Process Piping Fundamentals, Codes and Standards

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Process Piping Fundamentals, Codes and Standards

One of the most important components of the process infrastructure is the vast network of pipelines —literally millions and millions of miles. The term process piping generally refers to the system of pipes that transport fluids (e.g. fuels, chemicals, industrial gases, etc.) around an industrial facility involved in the manufacture of products or in the generation of power. It also is used to describe utility piping systems (e.g., air, steam, water, compressed air, fuels etc.) that are used in, or in support of the industrial process. Also, certain drainage piping, where corrosive or toxic fluids are being transported and severe conditions may be present, or where it is simply outside the scope of plumbing codes, is also sometimes classified as process piping. Some places where process piping is used are obvious, such as chemical and petrochemical plants, petroleum refineries, pharmaceutical manufacturing facilities, and pulp and paper plants. However, there are many other not so obvious places where process piping is commonplace, such as semiconductor facilities, automotive and aircraft plants, water treatment operations, waste treatment facilities and many others.

This course provides fundamental knowledge in the design of process piping. It covers the guidance on the applicable codes and materials.

This course is the 1st of a 9-module series that cover the entire gamut of piping engineering. All topics are introduced to readers with no or limited background on the subject.

This course is divided in Three (3) chapters:

CHAPTER -1: THE BASICS OF PIPING SYSTEM

This chapter covers the introduction to the pipe sizes, pipe schedules, dimensional tolerances, pressure ratings, frequently used materials, criterial for material selection, associations involved in generating piping codes, design factors depending on fluid type, pressure, temperature and corrosion, roles and responsibilities of piping discipline, key piping deliverables and cost of piping system.

CHAPTER – 2: DEFINITIONS, TERMINOLOGY AND ESSENTIAL VOCABULARY

This chapter provides essential definitions and terminology, each piping engineer and designer should familiar with. This is based on the Author's experience on the use of vocabulary in most design engineering, procurement and construction (EPC) companies.

CHAPTER – 3: DESIGN CODES AND STANDARDS

This chapter discusses the associations involved in generating piping codes and material specifications. It provides description of various ASME pressure piping codes such as B31.1 Power Piping, B31.3 Process Piping, B31.4 Pipeline Transportation Systems for Liquid Hydrocarbons, B31.5 Refrigeration Piping and Heat Transfer Components, B31.8 Gas Transmission and Distribution Piping Systems, B31.9 Building Services Piping and B31.11 Slurry Transportation Piping Systems. It also provides information on the associations involved in material specifications such as API - American Petroleum Institute Standards, ASTM – American Society of Testing Materials, ASME Piping Components Standards, American Welding Society (AWS), American Water Works Association (AWWA) and EN – European Standards.

CHAPTER - 1

1. THE BASICS OF PIPING SYSTEM

A piping system is an assembly of pipe, fittings, valves, and specialty components. All piping systems are engineered to transport a fluid or gas safely and reliably from one piece of equipment to another.

Piping is divided into two main categories:

- Small bore lines
- Large bore lines

As a general practice, those pipe lines with nominal diameters 2" (50mm) and under are classified as small bore and greater than 2" (50mm) NB as large bore.

This course is designed to introduce you to the basic concepts of piping engineering, which is all about designing, fabricating and constructing lines for conveying fluids.

1.1. ABBREVIATIONS

NPS	Nominal Pipe Size
DN	Diamètre Nominal
ID	Inside Diameter
OD	Outside Diameter
SCH	Schedule (Wall Thickness)
STD	Standard Weight Wall Thickness
XS	Extra Strong Wall Thickness
XXS	Double Extra Strong Wall Thickness

1.2. PIPE SIZES

Pipe sizes are designated by two numbers: Diameter and Thickness.

In the US, pipe size is designated by two non-dimensional numbers: Nominal Pipe Size (NPS) and schedule (SCH). Let's check some key relationships:

- Nominal pipe size (NPS) is used to describe a pipe by name only. Nominal pipe size (NPS) is generally associated with the inside diameter (ID) for sizes 1/8" to 12". For sizes 14" and beyond, the NPS is equal to the outside diameter (OD) in inches.

- Outside diameter (OD) and inside diameter (ID), as their names imply, refer to pipe by their actual outside and inside measurements. Outside diameter (OD) remains same for a given size irrespective of pipe thickness.
- Schedule refers to the pipe wall thickness. As the schedule number increases, the wall thickness increases, and the inside diameter (ID) is reduced.
- Nominal Bore (NB) along with schedule (wall thickness) is used in British standards classification.

Important

In process piping, the method of sizing pipe maintains a uniform outside diameter while varying the inside diameter. This method achieves the desired strength necessary for pipe to perform its intended function while operating under various temperatures and pressures. It is also important to maintain certain interchangeability of pipe fittings.

1.2.1. The European designation

The European designation equivalent to NPS is DN (Diamètre Nominal/nominal diameter). The pipe sizes are measured in millimetres.

Relationship - NPS and DN pipe sizes

NPS	½	3/4	1	1¼	1½	2	2½	3	3½	4
DN	15	20	25	32	40	50	65	80	90	100

Note - For NPS of 4 and larger, the DN is equal to the NPS multiplied by 25 (not 25.4).

1.3. PIPE SCHEDULES (SCH)

The Schedule of pipe refers to the wall thickness of pipe in the American system.

Eleven schedule numbers are available for Carbon Steel Pipes:

5, 10, 20, 30, 40, 60, 80, 100, 120, 140, & 160

The most popular schedule, by far, is 40.

Schedules 5, 60, 100, 120, & 140 have rarely been used.

Thickness of the pipe increases with the schedule number.

This means that:

- Schedule 80 steel pipes will be heavier and stronger than schedule 40 pipe.
- Schedule 80 pipe will provide greater factor of safety allowing it to handle much higher design pressures.
- Schedule 80 pipe will use more material and therefore costlier to make and install.

Stainless steel piping schedules generally match with Carbon Steel piping schedules, but are always identified with Suffix S from 1/8" to 12". Schedule 40S and 80S are the same as their corresponding schedule 40 and 80 in all sizes except 12" in schedule 40.

1.3.1. How to calculate Schedule?

A simple rule of thumb expression is:

Schedule Number = (1,000) (P/S)

Where,

- P = the internal working pressure, psig
- S = the allowable stress (psi) for the material of construction at the conditions of use.

<u>Example</u>

Calculate allowable internal pressure P for Schedule 40 mild steel pipe having ultimate tensile strength (S value) of 65,300 psi.

Rearrange the schedule equation:

P = SCH x S/1,000

Therefore, P = 40 x 65,300/1,000 = 2,612 psi.

This is reasonable, based on a current-day published value of 2,849-psi for 1-inch Schedule 40 steel pipe.

1.4. INTERNAL DIAMETER (ID) OF PIPE

For process engineers, the most important parameter for hydraulic sizing is the pipe Internal Diameter (ID).

The ID can then easily be calculated as:

ID = OD - 2t

Example

A 4 inches Schedule 40 pipe has an outside diameter of 4.500 inches, a wall thickness of 0.237 inches.

Therefore, Pipe ID = 4.5 inches – 2 x 0.237 inches = 4.026 inches

A 4 inches Schedule 80 pipe has an outside diameter of 4.500 inches, a wall thickness of 0.337 inches.

Therefore, Pipe ID = 4.5 inches – 2 x 0.337 inches = 3.826 inches

1.5. PIPING DIMENSIONAL STANDARDS

Pipe sizes are documented by a number of standards, including API 5L, **ANSI/ASME B36.10M** in the US, and BS 1600 and BS 1387 in the United Kingdom.

Typically, the pipe wall thickness is the controlled variable, and the Inside Diameter (I.D.) is allowed to vary. The pipe wall thickness has a variance of approximately 12.5 percent.

Standard Carbon Steel Welded and Seamless Pipe Sizes

ANSI/ASME B36.10

Nominal Pipe Size (NPS)	Pipe Schedule	Outside Diameter	Inside Diameter	Wall Thickness
0.75″	40	1.05″	0.824″	0.113″
0.75″	80	1.05″	0.742″	0.154″
0.75″	160	1.05″	0.612″	0.219″
1″	40	1.315″	1.049″	0.133″
1″	80	1.315″	0.957″	0.179″
1″	160	1.315″	0.815″	0.25″
1.25”	40	1.66″	1.38″	0.14″
1.25″	80	1.66″	1.278″	0.191″
1.25″	160	1.66″	1.16″	0.25″
1.5″	40	1.9″	1.61″	0.145″
1.5″	80	1.9″	1.5″	0.2″
1.5″	160	1.9″	1.338″	0.281″
2″	40	2.37″5	2.067″	0.154″
2″	80	2.37″5	1.939″	0.218″
2″	160	2.37″5	1.687″	0.344″
2.5″	40	2.87″5	2.469″	0.203″
2.5″	80	2.87″5	2.323″	0.276″
2.5″	160	2.87″5	2.125″	0.375″

Nominal Pipe Size (NPS)	Pipe Schedule	Outside Diameter	Inside Diameter	Wall Thickness
3″	40	3.5″	3.068″	0.216″
3″	80	3.5″	2.9″	0.3″
3″	160	3.5″	2.804″	0.438″
4″	40	4.5″	4.026″	0.237″
4″	80	4.5″	3.826″	0.337″
4″	160	4.5″	3.438″	0.531″
5″	40	5.563″	5.047″	0.258″
5″	80	5.563″	4.813″	0.375″
5″	160	5.563″	4.313″	0.625″
6″	40	6.625″	6.065″	0.28″
6″	80	6.625″	5.761″	0.432″
6″	160	6.625″	5.187″	0.719″
8″	40	8.625″	7.981″	0.322″
8″	80	8.625″	7.625″	0.5″
8″	160	8.625″	6.813″	0.906″
10″	40	10.75″	10.02″	0.365″
10″	80	10.75″	9.562″	0.594″
10″	160	10.75″	8.5″	1.125″
12″	40	12.75″	11.938″	0.406″
12″	80	12.75″	11.374″	0.688″
12″	160	12.75″	10.126″	1.312″

1.6. DIMENSIONAL TOLERANCES

The dimensional tolerances for pipes are provided by **ASTM A530** standard that permits following variations in pipe size, pipe lengths and the weight.

Nominal pipe size

- Up to 4" = ± 0.79 mm
- 5 thru 8" = + 1.58 mm / - 0.79 mm
- 10 thru 18" = + 2.37 mm / - 0.79 mm
- 20 thru 24" = + 3.18 mm / - 0.79 mm

Wall Thickness

Most piping standards allow pipe manufacturers a fabrication mill tolerance of 12.5% on the wall thickness.

- All Diameters = - 12.5% (+ tolerance not specified)

- Length = + 6.40 mm / - 0 mm
- Weight = + 10% / - 1.5%

1.7. PRESSURE RATINGS

The pressure rating of the pipe is associated to the maximum allowable working pressure. It is the ability of the pipe material to resist the internal pressure and pressure surges. It is defined by pipe schedule or thickness.

Minimum wall thickness of pipe is calculated by ASME B31.3 code (hoop stress) formula:

$$t = \frac{PD}{2(SE+PY)} + A$$

$$t_m = t + A$$

Where,

- t = required wall thickness, inches
- tm = minimum required wall thickness, inches
- P = Design pressure, psi
- D = Pipe outside diameter, inches.
- A = Corrosion allowance, inches
- S = Allowable Stress @ Design Temperature, psi (From ASME B31.3, Table A-1)
- E = Longitudinal-joint quality factor (From ASME B31.3, Table A-1B)
- Y = Wall thickness correction factor (From ASME B31.3, Table 304.1.1)

<u>Example</u>

Calculate the pipe wall thickness for following design conditions:

- Design Pressure (P) = 3000 psig
- Design Temp (T) = 85°C = 185 °F
- Diameter of Pipe (D) = 12”
- Material = API 5L Gr B Seamless
- Tensile Stress = 60Ksi = 60000Psi

- Yield Stress = 35Ksi = 35000Psi
- Allowable Stress @ Design Temperature (S) = 20000 Psi
- Corrosion Allowance (A) = 3mm = 0.1181099 inch
- Mill Tolerance = 12.5 %
- Longitudinal weld joints (E) = 1.0 for Seamless pipe.
- Values of Co-efficient (Y) = 0.4 (Below 900 °F)

Design Formula:

$$t = \frac{PD}{2(SE + PY)} + A$$

t = (3000 x 12) / 2 [(20000 x 1) + (3000 x 0.4)]

= 36000 / 42400

t = 0.849056 inch

t_m = t + A

= 0.849056 + 0.1181099

= 0.96716 inch

Most piping specifications allow the manufacturer a (-) 12.5% dimensional tolerance on the wall thickness; the minimum wall thickness can be as low as 87.5% (1 – Mill Tolerance) of the nominal value. Therefore, in selecting the pipe schedule, tm should be divided by 0.875 to get nominal thickness.

t_{nom}. = 0.96716 / 0.875

= 1.1053 inch

$t_{nom.}$ = 28.07462 mm (As per Design)

Therefore, Minimum Thickness Required = Sch 140 (28.58 mm)

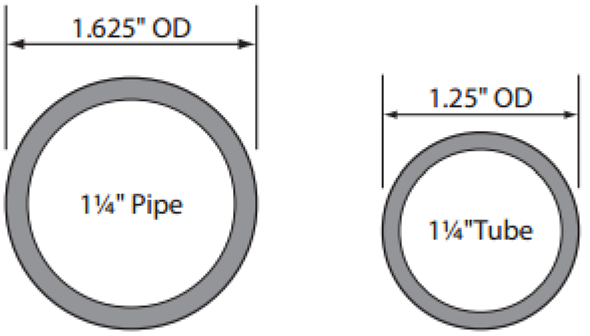
1.7.1. Pressure – Temperature Relationship

Among other parameters, the pressure rating of the pipe is also influenced by the temperature of the fluid. The hotter the fluid, the lower the pressure it can hold and therefore higher should be the pressure rating. Table below provides pressure ratings of Carbon Steel. Ratings are given for standard seamless pipe sizes at temperatures from 100°F to 750°F. All ratings are in psig and are based on ANSI/ASME B 31. 1.

1.8. DIFFERENCE BETWEEN PIPE AND TUBE

Tubing is supplied in sizes up to four inches in diameter but has a wall thickness less than that of either large bore or small bore piping. The essential difference between pipe and tube is that pipe is specified by nominal bore and schedule. Tube is specified by the outside diameter (OD) and a wall thickness.

For example: The actual outside diameter of 1¼" pipe is 1.625" – while 1¼" tube has a true 1.25" outside diameter



1.9. FREQUENTLY USED PIPE MATERIALS

1.9.1. Carbon Steel

The vast majority of piping is made of Carbon Steel.

Carbon steel contains only a tiny amount of carbon; sometimes much less than 1% and is classified as:

- Mild Steels - up to 0.3% Carbon
- Medium Carbon Steels (or simply Carbon Steels) - 0.3 to 0.6 % carbon
- High Carbon Steels - over 0.6% Carbon

The carbon %age influences the mechanical characteristics of the material.

- Material containing carbon more than 0.35 becomes brittle.
- Material containing carbon more than 0.43 are **NOT** weldable

Low carbon steel is the most common industrial piping material. The material specifications are governed by ASTM A53 and ASTM A106 standards which defines three Grades A, B and C. The grades refer to the tensile strength of the steel, with Grade C having the highest strength. Grade B permits higher carbon and manganese contents than Grade A. A106 is preferable for more stringent high temperature and high pressure services.

1.9.2. Alloy Steel

- Nickel Steels - These steels contain from 3.5% nickel to 5% nickel. The nickel increases the toughness and improves low temperature properties (up to -150°F/-100°C). Nickel steel containing more than 5% nickel has an increased resistance to corrosion and scale.
- Molybdenum - Molybdenum provides strength at elevated temperatures. It is often used in combination with chromium and nickel. The molybdenum adds toughness to the steel and can be used in place of tungsten to make the cheaper grades of high-speed steel for use in high-pressure tubing. An addition of about 0.5% Molybdenum greatly improves the strength of steel up to 900°F/480°C. Moly is often alloyed to resist corrosion of chlorides (like sea water).
- Chromium Steels - Chromium and silicon improve hardness, abrasion resistance and corrosion resistance. An addition of up to 9% Chromium combats the tendency to oxidize at high temperatures and resists corrosion from sulfur compounds. Stainless Steels contain at least 10.5% Chromium.
- Chrome Vanadium Steel - This steel has the maximum amount of strength with the least amount of weight. Steels of this type contain from 0.15% to 0.25% vanadium, 0.6% to 1.5% chromium, and 0.1% to 0.6% carbon.
- Tungsten Steel - This is a special alloy that has a characteristic property of red hardness. It has the ability to continue to cut after it becomes red-hot. A good grade of this steel contains from 13% to 19% tungsten, 1% to 2% vanadium, 3% to 5% chromium, and 0.6% to 0.8% carbon.
- Manganese Steels - Small amounts of manganese produce strong, free-machining steels. Larger amounts (between 2% and 10%) produce somewhat brittle steel, while still larger amounts (11% to 14%) produce steel that is tough and very resistant to wear after proper heat treatment.

1.9.3. Stainless Steel

Stainless steel pipe and tubing are used for a variety of reasons: to resist corrosion and oxidation, to resist high temperatures, for cleanliness and low maintenance costs, and to maintain the purity of materials which come in contact with stainless.

The ability of stainless steel to resist corrosion is achieved by the addition of a minimum of 12% chromium to the iron alloy. Nickel, molybdenum, titanium and other elements are often alloyed along in varying quantities to produce a wide range of Stainless Steel grades, each with its unique properties.

Stainless steel is classified by the American Iron and Steel Institute (AISI) into two general series named the 200-300 series and 400 series.

1.9.4. Austenitic Steel

The 200-300 series of stainless steel is known as Austenitic. There are eighteen different grades of Austenitic steel, of which type SS 304 is the most widely used.

Grade SS304 contains 18% chromium and 8% nickel. It has a maximum carbon content of .08%.

It is not recommended for use in the temperature range between 400°C and 900°C due to carbide precipitation at the grain boundaries which can result in inter-granular corrosion and early failure under certain conditions.

Type 304L. Is the same as 304 except that a 0.03% maximum carbon content is maintained which precludes carbon precipitation and permits the use of this analysis in welded assemblies under more severe corrosive conditions.

Grade SS316 contains 16% chromium, 10% nickel and 2% molybdenum. It has high resistance to chemical and salt water corrosion.

Stainless steel pipe is manufactured in accordance with ASTM A312 when 8" or smaller sizes are needed.

Large sizes (8" and up) of stainless steel pipe are covered by ASTM A358.

Extra light wall thickness (schedule 5S) and light wall thickness (schedule 10S) stainless steel pipes are covered by ASTM A409.

400 Series Stainless Steel

The 400 series of steel is subdivided into two main groups: Ferritic and Martensitic.

1.9.5. Ferritic Steel

These are plain chromium stainless steels with chromium content between 12 and 18% but with low carbon content in ranges of 0.08% to 0.20%. They offer moderate corrosion resistance, not hardenable by heat treatment.

- They are magnetic.
- Weldability and formability are poor.

- They are frequently used for a decorative trim with the equipment being subjected to high pressures and temperatures.
- The typical grade is 430.

1.9.6. Martensitic Steel

Martensitic SS exhibit relatively high carbon content (0.1-1.2%) with 12 to 18% chromium. They were the original commercial SS.

- They are magnetic.
- They offer moderate corrosion resistance and can be heat treated.
- They have high strength but weldability is bad.
- The typical grade is 410.

1.9.7. Duplex Stainless Steel

Duplex Stainless Steel has high chromium content (between 18 and 28%) and a reasonable amount of nickel (between 4.5 and 8%). These steels exhibit a combination of ferritic and austenitic structure and hence called duplex. Some duplex steels contain molybdenum from 2.5-4%.

- They offer excellent resistance to stress corrosion cracking.
- These have better resistance to chlorides.
- They are better than austenitic and ferritic steels in tensile and yield strength while offering good weldability and formability.
- The typical grade is 2205.

1.9.8. Cast Iron /Ductile Iron

Cast iron is any iron containing greater than **2%** carbon. The high carbon content makes it extremely hard and brittle. Cast iron has a high compressive strength and good wear resistance; however, it lacks ductility, malleability, and impact strength.

Two types of cast iron are used, grey cast iron and ductile iron. Both Grey Iron and Ductile Iron are prepared by adding carbon in the hot beds where they are liquefied but ductile iron develops high strength and ductility with the addition of small amounts of magnesium to gray iron.

1.9.9. Galvanized Pipe

Galvanized iron pipe (GI) is a regular iron pipe that is coated with a thin layer of zinc. The zinc greatly increases the life of the pipe by protecting it from rust and corrosion. GI usually comes in 6-meter (21-foot) lengths, and is joined together by threaded connections.

1.9.10. Titanium

Titanium has superb corrosion resistance especially for seawater duties in heat exchanger tubes/piping. This material is relatively expensive compared to most other materials; however, if lifetime costing is considered, it would likely be competitive.

1.9.11. Copper, Brass, Copper Nickel Alloys

Copper tubing is used where ease of fabrication is important.

70%/30% - Cu/Zn brass is a good general purpose material used for a variety of applications, e.g. heat exchanger tubes and closed circuit systems.

Brass with 76%/2%/0.04%- Cu/Al/As and Remainder Zn has good resistance to seawater attack and is used for diverse process plants for transferring seawater under turbulent conditions to resist corrosion and impingement attack.

Admiralty brass 70% /1%/29% - Cu/Sn/Zn has slightly improved resistance to polluted water compared to 70/30 brass.

Cupro Nickel Containing 31%/2% - Ni/Fe and “Kunifer" containing 10.5%/1.7% - Ni/Fe are also used for transferring seawater and high good strength at elevated temperatures.

1.9.12. Plastic Piping Systems

The two most common types of plastic pipe are Polyethylene (PE) and Polyvinyl chloride (PVC).

- Polyethylene pipe (PE) and HDPE are lightweight, flexible pipes that come in large coils 30 meters or more in length. The pipe varies in density and is generally joined by heat fusion. The joint is typically leak free.
- Plastic polyvinyl chloride pipe (PVC) is a rigid pipe, usually white or gray in color. It comes in 3 or 6 meter lengths and is joined primarily by solvent cement. The pipe varies in density and, when buried is extremely resistant to corrosion.

Plastic pipes do have limitations on the mechanical and thermal properties.

1.10. GRADES

In steel pipe, the word "grade" designates divisions within different types based on carbon content or mechanical properties (tensile and yield strengths).

- Grade A steel pipe has lower tensile and yield strengths than Grade B steel pipe. This is because it has lower carbon content. Grade A is more ductile and is better for cold bending and close coiling applications.
- Grade B steel pipe is better for applications where pressure, structural strength and collapse are factors. It is also easier to machine because of its higher carbon content. It is generally accepted for Grade B welds as well as Grade A.

1.11. PIPE CONSTRUCTION

- **Electric Resistance Welding (ERW)**
    - Electric Resistance Welding (ERW) pipe is manufactured by rolling metal and then welding it longitudinally across its length. The weld zone can also be heat treated, so the seam is less visible.
    - Welded pipe often has tighter dimensional tolerances than seamless, and can be cheaper if manufactured in large quantities. These can be manufactured up to 24” OD in a variety of lengths to over 100 feet.
    - It is mainly used for low/ medium pressure applications such as transportation of water / oil.
    - Other welding technique for pipe fabrication is fusion weld (FW) sometimes called “continuous weld” or spiral weld (SW) pipe. The basic difference between ERW and FW is:
        - No material is added during welding process in ERW.
        - Filler material is added during welding process in FW.
        - Large diameter pipe (about 10” or greater) may be ERW, or Submerged Arc Welded (SAW) pipe.

Submerged Arc Welded (SAW)

- Submerged Arc Welding (SAW) is an arc welding process where an arc is established between one or more continuous bare-solid or cored-metal electrodes and the work. The welding arc or arcs and molten puddle are shielded by a blanket of granular, fusible material. Filler metal is obtained from the electrodes, and on occasion, from a supplementary welding wire.

Seamless (SMLS)

- Seamless (SMLS) pipe is manufactured by piercing a billet followed by rolling or drawing, or both to the desired length; therefore, a seamless pipe does not have a welded joint in its cross-section.
- Seamless pipe is finished to dimensional and wall thickness specifications in sizes from 1/8 inch to 26 inch OD. Seamless pipe is produced in single and double random lengths. Single random lengths vary from 16'-0" to 20'-0" long. Pipes that are 2" and below are found in double random lengths measuring 35'-0" to 40'-0" long.
- Seamless pipe is generally more expensive to manufacture but provides higher pressure ratings.

<u>Important</u>

Pressure Piping Code B 31 was written to govern the manufacture of pipe. In particular, code B31.1.0 assigns a strength factor of 85% for a rolled pipe, 60% for a spiral-welded and 100% efficiency for a seamless pipe.

Generally, wider wall thicknesses are produced by the seamless method. Seamless pipe is usually preferred over seam welded pipe for reliability and safety.

Seamless pipes cannot be substituted for others. Only ERW and SAW pipes can be substituted.

Seam welded pipe should not be specified for installation in which it will be operating in the material's creep range [700°F (370°C) for carbon/low alloy steels and from 800°F (430°C) for high alloy and stainless steels]. However, for the many low-pressure uses of pipe, the continuous welded method is the most economical.

How to Identify Seamless or ERW Stainless Steel pipes?

To identify that a pipe supply is seamless or ERW, simply read the stencil on the side of the pipe

- If it is ASTM A53,
  - Type S means seamless.
  - Type F is furnace but welded.
  - Type E is Electrical resistance welded.

That's how it is the easiest way to identify whether pipe is seamless or ERW.

Recommended Guidelines

- All pipe lines carrying toxic inflammable fluids shall be seamless.
- Utility piping can be ERW or Seam welded.
- Steam pipe lines shall preferably be seamless.

1.12. PIPE PROCUREMENT

- **Standard Sizes**
  - NPS1/8, ¼, 3/8, ½, ¾, 1, 1½, 2, 3, 4, 6, 8,10,12,14,16,18, 20, 24, 28, 30, 32, 36, 40, 44, 48, 52, 56, 60.
  - NPS1¼, 2½, 3½, 5 are NOT used.
- **Standard Lengths**
  - Pipe is supplied in Random length (18 to 25 ft.) or double random length (38 to 48 ft.).
- **End Preparation**

Steel pipes can generally be specified with a specific end preparation at the time of purchase. Three end preps are standard.

  - **Plain Ends (PE) -** A plain end pipe is a pipe that has been cut at 90° perpendicular to the pipe run. This type of end is needed when being joined by mechanical couplings, socket weld fittings, or slip-on flange.

- **Bevel Ends (BE) -** A bevel is a surface that is not at a right angle (perpendicular) to another surface. The standard angle on a pipe bevel is 37.5° but other non-standard angles can be produced. Beveling of pipe or tubing is to prepare the ends for Butt welding.
- **Threaded Ends (TE) -** Typically used on pipe 3" and smaller, threaded connections are referred to as screwed pipe. With tapered grooves cut into the ends of a run of pipe, screwed pipe and screwed fittings can easily be assembled without welding or other permanent means of attachment. In the United States, the standard pipe thread is National (not nominal) Pipe Thread (NPT). The reason for this is that as NPT connections are assembled, they become increasingly more difficult for the process to leak. The standard taper for NPT pipe is 3/4" for every foot.

PLAIN END

THREAD END

BEVEL END

Common Abbreviations

Common abbreviations for the types of pipe ends are as follows:

Bevel End (BE)	End of Pipe (EOP)	Thread End (TE)
Bevel Both Ends (BBE)	Flange One End (FOE)	Thread Both Ends (TBE)
Bevel Large End (BLE)	Plain End (PE)	Thread Large End (TLE)
Bevel One End (BOE)	Plain Both Ends (PBE)	Thread One End (TOE)
Bevel Small End (BSE)	Plain One End (POE)	Thread Small End (TSE)
Bevel for Welding (BFW)		Threads Only (TO)
Butt weld End (BE)		Threads per Inch (TPI)

1.13. PIPING DESIGN

The main aim of piping design is to configure and lay equipment, piping and other accessories meeting relevant standards and statutory regulations. The piping design and engineering involves six (6) major steps:

- Selection of pipe materials on the basis of the characteristics of the fluid and operating conditions including maximum pressures and temperatures.
- Finding economical pipe diameter and wall thickness.
- Selection of joints, fittings and components such as flanges, branch connections, extruded tees, nozzle branches etc.
- Developing piping layout and isometrics.
- Performing stress analysis taking into account the potential upset conditions and an allowance for those upset conditions in the design of piping systems.
- Estimating material take-off (MTO) and raising material requisition.

1.13.1. Codes and Standards

The design basis for any project should state the required design codes for materials and equipment. This is usually set by the client, and the engineer should review the requirements to assure they are complete and not contradictory. Local laws may require special requirements for hurricanes, earthquakes or other public safety issues.

The main associations involved in generating piping codes and standards for process industry in US are:

- ASME: American Society of Mechanical Engineers
- ANSI: American National Standardization Institute
- ASTM: American Society of Testing Materials
- API: American Petroleum Institute (primarily for Oil & Gas Industry)

The basic rules for piping engineering are ASME B31 codes. The important codes are:

- ASME B31.1 - Power Piping
- ASME B31.2 - Fuel Gas Piping
- ASME B31.3 - Process Piping
- ASME B31.4 - Liquid Piping
- ASME B31.5 - Refrigeration Piping
- ASME B31.8 - Gas Distribution and Transportation

- ASME B31.9 - Building Service Piping
- ASME B31.11 - Slurry Piping
- ASME Boiler and Pressure Vessel Code applies to boiler supplied piping.
- For pipelines there are Department of Transportation requirements that may apply, such as CFR Part 192.
- For modifications to existing plants, OSHA 1910.119 may apply to Management of Change, Mechanical Integrity and Inspection Requirements.

Each Code provides the typical loading conditions to be considered; allowable stresses; minimum wall thickness calculations; and minimum fabrication, inspection and testing requirements.

1.13.2. Piping Material Specifications (PMS)

The Pipe Material Specification (PMS) is the primary specification document for piping engineers. This document describes the physical characteristics and specific material attributes of pipe, fittings and manual valves necessary for the needs of both design and procurement. These documents also become contractual to the project and those contractors that work under them.

- **Ten Essential Items of PMS**

  A piping specification should contain only those components and information that would typically be used from job to job. The ten line items below provide the primary component information and notations required for a typical piping system.

  - Pressure/Temperature limit of the spec
  - Limiting factor for Pressure/Temperature
  - Pipe material
  - Fitting type, rating and material
  - Flange type, rating and material
  - Gasket type, rating and material
  - Bolt & nut type and material

– Manual valves grouped by type
– Notes
– Branch chart matrix with corrosion allowance

1.14. DESIGN FACTORS

The design factors that influence piping engineering include:

- Fluid Service Categories (Type)
- Flowrate
- Corrosion rate
- Operating Pressure and Temperature

All this information is available in the Process Flow Diagrams (PFD's), Piping and Instrumentation Drawings (P&ID's) and Piping Material Specification (PMS).

1.15. FLUID SERVICE CATEGORIES

ASME B31.3 recognizes the following fluid service categories and a special design consideration based on pressure.

B31.3 Fluid Service	**B31.3 Definition**	**Containment System Characteristics**
Category D [Utility]	Category D fluid Service: a fluid service in which all of the following apply: 1) The fluid handled is nonflammable, nontoxic, and not damaging to human tissues; 2) The design gage pressure does not exceed 1035 kPa (150 psi); and 3) The design temperature is from -29ºC (-20ºF) to 186ºC (366ºF).	Lowest cost Usually not fire resistant Usually not blow-out resistant
Normal [Process]	Normal Fluid Service: a fluid service pertaining to most piping covered by this	Moderate cost May be fire resistant or

	Code, i.e., not subject to the rules of Category D, Category M or High Pressure Fluid Service.	not May be blow-out resistant or not
High Pressure	High Pressure Fluid Service: a fluid service for which the owner specifies the use of Chapter IX for piping design and construction. High Pressure Piping Service is defined as that in which the pressure is in excess of that allowed by the ASME B16.5 2500 flange class ratings.	High cost Usually fire resistant Usually blow-out resistant
Category M [Lethal]	Category M Fluid Service: a fluid service in which the potential for personnel exposure is judged to be significant and in which a single exposure to a very small quantity of a toxic fluid, caused by leakage, can produce serious irreversible harm to persons on breathing or bodily contact, even when prompt restorative measures are taken.	High cost Usually fire resistant Usually blow-out resistant

A variety of other service conditions may result in different types of deterioration including hydrogen damage, erosion, corrosion, fatigue, stress relief cracking etc. Embrittlement and creep are two of the several characteristics of metals associated with service related deterioration.

1.16. FACTORS DEPENDING UPON FLUID TYPE

1. Material

<u>Non corrosive fluids: Services where impurities are accepted</u>

- Example
  - Industrial water lines (cooling water)
  - Steam
  - Lube oil return / before filter lines

  - Air lines
  - Vents and drains
- Material
  - Carbon Steel
  - Low Alloy Steel (High T)

Corrosive fluids: Services where impurities are not accepted

- Example
  - Demineralized water
  - Lube oil after filters
  - Fuel gas / oil
  - Sea water (water containing Chlorine)
- Material
  - Stainless Steel
  - No Iron (Fe)
  - Copper/Nickel Alloys (Cu-Ni)

Aggressive Chemicals

- Example
  - Strong Acids / Bases
- Material
  - Plastic: PVC – TEFLON – PE
  - Rubber: NBR, Viton
  - Composites: RESIN GLASS

Refer to Chapter 3 for further discussion on piping materials.

2. Corrosion Allowances

Thickness of the pipe increases with respect to corrosion. Typical corrosion allowance for water is 3 mm.

3. **Type of Joints**

   Dangerous fluids are conveyed in fully welded pipes, were leaks are not accepted.

4. **Testing and Examination**

   For Dangerous Fluids 100% of joints are likely to be X-Ray examined

1.17. FACTORS DEPENDING UPON FLOWRATE

1. **Pipe Diameter**

   - For a given flow rate
     - Small diameter means higher velocity of the conveyed fluid.
     - Big diameter means slower velocity of the conveyed fluid.
   - Velocity of fluids in pipelines affects
     - Pressure losses along the pipeline.
     - Pressure losses are proportional to the square velocity.
     - Vibration of the pipeline.
   - Usual velocities of fluids inside pipelines are
     - Gas: 20 m/s - max. 40 / 50 m/sec.
     - Liquid: 2 to 4 m/s - max. 10 m/sec.

1.18. FACTORS DEPENDING UPON DESIGN PRESSURE

1. **Wall Thickness Calculation**
2. **Type of Joint**
   - Low pressure pipelines can be threaded or socket welded
   - High Pressure pipelines are Butt Welded
3. **Testing and Examination**
   - Non process Pipelines (For Example Vents and drain lines) may even have no tests at all
   - Low Pressure Pipelines can undergo only the Hydraulic Test

- For intermediate pressures a 10% to 50% of joints must be examined with X-rays
- High Pressure Pipelines are usually 100% X-ray examined.

Important

Note that the Design Pressure is selected based on Operating Pressure plus some tolerance to allow for system deviation from normal operating conditions. Determining the tolerance required can be complicated and needs to incorporate consideration of items similar to the following:

- Possible deadheading of pumps
- Possible loss of temperature controls causing a rise in pressure
- A change in reaction kinetics which could cause pressure rises.
- System pressurization using inert gas
- Thermal expansion of some fluids

1.19. FACTORS DEPENDING UPON TEMPERATURE

1. **Material**
   - Steel for High Temperature (Low Alloy Steel Creep Resistant)
2. **Wall Thickness Calculation**
3. **Thermal Insulation**
   - T > 60°C Insulation for Personnel Protection is mandatory for all pipeline parts that can be reached by hands.

Important

The design temperature of the fluid in the piping is generally assumed to be the highest temperature of the fluid in the equipment connected with such piping.

1.20. STRESS ANALYSIS

Hot lines must be routed properly. Provisions shall be taken so that when the temperature rises from ambient to an operating temperature, the thermal expansion of pipelines does not generate stresses too high for the pipes to withstand.

1.21. COST OF PIPING SYSTEM

The piping installation cost is made up of material 30%, fittings 10%, installation labor 25%, installation equipment 10%, supports 15% and P&G 10%. The total cost can vary from $600 to $1200 per meter, depending on the pipe diameter, slope of the terrain, and cross-country or well pad piping.

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CHAPTER - 2

2. DEFINITIONS, TERMINOLOGY AND ESSENTIAL VOCABULARY

- **BALANCE OF PLANT (BOP)**
  - This is another term for Offsite and/or anything else other than the Onsite Units or the Utility Block.
- **BATTERY LIMIT**
  - Line used on a plot plan to determine the outside limit of a unit. The Battery Limit line is usually established early in the project and documented on all discipline documents such as Plot Plans, Site Plans, Drawing Indexes, etc. In this area, feed to the plant or product from the plant is connected from an upstream process or.to a downstream process/storage.
- **BUILDING CODE**
  - A building code is a set of regulations legally adopted by a community to ensure public safety, health and welfare insofar as they are affected by building construction.
- **BOUNDARY**
  - Boundary of the equipment is the term used in a processing facility, by an imaginary line that completely encompasses the defined site. The term distinguishes areas of responsibility and defines the processing facility for the required scope of work.
- **BROWNFIELD PROJECTS**
  - Revamps and retrofits
  - Maintenance and repairs
  - Modifications and debottlenecking
  - Turnarounds and shutdowns
  - Inspection

- **CATALYTIC CRACKING**
  - A refining process for breaking down large, complex hydrocarbon molecules into smaller ones. A catalyst is used to accelerate the chemical reactions in the cracking process.
- **CODES AND STANDARDS**
  - A code is a set of regulations that tells you when to do something. A code will have requirements specifying the administration and enforcement of the document.
  - A standard is a series of requirements that tell you how to do something. A standard tends not to have any enforcement requirements. A standard becomes an enforceable document when it is adopted by reference in a code.
- **CONDENSATE**
  - Liquid hydrocarbons recovered by surface separators from natural gas. It is also referred to as natural gasoline and distillate.
- **COMMON CODES, STANDARDS AND PRACTICES**
  - ANSI (American National Standards Institute)
  - API (American Petroleum Institute)
  - ASME (American Society of Mechanical Engineers)
  - ASTM – American Society of Testing Materials
  - AWS (American Welding Society)–
  - AWWA (American Water Works Association)
  - CFR (Code of Federal Regulations)
  - Division of Weights & Measures
  - DOT (Department of Transportation)
  - FAR (Federal Accounting Regulations)
  - IRI (Insurance Regulators Institute)
  - Local Permits (Country, State, City, etc.)
  - MSS (Manufacturing Standards Society)

- NACE (National Association of Corrosion Engineers)
- NFPA (National Fire Protection Association)
- OIA (Oil Insurers Association)
- PFI (Pipe Fabrication Institute)
- TEMA = Thermal Exchangers Manufacturers Association
- USCG (United States Coast Guard) Regulations

- **CRYOGENIC LIQUIDS**
  - Cryogenic liquids are substances having sub-zero temperature.
- **DIKE**
  - A dike is an earth or concrete wall providing a specified liquid retention capacity. At many manufacturing or storage facilities, the flammable liquid storage area can be a number of small tanks within a common diked area.
- **DOWNSTREAM**
  - Those activities in the oil and gas industry which take place away from the source of the supply. Downstream operations commonly include refining and marketing endeavors.
- **ENVIRONMENT, HEALTH & SAFETY (EHS)**
  - An Environmental, Health and Safety (EHS) department, also called SHE (Safety, Health and Environmental) or HSE (Health, Safety and Environment) is the department in a company or an organization involved in environmental protection, work safety, occupational health and safety, compliance and best practices. For example, fire, explosion and release of harmful substances into the environment or the work area must be prevented. Organizations based in the United States are subject to EHS regulations in the Code of Federal Regulations, particularly CFR 29, 40, and 49.
- **EASEMENTS**
  - A vested or acquired right to use land other than as a tenant, for a specific purpose; such right being held by someone other than the

owner who holds the title to the land. An easement is typically a strip of land within which overhead power lines or underground pipes are run.

- **FEED**
  - FEED stands for Front End Engineering Design. The FEED is basic engineering which comes after the Conceptual design or Feasibility study. The FEED design focuses the technical requirements as well as rough investment cost for the project. The FEED can be divided into separate packages covering different portions of the project. The FEED package is used as the basis for bidding the Execution Phase Contracts (EPC, EPCI, etc) and is used as the design basis.
- **FEED STOCK**
  - Raw material or fuel required for an industrial process or manufacturing industry.
  - Grass Roots or Greenfield (New construction).
  - Power requirements and source.
- **FIRE CODE**
  - A fire code is a set of regulations legally adopted by a community that define minimum requirements and controls to safeguard life, property, or public welfare from the hazards of fire and explosion. A fire code can address a wide range of issues related to the storage, handling or use of substances, materials or devices. It also can regulate conditions hazardous to life, property, or public welfare in the occupancy of structures or premises.
- **GRADING**
  - Site grading is the process of adjusting the slope and elevation of the soil. Prior to construction or renovation, site grading may be performed to even out the surface and provide a solid foundation.
- **GREENFIELD PROJECTS**
  - New plant construction

- Plant expansions on a fresh site with minimum interfacing to the existing plant

- **GEOTECHNICAL**
  - Geotechnical engineering is the branch of engineering concerned with the analysis, design and construction of foundations, slopes, retaining structures, embankments, tunnels, levees, wharves, landfills and other systems that are made of or are supported by soil or rock.

- **HIGH FLASH STOCK**
  - High Flash Stock Are those having a closed up flash point of 55°C or over (such as heavy fuel oil, lubricating oils, transformer oils etc.). This category does not include any stock that may be stored at temperatures above or within 8°C of its flash point.

- **HYDROCARBON**
  - A hydrocarbon is an organic compound made of nothing more than carbons and hydrogens. Crude oil, tar, bitumen and condensate are all petroleum hydrocarbons.

- **Class I**
  - Hazardous locations or areas where flammable gases or vapors are/could become present in concentrations suitable to produce explosive and/or ignitable mixtures. Class I locations are further divided into 2 divisions:
  - Class I, Division 1: There are three different situations that could exist to classify an area as a Class I, Division 1 location.
    - When the atmosphere of an area or location is expected to contain explosive mixtures of gases, vapors or liquids during normal working operations. (This is the most common Class I, Div. 1)
    - An area where ignitable concentrations frequently exist because of repair or maintenance operations.

  - The release of ignitable concentrations of gases or vapors due to equipment breakdown, while at the same time causing electrical equipment failure.

- Class I, Division 2: One of the following three situations must exist in order for an area to be considered a Class I, Division 2 location.
  - An area where flammable liquids and gases are handled, but not expected to be in explosive concentrations. However, the possibility for these concentrations to exist might occur if there was an accidental rupture or other unexpected incident.
  - An area where ignitable gases or vapors are normally prevented from accumulating by positive mechanical ventilation, yet could exist in ignitable quantities if there was a failure in the ventilation systems.
  - Areas adjacent to Class I, Division 1 locations where it is possible for ignitable concentrations of gas/vapors to come into this area because there isn't proper ventilation.

- **Class II**
  - Class II hazardous locations are areas where combustible dust, rather than gases or liquids, may be present in varying hazardous concentrations.
  - Class II, Division 1: The following situations could exist, making an area become a Class II, Division 1 locations:
    - Where combustible dust is present in the air under normal operating conditions in such a quantity as to produce explosive or ignitable mixtures. This could be on a continuous, intermittent, or periodic basis.
    - Where an ignitable and/or explosive mixture could be produced if a mechanical failure or abnormal machinery operation occurs.
    - Where electrically conductive dusts in hazardous concentrations are present.

- Class II, Division 2: Such locations exist in response to one of the following conditions:
    - Where combustible dust is present but not normally in the air in concentrations high enough to be explosive or ignitable.
    - If dust becomes suspended in the air due to equipment malfunctions and if dust accumulation may become ignitable by abnormal operation or failure of electronic equipment.

- **Class III**
    - Class III hazardous locations contain easily ignitable fibers or flyings, but the concentration of these fibers or flyings are not suspended in the air in such quantities that would produce ignitable mixtures.
    - Class III, Division 1: These locations are areas where easily ignitable fibers or items that produce ignitable flyings are handled, manufactured or used in some kind of a process.
    - Class III, Division 2: These locations are areas where easily ignitable fibers are stored or handled.

- **Equipment for Class I Hazardous Locations**
    - The equipment used in Class I hazardous locations are housed in enclosures designed to contain any explosion that might occur if hazardous vapors were to enter the enclosure and ignite. These closures are also designed to cool and vent the products of this explosion is to prevent the surrounding environment from exploding. The lighting fixtures used in Class I hazardous locations must be able to contain an explosion as well as maintain a surface temperature lower than the ignition temperature of the surrounding hazardous atmosphere.

- **Equipment for Class II Hazardous Locations**
    - Class II hazardous locations make use of equipment designed to seal out dust. The enclosures are not intended to contain an internal explosion, but rather to eliminate the source of ignition so no explosion can occur within the enclosure. These enclosures are

also tested to make sure they do not overheat when totally covered with dust, lint or flyings.

- **Equipment for Class III Hazardous Locations**
  - Equipment used in Class III hazardous locations needs to be designed to prevent fibers and flyings from entering the housing. It also needs to be constructed in such a way as to prevent the escape of sparks or burning materials. It must also operate below the point of combustion. The same exception for the Class II hazardous location holds true for the Class III hazardous locations; fixed, dust-tight equipment, other than lighting fixtures, does not need to be marked with the class, group, division or operating temperature, as long as it is acceptable for Class III hazardous locations.

- **INVERT ELEVATION**
  - The elevation of an invert (lowest inside point) of a pipe or sewer at a given location in reference to a bench mark.
  - The pipe invert elevation is simply the elevation of the lowest inside level of the pipe at a specific point along the run of the pipe.
  - A 2% slope means the pipe invert will fall 2 feet for every 100 feet of pipe run.
  - For example, if the slope is 2%, then multiply the length by 2% to get the difference in elevation of the two points. If, for example, the invert elevation at point 1 is 2 meters, and the length of the pipe is 40.75 meters, the slope will be 2%; multiply 40.75 by 2% and you get 0.815. Therefore, the invert elevation at point 1 is 2 m, and the invert elevation at point 2 is equal to I.E.2 - 0.815 = 1.185.

- **ISOMETRIC DRAWINGS**
  - Isometric drawings are 3D representation of piping showing the bird's eye view of the piping indicating various valves, gages, supports, hangers, anchors and restraints. The drawing is an engineer's language and represents the information in a codified form to the down-stream agencies. The isometric of piping is used for construction and indicates the transportable segments of

piping. The isometric drawing contains Bill of Materials (BOM, also known as BOQ). The total weight of all the items covered in a single system is indicated. The isometric, in its final form, is used for field work.

- The isometric diagrams are used for giving inputs to the piping stress analysis computer programs like CAESAR II and CAEPIPE. The outputs of the piping stress analysis are used to up-date the isometrics. As the design is an iterative process (based on trial and error process), the design of the piping is done in several stages.
- The presently used Plant Design Systems (PDS) and Plant Design Management Systems (PDMS) computer programs assist in the preparation of piping isometrics.

- **LOW FLASH STOCKS**
  - Low-Flash Stocks are those having a closed up flash point under 55°C such as gasoline, kerosene, jet fuels, some heating oils, diesel fuels and any other stock that may be stored at temperatures above or within 8°C of its flash point.
- **OFFSITES**
  - In a process plant (Refinery, Chemical, Petrochemical, Power, etc.), any supporting facility that is not a direct part of the primary or secondary process reaction train or utility block is called offsites. Offsites are also called OSBL.
- **ONSITE**
  - Any single or collection of inter-related and inter-connected process equipment that perform an integrated process function. Typically, any Onsite Unit could be made to function independently of another Onsite Unit. Onsite Units are also called ISBL.
- **PROPERTY LINE**
  - A Property Line is the recorded boundary of a plot of land. It defines the separation between what is recognized legally as the Owner's land, non-Owner's or other land.

- **ON PROPERTY**
  - All land and or water inside the Property line shown on the property map or deed.
- **OFF PROPERTY**
  - Off property is any land (or water) outside of the Property line shown on the property map or deed.
- **RIGHT OF WAY (ROW)**
  - Any land (On Property or Off Property) set aside and designated for a specific use or purpose. A Right-of-Way within a piece of property may also be designated for use by someone other than the property owner.
- **SETBACK OR SETBACK LINE**
  - A line established by law, deed restriction, or custom, fixing the minimum distance from the property line of the exterior face of buildings, walls and any other construction form; street, road, or highway right-of-way line.
  - Setback is a clear area normally at the boundary of a piece of property with conditions and restrictions for building or use.
- **PRIMARY, SECONDARY AND BY-PRODUCTS**
  - Primary product is a product consisting of a natural raw material, an unmanufactured product, or intended as first stage output.
  - Secondary product is a product that has been processed from raw materials that is not classed as the primary product produced by the company
  - A by-product is a secondary product derived from a manufacturing process or chemical reaction. It is not the primary product or service being produced.
- **SEISMIC ZONE**
  - A Seismic zone is an area where the rate of seismic activity remains fairly consistent. This may mean that seismic activity is very rare, or that it is very common. Some people often use the

term "seismic zone" to talk about an area with an increased risk of seismic activity, while others prefer to talk about "seismic hazard zones" when discussing areas where seismic activity is more common.

- **TERRAIN**
  - A stretch of land, especially with regard to its physical features, for example – Level vs. Sloping.
- **ATMOSPHERIC TANK**
  - According to the NFPA, atmospheric storage tanks are defined as those tanks that are designed to operate at pressures between atmospheric and 6.9 kPa gage, as measured at the top of the tank. Such tanks are built in two basic designs: the cone-roof design where the roof remains fixed and the floating-roof design where the roof floats on top of the liquid and rises and falls with the liquid level.
- **PRESSURE VESSEL**
  - A pressure vessel is a container designed to hold gases or liquids at a pressure substantially different from the ambient pressure. The pressure differential is dangerous, and fatal accidents have occurred in the history of pressure vessel development and operation.
  - The ASME Code is a construction code for pressure vessels and contains mandatory requirements, specific prohibitions and non-mandatory guidance for pressure vessel materials, design, fabrication, examination, inspection, testing, and certification.
- **PETROCHEMICALS**
  - Petrochemicals are chemical products derived from petroleum. Primary petrochemicals are divided into three groups depending on their chemical structure:
    - **Olefins** include ethylene, propylene, and butadiene. Ethylene and propylene are important sources of industrial chemicals, resins, fibers, lubricants and plastics products. Butadiene is used in making synthetic rubber.

- **Aromatics** include benzene, toluene, and xylenes. Benzene is a raw material for dyes and synthetic detergents, and benzene and toluene for isocyanates MDI and TDI used in making polyurethanes. Manufacturers use xylenes to produce plastics and synthetic fibers.
- **Synthesis gas** is a mixture of carbon monoxide and hydrogen used to make ammonia and methanol. Ammonia is used to make the fertilizer urea, and methanol is used as a solvent and chemical intermediate.

– Oil refineries produce olefins and aromatics by fluid catalytic cracking of petroleum fractions. Aromatics are produced by catalytic reforming of naphtha.

- **SOUR GAS**
  – Natural gas contaminated with chemical impurities, notably hydrogen sulfide or other sulfur compounds, which cause a foul odor.
- **PLATFORM**
  – Structure used in offshore drilling on which the drilling rig, crew quarters and other related items are located.
- **PIPE RACK**
  – The pipe rack is the elevated supporting structure used to convey piping between equipment. This structure is also utilized for cable trays associated with electric-power distribution and for instrument tray.
- **SPILL CONTAINMENT**
  – Spill containment is where spills of chemicals, oils, sewage etc. are contained within a barrier or drainage system rather than being absorbed at the surface.
- **SLEEPERS**
  – The sleepers comprise the grade-level supporting structure for piping between equipment for facilities, e.g., tank farm or other remote areas.

- **UTILITY BLOCK**
  - A single or multiple grouping of facilities that generate the support services required by the Onsite Process units to function. This normally includes: Steam Generation, Plant Air, Instrument Air, Decimalized Water, Plant Water, etc.

CHAPTER - 3

3. DESIGN CODES AND STANDARDS

The manufacture and installation of pressure piping is tightly regulated by the American Society of Mechanical Engineers, ASME "B31" code series such as B31.1 or B31.3. These codes have their basis in the ASME Boiler and Pressure Vessel Codes and are mandatorily applied in Canada and the USA. Europe has an equivalent system of codes.

3.1. DIFFERENCE BETWEEN CODES AND STANDARDS

3.1.1. Design Codes

The “Codes” define the rules and regulations deemed necessary for safe design and construction. For example, the piping codes address the following design requirements:

- Allowable stresses and stress limits
- Allowable dead loads and load limits
- Allowable live loads and load limits
- Materials
- Minimum wall thickness
- Maximum deflection
- Seismic loads and
- Thermal expansion

Note that the piping codes DO NOT include components such as fittings, valves, flanges and meters; rather, they define the design requirements for these components by reference to industry standards.

3.1.2. Design Standards

The “Standards” provide specific design criteria and rules for individual components or classes of components such as valves, flanges and fittings. Standards apply to both dimensions and performance of system components.

- **Dimensional standards** provide configuration control parameters for components. The primary objective of dimensional standards is to ensure that similar components manufactured by different suppliers permit interchangeability.

- **Pressure-integrity standards** provide uniform minimum-performance criteria. The main objective is to ensure that the components designed and manufactured to the same standard will function in an equivalent manner. For example, all NPS 10 (DN 250) Class 150 ASTM A105 flanges, which are constructed in accordance with ASME B16.5, Pipe Flanges and Flanged Fittings, have a pressure-temperature rating of 230 psig (1590 kPa gauge) at 300°F (149°C).

3.2. PRESSURE PIPING CODES

The American Society of Mechanical Engineers (ASME) established the B31 Pressure Piping Code Committees to promote safety in pressure piping design and construction through published engineering criteria.

The intent of ASME B31 codes is to set forth engineering requirements deemed necessary for safe design and construction of piping installations. However, the Codes are not designed to replace competent engineering design or judgment. Most importantly, the Codes do not "approve," "rate," or "endorse" any items of construction, proprietary devices, or activity. The Codes do not put a limit on conservatism and, conversely, the Codes also allow for designs that are capable of more rigorous engineering analysis which justifies less conservative designs.

ASME B31 codes have the force of law in Canada and the USA. Even if there is no legal requirement, the client, and insurance underwriters may require compliance/with ASME codes. And at a minimum, good engineering practices should be followed that are described in the Codes. If a facility is outside the United States, there may be a set of international Codes that are prescribed.

Important

- The OWNER has the overall responsibility for meeting compliance with ASME B31 codes and standards for the design of piping installations.
- ASME Code is not intended to apply to piping that has been placed in service.

The following list defines the ASME Pressure Piping Codes used for the design, construction and inspection of pressurized piping systems.

3.2.1. B31.1 Power Piping

ASME B31.1 Code is typically used for the design and construction of power piping found in Electric Power Generating Stations, Industrial and Institutional Plants, Geothermal Heating Systems, and Central & District Heating and Cooling Systems. The code covers external piping for power boilers and high temperature, high-pressure water boilers in which steam or vapor is generated at a pressure of more than 15 psig and high-temperature water is generated at pressures exceeding 160 psig or temperatures exceeding 250°F.

- B31.1 is intended to be applied to:
  - ✓ Piping for steam, water, oil, gas, air and other services.
  - ✓ Metallic and nonmetallic piping.
  - ✓ All pressures.
  - ✓ All temperatures above -29°C (-20°F).
- B31.1 does NOT apply to:
  - × Boilers, pressure vessel heaters and components covered by the ASME Boiler and Pressure Vessel Code (BPVC). Note: A boiler needs pipe, both internally and externally. The internal pipe would come under the rules of Section I and the external piping would come under B31.1.
  - × Building heating and distribution steam and condensate systems designed for 15 psig or less.
  - × Hot water heating systems designed for 30 psig or less.

Important

B31.1 is mandatory for piping that is attached directly to an ASME Section I boiler up to the first isolation valve, except in the case of multiple boiler installations where it is mandatory up to the second isolation valve.

3.2.2. B31.3 Process Piping

ASME B31.3 Code is typically used for the design and construction of pressure piping found in Petroleum Refineries, Chemical, Pharmaceutical, Textile, Paper, Semiconductor, and Cryogenic Plants and related Processing Plants and Terminals.

- B31.3 is intended to be applied to:

- ✓ Piping for all fluid services.
- ✓ Metallic and nonmetallic piping.
- ✓ All pressures.
- ✓ All temperatures.

- B31.3 does NOT apply to:
  - × Piping systems designed for pressures at or above 0 but less than 15 psig, provided they meet certain other requirements including temperature ranges.
  - × Tubes and pipes internal to a heater enclosure.
  - × Pressure vessels and certain other equipment and piping.

Important

- Compatibility of materials with the service and hazards from instability of contained fluids are NOT within the scope of ASME B31.3.
- The OWNER is responsible for designating when certain fluid services, i.e. Category M (toxic), high purity, high pressure, elevated temperature or Category D (nonflammable, nontoxic fluids at low pressure and temperature) are applicable to specific systems and for designating if a Quality System is to be imposed.

3.2.3. B31.4 Pipeline Transportation Systems for Liquid Hydrocarbons

ASME B31.4 Code is typically used for the pipelines that transport liquids between plants, terminals and pumping regulating and metering stations.

The liquids include crude oil, condensate, natural gasoline, liquefied petroleum gas, carbon dioxide, liquid alcohol, liquid anhydrous ammonia, and liquid petroleum products between producers' lease facilities, tank farms, natural gas processing plants, refineries, stations, ammonia plants, terminals (marine, rail, and truck), and other delivery and receiving points.

- B31.4 is intended to be applied to:
  - ✓ Piping transporting liquids such as crude oil, condensate, natural gasoline, natural gas liquids, liquefied petroleum gas, carbon dioxide, liquid alcohol, liquid anhydrous ammonia, and liquid petroleum products.

- ✓ Piping at pipeline terminals (marine, rail, and truck), tank farms, pump stations, pressure reducing stations, and metering stations, including scraper traps, strainers, and loops;
- ✓ All pressures
- ✓ Temperatures from -29 to 121ºC (-20 to 250ºF) inclusive.

- B31.4 does NOT apply to:
    - × Auxiliary piping, e.g., water, air, or steam.
    - × Pressure vessels, heat exchangers and similar equipment.
    - × Piping designed at or below 1 bar (15 psig) at any temperature.
    - × Piping above 1 bar (15 psig) if temperature is below –20°F (–30°C) or above 250°F (120°C).
    - × Piping, casing or tubing used in oil well and related assemblies.
    - × Petroleum refinery piping with certain exceptions.
    - × Gas transmission and distribution lines.

3.2.4. B31.5 Refrigeration Piping and Heat Transfer Components

ASME B31.5 Code is typically used for the design and construction of pressure piping containing refrigerants or secondary coolants.

- B31.5 is intended to be applied to:
    - ✓ Refrigerant and secondary coolant piping.
    - ✓ Heat transfer components such as condensers and evaporators.
    - ✓ All pressures.
    - ✓ Temperatures at and above -320°F (-196°C)
- B31.5 does NOT apply to the following:
    - × Any self-contained or unit systems subject to the requirements of Underwriters Laboratories or another nationally recognized testing laboratory.
    - × Water piping.
    - × Piping designed for external or internal gauge pressure not exceeding 15 psi regardless of size.

- × Pressure vessels, compressors or pumps.

3.2.5. B31.8 Gas Transmission and Distribution Piping Systems

ASME B31.8 Code is typically used for gas transportation piping between sources and terminals. It includes gas pipelines, gas compressor stations, gas metering and regulation stations, gas mains, and service lines up to the outlet of the customer's meter set assembly.

- B31.8 is intended to be applied to:
  - ✓ Onshore and offshore pipeline facilities used for the transport of gas.
  - ✓ Gathering pipelines.
  - ✓ Gas distribution systems.
  - ✓ Piping at compressor, regulating and metering stations.
  - ✓ All pressures.
  - ✓ Temperatures from -29 to 232ºC (-20 to 450ºF) inclusive.

B31.8 covers the design, construction, operation, and maintenance of these piping systems, but it does not have requirements for auxiliary piping, such as water, air, steam or lubricating oil.

- B31.8 does NOT apply to the following:
  - × Pressure vessels covered by the BPVC.
  - × Piping with metal temperatures above 450°F (232°C) or below –20°F (–30°C).
  - × Piping beyond the outlet of the customer's meter assembly.
  - × Wellhead assemblies.
  - × Design and manufacture of heat exchangers to Tubular Exchanger Manufacturers Association (TEMA) standards.

3.2.6. B31.9 Building Services Piping

ASME B31.9 Code is typically used for the design and construction of piping found in Industrial, Institutional, Commercial, Public Buildings and multi-unit residences which do not require the range of sizes, pressures and temperatures covered by ASME B31.1 Power Piping Code.

- B31.9 is intended to be applied to:
  - ✓ Piping for water and anti-freeze solutions for heating and cooling, steam and steam condensate, air, combustible liquids and other nontoxic, nonflammable fluids contained in piping not exceeding the following:

    Dimensional limits

    - Carbon steel: NPS 42 (DN 1050) and 0.500 in. (12.7 mm) wall.
    - Stainless steel: NPS 24 (DN 600) and 0.500 in. (12.7 mm) wall.
    - Aluminum: NPS 12 (DN 300).
    - Brass and copper NPS 12 (DN 300), 12.125 in. (308 mm) for copper tube.
    - Thermoplastics: NPS 24 (DN 600).
    - Ductile Iron: NPS 24 (DN 600).
    - Reinforced Thermosetting Resin: NPS 24 (DN 600).
  - ✓ Pressure and temperature limits, inclusive:
    - Compressed air, steam and steam condensate to 1035 kPa (150 psi) gage.
    - Steam and steam condensate from ambient to 186ºC (366ºF).
    - Other gases from ambient to -18 to 93ºC (0 to 200ºF)
    - Liquids to 2415 kPa (350 psi) gage and from -18 to 121ºC (0 to 250ºF).
    - Vacuum to 1 Bar (14.7 psi).
  - ✓ Piping connected directly to ASME Section IV Heating Boilers.

3.2.7. B31.11 Slurry Transportation Piping Systems

ASME B31.11 Code is typically used for aqueous slurries of nonhazardous materials, such as coal, mineral ores and other solids, between the slurry processing plant and the receiving plant. One of the uses of these systems is in the mining industries in moving ores from the mines to elsewhere.

- B31.11 is intended to be applied to:
  - ✓ Piping transporting aqueous slurries of nonhazardous materials.
  - ✓ Piping in pumping, and regulating stations.
  - ✓ All pressures.
  - ✓ Temperatures from -29 to 121ºC (-20 to 250ºF) inclusive.
- B31.11does NOT apply to the following:
  - × Auxiliary piping such as for water, air, and similar liquids and gases.
  - × Pressure vessels.
  - × Piping designed for pressures below 15 psig at any temperature.
  - × Piping designed for pressures above 15 psig, when temperature is below —20°F (–30°C) or above 250°F (120°C).
  - × Piping within the battery limits of slurry processing plants and other non-storage facilities.
  - × Design and fabrication of proprietary items.

Code Applicability

There are a number of similarities in each Code, such as in the calculation of minimum wall thickness, inspection and testing. But the exact rules are different, depending on the type of facility. Allowable stresses are different in each code, reflecting a different factor of safety based on the expected use and operation of the facility.

In most plants, one piping code applies to all piping systems, but sometimes it is not appropriate to take this approach. A petrochemical plant may be designed to B 31.3, but there may be a power boiler supplying power and that piping should be designed to B31.1, and parts may be designed to ASME Boiler & Pressure Vessel Code. No one code fits all.

- Power piping is focused on high pressure and high temperature water and steam with very few chemicals. The plants tend to be vertical, which creates high thermal vertical movements that must be accommodated by spring supports. Plants are usually away from residential areas and the potential for damage to nearby landowners is typically insignificant.

- Petrochemical plants typically operate at much lower pressures and temperatures than power plants, but the various chemicals result in corrosion issues and the use of many special alloy materials. These plants are also laid out horizontally with most pipe supports being rigid on pipe racks. Plants are often in large industrial areas. If there is a fire or explosion, there is always a concern in minimizing the damage to the local area of a plant or a unit within a plant. Explosions may release hazardous chemicals in the air or in water, and thus mechanical integrity must always be a primary design criterion.
- Pipelines are typically underground with no thermal considerations. The pipes are not put in bending at supports, and thus design rules allow thinner pipe for the same pressure compared to B31.1 and B31.3. Pipelines may be in unpopulated areas, or running through suburban and urban areas. Because of the potential for damage to nearby landowners, rules are different based on the pipe's proximity to populated areas.

Important

It is the OWNER's responsibility to determine which code section is applicable to piping installations and to ensure compliance with the respective code, i.e., B31.1, B31.3, etc.

Exclusions

Piping systems that can be excluded from the application of ASME B31 include [ASME B31.3, para 300.1.3]:

- Piping systems designed for internal gage pressures at or above zero but less than 15 psi, provided the fluid handled is nonflammable, nontoxic, and not damaging to human tissue as defined in ASME B31.3 Para. 300.2 and its design temperature is between -20°F through 366°F
- Tubes, tube headers, crossovers, and manifolds of fired heaters, which are internal to the heater enclosure.

Caution

Once a Code has been selected to apply to a particular piping system, only that code should be applied. For example, it is not a practice to use a minimum wall thickness calculation from B31.3, an allowable stress value from B31.8, and an inspection method from B31.1. While it appears obvious that we cannot "cherry pick" the aspects we like from each Code, there are many times that the Codes are incomplete or give no guidance for certain conditions. In these situations, it is appropriate to research other codes, technical papers and other published documents for guidelines to properly engineer the piping system. With this information, a rational engineering judgment can be made that is at least as conservative as the governing Code.

3.3. How the Chapters are arranged?

While each section of the ASME B31 piping codes follows the same general setup of chapters described below, ASME B31.3 is used as the reference here.

- **Chapter I Scope and Definitions (para 300)** includes general information on responsibilities, intent of the Code, Code requirements, and scope. The chapter also includes specific nomenclature and definitions.
- **Chapter II Design (para 301 through 322)** defines the minimum sections that are required in the engineering design process. They are divided into six sub-sections:
  - **Part 1 Conditions and Criteria**

    Part 1, Conditions and Criteria, (para 301 through 302) describes the design pressure, design temperatures and forces to consider in design. Forces include ambient, dynamic, weight, thermal expansion and contraction, support movement, reduced ductility, cyclic and air condensation effects. Part 1 provides pressure-temperature ratings, stress criteria, design allowances, and the minimum design values along with permissible variations. Discussion is provided on how the allowables were generated and the application of allowables for different design conditions.
  - **Part 2 Pressure Design of Piping Components**

    Part 2, Pressure Design of Piping Components, (para 303 through 304) describes the design of straight pipe, bends, branches, closures, flanges, and reducers along with other pressure components under pressure only. Components manufactured in accordance with standards listed in Table 326.1 of B31.3 shall be considered suitable for use at the listed pressure-temperature ratings. The rules provided in para 304 are intended for pressure design of components not covered in Table 326.1.

- **Part 3 Fluid Service Requirements for Piping Components**

  Part 3, Fluid Service Requirements for Piping Components (para 305 through 309), discusses the types of components which can be used in the intended Fluid Service.

- **Part 4 Fluid Service Requirements for Piping Joints**

  Part 4, Fluid Service Requirements for Piping Joints (para 310 through 318), discusses the acceptable types and limitations of weld, braze, solder, threaded, or other joint configurations.

- **Part 5 Flexibility and Support**

  Part 5, Flexibility and Support (para 319 through 321.4), provides basic and specific requirements for flexibility analyses as well as providing the design requirements and analyses for piping supports. Formal flexibility analysis is not necessary if the design temperature is at or below 150°F and the piping is laid out with inherent flexibility, or the design temperature is at or below 250°F and the piping is analyzed for flexibility using simplified methods of calculation. Design of pipe supports are addressed in Standards such as Manufacturers Standardization Society of the Valve and Fittings Industry MSS-SP-58. Allowable stress levels for supports are provided in the American Institute of Steel Construction (AISC) Manual of Steel Construction and the AISC Standard N690.

- **Part 6 Systems**

  Part 6, Systems (para 322), defines requirements for instrument piping and pressure relieving devices.

- **Chapter III Materials** (para 323 through 325) describes where to find materials, how they are specified, and their limitations. Chapter III also describes how the materials are to be marked.

  When the materials are not listed by the ASME code, the material must be qualified in accordance with the requirements of the ASME Code. Reviewing the material of an unlisted component is done to ensure a specified minimum allowable stress at the design temperature. The sources for allowable stress values include the ASME B31 Codes of Pressure Piping and the ASME BPV Code Section II. BPV Code Cases should also be reviewed for allowable stresses for specific materials.

- **Chapter IV Standards for Piping Components** (para 326) describes where to find piping dimensional requirements.
- **Chapter V Fabrication, Assembly, and Erection** (para 327 through 335) describes how to create joints, form, or bend materials for system fabrication. Chapter V describes how to qualify the joint being manufactured and how to qualify personnel to perform joint fabrication (refers to ASME Section IX). Chapter V describes joint preparation, pre-heat requirements, filler material to use, performance of the weld detail, post heat treatment, and joint repair.
- **Chapter VI Inspection, Examination, and Testing** (para 340 through 346) explains responsibilities for inspection to B31.3 requirements. Chapter VI addresses the non-destructive examination (NDE) required for a particular service, qualification of the person performing the NDE, and the acceptance criteria for the NDE. Chapter VI describes the minimum pressure testing required and how to determine the testing requirements.
- Chapter VII Nonmetallic Piping and Piping Lined with Nonmetals
- Chapter VIII Piping for Category M Fluid Service
- Chapter IX High Pressure Piping
- **Appendices**

A Allowable Stresses and Quality Factors for Metallic Piping and Bolting Materials

B Stress Tables and Allowable Pressure Tables for Nonmetals

C Physical Properties of Piping Materials

D Flexibility and Stress Intensification Factors

E Reference Standards

F Precautionary Considerations

G Safeguarding

H Sample Calculations for Branch Reinforcement

J	Nomenclature
K	Allowable Stress for High Pressure Piping
L	Aluminum Alloy Pipe Flanges
M	Guide to Classifying Fluid Services
Q	Quality System Program
V	Allowable Variations in Elevated Temperature Service
X	Metallic Bellows Expansion Joints
Z	Preparation of Technical Inquiries

3.4. Process Steps or Expectations

In applying ASME Codes to pressure systems, it is important to note that the codes (ASME B31.3, Process Piping and ASME Boiler and Pressure Vessel (BPV) Section VIII, Rules for Construction of Pressure Vessels) are not design handbooks. The ASME Codes are to be used as a guide to the analyses that should be performed and do not eliminate the need for competent engineering judgment. The ASME Codes set forth engineering requirements deemed necessary for the safe design and construction of pressure systems.

To the greatest possible extent, code requirements for design are stated in terms of basic design principles and formulas. These are supplemented, as necessary, with specific requirements to assure uniform application of principles and to guide selection and application of pressure system elements.

3.5. ASSOCIATIONS PROVIDING PIPING MATERIAL SPECIFICATIONS

- American Petroleum Institute (API)
- American Society for Testing and Materials (ASTM)
- American Water Works Association (AWWA)
- American Welding Society (AWS)
- Manufacturers Standardization Society (MSS)
- National Association of Corrosion Engineers (NACE)
- National Fire Protection Association (NFPA)
- Society of Automotive Engineers (SAE)

3.5.1. API - American Petroleum Institute Standards

Rules, practices and standards for oil and gas industry are issued by this institute and followed by almost all oil and gas companies in the world.

Among the many standards issued by the institute, there is also a standard for the design of pipelines: API STANDARD 5L. Within this standard, materials for oil and gas transportation pipelines are specified, with denomination API 5L.

- API 5L
  - API 5L provides dimensions, weights, and test pressures for plain-end line pipe in sizes up to 80 inches in diameter.
  - Several weights are available in each line pipe diameter. The weight of the pipe in lb/ft, in turn, varies as the wall thickness for a given outside diameter. For instance, API Spec 5L lists 24 different weights in the 16-inch-diameter size (five weights are special weights), ranging from 31.75 lb/foot to 196.91 lb/foot.
  - The corresponding wall thickness ranges from 0.188 inch to 1.250 inches. As the wall thickness increases for a given outside diameter, the inside diameter of the pipe decreases from 15.624 inches for the lightest weight pipe to 13.500 inches for the line pipe weighing 196.91 lb/foot. Greater wall thicknesses are selected for high-pressure applications, or when the pipe segment might be subjected to unusual external forces such as seismic activities and landslides.

This is a family of carbon steels almost equivalent to ASTM A53 / A106.

Equipment specified to these standards is typically more robust than general industrial applications.

Common API standards are:

Spec. 5L	Line Pipe
Spec. 6D	Pipeline Valves
Spec. 6FA	Fire Test for Valves
Spec. 12D	Field Welded Tanks for Storage of Production Liquids
Spec. 12F	Shop Welded Tanks for Storage of Production Liquids

Spec. 12J	Oil and Gas Separators
Spec. 12K	Indirect Type Oil Field Heaters
Std. 594	Wafer and Wafer-Lug Check Valves
Std. 598	Valve Inspection and Testing
Std. 599	Metal Plug Valves - Flanged and Butt-Welding Ends
Std. 600	Steel Gate Valves-Flanged and Butt-Welding Ends
Std. 602	Compact Steel Gate Valves-Flanged Threaded, Welding, and Extended-Body Ends
Std. 603	Class 150, Cast, Corrosion-Resistant, Flanged-End Gate Valves
Std. 607	Fire Test for Soft-Seated Quarter-Turn Valves
Std. 608	Metal Ball Valves-Flanged and Butt-Welding Ends
Std. 609	Lug-and Wafer-Type Butterfly Valves
Std. 610	Centrifugal Pumps for Petroleum, Heavy Duty Chemical and Gas Industry Services
Std. 611	General Purpose Steam Turbines for Refinery Services
Std. 612	Special Purpose Steam Turbines for Refinery Services
Std. 613	Special Purpose Gear Units for Refinery Services
Std. 614	Lubrication, Shaft-Sealing and Control Oil Systems for Special Purpose Application
Std. 615	Sound Control of Mechanical Equipment for Refinery Services
Std. 616	Gas Turbines for Refinery Services
Std. 617	Centrifugal Compressors for General Refinery Services
Std. 618	Reciprocating Compressors for General Refinery Services
Std. 619	Rotary-Type Positive Displacement Compressors for General Refinery Services
Std. 620	Design and Construction of Large, Welded, Low Pressure Storage Tanks
Std. 630	Tube and Header Dimensions for Fired Heaters for Refinery Service
Std. 650	Welded Steel Tanks for Oil Storage
Std. 660	Heat Exchangers for General Refinery Service
Std. 661	Air-Cooled Heat Exchangers for General Refinery Service

Std. 670	Vibrations, Axial Position, and Bearing-Temperature Monitoring Systems
Std. 671	Special Purpose Couplings for Refinery Service
Std. 674	Positive Displacement Pumps-Reciprocating
Std. 675	Positive Displacement Pumps-Controlled Volume
Std. 676	Positive Displacement Pumps-Rotary
Std. 677	General Purpose Gear Units for Refineries Services
Std. 678	Accelerometer-Base Vibration Monitoring System
Std. 1104	Welding Pipelines and Related Facilities
Std. 2000	Venting Atmospheric and low-Pressure Storage Tanks - Non-Refrigerated and Refrigerated
RP 530	Calculation for Heater Tube Thickness in Petroleum Refineries
RP 560	Fired Heater for General Refinery Services
RP 682	Shaft Sealing System for Centrifugal and Rotary Pumps
RP 1110	Pressure Testing of Liquid Petroleum Pipelines
Publ. 941	Steel for Hydrogen Service at Elevated Temperature and Pressures in Petroleum Refineries and Petrochemical Plants
Publ. 2009	Safe Welding and Cutting Practices in Refineries
Publ. 2015	Safe Entry and Cleaning of Petroleum Storage Tanks

3.5.2. ASTM – American Society of Testing Materials

ASTM developed a collection of documents called material specifications for standardizing materials of large use in the industry.

- Specifications starting with “A” are for steel.
- Specifications starting with “B” are for non-ferrous alloys (bronze, brass, copper nickel alloys, aluminum alloys and so on).
- Specifications starting with “D” are for plastic material, as PVC.

An ASTM specification specifies the basic chemical composition of material and the process through which the material is shaped into the final product. Some of the common material standards are:

A 36	Specification for Structural Steel
A 53	Specification for Pipe, Steel, Black and Hot –Dipped, Zinc Coated Welded and Seamless
A 105	Specification for Forgings, Carbon Steel, for Piping Components
A 106	Specification for Seamless Carbon Steel Pipe for High Temperature Service
A 181	Specification for Forgings, Carbon Steel for General Purpose Piping
A 182	Specification for Forged or Rolled Alloy Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High Temperature Service
A 193	Specification for Alloy Steel and Stainless Steel Bolting Materials for High Temperature Service
A 194	Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure and High Temperature Service
A 234	Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures
A 333	Specification for Seamless and Welded Steel Pipe for Low Temperature Service
A 350	Specification for Forgings, Carbon and Low Alloy Steel Requiring Notch Toughness Testing for Piping Components
A 352	Specification for Steel Castings, Ferritic and Martensitic for Pressure Containing Parts Suitable for Low Temperature Service
A 420	Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Low Temperature Service
A 694	Specification for Forgings, carbon and Alloy Steel for Pipe Flanges, Fittings, Valves and Parts for High Pressure Transmission Service
A 707	Specifications for Flanges, Forged, Carbon and Alloy Steel for Low Temperature Service

Non-Ferrous Piping Materials

B 42	Seamless Copper Pipe
B 43	Seamless Red Brass Pipe
B 210	Specification for Aluminum and Aluminum-Alloy Drawn Seamless Tubes
B 241	Seamless Aluminum and Aluminum Alloy Pipe

B 251	Specification for General Requirements for Wrought Seamless Copper and Copper-Alloy Tube
B 315	Seamless Copper Alloy Pipe and Tube
B 337	Seamless & Welded Titanium and Titanium Alloy Pipe
B 429	Specification for Aluminum-Alloy Extruded Structural Pipe and Tube
B 466	Seamless Copper Nickel Pipe & Tube
B 467	Welded Copper Nickel pipe
B 658	Seamless & Welded Zirconium and Zirconium Alloy Pipe.
C 76	Specification for Concrete Pipe
C599	Process Glass Pipe and Fittings
D1785	UPVC Plastic Pipe
D 2239	Specification for Polyethylene Pipe
D2282	ABS Plastic Pipe (SDR-PR)
D2464	Threaded PVC Plastic Pipe Fittings, Sch 80
D2468	Socket-Type ABS Plastic Pipe Fittings, Sch 40
D2517	Reinforced Epoxy Resin Gas Pressure Pipe and Fittings
D2846	CPVC Plastic Hot and Cold Water Distribution Systems
D3261	Butt Heat Fusion PE Plastic Fittings for PE Plastic Pipe and Tubing
D5421	Contact Molded Fiberglass RTR Flanges
F423	PTFE Plastic-Lined Ferrous Metal Pipe and Fittings
F492	Polypropylene and PP Plastic-Lined Ferrous Metal Pipe and Fittings
D 3033/3034	UPVC Fittings

3.5.3. ASME Piping Components Standards

These standards provide design, dimensional and manufacturing criteria for many commonly used piping components for use in B31.3 process piping systems.

B16.1	Cast Iron Pipe Flanges and Flanged Fittings
B16.3	Malleable Iron Threaded Fittings, Class 150 and 300
B16.4	Cast Iron Threaded Fittings, Classes 125 and 250

B16.5	Pipe Flanges and Flanged Fittings
B16.9	Factory Made Wrought Steel Butt welding Fittings
B16.10	Face to Face and End to End Dimensions of Valves
B16.11	Forged Fittings, Socket Welding and Threaded
B16.12	Cast Iron Threaded Drainage Fittings
B16.14	Ferrous Pipe Plugs, Bushings and Locknuts with Pipe Threads
B16.15	Cast Bronze Threaded Fittings Class 125 and 250
B16.18	Cast Copper Alloy Solder Joint Pressure Fittings
B16.20	Ring Joint Gaskets and Grooves for Steel Pipe Flanges
B16.21	Nonmetallic Flat Gaskets for Pipe Flanges
B16.22	Wrought Copper and Copper Alloy Solder Joint Pressure Fittings
B16.23	Cast Copper Alloy Solder Joint Drainage Fittings – DWV
B16.24	Cast Copper Alloy Pipe Flanges and Flanged Fittings Class 150, 300, 400,600, 900, 1500 and 2500
B16.25	Butt welding Ends
B16.26	Cast Copper Alloy Fittings for Flared Copper Tubes
B16.28	Wrought Steel Butt welding Short Radius Elbows and Returns
B16.29	Wrought Copper and Wrought Copper Alloy Solder Joint Drainage Fittings DWV
B16.32	Cast Copper Alloy Solder Joint Fittings for Solvent Drainage Systems
B16.33	Manually Operated Metallic Gas Valves for Use in Gas Piping Systems Up to 125 psig (sizes ½ through 2)
B16.34	Valves – Flanged, Threaded and Welding End
B16.36	Orifice Flanges
B16.37	Hydrostatic Testing of Control Valves
B16.38	Large Metallic Valves for Gas Distribution (Manually Operated, NPS 2 ½ to 12, 125 psig maximum)
B16.39	Malleable Iron Threaded Pipe Unions, Classes 1150, 250 and 300
B16.40	Manually Operated Thermoplastic Gas Shutoffs and Valves in Gas Distribution
B16.41	Functional Qualification Requirement for Power Operated Active Valve Assemblies for Nuclear Power Plants
B16.42	Ductile Iron Pipe Flanges and Flanged Fittings, Class 150 and 300

B16.45	Cast Iron Fittings for Solvent Drainage Systems
B16.44	Manually Operated Metallic Gas Valves for Use in House Piping Systems
B16.47	Large Diameter Steel Flanges (NPS 26 through NPS 60)
B16.48	Steel Line Blanks
B16.49	Factory-Made Wrought Steel Butt-welding Induction Bends for Transportation and Distribution Systems
B16.50	Wrought Copper and Copper Alloy Braze-Joint Pressure Fittings
B16.51	Cast and Wrought Copper and Copper Alloy Press-Connect Pressure Fittings (draft)

3.5.4. American Welding Society (AWS)

These standards provide information on the welding fundamentals, weld design, welder's training qualifications, testing and inspection of the welds and guidance on the application and use of welds. Individual electrode manufacturers have given their own brand names for the various electrodes and the same are sold under these names.

3.5.5. American Water Works Association (AWWA)

These standards refer to the piping elements required for low pressure water services. These are less stringent than other standards and are rarely arbitrated by piping engineers.

***C104**	Cement-Mortar Lining for Ductile-Iron Pipe and Fittings for Water
C110	Ductile-Iron and Gray-Iron Fittings, 3 In.-48 In. (76 mm-1,219 mm), for Water
C115	Flanged Ductile-Iron Pipe with Ductile-Iron or Gray-Iron Threaded Flanges
C151	Ductile-Iron Pipe, Centrifugally Cast, for Water
***C153**	Ductile-Iron Compact Fittings for Water Service
C300	Reinforced Concrete Pressure Pipe, Steel Cylinder Type, for Water and Other Liquids
C302	Reinforced Concrete Pressure Pipe, Noncylinder Type, for Water and Other Liquids
***C501**	Cast-Iron Sluice Gates
***C502**	Dry-Barrel Fire Hydrants
***C503**	Wet-Barrel Fire Hydrants
C504	Rubber-Seated Butterfly Valves

***C507**	Ball Valves, 6 In. Through 48 In. (150 mm Through 1,200 mm)
***C508**	Swing-Check Valves for Waterworks Service, 2 In. (50 mm) Through 24 In. (600 mm) NPS
***C509**	Resilient-Seated Gate Valves for Water Supply Service
***C510**	Double Check Valve Backflow Prevention Assembly
***C511**	Reduced-Pressure Principle Backflow Prevention Assembly
C900	PVC Pressure Pipe, 4-inch through 12-inch, for Water
C950	Glass-Fiber-Reinforced Thermosetting Resin Pressure Pipe

* Not listed in ASME B31.3

3.5.6. MSS Standard Practices

The Manufacturers Standardization Society (MSS) standards are directed at general industrial applications. The most common MSS-SP standards are:

MSS SP 6	Standard Finishes for contact surface for flanges
MSS SP 25	Standard marking system for valves, fittings, flanges
MSS SP 42	Class 150 corrosion resistant gate, globe and check valves
MSS SP 43	Wrought stainless steel butt weld fittings
MSS SP 56	Pipe hanger supports; material, design and manufacture
MSS SP 61	Pressure testing of valves
MSS SP 67	Butterfly Valves
MSS SP 68	High Pressure off seat butterfly valves
MSS SP 69	Pipe hanger supports; selection and applications
MSS SP 70	Cast Iron Gate valves
MSS SP 71	Cast iron check valves
MSS SP 72	Ball Valves
MSS SP 78	Cast iron plug valves
MSS SP 80	Bronze gate, globe and check valves
MSS SP 81	Stainless steel bonnet less knife gate valves
MSS SP 83	Pipe unions
MSS SP 85	Cast iron globe valves

MSS SP 88	Diaphragm valves
MSS SP 89	Pipe hangers and supports; fabrication and installation practices
MSS SP 90	Pipe hangers and supports; guidelines on terminology
MSS SP 92	MSS valves user guide
MSS SP 108	Resilient seated eccentric CI plug valves

3.5.7. National Fire Protection Association (NFPA)

NFPA13	Installation of Sprinkler Systems
NFPA14	Installation of Standpipe, Private Hydrant, and Hose Systems
NFPA15	Water Spray Fixed Systems for Fire Protection
NFPA16	Installation of Foam-Water Sprinkler and Foam-Water Spray Systems
NFPA24	Installation of Private Fire Service Mains and Their Appurtenances
NFPA54	National Fuel Gas Code
NFPA58	Liquefied Petroleum Gas Code
NFPA59A	Production, Storage, and Handling of Liquefied Natural Gas (LNG)
NFPA Z662	Oil and Gas Pipeline Systems

3.5.8. Compressed Gas Association (CGA) Piping System Standards

CGA G2.1	Requirements for the Storage and Handling of Anhydrous Ammonia (ANSI K61.1)
CGA G4.4	Industrial Practices for Gaseous Oxygen Transmission and Distribution Piping Systems
CGA G5.4	Standard for Hydrogen Piping Systems at Consumer Locations

3.5.9. Chlorine Institute Piping System Standards (selected)

006	Piping Systems for Dry Chlorine
060	Chlorine Pipelines
094	Sodium Hydroxide Solution and Potassium Hydroxide Solution (Caustic): Storage Equipment and Piping Systems
163	Hydrochloric Acid Storage and Piping Systems

3.5.10. Unified Numbering System (UNS)

The UNS number itself is not a specification, since it establishes no requirements for form, condition, quality etc. It is a unified identification of metals and alloys for which controlling limits have been established in specifications elsewhere.

The UNS provides means of correlating many naturally used numbering systems currently administered by societies, trade associations, individual users and producers of metals and alloys, thereby avoiding confusion caused by the use of more than one identification number for the same material and by the opposite situation of having the same number assigned to two different materials.

UNS establishes 18 Series numbers of metals and alloys. Each UNS number consists of a single letter prefix followed by five digits. In most cases the alphabet is suggestive of the formula of metal identified.

A00001 - A99999	Aluminum & Al. Alloys.
C00001 - C99999	Copper & Copper alloys
E00001 - E99999	Rare earth & rare earth like metal &Alloys.
L00001 - L99999	Low melting metals & alloys
M00001 - M99999	Miscellaneous nonferrous metals & alloys
N00001 - N99999	Nickel & nickel alloys
P00001 - P99999	Precious Metals & alloys
R00001 - R99999	Reactive & refractory metal & alloys
Z00001 - Z99999	Zinc & Zinc alloys
D00001 - D99999	Specified Mech. Properties of Steels
F00001 - F99999	Cast Iron & Cast Steels
G00001 - G99999	AISI & SAE Carbon & Alloy Steels
H00001 - H99999	AISIH Steels
J00001 - J99999	Cast Steels
K00001 - K99999	Misc. steels & Ferrous alloys
S00001 - S99999	Stainless Steels
T00001 - T99999	Tool Steels
W00001 - W99999	Welding Filler Metals & Electrodes

3.5.11. EN – European Standards

EN 10088-1	List of corrosion resistant steel types
EN 10204	Types of inspection documents
EN 10296 -2	Welded round stainless steel tubes for general applications
EN 10297-2	Seamless round austenitic stainless steel tubes for general applications
EN 10217-7	Welded round austenitic stainless steel tubes for special applications
EN ISO 1127	Tolerance for stainless steel welded tube
EN 1092-1 type 5 PN 6-100	Blind flanges PN 6-100
EN 1092-1 type 1 PN 10	Flat welding flanges PN 10
EN 1092-1 type 11 PN 10	Welding neck flanges PN 10
EN 1092-1 type 11 PN 16	Welding neck flanges PN 16
EN 1092-1 type 11 PN 25	Welding neck flanges PN 25
EN 1092-1 type 11 PN 40	Welding neck flanges PN 40
EN 1092-1 PN 64	Welding neck flanges PN 64
EN 1092-1 PN 10	Collar rings and flanges PN 10

3.5.12. Canadian Standards Association

***Z245.1**	Steel Pipe
***Z245.6**	Coiled Aluminum Line Pipe and Accessories
***Z245.11**	Steel Fittings
***Z245.12**	Steel Flanges
***Z245.15**	Steel Valves

* Not listed in ASME B31.3

3.6. MAJOR ORGANIZATIONS FOR STANDARDS

Country	Organization	Abbreviation
USA	American National Standards Institute	ANSI
Canada	Standards Council of Canada	SCC
France	Association Francaise	AFNOR

United Kingdom	British Standards Institute	BSI
Europe	Committee of European Normalization	CEN
Germany	Deutsches Institut fur Normung	DIN
Japan	Japanese Industrial Standards Committee	JISC
Italy	Ente Nazionale Italiano di Unificazione	UNI
Sweeden	Swedish Standards Institution	SS
Norway	Norsk Sokkels Konkuranseposisjon	NORSOK
Worldwide	International Standards Organization	ISO

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This completes the 1st module of the 9 module series. Please refer to the other course modules in Annexure -1.

Annexure -1

DESCRIPTIONS OF ALL PIPING COURSES

MODULES 1 to 9

MODULE 1:	**PROCESS PIPING FUNDAMENTALS, CODES AND STANDARDS**
CHAPTER -1:	THE BASICS OF PIPING SYSTEM This chapter covers the introduction to the pipe sizes, pipe schedules, dimensional tolerances, pressure ratings, frequently used materials, criterial for material selection, associations involved in generating piping codes, design factors depending on fluid type, pressure, temperature and corrosion, roles and responsibilities of piping discipline, key piping deliverables and cost of piping system.
CHAPTER – 2:	DEFINITIONS, TERMINOLOGY AND ESSENTIAL VOCABULARY This chapter provides essential definitions and terminology, each piping engineer and designer should familiar with. This is based on the Author's experience on the use of vocabulary in most design engineering, procurement and construction (EPC) companies.
CHAPTER – 3:	DESIGN CODES AND STANDARDS This chapter discusses the associations involved in generating piping codes and material specifications. It provides description of various ASME pressure piping codes such as B31.1 Power Piping, B31.3 Process Piping, B31.4 Pipeline Transportation Systems for Liquid Hydrocarbons, B31.5 Refrigeration Piping and Heat Transfer Components, B31.8 Gas Transmission and Distribution Piping Systems, B31.9 Building Services Piping and B31.11 Slurry Transportation Piping Systems. It also provides information on the associations involved in material specifications such as API - American Petroleum Institute Standards, ASTM – American Society of Testing Materials, ASME Piping Components Standards, American Welding Society (AWS), American Water Works Association (AWWA) and EN – European Standards.

MODULE 2:	**PROCESS PIPING MATERIALS**
CHAPTER -1:	PIPING MATERIAL SELECTION & CHARACTERISTICS This chapter discusses about the selection criteria for piping materials covering service life, temperature, and pressure and corrosion considerations. It discusses the characteristics of piping materials required to prevent failures resulting from the environment, normal operation time exposure and upset conditions.
CHAPTER – 2:	MATERIALS – METALLIC PIPING This chapter discusses the most commonly used ASTM material

	designation standards for Carbon Steel, Stainless Steel, Alloy Steels, Duplex Steel, Cast Iron, Copper, Aluminum; Titanium and other materials. It gives the pertinent information of all relevant ASME/ASTM codes and standards highlighting the applications these are suited for.
CHAPTER -3:	SPECIAL PIPING MATERIALS This chapter discusses some specific considerations to piping selection for extreme high and cold temperatures. It provides specific information for hydrocarbon industry and the piping selection issues for mitigating the effects of Wet CO2 corrosion, Hydrogen exposure, Offshore environment, Sulfides and Sulfurous Gases, Halogenation Environments, Carburizing, Nitriding, Sulfur, Amine, Caustic and Chloride environment. Other applications include the cooling water, fire water, sour water services and Microbiological Induced Corrosion (MIC).
CHAPTER – 4:	MATERIALS – UNDERGROUND PIPING This chapter discusses the piping materials for underground services, including ductile iron, concrete pipes, plastic materials such as polyvinyl chloride (PVC), chlorinated polyvinyl chloride (CPVC), fiber reinforced plastic (FRP), reinforced polymer mortar (RPMP), polypropylene (PP), High density polyethylene (HDPE), cross-linked high-density polyethylene (PEX), polybutylene (PB), and acrylonitrile butadiene styrene (ABS).

MODULE 3:	**PROCESS PIPING HYDRAULICS, SIZING AND PRESSURE RATING**
CHAPTER -1:	PIPELINE HYDRAULICS This chapter covers basic hydraulics definitions, terminology and flow characteristics in pipe. It discusses the various flow conditions, continuity equation, Bernoulli's equation, flow regimes, laminar flow & turbulent flow, Reynold's Number (Re) and Moody's Chart for hydraulic line sizing. Procedures are included for calculating pressure drop considerations using the Darcy–Weisbach Equation and Hazen–Williams Equation. Finally, it covers the economic pipe sizing based on least annual cost approach.
CHAPTER – 2:	DESIGN OF PRESSURE PIPING This chapter deals with the methods to compute the pipe wall thickness. It describes the design conditions, pressure-temperature relationships, allowable stresses, theories of failure and the importance of hoop stress and longitudinal stress in pressure pipe sizing. It gives the pertinent information of all relevant ASME/ASTM codes and thickness allowances with examples. It includes an annexure at the end, which provides some solved examples.

MODULE 4:	PROCESS PIPING JOINTS, FITTINGS AND COMPONENTS
CHAPTER -1:	JOINTS AND FITTINGS This chapter describes the various types of pipe joints (weld, socket, thread, flanged), fittings (bends, elbow, tees, reducers, Stub ends, couplings, cross, cap, plug and nipples), Special pipe olets (weldolets, sockolets, threadolets, elbowlets, latrolets), expansion joints, strainers and traps. It discusses the criteria for the selection, and provides reference to the relevant ASME codes. Standard symbols and abbreviations are also shown.
CHAPTER – 2:	FLANGES, GASKETS & BOLTS This chapter covers the flanges, gaskets and bolts. It discusses the pressure rating concept for flanges, the types of flanges including weld neck, slip-on type, socket weld, reducing flange, lap joint, blind flange and orifice flanges. The selection recommendation for flat face, raised face and ring type flange is discussed. Selection criteria for different types of gaskets, bolts and fasteners, their standards, the advantages and limitations of each are provided. Reference of relevant ASME codes and their proper service applications in pressure piping applications is provided.
CHAPTER – 3:	VALVES This chapter describes the various types of valves and their applications. The characteristics, ratings, advantages and disadvantages of most commonly used valves such as gate valve, ball valve, globe valve, butterfly valve, check valve, diaphragm valve and various safety relief valves are provided. The material of construction and selection criteria is covered. Reference of relevant ASME codes and their proper service applications in pressure piping applications is provided.

MODULE 5:	PROCESS PIPING MATERIALS MANAGEMENT
CHAPTER -1:	PIPING MATERIAL MANAGEMENT The chapter describes the various inputs to the piping material activities such as the type of fluid service as per ASME B31.3, Process Flow Diagrams (PFD's), Piping and Instrumentation Diagrams (P&ID's), the line lists, the equipment data sheets and the nozzle schedules.
CHAPTER – 2:	PIPING DESIGN CRITERIA This chapter covers some good engineering practices to aid piping engineers and designers to carry out the design activities. It discusses the engineering guidelines for pipes, fittings, valves, insulation, corrosion, supports and anchors, expansion and contraction, vents and drains, utility stations, pipe line welding, non-destructive examination and heat tracing. Reference is made to appropriate codes and standards.

CHAPTER– 3:	PIPING MATERIAL SPECIFICATION (PMS) This chapter describes how PMS is generated, typical format of material specification; line numbering system, pipe class designation, fluid service designation, insulation service and piping material index.
CHAPTER– 4:	PIPE FABRICATION AND INSTALLATION This chapter describes the difference between the field fabrication, shop fabrication for generating spools and modular skid fabrication. It discusses the pros and cons of installation approaches and the technical requirements for shop fabrication.
CHAPTER– 5:	MATERIAL REQUISITION AND CONTROL This chapter describe the different stages of material take-offs, roles and responsibilities of procurement vs engineering, preparation of material requisition, technical requirements for materials, inspection and testing requirements, quality assurance plan, material traceability requirements, certification, storage and handling requirements, different attachments to material requisition and testing requirements.
CHAPTER– 6:	BID TABULATION This chapter describes the process of technical evaluation, commercial evaluation, qualifying criteria for bidders, purchase order and vendor document review and approval process.

MODULE 6:	**PROCESS PIPING PLANT DESIGN AND LAYOUT**
CHAPTER -1:	PLANT DESIGN AND LAYOUT This chapter describes the need for the Plot Plan, key issues and challenges. It discusses the key features in the development of a plot plan: Terrain, Throughput, Safety and Environment. It provides guidance on how to demarcate site area for process equipment, utilities and service buildings.
CHAPTER – 2:	EQUIPMENT LAYOUT This chapter covers the equipment layout principles to carry out the design activities. It provides the engineering guidelines for locating process equipment, utilities, loading and unloading facilities, piperacks and sleepers. It discusses the clearance and accessibility for crane, forklift, tube bundle pulling, and the different equipment such as process vessels, pumps, heat exchangers, furnaces (Fired Heaters), compressors, tank farms and LPG storage tanks. Reference is made to appropriate codes and standards.
CHAPTER– 3:	OSHA GUIDELINES FOR STAIRS, LADDERS AND PLATFORMS This chapter discusses the OSHA guidelines for Stairways, Handrails, Ladders (portable and fixed type), Cages and Wells, Safety Devices, and

	the layout and access requirements for Platforms (Ladders and Stairs).
CHAPTER– 4:	PIPING LAYOUT This chapter describes the basic principles of piping layout covering, safety, grouping, interferences, supports, pipe ways and rack piping. It discusses the offsite and yard piping, underground piping, utility stations, hose stations etc. The chapter provides system specific information for fire protection, compressed air, steam distribution, fuel oil systems. It also provides equipment specific guidelines for Control valves, Relief valves, Strainers, Instrumentation, Column/Tower and Vessel Piping, Heat Exchanger Piping, Cooling Towers, Heater/Furnace Piping, Pump Piping, Compressor Piping, Turbines and Flare Piping.
CHAPTER– 5:	PIPING DRAWINGS This chapter describes the various type of piping drawings, Orthographic Plans, Piping Isometric Drawings and Spool Isometrics. It provides information on the piping arrangement in 3-D Models, CAD layout in 2-D and 3-D environment, stages of model review, database capabilities and 3-D software tools.

MODULE 7:	**PROCESS PIPING SUPPORTS AND COMPONENTS**
CHAPTER -1:	OVERVIEW OF PIPE SUPPORTS This chapter provides an overview of pipe supports. It introduces readers to the function of supports; primary supports and secondary supports including hangers, restraints and braces. It discusses the necessary input and design steps for the selection of supports.
CHAPTER – 2:	PRIMARY SUPPORTS This chapter discusses yard piping and differentiates between piperacks and sleepers. It discusses the various configurations of piperacks and their layout requirements.
CHAPTER– 3:	SECONDARY SUPPORTS This chapter discusses the type of supports including rigid hangers, variable spring hangers, constant hangers, pipe shoes, various types of clamps, saddles, trunnion supports, roller supports, different types of brackets, restraints, snubbers, struts, braces, PTFE slide bearings etc.

MODULE 8:	**PROCESS PIPING STRESS ANALYSIS**
CHAPTER– 1:	FAILURE ANALYSIS This chapter discusses the material characteristics, strength, stress-strain curve, yield point, modulus of elasticity and relationship of elastic properties. It discusses various types of pipe failures and common causes

	of failures. It also provides information on the specifications of steel pipes, pipe grades, and ASTM material designation.
CHAPTER -2:	THERMAL EXPANSION AND FLEXIBILITY This chapter discusses the pipe failures due to stress caused by temperature variations and material expansion and contraction. It provides methods of increasing flexibility in the design by use of expansion loops, expansion joints, anchors and guides, and directional changes.
CHAPTER -3:	PIPE STRESS ANALYSIS This chapter discusses the fundamental concepts and factors responsible for pipe stress. It discusses theories of failure, hoop and longitudinal stresses, and acceptability conditions for allowable stress as prescribed by ASME B31.1 and B31.3 codes. It provides information on analyzing equipment nozzle loads, various prerequisites, tools and checklists for stress analysis.
CHAPTER -4:	PIPE SUPPORTS SPACING This chapter discusses the allowable pipe spans based on stress and deflection criteria. It includes examples to calculate the support spans and provides recommended spacing table and thumb rules.

MODULE 9:	**PROCESS PIPING CORROSION, INSULATION AND TESTING**
CHAPTER– 1:	PIPE CORROSION AND COATINGS This chapter discusses corrosion basics and the types of corrosion including Galvanic Corrosion, Pitting Corrosion, Selective Leaching, SS Corrosion, Crevice Corrosion, Microbial Corrosion, Cavitation and Erosive Corrosion, Chemical Corrosion, High-temperature Corrosion, Stray Current Corrosion, Stress Corrosion Cracking, etc. It discusses the different methods of protection from corrosion, material selection, use of inhibitors, cathodic protection, galvanizing, surface treatments, etc.
CHAPTER -2:	PIPE INSULATION This chapter discusses the different types of insulation materials and their applications. It provides the characteristics of common insulating materials such as Mineral Fiber, Cellular Materials, Calcium Silicate, Expanded Silica (Perlite), Elastomeric Foam, Foamed Plastic, Expanded Polystyrene and Polyurethane (PUR). It provides information on the protective coverings and finishes.
CHAPTER -3:	PRESSURE AND LEAK TESTING This chapter discusses the Hydrostatic and Pneumatic Testing methods, their requirements, challenges, and pros and cons. It describes when to perform the pressure testing and the applicable test pressures.

CHAPTER -4:	INSPECTION AND TESTING This chapter discusses various destructive and non-destructive testing methods such as Ultrasonic Testing, Eddy-Current Testing, Magnetic Particle Testing, Radiographic (X-Ray) Testing, and Dye-penetrant Testing, etc. It discusses the importance of material traceability.
CHAPTER -5:	PIPE AND COMPONENT IDENTIFICATION This chapter discusses the need for marking and color coding for pipe identification, pipe labelling in plant, component identification, packing and preservation, etc.

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