DESIGN AND ANALYSIS OF PIPING FOR CRUDE SEPARATION SYSTEM

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DESIGN AND ANALYSIS OF PIPING FOR CRUDE SEPARATION SYSTEM

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Master of Technology in Pipeline Engineering

By

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CERTIFICATE

This is to certify that the work contained in this thesis titled **"Design and Analysis of Piping for Crude Separation System"** has been carried out by Md Mujtaba Rafat under my supervision and has not been submitted elsewhere for a degree.

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ABSTRACT

The crude after being extracted from the oil wells is transported through pipelines to the first stage of its purification process that is to the Surface Development Facility where it is degasified, dewatered and soil content is removed. This project involves the successful development piping for crude separation area, which is an important part of surface development facility, in accordance to the ASME B31.3 with the help of 3D modeling software SmartPlant 3D.

The selection of critical lines in the system is done based on the critical line selection criteria mentioned in the Basis of Design for Stress Analysis document of WorleyParsons then the stress analysis is carried on the lines meeting the above mentioned criteria using CAESAR II software where it is subjected to various load cases like Sustained load case, Operational load case, Occasional load case and Expansion load case. The flange leakage and nozzle leakage analysis are performed on the flanges in the system and nozzle connecting the pumps.

ACKNOWLEDGEMENT

I express my sincere gratitude to **Dr. Suresh Kumar**, Head of the Department, for motivating me throughout my M.Tech.

I am sincerely thankful to **Mr. Ramesh M**, Assistant Professor for providing me the opportunity to work on this project. He motivated and inspired me during the time of difficulties and has fully supported me by providing the information needed.

I am highly indebted to **Mr. Mohammed Avais,** Director at Petrocon Institute of Piping Engineering for his guidance and constant supervision as well as for providing necessary information regarding the project. I wish to express a sense of gratitude and love to friends and beloved parents for their support, strength, help and for everything.

Md Mujtaba Rafat

NOMENCLATURE

SYMBOL	MEANING
T	Pressure design thickness (inches)
P	Internal design pressure (psi)
E	Joint efficiency factor
Y	Co-efficient
D	Outside diameter (inches)
S	Allowable stress (psi)
T	Pipe wall thickness (mm)
C	Corrosion allowance (mm)
W	Weight (N)
T1, T2, T3	Thermal Case 1, 2 ,3
HP	Hydro Pressure
U1, U2, U3	Seismic Load Case 1, 2 ,3
WIN 1, 2, 3	Wind load Case 1, 2,3
P1	Pressure
F	Stress range factor
L	Span length (m)
I	Moment of Inertia (m^4)
E	Modulus of Elasticity (N/m^2)
Subscripts	
M	Minimum
A	Allowable
C	At Minimum temperature
H	At Maximum temperature
L	Longitudinal
B	Bending
C	Concentrated

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1. INTRODUCTION

A typical well stream is a high velocity, turbulent, constantly expanding mixture of gases and hydrocarbon liquids, intimately mixed with water vapour, free water, solids, and other contaminants. As it flows from the hot, high pressure petroleum reservoir, the well stream is undergoing continuous pressure and temperature reduction. Gases evolve from the liquids, water vapour condenses, and some of the well stream changes in character from liquid to free gas. The gas is carrying liquid mist droplets, and the liquid is carrying gas bubbles.

The objectives of the Surface development facility are to perform the following:

- To separate the wellstream into its three fundamental components — gases, liquids and solid impurities
- To remove water from the liquid phase
- To treat crude oil to capture gas vapors
- To condition gas [1]

Crude Separation System is one of the areas of the Surface development facility which encompasses the following equipment; A Well stream separator, Heat exchangers, Centrifugal pumps, coolers and an Expansion drum.

A Separator is a vessel in which a mixture of immiscible fluids is separated; example crude oil, natural gas and water. The main principles used to achieve physical separation of gas and liquids are: gravity settling and coalescing

The Separator contains a Primary separation area where the bulk of the liquid from the inlet stream. For example, free liquids, slugs and large droplets are removed from the well stream, a Secondary Separation Section for removing the maximum amount of small liquid droplets without an elaborate design, a Mist Extraction Section for removing the maximum amount of tiny liquid droplets remaining in the gas stream and a Liquid Accumulation Section for receiving and disposing of the liquid collected. [2]

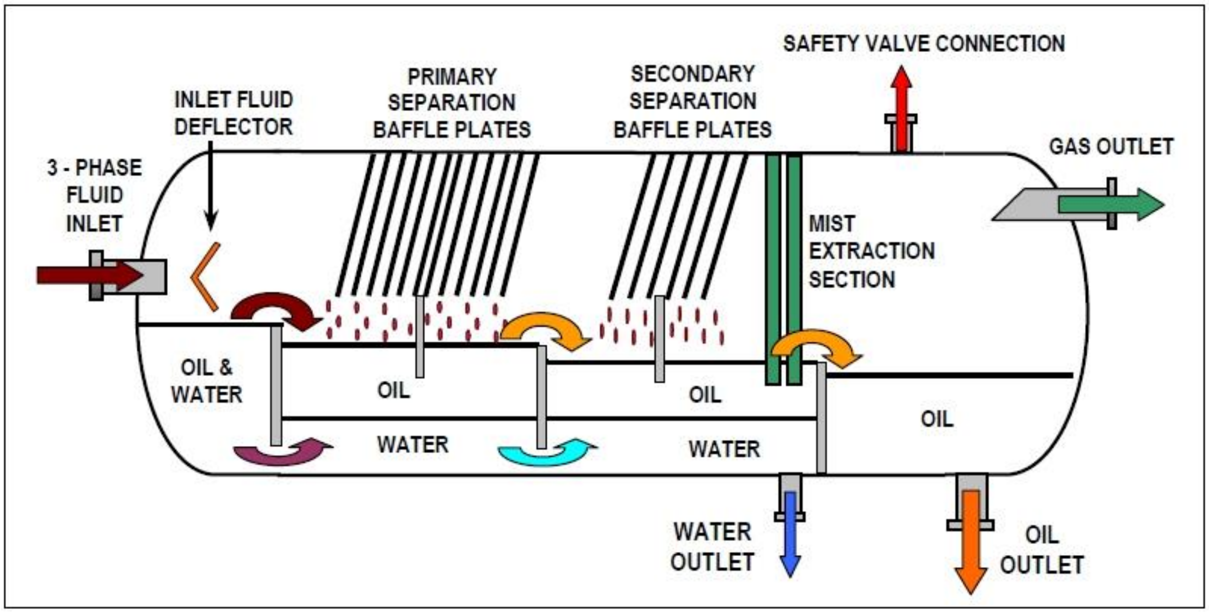


Figure 1-1 Horizontal 3 Phase Separator

Fields where a large amount of sand is produced, sand will accumulate in process equipment. Separators can be equipped with a Sand Fluidising System. This will allow solid particles that have settled in the separator to temporarily being fluidised by the injection water and the slurry simultaneously being drained off to the sand handling / produced water system for physical removal from the process. This can be done both whilst the separator is offline as well as online.

1.1 Importance of the Project

According to ASME B31.3-2004 for any Plant to work throughout its designed life span it is very much important that the code stress of the designed piping system at the given temperature and pressure must be within the allowable stress values for all the load cases applicable.

A good piping system has to be easily operational and must have adequate provision for maintenance. It should not only focus on the safety of equipment and personnel on the plant but also on the economic feasibility of the system. Hence the objective to design a piping system for the crude separation area which is both safe and economical is important.

1.2 Scope of the project

The project focuses on designing the piping for crude separation area which comprises of a Wellstream Separator, Heat exchangers, Centrifugal pumps, Expansion drum and Coolers.

The Wellstream is connected to the separator where the crude, water and natural gas are separated. Then the crude is pumped to the heat exchangers and then passed on to the metering station. The water used in the heat exchangers is cooled in the air coolers and passed to the expansion drum from where it is pumped back to the heat exchanger.

The piping for the above system is designed such that it meets the ASME B31.3 criteria, a standard for Process Piping, successfully by using a 3D modeling software SmartPlant 3D.

Additionally it is made sure that the designed piping is safe by conducting the CAESAR II analysis for Sustained, Operational, Occasional and Expansion load cases.

2. LITERATURE REVIEW

(Shetty & K, 2014) Solved the vibration problem in a vacuum pump for Mangalore refinery in their study they found out that the resonance was responsible for the vibration and he found the solution to be adjustments in the support locations whereas (Ghule & S. B. Belkar, 2014) made slight changes in the pump piping rerouting to reduce the loads on the pump nozzle and also increased the allowable load.

Concepts of flexibility, stress intensification and their equations provided in ASME B31 codes is explained by (Bhende & Tembhare, 2013) and have also compared the results of ASME B31 SIF with the results obtained by using Finite Element Analysis.

Stress values, forces and deflections in flare piping are analysed by (T.V.V.Satyanarayana, sreenivasulu, & kiran, 2013) and the design is made safe by adding an expansion loop to the system.

(Bisht & Jahan, 2014) Studied a wide range of abilities and covered the fundamentals and concepts used in stress analysis as well as they discussed about the engineering principles involved in material selection, application of code criteria and tools incorporated in CAESAR II.

Piping support span and deflection is calculated by (Prachi et al., 2014) they analysed the nozzle loads with and without intermediate support and concluded that the addition of unnecessary supports to the piping increases the moment on the nozzle and also (Vakharia , 2009) in their research determined the maximum support span by using maximum bending stress theory and compared it with the ASME B31.1 standard support spacing and U S Army Engineer's Manual. They found that the number of supports required is less by this method than the other two and even the deflection remained within the limits. To support their result they conducted the analysis on the above mentioned problem using ANSYS.

(Tambe, K.Dhande, & Jamadar, 2014) In their study conducted the flexibility and stress analysis for the two different piping routings they designed for connecting the two tanks.

They compared the cases and observed the effect of the flexibility of piping system on the nozzle loads.

Following literatures were studied

Table 1 Literature review

Problem discussed	Authors, Year
Vibration Analysis of a Piping System Attached With Pumps and Subjected to Resonance	Sunil Kumar Shetty and Raghunandana. K, (2014)
Determination of Maximum Support Span, Location and Necessity of Pipe Support	Tambe Prachi N et al.,(2014)
Modification in Pump Piping to Comply with Nozzle Allowable	Harshal M Ghule and S. B. Belkar, (2014)
Modeling and Stress Analysis of Flare Piping	Satyanarayana et al., (2013)
Determination of maximum span between pipe supports using maximum bending stress theory	Dr. D.P. Vakharia and Mohd. Farooq A, (2009)
Overview on Pipe Design using CAESAR II	Shweta Bisht and Farheen Jahan, (2014)
Flexibility and Stress Analysis of Piping System	Tambe Prachi N et al.,(2014)
Stress Intensification & Flexibility in Pipe Stress Analysis	Gaurav Bhende and Girish Tembhare (2013)

3. METHODOLOGY

Methodology adopted for designing and analysis of piping is as follows:

Step 1 : Development of Process flow diagram

Step 2 : Pipe thickness and Support span calculations

Step 3 : Modeling in SmartPlant 3D

Step 4 : Selection of critical lines

Step 5 : Extraction of isometric drawings

Step 6 : Modeling of critical lines in CAESAR II

Step 7 : Development of load cases

Step 8 : Conducting the CAESAR II analysis for support configuration.

3.1 Development of Process flow diagram

PFDs are the schematic illustrations of system descriptions. PFDs show the relationships between the major system components and subsystems and flow of product between them.

A typical PFD shows the following items:

- Process Piping
- Process flow direction
- Major equipment represented by simplified symbols
- Major bypass and recirculation lines
- Connection between systems. [3]

Figure 3-1 shows the developed Process Flow Diagram for Crude Separation system

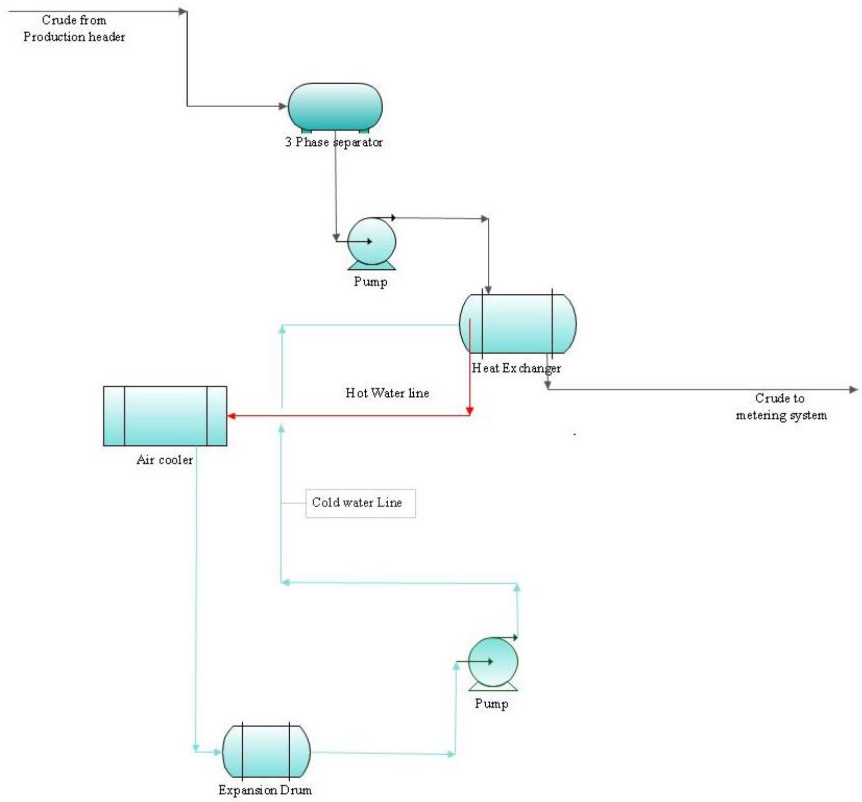


Figure 3-1 PFD for Crude Separation System

3.2 Pipe thickness and Support span calculations

Pipe thickness is calculated by using the formula

$$t = \frac{PD}{2(SE+PY)}$$

$$t_m = t + c \qquad [14]$$

Depending on the value of t_m calculated above the schedule number for the line is selected by using ASME B 36.10.

Maximum support span calculation

Design formulas for calculating bending stress and deflection between supports are derived from the usual beam formulas, which depend upon the method of support and the type of loading.

Maximum Bending stress,

$$S_b = \frac{(0.0624wL^2 + 0.1248w_cL)D}{I}$$

Maximum Deflection,

$$y = \frac{5wL^4 + 8w_cL^3}{384EI}$$

Total weight (w) = weight of pipe (w_p) + weight of fluid (w_f)

$$w_p = 0.02466(D - t)t$$

Weight of fluid = $\frac{\pi}{4}$ d^2 * density of fluid in N/m

For Support span to be safe the deflection should be less than $\frac{L}{600}$ [4]

3.3 Modeling in SmartPlant 3D

With the help of developed PFD and the P and ID’s provided by the company the modeling of crude separation system is done in the SmartPlant 3D in accordance to the ASME B31.3.The figures below show the modeled system.

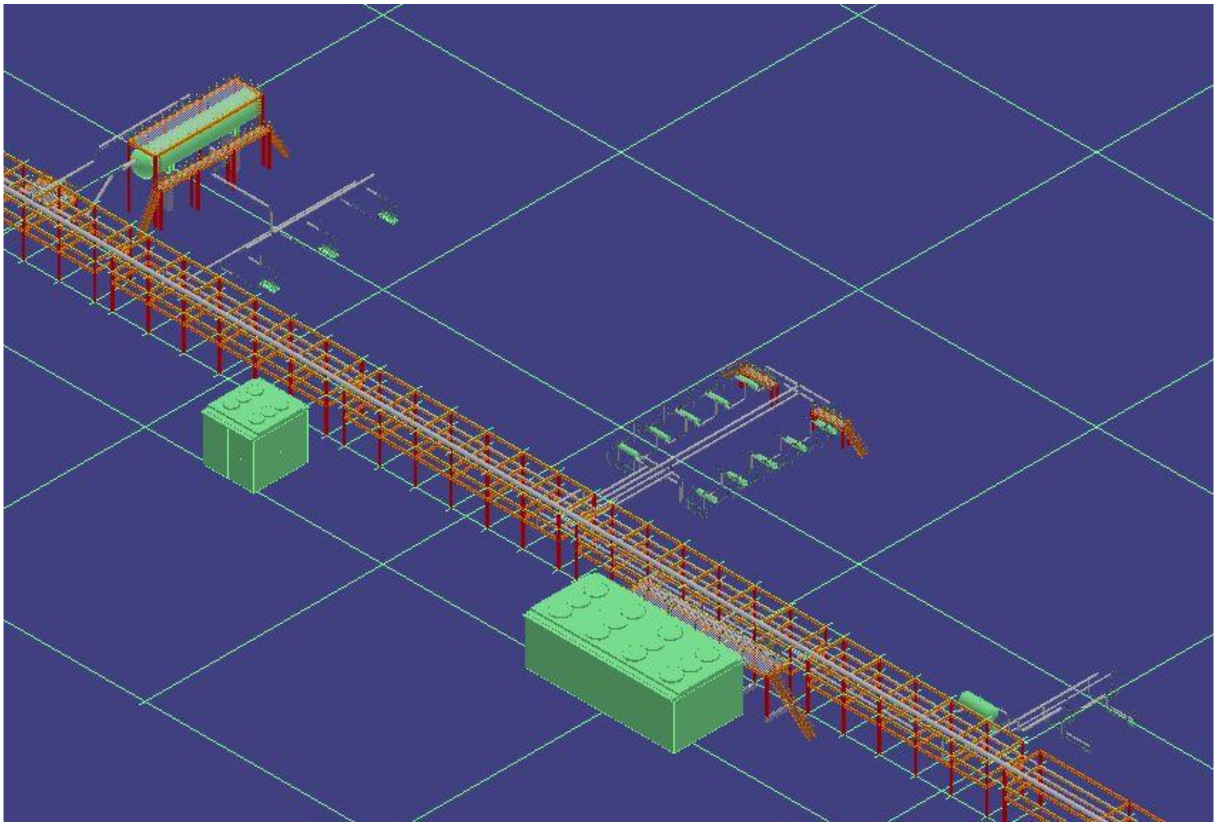


Figure 3-2 Overall View of System

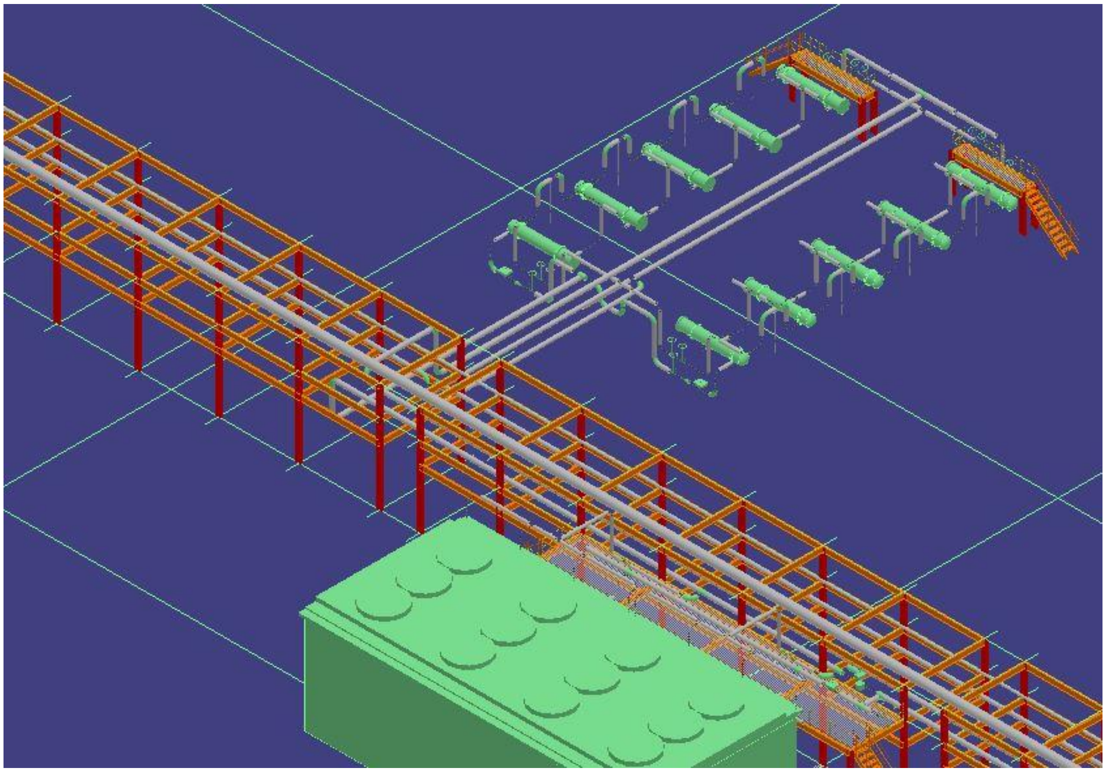


Figure 3-3 Close up view of Heat exchanger and Cooler

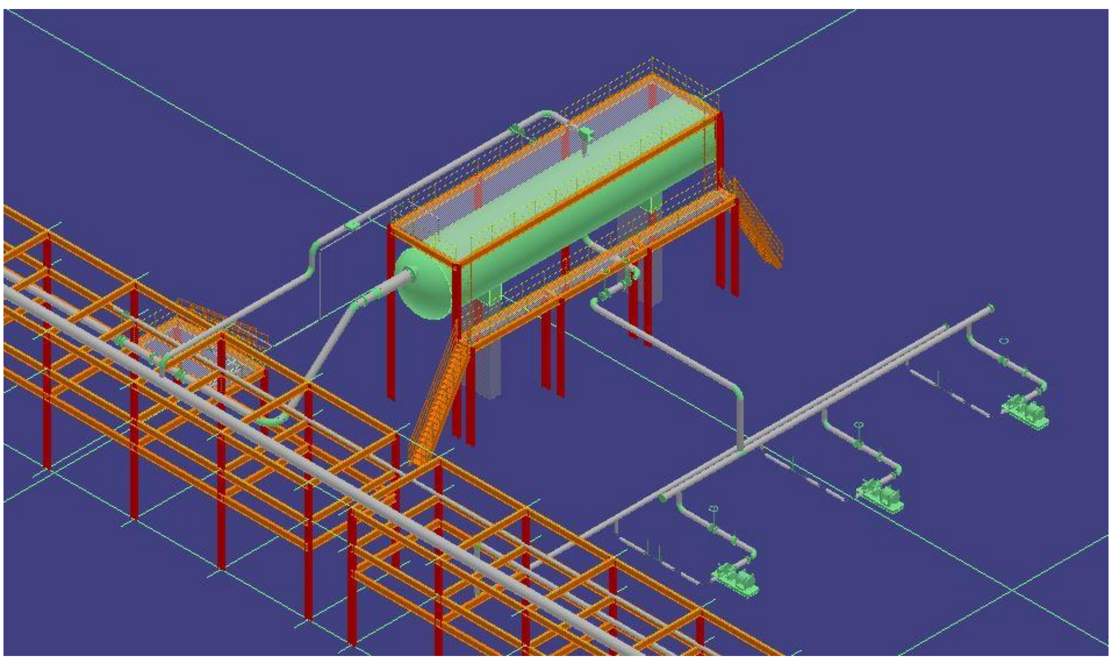


Figure 3-4 Close up view of 3 Phase Separator

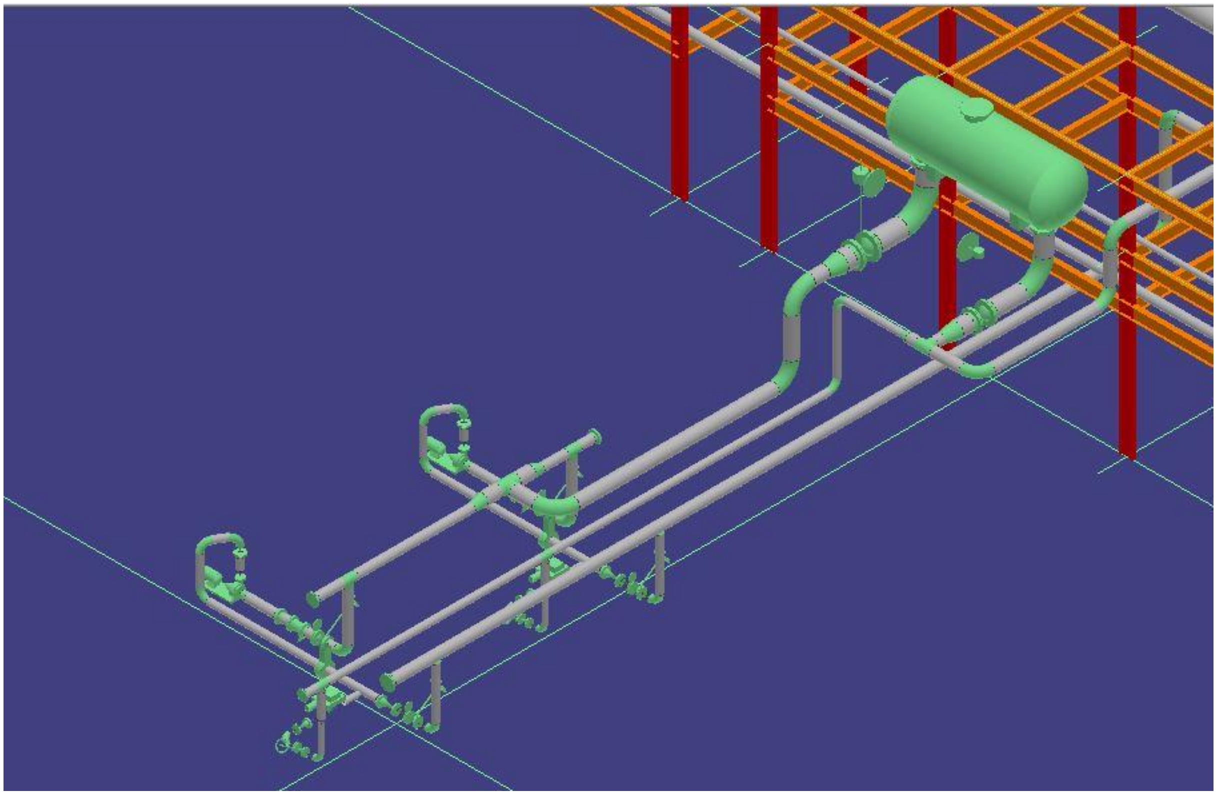


Figure 3-5 Close view of expansion drum

3.4 Selection of critical lines

The selection of critical lines is based on the following criteria

a. Pipes DN 500 and larger.
b. Process pipes DN 80 and larger if connected to rotating equipment.
c. Pipes connected to air-coolers and heat exchangers.
d. Pipes connected to pulsating equipment.
e. Pipes to and from boilers and heaters.
f. In cases where differential settlement of equipment and/or supports is expected.
g. Pipes where engineered items are required like spring supports, expansion joints, and snubbers.
h. Pipes subject to slug flow or water hammer.
i. Flare pipes DN 100 and larger. [5]

3.5 Extraction of isometric drawings

Based on the critical lines selected the isometric drawings are extracted and then edited using the SmartSketch Drawing Editor. The figures below show some of the isometric drawings.

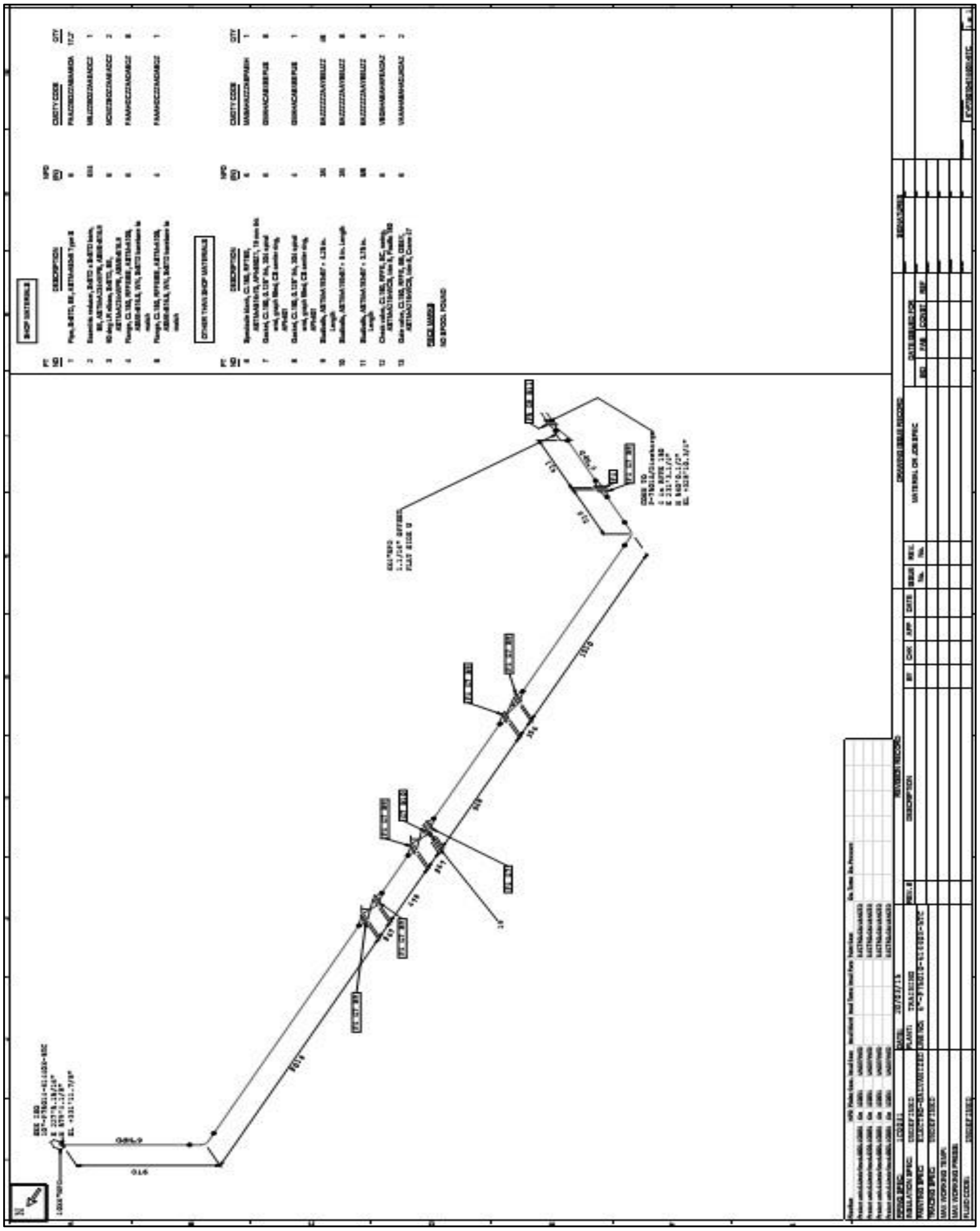


Figure 3-6 Isometric of Pump Suction

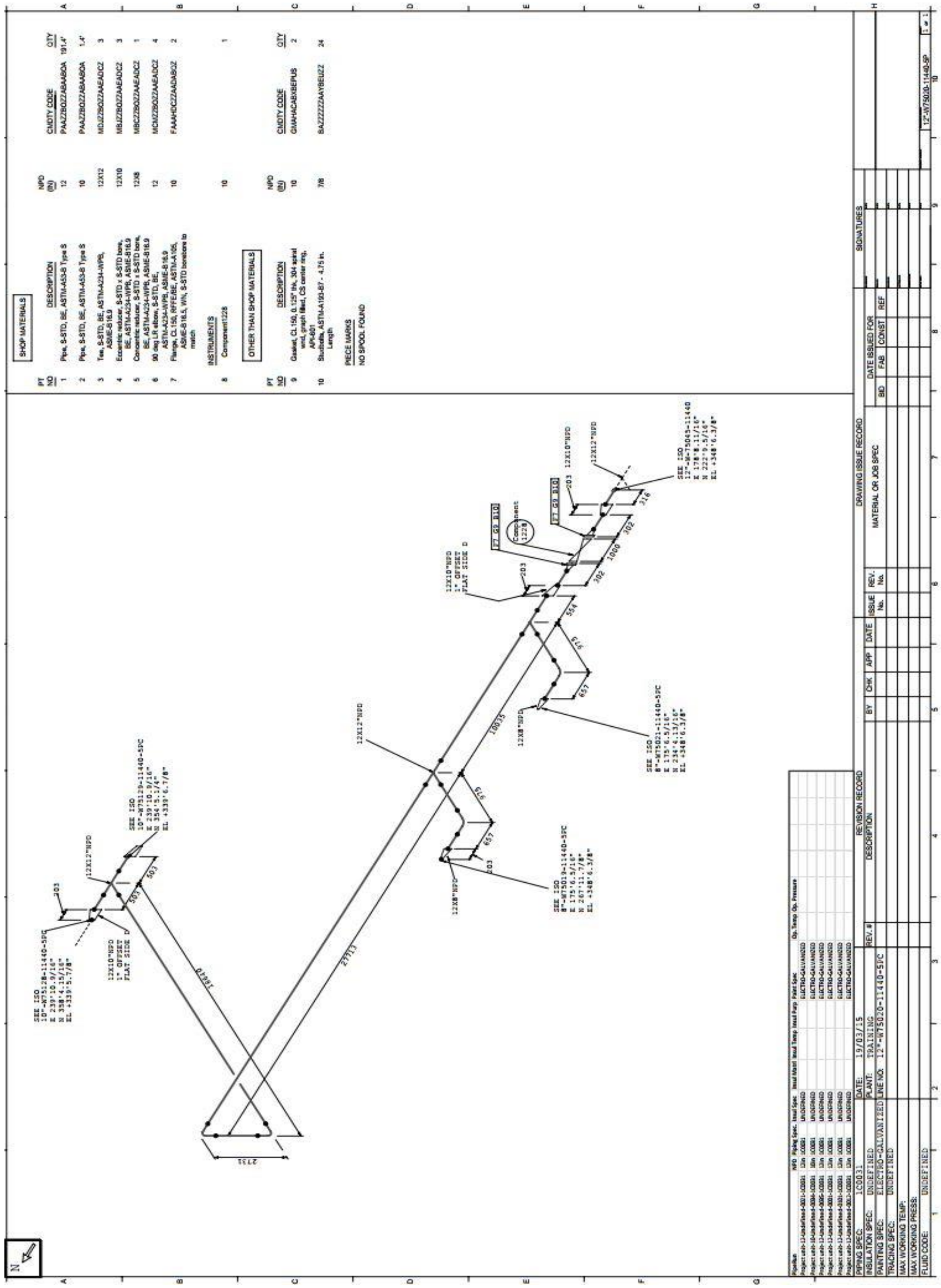


Figure 3-7 Isometric of cooler suction header

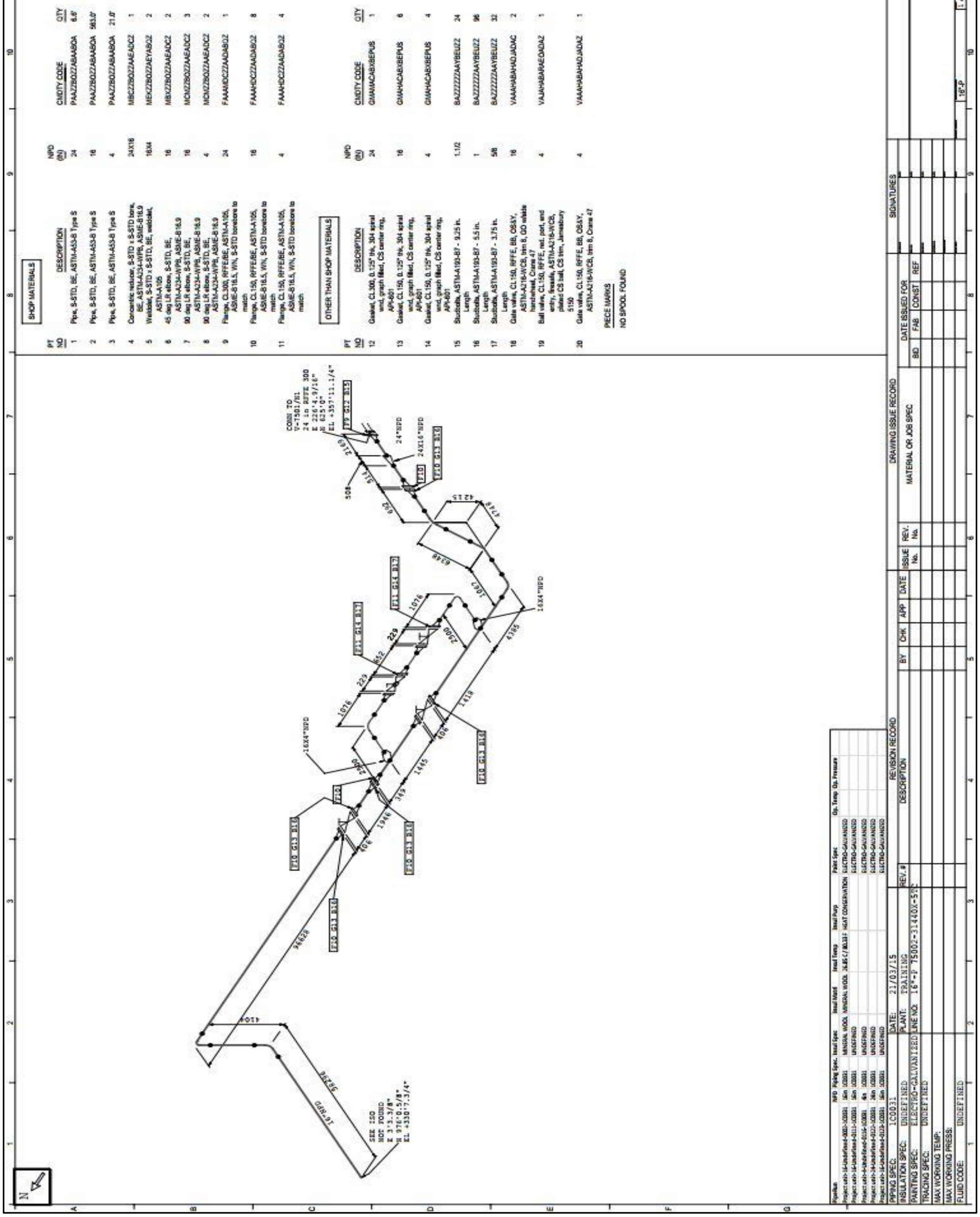


Figure 3-8 Isometric of 3 Phase Separator inlet

3.6 Modeling of critical lines in CAESAR II

After the extraction of isometric drawings of critical lines these lines are modeled in CAESAR II. The figures below show some of the critical lines modeled in CAESAR.

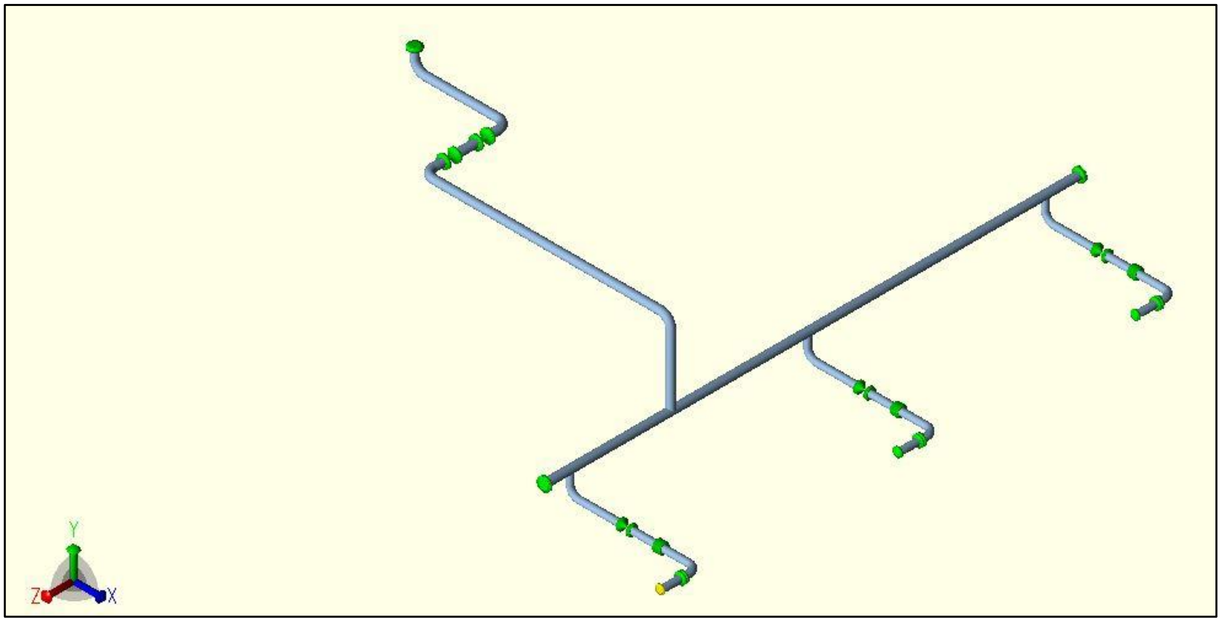


Figure 3-9 Pump Suction line from 3 Phase Separator

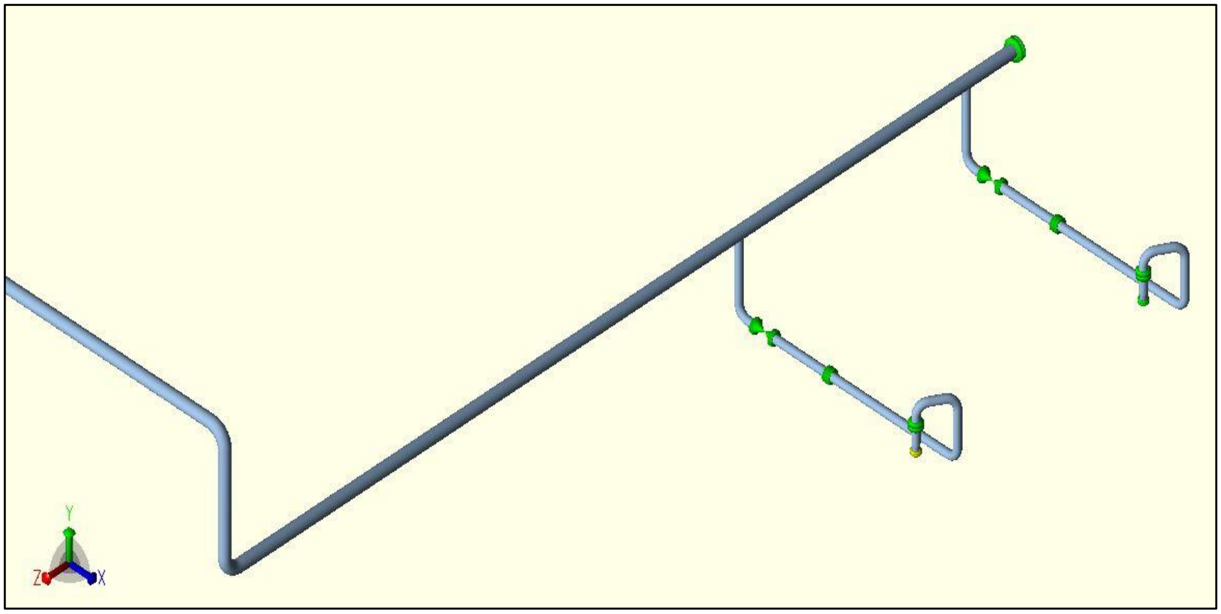


Figure 3-10 Cold water pump discharge to Heat exchanger

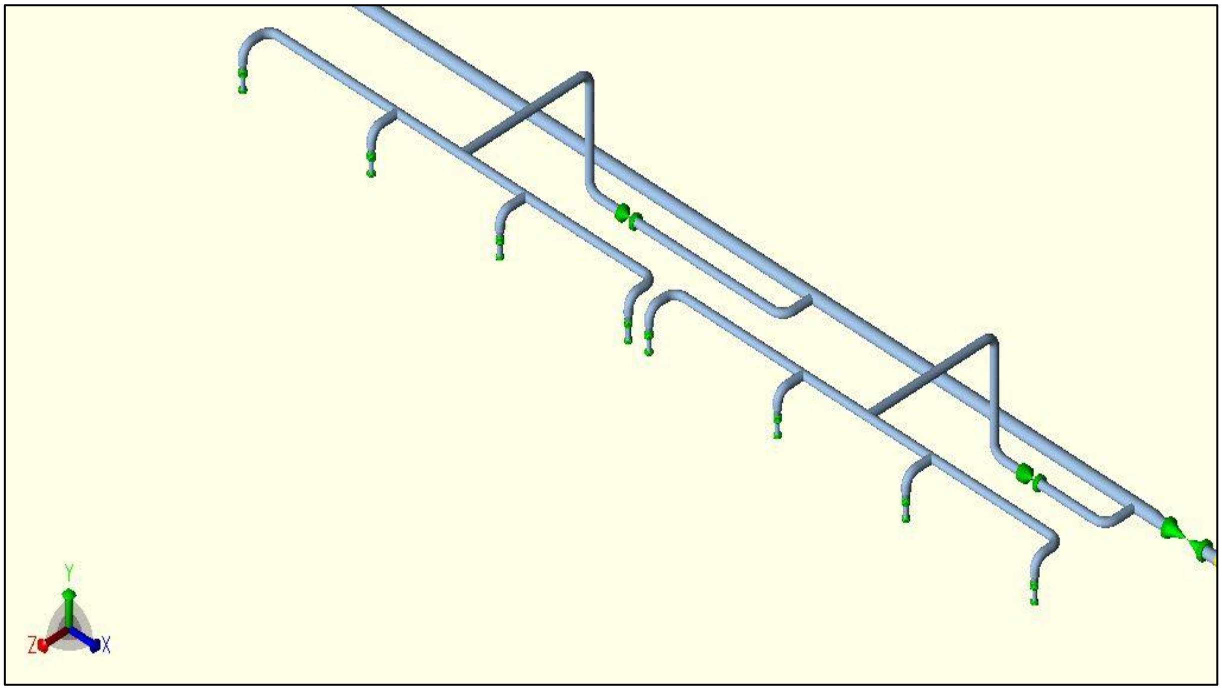


Figure 3-11 Hot Water inlet to Cooler

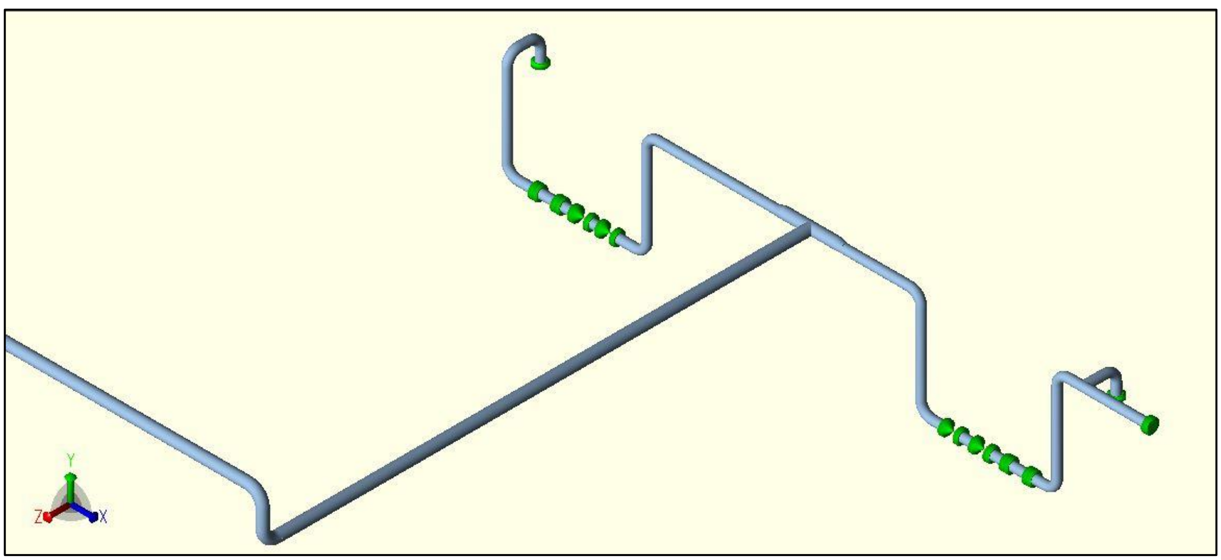


Figure 3-12 Hot Crude line to Heat Exchanger

3.7 Development of load cases

After a critical line is modeled in CAESAR the cases for Sustained, Operating, Expansion and Occasional loads are developed as follows

CASE 1 (HYD) WW+HP

CASE 2 (OPE) W+T1+P1

CASE 3 (OPE) W+T2+P1

CASE 4 (OPE) W+T3+P1

CASE 5 (SUS) W+P1

CASE 6 (OCC) W+T1+P1+U1

CASE 7 (OCC) W+T1+P1+U2

CASE 8 (OCC) W+T1+P1+U3

CASE 9 (OCC) W+T1+P1-U1

CASE 10 (OCC) W+T1+P1-U2

CASE 11 (OCC) W+T1+P1-U3

CASE 12 (OCC) W+P1+U1

CASE 13 (OCC) W+P1+U2

CASE 14 (OCC) W+P1+U3

CASE 15 (OCC) W+P1-U1

CASE 16 (OCC) W+P1-U2

CASE 17 (OCC) W+P1-U3

CASE 18 (OCC) W+T1+P1+WIN1

CASE 19 (OCC) W+T1+P1+WIN2

CASE 20 (OCC) W+T1+P1+WIN3

CASE 21 (OCC) W+T1+P1+WIN4

CASE 22 (OCC) W+P1+WIN1

CASE 23 (OCC) W+P1+WIN2

CASE 24 (OCC) W+P1+WIN3

CASE 25 (OCC) W+P1+WIN4

CASE 26 (EXP) L27=L2-L6

CASE 27 (EXP) L28=L3-L6

CASE 28 (EXP) L29=L4-L6

CASE 29 (OCC) L30=L18-L2

CASE 30 (OCC) L31=L19-L2

CASE 31 (OCC) L32=L20-L2

CASE 32 (OCC) L33=L21-L2

CASE 33(OCC) L34=L6-L2

CASE 34 (OCC) L35=L7-L2

CASE 35 (OCC) L36=L8-L2

CASE 36 (OCC) L37=L9-L2

CASE 37 (OCC) L38=L10-L2

CASE 38 (OCC) L39=L11-L2

3.8 Conducting the CAESAR II analysis for support configuration

Based on the Based CAESAR II analysis for the developed load cases the location of the support is decided to bring the loads within the desired limits.

The analysis are conducted for the following cases

Case 1 : Sustained + Code Compliance

Case 2 : Sustained + Occasional + Code Compliance

Case 3 : Operating + Occasional + Code Compliance

Case 4 : Operating + Displacement

Case 5 : Expansion + Displacement

In Code compliance the allowable load will be 1.3 times for occasional loads.

The formula used for calculating the allowable displacement stress range is

$S_A = f[1.25(S_c + S_h) - S_L]$ [14]

4. CALCULATIONS

Table 2 Pipe Thickness

Pipe	Diameter(in)	Thickness (mm), Schedule
Crude Pump suction	10	15.09, 80
Pump suction header	12	6.35, 20
Heat Exchanger Crude inlet	8	12.5, 80
Cooler inlet	12	8.38, 30
Cooler inlet	8	7.036, 30
Water Pump discharge	8	7.036, 30
Pump discharge header	12	8.382, 30

Table 3 Maximum support span

Pipe	Diameter (m)	I (m^4)	w (N/m)	$w_{c\ (N)}$	L (m)
Crude Pump suction	10	$5.57*10^{-5}$	1112.869	16132.76	8.7
Pump suction header	12	$4.117*10^{-5}$	1112.896	1732.64	9.5
Heat Exchanger Crude inlet	8	$4.109*10^{-5}$	1112.869	4512.704	7.9
Cooler inlet	12	$4.109*10^{-5}$	1112.869	8829.8	7.0
Cooler inlet	8	$2.622*10^{-5}$	1112.869	2030.168	5.8
Water Pump discharge	8	$2.633*10^{-5}$	1112.869	2303.098	7.0

5. RESULTS and DISCUSSIONS

CAESAR output of the critical lines solved is enlisted below. For any line to work safe throughout its designed life span the code stress on the line under various load cases should be under the allowed stress value and the displacements of the line should be within the limits.

5.1 Crude pump suction line

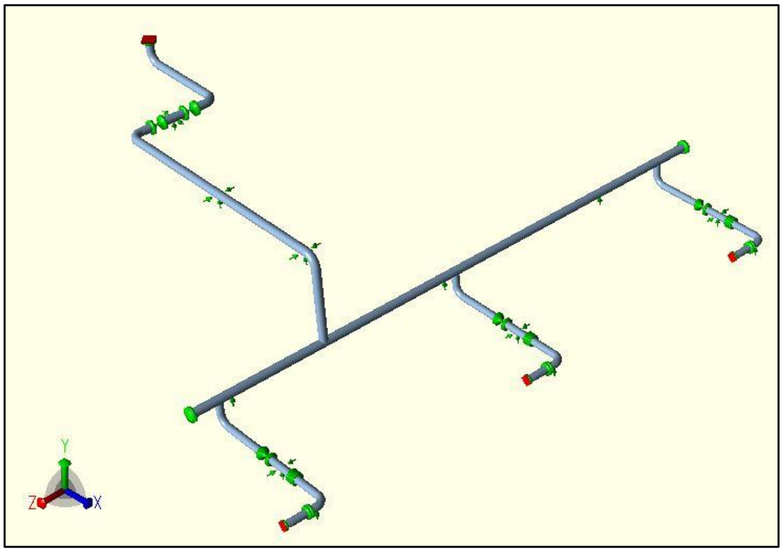
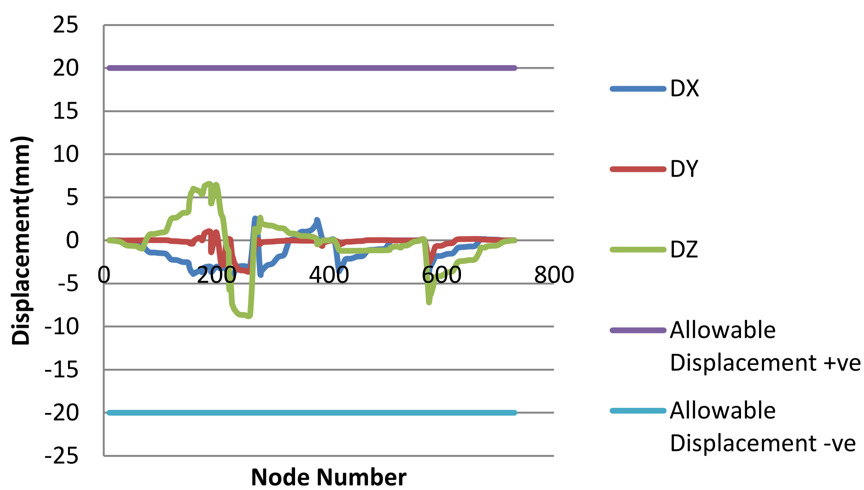


Figure 5-1 Supported Pump Suction line from 3 Phase Separator

Case 1 : Operating + Displacement



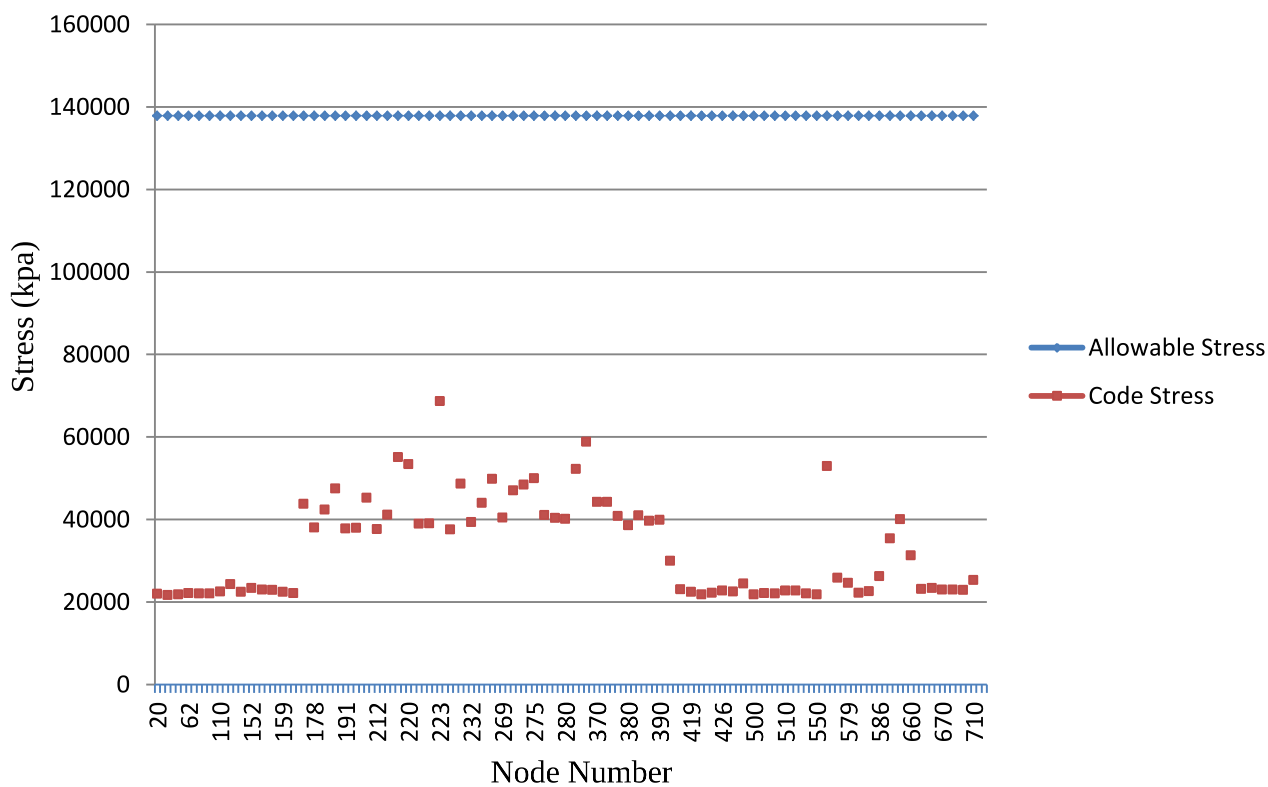
Case 2 : Sustained + Code Compliance

```
CASE 1 (SUS) W+P1


Piping Code: B31.3      = B31.3 -2010

***  CODE COMPLIANCE EVALUATION PASSED  ***

Highest Stresses: (   KPa    )
Ratio (%):                  49.8      @Node    223  LOADCASE: 3 (SUS) W+P1
Code Stress:             68707.3      Allowable Stress:   137895.1
Axial Stress:            39322.6      @Node    268  LOADCASE: 3 (SUS) W+P1
Bending Stress:          41838.7      @Node    230  LOADCASE: 3 (SUS) W+P1
Torsion Stress:           1788.2      @Node    580  LOADCASE: 3 (SUS) W+P1
Hoop Stress:             74790.6      @Node    178  LOADCASE: 3 (SUS) W+P1
Max Stress Intensity:    77436.7      @Node    223  LOADCASE: 3 (SUS) W+P1
```



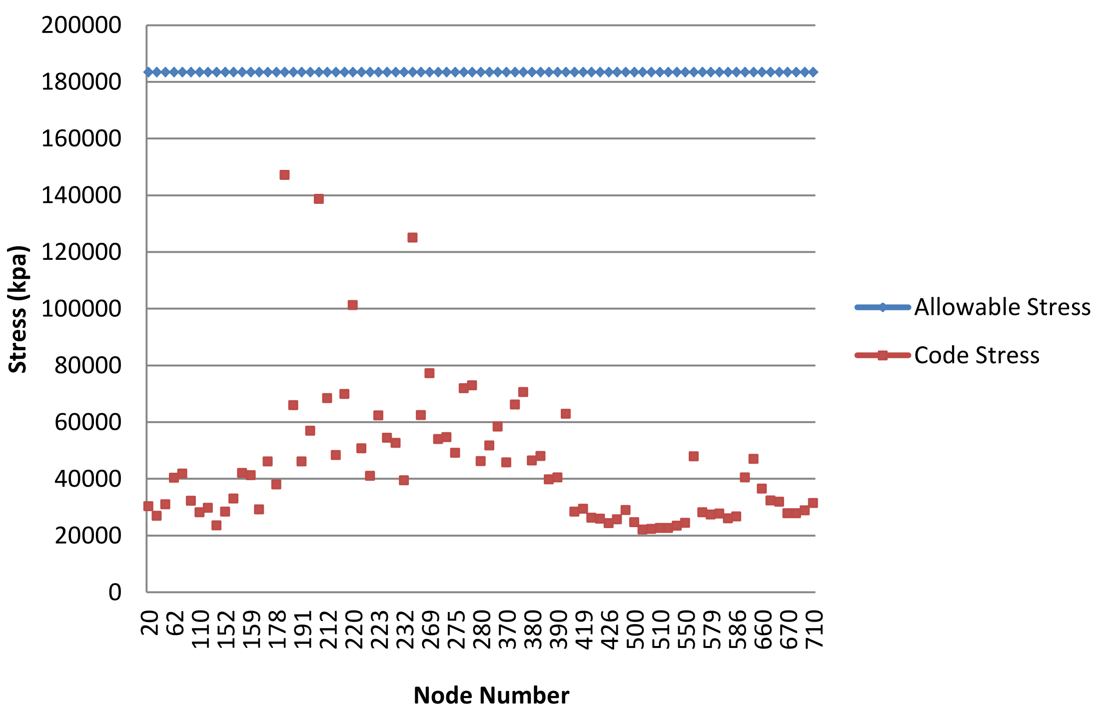
Case 3 : Operating + Occasional + Code Compliance

```
CASE 2 (OCC) W+T1+P1+U1

Piping Code: B31.3       = B31.3 -2010

***  CODE COMPLIANCE EVALUATION PASSED  ***

Highest Stresses: (   KPa     )
Ratio (%):                  80.2       @Node    170  LOADCASE: 4 (OCC) W+T1+P1+U1
Code Stress:            147121.2       Allowable Stress:   183400.5
Axial Stress:            37870.7       @Node    268  LOADCASE: 4 (OCC) W+T1+P1+U1
Bending Stress:         110958.4       @Node    170  LOADCASE: 4 (OCC) W+T1+P1+U1
Torsion Stress:          21120.2       @Node    170  LOADCASE: 4 (OCC) W+T1+P1+U1
Hoop Stress:             74790.6       @Node    178  LOADCASE: 4 (OCC) W+T1+P1+U1
Max Stress Intensity:   148486.1       @Node    170  LOADCASE: 4 (OCC) W+T1+P1+U1
```



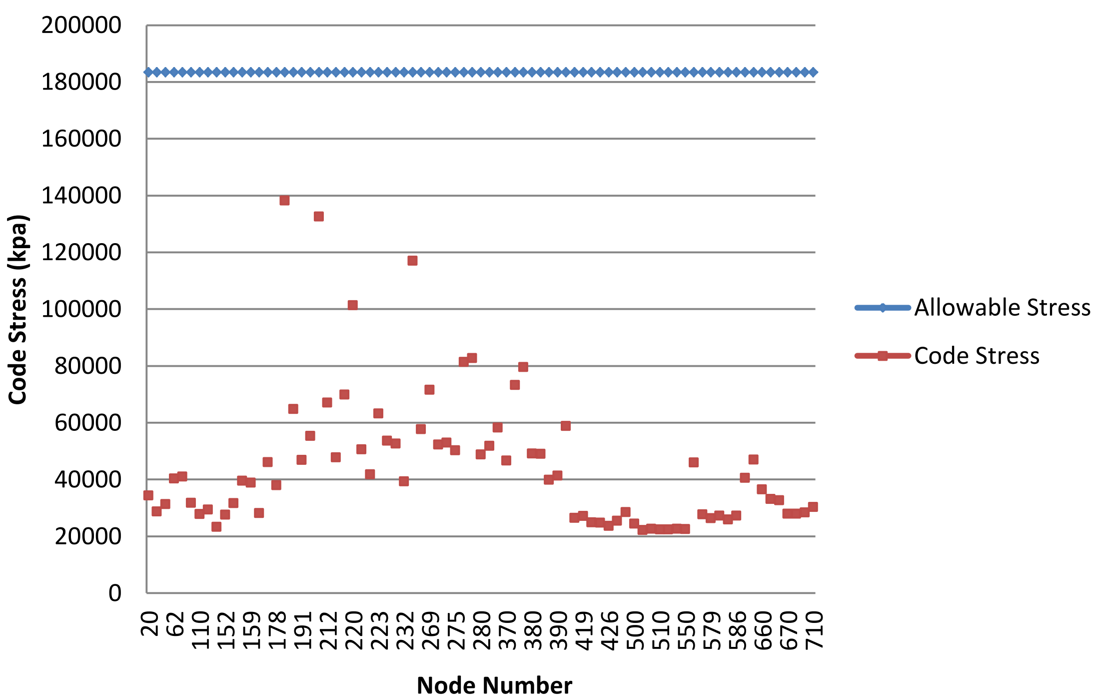
Case 3 : Operating + Occasional + Code Compliance

```
CASE 18 (OCC) W+T1+P1+WIN1


Piping Code: B31.3       = B31.3 -2010

***  CODE COMPLIANCE EVALUATION PASSED  ***

Highest Stresses: (   KPa    )
Ratio (%):                     75.3       @Node     170  LOADCASE: 18 (OCC)
Code Stress:               138157.4       Allowable Stress:   183400.5
Axial Stress:               37894.4       @Node     268  LOADCASE: 18 (OCC
Bending Stress:            101935.8       @Node     170  LOADCASE: 18 (OCC)
Torsion Stress:             19336.1       @Node     170  LOADCASE: 18 (OCC)
Hoop Stress:                74790.6       @Node     178  LOADCASE: 18 (OCC)
Max Stress Intensity:      139536.1       @Node     170  LOADCASE: 18 (OCC)
```



5.2 Water Pump Discharge line

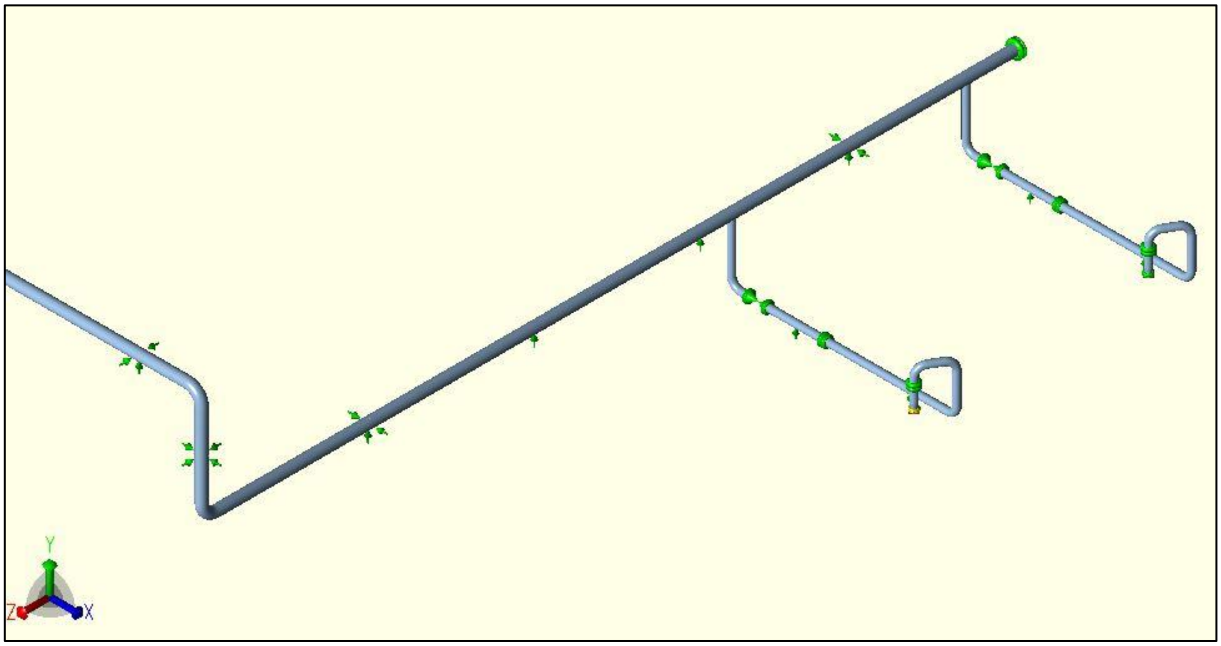
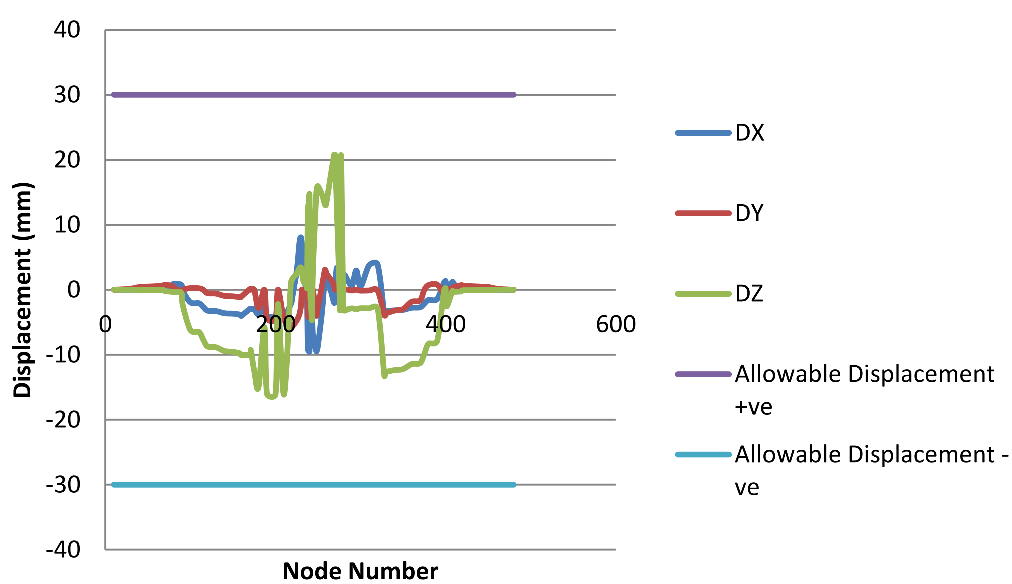


Figure 5-2 Supported water pmp discharge line

Case 1 : Operating + Displacement



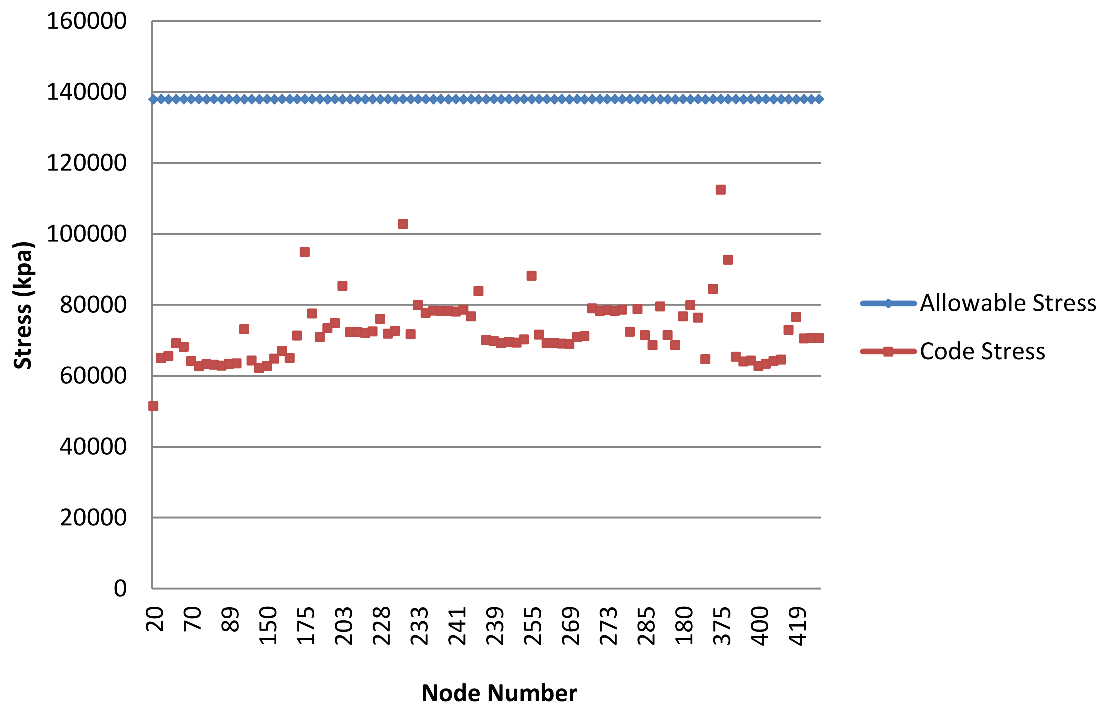
Case 2 : Sustained + Code Compliance

```
LOAD CASE DEFINITION KEY

CASE 3 (SUS) W+P1


Piping Code: B31.3       = B31.3 -2010
***  CODE COMPLIANCE EVALUATION PASSED  ***

Highest Stresses: (   KPa    )
Ratio (%):                  81.5      @Node    375  LOADCASE: 3 (SUS) W+P1
Code Stress:            112403.4      Allowable Stress:   137895.1
Axial Stress:            69642.0      @Node    228  LOADCASE: 3 (SUS) W+P1
Bending Stress:          51014.8      @Node    375  LOADCASE: 3 (SUS) W+P1
Torsion Stress:           1607.7      @Node    175  LOADCASE: 3 (SUS) W+P1
Hoop Stress:            139323.8      @Node    175  LOADCASE: 3 (SUS) W+P1
Max Stress Intensity:   146599.7      @Node    175  LOADCASE: 3 (SUS) W+P1
```



Case 3 : Operating + Occasional + Code Compliance

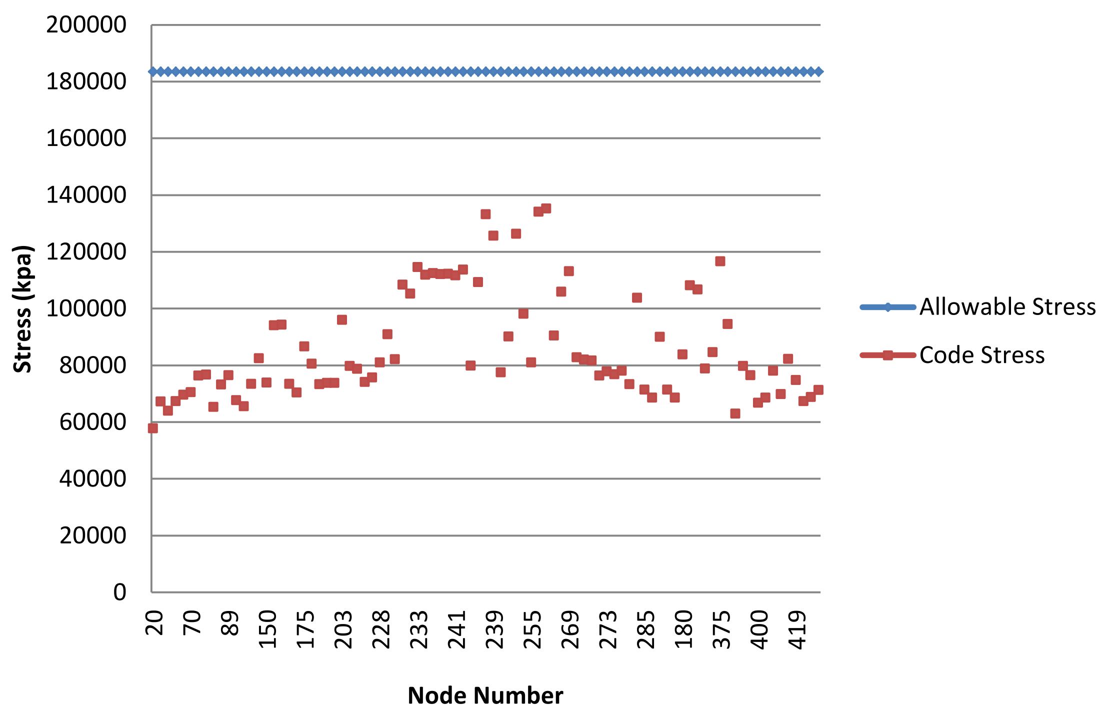
```
LOAD CASE DEFINITION KEY

CASE 4 (OCC) W+T1+P1+U1


Piping Code: B31.3      = B31.3 -2010

***  CODE COMPLIANCE EVALUATION PASSED  ***

Highest Stresses: (   KPa    )
Ratio (%):                   73.7        @Node    259  LOADCASE: 4 (OCC) W+T1+P1+U1
Code Stress:             135192.4        Allowable Stress:   183400.5
Axial Stress:            102859.7        @Node    232  LOADCASE: 4 (OCC) W+T1+P1+U1
Bending Stress:           68254.9        @Node    259  LOADCASE: 4 (OCC) W+T1+P1+U1
Torsion Stress:           17853.5        @Node    240  LOADCASE: 4 (OCC) W+T1+P1+U1
Hoop Stress:             139323.8        @Node    175  LOADCASE: 4 (OCC) W+T1+P1+U1
Max Stress Intensity:    256282.3        @Node    243  LOADCASE: 4 (OCC) W+T1+P1+U1
```



Case 3 : Operating + Occasional + Code Compliance

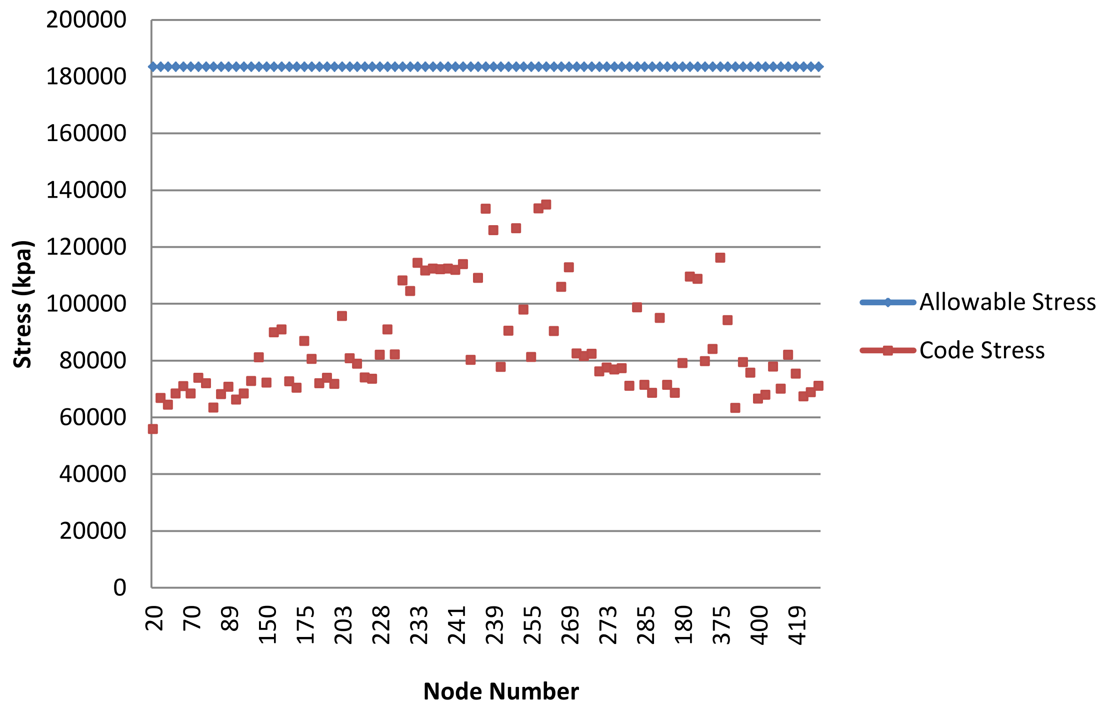
```
LOAD CASE DEFINITION KEY

CASE 17 (OCC) W+T1+P1+WIN1


Piping Code: B31.3        = B31.3 -2010

***  CODE COMPLIANCE EVALUATION PASSED  ***

Highest Stresses: (   KPa    )
Ratio (%):                      73.5       @Node    259  LOADCASE: 17 (OCC)
Code Stress:                134817.9       Allowable Stress:   183400.5
Axial Stress:               102503.9       @Node    233  LOADCASE: 17 (OCC)
Bending Stress:              67876.9       @Node    259  LOADCASE: 17 (OCC)
Torsion Stress:              17778.3       @Node    240  LOADCASE: 17 (OCC)
Hoop Stress:                139323.8       @Node    175  LOADCASE: 17 (OCC)
Max Stress Intensity:       256806.0       @Node    243  LOADCASE: 17 (OCC)
```



5.3 Cooler inlet

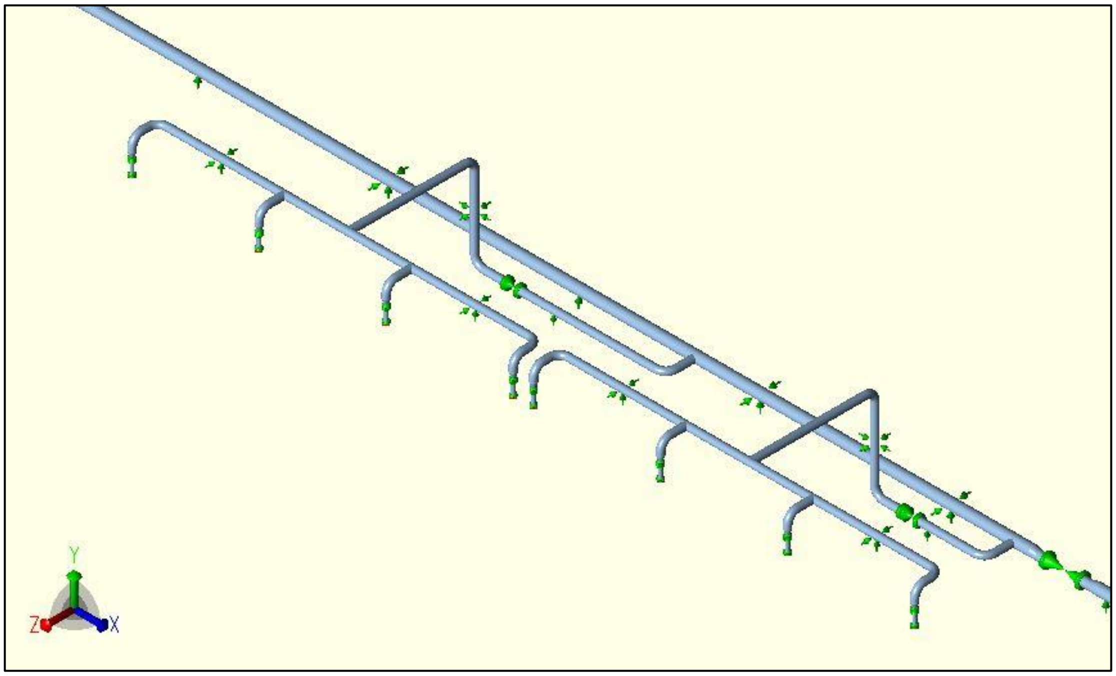
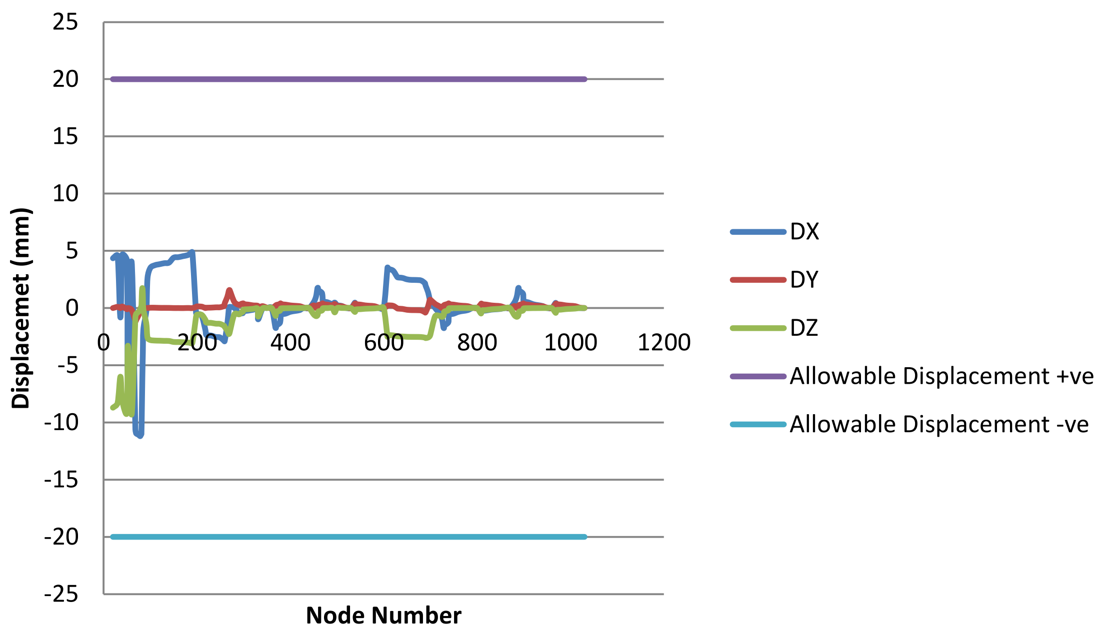


Figure 5-3 Supported cooler inlet line

Case 1 : Operating + Displacement



Case 2 : Sustained + Code Compliance

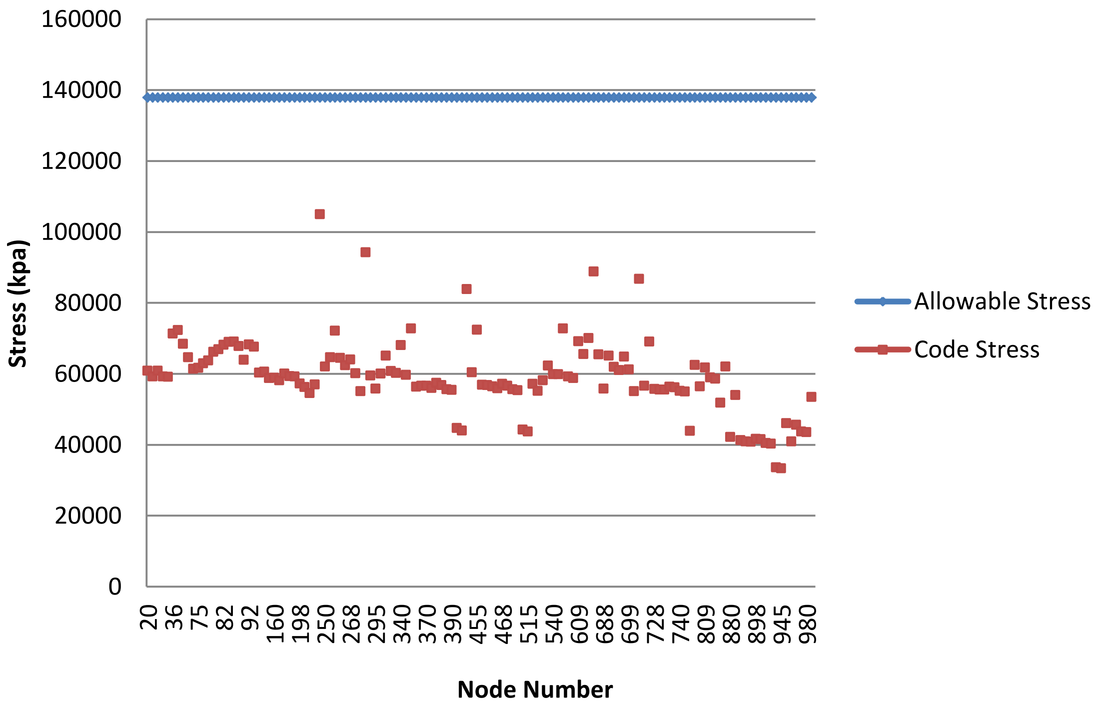
```
LOAD CASE DEFINITION KEY

CASE 3 (SUS) W+P1


Piping Code: B31.3      = B31.3 -2010

***  CODE COMPLIANCE EVALUATION PASSED  ***

Highest Stresses: (   KPa    )
Ratio (%):                  76.1       @Node    218  LOADCASE: 3 (SUS) W+P1
Code Stress:            104961.0       Allowable Stress:   137895.1
Axial Stress:            60308.3       @Node     78  LOADCASE: 3 (SUS) W+P1
Bending Stress:          55002.7       @Node    280  LOADCASE: 3 (SUS) W+P1
Torsion Stress:           5259.9       @Node    320  LOADCASE: 3 (SUS) W+P1
Hoop Stress:            120417.7       @Node     30  LOADCASE: 3 (SUS) W+P1
Max Stress Intensity:   126676.2       @Node     80  LOADCASE: 3 (SUS) W+P1
```



Case 3 : Operating + Occasional + Code Compliance

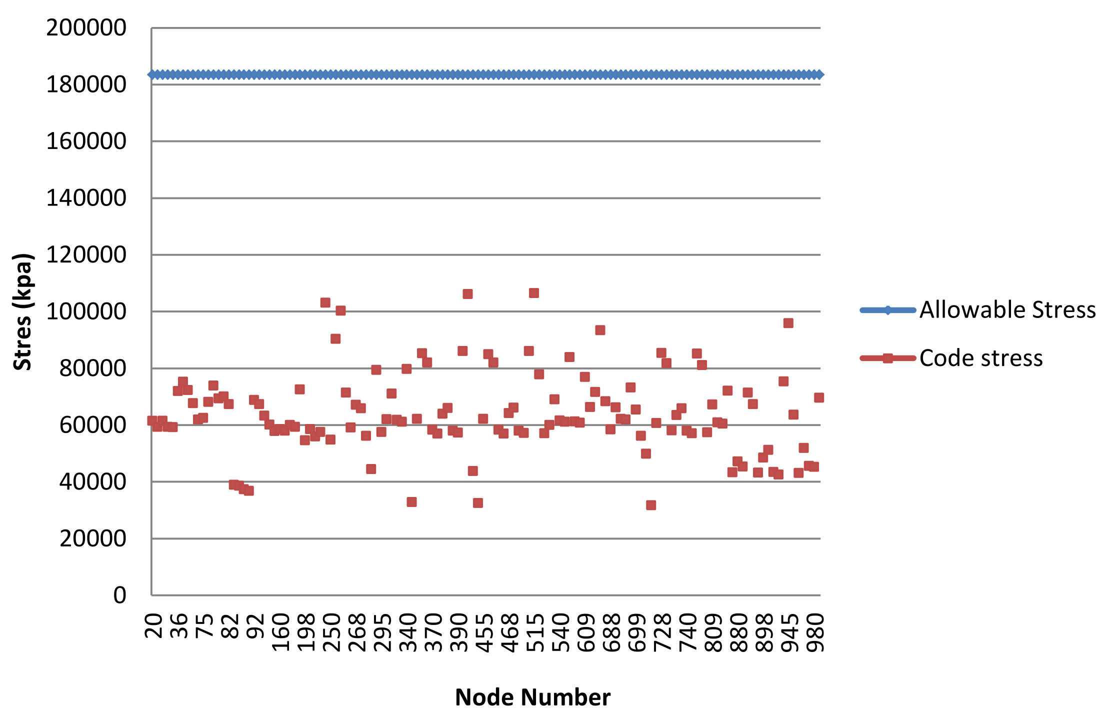
```
LOAD CASE DEFINITION KEY

CASE 4 (OCC) W+T1+P1+U1


Piping Code: B31.3       = B31.3 -2010

***  CODE COMPLIANCE EVALUATION PASSED  ***

Highest Stresses: (   KPa    )
Ratio (%):                     69.6       @Node    520  LOADCASE: 4 (OCC) W+T1+P1+U1
Code Stress:              127598.5       Allowable Stress:   183400.5
Axial Stress:              60266.7       @Node     78  LOADCASE: 4 (OCC) W+T1+P1+U1
Bending Stress:            92921.8       @Node    520  LOADCASE: 4 (OCC) W+T1+P1+U1
Torsion Stress:            25800.5       @Node    920  LOADCASE: 4 (OCC) W+T1+P1+U1
Hoop Stress:              120417.7       @Node     30  LOADCASE: 4 (OCC) W+T1+P1+U1
Max Stress Intensity:     158904.4       @Node    710  LOADCASE: 4 (OCC) W+T1+P1+U1
```



Case 3 : Operating + Occasional + Code Compliance

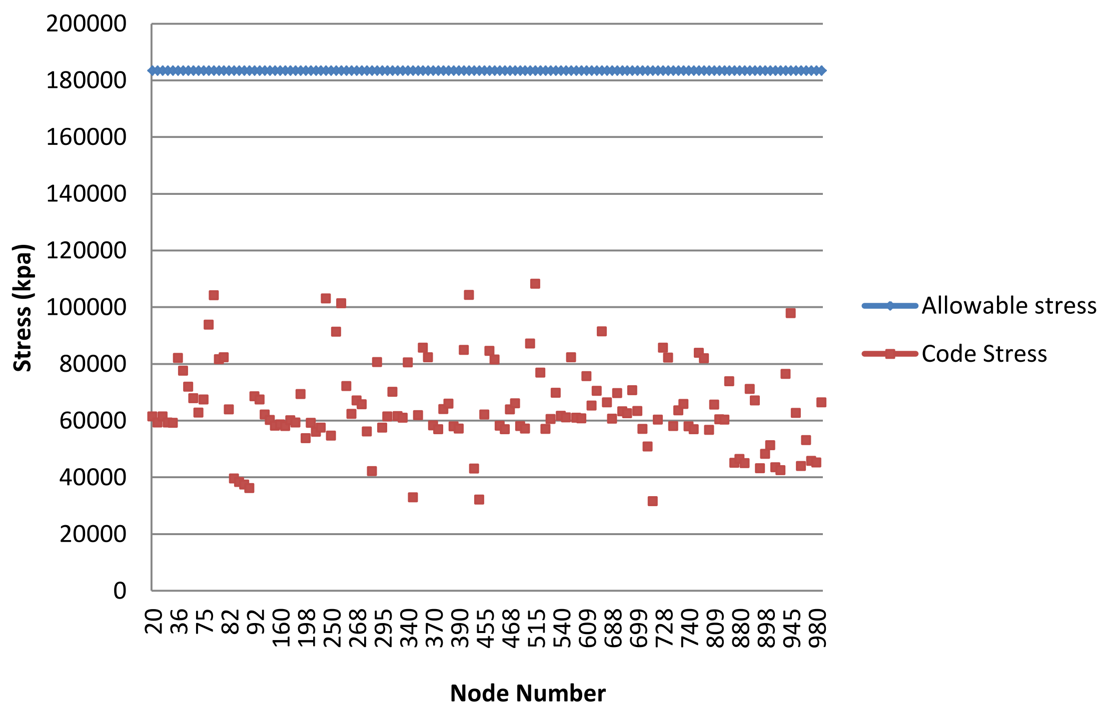
```
LOAD CASE DEFINITION KEY

CASE 16 (OCC) W+T1+P1+WIN1


Piping Code: B31.3       = B31.3 -2010

***  CODE COMPLIANCE EVALUATION PASSED  ***

Highest Stresses: (   KPa    )
Ratio (%):                       71.0      @Node     520  LOADCASE: 16 (OCC)
Code Stress:                 130174.8      Allowable Stress:   183400.5
Axial Stress:                 60253.6      @Node      78  LOADCASE: 16 (OCC)
Bending Stress:               95513.3      @Node     520  LOADCASE: 16 (OCC)
Torsion Stress:               26184.2      @Node     760  LOADCASE: 16 (OCC)
Hoop Stress:                 120417.7      @Node      30  LOADCASE: 16 (OCC)
Max Stress Intensity:        159852.8      @Node     710  LOADCASE: 16 (OCC)
```



5.4 Heat Exchanger Inlet

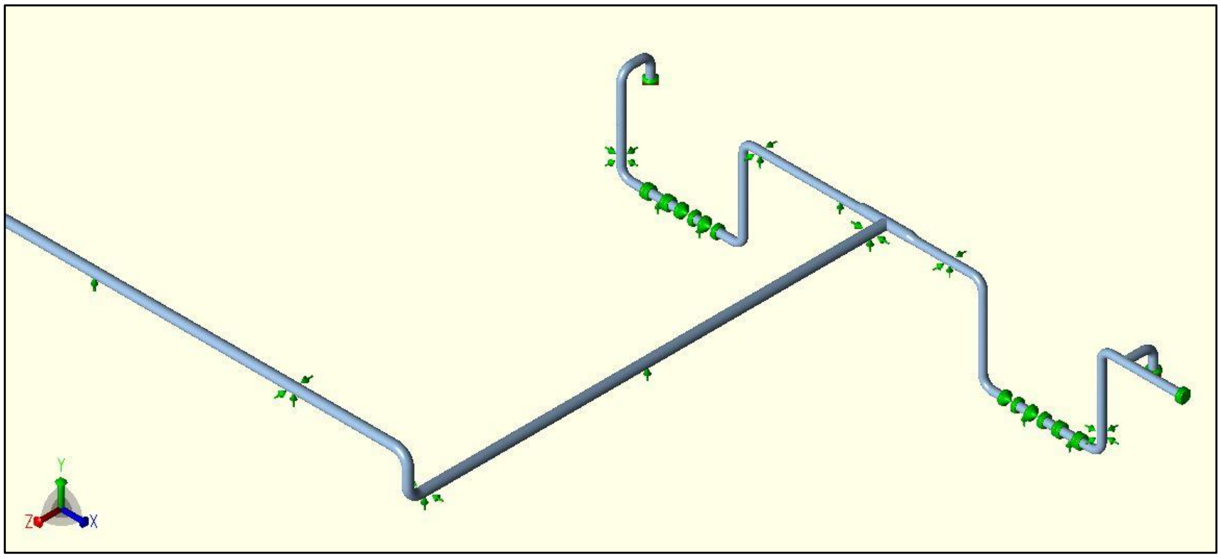
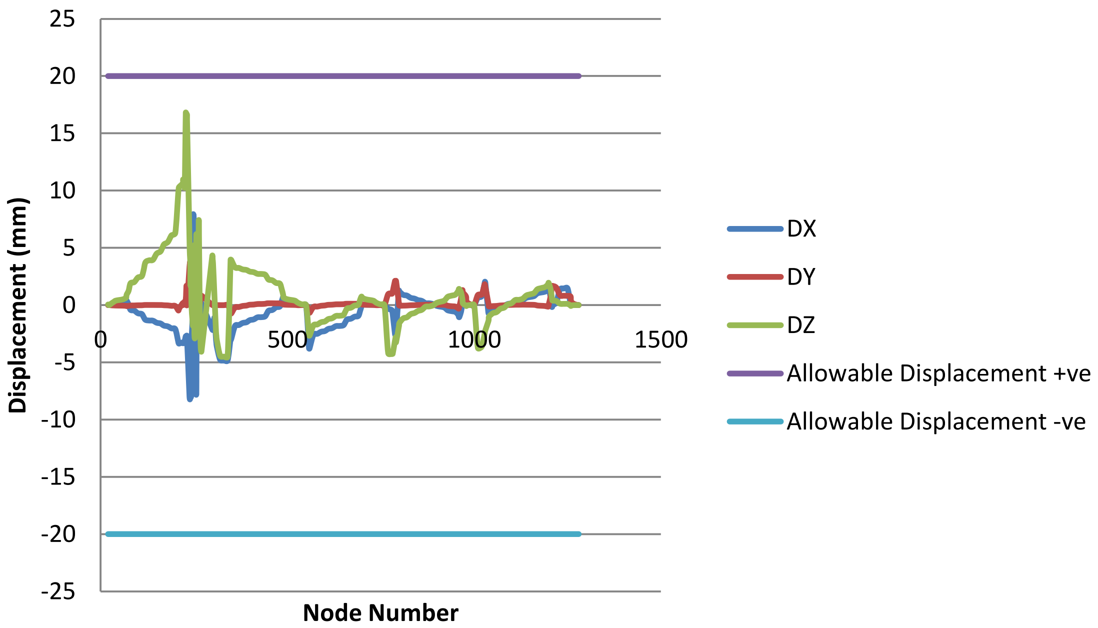


Figure 5-4 Supported Heat Exchanger inlet line

Case 1 : Operating + Displacement



Case 2 : Sustained + Code Compliance

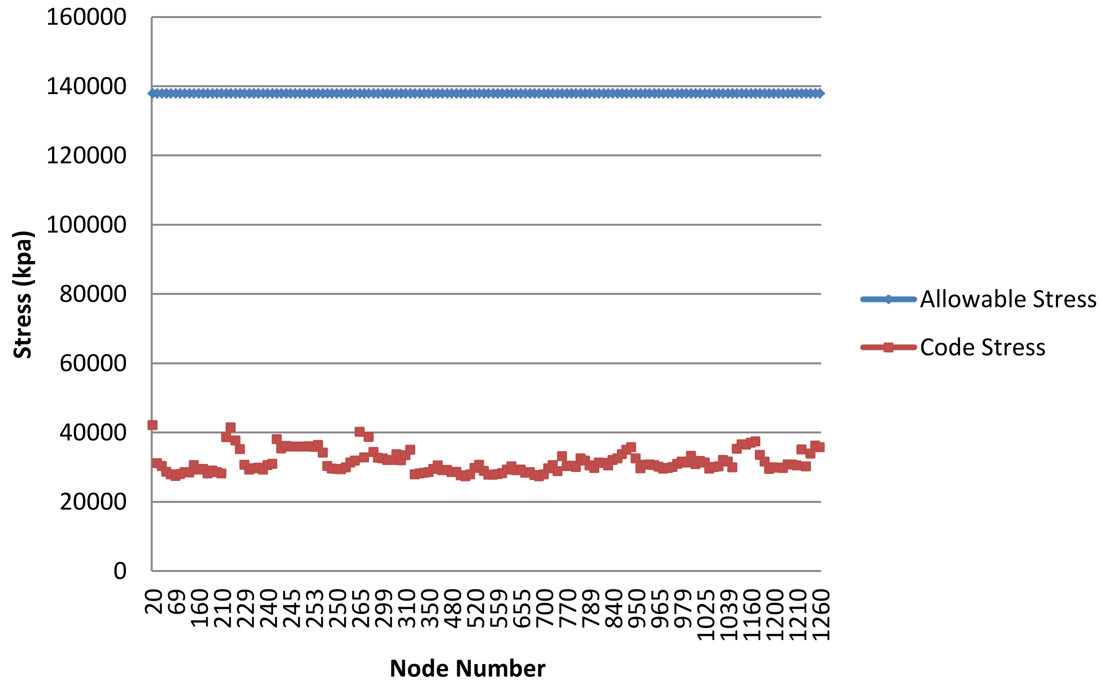
```
LOAD CASE DEFINITION KEY

CASE 3 (SUS) W+P1


Piping Code: B31.3       = B31.3 -2010

***  CODE COMPLIANCE EVALUATION PASSED  ***

Highest Stresses: (   KPa    )
Ratio (%):                   30.5       @Node     20  LOADCASE: 3 (SUS) W+P1
Code Stress:              42086.7       Allowable Stress:   137895.1
Axial Stress:             29672.1       @Node    790  LOADCASE: 3 (SUS) W+P1
Bending Stress:           15593.7       @Node     20  LOADCASE: 3 (SUS) W+P1
Torsion Stress:            1620.4       @Node   1258  LOADCASE: 3 (SUS) W+P1
Hoop Stress:              61767.8       @Node    221  LOADCASE: 3 (SUS) W+P1
Max Stress Intensity:     70966.1       @Node   1258  LOADCASE: 3 (SUS) W+P1
```



Case 3 : Operating + Occasional + Code Compliance

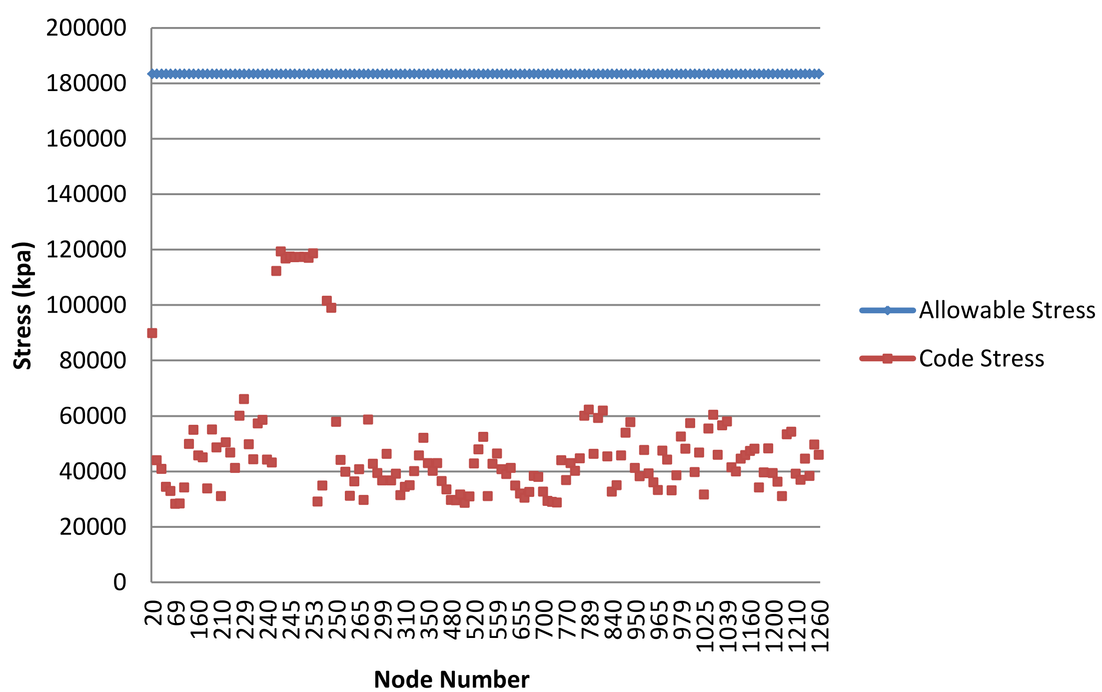
```
LOAD CASE DEFINITION KEY

CASE 4 (OCC) W+T1+P1+U1


Piping Code: B31.3      = B31.3 -2010

***  CODE COMPLIANCE EVALUATION PASSED  ***

Highest Stresses: (   KPa    )
Ratio (%):                  67.1       @Node    540  LOADCASE: 4 (OCC) W+T1+P1+U1
Code Stress:            123141.0       Allowable Stress:   183400.5
Axial Stress:           110799.7       @Node    254  LOADCASE: 4 (OCC) W+T1+P1+U1
Bending Stress:          96929.2       @Node    540  LOADCASE: 4 (OCC) W+T1+P1+U1
Torsion Stress:          11419.2       @Node    210  LOADCASE: 4 (OCC) W+T1+P1+U1
Hoop Stress:             61767.8       @Node    221  LOADCASE: 4 (OCC) W+T1+P1+U1
Max Stress Intensity:   183445.7       @Node    243  LOADCASE: 4 (OCC) W+T1+P1+U1
```



Case 3 : Operating + Occasional + Code Compliance

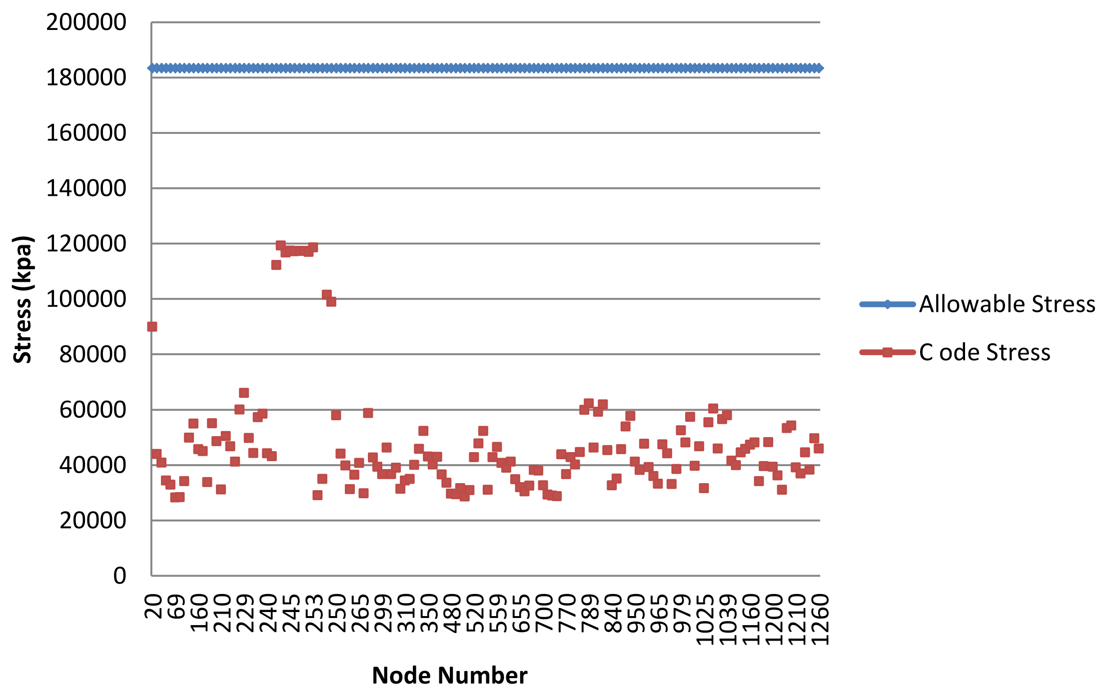
```
LOAD CASE DEFINITION KEY

CASE 16 (OCC) W+T1+P1+WIN1


Piping Code: B31.3       = B31.3 -2010

***  CODE COMPLIANCE EVALUATION PASSED  ***

Highest Stresses: (   KPa    )
Ratio (%):                    66.9       @Node     540  LOADCASE: 16
Code Stress:              122749.2       Allowable Stress:   183400.5
Axial Stress:             110783.6       @Node     243  LOADCASE: 16
Bending Stress:            96536.6       @Node     540  LOADCASE: 16
Torsion Stress:            11406.8       @Node     210  LOADCASE: 16
Hoop Stress:               61767.8       @Node     221  LOADCASE: 16
Max Stress Intensity:     183457.9       @Node     243  LOADCASE: 16
```



5.5 Nozzle leakage analysis for crude pump

Description:

Pump A

INPUT (CAESAR II Global Coordinates):

Horizontal Pump

Pump axis direction cosines (X, Z): (1.000, 0.000)

	Node #	Orientation	Nominal Diameter
Suction Nozzle	10	Side	8
Discharge Nozzle	23	Side	6

Table 4 Allowable (ratio) = 2.00

	Suction Nozzle	Discharge Nozzle
X Distance (mm)	0.0	0.0
Y Distance (mm)	400.0	400.0
Z Distance (mm)	0.0	0.0
X Force (N)	2019.5	2852.0
Y Force (N)	186.8	-921.0
Z Force (N)	2615.6	-1930.0
X Moment (Nm)	608.8	1178.0
Y Moment (Nm)	4098.6	3173.0
Z Moment (Nm)	-340.3	-40.0

OUTPUT (API 610 10th Edition Local Coordinates)

	Suction	Table 4 Values	Force & Moment Ratios	Status
x distance (mm)	0.0			
y distance (mm)	0.0			
z distance (mm)	400.0			
x force (N)	2019.5	3780	0.53	Passed
y force (N)	-2615.6	4893	0.53	Passed
z force (N)	186.8	3113	0.06	Passed
x moment (N.m)	608.8	3525	0.17	Passed
y moment (N.m)	340.3	1763	0.19	Passed
z moment (N.m)	4098.6	2576	1.59	Passed

	Discharge	Table 4 Values	Force & Moment Ratios	Status
x distance (mm)	0.0			
y distance (mm)	0.0			
z distance (mm)	400.0			
x force (N)	2852.0	2491	1.14	Passed
y force (N)	1930.0	3113	0.62	Passed
z force (N)	-921.0	2046	0.45	Passed
x moment (N.m)	1178.0	2305	0.51	Passed
y moment (N.m)	40.0	1180	0.03	Passed
z moment (N.m)	3173.0	1763	1.80	Passed

Check of Condition F.1.2.b	Requirement	Status
(FRSa/1.5FRSt4) + (MRSa/1.5MRSt4) = 0.902	< or = 2.00	Passed
(FRDa/1.5FRDt4) + (MRDa/1.5MRDt4) = 1.249	< or = 2.00	Passed

Check of Condition F.1.2.c	Requirement	Status
1.5 (FRSt4 + FRDt4) = 17148	> 4974 (FRCa)	Passed
2.0 (MYSt4 + MYDt4) = 5884	> 2329 (MYCa)	Passed
1.5 (MRSt4 + MRDt4) = 11816	> 7909 (MRCa)	Passed

Overall Pump Status ** PASSED **

6. CONCLUSIONS and SCOPE OF FUTURE WORK

Efficient piping and supporting in any plant is of paramount importance, it saves both the cost and increases the safety. In this thesis crude separation area of the surface development facility was successfully designed and analysed. All the load cases developed were passed so the designed system can withstand any load variations and work safely.

The load cases like snow load, transient loads can also be taken into account for analysis. Dynamic analysis of the lines can be carried out wherever applicable and the analysis of the remaining critical lines can be done. Other areas of the surface development facility can be taken into consideration for design and analysis.

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