

Outlet Nozzle (N2): FEA 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 12 09:31:13 2020.

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Model Notes
Model Notes

Input Echo:

Model Type : Cylindrical Shell

Parent Geometry

Parent Outside Diam. : 20.000 in.
Thickness : 0.203 in.
Fillet Along Shell : 0.375 in.

Parent Properties:

Cold Allowable : 17100.0 psi
Hot Allowable : 17100.0 psi
Material ID #2 : Low Alloy Steel
Ultimate Tensile (Amb) : 60000.0 psi
Yield Strength (Amb) : 35000.0 psi
Yield Strength (Hot) : 25900.0 psi
Elastic Modulus (Amb) : 29400000.0 psi
Poissons Ratio : 0.300
Weight Density : 0.2830E+00 lb./cu.in.

Nozzle Geometry

Nozzle Outside Diam. : 8.625 in.
Thickness : 0.375 in.
Length : 10.750 in.
Nozzle Weld Length : 0.375 in.
RePad Width : 3.000 in.
RePad Thickness : 0.375 in.
RePad Weld Leg : 0.375 in.
Nozzle Tilt Angle : 0.000 deg.
Distance from Top : 12.640 in.
Distance from Bottom : 42.312 in.

Nozzle Properties

Cold Allowable : 17100.0 psi
Hot Allowable : 17100.0 psi
Material ID #2 : Low Alloy Steel
Ultimate Tensile (Amb) : 60000.0 psi
Yield Strength (Amb) : 35000.0 psi
Yield Strength (Hot) : 25900.0 psi
Elastic Modulus (Amb) : 29400000.0 psi
Poissons Ratio : 0.300
Weight Density : 0.2830E+00 lb./cu.in.

Design Operating Cycles : 0.
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 : 650.00 deg.
Nozzle Outside Temperature : 650.00 deg.
Vessel Inside Temperature : 650.00 deg.
Vessel Outside Temperature : 650.00 deg.

Nozzle Pressure : 121.2 psi
Vessel Pressure : 121.2 psi

FEA Model Loads:

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	1000.0	1000.0	3750.0	-1281.2	2031.2

The "top" or "positive" end of this model is "free" in
the axial and translational directions.

Stresses will be calculated in the weld elements surrounding
the junction of the nozzle with the parent shell. This is
typically done to get accurate values for the pressure
stresses on the inside surface of the nozzle in the
longitudinal plane. The effect of any external loads will
overemphasized (too conservative) in this run.

Stresses are NOT 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 14.0 Jobname: OUTLETN \$P
Released Mar 2019 9:30am OCT 12,2020

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 14.0 Jobname: OUTLETN \$P
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Solution Data

Maximum Solution Row Size = 714
Number of Nodes = 2184
Number of Elements = 720
Number of Solution Cases = 7

Summation of Loads per Case

Case #	FX	FY	FZ
1	-576.	37319.	0.
2	424.	38077.	1000.
3	194386.	0.	0.
4	0.	0.	0.
5	0.	0.	0.
6	0.	0.	0.
7	-576.	37319.	0.

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ASME Code Stress Output Plots
FEPipe Version 14.0 Jobname: OUTLETN \$P
Released Mar 2019 9:31am OCT 12,2020

ASME Code Stress Output Plots \$X

1) Pl < spl="" (sus,membrane)="" case="" 1="" 2)="" qb="">< sps="" (sus,bending)="" case="" 1

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Stress Results - Notes
FEPipe Version 14.0 Jobname: OUTLETN \$P
Released Mar 2019 9:31am OCT 12,2020

Stress Results - Notes

- Results in this analysis were generated using the finite element solution method.
- Using 2013-2017 ASME Section VIII Division 2
- Use Polished Bar fatigue curve.
- Assume free end displacements of attached pipe (e.g. thermal loads) are secondary loads.
- Primary bending stresses at discontinuities are treated like secondary stresses.
- 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 14.0
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Jobname: OUTLETN
9:31am OCT 12,2020

\$P

ASME Overstressed Areas

\$X

*** NO OVERSTRESSED NODES IN THIS MODEL ***

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Highest Primary Stress Ratios
FEPipe Version 14.0
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Jobname: OUTLETN
9:31am OCT 12,2020

\$P

Highest Primary Stress Ratios

\$X

Pad/Header at Junction

Pl
5,063
psi

SPL
25,900
psi

Primary Membrane Load Case 1
Plot Reference:

1) Pl < spl="" (sus,membrane)="" case="" 1="" 19%="" branch="" at=""

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Highest Secondary Stress Ratios
FEPipe Version 14.0
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Jobname: OUTLETN
9:31am OCT 12,2020

\$P

Highest Secondary Stress Ratios

\$X

Pad/Header at Junction

Pl+Pb+Q
14,390
psi

SPS
60,900
psi

Primary+Secondary (Inner) Load Case 2

Plot Reference:

6) Pl+Pb+Q < sps="" (ope,inside)="" case="" 2="" 23%="" branch="" at=""

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Highest Fatigue Stress Ratios
FEPipe Version 14.0
Released Mar 2019

Jobname: OUTLETN
9:31am OCT 12,2020

\$P

Highest Fatigue Stress Ratios

\$X

Pad/Header at Junction

Pl+Pb+Q+F
9,714
psi

Damage Ratio
0.000 Life
0.005 Stress

Primary+Secondary+Peak (Inner) Load Case 2

Stress Concentration Factor = 1.350

Strain Concentration Factor = 1.000

Cycles Allowed for this Stress = 97,268,928.

"B31" Fatigue Stress Allowable = 42750.0

Mark1 Fatigue Stress Allowable = 245000.0

WRC 474 Mean Cycles to Failure = 4,867,838.

WRC 474 99% Probability Cycles = 1,130,865.

WRC 474 95% Probability Cycles = 1,570,086.

BS5500 Allowed Cycles(Curve F) = 709,425.

Membrane-to-Bending Ratio = 0.872

Bending-to-PL+PB+Q Ratio = 0.534

Plot Reference:

8) Pl+Pb+Q+F < sa="" (exp,inside)="" case="" 2="" branch="" at="" ju

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Stress Intensification Factors
FEPipe Version 14.0 Jobname: OUTLETN \$P
Released Mar 2019 9:31am OCT 12,2020

Stress Intensification Factors \$X

Branch/Nozzle Sif Summary

	Peak	Primary	Secondary	SSI
Axial :	8.878	6.576	13.153	3.051
Inplane :	2.820	2.089	4.178	2.608
Outplane:	6.046	4.478	8.956	2.793
Torsion :	1.007	1.011	1.492	1.853
Pressure:	1.437	1.084	2.129	2.007

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 $PD/2T$. 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 : 8.625 in.
Pipe Thk: 0.375 in.
Z approx: 20.046 cu.in.
Z exact : 19.214 cu.in.

(SSI = SIF^x)	Axial	Inpl	Outpl	Tors	Pres
SIF/SSI Exponents:	0.863	0.711	0.833	1.488	0.222

SIF/SSI exponent based on relationship between primary and peak stress factors from the finite element analysis.

B31.3 Branch Pressure i-factor = 12.866
Header Pressure i-factor = 2.904

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
	7.006 Inplane
	8.726 Outplane
	1.000 Torsional
B31.1 (Branch)	
Peak Stress Sif	0.000 Axial
	8.726 Inplane
	8.726 Outplane
	8.726 Torsional
WRC 330 (Branch)	
Peak Stress Sif	0.000 Axial
	4.726 Inplane
	8.726 Outplane
	4.726 Torsional

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Allowable Loads

\$X

SECONDARY Load Type (Range):		Maximum Individual Occuring	Conservative Simultaneous Occuring	Realistic Simultaneous Occuring
Axial Force	(lb.)	45002.	13817.	20725.
Inplane Moment	(in. lb.)	280048.	60799.	128973.
Outplane Moment	(in. lb.)	130647.	25491.	54074.
Torsional Moment	(in. lb.)	784069.	206827.	310240.
Pressure	(psi)	580.90	121.20	121.20

PRIMARY Load Type:		Maximum Individual Occuring	Conservative Simultaneous Occuring	Realistic Simultaneous Occuring
Axial Force	(lb.)	38278.	10152.	15228.
Inplane Moment	(in. lb.)	238201.	44673.	94765.
Outplane Moment	(in. lb.)	111125.	20677.	43864.
Torsional Moment	(in. lb.)	492242.	132004.	198007.
Pressure	(psi)	485.35	121.20	121.20

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.

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Flexibilities

\$X

The following stiffnesses should be used in a piping, "beam-type" analysis of the intersection. The stiffnesses 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 = 8.625 in.
Wall Thickness = 0.375 in.

Axial Translational Stiffness = 1490046. lb./in.
Inplane Rotational Stiffness = 948080. in.lb./deg
Outplane Rotational Stiffness = 306610. in.lb./deg
Torsional Rotational Stiffness = 5997212. in.lb./deg

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 $0.24361E+10$ lb.in.²

The value of (d) to use is: 8.250 in..

The resulting bending stiffness is in units of force x length per radian.

Axial Flexibility Factor	(k) =	2.059
Inplane Flexibility Factor	(k) =	5.436
Outplane Flexibility Factor	(k) =	16.809
Torsional Flexibility Factor	(k) =	0.859

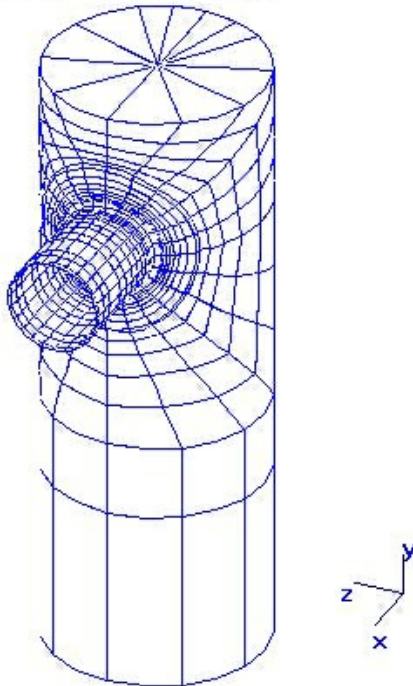
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Finite Element Model

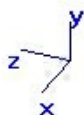
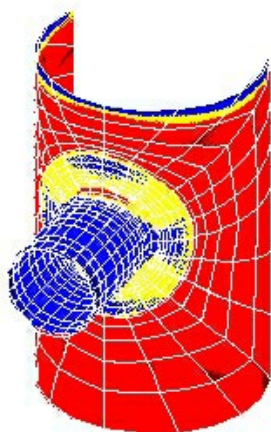
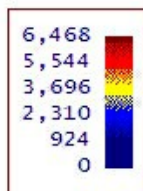
- [Finite Element Model](#)
- [1\) \$P_l < s_{pl}\$ \(sus="" membrane\)="" case="" 1="">](#)
- [2\) \$Q_b < s_{ps}\$ \(sus="" bending\)="" case="" 1="">](#)
- [3\) \$P_l + P_b + Q < s_{ps}\$ \(sus="" inside\)="" case="" 1="">](#)
- [4\) \$P_l + P_b + Q < s_{ps}\$ \(sus="" outside\)="" case="" 1="">](#)
- [5\) \$S_1 + S_2 + S_3 < 4s\$ \(sus="" s1+s2+s3\)="" case="" 1="">](#)
- [6\) \$P_l + P_b + Q < s_{ps}\$ \(ope="" inside\)="" case="" 2="">](#)
- [7\) \$P_l + P_b + Q < s_{ps}\$ \(ope="" outside\)="" case="" 2="">](#)
- [8\) \$P_l + P_b + Q + F < s_a\$ \(exp="" inside\)="" case="" 2="">](#)
- [9\) \$P_l + P_b + Q + F < s_a\$ \(exp="" outside\)="" case="" 2="">](#)
- [10\) Membrane < user="" \(ope="" membrane\)="" case="" 2="">](#)
- [11\) Bending < user="" \(ope="" bending\)="" case="" 2="">](#)
- [12\) \$P_l + P_b + Q + F < s_a\$ \(sif="" outside\)="" case="" 3="">](#)
- [13\) \$P_l + P_b + Q + F < s_a\$ \(sif="" outside\)="" case="" 4="">](#)
- [14\) \$P_l + P_b + Q + F < s_a\$ \(sif="" outside\)="" case="" 5="">](#)
- [15\) \$P_l + P_b + Q + F < s_a\$ \(sif="" outside\)="" case="" 6="">](#)
- [16\) \$P_l + P_b + Q + F < s_a\$ \(sif="" outside\)="" case="" 7="">](#)

[Tabular Results](#)

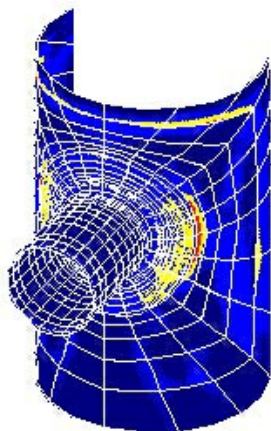
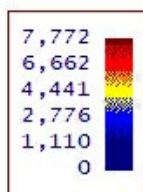
Finite Element Model



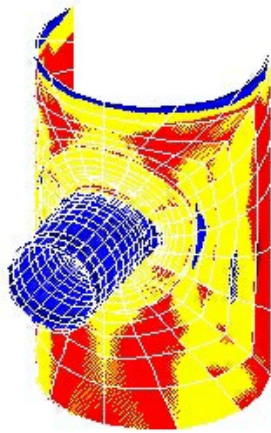
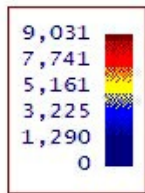
1) P1 < SPL (SUS Membrane) Case 1



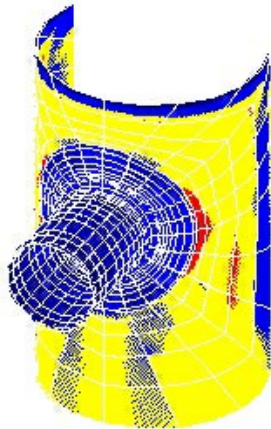
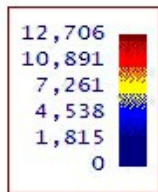
2) Qb < SPS (SUS Bending) Case 1



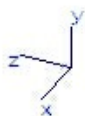
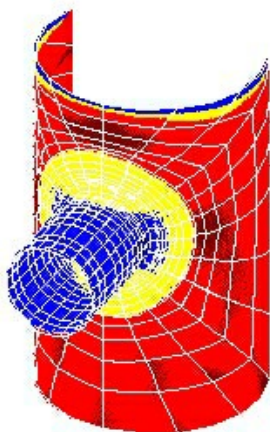
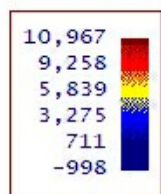
3) $P1+Pb+Q < SPS$ (SUS Inside) Case 1



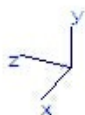
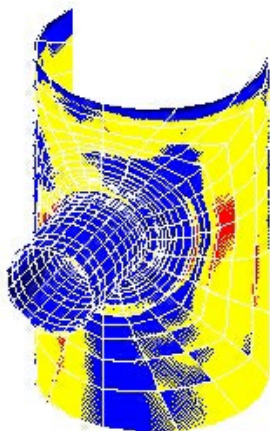
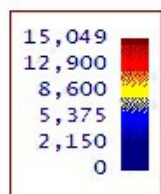
4) $P1+Pb+Q < SPS$ (SUS Outside) Case 1



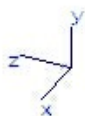
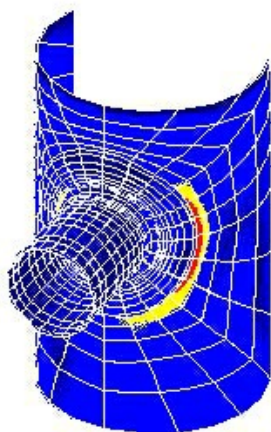
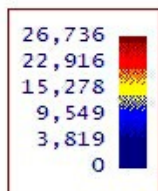
5) $S1+S2+S3 < 4S$ (SUS $S1+S2+S3$) Case 1



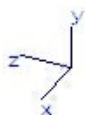
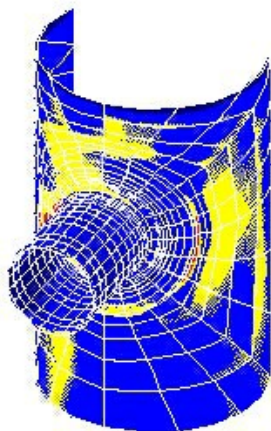
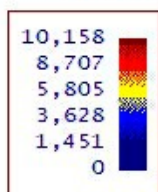
6) $P1+Pb+Q < SPS$ (OPE Inside) Case 2



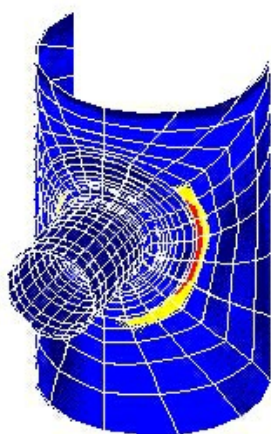
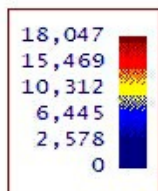
7) $P1+Pb+Q < SPS$ (OPE Outside) Case 2



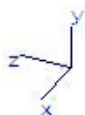
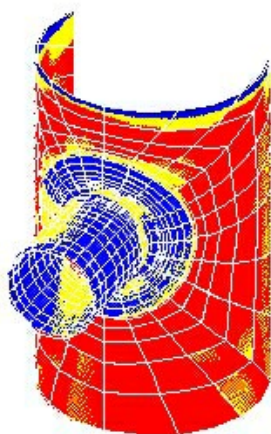
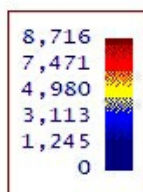
8) $P1+Pb+Q+F < Sa$ (EXP Inside) Case 2



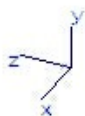
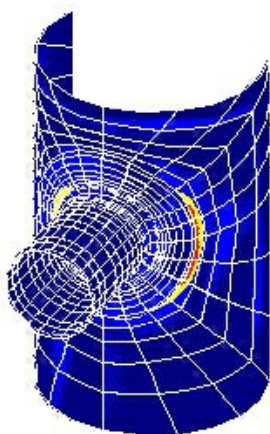
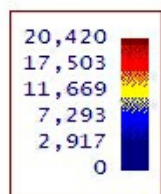
9) $P1+Pb+Q+F < Sa$ (EXP Outside) Case 2



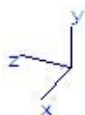
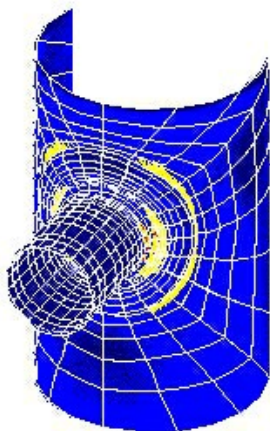
10) Membrane < User (OPE Membrane) Case 2



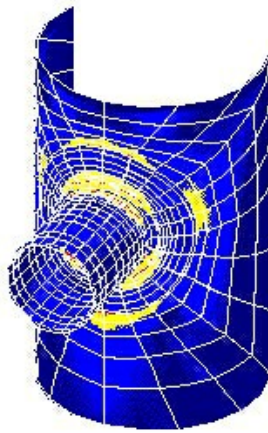
11) Bending < User (OPE Bending) Case 2



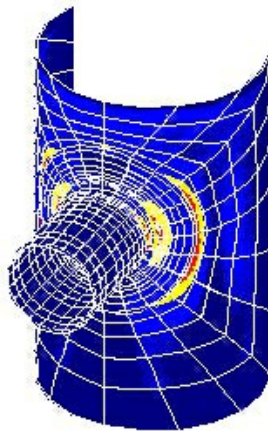
12) $P1+Pb+Q+F < Sa$ (SIF Outside) Case 3



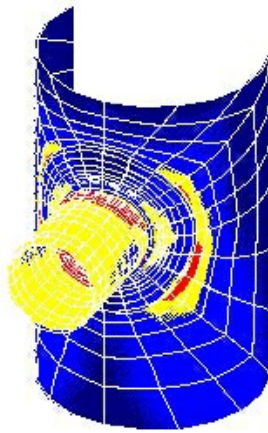
13) $P1+Pb+Q+F < Sa$ (SIF Outside) Case 4



14) $P1+Pb+Q+F < Sa$ (SIF Outside) Case 5



15) $P1+Pb+Q+F < Sa$ (SIF Outside) Case 6



16) $P1+Pb+Q+F < Sa$ (SIF Outside) Case 7

