PIPING SYSTEM EQUIPMENTS

Introduction
Equipments are devices that provide power, process and store materials. Equipments in piping systems depend on the specific industries using them. Specialized equipment can be found in petroleum, petrochemical, pulp and paper, food processing, brewing and power plants. It is important that new versions of equipment are used in designs and vendor’s equipment drawing for location and orientation of nozzles and connections for instrumentations and utilities must be consulted. Common equipments include pumps, tanks, vessels, heat exchangers, etc. Many of the following equipments will be found in some plants of different industry types.

Equipment Types
Pumps: A pump is mechanical device that increases the pressure on a liquid in order to move it. Pumps are the workhorses of process plants. They admit a liquid from on one side called suction and releases it under higher pressure through another side called discharge. Pumps may be classified into two groups of dynamic and positive displacement (PD). Dynamic pumps deliver variable quantities of liquid. The energy transfer element in dynamic pumps is called impeller. The impeller design determines the type of dynamic pump. In general, there are three types: radial, axial, and mixed flow pumps. The impeller design directs the flow path of the liquid through the pump and Fig. 1 shows schematically the three types of dynamic pumps.

![Dynamic Pumps Schematics](attachment:image.png)

**a) Radial flow**

**b) Axial flow**

**c) Mixed flow**

Fig. 1: Schematics of dynamic pumps

![Radial Centrifugal Pump](attachment:image2.png)

**Fig. 2: Radial centrifugal pump**
Dynamic radial flow pumps are also called centrifugal pumps which are the most popular in this group. Fig. 2 shows the main parts of a centrifugal pump. It uses centrifugal force to add energy or velocity to the liquid. Horizontal and vertical design models of pumps are available. Centrifugal pumps make up about 90% of pumps in process piping. A centrifugal pump must be “primed or liquid full” before it is started. Priming is the filling of the suction line of a pump with liquid. Liquid is pushed into the pump from the source by the suction head or pressure and priming prevents the pump from working on air. The proper functioning of a centrifugal pump depends on its NPSH (Net Positive Suction Head). This the vertical height difference between the pump suction center line level and the lowest liquid level in the supply source less friction losses in the pipe. The lowest liquid level is normally the lower tangent of the vertical vessels and the bottom of horizontal vessels. Liquid from the supply source can only flow into the pump due to sufficient suction pressure that can be provided by atmospheric pressure and or by a positive suction head. Insufficient NPSH leads to insufficient suction pressure which means that the vapor pressure of the liquid is higher than the suction pressure. When this happens, some of the liquid may change to vapor. Centrifugal pumps cannot pump only vapor, so the discharge pressure will drop and gas bubbles are created that strike the pump impellers like micro hammers causing vibrations and noise. This phenomenon is known as cavitation and can cause severe damage to impellers and seals. Centrifugal pumps are used over a wide range of conditions, especially in high capacity and moderate head applications. Single-stage centrifugal pumps running at 3500 rpm are more economical at lower flow rates and moderate heads. Multistage centrifugal pumps are preferred for high head conditions. Centrifugal pumps operating above 3500 rpm are often driven by steam or gas turbines and are used for high heads and moderate capacities. Axial and mixed flow pumps are used for very high flow rates and low heads.

PD pumps deliver a fixed volume of liquid on each stroke of pump piston or rotation of the pump shaft. PD pumps are of two types: namely rotary and reciprocating pumps. Rotary PD pumps move liquid by a rotating mechanical element and include screw, gear, lobe, and vane pumps. These are named after the mechanical elements that push the liquid through the pump. As these elements rotate, the liquid is admitted into the pump at the low pressure or inlet port and pushed out at the discharge or high pressure port. These pumps incorporate inlet and outlet valves to control the operating cycle. Fig. 3a shows the schematics of a gear pump; Fig. 3b a sliding vane pump; and Fig. 3c, a lobe pump.

Reciprocating pumps draw in liquid on the intake stroke into a chamber and moves it out from the chamber on the discharge stroke. They include piston, plunger, and diaphram pumps. The energy transfer elements in these pumps also identify each kind. Rotary pumps are used in moderate capacities and high heads for liquids of high viscosities. Reciprocating pumps can provide flow rates of 500 gpm from very low heads to high values of up to 15.25 km (50,000 ft). Fig. 4 shows the schematics of two types of PD pumps; namely piston pump (Fig. 4a) and diaphram pump (Fig. 4b).
Compressors: Compressors are used to pressurize and move gas or vapor with a minimum pressure of about 1 bar. They admit gases or vapors from one side (suction) and release them under pressure through another side (discharge) like pumps. The gas or vapor is compressed and discharged at the higher pressure. Compressors and pumps are designed and built on the same principles, the main difference between them is that compressors handle gases and vapor while pumps handle liquids. Compressors are used to provide feed gas pressures and clean dry air for instruments and control devices in piping systems. They are also used to compress gases such as light hydrocarbons, nitrogen, hydrogen, carbon dioxide, and chlorine. Compressors can be used to transfer granular powders and small plastic pallets from one place to another. Gases and vapor are compressible and take smaller volume under pressure by moving the molecules together. The higher the pressure, the smaller is the gas or vapor volume. In general; the volume of a gas or vapor is determined by both pressure and temperature. Compression of gases or vapors generates heat due to molecular friction. Compressors are classified like pumps, into dynamic and positive displacement. Reciprocating compressors are the most common kind. It operates by trapping a specific amount of gas between a piston and cylinder wall, reduces the gas volume by compression and releases it at a higher pressure. Industrial reciprocating compressors are usually large and can deliver up to 4.7 m$^3$/s (10,000 cfm) at pressures as high as 410 MPa (60,000 psi). Centrifugal compressors can deliver air flow rates from 0.24 to 47 m$^3$/s (500 to 100,000 cfm) at discharge pressure of up to 55 MPa (8000 psi). Axial compressors are used for delivering large flow rates of 3.8 to 470 m$^3$/s (8000 to 1000,000 cfm) and at discharge pressure up to 700 kPa (100 psi). Screw compressors in industrial settings can provide compressed air at up to 3.4 MPa (500 psi) with flow rates up to 9.8 m$^3$/s (20,000 cfm).

Fans and blowers: Fans are used primarily to induce air draft through a room while blowers are used to induce air draft over other equipment. Fans are designed to operate against low static pressures of up to 14 kPa (2 psi) with 0 to 1.5 kPa being typical. Blowers are designed against static pressures of 14 to 70 kPa (2 to 10 psi). Blowers are more powerful than fans.

Tanks: Tanks are storage devices for materials with internal pressure under 1.03 bar gauge (15 psig). They come in different shapes (cylindrical, spherical, rectangular, square, etc.) and sizes and may be horizontal or inclined. Spherical and spheroidal tanks are used for fluids with pressures above 5 psig. Hemispherical tanks are used in the pressure range of 2.5 to 15 psig. Gas-blanketed tanks are used to store hazardous feedstocks, reduce air, reduce flammability, and explosive range of vapors. Small tanks are usually fabricated at the shop and shipped to site for installation. However, confined spaces can require that fabrication of small tanks be
done on site. Tanks too big for shipment are erected on site with parts fabricated in shops and shipped to site for assembly. Extremely large tanks may be fabricated completely on site.

*Vessels* are special containers used in processing materials above 1.03 bar gauge (15 psig) pressures and usually at elevated temperatures. Fig. 5 shows the main parts of a horizontal vessel which is also called a drum. Processes such as distillation, cooking, chemical reactions, separation and accumulation occur inside a vessel.

![Fig. 5: Horizontal vessel (Drum)](image)

Tanks and vessels often have attachments such as nozzles, manhole, saddle, caps, etc. The shell is the wall of the tank. The caps form the ends or heads. The nozzle is a short pipe with a flange that provide piping interface. The saddle may be a steel or concrete support that carries the tank or vessel. A steel saddle is anchored to a concrete pad or foundation. The manhole is a special nozzle with an opening 18" or more in diameter that provides access into the tank for maintenance. Carbon steel can be used for a vessel containing non-corrosive material at 100 psi and 300°F. Hasteloy is used in a hot extremely corrosive environment. Vessel wall thickness depends on expected corrosion rate, strength of material, temperature and internal pressure. Vessel design sheets contain selection factors, service, and inspection frequency.

*Towers*: These are tall vertical vessels used to process raw materials into useful products such as distillation of crude oil to obtain various products. In a crude oil distillation tower, as the feed rises in the column, different products are extracted due to varying temperatures and pressures in the column sections. Towers are mounted on a base plate that is bolted to the foundation. The base plate is a flat metal ring that is welded to the bottom of the tower skirt. A skirt is a cylindrical support for a vertical vessel. A skirt access opening of 18" minimum diameter hole at 2'-6" above foundation is provided for workers to enter the tower for inspection and maintenance. Skirt vents of 3" or 4" diameter are provided at the top of the skirt that allows toxic and explosive gases to escape.

*Heat exchangers*: These are devices that allow the transfer of heat between two fluids in separate flow paths. Heat transfer occurs by conduct between the fluid containers and by convection within each fluid. The process fluid is often inside the pipe bundle which is surrounded by the heating fluid. The two fluids do not mix in the process. Heat exchangers may be used to control a chemical reaction or to re-boil a process fluid as is done in a distillation column. The heating fluid is often water or steam but specialized heating fluids are used in some processes where the operating temperature or heat transfer rate cannot be achieved with water. Brass tubes are used in many heat exchangers using water for cooling because they have better heat conductivity and tolerate water with impurities better than carbon steel. Heated fluids normally enter the heat exchanger at the bottom so that the heating fluids enter the equipment at the top. If the heat transfer is between two liquids, a counter flow pattern will usually produce greater overall heat transfer than parallel flow pattern, when other factors are fixed. Heat transfer is maximized when there is large temperature
The difference between the fluids, flow rate is high (maintain turbulent flow) and cross-sectional area is large. Heat exchangers have many different types of design. Their types include pipe coil, double pipe, shell and tube, plate, reboiler, spiral and air-cooled. The shell and tube is the most common and is designed to handle high flow rate in continuous operations. Fig. 6 shows the main parts of a shell and tube heat exchanger.

![Fig. 6: Shell and tube heat exchanger](image)

**Reboiler:** A heater that is used to keep the temperature of the circulating fluid at its boiling point. It replenishes the temperature of a feedstock or process fluid. Fig. 7 shows the main parts of a reboiler. They are used to maintain heat balance in distillation columns or towers and the kettle and thermosyphon reboilers are most common. The kettle-type reboiler design is similar to the shell-tube type heat exchanger.

![Fig. 7: Reboiler](image)

**Condensers:** A condenser is device that converts gas to liquid. Fig. 8 shows the main parts of a condenser. The gas enters the device on one side and comes out on the other side as a liquid. This is a special type of a heat exchanger, usually of the shell-and-tube type. Cooling fluids normally enter the condenser at the top so that the cooled fluids enter the equipment at the bottom. Condensers are commonly used in distillation columns to condense hot vapors into liquid.
Reactors: These are containers usually operated under high pressures and temperatures to convert raw materials into useful products by chemical reactions. Fig. 9 shows the main parts of a reactor. They combine raw materials with catalysts, gases, pressure, and heat to ensure proper reaction. Catalysts enhance chemical reactions by increasing or decreasing the rate of reaction without being consumed in the process. They can also help remove un-required materials from feedstock. Reactor types include stirred tank reactors, fixed bed reactors or converters, fluidized bed reactors, tubular reactors, and reaction furnaces. Stirred tank reactors contain a mixer or agitator that is mounted on the tank. The mixer is used to blend the content in the tank and the tank shell may be heated or cooled; depending on the process requirement. Fixed bed reactors have catalyst beds that are fixed in position so that the reactants are made to pass through them. Fluidized bed reactors employ the counter flow of a gas and suspended particles to separate heavier particles from the
lighter ones. The stream of suspended particles is introduced into the reactor at the side while the gas stream is pumped into the reactor from the base. The counter current agitates the particles so that the heavier ones eventually segregates to the bottom of the reactor and the lighter ones settle on top of the heavier particles. Tubular reactors are a special type of a heat exchanger that is used to control chemical reactions. Depending on the process requirements; they can range from simple jacketed containers to multi-pass shell and tube containers. Reaction furnaces consist of a firebox and a tube array that contain the process feedstock. The firebox provides the heat that is needed for the reactions in the tube array. Reaction furnaces are used for cracking and synthesizing processes.

Design models of reactors may be vertical, horizontal or spherical. Spherical reactors are structurally stronger than cylindrical ones but are more difficult to manufacture and hence costlier. Reactors are designed with serious consideration to corrosion, safety, heating and cooling media, and instrumentation. Reactions can produce corrosive by-products or products that can degrade common construction materials or create hazardous situations. Proper monitoring and control of reactors are therefore of paramount concern. Safety devices such as high-pressure relief valves and alarms, high-temperature alarms, emergency cooling, toxic chemical detection, and fire control units are provided. Instruments are installed to detect and control reaction conditions such as temperature, pressure, feed composition, and flow rates. Other instruments are needed to detect hot spots in catalyst beds, excessive pressure drops and impurities in the feeds or products.

Heaters or Furnaces: Heaters are also called furnaces and Fig. 10 shows the main parts of a furnace. They are used to heat up materials during processing. Furnaces may be grouped into two: direct fired or indirect fired. Combustion gases occupy most of the interior space in direct fired furnaces and examples include cabin, box, and A-framed furnaces. In indirect fired furnaces, the combustion gases are contained in tubes that occupy a small portion of the interior volume of the furnace. Furnaces use a combination of conductive, convective, and radiant heat transfer methods to transfer energy to the charge(s). Combustion is a chemical reaction between a fuel and oxygen. Complete combustion occurs only when the fuel and oxygen are mixed in the right proportion. Primary air enters the furnace through air shutters on the burners. Secondary air enters the furnace through air registers but air can also enter through the stack, peepholes, and cracks on the furnace.

Boiler: A heater that is fired by oil, natural gas or wood and converts water into steam. Boilers use a combination of heat conduction, convection, and radiation to change water into steam. The water tube boiler is the most common large commercial boiler. Fire tube boiler is used also and resembles a shell and tube heat exchanger. Condensates are removed from steam systems using steam traps which may be mechanical or thermostatic. Common mechanical steam traps are the inverted bucket steam trap and float steam trap. Thermostatic steam traps are cheaper and are more frequently used. They can respond to temperature differences between steam and condensate.

Kilns: Kilns are long slightly inclined large diameter vessels used to dry materials. They usually rotate during operations and are common in pulp and paper plants and cement factories.

Mixer: A vessel with a propeller used to mix liquids. It is also called an agitator. The propeller may be attached or removable from the vessel.

Clarifiers: A clarifier is an open tank that receives wastewater and effluents. Slugs are removed from the bottom that tapers toward the center but clarified liquid is obtained from the top over a weir.

Cyclone: A cyclone is a separation device with a stormy motion inside during operation. Materials enter at the base at an angle; the heavier ones fall to the bottom and the lighter ones exit at the top. It is common in the pulp and paper industries.

Evaporator: A device that removes water from liquid chemical compound by steam heating. The processed liquid becomes more concentrated. It is common in the pulp and paper industries.
Filter: A rotating vessel used to separate solids from liquids.

Refiner: A high speed grinding equipment used mainly in the food processing industries to convert coarse grains to fine grains.

Plate 1: Some equipment models with PDMS