Practical Process Plant Layout and Piping Design

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1

Introduction to Process Plant Layout and Piping Design

This chapter provides a brief introduction to Process Plant Layout and Piping Design. The fundamental aspects of process plant layout and piping design are discussed. An overview of the procedures and workflow methods used in plant layout and piping design is also provided and the physical quantities and units commonly used are presented.

Learning objectives

- Understanding the fundamental aspects of process plants, plant layout and piping design.
- Understanding the procedures and the workflow methods used in designing process plants and piping systems.
- Understanding the physical quantities and units used in process plant layout and piping design.

1.1 Plant layout fundamentals

Process plants encompass all types of facilities involved in the chemical/physical processing of raw materials into desired finished products or intermediates for further processing. Examples of such processing facilities include the following:

- Refineries.
- Chemical/Petrochemical Plants.
- Fertilizer Plants.
- Offshore Processing Facilities.
- Power Plants.
- Pulp and Paper Mills.
- Food/Beverage Industries.
- Pharmaceutical Plants.
- Water Treatment Plants.
- Waste Treatment Facilities.

The processing facilities included in the preceding list play a vital role in meeting the basic needs of humanity. Therefore, a proper design, maintenance and operation of such facilities is necessary to ensure steady, dependable supply of materials and products required for comfortable and productive living in the contemporary modern world.

Process plants are complex facilities consisting of equipment, piping systems, instruments, electrical systems, electronics, computers and control systems. Figure 1.1 is a picture of a section of a refinery that illustrates the complexity of the equipment, piping and other entities.

Figure 1.1
A small section of a refinery showing equipment, piping system and other items.

The design of process plants is a complex team effort involving different disciplines of engineering: process (chemical), mechanical, piping, electrical, instrumentation, controls, materials and project. It also requires considerable management and coordination skills.

The objective is to design and construct a plant in a cost-effective manner that will meet the process requirements and client specifications and that will operate in a safe reliable manner. Other factors to be considered in the design of process plants are:

- Short design, engineering and construction schedules and getting the plant on stream as quickly as possible.
- Minimizing or even eliminating field rework, which significantly increases plant construction costs.
- Constructability.
- Maintainability.
- Operability.
- Satisfying environmental requirements.
- Minimizing costs.

Figure 1.2 illustrates the interaction and teamwork between different disciplines in the plant layout and piping design effort.

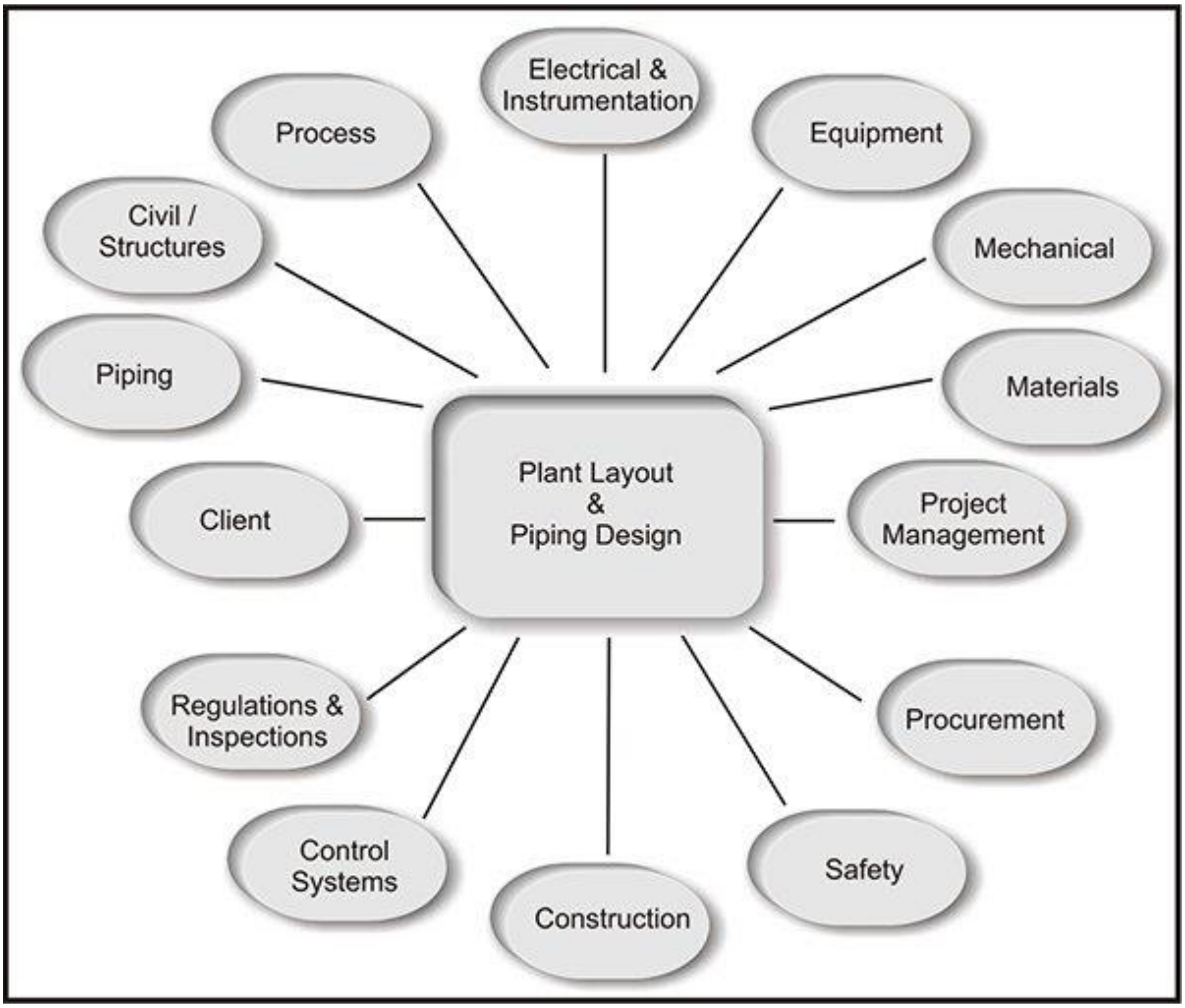


Figure 1.2

Plant Design and Piping Design Effort – Contributions from different disciplines

Tasks involved in plant layout and piping design
Plant Layout and Piping Design involve multiple tasks, which include:

- Development and refinement of "Plot Plans". Plot plans are representations of precise location of equipment and their associated infrastructure (foundations, ladders, platforms etc.). Plot plans are developed taking into consideration process, client and safety requirements. Plant coordinates are used extensively in specifying equipment locations. Plot plans are discussed in more detail in Chapter 4.
- Establishing equipment nozzle locations. Nozzles are components of equipment that connect to pipe.
- Routing of pipes. This is a dynamic and iterative process until the equipment and nozzle locations are finalized.
- Designing equipment ancillaries such as foundations, platforms, and stairways.
- Location of safety equipment such as fire hydrants and safety showers.
- Being cognizant of the location of structures, instruments, control valves, electrical raceways and miscellaneous plant items while routing pipe.

The salient skills and qualities required for plant layout and piping design are as follows:

- Sufficient knowledge of the process being used including function of each equipment. This information is obtained from the process group in the form of "Process Flow Diagrams (PFDs)". PFDs are discussed in detail in Chapter 2.
- Knowledge of the operating and maintenance procedures used for equipment.
- Common sense and attention to detail.
- Ability to think creatively to solve layout problems and challenges.
- Ability to think and visualize spatial relationships between plant items in three dimensions.
- Ability to effectively use computer tools such as 3D modeling software and pipe stress analysis software.
- Excellent communication skills.
- Ability to function effectively as a member of a multi-disciplinary project team.
- Effectively communicate and resolve layout issues and problems with project management.
- Ability to produce, maintain and update project drawings and documents.
- Awareness that conscientious, quality effort during the design and engineering phase can shorten project schedules resulting in economic benefits and client goodwill.

Data used in plant layout and piping design

Massive amounts of data is generated and used in plant layout and piping design. Proper management of plant data is necessary to ensure data accessibility and data integrity, which in turn contributes to the overall quality of the project. Plant data can be classified into three categories.

- **Project data** consists of information such as plant location, local codes and regulations, access roads, waterways, railways, seismic conditions, climate data (average temperature, wind speed and direction, and rainfall).
- **Design and engineering data** is internally generated during the design and engineering phases of the project. Examples of such data include equipment sizes, service conditions (temperature, pressure etc.), and mass flow rates.
- **Vendor data** consists of information provided by equipment vendors by means of vendor drawings and data sheets.

Rules of thumb for plant layout and piping design

The approach to plant layout and piping design can vary depending on the nature of the plant and the project. For example, the design philosophy for an offshore facility is quite different from that for an onshore chemical plant simply because of limited space available on offshore platforms. However, there are a few useful rules of thumb that can be followed.

- Knowledge and understanding of project requirements and project documents.
- Conservation of space and resources.
- Arrangement of equipment in a neat, organized manner taking into account process needs and safety.
- Attention to detail including adjacent equipment, supports and other items, which can cause potential clashes between piping and equipment/supports.
- Consideration of constructability, operability and maintainability of the plant.
- Routing of pipe in a neat, orderly and symmetrical manner keeping in mind the future needs of the plant.
- Avoiding excessive changes in elevations and directions.
- Ensuring consistency in design.
- Avoiding excessive amounts of relocations and revisions by "doing it right the first time".

Common abbreviations used in plant layout and piping design

- N,S,E,W: North, South, East and West
- CL: Centerline
- El: Elevation
- TOS: Top of Steel
- BOP: Bottom of Pipe
- POS: Point of Support
- BBP: Bottom of Baseplate
- ISBL: Inside Battery Limits
- OSBL: Outside Battery Limits
- AG: Above Ground
- UG: Underground
- ϕ: Diameter
- OD: Outside Diameter of pipe
- ID: Inside Diameter of pipe
- TL: Tangent Line
- TYP: Typical
- PFD: Process Flow Diagram
- P&ID: Piping and Instrumentation Diagram

Abbreviations used in PFDs and P&IDs are explained in Chapters 2 and 5 respectively.

1.2 Procedures and workflow methods used in plant layout and piping design

Front end engineering and design: The complex task of designing and building process plants consists of several phases – design, engineering, procurement and construction. The design phase itself consists of conceptual design, design study and detailed design. The conceptual design phase starts with the Process Flow Diagram (PFD) and client specifications. The project scope is also defined during this phase. The working documents used during this phase are the PFD and the Conceptual Plot Plan. Based on the PFD, a large chemical plant or offshore production facility is sub-divided into several small, manageable areas. A Plot Plan is then generated for each area. Boundary limits for each area are specified using spatial coordinates. The boundaries are known as match lines and play an important role in combining the smaller areas. In offshore platforms, plot plans are generated for each deck of the platform. The outcome of the conceptual design phase is usually preliminary sizes and locations of major equipment, which results in the plot plan for use during the design study phase.

The design study phase plot plan is reviewed and discussed by the client and by the project disciplines. Vessel supports and ancillaries are located during this phase. Preliminary routing of major lines also takes place during this phase. The outcome of the design study phase is a final plot plan and a preliminary Piping & Instrumentation Diagram (P&ID). The P&ID contains details and specifications of all equipment, piping, fittings, instrumentation and control valves. The P&ID also contains references to detailed drawings of equipment. The P&ID serves as the primary reference document in communication between engineering and design personnel in all disciplines. Thus, the P&ID is an important working document in the design and engineering of process plants and piping systems. The final plot plan and the P&ID must be approved by all disciplines including safety and loss control.

The conceptual design and design study phases together constitute the Front End Engineering and Design (FEED) phase of the project. The P&ID, plot plans and elevations are used in building a three dimensional electronic model of the process plant. This 3-D model will contain all the components of the plant including equipment, piping, fittings, control stations and support structures. In recent years, the ability to build 3-D electronic models has been greatly enhanced due to advancements in computer hardware and software.

Detailed design and engineering: The FEED phase is followed by the detailed design and engineering phase where every piece of equipment and every component of piping systems is finalized and specified for procurement. During this phase, piping isometric drawings known as "Issued-For Design (IFD)" drawings are generated for analysis and comment by piping engineers and engineers from other disciplines whose input is required. The IFD drawings are pictorial representations of the piping system and allied components containing all dimensional information. Piping engineers primarily use the IFD drawings for the following purposes:

- Pipe Stress Analysis: The piping systems are analyzed for stress and load to ensure that the pipes are not overstressed (both under installed and operating conditions) and are adequately supported. In many cases, piping systems need to have enough flexibility to allow for thermal expansion. Pipe stress analysis also includes computing loads and stresses on equipment nozzles and ensuring that they are within the allowable limits specified by applicable standards and codes. Pipe stress analysis is performed with the aid of stress analysis software.
- Code compliance: The code that governs the design of piping systems for process plants is ASME B31.3: Process Piping. Piping engineers are responsible for interpreting

the code using sound engineering judgment to ensure that the proposed design meets the code requirements.

- Piping material specifications: The piping engineer is responsible for specifying appropriate materials for the pipes. In accomplishing this task, the piping engineer takes into account operating conditions such as the pressure and temperature and also the chemical nature of the fluid being transported. Piping material specification is a very time consuming task but it is very important to specify the right material to ensure the safe and efficient operation of the plant.

The 3-D model is an extremely useful design tool that can be used by all disciplines during the detailed design and engineering phase. The 3-D model is constantly referenced during design review meetings and discussions. These meetings occur frequently and involve all the engineering disciplines and the client. The 3-D model is also useful in clash detection and interference checking. This process saves considerable money and effort by minimizing field rework and field rerouting of pipes. An engineering database is also generated as part of the electronic model. This database is useful in purchasing and procurement functions. As the design is reviewed and updated, so is the 3-D model.

After the detailed design and engineering phase, piping isometric fabrication drawings (also known as spool drawings) along with material specifications are issued for creating the required piping spools. Simultaneously, procurement lists are generated for fittings, instrumentation and other items in the piping system from the engineering database. The procurement lists are used for purchasing the items and contain all the information required to accomplish this task. The procurement lists are also known as “Bill of Materials (BOM)” or “Material Take-off”.

Foundations, structural members and major equipment are put in place using civil/structural drawings, equipment drawings, the 3-D model and other documents. Now the stage is set for the installation of the piping system. Drawings and documents known as “Issued for Construction (IFC)” are used for this purpose. Construction personnel assemble and install the piping system by using IFC drawings and documents.

Figure 1.3 illustrates the workflow methods used in process plant layout and piping design. It should be noted that workflow methods could vary depending on client and company preferences. It should also be noted that the entire process is iterative in nature. There is continuous interaction between the different phases of the project.

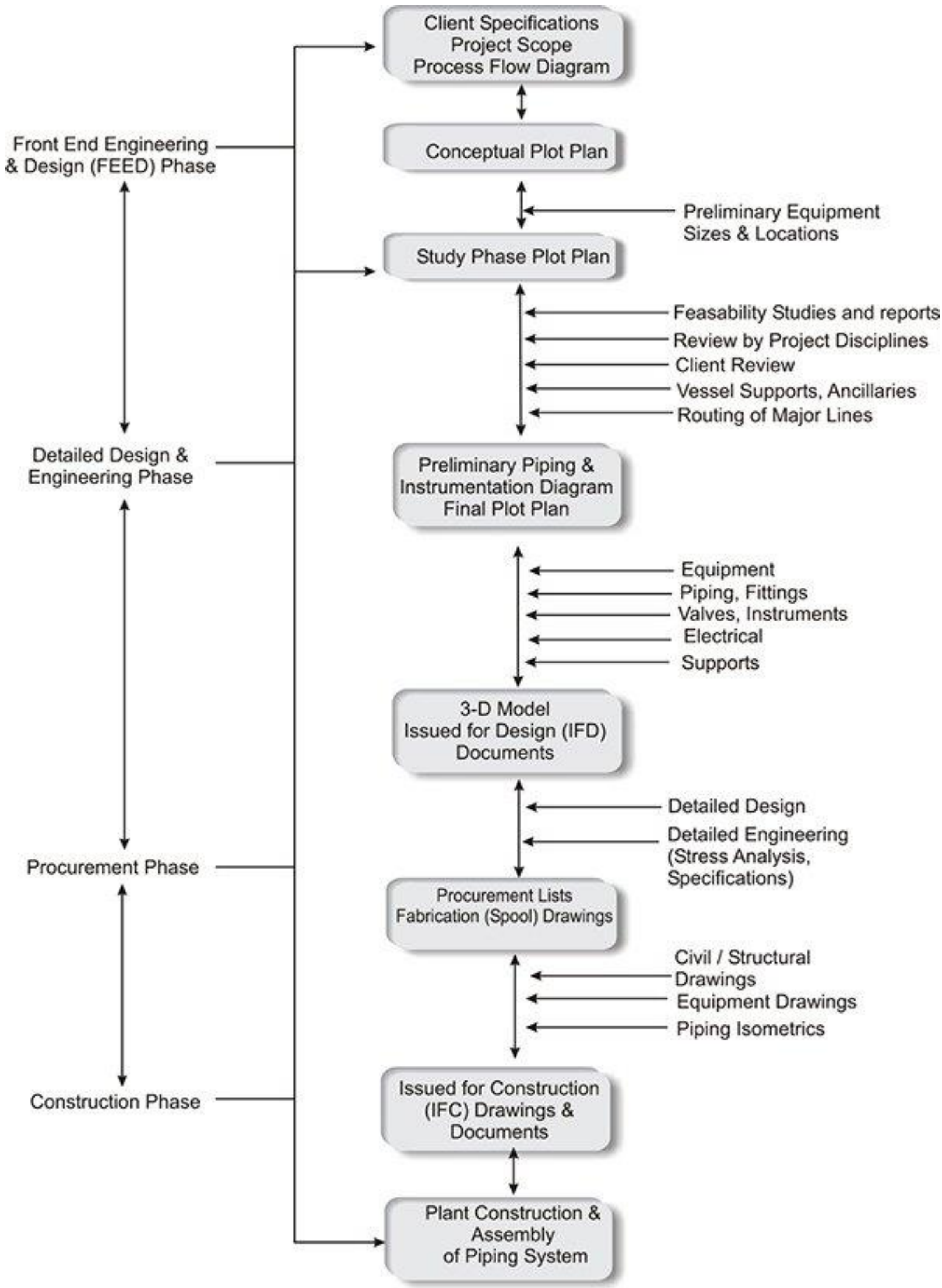


Figure 1.3

Procedures and Workflow Methods Used in Plant Layout and Piping Design

Organizations involved in providing standards and guidelines for plant layout and piping design

Some of the organizations that provide standards and guidelines for plant layout and piping design are listed here along with their web addresses.

- American Society for Mechanical Engineers (ASME): Publishes and updates codes for piping design. The code relevant to the design of piping systems is **ASME B31.3 – 2004 Process Piping**. (www.asme.org)
- Center for Chemical Process Safety (CCPS): Publishes documents and guidelines related to process safety. The focus is on preventing or mitigating catastrophic releases of chemicals, hydrocarbons, and other hazardous materials. CCPS has published guidelines for "Facility Siting and Layout". (www.aiche.org/ccps)
- Construction Industry Institute (CII): Provides guidelines for cost effective and safe construction methods and has several publications on constructability. (www.construction-institute.org)
- Society of Piping Engineers and Designers (SPED): Promotes excellence and quality in the practice of piping engineering and design. SPED emphasizes education and training and has certification programs for piping designers. (www.spedweb.org)
- Occupational Safety and Health Administration (OSHA): Provides regulations and safety standards for the operation of process plants. (www.osha.gov)
- National Fire Protection Association (NFPA): Provides fire protection standards for process plants and for gas storage and handling. (www.nfpa.org)

1.3 Physical quantities and units in plant layout and piping design

The physical quantities and units used in plant layout and piping design are summarized in Table 1.1. The units are specified both in the SI System and in the US Customary System (USCS).

Table 1.1
Physical Quantities and Units Used in Plant Layout and Piping Design

Physical Quantity	Symbol	SI System	USCS
Length	L	Meter (m)	Feet (ft)
Diameter	D	Millimeter (mm)	Inch (in)
Thickness	Δx	Millimeter (mm)	Inch (in)
Mass	m	Kilogram (kg)	Pound mass (lbm)

Time	t	Seconds (s)	Seconds (sec)
Temperature	T	Degree Celcius (°C)	Degree Farenheit (°F)
Area	A	Square meter (m^2)	Square feet (ft^2)
Volume	V	Cubic meter (m^3)	Cubic feet (ft^3)
Velocity	v	Meters/sec (m/s)	Feet/sec (ft/sec)
Acceleration	a	Meters/sec^2 (m/s^2)	Feet/sec^2 (ft/sec^2)
Force	F	Newton (N)	Pound force (lbf)
Pressure	P	Pascal (Pa)	Pounds/in^2 (psi)
Stress	s	Megapascal (Mpa)	Pounds/in^2 (psi)
Strain	ε	Mm/mm	in/in
Work	W	Newton-meter (N.m)	Foot pound force (ft-lbf)
Energy	E	Joule (J)	British thermal unit (Btu)
Energy flow	$\dot{E}$	kilowatts (kW)	Btu/sec or Btu/hr
Enthalpy	H	kilojoules (kJ)	Btu
Mass flow	$\dot{m}$	kg/s	Lbm/sec
Volume flow	$\dot{V}$	m^3/s	ft^3/sec

Notes: The unit of force in the SI system is Newton (N). A Newton is defined as the force required to produce an acceleration of 1 m/s2 on a body of mass 1 kg. The unit of force in the US Customary System (USCS) is Pound force (lbf). One pound force is the force required to accelerate 1 lbm at 32.2 ft/sec2. This leads to the use of a conversion constant, gc in USCS. The following equations are useful in understanding the units of different physical quantities.

$$1\ \mathrm{N} = \frac{1\ \mathrm{kg.m}}{\mathrm{s}^2} \qquad 1\ \mathrm{lbf} = \frac{32.2\ \mathrm{lbm\text{-}ft}}{\mathrm{sec}^2}$$

$$g_c = 32.2 \frac{\mathrm{lbm\text{-}ft}}{\mathrm{lbf\text{-}sec}^2}$$

$$1\ \mathrm{Pa} = 1 \frac{\mathrm{N}}{\mathrm{m}^2} \qquad 1\ \mathrm{psi} = 1 \frac{\mathrm{lbf}}{\mathrm{in}^2}$$

$$1\ \mathrm{J} = 1\ \mathrm{N.m} \qquad 1\ \mathrm{Btu} = 778\ \mathrm{ft\text{-}lbf}$$

$$1\ \mathrm{W} = 1 \frac{\mathrm{J}}{\mathrm{s}} \qquad 1\ \mathrm{hp} = \frac{550\ \mathrm{ft\text{-}lbf}}{\mathrm{sec}}$$

Unit Prefixes:

kilo (k) = 10^3	Mega (M) = 10^6	Giga (G) = 10^9
milli (m) = 10^{-3}	micro (μ) = 10^{-6}	nano (n) = 10^{-9}

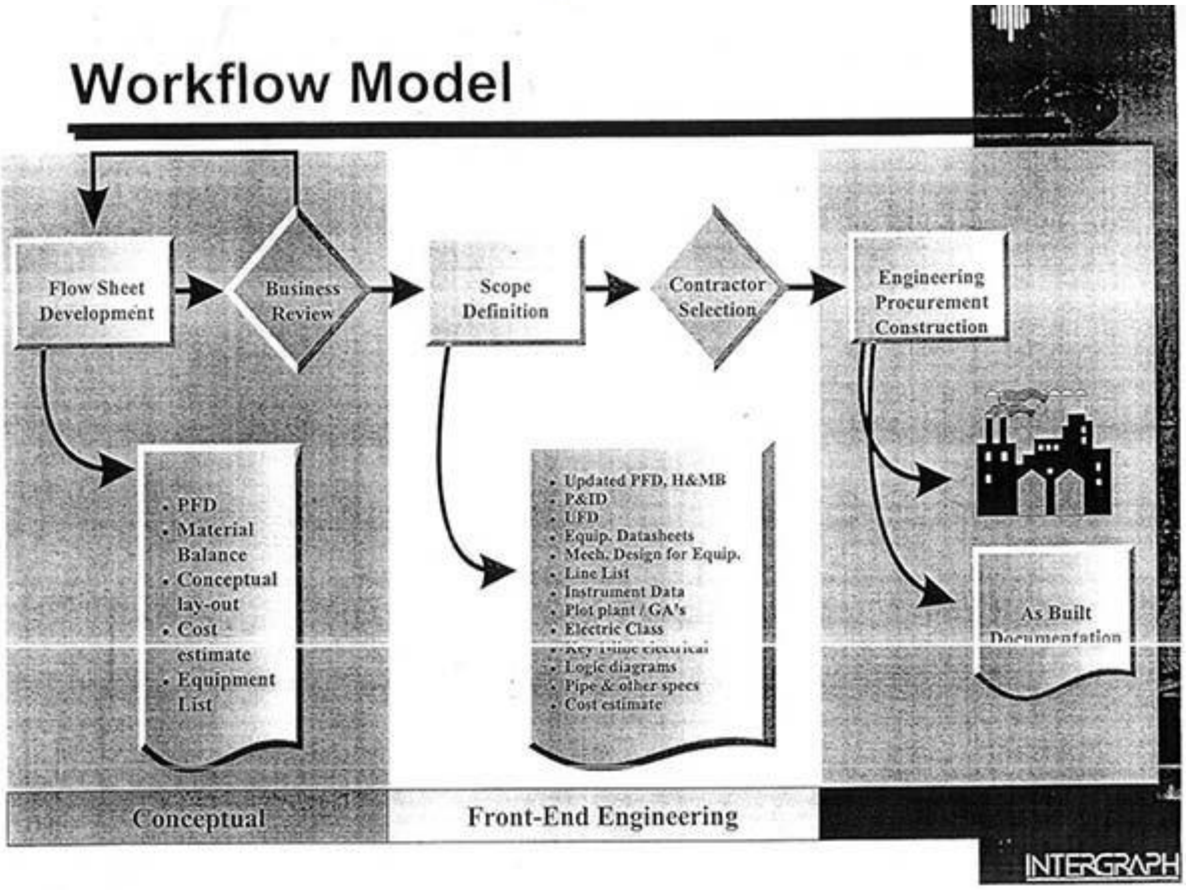


Figure 1.4
Workflow model

1.4 Summary

The objective of process plant layout and piping design activities is to design and construct a plant in a cost-effective manner that will meet the process requirements and client specifications and will operate in a safe, reliable manner. This chapter provides an understanding of the tasks involved and the skills required in these activities. It also provides brief guidelines for plant layout including some general rules of thumb. In addition to adequate and safe design, designers and engineers must consider issues such as constructability, maintainability and operability of a process plant. An overview of the tools, documents, workflow methods and procedures used in plant layout and piping design is also included in this chapter. Organizations that provide guidelines for plant layout and piping design are mentioned in this chapter along with their web addresses. Physical quantities typically used in plant layout and piping design are discussed along with their units both in the SI System and the US Customary System (USCS).

Fundamentals of Process Plant Layout and Piping Design

Practical Exercise 1

1. What are the main tasks of a plant layout designer? (Name just three)

2. Select the correct order of progress during a project.

A. Conceptual Plan, PFD, P&ID, Plot Plan.
B. PFD, Conceptual Plan, Plot Plan, P&ID.
C. PFD, P&ID, Conceptual Plan, Plot Plan.
D. Plot Plan, PFD, Conceptual Plan, P&ID.

3. Besides the design and engineering phases of a project, what other aspects of the project should a good designer be concerned about? Explain.

4. Expand the following abbreviations:

A. IFD:
B. TOS:
C. PFD:
D. ANSI:

5. Psi stands for ______________ and is a unit of _____________ and kPa stands for _____________.

6. The unit of pipe stress in the SI system is _______________.

7. The unit of force in the US customary system is ______________.

8. What are the possible consequences of not knowing maintenance requirements for a particular piece of equipment?

2

Introduction to Chemical Processing Methods

This chapter provides an overview of the processes used in chemical/petrochemical and other facilities. Process Flow Diagrams (PFDs) are also discussed in this chapter.

Learning objectives

- Understanding the processing methods used in the chemical industry.
- Understanding symbols and terminology used in PFDs.
- Interpreting PFDs and be able to use information from PFDs for plant layout and piping design.

2.1 Basic principles of chemical process technology

The chemical process industry primarily comprises processing raw materials such as crude oil and natural gas into finished products such as gasoline (petrol), aviation fuel, cooking gas, fertilizers and polymers to meet the needs of consumers. Chemical processing principles are also used in the production of processed foods and medicines, in water and wastewater treatment, and in pollution control. Thus, the chemical process industry plays a major role in meeting the basic needs of humanity viz., food, shelter, clothing, medicine and transportation. Some products of the chemical industry enter the market as consumer goods while others are intermediates used in the manufacture of consumer items. Considering the great variety of useful products produced by the chemical industry, it touches our lives like no other industry. Chemical and allied industries create and synthesize products and in this sense are different from many manufacturing industries that assemble products. The chemical industry accomplishes the transformation from raw materials to finished products through a series of chemical and physical changes.

Understanding the chemical process technology requires an understanding of the processes that are used in bringing about chemical and physical changes during commercial production. The study of the great number and the vast variety of chemical and physical changes used in the chemical process industry is greatly simplified by organizing the changes into ***unit operations*** and ***unit processes***. A comprehensive understanding of technologies used in chemical processing also requires knowledge of the scientific and engineering principles used in the development and use of such technologies.

Unit operations

Chemical processing consists of a sequence of steps some of which may involve only physical changes. Operations that accomplish physical changes in the material being processed are called unit operations. For example, the process used in manufacturing common salt consists of the following sequence of unit operations: transportation of solids and liquids, transfer of heat, evaporation, crystallization, drying and finally screening. Unit operations are identical in fundamental principles regardless of the material being processed. By systematically studying these operations, which clearly cross industry and process lines, the treatment of all processes can be unified and simplified. Physical and mathematical models developed for each unit operation can be applied across a broad spectrum of chemical industry. Some important unit operations, their application and equipment used are described here.

Distillation: Distillation is the process of separation of components by using the differences in their boiling points. The more volatile component (with a lower boiling point) vaporizes first and is condensed. Distillation is widely used in the chemical process industry. A very important application is the atmospheric distillation of crude oil used in the petroleum industry to derive products such as gasoline and kerosene. The equipment used in this process is a distillation column. The distillation column typically consists of trays through which the vapor bubbles up and the liquid flows down. It is equipped with a condenser on top and a reboiler at the bottom. In some cases, packing material is used instead of trays. The diameter of the column depends on the quantity of material being processed. The numbers of trays or stages dictate the height of the column. The number of stages is a function of the components in the mixture being separated and the vapor-liquid equilibrium characteristics. Condensers and reboilers are heat exchangers that are designed by using the principles of heat transfer.

Drying of solids: The unit operation here is the removal of moisture. Typical equipment used in drying are spray driers, rotary driers and tunnel driers. Each of these is described below with examples of applications in the chemical process industry.

- The spray drier is suitable for large capacity operation of liquid feed to give powdered, spherical, free flowing product. Spray driers are used in production of pigments, detergents, synthetic resins and inorganic salts.
- The rotary drier is suitable for drying free flowing granular solids that do not stick. High temperature rotary kilns are used in the manufacture of cement.
- The tunnel drier is used in drying pastes or powders in trays. It is also used in drying pottery, lumber and leather in sheet or shaped forms.

Evaporation: Evaporation is used in increasing the concentration of a solution by vaporizing a portion of the volatile solvent; usually water. The feed is a dilute solution and the product is a concentrated solution. Evaporation is used in the production of sugar and common salt. It is used in thickening the liquor in paper mills and also in producing potable water from seawater. Evaporators consist of vessels with a bank of tubes. The material to be concentrated flows inside the tubes and the heat required is generated by steam condensing on the outside of the tubes. The design of evaporators involves the principles of heat transfer and mass and energy balances. In a single-effect evaporator, the vapor from the boiling liquid is condensed and discarded. In a multiple-effect evaporator, the vapor from the first evaporator is fed into the steam chest of the second evaporator; the vapor from the second evaporator is fed into the steam chest of the third evaporator and so on. Multiple-effect evaporators decrease the consumption of steam required.

Gas absorption: In gas absorption, a liquid solvent absorbs one of the components in a mixture of gases. An example of gas absorption is absorption of ammonia from a mixture of ammonia and air using water as the solvent. This technique is also used in the removal of hydrogen sulfide from hydrocarbons. A common apparatus used in gas absorption is the packed tower. The device consists of a cylindrical tower, equipped with a gas inlet and distributing space at the bottom and a liquid inlet with a distributor at the top. The outlets for the liquid with the solute gas and the lean gas are located at the bottom and top respectively, thus achieving a counter flow of the liquid and gas streams. A mass of inert solid shapes forms the core of the tower between the inlet and outlet streams. This packing promotes intimate contact between the liquid and gas phases. The design of the absorption tower uses the principles of diffusion and mass transfer. The reverse process of gas absorption is known as desorption or gas stripping. In this case the solute is removed from the liquid solvent by contacting it with an inert gas. The pure solvent is then recycled and reused for gas absorption.

Liquid-liquid extraction: In this unit operation, one constituent from a liquid mixture is removed by using a liquid solvent. The liquid phase containing the solute and the solvent is known as the ‘extract’ whereas the liquid phase with the solute removed is known as the “raffinate”. As an example, naphthenes are removed from lube oil fractions using furfural as a solvent. Typical equipment used in liquid-liquid extraction includes a battery of mixers and settlers, packed columns and towers with mechanisms for agitation of the liquid phase to promote intimate contact.

Leaching: In leaching, a solvent is used in removing a soluble component from a mixture in the solid phase. This technique is widely used in the mining industry to recover valuable metal from ores. A common set-up used in leaching is percolation of solvent through a stationary bed of solid to be leached. Other techniques such as moving-bed leaching and dispersed-solid leaching are also available for use.

Crystallization: Crystallization is the formation of solid particles from a homogenous phase. Since a variety of materials are marketed in crystalline form, crystallization from solution is an important chemical processing technique. Crystallization is a very useful method for producing pure chemical substances in a satisfactory condition for packing and storing. It needs to be noted that pure crystals can be formed even from an impure solution. The process of crystallization is used in the production of common salt, sugar, dyes and pigments. Crystallization equipment can be classified into the following three categories:

- Tank crystallization – Here, super-saturation is achieved by cooling hot, saturated solutions. The cooling is achieved by natural convection and can be enhanced by cooling coils or cooling jackets.
- Evaporator-Crystallizers – Here, super-saturation is achieved by evaporation.
- Adiabatic Vacuum Crystallizers – Here, super-saturation is achieved by evaporation combined with adiabatic cooling, which causes nucleation and growth of crystals.

Other unit operations

- Filtration is used in separating solids from solutions. Examples of this operation are separation of minerals from slurries and pulp fibers from thick liquor in paper mills. Typical equipment used in filtration are rotary drum filters and filter press.

- Removal of particulate solids from gases is used in controlling air pollution and in cutting down product losses. Typical equipment used in achieving these are cyclone separators, electrostatic precipitators wet scrubbers.
- Centrifugation is used in separating very finely divided solids from liquid or liquids from liquid emulsions. This is achieved by the use of rotating centrifuges.
- Membrane Separation uses a semi-permeable membrane to achieve separation. This technique is used in dialysis where caustic is separated from sugar or cellulose due to the wide difference in molecular weights. Micro-porous Ni barriers are used in separating light uranium compounds from heavy uranium compounds, since the light compounds diffuse through the membrane or barrier.

Unit processes

Just as unit operations are useful in the systematic study of physical changes, the concepts of unit processes can be used in systematizing chemical changes or reactions found in chemical industries. The advantage is that prior performance data from a group of chemical reactions can be applied to the production of other chemicals using similar unit processes. As an example, nitration is a commonly used unit process. The nitration reaction is an exothermic reaction and has certain characteristics of reaction rates and reaction equilibrium. This data has led to the design for nitration reactors. These reactors are typically liquid phase reactors made of cast iron with provision for mixing of reactants and for heat removal. Similar designs can be used for other nitration reactors. Listing all unit processes used in the chemical industry is beyond the scope of this course manual. A few commonly occurring unit processes and their applications are described in the following paragraphs.
Alkylation: Alkylation is a unit process where an alkyl radical (-CH3) is added to a reactant. An example is alkylation of butylene in the presence of heat and catalyst to produce iso-octane, which is an important additive for gasoline.

Combustion: Combustion is burning of fuel where the fuel reacts with oxygen to form combustion products. More importantly, the heat released during combustion is used in process heating and in power generation.

Condensation: Condensation is a chemical reaction where water is one of the products. Condensation reactions are widely used in the manufacture of organic chemicals, dyestuffs and synthetic perfumes.

Cracking or Pyrolysis: Cracking is a unit process where high molecular weight compounds are broken down into useful products having lower molecular weights. Cracking is used in petroleum refining where the heavier fractions of crude distillation are broken down into more useful products. This reaction takes place in a fluid bed consisting of a catalyst. The reactors are known Fluid Catalytic Cracking Units (FCCU).

Esterification: Esterification is the reaction of an organic acid with alcohol to produce esters or organic salts. This reaction is used in manufacture of soaps and oils.

Halogenation: Halogenation is addition of chlorine molecule and is used in the production of organic chemicals.

Isomerization: Isomerization is used in changing the structural formula of organic compounds from straight chain to branched structure and is used in petroleum refining.

Polymerization: Polymerization reactions are used in building large polymer macromolecules. There are two types of polymerization reactions - addition polymerization and condensation polymerization. Polymerization reactions are used in the manufacture of plastics and synthetic fibers.

Engineering and scientific principles used in chemical process technology

Chemistry: The principles of chemistry are essential for understanding the basis of chemical reactions involved in chemical processing. Balanced chemical equations are important in calculating the yield of products.

Mass and energy balances: The principles of mass and energy balances are used in sizing of equipment for processes and also in determining energy requirements (heat addition or removal) for processes. Mass and energy balance calculations are used in monitoring the flow of material and energy through different units in any chemical plant. This involves the synthesis and analysis of Process Flow Diagrams (PFDs).

Fluid mechanics: In chemical processing, fluids must be transported between process units and different equipment. Fluids are typically transported in pipes. The principles of fluid mechanics are used in the design of piping systems in chemical process industries. Piping systems include pipes, fittings, valves, pumps and ancillary equipment. Important considerations in the design of piping systems are fluid properties (density, viscosity), fluid velocity and pressure and elevation differences. Principles of fluid mechanics are also used in measurement of pressure and flow rates of fluids. Pumps are used in providing the required energy for fluid transport. The most commonly used pump is a centrifugal pump.

Heat transfer: Addition or dissipation of heat is a common feature in the chemical industry. The principles of heat transfer are used in the design of heat exchangers, heating coils, furnaces, fired heaters, condensers, reboilers and jacketed vessels.

Thermodynamics: The concepts of thermodynamics have important applications in chemical processing. It is particularly useful in calculating the following quantities related to chemical reaction: heat of reaction – whether heat is absorbed (endothermic) or released (exothermic), equilibrium constant and how it is affected by changes in temperature and pressure, equilibrium conversion of a reactant. The principles of thermodynamics are also used in energy balances, in calculating heats of solution and absorption, in calculating heat effects in phase changes and in calculating efficiencies of energy producing and energy consuming devices.

Reaction kinetics: The principles of reaction kinetics are used in the design of chemical reactors and in the prediction of reaction rates, reaction conversions and the time required to achieve a particular level of conversion. Chemical reactors are classified as homogeneous (single phase) and heterogeneous (multiple) and further into batch reactors, stirred tank reactors and tubular reactors.

Process engineering economics: Process engineering economics is concerned with the economic aspects of the chemical process industry. Process engineering economics is used in estimation of capital costs, operating costs and other cost factors. It is also used in the calculation of rate of return for capital projects. The concepts of process engineering economics are used in evaluating alternatives and in selecting alternatives that minimize costs and maximize profits at the lowest capital expenditure. Any comprehensive evaluation of chemical process technology must include economic study and analysis.

Mass transfer: The principles of mass transfer and diffusion are used in the design of equipment such as distillation columns, absorption towers, dryers and ion-exchange units.

Process control and instrumentation: Appropriate instrumentation and communication methods are necessary to monitor the status of a given process. Proper control strategies and methods are essential in maintaining process variable within reasonable limits and also in ensuring process safety. An important tool in the synthesis of instrumentation and control strategies is the Process & Instrumentation Diagram (P&ID).

2.2 Process flow diagrams (PFDs)

Process flow diagrams (PFDs) are schematic representations of process plants that provide an overview of all the processing steps (unit operations and unit processes) used in process plants.

PFDs include the following information:

- All major equipment used in the plant. Equipment can be classified as **Process Equipment** (Reactors, Towers, Exchangers) and **Mechanical Equipment** (Pumps, Compressors, Blowers).
- Stream information and flow directions. Streams within a process plant can be classified into **Material Streams** and **Energy Streams**. Material streams show the flow of reactants, products and other fluids in the plant while energy streams show the flow of heat energy.
- Mass flow rates, compositions, temperature, and phase fraction (liquid or vapor) of each material stream.
- Energy (heat) transfer rates.
- Sometimes, the preceding information is presented in the form a “Stream Summary Table” instead of indicating it on the PFD.

Icons used in process flow diagrams

Figure 2.1 shows the icons commonly used in PFDs.

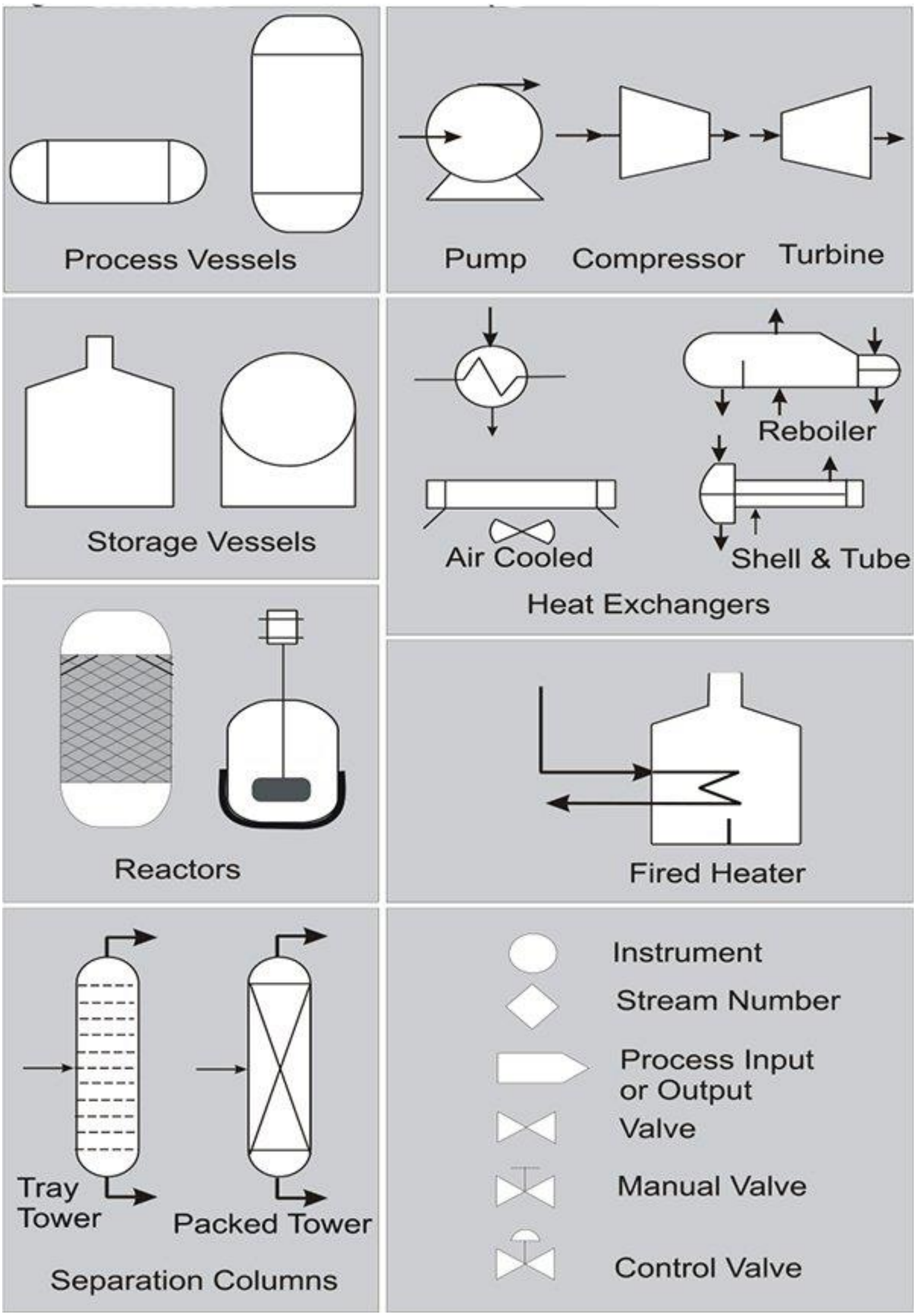


Figure 2.1

Icons Commonly Used in Process Flow Diagrams (From: Product & Process Design Principles, Warren Seider et al., 2nd ed., John Wiley and Sons, 2004)

Process flow diagram for the manufacture of vinyl chloride

Figure 2.2 shows the PFD for the manufacture of vinyl chloride using chlorine and ethylene as raw materials. Vinyl chloride is an important product since it is used in the manufacture of polyvinyl chloride (PVC). This manufacturing process involves three major steps.

- Direct chlorination of ethylene to produce ethylene dichloride (1, 2-dichloroethane).
- Pyrolysis of ethylene dichloride to produce vinyl chloride and hydrogen chloride.
- Separation and purification steps to separate vinyl chloride from hydrogen chloride and unreacted components.

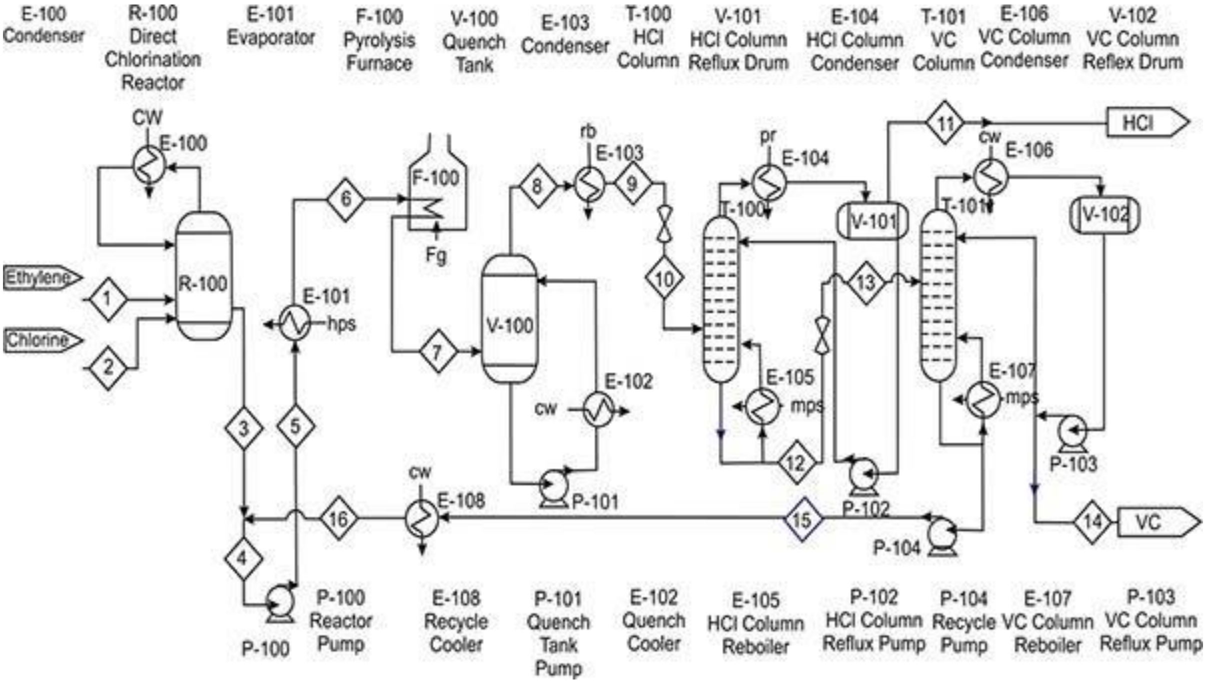


Figure 2.2
Process Flow Diagram for the Manufacture of Vinyl Chloride (From: Product & Process Design Principles, Warren Seider et al., 2nd ed., John Wiley and Sons, 2004)

Table 2.1 gives typical information on different streams in the PFD for the manufacture of vinyl chloride.

Table 2.1
Stream Information Table for PFD in Figure 2.2

Stream Number	1	2	3	4
Temperature (°C)	25	25	90	90
Pressure (Atm)	1.5	1.5	1.5	1.5
Vapor Fraction	1.0	1.0	0.0	0.0

Mass Flow (kg/hr)	20 410	51 545	71 955	1 19 910
Component Mole Fractions Ethylene Chlorine Ethylene dichloride Vinyl chloride Hydrogen Chloride	1 0 0 0 0	0 1 0 0 0	0 0 1 0 0	0 0 1 0 0

Stream Number	**5**	**6**	**7**	**8**
Temperature (°C)	91.3	242	500	170
Pressure (Atm)	26	26	26	26
Vapor Fraction	0.0	1.0	1.0	1.0
Mass Flow (lbm/hr)	1 19 910	1 19 910	1 19 910	1 19 910
Component Mole Fractions Ethylene Chlorine Ethylene dichloride Vinyl chloride Hydrogen Chloride	0 0 1 0 0	0 0 1 0 0	0 0 0.25 0.375 0.375	0 0 0.25 0.375 0.375

Stream Number	**9**	**10**	**11**	**12**
Temperature (°C)	6	6.5	-26.4	94.6
Pressure (Atm)	26	12	12	12
Vapor Fraction	0.0	0.0	1.0	0.0
Mass Flow (lbm/hr)	1 19 910	1 19 910	26 500	93 410

Component Mole Fractions Ethylene Chlorine Ethylene dichloride Vinyl chloride Hydrogen Chloride	 0 0 0.25 0.375 0.375	 0 0 0.25 0.375 0.375	 0 0 0 0 1	 0 0 0.4 0.6 0

Stream Number	**13**	**14**	**15**	**16**
Temperature (°C)	57.7	32.2	145.6	90
Pressure (Atm)	4.8	4.8	4.8	4.8
Vapor Fraction	0.23	0	0.0	0.0
Mass Flow (lbm/hr)	93 410	45 455	47 955	47 955
Component Mole Fractions Ethylene Chlorine Ethylene dichloride Vinyl chloride Hydrogen Chloride	 0 0 0.4 0.6 0	 0 0 0 1.0 0	 0 0 1.0 0 0	 0 0 1.0 0 0

Process utilities: All process plants require utilities such as steam and cooling water. The primary purpose of utilities is heating and cooling of process streams. Heating is accomplished by using steam. Cooling is accomplished by using cooling water and refrigerants. Table 2.2 lists the pressure and temperature ranges for utilities used in process heating. The utilities are listed in the order of increasing cost per kJ of heating. Table 2.3 lists utilities used in process cooling in the order of increasing cost per kJ of cooling.

Table 2.2
Pressure and Temperature Ranges for Heating Utilities

Utility	**Pressure Range (kPa)**	**Temperature Range (°C)**
Low Pressure Steam (LPS)	200 to 300	120 to 140
Medium Pressure Steam (MPS)	700 to 1400	160 to 190

High Pressure Steam (HPS)	2700 to 4200	230 to 260
Petroleum Oils (PO)		Below 320
Dowtherm (DT)		Below 400

Table 2.3
Utilities Used in Cooling

Utility	**Description**
Air Cooling (AC)	Supply at 30°C, ΔT = 5°C to 10°C
Cooling Water (CW)	Supply at 25°C, ΔT = 10°C to 15°C
Chilled Water (CHW)	ΔT = 25°C to 50°C
Refrigerated Brine (RB)	Cooling in the range of 10°C to –18°C
Propane Refrigerant (PR)	Cooling in the range of -6°C to –40°C

Equipment: Different types of process and mechanical equipment are used in process plants. They include vessels, towers, heat exchangers, fired heaters, pumps and compressors. Proper specification of equipment is an important task in process plant layout and design. Specifications required for each type of equipment are summarized in Table 2.4.

Table 2.4
Summary of Equipment Specifications

Equipment	**Specifications Required**
Vessels	Pressure, Temperature, Height, Diameter, Materials of Construction, Orientation.
Towers	Pressure, Temperature, Height, Diameter, Materials of Construction, Orientation, Number and type of trays, Height and Type of Packing.
Fired Heaters	Type, Duty, Tube Pressure and Temperature, Materials of Construction, Radiant and Convective Heat Transfer Areas.
Heat Exchangers	Type, Duty, Number of Shell and Tube Passes, Operating Pressure, Temperature, and Pressure Drop for both Shell and Tubes, Materials of Construction.
Pumps	Flow Rate, Suction and Discharge Pressures, Temperature, Shaft Power, Type of Driver, Materials of Construction.
Compressors	Inlet Flow Rate, Suction and Discharge Pressures, Temperature, Shaft Power, Type of Driver, Materials of Construction.

2.3 Summary

In this chapter, the basic principles of chemical technology have been discussed. Unit Operations and Unit Processes typically used in process plants have been described. Process Flow Diagrams (PFDs) and the information presented in PFDs have been discussed at length.

Fundamentals of Process Plant Layout and Piping Design

Practical Exercise 2

Given the attached PFD and the process description for the production of vinyl chloride:

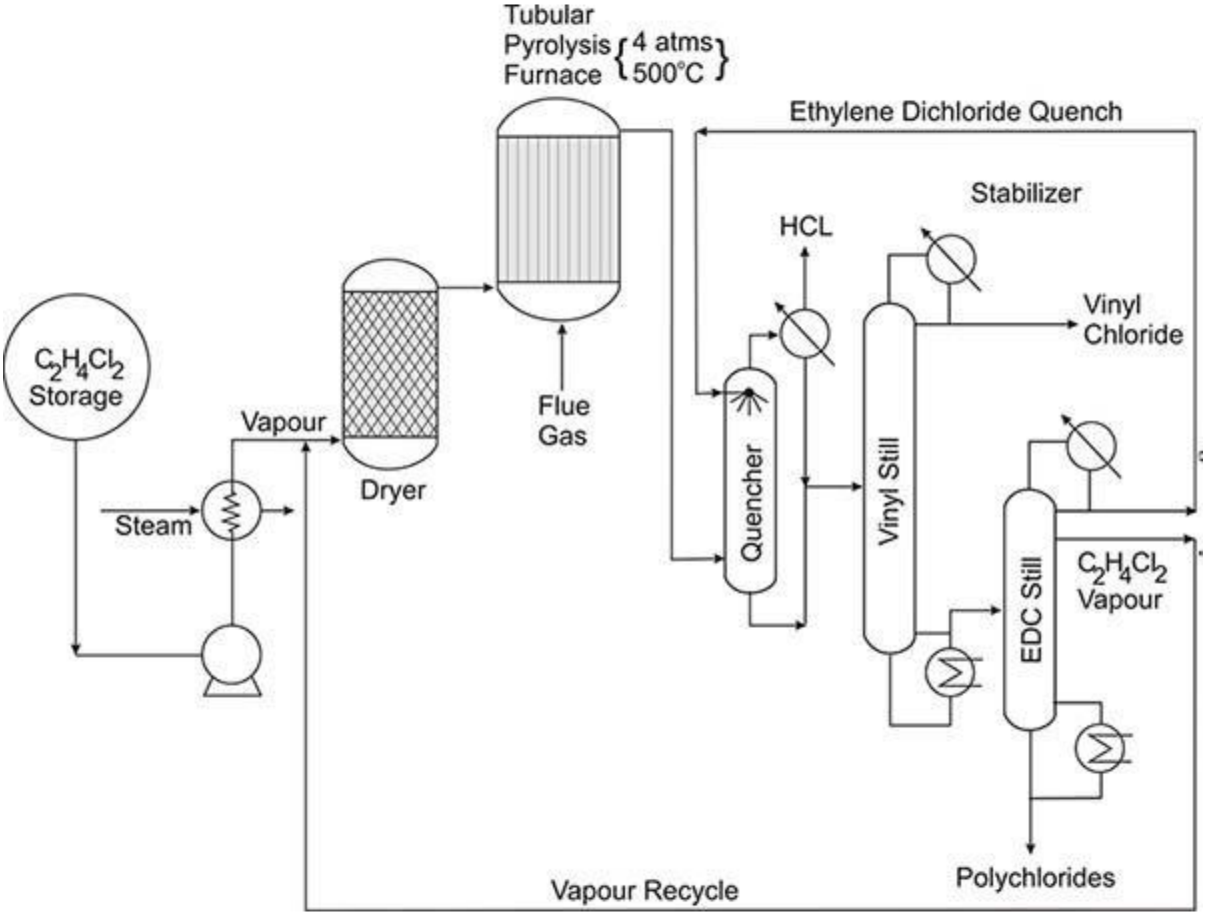
1. Identify unit operations and unit processes.
2. Specify the temperature and the pressure of some of the streams

Process Description For The Manufacture of Vinyl Chloride (VC) By Thermal Pyrolysis of Ethylene Dichloride (EDC)

Chemical Reaction: $$\underset{\text{EDC}}{C_2H_4Cl_2} \xrightarrow[4\text{ atm}]{500°C} \underset{\text{VC}}{C_2H_3Cl} + HCl$$

EDC vapor at a pressure of 4 atm. is dried by using a silica gel drier. It is then sent to a stainless steel tubular cracking furnace where the conditions are maintained at about 480-520°C and 4 atm. The furnace is heated by external flue gas. The contact surface catalyst within the tubes is pumice or charcoal. The conversion per pass is around 50% and the ultimate yield is about 95%. The product from the furnace is quenched with cold EDC to prevent the back reaction and to form condensable product components. Uncondensed gases are sent to a surface heat exchanger to condense any remaining EDC and VC present in vapor form. The non-condensable HCl is sent to an adjacent process area for further processing. The condensate is then sent to a VC still or fractionator where VC is taken as an overhead product and sent to storage after stabilization. The bottoms from the VC fractionator is to an EDC still to further separate EDC from heavier fractions. Part of the separated EDC is recycled in vapor form and the rest, in liquid form, is used for cold quench.

Process Flow Diagram: Vinyl Chloride Production



3

Equipment Used in Process Plants

In this chapter, equipment typically used in process plants is described. This includes process equipment such as reactors, towers and exchangers and mechanical equipment such as pumps and compressors. Process and mechanical equipment used in process plants are discussed in this chapter.

Learning objectives

- Process equipment: reactors, towers, exchangers and vessels.
- Mechanical equipment: pumps and compressors.
- Equipment nozzle specifications.
- Equipment drawings.
- Equipment foundations and supports.

3.1 Introduction

Equipment in process plants can be classified into two categories – process equipment and mechanical equipment. Process equipment is used in the different processing steps as indicated by the Process Flow Diagram (PFD). Reactors and heat exchangers are examples of process equipment. Mechanical equipment is used in the transport of fluids from one process unit to another and also in the compression of gases. Pumps and compressors are examples of mechanical equipment. Mechanical equipment consists of rotating machinery. Good practices in process plant layout and piping design requires adequate knowledge of equipment used in process plants and the ability to interpret equipment documents and drawings. Both these types of equipment are discussed in this chapter.

3.2 Process equipment

Towers

Towers are tall, slender pieces of vertical equipment found in process plants. The most important example of a tower is the distillation column, also known as a fractionating tower. The distillation column is used in the separation of components based on the differences in the boiling points of the components. For example, in the distillation of crude oil, preheated feed is fed to a “flash zone” in the column where liquid and vapor separate. The lighter fractions boil first and rise to the top of the column and the heavier fractions remain as liquid and settle at the bottom of the column. Figure 3.1a shows a PFD for a typical distillation column.

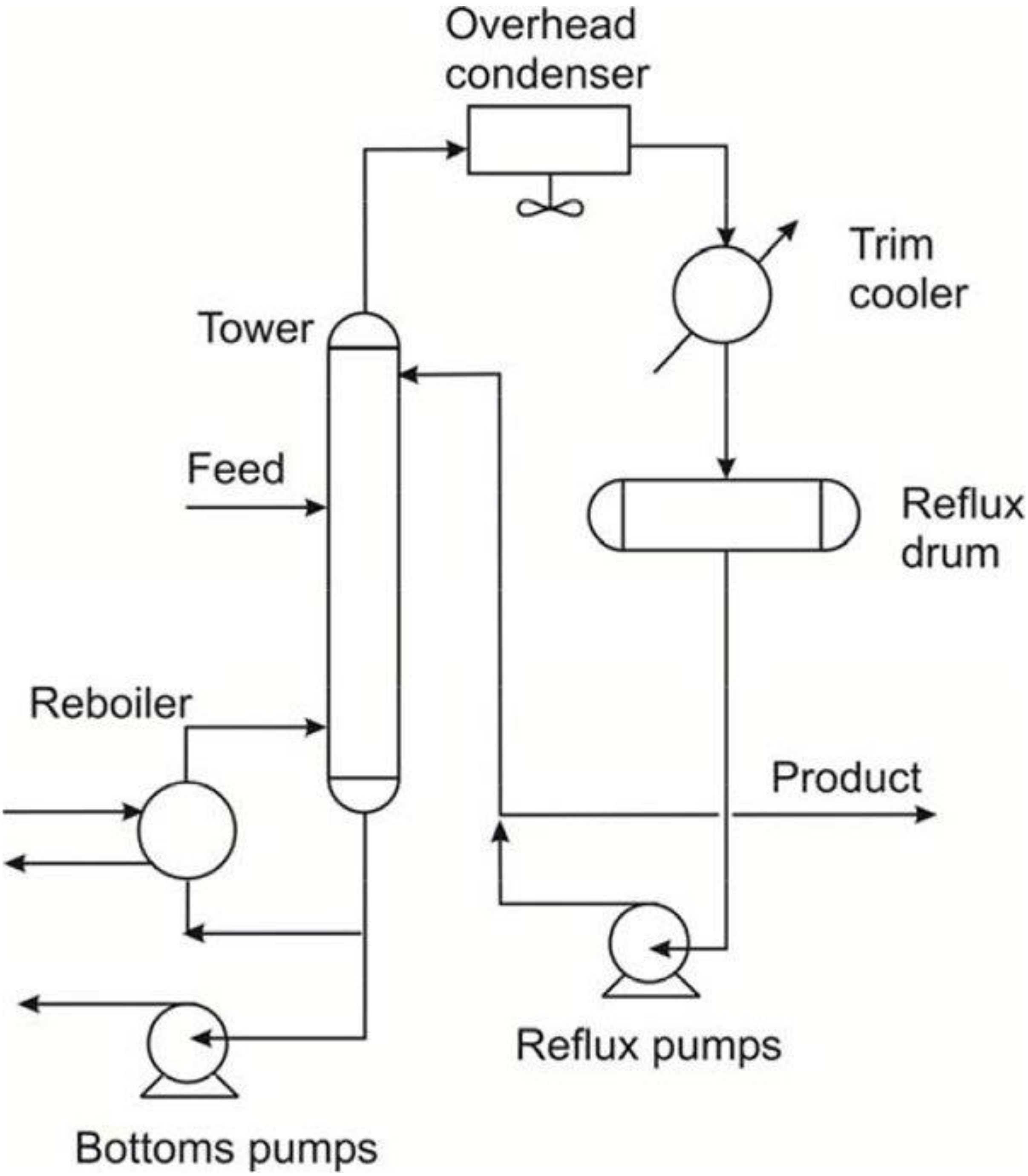


Figure 3.1a
Process Flow Diagram (PFD) for a Typical Distillation Column. (Source: "Process Plant Layout and Piping Design", Ed Bausbacher and Roger Hunt, Prentice Hall)

Layout and design considerations for towers
The following factors are considered in the design and layout of distillation columns:

- **Column height:** The column height is a function of the number of stages. The number of stages required depends on components being separated and their vapor-liquid equilibrium characteristics.
- **Column diameter:** The column diameter is a function of the mass flow rate of the mixture being separated.

- **Space for ancillary equipment:** A distillation column has associated with it ancillary equipment such as an overhead condenser, a reboiler at the bottom, a reflux drum and reflux and bottom pumps. The location and space occupied by the ancillary equipment must be considered during the design and layout of distillation columns.
- **Maintenance access:** Space must be provided for the use of davits and trolley beams and equipment used in the removal internal and external items of the tower.
- **Tower elevation:** The tower elevation is the distance from the grade to the Bottom Tangent Line (BTL) of the vessel. Factors used in determining tower elevation are - Net Positive Suction Head (NPSH) required for the bottoms pump, operator access, tower dimensions, type of heads, tower support (skirt), diameter of bottoms pipe and tower foundation.
- **Tower internals:** These are devices used in promoting contact between vapor and liquid phases and in ensuring even distribution of the liquid phase. Commonly used internal devices are trays and packing. In tray towers, the normal spacing between trays is two feet. Tray towers require the use of down comers which are channels that promote the flow of liquid from the top to bottom trays. Packed towers consist of a liquid distributor at the top, the packing material and packing support. Raschig rings and slotted rings are examples of packing materials.

Figure 3.1b shows a typical plan arrangement for a distillation column and Figure 3.1c shows the elevation view of a distillation column and its ancillary equipment.

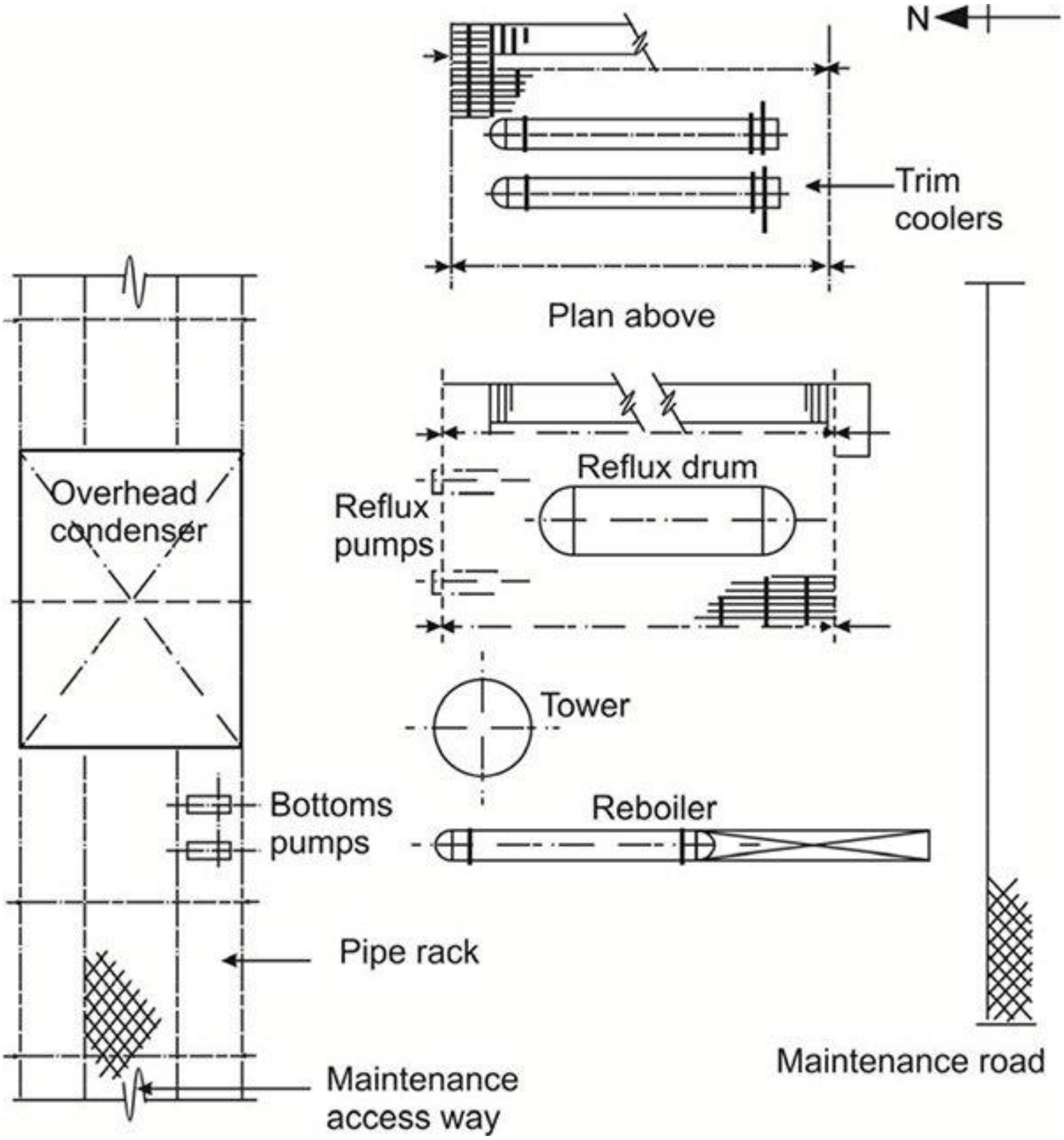


Figure 3.1b
Plan Arrangement for a Distillation Column (Source: "Process Plant Layout and Piping Design", Ed Bausbacher and Roger Hunt, Prentice Hall)

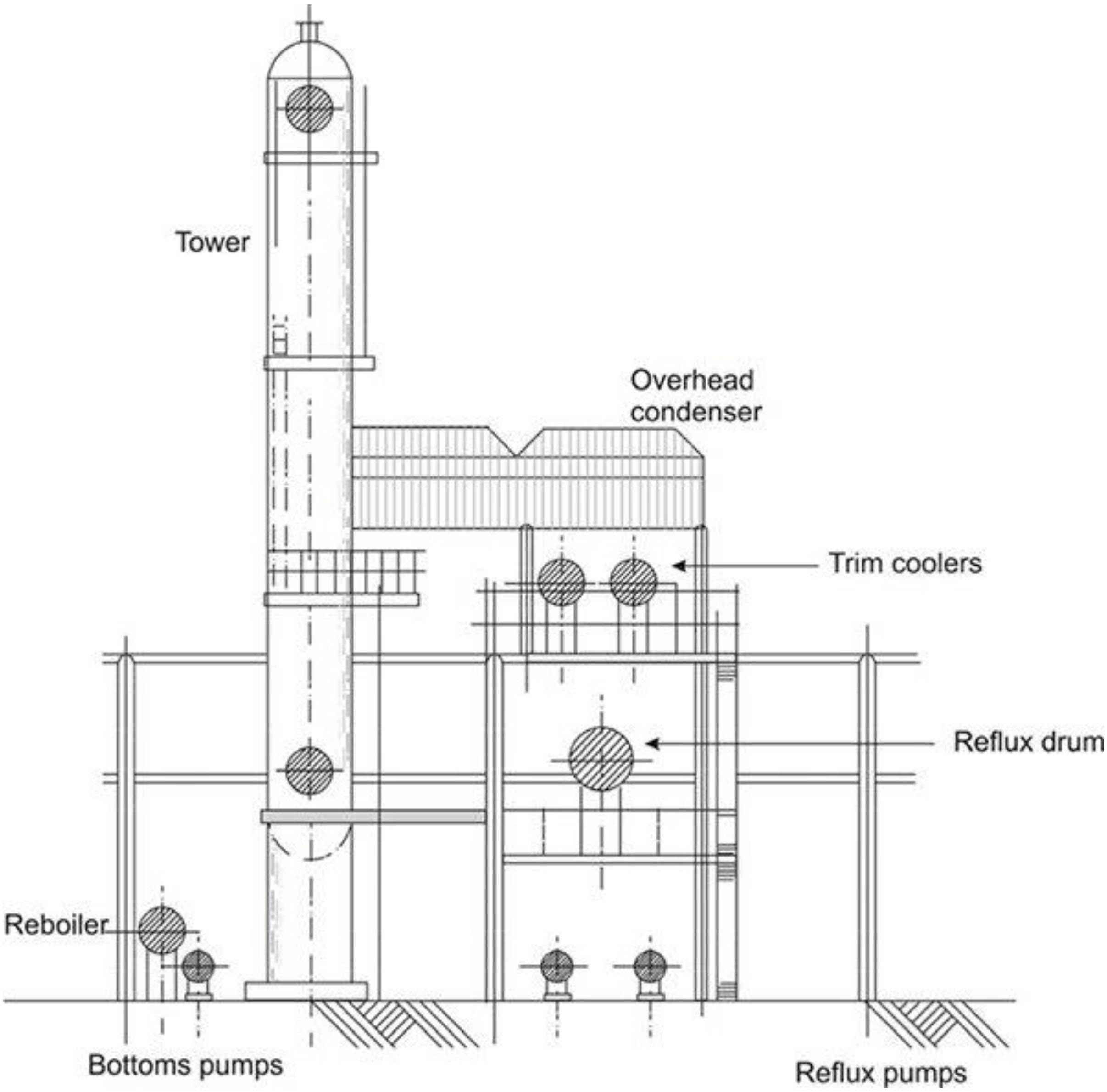


Figure 3.1c
Elevation View of a Distillation Column and Ancillary Equipment (Source: "Process Plant Layout and Piping Design", Ed Bausbacher and Roger Hunt, Prentice Hall)

A "Process Vessel Sketch" for a typical distillation column. The process vessel sketch gives the major dimensions of the column including the diameter and tangent-to-tangent height.

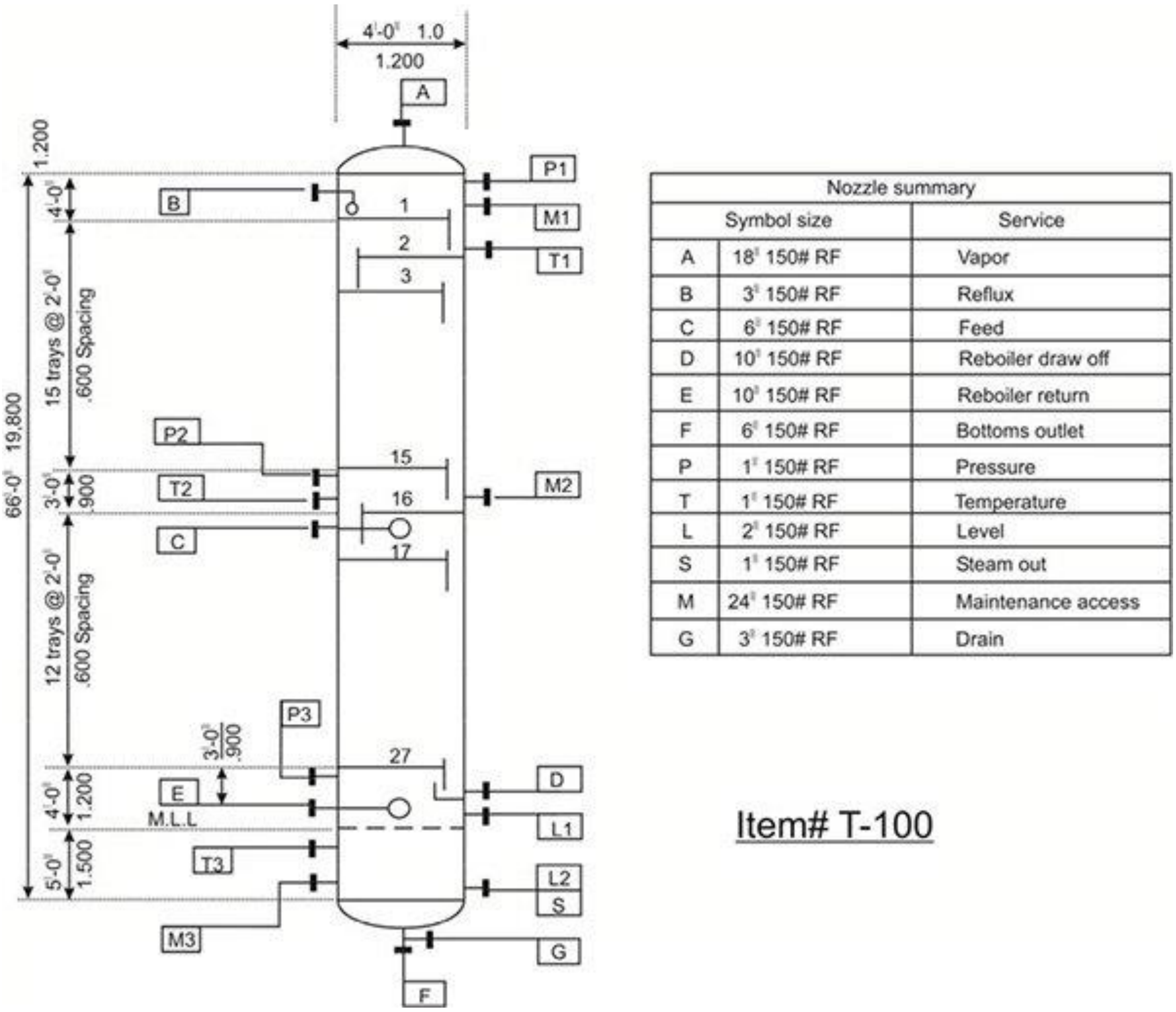


Figure 3.2
Process Vessel Sketch for a Distillation Column (Source: "Process Plant Layout and Piping Design", Ed Bausbacher and Roger Hunt, Prentice Hall)

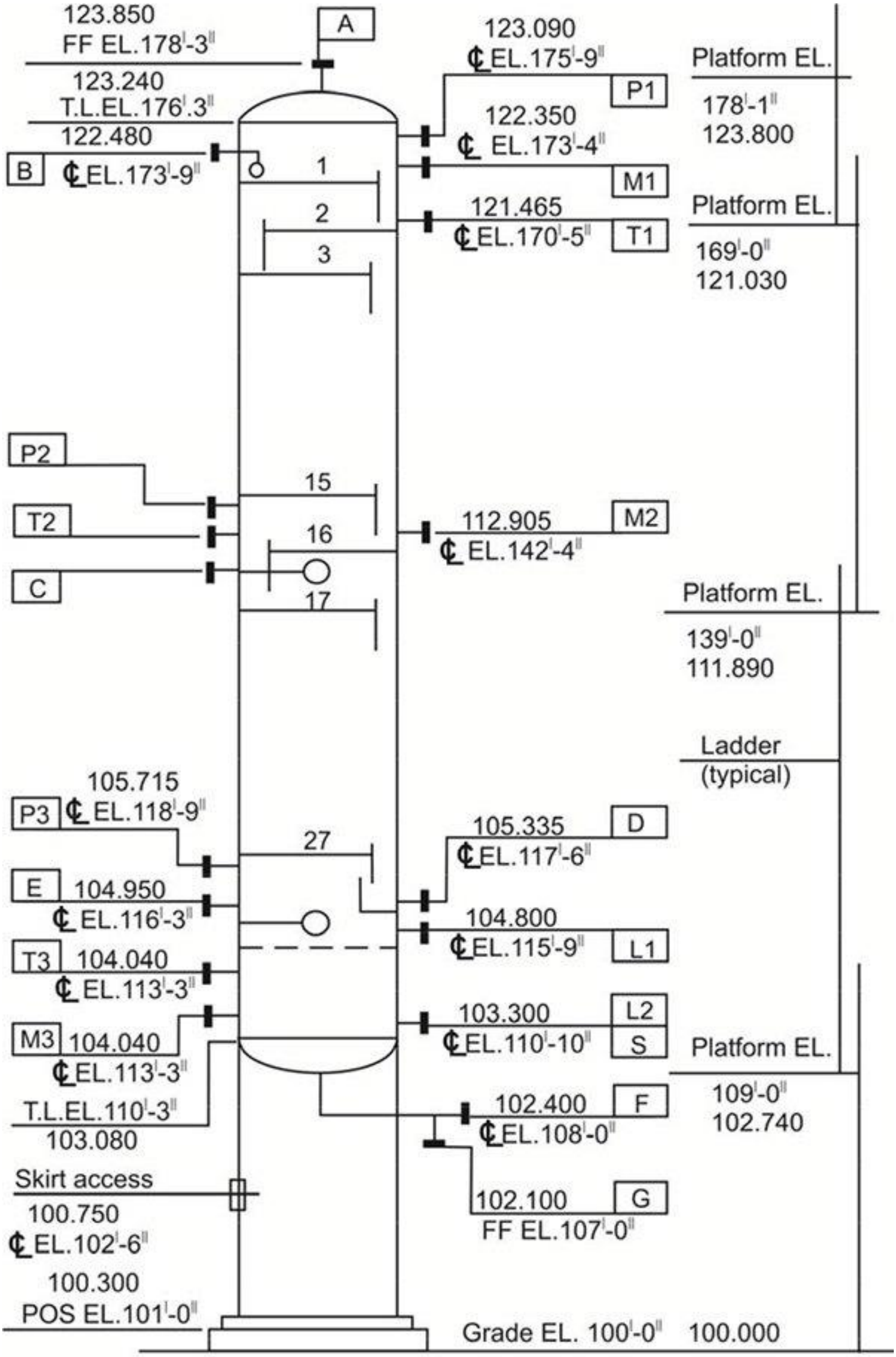
An important consideration in piping layout and design is the location of equipment nozzles. Equipment nozzles provide the connection between equipment and piping. In addition, nozzles are used for instrumentation such as temperature and pressure sensors. Large diameter nozzles are used in providing maintenance access. The process vessel sketch also includes information on the location of nozzles. The nozzles are described in a nozzle summary table, which is shown in Table 3.1. The process vessel sketch and the nozzle summary table provide information for vessel fabrication.

Table 3.1
Nozzle Summary for a Distillation Column

Symbol	Size and Rating	Service
A	18" 150# RF	Vapor
B	3" 150# RF	Reflux

C	6” 150# RF	Feed
D	10” 150# RF	Reboiler Draw Off
E	10” 150# RF	Reboiler Return
F	6” 150# RF	Botoms Outlet
Patient	1” 150# RF	Pressure
T	1” 150# RF	Temperature
L	2” 150# RF	Level
S	1” 150# RF	Steam Out
M	24” 150# RF	Maintenance Access
G	3” 150# RF	Drain

Platforms and ladders:
Tall towers are equipped with platforms and ladders to provide access for operation and maintenance. Platforms are attached to the tower using brackets. Circular platforms are commonly used. Usually, platforms have minimum width of about 3 ft beyond the projection of controls and instruments. The minimum headroom above a platform is about 7 ft. Ladders are used in accessing platforms and the maximum ladder run is 30 ft. Figure 3.3 shows nozzle and platform elevations for a typical distillation column.



T- 100

FF - Face of flange
TL - Tangent line
POS - Point of support

Figure 3.3
Nozzle and Platform Elevations for a Distillation Column (Source: "Process Plant Layout and Piping Design", Ed Bausbacher and Roger Hunt, Prentice Hall)

Tower piping: The piping associated with the tower is routed in areas away from ladders and platforms. Adequate spacing is provided between adjacent piping and the insulation thickness is taken into account in determining this spacing. Sufficient room for expansion must be provided for high temperature piping.

Reactors

Reactors are process units used in accomplishing unit processes. Unit processes are chemical reactions necessary to transform raw materials to finished products and were discussed in Chapter 2. Reactors are usually vertical, hollow steel vessels operating at high temperatures and pressures.

Layout and design considerations for reactors
The following factors must be considered in the layout and design of reactors:

- Facility for loading and removal of catalysts, mostly in the form of pellets. Very often, reactions take place in the presence of a 'catalyst' material that promotes the reaction but does not take part in the chemical reaction. Examples of catalysts are alumina, zinc oxide and platinum.
- Requirement of space for loading/unloading of catalyst.
- Flexibility of connecting lines to accommodate line expansion due to high temperature during operation and contraction during shut down.
- Location of sampling ports to sample catalyst pellets. It is necessary to sample and test the catalyst for its effectiveness. The catalyst needs to be regenerated periodically after it is "spent".
- Location and sizes of nozzles for catalyst unloading and loading.

The following factors are considered in determining the elevation of the Bottom Tangent Line (BTL) of a reactor: reactor dimensions, type of heads, type of support and catalyst unloading method. The piping layout for a reactor should minimize piping runs of expensive alloy piping and should also provide sufficient flexibility for high temperature piping.

Figure 3.4 shows the details for a typical reactor.

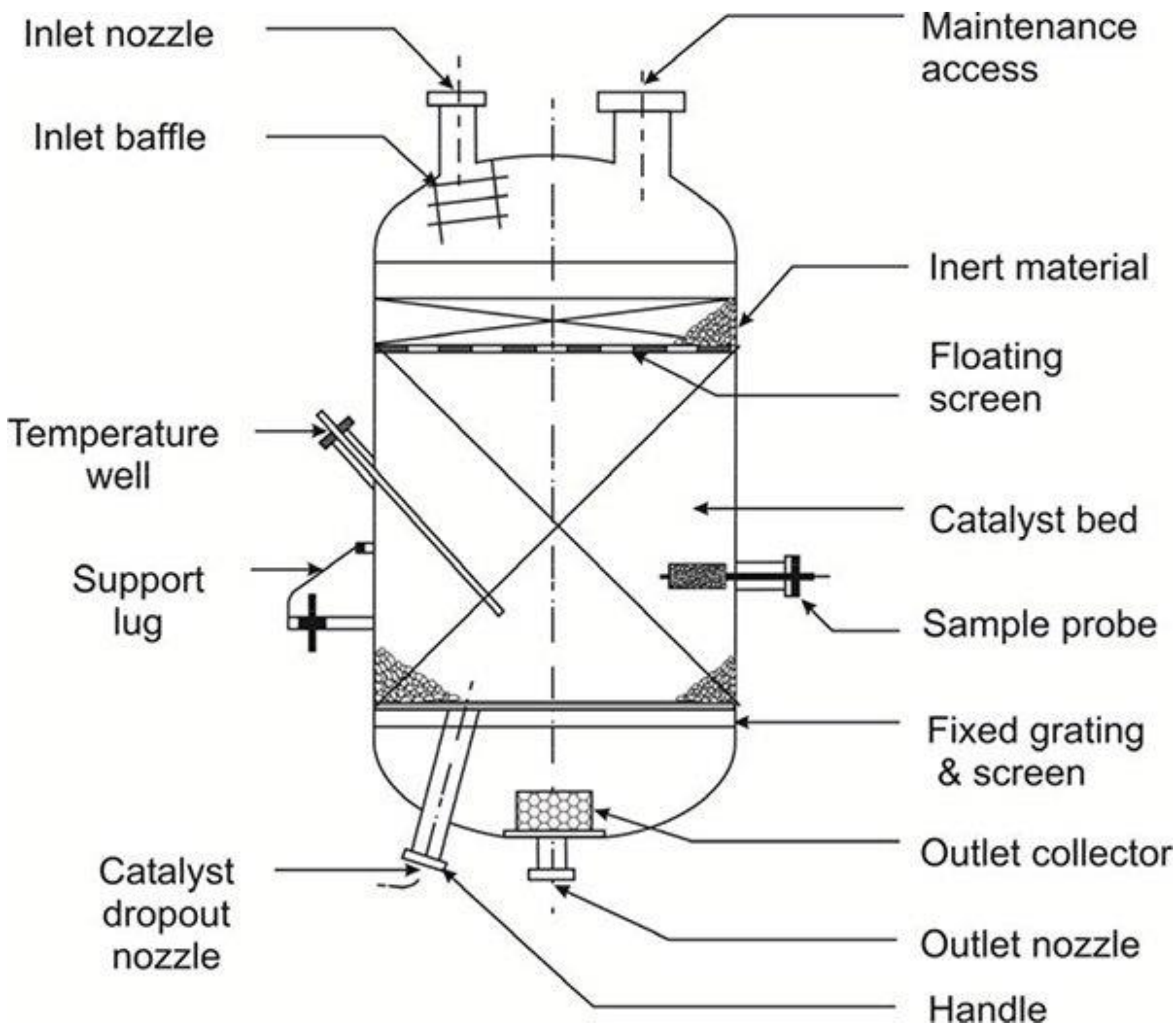
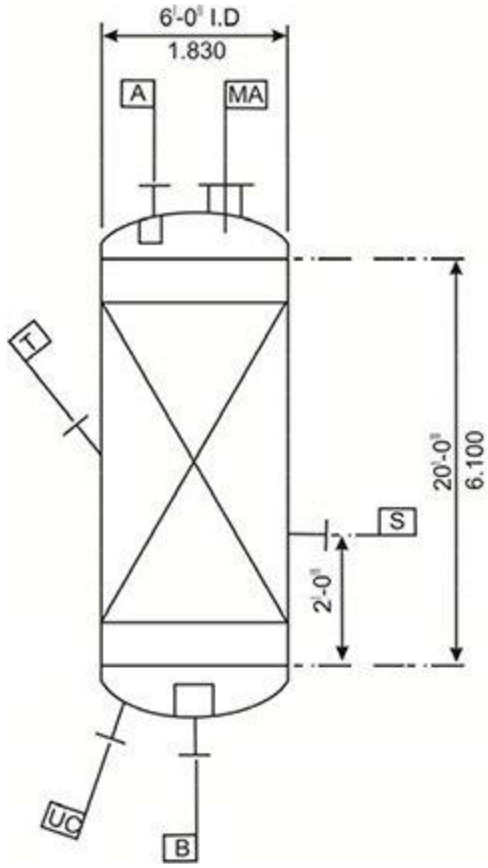


Figure 3.4

Typical Reactor Details (Source: "Process Plant Layout and Piping Design", Ed Bausbacher and Roger Hunt, Prentice Hall)

The important nozzles for a reactor are nozzles for raw material inlet and catalyst loading on the top head and nozzles for product outlet and catalyst unloading on the bottom head. In addition, there are several nozzles for temperature probes and sampling probes. The layout should leave sufficient room for the withdrawal of the probes. Figure 3.5 is a process vessel sketch for a reactor showing the location of the important nozzles.



Nozzle summary		
Symbol	Size	Service
A	8" 600# RF	Inlet
B	8" 600# RF	Outlet
S	3" 600# RF	Sample
T	1" 600# BJ	Temperature
UC	12" 600# RF	Catalyst drop out
MA	24" 600# RF	Maintenance access

Figure 3.5

Process Vessel Sketch for a Reactor (Source: "Process Plant Layout and Piping Design", Ed Bausbacher and Roger Hunt, Prentice Hall)

The different types of supports for a reactor are skirt support, lug support and ring girder support and are shown in Figure 3.6.

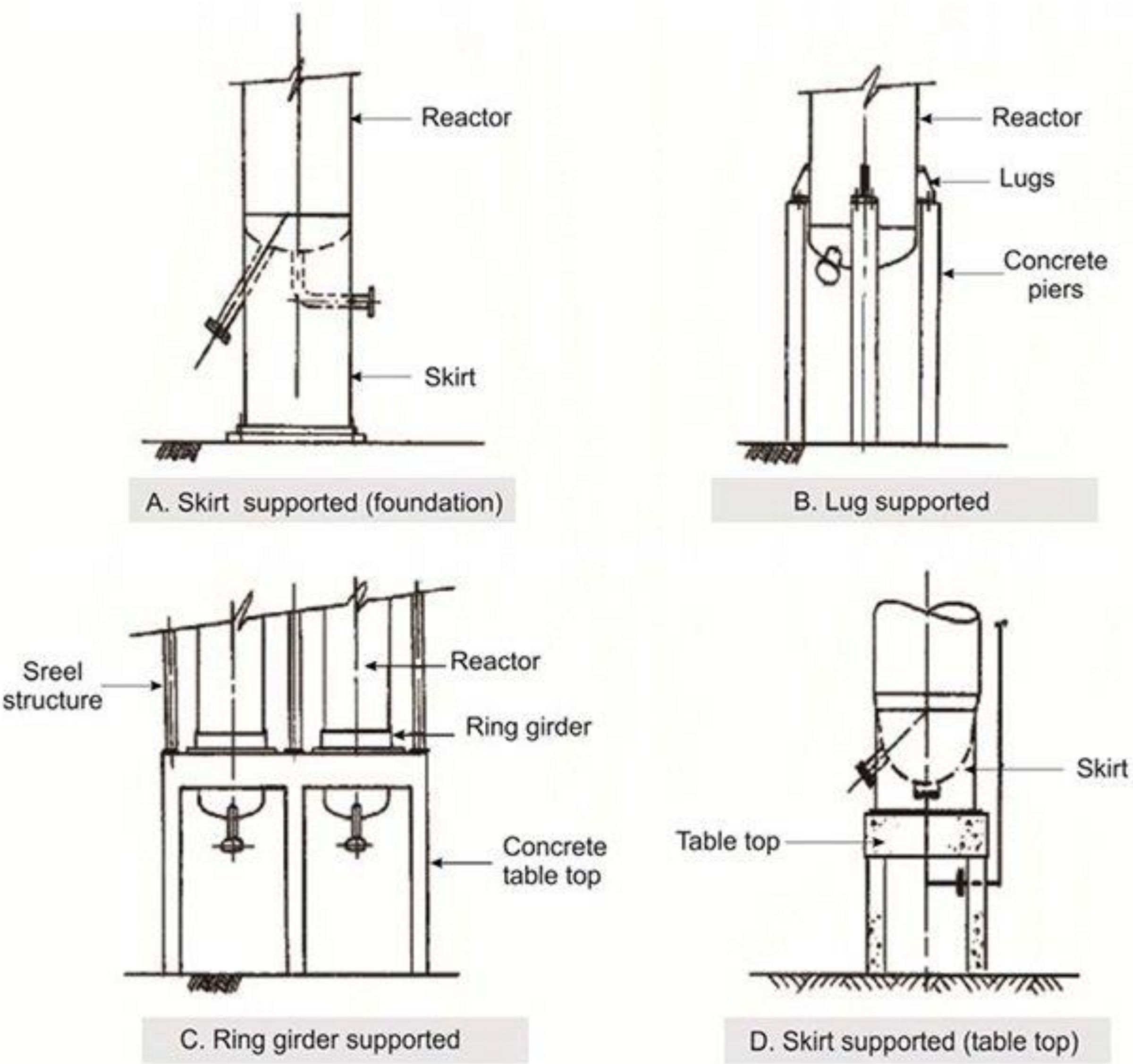


Figure 3.6
Methods for supporting a Reactor (Source: "Process Plant Layout and Piping Design", Ed Bausbacher and Roger Hunt, Prentice Hall)

Heat exchangers

Heat Exchangers are used in heating, cooling, vaporizing, and condensing process fluids by exchanging heat from other fluids or outside sources.

Types of heat exchangers: The five major types of heat exchangers are Shell and Tube, Double Pipe, Plate and Frame, Spiral, and Air-cooled and they are illustrated in Figure 3.7.

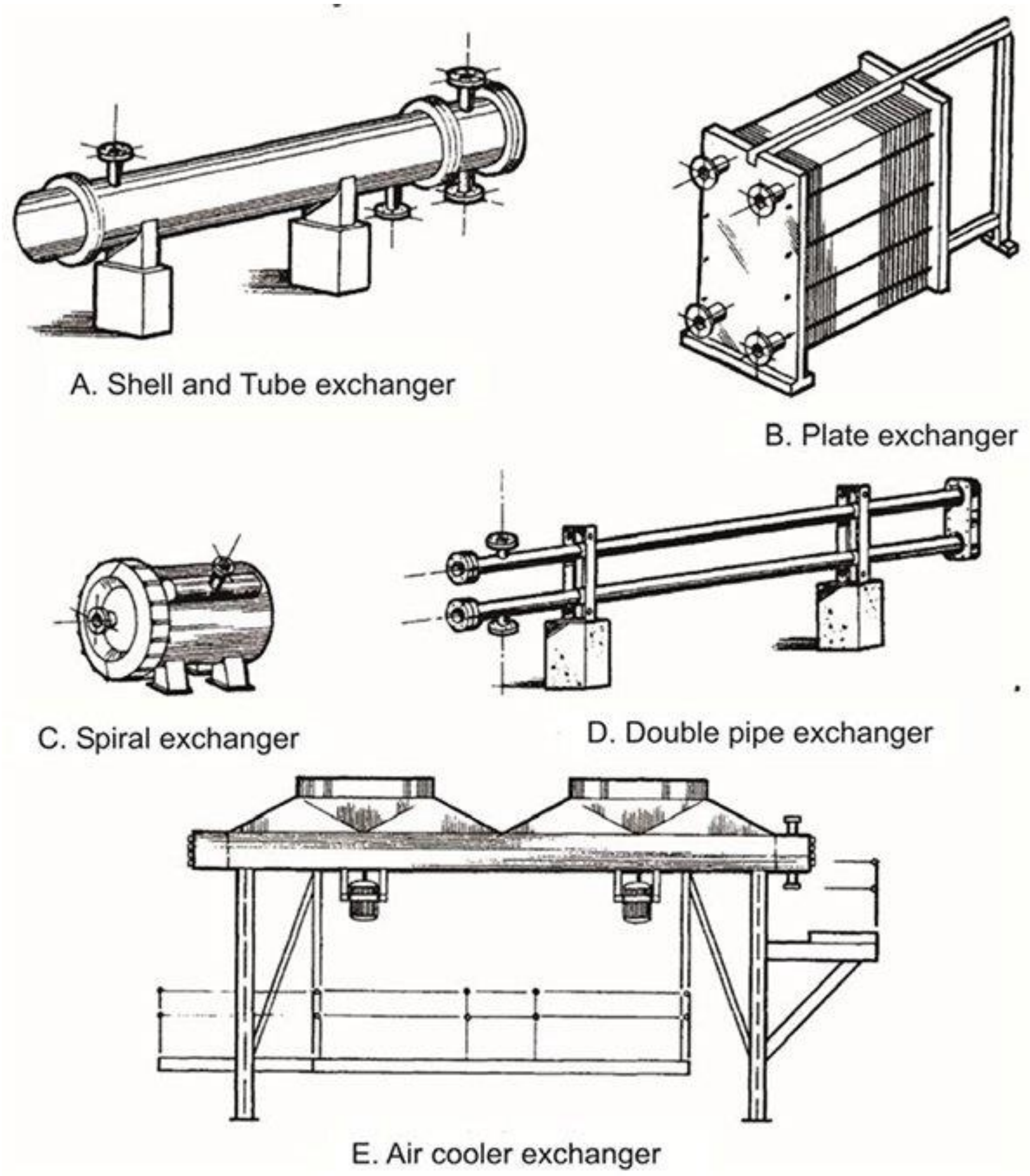


Figure 3.7
Types of Heat Exchangers (Source: "Process Plant Layout and Piping Design", Ed Bausbacher and Roger Hunt, Prentice Hall)

Heat exchanger applications:
Typical applications of heat exchangers are described here.

- **Coolers:** A process fluid is cooled using a cooling medium such as cooling water, refrigerant, air or dowtherm.
- **Heaters:** A process fluid is heated using heating media such as hot water, hot oil or condensing steam.
- **Chiller:** A process stream is cooled to very low temperature by using a refrigerant. The refrigerant absorbs heat from the process stream and evaporates.

- **Condensers:** Process vapors are condensed to liquid state by using cooling water, air or other medium.
- **Reboilers:** Used in distillation systems to boil/vaporize the bottoms liquid using steam/hot oil as the heating medium.
- **Heat/Energy conservation:** Hot, effluent streams are used in pre-heating feed streams before discharge. This saves energy and also reduces environmental problems.

A description of the five major types of exchangers is provided in the following section.
1. Shell and Tube Heat Exchanger (STHE): A typical STHE consists of a cylindrical shell containing a bundle of tubes. The shell side fluid passes over the tubes and the tube side fluid passes through the tubes causing exchange of heat between the tube fluids. The following points should be noted about the STHE:

- Nozzles are provided for the shell side and tube side fluids.
- Horizontal baffles are provided to create multiple passes on the tube side.
- Vertical baffles in the shell side to ensure a flow pattern that provides good contact between shell and tube side fluids.
- Tubes are supported in a frame called tube sheet.
- For horizontal installations, the exchanger is supported by saddles and by lugs for vertical installations.
- Layout for STHE: The most important factor is to provide enough space for the removal of tube bundles and for the removal of shell bonnet.

Figure 3.8 illustrates typical components of a Shell and Tube Heat Exchanger.

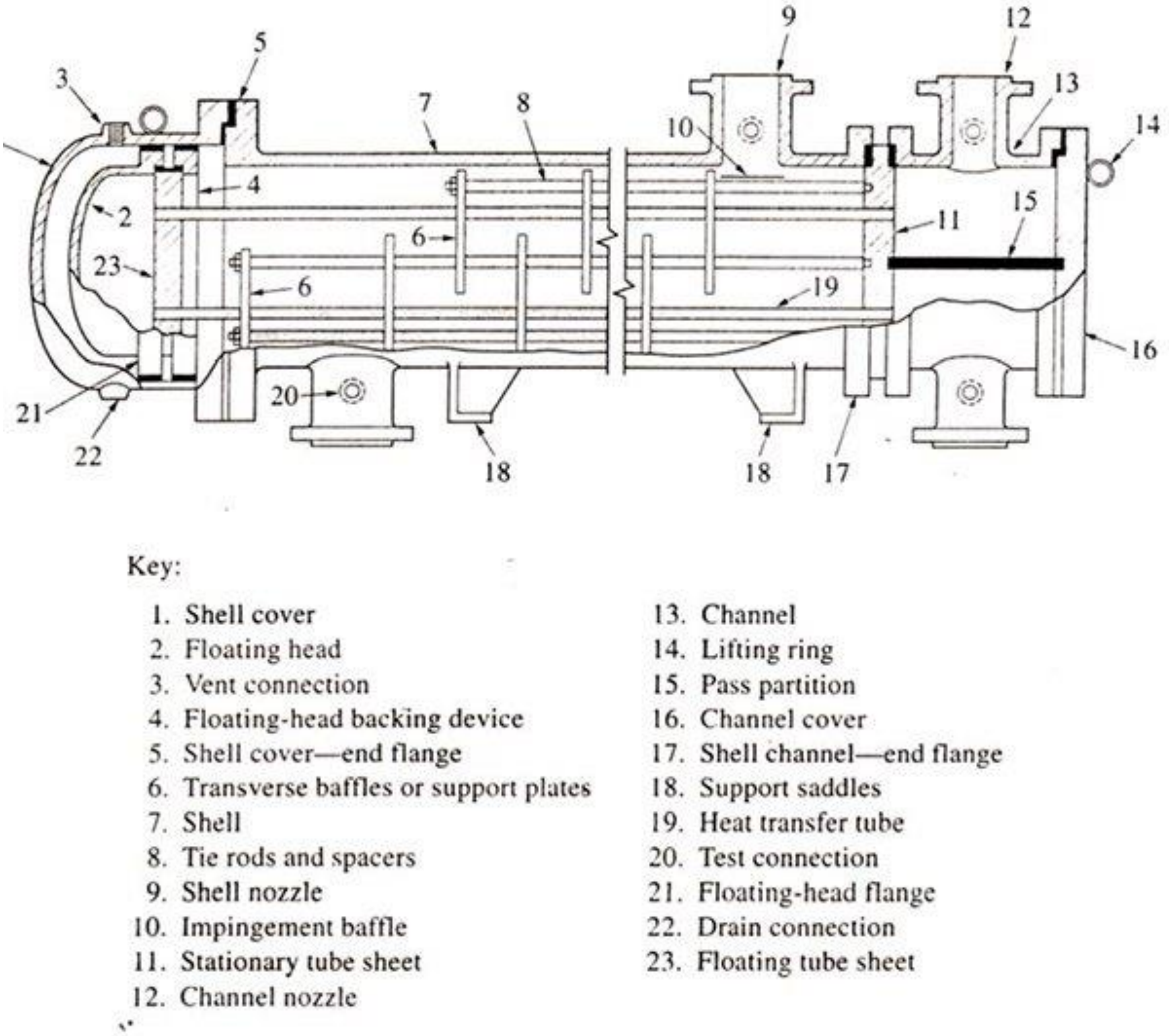


Figure 3.8
Shell and tube heat exchanger with floating head (courtesy of the Tubular Exchanger Manufacturers Association)

2. **Plate and frame exchangers:** They are generally used in low temperature, low pressure applications. The advantage they offer is economy of space. Sufficient space must be provided for plate removal and for controls.

3. **Spiral heat exchangers:** They have the advantages of economy of space and compact layout. Sufficient space must be provided for opening of swing cover plates and for controls.

4. **Double pipe heat exchangers:** They are also known as Fin Tube Heat Exchangers. They consist of two concentric pipes. One of the fluids flows in the inner tube and the other fluid flows in the annular region between the two tubes. The inner tube may be finned to increase heat transfer surface area. The disadvantage is the large amount of space occupied.

5. **Air-Cooled Heat Exchangers:** In this type of exchanger, circulating air is the cooling medium. It consists of a bank of tubes carrying the hot fluid, which is cooled by flow of air across the tube bank. Air fans and their drives occupy most of the space. Air-cooled exchangers are usually mounted on top of the pipe racks.

Layout and piping design for heat exchangers:
Heat Exchangers are located close to the process equipment they service. For example, a

reboiler is located close to the distillation tower it services. Some of the factors to be considered in the layout and piping design for heat exchangers include:

- Adequate space must be provided for the removal of channel heads, tube bundles and shell covers.
- Piping runs should be minimized for expensive, high temperature, alloy piping.
- High temperature lines should be routed so as to provide sufficient flexibility for thermal expansion.
- Sufficient space must be provided for operator and maintenance access.

Figure 3.9 illustrates typical layout for heat exchangers

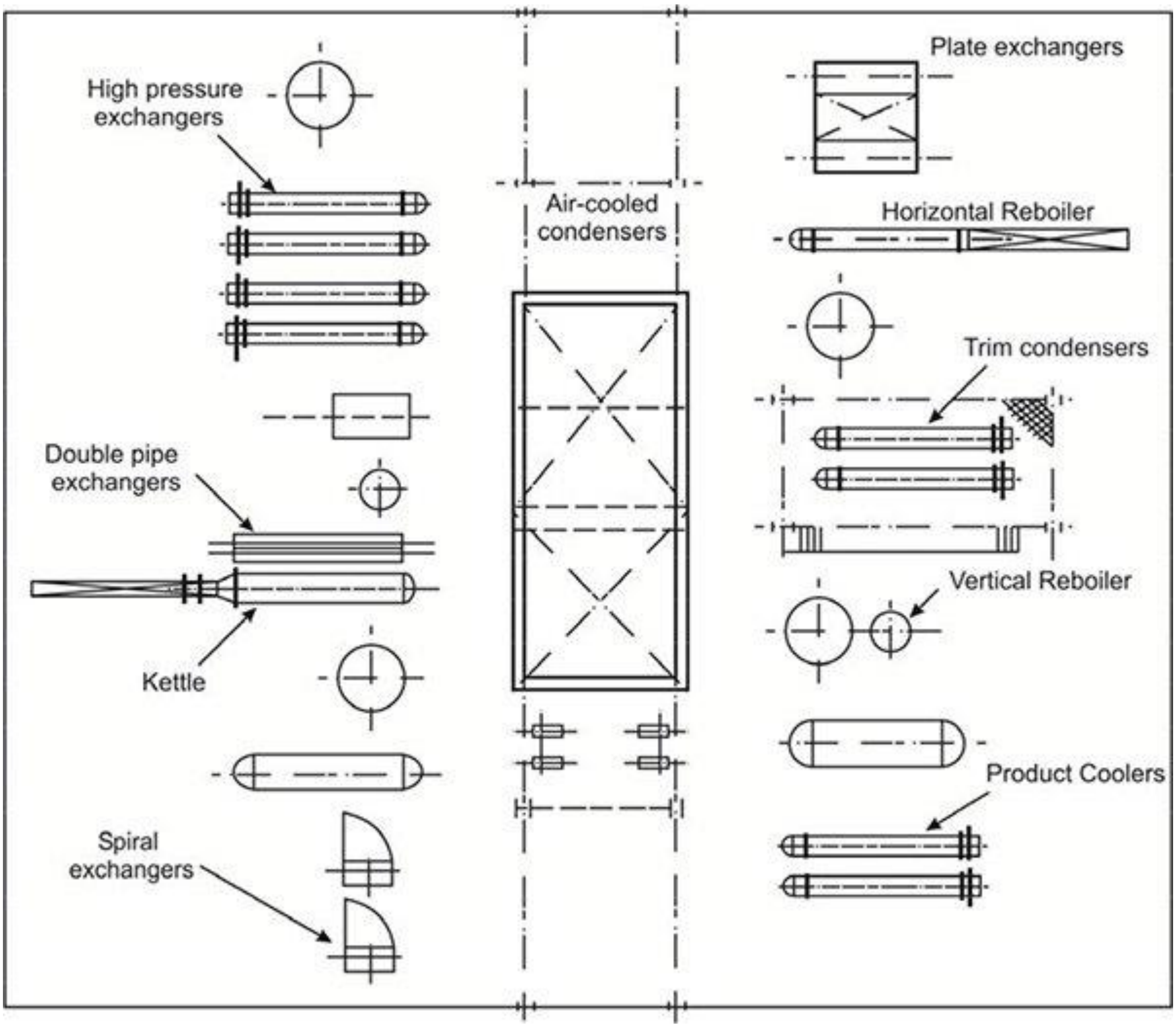


Figure 3.9
Typical Layout for Heat Exchangers (Source: "Process Plant Layout and Piping Design", Ed Bausbacher and Roger Hunt, Prentice Hall)

Vessels and other process equipment

Vessels can be grouped into horizontal vessels and vertical vessels. Horizontal vessels are also known as drums or accumulators. They are used in the storage of process liquids. Process liquids are received and collected in these vessels. Drums consist of nozzle connections for inlet and outlet and man-ways for maintenance access. They also consist of level gauges, indicators and alarms. Distillation columns and reactors, which were discussed earlier, are examples of vertical equipment. Another example of vertical equipment is a "Gas Absorption Tower". The gas absorption tower is a vertical column consisting of packing material, which provides the contact surface between the gas and the liquid. Liquid solvent is distributed from the top and the gas mixture is blown from the bottom. The liquid solvent absorbs the soluble portion of the gas mixture. For example, ammonia is absorbed from a mixture of ammonia and air using water as the solvent.

3.3 Mechanical equipment

Mechanical equipment is used in the transport of fluids and also in the compression of gases. Pumps are used in the transport of fluids and compressors are used in gas compression.

Pumps

Pumps are mechanical equipment used in the transport of fluids. Pumps add mechanical energy or "head" to the fluid being transported. The criteria used in the selection of pumps are as follows:

- Characteristics and properties of the fluid being pumped including density, viscosity, vapor pressure and chemical composition.
- The capacity or the volume flow rate (gpm or m3/s) of the fluid to be pumped.
- The head to be supplied by the pump. This is usually expressed in terms of feet (or meters) of the fluid being pumped.
- Pressure, temperature of the fluid being pumped.
- Space constraints.
- Cost factors – capital and operating costs.
- Maintenance requirements and reliability.

Classification of pumps

The three major types of pumps are – centrifugal pumps, reciprocating pumps and rotary pumps.

Centrifugal pumps:

Centrifugal pumps are the most commonly used pumps. They are very versatile pumps and can handle a broad range of flow rates and pressures. They operate at constant speeds. They can be configured either horizontally or vertically and in single or multiple stages. Figure 3.10 illustrates the typical components of a centrifugal pump, which consists of an impeller, a casing, and suction and discharge nozzles. Associated with the pump are the motor drive and the base plate.

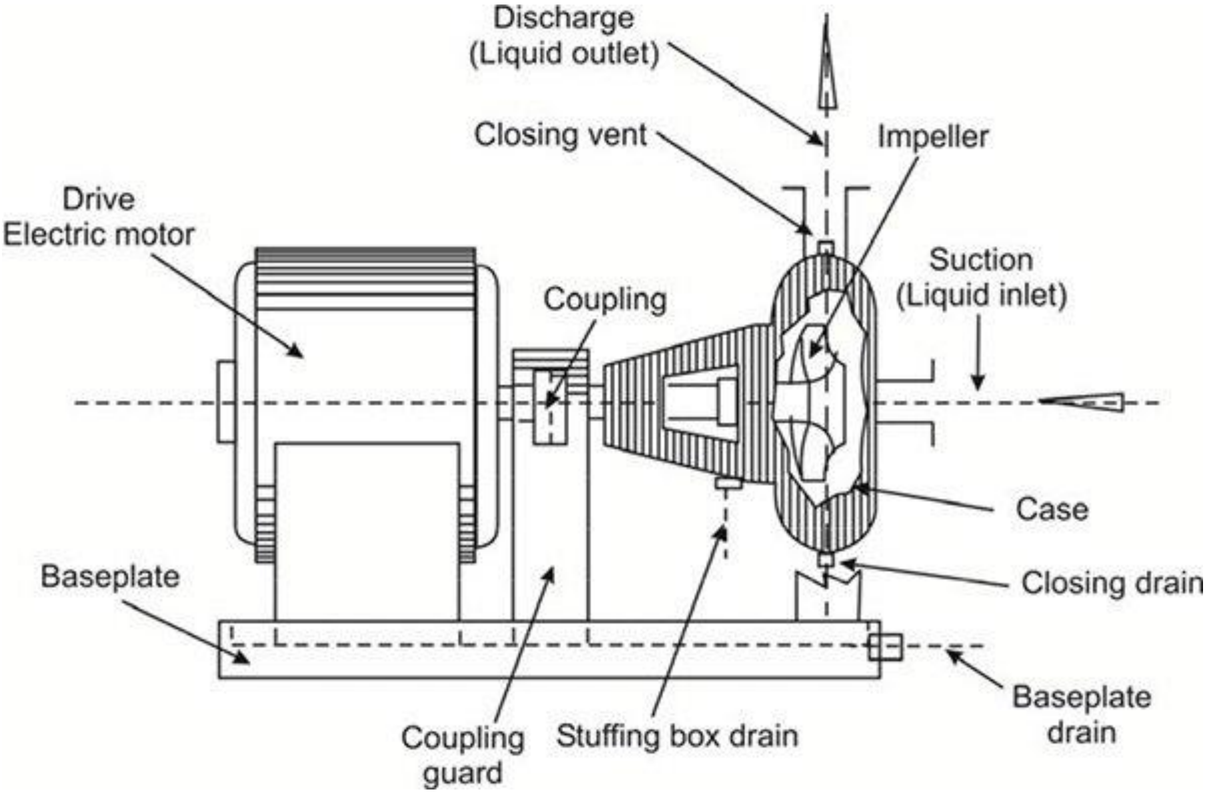


Figure 3.10
Typical Components of a Centrifugal Pump (Source: "Process Plant Layout and Piping Design", Ed Bausbacher and Roger Hunt, Prentice Hall)

Reciprocating pumps:
Reciprocating pumps consist of a piston-cylinder mechanism. They are typically used in injecting precise amount of fluids and in handling lower flow rates. Reciprocating pumps are also known as "Positive Displacement Pumps".

Rotary pumps:
Rotary pumps use gears, screws and cams to move the fluid. They are useful in pumping viscous fluids and in achieving a constant and smooth discharge.

Terminology associated with pumps

- **Net Positive Suction Head (NPSH):** The NPSH required (NPSHR) is a measure of the pressure drop from the inlet nozzle to the eye of the impeller. The pump manufacturer specifies the NPSHR usually in feet of water. The NPSH available (NPSHA) must be greater than NPSHR. NPSHA is determined by the layout of the source vessel and the pump.
- **Allowable Nozzle Loads:** Stresses are induced in the suction and discharge nozzles of the pump because of the forces and displacements of the connecting pipe. These stresses should be within limits specified by the vendor and by the codes. The limits specified are called as allowable loads.
- **Vapor Pressure and Cavitation:** The vapor pressure of the fluid being pumped is the saturation pressure at the operating temperature of the pump. This can be obtained from thermodynamic tables and charts. If the pressure in the pump suction drops below the vapor pressure, the liquid will flash forming some vapor. The liquid–vapor mixture leads to the formation of vapor bubbles, which collapse upon impact on the surfaces of the

impeller and the casing. This results in the erosion and damage of the impeller and casing surfaces. Cavitation also causes noise, loss of head and capacity.

Layout and design considerations for pumps and pump piping

- Pump piping must be adequately supported so as to avoid excessive loads on pump nozzles.
- Pump piping must be routed such that existing support structures can be used.
- The length of the suction piping must be minimized to avoid excessive pressure drops.
- Pump piping is routed so as to satisfy line flexibility requirements to allow room for line expansion and contraction (thermal effects).
- Pumps are located so as to optimize the use of existing structural steel for providing adequate support for pump piping. It is for this reason that pumps are located adjacent to pipe racks. Pumps can also be located directly under the process equipment serviced by the pump.

Figure 3.11 is a plan view of typical pump locations and Figure 3.12 is an elevation view of typical pump locations.

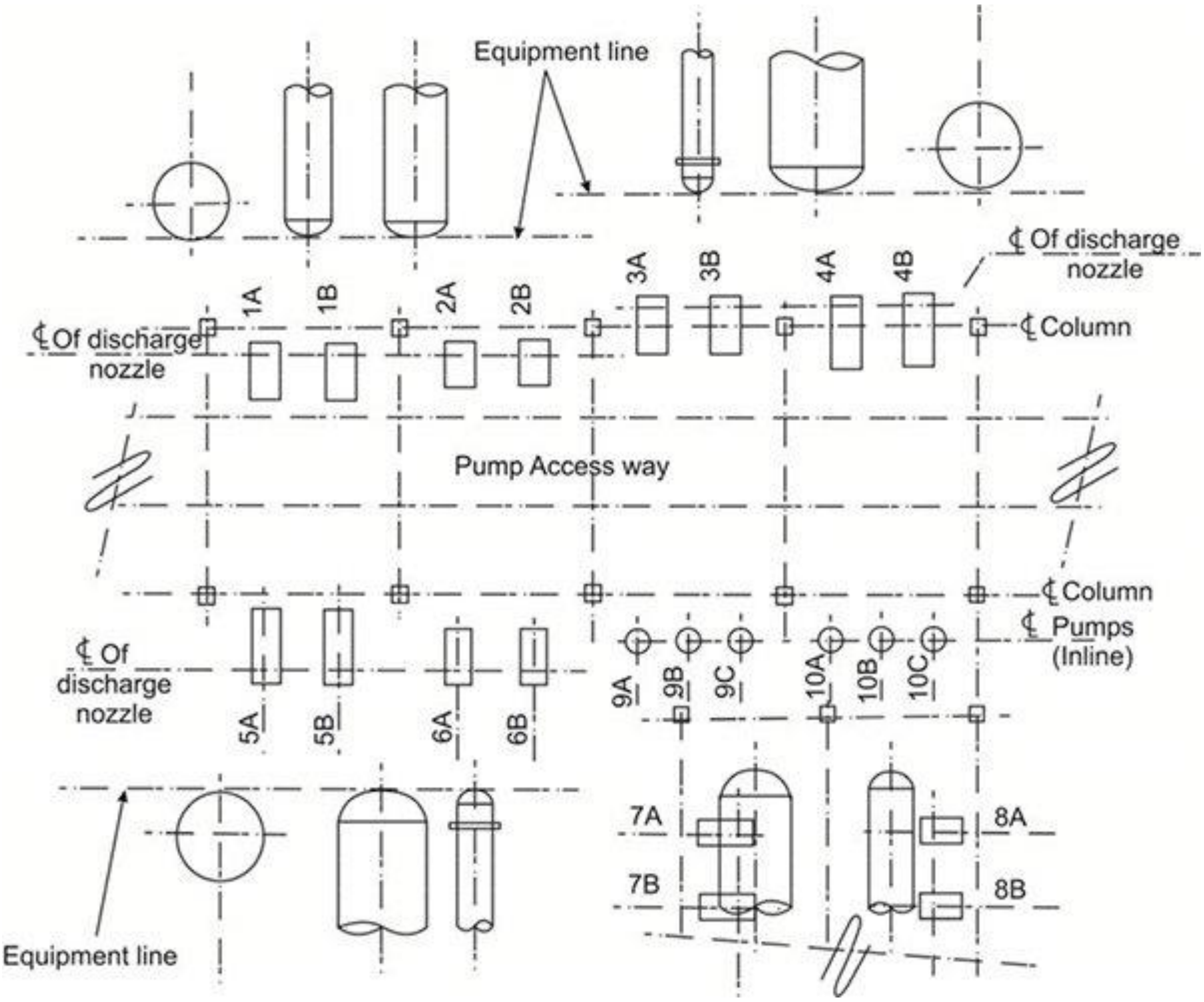


Figure 3.11

Plan View of Typical Pump Locations (Source: "Process Plant Layout and Piping Design", Ed Bausbacher and Roger Hunt, Prentice Hall)

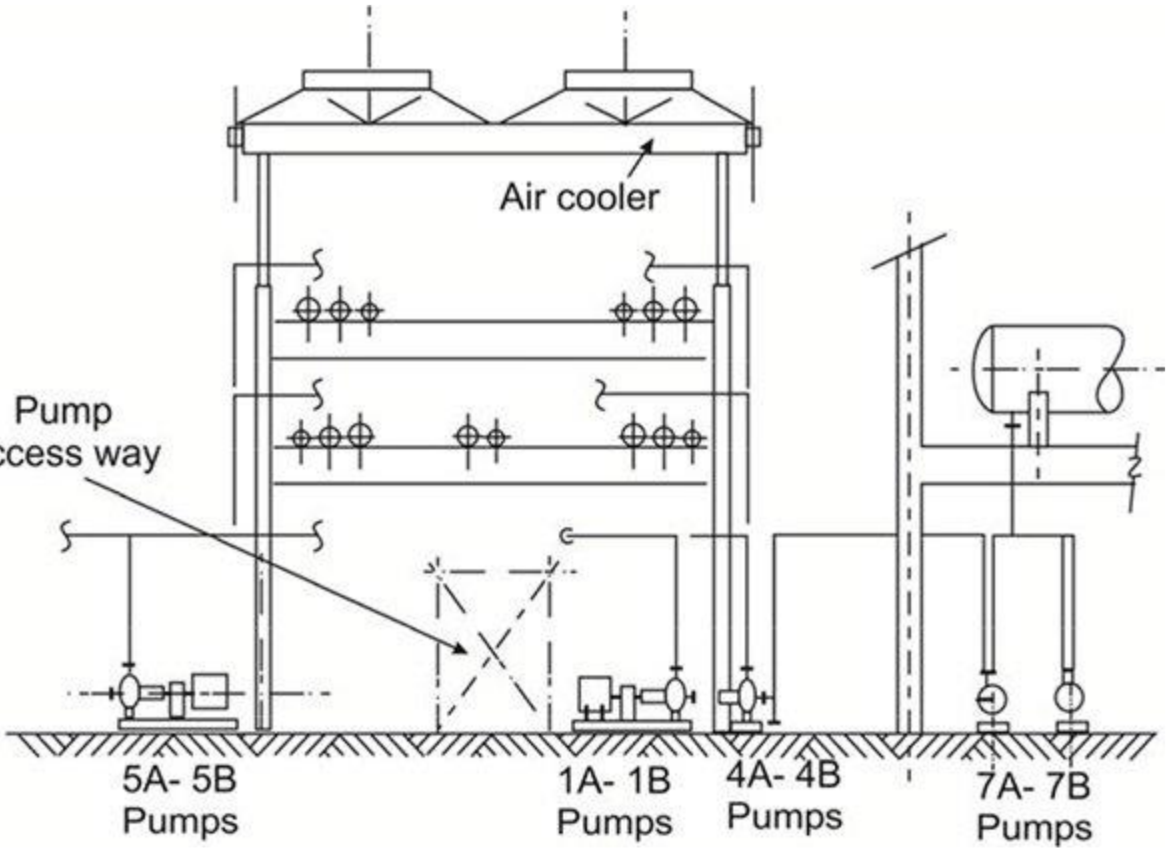


Figure 3.12
Elevation View of Typical Pump Locations (Source: "Process Plant Layout and Piping Design", Ed Bausbacher and Roger Hunt, Prentice Hall)

Configuration of pump piping
Pump piping consists of valves, strainers and pressure indicators. Figure 3.13 shows typical components of piping systems on the suction side as well as the discharge side. The suction side piping system consists of the suction line, a shut-off valve, a strainer to trap particles and an eccentric reducer. The discharge piping consists of a concentric reducer, a pressure indicator to monitor the discharge pressure of the pump, a check valve to prevent back flow, a gate valve and the discharge line.

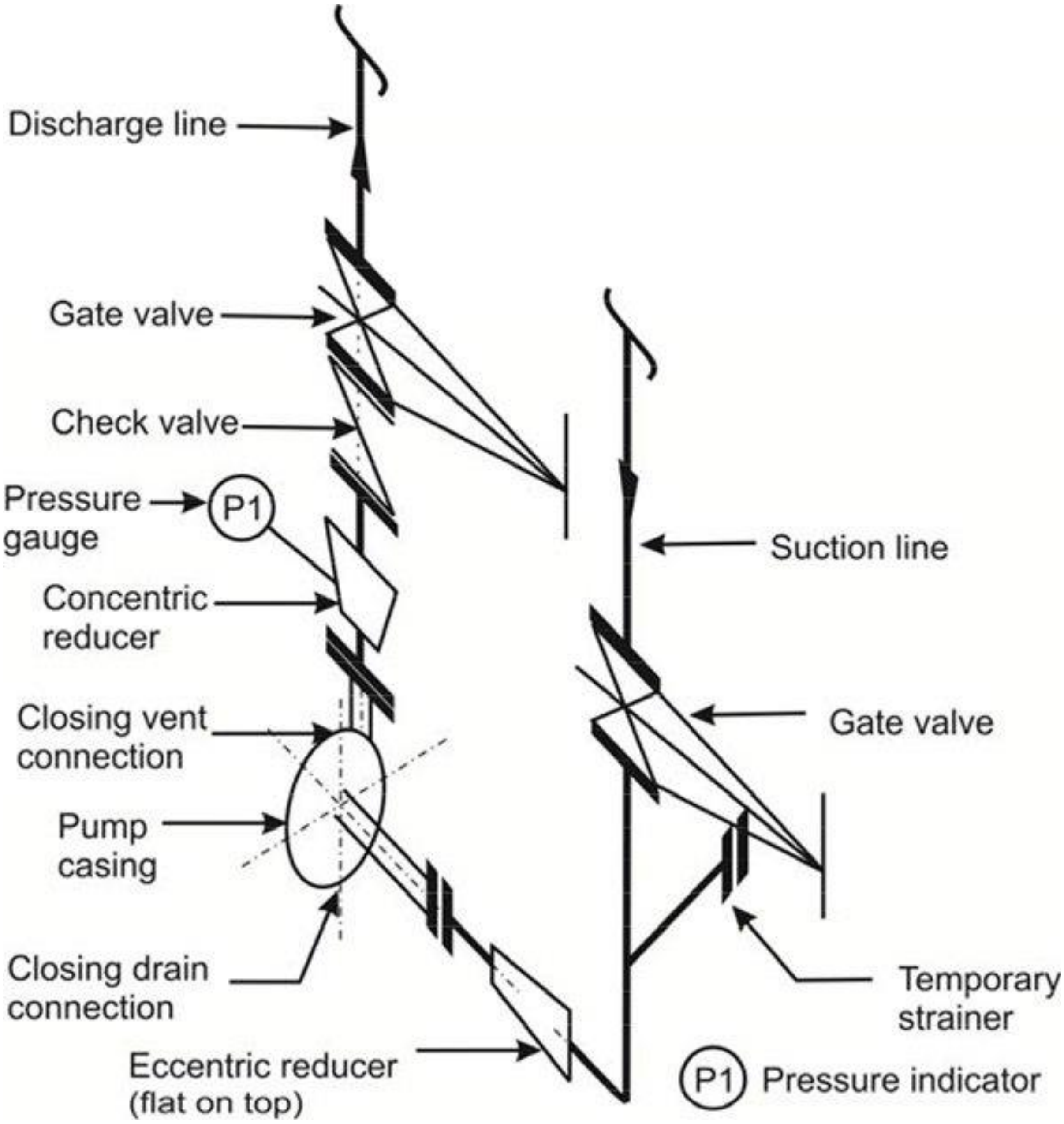


Figure 3.13
Typical Components of Suction and Discharge Piping (Source: "Process Plant Layout and Piping Design", Ed Bausbacher and Roger Hunt, Prentice Hall)

3.4 Summary

Process and mechanical equipment typically found in process plants have been discussed in this chapter. The different types of equipment, their typical applications and the factors to be considered in the design and layout of such equipment have been explained. The equipment considered in this chapter includes towers, reactors, heat exchangers and pumps. The nozzle specifications and supports for equipment have also been briefly discussed.

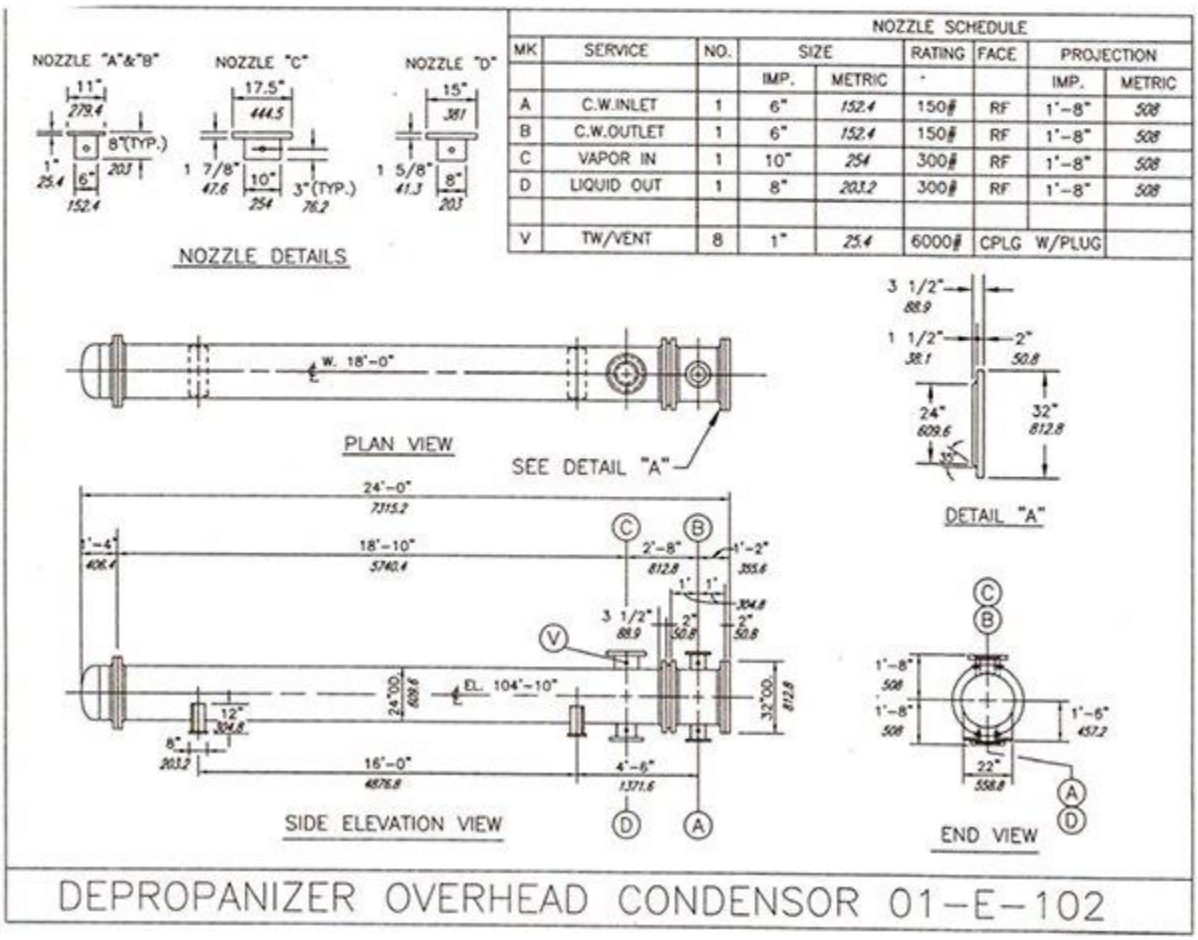


Figure 6-23. Shell and tube exchanger vendor data drawing.

Fundamentals of Process Plant Layout and Piping Design

Practical Exercise 3 (Towers and Reactors)

1. What are the two most important dimensions for a tower?

2. What does NPSH stand for?

3. Mention three important factors used in determining tower elevation.

4. What are the two different types of internals used in towers?

5. What is the purpose of reactors?

6. Name three types of supports typically used for supporting reactors.

4

Plant Layout and Plot Plans

This chapter discusses the basic principles used in plant layout. Plant layout specifications and guidelines are described. The starting point for the design of process plants and piping system is the generation of "Plot Plans" and equipment arrangement drawings. Examples of plot plans and equipment arrangement drawings are provided in this chapter.

Learning objectives

- Plant layout specifications.
- Guidelines and codes for plant layout.
- Safety considerations.
- Plot plans.
- Equipment arrangement drawings.

4.1 Plant layout specifications

Plant layout specifications provide guidelines and requirements for arrangement of equipment and structures within a plant. These guidelines take into account compliance with national and local codes and regulations. Additional factors to be considered are:

- Plant safety
- Plant operability
- Plant maintenance
- Site conditions – soil, seismic data etc.
- Environment
- Atmospheric conditions – prevailing winds, average ambient temperature

The following terminology is frequently used in plant layout and plot plans:

- **Operator Access:** This is the space required between units for operator functions such as walking, climbing, operating valves, viewing instruments and for safe exit in case of an emergency.

- **Maintenance access:** This is the space required for servicing of process equipment and for removal and restoration of components of equipment.

Some examples of plant layout specifications are listed here.

- Provision of adequate service roads and access paths for maintenance and emergency response. Recommended road widths are 24 ft for main roads, 16 ft for secondary roads and 10 ft for access paths.
- Minimum safety distances between hazardous equipment (at high temperature, high pressure) and inhabited spaces such as control rooms and administrative buildings.
- Minimum recommended distances between process units such as furnaces and reactors and other equipment.
- Equipment elevations allowing adequate room for supports, operation and maintenance. Usually grade or datum is fixed at 100 ft.
- Tall equipment adequately equipped with platforms and ladders to provide operator and maintenance access.
- A minimum head room of 7 ft above platforms and platform width should be a minimum of 3ft plus any equipment/instrument projections.
- Access to platforms is by means of ladders. Maximum vertical run for ladders is 30 ft and minimum width is 1' – 6".

4.2 Plot plans

Plot plans are plan view drawings of the processing facility. Plot plans specify the location of all equipment and associated structures (pipe racks, buildings) in the facility. Plot plans play a crucial in determining the real estate and space requirements for the plant and hence the cost of the plant. Plot plans are generated during the preliminary design phase but are constantly reviewed and updated as the project progresses. Plot plans are used in every phase of the project and they are used by every project discipline. The use of plot plans by different disciplines is described here.

- Piping: Layout of interconnecting piping systems (pipes and associated fittings).
- Civil engineering: Designing access roads and paths and in locating major support structures. Designing foundations, supports and drainage systems.
- Electrical Engineering: Location of electrical substations, switchgear, routing of cables and motor control centers.
- Instrumentation: Location of main control house, analyzer houses and cable trays.
- Process engineering: Hydraulic design, line sizing, pressure drop and pump requirements.
- Project management/scheduling: Proper and orderly completion of engineering/construction activities. Constructibility reviews and erection sequence of major equipment. Estimating the overall cost of the plant. Review of plant operability, maintenance and safety with the client.

Development of plot plans

The development of plot plans is not an exact science. It varies with the unique requirements of each process plant. The layout designer must anticipate field problems during construction, operation and maintenance. The goal is to produce a safe, cost-effective plant with ease of operation and maintenance.

As the project progresses, the following plot plans are produced in sequence.

- **Proposal Plot Plan:** This is developed during the estimate phase of the project. It includes only principal equipment, main supporting facilities and overall dimensions. It is used in the estimation of bulk materials and presented to the client for approval of the overall arrangement concept.
- **Planning Plot Plan:** This is produced after the award of the contract award. The proposal plot plan is reviewed, updated and approved by client. The planning plot plan serves as a working document for the plant layout phase of the project. In the planning plot plan, different areas of the plant are identified and equipment is tagged and positioned at appropriate locations.
- **Construction Plot Plan:** This is produced as a result of the activities in the plant layout phase of the project. At this stage, all equipment has been sized and positioned. Equipment positions are indicated in terms of coordinate dimensions (North-South, East-West, and Elevations). Additionally, the location of pipe racks, support structures and ancillaries has also been finalized. Locations of access roads, paths and buildings have also been finalized. This is the final plot plan and is used in the construction of the plant.

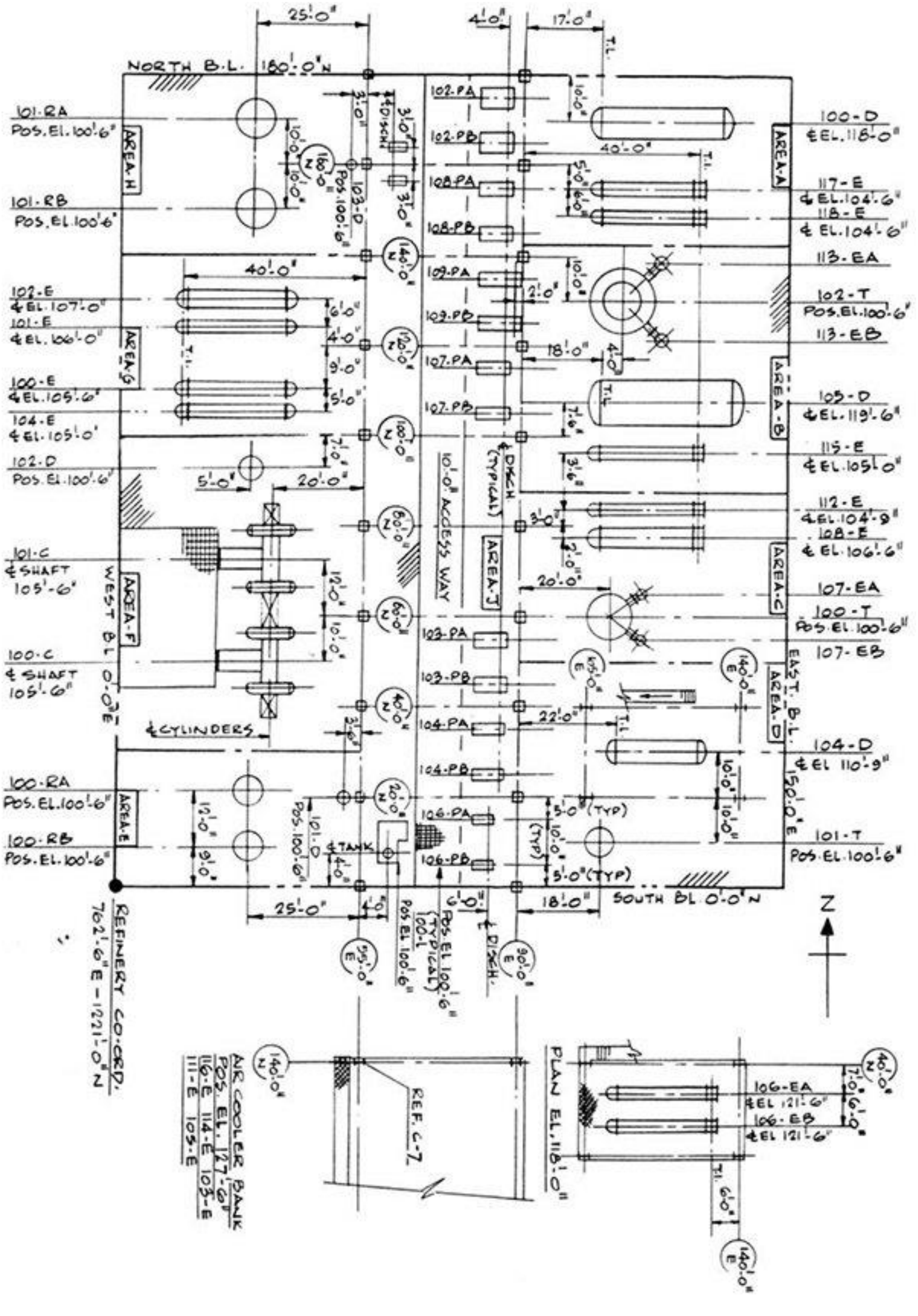


Figure 4.1

Sample construction plot plan (Source: "Process Plant Layout and Piping Design", Ed Bausbacher and Roger Hunt, Prentice Hall).

Documents used in the development of plot plans

- **Equipment Lists:** Major equipment includes reactors, towers, furnaces, exchangers, pumps, compressors, drums and miscellaneous (lube oil console, corrosion inhibitor packages etc.)
- **Process Flow Diagram:** Discussed in detail in Module 2.
- **Plant Layout Specifications:** Discussed earlier in this module.
- **Site Information:** Includes geographic information, information on roads, rivers, railroads, land contours, inhabited areas, real estate available, climate conditions including seasonal averages of temperatures, rainfall, prevailing winds etc.
- **Equipment Sketches:** The best available information is used during the preliminary phases. Equipment sizes are updated as the project progresses.
- **Materials of Construction:** Materials specialists identify critical piping, that is, piping with expensive, special alloys and heavy piping. It is important to locate equipment so as to minimize piping runs for critical lines.

Types of equipment arrangements

- **Grade Mounted Arrangement:** This is also known as "Horizontal In-Line Arrangement". In this arrangement, equipment is located in a rectangular area mostly at grade level and serviced by access roads and pipe racks. The advantages are it is easy to construct and it is easy to access for operation and maintenance. The disadvantages are large real estate required and longer run of piping and cables. This type of arrangement is mostly used in refineries and in chemical/petrochemical plants.

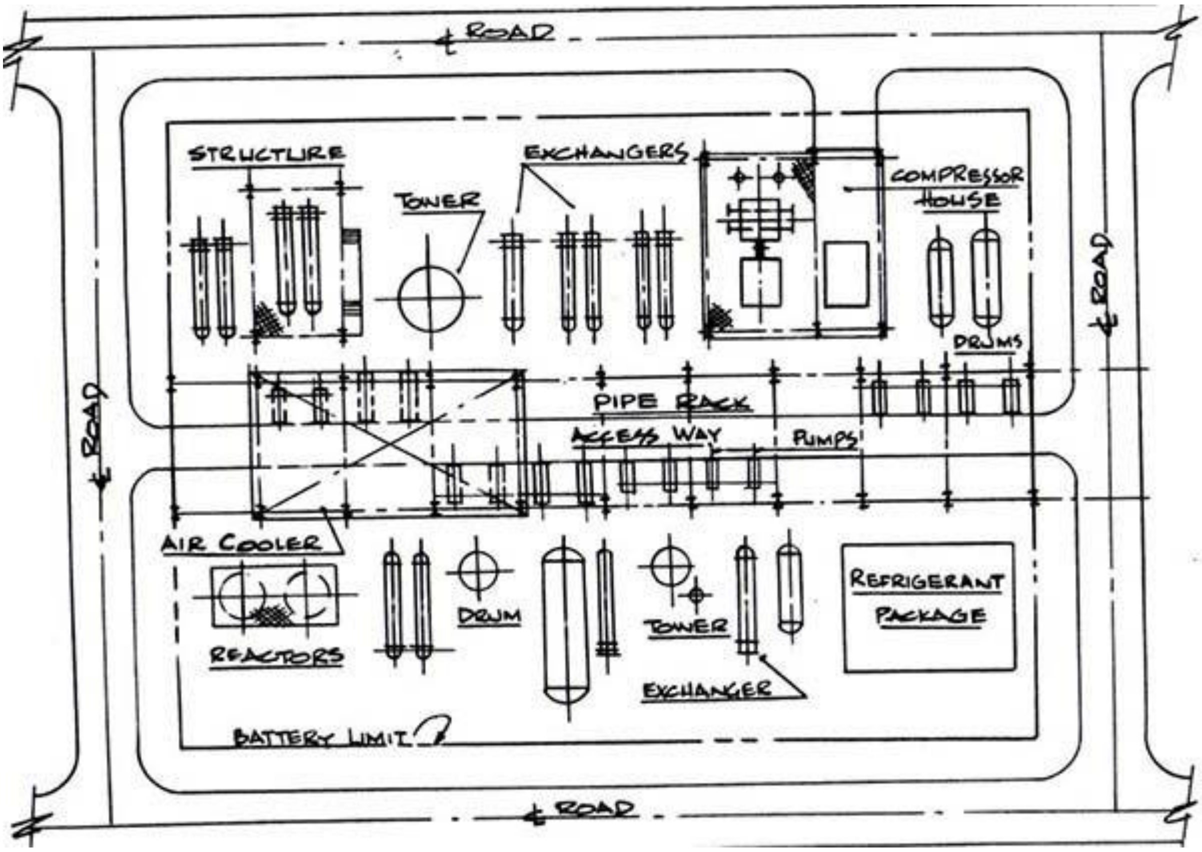


Figure 4.2
Grade Mounted Arrangement (Source: Process Plant Layout and Piping Disign, Ed Bausbacher and Roger Hunt)

- **Structure-mounted vertical arrangement:** In this arrangement, equipment is located in multi-level concrete or steel structures. The structures could be completely enclosed to accommodate extreme climates. Here, piping and cables are routed through different levels at some common points between levels or floors. Access to different levels is by means of elevators or stairs.

Advantages:
Small amount of space required, compact plants, protection from extreme weather conditions, accommodation of gravity feeds, smaller runs of piping and cables.

Disadvantages:
Construction is more complex, access for operation and maintenance is cumbersome, pumping costs can increase.
This type of arrangement is used in off shore platforms, pulp and paper mills, polymer manufacturing, food and beverage, pharmaceuticals, detergents and other consumer products.

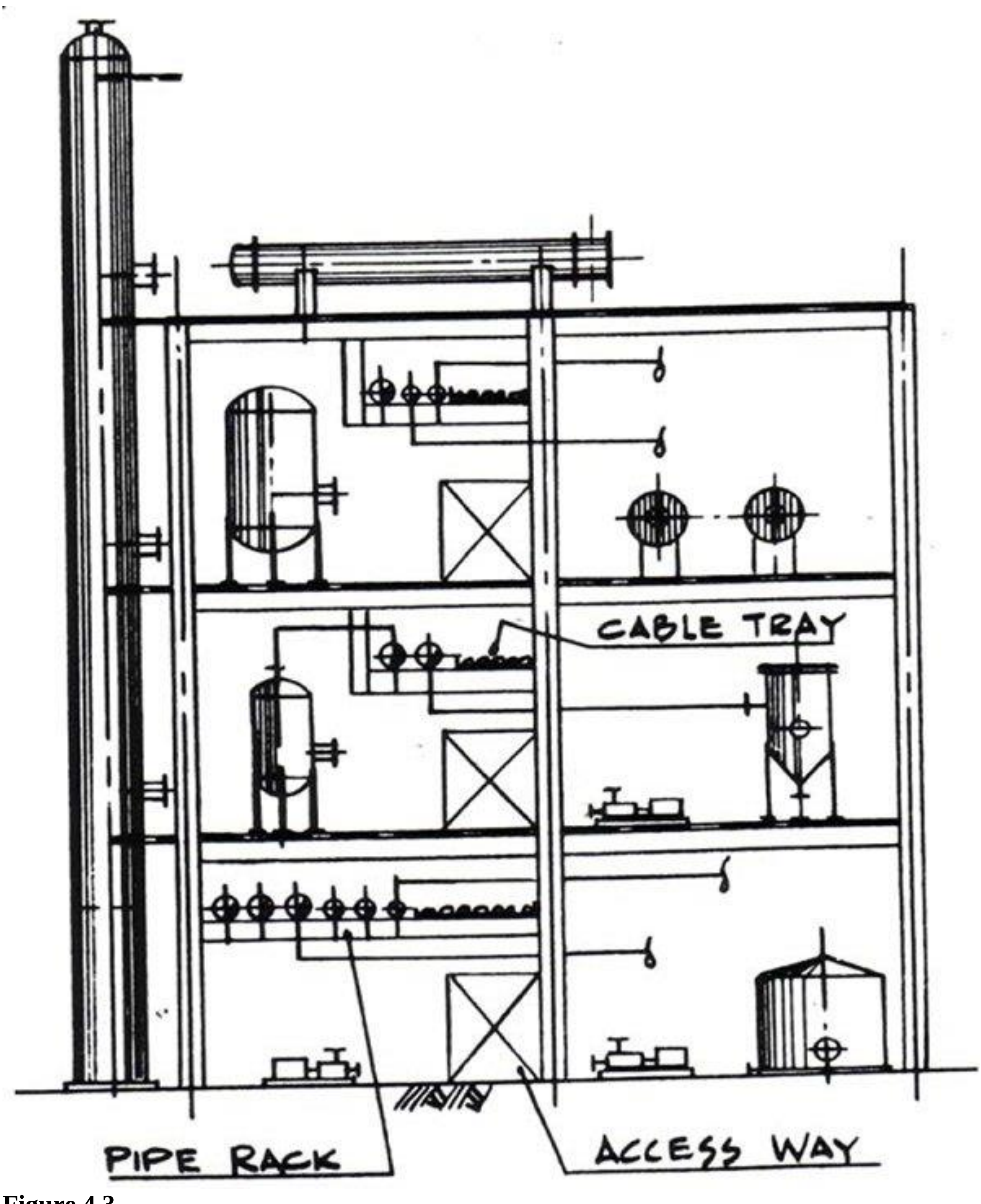


Figure 4.3
Structure Mounted Arrangement (Source: Process Plant Layout and Piping Design, Ed Bausbaucher and Roger Hunt)

Factors to be considered while developing plot plans

- Distances between equipment to meet safety and code requirements.
- Process Requirements.
- Divide the PFD into smaller, manageable subsystems based on unit operations and unit processes. These subsystems constitute different plant areas.

- Proper sequencing of equipment based on PFD.
- Consider constraints such as pressure drop, line pocketing and gravity feed.
- Discuss unknowns with process group
- Minimize piping runs for expensive, high temperature piping but provide sufficient line flexibility
- If possible, use common servicing units. For example, use common surface condenser for multiple compressors driven by steam turbines and common racks for piping and cables between different areas.
- Locate large sized, awkwardly shaped equipment first. Then locate symmetrical (rectangular, circular) equipment.
- Provide sufficient access for operation and maintenance.
- Towers: Removal of internals – trays, packing.
- Reactors: Space for catalyst loading, unloading.
- Shell and Tube HE: Removal and maintenance of tube bundles.
- Rotating equipment: Removal of casing and drives.
- Provide access roads and pathways (or stairs in vertical arrangement).
- Provide sufficient space to view instruments and operate control valves.
- Locate furnaces, compressors, stacks, reactors, control houses, and towers with wind direction in mind.
- Flammable vapors should be directed away from inhabited areas.
- Operating areas such as control rooms should not be in the direct path of smoke and vapors.
- **Pipe Racks:** Provide a way of organizing interconnecting pipes and cables between different areas/units of process plants. Pipe racks are either single or multilevel structural steel members usually spaced 20 ft apart. The width of the rack is dependent upon the number of pipes and cables to be supported with room for future expansion. The width is usually in the range of 20 ft to 40 ft. In a multilevel pipe rack, the lower level is used for process lines, the mid level is used for utility lines and the top level is used for cable trays.

Figure 4.1 shows a typical pipe rack configuration.

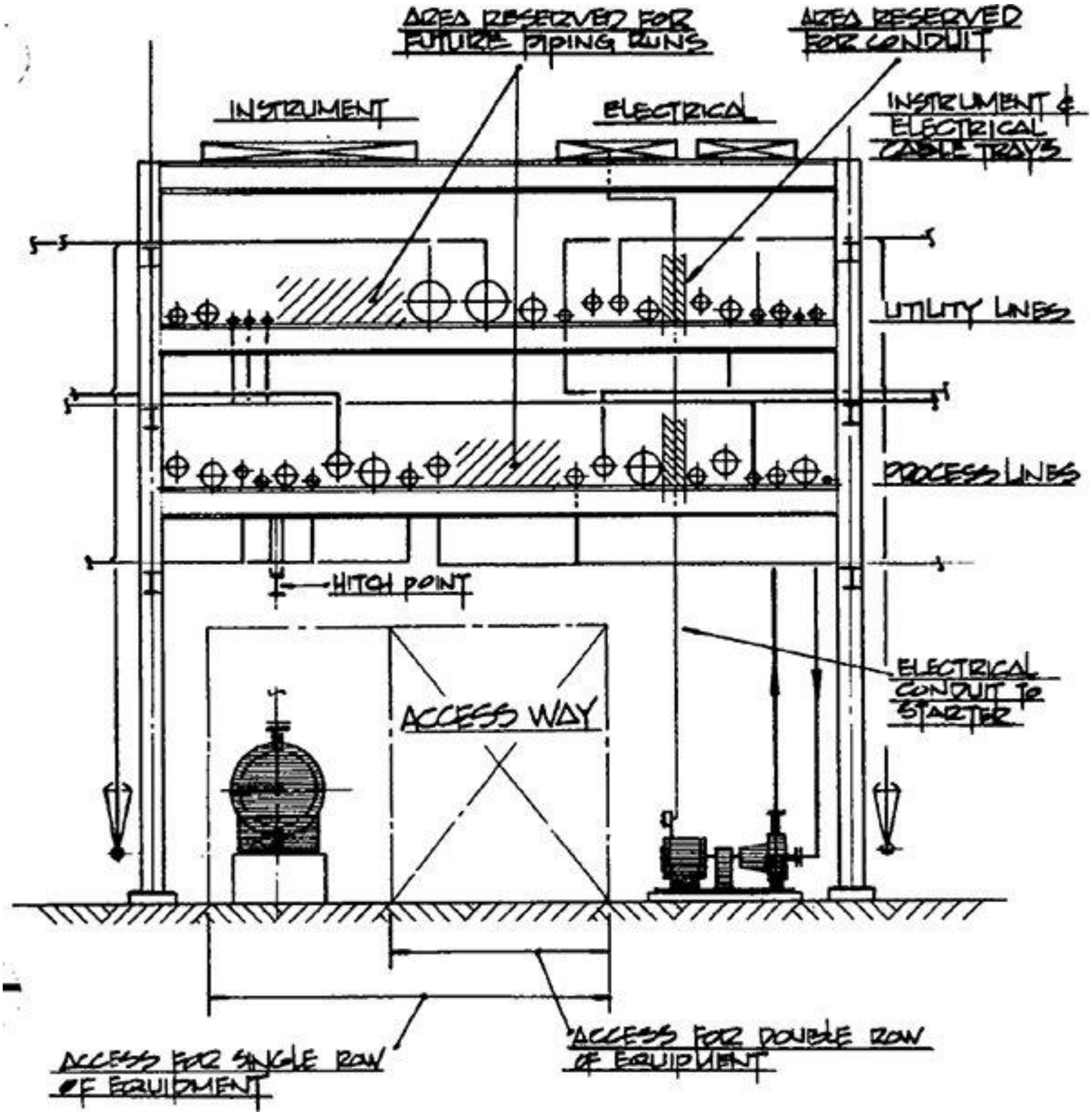


Figure 4.4
Typical Pipe Rack Configuration (Source: Process Plant Layout and Piping Design, Ed Bausbacher and Roger Hunt, Prentice Hall)

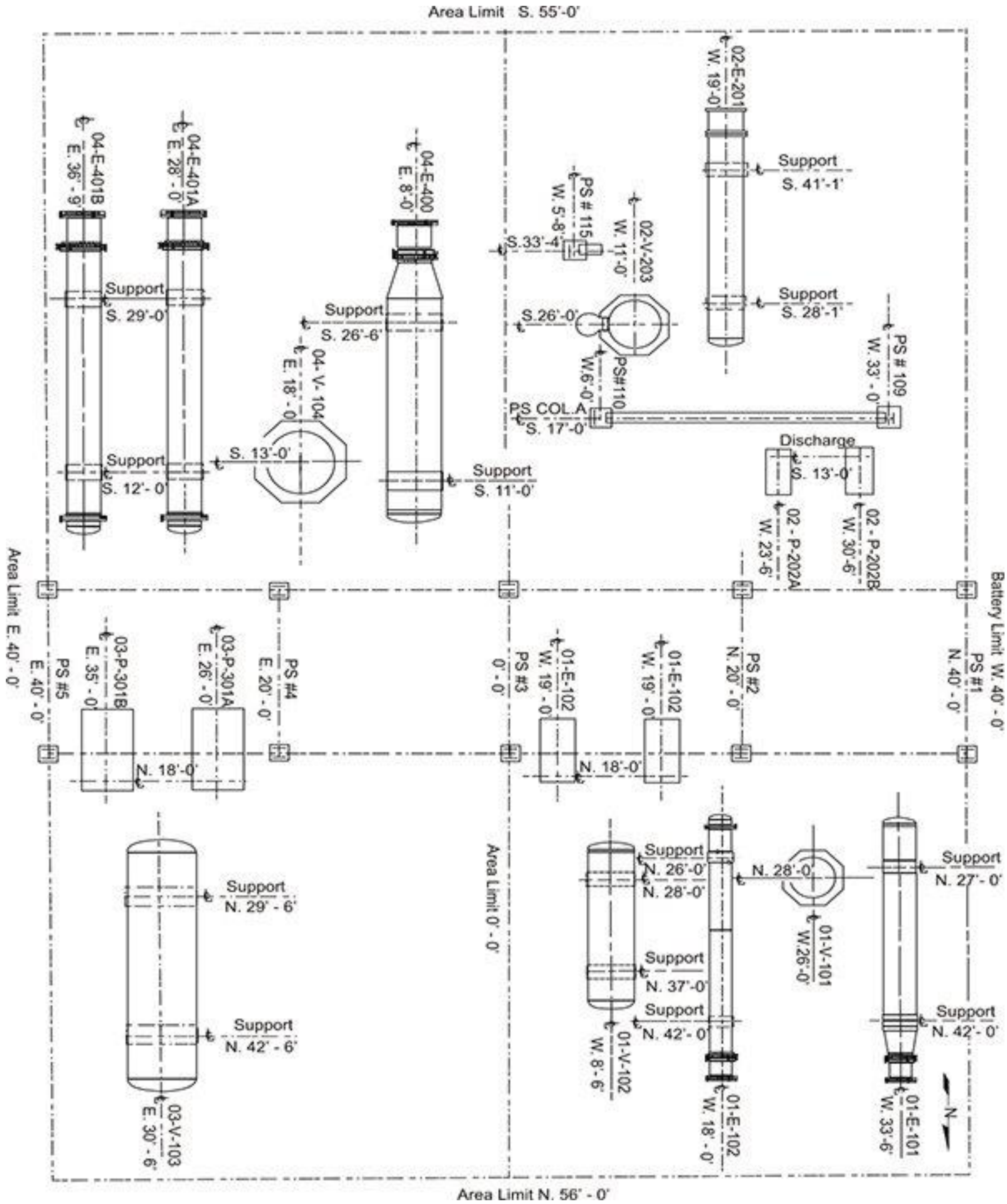


Figure 4.5

Equipment Arrangement Plan (Source: "Pipe Drafting and Design", Roy Parisher and Robert Rhea, Gulf Publishing)

4.3 Summary

Plant Layout is a very important preliminary activity in the design of process plants and piping systems. Plot plans are documents generated during the plant layout phase. The guidelines and procedures commonly used in the development of plot plans have been described in this chapter.

Fundamentals of Process Plant Layout and Piping Design

Practical Exercise 4

1. Using the PFD and the process description for the production of vinyl chloride (which were given in **Practical Exercise 2** , develop and sketch a suggested **“Plot Plan”** for the processing facility.

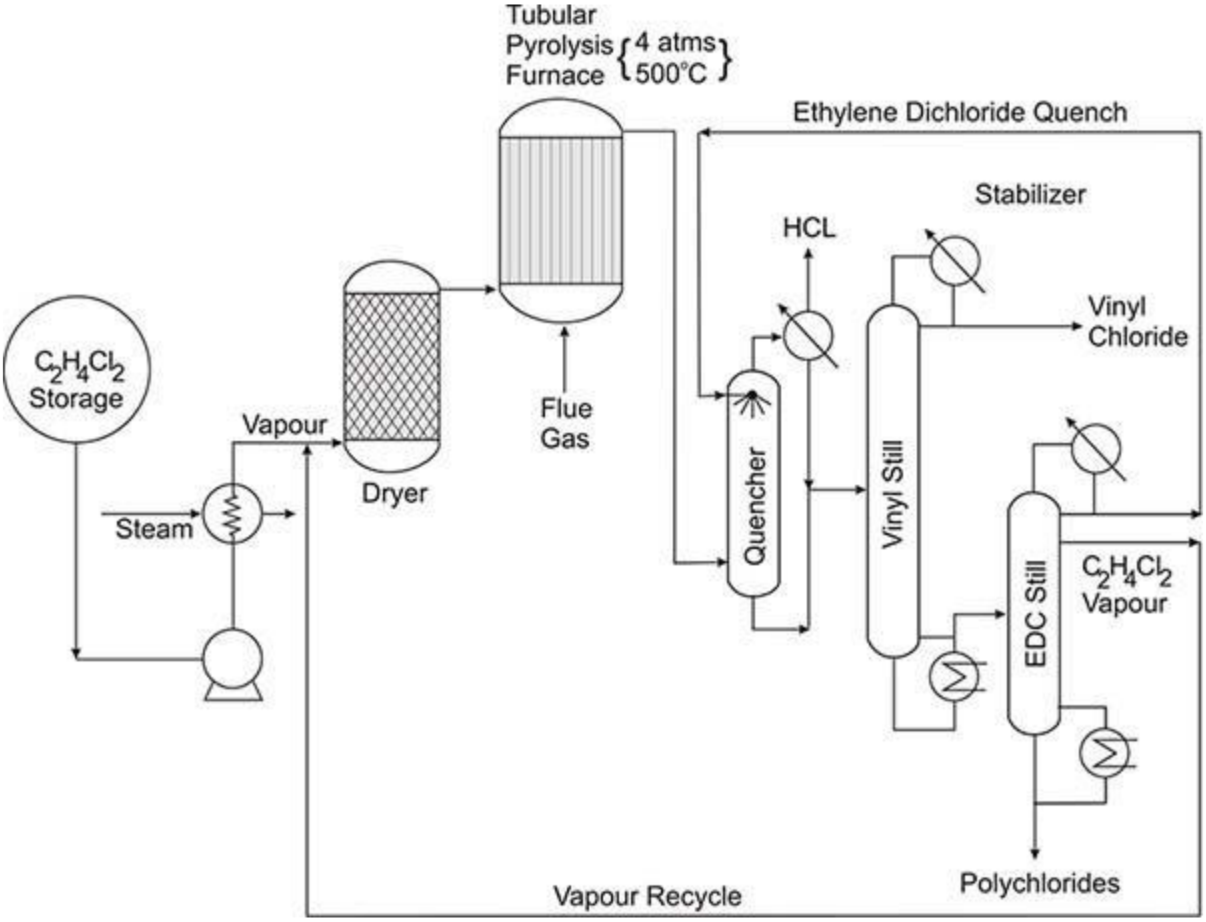
2. Compare and discuss the plot plan that you have developed with those by your peers in the class. Observe the difference and the good features in different plot plans for the same facility.

Process Description For The Manufacture of Vinyl Chloride (VC) By Thermal Pyrolysis of Ethylene Dichloride (EDC)

Chemical Reaction: $\underset{\text{EDC}}{C_2H_4Cl_2} \xrightarrow[4\ \text{atm}]{500°C} \underset{\text{VC}}{C_2H_3Cl} + HCl$

EDC vapor at a pressure of 4 atm. is dried by using a silica gel drier. It is then sent to a stainless steel tubular cracking furnace where the conditions are maintained at about 480-520°C and 4 atm. The furnace is heated by external flue gas. The contact surface catalyst within the tubes is pumice or charcoal. The conversion per pass is around 50% and the ultimate yield is about 95%. The product from the furnace is quenched with cold EDC to prevent the back reaction and to form condensable product components. Uncondensed gases are sent to a surface heat exchanger to condense any remaining EDC and VC present in vapor form. The non-condensable HCl is sent to an adjacent process area for further processing. The condensate is then sent to a VC still or fractionator where VC is taken as an overhead product and sent to storage after stabilization. The bottoms from the VC fractionator is to an EDC still to further separate EDC from heavier fractions. Part of the separated EDC is recycled in vapor form and the rest, in liquid form, is used for cold quench.

Process Flow Diagram: Vinyl Chloride Production



5

Piping and Instrumentation Diagrams (P&IDs), Control Valve Manifolds, Meter Runs

This chapter covers the fundamentals of Piping and Instrumentation Diagrams (P&IDs) and their significance in process plant layout and piping design. The symbols and terminologies used in P&IDs are described. Control valve manifolds and meter runs are also discussed in this chapter.

Learning objectives

- Understand the fundamental aspects of Piping and Instrumentation Diagrams (P&IDs).
- Know how P&IDs are used in process plant layout and piping design.
- Know the symbols and terminologies associated with P&IDs.
- Understand the layout and components of control valve manifolds.

- Understand the layout and components of flow meters.

5.1 Piping and instrumentation diagrams (P&IDs) and their role in process plant layout and piping design

Piping and Instrumentation Diagrams (P&IDs) play a crucial role in the design and engineering of process plants and piping systems. P&IDs are also known as “Engineering Flow Diagrams” or “Mechanical Flow Diagrams”. P&IDs are schematic diagrams that contain engineering and design details of the process plants. Thus, the P&IDs are much more detailed than PFDs. A P&ID is a working document that is used by every discipline involved in the design, engineering and construction of process plants. It is used as a reference for checking engineering and design documents and drawings associated with a project. P&IDs are also used in material take-off, that is, in generating a “Bill of Materials” for procurement and construction. P&IDs typically contain the following information:

- All the equipment and their specifications, usually presented in the form of a table.
- All piping and line specifications.
- All piping system components such as fittings, flanges and valves with their specifications.
- All instrumentation and control components.
- Flow directions.
- Information on process variables such as pressure and temperature.
- Material Specifications.
- Specialty Items such as strainers.

5.2 P&ID symbols and terminologies

Process instrumentation and control components

The primary functions of instrument and control components are monitoring, display, recording and control of process variables. Instrument and control symbols consist of an instrument bubble with the instrument abbreviation lettered inside the bubble. The abbreviation completely describes the function of the instrument/control component. Instruments/control elements can be grouped into different categories based on the process variable that the instrument or the control element is monitoring or controlling. The first letter in the instrument abbreviation indicates the process variable being monitored or controlled. The process variables are:

- Flow (F)
- Level (G)
- Pressure (P)
- Temperature (T)

Instruments can be further grouped into different categories based the function they perform. The second letter in the instrument abbreviation indicates the instrument function. The common functions performed by instrument and control components are:

- Alarms (A): Alarms are devices responsible for alerting plant operators about an upset condition of the process variable. Alarms typically consist of sound and light outputs that attract the attention of the plant operators.
- Controllers (C): Controllers are responsible for the control of the process variable. A typical controller receives input on the status of the process variable and compares the value with the “set point” and initiates the appropriate action. Actuators and control valves execute the control action.
- Indicator (I): An indicator is a device that indicates the value of the process variable. Typically, indicators are digital or analog devices located in a remote control building. Display devices are also located at the process unit for local access and back up purposes. Indicators located at the process unit are also known as “Gauges”. A Level Gauge (LG) is an indicator used in the measurement of liquid level in process vessels.
- Sensors: Sensors are devices that actually measure the value of the process variable. Examples of sensors are thermocouples and orifice meters used in temperature and flow measurements respectively. Transducers are used in converting the analog measurements into digital values.
- Recorders (R): Recorders are devices that record the value of the process variable in the form of time dependent graph or strip chart. This information is very useful in monitoring plant performance and in quality control of the products.
- Transmitters (T): Transmitters are devices that transmit the information on the process variable to controllers or to remotely located indicators.

Typically instrument abbreviations consist of two letters; the first indicating the process variable and the second indicating the instrument/controller function. As an example, the instrument abbreviation “TI” denotes a “Temperature Indicator”. Occasionally, third letter is included in the instrument abbreviation to describe a simultaneous function or a special function. The following examples illustrate this situation: the abbreviation “FRC” denotes a “Flow Recording Controller” which describes both the recording and control functions and the abbreviation “LAL” denotes a “Level Alarm Low” which describes an alarm used in the event of a low level upset condition.

The following list contains some of the instrument abbreviations and their expansions.

FC: Flow Controller	LC: Level Controller
FE: Flow Element	LG: Level Gauge
FIC: Flow Indicating Controller	LA: Level Alarm
FR: Flow Recorder	LAH: Level Alarm High
FRC: Flow Recording Controller	LAHH: Level Alarm High High
FT: Flow Transmitter	LAL: Level Alarm Low
FA: Flow Alarm	LI: Level Indicator

PC: Pressure Controller

PI: Pressure Indicator

PIC: Pressure Indicating Controller

PR: Pressure Recorder

PRC: Pressure Recording Controller

PSV: Pressure Safety Valve

PT: Pressure Transmitter

RV: Relief Valve

USD: Unit Shut Down

SDV: Shut Down Valve

SDY: Shut Down Valve Relay

LIC: Level Indicating Controller

TC: Temperature Controller

TI: Temperature Indicator

TIC: Temperature Indicating Controller

TR: Temperature Recorder

TRC: Temperature Recording Controller

TT: Temperature Transmitter

TW: Thermo Well

TY: Temperature Transducer / Relay

PSH: Pressure Switch High

ZI: Position / Limit Indicator

ZSC: Position / Unit Switch Closed

ZSO: Position / Unit Switch Open

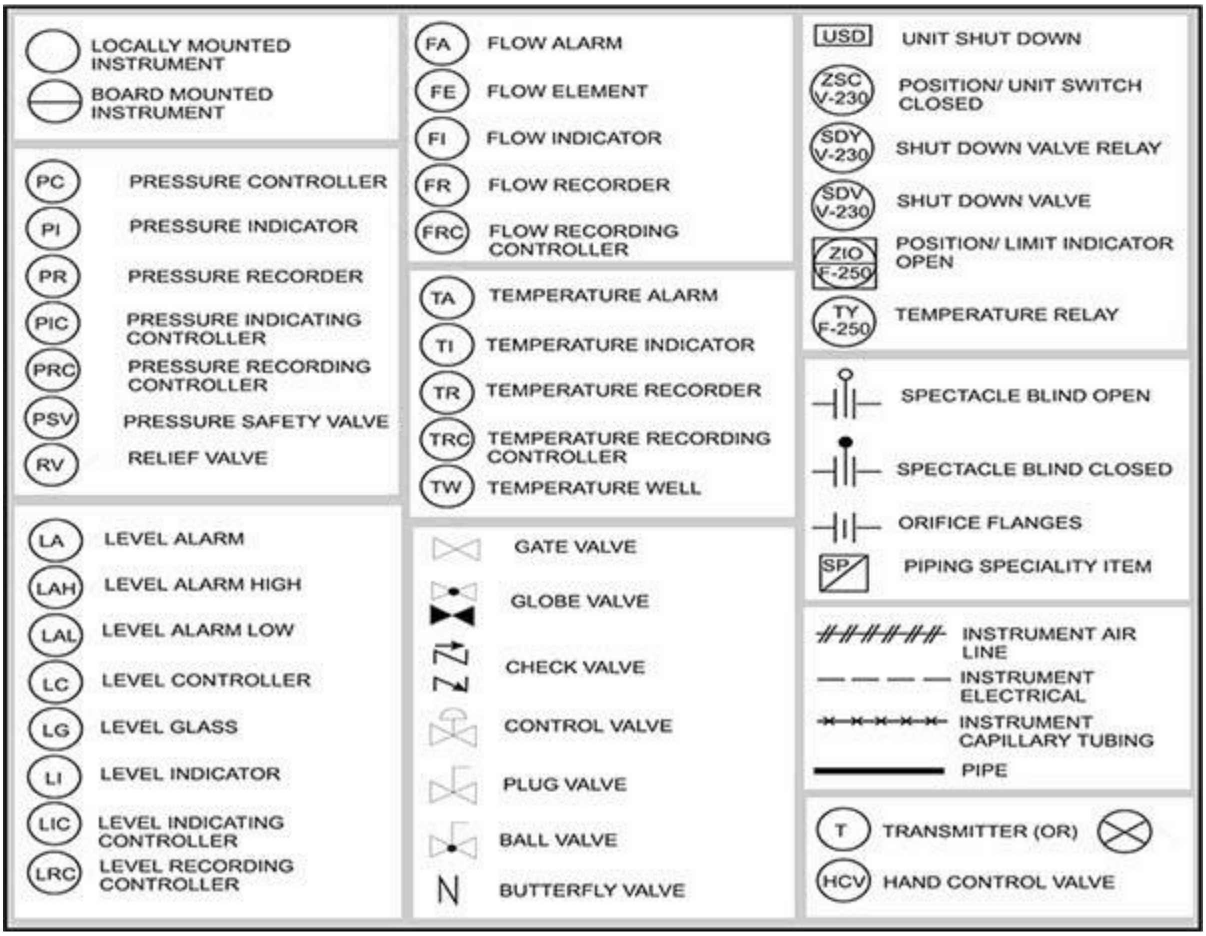


Figure 5.1

Typical instrument symbols used in P&IDs.

Sample piping and instrumentation diagram

Figure 5.2 represents a P&ID typically used in the design and engineering of process plants. The level of detail in this diagram is quite obvious and the P&ID contains design and engineering information that is used by different disciplines involved in the project. The following observations can be made about the P&ID shown in Figure 5.2.

- The three major equipments are: V – 230A Third Stage Suction Scrubber, C – 235 Third Stage Compressor, E – 236A Third Stage Discharge Cooler. The equipment table on the P&ID gives the details for each of this equipment. This includes the equipment dimensions, design pressure and temperature, and material of construction.
- Information on all the lines is given. Each line is labeled with the line specification. For example, the line leaving the compressor is labeled 6" – PG – 117 – GE – 2. The nominal pipe size is 6"; PG is the service abbreviation and denotes "Process Gas". 117 is the line sequence number. GE – 2 is the piping material specification. Information on all the valves and valve specifications can also be seen on the P&ID.
- Information on all the instrumentation is also presented. For example, the instrument PI / C235A-1 is the Pressure Indicator for C – 235A and is a board mounted instrument in the control room.

Service Abbrev. Used In The Above Piping Specification

Service Abbrev.	Service
AI	Instrument Air
AG	Acid Gas
AM	Amine
AU	Utility Air / Plant Air
AV	Atmosphere Vent
BD	Blowdowns
BG	Blanket Gas
C3	Propane
CD	Closed Drain
CH	Chemicals
CL	Chlorine
CS	Condensate
CW	Cooling Water
DE	Deluge Water
DF	Diesel Fuel
EX	Equipment Exhaust / WHRU
FG	Fuel Gas
FL	Flare
FW	Fire Water

Service Ab
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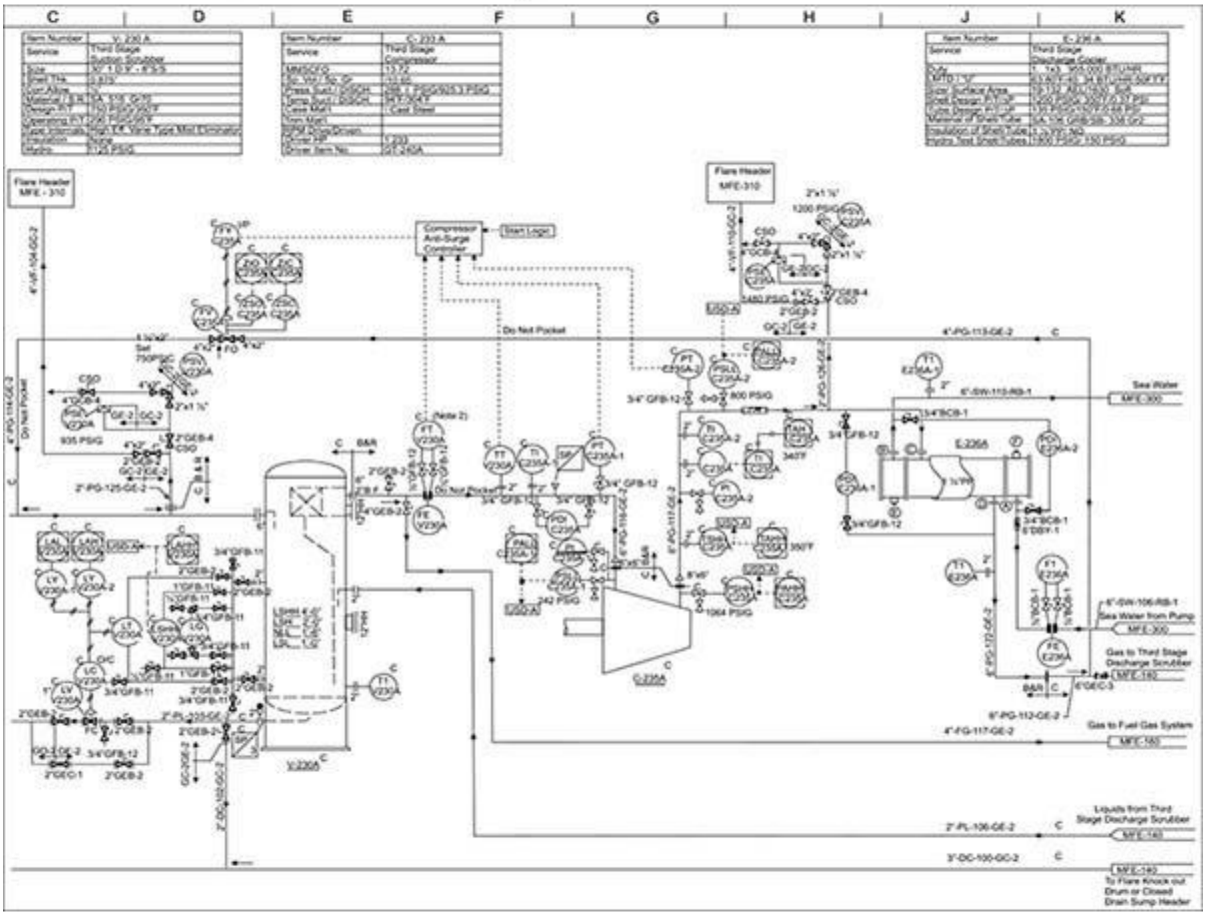


Figure 5.3
Sample Piping and Instrumentation Diagram (P&ID)

5.3 Layout and components of control valve manifolds

The function of a control valve is to control the flow rate of a fluid through a piping system. In addition to an automatic control valve, other components such as valves, fittings and piping are used as part of the system, which is known as a “Control Valve Manifold”. Figure 5.3 depicts a typical control valve manifold arrangement.

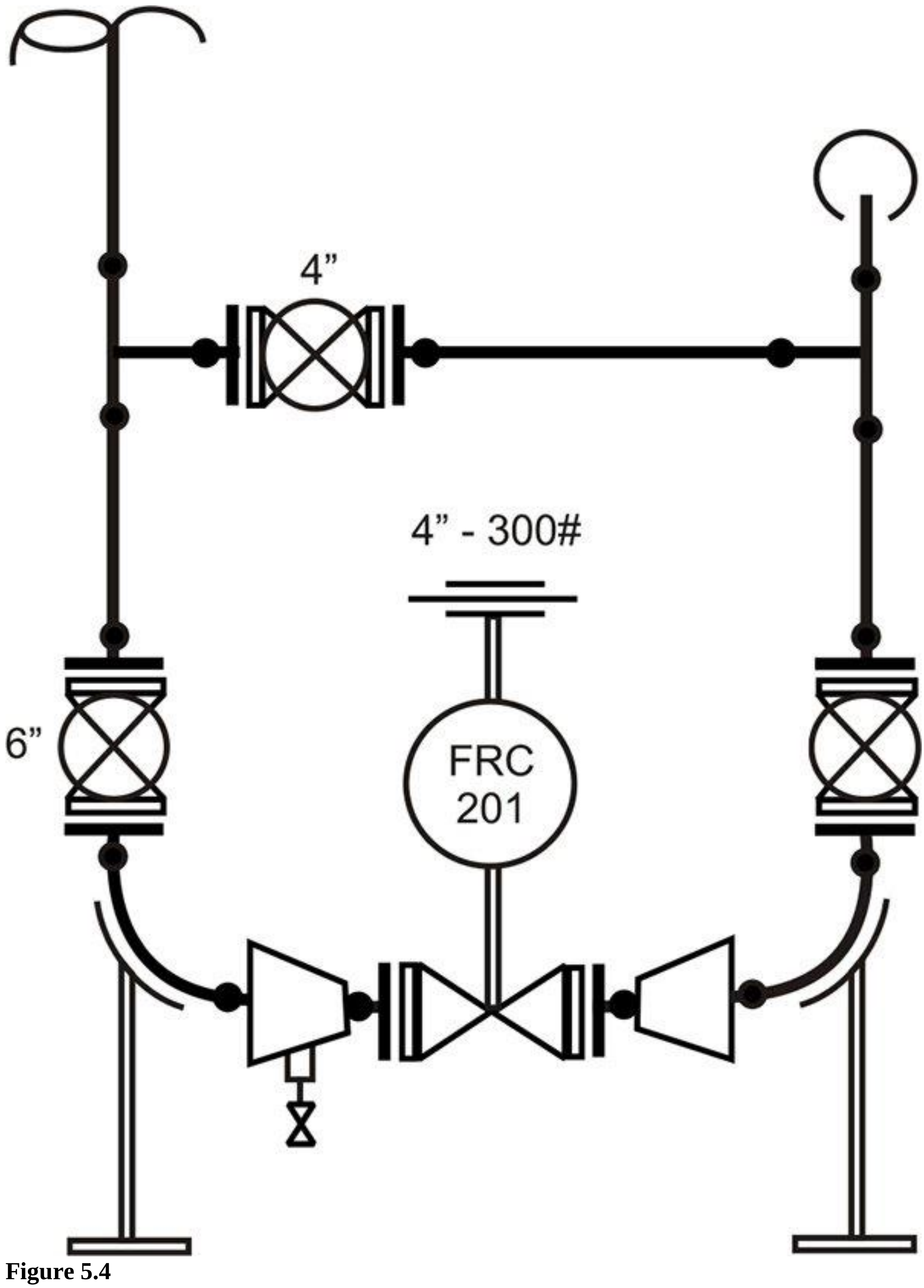


Figure 5.4
Typical Control Valve Manifold Arrangement

The main component in the system is the control valve, FRC 201, which is typically a globe valve with a hydraulic or pneumatic actuator that automatically controls the flow. Valves are discussed in greater detail in Chapter 8. On either side of the control valve are reducers. The reducers connect to a pair of block valves. When the block valves are open, the flow occurs through the control valve. When the block valves are closed, the flow occurs through the bypass valve shown on top of the control valve. The bypass valve is used in manually controlling the flow when the control valve is being serviced. There is a small drain valve that is opened after the block valves have been closed to drain the fluid accumulated in the system, thus avoiding spills. The following factors must be considered while designing a layout for a control valve manifold.

- Sufficient space must be provided for hand wheels. The hand wheels must be oriented away from piping, equipment, access ways, and other structures.
- Adequate spacing for locating the actuator on top of the control valve must be provided.
- The components of a control valve manifold have significant weight and must be adequately supported with suitable pipe supports.

5.4 Layout and components of flow meters

An orifice meter is typically used in measuring the flow rates of fluids. The orifice meter consists of an orifice plate and an orifice flange assembly as shown in Figure 5.4.

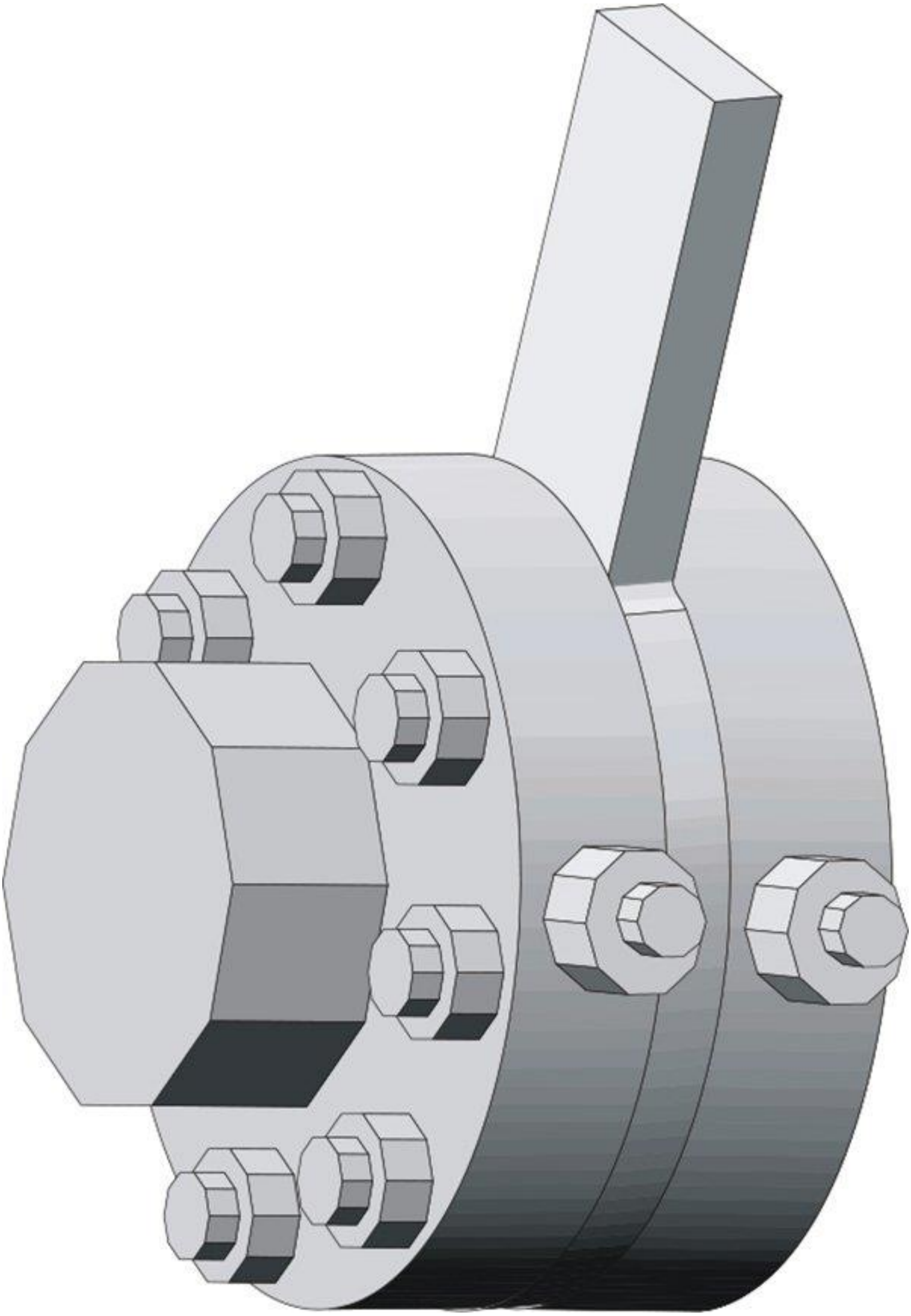


Figure 5.5
Typical Orifice Flange Assembly

An orifice plate is shown in Figure 5.6

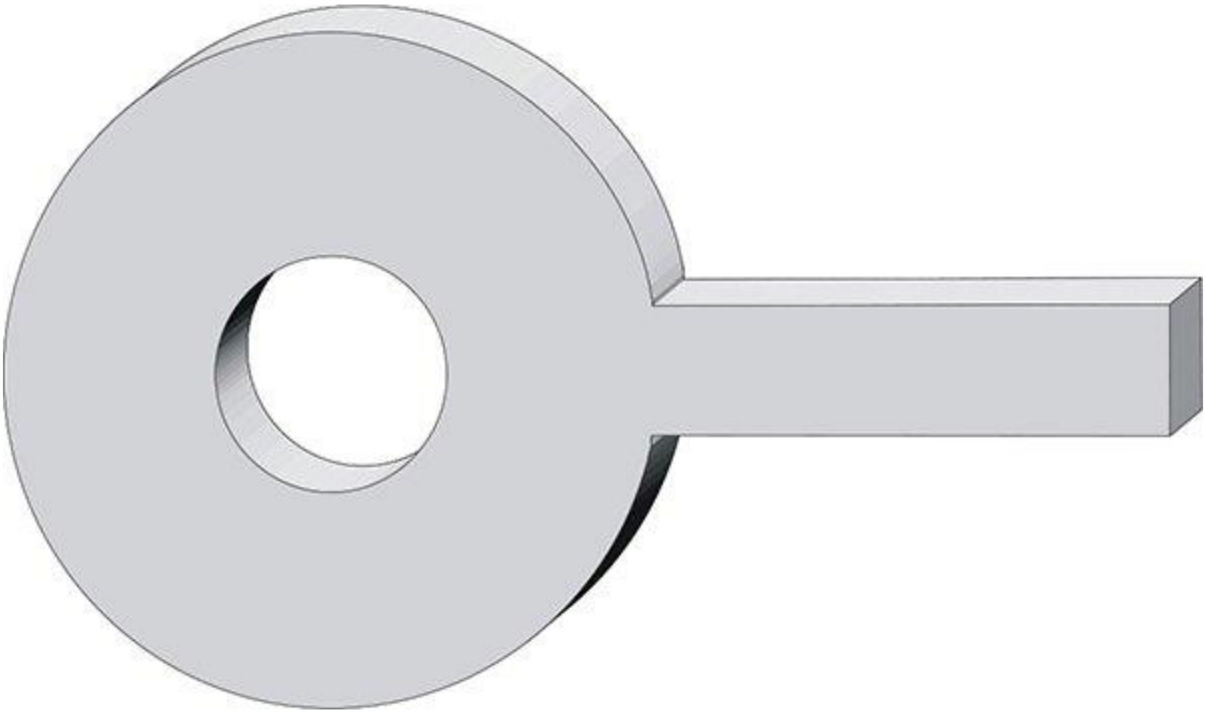


Figure 5.6
Orifice Plate

The orifice flanges have valve taps that are connected to pressure sensing instruments to measure the pressure difference. The pressure difference correlates with the flow rate. The following factors must be considered while designing a layout for orifice meters.

- The flow pattern through the orifice must be smooth with minimal turbulence. Turbulence is usually created by the presence of obstructions such as fittings and valves. Having sufficient length of straight pipe upstream and downstream of the orifice ensures a smooth flow pattern near the orifice. These lengths of straight pipe are known as “meter runs”.
- Piping layout for flow meters must include meter runs of at least 30 pipe diameters upstream of the orifice and 6 pipe diameters downstream of the orifice.

5.5 Summary

Piping and Instrumentation Diagrams (P&IDs) are important working documents used in the design and construction of process plants. Symbols and terminologies used in P&IDs have been explained in this chapter. The concepts required for understanding and using P&IDs have been explained. The points to be considered during the layout and design of control valve manifolds and flow meters have also been explained in this chapter.

Fundamentals of Process Plant Layout and Piping Design
Practical Exercise 5 (P&IDs)

1. Piping and Instrumentation Diagram (P&ID) is also known as ______________ ____.

2. P&IDs contain information on nominal pipe sizes (NPS).
A. True B. False.

3. P&IDs are schematic diagrams.
True B. False.

4. P&IDs give information on equipment locations.
True B. False.

5. The three most important process variables that need to monitored and controlled are ___________________, ______________________, and __________________.

6. Expand the following instrument abbreviations:

a. PSV: ______________________________________

b. FRC: ______________________________________

c. TI: ____

d. LAL: ______________________________________

e. HCV: ______________________________________

7. On a P&ID, the equipment table for a compressor includes the following entry:
Press. Suct. / Disch. 285 psig / 926 psig
Explain clearly the meaning of this entry.

6

Plant Layout and Piping Design Documentation and Tools

This chapter describes the documentation used in the design, procurement and construction of process plants and piping systems. Examples of documents used include Line Lists and Piping Specifications. This chapter also discusses the tools used in the design of process plants such as piping isometrics and 3D models.

Learning objectives

- Equipment Arrangement Drawings.
- Equipment Lists.
- Piping and Instrumentation Diagrams (P&IDs).
- Piping Line Lists.
- Piping Specifications.
- Piping Codes.
- Piping Isometrics.
- Bill of Materials.

- 3D Models

6.1 Importance of documentation in plant layout and piping design

Proper and accurate documentation is essential for the design and construction of process plants in a timely and cost-effective manner. Process plants and associated piping systems involve equipment, piping, fittings and instruments, which need to be accurately specified for procurement purposes. These specifications involve extensive amounts of dimensional, material and other data. The integrity of this data must be maintained through the different phases of the project needs to be accurate at the time of procurement of materials. The data is represented in different documents such as P&IDs, Equipment Lists, Line Lists, Valve Lists and Instrument Lists. Inappropriate and inconsistent documentation and data can lead to costly project delays, field re-work and even difficulties during plant operation and maintenance. Personnel involved in plant layout and piping design should be able understand and interpret these documents in an effective manner.

6.2 Equipment arrangement drawings

The equipment required for processing is obtained from the Process Flow Diagram (PFD, discussed in Chapter 2). With additional input, the precise location of equipment is determined and represented in the form of an “Equipment Arrangement Diagram”. The equipment arrangement drawing is a plan view of equipment locations. Figure 6.1 is an equipment arrangement drawing for a deck of an offshore platform. The location coordinates are provided in the “Equipment List” (discussed in the next section).

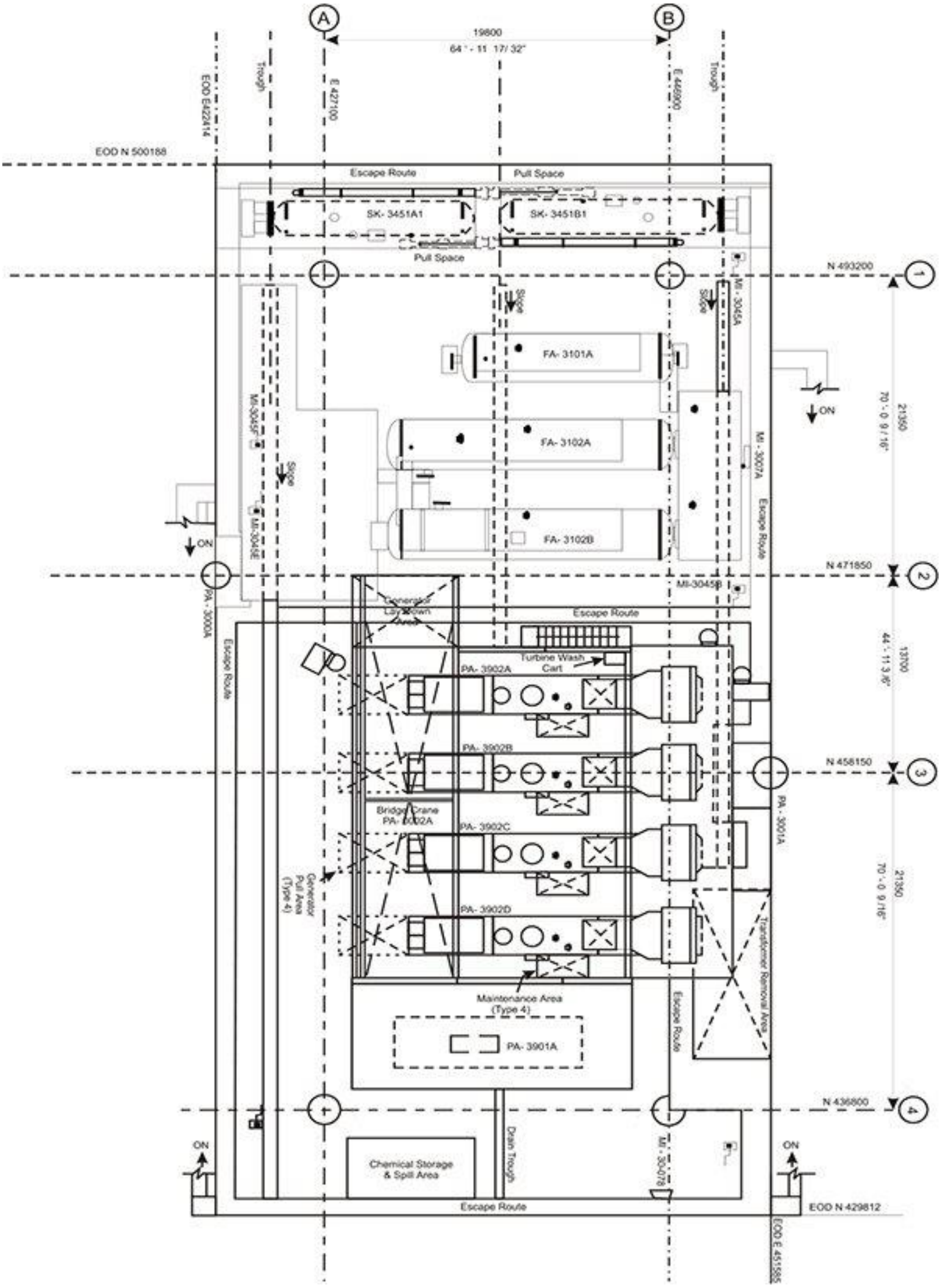


Figure 6.1
Equipment Arrangement Drawing

6.3 Equipment lists

Table 6.1 is the equipment list for the deck shown in Figure 6.1. The equipment list consists of the equipment tag and equipment description. The equipment location is provided by means of the coordinates in terms of North, East and Elevation. The coordinates in Table 6.1 are given in millimeters (mm). The equipment arrangement drawing and the equipment list should be used in conjunction with each other. It is quite common to place the equipment list on the equipment arrangement drawing.

Table 6.1
Equipment List

Tag	Description	North	East	Elev.
FA-3101A	Backup 1st/2nd Stage Compressor	487200	435248	45000
FA-3102A	2nd Stage Production Separator	480550	432200	45000
FA-3102B	2nd Stage Production Separator	474600	432200	45000
PA-3901A	Stand-by Generator Package	439447	433725	40513
PA-3902A	Main Power Generator Package	462554	432063	40665
PA-3902B	Main Power Generator Package	457054	432063	40665
PA-3902C	Main Power Generator Package	451554	432063	40665
PA-3902D	Main Power Generator Package	446054	432063	40665
SK-3451A1	TEG Regenerator Skid	495200	423588	40513
SK-3451B1	TEG Regenerator Skid	495200	437610	40513
R-1	Generator Building	437996	428631	40513

6.4 Piping and instrumentation diagrams (P&IDs)

Piping and Instrumentation Diagrams (P&IDs) are very important working documents in the design and engineering of process plants and piping systems. P&IDs have been discussed in detail in Chapter 5. The engineering details and specifications of all piping and associated components are represented on the P&ID. P&IDs are used in generating Piping Line Lists and also in material take-offs for valves and specialty items. Figure 5.2 represents a sample P&ID.

6.5 Piping line lists

Piping Line Lists are tables containing data associated with each pipe segment. In this sense, Piping Line Lists are databases that contain all information associated with a pipe segment.

Piping line number

Each pipe segment is assigned a unique "Line Identification Number", also known as "Line Number". The pipe segments are referenced using this line number. The line number consists of information on the line size, the fluid being serviced and the piping specification. The contents of a piping line number are explained using the following example: 10" – P – C – 0006 – EA21. In the preceding example:

- The line size is 10".
- "P" denotes the fluid being serviced which in this case is a "Process" fluid. Instrument Air is designated as "IA".
- The letter "C" refers to the area of the plant in which the line segment is located.
- "0006" is the unique sequencing number assigned to that pipe segment.
- "EA21" is the piping specification or piping material class that is explained in a later section.

Line numbers play a very important role in keeping track of work on that line. Piping designers and engineers communicate by referencing line numbers.

Typical data associated with a pipe segment can be classified into "Process Data" and "Mechanical Data". There are many items that are common for process data as well as mechanical data.

Process data

Process data is data related to the process aspects of the line segment and includes the following items.

- Line Number.
- Service (From Unit X To Unit Y, that is From Origin To Destination.).
- P&ID Number, which is the drawing number of the P&ID in which the pipe segment is located.
- Operating Pressure.
- Operating Temperature.
- Design Pressure.
- Design Temperature.
- Phase (Liquid, Vapor or a 2-phase mixture).
- Flow Rate (lbs/hr, kg/s, gpm, SCFM, SCMS).
- Molecular Weight.
- Density (lbm/ft^3, kg/m^3).
- Viscosity (cP, lbf-sec/ft^2, N.
s/m^2)
- Velocity (ft/sec, m/s).
- Equivalent Length (ft, m).
- Pressure Drop (psi, kPa).
- Process Remarks.
- Revision.

Mechanical data

Mechanical data is data related to the mechanical aspects of the line segment and includes the following items.

- Line Number.
- Service (From Unit X To Unit Y, that is From Origin To Destination.).
- P&ID Number, that is, the drawing number of the P&ID in which the pipe segment is located.
- Pipe Material.
- Operating Pressure.
- Operating Temperature.
- Design Pressure.
- Design Temperature.
- Insulation (Thickness, Purpose, Specification, Trace Type).
- Painting Code.
- Pressure Testing (method and test pressure used).
- Stress Relief.
- Cleaning Specifications.
- Mechanical Remarks.
- Revision.

6.6 Piping codes

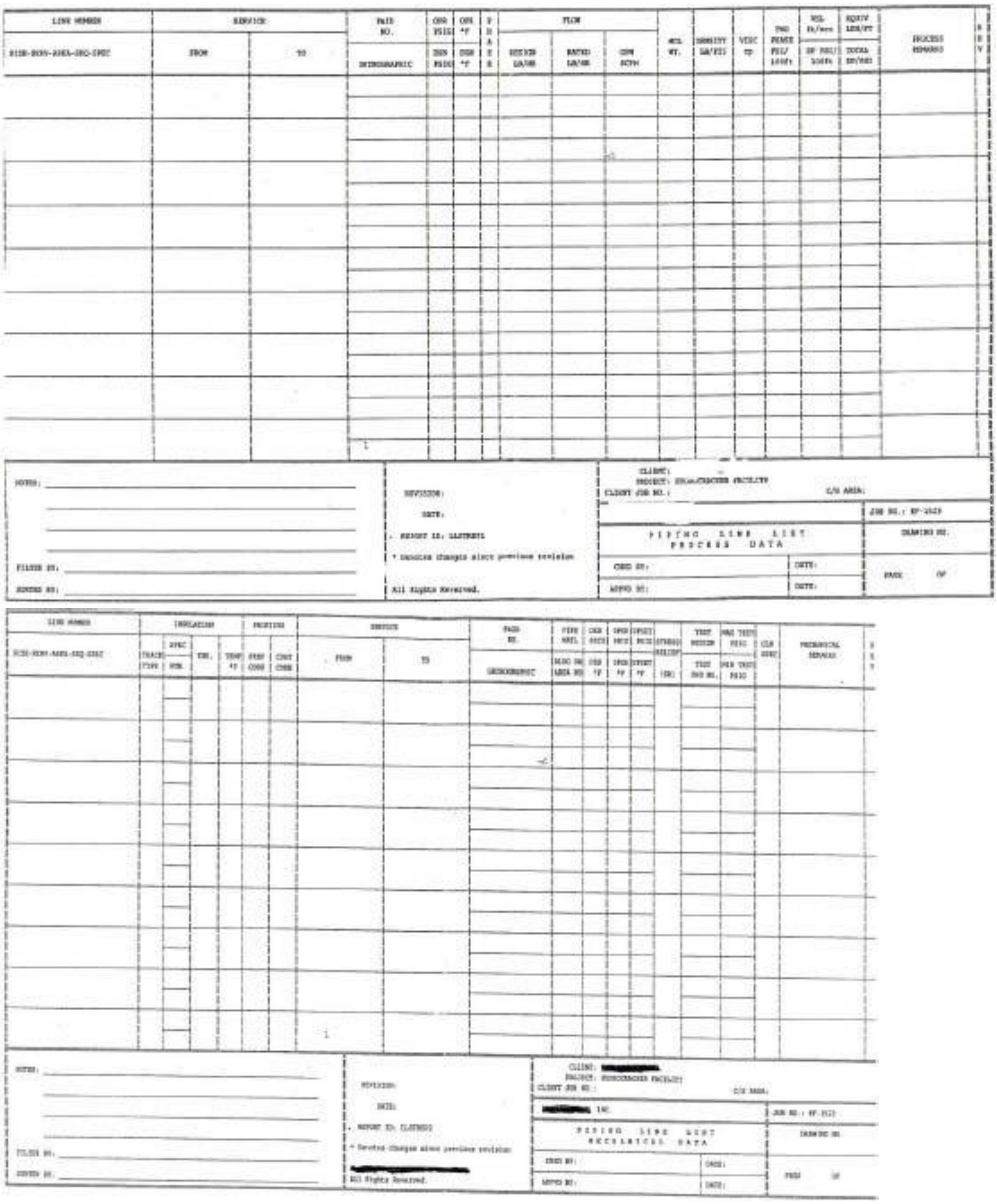
Piping codes are a broad set of guidelines for the design and engineering of piping facilities. The main objective of codes is to ensure the use of safe design practices and consequently the safe operation and maintenance of such facilities. Codes are developed by committees, which have a broad range of experience and expertise. Codes are influenced by government regulations for operator and worker safety in process plants. They are also constantly updated using feedback from various sources. The codes that govern design of piping systems are known as “B31 Code for Pressure Piping” and have been developed by the American Society of Mechanical Engineers (ASME). ASME B31 was earlier known as ANSI B31. ANSI represents American National Standards Institute. The different ASME B31 codes are listed here.

- **ASME B31.1:** Power Piping
- **ASME B31.2:** Fuel Gas Piping
- **ASME B31.3:** Process Piping
- **ASME B31.4:** Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids
- **ASME B31.5:** Refrigeration Piping and Heat Transfer Components
- **ASME B31.8:** Gas Transmission and Distribution Piping Systems
- **ASME B31.8S:** Managing System Integrity of Gas Pipelines

- **ASME B31.9:** Building Services Piping
- **ASME B31.11:** Slurry Transportation Piping Systems
- **ASME B31G:** Manual for Determining Remaining Strength of Corroded Pipelines

Among the codes listed here, the code that is most relevant to the design of process plants is ASME B31.3. A summary of ASME B31.3 Process Piping code is provided here.

ASME B31.3 Process Piping Code: Used in the design of chemical and petroleum plants and refineries processing chemicals and hydrocarbons, water and steam.
This code prescribes requirements for materials and components, design, fabrication, assembly, erection, examination, inspection and testing of piping. This code applies to piping for all fluids including: (1) raw, intermediate, and finished chemicals; (2) petroleum products; (3) gas, steam, air and water; (4) fluidized solids; (5) refrigerants; and (6) cryogenic fluids. Also included is piping which interconnects pieces or stages within a packaged equipment assembly.



6.7 Piping specification

Piping Specifications, also known as "pipe specs" are detailed guidelines for the design, fabrication and construction of the components of piping systems. Pipe specs are relevant to a particular project and are written to maintain uniformity and consistency through the different phases of the project. Pipe specs are also known as "Piping Specification Classes". The fluid flowing in the pipe, the material properties, the design temperature and the design pressure are considered in developing specification classes.

A sample pipe spec is shown in Figure 6.2.

Project Specification	- OFFSHORE PLATFORMS A1

SPECIFICATION BASICS (ASME B31.3)(Note 1)		SERVICES:	CW- Cool Water	FL- Flair	HR- HP Relief	SA- Start Air	ZG-Blanket Gas
		AD- Atmos. Drain	DF- Diesel Fuel	GH-Hydro.Gas	LH-Hydroc.Liq.	SC-Condens.	
Pipe	Carbon Steel A 106 Gr. B	AV- Atmos. Vent	DR-Clos. Drain	GL-Glycol	LR-LP.Relief	WH-Wtr/Oil/Gas	
Rating	ANSI 150 RF	RATING CONDITIONS		CONSTRUCTION SPECIFICS		Valves:	All Flanged
Size Range	½"to 42"	285 psig @ -20 to 100° F 260 psig @ 200° F 230 psig @ 300° F		1 ½" & Sm.: Socketweld 2" & Larger: Buttweld			
Corr. Allow.	0.125"						

Pipe (Per B36.10) (alsoAPI-5L)	A 106 Gr.B (24" & Sm.) API-5L-Gr.B (30" & Lgr.)	½"- 3/4"	Sch. 160,BBE	4" - 24"	Std. Wt., BBE
		1" - 3"	XS, BBE	30" - 42"	XS, BBE(API-5L-Gr.B,SAW/DSAW,St.Seam,95%JE)

Fittings (per B16.9)	ELBOWS, REDUCERS, TEES, LATERALS,CAPS, ETC.	1 ½" & Sm.	A105,6000#, Socketweld, Wall To Match Pipe
		2" & Larger	A234 Gr. WPB, Buttweld, Wall To Match Pipe
	WELDOLETS, ELBOLETS, LATEROLETS (per MSS.SP-9)		A105, Buttweld, Machine To Match Pipe Ends
	SOCKOLETS/ THREADOLETS		A105, 6000#, Socketweld,(6)
	PLUGS (per B16.11)		3/4" & Smaller: A276 Type 410SS, Solid Hex Head, MNPT
	UNIONS/ COUPLINGS		A105, 6000#, Socketweld
	SPECT. BLINDS (per API - 590)		A516. Gr. 70, Class 150, RF, Bore To Match Pipe
Flanges (per B16.5)	1 ½" & Sm.		A105,Socket Weld, Class 150, RF, Bore To Match Pipe
	2" & Larger		A105,Weld Neck, Class 150, RF, Bore To Match Pipe(30" & Larger per B16.47, Series A dimens.)
Orif.Flanges	(perB16.36)2"-24"		½" THRD, TAPS, A105, Weld Neck, Class 300, RF, Bore To Match Pipe
Bolts	A 193 Gr.B7 Stud Bolts & A 194 Gr.2H Hex Nuts; Blue Teflon Coated		
Gaskets	ANSI B16.20: 316L SS Spiral- Wound W/ Flexite Super Filter, Flexitallic Style"CG"		

Valves	Size Range	Type	End Conn.	Dimensional Std.	Tag Number
Gates	3/4" - 1 ½" 2" - 10" 12" - 24"	OS&Y OS&Y OS&Y, G.O.	RF RF RF	API- 602 API- 600 API- 600	VG- 60F VG- 60 VG- 60G
Globes	3/4" - 1 ½" 2" - 10" 12" - 24"	OS&Y OS&Y OS&Y, G.O.	RF RF RF	API- 602 API- 600 API- 600	VGL- 60F VGL- 60 VGL- 60G
Balls	3/4"x ½" ½" - 3/4" ½" - 1" 3/4"- 3" 3/4"- 3" 4" - 8" 4" - 8" 10" - 42" 10" - 42"	Float., Red. Floating Floating Float., Red Float., Full Trun, Red. Trun, Full Trun, Red., Go Trun, Full, Go	RF x FNPT FNPT MNPT x FNPT RF RF RF RF RF RF	CAD SPEC CAD SPEC CAD SPEC API - 6D API - 6D API - 6D API - 6D API - 6D API - 6D	VB-60J (Note 2) VB-401 (Note 3) VB-402 (Note 5) VB-606 (preferred) VB-60 VB-606M (preferred) VB-60M VB-606G(pref) / VB-606GL(>30") VB-60G(<24") / VB-60GL(>30")
Butterflies	3" - 4" 6" - 24"	Lok-Handle Gear Oper.	RF Lugged RF Lugged	API- 609 API- 609	VBT- 20 VBT- 20G
Checks	3/4 " - 1 ½" 3/4 " - 1 ½" 2" - 42 " 2" - 24 " 2" - 24 "	Swing Piston Swing Piston Dual Disc	RF RF RF RF RF	API- 602 API- 602 API- 600 API- 600 API- 594	VC- 60F (preferred) VC- 64F VC- 60(pref) / VC- 60L(>30") VC- 64 VC- 67 (Note 4)

Notes: 1. The above materials, ratings & wall thicknesses conform with ASME B31.3, 1996 Edition, incl. Addenda "a" & "b".
2. Use for instrumentation connections only.
3. Use for instrument isolation only.
4. Use only when needed to conserve space. Must be approved by client prior to using.
5. Use for instrument vents and drains only.
6. Use threaded connections for instrumentation use only.

Figure 6.2
Sample Piping Specification

Pipe specs use service conditions to establish many parameters as is evident from the sample shown in Figure 6.2. Piping engineers and designers use pipe specs to establish sizes, pound ratings, and dimensions of pipe, fittings, valves and associated equipment. Pipe specs are also used in pipe stress analysis to ensure that the stresses in the pipe material are within the limits specified by the code. The procurement department uses pipe specs to ensure the purchase of appropriate pipe, fittings, valves and other components of piping systems. Welders and fabricators use pipe specs to ensure the use of proper materials and joining methods.

Some of the parameters established by pipe specs include the following.

- Material specification and grade.
- Services for which the specification class can be used.
- Range of the nominal pipe size (NPS).
- Corrosion allowance.
- Pipe wall thickness.
- Flange Pound Ratings.
- Pressure and Temperature Limits.
- Type of connections to be used (threaded, socket weld, butt weld).
- Specifications of fittings (elbows, reducers, tees, unions, caps etc.)
- Specifications for orifice flanges, bolts and gaskets.
- Specifications for valves.

6.8 Piping isometrics

Piping isometrics are pictorial representations of piping systems. They help in the visualization of piping systems and are used in the design, procurement, fabrication and construction phases of the project. The pictorial representation is obtained by drawing along the isometric axes. One of the isometric axes is vertical while the other two are at an angle of 30° to the horizontal axis.

Figure 6.3 depicts the translation of a regular orthographic representation of a piping system into a piping isometric drawing. The most important step in generating a piping isometric drawing is to establish the North direction along one of the isometric axes. Consequently, the other directions are automatically established as shown in Figure 6.3. The point at which the pipe changes direction is called as “Turning Point (TP)”. The turning point signifies the use of elbows to effect the change in direction. Several turning points can be observed in Figure 6.3. Piping isometrics are also commonly known as “piping isos” or simply as “isos”. Isos are schematic single line drawings and are not drawn to scale. However, they are dimensioned and are drawn by maintaining proper proportions. The details of the components of the piping system such as materials and pound ratings are given by using callouts or notes.

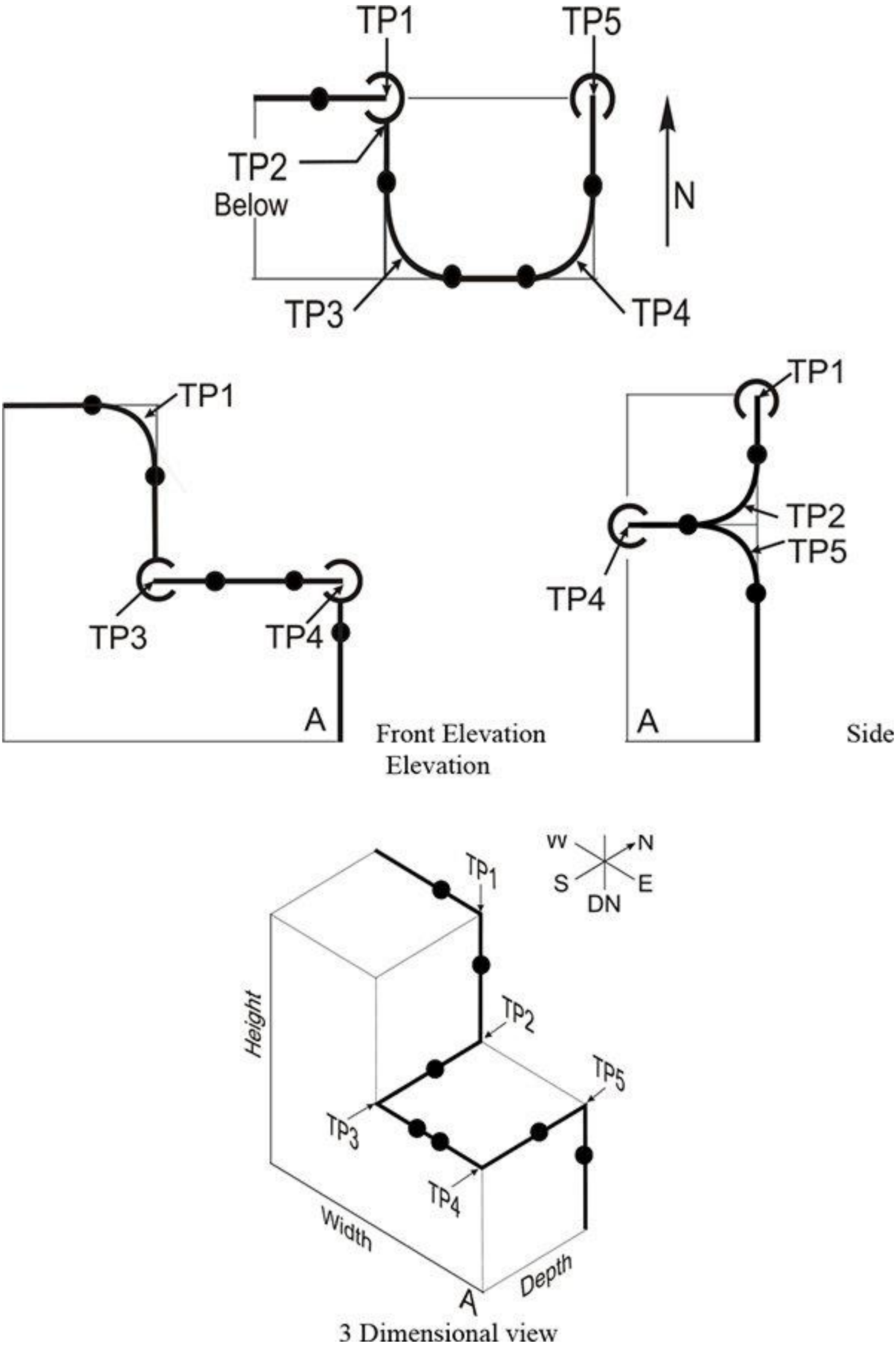
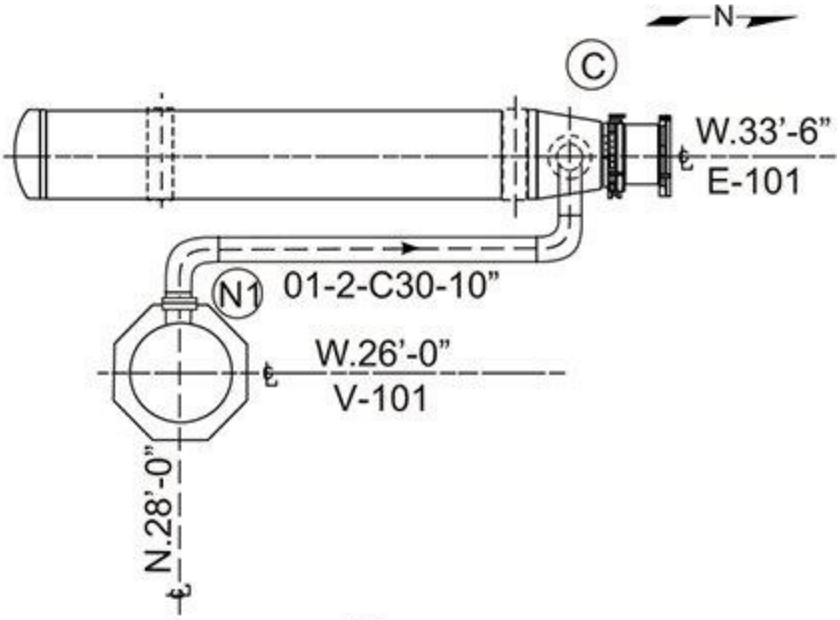
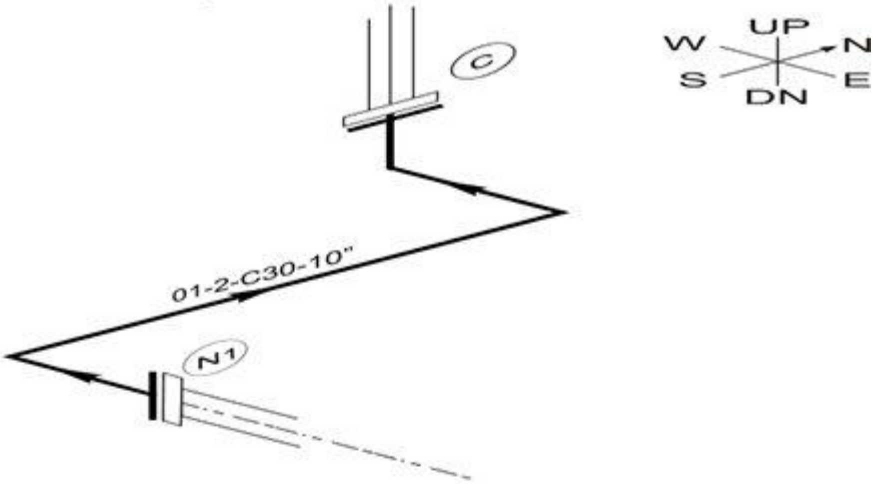


Figure 6.3 a,b,c,d

Piping Isometric Drawing Generated From a Corresponding Piping Orthographic Drawing (Source: "Pipe Drafting and Design", Roy Parisher and Robert Rhea, Gulf Publishing).

Figure 6.4 shows how a piping iso is generated for one of the lines (with line specification 01 – 2 – C30 – 10"), which connects nozzle N1 from vessel V – 101 with nozzle C of exchanger E – 101.


N
C
W.33'-6"
E-101
01-2-C30-10"
N1
W.26'-0"
V-101
N.28'-0"


UP
W
N
S
E
DN
C
01-2-C30-10"
N1

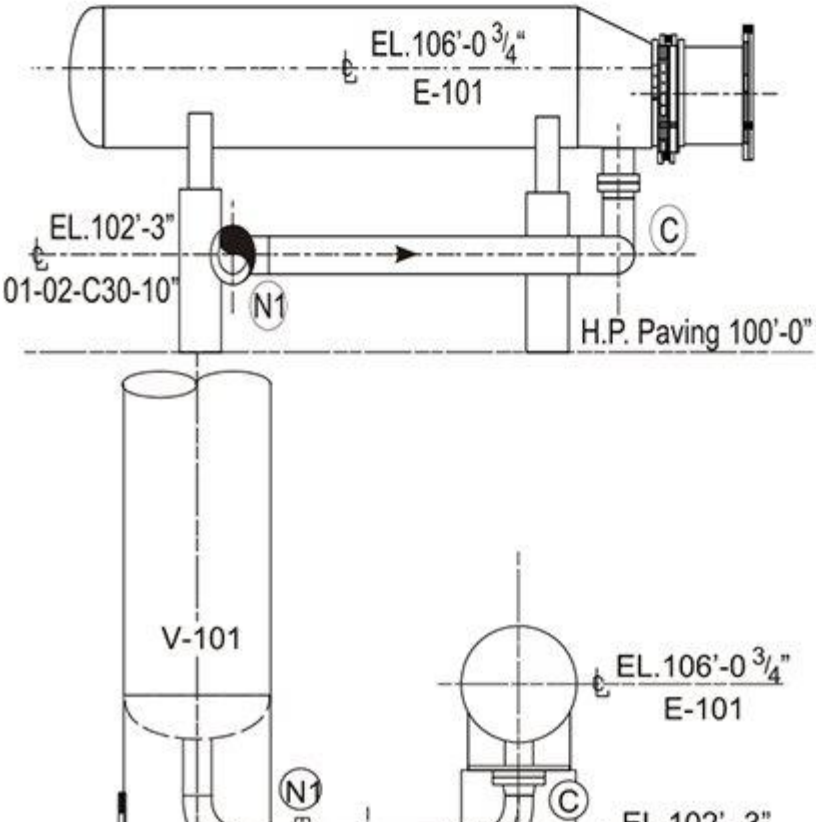

EL.106'-0 3/4"
E-101
EL.102'-3"
01-02-C30-10"
C
N1
H.P. Paving 100'-0"
V-101
EL.106'-0 3/4"
E-101
N1
C

Figure 6.4 a,b,c,d (Facing page)
Piping Iso For a Sample Line (Source: "Pipe Drafting and Design", Roy Parisher and Robert Rhea, Gulf Publishing).

6.9 Fabrication isos and bill of materials

One of the most important uses of isos is to generate the "Bill of Materials (BOM)" for each line in the process plant. The BOM is generated by using a process known as "material take-off". Using this process, all the components of a line are tabulated for purchase or procurement. The typical components of a line include the following items.

- Straight Pipe
- Elbows
- Flanges
- Tees
- Valves
- Instrument Items
- Gaskets
- Nuts
- Bolts
- Specialty Items

Properly dimensioned isos along with the BOM are provided to the fabricators who build the components of the line. Further, the isos serve as an aid to the construction and erection of the facility by providing construction personnel information on pipe routing and the locations of tie-ins and connections.

Figure 6.5 depicts a piping iso with the associated BOM.

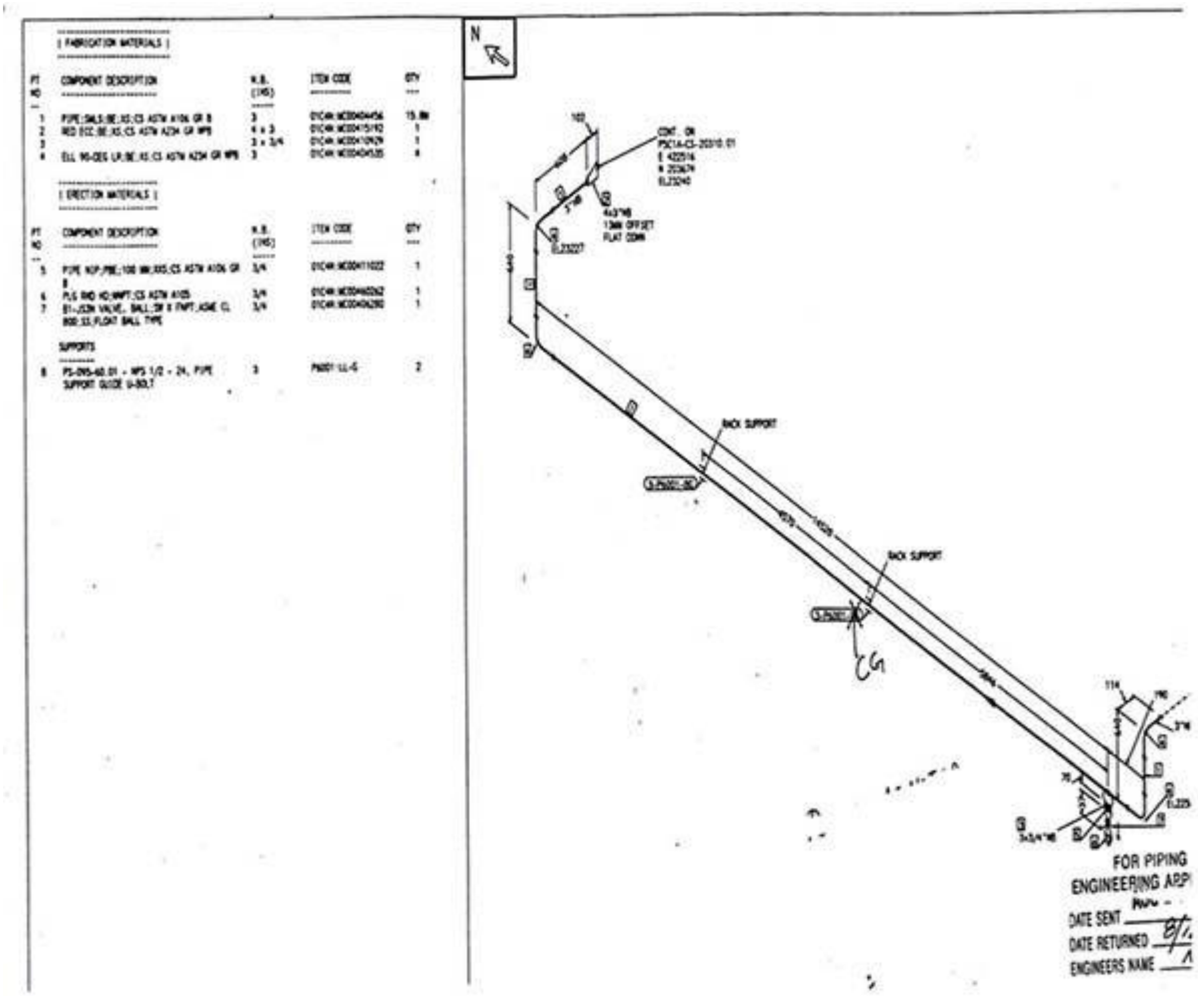


Figure 6.5
Isometric Drawing with bill of materials

6.10 Three dimensional (3D) models

The advances in computer technology and the availability of modeling software has made 3D modeling of piping systems an integral part of the design and engineering of process plants. The features and advantages 3D models of piping systems are listed here.

- 3D models are real-size representations of the processing facility including equipment, pipe, fittings, valves, instruments, support structures and foundations. Every single detail of the facility is captured in the 3D model.
- The engineering data associated with each component is also integrated into the model. This data forms the “engineering database” for the project and is updated as needed as the project progresses through different phases.
- 3D models are great visualization tools for designers, engineers and construction personnel.
- Most 3D modeling software are capable of performing “interference checking” and produce “clash reports” that alert designers about potential clashes between components of the process plants. The components can be relocated during the design phase thus saving expensive field rework and avoiding project delays.

- 3D models can be imported into animation software to create “walkthroughs”. Client walkthroughs are very useful in expediting the project and in improving the communication between the client and the engineering and design personnel.
- 3D models and animations are also used in producing training videos for the safe operation and maintenance of the plant.

Figure 6.6
3D Model of a Processing Facility Generated Using Intergraph PDS Software (Source: ppm.Intergraph.com).

Figure 6.7
3D Model of a Floating Production Storage and Off-loading (FPSO) Facility Generated Using Intergraph PDS Software (Source: ppm.Intergraph.com).

6.11 Summary

Design and engineering of piping facilities generates plenty of documents, which play a crucial role of representing the details of the facility and also in communication between engineers and designers from different disciplines. This chapter provides a working knowledge of documents such as equipment lists and piping line lists. Tools such as piping isometric drawings and 3D models also play a very important role in the design, engineering, procurement and construction of process plants. A basic understanding of these tools is provided in this chapter.

Fundamentals of Process Plant Layout and Piping Design

Practical Exercise 6

Generate a partial piping line list from the P & ID shown in Figure 5.2

7

Fundamentals of Piping

This chapter describes the fundamentals of a pipe.

Learning objectives

- Piping Materials, manufacturing methods, pipe size and dimensions.

7.1 Fundamentals of piping

- **Piping Materials:** Steel - Carbon Steel and Alloy Steels (SS), Cast Iron, Copper, Concrete, Brass, Aluminum, Composite (FRP).

Piping Materials are described by “Piping Specifications” – a document that describes the material composition and processing methods (discussed in Chapter 6)

The material to be used is dictated by service conditions, namely, fluid being transported, temperature and pressure

- **Pipe Manufacturing Methods:** Seamless Pipe, Butt Welded Pipe, Spiral Welded pipe.
- **Pipe Size and Dimensions:** OD/ID, Nominal Pipe Size (NPS)

Wall thickness = (OD – ID)/2

Wall thickness (weight): Standard (S), Extra strong (X), Double Extra strong (XX)
Also described in terms of pipe schedules. Schedule 40, 80, 120 etc.
For NPS 1/8” to 12” NPS, OD > NPS
For NPS 14” and above, OD = NPS
Commercial steel pipe data (Given in Appendix)

- **Methods of joining pipe:** Butt-Welded (BW), Screwed (SCRD) or Threaded (THRD) and Socket-Weld (SW).

End preparations: BE - Beveled Ends, TE - Threaded End, and PE - Plain End

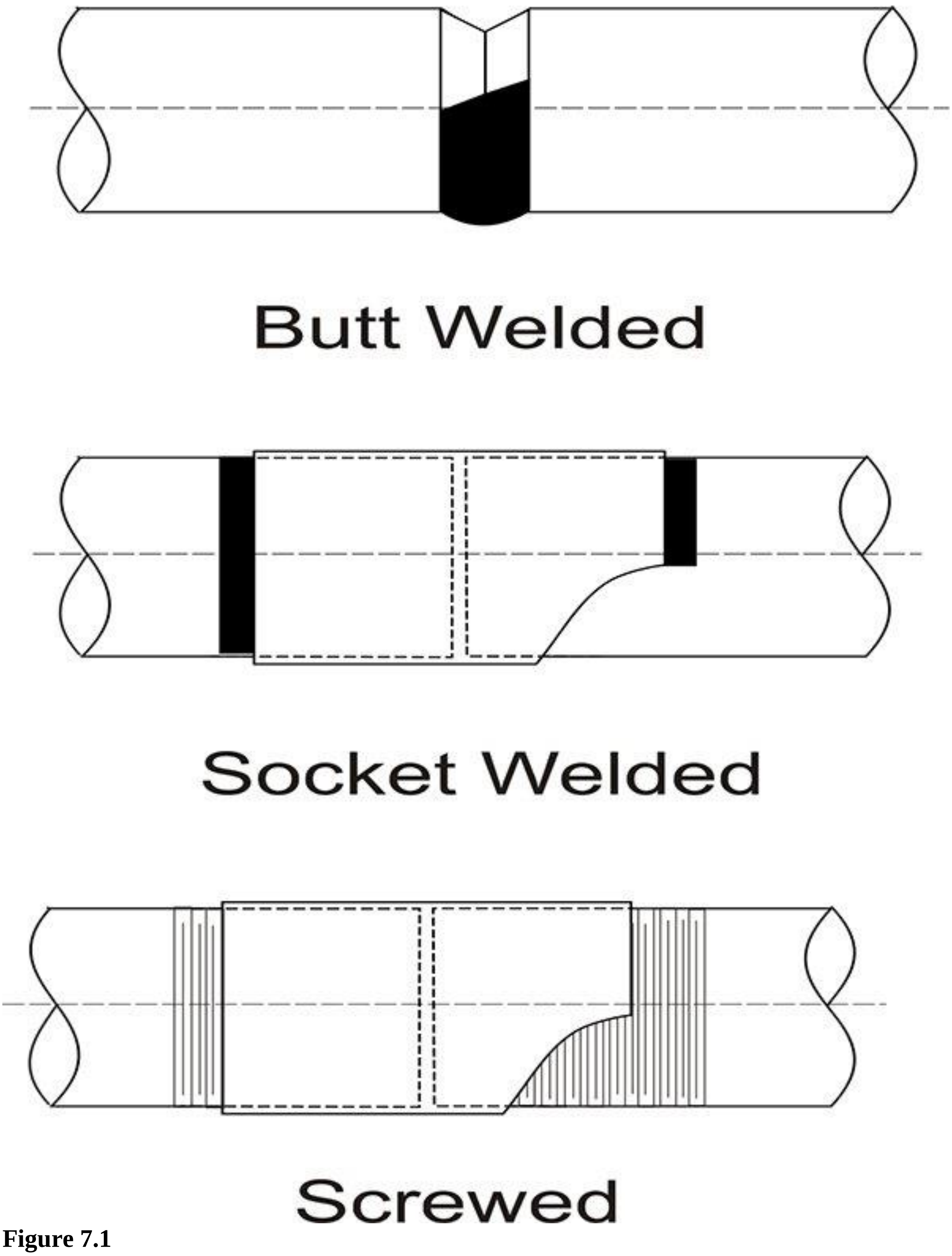
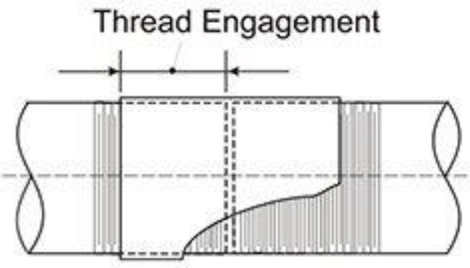


Figure 7.1
*Pipe Joining Methods***Table 7.1**
American Standard and API Thread

Engagement



Screwed

Dimensions: Inches - Millimeters			
Pipe Size		Thread Engagement	
Inches	Millimeters	Inches	Millimeters
½	13	½	13
3/4	20	9/16	14
1	2.54	11/16	18
1½	38	11/16	18
2	50.8	3/4	20
2½	63.5	15/16	24
3	76.2	1	25.4

(Source: Pipe Drafting and Design, Roy Parisher and Robert Rhea)

Fundamentals of Process Plant Layout and Piping Design

Practical Exercise 7

(Fundamentals of Pipe and Pipe Data)

1. The material to be used for piping is based on the following parameters: ______________, _______________and _________________________.
These parameters are collectively referred to as ___________________________.

2. The classification of pipe into Standard (S), Extra Strong (x) and Double Extra Strong (xx) is based on ____________________________.

3. A pipe has an OD of 10.75 in and its wall thickness is 0.365 in. The ID of the pipe is ____________.

4. The area of the metal for the pipe in question 3 is ____________.

5. The surface area of the pipe in question 3 per foot length is _________ ft^2.

6. Based on the results of question 5, the insulation surface area required for 150 ft of pipe is ____________ft^2.

7. The volume of the pipe material is the metal area x length of pipe. The weight of pipe is volume of pipe material x specific weight of pipe material. The specific weight of commercial steel is
490 lb / ft^3. (Show your calculations for this problem)

a. Calculate the weight of 6 in nominal steel pipe per foot length. The pipe ID is 5.761 in and the pipe OD is 6.625 in.
b. A section of an offshore platform uses 650 ft of this pipe. What is the total weight of the pipe?

Nominal Pipe Size (Inches)	Outside Diameter (D) (Inches)	Schedule No. (See Note 1)	Wall Thickness (t) (Inches)	Inside Diameter (d) (Inches)	Area of Metal (a) (Square Inches)	Transverse Internal Area (Square Inches)	Transverse Internal Area (See Note 2) (Square Feet)	Moment of Inertia (I) (Inches to 4th Power)	Weight of Pipe (Pounds per foot)	Weight of Water (Pounds per foot of pipe)	External Surface (Sq. Ft. per foot of pipe)	Section Modulus $\left(\frac{2I}{D}\right)$
10	10.750	20	.250	10.250	8.24	82.52	.5731	113.7	28.04	35.76	2.814	21.15
		30	.307	10.136	10.07	80.69	.5603	137.4	34.24	34.96	2.814	25.57
		40s	.365	10.020	11.90	78.86	.5475	160.7	40.48	34.20	2.814	29.90
		60x	.500	9.750	16.10	74.66	.5185	212.0	54.74	32.35	2.814	39.43
		80	.593	9.564	18.92	71.84	.4989	244.8	64.33	31.13	2.814	45.54
		100	.718	9.314	22.63	68.13	.4732	286.1	76.93	29.53	2.814	53.22
		120	.843	9.064	26.24	64.53	.4481	324.2	89.20	27.96	2.814	60.32
		140	1.000	8.750	30.63	60.13	.4176	367.8	104.13	26.06	2.814	68.43
		160	1.125	8.500	34.02	56.75	.3941	399.3	115.65	24.59	2.814	74.29
12	12.75	20	.250	12.250	9.82	117.86	.8185	191.8	33.38	51.07	3.338	30.2
		30	.330	12.090	12.87	114.80	.7972	248.4	43.77	49.74	3.338	39.0
		..s	.375	12.000	14.58	113.10	.7854	279.3	49.56	49.00	3.338	43.8
		40	.406	11.938	15.77	111.93	.7773	300.3	53.53	48.50	3.338	47.1
		..x	.500	11.750	19.24	108.43	.7528	361.5	65.42	46.92	3.338	56.7
		60	.562	11.626	21.52	106.16	.7372	400.4	73.16	46.00	3.338	62.8
		80	.687	11.376	26.03	101.64	.7058	475.1	88.51	44.04	3.338	74.6
		100	.843	11.064	31.53	96.14	.6677	561.6	107.20	41.66	3.338	88.1
		120	1.000	10.750	36.91	90.76	.6303	641.6	125.49	39.33	3.338	100.7
		140	1.125	10.500	41.08	86.59	.6013	700.5	133.68	37.52	3.338	109.9
		160	1.312	10.126	47.14	80.53	.5592	781.1	160.27	34.89	3.338	122.6
14	14.00	10	.250	13.500	10.80	143.14	.9940	255.3	36.71	62.03	3.665	36.6
		20	.312	13.376	13.42	140.52	.9758	314.4	45.68	60.89	3.665	45.0
		30s	.375	13.250	16.05	137.88	.9575	372.8	54.57	59.75	3.665	53.2
		40	.438	13.124	18.66	135.28	.9394	429.1	63.37	58.64	3.665	61.3
		..x	.500	13.000	21.21	132.73	.9217	483.8	72.09	57.46	3.665	69.1
		60	.593	12.814	24.98	128.96	.8956	562.3	84.91	55.86	3.665	80.3
		80	.750	12.500	31.22	122.72	.8522	687.3	106.13	53.18	3.665	98.2
		100	.937	12.126	38.45	115.49	.8020	824.4	130.73	50.04	3.665	117.8
		120	1.093	11.814	44.32	109.62	.7612	929.6	150.67	47.45	3.665	132.8
		140	1.250	11.500	50.07	103.87	.7213	1027.0	170.22	45.01	3.665	146.8
		160	1.406	11.188	55.63	98.31	.6827	1117.0	189.12	42.60	3.665	159.6
16	16.00	10	.250	15.500	12.37	188.69	1.3103	383.7	42.05	81.74	4.189	48.0
		20	.312	15.376	15.38	185.69	1.2895	473.2	52.36	80.50	4.189	59.2
		30s	.375	15.250	18.41	182.65	1.2684	562.1	62.58	79.12	4.189	70.3
		40x	.500	15.000	24.35	176.72	1.2272	731.9	82.77	76.58	4.189	91.5
		60	.656	14.688	31.62	169.44	1.1766	932.4	107.50	73.42	4.189	116.6
		80	.843	14.314	40.14	160.92	1.1175	1155.8	136.46	69.73	4.189	144.5
		100	1.031	13.938	48.48	152.58	1.0596	1364.5	164.83	66.12	4.189	170.5
		120	1.218	13.564	56.56	144.50	1.0035	1555.8	192.29	62.62	4.189	194.5
		140	1.438	13.124	65.78	135.28	.9394	1760.3	223.64	58.64	4.189	220.0
		160	1.593	12.814	72.10	128.96	.8956	1893.5	245.11	55.83	4.189	236.7
18	18.00	10	.250	17.500	13.94	240.53	1.6703	549.1	47.39	104.21	4.712	61.1
		20	.312	17.376	17.34	237.13	1.6467	678.2	59.03	102.77	4.712	75.5
		..s	.375	17.250	20.76	233.71	1.6230	806.7	70.59	101.18	4.712	89.6
		30	.438	17.124	24.17	230.30	1.5990	930.3	82.06	99.84	4.712	103.4
		..x	.500	17.000	27.49	226.98	1.5763	1053.2	92.45	98.27	4.712	117.0
		40	.562	16.876	30.79	223.68	1.5533	1171.5	104.75	96.93	4.712	130.1
		60	.750	16.500	40.64	213.83	1.4849	1514.7	138.17	92.57	4.712	168.3
		80	.937	16.126	50.23	204.24	1.4183	1833.0	170.75	88.50	4.712	203.8
		100	1.156	15.688	61.17	193.30	1.3423	2180.0	207.96	83.76	4.712	242.3
		120	1.375	15.250	71.81	182.66	1.2684	2498.1	244.14	79.07	4.712	277.6
		140	1.562	14.876	80.66	173.80	1.2070	2749.0	274.23	75.32	4.712	305.5
		160	1.781	14.438	90.75	163.72	1.1369	3020.0	308.51	70.88	4.712	335.6
20	20.00	10	.250	19.500	15.51	298.65	2.0740	756.4	52.73	129.42	5.236	75.6
		20s	.375	19.250	23.12	290.04	2.0142	1113.0	78.60	125.67	5.236	111.3
		30x	.500	19.000	30.63	283.53	1.9690	1457.0	104.13	122.87	5.236	145.7
		40	.593	18.814	36.15	278.00	1.9305	1703.0	122.91	120.46	5.236	170.4
		60	.812	18.376	48.95	265.21	1.8417	2257.0	166.40	114.92	5.236	225.7
		80	1.031	17.938	61.44	252.72	1.7550	2772.0	208.87	109.51	5.236	277.1
		100	1.281	17.438	75.33	238.83	1.6585	3315.2	256.10	103.39	5.236	331.5
		120	1.500	17.000	87.18	226.98	1.5762	3754.0	296.37	98.35	5.236	375.5
		140	1.750	16.500	100.33	213.82	1.4849	4216.0	341.10	92.66	5.236	421.7
		160	1.968	16.064	111.49	202.67	1.4074	4585.5	379.01	87.74	5.236	458.5
24	24.00	10	.250	23.500	18.65	433.74	3.0121	1315.4	63.41	187.95	6.283	109.6
		20s	.375	23.250	27.83	424.56	2.9483	1942.0	94.62	183.95	6.283	161.9
		..x	.500	23.000	36.91	415.48	2.8853	2549.5	125.49	179.87	6.283	212.5
		30	.562	22.876	41.39	411.00	2.8542	2843.0	140.80	178.09	6.283	237.0
		40	.687	22.626	50.31	402.07	2.7921	3421.3	171.17	174.23	6.283	285.1
		60	.968	22.064	70.04	382.35	2.6552	4652.8	238.11	165.52	6.283	387.7
		80	1.218	21.564	87.17	365.22	2.5362	5672.0	296.36	158.26	6.283	472.8
		100	1.531	20.938	108.07	344.32	2.3911	6849.9	367.40	149.06	6.283	570.8
		120	1.812	20.376	126.31	326.08	2.2645	7825.0	429.39	141.17	6.283	652.1
		140	2.062	19.876	142.11	310.28	2.1547	8625.0	483.13	134.45	6.283	718.9
		160	2.343	19.314	159.41	292.98	2.0346	9455.9	541.94	126.84	6.283	787.9

Courtesy of Crane Co.Commercial Wrought Steel Pipe

Data

Nominal Pipe Size (Inches)	Outside Diameter (D) (Inches)	Schedule No. (See Note 1)	Wall Thickness (t) (Inches)	Inside Diameter (d) (Inches)	Area of Metal (a) Square Inches	Transverse Internal Area: Square Inches	Transverse Internal Area (See Note 2): Square Feet	Moment of Inertia (I) Inches to 4th Power	Weight of Pipe Pounds per foot	Weight of Water Pounds per foot of pipe	External Surface Sq. Ft. per foot of pipe	Section Modulus $(2\frac{I}{D})$
1/8	0.405	40s	.068	.269	.0720	.0568	.00040	.00106	.244	.025	.106	.00523
		80x	.095	.215	.0925	.0364	.00025	.00122	.314	.016	.106	.00602
1/4	0.540	40s	.088	.364	.1250	.1041	.00072	.00331	.424	.045	.141	.01227
		80x	.119	.302	.1574	.0716	.00050	.00377	.535	.031	.141	.01395
3/8	0.675	40s	.091	.493	.1670	.1910	.00133	.00729	.567	.083	.178	.02160
		80x	.126	.423	.2173	.1405	.00098	.00862	.738	.061	.178	.02554
1/2	0.840	40s	.109	.622	.2503	.3040	.00211	.01709	.850	.132	.220	.04069
		80x	.147	.546	.3200	.2340	.00163	.02008	1.087	.102	.220	.04780
		160	.187	.466	.3836	.1706	.00118	.02212	1.300	.074	.220	.05267
		...xx	.294	.252	.5043	.050	.00035	.02424	1.714	.022	.220	.05772
3/4	1.050	40s	.113	.824	.3326	.5330	.00371	.03704	1.130	.231	.275	.07055
		80x	.154	.742	.4335	.4330	.00300	.04479	1.473	.188	.275	.08531
		160	.218	.614	.5698	.2961	.00206	.05269	1.940	.128	.275	.10036
		...xx	.308	.434	.7180	.148	.00103	.05792	2.440	.064	.275	.11032
1	1.315	40s	.133	1.049	.4939	.8640	.00600	.08734	1.678	.375	.344	.1328
		80x	.179	.957	.6388	.7190	.00499	.1056	2.171	.312	.344	.1606
		160	.250	.815	.8365	.5217	.00362	.1251	2.840	.230	.344	.1903
		...xx	.358	.599	1.0760	.282	.00196	.1405	3.659	.122	.344	.2136
1 1/4	1.660	40s	.140	1.380	.6685	1.495	.01040	.1947	2.272	.649	.435	.2346
		80x	.191	1.278	.8815	1.283	.00891	.2418	2.996	.555	.435	.2913
		160	.250	1.160	1.1070	1.057	.00734	.2839	3.764	.458	.435	.3421
		...xx	.382	.896	1.534	.630	.00438	.3411	5.214	.273	.435	.4110
1 1/2	1.900	40s	.145	1.610	.7995	2.036	.01414	.3099	2.717	.882	.497	.3262
		80x	.200	1.500	1.068	1.767	.01225	.3912	3.631	.765	.497	.4118
		160	.281	1.338	1.429	1.406	.00976	.4824	4.862	.608	.497	.5078
		...xx	.400	1.100	1.885	.950	.00660	.5678	6.408	.42	.497	.5977
2	2.375	40s	.154	2.067	1.075	3.355	.02330	.6657	3.652	1.45	.622	.5606
		80x	.218	1.939	1.477	2.953	.02050	.8679	5.022	1.28	.622	.7309
		160	.343	1.689	2.190	2.241	.01556	1.162	7.440	.97	.622	.979
		...xx	.436	1.503	2.656	1.774	.01232	1.311	9.029	.77	.622	1.104
2 1/2	2.875	40s	.203	2.469	1.704	4.788	.03322	1.530	5.79	2.07	.753	1.064
		80x	.276	2.323	2.254	4.238	.02942	1.924	7.66	1.87	.753	1.339
		160	.375	2.125	2.945	3.546	.02463	2.353	10.01	1.54	.753	1.638
		...xx	.552	1.771	4.028	2.464	.01710	2.871	13.70	1.07	.753	1.997
3	3.500	40s	.216	3.068	2.228	7.393	.05130	3.017	7.58	3.20	.916	1.724
		80x	.300	2.900	3.016	6.605	.04587	3.894	10.25	2.86	.916	2.225
		160	.438	2.624	4.205	5.408	.03755	5.032	14.32	2.35	.916	2.876
		...xx	.600	2.300	5.466	4.155	.02885	5.993	18.58	1.80	.916	3.424
3 1/2	4.000	40s	.226	3.548	2.680	9.886	.06870	4.788	9.11	4.29	1.047	2.394
		80x	.318	3.364	3.678	8.888	.06170	6.280	12.51	3.84	1.047	3.140
4	4.500	40s	.237	4.026	3.174	12.73	.08840	7.233	10.79	5.50	1.178	3.214
		80x	.337	3.826	4.407	11.50	.07986	9.610	14.98	4.98	1.178	4.271
		120	.438	3.624	5.595	10.31	.0716	11.65	19.00	4.47	1.178	5.178
		160	.531	3.438	6.621	9.28	.0645	13.27	22.51	4.02	1.178	5.898
		...xx	.674	3.152	8.101	7.80	.0542	15.28	27.54	3.38	1.178	6.791
5	5.563	40s	.258	5.047	4.300	20.01	.1390	15.16	14.62	8.67	1.456	5.451
		80x	.375	4.813	6.112	18.19	.1263	20.67	20.78	7.88	1.456	7.431
		120	.500	4.563	7.953	16.35	.1136	25.73	27.10	7.09	1.456	9.250
		160	.625	4.313	9.696	14.61	.1015	30.03	32.96	6.33	1.456	10.796
		...xx	.750	4.063	11.340	12.97	.0901	33.63	38.55	5.61	1.456	12.090
6	6.625	40s	.280	6.065	5.581	28.89	.2006	28.14	18.97	12.51	1.734	8.50
		80x	.432	5.761	8.405	26.07	.1810	40.49	28.57	11.29	1.734	12.22
		120	.562	5.501	10.70	23.77	.1650	49.61	36.40	10.30	1.734	14.98
		160	.718	5.189	13.32	21.15	.1469	58.97	45.30	9.16	1.734	17.81
		...xx	.864	4.897	15.64	18.84	.1308	66.33	53.16	8.16	1.734	20.02
8	8.625	20	.250	8.125	6.57	51.85	.3601	57.72	22.36	22.47	2.258	13.39
		30	.277	8.071	7.26	51.16	.3553	63.35	24.70	22.17	2.258	14.69
		40s	.322	7.981	8.40	50.03	.3474	72.49	28.55	21.70	2.258	16.81
		60	.406	7.813	10.48	47.94	.3329	88.73	35.64	20.77	2.258	20.58
		80x	.500	7.625	12.76	45.66	.3171	105.7	43.39	19.78	2.258	24.51
		100	.593	7.439	14.96	43.46	.3018	121.3	50.87	18.83	2.258	28.14
		120	.718	7.189	17.84	40.59	.2819	140.5	60.63	17.59	2.258	32.58
		140	.812	7.001	19.93	38.50	.2673	153.7	67.76	16.68	2.258	35.65
		...xx	.875	6.875	21.30	37.12	.2578	162.0	72.42	16.10	2.258	37.56
		160	.906	6.813	21.97	36.46	.2532	165.9	74.69	15.80	2.258	38.48

Note 1: The letters s,x, and xx in the column of Schedule Numbers indicate Standard, Extra Strong, and Double Extra Strong Pipe, respectively.

Note 2: The values shown in square feet for the Transverse Internal Area also represent the volume in cubic feet per foot of pipe length.

Courtesy of Crane Co.

Fundamentals of Process Plant Layout and Piping Design

Practical Exercise 7 - Metric

(Fundamentals of Pipe and Pipe Data)

1. The material to be used for piping is based on the following parameters: ______________, _______________and ________________________.
These parameters are collectively referred to as __________________________.

2. The classification of pipe into Standard (S), Extra Strong (x) and Double Extra Strong (xx) is based on ___________________________.

3. A pipe has an OD of 273.1mm and its wall thickness is 9.271mm. The ID of the pipe is ____________.

4. The area of the metal for the pipe in question 3 is ____________m^2.

5. The surface area of the pipe in question 3 per metre length is __________ m^2.

6. Based on the results of question 5, the insulation surface area required for 50 ft of pipe is ____________m^2.

7. The volume of the pipe material is the metal area x length of pipe. The weight of pipe is volume of pipe material x specific weight of pipe material. The specific weight of commercial steel is
7850kg/m. (Show your calculations for this problem)

a. Calculate the weight of DN 15.mm nominal steel pipe per metre length. The pipe ID is 146.3mm and the pipe OD is 168.3mm

b. A section of an offshore platform uses 200m of this pipe. What is the total weight of the pipe?

8

Components of a Piping System

This chapter describes fittings, flanges and valves. It describes their different types and sizes of fittings. It also describes flange types, ratings and different facings. Types of valves, their parts and valve operators are also described.

Learning objectives

- Fittings, its types and sizes
- Flanges, its types, ratings and facings
- Valves, its types and valve operators

8.1 Fittings

The elements of a piping system used in connecting and capping pipes are described here. Fittings accomplish change in pipe direction, create branch lines and facilitate change in pipe size.

Figure 8.1 illustrates the applications of fittings. Fitting connections could be:
BW (NPS > 3.0 in)
SW or SCRD (NPS ≤ 3.0 in)

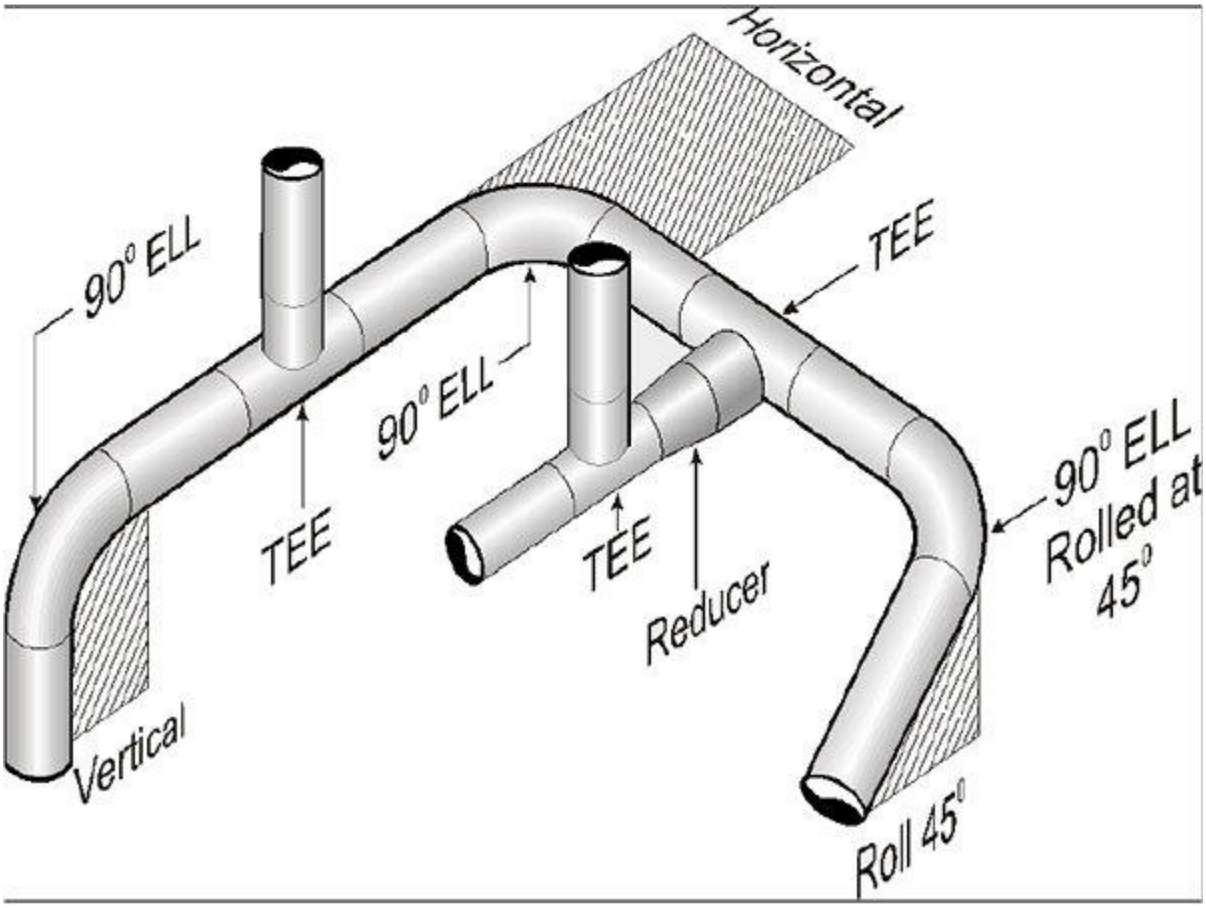


Figure 8.1
Pipe
Fittings

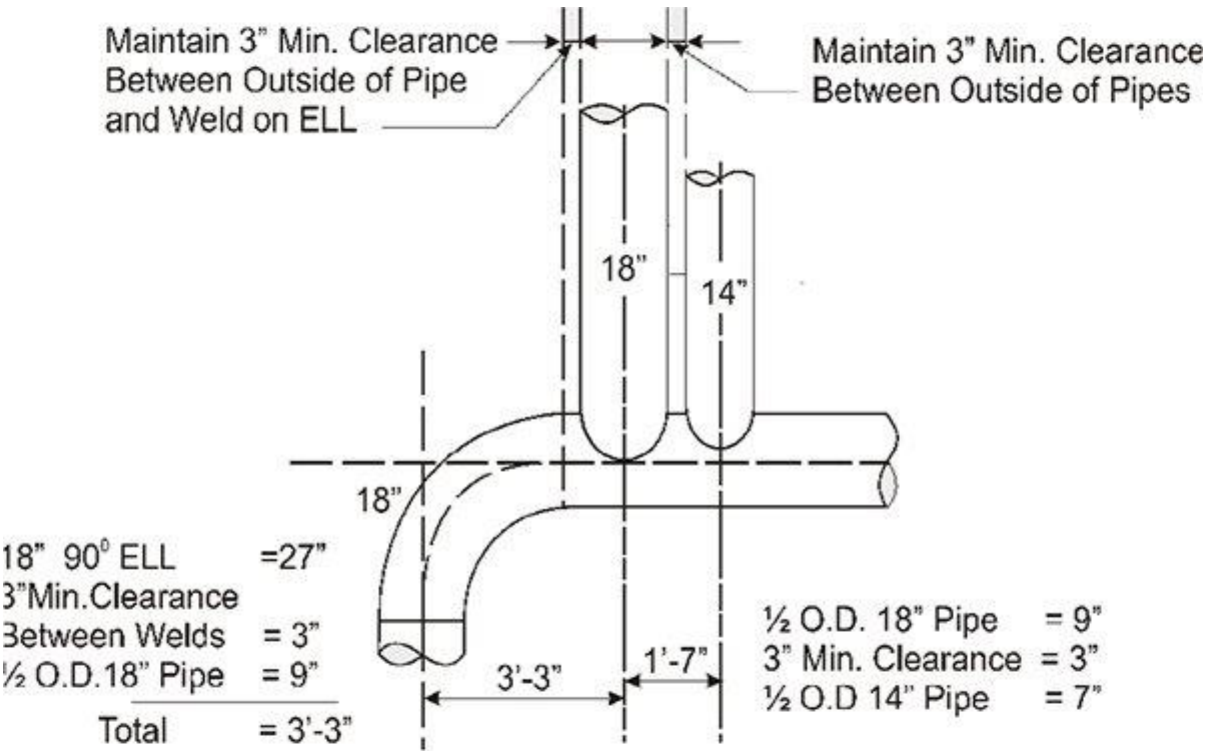


Figure 8.2

Welding Clearances for Stub-in fittings (Source: "Pipe Drafting and Design", Roy Parisher and Robert Rhea, 2nd Edition, Gulf Publishing.)

Examples of fittings are as follows:

- Elbows: Also known as "ell". They facilitate change in pipe direction. Most commonly used elbows are 90° and 45° elbows. Based on the turn radius, ells are classified as Long Radius (LR) and Short Radius (SR). For welded fittings and LR ell, the center to end distance is (1.5)(NPS) and for SR ell, it is (1.0)(NPS). (Refer to Appendix 3 for dimensions). Unless otherwise specified, LR ell is assumed. In AC ductwork, "mitered elbows" are used.
- Tees: Tees are used in providing branch connections. Tees are of two types - "straight tee" and "reducing tee". The main pipe off which the branches are created is known as the "header".
- Stub-ins: Here, holes are cut into the header and branch pipes are welded on. Reinforcing pads are used to strengthen the area around the hole. igure 8.2 illustrates welding clearances required for stub-ins.
- Reducers: Reducers are used in connecting pipes of different sizes. The two types of reducers are "concentric" and "eccentric". In concentric reducers, the pipe center lines up while in eccentric reducers there is an "offset" in pipe center lines and it is equal to one half the difference between the diameters. The configurations for eccentric reducers are "Flat On Bottom (FOB)" and "Flat On Top (FOT)". The FOB configuration can be supported on a pipe rack.
- Weld Cap: Used in sealing an open end of pipe.
- Pipe Nipples: Small lengths (usually 3 in) of pipe used between SCRD and SW fittings.

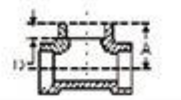
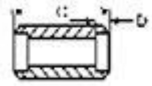
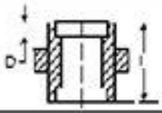
- Screwed (Threaded) and Socket Weld (SW) Fittings: Normally used for pipes with NPS 3 in and smaller. Forged Steel (FS) threaded and socket weld fittings are available in pressure classes of 3000 lbs and 6000 lbs.

Table 8.1 provides the dimensions for threaded and socket weld fittings.

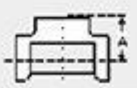
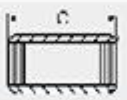
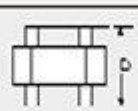
Table 8.1
Dimensions for Socket Weld and Thread

Fittings

SOCKET WELD FITTINGS

Nominal Pipe Sizes (Inches)			1/2"	3/4"	1"	1 1/4"	1 1/2"	2"	2 1/2"	3"
	3000 # 90°ELL	A	1 1/8	1 5/16	1 1/2	1 3/4	2	2 3/8	3	3 3/8
	6000 #	A	1 5/16	1 1/2	1 3/4	2	2 3/8	2 1/2	3 1/4	3 3/4
	3000 # TEE	A	1 1/8	1 5/16	1 1/2	1 3/4	2	2 3/8	3	3 3/8
	6000 #	A	1 5/16	1 1/2	1 3/4	2	2 3/8	2 1/2	3 1/4	3 3/4
	3000 # 45°ELL	B	7/8	1	1 1/8	1 5/16	1 7/16	1 11/16	2 1/16	2 1/2
	6000 #	B	1	1 1/8	1 5/16	1 11/32	1 11/16	1 23/32	2 1/16	2 1/2
	3000 # Coupling	C	1 7/8	2	2 3/8	2 5/8	3 1/8	3 3/8	3 5/8	4 1/4
	6000 #	C	1 7/8	2	2 3/8	2 5/8	3 1/8	3 3/8	3 5/8	4 1/4
	3000 # Union	E	1 15/16	2 1/4	2 1/2	2 13/16	3 1/16	3 7/16	4	4 5/16
	6000 #	E	2 5/16	2 1/2	2 13/16	2 3/4	2 7/8	3 11/16	3 15/16	4 5/8
Socket Depth	3000 #	D	1/2	9/16	5/8	11/16	3/4	7/8	1 3/8	1 1/8
	6000 #	D	11/16	3/4	7/8	15/16	1 1/8	1	1 1/2	1 5/8

SCREWED FITTINGS

Nominal Pipe Sizes (Inches)			1/2"	3/4"	1"	1 1/4"	1 1/2"	2"	2 1/2"	3"
	3000 # 90°ELL	A	1 5/16	1 1/2	1 3/4	2	2 3/8	2 1/2	3 3/8	3 3/4
	6000 #	A	1 1/2	1 3/4	2	2 3/8	2 1/2	3 3/8	3 3/4	4 3/16
	3000 # TEE	A	1 5/16	1 1/2	1 3/4	2	2 3/8	2 1/2	3 3/8	3 3/4
	6000 #	A	1 1/2	1 3/4	2	2 3/8	2 1/2	3 3/8	3 3/4	4 3/16
	3000 # 45°ELL	B	1	1 1/8	1 5/16	1 7/16	1 11/16	2	2 1/16	2 1/2
	6000 #	B	1 1/8	1 5/16	1 11/32	1 11/16	1 23/32	2 1/16	2 1/2	3 1/8
	3000 # Coupling	C	1 7/8	2	2 3/8	2 5/8	3 1/8	3 3/8	3 5/8	4 1/4
	6000 #	C	1 7/8	2	2 3/8	2 5/8	3 1/8	3 3/8	3 5/8	4 1/4
	3000 # Union	D	2 3/8	2 7/16	2 3/4	2 15/16	3 3/16	3 7/16	4 1/16	4 1/2
	6000 #	D	2 3/8	3 3/8	3 5/8	3 7/8	4 3/16	4 5/8		
Normal Thread Engagement	3000 #		1/2	9/16	11/16	11/16	11/16	3/4	15/16	1
	6000 #		1/2	9/16	11/16	11/16	11/16	3/4	15/16	1

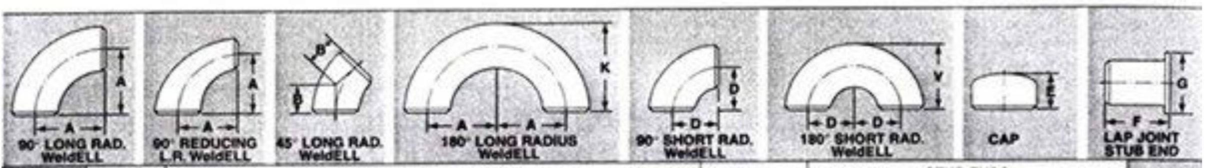
- Swages: Reducers for screwed and socket weld piping.

Note: When fittings are welded to each other, it is termed as "Fitting Make-up". Fitting make-up dimensioning exercises are given in Practical Exercises (PE) 8A and 8B and 8C. All fitting dimensions are given in Appendix 3.

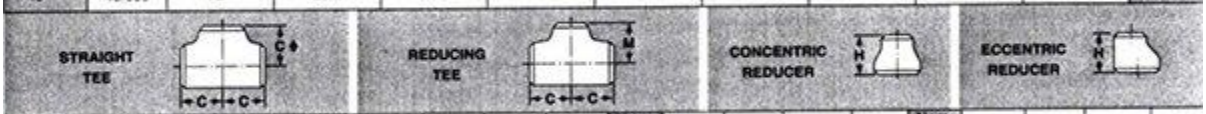
Abbreviations:

- BBE: Beveled Both Ends
- TBE: Threaded Both Ends
- PBE: Plain Both Ends
- BLE / TSE: Beveled Large End / Threaded Small End

Facing Page
Fitting Dimensions Chart (Source: Courtesy of Taylor Forge)



Nom. Pipe Size	Pipe O.D.	WeldELL A	WeldELL B	WeldELL D	WeldELL K	WeldELL V	CAPS* E	STUB ENDS F ANSI Std.	STUB ENDS G O.D. of Lap	STUB ENDS Corner Radius	Nom. Pipe Size
½	.840	1½	⅝	–	1⅞	–	1	3	1⅜	⅛	½
¾	1.050	1⅛	7/16	–	1 11/16	–	1	3	1 11/16	⅛	¾
1	1.315	1½	⅞	1	2 3/16	1⅝	1½	4	2	⅛	1
1¼	1.660	1⅞	1	1¼	2¾	2 1/16	1½	4	2½	3/16	1¼
1½	1.900	2¼	1⅛	1½	3¼	2 7/16	1½	4	2⅞	¼	1½
2	2.375	3	1⅜	2	4 3/16	3 3/16	1½	6	3⅝	5/16	2
2½	2.875	3¾	1¾	2½	5 3/16	3 15/16	1½	6	4⅛	5/16	2½
3	3.500	4½	2	3	6¼	4¾	2	6	5	⅜	3
3½	4.000	5¼	2¼	3½	7¼	5½	2½	6	5½	⅜	3½
4	4.500	6	2½	4	8¼	6¼	2½	6	6 3/16	7/16	4
5	5.563	7½	3⅛	5	10 5/16	7¾	3	8	7 5/16	7/16	5
6	6.625	9	3¾	6	12 5/16	9 5/16	3½	8	8½	½	6
8	8.625	12	5	8	16 5/16	12 5/16	4	8	10⅝	½	8
10	10.750	15	6¼	10	20⅛	15⅜	5	10	12¾	½	10
12	12.750	18	7½	12	24⅜	18⅜	6	10	15	½	12
14	14.000	21	8¾	14	28	21	6½	12	16¼	½	14
16	16.000	24	10	16	32	24	7	12	18½	½	16
18	18.000	27	11¼	18	36	27	8	12	21	½	18
20	20.000	30	12½	20	40	30	9	12	23	½	20
24	24.000	36	15	24	48	26	10½	12	27½	½	24
30	30.000	45	18½	30	60	45	10½	–	–	–	30
36	36.000	54	22¼	36	–	–	12	–	–	–	36
42	42.000	63	26	42	–	–	12	–	–	–	42
48	48.000	72	29⅛	48	–	–	13½	–	–	–	48



Nom. Pipe Size	Outlet	C	M	H
¾	¾	1⅛	...	...
	½	1⅛	1⅛	1½
1	1	1½	...	...
	¾	1½	1½	2
	½	1½	1½	2
1¼	1¼	1⅞	...	...
	1	1⅞	1⅞	2
	¾	1⅞	1⅞	2
	½	1⅞	1⅞	2
1½	1½	2¼	...	...
	1¼	2¼	2¼	2½
	1	2¼	2¼	2½
	¾	2¼	2¼	2½
	½	2¼	2¼	2½
2	2	2½	...	...
	1½	2½	2⅜	3
	1¼	2½	2¼	3
	1	2½	2	3
	¾	2½	1¾	3
2½	2½	3	...	...
	2	3	2¾	3½
	1½	3	2⅝	3½
	1¼	3	2½	3½
	1	3	2¼	3½
3	3	3⅜	...	...
	2½	3⅜	3¼	3½
	2	3⅜	3	3½
	1½	3⅜	2⅞	3½
	1¼	3⅜	2¾	3½

Nom. Pipe Size	Outlet	C	M	H
3½	3½	3¾	...	...
	3	3¾	3⅝	4
	2½	3¾	3½	4
	2	3¾	3¼	4
	1½	3¾	3⅛	4
4	4	4⅛	...	...
	3½	4⅛	4	4
	3	4⅛	3⅞	4
	2½	4⅛	3¾	4
	2	4⅛	3½	4
	1½	4⅛	3⅜	4
5	5	4⅞	...	...
	4	4⅞	4⅝	5
	3½	4⅞	4½	5
	3	4⅞	4⅜	5
	2½	4⅞	4¼	5
	2	4⅞	4⅛	5
6	6	5⅝	...	...
	5	5⅝	5⅜	5½
	4	5⅝	5⅛	5½
	3½	5⅝	5	5½
	3	5⅝	4⅞	5½
	2½	5⅝	4¾	5½
8	8	7	...	...
	6	7	6⅝	6
	5	7	6⅜	6
	4	7	6⅛	6
	3½	7	6	6

Nom. Pipe Size	Outlet	C	M	H
10	10	8½	...	...
	8	8½	8	7
	6	8½	7⅝	7
	5	8½	7½	7
	4	8½	7¼	7
12	12	10	...	...
	10	10	9½	8
	8	10	9	8
	6	10	8⅝	8
	5	10	8½	8
14	14	11	...	...
	12	11	10⅝	13
	10	11	10⅛	13
	8	11	9¾	13
	6	11	9⅜	13
16	16	12	...	...
	14	12	12	14
	12	12	11⅝	14
	10	12	11⅛	14
	8	12	10¾	14
	6	12	10⅜	14
18	18	13½	...	...
	16	13½	13	15
	14	13½	13	15
	12	13½	12⅝	15
	10	13½	12⅛	15
	8	13½	11¾	15

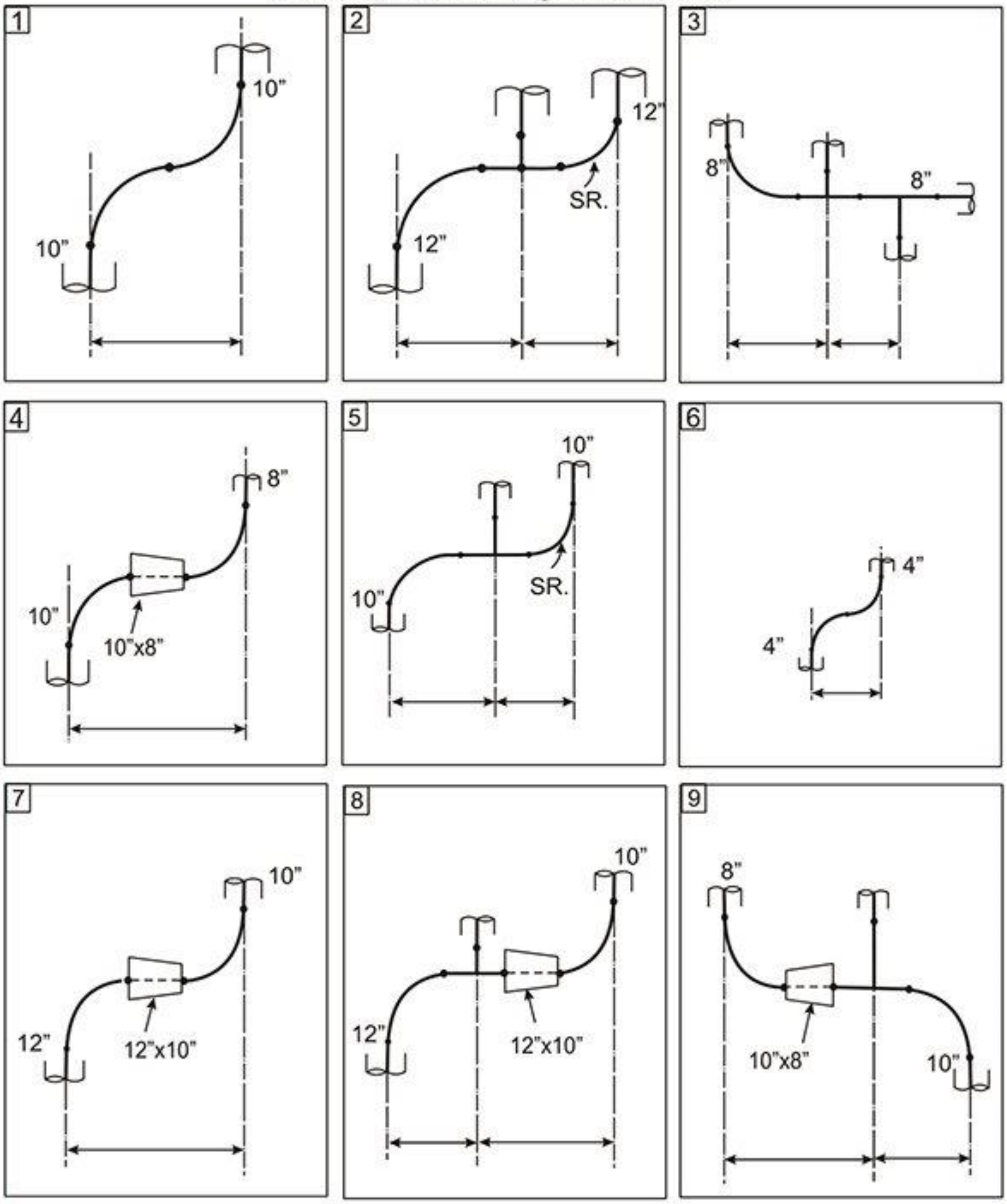
Nom. Pipe Size	Outlet	C	M	H
20	20	15	...	...
	18	15	14½	20
	16 & 14	15	14	20
	12	15	13⅝	20
	10	15	13⅛	20
	8	15	12¾	20
24	24	17	...	...
	20	17	17	20
	18	17	16½	20
	16 & 14	17	16	20
	12	17	15⅝	20
	10	17	15⅛	20
30	30	22	...	...
	24	22	21	24
	20	22	20	24
	18	22	19½	24
	16 & 14	22	19	24
36	36	26½	...	...
	30	26½	25	24
	24	26½	24	24
	20	26½	23	24
	18	26½	22½	24
	16	26½	22	24
42	42	30	28	...
	36 & 30	30	28	24
	24 & 20	30	26	24
48	48	35	33	...
	42	35	32	28
	36	35	31	28
	30	35	30	28
	24	35	29	28

♦ See M dimensions for branch height of 42" or 48" full branch tee. All dimensions are in inches.
See ANSI B16.9 for cap lengths when wall thicknesses are greater than x-stg.

Courtesy of Taylor Forge

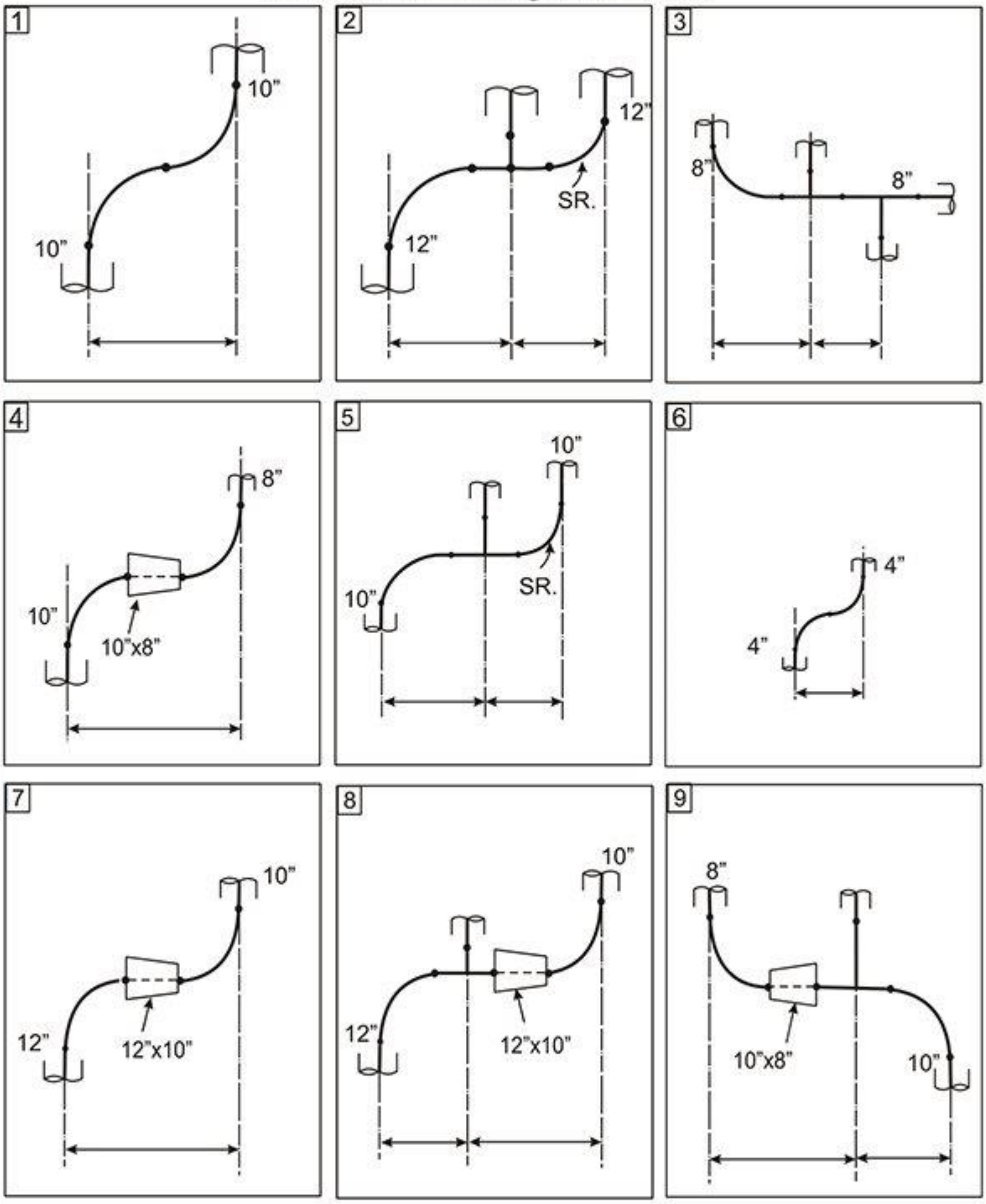
FITTING MAKE-UP

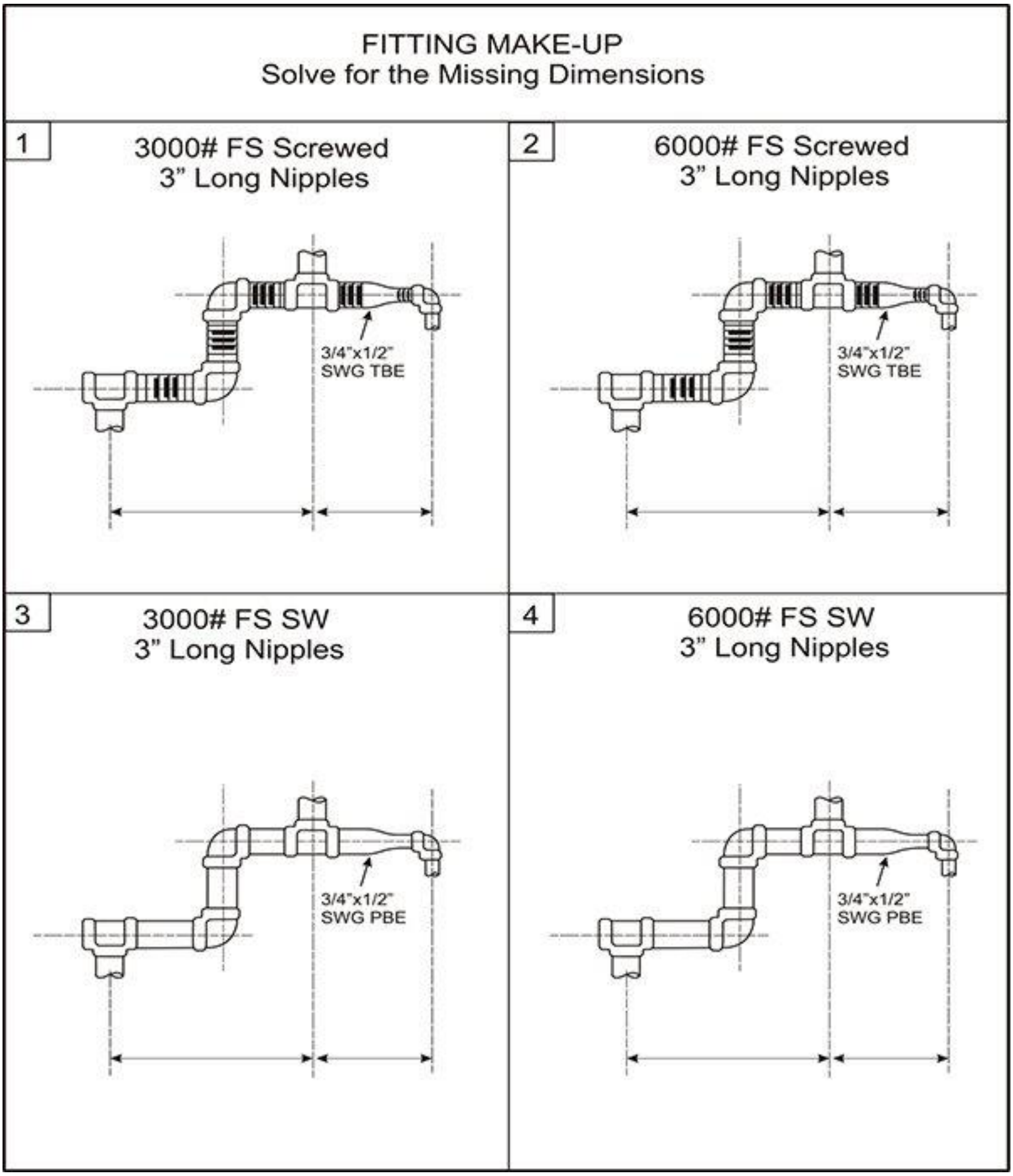
Solve for the Missing Dimensions



FITTING MAKE-UP

Solve for the Missing Dimensions





8.2 Flanges

Flanges are devices used in connecting pipes to equipment nozzles (Figures 8.3 and 8.4) and to devices such as valves. Flanged connections are an effective alternative to welded or threaded connections and provide an advantage of easy dismantling for maintenance and inspection.

Figure 8.3
Flange connecting pipe to a vessel

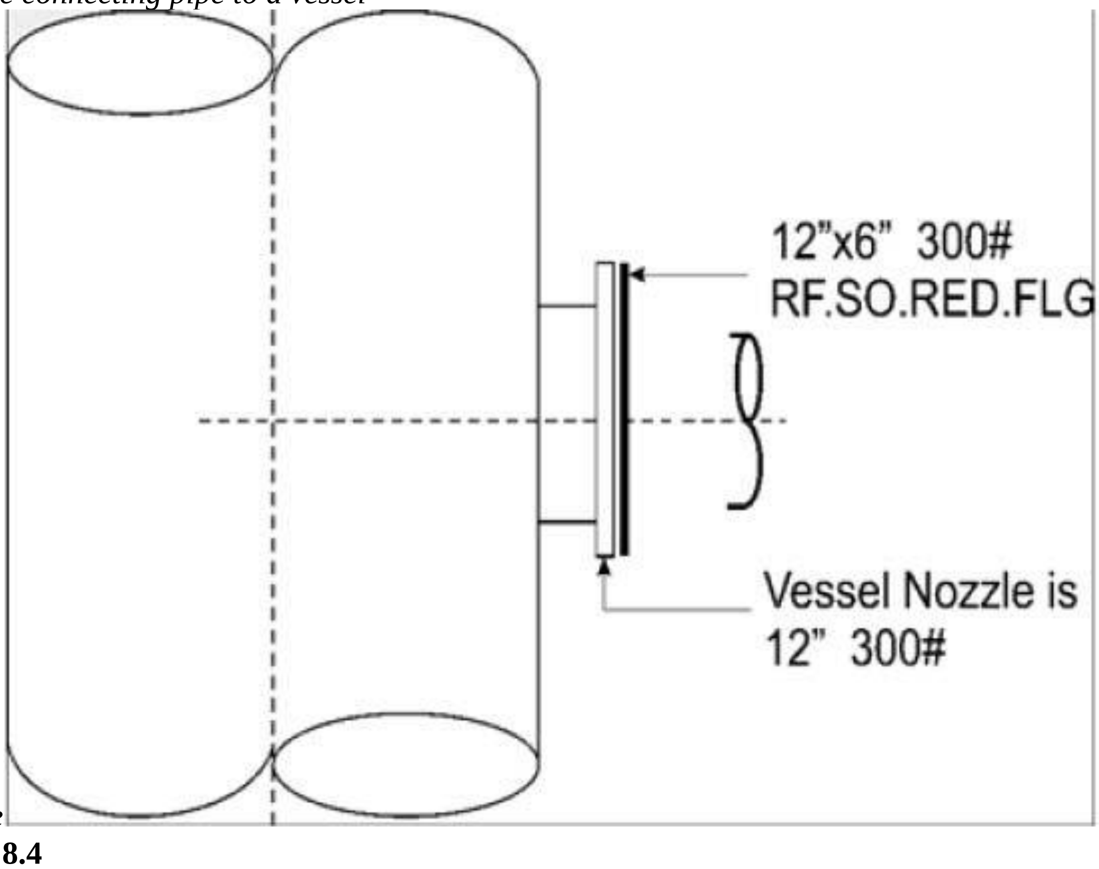


Figure 8.4
Reducing flange connecting pipe to vessel nozzle

Flange Ratings: Flanges are often identified by their ratings as in “150 pound flange” also represented as 150 # or 150 lb. Flange ratings are also known as “pressure ratings” and represent the maximum pressure allowed by the codes at a given temperature. Forged Steel (FS) flanges are available in the following ratings: 150 #, 300 #, 400 #, 600 #, 900 #, 1500 #, and 2500 #. A flange rating of 150 # means that it can be used up to a maximum pressure of 150 psig at a system temperature of 500°F. If the temperature increases to 750°F, the next higher rated flange (300 #) should be used. At a system temperature of 750°F, the maximum pressure allowed is 100 psig and therefore a 150 # flange will not suffice. Both the flange diameter and thickness increase with pressure ratings.

Flange dimensions are given in Appendices 4, 5, 6 and 7 for different ratings and different types of flanges.

Flange Facings:

- Flat Face (FF): The mating surfaces are flat. (Figure 8.5)
- Raised Face (RF): The mating surfaces have a raised face of 1/16” for 150 # and 300 # flanges and 1/4” for higher ratings. In the flange dimensions charts, the 1/4” raised face is nor included and must be added. However, the 1/16” dimension is included. (Figure 8.6)
- Ring Type Joint (RTJ): The mating surfaces have a groove which houses a metallic ring that provides the sealing mechanism when tightened. No gaskets are used. (Figure 8.7)

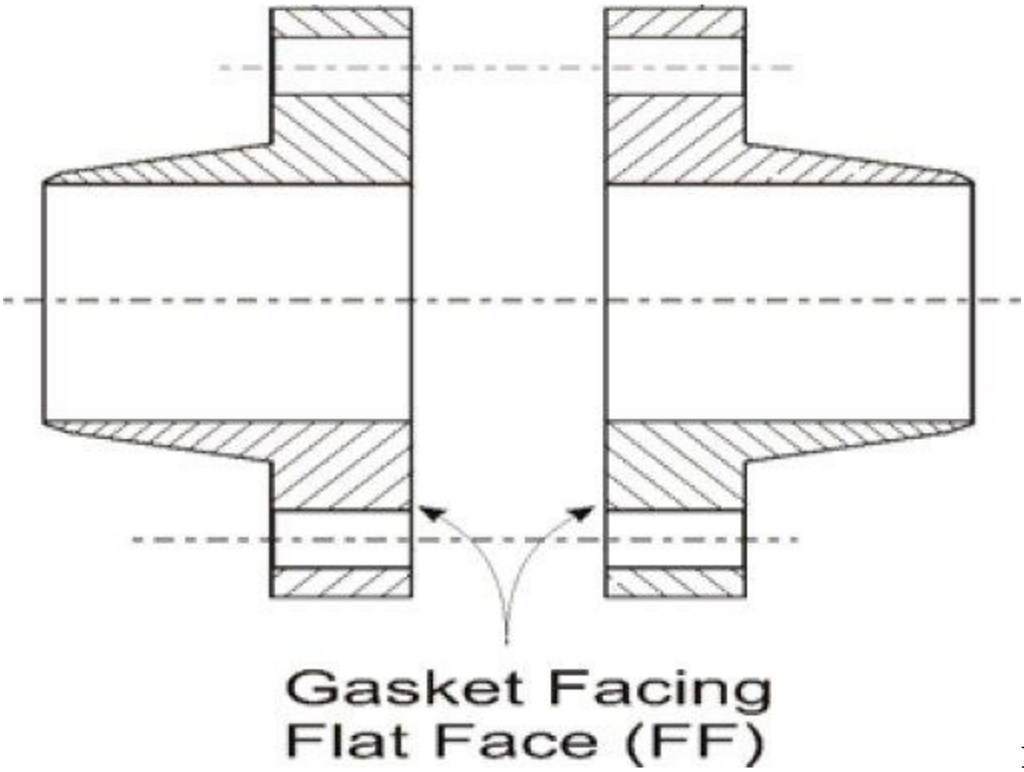


Figure 8.5

Flat Face Weld Neck Flange

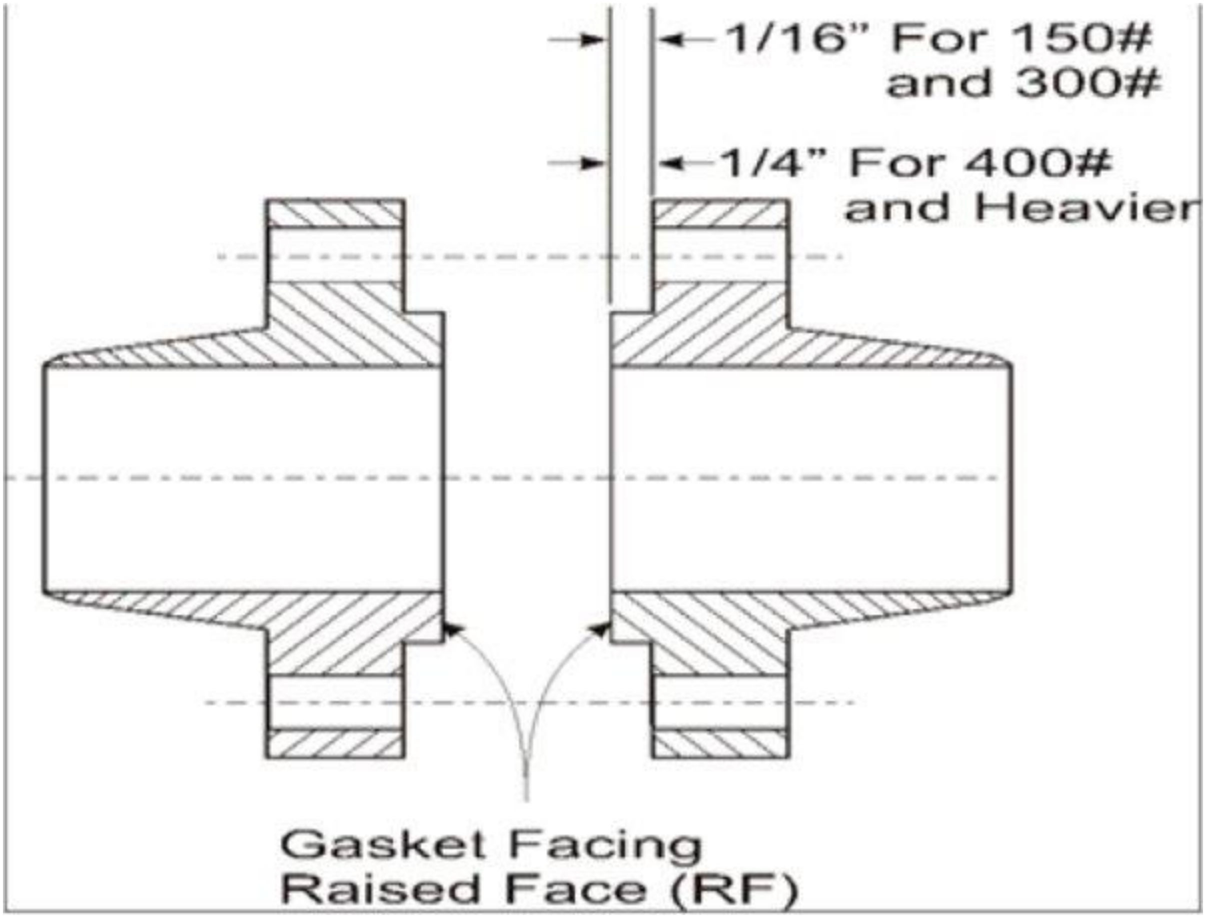


Figure 8.6
Raised Face Weld Neck Flange

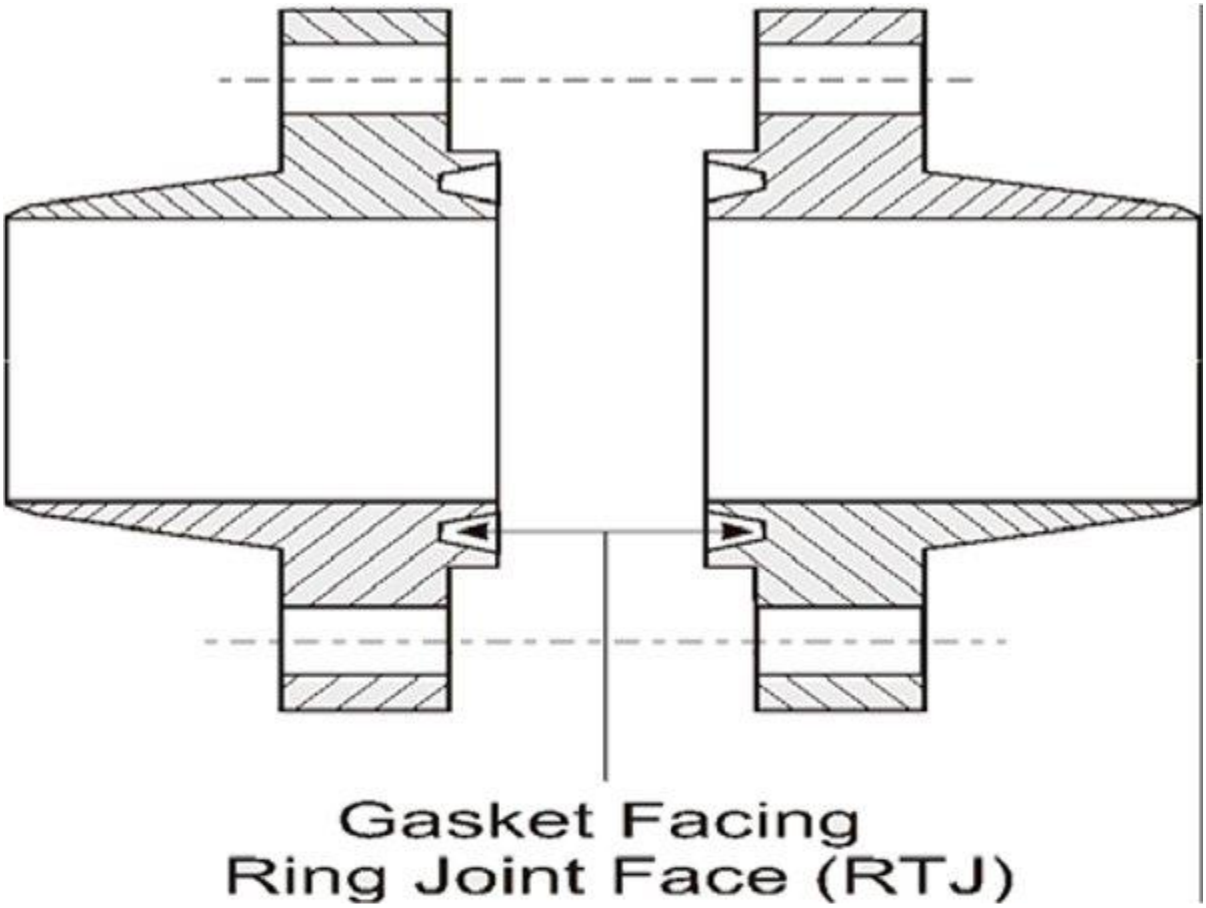


Figure 8.7
Ring Type Joint Weld Neck Flange

Types of Flanges:

- Weld Neck (WN)
- Slip-on (SO)
- Threaded (THRD)
- Socket Weld (SW)
- Lap Joint (LJ)
- Reducing (RED)
- Blind (BLD)

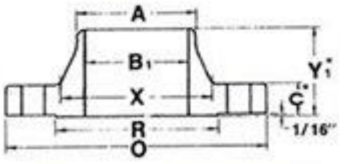
Flange Accessories:

- Bolts
- Gaskets

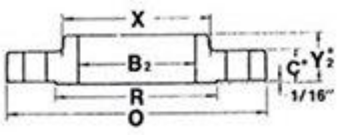
Abbreviations:
RFWN – Raised Face Weld Neck Flange.
Flange dimensioning problems are given in Practical Exercise 8D.

FLANGES DIMENSIONS

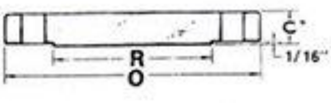
WELDING NECK



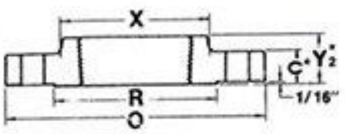
SLIP-ON



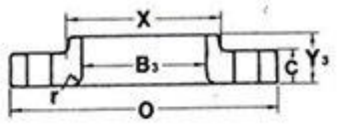
BLIND



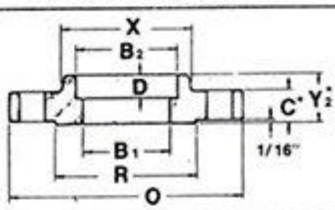
THREADED



LAP JOINT



SOCKET-WELD[3]



150-LB.

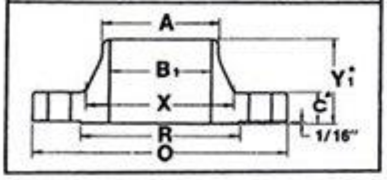
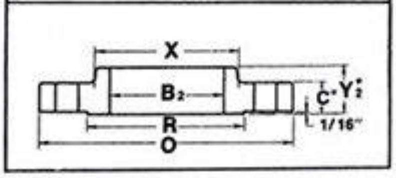
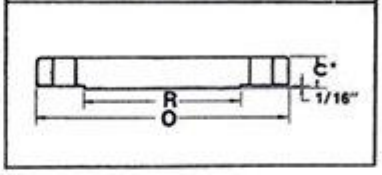
Nom. Pipe Size	Outside Diam. O	Thkn. (min.) C	O.D. of Raised Face R	Hub Diam. X	Length thru Hub: Wldg. Neck Y1	Length thru Hub: Slip-on Thrd. Sock. W. Y2	Length thru Hub: Lap Joint Y3	Bore: Wldg. Neck[2] B1	Bore: Slip-on Sock. W. B2	Bore: Lap Joint B3	Depth of Socket D	Approx. Weight (Lbs.): Wldg. Neck	Approx. Weight (Lbs.): Slip-On Thrd. Sock. W.	Approx. Weight (Lbs.): Lap Joint	Approx. Weight (Lbs.): Blind	Drilling: No. Holes	Drilling: Diam. Holes	Drilling: Bolt Circle Diam.
1/2	3 1/2	7/16	1 3/8	1 3/16	1 7/8	5/8	5/8	0.62	0.88	0.90	3/8	2	1	1	1	4	5/8	2 3/8
3/4	3 7/8	1/2	1 11/16	1 1/2	2 1/16	5/8	5/8	0.82	1.09	1.11	7/16	2	2	2	2	4	5/8	2 3/4
1	4 1/4	9/16	2	1 15/16	2 3/16	11/16	11/16	1.05	1.36	1.38	1/2	3	2	2	2	4	5/8	3 1/8
1 1/4	4 5/8	5/8	2 1/2	2 5/16	2 1/4	13/16	13/16	1.38	1.70	1.72	9/16	3	3	3	3	4	5/8	3 1/2
1 1/2	5	11/16	2 7/8	2 9/16	2 7/16	7/8	7/8	1.61	1.95	1.97	5/8	4	3	3	4	4	5/8	3 7/8
2	6	3/4	3 5/8	3 1/16	2 1/2	1	1	2.07	2.44	2.46	11/16	6	5	5	5	4	3/4	4 3/4
2 1/2	7	7/8	4 1/8	3 9/16	2 3/4	1 1/8	1 1/8	2.47	2.94	2.97	3/4	8	7	7	7	4	3/4	5 1/2
3	7 1/2	15/16	5	4 1/4	2 3/4	1 3/16	1 3/16	3.07	3.57	3.60	13/16	10	8	8	9	4	3/4	6
3 1/2	8 1/2	15/16	5 1/2	4 13/16	2 13/16	1 1/4	1 1/4	3.55	4.07	4.10	7/8	12	11	11	13	8	3/4	7
4	9	15/16	6 3/16	5 5/16	3	1 5/16	1 5/16	4.03	4.57	4.60	15/16	15	13	13	17	8	3/4	7 1/2
5	10	15/16	7 5/16	6 7/16	3 1/2	1 7/16	1 7/16	5.05	5.66	5.69	15/16	19	15	15	20	8	7/8	8 1/2
6	11	1	8 1/2	7 9/16	3 1/2	1 9/16	1 9/16	6.07	6.72	6.75	1 1/16	24	19	19	26	8	7/8	9 1/2
8	13 1/2	1 1/8	10 5/8	9 11/16	4	1 3/4	1 3/4	7.98	8.72	8.75	1 1/4	39	30	30	45	8	7/8	11 3/4
10	16	1 3/16	12 3/4	12	4	1 15/16	1 15/16	10.02	10.88	10.92	1 3/16	52	43	43	70	12	1	14 1/4
12	19	1 1/4	15	14 3/8	4 1/2	2 3/16	2 3/16	12.00	12.88	12.92	1 5/16	80	64	64	110	12	1	17
14	21	1 3/8	16 1/4	15 3/4	5	2 1/4	3 1/8	13.25	14.14	14.18	1 5/8	110	90	105	140	12	1 1/8	18 3/4
16	23 1/2	1 7/16	18 1/2	18	5	2 1/2	3 7/16	15.25	16.16	16.19	1 3/4	140	98	140	180	16	1 1/8	21 1/4
18	25	1 9/16	21	19 7/8	5 1/2	2 11/16	3 13/16	17.25	18.18	18.20	1 15/16	150	130	160	220	16	1 1/4	22 3/4
20	27 1/2	1 11/16	23	22	5 11/16	2 7/8	4 1/16	19.25	20.20	20.25	2 1/8	180	165	195	285	20	1 1/4	25
22	29 1/2	1 13/16	25 1/4	24 1/4	5 7/8	3 1/8	4 1/4	21.25	22.22	22.25	2 3/8	225	185	245	355	20	1 3/8	27 1/4
24	32	1 7/8	27 1/4	26 1/8	6	3 1/4	4 3/8	23.25	24.25	24.25	2 1/2	260	220	275	430	20	1 3/8	29 1/2

ANSI B16.5 covers only sizes through 24". Larger sizes as listed below have the same flange and drilling dimensions as Class 125 Cast Iron Flanges, ASA B16.1.

26	34 1/4	2	29 1/4	28 1/2	5	3 3/8	—	To be specified by purchaser	26.25	—	—	300	250	—	525	24	1 3/8	31 3/4
28	36 1/2	2 1/16	31 1/4	30 3/4	5 1/16	3 7/16	—		28.25	—	—	315	285	—	620	28	1 3/8	34
30	38 3/4	2 1/8	33 3/4	32 3/4	5 1/8	3 1/2	—		30.25	—	—	360	315	—	720	28	1 3/8	36
32	41 3/4	2 1/4	35 3/4	35	5 1/4	3 5/8	—		32.25	—	—	435	395	—	870	28	1 5/8	38 1/2
34	43 3/4	2 5/16	37 3/4	37	5 5/16	3 11/16	—		34.25	—	—	465	420	—	990	32	1 5/8	40 1/2
36	46	2 3/8	40 1/4	39 1/4	5 3/8	3 3/4	—		36.25	—	—	520	480	—	1125	32	1 5/8	42 3/4
42	53	2 5/8	47	46	5 5/8	4	—		42.25	—	—	750	680	—	1625	36	1 5/8	49 1/2

FLANGES

DIMENSIONS

WELDING NECK	SLIP-ON	BLIND
		

300-lb.

Nom. Pipe Size	Outside Diam. O	Thkn. (min.) C	O.D. of Raised Face R	Hub Diam. X	Length thru Hub: Wldg. Neck Y1	Length thru Hub: Slip-on Thrd. Sock. W. Y2	Length thru Hub: Lap Joint Y3	Bore □: Wldg. Neck [2] B1	Bore: Slip-On Sock. W. B2	Bore: Lap Joint B3	Depth of Sock. D	Approx. Weight (Lbs.): Wldg. Neck	Approx. Weight: Slip-On Thrd. Sock. W.	Approx. Weight: Lap Joint	Approx. Weight: Blind	Drilling: No. Holes	Drilling: Diam. Holes	Drilling: Bolt Circle Diam.
1/2	3 3/4	9/16	1 3/8	1 1/2	2 1/16	7/8	7/8	0.62	0.88	0.90	3/8	2	2	2	2	4	5/8	2 5/8
3/4	4 5/8	5/8	1 11/16	1 7/8	2 1/4	1	1	0.82	1.09	1.11	7/16	3	3	3	3	4	3/4	3 1/4
1	4 7/8	11/16	2	2 1/8	2 7/16	1 1/16	1 1/16	1.05	1.36	1.38	1/2	4	3	3	3	4	3/4	3 1/2
1 1/4	5 1/4	3/4	2 1/2	2 1/2	2 9/16	1 1/16	1 1/16	1.38	1.70	1.72	9/16	5	4	4	4	4	3/4	3 7/8
1 1/2	6 1/8	13/16	2 7/8	2 3/4	2 11/16	1 3/16	1 3/16	1.61	1.95	1.97	5/8	7	6	6	6	4	7/8	4 1/2
2	6 1/2	7/8	3 5/8	3 5/16	2 3/4	1 5/16	1 5/16	2.07	2.44	2.46	11/16	9	7	7	8	8	3/4	5
2 1/2	7 1/2	1	4 1/8	3 15/16	3	1 1/2	1 1/2	2.47	2.94	2.97	3/4	12	10	10	12	8	7/8	5 7/8
3	8 1/4	1 1/8	5	4 5/8	3 1/8	1 11/16	1 11/16	3.07	3.57	3.60	13/16	15	13	13	16	8	7/8	6 5/8
3 1/2	9	1 3/16	5 1/2	5 1/4	3 3/16	1 3/4	1 3/4	3.55	4.07	4.10	—	18	17	17	21	8	7/8	7 1/4
4	10	1 1/4	6 3/16	5 3/4	3 3/8	1 7/8	1 7/8	4.03	4.57	4.60	—	25	22	22	27	8	7/8	7 7/8
5	11	1 3/8	7 5/16	7	3 7/8	2	2	5.05	5.66	5.69	—	32	28	28	35	8	7/8	9 1/4
6	12 1/2	1 7/16	8 1/2	8 1/8	3 7/8	2 1/16	2 1/16	6.07	6.72	6.75	—	42	39	39	50	12	7/8	10 5/8
8	15	1 5/8	10 5/8	10 1/4	4 3/8	2 7/16	2 7/16	7.98	8.72	8.75	—	67	58	58	81	12	1	13
10	17 1/2	1 7/8	12 3/4	12 5/8	4 5/8	2 5/8	3 3/4	10.02	10.88	10.92	—	91	81	91	124	16	1 1/8	15 1/4
12	20 1/2	2	15	14 3/4	5 1/8	2 7/8	4	12.00	12.88	12.92	—	140	115	140	185	16	1 1/4	17 3/4
14	23	2 1/8	16 1/4	16 3/4	5 5/8	3	4 3/8	13.25	14.14	14.18	—	180	165	190	250	20	1 1/4	20 1/4
16	25 1/2	2 1/4	18 1/2	19	5 3/4	3 1/4	4 3/4	15.25	16.16	16.19	—	250	190	250	295	20	1 3/8	22 1/2
18	28	2 3/8	21	21	6 1/4	3 1/2	5 1/8	17.25	18.18	18.20	—	320	250	295	395	24	1 3/8	24 3/4
20	30 1/2	2 1/2	23	23 1/8	6 3/8	3 3/4	5 1/2	19.25	20.20	20.25	—	400	315	370	505	24	1 3/8	27
22	33	2 5/8	25 1/4	25 1/4	6 1/2	4	5 3/4	21.25	22.22	22.25	—	465	370	435	640	24	1 5/8	29 1/4
24	36	2 3/4	27 1/4	27 5/8	6 5/8	4 3/16	6	23.25	24.25	24.25	—	580	475	550	790	24	1 5/8	32
MSS—SP44 Class 300 ■**																**ASTM A105-II**		
26	38 1/4	3 1/8	29 1/2	28 3/8	7 1/4	—	—	To be specified by purchaser	—	—	—	670	570	—	1050	28	1 3/4	34 1/2
28	40 3/4	3 3/8	31 1/2	30 1/2	7 3/4	—	—		—	—	—	810	720	—	1275	28	1 3/4	37
30	43	3 5/8	33 3/4	32 3/16	8 1/4	—	—		—	—	—	930	810	—	1500	28	1 7/8	39 1/4
32	45 1/4	3 7/8	36	34 11/16	8 3/4	—	—		—	—	—	1025	890	—	1775	28	2	41 1/2
34	47 1/2	4	38	36 7/8	9 1/8	—	—		—	—	—	1200	1075	—	2025	28	2	43 1/2
36	50	4 1/8	40 1/4	39	9 1/2	—	—		—	—	—	1300	1200	—	2275	32	2 1/8	46
42	57	4 5/8	47	45 3/16	10 7/8	—	—		—	—	—	1740.	1610	—	3165	36	2 1/8	52 3/4

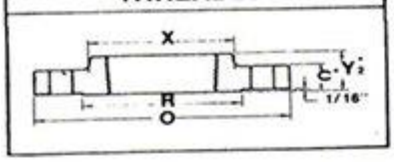
400-lb.

(NOTE: Sizes ½" thru 3½" are identical with 600 lb. flanges (see next page).)

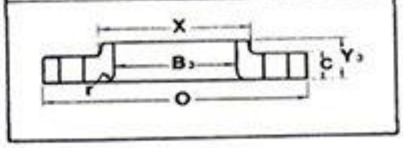
Nom. Pipe Size	Outside Diam. O	Thkn. (min.) C	O.D. of Raised Face R	Hub Diam. X	Length thru Hub: Wldg. Neck Y1	Length thru Hub: Slip-on Thrd. Sock. W. Y2	Length thru Hub: Lap Joint Y3	Bore: Wldg. Neck B1	Bore: Slip-On Sock. W. B2	Bore: Lap Joint B3	Depth of Sock. D	Approx. Weight (Lbs.): Wldg. Neck	Approx. Weight: Slip-On Thrd. Sock. W.	Approx. Weight: Lap Joint	Approx. Weight: Blind	Drilling: No. Holes	Drilling: Diam. Holes	Drilling: Bolt Circle Diam.
4	10	1 3/8	6 3/16	5 3/4	3 1/2	2	2	To be specified by purchaser	4.57	4.60	Not manufactured in 400-lb.	35	26	25	33	8	1	7 7/8
5	11	1 1/2	7 5/16	7	4	2 1/8	2 1/8		5.66	5.69		43	31	29	44	8	1	9 1/4
6	12 1/2	1 5/8	8 1/2	8 1/8	4 1/16	2 1/4	2 1/4		6.72	6.75		57	44	42	61	12	1	10 5/8
8	15	1 7/8	10 5/8	10 1/4	4 5/8	2 11/16	2 11/16		8.72	8.75		89	67	64	100	12	1 1/8	13
10	17 1/2	2 1/8	12 3/4	12 5/8	4 7/8	2 7/8	4		10.88	10.92		125	91	110	155	16	1 1/4	15 1/4
12	20 1/2	2 1/4	15	14 3/4	5 3/8	3 1/8	4 1/4		12.88	12.92		175	130	150	225	16	1 3/8	17 3/4
14	23	2 3/8	16 1/4	16 3/4	5 7/8	3 5/16	4 5/8		14.14	14.18		230	180	205	290	20	1 3/8	20 1/4
16	25 1/2	2 1/2	18 1/2	19	6	3 11/16	5		16.16	16.19		295	235	260	370	20	1 1/2	22 1/2
18	28	2 5/8	21	21	6 1/2	3 7/8	5 3/8		18.18	18.20		350	285	315	455	24	1 1/2	24 3/4
20	30 1/2	2 3/4	23	23 1/8	6 5/8	4	5 3/4		20.20	20.25		425	345	385	587	24	1 5/8	27
22	33	2 7/8	25 1/4	25 1/4	6 3/4	4 1/4	6		22.22	22.25		505	405	455	720	24	1 3/4	29 1/4
24	36	3	27 1/4	27 5/8	6 7/8	4 1/2	6 1/4		24.25	24.25		620	510	570	890	24	1 7/8	32
MSS—SP44 Class 400 ■**																**ASTM A105-II**		
26	38 1/4	3 1/2	29 1/2	28 5/8	7 5/8	—	—		—	—		750	650	—	1125	28	1 7/8	34 1/2
28	40 3/4	3 3/4	31 1/2	30 13/16	8 1/2	—	—		—	—		880	780	—	1425	28	2	37
30	43	4	33 3/4	32 15/16	8 5/8	—	—		—	—		1000	900	—	1675	28	2 1/8	39 1/4
32	45 1/4	4 1/4	36	35	9 1/8	—	—		—	—		1150	1025	—	1975	28	2 1/8	41 1/2
34	47 1/2	4 3/8	38	37 3/16	9 1/2	—	—		—	—		1300	1150	—	2250	28	2 1/8	43 1/2
36	50	4 1/2	40 1/4	39 3/8	9 7/8	—	—		—	—		1475	1325	—	2525	32	2 1/8	46

FLANGES DIMENSIONS

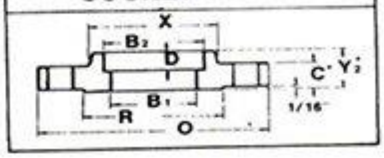
THREADED



LAP JOINT



SOCKET-WELD



600-lb.

Nom. Pipe Size	Outside Diam. O	Thkn. (min.) C	O.D. of Raised Face R	Hub Diam. X	Length thru Hub: Wldg. Neck Y1	Length thru Hub: Slip-On Thrd. Sock. W. Y2	Length thru Hub: Lap Joint Y3	Bore: Wldg. Neck B1	Bore: Slip-On Socket W. B2	Bore: Lap Joint B3	Depth of Socket D	Approx. Weight (Lbs.): Wldg. Neck	Approx. Weight (Lbs.): Slip-On Thrd. Sock. W.	Approx. Weight (Lbs.): Lap Joint	Approx. Weight (Lbs.): Blind	Drilling: No. Holes	Drilling: Diam. Holes	Drilling: Bolt Circle Diam.
½	3¾	9/16	1⅜	1½	2 1/16	⅞	⅞	To be specified by purchaser	0.88	0.90	⅜	2	2	2	2	4	⅝	2⅝
¾	4⅝	⅝	1 11/16	1⅞	2¼	1	1		1.09	1.11	7/16	4	3	3	3	4	¾	3¼
1	4⅞	11/16	2	2⅛	2 7/16	1 1/16	1 1/16		1 36	1.38	½	4	4	4	4	4	¾	3½
1¼	5¼	13/16	2½	2½	2⅝	1⅛	1⅛		1.70	1.72	9/16	6	5	5	5	4	¾	3⅞
1½	6⅛	⅞	2⅞	2¾	2¾	1¼	1¼		1.95	1.97	⅝	8	7	7	8	4	⅞	4½
2	6½	1	3⅝	3 5/16	2⅞	1 7/16	1 7/16		2.44	2.46	11/16	12	9	9	10	8	¾	5
2½	7½	1⅛	4⅛	3 15/16	3⅛	1⅝	1⅝		2.94	2.97	¾	18	13	12	15	8	⅞	5⅞
3	8¼	1¼	5	4⅝	3¼	1 13/16	1 13/16		3.57	3.60	13/16	23	16	15	20	8	⅞	6⅝
3½	9	1⅜	5½	5¼	3⅜	1 15/16	1 15/16		4.07	4.10	—	26	21	20	29	8	1	7¼
4	10¾	1½	6 3/16	6	4	2⅛	2⅛		4.57	4.60	—	42	37	36	41	8	1	8½
5	13	1¾	7 5/16	7 7/16	4½	2⅜	2⅜		5.66	5.69	—	68	63	61	68	8	1⅛	10½
6	14	1⅞	8½	8¾	4⅝	2⅝	2⅝		6.72	6.75	—	81	80	78	86	12	1⅛	11½
8	16½	2 3/16	10⅝	10¾	5¼	3	3		8.72	8.75	—	120	115	110	140	12	1¼	13¾
10	20	2½	12¾	13½	6	3⅜	4⅜		10.88	10.92	—	190	170	170	230	16	1⅜	17
12	22	2⅝	15	15¾	6⅛	3⅝	4⅝		12.88	12.92	—	225	200	200	295	20	1⅜	19¼
14	23¾	2¾	16¼	17	6½	3 11/16	5		14.14	14.18	—	280	230	250	355	20	1½	20¾
16	27	3	18½	19½	7	4 3/16	5½		16.16	16.19	—	390	330	365	495	20	1⅝	23¾
18	29¼	3¼	21	21½	7¼	4⅝	6		18.18	18.20	—	475	400	435	630	20	1¾	25¾
20	32	3½	23	24	7½	5	6½		20.20	20.25	—	590	510	570	810	24	1¾	28½
22	34¼	3¾	25¼	26¼	7¾	5¼	6⅞		22.22	22.25	—	720	590	670	1000	24	1⅞	30⅝
24	37	4	27¼	28¼	8	5½	7¼		24.25	24.25	—	830	730	810	1250	24	2	33
																		ASTM A105-II
MSS—SP44 Class 600** ■																		
26	40	4¼	29½	29 5/16	8¾	—	—		—	—	—	1025	950	—	1525	28	2	36
28	42¼	4⅜	31½	31⅝	9¼	—	—		—	—	—	1175	1075	—	1750	28	2⅛	38
30	44½	4½	33¾	33 15/16	9¾	—	—		—	—	—	1300	1175	—	2000	28	2⅛	40¼
32	47	4⅝	36	36⅛	10¼	—	—		—	—	—	1500	1375	—	2300	28	2⅜	42½
34	49	4¾	38	38 3/16	10⅝	—	—		—	—	—	1650	1500	—	2575	28	2⅜	44½
36	51¾	4⅞	40¼	40⅝	11⅛	—	—		—	—	—	1750	1600	—	2950	28	2⅝	47

900-lb.

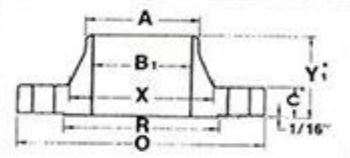
(NOTE: Sizes ½" thru 2½" are identical with 1500 lb. flanges (see next page).

Nom. Pipe Size	O	C	R	X	Y1	Y2	Y3	B1	B2	B3	D	Wldg. Neck	Slip-On Thrd. Sock. W.	Lap Joint	Blind	No. Holes	Diam. Holes	Bolt Circle Diam.
3	9½	1½	5	5	4	2⅛	2⅛	To be specified by purchaser	3.57	3.60	—	31	26	25	29	8	1	7½
4	11½	1¾	6 3/16	6¼	4½	2¾	2¾		4.57	4.60	—	53	53	51	54	8	1¼	9¼
5	13¾	2	7 5/16	7½	5	3⅛	3⅛		5.66	5.69	—	86	83	81	87	8	1⅜	11
6	15	2 3/16	8½	9¼	5½	3⅜	3⅜		6.72	6.75	—	110	110	105	115	12	1¼	12½
8	18½	2½	10⅝	11¾	6⅜	4	4½		8.72	8.75	—	175	170	190	200	12	1½	15½
10	21½	2¾	12¾	14½	7¼	4¼	5		10.88	10.92	—	260	245	275	290	16	1½	18½
12	24	3⅛	15	16½	7⅞	4⅝	5⅝		12.88	12.92	—	325	325	370	415	20	1½	21
14	25¼	3⅜	16¼	17¾	8⅜	5⅛	6⅛		14.14	14.18	—	400	400	415	520	20	1⅝	22
16	27¾	3½	18½	20	8½	5¼	6½		16.16	16.19	—	495	425	465	600	20	1¾	24¼
18	31	4	21	22¼	9	6	7½		18.18	18.20	—	680	600	650	850	20	2	27
20	33¾	4¼	23	24½	9¾	6¼	8¼		20.20	20.25	—	830	730	810	1075	20	2⅛	29½
22	—	—	—	—	—	—	—		—	—	—	—	—	—	—	—	—	—
24	41	5½	27¼	29½	11½	8	10½		24.25	24.25	—	1500	1400	1550	2025	20	2⅝	35½
																		ASTM A105-II
MSS—SP44 Class 900** ■																		
26	42¾	5½	29½	30½	11¼	—	—		—	—	—	1575	1525	—	2200	20	2⅞	37½
28	46	5⅝	31½	32¾	11¾	—	—		—	—	—	1850	1800	—	2575	20	3⅛	40¼
30	48½	5⅞	33¾	35	12¼	—	—		—	—	—	2150	2075	—	3025	20	3⅛	42¾
32	51¾	6¼	36	37¼	13	—	—		—	—	—	2575	2500	—	3650	20	3⅜	45½
34	55	6½	38	39⅝	13¾	—	—		—	—	—	3025	2950	—	4275	20	3⅝	48¼
36	57½	6¾	40¼	41⅞	14¼	—	—		—	—	—	3450	3350	—	4900	20	3⅝	50¾

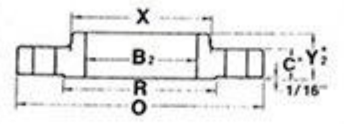
FLANGES

DIMENSIONS

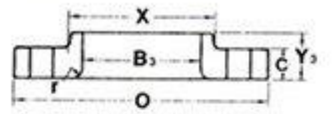
WELDING NECK



SLIP-ON



LAP JOINT



1500-lb.

Nom. Pipe Size	Outside Diam.	Thkn. (min.)	O.D. of Raised Face	Hub Diam.	Length thru Hub			Bore□			Depth of Socket	Approx. Wgt. (Lbs.)				Drilling		
					Wldg. Neck	Slip-On Thrd. ♦ Sock. W.	Lap Joint	Wldg. Neck	Slip-on Sock. W.	Lap Joint		Wldg. Neck	Slip-On♦ Thrd. Sock. W.	Lap Joint	Blind♦	No. Holes	Diam. Holes	Bolt Circle Diam.
	O	C	R	X	Y_1	Y_2	Y_3	B_1	B_2	B_3	D							
½	4 3/4	7/8	1 3/8	1 1/2	2 3/8	1 1/4	1 1/4	To be specified by customer	0.88	0.90	3/8	5	4	4	4	4	7/8	3 1/4
¾	5 1/8	1	1 11/16	1 3/4	2 3/4	1 3/8	1 3/8		1.09	1.11	7/16	6	5	5	6	4	7/8	3 1/2
1	5 7/8	1 1/8	2	2 1/16	2 7/8	1 5/8	1 5/8		1.36	1.38	1/2	9	8	8	8	4	1	4
1¼	6 1/4	1 1/8	2 1/2	2 1/2	2 7/8	1 5/8	1 5/8		1.70	1.72	9/16	10	9	9	9	4	1	4 3/8
1½	7	1 1/4	2 7/8	2 3/4	3 1/4	1 3/4	1 3/4		1.95	1.97	5/8	13	12	12	13	4	1 1/8	4 7/8
2	8 1/2	1 1/2	3 5/8	4 1/8	4	2 1/4	2 1/4		2.44	2.46	11/16	25	25	25	25	8	1	6 1/2
2½	9 5/8	1 5/8	4 1/8	4 7/8	4 1/8	2 1/2	2 1/2		2.94	2.97	3/4	36	36	35	35	8	1 1/8	7 1/2
3	10 1/2	1 7/8	5	5 1/4	4 5/8	2 7/8	2 7/8		3.57	3.60	—	48	48	47	48	8	1 1/4	8
3½	—	—	—	—	—	—	—		—	—	—	—	—	—	—	—	—	—
4	12 1/4	2 1/8	6 3/16	6 3/8	4 7/8	3 9/16	3 9/16		4.57	4.60	—	73	73	75	73	8	1 3/8	9 1/2
5	14 3/4	2 7/8	7 5/16	7 3/4	6 1/8	4 1/8	4 1/8		5.66	5.69	—	130	130	140	140	8	1 5/8	11 1/2
6	15 1/2	3 1/4	8 1/2	9	6 3/4	4 11/16	4 11/16		6.72	6.75	—	165	165	170	160	12	1 1/2	12 1/2
8	19	3 5/8	10 5/8	11 1/2	8 3/8	5 5/8	5 5/8		8.72	8.75	—	275	260	285	300	12	1 3/4	15 1/2
10	23	4 1/4	12 3/4	14 1/2	10	6 1/4	7		10.88	10.92	—	455	435	485	510	12	2	19
12	26 1/2	4 7/8	15	17 3/4	11 1/8	7 1/8	8 5/8		12.88	12.92	—	690	580	630	690	16	2 1/8	22 1/2
14	29 1/2	5 1/4	16 1/4	19 1/2	11 3/4	—	9 1/2		—	14.18	—	940	—	890	975	16	2 3/8	25
16	32 1/2	5 3/4	18 1/2	21 3/4	12 1/4	—	10 1/4		—	16.19	—	1250	—	1150	1300	16	2 5/8	27 3/4
18	36	6 3/8	21	23 1/2	12 7/8	—	10 7/8		—	18.20	—	1625	—	1475	1750	16	2 7/8	30 1/2
20	38 3/4	7	23	25 1/4	14	—	11 1/2		—	20.25	—	2050	—	1775	2225	16	3 1/8	32 3/4
22	—	—	—	—	—	—	—		—	—	—	—	—	—	—	—	—	—
24	46	8	27 1/4	30	16	—	13		—	24.25	—	3325	—	2825	3625	16	3 5/8	39

2500-lb.

Nom. Pipe Size	O	C	R	X	Y_1	Y_2	Y_3	B_1	B_2	B_3	D	Wldg. Neck	Slip-On Thrd. Sock. W.	Lap Joint	Blind	No. Holes	Diam. Holes	Bolt Circle Diam.
½	5 1/4	1 3/16	1 3/8	1 11/16	2 7/8	1 9/16	1 9/16	To be specified by customer	0.88	0.90	Not manufactured in 2500-lb.	7	7	7	7	4	7/8	3 1/2
¾	5 1/2	1 1/4	1 11/16	2	3 1/8	1 11/16	1 11/16		1.09	1.11		8	8	8	8	4	7/8	3 3/4
1	6 1/4	1 3/8	2	2 1/4	3 1/2	1 7/8	1 7/8		1.36	1.38		12	11	11	11	4	1	4 1/4
1¼	7 1/4	1 1/2	2 1/2	2 7/8	3 3/4	2 1/16	2 1/16		1.70	1.72		17	16	16	17	4	1 1/8	5 1/8
1½	8	1 3/4	2 7/8	3 1/8	4 3/8	2 3/8	2 3/8		1.95	1.97		25	22	22	23	4	1 1/4	5 3/4
2*	9 1/4	2	3 5/8	3 3/4	5	2 3/4	2 3/4		2.44	2.46		42	38	37	39	8	1 1/8	6 3/4
2½	10 1/2	2 1/4	4 1/8	4 1/2	5 5/8	3 1/8	3 1/8		2.94	2.97		52	55	53	56	8	1 1/4	7 3/4
3	12	2 5/8	5	5 1/4	6 5/8	3 5/8	3 5/8		3.57	3.60		94	83	80	86	8	1 3/8	9
3½	—	—	—	—	—	—	—		—	—		—	—	—	—	—	—	—
4	14	3	6 3/16	6 1/2	7 1/2	4 1/4	4 1/4		4.57	4.60		145	125	120	135	8	1 5/8	10 3/4
5	16 1/2	3 5/8	7 5/16	8	9	5 1/8	5 1/8		5.66	5.69		245	210	205	225	8	1 7/8	12 3/4
6	19	4 1/4	8 1/2	9 1/4	10 3/4	6	6		6.72	6.75		380	325	315	345	8	2 1/8	14 1/2
8	21 3/4	5	10 5/8	12	12 1/2	7	7		8.72	8.75		580	485	470	530	12	2 1/8	17 1/4
10	26 1/2	6 1/2	12 3/4	14 3/4	16 1/2	9	9		10.88	10.92		1075	930	900	1025	12	2 5/8	21 1/4
12	30	7 1/4	15	17 3/8	18 1/4	10	10		12.88	12.92		1525	1100	1100	1300	12	2 7/8	24 3/8

1. Dimensions are in inches. Prices on application.
2. Standard bore will be furnished unless otherwise specified.
3. Socket Weld flgs. are not mfd. in 150# type over 24", in 300# and 600# over 3", in 1500# over 2½", in 400# and 2500# in any size.
4. Specifications—All Taylor Forge flanges conform to ANSI Std. B16.5 or MSS SP44 as applicable and to ASTM Spec. A181 (for 150# and 300# flanges) or A105 (for 400# and heavier flanges.
5. Welding bevel standards and tolerances.
6. Pressure—Temperature ratings.
7. Threading details.
8. Large diameter flanges.

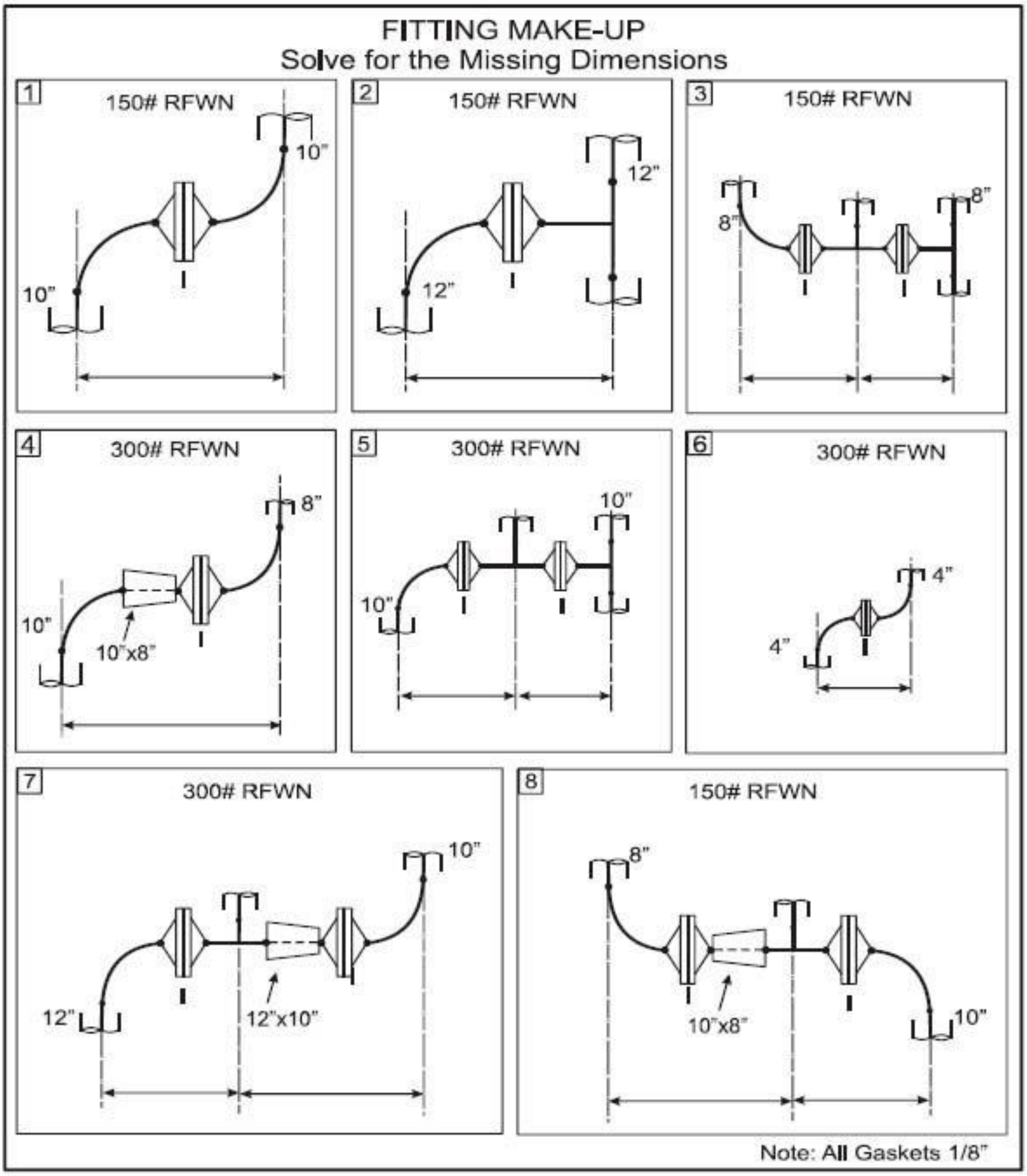
□ Minimum bores.

*Facings: 150# and 300# flanges (except Lap Joint) furnished with 1/16" raised face, which is included in the thickness and hub length shown, 400# and heavier flanges (except Lap Joint) furnished with ¼" raised face, which is not included in thickness or hub length dimensions.

**Refer to Taylor Forge Pipeline Catalog 723 for complete listings of MSS-SP44 and API 605 flanges.

♦ Dimension and blind flange is same as companion flange. However, this is not true for MSS blind flanges, class 300 or heavier, 26" and larger which have a greater thickness.

Courtesy of Taylor Forge



8.3 Valves

A valve is a device that controls and regulates the flow of fluids. The different functions that can be performed by a valve are:

- Turning flow on or off (flow switch)
- Increase/decrease flow rate
- Regulate pressure, temperature
- Isolate a unit
- Reverse the flow direction

Typical parts of a valve:

- Body
- Regulator or valve element
- Valve Seat
- Hand wheel
- Stem
- Valve ends (threaded, flanged, socket welded)

Types of valves (Figures 8.8 and 8.9):

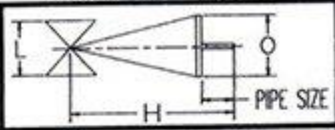
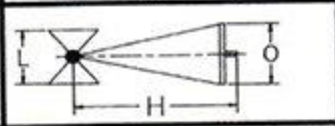
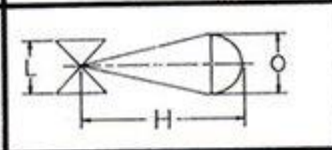
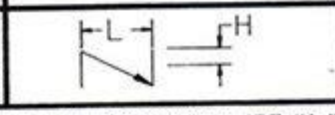
- Gate Valve: Consists of a gate as the regulator. Used primarily for on/off applications, that is fully open or fully closed.
- Globe Valve: Consists of a globe as the valve element. Used in throttling (gradually increasing or decreasing the flow) applications. Flow resistance and pressure drop are substantially higher than gate valves. Flow resistance coefficients are given in Table 8.2.
- Angle Valve: Used in throttling and in changing flow direction.
- Check Valve: Used in preventing back flow or flow in the reverse direction. Usually used in conjunction with gate or globe valves. The types are “Swing Check Valve” and “Lift Check Valve”.
- Ball Valves: Uses a hollow metal ball as the regulator. Provides tight closure and simple open/close operation.
- Plug Valve: Uses a hollow, tapered wedge as the valve element. Provides a tight closure but requires constant lubrication.
- Butterfly Valve: Has a very simple valve body (a ring), which houses a wafer as the valve element. Has lower turbulence and pressure drop and is useful for larger flow rates.
- Relief Valves: Pressure Safety Valve (PSV) is used in maintaining system pressure at safe levels. PSV opens when the system pressure exceeds safety limits and closes when the system returns to normal level.
- Control Valves: Usually automated globe valves used in monitoring and regulating process variables. Control Valve Manifolds are described in Chapter 5.

Valve Operators: Devices used in opening and closing valves. There are two types of operators – manual and automatic.

- Manual Operators: Hand wheels, Levers, Gears, Chains.
- Automatic Operators: They are also known as “actuators”. Actuators use external power to open and close valves. The power sources for actuators could be hydraulic, pneumatic, or electric motors.

VALVES

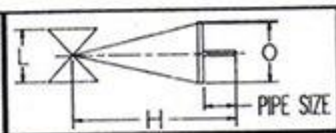
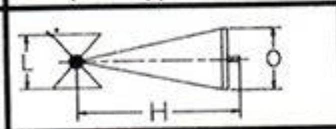
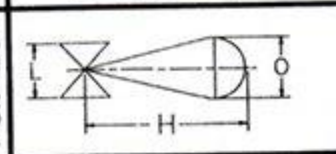
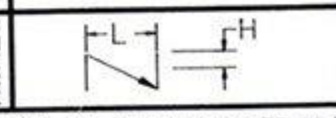
150#

NOMINAL PIPE SIZES (in)				2	3	4	6	8	10	12	14	16	18
O.D. of PIPE				2 3/8	3 1/2	4 1/2	6 5/8	8 5/8	10 3/4	12 3/4	14	16	18
VALVES	GATE		L	7	8	9	10 1/2	11 1/2	13	14	15	16	17
			H	15 3/4	20 3/4	25 3/4	35 1/4	44	52 1/2	60 1/2	70 1/4	79 3/4	89
			O	8	9	10	14	16	18	18	22	24	27
	GLOBE		L	8	9 1/2	11 1/2	16	19 1/2	*	*	*	*	*
			H	13 3/4	16 1/2	19 3/4	24 1/2	26	*	*	*	*	*
			O	8	9	10	12	16	*	*	*	*	*
	CONTROL		L	10	11 3/4	13 7/8	17 3/4	21 3/8	26 1/2	*	*	*	*
			H	27 7/8	28 7/16	29 7/16	38	39 1/4	46 1/4	*	*	*	*
			O	13 1/8	13 1/8	13 1/8	16	16	21 1/8	*	*	*	*
	CHECK		L	8	9 1/2	11 1/2	14	19 1/2	24 1/2	27 1/2	35	39	*
			H	5	6	7	9	10 1/4	12 1/8	13 3/4	18	20 1/2	*

NOTE: ALL DIMENSIONS ARE IN INCHES

* REFER to VENDOR CATALOG

150# RF

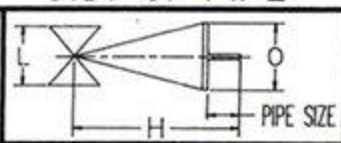
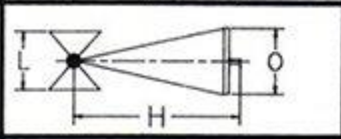
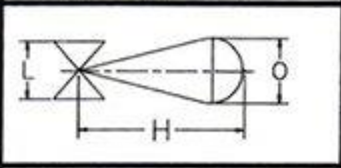
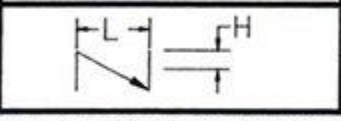
VALVES	GATE		L	7 1/2	8 1/2	9 1/2	11	12	13 1/2	14 1/2	15 1/2	16 1/2	17 1/2
			H	15 3/4	20 3/4	25 3/4	35 1/4	43	52 1/2	60 1/2	70 1/4	79 3/4	89
			O	8	9	10	14	14	18	18	22	24	27
	GLOBE		L	8 1/2	10	12	16 1/2	20	*	*	*	*	*
			H	13 3/4	16 1/2	19 3/4	24 1/2	26	*	*	*	*	*
			O	8	9	10	12	16	*	*	*	*	*
	CONTROL		L	10 1/2	12 1/4	14 3/8	18 1/4	21 7/8	27	*	*	*	*
			H	27 7/8	28 7/16	29 7/16	38	39 1/4	46 1/4	*	*	*	*
			O	13 1/8	13 1/8	13 1/8	16	16	21 1/8	*	*	*	*
	CHECK		L	8 1/2	10	12	14 1/2	20	25	28	35 1/2	39 1/2	*
			H	5	6	7	9	10 1/4	12 1/8	13 3/4	18	20 1/2	*

NOTE: ALL DIMENSIONS ARE IN INCHES

* REFER to VENDOR CATALOG

150# RTJ

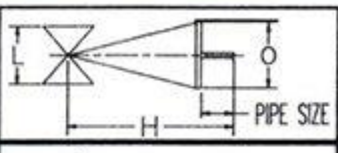
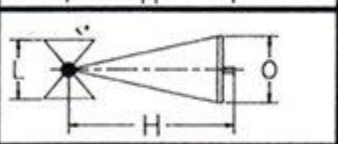
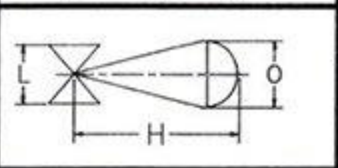
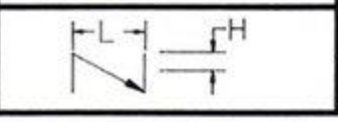
VALVES 300#

NOMINAL PIPE SIZES (in)			2	3	4	6	8	10	12	14	16	18
O.D. of PIPE			2 3/8	3 1/2	4 1/2	6 5/8	8 5/8	10 3/4	12 3/4	14	16	18
VALVES	GATE	 L	8 1/2	11 1/8	12	15 7/8	16 1/2	18	19 3/4	30	33	36
		H	18 1/2	23 1/4	28 1/4	38 1/8	47	56 1/2	64 1/4	74 3/4	80 1/8	91
		O	8	9	10	14	16	20	20	27	27	30
	GLOBE	 L	10 1/2	12 1/2	14	17 1/2	22	*	*	*	*	*
		H	17 3/4	20 1/2	24 3/4	29 3/4	36 1/2	*	*	*	*	*
		O	9	10	14	18	24	*	*	*	*	*
	CONTROL	 L	10 1/2	12 1/2	14 1/2	18 5/8	22 3/8	27 7/8	*	*	*	*
		H	27 7/8	28 7/16	29 7/16	38	39 1/4	46 1/4	*	*	*	*
		O	13 1/8	13 1/8	13 1/8	16	16	21 1/8	*	*	*	*
	CHECK	 L	10 1/2	12 1/2	14	17 1/2	21	24 1/2	28	*	*	*
		H	6 3/4	8 1/2	9 3/4	11 3/4	14	15	16 3/4	*	*	*

NOTE: ALL DIMENSIONS ARE IN INCHES

* REFER to VENDOR CATALOG

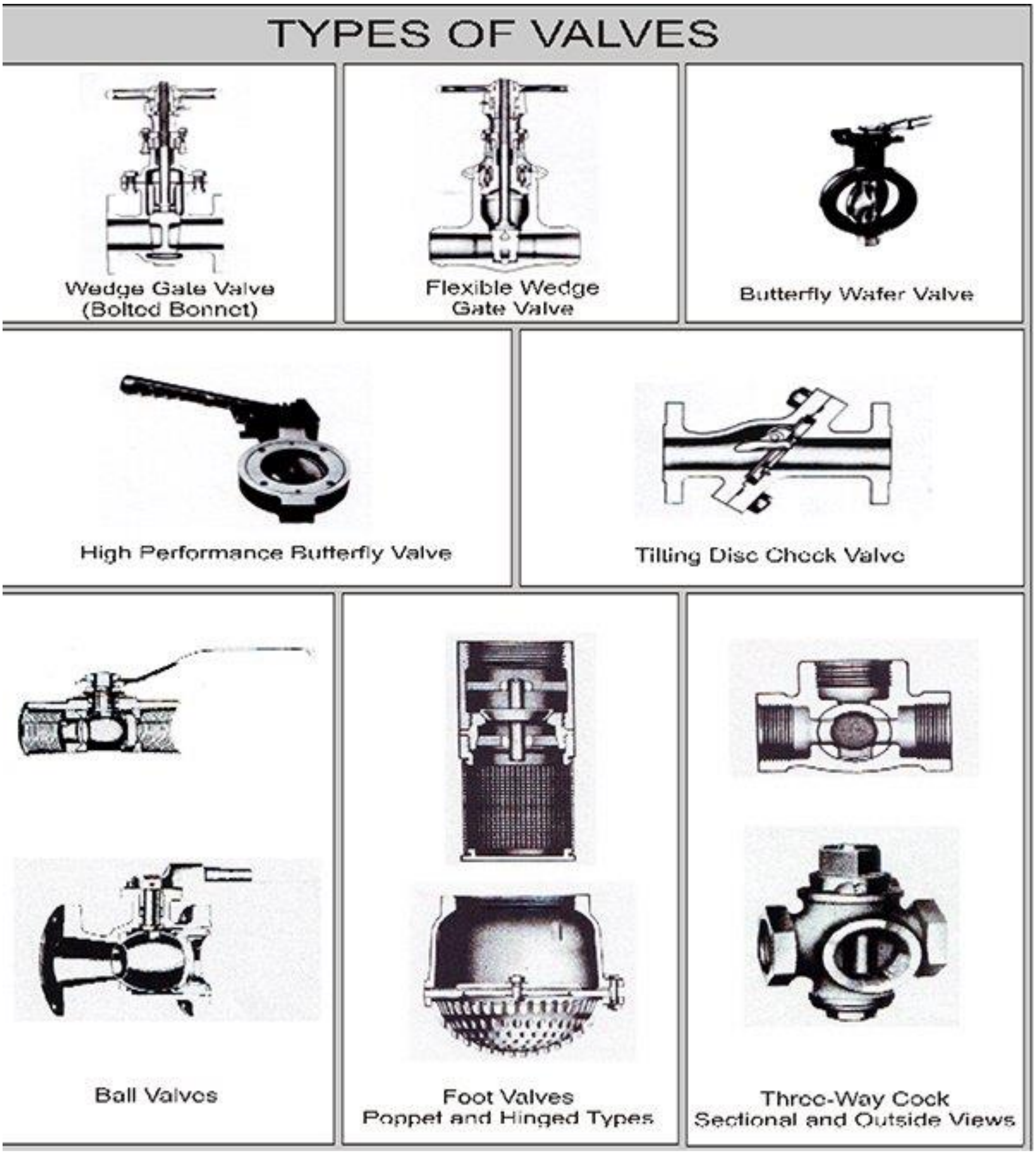
300# RF

VALVES	GATE	 L	9 1/8	11 3/4	12 5/8	16 1/2	17 1/8	18 5/8	20 3/8	30 5/8	33 5/8	36 5/8
		H	18 1/2	23 1/4	28 1/4	38 1/8	47	56 1/2	64 1/4	74 3/4	80 1/8	91
		O	8	9	10	14	16	20	20	27	27	30
	GLOBE	 L	11 1/8	13 1/8	14 5/8	18 1/8	22 5/8	*	*	*	*	*
		H	17 3/4	20 1/2	24 3/4	29 3/4	36 1/2	*	*	*	*	*
		O	9	10	14	18	24	*	*	*	*	*
	CONTROL	 L	11 1/8	13 1/8	15 1/8	19 1/4	23	28 1/2	*	*	*	*
		H	27 7/8	28 7/16	29 7/16	38	39 1/4	46 1/4	*	*	*	*
		O	13 1/8	13 1/8	13 1/8	16	16	21 1/8	*	*	*	*
	CHECK	 L	11 1/8	13 1/8	14 5/8	18 1/8	21 5/8	25 1/8	28 5/8	*	*	*
		H	6 3/4	8 1/2	9 3/4	11 3/4	14	15	16 3/4	*	*	*

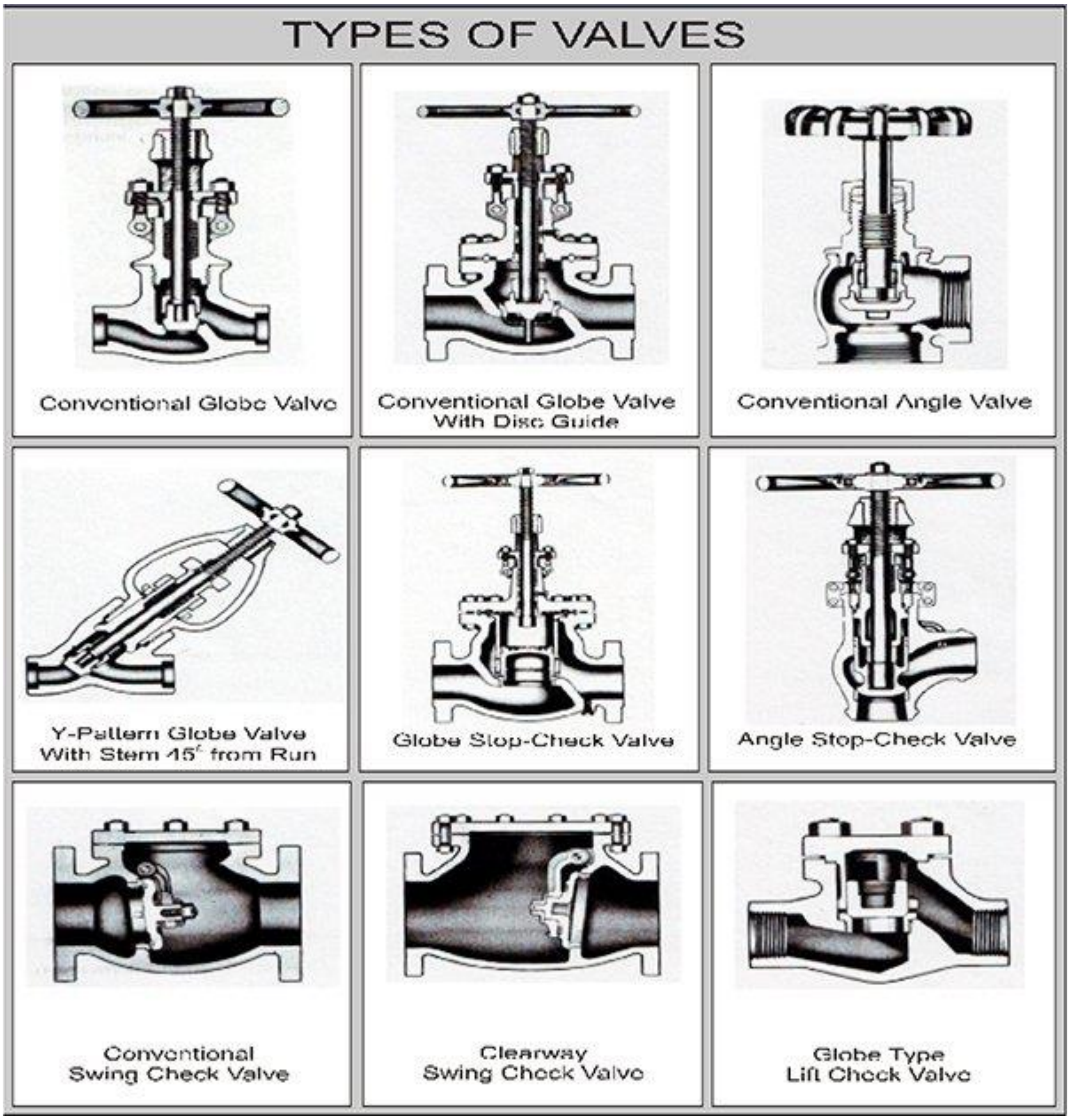
NOTE: ALL DIMENSIONS ARE IN INCHES

* REFER to VENDOR CATALOG

300# RTJ


TYPES OF VALVES
Wedge Gate Valve
(Bolted Bonnet)
Flexible Wedge
Gate Valve
Butterfly Wafer Valve
High Performance Butterfly Valve
Tilting Disc Check Valve
Ball Valves
Foot Valves
Poppet and Hinged Types
Three-Way Cock
Sectional and Outside Views

(a)



*(b)***Figure 8.8 a & b**

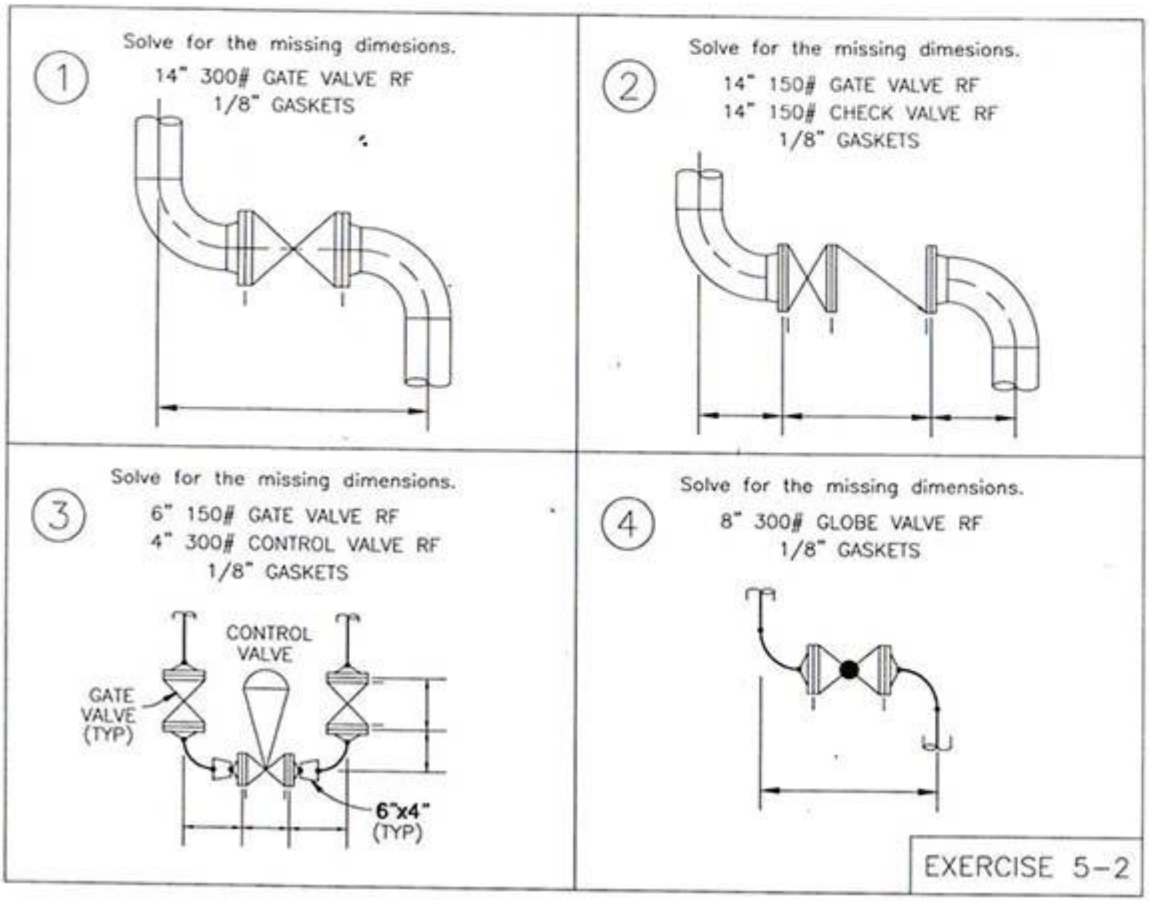
Types of Valves (Source: "Flow of Fluids", Crane Technical Paper no. 410)

Note: Valve dimensions for 300 # valves are given in Appendix 8.

Table 8.2
Friction Loss Coefficients for Fittings and Valves Source: "Chemical Engineers' Handbook", Perry, 5th edition, McGraw-Hill.

Type of Fitting or Valve	Additional Fric Velocity Heads
45° ELL, Standard	0.35
45° ELL, Long Radius	0.2
90° ELL, Standard	0.75
Long Radius	0.45
Square or Miter	1.3
180° Bend, Close Return	1.5
Tee, Standard, Along Run, Branch Blanked Off	0.4
Used as ELL, Entering Run	1.0
Used as ELL, Entering Branch	1.0
Branching Flow	1[c]
Coupling	0.04
Union	0.04
Gate Valve, Open	0.17
3/4 Open	0.9
½ Open	4.5
1/4 Open	24.0
Diaphragm Valve, Open	2.3
3/4 Open	2.6
½ Open	4.3
1/4 Open	21.0
Globe Valve, Bevel Seat, Open	6.0
½ Open	9.5
Composition Seat, Open	6.0
½ Open	8.5
Plug Disk, Open	9.0
3/4 Open	13.0
½ Open	36.0
1/4 Open	112.0
Angle Valve, Open	2.0
Y or Blowoff Valve, Open	3.0
Plug Cock 0 = 5°	0.05
10°	0.29
20°	1.56
40°	17.3
60°	206.0
Butterfly Valve θ = 5°	0.24
10°	0.52
20°	1.54
40°	10.8
60°	118.0
Check Valve, Swing	2.0'
Disk	10.0'
Ball	70.0'
Foot Valve	15.0
Water Meter, Disk	7.0'
Piston	15.0'
Rotary (Star shaped Disk)	10.0
Turbine-wheel	6.0'

[a] Flow of Fluids through Valves, Fittings, & Pipe, Tech. Paper 410, Crane Co., 1969.
[b] Freeman, "Experiments upon the Flow of Water in Pipes and Pipe Fittings", American Sc
New York, 1941.
[c] Gibson, "Hydraulics and Its Applications", 5th ed., P. 250, Constable, London, 1952.
[d] Giesecke and Badgett, "Heating, Piping, Air Conditioning, 4(6), 443–447 (1932)
[e] Giesecke, J. Am. Soc. Heat. Vent. Engrs., 32, 461 (1926).
[f] Gilman, "Heating, Piping, Air Conditioning, 27(4), 141–147 (1955)
[g] "Pipe Friction Manual", 3d ed., Hydraulic Institute, New York, 1961.
[h] Hoopes, Isakoff, Clarke, and Drew, Chem. Eng. Progr., 44, 691-696 (1948).



Practical exercises in Metric

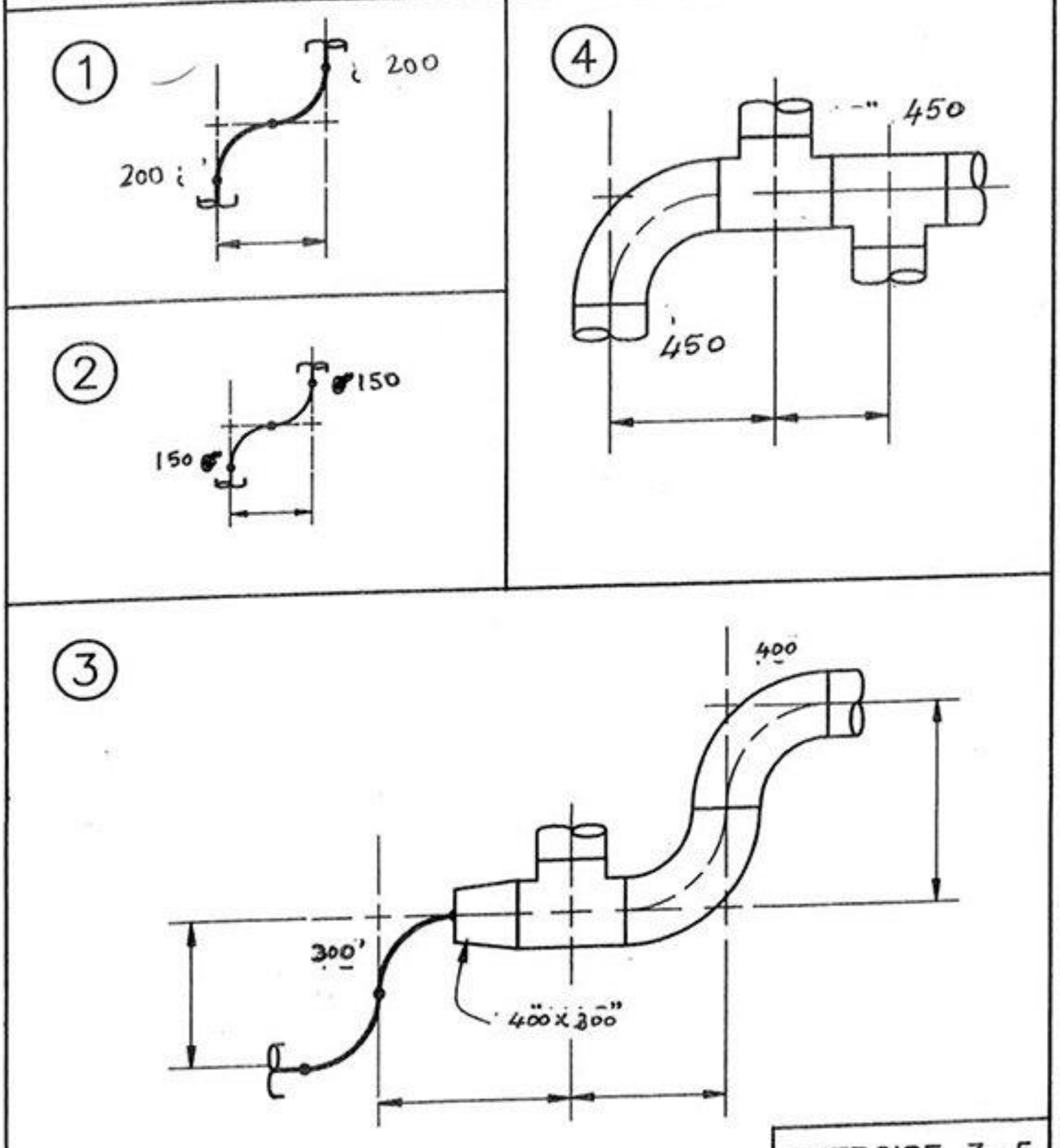
Practical Exercise 8A (Metric)

FITTING MAKE-UP

All dimensions in mm

8A

SOLVE FOR THE MISSING DIMENSIONS



EXERCISE 3–5

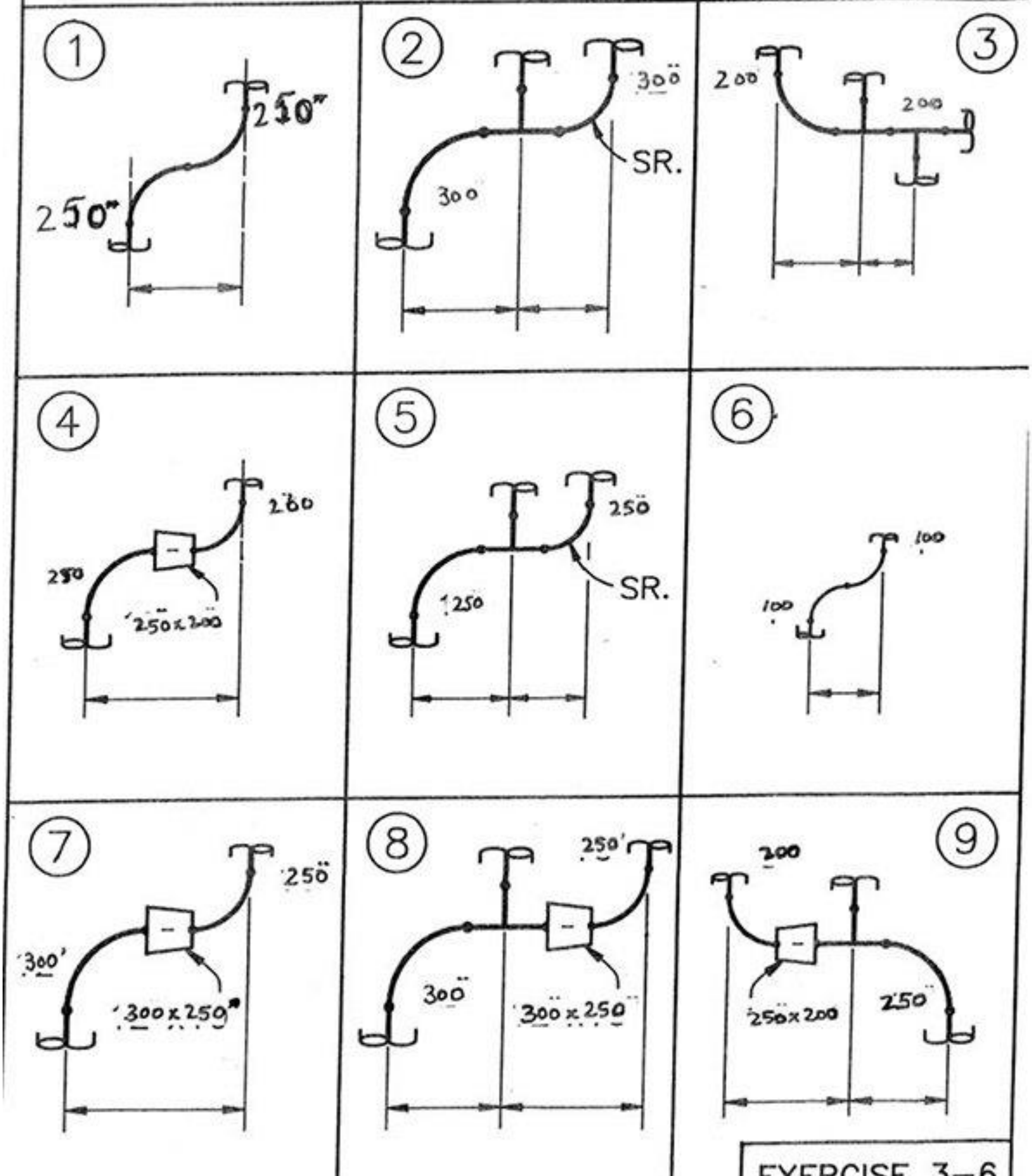
Practical Exercise 8B (Metric)

8B

FITTING MAKE–UP

SOLVE FOR THE MISSING DIMENSIONS

All dimensions in mm



EXERCISE 3–6

Practical Exercise 8 G (Metric)

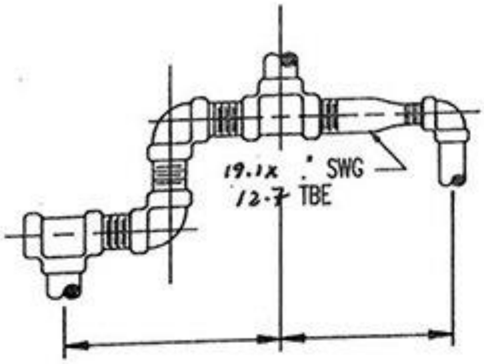
8G

FITTING MAKE-UP

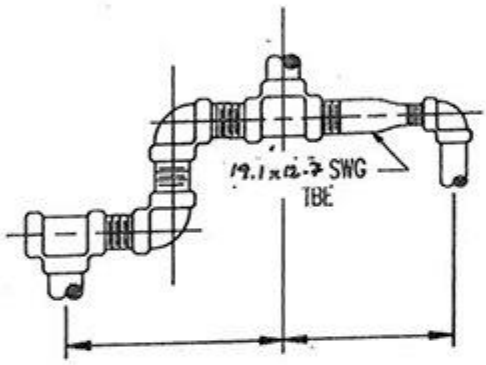
SOLVE FOR THE MISSING DIMENSIONS

All dimensions in mm

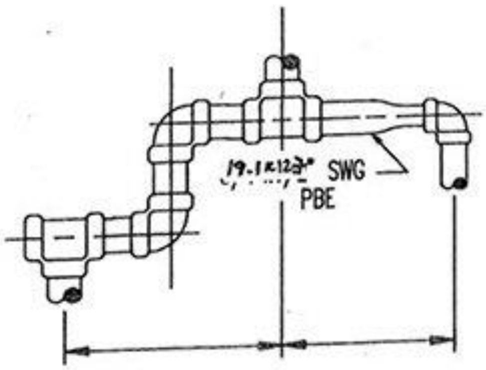
(1) 3000#FS SCREWED
75' LONG NIPPLES



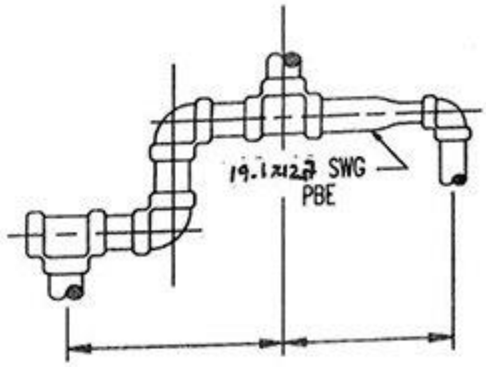
(2) 6000#FS SCREWED
75 LONG NIPPLES



(3) 3000# FS SW
75 LONG NIPPLES



(4) 6000# FS SW
75 LONG NIPPLES



EXERCISE 3-7

Practical Exercise 8D (Metric)

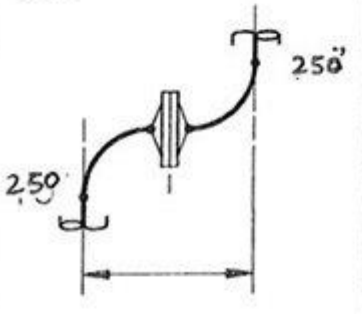
8D

FITTING MAKE-UP

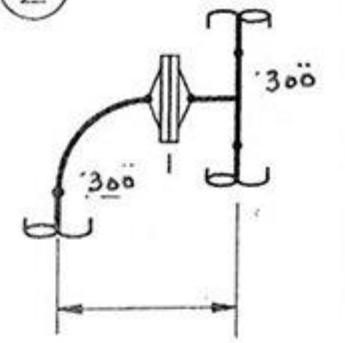
SOLVE FOR THE MISSING DIMENSIONS

All dimensions in mm

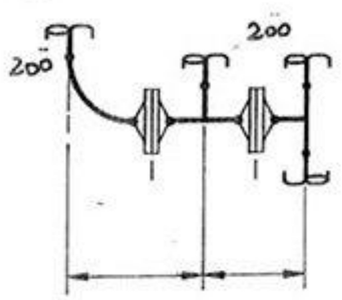
(1) 150# RFWN



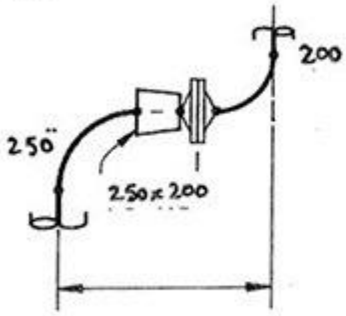
(2) 150# RFWN



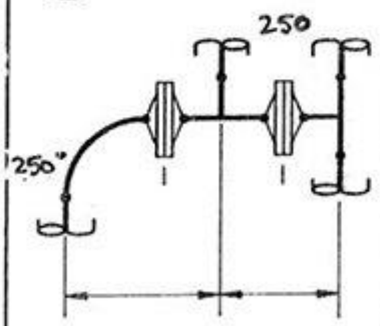
(3) 150# RFWN



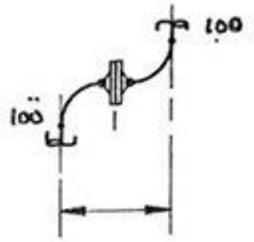
(4) 300# RFWN



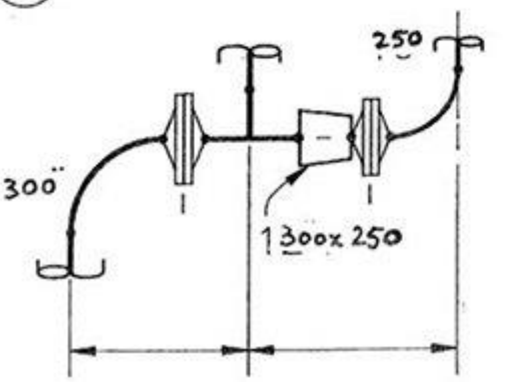
(5) 300# RFWN



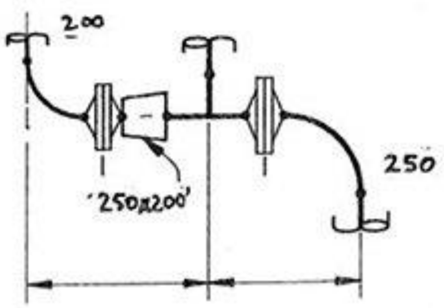
(6) 300# RFWN



(7). 300# RFWN



(8) 150# RFWN



NOTE: ALL GASKETS 3.2 mm

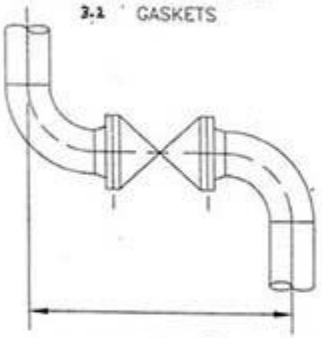
EXERCISE 4–3

PRACTICAL EXERCISE 8E (Metric) All dimensions in mm

① Solve for the missing dimesions.

350 300# GATE VALVE RF

3.2 GASKETS

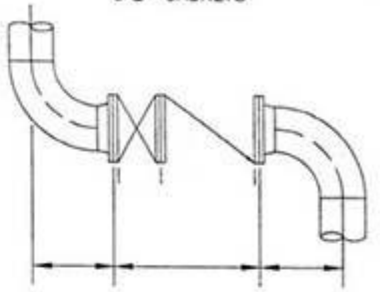


② Solve for the missing dimesions.

350 150# GATE VALVE RF

350 150# CHECK VALVE RF

3.2 GASKETS

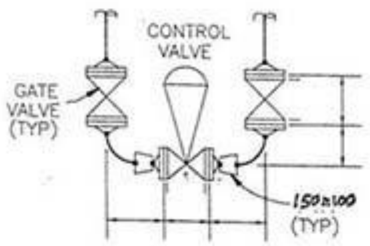


③ Solve for the missing dimensions.

150 150# GATE VALVE RF

100 300# CONTROL VALVE RF

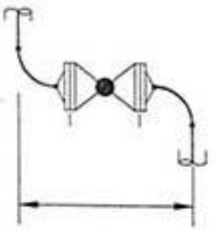
3.2 GASKETS



④ Solve for the missing dimensions.

200 300# GLOBE VALVE RF

3.2 GASKETS



EXERCISE 5-2

All dimensions in mm

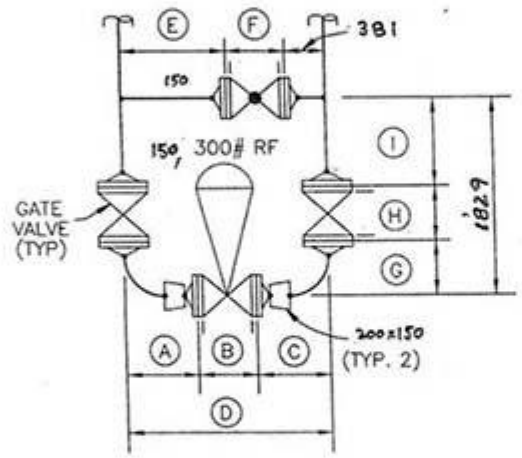
① Solve for the missing dimensions.

200, 150# GATE VALVE RF

150, 150# GLOBE VALVE RF

150, 300# CONTROL VALVE RF

3.2 GASKETS



A= ______

B= ______

C= ______

D= ______

E= ______

E=(D)−(F+381)

F= ______

G= ______

H= ______

I= ______

I=(1829)−(G+H)

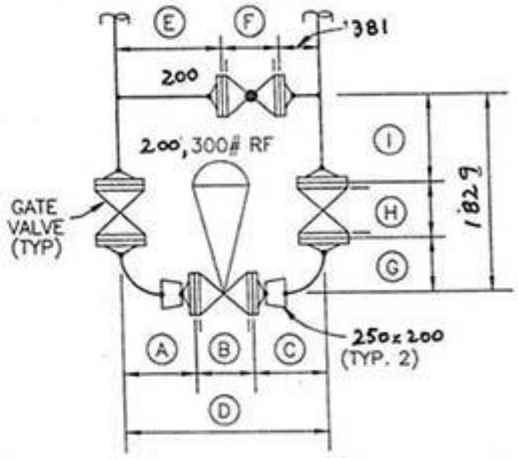
② Solve for the missing dimensions.

250, 150# GATE VALVE RF

200, 150# GLOBE VALVE RF

200, 300# CONTROL VALVE RF

3.2 GASKETS



A= ______

B= ______

C= ______

D= ______

E= ______

E=(D)−(F+381)

F= ______

G= ______

H= ______

I= ______

I=(1829)−(G+H)

EXERCISE 5-3

8.4 Summary

The different components of a piping system viz., fittings, flanges and Valves have been described in this chapter. Different types of fittings and pipe measures have been mentioned. Flange types, ratings and facings are listed here.

9

Pipe Routing

This chapter includes drawings for different pipe routings.

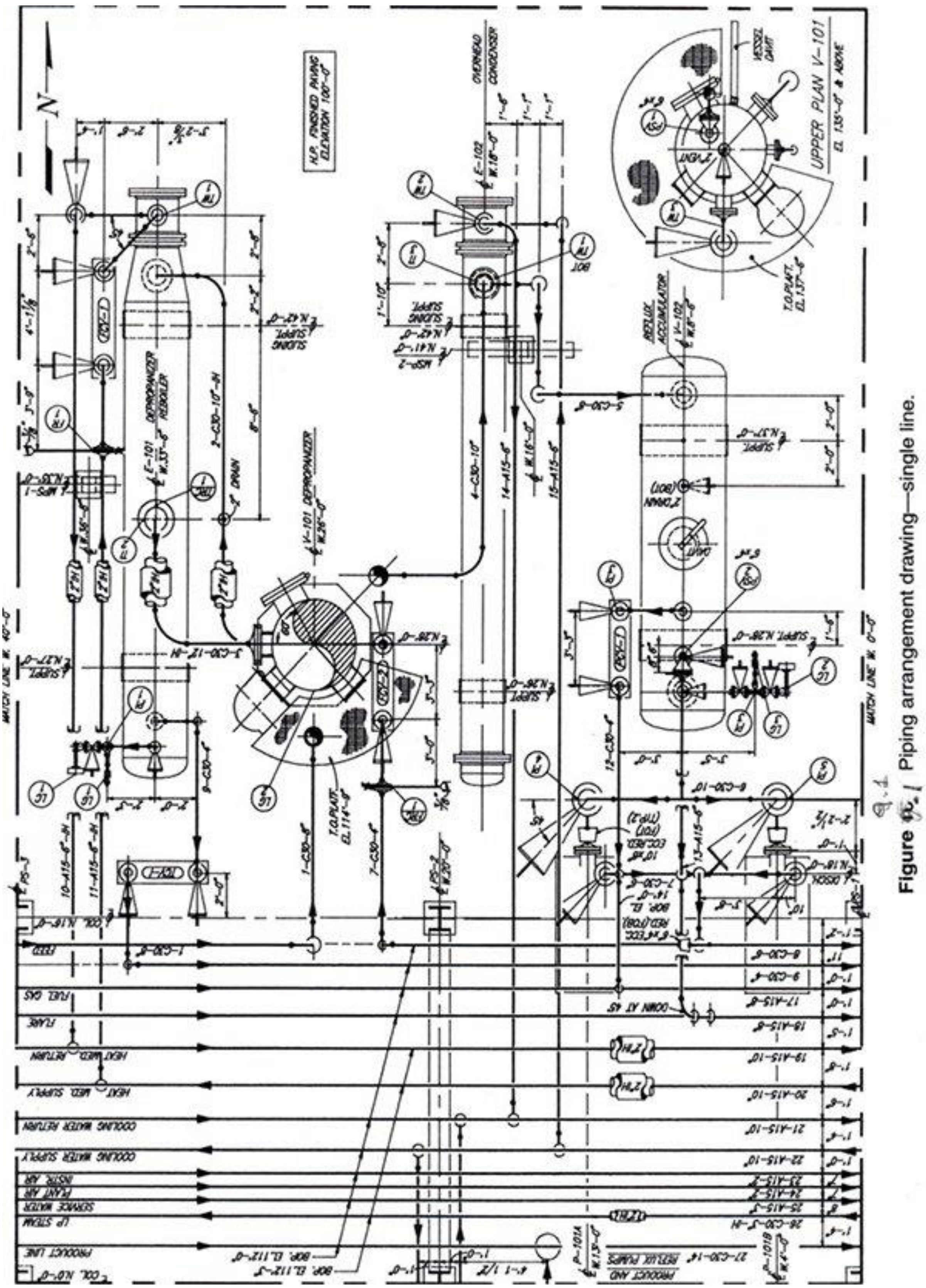


Figure 9.1
Piping arrangement drawing- single line

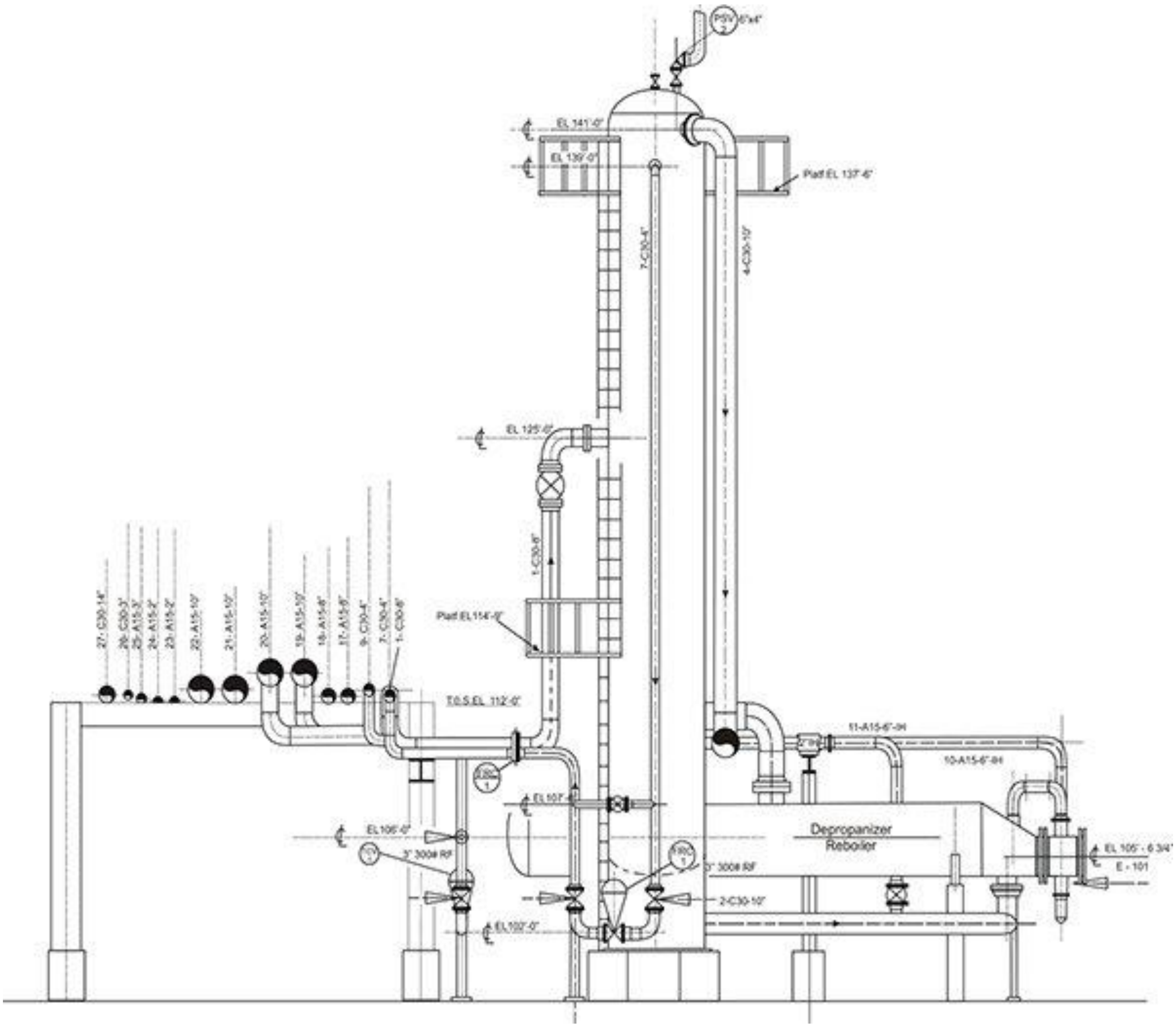


Figure 9.2
"Section A-A" Elevation view

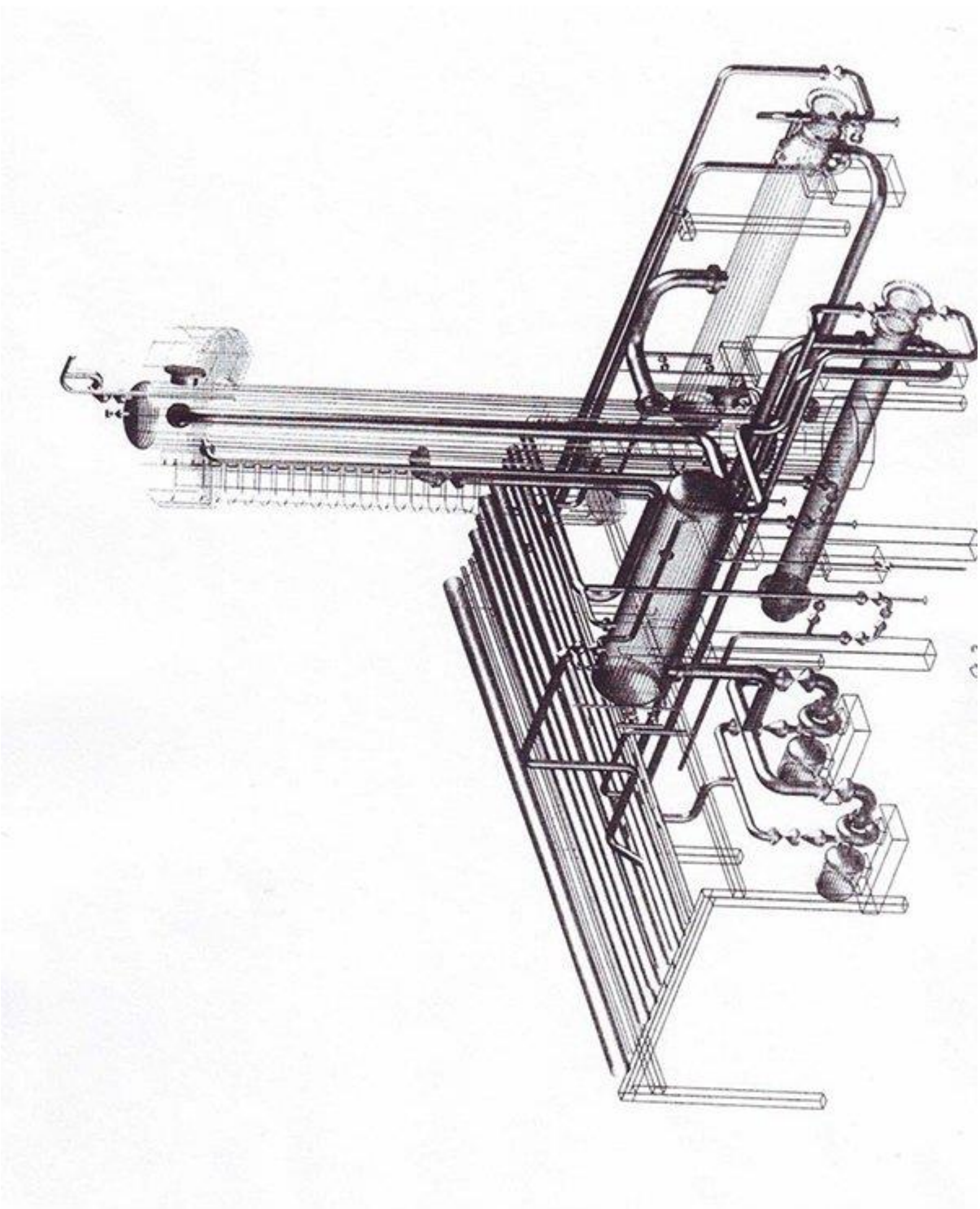


Figure 9.3
3-D model of Unit 01

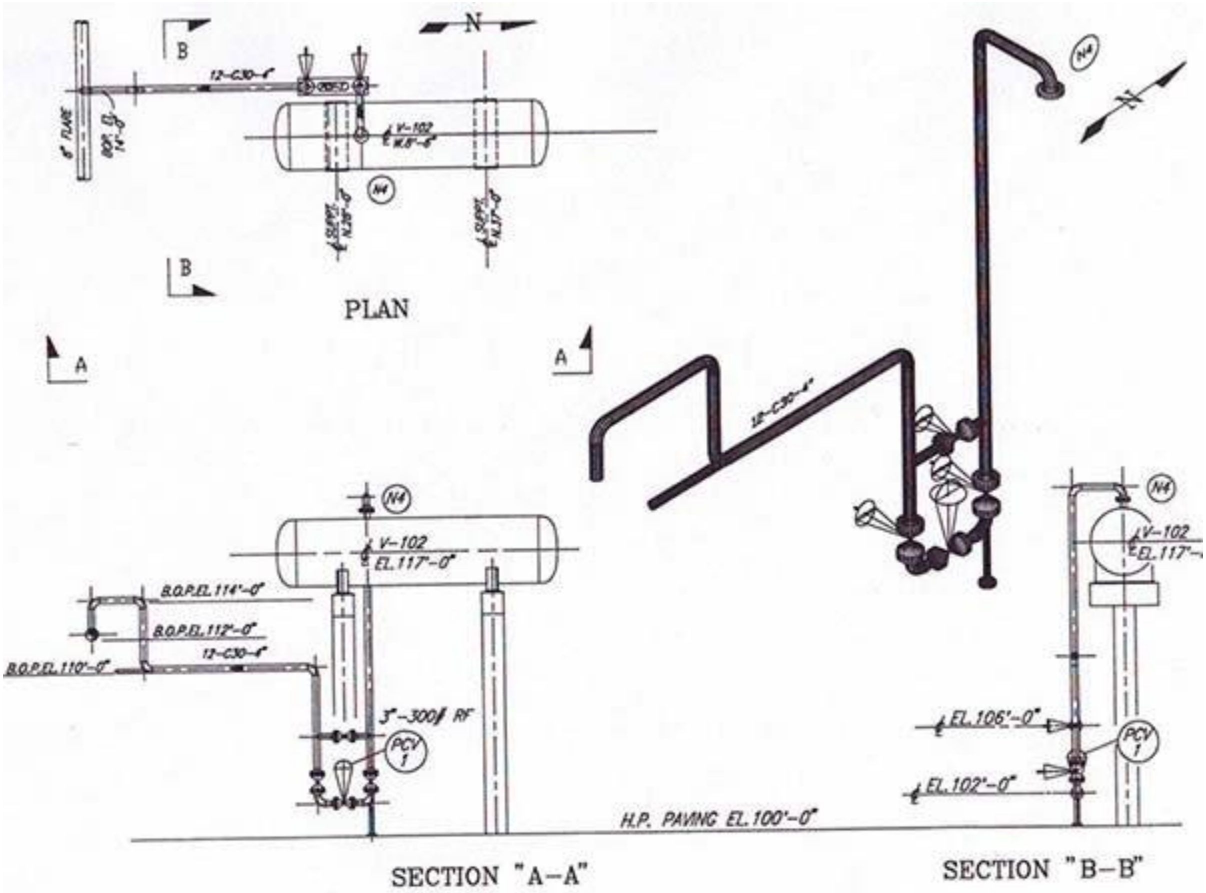


Figure 9.4
Line 01-12-C30-4 (Plans, Sections and Isometric)

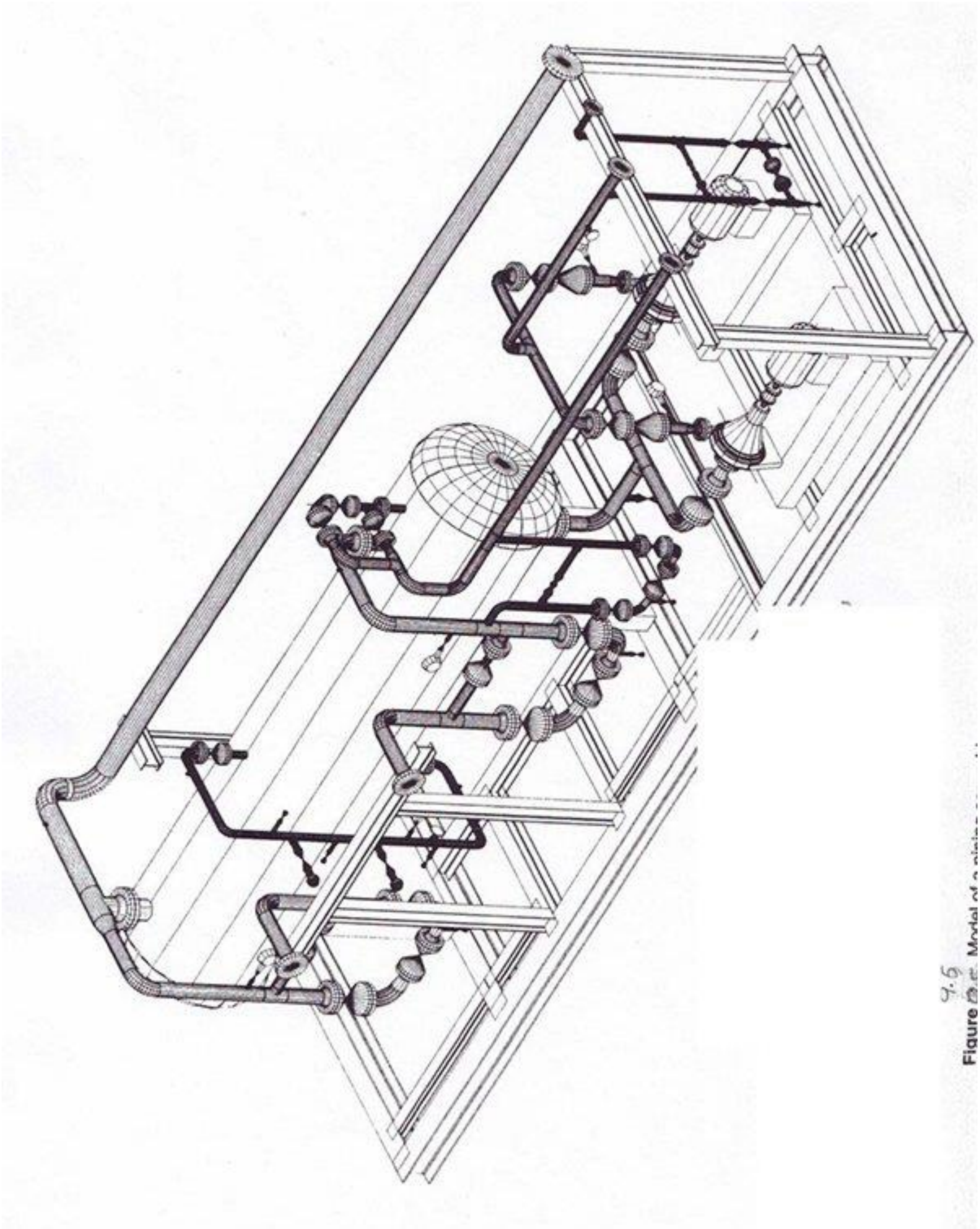


Figure 9.5
Model of a piping assembly mounted on a skid. (Model courtesy of Gene Eckert, ECAD, Inc.)

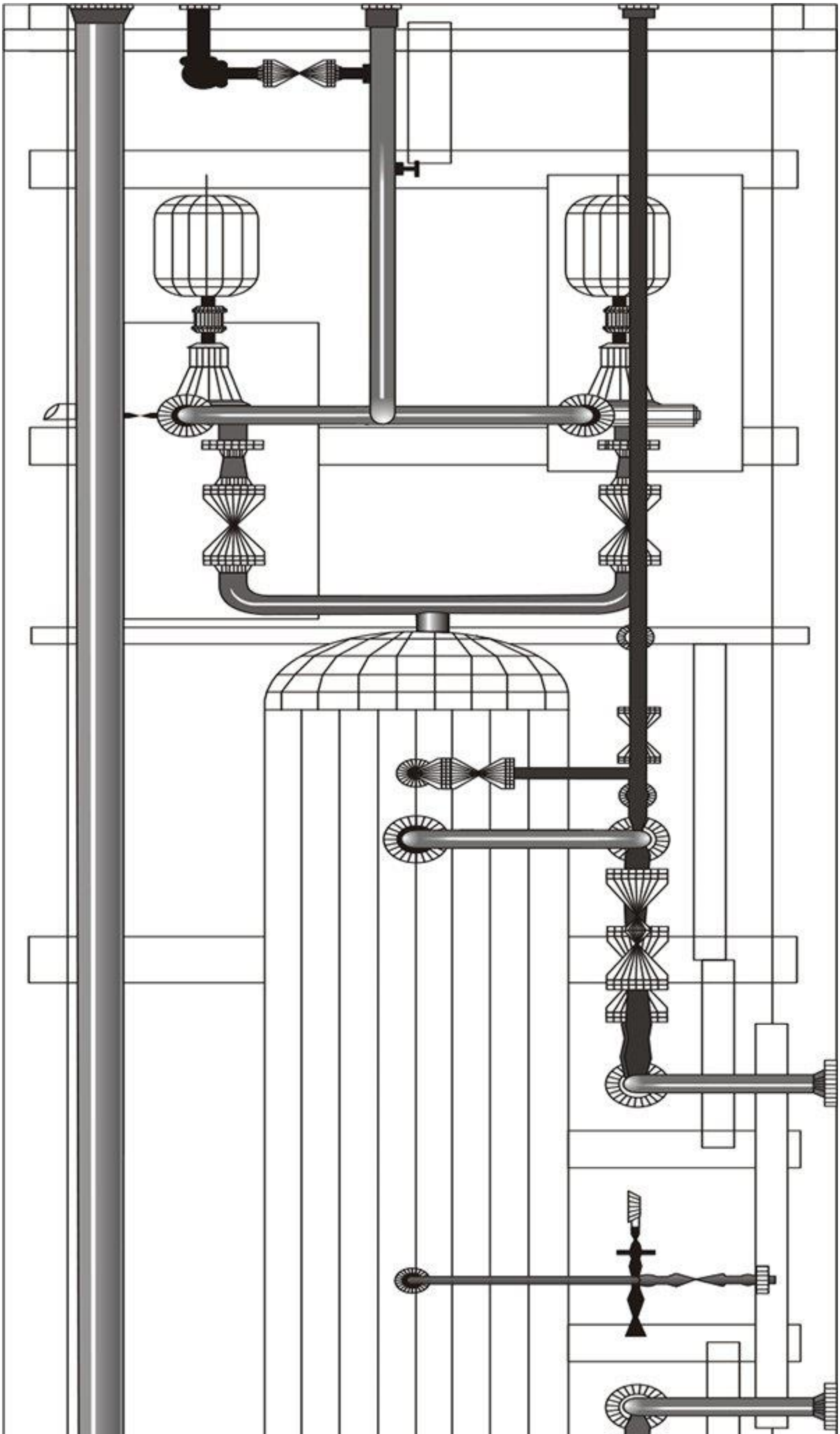


Figure 9.6
Skid Model, Plan View

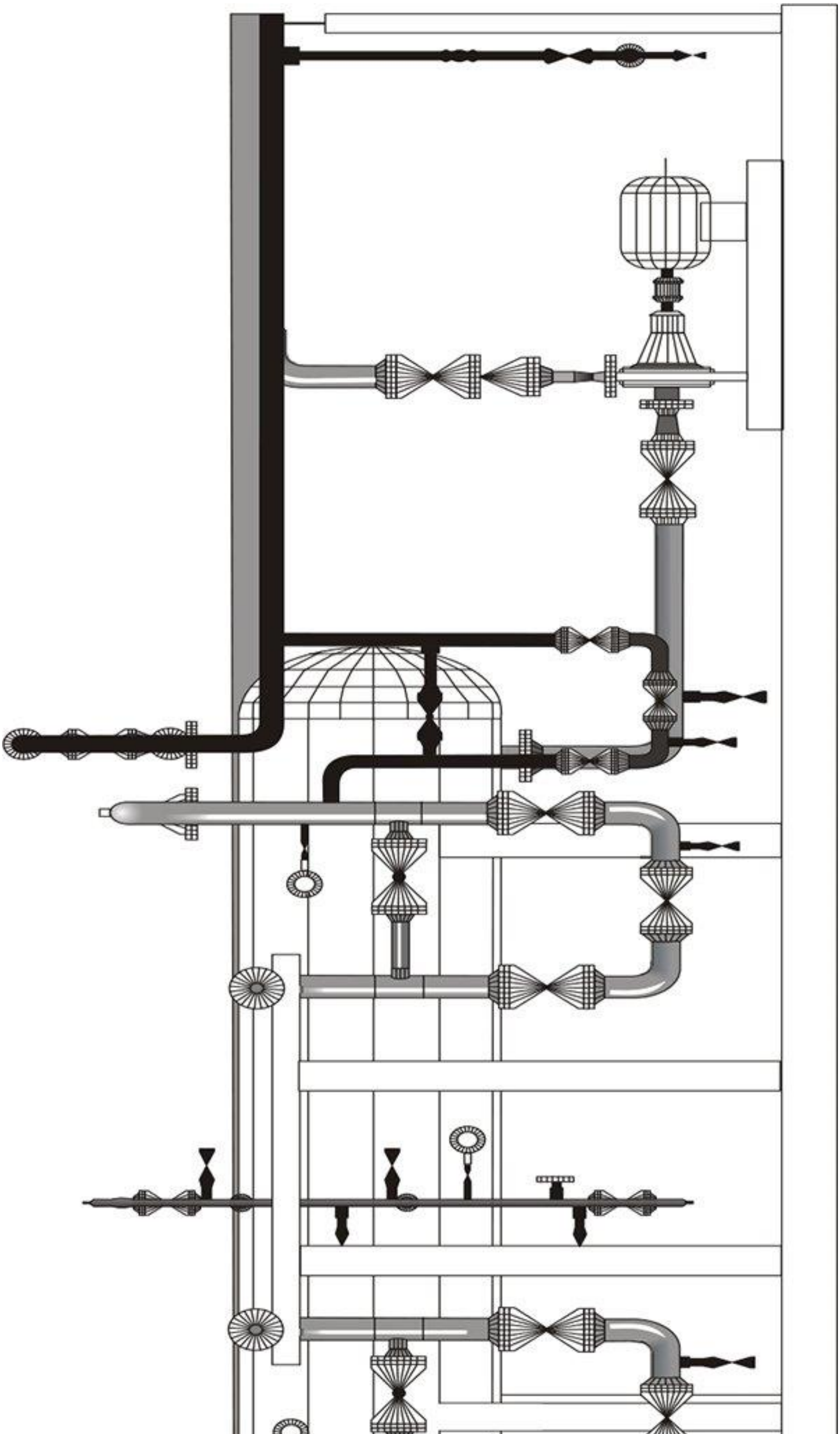
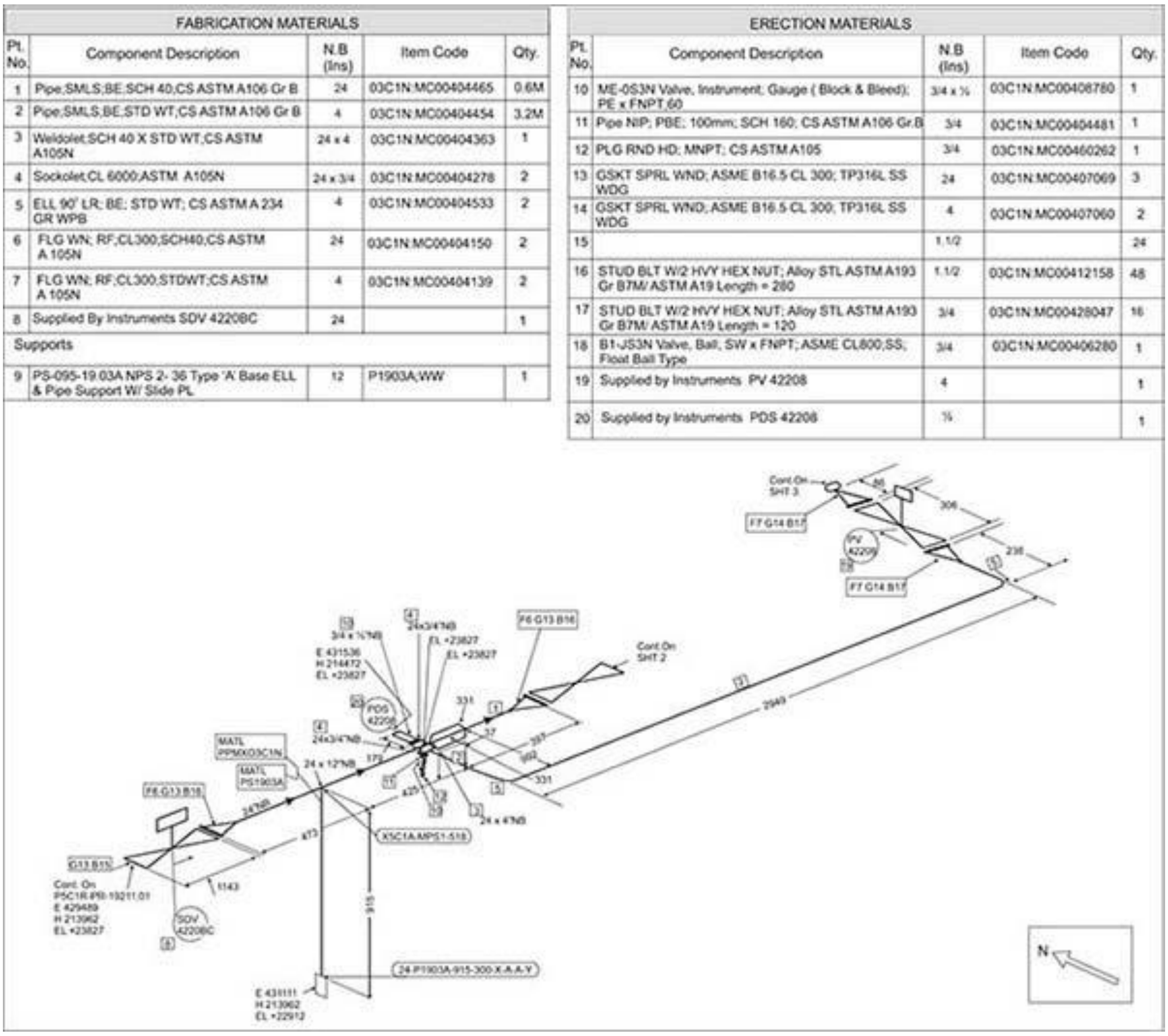


Figure 9.7
Skid Model, Elevation view.



FABRICATION MATERIALS

Pt. No.	Component Description	N.B (Ins)	Item Code	Qty.
1	Pipe;SMLS;BE;SCH 40;CS ASTM A106 Gr B	24	03C1N:MC00404465	0.6M
2	Pipe;SMLS;BE;STD WT;CS ASTM A106 Gr B	4	03C1N:MC00404454	3.2M
3	Weldolet;SCH 40 X STD WT;CS ASTM A105N	24 x 4	03C1N:MC00404363	1
4	Sockolet;CL 6000;ASTM A105N	24 x 3/4	03C1N:MC00404278	2
5	ELL 90' LR; BE; STD WT; CS ASTM A 234 GR WPB	4	03C1N:MC00404533	2
6	FLG WN; RF;CL300;SCH40;CS ASTM A 105N	24	03C1N:MC00404150	2
7	FLG WN; RF;CL300;STDWT;CS ASTM A 105N	4	03C1N:MC00404139	2
8	Supplied By Instruments SDV 42208C	24		1
Supports				
9	PS-095-19.03A NPS 2- 36 Type 'A' Base ELL & Pipe Support W/ Slide PL	12	P1903A;WW	1

ERECTION MATERIALS

Pt. No.	Component Description	N.B (Ins)	Item Code	Qty.
10	ME-0S3N Valve, Instrument; Gauge (Block & Bleed); PE x FNPT,60	3/4 x ½	03C1N:MC00406780	1
11	Pipe NIP; PBE; 100mm; SCH 160; CS ASTM A106 Gr.B	3/4	03C1N:MC00404481	1
12	PLG RND HD; MNPT; CS ASTM A105	3/4	03C1N:MC00460262	1
13	GSKT SPRL WND; ASME B16.5 CL 300; TP316L SS WDG	24	03C1N:MC00407069	3
14	GSKT SPRL WND; ASME B16.5 CL 300; TP316L SS WDG	4	03C1N:MC00407060	2
15		1.1/2		24
16	STUD BLT W/2 HVY HEX NUT; Alloy STL ASTM A193 Gr B7M/ ASTM A19 Length = 280	1.1/2	03C1N:MC00412158	48
17	STUD BLT W/2 HVY HEX NUT; Alloy STL ASTM A193 Gr B7M/ ASTM A19 Length = 120	3/4	03C1N:MC00428047	16
18	B1-JS3N Valve, Ball, SW x FNPT; ASME CL800;SS; Float Ball Type	3/4	03C1N:MC00406280	1
19	Supplied by Instruments PV 42208	4		1
20	Supplied by Instruments PDS 42208	½		1

Figure 9.8
Piping drawing used in fabrication and construction.

10

Piping Materials

This chapter provides an overview of materials commonly used in piping systems. It describes classification and specification of materials. It also describes factors used in selection of materials.

Learning objectives

- Introduction.
- Material classification systems and specifications.

- Common ASTM piping materials.
- Selection criteria for materials.
- Piping specifications (piping classes).
- Material testing and certificates.

10.1 Introduction

Selection of appropriate piping materials plays an important role in ensuring the safety and integrity of piping systems. The service conditions, namely, pressure, temperature and the nature of the fluid flowing in the pipe dictate the choice of materials. Cost is also an important factor. Evaluation of expected material behavior under given process conditions generally requires input from a material specialist. However, piping engineers and designers need to have a basic knowledge of material classifications, material specifications and material properties. Knowledge of material properties and designations is essential for performing pipe stress analysis.

10.2 Material classification system and specifications

Materials can be identified by the following methods:

- Generic descriptions
- Trade names
- Standardized alphanumeric designations

Generic descriptions: Generic descriptions group materials into broad categories based on composition and properties. Generic descriptions can range from broad descriptions to specific, detailed descriptions. Examples of generic descriptions are:

- Metals and non-metals
- Ferrous metals and non-ferrous metals
- Carbon steel (or low carbon steel)
- Low alloy steel (or Cr-Mo steel, or 2 1/4 Cr – 1 Mo Steel)
- Stainless steel (or Austenitic SS or 300 series Austenitic SS)

Trade Names: Manufactures use trade names to provide unique identification to their products. Examples of trade names are:

- Inconel 625
- Incoloy 825
- Hastelloy C-276
- Carlson Alloy 2205 Duplex SS
- Allegheny Ludlum AL 2205 Duplex SS
- UR52+ Duplex SS

Alphanumeric Description: Alphanumeric descriptions for materials originate from professional and standards organizations such as American Society for Testing of Materials (ASTM) and American Iron and Steel Institute (AISI). The overwhelming number of such descriptions has created a need for a common, widely accepted and used numbering system. The result has been the emergence of Unified Numbering System (UNS). However, the reality is that the use of prevailing designations from ASTM, AISI will continue despite the presence of UNS descriptors.

The alphanumeric designations of AISI and UNS are briefly described here.

AISI Numbering System: The AISI designation for carbon steels and low alloy steels consists of a four-digit number. The first and the second digits indicate the primary and secondary alloy classes to which the steel belongs. The third and fourth digits, xx, indicate the carbon content in 0.xx %. Examples of AISI material designations are:

- 1030: Plain carbon steel with 0.30% carbon
- 1320: Manganese Steels with 1.60-1.90% Mn and 0.20%C
- 25xx: 5% Nickel steels with 0.xx % C
- 33xx: Ni (3.25 – 3.75%), Cr (1.40 – 1.75%) Steels
- 41xx: Cr (about 1%), Mo (about 0.2%) Steels
- 51xx: Cr (about 1%) Steels
- 61xx: Cr (~1%), Vandium (~0.15%) Steels

Unified Numbering System (UNS): The Unified Numbering System avoids the confusion of multiple designations (from different organizations) for the same material by providing a unique and consistent identification number. UNS is not a specification; it does not specify requirements of quality, composition and mechanical properties. It provides the uniformity required for efficient indexing, record keeping and cross-referencing. The use of UNS is rapidly increasing and many codes such as B31.3 are beginning to use UNS designations.

The UNS designation has six alphanumeric characters – a letter prefix followed by five digits. Usually, the letter prefix indicates the family of metals (A for aluminum, S for Stainless Steels). Group examples of UNS designations are described here.

- G00001 – G99999: AISI and SAE (Society of Automotive Engineers) carbon and alloy steels
- S00001 – S99999: Heat and corrosion resistant stainless steels.
- A 00001 – A99999: Aluminum and aluminum alloys
- C00001 – C99999: Copper and copper alloys.

Specific examples of UNS designations are:

- UNS No. N04400 (Nickel alloy, equivalent ASTM designation: B165)
- UNS No. C71500 (copper alloy, equivalent ASTM designation: B467)
- UNS No. G10200 (AISI 1020 Carbon steel with 0.20% carbon)

Designations and Descriptions of Common Piping Materials: Most components of piping systems are constructed from carbon steels and alloy steels such as stainless steels. Common ASTM designations and descriptions of pipe materials are given here.

- ASTM A106 Gr.B: Carbon steel seamless pipe (most commonly used material for pipe)
- ASTM A53 Gr.B: Carbon steel seamless or Electric Resistance Welded (ERW) pipe.
- ASTM A333 Gr.6: Low and Intermediate Alloy Steel pipe

- ASTM A312 TP304: Seamless Stainless Steel pipe.
- ASTM B42: Copper alloy pipe
- ASTM B161: Nickel alloy pipe
- ASTM B210, Tempers O and H112: Aluminum alloy pipe (“O” indicates annealed material “H112” indicates strain-hardened material)

Common API (American Petroleum Institute) pipe materials are:

- API 5L, Seamless: Carbon Steel Seamless pipe
- API 5LX 46 Seamless: Carbon steel seamless pipe with specified Minimum Yield Strength of 46,000 psi (316.5 MPa)

In addition to pipe, piping systems consist of fittings (elbows, tees etc.), flanges and valves. Material designations of piping system components (other than pipe) are presented here.

Common ASTM Designations of Flanges, Pipe Fittings and valves:

- ASTM A 105: Carbon steel flanges and forged fittings
- ASTM A 182: Alloy Steel (for example, stainless steel) flanges, fittings and valves for high temperature service
- ASTM A 126: Gray Cast Iron Castings for Valves, Flanges and Pipe Fittings
- ASTM A 351: Austenitic Steel Casting for High Temperature Service
- ASTM A 350 Gr. LF 2: Carbon Steel/Low Alloy Steel forgings for piping components.
- ASTM A 182 Gr.F304: 18cr-8Ni stainless forgings for high temperature service

10.3 Piping specifications

Piping Specifications (also known as “Piping Materials Specifications” or “Piping Class”) provides detailed information on materials to be used for components of a piping system under certain conditions of temperature, pressure and fluid being serviced. An example of Piping Specification is shown in Figure 6.2. Piping specifications also contains information on required wall thickness, corrosion allowance, and Post Weld Heat Treatment (PWHT) and Radiographic Examinations. Piping Specifications are designated by alphanumeric representation such as A1, A2. These designations form part of the “Piping Line Number” on Piping and Instrumentation Diagrams (P&IDs), Piping Isometrics and other documents. A typical piping line number is 10” – PG – 0008 – A1. 10” is the Nominal Pipe Size (NPS), PG is the service designation, which, in this case, is Process Gas, 0008 is the line sequence number and A1 is the piping specification.

10.4 Material selection

The selection of appropriate material for a given application involves the consideration of the following aspects:
Process Requirements: Process requirements include pressure, temperature and the corrosion characteristics of the fluid being handled. Corrosion characteristics of the fluid being serviced play a major role. Carbon Steel piping should be adequate for non-corrosive substances as long as the temperature is not very high (less than 300°C or 572°F). For corrosive substances at normal temperature a lined pipe can provide satisfactory service. Stainless steel pipe is the preferred choice for corrosive substances and also for high

temperature service. For pipes handling corrosive fluids, adequate corrosion allowance must be indicated in the piping specifications. It is very important to note that codes usually do no provide guidelines on how to select materials for specific service conditions. For example, the following statements are found in ASME B31.3 concerning material selection: “Compatibility of materials with the service and hazards from instability of contained fluids are not within the scope of this code”. “Selection of materials to resist deterioration in service in not within the scope of this code”.

Mechanical Design: Mechanical design involves ensuring the mechanical integrity and safety of piping systems and pressure vessels. Mechanical design considers the following parameters:

- Allowable Stress (of the selected material at design temperature)
- Design Pressure
- Corrosion Allowance
- Requirements for Weld Procedure Qualification
- Forming and Bending Practices
- Post-Weld Procedures and Examinations

The codes usually have guidelines and formulas related to mechanical design since codes are primarily concerned with mechanical integrity and safety aspects. Some of the important aspects of mechanical design are the calculation of minimum required wall thickness for pressure piping and specifying appropriate class of flanges. The “Piping Specifications” or “Piping Class” discussed earlier is an outcome of mechanical design.

Economics and Availability: Cost is a very important factor in material selection. Different material options must be evaluated on the basis of “life-cycle” costs. For example, it may be cheaper to replace corroded tubes in a heat exchanger as compared to specifying a very expensive tube material. Procurement of expensive, high alloy steels may be difficult and can cause delays in the project. Sometimes, materials may not be available exactly in the form required which can force the specification to be revised.

10.5 Quality control and material certification

The materials being procured for a project have to meet the engineering and design requirements. Material vendors usually provide this confirmation through documents such as:

- Test Certificates
- Material Test Reports (MTRs)
- Certificates of Compliance

The materials procurement department should have quality checks in place to assure the quality of incoming material. Quality Assurance (QA) activities can range from visual inspection, verifying data stamped on commodities to random testing in detail.

Appendix A

Pipe Data and Fitting Dimensions

LINEAR CONVERSION

Inches to Millimeters

(1 inch = 25.4 millimeters)

In.	0	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16
0	0.0	1.6	3.2	4.8	6.4	7.9	9.5	11.1	12.7	14.3	15.9	17.5	19.1	20.6	22.2	23.8
1	25.4	27.0	28.6	30.2	31.8	33.3	34.9	36.5	38.1	39.7	41.3	42.9	44.5	46.0	47.6	49.2
2	50.8	52.4	54.0	55.6	57.2	58.7	60.3	61.9	63.5	65.1	66.7	68.3	69.9	71.4	73.0	74.6
3	76.2	77.8	79.4	81.0	82.6	84.1	85.7	87.3	88.9	90.5	92.1	93.7	95.3	96.8	98.4	100.0
4	101.6	103.2	104.8	106.4	108.0	109.5	111.1	112.7	114.3	115.9	117.5	119.1	120.7	122.2	123.8	125.4
5	127.0	128.6	130.2	131.8	133.4	134.9	136.5	138.1	139.7	141.3	142.9	144.5	146.1	147.6	149.2	150.8
6	152.4	154.0	155.6	157.2	158.8	160.3	161.9	163.5	165.1	166.7	168.3	169.9	171.5	173.0	174.6	176.2
7	177.8	179.4	181.0	182.6	184.2	185.7	187.3	188.9	190.5	192.1	193.7	195.3	196.9	198.4	200.0	201.6
8	203.2	204.8	206.4	208.0	209.6	211.1	212.7	214.3	215.9	217.5	219.1	220.7	222.3	223.8	225.4	227.0
9	228.6	230.2	231.8	233.4	235.0	236.5	238.1	239.7	241.3	242.9	244.5	246.1	247.7	249.2	250.8	252.4
10	254.0	255.6	257.2	258.8	260.4	261.9	263.5	265.1	266.7	268.3	269.9	271.5	273.1	274.6	276.2	277.8
11	279.4	281.0	282.6	284.2	285.8	287.3	288.9	290.5	292.1	293.7	295.3	296.9	298.5	300.0	301.6	303.2
12	304.8	306.4	308.0	309.6	311.2	312.7	314.3	315.9	317.5	319.1	320.7	322.3	323.9	325.4	327.0	328.6
13	330.2	331.8	333.4	335.0	336.6	338.1	339.7	341.3	342.9	344.5	346.1	347.7	349.3	350.8	352.4	354.0
14	355.6	357.2	358.8	360.4	362.0	363.5	365.1	366.7	368.3	369.9	371.5	373.1	374.7	376.2	377.8	379.4
15	381.0	382.6	384.2	385.8	387.4	388.9	390.5	392.1	393.7	395.3	396.9	398.5	400.1	401.6	403.2	404.8
16	406.4	408.0	409.6	411.2	412.8	414.3	415.9	417.5	419.1	420.7	422.3	423.9	425.5	427.0	428.6	430.2
17	431.8	433.4	435.0	436.6	438.2	439.7	441.3	442.9	444.5	446.1	447.7	449.3	450.9	452.4	454.0	455.6
18	457.2	458.8	460.4	462.0	463.6	465.1	466.7	468.3	469.9	471.5	473.1	474.7	476.3	477.8	479.4	481.0
19	482.6	484.2	485.8	487.4	489.0	490.5	492.1	493.7	495.3	496.9	498.5	500.1	501.7	503.2	504.8	506.4
20	508.0	509.6	511.2	512.8	514.4	515.9	517.5	519.1	520.7	522.3	523.9	525.5	527.1	528.6	530.2	531.8
21	533.4	535.0	536.6	538.2	539.8	541.3	542.9	544.5	546.1	547.7	549.3	550.9	552.5	554.0	555.6	557.2
22	558.8	560.4	562.0	563.6	565.2	566.7	568.3	569.9	571.5	573.1	574.7	576.3	577.9	579.4	581.0	582.6
23	584.2	585.8	587.4	589.0	590.6	592.1	593.7	595.3	596.9	598.5	600.1	601.7	603.3	604.8	606.4	608.0
24	609.6	611.2	612.8	614.4	616.0	617.5	619.1	620.7	622.3	623.9	625.5	627.1	628.7	630.2	631.8	633.4
25	635.0	636.6	638.2	639.8	641.4	642.9	644.5	646.1	647.7	649.3	650.9	652.5	654.1	655.6	657.2	658.8
26	660.4	662.0	663.6	665.2	666.8	668.3	669.9	671.5	673.1	674.7	676.3	677.9	679.5	681.0	682.6	684.2
27	685.8	687.4	689.0	690.6	692.2	693.7	695.3	696.9	698.5	700.1	701.7	703.3	704.9	706.4	708.0	709.6
28	711.2	712.8	714.4	716.0	717.6	719.1	720.7	722.3	723.9	725.5	727.1	728.7	730.3	731.8	733.4	735.0
29	736.6	738.2	739.8	714.4	743.0	744.5	746.1	747.7	749.3	750.9	752.5	754.1	755.7	757.2	758.8	760.4
30	762.0	763.6	765.2	766.8	768.4	769.9	771.5	773.1	774.7	776.3	777.9	779.5	781.1	782.6	784.2	785.8
31	787.4	789.0	790.6	792.2	793.8	795.3	796.9	798.5	800.1	801.7	803.3	804.9	806.5	808.0	809.6	811.2
32	812.8	814.4	816.0	817.6	819.2	820.7	822.3	823.9	825.5	827.1	828.7	830.3	831.9	833.4	835.0	836.6
33	838.2	839.8	841.4	843.0	844.6	846.1	847.7	849.3	850.9	852.5	854.1	855.7	857.3	858.8	860.4	862.0
34	863.6	865.2	866.8	868.4	870.0	871.5	873.1	874.7	876.3	877.9	879.5	881.1	882.7	884.2	885.8	887.4
35	889.0	890.6	892.2	893.8	895.4	896.9	898.5	900.1	901.7	903.3	904.9	906.5	908.1	909.6	911.2	912.8
36	914.4	916.0	917.6	919.2	920.8	922.3	923.9	925.5	927.1	928.7	930.3	931.9	933.5	935.0	936.6	938.2
37	939.8	941.4	943.0	944.6	946.2	947.7	949.3	950.9	952.5	954.1	955.7	957.3	958.9	960.4	962.0	963.6
38	965.2	966.8	968.4	970.0	971.6	973.1	974.7	976.3	977.9	979.5	981.1	982.7	984.3	985.8	987.4	989.0
39	990.6	992.2	993.8	995.4	997.0	998.5	1000.1	1001.7	1003.3	1004.9	1006.5	1008.1	1009.7	1011.2	1012.8	1014.4
40	1016.0	1017.6	1019.2	1020.8	1022.4	1023.9	1025.5	1027.1	1028.7	1030.3	1031.9	1033.5	1035.1	1036.6	1038.2	1039.8
41	1041.4	1043.0	1044.6	1046.2	1047.8	1049.3	1050.9	1052.5	1054.1	1055.7	1057.3	1058.9	1060.5	1062.0	1063.6	1065.2
42	1066.8	1068.4	1070.0	1071.6	1073.2	1074.7	1076.3	1077.9	1079.5	1081.1	1082.7	1084.3	1085.9	1087.4	1089.0	1090.6
43	1092.2	1093.8	1095.4	1097.0	1098.6	1100.1	1101.7	1103.3	1104.9	1106.5	1108.1	1109.7	1111.3	1112.8	1114.4	1116.0
44	1117.6	1119.2	1120.8	1122.4	1124.0	1125.5	1127.1	1128.7	1130.3	1131.9	1133.5	1135.1	1136.7	1138.2	1139.8	1141.4
45	1143.0	1144.6	1146.2	1147.8	1149.4	1150.9	1152.5	1154.1	1155.7	1157.3	1158.9	1160.5	1162.1	1163.6	1165.2	1166.8
46	1168.4	1170.0	1171.6	1173.2	1174.8	1176.3	1177.9	1179.5	1181.1	1182.7	1184.3	1185.9	1187.5	1189.0	1190.6	1192.2
47	1193.8	1195.4	1197.0	1198.6	1200.2	1201.7	1203.3	1204.9	1206.5	1208.1	1209.7	1211.3	1212.9	1214.4	1216.0	1217.6
48	1219.2	1220.8	1222.4	1224.0	1225.6	1227.1	1228.7	1230.3	1231.9	1233.5	1235.1	1236.7	1238.3	1239.8	1241.4	1243.0
49	1244.6	1246.2	1247.8	1249.4	1251.0	1252.5	1254.1	1255.7	1257.3	1258.9	1260.5	1262.1	1263.7	1265.2	1266.8	1268.4
50	1270.0	1271.6	1273.2	1274.8	1276.4	1277.9	1279.5	1281.1	1282.7	1284.3	1285.9	1287.5	1289.1	1290.6	1292.2	1293.8

Courtesy of Crane Co.

Tables P-1M present calculated data as a guide only. Spans are for pipe arranged in pipeways with the following assumptions: Bare pipe - continuous straight run with welded joints and two or more straight spans at each end.

SPANS - calculated with lines full of water and a maximum bending stress of 4 000 PSI

SAG - (deflection) calculated with lines empty (drained condition)

The following factors were not considered in calculating spans for these tables: Concentrated mechanical loads from flanges, valves, strainers, filters, and other inline equipment - weights of connecting branch lines - torsional loading from thermal movement - sudden reaction from lines(s) discharging contents - vibration - flattening effect of weight of contents in larger liquid filled lines - weight of insulation and pipe covering - weight of ice and snow - wind loads - seismic shock - reduction in wall thickness of pipe from threading or grooving.

DESIGN PRESSURE - calculated per ANSI B31.1 using allowable stress value of 9 000 PSI for seamless carbon steel pipe

BURSTING PRESSURE is approximate, calculated on yield strength of 30 000 PSI

[E in these tables is for 'Exponent', the power of 10 to which the number must be raised. Example: 1.0E5 = 100 000]

API = American Petroleum Institute's standard 5L, for 'Line pipe'. API pipe sizes; manufacturers' weights: Double-extra-strong (XXS), Extra-strong (XS), and Standard (STD), are included with schedule numbers in standard ANSI B36.10M. Also refer to 2.1.3

PIPE DATA: DIMENSIONS & STRESS PARAMETERS — TABLES P-1M

DN (mm) (NPS)	PIPING CODES and MANUFACTURERS' WEIGHTS	DIMENSIONS O.D. (mm)	I.D. (mm)	Wall (mm)	WEIGHTS Empty (kg/m)	Waterfilled (kg/m)	AREAS External (mm²/mm)	Internal (mm²/mm)	Flow (mm²)	Metal (mm²)	Moment of Inertia (10^4mm)	Section Modulus (10^3mm)	Radius of Gyration (mm)	Continuous Spans Span (m)	Sag (mm)	Code Pressures Design (MPa)	Bursting (MPa)
10	SCH 40 STD API	17.15	12.52	2.311	.8434	.9666	53.86	39.34	123.2	107.7	3.035	.3540	5.308	3.52	5.42	12.1	40.3
.375	SCH 80 XS API	17.15	10.74	3.200	1.098	1.188	53.86	33.75	90.66	140.2	3.587	.4185	5.058	3.45	5.52	19.9	66.4
15	SCH 40 STD API	21.34	15.80	2.769	1.265	1.461	67.03	49.63	196.0	161.5	7.114	.6669	6.637	3.93	5.39	12.6	42.1
.500	SCH 80 XS API	21.34	13.87	3.734	1.617	1.768	67.03	43.57	151.1	206.5	8.357	.7833	6.362	3.87	5.53	19.5	64.8
	SCH 160	21.34	11.79	4.775	1.945	2.054	67.03	37.03	109.1	248.4	9.225	.8648	6.094	3.77	5.43	27.5	91.6
	XXS API	21.34	6.401	7.468	2.548	2.580	67.03	20.11	32.18	325.4	10.09	.9458	5.569	3.52	4.94	52.1	174
20	SCH 40 STD API	26.67	20.93	2.870	1.680	2.024	83.79	65.75	344.0	214.6	15.42	1.156	8.475	4.39	5.17	9.14	30.5
.750	SCH 80 XS API	26.67	18.85	3.912	2.190	2.469	83.79	59.21	279.0	279.7	18.64	1.398	8.164	4.37	5.48	14.8	49.2
	SCH 160	26.67	15.54	5.563	2.888	3.078	83.79	48.84	189.8	368.9	21.97	1.647	7.717	4.25	5.48	24.5	81.7
	XXS API	26.67	11.02	7.823	3.627	3.722	83.79	34.63	95.44	463.2	24.11	1.808	7.215	4.05	5.16	39.8	133
25	SCH 40 STD API	33.40	26.64	3.378	2.495	3.052	104.9	83.71	557.6	318.6	36.35	2.177	10.68	4.91	5.08	8.77	29.2
1.00	SCH 80 XS API	33.40	24.31	4.547	3.227	3.691	104.9	76.37	464.1	412.1	43.96	2.632	10.33	4.91	5.43	13.8	45.9
	SCH 160	33.40	20.70	6.350	4.225	4.562	104.9	65.03	336.6	539.6	52.08	3.119	9.824	4.80	5.51	22.1	73.7
	XXS API	33.40	15.21	9.093	5.437	5.619	104.9	47.80	181.8	694.4	58.46	3.501	9.176	4.59	5.25	36.5	122
32	SCH 40 STD API	42.16	35.05	3.556	3.377	4.342	132.5	110.1	965.0	431.3	81.04	3.844	13.71	5.47	4.75	7.03	23.4
1.25	SCH 80 XS API	42.16	32.46	4.851	4.453	5.280	132.5	102.0	827.6	568.7	100.6	4.774	13.30	5.52	5.26	11.3	37.7
	SCH 160	42.16	29.46	6.350	5.594	6.276	132.5	92.56	681.8	714.5	118.2	5.604	12.86	5.49	5.49	16.5	55.2
	XXS API	42.16	22.76	9.703	7.748	8.155	132.5	71.50	406.8	989.5	142.0	6.734	11.98	5.28	5.41	29.5	98.5
40	SCH 40 STD API	48.26	40.89	3.683	4.039	5.352	151.6	128.5	1313	515.8	129.0	5.346	15.81	5.81	4.54	6.46	21.5
1.50	SCH 80 XS API	48.26	38.10	5.080	5.396	6.536	151.6	119.7	1140	689.1	162.8	6.748	15.37	5.90	5.14	10.5	34.9
	SCH 160	48.26	33.99	7.137	7.220	8.127	151.6	106.8	907.1	922.1	200.8	8.321	14.76	5.88	5.48	16.7	55.7
	XXS API	48.26	27.94	10.16	9.522	10.14	151.6	87.78	613.1	1216	236.4	9.795	13.94	5.71	5.47	26.8	89.4
50	SCH 40 STD API	60.32	52.50	3.912	5.428	7.593	189.5	164.9	2165	693.2	277.1	9.187	19.99	6.39	4.17	5.07	16.9
2.00	SCH 80 XS API	60.32	49.25	5.537	7.463	9.368	189.5	154.7	1905	953.1	361.3	11.98	19.47	6.57	4.91	8.72	29.1
	API	60.32	47.62	6.350	8.431	10.21	189.5	149.6	1781	1077	397.5	13.18	19.21	6.60	5.14	10.6	35.4
	SCH 160	60.32	42.85	8.738	11.09	12.53	189.5	134.6	1442	1416	484.6	16.07	18.50	6.58	5.47	16.4	54.7
	XXS	60.32	38.18	11.07	13.42	14.56	189.5	119.9	1145	1713	545.8	18.10	17.85	6.48	5.52	22.5	75.0

Thru DN 250, wall thicknesses for SCH 40S and SCH 80S stainless steel pipes are the same as for SCH 40 and SCH 80 carbon steel pipes

Source: “Piping Guide: Second Edition”, Sherwood, David R Whistance, Dennis J, Syentek Book Co. 1991.

PIPE DATA

TABLES P-1 M

DN (mm) [NPS]	PIPING CODES and MANUFACTURERS' WEIGHTS	DIMENSIONS O.D. (mm)	DIMENSIONS I.D. (mm)	DIMENSIONS Wall (mm)	WEIGHTS Empty (kg/m)	WEIGHTS Waterfilled (kg/m)	AREAS External (mm^2/mm)	AREAS Internal (mm^2/mm)	AREAS Flow (mm^2)	AREAS Metal (mm^2)	Moment of Inertia ($10^3 mm^4$)	Section Modulus ($10^3 mm^3$)	Radius of Gyration (mm)	Continuous Spans Span (m)	Continuous Spans Sag (mm)	Code Pressures Design (MPa)	Code Pressures Bursting (MPa)
65 2.50	SCH 40 STD API	73.03	62.71	5.156	8.608	11.70	229.4	197.0	3089	1099	636.6	17.44	24.06	7.09	4.37	5.96	19.9
	SCH 80 XS API	73.03	59.00	7.010	11.38	14.12	229.4	185.4	2734	1454	800.9	21.94	23.47	7.24	4.99	9.43	31.4
	SCH 160	73.03	53.98	9.525	14.88	17.17	229.4	169.6	2288	1900	979.3	26.82	22.70	7.26	5.39	14.4	48.0
	XXS API	73.03	44.98	14.02	20.35	21.94	229.4	141.3	1589	2599	1195	32.73	21.44	7.10	5.51	24.0	80.1
80 3.00	API	88.90	82.55	3.175	6.695	12.05	279.3	259.3	5352	855.1	786.5	17.69	30.33	7.04	2.67	1.98	6.58
	API	88.90	80.98	3.962	8.279	13.43	279.3	254.4	5150	1057	955.6	21.50	30.06	7.35	3.23	3.11	10.4
	API	88.90	79.35	4.775	9.882	14.83	279.3	249.3	4945	1262	1120	25.20	29.79	7.57	3.71	4.30	14.3
	SCH 40 STD API	88.90	77.93	5.486	11.26	16.03	279.3	244.8	4769	1438	1256	28.25	29.55	7.71	4.05	5.36	17.9
	API	88.90	76.20	6.350	12.89	17.45	279.3	239.4	4560	1647	1411	31.75	29.27	7.83	4.40	6.66	22.2
	API	88.90	74.63	7.137	14.36	18.73	279.3	234.4	4374	1833	1544	34.73	29.02	7.91	4.65	7.86	26.2
	API	88.90	73.66	7.620	15.24	19.50	279.3	231.4	4261	1946	1621	36.47	28.86	7.94	4.78	8.61	28.7
	SCH 80 XS API	88.90	66.65	11.13	21.28	24.77	279.3	209.4	3489	2718	2097	47.19	27.78	8.02	5.36	14.2	47.5
	SCH 160	88.90	58.42	15.24	27.61	30.29	279.3	183.5	2680	3527	2494	56.11	26.59	7.91	5.53	21.4	71.3
	XXS API																
100 4	API	114.3	108.0	3.175	8.679	17.83	359.1	339.1	9152	1108	1712	29.96	39.30	7.53	2.08	.971	3.24
	API	114.3	106.4	3.962	10.75	19.64	359.1	334.2	8887	1374	2093	36.62	39.04	7.93	2.60	1.84	6.14
	API	114.3	104.7	4.775	12.87	21.48	359.1	329.1	8618	1643	2468	43.19	38.76	8.24	3.06	2.75	9.17
	API	114.3	103.2	5.563	14.88	23.24	359.1	324.1	8361	1900	2816	49.27	38.49	8.46	3.45	3.64	12.1
	SCH 40 STD API	114.3	102.3	6.020	16.03	24.25	359.1	321.3	8213	2048	3010	52.68	38.34	8.56	3.66	4.16	13.9
	API	114.3	101.6	6.350	16.86	24.97	359.1	319.2	8107	2154	3148	55.08	38.23	8.63	3.79	4.54	15.1
	API	114.3	100.0	7.137	18.81	26.67	359.1	314.2	7858	2403	3465	60.62	37.97	8.76	4.08	5.45	18.2
	API	114.3	98.45	7.925	20.74	28.35	359.1	309.3	7612	2648	3767	65.91	37.71	8.86	4.33	6.37	21.2
	SCH 80 XS API	114.3	97.18	8.560	22.26	29.68	359.1	305.3	7417	2844	4000	69.99	37.51	8.92	4.50	7.12	23.7
	SCH 160 API	114.3	87.33	13.49	33.45	39.44	359.1	274.3	5989	4272	5524	96.65	35.96	9.09	5.29	13.2	44.0
	XXS API	114.3	80.06	17.12	40.92	45.96	359.1	251.5	5034	5227	6362	111.3	34.89	9.04	5.49	18.0	59.9
150 6	API	168.3	158.7	4.775	19.21	38.99	528.7	498.6	19787	2453	8203	97.50	57.83	9.19	2.13	1.48	4.92
	API	168.3	157.1	5.563	22.26	41.66	528.7	493.7	19396	2843	9421	112.0	57.56	9.52	2.48	2.07	6.90
	API	168.3	155.6	6.350	25.29	44.30	528.7	488.8	19009	3230	10603	126.0	57.29	9.80	2.81	2.67	8.89
	SCH 40 STD API	168.3	154.1	7.112	28.19	46.83	528.7	484.0	18639	3601	11714	139.2	57.04	10.0	3.09	3.25	10.8
	API	168.3	152.4	7.925	31.26	49.51	528.7	478.9	18248	3992	12862	152.9	56.76	10.2	3.37	3.88	12.9
	API	168.3	150.8	8.738	34.29	52.15	528.7	473.8	17860	4379	13975	166.1	56.49	10.4	3.62	4.51	15.0
	SCH 80 XS API	168.3	146.3	10.97	42.46	59.28	528.7	459.7	16817	5423	16853	200.3	55.75	10.7	4.18	6.28	20.9
	SCH 120 API	168.3	139.7	14.27	54.08	69.41	528.7	439.0	15333	6906	20649	245.4	54.68	10.9	4.76	8.96	29.9
	SCH 160 API	168.3	131.7	18.26	67.39	81.02	528.7	413.9	13633	8607	24569	292.0	53.43	11.0	5.18	12.3	41.0
	XXS	168.3	124.4	21.95	78.99	91.14	528.7	390.8	12151	10089	27610	328.2	52.31	11.0	5.39	15.5	51.8
200 8	API	219.1	209.5	4.775	25.17	59.65	688.2	658.2	34479	3215	18464	168.6	75.79	9.77	1.58	.985	3.28
	API	219.1	208.8	5.156	27.13	61.36	688.2	655.8	34229	3465	19833	181.1	75.65	9.98	1.73	1.20	4.01
	API	219.1	207.9	5.563	29.22	63.18	688.2	653.3	33963	3731	21277	194.2	75.51	10.2	1.89	1.44	4.79
	SCH 20 API	219.1	206.4	6.350	33.23	66.68	688.2	648.3	33451	4244	24026	219.3	75.24	10.5	2.18	1.89	6.31
	SCH 30 API	219.1	205.0	7.036	36.70	69.71	688.2	644.0	33007	4687	26369	240.7	75.01	10.8	2.41	2.29	7.64
	API	219.1	203.2	7.925	41.16	73.60	688.2	638.5	32437	5257	29338	267.8	74.71	11.1	2.70	2.81	9.38
	SCH 40 STD API	219.1	202.7	8.179	42.43	74.71	688.2	636.9	32275	5419	30172	275.5	74.62	11.2	2.78	2.96	9.87
	API	219.1	201.6	8.738	45.21	77.13	688.2	633.3	31921	5774	31985	292.0	74.43	11.3	2.95	3.29	11.0
	API	219.1	200.0	9.525	49.10	80.52	688.2	628.4	31424	6271	34489	314.9	74.16	11.5	3.17	3.76	12.5
	SCH 60	219.1	198.5	10.31	52.96	83.89	688.2	623.4	30931	6763	36935	337.2	73.90	11.6	3.37	4.23	14.1
	API	219.1	196.8	11.13	56.91	87.33	688.2	618.3	30426	7268	39399	359.7	73.63	11.8	3.56	4.71	15.7
	SCH 80 XS API	219.1	193.7	12.70	64.47	93.93	688.2	608.4	29460	8234	44002	401.7	73.10	12.0	3.90	5.67	18.9
	SCH 100	219.1	188.9	15.09	75.71	103.7	688.2	593.4	28025	9669	50566	461.6	72.32	12.3	4.31	7.13	23.8
	SCH 120 API	219.1	182.5	18.26	90.21	116.4	688.2	573.5	26173	11521	58556	534.6	71.29	12.5	4.73	9.13	30.4
	SCH 140 API	219.1	177.8	20.62	100.7	125.5	688.2	558.7	24836	12859	63984	584.1	70.54	12.5	4.96	10.6	35.5
	XXS API	219.1	174.6	22.23	107.6	131.6	688.2	548.6	23950	13744	67423	615.5	70.04	12.6	5.08	11.7	38.9
	SCH 160	219.1	173.1	23.01	111.0	134.5	688.2	543.7	23520	14174	69048	630.4	69.79	12.6	5.14	12.2	40.7

Thru DN 250, wall thicknesses for SCH 40S and SCH 80S stainless steel pipes are the same as for SCH 40 and SCH 80 carbon steel pipes

PIPE DATA

TABLES P-1 M

DN (mm) (NPS)	PIPING CODES and MANUFACTURERS' WEIGHTS	DIMENSIONS O.D. (mm)	DIMENSIONS I.D. (mm)	DIMENSIONS Wall (mm)	WEIGHTS Empty (kg/m)	WEIGHTS Waterfilled (kg/m)	AREAS External (mm²/mm)	AREAS Internal (mm²/mm)	AREAS Flow (mm²)	AREAS Metal (mm²)	Moment of Inertia (10⁴mm)	Section Modulus (10³mm)	Radius of Gyration (mm)	Continuous Spans Span (m)	Continuous Spans Sag (mm)	Code Pressures Design (MPa)	Code Pressures Bursting (MPa)
250	API	273.1	263.5	4.775	31.51	86.04	857.8	827.8	54532	4025	36218	265.3	94.86	10.2	1.20	.672	2.24
10	API	273.1	262.7	5.156	33.98	88.20	857.8	825.4	54217	4340	38944	285.3	94.73	10.4	1.33	.847	2.82
	API	273.1	261.9	5.563	36.60	90.48	857.8	822.9	53882	4674	41825	306.4	94.59	10.7	1.46	1.03	3.45
	SCH 20 API	273.1	260.3	6.350	41.66	94.89	857.8	817.9	53236	5320	47331	346.7	94.32	11.1	1.71	1.40	4.66
	API	273.1	258.9	7.087	46.36	99.00	857.8	813.3	52635	5921	52393	383.8	94.07	11.4	1.93	1.74	5.80
	SCH 30 API	273.1	257.5	7.798	50.88	102.9	857.8	808.8	52058	6498	57198	419.0	93.82	11.7	2.14	2.07	6.90
	API	273.1	255.6	8.738	56.81	108.1	857.8	802.9	51301	7255	63428	464.6	93.50	12.0	2.41	2.51	8.37
	SCH 40 STD API	273.1	254.5	9.271	60.16	111.0	857.8	799.6	50874	7683	66903	490.0	93.32	12.2	2.55	2.76	9.20
	API	273.1	250.8	11.13	71.68	121.1	857.8	787.9	49402	9154	78647	576.1	92.69	12.7	3.00	3.64	12.1
	SCH 60 XS API	273.1	247.7	12.70	81.33	129.5	857.8	778.0	48169	10388	88220	646.2	92.16	13.0	3.34	4.39	14.6
	SCH 80	273.1	242.9	15.09	95.74	142.1	857.8	763.0	46329	12227	1.0E5	747.5	91.36	13.3	3.78	5.55	18.5
	SCH 100 API	273.1	236.5	18.26	114.5	158.4	857.8	743.1	43938	14618	1.2E5	873.3	90.31	13.6	4.24	7.11	23.7
	SCH 120	273.1	230.2	21.44	132.7	174.3	857.8	723.1	41611	16946	1.4E5	989.4	89.28	13.8	4.60	8.71	29.0
	SCH 140 XXS API	273.1	222.2	25.40	154.7	193.5	857.8	698.2	38795	19762	1.5E5	1121	88.02	14.0	4.94	10.7	35.8
	SCH 160	273.1	215.9	28.58	171.8	208.5	857.8	678.3	36610	21947	1.7E5	1217	87.02	14.0	5.13	12.4	41.4
300		323.9	313.5	5.156	40.42	117.6	1017	985.0	77209	5162	65558	404.9	112.7	10.8	1.06	.714	2.38
12	API	323.9	312.7	5.563	43.55	120.4	1017	982.5	76809	5562	70458	435.1	112.5	11.0	1.18	.871	2.90
	SCH 20 API	323.9	311.2	6.350	49.59	125.6	1017	977.5	76038	6334	79843	493.1	112.3	11.5	1.39	1.18	3.92
	API	323.9	309.6	7.137	55.61	130.9	1017	972.6	75270	7102	89088	550.2	112.0	11.9	1.60	1.48	4.95
	API	323.9	308.0	7.925	61.59	136.1	1017	967.6	74506	7865	98192	606.4	111.7	12.3	1.81	1.79	5.97
	SCH 30 API	323.9	307.1	8.382	65.05	139.1	1017	964.7	74064	8307	1.0E5	638.7	111.6	12.4	1.93	1.97	6.57
	API	323.9	306.4	8.738	67.73	141.4	1017	962.5	73722	8650	1.1E5	663.5	111.5	12.6	2.02	2.11	7.04
	STD API	323.9	304.8	9.525	73.65	146.6	1017	957.6	72966	9406	1.2E5	718.0	111.2	12.9	2.21	2.42	8.07
	SCH 40 API	323.9	303.2	10.31	79.54	151.7	1017	952.6	72214	10158	1.2E5	771.7	110.9	13.1	2.39	2.73	9.11
	API	323.9	301.6	11.13	85.58	157.0	1017	947.5	71442	10930	1.3E5	826.2	110.6	13.3	2.58	3.06	10.2
	XS API	323.9	298.5	12.70	97.20	167.2	1017	937.6	69957	12414	1.5E5	929.4	110.1	13.7	2.90	3.69	12.3
	SCH 60 API	323.9	295.3	14.27	108.7	177.2	1017	927.7	68489	13883	1.7E5	1029	109.6	14.0	3.20	4.32	14.4
	API	323.9	292.1	15.88	120.3	187.3	1017	917.7	67012	15360	1.8E5	1128	109.0	14.3	3.47	4.97	16.6
	SCH 80 API	323.9	288.9	17.48	131.7	197.3	1017	907.6	65552	16820	2.0E5	1223	108.5	14.5	3.72	5.63	18.8
	API	323.9	285.8	19.05	142.8	207.0	1017	897.7	64130	18241	2.1E5	1313	108.0	14.6	3.93	6.28	20.9
	SCH 100	323.9	281.0	21.44	159.5	221.5	1017	882.7	62005	20367	2.3E5	1445	107.2	14.8	4.22	7.28	24.3
	SCH 120 XXS API	323.9	273.1	25.40	186.5	245.0	1017	857.8	58556	23815	2.7E5	1649	105.9	15.1	4.60	8.96	29.9
	SCH 140 API	323.9	266.7	28.58	207.6	263.4	1017	837.9	55865	26507	2.9E5	1801	104.9	15.2	4.84	10.3	34.4
	SCH 160 API	323.9	257.2	33.32	238.2	290.1	1017	808.0	51956	30416	3.3E5	2008	103.4	15.3	5.10	12.4	41.4
350	API	355.6	344.9	5.334	45.96	139.4	1117	1084	93445	5870	90034	506.4	123.9	11.1	.980	.712	2.37
14	API	355.6	344.5	5.563	47.90	141.1	1117	1082	93198	6117	93711	527.1	123.8	11.2	1.04	.793	2.64
	SCH 10 API	355.6	342.9	6.350	54.55	146.9	1117	1077	92347	6967	1.1E5	597.7	123.5	11.7	1.24	1.07	3.57
	API	355.6	341.3	7.137	61.18	152.7	1117	1072	91501	7814	1.2E5	667.3	123.2	12.1	1.43	1.35	4.50
	SCH 20 API	355.6	339.8	7.925	67.78	158.4	1117	1067	90659	8656	1.3E5	736.0	123.0	12.5	1.63	1.63	5.43
	API	355.6	338.1	8.738	74.55	164.3	1117	1062	89793	9521	1.4E5	805.9	122.7	12.9	1.82	1.92	6.40
	SCH 30 STD API	355.6	336.6	9.525	81.09	170.0	1117	1057	88959	10356	1.6E5	872.6	122.4	13.2	2.00	2.20	7.34
	SCH 40 API	355.6	333.3	11.13	94.27	181.5	1117	1047	87275	12040	1.8E5	1005	121.9	13.7	2.35	2.78	9.26
	API	355.6	331.8	11.91	100.7	187.2	1117	1042	86452	12862	1.9E5	1069	121.6	13.9	2.52	3.06	10.2
	XS API	355.6	330.2	12.70	107.1	192.8	1117	1037	85634	13681	2.0E5	1132	121.3	14.1	2.67	3.35	11.2
	SCH 60	355.6	325.4	15.09	126.4	209.6	1117	1022	83175	16140	2.3E5	1318	120.5	14.6	3.10	4.23	14.1
	API	355.6	323.9	15.88	132.7	215.0	1117	1017	82372	16943	2.4E5	1378	120.2	14.7	3.23	4.52	15.1
	SCH 80 API	355.6	317.5	19.05	157.7	236.9	1117	997.5	79173	20142	2.9E5	1609	119.2	15.1	3.70	5.70	19.0
	SCH 100 API	355.6	307.9	23.83	194.4	268.9	1117	967.5	74482	24833	3.4E5	1932	117.6	15.6	4.25	7.51	25.0
	SCH 120	355.6	300.0	27.79	224.1	294.8	1117	942.6	70698	28617	3.9E5	2178	116.3	15.8	4.59	9.04	30.1
	SCH 140 API	355.6	292.1	31.75	252.9	319.9	1117	917.7	67012	32303	4.3E5	2405	115.0	15.9	4.86	10.6	35.4
	SCH 160	355.6	284.2	35.71	281.0	344.4	1117	892.8	63425	35889	4.6E5	2614	113.8	16.0	5.07	12.2	40.7

Thru DN 250, wall thicknesses for SCH 40S and SCH 80S stainless steel pipes are the same as for SCH 40 and SCH 80 carbon steel pipes

PIPE DATA

TABLES P-1 M

DN (mm) [NPS]	PIPING CODES and MANUFACTURERS' WEIGHTS	DIMENSIONS			WEIGHTS		AREAS				Moment of Inertia	Section Modulus	Radius of Gyration	Continuous Spans		Code Pressures	
		O.D. (mm)	I.D. (mm)	Wall (mm)	Empty (kg/m)	Waterfilled (kg/m)	External (mm^2/mm)	Internal (mm^2/mm)	Flow (mm^2)	Metal (mm^2)	(10^{4}mm)	(10^{3}mm)	(mm)	Span (m)	Sag (mm)	Design (MPa)	Bursting (MPa)
550	SCH 10 API	558.8	546.1	6.350	86.29	320.5	1756	1716	2.3E5	11021	4.2E5	1505	195.3	12.6	.658	.680	2.27
22	API	558.8	544.5	7.137	96.86	329.7	1756	1711	2.3E5	12370	4.7E5	1684	195.1	13.1	.781	.857	2.86
	API	558.8	543.0	7.925	107.4	338.9	1756	1706	2.3E5	13715	5.2E5	1862	194.8	13.6	.906	1.03	3.45
	API	558.8	541.3	8.738	118.2	348.4	1756	1701	2.3E5	15099	5.7E5	2044	194.5	14.1	1.04	1.22	4.06
	SCH 20 STD API	558.8	539.8	9.525	128.7	357.5	1756	1696	2.3E5	16436	6.2E5	2219	194.2	14.5	1.16	1.39	4.65
	API	558.8	538.2	10.31	139.1	366.6	1756	1691	2.3E5	17770	6.7E5	2392	194.0	14.8	1.29	1.57	5.24
	API	558.8	536.5	11.13	149.9	376.0	1756	1686	2.3E5	19142	7.2E5	2570	193.7	15.2	1.42	1.76	5.86
	API	558.8	535.0	11.91	160.3	385.0	1756	1681	2.2E5	20467	7.7E5	2740	193.4	15.5	1.54	1.94	6.45
	SCH 30 XS API	558.8	533.4	12.70	170.6	394.1	1756	1676	2.2E5	21788	8.1E5	2909	193.1	15.8	1.66	2.12	7.05
	API	558.8	520.7	19.05	252.9	465.9	1756	1636	2.1E5	32303	1.2E6	4215	190.9	17.5	2.56	3.58	11.9
	SCH 60 API	558.8	514.3	22.23	293.3	501.1	1756	1616	2.1E5	37465	1.4E6	4834	189.9	18.0	2.94	4.32	14.4
	SCH 80 API	558.8	501.7	28.58	372.7	570.3	1756	1576	2.0E5	47599	1.7E6	6004	187.7	18.8	3.58	5.82	19.4
	SCH 100 API	558.8	489.0	34.93	450.1	637.8	1756	1536	1.9E5	57480	2.0E6	7089	185.6	19.4	4.08	7.36	24.5
	SCH 120	558.8	476.3	41.27	525.4	703.6	1756	1496	1.8E5	67107	2.3E6	8092	183.6	19.7	4.47	8.92	29.7
	SCH 140	558.8	463.6	47.63	598.8	767.6	1756	1456	1.7E5	76481	2.5E6	9018	181.5	19.9	4.77	10.5	35.0
	SCH 160	558.8	450.9	53.98	670.3	829.9	1756	1416	1.6E5	85602	2.8E6	9872	179.5	20.0	5.00	12.1	40.4
600	SCH 10 API	609.6	596.9	6.350	94.23	374.1	1915	1875	2.8E5	12034	5.5E5	1796	213.3	12.7	.577	.623	2.08
24	API	609.6	595.3	7.137	105.8	384.1	1915	1870	2.8E5	13509	6.1E5	2011	213.0	13.3	.688	.785	2.62
	API	609.6	593.8	7.925	117.3	394.2	1915	1865	2.8E5	14980	6.8E5	2224	212.7	13.8	.801	.947	3.16
	API	609.6	592.1	8.738	129.1	404.5	1915	1860	2.8E5	16494	7.4E5	2443	212.5	14.3	.920	1.11	3.72
	SCH 20 STD API	609.6	590.6	9.525	140.6	414.5	1915	1855	2.7E5	17956	8.1E5	2652	212.2	14.7	1.04	1.28	4.26
	API	609.6	589.0	10.31	152.0	424.5	1915	1850	2.7E5	19415	8.7E5	2860	211.9	15.1	1.15	1.44	4.80
	API	609.6	587.3	11.13	163.8	434.7	1915	1845	2.7E5	20917	9.4E5	3074	211.6	15.4	1.27	1.61	5.36
	API	609.6	585.8	11.91	175.1	444.6	1915	1840	2.7E5	22368	9.9E5	3278	211.4	15.8	1.39	1.77	5.91
	XS API	609.6	584.2	12.70	186.5	454.5	1915	1835	2.7E5	23815	1.1E6	3481	211.1	16.1	1.50	1.94	6.46
	SCH 30 API	609.6	581.1	14.27	209.0	474.2	1915	1825	2.7E5	26698	1.2E6	3883	210.5	16.6	1.72	2.27	7.56
	API	609.6	577.9	15.88	231.9	494.1	1915	1815	2.6E5	29611	1.3E6	4284	210.0	17.1	1.94	2.60	8.68
	SCH 40 API	609.6	574.6	17.48	254.5	513.9	1915	1805	2.6E5	32508	1.4E6	4678	209.4	17.5	2.15	2.94	9.80
	API	609.6	571.5	19.05	276.7	533.3	1915	1795	2.6E5	35343	1.5E6	5060	208.9	17.9	2.35	3.27	10.9
	SCH 60	609.6	560.4	24.61	354.2	600.8	1915	1760	2.5E5	45233	1.9E6	6359	207.0	18.9	2.98	4.46	14.9
	SCH 80	609.6	547.7	30.96	440.7	676.3	1915	1721	2.4E5	56285	2.4E6	7751	204.9	19.7	3.56	5.84	19.5
	SCH 100	609.6	531.8	38.89	545.9	768.1	1915	1671	2.2E5	69723	2.9E6	9357	202.2	20.3	4.13	7.60	25.3
	SCH 120	609.6	517.6	46.02	638.1	848.4	1915	1626	2.1E5	81488	3.3E6	10685	199.9	20.6	4.52	9.21	30.7
	SCH 140	609.6	504.9	52.37	717.9	918.1	1915	1586	2.0E5	91686	3.6E6	11778	197.9	20.8	4.79	10.7	35.6
	SCH 160	609.6	490.5	59.54	805.6	994.6	1915	1541	1.9E5	1.0E5	3.9E6	12916	195.6	20.9	5.02	12.4	41.2
650	API	660.4	647.7	6.350	102.2	431.7	2075	2035	3.3E5	13048	7.0E5	2113	231.3	12.9	.510	.575	1.92
26	API	660.4	646.1	7.137	114.7	442.6	2075	2030	3.3E5	14648	7.8E5	2367	231.0	13.4	.610	.724	2.41
	SCH 10 API	660.4	644.6	7.925	127.2	453.5	2075	2025	3.3E5	16244	8.6E5	2618	230.7	14.0	.713	.874	2.91
	API	660.4	642.9	8.738	140.1	464.7	2075	2020	3.2E5	17888	9.5E5	2876	230.4	14.5	.822	1.03	3.43
	STD API	660.4	641.4	9.525	152.5	475.6	2075	2015	3.2E5	19477	1.0E6	3124	230.1	14.9	.928	1.18	3.93
	API	660.4	639.8	10.31	164.9	486.4	2075	2010	3.2E5	21061	1.1E6	3370	229.9	15.3	1.03	1.33	4.43
	API	660.4	638.1	11.13	177.7	497.5	2075	2005	3.2E5	22693	1.2E6	3622	229.6	15.7	1.15	1.48	4.95
	API	660.4	636.6	11.91	190.0	508.3	2075	2000	3.2E5	24269	1.3E6	3865	229.3	16.0	1.25	1.64	5.45
	SCH 20 XS API	660.4	635.0	12.70	202.3	519.0	2075	1995	3.2E5	25842	1.4E6	4106	229.0	16.3	1.36	1.79	5.95
		660.4	631.9	14.27	226.9	540.4	2075	1985	3.1E5	28976	1.5E6	4582	228.5	16.9	1.57	2.09	6.97
	API	660.4	628.6	15.88	251.7	562.1	2075	1975	3.1E5	32144	1.7E6	5058	227.9	17.4	1.78	2.40	8.00
	API	660.4	622.3	19.05	300.5	604.7	2075	1955	3.0E5	38383	2.0E6	5982	226.9	18.3	2.17	3.02	10.1
700	API	711.2	698.5	6.350	110.1	493.3	2234	2194	3.8E5	14061	8.7E5	2456	249.2	13.0	.455	.534	1.78
28	API	711.2	696.9	7.137	123.6	505.1	2234	2189	3.8E5	15787	9.8E5	2751	248.9	13.6	.545	.672	2.24
	SCH 10 API	711.2	695.4	7.925	137.1	516.8	2234	2185	3.8E5	17509	1.1E6	3045	248.7	14.1	.639	.811	2.70
	API	711.2	693.7	8.738	151.0	529.0	2234	2179	3.8E5	19283	1.2E6	3345	248.4	14.6	.738	.954	3.18
	STD API	711.2	692.2	9.525	164.4	540.7	2234	2174	3.8E5	20997	1.3E6	3635	248.1	15.1	.836	1.09	3.65

PIPE DATA

TABLES P-1 M

DN (mm) [NPS]	PIPING CODES and MANUFACTURERS' WEIGHTS	DIMENSIONS O.D. (mm)	I.D. (mm)	Wall (mm)	WEIGHTS Empty (kg/m)	Waterfilled (kg/m)	AREAS External (mm²/mm)	Internal (mm²/mm)	Flow (mm²)	Metal (mm²)	Moment of Inertia (10⁴mm)	Section Modulus (10³mm)	Radius of Gyration (mm)	Continuous Spans Span (m)	Sag (mm)	Code Pressures Design (MPa)	Bursting (MPa)
	API	711.2	690.6	10.31	177.8	552.3	2234	2170	3.7E5	22707	1.4E6	3922	247.8	15.5	.935	1.23	4.11
	API	711.2	688.9	11.13	191.6	564.4	2234	2164	3.7E5	24468	1.5E6	4216	247.5	15.9	1.04	1.38	4.59
	API	711.2	687.4	11.91	204.9	576.0	2234	2159	3.7E5	26171	1.6E6	4500	247.3	16.2	1.14	1.52	5.06
	SCH 20 XS API	711.2	685.8	12.70	218.2	587.6	2234	2155	3.7E5	27869	1.7E6	4781	247.0	16.6	1.24	1.66	5.52
	SCH 30 API	711.2	679.5	15.88	271.5	634.1	2234	2135	3.6E5	34678	2.1E6	5897	245.9	17.7	1.63	2.23	7.42
	API	711.2	673.1	19.05	324.3	680.2	2234	2115	3.6E5	41423	2.5E6	6981	244.8	18.6	2.00	2.80	9.33
750 30	API	762.0	747.7	7.137	132.5	571.6	2394	2349	4.4E5	16926	1.2E6	3165	266.9	13.7	.490	.627	2.09
	SCH 10 API	762.0	746.2	7.925	147.0	584.3	2394	2344	4.4E5	18774	1.3E6	3503	266.6	14.2	.576	.757	2.52
	API	762.0	744.5	8.738	161.9	597.3	2394	2339	4.4E5	20677	1.5E6	3850	266.3	14.7	.667	.890	2.97
	STD API	762.0	743.0	9.525	176.3	609.8	2394	2334	4.3E5	22517	1.6E6	4184	266.1	15.2	.757	1.02	3.40
	API	762.0	741.4	10.31	190.7	622.4	2394	2329	4.3E5	24353	1.7E6	4515	265.8	15.6	.849	1.15	3.83
	API	762.0	739.7	11.13	205.5	635.3	2394	2324	4.3E5	26244	1.8E6	4856	265.5	16.1	.944	1.28	4.28
	API	762.0	738.2	11.91	219.8	647.8	2394	2319	4.3E5	28072	2.0E6	5183	265.2	16.4	1.04	1.42	4.72
	SCH 20 XS API	762.0	736.6	12.70	234.1	660.2	2394	2314	4.3E5	29896	2.1E6	5508	265.0	16.8	1.13	1.55	5.15
	SCH 30 API	762.0	730.3	15.88	291.4	710.2	2394	2294	4.2E5	37211	2.6E6	6800	263.9	18.0	1.50	2.08	6.92
	API	762.0	723.9	19.05	348.1	759.7	2394	2274	4.1E5	44464	3.1E6	8057	262.8	18.9	1.86	2.61	8.69
800 32	API	812.8	800.1	6.350	126.0	628.7	2553	2514	5.0E5	16088	1.3E6	3218	285.1	13.1	.367	.467	1.56
	API	812.8	798.5	7.137	141.5	642.3	2553	2509	5.0E5	18065	1.5E6	3607	284.9	13.8	.443	.588	1.96
	SCH 10 API	812.8	797.0	7.925	156.9	655.7	2553	2504	5.0E5	20039	1.6E6	3993	284.6	14.3	.522	.709	2.36
	API	812.8	795.3	8.738	172.8	669.6	2553	2499	5.0E5	22072	1.8E6	4390	284.3	14.9	.606	.834	2.78
	STD API	812.8	793.8	9.525	188.2	683.0	2553	2494	4.9E5	24037	1.9E6	4771	284.0	15.4	.689	.956	3.19
	API	812.8	792.2	10.31	203.6	696.4	2553	2489	4.9E5	25999	2.1E6	5151	283.7	15.8	.774	1.08	3.59
	API	812.8	790.5	11.13	219.4	710.2	2553	2484	4.9E5	28019	2.3E6	5540	283.5	16.2	.862	1.20	4.01
	API	812.8	789.0	11.91	234.7	723.6	2553	2479	4.9E5	29973	2.4E6	5915	283.2	16.6	.949	1.33	4.42
	SCH 20 XS API	812.8	787.4	12.70	250.0	736.9	2553	2474	4.9E5	31923	2.6E6	6287	282.9	17.0	1.04	1.45	4.83
	SCH 30 API	812.8	781.1	15.88	311.2	790.3	2553	2454	4.8E5	39745	3.2E6	7767	281.8	18.2	1.39	1.94	6.48
	SCH 40 API	812.8	777.8	17.48	341.9	817.1	2553	2444	4.8E5	43663	3.5E6	8499	281.3	18.7	1.56	2.19	7.32
	API	812.8	774.7	19.05	372.0	843.3	2553	2434	4.7E5	47504	3.7E6	9211	280.7	19.2	1.72	2.44	8.14
850 34	API	863.6	850.9	6.350	133.9	702.6	2713	2673	5.7E5	17101	1.6E6	3638	303.1	13.2	.333	.439	1.46
	API	863.6	849.3	7.137	150.4	716.9	2713	2668	5.7E5	19204	1.8E6	4078	302.8	13.9	.402	.553	1.84
	SCH 10 API	863.6	847.8	7.925	166.8	731.3	2713	2663	5.6E5	21303	1.9E6	4516	302.5	14.4	.475	.667	2.22
	API	863.6	846.1	8.738	183.7	746.0	2713	2658	5.6E5	23466	2.1E6	4965	302.3	15.0	.552	.785	2.62
	STD API	863.6	844.6	9.525	200.1	760.3	2713	2653	5.6E5	25557	2.3E6	5397	302.0	15.5	.629	.899	3.00
	API	863.6	843.0	10.31	216.5	774.6	2713	2648	5.6E5	27644	2.5E6	5828	301.7	15.9	.708	1.01	3.38
	API	863.6	841.3	11.13	233.3	789.3	2713	2643	5.6E5	29795	2.7E6	6269	301.4	16.4	.791	1.13	3.77
	API	863.6	839.8	11.91	249.6	803.5	2713	2638	5.5E5	31874	2.9E6	6694	301.1	16.8	.872	1.25	4.16
	SCH 20 XS API	863.6	838.2	12.70	265.8	817.6	2713	2633	5.5E5	33950	3.1E6	7117	300.9	17.1	.953	1.36	4.54
	SCH 30 API	863.6	831.9	15.88	331.0	874.5	2713	2613	5.4E5	42278	3.8E6	8798	299.8	18.4	1.28	1.83	6.09
	SCH 40 API	863.6	828.6	17.48	363.7	903.0	2713	2603	5.4E5	46452	4.2E6	9631	299.2	19.0	1.45	2.06	6.88
	API	863.6	825.5	19.05	395.8	931.0	2713	2593	5.4E5	50544	4.5E6	10442	298.7	19.5	1.61	2.30	7.66
900 36	API	914.4	901.7	6.350	141.8	780.4	2873	2833	6.4E5	18115	1.9E6	4084	321.1	13.3	.303	.415	1.38
	API	914.4	900.1	7.137	159.3	795.6	2873	2828	6.4E5	20343	2.1E6	4578	320.8	13.9	.367	.522	1.74
	SCH 10 API	914.4	898.6	7.925	176.7	810.8	2873	2823	6.3E5	22568	2.3E6	5070	320.5	14.5	.434	.630	2.10
	API	914.4	896.9	8.738	194.7	826.5	2873	2818	6.3E5	24861	2.5E6	5576	320.2	15.1	.506	.741	2.47
	STD API	914.4	895.4	9.525	212.0	841.6	2873	2813	6.3E5	27077	2.8E6	6062	319.9	15.6	.577	.849	2.83
	API	914.4	893.8	10.31	229.3	856.7	2873	2808	6.3E5	29290	3.0E6	6546	319.7	16.1	.651	.957	3.19
	API	914.4	892.1	11.13	247.2	872.3	2873	2803	6.3E5	31570	3.2E6	7043	319.4	16.5	.728	1.07	3.56
	API	914.4	890.6	11.91	264.5	887.4	2873	2798	6.2E5	33775	3.4E6	7522	319.1	16.9	.804	1.18	3.93
	SCH 20 XS API	914.4	889.0	12.70	281.7	902.4	2873	2793	6.2E5	35976	3.7E6	7999	318.8	17.3	.880	1.29	4.29
	API	914.4	885.9	14.27	316.1	932.4	2873	2783	6.2E5	40367	4.1E6	8944	318.3	18.0	1.03	1.50	5.01
	SCH 30 API	914.4	882.6	15.88	350.9	962.8	2873	2773	6.1E5	44812	4.5E6	9895	317.7	18.6	1.19	1.73	5.75
	SCH 40 API	914.4	876.3	19.05	419.6	1023	2873	2753	6.0E5	53584	5.4E6	11750	316.6	19.7	1.50	2.17	7.22

PIPE DATA

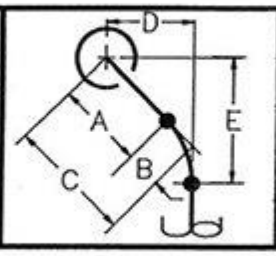
TABLES P-1 M

DN (mm) (NPS)	PIPING CODES and MANUFACTURERS' WEIGHTS	DIMENSIONS O.D. (mm)	I.D. (mm)	Wall (mm)	WEIGHTS Empty (kg/m)	Waterfilled (kg/m)	AREAS External (mm²/mm)	Internal (mm²/mm)	Flow (mm²)	Metal (mm²)	Moment of Inertia (10⁴mm⁴)	Section Modulus (10³mm³)	Radius of Gyration (mm)	Continuous Spans Span (m)	Sag (mm)	Code Pressures Design (MPa)	Bursting (MPa)
	API	711.2	690.6	10.31	177.8	552.3	2234	2170	3.7E5	22707	1.4E6	3922	247.8	15.5	.935	1.23	4.11
	API	711.2	688.9	11.13	191.6	564.4	2234	2164	3.7E5	24468	1.5E6	4216	247.5	15.9	1.04	1.38	4.59
	API	711.2	687.4	11.91	204.9	576.0	2234	2159	3.7E5	26171	1.6E6	4500	247.3	16.2	1.14	1.52	5.06
	SCH 20 XS API	711.2	685.8	12.70	218.2	587.6	2234	2155	3.7E5	27869	1.7E6	4781	247.0	16.6	1.24	1.66	5.52
	SCH 30 API	711.2	679.5	15.88	271.5	634.1	2234	2135	3.6E5	34678	2.1E6	5897	245.9	17.7	1.63	2.23	7.42
	API	711.2	673.1	19.05	324.3	680.2	2234	2115	3.6E5	41423	2.5E6	6981	244.8	18.6	2.00	2.80	9.33
750 30	API	762.0	747.7	7.137	132.5	571.6	2394	2349	4.4E5	16926	1.2E6	3165	266.9	13.7	.490	.627	2.09
	SCH 10 API	762.0	746.2	7.925	147.0	584.3	2394	2344	4.4E5	18774	1.3E6	3503	266.6	14.2	.576	.757	2.52
	API	762.0	744.5	8.738	161.9	597.3	2394	2339	4.4E5	20677	1.5E6	3850	266.3	14.7	.667	.890	2.97
	STD API	762.0	743.0	9.525	176.3	609.8	2394	2334	4.3E5	22517	1.6E6	4184	266.1	15.2	.757	1.02	3.40
	API	762.0	741.4	10.31	190.7	622.4	2394	2329	4.3E5	24353	1.7E6	4515	265.8	15.6	.849	1.15	3.83
	API	762.0	739.7	11.13	205.5	635.3	2394	2324	4.3E5	26244	1.8E6	4856	265.5	16.1	.944	1.28	4.28
	API	762.0	738.2	11.91	219.8	647.8	2394	2319	4.3E5	28072	2.0E6	5183	265.2	16.4	1.04	1.42	4.72
	SCH 20 XS API	762.0	736.6	12.70	234.1	660.2	2394	2314	4.3E5	29896	2.1E6	5508	265.0	16.8	1.13	1.55	5.15
	SCH 30 API	762.0	730.3	15.88	291.4	710.2	2394	2294	4.2E5	37211	2.6E6	6800	263.9	18.0	1.50	2.08	6.92
	API	762.0	723.9	19.05	348.1	759.7	2394	2274	4.1E5	44464	3.1E6	8057	262.8	18.9	1.86	2.61	8.69
800 32	API	812.8	800.1	6.350	126.0	628.7	2553	2514	5.0E5	16088	1.3E6	3218	285.1	13.1	.367	.467	1.56
	API	812.8	798.5	7.137	141.5	642.3	2553	2509	5.0E5	18065	1.5E6	3607	284.9	13.8	.443	.588	1.96
	SCH 10 API	812.8	797.0	7.925	156.9	655.7	2553	2504	5.0E5	20039	1.6E6	3993	284.6	14.3	.522	.709	2.36
	API	812.8	795.3	8.738	172.8	669.6	2553	2499	5.0E5	22072	1.8E6	4390	284.3	14.9	.606	.834	2.78
	STD API	812.8	793.8	9.525	188.2	683.0	2553	2494	4.9E5	24037	1.9E6	4771	284.0	15.4	.689	.956	3.19
	API	812.8	792.2	10.31	203.6	696.4	2553	2489	4.9E5	25999	2.1E6	5151	283.7	15.8	.774	1.08	3.59
	API	812.8	790.5	11.13	219.4	710.2	2553	2484	4.9E5	28019	2.3E6	5540	283.5	16.2	.862	1.20	4.01
	API	812.8	789.0	11.91	234.7	723.6	2553	2479	4.9E5	29973	2.4E6	5915	283.2	16.6	.949	1.33	4.42
	SCH 20 XS API	812.8	787.4	12.70	250.0	736.9	2553	2474	4.9E5	31923	2.6E6	6287	282.9	17.0	1.04	1.45	4.83
	SCH 30 API	812.8	781.1	15.88	311.2	790.3	2553	2454	4.8E5	39745	3.2E6	7767	281.8	18.2	1.39	1.94	6.48
	SCH 40 API	812.8	777.8	17.48	341.9	817.1	2553	2444	4.8E5	43663	3.5E6	8499	281.3	18.7	1.56	2.19	7.32
	API	812.8	774.7	19.05	372.0	843.3	2553	2434	4.7E5	47504	3.7E6	9211	280.7	19.2	1.72	2.44	8.14
850 34	API	863.6	850.9	6.350	133.9	702.6	2713	2673	5.7E5	17101	1.6E6	3638	303.1	13.2	.333	.439	1.46
	API	863.6	849.3	7.137	150.4	716.9	2713	2668	5.7E5	19204	1.8E6	4078	302.8	13.9	.402	.553	1.84
	SCH 10 API	863.6	847.8	7.925	166.8	731.3	2713	2663	5.6E5	21303	1.9E6	4516	302.5	14.4	.475	.667	2.22
	API	863.6	846.1	8.738	183.7	746.0	2713	2658	5.6E5	23466	2.1E6	4965	302.3	15.0	.552	.785	2.62
	STD API	863.6	844.6	9.525	200.1	760.3	2713	2653	5.6E5	25557	2.3E6	5397	302.0	15.5	.629	.899	3.00
	API	863.6	843.0	10.31	216.5	774.6	2713	2648	5.6E5	27644	2.5E6	5828	301.7	15.9	.708	1.01	3.38
	API	863.6	841.3	11.13	233.3	789.3	2713	2643	5.6E5	29795	2.7E6	6269	301.4	16.4	.791	1.13	3.77
	API	863.6	839.8	11.91	249.6	803.5	2713	2638	5.5E5	31874	2.9E6	6694	301.1	16.8	.872	1.25	4.16
	SCH 20 XS API	863.6	838.2	12.70	265.8	817.6	2713	2633	5.5E5	33950	3.1E6	7117	300.9	17.1	.953	1.36	4.54
	SCH 30 API	863.6	831.9	15.88	331.0	874.5	2713	2613	5.4E5	42278	3.8E6	8798	299.8	18.4	1.28	1.83	6.09
	SCH 40 API	863.6	828.6	17.48	363.7	903.0	2713	2603	5.4E5	46452	4.2E6	9631	299.2	19.0	1.45	2.06	6.88
	API	863.6	825.5	19.05	395.8	931.0	2713	2593	5.4E5	50544	4.5E6	10442	298.7	19.5	1.61	2.30	7.66
900 36	API	914.4	901.7	6.350	141.8	780.4	2873	2833	6.4E5	18115	1.9E6	4084	321.1	13.3	.303	.415	1.38
	API	914.4	900.1	7.137	159.3	795.6	2873	2828	6.4E5	20343	2.1E6	4578	320.8	13.9	.367	.522	1.74
	SCH 10 API	914.4	898.6	7.925	176.7	810.8	2873	2823	6.3E5	22568	2.3E6	5070	320.5	14.5	.434	.630	2.10
	API	914.4	896.9	8.738	194.7	826.5	2873	2818	6.3E5	24861	2.5E6	5576	320.2	15.1	.506	.741	2.47
	STD API	914.4	895.4	9.525	212.0	841.6	2873	2813	6.3E5	27077	2.8E6	6062	319.9	15.6	.577	.849	2.83
	API	914.4	893.8	10.31	229.3	856.7	2873	2808	6.3E5	29290	3.0E6	6546	319.7	16.1	.651	.957	3.19
	API	914.4	892.1	11.13	247.2	872.3	2873	2803	6.3E5	31570	3.2E6	7043	319.4	16.5	.728	1.07	3.56
	API	914.4	890.6	11.91	264.5	887.4	2873	2798	6.2E5	33775	3.4E6	7522	319.1	16.9	.804	1.18	3.93
	SCH 20 XS API	914.4	889.0	12.70	281.7	902.4	2873	2793	6.2E5	35976	3.7E6	7999	318.8	17.3	.880	1.29	4.29
	API	914.4	885.9	14.27	316.1	932.4	2873	2783	6.2E5	40367	4.1E6	8944	318.3	18.0	1.03	1.50	5.01
	SCH 30 API	914.4	882.6	15.88	350.9	962.8	2873	2773	6.1E5	44812	4.5E6	9895	317.7	18.6	1.19	1.73	5.75
	SCH 40 API	914.4	876.3	19.05	419.6	1023	2873	2753	6.0E5	53584	5.4E6	11750	316.6	19.7	1.50	2.17	7.22

WELDED FITTINGS–FLANGES 150# RFWN

NOM. PIPE SIZE (mm)		50.8	63.5	76.2	101.6	152.4	203.2	254	304.8	355.6	406.4	457.2
WELD FITTINGS: O.D. Of PIPE		60.3	73.0	88.9	114.3	152.4	203.2	254	304.8	355.6	406.4	457.2
90° L.R. ELL	A	76.2	95.3	114.3	152.4	228.6	304.8	381.0	457.2	533.4	609.6	685.8
45° L.R. ELL	B	34.9	44.5	50.8	63.5	95.3	127.0	158.8	190.5	222.3	254.0	285.8
HALF TEE	C	63.5	76.2	85.7	104.8	142.9	177.8	215.9	254	279.4	304.8	342.9
REDUCER	H	76.2	88.9	88.9	101.6	139.7	152.4	177.8	203.2	330.2	355.6	381.0

STD. 90° & 45°

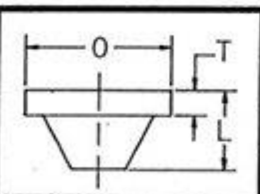


A	76.2	95.2	114.3	152.4	228.6	304.8	381.0	457.2	533.4	609.6	685.4
B	34.9	44.5	50.8	63.5	95.3	127.0	158.8	190.5	222.3	254.0	285.8
C	111.1	139.7	165.1	215.9	323.9	431.8	539.8	647.7	755.7	863.6	971.6
D	79.4	98.4	117.5	152.4	228.6	304.8	304.8	457.2	535.0	611.2	687.4
E	114.3	142.9	168.3	215.9	323.9	431.8	539.8	647.7	757.2	865.2	973.1

FITTING MAKE UP

90°&WN FLG	139.7	165.1	184.2	228.6	317.5	406.4	482.6	571.5	660.4	736.6	825.5
TEE&WN FLG	127.0	146.1	155.6	181.0	231.8	279.4	317.5	368.3	406.4	431.8	482.6
45°&WN FLG	98.4	114.3	120.7	139.7	184.2	228.6	260.4	304.8	349.3	381.0	482.6
RED.&WN FLG	139.7	158.8	158.8	177.8	228.6	254.0	279.4	317.5	457.2	482.6	520.7

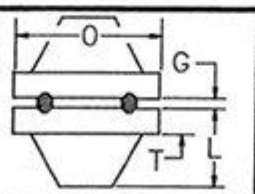
RFWN FLANGES



O	152.4	177.8	190.5	228.6	279.4	342.9	406.4	482.6	533.4	596.9	635
L	63.5	69.9	69.9	76.2	88.9	101.6	101.6	114.3	127	127	139.7
T	19.1	22.2	23.8	23.8	25.4	28.6	30.2	31.8	34.9	36.5	39.7

1.6 (mm) RAISED FACE INCLUDED ON 'L' &'T' DIMENSIONS

RTJ FLANGES

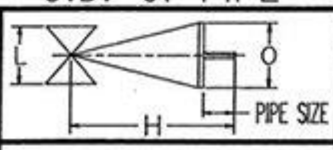
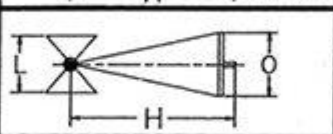
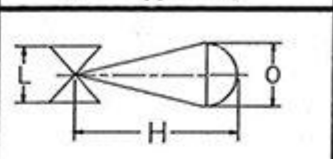
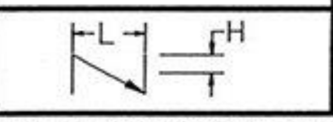


O	152.4	177.8	190.5	228.6	279.4	342.9	406.4	482.6	533.4	596.9	635.0
L	69.9	76.2	76.2	82.6	95.3	108	108	120.7	133.4	133.4	146.1
T	25.4	28.6	30.2	30.2	31.8	34.9	36.5	38.1	41.3	42.9	46
G	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	3.2	3.2	3.2

NOTE: ALL DIMENSIONS ARE IN MILLIMETERS 150#

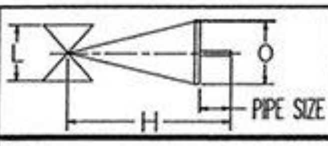
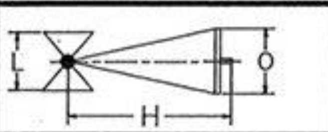
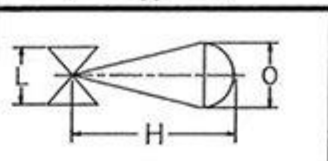
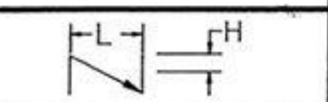
Source: "Pipe Drafting and Design". Parisher, Roy A and Rhea, Robert H, gulf Publishing, 2002.

VALVES 150#

NOMINAL PIPE SIZES (mm)			50.8	76.2	101.6	152.4	203.2	254	304.8	355.6	406.4	457.2
O.D. of PIPE			60.3	88.9	114.3	168.3	219.1	273.1	323.9	355.6	406.4	457.2
VALVES – GATE		L	177.8	203.2	228.6	266.7	292.1	330.2	355.6	381	406.4	431.8
		H	400.1	527.1	654.1	895.4	1092.2	1333.5	1536.7	1784.4	2025.7	2260.6
		O	203.2	228.6	254	355.6	406.4	457.2	457.2	558.8	609.6	685.8
VALVES – GLOBE		L	203.2	241.3	292.1	406.4	495.3	*	*	*	*	*
		H	349.3	419.1	501.7	622.3	660.4	*	*	*	*	*
		O	203.2	228.6	254	304.8	406.4	*	*	*	*	*
VALVES – CONTROL		L	254	298.5	352.4	450.9	542.9	673.1	*	*	*	*
		H	708.0	722.3	747.7	965.2	997	1174.8	*	*	*	*
		O	333.4	333.4	333.4	406.4	406.4	536.6	*	*	*	*
VALVES – CHECK		L	203.2	241.3	292.1	355.6	495.3	622.3	698.5	889	990	*
		H	127	152.4	177.8	228.6	260.4	308	349.3	457.2	520.7	*

NOTE: ALL DIMENSIONS ARE IN MILLIMETERS
* REFER to VENDOR CATALOG

150# RFWN

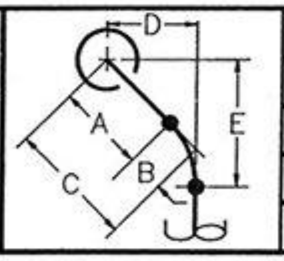
VALVES – GATE		L	190.5	215.9	241.3	279.4	304.8	342.9	368.3	393.7	419.1	444.5
		H	400.1	527.1	654.1	895.4	1092.2	1333.5	1536.7	1784.4	2025.7	2260.6
		O	203.2	228.6	254	355.6	406.4	457.2	457.2	558.8	609.6	685.8
VALVES – GLOBE		L	215.9	254	304.8	419.1	508	*	*	*	*	*
		H	349.3	419.1	501.7	622.3	660.4	*	*	*	*	*
		O	203.2	228.6	254	304.8	406.4	*	*	*	*	*
VALVES – CONTROL		L	266.7	311.2	365.1	463.6	555.6	685.8	*	*	*	*
		H	708.0	722.3	747.7	965.2	997	1174.8	*	*	*	*
		O	333.4	333.4	333.4	406.4	406.4	536.6	*	*	*	*
VALVES – CHECK		L	215.9	254	304.8	368.3	508	635	711.2	901.7	1003.3	*
		H	127	152.4	177.8	228.6	260.4	308	349.3	457.2	520.7	*

NOTE: ALL DIMENSIONS ARE IN MILLIMETERS
* REFER to VENDOR CATALOG

150# RTJ

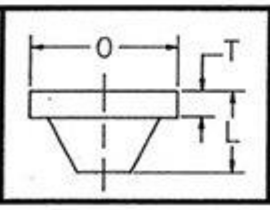
WELDED FITTINGS–FLANGES 300# RFWN

		NOM. PIPE SIZE (mm)		50.8	63.5	76.2	101.6	152.4	203.2	254	304.8	355.6	406.4	457.2
WELD	FITTINGS	O.D. Of PIPE		60.3	73.0	88.9	114.3	152.4	203.2	254	304.8	355.6	406.4	457.2
		90°L.R. ELL	A	76.2	95.3	114.3	152.4	228.6	304.8	381.0	457.2	533.4	609.6	685.8
		45°L.R. ELL	B	34.9	44.5	50.8	63.5	95.3	127.0	158.8	190.5	222.3	254.0	285.8
		HALF TEE	C	63.5	76.2	85.7	104.8	142.9	177.8	215.9	254	279.4	304.8	342.9
		REDUCER	H	76.2	88.9	88.9	101.6	139.7	152.4	177.8	203.2	330.2	355.6	381.0



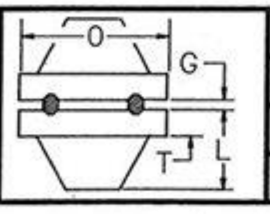
STD. 90° & 45° A	76.2	95.2	114.3	152.4	228.6	304.8	381.0	457.2	533.4	609.6	685.4
B	34.9	44.5	50.8	63.5	95.3	127.0	158.8	190.5	222.3	254.0	285.8
C	111.1	139.7	165.1	215.9	323.9	431.8	539.8	647.7	755.7	863.6	971.6
D	79.4	98.4	117.5	152.4	228.6	304.8	304.8	457.2	535.0	611.2	687.4
E	114.3	142.9	168.3	215.9	323.9	431.8	539.8	647.7	757.2	865.2	973.1

FITTING MAKE UP											
90°&WN FLG	146.1	171.5	193.7	238.1	0000	415.9	498.5	587.4	676.3	755.7	844.6
TEE&WN FLG	139.7	152.4	165.1	190.5	238.1	288.9	333.4	384.2	422.3	450.9	501.7
45°&WN FLG	104.8	120.7	142.9	149.2	193.7	238.1	276.2	320.7	365.1	400.1	444.5
RED.&WN FLG	146.1	165.1	168.3	187.3	238.1	263.5	295.3	333.4	473.1	501.7	539.8



RFWN FLANGES											
O	165.1	190.5	209.6	254	317.5	381	444.5	520.7	584.2	647.7	711.2
L	69.9	76.2	79.4	85.7	98.4	111.1	117.5	130.2	142.9	146.1	158.1
T	22.2	25.4	28.6	31.8	36.5	41.3	47.6	50.8	54	57.2	60.3

1.6 (mm) RAISED FACE INCLUDED ON 'L' &'T' DIMENSIONS

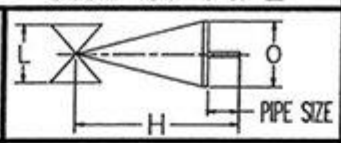
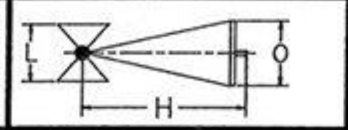
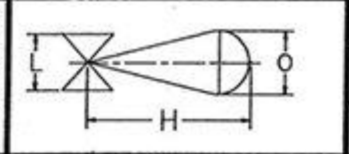
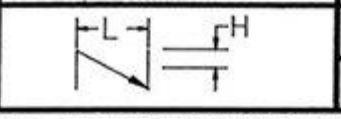


RTJ FLANGES											
O	165.1	190.5	209.6	254	317.5	381	444.5	520.7	584.2	647.7	711.2
L	77.8	84.1	87.3	93.7	106.4	119.1	125.4	138.1	150.8	154	166.7
T	28.6	31.8	34.9	38.1	42.9	47.6	54	57.2	60.3	63.5	66.7
G	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4

NOTE: ALL DIMENSIONS ARE IN MILLIMETERS 300#

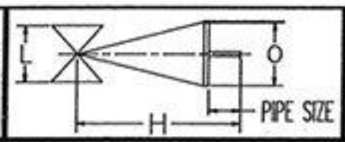
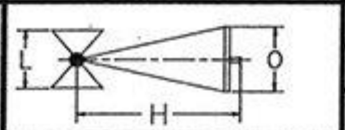
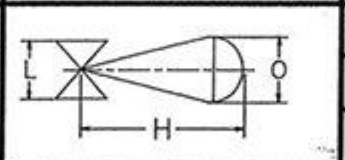
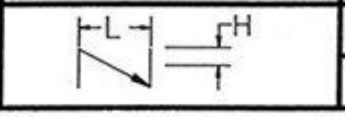
VALVES

300#

NOMINAL PIPE SIZES (mm)		50.8	76.2	101.6	152.4	203.2	254	304.8	355.6	406.4	457.2
O.D. of PIPE		60.3	88.9	114.3	168.3	219.1	273.1	323.9	355.6	406.4	457.2
GATE 	L	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
	H	469.9	590.6	717.6	968.4	1193.8	1435.1	1632	1898.7	2035.2	2311.4
	O	203.2	228.6	254	355.6	406.4	508	508	685.8	685.8	762
GLOBE 	L	0000	0000	0000	0000	0000	*	*	*	*	*
	H	450.9	520.7	628.7	755.7	927.1	*	*	*	*	*
	O	228.6	254	355.6	457	609.6	*	*	*	*	*
CONTROL 	L	0000	0000	0000	0000	0000	0000	*	*	*	*
	H	708	722.3	747.7	965.2	997	1174.8	*	*	*	*
	O	333.4	333.4	333.4	406.4	406.4	536.6	*	*	*	*
CHECK 	L	0000	0000	0000	0000	0000	0000	0000	*	*	*
	H	171.5	215.9	247.7	298.5	355.6	381	425.5	*	*	*

NOTE: ALL DIMENSIONS ARE IN MILLIMETERS
* REFER to VENDOR CATALOG

300# RFWN

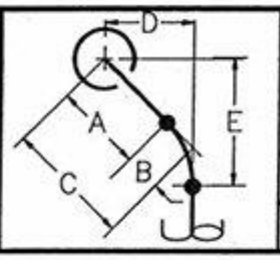
GATE 	L	231.8	298.5	320.7	419.1	435	473.1	517.5	777.9	854.1	930.3
	H	469.9	590.6	717.6	968.4	1193.8	1435.1	1632	1898.7	2035.2	2311.4
	O	203.2	228.6	254	355.6	406.4	508	508	685.8	685.8	762
GLOBE 	L	282.6	333.4	371.5	460.4	574.7	*	*	*	*	*
	H	450.9	520.7	628.7	755.7	927.1	*	*	*	*	*
	O	228.6	254	355.6	457	609.6	*	*	*	*	*
CONTROL 	L	282.6	333.4	384.2	489	584.2	723.9	*	*	*	*
	H	708	722.3	747.7	965.2	997	1174.8	*	*	*	*
	O	333.4	333.4	333.4	406.4	406.4	536.6	*	*	*	*
CHECK 	L	282.6	333.4	371.5	460.4	549.3	638.2	727.1	*	*	*
	H	171.5	215.9	247.7	298.5	355.6	381	425.5	*	*	*

NOTE: ALL DIMENSIONS ARE IN MILLIMETERS
* REFER to VENDOR CATALOG

300# RTJ

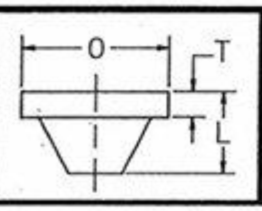
WELDED FITTINGS-FLANGES 600# RFWN

		NOM. PIPE SIZE (mm)	50.8	63.5	76.2	101.6	152.4	203.2	254	304.8	355.6	406.4	457.2
WELD FITTINGS	O.D. Of PIPE		60.3	73.0	88.9	114.3	152.4	203.2	254	304.8	355.6	406.4	457.2
	90°L.R. ELL	A	76.2	95.3	114.3	152.4	228.6	304.8	381.0	457.2	533.4	609.6	685.8
	45°L.R. ELL	B	34.9	44.5	50.8	63.5	95.3	127.0	158.8	190.5	222.3	254.0	285.8
	HALF TEE	C	63.5	76.2	85.7	104.8	142.9	177.8	215.9	254	279.4	304.8	342.9
	REDUCER	H	76.2	88.9	88.9	101.6	139.7	152.4	177.8	203.2	330.2	355.6	381.0

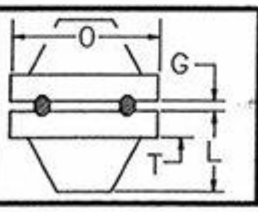


STD. 90° & 45°	A	76.2	95.2	114.3	152.4	228.6	304.8	381.0	457.2	533.4	609.6	685.4
	B	34.9	44.5	50.8	63.5	95.3	127.0	158.8	190.5	222.3	254.0	285.8
	C	111.1	139.7	165.1	215.9	323.9	431.8	539.8	647.7	755.7	863.6	971.6
	D	79.4	98.4	117.5	152.4	228.6	304.8	304.8	457.2	535.0	611.2	687.4
	E	114.3	142.9	168.3	215.9	323.9	431.8	539.8	647.7	757.2	865.2	973.1

FITTING MAKE UP	90°&WN FLG	155.6	181.0	203.2	260.4	352.4	444.5	539.8	619.1	704.9	793.8	876.3
	TEE&WN FLG	142.9	168.3	174.6	212.7	266.7	317.5	374.7	415.9	450.9	489	571.5
	45°&WN FLG	114.3	130.2	139.7	171.5	219.1	266.7	317.5	352.4	393.7	438.2	476.3
	RED.&WN FLG	155.6	174.6	177.8	209.6	263,5	292.1	336.6	365.1	501.7	539.8	571.5



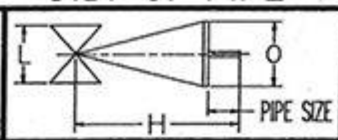
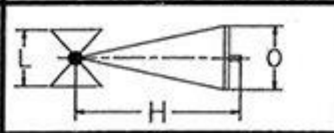
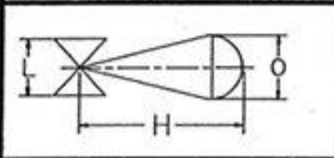
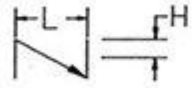
RFWN FLANGES	O	165.1	190.5	209.6	273.1	355.6	419.1	508	558.8	603.3	685.8	743
	L	79.4	85.7	88.9	108	123.8	139.7	158.8	161.9	174.6	184.2	190.5
	T	31.8	34.9	38.1	44.5	54	61.9	69.9	73	76.2	82.6	88.9
	6.4 (mm) RAISED FACE INCLUDED ON 'L' &'T' DIMENSIONS											



RTJ FLANGES	O	165.1	190.5	209.6	273.1	355.6	419.1	508	558.8	603.3	685.8	743
	L	81	87.3	90.5	109.5	125.4	141.3	160.3	163.5	173	185.7	192.1
	T	38.1	41.3	44.5	50.8	60.3	68.3	76.2	79.4	82.6	88.9	95.3
	G	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8

NOTE: ALL DIMENSIONS ARE IN MILLIMETERS 600#

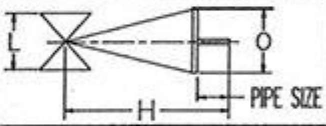
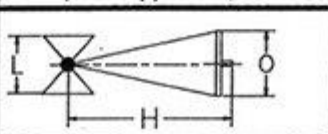
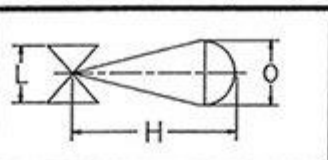
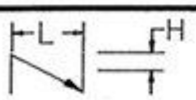
VALVES 600#

NOMINAL PIPE SIZES (mm)				50.8	76.2	101.6	152.4	203.2	254	304.8	355.6	406.4	457.2
O.D. of PIPE				60.3	88.9	114.3	168.3	219.1	273.1	323.9	355.6	406.4	457.2
VALVES	GATE		L	292.1	355.6	431.8	558.8	660.4	787.4	838.2	889	990	1092.2
			H	463.6	654.1	812.8	1085.9	1327.2	1581.2	1778	1962.2	2127.3	2381.3
			O	203.2	254	355.6	508	609.6	685.8	685.8	762	762	914.4
	GLOBE		L	292.1	355.6	431.8	558.8	*	*	*	*	*	*
			H	482.6	596.9	698.5	889	*	*	*	*	*	*
			O	254	304.8	457.2	609.6	*	*	*	*	*	*
	CONTROL		L	285.8	336.6	393.7	508	609.6	752.5	*	*	*	*
			H	708	722.3	747.7	965.2	997	1174.8	*	*	*	*
			O	333.4	333.4	333.4	406.4	406.4	536.6	*	*	*	*
	CHECK		L	292.1	355.6	431.8	558.8	660.4	787.4	863.6	*	*	*
			H	177.8	228.6	260.4	342.9	387.4	476.3	546.1	*	*	*

NOTE: ALL DIMENSIONS ARE IN MILLIMETERS

* REFER to VENDOR CATALOG

600# RFWN

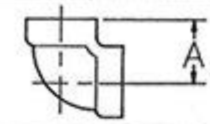
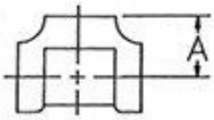
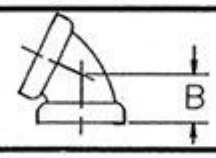
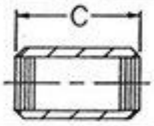
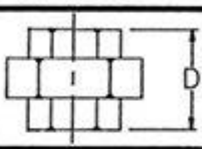
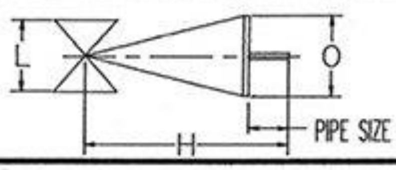
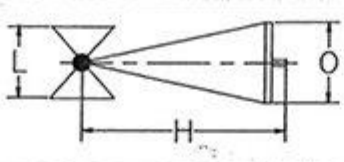
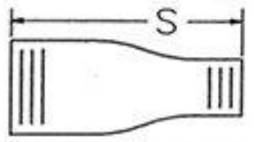
VALVES	GATE		L	295.3	358.8	435	562	663.6	790.6	841.4	892.2	993.8	1095.4
			H	463.6	654.1	812.8	1085.9	1327.2	1581.2	1778	1962.2	2127.3	2381.3
			O	203.2	254	355.6	508	609.6	685.8	685.8	762	762	914.4
	GLOBE		L	295.3	358	435	562	*	*	*	*	*	*
			H	482.6	596.9	698.5	889	*	*	*	*	*	*
			O	254	304.8	457.2	609.6	*	*	*	*	*	*
	CONTROL		L	288.9	339.7	396.9	511.2	612.8	755.7	*	*	*	*
			H	708	722.3	747.7	965.2	997	1174.8	*	*	*	*
			O	333.4	333.4	333.4	406.4	406.4	536.6	*	*	*	*
	CHECK		L	295.3	358	435	562	663.6	790.6	841.4	*	*	*
			H	177.8	228.6	260.4	342.9	387.4	476.3	546.1	*	*	*

NOTE: ALL DIMENSIONS ARE IN MILLIMETERS

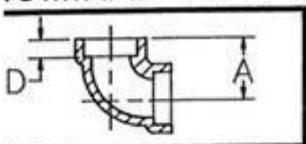
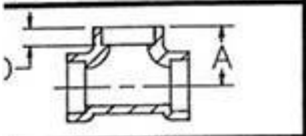
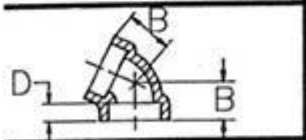
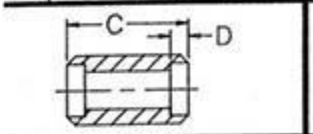
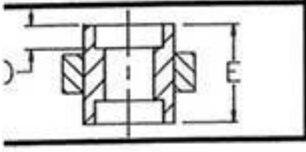
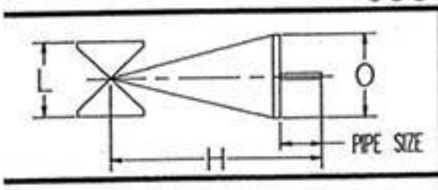
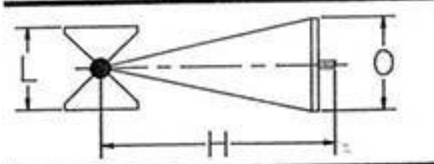
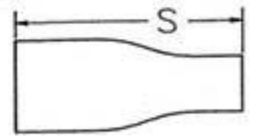
* REFER to VENDOR CATALOG

600# RTJ

SCREWED FITTINGS

NOMINAL PIPE SIZES (mm)			12.7	19.1	25.4	31.8	38.1	50.8	63.5	76.2
	3000 # 90°ELL	A	33.3	38.1	44.5	50.8	60.3	63.5	85.7	95.3
	6000 #	A	38.1	44.5	50.8	60.3	63.5	85.7	95.3	106.4
	3000 # TEE	A	33.3	38.1	44.5	50.8	60.3	63.5	85.7	95.3
	6000 #	A	38.1	44.5	50.8	60.3	63.5	85.7	95.3	106.4
	3000 # 45°ELL	B	25.4	28.6	33.3	36.5	42.9	50.8	52.4	63.5
	6000 #	B	28.6	33.3	34.9	42.9	44.5	52.4	63.5	79.4
	3000 # COUPLING	C	47.6	50.8	60.3	66.7	79.4	85.7	92.1	108
	6000 #	C	47.6	50.8	60.3	66.7	79.4	85.7	92.1	108
	3000 # UNION	D	54	58.7	63.5	71.4	79.4	88.9	100	114.3
	6000 #	D	73	85.7	92.1	98.4	106.4	117.5	131.8	150.8
NORMAL THREAD ENGAGEMENT	3000 #		12.7	14.3	17.5	17.5	17.5	19.1	23.8	25.4
	6000 #		12.7	14.3	17.5	17.5	17.5	19.1	23.8	25.4
	GATE	L	90.5	114.3	120.7	127	139.7	177.8	*	*
		H	165.1	209.6	242.9	276.2	290.5	357.2	*	*
		O	101.6	139.7	146.1	165.1	177.8	203.2	*	*
	GLOBE	L	92.1	117.5	158.8	177.8	196.9	228.6	*	*
		H	174.6	214.3	263.5	292.1	309.6	368.3	*	*
		O	101.6	120.7	146.1	203.2	203.2	203.2	*	*
	SWAGE	OUTLET	6.4 TO 9.5	6.4 TO 12.7	6.4 TO 19.1	6.4 TO 25.4	6.4 TO 31.8	6.4 TO 38.1	6.4 TO 57.2	6.4 TO 63.5
		S	95.3	76.2	88.9	101.6	114.3	165.1	177.8	203.2

SOCKET WELD FITTINGS

IOMINAL PIPE SIZES (mm)			12.7	19.1	25.4	31.8	38.1	50.8	63.5	76.2
	3000 # 90°ELL	A	28.6	33.3	38.1	44.5	50.8	60.3	76.2	85.7
	6000 #	A	33.3	38.1	44.5	50.8	60.3	63.5	82.6	95.3
	3000 # TEE	A	28.6	33.3	38.1	44.5	50.8	60.3	76.2	85.7
	6000 #	A	33.3	38.1	44.5	50.8	60.3	63.5	82.6	95.3
	3000 # 45°ELL	B	22.2	25.4	28.6	33.3	36.5	42.9	52.4	63.5
	6000 #	B	25.4	28.6	33.3	34.9	42.9	44.5	52.4	63.5
	3000 # COUPLING	C	34.9	38.1	44.5	47.6	50.8	63.5	63.5	69.9
	6000 #	C	34.9	38.1	44.5	47.6	50.8	63.5	63.5	69.9
	3000 # UNION	E	54	58.7	63.5	71.4	79.4	88.9	100	114.3
	6000 #	E	73	85.7	92.1	98.4	106.4	117.5	131.8	150.8
SOCKET DEPTH	3000 #	D	12.7	14.3	15.9	17.5	19.1	22.2	28.6	34.9
	6000 #	D	17.5	19.1	22.2	23.8	25.4	28.6	38.1	41.3
	GATE	L	90.5	114.3	120.7	127	139.7	177.8	*	*
		H	165.1	209.6	242.9	276.2	290.5	357.2	*	*
		O	101.6	139.7	146.1	165.1	177.8	203.2	*	*
	GLOBE	L	92.1	117.5	158.8	177.8	196.9	228.6	*	*
		H	174.6	214.3	263.5	292.1	309.6	368.3	*	*
		O	101.6	120.7	146.1	203.2	203.2	203.2	*	*
	SWAGE	OUTLET	6.4 TO 9.5	6.4 TO 12.7	6.4 TO 19.1	6.4 TO 25.4	6.4 TO 31.8	6.4 TO 38.1	6.4 TO 57.2	6.4 TO 63.5
		S	95.3	76.2	88.9	101.6	114.3	165.1	177.8	203.2