MODELING AND ANALYSIS OF WATER INJECTION SYSTEM

By

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May, 2015

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

Master of Technology in Pipeline Engineering

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CERTIFICATE

This is to certify that the work contained in this thesis titled **"Modeling and Analysis of Water Injection System**" has been carried out by Md Nadeem Raza Khan under my supervision and has not been submitted elsewhere for a degree.

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ACKNOWLEDGEMENT

First and Foremost, I would to thank the All Mighty, God who enabled me to embark upon this carrying on with this work.

Secondly, I would like to thank my project guide, **Mr. Ramesh M**, Assistant Professor for his guidance as well as for providing necessary information about the project.

I would like to express my profound thanks and gratitude to **Dr. Suresh Kumar**, The HOD, Dept. Mechanical Engineering, UPES. I would also like to thank all the teaching and non-teaching staff at UPES.

Also, I am highly indebted to **Mr. Mohammed Avais** at Petrocon Institute of Piping Engg., Bengaluru for his guidance and constant supervision as well as for providing necessary information regarding the project and also for his support in completing the project.

And last but not the least, I am greatly thankful to my parents, without whose encouragement and support, I wouldn’t have completed this project successfully. Finally I thank to one and all that helped me directly or indirectly for the completion of this project.

PROJECT ABSTRACT

In an Oil & Gas industry, when the production capacity of Oil wells drops or is inconsistent, Water is injected back into the reservoir, usually to increase pressure and thereby stimulating the production. Such a system is called Water Injection System. They are used in both off- shore and on-shore Hydrocarbon plants. However, in this project, we are aiming to design a Water Injection System for an Off-shore plant in order to enhance and stimulate the production capacity of Oil well in an Off-shore Hydrocarbon plant.

The detailed scope of this project involves Development of Piping Layout for a Water Injection System and its pipe stress analysis using Caesar II. Development of Piping involves Pressure Design of Piping system using ASME Codes, buildup of piping arrangement based on Piping and Instrument diagram in a 3D environment using SP3D. The model that is designed in SP3D is then built up once again in Caesar II where it is then subjected to stress analysis for various load cases like sustained load cases and displacement load cases. The flange systems are taken for flange leakage analysis and the pump nozzles are qualified using nozzle analysis.

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NOMENCLATURE

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

CHAPTER 1

INTRODUCTION

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

1.1 Water Injection System

Water injection refers to the method in oil industry where water is injected back into the reservoir, usually to increase pressure and thereby stimulate production. Water injection wells can be found both On-shore and off -shore, to increase Oil recovery from an existing Reservoir.

Water is injected to support pressure of the reservoir and to sweep or displace Oil from reservoir, and push it towards a well.

Normally, only 30% of the oil in a reservoir can be extracted, but water injection increases that percentage and maintains the production rate of a reservoir over a longer period.

Source of Injected Water:

Any and Every source of bulk water can be, and has been used for injection. The following sources of water are used for injection for recovery of oil.

Produced water is often used is an injection fluid this reduces the potential of causing formation damage due to incompatible fluids, although the risk of scaling and corrosion in injection flow lines or tubing remains.

Sea water is obviously the most convenient source for offshore production facilities, and it may be pumped inshore for use in land fields. Where possible, the water intake is placed at sufficient depth to reduce the concentration of algae, however, filtering, de oxygenation and bio coding is generally required.

Chapter 2

LITERATURE REVIEW

1. Leonidio Buk Jr (Petrobras), Otavio Cardoso Costa (Petrobras), Alexandre Guedes de Siqueira (Petrobras), Jader Brito Azevedo (Petrobras), Eduardo Jose Jesus Coelho (Petrobras), Cynthia Azevedo Andrade (Petrobras) published a paper on **Albacora Subsea Raw Water Injection Systems** which presents the Albacora field Subsea Raw Water Injection (SRWI) systems. Application of SRWI involves some challenges, which demand a detailed and systematic analysis in order to evaluate the technical feasibility and establish the requirements to implement this solution. This paper describes the evaluation process carried out and details the adopted solutions. Furthermore, the system installation and operation are presented.

The Albacora field is a mature field located at Campos Basin in water depths between 250 and 1100 meters. In order to increase the oil recovery, its reservoirs are requiring a significant amount of water injection, what was not considered in the initial phases of the Albacora field development project. Technical and economical constraints do not allow the use of conventional seawater injection plants, since current production units have no available area to implement a conventional water injection system. The selected alternative to overcome these constraints was the SRWI technology, by which seawater is injected in the reservoir with a minimum treatment, using mainly pieces of equipment installed at seabed.

The feasibility analysis involved studies of the seawater compatibility with the reservoir rock and fluids, microbiological control, corrosion, etc. The solution was specified based on these studies and included subsea pumps, back-flushing filters, well components and topside facilities. In order to achieve required seawater flow rates, the adopted solution considered the use of three subsea injection systems, injecting around 16,500 m^3/day in seven wells.

Waterflooding is still the most common method used worldwide for improving oil recovery. The SRWI technology can be an important alternative to inject seawater where it is not possible to use conventional systems, mainly in mature fields. The SRWI is expected to generate large economical and technical benefits to the Albacora project.

2. B.H. Caudle (The Atlantic Refining Co.), A.B. Dyes (The Atlantic Refining Co.) published a paper on **Improving Miscible Displacement by Gas-Water Injection** in which it states that miscible displacement recovers all oil in the area contacted by the injected fluid, whereas water or immiscible gas drives usually leave substantial amounts of oil as residual. However, the poor mobility ratios associated with a gas-driven miscible displacement cause the sweep pattern efficiency to be much lower than that obtained with water flooding. One way in which the sweep efficiency in a miscible displacement process can be increased is by decreasing the mobility behind the flooding front. This can be achieved by injecting water along with the gas which drives the miscible slug. This water reduces the relative permeability to gas in this area and thus lowers the total mobility. The main operating conditions for the simultaneous injection process are that a zone of gas exists between the miscible slug and the leading edge of the water and that a sufficient amount of gas be injected with the water to form the gas volume which is being left in the water zone. Laboratory model studies have shown that the ultimate sweep pattern efficiency can be as high as 90 per cent for a five-spot flooding system. If gas alone is used as the driving medium an ultimate sweep-out efficiency of about 60 per cent would be obtained in the same system.

3. **Vornel Walker** published a paper on **Computer aided design or draughting** in which he states that the benefits of computer aided design are indisputable; indeed it would be virtually unthinkable to design anything from a new component to a new plant without the aid of CAD. Today's packages have come a long way from the capabilities of the tools available in the early days. Vornel Walker of COADE Engineering Software provides a detailed guide through the development stages of CAD and focuses on the advanced features now available for the design of piping systems with sophisticated packages such as the CADWorx suite

4. **Robert A. Robleto** published a paper **Modeling Underground Pipe With Pipe Stress Analysis Program** in which the objective of this paper is the modeling of underground pipe in granular or sandy soil using a Pipe Stress Program for the evaluation of thermal, and pressure, to produce verifiable results. The use of a beam type pipe stress program to accurately perform stress analysis of underground piping can produce various results depending on the modeling. An updated presentation is available in B31.1 piping code with technical references, which gives some guidance in the use of pipe stress modeling. Modeling in a conservative way is difficult because what may be conservative to the underground piping may not be conservative at above ground transitions. An accurate methodology is required that produces verifiable results.

Verification is accomplished by comparison with the B31.1 example problem and manual calculation using "Beam on Elastic Foundation". Also discussed are the effects of SIF's and flexibility factors used in above ground pipe and their application to underground piping. Ovalization of the piping is inhibited by the soil and the SIF's and Flexibility factors are affected. Recommendations are given in the conclusion for the accurate modeling using beam type pipe stress analysis programs.

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

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

Chapter 3

COMPONENTS OF WATER INJECTION SYSTEM

3.1 Sea Water booster pumps:

The pumps lift water from the sea and pass it to the oxygen scavenger tank when the product water from the separator unit is not sufficient. There is a stand by booster pump in addition to the working booster pump.

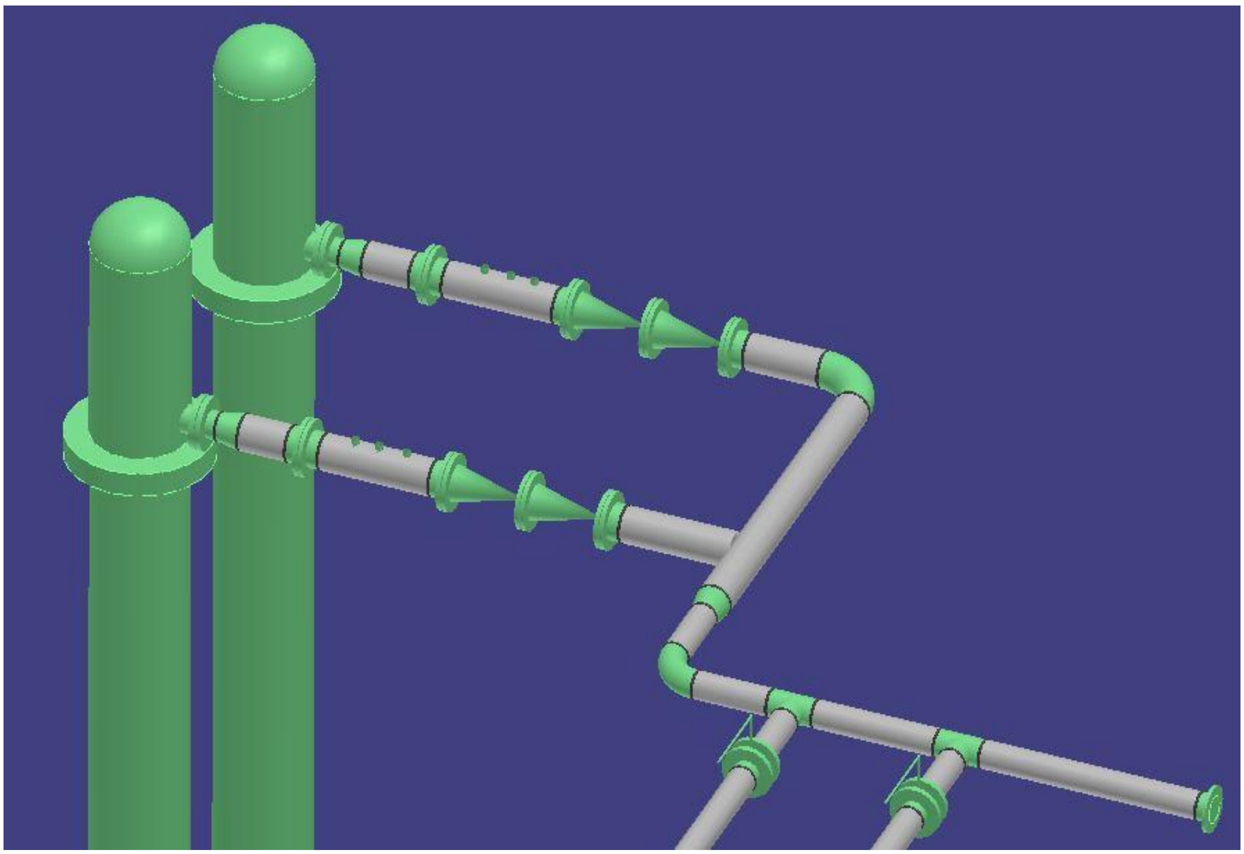


Fig 3.1 Sea water booster pumps

The sea water booster pumps have the following nozzles:

SBP01/Nozzle 1: connected to line 250-W-0001-A3S-NA

SBP02/Nozzle 2: connected to line 250-W-0009-A3S-NA

3.2. Sea Water Fine Filter:

The filter must clean the water and remove any impurities, such as shell and algae. Typical filtration is to 2 micrometers. But really depends on reservoir requirement. The filters are so fine so as not to block the pores of the reservoir. Sand filters are a common used filtration technology to remove solid impurities from the water. The sand filter has different beds with various sizes of sand granules. The sea water traverses the first, coarsest, layer of sand down to the finest and to clean the filter, the process is inverted. After the water is filtered it continues on to fill the de-oxygenation tower. Sand filter are bulky, heavy have some spillover of sand particles and require chemical to enhance water quality.

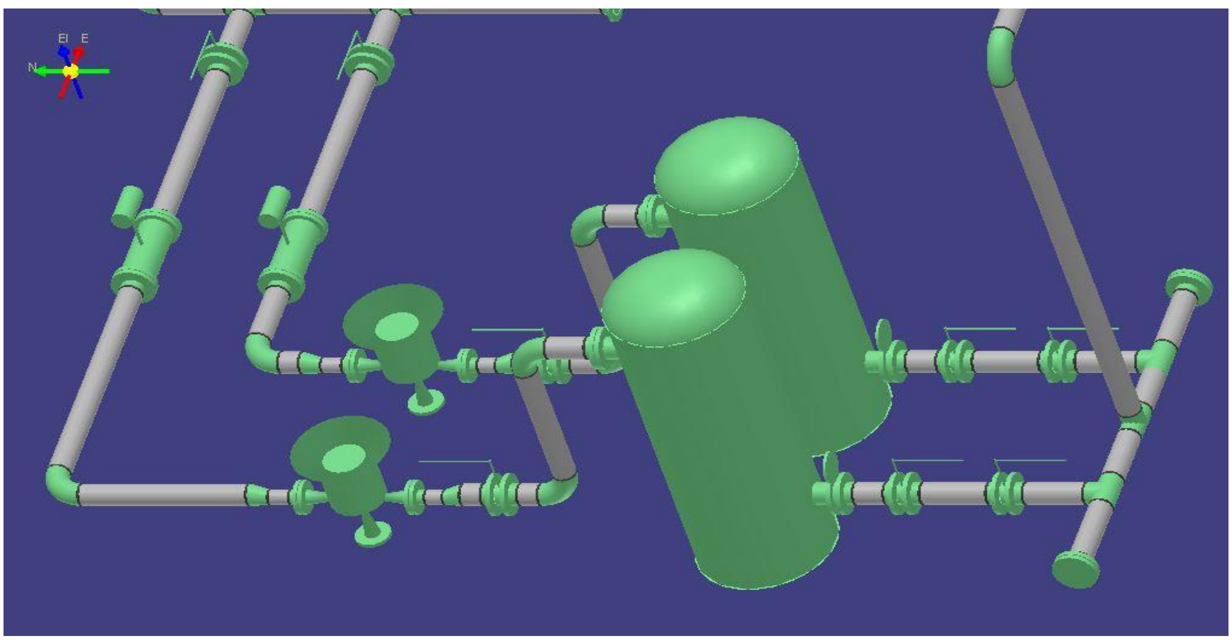


Fig 3.2: Sea water fine filters

The sea water fine filters have the following nozzles:

Filter01/N1: connected to line 200-W-0003-A3S-NA

Filter01/N2: Connected to line 150-W-0008-A3S-NA

Filter01/N3: Connected to Pressure relief line

Filter01/N4: connected drain header

Filter02/N1: connected to line 200-W-003-A3S-NA

Filter03/N2: connected to line 150-W-0008-A3S-NA

Filter02/N3: connected to pressure relief line

Filter 02/N4: connected drain header

3.3 Oxygen Scavenger tank:

It is also called de-aerator tank or de-oxygenation tank. Oxygen must be removed from the water because it promotes corrosion and growth of certain bacteria. Bacterial growth in the reservoir can produce toxic hydrogen supplied, a source of serious problems.

An oxygen scavenger tank brings the injected water into contact with a dry gas steam (gas is always readily available in the oilfield.) the filtered water drops in to the de oxygenation tower, splashing onto a series of trays , causing dissolved oxygen to be lost to the gas stream.

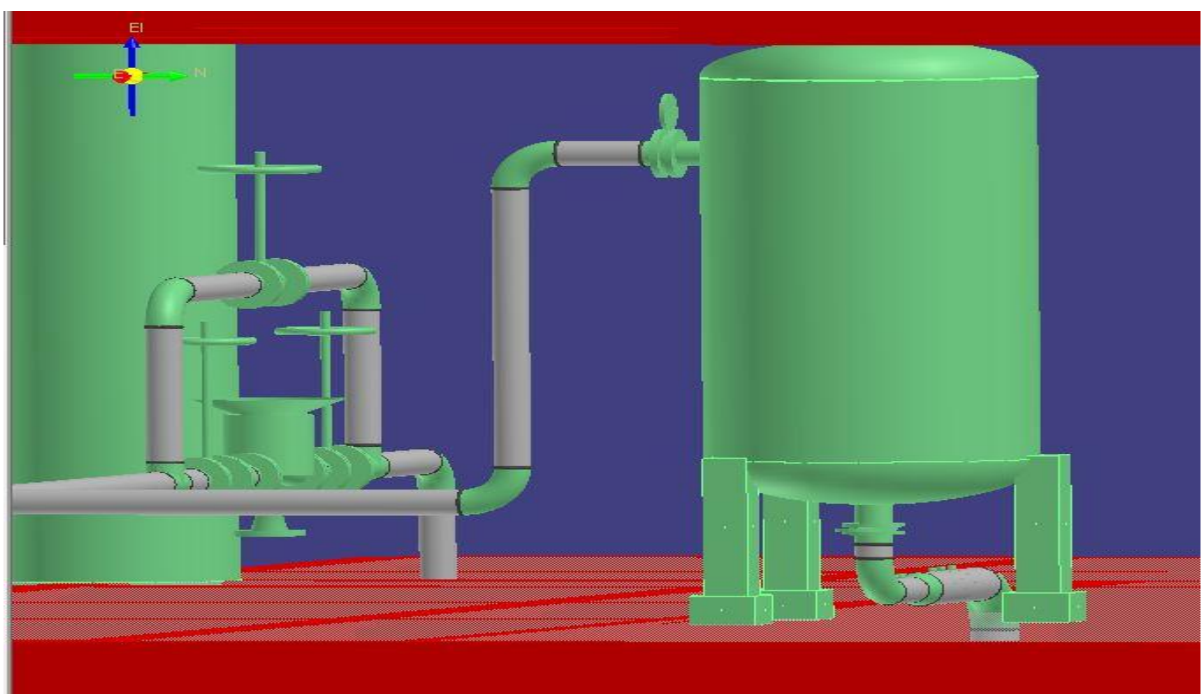


Fig 3.3: oxygen scavenger tank

The oxygen scavenger tank has the following nozzles:

OS/N1: connected to line 150-W-0008-A3S-NA

OS/N2: connected to line 150-W-0011-A1-NA

OS/N3: connected to the pressure relief line

OS/N4: connected to pressure gauge instrument

OS/N5: connected to the minimum flow recycle line

OS/N6: connected to the level transmitter

OS/N7: connected to level transmitter

3.4. Water injection pumps:

The high pressure, high flow water injection pumps are placed near to deoxygenating tower and boosting pumps. They fill the bottom of the reservoir with the filtered water to push the oil towards to the wells like a piston. The result of the injection is not quick, it needs time.

Water injection is used to prevent low pressure in the reservoir. The water replaces the oil which has been taken, keeping the production rate and pressures the same over the long term.

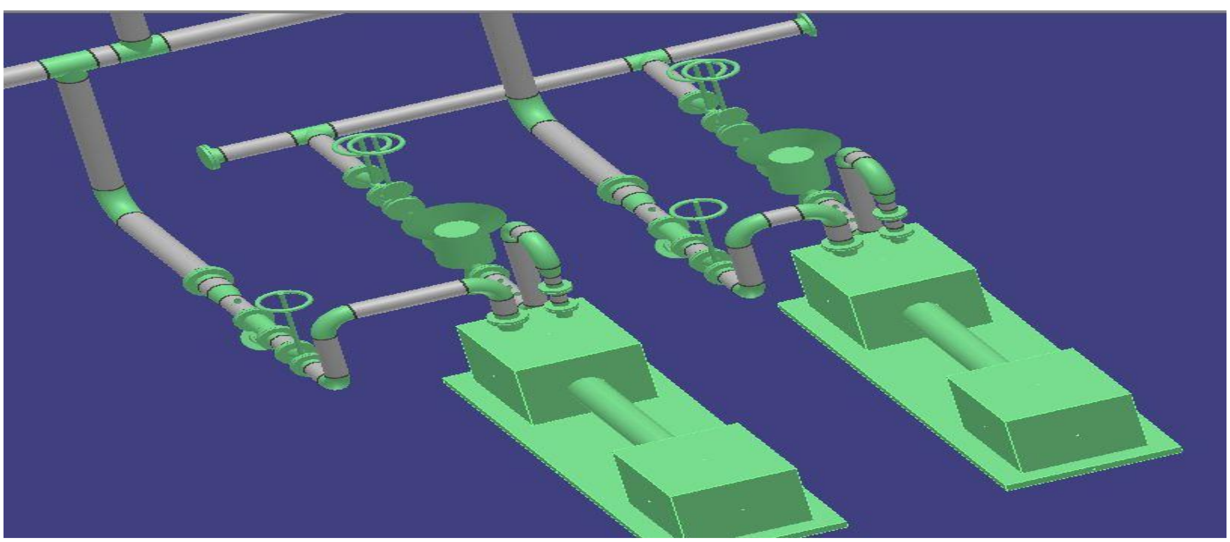


Fig 3.4 Water injection pumps.

The water injection pumps have the following nozzles:

WIP 01/Dish Nozzle: connected to line 100-W-0017-B1-NA

WIP 02/Dish nozzle: connected to line 100-W-00013-B1-NA

WIP 01/Suct Nozzle: connected to line 100-W-0016-B1-NA

WIP 02/Suct Nozzle: connected to line 100-W-0012-B1-NA

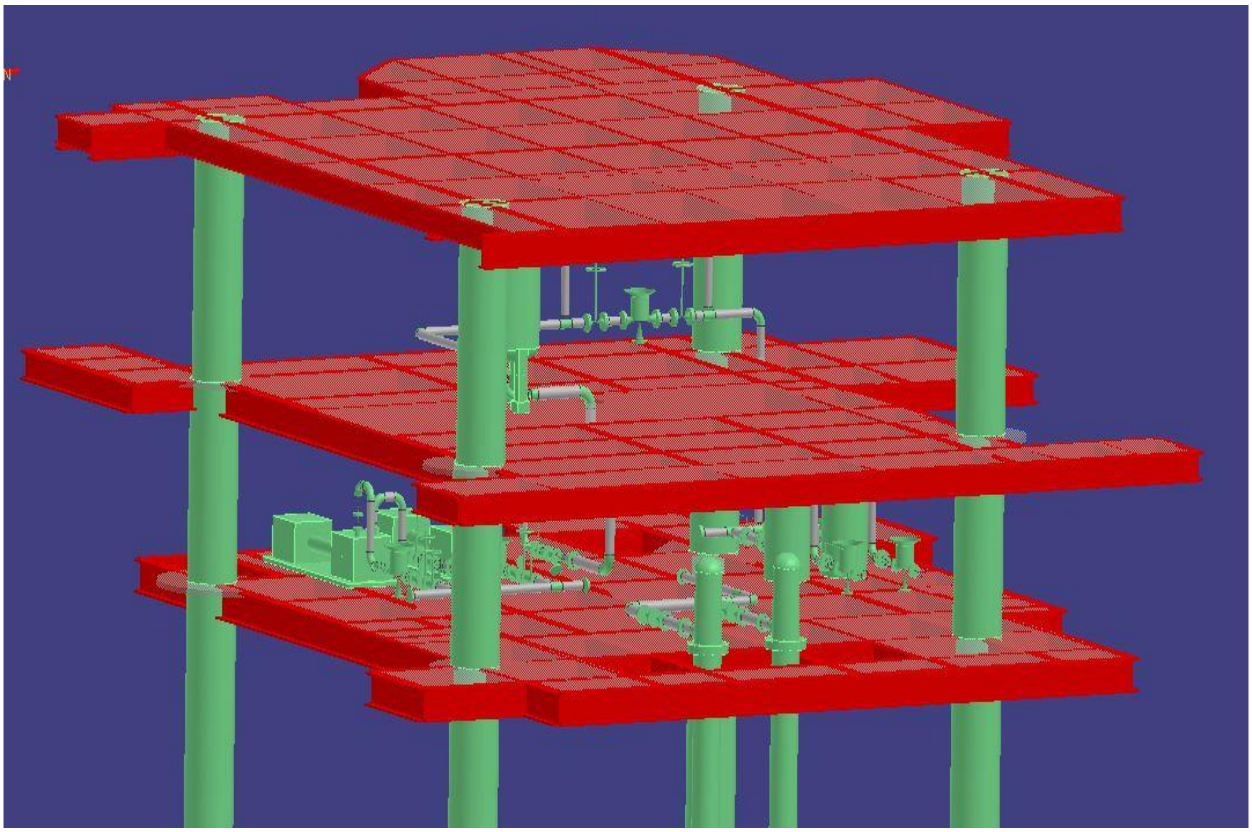


Fig 3.5 isometric view of the completed design of water injection system

Chapter 4

FLOW DIAGRAMS

Flow diagram represents the basic flow for a process and utility in a plant, it is basically developed by a chemical engineer.

Flow diagrams are of two types

1. Process flow diagram (pfd)

2. Utility flow diagram (ufd)

Process flow diagram (pfd) depicts the basic process involved in a plant with major equipment's, piping, instruments and it controls.

Utility flow diagrams (ufd) depicts the basics utilities required for a plant i.e. for operation and maintenance. The ufd is developed at a later stage once the process layout is built.

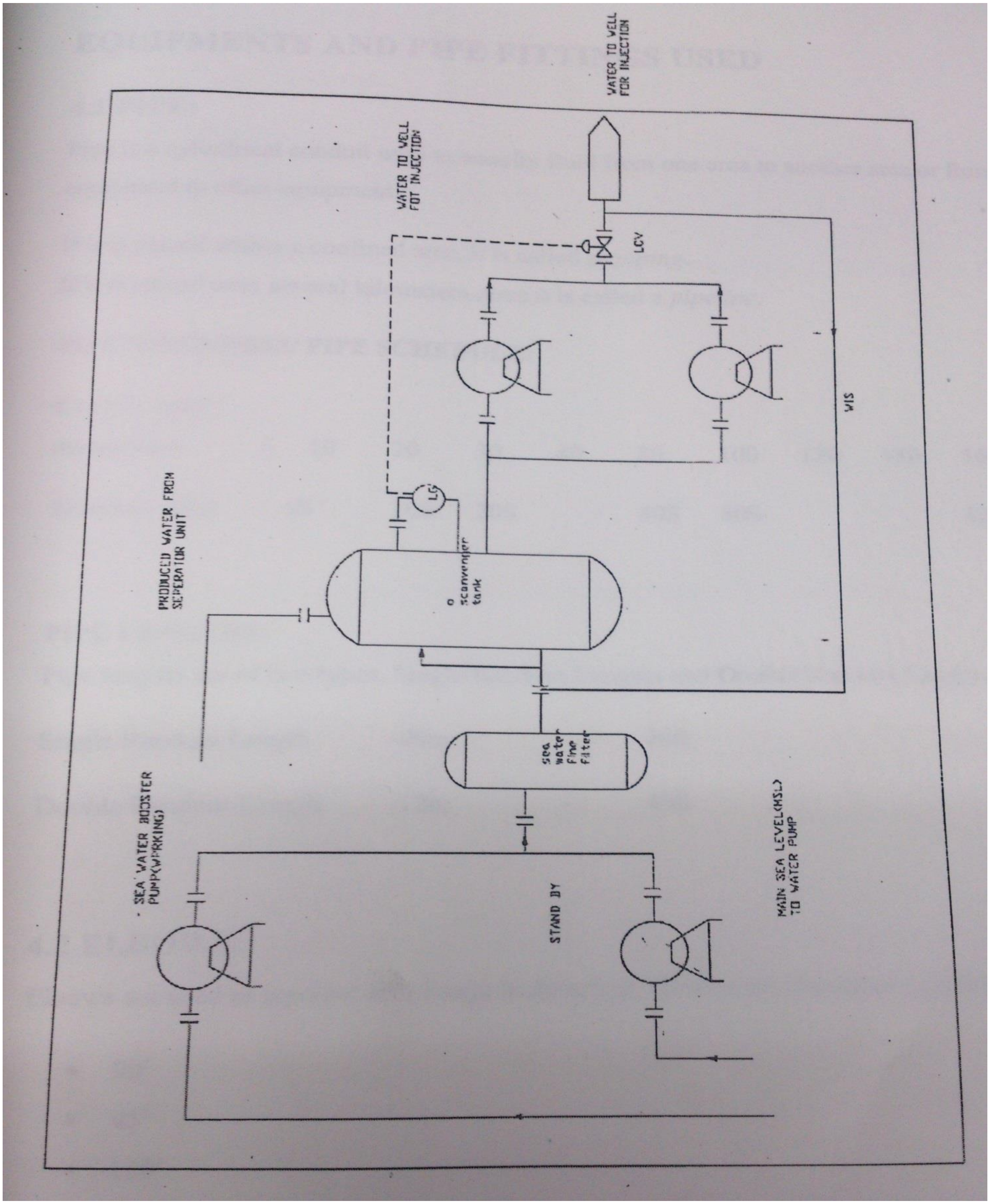


Fig 4.1 PFD of the water injection system

Chapter 5

EQUIPMENTS AND PIPE FITTINGS ARE USED

5.1 PIPE:

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

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

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

<u>PIPE THICKNESS/PIPE SCHEDULE</u>

Carbon steel/

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

PIPE LENGTHS:

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

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

5.2 ELBOWS:

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

- 90 degree
- 45 degree
- 180 degree

  90 degree elbows are again classified into two types:

- 90 degree long radius

- 90 degree short radius.

5.3 TEE

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

Equal tee

Unequal tee

5.4 REDUCERS:

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

- Concentric Reducers
- Eccentric reducers

Eccentric reducers are further classified into two types:

- Flat side up
- Flat side down

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

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

5.5 FLANGES:

Flanges are classified on basis of follows:

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

Weld Neck Flanges:

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

5.6 GASKETS:

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

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

Gaskets are of three types:

- Metallic
- Non-metallic
- Semi-metallic

5.7 Spectacle Blind:

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

5.8 STRAINERS / FILTERS

Strainers devices used to retain larger pieces while smaller pieces and liquids are allowed to pass through. Strainers are classified into the following

Temporary strainers

Permanent strainers

Temporary strainers

Installed in the new plants especially for removal of the construction debris from the line during initial operation.

Permanent strainers

It is installed in the permanent lines which are running to pumps, compressors, firefighting lines etc. It is further classified in to 3 types:

Basket strainer

Y type

T type

Basket strainer:

This is the type of strainer used for water injection system, used for the large quantities of flow rates for the removal of filtrates i.e, for line size above 6 inches. The strainers have hexagonal nuts on the top through which filters plate can be easily maintained. It has drain connection at the bottom which helps in draining the filtrates to drain header.

5.9 valves:

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

- isolation valves
- regulation valves
- checking valves
- safety valves
- special valves

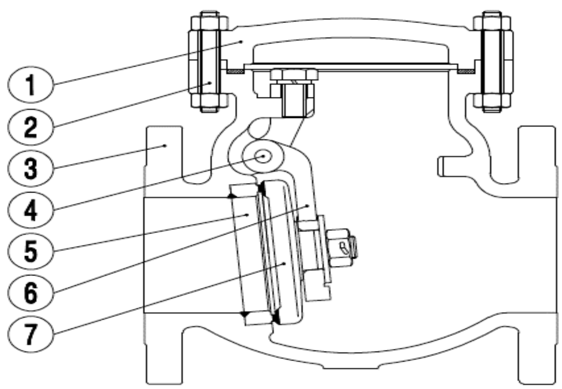
The valves that are used in the water injection system are.

5.9.1 Check valve:

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

Swing type check valve

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



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

Fig 5.1 Flanged swing check valve

Lift type check valve:

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

Wafer type check valve:

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

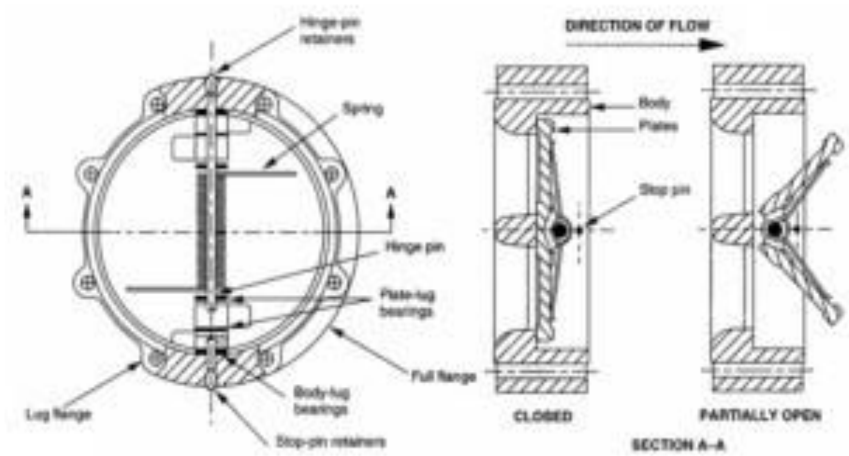
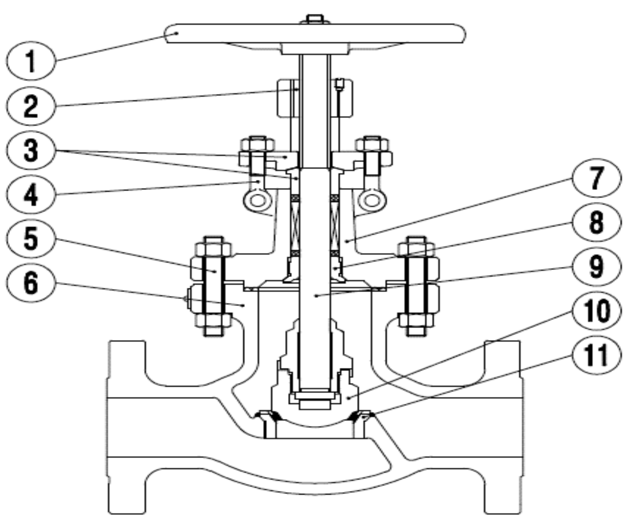


Fig 5.2 Wafer type check valve

5.9.2 Globe valve

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



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

Fig 5.3 flanged globe valve

5.9.3 Gate Valve:

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

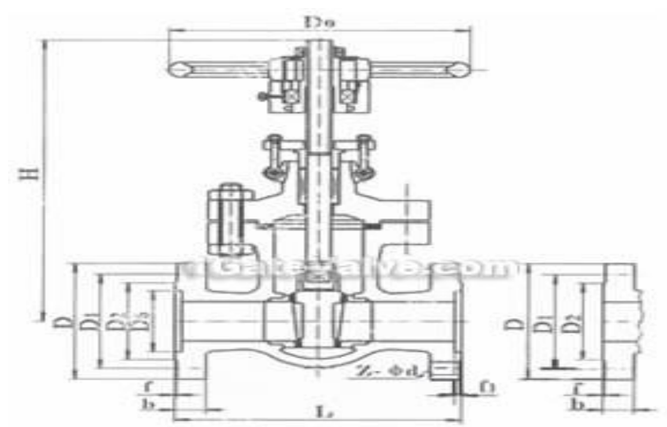


Fig 5.4 Flanged gate valve.

5.9.4 Ball Valve:

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

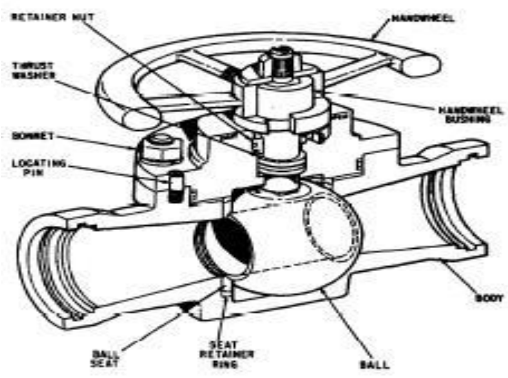


Figure 6-1.—Typical ball valve.

Fig 5.5 Flanged Ball valve.

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

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

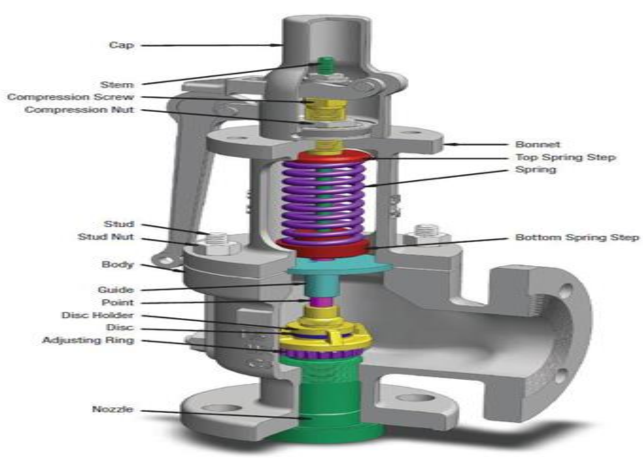


Fig 5.6 Relief valve

5.9.6 Control Valve:

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

- PCV (Pressure control valve)

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

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

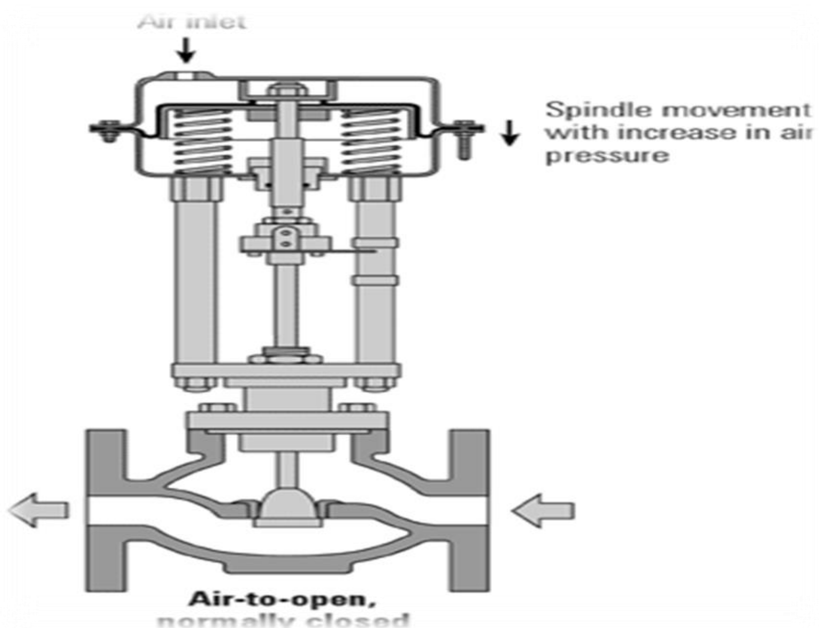


Fig 5.7 Flanged control valve

5.10 Pumps:

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

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

Centrifugal pumps:

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

- Centrifugal pumps are for large quantizes of fluid to be pumped at relatively lower head compared to Reciprocating pumps.
- Reciprocating pumps are used to transfer small quantities of liquid to be delivered at large heads.
- Rotary pumps are used for abrasive and viscous fluids.

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

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

- Front suction and top discharge.
- Top suction and top discharge.
- Side suction side discharge.

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

5.11 TANKS:

Tanks are classified into two i.e. Fixed tank and floating tanks. Tanks are used for storage of liquid hydrocarbon. The fixed roof tank stored in a tank can have an aggregate capacity of 60,000 cubic meters. The floating roof tanks shall effective capacity of 1, 20,000 cubic meters. Both fixed and floating roof tanks required concrete foundation for supporting.

Chapter 6

CODES AND STANDARDS

6.1 CODES

Codes are a set of rules and regulations required for safer design, construction, and erection of a plant. The wrong implementation of codes can lead to hazardous accidents which can claim lives. The failure of implementation of code can also be challenged by law.

6.1.1 ASME codes and their applications

ASME B 31.1 - power piping

ASME B 31.3 -process piping

ASME B 31.4 –liquid hydrocarbon transportation

ASME B 31.8 – gas hydrocarbon transportation

ASME B 31.9 – build service piping

ASME B 31.11 – slurry waste water treatment

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

ASME B 36.19 – stainless steel pipe

ASME B 16.5 – steel flanges below 24”

ASME B 16.20 – metallic gaskets

ASME B 16.21 – nonmetallic gaskets

ASME B 16.9 – butt welded fitting

ASME B 16.11 – socket welded / threaded fitting

ASME B 16.36 – orifice flanges

ASME B 16.48 – spectacle blind

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

6.2 Standards

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

6.2.1 API standards and their applications

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

Japan – **JIS** - Japanese industrialization society

America – **ASME** – American standard

America – **API** – American petroleum institute

Britain – **BS** – British standard

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

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

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

6.3 Scope of ASME B 31.3

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

This code applies to piping for all fluids, including:

- Raw, intermediate, and finished chemicals;
- Petroleum products
- Gas, steam, air, and water;
- Fluidized solids;
- Refrigerants;
- Cryogenic fluids (-151 F to -425 F)

Chapter 7

PIPING AND INSTRUMENTATION DIAGRAMS (P&ID)

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

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

PEFS (Process Engineering Flow Schemes)

MFD (Mechanical Flow Diagram)

ELD (Engineering Land Diagram)

EFD (Engineering flow diagram)

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

1. Line Sizing
2. Line Numbering

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

7.1 LINE SIZE CALCULATIONS

Line sizing is the first step involved in the development of P&ID. A process engineer evaluates the process to determine the flow rate for a particular process. The process involved in this particular project was evaluated and the flow rate was determined as 200 GPM and the velocity of fluid (water) is 3.25MPS. The calculation is based on the following equation,

Q=AV where,

The flow in meter cube per second (m^3/sec), Q=210 GPM

Therefore, Q= (2100*3.58) / (1000*60) =0.1253 m^3/sec

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

The velocity of the liquid in meter per second (m/sec), V= 3.65m/sec

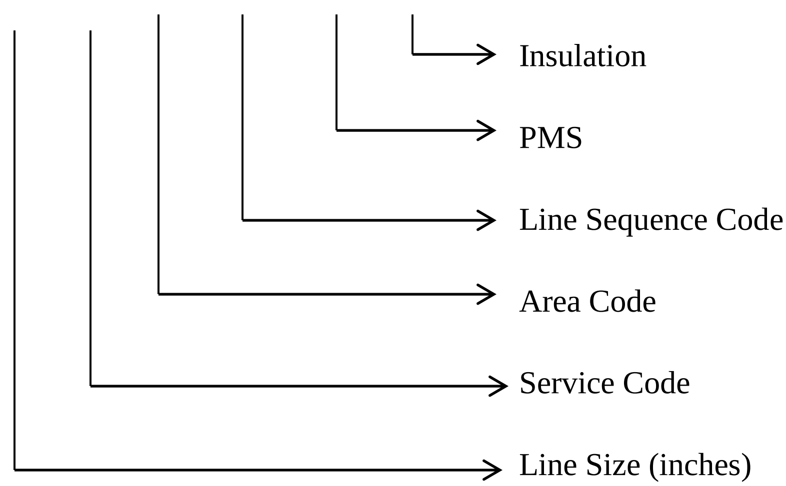
Substituting the above values in the equation, Q=AV, we get d=0.211582m

Since a safer design will be choosing an available line size above 0.211582m (8.33”), the line size chosen for this project is 0.254m (10”)

7.2 REPRESENTATION OF A LINE IN P&ID

The step to be carried out in the formation of P&ID after line size calculation is done is to represent the lines. A typical line numbering of the line is as follows:

0008” – W – 500 - 1000 – A1 – NA



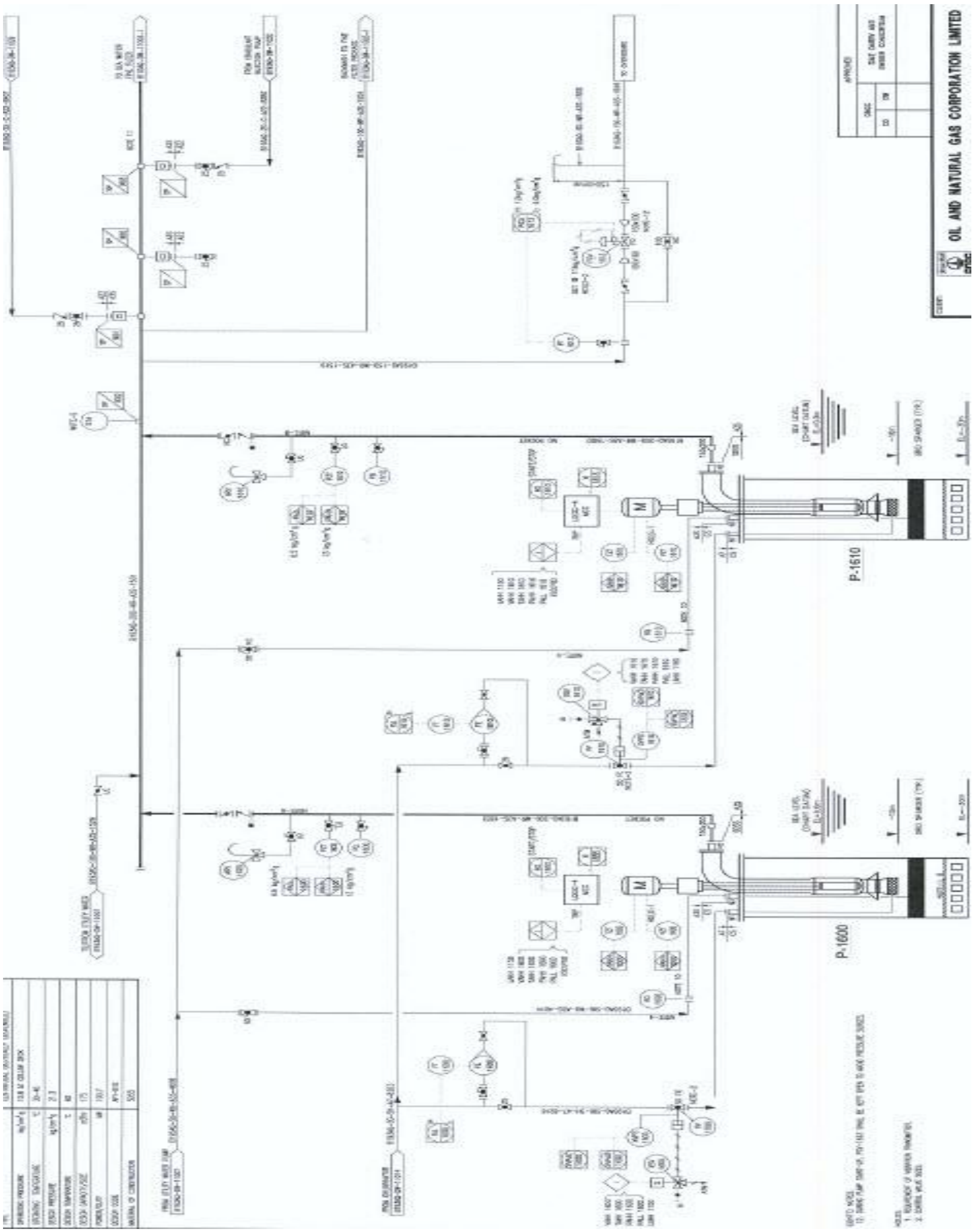


Fig 7.1 P&ID for sea water booster pumps

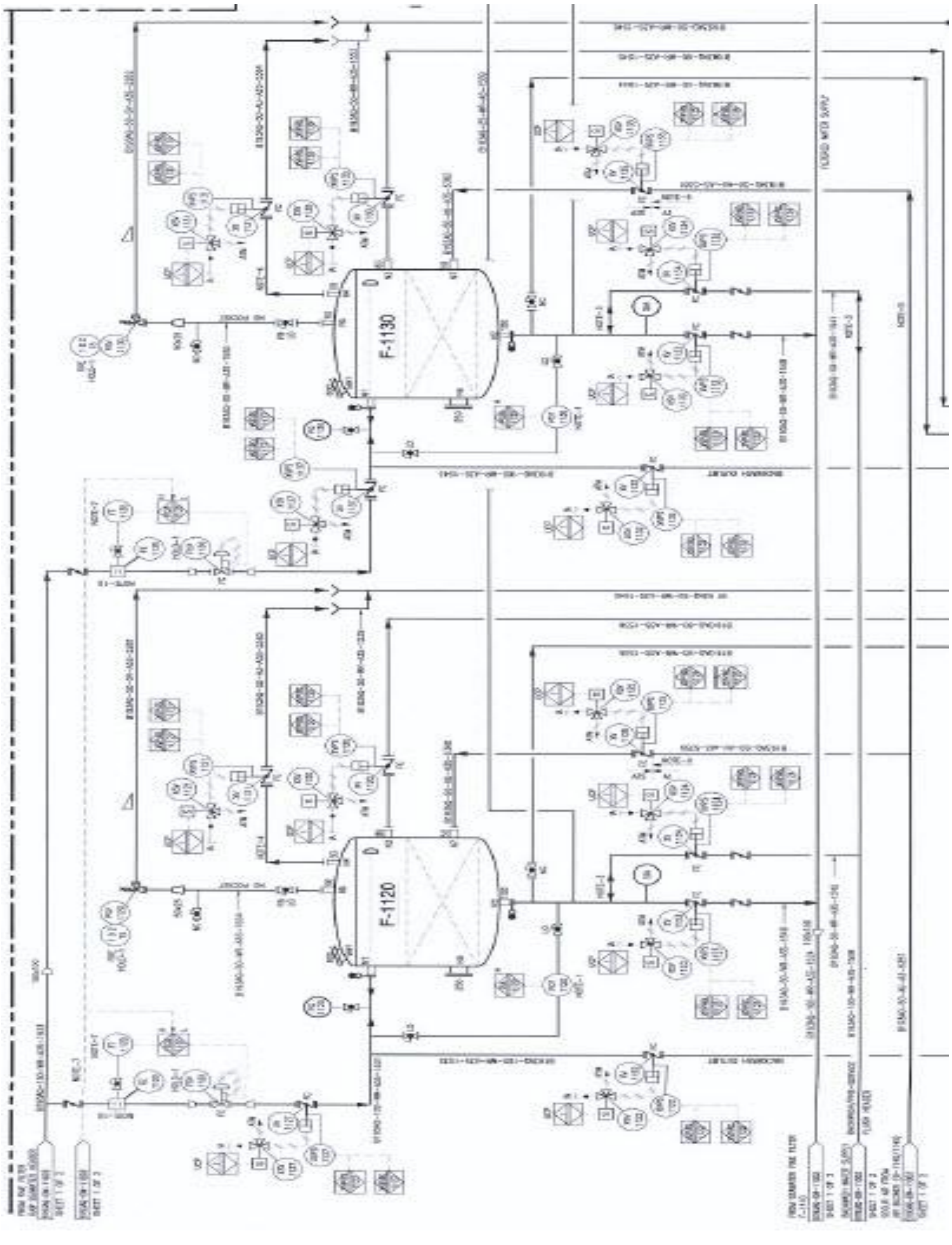


Fig 7.2 P&ID for sea water fine filters

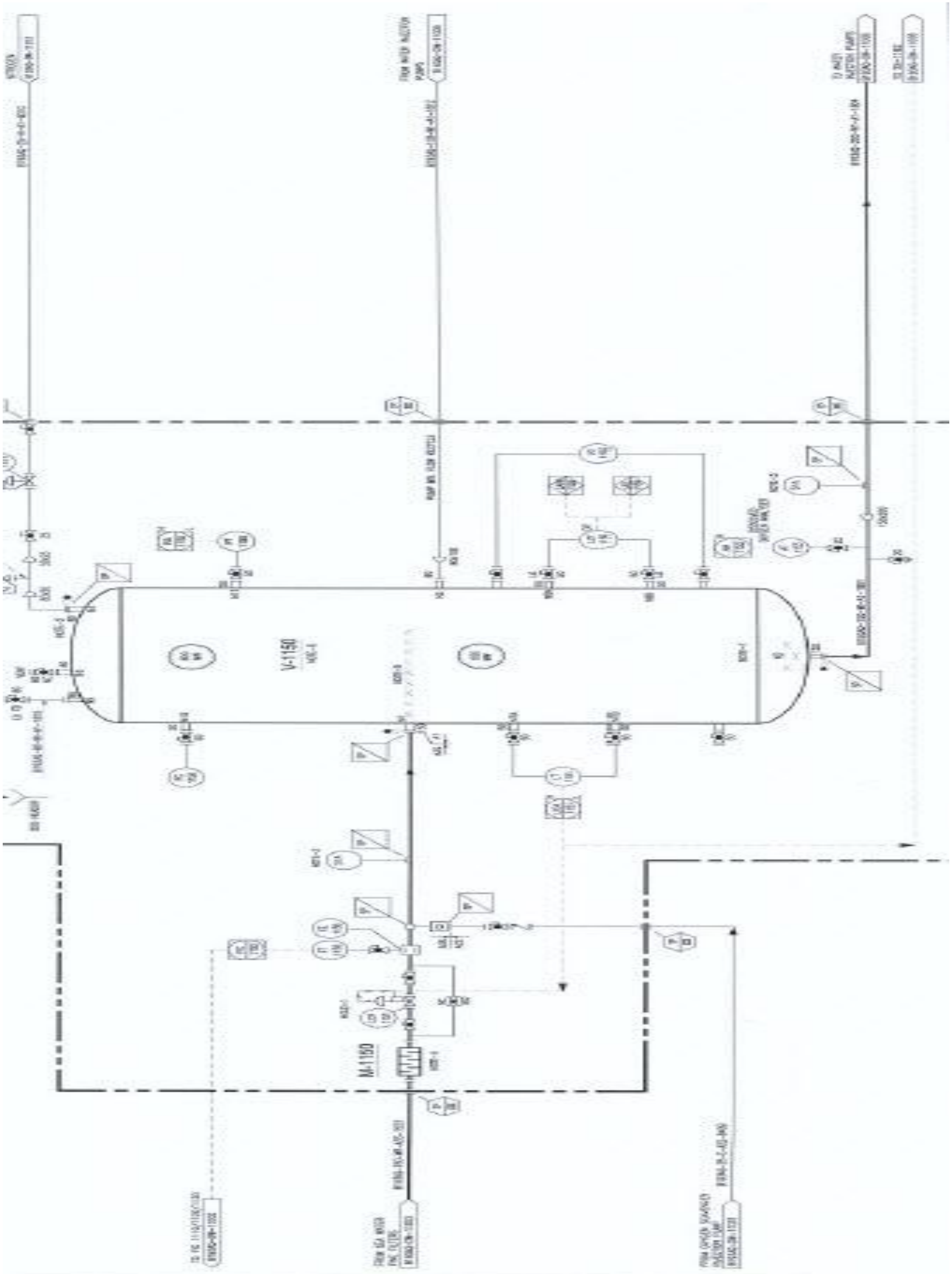


Fig 7.3 P&ID for oxygen scavenger tank

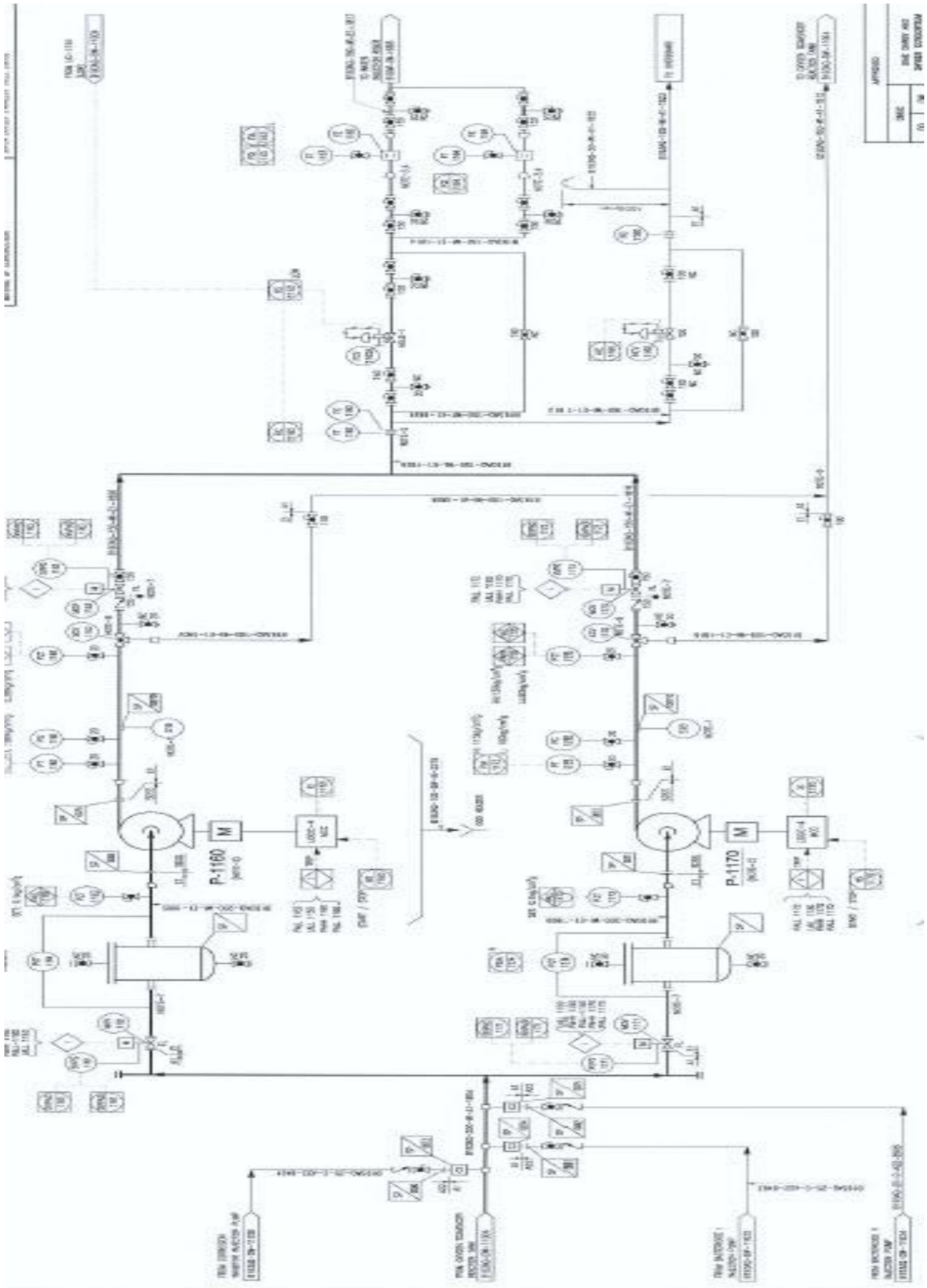


Fig 7.4 P&ID for water injection pump.

Chapter 8

SP3D (Smart Plant 3D)

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

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

Table 8.1 Comparison between 2D & 3D softwares

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

- A fully interactive, intuitive 3D design environment, with a Microsoft office style user interface based on .NET technology
- Hundreds of designers can work concurrently on a project, in a fully controlled manner with visibility of the entire design at all times
- Designers progressively create a highly intelligent 3D design by selecting and positioning parametric components from an extensive catalogue.
- Highly configurable, automatic generation of a wide range of reports and drawings direct from the SP3D database.

8.1 Piping Layout Requirements:

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

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

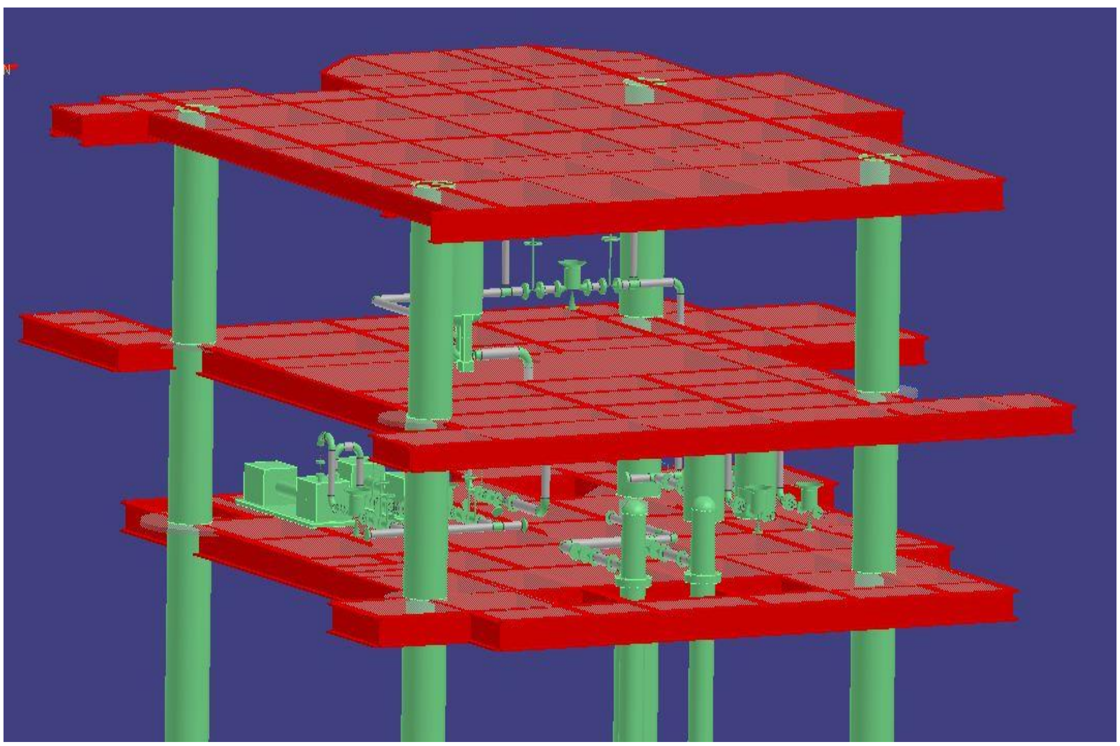


Fig 8.1 Isometric view of the WI system designed.

Chapter 9

PIPE THICKNESS CALCULATION AND SELECTION OF SCHEDULE FOR THE PIPE

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

$$\boldsymbol{t} = \frac{\boldsymbol{P}\times\boldsymbol{D}}{\mathbf{2}(\boldsymbol{S}\times\boldsymbol{E}+\boldsymbol{P}\times\boldsymbol{Y})} \quad \text{………..(9.1)}$$

Where,

P = Internal design pressure in psi

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

Y = Co-efficient as per ASME B 31.3

D = Outside diameter in inches

T = Pressure design thickness in inches

S = Allowable stress in psi based on ASME 31.3

C = Corrosion allowance

$t_{nominal} = t + C$

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

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

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

<u>250-W-001-A35-NA</u>

P = 228 psi

T = 60^0C = 140 F

D = 10 = 10.75 (NPS)

C = 6mm ÷ 25.4= 0.2362”

E = 1 (seamless tube)

Y = 0.4 as per code ASME B 31.3

S = 20 KSI = 20000 psi

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

t= 228× 10.75÷ $[2 \times 1 + 228 \times 0.4]$ = 0.061”= 0.00154m

$t_{nominal}$ = 0.061 + 0.2362 = 0.2972”= 0.00754m

$t_{minimum}$ = 0.2972 ÷0.875 = 0.3396” = 0.00867m

Schedule number = 40 (STD) from ASME B 36.10

250W-003-A3S-NA

P = 228 psi

T = 60^0C = 140 F

D = 10 = 10.75 (NPS)

C = 6mm ÷ 25.4= 0.2362”

E = 1 (seamless tube)

Y = 0.4 as per code ASME B 31.3

S = 20 KSI = 20000 psi

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

t= 228× 10.75÷ $[2 \times 1 + 228 \times 0.4]$ = 0.061”= 0.00154m

$t_{nominal}$ = 0.061 + 0.2362 = 0.2972”= 0.00754m

$t_{minimum}$ = 0.2972 ÷0.875 = 0.3396” = 0.00867m

Schedule number = 40 (STD) from ASME B 36.10

200-W-009-A3S- NA

P = 228 psi

T = 60^{0}C = 140 F

D = 8 = 8.625(NPS)

C = 6mm ÷ 25.4= 0.2362”

E = 1 (seamless tube)

Y = 0.4 as per code ASME B 31.3

S = 20 KSI = 20000 psi

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

t= 228× 8.625÷ $[2 \times (2000 \times 1 + 228 \times 0.4)]$ = 0.0489”= 0.00124m

$t_{nominal}$ = 0.0489 + 0.2362 = 0.2851”= 0.00724m

$t_{minimum}$ = 0.2851 ÷0.875 = 0.325” = 0.008255m

Schedule number = 40 (STD) from ASME B 36.10

200-W-004-A3S-NA

P = 228 psi

T = 60^{0}C = 140 F

D = 8 = 8.625(NPS)

C = 6mm ÷ 25.4= 0.2362”

E = 1 (seamless tube)

Y = 0.4 as per code ASME B 31.3

S = 20 KSI = 20000 psi

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

t= 228× 8.625÷ $[2 \times (2000 \times 1 + 228 \times 0.4)]$ = 0.0489”= 0.00124m

$t_{nominal}$ = 0.0489 + 0.2362 = 0.2851”= 0.00724m

$t_{minimum}$ = 0.2851 ÷0.875 = 0.325” = 0.008255m

Schedule number = 40 (STD) from ASME B 36.10

<u>200-W-0008-A35-NA</u>

P = 228 psi

T = 60^{0}C = 140 F

D = 6 = 6.625(NPS)

C = 6mm ÷ 25.4= 0.2362”

E = 1 (seamless tube)

Y = 0.4 as per code ASME B 31.3

S = 20 KSI = 20000 psi

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

t= 228× 6.625÷ $[2 \times (2000 \times 1 + 228 \times 0.4)]$ = 0.0375”= 0.000952m

$t_{nominal}$ = 0.0375 + 0.2362 = 0.2737”= 0.00695m

$t_{minimum}$ = 0.2737 ÷0.875 = 0.3129” = 0.00794m

Schedule number = 40 (STD) from ASME B 36.10

150-W-0011-A1-NA

P = 228 psi

T = 60^0C = 140 F

D = 6 = 6.625(NPS)

C = 6mm ÷ 25.4= 0.2362”

E = 1 (seamless tube)

Y = 0.4 as per code ASME B 31.3

S = 20 KSI = 20000 psi

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

t= 228× 6.625÷ $[2 \times (2000 \times 1 + 228 \times 0.4)]$ = 0.0375”= 0.000952m

$t_{nominal}$ = 0.0375 + 0.2362 = 0.2737”= 0.00695m

$t_{minimum}$ = 0.2737 ÷0.875 = 0.3129” = 0.00794m

Schedule number = 40 (STD) from ASME B 36.10

150-W-0012-B1-NA

P = 1992 psi

T = 60^0C = 140 F

D = 6 = 6.625(NPS)

C = 6mm ÷ 25.4= 0.2362”

E = 1 (seamless tube)

Y = 0.4 as per code ASME B 31.3

S = 20 KSI = 20000 psi

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

t= 1992× 6.625÷ $[2 \times (2000 \times 1 + 1992 \times 0.4)]$ = 0.031728”= 0.00805m

$t_{nominal}$ = 0.031728 + 0.2362 = 0.5534”= 0.0140m

$t_{minimum}$ = 0.5534 ÷0.875 = 0.6325” = 0.0160m

Schedule number = 120 (STD) from ASME B 36.10

150-W-0016-B1-NA

P = 1992 psi

T = 60^0C = 140 F

D = 6 = 6.625(NPS)

C = 6mm ÷ 25.4= 0.2362”

E = 1 (seamless tube)

Y = 0.4 as per code ASME B 31.3

S = 20 KSI = 20000 psi

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

t= 1992× 6.625÷ $[2 \times (2000 \times 1 + 1992 \times 0.4)]$ = 0.031728”= 0.00805m

$t_{nominal}$ = 0.031728 + 0.2362 = 0.5534"= 0.0140m

$t_{minimum}$ = 0.5534 ÷0.875 = 0.6325" = 0.0160m

Schedule number = 120 (STD) from ASME B 36.10

150-W-0031-B1-NA

P = 1992 psi

T = 60^0C = 140 F

D = 4 = 4.5(NPS)

C = 6mm ÷ 25.4= 0.2362"

E = 1 (seamless tube)

Y = 0.4 as per code ASME B 31.3

S = 20 KSI = 20000 psi

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

t= 1992× 4.5÷ $[2 \times (2000 \times 1 + 1992 \times 0.4)]$ = 0.2155"= 0.00547m

$t_{nominal}$ = 0.2155 + 0.2362 = 0.4517"= 0.0114m

$t_{minimum}$ = 0.4517 ÷0.875 = 0.5162" = 0.0131m

Schedule number = 160 (STD) from ASME B 36.10

100-W-0015-B1-NA

P = 1992 psi

T = 60^0C = 140 F

D = 4 = 4.5(NPS)

C = 6mm ÷ 25.4= 0.2362"

E = 1 (seamless tube)

Y = 0.4 as per code ASME B 31.3

S = 20 KSI = 20000 psi

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

t= 1992× 4.5÷ $[2 \times (2000 \times 1 + 1992 \times 0.4)]$ = 0.2155"= 0.00547m

$t_{nominal}$ = 0.2155 + 0.2362 = 0.4517"= 0.0114m

$t_{minimum}$ = 0.4517 ÷0.875 = 0.5162" = 0.0131m

Schedule number = 160 (STD) from ASME B 36.10

100-W-0017-B1-NA

P = 1992 psi

T = 60^0C = 140 F

D = 4 = 4.5(NPS)

C = 6mm ÷ 25.4= 0.2362"

E = 1 (seamless tube)

Y = 0.4 as per code ASME B 31.3

S = 20 KSI = 20000 psi

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

t= $1992\times 4.5\div [2\times(2000\times 1+1992\times 0.4)]$ = 0.2155”= 0.00547m

$t_{nominal}$ = 0.2155 + 0.2362 = 0.4517”= 0.0114m

$t_{minimum}$ = 0.4517 ÷0.875 = 0.5162” = 0.0131m

Schedule number = 160 (STD) from ASME B 36.10

Chapter 10

PIPE STRESS ANALYSIS USING CEASER II

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

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

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

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

The main objectives of the pipe stress analysis are to:

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

Chapter 11

BUIDING UP OF THE MODEL IN CAESER II

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

- Sea Water Booster Pump Discharge Systems
- Water Injection Suction System
- Water Injection Discharge System

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

- Wall Thickness
- Temperature
- Pressure

11.1 Sea Water Booster Pump Discharge System

It includes the following lines:

- 250-W-0001-A3S-NA
- 250-W-0003-A3S-NA
- 200-W-0004-A3S-NA
- 200-W-0009-A3S-NA

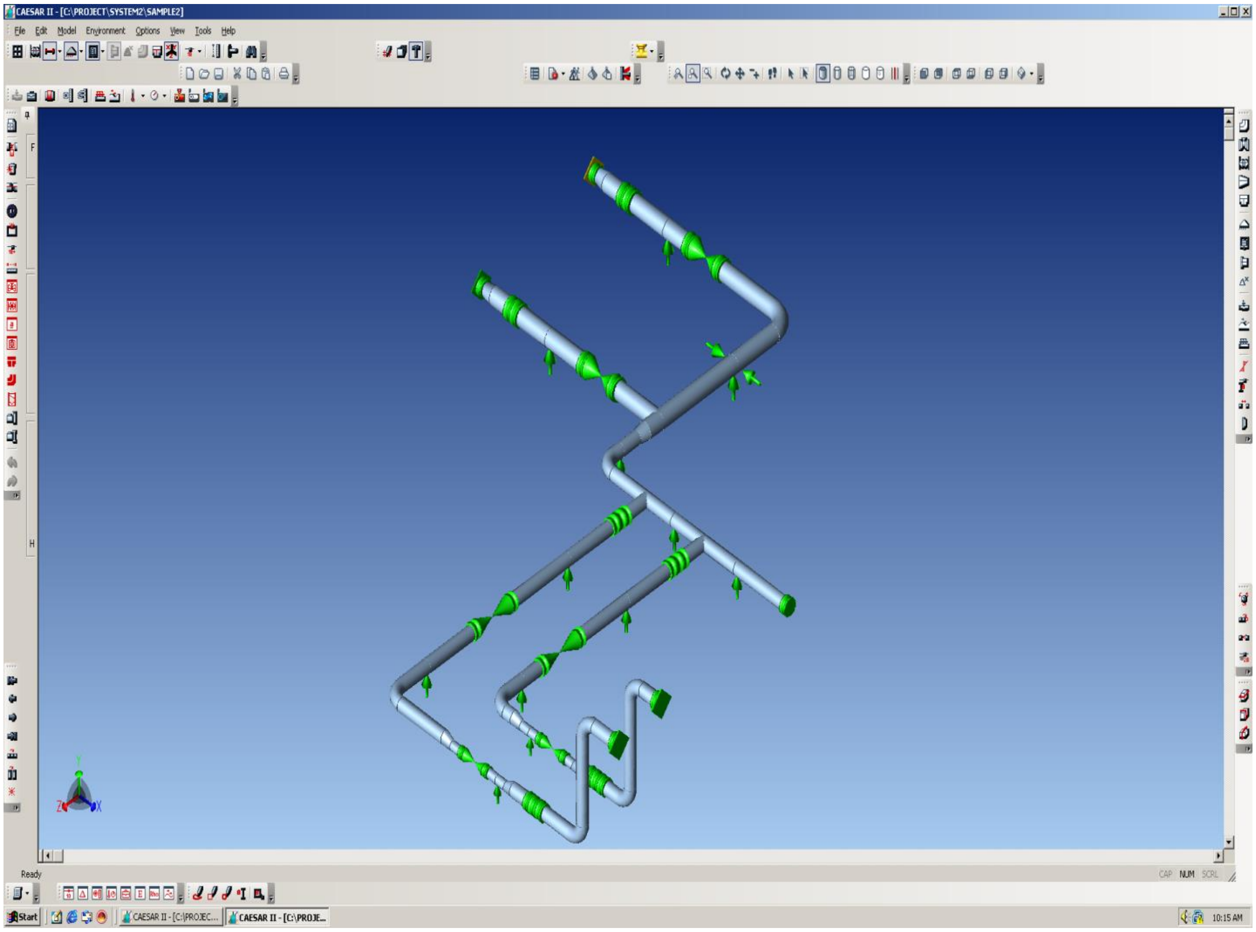


Fig 11.1: Sea water booster pump discharge system

11.2 Water Injection Suction System

It includes the following lines:

- 150-W -0011-A1-NA
- 150-W-0012-B1-NA
- 150-W-0016-B1-NA

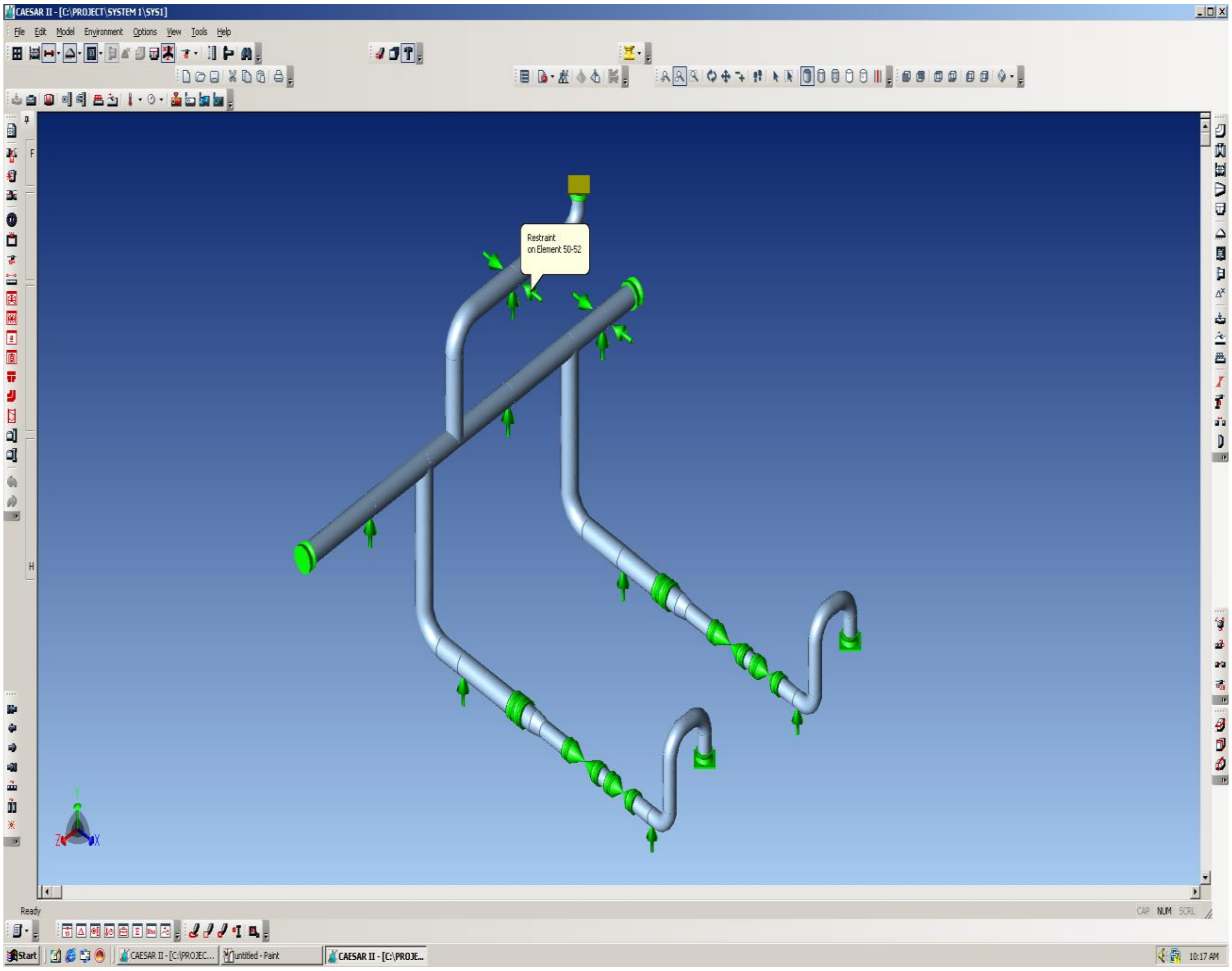


Fig11.2: Water injection suction system

Chapter 12

LOAD CASES TO BE CONSIDERED IN PIPE STRESS ANALYSIS

The stress analysis shall be carried using Caesar II software (version 5.20) and shall comply With the requirements of the code, standards and specifications defined in section 3.0, and Shall take into consideration the following load cases:

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

12.1 Sustained Load Cases:

Those loads that act due to forces present during normal operation of the system are called Sustained loads. This shall include only the effects of pressure, pipe deadweight, and insulation weight and weight of contents. This case is required to be performed mainly to check if the Code compliance requirements of sustained stress are satisfied by the piping system. Basically, the live weight and dead weight of the fluid is balanced by means of support at necessary points in the system.

Case 3: (SUS): W+P1

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

12.2 Operational Load Cases:

This shall include effects of pressure, temperature, pipe dead weight, insulation weight of the contents and other externally imposed displacement such as nozzle displacements etc. This load case is required to be performed to establish that the operating condition loads on the equipment nozzle and pipe supports are within safe limits.

12.3 Occasional Load cases:

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

12.3.1 Seismic Loads:

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

- North-South Direction G_x 0.063
- East-West Direction G_z 0.059
- Vertical Direction G_y 0.075

Various seismic load cases to be considered are:

1. W+P1+T1+U1
2. W+P1+T1+U2
3. W+P1+T1+U3
4. W+P1+T1-U1
5. W+P1+T1-U2
6. W+P1+T1-U3
7. U1
8. U2
9. U3
10. -U1
11. -U2
12. -U3

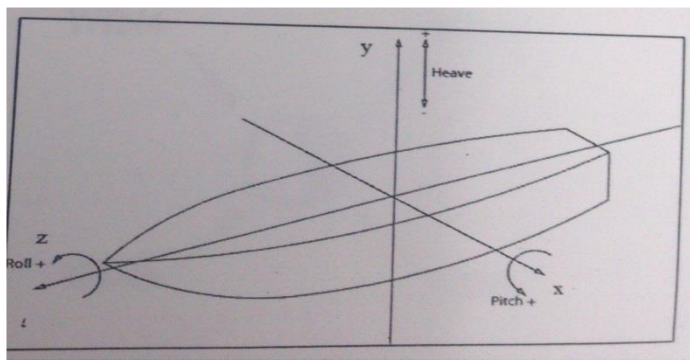


Fig 12.1 Direction of seismic load acting on a pipe

12.3.2 Wind Loads:

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

- 10 NB lines and smaller lines, which are guided in accordance with good Practice; generally do not need specific analysis.
- The impact of wind shall be considered for long, exposed piping. The pipe work Involved are normally riser lines, flare-stack lines, turbine-exhaust stack and Piping on bridge. For properly supported and restraint lines, wind loading need not be considered.

- When wind load is to be considered, a shape factor 0.65 and wind speed is to be applied in two separate direction only (+/- X and +/- Z direction)
- Wind loading/ speed at 10m above mean sea level to be considered is 67.9 m/s (3sec gust), which is based on 100 years. Return (1hour average) wind speed of44.83 m/s.
  Various Wind load cases considered are:

  1. W+P1+T1+WIN1
  2. W+P1+T1+WIN2
  3. W+P1+T1+WIN3
  4. W+P1+T1+WIN4
  5. WIN1
  6. WIN2
  7. WIN3
  8. WIN4

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

Tab 12.1: Velocity v/s Elevation chart

12.3.3 Wave Loads:

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

12.4 Displacement Loads:

Those loads which act on the pipe due to its displacement. Small and insignificant nodal displacements within the allowable limits are ignored, but if the displacement is more than10mm, then necessary guide supports or restraints must be provided to check that displacement. A gap of 3mm is allowed during the placement of guide supports. For further Illustration, refer displacement load case report of WI-Discharge given below.

DISPLACEMENTS REPORT: Nodal Movements

Displacements: 4 (OPE) W+T1+P1+H

NODE	DX in.	DY in.	DZ in.	RX deg.	RY deg.	RZ deg.
10	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000
20	-0.0000	-0.0017	0.0000	-0.0001	-0.0001	-0.0000
28	-0.0000	-0.0030	0.0000	-0.0013	-0.0018	-0.0008
29	-0.0011	-0.0052	0.0022	-0.0180	-0.0103	-0.0124
30	-0.0038	-0.0034	0.0061	-0.0339	-0.0249	-0.0185
40	-0.0114	0.0067	0.0129	-0.0390	-0.0288	-0.0212
50	-0.0144	0.0109	0.0155	-0.0400	-0.0292	-0.0219
52	-0.0211	0.0201	0.0212	-0.0406	-0.0291	-0.0228
58	-0.0345	0.0393	0.0330	-0.0388	-0.0263	-0.0246
59	-0.0392	0.0428	0.0387	-0.0270	-0.0178	-0.0227
60	-0.0434	0.0404	0.0431	-0.0121	-0.0136	-0.0203
70	-0.0552	0.0253	0.0475	-0.0027	-0.0033	-0.0171
72	-0.0550	0.0243	0.0318	-0.0009	0.0018	-0.0148
80	-0.0572	0.0230	0.0140	-0.0050	0.0034	-0.0122
82	-0.0585	0.0204	0.0044	-0.0078	0.0034	-0.0122
90	-0.0596	0.0178	-0.0033	-0.0084	0.0034	-0.0122
100	-0.0598	0.0172	-0.0053	-0.0084	0.0034	-0.0122
150	-0.0562	0.0255	0.0563	0.0042	-0.0021	-0.0138
152	-0.0575	0.0179	0.0720	0.0171	-0.0021	-0.0138
160	-0.0591	0.0038	0.0898	0.0207	-0.0021	-0.0138
170	-0.0592	0.0022	0.0918	0.0207	-0.0021	-0.0138
198	-0.0653	0.0003	0.0528	0.0020	0.0041	-0.0026
199	-0.0632	-0.0030	0.0524	0.0004	0.0049	0.0102
200	-0.0587	-0.0025	0.0515	0.0003	0.0078	0.0108
202	-0.0526	-0.0000	0.0494	-0.0008	0.0088	0.0050
210	-0.0379	-0.0022	0.0437	-0.0036	0.0107	-0.0075
220	-0.0360	-0.0027	0.0428	-0.0036	0.0107	-0.0075
230	-0.0341	-0.0033	0.0420	-0.0036	0.0107	-0.0075
240	-0.0317	-0.0041	0.0410	-0.0040	0.0109	-0.0071
250	-0.0290	-0.0048	0.0398	-0.0048	0.0113	-0.0059
260	-0.0224	-0.0055	0.0367	-0.0080	0.0124	0.0025

NODE	DX in.	DY in.	DZ in.	RX deg.	RY deg.	RZ deg.
270	-0.0207	-0.0054	0.0358	-0.0080	0.0124	0.0026
280	-0.0138	-0.0046	0.0324	-0.0081	0.0125	0.0031
290	-0.0121	-0.0044	0.0315	-0.0081	0.0125	0.0032
300	-0.0101	-0.0039	0.0305	-0.0091	0.0126	0.0070
310	-0.0084	-0.0034	0.0296	-0.0091	0.0126	0.0071
320	-0.0038	-0.0021	0.0273	-0.0092	0.0126	0.0074
330	-0.0021	-0.0016	0.0265	-0.0092	0.0126	0.0074
332	0.0022	-0.0000	0.0243	-0.0113	0.0125	0.0076
338	0.0035	0.0003	0.0236	-0.0119	0.0124	0.0071
339	0.0061	0.0021	0.0216	-0.0139	0.0129	0.0053
340	0.0065	0.0051	0.0192	-0.0187	0.0138	0.0075
348	0.0037	0.0141	0.0119	-0.0214	0.0127	0.0075
349	0.0025	0.0157	0.0082	-0.0251	0.0112	0.0044
350	0.0012	0.0140	0.0042	-0.0246	0.0077	0.0022
358	0.0006	0.0118	0.0020	-0.0239	0.0071	0.0014
359	0.0000	0.0084	0.0001	-0.0146	0.0034	0.0013
360	0.0000	0.0051	-0.0002	-0.0024	0.0018	0.0003
370	0.0000	0.0017	-0.0000	-0.0000	0.0000	0.0000
380	0.0000	0.0000	0.0000	-0.0000	0.0000	-0.0000
398	-0.0664	-0.0023	0.0203	-0.0073	0.0022	-0.0038
399	-0.0644	-0.0057	0.0214	-0.0093	0.0013	0.0095
400	-0.0599	-0.0051	0.0220	-0.0102	0.0000	0.0141
402	-0.0496	-0.0000	0.0220	-0.0111	-0.0003	0.0054
410	-0.0391	-0.0008	0.0222	-0.0121	-0.0004	-0.0053
420	-0.0372	-0.0012	0.0222	-0.0121	-0.0004	-0.0054
430	-0.0353	-0.0016	0.0222	-0.0121	-0.0004	-0.0054
440	-0.0329	-0.0022	0.0223	-0.0123	-0.0004	-0.0055
450	-0.0303	-0.0028	0.0223	-0.0127	-0.0004	-0.0051
460	-0.0237	-0.0037	0.0224	-0.0141	-0.0003	0.0009
470	-0.0220	-0.0036	0.0224	-0.0141	-0.0003	0.0010
480	-0.0151	-0.0033	0.0225	-0.0142	-0.0003	0.0014
490	-0.0134	-0.0032	0.0225	-0.0142	-0.0003	0.0015
500	-0.0113	-0.0029	0.0226	-0.0146	-0.0002	0.0051
510	-0.0097	-0.0026	0.0226	-0.0146	-0.0002	0.0051
520	-0.0051	-0.0016	0.0226	-0.0147	-0.0002	0.0053
530	-0.0034	-0.0012	0.0226	-0.0147	-0.0002	0.0054
532	0.0010	-0.0000	0.0226	-0.0156	0.0002	0.0059
538	0.0023	0.0003	0.0226	-0.0158	0.0003	0.0055
539	0.0049	0.0019	0.0217	-0.0173	0.0024	0.0050
540	0.0053	0.0049	0.0195	-0.0203	0.0037	0.0082
548	0.0022	0.0139	0.0119	-0.0219	0.0049	0.0083
549	0.0011	0.0155	0.0081	-0.0247	0.0045	0.0057
550	0.0004	0.0139	0.0042	-0.0240	0.0034	0.0040
558	0.0001	0.0117	0.0020	-0.0234	0.0032	0.0032
559	-0.0000	0.0084	0.0000	-0.0145	0.0018	0.0022
560	0.0000	0.0051	-0.0002	-0.0025	0.0012	0.0003
570	0.0000	0.0017	-0.0000	-0.0000	0.0000	-0.0000
580	0.0000	0.0000	-0.0000	-0.0000	0.0000	-0.0000

Displacements : 6 (SUS) W+P1+H

NODE	DX in.	DY in.	DZ in.	RX deg.	RY deg.	RZ deg.
10	-0.0000	-0.0000	0.0000	0.0000	-0.0000	0.0000
20	-0.0000	-0.0000	-0.0000	0.0000	-0.0000	0.0000
28	0.0000	-0.0000	-0.0000	0.0000	-0.0001	0.0000
29	0.0000	-0.0000	-0.0000	0.0003	-0.0002	0.0002
30	-0.0000	-0.0000	-0.0000	0.0001	-0.0007	0.0003
40	-0.0002	-0.0001	-0.0000	-0.0001	-0.0008	0.0005
50	-0.0003	-0.0000	-0.0000	-0.0001	-0.0009	0.0006
52	-0.0005	-0.0000	-0.0000	0.0000	-0.0009	0.0007
58	-0.0009	-0.0001	-0.0000	0.0000	-0.0008	0.0009
59	-0.0010	-0.0000	-0.0000	-0.0007	-0.0004	0.0011
60	-0.0008	0.0000	0.0001	-0.0010	-0.0001	0.0016
70	0.0003	0.0000	0.0007	-0.0010	0.0003	0.0020
72	0.0000	-0.0000	0.0007	0.0002	0.0005	0.0022
80	-0.0004	0.0001	0.0007	-0.0000	0.0005	0.0024
82	-0.0006	-0.0000	0.0007	-0.0009	0.0005	0.0024
90	-0.0007	-0.0005	0.0007	-0.0015	0.0005	0.0024
100	-0.0008	-0.0006	0.0007	-0.0015	0.0005	0.0024
150	0.0004	0.0006	0.0007	-0.0010	0.0002	0.0022
152	0.0005	-0.0000	0.0007	0.0038	0.0002	0.0022
160	0.0007	-0.0047	0.0007	0.0075	0.0002	0.0022
170	0.0007	-0.0053	0.0007	0.0075	0.0002	0.0022
198	0.0029	0.0007	0.0020	-0.0015	0.0001	0.0028
199	0.0034	0.0009	0.0023	-0.0020	-0.0000	0.0025
200	0.0035	0.0010	0.0024	-0.0022	-0.0002	-0.0032
202	0.0035	-0.0000	0.0025	-0.0023	-0.0002	-0.0071
210	0.0035	-0.0067	0.0026	-0.0027	-0.0003	-0.0114
220	0.0035	-0.0076	0.0026	-0.0027	-0.0003	-0.0114
230	0.0035	-0.0085	0.0026	-0.0027	-0.0003	-0.0114
240	0.0035	-0.0095	0.0027	-0.0028	-0.0003	-0.0100
250	0.0035	-0.0105	0.0027	-0.0029	-0.0003	-0.0072
260	0.0035	-0.0107	0.0028	-0.0034	-0.0003	0.0070
270	0.0035	-0.0102	0.0028	-0.0034	-0.0003	0.0072
280	0.0035	-0.0082	0.0029	-0.0034	-0.0003	0.0078
290	0.0035	-0.0077	0.0029	-0.0034	-0.0003	0.0079
300	0.0035	-0.0068	0.0029	-0.0035	-0.0003	0.0126
310	0.0035	-0.0059	0.0030	-0.0035	-0.0003	0.0128
320	0.0035	-0.0035	0.0030	-0.0035	-0.0003	0.0130
330	0.0035	-0.0026	0.0030	-0.0035	-0.0003	0.0131
332	0.0035	-0.0000	0.0031	-0.0038	-0.0003	0.0137
338	0.0035	0.0007	0.0031	-0.0039	-0.0003	0.0132
339	0.0030	0.0018	0.0029	-0.0043	-0.0001	0.0086
340	0.0022	0.0022	0.0024	-0.0051	0.0001	0.0063

NODE	DX in.	DY in.	DZ in.	RX deg.	RY deg.	RZ deg.
348	0.0001	0.0022	0.0005	-0.0056	0.0001	0.0053
349	-0.0004	0.0019	-0.0002	-0.0063	-0.0004	0.0037
350	-0.0004	0.0012	-0.0005	-0.0059	-0.0009	0.0030
358	-0.0004	0.0006	-0.0005	-0.0057	-0.0009	0.0027
359	-0.0002	0.0001	-0.0003	-0.0034	-0.0004	0.0020
360	-0.0000	0.0000	-0.0000	-0.0006	0.0000	0.0004
370	-0.0000	-0.0000	-0.0000	-0.0000	0.0000	0.0000
380	0.0000	-0.0000	-0.0000	-0.0000	0.0000	0.0000
398	0.0023	0.0002	0.0011	-0.0006	0.0002	0.0030
399	0.0028	0.0004	0.0012	-0.0011	0.0000	0.0034
400	0.0030	0.0008	0.0013	-0.0014	-0.0003	-0.0001
402	0.0030	-0.0000	0.0014	-0.0016	-0.0004	-0.0059
410	0.0030	-0.0041	0.0016	-0.0019	-0.0004	-0.0103
420	0.0030	-0.0049	0.0017	-0.0019	-0.0004	-0.0103
430	0.0030	-0.0057	0.0017	-0.0019	-0.0004	-0.0102
440	0.0030	-0.0067	0.0017	-0.0020	-0.0004	-0.0092
450	0.0030	-0.0076	0.0018	-0.0021	-0.0005	-0.0070
460	0.0030	-0.0081	0.0019	-0.0024	-0.0005	0.0047
470	0.0030	-0.0078	0.0019	-0.0024	-0.0005	0.0048
480	0.0030	-0.0064	0.0021	-0.0024	-0.0005	0.0053
490	0.0030	-0.0061	0.0021	-0.0024	-0.0005	0.0055
500	0.0030	-0.0054	0.0021	-0.0026	-0.0005	0.0099
510	0.0030	-0.0047	0.0022	-0.0026	-0.0005	0.0100
520	0.0030	-0.0029	0.0023	-0.0026	-0.0005	0.0102
530	0.0030	-0.0022	0.0023	-0.0026	-0.0005	0.0103
532	0.0030	-0.0000	0.0024	-0.0028	-0.0005	0.0110
538	0.0030	0.0005	0.0024	-0.0029	-0.0004	0.0106
539	0.0027	0.0015	0.0023	-0.0032	-0.0001	0.0069
540	0.0020	0.0017	0.0019	-0.0039	0.0001	0.0053
548	0.0002	0.0017	0.0004	-0.0044	0.0002	0.0046
549	-0.0002	0.0015	-0.0001	-0.0050	-0.0002	0.0032
550	-0.0003	0.0009	-0.0004	-0.0047	-0.0005	0.0026
558	-0.0003	0.0005	-0.0004	-0.0046	-0.0006	0.0023
559	-0.0001	0.0001	-0.0002	-0.0027	-0.0003	0.0017
560	-0.0000	-0.0000	-0.0000	-0.0005	0.0001	0.0003
570	-0.0000	-0.0000	-0.0000	-0.0000	0.0000	0.0000
580	0.0000	-0.0000	-0.0000	-0.0000	0.0000	0.0000

Chapter 13

TYPES OF PIPE STRESS ANALYSIS

Following are the various analysis carried out on the system using Caesar 11.

1. System Analysis:
2. Flange Leakage Analysis
3. Nozzle Analysis

13.1 System Analysis

It involves analysis based on different load cases to check if the system satisfies the code compliance requirement and displacements.

The reports generated by Caesar 11 after analyzing the system for the aforementioned load cases are furnished at the end of the report. Basically, system analysis includes 3 types of reports. They are:

- Code Compliance Extended Report
- Restraint Summary Extended Report
- Displacement Report

13.1.1 Code Compliance Extended Report

- Here, report is generated for sustained load case only.
- If the code stress ratio is below 50%, then the numbers of supports are more than required and we need to reduce the number of supports.
- If the code stress ratio is between 50%- 80%, then the arrangement of supports is considered to be good.
- If the code stress ratio is between 80%- 100%, then the number of supports are less than required and you are expected to increase the number of supports.
- If the code stress ratio is more than 100%, then the system has failed the code compliance requirement.

13.1.2 Restraint Summary Extended Report

- Here, reports are generated for all load case except hydro test load case.
- The Value of load acting in the vertical direction i.e, Fy should be less than 5000, preferably less than 2500.
- The displacement in the vertical direction should be either zero or negative. There shouldn't be any positive displacement in Y direction i.e Dy should be -ve or zero.

13.1.3 Displacement Report:

- Here, reports are generated for all load case except hydro test load case.
- The Value of displacements in X,Y, or Z direction should not be more than 10mm.
- If D_x is more than 10mm, then stops are provided at necessary nodes.
- If D_z is more than 10mm, then guide supports are provided at necessary nodes.
- The system is taken for analysis once again to check for displacements.

13.2 Flange Leakage Analysis

Flange leakage under pipe loads is evaluated by converting piping loads to an equivalent pressure. This value is then added to the actual system design pressure, the sum of which is then compared with the ASME B16.5 allowable pressure at corresponding load case temperature multiplied by 1.5.

Due to combined effect of internal pressure and bending moment, 900 class and above flange joints shall be checked for analysis using equivalent pressure method.

- The analysis is done on 900 # and above lines irrespective of size.
- The analysis is done on 24, inch and above lines irrespective of class.

$$P_{EQ} + P < 1.5 \text{ X } P_{ASME}$$

P_{eq} = equivalent pressure in bar.

P= Internal pressure in bar.

P_{ASME}= Working pressure at corresponding Temperature from ASME B 16.5

$$P_{eq} = \frac{(160 \times 10^6 \times M_f)}{\pi \times G^3} + \frac{(40 \times {}^{-}10^3 \times F_a)}{\pi \times G^2}$$

M_f=Resultant bending moment in KN-m

F_a = Axial force in KN

G= Effective Gasket diameter as per ASME 16.20 in mm

$$\mathbf{M_f = \sqrt{(M_x^2+M_y^2+M_z^2)}}$$

From operational load case analysis report the values of Mx, M_Y, M_Z are found to calculate M_f.

$$\mathbf{P_{eq} + P < 1.5 \times P_{ASME}}$$

If the above condition is satisfied, then the flange system taken for analysis is passed.

13.2.1. Analysis of the flange system of Water injection Discharge line:

Node No: 150

From operational load case analysis report the values of Mx, M_Y, M_Z are found to be as below:

Mx= 114.9 M_Y= 1.9 M_Z= 50.2

$$\mathbf{M = \sqrt{(M_x^2+M_y^2+M_z^2)}}$$

M= $\sqrt{(114.9^2 + 1.9^2 + 50.2^2)}$

= 125.40 Kg-m

= $125.40 \times 9.81 \times 10^{-3}$ Kn-m

= 1.23 KNm

F_A=F_z=7Kg

=$7 \times 9.81 \times 10^{-3}$ N =0.687 N ≈ 0

G =149.23 mm =0.14923m (as per ASME B16.20)

$$P_{eq} = \frac{160 \times 106 \times Mf}{\pi \times G3} + \frac{40 \times 103 \times Fa}{\pi \times G2}$$

$$P_{eg} := \frac{(160 \times 10^6 \times M_f)}{\pi \times G^3} + \frac{(40 \times {}^{-}10^3 \times F_a}{\pi \times G^2}$$

P_e = 18.852 bar=1885200 Pascal's

P=140 Kg/cm^2 = 137.2 bar

=13720000 Pascal's

P_{eq}+P= 156.057

=15605700 Pascal's

P_{ASME}≈139.8 bar (as per ASME B 16.5)

1.5* P_{ASME} = 209.7 bar = 20970000 Pascal's

P_{eq}+P= 15605700 < 20970000 Pascal's

Hence, the flange system has passed the analysis.

13.2.2 Analysis of the flange system of Water injection Suction line:

Node No: 150

From operational load case analysis report the values of M_x, M_y, M_Z are found to be as below:

Mx = 407.1 M_y = 8.3 M_Z=43.3

$M = \sqrt{(M_x^2+M_y^2+M_z^2)}$

$M = \sqrt{(407.1^2 + 8.3^2 + 43.3^2)}$

=407.2 Kn-m

= 407.2 X 9.81 x 10^{-3}KNM

= 3.99 KNM

$F_A=F_z$=7Kg

$=7\times9.81\times10^{-3}$ N =0.687 N ≈ 0

G = 211.15 mm = 0.21115m (as per ASME B 16.20)

$$P_{eg} := \frac{(160 \times 10^6 \times M_f)}{\pi \times G^3} + \frac{(40 \times {}^{-}10^3 \times F_a)}{\pi \times G^2}$$

$$P_{eq} = \frac{(160 \times 10^6 \times M_f)}{\Pi * 211.5^3} + \frac{(40 \times {}^{-}10^3 \times F_a)}{\pi \times 211.15^2}$$

P_{eq}=67.89 bar

=6789000 Pascal's

P = 140 $Kg_{/cm}{}^2$

=137.2 bar = 13720000 Pascal's

P_{eq}+P = 205.05

=20505000 Pascal's

$P_{ASME} \approx$ 139.8 bar (as per ASME B 16.5)

1.5* P_{ASME} = 209.7 bar = 20970000 Pascal's

P_{eq}+P= 20505000 < 20970000 Pascal's

Hence, the flange system has passed the analysis.

13.3 Nozzle Analysis

Nozzle Analysis involves qualifying of nozzles of Pumps, Compressors, Vessels, Fire heaters, as per the Nozzle allowable specified in respective equipment standards.

In this project, we have taken the following pump nozzles for Nozzle analysis:

- WIP-01(Pump A): Suction (node 10) and Discharge Nozzles (node 710).
- WIP-02(Pump B): Suction (node 550) and Discharge Nozzles (node 10).

And since we have used Centrifugal pumps only in our project for aforementioned reasons, we have referred to API 610 standards for all nozzle allowable values.

Following are the Nozzle Analysis reports for the pumps WIP-01 and WIP-02.

CASE 3 (HYD) WW+HP+H
CASE 4 (OPE) W+T1+P1+H
CASE 5 (OPE) W+T2+P1+H
CASE 6 (SUS) W+P1+H

NODE	Load Case	FX N.	FY N.	FZ N.	MX ft.lb.	MY ft.lb.	MZ ft.lb.	DX in.	DY in.	DZ in.
10		Rigid ANC								
	3 (HYD)	-32	-566	6	10.6	-23.2	7.5	-0.0000	-0.0000	0.0000
	4 (OPE)	-813	-92	-67	-494.9	-551.9	-405.0	-0.0000	-0.0000	-0.0000
	5 (OPE)	-667	-366	-43	-314.9	-470.5	-293.5	-0.0000	-0.0000	-0.0000
	6 (SUS)	-32	-566	6	10.6	-23.2	7.5	-0.0000	-0.0000	0.0000
	MAX	-813/4	-566/6	-67/4	-494.9/4	-551.9/4	-405.0/4	-0.0000/4	-0.0000/6	-0.0000/4
52		Rigid +Y; Rigid GUI w/gap								
	3 (HYD)	0	-917	0	0.0	0.0	0.0	-0.0005	-0.0000	-0.0000
	4 (OPE)	0	0	0	0.0	0.0	0.0	-0.0211	0.0201	0.0212
	5 (OPE)	0	0	0	0.0	0.0	0.0	-0.0174	0.0131	0.0149
	6 (SUS)	0	-917	0	0.0	0.0	0.0	-0.0005	-0.0000	-0.0000
	MAX		-917/6					-0.0211/4	0.0201/4	0.0212/4
72		Rigid +Y								
	3 (HYD)	0	-1016	0	0.0	0.0	0.0	0.0000	-0.0000	0.0007
	4 (OPE)	0	0	0	0.0	0.0	0.0	-0.0550	0.0243	0.0318
	5 (OPE)	0	0	0	0.0	0.0	0.0	-0.0421	0.0156	0.0217
	6 (SUS)	0	-1017	0	0.0	0.0	0.0	0.0000	-0.0000	0.0007
	MAX		-1017/6					-0.0550/4	0.0243/4	0.0318/4
82		Rigid +Y; Rigid GUI w/gap								
	3 (HYD)	0	-1319	0	0.0	0.0	0.0	-0.0006	-0.0000	0.0007
	4 (OPE)	0	0	0	0.0	0.0	0.0	-0.0585	0.0204	0.0044
	5 (OPE)	0	0	0	0.0	0.0	0.0	-0.0443	0.0109	0.0022

NODE	Load Case	FX N.	FY N.	FZ N.	MX ft.lb.	MY ft.lb.	MZ ft.lb.	DX in.	DY in.	DZ in.
	6 (SUS)	0	-1319	0	0.0	0.0	0.0	-0.0006	-0.0000	0.0007
	MAX		-1319/6					-0.0585/4	0.0204/4	0.0044/4
152		Rigid +Y								
	3 (HYD)	0	-2054	0	0.0	0.0	0.0	0.0005	-0.0000	0.0007
	4 (OPE)	0	0	0	0.0	0.0	0.0	-0.0575	0.0179	0.0720
	5 (OPE)	0	0	0	0.0	0.0	0.0	-0.0458	0.0069	0.0501
	6 (SUS)	0	-2054	0	0.0	0.0	0.0	0.0005	-0.0000	0.0007
	MAX		-2054/6					-0.0575/4	0.0179/4	0.0720/4
202		Rigid +Y								
	3 (HYD)	0	-5738	0	0.0	0.0	0.0	0.0035	-0.0000	0.0025
	4 (OPE)	0	-9628	0	0.0	0.0	0.0	-0.0526	-0.0000	0.0494
	5 (OPE)	0	-9598	0	0.0	0.0	0.0	-0.0365	-0.0000	0.0314
	6 (SUS)	0	-5738	0	0.0	0.0	0.0	0.0035	-0.0000	0.0025
	MAX		-9628/4					-0.0526/4	-0.0000/4	0.0494/4
332		Rigid +Y								
	3 (HYD)	0	-4336	0	0.0	0.0	0.0	0.0035	-0.0000	0.0031
	4 (OPE)	0	-4906	0	0.0	0.0	0.0	0.0022	-0.0000	0.0243
	5 (OPE)	0	-4593	0	0.0	0.0	0.0	0.0024	-0.0000	0.0168
	6 (SUS)	0	-4337	0	0.0	0.0	0.0	0.0035	-0.0000	0.0031
	MAX		-4906/4					0.0035/6	-0.0000/4	0.0243/4
380		Rigid ANC								
	3 (HYD)	3	-295	-1	-87.4	1.6	56.4	0.0000	-0.0000	-0.0000
	4 (OPE)	370	634	99	-358.2	208.3	-9.1	0.0000	0.0000	0.0000
	5 (OPE)	302	370	66	-271.2	152.7	-1.7	0.0000	0.0000	0.0000
	6	3	-295	-1	-87.4	1.6	56.4	0.0000	-0.0000	-0.0000

NODE	Load Case	FX N.	FY N.	FZ N.	MX ft.lb.	MY ft.lb.	MZ ft.lb.	DX in.	DY in.	DZ in.
	(SUS)									
	MAX	370/4	634/4	99/4	-358.2/4	208.3/4	56.4/3	0.0000/4	0.0000/4	0.0000/4
402		Rigid +Y								
	3 (HYD)	0	-4889	0	0.0	0.0	0.0	0.0030	-0.0000	0.0014
	4 (OPE)	0	-7517	0	0.0	0.0	0.0	-0.0496	-0.0000	0.0220
	5 (OPE)	0	-7334	0	0.0	0.0	0.0	-0.0339	-0.0000	0.0172
	6 (SUS)	0	-4890	0	0.0	0.0	0.0	0.0030	-0.0000	0.0014
	MAX		-7517/4					-0.0496/4	-0.0000/4	0.0220/4
532		Rigid +Y								
	3 (HYD)	0	-4094	0	0.0	0.0	0.0	0.0030	-0.0000	0.0024
	4 (OPE)	0	-4613	0	0.0	0.0	0.0	0.0010	-0.0000	0.0226
	5 (OPE)	0	-4296	0	0.0	0.0	0.0	0.0019	-0.0000	0.0171
	6 (SUS)	0	-4094	0	0.0	0.0	0.0	0.0030	-0.0000	0.0024
	MAX		-4613/4					0.0030/3	-0.0000/4	0.0226/4
580		Rigid ANC								
	3 (HYD)	29	-343	-5	-70.4	7.9	42.3	0.0000	-0.0000	-0.0000
	4 (OPE)	443	553	-32	-386.6	139.2	-18.3	0.0000	0.0000	-0.0000
	5 (OPE)	365	248	-23	-286.5	115.6	-6.5	0.0000	0.0000	-0.0000
	6 (SUS)	29	-343	-5	-70.4	7.9	42.3	0.0000	-0.0000	-0.0000
	MAX	443/4	553/4	-32/4	-386.6/4	139.2/4	42.3/3	0.0000/4	0.0000/4	-0.0000/4

Chapter 14
CONCLUSION

I have successfully completed the project which involved development of piping layout for water injection system in an offshore plant and analysis of the same using Caesar II.

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

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

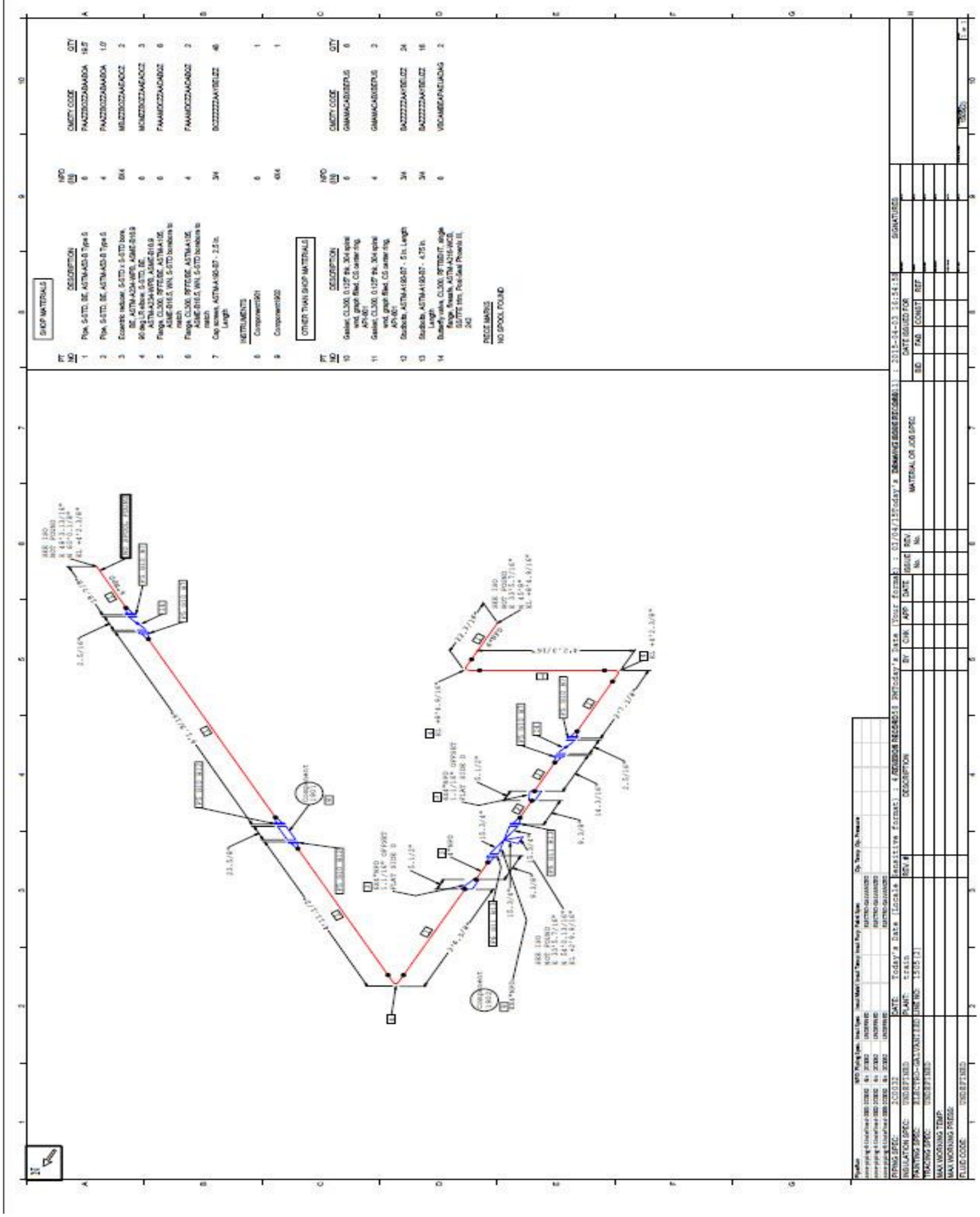
ANNEXURE 01

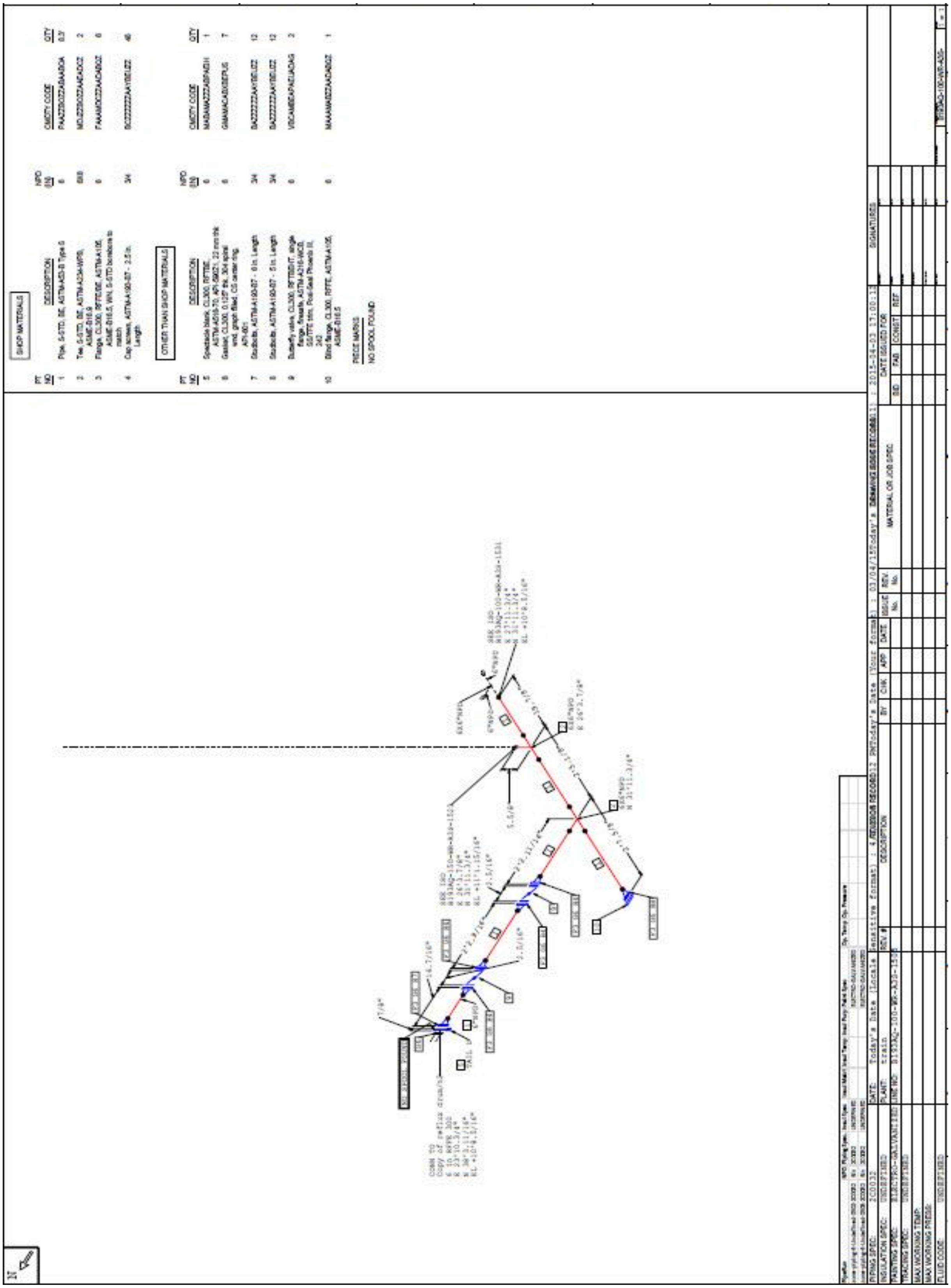
LINE LIST AND PIPE ISOMETRIC DRAWINGS

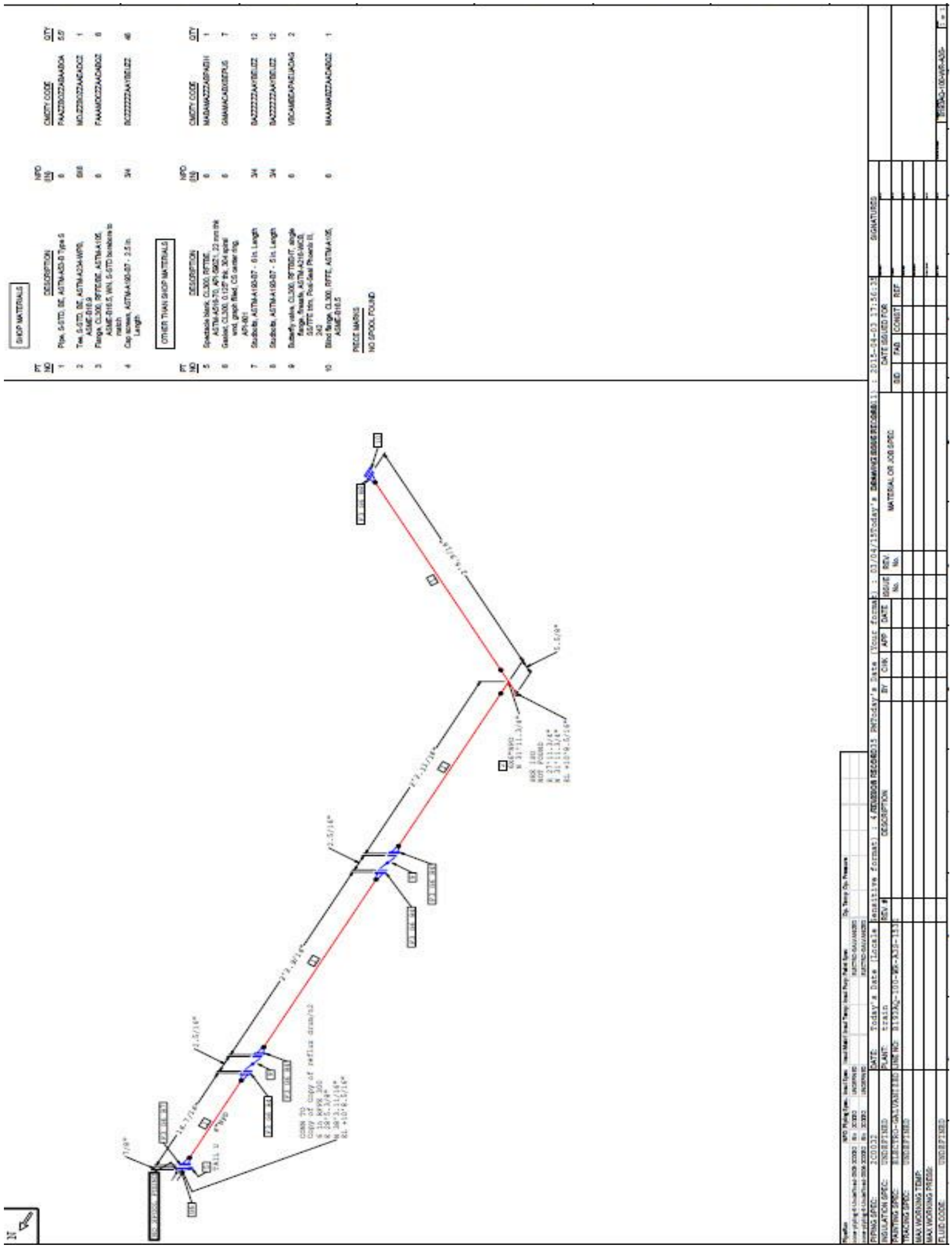
LINE LIST

LINE LIST

Sl No.	P&ID No.	Line No.	Line Size	PMS	From	To	Max Op Temp	Max Op Pressure	Design Temp	Design Pressure
1	1	250-W-0001-A3S-NA	10"	A3S	SBP-01/N1	0009/ELBO1	50deg F	150 psi	140 deg F	228 psi
2	1	250-W-0003-A3S-NA	10"	A3S	SBP-02/N1	0009/ELBO1	50deg F	150 psi	140 deg F	228 psi
3	1,2	200-W-0009-A3S-NA	8"	A3S	0009/ELBO1	FILTER-02/N1	50deg F	150 psi	140 deg F	228 psi
4	2	200-W-0004-A3S-NA	8"	A3S	0009/TEE1	FILTER-01/N1	50deg F	150 psi	140 deg F	228 psi
5	2,3	150-W-0008-A3S-NA	6"	A3S	FILTER-01&02/N2	OS-TANK/N1	50deg F	150 psi	140 deg F	228 psi
6	3,4	150-W-0011-A1-NA	6"	A1	OS-TANK/N2	0012&0016/FLAN1	50deg F	150 psi	140 deg F	228 psi
7	4	150-W-0012-B1-NA	6"	B1	0011/B2/ELBO1	WIP-02/SUCTION	50deg F	1200psi	140 deg F	1992 psi
8	4	150-W-0016-B1-NA	6"	B1	0011/B4/ELBO1	WIP-01/SUCTION	50deg F	1200psi	140 deg F	1992 psi
9	4	100-W-0013-B1-NA	4"	B1	WIP-01/DISCH	0015/TEE1	50deg F	1200psi	140 deg F	1992 psi
10	4	100-W-0015-B1-NA	4"	B1	0017/TEE2	0015/B1/ELBO2	50deg F	1200psi	140 deg F	1992 psi
11	4	100-W-0017-B1-NA	4"	B1	WIP-02/DISCH	0015/TEE1	50deg F	1200psi	140 deg F	1992 psi
12	3,4	100-w-0010-A1-NA	4"	B1	0013/TEE (Min flow)	OS-TANK/N5	50 deg F	150 psi	140 deg F	228 psi






SHOP MATERIALS
PT NO | DESCRIPTION | NPD (IN) | CMDTY CODE | QTY
1 Pipe, S-STD, BE, ASTM-A53-B Type S 6 5.5'
2 Tee, S-STD, BE, ASTM-A234-WPB, ASME-B16.9 6X6 1
3 Flange, CL300, RFFE/BE, ASTM-A105, ASME-B16.5, WN, S-STD borebore to match 6 6
4 Cap screws, ASTM-A193-B7 - 2.5 in. Length 3/4 46
OTHER THAN SHOP MATERIALS
5 Spectacle blank, CL300, RFTBE, ASTM-A516-70, API-590Z1, 22 mm thk 6 1
6 Gasket, CL300, 0.125" thk, 304 spiral wnd, graph filled, CS center ring, API-601 6 7
7 Studbolts, ASTM-A193-B7 - 6 in. Length 3/4 12
8 Studbolts, ASTM-A193-B7 - 5 in. Length 3/4 12
9 Butterfly valve, CL300, RFTBD-IT, single flange, firesafe, ASTM-A216-WCB, SS/TFE trim, Posi-Seal Phoenix III, 242 6 2
10 Blind flange, CL300, RFFE, ASTM-A105, ASME-B16.5 6 1
PIECE MARKS
NO SPOOL FOUND
CONN TO
Copy of Copy of reflux drum/n2
6 in RFFE 300
PIPING SPEC: 2C0032
INSULATION SPEC: UNDEFINED
PAINTING SPEC: ELECTRO-GALVANIZED
TRACING SPEC: UNDEFINED
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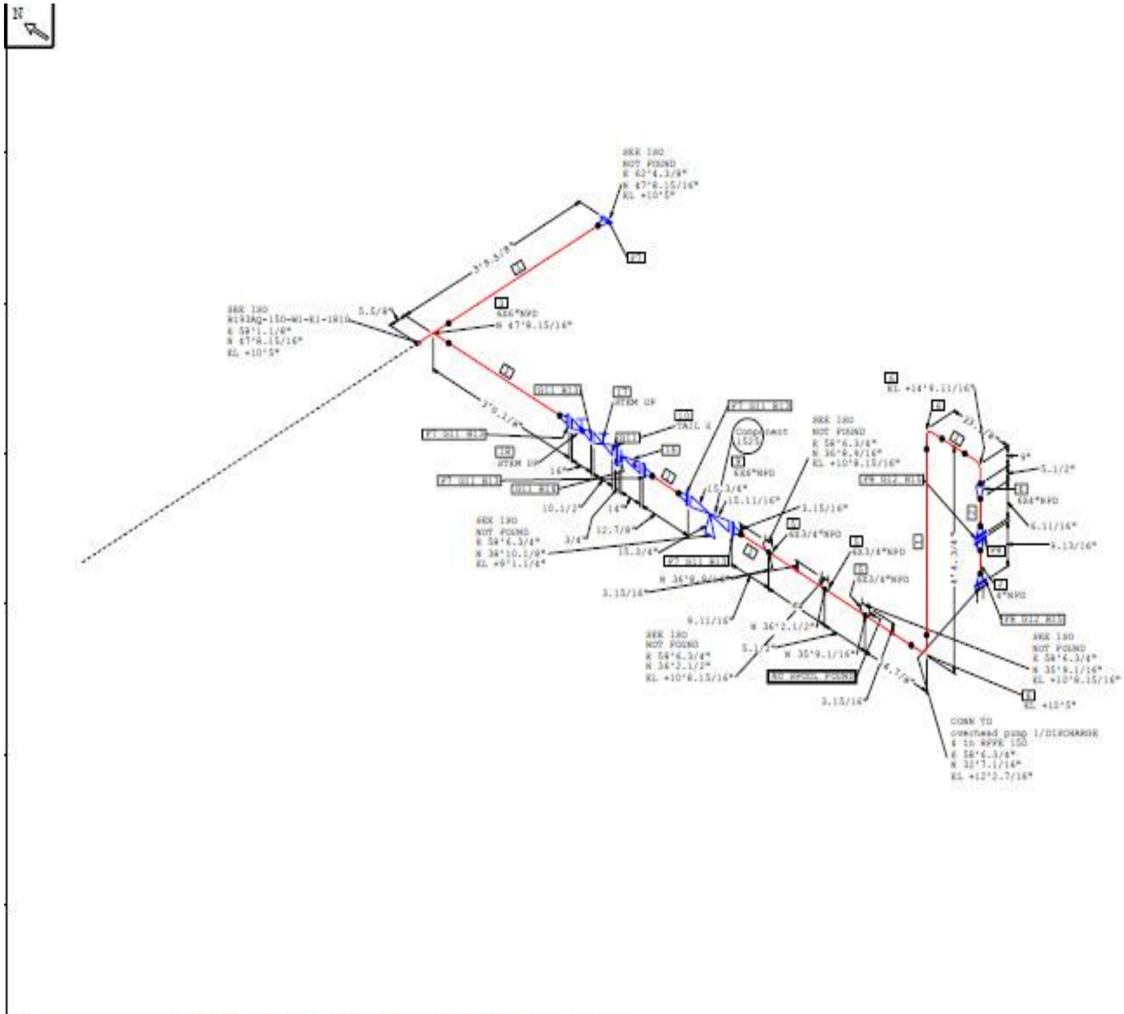
MAX WORKING PRESS:
FLUID CODE: UNDEFINED
PLANT: train
SIGNATURES
DATE ISSUED FOR
MATERIAL OR JOB SPEC



SHOP MATERIALS

PT NO	DESCRIPTION	NPD (IN)	CMDTY CODE	QTY
1	Pipe, S-STD, BE, ASTM-A53-B Type S	6	PAAZZBOZZABAABOA	11.1'
2	Pipe, S-STD, BE, ASTM-A53-B Type S	4	PAAZZBOZZABAABOA	0.7'
3	Tee, S-STD, BE, ASTM-A234-WPB, ASME-B16.9	6X6	MDJZZBOZZAAEADCZ	1
4	Concentric reducer, S-STD x S-STD bore, BE, ASTM-A234-WPB, ASME-B16.9	6X4	MBCZZBOZZAAEADCZ	1
5	Sockolet, CL3000, BE/SWE, sockolet, ASTM-A105	6X3/4	MELAWDFZZAEYABQZ	3
6	90 deg LR elbow, S-STD, BE, ASTM-A234-WPB, ASME-B16.9	6	MCMZZBOZZAAEADCZ	3
7	Flange, CL150, RFFE/BE, ASTM-A105, ASME-B16.5, WN, S-STD borebore to match	6	FAAAHDOZZAADABQZ	5
8	Flange, CL150, RFFE/BE, ASTM-A105, ASME-B16.5, WN, S-STD borebore to match	4	FAAAHDOZZAADABQZ	3

INSTRUMENTS

PT NO	DESCRIPTION	NPD (IN)	CMDTY CODE	QTY
9	Component1525	6X6		1

OTHER THAN SHOP MATERIALS

PT NO	DESCRIPTION	NPD (IN)	CMDTY CODE	QTY
10	Spectacle blank, CL150, RFTBE, ASTM-A516-70, API-590Z1, 19 mm thk	6	MABAHAZZZABPAEIH	1
11	Gasket, CL150, 0.125" thk, 304 spiral wnd, graph filled, CS center ring, API-601	6	GMAHACABXBEPUS	7
12	Gasket, CL150, 0.125" thk, 304 spiral wnd, graph filled, CS center ring, API-601	4	GMAHACABXBEPUS	2
13	Studbolts, ASTM-A193-B7 - 4.25 in. Length	3/4	BAZZZZZZAAYBDUZZ	40
14	Studbolts, ASTM-A193-B7 - 5 in. Length	3/4	BAZZZZZZAAYBDUZZ	8
15	Studbolts, ASTM-A193-B7 - 3.75 in. Length	5/8	BAZZZZZZAAYBDUZZ	16
16	Check valve, CL150, RFFE, BC, swing, ASTM-A216-WCB, trim 8, Pacific 180	6	VBGAHABAHAFEADAZ	1
17	Gate valve, CL150, RFFE, BB, OS&Y, ASTM-A216-WCB, trim 8, Crane 47	6	VAAAHABAHADJADAZ	1
18	Globe valve, CL150, RFFE, BB, OS&Y, ASTM-A216-WCB, trim 8, Crane 143	6	VALAHABAHACWADAZ	1

PIECE MARKS

NO SPOOL FOUND

PIPING SPEC:	1C0031
INSULATION SPEC:	UNDEFINED
PAINTING SPEC:	ELECTRO-GALVANIZED
TRACING SPEC:	UNDEFINED
MAX WORKING TEMP:	
MAX WORKING PRESS:	
FLUID CODE:	UNDEFINED

DATE: Today's Date (Locale Sensitive format) : 4/REVISION RECORD:32 PMToday's Date (Your format) : 02/04/15Today's DRAWING ISSUE RECORD11) : 2015-04-02 12:35:32

PLANT: train

LINE NO: B193AQ-150-WI-E1-1808

REV. #	DESCRIPTION	BY	CHK	APP	DATE	ISSUE No.	REV. No.	MATERIAL OR JOB SPEC	BID	FAB	CONST	REF

SIGNATURES

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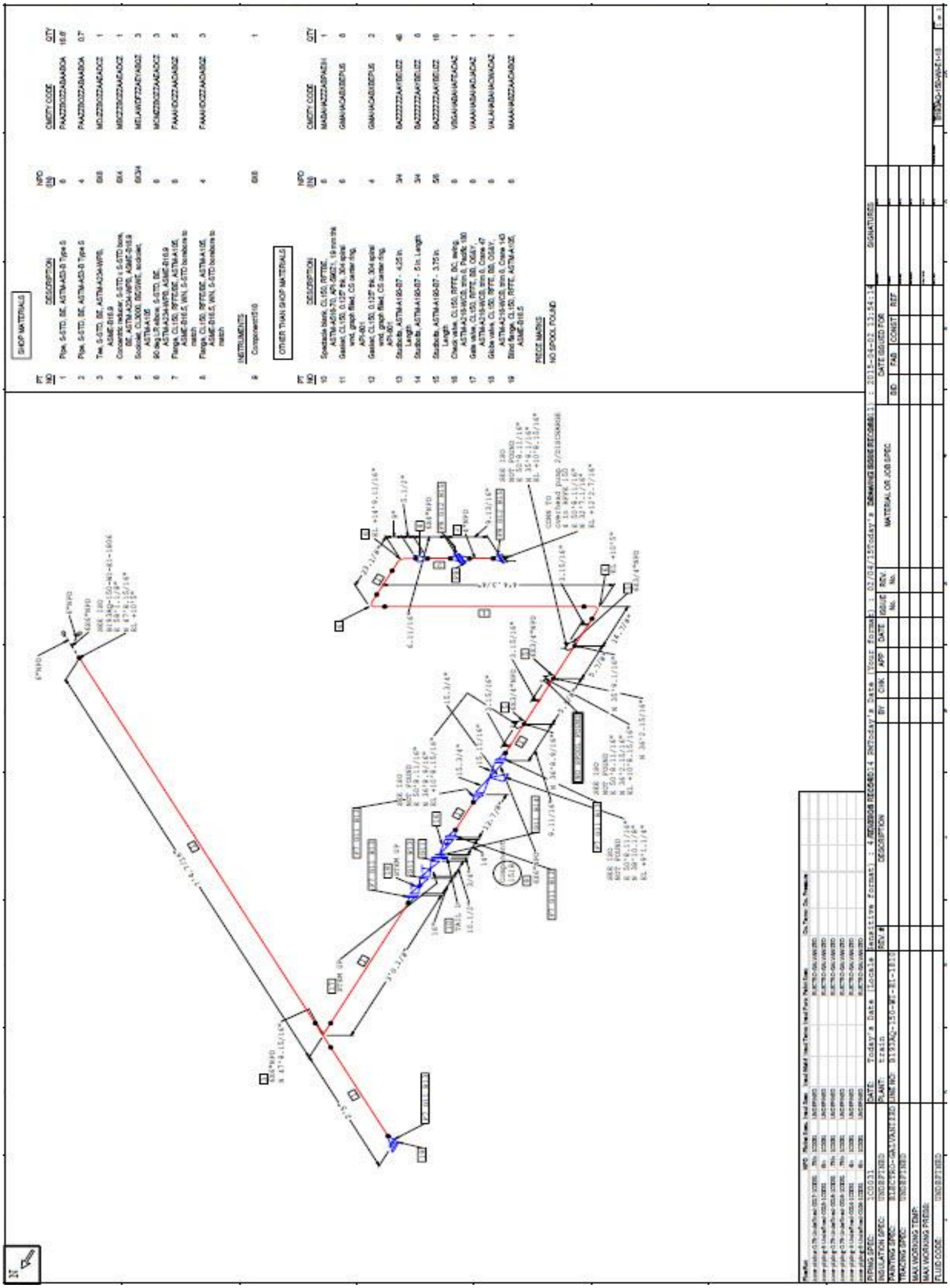
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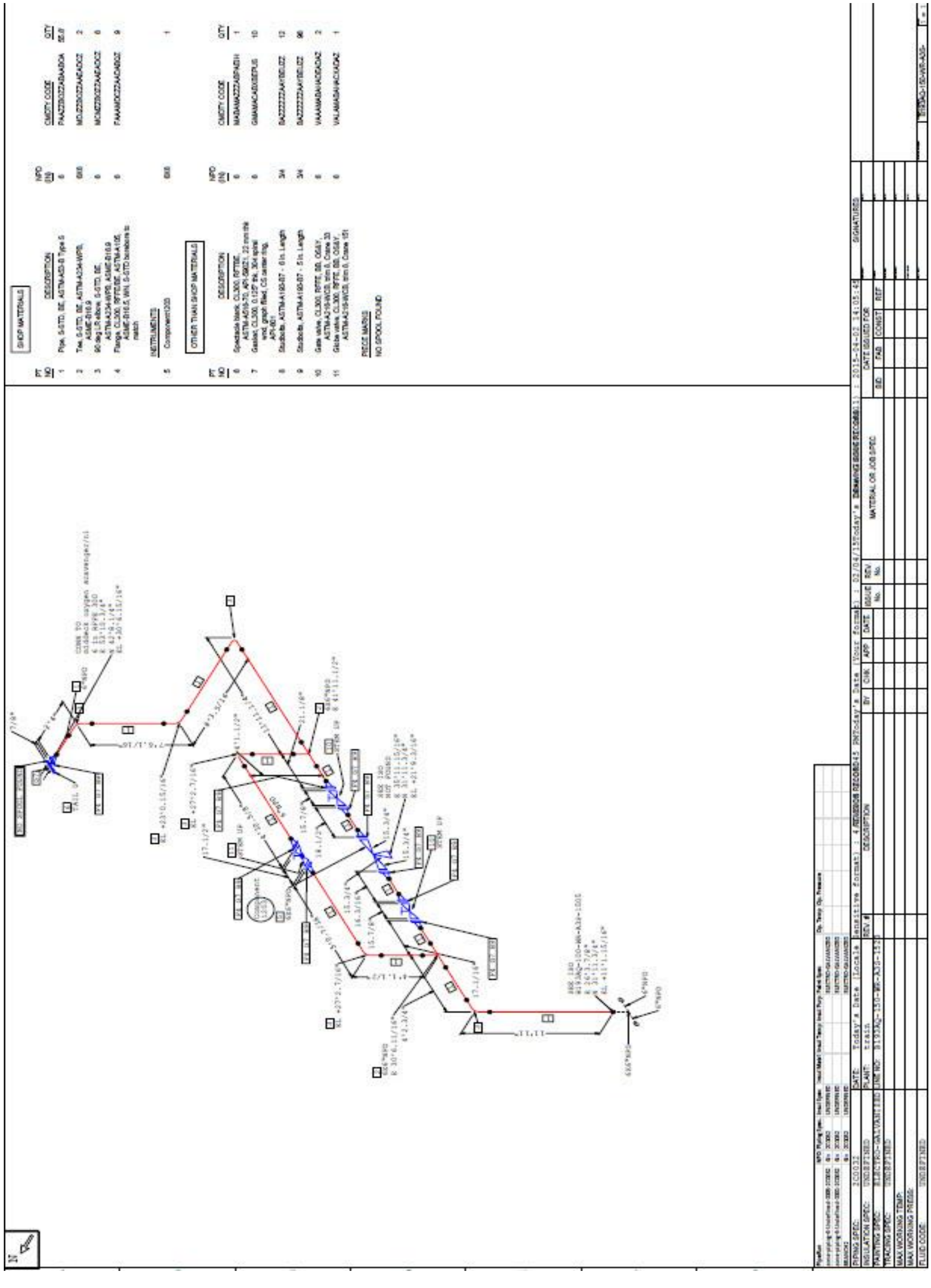
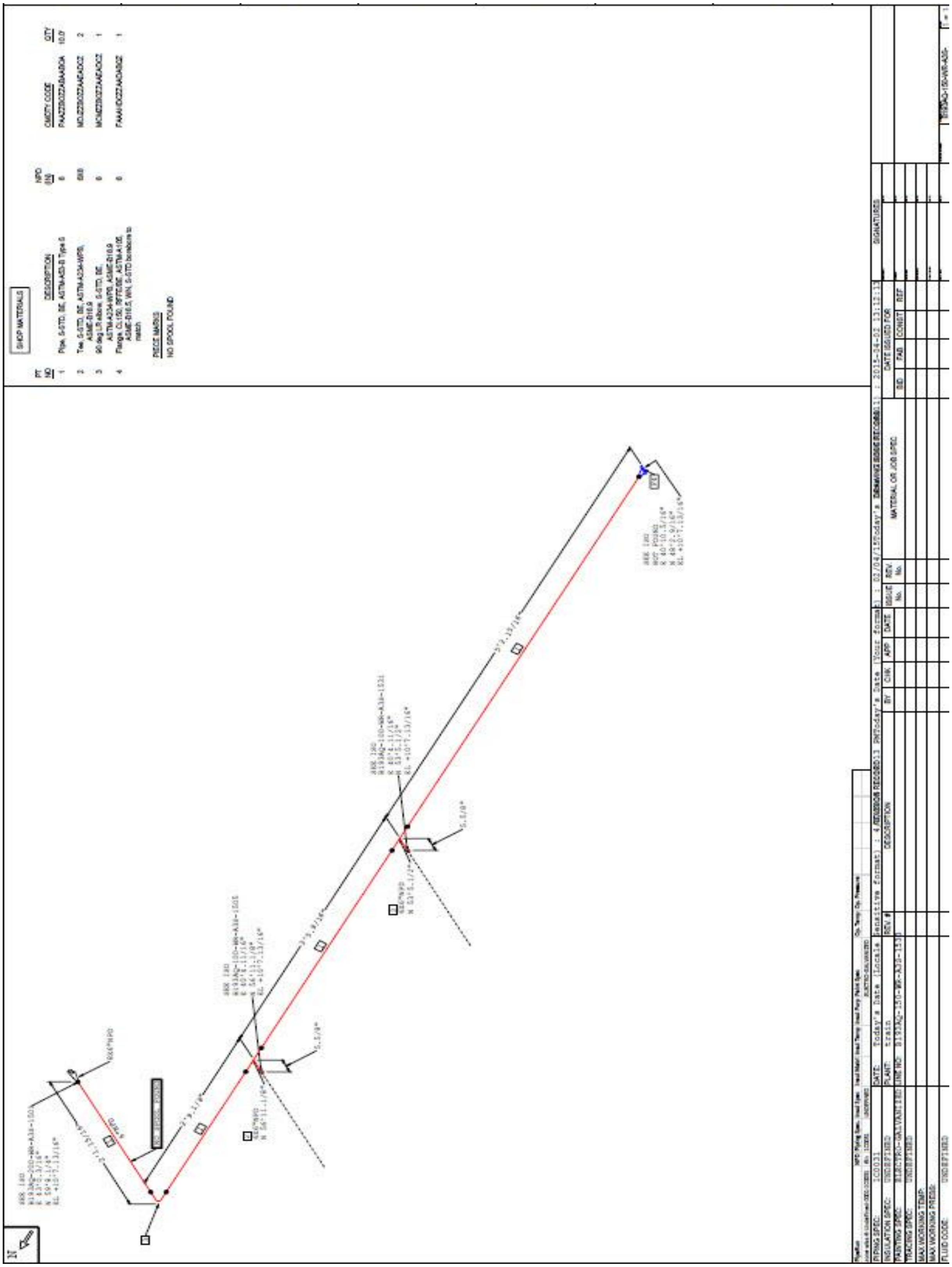
OTHER THAN SHOP MATERIALS

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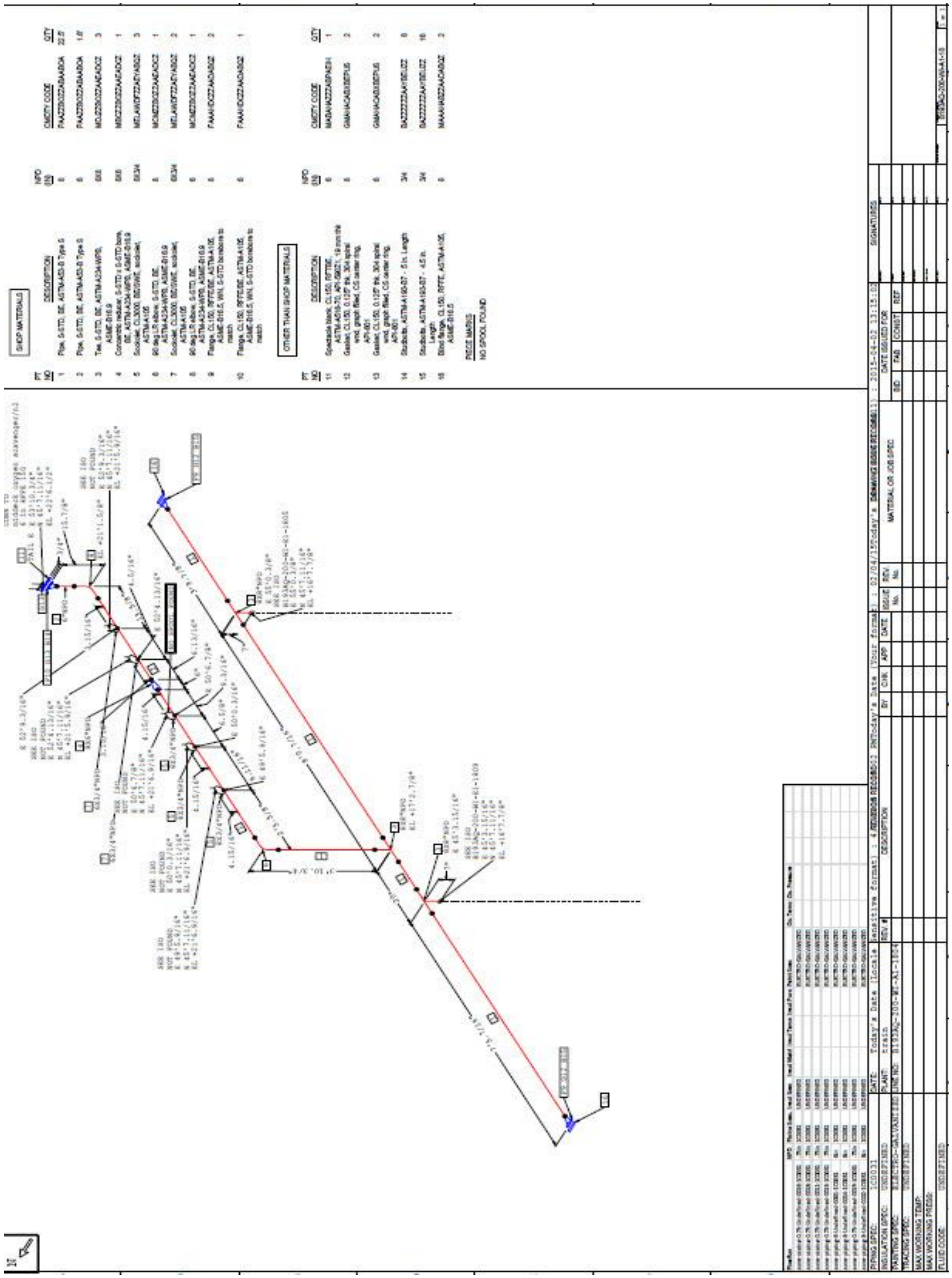

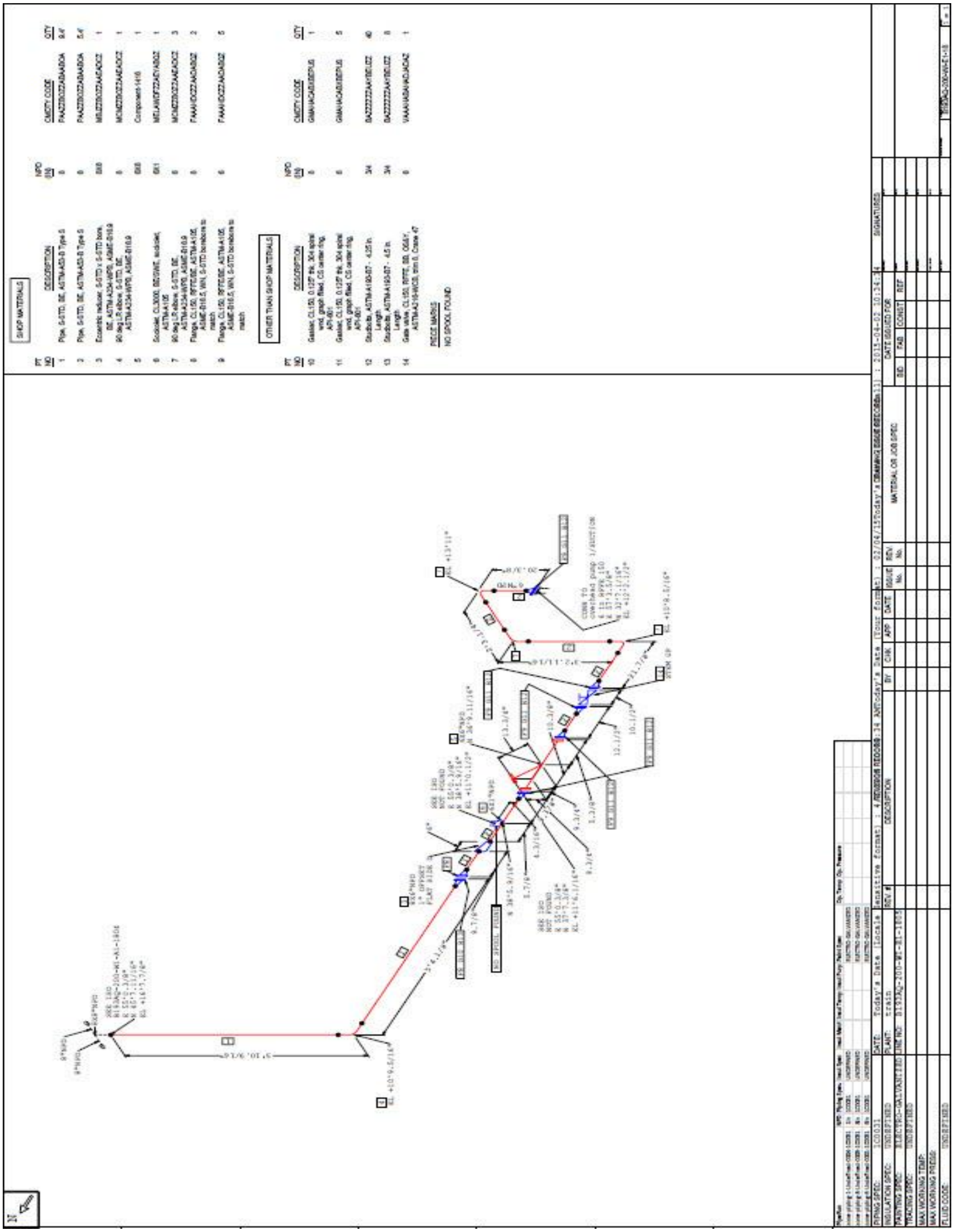

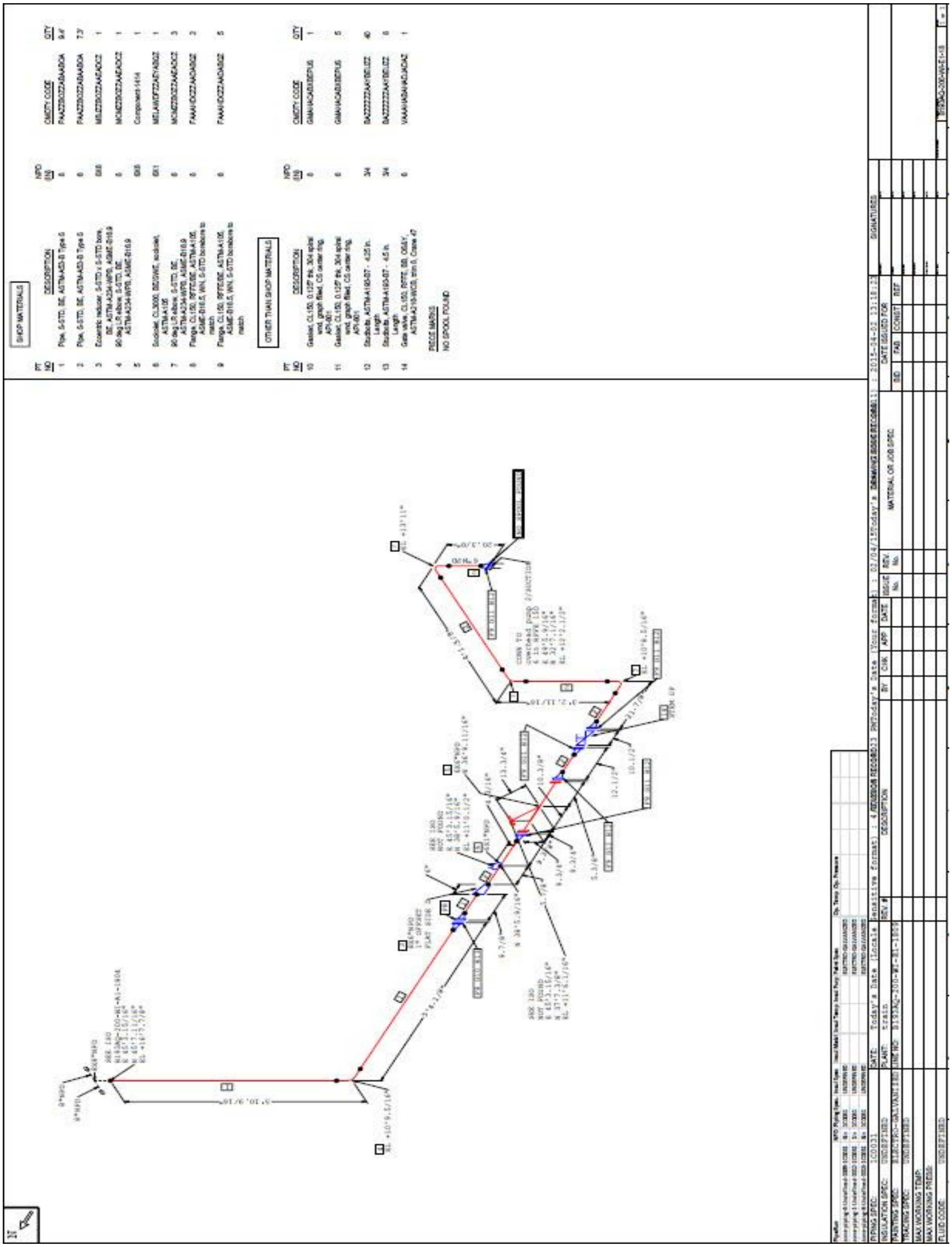

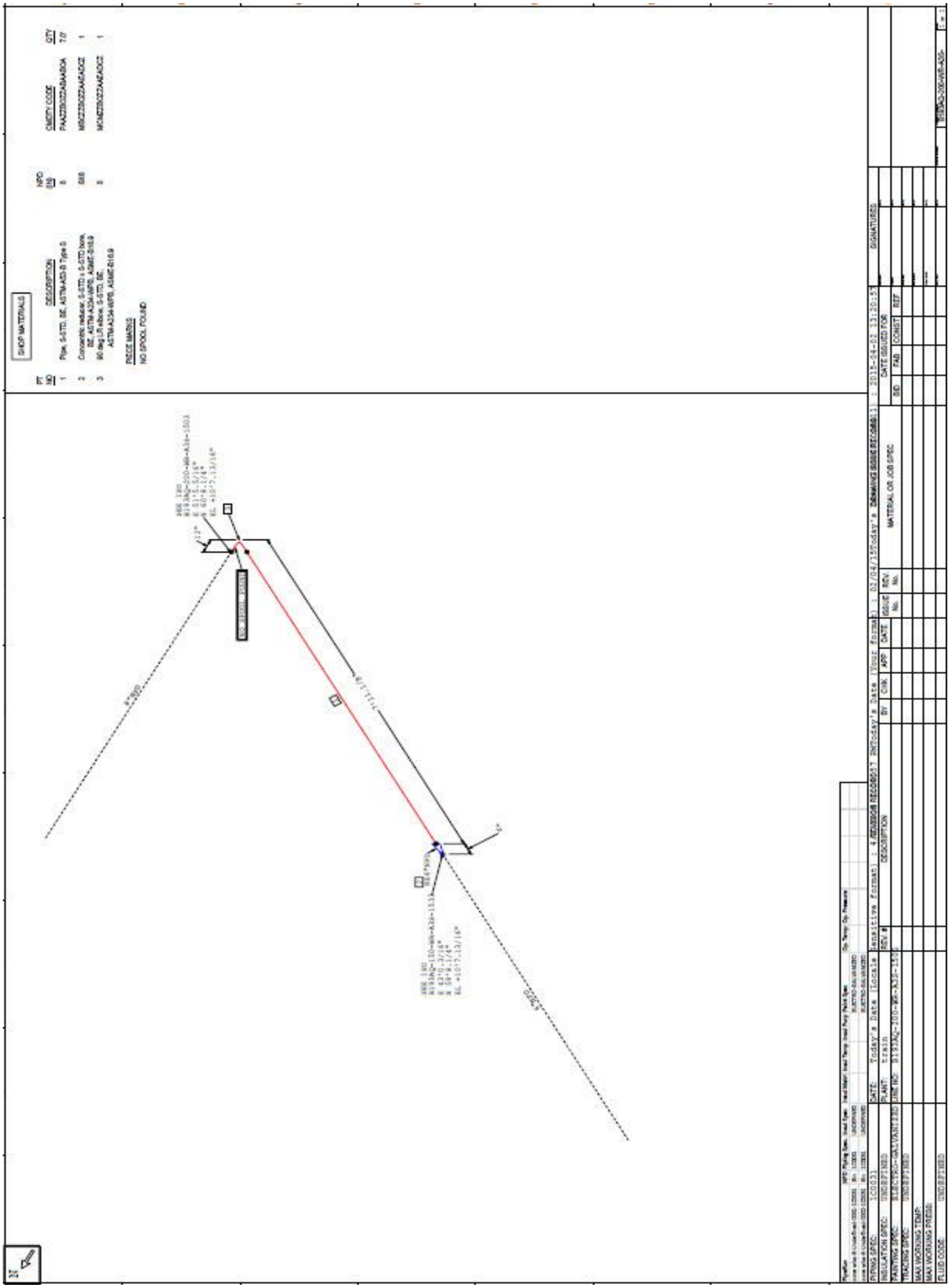

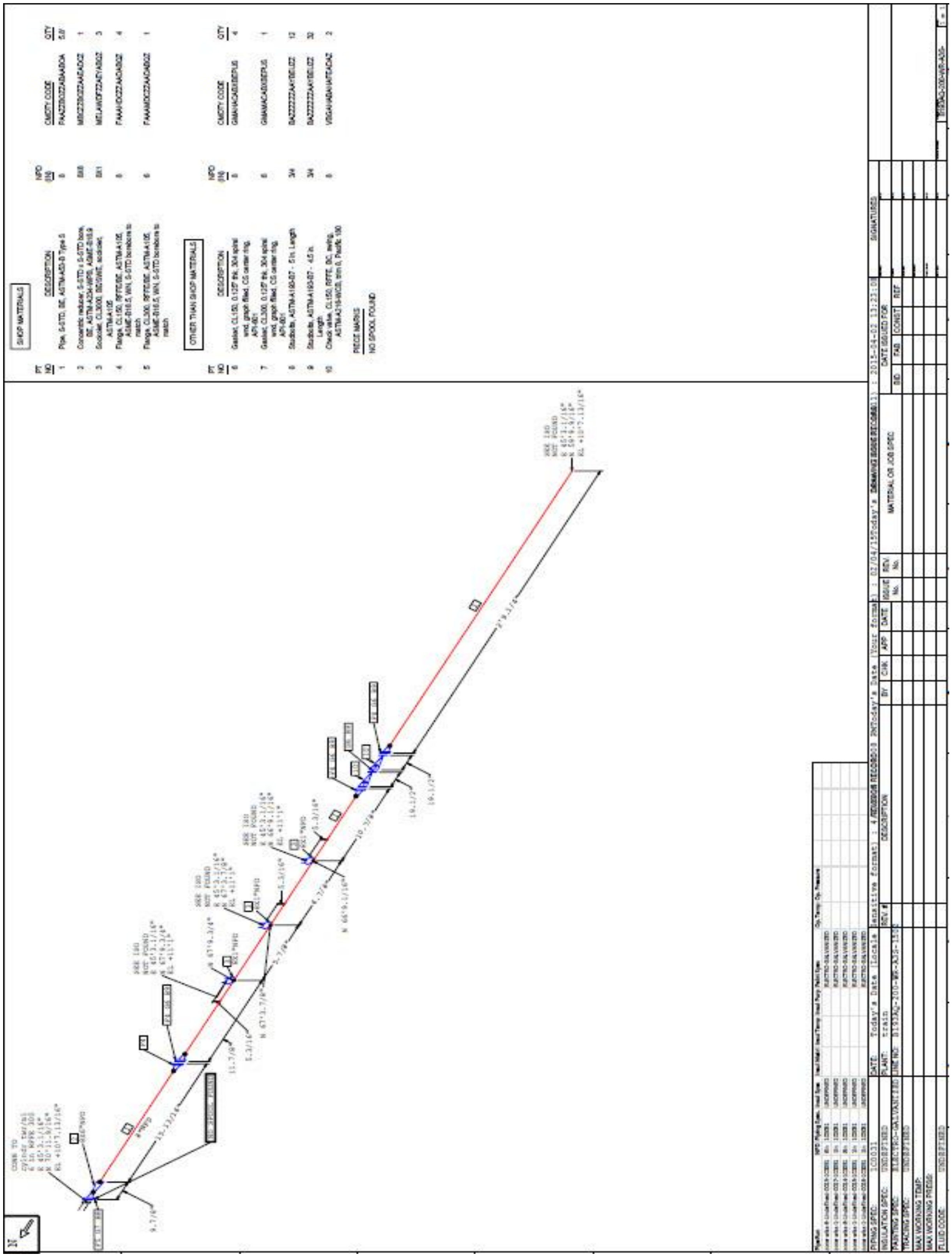

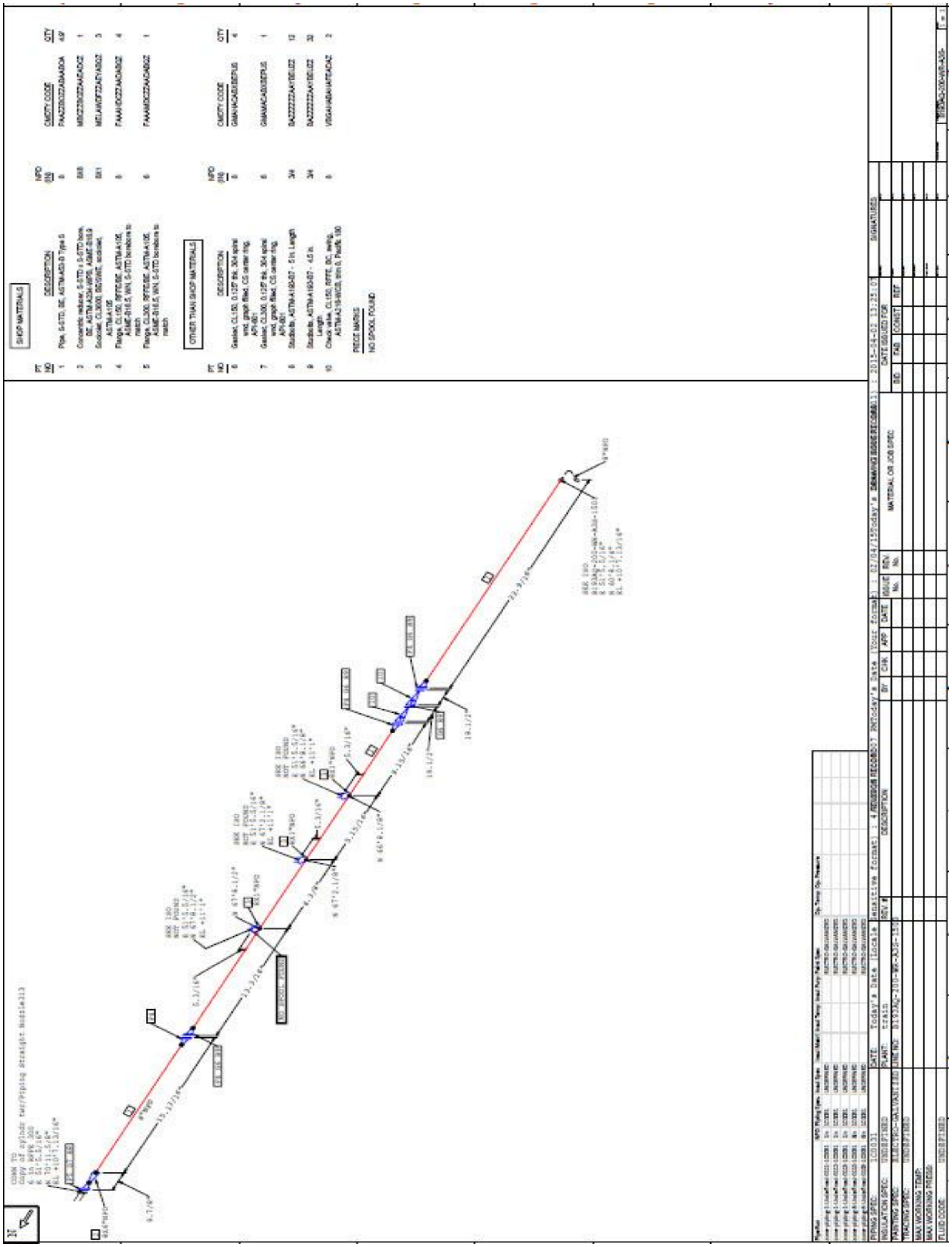

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