University of
Stavanger

Faculty of Science and Technology

MASTER'S THESIS

Study program/ Specialization: Offshore Technology/ Industrial Asset Management	Spring semester, 2013 Restricted access
Writer: Paturat Tasintu	…………………………………………… (Writer's signature)

Faculty supervisor:
Professor Tore Markeset

External supervisor(s):
Lene Merethe Ersland and Per Egil Olavesen, Aibel AS

Title of thesis:

Vibration analysis of offshore piping systems under maintenance and modification projects.

Credits (ECTS): 30

Key words: Vibration analysis, stress, ASME B31.3, PD5500	Pages: 67 + enclosure: 37 Stavanger, 17.06.2013 Date/year

Abstract

Piping vibration failures have been one of the major causes of downtime, fatigue failures, leaks, high noise, fires and explosion in petrochemical plants. Normally excessive vibration levels occur from pulsation of mechanical source. Also, oil and gas fields in offshore have developed in more challenging environment area. According to the harsh environment, the offshore structures will face a lot of challenged in engineering and maintenance. Especially in the wave loading which has high cyclic loading so it will accumulate damage on piping system and lead to fatigue failures. In order to prevent the vibration failures we to define the majors causes of vibration failures in offshore piping systems and find the effective technical solutions to modify the piping system due to its regulations and requirements base on currently standard.

Acknowledgement

First of all, I would like to thank my supervisor Professor Tore Markeset for kindly support and providing great suggestion over the thesis work preparation.

I am also grateful to my company supervisor Per Egil Olavesen and my line manager Lene Merethe Ersland from Aibel AS, my employer, for kindly support and nice attitude.

I have a special gratitude towards my family and friends, for understanding and cheerful.

LIST OF CONTENTS

Chapt. Page

1 INTRODUCTION

1.1 Background

Ekofisk is the Norway's oldest field in operation and is also one of the largest on the Norwegian continental shelf. The complex is operated by ConocoPhillips, The development has started from 1970 and located on Blocks 2/4 and 2/7 about 200 miles (322 kilometres) southwest of Stavanger. The 40-year-old field is situated in a water depth of 246 feet (75 meters) and has been redeveloped several times to increase the field's life expectancy until 2050 or further beyond.

The Ekofisk Complex was developed in stages, and has been upgraded and modernized several times. The Ekofisk Complex was given a major boost from 1998, when the ’new’ Ekofisk facility came on stream. This was a huge transition with new and modern platforms, at the same time as unprofitable fields were closed down and several old platforms were taken out of service. In this thesis focus on the Vibration analysis of offshore piping systems in the Eldfisk field (GREATER EKOFISK MODIFICATION CONTRACT) which is discussed in terms of modification impact on ageing piping systems. (ConocoPhillips Company)

1.2 Problem description

Piping vibration failures have been one of the major causes of downtime, fatigue failures, leaks, high noise, fires and explosion in petrochemical plants. Normally excessive vibration levels occur from pulsation of mechanical source. Also, oil and gas fields in offshore have developed in more challenging environment area. According to the harsh environment, the offshore structures will face a lot of challenged in engineering and maintenance. Especially in the wave loading which has high cyclic loading so it will accumulate damage on piping system and lead to fatigue failures.

1.3 Objective and scope

The propose of this thesis is to define the majors causes of vibration failures in offshore piping systems and find the effective technical solutions to modify the piping system to prevent the vibration failures by performing piping system analysis due to its regulations and requirements base on currently standard.

The scope of thesis will be as follows:

- Defines the criticality of problem that cause by vibration in offshore piping system.
- Discuss the design methodology of offshore piping system in the old days compares to today methodology.
- Defines possible solution to reduce vibration failures in existing piping system.
- Discuss requirement bases on today stands to avoid vibration failures in existing offshore piping systems

In the case study of Vibration analysis of offshore piping systems in the Eldfisk field (GREATER EKOFISK MODIFICATION CONTRACT) by using pipe stress program; TRIFLEX v3.3.3 and CAESAR II 2011, in accordance with its regulations and requirements base on Piping standards; ASME B31.3 For pressure piping, Norsok L-002 piping system layout, design and structural analysis and PD5500 Specification for unfired fusion welded pressure vessels.

2 STRESS ANALYSIS OF PIPING SYSTEMS

2.1 Regulation, Codes and Standard

In offshore oil and gas industry, pipe stress analysis is the importance technique for engineers to design piping systems without overloading and overstressing on the piping components and connected equipment. The piping stress analysis shall be performed in accordance with the requirements specified in the latest edition of the following codes and standards,

1. ASME B31.3 For pressure piping
2. NORSOK L-002 piping system layout, design and structural analysis, Edition 3, July 2009

ASME B31.3 has become the world's most widely used for process piping systems. Most of Norwegian offshore follows this code for designing offshore topside piping system. While NORSOK L-002 standard covers the basis for design and layout of process, drilling and utility piping for offshore oil and gas production facilities. Relevant parts of this standard may also be used for control room, laboratory, helideck and other facilities around the platform.

In the case of Greater Ekofisk Modifications project, offshore Completion Service for Modification to existing platforms in the Greater Ekofisk Area, the internal procedure for pipe specification is knows as the TCD 4583 rev 06 Piping Design Requirement for New Installations, Modifications and Repair of Existing Facilities.

However, due to lack of information about high cyclic fatigue failures in ASME B31.3, other codes need to be considered on this issue. There are different specifications which in fatigue failures, and the code used in this thesis is PD5500 British standard specification which is used as a reference in evaluating the fatigue life.

2.2 Pipe Stress analysis

Piping stress analyses is used to classify the static and dynamic loading resulting from temperature changes, internal and external pressures, and changes in fluid flow rate, the effects of gravity, seismic activity, fire, and other environmental conditions. Codes and standards establish the minimum scope of stress analyses. Some codes prescribe loading combinations with not-to-exceed stress limits. In general all lines shall be analysed to verify the integrity of the piping and supporting according to these governing principles in order to reduce the loading on equipment to the limitation of the equipment.(Nayyar, 2000)

The whole scope of this work is generally referred to as piping mechanical. In general, the purpose of pipe stress analysis can be summarized into two broad categories:

(a) *Ensure structural integrity*: This involves the calculation of stresses in the pipe due to all design loads. Methods need to be taken to keep the stress within the code allowable limits. This code stress check is based on the failures from breaks or cracks which should not occur in the piping. (J.C. Wachel, S.J. Morton and K.E. Atkins, 1990)

(b) *Maintain system operability*: According to the problems in the connecting equipment event a piping itself is very strong, but the system may not be able to operable. Flange leakage, valve sticking, high stress in the vessel nozzle, and excessive piping load on rotating equipment are some of these problems. Thus we normally need to maintain the system operates rather than to ensure the structural integrity. The mainly problem come from the lack of coordination between engineers of different disciplines. Rotating equipment manufacturers, for example, design non-pressure parts, such as support and base plate, according to the weight and the torque of the shaft. Then they specify the allowable piping load with that design, regardless of the fact that some practical piping load always exists and needs to be accommodated. The allowable loads they provide are generally much too small to be practical. However, these allowable values go unchallenged, because the industry as a whole gives no incentives to manufacturers to produce equipment that can resist the extra piping load. If engineers would request the extra strength or give preferential treatment to manufacturers that produce stronger equipment, an optimal solution might eventually be reached. (J.C. Wachel, S.J. Morton and K.E. Atkins, 1990)

2.2.1 General

- For topsides pipe work, all lines to be analyzed in accordance with the relevant project specification. As a general guidance, a line can be subject to stress analysis if it falls into any of the criteria in NORSOK L-002.
- Pressure and temperature data used in calculations shall be the design conditions given by the Process engineer in the Line List. If Line List is not available, then written confirmation of design conditions must be obtained from the process department before a pipe routing can be verified. If temperatures are felt too conservative and causing design problems, then stress should confirm with process that the temperatures provided are realistic for piping flexibility analysis.

2.2.2 Design Criteria

Imposed loads can be separated into external effects which may cause failure if they are excessive and stain effects that relate to changes in temperature which can be considered in primary, secondary, and localized stresses.

1. Primary stresses are the membrane, shear, and bending stresses that are caused by the imposed loads. Primary stresses satisfy the laws of the balance of internal and external forces and moment. Circumferential stresses are related to internal pressure. Longitudinal stresses are related to pressure and dead weight. Primary banding stresses are due to dead weight, wind and earthquake loads. Primary stresses are not self-limiting and will cause gross distortion or failure if they exceed the yield strength of the pipe (Nayyar, 2000).
2. Secondary stresses are related to the continuity of the piping system. They do not cause failure in ductile materials with a single load, but can cause fatigue failure if the load is cyclic. If secondary stresses exceed the pipe yield strength, they can affect to local deformations, load distribution, and reduce stress in the operating condition. Bending and torsional secondary stresses normally come form prestrained thermal loading, expansion, or contraction. Membrane, bending, and torsional secondary stresses can also come from a non-uniform temperature distribution (Nayyar, 2000).
3. Localized stresses are those which decrease rapidly within a short distance of their origin. For example the stresses occur near elbows, miters, tee junctions, supports, and restraints. Localized stresses have the same significance as secondary stress. Therefore they do not cause a major structural failure but the can cause fatigue failure (Nayyar, 2000).

2.2.3 Piping stress Critical Lines

A piping critical line is covered by the definitions below, and is intended to rover the special requirements of the Piping Stress Engineer. It is hence defined, as any line for which a flexibility review is required, or where the supporting is deemed to be critical and requiring a review by the stress engineer. As general guidance accordance to NORSOK

L-002, a line shall be subject to comprehensive stress analysis if it falls into any of the following categories (NORSOK L-002, 2009):

a) all lines at design temperature above 180 °C;
b) 4 in NPS and larger at design temperature above 130 °C;
c) 16 in NPS and larger at design temperature above 105 °C;
d) all lines which have a design temperature below -30 °C provided that the difference between the maximum and minimum design temperature is above
    - 190 °C for all piping,
    - 140 °C for piping 4 in NPS and larger,
    - 115 °C for piping 16 in NPS and larger.

NOTE These temperatures above are based on a design temperature 30 °C above maximum operating temperature. Where this is not the case, 30 °C must be subtracted from values above.

e) lines 3 in NPS and larger with wall thickness in excess of 10 % of outside diameter. Thin walled piping of 20 in NPS and larger with wall thickness less than 1 % of the outside diameter;
f) all lines 3 in NPS and larger connected to sensitive equipment, e.g. rotating equipment. However, lubrication oil lines, cooling medium lines etc. for such equipment shall not be selected due to this item;
g) all piping expected to be subjected to vibration due to internal and external loads (e.g. pressure transients, slugging, flow pulsation, external mechanical forces, vortex shedding induced oscillations, high gas velocities) and herby acoustic vibration of the pipe wall;
h) the ring-main and distribution firewater lines. Pressure surges (water hammer) and blast to be considered for the entire system;
i) all hydrocarbon lines containing oil and gas which shall be de-pressurized after a design blast/explosion event (see the design accidental load report for selection of lines);
j) all relief lines connected to pressure relief valves and rupture discs;
k) all blowdown lines 2 in NPS and larger excluding drains;
l) all piping along the derrick and the flare tower;
m) lines affected by external movements from structural deflections, connecting equipment, bridge movements, platform settlements, X-mas tree/wellhead, vessel hogging/sagging etc.;
n) GRP piping 3 in NPS and larger;
o) all lines 3 in NPS and larger subject to steam out;
p) long straight lines (typical 20 m);
q) all production and injection manifolds with connecting piping;
r) other lines as requested by the project "stress" engineer or Company;
s) lines falling into Category III according to the Pressure Equipment Directive (PED).

Manual calculations may be used in cases of simple configurations and low stresses. Lines 50 N.B. (2”) and smaller are not normally considered critical unless built from non-metallic or non-ferrous materials. The an-isotropic properties of composite materials (e.g. GRP), shall be considered in the flexibility analysis.

In some cases, judgement by the stress engineer is required during design development to ascertain if some lines are critical through having long runs, heavy valves etc.

All other piping systems outside the criteria mentioned above shall be evaluated in a simplified method to confirm that the line is acceptable according to the code.

For EU countries:

Lines falling into Category III according to the PED. The requirement is applicable for installations that require conformity with PED. All Category III lines shall be identified on critical line list.

2.2.4 Calculation Models

The calculation models of the piping system analysis shall contain sufficient connected piping to ensure properly defined boundary conditions. Special attention shall be given to boundary conditions with movements. In cases where the boundary is an equipment nozzle, even a relatively small movement can lead to excessive forces and moments, it is important to take action in the model calculations. (NORSOK L-002, 2009):

2.2.5 Environmental temperature

The minimum/maximum environmental temperature shall be as specified by the project. Unless otherwise specified, the following environmental temperatures shall apply for the North Sea (NORSOK L-002, 2009):

a) installation temperature: 4 °C
b) minimum ambient temperature: -7 °C
c) maximum ambient temperature: 22 °C

2.2.6 Loadings to be considered in piping design/ stress analysis

Various piping systems require different sets of load considerations. The stress engineer should not be limited to the guidelines shown in this chapter. It is the responsibility of the stress engineer to incorporate all load cases deemed necessary to cater for satisfactory design and verification.

1) Sustained loads

Weight

The weight of pipes, fittings, pipe contents and insulation shall be included in analysis as appropriate. Specific gravity of 1.0 will be used for the hydro test case, which is an occasional load.

Pressure

The pipeline design pressures as defined in the process line list shall be used in the pipe stress analysis. Test pressures will be used for the hydro-test case.

2) Displacement loads

Thermal

Maximum and minimum design temperatures as defined in the process line list shall generally be used in the pipe stress analysis.

All restraint loads shall be based on design temperature depending upon the piping geometry and process scenario, worst case operating temperature or range of temperatures shall be used. For pumps and compressors, normal operating temperature can be used to calculate nozzle loads and deflections. Stress range shall be based on temperature, being the algebraic difference between minimum to highest design temperature.

Displacement

Imposed displacements on piping during operation:

- Thermal expansion or contraction of the piping system at the boundary points
- Pre-stressing or stresses imposed during installation
- Movement of connected equipment, i.e. vessels and pumps
- Well growth, X-mas trees

3) Occasional loads

Occasional loads such as wind, wave, and flow induced reaction forces shall be combined with design pressure and weight. These loads act temporarily during service life of the piping and the different occasional loads do not need to be considered as acting concurrently.

4) Environmental loads (wind)

A wind speed shall be considered for all lines exposed to wind, and shall be considered as an occasional load.

5) Accidental loads (blast)

Only new lines which in flowlines and Pressure Safety valve (PSV) systems will be designed for blast, replacements of existing flowlines will not have blast applied and will be based on information (blast area, blast pressure) from the Safety department.

Permanent deformations in the piping will be accepted in an explosion (blast) case.

The effect of blast loads shall be evaluated for piping which is required to maintain the installation integrity in an explosion event. Normal working conditions with respect to temperature and pressure may be used for the blast calculation.

Drag load from explosion shall be calculated in the following way:

$F = p_{blast} \times A \times C_d \times DAF$ [N/m]

Where:

p_{blast} is the drag pressure from the blast [barg]

A is the projected area [m^2]

C_d is the coefficient of drag (to be determined for the actual pipe or equipment)

DAF is the dynamic amplification factor (minimum 1.5 if not evaluated in detail)

Note: For selection of drag factor reference is made to API RP 2FB and FABIG Technical note No.8

A simplified approach may be used in lack of accurate data. The static overpressure used for structural dimensioning may be used as basis, and an estimated drag pressure calculated as 1/3 x static overpressure may be used.

Maximum allowable stress in blast case shall be the minimum of 2.4S or $1.5S_y$ (S = ASME B31.3 allowable stress limit, S_y = pipe yield stress).

The standard SIF values can be multiplied with a factor of 0.75 for the explosion design case. However, the SIF values shall not be less than 1.0.

The potential effects of deck and wall deflections, due to blast loads (movement of equipment and pipe supports), need to be evaluated.

Note: It shall be documented that the mechanical joints and flanged connections on piping systems selected for blast calculations are leak free after the explosion event. However, it is acceptable that the mechanical joints and flanged connections leak during the explosion event.

6) Equipment and support reaction loads

Equipment and support reaction loads shall be evaluated. The support reaction loads shall be passed to the pipe support section via a copy of the completed stress isometric.

For those process lines that have been subjected to a blast analysis the pipe support reaction loads shall be listed separately on the stress sketch. This is because the design failure criterion for a blast load is not the same for a normal operating or occasional design load.

Allowable nozzle loads for mechanical equipment will be according to NORSOK R-001 and vender allowable values. The vendor allowable nozzle loads shall not be less than the NORSOK requirements.

2.3 Acoustic fatigue

High pressure drop across valves may cause acoustic fatigue in the piping system.

Flare systems are typically systems which should be evaluated for acoustic fatigue due to high pressure drop downstream of PSVs or blowdown valves.

The responsible Process Engineer shall guide the Stress Engineer as to the requirements of acoustic fatigue analysis for the specific systems, by either statement of such incidence on the process line list or by discussion with the Lead Stress Engineer.

Requirements given in the following documents shall be considered and included in the detail design:

- NORSOK standard L-002 Annex A and B (informative) Acoustic fatigue in piping systems.
- TCD 4583 rev 06 Piping Design Requirement for New Installations, Modifications and Repair of Existing Facilities

2.4 Vibration

Piping systems can start to vibrate due to excitation from various types of sources, e.g. internal pulsation type of flow and high velocity flow with mixed oil/ gas/ water densities.

These systems shall be given special consideration with regard to supporting, and more use of hold down supports and guides shall be considered. Supports with gaps should as far as possible be avoided.

Reduction in pipe wall thickness will result in a more flexible piping system, having a lower natural frequency than for carbon steel. Lines will then be more exposed to vibration.

It is a general design requirement that flow-lines must be designed and supported in a way that makes the lines flexible enough to operate with relatively high vertical movements. Stress isometrics for the existing flow-lines confirm that these lines seem to have been designed with a minimum of supporting elements, which confirm that the new lines may see vibration problems due to reduced wall thickness and lower natural frequency.

The natural frequency shall be checked for the individual flow-lines based on revised/ new design data (i.e. process line data, material data, support info and vertical movements)

It is reasonable to assume that the new lines will require additional pipe supports and also modifications to some of the existing supports.

In order to reduce the potential for dynamic movements, the lowest natural frequency of the flow line should preferably be above 4 Hz. A too stiff supporting may on the other hand lead to unacceptable loads and stress levels. The need for fatigue calculations shall be considered.

All pipe support elements included in calculations are considered infinitely stiff, and might be a too optimistic approach for some of the existing supports/ frames. Offshore surveys should confirm that reuse of existing supports/ frames will give the required stiffnesses.

2.5 ASME B31.3 Process piping

In the following, a brief description of the performed checks versus the ASME B31.3 is given. The checks are performed using the piping stress analysis program (TRIFLEX or CAESAR II).

2.5.1 Check 1, Internal Design Pressure

The hoop stress due to internal design pressure must fulfil the following criterion (section 304.1.2.(3a)):

$$t_{req} = \left[\frac{pD}{2(SE + pY)} + c \right] \cdot \left[\frac{100}{100 - MT} \right]$$

where,
p = Design pressure
D = Outer diameter
S = Allowable stress
E = Quality factor
Y = Material and temperature coefficient, here equal to 0.4.
t_{req} = Required wall thickness
MT = User supplied mill tolerance, percent or inches
C = Corrosion allowance

2.5.2 Check 2, Longitudinal, Sustained Stresses

The maximum longitudinal stresses are found as the sum of stresses due to bending moment and axial forces from sustained loads.

The sum of longitudinal stresses due to design pressure, weight and other sustained loads must fulfil the following criterion:

$$S_L = |S_N| + |S_b| < S_h \qquad \text{(Sect. 302.3.5.c)}$$

where,
S_L = Longitudinal stresses
S_N = Stresses from axial forces
S_b = Bending stresses
S_h = Basic allowable stress at maximum temperature, here equal to allowable stress S

2.5.3 Check 3, Displacement Stresses

The intention with this check is to calculate the maximum obtained displacement stress range and compare this with the allowable.

It is possible to choose between the use of the liberal code and the use of the non-liberal code. For the purposes of these calculations the non liberal code has been used.

The allowable displacement stress range is:

Non-liberal code

$S_A = f(1.25\ S_c + 0.25\ S_h)$ (1a)

Liberal code

$S_A = f[(1.25\ S_c + 0.25\ S_h) + S_h - S_L]$

$= f[1.25\ (S_c + S_h) - S_L]$ (1b)

where,

S_A = Allowable displacement stress range

S_h = As defined above

S_c = Basic allowable stress at minimum temperature, here equal to S_h

S_L = Longitudinal stress

F = Stress range reduction factor for displacement cyclic conditions for the total number of full displacement cycles over expected life. f is equal to 1.0, when the equivalent numbers of full displacement cycles are less than 7,000.

For the normal operating load cases the equivalent number of full displacement cycles is taken to be 7000, therefore the stress range reduction factor is equal to 1.

The computed displacement stress S_E due to full temperature cycle variation must fulfil the following criterion:

$$S_E = \sqrt{S_b^2 + 4S_t^2} < S_A \qquad \text{(Sect. 302.3.5.d)}$$

where,

S_b = Bending stresses

S_t = Torsional stresses

2.5.4 Check 4, Occasional Stresses

The sum of longitudinal stresses due to sustained loads and occasional loads may be as much as 1.33 times the basis allowable stress S (sect.302.3.6.a).

$$S_L = |S_N| + |S_b| + |S_o| < k \cdot S_h \qquad \text{(sect. 302.3.5.c)}$$

where,

S_L = Longitudinal stresses

S_N = Stresses from axial forces

S_b = Bending stresses

S_o = Occasional stresses

K = Factor, may be as much as 1.33

S_h = Basic allowable stress at maximum temperature

2.5.5 Check 5, Reaction Forces and moments

Reaction forces and moments to be used in design of restraints and supports for a piping system, and in evaluating the effects of piping displacement on connected equipment, shall be based on the reaction range R for the extreme displacement condition, using $E_{a.}$ (= modulus of elasticity at installation temperature.) (Sect. 319.5).

The reactions are based on the difference between the maximum (or minimum) temperature and the expected temperature during installation. (Sect. 319.3.1.b).

2.5.6 Check 6, Flange loads

The flange at the interface with the Xmas Tree wing valve has been checked for conformance by Triflex or CAESAR II program by using the Pressure Equivalent method. The forces and moments at the flange are converted to Pressure Equivalent and added to the design pressure, this is then compared to the maximum pressure allowed by the design code.

2.5.7 Check 7, Mechanical joints

The mechanical joints have been checked according to vendor maximum forces and moments.

2.5.8 Check 8, Natural frequency.

The natural frequency of the piping system should not be lower than 4 Hz in accordance to NORSOK standard L-002

2.6 PD5500 British standard specification

PD 5500 specifies requirements for the design, construction, inspection, testing and verification of compliance of unfired fusion welded pressure vessels.

In piping stress analysis, the horizontal displacements are the basis to calculate the stresses in the pipe system. These stresses are obtained by putting the displacements as applied movements in the analysis program (CAESAR II or Triflex). The stresses shall be the displacement stresses with both the negative and positive direction included. For fatigue sensitive circumferential welds i.e. flanges and bends, the longitudinal stress shall be used in accordance with ASME B31.3.
at P=0

Longitudinal Stress
$$S_L := \frac{\sqrt{\left(i_i \cdot M_i\right)^2 + \left(i_o \cdot M_o\right)^2}}{Z} + \frac{F_A}{A_{wall}} + P(OD - 2t)^2 \cdot \frac{\pi}{4A_{wall}}$$

For fatigue sensitive longitudinal welds i.e. olets, welded shoes, reinforcement plates and tees the Principal stress shall be used. A principal stress is not showed as ASME B31.3 requirement, but is available in Triflex and CAESAR II output according to PD5500. The global shear will then be added to the longitudinal stresses.

PD 5500 provides simplified methods to calculate stresses at nozzles due to internal pressure, thermal gradients and piping loads based on using stress concentration factors and the use of computer software. Fatigue evaluation procedures in PD 5500 require the determination of the maximum principal stress range for each individual cycle. Once the principal stresses are known, the fatigue evaluation is done in accordance to Annex C. The exemption provisions are based on conservative evaluations using allowable membrane stresses and fatigue design curves (S-N curves).

2.7 Pipe supports

Reaction forces on pipe supports shall be based on the algebraic difference between the installation temperature and the maximum (or minimum) design temperature. In special cases the maximum (or minimum) operating temperature may be used.

- Piping systems shall be properly guided and shall be properly evaluated with respect to line stops.
- Heavy valve sets shall, where possible, be anchored at one end and guided at the other end.
- Standard gaps for guides (i.e. 3mm) shall generally not be included in the computer calculation, only in special cases.
- The pipe supports shall be located close to valves, flanges and other heavy components. Due consideration must however be paid to the location of supports such that bolt tensioning and pulling of bolts can be performed without hindrance.

3 MAINTENANCE AND MODIFICATION (M&M) PROJECT ON GREATER EKOFISK MODIFICATION CONTRACT

In all businesses including M&M services, there is a constant tension between profit, growth, and control (see Figure1). If there are lacks adequate controls, a profitable business can be collapsed quickly. A wise manager knows that control is the foundation of any healthy business. If the company has a good control then the managers can focus on creating profit, after the business is profitable the manager can focus on growing the business. To be successful, we need to control how to design and use performance measurement and control techniques to implement a strategy to create a balance between profitability and growth control. (Simons, 2000)

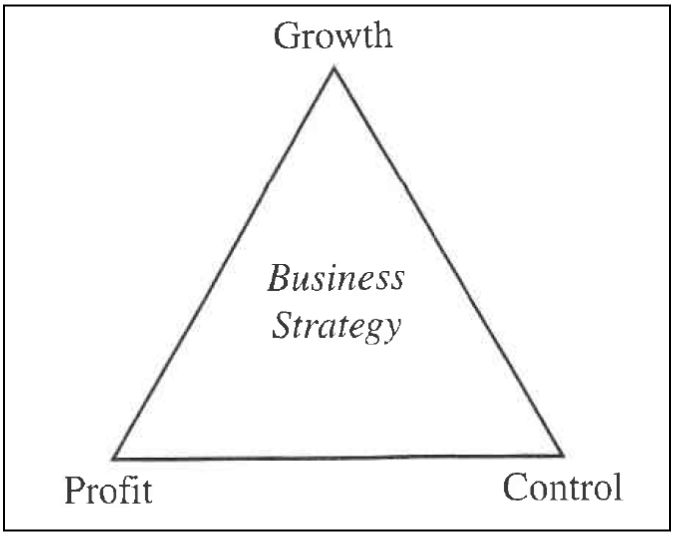


Figure 1: Tension of Profit, Growth, and Control. (Simons, 2000)

3.1 Project Management and Control

In accordance of TDC 6153 Greater Ekofisk Modification Projects Management Manual, the majority of the modification projects executed in the Greater Ekofisk are considered small projects, the “small project application” section of the guide should be utilized as the primary guideline for modification projects at Ekofisk. COP has developed a project management and development guide (PD&M) to provide guidance on the execution of projects. This guideline provides a flexible framework for developing and executing projects through the timely and appropriate use of proven project best practices and tools. Consistent and disciplined application by training project professionals, in conjunction with other business processes, will deliver value-adding project results that align with corporate business objectives.

The PD&M utilizes a phased approach, which consists of five distinct phases; the appraisal phase, optimize phase, define phase, execution phase and operation phase. The first three phases are considered the FEL stage of the project, with each phase proving more complete information upon which to base the decision of whether or not to proceed with the project. Correct execution of these phases minimizes the risk of over expenditure and provides the maximum opportunity for the project to be executed in a capital efficient and timely manner.

Given the nature of the projects in the portfolio of modification work in the Greater Ekofisk Area judgement must be used in deciding at which FEL phase to start project work and which deliverables will come from the phase in question. Applying the same level of FEL to all projects will result in non-value adding costs. A project proposal shall be the starting point for the Z8 estimate. Per the FEL process, a project must pass through formal phases within the project's lifecycle

1. Identify/FEL-0: At this gate, a project is identified and its key risks and uncertainties are assessed. If the project has economic viability, is aligned with the Facility's strategy and is ranked high among other projects, it can be progressed to the next phase
2. Appraise & Select/FEL-1: Several viable options are evaluated and the best technical option is selected for further work. Management is solicited through the AFF gate to decide whether to terminate the project or progress it
3. Optimize/FEL-2: The project cost, schedule, and execution plan are refined to seek Management approval to progress the project (AFD gate).
4. Define/FEL-3: Preliminary engineering is completed to support full project funding. After the AFE is approved by Management, the project is funded to begin project execution

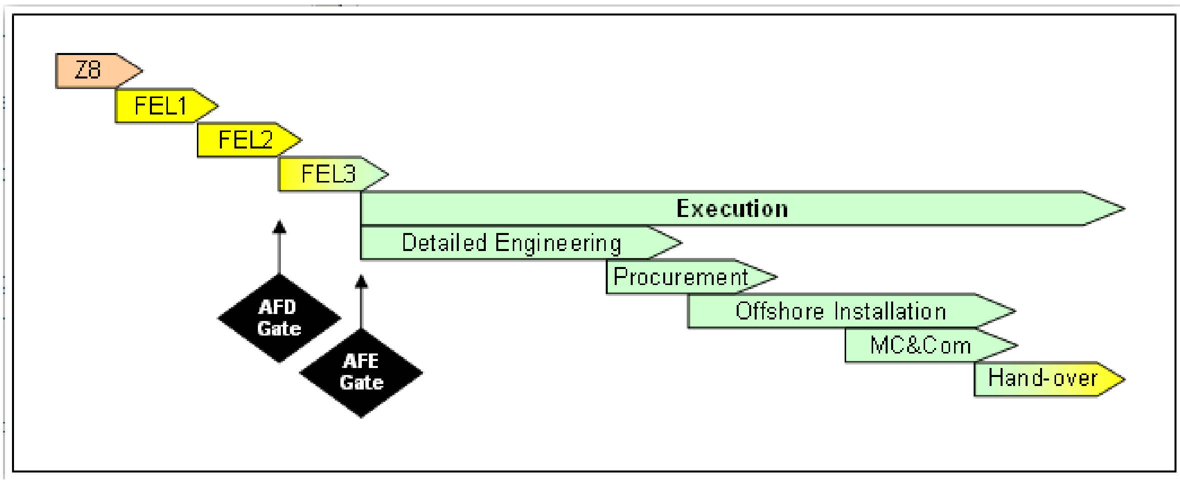


Figure 2: Project Development Process Overview

The project managers provide professional project management support to the asset teams. The project manager's role is to manage, organize and control assigned work or projects assigned to project area, in order to make sure that all work is done safely, efficiently, within time and costs, and meets contractual requirements while meeting the operational requirements set by the asset group.

In order to better control the huge amount of modification projects organised under GEM, the projects with equal or similar challenges are assembled in product groups. Additionally, this approach improves experience feedback between projects and engineering personnel when working within the same discipline and similar challenges regardless of which platform is concerned. The product groups are:

- Gas lift and flow line projects (P01)
- Fire water and deluge projects (P02)
- Process and utilities systems projects (P03)
- Structures and accommodation projects (P04)
- Control, electrical and instrumentation projects (P05)
- Crane projects (P06)
- PMO (P08)
- Front end loading (P09)

3.2 Project Management of Change

Modification projects are per definition, changes to the existing offshore installations and a management of change (MOC) process is required. A change is any event that results in a modification of project scope, schedule, resources, contract strategy or cost. In any project, change is inevitable and impacts cost or schedule or both. According to TDC 6153 Greater Ekofisk Modification Projects Management Manual, the GEM projects do not deal with repair work. The requirements to managing these changes are incorporated into the procedures implemented to control the modification process.

For a modification project the assigned project engineer (Norway Operations Facility Team) shall take the roles and responsibilities as change leader for that project, in the MOC process. The MoC process is initiated when the modification project is concluded to enter the FEL 1 phase and completed in PCS at handover to operation upon completion offshore.

Changes to a modification project during the execution phase, may have significant impact on cost and schedule. All such changes must be approved through the change order system. Changes to the project scope during the execution phases are based on thorough and documented evaluations, and that the change is required to ensure safe, efficient and reliable operation of the installation or the equipment installed.

Changes in modification projects may vary depending on the extent of the change. If the change is inside of the project a potential change system (PCID) is used to formalize and register potential changes in modification projects with HSE, plan or cost impact.

If the change also involves other business units, like operations, the change shall be initiated. The notification shall describe the change and make sure all the steps of the change process, like evaluation, approval, implementing and follow-up, are properly carried out.

If the change is a more comprehensive change, cooperation between the project manager and the change leader is important.

3.3 M&M contract description

In this thesis is in PMO project which can be executed in accordance with the Simplified minor EPCI (Engineering, Procurement, Construction and Installation) criteria’s below:

- The work shall not include a change in MOC (Management of Change)
- No changes to drawings/documentation (DFO)
- No information changes from existing module
- Single discipline engineering

For PMO’s that are less complex and where there are good empirical data on the solution and implementation, the Minor EPCI study may be excluded if agreed with Project Manager. In such cases no FEL sub-order should be estimated or created. The evaluation is based on work scope, multi discipline requirements, criticality and GEM’s recommendation. The organization chart of PMO (P08) project is shown in figure 3,

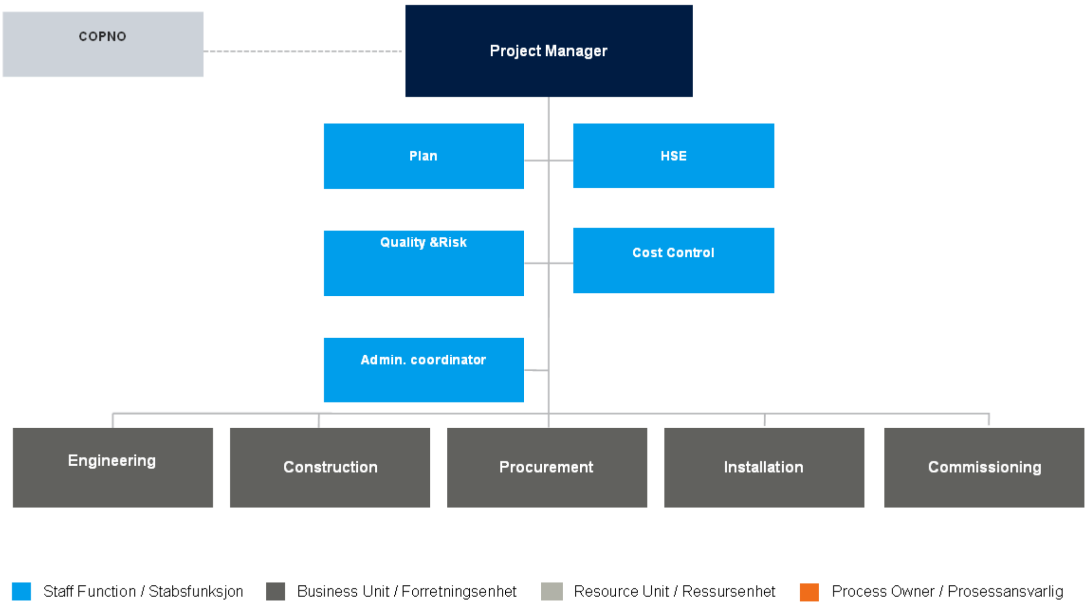


Figure 3: The organization chart of PMO (P08) project

3.4 M&M in the role of piping discipline projects

In order to perform all the engineering and construction activity in the project, the project manager has fully responsibility and control for all activity in the project should set the direction and organize the “project team” with planning, scheduling and cost. In the engineering department, the project engineer is assigned to be a coordinator to the engineering functions which is normally selected from the engineers who response the major engineering disciplined (Paul R. Smith and Thomas J. Van Laan, 1987).The project organization chart of engineering including of piping, structure, maintenance, instrument and control (I&C), mechanical, construction and safety shown in figure 4.

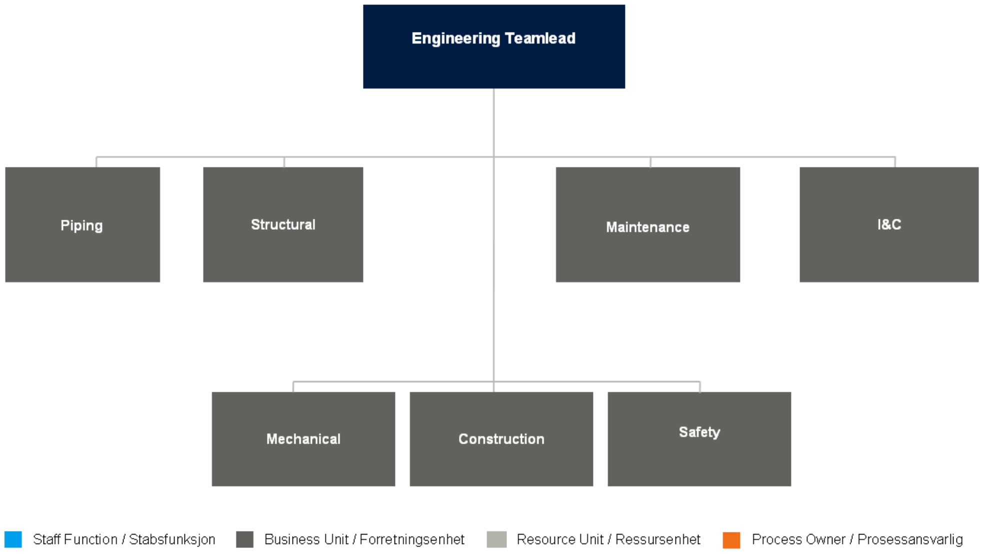


Figure 4: The project organization chart of engineering of PMO (P08) project

The engineering organization gives the authority and responsibility to the piping engineer to coordinate and manage the piping to meet the overall project objective. The responsibilities can be separated into the specific tasks below:

- Piping engineering, design, and layout
- Pip stress analysis
- Pipe support design
- Coordination of piping fabrication contract

Piping shall be designed to reduce the loading on equipment to the limitation of the equipment. Stress calculations considering relevant design data shall be performed to demonstrate that the structural integrity of piping systems complies with the relevant codes and specifications. Work-flow for piping discipline in M&M (PMO) project is shown in the figure 5.

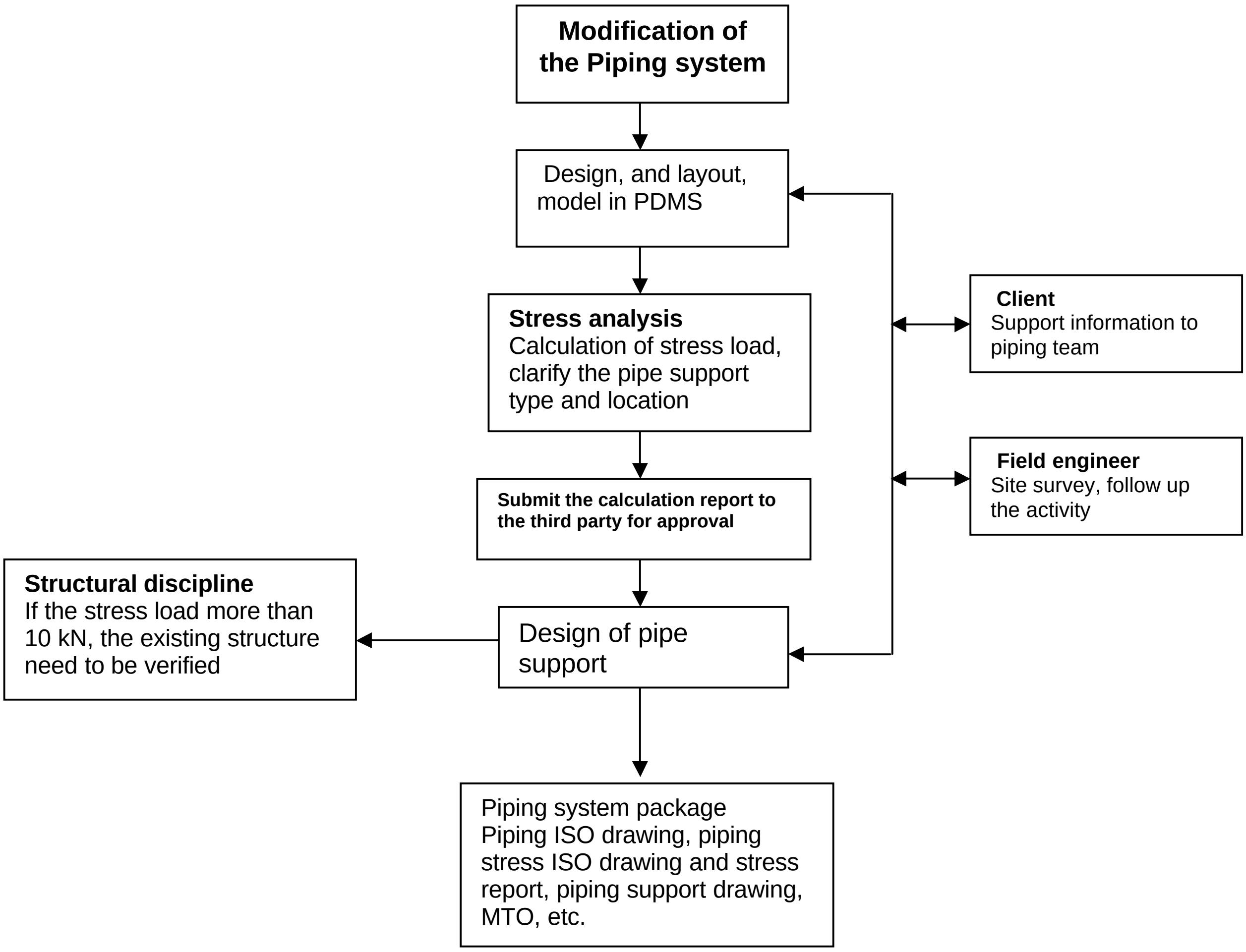


Figure 5: Work- flow for piping discipline in M&M (PMO) Project (Adapt from 04-04-WI-KL-08-ABL EIS and CAD for Pipe Stress Department)

The duties of piping engineer also including coordinating with the other project disciplines to ensure the piping and associated components are delivered to the site and erected in accordance with the codes and standards, technical specifications, construction schedule, and specified budget. Competence at the corporate level should be balances among four competing priorities are maximum productivity, low cost, smart safety and continuous development with shown in figure 6 (Antaki, 2003).

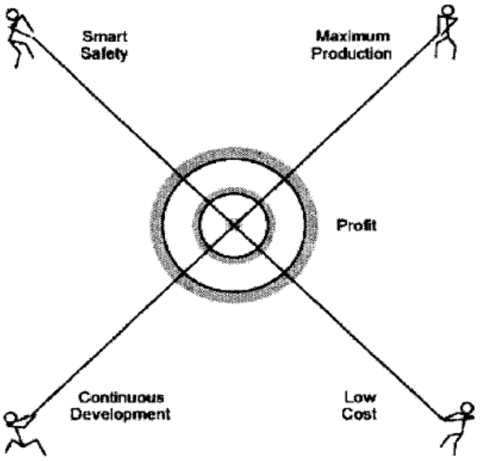


Figure 6: Profit as a Balance of Four Competing Priorities (Antaki, 2003)

4 BRIDGE PIPING FATIGUE

4.1 System definition

This system comprises the installation of the Atmospheric Vent Header from EKOM to Safe Location on Bridge line XXX-101-AD10-20”-VA-0 which includes stress analysis of the existing Atmospheric Vent Header from EKOM to Safe Location on Bridge between EKOM and EKOJ. The existing pipe spools will be replaced with new pipe spools of same piping specification with a minor routing change.

The existing line will be extended in order to obtain a safer outlet location point. This is done by replacing the vertical pipe section at the Open End on the bridge by a vertically extended pipe spool approximate 8 m.

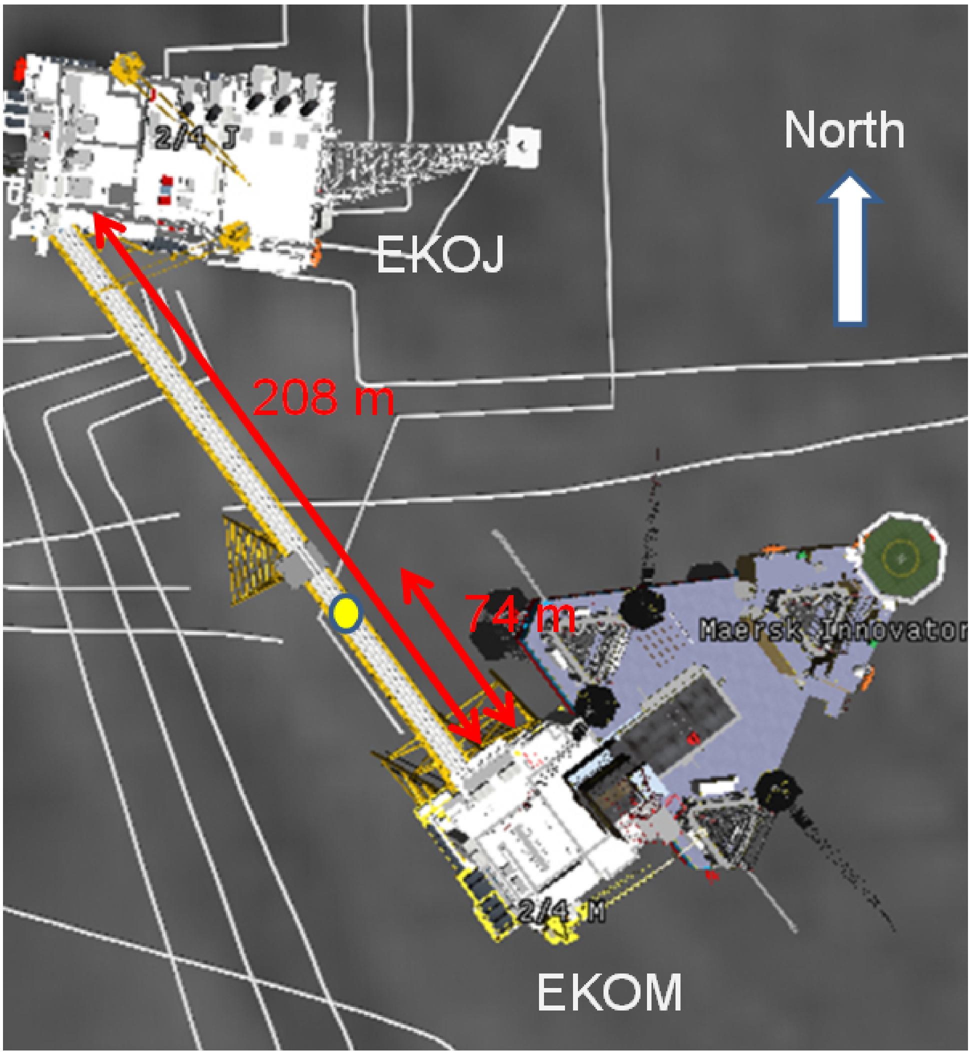


Figure 7: Top view of Atmospheric Vent Header from EKOM to Safe Location on Bridge between EKOM and EKOJ

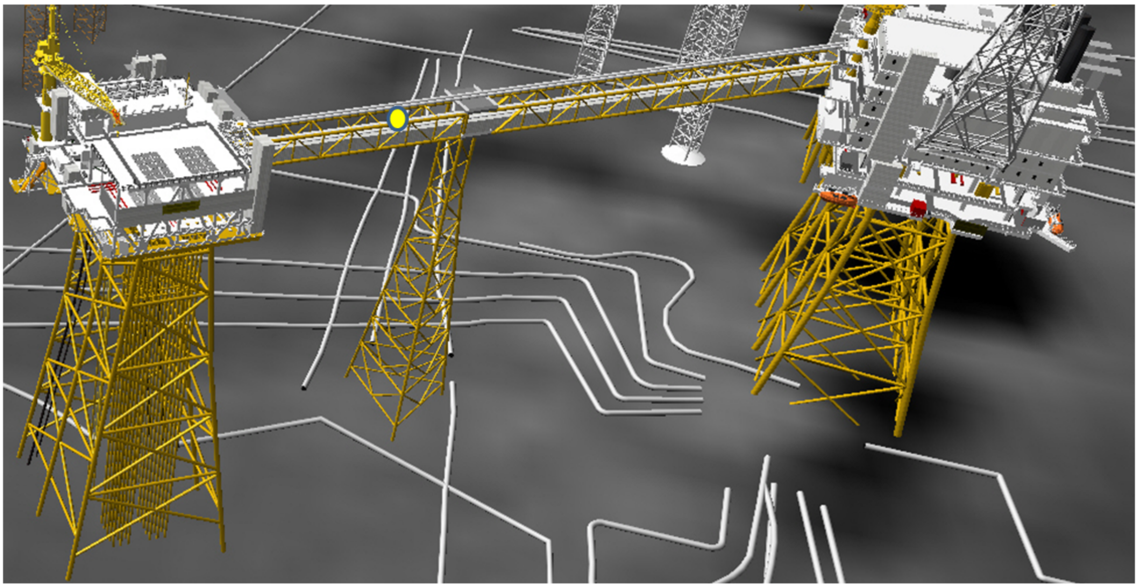


Figure 8: ISO view of Atmospheric Vent Header from EKOM to Safe Location on Bridge between EKOM and EKOJ

The calculations have been performed using TRIFLEX WINDOWS VERSION 3.2.2. pipe stress analysis software.

4.2 Design basis

4.2.1 Applicable codes and regulations

The piping shall be designed in compliance with ASME B31.3.

4.2.2 Material and material data

The piping class used is AD10 Super Duplex A928 S32760. The piping material used in the analysis is Super Duplex A790 UNS32760 which have the same value as material under consideration even though the chemical composition of the material might be different. The properties of materials are following below.

Super Duplex A790 S32760

Mechanical properties:

SMYS (Specified Minimum Yield Strength)	:	552 Mpa
SMTS (Specified Minimum Tensile Strength)	:	752 Mpa

Physical properties:

Density	:	8027 kg/m^3
Young’s modulus	:	202 Gpa
Linear thermal expansion		
From installation temp 4^{0}C to 130^{0}C	:	+2.11 mm/m (Triflex)
From installation temp 4^{0}C to -46^{0}C	:	-0.78 mm/m (Triflex)

4.2.3 Allowable stresses

Allowable stress	**ASME B31.3**
Allowable stress cold	250 Mpa
Allowable stress hot	241 Mpa

4.2.4 Piping dimensions

NPS [in]	**OD** [mm]	**wt** [mm]	**Sch**	**Corrosion Allow. (mm)**	**Mill Tol. (%)**	**Spec.**
20	508	5,54	10S	0	-12,5	AD10

4.2.5 Design parameters

Design temperatures and pressure are according to the process information. Ref. /5/

Max design temperature : + **130** °C

Min design temperature : - **46** °C

Installation temperature : + **4** °C

Max design pressure : **20** barg

Normal operate temperature : + **100** °C

Weight of contents

The weight of the contents given in the process line list is 0.91 kg/m^3

4.2.6 Blast considerations

NO Blast design for this system.

4.2.7 Bridge relative movements

In pipe stress calculation for piping system on the bridge, the stress due to +/-384 mm have been determined. Ref. /8/

4.2.8 Wind

In pipe stress calculation for piping system on the bridge, the wind has been applied on the complete system as an occasional load with 55 m/s wind speed.

4.2.9 Natural frequency calculation

The natural frequency of a satisfactory supported piping system should not be lower than 4 Hz.

4.2.10 Fatigue

Bridge movement induced by waves may lead to fatigue issue. In this case it is not regarded as a problem. This is based on the fact that the pipe terminates with an open end free to move and also that movements are not restrained by any guide, line-stop or other support function.

4.2.11 Boundary movements/conditions

The vertical pipe spools of line XXX-101-AD10-20" at the Safe Location on the bridge are to be replaced. The Vent line is routed across the bridge and at EKOM connected to line XXX-104-AD10-20” connected to the Slurry Holding Tank. The Vent line is terminated at the bridge between EKOM and EKOJ and longitudinal restrained in the bridge landing area.

The bridge is longitudinally supported at EKOJ and sliding supported at EKOM. As the line is terminated at the Bridge and not longitudinally restraint at the bridge, bridge movements due to wave actions are not considered relevant.
Effective boundary conditions for the system are:

- The connection of the new spools of line XXX-101-AD10-20" (node 245), to the existing line on the bridge is modelled by including the existing line up to the isolating support in node 150 (PS-50003-01).

All relevant boundary conditions for the calculation are considered and found to be acceptable.

4.3 Load case

The piping system is analysed in Triflex with load cases set up in the following below

Load case	Relevant loads
Displacement stress range	Design temperature range Thermal expansion of connected equipment
Operation	Weight Design pressure Temperature range: Max design/installation temperature Min design/installation temperature Thermal expansion of connected equipment
Operation + wind load	Weight Design pressure Temperature range: Max design/installation temperature Min design/installation temperature Thermal expansion of connected equipment Wind loads

4.4 Model analysis based on ASME B31.3

4.4.1 TRIFLEX models

The TRIFLEX models are based on the geometry of the piping system as given in the stress Isometric show in Figure 10 and the TRIFLEX input listing can be found in the appendix A.:

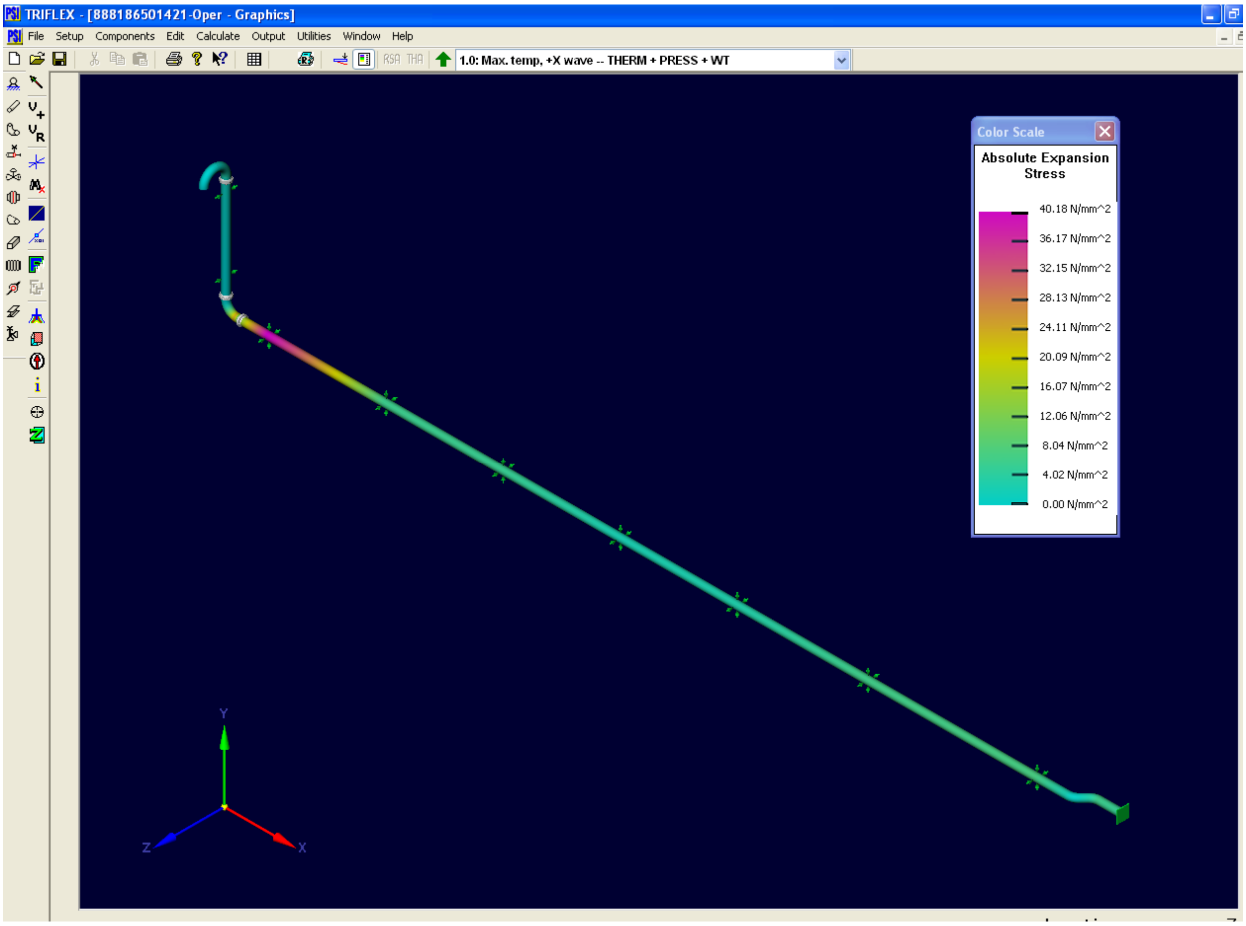


Figure 9: Pipe stress model of Atmospheric Vent Header from EKOM to Safe Location on Bridge between EKOM and EKOJ

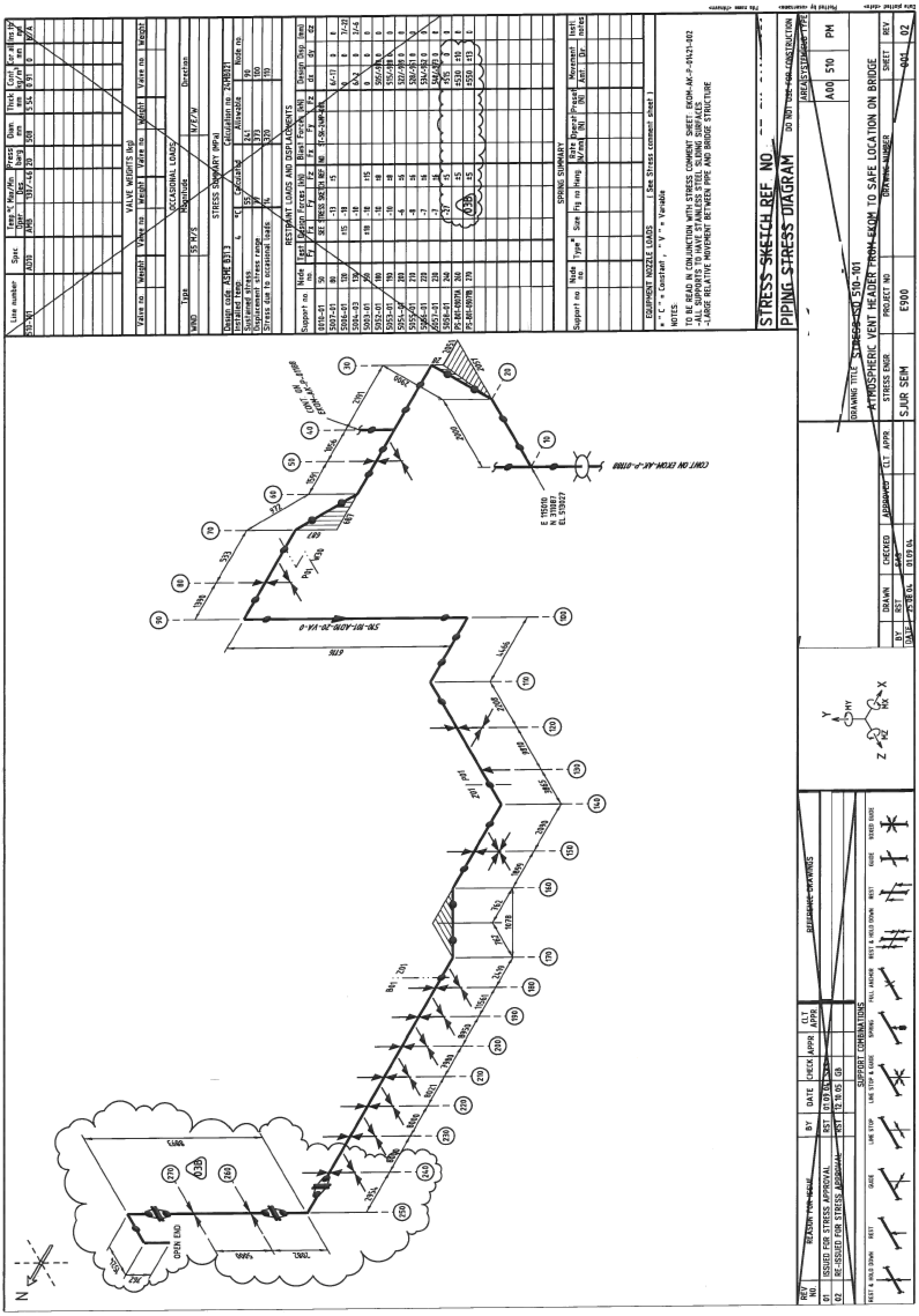


Figure 10: Pipe stress isometric drawing of Atmospheric Vent Header from EKOM to Safe Location on Bridge between EKOM and EKOJ

4.4.2 Sustained, displacement and occasional stresses

TRIFLEX calculation according to ASME B31.3

Table 1. Sustained, Displacement and Occasional stresses.(ASME B31,3)

Check	**Stress [MPa]**	**Allow. [MPa]**	**Node**	**Utilisation %**	**Load case**
Hoop stress SH	91	241	20”pipe	38	OPERATE
Sustained stress SL	85	241	240	35	OPERATE
Displacement stress SE	47	373	240	13	OPERATE
Occasional stress SL_o	147	320	250	46	WIND-N

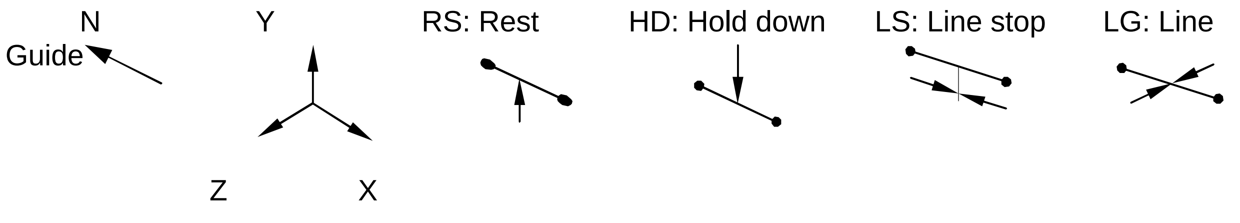
Note: The reported stresses are the highest utilized.

4.4.3 Pipe support forces, displacements and functions

The following pipe support forces and displacements are the maximums for all load cases.

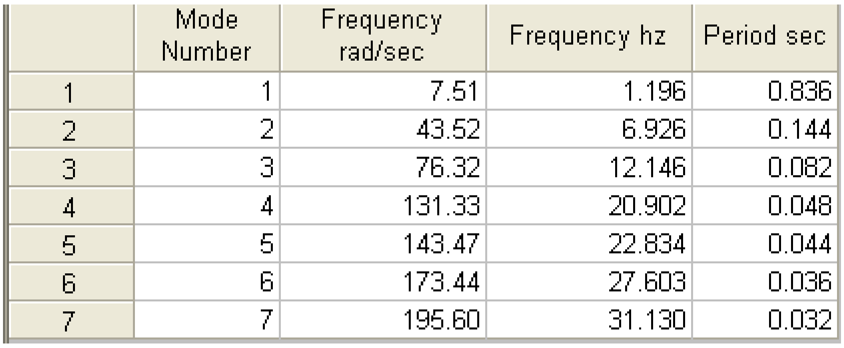
Table 2. Support forces, displacements and functions in normal operating cases.

Support Number	**Data Point**	**FX** (KN)	**FY** (KN)	**FZ** (KN)	**Dx** (mm)	**Dy** (mm)	**Dz** (mm)	**Support Functions**
5058-01	240	0	-27	±5	±515	0	0	RS, HD, LG
PS-B01-09071A	260	0	0	±5	±530	±10	0	LG
PS-B01-09071B	270	0	0	±5	±550	±13	0	LG



4.4.4 Natural Frequencies

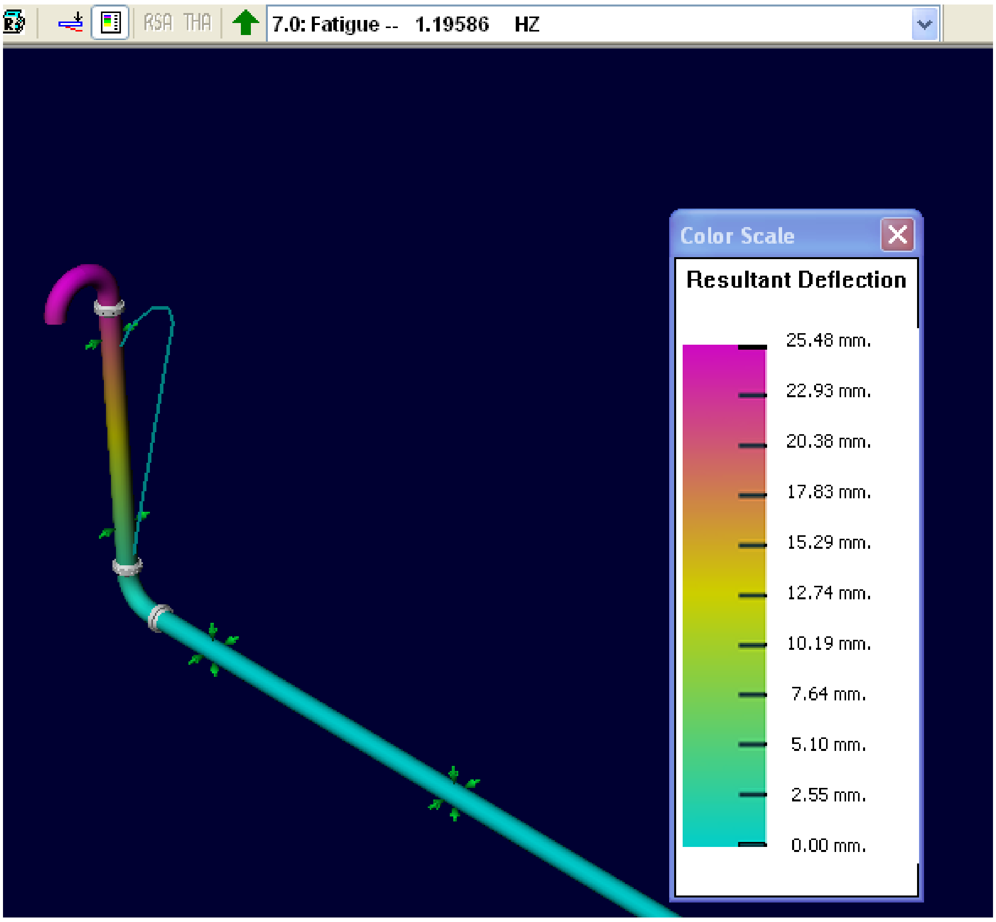
Table 3. Natural frequency



	Mode Number	Frequency rad/sec	Frequency hz	Period sec
1	1	7.51	1.196	0.836
2	2	43.52	6.926	0.144
3	3	76.32	12.146	0.082
4	4	131.33	20.902	0.048
5	5	143.47	22.834	0.044
6	6	173.44	27.603	0.036
7	7	195.60	31.130	0.032

At the first mode, a dynamic calculation of the system results in a low natural frequency (1.2Hz) located on the vertical pipe between node No. 250 to node No. 300. Therefore the line should be monitored during operation, and if necessary, damping devices could be installed on the vertical pipe support structure.

The natural frequencies at the other modes are more than 4 Hz which are considered as acceptable design and due to overcome the friction force that occurs on every rest supports in the loop. The horizontal friction force from each of the supports will counteract the pipe-vibrating mode.



7.0: Fatigue -- 1.19586 HZ

Figure 11: Natural frequencies and mode shapes at the first mode (a natural frequency is 1.19586 Hz)

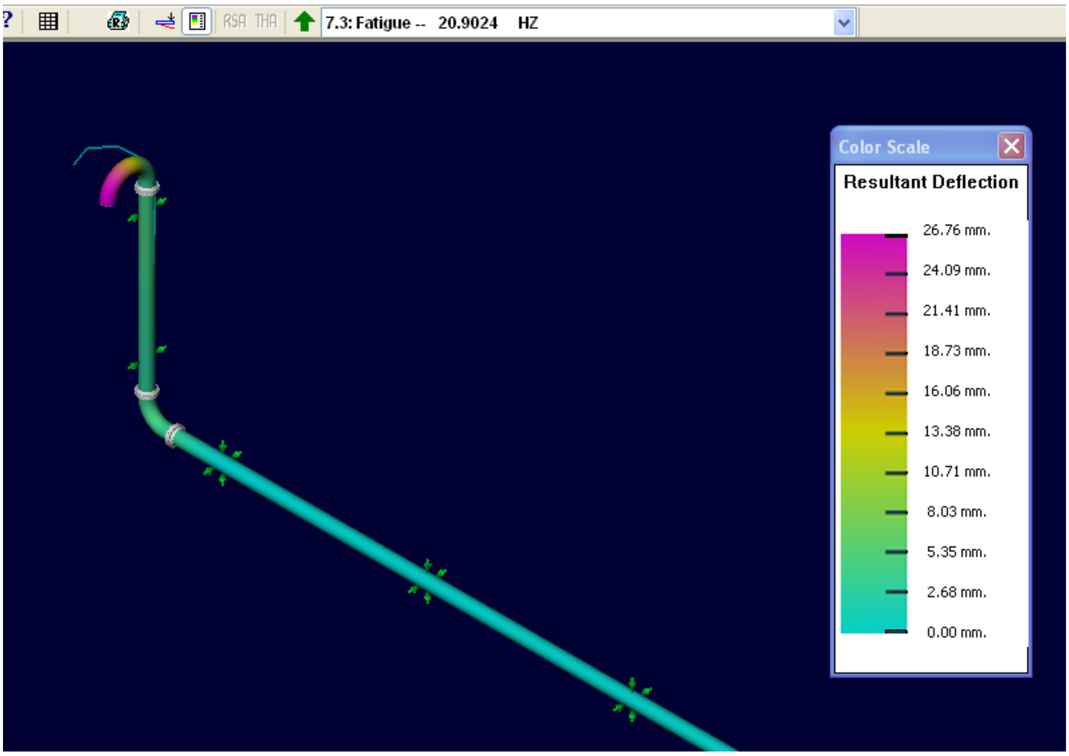


Figure 12: Natural frequencies and mode shapes at the mode No.4 (a natural frequency is 20.9024 Hz)

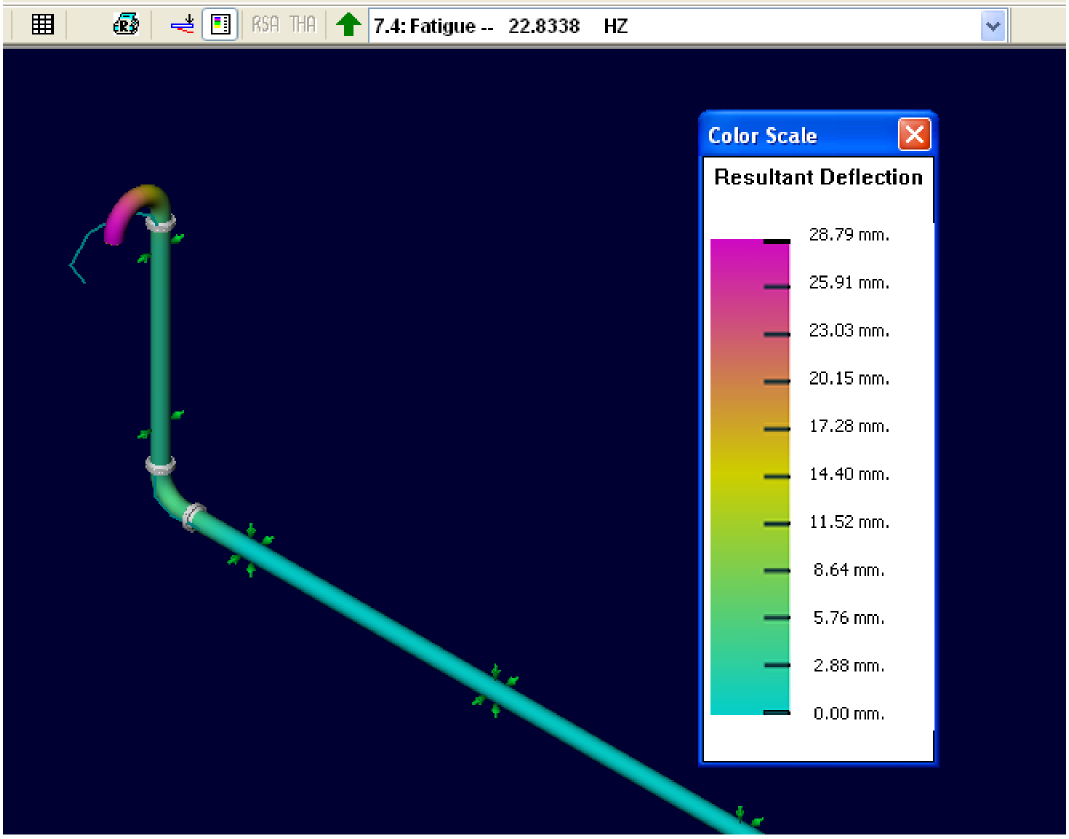


Figure 13: Natural frequencies and mode shapes at the mode No.5 (a natural frequency is 22.8338 Hz)

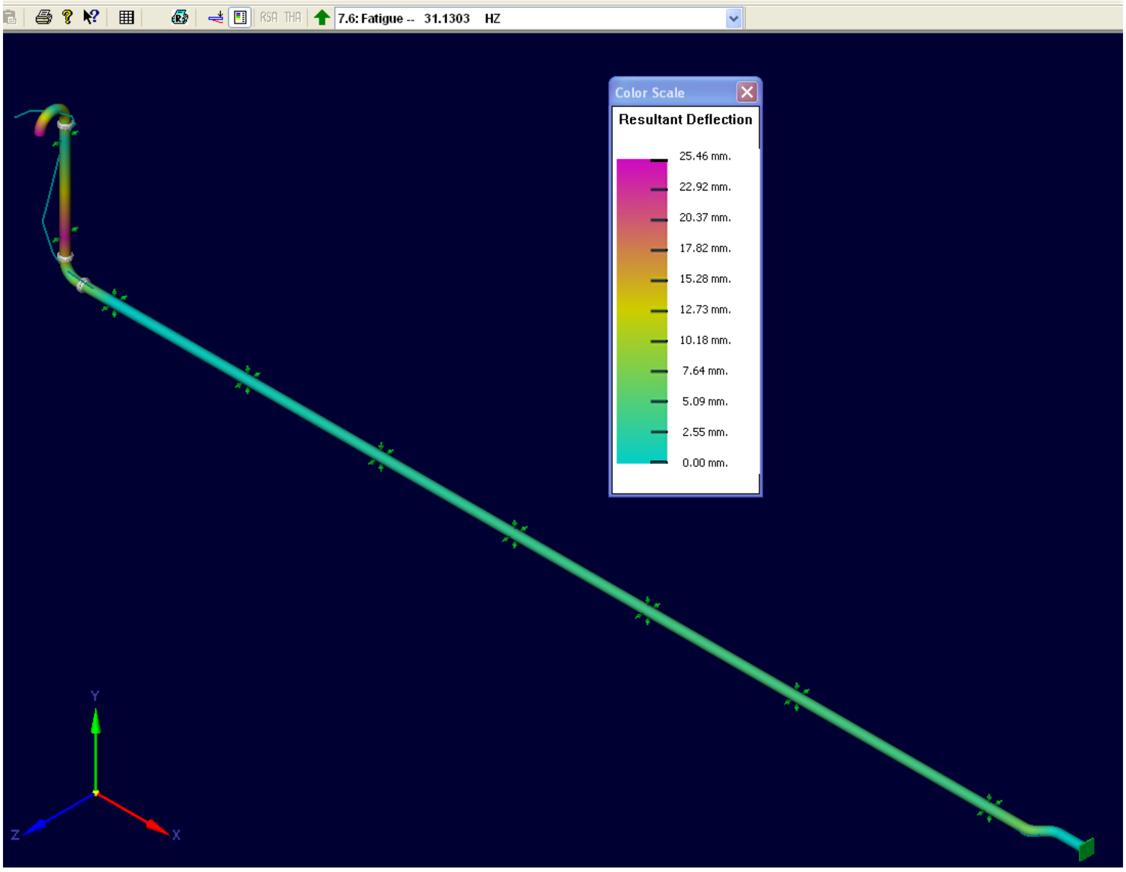


Figure 14: Natural frequencies and mode shapes at the mode No.7 (a natural frequency is 31.1303 Hz)

4.5 Fatigue analysis based on PD5500

The CAESAR II input listing that used for the fatigue analysis based on PD5500 refer to section 2.6 above and the maximum displacement stress ranges can be found in the appendix B. The *Simplified fatigue analysis using design curves in* appendix E (S-N curves) with following steps:

Step 1

Identify the various events to be experienced by the vessel which will give rise to fluctuating stresses and the frequencies at which they occur, as follows:

n_1 is the expected number of stress cycles at the lowest frequency;

n_2 is the expected number of stress cycles at the second lowest frequency;

n_3 is the expected number of stress cycles at the third lowest frequency; etc.

Step 2

For each frequency, calculate the maximum stress range due to pressure, due to change of temperature difference and due to mechanical loading. A conservative estimate of the stress range due to pressure change, *pr*, is:

$$S_r = (p_r/p)\ 3_f$$

and a conservative estimate of the stress range due to change of temperature difference • *T* is:

$$Sr = 2E\bullet\bullet\ T$$

Step 3

Check that the following equation is satisfied:

$$\frac{n_1}{N_1} + \frac{n_2}{N_2} + \frac{n_3}{N_3} + \frac{n_4}{N_4} + \dots \text{ etc.}$$
$$= \sum \frac{n_i}{N_i} \leq 0.6 \left(\frac{22}{e}\right)^{0.75}$$

Where
$i = 1, 2, 3$ etc.;
e is the maximum of greatest thickness or 22 mm;
Ni values are numbers of cycles obtained from the appropriate fatigue design curve in appendix E (S-N curves), at *Sri* values calculated in step 2, adjusted where necessary for elastic modulus by first multiplying *S*r by 2.09 _ $10^5/E$

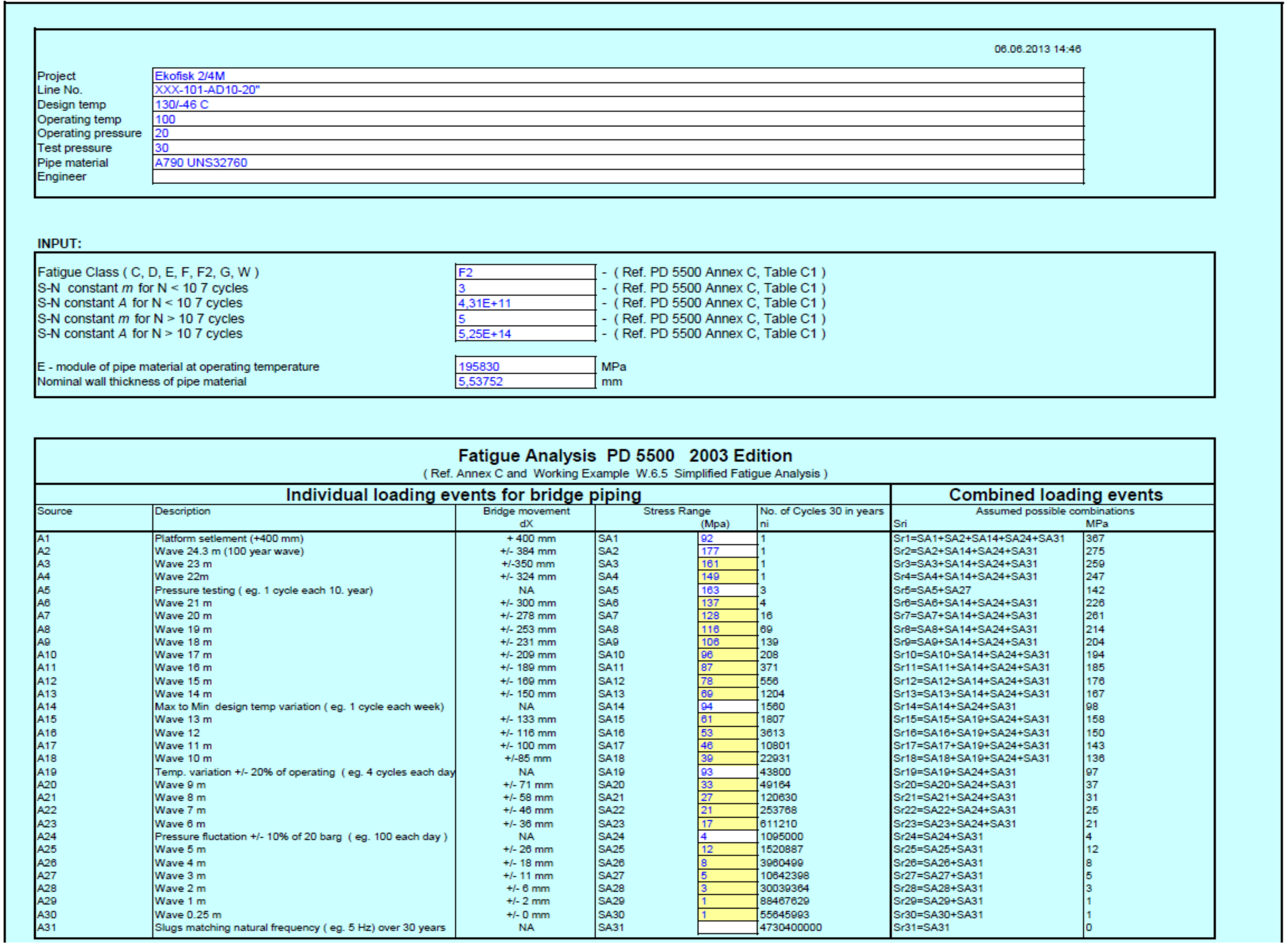
The *S–N* curves in Figure C.3 in appendix E have the form:

$$S_r^m N = A$$

where *m* and *A* are constants whose values are given in Table C.1 in appendix E. Different values apply for lives up to 107 cycles and for above 107 cycles.

The fatigue life analysis PD5500 for bridge piping is shown in table 4.

Table 4. Fatigue life analysis PD5500 – bridge piping



06.06.2013 14:46

Project	Ekofisk 2/4M
Line No.	XXX-101-AD10-20"
Design temp	130/-46 C
Operating temp	100
Operating pressure	20
Test pressure	30
Pipe material	A790 UNS32760
Engineer	

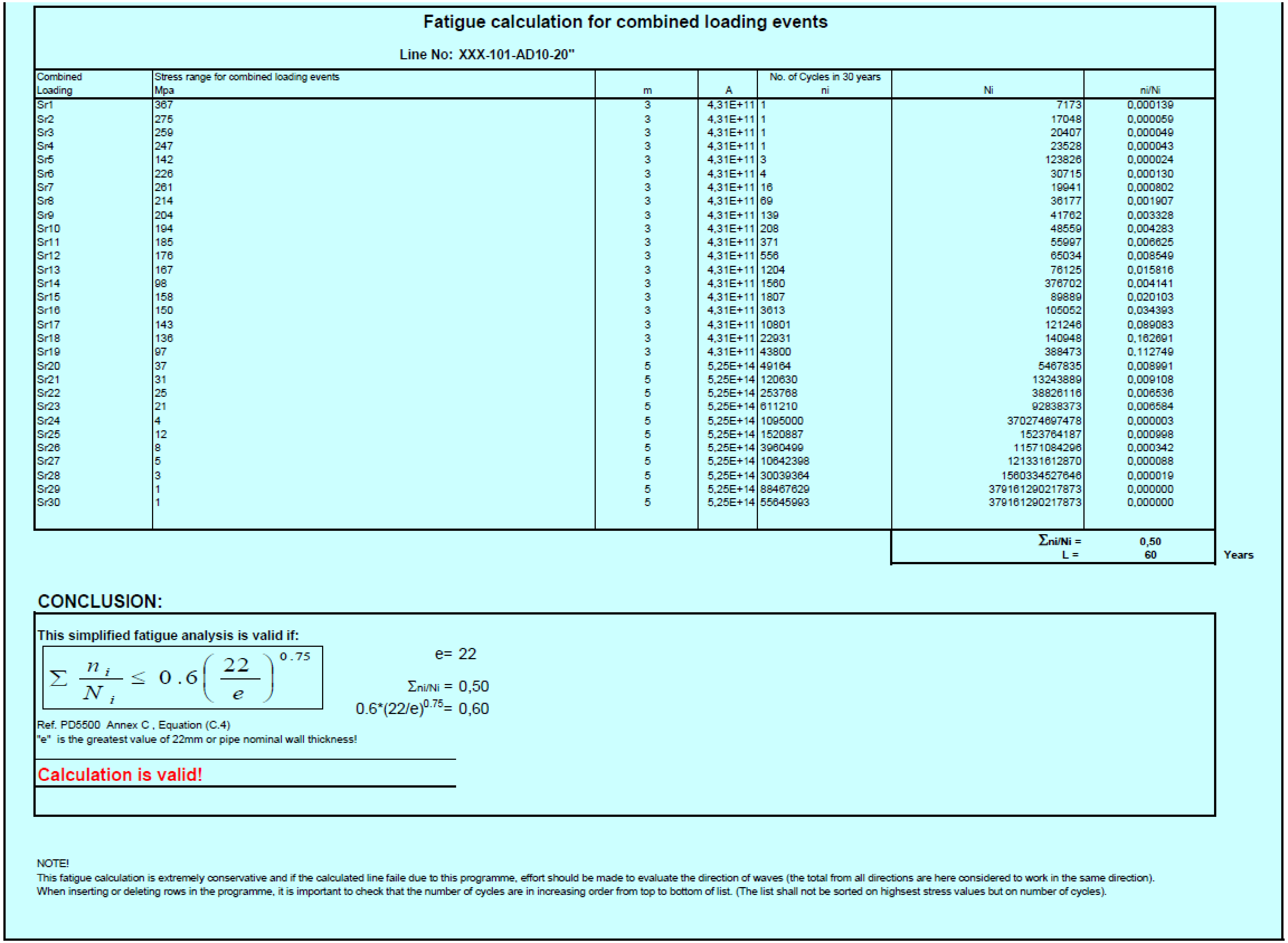
INPUT:

Fatigue Class (C, D, E, F, F2, G, W)	F2	- (Ref. PD 5500 Annex C, Table C1)
S-N constant *m* for N < 10 7 cycles	3	- (Ref. PD 5500 Annex C, Table C1)
S-N constant *A* for N < 10 7 cycles	4,31E+11	- (Ref. PD 5500 Annex C, Table C1)
S-N constant *m* for N > 10 7 cycles	5	- (Ref. PD 5500 Annex C, Table C1)
S-N constant *A* for N > 10 7 cycles	5,25E+14	- (Ref. PD 5500 Annex C, Table C1)
E - module of pipe material at operating temperature	195830	MPa
Nominal wall thickness of pipe material	5,53752	mm

Fatigue Analysis PD 5500 2003 Edition

(Ref. Annex C and Working Example W.6.5 Simplified Fatigue Analysis)

Individual loading events for bridge piping						Combined loading events	
Source	Description	Bridge movement dX	Stress Range	(Mpa)	No. of Cycles 30 in years ni	Assumed possible combinations Sri	MPa
A1	Platform setlement (+400 mm)	+ 400 mm	SA1	92	1	Sr1=SA1+SA2+SA14+SA24+SA31	367
A2	Wave 24.3 m (100 year wave)	+/- 384 mm	SA2	177	1	Sr2=SA2+SA14+SA24+SA31	275
A3	Wave 23 m	+/-350 mm	SA3	161	1	Sr3=SA3+SA14+SA24+SA31	259
A4	Wave 22m	+/- 324 mm	SA4	149	1	Sr4=SA4+SA14+SA24+SA31	247
A5	Pressure testing (eg. 1 cycle each 10. year)	NA	SA5	163	3	Sr5=SA5+SA27	142
A6	Wave 21 m	+/- 300 mm	SA6	137	4	Sr6=SA6+SA14+SA24+SA31	226
A7	Wave 20 m	+/- 278 mm	SA7	128	16	Sr7=SA7+SA14+SA24+SA31	261
A8	Wave 19 m	+/- 253 mm	SA8	116	69	Sr8=SA8+SA14+SA24+SA31	214
A9	Wave 18 m	+/- 231 mm	SA9	106	139	Sr9=SA9+SA14+SA24+SA31	204
A10	Wave 17 m	+/- 209 mm	SA10	96	208	Sr10=SA10+SA14+SA24+SA31	194
A11	Wave 16 m	+/- 189 mm	SA11	87	371	Sr11=SA11+SA14+SA24+SA31	185
A12	Wave 15 m	+/- 169 mm	SA12	78	556	Sr12=SA12+SA14+SA24+SA31	176
A13	Wave 14 m	+/- 150 mm	SA13	69	1204	Sr13=SA13+SA14+SA24+SA31	167
A14	Max to Min design temp variation (eg. 1 cycle each week)	NA	SA14	94	1560	Sr14=SA14+SA24+SA31	98
A15	Wave 13 m	+/- 133 mm	SA15	61	1807	Sr15=SA15+SA19+SA24+SA31	158
A16	Wave 12	+/- 116 mm	SA16	53	3613	Sr16=SA16+SA19+SA24+SA31	150
A17	Wave 11 m	+/- 100 mm	SA17	46	10801	Sr17=SA17+SA19+SA24+SA31	143
A18	Wave 10 m	+/-85 mm	SA18	39	22931	Sr18=SA18+SA19+SA24+SA31	136
A19	Temp. variation +/- 20% of operating (eg. 4 cycles each day	NA	SA19	93	43800	Sr19=SA19+SA24+SA31	97
A20	Wave 9 m	+/- 71 mm	SA20	33	49164	Sr20=SA20+SA24+SA31	37
A21	Wave 8 m	+/- 58 mm	SA21	27	120630	Sr21=SA21+SA24+SA31	31
A22	Wave 7 m	+/- 46 mm	SA22	21	253768	Sr22=SA22+SA24+SA31	25
A23	Wave 6 m	+/- 36 mm	SA23	17	611210	Sr23=SA23+SA24+SA31	21
A24	Pressure fluctation +/- 10% of 20 barg (eg. 100 each day)	NA	SA24	4	1095000	Sr24=SA24+SA31	4
A25	Wave 5 m	+/- 26 mm	SA25	12	1520887	Sr25=SA25+SA31	12
A26	Wave 4 m	+/- 18 mm	SA26	8	3960499	Sr26=SA26+SA31	8
A27	Wave 3 m	+/- 11 mm	SA27	5	10642398	Sr27=SA27+SA31	5
A28	Wave 2 m	+/- 6 mm	SA28	3	30039364	Sr28=SA28+SA31	3
A29	Wave 1 m	+/- 2 mm	SA29	1	88467629	Sr29=SA29+SA31	1
A30	Wave 0.25 m	+/- 0 mm	SA30	1	55645993	Sr30=SA30+SA31	1
A31	Slugs matching natural frequency (eg. 5 Hz) over 30 years	NA	SA31		4730400000	Sr31=SA31	0



Fatigue calculation for combined loading events

Line No: XXX-101-AD10-20"

Combined Loading	Stress range for combined loading events Mpa	m	A	No. of Cycles in 30 years ni	Ni	ni/Ni
Sr1	367	3	4,31E+11	1	7173	0,000139
Sr2	275	3	4,31E+11	1	17048	0,000059
Sr3	259	3	4,31E+11	1	20407	0,000049
Sr4	247	3	4,31E+11	1	23528	0,000043
Sr5	142	3	4,31E+11	3	123826	0,000024
Sr6	226	3	4,31E+11	4	30715	0,000130
Sr7	261	3	4,31E+11	16	19941	0,000802
Sr8	214	3	4,31E+11	69	36177	0,001907
Sr9	204	3	4,31E+11	139	41762	0,003328
Sr10	194	3	4,31E+11	208	48559	0,004283
Sr11	185	3	4,31E+11	371	55997	0,006625
Sr12	176	3	4,31E+11	556	65034	0,008549
Sr13	167	3	4,31E+11	1204	76125	0,015816
Sr14	98	3	4,31E+11	1560	376702	0,004141
Sr15	158	3	4,31E+11	1807	89889	0,020103
Sr16	150	3	4,31E+11	3613	105052	0,034393
Sr17	143	3	4,31E+11	10801	121246	0,089083
Sr18	136	3	4,31E+11	22931	140948	0,162691
Sr19	97	3	4,31E+11	43800	388473	0,112749
Sr20	37	5	5,25E+14	49164	5467835	0,008991
Sr21	31	5	5,25E+14	120630	13243889	0,009108
Sr22	25	5	5,25E+14	253768	38826116	0,006536
Sr23	21	5	5,25E+14	611210	92838373	0,006584
Sr24	4	5	5,25E+14	1095000	370274697478	0,000003
Sr25	12	5	5,25E+14	1520887	1523764187	0,000998
Sr26	8	5	5,25E+14	3960499	11571084296	0,000342
Sr27	5	5	5,25E+14	10642398	121331612870	0,000088
Sr28	3	5	5,25E+14	30039364	1560334527646	0,000019
Sr29	1	5	5,25E+14	88467629	379161290217873	0,000000
Sr30	1	5	5,25E+14	55645993	379161290217873	0,000000

Σni/Ni = **0,50**
L = **60** **Years**

CONCLUSION:

This simplified fatigue analysis is valid if:

$$\boxed{\sum \frac{n_i}{N_i} \leq 0.6\left(\frac{22}{e}\right)^{0.75}}$$

e= 22

$\Sigma_{ni/Ni}$ = 0,50

$0.6*(22/e)^{0.75}$= 0,60

Ref. PD5500 Annex C , Equation (C.4)
"e" is the greatest value of 22mm or pipe nominal wall thickness!

Calculation is valid!

NOTE!
This fatigue calculation is extremely conservative and if the calculated line faile due to this programme, effort should be made to evaluate the direction of waves (the total from all directions are here considered to work in the same direction).
When inserting or deleting rows in the programme, it is important to check that the number of cycles are in increasing order from top to bottom of list. (The list shall not be sorted on highsest stress values but on number of cycles).

4.6 Conclusion

All relevant load cases have been considered and calculated. In general, the calculations show acceptable stresses in the system and all calculated stresses are below allowable limits.

The lowest natural frequency reported is below the recommended value as given by COPNO and related to an oscillation in North-South direction of the extended vertical pipe spool at the termination of the 20” line on the bridge. According to the unacceptable low natural frequency, then the system has to go through a thorough fatigue assessment by calculate the fatigue lifetime based on the PD5500 method in PD5500. The estimated total fatigue life for this piping system is 60 years which can be considered as an acceptable fatigue design when compared with the design life time. However this system is also recommended to monitor the line during operation and if required damping devices are to be installed. Together with two new pipe supports (guide E/W) to be installed at the extended vertical pipe spool at the termination point at the bridge which show in Figure 15.

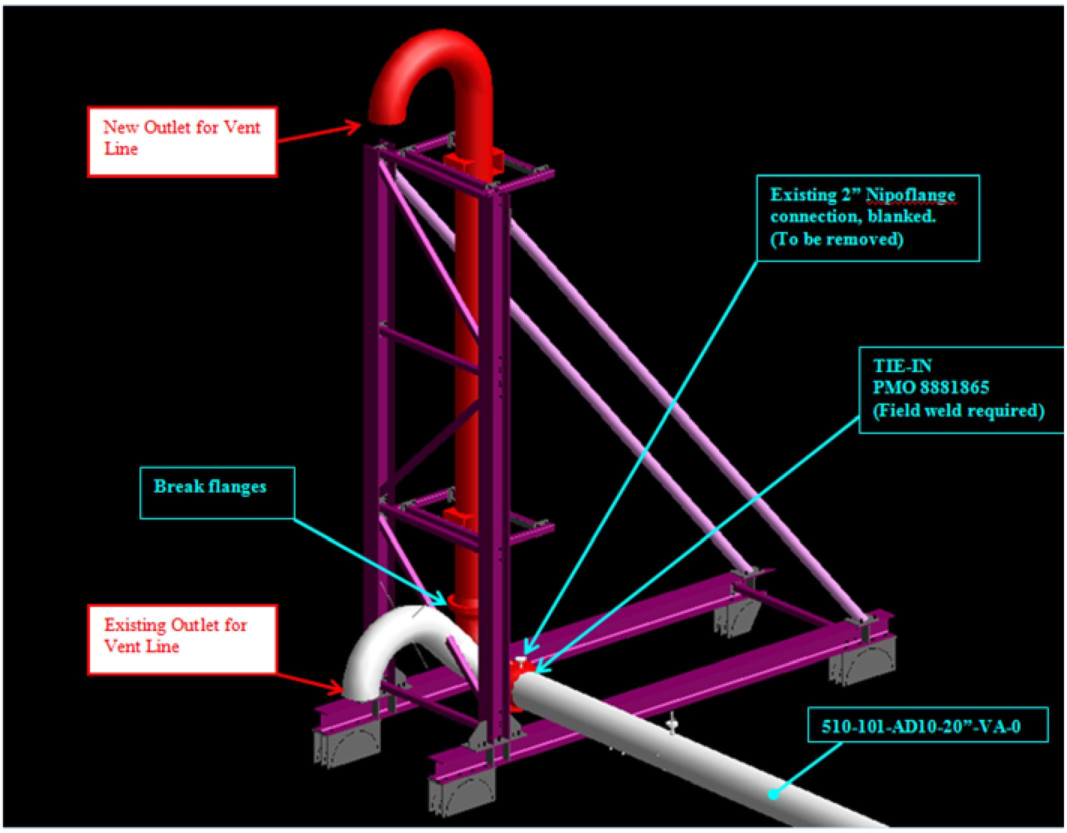


Figure 15: A vertically extended pipe spool for the Open End on the bridge

5 TEMPORARY EMERGENCY GENERATOR EXHAUST TO OPEN END

This system comprises of the installation of Line No.06189-AC01-4"-VA-3 from Temporary emergency Generator Exhaust to open end. The existing pipe spools will be replaced with new pipe spools of same piping specification with some changes on support type due to the high operating temperature.

The existing pipe spools will be replaced according to highly corroded exhaust pipe work from the flange connection above existing expansion bellow in the exhaust line of the diesel emergency generator 32 G810 as shown as the figures below:

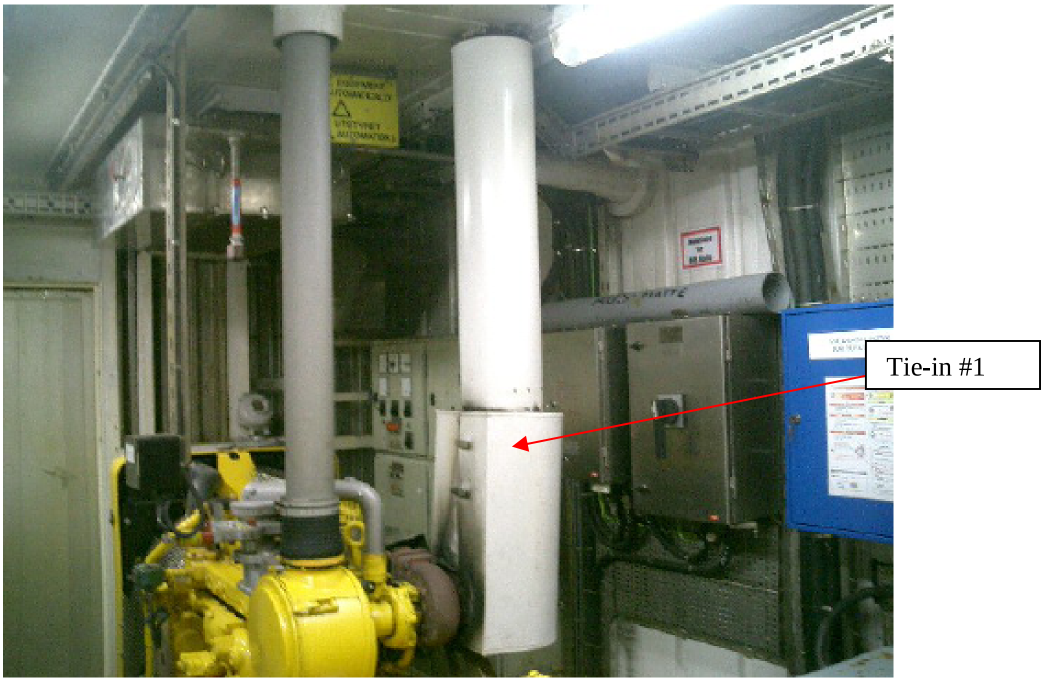


Figure 16: Tie in point 1 above bellows (inside insulation)

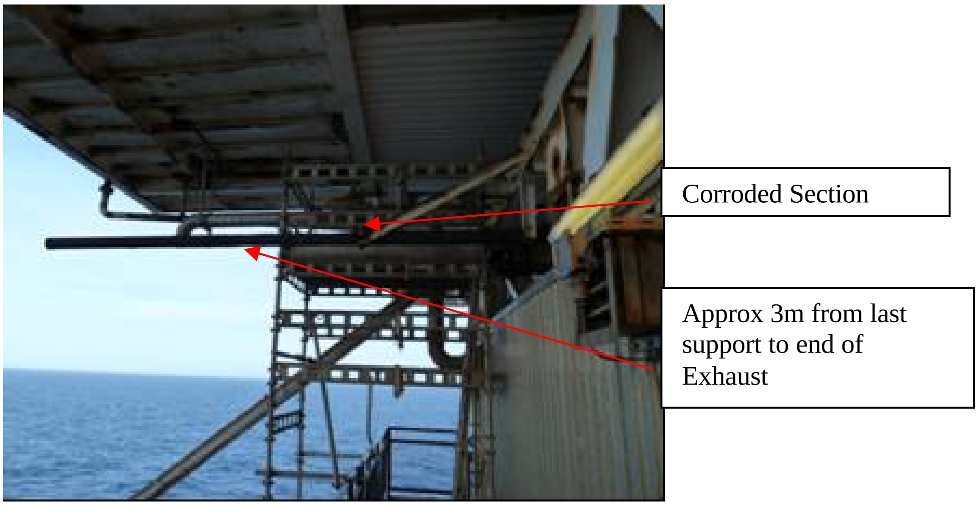


Figure 17: Overview Image taken from the south

Figure 18: Overview picture of the pipe on the roof of the room for emergency generator

Figure 19: Picture of "muffler", this is extremely corroded with more holes. Some have tried patches as the picture shows

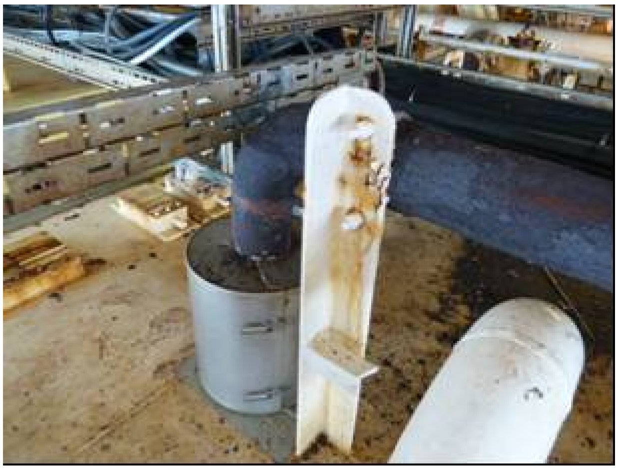


Figure 20: Reviewing the roof of the emergency generator room

Figure 21: Picture of close up of pipe by pipe support shown in the picture above. Rust Building ca.10mm

Figure 22: Picture of general rust build-up ca.10mm along the line

Figure 23: Picture of close up of the flange on the western side of the muffler

The calculations have been performed using CAESAR II VERSION 5.30 2011 pipe stress analysis software.

5.1 Design basis

5.1.1 Applicable codes and regulations

The piping shall be designed in compliance with ASME B31.3.

5.1.2 Material and material data

The piping class used is AC01 Carbon Steel A106 Gr. B. The properties of materials are following below.

Carbon Steel A106 Gr. B

Mechanical properties:

SMYS (Specified Minimum Yield Strength)	:	241 Mpa
SMTS (Specified Minimum Tensile Strength)	:	414 Mpa

Physical properties:

Density	:	7833 kg/m^3
Young's modulus	:	204 Gpa

5.1.3 Allowable stresses

Allowable stress	ASME B31.3
Allowable stress cold	138 Mpa
Allowable stress hot	75 Mpa

5.1.4 Piping dimensions

NPS [in]	OD [mm]	wt [mm]	Sch	Corrosion Allow. (mm)	Mill Tol. (%)	Spec.
4	114	6.02	40	3	-12,5	AC01

5.1.5 Design parameters

Design temperatures and pressure are according to the process information.

Max design temperature	:	+ **425** °C
Min design temperature	:	- **15** °C
Installation temperature	:	+ **4** °C
Max design pressure	:	**3.5** barg
Hydrotest pressure	:	**29.4** barg
Normal operate temperature	:	+ **395** °C

5.1.6 Weight of contents

The weight of the contents given in the process line list is 0.58 kg/m^3

5.1.7 Piping insulation

Personnel protection

5.1.8 Natural frequency calculation

The natural frequency of a satisfactory supported piping system should not be lower than 4 Hz.

5.1.9 Dynamic Loads

No dynamic loads in this line

5.1.10 Pressure test

Hydrotest pressure 29.4 barg

5.1.11 Fatigue

N/A

5.1.12 Boundary movements/conditions

The system effective boundary conditions are presented below:

Anchor at Node 10.

Free end at Node 180.

Support types have to change according to the high operating temperature by adding a vertical guide at support Node 70.

However it is unable to find the nozzle load of the temporary emergency generation Node 10 but the below expansion will help to decrease the affect from the nozzle load to this line and it have been successful in service for several years.

5.2 Load case

A short summary of the design load cases set up in CAESAR II is given below.

HP	Hydro static test pressure
W	Weight
T1	Maximum design temperature = 425 °C
T2	Minimum design temperature = -15 °C
T3	Normal operate temperature = 395 °C
P1	Maximum design pressure

Load case setup

L1	WW+HP		Hydro test case
L2	W+P1+T1		Operating case with Max design temp.
L3	W+P1+T2		Operating case with Min design temp.
L4	W+P1+T3		Operating case with normal operate temp.
L5	W+P1		Sustained case
L6	L2-L5	Algebraic	Thermal stress range T1
L7	L3-L5	Algebraic	Thermal stress range T2
L8	L4-L5	Algebraic	Thermal stress range T3

5.3 Model analysis based on ASME B31.3

5.3.1 CAESAR models

The CAESAR II models are based on the geometry of the piping system as given in the stress Isometric shown in Figure 25 and the CAESAR input listing can be found in the appendix C.:

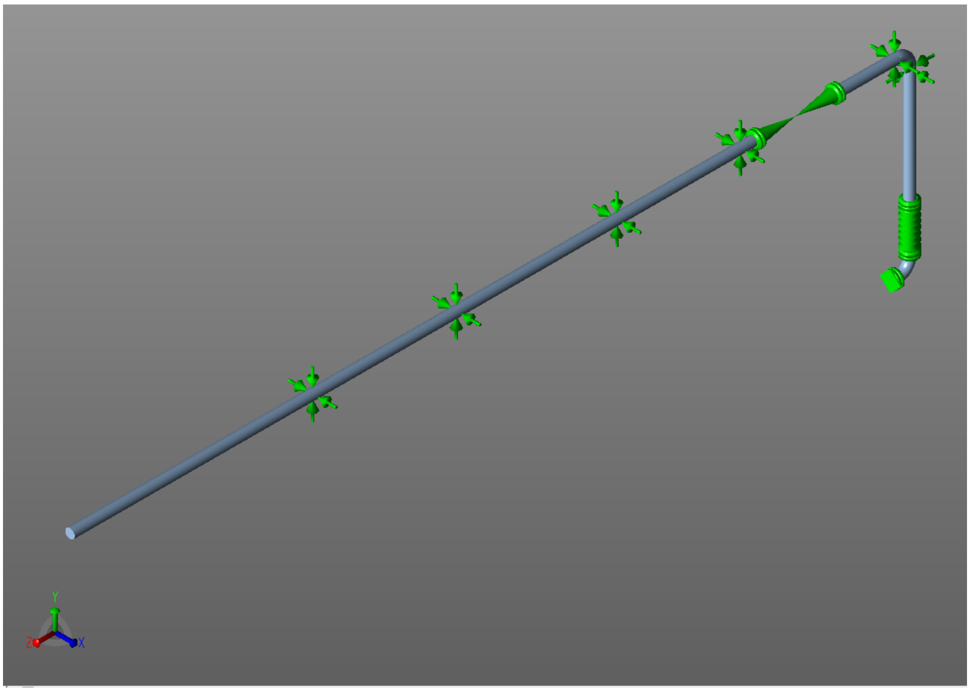


Figure 24: Pipe stress model of temporary emergency Generator Exhaust to open end

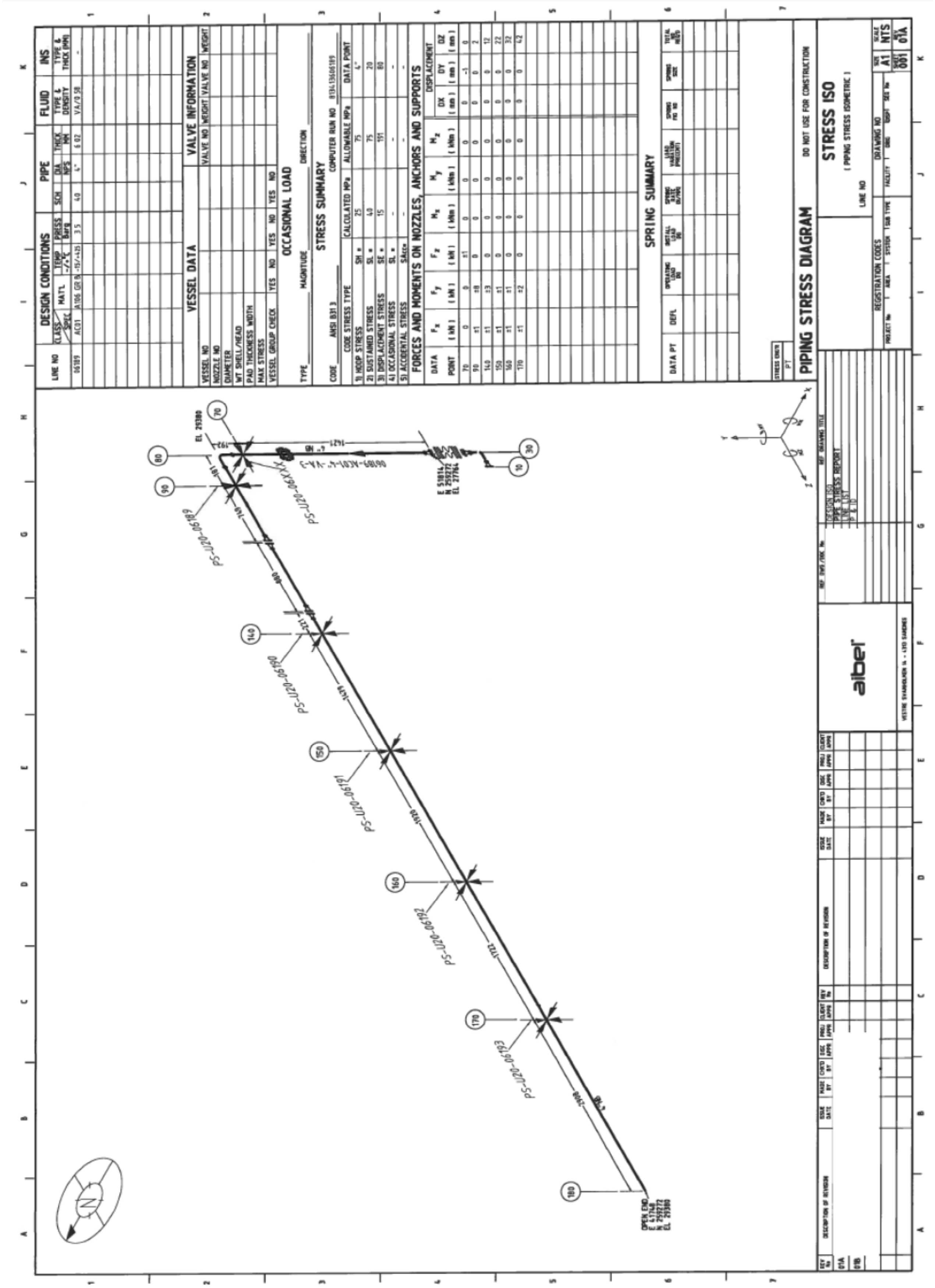


Figure 25: Pipe stress isometric drawing of temporary emergency Generator Exhaust to open end

5.3.2 Sustained, displacement and occasional stresses

CAESAR II calculation **813413606189** (COMBINED) according to ASME B31.3

Table 5. Sustained, Displacement and Occasional stresses.(ASME B31,3).

Check	Stress [MPa]	Allow. [MPa]	Node	Utilisation %	Load case
Hoop stress SH	25	75	4”pipe	33	OPERATE
Sustained stress SL	40	75	20	53	OPERATE
Displacement stress SE	15	191	80	7.8	OPERATE

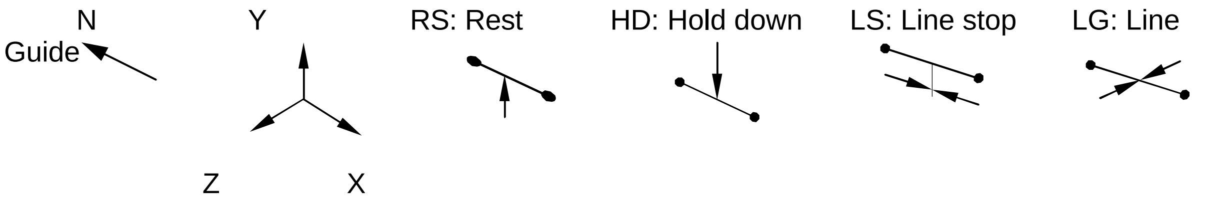
Note: The reported stresses are the highest utilized.

5.3.3 Pipe support forces, displacements and functions

The following pipe support forces and displacements are the maximums for all load cases.

Table 6. Support forces, displacements and functions in normal operating cases.

Support Number	Data Point	FX (KN)	FY (KN)	FZ (KN)	Dx (mm)	Dy (mm)	Dz (mm)	Support Functions
PS-U20-06189	70	0	0	±1	0	-1	0	LG
PS-U20-06189	90	±1	±8	0	0	0	2	RS, HD, LG
PS-U20-06190	140	±1	±3	0	0	0	12	RS, HD, LG
PS-U20-06191	150	±1	±1	0	0	0	22	RS, HD, LG
PS-U20-06192	160	±1	±1	0	0	0	32	RS, HD, LG
PS-U20-06193	170	±1	±2	0	0	0	42	RS, HD, LG



5.3.4 Natural Frequencies

Table 7. Natural frequency

MODE	FREQUENCY (Hz)	FREQUENCY (Rad/Sec)	PERIOD (Sec)
1	7.302	45.880	0.137
2	7.302	45.880	0.137
3	21.907	137.645	0.046
4	25.301	158.973	0.040
5	56.658	355.995	0.018

The natural frequencies are more than 4 Hz which are considered as acceptable design

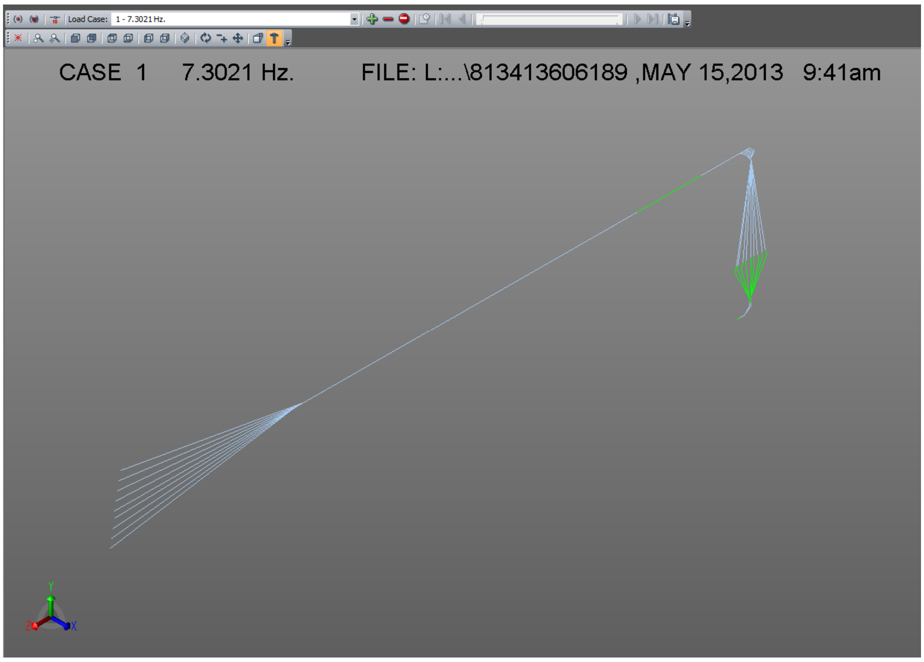
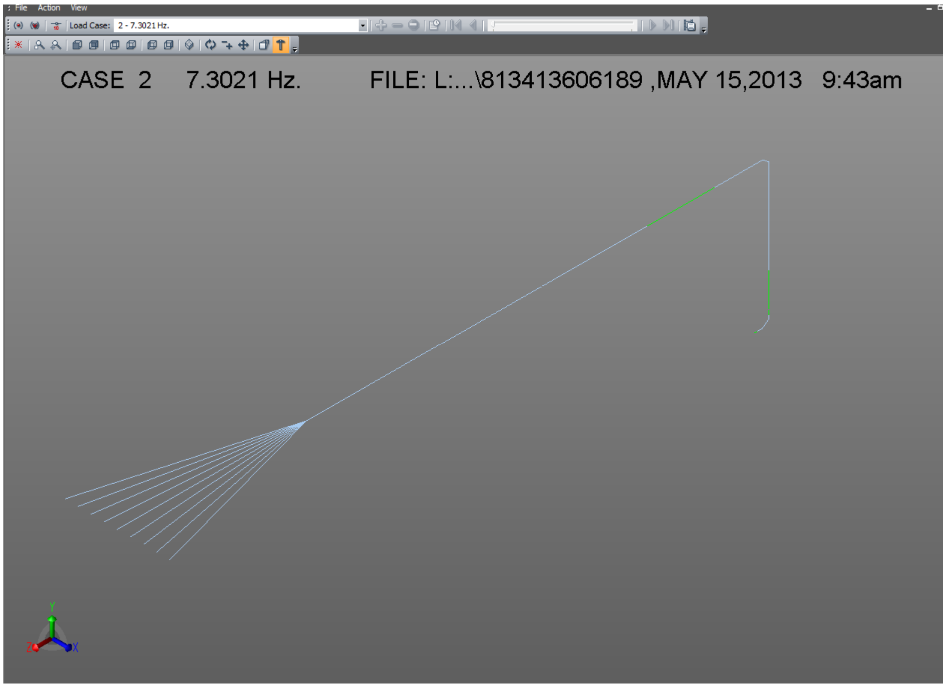
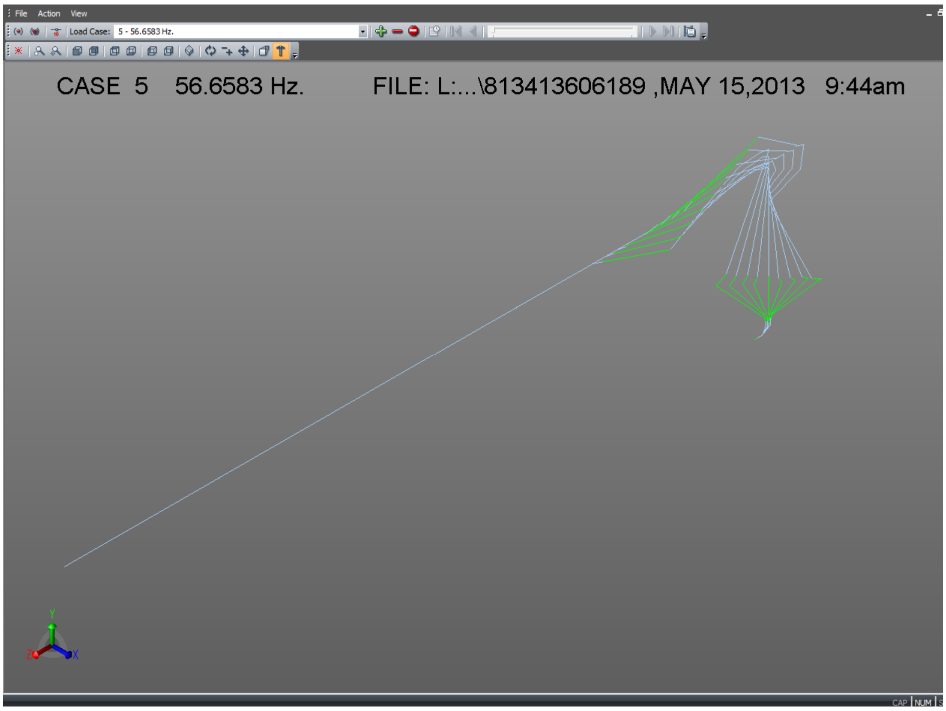


Figure 26: Natural frequencies and mode shapes at the mode No.1 (a natural frequency is 7.3021 Hz)



CASE 2 7.3021 Hz. FILE: L:...\813413606189 ,MAY 15,2013 9:43am

Figure 27: Natural frequencies and mode shapes at the mode No.2 (a natural frequency is 7.3021 Hz)



CASE 5 56.6583 Hz. FILE: L:...\813413606189 ,MAY 15,2013 9:44am

Figure 28: Natural frequencies and mode shapes at the mode No.5 (a natural frequency is 56.6583 Hz)

5.4 Conclusion

All relevant load cases have been considered and calculated. In general, the calculations show acceptable stresses in the system and all calculated stresses are below allowable limits. The vibration is acceptable according to the natural frequency of a satisfactory supported piping system is higher than 4 Hz. According to the existing system is lack of pipe support so in order to avoid vibration the pipe supports and clamps should be installed on one side of each bend and all heavy weight. The pipe support stiffness should be adequate to restrain the shaking forces in the piping to the desire amplitudes. According to the operating temperature on this line the pipe support guides with clearance are used as thermal expansion control devices. However they will not help to control piping vibration so the line stop should be added in the long run pipe routing.

6 SLURRY SYSTEM WITH PULSATION

6.1 System definition

This system comprises the installation of the Slurry system in Mud Handling system on EkoM lines XXX-374-AD10-3"-MH-0, XXX-375-AD10-3"-MH-0, XXX-376-AD10-3"-MH-0 and XXX-377-AD10-3"-MH-0 and new line XXX-377-AD10-3”-MH-0. The existing pipe spools will be replaced with new pipe spools of same piping specification with a minor routing change.

The existing and new line will be extended in order to avoid the system shutdown if one of the Slurry tanks is in maintenance as shown as the figures below:

EXISTING LAYOUT

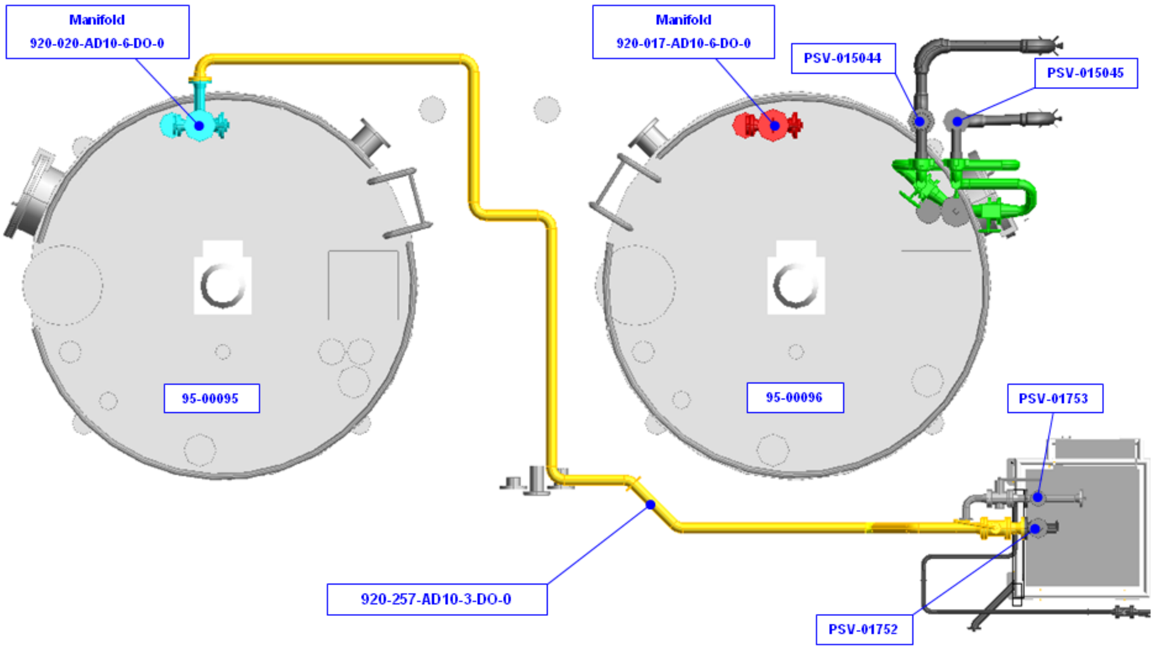


Figure 29: Existing layout (top view) of the Slurry system in Mud Handling system

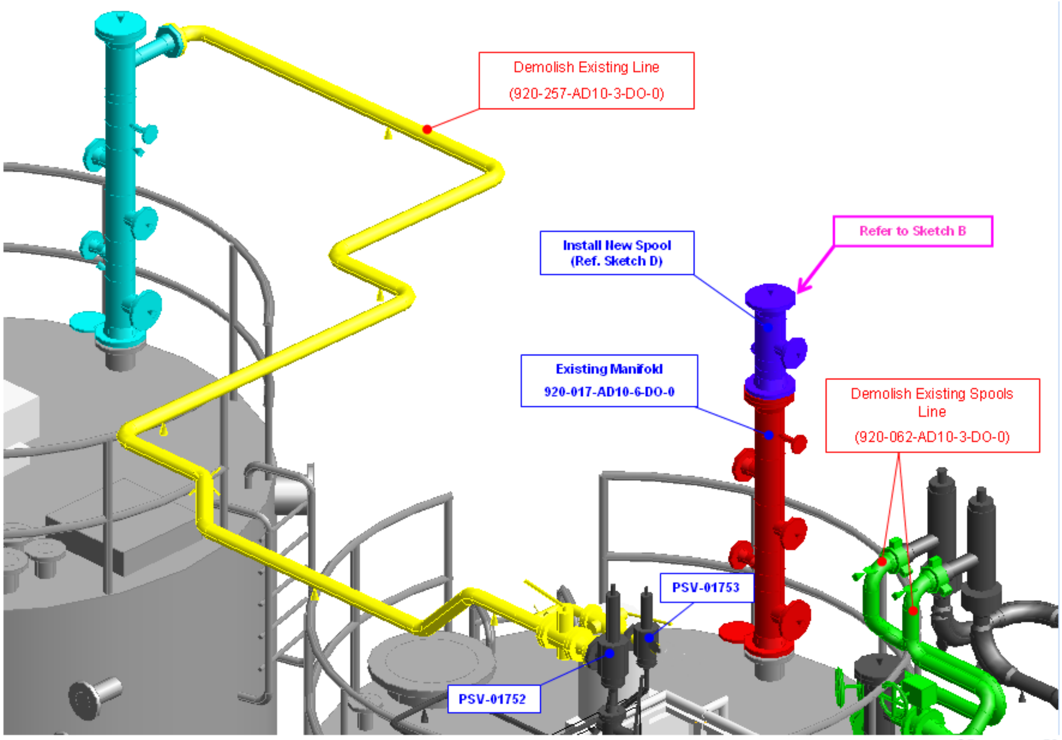


Figure 30: Existing layout (side view) of the Slurry system in Mud Handling system

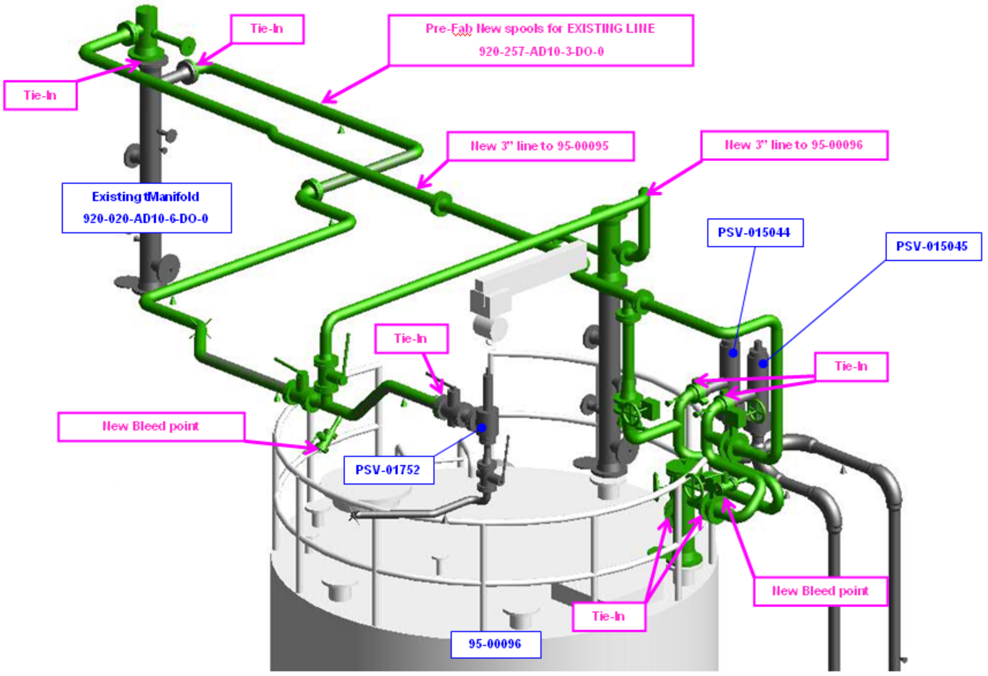


Figure 31: The overview the installation of the Slurry system in Mud Handling system

The calculations have been performed using TRIFLEX WINDOWS VERSION 3.2.2. pipe stress analysis software.

6.2 Design basis

6.2.1 Applicable codes and regulations

The piping shall be designed in compliance with ASME B31.3.

6.2.2 Material and material data

The piping class used are AD10 Super Duplex A790 UNS32760, AD20 Super Duplex A790 UNS31803 and KX01 Low Alloyed Steel A519 GR 4130N. The piping material used for carrying out the analysis in TRIFLEX WINDOWS VERSION 3.2.2 is ASME equivalent of A519 GR 4130N is API 5L X80 due to the fact that the standard A4130 is now superseded. The Carbon steel API 5L X80 has the same value as material under consideration even though the chemical composition of the material might be different. The properties of materials are following below.

Super Duplex A790 UNS32760

Mechanical properties:

SMYS (Specified Minimum Yield Strength) : 552 Mpa

SMTS (Specified Minimum Tensile Strength) : 752 Mpa

Physical properties:

Density : 8027 kg/m^3

Young’s modulus : 202 Gpa

Linear thermal expansion

From installation temp 4^0C to +130^0C : +2.11 mm/m (Triflex)

From installation temp 4^0C to -46^0C : -0.78 mm/m (Triflex)

Super Duplex A790 UNS31803

Mechanical properties:

SMYS (Specified Minimum Yield Strength) : 448 Mpa

SMTS (Specified Minimum Tensile Strength) : 620 Mpa

Physical properties:

Density : 8027 kg/m^3

Young’s modulus : 202 Gpa

Linear thermal expansion

From installation temp 4^0C to +120^0C : +1.94 mm/m (Triflex)

From installation temp 4^0C to -6^0C : -0.15 mm/m (Triflex)

Carbon Steel API 5L X80

Mechanical properties:

SMYS (Specified Minimum Yield Strength) : 552 Mpa

SMTS (Specified Minimum Tensile Strength) : 620 Mpa

Physical properties:

Density	:	7833 kg/m^3
Young's modulus	:	203 Gpa
Linear thermal expansion		
From installation temp 4^{0}C to +50^{0}C	:	+0.51mm/m (Triflex)
From installation temp 4^{0}C	:	0.00 mm/m (Triflex)

6.2.3 Allowable stresses

Allowable stress ASME B31.3	**A790 UNS32760**	**A790 UNS31803**	**API 5L X80**
Allowable stress cold	250 Mpa	207 Mpa	207 Mpa
Allowable stress hot	241 Mpa	203 Mpa	207 Mpa

6.2.4 Piping dimensions

NPS [in]	**OD** [mm]	**wt** [mm]	**Sch**	**Corrosion Allow. (mm)**	**Mill Tol. (%)**	**Spec.**
1	33.4	3.38	40S	0	-12.5	AD10
1-1/2	48.3	3.68	40S	0	-12.5	AD20
2	60.3	2.77	10S	0	-12.5	AD20
3	88.9	3.05	10S	0	-12.5	AD10
3	88.9	3.05	10S	0	-12.5	AD20
3	88.9	17.5	-	1.5	-12.5	KX01
6	168.3	3.40	10S	0	-12,5	AD10

6.2.5 Design parameters

Design temperatures and pressure are according to the process information. Ref. /5/

Line No.	**Max design temperature**	**Min design temperature**	**Installation temperature**	**Max design pressure**
XXX-374-AD10-3"-MH-0	**+ 130 °C**	**-46 °C**	**+ 4 °C**	**20 barg**
XXX -375-AD10-3"-MH-0	**+ 130 °C**	**-46 °C**	**+ 4 °C**	**20 barg**
XXX -377-AD10-3"-MH-0	**+ 130 °C**	**-46 °C**	**+ 4 °C**	**20 barg**

6.2.6 Weight of contents

The weight of the contents given in the process line lists are;

Line No.	**Weight of the contents**
XXX -374-AD10-3"-MH-0	1600 kg/m^3
XXX -375-AD10-3"-MH-0	1600 kg/m^3
XXX -377-AD10-3"-MH-0	1100 kg/m^3

6.2.7 Piping insulation

Insulation on the existing line

Line No.	**Insulation thickness**	**Material**
XXX -205-AD20-3-DO-4	30 mm	AS-Amosite Asbestos
XXX -256-AD20-2-DO-D	40 mm	AS-Amosite Asbestos

6.2.8 Blast considerations

NO Blast design for this system.

6.2.9 Wind

In pipe stress calculation for piping system on the Intermediate Desk Mezz, the wind has been applied on the complete system as an occasional load with 52.7 m/s wind speed.

6.2.10 Natural frequency calculation

The natural frequency of a satisfactory supported piping system should not be lower than 4 Hz.

6.2.11 Pulsation

The pressure pulsation force is calculated are taken from vendor information in existing stress report. Calculated force is used in a separate case and the supports loads are forwarded to Structural Department for verification. The pulsation load is 11 kN acting in axial direction towards the bend with higher pressure.

6.2.12 PSV reaction load

The PSV reaction load is not a load acting radial to the PSV, i.e. the reaction load of 65 kN is to be applied in the direction the valve will relief to (reference from the previous stress calculations from the existing report).

6.2.13 Boundary movements/conditions

The system effective boundary conditions are presented bellow.

Three way support at Node 10

Connect to equipment; Node 485, connect to Slurry holding Tank 95-00095-N15
Node 2090, connect to Slurry holding Tank 95-00096-N25

Node 2940, connect to Slurry holding Tank N-26/ 95-00096
Node 2720, connect to Drilling Pump Skid 67-05001-N32

6.3 Load case

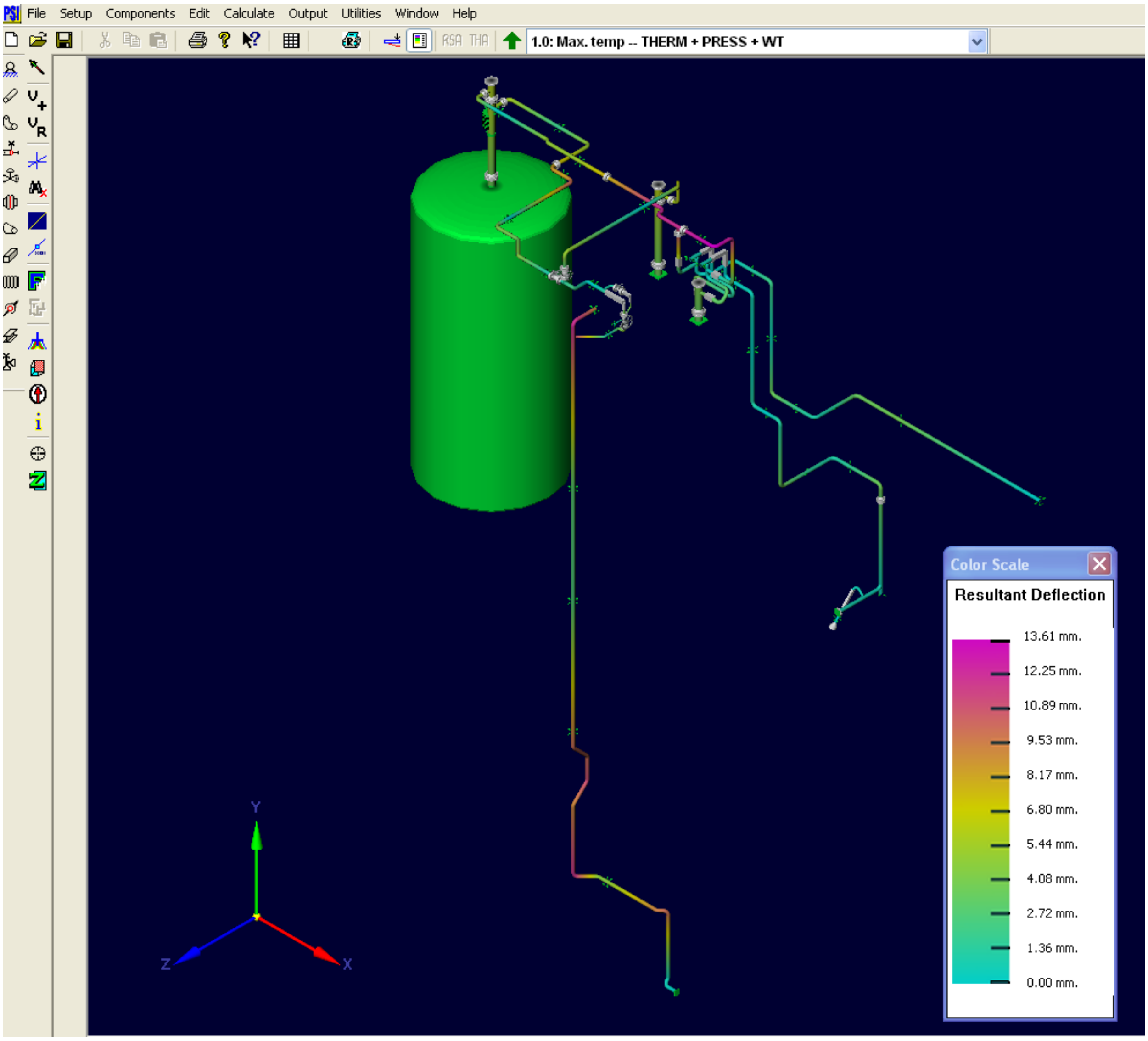
The piping system is analysed for the following load cases:

Load case	**Relevant loads**
Displacement stress range	Design temperature range Thermal expansion of connected equipment
Operation	Weight Design pressure Temperature range: Max design/installation temperature Min design/installation temperature Thermal expansion of connected equipment
Operation + wind load	Weight Design pressure Temperature range: Max design/installation temperature Min design/installation temperature Thermal expansion of connected equipment Wind loads

6.4 Model analysis based on ASME B31.3

6.4.1 TRIFLEX models

The TRIFLEX models are based on the geometry of the piping system as given in the stress Isometric show in Figure 33-39 and the TRIFLEX input listing can be found in the appendix D.:



1.0: Max. temp -- THERM + PRESS + WT

Figure 32: Pipe stress model of the Slurry system in Mud Handling system

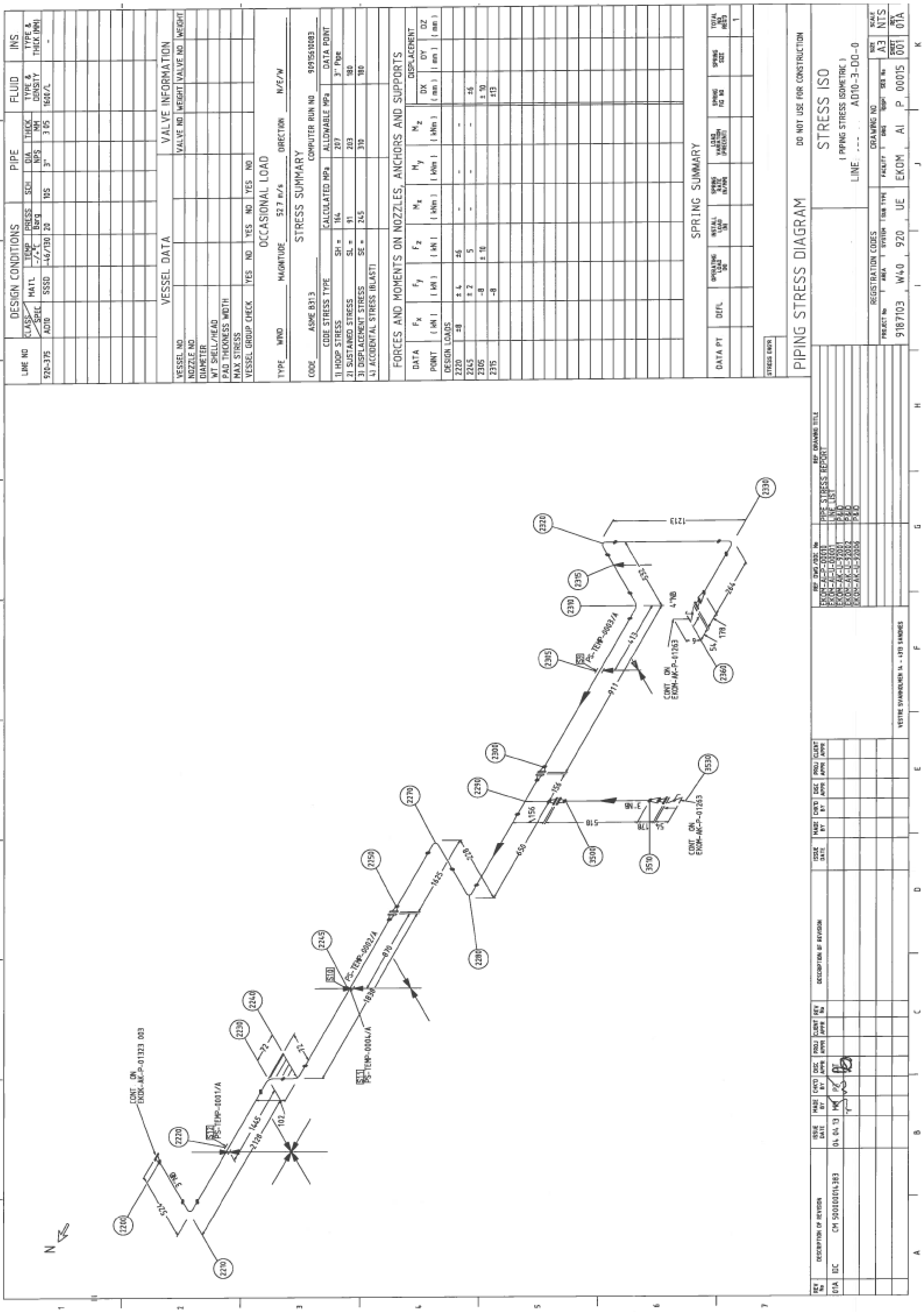


Figure 33: Pipe stress isometric drawing of the Slurry system in Mud Handling system

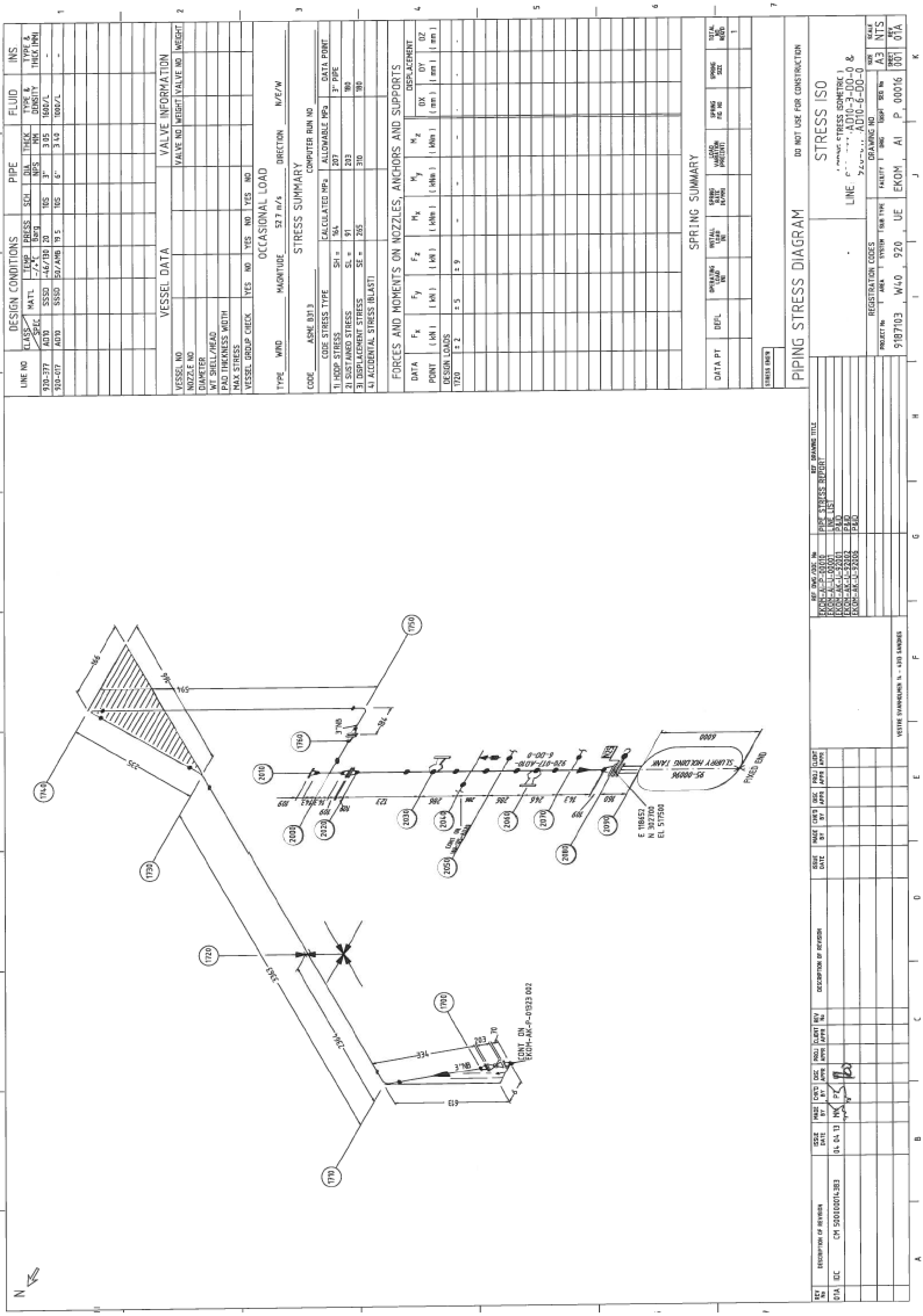


Figure 34: Pipe stress isometric drawing of the Slurry system in Mud Handling system sheet 1 of 6

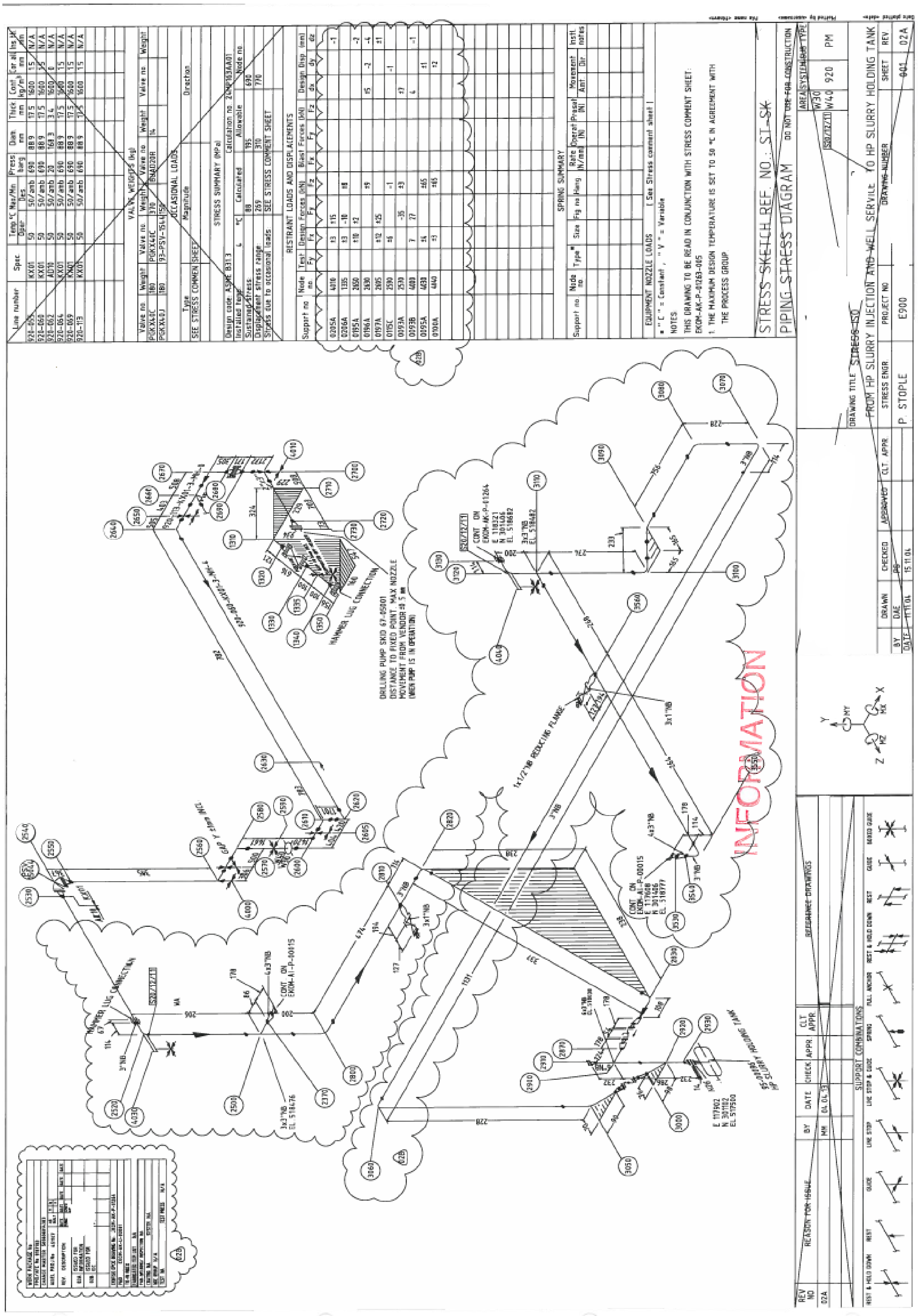


Figure 35: Pipe stress isometric drawing of the Slurry system in Mud Handling system sheet 2of 6

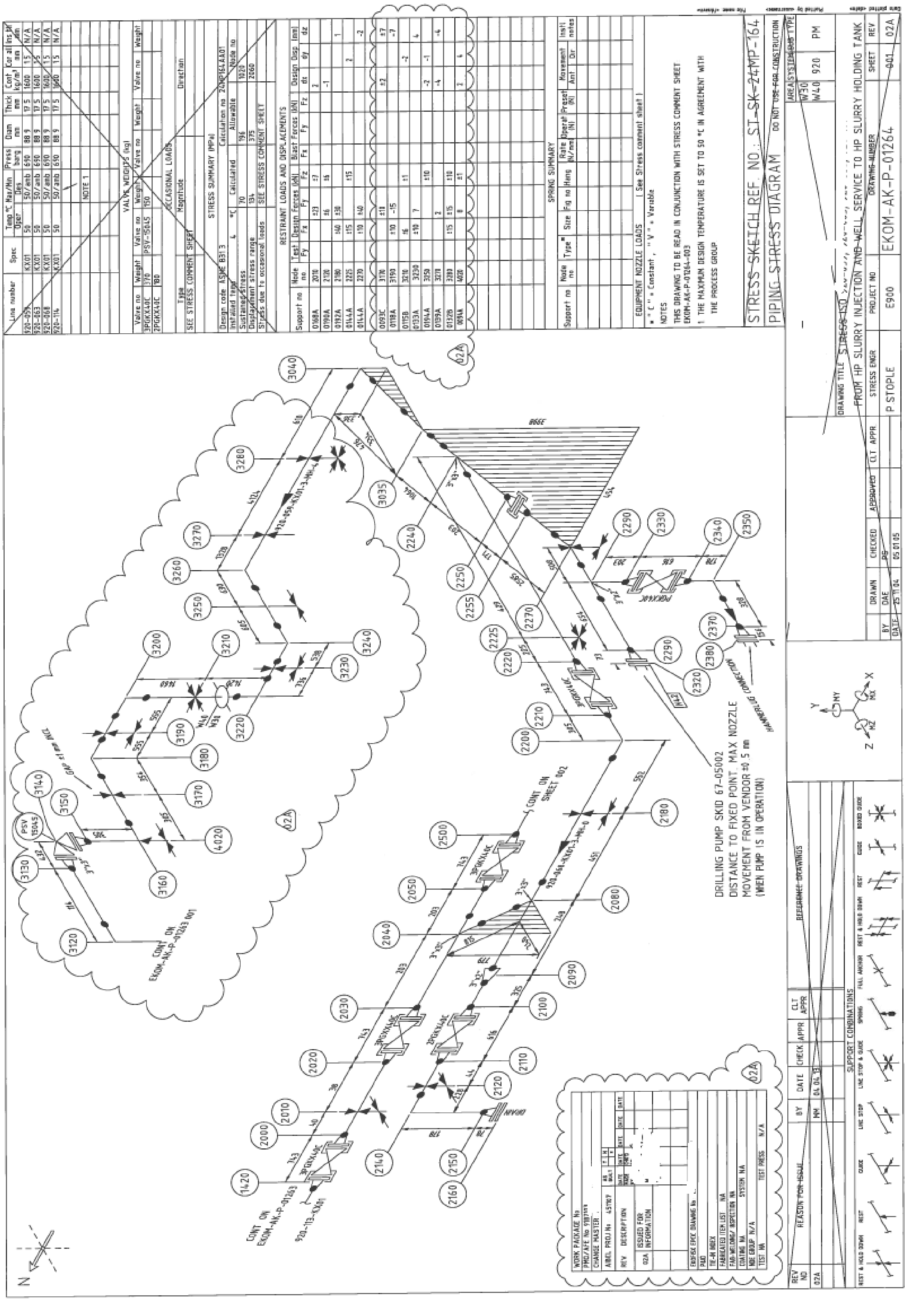


Figure 36: Pipe stress isometric drawing of the Slurry system in Mud Handling system sheet 3 of 6

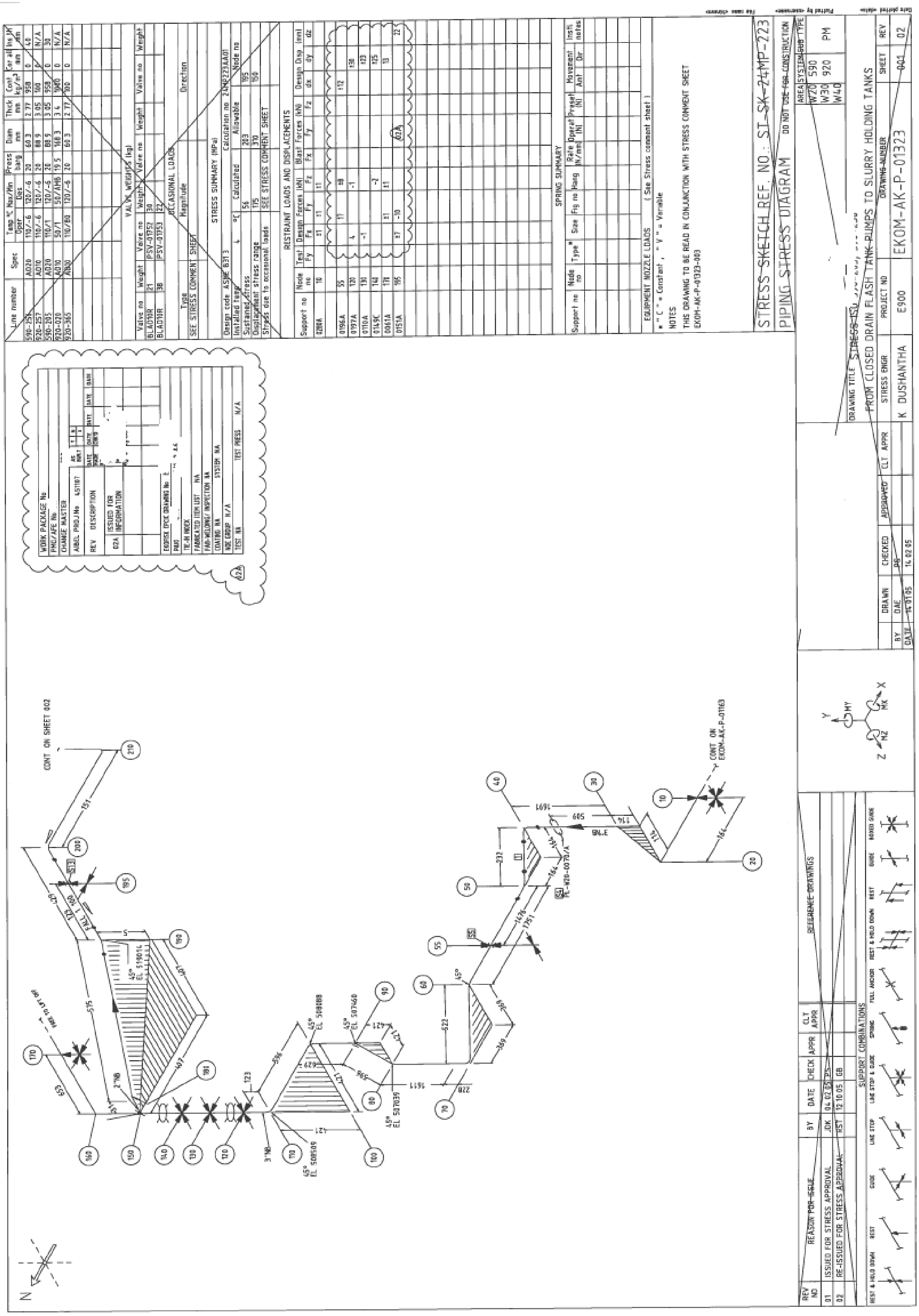


Figure 37: Pipe stress isometric drawing of the Slurry system in Mud Handling system sheet 4 of 6

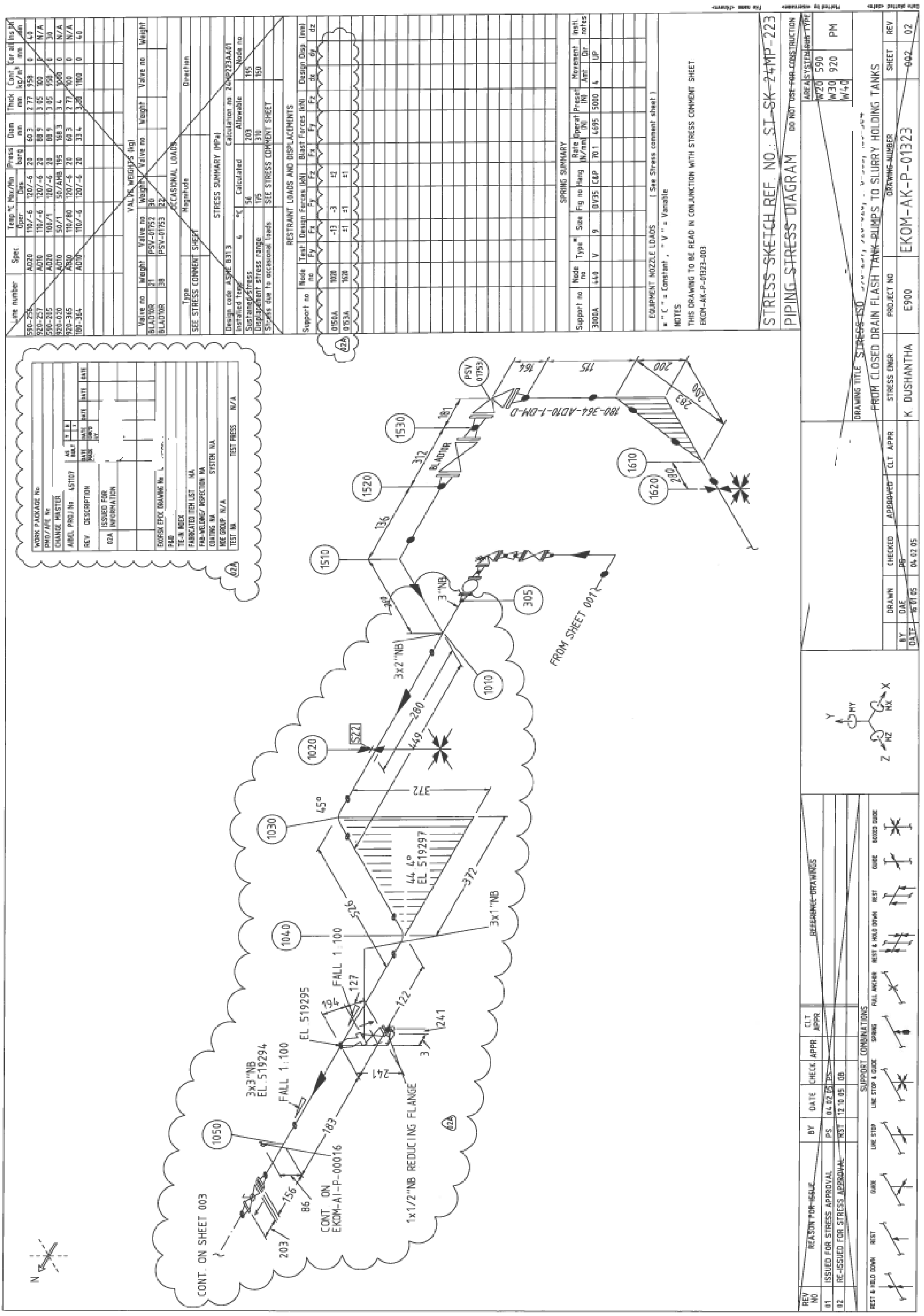


Figure 38: Pipe stress isometric drawing of the Slurry system in Mud Handling system sheet 5 of 6

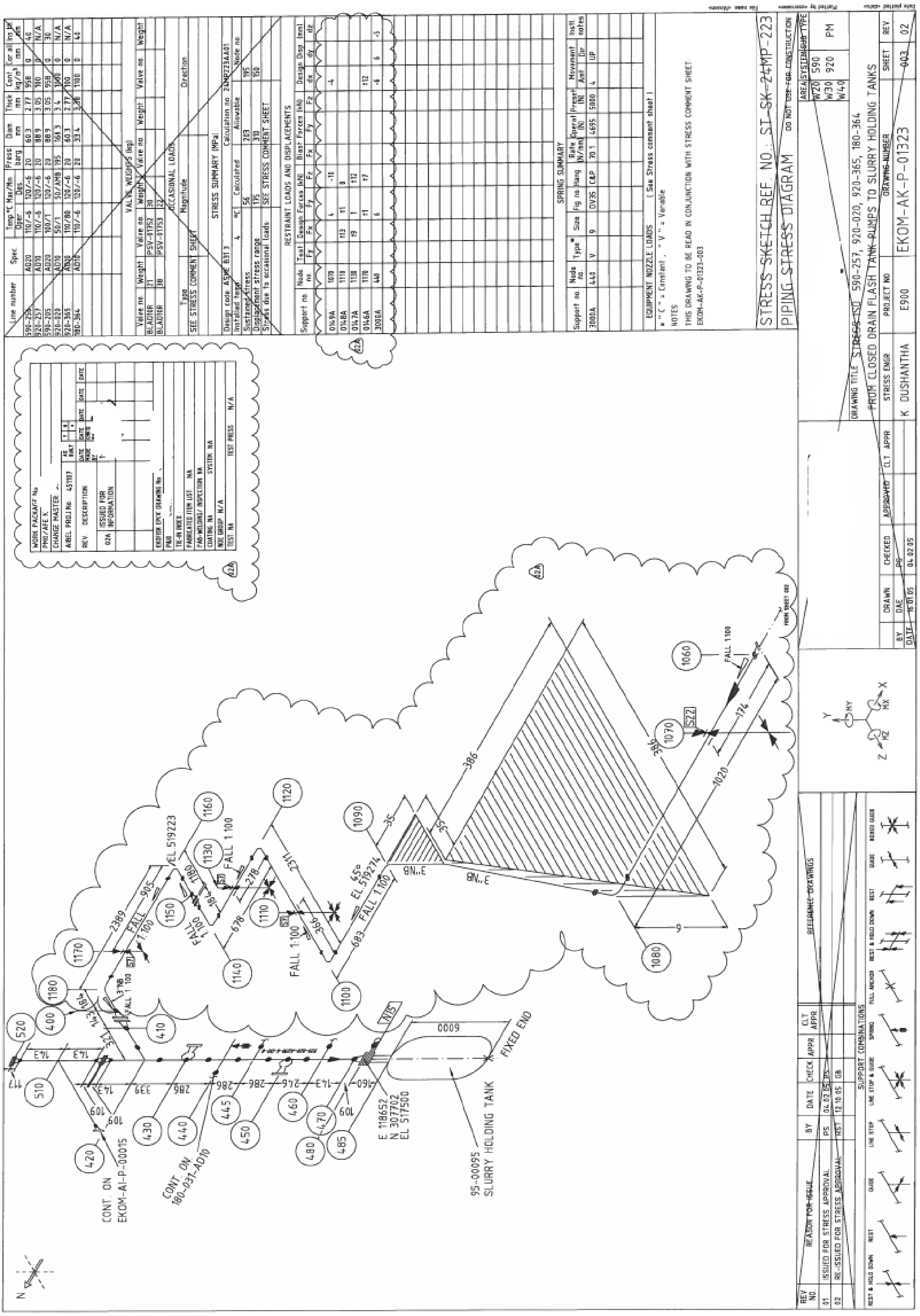


Figure 39: Pipe stress isometric drawing of the Slurry system in Mud Handling system sheet 6 of 6

6.4.2 Sustained, displacement and occasional stresses

TRIFLEX calculation 91871035901323 (COMBINED) according to ASME B31.3

Table 8. Sustained, Displacement and Occasional stresses.(ASME B31,3)

Check	**Stress [MPa]**	**Allow. [MPa]**	**Node**	**Utilisation %**	**Load case**
Hoop stress SH	164	207	3”pipe	79	OPERATE
Sustained stress SL	91	203	180	45	OPERATE
Displacement stress SE	265	310	180	86	OPERATE
Occasional stress SL_o	113	270	190	42	WIND-N

Table 7.1.1 Sustained, Displacement and Occasional stresses.(ASME B31,3)

Note :The reported stresses are the highest utilized.

6.4.3 Pipe support forces, displacements and functions

The following pipe support forces and displacements are the maximums for all load cases.

Table 9. Support forces, displacements and functions in normal operating cases.

Support Number	**Data Point**	**FX** (KN)	**FY** (KN)	**FZ** (KN)	**Dx** (mm)	**Dy** (mm)	**Dz** (mm)	**Support Functions**
0280A	10	±1	±1	±1				Anchor
0196A	55		6	1	±9			RS, HD, LG
0197A	120	±1		±1		-10		LG
0110A	130	±1		±1		±6		LG
0149C	140	±1		±1		±9		LG
0061A	170		±1	±1		+13		RS, LG, LS
0151A	195	±1	±4				±2	RS, HD, LG
0150A	1020	-10	±2	4				RS, HD, LG, LS
0149A	1070		5	-2	-2			RS, HD, LG
0148A	1110	9	±1	-6				RS, HD, LG, LS
0147A	1130	-3	1	9				RS, HD, LG, LS
0146A	1170		-1	-2	4			RS, HD, LG
3000A	440		7		-4	5	-2	SPRING
0153A	1620	±1	±1	±1				RS, HD, LG, LS
New support	1720	-1	-4	2				RS, HD, LG, LS
New support	2220	±2	±4	±2				RS, HD, LG, LS
New support	2245		2	±1	6			RS, HD, LG
New support	2305		+4	±1	13			RS, LG
New support	2315		+1		13			RS
0095A	2510	-2		±2		2		LG
0093A	2570		-25	±2	-1			RS, HD, LG
0115C	2590	4		±1		-1		LG
0197A	2605	-4	15				-1	RS, HD, LS

0196A	2630			1	3	-1		LS
0195A	2650	1	±2				-3	RS, HD, LS
0206A	1335	±3	±6	±3				RS, HD, LG, LS
0093C	3170		±2		1		-1	RS, HD
0118A	3190	1	-5				-4	RS, HD, LS
0115B	3210	2		±1		-1		LG
0133A	3230	-2	5				3	RS, HD, LS
0194A	3250			1	2	-1		LS
0139A	3270		3		-5		-5	RS, HD
0132B	3280	±15	±15	±10				RS, HD, LG, LS
0093B	4000	3	15				1	RS, HD, LS
0205A	4010	±2	7				-1	RS, HD, LG
0094A	4020		5	1	2			RS, HD, LS

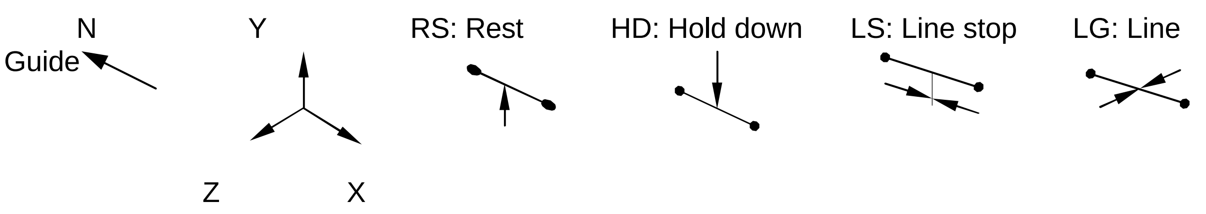
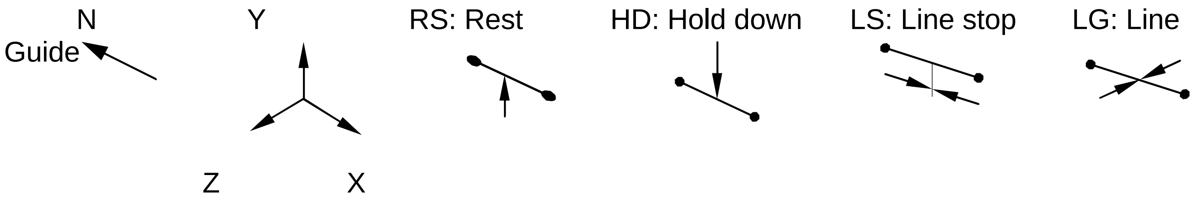


Table 10. Support forces and functions in Pulsation case

Support Number	Data Point	FX (KN)	FY (KN)	FZ (KN)	Dx (mm)	Dy (mm)	Dz (mm)	Support Functions
0280A	10	±1	±1	±1				Anchor
0196A	55		17	±8	±12			RS, HD, LG
0197A	120	4		-1		±30		LG
0110A	130	-1				±23		LG
0149C	140			-2		±25		LG
0061A	170		±1	±1		13		RS, LG, LS
0151A	195	±7	-10				22	RS, HD, LG
0150A	1020	-13	-3	±2				RS, HD, LG, LS
0149A	1070		4	-10	-4			RS, HD, LG
0148A	1110	±13	±1	8				RS, HD, LG, LS
0147A	1130	±9	1	±12				RS, HD, LG, LS
0146A	1170		±1	±7	±12			RS, HD, LG
3000A	440		6		-6	6	-5	SPRING
0153A	1620	±1	±1	±1				RS, HD, LG, LS
New support	1720	±2	±5	±9				RS, HD, LG, LS
New support	2220	-8	±4	-6				RS, HD, LG, LS
New support	2245		±2	5	6			RS, HD, LG
New support	2305		+8	±10	±10			RS, LG
New support	2315		+8		13			RS
0095A	2510	±10		±10		±4	1	LG
0093A	2570		-35	±3	±7			RS, HD, LG
0115C	2590	±6		-1		-1		LG
0197A	2605	±12	±25				±1	RS, HD, LS
0196A	2630			±9	±5	-2	-4	LS
0195A	2650	±10	±2				-2	RS, HD, LS

0206A	1335	±3	-10	±8				RS, HD, LG, LS
0093C	3170		±10		±2		±7	RS, HD
0118A	3190	±10	-15				-7	RS, HD, LS
0115B	3210	±6		±1		-2		LG
0133A	3230	±10	7				4	RS, HD, LS
0194A	3250			±10	-2	-1		LS
0139A	3270		2		-4		-4	RS, HD
0132B	3280	±15	±15	±10				RS, HD, LG, LS
0093B	4000	7	27		4		1	RS, HD, LS
0205A	4010	±3	±15				-1	RS, HD, LG
0094A	4020		8	±1	2	4		RS, HD, LS



6.4.4 Equipment Nozzle loads

Table 11. *EQUIPMENT NO. 95-00095 and 95-00096 (Slurry holding Tank)*
Nozzle no.N-15/ 95-00095 (Node no. 485), Nozzle no.N-25/ 95-00096 (Node no. 2090) and Nozzle no.N-26/ 95-00096 (Node no. 2090).

Case	**Node**	**Forces (N)**				**Moment (Nm)**				**Displacement (mm)**		
		F_x	**F_y**	**F_z**	**F**	**M_x**	**M_y**	**M_z**	**M**	**D_x**	**D_y**	**D_z**
Max. from combined case	**485**	-1875	3010	-313	**3560**	595	531	2411	**2539**	-0.13	3.61	-0.84
	2090	-568	-2980	-764	**3128**	-1546	316	458	**1643**	-0.13	3.61	-0.84
	2940	720	-4116	118	**4180**	-617	-248	-1340	**1496**	0	3.40	0
Allowable		**3882**	**3882**	**3882**	**6724**	**3750**	**3750**	**3750**	**6495**			

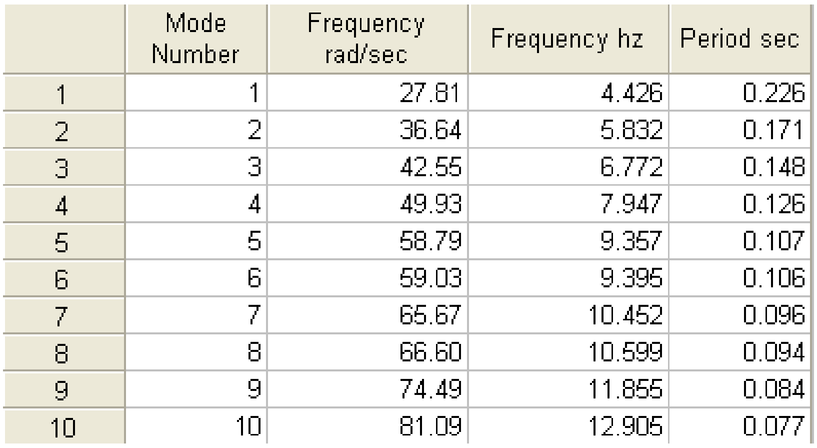
Table 12. *EQUIPMENT NO. 67-05001 (Drilling Pump Skid)*
Nozzle no.N-32/ 67-05001 (Node no. 2720)

Case	**Node**	**Forces (N)**				**Moment (Nm)**				**Displacement (mm)**		
		F_x	**F_y**	**F_z**	**F**	**M_x**	**M_y**	**M_z**	**M**	**D_x**	**D_y**	**D_z**
Max. from combined case	**2720**	2014	534	-1418	**2520**	243	-1625	-219	**1658**	±1	0	0
Allowable		**10600**	**10600**	**10600**	**18360**	**12400**	**12400**	**12400**	**21477**			

All of the equipment nozzle loads are in existing location. The nozzle load and maximum component values from the various load cases and the allowable loads are taken from vendor information in existing stress report. All pipe loadings acting on equipment nozzle are within the nozzle load allowable.

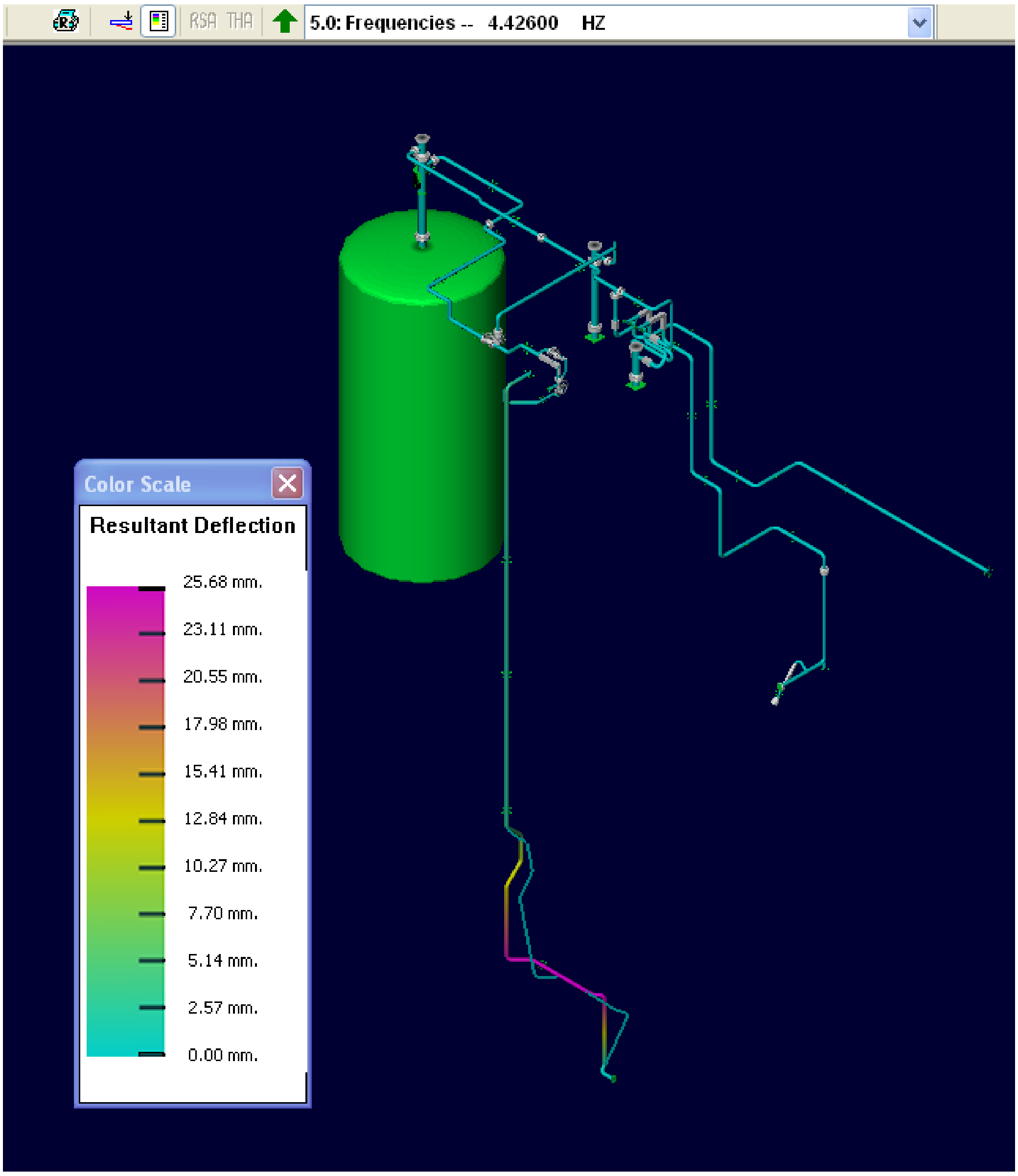
7.4 Natural Frequencies

Table 13. Natural frequency



	Mode Number	Frequency rad/sec	Frequency hz	Period sec
1	1	27.81	4.426	0.226
2	2	36.64	5.832	0.171
3	3	42.55	6.772	0.148
4	4	49.93	7.947	0.126
5	5	58.79	9.357	0.107
6	6	59.03	9.395	0.106
7	7	65.67	10.452	0.096
8	8	66.60	10.599	0.094
9	9	74.49	11.855	0.084
10	10	81.09	12.905	0.077

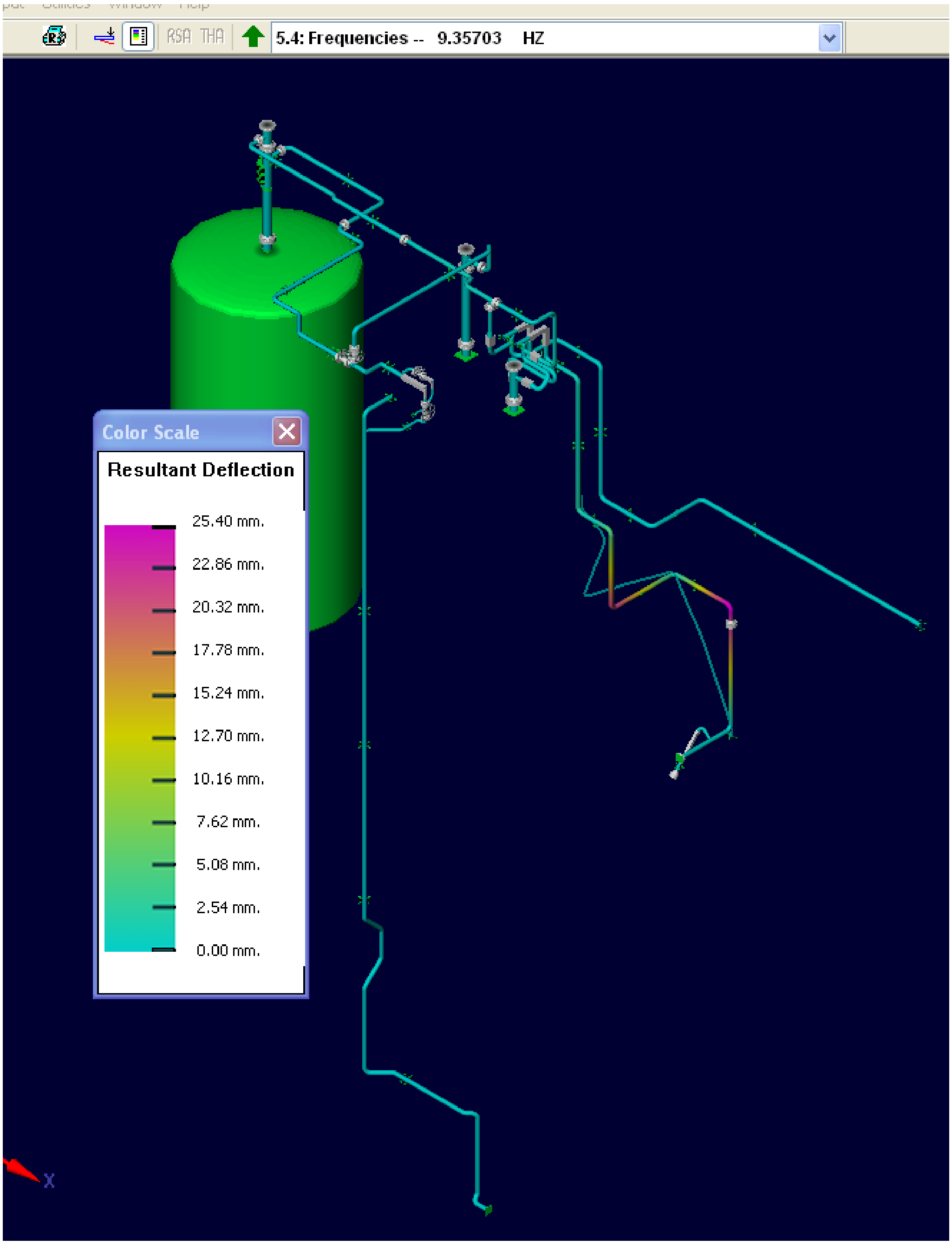
The natural frequencies are more than 4 Hz which are considered as acceptable design.



5.0: Frequencies -- 4.42600 HZ

Resultant Deflection

Figure 40: Natural frequencies and mode shapes at the first mode (a natural frequency is 4.42600 Hz)



5.4: Frequencies -- 9.35703 HZ

Figure 41: Natural frequencies and mode shapes at the mode No.5 (a natural frequency is 9.35703 Hz)

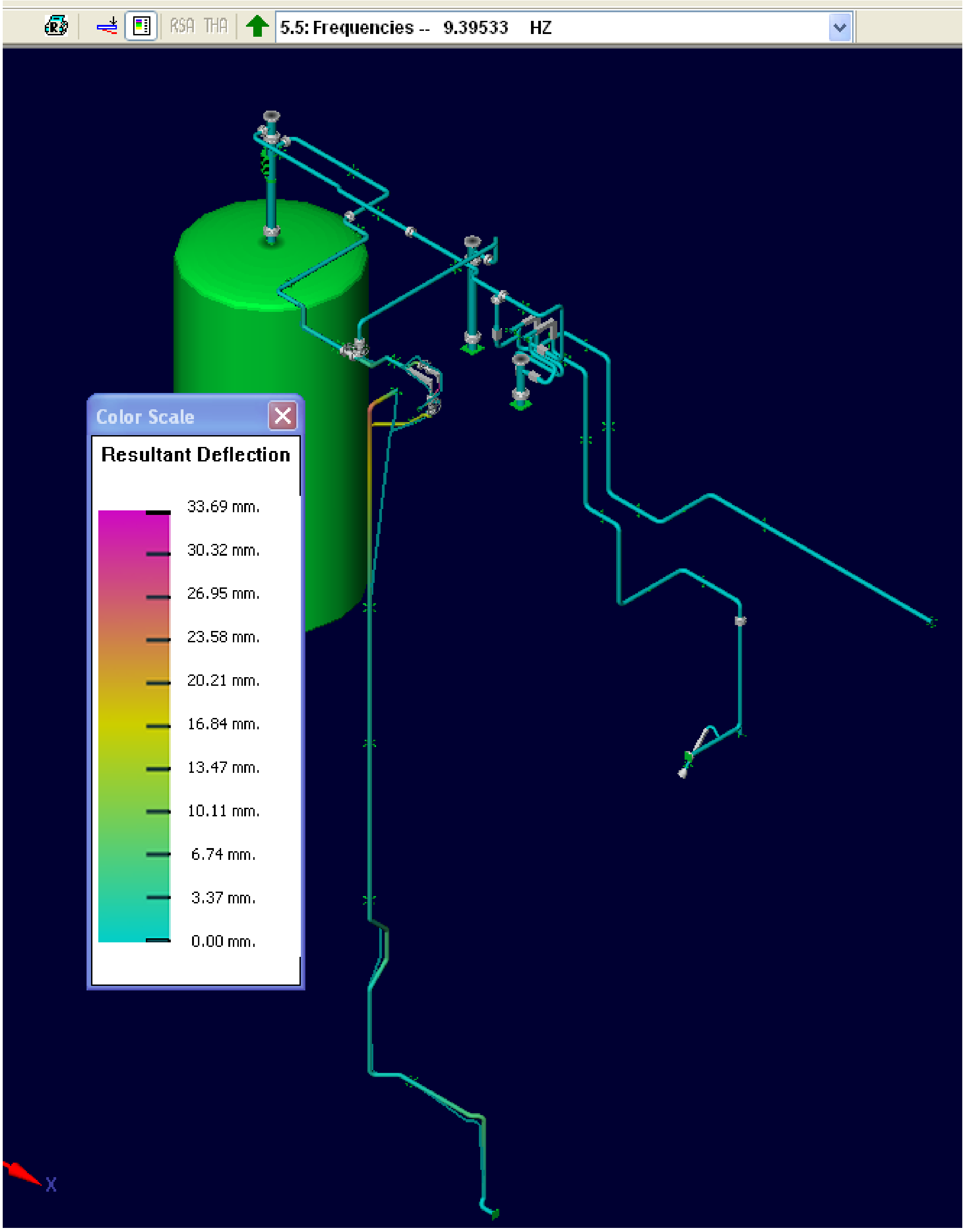


Figure 42: Natural frequencies and mode shapes at the mode No.6 (a natural frequency is 9.39533 Hz)

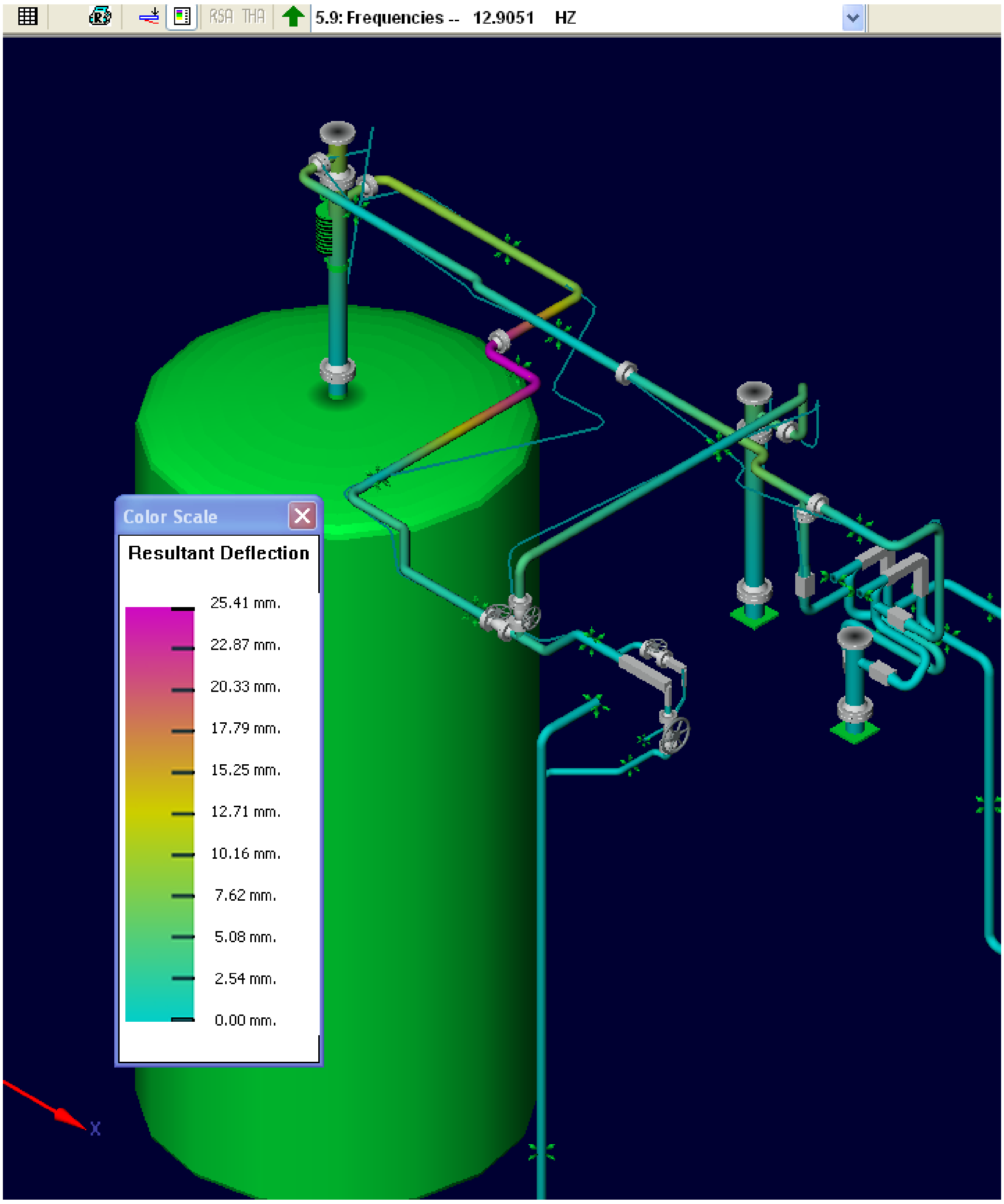


Figure 43: Natural frequencies and mode shapes at the mode No.10 (a natural frequency is 12.9051 Hz)

6.5 Conclusion

When a pulsation resonance is found, acoustic change to the piping system can be the most effective way to reduce the amplitude of the pulsations. Probably the most effective element that can be conveniently used in existing systems is an orifice plate as an acoustical resistance element by located at a pressure pulsation node 4030 and 4040 (Wachel, et al., 1990). In this case all relevant load cases have been considered and calculated. In general, the calculations show acceptable stresses in the system and all calculated stresses are below allowable limits. The vibration is acceptable according to the natural frequency of a satisfactory supported piping system is higher than 4 Hz. The effective to avoid for the new line is to add pipe restraints such as support or clamps to shorten the vibration span. Pipe supports and clamps should be installed on one side of each bend and all heavy weight. The pipe support stiffness should be adequate to restrain the shaking forces in the piping to the desire amplitudes. Pipe support guides with clearance are used as thermal expansion control devices but they will not help to control piping vibration. Thus the line stop should be added in the long run pipe routing. In this systems also have pressure safety valves (PSV) or pressure relief valves (PRV) so the wall thickness of the piping should be one-haft inch or grater if there is a possibility of sonic flow downstream of the valve. In this case we considered used elbow SCH160 (thickness 11.1252 mm) with the trunnion pipe support which shown in figure 44. The trunnion stress calculation is in appendix F.

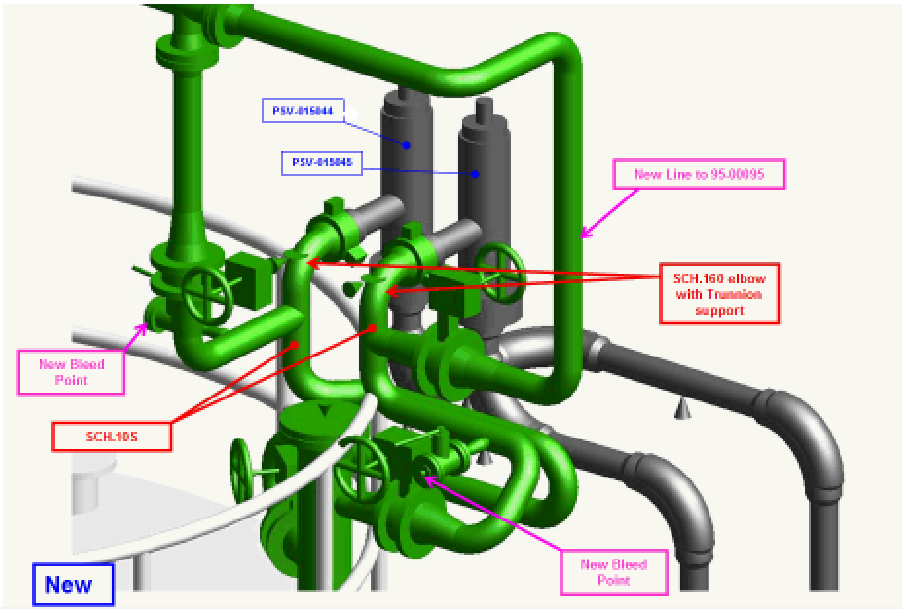


Figure 44: Pressure safety valves (PSV) and trunnion supports.

7 CONCLUSION

In order to avoid the fatigue in a piping system, we have to consider the lowest natural frequencies of the system which should be above 4 Hz for mitigating fatigue induced failures by low frequencies of vibrations. This can be done by performing a modal analysis, if the vibration levels are judges to be excessive the pipe support structure, piping configuration, pipe span length have to be modified to make the system acceptable. The most effective way to solve a vibration problem is to add pipe restrains such at piers, supports or clamps to shorten the vibration span which also used in the case study of a temporary emergency Generator Exhaust to open end of and the Slurry system with a pulsation. Some general guidelines that can be used for reduce the vibration are outline below (Wachel, et al., 1990).

- Pipe supports and clamps should be installed on one side of each bend, at all heavy weights, and at all piping discontinuities.
- The pipe support and clamps should be adequate to restrain the shaking forces in the piping to the desired amplitudes and should be greater than twice the basic span stiffness in order to effectively enforce and node at the support location.
- Vents, drains, bypass, and instrument piping should be braced to the main pipe to eliminate relative vibrations between the small-bore piping and the main pipe.
- Restrains, supports, or gussets should not be directly welded to the pressure vessels or the piping if only they are subjected to the appropriate heat treatment. Then we need to add a saddle-type clamp around the pipe and the braces to the clamp.
- Pipe guide with clearance ate used as thermal expansion control devices but are ineffective in controlling piping vibrations. Thus in order to reduce vibration, the piping clamps should have contact with the pipe over 180 degree of the circumference (line-stop).
- The piping span natural frequency should not ne coincident with the excitation frequencies.
- In piping system with high vibration, the vibration can be reduced by adding constrained-layer damping.
- In systems with pressure reducing valves, the wall thickness of the piping should be one-haft inch or grater if there is a possibility of sonic flow downstream of the valve. Full saddle reinforcement tees of welding tees should be used downstream of sonically chocked valves of where there is a possibility of sonic flow occurring at the branch pipe intersection.

However, sometimes it can be challenging to achieve this requirement, especially for the piping systems that has large expansion loops. As in the analysed example for bridge piping between two offshore platforms, the lowest natural frequency calculated is 1.2 Hz and this is due to the large expansion loop that used to accommodate the high relative displacements of the platforms and not able to have enough guides for the piping expansion loop so it is hard to have a higher natural frequency for this system. Thus we need to do extensive fatigue analysis by using PD5500 to estimate the service life time and if the fatigue life estimation is satisfied compared to the designed life time, this system can be acceptable. However this approach should not be used in the industrial fatigue analyses unless otherwise have good understandings about the analytical expression and the assumptions. Together with the coordination with the other project disciplines to ensure the piping and related components will be delivered to the site and built according to the codes and standards, technical specifications, construction schedule, and budget. The ability of the organization should be balances among four competing priorities are maximum productivity, low cost, smart safety and continuous development which mention in section 3 above.

8 REFERENCES

- Antaki, G. A. (2003). *Piping and Pipeline Engineering: Design, Construction, Maintenance, Integrity and Repair.* Aiken, South Carolina: Marcel Dekker, Inc.
- ASME B31.3. (2012). *Process Piping, American Society of Mechanical Engineers.* New York: N.Y.
- *ConocoPhillips Company*. (u.d.). Hentet fra ConocoPhillips Company Web site: http://www.conocophillips.no/EN/Norwegian%20shelf/Ekofisk/EkoEko/Pages/index.aspx
- DNV-RP-D101. (2008). *STRUCTURAL ANALYSIS OF PIPING SYSTEMS.* Norway: DET NORSKE VERITAS (DNV).
- J.C. Wachel, S.J. Morton and K.E. Atkins. (1990). *Piping vibration analysis.* Texas: Texas A&M University.
- Nayyar, M. L. (2000). *PIPING HANDBOOK 7th Ed.* New York: McGraw-Hill.
- NORSOK L-002. (2009). *Piping system layout, design and structural analysis, Edition 3.* Lysaker: NORSOK .
- NORSOK R-001. (1997). Mechanical equipment*, Edition 3.* Lysaker: NORSOK
- Paul R. Smith and Thomas J. Van Laan. (1987). *Piping and Pipe Support Systems: Desing and Engineering.* New York: McGraw-Hill .
- PD 5500 . (2003). *Specification for unfired fusion welded pressure vessels.* British Standards Institution on ERC Specs and Standards.
- Simons, R. (2000). *Performance measurement and control systems for implementing strategy: text & cases.* Upper Saddle River, NJ.: Prentice Hall.

APPENDIX A: TRIFLEX INPUT ECHO FOR BRIDGE PIPING FATIGUE

```
TITLPMO 8881865 SD13 Brennbar atm kald vent EkoM
EMP. NO.: , ENGR. INIT:
PLANT LOC.: P30, PLANT NAME: EKOM
Problem: 888186501421-Oper, Max. temp, +X wave

OPTN,SAVEBIN,NSD,T+P+W,B313,IN=IU1,OUT=IU1,EQ,
 MAXIT=20,PSTIFF,FRICP=20,WTDEN=999.552,PIW
150A,WTON,BUOYOFF,MOVX=384,NOD=500,THK=5.5372,CA=0,CONWT=1.73,EMOD=0.2020,
 EXP=2.11,PDEN=8027.17,PRESS=20
C
160B,X=-1899.000000,BRR=1.5,NOD=500,THK=5.5372,CONWT=1.72997,EMOD=0.2020,
 EXP=2.11,PDEN=8027.17,PRESS=20
170B,X=-762.000000,Z=762.000000,BRR=1.5
180R,X=-2419.000000,REST=Y,Z
190R,X=-11561.000000,REST=Y,Z
200R,X=-8950.000000,REST=Y,Z
210R,X=-7980.000000,REST=Y,Z
220R,X=-8021.000000,REST=Y,Z
230R,X=-8000.000000,REST=Y,Z
240R,X=-8000.000000,REST=Y,Z
245F,X=-2000.000000,FRATE=150,FLNGS=2,FLGWT=1378.95,FLGLN=144.462,FLGIF=1,
 FLTYP=WNK
250B,X=-954.000000,BRR=1.5
255F,Y=1100.000000,FRATE=150,FLNGS=2,FLGWT=1378.95,FLGLN=144.462,FLGIF=1,
 FLTYP=WNK
260R,Y=982.000000,REST=Z
270R,Y=5000.000000,REST=Z
280F,Y=904.000000,FRATE=150,FLNGS=2,FLGWT=1378.95,FLGLN=144.462,FLGIF=1,
 FLTYP=WNK
290B,Y=907.000000,BRR=1.5
300B,Z=1524.000000,BRR=1.5
310R,Y=-762.000000
X
B313,FROM=150,TO=150,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=160,TO=160,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=170,TO=170,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=180,TO=180,SC=250.00,SH=241.00,SE=241.00
```

```
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=190,TO=190,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=200,TO=200,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=210,TO=210,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=220,TO=220,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=230,TO=230,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=240,TO=240,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=245,TO=245,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=250,TO=250,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=255,TO=255,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=260,TO=260,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=270,TO=270,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=280,TO=280,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=290,TO=290,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=300,TO=300,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=310,TO=310,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
X
END
```

APPENDIX B: MAXIMUM STRESS RANGES FOR FATIGUE LIFE ANALYSIS PD5500 AND CAESAR II INPUT LISTING – BRIDGE PIPING FATIGUE MODEL

CAESAR II 2011 R1 Ver.5.31.00.0000, (Build 120525)   Date: MAY 21, 2013   Time: 15:44
Job: H:\1THESES\CAESAR II\8881865
Licensed To: Seat   -- ID #332

```
Piping Code: B31.3      = B31.3 -2008, December 31, 2008
```

STRESS RANGE SA1

```
CODE STRESS CHECK PASSED      : LOADCASE 16 (EXP) L16=L4-L13

Highest Stresses: (KPa       ) LOADCASE 16 (EXP) L16=L4-L13
CodeStress Ratio (%):       24.7  @Node    140
Code Stress:            91992.6  Allowable:   373015.6
Axial Stress:             304.5  @Node    140
Bending Stress:         91992.6  @Node    140
Torsion Stress:             0.0  @Node    249
Hoop Stress:                0.0  @Node    120
3D Max Intensity:       92297.1  @Node    140
```

STRESS RANGE SA2

```
 CODE STRESS CHECK PASSED      : LOADCASE 25 (EXP) L25=L17+L18

Highest Stresses: (KPa       ) LOADCASE 25 (EXP) L25=L17+L18
CodeStress Ratio (%):       47.4  @Node    140
Code Stress:           176625.8  Allowable:   373015.6
Axial Stress:             584.7  @Node    140
Bending Stress:        176625.8  @Node    140
Torsion Stress:             0.0  @Node    249
Hoop Stress:                0.0  @Node    120
3D Max Intensity:      177210.5  @Node    140
```

STRESS RANGE SA3

```
 CODE STRESS CHECK PASSED      : LOADCASE 26 (EXP) L26=L19+L20

Highest Stresses: (KPa       ) LOADCASE 26 (EXP) L26=L19+L20
CodeStress Ratio (%):       43.2  @Node    140
Code Stress:           160987.0  Allowable:   373015.6
Axial Stress:             532.9  @Node    140
Bending Stress:        160987.0  @Node    140
Torsion Stress:             0.0  @Node    249
Hoop Stress:                0.0  @Node    120
3D Max Intensity:      161520.0  @Node    140
```

STRESS RANGE SA4

```
 CODE STRESS CHECK PASSED      : LOADCASE 27 (EXP) L27=L21+L22

Highest Stresses: (KPa       ) LOADCASE 27 (EXP) L27=L21+L22
CodeStress Ratio (%):       40.0  @Node    140
Code Stress:           149028.0  Allowable:   373015.6
Axial Stress:             493.3  @Node    140
Bending Stress:        149028.0  @Node    140
Torsion Stress:             0.0  @Node    249
Hoop Stress:                0.0  @Node    120
3D Max Intensity:      149521.3  @Node    140
```

STRESS RANGE SA5

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

Highest Stresses: (KPa       ) LOADCASE 1 (HYD) WW+HP
CodeStress Ratio (%):        0.0  @Node    240
Code Stress:           163407.3  Allowable:        0.0
Axial Stress:           66692.6  @Node    289
Bending Stress:         96841.7  @Node    240
```

```
Torsion Stress:          1109.7  @Node    140
Hoop Stress:           134614.7  @Node    120
3D Max Intensity:      164296.7  @Node    240

STRESS RANGE SA6
 CODE STRESS CHECK PASSED      : LOADCASE 28 (EXP) L28=L23+L24

Highest Stresses: (KPa       ) LOADCASE 28 (EXP) L28=L23+L24
CodeStress Ratio (%):      37.0  @Node    140
Code Stress:           137988.9  Allowable:   373015.6
Axial Stress:             456.8  @Node    140
Bending Stress:        137988.9  @Node    140
Torsion Stress:             0.0  @Node    249
Hoop Stress:                0.0  @Node    120
3D Max Intensity:      138445.7  @Node    140

STRESS RANGE SA14
CODE STRESS CHECK PASSED      : LOADCASE 14 (EXP) L14=L2-L13

Highest Stresses: (KPa       ) LOADCASE 14 (EXP) L14=L2-L13
CodeStress Ratio (%):      25.2  @Node    140
Code Stress:            94036.6  Allowable:   373015.6
Axial Stress:             311.3  @Node    140
Bending Stress:         94036.6  @Node    140
Torsion Stress:             0.1  @Node    249
Hoop Stress:                0.0  @Node    120
3D Max Intensity:       94347.9  @Node    140


CAESAR II 2011 R1  Ver.5.31.00.0000,  (Build 120525)   Date: MAY 21, 2013   Time: 16:6
Job: H:\1THESES\CAESAR II\8881865 D278 TO 209
Licensed To: Seat   --  ID #332

Piping Code: B31.3      = B31.3 -2008, December 31, 2008


STRESS RANGE SA7
 CODE STRESS CHECK PASSED      : LOADCASE 23 (EXP) L23=L15+L16

Highest Stresses: (KPa       ) LOADCASE 23 (EXP) L23=L15+L16
CodeStress Ratio (%):      34.3  @Node    140
Code Stress:           127869.7  Allowable:   373015.6
Axial Stress:             423.3  @Node    140
Bending Stress:        127869.7  @Node    140
Torsion Stress:             0.0  @Node    249
Hoop Stress:                0.0  @Node    120
3D Max Intensity:      128293.0  @Node    140

STRESS RANGE SA8
 CODE STRESS CHECK PASSED      : LOADCASE 24 (EXP) L24=L17+L18

Highest Stresses: (KPa       ) LOADCASE 24 (EXP) L24=L17+L18
CodeStress Ratio (%):      31.2  @Node    140
Code Stress:           116370.6  Allowable:   373015.6
Axial Stress:             385.2  @Node    140
Bending Stress:        116370.6  @Node    140
Torsion Stress:             0.0  @Node    249
Hoop Stress:                0.0  @Node    120
3D Max Intensity:      116755.9  @Node    140

STRESS RANGE SA9
 CODE STRESS CHECK PASSED      : LOADCASE 25 (EXP) L25=L19+L20

Highest Stresses: (KPa       ) LOADCASE 25 (EXP) L25=L19+L20
CodeStress Ratio (%):      28.5  @Node    140
```

```
Code Stress:          106251.4  Allowable:   373015.6
Axial Stress:           351.7  @Node    140
Bending Stress:       106251.4  @Node    140
Torsion Stress:           0.0  @Node    249
Hoop Stress:              0.0  @Node    120
3D Max Intensity:     106603.2  @Node    140
```

STRESS RANGE SA10

```
 CODE STRESS CHECK PASSED      : LOADCASE 26 (EXP) L26=L21+L22

Highest Stresses: (KPa       ) LOADCASE 26 (EXP) L26=L21+L22
CodeStress Ratio (%):       25.8  @Node    140
Code Stress:            96132.3  Allowable:   373015.6
Axial Stress:           318.2  @Node    140
Bending Stress:         96132.3  @Node    140
Torsion Stress:           0.0  @Node    249
Hoop Stress:              0.0  @Node    120
3D Max Intensity:       96450.5  @Node    140
```

CAESAR II 2011 R1 Ver.5.31.00.0000, (Build 120525)   Date: MAY 21, 2013   Time: 16:14
Job: H:\1THESES\CAESAR II\8881865 D189 TO 133
Licensed To: Seat   -- ID #332

```
Piping Code: B31.3      = B31.3 -2008, December 31, 2008
```

STRESS RANGE SA11

```
 CODE STRESS CHECK PASSED      : LOADCASE 23 (EXP) L23=L15+L16

Highest Stresses: (KPa       ) LOADCASE 23 (EXP) L23=L15+L16
CodeStress Ratio (%):       23.3  @Node    140
Code Stress:            86933.0  Allowable:   373015.6
Axial Stress:           287.8  @Node    140
Bending Stress:         86933.0  @Node    140
Torsion Stress:           0.0  @Node    249
Hoop Stress:              0.0  @Node    120
3D Max Intensity:       87220.8  @Node    140
```

STRESS RANGE SA12

```
 CODE STRESS CHECK PASSED      : LOADCASE 24 (EXP) L24=L17+L18

Highest Stresses: (KPa       ) LOADCASE 24 (EXP) L24=L17+L18
CodeStress Ratio (%):       20.8  @Node    140
Code Stress:            77733.7  Allowable:   373015.6
Axial Stress:           257.3  @Node    140
Bending Stress:         77733.7  @Node    140
Torsion Stress:           0.0  @Node    249
Hoop Stress:              0.0  @Node    120
3D Max Intensity:       77991.1  @Node    140
```

STRESS RANGE SA13

```
 CODE STRESS CHECK PASSED      : LOADCASE 25 (EXP) L25=L19+L20

Highest Stresses: (KPa       ) LOADCASE 25 (EXP) L25=L19+L20
CodeStress Ratio (%):       18.5  @Node    140
Code Stress:            68994.4  Allowable:   373015.6
Axial Stress:           228.4  @Node    140
Bending Stress:         68994.4  @Node    140
Torsion Stress:           0.0  @Node    249
Hoop Stress:              0.0  @Node    120
3D Max Intensity:       69222.8  @Node    140
```

STRESS RANGE SA15

```
CODE STRESS CHECK PASSED      : LOADCASE 26 (EXP) L26=L21+L22
```

```
Highest Stresses: (KPa       ) LOADCASE 26 (EXP) L26=L21+L22
CodeStress Ratio (%):      16.4  @Node    140
Code Stress:            61175.1  Allowable:   373015.6
Axial Stress:           202.5  @Node    140
Bending Stress:          61175.1  @Node    140
Torsion Stress:            0.0  @Node    249
Hoop Stress:               0.0  @Node    120
3D Max Intensity:        61377.6  @Node    140


CAESAR II 2011 R1  Ver.5.31.00.0000,  (Build 120525)   Date: MAY 21, 2013   Time: 16:24
Job: H:\1THESES\CAESAR II\8881865 D116 TO 71
Licensed To: Seat   --  ID #332

Piping Code: B31.3      = B31.3 -2008, December 31, 2008

STRESS RANGE SA16
 CODE STRESS CHECK PASSED      : LOADCASE 23 (EXP) L23=L15+L16

Highest Stresses: (KPa       ) LOADCASE 23 (EXP) L23=L15+L16
CodeStress Ratio (%):      14.3  @Node    140
Code Stress:            53355.7  Allowable:   373015.6
Axial Stress:           176.6  @Node    140
Bending Stress:          53355.7  @Node    140
Torsion Stress:            0.0  @Node    249
Hoop Stress:               0.0  @Node    120
3D Max Intensity:        53532.3  @Node    140

STRESS RANGE SA17
 CODE STRESS CHECK PASSED      : LOADCASE 24 (EXP) L24=L17+L18

Highest Stresses: (KPa       ) LOADCASE 24 (EXP) L24=L17+L18
CodeStress Ratio (%):      12.3  @Node    140
Code Stress:            45996.3  Allowable:   373015.6
Axial Stress:           152.3  @Node    140
Bending Stress:          45996.3  @Node    140
Torsion Stress:            0.0  @Node    249
Hoop Stress:               0.0  @Node    120
3D Max Intensity:        46148.6  @Node    140

STRESS RANGE SA18
 CODE STRESS CHECK PASSED      : LOADCASE 25 (EXP) L25=L19+L20

Highest Stresses: (KPa       ) LOADCASE 25 (EXP) L25=L19+L20
CodeStress Ratio (%):      10.5  @Node    140
Code Stress:            39096.8  Allowable:   373015.6
Axial Stress:           129.4  @Node    140
Bending Stress:          39096.8  @Node    140
Torsion Stress:            0.0  @Node    249
Hoop Stress:               0.0  @Node    120
3D Max Intensity:        39226.3  @Node    140

STRESS RANGE SA20
 CODE STRESS CHECK PASSED      : LOADCASE 26 (EXP) L26=L21+L22

Highest Stresses: (KPa       ) LOADCASE 26 (EXP) L26=L21+L22
CodeStress Ratio (%):       8.8  @Node    140
Code Stress:            32657.4  Allowable:   373015.6
Axial Stress:           108.1  @Node    140
Bending Stress:          32657.4  @Node    140
Torsion Stress:            0.0  @Node    249
Hoop Stress:               0.0  @Node    120
3D Max Intensity:        32765.5  @Node    140
```

```
CAESAR II 2011 R1  Ver.5.31.00.0000,  (Build 120525)   Date: MAY 21, 2013   Time: 16:29
Job: H:\1THESES\CAESAR II\8881865 D58 TO 26
Licensed To: Seat   --  ID #332

Piping Code: B31.3      = B31.3 -2008, December 31, 2008

STRESS RANGE SA21

 CODE STRESS CHECK PASSED      : LOADCASE 23 (EXP) L23=L15+L16

Highest Stresses: (KPa       ) LOADCASE 23 (EXP) L23=L15+L16
CodeStress Ratio (%):        7.2  @Node    140
Code Stress:             26677.8  Allowable:   373015.6
Axial Stress:               88.3  @Node    140
Bending Stress:          26677.8  @Node    140
Torsion Stress:              0.0  @Node    249
Hoop Stress:                 0.0  @Node    120
3D Max Intensity:        26766.2  @Node    140

STRESS RANGE SA22
 CODE STRESS CHECK PASSED      : LOADCASE 24 (EXP) L24=L17+L18

Highest Stresses: (KPa       ) LOADCASE 24 (EXP) L24=L17+L18
CodeStress Ratio (%):        5.7  @Node    140
Code Stress:             21158.3  Allowable:   373015.6
Axial Stress:               70.0  @Node    140
Bending Stress:          21158.3  @Node    140
Torsion Stress:              0.0  @Node    249
Hoop Stress:                 0.0  @Node    120
3D Max Intensity:        21228.3  @Node    140

STRESS RANGE SA23
 CODE STRESS CHECK PASSED      : LOADCASE 25 (EXP) L25=L19+L20

Highest Stresses: (KPa       ) LOADCASE 25 (EXP) L25=L19+L20
CodeStress Ratio (%):        4.4  @Node    140
Code Stress:             16558.7  Allowable:   373015.6
Axial Stress:               54.8  @Node    140
Bending Stress:          16558.7  @Node    140
Torsion Stress:              0.0  @Node    249
Hoop Stress:                 0.0  @Node    120
3D Max Intensity:        16613.5  @Node    140

STRESS RANGE SA25
 CODE STRESS CHECK PASSED      : LOADCASE 26 (EXP) L26=L21+L22

Highest Stresses: (KPa       ) LOADCASE 26 (EXP) L26=L21+L22
CodeStress Ratio (%):        3.2  @Node    140
Code Stress:             11959.0  Allowable:   373015.6
Axial Stress:               39.6  @Node    140
Bending Stress:          11959.0  @Node    140
Torsion Stress:              0.0  @Node    249
Hoop Stress:                 0.0  @Node    120
3D Max Intensity:        11998.6  @Node    140

CAESAR II 2011 R1  Ver.5.31.00.0000,  (Build 120525)   Date: MAY 21, 2013   Time: 16:38
Job: H:\1THESES\CAESAR II\8881865 D18 TO 2
Licensed To: Seat   --  ID #332

Piping Code: B31.3      = B31.3 -2008, December 31, 2008

STRESS RANGE SA26
 CODE STRESS CHECK PASSED      : LOADCASE 23 (EXP) L23=L15+L16

Highest Stresses: (KPa       ) LOADCASE 23 (EXP) L23=L15+L16
```

```
CodeStress Ratio (%):       2.2  @Node    140
Code Stress:             8279.3  Allowable:   373015.6
Axial Stress:            27.4  @Node    140
Bending Stress:           8279.3  @Node    140
Torsion Stress:             0.0  @Node    249
Hoop Stress:                0.0  @Node    120
3D Max Intensity:         8306.7  @Node    140
```

STRESS RANGE SA27

```
 CODE STRESS CHECK PASSED      : LOADCASE 24 (EXP) L24=L17+L18

Highest Stresses: (KPa       ) LOADCASE 24 (EXP) L24=L17+L18
CodeStress Ratio (%):       1.4  @Node    140
Code Stress:             5059.6  Allowable:   373015.6
Axial Stress:            16.7  @Node    140
Bending Stress:           5059.6  @Node    140
Torsion Stress:             0.0  @Node    249
Hoop Stress:                0.0  @Node    120
3D Max Intensity:         5076.3  @Node    140
```

STRESS RANGE SA28

```
 CODE STRESS CHECK PASSED      : LOADCASE 25 (EXP) L25=L19+L20

Highest Stresses: (KPa       ) LOADCASE 25 (EXP) L25=L19+L20
CodeStress Ratio (%):       0.7  @Node    140
Code Stress:             2759.8  Allowable:   373015.6
Axial Stress:             9.1  @Node    140
Bending Stress:           2759.8  @Node    140
Torsion Stress:             0.0  @Node    249
Hoop Stress:                0.0  @Node    120
3D Max Intensity:         2768.9  @Node    140
```

STRESS RANGE SA29

```
 CODE STRESS CHECK PASSED      : LOADCASE 26 (EXP) L26=L21+L22

Highest Stresses: (KPa       ) LOADCASE 26 (EXP) L26=L21+L22
CodeStress Ratio (%):       0.2  @Node    140
Code Stress:              919.9  Allowable:   373015.6
Axial Stress:             3.0  @Node    140
Bending Stress:            919.9  @Node    140
Torsion Stress:             0.0  @Node    249
Hoop Stress:                0.0  @Node    120
3D Max Intensity:          923.0  @Node    140
```

CAESAR II 2011 R1 Ver.5.31.00.0000, (Build 120525)   Date: JUN 6, 2013   Time: 14:42
Job: H:\1THESES\CAESAR II\8881865 20 PERCENT OF OPE TEMP
Licensed To: Seat   -- ID #332

STRESS SUMMARY REPORT: Highest Stresses Mini Statement

Various Load Cases

```
Piping Code: B31.3      = B31.3 -2008, December 31, 2008
LISTING OF STATIC LOAD CASES FOR THIS ANALYSIS

1 (HYD) WW+HP
2 (OPE) W+D1+T1+P1
3 (OPE) W+D2+T2+P1
4 (OPE) W+D1+P1
5 (OPE) W+D2+P1
6 (OPE) W+D3+P1
7 (OPE) W+D4+P1
8 (OPE) W+D5+P1
9 (OPE) W+D6+P1
```

```
10 (OPE) W+D7+P1
11 (OPE) W+D8+P1
12 (OPE) W+D9+P1
13 (SUS) W+P1
14 (EXP) L14=L2-L13
15 (EXP) L15=L3-L13
16 (EXP) L16=L4-L13
17 (EXP) L17=L5-L13
18 (EXP) L18=L6-L13
19 (EXP) L19=L7-L13
20 (EXP) L20=L8-L13
21 (EXP) L21=L9-L13
22 (EXP) L22=L10-L13
23 (EXP) L23=L11-L13
24 (EXP) L24=L12-L13
25 (EXP) L25=L17+L18
26 (EXP) L26=L19+L20
27 (EXP) L27=L21+L22
28 (EXP) L28=L23+L24


STRESS RANGE SA19
 CODE STRESS CHECK PASSED      : LOADCASE 14 (EXP) L14=L2-L13

Highest Stresses: (KPa       ) LOADCASE 14 (EXP) L14=L2-L13
CodeStress Ratio (%):       25.1  @Node    140
Code Stress:            93869.5  Allowable:   373481.0
Axial Stress:           310.7  @Node    140
Bending Stress:          93869.5  @Node    140
Torsion Stress:            0.1  @Node    249
Hoop Stress:               0.0  @Node    120
3D Max Intensity:        94180.2  @Node    140

 CODE STRESS CHECK PASSED      : LOADCASE 15 (EXP) L15=L3-L13


CAESAR II 2011 R1  Ver.5.31.00.0000,  (Build 120525)   Date: MAY 21, 2013   Time: 16:55
Job: H:\1THESES\CAESAR II\8881865 10 PERCENT OF OPE PRE
Licensed To: Seat   --  ID #333

Piping Code: B31.3      = B31.3 -2008, December 31, 2008
LISTING OF STATIC LOAD CASES FOR THIS ANALYSIS


1 (HYD) WW+HP
2 (OPE) W+T1+P1
3 (OPE) W+T2+P2
4 (SUS) W+P1
5 (SUS) W+P2
6 (EXP) L6=L2-L4
7 (EXP) L7=L3-L4

STRESS RANGE SA24
 CODE STRESS CHECK PASSED      : LOADCASE 6 (EXP) L6=L2-L4

Highest Stresses: (KPa       ) LOADCASE 6 (EXP) L6=L2-L4
CodeStress Ratio (%):        1.1  @Node    140
Code Stress:             4229.1  Allowable:   373015.6
Axial Stress:            75.6  @Node    160
Bending Stress:           4229.1  @Node    140
Torsion Stress:            0.0  @Node    249
Hoop Stress:               0.0  @Node    120
3D Max Intensity:         4243.8  @Node    140
```

```
CAESAR II 2011 R1  Ver.5.31.00.0000,  (Build 120525)   Date: MAY 21, 2013   Time: 15:44
Job: H:\1THESES\CAESAR II\8881865
Licensed To: Seat   --  ID #332


LISTING OF STATIC LOAD CASES FOR THIS ANALYSIS


1 (HYD) WW+HP
2 (OPE) W+D1+T1+P1
3 (OPE) W+D2+T2+P1
4 (OPE) W+D1+P1
5 (OPE) W+D2+P1
6 (OPE) W+D3+P1
7 (OPE) W+D4+P1
8 (OPE) W+D5+P1
9 (OPE) W+D6+P1
10 (OPE) W+D7+P1
11 (OPE) W+D8+P1
12 (OPE) W+D9+P1
13 (SUS) W+P1
14 (EXP) L14=L2-L13
15 (EXP) L15=L3-L13
16 (EXP) L16=L4-L13
17 (EXP) L17=L5-L13
18 (EXP) L18=L6-L13
19 (EXP) L19=L7-L13
20 (EXP) L20=L8-L13
21 (EXP) L21=L9-L13
22 (EXP) L22=L10-L13
23 (EXP) L23=L11-L13
24 (EXP) L24=L12-L13
25 (EXP) L25=L17+L18
26 (EXP) L26=L19+L20
27 (EXP) L27=L21+L22
28 (EXP) L28=L23+L24
Job Description:

   PROJECT:8134136

   CLIENT :ConocoPhillips

   ANALYST:Aibel AS

   PIPING CODE:ASME B31.3

 PIPE DATA
 -----------------------------------------------------------------------------
 -----------------------------------------------------------------------------
 From  110  To  120 DZ= 2,208.000 mm.
 PIPE
    Dia= 20.000 in.   Wall= 5.537 mm.   Cor= .0000 mm.
 GENERAL
    T1= 130 C   T2= -46 C   T3= 4 C   P1= 20.0000 bars   PHyd= 30.0000 bars
    Mat= (340)A790 S32760   E= 195,825,104 KPa   EH1= 187,561,584 KPa
    EH2= 197,907,952 KPa   EH3= 195,825,104 KPa   EH4= 195,825,104 KPa
    EH5= 195,825,104 KPa   EH6= 195,825,104 KPa   EH7= 195,825,104 KPa
    EH8= 195,825,104 KPa   EH9= 195,825,104 KPa   v = .292
    Pipe Den=8027.1997070 kg/cu.m.   Fluid Den= .9100000 kg/cu.m.
    Insul Thk= .000 mm.
 RESTRAINTS
    Node  120  Y
    Node  120  X
 WIND
    Wind Shape= .600
```

```
-----------------------------------------------------------------------------
From  120  To  130 DZ= 9,810.000 mm.
RESTRAINTS
  Node  130  +Y
-----------------------------------------------------------------------------
From  130  To  140 DZ= 3,685.000 mm.
BEND at "TO" end
  Radius= 762.000 mm. (LONG)   Bend Angle= 90.000   Angle/Node @1= 45.00 139
  Angle/Node @2= .00 138
-----------------------------------------------------------------------------
From  140  To  150  DX= -2,090.000 mm.
RESTRAINTS
  Node  150  Y
  Node  150  X
  Node  150  Z
-----------------------------------------------------------------------------
From  150  To  160  DX= -1,899.000 mm.
  E= 195,825,104 KPa   EH1= 187,561,584 KPa   EH2= 197,907,952 KPa
  EH3= 195,825,104 KPa   EH4= 195,825,104 KPa   EH5= 195,825,104 KPa
  EH6= 195,825,104 KPa   EH7= 195,825,104 KPa   EH8= 195,825,104 KPa
  EH9= 195,825,104 KPa   v = .292   Pipe Den=8027.1997070 kg/cu.m.
BEND at "TO" end
  Radius= 762.000 mm. (LONG)   Bend Angle= 45.000   Angle/Node @1= 22.50 159
  Angle/Node @2= .00 158
DISPLACEMENTS
  Node  150   DX1= 400.000 mm.   DY1= .000 mm.   DZ1= .000 mm.   RX1= .000
  RY1= .000   RZ1= .000   DX2= 384.000 mm.   DY2= .000 mm.   DZ2= .000 mm.
  RX2= .000   RY2= .000   RZ2= .000   DX3= -384.000 mm.   DY3= .000 mm.
  DZ3= .000 mm.   RX3= .000   RY3= .000   RZ3= .000   DX4= 350.000 mm.
  DY4= .000 mm.   DZ4= .000 mm.   RX4= .000   RY4= .000   RZ4= .000
  DX5= -350.000 mm.   DY5= .000 mm.   DZ5= .000 mm.   RX5= .000   RY5= .000
  RZ5= .000   DX6= 324.000 mm.   DY6= .000 mm.   DZ6= .000 mm.   RX6= .000
  RY6= .000   RZ6= .000   DX7= -324.000 mm.   DY7= .000 mm.   DZ7= .000 mm.
  RX7= .000   RY7= .000   RZ7= .000   DX8= 300.000 mm.   DY8= .000 mm.
  DZ8= .000 mm.   RX8= .000   RY8= .000   RZ8= .000   DX9= -300.000 mm.
  DY9= .000 mm.   DZ9= .000 mm.   RX9= .000   RY9= .000   RZ9= .000
ALLOWABLE STRESSES
  B31.3 (2008)        Cycle Max Switch =   Sc= 250,274 KPa   Sh1= 240,693 KPa
  Sh3= 250,274 KPa   Sh4= 250,274 KPa   Sh5= 250,274 KPa   Sh6= 250,274 KPa
  Sh7= 250,274 KPa   Sh8= 250,274 KPa   Sh9= 250,274 KPa
-----------------------------------------------------------------------------
From  160  To  170  DX= -762.000 mm.  DZ= 762.000 mm.
BEND at "TO" end
  Radius= 762.000 mm. (LONG)   Bend Angle= 45.000   Angle/Node @1= 22.50 169
-----------------------------------------------------------------------------
From  170  To  180  DX= -2,419.000 mm.
RESTRAINTS
  Node  180  Y
  Node  180  Z
-----------------------------------------------------------------------------
From  180  To  190  DX= -11,561.000 mm.
RESTRAINTS
  Node  190  Y
  Node  190  Z
-----------------------------------------------------------------------------
From  190  To  200  DX= -8,950.000 mm.
RESTRAINTS
  Node  200  Y
  Node  200  Z
-----------------------------------------------------------------------------
From  200  To  210  DX= -7,980.000 mm.
RESTRAINTS
  Node  210  Y
  Node  210  Z
-----------------------------------------------------------------------------
```

```
From  210  To  220  DX= -8,021.000 mm.
RESTRAINTS
   Node  220  Y
   Node  220  Z
----------------------------------------------------------------------------
From  220  To  230  DX= -8,000.000 mm.
RESTRAINTS
   Node  230  Y
   Node  230  Z
----------------------------------------------------------------------------
From  230  To  240  DX= -8,000.000 mm.
RESTRAINTS
   Node  240  Y
   Node  240  Z
----------------------------------------------------------------------------
From  240  To  242  DX= -1,904.000 mm.
----------------------------------------------------------------------------
From  242  To  245  DX= -288.000 mm.
RIGID  Weight= 2.19 KN.
----------------------------------------------------------------------------
From  245  To  250  DX= -762.000 mm.
BEND at "TO" end
   Radius= 762.000 mm. (LONG)   Bend Angle= 90.000   Angle/Node @1= 45.00 249
----------------------------------------------------------------------------
From  250  To  254 DY= 762.000 mm.
----------------------------------------------------------------------------
From  254  To  256 DY= 288.000 mm.
RIGID  Weight= 2.19 KN.
----------------------------------------------------------------------------
From  256  To  260 DY= 1,032.000 mm.
RESTRAINTS
   Node  260  Z
----------------------------------------------------------------------------
From  260  To  270 DY= 5,000.000 mm.
RESTRAINTS
   Node  270  Z
----------------------------------------------------------------------------
From  270  To  272 DY= 761.000 mm.
----------------------------------------------------------------------------
From  272  To  275 DY= 288.000 mm.
RIGID  Weight= 2.19 KN.
----------------------------------------------------------------------------
From  275  To  280 DY= 762.000 mm.
BEND at "TO" end
   Radius= 762.000 mm. (LONG)   Bend Angle= 90.000   Angle/Node @1= 45.00 279
----------------------------------------------------------------------------
From  280  To  290 DZ= 1,524.000 mm.
BEND at "TO" end
   Radius= 762.000 mm. (LONG)   Bend Angle= 90.000   Angle/Node @1= 45.00 289
----------------------------------------------------------------------------
From  290  To  300 DY= -762.000 mm.
```

APPENDIX C: MAXIMUM STRESS RANGES AND CAESAR II INPUT LISTING – TEMPORARY EMERGENCY GENERATOR EXHAUST TO OPEN END MODEL

```
CAESAR II 2011 R1  Ver.5.31.00.0000,  (Build 120525)   Date: MAY 6, 2013   Time: 12:47
Job: H:\PMO STRESS\COMPREHENSIVE\PMO8134136\REV 0...\813413606189
Licensed To: Seat   --  ID #332
Piping Code: B31.3      = B31.3 -2008, December 31, 2008

 CODE STRESS CHECK PASSED      : LOADCASE 1 (HYD) WW+HP

Highest Stresses: (KPa       ) LOADCASE 1 (HYD) WW+HP
CodeStress Ratio (%):       12.8  @Node    170
Code Stress:            30880.2  Allowable:   241311.0
Axial Stress:           12069.4  @Node     78
Bending Stress:         19088.7  @Node    170
Torsion Stress:             0.0  @Node     20
Hoop Stress:            24971.4  @Node     70
3D Max Intensity:       31809.5  @Node    170

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

Highest Stresses: (KPa       ) LOADCASE 5 (SUS) W+P1
CodeStress Ratio (%):       53.6  @Node     20
Code Stress:            40410.4  Allowable:    75391.1
Axial Stress:            3182.0  @Node     20
Bending Stress:         37228.4  @Node     20
Torsion Stress:             0.0  @Node     20
Hoop Stress:             6273.8  @Node     29
3D Max Intensity:       40410.4  @Node     20

 CODE STRESS CHECK PASSED      : LOADCASE 6 (EXP) L6=L2-L5

Highest Stresses: (KPa       ) LOADCASE 6 (EXP) L6=L2-L5
CodeStress Ratio (%):        7.8  @Node     80
Code Stress:            14837.7  Allowable:   191212.8
Axial Stress:            1104.9  @Node     30
Bending Stress:         14837.7  @Node     80
Torsion Stress:             0.0  @Node     20
Hoop Stress:                0.0  @Node     20
3D Max Intensity:       27314.0  @Node     80

 CODE STRESS CHECK PASSED      : LOADCASE 7 (EXP) L7=L3-L5

Highest Stresses: (KPa       ) LOADCASE 7 (EXP) L7=L3-L5
CodeStress Ratio (%):        0.3  @Node     80
Code Stress:              517.4  Allowable:   206838.0
Axial Stress:              38.5  @Node     30
Bending Stress:           517.4  @Node     80
Torsion Stress:             0.0  @Node     20
Hoop Stress:                0.0  @Node     20
3D Max Intensity:         952.5  @Node     80

 CODE STRESS CHECK PASSED      : LOADCASE 8 (EXP) L8=L4-L5

Highest Stresses: (KPa       ) LOADCASE 8 (EXP) L8=L4-L5
CodeStress Ratio (%):        6.9  @Node     80
Code Stress:            13566.9  Allowable:   195624.2
Axial Stress:            1010.3  @Node     30
Bending Stress:         13566.9  @Node     80
Torsion Stress:             0.0  @Node     20
Hoop Stress:                0.0  @Node     20
3D Max Intensity:       24974.7  @Node     80
```

```
LISTING OF STATIC LOAD CASES FOR THIS ANALYSIS


1 (HYD) WW+HP
2 (OPE) W+T1+P1
3 (OPE) W+T2+P1
4 (OPE) W+T3+P1
5 (SUS) W+P1
6 (EXP) L6=L2-L5
7 (EXP) L7=L3-L5
8 (EXP) L8=L4-L5


 Job Description:

   PROJECT:8134136

   CLIENT :ConocoPhillips

   ANALYST:Aibel AS

   PIPING CODE:ASME B31.3

 PIPE DATA
 -----------------------------------------------------------------------------
 -----------------------------------------------------------------------------
 From  10  To  20 DZ= -76.000 mm.
 PIPE
    Dia= 4.500 in.   Wall= 6.020 mm.   Cor= 3.0000 mm.
 GENERAL
    T1= 425 C   T2= -15 C   T3= 395 C   P1= 3.5000 bars   PHyd= .0000 bars
    Mat= (106)A106 B   E= 204,098,624 KPa   EH1= 167,102,784 KPa
    EH2= 204,884,544 KPa   EH3= 171,667,488 KPa   EH4= 204,098,624 KPa
    EH5= 204,098,624 KPa   EH6= 204,098,624 KPa   EH7= 204,098,624 KPa
    EH8= 204,098,624 KPa   EH9= 204,098,624 KPa   v = .292
    Pipe Den=7833.4399414 kg/cu.m.   Fluid Den= .5800000 kg/cu.m.
    Insul Thk= .000 mm.
 RIGID  Weight= .09 KN.
 RESTRAINTS
    Node  10  ANC
 ALLOWABLE STRESSES
    B31.3 (2008)        Cycle Max Switch =   Sc= 137,892 KPa   Sh1= 75,391 KPa
    Sh2= 137,892 KPa   Sh3= 93,037 KPa   Sh4= 137,892 KPa   Sh5= 137,892 KPa
    Sh6= 137,892 KPa   Sh7= 137,892 KPa   Sh8= 137,892 KPa   Sh9= 137,892 KPa
    Sy= 241,311 KPa
 -----------------------------------------------------------------------------
 From  20  To  30 DZ= -153.000 mm.
 DOUBLE FLANGED BEND at "TO" end
    Radius= 152.400 mm. (LONG)   Bend Angle= 90.000   Angle/Node @1= 45.00 29
 -----------------------------------------------------------------------------
 From  30  To  40 DY= 152.000 mm.
 -----------------------------------------------------------------------------
 From  40  To  50 DY= 76.000 mm.
 GENERAL
    Mat= (383)A516 70   E= 204,098,624 KPa   EH1= 167,102,784 KPa
    EH2= 204,884,544 KPa   EH3= 171,862,160 KPa   EH4= 204,098,624 KPa
    EH5= 204,098,624 KPa   EH6= 204,098,624 KPa   EH7= 204,098,624 KPa
    EH8= 204,098,624 KPa   EH9= 204,098,624 KPa   v = .292
    Pipe Den=7833.4399414 kg/cu.m.
 RIGID  Weight= .20 KN.
 ALLOWABLE STRESSES
    B31.3 (2008)        Cycle Max Switch =   Sc= 160,644 KPa   Sh1= 83,918 KPa
    Sh2= 160,644 KPa   Sh3= 105,447 KPa   Sh4= 160,644 KPa   Sh5= 160,644 KPa
```

```
   Sh6= 160,644 KPa   Sh7= 160,644 KPa   Sh8= 160,644 KPa   Sh9= 160,644 KPa
   Sy= 261,995 KPa
-----------------------------------------------------------------------------
From  50  To  60 DY= 444.000 mm.
EXPANSION JOINT
   Axial K= 1,236 lb./in.   Trans K= 2,482 lb./in.   Eff Dia= 131.100 mm.
-----------------------------------------------------------------------------
From  60  To  65 DY= 76.000 mm.
   PHyd= 29.4000 bars
RIGID  Weight= .20 KN.
ALLOWABLE STRESSES
   B31.3 (2008)        Cycle Max Switch =   Sc= 160,644 KPa   Sh1= 83,918 KPa
   Sh2= 160,644 KPa   Sh3= 105,447 KPa   Sh4= 160,644 KPa   Sh5= 160,644 KPa
   Sh6= 160,644 KPa   Sh7= 160,644 KPa   Sh8= 160,644 KPa   Sh9= 160,644 KPa
   Sy= 261,995 KPa
-----------------------------------------------------------------------------
From  65  To  70 DY= 1,345.000 mm.
PIPE
   Dia= 4.500 in.   Wall= 6.020 mm.
GENERAL
   Mat= (106)A106 B   E= 204,098,624 KPa   EH1= 167,102,784 KPa
   EH2= 204,884,544 KPa   EH3= 171,667,488 KPa   EH4= 204,098,624 KPa
   EH5= 204,098,624 KPa   EH6= 204,098,624 KPa   EH7= 204,098,624 KPa
   EH8= 204,098,624 KPa   EH9= 204,098,624 KPa   v = .292
   Pipe Den=7833.4399414 kg/cu.m.   Insul Thk= 76.200 mm.
   Insul Den= 136.1579285 kg/cu.m.
RESTRAINTS
   Node  70  Guide
ALLOWABLE STRESSES
   B31.3 (2008)        Cycle Max Switch =   Sc= 137,892 KPa   Sh1= 75,391 KPa
   Sh2= 137,892 KPa   Sh3= 93,037 KPa   Sh4= 137,892 KPa   Sh5= 137,892 KPa
   Sh6= 137,892 KPa   Sh7= 137,892 KPa   Sh8= 137,892 KPa   Sh9= 137,892 KPa
   Sy= 241,311 KPa
-----------------------------------------------------------------------------
From  70  To  80 DY= 192.000 mm.
PIPE
   Dia= 4.500 in.   Wall= 6.020 mm.
GENERAL
   Insul Thk= .000 mm.   Insul Den= .0000000 kg/cu.m.
BEND at "TO" end
   Radius= 152.400 mm. (LONG)   Bend Angle= 90.000   Angle/Node @1= 45.00 79
   Angle/Node @2= .00 78
-----------------------------------------------------------------------------
From  80  To  90 DZ= 181.000 mm.
RESTRAINTS
   Node  90  Y
   Node  90  X
-----------------------------------------------------------------------------
From  90  To  100 DZ= 673.000 mm.
-----------------------------------------------------------------------------
From  100  To  110 DZ= 76.000 mm.
RIGID  Weight= .09 KN.
-----------------------------------------------------------------------------
From  110  To  120 DZ= 880.000 mm.
RIGID  Weight= 1.08 KN.
-----------------------------------------------------------------------------
From  120  To  130 DZ= 76.000 mm.
RIGID  Weight= .09 KN.
-----------------------------------------------------------------------------
From  130  To  140 DZ= 145.000 mm.
RESTRAINTS
   Node  140  Y
   Node  140  X
-----------------------------------------------------------------------------
From  140  To  150 DZ= 1,479.000 mm.
```

```
RESTRAINTS
   Node  150  Y
   Node  150  X
-----------------------------------------------------------------------------
From  150  To  160 DZ= 1,920.000 mm.
RESTRAINTS
   Node  160  Y
   Node  160  X
-----------------------------------------------------------------------------
From  160  To  170 DZ= 1,722.000 mm.
RESTRAINTS
   Node  170  Y
   Node  170  X
-----------------------------------------------------------------------------
From  170  To  180 DZ= 2,908.000 mm.
```

APPENDIX D: TRIFLEX INPUT ECHO FOR SLURRY SYSTEM WITH PULSATION

```
TITLPMO 9187103 – SD13 J152 MODIFISERE SLURRY SYSTEM
 ACCT: , CLIENT: ConocoPhilips, COST CODE: GEMC
 EMP. NO.: , ENGR. INIT:
 PLANT LOC.: W40, PLANT NAME: EKOM
 Problem: 91871035901323-Oper, Max. temp

OPTN,SAVEBIN,NSD,T+P+W,B313,IN=IU1,OUT=IU1,EQ,
 MAXIT=20,PSTIFF,FRICP=20,WTDEN=999.552,PIW
10A,WTON,BUOYOFF,NOD=80,THK=3.048,CA=0,INTHK=29.9999,INWT=28.17,CONWT=50.57,
 EMOD=0.2020,EXP=1.94,PDEN=8027.17,PRESS=20
C
20B,X=-378.000000,BRR=1.5
30B,Y=114.000000,Z=-114.000000,BRR=1.5
40B,Y=1738.000000,BRR=1.5
50B,X=-164.000000,Z=164.000000,BRR=1.5
55R,X=-1476.000000,REST=Y,Z
60B,X=-275.000000,BRR=1.5
70B,X=-369.000000,Z=369.000000,BRR=1.5
80B,Y=1839.000000,BRR=1.5
90B,Y=421.000000,Z=-421.000000,BRR=1.5
100B,Y=629.000000,BRR=1.5
110B,Y=421.000000,Z=421.000000,BRR=1.5
120R,Y=415.000000,REST=X,Z
130R,Y=3350.000000,REST=X,Z
140R,Y=2881.000000,REST=X,Z
150R,Y=3852.000000,SIE=T
160B,Y=440.000000,BRR=1.5
170R,Z=-653.000000,REST=X,+Y,Z
180B,FROM=150,Z=-108.000000,BRR=1.5,NOD=50,THK=2.7686,INTHK=39.9999,
 INWT=31.69,CONWT=22.14,EMOD=0.2020,EXP=1.94,PDEN=8027.17,PRESS=20
190B,X=407.000000,Z=-407.000000,BRR=1.5
195R,Z=-129.000000,NOD=50,THK=2.7686,INTHK=39.9999,INWT=31.69,CONWT=22.14,
 EMOD=0.2020,EXP=1.94,PDEN=8027.17,PRESS=20,REST=X,Y
200B,Z=-300.000000,BRR=1
210B,X=152.399994,BRR=1
260V,Y=477.000000,FRATE=150,FLNGS=2,VALWT=279,VALLN=311,VALIF=4,VLTYP=USR,
 FLGWT=26.6893,FLGLN=42.672,FLGIF=1.5,FLTYP=AAA
280R,Y=76.199997,NOD=44.45,THK=3.2258,INTHK=39.9999,INWT=27.88,CONWT=12.33,
 EMOD=0.2020,EXP=1.94,PDEN=8027.17,PRESS=20
290J,Y=189.000000,JTWT=171,JLEN=189,NOD=40,THK=3.683,INTHK=39.9999,INWT=27.88,
 CONWT=12.33,EMOD=0.2020,EXP=1.94,PDEN=8027.17,PRESS=20
300J,X=-194.000000,JTWT=202,JLEN=194,NOD=80,THK=3.048,CONWT=5.28,EMOD=0.2020,
 EXP=1.94,PDEN=8027.17,PRESS=20
305J,X=-349.000000,JTWT=483,JLEN=349,NOD=80,THK=3.048,CONWT=5.28,EMOD=0.2020,
 EXP=1.94,PDEN=8027.17,PRESS=20
1010R,X=-85.000000,SIE=T
1020R,X=-280.000000,REST=X,Y,Z
1030B,X=-169.000000,BRR=1.5
1040B,X=-372.000000,Y=-372.000000,BRR=1.5
1050R,X=-305.000000,SIE=T
1060V,X=-429.000000,FRATE=150,FLNGS=2,VALWT=346.961,VALLN=204.216,VALIF=4,
 VLTYP=AAA,FLGWT=66.7233,FLGLN=69.8501,FLGIF=0.7,FLTYP=WNK
1070R,X=-104.000000,REST=Y,Z
1080B,X=-846.000000,BRR=1.5
1090B,X=-420.000000,Z=-420.000000,BRR=1.5
1100B,X=-683.000000,BRR=1.5
1110R,Z=-366.000000,REST=X,Y,Z
1120B,Z=-1945.000000,BRR=1.5
1130R,X=-278.000000,REST=Y,Z
1140B,X=-400.000000,BRR=1.5
1150F,Z=-254.000000,FRATE=150,FLNGS=2,FLGWT=66.7233,FLGLN=69.8501,FLGIF=0.7,
 FLTYP=WNK
```

```
1160B,Z=-926.000000,BRR=1.5
1170R,X=-905.000000,REST=Y,Z
1180B,X=-1484.000000,BRR=1.5
410F,Z=254.000000,FRATE=150,FLNGS=2,FLGWT=66.7233,FLGLN=69.8501,FLGIF=0.7,
 FLTYP=WNK
420R,Z=279.000000,SIE=T
430R,Y=-339.000000,SIE=W,NOD=150,THK=3.4036,CONWT=200.72,EMOD=0.2020,EXP=0.75,
 PDEN=8027.17,PRESS=19.5
440R,Y=-286.000000,SPRG=5000,70.1
445R,Y=-286.000000,SIE=T
450R,Y=-286.000000,SIE=W
460R,Y=-246.000000,SIE=T
480F,Y=-361.000000,FRATE=150,FLNGS=2,FLGWT=137.895,FLGLN=88.9001,FLGIF=0.7,
 FLTYP=WNK
485R,Y=-160.000000
485A,MOV=-0.12,3.6,-0.84
C
500F,FROM=420,Y=361.000000,FRATE=150,FLNGS=2,FLGWT=137.895,FLGLN=88.9001,
 FLGIF=0.7,FLTYP=WNK
510R,Y=143.000000,SIE=T
1510B,FROM=1010,Z=-260.000000,BRR=1.5,NOD=50,THK=2.7686,CONWT=2.31,
 EMOD=0.2020,EXP=1.94,PDEN=8027.17,PRESS=20
1530V,X=380.000000,FRATE=150,FLNGS=2,VALWT=213.515,VALLN=176.784,VALIF=4,
 VLTYP=AAA,FLGWT=26.6893,FLGLN=63.4999,FLGIF=0.6,FLTYP=WNK
1540J,X=181.000000,JTWT=181,JLEN=181
1550J,Y=-164.000000,JTWT=128,JLEN=164,NOD=25,THK=3.3782,CONWT=0.55,
 EMOD=0.2020,EXP=1.94,PDEN=8027.17,PRESS=20
1600B,Y=-115.000000,BRR=1.5
1610B,Y=-200.000000,Z=200.000000,BRR=1.5
1620R,Z=280.000000,REST=X,Y,Z
520F,FROM=510,Y=232.000000,FRATE=150,FLNGS=1,FLGWT=137.895,FLGLN=88.9001,
 FLGIF=0.7,FLTYP=WNK,NOD=150,THK=3.4036,CONWT=200.72,EMOD=0.2020,EXP=0.75,
 PDEN=8027.17,PRESS=19.5
1700V,FROM=1050,X=-4.198820,Y=428.979004,FRATE=150,FLNGS=2,VALWT=346.961,
 VALLN=204.216,VALIF=4,VLTYP=AAA,FLGWT=66.7233,FLGLN=69.8501,FLGIF=0.7,
 FLTYP=WNK,NOD=80,THK=3.048,CONWT=58.06,EMOD=0.2020,EXP=2.11,PDEN=8027.17,
 PRESS=20
1710B,X=-3.327740,Y=339.984009,BRR=1.5
1720R,Z=-2364.000000,REST=X,Y,Z
1730B,Z=-999.000000,BRR=1.5
1740B,X=-166.000000,Z=-166.000000,BRR=1.5
1750B,Y=-594.000000,BRR=1.5
1760F,X=-254.000000,FRATE=150,FLNGS=2,FLGWT=66.7233,FLGLN=69.8501,FLGIF=0.7,
 FLTYP=WNK
2000R,X=-321.000000,SIE=T
2010F,Y=213.000000,FRATE=150,FLNGS=1,FLGWT=137.895,FLGLN=88.9001,FLGIF=0.7,
 FLTYP=WNK,NOD=150,THK=3.4036,CONWT=200.72,EMOD=0.2020,EXP=0.75,PDEN=8027.17,
 PRESS=19.5
2020F,FROM=2000,Y=-283.000000,FRATE=150,FLNGS=2,FLGWT=137.895,FLGLN=88.9001,
 FLGIF=0.7,FLTYP=WNK
2030R,Y=-232.000000,SIE=W
2040R,Y=-286.000000,SIE=T
2050R,Y=-286.000000,SIE=T
2060R,Y=-286.000000,SIE=W
2070R,Y=-246.000000,SIE=T
2080F,Y=-302.000000,FRATE=150,FLNGS=2,FLGWT=137.895,FLGLN=88.9001,FLGIF=0.7,
 FLTYP=WNK
2090R,Y=-160.000000
2090A,MOV=-0.12,3.6,-0.84
C
2200F,FROM=510,Z=283.000000,FRATE=150,FLNGS=2,FLGWT=66.7233,FLGLN=69.8501,
 FLGIF=0.7,FLTYP=WNK,NOD=80,THK=3.048,CONWT=84.46,EMOD=0.2020,EXP=2.11,
 PDEN=8027.17,PRESS=20
2210B,Z=184.000000,BRR=1.5,NOD=80,THK=3.048,CONWT=84.4575,EMOD=0.2020,
 EXP=2.11,PDEN=8027.17,PRESS=20
```

```
2220R,X=1484.000000,REST=X,Y,Z
2230B,X=644.000000,BRR=1.5
2240B,X=72.000000,Z=72.000000,BRR=1.5
2245R,X=965.000000,REST=Y,Z
2250F,X=873.000000,FRATE=150,FLNGS=2,FLGWT=66.7233,FLGLN=69.8501,FLGIF=0.7,
 FLTYP=WNK
2270B,X=1625.000000,BRR=1.5
2280B,Z=228.000000,BRR=1.5
2290R,X=650.000000,SIE=T
2300F,X=226.000000,FRATE=150,FLNGS=2,FLGWT=66.7233,FLGLN=69.8501,FLGIF=0.7,
 FLTYP=WNK
2305R,X=428.000000,REST=Y,Z
2310B,X=413.000000,BRR=1.5
2315R,Z=-266.000000
2320B,Z=-266.000000,BRR=1.5
2330B,Y=-1213.000000,BRR=1.5
2340R,X=-264.000000,NOD=80,THK=3.048,CONWT=84.46,EMOD=0.2020,EXP=2.11,
 PDEN=8027.17,PRESS=20
2350R,X=-101.599998,NOD=88.9,THK=3.048,CONWT=144.219,EMOD=0.2020,EXP=2.11,
 PDEN=8027.17,PRESS=20
2360J,X=-206.000000,JTWT=231,JLEN=206,NOD=100,THK=3.048,CONWT=144.219,
 EMOD=0.2020,EXP=2.11,PDEN=8027.17,PRESS=20
2370R,X=-101.599998,NOD=88.9,THK=3.048,CONWT=84.4575,EMOD=0.2020,EXP=0.75,
 PDEN=8027.17,PRESS=20
2500R,X=-86.000000,SIE=T,NOD=80,THK=3.048,CONWT=84.4575,EMOD=0.2020,EXP=0.75,
 PDEN=8027.17,PRESS=20
2520B,Y=206.300003,BRR=1.5,NOD=80,THK=11.1252,CONWT=54.72,EMOD=0.2020,
 EXP=0.75,PDEN=8027.17,PRESS=20
2530R,Z=-114.000000,NOD=80,THK=3.048,CA=1.5,CONWT=84.46,EMOD=0.2020,EXP=0.75,
 PDEN=8027.17,PRESS=20
2540J,Z=-432.000000,JTWT=590,JLEN=432,NOD=80,THK=17.4752,CONWT=35.85,
 EMOD=0.2040,EXP=0.51,PDEN=7833.41,PRESS=690
2550J,Y=-367.000000,JTWT=1080,JLEN=367
2555R,Y=-190.000000
2560B,Y=-115.000000,BRR=1.5
2570R,X=306.000000,REST=Y,Z
2580B,X=500.000000,BRR=1.5
2590R,Y=-1461.000000,REST=X,Z
2600B,Y=-1420.000000,BRR=1.5
2605R,X=404.000000,REST=X,Y
2610B,X=420.000000,BRR=1.5
2620B,Y=-1701.000000,BRR=1.5
2630R,Z=-783.000000,REST=Z
2640B,Z=-782.000000,BRR=1.5
2650R,X=505.000000,REST=X,Y
2660R,X=403.000000,SIE=T
2670B,X=508.000000,BRR=1.5
2680F,Y=-476.000000,FRATE=150,FLNGS=2,FLGWT=205.7,FLGLN=86,FLGIF=1.5,
 FLTYP=USR
2690R,Y=-2057.000000
2700B,Y=-115.000000,BRR=1.5
2710R,Z=508.000000,SIE=T
2720F,Z=776.000000,FRATE=150,FLNGS=1,FLGWT=60,FLGLN=73,FLGIF=1,FLTYP=USR
2720A,MOVX=1
C
1310B,FROM=2710,X=-229.000000,Y=229.000000,BRR=1.5,NOD=50,THK=12.4968,
 CONWT=15.38,EMOD=0.2040,EXP=0.51,PDEN=7833.41,PRESS=690
1320R,X=-19.302601,Y=-112.679001,Z=65.990898
1330J,X=-90.078903,Y=-525.835999,Z=307.958008,JTWT=1950,JLEN=616
1335R,X=-14.623200,Y=-85.362999,Z=49.993198,REST=X,Y,Z
1350F,X=-37.435398,Y=-218.529007,Z=127.983002,FRATE=150,FLNGS=1,FLGWT=100,
 FLGLN=156,FLGIF=1,FLTYP=USR
2800B,FROM=2500,Y=-200.000000,BRR=1.5,NOD=80,THK=3.048,CA=0,CONWT=84.46,
 EMOD=0.2020,EXP=0.75,PDEN=8027.17,PRESS=20
2810R,X=474.000000,SIE=T
```

```
2820B,X=174.000000,BRR=1.5
2830B,Y=-238.000000,Z=238.000000,BRR=1.5
2840R,X=-114.300003
2850R,X=-101.599998,Y=12.700000,NOD=88.9,THK=3.048,CONWT=144.22,EMOD=0.2020,
 EXP=0.75,PDEN=8027.17,PRESS=20
2860J,X=-212.000000,JTWT=231,JLEN=212,NOD=100,THK=3.048,CONWT=144.22,
 EMOD=0.2020,EXP=0.75,PDEN=8027.17,PRESS=20
2870R,X=-101.599998,Y=-12.700000,NOD=88.9,THK=3.048,CONWT=84.46,EMOD=0.2020,
 EXP=0.75,PDEN=8027.17,PRESS=20
2900R,X=-124.000000,SIE=T,NOD=80,THK=3.048,CONWT=84.46,EMOD=0.2020,EXP=0.75,
 PDEN=8027.17,PRESS=20
2910F,Y=232.000000,FRATE=150,FLNGS=1,FLGWT=137.895,FLGLN=88.9001,FLGIF=0.7,
 FLTYP=WNK,NOD=150,THK=3.4036,CONWT=321.15,EMOD=0.2020,EXP=0.75,PDEN=8027.17,
 PRESS=20
2920R,FROM=2900,Y=-286.000000,SIE=T
2930F,Y=-321.000000,FRATE=150,FLNGS=2,FLGWT=105,FLGLN=88.9001,FLGIF=0.7,
 FLTYP=WNK
2940R,Y=-126.000000
2940A,MOVY=3.4
C
3000R,FROM=2920,X=-97.654602,Z=-76.417099,NOD=80,THK=3.048,CONWT=84.46,
 EMOD=0.2020,EXP=0.75,PDEN=8027.17,PRESS=20
3010R,X=-80.013802,Y=12.700000,Z=-62.612701,NOD=88.9,THK=3.048,CONWT=144.22,
 EMOD=0.2020,EXP=0.75,PDEN=8027.17,PRESS=20
3020J,X=-166.957993,Z=-130.649002,JTWT=320,JLEN=212,NOD=100,THK=3.048,
 CONWT=144.22,EMOD=0.2020,EXP=0.75,PDEN=8027.17,PRESS=20
3030R,X=-80.013702,Y=-12.700000,Z=-62.612801,NOD=88.9,THK=3.048,CONWT=84.46,
 EMOD=0.2020,EXP=0.75,PDEN=8027.17,PRESS=20
3050B,X=-90.015404,Z=-70.439400,BRR=1.5,NOD=80,THK=3.048,CONWT=84.46,
 EMOD=0.2020,EXP=0.75,PDEN=8027.17,PRESS=20
3060B,Y=228.600006,BRR=1.5
3065R,X=500.000000
3070B,X=631.000000,BRR=1.5
3080B,Y=228.600006,BRR=1.5
3090B,X=-756.000000,BRR=1.5
3100B,X=-165.000000,Z=165.000000,BRR=1.5
3110R,Y=274.000000,SIE=T
3120B,Y=200.000000,BRR=1.5,NOD=80,THK=11.1252,CONWT=54.72,EMOD=0.2020,
 EXP=0.75,PDEN=8027.17,PRESS=20
3130R,Z=-114.000000,NOD=80,THK=3.048,CONWT=84.46,EMOD=0.2020,EXP=0.75,
 PDEN=8027.17,PRESS=20
3140J,Z=-342.000000,JTWT=590,JLEN=342,NOD=80,THK=17.4752,CA=1.5,CONWT=35.85,
 EMOD=0.2040,EXP=0.51,PDEN=7833.41,PRESS=690
3150J,Y=-367.000000,JTWT=1080,JLEN=367
3155R,Y=-190.000000
3160B,Y=-115.000000,BRR=1.5
3170R,Z=-305.000000,REST=Y
3180B,Z=-354.000000,BRR=1.5
3190R,X=555.000000,REST=X,Y
3200B,X=555.000000,BRR=1.5
3210R,Y=-1460.000000,REST=X,Z
3220B,Y=-1420.000000,BRR=1.5
3230R,X=736.000000,REST=X,Y
3240B,X=538.000000,BRR=1.5
3250R,Z=-605.000000,REST=Z
3260B,Z=-630.000000,BRR=1.5
3270R,X=1328.000000,REST=Y
3280R,X=4124.000000,REST=X,Y,Z
3500F,FROM=2290,Y=-226.000000,FRATE=150,FLNGS=2,FLGWT=66.7233,FLGLN=69.8501,
 FLGIF=0.7,FLTYP=WNK,NOD=80,THK=3.048,CA=0,CONWT=84.46,EMOD=0.2020,EXP=2.11,
 PDEN=8027.17,PRESS=20
3510R,Y=-448.000000
3520R,Y=-101.599998,NOD=88.9,THK=3.048,CONWT=144.22,EMOD=0.2020,EXP=2.11,
 PDEN=8027.17,PRESS=20
3530J,Y=-206.000000,JTWT=271.46,JLEN=206,NOD=100,THK=3.048,CONWT=144.22,
```

```
 EMOD=0.2020,EXP=2.11,PDEN=8027.17,PRESS=20
3540R,Y=-101.599998,NOD=88.9,THK=3.048,CONWT=84.46,EMOD=0.2020,EXP=0.75,
 PDEN=8027.17,PRESS=20
3550B,Y=-114.300003,BRR=1.5,NOD=80,THK=3.048,CONWT=84.46,EMOD=0.2020,EXP=0.75,
 PDEN=8027.17,PRESS=20
3560R,Z=-264.000000,SIE=W
3110R,Z=-268.000000
4000R,FROM=2555,Y=-287.000000,NOD=80,THK=17.4752,CONWT=35.85,EMOD=0.2040,
 EXP=0.51,PDEN=7833.41,PRESS=0,REST=X,+Y
4010R,FROM=2690,Y=-252.000000,REST=X,Y
4020R,FROM=3155,Y=-250.000000,REST=+Y,Z
4030R,FROM=2530,Z=302.000000,NOD=80,THK=3.048,CONWT=84.46,EMOD=0.2040,
 EXP=0.51,PDEN=7833.41,PRESS=0,REST=X,Z
4040R,FROM=3130,Z=302.000000,REST=X,Z
X
B313,FROM=10,TO=10,SC=207.00,SH=203.00,SE=203.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=20,TO=20,SC=207.00,SH=203.00,SE=203.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=30,TO=30,SC=207.00,SH=203.00,SE=203.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=40,TO=40,SC=207.00,SH=203.00,SE=203.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=50,TO=50,SC=207.00,SH=203.00,SE=203.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=55,TO=55,SC=207.00,SH=203.00,SE=203.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=60,TO=60,SC=207.00,SH=203.00,SE=203.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=70,TO=70,SC=207.00,SH=203.00,SE=203.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=80,TO=80,SC=207.00,SH=203.00,SE=203.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=90,TO=90,SC=207.00,SH=203.00,SE=203.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=100,TO=100,SC=207.00,SH=203.00,SE=203.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=110,TO=110,SC=207.00,SH=203.00,SE=203.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=120,TO=120,SC=207.00,SH=203.00,SE=203.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=130,TO=130,SC=207.00,SH=203.00,SE=203.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=140,TO=140,SC=207.00,SH=203.00,SE=203.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=150,TO=150,SC=207.00,SH=203.00,SE=203.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=160,TO=160,SC=207.00,SH=203.00,SE=203.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=170,TO=150,SC=207.00,SH=203.00,SE=203.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=180,TO=180,SC=207.00,SH=203.00,SE=203.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=190,TO=190,SC=207.00,SH=203.00,SE=203.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=195,TO=195,SC=207.00,SH=203.00,SE=203.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=200,TO=200,SC=207.00,SH=203.00,SE=203.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=210,TO=210,SC=207.00,SH=203.00,SE=203.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=260,TO=260,SC=207.00,SH=203.00,SE=203.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=280,TO=280,SC=207.00,SH=203.00,SE=203.00
 F=1,Y=0.4,K=1.33,MTP=12.5
```

```
B313,FROM=290,TO=290,SC=207.00,SH=203.00,SE=203.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=300,TO=300,SC=207.00,SH=203.00,SE=203.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=305,TO=305,SC=207.00,SH=203.00,SE=203.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1010,TO=1010,SC=250.00,SH=243.00,SE=243.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1020,TO=1020,SC=250.00,SH=243.00,SE=243.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1030,TO=1030,SC=250.00,SH=243.00,SE=243.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1040,TO=1040,SC=250.00,SH=243.00,SE=243.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1050,TO=1050,SC=250.00,SH=243.00,SE=243.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1060,TO=1060,SC=250.00,SH=243.00,SE=243.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1070,TO=1070,SC=250.00,SH=243.00,SE=243.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1080,TO=1080,SC=250.00,SH=243.00,SE=243.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1090,TO=1090,SC=250.00,SH=243.00,SE=243.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1100,TO=1100,SC=250.00,SH=243.00,SE=243.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1110,TO=1110,SC=250.00,SH=243.00,SE=243.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1120,TO=1120,SC=250.00,SH=243.00,SE=243.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1130,TO=1130,SC=250.00,SH=243.00,SE=243.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1140,TO=1140,SC=250.00,SH=243.00,SE=243.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1150,TO=1150,SC=250.00,SH=243.00,SE=243.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1160,TO=1160,SC=250.00,SH=243.00,SE=243.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1170,TO=1170,SC=250.00,SH=243.00,SE=243.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1180,TO=1180,SC=250.00,SH=243.00,SE=243.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=410,TO=410,SC=250.00,SH=243.00,SE=243.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=420,TO=420,SC=250.00,SH=243.00,SE=243.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=430,TO=430,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=440,TO=440,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=445,TO=445,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=450,TO=450,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=460,TO=460,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=480,TO=480,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=485,TO=485,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=485,TO=420,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=500,TO=500,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=510,TO=1010,SC=250.00,SH=250.00,SE=250.00
```

```
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1510,TO=1510,SC=250.00,SH=243.00,SE=243.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1530,TO=1530,SC=250.00,SH=243.00,SE=243.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1540,TO=1540,SC=250.00,SH=243.00,SE=243.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1550,TO=1550,SC=250.00,SH=243.00,SE=243.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1600,TO=1600,SC=250.00,SH=243.00,SE=243.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1610,TO=1610,SC=250.00,SH=243.00,SE=243.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1620,TO=510,SC=250.00,SH=243.00,SE=243.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=520,TO=1050,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1700,TO=1700,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1710,TO=1710,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1720,TO=1720,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1730,TO=1730,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1740,TO=1740,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1750,TO=1750,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1760,TO=1760,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2000,TO=2000,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2010,TO=2000,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2020,TO=2020,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2030,TO=2030,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2040,TO=2040,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2050,TO=2050,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2060,TO=2060,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2070,TO=2070,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2080,TO=2080,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2090,TO=2090,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2090,TO=510,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2200,TO=2200,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2210,TO=2210,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2220,TO=2220,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2230,TO=2230,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2240,TO=2240,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2245,TO=2245,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
```

```
B313,FROM=2250,TO=2250,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2270,TO=2270,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2280,TO=2280,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2290,TO=2290,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2300,TO=2300,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2305,TO=2305,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2310,TO=2310,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2315,TO=2315,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2320,TO=2320,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2330,TO=2330,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2340,TO=2340,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2350,TO=2350,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2360,TO=2360,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2370,TO=2370,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2500,TO=2500,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2520,TO=2520,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2530,TO=2530,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2540,TO=2540,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2550,TO=2550,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2555,TO=2555,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2560,TO=2560,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2570,TO=2570,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2580,TO=2580,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2590,TO=2590,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2600,TO=2600,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2605,TO=2605,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2610,TO=2610,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2620,TO=2620,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2630,TO=2630,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2640,TO=2640,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2650,TO=2650,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2660,TO=2660,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2670,TO=2670,SC=207.00,SH=207.00,SE=207.00
```

```
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2680,TO=2680,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2690,TO=2690,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2700,TO=2700,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2710,TO=2710,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2720,TO=2720,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2720,TO=2710,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1310,TO=1310,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1320,TO=1320,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1330,TO=1330,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1335,TO=1335,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=1350,TO=2500,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2800,TO=2800,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2810,TO=2810,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2820,TO=2820,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2830,TO=2830,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2840,TO=2840,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2850,TO=2850,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2860,TO=2860,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2870,TO=2870,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2900,TO=2900,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2910,TO=2900,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2920,TO=2920,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2930,TO=2930,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2940,TO=2940,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=2940,TO=2920,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3000,TO=3000,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3010,TO=3010,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3020,TO=3020,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3030,TO=3030,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3050,TO=3050,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3060,TO=3060,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3065,TO=3065,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
```

```
B313,FROM=3070,TO=3070,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3080,TO=3080,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3090,TO=3090,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3100,TO=3100,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3110,TO=3110,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3120,TO=3120,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3130,TO=3130,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3140,TO=3140,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3150,TO=3150,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3155,TO=3155,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3160,TO=3160,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3170,TO=3170,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3180,TO=3180,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3190,TO=3190,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3200,TO=3200,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3210,TO=3210,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3220,TO=3220,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3230,TO=3230,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3240,TO=3240,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3250,TO=3250,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3260,TO=3260,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3270,TO=3270,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3280,TO=2290,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3500,TO=3500,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3510,TO=3510,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3520,TO=3520,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3530,TO=3530,SC=250.00,SH=241.00,SE=241.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3540,TO=3540,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3550,TO=3550,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3560,TO=3560,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=3110,TO=2555,SC=250.00,SH=250.00,SE=250.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=4000,TO=2690,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=4010,TO=3155,SC=207.00,SH=207.00,SE=207.00
```

```
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=4020,TO=2530,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=4030,TO=3130,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
B313,FROM=4040,TO=4040,SC=207.00,SH=207.00,SE=207.00
 F=1,Y=0.4,K=1.33,MTP=12.5
X
END
```

APPENDIX E: THE APPROPRIATE FATIGUE DESIGN CURVE (S-N CURVES)

Class	Constants of S–N curve				Stress range at $N = 10^7$ cycles
	for $N < 10^7$ cycles		for $N > 10^7$ cycles		
	m	A[a]	m	A[a]	N/mm^2
C[b]	3.5	4.22×10^{13}	5.5	2.55×10^{17}	78
D	3	1.52×10^{12}	5	4.18×10^{15}	53
E	3	1.04×10^{12}	5	2.29×10^{15}	47
F	3	6.33×10^{11}	5	1.02×10^{15}	40
F2	3	4.31×10^{11}	5	5.25×10^{14}	35
G	3	2.50×10^{11}	5	2.05×10^{14}	29
W	3	1.58×10^{11}	5	9.77×10^{13}	25

[a] For $E = 2.09 \times 10^5$ N/mm^2.

[b] If $S_r > 766$ N/mm^2 or $N < 3\ 380$ cycles, use class D curve.

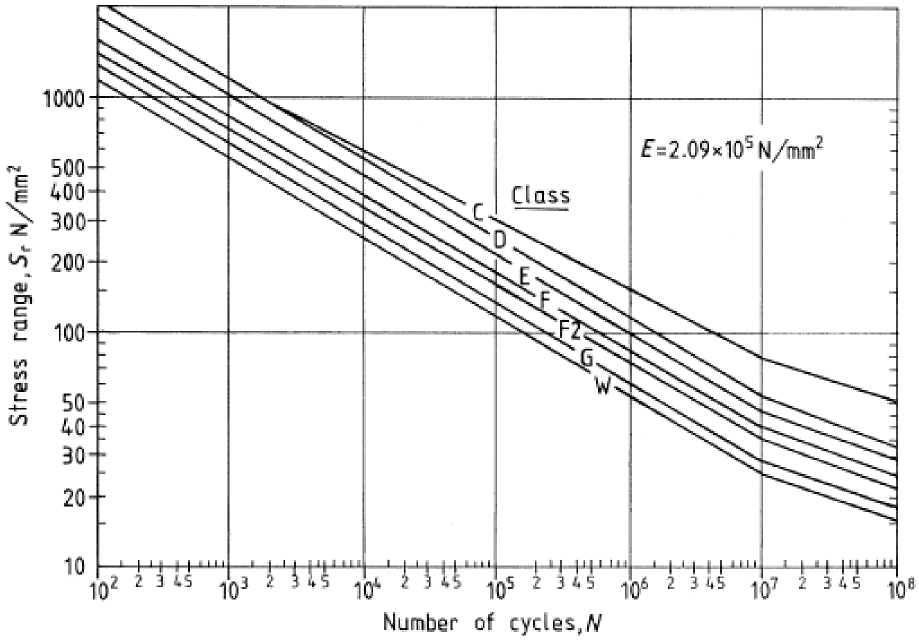


Figure C.3 — Fatigue design S–N curves for weld details applicable to ferritic steels up to and including 350 °C, austenitic stainless steels up to and including 430 °C and aluminium alloys up to and including 100 °C

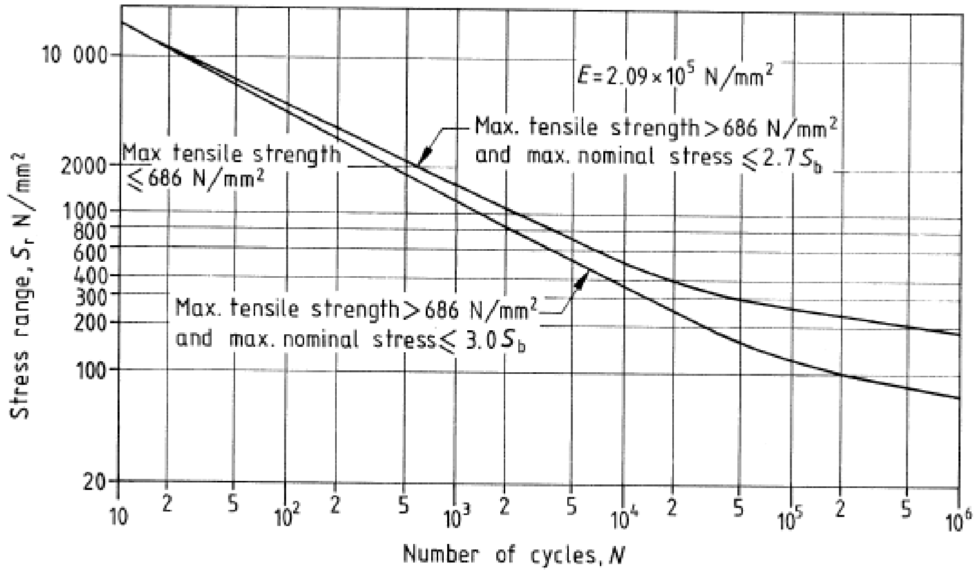
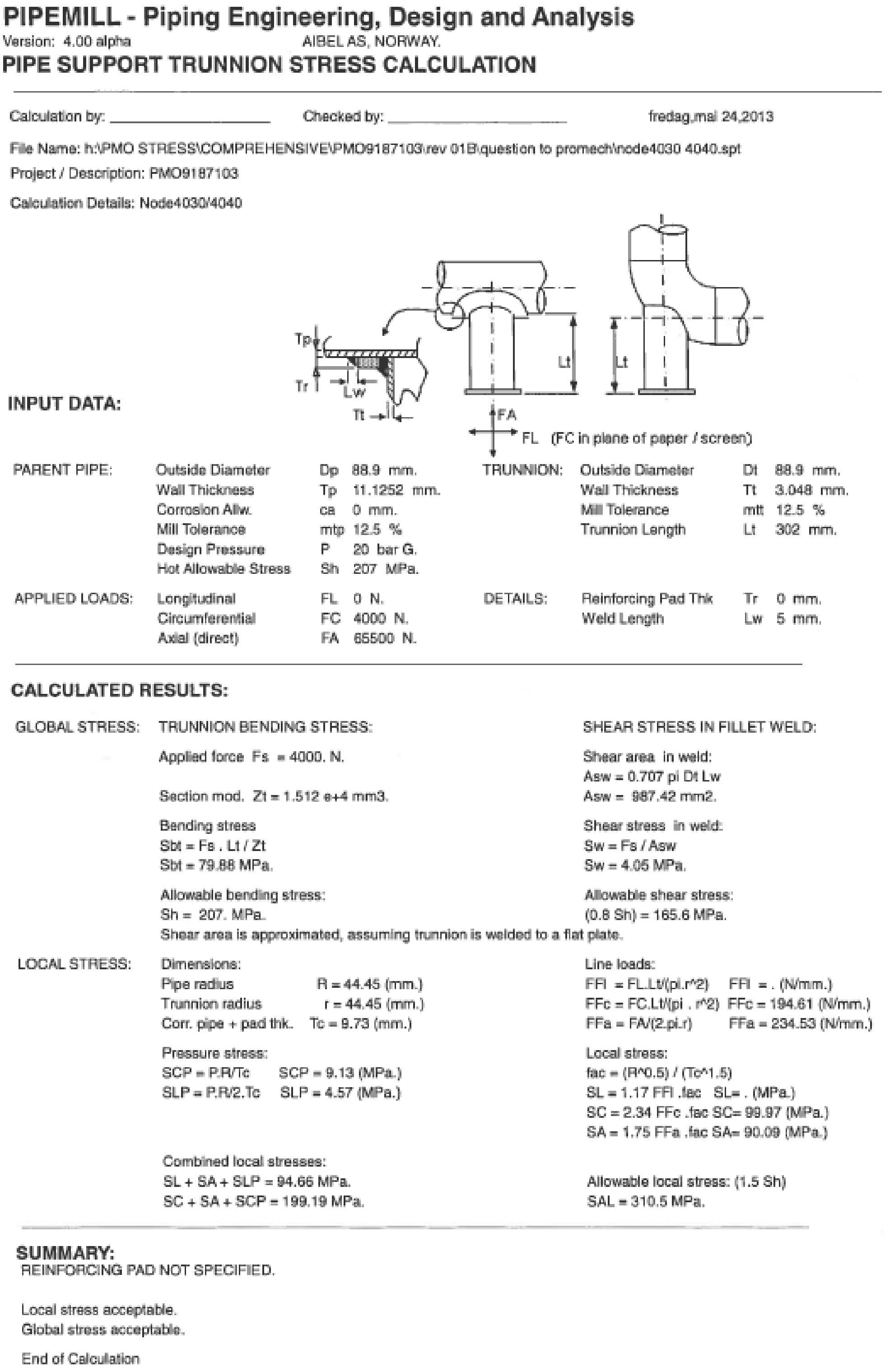


Figure C.4 — Fatigue design *S–N* curves for bolting applicable to ferritic steels up to and including 350 °C, austenitic stainless steels up to and including 430 °C and aluminium alloys up to and including 100 °C

APPENDIX F: PIPE SUPPORT TRUNNION STRESS CALCATION



PIPEMILL - Piping Engineering, Design and Analysis

Version: 4.00 alpha AIBEL AS, NORWAY.

PIPE SUPPORT TRUNNION STRESS CALCULATION

Calculation by: ____________________ Checked by: ________________________ fredag,mai 24,2013

File Name: h:\PMO STRESS\COMPREHENSIVE\PMO9187103\rev 01B\question to promech\node4030 4040.spt

Project / Description: PMO9187103

Calculation Details: Node4030/4040

INPUT DATA:

(FC in plane of paper / screen)

PARENT PIPE:	Outside Diameter	Dp	88.9 mm.	TRUNNION:	Outside Diameter	Dt	88.9 mm.
	Wall Thickness	Tp	11.1252 mm.		Wall Thickness	Tt	3.048 mm.
	Corrosion Allw.	ca	0 mm.		Mill Tolerance	mtt	12.5 %
	Mill Tolerance	mtp	12.5 %		Trunnion Length	Lt	302 mm.
	Design Pressure	P	20 bar G.				
	Hot Allowable Stress	Sh	207 MPa.				
APPLIED LOADS:	Longitudinal	FL	0 N.	DETAILS:	Reinforcing Pad Thk	Tr	0 mm.
	Circumferential	FC	4000 N.		Weld Length	Lw	5 mm.
	Axial (direct)	FA	65500 N.				

CALCULATED RESULTS:

GLOBAL STRESS: TRUNNION BENDING STRESS:

Applied force Fs = 4000. N.

Section mod. Zt = 1.512 e+4 mm3.

Bending stress
Sbt = Fs . Lt / Zt
Sbt = 79.88 MPa.

Allowable bending stress:
Sh = 207. MPa.

SHEAR STRESS IN FILLET WELD:

Shear area in weld:
Asw = 0.707 pi Dt Lw
Asw = 987.42 mm2.

Shear stress in weld:
Sw = Fs / Asw
Sw = 4.05 MPa.

Allowable shear stress:
(0.8 Sh) = 165.6 MPa.

Shear area is approximated, assuming trunnion is welded to a flat plate.

LOCAL STRESS: Dimensions:

Pipe radius	R = 44.45 (mm.)
Trunnion radius	r = 44.45 (mm.)
Corr. pipe + pad thk.	Tc = 9.73 (mm.)

Pressure stress:
SCP = P.R/Tc SCP = 9.13 (MPa.)
SLP = P.R/2.Tc SLP = 4.57 (MPa.)

Line loads:
FFl = FL.Lt/(pi.r^2) FFl = . (N/mm.)
FFc = FC.Lt/(pi . r^2) FFc = 194.61 (N/mm.)
FFa = FA/(2.pi.r) FFa = 234.53 (N/mm.)

Local stress:
fac = (R^0.5) / (Tc^1.5)
SL = 1.17 FFl .fac SL= . (MPa.)
SC = 2.34 FFc .fac SC= 99.97 (MPa.)
SA = 1.75 FFa .fac SA= 90.09 (MPa.)

Combined local stresses:
SL + SA + SLP = 94.66 MPa.
SC + SA + SCP = 199.19 MPa.

Allowable local stress: (1.5 Sh)
SAL = 310.5 MPa.

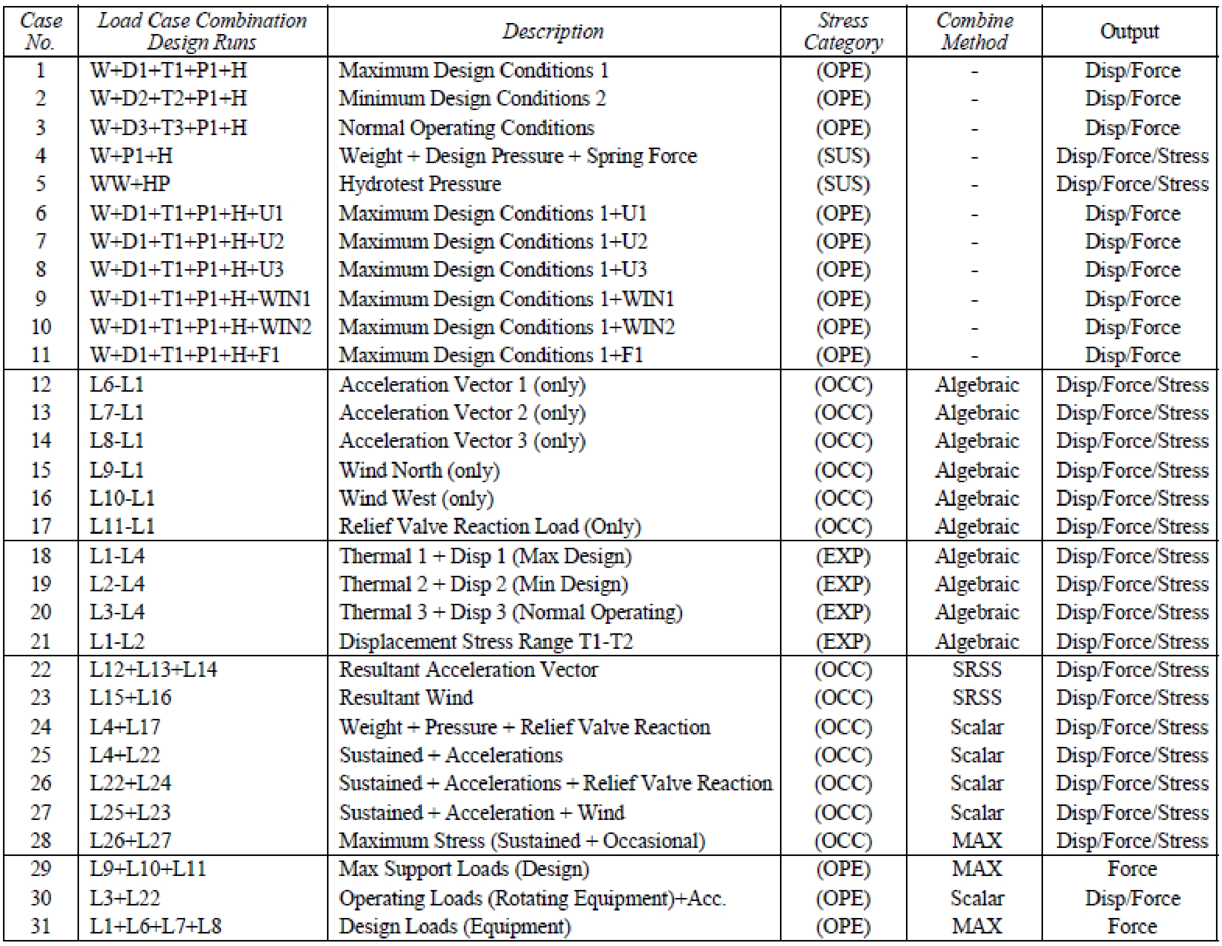
SUMMARY:
REINFORCING PAD NOT SPECIFIED.

Local stress acceptable.
Global stress acceptable.

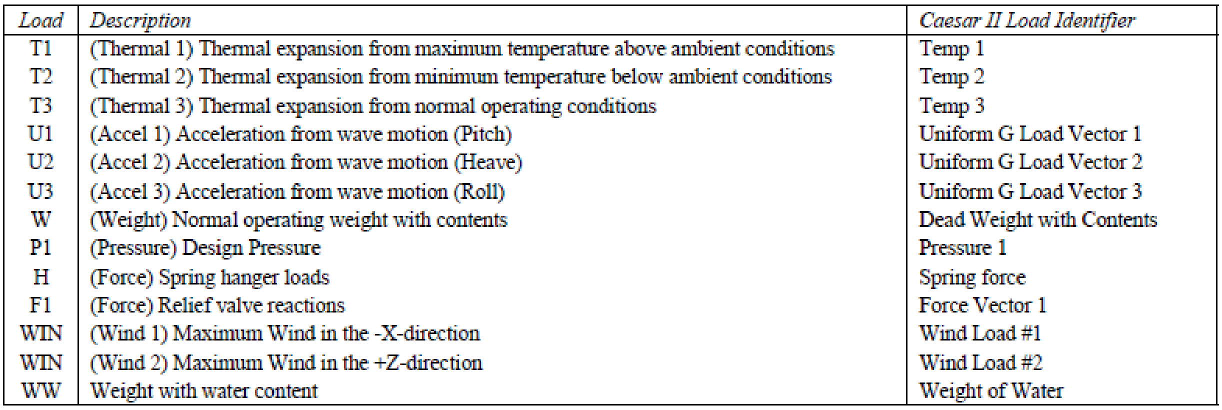
End of Calculation

APPENDIX G: TYPICAL LOAD CASE COMBINATION

Typical project load case combinations for operatinal and occasional loads. (Accidental blast loads and other accidental loads have to be treated separately). (DNV, 2008)



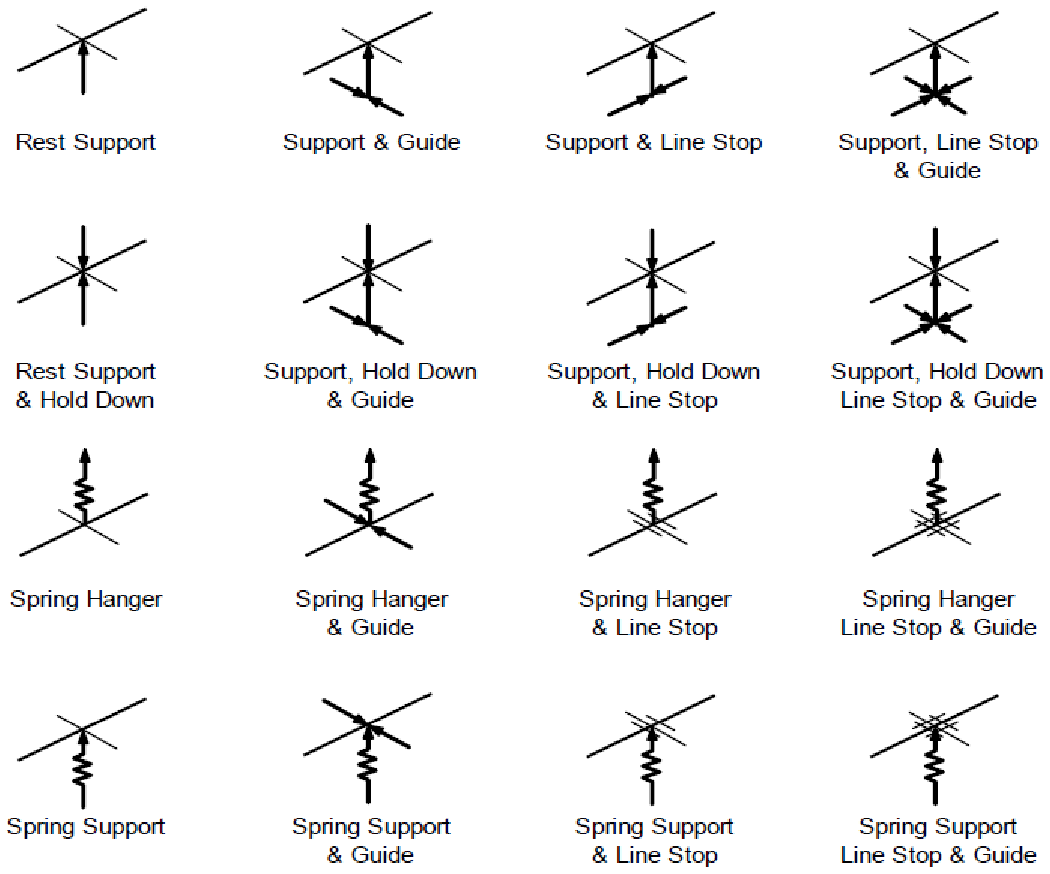
Case No.	*Load Case Combination Design Runs*	*Description*	*Stress Category*	*Combine Method*	Output
1	W+D1+T1+P1+H	Maximum Design Conditions 1	(OPE)	-	Disp/Force
2	W+D2+T2+P1+H	Minimum Design Conditions 2	(OPE)	-	Disp/Force
3	W+D3+T3+P1+H	Normal Operating Conditions	(OPE)	-	Disp/Force
4	W+P1+H	Weight + Design Pressure + Spring Force	(SUS)	-	Disp/Force/Stress
5	WW+HP	Hydrotest Pressure	(SUS)	-	Disp/Force/Stress
6	W+D1+T1+P1+H+U1	Maximum Design Conditions 1+U1	(OPE)	-	Disp/Force
7	W+D1+T1+P1+H+U2	Maximum Design Conditions 1+U2	(OPE)	-	Disp/Force
8	W+D1+T1+P1+H+U3	Maximum Design Conditions 1+U3	(OPE)	-	Disp/Force
9	W+D1+T1+P1+H+WIN1	Maximum Design Conditions 1+WIN1	(OPE)	-	Disp/Force
10	W+D1+T1+P1+H+WIN2	Maximum Design Conditions 1+WIN2	(OPE)	-	Disp/Force
11	W+D1+T1+P1+H+F1	Maximum Design Conditions 1+F1	(OPE)	-	Disp/Force
12	L6-L1	Acceleration Vector 1 (only)	(OCC)	Algebraic	Disp/Force/Stress
13	L7-L1	Acceleration Vector 2 (only)	(OCC)	Algebraic	Disp/Force/Stress
14	L8-L1	Acceleration Vector 3 (only)	(OCC)	Algebraic	Disp/Force/Stress
15	L9-L1	Wind North (only)	(OCC)	Algebraic	Disp/Force/Stress
16	L10-L1	Wind West (only)	(OCC)	Algebraic	Disp/Force/Stress
17	L11-L1	Relief Valve Reaction Load (Only)	(OCC)	Algebraic	Disp/Force/Stress
18	L1-L4	Thermal 1 + Disp 1 (Max Design)	(EXP)	Algebraic	Disp/Force/Stress
19	L2-L4	Thermal 2 + Disp 2 (Min Design)	(EXP)	Algebraic	Disp/Force/Stress
20	L3-L4	Thermal 3 + Disp 3 (Normal Operating)	(EXP)	Algebraic	Disp/Force/Stress
21	L1-L2	Displacement Stress Range T1-T2	(EXP)	Algebraic	Disp/Force/Stress
22	L12+L13+L14	Resultant Acceleration Vector	(OCC)	SRSS	Disp/Force/Stress
23	L15+L16	Resultant Wind	(OCC)	SRSS	Disp/Force/Stress
24	L4+L17	Weight + Pressure + Relief Valve Reaction	(OCC)	Scalar	Disp/Force/Stress
25	L4+L22	Sustained + Accelerations	(OCC)	Scalar	Disp/Force/Stress
26	L22+L24	Sustained + Accelerations + Relief Valve Reaction	(OCC)	Scalar	Disp/Force/Stress
27	L25+L23	Sustained + Acceleration + Wind	(OCC)	Scalar	Disp/Force/Stress
28	L26+L27	Maximum Stress (Sustained + Occasional)	(OCC)	MAX	Disp/Force/Stress
29	L9+L10+L11	Max Support Loads (Design)	(OPE)	MAX	Force
30	L3+L22	Operating Loads (Rotating Equipment)+Acc.	(OPE)	Scalar	Disp/Force
31	L1+L6+L7+L8	Design Loads (Equipment)	(OPE)	MAX	Force



Load	*Description*	*Caesar II Load Identifier*
T1	(Thermal 1) Thermal expansion from maximum temperature above ambient conditions	Temp 1
T2	(Thermal 2) Thermal expansion from minimum temperature below ambient conditions	Temp 2
T3	(Thermal 3) Thermal expansion from normal operating conditions	Temp 3
U1	(Accel 1) Acceleration from wave motion (Pitch)	Uniform G Load Vector 1
U2	(Accel 2) Acceleration from wave motion (Heave)	Uniform G Load Vector 2
U3	(Accel 3) Acceleration from wave motion (Roll)	Uniform G Load Vector 3
W	(Weight) Normal operating weight with contents	Dead Weight with Contents
P1	(Pressure) Design Pressure	Pressure 1
H	(Force) Spring hanger loads	Spring force
F1	(Force) Relief valve reactions	Force Vector 1
WIN	(Wind 1) Maximum Wind in the -X-direction	Wind Load #1
WIN	(Wind 2) Maximum Wind in the +Z-direction	Wind Load #2
WW	Weight with water content	Weight of Water

APPENDIX H: RESTRAINT SYMBOLS

Typical descriptions are: RS = Rest Support, HD =Hold Down, LG =Line Guide, LS = Line Stop. Restraint description for a coordinate system with the +Y axis pointing upwards could then be: LGX = Line Guide in ±X direction, LGZ = Line Guide in ± Z direction, LSX = Line Stop in ± X direction, LSZ = Line Stop in ± Z direction. (DNV, 2008)



Rest Support

Support & Guide

Support & Line Stop

Support, Line Stop & Guide

Rest Support & Hold Down

Support, Hold Down & Guide

Support, Hold Down & Line Stop

Support, Hold Down Line Stop & Guide

Spring Hanger

Spring Hanger & Guide

Spring Hanger & Line Stop

Spring Hanger Line Stop & Guide

Spring Support

Spring Support & Guide

Spring Support & Line Stop

Spring Support Line Stop & Guide

Figure 45: Restraint symbols