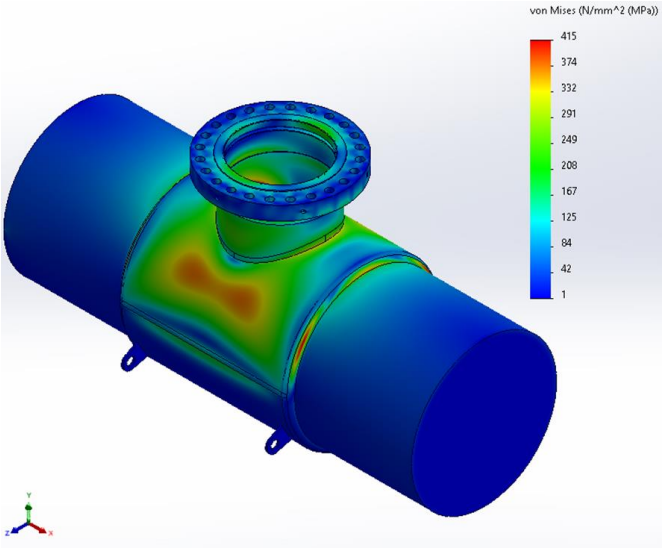
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Mechanical calculation



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Project number:	Client: TotalEnergies
OE25026	
Document:	Developed by: propipe
Technical Report	
Document number:	
OE25026-RP-PRO-STOPPLE-001	

Project name:

MECHANICAL CALCULATION FOR THREE STOPPLE FITTINGS W/FLOW THROUGT PLUG OF *24" X 42"*, *12" X 16"* AND *12" X 14"*

Document title:

NUMERICAL ANALYSIS (FINITE ELEMENT ANALYSIS) AS PER ASME CODE, SECTION VIII DIV.2

Rev	Date	Description	Developed	Checked	Approved
RA	24/06/25	Issued for comments	RFF	LAH	JOT

propipe

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1 Project Description

As requested by the company **PROPIPE HOLDING GROUP**, the scope of work is as follows: **Mechanical calculation of three Hot tap fittings: 24" x 42", 12" x 16" and 12" x 14"- 600# - LS Stopple fitting w/flow through plug.**

To complement the design rules specified in the ASME B31.8 code and to provide a more accurate evaluation of the induced stresses, this report presents the Finite Element Analysis of the components in accordance with ASME VIII Div. 2 Ed. 2023, Part 5 Design by Analysis.

2 Executive summary

Based on the conducted studies and applied premises, it can be concluded that the three Diameter-Stopple fittings comply with the code requirements for membrane, bending, and localized stresses.

3 Information received

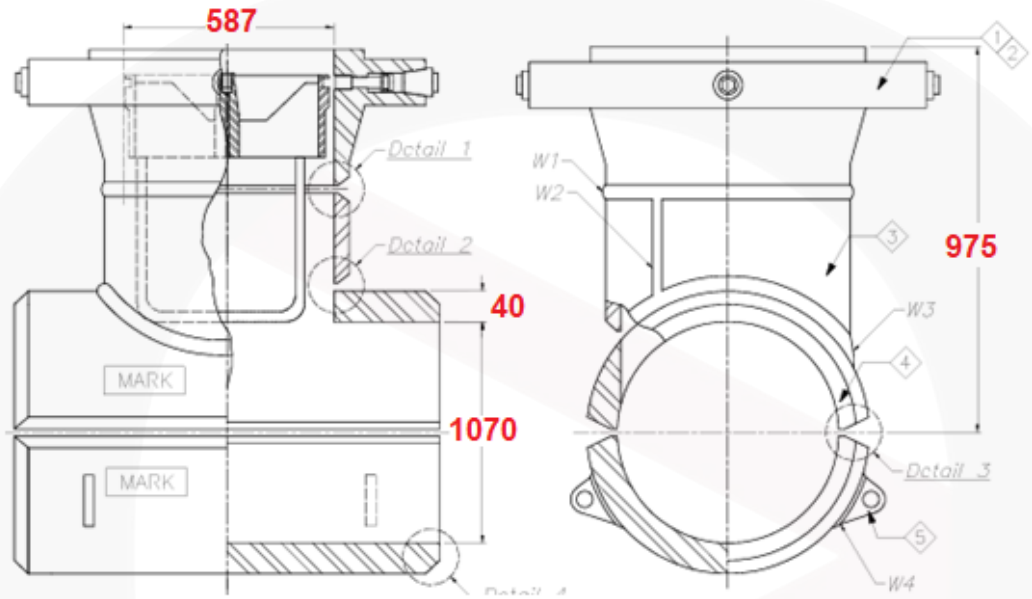
The information provided by the client to carry out this analysis is as follows.

Item	Document	Description	Rev
1	24-338 R031	General stopple drawing	3
2	PLF-2460-01-WT16 R00	24"-Flange drawing	0
3	PLF-1260-01 R00	12"-Flange drawing	0
4	IQ-GMP-40-GA01-389010	Datasheet Split tee - IFC	1
5	IQ-GMP-40-GA01-400009 PKG D	FEA Specification	0

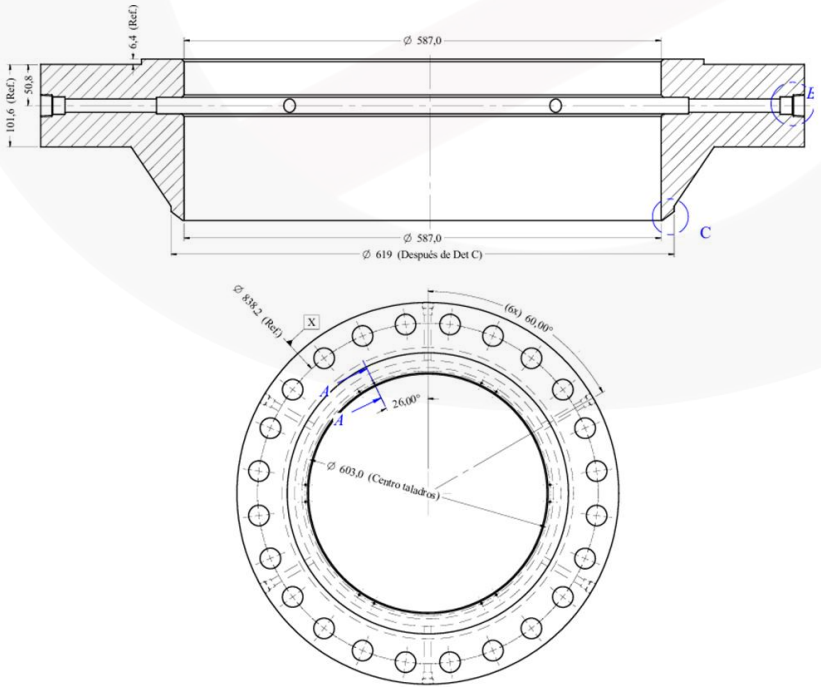
4 2D general dimensions

The following images show the general layouts of the parts used for the calculation of **the three diameter Stopple Fitting**:

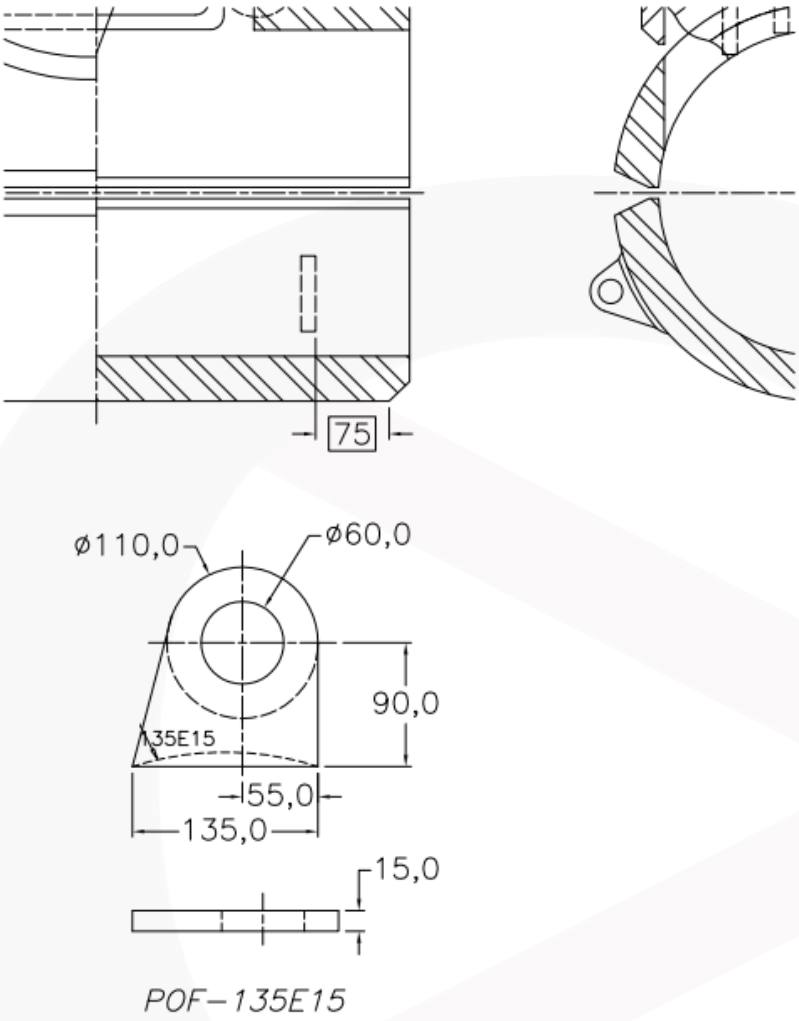
A. 24" 600# x 42" Hot Tap Fitting



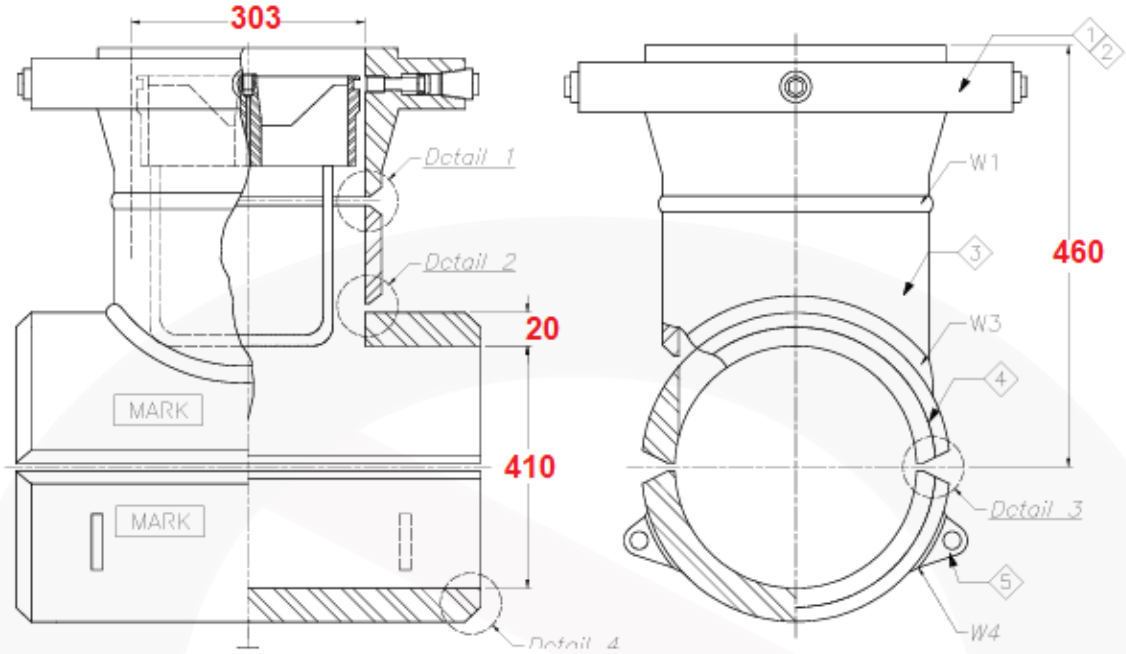
B. 24"-600#-Flange



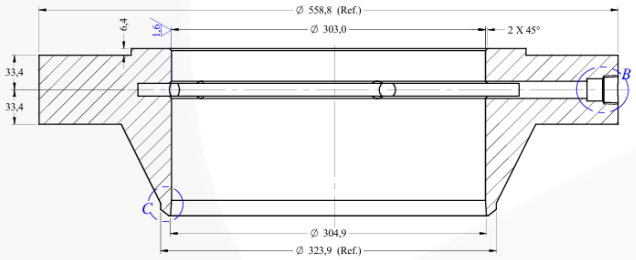
C. Lifting lugs detail (Typ.)

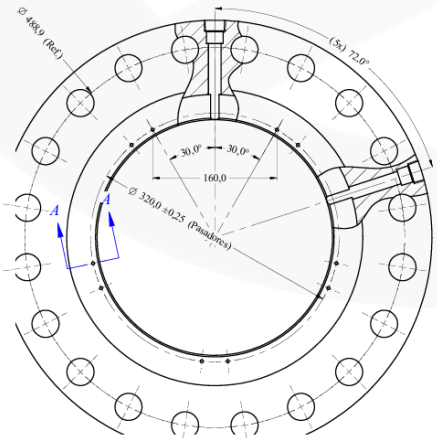


D. 12” 600# x 16” Hot Tap Fitting

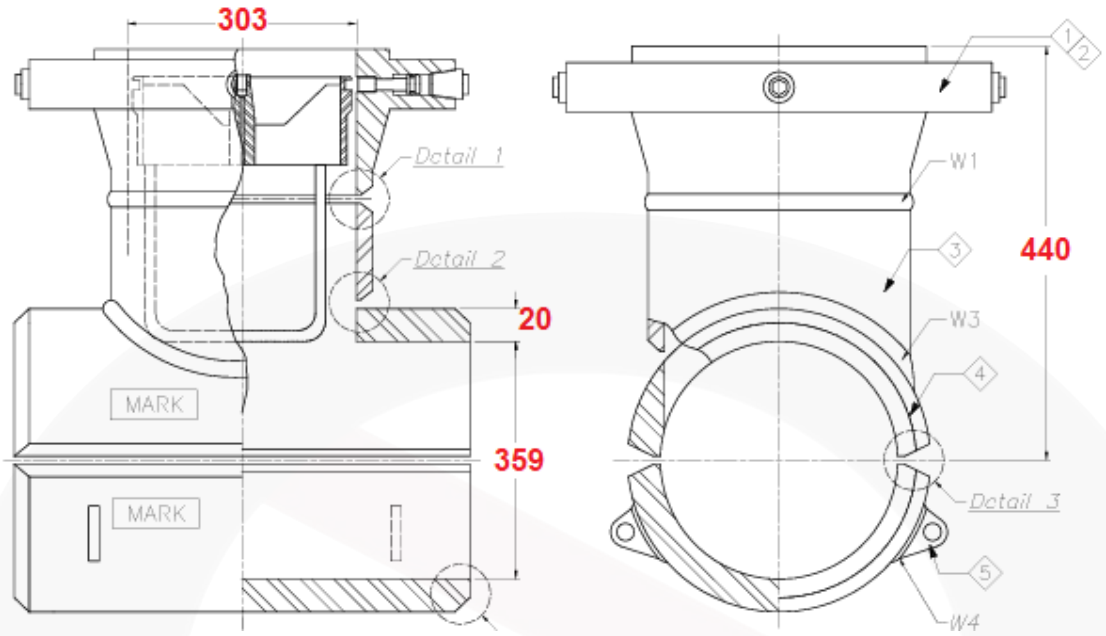


E. 12”-600#-Flange

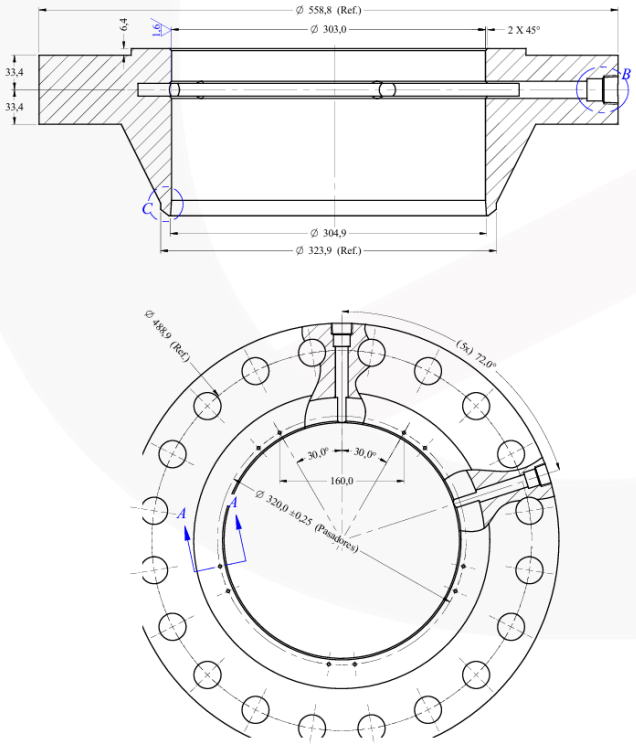




F. 12” 600# x 14” Hot Tap Fitting



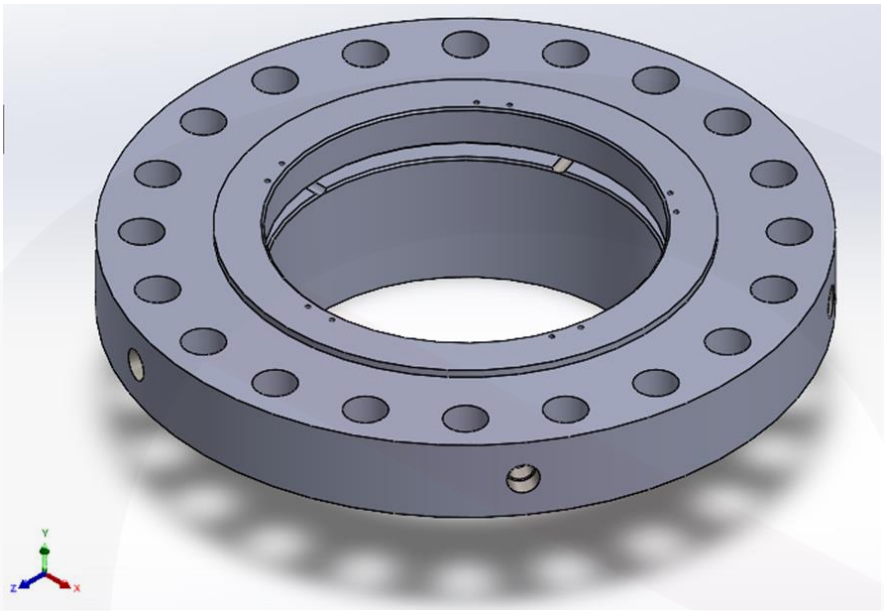
G. 12”-600#-Flange



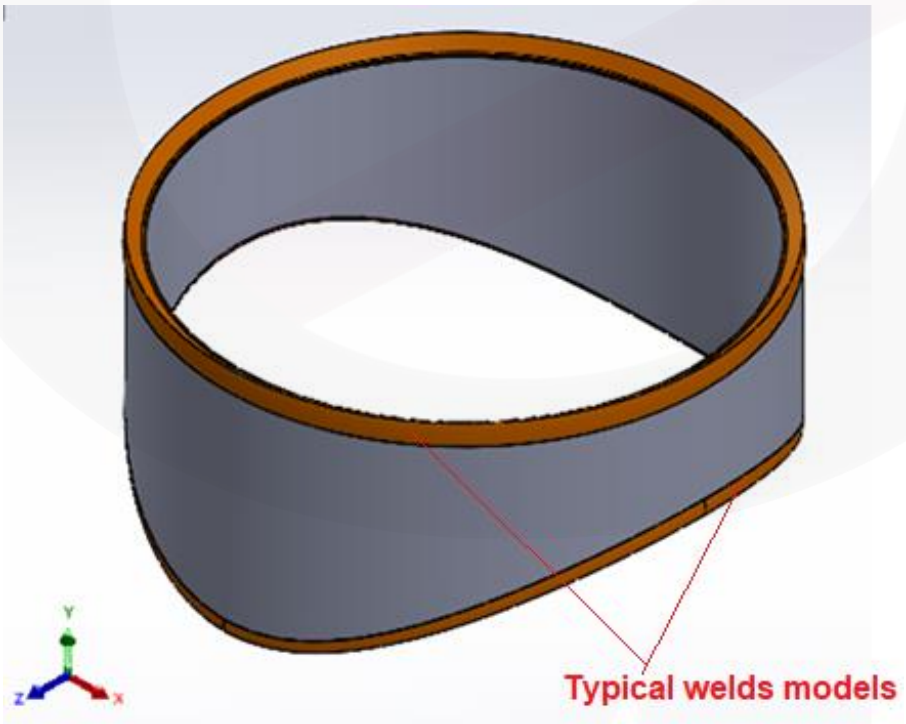
5 3D model parts for FEA assembly analysis

The following images show the 3D model parts of the **24" x 42", 12" x 16",** and **12" x 14" diameter Stopple Fittings:"**

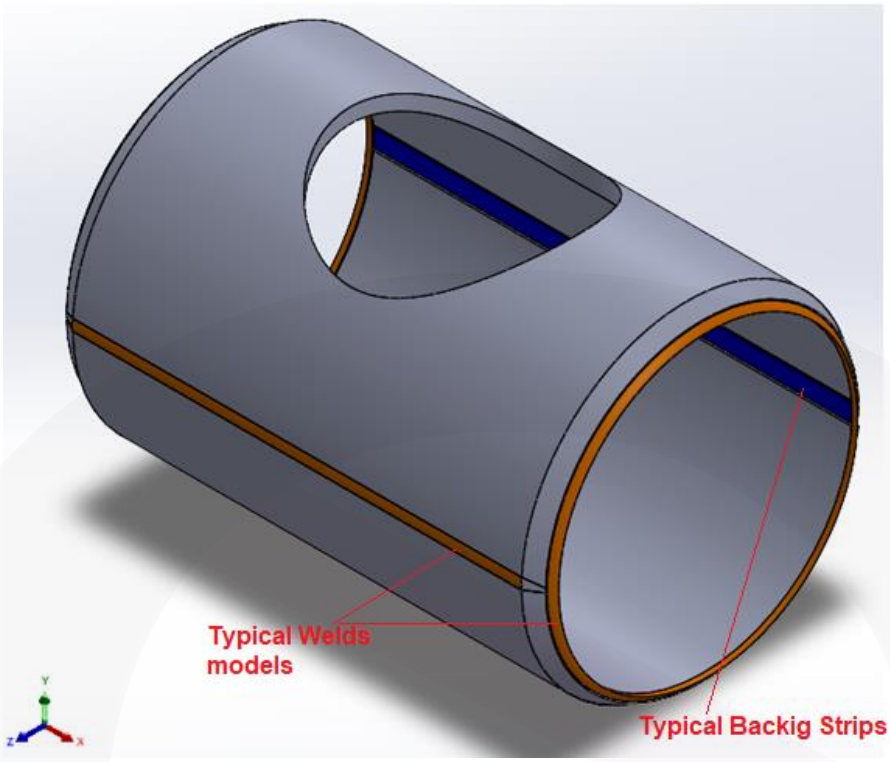
A. ***Flange mark 1*** *(two parts with different dimensions, shown only one as reference)*



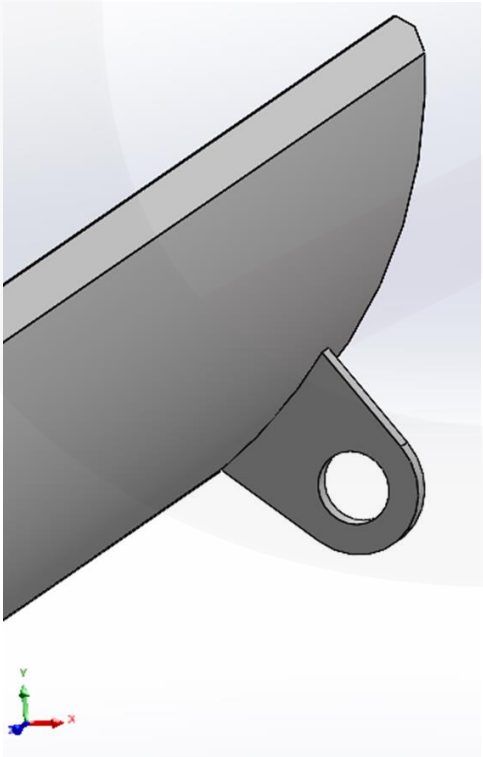
B. ***Branch (neck) mark 3*** *(three parts with different dimensions, shown only one as reference)*



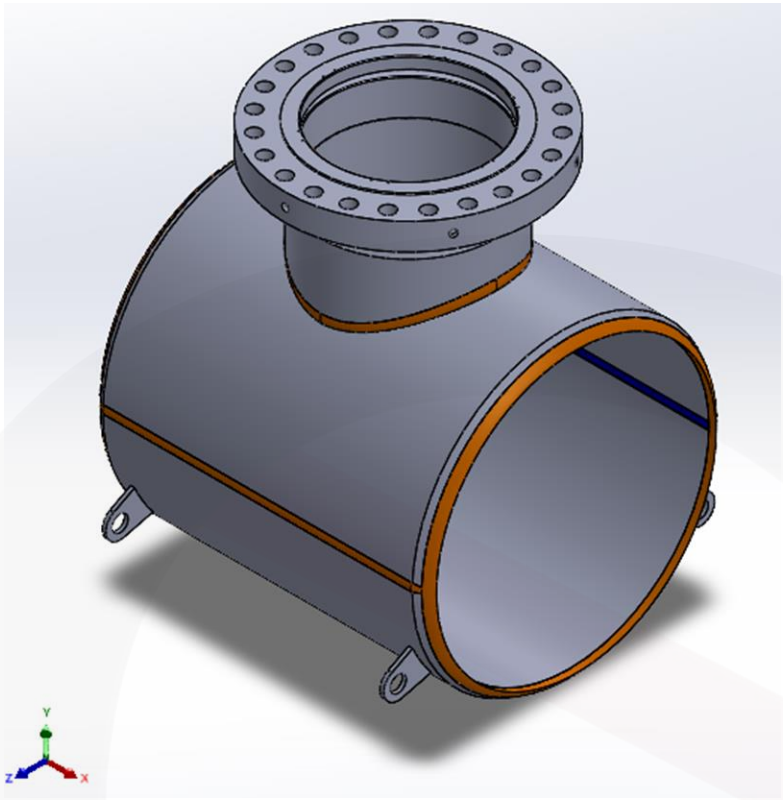
C. *Run mark 4, 6 (three parts with different dimensions, shown only one as reference)*

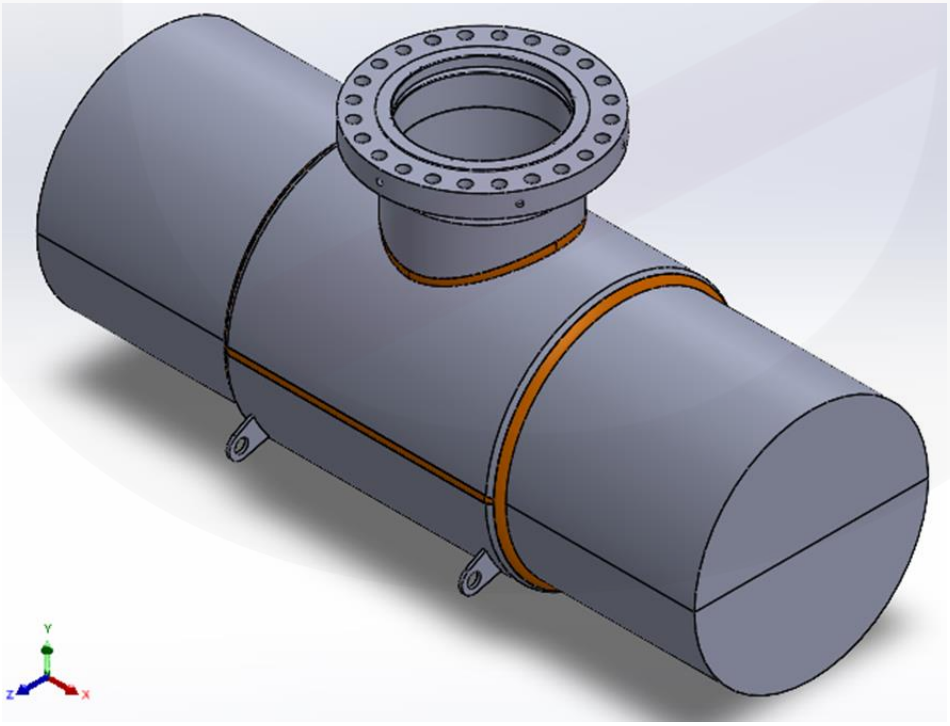


D. *Lifting lugs mark 5 (three parts with different dimensions, shown only one as reference)*



E. ***Stopple Fitting assembly and a portion of existing pipeline*** *(three parts with different dimensions, shown only one as reference)*





Three different Ø"- 600# LS Stopple Fittings and a portion of the existing pipeline, 3D models

6 Design, proposed calculation conditions and assumptions for the analysis

Based on the information received, as indicated in **section 3** of this document, and the communications maintained, the data and proposed conditions for the ***three Hot Tap - 600# LS Stopple Fittings*** analysis are described in the following sections.

6.1 General main design conditions for Hot Tap 42" x 24" Gas Pipeline

- Pipeline diameter: **42", 14.3 mm thickness.**
- Ambient temperature: **0 ºC**
- Desing temperature: **85 ºC**
- Desing pressure: **94 barg**
- Hydrostatic test pressure: **141 barg at 30 ºC.**
- Test fluid: Water, SG=1
- Calculation of fluid density: **Not considered, as gas fluid is very lightweight.**
- Main dimensions of the flanges ***ANSI/ASME 16.5***.
- Insulated line not applied.
- Verification code: **ASME VIII DIV 2 Part 5**
- Additional loads applied to the calculation on ***24"- 600# LS Stopple Fitting***
    a. Dead weight Tapping Machine Equipment: ***5000 Kg***
    b. Torque for cutting***:10000 Nm.***

Materials 42" x 24"

Item numbers on material table below according to the drawing ***ACRC-4224-60LS-FT***:

COMPONENTS HOT TAP FITTING – LS FLOW THROUGH PLUG				
Mark	Description	Standard	Materia	Remarks
1	LS Flange	ASME B16.5	A694 F60 (1)(2)(4)(8)	
2	Flow Through Plug w/pig Guide bars	PROPIPE	P355N (1)(4)	
3	Reduced Split tee	ASME B31.8/4 MSS SP75	P460 NL2(1)(4)(9) (EN-10028-3)	
4				
5	Lifting Lug	PROPIPE	A516 Gr60	wt = 15 mm
6	Backing Strip		S235 (EN-10025-2)	wt=2 mm, width=25 mm, length="L"

All materials and its characteristics are homologated in accordance with the rules ***ASME BPVC Section II Part D***

6.2 General main design conditions for Hot Tap 12” x 16” and 12” x 14” Gas Pipeline

- Pipeline diameter: **16”, 9.5 mm thickness.**
- Pipeline diameter: **14”, 6.35 mm thickness.**
- Ambient temperature: **0 ºC**
- Desing temperature: **80 ºC**
- Desing pressure: **94 barg**
- Hydrostatic test pressure: **141 barg at 30 ºC.**
- Test fluid: Water, SG=1
- Calculation of fluid density: **Not considered, as gas fluid is very lightweight.**
- Main dimensions of the flanges *ANSI/ASME 16.5*.
- Insulated line not applied.
- Verification code: **ASME VIII DIV 2 Part 5**
- Additional loads applied to the calculation on *12”- 600# LS Stopple Fitting*
    c. Dead weight Tapping Machine Equipment: *2600 Kg*
    d. Torque for cutting*:10000 Nm.*

Materials 12” x 16” and 12” x 14”

- **12” x 16”** Item numbers on material table below according to *ACRC-1612-60LS-FT*:

COMPONENTS HOT TAP FITTING – LS FLOW THROUGH PLUG				
Mark	Description	Standard	Material	Remarks
1	LS Flange	ASME B16.5	A694 F60 (1)(2)(4)(8) 3	
2	Fow Through Plug w/pig Guide bars	PROPIPE	P355N (EN-10216-3) (1)(4)	
4	Reduced Split tee	ASME B31.8/4 MSS SP75	P460 NL2(1)(4)(9) (EN-10028-3) 3A	
3			API5L x60 (4) 3	
5	Lifting Lug	PROPIPE	A516 Gr60	wt = 15 mm
6	Backing Strip		S235 (EN-10025-2)	wt=2 mm, width=25 mm, length="L"

- **12” x 14”** Item numbers on material table below according to *ACRC-1412-60LS-FT*:

COMPONENTS HOT TAP FITTING – LS FLOW THROUGH PLUG				
Mark	Description	Standard	Material	Remarks
1	LS Flange	ASME B16.5	A694 F60 (1)(2)(4)(8) 3	
2	Fow Through Plug w/pig Guide bars	PROPIPE	P355N (EN-10216-3) (1)(4)	
4	Reduced Split tee	ASME B31.8/4 MSS SP75	P460 NL2(1)(4)(9)(EN-10028-3) 3A	
3			API5L x60 (4) 3	
5	Lifting Lug	PROPIPE	A516 Gr60	wt = 15 mm
6	Backing Strip		S235 (EN-10025-2)	wt=2 mm, width=25 mm, length="L"

All materials and its characteristics are homologated in accordance with the rules *ASME BPVC Section II Part D*

6.3 Pipeline materials for Ø: 42”, 16” and 14”

CONNECTING PIPE DETAILS					
Existing Pipe Specification			Branch Pipe Specification		
Material	Nominal Diameter	Thickness, mm	Material	Nominal Diameter	Thickness, mm
API 5L X60, PSL2, SAWL, 3LPE Coated	42"	14.3 mm (Note-9)	API 5L X60, PSL2, SAWL	24"	14.3 mm

CONNECTING PIPE DETAILS					
Existing Pipe Specification			Branch Pipe Specification		
Material	Nominal Diameter	Thickness, mm	Material	Nominal Diameter	Thickness, mm
API 5L X60, PSL2, SAWL, 3LPE Coated	16"	9.5 mm (Note-9)	API 5L X52, PSL2, SMLS	12"	9.53mm

CONNECTING PIPE DETAILS					
Existing Pipe Specification			Branch Pipe Specification		
Material	Nominal Diameter	Thickness, mm	Material	Nominal Diameter	Thickness, mm
API 5L X52	14"	6.35 / 7.1 mm (Note-9)	API 5L X52, PSL2, SMLS	12"	9.53mm

6.4 General conditions and assumptions for the FEA Analysis

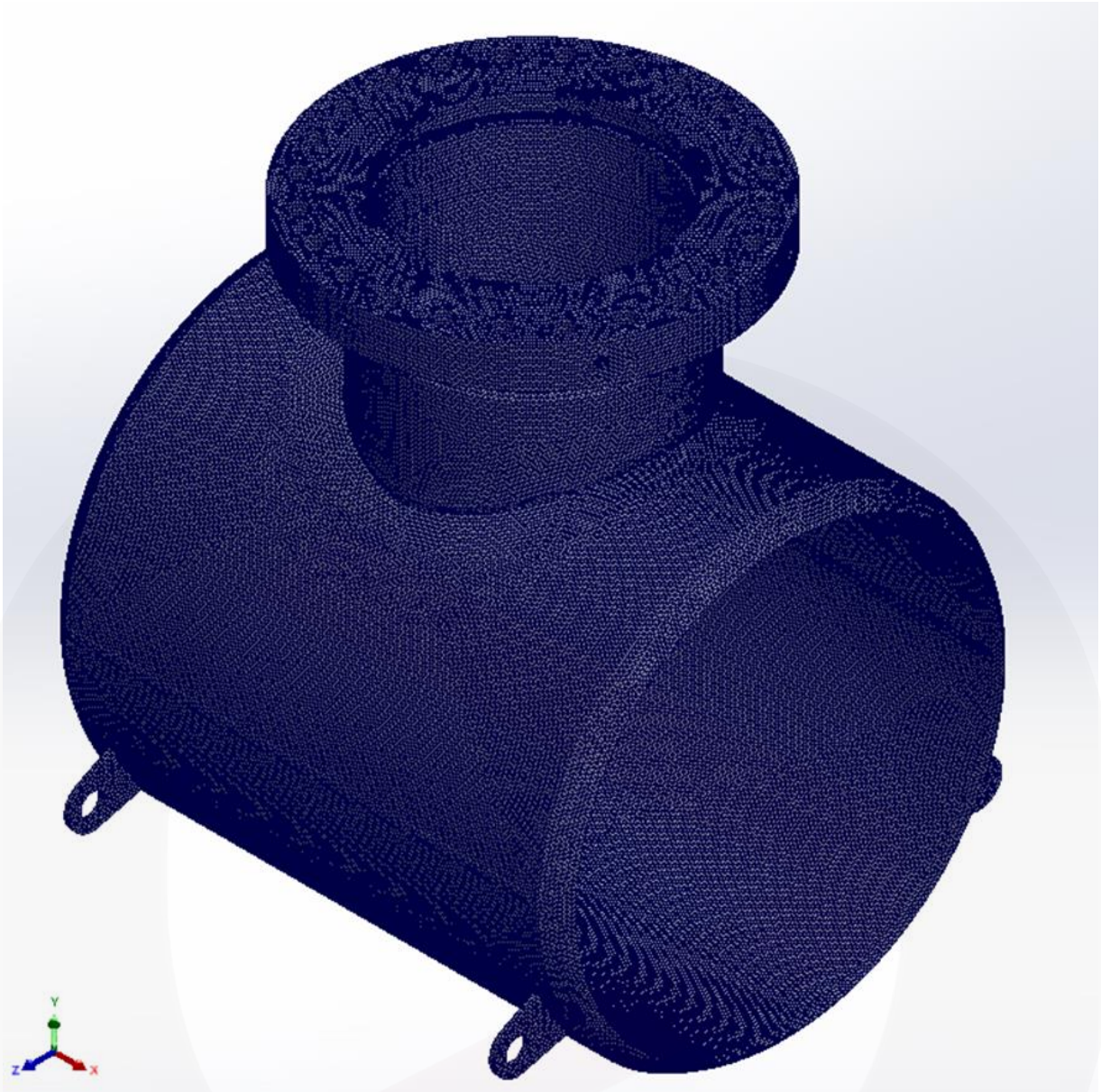
- Calculation code: **ASME VIII-2, part 5.5.2.1 and 5.3.2**
- Calculation according to the pressure-temperature conditions as specified in **table 5.3** and **document Nº IQ-GMP-40-GA01-389010**
- Maximum corrosion allowance per **document Nº IQ-GMP-40-GA01-389010**
- Carbon steel average density materials: **7800 kg/m^3**
- Internal weight as calculation part volume and density.
- Applied external nozzles loads for this study:
  - Hot tap Machine dead weight and cutting torque action.
- Thermal considerations at **T = Maximum design**:
  - **Linear thermal distribution assumed between max design temperature and ambient.**
  - **Free convection coefficient around all the fitting and underground pipeline; 4 W/(m^2 ˚K)**

6.5 3D model Mesh configuration

The following images show the ***typical 3D model*** mesh for the ***three diameter Stopple Fittings***, which are essential for performing the FEA analysis (*only one of the three is shown):*



3D Mesh model of the Hot Tap 42" x 24"

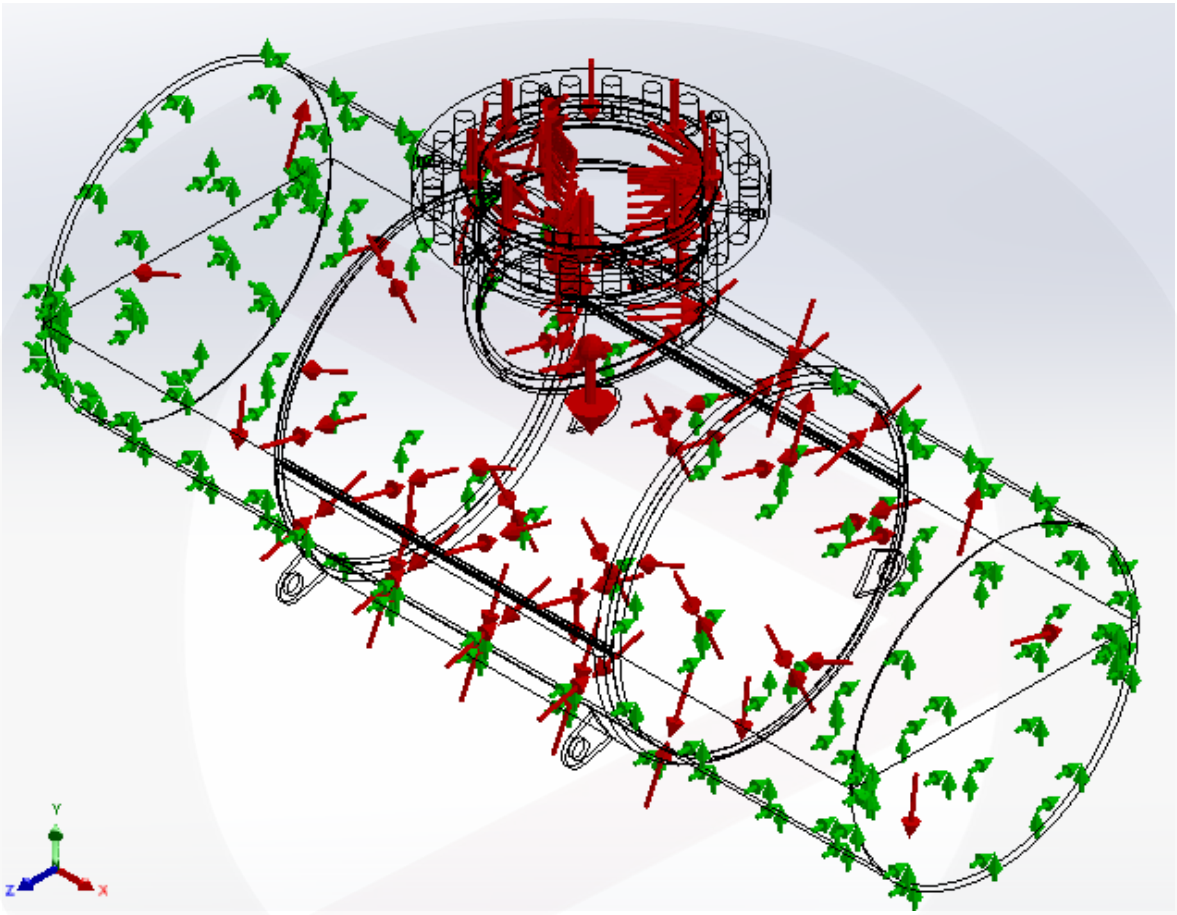


3D Mesh detail of the Hot Tap 42” x 24”

6.6 Typical boundary conditions and applied loads on Stopple Fittings

The following general boundary conditions were applied to the FEA analysis:

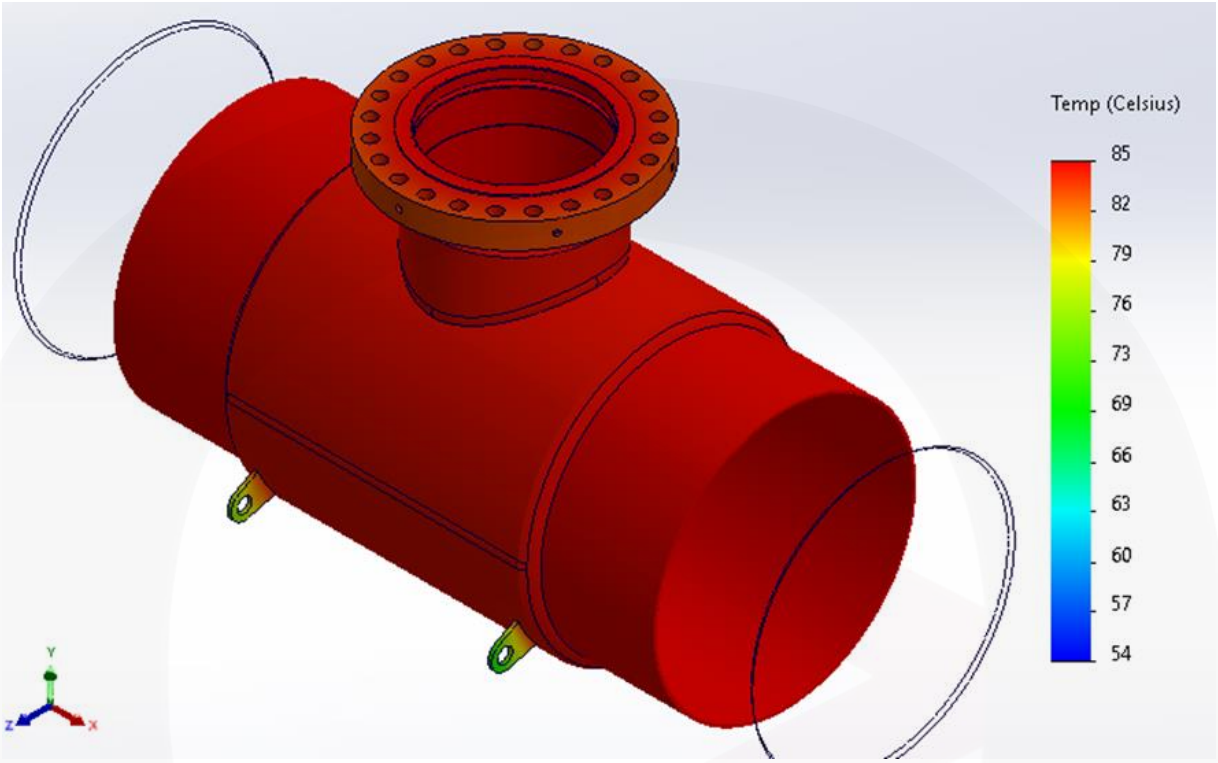
- ✓ Gravity force
- ✓ Internal pressure
- ✓ Temperature
- ✓ Dead hot tap cutting machine
- ✓ Torque of the hot tap machine at moment of cutting procedure
- ✓ Translational restriction at pipeline and internal pressure for the typical Stopple fittings



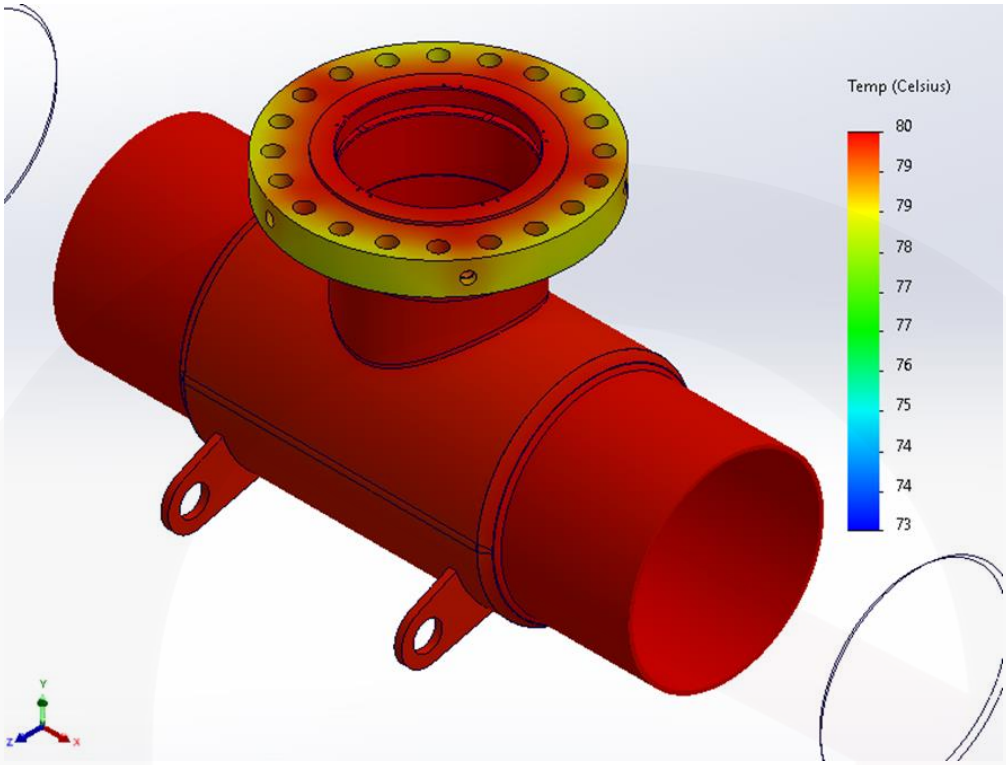
6.7 Temperature distribution for the three different Stopple fittings

The general thermal distribution for the design conditions was calculated to include the thermal load condition, the corresponding load pressure, and the dead load of the cutting hot tap machine. The following images show each distribution:

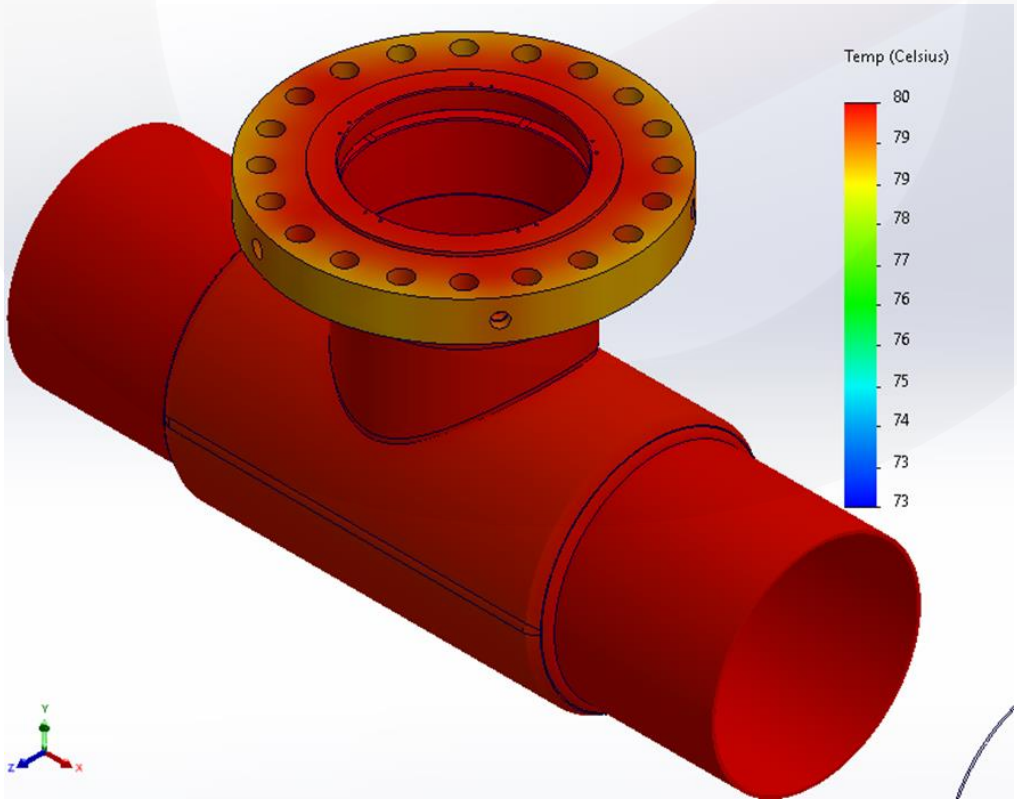
- 42” x 24” - 600# LS Stopple Fitting, 3D models design temperature distribution



- 16” x 12” - 600# LS Stopple Fitting, 3D models design temperature distribution



14” x 12” - 600# LS Stopple Fitting, 3D models design temperature distribution



7 Calculation methodology

The methodology followed for the analysis is as detailed in ***section 5.2.2*** of ***ASME VIII Division 2***, including the assessment procedure in ***paragraph 5.2.2.4 for protection against plastic collapse and Paragraph 5.3.2 for protection against local failure***.

7.1 FEA Load cases for the equipment stress assessment

The following table summarizes the combination of the different ***Temperature-Pressure*** loads on the ***Stopple fitting*** applied to estimate the stress between the Stopple fitting and the hole on the pipeline, under the finite element analysis technique (FEA).

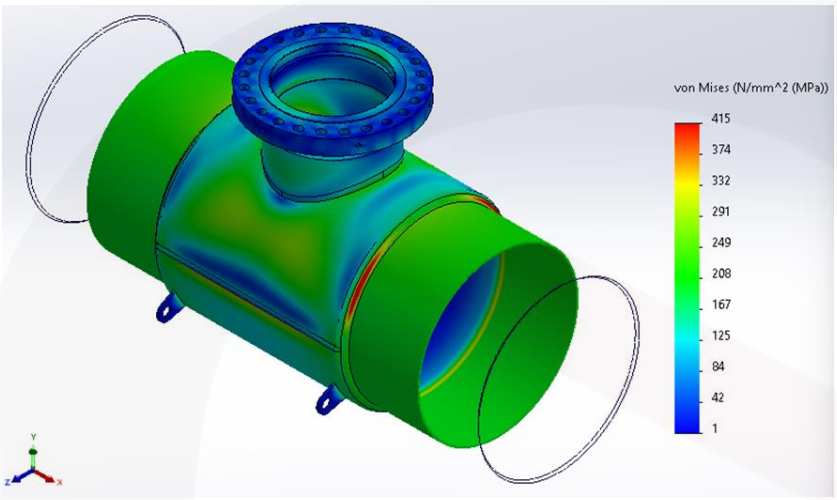
LOAD CASES COMBINATION ACCORGING TO ASME VIII DIV. 2, PART 5, TABLE 5.3		
FEA - Load cases according to table 5.3 VIII Div. 2	**ASME VIII DIV. 2 load combinations**	**Design loads**
3	P+D+external loads+T	P_m
		P_L
		$P_L + P_b$
18	Pt+Ps+D+0,6W_{PT}	$P_L + P_b$+Q
FEA 3 Linearization, design plus external loads	For (P+D+external loads+T)	Pm, P_L, P_L+P_b
FEA 18 Linearization, Test condition	For (Pt+Ps+D+0,6WPT)	Pm, Pm+P_b
LOADS		
P	Design pressure	
D	Deadweight	
T	Design Temperature	
Stresses		
Pm	General primary membrane	
PL	Local primary membrane	
Pb	Bending	
Q	Secondary stress	
PL+Pb	Local primary membrane plus Bending	
PL+Pb+Q	Range of Primary plus Secondary Q	

Note: ***FEA Internal load cases numbering 1 thermal, 2 Desing condition plus thermal, 3 Test condition, 4 and 5 FEA linearization.***

8 Maximum FEA response for each fitting dimension during hot tapping operation.

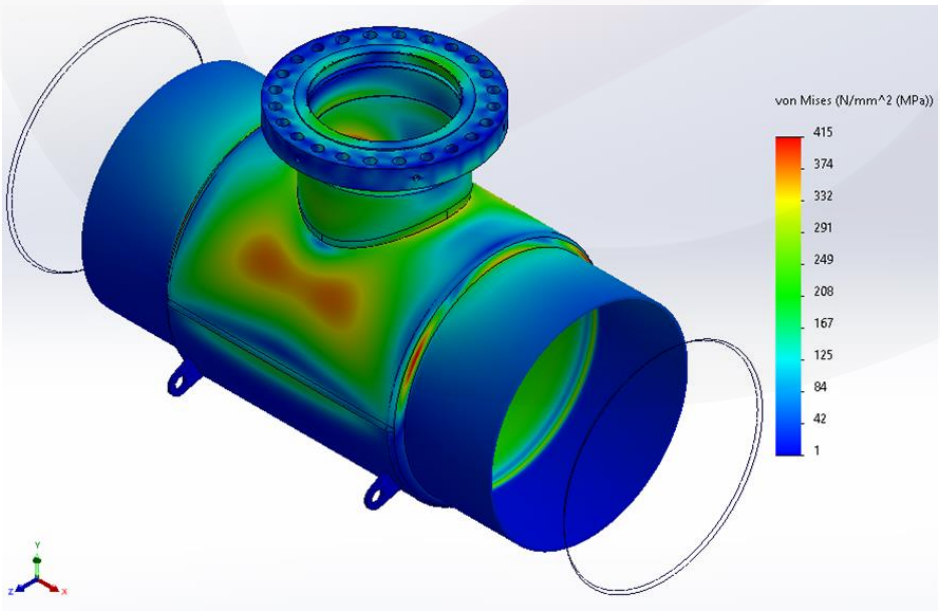
The FEA analysis was conducted to obtain the ***maximum equivalent Von Mises stress*** response, according to the load condition combinations specified in ***ASME VIII Division 2, Table 5.3***, for the cutting hole and test conditions. Below are the relevant results.

A. *42" x 24" Von Mises stress distribution and design condition*



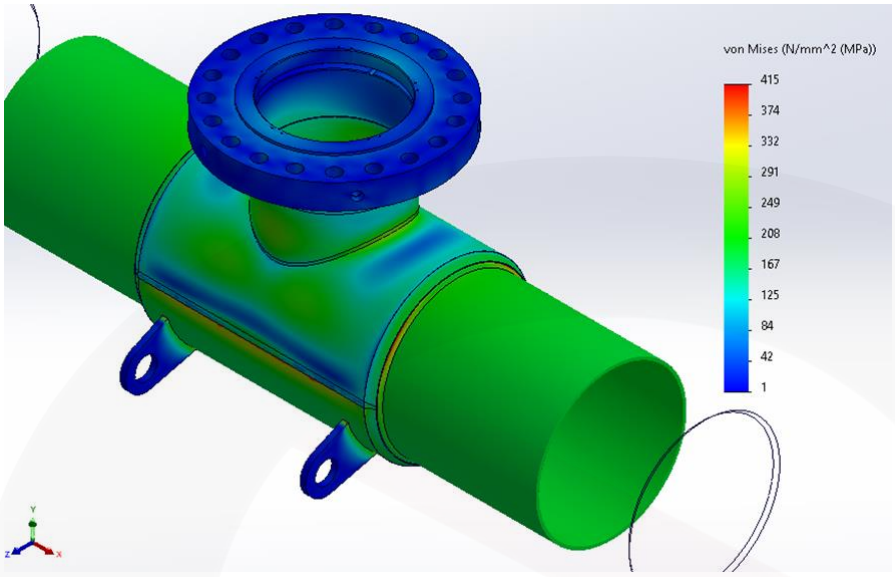
The maximum stress points are localized at the welds between the split tee and the pipeline.

B. *42" x 24" Von Mises stress distribution* under Test condition.



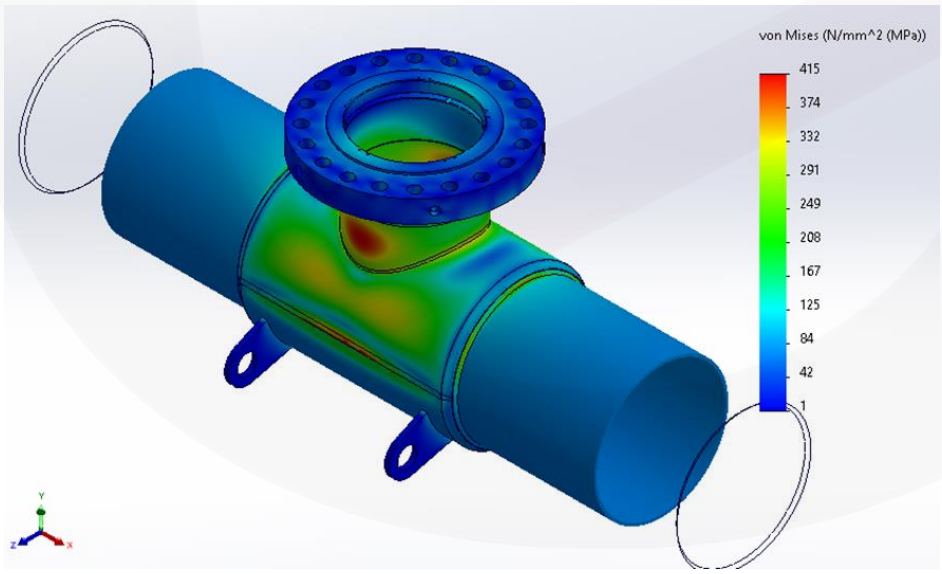
The maximum stress points for Test Condition are at the neck (mark 3) near the welds, the upper part of the split tee (mark 4) and some localized areas at the welds.

C. *16" x 12" Von Mises stress distribution and design condition*



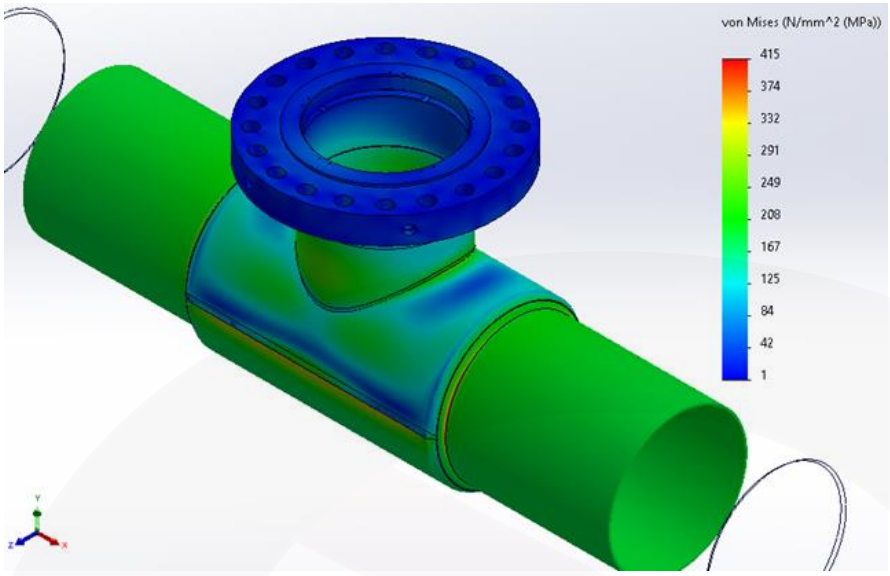
Similar stress distribution as the previous one.

D. *16" x 12" Von Mises stress distribution* under Test condition.



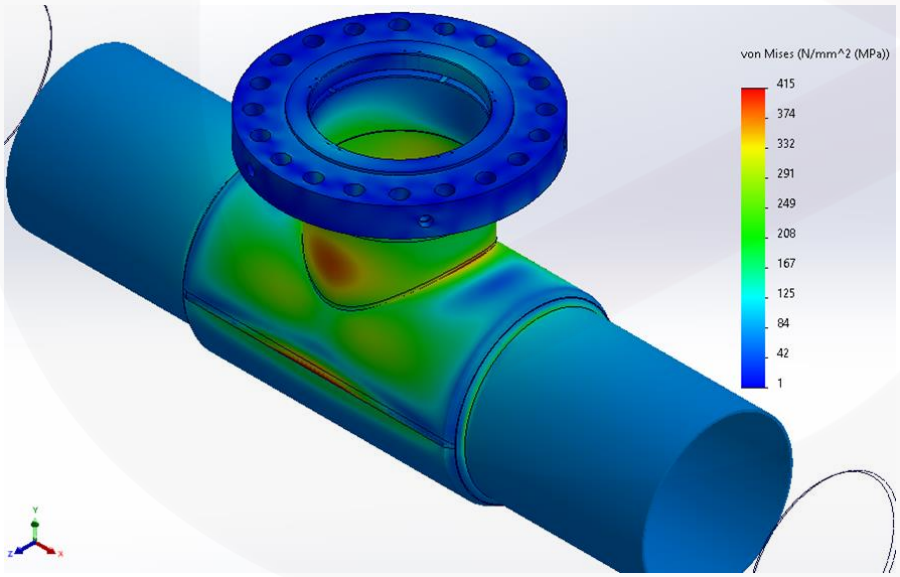
The maximum stress points for Test Condition are aging at the neck (mark 3), the upper part of the split tee (mark 4) and some localized areas at the longitudinal welds.

E. *14" x 12" Von Mises stress distribution and design condition*



Similar stress distribution as the previous one.

F. *14" x 12" Von Mises stress distribution* under Test condition.



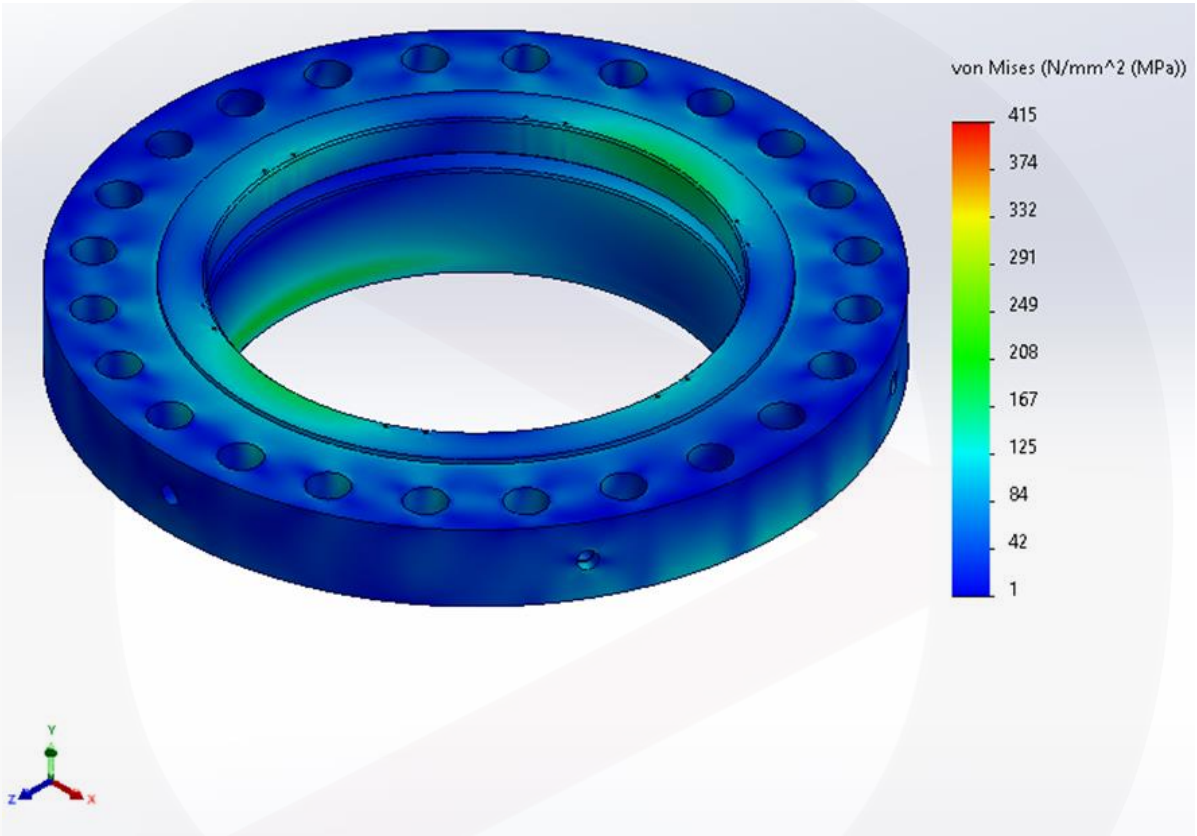
Similar stress distribution as the 16" x 12" Hot tap.

8.1 Stress linearization for the 42” x 24” Stopple Fitting.

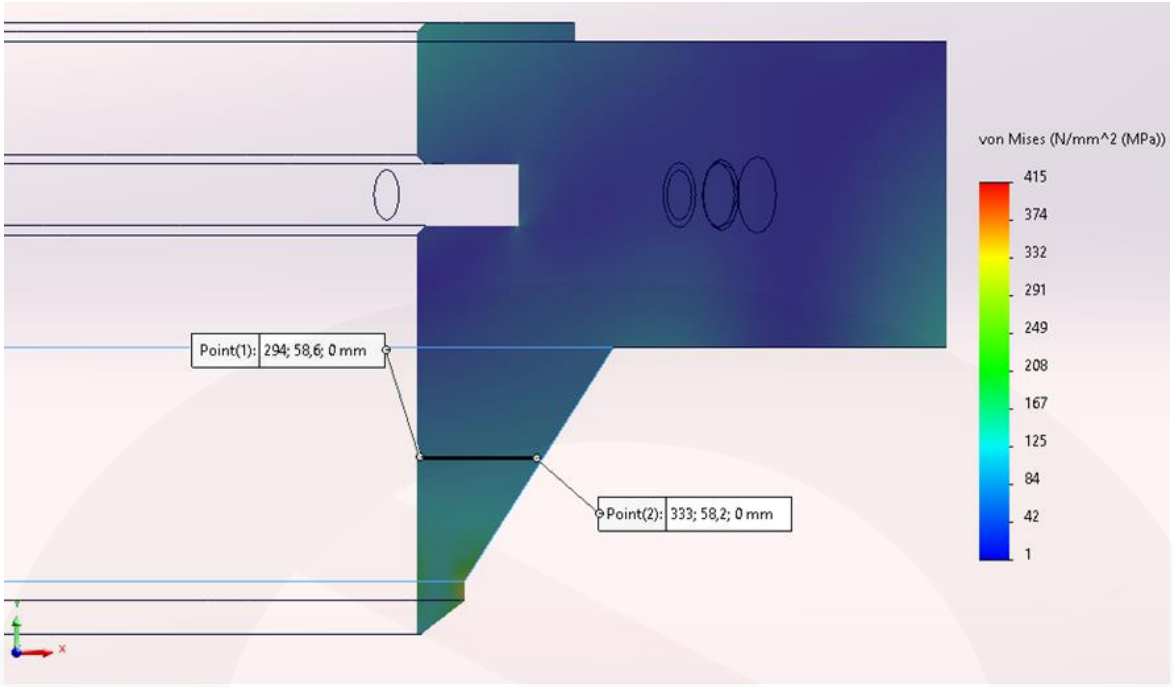
The following imagens summarized the stress linearization performed to the following parts: *Flange*, *branch neck*, *upper and lower half shell of the stopple fitting* and a *portion of the pipeline*.

Desing condition

- 24”-600# Flange (Mark 1)



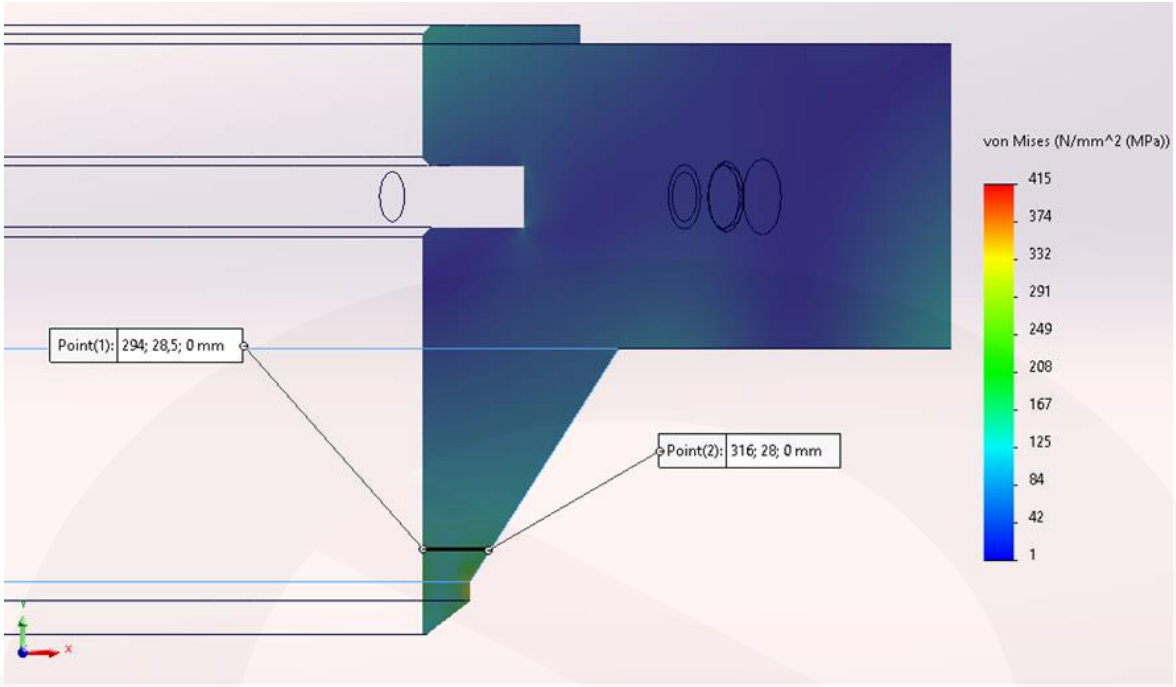
A. Pm



Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	-15	-11	0	0	-0	13
Bending (Point 2)	-0	15	11	-0	-0	0	13
Membrane Stress	-3	28	102	6	-0	-0	94
Membrane Stress + Bending (Point 1)	-3	13	92	6	-0	-1	88
Membrane Stress + Bending (Point 2)	-3	43	113	6	-0	-0	102
Peak (Point 1)	-6	-8	-0	-7	0	0	14
Peak (Point 2)	13	-11	-1	12	-0	-0	29

Pm=94 Mpa

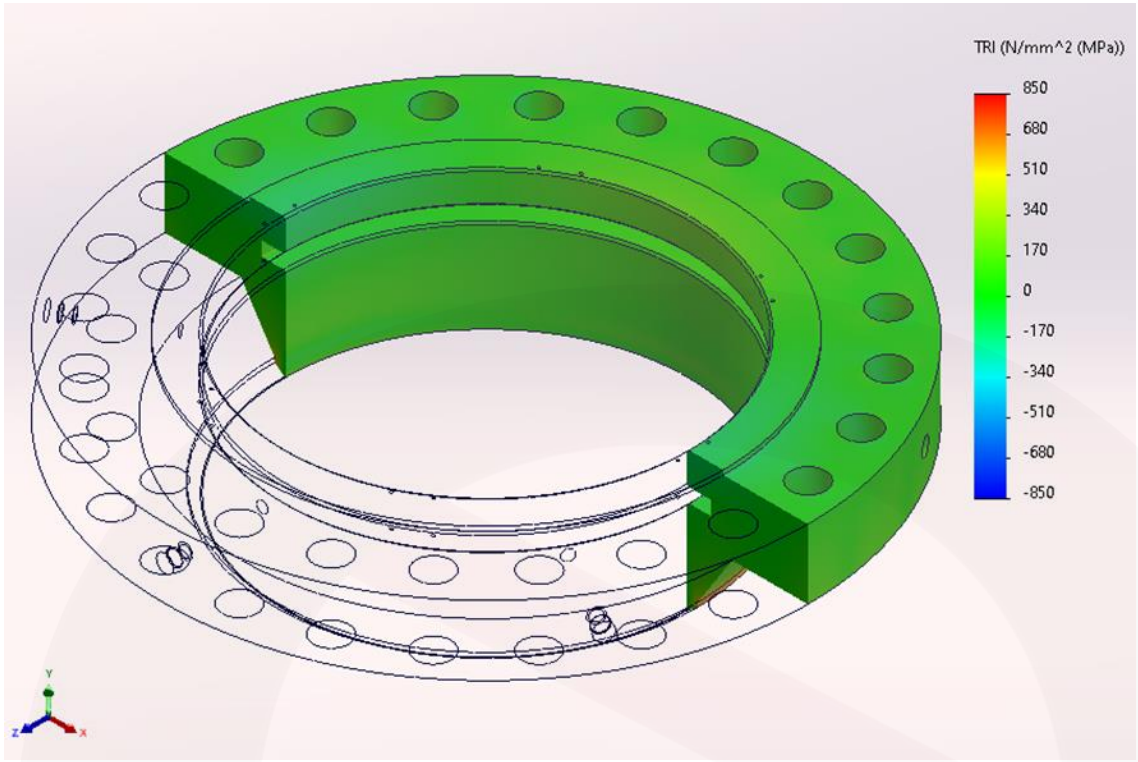
B. PL, PL+PB

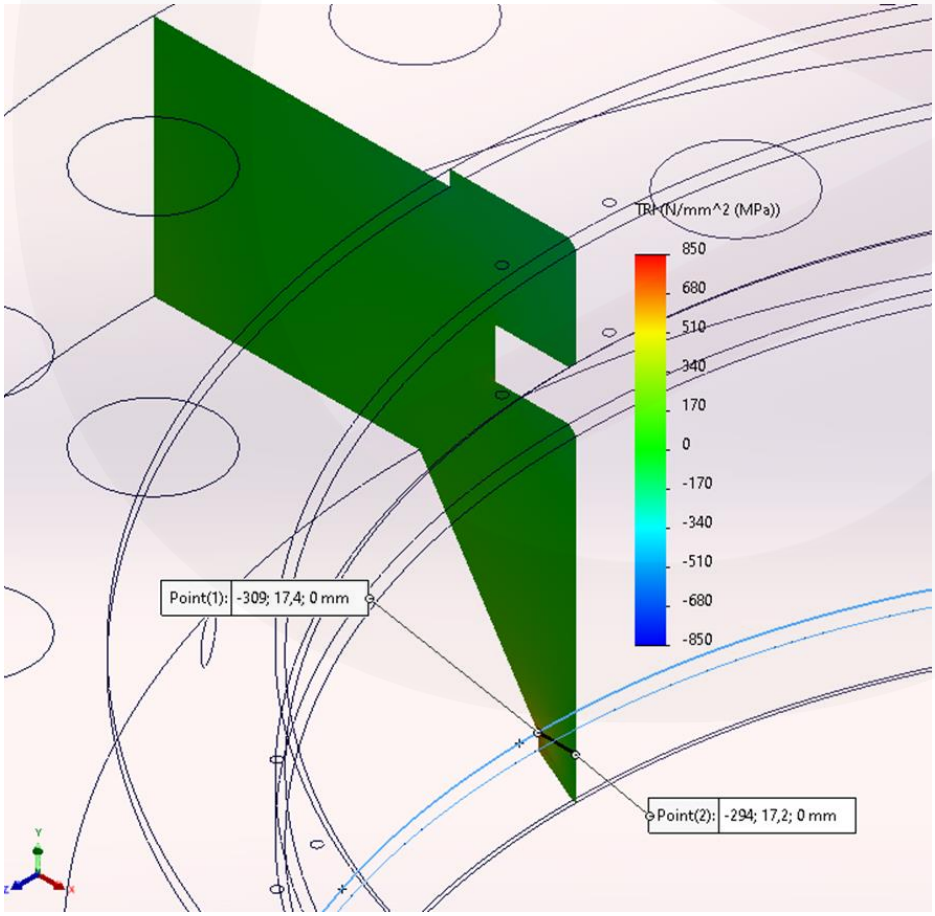


Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	-101	-34	0	0	-1	90
Bending (Point 2)	-0	101	34	-0	-0	1	90
Membrane Stress	2	61	144	10	-0	-1	125
Membrane Stress + Bending (Point 1)	2	-40	110	10	-0	-1	136
Membrane Stress + Bending (Point 2)	2	163	178	10	-0	-0	170
Peak (Point 1)	-11	-31	-5	-18	0	-0	39
Peak (Point 2)	34	-48	-9	58	-0	-0	124

PL= 125 Mpa; PL+PB=170 Mpa

C. Triaxial stress for localized 24”-600# Flange





Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	229	70	0	0	0	204
Bending (Point 2)	-0	-229	-70	-0	-0	-0	204
Membrane Stress	20	85	159	-15	-0	1	123
Membrane Stress + Bending (Point 1)	20	314	228	-15	-0	1	264
Membrane Stress + Bending (Point 2)	20	-144	89	-15	-0	0	209
Peak (Point 1)	35	38	13	-57	1	2	102
Peak (Point 2)	-28	24	7	20	0	2	58

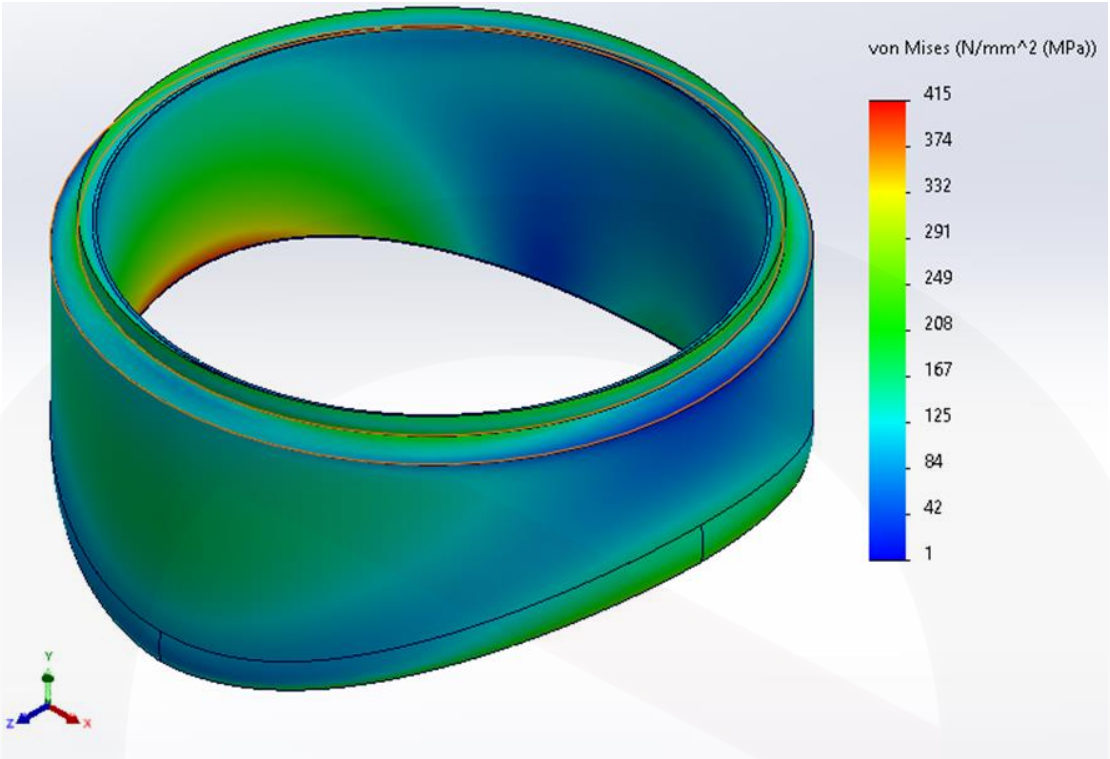
Maximum triaxial stress, (σ1+ σ2+ σ3) =264 Mpa

The following table summarizes the results obtained for the flange compared to the allowable amounts established by the code in part 5.

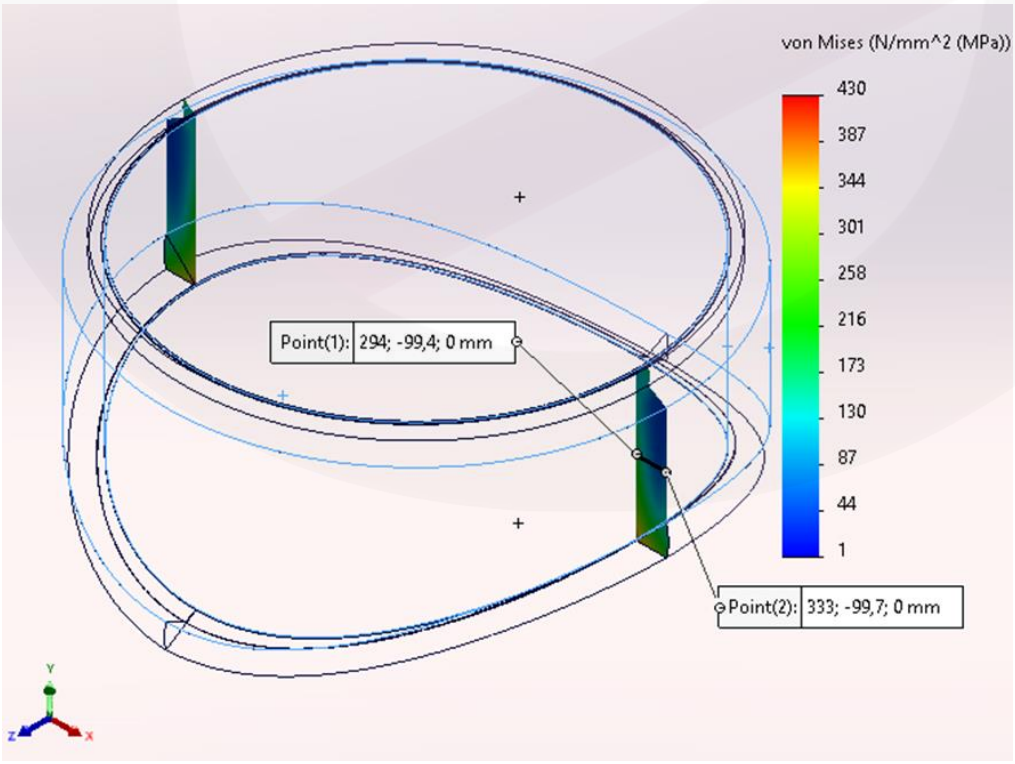
Hot Tap 24" x 42"-Allowable Stresses per VIII DIV 2, *Pd=94 bar, Td=85 °C*

Item	Part/Material	FEA Case per VIII Div 2 Part 5	Condition	ASME VIII DIV. 2 Load combinations	Type of Stress	*FEA "Se" or Triaxial stress* (MPa)	"S" Allow. Stress (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4) or as indicated	Allow. Stress (MPa)	Result
1	(Mark 1) 24"-600#-RF-LS *FLANGE A694F60*	3	Design	P+D+External loads+T	P_m	*94*	214,6	$P_m \leq S$	S (Eq. 5.2)	214,6	*Check*
					P_L	*125*		$P_L \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.3)	321,9	*Check*
					PL+Pb	*170*		$(P_L+P_b) \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.4)	321,9	*Check*
		3	Local	P+D+External loads+T	σ1+σ2+σ3	*264*		(σ1+σ2+σ3) ≤ 4*S	Per 5.3.2 (Eq. 5,5)	858,4	*Check*

- 24”-Neck (Mark 3)



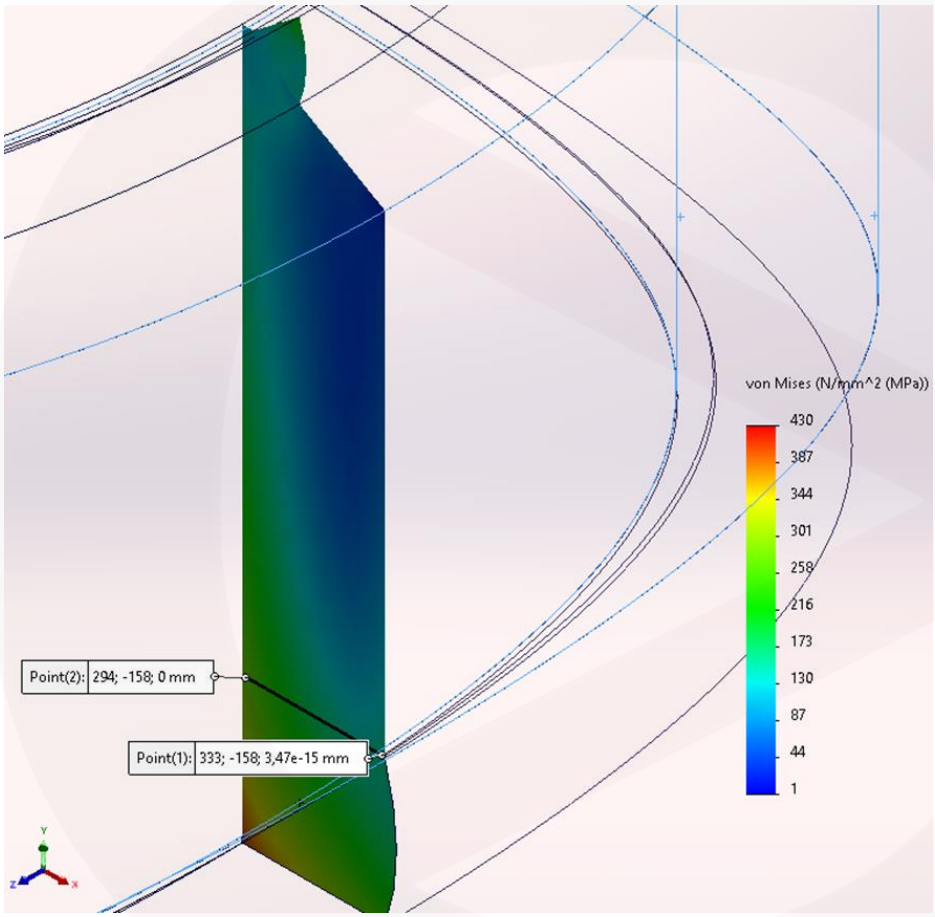
A. Pm



Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	131	97	0	0	0	117
Bending (Point 2)	-0	-131	-97	-0	-0	-0	117
Membrane Stress	-3	55	96	6	-0	-1	86
Membrane Stress + Bending (Point 1)	-3	185	193	6	-0	-0	192
Membrane Stress + Bending (Point 2)	-3	-76	-1	6	-0	-1	75
Peak (Point 1)	-7	1	4	-7	-0	-0	15
Peak (Point 2)	3	1	3	-4	0	0	7

Pm=86 Mpa

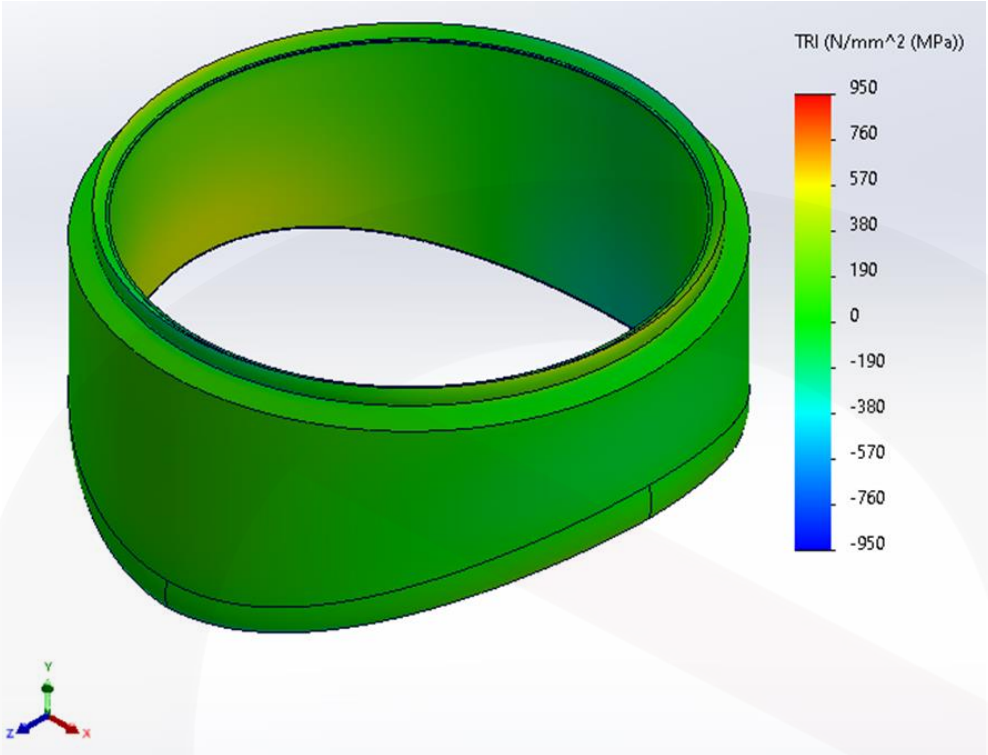
B. PL, PL+PB

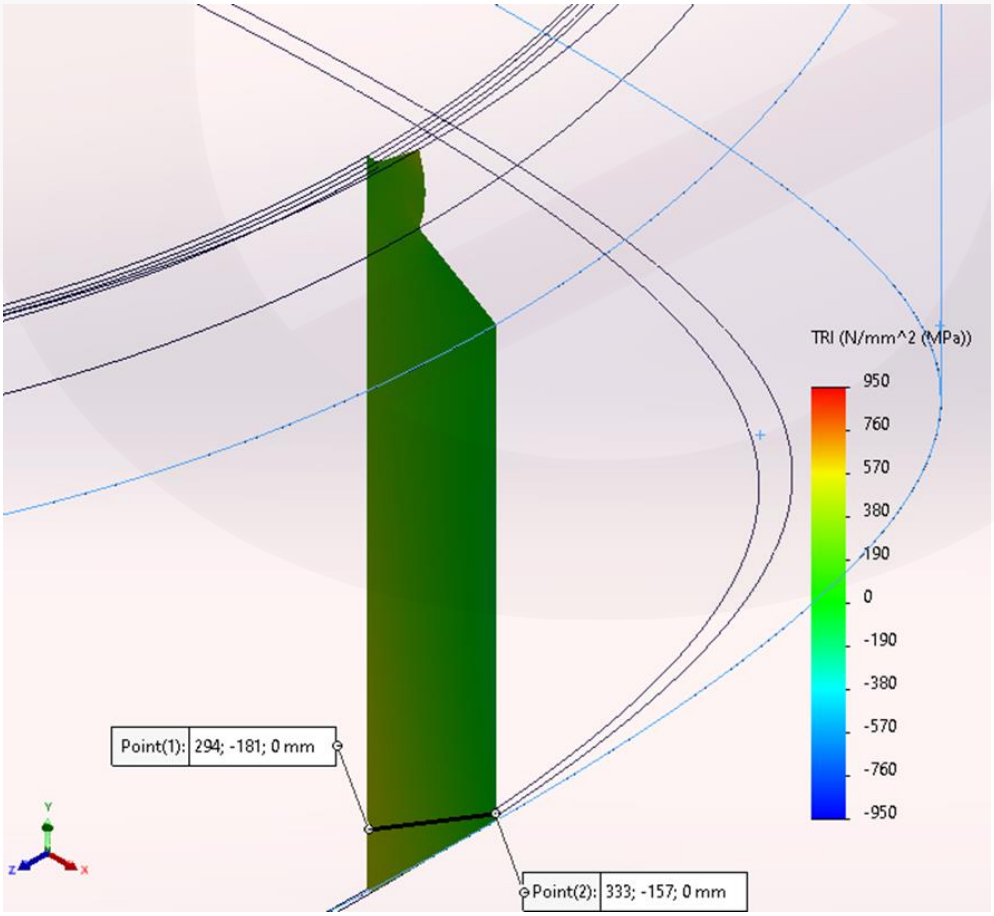


Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	-138	-117	0	0	0	128
Bending (Point 2)	-0	138	117	-0	-0	-0	128
Membrane Stress	-4	51	195	-5	0	1	178
Membrane Stress + Bending (Point 1)	-4	-87	79	-5	0	1	143
Membrane Stress + Bending (Point 2)	-4	189	312	-5	0	0	275
Peak (Point 1)	-1	-9	1	12	-0	-0	23
Peak (Point 2)	-5	1	4	5	-0	-0	11

PL= 178 Mpa; PL+PB=275 Mpa

C. Triaxial stress for localized 24”-600# Flange





Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	93	153	0	0	0	134
Bending (Point 2)	-0	-93	-153	-0	-0	-0	134
Membrane Stress	1	40	227	15	-0	-0	211
Membrane Stress + Bending (Point 1)	1	133	381	15	-0	-0	335
Membrane Stress + Bending (Point 2)	1	-54	74	15	-0	-1	114
Peak (Point 1)	31	-26	2	53	0	-0	105
Peak (Point 2)	-24	-26	1	-55	0	0	98

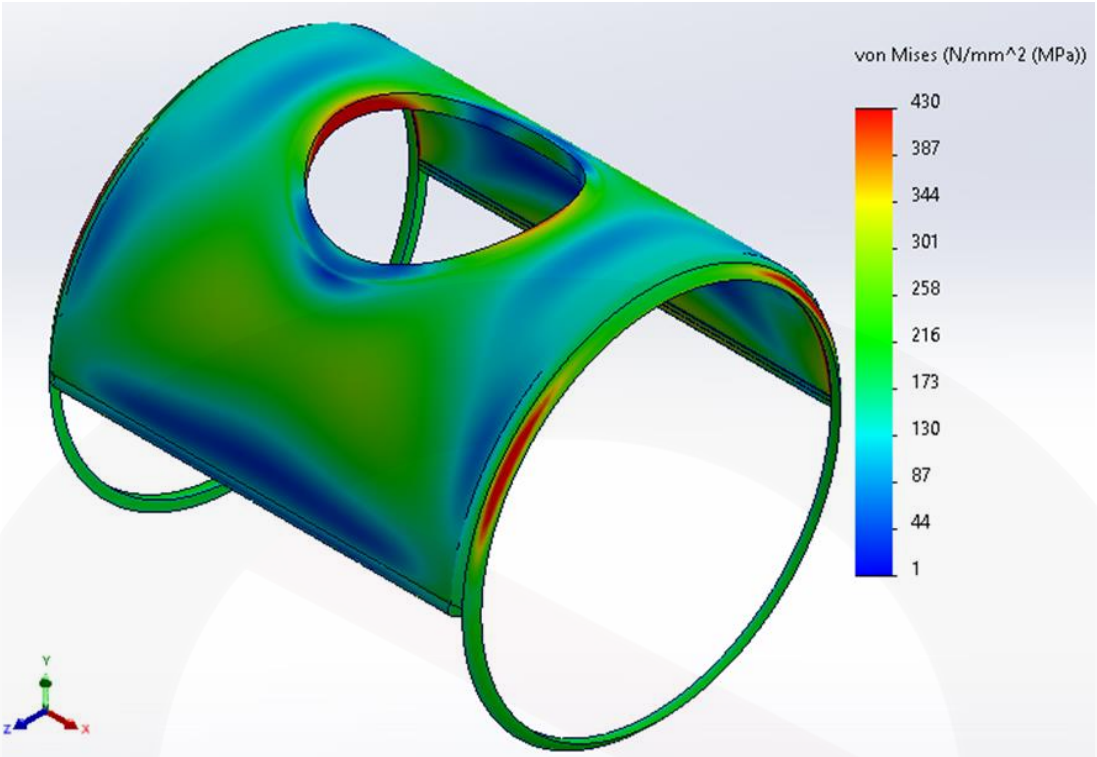
Maximum triaxial stress, (σ1+ σ2+ σ3) =335 Mpa

The following table summarizes the results obtained for the neck compared to the allowable amounts established by the code in part 5.

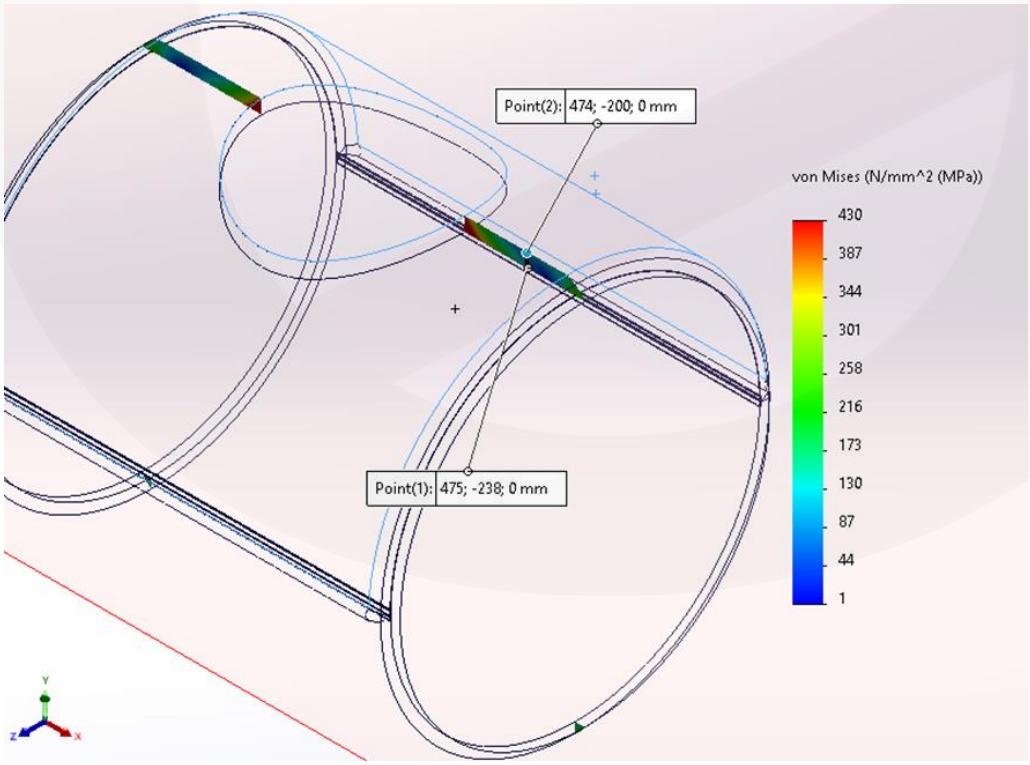
Hot Tap 24" x 42"-Allowable Stresses per VIII DIV 2, *Pd=94 bar, Td=85 °C*

Item	Part/Material	FEA Case per VIII Div 2 Part 5	Condition	ASME VIII DIV. 2 Load combinations	Type of Stress	*FEA "Se" or Triaxial stress* (MPa)	"S" Allow. Stress (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4) or as indicated	Allow. Stress (MPa)	Result
2	(Mark 3) 24"-Neck-P460-NL2	3	Design	P+D+External loads+T	P_m	*86*	237,5	$P_m \leq S$	S (Eq. 5.2)	237,5	*Check*
					P_L	*178*		$P_L \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.3)	356,25	*Check*
					PL+Pb	*275*		$(P_L+P_b) \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.4)	356,25	*Check*
		3	Local	P+D+External loads+T	σ1+σ2+σ3	*335*		(σ1+σ2+σ3) ≤ 4*S	Per 5.3.2 (Eq. 5,5)	950	*Check*

- 42” x 24”-Reduced Split tee (Mark 4)



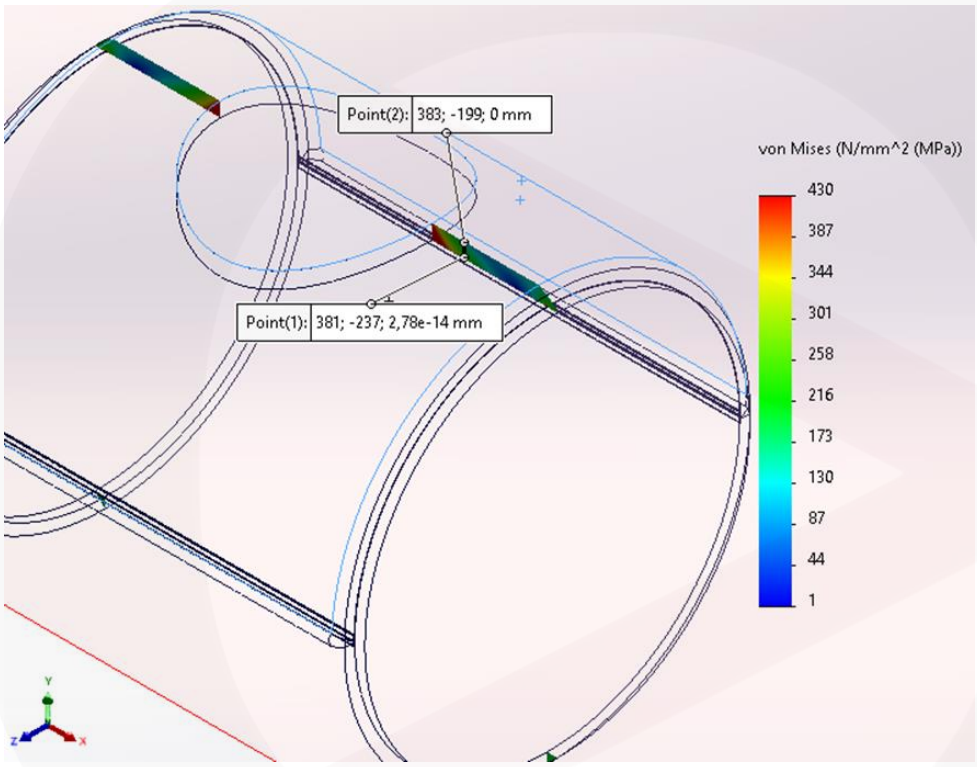
A. Pm



Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	-50	24	0	0	-0	65
Bending (Point 2)	-0	50	-24	-0	-0	0	65
Membrane Stress	-5	65	82	-5	-0	-0	80
Membrane Stress + Bending (Point 1)	-5	16	106	-5	-0	-0	102
Membrane Stress + Bending (Point 2)	-5	115	59	-5	-0	-0	104
Peak (Point 1)	-5	-1	0	5	-0	0	10
Peak (Point 2)	5	-0	1	7	0	0	13

Pm=80 Mpa

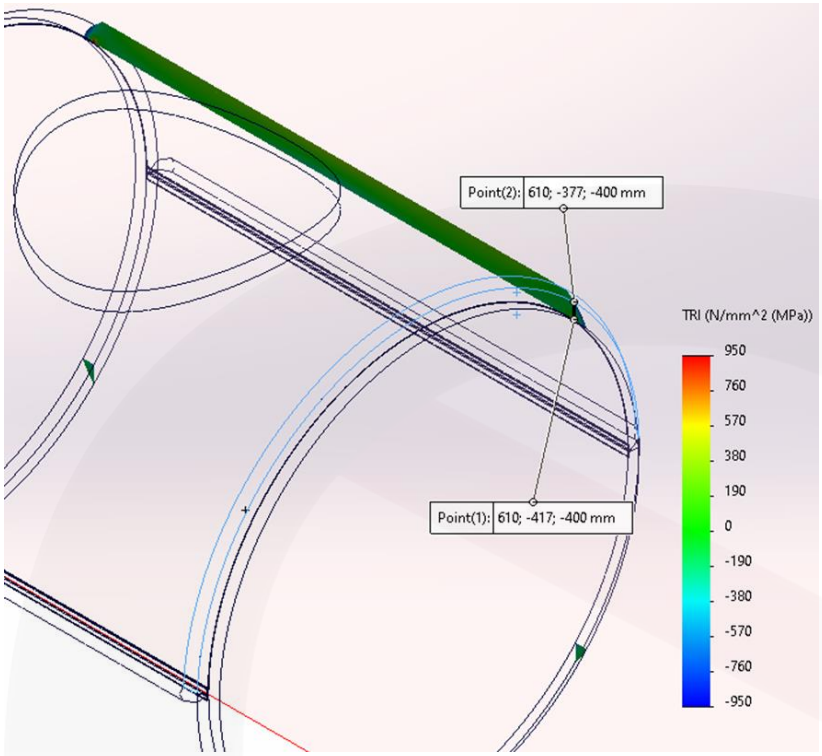
B. PL, PL+PB



Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	31	74	0	0	-0	64
Bending (Point 2)	-0	-31	-74	-0	-0	0	64
Membrane Stress	-3	74	231	-7	-0	-0	207
Membrane Stress + Bending (Point 1)	-3	105	305	-7	-0	-0	271
Membrane Stress + Bending (Point 2)	-3	43	157	-7	-0	-0	144
Peak (Point 1)	-5	2	2	0	0	-0	7
Peak (Point 2)	3	-0	1	5	0	-0	8

PL= 207 Mpa; PL+PB=271 Mpa

C. *Triaxial stress for localized 24”-600# Flange*



Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	340	227	0	0	-167	416
Bending (Point 2)	-0	-340	-227	-0	-0	167	416
Membrane Stress	2	-3	25	39	-142	-48	270
Membrane Stress + Bending (Point 1)	2	338	252	39	-142	-214	542
Membrane Stress + Bending (Point 2)	2	-343	-202	39	-142	119	445
Peak (Point 1)	236	253	76	153	-26	-50	329
Peak (Point 2)	-128	170	59	-98	54	-39	331

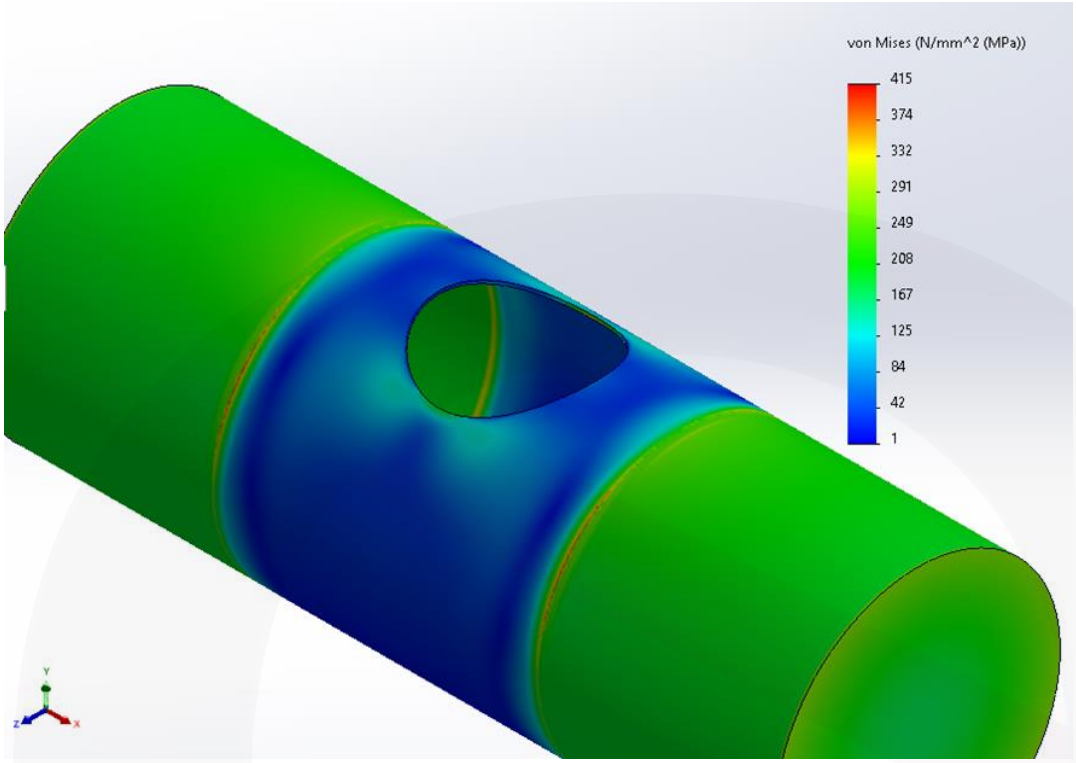
Maximum triaxial stress, (σ1+ σ2+ σ3) =542 Mpa

The following table summarizes the results obtained for the mark 4 part compared to the allowable amounts established by the code in part 5.

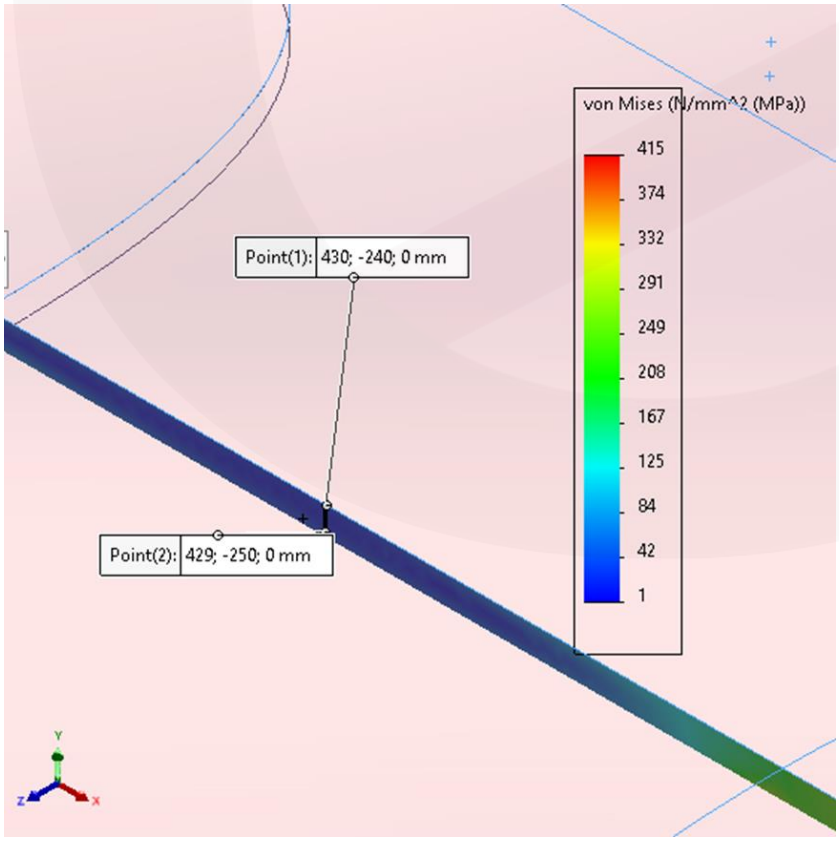
Hot Tap 24" x 42"-Allowable Stresses per VIII DIV 2, *Pd=94 bar, Td=85 ℃*

Item	Part/Material	FEA Case per VIII Div 2 Part 5	Condition	ASME VIII DIV. 2 Load combinations	Type of Stress	*FEA "Se" or Triaxial stress* (MPa)	"S" Allow. Stress (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4) or as indicated	Allow. Stress (MPa)	Result
3	(Mark 4) 42"- *Reduced Split tee* - P460-NL2	3	Design	P+D+External loads+T	P_m	*80*	237,5	$P_m \leq S$	S (Eq. 5.2)	237,5	*Check*
					P_L	*207*		$P_L \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.3)	356,25	*Check*
					PL+Pb	*271*		$(P_L+P_b) \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.4)	356,25	*Check*
		3	Local	P+D+External loads+T	σ1+σ2+σ3	*542*		$(\sigma1+\sigma2+\sigma3) \leq 4*S$	Per 5.3.2 VIII Div. 2 (Eq. 5,5)	950	*Check*

- 42”-Existing Pipeline



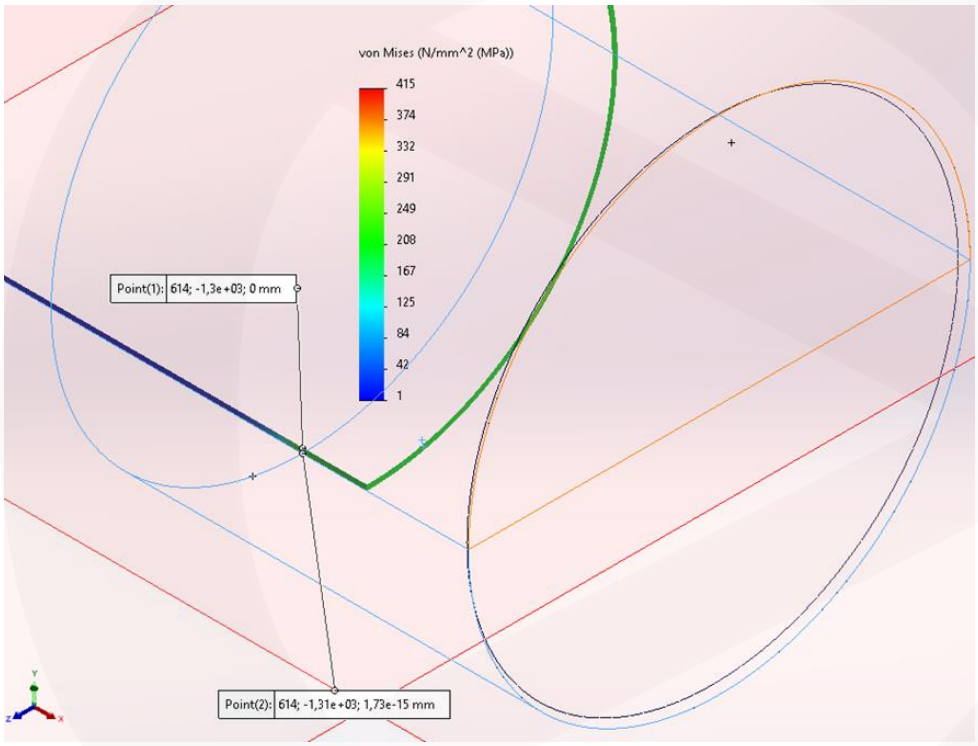
A. Pm



Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	10	-24	0	0	-0	30
Bending (Point 2)	-0	-10	24	-0	-0	0	30
Membrane Stress	-9	-2	-2	-2	0	-0	8
Membrane Stress + Bending (Point 1)	-9	8	-26	-2	0	-0	29
Membrane Stress + Bending (Point 2)	-9	-12	22	-2	0	0	33
Peak (Point 1)	-0	0	0	0	0	0	1
Peak (Point 2)	-0	-0	0	1	-0	-0	2

Pm=8 Mpa

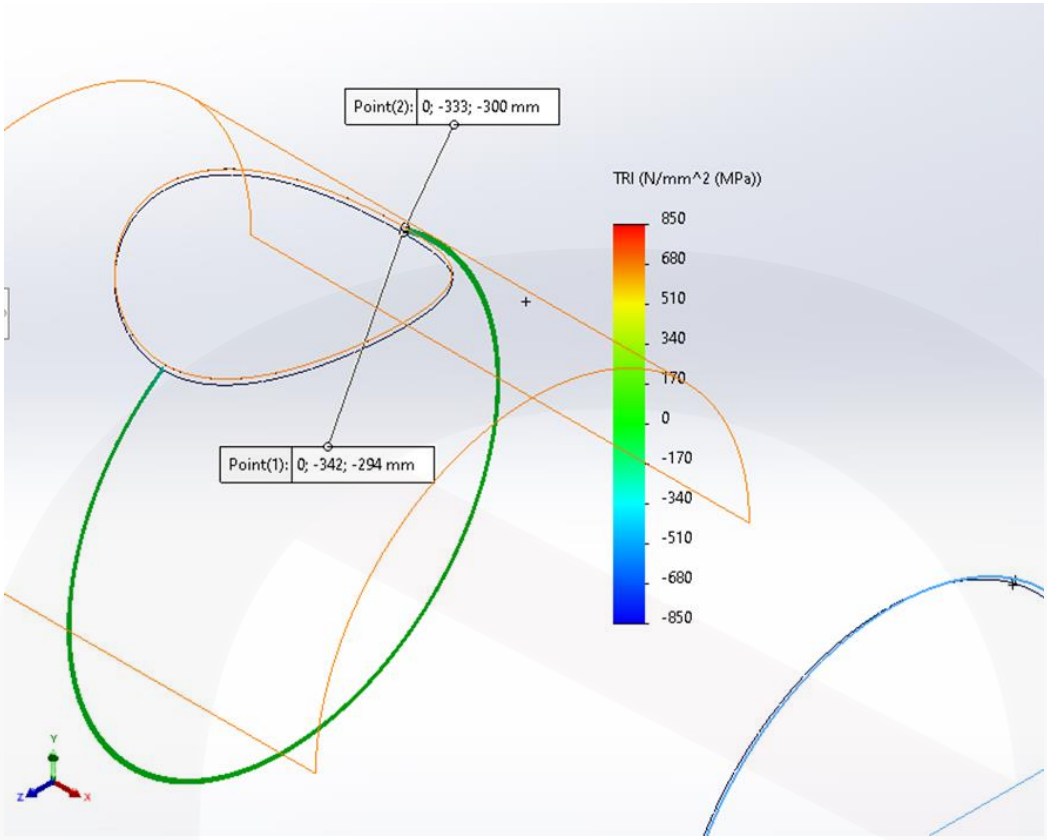
B. PL, PL+PB



Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	195	66	0	0	-0	171
Bending (Point 2)	-0	-195	-66	-0	-0	0	171
Membrane Stress	-60	-30	-225	18	0	1	184
Membrane Stress + Bending (Point 1)	-60	164	-159	18	0	0	288
Membrane Stress + Bending (Point 2)	-60	-225	-291	18	0	1	209
Peak (Point 1)	61	4	5	17	-0	-0	64
Peak (Point 2)	-40	24	10	-22	0	-0	70

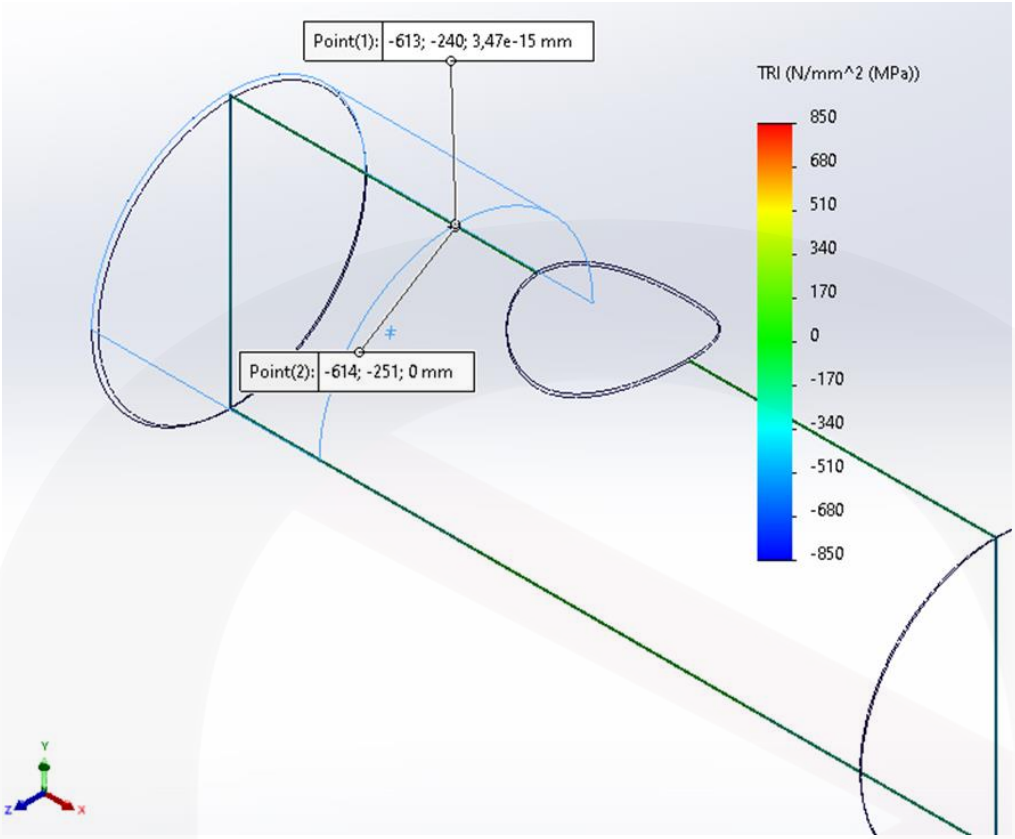
PL= 184 Mpa; PL+PB=288 Mpa

C. Triaxial stress for localized Pipeline



Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	1	-78	0	0	1	79
Bending (Point 2)	-0	-1	78	-0	-0	-1	79
Membrane Stress	-9	-13	-274	-0	-0	-0	263
Membrane Stress + Bending (Point 1)	-9	-12	-352	-0	-0	0	341
Membrane Stress + Bending (Point 2)	-9	-14	-196	-0	-0	-1	184
Peak (Point 1)	0	0	1	-0	-0	-0	1
Peak (Point 2)	0	0	0	1	-0	1	2

Maximum triaxial stress, **(σ1+ σ2+ σ3) =341 Mpa**



Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	-134	-38	0	0	0	120
Bending (Point 2)	-0	134	38	-0	-0	-0	120
Membrane Stress	-8	11	-196	-17	-1	1	201
Membrane Stress + Bending (Point 1)	-8	-123	-234	-17	-1	1	198
Membrane Stress + Bending (Point 2)	-8	146	-158	-17	-1	0	265
Peak (Point 1)	1	-18	-5	-56	-1	0	99
Peak (Point 2)	1	-28	-9	11	1	-0	32

Maximum triaxial stress, (σ1+ σ2+ σ3) =265 Mpa

The following table summarizes the results obtained for the pipeline part compared to the allowable amounts established by the code in part 5.

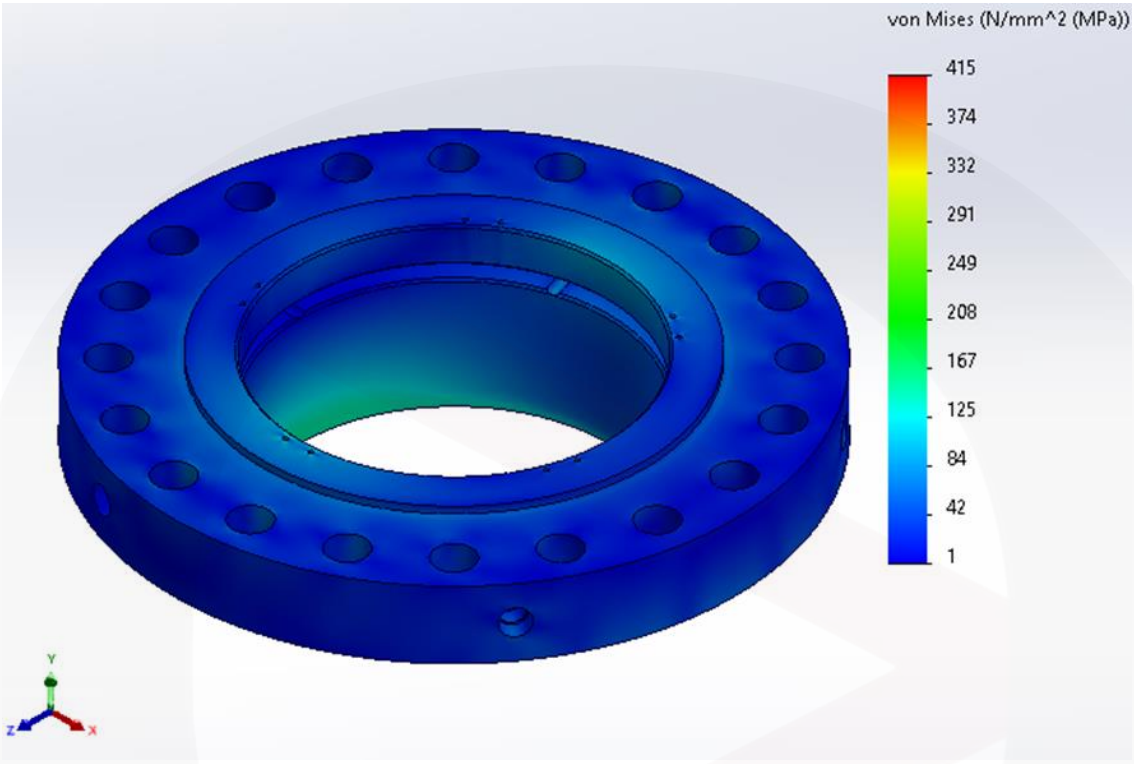
Hot Tap 24" x 42"-Allowable Stresses per VIII DIV 2, *Pd=94 bar, Td=85 °C*											
Item	Part/Material	FEA Case per VIII Div 2 Part 5	Condition	ASME VIII DIV. 2 Load combinations	Type of Stress	FEA "Se" or Triaxial stress (MPa)	"S" Allow. Stress (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4) or as indicated	Allow. Stress (MPa)	Result
4	Existing 42"-Pipeline -API 5LX60	3	Design	P+D+External loads+T	P_m	*8*	214,6	$P_m \leq S$	S (Eq. 5.2)	214,6	*Check*
					P_L	*184*		$P_L \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.3)	321,9	*Check*
					PL+Pb	*288*		$(P_L+P_b) \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.4)	321,9	*Check*
		3	Local	P+D+External loads+T	σ1+σ2+σ3	*341*		(σ1+σ2+σ3) ≤ 4*S	Per 5.3.2 VIII Div. 2 (Eq. 5,5)	858,4	*Check*

8.2 Stress linearization for the 16” x 12” Stopple Fitting.

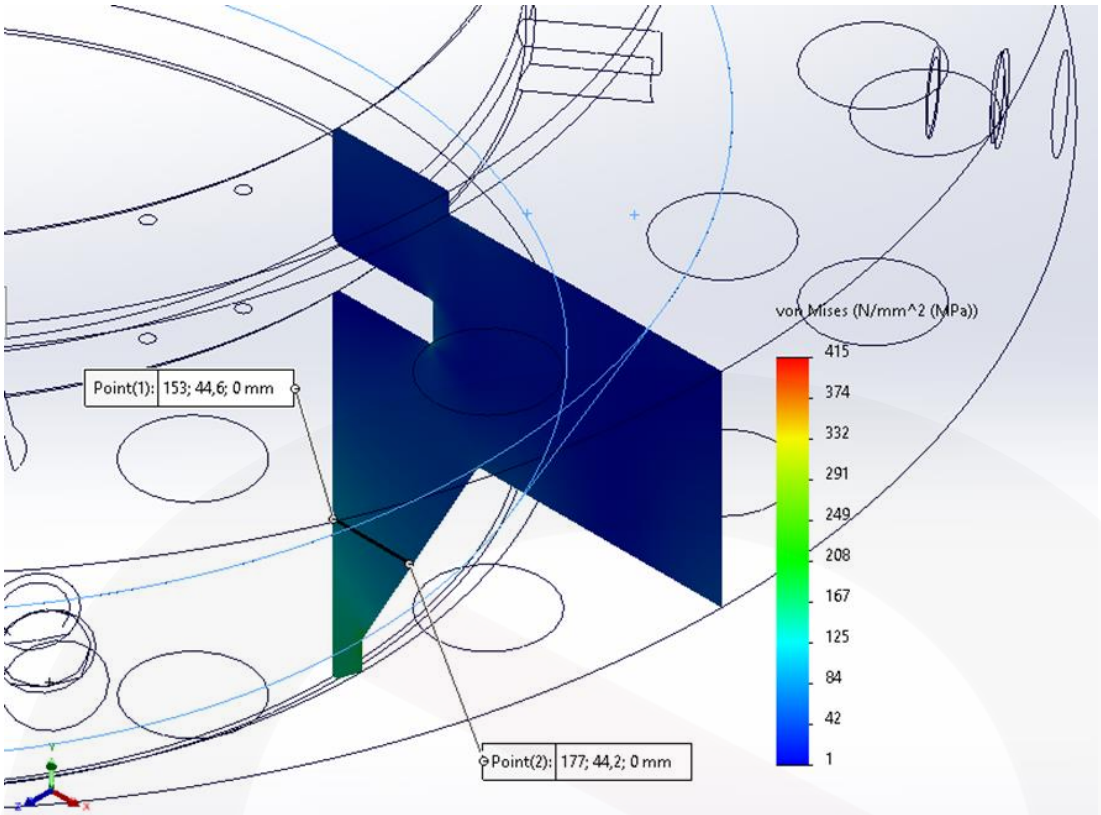
The following imagens summarized the stress linearization performed to the following parts: *Flange*, *branch neck*, *upper and lower half shell of the stopple fitting* and a *portion of the pipeline*.

Desing condition

- 12”-600# Flange (Mark 1)



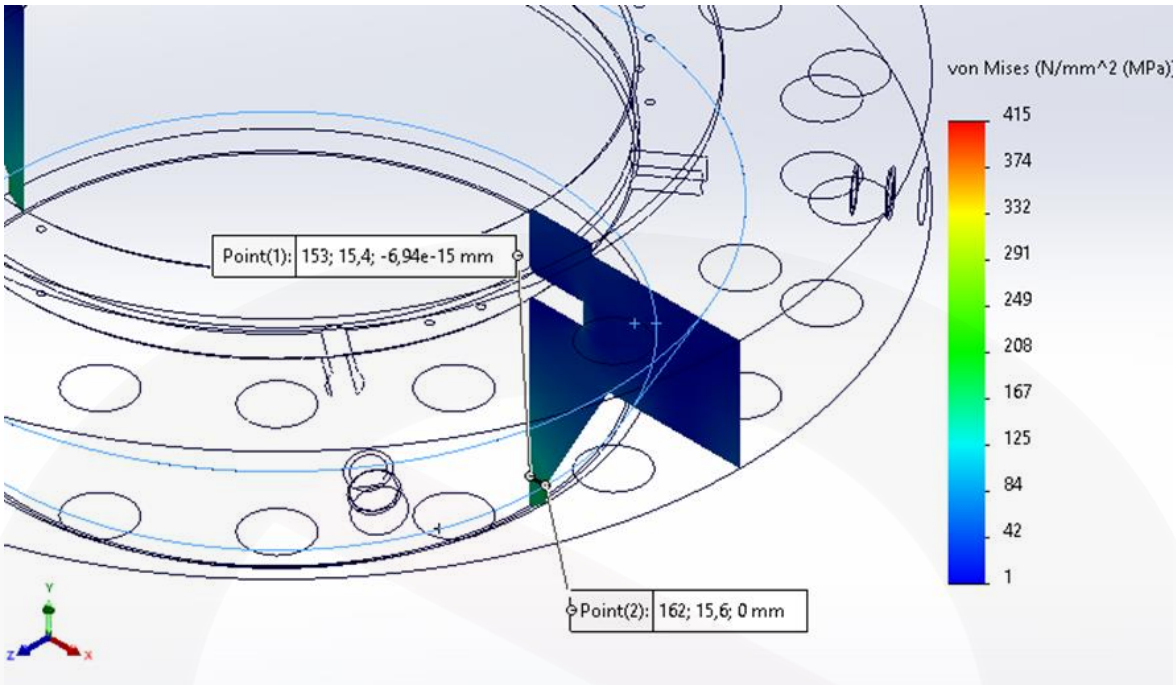
A. Pm



Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	15	12	0	0	-0	14
Bending (Point 2)	-0	-15	-12	-0	-0	0	14
Membrane Stress	-2	29	99	6	-1	-4	90
Membrane Stress + Bending (Point 1)	-2	45	111	6	-1	-4	99
Membrane Stress + Bending (Point 2)	-2	14	87	6	-1	-4	83
Peak (Point 1)	-7	-0	1	-7	1	0	14
Peak (Point 2)	6	-0	1	2	-1	0	7

Pm=90 Mpa

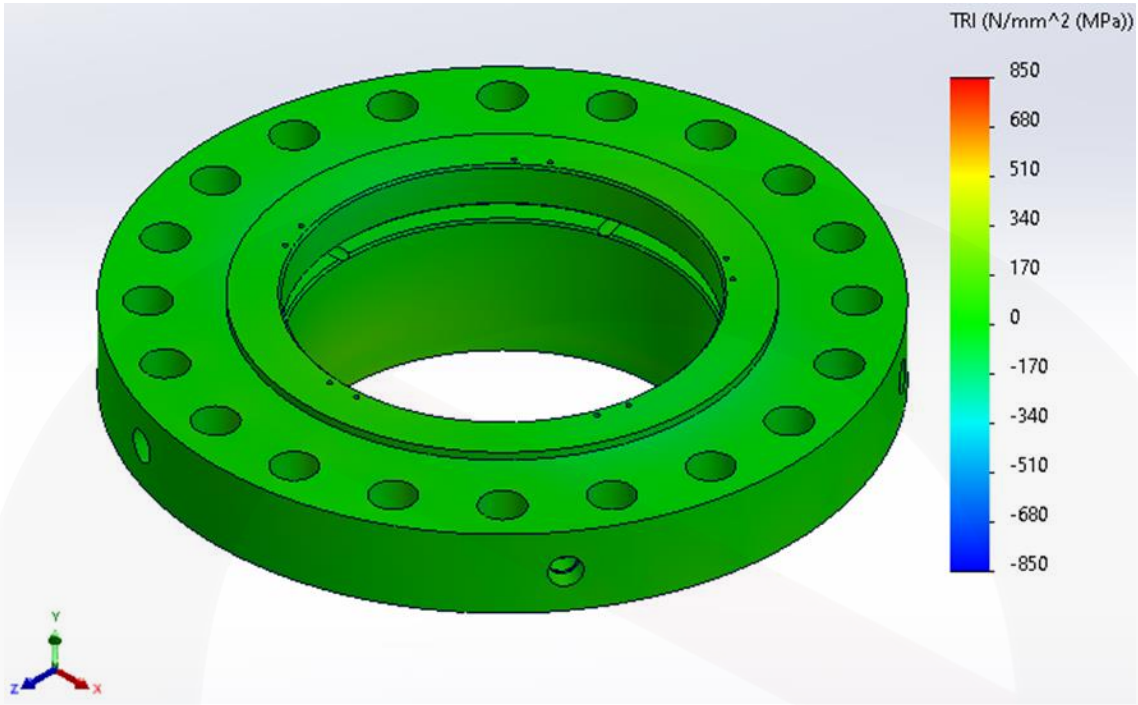
B. PL, PL+PB

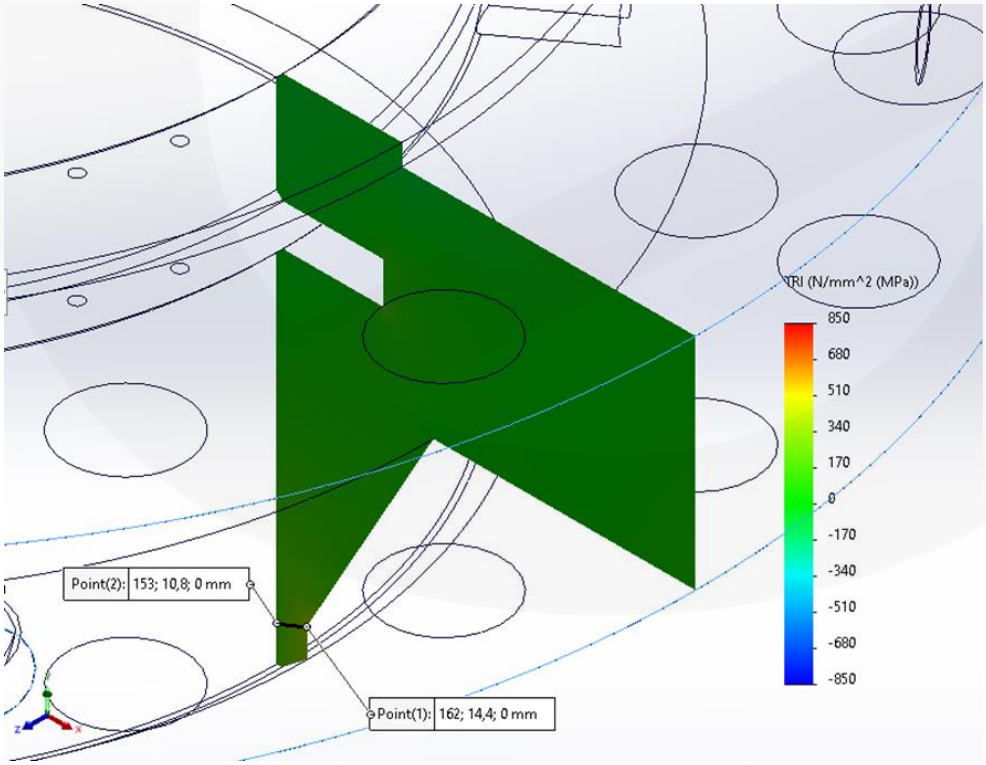


Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	-81	-19	0	0	0	73
Bending (Point 2)	-0	81	19	-0	-0	-0	73
Membrane Stress	2	88	165	9	-1	-9	143
Membrane Stress + Bending (Point 1)	2	8	146	9	-1	-9	143
Membrane Stress + Bending (Point 2)	2	169	184	9	-1	-10	177
Peak (Point 1)	-9	5	3	-12	1	0	25
Peak (Point 2)	18	11	5	26	-2	-1	47

PL= 143 Mpa; PL+PB=177 Mpa

C. Triaxial stress for localized 12”-600# Flange





Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	64	20	0	0	1	57
Bending (Point 2)	-0	-64	-20	-0	-0	-1	57
Membrane Stress	24	76	171	41	5	9	148
Membrane Stress + Bending (Point 1)	24	140	191	41	5	10	165
Membrane Stress + Bending (Point 2)	24	12	150	41	5	9	152
Peak (Point 1)	42	1	2	42	2	-0	84
Peak (Point 2)	-31	1	2	-34	-1	-0	67

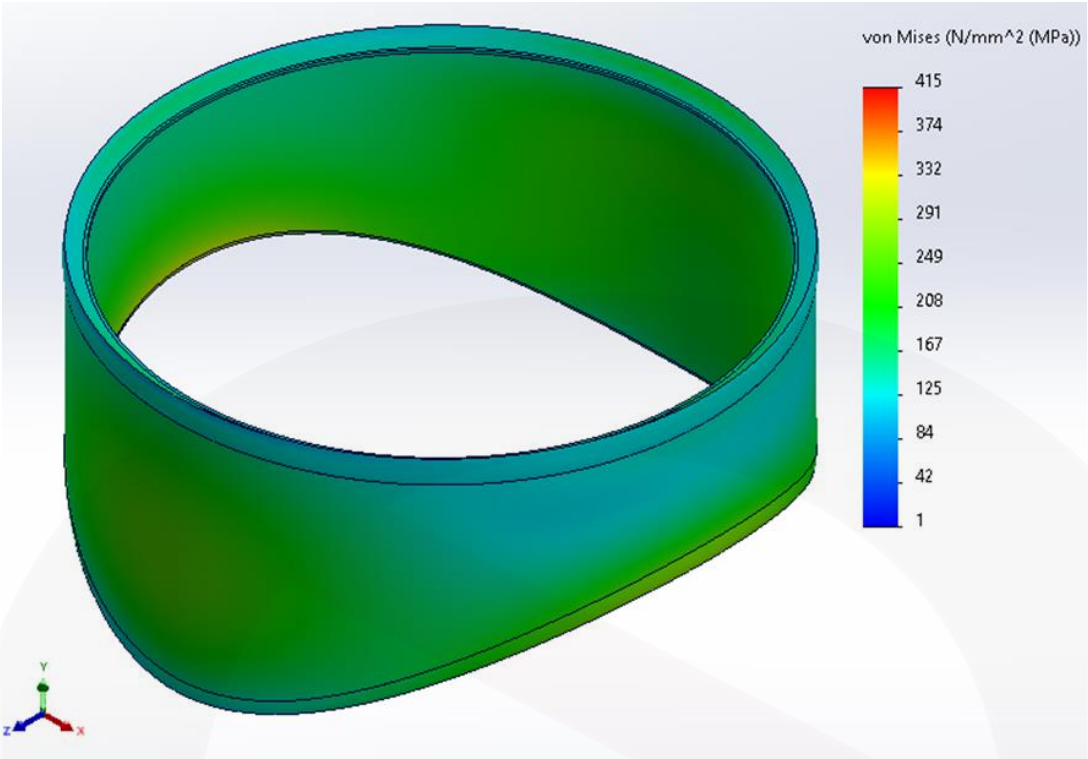
Maximum triaxial stress, **(σ1+ σ2+ σ3) =165 Mpa**

The following table summarizes the results obtained for the flange compared to the allowable amounts established by the code in part 5.

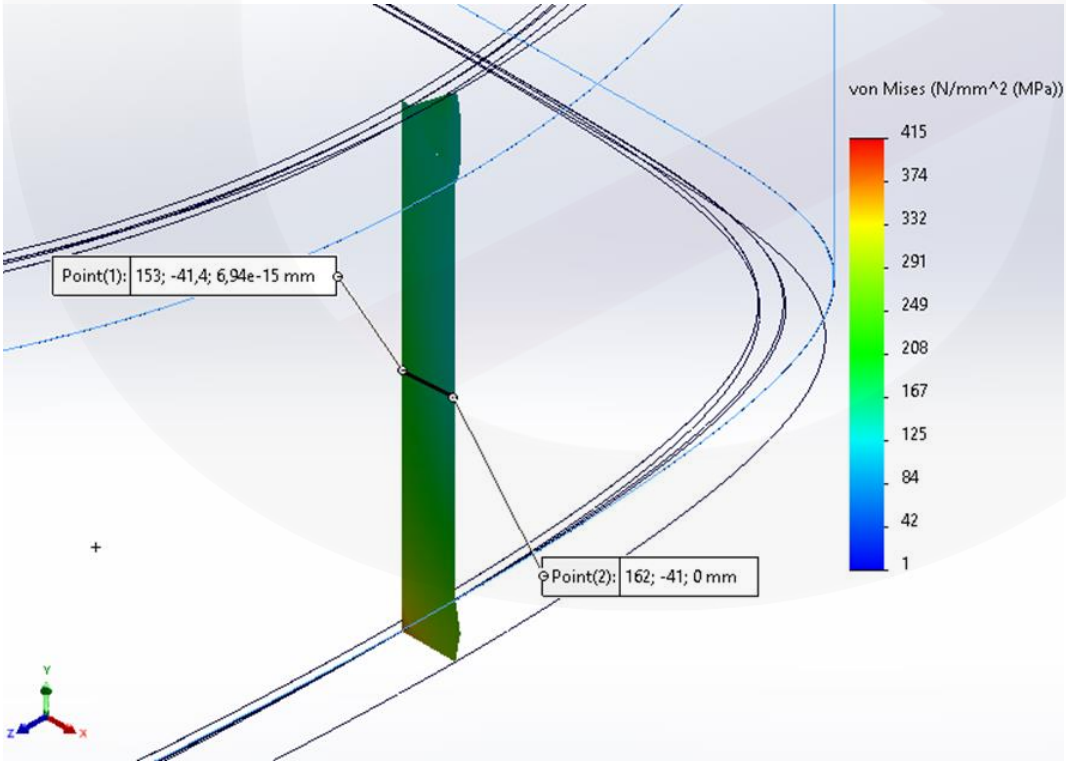
Hot Tap 12" x 16"-Allowable Stresses per VIII DIV 2, *Pd=94 bar, Td=80 ℃*

Item	Part/Material	FEA Case per VIII Div 2 Part 5	Condition	ASME VIII DIV. 2 Load combinations	Type of Stress	FEA "Se" or Triaxial stress (MPa)	"S" Allow. Stress (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4) or as indicated	Allow. Stress (MPa)	Result
2	(Mark 3) 12"-Neck-API 5L-X60	3	Design	P+D+External loads+T	P_m	*167*	214,6	$P_m \leq S$	S (Eq. 5.2)	214,6	*Check*
					P_L	*266*		$P_L \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.3)	321,9	*Check*
					PL+Pb	*287*		$(P_L+P_b) \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.4)	321,9	*Check*
		3	Local	P+D+External loads+T	σ1+σ2+σ3	*358*		(σ1+σ2+σ3) ≤ 4*S	Per 5.3.2 (Eq. 5,5)	858,4	*Check*

- 12”-Neck (Mark 3)



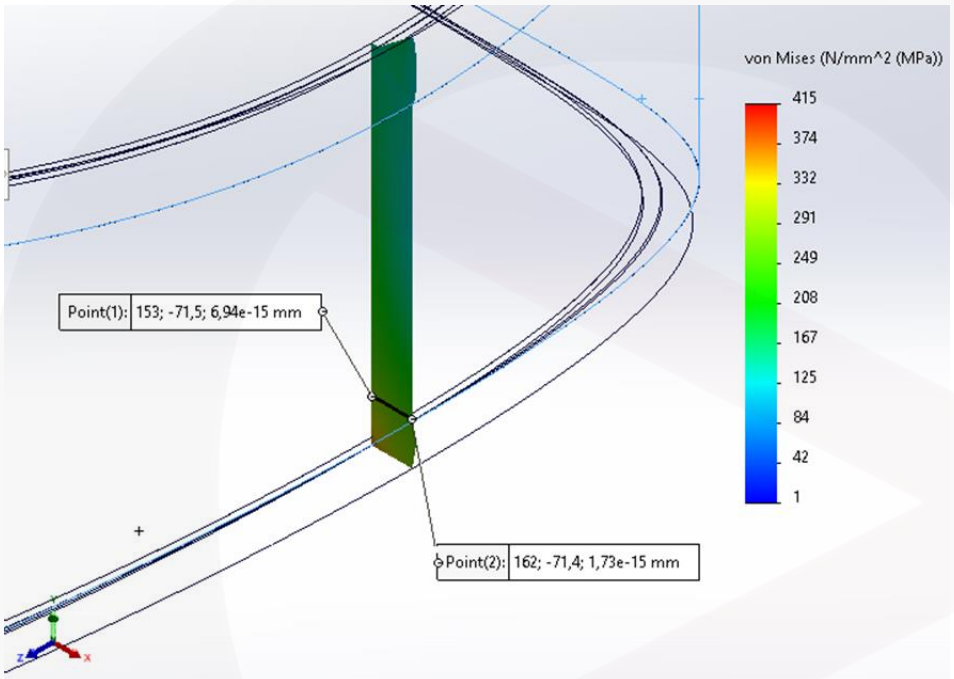
A. Pm



Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	54	32	0	0	1	47
Bending (Point 2)	-0	-54	-32	-0	-0	-1	47
Membrane Stress	-4	110	187	6	-0	-9	167
Membrane Stress + Bending (Point 1)	-4	165	219	6	-0	-9	202
Membrane Stress + Bending (Point 2)	-4	56	154	6	-0	-10	140
Peak (Point 1)	-4	1	0	3	-0	0	7
Peak (Point 2)	4	2	1	-2	-0	0	5

Pm=167 Mpa

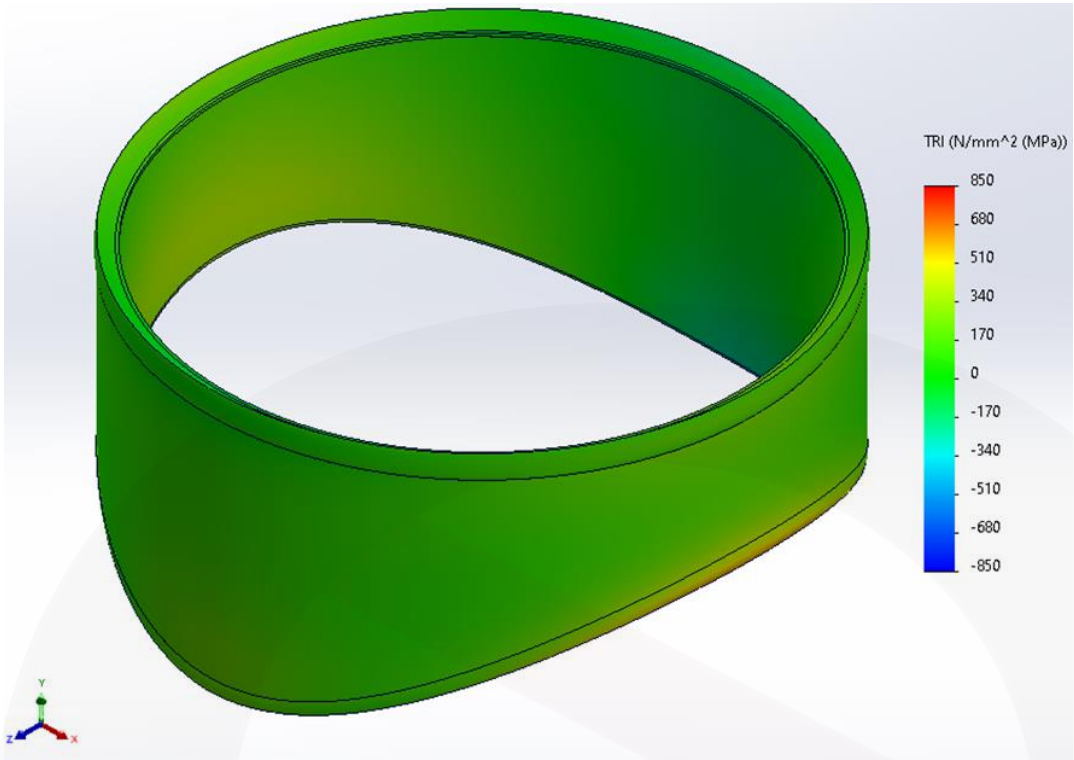
B. PL, PL+PB

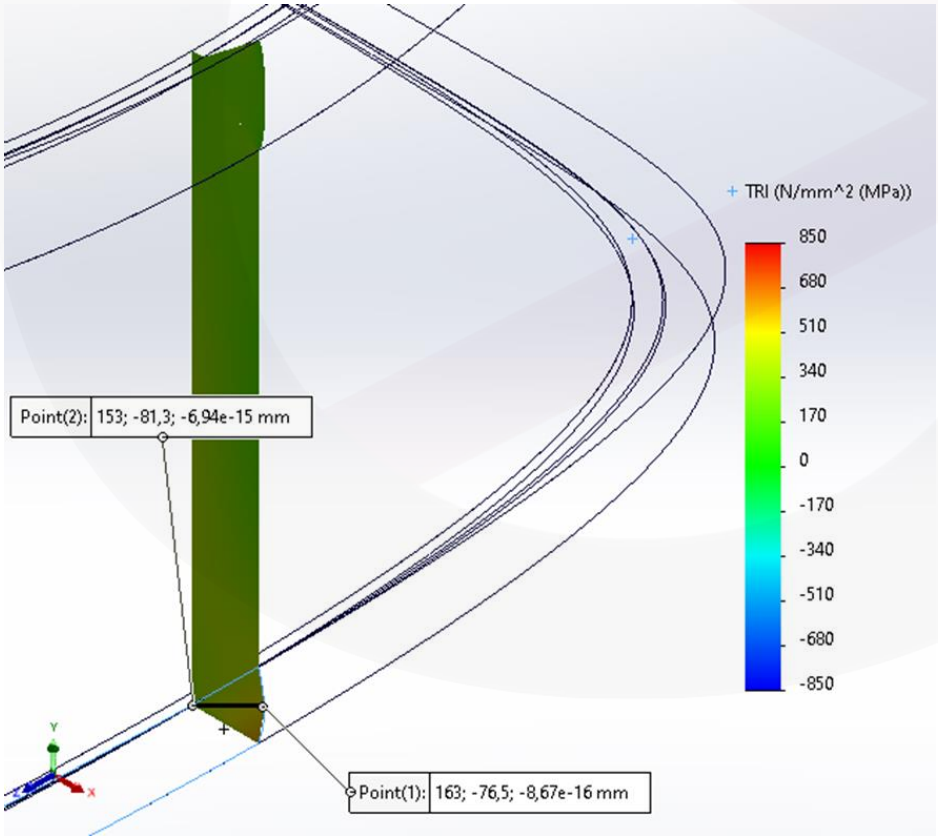


Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	-32	14	0	0	1	41
Bending (Point 2)	-0	32	-14	-0	-0	-1	41
Membrane Stress	-4	102	298	-13	0	-10	266
Membrane Stress + Bending (Point 1)	-4	70	312	-13	0	-9	287
Membrane Stress + Bending (Point 2)	-4	134	284	-13	0	-11	251
Peak (Point 1)	-6	-1	-0	5	-0	-0	11
Peak (Point 2)	7	-3	-1	-5	0	1	12

PL= 266 Mpa; PL+PB=287 Mpa

C. Triaxial stress for localized 12”-Neck





Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	94	-19	0	0	3	105
Bending (Point 2)	-0	-94	19	-0	-0	-3	105
Membrane Stress	12	87	340	6	3	8	298
Membrane Stress + Bending (Point 1)	12	181	321	6	3	10	269
Membrane Stress + Bending (Point 2)	12	-8	359	6	3	5	358
Peak (Point 1)	12	-4	0	32	-0	0	57
Peak (Point 2)	-8	-2	2	-6	1	1	14

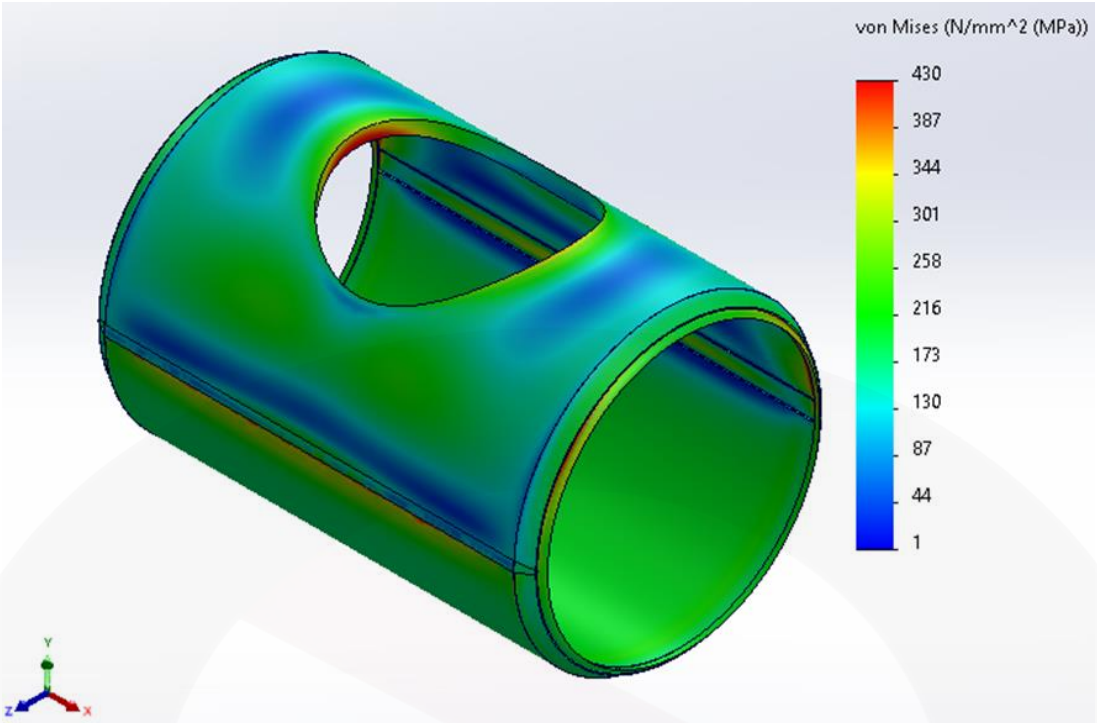
Maximum triaxial stress, **(σ1+ σ2+ σ3) =358 Mpa**

The following table summarizes the results obtained for the neck compared to the allowable amounts established by the code in part 5.

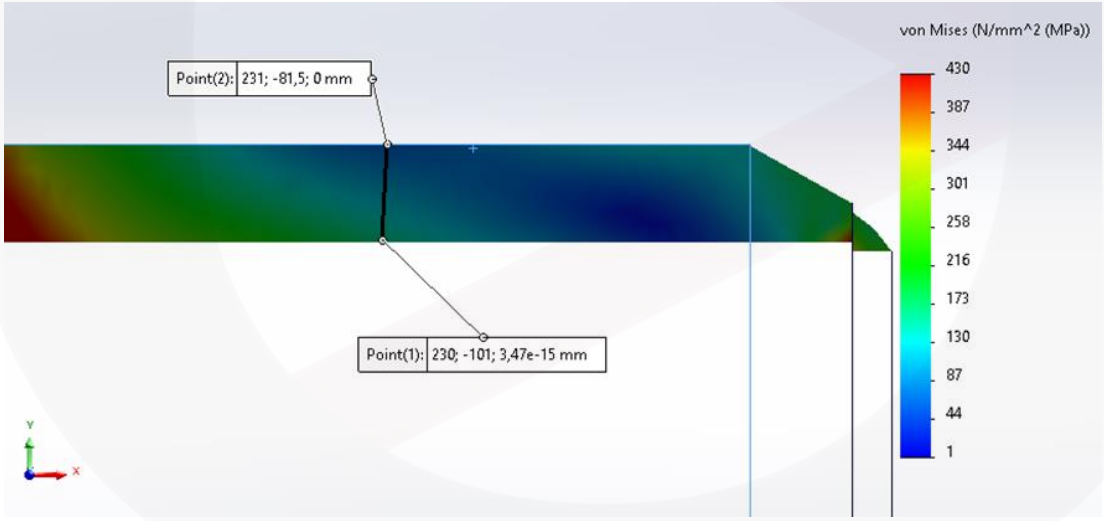
Hot Tap 12" x 16"-Allowable Stresses per VIII DIV 2, *Pd=94 bar, Td=80 °C*

Item	Part/Material	FEA Case per VIII Div 2 Part 5	Condition	ASME VIII DIV. 2 Load combinations	Type of Stress	*FEA "Se" or Triaxial stress* (MPa)	"S" Allow. Stress (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4) or as indicated	Allow. Stress (MPa)	Result
2	(Mark 3) 12"-Neck-API 5L-X60	3	Design	P+D+External loads+T	P_m	*167*	214,6	$P_m \leq S$	S (Eq. 5.2)	214,6	*Check*
					P_L	*266*		$P_L \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.3)	321,9	*Check*
					PL+Pb	*287*		$(P_L+P_b) \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.4)	321,9	*Check*
		3	Local	P+D+External loads+T	σ1+σ2+σ3	*358*		(σ1+σ2+σ3) ≤ 4*S	Per 5.3.2 (Eq. 5,5)	858,4	*Check*

➢ 16” x 12”-Reduced Split tee (Mark 4)



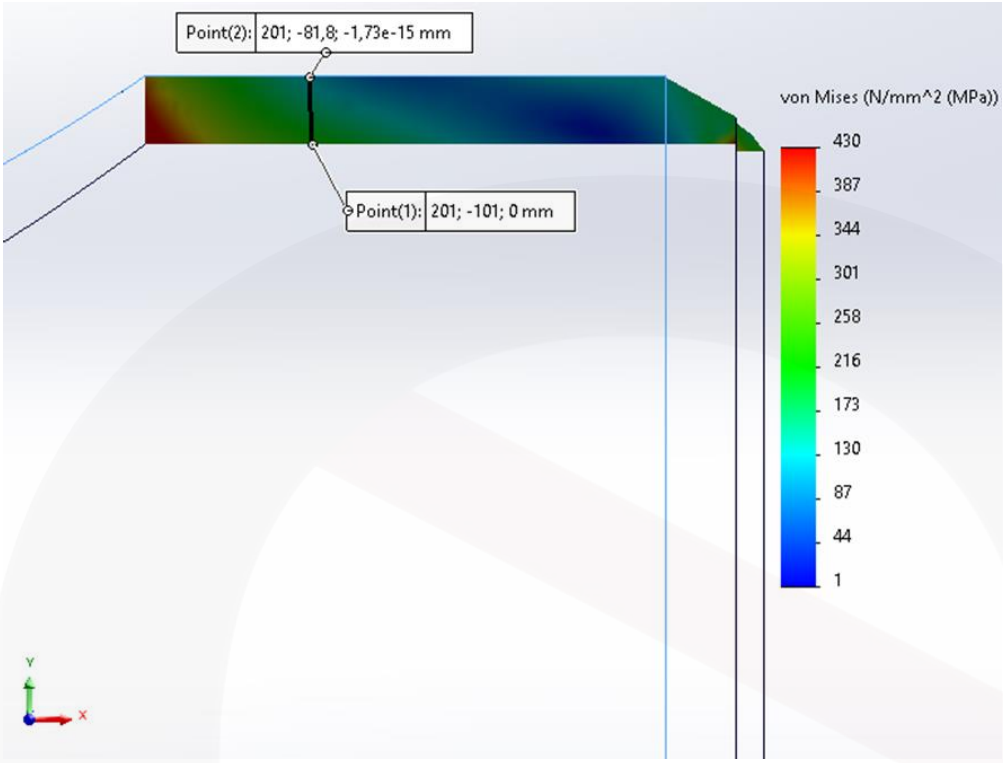
A. Pm



Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	7	53	0	0	0	50
Bending (Point 2)	-0	-7	-53	-0	-0	-0	50
Membrane Stress	-2	49	119	-12	0	-1	107
Membrane Stress + Bending (Point 1)	-2	57	172	-12	0	-1	155
Membrane Stress + Bending (Point 2)	-2	42	65	-12	0	-2	64
Peak (Point 1)	-6	1	1	6	0	-0	12
Peak (Point 2)	3	4	3	8	-0	0	13

Pm=107 Mpa

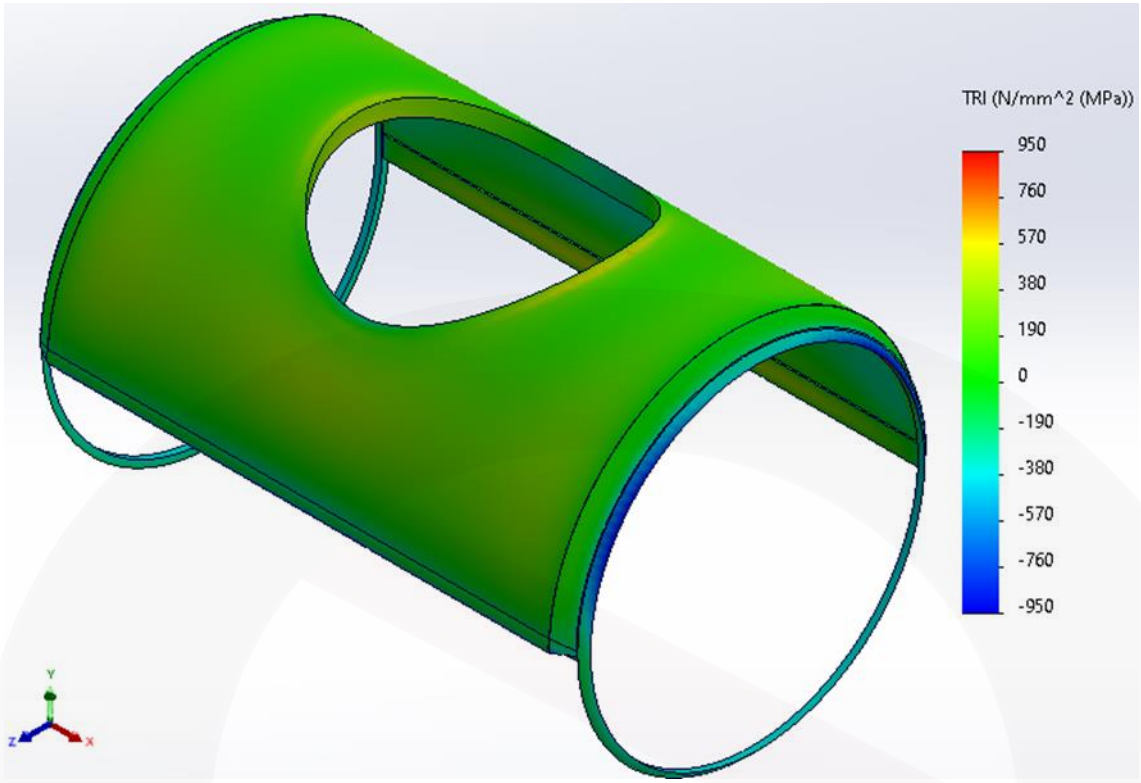
B. PL, PL+PB

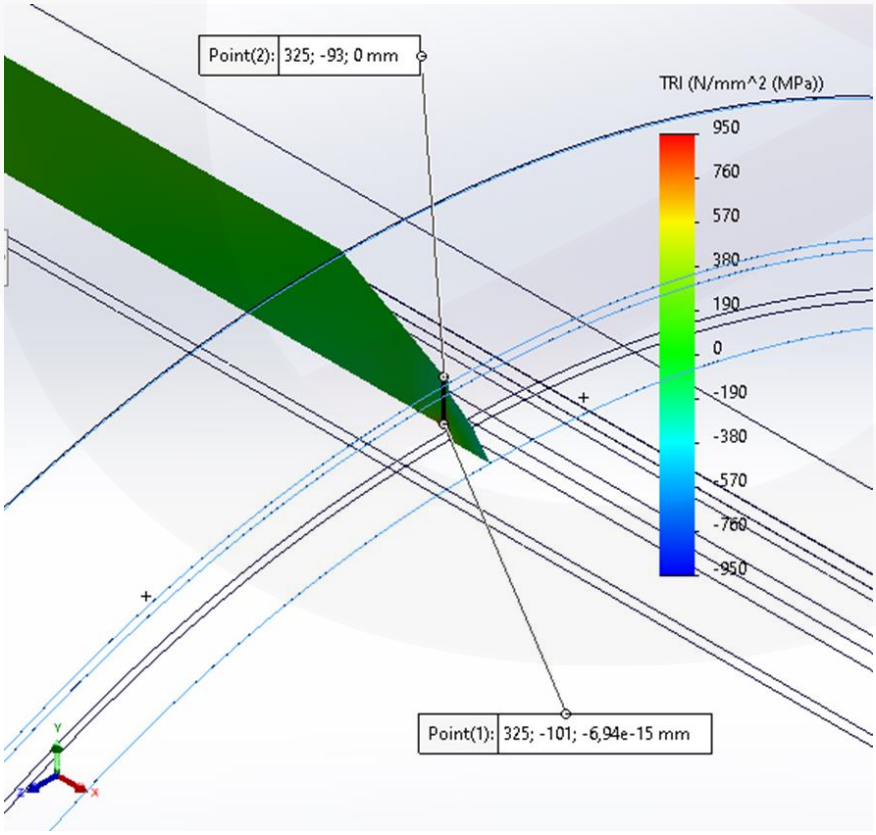


Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	64	73	0	0	1	69
Bending (Point 2)	-0	-64	-73	-0	-0	-1	69
Membrane Stress	-4	54	187	-1	-0	-1	170
Membrane Stress + Bending (Point 1)	-4	119	260	-1	-0	-0	229
Membrane Stress + Bending (Point 2)	-4	-10	114	-1	-0	-2	121
Peak (Point 1)	-5	0	2	5	0	-0	11
Peak (Point 2)	3	0	1	-1	0	-0	3

PL= 170 Mpa; PL+PB=229 Mpa

C. *Triaxial stress for localized- 16" x 12"*-Reduced Split tee (Mark 4)





Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	159	62	0	0	-2	139
Bending (Point 2)	-0	-159	-62	-0	-0	2	139
Membrane Stress	64	50	-146	55	-3	-3	225
Membrane Stress + Bending (Point 1)	64	210	-85	55	-3	-5	272
Membrane Stress + Bending (Point 2)	64	-109	-208	55	-3	-1	257
Peak (Point 1)	67	6	3	87	-0	-0	163
Peak (Point 2)	-40	43	18	-58	-0	-0	124

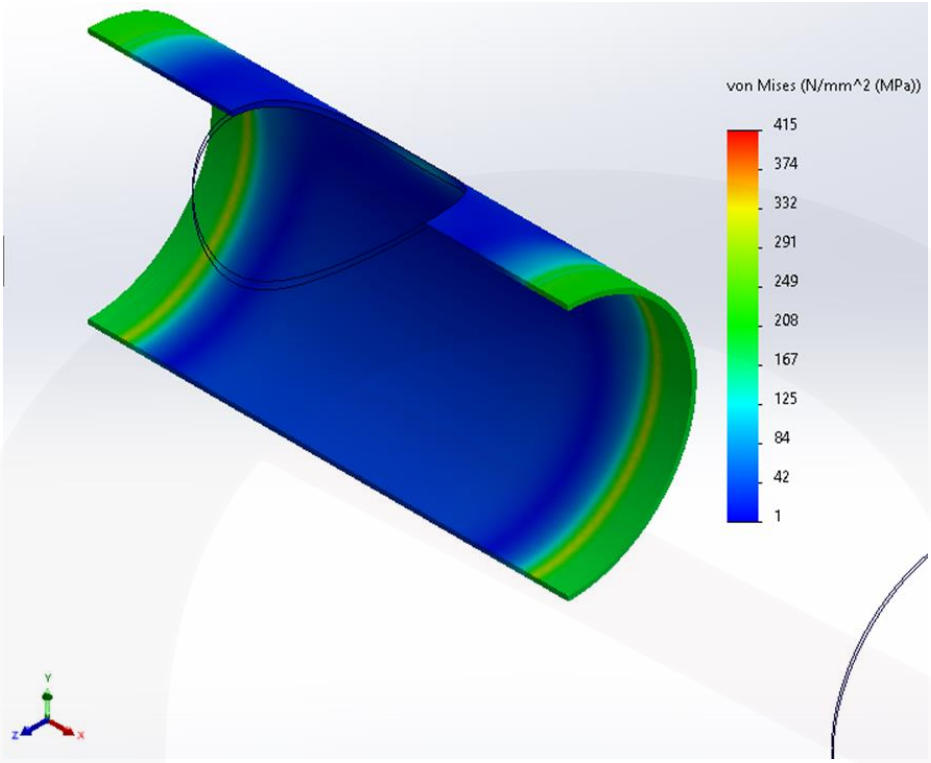
Maximum triaxial stress, (σ1+ σ2+ σ3) =272 Mpa

The following table summarizes the results obtained for the mark 4 part compared to the allowable amounts established by the code in part 5.

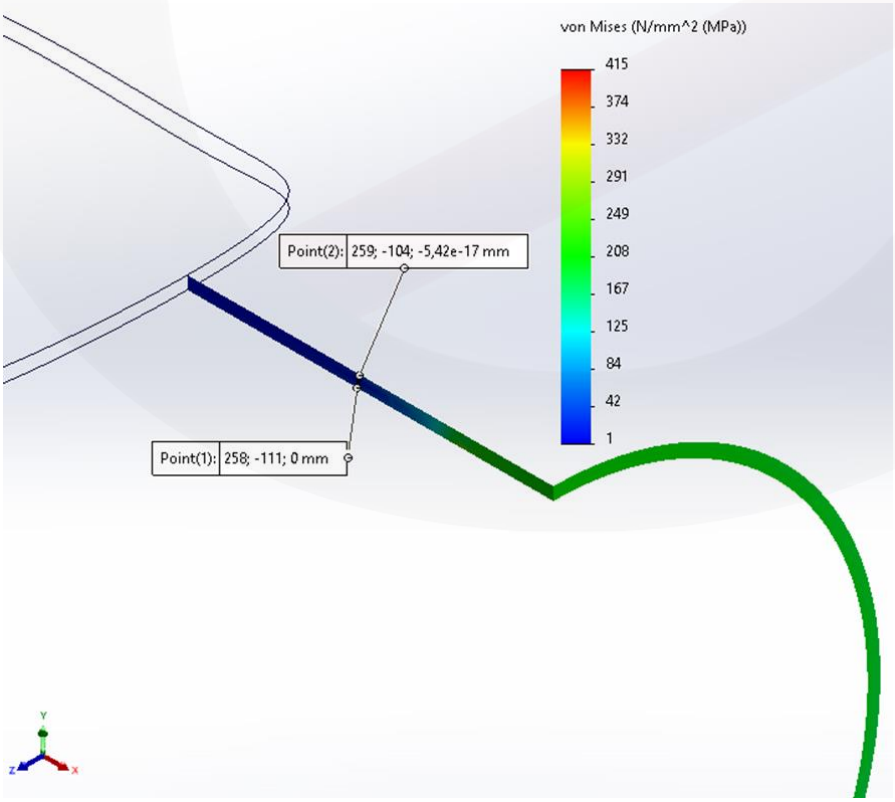
Hot Tap 12" x 16"-Allowable Stresses per VIII DIV 2, *Pd=94 bar, Td=80 °C*

Item	Part/Material	FEA Case per VIII Div 2 Part 5	Condition	ASME VIII DIV. 2 Load combinations	Type of Stress	FEA "Se" or Triaxial stress (MPa)	"S" Allow. Stress (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4) or as indicated	Allow. Stress (MPa)	Result
3	(Mark 4) 16"-*Run* - P460-NL2	3	Design	P+D+External loads+T	P_m	*107*	237,5	$P_m \leq S$	S (Eq. 5.2)	237,5	*Check*
					P_L	*170*		$P_L \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.3)	356,25	*Check*
					PL+Pb	*229*		$(P_L+P_b) \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.4)	356,25	*Check*
		3	Local	P+D+External loads+T	σ1+σ2+σ3	*272*		$(\sigma1+\sigma2+\sigma3) \leq 4*S$	Per 5.3.2 VIII Div. 2 (Eq. 5,5)	950	*Check*

- 16”-Existing Pipeline



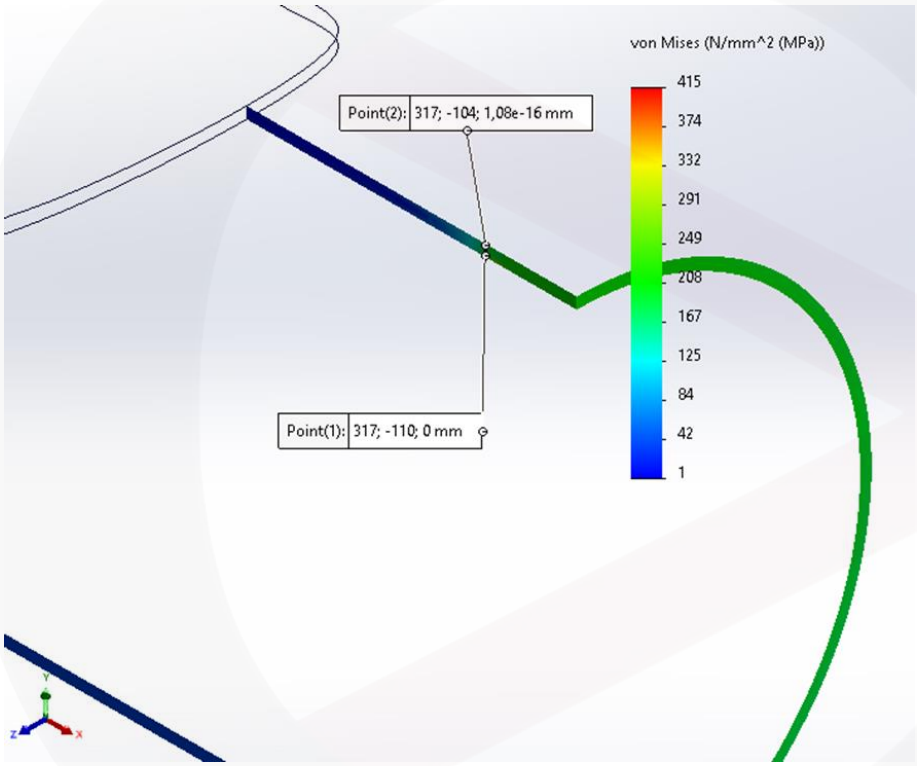
A. Pm



Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	-44	-7	0	0	-0	41
Bending (Point 2)	-0	44	7	-0	-0	0	41
Membrane Stress	-9	-12	-11	-2	-0	0	4
Membrane Stress + Bending (Point 1)	-9	-56	-18	-2	-0	0	43
Membrane Stress + Bending (Point 2)	-9	32	-4	-2	-0	0	39
Peak (Point 1)	-1	1	0	8	-0	-0	13
Peak (Point 2)	1	-0	-0	-8	0	-0	14

Pm=4 Mpa

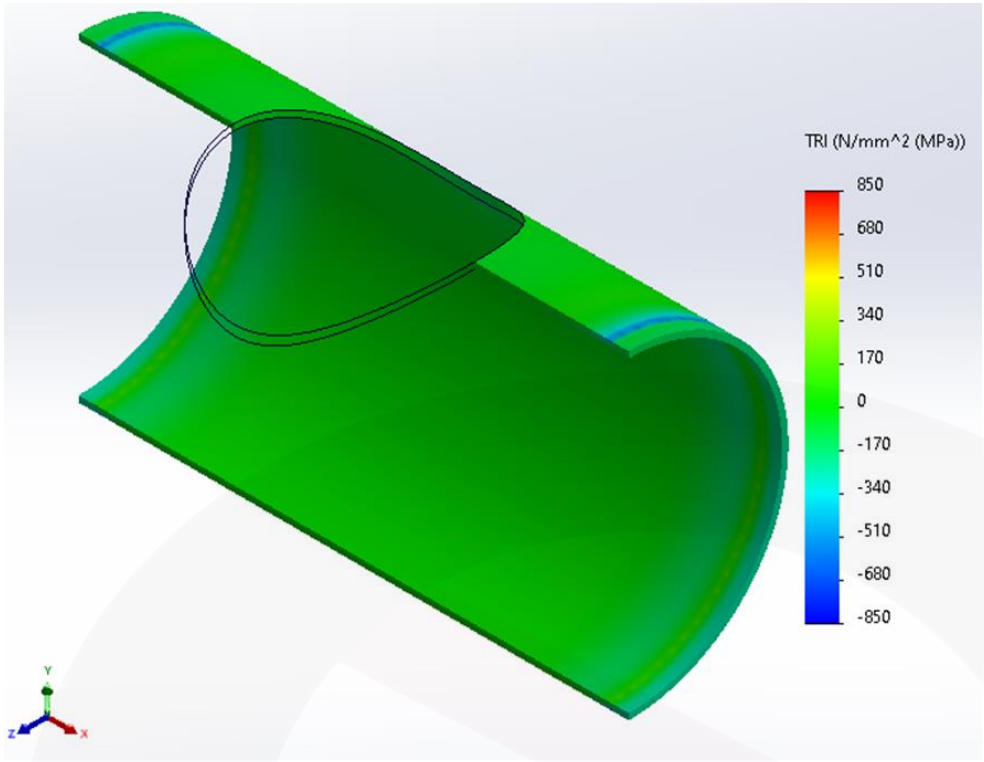
B. PL, PL+PB

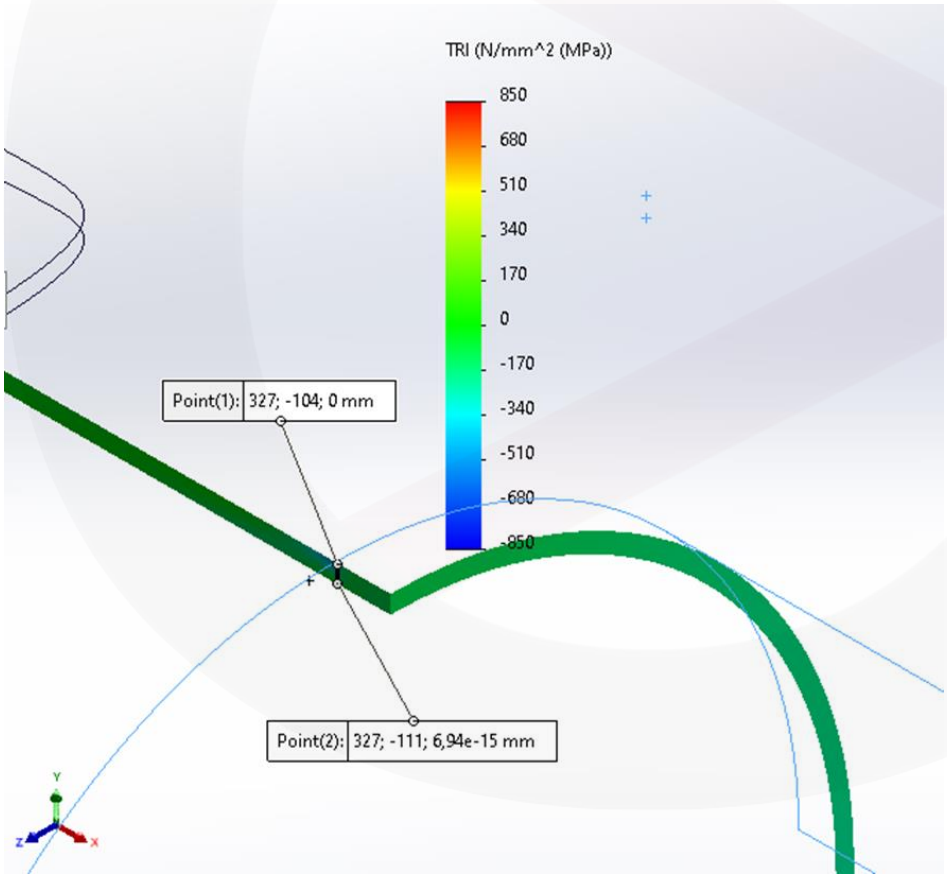


Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	99	26	0	0	-0	89
Bending (Point 2)	-0	-99	-26	-0	-0	0	89
Membrane Stress	-10	-23	-177	17	1	-0	163
Membrane Stress + Bending (Point 1)	-10	76	-151	17	1	-1	200
Membrane Stress + Bending (Point 2)	-10	-122	-203	17	1	-0	170
Peak (Point 1)	-3	-0	0	-11	-0	0	19
Peak (Point 2)	4	2	1	10	-0	0	17

PL= 163 Mpa; PL+PB=200 Mpa

C. Triaxial stress for localized 16”- Pipeline





Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	-127	-40	0	0	0	112
Bending (Point 2)	-0	127	40	-0	-0	-0	112
Membrane Stress	-32	-4	-200	14	1	0	185
Membrane Stress + Bending (Point 1)	-32	-131	-240	14	1	0	182
Membrane Stress + Bending (Point 2)	-32	123	-160	14	1	-0	247
Peak (Point 1)	-17	12	4	25	-0	0	51
Peak (Point 2)	19	3	1	-24	0	0	46

Maximum triaxial stress, (σ1+ σ2+ σ3) =247 Mpa

The following table summarizes the results obtained for the pipeline part compared to the allowable amounts established by the code in part 5.

Hot Tap 12" x 16"-Allowable Stresses per VIII DIV 2, *Pd=94 bar, Td=80 °C*

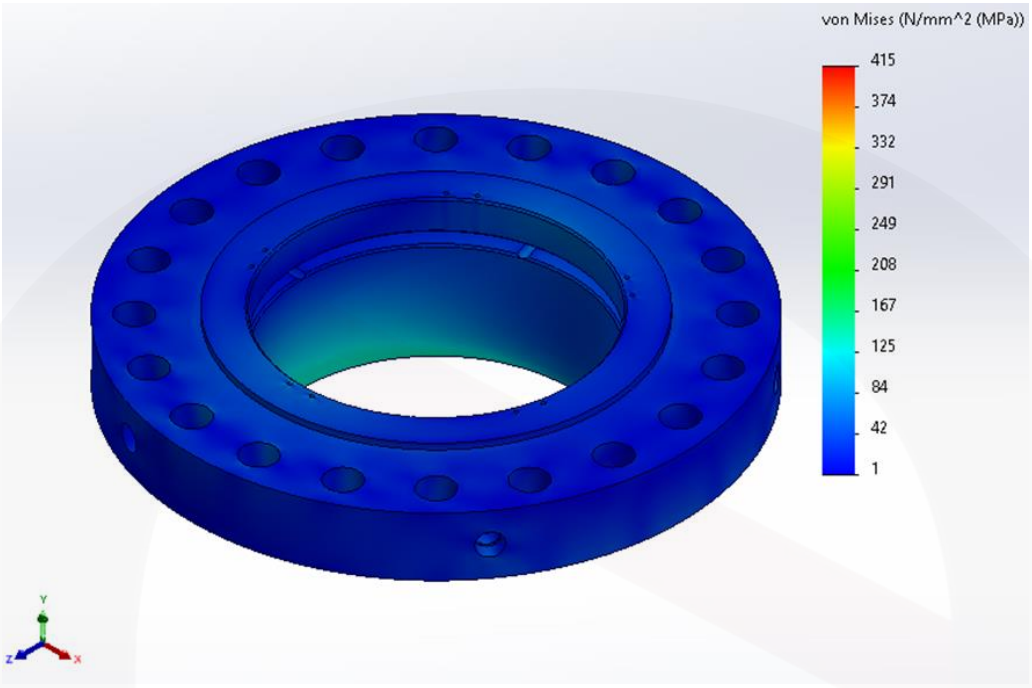
Item	Part/Material	FEA Case per VIII Div 2 Part 5	Condition	ASME VIII DIV. 2 Load combinations	Type of Stress	FEA "Se" or Triaxial stress (MPa)	"S" Allow. Stress (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4) or as indicated	Allow. Stress (MPa)	Result
4	Existing 16"-Pipeline -API 5LX60	3	Design	P+D+External loads+T	P_m	*4*	214,6	$P_m \leq S$	S (Eq. 5.2)	214,6	*Check*
					P_L	*163*		$P_L \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.3)	321,9	*Check*
					PL+Pb	*200*		$(P_L+P_b) \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.4)	321,9	*Check*
		3	Local	P+D+External loads+T	σ1+σ2+σ3	*247*		(σ1+σ2+σ3) ≤ 4*S	Per 5.3.2 VIII Div. 2 (Eq. 5,5)	858,4	*Check*

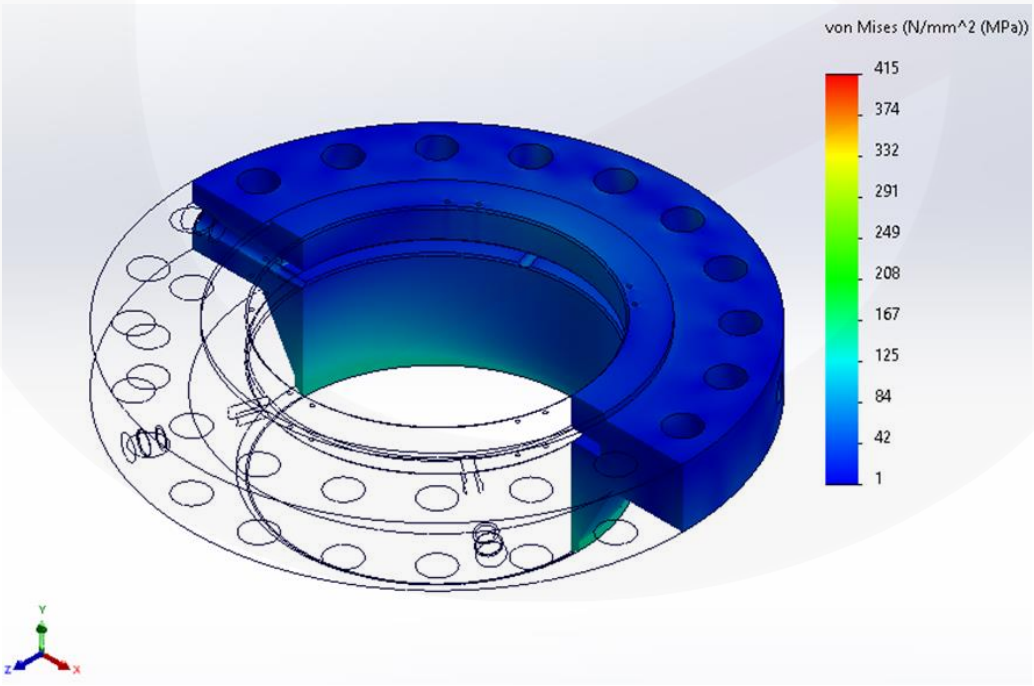
8.3 Stress linearization for the 14” x 12” Stopple Fitting.

The following imagens summarized the stress linearization performed to the following parts: *Flange*, *branch neck*, *upper and lower half shell of the stopple fitting* and a *portion of the pipeline*.

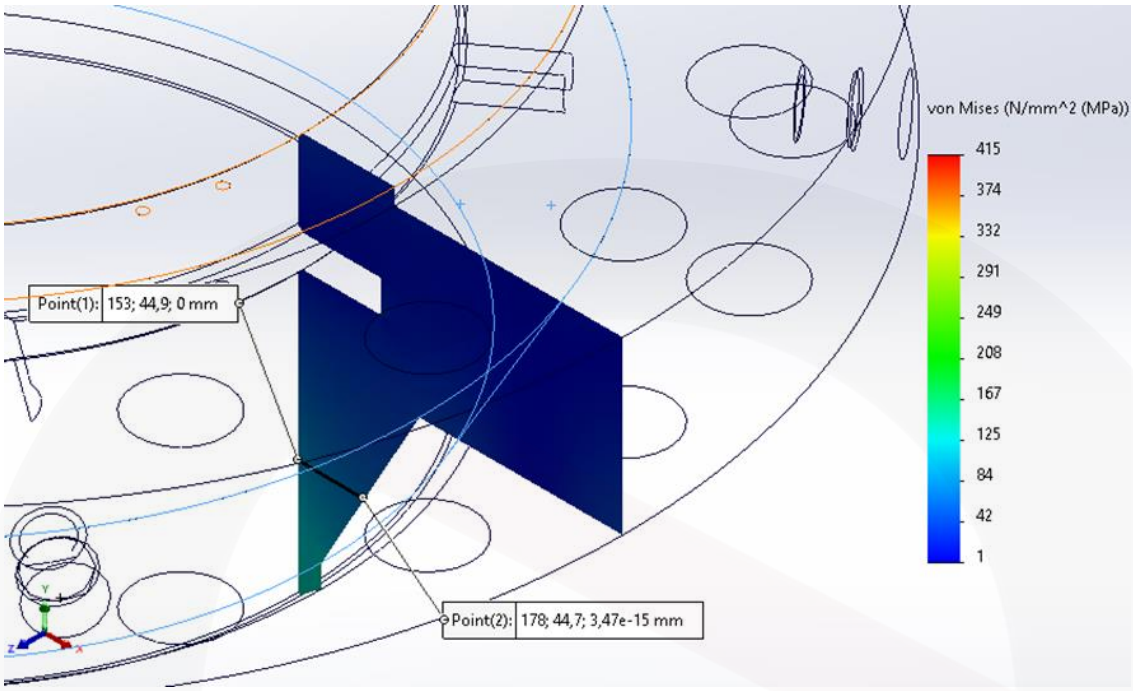
Desing condition

- 12”-600# Flange (Mark 1)





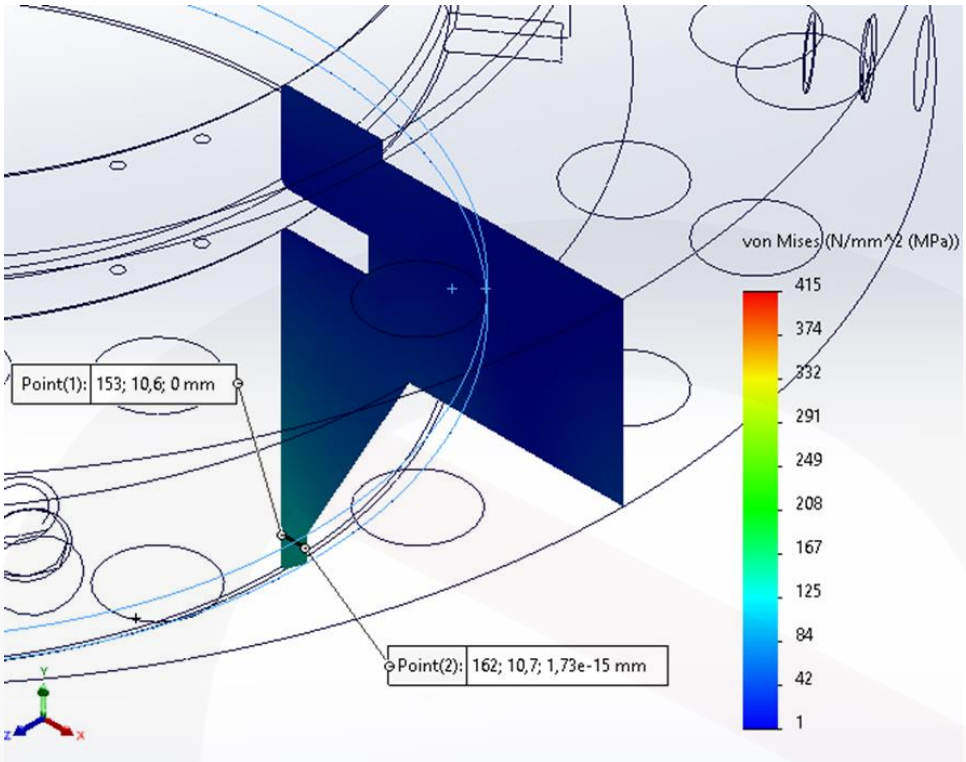
A. Pm



Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	18	13	0	0	-1	16
Bending (Point 2)	-0	-18	-13	-0	-0	1	16
Membrane Stress	-3	20	86	3	-0	-2	81
Membrane Stress + Bending (Point 1)	-3	38	100	3	-0	-3	90
Membrane Stress + Bending (Point 2)	-3	2	73	3	-0	-1	74
Peak (Point 1)	-6	1	1	-3	0	0	9
Peak (Point 2)	4	1	1	-1	-0	0	4

Pm=81 Mpa

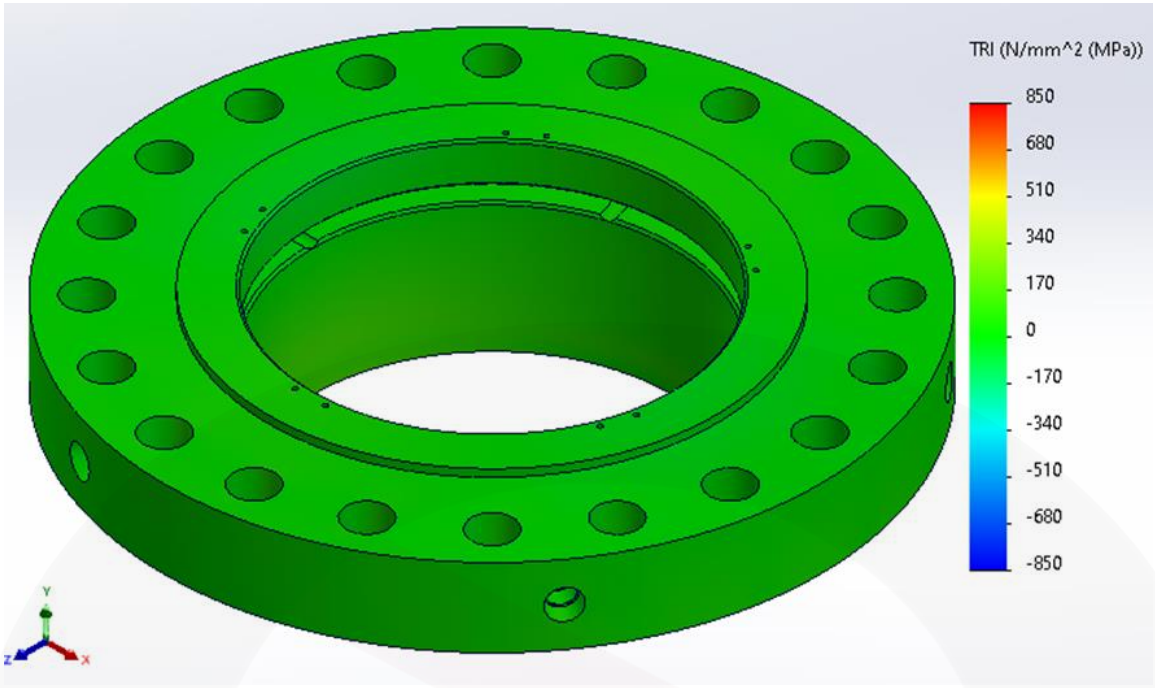
B. PL, PL+PB

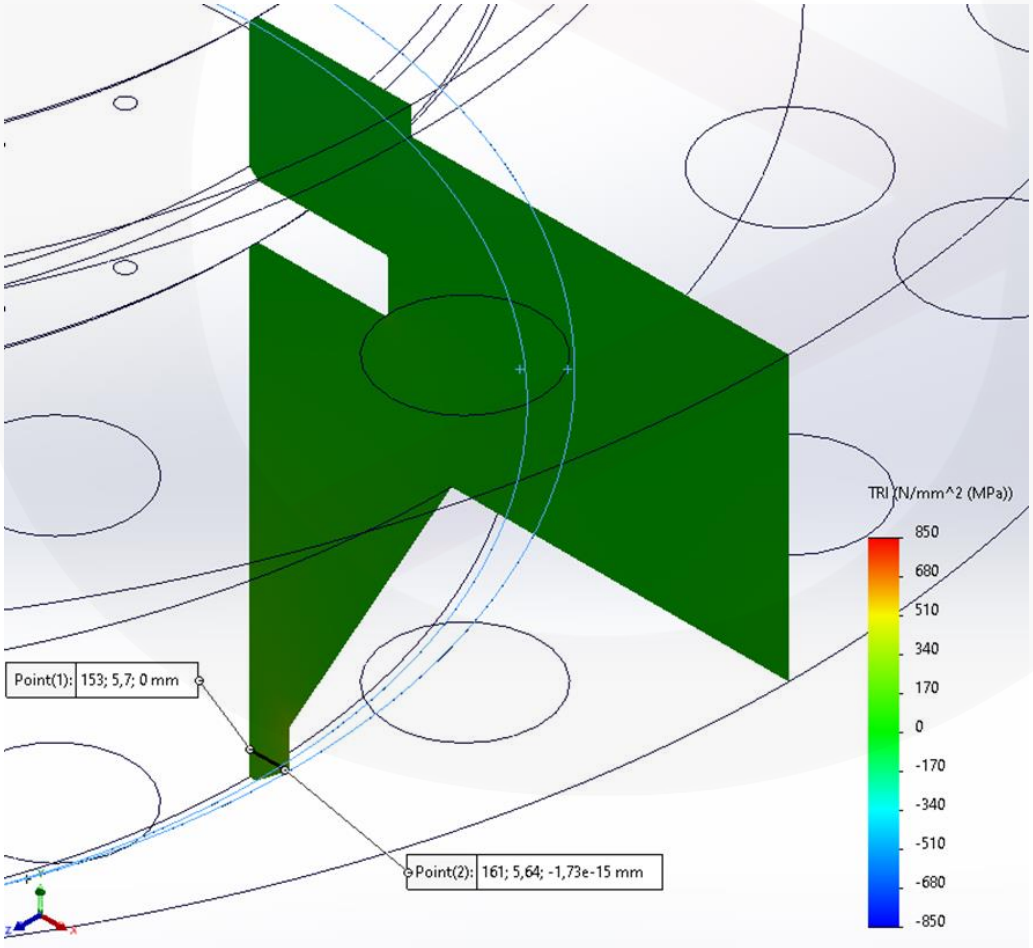


Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	-59	-12	0	0	0	54
Bending (Point 2)	-0	59	12	-0	-0	-0	54
Membrane Stress	0	64	145	5	-0	-8	127
Membrane Stress + Bending (Point 1)	0	6	134	5	-0	-8	132
Membrane Stress + Bending (Point 2)	0	123	157	5	-0	-8	144
Peak (Point 1)	-8	3	-0	-3	0	-0	12
Peak (Point 2)	7	3	1	7	-1	-0	14

PL= 127 Mpa; PL+PB=144 Mpa

C. Triaxial stress for localized 12”-600# Flange





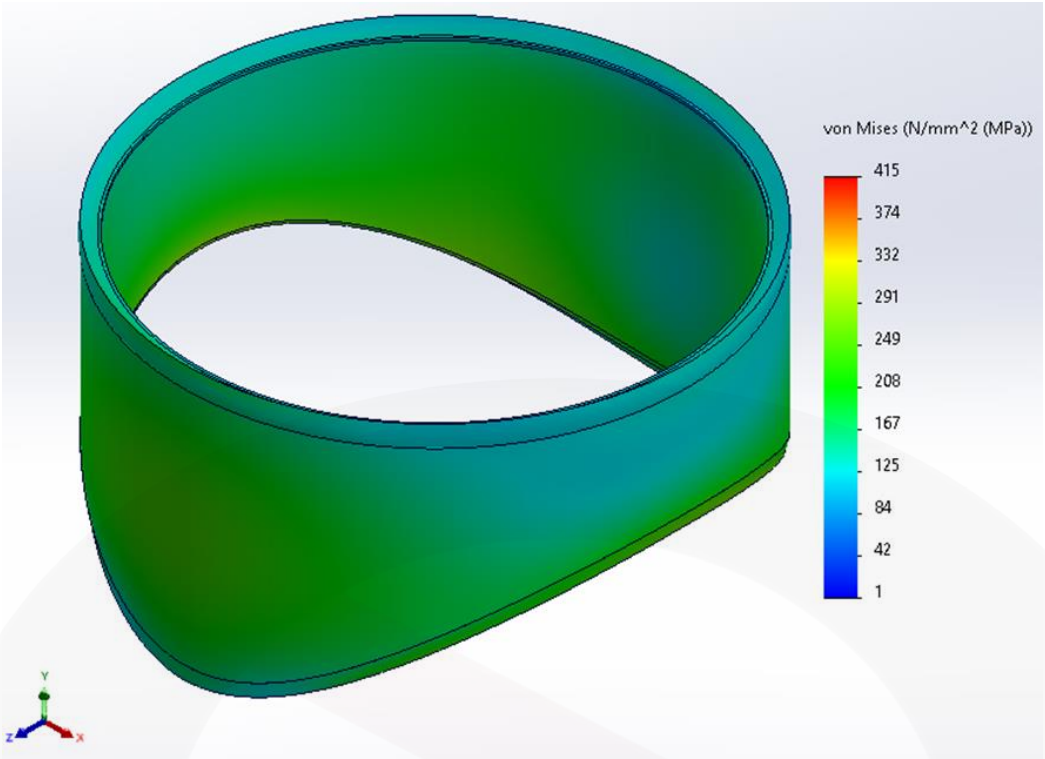
Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	-49	-8	0	0	0	46
Bending (Point 2)	-0	49	8	-0	-0	-0	46
Membrane Stress	-5	67	147	3	0	-8	132
Membrane Stress + Bending (Point 1)	-5	18	139	3	0	-8	135
Membrane Stress + Bending (Point 2)	-5	116	155	3	0	-8	145
Peak (Point 1)	-5	0	-0	1	-0	-0	5
Peak (Point 2)	3	-1	-1	-5	0	-0	10

Maximum triaxial stress, (σ1+ σ2+ σ3) =145 Mpa

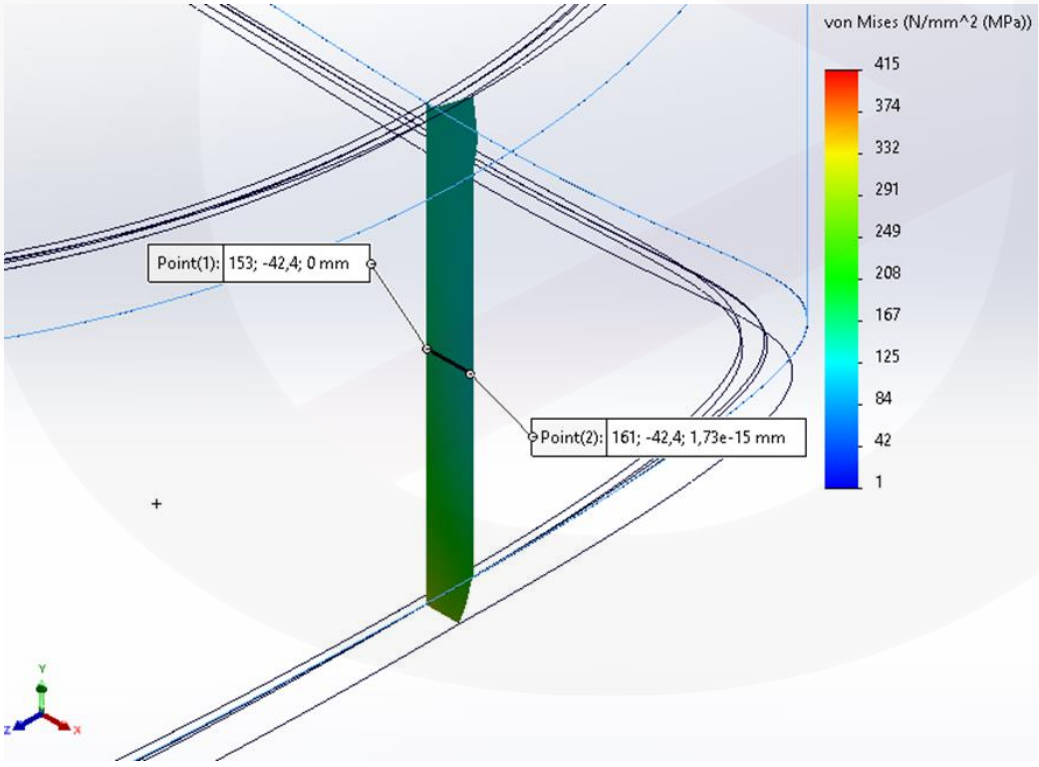
The following table summarizes the results obtained for the flange compared to the allowable amounts established by the code in part 5.

Hot Tap 12" x 14"-Allowable Stresses per VIII DIV 2, *Pd=94 bar, Td=80 °C*											
Item	Part/Material	FEA Case per VIII Div 2 Part 5	Condition	ASME VIII DIV. 2 Load combinations	Type of Stress	*FEA "Se" or Triaxial stress* (MPa)	"S" Allow. Stress (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4) or as indicated	Allow. Stress (MPa)	Result
1	(Mark 1) 12"-600#-RF-LS *FLANGE A694F60*	3	Design	P+D+External loads+T	P_m	*81*	214,6	$P_m \leq S$	S (Eq. 5.2)	214,6	*Check*
					P_L	*127*		$P_L \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.3)	321,9	*Check*
					PL+Pb	*144*		$(P_L+P_b) \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.4)	321,9	*Check*
		3	Local	P+D+External loads+T	σ1+σ2+σ3	*145*		(σ1+σ2+σ3) ≤ 4*S	Per 5.3.2 (Eq. 5,5)	858,4	*Check*

- 12”-Neck (Mark 3)



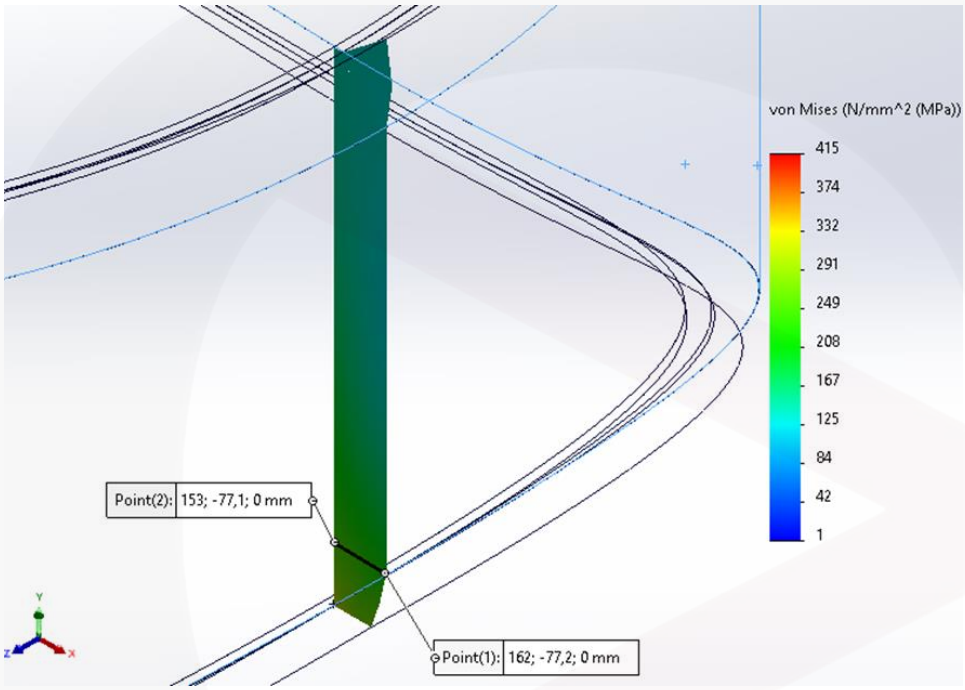
A. Pm



Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	31	21	0	0	1	28
Bending (Point 2)	-0	-31	-21	-0	-0	-1	28
Membrane Stress	-5	82	163	2	-0	-9	146
Membrane Stress + Bending (Point 1)	-5	113	184	2	-0	-8	165
Membrane Stress + Bending (Point 2)	-5	51	141	2	-0	-10	129
Peak (Point 1)	-4	0	0	-0	0	0	5
Peak (Point 2)	5	0	0	0	0	0	4

Pm=146 Mpa

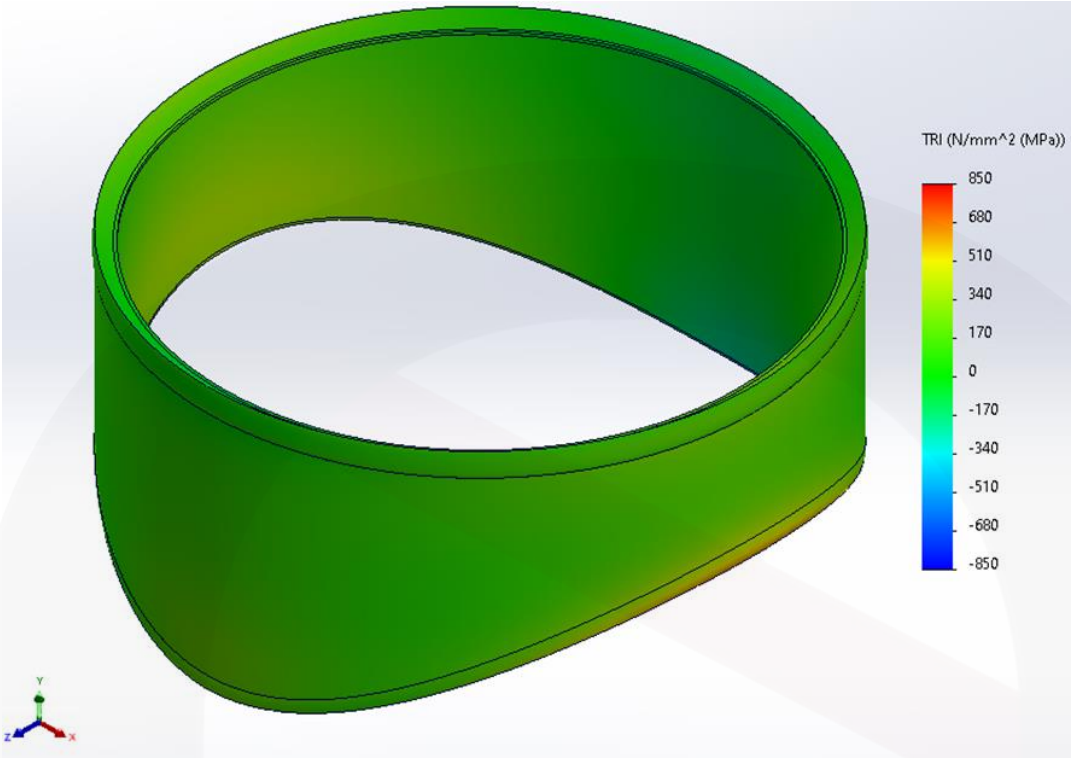
B. PL, PL+PB

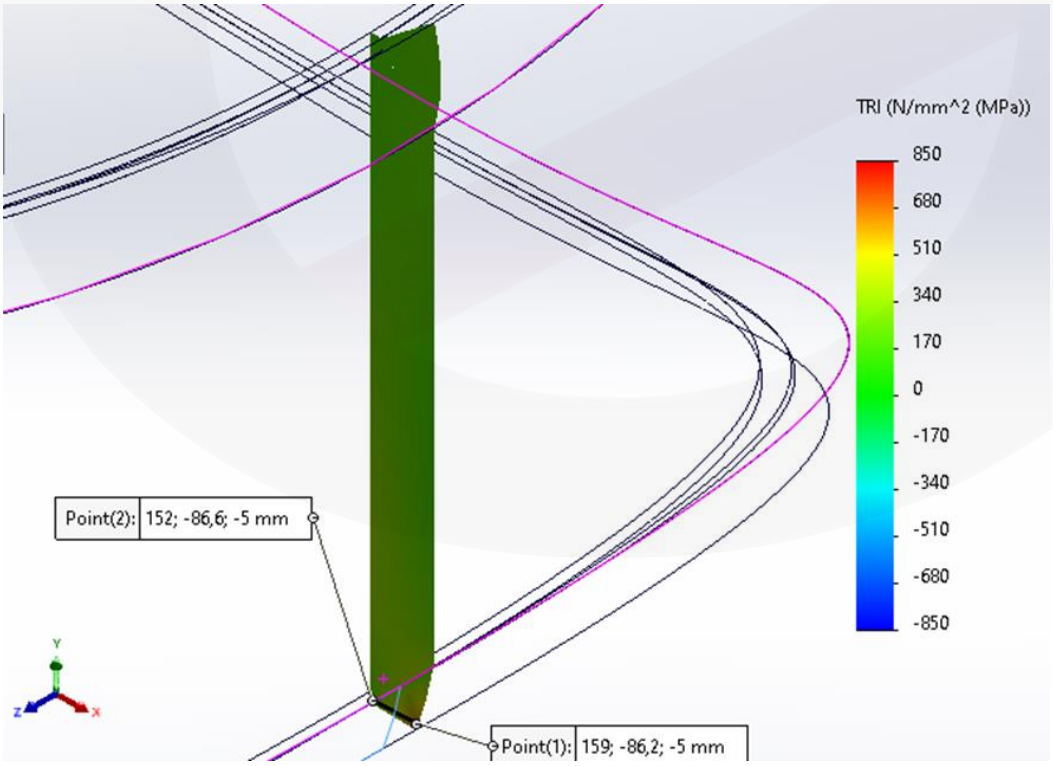


Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	1	-15	0	0	3	17
Bending (Point 2)	-0	-1	15	-0	-0	-3	17
Membrane Stress	-8	95	259	-8	0	12	234
Membrane Stress + Bending (Point 1)	-8	97	243	-8	0	15	221
Membrane Stress + Bending (Point 2)	-8	94	274	-8	0	9	248
Peak (Point 1)	9	-3	-1	9	1	-0	19
Peak (Point 2)	-6	-2	-0	-7	-0	2	13

PL= 234 Mpa; PL+PB=248 Mpa

C. Triaxial stress for localized 12”-Neck





Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	123	22	0	0	9	115
Bending (Point 2)	-0	-123	-22	-0	-0	-9	115
Membrane Stress	29	98	325	-13	-13	16	272
Membrane Stress + Bending (Point 1)	29	222	347	-13	-13	26	283
Membrane Stress + Bending (Point 2)	29	-25	303	-13	-13	7	307
Peak (Point 1)	12	-8	-3	3	-1	-2	19
Peak (Point 2)	-24	4	-1	21	3	0	44

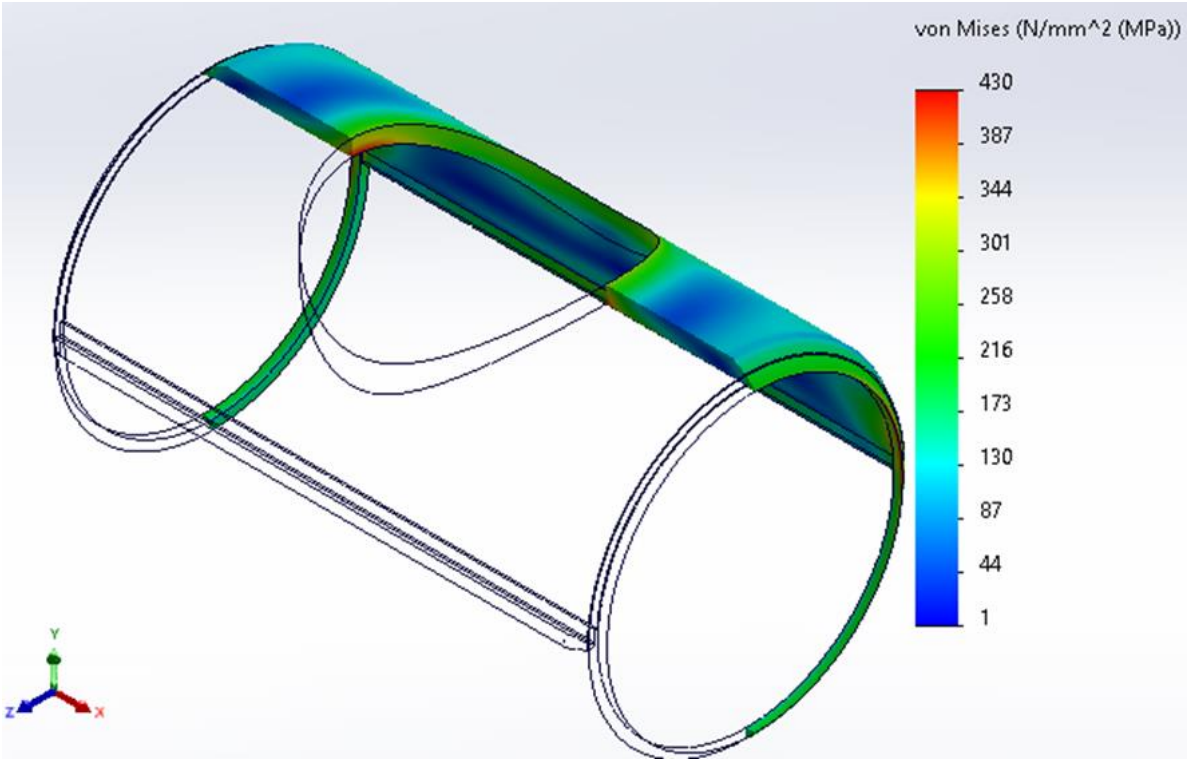
Maximum triaxial stress, **(σ1+ σ2+ σ3) =307 Mpa**

The following table summarizes the results obtained for the neck compared to the allowable amounts established by the code in part 5.

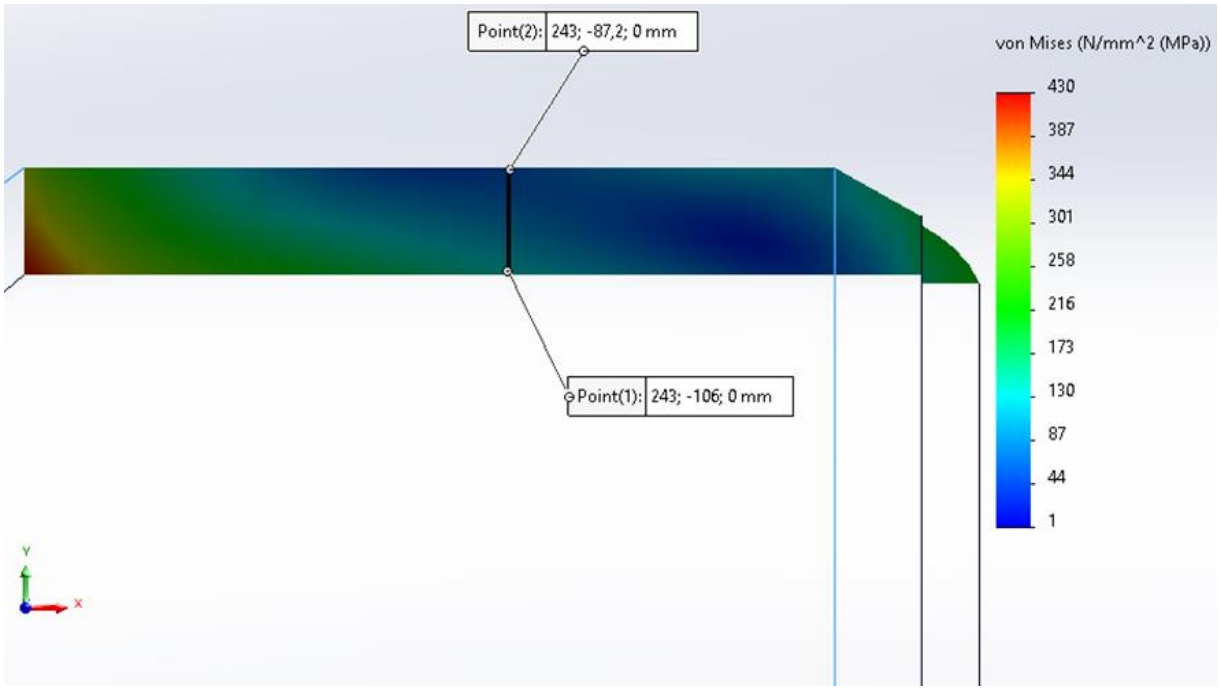
Hot Tap 12" x 14"-Allowable Stresses per VIII DIV 2, *Pd=94 bar, Td=80 °C*

Item	Part/Material	FEA Case per VIII Div 2 Part 5	Condition	ASME VIII DIV. 2 Load combinations	Type of Stress	*FEA "Se" or Triaxial stress* (MPa)	"S" Allow. Stress (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4) or as indicated	Allow. Stress (MPa)	Result
2	(Mark 3) 12"-Neck-API 5L-X60	3	Design	P+D+External loads+T	P_m	*146*	214,6	$P_m \leq S$	S (Eq. 5.2)	214,6	*Check*
					P_L	*243*		$P_L \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.3)	321,9	*Check*
					PL+Pb	*248*		$(P_L+P_b) \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.4)	321,9	*Check*
		3	Local	P+D+External loads+T	σ1+σ2+σ3	*307*		(σ1+σ2+σ3) ≤ 4*S	Per 5.3.2 (Eq. 5,5)	858,4	*Check*

- *14" x 12"*-Reduced Split tee (Mark 4)



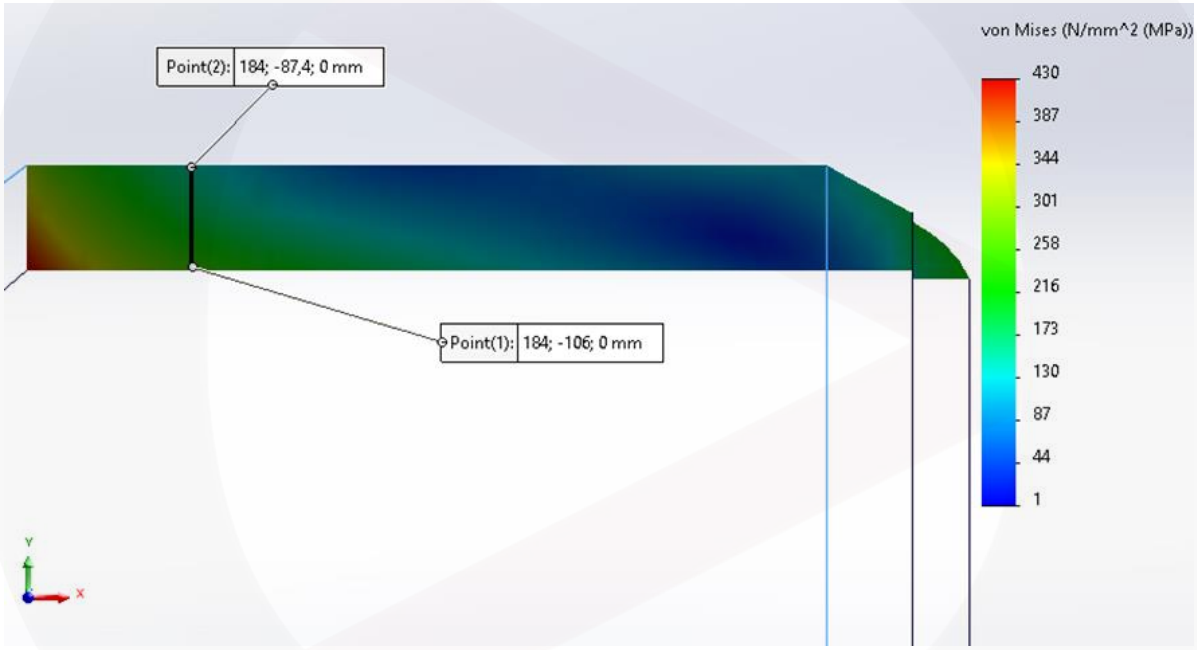
A. Pm



Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	-23	42	0	0	-3	58
Bending (Point 2)	-0	23	-42	-0	-0	3	58
Membrane Stress	-3	37	89	-10	-0	-8	84
Membrane Stress + Bending (Point 1)	-3	14	132	-10	-0	-11	130
Membrane Stress + Bending (Point 2)	-3	61	47	-10	-0	-5	61
Peak (Point 1)	-5	2	2	7	0	-0	15
Peak (Point 2)	3	1	2	8	0	0	14

Pm=84 Mpa

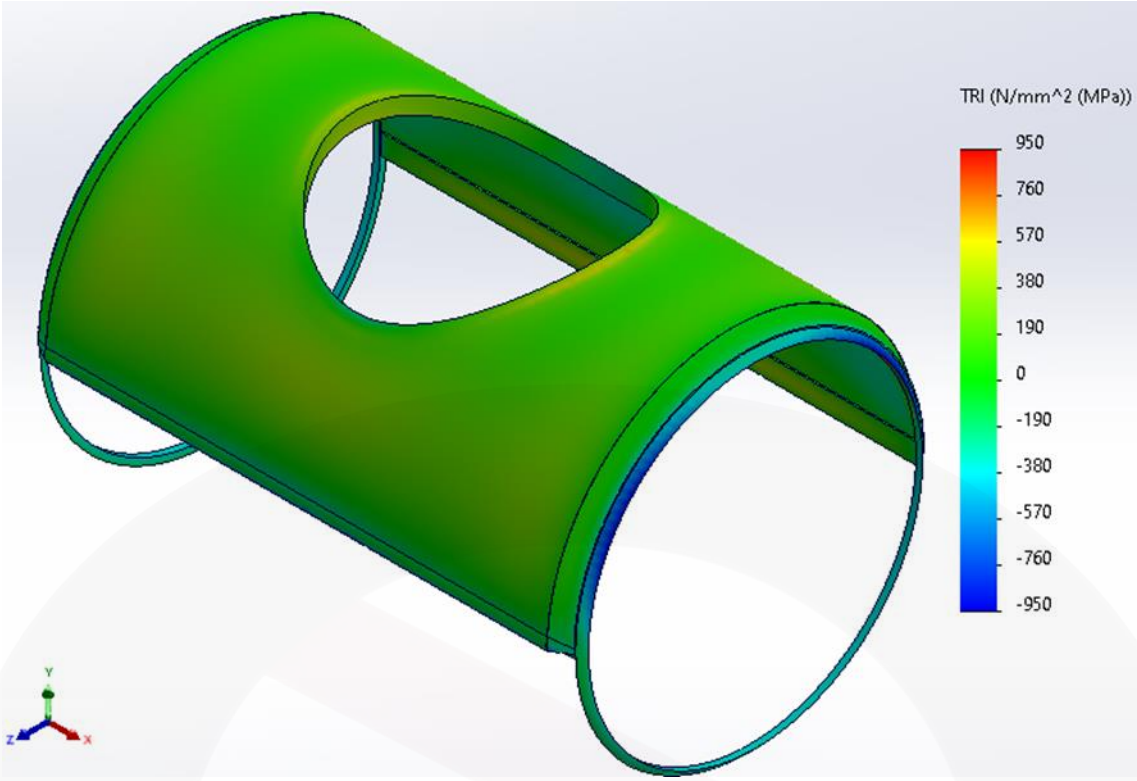
B. PL, PL+PB

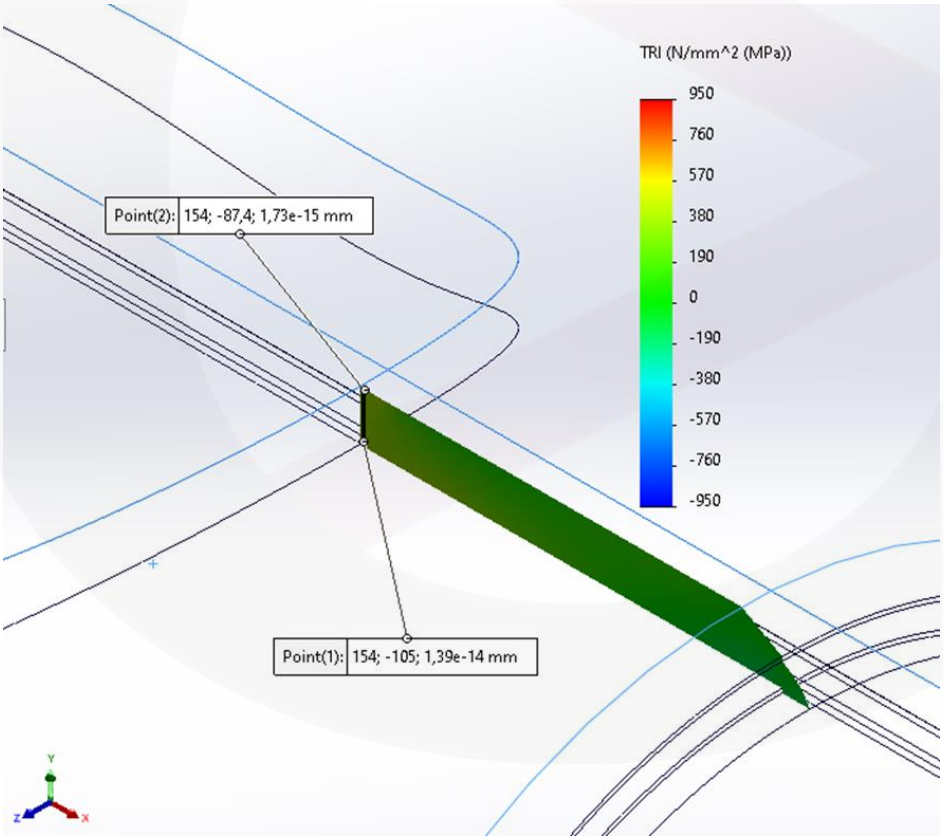


Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	67	78	0	0	-3	73
Bending (Point 2)	-0	-67	-78	-0	-0	3	73
Membrane Stress	-3	39	206	5	-1	-9	192
Membrane Stress + Bending (Point 1)	-3	106	283	5	-1	-12	251
Membrane Stress + Bending (Point 2)	-3	-29	128	5	-1	-6	146
Peak (Point 1)	-5	0	2	-2	1	-0	7
Peak (Point 2)	2	0	2	-5	1	-0	9

PL= 192 Mpa; PL+PB=251 Mpa

C. Triaxial stress for localized 14" x 12"-Reduced Split tee (Mark 4)





Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	-5	46	0	0	-0	49
Bending (Point 2)	-0	5	-46	-0	-0	0	49
Membrane Stress	17	-6	359	-4	-9	-1	355
Membrane Stress + Bending (Point 1)	17	-11	406	-4	-9	-1	404
Membrane Stress + Bending (Point 2)	17	-1	313	-4	-9	-1	306
Peak (Point 1)	-23	7	4	2	7	-0	31
Peak (Point 2)	15	6	1	-10	-6	-0	23

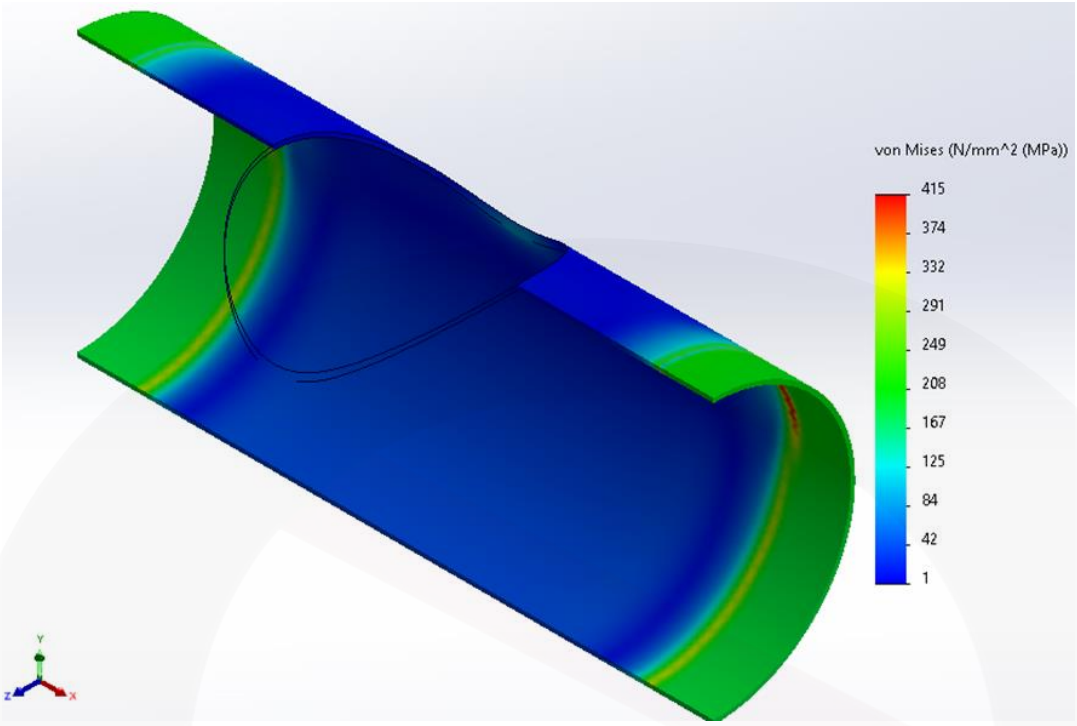
Maximum triaxial stress, (σ1+ σ2+ σ3) =404 Mpa

The following table summarizes the results obtained for the mark 4 part compared to the allowable amounts established by the code in part 5.

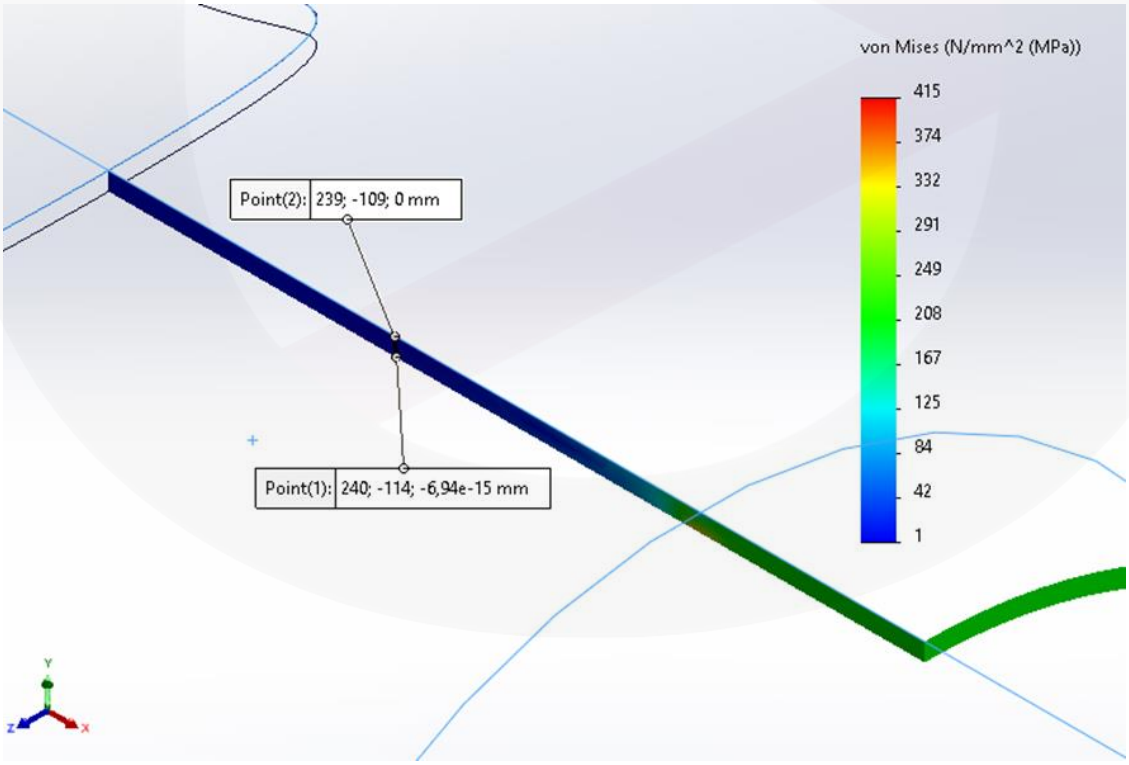
Hot Tap 12" x 14"-Allowable Stresses per VIII DIV 2, *Pd=94 bar, Td=80 °C*

Item	Part/Material	FEA Case per VIII Div 2 Part 5	Condition	ASME VIII DIV. 2 Load combinations	Type of Stress	*FEA "Se" or Triaxial stress* (MPa)	"S" Allow. Stress (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4) or as indicated	Allow. Stress (MPa)	Result
3	(Mark 4) 16"-*Run* - P460-NL2	3	Design	P+D+External loads+T	P_m	*84*	237,5	$P_m \leq S$	S (Eq. 5.2)	237,5	*Check*
					P_L	*192*		$P_L \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.3)	356,25	*Check*
					PL+Pb	*251*		$(P_L+P_b) \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.4)	356,25	*Check*
		3	Local	P+D+External loads+T	σ1+σ2+σ3	*404*		$(\sigma1+\sigma2+\sigma3) \leq 4*S$	Per 5.3.2 VIII Div. 2 (Eq. 5,5)	950	*Check*

- 14”-Existing Pipeline



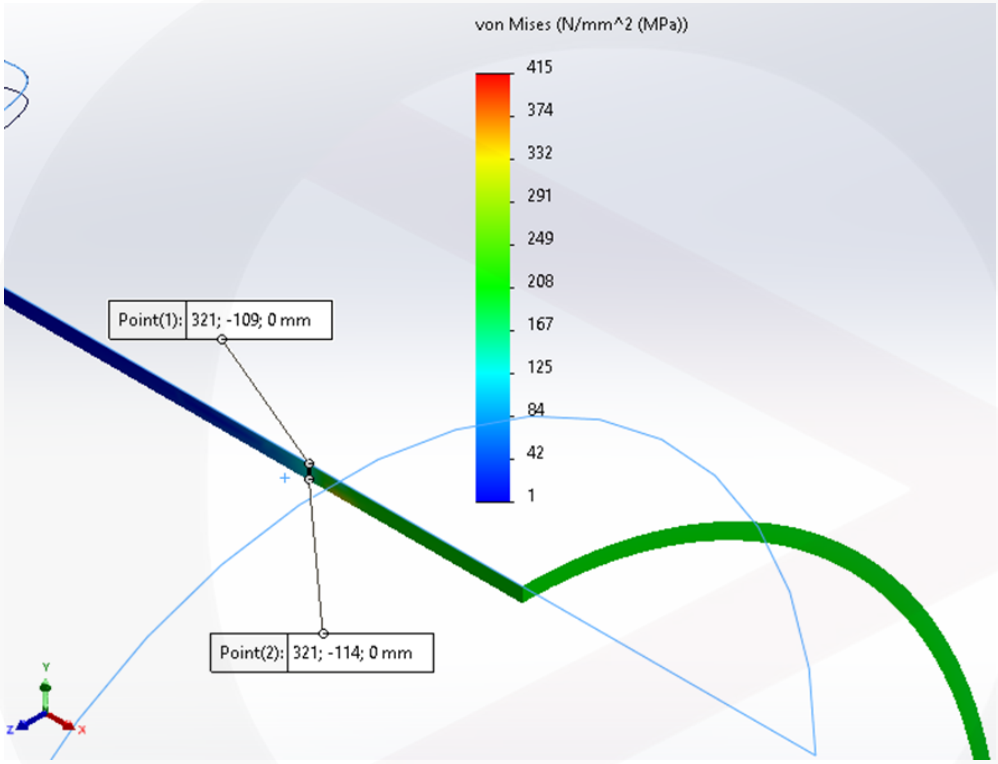
A. Pm



Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	3	7	0	0	-0	6
Bending (Point 2)	-0	-3	-7	-0	-0	0	6
Membrane Stress	-9	-9	-4	-0	-0	0	5
Membrane Stress + Bending (Point 1)	-9	-6	3	-0	-0	-0	11
Membrane Stress + Bending (Point 2)	-9	-12	-11	-0	-0	0	3
Peak (Point 1)	0	0	0	0	0	-0	1
Peak (Point 2)	-0	1	0	-0	0	-0	1

Pm=5 Mpa

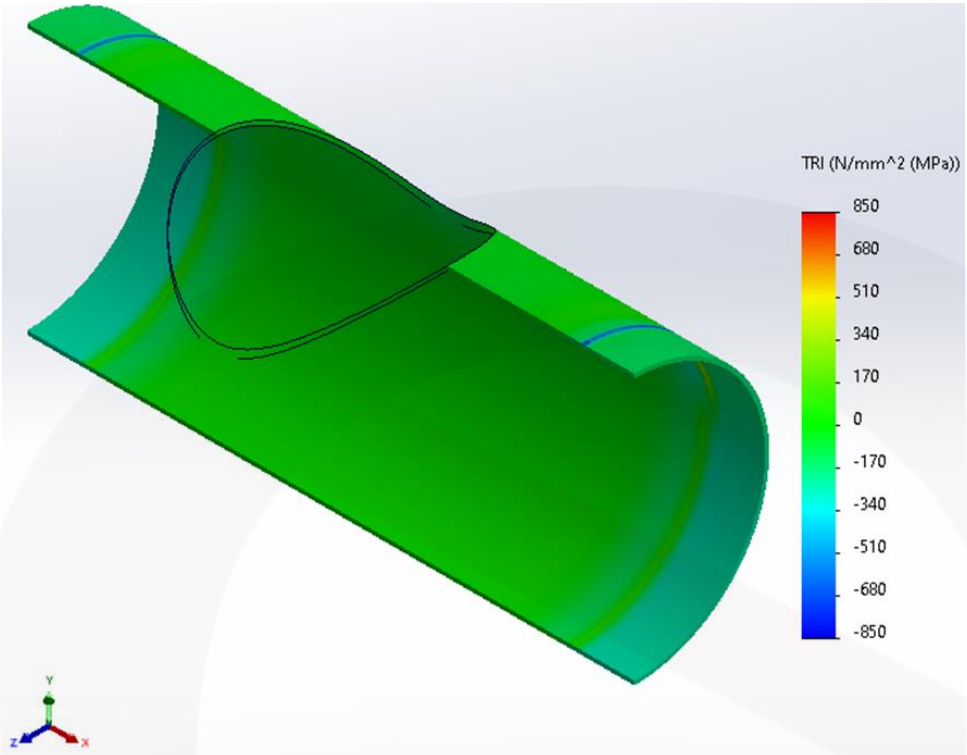
B. PL, PL+PB

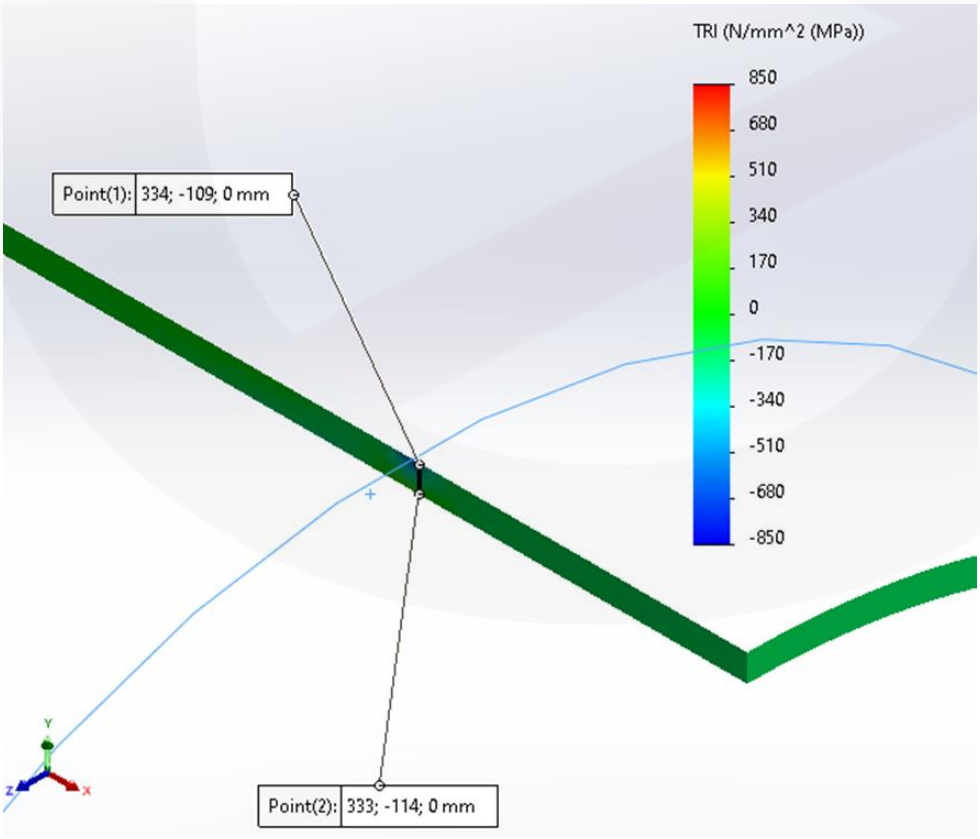


Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	1	3	0	0	0	3
Bending (Point 2)	-0	-1	-3	-0	-0	-0	3
Membrane Stress	19	-9	-130	17	5	6	141
Membrane Stress + Bending (Point 1)	19	-8	-127	17	5	6	139
Membrane Stress + Bending (Point 2)	19	-10	-133	17	5	6	144
Peak (Point 1)	11	9	1	9	1	-0	18
Peak (Point 2)	-25	16	1	-10	-2	-0	40

PL= 141 Mpa; PL+PB=144 Mpa

C. Triaxial stress for localized Pipeline





Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	-171	-68	0	0	-1	149
Bending (Point 2)	-0	171	68	-0	-0	1	149
Membrane Stress	-93	32	-207	-7	-9	8	208
Membrane Stress + Bending (Point 1)	-93	-139	-276	-7	-9	7	166
Membrane Stress + Bending (Point 2)	-93	203	-139	-7	-9	8	322
Peak (Point 1)	-51	16	10	9	-7	-0	67
Peak (Point 2)	72	4	3	-3	9	-0	70

Maximum triaxial stress, (σ1+ σ2+ σ3) =322 Mpa

The following table summarizes the results obtained for the pipeline part compared to the allowable amounts established by the code in part 5.

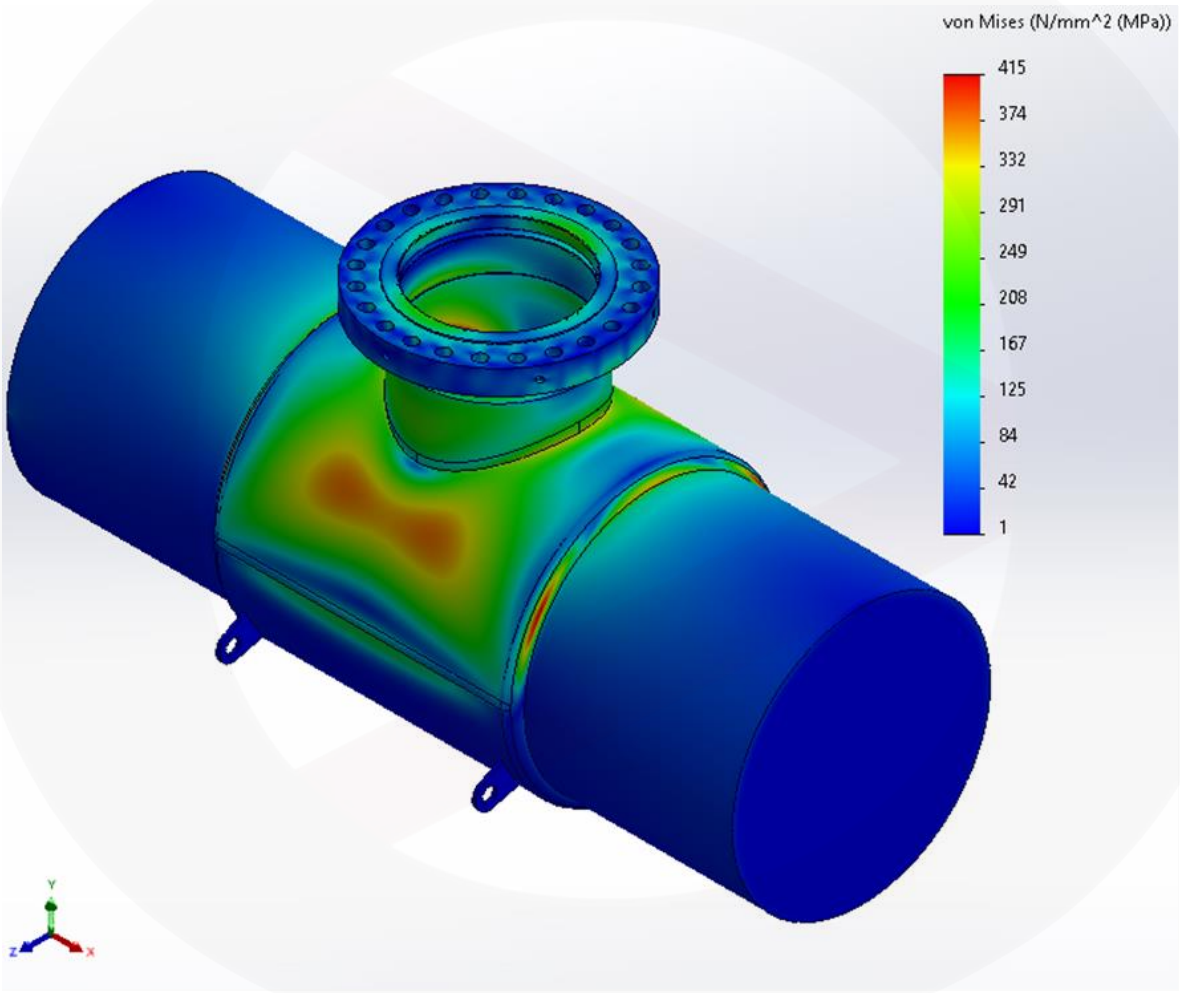
Hot Tap 12" x 14"-Allowable Stresses per VIII DIV 2, *Pd=94 bar, Td=80 ℃*

Item	Part/Material	FEA Case per VIII Div 2 Part 5	Condition	ASME VIII DIV. 2 Load combinations	Type of Stress	FEA "Se" or Triaxial stress (MPa)	"S" Allow. Stress (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4) or as indicated	Allow. Stress (MPa)	Result
4	Existing 16"-Pipeline -API 5LX52	3	Design	P+D+External loads+T	P_m	*5*	214,6	$P_m \leq S$	S (Eq. 5.2)	214,6	*Check*
					P_L	*141*		$P_L \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.3)	321,9	*Check*
					PL+Pb	*144*		$(P_L+P_b) \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.4)	321,9	*Check*
		3	Local	P+D+External loads+T	σ1+σ2+σ3	*322*		(σ1+σ2+σ3) ≤ 4*S	Per 5.3.2 VIII Div. 2 (Eq. 5,5)	858,4	*Check*

9 Maximum FEA response for testing condition.

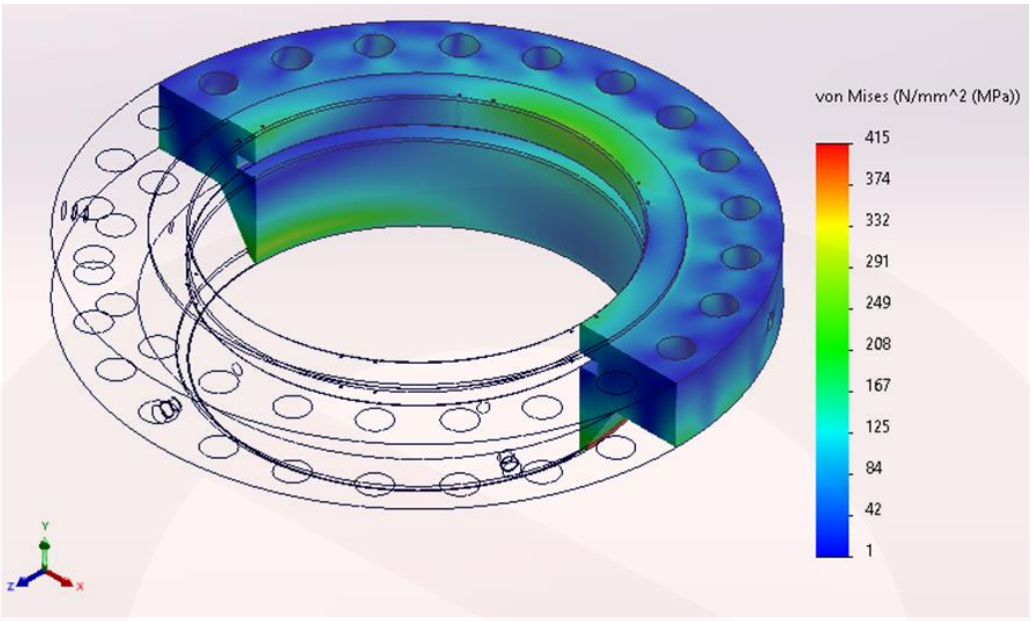
The FEA analysis was conducted to obtain the ***maximum equivalent Von Mises stress response under testing conditions,*** according to the load condition combinations specified in ***ASME VIII Division 2, Table 5.3***. Below are the relevant results for the three analysed fittings.

9.1 Stress linearization for 42” x 24” at test condition.

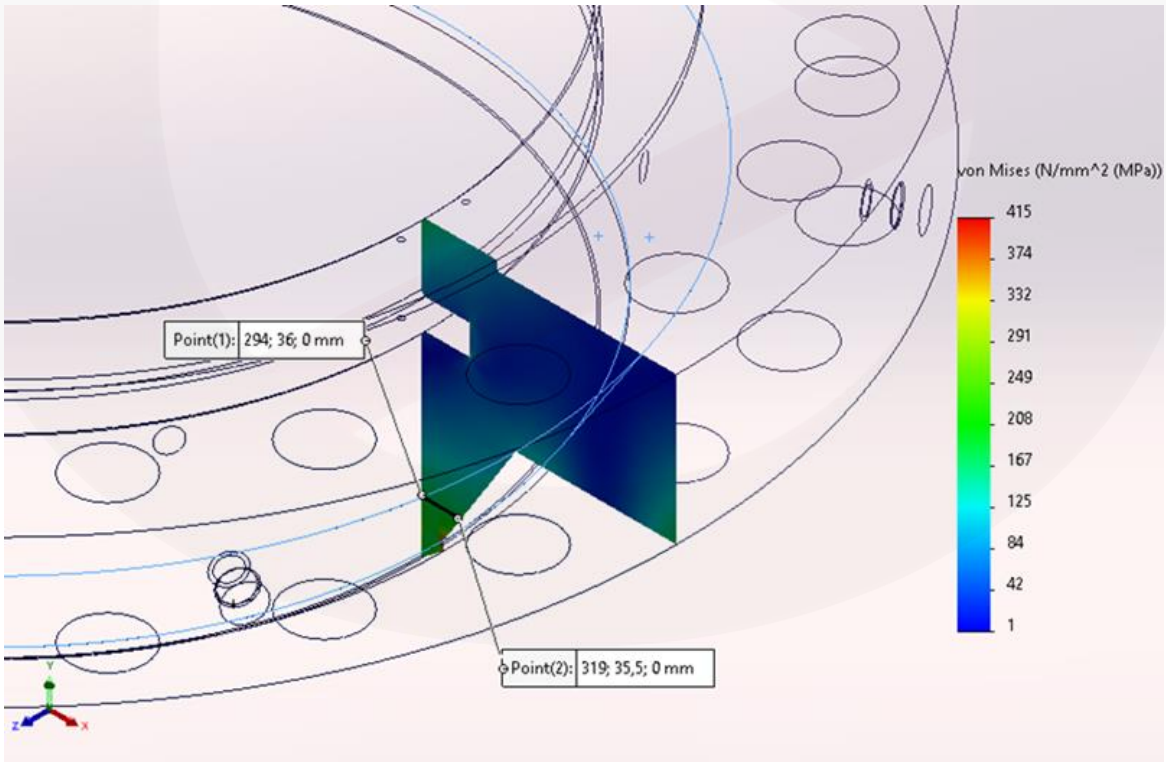


Test condition

- 24”-600# Flange (Mark 1)



A. Pm, Pm+Pb



Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	-85	-29	0	0	0	74
Bending (Point 2)	-0	85	29	-0	-0	-0	74
Membrane Stress	-6	62	187	8	-0	0	170
Membrane Stress + Bending (Point 1)	-6	-23	158	8	-0	0	173
Membrane Stress + Bending (Point 2)	-6	147	217	8	-0	-0	198
Peak (Point 1)	-8	-32	-10	-13	0	-0	31
Peak (Point 2)	34	-42	-8	49	-0	-0	108

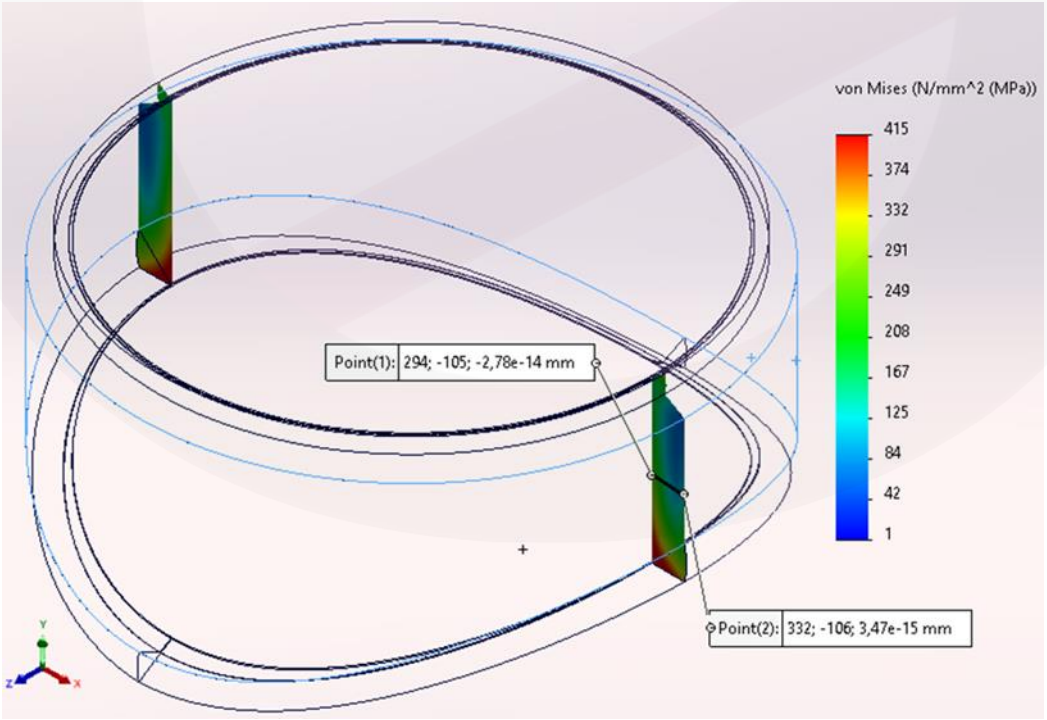
Pm=170 Mpa; Pm+Pb=198 Mpa

The following table summarizes the results obtained for the flange at Test condition compared to the allowable amounts established by the code in part 5.

Test condition VIII DIV 2, Ptest=141bar; T=30°C										
Item	Part/Material	FEA Case per VIII Div 2 Part 5	ASME VIII DIV. 2 Load combinations	Type of Stress	*FEA "Se"* Von Mises (MPa)	"Sy" (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4)	Allow. Stress (MPa)	Result
1	(Mark 1) 24"-600#-RF-LS FLANGE A694F60	18	$Pt+P_s+D+0,6W_{PT}$	Pm	170	415	Pm ≤ βT*SY	βT*SY (Eq. 4.1.3)	394	*Check*
				Pm+Pb	198		Pm+Pb ≤ ϒmin*SY	ϒmin*SY (Eq. 4.1.4)	591	*Check*

➢ 24”-Neck (Mark 3)

A. Pm, Pm+Pb



Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	184	128	0	0	-0	164
Bending (Point 2)	-0	-184	-128	-0	-0	0	164
Membrane Stress	-5	74	148	5	-0	-0	132
Membrane Stress + Bending (Point 1)	-5	258	276	5	-0	-0	272
Membrane Stress + Bending (Point 2)	-5	-111	20	5	-0	0	120
Peak (Point 1)	-9	-8	-4	-14	-0	0	25
Peak (Point 2)	4	-1	3	0	0	0	4

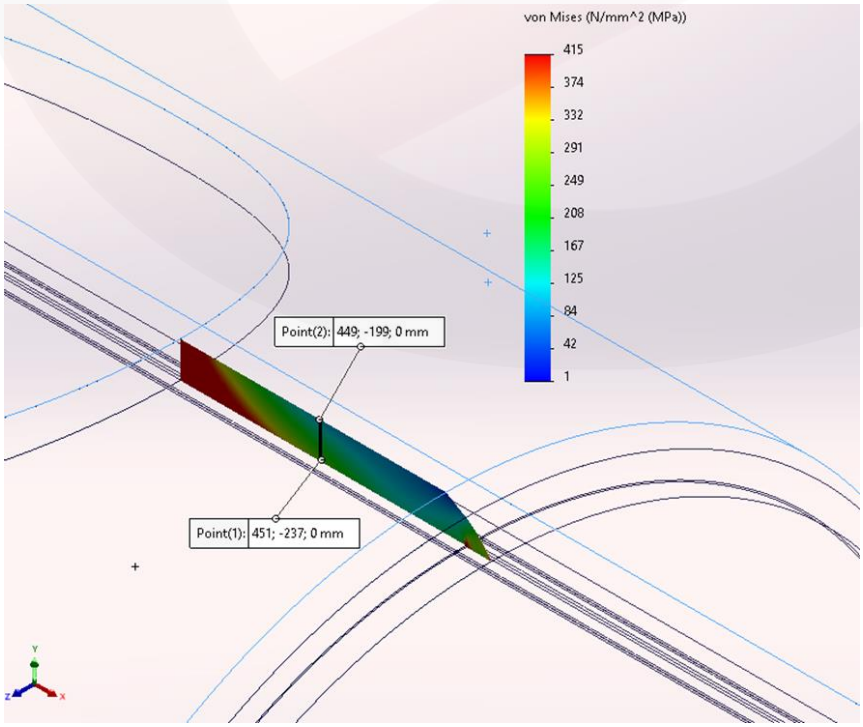
Pm=132 Mpa; Pm+Pb=272 Mpa

The following table summarizes the results obtained for the neck at Test condition compared to the allowable amounts established by the code in part 5.

Test condition VIII DIV 2, Ptest=141bar; T=30°C										
Item	Part/Material	FEA Case per VIII Div 2 Part 5	ASME VIII DIV. 2 Load combinations	Type of Stress	*FEA "Se"* Von Mises (MPa)	"Sy" (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4)	Allow. Stress (MPa)	Result
2	(Mark 3) 24"-Neck- P460-NL2	18	Pt+Ps+D+0,6W_{PT}	Pm	132	430	Pm ≤ βT*SY	βT*SY (Eq. 4.1.3)	409	*Check*
				Pm+Pb	272		Pm+Pb ≤ ϒmin*SY	ϒmin*SY (Eq. 4.1.4)	613	*Check*

- *42" x 24"*-Reduced Split tee (Mark 4)

A. Pm, Pm+Pb



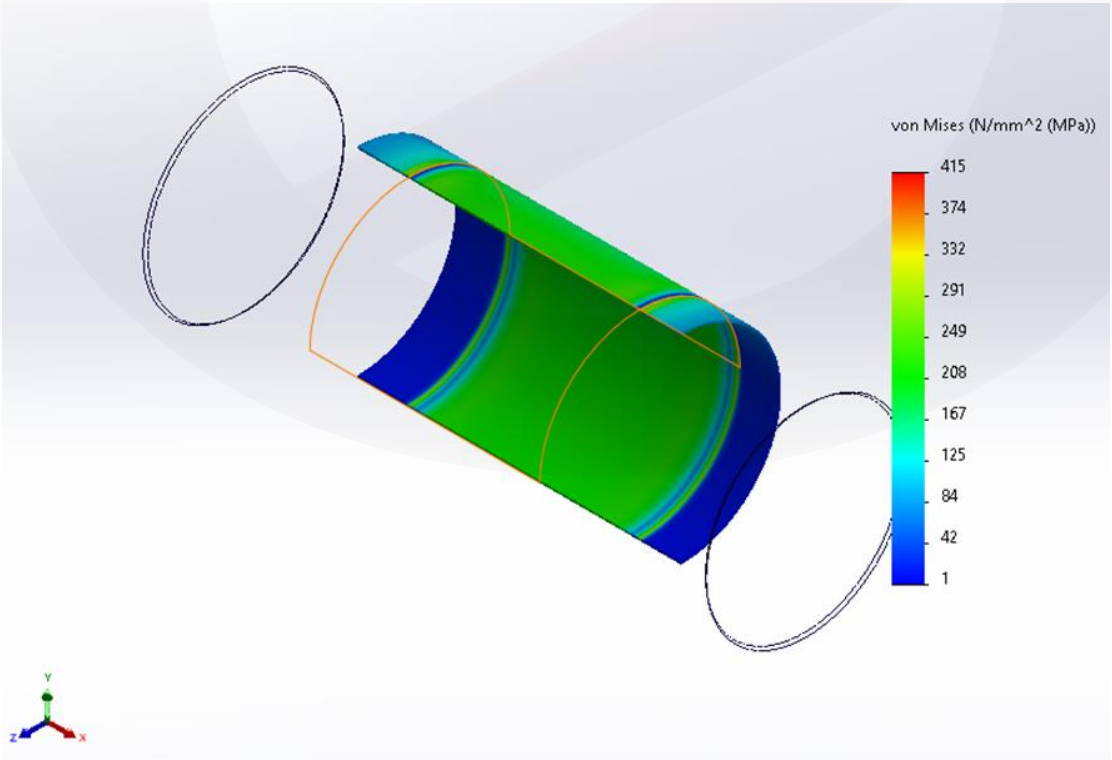
Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	51	81	0	0	-0	71
Bending (Point 2)	-0	-51	-81	-0	-0	0	71
Membrane Stress	-6	116	196	-3	0	-0	176
Membrane Stress + Bending (Point 1)	-6	167	276	-3	0	-0	246
Membrane Stress + Bending (Point 2)	-6	65	115	-3	0	-0	105
Peak (Point 1)	-7	-1	1	8	-0	0	16
Peak (Point 2)	6	-1	1	5	-0	-0	10

Pm=176 Mpa; Pm+Pb=246 Mpa

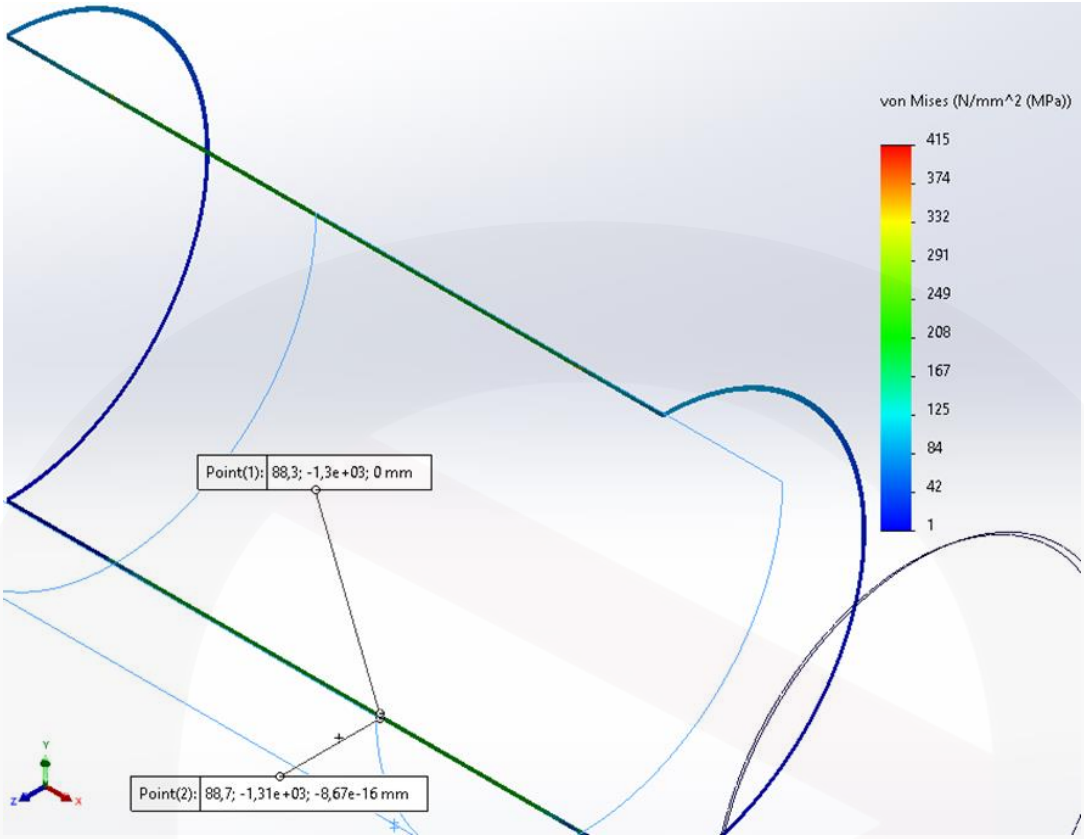
The following table summarizes the results obtained for the reduced Split tee at Test condition compared to the allowable amounts established by the code in part 5.

Test condition VIII DIV 2, Ptest=141bar; T=30°C										
Item	Part/Material	FEA Case per VIII Div 2 Part 5	ASME VIII DIV. 2 Load combinations	Type of Stress	*FEA "Se"* Von Mises (MPa)	"Sy" (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4)	Allow. Stress (MPa)	Result
3	(Mark 4) 42"-Run-P460-NL2	18	Pt+Ps+D+0,6W_{PT}	Pm	176	430	Pm ≤ βT*SY	βT*SY (Eq. 4.1.3)	409	*Check*
				Pm+Pb	246		Pm+Pb ≤ ϒmin*SY	ϒmin*SY (Eq. 4.1.4)	613	*Check*

- 42”-Existing Pipeline



A. Pm, Pm+Pb



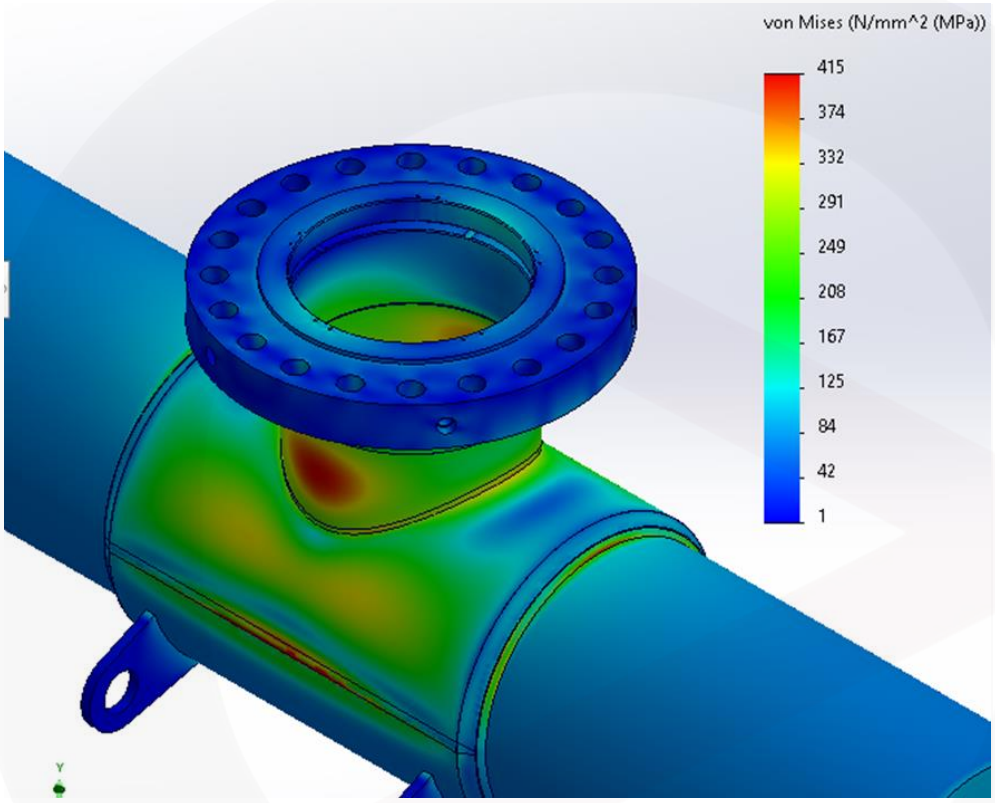
Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	-6	-7	0	0	0	6
Bending (Point 2)	-0	6	7	-0	-0	-0	6
Membrane Stress	-12	-52	-230	-2	0	0	201
Membrane Stress + Bending (Point 1)	-12	-58	-237	-2	0	1	206
Membrane Stress + Bending (Point 2)	-12	-46	-223	-2	0	-0	197
Peak (Point 1)	2	-4	-4	-1	-0	0	6
Peak (Point 2)	-3	-3	-3	0	-0	0	1

Pm=201 Mpa; Pm+Pb=206 Mpa

The following table summarizes the results obtained for the existing pipeline at Test condition compared to the allowable amounts established by the code in part 5.

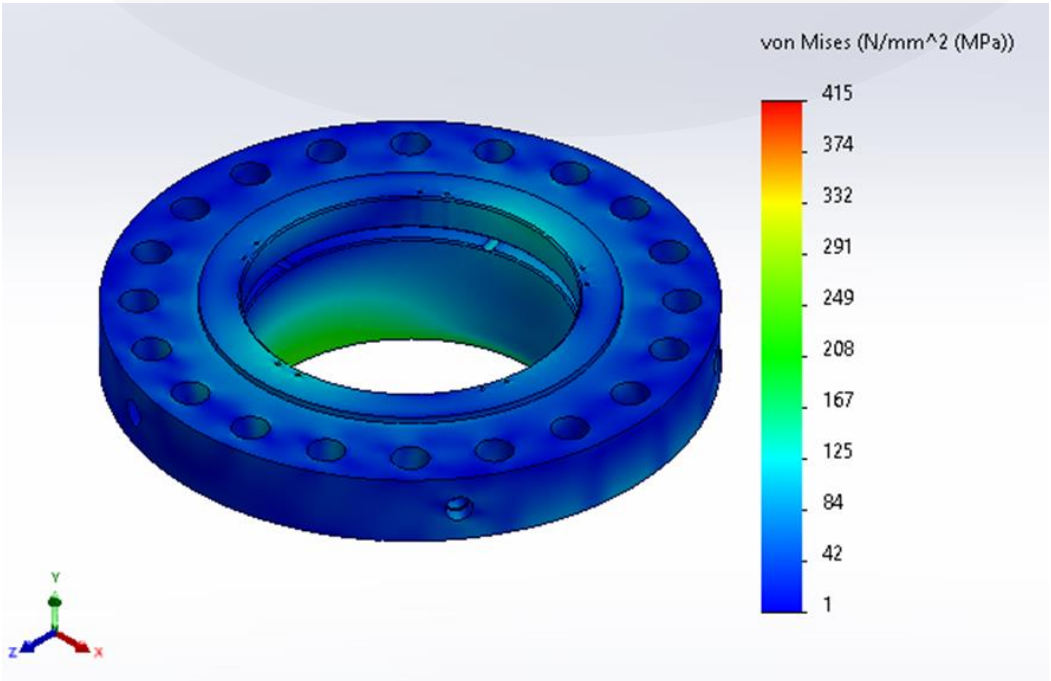
Test condition VIII DIV 2, Ptest=141bar; T=30°C										
Item	Part/Material	FEA Case per VIII Div 2 Part 5	ASME VIII DIV. 2 Load combinations	Type of Stress	*FEA "Se"* Von Mises (MPa)	"Sy" (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4)	Allow. Stress (MPa)	Result
4	Existing 42"-Pipeline -API 5LX60	18	Pt+Ps+D+0,6W_{PT}	Pm	201	415	Pm ≤ βT*SY	βT*SY (Eq. 4.1.3)	394	*Check*
				Pm+Pb	206		Pm+Pb ≤ Ymin*SY	Ymin*SY (Eq. 4.1.4)	591	*Check*

9.2 Stress linearization for 16” x 12” at test condition.

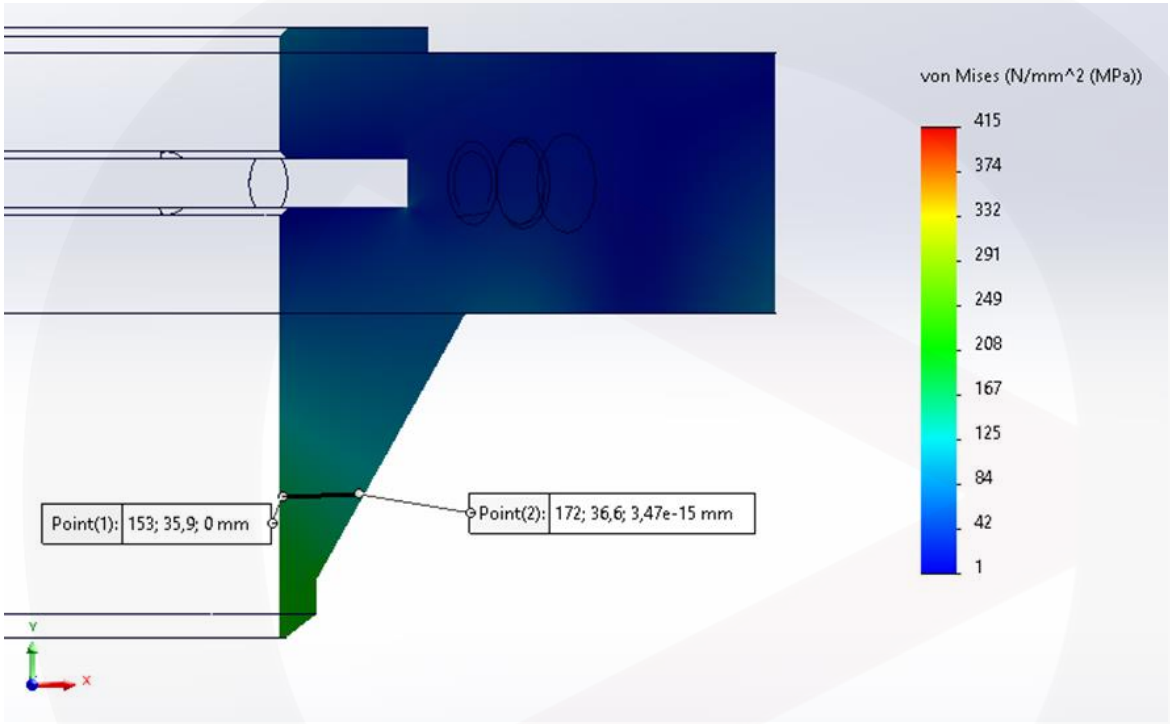


Test condition

- 12”-600# Flange (Mark 1)



A. Pm, Pm+Pb



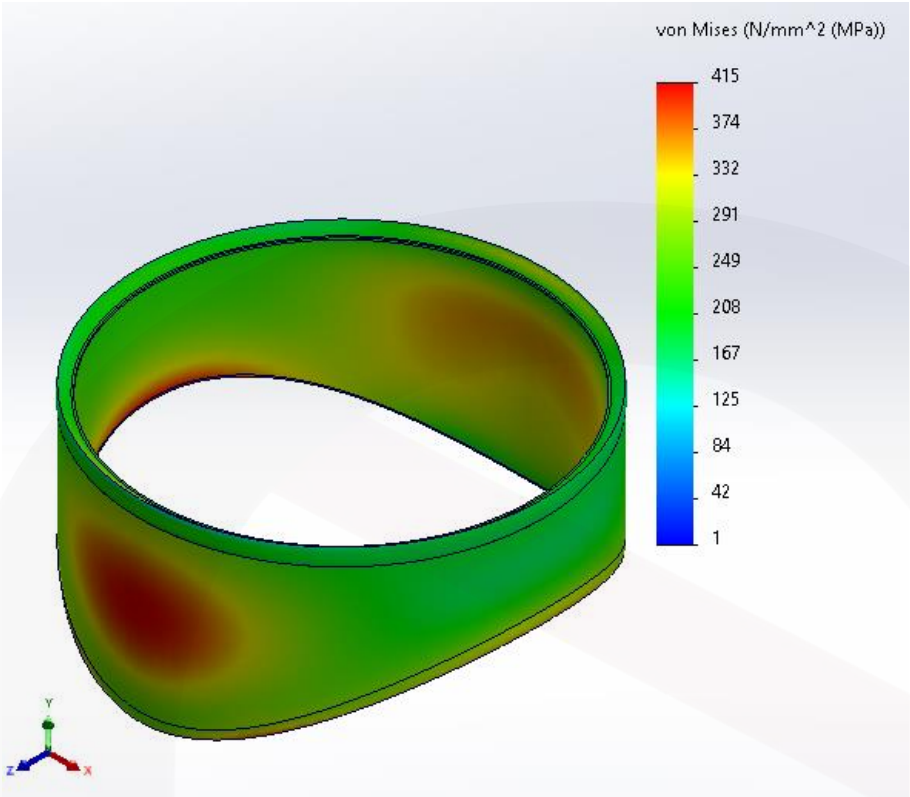
Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	14	15	0	0	1	15
Bending (Point 2)	-0	-14	-15	-0	-0	-1	15
Membrane Stress	-5	37	162	8	1	3	151
Membrane Stress + Bending (Point 1)	-5	51	177	8	1	4	162
Membrane Stress + Bending (Point 2)	-5	22	147	8	1	2	141
Peak (Point 1)	-9	-2	1	-6	-1	0	13
Peak (Point 2)	9	-3	1	2	1	0	12

Pm=151 Mpa; Pm+Pb=162 Mpa

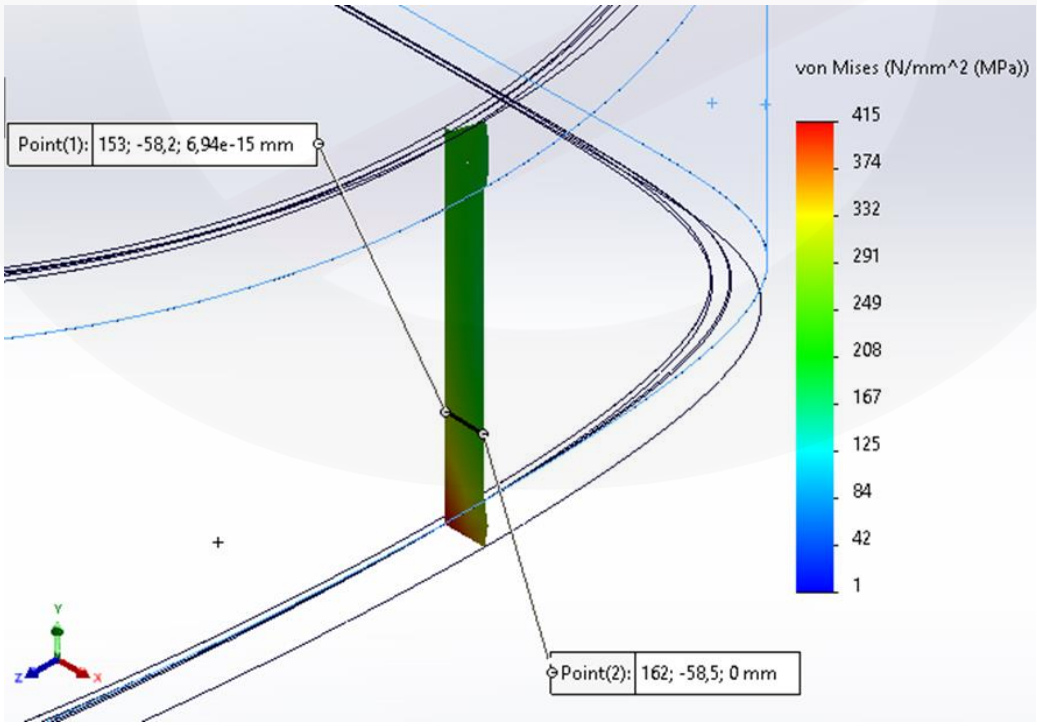
The following table summarizes the results obtained for the flange at Test condition compared to the allowable amounts established by the code in part 5.

Test condition VIII DIV 2, Ptest=141bar; T=30°C										
Item	Part/Material	FEA Case per VIII Div 2 Part 5	ASME VIII DIV. 2 Load combinations	Type of Stress	*FEA "Se"* Von Mises (MPa)	"Sy" (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4)	Allow. Stress (MPa)	Result
1	(Mark 1) 12"-600#-RF-LS FLANGE A694F60	18	$Pt+P_s+D+0,6W_{PT}$	Pm	151	415	Pm ≤ βT*SY	βT*SY (Eq. 4.1.3)	394	*Check*
				Pm+Pb	162		Pm+Pb ≤ ϒmin*SY	ϒmin*SY (Eq. 4.1.4)	591	*Check*

- 12”-Neck (Mark 3)



A. Pm, Pm+Pb



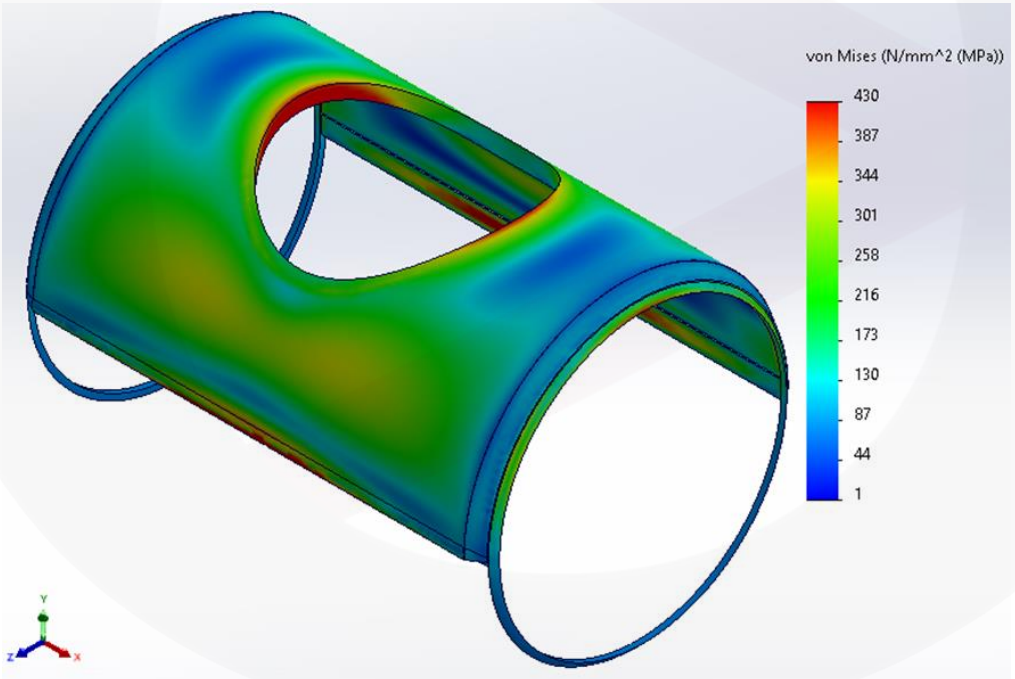
Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	66	48	0	0	1	59
Bending (Point 2)	-0	-66	-48	-0	-0	-1	59
Membrane Stress	-6	116	294	-5	-0	7	262
Membrane Stress + Bending (Point 1)	-6	182	342	-5	-0	8	302
Membrane Stress + Bending (Point 2)	-6	49	246	-5	-0	6	230
Peak (Point 1)	-6	1	-0	-2	-0	-0	7
Peak (Point 2)	6	1	0	2	-0	0	7

Pm=262 Mpa; Pm+Pb=302 Mpa

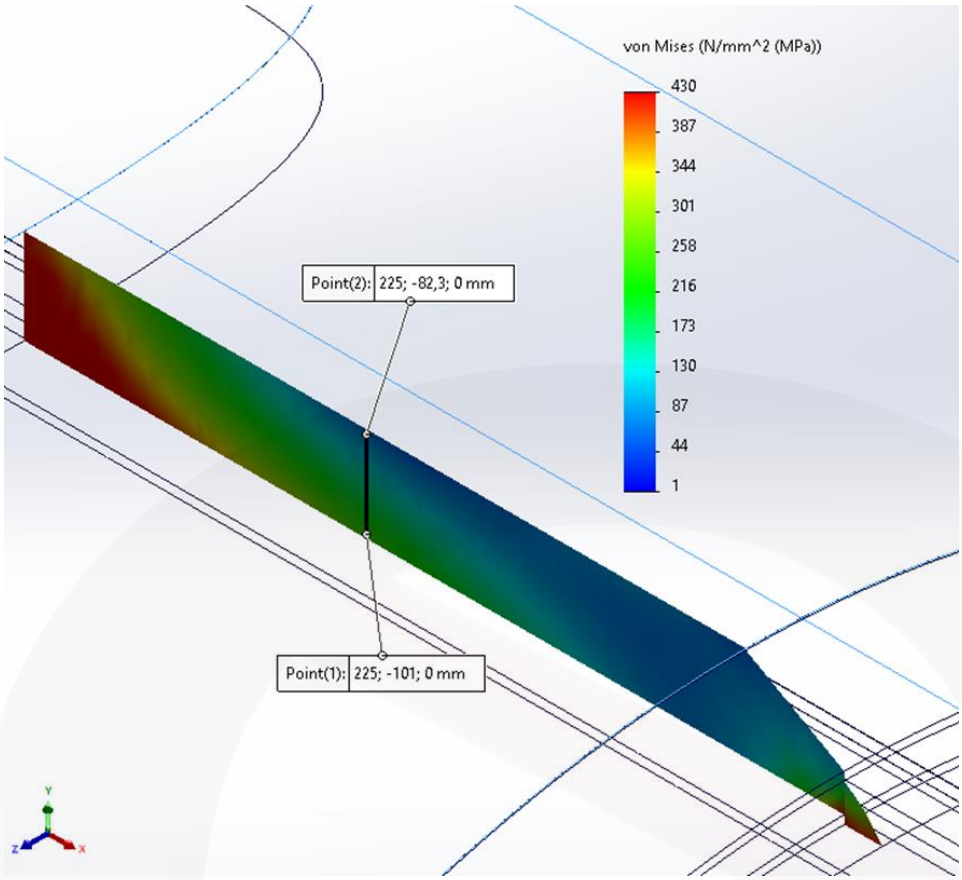
The following table summarizes the results obtained for the neck at Test condition compared to the allowable amounts established by the code in part 5.

Test condition VIII DIV 2, Ptest=141bar; T=30°C										
Item	Part/Material	FEA Case per VIII Div 2 Part 5	ASME VIII DIV. 2 Load combinations	Type of Stress	*FEA "Se"* Von Mises (MPa)	"Sy" (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4)	Allow. Stress (MPa)	Result
2	(Mark 3) 12"-Neck- API 5L-X60	18	$Pt+Ps+D+0,6W_{PT}$	Pm	262	415	$Pm \leq \beta T*SY$	$\beta T*SY$ (Eq. 4.1.3)	394	*Check*
				Pm+Pb	302		$Pm+Pb \leq \gamma min*SY$	$\gamma min*SY$ (Eq. 4.1.4)	591	*Check*

- *16" x 12"*-Reduced Split tee (Mark 4)



A. Pm, Pm+Pb



Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	49	96	0	0	-1	83
Bending (Point 2)	-0	-49	-96	-0	-0	1	83
Membrane Stress	-5	73	177	-9	0	-0	159
Membrane Stress + Bending (Point 1)	-5	122	272	-9	0	-1	241
Membrane Stress + Bending (Point 2)	-5	24	81	-9	0	1	78
Peak (Point 1)	-8	3	4	6	0	-0	15
Peak (Point 2)	5	-2	1	6	-0	0	12

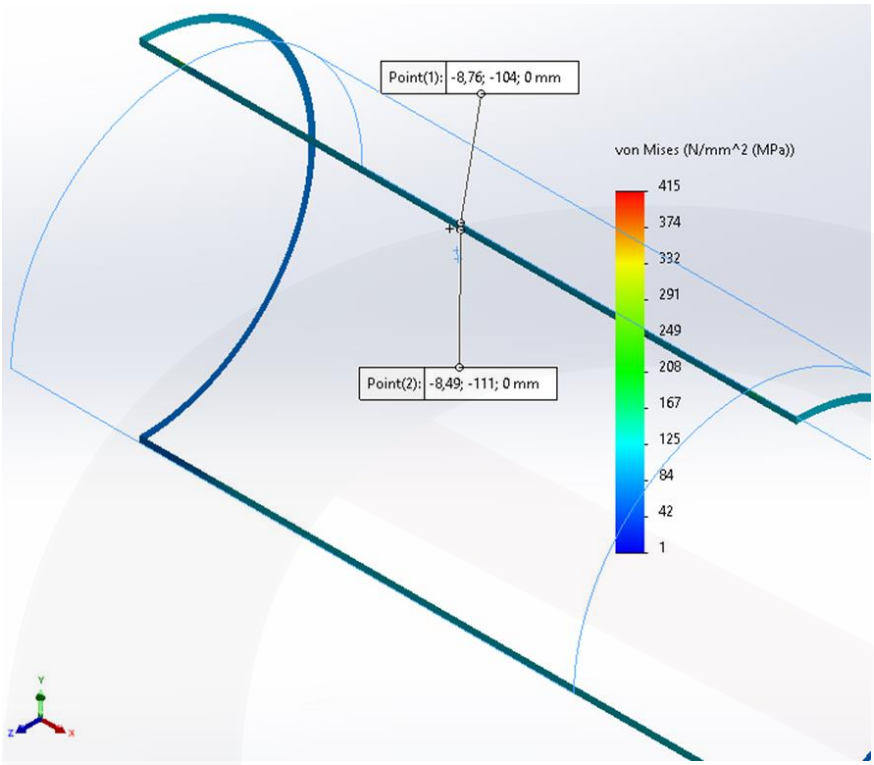
Pm=159 Mpa; Pm+Pb=241 Mpa

The following table summarizes the results obtained for the reduced Split tee at Test condition compared to the allowable amounts established by the code in part 5.

Test condition VIII DIV 2, Ptest=141bar; T=30°C										
Item	Part/Material	FEA Case per VIII Div 2 Part 5	ASME VIII DIV. 2 Load combinations	Type of Stress	*FEA "Se"* Von Mises (MPa)	"Sy" (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4)	Allow. Stress (MPa)	Result
3	(Mark 4) 16"-Run-P460-NL2	18	Pt+Ps+D+0,6W_{PT}	Pm	159	430	Pm ≤ βT*SY	βT*SY (Eq. 4.1.3)	409	*Check*
				Pm+Pb	241		Pm+Pb ≤ ϒmin*SY	ϒmin*SY (Eq. 4.1.4)	613	*Check*

➢ 16”-Existing Pipeline

A. Pm, Pm+Pb



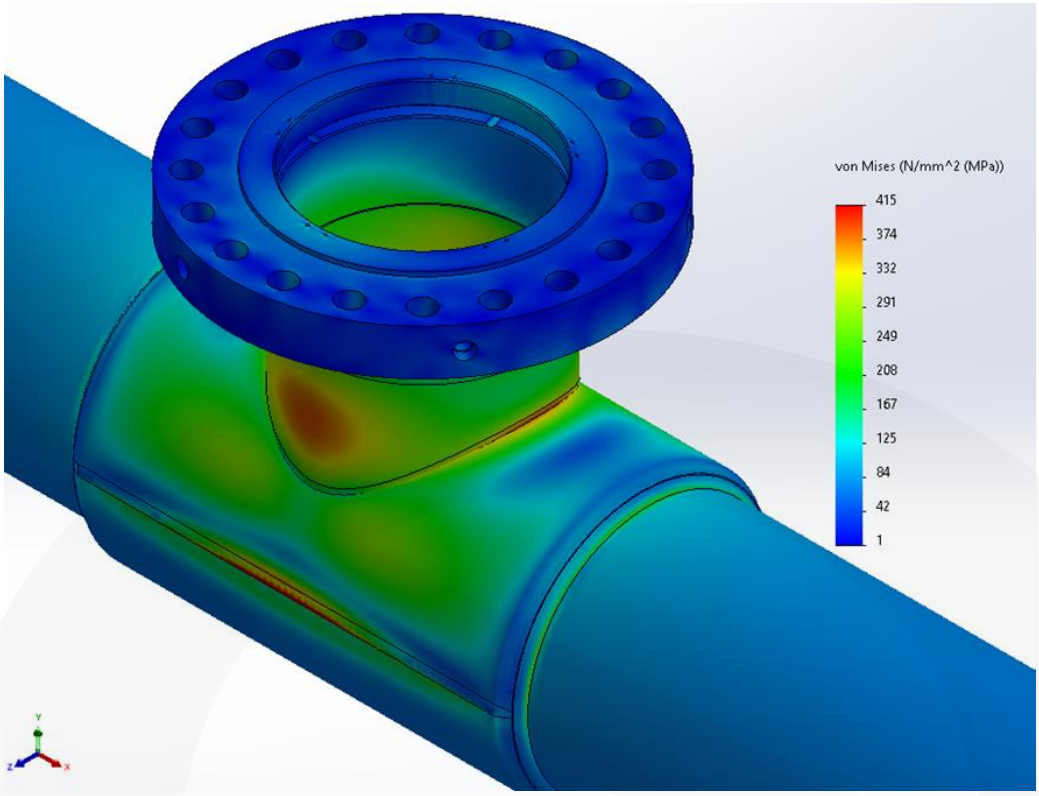
Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	-5	-9	0	0	-0	8
Bending (Point 2)	-0	5	9	-0	-0	0	8
Membrane Stress	-12	-97	-129	-3	0	0	105
Membrane Stress + Bending (Point 1)	-12	-102	-138	-3	0	0	113
Membrane Stress + Bending (Point 2)	-12	-92	-120	-3	0	0	97
Peak (Point 1)	-2	0	0	-0	0	0	2
Peak (Point 2)	2	-0	-0	0	0	-0	2

Pm=105 Mpa; Pm+Pb=113 Mpa

The following table summarizes the results obtained for the existing pipeline at Test condition compared to the allowable amounts established by the code in part 5.

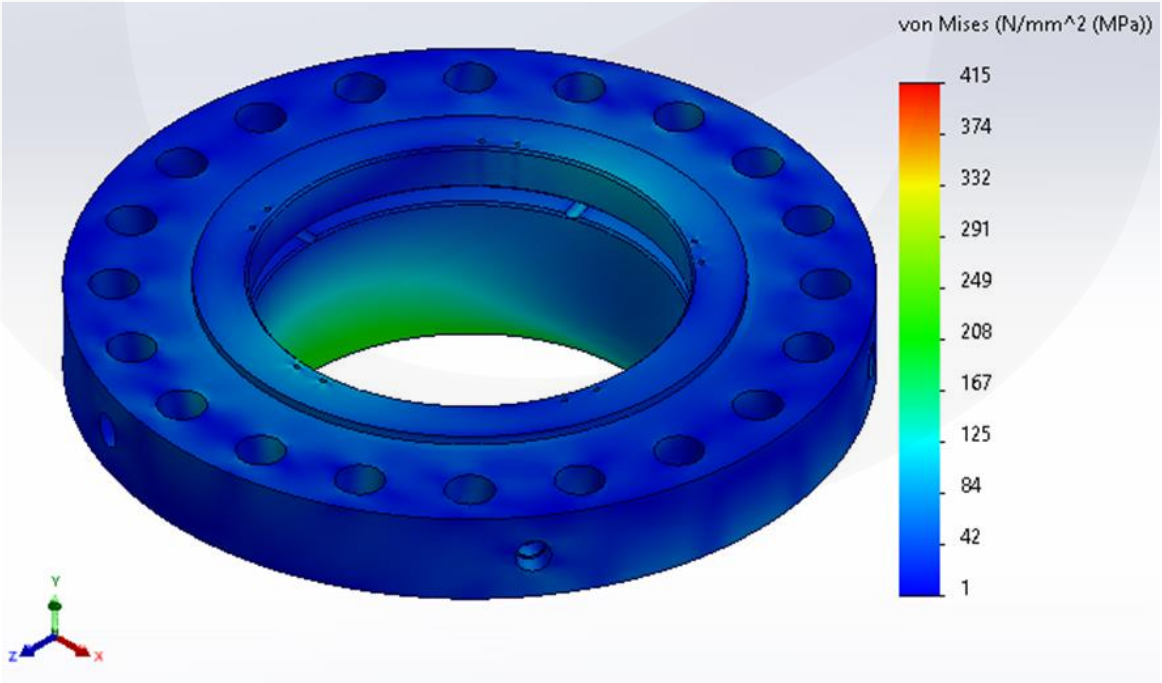
Test condition VIII DIV 2, Ptest=141bar; T=30°C										
Item	Part/Material	FEA Case per VIII Div 2 Part 5	ASME VIII DIV. 2 Load combinations	Type of Stress	*FEA "Se"* Von Mises (MPa)	"Sy" (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4)	Allow. Stress (MPa)	Result
4	Existing 16"-Pipeline -API 5LX52	18	Pt+Ps+D+0,6W_{PT}	Pm	105	359	Pm ≤ βT*SY	βT*SY (Eq. 4.1.3)	341	*Check*
				Pm+Pb	113		Pm+Pb ≤ ϒmin*SY	ϒmin*SY (Eq. 4.1.4)	512	*Check*

9.3 Stress linearization for 14” x 12” at test condition.

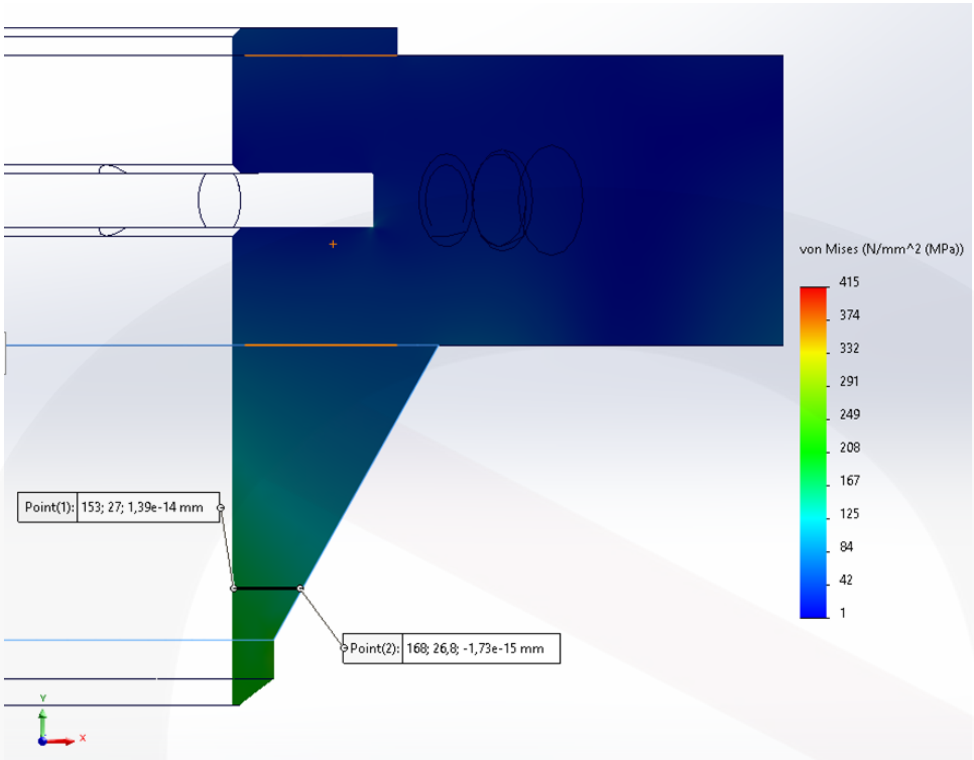


Test condition

- 12”-600# Flange (Mark 1)



A. Pm, Pm+Pb



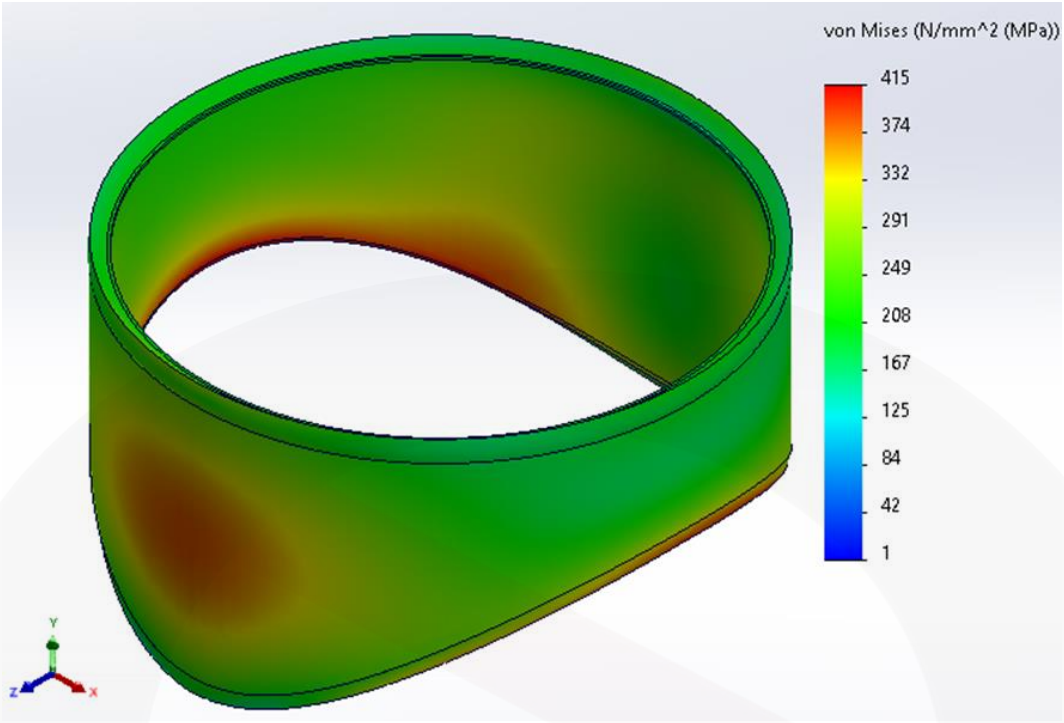
Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	8	15	0	0	-0	13
Bending (Point 2)	-0	-8	-15	-0	-0	0	13
Membrane Stress	-7	58	179	4	1	2	164
Membrane Stress + Bending (Point 1)	-7	66	194	4	1	2	176
Membrane Stress + Bending (Point 2)	-7	50	165	4	1	2	152
Peak (Point 1)	-7	-7	-0	-10	-1	-0	19
Peak (Point 2)	14	-13	-1	15	0	-0	36

Pm=164 Mpa; Pm+Pb=176 Mpa

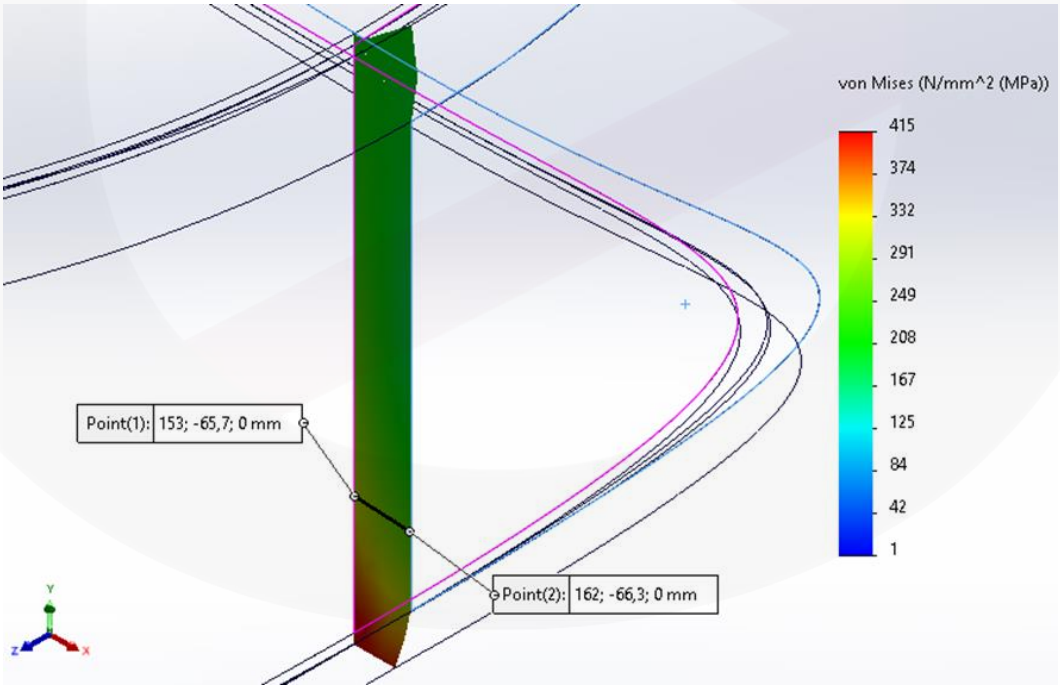
The following table summarizes the results obtained for the flange at Test condition compared to the allowable amounts established by the code in part 5.

Test condition VIII DIV 2, Ptest=141bar; T=30°C										
Item	Part/Material	FEA Case per VIII Div 2 Part 5	ASME VIII DIV. 2 Load combinations	Type of Stress	*FEA "Se"* Von Mises (MPa)	"Sy" (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4)	Allow. Stress (MPa)	Result
1	(Mark 1) 12"-600#-RF-LS FLANGE A694F60	18	$Pt+P_s+D+0,6W_{PT}$	Pm	164	415	$Pm \leq \beta T*SY$	$\beta T*SY$ (Eq. 4.1.3)	394	*Check*
				Pm+Pb	176		$Pm+Pb \leq \gamma min*SY$	$\gamma min*SY$ (Eq. 4.1.4)	591	*Check*

- 12”-Neck (Mark 3)



A. Pm, Pm+Pb



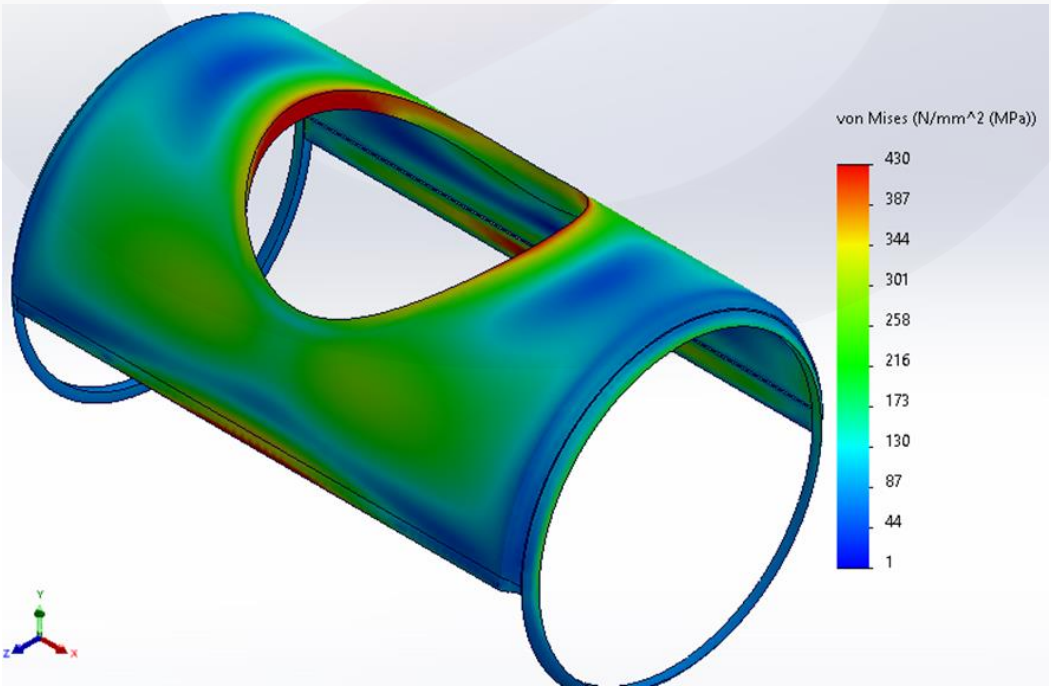
Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	68	42	0	0	2	60
Bending (Point 2)	-0	-68	-42	-0	-0	-2	60
Membrane Stress	-6	125	315	-11	-0	-3	280
Membrane Stress + Bending (Point 1)	-6	193	357	-11	-0	-2	316
Membrane Stress + Bending (Point 2)	-6	57	272	-11	-0	-5	254
Peak (Point 1)	-6	-1	-1	-5	1	0	10
Peak (Point 2)	5	2	0	5	1	0	11

Pm=280 Mpa; Pm+Pb=316 Mpa

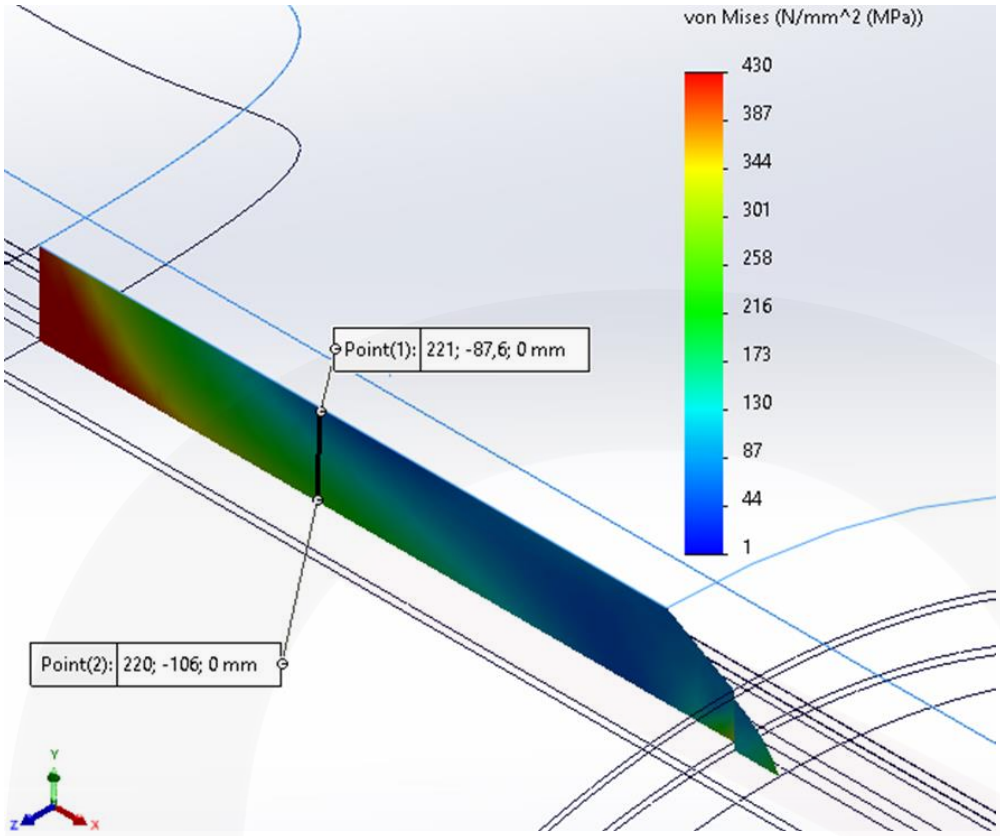
The following table summarizes the results obtained for the neck at Test condition compared to the allowable amounts established by the code in part 5.

Test condition VIII DIV 2, Ptest=141bar; T=30°C										
Item	Part/Material	FEA Case per VIII Div 2 Part 5	ASME VIII DIV. 2 Load combinations	Type of Stress	*FEA "Se"* Von Mises (MPa)	"Sy" (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4)	Allow. Stress (MPa)	Result
2	(Mark 3) 12"-Neck- API 5L-X60	18	Pt+Ps+D+0,6W_{PT}	Pm	280	415	Pm ≤ βT*SY	βT*SY (Eq. 4.1.3)	394	*Check*
				Pm+Pb	316		Pm+Pb ≤ ϒmin*SY	ϒmin*SY (Eq. 4.1.4)	591	*Check*

- *14" x 12"*-Reduced Split tee (Mark 4)



A. Pm, Pm+Pb



Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	-63	-97	0	0	-4	85
Bending (Point 2)	-0	63	97	-0	-0	4	85
Membrane Stress	-4	66	168	-13	0	7	152
Membrane Stress + Bending (Point 1)	-4	4	71	-13	0	4	75
Membrane Stress + Bending (Point 2)	-4	129	265	-13	0	11	235
Peak (Point 1)	4	1	3	9	-0	0	17
Peak (Point 2)	-8	4	3	4	-0	0	14

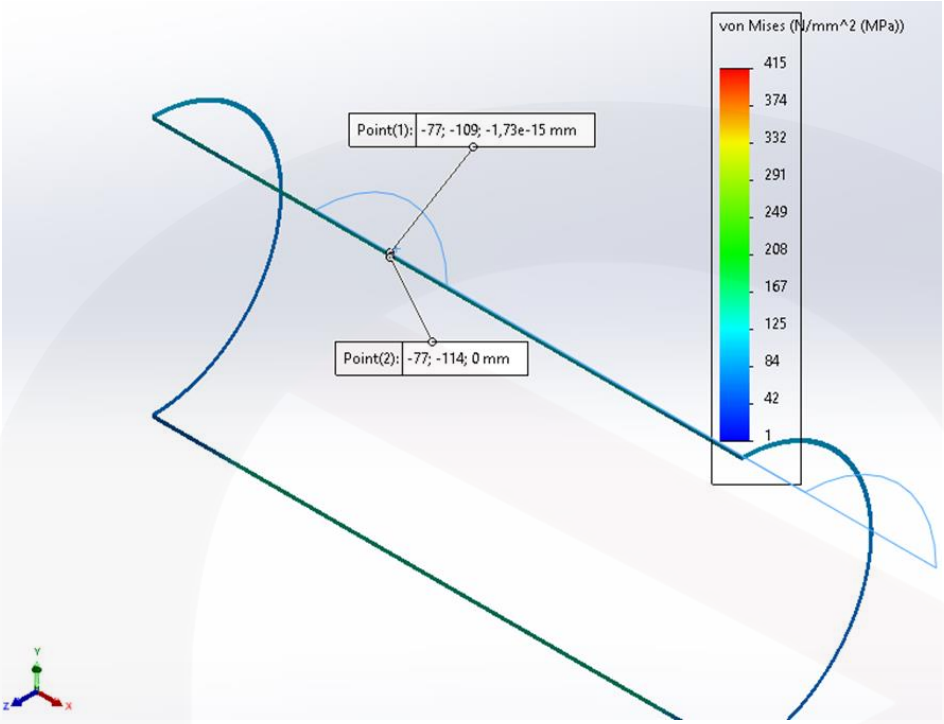
Pm=152 Mpa; Pm+Pb=235 Mpa

The following table summarizes the results obtained for the reduced Split tee at Test condition compared to the allowable amounts established by the code in part 5.

Test condition VIII DIV 2, Ptest=141bar; T=30°C										
Item	Part/Material	FEA Case per VIII Div 2 Part 5	ASME VIII DIV. 2 Load combinations	Type of Stress	*FEA "Se"* Von Mises (MPa)	"Sy" (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4)	Allow. Stress (MPa)	Result
3	(Mark 4) 16"-Run-P460-NL2	18	Pt+Ps+D+0,6W_{PT}	Pm	152	430	Pm ≤ βT*SY	βT*SY (Eq. 4.1.3)	409	*Check*
				Pm+Pb	235		Pm+Pb ≤ ϒmin*SY	ϒmin*SY (Eq. 4.1.4)	613	*Check*

➢ 14”-Existing Pipeline

A. Pm, Pm+Pb



Quantity, Units: N/mm^2 (MPa)	Normal T	Normal N	Normal H	Shear TN	Shear HT	Shear NH	von Mises
Bending (Point 1)	0	-4	-7	0	0	0	6
Bending (Point 2)	-0	4	7	-0	-0	-0	6
Membrane Stress	-12	-104	-161	1	-0	0	130
Membrane Stress + Bending (Point 1)	-12	-107	-168	1	-0	0	136
Membrane Stress + Bending (Point 2)	-12	-100	-154	1	-0	0	124
Peak (Point 1)	-2	-0	0	0	0	-0	2
Peak (Point 2)	2	-0	-0	-0	0	-0	2

Pm=130 Mpa; Pm+Pb=136 Mpa

The following table summarizes the results obtained for the existing pipeline at Test condition compared to the allowable amounts established by the code in part 5.

14" X 12" Test condition VIII DIV 2, Ptest=141bar; T=30°C											
Item	Part/Material	FEA Case per VIII Div 2 Part 5	ASME VIII DIV. 2 Load combinations	Type of Stress	*FEA "Se"* Von Mises (MPa)	"Sy" (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4)	Allow. Stress (MPa)	Result	Result
4	Existing 16"-Pipeline -API 5LX52	18	Pt+Ps+D+0,6W_{PT}	Pm	130	360	Pm ≤ βT*SY	βT*SY (Eq. 4.1.3)	342	*Check*	
				Pm+Pb	136		Pm+Pb ≤ Ymin*SY	Ymin*SY (Eq. 4.1.4)	513	*Check*	

10 Stress summary according to table 5.3 ASME VIII Div. 2 for each Hot Tap fittings dimension

The following tables summarize ***the linearized stress assessment*** and compare the allowable stress for each ***Diameter-Stopple fitting, including the existing pipeline, during the hot tapping operation***.

- *Hot tap-42" x 24"*

Hot Tap 24" x 42"-Allowable Stresses per VIII DIV 2, *Pd=94 bar, Td=85 °C*											
Item	**Part/Material**	**FEA Case per VIII Div 2 Part 5**	**Condition**	**ASME VIII DIV. 2 Load combinations**	**Type of Stress**	***FEA "Se" or Triaxial stress* (MPa)**	**"S" Allow. Stress (MPa)**	**VIII DIV 2 rule**	**ASME VIII DIV. 2 (5.2.2.4) or as indicated**	**Allow. Stress (MPa)**	**Result**
1	(Mark 1) 24"-600#-RF-LS *FLANGE A694F60*	3	Design	P+D+External loads+T	P_m	*94*	214,6	$P_m \leq S$	S (Eq. 5.2)	214,6	*Check*
					P_L	*125*		$P_L \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.3)	321,9	*Check*
					PL+Pb	*170*		$(P_L+P_b) \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.4)	321,9	*Check*
		3	Local	P+D+External loads+T	σ1+σ2+σ3	*264*		(σ1+σ2+σ3) ≤ 4*S	Per 5.3.2 (Eq. 5,5)	858,4	*Check*
Item	**Part/Material**	**FEA Case per VIII Div 2 Part 5**	**Condition**	**ASME VIII DIV. 2 Load combinations**	**Type of Stress**	**FEA "Se" or Triaxial stress (MPa)**	**"S" Allow. Stress (MPa)**	**VIII DIV 2 rule**	**ASME VIII DIV. 2 (5.2.2.4) or as indicated**	**Allow. Stress (MPa)**	**Result**
2	(Mark 3) 24"-Neck-P460-NL2	3	Design	P+D+External loads+T	P_m	*86*	237,5	$P_m \leq S$	S (Eq. 5.2)	237,5	*Check*
					P_L	*178*		$P_L \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.3)	356,25	*Check*
					PL+Pb	*275*		$(P_L+P_b) \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.4)	356,25	*Check*
		3	Local	P+D+External loads+T	σ1+σ2+σ3	*335*		(σ1+σ2+σ3) ≤ 4*S	Per 5.3.2 (Eq. 5,5)	950	*Check*
Item	**Part/Material**	**FEA Case per VIII Div 2 Part 5**	**Condition**	**ASME VIII DIV. 2 Load combinations**	**Type of Stress**	**FEA "Se" or Triaxial stress (MPa)**	**"S" Allow. Stress (MPa)**	**VIII DIV 2 rule**	**ASME VIII DIV. 2 (5.2.2.4) or as indicated**	**Allow. Stress (MPa)**	**Result**
3	(Mark 4) 42"-*Reduced Split tee* - P460-NL2	3	Design	P+D+External loads+T	P_m	*80*	237,5	$P_m \leq S$	S (Eq. 5.2)	237,5	*Check*
					P_L	*207*		$P_L \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.3)	356,25	*Check*
					PL+Pb	*271*		$(P_L+P_b) \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.4)	356,25	*Check*
		3	Local	P+D+External loads+T	σ1+σ2+σ3	*542*		(σ1+σ2+σ3) ≤ 4*S	Per 5.3.2 VIII Div. 2 (Eq. 5,5)	950	*Check*
Item	**Part/Material**	**FEA Case per VIII Div 2 Part 5**	**Condition**	**ASME VIII DIV. 2 Load combinations**	**Type of Stress**	**FEA "Se" or Triaxial stress (MPa)**	**"S" Allow. Stress (MPa)**	**VIII DIV 2 rule**	**ASME VIII DIV. 2 (5.2.2.4) or as indicated**	**Allow. Stress (MPa)**	**Result**
4	Existing 42"-Pipeline -API 5LX60	3	Design	P+D+External loads+T	P_m	*8*	214,6	$P_m \leq S$	S (Eq. 5.2)	214,6	*Check*
					P_L	*184*		$P_L \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.3)	321,9	*Check*
					PL+Pb	*288*		$(P_L+P_b) \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.4)	321,9	*Check*
		3	Local	P+D+External loads+T	σ1+σ2+σ3	*341*		(σ1+σ2+σ3) ≤ 4*S	Per 5.3.2 VIII Div. 2 (Eq. 5,5)	858,4	*Check*

P	Design pressure
Ps	Static pressure, *not considered, gas*
D	Dead loads
T	Temperature

- *Hot Tap-16" x 12"*

Hot Tap 12" x 16"-Allowable Stresses per VIII DIV 2, *Pd=94 bar, Td=80 ºC*											
Item	Part/Material	FEA Case per VIII Div 2 Part 5	Condition	ASME VIII DIV. 2 Load combinations	Type of Stress	*FEA "Se" or Triaxial stress* (MPa)	"S" Allow. Stress (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4) or as indicated	Allow. Stress (MPa)	Result
1	(Mark 1) 12"-600#-RF-LS *FLANGE A694F60*	3	Design	P+D+External loads+T	P_m	*90*	214,6	$P_m \leq S$	S (Eq. 5.2)	214,6	*Check*
					P_L	*143*		$P_L \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.3)	321,9	*Check*
					PL+Pb	*177*		$(P_L+P_b) \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.4)	321,9	*Check*
		3	Local	P+D+External loads+T	σ1+σ2+σ3	*165*		$(\sigma1+\sigma2+\sigma3) \leq 4*S$	Per 5.3.2 (Eq. 5,5)	858,4	*Check*
Item	Part/Material	FEA Case per VIII Div 2 Part 5	Condition	ASME VIII DIV. 2 Load combinations	Type of Stress	FEA "Se" or Triaxial stress (MPa)	"S" Allow. Stress (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4) or as indicated	Allow. Stress (MPa)	Result
2	(Mark 3) 12"-Neck-API 5L-X60	3	Design	P+D+External loads+T	P_m	*167*	214,6	$P_m \leq S$	S (Eq. 5.2)	214,6	*Check*
					P_L	*266*		$P_L \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.3)	321,9	*Check*
					PL+Pb	*287*		$(P_L+P_b) \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.4)	321,9	*Check*
		3	Local	P+D+External loads+T	σ1+σ2+σ3	*358*		$(\sigma1+\sigma2+\sigma3) \leq 4*S$	Per 5.3.2 (Eq. 5,5)	858,4	*Check*
Item	Part/Material	FEA Case per VIII Div 2 Part 5	Condition	ASME VIII DIV. 2 Load combinations	Type of Stress	FEA "Se" or Triaxial stress (MPa)	"S" Allow. Stress (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4) or as indicated	Allow. Stress (MPa)	Result
3	(Mark 4) 16"-*Run* - P460-NL2	3	Design	P+D+External loads+T	P_m	*107*	237,5	$P_m \leq S$	S (Eq. 5.2)	237,5	*Check*
					P_L	*170*		$P_L \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.3)	356,25	*Check*
					PL+Pb	*229*		$(P_L+P_b) \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.4)	356,25	*Check*
		3	Local	P+D+External loads+T	σ1+σ2+σ3	*272*		$(\sigma1+\sigma2+\sigma3) \leq 4*S$	Per 5.3.2 VIII Div. 2 (Eq. 5,5)	950	*Check*
Item	Part/Material	FEA Case per VIII Div 2 Part 5	Condition	ASME VIII DIV. 2 Load combinations	Type of Stress	FEA "Se" or Triaxial stress (MPa)	"S" Allow. Stress (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4) or as indicated	Allow. Stress (MPa)	Result
4	Existing 16"-Pipeline -API 5LX60	3	Design	P+D+External loads+T	P_m	*4*	214,6	$P_m \leq S$	S (Eq. 5.2)	214,6	*Check*
					P_L	*163*		$P_L \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.3)	321,9	*Check*
					PL+Pb	*200*		$(P_L+P_b) \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.4)	321,9	*Check*
		3	Local	P+D+External loads+T	σ1+σ2+σ3	*247*		$(\sigma1+\sigma2+\sigma3) \leq 4*S$	Per 5.3.2 VIII Div. 2 (Eq. 5,5)	858,4	*Check*

P	Design pressure
Ps	Static pressure, *not considered, gas*
D	Dead loads
T	Temperature

- *Hot Tap-14" x 12"*

Hot Tap 12" x 14"-Allowable Stresses per VIII DIV 2, *Pd=94 bar, Td=80 ºC*											
Item	Part/Material	FEA Case per VIII Div 2 Part 5	Condition	ASME VIII DIV. 2 Load combinations	Type of Stress	*FEA "Se" or Triaxial stress* (MPa)	"S" Allow. Stress (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4) or as indicated	Allow. Stress (MPa)	Result
1	(Mark 1) 12"-600#-RF-LS *FLANGE A694F60*	3	Design	P+D+External loads+T	P_m	*81*	214,6	$P_m \leq S$	S (Eq. 5.2)	214,6	*Check*
					P_L	*127*		$P_L \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.3)	321,9	*Check*
					PL+Pb	*144*		$(P_L+P_b) \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.4)	321,9	*Check*
		3	Local	P+D+External loads+T	σ1+σ2+σ3	*145*		(σ1+σ2+σ3) ≤ 4*S	Per 5.3.2 (Eq. 5,5)	858,4	*Check*
Item	Part/Material	FEA Case per VIII Div 2 Part 5	Condition	ASME VIII DIV. 2 Load combinations	Type of Stress	FEA "Se" or Triaxial stress (MPa)	"S" Allow. Stress (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4) or as indicated	Allow. Stress (MPa)	Result
2	(Mark 3) 12"-Neck-API 5L-X60	3	Design	P+D+External loads+T	P_m	*146*	214,6	$P_m \leq S$	S (Eq. 5.2)	214,6	*Check*
					P_L	*243*		$P_L \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.3)	321,9	*Check*
					PL+Pb	*248*		$(P_L+P_b) \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.4)	321,9	*Check*
		3	Local	P+D+External loads+T	σ1+σ2+σ3	*307*		(σ1+σ2+σ3) ≤ 4*S	Per 5.3.2 (Eq. 5,5)	858,4	*Check*
Item	Part/Material	FEA Case per VIII Div 2 Part 5	Condition	ASME VIII DIV. 2 Load combinations	Type of Stress	FEA "Se" or Triaxial stress (MPa)	"S" Allow. Stress (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4) or as indicated	Allow. Stress (MPa)	Result
3	(Mark 4) 16"-*Run* - P460-NL2	3	Design	P+D+External loads+T	P_m	*84*	237,5	$P_m \leq S$	S (Eq. 5.2)	237,5	*Check*
					P_L	*192*		$P_L \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.3)	356,25	*Check*
					PL+Pb	*251*		$(P_L+P_b) \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.4)	356,25	*Check*
		3	Local	P+D+External loads+T	σ1+σ2+σ3	*404*		(σ1+σ2+σ3) ≤ 4*S	Per 5.3.2 VIII Div. 2 (Eq. 5,5)	950	*Check*
Item	Part/Material	FEA Case per VIII Div 2 Part 5	Condition	ASME VIII DIV. 2 Load combinations	Type of Stress	FEA "Se" or Triaxial stress (MPa)	"S" Allow. Stress (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4) or as indicated	Allow. Stress (MPa)	Result
4	Existing 16"-Pipeline -API 5LX52	3	Design	P+D+External loads+T	P_m	*5*	214,6	$P_m \leq S$	S (Eq. 5.2)	214,6	*Check*
					P_L	*141*		$P_L \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.3)	321,9	*Check*
					PL+Pb	*144*		$(P_L+P_b) \leq S_{PL}$	S_{pL}=1.5*S (Eq. 5.4)	321,9	*Check*
		3	Local	P+D+External loads+T	σ1+σ2+σ3	*322*		(σ1+σ2+σ3) ≤ 4*S	Per 5.3.2 VIII Div. 2 (Eq. 5,5)	858,4	*Check*

P	Design pressure
Ps	Static pressure, *not considered, gas*
D	Dead loads
T	Temperature

According to the above summary tables, the main conclusions are:

- The highest membrane stress "*Pm*" is typically localized on the ***branch element*** (*mark 3*).
- The highest local membrane stress "*Pl*" for the *16" x 12"* and *14" x 12"* fittings is localized on the branch element (*mark 3*), while for the largest fitting, *42" x 24"*, it is localized at *mark 4*.
- The highest local membrane plus bending stress *"Pl+Pb"* is typically localized between *mark 3* and *mark 4*.
- The highest local principal stress (*σ1+σ2+σ3*) is typically localized between *mark 3* and *mark 4*.
- The safety factor for the entire fitting ranges between *1.10* and *1.9*, considering external loads from the hot tapping operation under design conditions as the worst-case scenario. During normal operation, all stresses will decrease.

Based on the conducted studies and applied premises, it can be concluded that the three Diameter-Stopple fittings do not present any issues from the perspective of primary and local stress.

11 Stress summary at test condition for each Hot Tap fittings dimension

The following tables summarize the ***linearized stress*** assessment and compare the allowable stress for each ***Diameter-Stopple fitting, including the existing pipeline, under test conditions***.

11.1 Hot tap-42" x 24"

42" X 24" Test condition VIII DIV 2, Ptest=141bar; T=30°C										
Item	Part/Material	FEA Case per VIII Div 2 Part 5	ASME VIII DIV. 2 Load combinations	Type of Stress	*FEA "Se"* Von Mises (MPa)	"Sy" (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4)	Allow. Stress (MPa)	Result
1	(Mark 1) 24"-600#-RF-LS FLANGE A694F60	18	$Pt+P_s+D+0,6W_{PT}$	Pm	170	415	$Pm \leq \beta T*SY$	$\beta T*SY$ (Eq. 4.1.3)	394	*Check*
				Pm+Pb	198		$Pm+Pb \leq \gamma min*SY$	$\gamma min*SY$ (Eq. 4.1.4)	591	*Check*
2	(Mark 3) 24"-Neck- P460-NL2	18	$Pt+Ps+D+0,6W_{PT}$	Pm	132	430	$Pm \leq \beta T*SY$	$\beta T*SY$ (Eq. 4.1.3)	409	*Check*
				Pm+Pb	272		$Pm+Pb \leq \gamma min*SY$	$\gamma min*SY$ (Eq. 4.1.4)	613	*Check*
3	(Mark 4) 42"-Run-P460-NL2	18	$Pt+Ps+D+0,6W_{PT}$	Pm	176	430	$Pm \leq \beta T*SY$	$\beta T*SY$ (Eq. 4.1.3)	409	*Check*
				Pm+Pb	246		$Pm+Pb \leq \gamma min*SY$	$\gamma min*SY$ (Eq. 4.1.4)	613	*Check*
4	Existing 42"-Pipeline -API 5LX60	18	$Pt+Ps+D+0,6W_{PT}$	Pm	201	415	$Pm \leq \beta T*SY$	$\beta T*SY$ (Eq. 4.1.3)	394	*Check*
				Pm+Pb	206		$Pm+Pb \leq \gamma min*SY$	$\gamma min*SY$ (Eq. 4.1.4)	591	*Check*

Note: ***Wpt*** It was not applied because wind is not considered for this system as it is a hot tap underground.

Pt	Test pressure
Ps	Static pressure
D	Dead loads
T	Test Temperature

11.2 Hot tap-16” x 12”

16" X 12" Test condition VIII DIV 2, Ptest=141bar; T=30°C										
Item	Part/Material	FEA Case per VIII Div 2 Part 5	ASME VIII DIV. 2 Load combinations	Type of Stress	*FEA "Se"* Von Mises (MPa)	"Sy" (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4)	Allow. Stress (MPa)	Result
1	(Mark 1) 12"-600#-RF-LS FLANGE A694F60	18	$Pt+P_s+D+0,6W_{PT}$	Pm	151	415	$Pm \leq \beta T*SY$	βT*SY (Eq. 4.1.3)	394	*Check*
				Pm+Pb	162		$Pm+Pb \leq \gamma min*SY$	γmin*SY (Eq. 4.1.4)	591	*Check*
2	(Mark 3) 12"-Neck- API 5L-X60	18	$Pt+Ps+D+0,6W_{PT}$	Pm	262	415	$Pm \leq \beta T*SY$	βT*SY (Eq. 4.1.3)	394	*Check*
				Pm+Pb	302		$Pm+Pb \leq \gamma min*SY$	γmin*SY (Eq. 4.1.4)	591	*Check*
3	(Mark 4) 16"-Run-P460-NL2	18	$Pt+Ps+D+0,6W_{PT}$	Pm	159	430	$Pm \leq \beta T*SY$	βT*SY (Eq. 4.1.3)	409	*Check*
				Pm+Pb	241		$Pm+Pb \leq \gamma min*SY$	γmin*SY (Eq. 4.1.4)	613	*Check*
4	Existing 16"-Pipeline -API 5LX60	18	$Pt+Ps+D+0,6W_{PT}$	Pm	105	415	$Pm \leq \beta T*SY$	βT*SY (Eq. 4.1.3)	394	*Check*
				Pm+Pb	113		$Pm+Pb \leq \gamma min*SY$	γmin*SY (Eq. 4.1.4)	591	*Check*

Note: ***Wpt*** It was not applied because wind is not considered for this system as it is a hot tap underground.

Pt	Test pressure
Ps	Static pressure
D	Dead loads
T	Test Temperature

11.3 Hot tap-14” x 12”

14" X 12" Test condition VIII DIV 2, Ptest=141bar; T=30°C											
Item	Part/Material	FEA Case per VIII Div 2 Part 5	ASME VIII DIV. 2 Load combinations	Type of Stress	*FEA "Se"* Von Mises (MPa)	"Sy" (MPa)	VIII DIV 2 rule	ASME VIII DIV. 2 (5.2.2.4)	Allow. Stress (MPa)	Result	Result
1	(Mark 1) 12"-600#-RF-LS FLANGE A694F60	18	$Pt+P_s+D+0,6W_{PT}$	Pm	164	415	Pm ≤ βT*SY	βT*SY (Eq. 4.1.3)	394	*Check*	
				Pm+Pb	176		Pm+Pb ≤ ϒmin*SY	ϒmin*SY (Eq. 4.1.4)	591	*Check*	
2	(Mark 3) 12"-Neck- API 5L-X60	18	$Pt+Ps+D+0,6W_{PT}$	Pm	280	415	Pm ≤ βT*SY	βT*SY (Eq. 4.1.3)	394	*Check*	
				Pm+Pb	316		Pm+Pb ≤ ϒmin*SY	ϒmin*SY (Eq. 4.1.4)	591	*Check*	
3	(Mark 4) 16"-Run-P460-NL2	18	$Pt+Ps+D+0,6W_{PT}$	Pm	152	430	Pm ≤ βT*SY	βT*SY (Eq. 4.1.3)	409	*Check*	
				Pm+Pb	235		Pm+Pb ≤ ϒmin*SY	ϒmin*SY (Eq. 4.1.4)	613	*Check*	
4	Existing 16"-Pipeline -API 5LX52	18	$Pt+Ps+D+0,6W_{PT}$	Pm	130	360	Pm ≤ βT*SY	βT*SY (Eq. 4.1.3)	342	*Check*	
				Pm+Pb	136		Pm+Pb ≤ ϒmin*SY	ϒmin*SY (Eq. 4.1.4)	513	*Check*	

Note: ***Wpt*** It was not applied because wind is not considered for this system as it is a hot tap underground.

Pt	Test pressure
Ps	Static pressure
D	Dead loads
T	Test Temperature

As observed, the three fittings are below the permissible limit for the hydrostatic test condition, thus complying with ASME VIII Div 2 Part 5 rules.

12 Conclusion

- *According to the results, the three complete stopple fittings and the surrounding pipeline area are not expected to experience overstress under the applied loads.*
- The highest membrane stress "*Pm*" is typically localized on the *branch element* (*mark 3*).
- The highest local membrane stress "*Pl*" for the *16" x 12"* and *14" x 12"* fittings is localized on the branch element (*mark 3*), while for the largest fitting, *42" x 24"*, it is localized at *mark 4*.
- The highest local membrane plus bending stress *"Pl+Pb"* is typically localized between *mark 3* and *mark 4*.
- The highest local principal stress (*σ1+σ2+σ3*) is typically localized between *mark 3* and *mark 4*.
- The safety factor for the entire fitting ranges between *1.10* and *1.9*, considering external loads from the hot tapping operation under design conditions as the worst-case scenario. *During normal operation, all stresses will decrease.*

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