TABLE OF CONTENTS

CHAPTER 1 : INTRODUCTION

CHAPTER 2 : LITERATURE REVIEW

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

GDC	Gas District Cooling
UTP	Universiti Teknologi Petronas
GTG	Gas Turbine Generator
HRSG	Heat Recovery Steam Generator
SAC	Steam Absorbtion Chiller
TES	Thermal Energy Storage
ACC	Air Cooled Chiller
AGB	Auxiliary Gas Boiler
ASME	American Society of Mechanical Engineers
DCR	Distributed Control Room
PGB	PETRONAS Gas Berhad
P&ID	Piping and Instrumentation Diagram
JIS	Japan International Standard
NPS	Nominal Pipe Size

CHAPTER 1

INTRODUCTION

1.1 Background Study

A Gas District Cooling (GDC) system in UTP is a centralized energy plant that generates chilled water for air-conditioning requirements of buildings within a district which is within UTP compound. Compared with conventional air-conditioning systems, the district cooling system uses energy more efficiently because a single system applies over a wide area and to various buildings, levels off the energy load and saves fuel. In addition, the cooling plant has a dual function of co-generating electricity and thermal energy which can reduce the dependency on the Malaysia's National Electricity Grid [1].

There are several sub-systems systems available in the GDC UTP plant:

a) Gas Turbine Generator (GTG) system
b) Heat Recovery Steam Generator (HRSG) system
c) Steam Absorption Chiller (SAC) system
d) Thermal Energy Storage (TES) system
e) Air Cooled Chiller (ACC) system

At the GDC UTP plant, natural gas, piped in from the source is fired to drive gas turbines, producing electricity which is supplied to UTP and also consumed within the plant. The exhaust heat that is cogenerated with the electricity is then harnessed to produce steam which is used to drive the steam-driven chillers that chill the water. The chilled water produced is piped to UTP buildings. Once thermally spent, the water returns to the plant to be re-chilled [1].

Various types of fluids are being transported in GDC UTP plant. There are basically natural gas, diesel, chilled water and instrument air. These fluids are conveyed through series of piping systems stretching across the whole plant. The piping systems consist of pipes as small as 2” in diameter up to 30” in diameter. Of all the piping system existed in GDC UTP plant, not all consists of critical piping system. The selection of piping categories is based on the conditions specified in the project design criteria. The conditions can be the temperature, pressure or even the size of that pipe.

Only the critical piping systems need to undergo thorough stress analysis to determine its allowable stress range in the pipe. This is because only the critical piping systems are exposed to serious condition hence making the pipe exposed to various form of failures. Analysis needs to be carried out in order to determine the limiting values of the forces and moments which the pipe is permitted to impose [2].

Pipe stress analysis is the study of pipes in a plant system to ensure that the developed stresses and equipment nozzle loads are less than the specified allowable under operating conditions of a particular system and even during the most stringent operating conditions [2]. It is a term applied to calculations, which address the static and dynamic loading resulting from the effects of gravity, temperature changes, internal and external pressures, changes in fluid flow rate and seismic activity [3]. Codes and standards establish the minimum requirements of stress analysis as each system may cover different codes and standards depending on the design. Codes and standards used may also differ according to the type of process involved in the plant where different codes will give different sets of limitations.

1.2 Problem Statement

1.2.1 Problem Identification

The Gas District Cooling (GDC) UTP plant construction began in 2001 and was commissioned in April 2003 to supply both chilled water and electricity to the Universiti Teknologi Petronas (UTP) campus in Tronoh, Perak. There are various kinds of piping systems available in the plant where the pipes are identified according to the fluids that they convey. In a plant, pipes are the main transportation medium for almost all the processes and also very critical to ensure the smooth running of the plant. Pipes that undergo severe stresses will affect greatly on the performance of the plant

To date, no study was conducted to check the stresses that may be present in the critical piping system at GDC UTP plant and its future performance. In this study, stresses in the critical piping system are identified to be one of the causes for failure of the plant in the future performance. Thus, the reliability and the integrity of the current design of the piping system need to be verified so any rectification can be made to improve the plant's performance.

1.2.2 Significant of Project

GDC UTP plant is the supplier for electricity and also chilled water for air-conditioning in UTP. With such major contribution to UTP, the study concerning the stresses of the critical pipe in GDC plant of UTP is really crucial to determine the performance of the plant in the future. With the completion of this project, it is hoped that it would clearly explains the stresses that occur in the piping system of GDC UTP plant and also discover any stress problems in the piping system.

The study would also be important to identify potential problems in the critical piping system so that rectifications can be made to improve the design of the pipe in order to minimize the stresses exerted on the pipe. The information gained from this study would also initiate further studies to be conducted in examining stresses on the pipe and hence, a more precise way of designing a pipe will be made.

1.3 Objectives and Scope of Study

The main objectives of this project are:

a) To determine the critical piping systems in the GDC UTP plant.
b) To verify the critical piping systems and determine the stresses as per the governing codes.
c) To recommend methods of rectification in order to improve the plant’s piping integrity

The scope of this study would be to evaluate the stresses in the piping systems where individual pipe are examined and studied independently so that only the critical piping system are chosen. The characteristics of each piping system such as size, material and thickness are studied to determine which pipe has the required criteria for critical system. The critical pipings are then analyzed for stresses involved and check whether current installation of pipes exerts stresses that are allowed by the governing code. Lastly, any rectification would be made prior to any problems encountered during analysis of the stresses.

Due to lack of time, this study is not aimed at all available piping system. Instead, only the critical piping are being studied. Though there may not be a precise explanation about some stresses due to constraint of sources, the general comparative discussion of the results would give some general idea of the stresses that may happen in the critical piping system

CHAPTER 2

LITERATURE REVIEW

2.1 Gas District Cooling in UTP

Gas District Cooling (GDC) system in UTP has been designed to produce electrical power and steam from Cogeneration System located at Cogeneration Plant, and chilled water from chilled water system (District Cooling Plant). Electrical power produced from Cogeneration system is supplied not only to UTP buildings but also to the plant itself. However, steam from the Cogeneration system is mainly used to produce chilled water by using the Steam Absorption Chiller (SAC) [4].

The purpose of adopting GDC system in UTP:

a) To utilize natural gas as primary energy for the plant that will improve the problem of peak load demand of electricity, and improve the electrical supply/demand balance in Malaysia
b) To supply reliable chilled water within a temperature range of 6.0°C±0.5°C in 30 minutes average
c) To optimize the utilization of primary energy by incorporating Cogeneration (GTG/HRSG) System.
d) To adapt proven technology for a long-term operational reliability
e) To adapt environmental friendly system

The current system consists of 2 nos. of SAC, 4 nos. of Air Cooled Chiller (ACC) and 1 no. of Thermal Energy Storage (TES) which can cover cooling demands of 4000 Refrigerant Tonnage (expected cooling demand in 1A Stage) from buildings in UTP. 2 nos. of Gas Turbine Generator (GTG) with Heat Recovery Steam Generator (HRSG) are installed in 1A Stage Cogeneration Plant, which are able to generate up to 8.4MW (maximum) of electrical power [4,5].

Figure 2.1 shows the system of GDC UTP. There are additional 2 nos. of SAC, 1 unit of Auxiliary Gas Boiler (AGB) with a capacity of 6 ton/h which are used as back-up system to supply steam to SAC to produce chilled water.

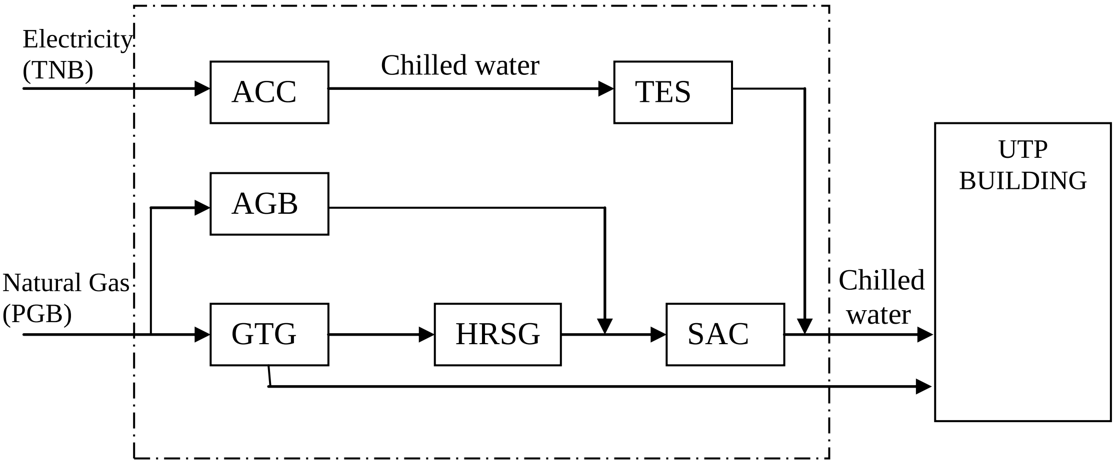


Figure 2.1 : District Cooling System

In GDC plant, GTG which utilizes natural gas as its primary source of energy is operating daily in order to produce and supply electric power to UTP buildings and for internal plant usage. Natural gas used is supplied by Petronas Gas Berhad through gas pipelines that stretched all the way from Lumut to UTP. The piping system that connects the source of gas and to the turbine is quite critical and important since gas is the main source of energy to run the turbine in order to generate electricity.

Currently, there are two GTGs running to produce electricity which can generate up to 8.4MW of electricity. UTP only consumes around 5 to 6MW of electricity which is below the maximum power that the GTGs can supply (8.4MW). Besides supplying electricity to UTP buildings, the plant also consumes the electricity produced by GTG for in-plant use to run other equipments in the plant.

GTG (see **Figure 2.2**) will produce waste heat at about 500°C. Waste heat from GTG is used to produce steam through HRSG then supplied to SAC for the chillers to produce chilled water for UTP buildings.

Figure 2.2 : Gas Turbine of GDC plant

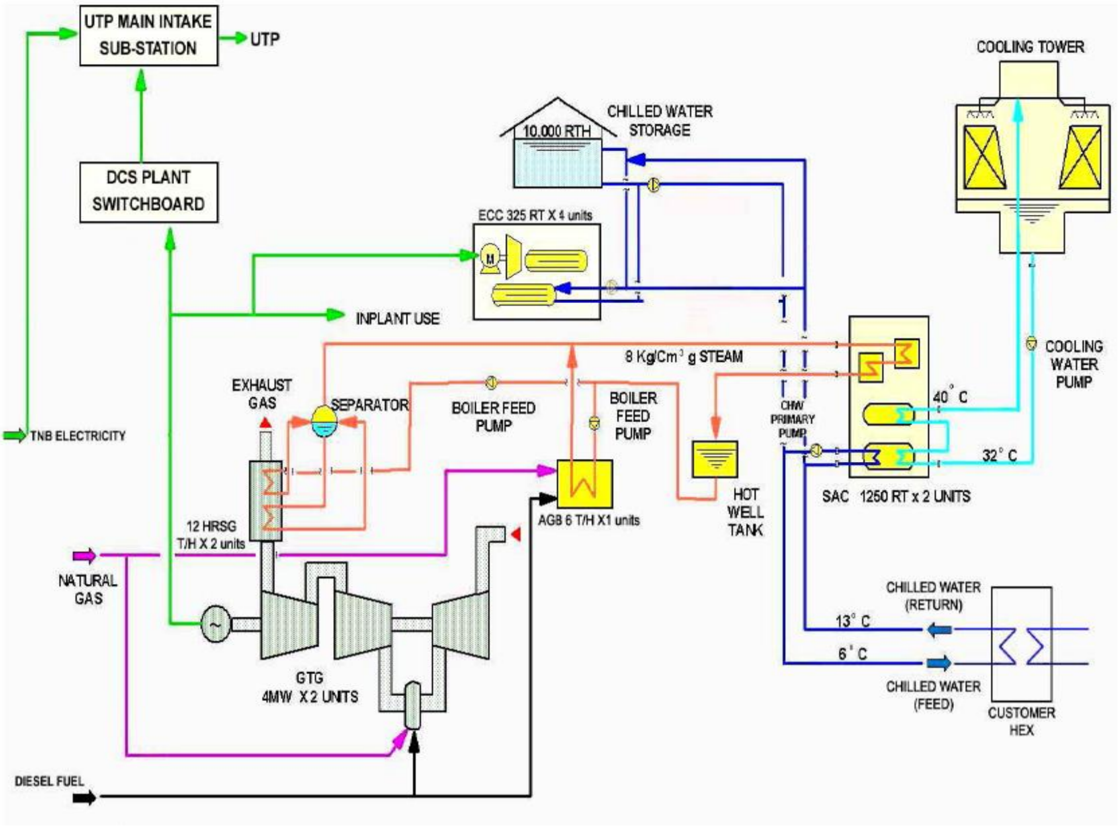


Figure 2.3 : Schematic drawing of the plant

Chilled water will be transported through pipelines to academic blocks, chancellor hall and also to the new mosque. **Figure 2.3** shows the feed chilled water to UTP is at 6°C and will be returned back to the plant at about 13.5°C. The returned water is then chilled back by SAC to 6°C and feed back to UTP again. Both SACs will be operating during daytime at normal operation mode and at least one will be running during night time due to low demand from UTP.

Thermal Energy Storage (TES) tank is another source of chilled water that is used to supply chilled water during daytime (peak hours) where during night time, TES tank is being charged by Air Cooled Chiller (ACC). Besides charging the TES tank, ACC is also capable to supply chilled water directly to UTP during very low demand situation from UTP or when the TES system is under maintenance.

2.2 Piping System at GDC UTP

Piping system take up almost half of GDC plant of UTP. There is a number of piping system available in GDC plant in UTP due to the fact that GDC itself consists of many systems (e.g GTG, HRSG, SAC system etc). There are pipes for every subsystem of the plant. Pipes are installed to connect one equipment to another. Identification of the criticality for each pipe based on its operating condition is important as this will lead to the selection of critical system to be analyzed in the later stage of this study.

The critical piping system may consist of pipes that undergo large stresses due to the mechanical equipment involved in that system. It also can be caused by elevated temperature on the pipe itself for example at GTG system where the heat from exhaust gas can reach up to 500°C [4]. The critical piping may also lead to overstressing and overloading of piping components (flanges, valves etc) and also the connection of equipment [6].

Distributed Control Room (DCR) is a room used to observe the plant operation. From DCR, the condition for each equipment and piping system can be monitored at the centralized computers. This condition includes temperature, pressure, flow rate of fluid in the system and also power supplied by GTG. For temperature, pressure and flow rate the conditions vary for each system. From the DCR, Field Operator (FO) and engineers can determine which system is having problem. When problems detected, engineers can make changes on the setting of the equipment involved to meet the required conditions.

There are four (4) major types of fluids being used in GDC plant of UTP. They are used to differentiate the piping system. They are:

a) Gas
b) Fuel
c) Chilled water
d) Instrument air

Each fluid has different conditions in term of operating temperature and pressure depending on the process the fluid undergone. This factor will be used to identify which type of system that can be considered as critical.

2.2.1 Gas (Natural Gas) Piping System

Gas is used as the primary energy supplyto power the two GTGs. For UTP GDC plant, they use Natural Gas supplied by Petronas Gas Berhad (PGB) through underground pipelines. Natural gas is used as it is cheap. Besides GTG, gas is also used as the energy supply for AGB.

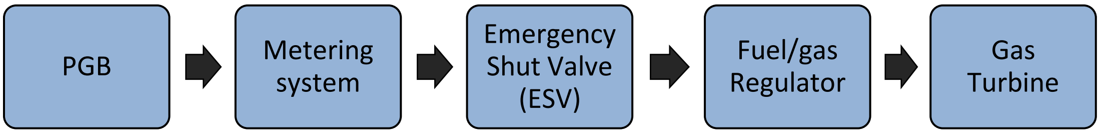


Figure 2.4 : Gas Piping System For GTG

Figure 2.4 shows that gas from PGB will be transported to GDC plant through underground pipelines where it goes through metering system first. From there, gas will be transported to Emergency Shut Valve (ESV) through 4” pipes. ESV is used to shut or cut the gas flows to the next process if there is any failure or accident occurs in the system. From **Figure 2.5**, the gas will be supplied to gas regulator through 4” pipe from ESV. Gas regulator is used to ensure that the pressure of the supplied gas to the gas turbine will be 18 bar or 1800kpa. Any excess pressure of supplied gas will cause the GTG to not working at its full performance or may cause failure to GTG.

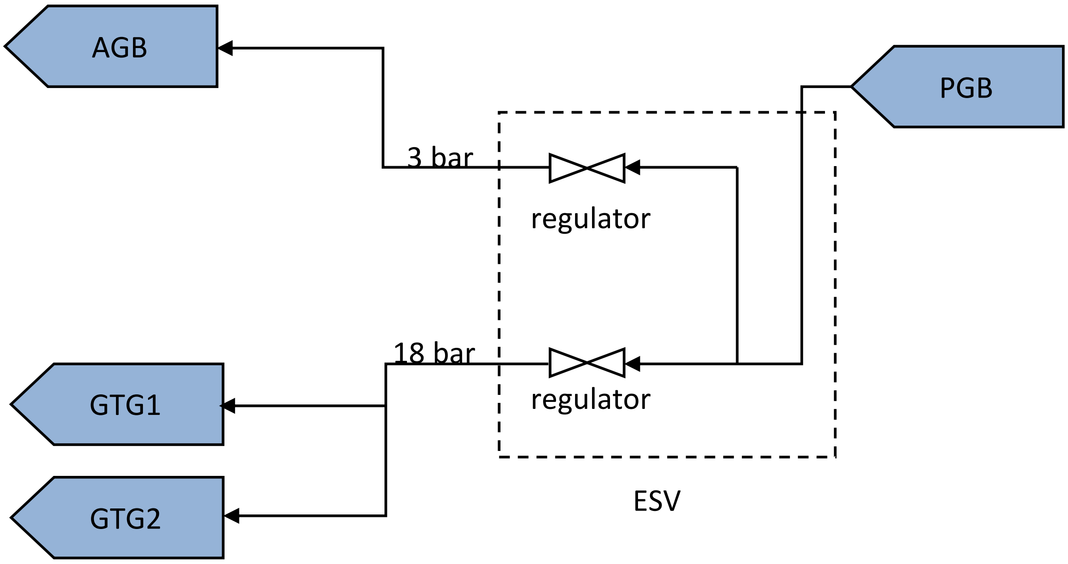


Figure 2.5 : Schematic Diagram For Gas System

2.2.2 Liquid Fuel (Diesel) Piping System

Liquid Fuel (Diesel) is used as a backup energy supply for AGB and GTG. When there is disruption to gas supply to GTG and AGB, diesel fuel will be used. GDC plant uses diesel as the secondary energy supply. Unlike gas, diesel is stored first in a diesel tank before being used (see **Figure 2.6**). The diesel will only be used at conditions when there is no supply of natural gas to GTG due to cut-off at the distribution pipeline. Diesel from storage tank is pumped to GTGs and AGB to operate.

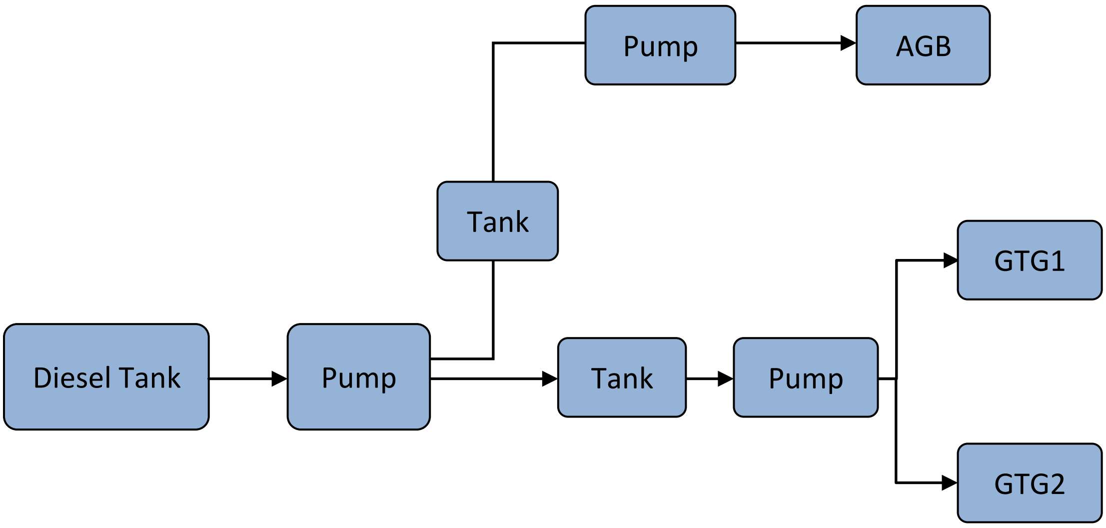


Figure 2.6 : Diesel Piping System

2.2.3 Chilled Water Piping System

Chilled water is supplied by SAC, ACC and TES tank as in **Figure 2.7**. The supplied chilled water to UTP is 6°C in temperature and will be returned back to GDC plant at about 13.5°C. The chilled water is transported through series of piping systems and pumps. The chilled water is used to cool down UTP building like academic blocks, chancellor hall and also the new mosque through air-conditioning.

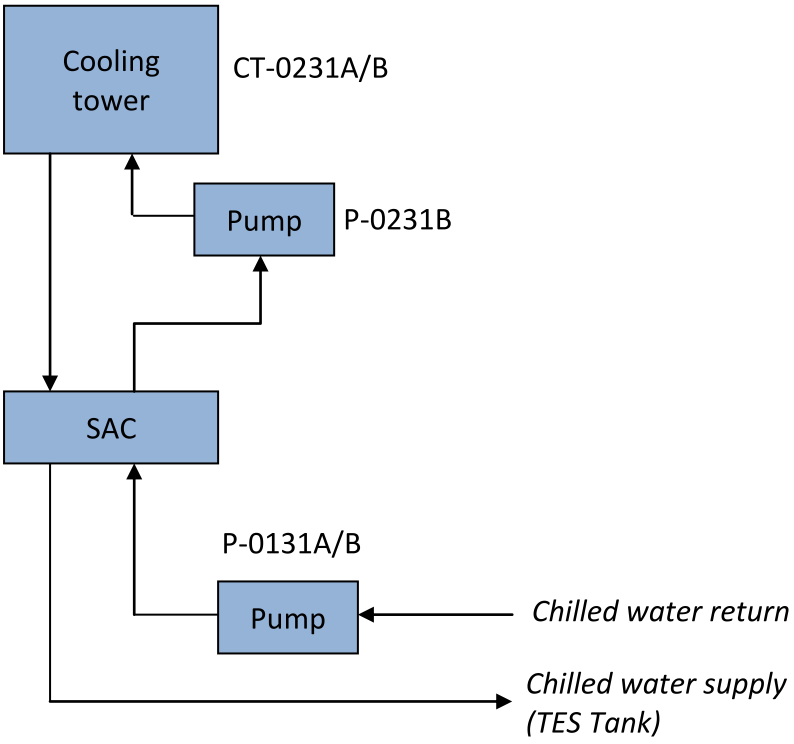


Figure 2.7 : Chilled Water Piping System

The pressure for the fluid (chilled water) in the piping system is around 2.5 bar or 250kpa. There are pumps used to flow the supply and return water. Pumps (P-0231A/B and P-0131) have flow rates of 920m³/h and 504m³/h respectively. These pumps will be a major equipment to pressurize and flow the chilled water and any failure to this equipment or any disturbance to piping system can cause problems (disruptions to flows) to the plant and to the air-conditioning system in UTP buildings.

In chilled water systems, water as a secondary refrigerant, is distributed throughout the entire hydraulic network in order to achieve the design heat transfer in every coil of the building. A heat load is the rate of heat transfer from the case coils required to maintain an environment comfort standard [16].

Water (make-up) will be supplied to the cooling tower (CT-0231A/B) by Lembaga Air Perak. Type of cooling tower used in GDC UTP is square counter flow cooling tower which has a circulating water flow rate of 966m³/h. In the plant, make-up water pipe is represented by blue color pipe. From cooling tower, the water will be pumped to SAC for cooling and the pipe is represented as green color pipe.

2.2.4 Instrument Air Piping System

Instrument air is used to operate instrument valves that regulate pressure, flow, temperature and liquid levels [7]. These valves are used in almost all mechanical equipment in GDC plant such as GTG, HRSG etc. There are located at pipes connected to all mechanical equipments. Any interruption or failure in the instrument air piping system can cause the equipment failure or even shut down of the plant (GDC).

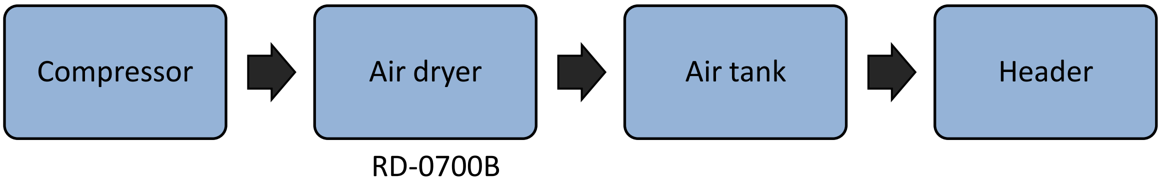


Figure 2.8 : Flow Diagram For Instrument Air

Figure 2.8 shows the flow diagram for instrument air in GDC plant. Air Compressor produces pressurized or compressed air in this piping system. The compressed air goes through air dryer (RD-0700B) to get rid any moisture from the air. From there, it is be stored in the air tank before it will be sent to headers for it to operate the valves.

Instrument air is used to operate valve actuator; sensor, signal converter or other devices that requires some finite volume of air to operate instead of manually operate the device. Other uses of instrument quality air include pneumatic motors, pumps, chucks, and convenience outlets for tools and other irregularly used devices [8].

2.3 Pipe Stress Analysis

Stress analysis determines the stress in materials and structures (In this case pipes) subjected to static or dynamic forces or loads. The aim of the analysis is usually to determine whether the element or collection of elements, usually referred to as a structure, can safely withstand the specified forces. Pipe stress analysis provides the essential technique to design piping system without overstressing and overloading the piping components and connected equipments [6].

2.3.1 Purpose of Pipe Stress Analysis

Basically, the purpose of pipe stress analysis is to ensure:

a) Safety of piping and piping components
b) Safety of connected equipment and supporting structure
c) Piping deflections are within limits
d) System stresses are within those allowed by the applicable or governing code (e.g ASME B31.3)
e) Selection of the right type of pipe supports
f) Piping loads are within the acceptable limits of the designed pipe supports and structural members

2.3.2 Governing Codes

Governing code refers to the applicable pipe design and fabrication code [9,13,14]. The codes are:

a) ASME B31.1 for power plant piping.
b) ASME B31.3 for chemical process plant piping.
c) ASME B31.4 for oil transmission pipelines.
d) ASME B31.5 for refrigeration piping.
e) ASME B31.8 for gas transmission pipelines.
f) ASME B31.9 for gas, steam and water building services piping.
g) ASME B31.11 for slurry transportation piping.
h) AWWA for water works piping.
i) NFPA-13 and -24 for fire protection mains and sprinkler systems

Among the variables that are regularly used in this analysis are force and moment. Force is a vector quantity with the direction and magnitude of the push (compression), pull (tension), or shear effects. Moment is a vector quantity with the direction and magnitude of twisting and bending effects [6].

In addition to forces and moments, stress and strain are also important in the analysis. Stress can be defined as the internal resistance per unit area to the deformation caused by the applied load while strain is unit deformation under applied load. The relationship between stress and strain can be seen in a curve when unit load or stress is plotted against unit elongation, technically known as strain [6].

2.3.3 Types of Major Stresses

There are three (3) major categories of stresses:

a) Primary stresses
b) Secondary stresses
c) Peak stresses

Primary stresses are developed by the imposed loading and are necessary to satisfy the equilibrium between external and internal forces and moments of the piping system. Primary stresses include:

a) Direct Longitudinal and circumferential stress due to internal pressure
b) Bending stress and torsional stress due to dead load, snow and ice load, wind and earthquake load.
c) Direct bending and torsional stress due to restrained thermal loading, which is due to external forces from anchored pipe.

Secondary stresses are developed by the constraint of displacements of a structure. These displacements can be caused either by thermal expansion or by outwardly imposed restraint and anchor point movements. For peak stresses, they cause no significant distortion. Peak stresses are the highest stresses in the region under consideration and are responsible for causing fatigue failure as explained in [3].

2.3.4 Type of Loads

There are three (3) types of loads occur in a piping system [2]. They are:

a)	Sustained	-	Self weight of pipe and contents plus loads due to pressure and any other sustained forces
b)	Occasional	-	Loads due to wind and earthquake or other occasional sources
c)	Displacement	-	Loads due to thermal expansion or contradiction due to temperature differentials form both the external conditions and the content of the pipe

The allowable stresses for each type of load are as follows:

Sustained

$$S_L \leq S_H \tag{1}$$

Occasional

$$S_L \leq 1.33 S_H \tag{2}$$

Thermal (Displacement)

$$S_A = f\left(1.25 S_C + S_H\right) \tag{3}$$

When S_H is greater than S_L , the difference between them may be added to the term $0.25 S_H$ in Eq. (3). This is called *Liberal Allowable Stresses*. The allowable stress range hence is calculated by:

$$S_A = f\left[1.25\left(S_C + S_H\right) - S_L\right] \tag{4}$$

Where:

S_L = The sum of longitudinal stresses in any component in a piping system, due to pressure, weight, and other sustained loadings

S_H = Basic allowable stress (HOT) at maximum metal temperature expected during the displacement cycle under analysis

S_C = Basic allowable stress (COLD) at minimum metal temperature expected during the displacement cycle under analysis

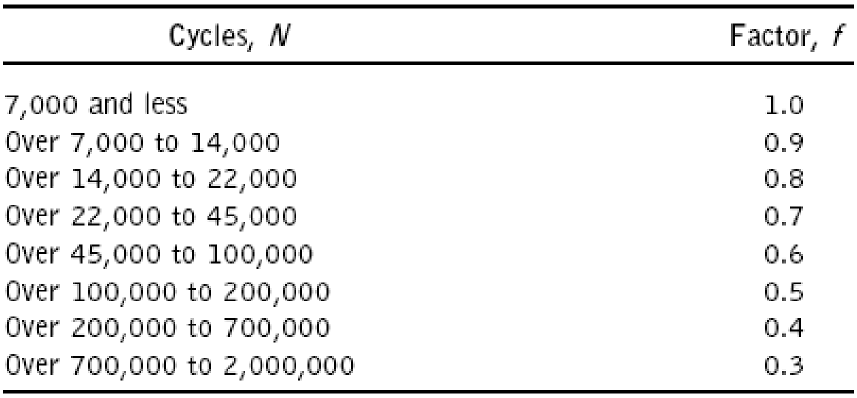
f = Stress reduction factor (fatigue) from **Table 2.1**

S_A = Allowable displacement stress range

N = Equivalent number of full displacement cycles during the expected service life of the piping system

The expression liberal stresses will only be employed when there is at least one sustained stress case in the load set. If there is more than one sustained stress case in a single problem, then the largest of S_L, considering all of the sustained cases, for any single element end will be chosen to subtract from S_H. Because the sustained stress varies from one pipe to another, the allowable expansion stress will also vary [10].

Table 2.1 : Stress-range reduction factors, *f*



Cycles, N	Factor, f
7,000 and less	1.0
Over 7,000 to 14,000	0.9
Over 14,000 to 22,000	0.8
Over 22,000 to 45,000	0.7
Over 45,000 to 100,000	0.6
Over 100,000 to 200,000	0.5
Over 200,000 to 700,000	0.4
Over 700,000 to 2,000,000	0.3

The range of bending and torsional stresses shall be computed using the reference modulus of elasticity at 21°C (70°F), E_a, to determine the computed displacement stress range S_E, which shall not exceed the allowable stress range S_A

Bending Stress

Bending stress is the normal stress that is induced at a point in a body subjected to loads that cause it to bend. When a load is applied perpendicular to the length of a beam (with two supports on each end), bending moments are induced in the beam

$$\sigma = \frac{Mc}{I} \tag{5}$$

Where:

σ = Bending stress

M = Moment at cross section

c = Distance from neutral axis to outer surface

I = Cross section moment of inertia, $I = \frac{\pi}{64}({d_o}^4 - {d_i}^4)$

Hoop Stress

Hoop stress is a mechanical stress defined for rotationally-symmetric objects being the result of forces acting circumferentially

$$\sigma_h = \frac{Pd}{2t} \tag{6}$$

Where:

σ_h = Hoop Stress

P = Internal Pressure in Pipe

d = Internal Diameter of pipe

t = Wall thickness of pipe

Axial Stress

Axial stress is a stress exerted by a force along the axis of the pipe

$$\sigma_a = \frac{F}{A} = \frac{Pd^2}{(d+2t)^2 - t^2} \tag{7}$$

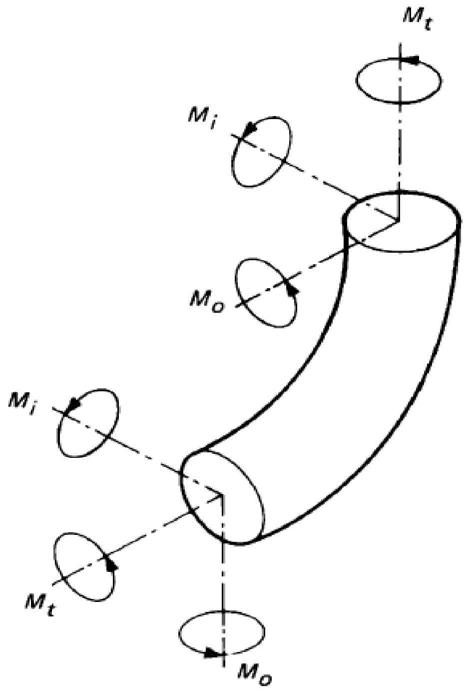


Figure 2.9 : Moments In Bends

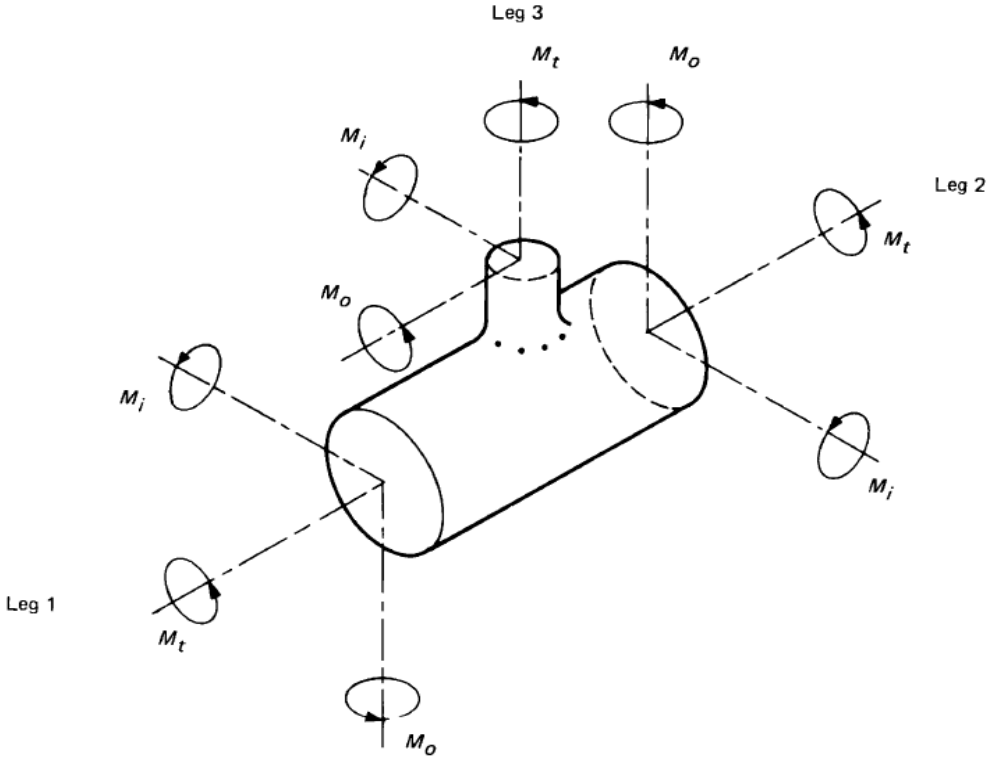


Figure 2.10 : Moments In Branch Connection

$$S_b = \frac{\sqrt{(i_i M_i)^2 + (i_o M_o)^2}}{Z} \tag{8}$$

where

S_b = Resultant bending stress

i_i = In-plane stress intensification factor from Appendix 2

i_o = Out-plane stress intensification factor from Appendix 2

M_i = In-plane bending moment

M_o = Out-plane bending moment

Z = Section modulus of pipe

For analyzed piping, allowable axial force and bending moment shall be within the limits specified below.

The Total Pressure $P_T = P_{eq} + P_D$ (9)

The equivalent pressure $P_{eq} = \frac{4F}{(\pi G^2)} + \frac{16M}{(\pi G^3)}$ (10)

Where:

P_{eq} = Equivalent pressures due to pipe loading only
F = Tensile axial force acting at the flange
M = Bending moment acting at the flange
G = Effective gasket diameter (reactive load location)
P_D = Design pressure
P_T $\leq$ 1.5 times pressure limit of the flange as per ASME B16.5

Such calculations are called *Flange Leakage Calculation* where it is used to determine the stress level at each flange nozzles and check whether it is within the stress allowable limit.

For process plant, the use of ASME B31.3 Process Piping code is widely being used. This code governs all piping within the property limits of facilities engaged in the processing or handling of chemical, petroleum or related products. Examples are a chemical plant, petroleum refinery, loading terminal, natural gas processing plant, bulk plant, compounding plant and tank farm. The loadings required to be considered are pressure, weight (live and dead loads), impact, wind, earthquake-induced horizontal forces, vibration discharge reactions, thermal expansion and contraction, temperature gradients and anchor movement [10,15]. Under ASME B31.3, the allowable stresses for each type of load are different and hence to comply with the code each of the three allowable stresses must be satisfied [2]. The code also states that the allowable stress is temperature dependent (i.e as temperature increases, allowable stress decreases) [2].

For this project, the use of ASME B31.1 Power Piping code will be used due to the type of plant for GDC of UTP. The code is basically for piping typically found in electric power generating stations, in industrial and institutional plants, geothermal heating systems, and central and district heating and cooling systems [17].

Power piping systems shall be designed to have sufficient flexibility to prevent pipe movements from causing failure from overstress of the pipe material or anchors, leakage at joints, or detrimental distortion of connected equipment resulting from excessive thrusts and moments. Flexibility shall be provided by changes of direction in the piping through the use of bends, loops, or offsets; or provisions shall be made to absorb thermal movements by utilizing expansion, swivel, or ball joints, corrugated pipe, or flexible metal hose assemblies [17].

In this project, the use of stress analysis software (CAESAR II 5.0) is needed in order to ease the job analyzing the critical pipes. The software allows quick and accurate analysis of piping system subjected to wide variety of loads that take in account weight, pressure, thermal, seismic and other static and dynamic conditions.

CHAPTER 3

METHODOLOGY

3.1 Project Work

Figure 3.1 shows the procedures that have been followed in order to carry out and implement the project. This is to ensure that the project can be accomplished within the given timeframe. A Gantt chart of the project is as attached in **APPENDIX 1**.

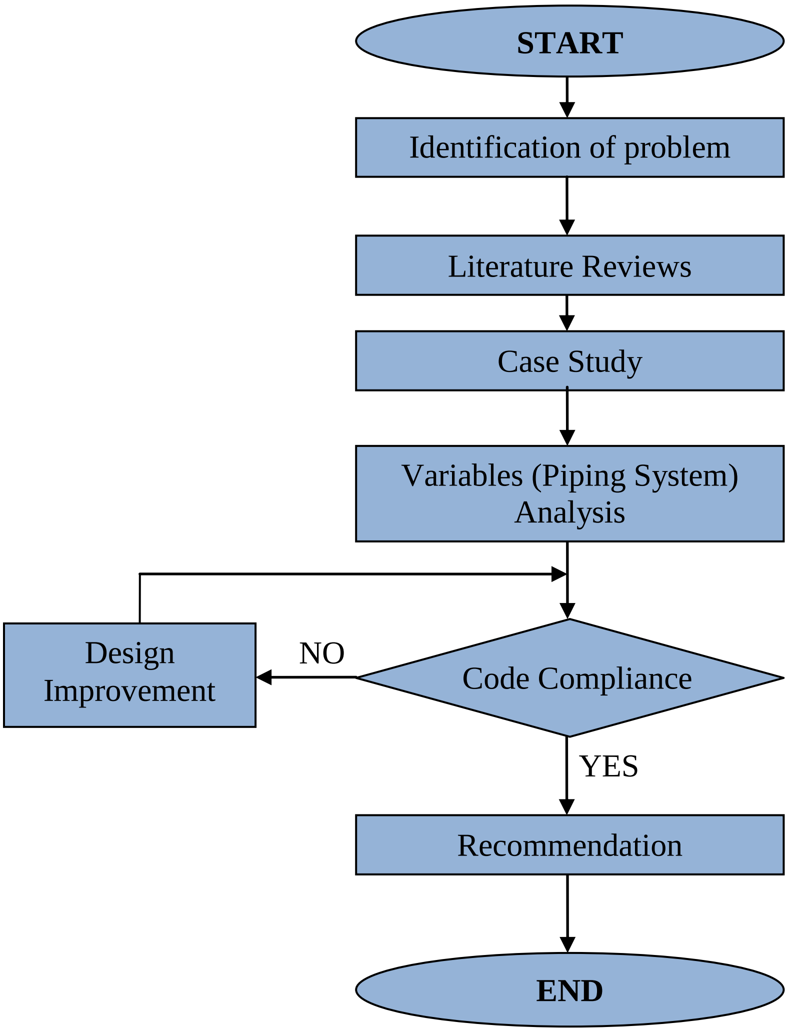


Figure 3.1 : Flowchart For The Project

3.1.1 Literature Review

Research on elements of this project involved in this stage where it includes the study of GDC plant operation, piping system at GDC and also piping stress analysis. Visits to GDC plant were made in order to get first-hand information and experience regarding the plant's operation. By doing this, the author can understand more on the plant's operation and relate the operation to the case study of this project.

Apart from that, the identification of the piping systems in the plant was made to differentiate the type of piping system available there. There is basically a number of piping systems installed in the plant. The study will only highlight the critical piping system in the plant since the systems are dealing with higher level of stresses compared to non-critical system. In order to do this, familiarization with the plant's system was emphasized first in order to determine the critical systems.

Research on journals, engineering books and design manuals were also conducted in this stage to understand more about the study especially regarding piping stress analysis. Data from the plant such as isometric drawing, plant layout and plant's equipment specification were also obtained to help the study.

3.1.2 Case Study

The study focuses the critical piping system of the plant. Critical piping systems in GDC plant shall be identified in order to finalize the systems that will be studied. As mentioned earlier, only the critical piping systems will be studied instead of all the systems. In order to do this, the author needs to check all the piping system's specifications with the plant's personnel. By referring to all the specifications, the piping systems are categorized according to the piping system's condition. There are:

a) Temperature
b) Pressure
c) Pipe geometry
d) Pipe Dimension
e) Fluids flowing through the system
f) Equipment connected to the pipe

From the information collected, the author can then specify which systems will be taken for further analysis. The specified systems will be called as variables. Variables definition is the first task in analyzing a pipe system [2]. Generally the extent of a piping system is defined by the following criteria:

a) Common process conditions
b) Connections to equipment or vessels
c) Common pipe materials and piping specifications – although it is quite acceptable to have a variety of materials and specifications within a single analysis

A system may consist of one line of pipe, a group of lines or a whole network complete with branches [2].

The three methods of pipe flexibility assessment:

a) Category 1 lines – Visual Analysis

All lines under this category are exempted from a formal analysis.

b) Category 2 lines – Simplified Analysis

Formal Analysis Not Required. No formal analysis of adequate flexibility is required for a piping system which:

- Duplicates, or replaces without significant change, a system operating with a successful service record
- Can readily be judged adequate by comparison with previously analyzed system
- Is of uniform size, has no more than two points of fixation, no intermediate restraints and falls within the limitations of empirical.

c) Category 3 lines (Critical Line) – Comprehensive Analysis

All the pipes in the lines shall be analyzed using stress analysis software (e.g CAESAR II 5.0). Piping geometry will be modeled based on the latest piping isometrics available during the analysis

Category 3 lines are referred as critical lines. These lines are the ones that shall be chosen to be analyzed comprehensively using stress analysis software. The criteria for selecting the critical line is shown in **Table 3.1**

Table 3.1 : Line Selection Criteria

No.	Line Descriptions	Temp. Ranges (°C) (Design)	Diameter Range (NS)	Analysis Category
1.	Connections to pressure vessels, heat exchangers, air coolers (process connection)	All	80 & below	1
		All	≥100	**3**
2.	Connections to reciprocating & rotating equipment (process connection)	All	40 & below	1
		All	≥50	**3**
3.	Pressure relief/blowdown system/vent systems (except for direct atmospheric discharge vents	All	≤40	1
		All	≥50	**3**
4.	Low temperature	≤-20 & below	≤80	1
		≤-20 & below	≥100	**3**
5.	Line subject to large terminal displacements	All	≥80	**3**
		All	≤50	2
6.	Mechanical Vibration	All	All	**3**
7.	High temperature service general piping	209 & above	≤50	1
			≤80	2
			≥100	**3**
		121 to 208	≤50	1
			≤150	2
			≥200	**3**
		≤120	≤100	1
			≤250	2
			≥300	**3**
8.	High pressure service (class 900 & above)	All	≤80	2
		All	≥100	**3**
9.	Large diameter lines	All	250 to 350	2
		All	≥400	**3**
10.	Connection to tanks	All	≤100	1
		All	≤250	2
		All	≥300	**3**

Variables Analysis (Piping Stress)

Analysis is conducted on the chosen variables. In this project, CAESAR II 5.0 software is used to model the geometry of the variables and also to conduct analysis. The pipes are modeled according to the design or layout of the piping system. In order to ensure the smoothness of the analysis, some essentials steps need to be taken accordingly. **Figure 3.2** shows the flow of the analysis

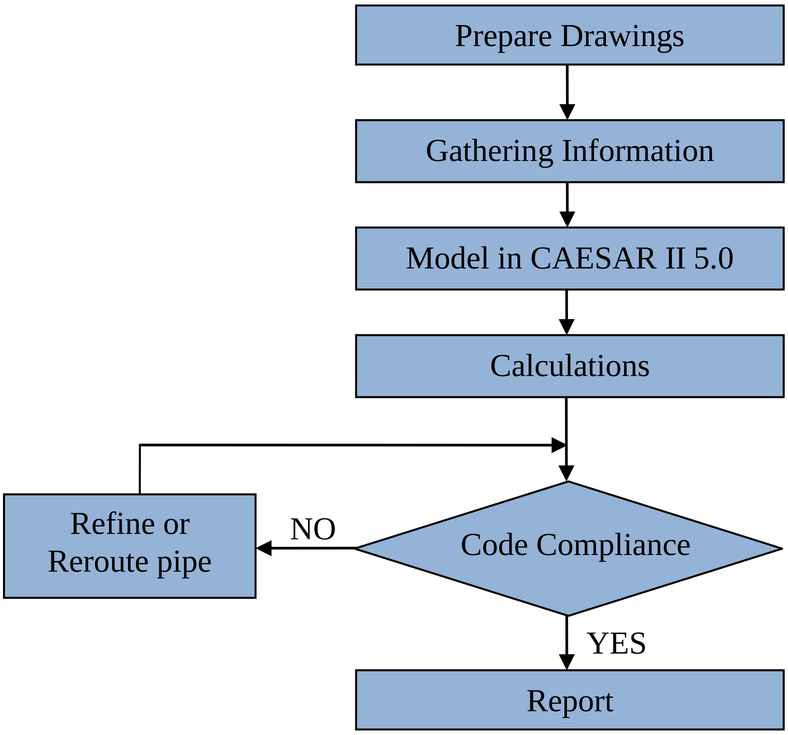


Figure 3.2 : Flowchart For The Analysis Work

Steps in analyzing a piping system using CAESAR II 5.0 software:

a) Drawings of the piping system (P&ID and Pipe Isometric Drawing) are acquired first in order to know the geometry and orientation of the piping system. Isometric drawings are obtained from the plant and the example of the pipe's isometric drawing is shown in **Figure 3.3.** From the isometric drawing, the 3-axis; x-axis, y-axis and z-axis are pre-determined first in order to ease the modeling task. **Figure 3.3** shows the axis that has been determined. Z-axis is set to be pointing towards south.

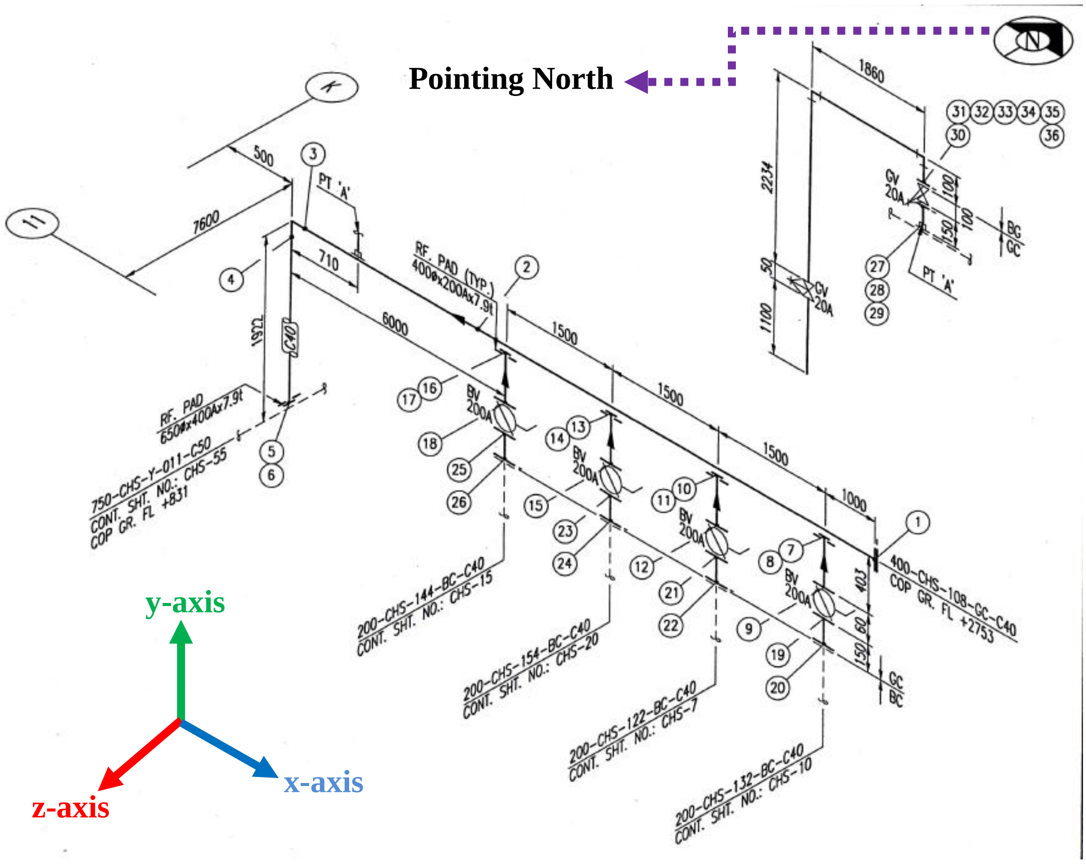


Figure 3.3 : Isometric Drawing for CHS-108-P1A

b) Information about the piping system are also obtained first in order to key in the data into CAESAR II 5.0 software. All the data are acquired from the plant's piping specification.

The information needed is as follows:

- Nominal pipe size, schedule and material
- Corrosion allowance
- Operating temperature and pressure
- Properties at boundaries, like displacements, restrains and hangers
- Piping code
- Insulation thickness and density
- Content density

c) After all the information is prepared, the piping system are modeled by using CAESAR II. Pipes are modeled according to the isometric drawing of the system. The pipes are divided into nodes to ease the modeling. Nodes for each point of the pipe were initialized first to ease the work. The more the number of nodes, the easier it is to track which point is having certain type or amount of stress. **Figure 3.4** shows the nodes in the modeled pipe.

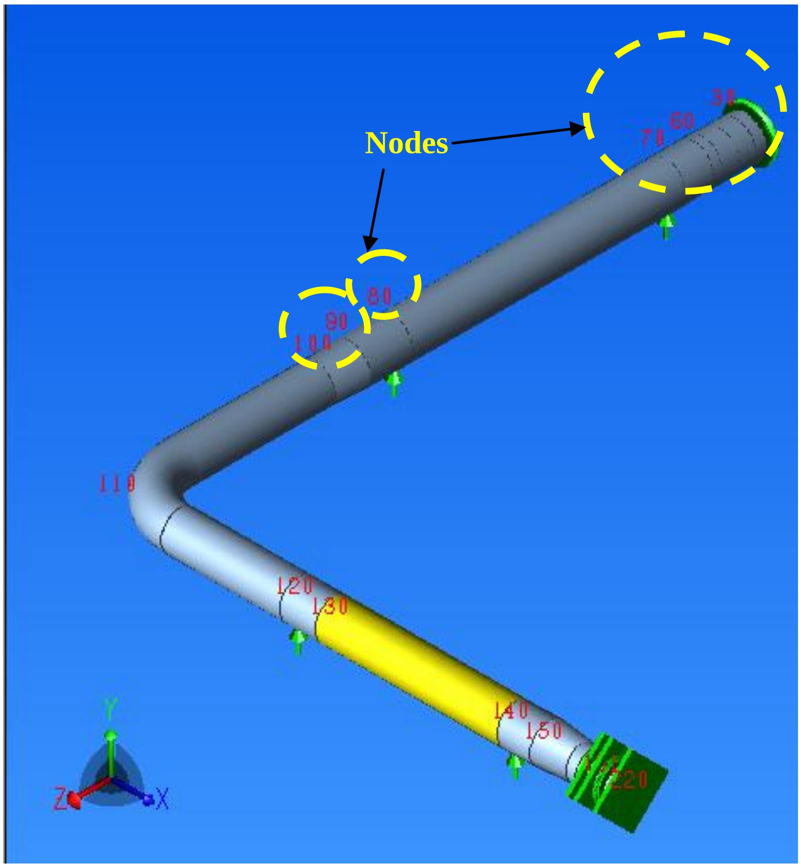
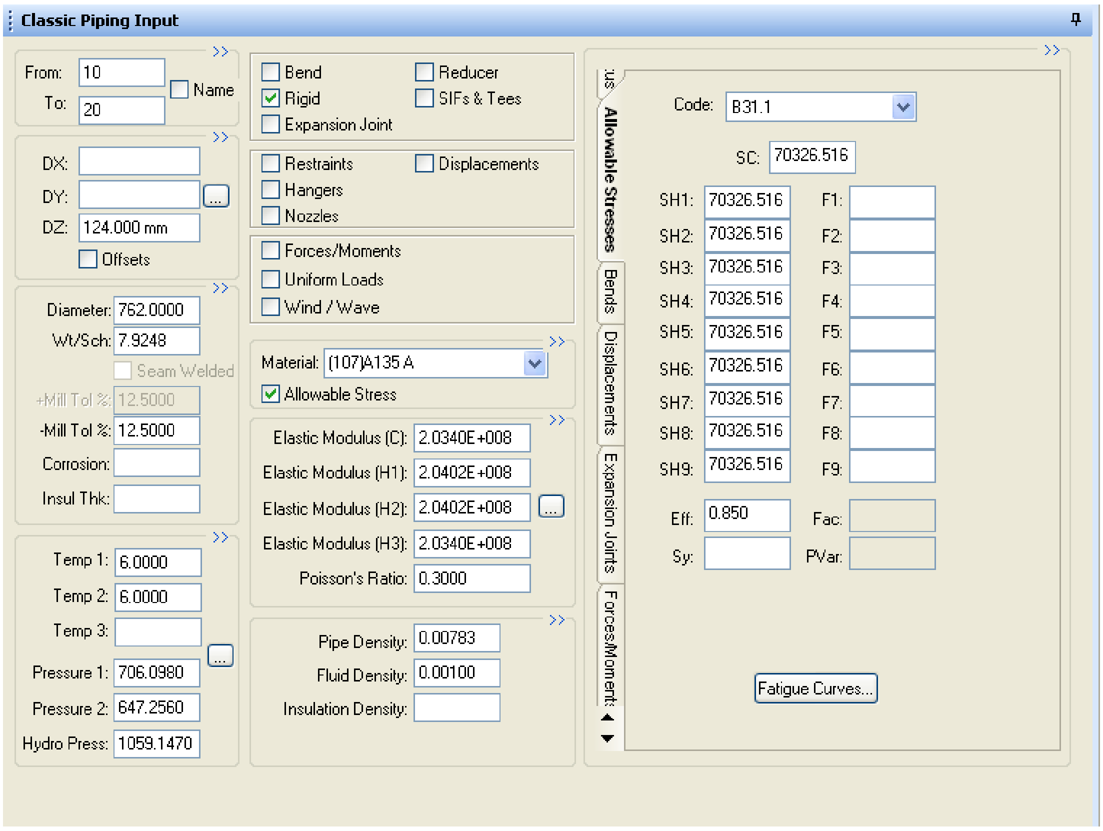


Figure 3.4 : Nodes in Pipe Modeling

If there are any valves or flanges in the piping system, they will be represented as a rigid body in CAESAR II with the exact weight of each component. The best place to initially define the extent of piping systems is on a process flow diagram or a P&ID [2]. After an initial pass at defining the extent of the systems, a preliminary review of system geometry should be made. Always keep the option open to split systems into separate calculations or combine systems into a single calculation as the piping becomes more defined.

d) All the data required for the analysis earlier (as in piping schedule and isometric drawings) were put in to the stress spreadsheet as in **Figure 3.5.** The data will then be converted into modeled pipe.



From: 10
To: 20
☐ Name
DX:
DY:
DZ: 124.000 mm
☐ Offsets
Diameter: 762.0000
Wt/Sch: 7.9248
☐ Seam Welded
+Mill Tol %: 12.5000
-Mill Tol %: 12.5000
Corrosion:
Insul Thk:
Temp 1: 6.0000
Temp 2: 6.0000
Temp 3:
Pressure 1: 706.0980
Pressure 2: 647.2560
Hydro Press: 1059.1470

☐ Bend ☐ Reducer
☑ Rigid ☐ SIFs & Tees
☐ Expansion Joint
☐ Restraints ☐ Displacements
☐ Hangers
☐ Nozzles
☐ Forces/Moments
☐ Uniform Loads
☐ Wind / Wave
Material: (107)A135 A
☑ Allowable Stress
Elastic Modulus (C): 2.0340E+008
Elastic Modulus (H1): 2.0402E+008
Elastic Modulus (H2): 2.0402E+008
Elastic Modulus (H3): 2.0340E+008
Poisson's Ratio: 0.3000
Pipe Density: 0.00783
Fluid Density: 0.00100
Insulation Density:

Code: B31.1
SC: 70326.516
SH1: 70326.516 F1:
SH2: 70326.516 F2:
SH3: 70326.516 F3:
SH4: 70326.516 F4:
SH5: 70326.516 F5:
SH6: 70326.516 F6:
SH7: 70326.516 F7:
SH8: 70326.516 F8:
SH9: 70326.516 F9:
Eff: 0.850 Fac:
Sy: PVar:

Figure 3.5 : CAESAR II 5.0 Spreadsheet

e) After the pipe system has been modeled, calculation for the piping system is made. The calculations are generated for CAESAR II with given load cases. Load cases are the type of load that we intent to put on the system. As mentioned in the previous chapter, the loads could be sustained loads, occasional loads and displacement loads. This load could be for operating condition of the system or design condition which refers to the maximum load applied according to the design specifications.

f) Next, the result of the calculation will be generated by CAESAR II and will be displayed in various forms of output:

  - Displacements (system deflection)
  - Restraint loads
  - Stresses
  - Code Compliance (system’s governing code)

g) Reports of each output are obtained after analyzing the piping system. The reports are really important because each of these report provide specific information as to how the system is reacting to a given load condition.

3.1.3 Results/Analysis

The result obtained from the analysis is analyzed and conform to governing codes (e.g. ASME B31.1). The piping codes are a direct outgrowth of the theory mentioned in Eq. (1,2,3,4,5,6) and the satisfaction of both a primary and secondary load. The various codes have criteria for different kinds of loads and the maximum stress intensification that that it must satisfy. As an example, ASME B31.3 which is used in chemical plant and petroleum refinery piping, there are criteria for calculating the sustained and expansion load. If the analysis does not comply with the governing code, recommendation will be made in order to reduce stresses in piping system. Recommendations can be in the form of design modification and refinement in order to cope the governing code.

There some general guidelines in doing the flexibility analysis of the piping system. The guidelines are:

a) Thermal expansion of connected equipment shall be considered in assessing the piping flexibility.
b) To increase the flexibility of a piping system, loops and/or deflection legs should be considered in preference to any type of expansion joint.
c) Frictional loads should always be included in the support/restraint loads to be furnished to the structural group.

d) Application of cold spring (cold pull) is an option to reduce operating loads and expansion stresses but its application increases the stresses and reactions at the equipment connections in the sustained case.

e) For rack piping, where expansion loops are provided, process lines tying to the header shall be located at least 6m from the loop.

f) Thin wall piping systems (DN ≥ 450), are analyzed for local stresses at supports and stress intensifications at branches and bends

g) Flange leakage calculations are done if the following stress levels are found in the above service lines during preliminary stress analysis.

- Sustained stress at any flanged joint exceeds 50% of the code allowable stress
- Expansion stress at any flanged joint exceeds 60% of the code allowable stress.

h) Pipes connected to equipment located on an elevated structure are analyzed with the structural deflection due to loads caused by equipment that is empty, filled-in and in operating condition.

i) Reducing tees/weldolets/sweepolets are recommended in relief piping system at branch connections.

j) For spring hangers, the spring load shall include the weight of clamp assembly.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Critical Piping System in GDC UTP

There are basically four (4) types of piping systems in GDC UTP plant. The piping systems are divided according to the operating fluid that flows through the pipe. **Table 4.1** shows the summary of description for each pipe according to the surveys conducted. The description comprises of the piping system function, pipe size, pipe condition (pressure and temperature) etc. The data was obtained as per Piping Schedule document; drawing number: A/SM/UTP/I/001 as in **APPENDIX 3.**

They are:

a) Natural Gas (Primary Fuel)
  - Primary energy supply to Gas Turbine Generator (GTG)
  - Natural Gas supplied by PGB

b) Diesel (Secondary Fuel)
  - Secondary energy supply to GTG and AGB

c) Chilled Water
  - Generated by SAC, ACC and Cooling tower
  - Supply 6°C of water to UTP and return back 13.5°C

d) Instrument Air
  - Used to operate instrument valves

Table 4.1 : Piping system description

Piping System	Location	Description
Natural Gas (Primary Energy Supply)	• GTG1 & GTG2 • AGB	• Main energy supply to GTG and AGB • Use natural gas supplied via pipelines from LUMUT by PGB • Pipe size (diameter): ➢ 4” - From metering system to fuel/gas regulator (see Figure 4) ➢ 1” – From fuel/gas regulator to GTGs • Gas pressure: 26.5 bar (2650kpa) when entering GTGs, 3.5bar (350kpa) when entering AGB • Pipe material: Seamless and welded black and hot-dipped galvanized steel
Diesel (Secondary Energy Supply)	• GTG1 & GTG2 • AGB	• Back-up energy supply to GTG and AGB • Pumps are used to transport fuel to each GTGs and AGB • Pipe size (diameter) – 1” and 1 ½” • Pipe Material: Seamless and welded black and hot-dipped galvanized steel
Chilled Water	• Cooling tower • SAC • ACC	• Supply water – 6°C, Return water – 13.5°C (Design Condition) • Pipe size – Large diameter (30” for Chilled Water Supply & Return Piping) • Pumps are used to transport make-up water and chilled water (P-0231B, P-0131A/B) • Pipe Material: Arc Welded Carbon Steel
Instrument Gas	• Compressor • Header	• Used to operate instrument valves • Supplied by compressor and will be stored in air tank before distributing it to other instrument • Pressure of air is 8bar (800kpa) when it reaches air tank

As mentioned in CHAPTER 3, lines are divided into three (3) categories. The criteria for selecting the lines for analysis are defined in **Table 3.2.** In this study, category 1 and 2 lines were neglected due to constraints of time and besides the objective of the study are to analyze the critical pipe only. Critical pipes were selected to undergo in-depth analysis using stress analysis software. From hundreds of piping lines available in GDC plant, only the most critical one were selected.

From the observation, the Chilled Water Supply and Return piping system is chosen as the most critical piping system and falls under Category 3. **Figure 4.1** shows the piping system which is represented by dark blue lines.

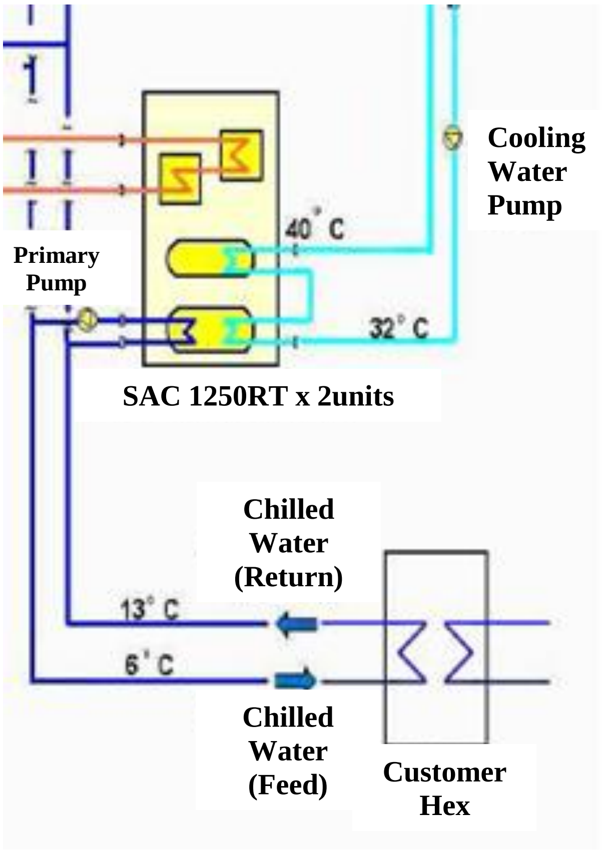


Figure 4.1 : Chilled Water Return & Supply System

The layout for the selected piping system is available as per the External Piping Support Plan Layout (1) for Cooler Chiller & TES Tank area in **APPENDIX 2.** The specification of description of the lines that are going to be analyzed were obtained from Piping Schedule; drawing number A/SM/UTP/F/200 from GDC plant as in **APPENDIX 3.** Description of Chilled Water Supply and Return Piping:

a) It carries chilled water at temperature range between 6°C and 13.5°C
b) The Design Pressure is 7.2 $^{kgf}/_{cm^2G}$ which is equivalent to 706.098kPaG
c) Pipe size varies from NPS 600 up to 750 which equivalent to 24” up to 30” pipe
d) Pipe material : STPY 400 SAW, Arc Welded Carbon Steel Pipe

The detailed specifications of the pipe line which include the data required for analysis are as **Table 4.2.**

Table 4.2 : Chilled Water Pipe Line Specification

System	Chilled Water		
Fluid	Chilled Water		
Pressure	1.4-6.6		kgf/cm²G
Temperature	6.0-13.5		°C
Class	JIS 10K		
Pipe	STPY400 – Arc Welded Carbon Steel SAW – Submerged Arc Welding t = 7.9 mm		
Flange	JIS 10K	PL-FF	SS400
Insulation	Urethane Foam Thickness = 50mm Code = C50		

By referring to the critical line selection criteria in **Table 3.1**, these pipes were chosen as *Category 3* (refer **Table 4.2**) lines where comprehensive analysis needs to be performed due to the reasons below:

a) As per criteria no. 2, the pipes are connected to reciprocating or rotating equipment which is pumps and have diameter larger than NPS 50. The pumps are P-0111A, P-0111B, P-0112A and P-0112B. The diameter of the pipes selected is in the range of NPS 600 to 750 which is equivalent to 24" to 30" pipe.
b) As per criteria no. 9, the piping lines selected are large piping lines where the pipes have a minimum diameter of NPS 600 (24") and maximum diameter of NPS 750 (30").

4.2 Stress Analysis on Chosen Variables

Stress analysis on the critical piping system is performed when the critical line has been confirmed. Data and specification of each pipe system are obtained and to be put in table as per **Table 4.3** to ease the analysis.

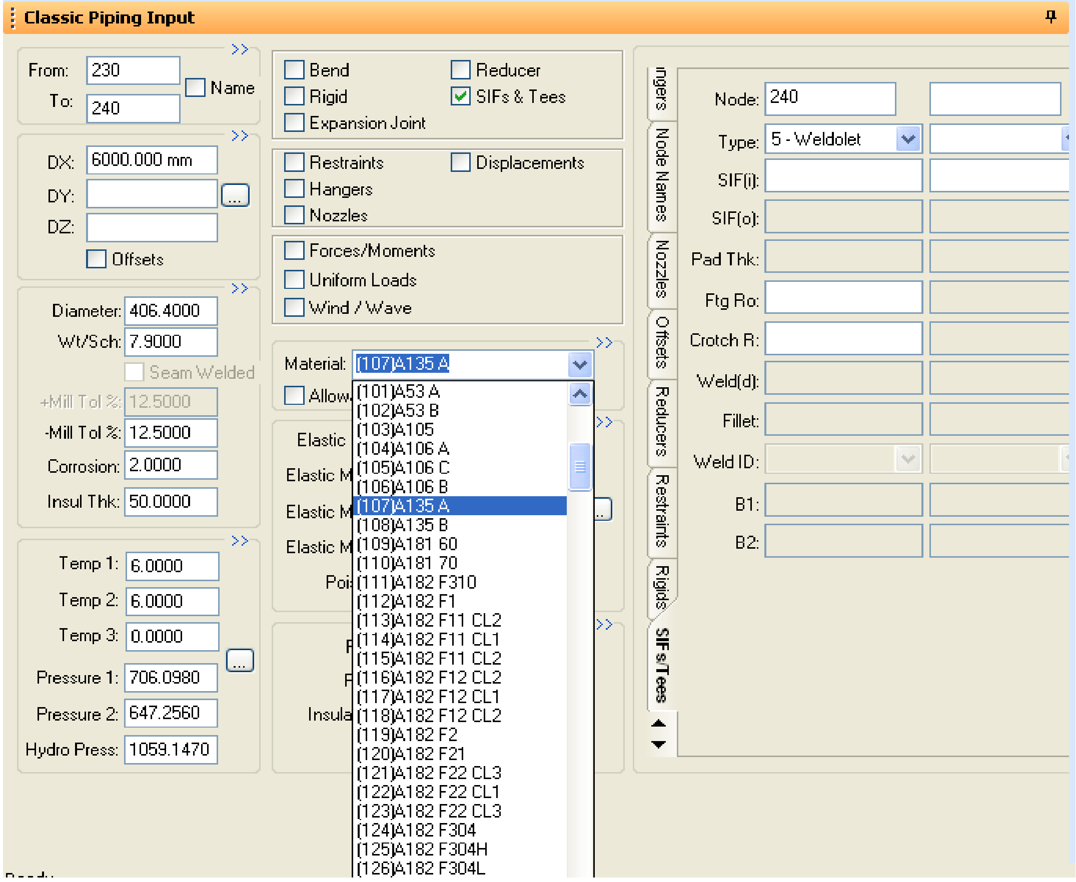
Table 4.3 : Pipe Line List

No.	**Size**	**Drawing no.**	**Process Design Condition**		**Operating Condition**	
			Max/min Pressure (Kpag)	Max/min Temperature (°C)	Max/min Pressure (Kpag)	Max/min Temperature (°C)
1.	30”/28”/24”	CHS-011-P1A	706.098	6.0	647.256	6.0
2.	30”/28”/24”	CHR-021-P1A	706.098	13.5	647.256	13.5
3.	16”	CHS-108-P1A	706.098	6.0	647.256	6.0

The isometric drawings of both piping lines were prepared as in **APPENDIX 4.**

First problem occurred when the spreadsheet in CAESAR II does not have input for the material of pipe used in the line which is Arc-welded Carbon Steel, JIS G3457 STPY400 where JIS is for Japanese International Standard. The software mostly covers ASTM standard pipe. So, material with standard (ASTM) similar to those used in JIS standard will be used where ASTM A134 – Specification for Pipe, Steel, Electric-Fusion (Arc)-Welded (Sizes NPS 16 and above) was used as stated in World Standard Conference Table in [18].

Due to unavailability of the ASTM A134 material, a similar material that has the same limiting properties is used. **Figure 4.2** shows material ASTM A135 – Electric Resistance Steel Pipe is used to replace ASTM A134.



Classic Piping Input

From: 230 ☐ Name
To: 240

DX: 6000.000 mm
DY:
DZ:
☐ Offsets

Diameter: 406.4000
Wt/Sch: 7.9000
☐ Seam Welded
+Mill Tol %: 12.5000
-Mill Tol %: 12.5000
Corrosion: 2.0000
Insul Thk: 50.0000

Temp 1: 6.0000
Temp 2: 6.0000
Temp 3: 0.0000
Pressure 1: 706.0980
Pressure 2: 647.2560
Hydro Press: 1059.1470

☐ Bend ☐ Reducer
☐ Rigid ☑ SIFs & Tees
☐ Expansion Joint

☐ Restraints ☐ Displacements
☐ Hangers
☐ Nozzles

☐ Forces/Moments
☐ Uniform Loads
☐ Wind / Wave

Material: (107)A135 A
☐ Allow

Node: 240
Type: 5 - Weldolet
SIF(i):
SIF(o):
Pad Thk:
Ftg Ro:
Crotch R:
Weld(d):
Fillet:
Weld ID:
B1:
B2:

Figure 4.2 : Pipe Stress Spreadsheet in CAESAR II 5.0

The completed model of the pipes is shown in **Figure 4.3**

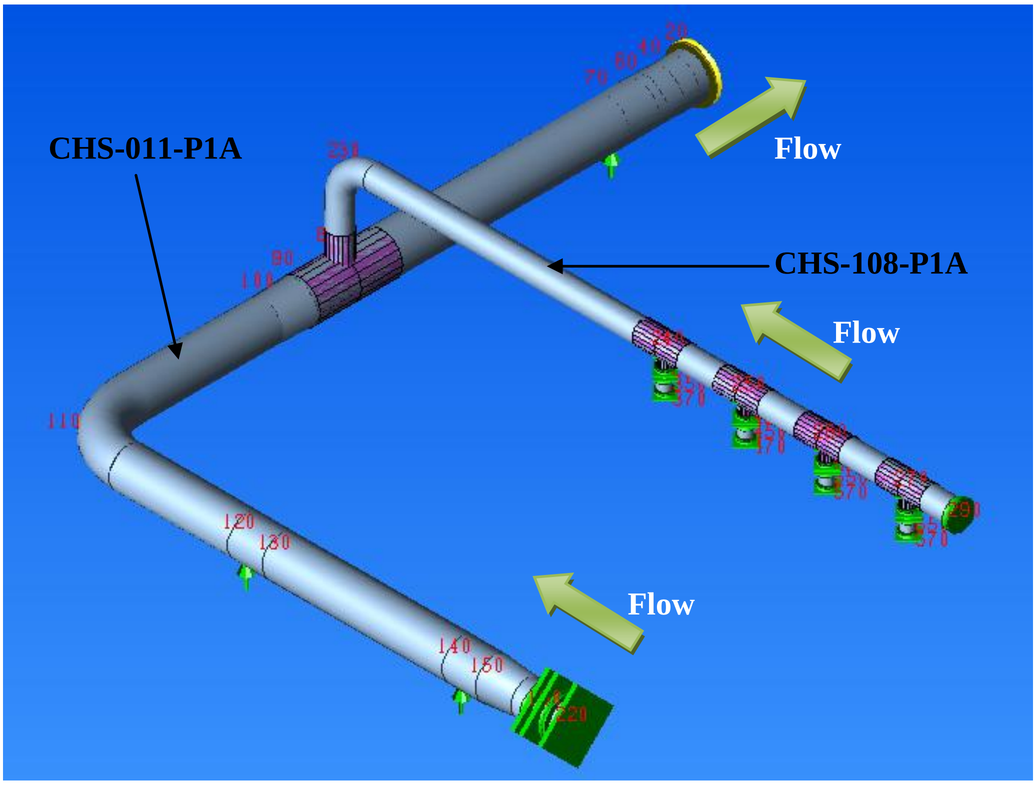


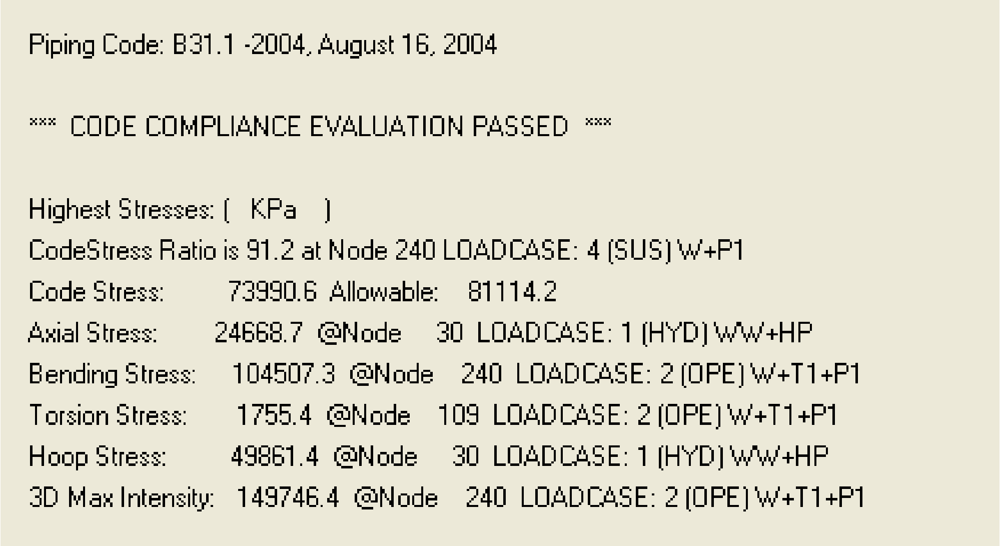
Figure 4.3 : Pipe Model From CAESAR II 5.0

4.2.1 Code Compliance Analysis

The piping model was later calculated by using CAESAR II's batch run option. The calculation was made in order to check whether the loads at each node are within the maximum allowable load governed by ASME B31.1. Types of load cases used in this analysis are:

a) Sustained Loads
b) Displacement Loads due to expansion of pipe
c) Operating Load Case
d) Hydrotest Load Case

The result from the calculation was the pipe passed the allowable stress as governed in ASME B31.1. CAESAR II identified specific nodes along the pipe where the particular stresses occur at its highest value. **Figure 4.4** shows the result of code compliance evaluation test and the stresses that occur at the specified nodes.



```
Piping Code: B31.1 -2004, August 16, 2004

***  CODE COMPLIANCE EVALUATION PASSED  ***

Highest Stresses: (   KPa    )
CodeStress Ratio is 91.2 at Node 240 LOADCASE: 4 (SUS) W+P1
Code Stress:        73990.6  Allowable:    81114.2
Axial Stress:       24668.7  @Node    30  LOADCASE: 1 (HYD) WW+HP
Bending Stress:    104507.3  @Node   240  LOADCASE: 2 (OPE) W+T1+P1
Torsion Stress:      1755.4  @Node   109  LOADCASE: 2 (OPE) W+T1+P1
Hoop Stress:        49861.4  @Node    30  LOADCASE: 1 (HYD) WW+HP
3D Max Intensity:  149746.4  @Node   240  LOADCASE: 2 (OPE) W+T1+P1
```

Figure 4.4 : Code Compliance Report

From **Figure 4.4,** the largest code stress exerted on the pipe is 73990.6 KPa. The stress exerted is below the allowable stress as governed by B31.1, 81114.2 KPa. However, the value of the allowable stress calculated by CAESAR II 5.0 is a bit low compared to actual allowable stress according to Eq. (3).

From Eq. (3): $S_A = f\left(1.25S_C + S_H\right)$

Where, from CAESAR II 5.0 datasheet:

S_H	=	68947.398 Kpa
S_C	=	68947.977 Kpa
f	=	0.5 (assume it has more than 100,000 cycles of operation)

$$S_A = (0.5\left[1.25\left(68947.977\right) + 1.25\left(68947.398\right)\right]$$

$$S_A = \underline{\underline{84460.9\,\text{Kpa}}}$$

The new value of allowable stress somehow will not affect the result of the evaluation since the highest code stress still does not exceed the allowable stresses as governed by the code.

Other stresses highlighted at their highest value are as below:

Axial Stress	=	24668.7 KPa	[Node 30]
Bending Stress	=	104507.3 KPa	[Node 240]
Torsion Stress	=	1755.4 KPa	[Node 109]
Hoop Stress	=	49861.4 KPa	[Node 30]

Using Eq. (6), the Hoop Stress, σ_h was calculated:

$$\sigma_h = \frac{Pd}{2t}$$ with P = 1.0591470 MPa, d = 746.1504 mm and t = 7.9248 mm

$$\sigma_h = \frac{(1.0591470)(746.1504)}{2(7.9248)} = 49.86138\ MPa = \underline{49861.38\ KPa}$$

From the calculated Hoop Stress from Eq. (6), the value of Hoop Stress was exactly the same value as generated by CAESAR II 5.0. This proves that the stresses calculated by CAESAR II 5.0 is accurate and follows the formula.

Using Eq. (7), the Axial Stress, σ_a was calculated:

$$\sigma_a = \frac{F}{A} = \frac{Pd^2}{(d+2t)^2 - t^2}$$

with P = 1.0591470 MPa, d = 746.1504 mm and t = 7.9248 mm

$$\sigma_h = \frac{(1.0591470)(746.1504)^2}{(746.1504+2(7.9248))^2-(7.9248)^2} = 24.666667\ MPa = \underline{24666.667\ KPa}$$

From the calculated Axial Stress from Eq. (6), the value of Axial Stress was almost the same as generated by CAESAR II 5.0. This also proves the stress calculated generated in CAESAR II 5.0 follows the same formula and can be used for analysis.

Figure 4.5 shows the location of each stresses generated by CAESAR II 5.0

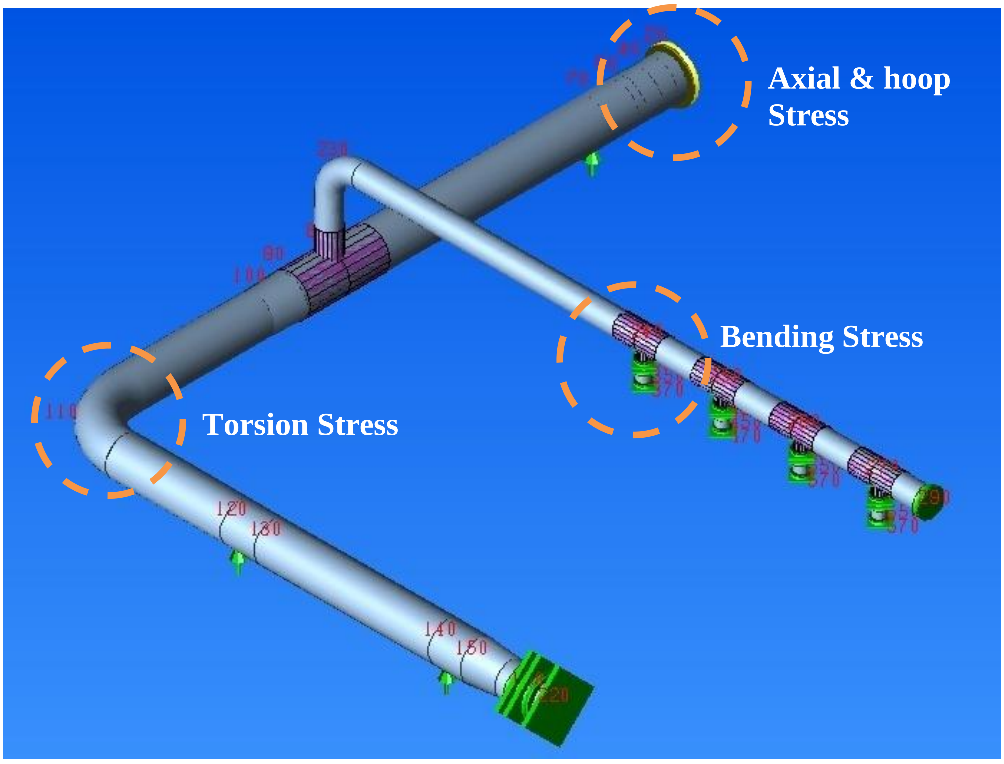


Figure 4.5 : Stress Location In the Piping System

From the stresses that have been generated, bending stress (at Node 240) is found to be the highest being exerted to the pipe with a value of 104507.3 KPa. The stress is well above the maximum allowable stresses governed by the code.

4.2.2 Displacement Analysis

The analysis is conducted to determine the displacement of the piping system at each node. The displacement can be in various directions:

a) x-axis
b) y-axis
c) z-axis

The result of the displacement analysis is as shown in **APPENDIX 5**

From the displacement analysis, the highest displacement for x-axis is at Node 10 (5.797mm), y-axis at Node 100 (-6.643mm acting downwards) and z-axis at Node 109 (-1.776mm). Visual representation of the deflected pipe is shown in **Figure 4.6. Figure 4.6** shows a clearer view on the condition of the pipe when displaced.

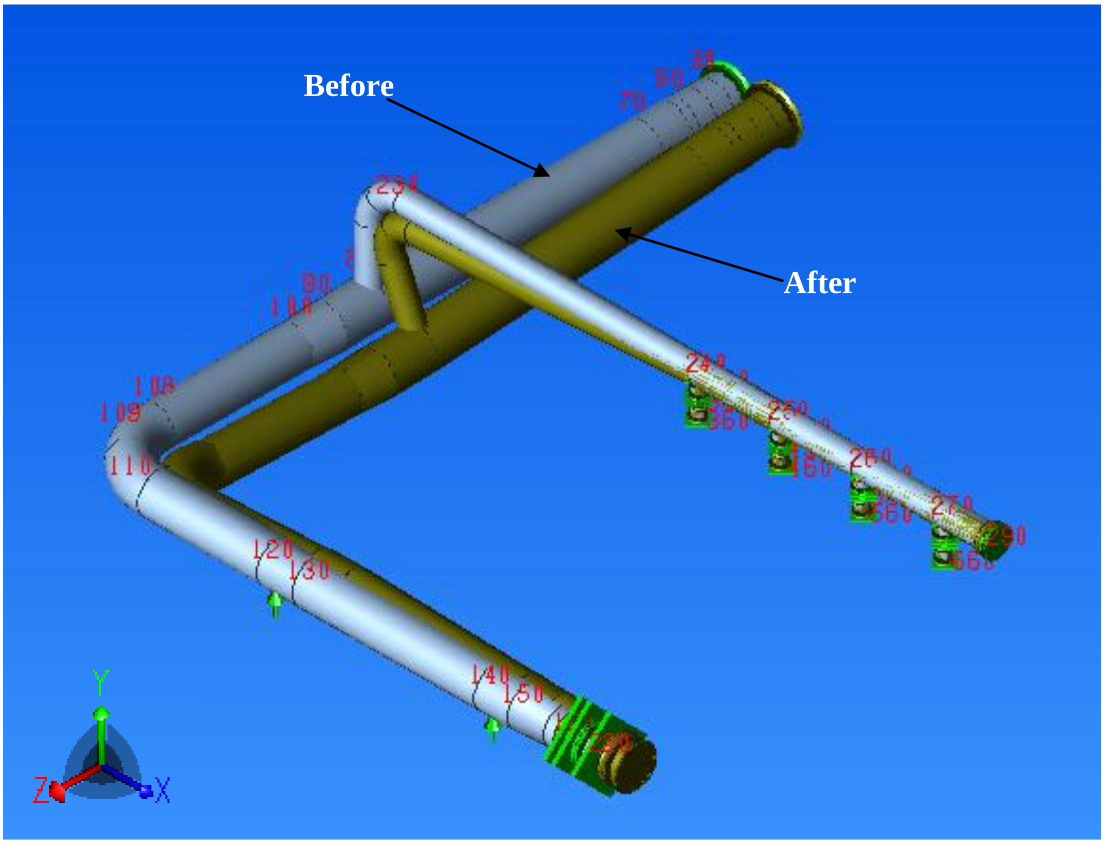


Figure 4.6 : Displacement Analysis

4.2.3 Stress Analysis Discussion

The analysis conducted on the piping system has proved the pipe does not exceed the maximum allowable stress governed by ASME B31.1. This also proves that the stresses exerted on the piping system are under control or safe. Although the pipe passed the analysis, there are one issues regarding one of the stresses that can become a problem. From the results, bending stress at Node 240 is found to be the highest exerted stress with a value of 104507.3 KPa which exceeds the maximum allowable stress of 84460.8 KPa.

The reason to this excess stress is because of constraints of movements along pipe CHS-108-P1A. As shown in **Figure 4.7,** the yellow highlighted circles are the point where the pipes will continue to another sets of pipe. In this analysis, those pipes are excluded from the analysis because the size of the pipe is below the minimum required size of pipe that requires comprehensive analysis or critical line (refer **Table 4.2**). The pipes are:

a) 200-CHS-144-BC-C40
b) 200-CHS-154-BC-C40
c) 200-CHS-122-BC-C40
d) 200-CHS-132-BC-C40

Since all four (4) pipes have NPS 200 in diameter, the pipes are ruled out. Hence, the end parts of each connection where anchored or fixed due to no displacements can be generated because of the excluded pipes. The anchored ends of the pipes has resulted no such movement on the pipes. Displacements that occur along CHS-011-P1A pipe cause a huge stress on the first point of the anchored ends of the point (Node 240) which cause huge bending stresses on that point

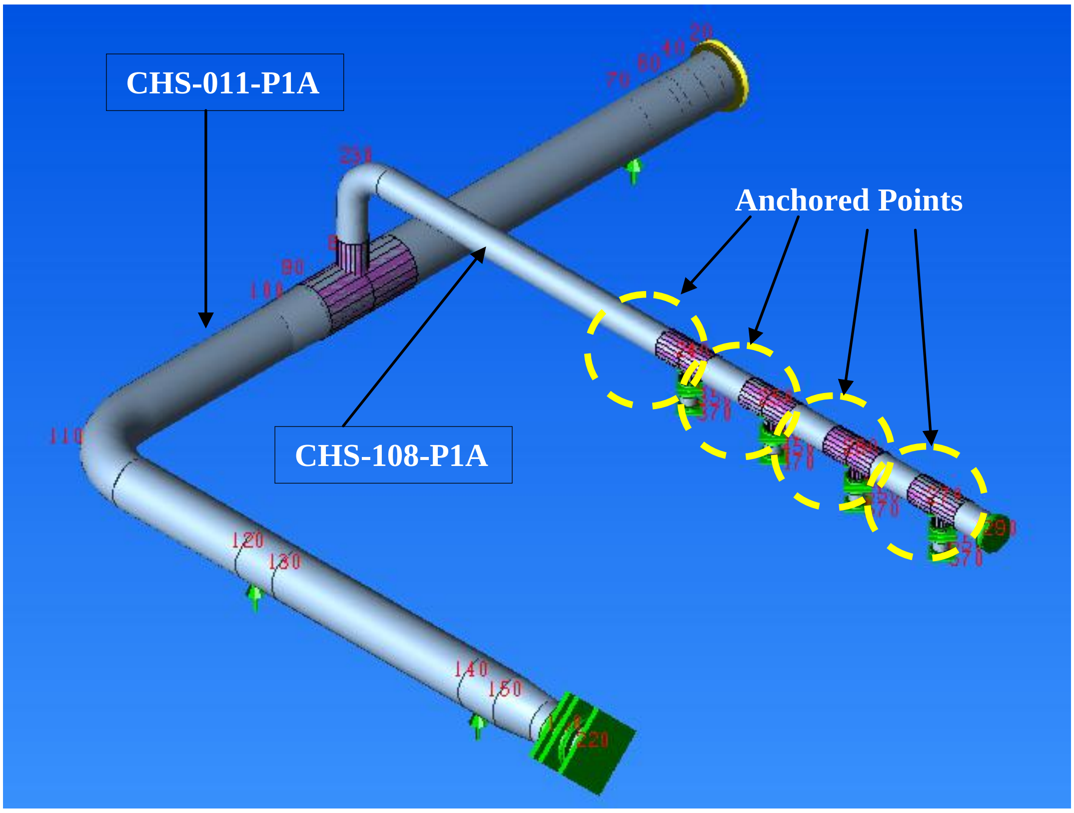


Figure 4.7 : Anchored Points at CHS-108-P1A Pipe

For the displacement of the piping system during operating and design condition, the pipe tends to displace more towards positive x-axis and negative y-axis. This can be proven from top and side view of the piping system as in **Figure 4.8** and **4.9.**

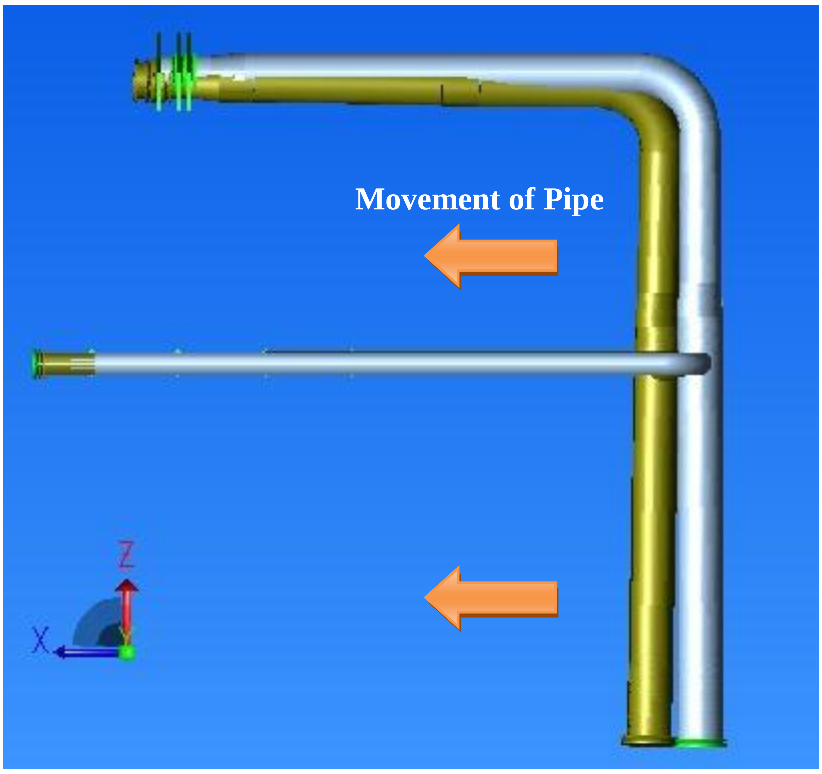


Figure 4.8 : Top View of Deflected Pipe

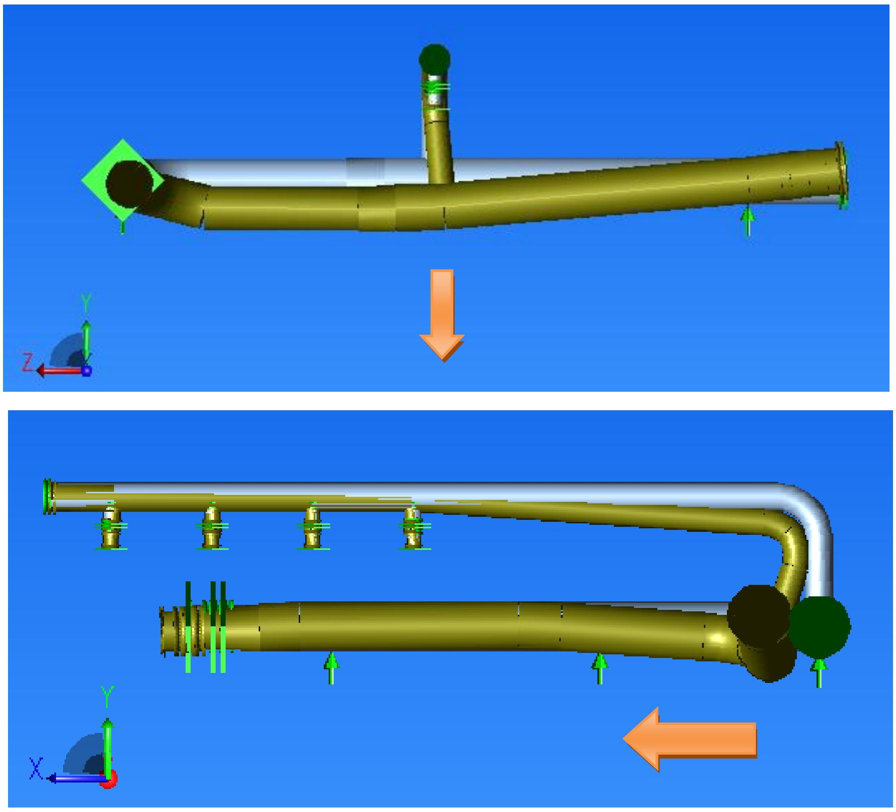


Figure 4.9 : Side Views of Deflected Pipe

This displacement has resulted in excess stress especially bending stress at Node 240. Although the displacement is really small (6.643mm acting downwards) compared to the size of the pipe (CHS-011-P1A pipe – NPS 750mm diameter or 30”), the stress that get affected due to the displacement is huge. In order to overcome the overstressing, addition of support at certain point will reduce the load especially sustained load. For this pipe, sustained load contributes a lot of stress due to its huge size.

4.3 Proposal to Reduce Stresses in Critical Piping System

By adding support at Node 80 (**Figure 4.10**), stresses on the pipe can be reduced. This is shown in the code compliance evaluation analysis as shown in **Figure 4.11.**

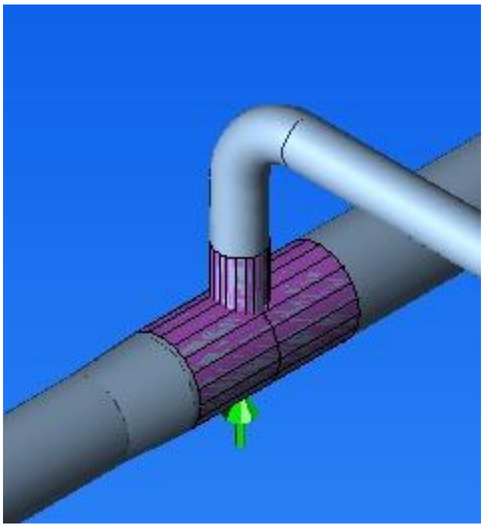
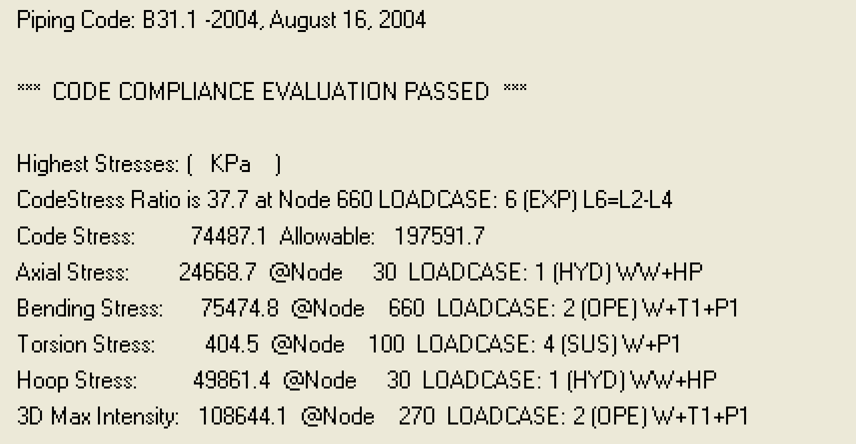


Figure 4.10 : New Support Addition



```
Piping Code: B31.1 -2004, August 16, 2004

***  CODE COMPLIANCE EVALUATION PASSED  ***

Highest Stresses: (   KPa    )
CodeStress Ratio is 37.7 at Node 660 LOADCASE: 6 (EXP) L6=L2-L4
Code Stress:        74487.1  Allowable:   197591.7
Axial Stress:       24668.7  @Node     30  LOADCASE: 1 (HYD) WW+HP
Bending Stress:     75474.8  @Node    660  LOADCASE: 2 (OPE) W+T1+P1
Torsion Stress:       404.5  @Node    100  LOADCASE: 4 (SUS) W+P1
Hoop Stress:        49861.4  @Node     30  LOADCASE: 1 (HYD) WW+HP
3D Max Intensity:  108644.1  @Node    270  LOADCASE: 2 (OPE) W+T1+P1
```

Figure 4.11 : Code Compliance Report For Added Support

Figure 4.11 shows that the stresses of the piping system after the added support are within the allowable stress as governed by the code. This shows that the added support does not affect the overall stresses of the pipe. Besides, the bending stress has also decreased where the highest bending stress exerted by the pipe is 74487.7 KPa at Node 660. This also proves that the support that has been added does reduce the stresses on the pipe.

The displacement of the piping system during operation and also design condition has also decreased. The results of the displacement using design condition parameters are included in **APPENDIX 6**. Comparison of maximum displacement by all x-axis, y-axis and also z-axis are shown in **Table 4.4**

Table 4.4 : Comparison of Maximum Displacement

	Displacement (mm)	
	Before Addition of Support	**After Addition of Support**
x-axis	5.797	**1.999**
y-axis	-6.643	**-1.158**
z-axis	-1.776	**-1.081**

A noticeable reduction of displacement of up to 80% has proven the effectiveness of the addition of one extra support on the pipe. This can be used as one of the method to improve the stresses on the piping system on the plant.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This research investigated the stresses on piping system in Gas District Cooling (GDC) UTP plant. Throughout the research period, all the information was gathered from all reliable resources such as design data, plant layout, plant drawings, journals, manuals and online resources. Studies done on the stresses on critical piping systems in the GDC UTP plant will prove to be important to determine the future performance of the plant.

From the studies conducted, the following conclusion could be made:

a) Four (4) types of critical piping systems have been identified in GDC UTP plant. The piping systems can be divided into 4 types according to the fluid they are carrying; natural gas (primary fuel), diesel (secondary fuel), chilled water and also instrument air piping system. These types of systems are found to be important as it affects greatly to the operation of the plant. Critical pipes were selected to be analyzed because critical pipe will undergo severe stresses. In stress analysis, piping lines are divided to 3 categories; category 1, category 2 and category 3 lines. Category 3 lines are pipes that require formal analysis using piping stress software because of its severity. All pipes in GDC UTP plant have been observed and from that, Chilled Water Supply and Return Piping system was chosen to be analyzed because its specification fulfills the requirement for critical piping line. The requirements that have been fulfilled are the piping system have large diameters (24” to 30”) and also connected to rotating equipment which is pump that can exert stresses on the pipe.

b) The chilled water piping systems (drawing no. CHS-011-P1A and CHS-108-P1A) had been modeled in CAESAR II 5.0 and also analyzed using its batch run option. The analysis showed that the stresses were well below the maximum allowable design limit. This means that the pipe complies with the governing ASME B31.1 code where the maximum stress exerted to the pipe (73990.6 KPa) is less than the maximum allowable stress which is 84460.9 KPa. This also means the current installation of pipe system can be considered safe. However, the value of bending stress had become an important issue considering the size of the pipe of the piping system. The bending stress exerted at Node 240 is 104507.3 KPa which exceed the maximum allowable stress. Although overall stresses can be considered safe, this particular stress may cause problems in the future.

c) To rectify the bending stress problem, some modification method has to be considered to reduce the bending stress. It was recommended that by adding new supports could reduce this stress. The support could greatly reduce the bending stress up to 80% by decreasing the displacement due to expansion. This method could be recommended to be implemented at GDC UTP plant.

.

5.2 Recommendation

Additional works might be required especially in the analysis part. Therefore, further analysis could be made especially by expanding the number of pipe to be analyzed. For future work, a more extended range of piping system can be chosen to decrease any redundancy especially at anchored point of pipe in the analysis. This will give more accurate results hence making the study more reliable. Next, more lines will be chosen to be analyzed so that not only the critical lines will be checked for problems other lines also will be checked. The more piping lines being checked, the more information will be gained on the piping systems of the plant. Hopefully this will present proactive steps in identifying problem piping system so that further actions can be taken to ensure the smooth running of the plant.

REFERENCES

[1] *Gas District Cooling System* <http://www.petronas.com.my/internet/corp/centralrep2.nsf/0ddc209ca3aa90e848256e9900178727/2645645853525e8348256a95004be9c5?OpenDocument>

[2] Hounsham, B. 2002, *Introduction to Pipe Stress Analysis*. MMC Oil & Gas Engineering Group

[3] Azeem, H. 2001, *Stress Analysis for Process Piping*. J-Tech PVT LTD.

[4] ”*Volume 1: General Description of Cogeneration/District Cooling Plant, Universiti Teknologi Petronas.*”. Shinryo (M) Sdn Bhd.

[5] Tamiru, A. 2008, *Intelligent Fault Detection And Diagnosis (IFDD) System For A Cogeneration And Cooling Plant: Preliminary Model Development For A Single-Shaft Gas Turbine Generator*, Universiti Teknologi Petronas.

[6] Kannapan, S. 2008, *Introduction to Pipe Stress Analysis*, ABI Enterprise, Inc.

[7] *Convert Gas Pneumatic Controls to Instrument Air*, Natural Gas STAR. United States. Environmental Protection Agency

[8] Bullough, B. D. Process Engineering Specialist. 2004, *Piping Design of Instrument Air Distribution Systems*, Sebesta Blomberg & Associates, Inc.

[9] Antaki, G. 2000, *Part Ii - Seismic Design Of Critical Piping Systems*, Multidisciplinary Center for Earthquake Engineering Research (MCEER) and National Science Foundation (NSF), Las Vegas

[10] 2002, *Process Piping : ASME Code For Pressure Piping*, The American Society of Mechanical Engineers

[11] 2001, *Process Piping : ASME Code For Pressure Piping*, The American Society of Mechanical Engineers

[12] Campbell, T. 2006, *Excessive Piping Design Workflow Iterations and a Novel Solution: The Conceptual Piping Stress Tool*, MSc. Thesis. University Of Calgary

[13] Lagan, C. 2005, *CAESAR II : Pipe Stress Analysis Software Training and Workshop*, EDS Asia Sdn. Bhd.

[14] Clarkson, J. 2001, *Pipe Stress Analysis : Recommended Guidelines for Piping Engineers*, KVAERNER

[15] *Pipe Line Rules of Thumb Handbook*, Gulf Publishing Company, Book Division

[16] 6 Oct 2008 http://www.nanomagnetics.org/chilledwatertips/basics.php

[17] 2001, *Power Piping : ASME Code For Pressure Piping*, The American Society of Mechanical Engineers

[18] *JIS G3457 Arc Welded Carbon Steel Pipes (JIS G 3457 / JISG3457)* http://www.e-pipe.co.kr/EJIS/pipe-text/pipe/3583.html

APPENDIX 1: Project Gantt Chart

Final Year Project 1

No.	Detail/Week	1	2	3	4	5	6	7	8		9	10	11	12	13	14
1	Selection of Project Topic	■	■							Mid-semester Break						
2	Preliminary Research Work	■	■	■	■											
	• GDC UTP	■	■													
	• Piping System			■	■											
3	Submission of Preliminary Report				○											
4	Project Work Continues					■	■	■	■							
	• Data Acquisition From GDC					■										
	• Analysis of Data/Specification						■	■	■							
5	Submission of Progress Report								○							
6	Seminar								○							
7	Project Work Continues										■	■	■	■	■	■
	Submission of Interim Report														○	
8	Oral Presentation														○	

* ○ = milestone

Finale Year Project 2

No.	Detail/Week	1	2	3	4	5	6	7	8		9	10	11	12	13	14
1	Project Work Continues	▨	▨	▨	▨					**Mid-semester Break**						
	• Critical Line Selection	▨	▨													
	• Pipe Isometric Drawings			▨	▨											
2	Submission of Progress Report I				○											
3	Project Work Continues					▨	▨	▨	▨							
	• Flexibility Analysis					▨										
	• Stress Analysis						▨	▨	▨							
4	Submission of Progress Report II								○							
5	Seminar								○							
6	Project Work Continues										▨	▨	▨	▨	▨	▨
	• Stress Analysis Continues										▨	▨	▨	▨	▨	▨
	• Modifications of Design														▨	▨
7	Poster Submission														○	
8	Final Presentation														○	
9	Dessertation															○