

Notes

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 : 924.878 mm.
Tee OD at Branch : 620.078 mm.
Tee Thk at Run : 14.764 mm.
Tee Thk at Branch : 14.764 mm.
Tee Crotch Radius : 97.536 mm.
Run Fitting Length : 1346.200 mm.
Br. Fitting Length : 637.791 mm.
-side Att. Pipe (User): 4195.070 mm.
+side Att. Pipe (User): 4195.070 mm.
Branch Att. Pipe (User): 1722.700 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): 16.240 mm.
Center 45deg (User): 16.240 mm.
Center Circ. (User): 16.240 mm.
Run Long. (User): 14.764 mm.
Run 45deg (User): 15.133 mm.
Run Circ. (User): 15.502 mm.
Branch Long. (User): 16.240 mm.
Branch 45deg (User): 16.240 mm.
Branch Circ. (User): 16.240 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 0.00
Operating : 0.000 0.000 0.000 0.000 0.000 0.00
Occasional: 0.000 0.000 0.000 0.000 0.000 0.00
Thermal : 0.000 0.000 0.000 0.000 0.000 0.00

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

2: 1:10 20 Aug 2016

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

2: 1:10 20 Aug 2016

Tee Geometry

924.878 < OD Fitting at Run Pipe Connection (mm.)
620.078 < 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.)
637.791 < Fitting Height, Centerline to branch weld (mm.)

14.764 < Nominal Fitting Thickness in Run
14.764 < Nominal Fitting Thickness in Branch

Optional Tee Profile Thicknesses

16.240 < Center of Crotch, Longitudinal Plane (mm.)
16.240 < Center of Crotch, @45° (mm.)
16.240 < Center of Crotch, Circumferential Plane (mm.)

14.764 < Base of Crotch, Longitudinal Plane (mm.)
15.133 < Base of Crotch, @45° (mm.)
15.502 < Base of Crotch, Circumferential Plane (mm.)

16.240 < Top of Crotch, Longitudinal Plane (mm.)
16.240 < Top of Crotch, @45° (mm.)
16.240 < Top of Crotch, Circumferential Plane (mm.)

< Circumferential Plane, Bottom of fitting (mm.)

Attached Pipe Dimensions

Attached Pipe Dimensions

4195.070 < Left End Pipe Length (mm.)
4195.070 < Right End Pipe Length (mm.)
1722.700 < 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

2: 1:10 20 Aug 2016

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)

Input Data Echo 2: 1:10 20 Aug 2016

< 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

Input Data Echo 2: 1:10 20 Aug 2016

< 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.)
PRIMARY < Analyze Occasional Loads as (P)primary or (F)atigue
C < 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

2: 1:10 20 Aug 2016

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

2: 1:10 20 Aug 2016

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	701190.	-5345.	0.
2	701190.	-5345.	0.
3	-6.	307403056.	-20.
4	2.	0.	0.
5	1.	0.	2.
6	0.	0.	0.
7	701190.	-5345.	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

2: 1:10 20 Aug 2016

- 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

2: 1:10 20 Aug 2016

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) ...	17119.	MPa
Case 4		
Nominal Stress (M/Z) ...	116.	MPa
Case 5		
Nominal Stress (M/Z) ...	116.	MPa
Case 6		
Nominal Stress (M/Z) ...	116.	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) ...	17119.	MPa
Case 4		
Nominal Stress (M/Z) ...	116.	MPa
Case 5		
Nominal Stress (M/Z) ...	116.	MPa
Case 6		
Nominal Stress (M/Z) ...	116.	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

2: 1:10 20 Aug 2016

Expansion Stress MPa	B31 Allowable MPa	ASME Allowable MPa	Mark1 Allowable MPa	Regions / Notes
65.	345.	12236.	1689.	Tee Crotch Area Load Case 2, Inner, Plot 6
45.	345.	12236.	1689.	Tee Body Load Case 2, Outer, Plot 7

ASME Overstressed Areas

2: 1:10 20 Aug 2016

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

Highest Primary Stress Ratios

2: 1:10 20 Aug 2016

Tee Crotch Area

P1	(1.5)(S)	Primary Membrane Load Case 1
101	207	Plot Reference:
MPa	MPa	1) P1 < (1.5)(S) (SUS,Membrane) Case 1

48%

Tee Body

P1	(1.5)(S)	Primary Membrane Load Case 1
77	207	Plot Reference:
MPa	MPa	1) P1 < (1.5)(S) (SUS,Membrane) Case 1

37%

Highest Secondary Stress Ratios

2: 1:10 20 Aug 2016

Tee Crotch Area

Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 2
131	414	Plot Reference:
MPa	MPa	4) Pl+Pb+Q < SPS (OPE,Inside) Case 2

31%

Tee Body

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
90	414	Plot Reference:
MPa	MPa	5) Pl+Pb+Q < SPS (OPE,Outside) Case 2

21%

Highest Fatigue Stress Ratios

2: 1:10 20 Aug 2016

Tee Crotch Area

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Inner) Load Case 2
65	0.000 Life	Stress Concentration Factor = 1.000
MPa	0.005 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 1.2059E8
Allowable		"B31" Fatigue Stress Allowable = 345.0
12,236.4		Mark1 Fatigue Stress Allowable = 1689.2
MPa		WRC 474 Mean Cycles to Failure = 1,752,182.
		WRC 474 99% Probability Cycles = 407,048.
0%		WRC 474 95% Probability Cycles = 565,135.
		BS5500 Allowed Cycles(Curve F) = 323,713.
		Membrane-to-Bending Ratio = 2.961
		Bending-to-PL+PB+Q Ratio = 0.252
		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
45	0.000 Life	Stress Concentration Factor = 1.000
MPa	0.004 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 1.0000E11
Allowable		"B31" Fatigue Stress Allowable = 345.0
12,236.4		Mark1 Fatigue Stress Allowable = 1689.2
MPa		WRC 474 Mean Cycles to Failure = 6,344,108.
		WRC 474 99% Probability Cycles = 1,473,794.
0%		WRC 474 95% Probability Cycles = 2,046,177.
		BS5500 Allowed Cycles(Curve F) = 997,310.
		Membrane-to-Bending Ratio = 0.728
		Bending-to-PL+PB+Q Ratio = 0.579
		Plot Reference:
		7) Pl+Pb+Q+F < Sa (EXP,Outside) Case 2

Highest Stress Ratios Per Region

2: 1:10 20 Aug 2016

Tee Crotch Area

Pl	(1.5)(S)	Primary Membrane Load Case 1
101	207	Plot Reference:
MPa	MPa	1) Pl < (1.5)(S) (SUS,Membrane) Case 1
48%		
Qb	SPS	Primary Bending Load Case 1
75	414	Plot Reference:
MPa	MPa	2) Qb < SPS (SUS,Bending) Case 1
18%		
S1+S2+S3	4S	Part 5 (5.3.2) Load Case 1
124	552	Plot Reference:
MPa	MPa	3) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 1
22%		
Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 2
131	414	Plot Reference:
MPa	MPa	4) Pl+Pb+Q < SPS (OPE,Inside) Case 2
31%		
Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
103	414	Plot Reference:
MPa	MPa	5) Pl+Pb+Q < SPS (OPE,Outside) Case 2
24%		
Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Inner) Load Case 2
65	0.000 Life	Stress Concentration Factor = 1.000
MPa	0.005 Stress	Strain Concentration Factor = 1.000
Allowable		Cycles Allowed for this Stress = 1.2059E8
12,236.4		"B31" Fatigue Stress Allowable = 345.0
MPa		Mark1 Fatigue Stress Allowable = 1689.2
		WRC 474 Mean Cycles to Failure = 1,752,182.
0%		WRC 474 99% Probability Cycles = 407,048.
		WRC 474 95% Probability Cycles = 565,135.
		BS5500 Allowed Cycles(Curve F) = 323,713.
		Membrane-to-Bending Ratio = 2.961
		Bending-to-PL+PB+Q Ratio = 0.252
		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
51	0.000 Life	Stress Concentration Factor = 1.000
MPa	0.004 Stress	Strain Concentration Factor = 1.000
Allowable		Cycles Allowed for this Stress = 1.5675E10
12,236.4		"B31" Fatigue Stress Allowable = 345.0
MPa		Mark1 Fatigue Stress Allowable = 1689.2
		WRC 474 Mean Cycles to Failure = 3,702,754.
		WRC 474 99% Probability Cycles = 860,183.

Highest Stress Ratios Per Region 2: 1:10 20 Aug 2016

0%			WRC 474 95% Probability Cycles = 1,194,256. BS5500 Allowed Cycles(Curve F) = 664,460. Membrane-to-Bending Ratio = 15.705 Bending-to-PL+PB+Q Ratio = 0.060 Plot Reference: 7) Pl+Pb+Q+F < Sa (EXP,Outside) Case 2
Membrane	User		Component Evaluation Load Case 2
101	414		Plot Reference:
MPa	MPa		8) Membrane < User (OPE,Membrane) Case 2
24%			
Bending	User		Component Evaluation Load Case 2
75	414		Plot Reference:
MPa	MPa		9) Bending < User (OPE,Bending) Case 2
18%			
Tee Body			
P1	(1.5)(S)		Primary Membrane Load Case 1
77	207		Plot Reference:
MPa	MPa		1) P1 < (1.5)(S) (SUS,Membrane) Case 1
37%			
Qb	SPS		Primary Bending Load Case 1
72	414		Plot Reference:
MPa	MPa		2) Qb < SPS (SUS,Bending) Case 1
17%			
S1+S2+S3	4S		Part 5 (5.3.2) Load Case 1
105	552		Plot Reference:
MPa	MPa		3) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 1
19%			
Pl+Pb+Q	SPS		Primary+Secondary (Inner) Load Case 2
83	414		Plot Reference:
MPa	MPa		4) Pl+Pb+Q < SPS (OPE,Inside) Case 2
19%			
Pl+Pb+Q	SPS		Primary+Secondary (Outer) Load Case 2
90	414		Plot Reference:
MPa	MPa		5) Pl+Pb+Q < SPS (OPE,Outside) Case 2
21%			
Pl+Pb+Q+F	Damage Ratio		Primary+Secondary+Peak (Inner) Load Case 2
41	0.000 Life		Stress Concentration Factor = 1.000
MPa	0.003 Stress		Strain Concentration Factor = 1.000
			Cycles Allowed for this Stress = 1.0000E11

Highest Stress Ratios Per Region

2: 1:10 20 Aug 2016

Allowable		"B31" Fatigue Stress Allowable = 345.0
12,236.4		Mark1 Fatigue Stress Allowable = 1689.2
MPa		WRC 474 Mean Cycles to Failure = 7,419,715.
		WRC 474 99% Probability Cycles = 1,723,667.
0%		WRC 474 95% Probability Cycles = 2,393,095.
		BS5500 Allowed Cycles(Curve F) = 1,275,575.
		Membrane-to-Bending Ratio = 3.052
		Bending-to-PL+PB+Q Ratio = 0.247
		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
45	0.000 Life	Stress Concentration Factor = 1.000
MPa	0.004 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 1.0000E11
Allowable		"B31" Fatigue Stress Allowable = 345.0
12,236.4		Mark1 Fatigue Stress Allowable = 1689.2
MPa		WRC 474 Mean Cycles to Failure = 6,344,108.
		WRC 474 99% Probability Cycles = 1,473,794.
0%		WRC 474 95% Probability Cycles = 2,046,177.
		BS5500 Allowed Cycles(Curve F) = 997,310.
		Membrane-to-Bending Ratio = 0.728
		Bending-to-PL+PB+Q Ratio = 0.579
		Plot Reference:
		7) Pl+Pb+Q+F < Sa (EXP,Outside) Case 2
Membrane	User	Component Evaluation Load Case 2
77	414	Plot Reference:
MPa	MPa	8) Membrane < User (OPE,Membrane) Case 2
		18%
Bending	User	Component Evaluation Load Case 2
72	414	Plot Reference:
MPa	MPa	9) Bending < User (OPE,Bending) Case 2
		17%

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

Tee Crotch Area

P1	(1.5)(S)	Primary Membrane Load Case 1
101	207	Plot Reference:
MPa	MPa	1) P1 < (1.5)(S) (SUS,Membrane) Case 1

48%

Tee Crotch Area

Qb	SPS	Primary Bending Load Case 1
75	414	Plot Reference:
MPa	MPa	2) Qb < SPS (SUS,Bending) Case 1

18%

Tee Crotch Area

S1+S2+S3	4S	Part 5 (5.3.2) Load Case 1
124	552	Plot Reference:
MPa	MPa	3) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 1

22%

Tee Body

P1	(1.5)(S)	Primary Membrane Load Case 1
77	207	Plot Reference:
MPa	MPa	1) P1 < (1.5)(S) (SUS,Membrane) Case 1

37%

Tee Body

Qb	SPS	Primary Bending Load Case 1
72	414	Plot Reference:
MPa	MPa	2) Qb < SPS (SUS,Bending) Case 1

17%

Tee Body

S1+S2+S3	4S	Part 5 (5.3.2) Load Case 1
105	552	Plot Reference:
MPa	MPa	3) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 1

19%

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

Tee Crotch Area

Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 2
131	414	Plot Reference:
MPa	MPa	4) Pl+Pb+Q < SPS (OPE,Inside) Case 2

31%

Tee Crotch Area

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
103	414	Plot Reference:
MPa	MPa	5) Pl+Pb+Q < SPS (OPE,Outside) Case 2

24%

Tee Crotch Area

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Inner) Load Case 2
65	0.000 Life	Stress Concentration Factor = 1.000
MPa	0.005 Stress	Strain Concentration Factor = 1.000

Allowable
12,236.4
MPa

0%

Cycles Allowed for this Stress = 1.2059E8
"B31" Fatigue Stress Allowable = 345.0
Mark1 Fatigue Stress Allowable = 1689.2
WRC 474 Mean Cycles to Failure = 1,752,182.
WRC 474 99% Probability Cycles = 407,048.
WRC 474 95% Probability Cycles = 565,135.
BS5500 Allowed Cycles(Curve F) = 323,713.
Membrane-to-Bending Ratio = 2.961
Bending-to-PL+PB+Q Ratio = 0.252
Plot Reference:
6) Pl+Pb+Q+F < Sa (EXP,Inside) Case 2

Tee Crotch Area

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Outer) Load Case 2
51	0.000 Life	Stress Concentration Factor = 1.000
MPa	0.004 Stress	Strain Concentration Factor = 1.000

Allowable
12,236.4
MPa

0%

Cycles Allowed for this Stress = 1.5675E10
"B31" Fatigue Stress Allowable = 345.0
Mark1 Fatigue Stress Allowable = 1689.2
WRC 474 Mean Cycles to Failure = 3,702,754.
WRC 474 99% Probability Cycles = 860,183.
WRC 474 95% Probability Cycles = 1,194,256.
BS5500 Allowed Cycles(Curve F) = 664,460.
Membrane-to-Bending Ratio = 15.705
Bending-to-PL+PB+Q Ratio = 0.060
Plot Reference:
7) Pl+Pb+Q+F < Sa (EXP,Outside) Case 2

Tee Crotch Area

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

Membrane User Component Evaluation Load Case 2
101 414 Plot Reference:
MPa MPa 8) Membrane < User (OPE,Membrane) Case 2
24%

Tee Crotch Area

Bending User Component Evaluation Load Case 2
75 414 Plot Reference:
MPa MPa 9) Bending < User (OPE,Bending) Case 2
18%

Tee Body

Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 2
83 414 Plot Reference:
MPa MPa 4) Pl+Pb+Q < SPS (OPE,Inside) Case 2
19%

Tee Body

Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 2
90 414 Plot Reference:
MPa MPa 5) Pl+Pb+Q < SPS (OPE,Outside) Case 2
21%

Tee Body

Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Inner) Load Case 2
41 0.000 Life Stress Concentration Factor = 1.000
MPa 0.003 Stress Strain Concentration Factor = 1.000
Cycles Allowed for this Stress = 1.0000E11
Allowable "B31" Fatigue Stress Allowable = 345.0
12,236.4 Markl Fatigue Stress Allowable = 1689.2
MPa WRC 474 Mean Cycles to Failure = 7,419,715.
WRC 474 99% Probability Cycles = 1,723,667.
WRC 474 95% Probability Cycles = 2,393,095.
BS5500 Allowed Cycles(Curve F) = 1,275,575.
Membrane-to-Bending Ratio = 3.052
Bending-to-PL+PB+Q Ratio = 0.247
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 2: 1:10 20 Aug 2016

45	0.000 Life	Stress Concentration Factor = 1.000
MPa	0.004 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 1.0000E11
Allowable		"B31" Fatigue Stress Allowable = 345.0
12,236.4		Markl Fatigue Stress Allowable = 1689.2
MPa		WRC 474 Mean Cycles to Failure = 6,344,108.
		WRC 474 99% Probability Cycles = 1,473,794.
0%		WRC 474 95% Probability Cycles = 2,046,177.
		BS5500 Allowed Cycles(Curve F) = 997,310.
		Membrane-to-Bending Ratio = 0.728
		Bending-to-PL+PB+Q Ratio = 0.579
		Plot Reference:
		7) P1+Pb+Q+F < Sa (EXP,Outside) Case 2

Tee Body

Membrane	User	Component Evaluation Load Case 2
77	414	Plot Reference:
MPa	MPa	8) Membrane < User (OPE,Membrane) Case 2

18%

Tee Body

Bending	User	Component Evaluation Load Case 2
72	414	Plot Reference:
MPa	MPa	9) Bending < User (OPE,Bending) Case 2

17%

Stress Intensification Factors

2: 1:10 20 Aug 2016

Branch/Nozzle Sif Summary

	Peak	Primary	Secondary	SSI
Axial :	7.139	3.415	14.277	1.572
Inplane :	1.624	2.471	3.249	1.175
Outplane :	5.641	2.864	11.282	1.489
Torsion :	1.019	1.906	2.037	1.009
Pressure :	1.263	1.955	2.526	1.055

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_o/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 ^x)	Axial	Inpl	Outpl	Tors	Pres
SIF/SSI Exponents:	0.625	1.864	0.608	34.878	2.871

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

B31.3 Branch Pressure i-factor = 3.849
 Header Pressure i-factor = 2.553

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	3.444	Inplane
	4.259	Outplane

B31.1 (Branch)

Peak Stress Sif	0.000	Axial
	4.396	Inplane
	4.396	Outplane
	4.396	Torsional

From Mark1	3.444	Inplane
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Stress Intensification Factors

2: 1:10 20 Aug 2016

4.259

Outplane

Allowable Loads

2: 1:10 20 Aug 2016

SECONDARY		Maximum	Conservative	Realistic
Load Type (Range):		Individual	Simultaneous	Simultaneous
		Occuring	Occuring	Occuring
Axial Force	(N)	520681.	130443.	195664.
Inplane Moment	(mm. N)	337988256.	54512680.	115638856.
Outplane Moment	(mm. N)	97329096.	17241548.	36574844.
Torsional Moment	(mm. N)	538980608.	131529368.	197294048.
Pressure	(MPa)	3.41	1.08	1.08

PRIMARY		Maximum	Conservative	Realistic
Load Type:		Individual	Simultaneous	Simultaneous
		Occuring	Occuring	Occuring
Axial Force	(N)	1088484.	185493.	278240.
Inplane Moment	(mm. N)	222220208.	26777778.	56804244.
Outplane Moment	(mm. N)	191706016.	23100784.	49004160.
Torsional Moment	(mm. N)	288031488.	49084672.	73627008.
Pressure	(MPa)	2.21	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

2: 1:10 20 Aug 2016

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 = 256823. N /mm.
Inplane Rotational Stiffness = 1097447808. mm. N /deg
Outplane Rotational Stiffness = 128281376. mm. N /deg
Torsional Rotational Stiffness = 2636375296. 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) = 2.060
Inplane Flexibility Factor (k) = 4.284
Outplane Flexibility Factor (k) = 36.651
Torsional Flexibility Factor (k) = 1.783