PIPE:

It is a Tubular item made of metal, plastic, glass etc. meant for conveying Liquid, Gas or any thing that flows.

It is a very important component for any industrial plant. And it’s engineering plays a major part in overall engineering of a Plant.
PIPING

• The term *Piping* means not only pipe but includes components like fittings, flanges, valves, bolts, gaskets, bellows etc.
Selection of Piping Materials

• **Materials selection** for achievement of metallurgical stability shall be made on the basis of design condition and to resist possible exposures against fire, corrosion, operating condition, service etc.

• The designer is confronted with the following concerns regarding the material of construction as he begins the design. These are:
  
a) Resistance to stress
b) Resistance to wear
   Design Life, Resistance to corrosion etc.
ENGINEERING MATERIALS

- (1) METALLIC  (2) NON-METALLIC
  (i) FERROUS  (i) ORGANIC
  (ii) NON-FERROUS  (ii) INORGANIC

(3) COMPOSITES

<table>
<thead>
<tr>
<th>FERROUS</th>
<th>NON-FERROUS</th>
<th>ORGANIC</th>
<th>INORGANIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Steel</td>
<td>Nickel</td>
<td>Plastics</td>
<td>Ceramics</td>
</tr>
<tr>
<td>Low Alloy Steels</td>
<td>Monel</td>
<td>Thermo-Plastics</td>
<td>Graphite</td>
</tr>
<tr>
<td>Stainless Steels</td>
<td>Brasses</td>
<td>Thermo-Setting</td>
<td>Glass</td>
</tr>
</tbody>
</table>
Most commonly used materials in refineries are

- **Carbon Steel**
  This is the most common and cheapest material used in process plants. Carbon steels are used in most general refinery applications. It is routinely used for most organic chemicals and neutral or basic aqueous solutions at moderate temperatures. Carbon steels are extensively used in temperature range of (-) 29 deg cent to 427 deg cent... Low Carbon steel (LTCS) can be used to a low temperature of (- 46) deg cent...

- **Alloy Steels**
  Low Alloy Steels contain one or more alloying elements to improve mechanical or corrosion resisting properties of carbon steel. Nickel increases toughness and improves low temperature properties & corrosion resistance. Chromium and silicon improve hardness, abrasion resistance, corrosion resistance and resistance to oxidation. Molybdenum provides strength at elevated temperatures. Some of the low alloy steels are listed below.
• **Stainless Steels**
  • They are heat & corrosion resistant, noncontaminating and easily fabricated into complex shapes. There are three groups of Stainless steels, viz, Martensitic, Ferritic & Austenitic.

• Various codes, symbols in piping design are:
  • ASME   - American society of mechanical engg.
  • API     - American petroleum institute.
  • ANSI    - American National Standards institute.
<table>
<thead>
<tr>
<th>ASTM NUMBER</th>
<th>TYPE</th>
<th>MATERIAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-53</td>
<td>Gr. A,B</td>
<td>CARBON STEEL</td>
</tr>
<tr>
<td>A-106</td>
<td>Gr. A,B</td>
<td>CARBON STEEL</td>
</tr>
<tr>
<td>A-333</td>
<td>Gr. 1</td>
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<tr>
<td>A-335</td>
<td>P1</td>
<td>CARBON MOLY</td>
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<td>A-335</td>
<td>P11</td>
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<tr>
<td>A-335</td>
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<tr>
<td>A-333</td>
<td>Gr. 3</td>
<td>NICKEL</td>
</tr>
</tbody>
</table>
PREPARATION OF STANDARD PMS/VMS

- PMS is a Bible for a Piping Engineer. It consists all about material details, dimension details, type of ends, schedules/thicknesses, branch offs, NDT requirements, various codes/standards being followed etc for all Piping items. Main Piping items detailed out in PMS are listed below:
  - Pipes
  - Fitting
  - Flanges
  - Misc items (Steam traps/Strainers) etc
  - Bolts
  - Gaskets
  - Valves
In any plant various fluids flow through pipes from one end to other. We have to transfer the content of Tank no. 1 to the other two tanks. We will need to connect pipes to transfer the fluids from Tank-1 to Tank-2 and Tank-3
To solve these problems we need the pipe components, which are called **PIPE FITTINGS**.
There are various types of fittings for various purposes, some common types are - Elbows/Bends, Tees/Branches, Reducers/Expanders, Couplings, Olets, etc.

Anyway, the pipes and fittings are in place, but the ends are yet to be joined with the Tank nozzles.

We now have to complete the end connections. These, in piping term, we call TERMINAL CONNECTIONS.
These are flanged joints

But if we want to control the flow from Tank-1 to other tanks.

We need some arrangement to stop the flow if needed.

This is a welded joint

To control the flow in a pipe line we need to fit a special component.

That is called - VALVE
FLANGES

• Flanges provide a bolted, separable joint in piping. The most of valves have flanged ends and must have a companion or matching flange attached. A gasket is then inserted between them, and the bolts are tightened to form a flanged joint.

When to use Flanges?
• Where there is a clear need for removal of valves or equipment, for access of maintenance, or for blinding.
• Because all flanged connections are potential leak source, their use should be kept to the minimum needed for safe and reasonably convenient operation and maintenance.
TYPES OF FLANGES

- **Weld Neck (WN):** The welding neck flanges are attached by butt-welding to the pipes.

- **Socket Weld (SW):** The socket weld flanges are welded only on one side and are not recommended for severe services. These are used for small-bore lines only.

- **Slip-on (SO):** The slips on flanges are attached by welding inside as well as outside.

- **Lap-Joint (LJ):** The lap joint flanges are used with the stub ends when piping is of a costly material.
1. SLIP ON FLANGE

LAP-JOINT FLANGE (with Stub-end)
MATERIAL:

• Flanges are made of carbon steel forging having a highly refined grain structure and generally excellent physical properties well in excess of recognized minimum requirements. In addition to this, flanges in 300 pound and higher pressure classes can be made of Chrome-Molybdenum Forged steel (ASTM A182 GRADE F5A).
BOLTS & GASKETS

• Choice of bolting material is governed by service fluid and its temperature.
• The most commonly used bolts for flanges in refinery piping are the ASTM A193 Gr.B7 Stud bolts which fall into the high strength group. The temperature range is from –29°C to 454°C.
• A gasket is a thin circular disc, made up of soft compressive material. The most of valves have flanged ends and must have a companion or matching flange attached. A gasket is then inserted between them, and the bolts are tightened to form a flanged joint.
There are many types of valves, categorized based on their construction and functionality. Those are - Gate, Globe, Check, etc.

Other than valves, another important line component of pipe line is a filter, which cleans out derbies from the flowing fluid. This is called a STRAINER.
VALVES

• Valves stop or open and regulate flow. Some of the basic valve types are gate, globe, check, Ball, Plug, etc.

• **GATE VALVE**: It is usually manually operated and is designed for open or shut operation. Flow can enter either end of the gate body.

• **GLOBE VALVE**: is for throttling. Good examples of globe valves are the faucets on washbasin which throttle or adjust the flow to suit a person’s needs. Flow must enter the valve and flow up, against the seat, and change the direction again to the outlet.

• **CHECK VALVE**: “checks” flow. It lets flow go one way and will not let it reverse. When you have a check valve in a line, you have made a one-way street. The flow can go one way.
When some fluid is flowing in a pipe we may also like know the parameters like, pressure, temperature, flow rate etc. of the fluid.
Here are some of the pipe supporting arrangements. There can be numerous variants. All depend on piping designer’s preference and judgement.
Pipe Systems

• All piping systems need to have support.
  – The can be from the top, sides or underneath piping system.
  – The will be installed is such a way as to allow for support of the piping in the system, plus the weight of the fluid contained within.
  – Must allow for expansion of the system piping
  – Types of supports:
    • Spring
    • Solid clamp
    • Roller
Valves

• Purpose: to control system fluid flow for
  – Maintenance
  – Operation
  – Casualty Control

• Proper procedure for opening
  – Open fully then back off ¼ turn.
    • Valve won’t jam
    • The next person won’t try to open it further
Valves

• Major components
  – Disk attached to stem.
    • Disk seats against a seating surface in the body
  – Seat-
    • The seat and disc of valves used for high temperature service are often surfaced with a hardened material
  – Valve Body-
  – Bonnet
  – Stuffing Box
  – Packing gland or packing nut
  – Valve wheel (Hand wheel)
Types of valves - Globe

- Disc attached to stem
- Disc seats against a seating surface
- May be fully open & closed, or partially open
- Good for throttling.
- Large pressure drops across globe valves, especially when throttling.
- Should be installed so that the flow comes from under the seat.
  - System pressure will assist in opening the valve
  - If the packing needs attention, there will be no system pressure in the bonnet of the valve.
Gate Valve

- Flat (parallel) or tapered gate interposed perpendicular to axis of flow.
- Allows for straight through flow with little restriction or pressure drop.
- Not practical for throttling applications (the disc will vibration & chatter)
- Operate fully open or closed.
- Come in a wide variety of sizes and types
  - Rising Stem
  - Non Rising Stem
Needle Point Valves

- For fine adjustment of flow.
  - Tapered point at the inside end of the valve stem.
  - Used for throttling, especially when small quantities of gas or liquid are to be flowing.
Butterfly

- Lightweight, less space required than a gate or globe.
- Quick acting (requires only ¼ turn.)
- Can be used to throttle.
- Low pressure application
- Smaller place.
Check Valves

- Some are automatically operated with no hand wheels or stems and some have the capability of being shut off.
- Used to prevent return or back flow
- Several Types
  - Lift Check
  - Swing Check
  - Ball
  - Stop Check Valves (can be positively shut off)
Ball valves

- Quick opening (1/4 Turn)
- Excellent for full flow applications
- Can also be used for throttling
- The fluid flow acting on the partially exposed ball can cause erosion.
- High pressure

• **plug valve**

1. Handle
2. Stem
3. Handle nut
4. Lockwasher
5. O-ring packing
6. O-ring cap gasket
7. Seat
8. Ball
9. Cap
10. Cap bolt
11. Body
• Prevents the passage of grit, scale, marine life, and other foreign matter that could obstruct pump suction valves, throttle valves etc

• Baskets can be removed for easy cleaning.
  – Simplex — only one basket, flow must be stopped to clean
  – Duplex — two baskets — flow may be diverted to allow cleaning of off-line strainer
  – Y-Strainers
Steam Traps

• **Steam traps are used in systems to**
  – Drain condensate from heat exchangers
    • They hold steam in heat exchangers until it has completely collapsed to condensate.
      – Allows latent heat available in steam to be exchanged
    – They are used in low points of steam piping systems help avoid water hammer

• **Three main functions of steam traps are**
  – **Allow condensate** which was steam to collect and flow back to the condensate system.
  – **Vent air** and other gases
  – **Prevent the escape of steam**- loss of available latent heat.
Steam Traps and Pipes

• A steam trap is an **automatic valve**
  – it senses the difference between steam and condensate.

• The trap **discharges the condensate**
  – with little or no loss of steam,
  – which contributes to high operating efficiency.

• Steam traps are divided into **three main groups**:
  – **thermostatic**
  – **mechanical**
Thermostatic Traps

• It measure temperature

• The balanced-pressure thermostatic trap has a liquid-filled bellows that expands and contracts.
  
  – When steam is in contact with the bellows
    • causes the bellows to expand
    • closes the valve

  – If condensate or air is in contact with the bellows,
    • bellows contracts and condensate is discharged

• Steam pressure does not affect the operation of this trap,
Thermostatic Traps

- **The bimetallic trap** also works according to the thermostatic principle.
  - Two strips of suitably **different metal bonded together**
  - The top strip expands more than the bottom one when heated
  - allowing cool air and condensate to pass through

- **As steam enters the traps and heats up the bimetallic strip, the strip bends and closes off the valve.**
Thermostatic Traps

- The liquid expansion thermostatic trap is operated by the expansion and contraction of a liquid-filled thermostat
  - When the steam is turned on, air and condensate pass through the open trap.
  - As the condensate temperature increases, the oil in the thermostatic element expands and closes off the valve.
- An adjusting nut positions the valve relative to its seat, which allows the trap to be set at a given temperature, usually 212°F, or lower.
- Some liquid expansion traps are used for freeze protection. When the temperature drops to 40°F, the trap opens, creating enough flow to prevent freeze-up.
Mechanical Traps

• Mechanical traps distinguish between steam and condensate by their different densities.

• Various floats are used to operate the discharge valve.
  – a ball floats on the surface of the condensate
  – as the condensate level drops, • ball covers the discharge passage • prevents the loss of steam

• Air must be removed for the trap
  – can be vented automatically from the...
• Figure shows a float-and-thermostatic trap
  – Float rises when condensate enters, opening the valve
  – The valve closes if there is no condensate in the trap
  – If there is a temperature drop caused by air, the valve opens.
  – Element expands and closes when steam enters the trap.
Mechanical Traps

- **The inverted bucket trap**
- **When system condensate enters**
  - bucket is at the bottom and **valve open**
  - Air vented through a small hole on top of the inverted bucket
  - water level rises on both the inside and outside of the bucket
- **As steam fills the inverted bucket and makes it float, close valve.**
  - Steam slowly escapes out of the bucket through the vent hole.
- **If the escaping steam is replaced by condensate,**
  - bucket sinks
  - opens the valve
Thermodynamic Traps

• Or disk traps,
  – identify steam and condensate by the difference in their kinetic energy or velocity as they flow through the trap

• Low pressure flash steam
  – pushing down on the large surface on top of the disk
  – overcomes the force of the live steam pushing up in the smaller, exposed disk area.
THERMODYNAMIC TRAPS

(i) Peripheral outlets

(ii) Disc
Inlet

(iii) Control chamber

(iv) Flat sealing face
Thermodynamic Traps

• After startup, cool condensate lift the disk off its seat

• As the temperature of the condensate increases,
  – Some of it flashes into steam
  – The mixture of steam and condensate flows outward across the underside of the disk.
  – Because flash steam has a larger volume
    • the flow increases as more flash steam is formed
    • high velocity causes a low-pressure area
      – to be formed under the disk and
  – the expanding flash steam exerts pressure on top of the disk,
    • forcing the disk downward and stopping all flow
Thermodynamic Traps

– although the flash steam pressure is much lower
– but the large exposed area

• As the flash steam above loses heat, some of it condenses, reducing the pressure above the disk.

• The disk is again lifted off its seat, and the cycle repeats itself.
PIPING FLEXIBILITY

All piping must be designed for thermal expansion under start up, operating and shut down conditions without over stressing the piping, valves or equipments. Adequate flexibility for the steam out conditions at temp of 120deg.c provisions for expansion or contraction shall normally be made with bends, off-sets.

**DESIGN CONDITIONS:**

- Operating conditions: - normal design conditions of pressure & temperature are expected to co-exist. These usual operations include all manipulations & control functions such as throttling, blowing, and bypassing.
- Temporary conditions: - these do not include more severe temporary conditions such as those incidentals to start up, steam out or abnormal.
PIPING LAYOUT

• Detailed equipment layout including key plan.
• Preparation of piping studies.
• Fixing the orientation.
• Piping supports.
• Line isometric & vessel trims.
• Model preparation & field engg.

**BASIS OF EQUIPMENT LAYOUT:**
• Equipment layout shall be developed based on the following data:
  • P&IDs (Piping & instrumentation diagram)
  • Overall plot plan
  • Wind direction
  • Equipment data sheets
  • Indicative equipment layout from process licensor.
Pipe sizes are selected, pipe material and pipe wall thickness are selected.

Types of Valves are planned

Also the types of instruments required are planned

We represent the whole thing in a drawing which is called Piping and Instrumentation Drawing, in short P&ID. For P&ID generation we use SPP&ID software.

All the pipe lines system information in the drawing has to enter for P&ID.

So the SPP&ID drawing is an Intelligent drawing which under it’s surface carries all the information about a pipe like, Pipe size, Flowing Fluid, etc.
This is a screen picture of a P&ID made by SPP&ID. If we click on any line, it will show the data embedded.
INSULATION

Insulation of piping & fitting is required for the following purpose:

• Heat conservation.
• Process stabilization to assist process control.
• Steam tracing.
• Steam jacketing.
• Fire hazard protection to prevent fast boil-off of liquid.
MATERIALS USED FOR INSULATION:

HOT INSULATION
- High quality & good appearance.
- Low chloride content.
- Chemically inert.
- Impervious to hot water & steam.
- Non corrosive to steel & aluminum.

COLD INSULATION
- All materials used for insulation, fixing, sealing, etc. shall be used as under:
  - Operating temp range                          Insulation material
    - -195 to +85 deg.c                             PUF or Polystyrene
    - -195 to +120 deg.c                           PUF
    - -30 to +120 deg.c                            PUF or polystyrene
- Other requirements for insulating materials remain same as for hot insulation.
Pipe Stress Analysis

- We need to check and confirm the pipe is not going to fail with these loading.
- This process of checking the stress developed in the piping due to various loading is called **Pipe Stress Analysis/Flexibility analysis**.

- In the process of Analysis we apply various postulated loading on the pipe and find out the stress resulted from these loading.
- Then we check with governing codes if those stresses generated are acceptable or not.

- We check support load & movement for various loading condition.
- We also check out the terminal point loading generated from pipe to the equipment connected to the pipe. This loading are to be within acceptable limits of the equipment suggested by the vendors.
- We also find out the pipe growth due to change in temperature and need to keep the movement of pipe within acceptable limits.

- **Pipe Stress Analysis is an Interactive and Iterative process.** Each step is checked

- If a check fails we have to go back, modify the layout and restart the analysis.
PIPE STRESS ANALYSIS

Inputs
- Geometric layout of Pipe
- Pipe supporting configuration
- Pipe Diameter and Thickness
- Pressure inside Pipe
- Cold and Hot temperatures of Pipe
- Weight of Pipe and insulation
- Weight of carrying Fluid
- Pipe material Property (Young’s Modulus, Thermal Expansion Coefficient)

Tools we use
- PIPSYS - is an integrated pipe stress analysis module of PLADES 2000
- CEASER - Commercial Piping analysis software

Outputs
- Stress of the pipe at various loading conditions
- Load at various supports and restrains.
- Movement of pipe at support locations
- Pipe terminal point loading.

Codes and Standards
- In general Power Plant Piping have to comply stipulations of ASME ANSI B31.1
Pipe Routing

- The following figures show a layout (looking from the top) and plan (looking from the side) view of vessels.
- We want to rout pipe from the feed tank to the reactor.
Pipe Routing Exercise

• Form groups of two.
• Draw a three dimensional routing for pipe from the steam header to the feed tank on both the plan view and the layout view.
Size the Pump

1. Determine optimum pipe size.

2. Determine pressure drop through pipe run.

Diagram:
- 200 ft pipe run
- Globe valve
- 150 ft pipe run
- Check valve
- 100 gpm flow
Optimum Pipe Diameter

The optimum pipe diameter gives the least total cost for annual pumping power and fixed costs. As $D$ increases, fixed costs increase, but pumping power costs decrease.
Optimum Pipe Diameter

Total Cost

Annualized Capital Cost

Pumping Power Cost

Optimum
Example

Two methods to determine the optimum diameter:
Velocity guidelines and Nomograph.

Example: What is the optimum pipe diameter for 100 gpm water.
sizing steel pipelines

Turbulent flow

<table>
<thead>
<tr>
<th>Type of fluid</th>
<th>Reasonable velocity, ft/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water or fluid similar to water</td>
<td>3–10</td>
</tr>
<tr>
<td>Low-pressure steam (25 psig)</td>
<td>50–100</td>
</tr>
<tr>
<td>High-pressure steam (100 psig and up)</td>
<td>100–200</td>
</tr>
<tr>
<td>Air at ordinary pressures (25–50 psig)</td>
<td>50–100</td>
</tr>
</tbody>
</table>

The preceding values apply for motor drives. Multiply indicated velocities by 0.6 to give reasonable velocities when steam turbine drives are used.

Viscous flow (liquids)

<table>
<thead>
<tr>
<th>Nominal pipe diameter, in.</th>
<th>$\mu_e = 50$</th>
<th>$\mu_e = 100$</th>
<th>$\mu_e = 1000$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.5–3</td>
<td>1–2</td>
<td>0.3–0.6</td>
</tr>
<tr>
<td>2</td>
<td>2.5–3.5</td>
<td>1.5–2.5</td>
<td>0.5–0.8</td>
</tr>
<tr>
<td>4</td>
<td>3.5–5.0</td>
<td>2.5–3.5</td>
<td>0.8–1.2</td>
</tr>
<tr>
<td>8</td>
<td>4.0–5.0</td>
<td></td>
<td>1.3–1.8</td>
</tr>
</tbody>
</table>

† $\mu_e = $ viscosity, centipoises.
Using Velocity Guidelines

- Velocity = 3-10 ft/s = flow rate/area
- Given a flow rate (100 gpm), solve for area.
- Area = $(\pi/4)D^2$, solve for optimum D.

- Optimum pipe diameter = 2.6-3.6 in.
  Select standard size, nominal 3 in. pipe.
Nomograph
- Convert gpm to cfm \( \Rightarrow 13.4 \text{ cfm.} \)
- Find cfm on left axis.
- Find density (62 lb/ft\(^3\)) on right axis.
- Draw a line between points.
- Read optimum diameter from middle axis.

Figure 13-2: Nomograph for estimation of optimum economic pipe diameters with turbulent or viscous flow based on Eqs. (15) and (16).
Practice Problem

• Find the optimum pipe diameter for 100 ft$^3$ of air at 40 psig/min.

• $A = \frac{s}{50\text{ft}}\left(\frac{\text{min}}{60\text{ s}}\right)(100 \text{ ft}^3/\text{min}) = 0.033 \text{ ft}^2$

• $0.033 \text{ ft}^2 = 3.14d^2/4$

• $d = 2.47 \text{ in}$