MODELING AND STRESS ANALYSIS OF PIPING SYSTEM

By

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Dehradun

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MODELING AND STRESS ANALYSIS OF PIPING SYSTEM

A thesis submitted in partial fulfilment of the requirements for the Degree of

Master of Technology

(Pipeline Engineering)

By

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CERTIFICATE

This is to certify that the work contained in this thesis titled "**MODELING AND ANALYSIS OF PIPING SYSTEM**" has been carried out by **ADAM SHA S** under my supervision and has not been submitted elsewhere for a degree.

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We have taken efforts in this project. However, it would not have been possible without the kind support and help of many individuals and organizations. We would like to extend our sincere thanks to all of them

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CONTENTS

Nomenclature

P =initial pressure, psi

Do= outside diameter, inch

S= allowable stress, psi

A= allowance, additional thickness provided for material removed by threading, corrosion etc.

Y=coefficient that takes material properties and design temperature into account

tm =Nominal thickness, inch

L= Span length, feet

W=weight of the pipeline, Kg/m

Wt = Total weight of the system, Kg/m

T1 = design temperature, 0˚C

T2 = Operating temperature, 0˚C

P1 = Design pressure, Kg/mm2

P2 = Operating Pressure Kg/mm2

ABSTRACT

.This project deals with the loading and unloading area of crude oil products after refining.

This location has been divided as Loading & Unloading area. Trucks will enter into the Loading area to load a crude oil product like Kerosene, Petrol, Diesel, Naphtha, Gas etc.

Unloading area will be used to unload Condensate crude oil from various place of plant through trucks. Condensate crude oil will be re circulated for other purpose. In general, Oil & Gas refinery plants are more dangerous due to handling of Flammable products. So, safety is most important part in case of any fire accident. Firefighting system must be used to save the human and commercial resources. Truck Loading & Unloading areas are must be covered by effective Fire Fighting system. Hydrant & Monitors are primary equipment's of Fire Fighting System. Pipe routing must underground in order to avoid the problems to the Truck access in to the area.

The detailed scope of this project involves Development of Piping Layout for a loading and unloading area and its pipe stress analysis using Caesar II. Development of Piping involves Pressure Design of Piping system using ASME Codes, buildup of piping arrangement based on Piping and Instrument diagram in a 3D environment using SP3D. The model that is designed in SP3D is then built up once again in Caesar II where it is then subjected to stress analysis for various load cases like sustained load cases and displacement load cases.

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CHAPTER 1

INTRODUCTION

INTRODUCTION

This project involves Development of Piping Layout for a Loading and Unloading area and its analysis using Caesar II. The Piping Layout involves Pressure Design of Piping System using ASME Codes, Buildup of Piping arrangement using P&ID in a 3D environment and stress Analysis of the same using Caesar II.

1.1 LOADING AND UNLOADING SYSTEM

This location has been divided as Loading & Unloading area. Trucks will enter into the Loading area to load a crude oil product like Kerosene, Petrol, Diesel, Naphtha, Gas etc.

Unloading area will be used to unload Condensate crude oil from various place of plant through trucks. Condensate crude oil will be re circulated for other purpose. In general, Oil & Gas refinery plants are more dangerous due to handling of Flammable products. So, safety is most important part in case of any fire accident. Firefighting system must be used to save the human and commercial resources. Truck Loading & Unloading areas are must be covered by effective Fire Fighting system. Hydrant & Monitors are primary equipment's of Fire Fighting System. Pipe routing must underground in order to avoid the problems to the Truck access in to the area.

CHAPTER 2

LITERATURE REVIEW

Prachi N. Tambe, Dr. Kishor K Dhande, Prof. N. I. Jamadar published a paper on **Flexibility and Stress Analysis of Piping System using CAESAR II** in which Process Plant can be operated safely and efficiently with the help of good design of equipment's and piping systems connecting to the various equipment's like tanks, heat exchangers, pumps etc. Design of piping system includes the pipe and fitting sizing, thickness calculation, equipment layout, pipe routing, support type, support location finalization and stress analysis. This study explains the stress analysis of piping system as per process piping code ASME B 31.3 using 3D software tool CAESAR II. Major requirements in piping stress analysis are to provide adequate flexibility for absorbing thermal expansion, code compliance for stresses incurred in piping system, safe nozzle loads and displacement. The design is said to be safe if all these are in allowable range as per code. In this study, the criterion of selection of piping system for flexibility analysis is explained analytically. The two piping systems are stress analyzed, compared and the effect of flexibility of piping system on nozzle loads and stresses developed are observed. The software output is discussed and safer piping system is identified.

Navath Ravikiran, V. Srinivas Reddy , G. Kiran Kumar published a paper on **3D Modeling and Stress Analysis of Flare Piping** in which for transportation of fluid, steam or air piping system is widely used. For installing the piping system pipes, flanges, piping supports, valves, piping fittings etc. are used, which are piping elements. They are manufactured as per Codes and standards. Equipment and piping layout design as per process requirement and available space. Above layout made out by the help of General arrangement drawing, plant layout and P& ID. Then after flexibility providing to piping system, for compensate the different loads by the engineer. Stresses in pipe or piping systems are generated due to loads like expansion & contraction due to thermal load, seismic load, wind load, sustained load, reaction load etc. the stress analysis is done by help of software like CAESAR II. In this paper, a Flare pipe line is designed and 3D modeling is prepared in PDMS software. Attention is focused for stress analysis by Caesar-II software. So that various stress values, forces and deflections are analyzed at each node to make the design at safe operating conditions.

Shweta Bisht and Farheen Jahan published a paper on **An Overview on Pipe Design using caesar II** in which Design of piping system constitutes a major part of the design and engineering effort in the world of fluid conveyance. Stress analysis is a critical component of piping design through which important parameters such as piping safety, safety of related components and connected equipment and piping deflection can be checked and rectified timely. The objective of pipe stress analysis is to prevent premature failure of piping and piping components and ensuring that piping stresses are kept within allowable limits. This paper is designed for studying a wide range of abilities and backgrounds and will cover the fundamental principles and concepts used in pipe stress analysis. In addition to meeting the needs of design, the paper is structured to provide a deep understanding of the engineering principles involved in material selection, application of code criteria and the capabilities and tools incorporated in stress analysis software.

Mr. Suyog U. Bhave published a paper on **Calculation Methodologies for The Design of Piping Systems** in which t- Piping systems are constantly present in industrial facilities, being in some cases associated with the transport of fuels, processing of crude oils and chemical plants. Due to the nature of those fluids, the design of the piping system that transports them is a task of great responsibility, which must follow codes and standards to guarantee the system's structural integrity. Many times the piping systems operate at a temperature higher than the temperature at which they are assembled, leading to the thermal expansion of the system's pipes and since no piping system is free to expand, the thermal expansion will lead to stresses. Besides the stresses caused by thermal expansion, the studied systems will also are subjected to constant loads caused by their weight, as well as occasional loads like wind, earthquake. In this perspective, calculation methodologies were developed in order to do quick analysis of the most common configurations, according to the codes like ASME B31.3, allowing that way improvements on the flexibility of the projected systems.

Bahaa Shehadeh, Shivakumar, Ranganathan, Farid H Abed published paper on Optimization of piping expansion loops using ASME B31.3 in which Piping is the main transportation method for fluids from one location to another within an industrial plant. Design and routing of piping is heavily influenced by the stresses generated due to thermal effects and high pressure of the operating fluid. In particular, pressurized fluids create critical loads on the supports and elbows of the pipe which increases the overall stresses in the piping. Moreover, long pipes operating under high temperature gradients tend to expand significantly. Therefore, designers and engineers usually provide an expansion loop in order to relieve the pipe from the critical stresses. However, expansion loops require extra space, supports, elbows, bends, additional steel structure that could adversely affect the operating cost. It is therefore necessary to optimize the geometry, the number of expansion loops, and the supports. Reducing the number of loops in one single system or reducing the length of the loop itself is always favored as long as stresses are within safe limits. Usually, the commercial software (Pipe Data) is used in the industry to get the dimensions of the expansion loop. However, this software is mostly based on empirical models that rely on past experience rather than engineering fundamentals. Accordingly, this paper conducts an optimization analysis concerning the expansion loop dimensions and the number of supports without compromising on the safety of piping. The design approach is conducted as per the guidelines of ASME B31.3 (Process Piping) code and uses the commercial software (CAESAR II) for stress calculations. A full comparison for the expansion loop dimension is conducted between the empirical approach and the optimization analysis using ASME B31.3 for one of the existing oilfield projects. Results indicate that optimization reduces the dimensions and the number of expansion loops as well as the total number of supports. This results in significant savings in the piping cost without any compromise on the safety.

CHAPTER – 3

ELEMENTS OF A SYSTEM

3.1 PRODUCT BOOSTER PUMP

Crude oil and petroleum products pumping stations and gas compressor stations are located at wellheads and along the pipeline route as needed to maintain pressure and volume. Pumps are driven by electric motors or diesel engines, and turbines may be powered by fuel oil, gas or steam. Many of these stations are automatically controlled and not staffed at most times. Pumps, with and without vapour return lines or pressure equalizing lines, are commonly used in smaller pipelines for transport of LNG, LPG and compressed natural gas (CNG).

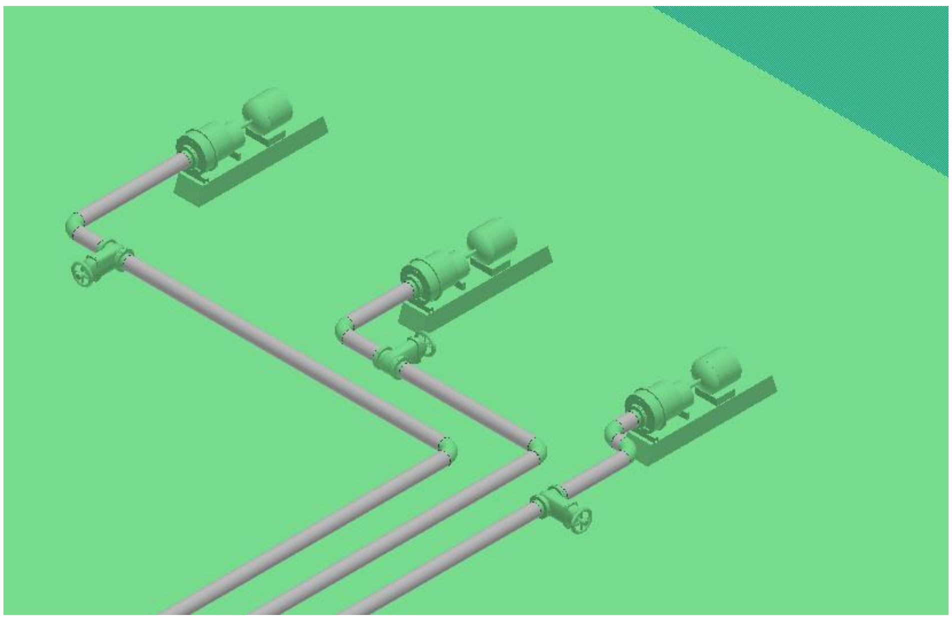


Fig 3.1: Booster pumps

The figure 1 shows the pumping of crude oil products from the refinery to the vessel through connecting pipes.

3.2 STORAGE VESSEL

A storage tank is a container, usually for holding liquids, sometimes for compressed gases (gas tank).

Storage tanks are available in many shapes: vertical and horizontal cylindrical; open top and closed top; flat bottom, cone bottom, slope bottom and dish bottom. Large tanks tend to be vertical cylindrical, or to have rounded corners transition from vertical side wall to bottom profile, to easier withstand hydraulic hydrostatically induced pressure of contained liquid. Most container tanks for handling liquids during transportation are designed to handle varying degrees of pressure.

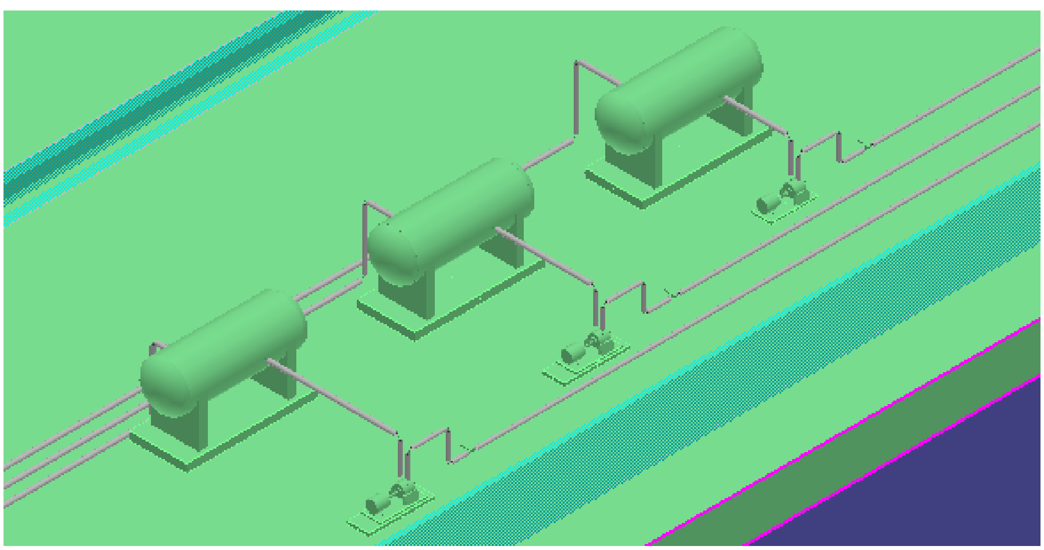


Fig 3.2: storage vessel

The figure 2 represents the storage of petroleum products which are all transferred for distribution from the refinery plant.

3.3 LOADING AND UNLOADING AREA

Trucks will enter into the Loading area to load a crude oil product like Kerosene, Petrol, Diesel, Naphtha, Gas etc. Unloading area will be used to unload Condensate crude oil from various place of plant through trucks. Condensate crude oil will be re circulated for other purpose.

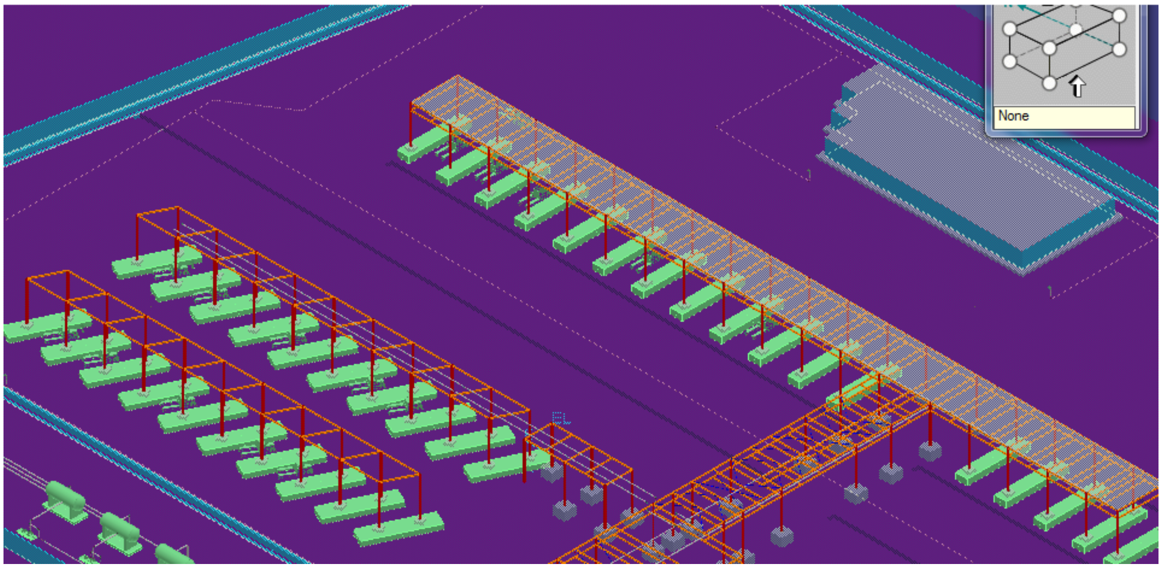


Fig 3.3: Loading and Unloading area

3.4 LOADING RACK FIRE PROTECTION

Fires and explosions at top and bottom tank car and tank truck loading racks may occur from causes such as electrostatic build-up and incendiary spark discharge in a flammable atmosphere, unauthorized hot work, flashback from a vapour recovery unit, smoking or other unsafe practices.

Sources of ignition, such as smoking, running internal combustion engines and hot work activity, should be controlled at the loading rack at all times, and particularly during loading or

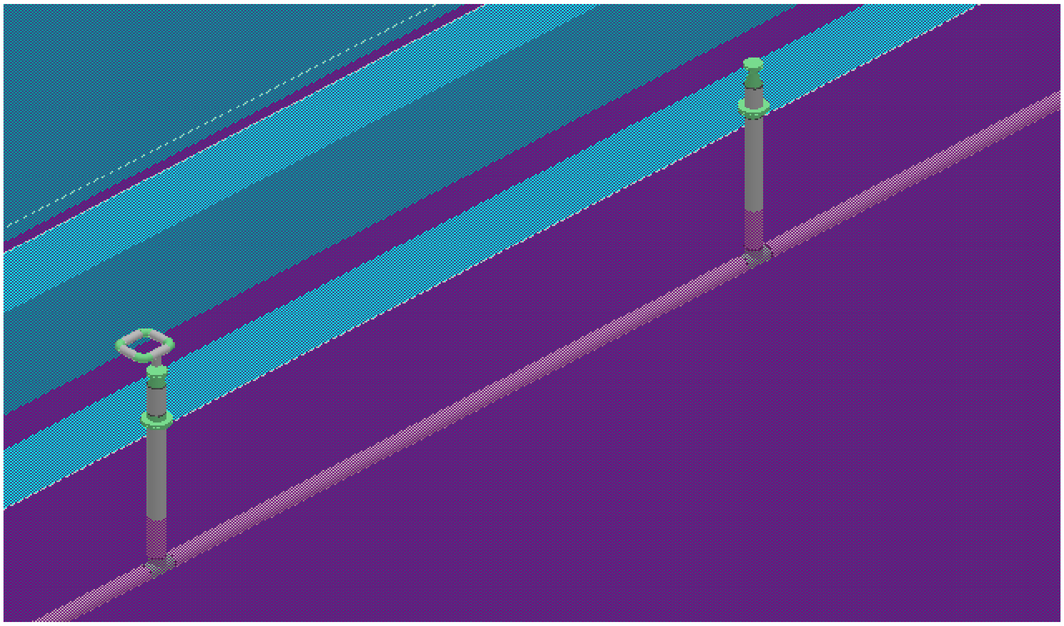


Fig 3.4: Fire protection system

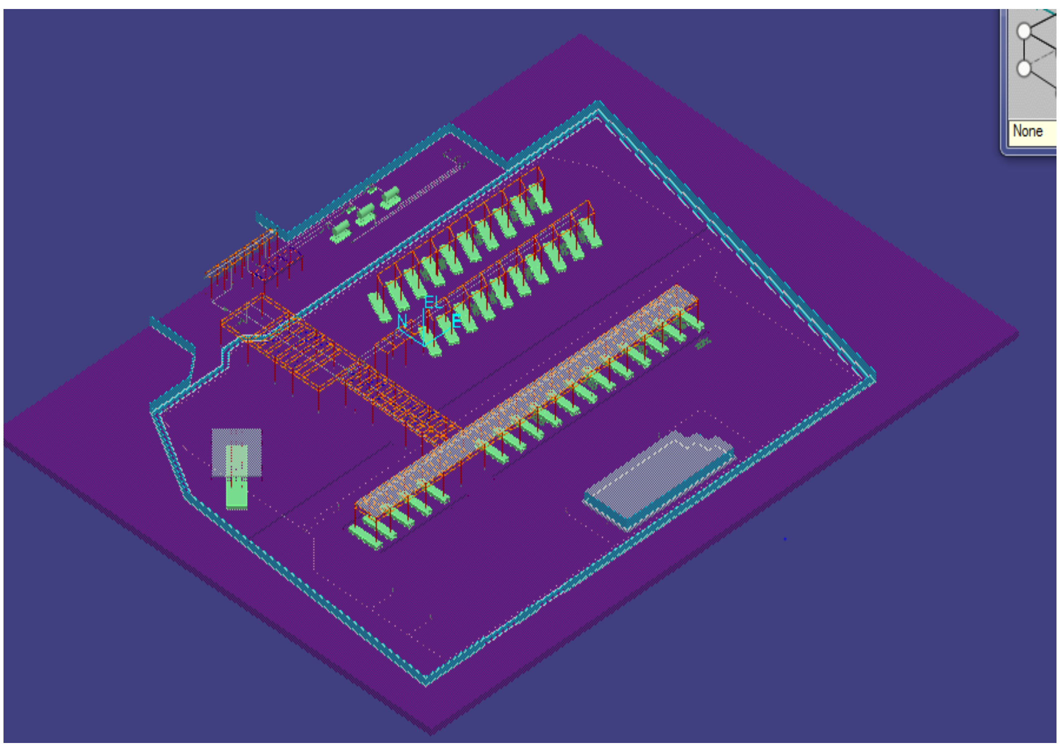


Fig 3.5: Loading and Unloading system (Isometric view)

Other operations when a spill or release may occur. Loading racks may be equipped with portable fire extinguishers and manually or automatically operated foam, water or dry chemical fire extinguishing systems. If vapour recovery systems are in use, flame arrestors should be provided to prevent flashback from the recovery unit to the loading rack.

Drainage should be provided at loading racks to divert product spills away from the loader, tank truck or tank car and the loading rack pad. Drains should be provided with fire traps to prevent migration of flames and vapours through sewer systems. Other loading-rack safety considerations include emergency shut-down controls placed at loading spots and other strategic locations in the terminal and automatic pressure-sensing valves which stop product flow to the rack in case of a leak in the product lines. Some companies have installed automatic brake lock systems on their tank truck fill connections, which lock the brakes and will not allow the truck to be moved from the rack until the fill lines have been disconnecte

CHAPTER 4

EQUIPMENT'S AND PIPE FITTINGS USED

4.1 PIPE:

Pipe is a cylindrical conduit used to transfer fluid from one area to another area or from one equipment to another equipment.

If it is place within a confined area, it is called piping.

If it is spread over several Km then it is called pipeline.

PIPE THICKNESS/PIPE SCHEDULE

Carbon steel/											
Aluminum :	**5**	**10**	**20**	**30**	**40**	**80**	**100**	**120**	**140**	**160**	
Stainless steel:	**5S**	**10S**	**20S**		**40S**	**80S**					**160S**

PIPE LENGTHS:

Pipe lengths are of two types' single random length and double random length

- Single random length - 06m - 20ft
- Double random length - 12m - 40f

4.2 ELBOWS:

Elbows are used in pipeline for changing direction. Elbows are classified into three types:

- 90 degree
- 45 degree
- 180 degree

90 degree elbows are again classified into two types:

- 90 degree long radius
- 90 degree short radius.

4.3 TEE

Tee is used to either combine or split fluid flow. It is type of in which T shaped having two outlets. IT is available as

Equal tee

Unequal tee

4.4 REDUCERS:

Reducers are used to reduce the size of line. It is classified into two types,

- Concentric Reducers
- Eccentric reducers

Eccentric reducers are further classified into two types:

- Flat side up
- Flat side down

Eccentric flat side down reducers is used in sleepers & pipe rack to maintain a bottom of pipe. It is also used in control station assembly if spool available is less than supporting of a line.

Eccentric flat side up reducers is used in suction line to avoid cavitation, in concentric reducers air gets constrained to the liquid causing cavitation of the impeller.

4.5 FLANGES:

Flanges are classified on basis of follows:

- Weld neck
- Slip on
- Socket weld
- Threaded
- Orifice flange
- Slip End/ Lap joint

Weld Neck Flanges:

Weld neck flanges have a taper hub, which makes a more robust for high pressure and high temperature application. These types of flanges are most recommended for above 2 inch

4.6 GASKETS:

Gaskets are used between the flanges to have a leak proof joint and form a good mechanical interlock. The gaskets are selected based on:

- Pressure and temperature of fluid,
- Corrosion nature of fluid

Gaskets are of three types:

- Metallic
- Non-metallic
- Semi-metallic

4.7 SPECTACLE BLIND:

Spectacle blind also known as figure 8 blind, is generally a piece of metal that is cut to fit between two pipe flanges and usually sandwiched between two gaskets. A spectacle blind is often made for two metal discs that are attached to each other by a small section of steel. The shape is similar to pair of glasses or spectacles. Hence the name spectacle blind. One end of blind will have an opening to allow flow through pipe during operation and the other end is solid to block flow during maintenance. They are generally installed as a permanent device to separate process piping system

4.8 valves:

Valves are controls consisting of a mechanical device for controlling, isolating, regulating and ensuring the safety of the flow of a fluid in a line. The types of valves based on their functions are as listed below.

.isolation valves

.regulation valves

.checking valves

.safety valves

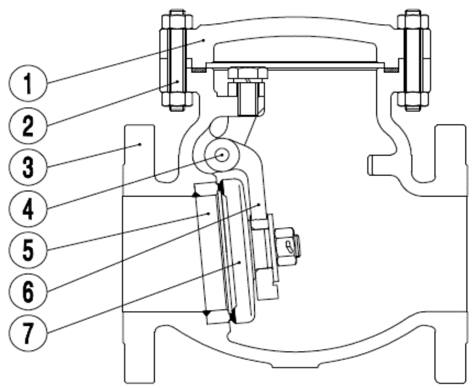
.special valves

4.9.1 Check valve:

Check valve used for a unidirectional flow called non return valve. Used in pump discharge line, compressor line etc.

Swing type check valve

It is available from 2" to 36". It is recommended in both horizontal lines and vertical lines. In lines above 16", this valve becomes heavier and hence, not recommended for horizontal lines since there is are alternatives available.



IT.	DESCRIPTION
1	COVER
2	BOLT
3	BODY
4	HINGE PIN
5	SEAT RING
6	HINGE
7	DISC

Fig 4.9.1 Flanged swing check valve

Lift type check valve:

It is of two types' ball lift and piston lift. Ball lift is available from ¼" to 2" and can be used on horizontal position as well as vertical position. Piston lift is available from ¼" to 24".

Wafer type check valve:

It is of two types single plate wafer, dual plate wafer. Wafer type check valves are compact in shape API 594 is the standard for the valves.

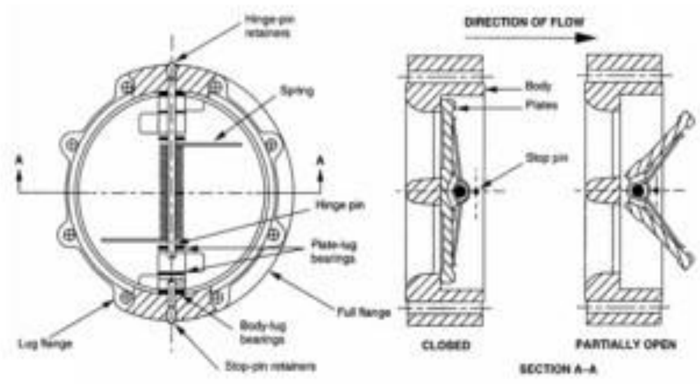
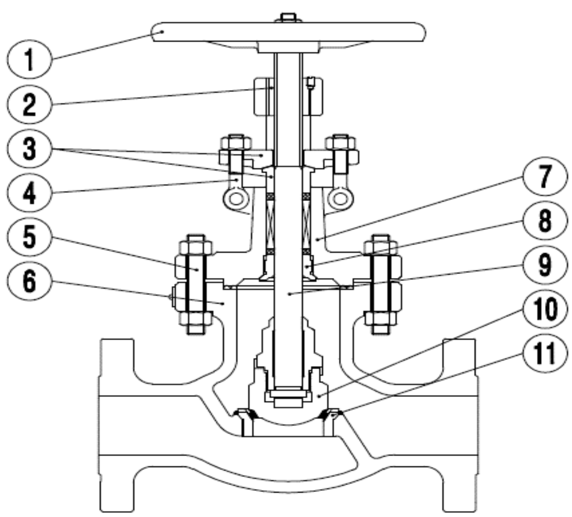


Fig 4.9.1.1 Wafer type check valve

4.9.2 Globe valve

It is a type of regulation valve used in hydrocarbon power and chemical industries. Globe valve finds its application in the bypass line of control valve. Globe valve has highest pressure drop among all the valves. Also, the water hammer effect is less.



IT.	DESCRIPTION
1	HANDWHEEL
2	YOKE SLEEVE
3	GLAND FLANGE
4	GLAND EYE BOLT
5	BONNET BOLT
6	BODY
7	BONNET
8	BACK SEAT
9	STEM
10	DISC
11	SEAT RING

Fig 4.9.2 flanged globe valve

4.9.3 Gate Valve:

It is a type of isolation valve usually recommended for liquid services. PRESSURE DROP is relatively less. Water hammer effect is also less. The gate valve is ideally suited for liquid services. Gate valve is not used for regulation pumps. It is more prone to leakage. In case of lines above 12”, Gate valve is usually motor operated becomes difficult.

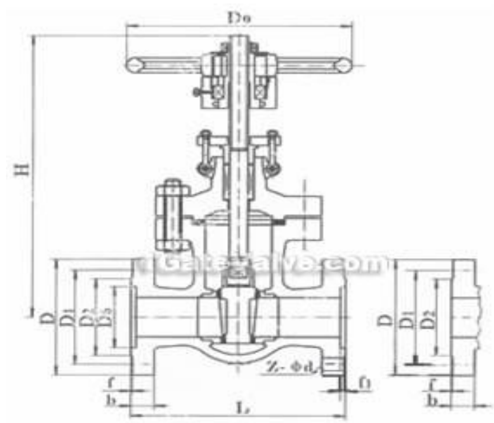


Fig 4.9.3 Flanged gate valve.

4.9.4 Ball Valve:

It is a type of valve recommended for compressed air, gas and liquid services. Pressure drop is less; water hammer effect is more since it is quarterly operated valve. It can be used for regulation purpose but not for prolonged time. Unlike others valve, it has a packing gland and package material instead of bonnet.

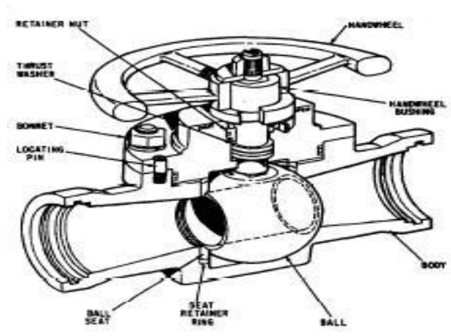


Figure 6-1.—Typical ball valve.

Fig 4.9.4 Flanged Ball valve.

4.9.5 Pressure safety valve (PSV)/ Pressure relief valve (PRV):

The PSV is used for gas services and it is fast in action. Both PSV and PRV are connected to the KNOCKOUT DRUM (K.O. DRUM). The knockout drums separate liquid from the fumes and sends the fumes to the flare area for burning.

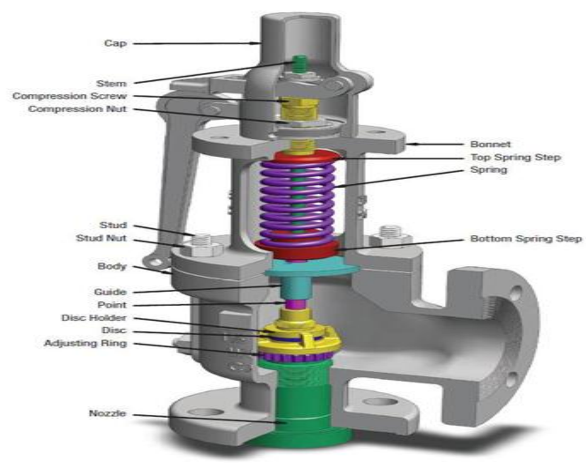


Fig 4.9.5 Relief valve

4.9.6 Control Valve:

Control valves are used to control the flow of fluid in the line. The different types of control valves are:

- PCV (Pressure control valve)
- TCV (Temperature control valve)

- LCV (level control valve)
- FCV (Flow control valve)

Control valves are pneumatically operated, hydraulically operated, electrically operated or Solenoid operated valves. These valves are directly controlled by control stations based on the logic diagram prepared by the instrument engineer.

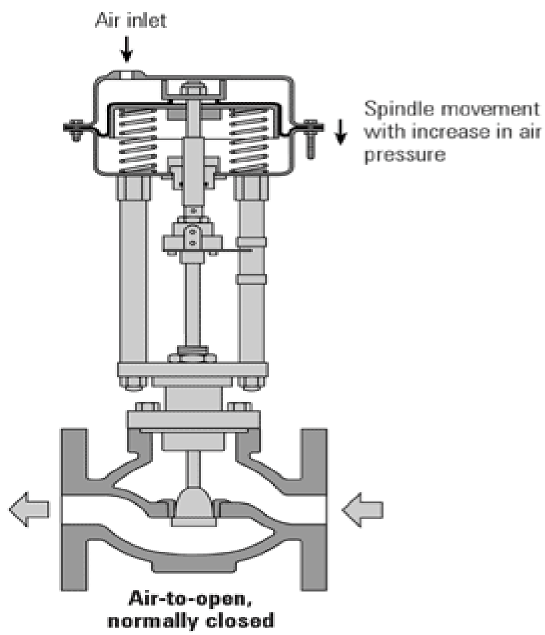


Fig4.9.6 Flanged control valve

4.9 Pumps:

Pumps are mechanical devices that movies fluid or gas by pressure or suction. In Hyderabad industry, pumps are only in liquid services. Pumps are classified into:

- Centrifugal pumps
- Reciprocating pumps
- Rotary pumps
- Diaphragm Pumps

Centrifugal pumps:

In this project, we have used centrifugal pumps for the following reasons.

- Centrifugal pumps are for large quantizes of fluid to be pumped at relatively lower head compared to Reciprocating pumps.

- Reciprocating pumps are used to transfer small quantities of liquid to be delivered at large heads.

- Rotary pumps are used for abrasive and viscous fluids.

Centrifugal pumps are classified into horizontal and vertical pumps on the alignment of the motor arrangement.

The horizontal pumps are again classified based on their nozzle arrangement:

- Front suction and top discharge.

- Top suction and top discharge.

- Side suction side discharge.

Vertical pumps are also called as vertical inline pumps and they are recommended when the required NPSH (Nominal pipe size) cannot be met. The NPSH required is provided by the vendor. Always NPSH available shall be greater than the NPSH required better efficiency of the pumps.

CHAPTER 5

CODES AND STANDARDS

5.1 CODES

CODES ARE A SET OF RULES and regulations required for safer design, construction, and erection of a plant. The implementation of codes can lead to hazardous accidents which can claim lives. The failure of implementation of code can also be challenged by law.

5.1.1 ASME codes and their applications

ASME B 31.1 - power piping

ASME B 31.3 -process piping

ASME B 31.4 –liquid hydrocarbon transportation

ASME B 31.8 – gas hydrocarbon transportation

ASME B 31.9 – build service piping

ASME B 31.11 – slurry waste water treatment

ASME B 36.10 – wrought/carbon steel /alloy steel pipe

ASME B 36.19 – stainless steel pipe

ASME B 16.5 – steel flanges below 24”

ASME B 16.20 – metallic gaskets

ASME B 16.21 – nonmetallic gaskets

ASME B 16.9 – butt welded fitting

ASME B 16.11 – socket welded / threaded fitting

ASME B 16.36 – orifice flanges

ASME B 16.48 – spectacle blind

ASME B 16.10 – face to face end to end dimension of valve

5.2 standards

Standards are also called as dimensional standard required maintaining the dimensional uniformity throughout the globe .the failure of implementation of standard can lead to rejection of the manufacturing order.

5.2.1 API standards and their applications

India – **BIS** –bureau of Indian standards

Japan – **JIS -** Japanese industrialization society

America – **ASME** – American standard

America – **API** – American petroleum institute

Britain – **BS** – British standard

Europe – **DIN** –deutsche institute for norming

France – **AFNOR-** association for France & normalization

Saudi – **ARAMCO** –Arabian American company standards

5.3 Scope of ASME b 31.3

This code prescribes requirements for materials and components, design, fabrication, assembly, erection, examination, inspection, and testing of piping.

This code applies to piping for all fluids, including:

- Raw, intermediate, and finished chemicals;
- Petroleum products
- Gas, steam, air, and water;
- Fluidized solids;
- Refrigerants

CHAPTER 6

6.1 PIPING AND INSTRUMENTATION DIAGRAM (P & ID)

It is a schematic representation of pipe and its fittings with instruments and its control which helps in the development of layouts. It is a diagram in the process industry, which shows the piping of the process flow together with the installed equipment and instrumentation.

Different names given for Piping and Instrumentation diagrams in the piping industry are:

PEFS (Process Engineering Flow Schemes)

MFD (Mechanical Flow Diagram)

ELD (Engineering Land Diagram)

EFD (Engineering flow diagram)

The steps involved in the development of P&IDs are the following:

1. Line Sizing

2. Line Numbering

P&IDs play a significant role in the maintenance of the process that it describes. It is critical to demonstrate the physical sequence of equipment and systems, as well as how these systems connect. During the design stage, the diagram also provides the basis for the development of system control schemes, allowing for further safety and operational investigations, such as the hazard and operational study (HAZOP)

6.2 LINE SIZE CALCULATIONS

Line sizing is the first step involved in the development of P&ID. A process engineer evaluates the process to determine the flow rate for a particular process. The process involved in this particular project was evaluated and the flow rate was determined as 2200 GPM and 1600 GPM and the velocity of fluid (Products) is 3.8MPS and 3.25MPS. The calculation is based on the following equation,

Q=AV where

<u>Main Line</u>

The flow in meter cube per second (m^3/sec), Q=2200 GPM

Therefore, Q= (2100*3.58) / (1000*60) =0.1387 m^3/sec

The area of the pipe in square meter (m^2), A= $(\pi*d^2)/4$

The velocity of the liquid in meter per second (m/sec), V= 3.8m/sec

Substituting the above values in the equation, Q=AV, we get d=0.215m

Since a safer design will be choosing an available line size above 0.21m (8.48”), the line size chosen for this project is 0.254m (10”)

<u>Branch line</u>

The flow in meter cube per second (m^3/sec), Q=1600 GPM

Therefore, Q= (2100*3.58) / (1000*60) =0.10094 m^3/sec

The area of the pipe in square meter (m^2), A= $(\pi*d^2)/4$

The velocity of the liquid in meter per second (m/sec), V= 3.25m/sec

Substituting the above values in the equation, Q=AV, we get d=0.19890m

Since a safer design will be choosing an available line size above 0.1989 (7.83”), the line size chosen for this project is 0.2032 (8”)

6.3 SP3D (Smart Plant 3D)

In this project, the software used for the design of equipment's, structures and piping is SP3D

	2D software	**3D software**
Quality of Output Drawings	Good Checkers required	No need of good checkers
Time Consumption	Almost twice the time	Half the time consumed using 2D
Clashes	Lots of clashes	Less Clashes

Table 6.3 comparison between 2d & 3D soft wares

SP3D includes comprehensive functions for all aspects of 3D plant design. Some of them are listed below:

- A fully interactive, intuitive 3D design environment, with a Microsoft office style user interface based on .NET technology

- Hundreds of designers can work concurrently on a project, in a fully controlled manner with visibility of the entire design at all times

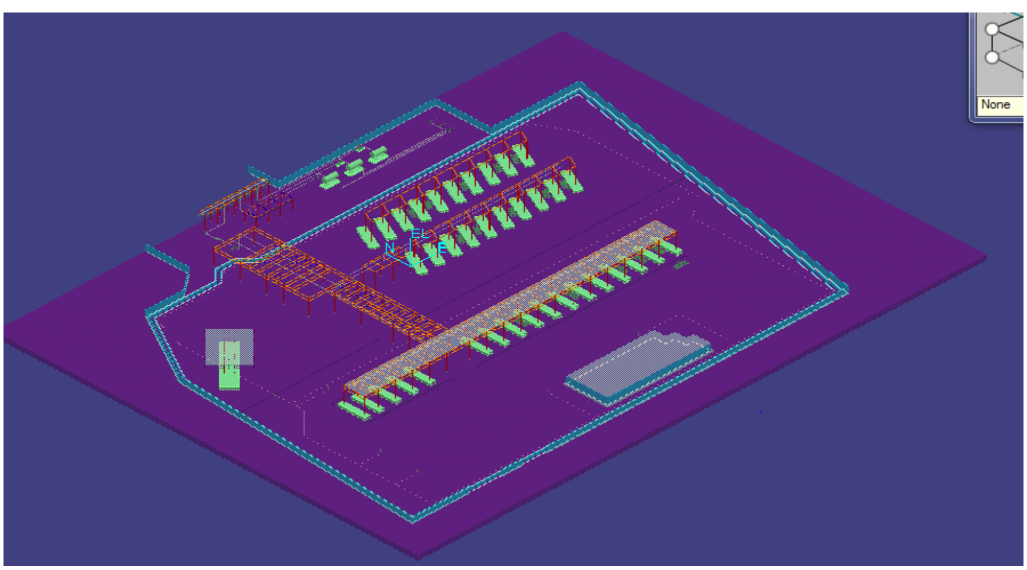
- Designers progressively create a highly intelligent 3D design by selecting and positioning parametric components from an extensive catalogue.

- Highly configurable, automatic generation of a wide range of reports and drawings direct from the SP3D database.

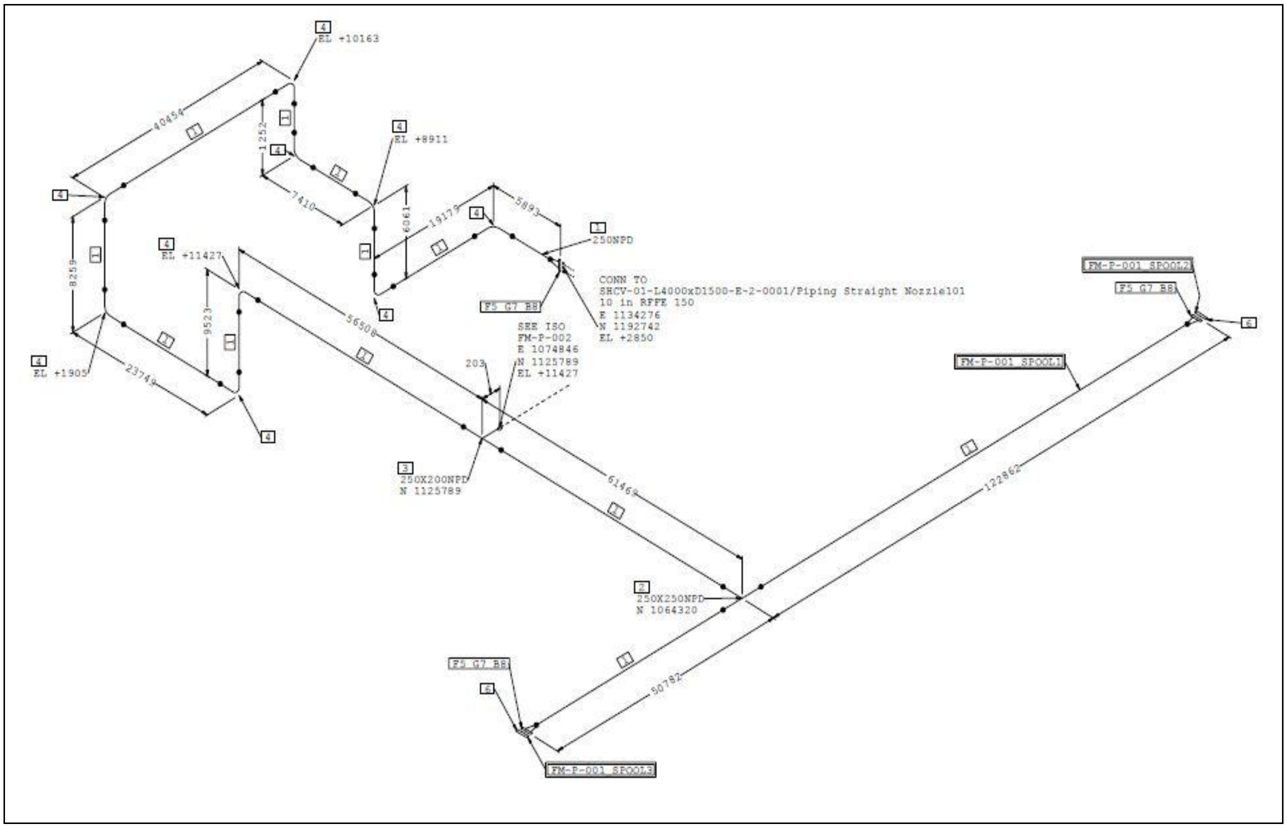
6.3.1 Piping Layout Requirements:

The layout of equipment and piping shall be based on the following principles [1] to provide a neat and economical layout, allowing for easy supporting and adequate flexibility to meet equipment allowable nozzle load.

- To locate all the equipment's identified on the equipment list.
- To comply with standards, regulations, codes, piping specification and sound engineering practices
- To maximize safety of personal, equipment of facilities.
- To provide means of escape and access for firefighting.
- To satisfy all the requirements indicated in process documents (P&IDs).
- To minimize shut-down duration.



6.4 ISOMETRIC DRAWINGS

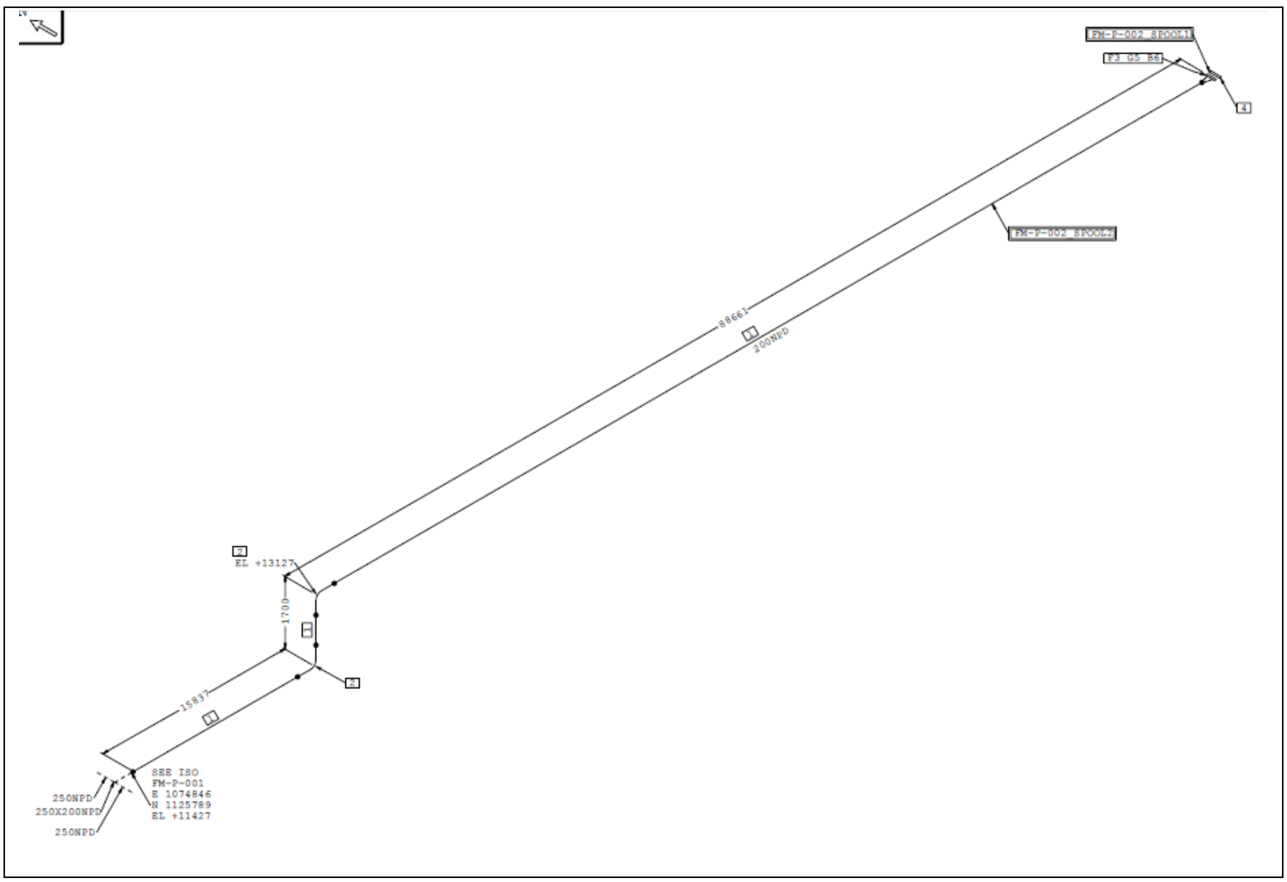


SHOP MATERIAL

PT NO	DESCRIPTION	NPD (MM)	CMDTY CODE	QTY
1	Pipe S-STD BE	250	PIPEBE142DSCHI	214.9
2	Tee.BE.S-STD	250X250	TEE39264D	1
3	90 Degree Elbow	250	90E39264D	1
4	Weld Neck Flange 150	250	FWN35B150AG	1

OTHER THAN SHOP MATERIALS

PT NO	DESCRIPTION	NPD (MM)	CMDTY	QTY
5	Gasket,CL 150,G653,0.125"thk,304 spiral wind, graph filled.CS center ring.API-601	250	XDAABZZQSG	1
6	ASTM-A-193 STUDS w/ASTM-A-194-2H hvy hex nuts-120.65 mm length	22	YZZZHZZFFF	12
7	Pipe Material		(106)A106 B	



6.5 PIPE THICKNESS CALCULATION AND SELECTION OF SCHEDULE FOR THE PIPE

As per ASME B 31.3, thickness of the pipe can be calculated using the following equation

$$t = \frac{P \times D}{2(S \times E + P \times Y)} \quad \ldots\ldots\ldots..$$

Where,

P = Internal design pressure in psi

E = Joint efficiency factor based on manufacturing method (ASME B 31.3)

Y = Co-efficient as per ASME B 31.3

D = Outside diameter in inches

T = Pressure design thickness in inches

S = Allowable stress in psi based on ASME 31.3

C = Corrosion allowance

$t_{nominal} = t + C$

$t_{minimum} = t_{nominal} \div 0.875$

This value of $t_{minimum}$ is the minimum required thickness of the given line including mechanical, corrosion and erosion allowances.

Based on the value of $t_{minimum}$ obtained above, the schedule number is selected for the line using ASME B36.10

FOR 250 MM PIPE DIAMETER

P = 250 BAR=362.59 psi

T = 300^0C = 572 F

D = 10 = 8.625 (NPS)

C = 3mm ÷ 25.4= 0.118”

E = 1 (seamless tube)

Y = 0.7 as per code ASME B 31.3

S = 17.3 KSI = 17300 psi

$$t = \frac{P \times D}{2(S \times E + P \times Y)}$$

t= 362.59× 10.75÷ $2[17300 \times 1 + 362.59 \times 0.7]$ = 0.11102”= 0.00154m

= 0.11102 + 0.2362 = 0.34722”= 0.008819m

$t_{minimum}$ = 0.34722 ÷0.875 = 0.365” = 0.00927m

Schedule number = 40 (STD) from ASME B 36.10

FOR 200 MM PIPE DIAMETER

P = 250 BAR=362.59 psi

T = 300^0C = 572 F

D = 8 = 8.625 (NPS)

C = 3mm ÷ 25.4= 0.118”

E = 1 (seamless tube)

Y = 0.7 as per code ASME B 31.3

S = 17.3 KSI = 17300 psi

$$t = \frac{P \times D}{2(S \times E + P \times Y)}$$

t= 362.59× 8.625÷ $2[17300 \times 1 + 362.59 \times 0.7]$ = 0.08907”= 0.002262m

= 0.8907 + 0.2362 = 0.3252”= 0.008819m

$t_{minimum}$ = 0.3252 ÷0.875 = 0.3716” = 0.00944m

Schedule number = 40 (STD) from ASME B 36.10

<u>FOR 150 MM PIPE DIAMETER</u>

P = 250 BAR=362.59 psi

T = 300^0C = 572 F

D = 6 = 6.625 (NPS)

C = 3mm ÷ 25.4= 0.118”

E = 1 (seamless tube)

Y = 0.7 as per code ASME B 31.3

S = 17.3 KSI = 17300 psi

$$t = \frac{P \times D}{2(S \times E + P \times Y)}$$

t= 362.59× 6.625÷ $2[17300 \times 1 + 362.59 \times 0.7]$ = 0.00684”= 0.001737m

= 0.8907 + 0.2362 = 0.3046”= 0.007736m

$t_{minimum}$ = 0.3252 ÷0.875 = 0.3481” = 0.008842m

Schedule number = 40 (STD) from ASME B 36.10

CHAPTER 7

STRESS ANALYSIS

7.1 PIPE STRESS ANALYSIS USING CEASER II

Once the piping layout has been design in SP3D, the first step is to identify and select the critical lines in the designed system.

Critical lines are selected based on the following criteria [2]:

- Lines connected to the pressure vessels, heat exchanger, air coolers.
- Lines connected to rotating, reciprocating, strain sensitive equipment's.
- Pressure relief/ Blow down system lines.
- Low temperature service (Sub-Zero) lines.
- High temperature Service lines.
- Larger Diameter lines.
- Lines with expansion joint.
- Critical service lines (Lethal contents, high integrity etc.)

In the light of the aforementioned criteria, the following lines of the water injection system has been identified and selected as critical lines, thereby sending them for pipe stress analysis using Caesar II after building up the model once again in the aforementioned software. All the lines in the system are grouped into the following three systems.

The main objectives of the pipe stress analysis are to:

- Satisfy the code requirement in ASME B 31.3.
- Confirm that the piping load on the sensitive equipment do not exceed the allowable values.
- Identify the support locations and special support requirements such as springs, rigid strut etc.

7.2 BUIDING UP OF THE MODEL IN CAESER II

All the critical lines mentioned above, subject to pipe stress analysis are grouped into three systems namely,

- Loading system
- Unloading system
- Fire water system

These systems are then built up once again in Caeser II using the pipe Isometrics drawings obtained from SP3D. They are then checked for the following:

- Wall Thickness
- Temperature
- Pressure

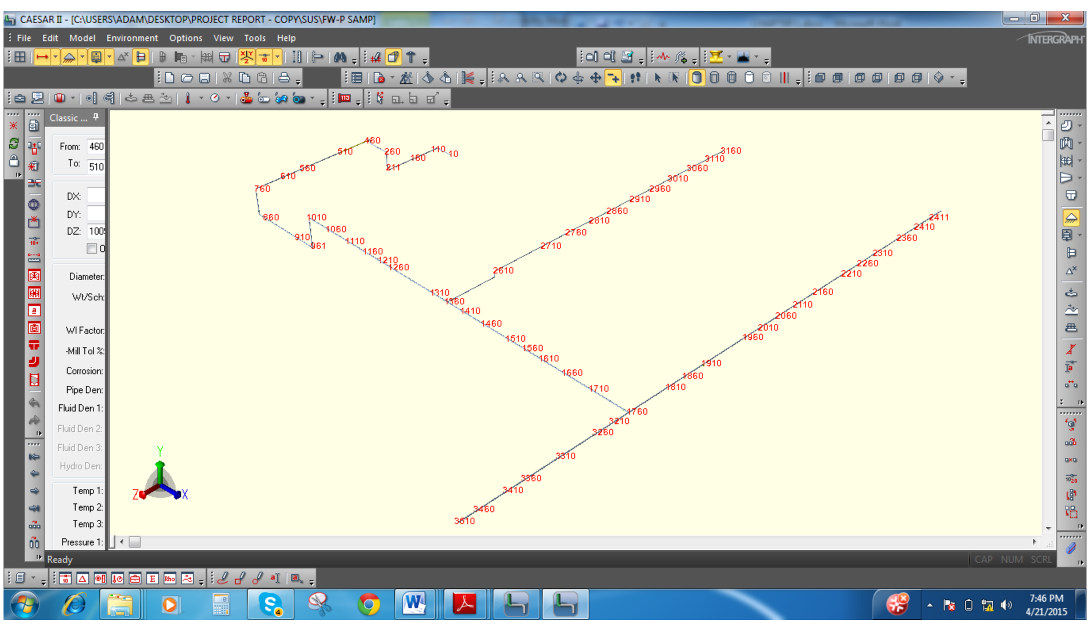


Fig 7.2: Modeling of loading and unloading system

7.3 LOAD CASES TO BE CONSIDERED IN PIPE STRESS ANALYSIS

The stress analysis shall be carried using Caesar II software (version 5.20) and shall comply

With the requirements of the code, standards and specifications defined in section 3.0, and shall take into consideration the following load cases:

- Sustained Load cases
- Operational Load Cases
- Occasional Load cases
- Displacement Load Cases

7.3.1 Sustained Load Cases:

Those loads that act due to forces present during normal operation of the system are called

Sustained loads. This shall include only the effects of pressure, pipe deadweight, and insulation

Weight and weight of contents. This case is required to be performed mainly to check if the

Code compliance requirements of sustained stress are satisfied by the piping system.

Basically, the live weight and dead weight of the fluid is balanced by means of support at necessary points in the system.

Case 3: (SUS): W+P1

$$S_{sus} \leq S_{allowable}$$

LOAD CASE DEFINITION KEY

CASE 2 (SUS) W+P1

7.3.1.1 CODE COMPLIANCE REPORT

Piping Code: B31.3 = B31.3 -2010, March 31, 2011

*** CODE COMPLIANCE EVALUATION PASSED ***

Highest Stresses: (KPa)

Ratio (%): 78.3 @Node 2810 LOADCASE: 2 (SUS) W+P1

Code Stress: 100228.13 Allowable Stresses: 127966.7

Axial Stress: 17553.4 @Node 211 LOADCASE: 2 (SUS) W+P1

Bending Stress: 119321.7 @Node 2818 LOADCASE: 2 (SUS) W+P1

Torsion Stress: 19996.3 @Node 1780 LOADCASE: 2 (SUS) W+P1

Hoop Stress: 32222.2 @Node 58 LOADCASE: 2 (SUS) W+P1

Max Stress Intensity: 133049.0 @Node 2818 LOADCASE: 2 (SUS) W+P1

Table 7.3.1.1: Code Evaluation

Load Case	From Node	Code Stress KPa	Allowable Stress KPa	To Node	Code Stress KPa	Allowable Stress KPa	Piping Code
2(SUS)	10	34923.5	127966.7	58	47580.5	127966.7	B31.3
2(SUS)	58	59641.7	127966.7	59	67417.8	127966.7	B31.3
2(SUS)	59	67417.8	127966.7	60	74295.9	127966.7	B31.3
2(SUS)	60	54991.7	127966.7	110	64535.8	127966.7	B31.3
2(SUS)	110	64535.8	127966.7	120	29303.7	127966.7	B31.3
2(SUS)	120	29303.7	127966.7	160	92514.1	127966.7	B31.3
2(SUS)	160	92514.1	127966.7	210	71221.0	127966.7	B31.3
2(SUS)	210	49328.2	127966.7	211	38866.9	127966.7	B31.3
2(SUS)	211	36973.2	127966.7	220	33020.5	127966.7	B31.3
2(SUS)	220	33020.5	127966.7	260	25775.2	127966.7	B31.3
2(SUS)	260	22875.6	127966.7	310	84656.5	127966.7	B31.3
2(SUS)	310	84656.5	127966.7	360	27868.2	127966.7	B31.3

Load Case	From Node	Code Stress KPa	Allowable Stress KPa	To Node	Code Stress KPa	Allowable Stress KPa	Piping Code
2(SUS)	360	24231.0	127966.7	410	27786.1	127966.7	B31.3
2(SUS)	410	23608.6	127966.7	460	21918.2	127966.7	B31.3
2(SUS)	460	21918.2	127966.7	470	30915.6	127966.7	B31.3
2(SUS)	470	30915.6	127966.7	480	75636.1	127966.7	B31.3
2(SUS)	480	75636.1	127966.7	490	47074.3	127966.7	B31.3
2(SUS)	490	47074.3	127966.7	518	32270.4	127966.7	B31.3
2(SUS)	518	43816.5	127966.7	519	39368.9	127966.7	B31.3
2(SUS)	519	39368.9	127966.7	520	37100.7	127966.7	B31.3
2(SUS)	520	28650.9	127966.7	530	18289.8	127966.7	B31.3
2(SUS)	530	17307.1	127966.7	540	54352.6	127966.7	B31.3
2(SUS)	540	37949.8	127966.7	550	71257.4	127966.7	B31.3
2(SUS)	550	48476.0	127966.7	560	52715.1	127966.7	B31.3
2(SUS)	560	52715.1	127966.7	610	40799.6	127966.7	B31.3
2(SUS)	610	40854.9	127966.7	660	47616.5	127966.7	B31.3
2(SUS)	660	47616.5	127966.7	710	46475.5	127966.7	B31.3
2(SUS)	710	46475.5	127966.7	760	20811.8	127966.7	B31.3
2(SUS)	760	19242.1	127966.7	770	18415.2	127966.7	B31.3
2(SUS)	770	18415.2	127966.7	810	20560.5	127966.7	B31.3
2(SUS)	810	18468.8	127966.7	860	64722.8	127966.7	B31.3
2(SUS)	860	64722.8	127966.7	870	52108.6	127966.7	B31.3
2(SUS)	870	52108.6	127966.7	910	63097.1	127966.7	B31.3
2(SUS)	910	63150.1	127966.7	960	18395.9	127966.7	B31.3
2(SUS)	960	17320.0	127966.7	961	17311.4	127966.7	B31.3
2(SUS)	961	15091.2	127966.7	1010	18224.9	127966.7	B31.3
2(SUS)	1010	17120.6	127966.7	1060	72741.5	127966.7	B31.3
2(SUS)	1060	72741.5	127966.7	1110	60097.9	127966.7	B31.3
2(SUS)	1110	60097.9	127966.7	1160	61760.6	127966.7	B31.3
2(SUS)	1160	61760.6	127966.7	1210	27146.0	127966.7	B31.3
2(SUS)	1210	27146.0	127966.7	1260	71148.5	127966.7	B31.3
2(SUS)	1260	71148.5	127966.7	1310	64228.5	127966.7	B31.3
2(SUS)	1310	64228.5	127966.7	1360	77428.9	127966.7	B31.3
2(SUS)	1360	78351.1	127966.7	1410	87127.9	127966.7	B31.3
2(SUS)	1410	87127.9	127966.7	1460	29566.9	127966.7	B31.3
2(SUS)	1460	29566.9	127966.7	1510	36576.6	127966.7	B31.3
2(SUS)	1510	36576.6	127966.7	1518	36687.6	127966.7	B31.3
2(SUS)	1518	41663.4	127966.7	1519	51663.4	127966.7	B31.3
2(SUS)	1519	51663.4	127966.7	1520	48346.3	127966.7	B31.3
2(SUS)	1520	39790.1	127966.7	1530	40857.2	127966.7	B31.3
2(SUS)	1530	39098.6	127966.7	1532	38033.7	127966.7	B31.3
2(SUS)	1532	38033.7	127966.7	1540	64566.1	127966.7	B31.3
2(SUS)	1540	51674.0	127966.7	1550	33164.6	127966.7	B31.3
2(SUS)	1550	27944.6	127966.7	1560	71757.7	127966.7	B31.3

Load Case	From Node	Code Stress KPa	Allowable Stress KPa	To Node	Code Stress KPa	Allowable Stress KPa	Piping Code
2(SUS)	1560	71757.7	127966.7	1610	69003.2	127966.7	B31.3
2(SUS)	1610	69003.2	127966.7	1660	49054.8	127966.7	B31.3
2(SUS)	1660	49054.8	127966.7	1710	72881.3	127966.7	B31.3
2(SUS)	1710	72881.3	127966.7	1711	37066.4	127966.7	B31.3
2(SUS)	1711	37087.0	127966.7	1720	46344.3	127966.7	B31.3
2(SUS)	1720	46344.3	127966.7	1760	45828.3	127966.7	B31.3
2(SUS)	1760	29632.3	127966.7	1761	98422.1	127966.7	B31.3
2(SUS)	1761	98422.1	127966.7	1768	26434.0	127966.7	B31.3
2(SUS)	1768	27991.9	127966.7	1769	38595.1	127966.7	B31.3
2(SUS)	1769	38595.1	127966.7	1770	40040.4	127966.7	B31.3
2(SUS)	1770	33086.0	127966.7	1780	43831.6	127966.7	B31.3
2(SUS)	1780	43546.8	127966.7	1781	49964.6	127966.7	B31.3
2(SUS)	1781	49964.6	127966.7	1790	74259.0	127966.7	B31.3
2(SUS)	1790	57526.7	127966.7	1800	20211.6	127966.7	B31.3
2(SUS)	1800	18844.0	127966.7	1810	16722.0	127966.7	B31.3
2(SUS)	1810	16722.0	127966.7	1860	48044.9	127966.7	B31.3
2(SUS)	1860	48044.9	127966.7	1910	76932.4	127966.7	B31.3
2(SUS)	1910	76932.4	127966.7	1960	59851.2	127966.7	B31.3
2(SUS)	1960	59851.2	127966.7	2010	25993.9	127966.7	B31.3
2(SUS)	2010	25993.9	127966.7	2060	60112.4	127966.7	B31.3
2(SUS)	2060	60112.4	127966.7	2110	47107.2	127966.7	B31.3
2(SUS)	2110	47107.2	127966.7	2160	59214.3	127966.7	B31.3
2(SUS)	2160	59214.3	127966.7	2210	58183.2	127966.7	B31.3
2(SUS)	2210	58183.2	127966.7	2260	46622.6	127966.7	B31.3
2(SUS)	2260	46622.6	127966.7	2310	51726.0	127966.7	B31.3
2(SUS)	2310	51726.0	127966.7	2360	65050.8	127966.7	B31.3
2(SUS)	2360	65050.8	127966.7	2410	57245.2	127966.7	B31.3
2(SUS)	2410	57245.2	127966.7	2411	50563.5	127966.7	B31.3
2(SUS)	2411	50563.5	127966.7	2460	15509.5	127966.7	B31.3
2(SUS)	1360	75321.2	127966.7	2510	65565.3	127966.7	B31.3
2(SUS)	2510	65565.3	127966.7	2520	31483.5	127966.7	B31.3
2(SUS)	2520	31483.5	127966.7	2530	67242.6	127966.7	B31.3
2(SUS)	2530	67242.6	127966.7	2560	22099.7	127966.7	B31.3
2(SUS)	2560	19405.6	127966.7	2561	17872.4	127966.7	B31.3
2(SUS)	2561	17872.4	127966.7	2610	27293.1	127966.7	B31.3
2(SUS)	2610	22545.5	127966.7	2660	93343.3	127966.7	B31.3
2(SUS)	2660	93343.3	127966.7	2670	31132.0	127966.7	B31.3
2(SUS)	2670	30387.4	127966.7	2710	89644.0	127966.7	B31.3
2(SUS)	2710	89644.0	127966.7	2760	68284.8	127966.7	B31.3
2(SUS)	2760	68284.8	127966.7	2810	118129.7	127966.7	B31.3
2(SUS)	2810	118129.7	127966.7	2818	70075.0	127966.7	B31.3
2(SUS)	2818	103218.6	127966.7	2819	81937.6	127966.7	B31.3

Load Case	From Node	Code Stress KPa	Allowable Stress KPa	To Node	Code Stress KPa	Allowable Stress KPa	Piping Code
2(SUS)	2819	81937.6	127966.7	2820	73600.6	127966.7	B31.3
2(SUS)	2820	50475.7	127966.7	2830	67241.4	127966.7	B31.3
2(SUS)	2830	47422.2	127966.7	2840	81365.9	127966.7	B31.3
2(SUS)	2840	56777.7	127966.7	2850	91544.1	127966.7	B31.3
2(SUS)	2850	62724.3	127966.7	2900	56893.2	127966.7	B31.3
2(SUS)	2900	56893.2	127966.7	2910	114918.9	127966.7	B31.3
2(SUS)	2910	114918.9	127966.7	2960	54390.0	127966.7	B31.3
2(SUS)	2960	54390.0	127966.7	3010	103437.1	127966.7	B31.3
2(SUS)	3010	103485.8	127966.7	3060	61529.4	127966.7	B31.3
2(SUS)	3060	61529.4	127966.7	3110	105989.9	127966.7	B31.3
2(SUS)	3110	105989.9	127966.7	3160	13776.0	127966.7	B31.3
2(SUS)	1760	28433.7	127966.7	3210	35742.5	127966.7	B31.3
2(SUS)	3210	35742.5	127966.7	3260	52771.5	127966.7	B31.3
2(SUS)	3260	52771.5	127966.7	3310	41025.6	127966.7	B31.3
2(SUS)	3310	41025.6	127966.7	3360	55227.2	127966.7	B31.3
2(SUS)	3360	55232.1	127966.7	3410	41393.5	127966.7	B31.3
2(SUS)	3410	41393.5	127966.7	3460	57941.1	127966.7	B31.3
2(SUS)	3460	57941.1	127966.7	3510	15509.5	127966.7	B31.3

7.3.1.2 RESTRAIN REPORT

Supports are provided to the piping to resist various loads.

Table 7.3.1.2 Restrain report

Node	FX N.	FY N.	FZ N.	MX N.m.	MY N.m.	MZ N.m.	
10	0	0	0	0	0	0	Flex X
10	0	0	0	12946	0	0	Rigid RX
10	0	0	0	0	0	0	Rigid Z
10	0	0	0	0	0	-293	Flex RZ
10	0	-3455	0	0	0	0	Rigid Y
10	0	0	0	0	-0	0	Flex RY
110	0	-16827	0	0	0	0	Rigid +Y
211	0	-16294	0	0	0	0	Rigid +Y
310	0	-16725	0	0	0	0	Rigid +Y
510	0	-15777	0	0	0	0	Rigid +Y
560	0	-17347	0	0	0	0	Rigid +Y
660	0	-15567	0	0	0	0	Rigid +Y
860	0	-17083	0	0	0	0	Rigid +Y

Node	FX N.	FY N.	FZ N.	MX N.m.	MY N.m.	MZ N.m.	
910	0	-16093	0	0	0	0	Rigid +Y
961	0	-15109	0	0	0	0	Rigid +Y
1060	0	-17814	0	0	0	0	Rigid +Y
1160	0	-15285	0	0	0	0	Rigid +Y
1260	0	-16858	0	0	0	0	Rigid +Y
1310	0	-14962	0	0	0	0	Rigid +Y
1410	0	-14966	0	0	0	0	Rigid +Y
1510	0	-17128	0	0	0	0	Rigid +Y
1610	0	-16977	0	0	0	0	Rigid +Y
1710	0	-15546	0	0	0	0	Rigid +Y
1720	0	-21654	0	0	0	0	Rigid +Y
1810	0	-15966	0	0	0	0	Rigid +Y
1910	0	-16770	0	0	0	0	Rigid +Y
1960	0	-16651	0	0	0	0	Rigid +Y
2060	0	-16538	0	0	0	0	Rigid +Y
2160	0	-16120	0	0	0	0	Rigid +Y
2210	0	-15457	0	0	0	0	Rigid +Y
2310	0	-14169	0	0	0	0	Rigid +Y
2360	0	-16433	0	0	0	0	Rigid +Y
2411	0	-14430	0	0	0	0	Rigid +Y
2510	0	-12499	0	0	0	0	Rigid +Y
2660	0	-14306	0	0	0	0	Rigid +Y
2710	**0**	**-13525**	**0**	**0**	**0**	**0**	**Rigid +Y**
2810	0	-15120	0	0	0	0	Rigid +Y
2910	0	-13344	0	0	0	0	Rigid +Y
3010	0	-13650	0	0	0	0	Rigid +Y
3110	0	-13071	0	0	0	0	Rigid +Y
3260	0	-14079	0	0	0	0	Rigid +Y
3310	0	-12154	0	0	0	0	Rigid +Y
3360	0	-14940	0	0	0	0	Rigid +Y
3460	0	-14709	0	0	0	0	Rigid +Y

7.3.1.3 Stress Report

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

CODE STRESS CHECK PASSED : LOADCASE 2 (SUS) W+P1

Highest Stresses: (KPa)

Ratio (%): 78.3 @Node 2810

Code Stress:	100228.1	Allowable Stress:	127966.7
Axial Stress:	17553.4	@Node	211
Bending Stress:	119321.7	@Node	2818
Torsion Stress:	19996.3	@Node	1780
Hoop Stress:	32222.2	@Node	58
Max Stress Intensity:	133049.0	@Node	2818

Table 7.3.1.3: Stress Report

Node	Axial Stress KPa	Bending Stress KPa	Torsion Stress KPa	Hoop Stress KPa	Max Stre Intensity KPa	SIF In Plane	SIF Out Plane	Code Stress KPa	Allowable Stress KPa	Ratio %	Piping Code
10	15841.3	2187.9	14954.9	32222.2	43960.5	1.000	1.000	34923.5	127966.7	27.3	B31.3
58	15841.3	21162.8	-14954.9	32222.2	50912.4	1.000	1.000	47580.5	127966.7	37.2	B31.3
58	15841.3	47677.9	14954.9	32222.2	70208.9	2.256	1.880	59641.7	127966.7	46.6	B31.3
59	15916.7	63930.8	-10798.8	32222.2	81930.9	2.256	1.880	67417.8	127966.7	52.7	B31.3
59	15916.7	63930.8	10798.8	32222.2	82716.8	2.256	1.880	67417.8	127966.7	52.7	B31.3
60	15753.6	78039.4	688.0	32222.2	93314.9	2.256	1.880	74295.9	127966.7	58.1	B31.3
60	15753.6	39220.9	-688.0	32222.2	54991.7	1.000	1.000	54991.7	127966.7	43.0	B31.3
110	15753.6	48767.5	688.0	32222.2	64047.6	1.000	1.000	64535.8	127966.7	50.4	B31.3
110	15753.6	48767.5	-688.0	32222.2	64535.8	1.000	1.000	64535.8	127966.7	50.4	B31.3
120	15753.6	13517.8	688.0	32222.2	36095.8	1.000	1.000	29303.7	127966.7	22.9	B31.3
120	15753.6	13517.8	-688.0	32222.2	36089.4	1.000	1.000	29303.7	127966.7	22.9	B31.3
160	15753.6	76750.3	688.0	32222.2	92026.0	1.000	1.000	92514.1	127966.7	72.3	B31.3
160	15753.6	76750.3	-688.0	32222.	92514.1	1.00	1.00	92514.1	127966.7	72.3	B31.3

Node	Axial Stress KPa	Bending Stress KPa	Torsion Stress KPa	Hoop Stress KPa	Max Stress Intensity KPa	SIF In Plane	SIF Out Plane	Code Stress KPa	Allowable Stress KPa	Ratio %	Piping Code
				2		0	0				
210	17084.1	71809.9	3151.7	32222.2	86393.5	2.256	1.880	71221.0	127966.7	55.7	B31.3
210	17084.1	31839.6	-3151.7	32222.2	49478.3	1.000	1.000	49328.2	127966.7	38.5	B31.3
211	17553.4	20798.9	3151.7	32222.2	41053.8	1.000	1.000	38866.9	127966.7	30.4	B31.3
211	15633.0	20798.9	-3151.7	32222.2	39585.6	1.000	1.000	36973.2	127966.7	28.9	B31.3
220	15811.8	16601.5	3151.7	32222.2	38011.4	1.000	1.000	33020.5	127966.7	25.8	B31.3
220	15811.8	16601.5	-3151.7	32222.2	37831.8	1.000	1.000	33020.5	127966.7	25.8	B31.3
260	15527.0	11988.6	-3975.2	32222.2	37625.1	2.256	1.880	25775.2	127966.7	20.1	B31.3
260	15527.0	5922.6	3975.2	32222.2	37024.3	1.000	1.000	22875.6	127966.7	17.9	B31.3
310	15527.0	68755.3	-3975.2	32222.2	84621.5	1.000	1.000	84656.5	127966.7	66.2	B31.3
310	15527.0	68755.3	3975.2	32222.2	84656.5	1.000	1.000	84656.5	127966.7	66.2	B31.3
360	14655.8	16610.6	-3220.3	32222.2	37744.8	2.256	1.880	27868.2	127966.7	21.8	B31.3
360	14655.8	8703.6	3220.3	32222.2	36914.3	1.000	1.000	24231.0	127966.7	18.9	B31.3
410	15440.5	16303.2	-1280.6	32222.2	36438.2	2.256	1.880	27786.1	127966.7	21.7	B31.3
410	15440.5	8028.9	1280.6	32222.2	36151.8	1.000	1.000	23608.6	127966.7	18.4	B31.3
460	15440.5	6327.6	-1280.6	32222.2	36133.5	1.000	1.000	21918.2	127966.7	17.1	B31.3
460	15440.5	6327.6	1280.6	32222.2	36134.8	1.000	1.000	21918.2	127966.7	17.1	B31.3
470	15440.5	15368.9	-1280.6	32222.2	36358.7	1.000	1.000	30915.6	127966.7	24.2	B31.3
470	15440.5	15368.9	1280.6	32222.2	36369.4	1.000	1.000	30915.6	127966.7	24.2	B31.3
480	15440.5	60152.3	-1280.6	32222.2	75774.0	1.000	1.000	75636.1	127966.7	59.1	B31.3
480	15440.5	60152.3	1280.6	32222.	75636.1	1.00	1.00	75636.1	127966.7	59.1	B31.3

Node	Axial Stress KPa	Bending Stress KPa	Torsion Stress KPa	Hoop Stress KPa	Max Stre Intensity KPa	SIF In Plane	SIF Out Plane	Code Stress KPa	Allowable Stress KPa	Ratio %	Piping Code
				2		0	0				
490	15440.5	31564.1	-1280.6	32222.2	47429.5	1.000	1.000	47074.3	127966.7	36.8	B31.3
490	15440.5	31564.1	1280.6	32222.2	47493.0	1.000	1.000	47074.3	127966.7	36.8	B31.3
518	15440.5	16728.2	-1280.6	32222.2	36486.2	1.000	1.000	32270.4	127966.7	25.2	B31.3
518	15440.5	37734.8	1280.6	32222.2	53236.9	2.256	1.880	43816.5	127966.7	34.2	B31.3
519	15925.2	31216.6	-784.5	32222.2	47440.6	2.256	1.880	39368.9	127966.7	30.8	B31.3
519	15925.2	31216.6	784.5	32222.2	47416.5	2.256	1.880	39368.9	127966.7	30.8	B31.3
520	16219.0	27839.1	204.4	32222.2	44558.0	2.256	1.880	37100.7	127966.7	29.0	B31.3
520	16219.0	12429.0	-204.4	32222.2	36023.9	1.000	1.000	28650.9	127966.7	22.4	B31.3
530	15440.5	3357.0	-1733.6	32222.2	36189.9	2.256	1.880	18289.8	127966.7	14.3	B31.3
530	15440.5	1515.8	1733.6	32222.2	36174.0	1.000	1.000	17307.1	127966.7	13.5	B31.3
540	14052.9	53723.7	-430.8	32222.2	70695.0	2.256	1.880	54352.6	127966.7	42.5	B31.3
540	14052.9	23887.1	430.8	32222.2	41661.6	1.000	1.000	37949.8	127966.7	29.7	B31.3
550	15440.5	74361.2	-1280.6	32222.2	89976.1	2.256	1.880	71257.4	127966.7	55.7	B31.3
550	15440.5	32967.8	1280.6	32222.2	48783.2	1.000	1.000	48476.0	127966.7	37.9	B31.3
560	15440.5	37212.3	-1280.6	32222.2	52852.9	1.000	1.000	52715.1	127966.7	41.2	B31.3
560	15440.5	37212.3	1280.6	32222.2	52715.1	1.000	1.000	52715.1	127966.7	41.2	B31.3
610	15440.5	25278.7	-1280.6	32222.2	41649.8	1.000	1.000	40799.6	127966.7	31.9	B31.3
610	15495.9	25278.7	1280.6	32222.2	41728.9	1.000	1.000	40854.9	127966.7	31.9	B31.3
660	15495.9	32051.7	-1280.6	32222.2	47859.2	1.000	1.000	47616.5	127966.7	37.2	B31.3
660	15495.9	32051.7	1280.6	32222.	47885.9	1.00	1.00	47616.5	127966.7	37.2	B31.3

Node	Axial Stress KPa	Bending Stress KPa	Torsion Stress KPa	Hoop Stress KPa	Max Stre Intensity KPa	SIF In Plane	SIF Out Plane	Code Stress KPa	Allowable Stress KPa	Ratio %	Piping Code
				2		0	0				
710	15495.9	30908.9	-1280.6	32222.2	46810.3	1.000	1.000	46475.5	127966.7	36.3	B31.3
710	15495.9	30908.9	1280.6	32222.2	46837.0	1.000	1.000	46475.5	127966.7	36.3	B31.3
760	16125.7	6247.4	-73.3	32222.2	36019.3	2.256	1.880	20811.8	127966.7	16.3	B31.3
760	16125.7	3115.9	73.3	32222.2	36019.2	1.000	1.000	19242.1	127966.7	15.0	B31.3
770	15477.7	2937.0	-73.3	32222.2	36019.2	1.000	1.000	18415.2	127966.7	14.4	B31.3
770	15477.7	2937.0	73.3	32222.2	36019.2	1.000	1.000	18415.2	127966.7	14.4	B31.3
810	15442.7	6821.8	122.3	32222.2	36020.0	2.256	1.880	20560.5	127966.7	16.1	B31.3
810	15442.7	3024.4	-122.3	32222.2	36019.8	1.000	1.000	18468.8	127966.7	14.4	B31.3
860	15442.7	49279.6	122.3	32222.2	64856.3	1.000	1.000	64722.8	127966.7	50.6	B31.3
860	15442.7	49279.6	-122.3	32222.2	64722.8	1.000	1.000	64722.8	127966.7	50.6	B31.3
870	15442.7	14128.5	10831.0	32222.2	43904.3	1.000	1.000	36687.6	127966.7	28.7	B31.3
870	15442.7	36665.3	-122.3	32222.2	52108.6	1.000	1.000	52108.6	127966.7	40.7	B31.3
910	15442.7	47654.0	122.3	32222.2	63230.6	1.000	1.000	63097.1	127966.7	49.3	B31.3
910	15495.6	47654.0	-122.3	32222.2	63150.1	1.000	1.000	63150.1	127966.7	49.3	B31.3
960	15751.2	3522.8	-154.3	32222.2	36020.3	2.256	1.880	18395.9	127966.7	14.4	B31.3
960	15751.2	1566.0	154.3	32222.2	36020.1	1.000	1.000	17320.0	127966.7	13.5	B31.3
961	15773.6	1535.1	-154.3	32222.2	36020.2	1.000	1.000	17311.4	127966.7	13.5	B31.3
961	13553.0	1535.1	154.3	32222.2	36020.3	1.000	1.000	15091.2	127966.7	11.8	B31.3
1010	15495.6	3625.9	-299.3	32222.2	36024.2	2.256	1.880	18224.9	127966.7	14.2	B31.3
1010	15495.6	1614.5	299.3	32222.	36023.6	1.00	1.00	17120.6	127966.7	13.4	B31.3

Node	Axial Stress KPa	Bending Stress KPa	Torsion Stress KPa	Hoop Stress KPa	Max Stre Intensity KPa	SIF In Plane	SIF Out Plane	Code Stress KPa	Allowable Stress KPa	Ratio %	Piping Code
				2		0	0				
1060	15495.6	57243.4	-299.3	32222.2	72769.1	1.000	1.000	72741.5	127966.7	56.8	B31.3
1060	15495.6	57243.4	299.3	32222.2	72741.5	1.000	1.000	72741.5	127966.7	56.8	B31.3
1110	15495.6	44599.3	-299.3	32222.2	60125.6	1.000	1.000	60097.9	127966.7	47.0	B31.3
1110	15495.6	44599.3	299.3	32222.2	60097.9	1.000	1.000	60097.9	127966.7	47.0	B31.3
1160	15495.6	46262.1	-299.3	32222.2	61788.2	1.000	1.000	61760.6	127966.7	48.3	B31.3
1160	15495.6	46262.1	299.3	32222.2	61760.6	1.000	1.000	61760.6	127966.7	48.3	B31.3
1210	15495.6	11643.8	-299.3	32222.2	36029.6	1.000	1.000	27146.0	127966.7	21.2	B31.3
1210	15495.6	11643.8	299.3	32222.2	36029.6	1.000	1.000	27146.0	127966.7	21.2	B31.3
1260	15495.6	55650.3	-299.3	32222.2	71176.1	1.000	1.000	71148.5	127966.7	55.6	B31.3
1260	15495.6	55650.3	299.3	32222.2	71148.5	1.000	1.000	71148.5	127966.7	55.6	B31.3
1310	15495.6	48730.1	-299.3	32222.2	64256.2	1.000	1.000	64228.5	127966.7	50.2	B31.3
1310	15495.6	48730.1	299.3	32222.2	64228.5	1.000	1.000	64228.5	127966.7	50.2	B31.3
1360	15495.6	82574.6	-299.3	32222.2	98099.7	2.040	2.387	77428.9	127966.7	60.5	B31.3
1360	15481.2	79754.5	-10831.0	32222.2	97668.3	2.040	2.387	78351.1	127966.7	61.2	B31.3
1410	15481.2	68910.8	10831.0	32222.2	87182.5	1.000	1.000	87127.9	127966.7	68.1	B31.3
1410	15481.2	68910.8	-10831.0	32222.2	87127.9	1.000	1.000	87127.9	127966.7	68.1	B31.3
1460	15481.2	4642.4	10831.0	32222.2	41325.9	1.000	1.000	29566.9	127966.7	23.1	B31.3
1460	15481.2	4642.4	-10831.0	32222.2	41338.2	1.000	1.000	29566.9	127966.7	23.1	B31.3
1510	15481.2	13990.9	10831.0	32222.2	43855.8	1.000	1.000	36576.6	127966.7	28.6	B31.3
1510	15481.2	13990.9	-	32222.	43877.2	1.00	1.00	36576.6	127966.7	28.6	B31.3

Node	Axial Stress KPa	Bending Stress KPa	Torsion Stress KPa	Hoop Stress KPa	Max Stre Intensity KPa	SIF In Plane	SIF Out Plane	Code Stress KPa	Allowable Stress KPa	Ratio %	Piping Code
			10831.0	2		0	0				
1518	15481.2										
1518	15481.2	26810.7	-10831.0	32222.2	50095.1	2.256	1.880	41663.4	127966.7	32.6	B31.3
1519	15492.9	47839.5	2736.9	32222.2	63601.5	2.256	1.880	51663.4	127966.7	40.4	B31.3
1519	15492.9	47839.5	-2736.9	32222.2	63568.6	2.256	1.880	51663.4	127966.7	40.4	B31.3
1520	15514.3	41041.8	-6965.6	32222.2	58237.1	2.256	1.880	48346.3	127966.7	37.8	B31.3
1520	15514.3	21757.3	6965.6	32222.2	43662.2	1.000	1.000	39790.1	127966.7	31.1	B31.3
1530	15481.2	13395.8	-15950.1	32222.2	48280.5	2.256	1.880	40857.2	127966.7	31.9	B31.3
1530	15481.2	7125.8	15950.1	32222.2	46190.3	1.000	1.000	39098.6	127966.7	30.6	B31.3
1532	15481.2	5229.4	-15950.1	32222.2	45629.9	1.000	1.000	38033.7	127966.7	29.7	B31.3
1532	15481.2	5229.4	15950.1	32222.2	45646.7	1.000	1.000	38033.7	127966.7	29.7	B31.3
1540	15504.6	62115.9	8851.9	32222.2	79623.4	2.256	1.880	64566.1	127966.7	50.5	B31.3
1540	15504.6	33042.1	-8851.9	32222.2	52718.2	1.000	1.000	51674.0	127966.7	40.4	B31.3
1550	15481.2	23480.7	1098.1	32222.2	40030.2	2.256	1.880	33164.6	127966.7	25.9	B31.3
1550	15481.2	12376.9	-1098.1	32222.2	36175.0	1.000	1.000	27944.6	127966.7	21.8	B31.3
1560	15481.2	56242.8	1098.1	32222.2	71814.1	1.000	1.000	71757.7	127966.7	56.1	B31.3
1560	15481.2	56242.8	-1098.1	32222.2	71757.7	1.000	1.000	71757.7	127966.7	56.1	B31.3
1610	15481.2	53487.0	1098.1	32222.2	69059.6	1.000	1.000	69003.2	127966.7	53.9	B31.3
1610	15481.2	53487.0	-1098.1	32222.2	69003.2	1.000	1.000	69003.2	127966.7	53.9	B31.3
1660	15481.2	33524.3	1098.1	32222.2	49190.5	1.000	1.000	49054.8	127966.7	38.3	B31.3
1660	15481.2	33524.3	-1098.1	32222.2	49226.9	1.000	1.000	49054.8	127966.7	38.3	B31.3

Node	Axial Stress KPa	Bending Stress KPa	Torsion Stress KPa	Hoop Stress KPa	Max Stre Intensity KPa	SIF In Plane	SIF Out Plane	Code Stress KPa	Allowable Stress KPa	Ratio %	Piping Code
1710	15481.2	57367.0	1098.1	32222.2	72937.8	1.000	1.000	72881.3	127966.7	57.0	B31.3
1710	15481.2	57367.0	-1098.1	32222.2	72881.3	1.000	1.000	72881.3	127966.7	57.0	B31.3
1711	15481.2	21520.1	1098.1	32222.2	38389.9	1.000	1.000	37066.4	127966.7	29.0	B31.3
1711	15501.8	21520.1	-1098.1	32222.2	38420.2	1.000	1.000	37087.0	127966.7	29.0	B31.3
1720	15501.8	30790.4	1098.1	32222.2	46672.8	1.000	1.000	46344.3	127966.7	36.2	B31.3
1720	15501.8	30790.4	-1098.1	32222.2	46687.9	1.000	1.000	46344.3	127966.7	36.2	B31.3
1760	15501.8	40365.0	1098.1	32222.2	55925.3	2.040	2.387	45828.3	127966.7	35.8	B31.3
1760	15509.5	11804.7	-8433.8	32222.2	41076.3	2.040	2.387	29632.3	127966.7	23.2	B31.3
1761	15509.5	81456.5	8433.8	32222.2	98422.1	1.000	1.000	98422.1	127966.7	76.9	B31.3
1761	15509.5	81456.5	-8433.8	32222.2	98422.1	1.000	1.000	98422.1	127966.7	76.9	B31.3
1768	15509.5	4843.4	8433.8	32222.2	39601.6	1.000	1.000	26434.0	127966.7	20.7	B31.3
1768	15509.5	9106.0	-8433.8	32222.2	40409.9	2.256	1.880	27991.9	127966.7	21.9	B31.3
1769	15509.3	29568.6	4164.2	32222.2	46830.3	2.256	1.880	38595.1	127966.7	30.2	B31.3
1769	15509.3	29568.6	-4164.2	32222.2	46830.5	2.256	1.880	38595.1	127966.7	30.2	B31.3
1770	15509.2	32237.0	-2654.0	32222.2	48414.5	2.256	1.880	40040.4	127966.7	31.3	B31.3
1770	15509.2	17148.2	2654.0	32222.2	37647.6	1.000	1.000	33086.0	127966.7	25.9	B31.3
1780	15509.5	3239.1	-19996.3	32222.2	48532.7	2.256	1.880	43831.6	127966.7	34.3	B31.3
1780	15509.5	1721.7	19996.3	32222.2	48103.0	1.000	1.000	43546.8	127966.7	34.0	B31.3
1781	15509.5	14441.3	-19996.3	32222.2	52414.0	1.000	1.000	49964.6	127966.7	39.0	B31.3
1781	15509.5	14441.3	19996.3	32222.2	52414.0	1.000	1.000	49964.6	127966.7	39.0	B31.3

Node	Axial Stress KPa	Bending Stress KPa	Torsion Stress KPa	Hoop Stress KPa	Max Stre Intensity KPa	SIF In Plane	SIF Out Plane	Code Stress KPa	Allowable Stress KPa	Ratio %	Piping Code
1790	15509.7	77538.3	4693.4	32222.2	93519.8	2.256	1.880	74259.0	127966.7	58.0	B31.3
1790	15509.7	41246.1	-4693.4	32222.2	57526.7	1.000	1.000	57526.7	127966.7	45.0	B31.3
1800	15509.5	6269.5	0.0	32222.2	36018.9	2.256	1.880	20211.6	127966.7	15.8	B31.3
1800	15509.5	3334.5	0.0	32222.2	36018.9	1.000	1.000	18844.0	127966.7	14.7	B31.3
1810	15509.5	1212.5	-0.0	32222.2	36018.9	1.000	1.000	16722.0	127966.7	13.1	B31.3
1810	15509.5	1212.5	-0.0	32222.2	36018.9	1.000	1.000	16722.0	127966.7	13.1	B31.3
1860	15509.5	32535.5	0.0	32222.2	48202.4	1.000	1.000	48044.9	127966.7	37.5	B31.3
1860	15509.5	32535.5	0.0	32222.2	48202.4	1.000	1.000	48044.9	127966.7	37.5	B31.3
1910	15509.5	61422.9	-0.0	32222.2	76932.4	1.000	1.000	76932.4	127966.7	60.1	B31.3
1910	15509.5	61422.9	0.0	32222.2	76932.4	1.000	1.000	76932.4	127966.7	60.1	B31.3
1960	15509.5	44341.8	-0.0	32222.2	59851.2	1.000	1.000	59851.2	127966.7	46.8	B31.3
1960	15509.5	44341.8	0.0	32222.2	59851.2	1.000	1.000	59851.2	127966.7	46.8	B31.3
2010	15509.5	10484.4	0.0	32222.2	36018.9	1.000	1.000	25993.9	127966.7	20.3	B31.3
2010	15509.5	10484.4	-0.0	32222.2	36018.9	1.000	1.000	25993.9	127966.7	20.3	B31.3
2060	15509.5	44603.0	0.0	32222.2	60112.4	1.000	1.000	60112.4	127966.7	47.0	B31.3
2060	15509.5	44603.0	0.0	32222.2	60112.4	1.000	1.000	60112.4	127966.7	47.0	B31.3
2110	15509.5	31597.8	0.0	32222.2	47332.2	1.000	1.000	47107.2	127966.7	36.8	B31.3
2110	15509.5	31597.8	0.0	32222.2	47332.2	1.000	1.000	47107.2	127966.7	36.8	B31.3
2160	15509.5	43704.9	-0.0	32222.2	59214.3	1.000	1.000	59214.3	127966.7	46.3	B31.3
2160	15509.5	43704.9	0.0	32222.2	59214.3	1.000	1.000	59214.3	127966.7	46.3	B31.3

Node	Axial Stress KPa	Bending Stress KPa	Torsion Stress KPa	Hoop Stress KPa	Max Stre Intensity KPa	SIF In Plane	SIF Out Plane	Code Stress KPa	Allowable Stress KPa	Ratio %	Piping Code
2210	15509.5	42673.7	0.0	32222.2	58183.2	1.000	1.000	58183.2	127966.7	45.5	B31.3
2210	15509.5	42673.7	0.0	32222.2	58183.2	1.000	1.000	58183.2	127966.7	45.5	B31.3
2260	15509.5	31113.2	0.0	32222.2	46882.5	1.000	1.000	46622.6	127966.7	36.4	B31.3
2260	15509.5	31113.2	-0.0	32222.2	46882.5	1.000	1.000	46622.6	127966.7	36.4	B31.3
2310	15509.5	36216.6	0.0	32222.2	51726.0	1.000	1.000	51726.0	127966.7	40.4	B31.3
2310	15509.5	36216.6	-0.0	32222.2	51726.0	1.000	1.000	51726.0	127966.7	40.4	B31.3
2360	15509.5	49541.4	0.0	32222.2	65050.8	1.000	1.000	65050.8	127966.7	50.8	B31.3
2360	15509.5	49541.4	-0.0	32222.2	65050.8	1.000	1.000	65050.8	127966.7	50.8	B31.3
2410	15509.5	41735.7	0.0	32222.2	57245.2	1.000	1.000	57245.2	127966.7	44.7	B31.3
2410	15509.5	41735.7	-0.0	32222.2	57245.2	1.000	1.000	57245.2	127966.7	44.7	B31.3
2411	15509.5	35054.1	0.0	32222.2	50563.5	1.000	1.000	50563.5	127966.7	39.5	B31.3
2411	15509.5	35054.1	0.0	32222.2	50563.5	1.000	1.000	50563.5	127966.7	39.5	B31.3
2460	15509.5	0.0	-0.0	32222.2	36018.9	1.000	1.000	15509.5	127966.7	12.1	B31.3
1360	14471.9	81132.4	4.4	28750.0	95604.3	2.040	2.387	75321.2	127966.7	58.9	B31.3
2510	14471.9	51093.4	-5.2	28750.0	64173.6	1.000	1.000	65565.3	127966.7	51.2	B31.3
2510	14471.9	51093.4	5.2	28750.0	65565.3	1.000	1.000	65565.3	127966.7	51.2	B31.3
2520	14471.9	17011.5	-5.2	28750.0	32622.9	1.000	1.000	31483.5	127966.7	24.6	B31.3
2520	14471.9	17011.5	5.2	28750.0	32622.5	1.000	1.000	31483.5	127966.7	24.6	B31.3
2530	14471.9	52770.7	-5.2	28750.0	65850.8	1.000	1.000	67242.6	127966.7	52.5	B31.3
2530	14471.9	52770.7	5.2	28750.0	67242.6	1.000	1.000	67242.6	127966.7	52.5	B31.3

Node	Axial Stress KPa	Bending Stress KPa	Torsion Stress KPa	Hoop Stress KPa	Max Stre Intensity KPa	SIF In Plane	SIF Out Plane	Code Stress KPa	Allowable Stress KPa	Ratio %	Piping Code
2560	14823.9	9699.8	104.5	28750.0	32553.5	2.118	1.765	22099.7	127966.7	17.3	B31.3
2560	14823.9	4580.6	-104.5	28750.0	32552.8	1.000	1.000	19405.6	127966.7	15.2	B31.3
2561	14914.2	2957.0	104.5	28750.0	32552.8	1.000	1.000	17872.4	127966.7	14.0	B31.3
2561	14914.2	2957.0	-104.5	28750.0	32552.7	1.000	1.000	17872.4	127966.7	14.0	B31.3
2610	14471.9	17095.0	-0.0	28750.0	32699.3	2.118	1.765	27293.1	127966.7	21.3	B31.3
2610	14471.9	8073.6	0.0	28750.0	32552.1	1.000	1.000	22545.5	127966.7	17.6	B31.3
2660	14471.9	78871.4	-0.0	28750.0	91951.5	1.000	1.000	93343.3	127966.7	72.9	B31.3
2660	14471.9	78871.4	0.0	28750.0	93343.3	1.000	1.000	93343.3	127966.7	72.9	B31.3
2670	14471.9	16660.1	-0.0	28750.0	32552.1	1.000	1.000	31132.0	127966.7	24.3	B31.3
2670	13727.3	16660.1	0.0	28750.0	32552.1	1.000	1.000	30387.4	127966.7	23.7	B31.3
2710	13727.3	75916.7	-0.0	28750.0	89741.5	1.000	1.000	89644.0	127966.7	70.1	B31.3
2710	13727.3	75916.7	0.0	28750.0	89644.0	1.000	1.000	89644.0	127966.7	70.1	B31.3
2760	13727.3	54557.5	-0.0	28750.0	68382.3	1.000	1.000	68284.8	127966.7	53.4	B31.3
2760	13727.3	54557.5	0.0	28750.0	68284.8	1.000	1.000	68284.8	127966.7	53.4	B31.3
2810	13727.3	104402.4	-0.0	28750.0	118227.2	1.000	1.000	118129.7	127966.7	92.3	B31.3
2810	13727.3	104402.4	0.0	28750.0	118129.7	1.000	1.000	118129.7	127966.7	92.3	B31.3
2818	13727.3	56347.8	-0.0	28750.0	70172.6	1.000	1.000	70075.0	127966.7	54.8	B31.3
2818	13727.3	119321.7	0.0	28750.0	133049.0	2.118	1.765	103218.6	127966.7	80.7	B31.3
2819	11862.1	93434.1	-2.5	28750.0	109124.1	2.118	1.765	81937.6	127966.7	64.0	B31.3
2819	11862.1	93434.1	2.5	28750.0	105296.2	2.118	1.765	81937.6	127966.7	64.0	B31.3

Node	Axial Stress KPa	Bending Stress KPa	Torsion Stress KPa	Hoop Stress KPa	Max Stress Intensity KPa	SIF In Plane	SIF Out Plane	Code Stress KPa	Allowable Stress KPa	Ratio %	Piping Code
2820	11160.7	83253.2	-3.4	28750.0	99644.6	2.118	1.765	73600.6	127966.7	57.5	B31.3
2820	11160.7	39315.0	3.4	28750.0	55061.2	1.000	1.000	50475.7	127966.7	39.4	B31.3
2830	13727.3	71352.1	-3.3	28750.0	85177.0	2.118	1.765	67241.4	127966.7	52.5	B31.3
2830	13727.3	33694.9	3.3	28750.0	47422.2	1.000	1.000	47422.2	127966.7	37.1	B31.3
2840	14974.8	88521.5	1.8	28750.0	101098.8	2.118	1.765	81365.9	127966.7	63.6	B31.3
2840	14974.8	41802.9	-1.8	28750.0	56777.7	1.000	1.000	56777.7	127966.7	44.4	B31.3
2850	13727.3	103755.8	-0.0	28750.0	117580.6	2.118	1.765	91544.1	127966.7	71.5	B31.3
2850	13727.3	48997.0	0.0	28750.0	62724.3	1.000	1.000	62724.3	127966.7	49.0	B31.3
2900	13727.3	43166.0	-0.0	28750.0	56990.8	1.000	1.000	56893.2	127966.7	44.5	B31.3
2900	13727.3	43166.0	0.0	28750.0	56893.2	1.000	1.000	56893.2	127966.7	44.5	B31.3
2910	13727.3	101191.6	-0.0	28750.0	115016.5	1.000	1.000	114918.9	127966.7	89.8	B31.3
2910	13727.3	101191.6	0.0	28750.0	114918.9	1.000	1.000	114918.9	127966.7	89.8	B31.3
2960	13727.3	40662.8	0.0	28750.0	54487.6	1.000	1.000	54390.0	127966.7	42.5	B31.3
2960	13727.3	40662.8	-0.0	28750.0	54390.0	1.000	1.000	54390.0	127966.7	42.5	B31.3
3010	13727.3	89709.8	0.0	28750.0	103534.6	1.000	1.000	103437.1	127966.7	80.8	B31.3
3010	13776.0	89709.8	0.0	28750.0	103485.8	1.000	1.000	103485.8	127966.7	80.9	B31.3
3060	13776.0	47753.3	0.0	28750.0	61529.4	1.000	1.000	61529.4	127966.7	48.1	B31.3
3060	13776.0	47753.3	0.0	28750.0	61529.4	1.000	1.000	61529.4	127966.7	48.1	B31.3
3110	13776.0	92213.9	-0.0	28750.0	105989.9	1.000	1.000	105989.9	127966.7	82.8	B31.3
3110	13776.0	92213.9	0.0	28750.0	105989.9	1.000	1.000	105989.9	127966.7	82.8	B31.3

Node	Axial Stress KPa	Bending Stress KPa	Torsion Stress KPa	Hoop Stress KPa	Max Stre Intensity KPa	SIF In Plane	SIF Out Plane	Code Stress KPa	Allowable Stress KPa	Ratio %	Piping Code
3160	13776.0	0.0	-0.0	28750.0	32552.1	1.000	1.000	13776.0	127966.7	10.8	B31.3
1760	15504.6	17238.9	0.0	32222.2	36018.9	2.040	2.387	28433.7	127966.7	22.2	B31.3
3210	15504.6	20238.0	-0.0	32222.2	36795.2	1.000	1.000	35742.5	127966.7	27.9	B31.3
3210	15504.6	20238.0	0.0	32222.2	36795.2	1.000	1.000	35742.5	127966.7	27.9	B31.3
3260	15504.6	37266.9	-0.0	32222.2	52781.3	1.000	1.000	52771.5	127966.7	41.2	B31.3
3260	15504.6	37266.9	0.0	32222.2	52771.5	1.000	1.000	52771.5	127966.7	41.2	B31.3
3310	15504.6	25521.1	-0.0	32222.2	41697.9	1.000	1.000	41025.6	127966.7	32.1	B31.3
3310	15504.6	25521.1	0.0	32222.2	41697.9	1.000	1.000	41025.6	127966.7	32.1	B31.3
3360	15504.6	39722.6	-0.0	32222.2	55236.9	1.000	1.000	55227.2	127966.7	43.2	B31.3
3360	15509.5	39722.6	0.0	32222.2	55232.1	1.000	1.000	55232.1	127966.7	43.2	B31.3
3410	15509.5	25884.0	-0.0	32222.2	42029.8	1.000	1.000	41393.5	127966.7	32.3	B31.3
3410	15509.5	25884.0	0.0	32222.2	42029.8	1.000	1.000	41393.5	127966.7	32.3	B31.3
3460	15509.5	42431.7	-0.0	32222.2	57941.1	1.000	1.000	57941.1	127966.7	45.3	B31.3
3460	15509.5	42431.7	0.0	32222.2	57941.1	1.000	1.000	57941.1	127966.7	45.3	B31.3
3510	15509.5	0.0	-0.0	32222.2	36018.9	1.000	1.000	15509.5	127966.7	12.1	B31.3

7.3.2 OPERATIONAL LOAD CASES:

This shall include effects of pressure, temperature, pipe dead weight, insulation weight of the contents and other externally imposed displacement such as nozzle.

Displacements etc. This load case is required to be performed to establish that the operating condition loads on the equipment nozzle and pipe supports are within safe limits.

7.3.2.1 Displacement Loads:

Those loads which act on the pipe due to its displacement. Small and insignificant nodal displacements within the allowable limits are ignored, but if the displacement is more than 10mm, then necessary guide supports or restraints must be provided to check that displacement. A gap of 3mm is allowed during the placement of guide supports. For further Illustration, refer displacement load case report of WI-Discharge given below.

Table 7.3.2.1: Displacement

Node	DX mm.	DY mm.	DZ mm.	RX deg.	RY deg.	RZ deg.
10	0.600	-0.000	-0.000	0.0000	-0.4458	-0.1317
58	-20.420	17.368	-34.584	0.5105	-0.1673	-0.2247
59	-21.477	17.303	-34.468	0.5628	0.0487	-0.1779
60	-21.154	14.697	-33.225	0.6991	0.2549	-0.1322
110	-15.226	-0.000	-28.935	0.8058	0.3360	-0.1165
120	-0.000	-38.597	-19.404	0.9015	0.3114	-0.0815
160	14.999	-97.990	-0.000	0.3068	0.0532	-0.0103
210	10.782	-10.037	33.157	-0.7264	0.0514	0.1218
211	5.000	-0.000	5.000	-0.4704	0.1419	0.1231
220	2.916	3.816	-2.163	-0.3620	0.1764	0.1160
260	-2.432	11.043	-11.486	-0.2772	0.2684	0.0995
310	-16.261	-0.000	-0.000	-0.3421	-0.0134	0.3348
360	-32.431	-26.589	-13.645	-0.3837	-0.2229	0.4533
410	-40.075	-21.528	-17.612	-0.1944	-0.1210	0.3657
460	-41.306	-19.555	-15.232	-0.1709	-0.1047	0.3491
470	-45.193	-8.900	-0.000	-0.1590	-0.0092	0.2425
480	-39.665	-0.000	23.148	0.1521	0.1073	0.0801
490	-22.244	-29.624	47.851	0.0638	0.1931	-0.0931
518	-4.666	-5.947	65.773	-0.6563	0.2305	-0.2188
519	-3.123	-1.838	65.147	-0.9456	0.2506	-0.2355
520	-1.453	1.159	60.563	-1.1839	0.2648	-0.2731
530	14.319	15.498	8.950	-0.3604	0.3111	-0.3646
540	17.849	16.636	10.435	0.7567	0.3059	-0.4204
550	-0.666	1.485	-29.324	0.6868	0.3051	-0.5084
560	0.000	-0.000	-28.849	0.6791	0.3055	-0.5117

Node	DX mm.	DY mm.	DZ mm.	RX deg.	RY deg.	RZ deg.
610	40.154	-32.913	0.000	-0.2697	0.2848	-0.7141
660	62.825	9.863	19.391	-0.5416	0.2183	-0.8497
710	63.072	10.478	19.638	-0.5383	0.2172	-0.8515
760	63.800	23.633	27.195	0.2544	0.1165	-0.9664
770	-0.000	9.840	0.000	0.4950	0.0199	-1.0541
810	-66.474	-7.644	-33.213	0.3939	-0.1397	0.0792
860	-56.797	-0.000	-26.075	0.3684	-0.1783	0.1134
870	-26.335	-12.111	-0.000	0.2879	-0.1596	0.0018
910	0.000	-0.000	13.321	0.2183	-0.0661	0.0032
960	23.325	-0.477	17.952	0.1267	0.0210	0.6256
961	21.944	-0.000	18.228	0.1257	0.0221	0.6389
1010	-93.333	35.718	33.243	0.0714	0.1216	0.0242
1060	-62.363	-0.000	12.925	0.0505	0.1582	-0.4525
1110	-30.276	-45.650	-10.518	0.0289	0.1537	0.0941
1160	-2.000	-0.000	-28.212	0.0098	0.1140	0.3132
1210	20.516	10.391	-37.296	-0.0054	0.0583	-0.0228
1260	37.325	-0.000	-39.730	-0.0168	0.0028	-0.3146
1310	99.790	-0.000	0.000	-0.0590	-0.3075	0.3672
1360	120.404	14.015	22.571	-0.0730	-0.0332	-0.0556
1410	134.428	-0.000	22.882	0.1637	0.0673	-0.4286
1460	152.260	-50.862	-0.000	0.4646	0.5624	-0.6906
1510	160.573	-76.357	-27.551	0.6049	0.8801	-0.6387
1518	161.049	-77.746	-29.491	0.6129	0.8977	-0.6346
1519	159.984	-79.286	-34.677	0.6632	1.1736	-0.5538
1520	154.339	-76.994	-38.111	0.7645	1.4233	-0.5064
1530	17.889	3.214	-63.534	0.6982	0.2658	-0.2988
1532	20.268	-0.000	-65.628	0.6394	0.1175	-0.2968
1540	24.192	-16.125	-49.276	0.1763	-1.4858	-0.0861
1550	-149.851	-13.394	-17.796	-0.1631	-1.3556	0.2599
1560	-137.255	-0.000	49.152	-0.1424	-0.9703	0.1159
1610	-85.158	-0.000	129.289	-0.0567	0.1801	-0.0992
1660	-52.097	-22.623	71.037	-0.0024	0.5404	0.0833
1710	-26.651	-0.000	1.555	0.0395	0.6222	0.0761
1711	0.000	-8.532	-70.470	0.0833	0.5255	-0.0083
1720	22.888	-0.000	-114.593	0.1209	0.2941	0.0531
1760	29.311	0.138	-121.949	0.1314	0.2045	-0.0337
1761	-5.000	-0.000	-140.995	-0.2795	0.6232	-0.2770
1768	-122.775	-71.372	-167.282	-0.6819	1.3141	-0.6128
1769	-129.677	-73.246	-165.542	-0.6432	1.4943	-0.6442
1770	-133.665	-71.308	-158.635	-0.6155	1.6550	-0.7154
1780	-162.168	6.622	8.196	-0.6047	0.4761	-0.5344
1781	-166.632	-0.000	5.816	-0.6158	0.3419	-0.4623
1790	-164.178	-32.948	-0.450	-0.4851	-1.0946	0.0774
1800	-132.222	0.631	150.480	-0.2910	-1.1965	0.5218

Node	DX mm.	DY mm.	DZ mm.	RX deg.	RY deg.	RZ deg.
1810	-129.622	-0.000	150.004	-0.2903	-1.1864	0.5218
1860	-32.305	-16.184	128.003	0.0375	-0.7574	0.5218
1910	32.248	-0.000	102.192	-0.0031	-0.3521	0.5218
1960	45.607	-0.000	45.908	0.0972	0.1645	0.5218
2010	27.082	-1.399	25.811	-0.0182	0.2270	0.5218
2060	0.000	-0.000	-0.000	-0.0984	0.2132	0.5218
2110	-21.402	-18.408	-25.851	-0.0188	0.1499	0.5218
2160	-36.535	-0.000	-53.610	0.1031	0.0898	0.5218
2210	-46.363	-0.000	-98.536	-0.0986	0.0094	0.5218
2260	-45.233	-17.419	-124.387	-0.0081	-0.0273	0.5218
2310	-40.174	-0.000	-150.237	0.1312	-0.0571	0.5218
2360	-26.065	-0.000	-191.349	-0.1849	-0.0900	0.5218
2410	-12.871	-29.499	-221.015	0.0163	-0.1029	0.5218
2411	-0.000	-0.000	-247.721	0.2647	-0.1066	0.5218
2460	8.884	14.223	-265.942	0.1401	-0.1066	0.5218
2510	103.439	-0.000	11.441	-0.5253	0.6328	-0.1863
2520	61.092	-37.299	0.000	-0.7774	0.9146	-0.3207
2530	2.000	-78.426	-15.233	-0.2906	0.6551	-0.4998
2560	-25.989	-47.628	-32.839	1.0382	0.0128	-0.8334
2561	-18.657	-45.719	-23.613	1.0685	-0.0097	-0.8451
2610	-4.878	-36.914	-7.961	0.9742	-0.0938	-0.8817
2660	-0.000	-0.000	-17.736	0.5832	-0.1006	-0.8817
2670	4.164	16.711	-44.394	-0.0007	0.0163	-0.8817
2710	0.000	-0.000	-70.541	-0.5795	0.0377	-0.8817
2760	-3.660	-105.764	-104.306	-0.0606	0.0116	-0.8817
2810	-4.220	-0.000	-136.166	1.0543	-0.0022	-0.8817
2818	-4.185	14.383	-139.213	1.0296	-0.0029	-0.8817
2819	-2.820	18.620	-138.384	1.0931	-0.0040	-0.8820
2820	0.453	21.144	-134.515	1.1705	-0.0044	-0.8822
2830	78.965	39.162	-55.127	-0.6520	-0.0105	-0.8795
2840	74.854	-5.286	-55.940	-1.7689	-0.0133	-0.8756
2850	-2.879	-30.345	102.687	-0.7792	-0.0167	-0.8733
2900	-1.814	-49.175	89.107	0.1338	-0.0172	-0.8733
2910	-0.000	-0.000	63.720	0.1562	-0.0129	-0.8733
2960	1.195	-30.847	33.764	-0.0817	-0.0049	-0.8733
3010	1.417	-0.000	-0.000	-0.0564	0.0016	-0.8733
3060	0.848	-43.427	-33.826	0.0636	0.0053	-0.8733
3110	0.000	-0.000	-64.347	0.0347	0.0064	-0.8733
3160	-0.771	-48.888	-90.538	-0.5544	0.0064	-0.8733
3210	25.730	-7.076	-101.936	-0.0285	-0.2205	-0.0337
3260	0.000	-0.000	-81.923	-0.0115	-0.2785	-0.0337
3310	-31.158	-0.000	-39.057	-0.0379	-0.0532	-0.0337
3360	-27.946	-0.000	0.000	0.0923	0.0771	-0.0337
3410	-18.947	-14.365	20.047	0.0905	0.1160	-0.0337

Node	DX mm.	DY mm.	DZ mm.	RX deg.	RY deg.	RZ deg.
3460	-0.000	-0.000	51.540	-0.0787	0.1392	-0.0337
3510	12.768	-4.262	71.586	0.0873	0.1392	-0.0337

7.3.2.2 RESTRAIN REPORT

Table 7.3.2.2: Restrain report

Node	FX N.	FY N.	FZ N.	MX N.m.	MY N.m.	MZ N.m.	
10	0	0	0	0	0	0	Flex X
10	0	0	0	12946	0	0	Rigid RX
10	0	0	0	0	0	0	Rigid Z
10	0	0	0	0	0	-293	Flex RZ
10	0	-3455	0	0	0	0	Rigid Y
10	0	0	0	0	-0	0	Flex RY
110	0	-16827	0	0	0	0	Rigid +Y
211	0	-16294	0	0	0	0	Rigid +Y
310	0	-16725	0	0	0	0	Rigid +Y
510	0	-15777	0	0	0	0	Rigid +Y
560	0	-17347	0	0	0	0	Rigid +Y
660	0	-15567	0	0	0	0	Rigid +Y
860	0	-17083	0	0	0	0	Rigid +Y
910	0	-16093	0	0	0	0	Rigid +Y
961	0	-15109	0	0	0	0	Rigid +Y
1060	0	-17814	0	0	0	0	Rigid +Y
1160	0	-15285	0	0	0	0	Rigid +Y
1260	0	-16858	0	0	0	0	Rigid +Y
1310	0	-14962	0	0	0	0	Rigid +Y
1410	0	-14966	0	0	0	0	Rigid +Y
1510	0	-17128	0	0	0	0	Rigid +Y
1610	0	-16977	0	0	0	0	Rigid +Y
1710	0	-15546	0	0	0	0	Rigid +Y
1720	0	-21654	0	0	0	0	Rigid +Y
1810	0	-15966	0	0	0	0	Rigid +Y
1910	0	-16770	0	0	0	0	Rigid +Y
1960	0	-16651	0	0	0	0	Rigid +Y
2060	0	-16538	0	0	0	0	Rigid +Y
2160	0	-16120	0	0	0	0	Rigid +Y
2210	0	-15457	0	0	0	0	Rigid +Y
2310	0	-14169	0	0	0	0	Rigid +Y
2360	0	-16433	0	0	0	0	Rigid +Y
2411	0	-14430	0	0	0	0	Rigid +Y

Node	FX N.	FY N.	FZ N.	MX N.m.	MY N.m.	MZ N.m.	
2510	0	-12499	0	0	0	0	Rigid +Y
2660	0	-14306	0	0	0	0	Rigid +Y
2710	0	-13525	0	0	0	0	Rigid +Y
2810	0	-15120	0	0	0	0	Rigid +Y
2910	0	-13344	0	0	0	0	Rigid +Y
3010	0	-13650	0	0	0	0	Rigid +Y
3110	0	-13071	0	0	0	0	Rigid +Y
3260	0	-14079	0	0	0	0	Rigid +Y
3310	0	-12154	0	0	0	0	Rigid +Y
3360	0	-14940	0	0	0	0	Rigid +Y
3460	0	-14709	0	0	0	0	Rigid +Y

7.3.3 Expansion Load

These are loads due to displacement of piping**.** E.g. Thermal expansion, seismic anchor movements and building settlement.

LOAD CASE DEFINITION KEY

CASE 3 (EXP) L3=L1-L2

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

*** CODE COMPLIANCE EVALUATION PASSED ***

Highest Stresses: (KPa)

Ratio (%): 85.4 @Node 1540 LOADCASE: 3 (EXP) L3=L1-L2

Code Stress: 228546.7 Allowable Stresses: 267761.2

Axial Stress: 2945.8 @Node 480 LOADCASE: 3 (EXP) L3=L1-L2

Bending Stress: 238499.9 @Node 1530 LOADCASE: 3 (EXP) L3=L1-L2

Torsion Stress: 9199.7 @Node 360 LOADCASE: 3 (EXP) L3=L1-L2

Hoop Stress: 0.0 @Node 58 LOADCASE: 3 (EXP) L3=L1-L2

Max Stress Intensity: 240096.8 @Node 1530 LOADCASE: 3 (EXP) L3=L1-L2

Table 7.3.3: Code Evaluation

Load Case	From Node	Code Stress KPa	Allowable Stress KPa	To Node	Code Stress KPa	Allowable Stress KPa	Piping Code
3(EXP)	10	5190.4	297403.8	58	69015.8	284746.8	B31.3
3(EXP)	58	155577.4	272685.6	59	157175.8	264909.5	B31.3
3(EXP)	59	157175.8	264909.5	60	144891.6	258031.4	B31.3
3(EXP)	60	64317.5	277335.6	110	35294.7	267791.5	B31.3
3(EXP)	110	35294.7	267791.5	120	30105.5	303023.6	B31.3
3(EXP)	120	30105.5	303023.6	160	18456.2	239813.1	B31.3
3(EXP)	160	18456.2	239813.1	210	11167.8	261106.3	B31.3
3(EXP)	210	7226.0	282999.1	211	39008.9	293460.4	B31.3
3(EXP)	211	39008.9	295354.1	220	22173.8	299306.8	B31.3
3(EXP)	220	22173.8	299306.8	260	14723.8	306552.0	B31.3
3(EXP)	260	14272.5	309451.6	310	64826.3	247670.8	B31.3
3(EXP)	310	64826.3	247670.8	360	26567.7	304459.1	B31.3
3(EXP)	360	20468.3	308096.2	410	49237.0	304541.2	B31.3
3(EXP)	410	24751.0	308718.6	460	24122.3	310409.1	B31.3
3(EXP)	460	24122.3	310409.1	470	20142.3	301411.7	B31.3
3(EXP)	470	20142.3	301411.7	480	14332.6	256691.2	B31.3
3(EXP)	480	14332.6	256691.2	490	27766.6	285253.0	B31.3
3(EXP)	490	27766.6	285253.0	518	51246.1	300056.8	B31.3
3(EXP)	518	114779.2	288510.8	519	105731.0	292958.4	B31.3
3(EXP)	519	105731.0	292958.4	520	77012.2	295226.6	B31.3
3(EXP)	520	34367.8	303676.3	530	219574.0	314037.5	B31.3
3(EXP)	530	97422.8	315020.2	540	163770.4	277974.7	B31.3
3(EXP)	540	72649.9	294377.5	550	140942.6	261069.9	B31.3
3(EXP)	550	62765.0	283851.3	560	63407.6	279612.2	B31.3

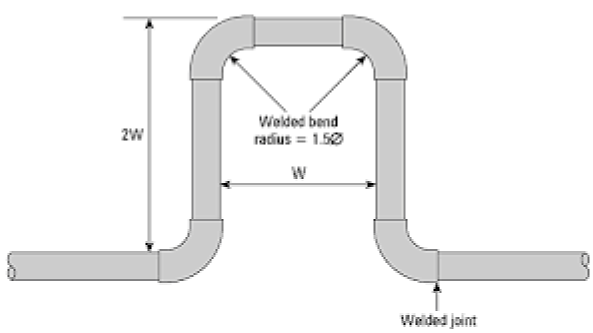
Load Case	From Node	Code Stress KPa	Allowable Stress KPa	To Node	Code Stress KPa	Allowable Stress KPa	Piping Code
3(EXP)	560	63407.6	279612.2	610	32334.1	291527.7	B31.3
3(EXP)	610	32334.1	291472.3	660	14442.7	284710.8	B31.3
3(EXP)	660	14442.7	284710.8	710	12769.3	285851.8	B31.3
3(EXP)	710	12769.3	285851.8	760	153144.2	311515.5	B31.3
3(EXP)	760	68513.3	313085.2	770	17050.3	313912.0	B31.3
3(EXP)	770	17050.3	313912.0	810	187010.0	311766.8	B31.3
3(EXP)	810	83108.2	313858.5	860	22300.9	267604.5	B31.3
3(EXP)	860	22300.9	267604.5	870	14516.8	280218.7	B31.3
3(EXP)	870	14516.8	280218.7	910	7420.5	269230.1	B31.3
3(EXP)	910	7420.5	269177.2	960	105980.1	313931.3	B31.3
3(EXP)	960	47128.3	315007.3	961	45659.4	315015.9	B31.3
3(EXP)	961	45659.4	317236.1	1010	129111.5	314102.4	B31.3
3(EXP)	1010	57264.9	315206.7	1060	26458.5	259585.8	B31.3
3(EXP)	1060	26458.5	259585.8	1110	8462.8	272229.3	B31.3
3(EXP)	1110	8462.8	272229.3	1160	9705.9	270566.7	B31.3
3(EXP)	1160	9705.9	270566.7	1210	7985.0	305181.3	B31.3
3(EXP)	1210	7985.0	305181.3	1260	9031.0	261178.8	B31.3
3(EXP)	1260	9031.0	261178.8	1310	15110.0	268098.8	B31.3
3(EXP)	1310	15110.0	268098.8	1360	167587.7	254898.4	B31.3
3(EXP)	1360	41123.2	253976.2	1410	39057.5	245199.4	B31.3
3(EXP)	1410	39057.5	245199.4	1460	63878.8	302760.3	B31.3
3(EXP)	1460	63878.8	302760.3	1510	60332.8	295750.7	B31.3
3(EXP)	1510	60332.8	295750.7	1518	60129.9	295639.7	B31.3
3(EXP)	1518	135637.8	290663.9	1519	127872.2	280663.9	B31.3
3(EXP)	1519	127872.2	280663.9	1520	111054.2	283981.0	B31.3

Load Case	From Node	Code Stress KPa	Allowable Stress KPa	To Node	Code Stress KPa	Allowable Stress KPa	Piping Code
3(EXP)	1520	49232.0	292537.2	1530	238501.0	291470.1	B31.3
3(EXP)	1530	105726.6	293228.6	1532	106739.3	294293.6	B31.3
3(EXP)	1532	106739.3	294293.6	1540	228546.7	267761.2	B31.3
3(EXP)	1540	101312.6	280653.3	1550	118261.0	299162.7	B31.3
3(EXP)	1550	52423.7	304382.7	1560	47062.0	260569.6	B31.3
3(EXP)	1560	47062.0	260569.6	1610	24877.7	263324.1	B31.3
3(EXP)	1610	24877.7	263324.1	1660	10800.4	283272.5	B31.3
3(EXP)	1660	10800.4	283272.5	1710	53.2	259446.0	B31.3
3(EXP)	1710	53.2	259446.0	1711	11382.2	295260.8	B31.3
3(EXP)	1711	11382.2	295240.3	1720	21108.9	285983.0	B31.3
3(EXP)	1720	21108.9	285983.0	1760	48633.7	286499.0	B31.3
3(EXP)	1760	54551.4	302695.0	1761	48527.0	233905.2	B31.3
3(EXP)	1761	48527.0	233905.2	1768	41378.9	305893.3	B31.3
3(EXP)	1768	93345.5	304335.3	1769	87528.3	293732.2	B31.3
3(EXP)	1769	87528.3	293732.2	1770	74723.5	292286.9	B31.3
3(EXP)	1770	33124.0	299241.3	1780	216001.0	288495.6	B31.3
3(EXP)	1780	95750.6	288780.5	1781	96397.9	282362.7	B31.3
3(EXP)	1781	96397.9	282362.7	1790	206725.6	258068.2	B31.3
3(EXP)	1790	91638.9	274800.6	1800	82245.7	312115.7	B31.3
3(EXP)	1800	36458.5	313483.3	1810	36329.0	315605.3	B31.3
3(EXP)	1810	36329.0	315605.3	1860	30346.3	284282.4	B31.3
3(EXP)	1860	30346.3	284282.4	1910	23327.7	255394.9	B31.3
3(EXP)	1910	23327.7	255394.9	1960	8022.6	272476.1	B31.3
3(EXP)	1960	8022.6	272476.1	2010	2557.8	306333.4	B31.3
3(EXP)	2010	2557.8	306333.4	2060	4460.8	272214.8	B31.3

Load Case	From Node	Code Stress KPa	Allowable Stress KPa	To Node	Code Stress KPa	Allowable Stress KPa	Piping Code
3(EXP)	2060	4460.8	272214.8	2110	3995.3	285220.0	B31.3
3(EXP)	2110	3995.3	285220.0	2160	3495.4	273112.9	B31.3
3(EXP)	2160	3495.4	273112.9	2210	2686.4	274144.1	B31.3
3(EXP)	2210	2686.4	274144.1	2260	2220.9	285704.7	B31.3
3(EXP)	2260	2220.9	285704.7	2310	1755.4	280601.3	B31.3
3(EXP)	2310	1755.4	280601.3	2360	1015.1	267276.4	B31.3
3(EXP)	2360	1015.1	267276.4	2410	480.9	275082.1	B31.3
3(EXP)	2410	480.9	275082.1	2411	0.0	281763.8	B31.3
3(EXP)	2411	0.0	281763.8	2460	0.0	316817.8	B31.3
3(EXP)	1360	191546.2	257006.0	2510	66736.1	266761.9	B31.3
3(EXP)	2510	66736.1	266761.9	2520	18143.8	300843.8	B31.3
3(EXP)	2520	18143.8	300843.8	2530	59197.5	265084.7	B31.3
3(EXP)	2530	59197.5	265084.7	2560	75253.0	310227.5	B31.3
3(EXP)	2560	37689.3	312921.7	2561	18096.2	314454.9	B31.3
3(EXP)	2561	18096.2	314454.9	2610	63100.4	305034.1	B31.3
3(EXP)	2610	30360.3	309781.8	2660	16381.7	238984.0	B31.3
3(EXP)	2660	16381.7	238984.0	2670	15738.3	301195.3	B31.3
3(EXP)	2670	15738.3	301939.9	2710	16583.8	242683.3	B31.3
3(EXP)	2710	16583.8	242683.3	2760	28572.7	264042.5	B31.3
3(EXP)	2760	28572.7	264042.5	2810	71116.4	214197.6	B31.3
3(EXP)	2810	71116.4	214197.6	2818	67087.6	262252.3	B31.3
3(EXP)	2818	142063.8	229108.7	2819	134280.3	250389.6	B31.3
3(EXP)	2819	134280.3	250389.6	2820	120014.2	258726.7	B31.3
3(EXP)	2820	56675.4	281851.6	2830	203632.1	265085.9	B31.3
3(EXP)	2830	96162.5	284905.1	2840	210375.5	250961.3	B31.3

Load Case	From Node	Code Stress KPa	Allowable Stress KPa	To Node	Code Stress KPa	Allowable Stress KPa	Piping Code
3(EXP)	2840	99346.7	275549.6	2850	106872.3	240783.2	B31.3
3(EXP)	2850	50468.8	269603.0	2900	32510.2	275434.1	B31.3
3(EXP)	2900	32510.2	275434.1	2910	1133.2	217408.4	B31.3
3(EXP)	2910	1133.2	217408.4	2960	535.1	277937.3	B31.3
3(EXP)	2960	535.1	277937.3	3010	332.1	228890.2	B31.3
3(EXP)	3010	332.1	228841.5	3060	157.5	270797.9	B31.3
3(EXP)	3060	157.5	270797.9	3110	0.0	226337.4	B31.3
3(EXP)	3110	0.0	226337.4	3160	0.0	318551.2	B31.3
3(EXP)	1760	103185.1	303893.5	3210	20019.7	296584.7	B31.3
3(EXP)	3210	20019.7	296584.7	3260	10537.6	279555.8	B31.3
3(EXP)	3260	10537.6	279555.8	3310	7150.9	291301.7	B31.3
3(EXP)	3310	7150.9	291301.7	3360	4065.1	277100.1	B31.3
3(EXP)	3360	4065.1	277095.2	3410	2483.9	290933.8	B31.3
3(EXP)	3410	2483.9	290933.8	3460	0.0	274386.1	B31.3
3(EXP)	3460	0.0	274386.1	3510	0.0	316817.8	B31.3

7.3.3.1 Expansion Loop



$$W = \frac{6.2225 * \sqrt{\Delta}\, D}{5}$$

L=W*2

W-Width of the loop

L-Length of the loop

D-Outside diameter of the pipe

$\sqrt{\Delta}$-Deflection of pipe

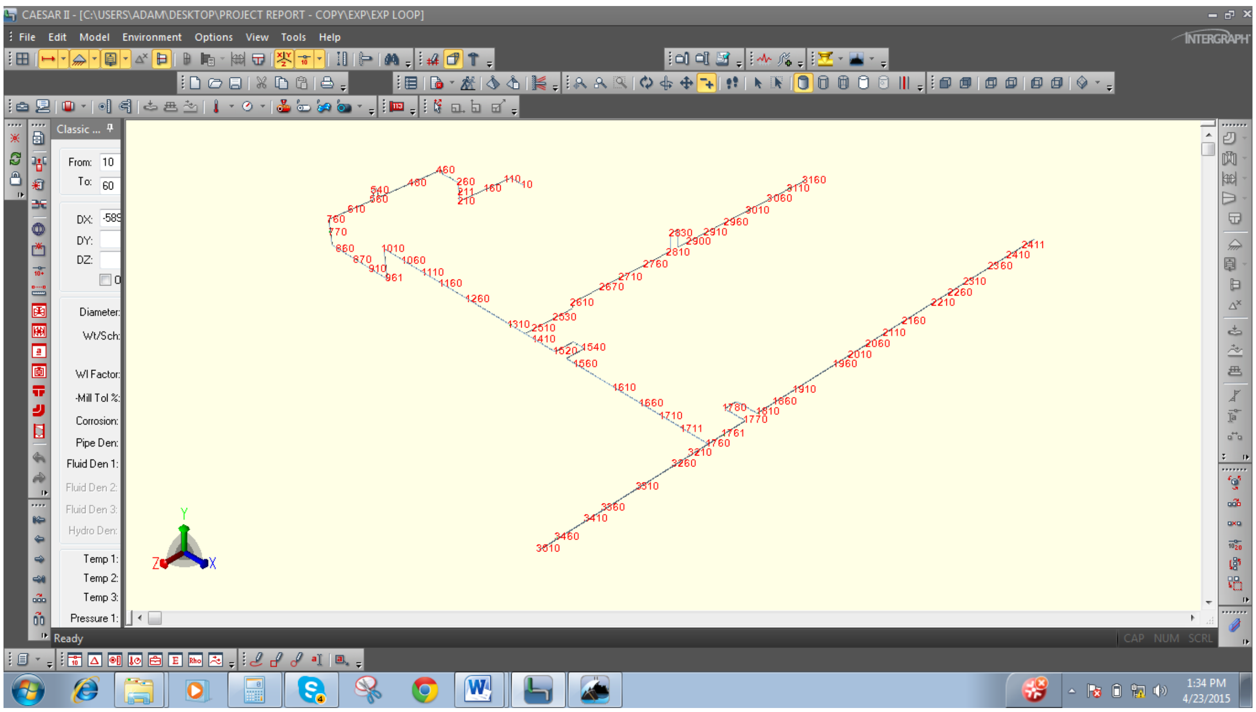


Fig 7.3.3.1:Expansion Loop

LOAD CASE DEFINITION KEY

CASE 1 (OPE) W+T1+P1

CASE 2 (SUS) W+P1

CASE 3 (EXP) L3=L1-L2

Table 7.3.3.1 Loop Determination

Node	Load Case	FX N.	FY N.	FZ N.	MX N.m.	MY N.m.	MZ N.m.
10		Flex X; Rigid RX; Rigid Z; Flex RZ; Rigid Y; Flex RY					
	1(OPE)	8022	-3213	-3625	12707	-1043	-308
	2(SUS)	-2261	-3455	1663	11854	828	-258
	3(EXP)	10283	242	-5288	853	-1871	-50
	MAX	10283/L3	-3455/L2	-5288/L3	12707/L1	-1871/L3	-308/L1
110		Rigid +Y					
	1(OPE)	0	-16950	0	0	0	0
	2(SUS)	0	-16422	0	0	0	0
	3(EXP)	0	-528	0	0	0	0
	MAX		-16950/L1				
120		Rigid GUI					
	1(OPE)	-9110	0	0	0	0	0
	2(SUS)	2101	0	0	0	0	0
	3(EXP)	-11211	0	0	0	0	0
	MAX	-11211/L3					
160		Rigid +Z					
	1(OPE)	0	0	-1071	0	0	0
	2(SUS)	0	0	0	0	0	0
	3(EXP)	0	0	-1071	0	0	0
	MAX			-1071/L1			
211		Rigid +Y; Rigid GUI w/gap; Rigid GUI w/gap					

Node	Load Case	FX N.	FY N.	FZ N.	MX N.m.	MY N.m.	MZ N.m.
	1(OPE)	1255	-13161	13167	0	0	0
	2(SUS)	40	-13086	0	0	0	0
	3(EXP)	1214	-75	13167	0	0	0
	MAX	1255/L1	-13161/L1	13167/L1			
310		Rigid +Y; Rigid GUI					
	1(OPE)	0	-19420	-18410	0	0	0
	2(SUS)	0	-19479	-2134	0	0	0
	3(EXP)	0	59	-16277	0	0	0
	MAX		-19479/L2	-18410/L1			
470		Rigid +Z					
	1(OPE)	0	0	-10605	0	0	0
	2(SUS)	0	0	0	0	0	0
	3(EXP)	0	0	-10605	0	0	0
	MAX			-10605/L1			
480		Rigid +Y					
	1(OPE)	0	-19860	0	0	0	0
	2(SUS)	0	-18111	0	0	0	0
	3(EXP)	0	-1749	0	0	0	0
	MAX		-19860/L1				
560		Rigid +Y; Rigid GUI					
	1(OPE)	122	-17712	0	0	0	0
	2(SUS)	143	-21421	0	0	0	0
	3(EXP)	-21	3709	0	0	0	0
	MAX	143/L2	-21421/L2				
610		Rigid –Z					
	1(OPE)	0	0	11898	0	0	0
	2(SUS)	0	0	378	0	0	0
	3(EXP)	0	0	11520	0	0	0
	MAX						

Node	Load Case	FX N.	FY N.	FZ N.	MX N.m.	MY N.m.	MZ N.m.
				11898/L1			
660		Rigid +Y					
	1(OPE)	0	0	0	0	0	0
	2(SUS)	0	-14571	0	0	0	0
	3(EXP)	0	14571	0	0	0	0
	MAX		-14571/L2				
770		Rigid GUI; Rigid GUI					
	1(OPE)	-10727	0	9235	0	0	0
	2(SUS)	-478	0	31	0	0	0
	3(EXP)	-10249	0	9204	0	0	0
	MAX	-10727/L1		9235/L1			
860		Rigid +Y					
	1(OPE)	0	-34632	0	0	0	0
	2(SUS)	0	-17890	0	0	0	0
	3(EXP)	0	-16742	0	0	0	0
	MAX		-34632/L1				
870		Rigid GUI					
	1(OPE)	0	0	-697	0	0	0
	2(SUS)	0	0	96	0	0	0
	3(EXP)	0	0	-794	0	0	0
	MAX			-794/L3			
910		Rigid +Y; Rigid –X					
	1(OPE)	5670	-18631	0	0	0	0
	2(SUS)	361	-16081	0	0	0	0
	3(EXP)	5309	-2550	0	0	0	0
	MAX	5670/L1	-18631/L1				
961		Rigid +Y					
	1(OPE)	0	-16147	0	0	0	0

Node	Load Case	FX N.	FY N.	FZ N.	MX N.m.	MY N.m.	MZ N.m.
	2(SUS)	0	-15131	0	0	0	0
	3(EXP)	0	-1015	0	0	0	0
	MAX		-16147/L1				
1060		Rigid +Y					
	1(OPE)	0	-12795	0	0	0	0
	2(SUS)	0	-17740	0	0	0	0
	3(EXP)	0	4945	0	0	0	0
	MAX		-17740/L2				
1160		Rigid +Y; Rigid +X w/gap					
	1(OPE)	-9919	-16518	0	0	0	0
	2(SUS)	0	-15307	0	0	0	0
	3(EXP)	-9919	-1211	0	0	0	0
	MAX	-9919/L1	-16518/L1				
1260		Rigid +Y					
	1(OPE)	0	-16517	0	0	0	0
	2(SUS)	0	-16824	0	0	0	0
	3(EXP)	0	307	0	0	0	0
	MAX		-16824/L2				
1310		Rigid +Y; Rigid GUI					
	1(OPE)	0	-13633	4990	0	0	0
	2(SUS)	0	-14691	-2171	0	0	0
	3(EXP)	0	1057	7161	0	0	0
	MAX		-14691/L2	7161/L3			
1410		Rigid +Y					
	1(OPE)	0	-14719	0	0	0	0
	2(SUS)	0	-15524	0	0	0	0
	3(EXP)	0	805	0	0	0	0
	MAX		-15524/L2				

Node	Load Case	FX N.	FY N.	FZ N.	MX N.m.	MY N.m.	MZ N.m.
1460		Rigid GUI					
	1(OPE)	0	0	-4002	0	0	0
	2(SUS)	0	0	-1255	0	0	0
	3(EXP)	0	0	-2747	0	0	0
	MAX			-4002/L1			
1532		Rigid +Y					
	1(OPE)	0	-13117	0	0	0	0
	2(SUS)	0	-13076	0	0	0	0
	3(EXP)	0	-42	0	0	0	0
	MAX		-13117/L1				
1560		Rigid +Y					
	1(OPE)	0	-18672	0	0	0	0
	2(SUS)	0	-18611	0	0	0	0
	3(EXP)	0	-60	0	0	0	0
	MAX		-18672/L1				
1610		Rigid +Y					
	1(OPE)	0	-17496	0	0	0	0
	2(SUS)	0	-17516	0	0	0	0
	3(EXP)	0	20	0	0	0	0
	MAX		-17516/L2				
1710		Rigid +Y					
	1(OPE)	0	-18194	0	0	0	0
	2(SUS)	0	-18190	0	0	0	0
	3(EXP)	0	-5	0	0	0	0
	MAX		-18194/L1				
1711		Rigid –X					
	1(OPE)	10437	0	0	0	0	0
	2(SUS)	140	0	0	0	0	0
	3(EXP)	10297	0	0	0	0	0
	MAX	10437/L1					

Node	Load Case	FX N.	FY N.	FZ N.	MX N.m.	MY N.m.	MZ N.m.
1720		Rigid +Y					
	1(OPE)	0	-11403	0	0	0	0
	2(SUS)	0	-11404	0	0	0	0
	3(EXP)	0	1	0	0	0	0
	MAX		-11404/L2				
1761		Rigid GUI w/gap; Rigid +Y					
	1(OPE)	-2138	-18269	0	0	0	0
	2(SUS)	0	-18270	0	0	0	0
	3(EXP)	-2138	1	0	0	0	0
	MAX	-2138/L1	-18270/L2				
1781		Rigid +Y					
	1(OPE)	0	-13427	0	0	0	0
	2(SUS)	0	-13427	0	0	0	0
	3(EXP)	0	0	0	0	0	0
	MAX		-13427/L2				
1810		Rigid +Y					
	1(OPE)	0	-12478	0	0	0	0
	2(SUS)	0	-12478	0	0	0	0
	3(EXP)	0	0	0	0	0	0
	MAX		-12478/L2				
1910		Rigid +Y					
	1(OPE)	0	-19081	0	0	0	0
	2(SUS)	0	-19081	0	0	0	0
	3(EXP)	0	-0	0	0	0	0
	MAX		-19081/L1				
1960		Rigid +Y					
	1(OPE)	0	-15874	0	0	0	0
	2(SUS)	0	-15874	0	0	0	0
	3(EXP)	0	0	0	0	0	0
	MAX		-				

Node	Load Case	FX N.	FY N.	FZ N.	MX N.m.	MY N.m.	MZ N.m.
			15874/L2				
2060		Rigid +Y; Rigid GUI; Rigid +Z					
	1(OPE)	436	-15933	-8314	0	0	0
	2(SUS)	-2	-15933	0	0	0	0
	3(EXP)	438	-0	-8314	0	0	0
	MAX	438/L3	-15933/L1	-8314/L1			
2160		Rigid +Y					
	1(OPE)	0	-15741	0	0	0	0
	2(SUS)	0	-15741	0	0	0	0
	3(EXP)	0	0	0	0	0	0
	MAX		-15741/L2				
2210		Rigid +Y					
	1(OPE)	0	-15581	0	0	0	0
	2(SUS)	0	-15581	0	0	0	0
	3(EXP)	0	0	0	0	0	0
	MAX		-15581/L1				
2310		Rigid +Y					
	1(OPE)	0	-14139	0	0	0	0
	2(SUS)	0	-14139	0	0	0	0
	3(EXP)	0	0	0	0	0	0
	MAX		-14139/L1				
2360		Rigid +Y					
	1(OPE)	0	-16442	0	0	0	0
	2(SUS)	0	-16442	0	0	0	0
	3(EXP)	0	0	0	0	0	0
	MAX		-16442/L1				
2411		Rigid +Y; Rigid GUI					

Node	Load Case	FX N.	FY N.	FZ N.	MX N.m.	MY N.m.	MZ N.m.
	1(OPE)	-27	-14429	0	0	0	0
	2(SUS)	0	-14429	0	0	0	0
	3(EXP)	-27	0	0	0	0	0
	MAX	-27/L3	-14429/L1				
2510		Rigid +Y					
	1(OPE)	0	-11478	0	0	0	0
	2(SUS)	0	-8496	0	0	0	0
	3(EXP)	0	-2982	0	0	0	0
	MAX		-11478/L1				
2520		Rigid –Z					
	1(OPE)	0	0	5289	0	0	0
	2(SUS)	0	0	0	0	0	0
	3(EXP)	0	0	5289	0	0	0
	MAX			5289/L1			
2530		Rigid GUI w/gap					
	1(OPE)	5247	0	0	0	0	0
	2(SUS)	-99	0	0	0	0	0
	3(EXP)	5347	0	0	0	0	0
	MAX	5347/L3					
2660		Rigid +Y; Rigid GUI					
	1(OPE)	-1783	-13473	0	0	0	0
	2(SUS)	-2	-14754	0	0	0	0
	3(EXP)	-1781	1281	0	0	0	0
	MAX	-1783/L1	-14754/L2				
2670		Rigid –Z					
	1(OPE)	0	0	0	0	0	0
	2(SUS)	0	0	3593	0	0	0
	3(EXP)	0	0	-3593	0	0	0
	MAX			3593/L2			
2710		Rigid +Y; Rigid GUI					
	1(OPE)	168	-14309	0	0	0	0
	2(SUS)	4	-13138	0	0	0	0
	3(EXP)	165	-1171	0	0	0	0
	MAX	168/L1	-14309/L1				
2810		Rigid +Y					
	1(OPE)	0	-19352	0	0	0	0
	2(SUS)	0	-21607	0	0	0	0
	3(EXP)	0	2255	0	0	0	0
	MAX		-21607/L2				
2910		Rigid +Y;					

Node	Load Case	FX N.	FY N.	FZ N.	MX N.m.	MY N.m.	MZ N.m.
		Rigid GUI					
	1(OPE)	-15	-16313	0	0	0	0
	2(SUS)	-0	-15174	0	0	0	0
	3(EXP)	-14	-1139	0	0	0	0
	MAX	-15/L1	-16313/L1				
3010		Rigid +Y; Rigid +Z					
	1(OPE)	0	-14436	-6845	0	0	0
	2(SUS)	0	-14457	-235	0	0	0
	3(EXP)	0	21	-6609	0	0	0
	MAX		-14457/L2	-6845/L1			
3110		Rigid +Y; Rigid GUI					
	1(OPE)	3	-13371	0	0	0	0
	2(SUS)	0	-13368	0	0	0	0
	3(EXP)	3	-3	0	0	0	0
	MAX	3/L1	-13371/L1				
3260		Rigid +Y; Rigid GUI					
	1(OPE)	2479	-14807	0	0	0	0
	2(SUS)	55	-14806	0	0	0	0
	3(EXP)	2424	-1	0	0	0	0
	MAX	2479/L1	-14807/L1				
3360		Rigid +Y; Rigid –Z					
	1(OPE)	0	-14944	8990	0	0	0
	2(SUS)	0	-14944	33	0	0	0
	3(EXP)	0	-0	8956	0	0	0
	MAX		-14944/L1	8990/L1			
3460		Rigid +Y; Rigid					

Node	Load Case	FX N.	FY N.	FZ N.	MX N.m.	MY N.m.	MZ N.m.
		GUI					
	1(OPE)	-121	-14709	0	0	0	0
	2(SUS)	-2	-14709	0	0	0	0
	3(EXP)	-119	0	0	0	0	0
	MAX	-121/L1	-14709/L2				

7.4.4 Occasional Load cases:

Those present during rare intervals of operations. It includes the following loads:

7.4.4.1 Seismic Loads:

Seismic loading is one of the basic concepts of earthquake engineering which means application of an earthquake-generated agitation to a structure. As per preliminary information the values for the seismic acceleration (acceleration in 'g') to be considered are:

- North-South Direction
- East-West Direction
- Vertical Direction

Various seismic load cases to be considered are:

1. W+P1+T1=U1
2. W+P1+T1+U2
3. W+P1+T1+U3
4. W+P1+T1-U1
5. W+P1+T1-U2
6. W+P1+T1-U3
7. U1

8. U2

9. U3

10. -U1

11. -U2

12. -U3

7.4.4.2 Wind Loads:

Wind loading should be considered on a case by case basis. In determining the need for analysis, it should be noted that

- 10 NB lines and smaller lines, which are guided in accordance with good Practice; generally do not need specific analysis.
- The impact of wind shall be considered for long, exposed piping. The pipe work Involved are normally riser lines, flare-stack lines, turbine-exhaust stack and Piping on bridge. For properly supported and restraint lines, wind loading need Not be considered.
- When wind load is to be considered, a shape factor 0.65 and wind speed is to be Applied in two separate direction only (+/- X and +/- Z direction)
- Wind loading/ speed at 10m above mean sea level to be considered is 67.9 m/s (3 Sec gust), which is based on 100 years. Return (1hour average) wind speed of 44.83 m/s

  Various Wind load cases considered are:

1. W+P1+T1+WIN1
2. W+P1+T1+WIN2
3. W+P1+T1+WIN3
4. W+P1+T1+WIN3
5. WIN1

6. WIN2

7. WIN3

8. WIN4

Velocity(m/s)	Elevation(m)
58	10
62	20
64	30
67.7	40
69.57	50
70.79	60
71.95	70
72.9	80
73.7	90
74.45	100

7.4.4.3 Wave Loads:

Wave loads are not considered for this project as it is an off shore plant and is designed keeping in mind the highest tide. Wave loads are primarily considered for designing on-shore Plants at areas close to the sea which has a history of flooding.

Chapter 8

CONCLUSION

We have successfully completed the project which involved development of piping layout for loading and unloading system in an onshore plant and analysis of the same using Caesar II.

The various task performed by us during this period are listed below and the observation and results obtained are furnished in this project report

- Process flow diagram (PFD) was developed.
- Piping and instrumentation diagram (P&IDs) were developed.
- Equipment's are designed in SP3D based on PFDs and P&IDs.
- 3D designing of piping layout was done for all the lines in complains with safety requirements mentioned in ASME B 31.3
- Generation of pipe isometrics for all lines.
- Selection of critical lines and non-critical lines
- Critical lines are subjected stress analysis under different load cases using Caesar II and it was found to have passed the test.
- Expansion loop calculation done.

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