

Notes

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Results shown below, under stresses are:  
- Front Pipe (+side attached run pipe)  
- Back Pipe (-side attached run pipe)  
- Top Pipe (Branch attached pipe)  
- Tee Body (branch and run fitting lengths outside crotch area)  
- Transition to front pipe (Transition from weld to +side run pipe)  
- Transition to back pipe (Transition from weld to -side run pipe)  
- Transition to top pipe (Transition from weld to branch pipe)  
- Tee Crotch Area

Type Of Model : Welding Tee (Shell)  
Units : Metric  
Stress Calculation : AVERAGED

Vectors

-----  
Run Vector : 1.000, 0.000, 0.000  
Branch Vector : 0.000, 1.000, 0.000  
Gravity : 0.000, -1.000, 0.000

Model Geometry

-----  
Tee OD at Run : 914.400 mm.  
Tee OD at Branch : 609.600 mm.  
Tee Thk at Run : 9.525 mm.  
Tee Thk at Branch : 9.525 mm.  
Tee Crotch Radius : 97.536 mm.  
Run Fitting Length : 1346.200 mm.  
Br. Fitting Length : 631.976 mm.  
-side Att. Pipe (Comp): 2743.200 mm.  
+side Att. Pipe (Comp): 2743.200 mm.  
Branch Att. Pipe (Comp): 1828.800 mm.

Optional Entries (Options Screen)

-----  
(User) - User defined values.  
(Comp) - Default values used, computer generated.  
Opt. -side OD (User) : 914.400 mm.  
Opt. +side OD (User) : 914.400 mm.  
Opt. Branch OD (User) : 609.600 mm.  
Opt. -side Thk (User): 9.525 mm.  
Opt. +side Thk (User): 9.525 mm.  
Opt. Branch Thk (User): 9.525 mm.

Weld Details and SCF

-----  
-side Weld Len. (User): 0.000 mm.  
+side Weld Len. (User): 0.000 mm.  
Branch Weld Len. (User): 0.000 mm.  
Crotch Area SCF (User): 1.000

Crotch Thickness Profile

-----  
The values below may be computer generated or defined by the user.  
(User) - User defined values.  
(Comp) - Default values used, computer generated.

Center Long. (User): 9.525 mm.  
Center 45deg (User): 9.525 mm.  
Center Circ. (User): 9.525 mm.  
Run Long. (User): 9.525 mm.  
Run 45deg (User): 9.525 mm.  
Run Circ. (User): 9.525 mm.  
Branch Long. (User): 9.525 mm.  
Branch 45deg (User): 9.525 mm.  
Branch Circ. (User): 9.525 mm.

Loads

-----  
Loads Applied at : End of Branch  
Loads Defined as : GLOBAL

Forces in ( N ) and Moments in ( mm. N )  
FX FY FZ MX MY MZ  
Weight : 0.000 0.000 0.000 0.000 0.000 0.000  
Operating : 0.000 0.000 0.000 0.000 0.000 0.000  
Occasional: 0.000 0.000 0.000 0.000 0.000 0.000  
Thermal : 0.000 0.000 0.000 0.000 0.000 0.000

Pressure : 1.078 MPa

Material Properties

-----  
-side - negative outplane side, this is defined as the negative section of the run.  
+side - Positive outplane side, positive section of the run.  
Branch - The attached branch on the tee.

Tee Cold Allowable : 138.000 MPa

Input Data Echo

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General

1 < Number of Operating Load Cycles  
1 < Number of Occasional Load Cycles  
YES < Compute Intersections Sif's and Stiffnesses  
(YES/NO/RUN) If RUN then compute Sif's and  
Stiffnesses for loads thru the run pipe.  
1.000, 0.000, 0.000 < Header Orientation (Local "Z")  
0.000, 1.000, 0.000 < Nozzle Orientation (Local "Y")  
(Nozzle and Header Directions Should Be Orthogonal)  
PIPE LENGTHS FOR LOAD REDUCTION ESTIMATE  
0.000 < Inplane attached pipe length (mm.)  
0.000 < Outplane attached pipe length (mm.)  
0.000 < Axial attached pipe length (mm.)  
NO < Save Stiffness Matrix  
NO < Reuse Saved Stiffness Matrix (Only Loads Changed)  
21.100 < Ambient Temperature  
YES < Add Branch Pressure Thrust  
NO Include Weight Loads (Y/N)  
0.000, -1.000, 0.000 Direction of Gravity (vx,vy,vz)  
YES Include Pressure Loads (Y/N)  
YES Include Thermal Loads (Y/N)  
NO Include Wind Loads (Y/N)  
OCC Include Wind in Which Load Cases ?  
(WGT, OPE, OCC, THE)  
Wind Direction (wx,wy,wz)  
Elev.(mm.), Pressure ( N /sq.mm.)  
Elev.(mm.), Pressure ( N /sq.mm.)

Enter Insulation/Refractory Data Below: (mm.) and ( N per cu.mm.)

Insulation Thick. > Insul. Density >  
Refractory Thick. > Refrt. Density >

Tee Geometry

Input Data Echo

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Tee Geometry

914.400 < OD Fitting at Run Pipe Connection (mm.)  
609.600 < OD Fitting at Branch Pipe Connection (mm.)  
97.536 < Crotch Radius in Longitudinal Plane (mm.)  
1346.200 < Fitting Length along run (weld-to-weld) (mm.)  
631.976 < Fitting Height, Centerline to branch weld (mm.)  
9.525 < Nominal Fitting Thickness in Run  
9.525 < Nominal Fitting Thickness in Branch  
Optional Tee Profile Thicknesses  
9.525 < Center of Crotch, Longitudinal Plane (mm.)  
9.525 < Center of Crotch, @45° (mm.)  
9.525 < Center of Crotch, Circumferential Plane (mm.)  
9.525 < Base of Crotch, Longitudinal Plane (mm.)  
9.525 < Base of Crotch, @45° (mm.)  
9.525 < Base of Crotch, Circumferential Plane (mm.)  
9.525 < Top of Crotch, Longitudinal Plane (mm.)  
9.525 < Top of Crotch, @45° (mm.)  
9.525 < Top of Crotch, Circumferential Plane (mm.)  
< Circumferential Plane, Bottom of fitting (mm.)

Attached Pipe Dimensions

Attached Pipe Dimensions

2743.200 < Left End Pipe Length (mm.)  
2743.200 < Right End Pipe Length (mm.)  
1828.800 < Top(Branch) Pipe Length (mm.)  
914.400 < Left Pipe OD (If different from tee) (mm.)  
914.400 < Right Pipe OD (If different from tee) (mm.)  
609.600 < Top Pipe OD (If different from tee) (mm.)  
9.525 < Left Pipe Thickness (If different from tee) (mm.)  
9.525 < Right Pipe Thickness (If different from tee) (mm.)  
9.525 < Top Pipe Thickness (If different from tee) (mm.)  
0.000 < Left Pipe Weld Length (mm.)  
0.000 < Right Pipe Weld Length (mm.)  
0.000 < Top Pipe Weld Length (mm.)  
< Loading Ring Axial Length (mm.)

Input Data Echo

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Material Properties

TEE Material Properties:

1.078 < Pressure ( N /sq.mm.)  
21.100 < Inside Temperature (deg)  
21.100 < Outside Temperature (deg)  
1 < Tee Material for Fatigue Calculations (1-6)  
138.000 < Tee Cold Allowable Stress (MPa)  
138.000 < Tee Hot Allowable Stress (MPa)  
< Tee Tensile Strength (@Ambient) (MPa)  
< Tee Yield Strength (@Ambient) (MPa)  
< Tee Yield Strength (@Temperature) (MPa)  
199950.000 < Tee Elastic Modulus (@Ambient) (MPa)  
0.300 < Tee Poissons Ratio  
0.117E-04 < Tee Expansion Coefficient (mm./mm./deg)  
0.000 < Density of Tee Pipe ( N /cu.mm.)

"Only enter attached pipe properties below, if they are  
different than those entered for the tee."

LEFT End Pipe Material Properties:

1 < Left Pipe Material for Fatigue Calculations (1-6)  
138.000 < Left Pipe Cold Allowable Stress (MPa)  
138.000 < Left Pipe Hot Allowable Stress (MPa)  
< Left Pipe Tensile Strength (@Ambient) (MPa)  
< Left Pipe Yield Strength (@Ambient) (MPa)  
< Left Pipe Yield Strength (@Temperature) (MPa)  
199950.000 < Left Pipe Elastic Modulus (@Ambient) (MPa)  
0.300 < Left Pipe Poissons Ratio  
0.117E-04 < Left Pipe Expansion Coefficient (mm./mm./deg)

RIGHT End Pipe Material Properties:

1 < Right Pipe Material for Fatigue Calculations (1-6)  
138.000 < Right Pipe Cold Allowable Stress (MPa)  
138.000 < Right Pipe Hot Allowable Stress (MPa)  
< Right Pipe Tensile Strength (@Ambient) (MPa)

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< Right Pipe Yield Strength (@Ambient) (MPa)  
< Right Pipe Yield Strength (@Temperature) (MPa)  
199950.000 < Right Pipe Elastic Modulus (@Ambient) (MPa)  
0.300 < Right Pipe Poissons Ratio  
0.117E-04 < Right Pipe Expansion Coefficient (mm./mm./deg)

BRANCH Pipe Material Properties:

1 < Branch Pipe Material for Fatigue Calculations  
138.000 < Branch Pipe Cold Allowable Stress (MPa)  
138.000 < Branch Pipe Hot Allowable Stress (MPa)  
< Branch Pipe Tensile Strength (@Ambient) (MPa)  
< Branch Pipe Yield Strength (@Ambient) (MPa)  
< Branch Pipe Yield Strength (@Temperature) (MPa)  
199950.000 < Branch Pipe Elastic Modulus (@Ambient) (MPa)  
0.300 < Branch Pipe Poissons Ratio  
0.117E-04 < Branch Pipe Expansion Coefficient (mm./mm./deg)

Loads

3 < Loads Entered below act:  
1 - At the branch/header centerline intersection  
2 - At the surface of the header/vessel  
3 - At the end of the branch

GLOBAL < Loads Entered in (L)ocal or (G)lobal coordinates

FORCE	FORCE	FORCE	MOMENT	MOMENT	MOMENT	
Axial	Inplane	Outplane	Torsion	In-plane	Outplane	
N	N	N	mm. N	mm. N	mm. N	
.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	WEIGHT
.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	OPERATING
.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	OCCASIONAL
.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	THERMAL

Node ID's

< Node Number for Branch End

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< Node Number for +Z Header End  
< Node Number for -Z Header End

Optional

1 < Crotch Area Stress Concentration  
YES < Free +Outplane End of Header/Vessel (Open End)  
NO < Free -Outplane End of Header/Vessel (Open End)  
NO < Remove Bottom Half of Model  
0.000 < Length of Branch to Remove for Join (mm.)  
0.000 < Length of +Outplane to Remove for Join (mm.)  
0.000 < Length of -Outplane to Remove for Join (mm.)  
C PRIMARY < Analyze Occasional Loads as (P)primary or (F)atigue  
< Nominal Stress computed at (S)urface or (C)enterline  
AVERAGED < Nodal Stress Calculation: AVERAGED/NOTAVERAGED/  
GAUSSAVERAGE/GAUSSNOTAVERAGE  
10000.000 < Relative Stiffness (to branch) of Loading Ring  
MESH CONTROL PARAMETERS  
< Density Index for Nodes at Intersection  
( > 0 for more elements at the intersection)  
1.00000 < Global Mesh Multiplier Override  
0.00000 < Merge Nodes Override  
0.000 < Intersection Tolerance Override  
YES < Adjust Determinant of Jacobian for Poorly Shaped  
Elements. (Should be used with caution. Stiffnesses  
of poorly shaped elements computed approximately.)  
< Branch mesh area sweep factor (>0.8)  
32 < Number of nodes around branch circumference, <OR>  
< Number of nodes around header  
7 < Number of nodes radially in crotch  
5 < Number of nodes radially in header adjacent to crotch  
5 < Number of nodes radially in tee above crotch area  
< Number of nodes in bottom surfaces  
< Number of nodes circumferentially around branch per  
surface. (Note 6 total surfaces around branch.)  
< Number of nodes along +Outplane attached pipe  
< Number of nodes along -Outplane attached pipe  
< Number of nodes along branch attached pipe  
1 < Adjust Attached Pipe Midsurface

Input Data Echo

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Database Operations

- 0 < Database "Read/Write" Option
- 0 - No Database Operation
- 1 - Write Out Database for this Job for later "Reading"
- 2 - Read In Database(s) to "Include" with this Job

Enter the node numbers in this model that will be connected to nodes in another database. The node number may correspond to any element end. This list is used with database options 1 or 2.

Enter the names of the jobs whose databases are to be read into and "INCLUDED" with this job. (These jobs must already have had their databases written to the hard disk.) These names are only used with database option 2.

(Optional See ?-Help)

JOBNAMES

Coordinate Shift (X,Y,Z) (mm.)

Load Case Report

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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

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



Solution Data

Maximum Solution Row Size = 936  
Number of Nodes = 2694  
Number of Elements = 890  
Number of Solution Cases = 7

Summation of Loads per Case

Case #	FX	FY	FZ
1	693139.	1.	0.
2	693139.	1.	0.
3	-12.	191675368.	111.
4	0.	0.	0.
5	0.	0.	-1.
6	0.	0.	0.
7	693139.	1.	0.

Beam Detailed Results

Notes:

For pipe, there are five stress values printed for each end node on an 18dof element: Saa, Sab, Sac, Scc, and SI.

where  
Saa = Axial stress  
Sab = Shear stress normal to the pipe skin  
Sac = Shear stress along circumferential direction  
Scc = Hoop stress  
SI = Stress intensity

If an element is lined with refractory layers, four stress values are printed for each layer of refractory at each element end node.

where  
MxPr = Maximum principal stress  
MnPr = Minimum principal stress  
SI = Stress intensity  
Se = von Mises stress

LOAD CASE 1 --> (Pr Only)

LOAD CASE 2 -->

LOAD CASE 3 -->

LOAD CASE 4 -->

LOAD CASE 5 -->

LOAD CASE 6 -->

LOAD CASE 7 -->

ASME Code Stress Output Plots

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- 1) P1 < (1.5)(S) (SUS,Membrane) Case 1
- 2) Qb < SPS (SUS,Bending) Case 1
- 3) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 1
- 4) P1+Pb+Q < SPS (OPE,Inside) Case 2
- 5) P1+Pb+Q < SPS (OPE,Outside) Case 2
- 6) P1+Pb+Q+F < Sa (EXP,Inside) Case 2
- 7) P1+Pb+Q+F < Sa (EXP,Outside) Case 2
- 8) Membrane < User (OPE,Membrane) Case 2
- 9) Bending < User (OPE,Bending) Case 2
- 10) P1+Pb+Q+F < Sa (SIF,Outside) Case 3
- 11) P1+Pb+Q+F < Sa (SIF,Outside) Case 4
- 12) P1+Pb+Q+F < Sa (SIF,Outside) Case 5
- 13) P1+Pb+Q+F < Sa (SIF,Outside) Case 6
- 14) P1+Pb+Q+F < Sa (SIF,Outside) Case 7

Region Data

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Tee Crotch Area

Cold Allowable .....	138.	MPa
Cold Elastic Modulus .....	199950.	MPa
Hot Allowable @ 21 deg ..	138.	MPa
Case 1		
Pressure Stress (Pd/2t) ..	52.	MPa
Case 2		
Pressure Stress (Pd/2t) ..	52.	MPa
Case 3		
Nominal Stress (M/Z) ...	10674.	MPa
Case 4		
Nominal Stress (M/Z) ...	72.	MPa
Case 5		
Nominal Stress (M/Z) ...	72.	MPa
Case 6		
Nominal Stress (M/Z) ...	72.	MPa
Case 7		
Nominal Stress (M/Z) ...	52.	MPa
Smallest Thickness .....	9.525	mm.
Stress Concentration .....	1.000	

Tee Body

Cold Allowable .....	138.	MPa
Cold Elastic Modulus .....	199950.	MPa
Hot Allowable @ 21 deg ..	138.	MPa
Case 1		
Pressure Stress (Pd/2t) ..	52.	MPa
Case 2		
Pressure Stress (Pd/2t) ..	52.	MPa
Case 3		
Nominal Stress (M/Z) ...	10674.	MPa
Case 4		
Nominal Stress (M/Z) ...	72.	MPa
Case 5		
Nominal Stress (M/Z) ...	72.	MPa
Case 6		
Nominal Stress (M/Z) ...	72.	MPa
Case 7		
Nominal Stress (M/Z) ...	52.	MPa
Smallest Thickness .....	9.525	mm.
Stress Concentration .....	1.000	

Stress Results - Notes

- Results in this analysis were generated using the finite element solution method.
- Using 07-12 ASME Section VIII Division 2
- Use Polished Bar fatigue curve.
- Ratio between Operating and Design Pressure = 1.000000  
Assume pressure increases all other stresses.
- Assume free end displacements of attached pipe are secondary loads within limits of nozzle reinforcement.
- User OVERRIDE - USE Stress Intensity (TRESKA) for ASME Calculation.  
Tresca may be 10% higher than equivalent stress.
- S1+S2+S3 evaluation omitted from operating stress.  
Include S1+S2+S3 evaluation in primary case evaluation.  
Assume bending stress not local primary for S1+S2+S3.
- Use local tensor values for averaged and not averaged stresses.
- Use shell midsurface diameter for nozzle pressure thrust load - may not be conservative.

B31 Expansion Stresses

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Expansion Stress MPa	B31 Allowable MPa	ASME Allowable MPa	Mark1 Allowable MPa	Regions / Notes
104.	345.	12236.	1689.	Tee Crotch Area Load Case 2, Inner, Plot 6
77.	345.	12236.	1689.	Tee Body Load Case 2, Outer, Plot 7

ASME Overstressed Areas

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

Highest Primary Stress Ratios

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Tee Crotch Area

P1	(1.5)(S)	Primary Membrane Load Case 1
168	207	Plot Reference:
MPa	MPa	1) P1 < (1.5)(S) (SUS,Membrane) Case 1

81%

Tee Body

P1	(1.5)(S)	Primary Membrane Load Case 1
126	207	Plot Reference:
MPa	MPa	1) P1 < (1.5)(S) (SUS,Membrane) Case 1

60%



Highest Secondary Stress Ratios

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Tee Crotch Area

Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 2
208	414	Plot Reference:
MPa	MPa	4) Pl+Pb+Q < SPS (OPE,Inside) Case 2

50%

Tee Body

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
154	414	Plot Reference:
MPa	MPa	5) Pl+Pb+Q < SPS (OPE,Outside) Case 2

37%

Highest Fatigue Stress Ratios

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Tee Crotch Area

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Inner) Load Case 2
104	0.000 Life	Stress Concentration Factor = 1.000
MPa	0.008 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 260,275.
Allowable		"B31" Fatigue Stress Allowable = 345.0
12,236.4		Markl Fatigue Stress Allowable = 1689.2
MPa		WRC 474 Mean Cycles to Failure = 599,503.
		WRC 474 99% Probability Cycles = 139,270.
0%		WRC 474 95% Probability Cycles = 193,359.
		BS5500 Allowed Cycles(Curve F) = 80,779.
		Membrane-to-Bending Ratio = 2.743
		Bending-to-PL+PB+Q Ratio = 0.267
		Plot Reference:
		6) Pl+Pb+Q+F < Sa (EXP,Inside) Case 2

Tee Body

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Outer) Load Case 2
77	0.000 Life	Stress Concentration Factor = 1.000
MPa	0.006 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 4,738,299.
Allowable		"B31" Fatigue Stress Allowable = 345.0
12,236.4		Markl Fatigue Stress Allowable = 1689.2
MPa		WRC 474 Mean Cycles to Failure = 1,694,395.
		WRC 474 99% Probability Cycles = 393,623.
0%		WRC 474 95% Probability Cycles = 546,496.
		BS5500 Allowed Cycles(Curve F) = 198,887.
		Membrane-to-Bending Ratio = 0.606
		Bending-to-PL+PB+Q Ratio = 0.623
		Plot Reference:
		7) Pl+Pb+Q+F < Sa (EXP,Outside) Case 2

Highest Stress Ratios Per Region

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Tee Crotch Area

Pl	(1.5)(S)	Primary Membrane Load Case 1
168	207	Plot Reference:
MPa	MPa	1) Pl < (1.5)(S) (SUS,Membrane) Case 1
81%		
Qb	SPS	Primary Bending Load Case 1
142	414	Plot Reference:
MPa	MPa	2) Qb < SPS (SUS,Bending) Case 1
34%		
S1+S2+S3	4S	Part 5 (5.3.2) Load Case 1
210	552	Plot Reference:
MPa	MPa	3) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 1
37%		
Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 2
208	414	Plot Reference:
MPa	MPa	4) Pl+Pb+Q < SPS (OPE,Inside) Case 2
50%		
Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
189	414	Plot Reference:
MPa	MPa	5) Pl+Pb+Q < SPS (OPE,Outside) Case 2
45%		
Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Inner) Load Case 2
104	0.000 Life	Stress Concentration Factor = 1.000
MPa	0.008 Stress	Strain Concentration Factor = 1.000
Allowable		Cycles Allowed for this Stress = 260,275.
12,236.4		"B31" Fatigue Stress Allowable = 345.0
MPa		Mark1 Fatigue Stress Allowable = 1689.2
		WRC 474 Mean Cycles to Failure = 599,503.
		WRC 474 99% Probability Cycles = 139,270.
0%		WRC 474 95% Probability Cycles = 193,359.
		BS5500 Allowed Cycles(Curve F) = 80,779.
		Membrane-to-Bending Ratio = 2.743
		Bending-to-PL+PB+Q Ratio = 0.267
		Plot Reference:
		6) Pl+Pb+Q+F < Sa (EXP,Inside) Case 2
Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Outer) Load Case 2
94	0.000 Life	Stress Concentration Factor = 1.000
MPa	0.008 Stress	Strain Concentration Factor = 1.000
Allowable		Cycles Allowed for this Stress = 402,206.
12,236.4		"B31" Fatigue Stress Allowable = 345.0
MPa		Mark1 Fatigue Stress Allowable = 1689.2
		WRC 474 Mean Cycles to Failure = 799,285.
		WRC 474 99% Probability Cycles = 185,681.

Highest Stress Ratios Per Region

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0%  
WRC 474 95% Probability Cycles = 257,795.  
BS5500 Allowed Cycles(Curve F) = 107,519.  
Membrane-to-Bending Ratio = 4.984  
Bending-to-PL+PB+Q Ratio = 0.167  
Plot Reference:  
7) Pl+Pb+Q+F < Sa (EXP,Outside) Case 2

Membrane User Component Evaluation Load Case 2  
168 414 Plot Reference:  
MPa MPa 8) Membrane < User (OPE,Membrane) Case 2

40%  
Bending User Component Evaluation Load Case 2  
142 414 Plot Reference:  
MPa MPa 9) Bending < User (OPE,Bending) Case 2

34%  
Tee Body

P1 (1.5)(S) Primary Membrane Load Case 1  
126 207 Plot Reference:  
MPa MPa 1) P1 < (1.5)(S) (SUS,Membrane) Case 1

60%  
Qb SPS Primary Bending Load Case 1  
129 414 Plot Reference:  
MPa MPa 2) Qb < SPS (SUS,Bending) Case 1

31%  
S1+S2+S3 4S Part 5 (5.3.2) Load Case 1  
171 552 Plot Reference:  
MPa MPa 3) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 1

30%  
Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 2  
138 414 Plot Reference:  
MPa MPa 4) Pl+Pb+Q < SPS (OPE,Inside) Case 2

33%  
Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 2  
154 414 Plot Reference:  
MPa MPa 5) Pl+Pb+Q < SPS (OPE,Outside) Case 2

37%  
Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Inner) Load Case 2  
69 0.000 Life Stress Concentration Factor = 1.000  
MPa 0.006 Stress Strain Concentration Factor = 1.000  
Cycles Allowed for this Stress = 39,180,460.

Highest Stress Ratios Per Region

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Allowable "B31" Fatigue Stress Allowable = 345.0  
12,236.4 Markl Fatigue Stress Allowable = 1689.2  
MPa WRC 474 Mean Cycles to Failure = 2,140,100.  
WRC 474 99% Probability Cycles = 497,165.  
0% WRC 474 95% Probability Cycles = 690,251.  
BS5500 Allowed Cycles(Curve F) = 276,818.  
Membrane-to-Bending Ratio = 4.819  
Bending-to-PL+PB+Q Ratio = 0.172  
Plot Reference:  
6) Pl+Pb+Q+F < Sa (EXP,Inside) Case 2

Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Outer) Load Case 2  
77 0.000 Life Stress Concentration Factor = 1.000  
MPa 0.006 Stress Strain Concentration Factor = 1.000

Allowable "B31" Fatigue Stress Allowable = 345.0  
12,236.4 Markl Fatigue Stress Allowable = 1689.2  
MPa WRC 474 Mean Cycles to Failure = 1,694,395.  
WRC 474 99% Probability Cycles = 393,623.  
0% WRC 474 95% Probability Cycles = 546,496.  
BS5500 Allowed Cycles(Curve F) = 198,887.  
Membrane-to-Bending Ratio = 0.606  
Bending-to-PL+PB+Q Ratio = 0.623  
Plot Reference:  
7) Pl+Pb+Q+F < Sa (EXP,Outside) Case 2

Membrane User Component Evaluation Load Case 2  
126 414 Plot Reference:  
MPa MPa 8) Membrane < User (OPE,Membrane) Case 2

30%

Bending User Component Evaluation Load Case 2  
129 414 Plot Reference:  
MPa MPa 9) Bending < User (OPE,Bending) Case 2

31%

Highest Stresses Per Load Case 1 1: 5:10 20 Aug 2016

Tee Crotch Area

P1	(1.5)(S)	Primary Membrane Load Case 1
168	207	Plot Reference:
MPa	MPa	1) P1 < (1.5)(S) (SUS,Membrane) Case 1

81%

Tee Crotch Area

Qb	SPS	Primary Bending Load Case 1
142	414	Plot Reference:
MPa	MPa	2) Qb < SPS (SUS,Bending) Case 1

34%

Tee Crotch Area

S1+S2+S3	4S	Part 5 (5.3.2) Load Case 1
210	552	Plot Reference:
MPa	MPa	3) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 1

37%

Tee Body

P1	(1.5)(S)	Primary Membrane Load Case 1
126	207	Plot Reference:
MPa	MPa	1) P1 < (1.5)(S) (SUS,Membrane) Case 1

60%

Tee Body

Qb	SPS	Primary Bending Load Case 1
129	414	Plot Reference:
MPa	MPa	2) Qb < SPS (SUS,Bending) Case 1

31%

Tee Body

S1+S2+S3	4S	Part 5 (5.3.2) Load Case 1
171	552	Plot Reference:
MPa	MPa	3) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 1

30%

Highest Stresses Per Load Case 2 1: 5:10 20 Aug 2016

Tee Crotch Area

Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 2
208	414	Plot Reference:
MPa	MPa	4) Pl+Pb+Q < SPS (OPE,Inside) Case 2

50%

Tee Crotch Area

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
189	414	Plot Reference:
MPa	MPa	5) Pl+Pb+Q < SPS (OPE,Outside) Case 2

45%

Tee Crotch Area

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Inner) Load Case 2
104	0.000 Life	Stress Concentration Factor = 1.000
MPa	0.008 Stress	Strain Concentration Factor = 1.000

Cycles Allowed for this Stress = 260,275.  
"B31" Fatigue Stress Allowable = 345.0  
Mark1 Fatigue Stress Allowable = 1689.2  
WRC 474 Mean Cycles to Failure = 599,503.  
WRC 474 99% Probability Cycles = 139,270.  
WRC 474 95% Probability Cycles = 193,359.  
BS5500 Allowed Cycles(Curve F) = 80,779.  
Membrane-to-Bending Ratio = 2.743  
Bending-to-PL+PB+Q Ratio = 0.267  
Plot Reference:  
6) Pl+Pb+Q+F < Sa (EXP,Inside) Case 2

Allowable  
12,236.4  
MPa

0%

Tee Crotch Area

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Outer) Load Case 2
94	0.000 Life	Stress Concentration Factor = 1.000
MPa	0.008 Stress	Strain Concentration Factor = 1.000

Cycles Allowed for this Stress = 402,206.  
"B31" Fatigue Stress Allowable = 345.0  
Mark1 Fatigue Stress Allowable = 1689.2  
WRC 474 Mean Cycles to Failure = 799,285.  
WRC 474 99% Probability Cycles = 185,681.  
WRC 474 95% Probability Cycles = 257,795.  
BS5500 Allowed Cycles(Curve F) = 107,519.  
Membrane-to-Bending Ratio = 4.984  
Bending-to-PL+PB+Q Ratio = 0.167  
Plot Reference:  
7) Pl+Pb+Q+F < Sa (EXP,Outside) Case 2

Allowable  
12,236.4  
MPa

0%

Tee Crotch Area

Highest Stresses Per Load Case 2 1: 5:10 20 Aug 2016

Membrane User Component Evaluation Load Case 2  
168 414 Plot Reference:  
MPa MPa 8) Membrane < User (OPE,Membrane) Case 2  
40%

Tee Crotch Area

Bending User Component Evaluation Load Case 2  
142 414 Plot Reference:  
MPa MPa 9) Bending < User (OPE,Bending) Case 2  
34%

Tee Body

Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 2  
138 414 Plot Reference:  
MPa MPa 4) Pl+Pb+Q < SPS (OPE,Inside) Case 2  
33%

Tee Body

Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 2  
154 414 Plot Reference:  
MPa MPa 5) Pl+Pb+Q < SPS (OPE,Outside) Case 2  
37%

Tee Body

Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Inner) Load Case 2  
69 0.000 Life Stress Concentration Factor = 1.000  
MPa 0.006 Stress Strain Concentration Factor = 1.000  
Cycles Allowed for this Stress = 39,180,460.  
Allowable "B31" Fatigue Stress Allowable = 345.0  
12,236.4 Markl Fatigue Stress Allowable = 1689.2  
MPa WRC 474 Mean Cycles to Failure = 2,140,100.  
WRC 474 99% Probability Cycles = 497,165.  
WRC 474 95% Probability Cycles = 690,251.  
BS5500 Allowed Cycles(Curve F) = 276,818.  
Membrane-to-Bending Ratio = 4.819  
Bending-to-PL+PB+Q Ratio = 0.172  
Plot Reference:  
6) Pl+Pb+Q+F < Sa (EXP,Inside) Case 2

Tee Body

Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Outer) Load Case 2



Highest Stresses Per Load Case 2

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77 0.000 Life Stress Concentration Factor = 1.000  
MPa 0.006 Stress Strain Concentration Factor = 1.000  
Cycles Allowed for this Stress = 4,738,299.  
Allowable "B31" Fatigue Stress Allowable = 345.0  
12,236.4 MPa Markl Fatigue Stress Allowable = 1689.2  
WRC 474 Mean Cycles to Failure = 1,694,395.  
WRC 474 99% Probability Cycles = 393,623.  
0% WRC 474 95% Probability Cycles = 546,496.  
BS5500 Allowed Cycles(Curve F) = 198,887.  
Membrane-to-Bending Ratio = 0.606  
Bending-to-PL+PB+Q Ratio = 0.623  
Plot Reference:  
7) P1+Pb+Q+F < Sa (EXP,Outside) Case 2

Tee Body

Membrane User Component Evaluation Load Case 2  
126 414 Plot Reference:  
MPa MPa 8) Membrane < User (OPE,Membrane) Case 2

30%

Tee Body

Bending User Component Evaluation Load Case 2  
129 414 Plot Reference:  
MPa MPa 9) Bending < User (OPE,Bending) Case 2

31%

Stress Intensification Factors

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Branch/Nozzle Sif Summary

	Peak	Primary	Secondary	SSI
Axial :	11.164	7.700	22.328	1.742
Inplane :	3.042	4.644	6.084	1.448
Outplane :	9.404	6.807	18.809	1.674
Torsion :	1.914	3.483	3.827	1.383
Pressure :	2.006	3.248	4.012	1.174

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<sub>o</sub>/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 : 609.600 mm.  
Pipe Thk: 9.525 mm.  
Z approx: 2693801.250 cu.mm.  
Z exact : 2652378.750 cu.mm.

(SSI = SIF <sup>x</sup> )	Axial	Inpl	Outpl	Tors	Pres
SIF/SSI Exponents:	0.846	1.380	0.856	1.923	1.692

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

B31.3 Branch Pressure i-factor = 6.114  
Header Pressure i-factor = 4.055

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
	3.547	Inplane
	4.396	Outplane
	1.000	Torsional
From Mark1 .....	8.023	Inplane
	10.364	Outplane
B31.1 (Branch)		
Peak Stress Sif ....	0.000	Axial
	4.396	Inplane
	4.396	Outplane
	4.396	Torsional
From Mark1 .....	8.023	Inplane

Stress Intensification Factors

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10.364

Outplane

Allowable Loads

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SECONDARY		Maximum	Conservative	Realistic
Load Type (Range):		Individual	Simultaneous	Simultaneous
		Occuring	Occuring	Occuring
Axial Force	( N )	332948.	60386.	90579.
Inplane Moment	(mm. N )	180489200.	21207612.	44988136.
Outplane Moment	(mm. N )	58381504.	7487252.	15882858.
Torsional Moment	(mm. N )	286915104.	47676996.	71515496.
Pressure	(MPa )	2.15	1.08	1.08

PRIMARY		Maximum	Conservative	Realistic
Load Type:		Individual	Simultaneous	Simultaneous
		Occuring	Occuring	Occuring
Axial Force	( N )	482748.	30255.	45382.
Inplane Moment	(mm. N )	118215720.	5238816.	11113205.
Outplane Moment	(mm. N )	80657472.	3574394.	7582434.
Torsional Moment	(mm. N )	157617984.	9878218.	14817327.
Pressure	(MPa )	1.33	1.08	1.08

NOTES:

- 1) Maximum Individual Occuring Loads are the maximum allowed values of the respective loads if all other load componets 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.

Flexibilities

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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 = 609.600 mm.  
Wall Thickness = 9.525 mm.

Axial Translational Stiffness = 100847. N /mm.  
Inplane Rotational Stiffness = 646113408. mm. N /deg  
Outplane Rotational Stiffness = 72152360. mm. N /deg  
Torsional Rotational Stiffness = 1391605376. mm. N /deg

Intersection Flexibility Factors for Branch/Nozzle

Find axial stiffness:  $K = 3EI/(kd)^3$  N /mm.  
Find bending and torsional stiffnesses:  $K = EI/(kd)$  mm. N per radian.  
The EI product is 0.16165E+15 N mm.^2  
The value of (d) to use is: 600.075 mm..  
The resulting bending stiffness is in units of force x length per radian.

Axial Flexibility Factor (k) = 2.813  
Inplane Flexibility Factor (k) = 7.277  
Outplane Flexibility Factor (k) = 65.162  
Torsional Flexibility Factor (k) = 3.379