L & T- CHIYODA LIMITED

Internship Training
Plant and Piping Engineering

PREPARED BY:

Anirudh Topiwala
7^{TH} Semester, Mechanical Engineering,
Institute of Technology, Nirma University
Ahmedabad.

AT:

PIPING ENGINEERING DEPARTMENT
L & T CHIYODA LIMITED - Knowledge City,
National highway no.8,
Between Ajwa & Waghodia Crossing,
Vadodara-390019

CERTIFICATE

This is to certify that **Mr. Anirudh Topiwala,** a student of 7th Semester, **Mechanical Engineering Department, Institute of Technology, Nirma University** has successfully completed his training at **L&T-CHIYODA Limited,** Vadodara. His training period was from **22nd May, 2016** to **2nd July, 2016**.

TRAINING NAME: ***PLANT & PIPING ENGINEERING***

We acknowledge that the work has been accomplished satisfactorily. During his training period, he was found to be a dedicated person and his work and conduct were found to be very good. We wish him a bright future ahead.

Date: 2nd July, 2016.

Mr. Sandeep Sharma
Head,
Plant & Piping Engg Dept,
L&T Chiyoda Ltd.
Vadodara.

Ms. Elizabeth Praveen
Head,
Human Resource,
L&T Chiyoda Ltd,
Vadodara.

Acknowledgment

Training is very important aspect in **Bachelor of Engineering** as it provides an opportunity to expose one’s self to the industrial ambiance, even before having graduation. It gives a great industrial learning experience and a lot of practical knowledge which one cannot expect sitting in the classroom or reading the books, journals etc.

It is also an opportunity to use theoretical knowledge in practical circumstances. Basically it is a synthesis of knowledge & experience of the experts of the relevant fields. The valuable guidance and motivation provided by experts, generates feelings of immense respect for them.

Hence I take the opportunity to express my gratitude towards the people without whom I could not be having such a great industrial exposure. I am heartily thankful to **Mr. Sandeep Sharma** the Head of the Plant & Piping Engineering Department.

I would also like to thank **Mr. Ankur Modi, Mr. Yuvrajsinh Parmar & Mr. Ashvin Shrimali** and all other staff members for their continuous support and valuable guidance for making my training successful.

Anirudh Topiwala
Institute of Technology, Nirma University

PREFACE

Piping systems in Chemical, Petrochemical, Hydrocarbon plants are comparable to the veins and arteries through which fluids, vapors, slurries, solids etc flow under various conditions as imposed by the process design of the plant such as high temperature, pressure, flow, and combination of these. In addition to above, corrosion, erosion, toxic conditions, and radioactivity add to more problems and difficulties in piping design. With the process conditions becoming more and more severe by the advancement in process development, a continuous effort is required to be carried simultaneously to cope up with the demands of process.

Piping, because of its nature, requires a number of day to day decisions on matters of detail, which, in some ways are often more difficult to solve than major issues connected with the project. It is this same detail which can cause expensive delays in design and construction and consequently in commissioning. All too often in the past, piping has been regarded as an unimportant job in the overall project engineering instead of being treated as a function requiring as a wide a knowledge, experience and variety skills as any other branch of engineering.

One of the major tasks in any process industry is the transportation of materials often in fluid from one place to another. The most commonly adopted method for the same is to force the fluid through the piping system. The piping system is the inter-connected piping subjected to the same set of design conditions. The piping system involves pipes but also fittings, valves and other specialties. These items are known as piping elements.

This project deals with some of the details of piping materials and their uses in industry, basics of engineering aspects of designing, material study, layout and stress analysis. While my stay in the industry I learned that a piping engineer has to deal with minute details ranging from layout to materials to stress analysis and even a small mistake can cause destruction in the plant. So efficiency and precision is one of the most important aspects in the life of a piping engineer. Other thing that amazed me is how each and every department depend on each other ranging from process, electrical, equipments, machinery, project management etc, and how a piping engineer with his skills and precision works accordingly and gives a required output.

COMPANY 'S PROFILE

❖ Larsen & Toubro Limited

An engineering & construction is major among the largest and most reputed companies in India's private sector. Its reputation is based on a strong customer orientation the technological sophistication that characterizes its products and projects, and an impressive record of achievement across six decades.

Two Danish engineers, Mr.Henning Holock Larsen and Mr. Soren Kristina Toubro, founded L&T in the year 1938. Today L&T is the largest technology driven company in south Asia with leading edge capabilities in the field of infrastructure and basic industries and ranks among the top ten in India's private sector. L&T has initiated a transformation process to ensure that it emerges as knowledge based premium conglomerate in the shortest possible time. Its portfolio consists of an Engineering core, and Thrust areas Information Technology and Communication.
L&T is engaged in four principal business segments and enjoys market dominance in all of them. Engineering & Construction is the largest business segment of the company generating over 60% of the revenues. From a fabrication and construction led business, the Company has graduated to a technology based EPC Company with capabilities for the execution of large sale turnkey projects for industries such as power, hydrocarbons, oil & gas, and petrochemicals.

❖ L&T-CHIYODA LIMITED (LTC)

Premier engineering, manufacturing and Construction Company & Chiyoda Corporation, Japan, World renowned Engineering Company with five decades of experience in Hydrocarbon and Related fields, incorporated on 19 November 1994.

LTC commenced operations in February 1995 and is catering to national & international clients, both directly and through its parent Companies. LTC offers international grade engineering and project management services with integrated engineering concepts, supported by state-of-the-art computer hardware and Software facilities operating in a networking environment. Working towards positive engineering through plant modeling in electronic media, LTC offers a creative response to clients' needs. The actual plant itself is 'visualized' to a very close reality in the engineering office during the detailed engineering stage, resulting in high efficiency and accuracy in engineering and ease of construction. LTC has specialized in the engineering for fast track EPC jobs of multiple Complexities; repeatedly proving it is adaptability from time to time.

➢ Function of various Departments

Process engineering	Project Service Division	Instrumentation & control Systems	Plant & Piping Engineering	Electrical engineering
▪ Process simulation study ▪ Sizing of columns vessels & drums ▪ Thermal rating of heat exchangers ▪ Line sizing & hydraulic calculations ▪ Process data for equipment & Instrument ▪ Preparation of Operating Manual ▪ Modeling support & review	▪ Contract review-Technical ▪ Project Scheduling ▪ Preparation of Project Schedule data (PDS) ▪ Area classification ▪ Progress reporting/monitoring ▪ Interface with Customer & licensor ▪ Project Quality Assurance (PQA) ▪ Design Review Co-ordination	▪ Basic design of control Systems ▪ Sizing & selection of Valves ▪ Engineering of Digital Distribution Control System ▪ Instruments Installation Engineering including all related drawings ▪ Modeling support & review	▪ Piping Plan & Equipment layout ▪ 3D modeling ▪ Construction Dwg. Including piping general arrangement and isometric ▪ Design calculation for detail engineering ▪ Stress analysis for piping system ▪ Piping specification ▪ Firefighting system design ▪ Preparation of Bill of Quantities (BOQ)	▪ Basis engineering of electrical system including hazardous area classification ▪ System studies including short circuit calculation, load flow, Transient & Harmonic ▪ analysis ▪ Specification for all electrical equipment

Machinery Engineering	Civil and structural engineering	Equipment Engineering	Computer systems and engineering	Personnel and Human Resources
▪ Sizing, selection and estimation of pumps, compressor and turbines ▪ Preparation of machine specifications ▪ Study of overall dynamics of rotating machinery ▪ Material handling system engineering	▪ Basic design and detail engineering of plant and non-plant buildings, shelters etc. ▪ Architectural drawing For Buildings	▪ Mechanical engineering and design of pressure vessels, reactors, columns, heat ▪ Exchangers ▪ Basic design and engineering of air fin coolers, refrigeration, and air conditioning ▪ Distillation column ▪ Procurement engineering for boilers and fired heaters ▪ Modeling support and review	▪ Set-up, interfacing and Mgt. of network ▪ Evaluation, verification and development of software ▪ Customization support in engineering application ▪ Office automation and information systems ▪ Installation and maintenance of computer hardware and Software	-

➢ **About the Plant and Piping Engineering Department**

Plant and piping engineering department is inter-connected dept. with its activities divided into the following heads:

- **Flexibility Analysis**
- **Material**
- **Layout**

Some of the sub-activities related to piping design performed under these major heads are:

- ## Flexibility Analysis

1) Stress analysis of critical lines
2) Supports for the piping system
3) Evaluation of piping forces and Moments for nozzle design.
4) Estimating the design loads
5) Optimization of Piping Design.

- **Material**

  1) Preparation of PMS\VMS
  2) Material take off
  3) Floating material Requisition
  4) Calculation of Pipe thickness

- **Layout**

  1) Equipment layout
  2) Civil information drawing
  3) Nozzle orientation plans
  4) Piping – General assembly drawing
  5) Isometric

INDEX

PIPING SUPORTS

(C)LAYOUT

CODES & STANDARDS

PLANT LAYOUT

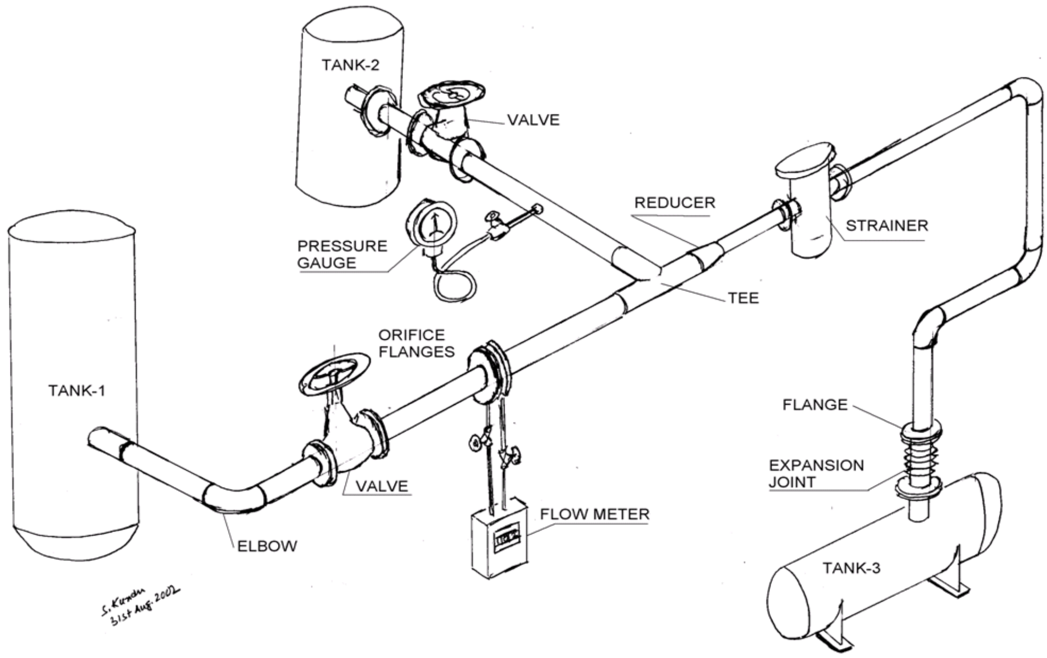
EQUIPMENT LAYOUT

- **PIPING SYSTEM**
  - **INTRODUCTION**

About two decades ago, in India, the design procedure for piping systems for Refineries, Petrochemicals and Fertilizer Plants, in magnitude, depth and complexities were not fully evolved. Only in the recent past, we were exposed in detail to this field. Now we are self sufficient in the field of piping technology and design.

Piping network is subjected to almost all the severest conditions of the plant such as high temperature, Pressure, flow and combination of these. All too often in the past, piping has been regarded as an unimportant job in the overall project engineering instead of being treated as a function requiring as wide a knowledge, experience and variety skills as any other branch of engineering.

In the recent years, the trend is to develop better techniques so as to save time in piping activities. Computer is being used extensively to obtain rapid solutions to the more complex problems of plant design and, in so for as piping is concerned, to the solving of problems of pipe stressing. More recently, it is being employed for production of piping detail drawings, piping isometrics, and bill of materials, cost estimation and control. Piping engineer has therefore a further responsibility in understanding and application of continually growing techniques of this nature.



MATERIAL

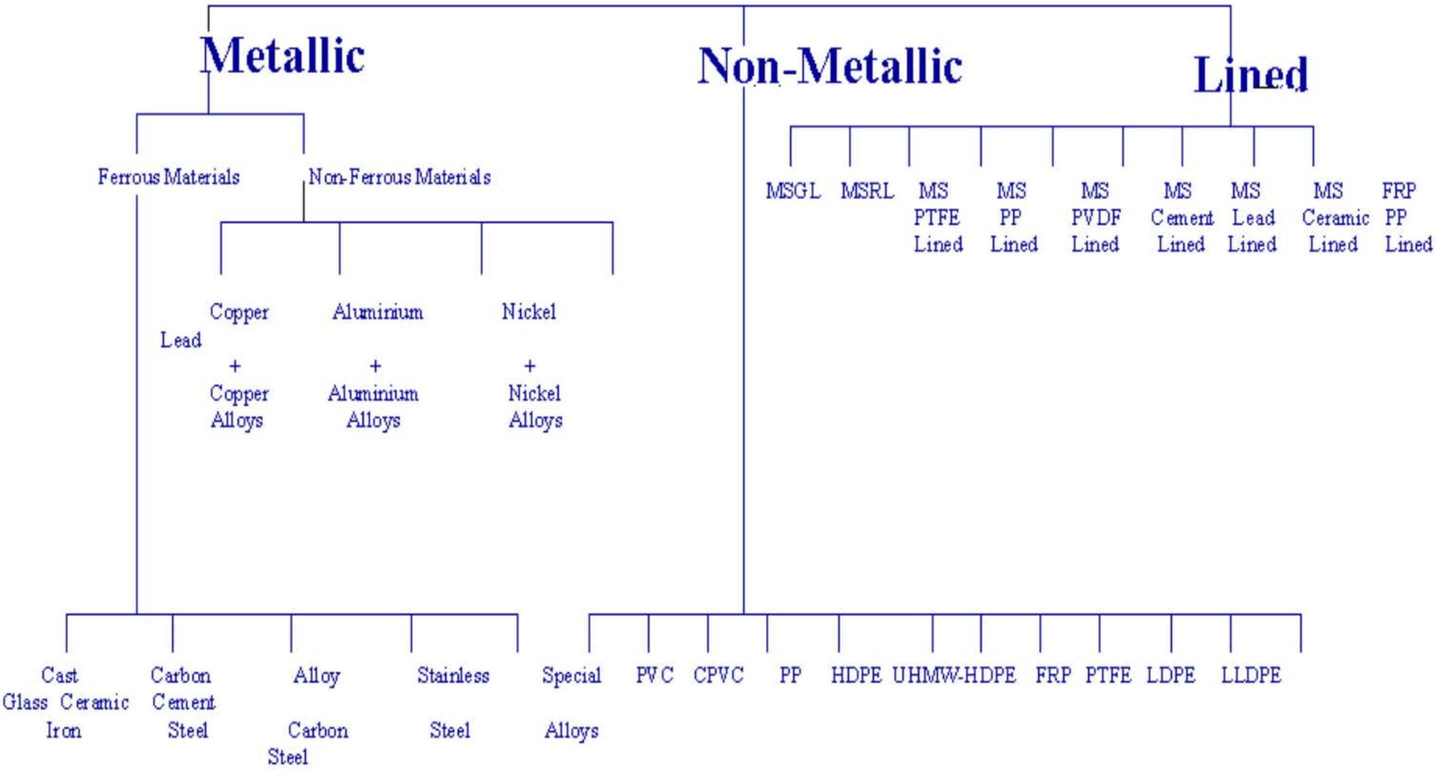
INTRODUCTION

- Selection of piping material for refinery and petrochemical plants requires collaboration between the corrosion, piping and process engineers, and usually involves more than determining if a material is compatible with a given environment. Many questions must be answered before a pipe and valve specification can be written.
- Is the alloy available in the size and thickness required?
- Is it the most economical choice?
- Steel pipe normally refers to carbon-steel pipe
- Seam-welded steel pipe is made from plate
- Seamless pipe is made using dies
- Common finishes are 'black' ('plain' or 'mill' finish) and galvanized

SELECTING MATERIAL:

- Correctly selected steel pipe offers the strength and durability required for the application
- The selected pipe must withstand the conditions of use, especially pressure, temperature and corrosion conditions
- These requirements are met by selecting pipe made to an appropriate standard.
- The design should meet the requirements of the relevant code.
- The material used shall be in accordance with latest revision of the Standards.
- If ASTM materials are used, then the materials adopted by ASME/ANSI should be preferred.
- The selection of material should follow the norms below:

1. Carbon steel shall be used up to 425 C.
2. Low temperature steel shall be used below 20 C.
3. Alloy carbon steel shall be used above 425 C.
4. for corrosive fluids recommendations from the process licensor to be followed.



CODES AND STANDARS FOR PIPE MATERIAL

- American Standards
- British Standards
- Indian Standards

AMERICAN STANDARS

- The American National Standard Institute (ANSI)
- The American society of Testing and Materials(ASTM)
- The American society of Mechanical Engineers (ASME).

(1) Piping Elements

- One of the most important tasks in any process industry is the transportation of materials, usually in liquid form.
- Pipes are tubular structures which connect various instruments or devices to form a complete system.
- The piping system not only includes pipes but also the valves and the fittings associated with it.
- Piping element is defined as any material or work required to plan and install the piping system.
- The basic components include:
    1. Pipes
    2. Fittings
    3. Flanges
    4. Gaskets
    5. Bolting
    6. Valves
    7. Specialties
- Piping elements should confirm to the existing codes and standards as far as possible.
- Piping Specification is a document specifying each of the components.
- Different material specifications are segregated in different piping class.
- Selection of piping class depends upon the designer.

Material Selection of Piping Components

- The selection of piping elements requires the knowledge of corrosion properties, strength and engineering characteristics, relative cost and availability.
- The essential mechanical properties while selection are:
    1. Yield strength
    2. Ultimate strength
    3. Percentage elongation
    4. Impact strength
    5. Creep rupture strength
    6. Fatigue endurance strength

- The Piping design criteria originates from the line list, which specifies design conditions with respect to pressure and temperature.
- In absence of this data, the piping engineer refers to the predefined basic data.

1. Pipe

- It can be defined as a pressure tight cylinder used to convey a fluid..
- Based on methods of manufacture pipes could be classified as:3
    1. Welded
        - Electric Resistance Weld(ERW)+
        - Furnace Butt Welded
        - Electric Fusion Welded
        - Double submerged arc welding
        - Spiral Welded
    2. Seamless

- The material of the pipe is selected from the various ASTM standards.
- A tube can be identifies as a smaller version of pipe. The major differences between pipe and tube are listed below.

DIFFERENCE BETN. PIPE & TUBE

Tube is identified by OD and thickness in inches or mm or wire gauge.	Pipe is identified by Nominal Bore and thickness is defined by Schedule.
Lower thickness and higher ductility permits rolling into coils without high differential stress between inside and outside of coil.	Lower ductility makes pipe unsuitable for coils, instrumentation.
Normally used in heat exchangers, coils for heat transfer and instrumentation.	Normally used in bulk fluid transfers.
These days Eddy Current Testing (ET) and Ultrasonic Testing (UT) are the most frequently NDT methods as a substitute for Hydrotest (HT)	Testing as per the respective ASTM code.
Limitation in sizes.	No limitation.

6

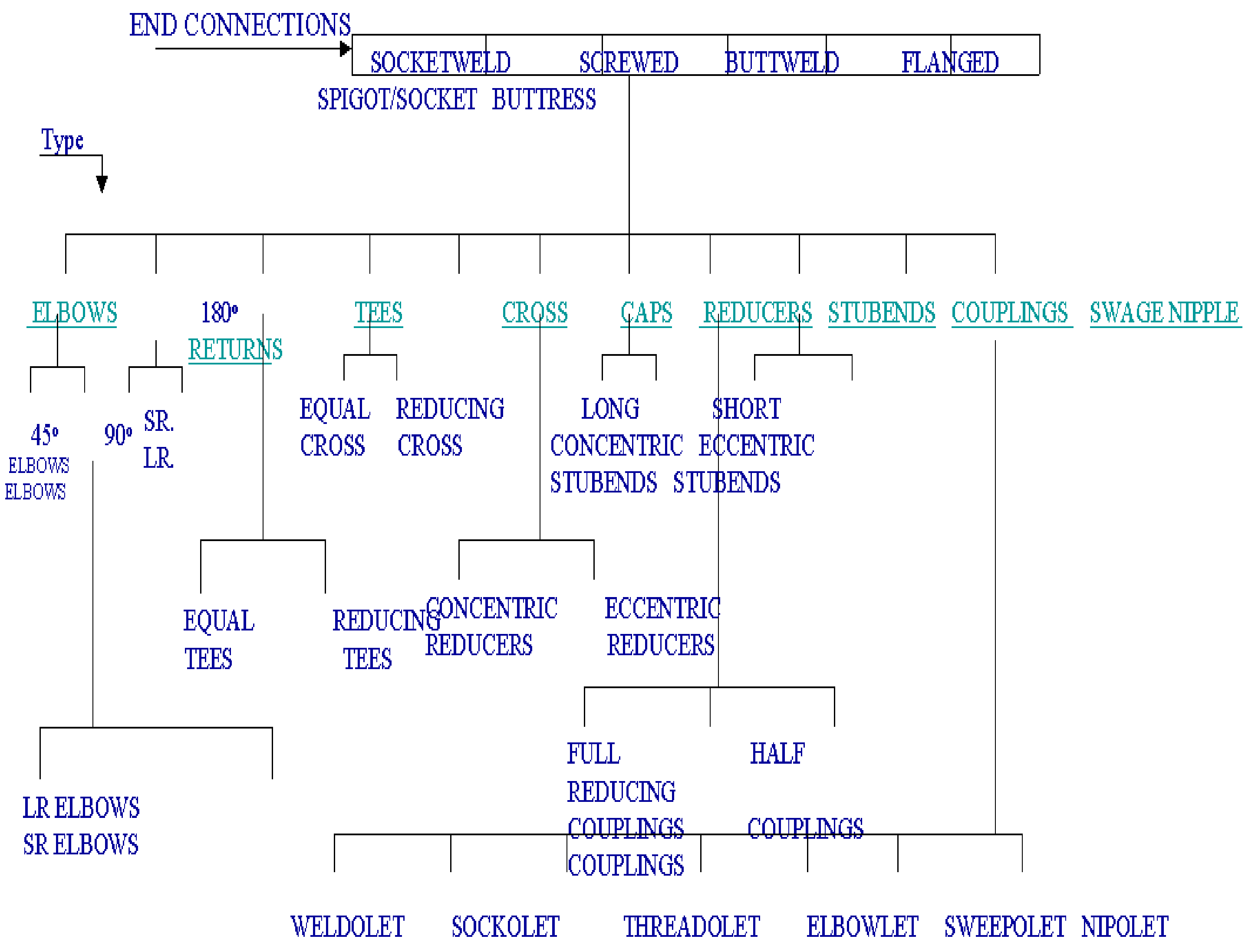
As a second thought "Pipe is a big tube and tube is a small pipe".

2. Pipe Ends

- Based on the material of construction and the pipe to pipe joint, the ends of the pipes are specified as below:

TYPE OF END	DONE BY PROCESS
Beveled ends	Butt welding
Plain ends	Fillet welding
Screwed ends	Threaded connection
Flanged ends	Bolt connection
Spigot/Socket	Cement joint

3. Pipe Fittings



STANDARD PIPE FITTING

- These are used for mainly three reasons:
    1. To change direction of flow by some angle.
    2. To enable the transition between pipes of different diameters.
    3. For branching from main pipe

Types of fittings:

1 Elbow:

- This are used to make 90° or 45° the changes in direction of run pipe.
- This can be done by butt welding.
- There is also the 22.5° elbow is available for cast iron.

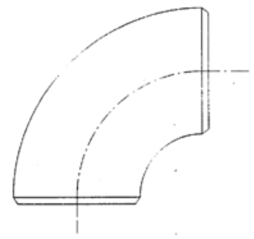


Fig. 2.2: Short Radius Elbow (R=1D)

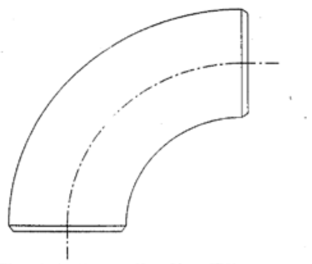


Fig. 2.3: Long Radius Elbow (R=1.5D)

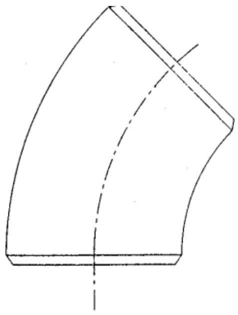
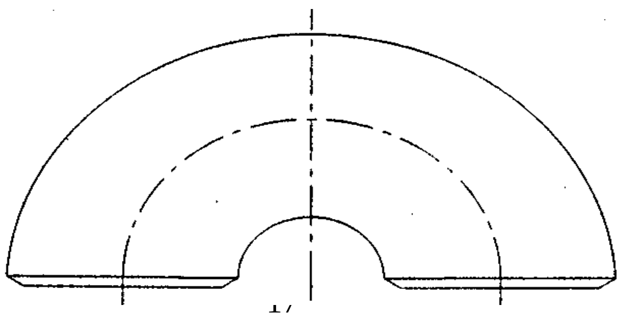


Fig. 2.4: Elbows - 45°

2. Return

This is used to direction of 180°.this is mainly used of **heat coils** or **heat exchanger** etc.



3. Tees

- This is used for branching off for low pressure services.

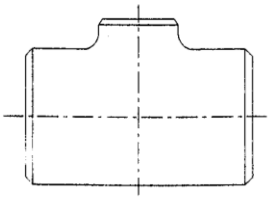
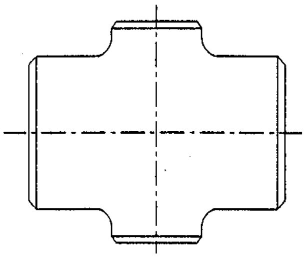


Fig. 2.9: Tees – Butt weld

4. Cross

- This is fitting very rarely used in piping systems. In this fitting there are two types of crosses.
  (1) Straight (2) Reducing

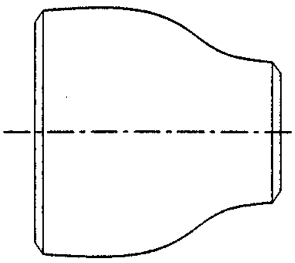


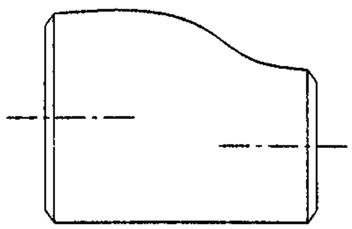
5. Reducers

- These also of two types:

1. Concentric: this is when the center line of both the larger and the smaller pipe is coincident.
2. Eccentric: this is when one of the outside surfaces is to be maintained in line.

(1) Concentric (2) Eccentric

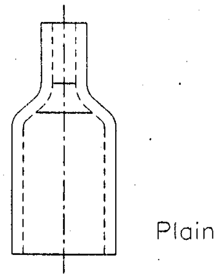


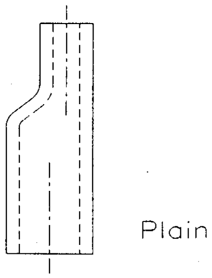


6. Swage nipple

- They are like reducers but are used to connect butt welded pipe to smaller screwed or socket welded pipe.

(1) Concentric (2) Eccentric





7. General rules:

- Socket-welded construction is not advisable in the following services:
  · Services in which crevice corrosion can occur;
  · ASME rating class above 900;
  · Lower design temperature below-29 `C;
  · Very toxic service;
  · Hydrogen service.
- In order to avoid excessive shrinkage stresses during weld solidification a gap shall be left between the end of the pipe and the stop of the socket-welding component before welding.
- Failure to ensure this gap can lead to premature piping failures.
- Socket-welded connections cannot be properly radiographed to verify weld quality; they can only be inspected by surface techniques such as magnetic particle or liquid penetrant.
- Bending may be an economic alternative to welding elbows for changing the pipe direction.
- Factors which will influence the choice between elbows and bending are:
  · local experience with bending;
  · Availability of pipe bending machines

8. Flanges:

- It is used when joint need dismantling. This is used at equipments, valves & specialties.
- Flanges are piping components used for connecting pipes which needs dismantling &periodic maintenance, other piping components like valves, specialties, instrument items like orifice, flow meters etc on to the pipes.
- A flanged joint is composed of three separate & independent although interrelated components; the flanges, the gaskets & the fasteners.

- Pressure-Temperature rating charts, in the standard ANSI B 16.5, specify the pressure to which the flange can be subjected to at a particular temperature. The indicated pressure class of 150 #, 300 #, etc. is the basic ratings and the flanges can withstand higher pressures at lower temperatures. ANSI B 16.5 indicates the allowable pressures for various materials of construction as well.
- They can be classified as:

(1) Based on pipe attachment

- Slip-on raised flange
- Socket weld raised flange
- Threaded raised face flange
- Welding neck raised face flange

(2) Based on facing

- Flat face
- Raised face
- Ring type

(3) Based on face finish

(4) Based on pressure-temperature

(5) Based on material of construction

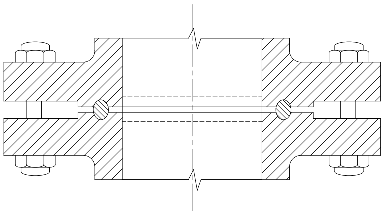
9. Gaskets

- Full face
- Ring type
- Metal jacketed

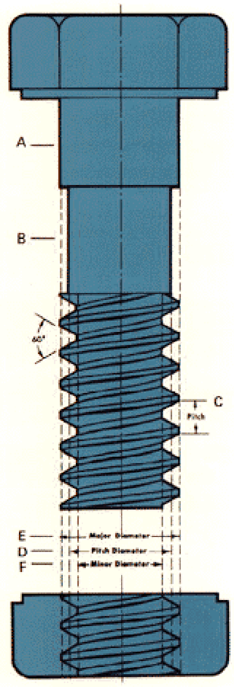
10. BOLTING

- Depending upon the service its pressure or temperature the type of gasket, type of bolting is selected.
- For low pressure, low temperature mechanical bolt are used.
- It consist hexagonal head, hexagonal nut and round washer.

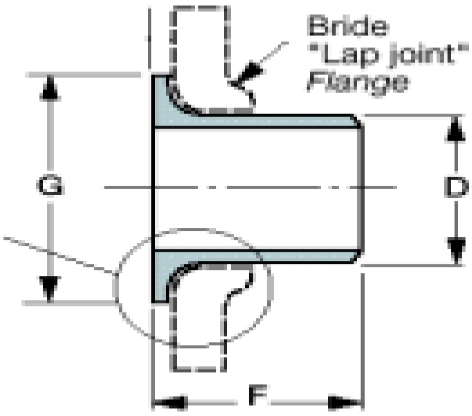
Flange



Ring joint Facing Flanges



Fastener

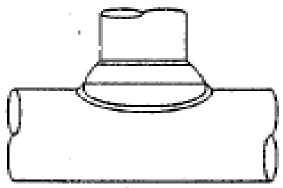


Lap Joint Flange

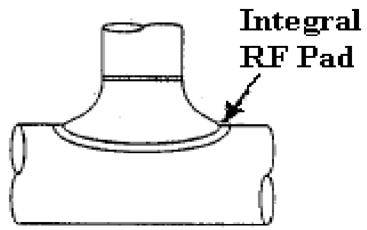
Gaskets

11. Special Fittings:

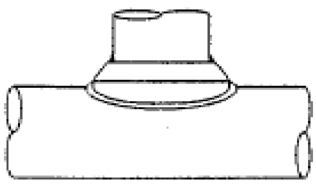
Weldolet, Sockolet, Threadolet, Elbolet, Sweepolet, Nipolet, Latrole



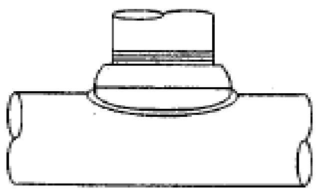
Weldolet



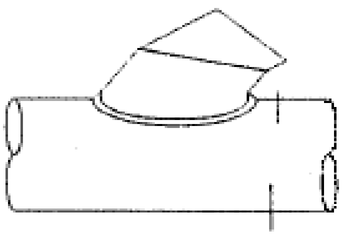
Sweepolet



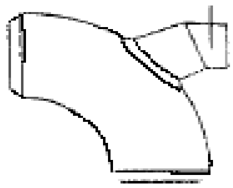
Sockolet



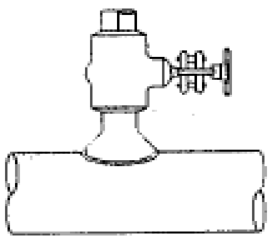
Thredolet



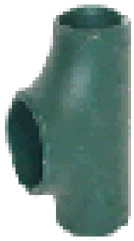
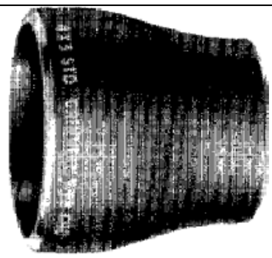
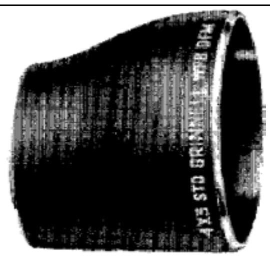
Latrolet



Elbolet



Nipolet

TYPE OF FITTING	FIGURE
90° ELBOW	
45°ELBOW	
TEE	
CROSS	
CONCENTRIC REDUCER	
ECCENTRIC REDUCER	

5. Valves

- They cost about 8-10 % of the total capital expenditure.
- In terms of unit also valves exceed any other piping component.
- Valve functions can be defined as ON/OFF service, throttling service (control), prevention of reverse flow (or back flow), pressure control, regulation and pressure relief.
- Valves can be classified as either linear (gate valve) or rotary (ball valve) based on the action of the closure member. The shape of their closure member such as gate, globe, butterfly, ball, plug, diaphragm, pinch, and check also classifies them.
- Their primary function, however, is to control the flow of liquids and gases, including plain water, corrosive fluids, steam, toxic gases, or any number of fluids with widely varying characteristics.
- Valves must also be able to withstand the pressure and temperature variations of the systems in which they are used.
- Some valves on combined water service mains, and those handling flammable material, may be required to be fire safe or approved for fire protection use.
- Pressure regulating valves are discussed in their respective chapters.

Valve Functions

- The possible valve functions must be known before being able to select the appropriate valve type for a particular application. Fluid flows through a pipe, and valves are used to control the flow. A valve may be used to block flow, throttle flow, or prevent flow reversal.
- **Blocking Flow**
  The block-flow function provides completely on or completely off flow control of a fluid, generally without throttling or variable control capability.

It might be necessary to block flow to take equipment out of service for maintenance while the rest of the unit remains in operation, or to separate two portions of a single system to accommodate various operating scenarios.

- **Throttling Flow**

Throttling may increase or decrease the amount of fluid flowing in the system and can also help control pressure within the system. It might be necessary to throttle flow to regulate the filling rate of a pressure vessel, or to control unit operating pressure levels.

- **Preventing Flow Reversal**

It might be necessary to automatically prevent fluid from reversing its direction during sudden pressure changes or system upsets. Preventing reverse flow might be necessary to avoid damage to a pump or a compressor, or to automatically prevent backflow into the upstream part of the system due to process reasons.

General procedure for valve selection.

- Identify design information including pressure and temperature, valve function, material, etc.
- Identify potentially appropriate valve types and components based on application and function (i.e., block, throttle, or reverse flow prevention).
- Determine valve application requirements (i.e., design or service limitations).
- Finalize valve selection. Check factors to consider if two or more valves are suitable. Provide full
- Technical description specifying type, material, flange rating, etc.

- **Valves can be classified as:**

1. Based on function

Isolation valves	**Regulation Valves**	**Non Return valves**	**Special Purpose Valves**
Gate	Globe	Check	Multi Port
Ball	Needle		Flush Bottom
Plug	Butterfly		Float
Piston	Diaphragm		Foot
Diaphragm	Piston		Line Blind
Butterfly	Pinch		Knife Gate
Pinch			

2. Based on type of End Connection:

   1. Screwed Ends
   2. Socket Weld Ends
   3. Flanged Ends
   4. Butt Weld Ends
   5. Socketted Ends
   6. Water type Ends
   7. Buttress Ends

3. Based on type of Material Used:

   1. Cast iron
   2. Ductile iron
   3. Bronze
   4. Gun metal
   5. Carbon steel
   6. stainless steel
   7. Alloy carbon steel
   8. Poly propylene
   9. Special alloys
   10. Fluoro Polymer/ Elastomer lined metals
   11. Glass

4. for corrosive fluids recommendations from the process licensor to be followed.

COMPONENT OF VALVES

- Valve body
- Disc
- Seat
- Bonnet
- Packing
- Packing nut
- Stem
- Wheel/Operating mechanism

BASIC STRUCTURE OF GATE VALVE

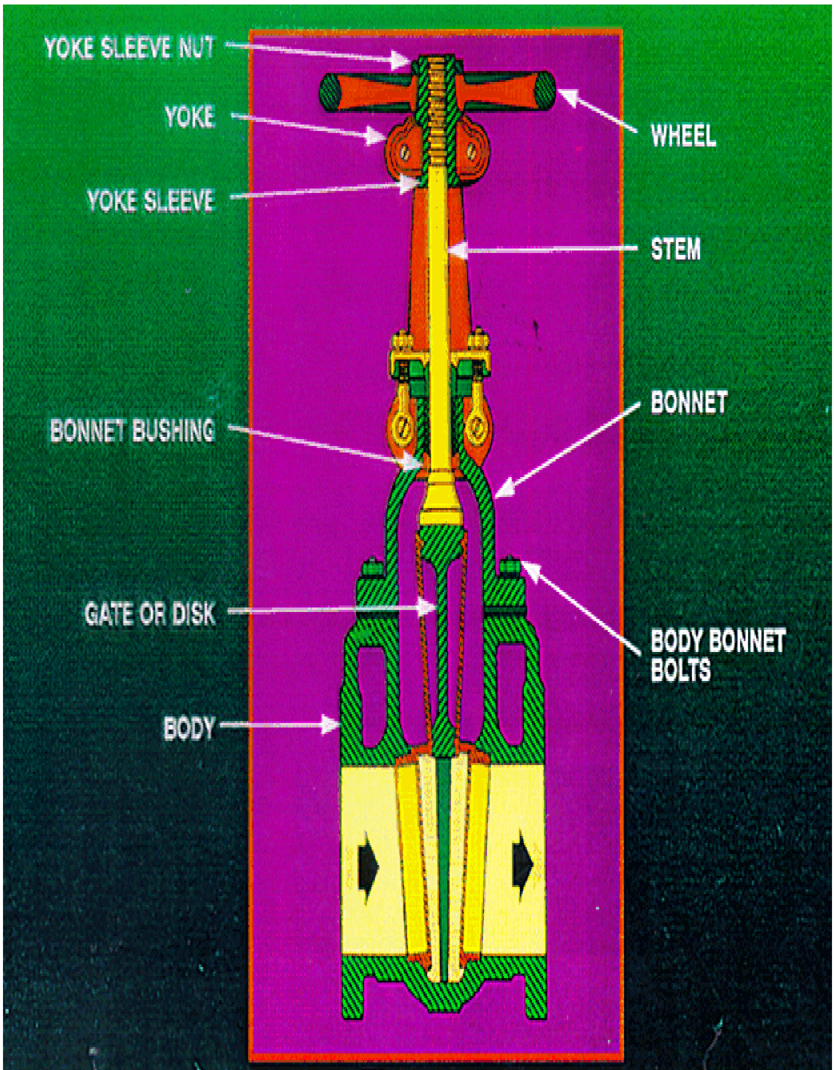


Figure 11-5

CUTAWAY VIEW OF A GATE STOP VALVE (rising stem type)

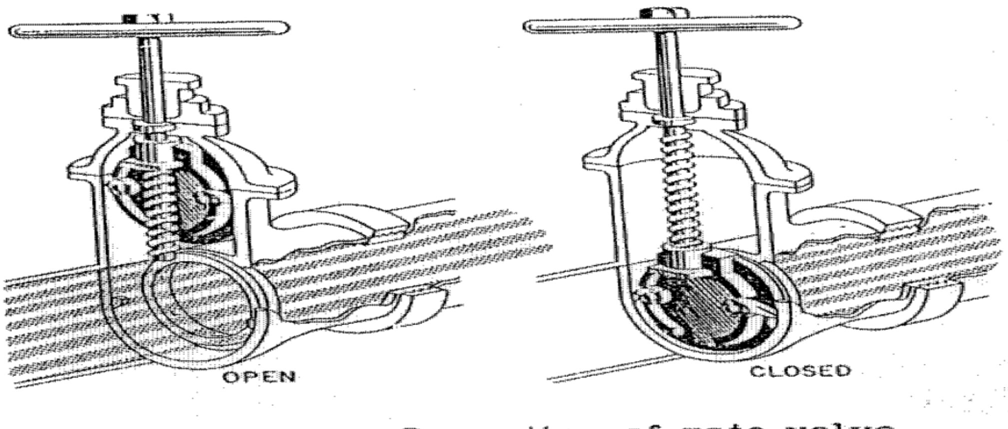
ADVANTAGES OF GATE VALVE

- It offers little resistance to flow when it is opened. When it is closed, the two seats reduce the chances of internal leakage.
- It can be used in more places because it is manufactured in wide range of sizes and pressure classes than any other stop valve.
- It is mfg by many companies, so it is inexpensive. The gate valve is typically the least expensive valve in a given size.
- It is versatile. It can be combined in different ways to meet many specific applications.

LIMITATION OF GATE VALVE

- For a given size, it is usually larger and heavier than other types of stop valves.
- In gate valve, long distance has to be traveled from the open to closed position, so it is less desirable when frequent manual operation is required.
- It should not be used with the fluids containing solids, and should not be used for regulating the flow.

OPERATION OF GATE VALVE



—Operation of gate valve.

BASIC STRUCTURE OF GLOBAL VALVE

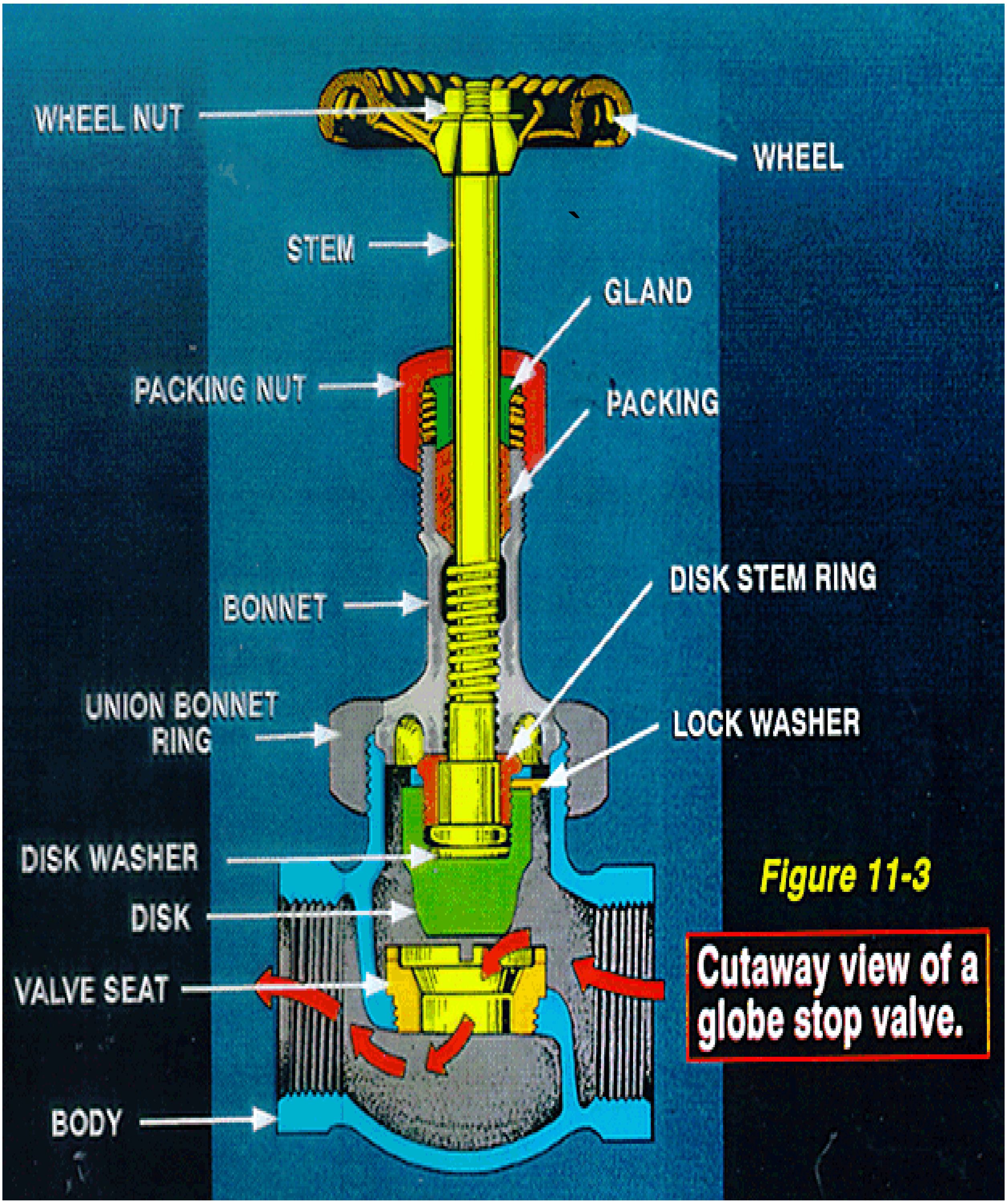
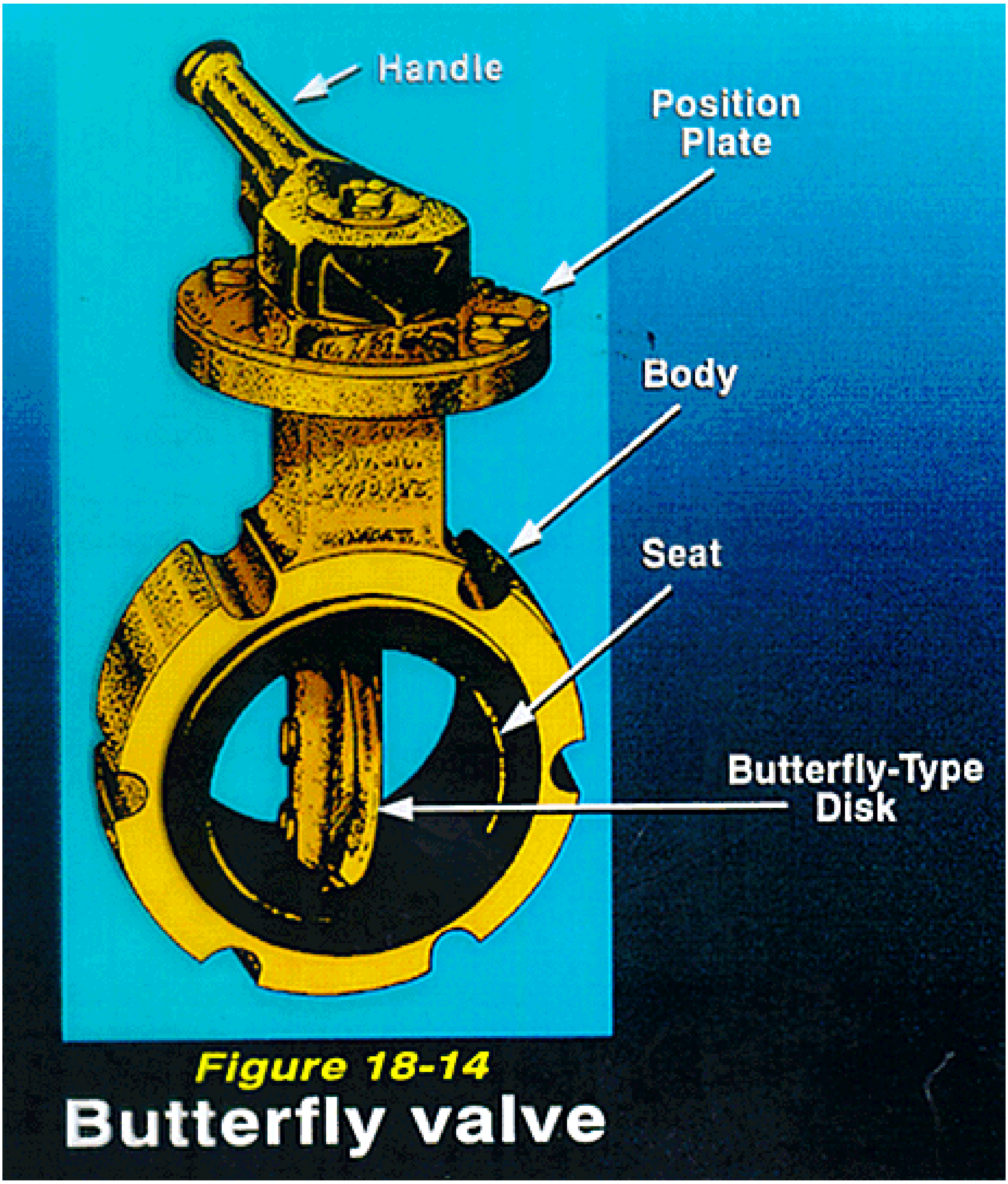


Figure 11-3

Cutaway view of a globe stop valve.

BASIC STRUCTURE OF BUTTERFLY VALVE



2. THICKNESS CALCULATIONS FOR PIPE

- Initially thickness is calculated based on internal gauge pressure and then it is verified by different methods for different conditions.
- The ambient conditions play a major role in determining the pipe thickness. Some of them are;
  1. Cooling Effects on Pressure: because of excessive cooling vacuum can be created, thus pipe should be able to withstand the excessive pressure.
  2. Fluid Expansion Effects
  3. Atmospheric Icing (when design minimum temp is below 0`c)
  4. Low Ambient Temperature
- Some dynamic effects which the pipe needs to sustains are:
  `
  1. Impact
  2. Wind
  3. Earthquake
  4. Vibration
  5. Discharge Reactions
- Various methods used for verification of the pipe thickness are as follows.

  - External pressure verification
  - Under ground thickness calculation
  - Thread check
  - Bend check
  - Hydro test calculation
  - Indian boiler regulation (IBR)

Thickness calculation based on internal gauge pressure

- The required thickness of straight sections of pipe shall be determined in accordance with following equation.

$$t_m = t + c$$

- The minimum thickness, t, for the pipe selected, considering manufacturer's minus tolerance, shall be not less than tm, so as to make the pipe safe also in the worst condition.
- The equation for thickness for internally pressurized pipe is:

$$\mathbf{t = PD/2(SEW+PY)}$$

Where:

- c = sum of the mechanical allowances (thread or groove depth) plus corrosion and erosion allowances. For threaded components, the nominal thread depth (dimension h of ASME B1.20.1, or equivalent) shall apply. For machined surfaces or grooves where the tolerance is not specified, the tolerance shall be assumed to be 0.5 mm (0.02 in.) in addition to the specified depth of the cut.

- D = outside diameter of pipe as listed in tables of standards or specifications or as measured
- d = inside diameter of pipe. For pressure design calculation, the inside diameter of the pipe is the maximum value allowable under the purchase specification.

- E = quality factor from Table A-1A or A-1B. It depends on material and the method of manufacturing.

- P = internal design gage pressure

- S = stress value for material from Table A-1

- T = pipe wall thickness (measured or minimum in accordance with the purchase specification)

- t = pressure design thickness, as calculated in accordance with para. 304.1.2 of ASME 31.3 for internal pressure or as determined in accordance with para. 304.1.3 of ASME 31.3 for external pressure
- tm = minimum required thickness, including mechanical, corrosion, and erosion allowances

- W = weld joint strength reduction factor in accordance with para. 302.3.5(e) of ASME 31.3

- Y = coefficient from Table 304.1.1, valid for $t < D/6$ and for materials shown.

- The above formula is only valid for $t<D/6$, or for thin pipes. For thick pipes or for $P/SE>0.385$, calculation of pressure design thickness for straight pipe requires special consideration of factors such as theory of failure, effects of fatigue, and thermal stress.

CASE STUDY FOR THICKNESS CALCULATIONS AND VERIFICATION.

- Following specifications were given for the design of the pipe by Process Licenser.

TEMPERATURE (Deg. C) AND PRESSURE (Kg/cm2G) RATINGS (ASME Material Group 1.1)

Temp (°C)	-29	93	149	260	343	371	**DIA METER**
PRE SSURE (kg/cm^2g)	20.03	18.28	16.17	11.95	8.78	7.73	0.5’’ to 24’’
	16.02	14.62	12.94	9.56	7.02	6.18	26’’ to 64’’

- To finding the thickness ASME B 31.3, the piping process code in table 304.1.1 gives the formula of the thickness.

$$Tm = T + C$$
$$\text{Where } T = PD / 2(SE + PY)$$

Where

P	=	Internal pressure gauge	(kg/mm^2g)
D	=	Outside diameter of pipe	(mm)
S	=	Allowable Stress (Taken from ASME B 31.3 TABLE A-1A)	(kg/mm^2)
E	=	Joint quality factor (Taken from ASME B 31.3 TABLE A-1B)	
W	=	Weld Joint Reduction Factor (Taken from ASME B 31.3 TABLE 302.3.5)	
Y	=	Co-efficient factor (Taken from ASME B 31.3 TABLE 304.1.1)	
C1	=	Corrosion Allowance	

$$Tm = (PD / 2(SEW + PY) + C1$$

- The below PT table Readings and line conditions are represented below in tabular format.

RATING	150#
MATERIAL	CARBON STEEL
CORROSION ALLOWANCE	1.5mm
PIPE CLASS	A1A

Temperature & Pressure Rating

TEMPERATURE (Deg. C) AND PRESSURE (Kg/cm2G) RATINGS (ASME Material Group 1.1)

Temp (°C)	-29	93	149	260	343	371	**DIA METER**
PRE SSURE (kg/cm^2g)	20.03	18.28	16.17	11.95	8.78	7.73	0.5’’ to 24’’
	16.02	14.62	12.94	9.56	7.02	6.18	26’’ to 64’’

- Here for 0.5’’ to 24’’ pipe is to be designed on full PT rating as per the ASME 16.5 and for 24’’ to 64’’ is to be deigned on 80% of full PT rating as per client’s requirement.
- Given pressure and temperature range falls under class 150 as per ASME 16.5.
- Now we will go through a step by step process in determining the thickness of pipe.
- The calculations made are on the bases of taking P-T reading with material A105 and allowable stresses of A106(B) or A672 GR B65 class22 depending upon the pipe diameter.
- P-T rating taken from Table 2-1.1 (Pressure–Temperature Ratings for Group 1.1 Materials); ASME B16.5-2013
- Allowable stresses taken from Table A-1 (Basic Allowable Stresses in Tension for Metals); ASME B31.3-2014

STEP 1:

- For all the above temperatures find the allowable stress value from table A-1 in ASME B31.3
- Now calculate the P/SE ratio for each of the above combination.
- The combination, for which P/S ratio is maximum, indicates the worst extreme condition.

SR. NO.	PRESSURE (kg/mm²g)	STRESS (N/mm²)	P / SE	TEMP (`C)	MATERIAL
1.	2203.3	140613.9	0.015669148	38	A106(B)
2.	1778.7	140613.9	0.012649532	149	
3.	965.8	121631.0372	0.007940407	343	
4.	850.3	117412.6197	0.007241981	371	
1	1762.2	152566.0987	0.011550403	38	A672 GR B65 class22
2	1423.4	144814.6174	0.009829118	149	
3	772.2	121675.961	0.006346365	343	
4	679.8	117412.6197	0.005789838	371	

- From the above readings we can say that, the worst condition or the condition of maximum thickness is at 38`c.
- Therefore, we will use the temperature and pressure at 38`c to find the resultant thickness of the pipe.

STEP 2:

- Now from Table 302.3.5 in ASME B31.3 based on temp and material select the weld joint strength reduction factor W.
- Here for given parameters

  W = 1

DIAMETER	O.D	P	STRESS	C3	C	Tm	Total Thickness	Material
NPS(in)	mm	(kg/m m^2g)	(N/mm²)	mm	mm	mm	tm+c mm	
0.5	21.3	10405	112517.58	0.5	2	0.165837016	2.16583702	A106(B)
6	168.3	9582	112517.58	0.5	2	1.310345996	3.310346	
24	610	9210	112517.58	0.593	2.09	4.749322981	6.84298835	
42	1067	8472	112517.58	0.3	1.8	6.133801115	7.93380111	A672 GR B65 class22
56	1422	7452	112517.58	0.3	1.8	8.174569058	9.97456906	
64	1626	5800	112517.58	0.3	1.8	9.347292045	11.147292	

STEP 3:

- Now from table A1-A or A1-B in ASME B31.3 select the weld quality factor E on the basis of material specification.
- Here for given material specification

  E = 1

STEP 4:

- Now from Table 304.1.1 in ASME B31.3 select the Y coefficient based on material and temperature.
- Here for given case

  Y = 0.4

STEP 5:

- Now put all the selected values given equation for given outside dia D :

  t = PD/2(SEW+PY)

STEP 6:

- Now add the corrosion allowance and milling tolerance in the calculated to get tm
- Here

  C.A. = 1.5 mm (As per given in PMS), And milling tolerance is 12.5%
- We get the thickness of pipe at 38`c as seen below:
- Some values which are constant for all diameters are:
- E=1 (quality factor)
- Y=0.4 (coefficient)
- W= 1 (Weld Joint factor)
- C1=0.6 (corrosion allowance)
- C2=0 (thread allowance)
- C3= mill tolerance
- Overall c= c1+c2+c3
- Total thickness= tm +c
- P= internal pressure ((kg/mm2g))
- S= Allowable stresses(s) (kg/mm2)

STEP 7:

- Now we will select the standard thickness with respect to the total thickness found out.
- Usually the procured thickness is very high with respect to the standard thickness because of various reasons. Some of these reasons are discussed later in the report

Sr. No.	O.D (mm)	Tm (mm)	Total Thickness (mm)	Procured Thickness (mm)	Procured Thickness without allowance	Material
1	21.3	0.165837016	2.16583702	3.73	1.73	A106(B)
2	168.3	1.310345996	3.310346	7.11	5.11	
3	610	4.749322981	6.84298835	8.74	6.646334627	
4	1067	6.133801115	7.93380111	12.7	10.9	A672 GR B65 class22
5	1422	8.174569058	9.97456906	14.27	12.47	
6	1626	9.347292045	11.147292	17.48	15.68	

- We can see that the difference between procured thickness and the total thickness increases with increase in diameter. This is because with increase in dia the stress caused due to various effects increases significantly.
- Some of these factors which affects the thickness are:
    - External pressure verification
    - Under ground thickness calculation
    - Thread check
    - Bend check
    - Hydro test calculation
    - Indian boiler regulation (IBR)
- Lets go through each factor one by one

1. Bend check

The minimum required thickness tm of a bend, after bending, in its finished form,
Shall be determined in accordance with following equations.

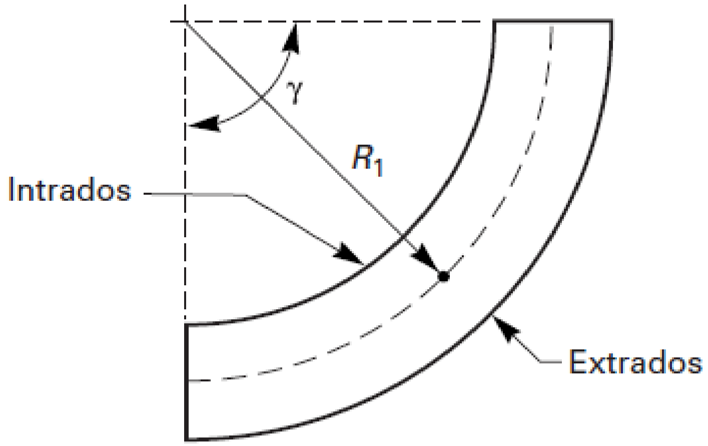
t = PD/2[(SEW/I) + PY]

Where at the intrados (inside bend radius)

I = (4(R1/D) − 1)/(4(R1/D) − 2)

And at the extrados (outside bend radius)

I = (4(R1/D) + 1)/(4(R1/D) + 2)



At the sidewall on the bend centerline radius, I = 1.0, and where R1 = bend radius of welding elbow or pipe bend
Thickness variations from the intrados to the extrados and along the length of the bend shall be gradual.

When pipes are bent on site to achieve curve, it becomes mandatory to check whether the pipe will be able to sustain the pressure or not because of variation in thickness at intrados and extrados of the pipe.

Hence thickness at intrados and extrados is calculated as shown below for different diameters of the pipes and for the different curve radius as per the equation shown above.

For all the conditions procured thickness after removing allowance at the intrados and extrados is greater than the actual design thickness. Hence pipes will be able to handle the design internal pressure. Here, pipe of thickness 6’’ (168.3mm O.D) is checked.

- The check is done at 38`c as it is the point of worst condition or maximum thickness.

Sr. No.	Outside Dia Meter (mm)	Bend Radius	Bend Radius (mm)	Intra Dos	Extra Dos	Tm (Intra dos) (mm)	Tm (Extra dos) (mm)
1.	168.3	1D	168.3	1.5	0.833	1.959417	1.09309
2.	168.3	3D	504.9	1.1	0.928571	1.440483	1.217291
3.	168.3	6D	1009.8	1.045455	0.961538	1.369519	1.26025

- If we want to compare it with standard thickness, we will also have to add the various tolerances to the respective intrados and extrados thickness.
- The tolerance ‘C’ can be obtained from previous data.
- Intrados thickness will always be more than extrados thickness.

2. Leak test or Hydro test

- Prior to initial operation, each piping system shall be leak tested. Each weld and each piping component, except bolting and individual gaskets to be used during final system assembly and pressure-relieving devices to be used during operation, shall be hydrostatically or pneumatically leak tested.

- The hydrostatic test pressure at every point in a metallic piping system shall be as follows:
  (a) Not less than 1.25 times the design pressure.
  (b) When the design temperature is greater than the test temperature, the minimum test pressure, at the point under consideration, shall be calculated by following equation.

- Pt = 1.5PST/S

- Where

P = internal design gage pressure
Pt = minimum test gage pressure
S = allowable stress at component design temperature for the prevalent pipe material; see Appendix K, Table K-1
ST = allowable stress at test temperature for the prevalent pipe material; see Table K-1

- First we will find the maximum allowable pressure; this is done using the previous equation of thickness.
- The thickness is taken as procured thickness and the pressure is found out.
- The value of stress is taken as yield strength, as we want to check for pipe failure.
- The values of E, Y, W and C(total allowance) will be same as before.
- The yield strength for both the material comes out to be 246074.3528 (kg/mm2)
- Using
  P= (2*S*E*W*t)/(D-2*t*Y).

- ST(kg/mm2)= 163815.212

- S(N/mm2))= 149247.6103

- ST/S = 1.097606934

Sr. No.	Dia(NPS) in	Outside Diameter (mm)	Procured Thickness without allowance	Maximum allowed pressure (kg/mm)	Material
1.	2	60.3	1.73	14451.37587	A106(B)
2.	4	114.3	3.08	13553.93624	
3.	6	168.3	5.11	15314.83622	
4.	24	610	6.646334627	5409.421714	
5.	26	660	7.73	5818.624038	A672 GR B65 class22
6.	42	1067	10.9	5068.999595	
7.	56	1422	12.47	4346.310232	
8.	64	1626	15.68	4782.833684	

- Maximum pressure which is being used in the industry is 104.05 kg/cm2. Therefore a minimum safety of at least 2.1 times the pressure used, is ensured.
- Now we will find pressure for hydro test and pneumatic test. This pressure should be less than the Maximum allowed pressure.
- For hydrostatic:
  Pt= 1.5*P*ST/S = 2476.324725

- For Pneumatic
  Pt= 1.1*P*ST/S= 2179.165758

- As both the test pressures are less than the maximum allowable pressures at respective diameters, the pipe is safe.

3) **External Pressure check**

- Value of A taken from Table G, ASME Section 2
- Temperature = 38°C
- Pressure = 17.7bar
- Material = A106(C)
- C1(corrosion allowance) = 1.5mm
- C2(thread allowance) = 0mm
- C3(mill allowance) = 0.5mm

Sr. No.	Dia meter (mm)	Procured Thickness without allowance (mm)	L/Do	Do/t	A	B	Allowable Pressure (bar)	Design Pressure (bar)
1.	60.3	1.73	50	34.85549	0.00661	17248.50	45.49229577	17.7
2.	114.3	3.08	50	37.11039	0.00401	17002.99	42.11992579	17.7
3.	168.3	5.11	50	32.93542	0.00882	17314.80	48.32949112	17.7

- As the Allowable pressure is greater then the design pressure the pipe is safe under external loading.

4) Thread Check

- When threads are required on the pipe, pipe should be designed accordingly and the height of the threads should be added to the designed thickness and then pipe specifications should be given for the procurement.

- Here we have followed the reverse process.

- We can obtain the standard pitch for the given diameter of the pipe from ANSI B1.20.1.

- Relation between height of the thread and pitch can be given as,
$$h=0.866025p$$
- If thickness after removing allowances and thread height from the procured thickness is higher than the designed thickness, then threads are allowed to be produced on that pipe, otherwise threads should be avoided.

- Sample calculations for thread check are shown below.
- Extra thickness left = Procured thickness – h – Original thickness
- Note: all the above thickness are without any allowances
- Here for 1.5''and 6" dia. pipe thickness after removing allowances and thread height from procured pipe thickness is higher than the designed thickness. Hence threads are allowed to be produced on the pipe.

- But for pipe diameters 2''in pipe thickness after removing allowances and thread height from procured pipe thickness is smaller than the designed thickness. Hence threads are not allowed to be produced on these pipes.

O.D (mm)	**Thread per inch**	**Pitch**	**H=0.866025 P**	**Procured Thickness without allowance (mm)**	**Tm (mm)**	**Extra thickness**
60.3	11.5	2.2086	1.9127	1.73	0.469482255	-0.652267
114.3	8	3.175	2.7496	3.08	1.310345996	1.05002
168.3	8	3.175	2.7496	5.11	0.376052951	1.29116

Flexibility Analysis

➢ PIPING FLEXIBILITY ANALYSIS

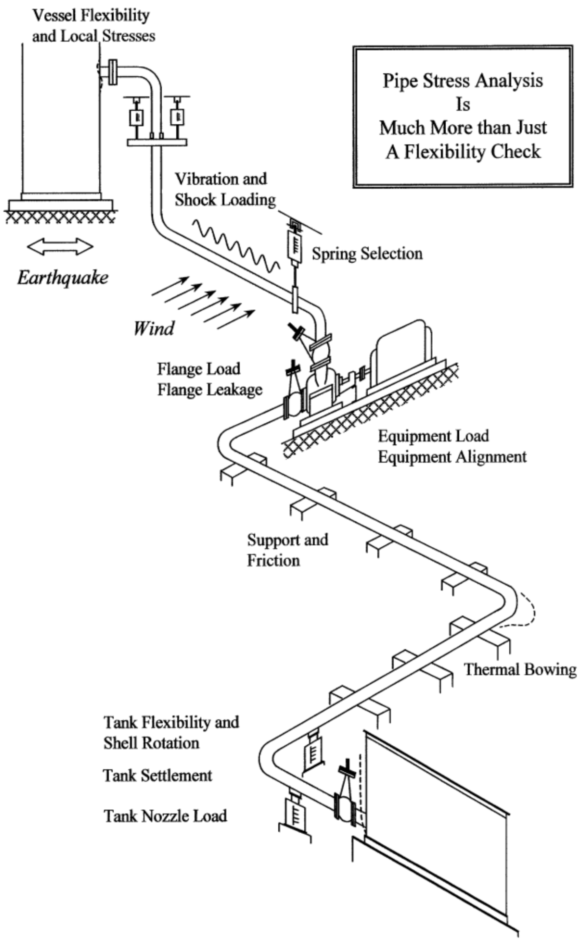
- Pipe stress Engineers calculate the stress in a piping system subject to normal operating loads such as pressure, weight, and thermal expansion, and occasional loads such as wind, earthquake, and water hammer.

- All piping systems are connected to equipment such as vessels, tanks, pumps, turbines, and compressors; the piping stress analysis also involves evaluation of the effect of the piping forces and moments to the connecting equipment.

- As the piping stress is controlled by the arrangement of the supports and restraints, the scope of piping stress includes also pipe supports.

- The whole scope of this work is generally referred to as piping mechanical.

➢ REASONS FOR THE PERFORMING FLEXIBILITY ANALYSIS



1. In order to keep stresses in the pipe and fittings within code allowable levels.
2. In order to keep nozzle loadings on attached equipment within allowable of manufacturers or recognized standards (NEMA SM23, API 610, API 617, etc.)
3. In order to keep vessel stresses at piping connections within ASME Section VIII allowable levels.
4. In order to calculate design loads for sizing supports and restraints.
5. In order to determine piping displacements for interference checks.
6. In order to solve dynamic problems in piping, such as those due to mechanical vibration, acoustic vibration, fluid hammer, pulsation, transient flow, and relief valve discharge.
7. In order to calculate and check Flange Leakages.
8. In order to help optimize piping design.

MECHANICAL PROPERTIES FOR THE DESIGN

Mechanical properties of any MOC (Material of Construction) are dependent on their chemical composition and method of manufacturing.

Various properties of MOC are:

Stress:	It is an internal resistance developed in the body which, when acted upon any external force. Analysis of stress in pipes is most important factor in that influence the designing of that pipe.
Strain:	The change in dimension of the body due the loads acting on it can be termed as strain in that body. It is generally expressed in δl. It gives us fair idea about the stress acting on the body.
Toughness:	The resistance offered by body against any type of penetration given to it. It is expressed in toughness number which is specific for every different material.
Hardness:	It is the resistance offered by body against all types of penetration, external pressures and shocks. It is expressed in same way as toughness (hardness number).
Creep:	It is the effect of load observed in body at high temperatures and reason for deformation of body at high temperatures.

Mechanical design fundamentals

- Failure of structure part is said to occur when stress, strains or a certain function of stress/strain in structure reach a critical point.
- A designer must know two things:
  -How the stress and strain in structure can be calculated from applied loads.
  -Critical combination of stresses and strains at which failure would occur.

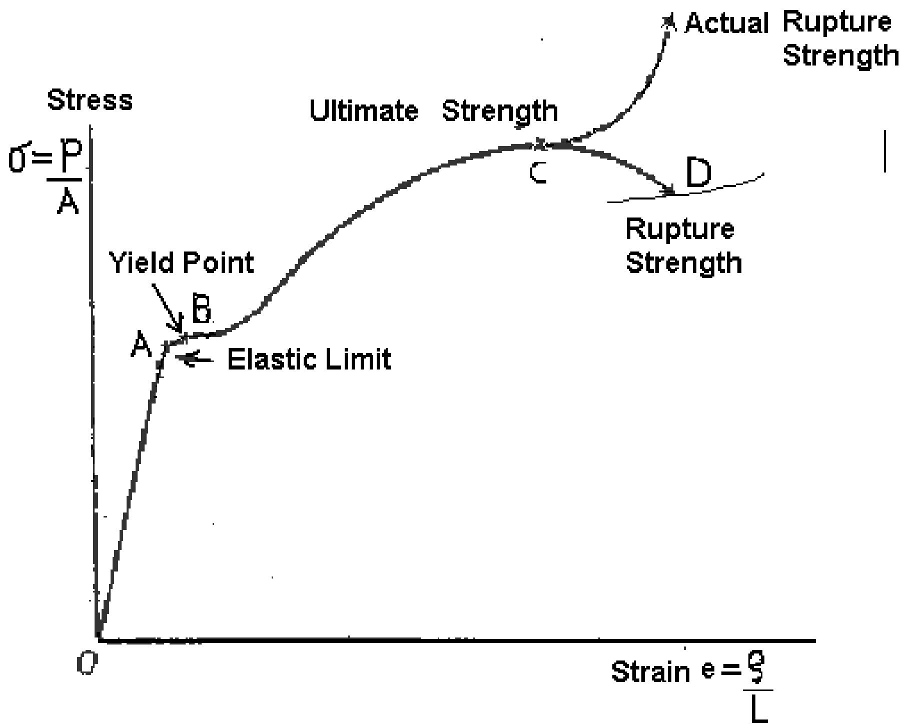
➢ STRESS-STRAIN CURVE

- For a Material taken under a tensile test, a stress-strain curve is obtained through which its elastic limit, yielding points and fracture points can be known.

Elastic limit: For load acting on specimen, if stress is proportional to strain up to certain limit where upon removing load gives its original shape can be termed as Elastic Limit of specimen.

Yield point: The highest stress that the metal can withstand under sustained load without continuing to elongate under same load is called yield point. The extreme stress values among these are called upper and lower yield points.

Stress-strain curves are different for different materials and at different temperatures for same material.



Modulus of Elasticity: Known as Young's modulus, is a simply the slope of straight line representing the elastic line in stress strain curves. It's often used to convert measured strain value if the structural element to corresponding stress value if the structural element were to produce that much deformation while still in elastic region. It can simply be calculated by Є (Young's modulus) = σ (stress)/E (strain).

Yield stress: The stress developed just before the rupture/fracture occurs is called yield stress.

Ultimate tensile Strength: While ultimate tensile strength (UTS) is that value of stress beyond which plastic instability sets. Design should be such that this level of stresses is not reached during life of any structural element.

Allowable stress: Yield stress is used to decide the allowable stress for any MOC at any temperature by incorporating a suitable safety factor. Allowable stress is defined as the UTS divided a safety factor.

Proof stress- The stress developed during the unloading of any element at elastic limit is called proof stress or resilience. When yield point is not easily defined based on the shape of the stress-strain curve. The value of this stress is arbitrarily assumed at 0.2% of strain. For e.g. high strength steel and aluminum alloys do not exhibit yield point so this stress is used. An important point about the proof stress is that it can be altered by preceding plastic deformation. Requirement of this stress is: It acts as a substitute for yield stress whenever it is not possible to define it.

Fatigue behavior- The final failure under sustained load due to plastic instability because of load carrying cross-section diminished to compensate for elongation, which lead to higher stresses causing the further elongation, such failure are termed as catastrophic failure. This failure occurs almost suddenly as soon as the load crosses threshold stresses.

Factor of Safety: It is defined as the ratio of ultimate strength of material to the maximum allowable (yield) stress of the body.

Section modulus: It is the ratio of radius or length of any body to its moment of inertia. It is expressed in in^3. It gives us idea about stress concentration in object.

➢ PIPE FAILURE

- Failure is a phase when material cannot withstand the forces acting on it and thus becomes non-operational and has to be changed.
- Failure occurs in a structure by :
  1) Excessive elastic deformation.
  2) Excessive non-elastic deformation
  3) Fracture

- For safety and reliability of working condition of pipes some theories are calculated for the failure of pipe.

  1) Maximum shear theory (Tresca theory)
  2) Maximum principal stress theory (Rankine theory)
  3) Octahedral shear stress theory (Von Mises theory)

1. Maximum shear theory(Tresca theory)

- This theory uses shear stress as a subject of equation for calculating failures of the pipes.

- This is very relevant to ductile metals. It is conservative and relatively easy to apply.

- It assumes that failure occurs when a maximum shear stress attains a certain value. This value being the value of shear strength at failure in the tensile test.

- In this instance it is appropriate to choose the yield point as practical failure.

- According to theory:

"Failure occurs when maximum shear stress reaches maximum shear stress at yield point of the body."

In uniaxial test,

$$\tau_{max}= 0.5\ [(S_L - S_H)^2 + 4\tau^2]^{0.5}$$

Thus above equation can be modified as:

$$\tau_{max}=(S_1)/2;\ \text{Or}\ \tau_{max}=(S_{yield})/2.$$

Thus according to tresca theory:

Plastic deformation occurs IN 3-D stress state when shear stress reaches S_{yield}/2.

2. **Maximum principal stress theory(Rankine theory)**

- Rankine's Theory assumes that failure will occur when the maximum principal stress at any point reaches a value equal to the tensile stress in a simple tension specimen at failure. This theory does not take into account the effect of the other two principal stresses.

- It's good for brittle materials (like cast iron), but not ductile ones (like aluminum).
- This theory makes principal stress as a subject of equation for calculating the failure in pipe.
- According to this theory:

”**Failure occurs when maximum principal stress reaches the maximum principal stress at yield point of the material.”**

In uniaxial test, the applied load give rise only axial stress (S_L) and S_H and S_R as well as shear stress are absent. Thus,
$S_L = S_Y$, $S_H = 0$, $S_R = 0$
Therefore, $S_1 = S_Y$, $S_2 = S_3 = 0$

Plastic deformation occurs whenever principal stress (S_1) exceeds principal stress at yield point (S_{yield}).

3. **Octahedral shear stress theory(Von Mises theory)**

- The Von Mises stress is used to predict yielding of materials under any loading condition from results of simple uniaxial tensile tests.

- This theory says that:

”Failure occurs when octahedral shear stress of the body reaches the octahedral shear stress of the body at yield point.”

The octahedral shear stress is calculated as:

$$Toct=1/3[(S_1-S_2)^2 + (S_2-S_3)^2 + (S_3-S_1)^2]^{1/2}$$

In an uniaxial stress condition we have $S_2= S_3=0$;
Thus,

$$\tau_{oct}=2^{1/2}(S_{yield})/3.$$

Therefore according to Von Mises theory:

Plastic deformation in 3-D shear stress state when maximum octahedral shear stress reaches the maximum octahedral shear stress at yield point.

REQUIREMENTS OF ASME B31.3 (PROCESS PIPING CODE)

- 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, anchor movements.

ALLOWABLE STRESS AS PER CODE B31.3

- The allowable stress for a piping system or a piping component material is based on a function of the yield or tensile strength of the material at cold to moderate temperatures, or is based on creep rates or stress for ruptures in elevated temperature service.
- Cold Allowable Stress (Sc): -
  The term Sc is the allowable stress at the cold condition, which includes cryogenic service, or ambient installed temperature for elevated temperature service
- Hot Allowable Stress (S_h): -
  S_h is the allowable stress for material in the hot operating condition, which would be the design temperature for elevated temperature service or ambient for cold or cryogenic service.

- The values of Sc & Sh are tabulated in Appendix A Table A – 1 of the B 31. 3.

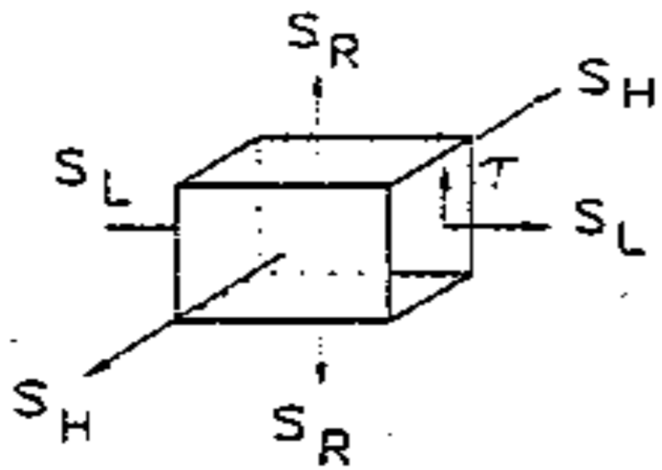
- B31.3 establishes maximum allowable stress limits that can be safely accommodated by a piping system before failure will commence for two separate stress loading condition. These limits are for stress level that can cause a failure from a single loading, Sh, and those that can cause failure from repeated cyclic loading, S_A.

- The allowable stress range S_A, is the stress limit for those stresses that are repeated and cyclic in nature, or simply, it is the allowable stress to be compared to the calculated displacement stress range, S_E (a secondary stress).
  $S_A = f\ (1.25\ Sc + 0.25\ S_h)$ or
  $S_A = f\ [1.25\ (Sc + S_h) - S_L]$

  S_L = longitudinal stress.
  f is the stress-range reduction factor presented in B 31.3 Table 302.3.5.

➢ PIPE UNDER STRESS

Stress: It is an internal resistance developed in the body which, when acted upon any external force. Analysis of stress in pipes is most important factor in that influence the designing of that pipe.



When we calculate stresses, we choose a set of orthogonal direction and define the stresses in this co-ordinate system. For example , in a pipe subjected to internal pressure or any other load, the most used choice of co-ordinate system is the one comprising of axial or longitudinal direction(L), circumferential (hoop's) direction(H) and radial direction (R) as shown in fig. below. Stresses in the pipe wall are expresses as axial (S_L), hoop's stress (S_h) and radial (S_R).

These stresses which stretch or compress a grain/crystal are called normal stress because they are normal to the surface of the crystal.

➢ Type of Stresses Developed

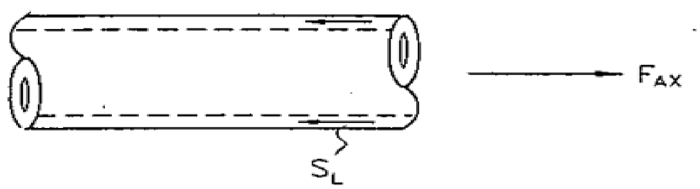
- There are mainly three types of principle stresses.

1. Longitudinal Stress
2. Hoope or circumferential stress
3. Radial Stress

- Other stresses include torsional, shear and bending stresses.

1) Longitudinal Stress

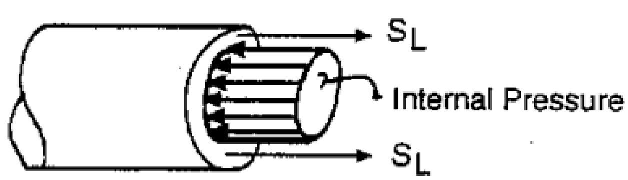
- They are the stresses acting parallel to the longitudinal axis of the pipe.
- This stress can be calculated using the basic formula of: stress =force/active area.



- Schematic diagram of this stress is given above

- $S_L = F_{ax}/A_m$,
  Where,
  S_L=longitudinal stress, psi,
  F_{ax}=internal axial force,
  A_m=pipe cross section area= $\pi (d_o^2 - d_i^2)/4$
  d_i =internal diameter of the pipe

- The force acts due to fluid present inside the pipe. This is similar to longitudinal stress due to normal pressure.
- This stress can be calculated using the basic formula of: stress =force/active area.



- Schematic diagram of longitudinal stress due to internal pressure.

  $S_L = F/A_m$,
  $S_L = PA_i/A_m$, (Force = pressure x area)

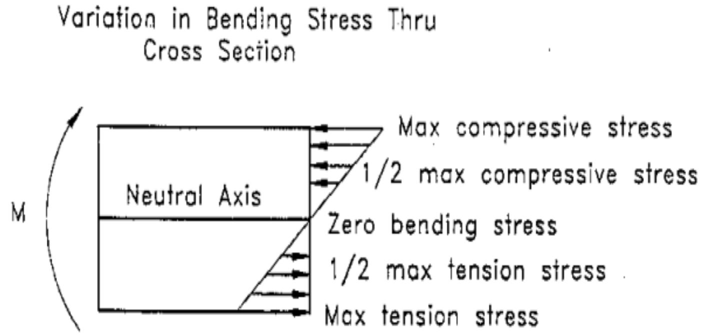
For uniform thin walled pipe, considering forces applied ($F = Pd_il$) and area of pipe over length l ($A_m = 4tl$), modification in above formula is,

$S_L = Pd_il/4tl = Pd_i/4t$.
Where,
S_L =Longitudinal stress due to internal pressure,
P =Design pressure, psig,
A_i =-internal area of pipe,
A_m =mean area of pipe.
d_i =internal diameter of pipe
t = thickness of pipe.

2) **Bending Stress**

- Bending stress is a special type of stress that is developed due to a different type of loading called bending load.

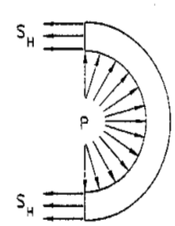
- Bending load is defined as the external agency which causes bending in the element, resulting into development of bending stress in it.
- Pipe bending is caused mainly due to this load under uniform distributed (U.D.L) or pin concentrated bending load. The main reason behind the bending stress developed is a characteristic called bending moment (M_b.)
- For above two types of bending loads. M_b can be calculated by following formulae.
  For U.D.L. = $wL^2/8$;
  M_b for concentrated load= $wL^2/12$.
  But for practical purpose, M_b used is: $wL^2/10$.



General formula for calculating bending stress is :
$S_L=M_{b*}c/I$
Where,
c=distance of point interest from neutral axis of cross section, in.
M_b=Bending moment acting on cross section, in lb.
I=moment of inertia=in^4,
$= \pi (d_o^4-d_i^4)/64$.
$S_{max}=M_bR_o/I=M_b/Z$.
R_o= outer (extreme) radius of pipe.
Z=section modulus of pipe, in^3
$=I/R_o$

(3) Hoop Stress

- They are the stresses developed in the direction orthogonal to axial direction caused by internal pressure.



Schematic diagram of hoop stress developed.

- Magnitude of hoop stress can vary from pipe walls, and can be calculated by Lame's equation,

$S_H=P*[(r_o^2 - r_i^2)/r^2]*[1 + r_o^2/x^2]$

Where,

S_H=Hoop stress developed
P=Load acting
r_i=internal radius of pipe
r_o=outer radius of pipe
r=mean radius.
X = distance from center at which stress to be calculated

- The hoop stress can be arbitrarily approximated over the thin-walled cylinders, assuming applied force over arbitrary length of pipe, l ($F = Pd_il$) and is resisted by same pipe wall over same length, (A_m=2tl).

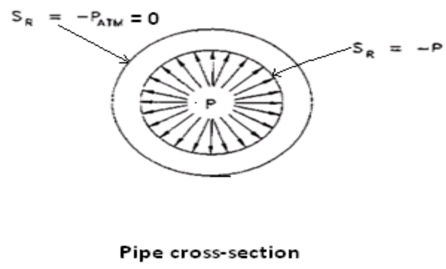
$$S_H = Pd_il/2tl$$

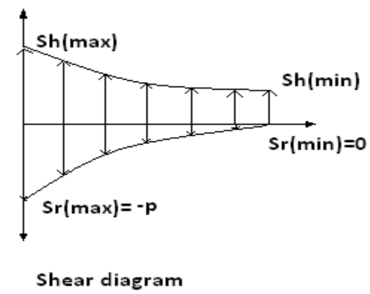
This is the governing factor for calculating the thickness of the pipe.

(4) Radial Stress

- They are the stresses developed in the third orthogonal direction or parallel to radius produced by internal pressure, varying from pressure of internal fluid (inner wall) to outer wall pressure (atmospheric).

$S_R=P* [(r_o^2 - r_i^2)/r^2]*[1 – r_o^2/x^2]$
S_R=radial stress due to pressure,



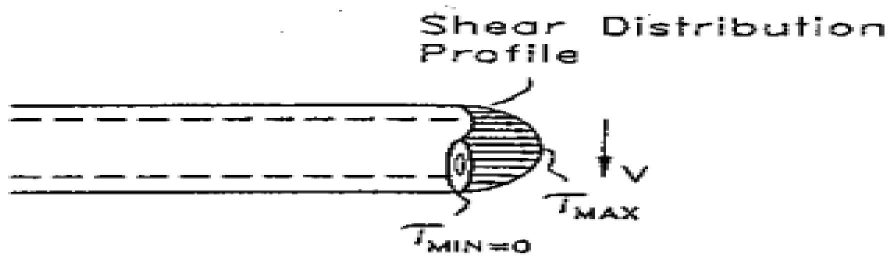


Schematic diagram of radial stress developed in pipe.

Radial Stress is neglected in the analysis, as they are negligible.

(5) Shear Stress

- They are the stresses developed along the sides of the face of plane, along with the direction of crystals which causes the dislocation of crystals, causing the pipe to shear.

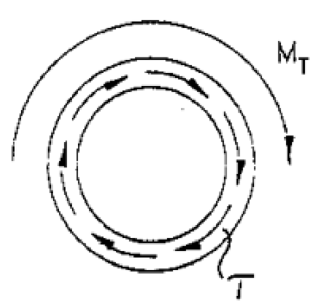


Schematic diagram of shear stress acting.

τ_{max}=VQ/A_m,

Where,
τ_{max}=shear stress,
Q=shear form factor,
A_m=area of pipe,
V=Shear force.

- Shear stress can also be caused by torsional loads



Schematic diagram of shear stress due to torsion

$\tau = M_t c/R$

Where,

M_t=internal torsional moment,

R=torsional resistance of c/s, in^4. = 2I

c= distance of neutral axis from point of consideration on the body.

τ is maximized when c reaches its ultimate value(i.e. extreme radius of the object)thus condition for τ_{max} is c=R_o(extreme radius of the object) below equation

$\tau_{max} = M_t c/2I = M_t/2Z$.

Total shear stress (τ_{max}) =$VQ/A_m + M_T/2Z$.

- Thus, this explains about classification and general formulae of stresses acting on pipes.

➢ SUSTAINED AND EXPANSION STRESSES

- **SUSTAINED STRESS**

- Sustained load stresses are stresses caused by pressure and weight of pipe which does not diminished with time.
- Information on sustained stress is given in the ASME code B31.3 for petrochemical and refinery piping.
- But everything cannot be given in the code so engineers need to calculate the longitudinal stress developed in pipe due to weight and pressure and should ensure that it doesn't exceed S_A (Allowable stress). This can be shown below.

- Sustained stress = Axial stress + Bending stress + Hoop stress <= Allowable stress.

- $S_L = F_{ax}/A_m + [(i_i M_i)^2 + (i_o M_o)^2]^{1/2} /Z + Pd_o/4t <= S_A$
- Where,

  S_L = sustained stress.

  S_A= basic allowable material stress.

  F_{ax}= axial force,

  M_i = in-plane bending moment due to sustained load, in lb

  M_o = out-plane bending moment due to sustained load, lb

  I_i, I_o = in-plane and out plane intensification factors.

  Z = section modulus.

  P = design pressure.

  t=thickness of pipe.

  A_m = mean area of cross section of pipe.

  d_o = outer diameter of pipe.
- Here, Allowable sustained stress is taken equal to Hot stress (Sh)

  Sh= Sa

- **EXPANSION STRESS**

  - While plant under operation, pipes carries fluids which are at high temperatures, due to heat there is expansion of pipes and joints. So the stress developed due to expansion of pipes is termed as expansion stress.

  - Expansion stress = Axial stress + (Effect of Bending and Torsion moment) <= Allowable stress.
  - $S_E = F_{ax}/A_m + [(I_iM_i)^2 + (I_oM_o)^2 + 4M_T^2]^{1/2}/Z <= S_A = f(1.25S_C + 0.25\ S_H)$ (as per ASME B31.3 appendix for pipe stresses)
  - Where
    S_E = Expansion stress
    S_A= basic allowable material stress
    F_{ax}= axial force
    M_i = in-plane bending moment due to sustained load, in lb
    M_o = out-plane bending moment due to sustained load, lb
    I_i, I_o = in-plane and out plane intensification factors.
    Z = section modulus.
    P = design pressure.
    t=thickness of pipe.
    A_m = mean area of cross section of pipe.
    d_o = outer diameter of pipe.
    S_C= basic material stress at cold (installation) temperature, as per appendix A of B31.3 code.
    S_H= allowable stress at hot (operational) temperature.

➢ LOADS ON PIPING

- **PRIMARY LOADS**

These are typically steady or sustained types of loads such as internal fluid pressure, external fluid pressure, gravitational forces acting on pipe, weight of that pipe and fluid forces due to relief or blown down, pressure waves generated due to water hammer effect.

The last two may not be necessarily sustained loads. Primary loads are not self-limiting, as the plastic deformation begins it continues unabated until force equilibrium is achieved, or until failure of cross section occurs.

They are not cyclic in nature. Allowable limits for stresses are related through failure modes by advanced theories like Von-Mises, Tresca and Rankine theory.

- **SECONDARY LOADS**

The loads that have their origin in some other forces. Secondary loads are caused by displacement because of fluid temperature inside piping system. For example the pipe connected to a storage tank may be under load if tank nozzle to which it is connected moves down due to tank settlement. Also various other forces like seismic, wind, vibration, discharge etc can be kept in this classification.

They are usually displacement driven and are almost self limiting i.e. they tend to dissipate the loads through yielding or deflection.

They are mostly cyclic in nature, and allowable stresses for secondary loads are based upon cyclic and fatigue modes. A single application of load does not produce failure; rather fatigue failure occurs after number of loads occurring on it.

LOADINGS AND THEIR EFFECTS

Several loadings are experienced by the piping systems during their service life. However, not all the loadings produce the same kind of effect and hence their design treatment cannot be the same. They can be divided into types as shown in Table below.

The loads like pressure, weight etc. are characterized by their persistence on the system till collapse. These loads cause continuous strain. Generally the allowable stress for these loadings is S_h (The allowable stress at hot condition).

However, some of the loadings of this type occur occasionally and in recognition of their short duration, codes permit higher allowable stresses by ‘Occasional load factor’. On the other hand, loads like thermal displacements persist only till the requisite finite strain. In other words, if the required thermal displacement is permitted by the system without any resistance, the load no longer persists.

Generally the stresses due to these loads are limited to ‘Allowable stress range’. However, some of the loadings of this type, like differentials settlements, creep etc. are non-repetitive and hence codes permit higher allowable stresses.

CLASSIFICATION OF TYPICAL PIPING DESIGN LOADS

CLASSIFICATION	KIND OF LOAD	SUMMARY
Results in collapse independently of strain if it becomes excessive.	Self weight	Pipe, valve and fitting weight. Fluid weight. Insulation weight.
	Fluid Pressure	Internal/external pressure.
	Snow	For outdoors piping at a snowy area.
Results in collapse independently of strain if it becomes excessive	Vibration	Pulsation caused by reciprocating pump or compressor. Mechanical vibration.
	Test Pressure	For pressure test or leak test.
	Earthquake	Ground motion by earthquake.
	Wind	Wind pressure
	Impact Pressure	Water hammer caused by emergency stop of pump or by emergency shut down of valve.
Results in only finite strain and no collapse by itself	Thermal Load	Constraint of thermal expansion or contraction of piping.
	Forced Displacement	Displacement difference (caused by differential settlement or thermal expansion of equipment) between piping and equipment.
	Initial Deformation	Misalignment. Cold spring for control of reaction forces and moments to equipment.

➢ Piping Supports

- Pipes are to be supported for safe operation of plant. Pipe supports are provided to avoid excessive sagging, to guide the piping in controlled directions, to limit the loads on the equipment, to take care of all load conditions like testing, operation, maintenance, as well as occasional loads.
- They are mainly divided into two parts critical (wherein flexibility calculations are necessary) and non critical (where flexibility calculations are not necessary).
- Critical supports are further sub dived into:
  1. Primary supports:
     - A) Resting:
       1. Pad
       2. Shoe (saddle)
       3. Trunion (duck pad)
       4. Adjustable
     - B) Guide:
       1. Single directional
       2. 2D Guide
     - C) Axial stop
     - D) Anchor
       1. Welded
       2. Non Welded
     - E) Sliding

2. Secondary Supports

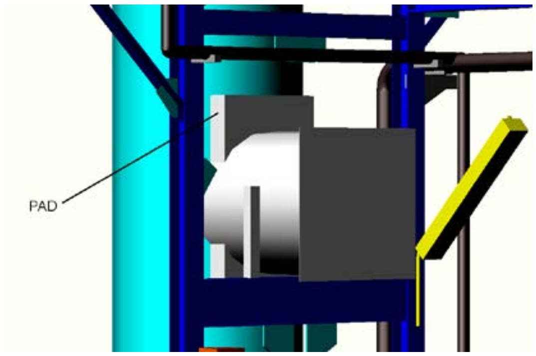
- Special supports are either combination of standard supports or are deviations from standard supports.
- Special Items:
  - I. Provide - based on flexibility calculations.
  - II. Procured from vendor by providing input from flexibility calculations.

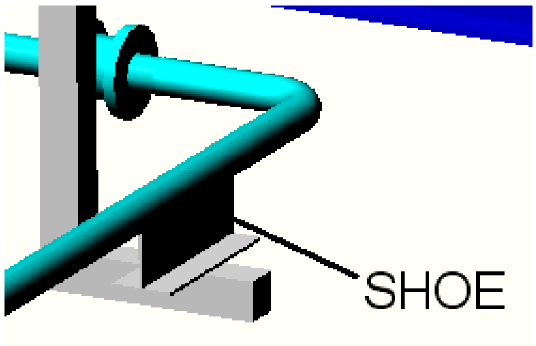
- Following are few of the special items used for supporting :
  - I. Springs
  - II. Rigid Hangers
  - III. Restruts
  - IV. Vibration Eliminators – Snubbers, Sway braces, Viscous dampers

- Flexible Supports:

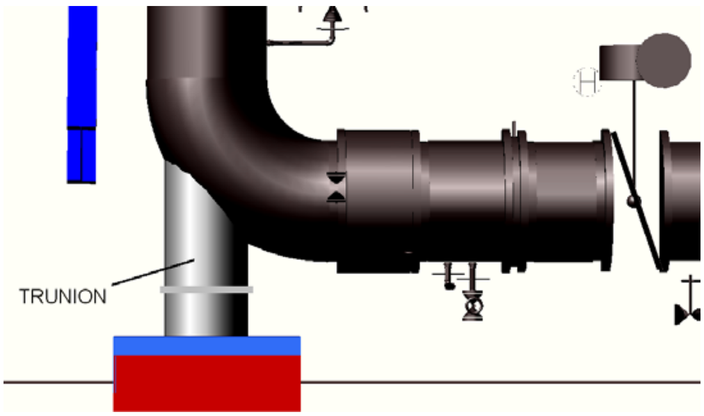
When vertical displacement occurs as a result of thermal expansion it is necessary to provide a flexible support which applies supporting force throughout the contraction and expansion cycle of the system.
Flexible hangers are two types:

1. Constant Spring
2. Variable Spring.

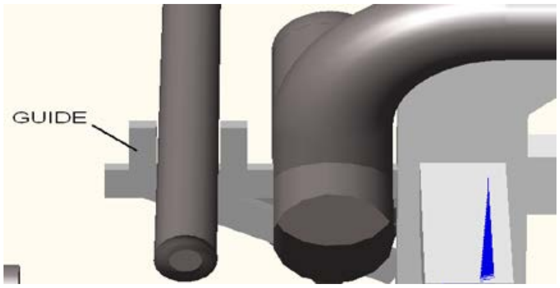


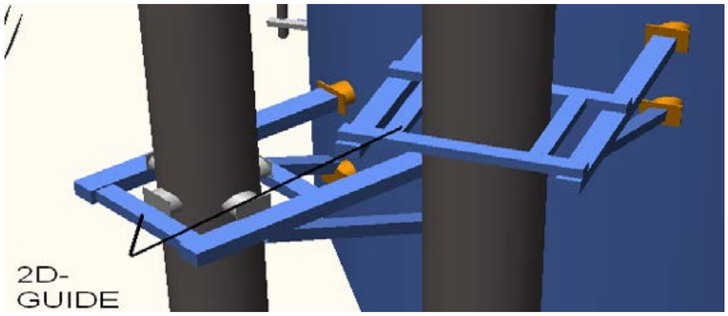


Pad

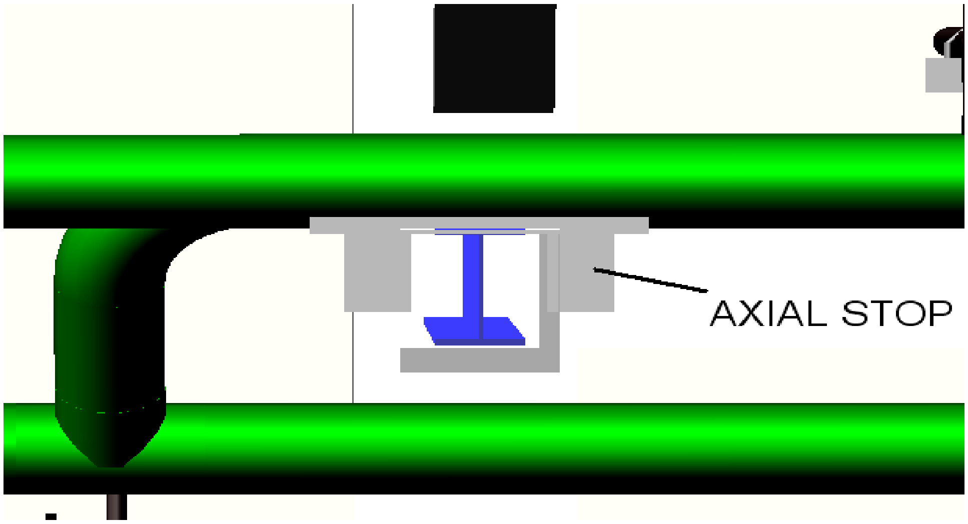


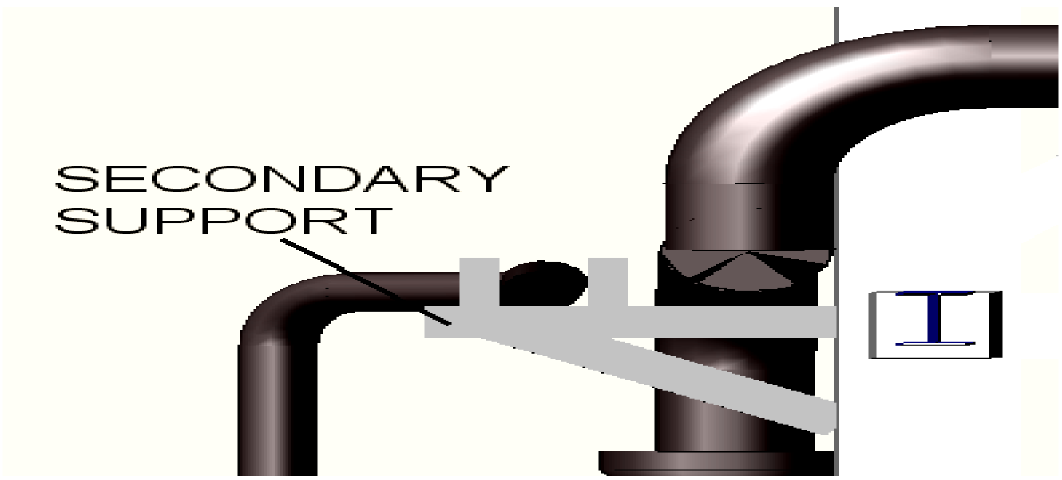
Trunion





Single Direction and 2D Guide Ways





Flexibility analysis of Piping System

- In this, we carried out the modeling and Flexibility analysis of a piping system in Caesar II

- CAESAR II is a FEA pipe stress analysis software program developed, marketed and sold by COADE Engineering Software. This software package is an engineering tool used in the mechanical design and analysis of piping systems.

- The CAESAR II user creates a model of the piping system using simple beam elements and defines the loading conditions imposed on the system.

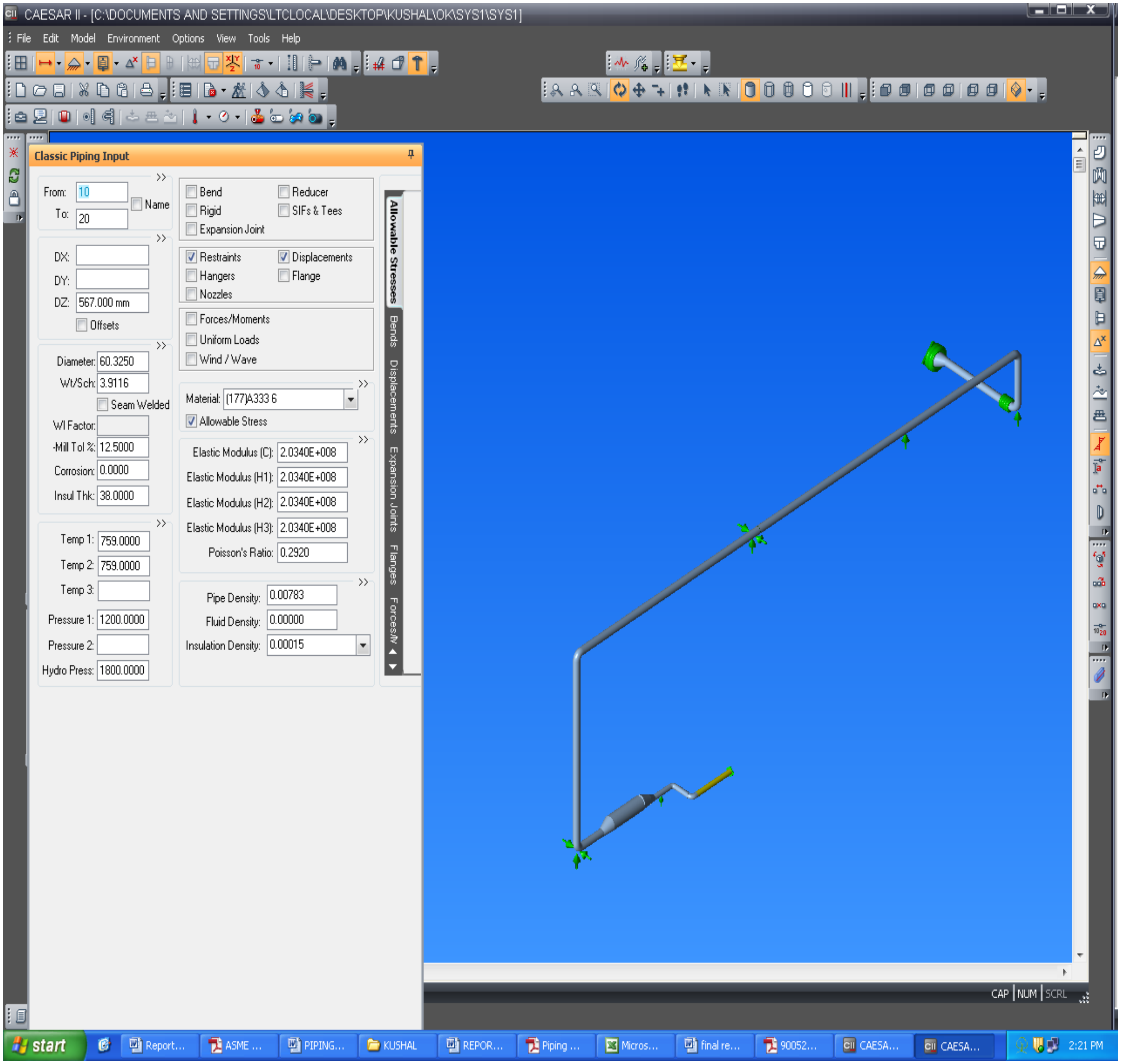
- With this input, CAESAR II produces results in the form of displacements, loads, and stresses throughout the system. Additionally, CAESAR II compares these results to limits specified by recognized codes and standards.

- **The complete process is explained as follows:**

1. First, we create the model of the piping system from the Piping isometric.

2. The inputs are then entered. The required inputs are:

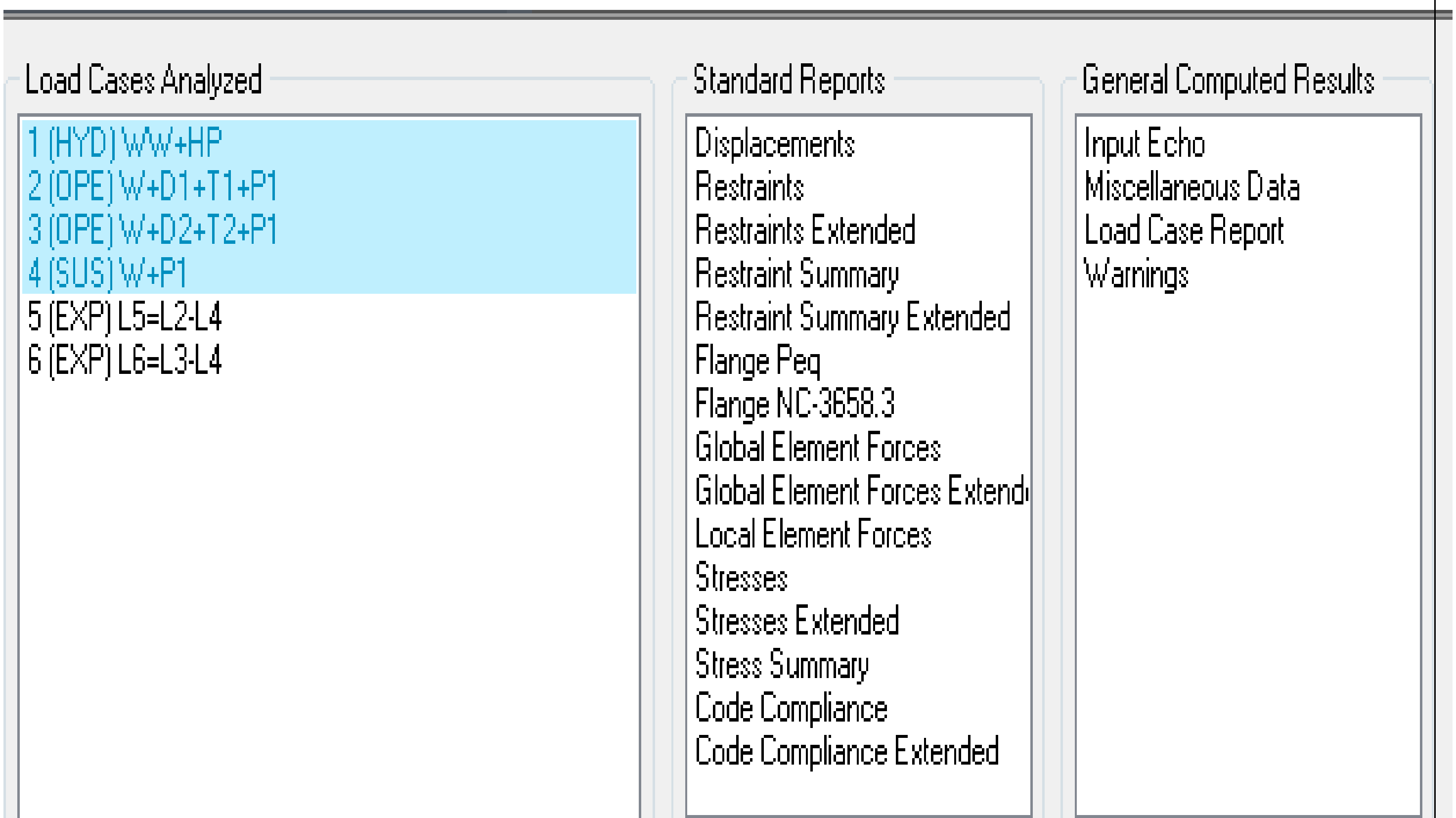
- Material
- Design temperature and pressure
- Working temperature and pressure.
- Thickness of pipe
- Density of fluid.
- Insulation
- Allowances(corrosion, mill, thread, etc)
- Nozzle Displacement if any



Model from isometric

3. Once the model is ready, we check for errors and proceed with the analysis by generating the report.
4. Various reports can be generated based upon the required conditions.
5. Usually we check for three loading conditions

- Sustained
- Operating
- Hydro, expansion and occasional



6. We first check for sustained loading conditions. In this we check for

- Displacement in the pipes
- Stresses generated due to sustained loads, mainly sagging.
- A minimum sagging of 5mm is usually tolerable.
- We can see that the code stress is greater than the allowable stress by a ration of 6.1(code stress ratio), therefore the pipe is safe.

```
Highest Stresses: (   KPa    ) LOADCASE 4 (SUS) W+P1
CodeStress Ratio (%):       6.1  @Node    240
Code Stress:             8465.2  Allowable:   137895.1
Axial Stress:            6216.2  @Node     90
Bending Stress:          4496.3  @Node    240
Torsion Stress:           187.4  @Node     20
Hoop Stress:            12996.4  @Node     80
3D Max Intensity:       14822.9  @Node    360
```

7. Then we generate the report for operating condition.

- The stresses at support and nozzles are checked in this condition.
- The stresses generated are compared with allowable stresses given in the support and nozzle load standards.

```
 NO CODE STRESS CHECK PROCESSED: LOADCASE 2 (OPE) W+D1+T1+P1

Highest Stresses: (   KPa    ) LOADCASE 2 (OPE) W+D1+T1+P1
OPE Stress Ratio (%):        0.0  @Node    260
OPE  Stress:           293078.7  Allowable:        0.0
Axial Stress:            6268.8  @Node     80
Bending Stress:        290245.6  @Node    260
Torsion Stress:         63101.1  @Node    310
Hoop Stress:            12996.4  @Node     80
3D Max Intensity:      297098.3  @Node    260

 NO CODE STRESS CHECK PROCESSED: LOADCASE 3 (OPE) W+D2+T2+P1

Highest Stresses: (   KPa    ) LOADCASE 3 (OPE) W+D2+T2+P1
OPE Stress Ratio (%):        0.0  @Node    258
OPE  Stress:            78002.4  Allowable:        0.0
Axial Stress:            6237.2  @Node    170
Bending Stress:         73959.7  @Node    258
Torsion Stress:         14751.6  @Node    310
Hoop Stress:            12996.4  @Node     80
3D Max Intensity:       78403.6  @Node    210
```

8. Finally we check for Hydro, Expansion and occasional loading

- Again the stresses are checked so that they are below the allowable stresses.
- For Hydro load we will only consider the hydrostatic pressure and force due to weight of pipe.
- We can see that the code stress is less than the allowable stress by a factor of 4.9(code stress ratio), thus the pipe is safe under this condition.

Stress Summary

```
CAESAR II Ver.5.20.3,  (Build 100715)   Date: JUN 21, 2016    Time: 15:18
Job: C:\DOCUMENTS AND SETTINGS\LTCLOCAL\DESKTOP\KUSHAL\OK...\SYS1
Licensed To: L&T CHIYODA LIMITED   --   ID #34882
STRESS SUMMARY REPORT: Highest Stresses Mini Statement
Various Load Cases

LOAD CASE DEFINITION KEY

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


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

Highest Stresses: (   KPa    ) LOADCASE 1 (HYD) WW+HP
CodeStress Ratio (%):        4.9  @Node    240
Code Stress:             11806.3  Allowable:   241316.5
Axial Stress:             9322.8  @Node     90
Bending Stress:           5849.2  @Node    240
Torsion Stress:            222.5  @Node     20
Hoop Stress:             19494.6  @Node     80
3D Max Intensity:        22234.4  @Node    360
```

9. If in any of the above condition the stresses exceed the allowable stresses, then parameters are adjusted to make the system safe. Usually the supports are adjusted to bring down the stresses under the limit.

LAY-OUT

- Importance of Plant Layout, Process Plants Such as Refineries and Petrochemical Plants are Complex Facilities Consisting of Equipment, Piping Systems, Civil and Structures, Instruments, Electrical Systems, Electronics, Computers, and Control Systems. The Design, Engineering and Construction of Process Plants Involves Multidisciplinary Team Effort.
- Plant Layout Plays an Important Role in the Design of New Process Plants or in Retrofit Projects for Existing Plants as Construction Costs as well as Operating and Maintenance Costs are Highly Influenced by the Plant Layout.
- Plant Layout Consists of Two Main Elements

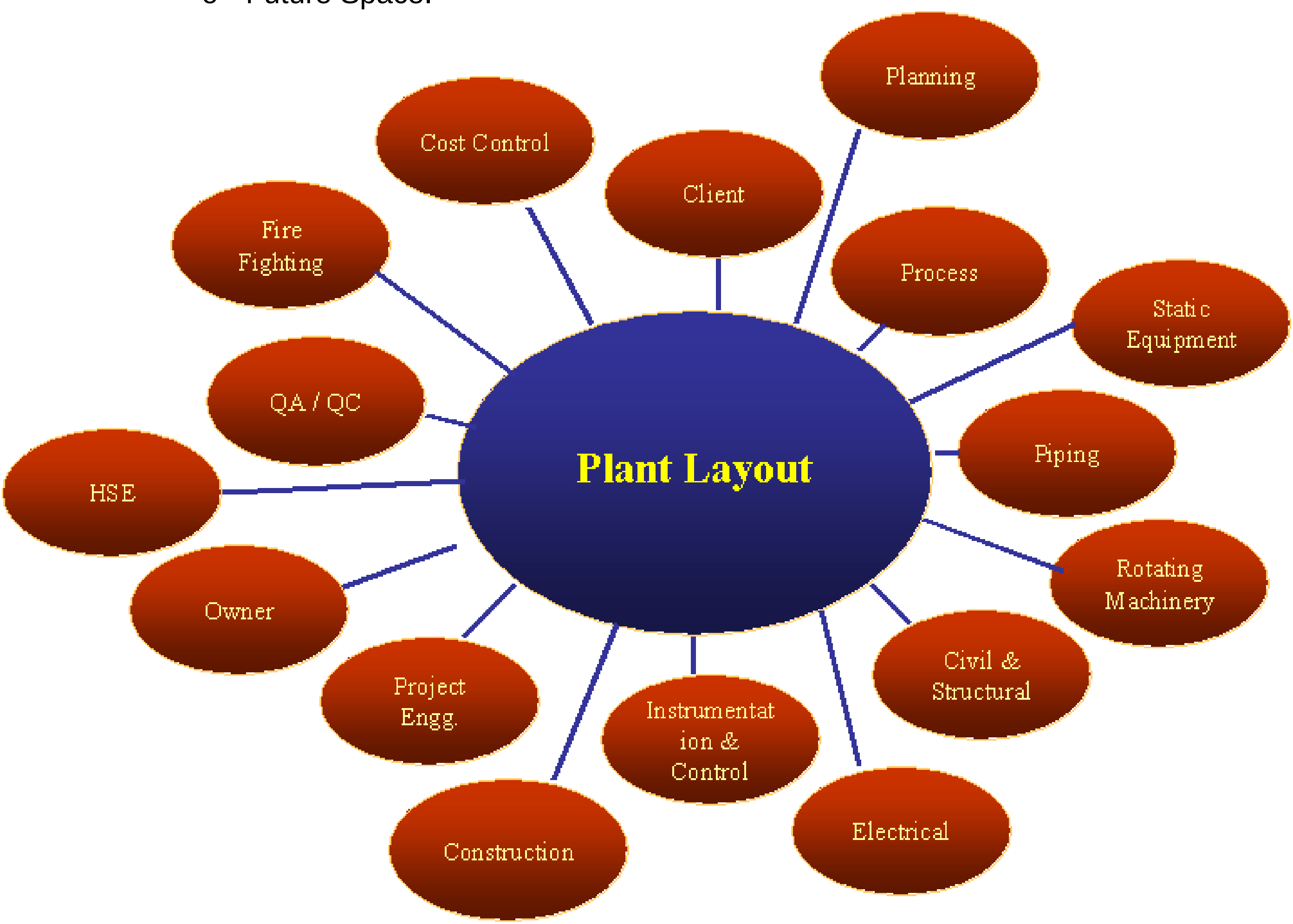
1. Overall Plot Plan
2. Equipment Layout

➢ OVERALL PLOT PLAN

- Provides Information in Block Form.
- Representation of Different Buildings and Plants e.g.
    - Process Production Units
    - Utility Units
    - Waste Treatment Units
    - Storage Areas – Including Warehouses
    - Sub – Station, Switch Yard
    - Control Room
    - Offices, Administration Bldg., Laboratories, etc.
    - Fire Station
- Indicates Details of Ground Profile.
- Access to Plant(s) viz. Roads, Rail tracks, Racks, Trenches, Sewers, future space, etc.

EQUIPMENT LAYOUT

- Equipment Layout also Called as Unit Plot Plan
- Provides Detailed Information for the Unit / Plant
  - Location & Arrangement of Equipments.
  - Mounting of Equipments.
  - Maintenance of Equipments.
  - Civil and Structural Arrangement.
  - Electrical & Instrumentation Installation.
  - Safety and Fire Fighting Details.
  - Environmental Protection.
  - Paved Areas, Basin, Dykes, etc.
  - Road Access.
  - Service Areas.
  - Future Space.



INPUT DATA FOR PLOT PLANT AND EQUIPMENT LAYOUT

Although there is a vast amount of input data throughout the life cycle of the project, the data basically falls into four distinct categories.

- Project Design Data – Is Supplied by the Client or Project Engineering
- Vendor Data – Pertaining to Equipment and Specialty Bulk Items
- Engineering Data – Developed in the Process of Detail Engineering
- Statutory rules/ regulations

Plot Plan/Equipment Layout Should Contain at Least

- o Drawing title block, reference drawing no, scale of the drawing, category of document, revision details and drawing issue status, names and signatures.
- o Soft copy file name.
- o North mark, wind direction and coordinates of bench mark.
- o Notes and Legends, Key plan in scale.
- o All equipments as per contract, relative location of equipments, elevation of equipments
- o Necessary dimensions, coordinates, elevations and detailed information if required
- o Circles are marked for safety distances as per applicable norms.
- o Battery limits of plant and battery limit of package items. Scope Demarcation at Battery limits.
- o Items under hold properly marked.
- o Equipment list with relevant dimensions.
- o Number and location for all grids of pipe rack, structure, buildings and trestles.
- o Location and list of tie in points.

- Indication of roads, open ditch, dyke, fence, access way, ramps, buildings and sheds.
- Platform, ladder and stairway of equipment and structures, required platform interconnections.
- Equipments are adequately located and location of future equipments.
- Pavement limits and type of pavement.
- Adequacy of stairs & ladder for any structures as per ITB requirements and statutory regulations.
- P&ID’s (PROCESS) REQUIREMENTS.
- Licensor’s recommendation.

BASICS FOR DEVELOPING AND FINALIZING PLANT LAYOUT

- **General points**
  - Economical Aspect.
  - Aesthetics.
  - Contractual Requirements.
  - Legal Requirements.
- **Process related points**
  - Process Flow Diagram (PFD) or Process Sequence
  - Process Data Sheets
  - Process Description
  - Utility Requirements
  - Process & Utility P&ID’s
  - Equipment List with Dimensions & Tag nos.
  - Available Plot Area
  - Adjacent Plants & Interconnections within Plants
  - Safety Clearances
  - Disposal of Waste
  - Shut Down Philosophy for Adjacent Plants – Together or Separately

- **Construction Feasibility, Maintenance Requirements, Operational convenience, Accessibility, Material Movement, Miscellaneous.**
  - Geo / Topo – graphical data / Contour Data.
  - Major Details of Buildings / Structure.
  - Hazardous Area Classification.
  - Standard and Codes Adopted.
  - Maintenance / Operation Access / Area Available for Construction.
  - Electrical / Instrument Cable Trays / Trenches.
  - Soil Data
  - Existing U/G Facilities & Other Civil Foundation / Raft Location Data
  - Prevailing Wind Direction, Actual & Plant North Direction
  - Overall Plot Plan
  - Basic Engineering Design Data (BEDD) / Project Specifications
  - Rail and Road Approach & Location of Marshaling Yard.
  - Fabrication Yard, Equipment Lay Down Area, Crane Movement Area, Crane Hold Down Area Etc.
  - Proposed Piping / Electrical Battery Limit Location.
  - Location of Local Sewer Line.
  - Availability of Utilities Like Water / Power
  - Future Expansion Requirements

- **Vendor data**

  Overall Dimension & Layout for all Purchased Equipment and Specialty Items are Required for Development of Plot Plan / Equipment Layout (Preliminary Vendor Drawing Preferred at the Beginning)

  - Pumps
  - Compressors
  - Air Coolers
  - Furnace / Heaters
  - Filters

- Specific Requirements of Loading & Unloading of Process Related Items
- Stack (Flare)
- Package Units Like DM Plant, ETP, Boiler House, Refrigeration etc.

- **Internally generated engineering data**

  Some of the data is internally generated during detailing as input to development of plot plan like

  - Document Number Revisions, Templates etc.
  - Inter Distance Between the Various Critical Equipments as per the Statutory Guidelines, Rules & Regulations.
  - Location of Utility Hose Stations.
  - Location of Safety Shower and Eye Wash.
  - Pipe Rack Configuration.
  - Piping Route Study.
  - Sizing of Buildings.
  - Finalization of Dimensions & Elevations of Equipment Mounted Platforms, Technological Structure Floors, Pipe Racks.
  - Main Cable Tray Routing U/G or A/G (Electrical and Instrumentation)
  - Location of Sub-station Building / Control Room
  - Specific Comments on Plot Layout w.r.t. Hazardous Area Classification.
  - Location of Entry of the Main Cables in Plot Plan (Electrical and Instrumentation)
  - Location of Analyzer shelters

➢ Inter-distance due to Safety, Approachability

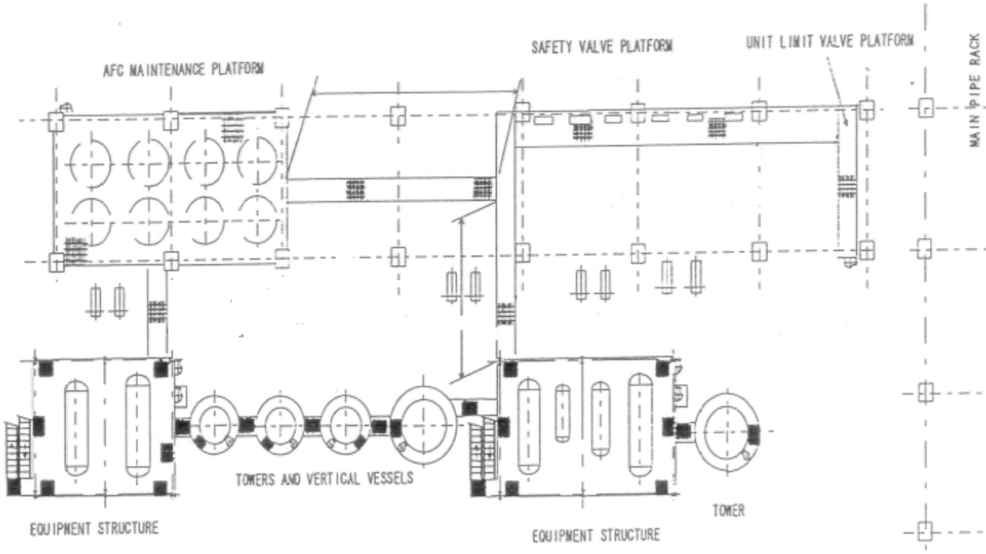
Inter Unit or Inter Equipment or Inter Facility Arrangement / Distances Shall Be Based Upon

- Prevailing Wind Direction – to Avoid Spreading of Hazardous / Noxious Substance. Towards Area Free From Flames and Personnel.
- The Nature of Chemicals Handled and Type of Reaction.
- Fire, Explosion and Leak Risks Involved.
- Expected or Planned Fire Fighting System.
- Minimum Clearance As Per Local Regulations or Client standard. Examples : GAP, OISD etc.

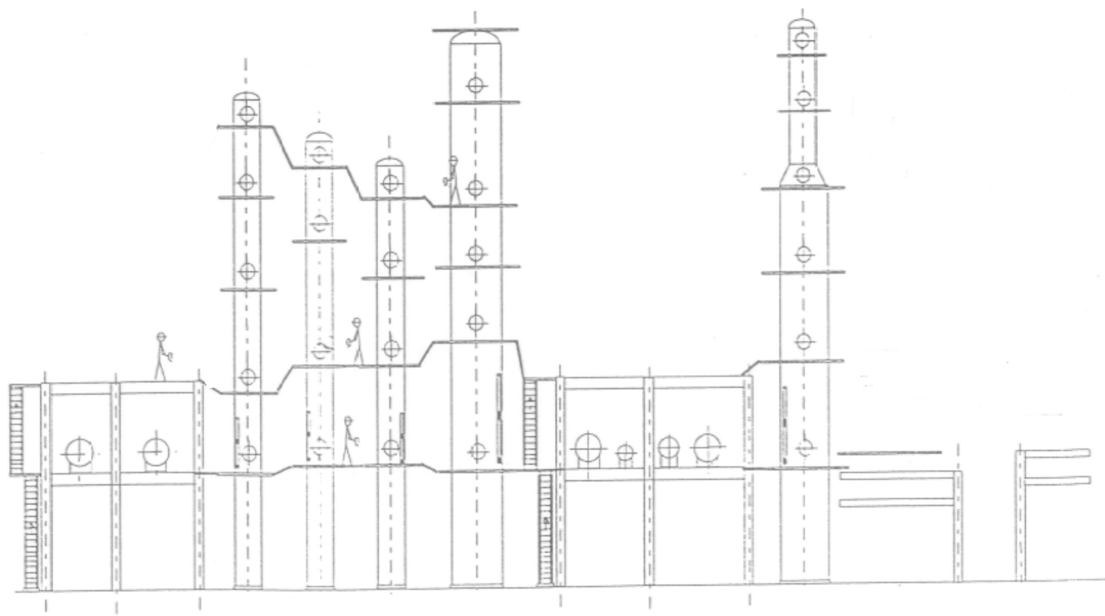
➢ **Space requirements for**

- Equipment located on the structure.
- Heating, Ventilation and Air Conditioning.
- Piping.
- Electrical items.
- Instrument items.
- Escape ways.
- Access requirements.

Walkway connections



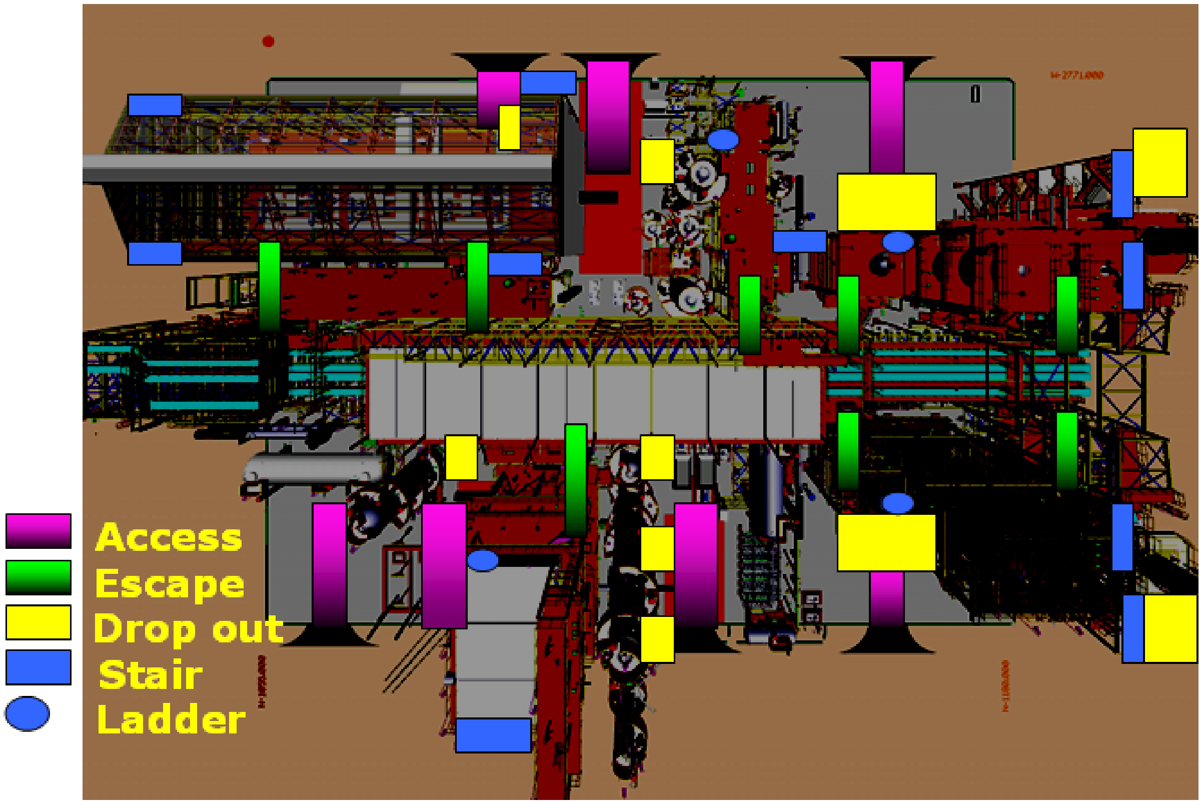
PLAN VIEW



ELEVATION VIEW

Platforms access ways

- For operating and maintenance requirements of equipment.
- To cut-off, regulate and control piping devices.

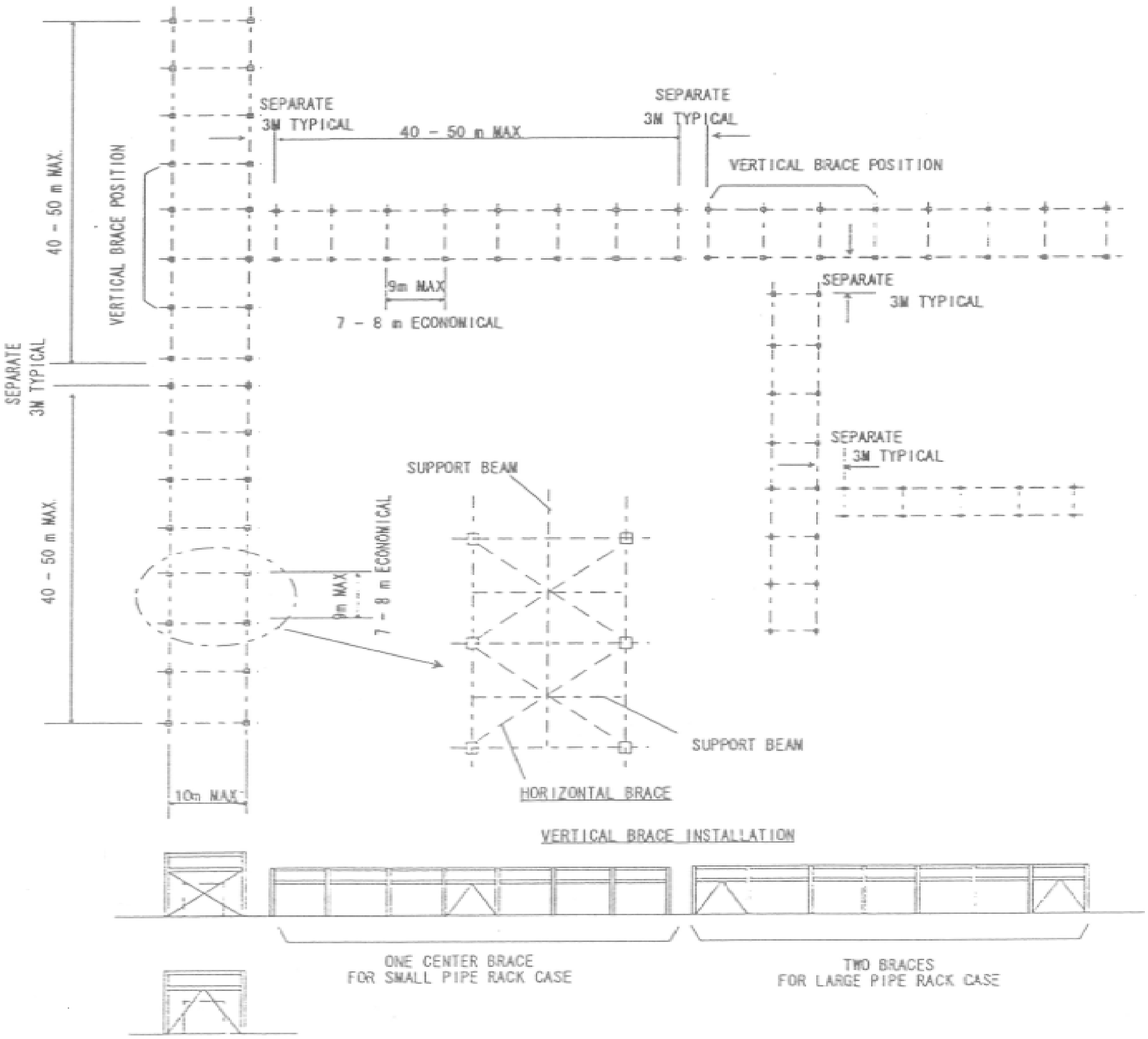


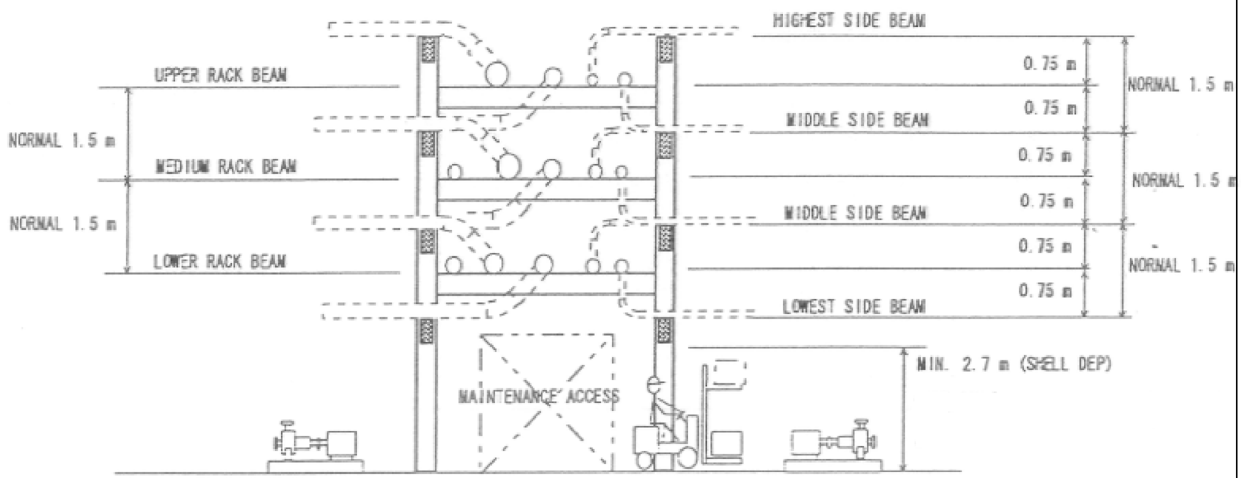
Equipment

- Provision of Equipment Supported Platform
- Any Structure for Guided Columns
- Vessels (excluding – columns and exchangers)

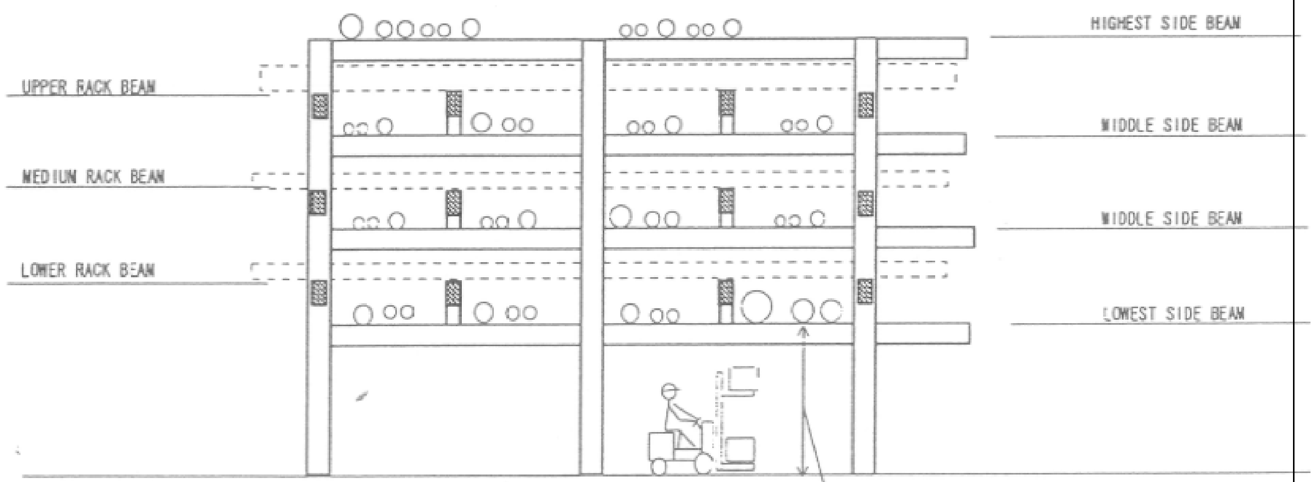
Space requirements for

- Mounting.
- Dismantling – whole / part.
- Related piping
- Access for person and vehicles.


SEPARATE
3M TYPICAL
40 - 50 m MAX
SEPARATE
3M TYPICAL
VERTICAL BRACE POSITION
40 - 50 m MAX.
VERTICAL BRACE POSITION
9m MAX
7 - 8 m ECONOMICAL
SEPARATE
3M TYPICAL
SEPARATE
3M TYPICAL
SEPARATE
3M TYPICAL
SUPPORT BEAM
40 - 50 m MAX.
9m MAX
7 - 8 m ECONOMICAL
SUPPORT BEAM
HORIZONTAL BRACE
10m MAX
VERTICAL BRACE INSTALLATION
ONE CENTER BRACE
FOR SMALL PIPE RACK CASE
TWO BRACES
FOR LARGE PIPE RACK CASE



SECTIONAL VIEW



SIDE VIEW

- **Pipe Routine on Pipe Racks**
  - Pipe are spaced on tire based on Pipe spacing chart
  - Future space in pipe rack tire shall be considered based on project specification.
  - General rule of arranging is that, a rack with heavier lines shall be near to the column & small bore lines should be in the center of pipe rack tire, wherever possible.
  - Also, if there is a reverse in direction of lines then it should be at a different height.
  - For example, if rack is in North-South direction, then all N-S pipe lines inside & outside of the pipe rack shall run at pipe rack tire elevation & all E-W lines shall run at side/longitudinal P/R beam elevation.

- Line Shall run on the Pipe Rack ,
    - If the distance between source & destination point is long enough.
    - Battery Limit Lines
    - If lines are Utility header.
- Expansion loop shall be minimized. The lines which are having expansion loop shall be grouped together with hottest & largest line outside.
- Adequate space shall be considered for pipe movement by thermal expansion, especially near expansion loops.
- Piping shall be designed to avoid drain & air pocket as practicable as possible.
- Cold lines & Hot lines shall be routed on opposite side of the pipe rack to simplify location expansion loops.

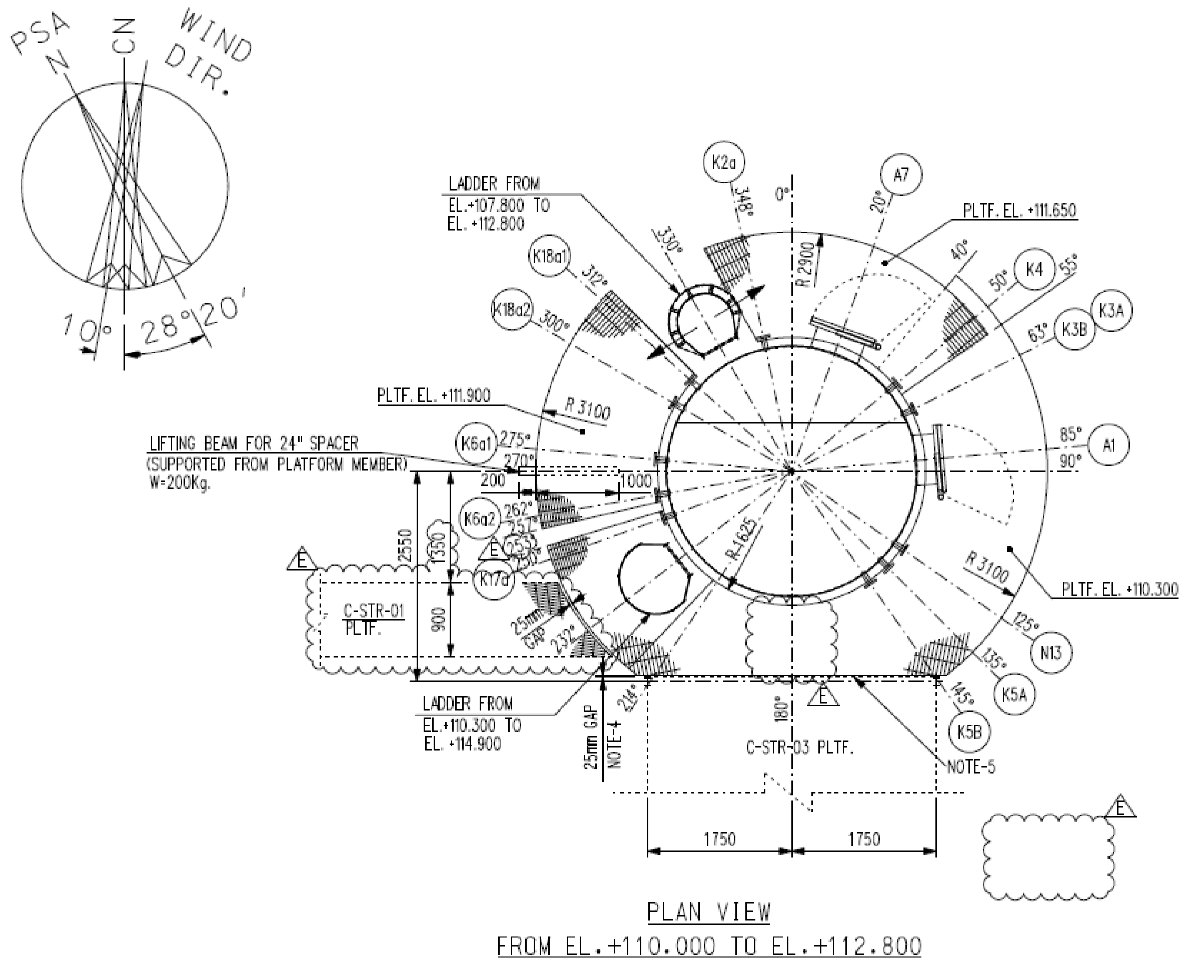
NOZZLE ORIENTATION

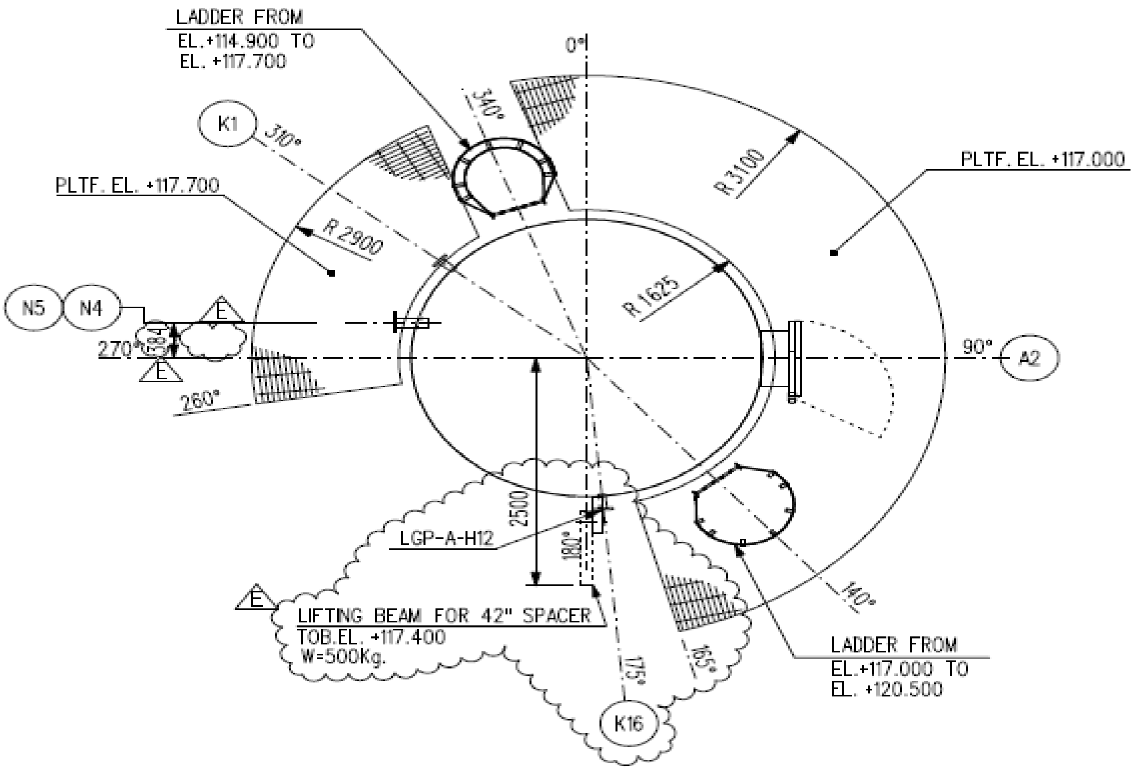
Types of Nozzle

- Process Nozzles - Feed / Withdrawal
- Manholes / Hand holes
- Re-boiler
- Reflux Nozzle.
- Instrumentation / Control - PG, TG, LG, etc.
- Utility Nozzles - Drain, Vent, Steam Flushing

Layout - Aspect

- Ideally Column and their related equipments are located on either side of central pipe rack server by an auxiliary road for maintenance.
- Columns are not stand alone operation. They are usually located within a process unit adjacent to its related equipments.
- Related equipments like: Pumps, Reboiler, Drum & AF Cooler or Condenser.

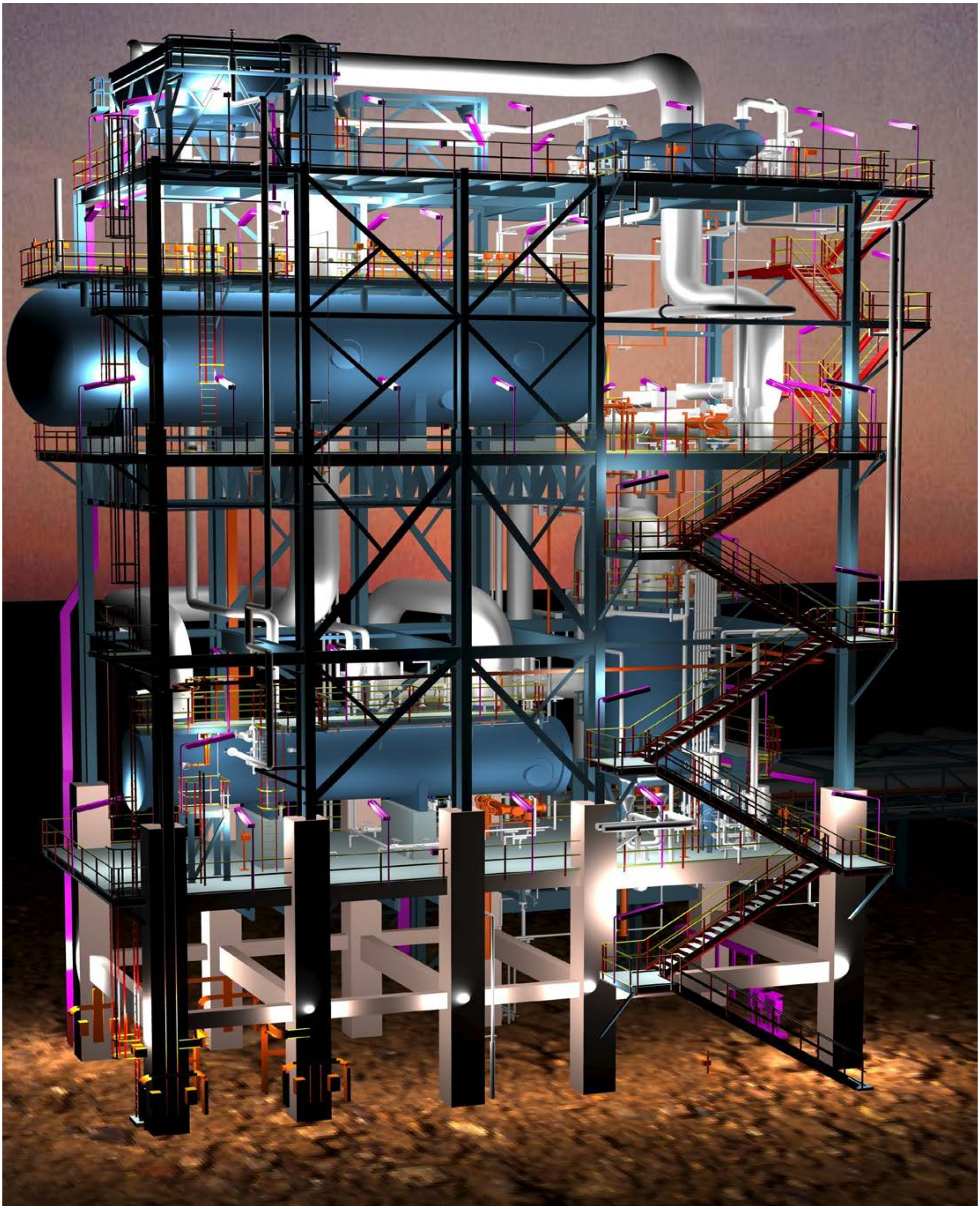

PSA N
CN
WIND DIR.
10°
28°20'
LADDER FROM EL.+107.800 TO EL. +112.800
PLTF. EL. +111.650
PLTF. EL. +111.900
LIFTING BEAM FOR 24" SPACER (SUPPORTED FROM PLATFORM MEMBER) W=200Kg.
PLTF. EL. +110.300
C-STR-01 PLTF.
LADDER FROM EL.+110.300 TO EL. +114.900
25mm GAP
NOTE-4
C-STR-03 PLTF.
NOTE-5
R 2900
R 3100
R 1625
1750
1750
PLAN VIEW
FROM EL.+110.000 TO EL.+112.800



PLAN VIEW
FROM EL.+116.500 TO EL.+120.000

Here Nozzle orientation diagram is shown for two different orientations.

Information like angle of different nozzle, platform area, ladder etc. at different elevations can be achieved from the nozzle orientation diagram.



The complete piping system modeled in the software