STRESS ANALYSIS OF THE INTERLINK PIPELINE FROM THE ESSAR CRUDE LINE TO THE IOCL TANK FARM

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A thesis submitted in partial fulfillment of the requirements for the Degree of Master of Technology

(Pipeline Engineering)

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CERTIFICATE

This is to certify that the work contained in this thesis titled “**STRESS ANALYSIS OF THE INTERLINK PIPELINE FROM THE ESSAR CRUDE LINE TO THE IOCL TANK FARM**” has been carried out by Mr. MAHESH.V under my/our supervision and has not been submitted elsewhere for a degree.

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Apart from the effort of oneself, the success of mu project depends largely on the encouragement and guidelines of many others. I take this opportunity to express my gratitude that was instrumental in my successful completion of the project.

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Moreover I thank each and every one of the Essar Family and various professors and staffs from UPES for their warm support and co-operation in successful planning and completion of project work.

Abstract

This project makes use of Caesar stress analysis software in great way. Using this software, it has been found out that the design and operating factors have been satisfactory and within the design limits. Various types of pipeline supports have been studied, the span length, design specifications of the supports have been analyzed.

With the help of P&ID diagram, I have got the understanding of various fittings and its specifications which are used in pipelines. The process of site inspection has provided me an outlook of the pipeline layout and its isometric drawing using Auto Cad has been drawn.

Many soil characteristics have been modeled using the Caesar software. These soil characteristics along with supports and various load conditions were used to model the pipeline and find out the stresses at multiple nodes.

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Nomenclature

P =initial pressure, psi

D_o= 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

Z = section modules, in^3

t_m =Nominal thickness, inch

L= Span length, feet

W=weight of the pipeline, Kg/m

W_t = Total weight of the system, Kg/m

T1 = design temperature, ^0C

T2 = Operating temperature, ^0C

P1 = Design pressure, Kg/mm^2

P2 = Operating Pressure Kg/mm^3

SPM= Single Point Mooring

COT= Crude Oil Tankage

Company Profile

The Essar Refinery is an oil refinery at Vadinar, Gujarat, India. It is owned and operated by the Essar Oil. Construction of the refinery started in 1996. The refinery project was delayed several times due to environmental concerns and financial problems, including initial cost over runs and a shortfall in equity contributions. In 1998, it was 60% complete but was struck by a cyclone that caused considerable damage. Construction was restarted in 2005 and the refinery was completed in 2006. Essar Oil reported commercial production of 10.5mtpa in May 2008.The units commissioned in the first phase were the CDU, VDU, sulphur gas unit, naphtha hydrotreater, catalytic cracker and visbreaker. The fluid catalytic cracker and a diesel hydro desulphuriser were commissioned in November 2006. The FCC and DHDS plants were modified so as to be compliant with the cleaner Euro III and Euro IV fuels. The refinery configuration lends itself well to de-bottlenecking and its capacity is enhanced to 14mtpa in 2009. The docking facilities include an SBM capable of handling vessels up to 350,000DWT with a capacity of 25mtpa, tankages with interconnecting pipelines of 20mtpa capacity, marine product dispatch capacity of 12mtpa and rail-car and truck-loading facilities. The refinery is expanded to a capacity of 20 million tons per annum. Essar Oil Ltd (EOL) announced the completion of the Rs 8,300-crore expansion of its Vadinar Refinery with the successful commissioning of the final Delayed Coker unit (DCU), which is amongst the world's largest. The Vadinar Refinery is now India's second largest single-location refinery, with an annual capacity of 20 million tons (405,000 barrels per day) and a complexity of 11.8, which also makes it among the world's most complex refineries.

The capacity expansion and complexity enhancement gives the Vadinar Refinery the capability to process much heavier crude diet. The share of ultra-heavy crude, which currently constitute 20% of crude basket, will go up to 60%; and as a result the overall share of heavy and ultra-heavy crude will go up to 80% of the refinery's total crude basket. The company has already entered into long-term crude sourcing contract with global suppliers, including several national oil companies from Latin America

1.0. Chapter 1

1.1. Introduction

This project deals with stress analysis using CEASER II software for a crude line interconnection with and existing 48' inch pipeline of Essar from jetty to Crude Oil Tankage (COT). The crude line which will be considered here is the 42" Pipeline. The pipeline will be from the IOCL COT area. In near future if a situation arises when our Single Point Mooring system (SPM) is already in its 100% productivity and refinery is in need of row crude the IOCL SPM can be directly put in for our use and the surplus amount of crude to feed the COT tanks can be arranged through the new 42" pipeline. The other strategic advantage which Essar will be gaining from such a pipeline is that if there is some maintenance or shut down in SBM there won't be any product supply, so this will act as an alternate source. It can also be used in the time of storage in product supply from SBM. Product can be obtained with the minimum transportation cost by this pipeline.

In this project the entire stress analysis for this pipeline using CAESAR II software. CAESAR II is a PC-based pipe stress analysis software program developed, marketed and sold by COADE Engineering Software. At first the design of the 42" pipeline will be analyzed with stress analysis at maximum design conditions. Pipe stress analysis involves those calculations that address static and dynamic loading in pipe that result from various factors such as internal and external pressures, changes in temperature and fluid flow rate and changes due to gravity and seismic activity It also interprets the maximum displacement of load in the pipeline. The maximum load withstanding capacity of the carbon steel material is also interpreted. So in short it gives us an detailed idea regarding the maximum operating conditions and the chance for its failure.

2.0. Chapter 2

2.1. Literature review

1. **Behavior of Buried pipeline subjected to External Loading, by Paul Chi Fal Ng (1994):**

   Chapter 2.5 of this book MODELS OF SOIL/PIPELINE INTRACTION has helped me to understand the various soil characteristics and its interaction with pipelines. With this theory in mind models work created in Caesar.

2. **Pipe Stress Analysis by Sam Kannappan(1993) :**

   From this book chapter 6 PIPELINE SUPPORTS, the types of supports and the uses at different conditions were studied. With the help of this understanding I was able to choose the right support for this project. The span length calculations from this chapter were used to find out the required span length for the support marking.

3. **Pipeline Stress Analysis by Adwait. A. Josh (2001)**

   The types of loads and the manner in which they act on the pipeline were studied from this book. These load factors which lead to pipeline failures and their remedies were also studies.

4. **Stress analysis methods for underground pipe lines by Liang-Chaun Peng**

   From this book, the different loads due to burring pipeline underground have been analyzed. These concepts were used for the Caesar modeling of the pipeline

5. **Guidelines for the Design of Buried Steel Pipe by American Lifelines Alliance**

   The pipe expansion and displacement at various operating and design conditions was studied. Because of this I was able to choose the right support.

6. **Pipe Stress Analysis by IDC Technologies Pyt Ltd (2008)**

From this document chapter 1.6 ‘thermal effects and flexibility in pipeline system’ has given me to the idea about the behavior of the pipe with the different thermal conditions. This gave better understanding about the pipe failures and the allowable limits.

7. **Seismic And Thermal Analysis of Buried Piping by Richard Stuart(1996)**

By this journal it has been found that the different seismic and thermal effect acting on the buried pipes. This helped me to design different load conditions of the required pipe structure.

8. **ASME 31.3 -2012 ,Process piping**

The standards and limits set for piping has given me an understanding of designing pipes.

9. **Documents from ESSAR**

The operating and design conditions of existing pipeline and its mechanical properties were analyzed. The various design factors and design criteria were also studied.

3.0. Scope

Essar is planning to construct a interlink pipeline between the 48 inch crude line form jetty to COT area and the Tank farm of the IOCL, to improve the reliability . The expected benefits are to avoid the shut out condition due to the product shortage by various reasons. The scope of the project is to identify whether the different design specification and operational parameters are feasible or not. Pipeline and pipeline components are subjected to different types of stresses just like other mechanical components. Overstressing can result in premature failure of pipe and pipeline components and it is therefore important to ensure that pipeline stresses are kept within allowable limits. This is precisely why pipeline systems are subjected to stress analysis. Pipe stress analysis involves those calculations that address static and dynamic loading in pipe that result from various factors such as internal and external pressures, changes in temperature and fluid flow rate and changes due to gravity and seismic activity.

4.0. Chapter 3

4.1. Theoretical development

Caesar –II is a complete pipe stress analysis software program that allows quick and accurate analysis of piping or pipeline system for various load conditions subjected to weight, pressure, thermal, seismic as well as other static and dynamic loads .Caesar-II is universally accepted analysis package, which can analysis of pipe system of any size and complexity .it is uses the finite element analysis method. By this software pipe stress analysis along with connected structure is possible, as it has a built in structural module.

Some of the important points about this software are mentioned below.

- It includes more option and more technical capabilities compared to other software.
- Software is user-friendly and acceptable by client globally
- It is proven stable and reliable software in constant of heavy use
- The software is tested with stringent quality assurance standards
- The software is having continuous up gradation and improvement
- The software got interface with PDS
- It got interactive Graphics which is very useful while stress analysis
- The software got Extensive on-line help
- Stress analysis of underground buried pipeline system is possible
- It is capable of analyzing of special pipe supports like hangers etc., and also special component like expansion joint etc.

4.2. Inputs required for Caesar II

- Material selection and specification
- Size of the pipe
- Thick ness of the pipe
- Operating and design conditions
- P&ID diagram
- Fitting and its specification
- Isometric drawing
- Supports and support marking
- Load cases
- Soil characteristics

4.2.1. Material selection

Selection of piping materials for refinery and petrochemical plants requires collaboration between the corrosion piping and process engineers, and usually involves more than determining if a material is compatible with a given environment. Many questions must be answered before a pipe and valve specification can be written.

- Is the alloy available in the size and thickness required
- Is it the most economical choice
- Should it be specified as seamless or welded
- Is it suitable for the maximum anticipated operating temperature or will long-term exposure to these temperatures cause its mechanical properties to deteriorate
- Will it require special welding or heat treatment requirements

It should be noted at the outset that the best approach to corrosion control may not involve the use of corrosion resistant alloy materials.

Often adequate life can be obtained in corrosion services with carbon steel piping in conjunction with control of process and operating variables. In other cases, in particular those piping systems handling corrosive fluids at elevated temperatures, there is no alternative to corrosion-resistant materials. Also, low or elevated temperature service conditions can dictate the use of special materials.

In most major projects, the preparation of the pipe and valve specifications starts in the piping department of an engineering contractor. These engineering firms have standardized specifications which are usually coded to:

1. Materials of construction

2. Primary flange pressure classification and

3. Minimum allowances for corrosion.

The codes are often sub grouped to provide for variations in valve trim material, types of small fittings, screwed or socket welded, or special heat treatment or material requirements etc.

In this project we are planning to take a interlink line from the existing crude feeder line. Then the operating and design conditions of both lines will be equal. The existing crude pipe line is API 5L Gr 52

The physical properties are:

Yield strength : 52000 psi

Tensile strength : 68000 psi

Density of the steel: 7850 kg/m3

The maximum allowable flow rate of the 48 inch pipeline is 10 MMTPA with a design temperature and pressure of 65^0C and 18 kg/cm^2.

By the capacity of the SPM (Single Point Mooring system) and the vessels (ships) the flow rate should not exceed to 7-8MMTP, and the pressure and temperature always lesser than the design criteria. If the same material has been chosen for the new interlink line, the mechanical or physical properties will be very much higher than what it required, and moreover which increases the cost of the project. So the design engineer should go for the material selection. It is usually desirable to employ the fewest possible different piping materials. This reduces construction costs and is of particular interest to the maintenance departments or the operating company. So the material of the proposed line has to be selected from std. API 5L with lower grade than 52. By the most economic concern and availability it is selected as API 5L Gr 46. The selected material further goes to different quality tests.

The physical and chemical properties are shown below.

Material: API 5L X 46

Physical properties

Yield strength : 46000 psi

Tensile strength : 63000 psi

Elongation : variable depends on temperature

Density : 7850 kg/m3

Chemical properties

C% - 0.29 (max)

Mn - 1.35(max)

P - 0.040

S - 0.050

4.2.2. Design and Operating parameters

By the calculation from the operation department the design temperature and pressure of the system will be

Flow = 1.2-2 m^3/sec

Pressure = 18Kg/cm2

Temperature = 650c

By the atmospheric condition the max temperature is 460C (May and June) and the min temperature is 70C (Jan and Feb), the temperature of the crude oil is mostly 400C (from the specification of crude oil).Therefore the operating parameters are

Pressure = 8Kg/cm2

Temperature = 400C

Hydro test pressure = 1.5 * 18 = 27 kg/cm2

4.2.3 Line sizing

According to a 1979 American survey, as much as 30% of the total cost of the typical chemical process plat goes for piping, piping element and valves. A significant amount of operating cost (energy) is also used up in forcing through its component. A significant amount of the maintain cost is also for the pipe and associated things. Proper sizing with optimal calculations required. The main criteria generally used in the line sizing are

- Velocity consideration
- Available pressure drop
- Economic consideration

After the various calculations and economic consideration the process department finalized with the diameter of 42 inch for the interlink pipeline.

4.2.4. Thickness Calculation

$$t_m = \frac{PD_o}{2(SE_q + PY)} + A$$

P=initial pressure psi

Do= outside diameter inch

S= allowable stress

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

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

P = 18 x 14.2= 255 psi

S = mat. API 5L gr X42= 42000 psi

Y = 0.4 (because the temperature is less tan)

Corrosion allowance = 3mm = 0.1181 inch

Total = 0.127 + 0.1181 = 0.2451

Mill tolerance = 12.5%

Nominal thickness (min) = 0.28011 inch

By this calculation we get the value 0.28011 inch = 7.114 mm

The thickness of the pipeline should not goes lesser than 7.114mm. It should be higher than the calculated value.

By the ABB Lummus Crest Mauritius specification

Input symbol	commodity	Min size	Max size	Comm.code	Shed/class	description	material	Thickness
PI	PLAN END/BEVEL END	30	42	11210R	XS	STR SEAM SAW,ASME B36.10/B16.25	API 5L	0.5

Thickness of the pipeline = 0.5 inch =12.7mm.

4.3. Pipeline layout

The layout out of the pipeline is completely depends on the isometric diagram. The isometric drawings are a means of drawing an object in picture from better clarifying the object's appearance. These types of drawing resemble a picture of an object that drawn in three dimensions. AUTO CAD software is used to draw the isometric drawing. Basically conceptual drawing and routing of the pipeline based P&ID. All the condition laid down in P&ID is full filled. The P&ID the gives the better understanding about the process, requirement and the component which will be attach to the pipeline. The P&ID is generating by the process department.

Inputs require for the pipeline layout

- P&ID
- Catalogue information for equipment/fittings
- Pipe specification
- Equipment layout
- Plot plan
- Design guide line/standard

4.3.1 P&ID Diagram

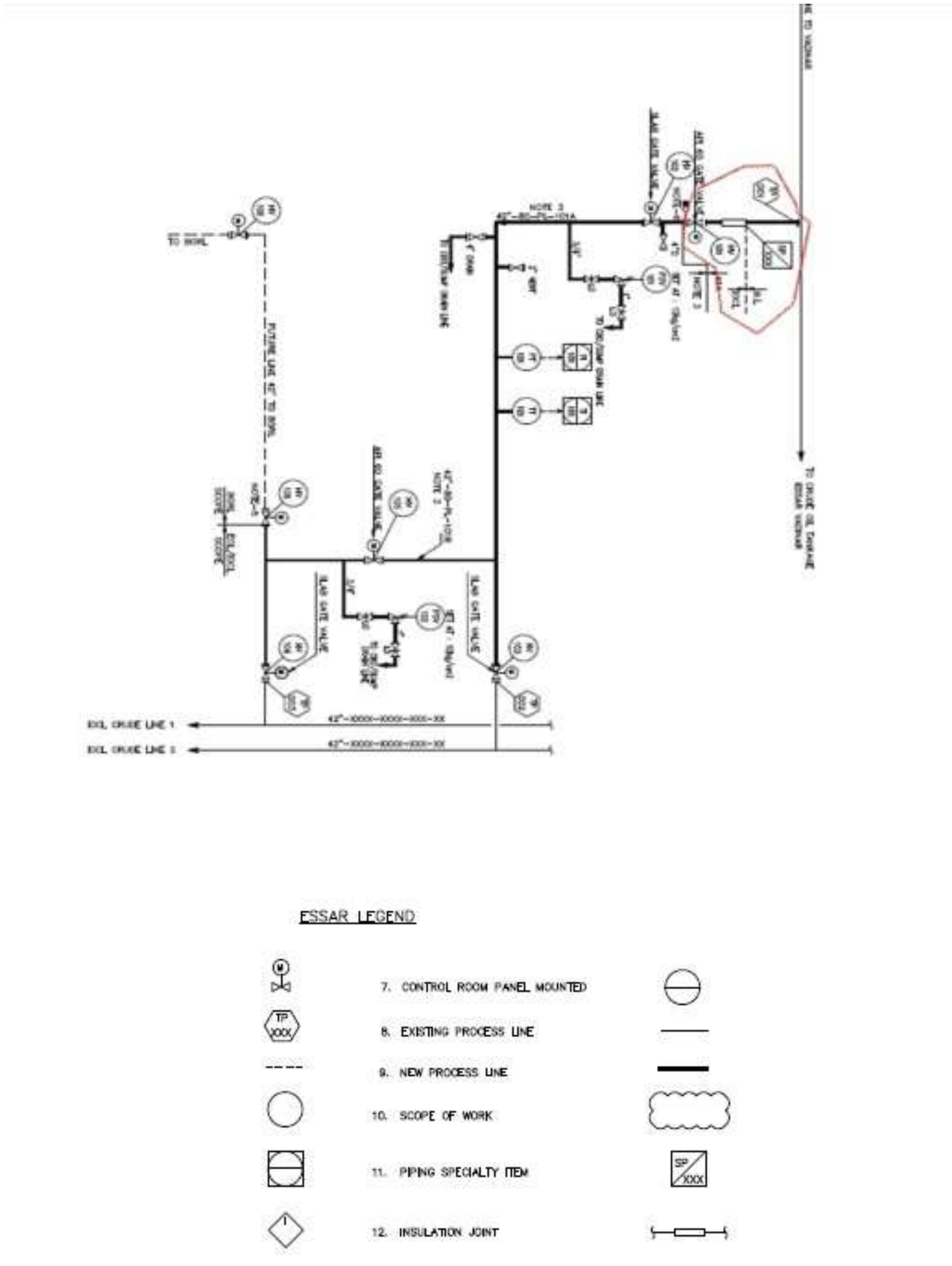

Figure source : ESSAR DOCS: IGP/14-15/P&ID- DRG/ESSAR/03 R-01

Figure 1 P&ID

The above figure shows the P&ID diagram of full process. But Essar is planning to execute the first portion where the marking is given in the above diagram.

4.3.3. Fittings and specifications

Monolithic Joint

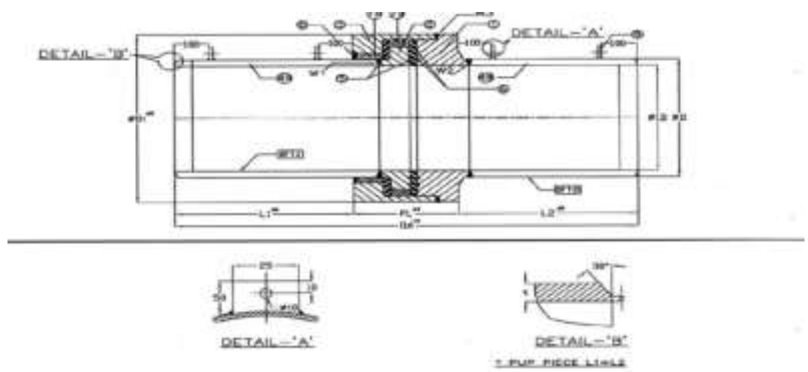

Figure source : ESSAR DOCS: IGP/14-15/MIJ- DRG/ESSAR/010 R-01

Figure 2 Monolithic joint

A Monolithic Insulating Joint is a welded pre-Fabricated 3-pieces union, for pipeline electrical sectioning, commonly used when the Cathodic Protection is present to prevent any interference with the corrosion control. In addition, the design phase involves a finite element analysis to identify the most stressed areas and to control the heat loss during welding operations. The construction is specifically oriented to the connected pipes, assuring a comparable overall strength, matching all the internal dimension to allow possible pig smooth passage; the pups length is calculated in order to protect the joint mechanical and electrical integrity during the welding activities

Monolithic isolation fittings will serve as a positive leak proof, long lasting block against the flow of electric current in all piping systems. When the isolation fitting is buried, you bury maintenance costs forever - an especially important feature for system operators and engineers

SIZE	RATING	D	ID	D1	A	PL	t	PIPE MAT	DF T.I
Inch	ANSI	mm	mm	Mm	mm	mm	mm	Grade	Microns
42	150#	1067	1041.6	1273	1502	502	12.7	API 5L GR B	300

Total weight of the rigid (monolithic joint) = 15809 .990

Flanged gate valve

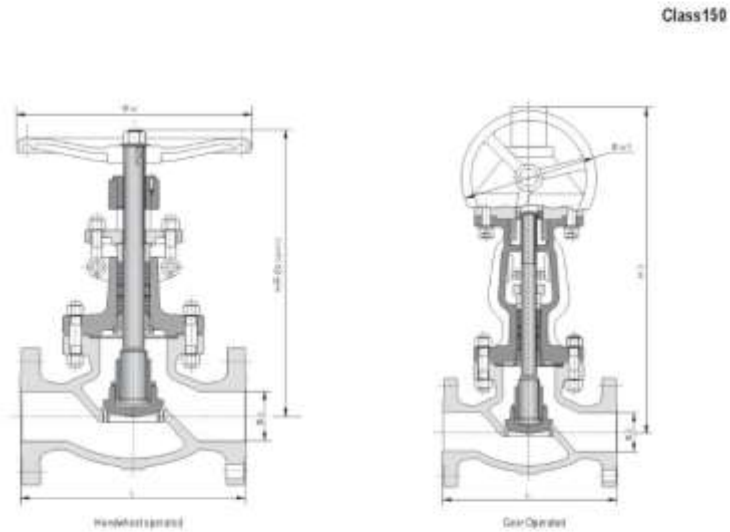

Fig. source: www.pinstake.com

Figure 3 Flanged gate valve

Specification

Design Spec	:	API6d
Design Spec, End Flanges	:	ASMEB16.47 (A)
Type of wedge	:	Flexible
Type Of Bonnet	:	Bolted
Type Of Gasket	:	Spiral Wound
Finish, Flange Facing	:	Smooth 125 to 250aarh
Facing, Flange	:	Raised Face
Pressure Designation	:	Class 150
Mat, Body	:	Carbon Steel
Mat, Trim	:	13 % Cr,Full Stellited
Mat, Gasket(S)	:	Stainless Steel 316
Gasket, Filling	:	Graphite
Mat Spec, Gasket	:	Stainless Steel 316
Mat Spec, Body	:	ASTM A216 WCB
Mat Spec, Bonnet	:	ASTM A216 WCB
Mat, Packing, Gland	:	Graphite
Mat Spec, Bolt	:	A-193 B7
Mat Spec, Nut(S)	:	ASTM A194-2h
Operator	:	Gear Size : 42inch
Additional Data	:	Service : Crude Oil
Total rigid weight	:	50031

Flange

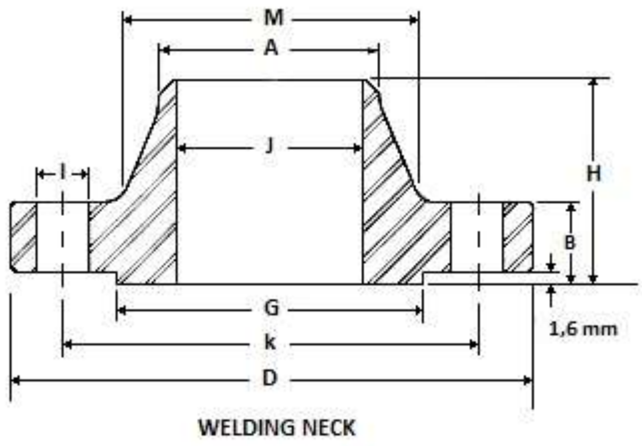

Fig. source : www.tria-group.com

Figure 4 Welded neck flange

Design spec	:	ASME B16.7
Type	:	Welded neck
Pressure Designation	:	150
Mat body	:	Carbon steel
Mat spec bolt	:	A-193 B7
Mat spec nut	:	Astm 194-2h
Total rigid weight	:	330N

Dimension

Overall dia (D)	:	53 inch
Dia of hole circle(K)	:	49.50 inch
Face dia (G)	:	47 inch
Flange thickness(B)	:	3.81 inch
Overall length (H)	:	6.7 inch
Dia of welded bevel end(A)	:	42 inch
Hub dia (M)	:	43 inch

4.3.4. Site inspection

Figure 5 site view

Before any isometric drawing the site inspection is must for any design engineer. The figure shows the proposed site for the laying of the interlink pipeline.

During the site inspection it has been observed that

- There is a 7 m. approach road is passing through the site. This is the connecting road between the jetty and the refinery
- There is an effective drainage system(0.9m) running parallel to the road
- There is boundary wall of IOC is situated 35m from the tap of point
- BSNL OFC cable is also passing parallel to the road
- A pocket road is also passing through the other site on the other side of IOC boundary wall
- It Is also observed that the type of soil is gravel in nature

Plot plan is drowned by these observations. The plot plan of the interlinked pipeline is shown below.

4.3.5. Plot plan

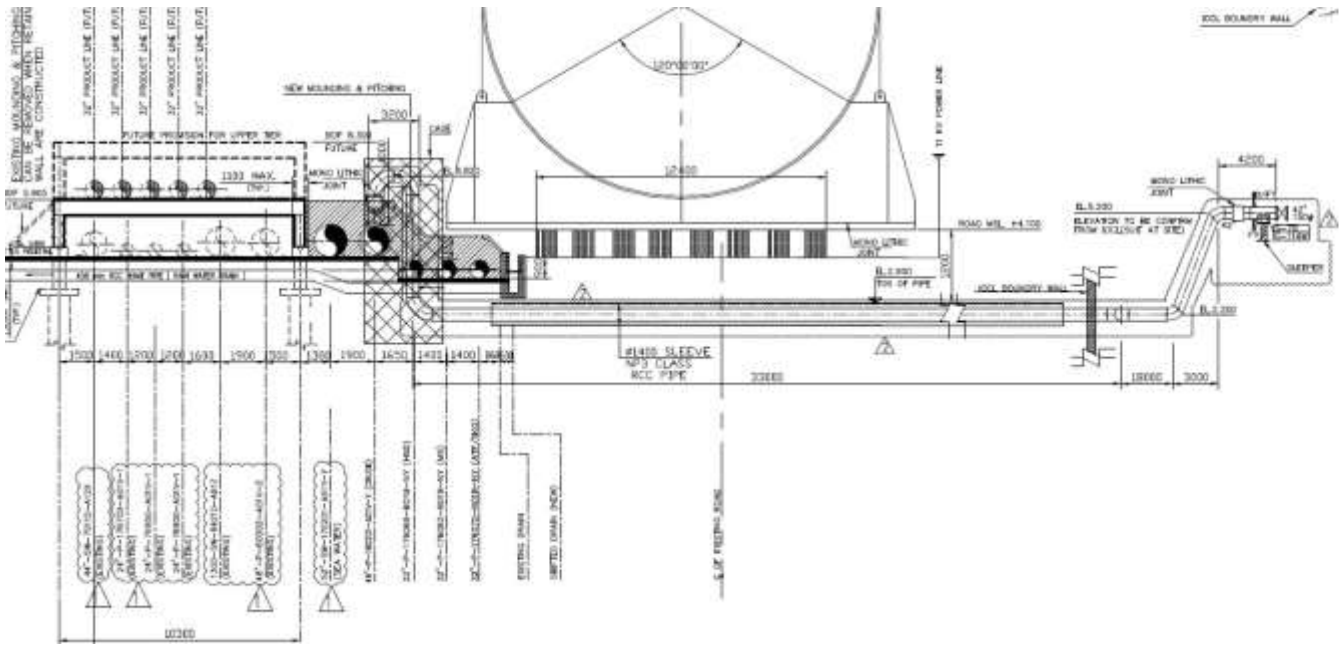

Figure 6.1 plot plan (side view)

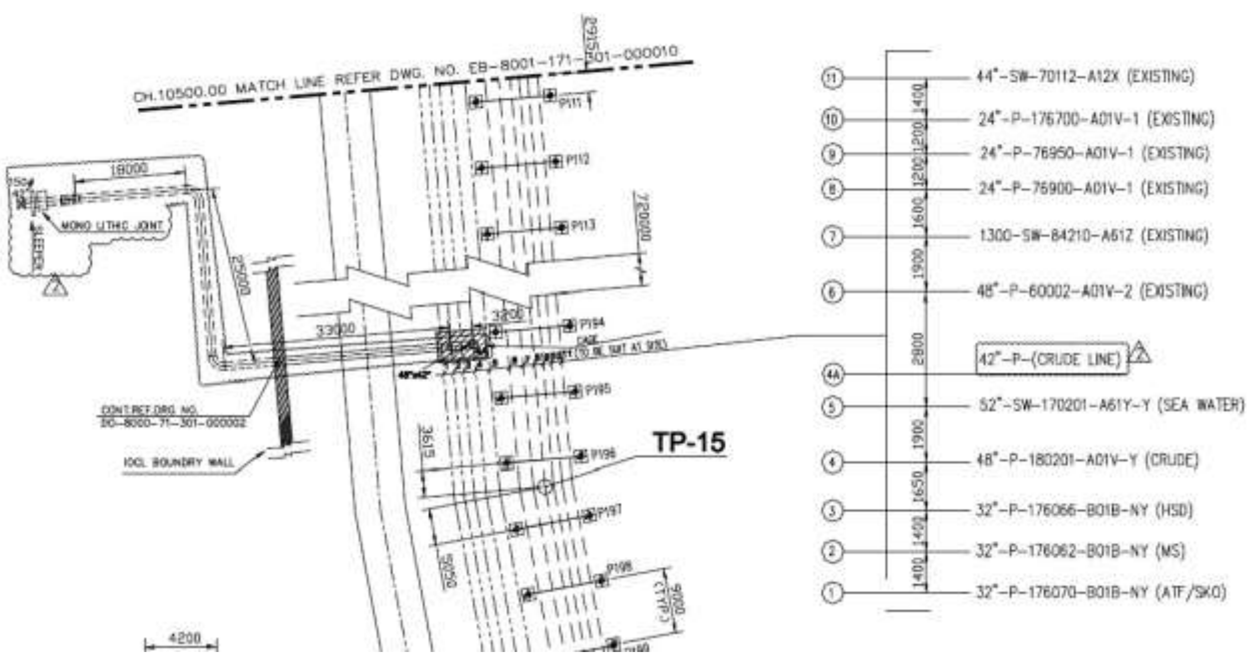

Fig.source : Essar docs- IGP 11160X35

Figure 6.2 plot plan (top view)

4.3.6. Isometric drawing

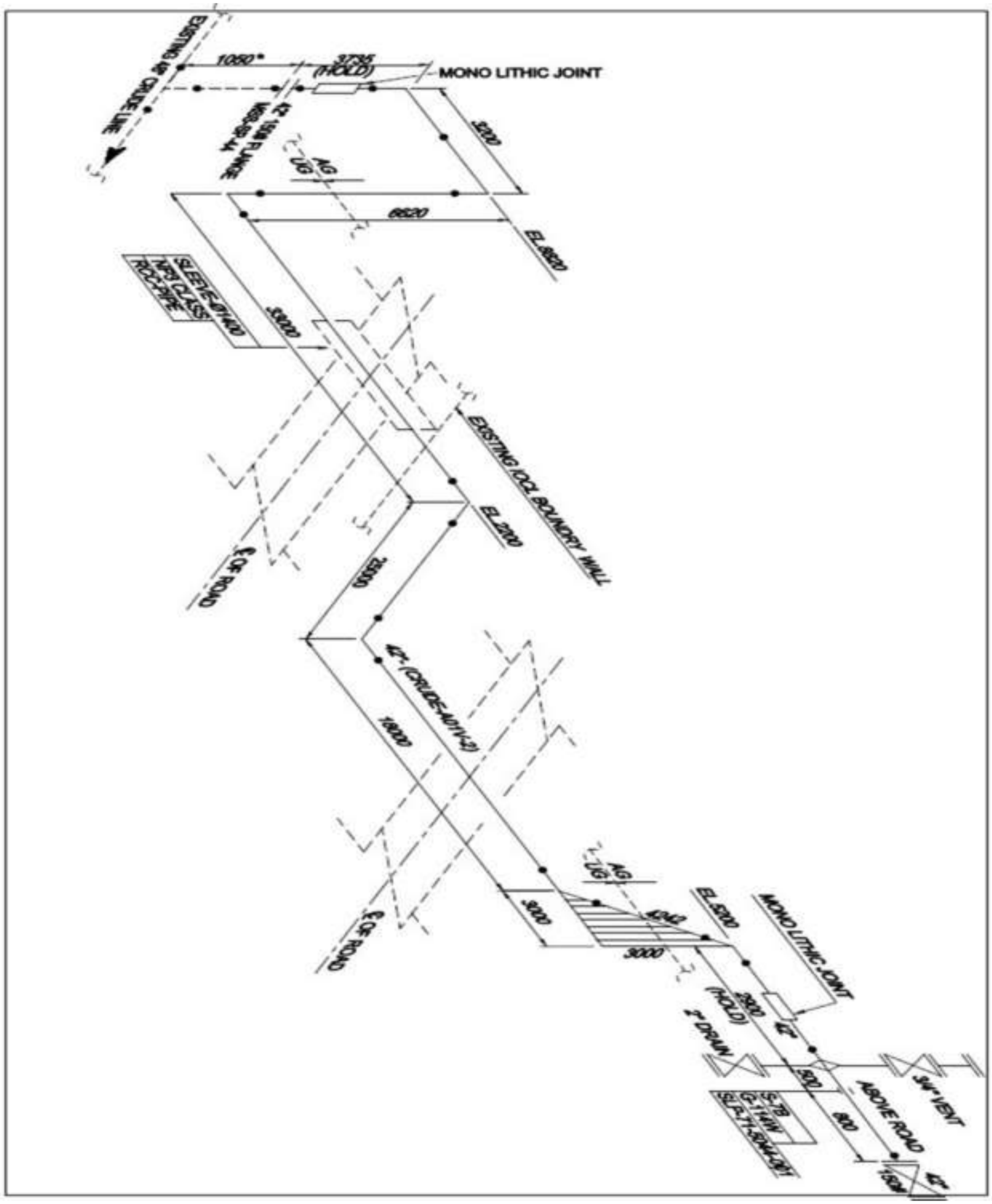

Figure 7 isometric drawing

4.4. Pipe line support

Pipeline supports are implemented for the following purpose

- To support the weight of pipe and component during the operation
- To take load due to thermal expansion
- To absorb vibration in the piping system
- To support the hydraulic thrust in piping
- To support the system during the shutdown condition
- To support system during maintains
- To take earthquake load
- To take wind load

Pipeline supports are broadly classifieds into

I. Primary support : This is directly attached to the pipe, this supports generally having the same material as the pipe

II. Secondary support: This is directly attached to the structure or foundation to support the primary support. This is generally consisting of concrete or reinforced concrete block. The design of the secondary supports is done with respected to the pipe weight stresses of the system etc.

4.4.1. Types of primary supports

Rest support

This is the most commonly used support meant for supporting only the pipe weight vertically. It allows to move axial as well as the transverse direction but restricts only the vertical downward movement. Pipes simply rest on the structure.

The rest support commonly used for large bore cross country pipelines, and buried pipes

Shoe weld support

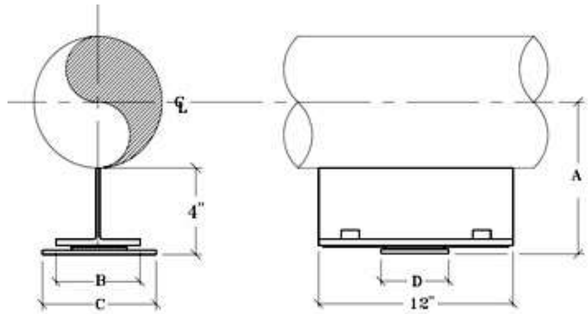

Fig. source :www.pipingtech.com

Figure 8.1 shoe weld support

This is generally used to support insulated lines, which cannot be directly supported on steel structure. Usually a I –beam cut into two half is used as a shoe. Shoe height depends upon the insulation thickness. It allows pipe to move in axial as well as transverse direction but restricts only the vertical downward movement. Shoe is directly welded to the pipe.

Shoe clamp support

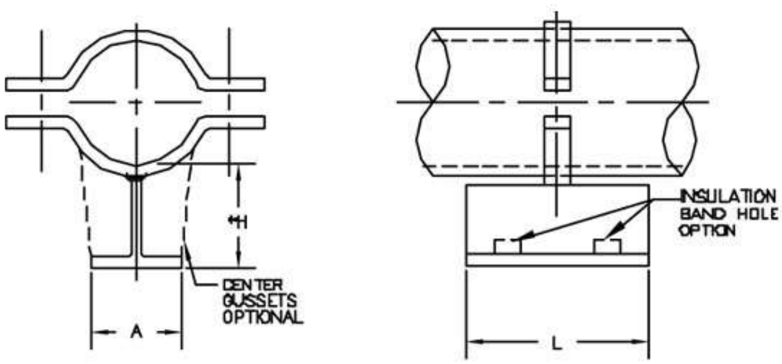

Fig source :www.gshangers.com

Figure 8.2 shoe clamp support

This support is similar to the shoe weld support. Shoe is welded to the clamp put around pipe. The clamp is provided to reduce the excessive vibration of the pipeline system. This clamp also restricted the lateral displacement of the vibration.

Guide support

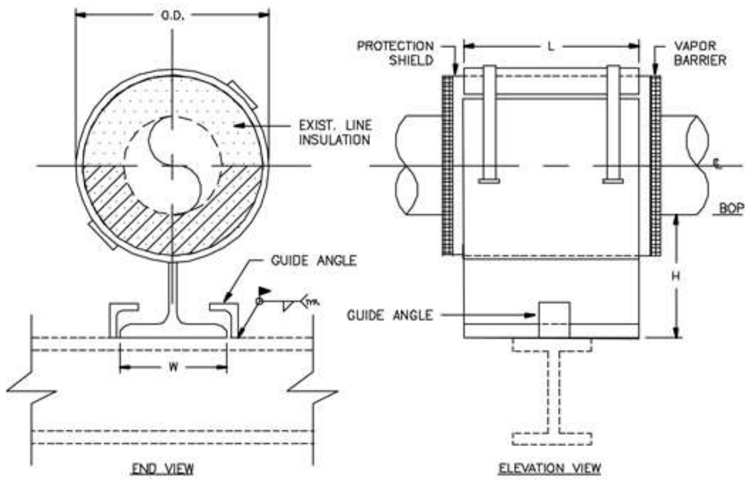

Fig. source :www.pipingtech.com

Figure 8.3 guide support

This type of support is used to restrict the movement of the pipe traverse direction i.e., perpendicular to length of pipe but allow movement in longitudinal direction. This is also commonly used support. A design engineer can easily alter the magnitude of the transverse motion of the pipeline by adjusting the gap between the guides.

Anchor support

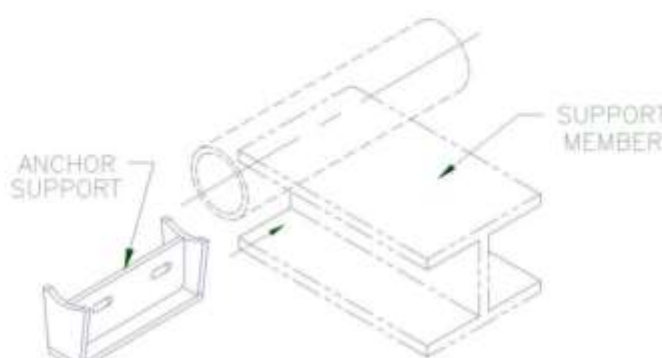

Fig.source:www.pipeshields.com

Figure 8.5 anchor support

The above figure shows the diagram of the anchor support. This type of support is used to restricted movement of all three dimensional direction

Hanger support

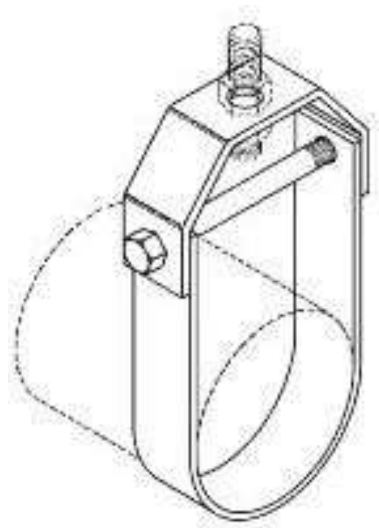

Fig. source :www.plumbinghelp.ca

Figure 8.6 hanger support

As the name suggested in hanger support pipe is hung from the overhead structure using the hanger rod, which is commonly used in the refineries.

5.6.2. Selection of support

In our case we are using the large bore pipe (42inch), and the pipeline is buried. The pipeline does not connect with the sophisticated equipment like pump compressor etc. There for the vibration of the total system will be negligible. But the pipe will have the tendency of expansion and the shifting the place due the operating temperature and pressure.

While the designing of the pipeline, the designer should consider the worst case scenario. So for reducing the vertical downward movement and the transverse movement, the guide support and rest support are selected. A concrete casing or the sleeve support has to select to reduce the effect of moving loads during the passing of the vehicles on the road.

4.4.1. Support spacing

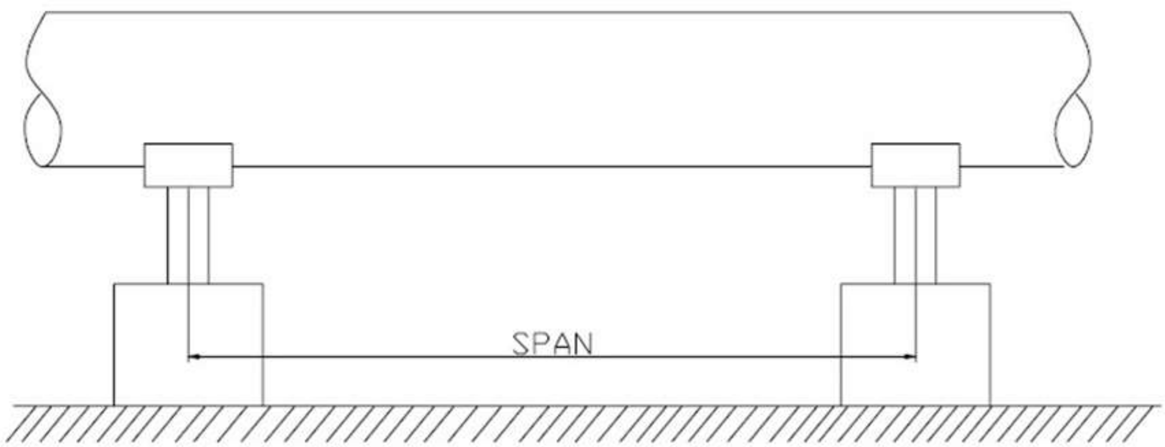

Fig. source :www.iplex.com.au

Figure 9 span

Straight cross-country pipelines are supported throughout the length of pipeline on different forms of supports at more or less regular spans. The material is usually alloy metal, which is chosen based on the fluid to be transported. These pipelines are supported on different forms of supports; Metal in RCC supports, Metal frame supports, Small Trusses, etc. The span length is the maximum allowable length between two successive adjacent supports. If there is two supports with having higher span length than the allowable span length the pipeline will fail due to the bending moment, weight of the material and other external loads. So it is very important to calculate the maximum span length before constructing the pipeline

Span length calculation

For uniformly distributed and simply supported beam

$L = \sqrt{\frac{0.4ZS_h}{W}}$: based on limit stress

The expectations are

I. The pipeline in static state, expect for movement included by temperature changes ,effect of pulsation ,vibration

II. Concentrated load similar to valve are not considered

W_t = weight of pipe + weight of soil +weight of flowing medium

= 7850x (3.14/4) x (1.06^2-1.05^2) + 1847x1.2x1.06

= 130.023 + 2349.389

= 2479.339 kg/m = 1663.68 lb/ft

Z = section modules = $\frac{3.14}{32} * (\frac{42^4 - 41.5^4}{42})$

= 306.594 in^3

S_h = hot tensile stress (psi) = 630000 psi

$$L = \sqrt{\frac{0.4 * 306.5944 * 63000}{1663.68}}$$

= 68.147 feet

Therefore the maximum length between two supports is 68.147 feet or 20.17m

4.4.2. Design of Support
Guide support

By the pipe specification manual

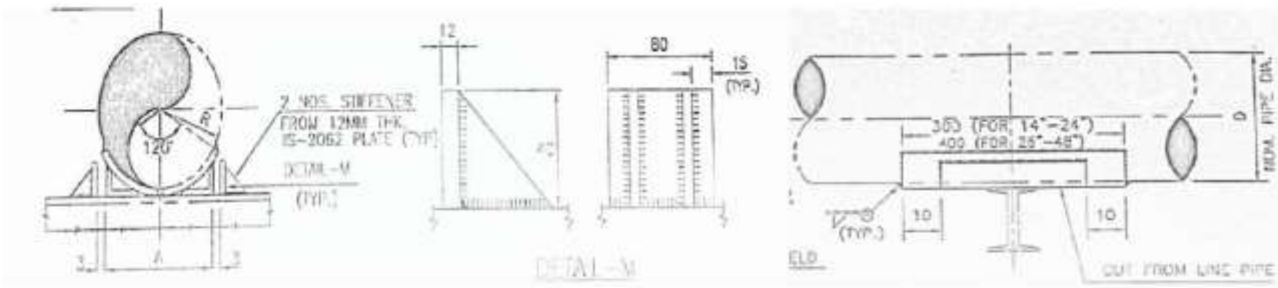

Fig. source: pipeline support specification hand book

Figure 10 design of support

PIPE SADDLE FOR
C.S BARE PIPE
SIZE 14" THRU 48" TYPE-S6A
(FOR TEMP, UPTO 343^{0}C)

Dimension

Nominal dia.	Shd.	R	A	h	Angle -Size
42	XS	533	508	63	150 x 75 x 10

- In case the pipe – schedule is not the same as the tabulated above, the dimensions "A" and "h" shall be modified accordingly
- Protection shield shall be cut from line pipe or rolled from plate of material equivalent to that of pipe.
- Thickness of the protection shield shall be same as the line pipe or 12mm whichever is less

Sleeve support

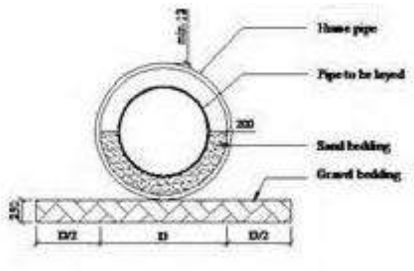

Fig. source: www. Pipe shields .com

Figure.10.1. Sleeve support

Sleeve support is used to withstand to the moving load exerted by the vehicles. Pipe sleeve may also act as a covering to create a barrier between a pipe and other surface. These sleeves are used during the construction of a building or pipe system

Specification

Pipe dia(mm)	Sleeve dia(mm)	Thickness(mm)	Material	Class	Type
1066.8	1400	24	RCC	NP3	Medium duty

4.5. Guide lines for locating pipe Support

- Support should be located as close as possible to the concrete loads so that the bending moments is minimum.
- When there is change in direction the tabulated supported spacing value should be limited to 75% to reduce eccentric load.
- In vertical pipe run there will be moment and stress developed. To avoid sagging by its own weight and vertical run pipe runs are supported by guides at a span twice the normal horizontal span.

4.6. Support marking

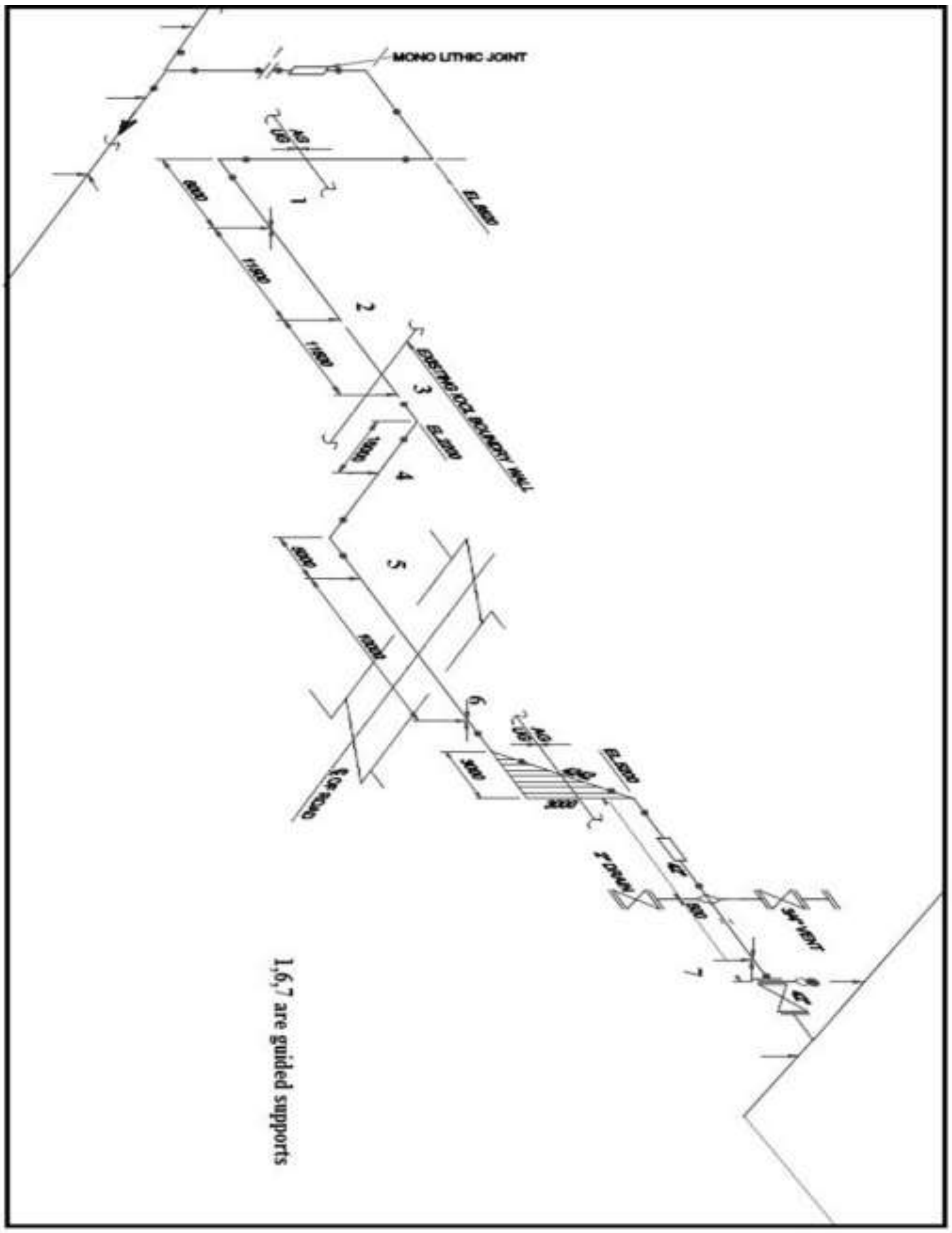

Figure 11 support marking

Here 1, 6,7are guide support and 2, 3, 4,5are rest support. The supports are placed below the maximum span length.

5.0. Load features

5.1. Classification of Loads And Failure Modes

Pressure design of piping or equipment uses one criterion for design. Under a steady application of load (e.g.. pressure), it ensures against failure of the system as perceived by one of the failure theories. If a pipe designed for a certain pressure experiences a much higher pressure, the pipe would rupture even if such load (pressure) is applied only once. The failure or rupture is sudden and complete. Such a failure is called catastrophic failure. It takes place only when the load exceeds far beyond the load for which design was carried out. Over the years, it has been realized that systems, especially piping, systems can fail even when the loads are always under the limits considered safe, but the load application is cyclic (e.g. high pressure, low pressure, high pressure, ..). Such a failure is not guarded against by conventional pressure design formula or compliance with failure theories. For piping system design, it is well established that these two types of loads must be treated separately and together guard against catastrophic and fatigue failure. The loads the piping system (or for that matter any structural part) faces are broadly classified as primary loads and secondary loads.

Primary Loads

These are typically steady or sustained types of loads such as internal fluid pressure, external pressure, gravitational forces acting on the pipe such as weight of pipe and fluid, forces due to relief or blow down pressure waves generated due to water hammer effects. The last two loads are not necessarily sustained loads. All these loads occur because of forces created and acting on the pipe. In fact, primary loads have their origin in some force acting on the pipe causing tension, compression, torsion etc leading to normal and shear stresses. A large load of this type often leads to plastic deformation. The deformation is limited only if the material shows strain hardening characteristics. If it has no strain hardening property or if the load is so excessive that the plastic instability sets in, the system would continue to deform till rupture. Primary loads are not self-limiting. It means that the stresses continue to exist as long as the load persists and deformation does not stop because the system has deformed into a no-stress condition but because strain hardening has come into play

Secondary Loads

Just as the primary loads have their origin in some force, secondary loads are caused by displacement of some kind. For example, the pipe connected to a storage tank may be under load if the tank nozzle to which it is connected moves down due to tank settlement. Similarly, pipe connected to a vessel is pulled upwards because the vessel nozzle moves up due to vessel expansion. Also, a pipe may vibrate due to vibrations in the rotating equipment it is attached to. A pipe may experience expansion or contraction once it is subjected to temperatures higher or lower respectively as compared to temperature at which it was assembled.

The secondary loads are often cyclic but not always. For example load due to tank settlement is not cyclic. The load due to vessel nozzle movement during operation is cyclic because the displacement is withdrawn during shut-down and resurfaces again after fresh start-up. A pipe subjected to a cycle of hot and cold fluid similarly undergoes cyclic loads and deformation. Failure under such loads is often due to fatigue and not catastrophic in nature.

5.2. Building static Load Cases

Load case definition in Caesar II

'The Caesar II load case editor' is a versatile instrument for combining native and combination loads in nearly any manner required by the various piping and pipeline codes supported by Caesar II.

To enter static load case editor from Caesar II main menu select Static.

Standard load case for B31.3, B31.3 ASME SEC III class 2 and 3, NAVY 505, B31.4, B31.5, B31.8, B31.11 etc. Piping and Pipeline codes are given below

These are the basic load cases which are recommended by the Caesar II software

L1 W +T1 + P1 (OPE)

L2 W + P1 (SUS)

L3 L1-L2 (EXP)

Load case with thermal displacement

Generally thermal displacement are associated with specified operational condition (D1 is applied with T1; D2 is applied with T2 etc.). When one temperature is below ambient and one is above ambient. We will want to determine the full expression stress range as described below

L1 W + T1+D1+P1 (OPE)

L2 W +T2+D2+P2 (OPE)

L3 W + P1 (SUS)

L4 L1-L2 (EXP) *effect of D1 and T1

L5 L2-L3(EXP) * effect of D2 and T2

L6 L1-L2 (EXP) * full expression stress range

Load case with Thermal expansion and settlement

For settlement, use a ‘C node’ on any affected restraints. This C node must be a node number not used elsewhere in the model. Then place the settlement on the C node using displacement vector not already used for thermal displacement.

L1 W+T1+D1+D3+P1 (OPE)

L2 W+ T1+D2+D3+P2 (OPE)

L3 W+P1 (SUS)

L4 L1-L3 (EXP) *effect of T1, D1 and settlement

L5 L2-L3 (EXP) * effect of T2, D2 and settlement

L6 L1-L2 (EXP) * full expansion range with settlement

Settlement is elevated as an expansion load because it is strain-related half cycle.

Static seismic load factor

The seismic load factor is likely occur while the pipeline system is in operation .this load is the load case that we want to consider. The operating case should have all operating loads plus the seismic load. This load case is then used in conjunction with the standard operating case to segregates the effect of the seismic load, which then combined with static load case for crude compliance consideration. Then on the first input spreadsheet activate the Uniform Loads field and enter the Seismic Loading Gs. Typically you should input the X-direction acceleration in vector 1, Y-direction acceleration inventor 2, and Z-direction acceleration in vector 3. This makes load case generation easier. Since any seismic event is likely to occur while the piping system is in operation this is the load case that we want to consider. The operating case should have all operating loads plus the seismic load. This load case is then used in conjunction with the standard operating case to segregate the effect of the seismic load, which then is combined with the static sustained load case for code compliance consideration

L1 W+T1+P1 (OPE)

L2 W+T1+P1+U1 (OPE)

L3 W+T1+P1-U1 (OPE)

L4 W+T1+P1+U2 (OPE)

L5 W+T1+P1-U2 (OPE)

L6 W+T1+P1+U3 (OPE)

L7 W+T1+P1-U3 (OPE)

L8 W+P1 (SUS)

L9 L1-L8 (EXP)

L10 L2-L1 (OCC)

L11 L3-L1 (OCC)

L12 L4-L1 (OCC)

L13 L5-L1 (OCC)

L14 L6-L1 (OCC)

L15 L7-L1 (OCC)

In load cases 2 through 7 above we include all the loads and call these operating cases. The subtracted uniform load vectors simply reverse the direction of the uniform load applied. Use these load case results for occasional restraint loads and occasional displacements. Load Cases 10 through 15 represent the segregated occasional loads. Even though we designate these as occasional load cases we don’t need a code stress check here as these are only part of the final solution for code compliance. Therefore under the Load Case Options tab we can select Suppress for the Output Status. Also these combination load cases all use the Algebraic Combination Method under the Load Case Options tab. Load cases 16 through 21 are all used for code compliance. We add the segregated occasional results to the sustained case results and use either the Scalar or ABS (Absolute Value) Combination Method under the Load Case Options tab. Both scalar and absolute will give us the same code stress results although the displacements, forces, and moments could be different.

6.0. Soil properties

In the case of the long transmission pipeline system the major portion of the pipes always normally buried or underground, therefor the soil-interaction analysis is the vital part of the pipeline design. The Caesar II which investigated the different soil forces that are acting on the pipeline.

The main two different forces which is acting on the buried pipeline are shown below

Axial friction force:

Friction force is the first and major soil force which is acting on the underground pipeline, it resist the movement of pipe while the thermal expansion and contraction. The section covers friction force that created against the axial movement of the pipe.

Theoretically, frictional force is the product of frictional coefficient of the soil (which is dependent on the type of the soil) and the total normal force which is acting all around the pipe.

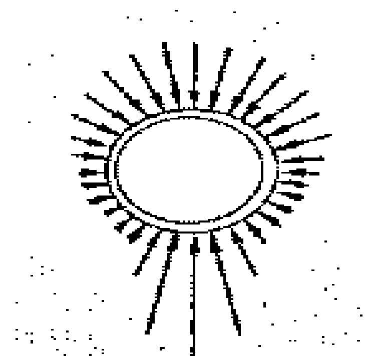

Fig.source :www.law.resourse.org

Figure 12.1 axial force

Lateral soil force

There are mainly three different lateral soil forces normally encountered in the pipe line analysis.

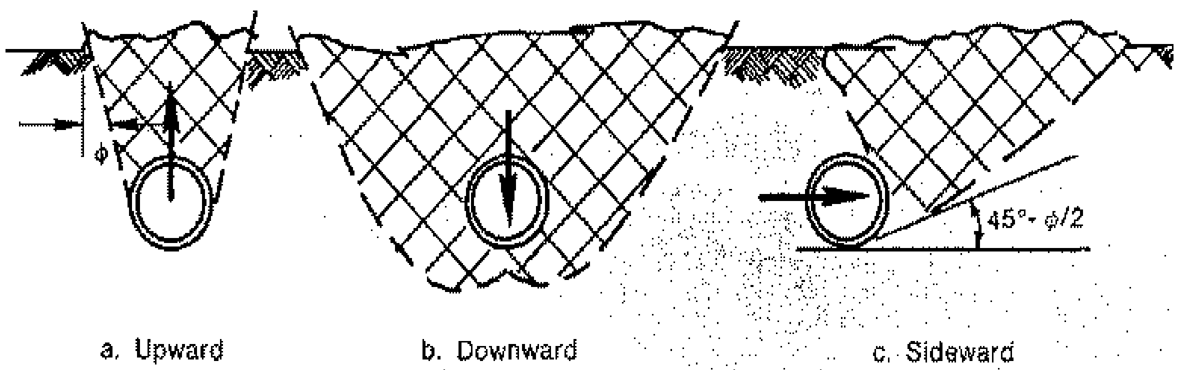

Fig. source: www.law.resourse.org

Figure 12.1 lateral force

Each lateral force can be idealized in to two stages 1) Elastic stage 2) plastic stage

In elastic stage the resistance force, which is proportional to the pipe displacement whereas in plastic stage the resistance remains constant regardless of displacement.

Though the elastic constant can be evaluated directly by test or published methods, they are generally very sensitive to the data gathered. Several authorities have proposed that the ultimate stress will be equal to the 1.5 to 2 percent of the pipe bottom depth.

From the several findings, elastic constant can be evaluated from ultimate resistance by taking 1.5 percent of the depth as yield displacement. Using 1.5 instead of 2 percent will give more realistic secant modules. This can underestimate the modulus for the initial displacement.

When the pipe moves horizontally due the different temperature, pressure and seismic conditions, it creates a passive soil pressure at the front surface, and at the same time it receives the active soil force at the back.

These forces are also leads to the failure of the pipe line, while using the Cesar software we can identify these forces and can apply suitable remedial action against them.

6.1. Soil modeling

Soil model type: American lifeline alliance

Soil classification: gravel

F coating factor:

Coating department factor relating the internal frictional angle of soil to the frictional angle at the soil-pipe interface

Typical values are

Concrete	-1.0
Coal tar	- 0.9
Rough pipe	-0.8
Smooth steel	-0.8
Fusion bond epoxy	-0.6
Poly ethylene	-0.6

In our case we are using the rough pipe without coating so the F coating factor will be 0.8

Dry soil density

The dry soil density of the soil is the density of the soil when which is in dry state, without the content of the moister. The dry soil density always be higher than the wet soil density

The Dry density = 1.847×10^{-3} kg/cm^3

Effective density soil

The effective density of the soil may differ from the dry density .If the soil is wet (and buoyant), in which case the effective density of the soil is less than the dry density of the soil .If it is expected that the water table may engulf the pipe even foe a short time, it is probably appropriate to enter a wet effective density. If the soil is experts to remain dry, then the dry soil density should come to role.

Wet soil density = 1.155 x 10^{-3} kg/cm^3

Depth of the pipe (H)

The length of the depth from the top of the pipe and soil surface

Depth = 1.2 m

Co efficient of earth pressure

The typical value of the co efficient of earth pressure KO=1

Yield displacement factor (axial)

The value of the soil displacement at which the ultimate axial restraint load is developed

Yield displacement factor = 0.1 inch (2.5mm)

Yield displacement factor (lateral D_p)

The value of the soil displacement at which the ultimate lateral restraint load is developed

D_p = 0.04(H+ D/2)

= 0.04(1.2+ 1.06/2)

= 0.0692, considering 0.1 , however the calculated value must be the maximum multiple D

Yield displacement factor (upward dQ_u)

The value of the soil displacement at which the ultimate upward load is developed to the soil

dQ_u=0.01

Yield displacement factor (downward dQ_d)

The value of the soil displacement at which the ultimate down restraint load developed

$dQ_d = 0.12$

Yield displacement factor (upward, max dQ_u)

The value of soil displacement at which the ultimate upward load is displaced, this can calculated by the equation

dQ_u = min(multiple of H) x H , (multiple of D) x D
= 0.01 x 12
= 0.012

Thermal expansion co efficient

The thermal expansion coefficient of the soil = 11.22131 L/deg C

7.0. Pipe modeling

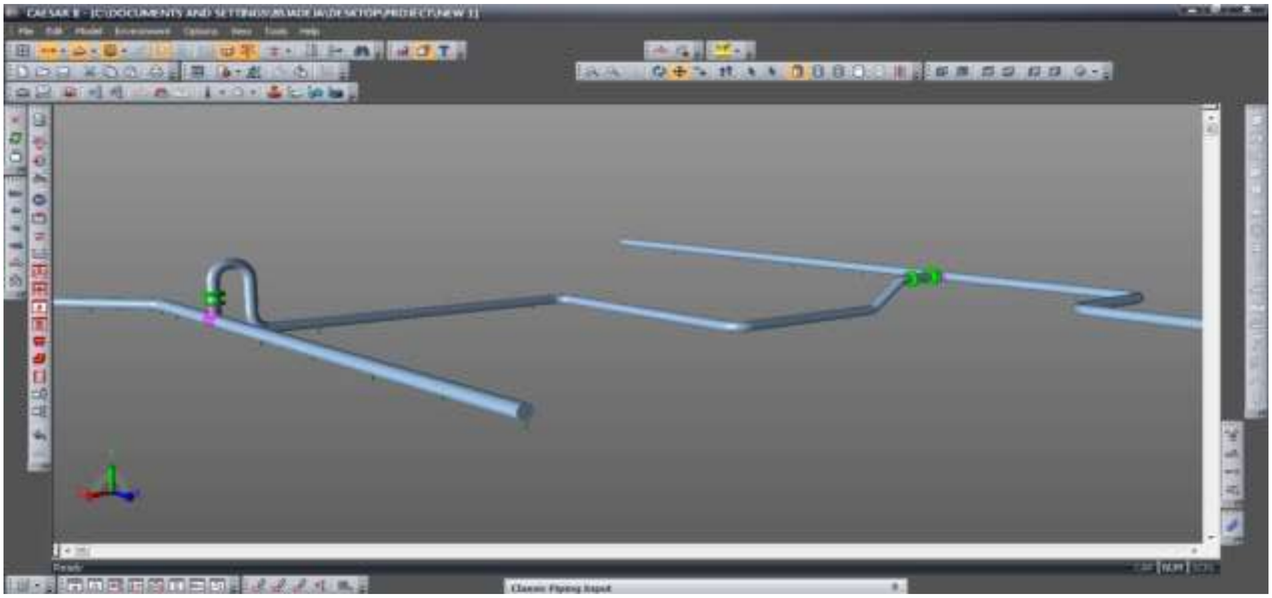

Figure 13 pipeline modeling

The above figure shows the effective model diagram of the pipeline by the Caesar II software. By modeling of the line it should be specify the material, diameter, thickness, corrosion allowance, length of each specimen, supports, span length, pipeline fittings, specifications, rigid weights, design and operating parameters and soil properties etc.

After inputting all the details in software the next step is the static analysis. The analysis is started by selecting the 'Analysis –static' from the Main menu. The first step in the static analysis is to specify the load sets for the analysis. For a new model Caesar II assists in this step by reviewing all load categories (e.g. temperature, pressure, displacement, forces, weight, etc.) specified in the input. The selection of the load cases (described above pages) Caesar II will proceed with static analysis. The program continues with the data processing by building, sorting, and the equation (matrix) data for the system and the load cases. Once this is done the Caesar II solution module is entered briefly. The software will analyze all the load condition (operating, sustain, expansion etc.).

7.1. Soil inputting

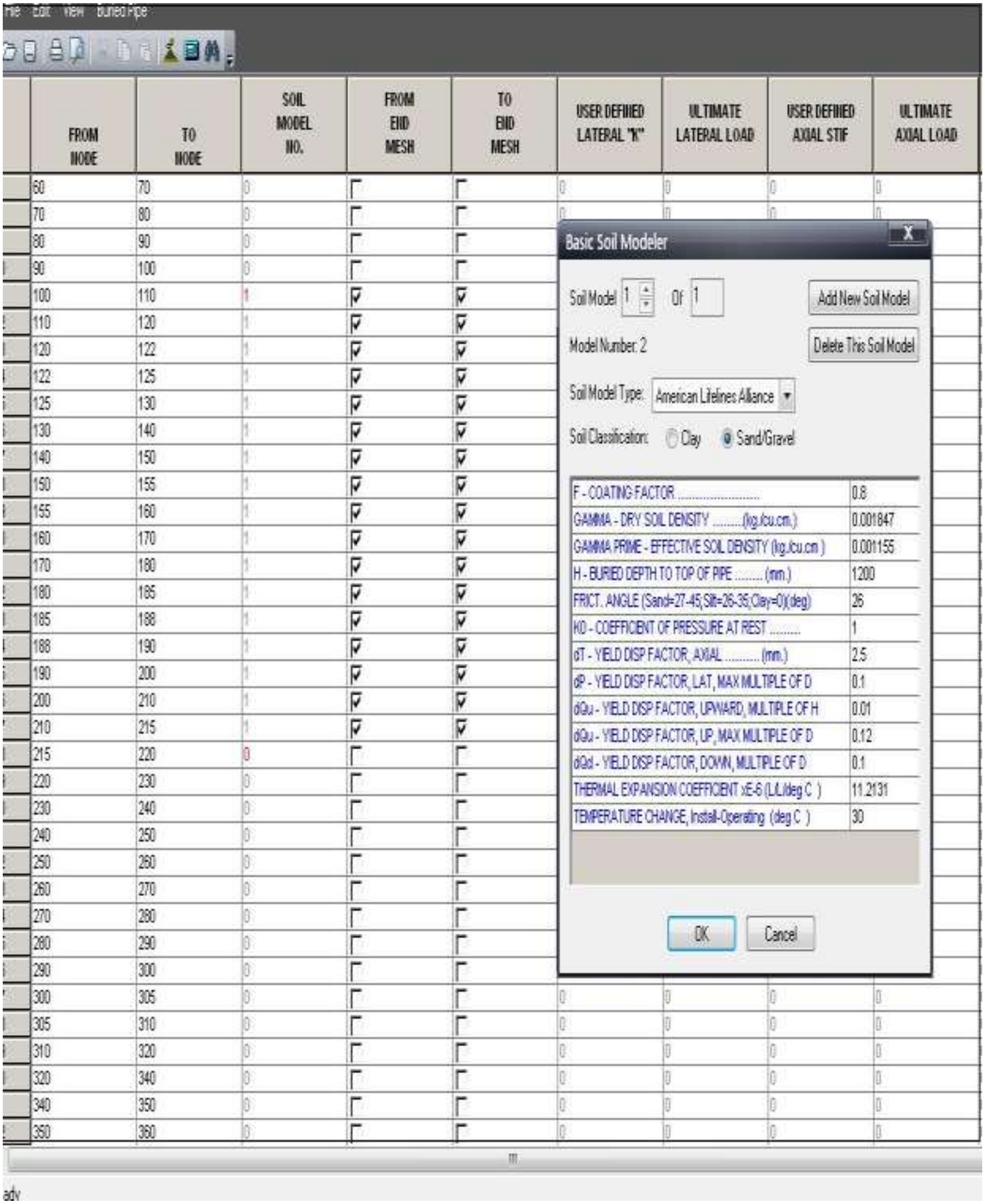

Figure 14. Soil modeling

8.0. Chapter 4

Results and Discussion

CAESAR II Ver.5.20.2, (Build 100122) Date: APR 7, 2015 Time: 12:0
Job: C:\DOCUMENTS AND SETTINGS\BSJADEJA\DESKTOP\PROJ...\ESSAR.NEW
Licensed To: ESSAR ENGINEERING SERVICES LIMITED - MUMBAI -- ID #28707

LISTING OF STATIC LOAD CASES FOR THIS ANALYSIS

1 (HYD) WW+HP
2 (OPE) W+T1+P1
3 (OPE) W+T2+P2
4 (OPE) W+T3+P1
5 (SUS) W+P1
6 (SUS) W+P2
7 (OCC) W+T1+P1+U1
8 (OCC) W+T1+P1-U1
9 (OCC) W+T1+P1+U2
10 (OCC) W+T1+P1-U2
11 (OCC) W+T1+P1+U3
12 (OCC) W+T1+P1-U3
13 (EXP) L13=L2-L5
14 (EXP) L14=L3-L6

CAESAR II Ver.5.20.2, (Build 100122) Date: APR 7, 2015 Time: 12:0
Job: C:\DOCUMENTS AND SETTINGS\BSJADEJA\DESKTOP\PROJ...\ESSAR.NEW
Licensed To: ESSAR ENGINEERING SERVICES LIMITED - MUMBAI -- ID #28707

INPUT LISTING

PROJECT: STRESS ANALYSIS OF THE INTERLINK PIPELINE

ANALYST: MAHESH V

PIPE DATA

From 10 To 15 DY=
.171 m. PIPE

Dia= 42.000 in. Wall= 12.700 mm. Insul= .000 mm. Cor= 3.0000 mm. GENERAL

T1= 65 C T2= 50 C T3= 40 C P1= 1.7680 N./sq.mm. P2= .7848 N./sq.mm. PHyd= 2.6487 N./sq.mm. Mat= (323)API-5L X46 E= 203,391 N./sq.mm. EH1= 200,675 N./sq.mm. EH2= 201,792 N./sq.mm. EH3= 202,536 N./sq.mm. EH4= 203,391 N./sq.mm. EH5= 203,391 N./sq.mm. EH6= 203,391 N./sq.mm. EH7= 203,391 N./sq.mm. EH8= 203,391 N./sq.mm. EH9= 203,391 N./sq.mm. v = .292 Density= 7,850.0005 kg/cu.m. Fluid= 866.9999390 kg/cu.m.

RIGID Weight=
3,385.00 N.
UNIFORM LOAD

UX1= .00 N./cm. UY1= .00 N./cm. UZ1= .00 N./cm. UX2= .00 N./cm. UY2= .00 N./cm. UZ2= .00 N./cm. UX3= .00 N./cm. UY3= .00 N./cm. UZ3= .00 N./cm.

From 15 To 20 DX= .000 m. DY= .500 m. DZ= .000 m.

From 20 To 30 DX= .000 m. DY= .502 m. DZ=
.000 m. RIGID Weight=15,809.99 N.
ALLOWABLE STRESSES
B31.3 (2006) Cycle Max Switch = Sc= 145 N./sq.mm.
Sh1= 145 N./sq.mm. Sh2= 145 N./sq.mm. Sh3= 145 N./sq.mm.
Sh4= 145 N./sq.mm. Sh5= 145 N./sq.mm. Sh6= 145 N./sq.mm.
Sh7= 145 N./sq.mm. Sh8= 145 N./sq.mm. Sh9= 145 N./sq.mm.

From 30 To 40 DX= .000 m. DY= .500 m. DZ= .000 m.

From 40 To 50 DX= .000 m. DY= .462 m. DZ= .000 m.

From 50 To 60 DX= .000 m. DY= 1.600 m. DZ=
.000 m. BEND at "TO" end

Radius= 1,600.200 mm. (LONG) Bend Angle= 90.000 Angle/Node @1= 45.00 59

From 60 To 70 DX= .000 m. DY= .000 m. DZ= -1.600 m.

From 70 To 80 DX= .000 m. DY= .000 m. DZ= -
1.600 m. BEND at "TO" end
Radius= 1,600.200 mm. (LONG) Bend Angle= 90.000 Angle/Node @1= 45.00 79

From 80 To 90 DX= .000 m. DY= -1.600 m. DZ= .000 m.

From 90 To 100 DX= .000 m. DY= -3.420 m. DZ= .000 m.

From 100 To 110 DX= .000 m. DY= -1.600 m. DZ=
.000 m. BEND at "TO" end
Radius= 1,600.200 mm. (LONG) Bend Angle= 90.000 Angle/Node @1= 45.00 109

From 110 To 120 DX= .000 m. DY= .000 m. DZ= -1.600 m.

From 120 To 122 DX= .000 m. DY= .000 m. DZ= -
4.400 m. RESTRAINTS
Node 122 +Y Mu =
.45 Node 122 Guide
Mu = .45

From 122 To 123 DZ= -
11.500 m. RESTRAINTS
Node 123 +Y Mu = .45

From 123 To 125 DZ= -
11.500 m. RESTRAINTS
Node 125 +Y Mu = .45

From 125 To 130 DX= .000 m. DY= .000 m. DZ= -2.400 m.

From 130 To 140 DX= .000 m. DY= .000 m. DZ= -
1.600 m. BEND at "TO" end
Radius= 1,600.200 mm. (LONG) Bend Angle= 90.000 Angle/Node @1= 45.00 139

From 140 To 150 DX= 1.600 m. DY= .000 m. DZ= .000 m.

From 150 To 155 DX=
13.400 m. RESTRAINTS
Node 155 +Y Mu = .45

CAESAR II Ver.5.20.2, (Build 100122) Date: APR 7, 2015   Time: 12:0

From 160 To 170 DX= 1.600 m. DY= .000 m. DZ=
.000 m. BEND at "TO" end
Radius= 1,600.200 mm. (LONG) Bend Angle= 90.000

From 170 To 180 DX= .000 m. DY= .000 m. DZ= -1.600 m.

From 180 To 185 DX= .000 m. DY= .000 m. DZ= -
3.400 m. RESTRAINTS
Node 185 +Y Mu = .45

From 185 To 188 DZ= -
10.000 m. RESTRAINTS
Node 188 +Y Mu =
.45 Node 188 Guide
Mu = .45

From 188 To 190 DZ= -2.340 m.

From 190 To 200 DX= .000 m. DY= .000 m. DZ= -
.660 m. BEND at "TO" end
Radius= 1,600.200 mm. (LONG) Bend Angle= 34.091 Angle/Node @1= 17.05 199

From 200 To 210 DX= .000 m. DY= .447 m. DZ= -.660 m.

From 210 To 215 DY= .599 m. DZ= -.847 m.

From 215 To 220 DY= 1.468 m. DZ= -2.075 m.

From 220 To 230 DX= .000 m. DY= .467 m. DZ= -
.660 m. BEND at "TO" end
Radius= 1,600.200 mm. (LONG) Bend Angle= 35.265 Angle/Node @1= 17.63 229

From 230 To 240 DX= .000 m. DY= .000 m. DZ= -
.660 m. ALLOWABLE STRESSES
B31.3 (2006)   Cycle Max Switch = Sc= 145 N./sq.mm.
Sh1= 145 N./sq.mm. Sh2= 145 N./sq.mm.   Sh3= 145 N./sq.mm.
Sh4= 145 N./sq.mm. Sh5= 145 N./sq.mm.   Sh6= 145 N./sq.mm.
Sh7= 145 N./sq.mm. Sh8= 145 N./sq.mm.   Sh9= 145 N./sq.mm.

From 240 To 250 DX= .000 m. DY= .000 m. DZ= -.500 m.

From 250 To 260 DX= .000 m. DY= .000 m. DZ= -
.502 m. RIGID Weight=15,809.99 N.

From 270 To 280 DX= .000 m. DY= .000 m. DZ= -.738 m.

From 280 To 290 DX= .000 m. DY= .000 m. DZ= -
.500 m. SIF's & TEE's
Node 290

From 290 To 300 DX= .000 m. DY= .000 m. DZ= -
.800 m. RESTRAINTS
Node 290 +Y Mu = .45
Node 290 Guide Gap= 10.000 mm. Mu = .30

From 300 To 305 DX= .000 m. DY= .000 m. DZ= -
1.060 m. RIGID Weight=53,503.00 N.

From 305 To 310 DZ= -
.940 m. SIF's & TEE's
Node 310 Welding Tee

From 310 To 315 DX=
2.000 m. RESTRAINTS
Node 315 +Y Mu = .30
Node 315 Guide Gap= 20.000 mm. Mu = .30

From 315 To 320 DX=
10.000 m. RESTRAINTS
Node 320 +Y Mu
= .45 SIF's &
TEE's
Node 320 Welding Tee

From 320 To 340 DX= 5.000 m.

From 340 To 350 DX= 1.600 m. DY= .000 m. DZ=
.000 m. BEND at "TO" end
Radius= 1,600.200 mm. (LONG) Bend Angle= 90.000 Angle/Node @1= 45.00 349

From 350 To 360 DX= .000 m. DY= .000 m. DZ= -
1.600 m. RESTRAINTS
Node 360 +Y Mu = .30

From 360 To 370 DX= .000 m. DY= .000 m. DZ= -
8.400 m. RESTRAINTS
Node 370 +Y Mu = .45

Insul= 260.0000
kg/cu.m. BEND
at "TO" end
Radius= 1,600.200 mm. (LONG) Bend Angle= 90.000 Angle/Node @1= 45.00 379

From 380 To 390 DX= 1.600 m. DY= .000 m. DZ= .000 m.

From 390 To 400 DX= 18.400 m. DY= .000 m. DZ=
.000 m. RESTRAINTS
Node 400 +Y Mu = .45
Node 400 LIM Gap= 10.000 mm. Mu =
.30 Node 400 Guide Gap= 10.000 mm.
Mu = .30

From 400 To 410 DX= 7.829 m. DY= .000 m. DZ= .000 m.

From 310 To 500 DX= -10.000 m. DY= .000 m. DZ=
.000 m. RESTRAINTS
Node 500 +Y Mu = .45

From 500 To 510 DX= -10.000 m. DY= .000 m. DZ=
.000 m. RESTRAINTS
Node 510 +Y Mu =
.45 Node 510 Guide
Mu = .30

From 510 To 520 DX= -10.000 m. DY= .000 m. DZ=
.000 m. RESTRAINTS
Node 520 +Y Mu = .45

From 520 To 530 DX= -10.000 m. DY= .000 m. DZ=
.000 m. RESTRAINTS
Node 530 +Y Mu =
.45 Node 530 Guide
Mu = .30

From 530 To 540 DX= -10.000 m. DY= .000 m. DZ=
.000 m. RESTRAINTS
Node 540 +Y Mu = .45

From 10 To 5 DY= -
.171 m. RIGID
Weight= 3,385.00 N.

From 5 To 550 DY= -
1.488 m. SIF's & TEE's
Node 550 Welding Tee

Dia= 48.000 in. Wall= 14.300 mm. Insul= .000 mm.
GENERAL
Mat= (331)API-5L X52 E= 203,391 N./sq.mm. EH1= 200,675 N./sq.mm.
EH2= 201,792 N./sq.mm. EH3= 202,536 N./sq.mm. EH4= 203,391 N./sq.mm.

EH5= 203,391 N./sq.mm. EH6= 203,391 N./sq.mm. EH7= 203,391 N./sq.mm.
EH8= 203,391 N./sq.mm. EH9= 203,391 N./sq.mm. v = .292
Density= 7,833.4399 kg/cu.m.
RESTRAINTS
Node 560 +Y Mu = .30
ALLOWABLE STRESSES
B31.3 (2006) Cycle Max Switch = Sc= 152 N./sq.mm.
Sh1= 152 N./sq.mm. Sh2= 152 N./sq.mm. Sh3= 152 N./sq.mm.
Sh4= 152 N./sq.mm. Sh5= 152 N./sq.mm. Sh6= 152 N./sq.mm.
Sh7= 152 N./sq.mm. Sh8= 152 N./sq.mm. Sh9= 152 N./sq.mm.

From 560 To 710 DX= 6.000 m.
PIPE
Dia= 48.000 in. Wall= 14.300 mm. Insul= .000 mm.
RESTRAINTS
Node 710 +Y Mu = .45

From 550 To 570 DX= -9.000 m. DY= .000 m. DZ= .000 m.
RESTRAINTS
Node 570 +Y Mu = .45
SIF's & TEE's
Node 570 Welding Tee

From 570 To 580 DX= -3.615 m. DY= .000 m. DZ= .000 m.
BEND at "TO" end
Radius= 1,828.800 mm. (LONG) Bend Angle= 42.734 Angle/Node @1=
21.37 579 Angle/Node @2= .00 578
RESTRAINTS
Node 580 +Y Mu = .45

From 580 To 590 DX= -5.050 m. DY= .000 m. DZ=
4.666 m. RESTRAINTS
Node 590 +Y Mu = .45

From 590 To 600 DX= -9.000 m. DY= .000 m. DZ=
8.315 m. RESTRAINTS
Node 600 +Y Mu = .45
Node 600 Guide Gap= 5.000 mm. Mu = .30

Node 610 +Y Mu = .45

From 610 To 620 DX= -9.000 m. DY= .000 m. DZ=
8.307 m. RESTRAINTS
Node 620 +Y Mu = .45

From 710 To 630 DX= 9.000 m. DY= .000 m. DZ=

.000 m. PIPE

Dia= 48.000 in. Wall= 14.300 mm. Insul= .000
mm. RESTRAINTS

Node 630 +Y Mu =
.45 Node 630 Guide
Mu = .30

From 630 To 640 DX= 9.000 m. DY= .000 m. DZ=
.000 m. PIPE

Dia= 48.000 in. Wall= 14.300 mm. Insul= .000
mm. RESTRAINTS
Node 640 +Y Mu = .45

From 640 To 650 DX= 9.000 m. DY= .000 m. DZ=
.000 m. PIPE

Dia= 48.000 in. Wall= 14.300 mm. Insul= .000
mm. RESTRAINTS

Node 650 +Y Mu =
.45 Node 650 Guide
Mu = .30

From 650 To 660 DX= 9.000 m. DY= .000 m. DZ=
.000 m. PIPE

Dia= 48.000 in. Wall= 14.300 mm. Insul= .000 mm. Cor= 3.0000
mm. RESTRAINTS
Node 660 +Y Mu = .45

MATERIAL Changes:
10 15 Mat= (323)API-5L X46 E= 203,391 N./sq.mm.
v = .292 Density= 7,850.0005 kg/cu.m.
550 560 Mat= (331)API-5L X52 E= 203,391 N./sq.mm.
v = .292 Density= 7,833.4399 kg/cu.m.

		Sh4= 145 N./sq.mm.	Sh5= 145 N./sq.mm.
		Sh6= 145 N./sq.mm.	Sh7= 145 N./sq.mm.
		Sh8= 145 N./sq.mm.	Sh9= 145 N./sq.mm.
230	240	B31.3 (2006)	Cycle Max Switch =
		Sc= 145 N./sq.mm.	Sh1= 145 N./sq.mm.
		Sh2= 145 N./sq.mm.	Sh3= 145 N./sq.mm.
		Sh4= 145 N./sq.mm.	Sh5= 145 N./sq.mm.
		Sh6= 145 N./sq.mm.	Sh7= 145 N./sq.mm.
		Sh8= 145 N./sq.mm.	Sh9= 145 N./sq.mm.
550	560	B31.3 (2006)	Cycle Max Switch =
		Sc= 152 N./sq.mm.	Sh1= 152 N./sq.mm.
		Sh2= 152 N./sq.mm.	Sh3= 152 N./sq.mm.
		Sh4= 152 N./sq.mm.	Sh5= 152 N./sq.mm.
		Sh6= 152 N./sq.mm.	Sh7= 152 N./sq.mm.
		Sh8= 152 N./sq.mm.	Sh9= 152 N./sq.mm.

BEND ELEMENTS

50	60	Radius= 1,600.200 mm. (LONG) Bend Angle= 90.000 Angle/Node @1= 45.00 59
70	80	Radius= 1,600.200 mm. (LONG) Bend Angle= 90.000 Angle/Node @1= 45.00 79
100	110	Radius= 1,600.200 mm. (LONG) Bend Angle= 90.000 Angle/Node @1= 45.00 109
130	140	Radius= 1,600.200 mm. (LONG) Bend Angle= 90.000 Angle/Node @1= 45.00 139
160	170	Radius= 1,600.200 mm. (LONG) Bend Angle= 90.000
190	200	Radius= 1,600.200 mm. (LONG) Bend Angle= 34.091 Angle/Node @1= 17.05 199
220	230	Radius= 1,600.200 mm. (LONG) Bend Angle= 35.265 Angle/Node @1= 17.63 229
340	350	Radius= 1,600.200 mm. (LONG) Bend Angle= 90.000 Angle/Node @1= 45.00 349
370	380	Radius= 1,600.200 mm. (LONG) Bend Angle= 90.000 Angle/Node @1= 45.00 379

RIGIDS

10	15	RIGID Weight= 3,385.00 N.
20	30	RIGID Weight=15,809.99 N.
250	260	RIGID Weight=15,809.99 N.
300	305	RIGID Weight=53,503.00 N.
10	5	RIGID Weight= 3,385.00 N.

SIF's & TEE's

280	290	Node 290	
305	310	Node 310	Welding Tee
315	320	Node 320	Welding Tee
5	550	Node 550	Welding Tee
550	570	Node 570	Welding Tee

RESTRAINTS

NODE	TYPE	GAP CNODE	STIF1	YIELD STIF2	Dir FORCE	Vectors	
122	+Y			.45	.000	1.000	.000
122	Guide			.45	.000	.000	.000
123	+Y			.45	.000	1.000	.000
125	+Y			.45	.000	1.000	.000
155	+Y			.45	.000	1.000	.000
185	+Y			.45	.000	1.000	.000
188	+Y			.45	.000	1.000	.000
188	Guide			.45	.000	.000	.000
290	+Y			.45	.000	1.000	.000
290	Guide	10.00		.30	.000	.000	.000
315	+Y			.30	.000	1.000	.000
315	Guide	20.00		.30	.000	.000	.000
320	+Y			.45	.000	1.000	.000
360	+Y			.30	.000	1.000	.000
370	+Y			.45	.000	1.000	.000
400	+Y			.45	.000	1.000	.000
400	LIM	10.00		.30	.000	.000	.000
400	Guide	10.00		.30	.000	.000	.000
500	+Y			.45	.000	1.000	.000
510	+Y			.45	.000	1.000	.000
510	Guide			.30	.000	.000	.000
520	+Y			.45	.000	1.000	.000
530	+Y			.45	.000	1.000	.000
530	Guide			.30	.000	.000	.000
540	+Y			.45	.000	1.000	.000
560	+Y			.30	.000	1.000	.000
710	+Y			.45	.000	1.000	.000
570	+Y			.45	.000	1.000	.000
580	+Y			.45	.000	1.000	.000
590	+Y			.45	.000	1.000	.000
600	+Y			.45	.000	1.000	.000
600	Guide		5.00	.30	.000	.000	.000
610	+Y			.45	.000	1.000	.000
620	+Y			.45	.000	1.000	.000
630	+Y			.45	.000	1.000	.000
630	Guide			.30	.000	.000	.000
640	+Y			.45	.000	1.000	.000
650	+Y			.45	.000	1.000	.000
650	Guide			.30	.000	.000	.000

UNIFORM LOAD Changes

10 15 X1 Dir = .00 N./cm. Y1 Dir = .00 N./cm.
Z1 Dir = .00 N./cm.
X2 Dir = .00 N./cm. Y2 Dir = .00 N./cm.
Z2 Dir = .00 N./cm.
X3 Dir = .00 N./cm. Y3 Dir = .00 N./cm.
Z3 Dir = .00 N./cm.

INUT UNITS USED...

UNITS= SINOM/SCH INPUT= ON

LENGTH	inches	x	25.400	=	mm.
FORCE	pounds	x	4.448	=	N.
MASS(dynamics)	pounds	x	0.454	=	kg.
MOMENTS(INPUT)	inch-pounds	x	0.113	=	N.m.
MOMENTS(OUTPUT)	inch-pounds	x	0.113	=	N.m.
STRESS	lbs./sq.in.	x	0.007	=	N./sq.mm.
TEMP. SCALE	degrees F.	x	0.556	=	C
PRESSURE	Psig	x	0.007	=	N./sq.mm.
ELASTIC MODULUS	lbs./sq.in.	x	0.007	=	N./sq.mm.

PIPE DENSITY lbs./cu.in. x 27680.000 = kg/cu.m.
INSULATION DENS. lbs./cu.in. x 27680.000 = kg/cu.m.
FLUID DENSITY lbs./cu.in. x 27680.000 = kg/cu.m.
TRANSL. STIF lbs./in. x 1.751 = N./cm.
ROTATIONAL STIF in.lb./deg. x 0.113 =N.m./deg
UNIFORM LOAD lb./in. x 1.751 =N./cm.
G LOAD g's x 1.000 = g's
WIND LOAD lbs./sq.in. x 6894.757 = N./sq.m.
ELEVATION inches x 0.025 = m.
COMPOUND LENGTH inches x 0.025= m.
DIAMETER inches x 1.000 = in.
WALL THICKNESS inches x 25.400 = mm.

SETUP FILE PARAMETERS

CONNECT GEOMETRY THRU CNODES = YES
MIN ALLOWED BEND ANGLE = 5.00000
MAX ALLOWED BEND ANGLE = 95.0000
BEND LENGTH ATTACHMENT PERCENT = 1.00000
MIN ANGLE TO ADJACENT BEND PT = 5.00000
LOOP CLOSURE TOLERANCE = 25.4000 mm.
THERMAL BOWING HORZ TOLERANCE = 0.100000E-03
AUTO NODE NUMBER INCREMENT= 10.0000
Z AXIS UP= NO
USE PRESSURE STIFFENING = DEFAULT
ALPHA TOLERANCE = 0.500000E-01
RESLD-FORCE = NO
HGR DEF RESWGT STIF = 0.175120E+13 N./cm.
DECOMP SNG TOL = 0.100000E+11
BEND AXIAL SHAPE = YES
FRICT STIF = 0.175120E+07 N./cm.
FRICT NORM FORCE VAR = 0.150000
FRICT ANGLE VAR = 15.0000
FRICT SLIDE MULT = 1.00000
ROD TOLERANCE = 1.00000
ROD INC = 2.00000
INCORE NUMERICAL CHECK = NO
OUTCORE NUMERICAL CHECK = NO
DEFAULT TRANS RESTRAINT STIFF= 0.175120E+13 N./cm.
DEFAULT ROT RESTRAINT STIFF= 0.112980E+12 N.m./deg
IGNORE SPRING HANGER STIFFNESS = NO
MISSING MASS ZPA = EXTRACTED
MIN WALL MILL TOLERANCE = 12.5000

DEFAULT AMBIENT TEMPERATURE= 21.1142C
BOURDON PRESSURE= NONE
COEFFICIENT OF FRICTION (MU) = 0.300000
INCLUDE SPRG STIF IN HGR OPE = NO
INCLUDE INSULATION IN HYDROTEST = NO
REDUCED INTERSECTION = B31.1(POST1980)
USE WRC329 NO
NO REDUCED SIF FOR RFT AND WLT NO
B31.1 REDUCED Z FIX = YES
CLASS 1 BRANCH FLEX NO
ALL STRESS CASES CORRODED = NO
ADD TORSION IN SL STRESS = DEFAULT
ADD F/A IN STRESS = DEFAULT
OCCASIONAL LOAD FACTOR = 0.000000
DEFAULT CODE = B31.3
B31.3 SUS CASE SIF FACTOR = 1.00000
ALLOW USERS BEND SIF = NO
USE SCHNEIDER NO
YIELD CRITERION STRESS = MAX 3D SHEAR
USE PD/4T NO
BASE HOOP STRESS ON ? = ID
EN13480 USE IN OUTPLANE SIFS= NO
LIBERAL EXPANSION ALLOWABLE= YES
B31.3 SEC 319.2.3C SAXIAL= NO
B31.3 WELDING/CONTOUR TEE ISB16.9 NO
PRESSURE VARIATION IN EXP CASE= DEFAULT
IMPLEMENT B313 APP-P YES
IMPLEMENT B313 CODE CASE 178 NO
IGNORE B31.3 Wc FACTOR= NO
USE FRP SIF = YES
USE FRP FLEX = YES
BS 7159 Pressure Stiffening= Design Strain
FRP Property Data File= CAESAR.FRP
FRP Emod (axial) = 22062.7 N./sq.mm.
FRP Ratio Gmod/Emod (axial) = 0.250000
FRP Ea/Eh*Vh/a = 0.152730
FRP Laminate Type = THREE
FRP Alpha = 21.5983 C
FRP Density = 1660.80 kg/cu.m.
EXCLUDE f2 FROM UKOOA BENDING = NO

Rigid/ExpJt Print Flag 1.000
Bourdon Option .... .000
Loop Closure Flag .... .000
Thermal Bowing Delta Temp .. .000 C
Liberal Allowable Flag 1.000
Uniform Load Option .... .000
Ambient Temperature .... 21.114 C
Plastic (FRP) Alpha 21.598
Plastic (FRP) GMOD/EMODa ... .250
Plastic (FRP) Laminate Type. 3.000
Eqn Optimizer .... .000
Node Selection .... .000
Eqn Ordering .... .000
Collins .... .000
Degree Determination .... .000
User Eqn Control .... .000

COORDINATE REPORT

(mm.)-------------------- /

NODE	X	Y	Z
10	.0000	.0000	.0000
15	.0000	171.0000	.0000
20	.0000	671.0000	.0000
30	.0000	1173.0000	.0000
40	.0000	1673.0000	.0000
50	.0000	2135.0000	.0000
60	.0000	3735.0000	.0000
70	.0000	3735.0000	-1600.0000
80	.0000	3735.0000	-3200.0000
90	.0000	2135.0000	-3200.0000
100	.0000	-1285.0000	-3200.0000
110	.0000	-2885.0000	-3200.0000
120	.0000	-2885.0000	-4800.0000
122	.0000	-2885.0000	-9200.0000
123	.0000	-2885.0000	-20700.0000
125	.0000	-2885.0000	-32200.0000
130	.0000	-2885.0000	-34600.0000
140	.0000	-2885.0000	-36200.0000
150	1600.0000	-2885.0000	-36200.0000
155	15000.0000	-2885.0000	-36200.0000
160	23400.0000	-2885.0000	-36200.0000
170	25000.0000	-2885.0000	-36200.0000
180	25000.0000	-2885.0000	-37800.0000
185	25000.0000	-2885.0000	-41200.0000

190	25000.0000	-2885.0000	-53540.0000
200	25000.0000	-2885.0000	-54200.0000
210	25000.0000	-2438.3000	-54860.0000
215	25000.0000	-1839.5039	-55706.6484
220	25000.0000	-371.7000	-57782.0000
230	25000.0000	95.0001	-58442.0000
240	25000.0000	95.0001	-59102.0000
250	25000.0000	95.0001	-59602.0000
260	25000.0000	95.0001	-60104.0000
270	25000.0000	95.0001	-60604.0000
280	25000.0000	95.0001	-61342.0000
290	25000.0000	95.0001	-61842.0000
300	25000.0000	95.0001	-62642.0000
305	25000.0000	95.0001	-63702.0000
310	25000.0000	95.0001	-64642.0000
315	27000.0000	95.0001	-64642.0000
320	37000.0000	95.0001	-64642.0000
340	42000.0000	95.0001	-64642.0000
350	43600.0000	95.0001	-64642.0000
360	43600.0000	95.0001	-66242.0000
370	43600.0000	95.0001	-74642.0000
380	43600.0000	95.0001	-76242.0000
390	45200.0000	95.0001	-76242.0000
400	63600.0000	95.0001	-76242.0000
410	71429.0000	95.0001	-76242.0000
310	25000.0000	95.0001	-64642.0000
500	15000.0000	95.0001	-64642.0000
510	5000.0000	95.0001	-64642.0000
520	-5000.0000	95.0001	-64642.0000
530	-15000.0000	95.0001	-64642.0000
540	-25000.0000	95.0001	-64642.0000
10	.0000	.0000	.0000
5	.0000	-171.0000	.0000
550	.0000	-1659.0000	.0000
560	3000.0000	-1659.0000	.0000
710	9000.0000	-1659.0000	.0000
550	.0000	-1659.0000	.0000
570	-9000.0000	-1659.0000	.0000
580	-12615.0000	-1659.0000	.0000
590	-17665.0000	-1659.0000	4665.5898
600	-26665.0000	-1659.0000	12980.5068
610	-35665.0000	-1659.0000	21275.1562
620	-44665.0000	-1659.0000	29582.1562
710	9000.0000	-1659.0000	.0000

630	18000.0000	-1659.0000	
640	27000.0000	-1659.0000	.0000
650	36000.0000	-1659.0000	.0000
660	45000.0000	-1659.0000	.0000

CASE 1 (HYD) WW+HP
HYDRO TEST CASE
Keep/Discard: Keep
Display: Disp/Force/Stress
Elastic Modulus: EC
Friction Mult.: 1.0000
Flg Analysis Temp: None

CASE 2 (OPE) W+T1+P1
OPERATING CASE CONDITION 1
Keep/Discard: Keep
Display: Disp/Force/Stress
Elastic Modulus: EC
Friction Mult.: 1.0000
Flg Analysis Temp: None

CASE 3 (OPE) W+T2+P2
OPERATING CASE CONDITION 2
Keep/Discard: Keep
Display: Disp/Force/Stress
Elastic Modulus: EC
Friction Mult.: 1.0000
Flg Analysis Temp: None

CASE 4 (OPE) W+T3+P1
OPERATING CASE CONDITION 3
Keep/Discard: Keep
Display: Disp/Force/Stress
Elastic Modulus: EC
Friction Mult.: 1.0000
Flg Analysis Temp: None

CASE 5 (SUS) W+P1
SUSTAINED CASE CONDITION 1
Keep/Discard: Keep
Display: Disp/Force/Stress
Elastic Modulus: EC
Friction Mult.: 1.0000
Flg Analysis Temp: None

CASE 6 (SUS) W+P2

SUSTAINED CASE CONDITION 2
Keep/Discard: Keep
Display: Disp/Force/Stress
Elastic Modulus: EC
Friction Mult.: 1.0000
Flg Analysis Temp: None

CASE 7 (OCC) W+T1+P1+U1
Keep/Discard: Keep
Display: Disp/Force/Stress
Elastic Modulus: EC
Friction Mult.: 1.0000
OCC Load Factor: 0.0000
Flg Analysis Temp: None

CASE 8 (OCC) W+T1+P1-U1
Keep/Discard: Keep
Display: Disp/Force/Stress
Elastic Modulus: EC
Friction Mult.: 1.0000
OCC Load Factor: 0.0000
Flg Analysis Temp: None
CASE 9 (OCC) W+T1+P1+U2
Keep/Discard: Keep
Display: Disp/Force/Stress
Elastic Modulus: EC
Friction Mult.: 1.0000
OCC Load Factor: 0.0000
Flg Analysis Temp: None

CASE 10 (OCC) W+T1+P1-U2
Keep/Discard: Keep
Display: Disp/Force/Stress
Elastic Modulus: EC
Friction Mult.: 1.0000
OCC Load Factor: 0.0000
Flg Analysis Temp: None

CASE 11 (OCC) W+T1+P1+U3
Keep/Discard: Keep

Elastic Modulus: EC
Friction Mult.: 1.0000
OCC Load Factor: 0.0000
Flg Analysis Temp: None

CASE 12 (OCC) W+T1+P1-U3
Keep/Discard: Keep
Display: Disp/Force/Stress
Elastic Modulus: EC
Friction Mult.: 1.0000
OCC Load Factor: 0.0000
Flg Analysis Temp: None

CASE 13 (EXP) L13=L2-L5
EXPANSION CASE CONDITION 2
Keep/Discard: Keep
Display: Disp/Force/Stress
Combination Method: ALG
Flg Analysis Temp: None

CASE 14 (EXP) L14=L3-L6
EXPANSION CASE CONDITION 3
Keep/Discard: Keep
Display: Disp/Force/Stress
Combination Method: ALG
Flg Analysis Temp: None
LOAD CASE DEFINITION KEY
CASE 1 (HYD) WW+HP
CASE 2 (OPE) W+T1+P1
CASE 3 (OPE) W+T2+P2
CASE 4 (OPE) W+T3+P1
CASE 5 (SUS) W+P1
CASE 6 (SUS) W+P2
CASE 7 (OCC) W+T1+P1+U1
CASE 8 (OCC) W+T1+P1-U1
CASE 9 (OCC) W+T1+P1+U2
CASE 10 (OCC) W+T1+P1-U2
CASE 11 (OCC) W+T1+P1+U3
CASE 12 (OCC) W+T1+P1-U3
CASE 13 (EXP) L13=L2-L5
CASE 14 (EXP) L14=L3-L6

NODE	Load Case	FX N.	FY N.	FZ N.	MX N.m.	MY N.m.	MZ N.m.
122		Rigid +Y; Rigid GUI					
	1(HYD)	-4672	-214227	-5046	0	0	0
	2(OPE)	910	-198139	89572	0	0	0
	3(OPE)	-963	-196549	88881	0	0	0
	4(OPE)	-3173	-195840	89556	0	0	0
	5(SUS)	-4227	-193782	-4565	0	0	0
	6(SUS)	-4227	-193782	-4565	0	0	0
	7(OCC)	910	-198139	89572	0	0	0
	8(OCC)	910	-198139	89572	0	0	0
	9(OCC)	910	-198139	89572	0	0	0
	10(OCC)	910	-198139	89572	0	0	0
	11(OCC)	910	-198139	89572	0	0	0
	12(OCC)	910	-198139	89572	0	0	0
	13(EXP)	5137	-4356	94137	0	0	0
	14(EXP)	3264	-2767	93446	0	0	0
	MAX	5137/L13	-214227/L1	94137/L13			
123		Rigid +Y					
	1(HYD)	2064	-79160	-2061	0	0	0
	2(OPE)	-713	-71880	-32338	0	0	0
	3(OPE)	1859	-71705	-32214	0	0	0
	4(OPE)	5902	-71690	-31716	0	0	0
	5(SUS)	1867	-71581	-1865	0	0	0
	6(SUS)	1867	-71581	-1865	0	0	0
	7(OCC)	-713	-71880	-32338	0	0	0
	8(OCC)	-713	-71880	-32338	0	0	0
	9(OCC)	-713	-71880	-32338	0	0	0
	10(OCC)	-713	-71880	-32338	0	0	0
	11(OCC)	-713	-71880	-32338	0	0	0
	12(OCC)	-713	-71880	-32338	0	0	0
	13(EXP)	-2580	-300	-30473	0	0	0
	14(EXP)	-8	-124	-30349	0	0	0
	MAX	5902/L4	-79160/L1	-32338/L2			
125		Rigid +Y					
	1(HYD)	-526	-194342	-1665	0	0	0
	2(OPE)	-35947	-174765	-69948	0	0	0
	3(OPE)	-31763	-175015	-72068	0	0	0
	4(OPE)	-30506	-175221	-72709	0	0	0
	5(SUS)	-476	-175774	-1506	0	0	0

	6(SUS)	-476	-175774	-1506	0	0	0
	7(OCC)	-35947	-174765	-69948	0	0	0
	8(OCC)	-35947	-174765	-69948	0	0	0
	9(OCC)	-35947	-174765	-69948	0	0	0
	10(OCC)	-35947	-174765	-69948	0	0	0
	11(OCC)	-35947	-174765	-69948	0	0	0
	12(OCC)	-35947	-174765	-69948	0	0	0
	13(EXP)	-35471	1009	-68442	0	0	0
	14(EXP)	-31287	759	-70561	0	0	0
	MAX	-35947/L2	-194342/L1	-72709/L4			
155		Rigid +Y					
	1(HYD)	371	-197019	-53	0	0	0
	2(OPE)	6194	-179298	547	0	0	0
	3(OPE)	5990	-179357	-669	0	0	0
	4(OPE)	8622	-179292	529	0	0	0
	5(SUS)	338	-178196	-48	0	0	0
	6(SUS)	338	-178196	-48	0	0	0
	7(OCC)	6194	-179298	547	0	0	0
	8(OCC)	6194	-179298	547	0	0	0
	9(OCC)	6194	-179298	547	0	0	0
	10(OCC)	6194	-179298	547	0	0	0
	11(OCC)	6194	-179298	547	0	0	0
	12(OCC)	6194	-179298	547	0	0	0
	13(EXP)	5856	-1102	595	0	0	0
	14(EXP)	5651	-1161	-621	0	0	0
	MAX	8622/L4	-197019/L1	-669/L3			
185		Rigid +Y					
	1(HYD)	-748	-142036	-900	0	0	0
	2(OPE)	23293	-118961	48199	0	0	0
	3(OPE)	21253	-120172	49726	0	0	0
	4(OPE)	19126	-121285	51117	0	0	0
	5(SUS)	-689	-128447	-790	0	0	0
	6(SUS)	-689	-128447	-790	0	0	0
	7(OCC)	23293	-118961	48199	0	0	0
	8(OCC)	23293	-118961	48199	0	0	0
	9(OCC)	23293	-118961	48199	0	0	0
	10(OCC)	23293	-118961	48199	0	0	0
	11(OCC)	23293	-118961	48199	0	0	0
	12(OCC)	23293	-118961	48199	0	0	0
	13(EXP)	23982	9486	48989	0	0	0
	14(EXP)	21942	8275	50516	0	0	0

	MAX	23982/L13	-142036/L1	51117/L4			
188		Rigid +Y; Rigid GUI					
	1(HYD)	1535	-111796	-1782	0	0	0
	2(OPE)	13815	-152097	27211	0	0	0
	3(OPE)	4742	-145480	19854	0	0	0
	4(OPE)	-661	-139437	10964	0	0	0
	5(SUS)	1411	-101159	-1592	0	0	0
	6(SUS)	1411	-101159	-1592	0	0	0
	7(OCC)	13815	-152097	27211	0	0	0
	8(OCC)	13815	-152097	27211	0	0	0
	9(OCC)	13815	-152097	27211	0	0	0
	10(OCC)	13815	-152097	27211	0	0	0
	11(OCC)	13815	-152097	27211	0	0	0
	12(OCC)	13815	-152097	27211	0	0	0
	13(EXP)	12404	-50938	28803	0	0	0
	14(EXP)	3331	-44321	21446	0	0	0
	MAX	13815/L2	-152097/L2	28803/L13			
290		Rigid +Y; Rigid GUI w/gap					
	1(HYD)	-2025	-207000	1444	0	0	0
	2(OPE)	41671	-111599	-28028	0	0	0
	3(OPE)	46338	-123205	-30440	0	0	0
	4(OPE)	49955	-133341	-33241	0	0	0
	5(SUS)	-1861	-191982	1275	0	0	0
	6(SUS)	-1861	-191982	1275	0	0	0
	7(OCC)	41671	-111599	-28028	0	0	0
	8(OCC)	41671	-111599	-28028	0	0	0
	9(OCC)	41671	-111599	-28028	0	0	0
	10(OCC)	41671	-111599	-28028	0	0	0
	11(OCC)	41671	-111599	-28028	0	0	0
	12(OCC)	41671	-111599	-28028	0	0	0
	13(EXP)	43531	80383	-29303	0	0	0
	14(EXP)	48199	68777	-31715	0	0	0
	MAX	49955/L4	-207000/L1	-33241/L4			
315		Rigid +Y; Rigid GUI w/gap					

	1(HYD)	259	-97598	1270	0	0	0
	2(OPE)	34358	-128171	-17263	0	0	0
	3(OPE)	33072	-121333	-15204	0	0	0
	4(OPE)	32043	-115809	-13428	0	0	0
	5(SUS)	238	-89574	1137	0	0	0
	6(SUS)	238	-89574	1137	0	0	0
	7(OCC)	34358	-128171	-17263	0	0	0
	8(OCC)	34358	-128171	-17263	0	0	0
	9(OCC)	34358	-128171	-17263	0	0	0
	10(OCC)	34358	-128171	-17263	0	0	0
	11(OCC)	34358	-128171	-17263	0	0	0
	12(OCC)	34358	-128171	-17263	0	0	0
	13(EXP)	34120	-38597	-18400	0	0	0
	14(EXP)	32834	-31759	-16341	0	0	0
	MAX	34358/L2	-128171/L2	-18400/L13			
320		Rigid +Y					
	1(HYD)	201	-92599	79	0	0	0
	2(OPE)	35555	-79872	5265	0	0	0
	3(OPE)	35503	-80007	5980	0	0	0
	4(OPE)	35499	-80255	6642	0	0	0
	5(SUS)	185	-83576	74	0	0	0
	6(SUS)	185	-83576	74	0	0	0
	7(OCC)	35555	-79872	5265	0	0	0
	8(OCC)	35555	-79872	5265	0	0	0
	9(OCC)	35555	-79872	5265	0	0	0
	10(OCC)	35555	-79872	5265	0	0	0
	11(OCC)	35555	-79872	5265	0	0	0
	12(OCC)	35555	-79872	5265	0	0	0
	13(EXP)	35370	3703	5191	0	0	0
	14(EXP)	35318	3569	5906	0	0	0
	MAX	35555/L2	-92599/L1	6642/L4			
360		Rigid +Y					
	1(HYD)	89	-82509	-23	0	0	0
	2(OPE)	22088	-75631	5190	0	0	0
	3(OPE)	22050	-75595	5304	0	0	0
	4(OPE)	21995	-75531	5447	0	0	0
	5(SUS)	82	-74670	-21	0	0	0
	6(SUS)	82	-74670	-21	0	0	0
	7(OCC)	22088	-75631	5190	0	0	0
	8(OCC)	22088	-75631	5190	0	0	0
	9(OCC)	22088	-75631	5190	0	0	0
	10(OCC)	22088	-75631	5190	0	0	0

	11(OCC)	22088	-75631	5190	0	0	0
	12(OCC)	22088	-75631	5190	0	0	0
	13(EXP)	22006	-961	5211	0	0	0
	14(EXP)	21968	-926	5325	0	0	0
	MAX	22088/L2	-82509/L1	5447/L4			
370		Rigid +Y					
	1(HYD)	-5	-176716	-19	0	0	0
	2(OPE)	-71251	-159876	-9965	0	0	0
	3(OPE)	-71490	-159876	-8075	0	0	0
	4(OPE)	-71603	-159874	-6989	0	0	0
	5(SUS)	-4	-159830	-18	0	0	0
	6(SUS)	-4	-159830	-18	0	0	0
	7(OCC)	-71251	-159876	-9965	0	0	0
	8(OCC)	-71251	-159876	-9965	0	0	0
	9(OCC)	-71251	-159876	-9965	0	0	0
	10(OCC)	-71251	-159876	-9965	0	0	0
	11(OCC)	-71251	-159876	-9965	0	0	0
	12(OCC)	-71251	-159876	-9965	0	0	0
	13(EXP)	-71246	-46	-9947	0	0	0
	14(EXP)	-71485	-46	-8057	0	0	0
	MAX	-71603/L4	-176716/L1	-9965/L2			
400		Rigid +Y; Rigid LIM w/gap; Rigid GUI w/gap					
	1(HYD)	-1	-220750	0	0	0	0
	2(OPE)	89632	-199624	-5975	0	0	0
	3(OPE)	89693	-199625	-4976	0	0	0
	4(OPE)	89735	-199627	-4180	0	0	0
	5(SUS)	-1	-199654	0	0	0	0
	6(SUS)	-1	-199654	0	0	0	0
	7(OCC)	89632	-199624	-5975	0	0	0
	8(OCC)	89632	-199624	-5975	0	0	0
	9(OCC)	89632	-199624	-5975	0	0	0
	10(OCC)	89632	-199624	-5975	0	0	0
	11(OCC)	89632	-199624	-5975	0	0	0
	12(OCC)	89632	-199624	-5975	0	0	0
	13(EXP)	89633	30	-5975	0	0	0
	14(EXP)	89695	29	-4976	0	0	0
	MAX	89735/L4	-220750/L1	-5975/L13			

500		Rigid +Y						
	1(HYD)	181	-123374	-28	0	0	0	
	2(OPE)	39095	-115331	-34134	0	0	0	
	3(OPE)	42284	-115755	-30421	0	0	0	
	4(OPE)	45439	-115817	-25526	0	0	0	
	5(SUS)	167	-111808	-30	0	0	0	
	6(SUS)	167	-111808	-30	0	0	0	
	7(OCC)	39095	-115331	-34134	0	0	0	
	8(OCC)	39095	-115331	-34134	0	0	0	
	9(OCC)	39095	-115331	-34134	0	0	0	
	10(OCC)	39095	-115331	-34134	0	0	0	
	11(OCC)	39095	-115331	-34134	0	0	0	
	12(OCC)	39095	-115331	-34134	0	0	0	
	13(EXP)	38928	-3524	-34104	0	0	0	
	14(EXP)	42117	-3948	-30392	0	0	0	
	MAX	45439/L4	-123374/L1	-34134/L2				
510		Rigid +Y; Rigid GUI						
	1(HYD)	121	-114638	-9	0	0	0	
	2(OPE)	-47995	-102468	-6280	0	0	0	
	3(OPE)	-46108	-102374	-133	0	0	0	
	4(OPE)	-45379	-102377	3320	0	0	0	
	5(SUS)	111	-103615	-7	0	0	0	
	6(SUS)	111	-103615	-7	0	0	0	
	7(OCC)	-47995	-102468	-6280	0	0	0	
	8(OCC)	-47995	-102468	-6280	0	0	0	
	9(OCC)	-47995	-102468	-6280	0	0	0	
	10(OCC)	-47995	-102468	-6280	0	0	0	
	11(OCC)	-47995	-102468	-6280	0	0	0	
	12(OCC)	-47995	-102468	-6280	0	0	0	
	13(EXP)	-48105	1146	-6273	0	0	0	
	14(EXP)	-46219	1241	-126	0	0	0	
	MAX	-48105/L13	-114638/L1	-6280/L2				
520		Rigid +Y						
	1(HYD)	80	-112654	2	0	0	0	
	2(OPE)	-45839	-102190	3665	0	0	0	
	3(OPE)	-45957	-102214	1903	0	0	0	
	4(OPE)	-45993	-102213	500	0	0	0	
	5(SUS)	74	-101906	2	0	0	0	
	6(SUS)	74	-101906	2	0	0	0	
	7(OCC)	-45839	-102190	3665	0	0	0	

	8(OCC)	-45839	-102190	3665	0	0	0
	9(OCC)	-45839	-102190	3665	0	0	0
	10(OCC)	-45839	-102190	3665	0	0	0
	11(OCC)	-45839	-102190	3665	0	0	0
	12(OCC)	-45839	-102190	3665	0	0	0
	13(EXP)	-45913	-284	3663	0	0	0
	14(EXP)	-46030	-308	1901	0	0	0
	MAX	-46030/L14	-112654/L1	3665/L2			
530		Rigid +Y; Rigid GUI					
	1(HYD)	58	-130793	-0	0	0	0
	2(OPE)	-53539	-118224	1127	0	0	0
	3(OPE)	-53281	-118218	276	0	0	0
	4(OPE)	-53200	-118218	7	0	0	0
	5(SUS)	54	-118290	-0	0	0	0
	6(SUS)	54	-118290	-0	0	0	0
	7(OCC)	-53539	-118224	1127	0	0	0
	8(OCC)	-53539	-118224	1127	0	0	0
	9(OCC)	-53539	-118224	1127	0	0	0
	10(OCC)	-53539	-118224	1127	0	0	0
	11(OCC)	-53539	-118224	1127	0	0	0
	12(OCC)	-53539	-118224	1127	0	0	0
	13(EXP)	-53592	67	1127	0	0	0
	14(EXP)	-53335	72	277	0	0	0
	MAX	-53592/L13	-130793/L1	1127/L13			
540		Rigid +Y					
	1(HYD)	48	-45895	0	0	0	0
	2(OPE)	-18682	-41521	-323	0	0	0
	3(OPE)	-18684	-41522	-118	0	0	0
	4(OPE)	-18685	-41522	-20	0	0	0
	5(SUS)	44	-41510	0	0	0	0
	6(SUS)	44	-41510	0	0	0	0
	7(OCC)	-18682	-41521	-323	0	0	0
	8(OCC)	-18682	-41521	-323	0	0	0
	9(OCC)	-18682	-41521	-323	0	0	0
	10(OCC)	-18682	-41521	-323	0	0	0
	11(OCC)	-18682	-41521	-323	0	0	0
	12(OCC)	-18682	-41521	-323	0	0	0
	13(EXP)	-18726	-11	-323	0	0	0
	14(EXP)	-18729	-11	-118	0	0	0

	MAX	-18729/L14	-45895/L1	-323/L13			
560		Rigid +Y					
	1(HYD)	479	-276489	7790	0	0	0
	2(OPE)	-4064	-251985	-19653	0	0	0
	3(OPE)	-15807	-250807	-6040	0	0	0
	4(OPE)	-26114	-250484	4647	0	0	0
	5(SUS)	433	-251900	7048	0	0	0
	6(SUS)	433	-251900	7048	0	0	0
	7(OCC)	-4064	-251985	-19653	0	0	0
	8(OCC)	-4064	-251985	-19653	0	0	0
	9(OCC)	-4064	-251985	-19653	0	0	0
	10(OCC)	-4064	-251985	-19653	0	0	0
	11(OCC)	-4064	-251985	-19653	0	0	0
	12(OCC)	-4064	-251985	-19653	0	0	0
	13(EXP)	-4497	-85	-26701	0	0	0
	14(EXP)	-16241	1092	-13088	0	0	0
	MAX	-26114/L4	-276489/L1	-26701/L13			
570		Rigid +Y					
	1(HYD)	371	-198514	2247	0	0	0
	2(OPE)	-35146	-176777	-71365	0	0	0
	3(OPE)	-36028	-180536	-72816	0	0	0
	4(OPE)	-37400	-181843	-72782	0	0	0
	5(SUS)	336	-180170	2032	0	0	0
	6(SUS)	336	-180170	2032	0	0	0
	7(OCC)	-35146	-176777	-71365	0	0	0
	8(OCC)	-35146	-176777	-71365	0	0	0
	9(OCC)	-35146	-176777	-71365	0	0	0
	10(OCC)	-35146	-176777	-71365	0	0	0
	11(OCC)	-35146	-176777	-71365	0	0	0
	12(OCC)	-35146	-176777	-71365	0	0	0
	13(EXP)	-35482	3392	-73397	0	0	0
	14(EXP)	-36364	-366	-74848	0	0	0
	MAX	-37400/L4	-198514/L1	-74848/L14			

580		Rigid +Y					
	1(HYD)	268	-7170	-364	0	0	0
	2(OPE)	0	0	0	0	0	0
	3(OPE)	0	0	0	0	0	0
	4(OPE)	0	0	0	0	0	0
	5(SUS)	242	-6113	-329	0	0	0
	6(SUS)	242	-6113	-329	0	0	0
	7(OCC)	0	0	0	0	0	0
	8(OCC)	0	0	0	0	0	0
	9(OCC)	0	0	0	0	0	0
	10(OCC)	0	0	0	0	0	0
	11(OCC)	0	0	0	0	0	0
	12(OCC)	0	0	0	0	0	0
	13(EXP)	-242	6113	329	0	0	0
	14(EXP)	-242	6113	329	0	0	0
	MAX	268/L1	-7170/L1	-364/L1			
590		Rigid +Y					
	1(HYD)	247	-156176	-253	0	0	0
	2(OPE)	-33062	-146678	-57128	0	0	0
	3(OPE)	-28331	-145538	-59047	0	0	0
	4(OPE)	-22164	-145140	-61437	0	0	0
	5(SUS)	223	-141232	-229	0	0	0
	6(SUS)	223	-141232	-229	0	0	0
	7(OCC)	-33062	-146678	-57128	0	0	0
	8(OCC)	-33062	-146678	-57128	0	0	0
	9(OCC)	-33062	-146678	-57128	0	0	0
	10(OCC)	-33062	-146678	-57128	0	0	0
	11(OCC)	-33062	-146678	-57128	0	0	0
	12(OCC)	-33062	-146678	-57128	0	0	0
	13(EXP)	-33285	-5447	-56899	0	0	0
	14(EXP)	-28554	-4306	-58818	0	0	0
	MAX	-33285/L13	-156176/L1	-61437/L4			
600		Rigid +Y; Rigid GUI w/gap					
	1(HYD)	180	-184467	-162	0	0	0
	2(OPE)	-58676	-167311	47178	0	0	0
	3(OPE)	-53199	-166685	52879	0	0	0

	4(OPE)	-49013	-166465	56649	0	0	0
	5(SUS)	163	-166749	-147	0	0	0
	6(SUS)	163	-166749	-147	0	0	0
	7(OCC)	-58676	-167311	47178	0	0	0
	8(OCC)	-58676	-167311	47178	0	0	0
	9(OCC)	-58676	-167311	47178	0	0	0
	10(OCC)	-58676	-167311	47178	0	0	0
	11(OCC)	-58676	-167311	47178	0	0	0
	12(OCC)	-58676	-167311	47178	0	0	0
	13(EXP)	-58839	-563	47325	0	0	0
	14(EXP)	-53361	64	53026	0	0	0
	MAX	-58839/L13	-184467/L1	56649/L4			
610		Rigid +Y					
	1(HYD)	131	-207188	-121	0	0	0
	2(OPE)	-56949	-187123	62027	0	0	0
	3(OPE)	-58509	-187288	60661	0	0	0
	4(OPE)	-60078	-187346	59145	0	0	0
	5(SUS)	118	-187294	-110	0	0	0
	6(SUS)	118	-187294	-110	0	0	0
	7(OCC)	-56949	-187123	62027	0	0	0
	8(OCC)	-56949	-187123	62027	0	0	0
	9(OCC)	-56949	-187123	62027	0	0	0
	10(OCC)	-56949	-187123	62027	0	0	0
	11(OCC)	-56949	-187123	62027	0	0	0
	12(OCC)	-56949	-187123	62027	0	0	0
	13(EXP)	-57067	171	62137	0	0	0
	14(EXP)	-58628	6	60770	0	0	0
	MAX	-60078/L4	-207188/L1	62137/L13			
620		Rigid +Y					
	1(HYD)	110	-73277	-101	0	0	0
	2(OPE)	-21614	-66275	20549	0	0	0
	3(OPE)	-22011	-66245	20104	0	0	0
	4(OPE)	-22083	-66235	20018	0	0	0
	5(SUS)	99	-66240	-92	0	0	0
	6(SUS)	99	-66240	-92	0	0	0
	7(OCC)	-21614	-66275	20549	0	0	0
	8(OCC)	-21614	-66275	20549	0	0	0

	9(OCC)	-21614	-66275	20549	0	0	0
	10(OCC)	-21614	-66275	20549	0	0	0
	11(OCC)	-21614	-66275	20549	0	0	0
	12(OCC)	-21614	-66275	20549	0	0	0
	13(EXP)	-21714	-35	20641	0	0	0
	14(EXP)	-22110	-5	20196	0	0	0
	MAX	-22110/L14	-73277/L1	20641/L13			
630		Rigid +Y; Rigid GUI					
	1(HYD)	362	-147592	-378	0	0	0
	2(OPE)	64912	-133593	15985	0	0	0
	3(OPE)	62692	-133490	8737	0	0	0
	4(OPE)	61127	-133454	3575	0	0	0
	5(SUS)	328	-133482	-342	0	0	0
	6(SUS)	328	-133482	-342	0	0	0
	7(OCC)	64912	-133593	15985	0	0	0
	8(OCC)	64912	-133593	15985	0	0	0
	9(OCC)	64912	-133593	15985	0	0	0
	10(OCC)	64912	-133593	15985	0	0	0
	11(OCC)	64912	-133593	15985	0	0	0
	12(OCC)	64912	-133593	15985	0	0	0
	13(EXP)	64585	-111	16327	0	0	0
	14(EXP)	62364	-8	9080	0	0	0
	MAX	64912/L2	-147592/L1	16327/L13			
640		Rigid +Y					
	1(HYD)	183	-128924	75	0	0	0
	2(OPE)	52411	-116503	-1275	0	0	0
	3(OPE)	52428	-116527	-991	0	0	0
	4(OPE)	52438	-116536	-601	0	0	0
	5(SUS)	166	-116529	68	0	0	0
	6(SUS)	166	-116529	68	0	0	0
	7(OCC)	52411	-116503	-1275	0	0	0
	8(OCC)	52411	-116503	-1275	0	0	0
	9(OCC)	52411	-116503	-1275	0	0	0
	10(OCC)	52411	-116503	-1275	0	0	0
	11(OCC)	52411	-116503	-1275	0	0	0
	12(OCC)	52411	-116503	-1275	0	0	0

	13(EXP)	52245	26	-1343	0	0	0
	14(EXP)	52262	2	-1060	0	0	0
	MAX	52438/L4	-128924/L1	-1343/L13			
650		Rigid +Y; Rigid GUI					
	1(HYD)	147	-153529	-10	0	0	0
	2(OPE)	63036	-138796	-1926	0	0	0
	3(OPE)	62758	-138790	-1007	0	0	0
	4(OPE)	62571	-138788	-389	0	0	0
	5(SUS)	133	-138790	-9	0	0	0
	6(SUS)	133	-138790	-9	0	0	0
	7(OCC)	63036	-138796	-1926	0	0	0
	8(OCC)	63036	-138796	-1926	0	0	0
	9(OCC)	63036	-138796	-1926	0	0	0
	10(OCC)	63036	-138796	-1926	0	0	0
	11(OCC)	63036	-138796	-1926	0	0	0
	12(OCC)	63036	-138796	-1926	0	0	0
	13(EXP)	62903	-6	-1917	0	0	0
	14(EXP)	62625	-0	-998	0	0	0
	MAX	63036/L2	-153529/L1	-1926/L2			
660		Rigid +Y					
	1(HYD)	126	-53739	0	0	0	0
	2(OPE)	21858	-48578	302	0	0	0
	3(OPE)	21859	-48579	203	0	0	0
	4(OPE)	21860	-48579	101	0	0	0
	5(SUS)	114	-48579	0	0	0	0
	6(SUS)	114	-48579	0	0	0	0
	7(OCC)	21858	-48578	302	0	0	0
	8(OCC)	21858	-48578	302	0	0	0
	9(OCC)	21858	-48578	302	0	0	0
	10(OCC)	21858	-48578	302	0	0	0
	11(OCC)	21858	-48578	302	0	0	0
	12(OCC)	21858	-48578	302	0	0	0
	13(EXP)	21744	1	301	0	0	0
	14(EXP)	21745	0	202	0	0	0
	MAX	21860/L4	-53739/L1	302/L2			

NODE	Load Case	FX N.	FY N.	FZ N.	MX N.m.	MY N.m.	MZ N.m.
710		Rigid +Y					
	1(HYD)	366	-63842	69	0	0	0
	2(OPE)	24169	-56406	7755	0	0	0
	3(OPE)	24693	-57185	7242	0	0	0
	4(OPE)	25153	-57453	5981	0	0	0
	5(SUS)	331	-57242	63	0	0	0
	6(SUS)	331	-57242	63	0	0	0
	7(OCC)	24169	-56406	7755	0	0	0
	8(OCC)	24169	-56406	7755	0	0	0
	9(OCC)	24169	-56406	7755	0	0	0
	10(OCC)	24169	-56406	7755	0	0	0
	11(OCC)	24169	-56406	7755	0	0	0
	12(OCC)	24169	-56406	7755	0	0	0
	13(EXP)	23838	837	7692	0	0	0
	14(EXP)	24362	57	7180	0	0	0
	MAX	25153/L4	-63842/L1	7755/L2			

LOAD CASE DEFINITION KEY

CASE 1 (HYD) WW+HP
CASE 2 (OPE) W+T1+P1
CASE 3 (OPE) W+T2+P2
CASE 4 (OPE) W+T3+P1
CASE 5 (SUS) W+P1
CASE 6 (SUS) W+P2
CASE 7 (OCC) W+T1+P1+U1
CASE 8 (OCC) W+T1+P1-U1
CASE 9 (OCC) W+T1+P1+U2
CASE 10 (OCC) W+T1+P1-U2
CASE 11 (OCC) W+T1+P1+U3
CASE 12 (OCC) W+T1+P1-U3
CASE 13 (EXP) L13=L2-L5
CASE 14 (EXP) L14=L3-L6

Piping Code: B31.3 = B31.3 -2006, May 31, 2007

NO CODE STRESS CHECK PROCESSED: LOADCASE 1 (HYD) WW+HP

Highest Stresses: (N./sq.mm.) LOADCASE 1 (HYD) WW+HP
CodeStress Ratio (%): 0.0 @Node 570
Code Stress: 125.4 Allowable: 0.0
Axial Stress: 54.5 @Node 580
Bending Stress: 70.9 @Node 570
Torsion Stress: 3.4 @Node 350
Hoop Stress: 110.3 @Node 560
3D Max Intensity: 126.4 @Node 570

CODE STRESS CHECK PASSED : LOADCASE 2 (OPE) W+T1+P1

Highest Stresses: (N./sq.mm.) LOADCASE 2 (OPE) W+T1+P1
OPE Stress Ratio (%): 74.5 @Node 310
OPE Stress: 269.5 Allowable: 362.0
Axial Stress: 36.0 @Node 660
Bending Stress: 105.0 @Node 310
Torsion Stress: 3.1 @Node 350
Hoop Stress: 73.6 @Node 560
3D Max Intensity: 186.8 @Node 180

CODE STRESS CHECK PASSED : LOADCASE 3 (OPE) W+T2+P2

Highest Stresses: (N./sq.mm.) LOADCASE 3 (OPE) W+T2+P2
OPE Stress Ratio (%): 39.8 @Node 310
OPE Stress: 144.0 Allowable: 362.0
Axial Stress: 15.9 @Node 80
Bending Stress: 79.9 @Node 310
Torsion Stress: 3.1 @Node 350
Hoop Stress: 32.7 @Node 560
3D Max Intensity: 127.7 @Node 310

CODE STRESS CHECK PASSED :
LOADCASE 4 (OPE) W+T3+P1

Highest Stresses: (N./sq.mm.) LOADCASE 4 (OPE) W+T3+P1
OPE Stress Ratio (%): 64.6 @Node 570
OPE Stress: 244.9 Allowable: 379.2
Axial Stress: 36.0 @Node 660
Bending Stress: 72.4 @Node 570
Torsion Stress: 3.1 @Node 350
Hoop Stress: 73.6 @Node 560
3D Max Intensity: 142.1 @Node 570

CODE STRESS CHECK PASSED : LOADCASE 5 (SUS) W+P1

Highest Stresses: (N./sq.mm.) LOADCASE 5 (SUS) W+P1
CodeStress Ratio (%): 84.0 @Node 570
Code Stress: 127.4 Allowable: 151.7
Axial Stress: 47.7 @Node 220
Bending Stress: 81.0 @Node 570
Torsion Stress: 4.0 @Node 350
Hoop Stress: 95.5 @Node 20
3D Max Intensity: 127.7 @Node 570

CODE STRESS CHECK PASSED : LOADCASE 6 (SUS) W+P2

Highest Stresses: (N./sq.mm.) LOADCASE 6 (SUS) W+P2
CodeStress Ratio (%): 67.0 @Node 570
Code Stress: 101.6 Allowable: 151.7
Axial Stress: 21.4 @Node 220
Bending Stress: 81.0 @Node 570
Torsion Stress: 4.0 @Node 350
Hoop Stress: 42.4 @Node 20
3D Max Intensity: 101.6 @Node 570

CODE STRESS CHECK PASSED : LOADCASE 7 (OCC) W+T1+P1+U1

Highest Stresses: (N./sq.mm.) LOADCASE 7 (OCC) W+T1+P1+U1
CodeStress Ratio (%): 93.1 @Node 310
Code Stress: 179.2 Allowable: 192.6
Axial Stress: 47.3 @Node 410
Bending Stress: 136.4 @Node 310
Torsion Stress: 4.1 @Node 350
Hoop Stress: 95.5 @Node 20
3D Max Intensity: 187.4 @Node 310

CODE STRESS CHECK PASSED : LOADCASE 8 (OCC) W+T1+P1-U1

Highest Stresses: (N./sq.mm.) LOADCASE 8 (OCC) W+T1+P1-U1
Code Stress Ratio
(%): 93.1 @Node 310
Code Stress: 179.2 Allowable: 192.6
Axial Stress: 47.3 @Node 410
Bending Stress: 136.4 @Node 310
Torsion Stress: 4.1 @Node 350
Hoop Stress: 95.5 @Node 20
3D Max Intensity: 187.4 @Node 310

CODE STRESS CHECK PASSED : LOADCASE 9 (OCC) W+T1+P1+U2

Highest Stresses: (N./sq.mm.) LOADCASE 9 (OCC) W+T1+P1+U2
Code Stress Ratio
(%): 93.1 @Node 310
Code Stress: 179.2 Allowable: 192.6
Axial Stress: 47.3 @Node 410
Bending Stress: 136.4 @Node 310
Torsion Stress: 4.1 @Node 350
Hoop Stress: 95.5 @Node 20
3D Max Intensity: 187.4 @Node 310

CODE STRESS CHECK PASSED : LOADCASE 10 (OCC) W+T1+P1-U2

Highest Stresses: (N./sq.mm.) LOADCASE 10 (OCC) W+T1+P1-U2
Code Stress Ratio
(%): 93.1 @Node 310
Code Stress: 179.2 Allowable: 192.6
Axial Stress: 47.3 @Node 410
Bending Stress: 136.4 @Node 310
Torsion Stress: 4.1 @Node 350
Hoop Stress: 95.5 @Node 20

3D Max Intensity: 187.4 @Node 310

CODE STRESS CHECK PASSED : LOADCASE 11 (OCC) W+T1+P1+U3

Highest Stresses: (N./sq.mm.) LOADCASE 11 (OCC) W+T1+P1+U3
CodeStress Ratio (%): 93.1 @Node 310
Code Stress: 179.2 Allowable: 192.6
Axial Stress: 47.3 @Node 410
Bending Stress: 136.4 @Node 310
Torsion Stress: 4.1 @Node 350
Hoop Stress: 95.5 @Node 20
3D Max Intensity: 187.4 @Node 310

CODE STRESS CHECK PASSED : LOADCASE 12 (OCC) W+T1+P1-U3

Highest Stresses: (N./sq.mm.) LOADCASE 12 (OCC) W+T1+P1-U3
CodeStress Ratio (%): 93.1 @Node 310
Code Stress: 179.2 Allowable: 192.6
Axial Stress: 47.3 @Node 410
Bending Stress: 136.4 @Node 310
Torsion Stress: 4.1 @Node 350
Hoop Stress: 95.5 @Node 20
3D Max Intensity: 187.4 @Node 310

CODE STRESS CHECK PASSED : LOADCASE 13 (EXP) L13=L2-L5

Highest Stresses: (N./sq.mm.) LOADCASE 13 (EXP) L13=L2-L5
CodeStress Ratio (%): 33.7 @Node 310
Code Stress: 121.9 Allowable: 362.0
Axial Stress: 4.2 @Node 510
Bending Stress: 104.6 @Node 310
Torsion Stress: 1.4 @Node 230
Hoop Stress: 0.0 @Node 15
3D Max Intensity: 140.2 @Node 310

CODE STRESS CHECK PASSED : LOADCASE 14 (EXP) L14=L3-L6

Highest Stresses: (N./sq.mm.) LOADCASE 14 (EXP) L14=L3-L6
CodeStress Ratio (%): 26.6 @Node 310

Code Stress: 96.3 Allowable: 362.0

7.1. Discussion

Various load cases that have been used in this project which are operational load case, Expansion load cases, Occasional load cases, Hydro test load cases and Sustained load cases have been used to find out to find out the stress of the pipeline segments with the help of parameters like design temperature, design pressure, operating temperature operating pressure, weight of the pipe, different soil characteristics. The stress analysis summery has been generated with these load cases with the help of Caesar II software. Tables have also been generated which indicates the displacement at each nodes in the pipeline due to the different parameters.

8.0. Conclusion

The review of the pipe stresses show that the pipe has adequate wall thickness and supports to keep within the sustained allowable stress and also enough flexibility to remain below the expansion allowable stress limit. The Caesar II software analyzes every component of the pipe and calculates the different stresses with different load conditions. After the serious of operation it states that the design parameters will withstand with in the allowable stresses. The equipment loads are also checked to ensure a safe and effective design and the review from the displacement does not reveal any interference problem from pipe expansion. By the analysis it is observed the selected supports and its placement are right enough to reduce the over bending, displacement of the system.

After reviewing all the results from the software it is cleared that the design of the interlink pipeline is safe enough to construct.

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