Plot Reference:
                                10) Pl+Pb+Q < SPS (EXP,Inside) Case 5
              35%

  Pl+Pb+Q            SPS        Primary+Secondary (Outer) Load Case 5
   18,669         68,995        Min Prin. Stress = -18996. (82% Neg, 30% NegHi)
      psi            psi        Plot Reference:
                                11) Pl+Pb+Q < SPS (EXP,Outside) Case 5
              27%

Pl+Pb+Q+F    Damage Ratio       Primary+Secondary+Peak (Inner) Load Case 5
   24,549     0.007 Life        Stress Concentration Factor = 1.000
      psi     0.292 Stress      Strain Concentration Factor = 1.000
                                Cycles Allowed for this Stress = 982,128.
Allowable                       "B31" Fatigue Stress Allowable = 100003.8
   83,994                       Markl Fatigue Stress Allowable = 83402.0
      psi                       WRC 474 Mean Cycles to Failure = 937,972.
                                WRC 474 99% Probability Cycles = 217,903.
      29%                       WRC 474 95% Probability Cycles = 302,536.
                                BS5500 Allowed Cycles(Curve F) = 142,898.
                                Membrane-to-Bending Ratio = 0.984
                                Bending-to-PL+PB+Q Ratio = 0.504
                                Plot Reference:
                                12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 5

Pl+Pb+Q+F    Damage Ratio       Primary+Secondary+Peak (Outer) Load Case 5
   18,669     0.000 Life        Stress Concentration Factor = 1.000
      psi     0.222 Stress      Strain Concentration Factor = 1.000
                                Cycles Allowed for this Stress = 2.1271E8
Allowable                       "B31" Fatigue Stress Allowable = 100003.8
   83,994                       Markl Fatigue Stress Allowable = 83402.0
      psi                       WRC 474 Mean Cycles to Failure = 2,395,198.
                                WRC 474 99% Probability Cycles = 556,437.
      22%                       WRC 474 95% Probability Cycles = 772,554.
                                BS5500 Allowed Cycles(Curve F) = 324,908.
                                Membrane-to-Bending Ratio = 0.318
                                Bending-to-PL+PB+Q Ratio = 0.759
                                Plot Reference:
                                13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5
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```
Compressive Stress Summary
FEPipe Version 15.0          Jobname: NOZZLE               $P
Released Jan. 2021            11:57am  DEC 16,2022
```

```
Compressive Stress Summary (psi)                        $X

Nomenclature:
-------------
Min Stress        - Compressive Membrane and Bending Stress
Pts in Region     - No. of nodes in the model region
>5% Compression   - 5% or more of Compressive Stress Limit
>50% Compression  - 50% or more of Compressive Stress Limit

Compressive Stress Limit = -0.55 Min(Sy, kEt/R), Section
slenderness ratio (elastic buckling) not considered.
```

| # | Load Type | Case | Min Stress | Pts in Region | >5% Compression and Bending | >50% Compression and Bending | Region |
|---|---|---|---|---|---|---|---|
| 1 | SUSTAINED | 2 | -36. | 1220 | 1% | 0% | Shell in Plate # 1 Vicinity |
| 2 | OPERATING | 4 | -6676. | 1220 | 98% | 29% | Shell in Plate # 1 Vicinity |
| 3 | EXPANSION | 5 | -6676. | 1220 | 98% | 29% | Shell in Plate # 1 Vicinity |
| 4 | SUSTAINED | 2 | -2. | 236 | 0% | 0% | Shell SCR at Plate # 1 |
| 5 | OPERATING | 4 | -7404. | 236 | 99% | 20% | Shell SCR at Plate # 1 |
| 6 | EXPANSION | 5 | -7404. | 236 | 99% | 20% | Shell SCR at Plate # 1 |
| 7 | SUSTAINED | 2 | -5. | 300 | 0% | 0% | Pad SCR for Plate # 1 |
| 8 | OPERATING | 4 | -8477. | 300 | 99% | 6% | Pad SCR for Plate # 1 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 9 | EXPANSION | 5 | -8477. | 300 | 99% | 6% | Pad SCR for Plate # 1 |
| 10 | SUSTAINED | 2 | -319. | 32 | 15% | 0% | Long Plate SCR for Plate # 1 |
| 11 | OPERATING | 4 | -20807. | 32 | 78% | 56% | Long Plate SCR for Plate # 1 |
| 12 | EXPANSION | 5 | -20807. | 32 | 78% | 56% | Long Plate SCR for Plate # 1 |
| 13 | SUSTAINED | 2 | -233. | 40 | 7% | 2% | Long Plate for Plate # 1 |
| 14 | OPERATING | 4 | -18996. | 40 | 82% | 30% | Long Plate for Plate # 1 |
| 15 | EXPANSION | 5 | -18996. | 40 | 82% | 30% | Long Plate for Plate # 1 |

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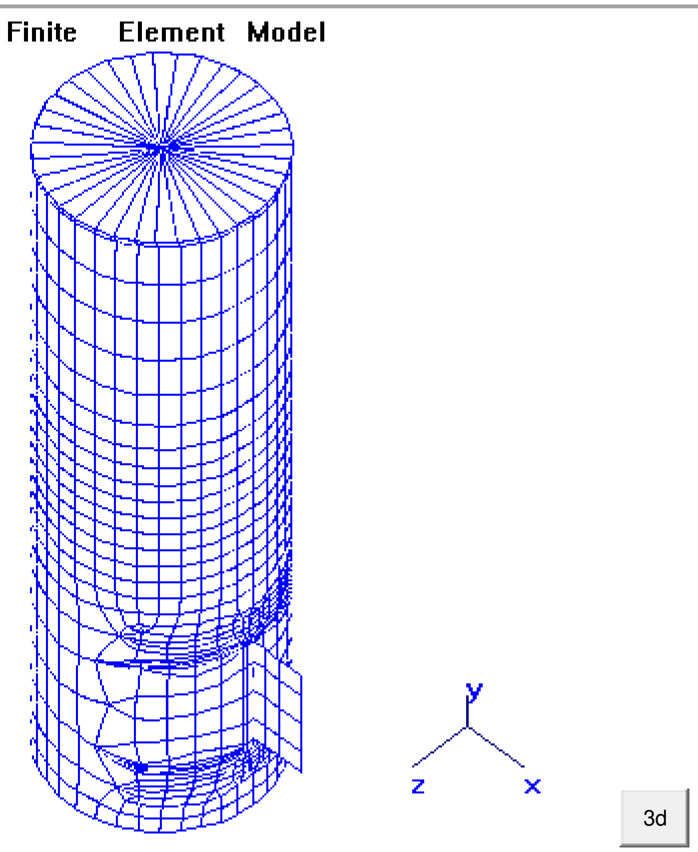
*Finite Element Model*

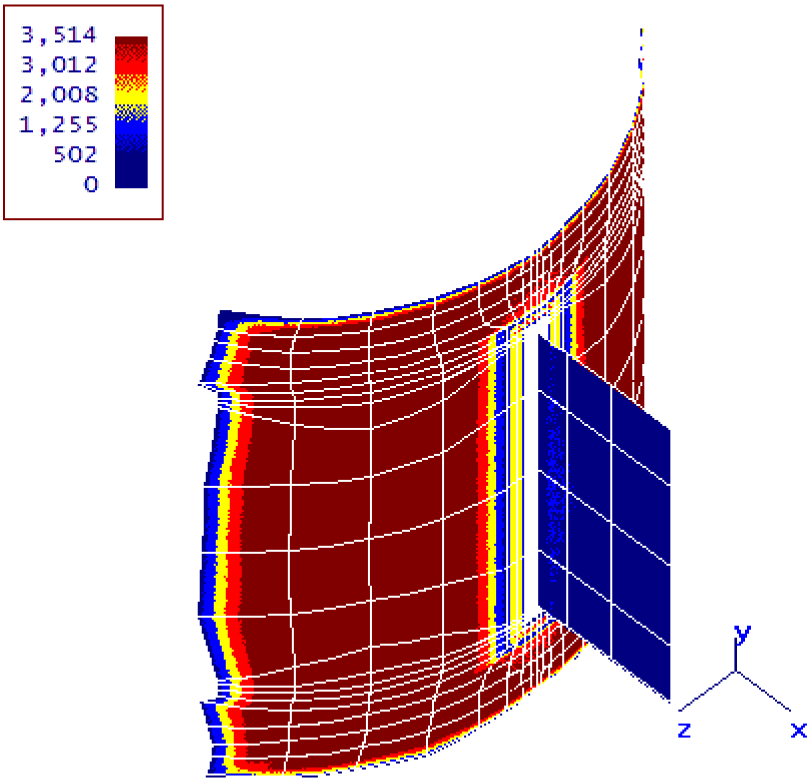
- Finite Element Model

*Area of Discontinuity at Plate*

- 1) Pl < SPL (SUS Membrane) Case 2
- 2) Qb < SPS (SUS Bending) Case 2
- 3) Pl+Pb+Q < SPS (SUS Inside) Case 2
- 4) Pl+Pb+Q < SPS (SUS Outside) Case 2
- 5) S1+S2+S3 < 4S (SUS S1+S2+S3) Case 2
- 6) Pl+Pb+Q < SPS (OPE Inside) Case 4
- 7) Pl+Pb+Q < SPS (OPE Outside) Case 4
- 8) Membrane < User (OPE Membrane) Case 4
- 9) Bending < User (OPE Bending) Case 4
- 10) Pl+Pb+Q < SPS (EXP Inside) Case 5
- 11) Pl+Pb+Q < SPS (EXP Outside) Case 5
- 12) Pl+Pb+Q+F < 2Sa (EXP Inside) Case 5
- 13) Pl+Pb+Q+F < 2Sa (EXP Outside) Case 5



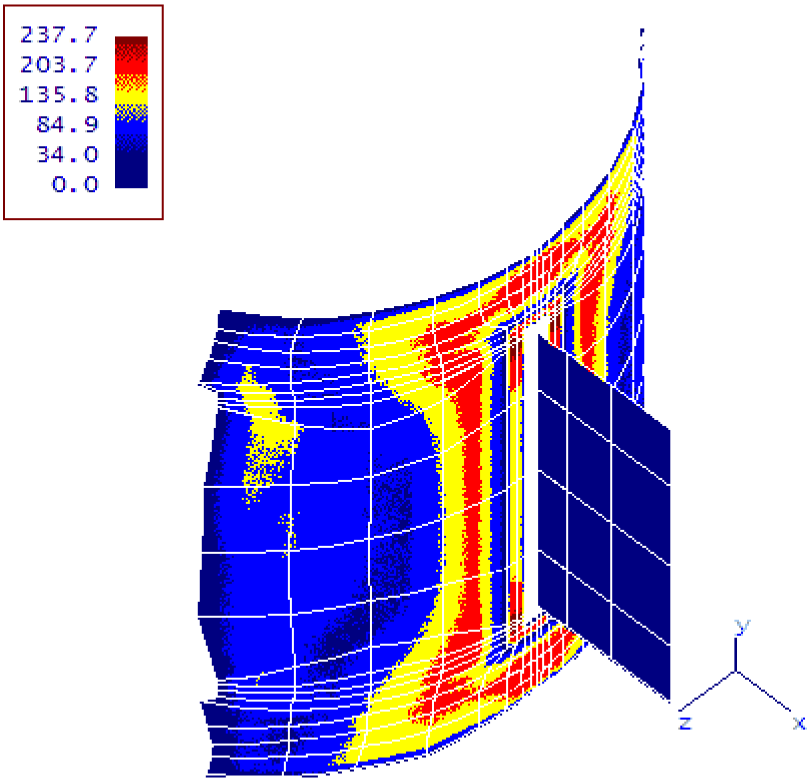
1) Pl < SPL (SUS Membrane) Case 2




- 3d(Small) 3d
- 3d(Deformed)

---

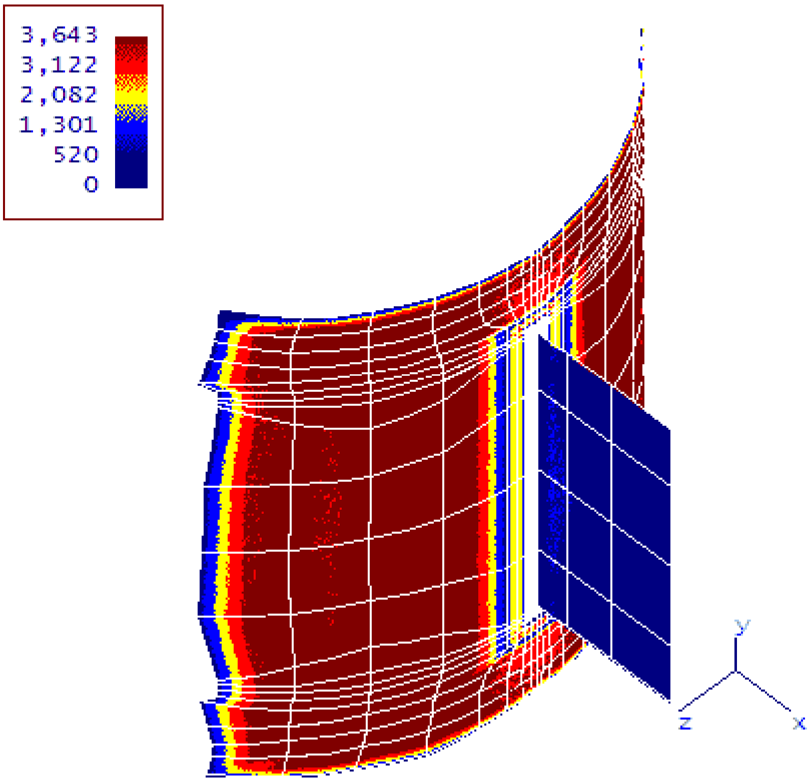
2) Qb < SPS (SUS Bending) Case 2




- 3d(Small) 3d
- 3d(Deformed)

---

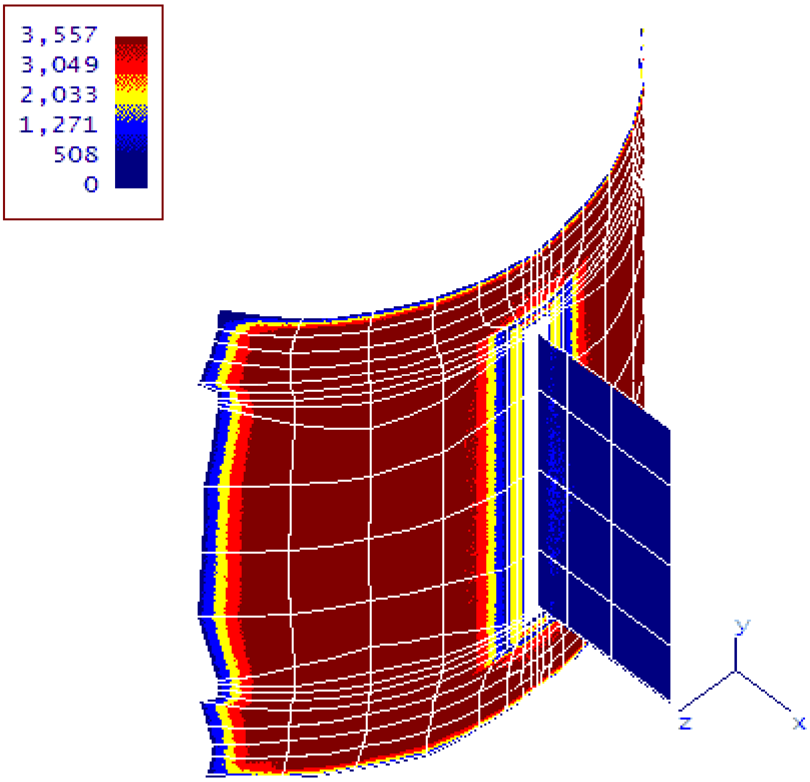
3) Pl+Pb+Q < SPS (SUS Inside) Case 2




- 3d(Small) 3d
- 3d(Deformed)

---

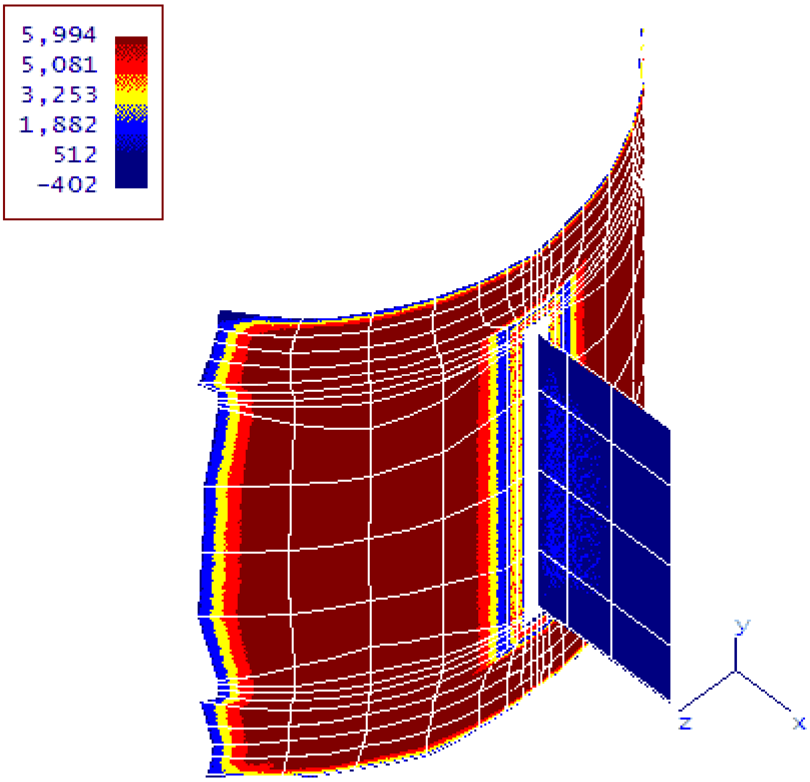
4) Pl+Pb+Q < SPS (SUS Outside) Case 2




- 3d(Small) 3d
- 3d(Deformed)

---

5) S1+S2+S3 < 4S (SUS S1+S2+S3) Case 2

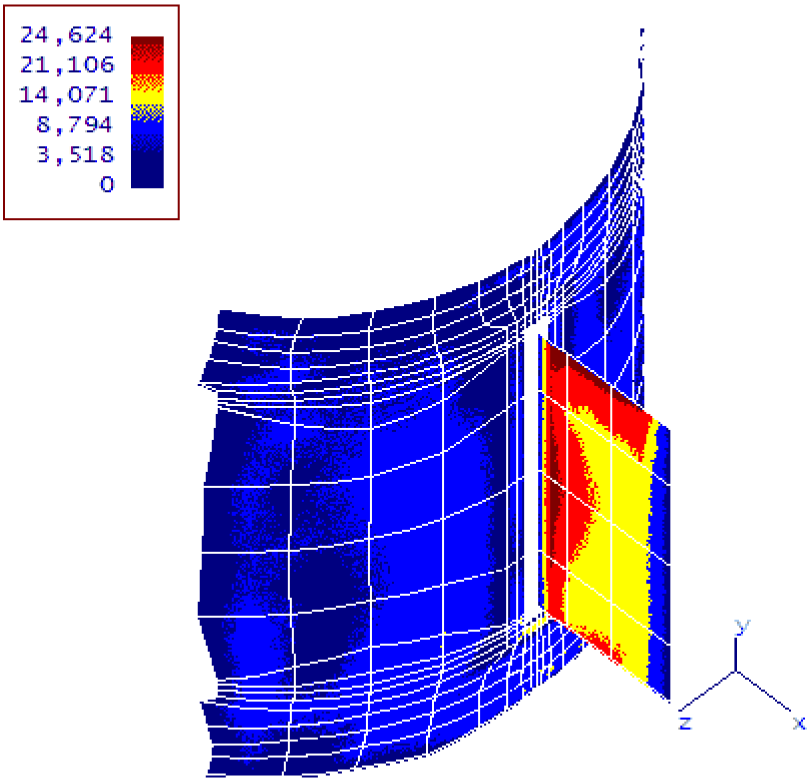



3d(Small) 3d

- 3d(Deformed)

---

6) Pl+Pb+Q < SPS (OPE Inside) Case 4

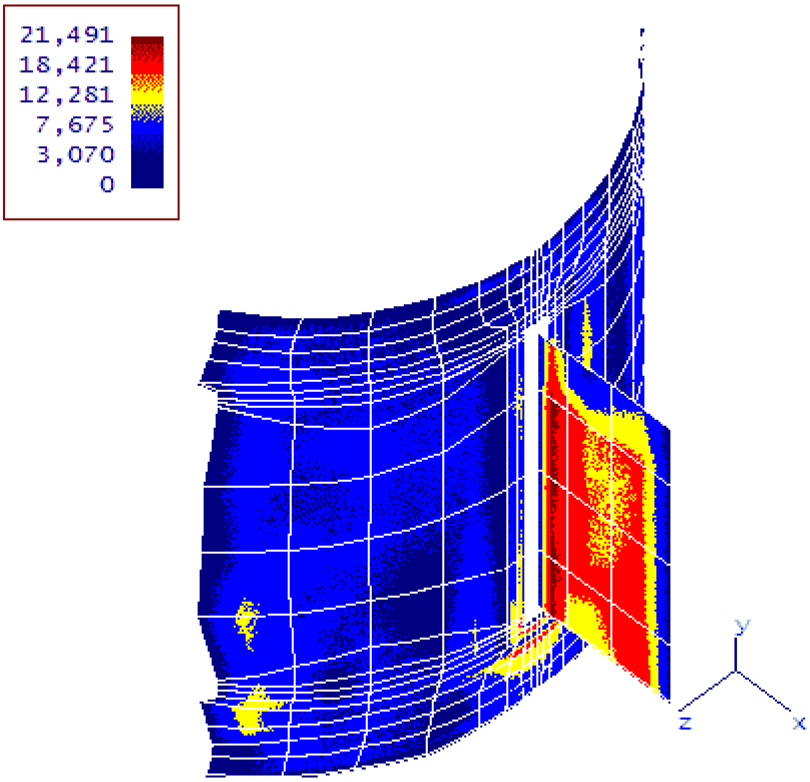



3d(Small) 3d

- 3d(Deformed)

---

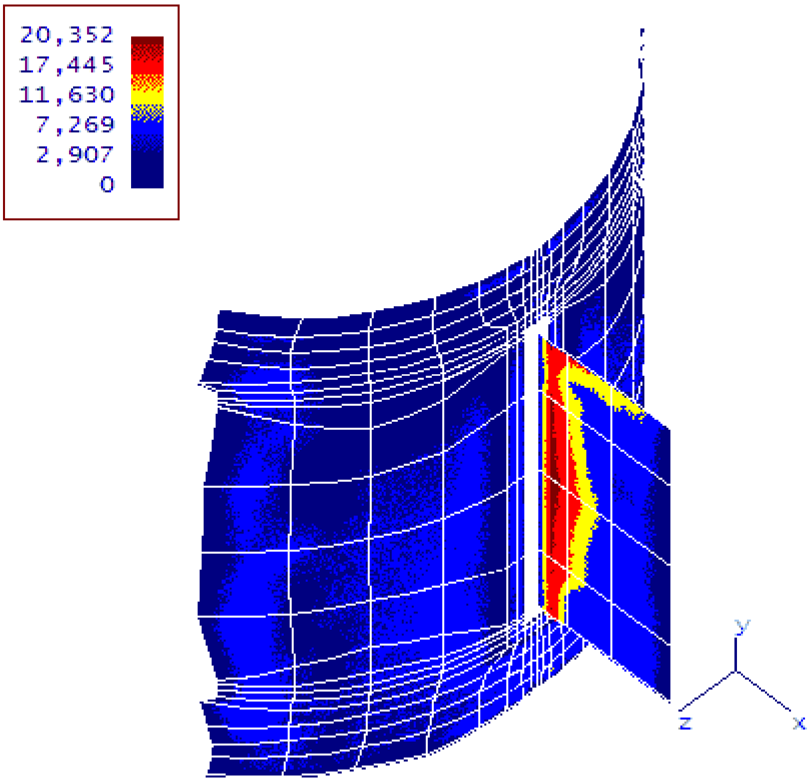
7) Pl+Pb+Q < SPS (OPE Outside) Case 4




- 3d(Small) 3d
- 3d(Deformed)

---

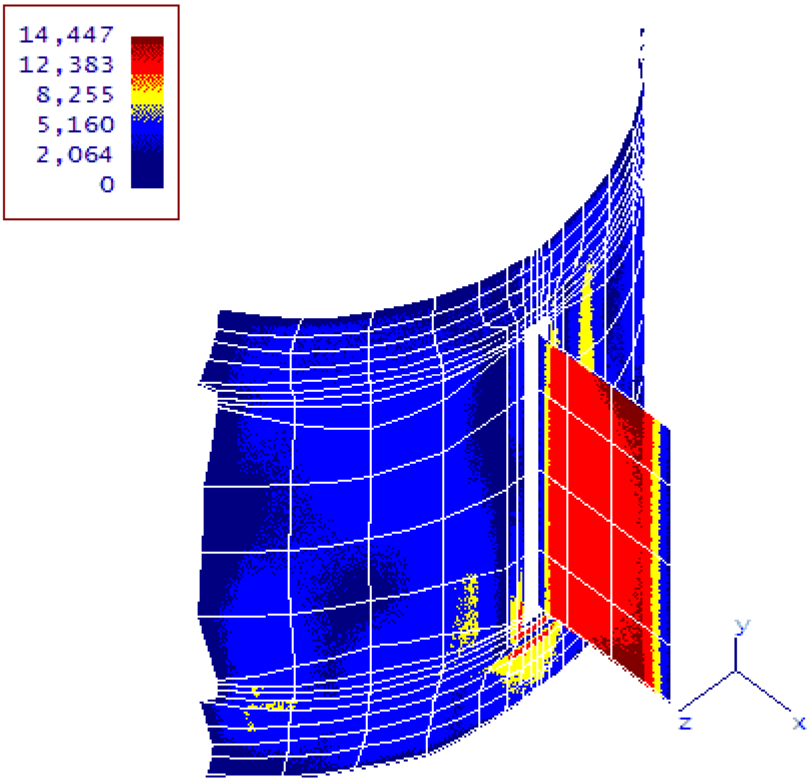
- 8) Membrane < User (OPE Membrane) Case 4




- 3d(Small) 3d
- 3d(Deformed)

---

9) Bending < User (OPE Bending) Case 4

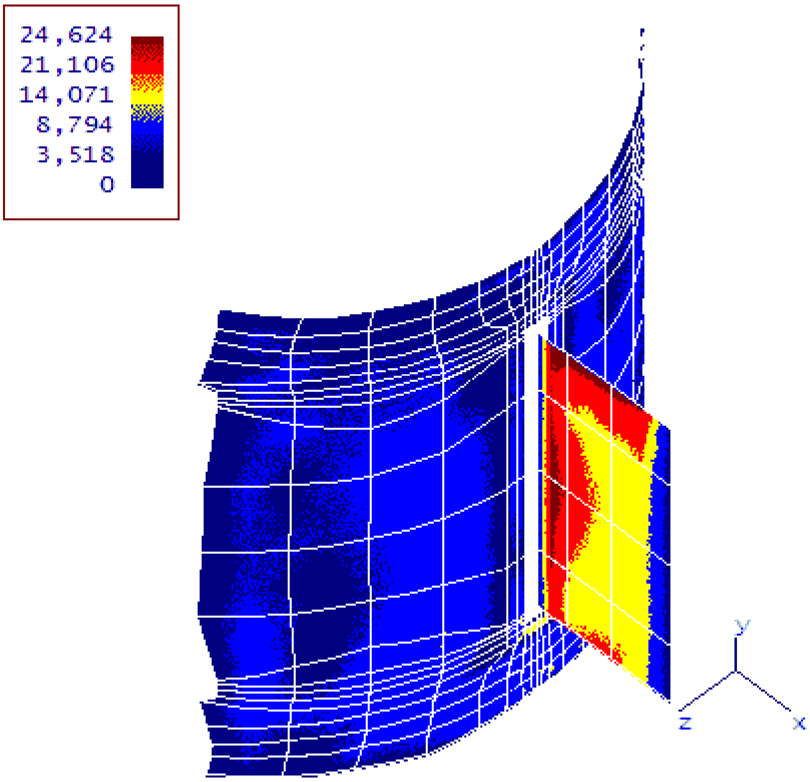



3d(Small) 3d

- 3d(Deformed)

---

- 10) P1+Pb+Q < SPS (EXP Inside) Case 5

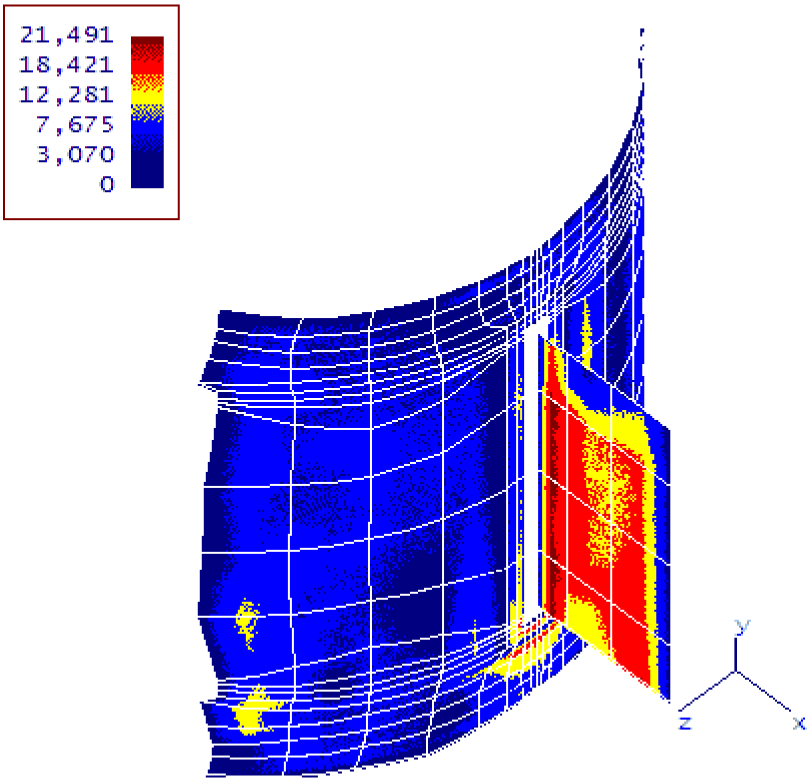



3d(Small) 3d

-
- 

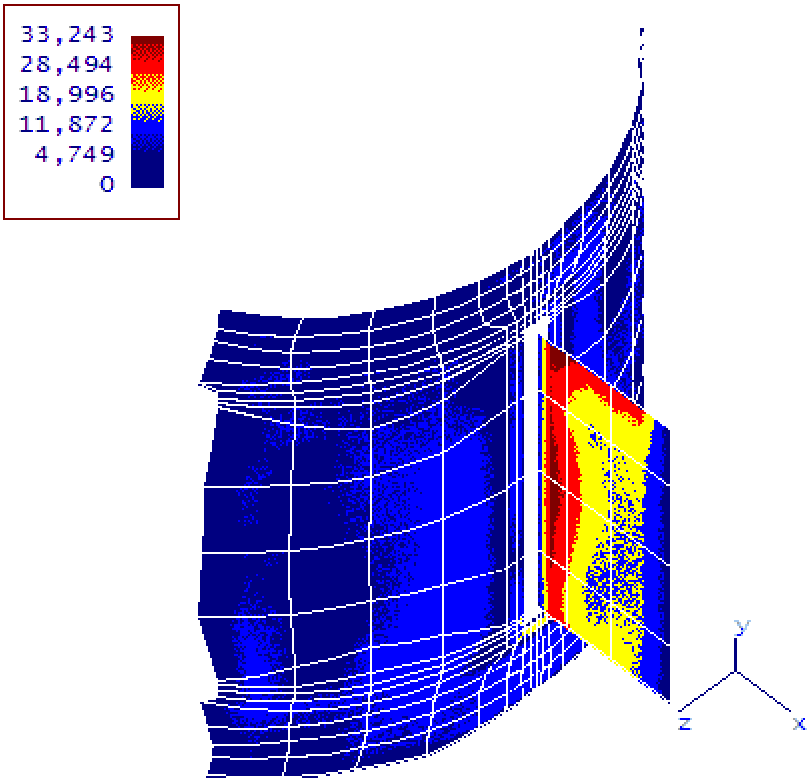
---

11) Pl+Pb+Q < SPS (EXP Outside) Case 5



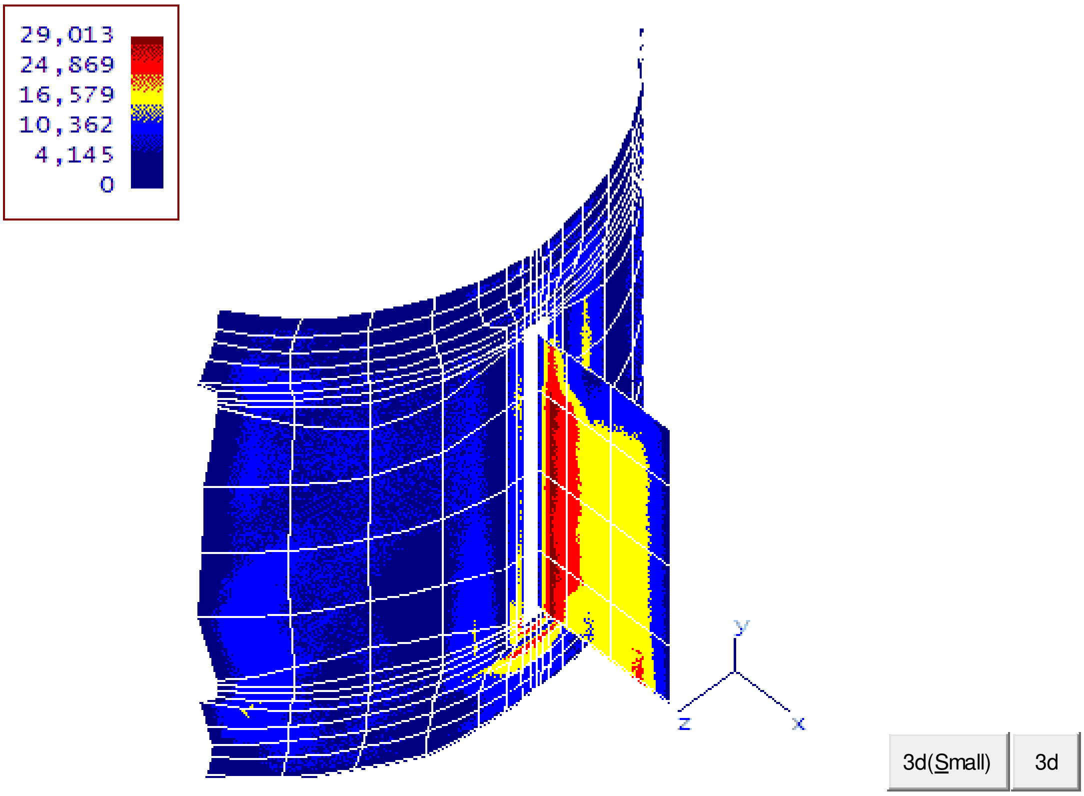

3d(Small) 3d

12) Pl+Pb+Q+F < 2Sa (EXP Inside) Case 5




3d(Small) 3d

13) Pl+Pb+Q+F < 2Sa (EXP Outside) Case 5

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**Tabular Results**

Results were generated with the finite element program FE/Pipe®. Stress results are post-processed in accordance with the rules specified in ASME Section III and ASME Section VIII, Division 2.

Analysis Time Stamp: Fri Dec 16 12:09:50 2022.



---

```
Model Notes
Model Notes

  Input Echo:

  Description:

          PLC-1D,E,F For Platform #1
          PLC-2E,G,H For Platform #2
          PLC-3F For Platform #3

  Model Type                    : Cylindrical Shell

  Parent Geometry
         Parent Outside Diam.   :      30.037 in.
         Thickness              :       0.394 in.
         Fillet Along Shell     :       0.394 in.

  Parent Properties:
         Cold Allowable         :     16693.8 psi
         Hot  Allowable         :     14793.9 psi
         Material DB # 1071122.
         Ultimate Tensile (Amb) :     69995.4 psi
         Yield Strength (Amb)   :     25004.6 psi
         Yield Strength (Hot)   :     16403.8 psi
         Elastic Modulus (Amb)  :  28301000.0 psi
         Poissons Ratio         :       0.300
         Expansion Coefficient  :  0.9700E-05 in./in./deg.
         Weight Density         :  0.0000E+00 lb./cu.in.(NOT USED)

  Structural Attachment Type    :  "I" Beam

         Flange Thickness       :       0.394 in.
         Flange Width           :       6.496 in.
         Web    Thickness       :       0.394 in.
         Web    Height          :       7.913 in.
         Length                 :       3.329 in.

         Rectangular Pad Width  :       8.425 in.
         Rectangular Pad Height :      12.795 in.
         Rectangular Pad Thick  :       0.394 in.
         Nozzle Tilt Angle      :       0.000 deg.
         Distance from Top      :      49.213 in.
         Distance from Bottom   :      49.212 in.

  Nozzle Properties
         Cold Allowable         :     20000.8 psi
         Hot  Allowable         :     20000.8 psi
         Material DB # 1016422.
         Ultimate Tensile (Amb) :     69995.4 psi
         Yield Strength (Amb)   :     37999.9 psi
```

```
       Yield Strength (Hot)    :     30994.6 psi
       Elastic Modulus (Amb)   :  29402000.0 psi
       Poissons Ratio          :       0.300
       Expansion Coefficient   :  0.7300E-05 in./in./deg.
       Weight Density          :  0.0000E+00 lb./cu.in. (NOT USED)

Design Operating Cycles        :       7000.
Ambient Temperature (Deg.)     :       69.98

Thermal Stresses will be introduced into this analysis due to the
differences in temperature and/or thermal expansion coefficients.
The following temperatures have been specified for the analysis:

Nozzle Inside  Temperature     :      500.00 deg.
Nozzle Outside Temperature     :      500.00 deg.
Vessel Inside  Temperature     :      500.00 deg.
Vessel Outside Temperature     :      500.00 deg.
Nozzle Pressure                :       105.2 psi
Vessel Pressure                :       105.2 psi

Operating Pressure             :        10.1 psi

The operating pressure is used for secondary and peak stress
cases. The design pressure is used for primary cases. The ratio
of the operating/design pressure = 0.097

User Defined Load Input Echo for the ATTACHMENT:
Loads are given at the End of Nozzle
Loads are defined in Global Coordinates

Forces( lb.)  Moments (ft-lb)
```

| Load Case | FX | FY | FZ | MX | MY | MZ |
|---|---|---|---|---|---|---|
| OPER: | 1000.0 | -4000.0 | 1000.0 | 0.0 | 3000.0 | 12500.0 |

```
FEA Model Loads:
These are the actual Attachment loads applied to
the FEA model.
These are the User Defined Loads translated to the
end of the nozzle and reported in global coordinates.

Forces( lb.)  Moments (ft-lb)
```

| Load Case | FX | FY | FZ | MX | MY | MZ |
|---|---|---|---|---|---|---|
| OPER: | 1000.0 | -4000.0 | 1000.0 | 0.0 | 3000.0 | 12500.0 |

```
The "top" or "positive" end of this model is "free" in
the axial and translational directions.

Stresses ARE nodally AVERAGED.

Vessel Centerline  Vector      :  0.000   1.000   0.000
Nozzle Orientation Vector      :  1.000   0.000   0.000
```

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```
Load Case Report
FEPipe Version 15.0           Jobname: NOZZLE                  $P
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Load Case Report                                        $X

Inner and outer element temperatures are the same
throughout the model.  No thermal ratcheting
calculations will be performed.

THE   5  LOAD CASES ANALYZED ARE:

  1   WEIGHT ONLY    (Wgt Only)

      Weight ONLY case run to get the stress range
      between the installed and the operating states.
```

```
      /-------- Loads in Case   1
        Loads due to Weight

  2   SUSTAINED      (Wgt+Pr)

      Sustained case run to satisfy local primary
      membrane and bending stress limits.

      /-------- Loads in Case   2
        Loads due to Weight
        Pressure Case    1

  3   Thermal ONLY

      Thermal ONLY case run in the event expansion
      stresses exceed the secondary stress allowable.

      /-------- Loads in Case   3
        Temperature Case    1
        Loads from (Thermal Only)

  4   OPERATING

      Case run to compute the operating stresses used in
      secondary, peak and range calculations as needed.

      /-------- Loads in Case   4
        Pressure Case    1
        Temperature Case    1
        Loads from (Operating)

  5   RANGE          (Fatigue Calc Performed)

      Case run to get the RANGE of stresses.
      as described in NB-3222.2, 5.5.3.2, 5.5.5.2 or 5.5.6.1.

      /-------- Combinations in Range Case   5
        Plus  Stress Results from CASE   4
        Minus Stress Results from CASE   1
```

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```
Solution Data
FEPipe Version 15.0           Jobname: NOZZLE              $P
Released Jan. 2021             12:09am  DEC 16,2022
```

Solution Data

```
Maximum Solution Row Size =    1890
Number of Nodes           =    5167
Number of Elements        =    1740
Number of Solution Cases  =       4
```

Summation of Loads per Case

| Case # | FX | FY | FZ |
|---|---|---|---|
| 1 | 0. | 0. | 0. |
| 2 | 0. | 72568. | 0. |
| 3 | 0. | 0. | 0. |
| 4 | 1000. | 68568. | 1000. |

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```
ASME Code Stress Output Plots
FEPipe Version 15.0           Jobname: NOZZLE              $P
Released Jan. 2021             12:09am  DEC 16,2022
```

ASME Code Stress Output Plots $X

1) Pl < SPL (SUS,Membrane) Case 2

2) Qb < SPS (SUS,Bending) Case 2

3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2

6) Pl+Pb+Q < SPS (OPE,Inside) Case 4

7) Pl+Pb+Q < SPS (OPE,Outside) Case 4

8) Membrane < User (OPE,Membrane) Case 4

9) Bending < User (OPE,Bending) Case 4

10) Pl+Pb+Q < SPS (EXP,Inside) Case 5

11) Pl+Pb+Q < SPS (EXP,Outside) Case 5

12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 5

13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5

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---

Stress Results - Notes
FEPipe Version 15.0 Jobname: NOZZLE $P
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Stress Results - Notes

- Results in this analysis were generated using the finite element solution method.

- Using 2019 ASME Section VIII Division 2

- Use Polished Bar fatigue curve.

- Ratio between Operating and Design Pressure = 9.6528761E-02
  Range cases use operating pressure. Primary cases use design pressure.

- Assume free end displacements of attached pipe (e.g. thermal loads) are secondary loads.

- Primary bending stresses at discontinuities are treated like secondary stresses. (Pb=0)

- Use Equivalent Stress (Von Mises).

- TRIAXIAL Stress Guidelines:
  S1+S2+S3 evaluation omitted from operating stress.
  Include S1+S2+S3 evaluation in primary case evaluation.
  Bending stress NOT included for all S1+S2+S3 calculations.

- Use local tensor values for averaged and not averaged stresses.

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---

ASME Overstressed Areas
FEPipe Version 15.0 Jobname: NOZZLE $P
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```
ASME Overstressed Areas                                $X


             *** NO OVERSTRESSED NODES IN THIS MODEL ***
```

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---

```
Highest Primary Stress Ratios
FEPipe Version 15.0           Jobname: NOZZLE               $P
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Highest Primary Stress Ratios                          $X


Shell SCR at Plate # 1

       Pl            SPL     Primary Membrane Load Case 2
    3,618         22,191     Min Prin. Stress = -3. ( 0% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
            16%


Circ Plate SCR for Plate # 1

       Pl            SPL     Primary Membrane Load Case 2
      485         30,995     Min Prin. Stress = -540. (64% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
             1%


Long Plate SCR for Plate # 1

       Pl            SPL     Primary Membrane Load Case 2
      199         30,995     Min Prin. Stress = -94. (23% Neg, 13% NegHi)
      psi            psi     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
             0%


Pad SCR for Plate # 1

       Pl            SPL     Primary Membrane Load Case 2
    2,108         30,995     Min Prin. Stress = -5. ( 0% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
             6%


Shell in Plate # 1 Vicinity

       Pl            SPL     Primary Membrane Load Case 2
    3,465         22,191     Min Prin. Stress = -4. ( 0% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
            15%


Circ Plate for Plate # 1

       Pl            SPL     Primary Membrane Load Case 2
      179         30,995     Min Prin. Stress = -132. (99% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
             0%


Long Plate for Plate # 1

       Pl            SPL     Primary Membrane Load Case 2
```

```
       97          30,995     Min Prin. Stress = -98. (50% Neg, 50% NegHi)
      psi            psi      Plot Reference:
                              1) Pl < SPL (SUS,Membrane) Case 2
           0%


Pad for Plate # 1

       Pl            SPL      Primary Membrane Load Case 2
    1,679          30,995     Min Prin. Stress = 0. ( 0% Neg, 0% NegHi)
      psi            psi      Plot Reference:
                              1) Pl < SPL (SUS,Membrane) Case 2
           5%
```

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---

```
Highest Secondary Stress Ratios
FEPipe Version 15.0           Jobname: NOZZLE                $P
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Highest Secondary Stress Ratios                        $X

In combination case  5 the max range stress divided
by the max component stress is 1.00. The case tensor components
are NEVER additive and so the combination case will have
LOWER stresses than the largest of any of the individual
cases by between 1 and 20%.

Load       Combined/Max        Combined/Max
Case        (Inside)             (Outside)
------     -------------       -------------
   5          1.000                1.000


Shell SCR at Plate # 1

  Pl+Pb+Q            SPS      Primary+Secondary (Outer) Load Case 4
   27,096          47,232     Min Prin. Stress = -14597. (99% Neg, 53% NegHi)
      psi            psi      Plot Reference:
                              7) Pl+Pb+Q < SPS (OPE,Outside) Case 4
          57%

  Pl+Pb+Q            SPS      Primary+Secondary (Outer) Load Case 5
   27,096          47,232     Min Prin. Stress = -14597. (99% Neg, 53% NegHi)
      psi            psi      Plot Reference:
                              11) Pl+Pb+Q < SPS (EXP,Outside) Case 5
          57%


Circ Plate SCR for Plate # 1

  Pl+Pb+Q            SPS      Primary+Secondary (Inner) Load Case 4
   29,561          68,995     Min Prin. Stress = -29113. (97% Neg, 63% NegHi)
      psi            psi      Plot Reference:
                              6) Pl+Pb+Q < SPS (OPE,Inside) Case 4
          42%

  Pl+Pb+Q            SPS      Primary+Secondary (Inner) Load Case 5
   29,561          68,995     Min Prin. Stress = -29113. (97% Neg, 63% NegHi)
      psi            psi      Plot Reference:
                              10) Pl+Pb+Q < SPS (EXP,Inside) Case 5
          42%


Long Plate SCR for Plate # 1

  Pl+Pb+Q            SPS      Primary+Secondary (Outer) Load Case 4
   14,278          68,995     Min Prin. Stress = -821. (70% Neg, 30% NegHi)
      psi            psi      Plot Reference:
                              7) Pl+Pb+Q < SPS (OPE,Outside) Case 4
          20%

  Pl+Pb+Q            SPS      Primary+Secondary (Outer) Load Case 5
   14,278          68,995     Min Prin. Stress = -821. (70% Neg, 30% NegHi)
      psi            psi      Plot Reference:
```

```
                              11) Pl+Pb+Q < SPS (EXP,Outside) Case 5
            20%

Pad SCR for Plate # 1

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 4
   22,408         68,995     Min Prin. Stress = -14138. (98% Neg, 9% NegHi)
      psi            psi     Plot Reference:
                             7) Pl+Pb+Q < SPS (OPE,Outside) Case 4
            32%

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 5
   22,408         68,995     Min Prin. Stress = -14138. (98% Neg, 9% NegHi)
      psi            psi     Plot Reference:
                             11) Pl+Pb+Q < SPS (EXP,Outside) Case 5
            32%

Shell in Plate # 1 Vicinity

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 4
   18,397         47,232     Min Prin. Stress = -9147. (98% Neg, 49% NegHi)
      psi            psi     Plot Reference:
                             6) Pl+Pb+Q < SPS (OPE,Inside) Case 4
            38%

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 5
   18,397         47,232     Min Prin. Stress = -9147. (98% Neg, 49% NegHi)
      psi            psi     Plot Reference:
                             10) Pl+Pb+Q < SPS (EXP,Inside) Case 5
            38%

Circ Plate for Plate # 1

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 4
   18,204         68,995     Min Prin. Stress = -17799. (99% Neg, 58% NegHi)
      psi            psi     Plot Reference:
                             6) Pl+Pb+Q < SPS (OPE,Inside) Case 4
            26%

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 5
   18,204         68,995     Min Prin. Stress = -17799. (99% Neg, 58% NegHi)
      psi            psi     Plot Reference:
                             10) Pl+Pb+Q < SPS (EXP,Inside) Case 5
            26%

Long Plate for Plate # 1

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 4
    3,716         68,995     Min Prin. Stress = -1039. (99% Neg, 50% NegHi)
      psi            psi     Plot Reference:
                             7) Pl+Pb+Q < SPS (OPE,Outside) Case 4
             5%

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 5
    3,716         68,995     Min Prin. Stress = -1039. (99% Neg, 50% NegHi)
      psi            psi     Plot Reference:
                             11) Pl+Pb+Q < SPS (EXP,Outside) Case 5
             5%

Pad for Plate # 1

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 4
   11,809         68,995     Min Prin. Stress = -7721. (99% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             6) Pl+Pb+Q < SPS (OPE,Inside) Case 4
            17%

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 5
   11,809         68,995     Min Prin. Stress = -7721. (99% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             10) Pl+Pb+Q < SPS (EXP,Inside) Case 5
            17%
```

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```
Highest Fatigue Stress Ratios
FEPipe Version 15.0          Jobname: NOZZLE                 $P
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Highest Fatigue Stress Ratios                          $X


Shell SCR at Plate # 1

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 5
   36,580     0.007 Life     Stress Concentration Factor = 1.350
      psi     0.309 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1,003,418.
Allowable                    "B31" Fatigue Stress Allowable = 78719.4
  118,449                    Markl Fatigue Stress Allowable = 95657.0
      psi                    WRC 474 Mean Cycles to Failure = 818,100.
                             WRC 474 99% Probability Cycles = 190,056.
      30%                    WRC 474 95% Probability Cycles = 263,872.
                             BS5500 Allowed Cycles(Curve F) = 119,145.
                             Membrane-to-Bending Ratio = 0.504
                             Bending-to-PL+PB+Q Ratio = 0.665
                             Plot Reference:
                             13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5


Circ Plate SCR for Plate # 1

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 5
   39,907     0.076 Life     Stress Concentration Factor = 1.350
      psi     0.475 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 91,518.
Allowable                    "B31" Fatigue Stress Allowable = 100003.8
   83,994                    Markl Fatigue Stress Allowable = 83402.0
      psi                    WRC 474 Mean Cycles to Failure = 628,939.
                             WRC 474 99% Probability Cycles = 146,111.
      47%                    WRC 474 95% Probability Cycles = 202,860.
                             BS5500 Allowed Cycles(Curve F) = 81,845.
                             Membrane-to-Bending Ratio = 34.017
                             Bending-to-PL+PB+Q Ratio = 0.029
                             Plot Reference:
                             12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 5


Long Plate SCR for Plate # 1

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 5
   19,276     0.000 Life     Stress Concentration Factor = 1.350
      psi     0.229 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.1385E8
Allowable                    "B31" Fatigue Stress Allowable = 100003.8
   83,994                    Markl Fatigue Stress Allowable = 83402.0
      psi                    WRC 474 Mean Cycles to Failure = 6,109,608.
                             WRC 474 99% Probability Cycles = 1,419,344.
      22%                    WRC 474 95% Probability Cycles = 1,970,609.
                             BS5500 Allowed Cycles(Curve F) = 726,280.
                             Membrane-to-Bending Ratio = 62.149
                             Bending-to-PL+PB+Q Ratio = 0.016
                             Plot Reference:
                             13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5


Pad SCR for Plate # 1

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 5
   30,251     0.026 Life     Stress Concentration Factor = 1.350
      psi     0.360 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 271,291.
Allowable                    "B31" Fatigue Stress Allowable = 100003.8
   83,994                    Markl Fatigue Stress Allowable = 83402.0
      psi                    WRC 474 Mean Cycles to Failure = 1,090,482.
                             WRC 474 99% Probability Cycles = 253,334.
      36%                    WRC 474 95% Probability Cycles = 351,727.
                             BS5500 Allowed Cycles(Curve F) = 187,891.
                             Membrane-to-Bending Ratio = 0.246
                             Bending-to-PL+PB+Q Ratio = 0.803
                             Plot Reference:
                             13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5
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Shell in Plate # 1 Vicinity

Pl+Pb+Q+F     Damage Ratio     Primary+Secondary+Peak (Inner) Load Case 5
   18,397      0.000 Life      Stress Concentration Factor = 1.000
      psi      0.155 Stress    Strain Concentration Factor = 1.000
                               Cycles Allowed for this Stress = 1.0000E11
Allowable                      "B31" Fatigue Stress Allowable = 78719.4
  118,449                      Markl Fatigue Stress Allowable = 95657.0
      psi                      WRC 474 Mean Cycles to Failure = 2,639,187.
                               WRC 474 99% Probability Cycles = 613,119.
      15%                      WRC 474 95% Probability Cycles = 851,250.
                               BS5500 Allowed Cycles(Curve F) = 380,717.
                               Membrane-to-Bending Ratio = 0.884
                               Bending-to-PL+PB+Q Ratio = 0.531
                               Plot Reference:
                               12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 5


Circ Plate for Plate # 1

Pl+Pb+Q+F     Damage Ratio     Primary+Secondary+Peak (Inner) Load Case 5
   18,204      0.000 Life      Stress Concentration Factor = 1.000
      psi      0.217 Stress    Strain Concentration Factor = 1.000
                               Cycles Allowed for this Stress = 3.4832E8
Allowable                      "B31" Fatigue Stress Allowable = 100003.8
   83,994                      Markl Fatigue Stress Allowable = 83402.0
      psi                      WRC 474 Mean Cycles to Failure = 2,861,712.
                               WRC 474 99% Probability Cycles = 664,814.
      21%                      WRC 474 95% Probability Cycles = 923,024.
                               BS5500 Allowed Cycles(Curve F) = 350,453.
                               Membrane-to-Bending Ratio = 30.150
                               Bending-to-PL+PB+Q Ratio = 0.032
                               Plot Reference:
                               12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 5


Long Plate for Plate # 1

Pl+Pb+Q+F     Damage Ratio     Primary+Secondary+Peak (Outer) Load Case 5
    3,716      0.000 Life      Stress Concentration Factor = 1.000
      psi      0.044 Stress    Strain Concentration Factor = 1.000
                               Cycles Allowed for this Stress = 1.0000E11
Allowable                      "B31" Fatigue Stress Allowable = 100003.8
   83,994                      Markl Fatigue Stress Allowable = 83402.0
      psi                      WRC 474 Mean Cycles to Failure = 4.1083E8
                               WRC 474 99% Probability Cycles = 95,440,648.
       4%                      WRC 474 95% Probability Cycles = 1.3251E8
                               BS5500 Allowed Cycles(Curve F) = 1.0749E8
                               Membrane-to-Bending Ratio = 19.489
                               Bending-to-PL+PB+Q Ratio = 0.049
                               Plot Reference:
                               13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5


Pad for Plate # 1

Pl+Pb+Q+F     Damage Ratio     Primary+Secondary+Peak (Inner) Load Case 5
   11,809      0.000 Life      Stress Concentration Factor = 1.000
      psi      0.141 Stress    Strain Concentration Factor = 1.000
                               Cycles Allowed for this Stress = 1.0000E11
Allowable                      "B31" Fatigue Stress Allowable = 100003.8
   83,994                      Markl Fatigue Stress Allowable = 83402.0
      psi                      WRC 474 Mean Cycles to Failure = 7,518,001.
                               WRC 474 99% Probability Cycles = 1,746,533.
      14%                      WRC 474 95% Probability Cycles = 2,424,876.
                               BS5500 Allowed Cycles(Curve F) = 1,283,632.
                               Membrane-to-Bending Ratio = 0.608
                               Bending-to-PL+PB+Q Ratio = 0.622
                               Plot Reference:
                               12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 5
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Highest Stress Ratios Per Region                       $X

Shell SCR at Plate # 1

      Pl            SPL     Primary Membrane Load Case 2
   3,618         22,191     Min Prin. Stress = -3. ( 0% Neg, 0% NegHi)
     psi            psi     Plot Reference:
                            1) Pl < SPL (SUS,Membrane) Case 2
            16%

      Qb            SPS     Primary Bending Load Case 2
     257         47,232     Min Prin. Stress = -3. ( 0% Neg, 0% NegHi)
     psi            psi     Plot Reference:
                            2) Qb < SPS (SUS,Bending) Case 2
             0%

 Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 2
   3,775         47,232     Min Prin. Stress = -3. ( 0% Neg, 0% NegHi)
     psi            psi     Plot Reference:
                            3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
             7%

 Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 2
   3,493         47,232     Min Prin. Stress = -3. ( 0% Neg, 0% NegHi)
     psi            psi     Plot Reference:
                            4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
             7%

S1+S2+S3             4S     Part 5 (5.3.2) Load Case 2
   5,942         59,176     Min Prin. Stress = -3. ( 0% Neg, 0% NegHi)
     psi            psi     Plot Reference:
                            5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
            10%

 Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 4
  24,003         47,232     Min Prin. Stress = -14597. (99% Neg, 53% NegHi)
     psi            psi     Plot Reference:
                            6) Pl+Pb+Q < SPS (OPE,Inside) Case 4
            50%

 Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 4
  27,096         47,232     Min Prin. Stress = -14597. (99% Neg, 53% NegHi)
     psi            psi     Plot Reference:
                            7) Pl+Pb+Q < SPS (OPE,Outside) Case 4
            57%

Membrane           User     Component Evaluation Load Case 4
  11,685         47,232     Min Prin. Stress = -14597. (99% Neg, 53% NegHi)
     psi            psi     Plot Reference:
                            8) Membrane < User (OPE,Membrane) Case 4
            24%

 Bending           User     Component Evaluation Load Case 4
  20,076         47,232     Min Prin. Stress = -14597. (99% Neg, 53% NegHi)
     psi            psi     Plot Reference:
                            9) Bending < User (OPE,Bending) Case 4
            42%

 Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 5
  24,003         47,232     Min Prin. Stress = -14597. (99% Neg, 53% NegHi)
     psi            psi     Plot Reference:
                            10) Pl+Pb+Q < SPS (EXP,Inside) Case 5
            50%

 Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 5
  27,096         47,232     Min Prin. Stress = -14597. (99% Neg, 53% NegHi)
     psi            psi     Plot Reference:
                            11) Pl+Pb+Q < SPS (EXP,Outside) Case 5
            57%

Pl+Pb+Q+F   Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 5
  32,404     0.003 Life     Stress Concentration Factor = 1.350
     psi     0.274 Stress   Strain Concentration Factor = 1.000
                            Cycles Allowed for this Stress = 2,229,020.
Allowable                   "B31" Fatigue Stress Allowable = 78719.4
 118,449                    Markl Fatigue Stress Allowable = 95657.0
     psi                    WRC 474 Mean Cycles to Failure = 1,234,538.
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                                WRC 474 99% Probability Cycles = 286,800.
      27%                       WRC 474 95% Probability Cycles = 398,191.
                                BS5500 Allowed Cycles(Curve F) = 171,404.
                                Membrane-to-Bending Ratio = 0.613
                                Bending-to-PL+PB+Q Ratio = 0.620
                                Plot Reference:
                                12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 5

Pl+Pb+Q+F    Damage Ratio       Primary+Secondary+Peak (Outer) Load Case 5
   36,580     0.007 Life        Stress Concentration Factor = 1.350
      psi     0.309 Stress      Strain Concentration Factor = 1.000
                                Cycles Allowed for this Stress = 1,003,418.
Allowable                       "B31" Fatigue Stress Allowable = 78719.4
  118,449                       Markl Fatigue Stress Allowable = 95657.0
      psi                       WRC 474 Mean Cycles to Failure = 818,100.
                                WRC 474 99% Probability Cycles = 190,056.
      30%                       WRC 474 95% Probability Cycles = 263,872.
                                BS5500 Allowed Cycles(Curve F) = 119,145.
                                Membrane-to-Bending Ratio = 0.504
                                Bending-to-PL+PB+Q Ratio = 0.665
                                Plot Reference:
                                13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5


Circ Plate SCR for Plate # 1

       Pl            SPL        Primary Membrane Load Case 2
      485         30,995        Min Prin. Stress = -540. (64% Neg, 0% NegHi)
      psi            psi        Plot Reference:
                                1) Pl < SPL (SUS,Membrane) Case 2
             1%

       Qb            SPS        Primary Bending Load Case 2
      109         68,995        Min Prin. Stress = -540. (64% Neg, 0% NegHi)
      psi            psi        Plot Reference:
                                2) Qb < SPS (SUS,Bending) Case 2
             0%

  Pl+Pb+Q            SPS        Primary+Secondary (Inner) Load Case 2
      554         68,995        Min Prin. Stress = -540. (64% Neg, 0% NegHi)
      psi            psi        Plot Reference:
                                3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
             0%

  Pl+Pb+Q            SPS        Primary+Secondary (Outer) Load Case 2
      554         68,995        Min Prin. Stress = -540. (64% Neg, 0% NegHi)
      psi            psi        Plot Reference:
                                4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
             0%

 S1+S2+S3             4S        Part 5 (5.3.2) Load Case 2
     -574         80,003        Min Prin. Stress = -540. (64% Neg, 0% NegHi)
      psi            psi        Plot Reference:
                                5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
             0%

  Pl+Pb+Q            SPS        Primary+Secondary (Inner) Load Case 4
   29,561         68,995        Min Prin. Stress = -29113. (97% Neg, 63% NegHi)
      psi            psi        Plot Reference:
                                6) Pl+Pb+Q < SPS (OPE,Inside) Case 4
            42%

  Pl+Pb+Q            SPS        Primary+Secondary (Outer) Load Case 4
   27,915         68,995        Min Prin. Stress = -29113. (97% Neg, 63% NegHi)
      psi            psi        Plot Reference:
                                7) Pl+Pb+Q < SPS (OPE,Outside) Case 4
            40%

 Membrane           User        Component Evaluation Load Case 4
   28,737         68,995        Min Prin. Stress = -29113. (97% Neg, 63% NegHi)
      psi            psi        Plot Reference:
                                8) Membrane < User (OPE,Membrane) Case 4
            41%

  Bending           User        Component Evaluation Load Case 4
    5,163         68,995        Min Prin. Stress = -29113. (97% Neg, 63% NegHi)
      psi            psi        Plot Reference:
                                9) Bending < User (OPE,Bending) Case 4
             7%

  Pl+Pb+Q            SPS        Primary+Secondary (Inner) Load Case 5
   29,561         68,995        Min Prin. Stress = -29113. (97% Neg, 63% NegHi)
```

```
     psi           psi     Plot Reference:
                           10) Pl+Pb+Q < SPS (EXP,Inside) Case 5
          42%

   Pl+Pb+Q         SPS     Primary+Secondary (Outer) Load Case 5
    27,915      68,995     Min Prin. Stress = -29113. (97% Neg, 63% NegHi)
       psi         psi     Plot Reference:
                           11) Pl+Pb+Q < SPS (EXP,Outside) Case 5
          40%

 Pl+Pb+Q+F   Damage Ratio  Primary+Secondary+Peak (Inner) Load Case 5
    39,907    0.076 Life   Stress Concentration Factor = 1.350
       psi    0.475 Stress Strain Concentration Factor = 1.000
                           Cycles Allowed for this Stress = 91,518.
 Allowable                 "B31" Fatigue Stress Allowable = 100003.8
    83,994                 Markl Fatigue Stress Allowable = 83402.0
       psi                 WRC 474 Mean Cycles to Failure = 628,939.
                           WRC 474 99% Probability Cycles = 146,111.
       47%                 WRC 474 95% Probability Cycles = 202,860.
                           BS5500 Allowed Cycles(Curve F) = 81,845.
                           Membrane-to-Bending Ratio = 34.017
                           Bending-to-PL+PB+Q Ratio = 0.029
                           Plot Reference:
                           12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 5

 Pl+Pb+Q+F   Damage Ratio  Primary+Secondary+Peak (Outer) Load Case 5
    37,685    0.061 Life   Stress Concentration Factor = 1.350
       psi    0.449 Stress Strain Concentration Factor = 1.000
                           Cycles Allowed for this Stress = 115,255.
 Allowable                 "B31" Fatigue Stress Allowable = 100003.8
    83,994                 Markl Fatigue Stress Allowable = 83402.0
       psi                 WRC 474 Mean Cycles to Failure = 752,263.
                           WRC 474 99% Probability Cycles = 174,761.
       44%                 WRC 474 95% Probability Cycles = 242,637.
                           BS5500 Allowed Cycles(Curve F) = 97,189.
                           Membrane-to-Bending Ratio = 34.017
                           Bending-to-PL+PB+Q Ratio = 0.029
                           Plot Reference:
                           13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5


 Long Plate SCR for Plate # 1

        Pl         SPL     Primary Membrane Load Case 2
       199      30,995     Min Prin. Stress = -94. (23% Neg, 13% NegHi)
       psi         psi     Plot Reference:
                           1) Pl < SPL (SUS,Membrane) Case 2
           0%

        Qb         SPS     Primary Bending Load Case 2
         0      68,995     Min Prin. Stress = -94. (23% Neg, 13% NegHi)
       psi         psi     Plot Reference:
                           2) Qb < SPS (SUS,Bending) Case 2
           0%

   Pl+Pb+Q         SPS     Primary+Secondary (Inner) Load Case 2
       199      68,995     Min Prin. Stress = -94. (23% Neg, 13% NegHi)
       psi         psi     Plot Reference:
                           3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
           0%

   Pl+Pb+Q         SPS     Primary+Secondary (Outer) Load Case 2
       199      68,995     Min Prin. Stress = -94. (23% Neg, 13% NegHi)
       psi         psi     Plot Reference:
                           4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
           0%

  S1+S2+S3          4S     Part 5 (5.3.2) Load Case 2
       209      80,003     Min Prin. Stress = -94. (23% Neg, 13% NegHi)
       psi         psi     Plot Reference:
                           5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
           0%

   Pl+Pb+Q         SPS     Primary+Secondary (Inner) Load Case 4
    14,051      68,995     Min Prin. Stress = -821. (70% Neg, 30% NegHi)
       psi         psi     Plot Reference:
                           6) Pl+Pb+Q < SPS (OPE,Inside) Case 4
          20%

   Pl+Pb+Q         SPS     Primary+Secondary (Outer) Load Case 4
    14,278      68,995     Min Prin. Stress = -821. (70% Neg, 30% NegHi)
       psi         psi     Plot Reference:
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```
                            7) Pl+Pb+Q < SPS (OPE,Outside) Case 4
             20%

   Membrane          User     Component Evaluation Load Case 4
     14,163        68,995     Min Prin. Stress = -821. (70% Neg, 30% NegHi)
        psi           psi     Plot Reference:
                              8) Membrane < User (OPE,Membrane) Case 4
             20%

    Bending          User     Component Evaluation Load Case 4
        437        68,995     Min Prin. Stress = -821. (70% Neg, 30% NegHi)
        psi           psi     Plot Reference:
                              9) Bending < User (OPE,Bending) Case 4
              0%

    Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 5
     14,051        68,995     Min Prin. Stress = -821. (70% Neg, 30% NegHi)
        psi           psi     Plot Reference:
                              10) Pl+Pb+Q < SPS (EXP,Inside) Case 5
             20%

    Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 5
     14,278        68,995     Min Prin. Stress = -821. (70% Neg, 30% NegHi)
        psi           psi     Plot Reference:
                              11) Pl+Pb+Q < SPS (EXP,Outside) Case 5
             20%

  Pl+Pb+Q+F    Damage Ratio   Primary+Secondary+Peak (Inner) Load Case 5
     18,969     0.000 Life    Stress Concentration Factor = 1.350
        psi     0.226 Stress  Strain Concentration Factor = 1.000
                              Cycles Allowed for this Stress = 1.5570E8
  Allowable                   "B31" Fatigue Stress Allowable = 100003.8
     83,994                   Markl Fatigue Stress Allowable = 83402.0
        psi                   WRC 474 Mean Cycles to Failure = 6,423,192.
                              WRC 474 99% Probability Cycles = 1,492,194.
        22%                   WRC 474 95% Probability Cycles = 2,071,753.
                              BS5500 Allowed Cycles(Curve F) = 762,023.
                              Membrane-to-Bending Ratio = 62.149
                              Bending-to-PL+PB+Q Ratio = 0.016
                              Plot Reference:
                              12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 5

  Pl+Pb+Q+F    Damage Ratio   Primary+Secondary+Peak (Outer) Load Case 5
     19,276     0.000 Life    Stress Concentration Factor = 1.350
        psi     0.229 Stress  Strain Concentration Factor = 1.000
                              Cycles Allowed for this Stress = 1.1385E8
  Allowable                   "B31" Fatigue Stress Allowable = 100003.8
     83,994                   Markl Fatigue Stress Allowable = 83402.0
        psi                   WRC 474 Mean Cycles to Failure = 6,109,608.
                              WRC 474 99% Probability Cycles = 1,419,344.
        22%                   WRC 474 95% Probability Cycles = 1,970,609.
                              BS5500 Allowed Cycles(Curve F) = 726,280.
                              Membrane-to-Bending Ratio = 62.149
                              Bending-to-PL+PB+Q Ratio = 0.016
                              Plot Reference:
                              13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5


  Pad SCR for Plate # 1

         Pl           SPL     Primary Membrane Load Case 2
      2,108        30,995     Min Prin. Stress = -5. ( 0% Neg, 0% NegHi)
        psi           psi     Plot Reference:
                              1) Pl < SPL (SUS,Membrane) Case 2
              6%

         Qb           SPS     Primary Bending Load Case 2
        475        68,995     Min Prin. Stress = -5. ( 0% Neg, 0% NegHi)
        psi           psi     Plot Reference:
                              2) Qb < SPS (SUS,Bending) Case 2
              0%

    Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 2
      2,338        68,995     Min Prin. Stress = -5. ( 0% Neg, 0% NegHi)
        psi           psi     Plot Reference:
                              3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
              3%

    Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 2
      1,998        68,995     Min Prin. Stress = -5. ( 0% Neg, 0% NegHi)
        psi           psi     Plot Reference:
                              4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
```

```
           2%

 S1+S2+S3           4S     Part 5 (5.3.2) Load Case 2
    3,512       80,003     Min Prin. Stress = -5. ( 0% Neg, 0% NegHi)
      psi          psi     Plot Reference:
                           5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
           4%

  Pl+Pb+Q          SPS     Primary+Secondary (Inner) Load Case 4
   20,825       68,995     Min Prin. Stress = -14138. (98% Neg, 9% NegHi)
      psi          psi     Plot Reference:
                           6) Pl+Pb+Q < SPS (OPE,Inside) Case 4
          30%

  Pl+Pb+Q          SPS     Primary+Secondary (Outer) Load Case 4
   22,408       68,995     Min Prin. Stress = -14138. (98% Neg, 9% NegHi)
      psi          psi     Plot Reference:
                           7) Pl+Pb+Q < SPS (OPE,Outside) Case 4
          32%

 Membrane         User     Component Evaluation Load Case 4
    9,337       68,995     Min Prin. Stress = -14138. (98% Neg, 9% NegHi)
      psi          psi     Plot Reference:
                           8) Membrane < User (OPE,Membrane) Case 4
          13%

  Bending         User     Component Evaluation Load Case 4
   18,874       68,995     Min Prin. Stress = -14138. (98% Neg, 9% NegHi)
      psi          psi     Plot Reference:
                           9) Bending < User (OPE,Bending) Case 4
          27%

  Pl+Pb+Q          SPS     Primary+Secondary (Inner) Load Case 5
   20,825       68,995     Min Prin. Stress = -14138. (98% Neg, 9% NegHi)
      psi          psi     Plot Reference:
                           10) Pl+Pb+Q < SPS (EXP,Inside) Case 5
          30%

  Pl+Pb+Q          SPS     Primary+Secondary (Outer) Load Case 5
   22,408       68,995     Min Prin. Stress = -14138. (98% Neg, 9% NegHi)
      psi          psi     Plot Reference:
                           11) Pl+Pb+Q < SPS (EXP,Outside) Case 5
          32%

Pl+Pb+Q+F   Damage Ratio   Primary+Secondary+Peak (Inner) Load Case 5
   28,114    0.018 Life    Stress Concentration Factor = 1.350
      psi    0.335 Stress  Strain Concentration Factor = 1.000
                           Cycles Allowed for this Stress = 379,071.
Allowable                  "B31" Fatigue Stress Allowable = 100003.8
   83,994                  Markl Fatigue Stress Allowable = 83402.0
      psi                  WRC 474 Mean Cycles to Failure = 1,410,160.
                           WRC 474 99% Probability Cycles = 327,599.
      33%                  WRC 474 95% Probability Cycles = 454,837.
                           BS5500 Allowed Cycles(Curve F) = 234,078.
                           Membrane-to-Bending Ratio = 0.502
                           Bending-to-PL+PB+Q Ratio = 0.666
                           Plot Reference:
                           12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 5

Pl+Pb+Q+F   Damage Ratio   Primary+Secondary+Peak (Outer) Load Case 5
   30,251    0.026 Life    Stress Concentration Factor = 1.350
      psi    0.360 Stress  Strain Concentration Factor = 1.000
                           Cycles Allowed for this Stress = 271,291.
Allowable                  "B31" Fatigue Stress Allowable = 100003.8
   83,994                  Markl Fatigue Stress Allowable = 83402.0
      psi                  WRC 474 Mean Cycles to Failure = 1,090,482.
                           WRC 474 99% Probability Cycles = 253,334.
      36%                  WRC 474 95% Probability Cycles = 351,727.
                           BS5500 Allowed Cycles(Curve F) = 187,891.
                           Membrane-to-Bending Ratio = 0.246
                           Bending-to-PL+PB+Q Ratio = 0.803
                           Plot Reference:
                           13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5


Shell in Plate # 1 Vicinity

       Pl          SPL     Primary Membrane Load Case 2
    3,465       22,191     Min Prin. Stress = -4. ( 0% Neg, 0% NegHi)
      psi          psi     Plot Reference:
                           1) Pl < SPL (SUS,Membrane) Case 2
          15%
```

```
       Qb            SPS     Primary Bending Load Case 2
      366         47,232     Min Prin. Stress = -4. ( 0% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             2) Qb < SPS (SUS,Bending) Case 2
             0%

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 2
    3,561         47,232     Min Prin. Stress = -4. ( 0% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
             7%

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 2
    3,491         47,232     Min Prin. Stress = -4. ( 0% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
             7%

 S1+S2+S3             4S     Part 5 (5.3.2) Load Case 2
    5,977         59,176     Min Prin. Stress = -4. ( 0% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
            10%

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 4
   18,397         47,232     Min Prin. Stress = -9147. (98% Neg, 49% NegHi)
      psi            psi     Plot Reference:
                             6) Pl+Pb+Q < SPS (OPE,Inside) Case 4
            38%

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 4
   10,330         47,232     Min Prin. Stress = -9147. (98% Neg, 49% NegHi)
      psi            psi     Plot Reference:
                             7) Pl+Pb+Q < SPS (OPE,Outside) Case 4
            21%

 Membrane           User     Component Evaluation Load Case 4
    9,992         47,232     Min Prin. Stress = -9147. (98% Neg, 49% NegHi)
      psi            psi     Plot Reference:
                             8) Membrane < User (OPE,Membrane) Case 4
            21%

  Bending           User     Component Evaluation Load Case 4
   11,193         47,232     Min Prin. Stress = -9147. (98% Neg, 49% NegHi)
      psi            psi     Plot Reference:
                             9) Bending < User (OPE,Bending) Case 4
            23%

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 5
   18,397         47,232     Min Prin. Stress = -9147. (98% Neg, 49% NegHi)
      psi            psi     Plot Reference:
                             10) Pl+Pb+Q < SPS (EXP,Inside) Case 5
            38%

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 5
   10,330         47,232     Min Prin. Stress = -9147. (98% Neg, 49% NegHi)
      psi            psi     Plot Reference:
                             11) Pl+Pb+Q < SPS (EXP,Outside) Case 5
            21%

Pl+Pb+Q+F   Damage Ratio     Primary+Secondary+Peak (Inner) Load Case 5
   18,397     0.000 Life     Stress Concentration Factor = 1.000
      psi     0.155 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 78719.4
  118,449                    Markl Fatigue Stress Allowable = 95657.0
      psi                    WRC 474 Mean Cycles to Failure = 2,639,187.
                             WRC 474 99% Probability Cycles = 613,119.
      15%                    WRC 474 95% Probability Cycles = 851,250.
                             BS5500 Allowed Cycles(Curve F) = 380,717.
                             Membrane-to-Bending Ratio = 0.884
                             Bending-to-PL+PB+Q Ratio = 0.531
                             Plot Reference:
                             12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 5

Pl+Pb+Q+F   Damage Ratio     Primary+Secondary+Peak (Outer) Load Case 5
   10,330     0.000 Life     Stress Concentration Factor = 1.000
      psi     0.087 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 78719.4
  118,449                    Markl Fatigue Stress Allowable = 95657.0
```

```
     psi                     WRC 474 Mean Cycles to Failure = 17,436,496.
                             WRC 474 99% Probability Cycles = 4,050,730.
      8%                     WRC 474 95% Probability Cycles = 5,624,008.
                             BS5500 Allowed Cycles(Curve F) = 2,150,209.
                             Membrane-to-Bending Ratio = 0.410
                             Bending-to-PL+PB+Q Ratio = 0.709
                             Plot Reference:
                             13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5


Circ Plate for Plate # 1

      Pl           SPL       Primary Membrane Load Case 2
     179        30,995       Min Prin. Stress = -132. (99% Neg, 0% NegHi)
     psi           psi       Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
            0%

      Qb           SPS       Primary Bending Load Case 2
      29        68,995       Min Prin. Stress = -132. (99% Neg, 0% NegHi)
     psi           psi       Plot Reference:
                             2) Qb < SPS (SUS,Bending) Case 2
            0%

  Pl+Pb+Q          SPS       Primary+Secondary (Inner) Load Case 2
     202        68,995       Min Prin. Stress = -132. (99% Neg, 0% NegHi)
     psi           psi       Plot Reference:
                             3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
            0%

  Pl+Pb+Q          SPS       Primary+Secondary (Outer) Load Case 2
     202        68,995       Min Prin. Stress = -132. (99% Neg, 0% NegHi)
     psi           psi       Plot Reference:
                             4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
            0%

 S1+S2+S3           4S       Part 5 (5.3.2) Load Case 2
    -101        80,003       Min Prin. Stress = -132. (99% Neg, 0% NegHi)
     psi           psi       Plot Reference:
                             5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
            0%

  Pl+Pb+Q          SPS       Primary+Secondary (Inner) Load Case 4
  18,204        68,995       Min Prin. Stress = -17799. (99% Neg, 58% NegHi)
     psi           psi       Plot Reference:
                             6) Pl+Pb+Q < SPS (OPE,Inside) Case 4
           26%

  Pl+Pb+Q          SPS       Primary+Secondary (Outer) Load Case 4
  17,061        68,995       Min Prin. Stress = -17799. (99% Neg, 58% NegHi)
     psi           psi       Plot Reference:
                             7) Pl+Pb+Q < SPS (OPE,Outside) Case 4
           24%

 Membrane         User       Component Evaluation Load Case 4
  17,632        68,995       Min Prin. Stress = -17799. (99% Neg, 58% NegHi)
     psi           psi       Plot Reference:
                             8) Membrane < User (OPE,Membrane) Case 4
           25%

  Bending         User       Component Evaluation Load Case 4
     973        68,995       Min Prin. Stress = -17799. (99% Neg, 58% NegHi)
     psi           psi       Plot Reference:
                             9) Bending < User (OPE,Bending) Case 4
            1%

  Pl+Pb+Q          SPS       Primary+Secondary (Inner) Load Case 5
  18,204        68,995       Min Prin. Stress = -17799. (99% Neg, 58% NegHi)
     psi           psi       Plot Reference:
                             10) Pl+Pb+Q < SPS (EXP,Inside) Case 5
           26%

  Pl+Pb+Q          SPS       Primary+Secondary (Outer) Load Case 5
  17,061        68,995       Min Prin. Stress = -17799. (99% Neg, 58% NegHi)
     psi           psi       Plot Reference:
                             11) Pl+Pb+Q < SPS (EXP,Outside) Case 5
           24%

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 5
  18,204      0.000 Life     Stress Concentration Factor = 1.000
     psi      0.217 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 3.4832E8
```

```
Allowable                   "B31" Fatigue Stress Allowable = 100003.8
   83,994                   Markl Fatigue Stress Allowable = 83402.0
      psi                   WRC 474 Mean Cycles to Failure = 2,861,712.
                            WRC 474 99% Probability Cycles = 664,814.
      21%                   WRC 474 95% Probability Cycles = 923,024.
                            BS5500 Allowed Cycles(Curve F) = 350,453.
                            Membrane-to-Bending Ratio = 30.150
                            Bending-to-PL+PB+Q Ratio = 0.032
                            Plot Reference:
                            12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 5

Pl+Pb+Q+F    Damage Ratio   Primary+Secondary+Peak (Outer) Load Case 5
   17,061     0.000 Life    Stress Concentration Factor = 1.000
      psi     0.203 Stress  Strain Concentration Factor = 1.000
                            Cycles Allowed for this Stress = 1.2614E9
Allowable                   "B31" Fatigue Stress Allowable = 100003.8
   83,994                   Markl Fatigue Stress Allowable = 83402.0
      psi                   WRC 474 Mean Cycles to Failure = 3,504,644.
                            WRC 474 99% Probability Cycles = 814,176.
      20%                   WRC 474 95% Probability Cycles = 1,130,397.
                            BS5500 Allowed Cycles(Curve F) = 425,688.
                            Membrane-to-Bending Ratio = 30.150
                            Bending-to-PL+PB+Q Ratio = 0.032
                            Plot Reference:
                            13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5


Long Plate for Plate # 1

       Pl            SPL    Primary Membrane Load Case 2
       97         30,995    Min Prin. Stress = -98. (50% Neg, 50% NegHi)
      psi            psi    Plot Reference:
                            1) Pl < SPL (SUS,Membrane) Case 2
             0%

       Qb            SPS    Primary Bending Load Case 2
        0         68,995    Min Prin. Stress = -98. (50% Neg, 50% NegHi)
      psi            psi    Plot Reference:
                            2) Qb < SPS (SUS,Bending) Case 2
             0%

  Pl+Pb+Q            SPS    Primary+Secondary (Inner) Load Case 2
       97         68,995    Min Prin. Stress = -98. (50% Neg, 50% NegHi)
      psi            psi    Plot Reference:
                            3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
             0%

  Pl+Pb+Q            SPS    Primary+Secondary (Outer) Load Case 2
       97         68,995    Min Prin. Stress = -98. (50% Neg, 50% NegHi)
      psi            psi    Plot Reference:
                            4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
             0%

 S1+S2+S3             4S    Part 5 (5.3.2) Load Case 2
     -100         80,003    Min Prin. Stress = -98. (50% Neg, 50% NegHi)
      psi            psi    Plot Reference:
                            5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
             0%

  Pl+Pb+Q            SPS    Primary+Secondary (Inner) Load Case 4
    3,611         68,995    Min Prin. Stress = -1039. (99% Neg, 50% NegHi)
      psi            psi    Plot Reference:
                            6) Pl+Pb+Q < SPS (OPE,Inside) Case 4
             5%

  Pl+Pb+Q            SPS    Primary+Secondary (Outer) Load Case 4
    3,716         68,995    Min Prin. Stress = -1039. (99% Neg, 50% NegHi)
      psi            psi    Plot Reference:
                            7) Pl+Pb+Q < SPS (OPE,Outside) Case 4
             5%

 Membrane           User    Component Evaluation Load Case 4
    3,659         68,995    Min Prin. Stress = -1039. (99% Neg, 50% NegHi)
      psi            psi    Plot Reference:
                            8) Membrane < User (OPE,Membrane) Case 4
             5%

  Bending           User    Component Evaluation Load Case 4
      188         68,995    Min Prin. Stress = -1039. (99% Neg, 50% NegHi)
      psi            psi    Plot Reference:
                            9) Bending < User (OPE,Bending) Case 4
             0%
```

```
  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 5
    3,611        68,995     Min Prin. Stress = -1039. (99% Neg, 50% NegHi)
      psi           psi     Plot Reference:
                            10) Pl+Pb+Q < SPS (EXP,Inside) Case 5
             5%

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 5
    3,716        68,995     Min Prin. Stress = -1039. (99% Neg, 50% NegHi)
      psi           psi     Plot Reference:
                            11) Pl+Pb+Q < SPS (EXP,Outside) Case 5
             5%

Pl+Pb+Q+F    Damage Ratio   Primary+Secondary+Peak (Inner) Load Case 5
    3,611     0.000 Life    Stress Concentration Factor = 1.000
      psi     0.043 Stress  Strain Concentration Factor = 1.000
                            Cycles Allowed for this Stress = 1.0000E11
Allowable                   "B31" Fatigue Stress Allowable = 100003.8
   83,994                   Markl Fatigue Stress Allowable = 83402.0
      psi                   WRC 474 Mean Cycles to Failure = 4.4931E8
                            WRC 474 99% Probability Cycles = 1.0438E8
       4%                   WRC 474 95% Probability Cycles = 1.4492E8
                            BS5500 Allowed Cycles(Curve F) = 1.2403E8
                            Membrane-to-Bending Ratio = 19.489
                            Bending-to-PL+PB+Q Ratio = 0.049
                            Plot Reference:
                            12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 5

Pl+Pb+Q+F    Damage Ratio   Primary+Secondary+Peak (Outer) Load Case 5
    3,716     0.000 Life    Stress Concentration Factor = 1.000
      psi     0.044 Stress  Strain Concentration Factor = 1.000
                            Cycles Allowed for this Stress = 1.0000E11
Allowable                   "B31" Fatigue Stress Allowable = 100003.8
   83,994                   Markl Fatigue Stress Allowable = 83402.0
      psi                   WRC 474 Mean Cycles to Failure = 4.1083E8
                            WRC 474 99% Probability Cycles = 95,440,648.
       4%                   WRC 474 95% Probability Cycles = 1.3251E8
                            BS5500 Allowed Cycles(Curve F) = 1.0749E8
                            Membrane-to-Bending Ratio = 19.489
                            Bending-to-PL+PB+Q Ratio = 0.049
                            Plot Reference:
                            13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5


Pad for Plate # 1

       Pl           SPL     Primary Membrane Load Case 2
    1,679        30,995     Min Prin. Stress = 0. ( 0% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            1) Pl < SPL (SUS,Membrane) Case 2
             5%

       Qb           SPS     Primary Bending Load Case 2
      196        68,995     Min Prin. Stress = 0. ( 0% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            2) Qb < SPS (SUS,Bending) Case 2
             0%

  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 2
    1,859        68,995     Min Prin. Stress = 0. ( 0% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
             2%

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 2
    1,507        68,995     Min Prin. Stress = 0. ( 0% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
             2%

 S1+S2+S3            4S     Part 5 (5.3.2) Load Case 2
    3,047        80,003     Min Prin. Stress = 0. ( 0% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
             3%

  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 4
   11,809        68,995     Min Prin. Stress = -7721. (99% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            6) Pl+Pb+Q < SPS (OPE,Inside) Case 4
            17%
```

```
  Pl+Pb+Q          SPS     Primary+Secondary (Outer) Load Case 4
    9,347       68,995     Min Prin. Stress = -7721. (99% Neg, 0% NegHi)
      psi          psi     Plot Reference:
                           7) Pl+Pb+Q < SPS (OPE,Outside) Case 4
           13%

 Membrane         User     Component Evaluation Load Case 4
    4,805       68,995     Min Prin. Stress = -7721. (99% Neg, 0% NegHi)
      psi          psi     Plot Reference:
                           8) Membrane < User (OPE,Membrane) Case 4
            6%

  Bending         User     Component Evaluation Load Case 4
    7,904       68,995     Min Prin. Stress = -7721. (99% Neg, 0% NegHi)
      psi          psi     Plot Reference:
                           9) Bending < User (OPE,Bending) Case 4
           11%

  Pl+Pb+Q          SPS     Primary+Secondary (Inner) Load Case 5
   11,809       68,995     Min Prin. Stress = -7721. (99% Neg, 0% NegHi)
      psi          psi     Plot Reference:
                           10) Pl+Pb+Q < SPS (EXP,Inside) Case 5
           17%

  Pl+Pb+Q          SPS     Primary+Secondary (Outer) Load Case 5
    9,347       68,995     Min Prin. Stress = -7721. (99% Neg, 0% NegHi)
      psi          psi     Plot Reference:
                           11) Pl+Pb+Q < SPS (EXP,Outside) Case 5
           13%

Pl+Pb+Q+F   Damage Ratio   Primary+Secondary+Peak (Inner) Load Case 5
   11,809    0.000 Life    Stress Concentration Factor = 1.000
      psi    0.141 Stress  Strain Concentration Factor = 1.000
                           Cycles Allowed for this Stress = 1.0000E11
Allowable                  "B31" Fatigue Stress Allowable = 100003.8
   83,994                  Markl Fatigue Stress Allowable = 83402.0
      psi                  WRC 474 Mean Cycles to Failure = 7,518,001.
                           WRC 474 99% Probability Cycles = 1,746,533.
      14%                  WRC 474 95% Probability Cycles = 2,424,876.
                           BS5500 Allowed Cycles(Curve F) = 1,283,632.
                           Membrane-to-Bending Ratio = 0.608
                           Bending-to-PL+PB+Q Ratio = 0.622
                           Plot Reference:
                           12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 5

Pl+Pb+Q+F   Damage Ratio   Primary+Secondary+Peak (Outer) Load Case 5
    9,347    0.000 Life    Stress Concentration Factor = 1.000
      psi    0.111 Stress  Strain Concentration Factor = 1.000
                           Cycles Allowed for this Stress = 1.0000E11
Allowable                  "B31" Fatigue Stress Allowable = 100003.8
   83,994                  Markl Fatigue Stress Allowable = 83402.0
      psi                  WRC 474 Mean Cycles to Failure = 16,557,389.
                           WRC 474 99% Probability Cycles = 3,846,501.
      11%                  WRC 474 95% Probability Cycles = 5,340,458.
                           BS5500 Allowed Cycles(Curve F) = 2,588,731.
                           Membrane-to-Bending Ratio = 0.521
                           Bending-to-PL+PB+Q Ratio = 0.658
                           Plot Reference:
                           13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5
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```
Compressive Stress Summary
FEPipe Version 15.0           Jobname: NOZZLE                $P
Released Jan. 2021             12:09am  DEC 16,2022



Compressive Stress Summary (psi)                      $X

Nomenclature:
-------------
Min Stress        - Compressive Membrane and Bending Stress
Pts in Region     - No. of nodes in the model region
>5% Compression   - 5% or more of Compressive Stress Limit
>50% Compression - 50% or more of Compressive Stress Limit
```

Compressive Stress Limit = -0.55 Min(Sy, kEt/R), Section slenderness ratio (elastic buckling) not considered.

| # | Load Type | Case | Min Stress | Pts in Region | >5% Compression and Bending | >50% Compression and Bending | Region |
|---|---|---|---|---|---|---|---|
| 1 | SUSTAINED | 2 | -4. | 1292 | 0% | 0% | Shell in Plate # 1 Vicinity |
| 2 | OPERATING | 4 | -9147. | 1292 | 98% | 49% | Shell in Plate # 1 Vicinity |
| 3 | EXPANSION | 5 | -9147. | 1292 | 98% | 49% | Shell in Plate # 1 Vicinity |
| 4 | SUSTAINED | 2 | -3. | 580 | 0% | 0% | Shell SCR at Plate # 1 |
| 5 | OPERATING | 4 | -14597. | 580 | 99% | 53% | Shell SCR at Plate # 1 |
| 6 | EXPANSION | 5 | -14597. | 580 | 99% | 53% | Shell SCR at Plate # 1 |
| 7 | SUSTAINED | 2 | -5. | 796 | 0% | 0% | Pad SCR for Plate # 1 |
| 8 | OPERATING | 4 | -14138. | 796 | 98% | 9% | Pad SCR for Plate # 1 |
| 9 | EXPANSION | 5 | -14138. | 796 | 98% | 9% | Pad SCR for Plate # 1 |
| 10 | SUSTAINED | 2 | 0. | 32 | 0% | 0% | Pad for Plate # 1 |
| 11 | OPERATING | 4 | -7721. | 32 | 99% | 0% | Pad for Plate # 1 |
| 12 | EXPANSION | 5 | -7721. | 32 | 99% | 0% | Pad for Plate # 1 |
| 13 | SUSTAINED | 2 | -540. | 124 | 64% | 0% | Circ Plate SCR for Plate # 1 |
| 14 | OPERATING | 4 | -29113. | 124 | 97% | 63% | Circ Plate SCR for Plate # 1 |
| 15 | EXPANSION | 5 | -29113. | 124 | 97% | 63% | Circ Plate SCR for Plate # 1 |
| 16 | SUSTAINED | 2 | -132. | 12 | 99% | 0% | Circ Plate for Plate # 1 |
| 17 | OPERATING | 4 | -17799. | 12 | 99% | 58% | Circ Plate for Plate # 1 |
| 18 | EXPANSION | 5 | -17799. | 12 | 99% | 58% | Circ Plate for Plate # 1 |
| 19 | SUSTAINED | 2 | -94. | 30 | 23% | 13% | Long Plate SCR for Plate # 1 |
| 20 | OPERATING | 4 | -821. | 30 | 70% | 30% | Long Plate SCR for Plate # 1 |
| 21 | EXPANSION | 5 | -821. | 30 | 70% | 30% | Long Plate SCR for Plate # 1 |
| 22 | SUSTAINED | 2 | -98. | 2 | 50% | 50% | Long Plate for Plate # 1 |
| 23 | OPERATING | 4 | -1039. | 2 | 99% | 50% | Long Plate for Plate # 1 |
| 24 | EXPANSION | 5 | -1039. | 2 | 99% | 50% | Long Plate for Plate # 1 |

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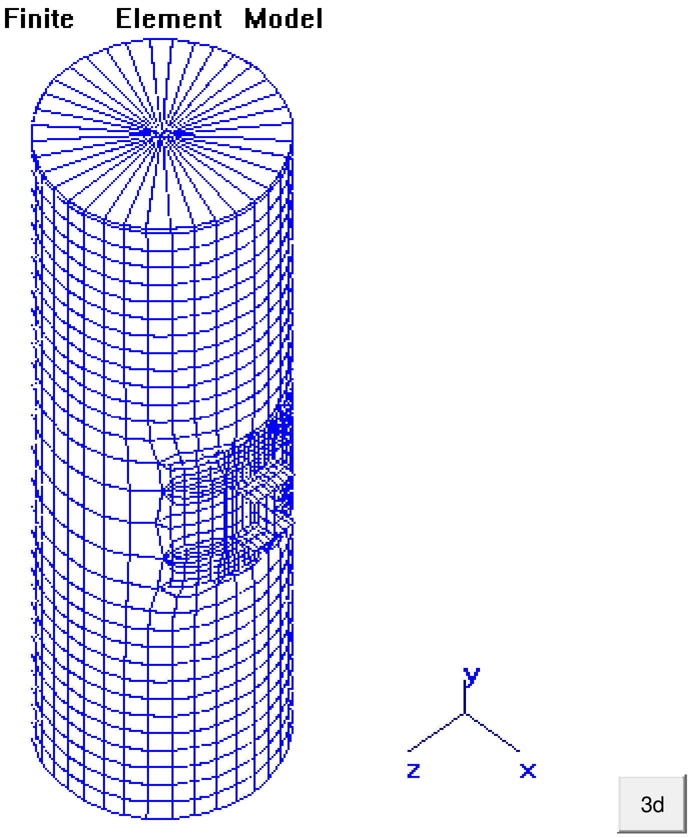
*Finite Element Model*

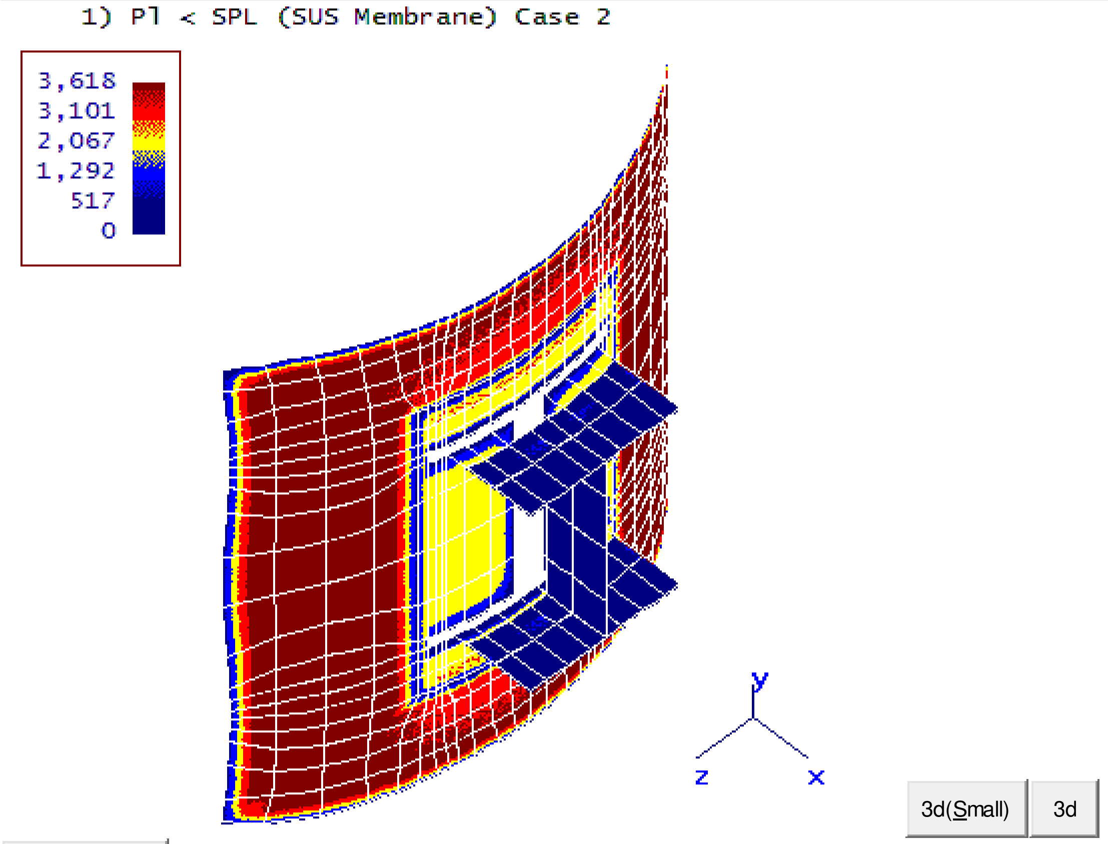
- Finite Element Model

*Area of Discontinuity at Plate*

- 1) Pl < SPL (SUS Membrane) Case 2
- 2) Qb < SPS (SUS Bending) Case 2
- 3) Pl+Pb+Q < SPS (SUS Inside) Case 2
- 4) Pl+Pb+Q < SPS (SUS Outside) Case 2
- 5) S1+S2+S3 < 4S (SUS S1+S2+S3) Case 2
- 6) Pl+Pb+Q < SPS (OPE Inside) Case 4
- 7) Pl+Pb+Q < SPS (OPE Outside) Case 4
- 8) Membrane < User (OPE Membrane) Case 4
- 9) Bending < User (OPE Bending) Case 4
- 10) Pl+Pb+Q < SPS (EXP Inside) Case 5
- 11) Pl+Pb+Q < SPS (EXP Outside) Case 5
- 12) Pl+Pb+Q+F < 2Sa (EXP Inside) Case 5
- 13) Pl+Pb+Q+F < 2Sa (EXP Outside) Case 5

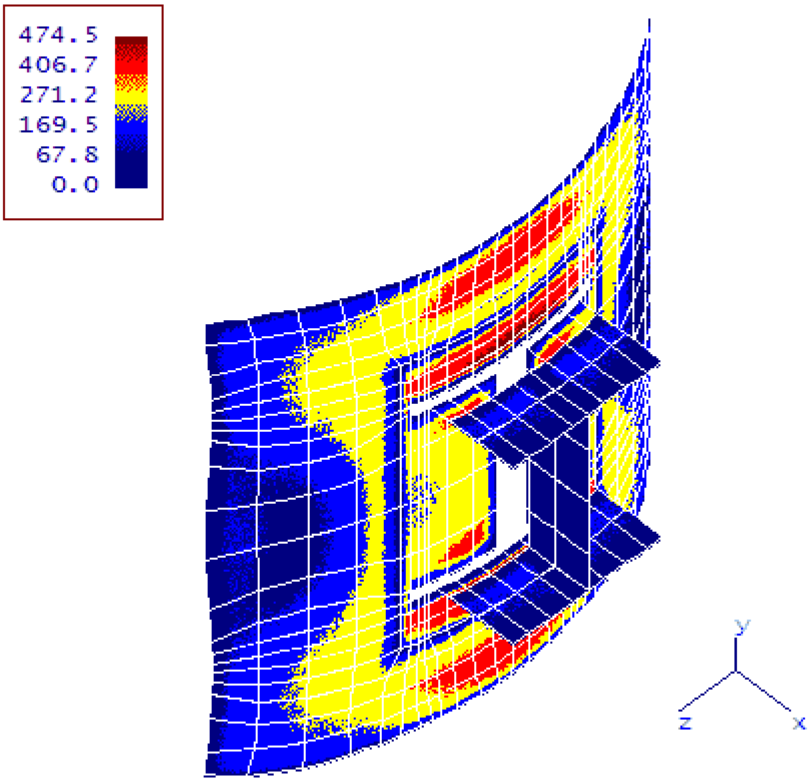

Finite Element Model
y
z
x
3d

-
- 


1) Pl < SPL (SUS Membrane) Case 2
3,618
3,101
2,067
1,292
517
0
y
z
x
3d(Small)
3d

- 3d(Deformed)
-

2) Qb < SPS (SUS Bending) Case 2




3d(Small) 3d

- 3d(Deformed)

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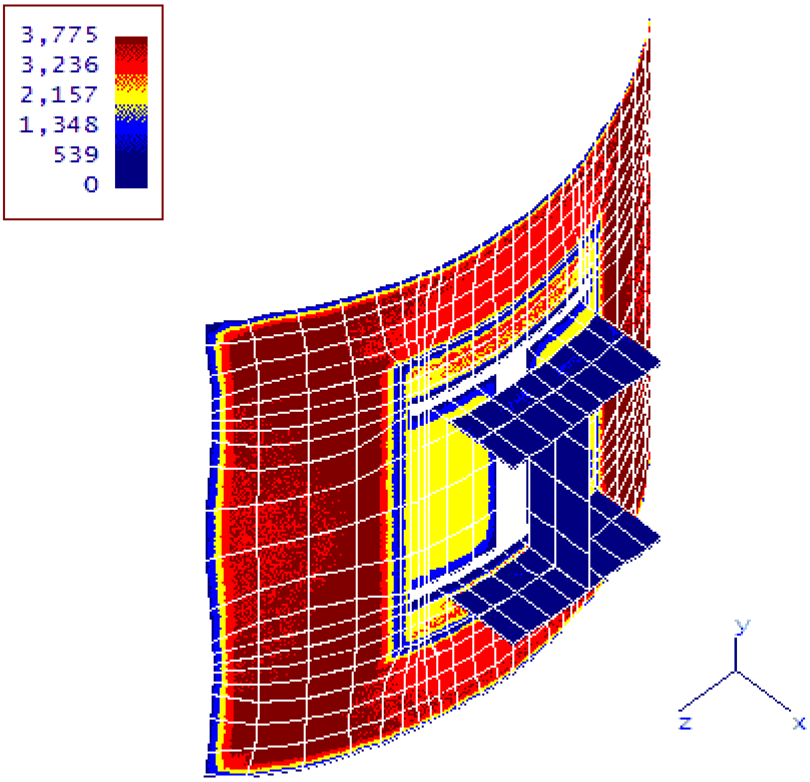
- 3) Pl+Pb+Q < SPS (SUS Inside) Case 2




3d(Small) 3d

- 3d(Deformed)

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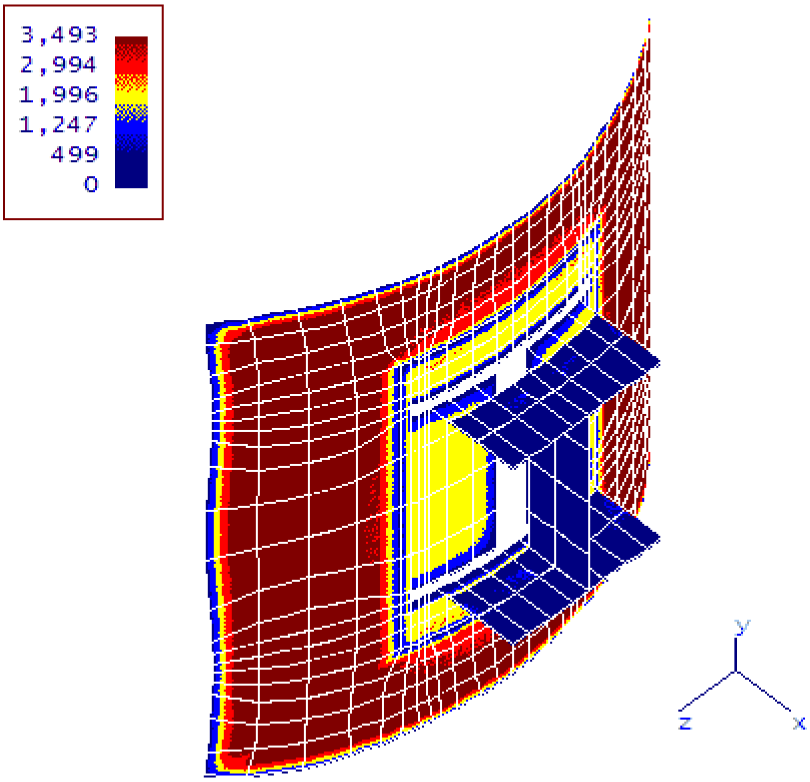
4) Pl+Pb+Q < SPS (SUS Outside) Case 2




3d(Small) 3d

- 3d(Deformed)
-

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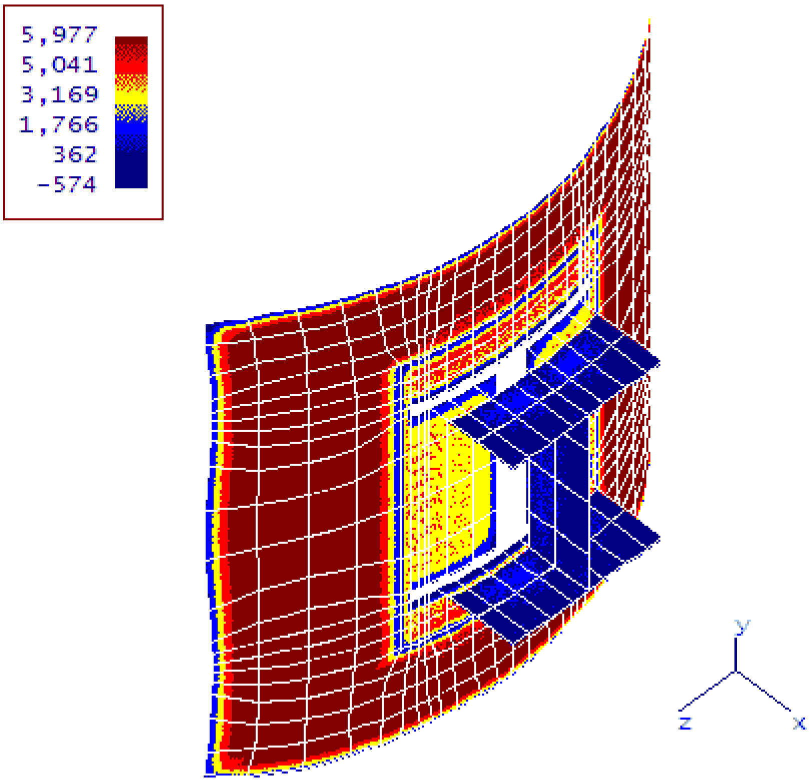
5) S1+S2+S3 < 4S (SUS S1+S2+S3) Case 2




3d(Small) 3d

- 3d(Deformed)
-

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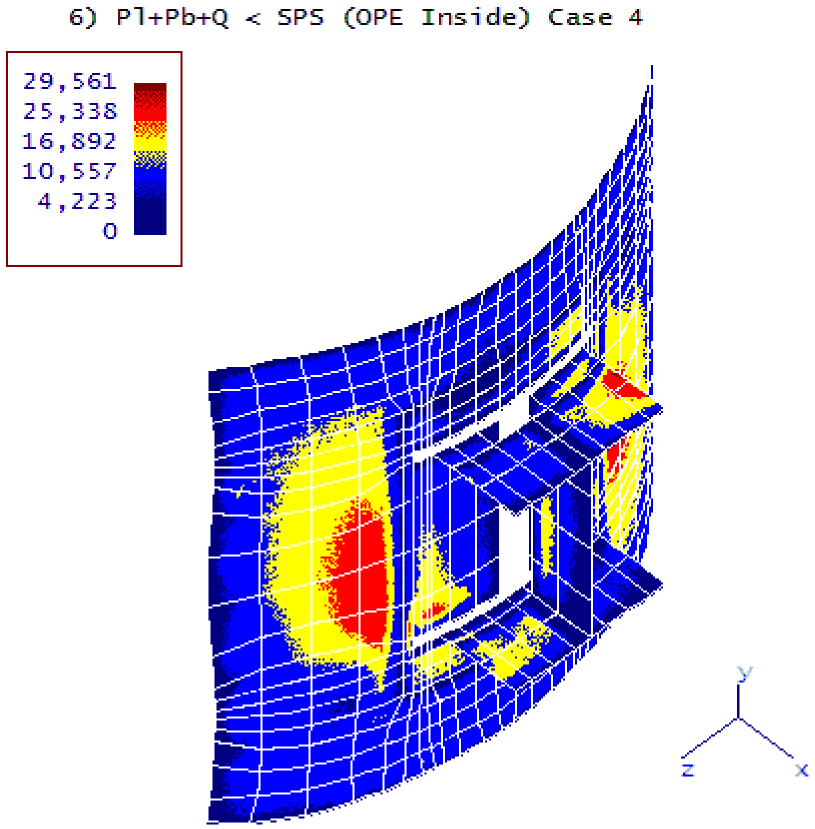
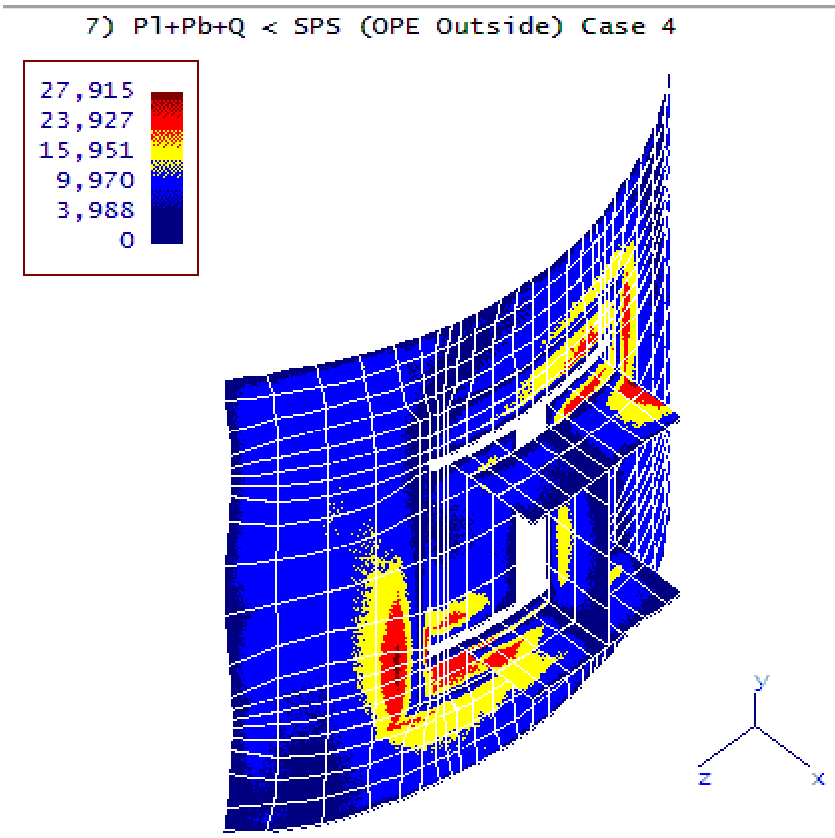
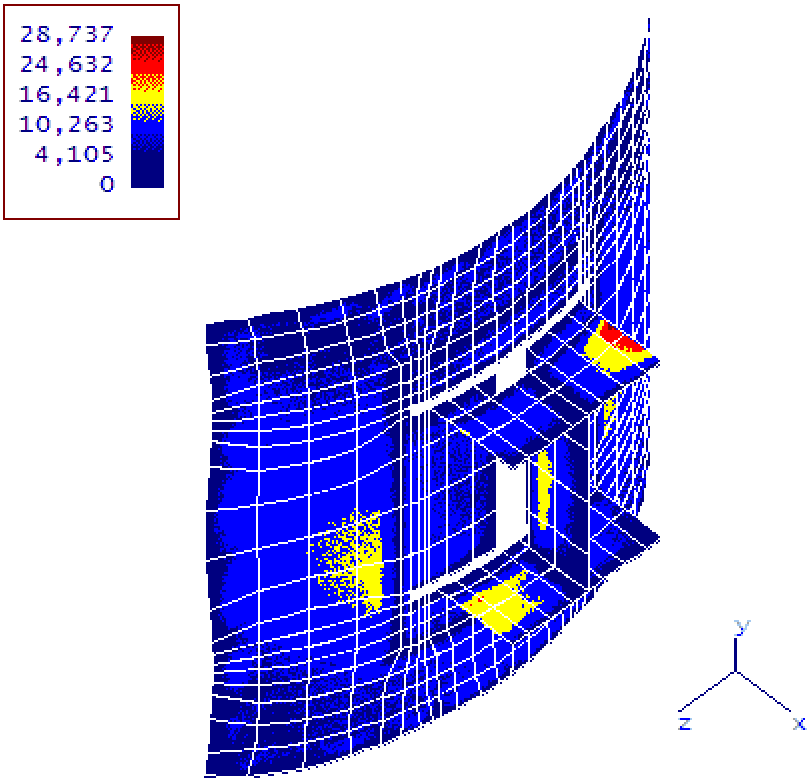



- 3d(Small) 3d
  3d(Deformed)
- ---




- 3d(Small) 3d
  3d(Deformed)
- ---

8) Membrane < User (OPE Membrane) Case 4

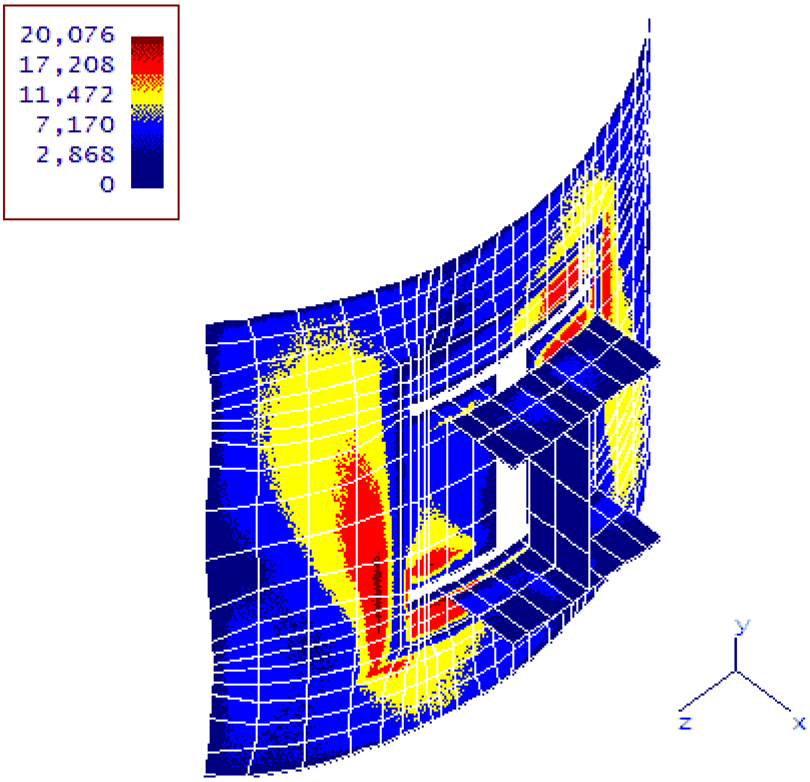



- 3d(Small) 3d

3d(Deformed)

---

9) Bending < User (OPE Bending) Case 4

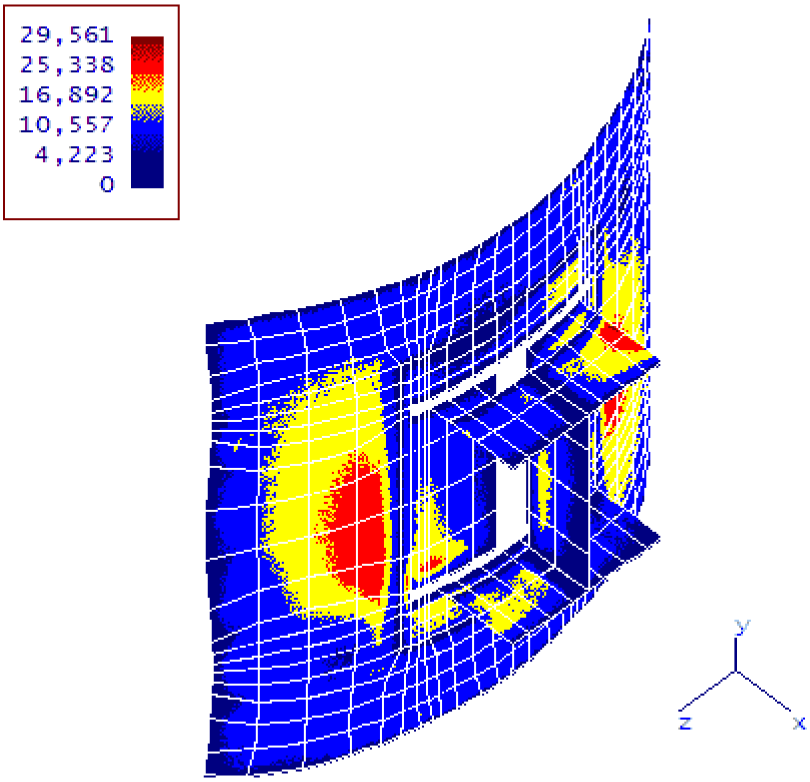



- 3d(Small) 3d

3d(Deformed)

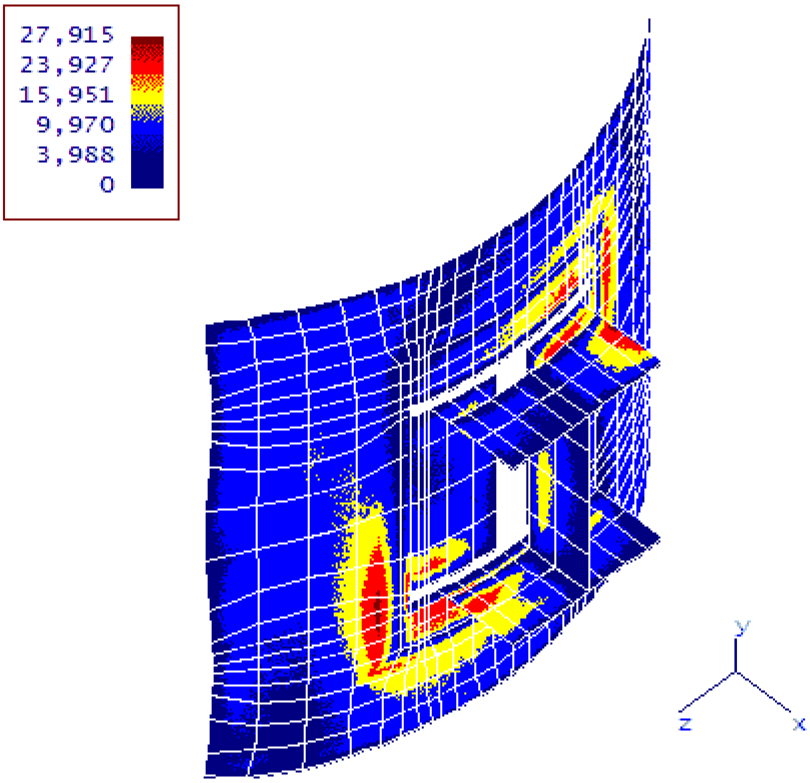
---

10) Pl+Pb+Q < SPS (EXP Inside) Case 5



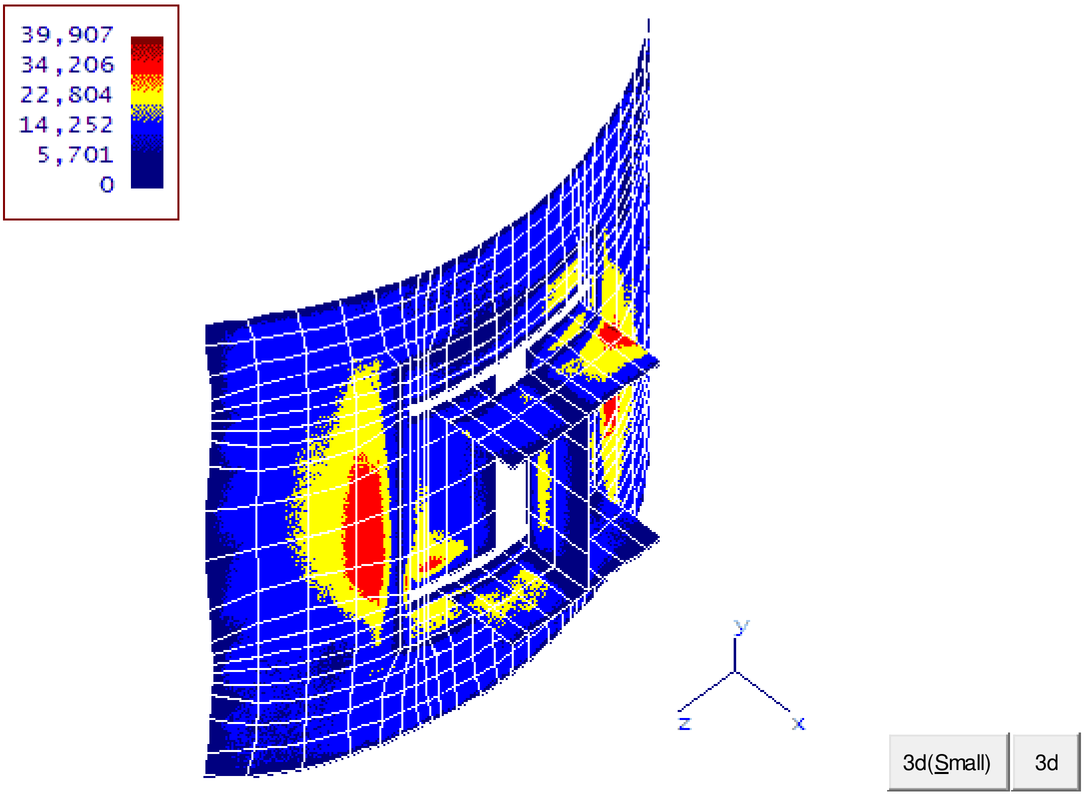

3d(Small) 3d

11) Pl+Pb+Q < SPS (EXP Outside) Case 5

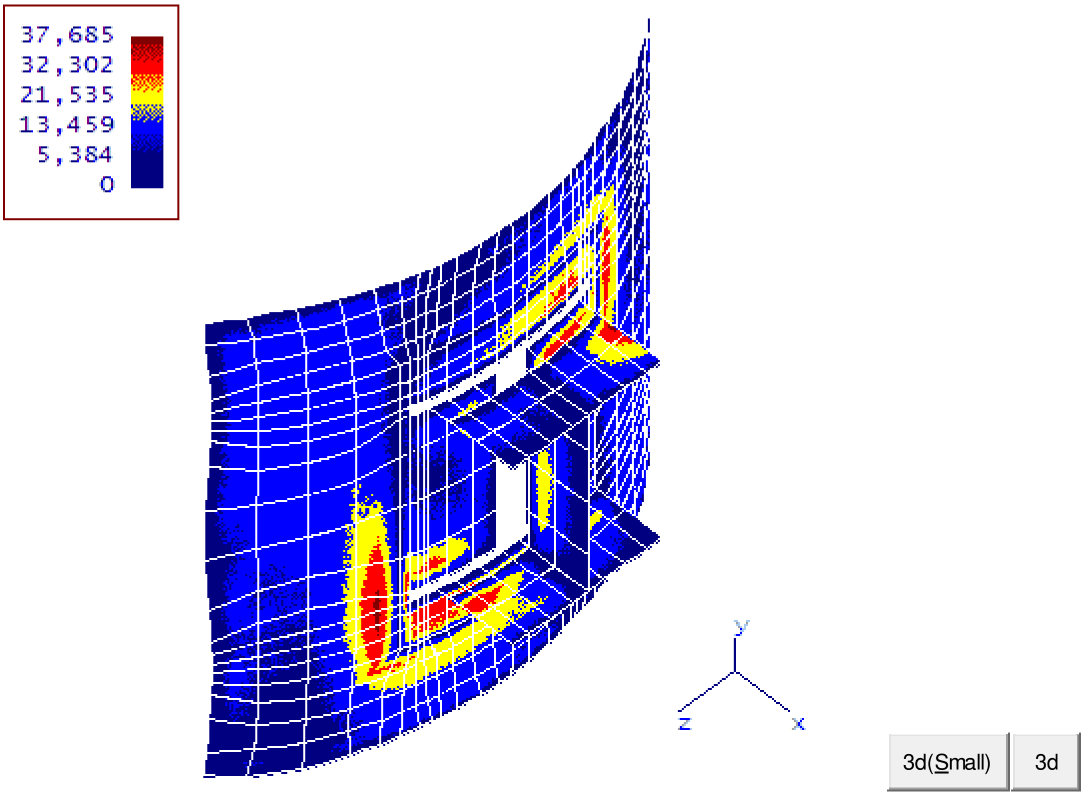



3d(Small) 3d

12) Pl+Pb+Q+F < 2Sa (EXP Inside) Case 5




13) Pl+Pb+Q+F < 2Sa (EXP Outside) Case 5



**Tabular Results**

Results were generated with the finite element program FE/Pipe®. Stress results are post-processed in accordance with the rules specified in ASME Section III and ASME Section VIII, Division 2.

Analysis Time Stamp: Tue Nov 29 17:36:28 2022.



---

```
Model Notes
Model Notes

  Input Echo:

  Description:

          Ladder Cleat

  Model Type                   : Cylindrical Shell

  Parent Geometry
         Parent Outside Diam.  :      30.037 in.
         Thickness             :       0.394 in.

  Parent Properties:
         Cold Allowable        :     16700.0 psi
         Hot  Allowable        :     14800.0 psi
         Material DB # 1071122.
         Ultimate Tensile (Amb) :     70000.0 psi
         Yield Strength (Amb)  :     25000.0 psi
         Yield Strength (Hot)  :     16400.0 psi
         Elastic Modulus (Amb)  :  28300000.0 psi
         Poissons Ratio        :       0.300
         Expansion Coefficient  :  0.9700E-05 in./in./deg.
         Weight Density        :  0.0000E+00 lb./cu.in.(NOT USED)

  Structural Attachment Type    :  Longitudinal Lug

         Thickness             :       0.394 in.
         Height                :       6.000 in.
         Length                :      12.283 in.

         Rectangular Pad Width  :       2.441 in.
         Rectangular Pad Height :       7.992 in.
         Rectangular Pad Thick  :       0.394 in.
         Nozzle Tilt Angle     :       0.000 deg.
         Distance from Top     :      47.244 in.
         Distance from Bottom  :      51.181 in.

  Nozzle Properties
         Cold Allowable        :     20000.0 psi
         Hot  Allowable        :     20000.0 psi
         Material DB # 1016422.
         Ultimate Tensile (Amb) :     70000.0 psi
         Yield Strength (Amb)  :     38000.0 psi
         Yield Strength (Hot)  :     31000.0 psi
         Elastic Modulus (Amb)  :  29400000.0 psi
         Poissons Ratio        :       0.300
         Expansion Coefficient  :  0.7300E-05 in./in./deg.
         Weight Density        :  0.0000E+00 lb./cu.in. (NOT USED)
```

```
Design Operating Cycles       :       7000.
Ambient Temperature (Deg.)    :       69.98

Thermal Stresses will be introduced into this analysis due to the
differences in temperature and/or thermal expansion coefficients.
The following temperatures have been specified for the analysis:

Nozzle Inside  Temperature    :      500.00 deg.
Nozzle Outside Temperature    :      500.00 deg.
Vessel Inside  Temperature    :      500.00 deg.
Vessel Outside Temperature    :      500.00 deg.
Nozzle Pressure               :       105.0 psi
Vessel Pressure               :       105.0 psi

Operating Pressure            :        10.0 psi

The operating pressure is used for secondary and peak stress
cases. The design pressure is used for primary cases. The ratio
of the operating/design pressure = 0.095

User Defined Load Input Echo for the ATTACHMENT:
Loads are given at the End of Nozzle
Loads are defined in Global Coordinates

Forces( lb.)  Moments (ft-lb)

Load Case        FX          FY          FZ          MX          MY          MZ
---------------------------------------------------------------------------
   OPER:      300.0      -760.0       210.0       316.0        87.5        52.5


FEA Model Loads:
These are the actual Attachment loads applied to
the FEA model.
These are the User Defined Loads translated to the
end of the nozzle and reported in global coordinates.

Forces( lb.)  Moments (ft-lb)

Load Case        FX          FY          FZ          MX          MY          MZ
---------------------------------------------------------------------------
   OPER:      300.0      -760.0       210.0       316.0        87.5        52.5

The "top" or "positive" end of this model is "free" in
the axial and translational directions.

Stresses ARE nodally AVERAGED.

No weld dimensions have been given for the nozzle
connection to the shell. This will produce conservative
results for external loads and may tend to produce more
realistic inside surface pressure stresses.

Vessel Centerline  Vector     :  0.000   1.000   0.000
Nozzle Orientation Vector     :  1.000   0.000   0.000
```

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---

```
Load Case Report
FEPipe Version 15.0          Jobname: NOZZLE                 $P
Released Jan. 2021            5:35pm   NOV 29,2022



Load Case Report                                      $X

Inner and outer element temperatures are the same
throughout the model.  No thermal ratcheting
calculations will be performed.

THE   5  LOAD CASES ANALYZED ARE:

  1   WEIGHT ONLY    (Wgt Only)

      Weight ONLY case run to get the stress range
      between the installed and the operating states.
```

```
     /-------- Loads in Case   1
       Loads due to Weight

 2   SUSTAINED      (Wgt+Pr)

     Sustained case run to satisfy local primary
     membrane and bending stress limits.

     /-------- Loads in Case   2
       Loads due to Weight
       Pressure Case    1

 3   Thermal ONLY

     Thermal ONLY case run in the event expansion
     stresses exceed the secondary stress allowable.

     /-------- Loads in Case   3
       Temperature Case    1
       Loads from (Thermal Only)

 4   OPERATING

     Case run to compute the operating stresses used in
     secondary, peak and range calculations as needed.

     /-------- Loads in Case   4
       Pressure Case    1
       Temperature Case    1
       Loads from (Operating)

 5   RANGE          (Fatigue Calc Performed)

     Case run to get the RANGE of stresses.
     as described in NB-3222.2, 5.5.3.2, 5.5.5.2 or 5.5.6.1.

     /-------- Combinations in Range Case   5
       Plus  Stress Results from CASE   4
       Minus Stress Results from CASE   1
```

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---

```
Solution Data
FEPipe Version 15.0          Jobname: NOZZLE              $P
Released Jan. 2021            5:35pm   NOV 29,2022
```

Solution Data

```
Maximum Solution Row Size =    1500
Number of Nodes           =    4939
Number of Elements        =    1660
Number of Solution Cases  =       4
```

Summation of Loads per Case

| Case # | FX | FY | FZ |
|---|---|---|---|
| 1 | 0. | 0. | 0. |
| 2 | 0. | 72464. | 0. |
| 3 | 0. | 0. | 0. |
| 4 | 300. | 71704. | 210. |

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---

```
ASME Code Stress Output Plots
FEPipe Version 15.0          Jobname: NOZZLE              $P
Released Jan. 2021            5:36pm   NOV 29,2022
```

ASME Code Stress Output Plots $X

1) Pl < SPL (SUS,Membrane) Case 2

2) Qb < SPS (SUS,Bending) Case 2

3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2

6) Pl+Pb+Q < SPS (OPE,Inside) Case 4

7) Pl+Pb+Q < SPS (OPE,Outside) Case 4

8) Membrane < User (OPE,Membrane) Case 4

9) Bending < User (OPE,Bending) Case 4

10) Pl+Pb+Q < SPS (EXP,Inside) Case 5

11) Pl+Pb+Q < SPS (EXP,Outside) Case 5

12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 5

13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5

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---

Stress Results - Notes
FEPipe Version 15.0 Jobname: NOZZLE $P
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Stress Results - Notes

- Results in this analysis were generated using the finite element solution method.

- Using 2019 ASME Section VIII Division 2

- Use Polished Bar fatigue curve.

- Ratio between Operating and Design Pressure = 9.5238097E-02
  Range cases use operating pressure. Primary cases use design pressure.

- Assume free end displacements of attached pipe (e.g. thermal loads) are secondary loads.

- Primary bending stresses at discontinuities are treated like secondary stresses. (Pb=0)

- Use Equivalent Stress (Von Mises).

- TRIAXIAL Stress Guidelines:
  S1+S2+S3 evaluation omitted from operating stress.
  Include S1+S2+S3 evaluation in primary case evaluation.
  Bending stress NOT included for all S1+S2+S3 calculations.

- Use local tensor values for averaged and not averaged stresses.

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---

ASME Overstressed Areas
FEPipe Version 15.0 Jobname: NOZZLE $P
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```
ASME Overstressed Areas                                $X


             *** NO OVERSTRESSED NODES IN THIS MODEL ***
```

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```
Highest Primary Stress Ratios
FEPipe Version 15.0           Jobname: NOZZLE                  $P
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Highest Primary Stress Ratios                          $X


Shell SCR at Plate # 1

       Pl             SPL     Primary Membrane Load Case 2
    3,497          22,200     Min Prin. Stress = -3. ( 0% Neg, 0% NegHi)
      psi             psi     Plot Reference:
                              1) Pl < SPL (SUS,Membrane) Case 2
            15%


Long Plate SCR for Plate # 1

       Pl             SPL     Primary Membrane Load Case 2
      383          31,000     Min Prin. Stress = -408. (18% Neg, 0% NegHi)
      psi             psi     Plot Reference:
                              1) Pl < SPL (SUS,Membrane) Case 2
             1%


Pad SCR for Plate # 1

       Pl             SPL     Primary Membrane Load Case 2
    2,143          31,000     Min Prin. Stress = -6. ( 0% Neg, 0% NegHi)
      psi             psi     Plot Reference:
                              1) Pl < SPL (SUS,Membrane) Case 2
             6%


Shell in Plate # 1 Vicinity

       Pl             SPL     Primary Membrane Load Case 2
    3,479          22,200     Min Prin. Stress = -2. ( 0% Neg, 0% NegHi)
      psi             psi     Plot Reference:
                              1) Pl < SPL (SUS,Membrane) Case 2
            15%


Long Plate for Plate # 1

       Pl             SPL     Primary Membrane Load Case 2
      212          31,000     Min Prin. Stress = -211. ( 1% Neg, 0% NegHi)
      psi             psi     Plot Reference:
                              1) Pl < SPL (SUS,Membrane) Case 2
             0%
```

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```
Highest Secondary Stress Ratios
FEPipe Version 15.0           Jobname: NOZZLE                  $P
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```

```
Highest Secondary Stress Ratios                        $X

In combination case  5 the max range stress divided
by the max component stress is 1.00. The case tensor components
are NEVER additive and so the combination case will have
LOWER stresses than the largest of any of the individual
cases by between 1 and 20%.

Load      Combined/Max       Combined/Max
Case        (Inside)           (Outside)
------    -------------      -------------
   5         1.000              1.000


Shell SCR at Plate # 1

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 4
    8,938        47,250     Min Prin. Stress = -2506. (88% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            7) Pl+Pb+Q < SPS (OPE,Outside) Case 4
           18%

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 5
    8,938        47,250     Min Prin. Stress = -2506. (88% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            11) Pl+Pb+Q < SPS (EXP,Outside) Case 5
           18%


Long Plate SCR for Plate # 1

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 4
   33,333        69,000     Min Prin. Stress = -23236. (99% Neg, 31% NegHi)
      psi           psi     Plot Reference:
                            7) Pl+Pb+Q < SPS (OPE,Outside) Case 4
           48%

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 5
   33,333        69,000     Min Prin. Stress = -23236. (99% Neg, 31% NegHi)
      psi           psi     Plot Reference:
                            11) Pl+Pb+Q < SPS (EXP,Outside) Case 5
           48%


Pad SCR for Plate # 1

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 4
    9,656        69,000     Min Prin. Stress = -5815. (98% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            7) Pl+Pb+Q < SPS (OPE,Outside) Case 4
           13%

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 5
    9,656        69,000     Min Prin. Stress = -5815. (98% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            11) Pl+Pb+Q < SPS (EXP,Outside) Case 5
           13%


Shell in Plate # 1 Vicinity

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 4
   10,517        47,250     Min Prin. Stress = -4060. (82% Neg, 15% NegHi)
      psi           psi     Plot Reference:
                            7) Pl+Pb+Q < SPS (OPE,Outside) Case 4
           22%

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 5
   10,517        47,250     Min Prin. Stress = -4060. (82% Neg, 15% NegHi)
      psi           psi     Plot Reference:
                            11) Pl+Pb+Q < SPS (EXP,Outside) Case 5
           22%


Long Plate for Plate # 1

  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 4
   26,790        69,000     Min Prin. Stress = -16496. (99% Neg, 33% NegHi)
      psi           psi     Plot Reference:
                            6) Pl+Pb+Q < SPS (OPE,Inside) Case 4
           38%
```

```
  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 5
   26,790        69,000     Min Prin. Stress = -16496. (99% Neg, 33% NegHi)
      psi           psi     Plot Reference:
                            10) Pl+Pb+Q < SPS (EXP,Inside) Case 5
           38%
```

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```
Highest Fatigue Stress Ratios
FEPipe Version 15.0           Jobname: NOZZLE              $P
Released Jan. 2021             5:36pm   NOV 29,2022
```

```
Highest Fatigue Stress Ratios                          $X


Shell SCR at Plate # 1

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 5
   12,067     0.000 Life     Stress Concentration Factor = 1.350
      psi     0.102 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 78750.0
  118,449                    Markl Fatigue Stress Allowable = 95657.0
      psi                    WRC 474 Mean Cycles to Failure = 26,145,738.
                             WRC 474 99% Probability Cycles = 6,074,002.
      10%                    WRC 474 95% Probability Cycles = 8,433,107.
                             BS5500 Allowed Cycles(Curve F) = 3,319,496.
                             Membrane-to-Bending Ratio = 0.436
                             Bending-to-PL+PB+Q Ratio = 0.696
                             Plot Reference:
                             13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5


Long Plate SCR for Plate # 1

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 5
   45,000     0.139 Life     Stress Concentration Factor = 1.350
      psi     0.536 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 50,444.
Allowable                    "B31" Fatigue Stress Allowable = 100000.0
   83,994                    Markl Fatigue Stress Allowable = 83402.0
      psi                    WRC 474 Mean Cycles to Failure = 507,219.
                             WRC 474 99% Probability Cycles = 117,834.
      53%                    WRC 474 95% Probability Cycles = 163,600.
                             BS5500 Allowed Cycles(Curve F) = 57,082.
                             Membrane-to-Bending Ratio = 0.459
                             Bending-to-PL+PB+Q Ratio = 0.685
                             Plot Reference:
                             13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5


Pad SCR for Plate # 1

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 5
   13,036     0.000 Life     Stress Concentration Factor = 1.350
      psi     0.155 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 100000.0
   83,994                    Markl Fatigue Stress Allowable = 83402.0
      psi                    WRC 474 Mean Cycles to Failure = 14,452,905.
                             WRC 474 99% Probability Cycles = 3,357,602.
      15%                    WRC 474 95% Probability Cycles = 4,661,674.
                             BS5500 Allowed Cycles(Curve F) = 2,348,264.
                             Membrane-to-Bending Ratio = 0.501
                             Bending-to-PL+PB+Q Ratio = 0.666
                             Plot Reference:
                             13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5


Shell in Plate # 1 Vicinity

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 5
   10,517     0.000 Life     Stress Concentration Factor = 1.000
      psi     0.089 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
```

```
Allowable                    "B31" Fatigue Stress Allowable = 78750.0
  118,449                    Markl Fatigue Stress Allowable = 95657.0
      psi                    WRC 474 Mean Cycles to Failure = 15,136,993.
                             WRC 474 99% Probability Cycles = 3,516,524.
       8%                    WRC 474 95% Probability Cycles = 4,882,321.
                             BS5500 Allowed Cycles(Curve F) = 2,037,817.
                             Membrane-to-Bending Ratio = 0.908
                             Bending-to-PL+PB+Q Ratio = 0.524
                             Plot Reference:
                             13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5


Long Plate for Plate # 1

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 5
   26,790     0.015 Life     Stress Concentration Factor = 1.000
      psi     0.319 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 472,458.
Allowable                    "B31" Fatigue Stress Allowable = 100000.0
   83,994                    Markl Fatigue Stress Allowable = 83402.0
      psi                    WRC 474 Mean Cycles to Failure = 1,027,272.
                             WRC 474 99% Probability Cycles = 238,649.
      31%                    WRC 474 95% Probability Cycles = 331,339.
                             BS5500 Allowed Cycles(Curve F) = 109,950.
                             Membrane-to-Bending Ratio = 0.161
                             Bending-to-PL+PB+Q Ratio = 0.862
                             Plot Reference:
                             12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 5
```

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---

```
Highest Stress Ratios Per Region
FEPipe Version 15.0           Jobname: NOZZLE                $P
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Highest Stress Ratios Per Region                       $X


Shell SCR at Plate # 1

       Pl            SPL     Primary Membrane Load Case 2
    3,497         22,200     Min Prin. Stress = -3. ( 0% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
            15%

       Qb            SPS     Primary Bending Load Case 2
      163         47,250     Min Prin. Stress = -3. ( 0% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             2) Qb < SPS (SUS,Bending) Case 2
             0%

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 2
    3,626         47,250     Min Prin. Stress = -3. ( 0% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
             7%

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 2
    3,387         47,250     Min Prin. Stress = -3. ( 0% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
             7%

 S1+S2+S3             4S     Part 5 (5.3.2) Load Case 2
    5,926         59,200     Min Prin. Stress = -3. ( 0% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
            10%

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 4
    4,084         47,250     Min Prin. Stress = -2506. (88% Neg, 0% NegHi)
      psi            psi     Plot Reference:
                             6) Pl+Pb+Q < SPS (OPE,Inside) Case 4
             8%
```

```
  Pl+Pb+Q           SPS      Primary+Secondary (Outer) Load Case 4
    8,938        47,250      Min Prin. Stress = -2506. (88% Neg, 0% NegHi)
      psi           psi      Plot Reference:
                             7) Pl+Pb+Q < SPS (OPE,Outside) Case 4
           18%

 Membrane          User      Component Evaluation Load Case 4
    2,873        47,250      Min Prin. Stress = -2506. (88% Neg, 0% NegHi)
      psi           psi      Plot Reference:
                             8) Membrane < User (OPE,Membrane) Case 4
            6%

  Bending          User      Component Evaluation Load Case 4
    6,341        47,250      Min Prin. Stress = -2506. (88% Neg, 0% NegHi)
      psi           psi      Plot Reference:
                             9) Bending < User (OPE,Bending) Case 4
           13%

  Pl+Pb+Q           SPS      Primary+Secondary (Inner) Load Case 5
    4,084        47,250      Min Prin. Stress = -2506. (88% Neg, 0% NegHi)
      psi           psi      Plot Reference:
                             10) Pl+Pb+Q < SPS (EXP,Inside) Case 5
            8%

  Pl+Pb+Q           SPS      Primary+Secondary (Outer) Load Case 5
    8,938        47,250      Min Prin. Stress = -2506. (88% Neg, 0% NegHi)
      psi           psi      Plot Reference:
                             11) Pl+Pb+Q < SPS (EXP,Outside) Case 5
           18%

Pl+Pb+Q+F   Damage Ratio     Primary+Secondary+Peak (Inner) Load Case 5
    5,513     0.000 Life     Stress Concentration Factor = 1.350
      psi     0.047 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 78750.0
  118,449                    Markl Fatigue Stress Allowable = 95657.0
      psi                    WRC 474 Mean Cycles to Failure = 2.9410E8
                             WRC 474 99% Probability Cycles = 68,322,360.
       4%                    WRC 474 95% Probability Cycles = 94,858,344.
                             BS5500 Allowed Cycles(Curve F) = 81,105,912.
                             Membrane-to-Bending Ratio = 0.659
                             Bending-to-PL+PB+Q Ratio = 0.603
                             Plot Reference:
                             12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 5

Pl+Pb+Q+F   Damage Ratio     Primary+Secondary+Peak (Outer) Load Case 5
   12,067     0.000 Life     Stress Concentration Factor = 1.350
      psi     0.102 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 78750.0
  118,449                    Markl Fatigue Stress Allowable = 95657.0
      psi                    WRC 474 Mean Cycles to Failure = 26,145,738.
                             WRC 474 99% Probability Cycles = 6,074,002.
      10%                    WRC 474 95% Probability Cycles = 8,433,107.
                             BS5500 Allowed Cycles(Curve F) = 3,319,496.
                             Membrane-to-Bending Ratio = 0.436
                             Bending-to-PL+PB+Q Ratio = 0.696
                             Plot Reference:
                             13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5


Long Plate SCR for Plate # 1

       Pl           SPL      Primary Membrane Load Case 2
      383        31,000      Min Prin. Stress = -408. (18% Neg, 0% NegHi)
      psi           psi      Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
            1%

       Qb           SPS      Primary Bending Load Case 2
        0        69,000      Min Prin. Stress = -408. (18% Neg, 0% NegHi)
      psi           psi      Plot Reference:
                             2) Qb < SPS (SUS,Bending) Case 2
            0%

  Pl+Pb+Q           SPS      Primary+Secondary (Inner) Load Case 2
      383        69,000      Min Prin. Stress = -408. (18% Neg, 0% NegHi)
      psi           psi      Plot Reference:
                             3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
            0%
```

```
  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 2
      383        69,000     Min Prin. Stress = -408. (18% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
             0%

 S1+S2+S3            4S     Part 5 (5.3.2) Load Case 2
     -476        80,000     Min Prin. Stress = -408. (18% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
             0%

  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 4
   28,072        69,000     Min Prin. Stress = -23236. (99% Neg, 31% NegHi)
      psi           psi     Plot Reference:
                            6) Pl+Pb+Q < SPS (OPE,Inside) Case 4
            40%

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 4
   33,333        69,000     Min Prin. Stress = -23236. (99% Neg, 31% NegHi)
      psi           psi     Plot Reference:
                            7) Pl+Pb+Q < SPS (OPE,Outside) Case 4
            48%

 Membrane          User     Component Evaluation Load Case 4
   16,836        69,000     Min Prin. Stress = -23236. (99% Neg, 31% NegHi)
      psi           psi     Plot Reference:
                            8) Membrane < User (OPE,Membrane) Case 4
            24%

  Bending          User     Component Evaluation Load Case 4
   27,695        69,000     Min Prin. Stress = -23236. (99% Neg, 31% NegHi)
      psi           psi     Plot Reference:
                            9) Bending < User (OPE,Bending) Case 4
            40%

  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 5
   28,072        69,000     Min Prin. Stress = -23236. (99% Neg, 31% NegHi)
      psi           psi     Plot Reference:
                            10) Pl+Pb+Q < SPS (EXP,Inside) Case 5
            40%

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 5
   33,333        69,000     Min Prin. Stress = -23236. (99% Neg, 31% NegHi)
      psi           psi     Plot Reference:
                            11) Pl+Pb+Q < SPS (EXP,Outside) Case 5
            48%

Pl+Pb+Q+F  Damage Ratio     Primary+Secondary+Peak (Inner) Load Case 5
   37,898   0.062 Life      Stress Concentration Factor = 1.350
      psi   0.451 Stress    Strain Concentration Factor = 1.000
                            Cycles Allowed for this Stress = 112,947.
Allowable                   "B31" Fatigue Stress Allowable = 100000.0
   83,994                   Markl Fatigue Stress Allowable = 83402.0
      psi                   WRC 474 Mean Cycles to Failure = 773,681.
                            WRC 474 99% Probability Cycles = 179,737.
      45%                   WRC 474 95% Probability Cycles = 249,545.
                            BS5500 Allowed Cycles(Curve F) = 95,565.
                            Membrane-to-Bending Ratio = 1.164
                            Bending-to-PL+PB+Q Ratio = 0.462
                            Plot Reference:
                            12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 5

Pl+Pb+Q+F  Damage Ratio     Primary+Secondary+Peak (Outer) Load Case 5
   45,000   0.139 Life      Stress Concentration Factor = 1.350
      psi   0.536 Stress    Strain Concentration Factor = 1.000
                            Cycles Allowed for this Stress = 50,444.
Allowable                   "B31" Fatigue Stress Allowable = 100000.0
   83,994                   Markl Fatigue Stress Allowable = 83402.0
      psi                   WRC 474 Mean Cycles to Failure = 507,219.
                            WRC 474 99% Probability Cycles = 117,834.
      53%                   WRC 474 95% Probability Cycles = 163,600.
                            BS5500 Allowed Cycles(Curve F) = 57,082.
                            Membrane-to-Bending Ratio = 0.459
                            Bending-to-PL+PB+Q Ratio = 0.685
                            Plot Reference:
                            13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5


Pad SCR for Plate # 1

       Pl           SPL     Primary Membrane Load Case 2
```

```
    2,143        31,000     Min Prin. Stress = -6. ( 0% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            1) Pl < SPL (SUS,Membrane) Case 2
            6%

       Qb           SPS     Primary Bending Load Case 2
      220        69,000     Min Prin. Stress = -6. ( 0% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            2) Qb < SPS (SUS,Bending) Case 2
            0%

  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 2
    2,227        69,000     Min Prin. Stress = -6. ( 0% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
            3%

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 2
    2,077        69,000     Min Prin. Stress = -6. ( 0% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
            3%

 S1+S2+S3            4S     Part 5 (5.3.2) Load Case 2
    3,624        80,000     Min Prin. Stress = -6. ( 0% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
            4%

  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 4
    6,193        69,000     Min Prin. Stress = -5815. (98% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            6) Pl+Pb+Q < SPS (OPE,Inside) Case 4
            8%

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 4
    9,656        69,000     Min Prin. Stress = -5815. (98% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            7) Pl+Pb+Q < SPS (OPE,Outside) Case 4
           13%

 Membrane          User     Component Evaluation Load Case 4
    3,837        69,000     Min Prin. Stress = -5815. (98% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            8) Membrane < User (OPE,Membrane) Case 4
            5%

  Bending          User     Component Evaluation Load Case 4
    7,130        69,000     Min Prin. Stress = -5815. (98% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            9) Bending < User (OPE,Bending) Case 4
           10%

  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 5
    6,193        69,000     Min Prin. Stress = -5815. (98% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            10) Pl+Pb+Q < SPS (EXP,Inside) Case 5
            8%

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 5
    9,656        69,000     Min Prin. Stress = -5815. (98% Neg, 0% NegHi)
      psi           psi     Plot Reference:
                            11) Pl+Pb+Q < SPS (EXP,Outside) Case 5
           13%

Pl+Pb+Q+F   Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 5
    8,360    0.000 Life     Stress Concentration Factor = 1.350
      psi    0.100 Stress   Strain Concentration Factor = 1.000
                            Cycles Allowed for this Stress = 1.0000E11
Allowable                   "B31" Fatigue Stress Allowable = 100000.0
   83,994                   Markl Fatigue Stress Allowable = 83402.0
      psi                   WRC 474 Mean Cycles to Failure = 64,753,364.
                            WRC 474 99% Probability Cycles = 15,043,081.
       9%                   WRC 474 95% Probability Cycles = 20,885,722.
                            BS5500 Allowed Cycles(Curve F) = 8,902,927.
                            Membrane-to-Bending Ratio = 0.651
                            Bending-to-PL+PB+Q Ratio = 0.606
                            Plot Reference:
                            12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 5

Pl+Pb+Q+F   Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 5
   13,036    0.000 Life     Stress Concentration Factor = 1.350
```

```
      psi     0.155 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 100000.0
   83,994                    Markl Fatigue Stress Allowable = 83402.0
      psi                    WRC 474 Mean Cycles to Failure = 14,452,905.
                             WRC 474 99% Probability Cycles = 3,357,602.
      15%                    WRC 474 95% Probability Cycles = 4,661,674.
                             BS5500 Allowed Cycles(Curve F) = 2,348,264.
                             Membrane-to-Bending Ratio = 0.501
                             Bending-to-PL+PB+Q Ratio = 0.666
                             Plot Reference:
                             13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5


Shell in Plate # 1 Vicinity

       Pl           SPL      Primary Membrane Load Case 2
    3,479        22,200      Min Prin. Stress = -2. ( 0% Neg, 0% NegHi)
      psi           psi      Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
            15%

       Qb           SPS      Primary Bending Load Case 2
      133        47,250      Min Prin. Stress = -2. ( 0% Neg, 0% NegHi)
      psi           psi      Plot Reference:
                             2) Qb < SPS (SUS,Bending) Case 2
             0%

  Pl+Pb+Q           SPS      Primary+Secondary (Inner) Load Case 2
    3,550        47,250      Min Prin. Stress = -2. ( 0% Neg, 0% NegHi)
      psi           psi      Plot Reference:
                             3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
             7%

  Pl+Pb+Q           SPS      Primary+Secondary (Outer) Load Case 2
    3,505        47,250      Min Prin. Stress = -2. ( 0% Neg, 0% NegHi)
      psi           psi      Plot Reference:
                             4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
             7%

 S1+S2+S3            4S      Part 5 (5.3.2) Load Case 2
    5,947        59,200      Min Prin. Stress = -2. ( 0% Neg, 0% NegHi)
      psi           psi      Plot Reference:
                             5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
            10%

  Pl+Pb+Q           SPS      Primary+Secondary (Inner) Load Case 4
    6,712        47,250      Min Prin. Stress = -4060. (82% Neg, 15% NegHi)
      psi           psi      Plot Reference:
                             6) Pl+Pb+Q < SPS (OPE,Inside) Case 4
            14%

  Pl+Pb+Q           SPS      Primary+Secondary (Outer) Load Case 4
   10,517        47,250      Min Prin. Stress = -4060. (82% Neg, 15% NegHi)
      psi           psi      Plot Reference:
                             7) Pl+Pb+Q < SPS (OPE,Outside) Case 4
            22%

 Membrane          User      Component Evaluation Load Case 4
    5,750        47,250      Min Prin. Stress = -4060. (82% Neg, 15% NegHi)
      psi           psi      Plot Reference:
                             8) Membrane < User (OPE,Membrane) Case 4
            12%

  Bending          User      Component Evaluation Load Case 4
    6,141        47,250      Min Prin. Stress = -4060. (82% Neg, 15% NegHi)
      psi           psi      Plot Reference:
                             9) Bending < User (OPE,Bending) Case 4
            12%

  Pl+Pb+Q           SPS      Primary+Secondary (Inner) Load Case 5
    6,712        47,250      Min Prin. Stress = -4060. (82% Neg, 15% NegHi)
      psi           psi      Plot Reference:
                             10) Pl+Pb+Q < SPS (EXP,Inside) Case 5
            14%

  Pl+Pb+Q           SPS      Primary+Secondary (Outer) Load Case 5
   10,517        47,250      Min Prin. Stress = -4060. (82% Neg, 15% NegHi)
      psi           psi      Plot Reference:
                             11) Pl+Pb+Q < SPS (EXP,Outside) Case 5
            22%
```

```
Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 5
    6,712     0.000 Life     Stress Concentration Factor = 1.000
      psi     0.057 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 78750.0
  118,449                    Markl Fatigue Stress Allowable = 95657.0
      psi                    WRC 474 Mean Cycles to Failure = 60,238,392.
                             WRC 474 99% Probability Cycles = 13,994,192.
       5%                    WRC 474 95% Probability Cycles = 19,429,452.
                             BS5500 Allowed Cycles(Curve F) = 7,839,911.
                             Membrane-to-Bending Ratio = 1.408
                             Bending-to-PL+PB+Q Ratio = 0.415
                             Plot Reference:
                             12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 5

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 5
   10,517     0.000 Life     Stress Concentration Factor = 1.000
      psi     0.089 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 78750.0
  118,449                    Markl Fatigue Stress Allowable = 95657.0
      psi                    WRC 474 Mean Cycles to Failure = 15,136,993.
                             WRC 474 99% Probability Cycles = 3,516,524.
       8%                    WRC 474 95% Probability Cycles = 4,882,321.
                             BS5500 Allowed Cycles(Curve F) = 2,037,817.
                             Membrane-to-Bending Ratio = 0.908
                             Bending-to-PL+PB+Q Ratio = 0.524
                             Plot Reference:
                             13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5


Long Plate for Plate # 1

       Pl           SPL      Primary Membrane Load Case 2
      212        31,000      Min Prin. Stress = -211. ( 1% Neg, 0% NegHi)
      psi           psi      Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
             0%

       Qb           SPS      Primary Bending Load Case 2
        0        69,000      Min Prin. Stress = -211. ( 1% Neg, 0% NegHi)
      psi           psi      Plot Reference:
                             2) Qb < SPS (SUS,Bending) Case 2
             0%

  Pl+Pb+Q           SPS      Primary+Secondary (Inner) Load Case 2
      212        69,000      Min Prin. Stress = -211. ( 1% Neg, 0% NegHi)
      psi           psi      Plot Reference:
                             3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
             0%

  Pl+Pb+Q           SPS      Primary+Secondary (Outer) Load Case 2
      212        69,000      Min Prin. Stress = -211. ( 1% Neg, 0% NegHi)
      psi           psi      Plot Reference:
                             4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
             0%

 S1+S2+S3            4S      Part 5 (5.3.2) Load Case 2
     -210        80,000      Min Prin. Stress = -211. ( 1% Neg, 0% NegHi)
      psi           psi      Plot Reference:
                             5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
             0%

  Pl+Pb+Q           SPS      Primary+Secondary (Inner) Load Case 4
   26,790        69,000      Min Prin. Stress = -16496. (99% Neg, 33% NegHi)
      psi           psi      Plot Reference:
                             6) Pl+Pb+Q < SPS (OPE,Inside) Case 4
            38%

  Pl+Pb+Q           SPS      Primary+Secondary (Outer) Load Case 4
   26,751        69,000      Min Prin. Stress = -16496. (99% Neg, 33% NegHi)
      psi           psi      Plot Reference:
                             7) Pl+Pb+Q < SPS (OPE,Outside) Case 4
            38%

 Membrane          User      Component Evaluation Load Case 4
   11,204        69,000      Min Prin. Stress = -16496. (99% Neg, 33% NegHi)
      psi           psi      Plot Reference:
                             8) Membrane < User (OPE,Membrane) Case 4
            16%

  Bending          User      Component Evaluation Load Case 4
```

```
   25,600          69,000     Min Prin. Stress = -16496. (99% Neg, 33% NegHi)
      psi             psi     Plot Reference:
                              9) Bending < User (OPE,Bending) Case 4
            37%

  Pl+Pb+Q             SPS     Primary+Secondary (Inner) Load Case 5
   26,790          69,000     Min Prin. Stress = -16496. (99% Neg, 33% NegHi)
      psi             psi     Plot Reference:
                              10) Pl+Pb+Q < SPS (EXP,Inside) Case 5
            38%

  Pl+Pb+Q             SPS     Primary+Secondary (Outer) Load Case 5
   26,751          69,000     Min Prin. Stress = -16496. (99% Neg, 33% NegHi)
      psi             psi     Plot Reference:
                              11) Pl+Pb+Q < SPS (EXP,Outside) Case 5
            38%

Pl+Pb+Q+F    Damage Ratio     Primary+Secondary+Peak (Inner) Load Case 5
   26,790     0.015 Life      Stress Concentration Factor = 1.000
      psi     0.319 Stress    Strain Concentration Factor = 1.000
                              Cycles Allowed for this Stress = 472,458.
Allowable                     "B31" Fatigue Stress Allowable = 100000.0
   83,994                     Markl Fatigue Stress Allowable = 83402.0
      psi                     WRC 474 Mean Cycles to Failure = 1,027,272.
                              WRC 474 99% Probability Cycles = 238,649.
      31%                     WRC 474 95% Probability Cycles = 331,339.
                              BS5500 Allowed Cycles(Curve F) = 109,950.
                              Membrane-to-Bending Ratio = 0.161
                              Bending-to-PL+PB+Q Ratio = 0.862
                              Plot Reference:
                              12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 5

Pl+Pb+Q+F    Damage Ratio     Primary+Secondary+Peak (Outer) Load Case 5
   26,751     0.015 Life      Stress Concentration Factor = 1.000
      psi     0.318 Stress    Strain Concentration Factor = 1.000
                              Cycles Allowed for this Stress = 475,610.
Allowable                     "B31" Fatigue Stress Allowable = 100000.0
   83,994                     Markl Fatigue Stress Allowable = 83402.0
      psi                     WRC 474 Mean Cycles to Failure = 1,015,441.
                              WRC 474 99% Probability Cycles = 235,901.
      31%                     WRC 474 95% Probability Cycles = 327,523.
                              BS5500 Allowed Cycles(Curve F) = 110,432.
                              Membrane-to-Bending Ratio = 0.192
                              Bending-to-PL+PB+Q Ratio = 0.839
                              Plot Reference:
                              13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 5
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```
Compressive Stress Summary
FEPipe Version 15.0          Jobname: NOZZLE                $P
Released Jan. 2021            5:36pm   NOV 29,2022
```

```
Compressive Stress Summary (psi)                        $X

Nomenclature:
-------------
Min Stress        - Compressive Membrane and Bending Stress
Pts in Region     - No. of nodes in the model region
>5% Compression   - 5% or more of Compressive Stress Limit
>50% Compression  - 50% or more of Compressive Stress Limit

Compressive Stress Limit = -0.55 Min(Sy, kEt/R), Section
slenderness ratio (elastic buckling) not considered.
```

| # | Load Type | Case | Min Stress | Pts in Region | >5% Compression and Bending | >50% Compression and Bending | Region |
|---|---|---|---|---|---|---|---|
| 1 | SUSTAINED | 2 | -2. | 1108 | 0% | 0% | Shell in Plate # 1 Vicinity |
| 2 | OPERATING | 4 | -4060. | 1108 | 82% | 15% | Shell in Plate # 1 Vicinity |
| 3 | EXPANSION | 5 | -4060. | 1108 | 82% | 15% | Shell in Plate # 1 Vicinity |
| 4 | SUSTAINED | 2 | -3. | 348 | 0% | 0% | Shell SCR at Plate # 1 |
| 5 | OPERATING | 4 | -2506. | 348 | 88% | 0% | Shell SCR at Plate # 1 |
| 6 | EXPANSION | 5 | -2506. | 348 | 88% | 0% | Shell SCR at Plate # 1 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 7 | SUSTAINED | 2 | -6. | 424 | 0% | 0% | Pad SCR for Plate # 1 |
| 8 | OPERATING | 4 | -5815. | 424 | 98% | 0% | Pad SCR for Plate # 1 |
| 9 | EXPANSION | 5 | -5815. | 424 | 98% | 0% | Pad SCR for Plate # 1 |
| 10 | SUSTAINED | 2 | -408. | 32 | 18% | 0% | Long Plate SCR for Plate # 1 |
| 11 | OPERATING | 4 | -23236. | 32 | 99% | 31% | Long Plate SCR for Plate # 1 |
| 12 | EXPANSION | 5 | -23236. | 32 | 99% | 31% | Long Plate SCR for Plate # 1 |
| 13 | SUSTAINED | 2 | -211. | 104 | 1% | 0% | Long Plate for Plate # 1 |
| 14 | OPERATING | 4 | -16496. | 104 | 99% | 33% | Long Plate for Plate # 1 |
| 15 | EXPANSION | 5 | -16496. | 104 | 99% | 33% | Long Plate for Plate # 1 |

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*Finite Element Model*

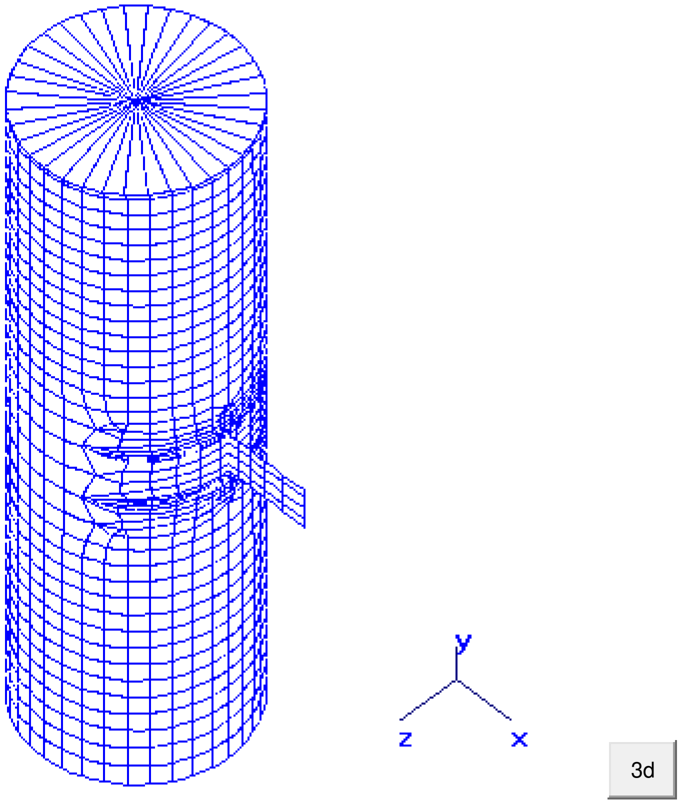
- Finite Element Model

*Area of Discontinuity at Plate*

- 1) Pl < SPL (SUS Membrane) Case 2
- 2) Qb < SPS (SUS Bending) Case 2
- 3) Pl+Pb+Q < SPS (SUS Inside) Case 2
- 4) Pl+Pb+Q < SPS (SUS Outside) Case 2
- 5) S1+S2+S3 < 4S (SUS S1+S2+S3) Case 2
- 6) Pl+Pb+Q < SPS (OPE Inside) Case 4
- 7) Pl+Pb+Q < SPS (OPE Outside) Case 4
- 8) Membrane < User (OPE Membrane) Case 4
- 9) Bending < User (OPE Bending) Case 4
- 10) Pl+Pb+Q < SPS (EXP Inside) Case 5
- 11) Pl+Pb+Q < SPS (EXP Outside) Case 5
- 12) Pl+Pb+Q+F < 2Sa (EXP Inside) Case 5
- 13) Pl+Pb+Q+F < 2Sa (EXP Outside) Case 5

---

**Finite Element Model**

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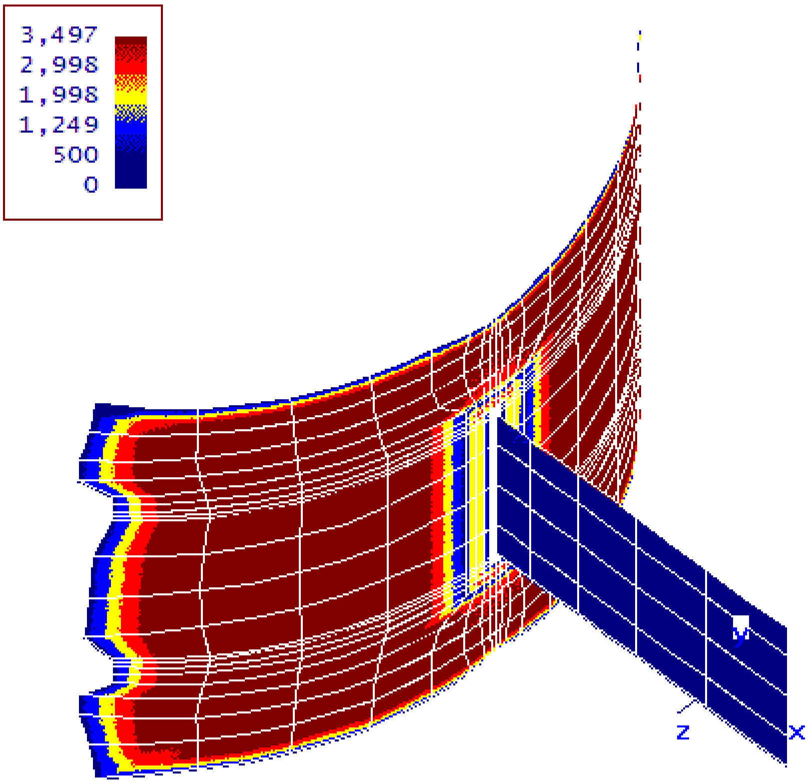
1) Pl < SPL (SUS Membrane) Case 2




3d(Small) 3d

- 3d(Deformed)

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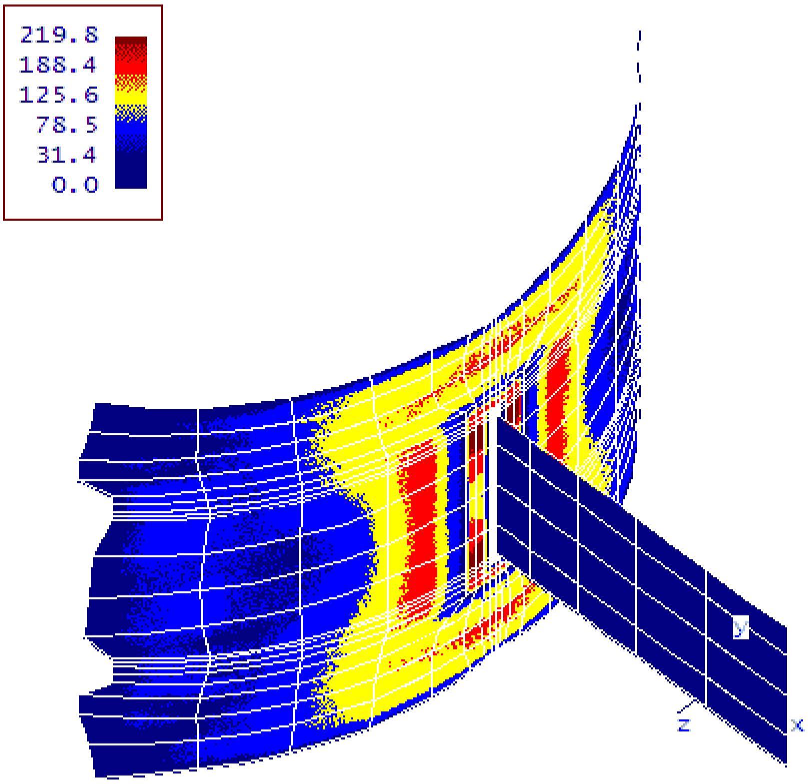
2) Qb < SPS (SUS Bending) Case 2




3d(Small) 3d

- 3d(Deformed)

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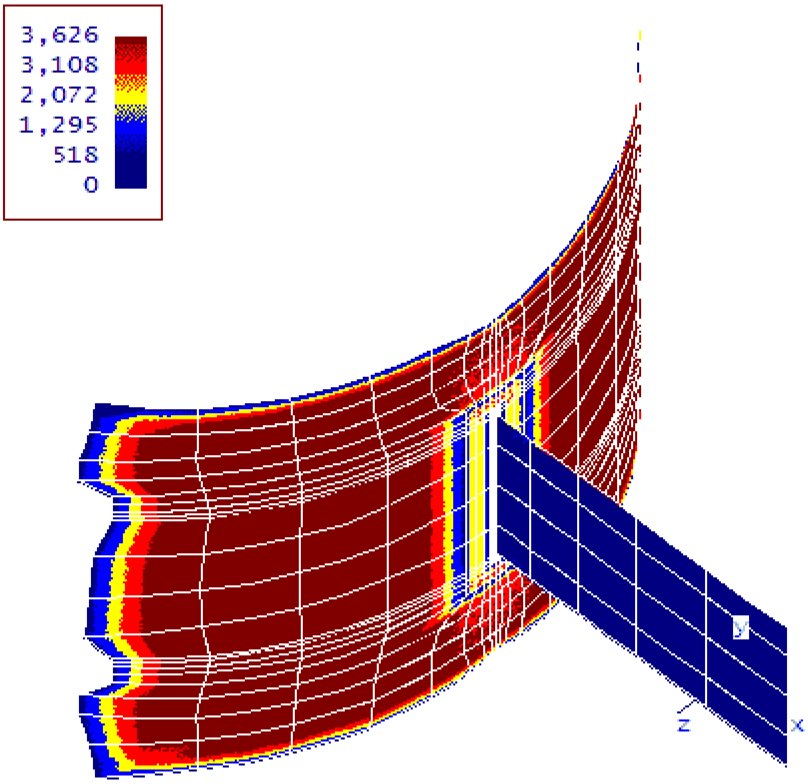
3) Pl+Pb+Q < SPS (SUS Inside) Case 2




- 3d(Small) 3d
- 3d(Deformed)

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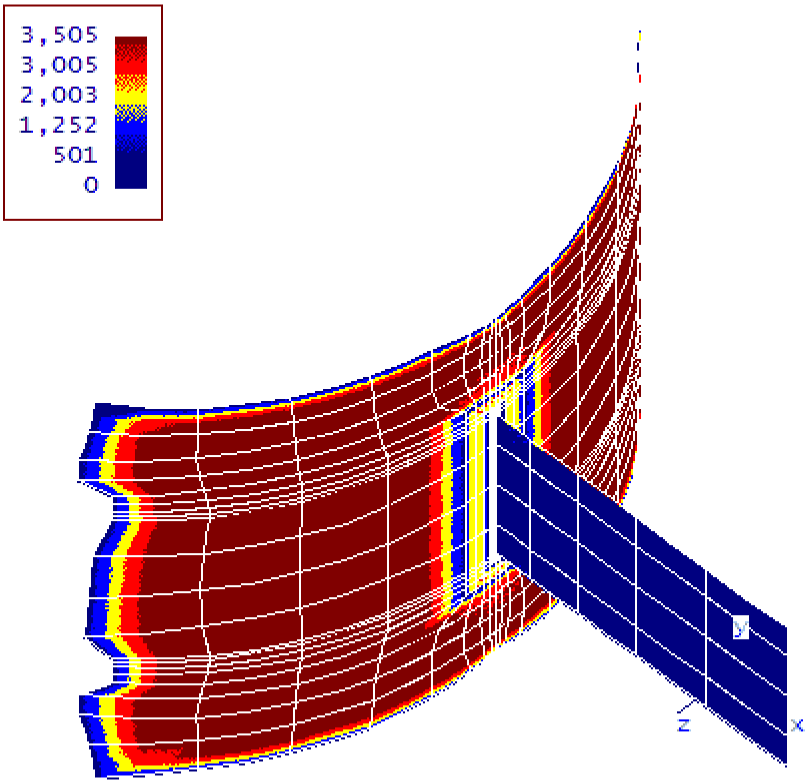
4) Pl+Pb+Q < SPS (SUS Outside) Case 2




- 3d(Small) 3d
- 3d(Deformed)

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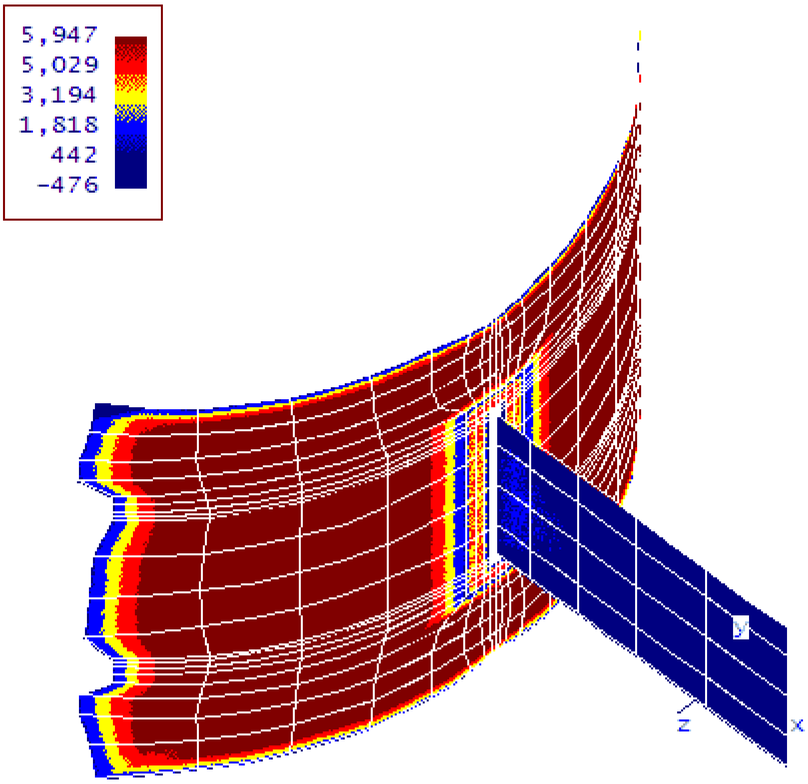
5) S1+S2+S3 < 4S (SUS S1+S2+S3) Case 2




3d(Small) 3d

- 3d(Deformed)

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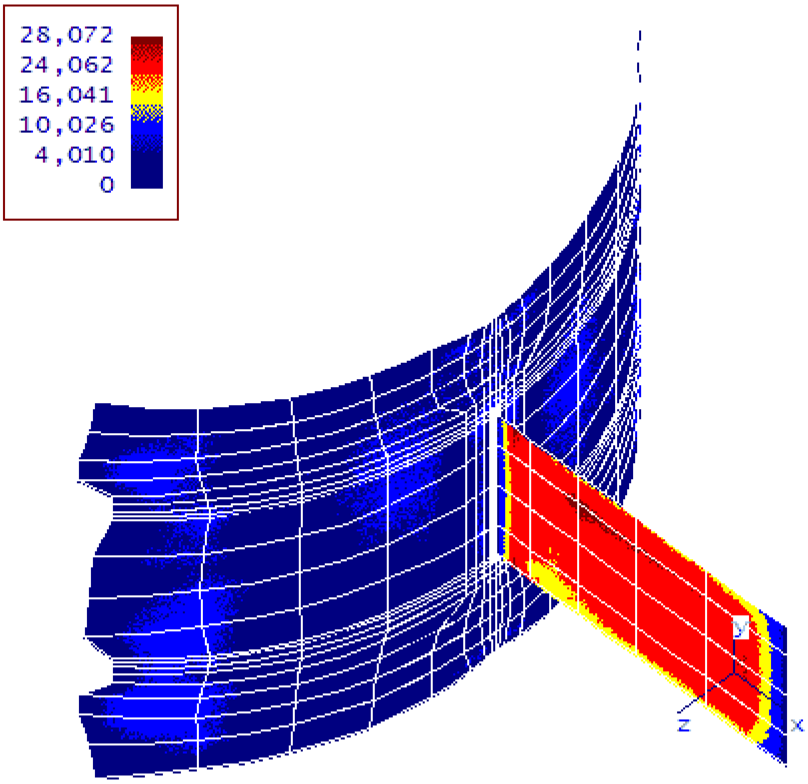
6) Pl+Pb+Q < SPS (OPE Inside) Case 4




3d(Small) 3d

- 3d(Deformed)

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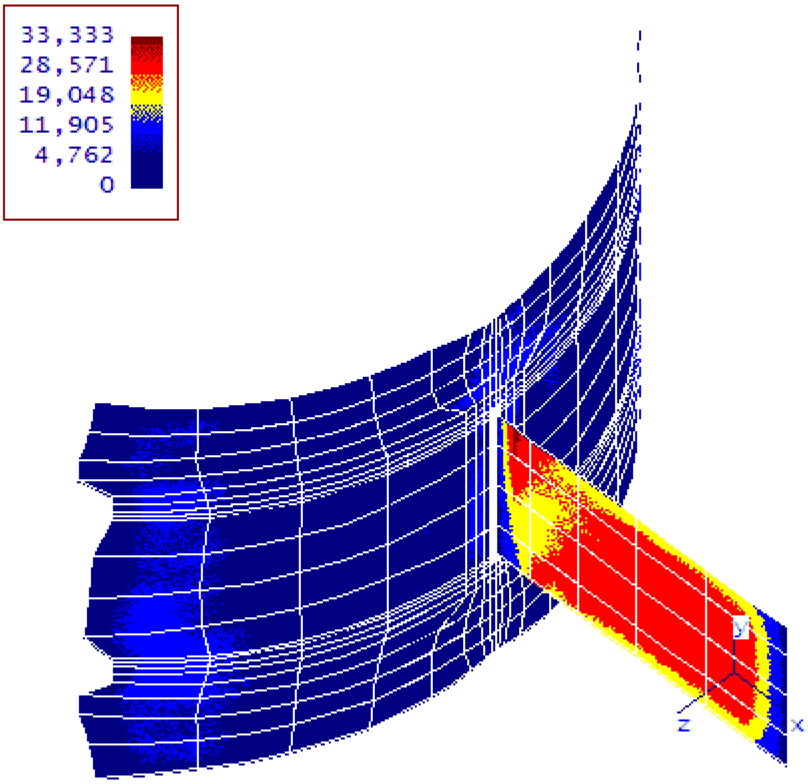
7) Pl+Pb+Q < SPS (OPE Outside) Case 4




3d(Small) 3d

- 3d(Deformed)

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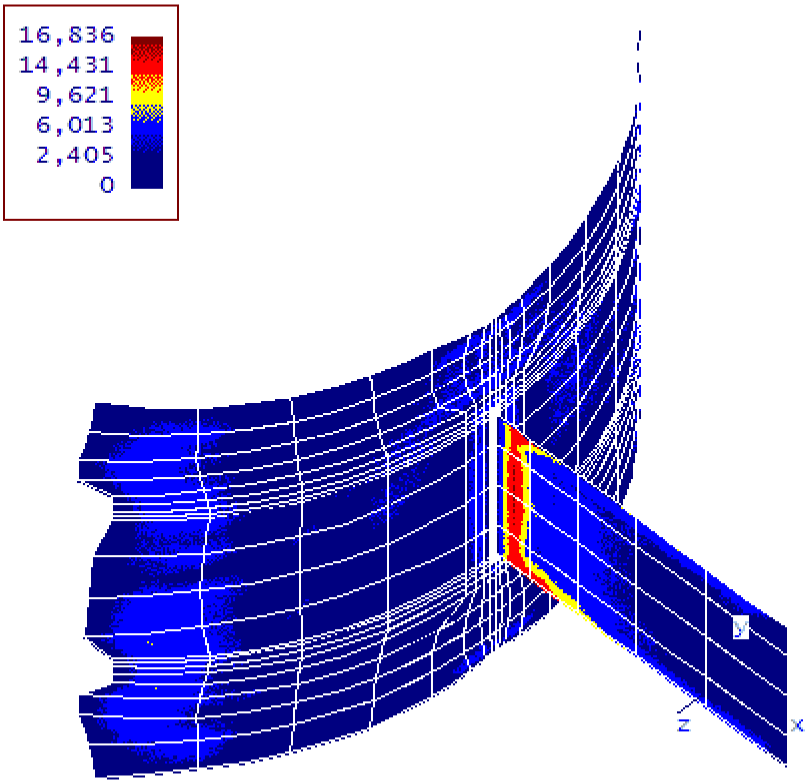
8) Membrane < User (OPE Membrane) Case 4




3d(Small) 3d

- 3d(Deformed)

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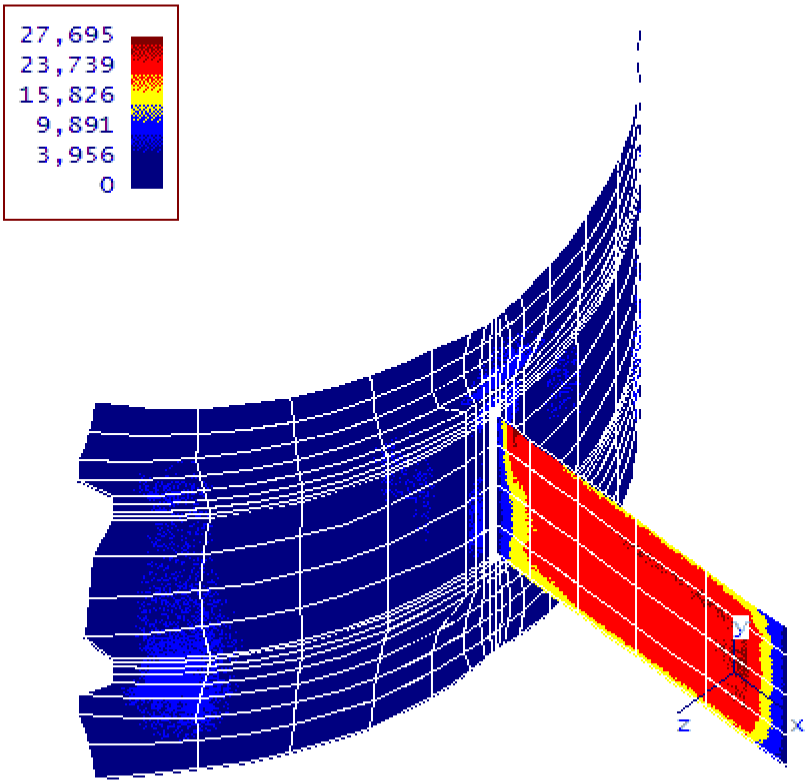
9) Bending < User (OPE Bending) Case 4




- 3d(Small) 3d

  3d(Deformed)

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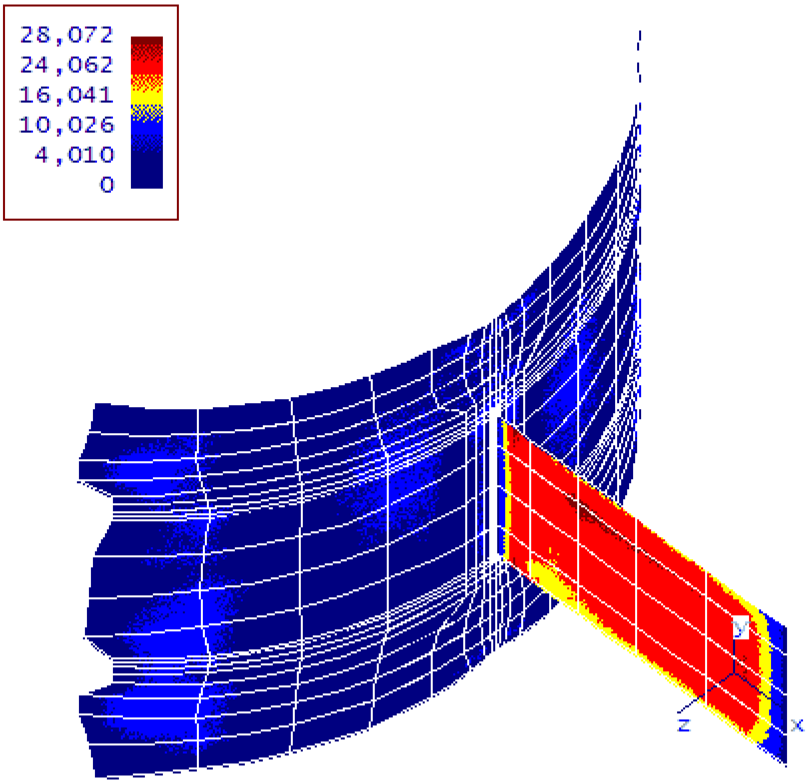
10) Pl+Pb+Q < SPS (EXP Inside) Case 5




- 3d(Small) 3d
- 

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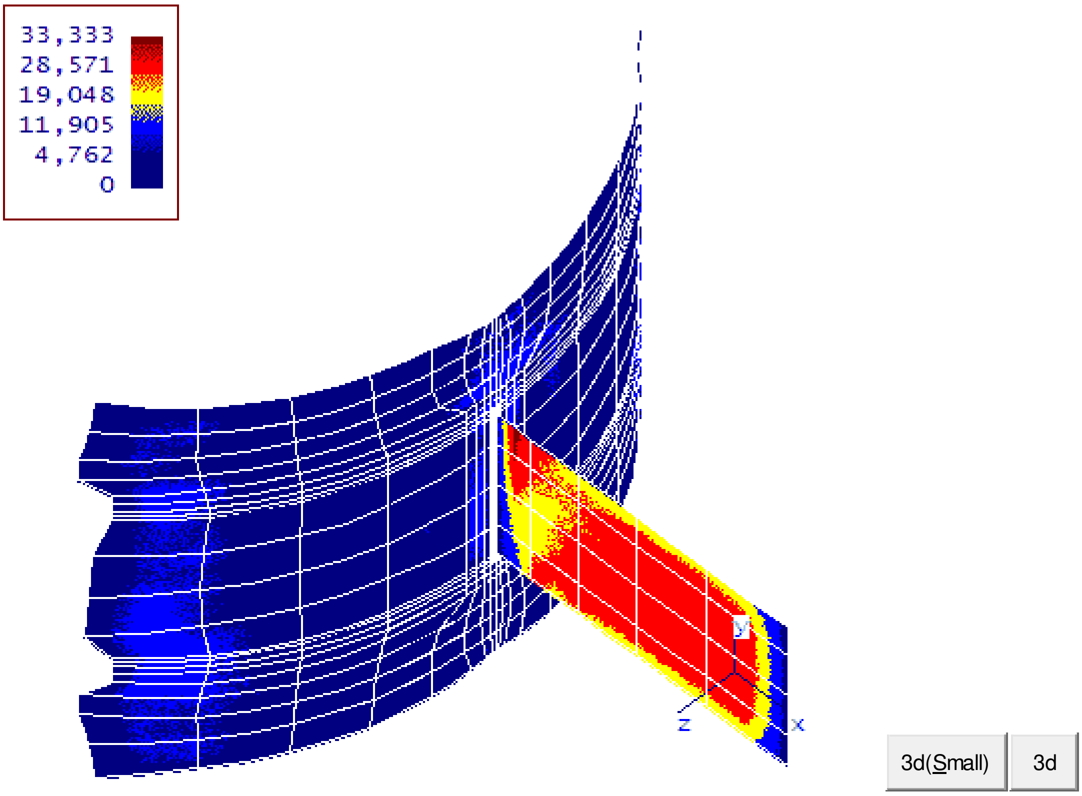
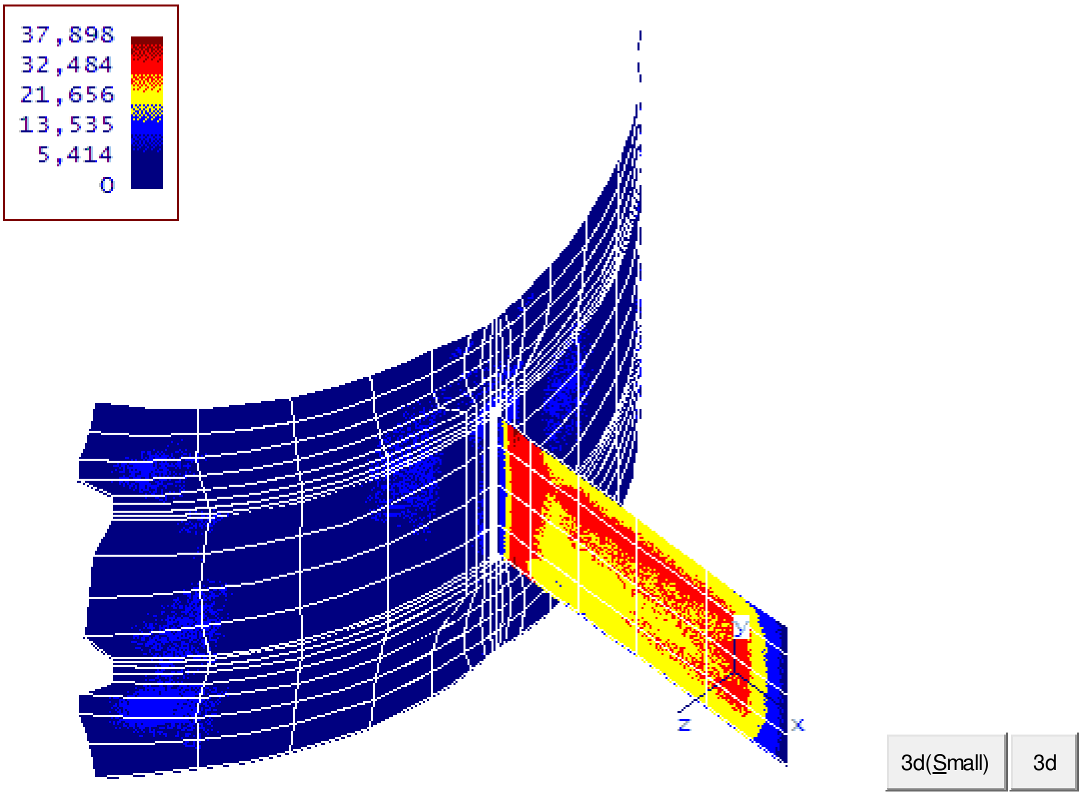
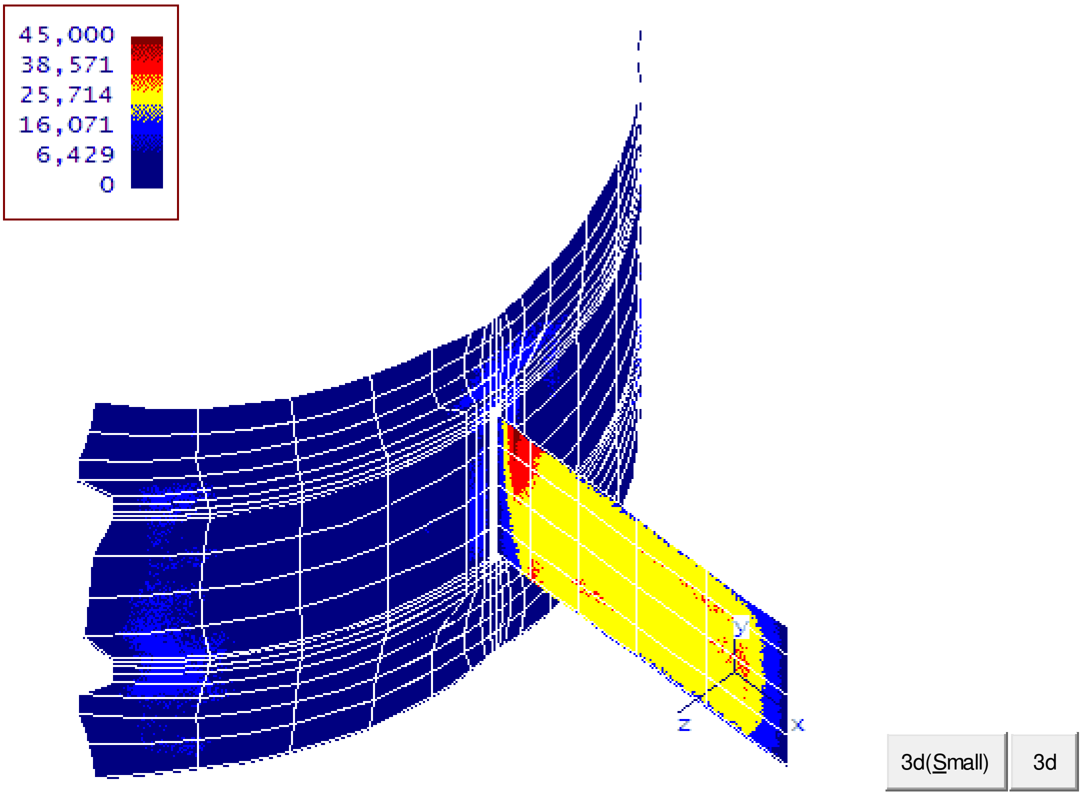
11) Pl+Pb+Q < SPS (EXP Outside) Case 5




12) Pl+Pb+Q+F < 2Sa (EXP Inside) Case 5



13) Pl+Pb+Q+F < 2Sa (EXP Outside) Case 5

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