Generation-Oahu Division
Operator Trainee Training Program

Section 9
PUMPS

OBJECTIVES:

1. Discuss the basic construction and function of postive displacement pumps
2. Describe the construction and operating principles of centrifugal pumps
3. Describe the operating principles of jet (ejector) pumps.

Section 9
PUMPS

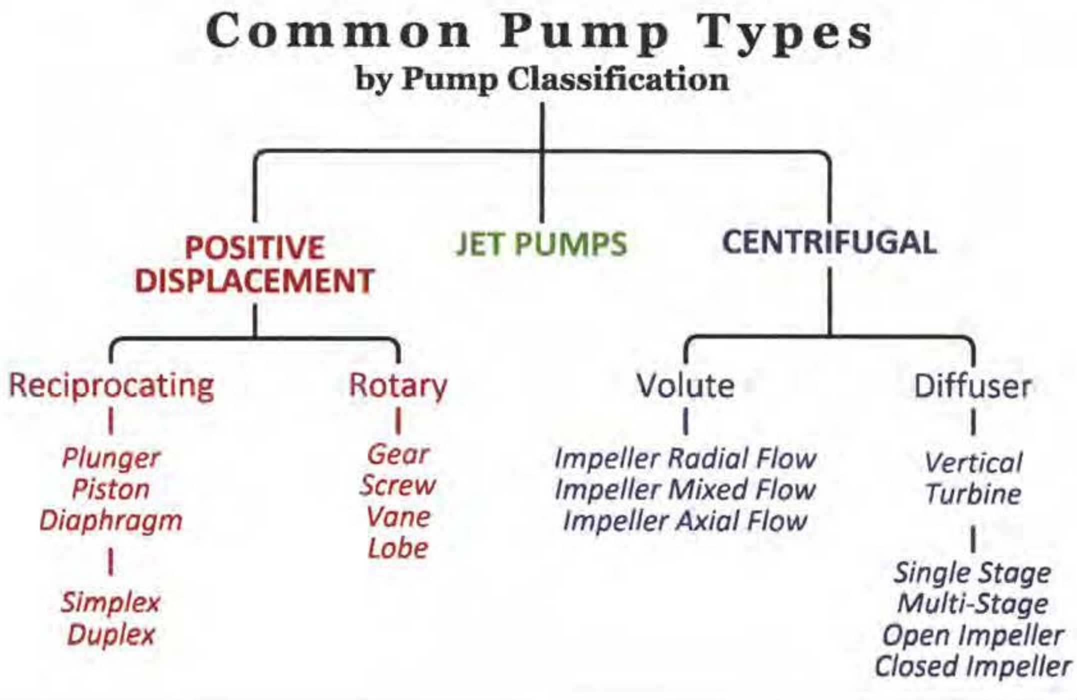
Pumps are one of the most common pieces of mechanical equipment to be found in a power plant. Every operator is involved to some extent with the proper operation of this type of equipment.

There are many different types of pumps available and they utilize different principles in their operation; however, they all have one basic purpose. The purpose of any pump is to add energy to the liquid they are handling in order to raise its pressure. The added pressure permits flow of the liquid through a piping system to some area of lower pressure.

Five of the most common types of pumps will be discussed in this section. The discussion will include their basic construction and operating principles. At the conclusion of this part, details on the centrifugal pump, which is the most common, will be given and some general operating information will be provided.

POSITIVE DISPLACEMENT PUMPS

A positive displacement pump is one in which a constant positive volume of liquid is displaced or moved during each pumping



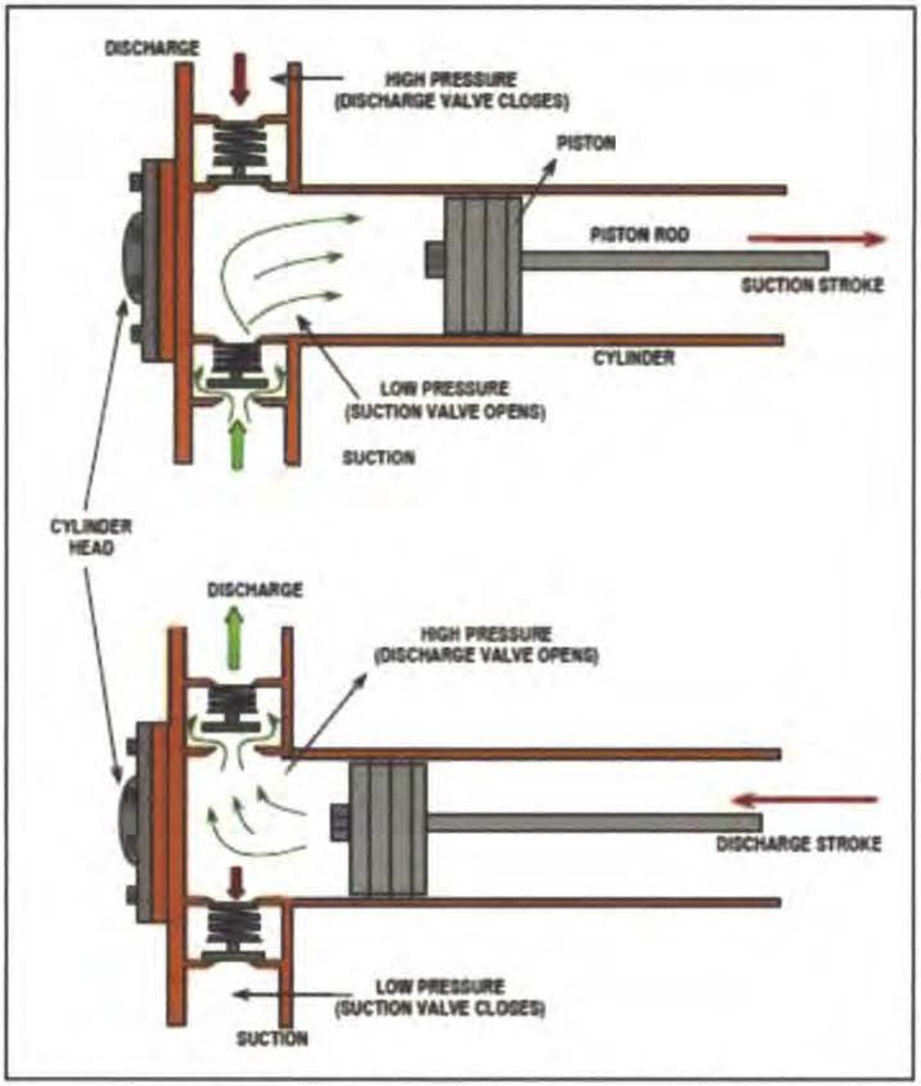


Figure 9-1a Single Acting Reciprocating Pump

cycle. The volume of liquid pumped or moved is equal to the volume displaced by the piston or other moving part. Positive displacement pumps can be further divided into two classes determined by the motion of the pumping element. These types or classes are reciprocating where the motion is back and forth and rotary where rotational motion is used. The reciprocating pump will be considered first.

In a reciprocating pump a piston moves back and forth in a cylinder. Figures 9-1a & 9-1b show diagrams of such a pump. Liquid is forced through the discharge valve as power is applied to the piston. The discharge pressure of the pump is determined by the discharge piping or head and not by the pump. The piston will develop whatever pressure is necessary to cause the liquid to flow from the cylinder through the discharge valve. The discharge pressure is limited only by the mechanical strength of the pump and the power of the driving unit. On many reciprocating pumps there is an air chamber installed on the discharge to make the flow more steady. The air in the chamber is compressed during the discharge stroke. When the piston reaches the end of the stroke, expansion of the air tends to keep the liquid in motion and the pressure up until the next stroke begins. In general, reciprocating

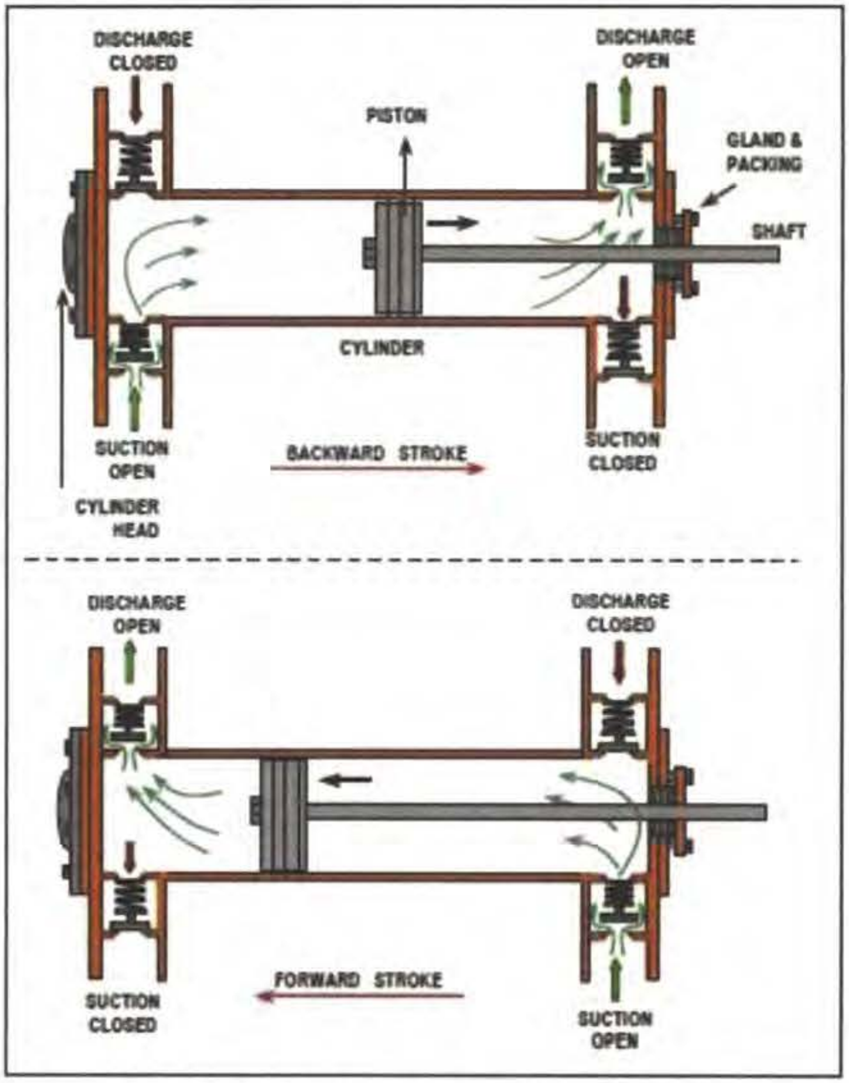


Figure 9-1b Double Acting Reciprocating Pump

pumps are most efficient for relatively small flow rates and high pressures. They are usually operated at slow speeds (40-200 crankshaft RPM) because of the reciprocating motion and the valves. These pumps may be classed as single or double action (see Figures 9-1a & 9-1b) depending on whether one or both ends of the piston are used. In addition, they may be classified according to the number of pistons used. A simplex pump has one, a duplex two, and a triplex three cylinders. The driving mechanism may be a reciprocating device or a motor or turbine in which case the rotary motion of the driver is converted to reciprocating motion by a crankshaft.

In a rotary type of positive displacement pump the action is one of rotation rather than reciprocation. The flow from a rotary pump is fairly steady whereas the flow from the reciprocating pump is pulsating. There arc many different designs of rotary pumps. A few of the more common types are illustrated. Figure 9-2 shows a gear pump. It includes a pair of meshed gears in a casing. As the gears rotate, the liquid is trapped between the gear teeth and the casing is carried around to the discharge. During each revolution of the gears a certain volume of liquid is transferred from suction to discharge. The exact amount depends on the size of the spaces between the gear teeth

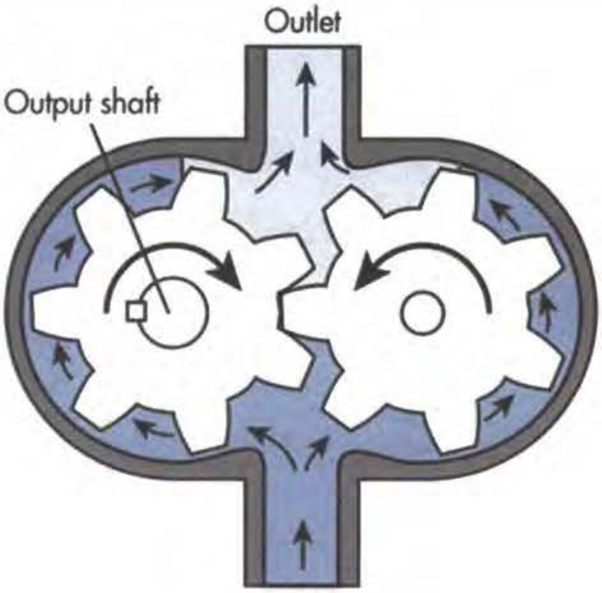


Figure 9-2 Gear Pump

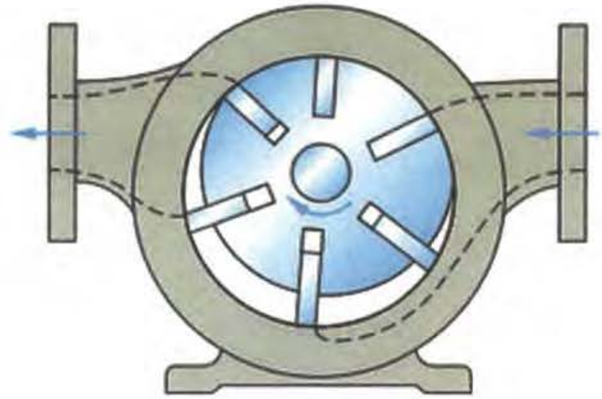


Figure 9-3 Vane Pump

and the case. The pressure developed by a rotary pump is, as with a reciprocating pump, whatever is required to force the liquid through the system. Figure 9-3 shows another type of rotary pump known as a vane pump. The rotating member with its sliding vanes is set off center in the casing. The vanes slide in and out of the rotating part and always stay in contact with the inside of the case. The entering liquid is trapped between the vanes and is carried around to the discharge. Many different designs of lobe type pumps have been devised. A two lobe model is shown in Figure 9-4. The two lobes, mounted on parallel shafts, rotate in opposite directions. A pair of timing gears, located at one end of the shafts, maintains the proper relation between the lobes throughout the rotation. Liquid is drawn into the space between the lobe and the case and is pushed from inlet to outlet.

Screw pumps, an example of which is shown in Figure 9-5, draw the liquid into one or both ends of the rotor where it is trapped in the pockets formed by the threads. It is moved along to the discharge point much like a nut on a thread. Screw pumps may have one, two, or three screws.

When only a single screw is used, liquid enters at one end and is discharged at the other end.

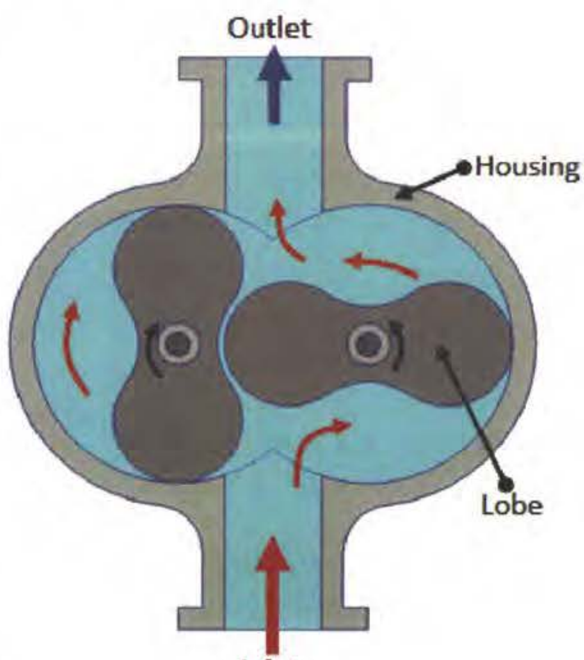
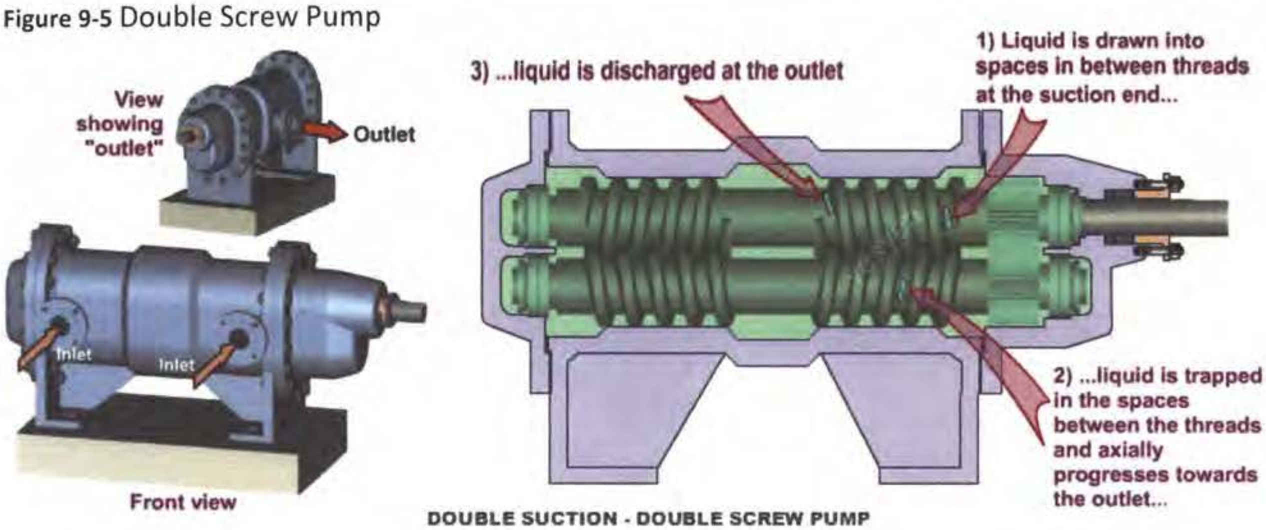


Figure 9-4 Two Lobe Pump

Figure 9-5 Double Screw Pump



JET PUMPS

In a jet pump the pressure of a fluid is increased as it flows through an arrangement of fixed channels. The jet pump has no moving parts. A so-called motive fluid is used to pump some other fluid. These pumps are frequently called by other names such as injector, ejector, evacuator, or aspirator. Figure 9-6 illustrates a simplified jet pump. It consists of a nozzle, inlet line, mixing chamber, and diffuser. The motive or actuating fluid enters the nozzle at a high pressure. The nozzle converts the pressure energy of the motive fluid to velocity. The motive fluid then leaves the nozzle with a very high velocity and low pressure. The low pressure in the mixing chamber causes the liquid being pumped to flow into the mixing chamber through the inlet line. This entering liquid is then entrained and mixed with the high velocity motive fluid. An exchange of energy takes place which in effect slows down the motive fluid and speeds up the incoming liquid. The mixture still has quite a high velocity as it enters the diffuser section. In this section, the velocity energy of the mixture is converted to pressure energy by slowing down. The discharge consists of a mixture of the two fluids at a pressure that is higher than the liquid inlet pressure but

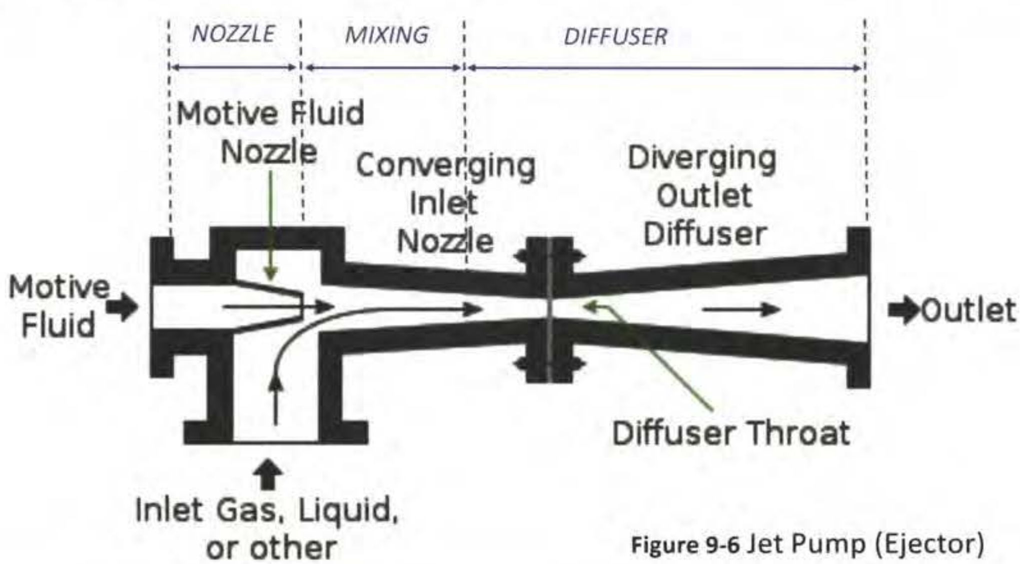
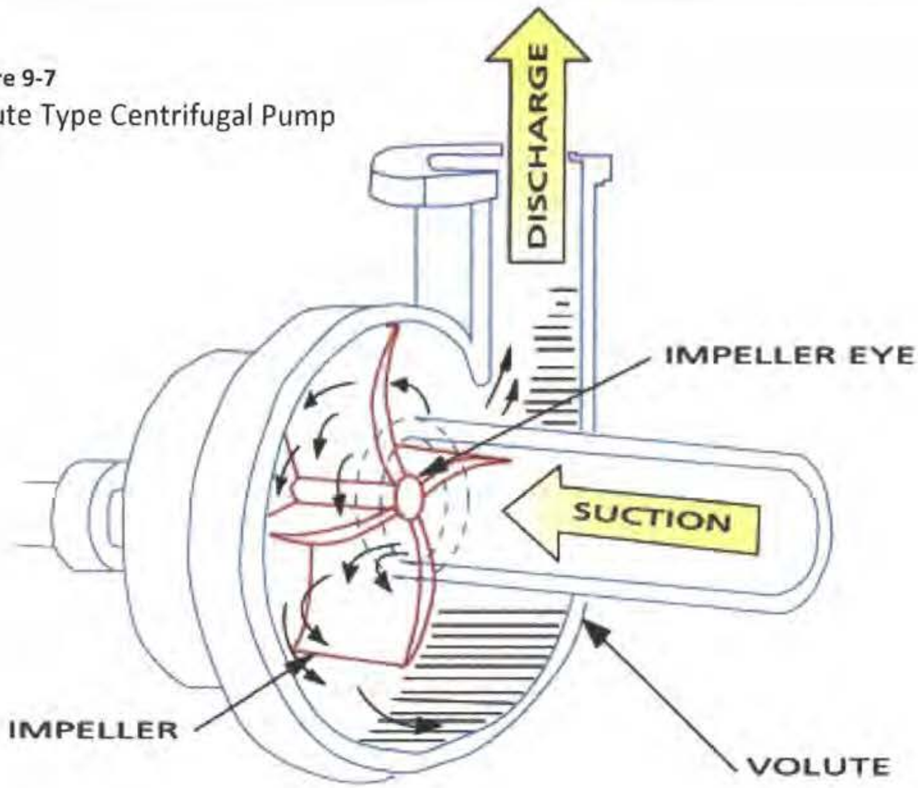


Figure 9-6 Jet Pump (Ejector)

Figure 9-7
Volute Type Centrifugal Pump



lower than the motive fluid inlet pressure. Different fluids may be used to supply the motive power and they can pump different fluids. For example, in the steam jet air ejector, steam is the motive fluid used to pump air from the condenser. In some main turbine hydraulic systems, oil is used as both the motive fluid and the pumped fluid.

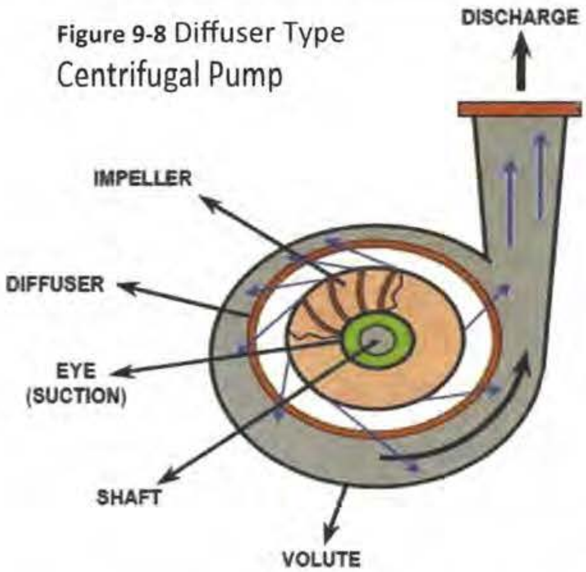
CENTRIFUGAL PUMPS

Centrifugal pumps are one of the most popular types because of their simplicity, compactness, low cost, and ability to operate under a wide variety of conditions. The action in a centrifugal pump depends mostly upon centrifugal force due to rotation. Centrifugal force is the name given to the force that tends to move a rotating body away from the center of rotation. Every piece of rotating equipment has centrifugal force acting on it. The amount of force produced depends on the weight of the body, its distance from the center rotation, and the speed of rotation.

The essential parts of a centrifugal pump are a rotating member with vanes, called the impeller, and a case surrounding it. The impeller may be driven by an electric motor, steam turbine, or internal combustion engine. Figure 9-7 shows a simple centrifugal pump. In this figure, liquid is led through the inlet or suction line to the center or eye of the rotating impeller. The rotating impeller throws the liquid out into the volute section from where it is led through the discharge nozzle to the discharge piping. The fluid leaves the impeller with a high velocity. An important function of the pump flow passages, such as the volute and nozzle, is to efficiently convert the kinetic energy of the liquid to pressure.

Centrifugal pumps are sometimes classified as volute type pumps or diffuser type pumps. Figure 9-7 shows a volute type pump in which the liquid is discharged directly into the volute from the impeller. In the diffuser type of pump, shown in Figure 9-8, there is a

Figure 9-8 Diffuser Type Centrifugal Pump



diffuser, consisting of a series of fixed guide vanes, surrounding the impeller. The function of the diffuser is to guide the liquid and reduce its velocity. There is a reduction in kinetic energy and an increase in static pressure in the diffuser. The diffuser tends to make the static pressure distribution around the impeller more uniform.

The centrifugal pump differs from the reciprocating pump in many respects. The discharge valve of a centrifugal pump can be closed without causing the pressure to rise above a certain value. If the discharge valve is closed, the rotating impeller simply chums and heats up the liquid. If the discharge valve of a reciprocating pump is closed, the pump would stop or something would burst. The discharge from a centrifugal pump is relatively smooth and steady where the reciprocating pump discharge is pulsating.

Centrifugal pumps are built with many different arrangements of impellers and with many other variations in the details of construction. In the single suction pump, liquid enters the impeller eye from one side only. In the double suction pump, liquid enters from both sides of the impeller. A pump may be staged with several impellers on one shaft, thus making it essentially several pumps in series. In a two stage pump, for example, two impellers are mounted on the same shaft. The discharge from the first impeller enters the inlet of the second impeller. Each stage of the pump increases the pressure. Very high pressures are available by the use of many stages.

AXIAL FLOW PUMPS

In axial flow pumps the flow of liquid is along or parallel to the axis of rotation or the shaft. This is completely different from the centrifugal pump which is a radial flow pump. In the centrifugal pump the flow is radially outward from the shaft or axis. Axial flow

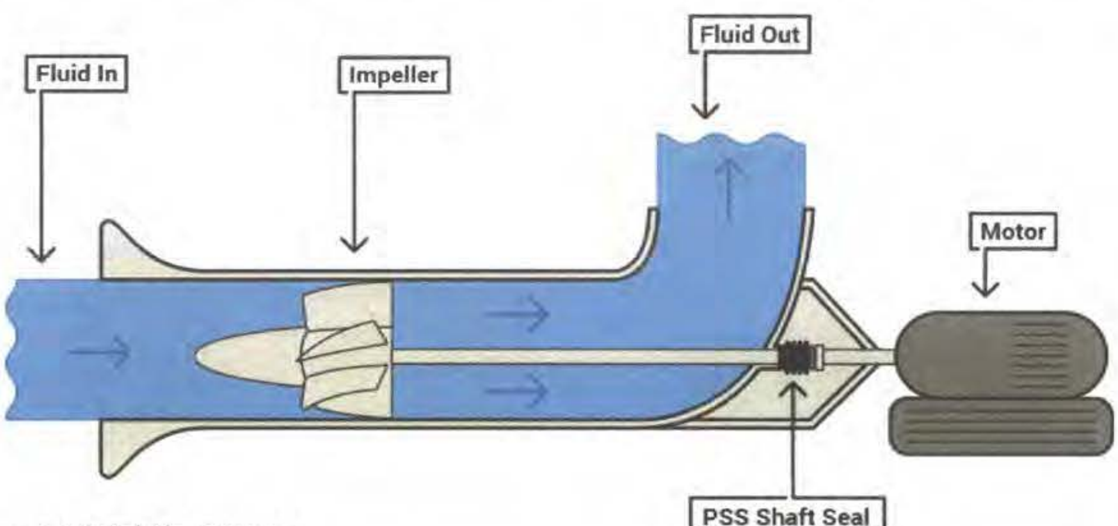


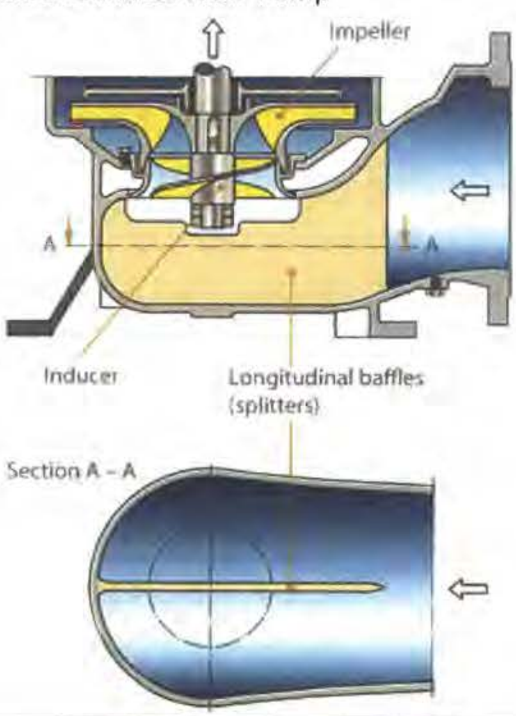
Figure 9-9 Axial Flow Pump

pumps are best suited for large volume flow rates and low pressure increases. An axial flow pump may consist of a single runner in a cylindrical case, or it may consist of a runner with one or two sets of fixed guide vanes. This type of pump develops pressure by having the runner blades shaped u air foil sections like an airplane propeller. The shape or inclined angle of the rotating blades produces a force on the liquid, thereby raising its pressure. Figure 9-9 shows a simplified schematic diagram of an axial flow pump. This type of pump is seldom used in a power plant.

MIXED FLOW PUMPS

Mixed flow is the name given to pumps that combine the radial flow of centrifugal pumps with axial flow. In the mixed flow pump the liquid enters the impeller in an axial direction and discharges in both an axial and radial direction usually into a volute type casing. The discharge pressure is developed partly by centrifugal action and partly by the dynamic lift of the impeller on the liquid. The action in a mixed flow impeller is shown in Figure 9-10. This type of pump is frequently used for circulating water pump service in power plants. In this application the pump is installed vertically with the suction submerged in the water at all times. These pumps deliver large flow rates at medium head with a low rotational speed.

Figure 9-10 Mixed Flow Pump



CENTRIFUGAL PUMP DETAILS

The basic theory and construction of centrifugal pumps has been discussed. The following discussion will cover some of the more detailed parts of the pump with which the operator is most concerned. The topics to be covered include shaft sealing, bearings, and hydraulic balance.

Shaft Sealing

Since centrifugal pumps operate with a wide range of pressures, from high vacuum to very high pressure, it is necessary to have a positive seal where the shaft penetrates the case. If the shaft is not sealed, there may be leakage of air into the pump or leakage of water out of the pump. There are many different sealing methods in use. The choice depends among other things on the pressure and temperature of the liquid being pumped and the size of the pump. The simplest type of seal is the stuffing box. This method is used on most smaller pumps and when the pressure is low. The stuffing box consists of an annular space in the casing around the shaft. Rings of packing material are placed in this space. The packing rings are compressed and held in place by a follower or gland. The gland is in turn held in place by studs with adjusting nuts. A simple stuffing box is shown in Figure 9-11. As the adjusting nuts are tightened, they move the gland in and compress the packing. This in effect squeezes the packing out radially making a tight seal between the rotating shaft and the inside wall of the stuffing box. The shaft is rotating

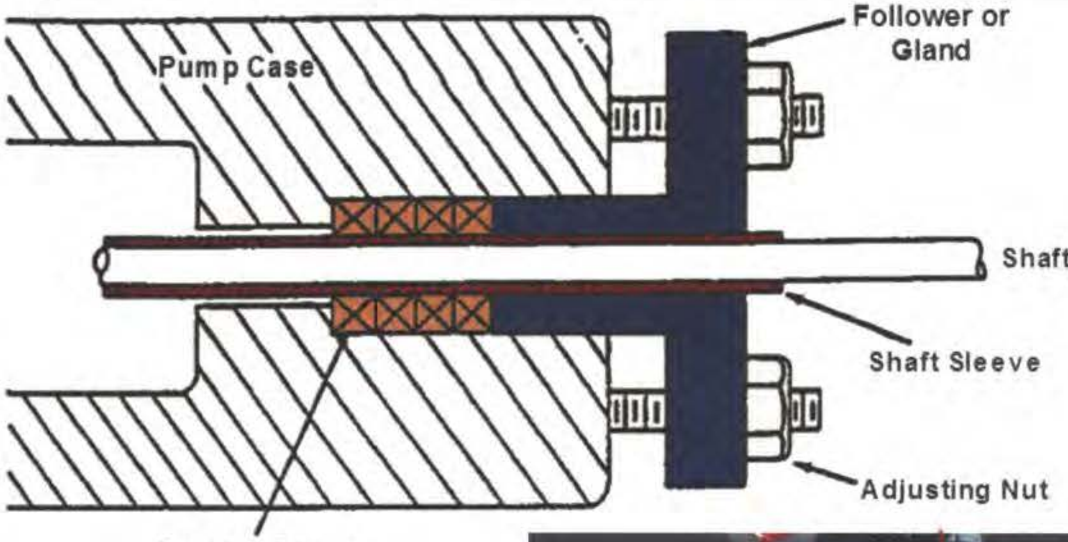
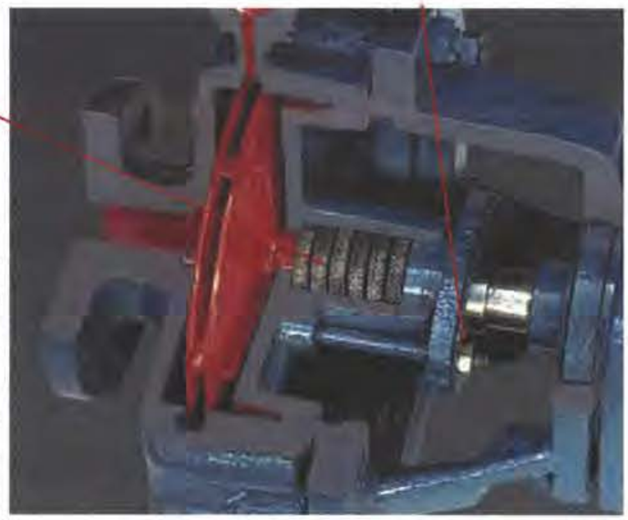


Figure 9-11 Stuffing Box



at a high speed and is rubbing against the packing which causes a lot of friction.

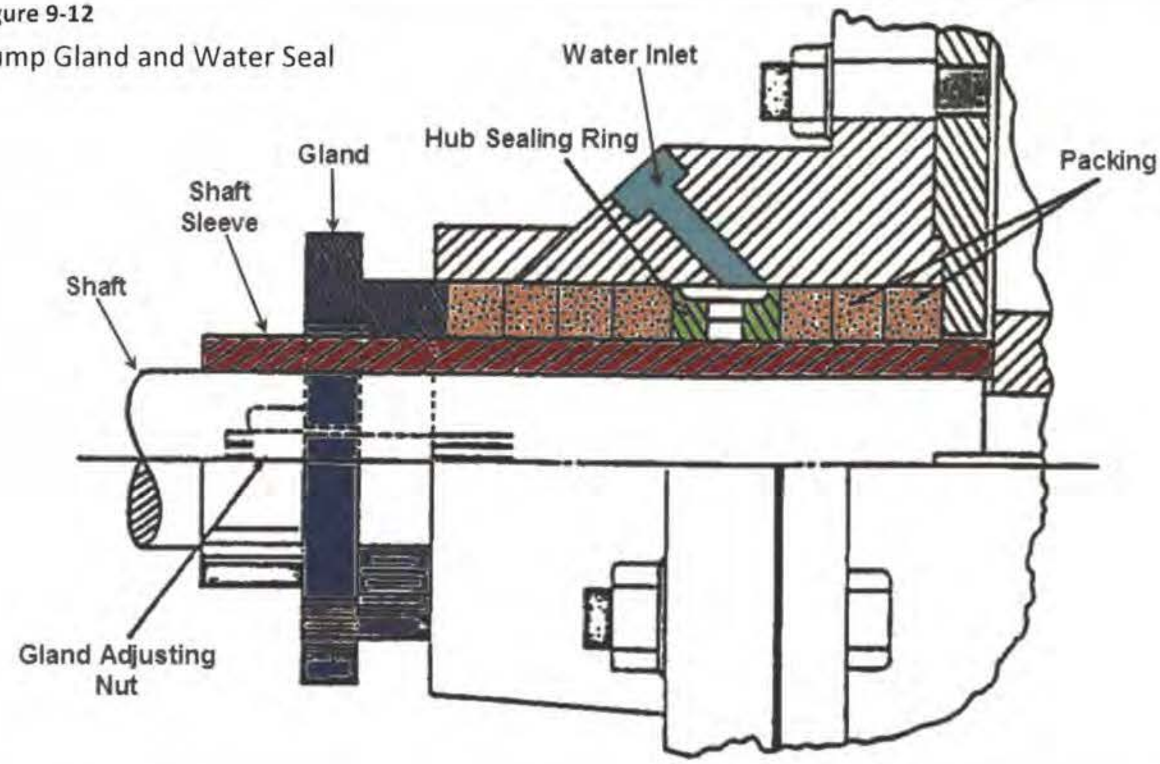
If there is no lubrication, the packing will quickly burn up and can seriously damage the shaft. Lubrication is normally provided by keeping the gland loose enough so that a small flow of water leaks out of the pump. The water acts as a lubricant and keeps the packing cool. The gland should only be adjusted while the pump is running so that the leakage flow can be observed. The nuts should be adjusted evenly and only a small amount at a time. This method of sealing cannot always be used.

If the pump suction is under a vacuum so that leakage outward is impossible or if the liquid is too hot to provide adequate packing cooling, a different type of seal must be used. Usually, in these cases a supply of cool, clean water is piped to the stuffing box. This water, known as cooling or sealing water, is injected through a drilled passage in the case into a ring usually located at approximately the center of the box. The ring, known as a lantern ring or sealing ring. is usually constructed of metal made in a skeleton design. The ring distributes the sealing water uniformly around the shaft. This type of seal is shown in Figure 9-12. To insure that sealing water flows in both directions along the shaft the sealing water pressure should be approximately 10 psi higher pressure than the pump suction pressure.

With pumps in the highest pressure range, namely, boiler feed pumps, the pressure is frequently too high to permit use of regular packing. To handle this situation so-called packless stuffing boxes have been developed. These are quite similar to the water injection seal shown in Figure 9-12 except that the rings of packing material are replaced by a metallic breakdown bushing. This bushing acts as a labyrinth and forces the water to travel a tortuous path, thereby reducing its pressure. Sealing water is injected into a lantern ring in this bushing. In this type of seal there is no contact between the bushing

Figure 9-12

Pump Gland and Water Seal



and the shaft. The clearance, however, is kept very small. The type of seal used on many of the newest pumps under all service conditions is the mechanical seal. This seal differs from the packless seal discussed previously in that there is definite contact between the seal and the shaft. The usual mechanical seal consists of two basic parts, one rotating and one stationary. The rotating part is attached to the shaft and is in contact with the stationary part of the seal. A slight pressure between these parts is maintained by a spring. The mating surfaces must be perfectly flat and smooth. Lubrication must be supplied at this scaling surface and it can be either the liquid in the pump or from some separate source. Frequently, a separate external supply of water is used to cool the seal. The cooling water is usually in a closed circuit and does not mix with the liquid in the pump.

Pump Shafts

One of the most important and expensive

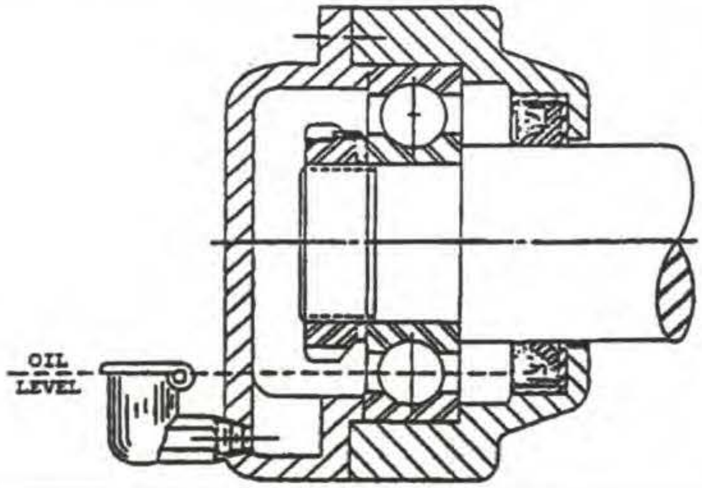


Figure 9-13—Oil Lubricated Ball Bearing

This illustration shows the application of a simple oil cup, providing a positive controlled supply of oil. The top of the oil cup should be located in such a position that the oil level will reach to the middle of the lowest ball. This type of oil cup requires frequent inspection and refilling to maintain the oil level.

parts of a large pump is the shaft. These shafts are usually protected against wear, particularly in the area of the seal by shaft sleeves. The sleeve is made of hardened steel and is installed over the shaft to protect it.

Pump Bearings

Many different types of bearings are used with centrifugal pumps. Ball and roller bearings are common in smaller pumps while babbitted sleeve bearings are used on large pumps. Any bearing will only perform its job satisfactorily if it has proper lubrication. Ball and roller bearings may be lubricated by either oil or grease. Sleeve bearings are always oil lubricated. Oil lubricated ball and roller bearings have a small storage space and level indicator as part of the bearing housing. A grease fitting is supplied for grease lubricated bearings. Figures 9-13 and 9-14 show typical oil and grease lubricated ball bearing applications. Sleeve bearings usually have a separate circulating lube oil system. The oil is circulated by a pump through the bearings and a lube oil cooler back to a reservoir. The oil pump is frequently mounted on the main pump shaft, in which case a small motor driven auxiliary oil pump is provided for startup and shutdown.

Hydraulic Balance

Since the pressure of the liquid is constantly increasing from inlet to discharge, it is possible to produce unbalanced hydraulic forces acting on the rotating shaft. The pressure on the discharge side of each impeller is considerably greater than the pressure on the inlet side. For a multistage pump these unbalanced forces can produce a large thrust toward the suction of the pump. A thrust bearing is used to compensate for this thrust; however, in large multistage pumps such as boiler feed pumps, a very large thrust bearing would be required. To reduce the load on this bearing and therefore reduce its size, other methods of balancing the hydraulic forces are used. If the pump has an even number of impellers, half of them can be mounted facing in one direction and half in the other direction thereby balancing the thrust. This method complicates the design and construction of the pump and is seldom used. The most common method is to provide a balancing disc or balancing drum at the discharge end of the pump. This device is mounted on the shaft and has one side exposed to discharge pressure while the other side is essentially at suction pressure.

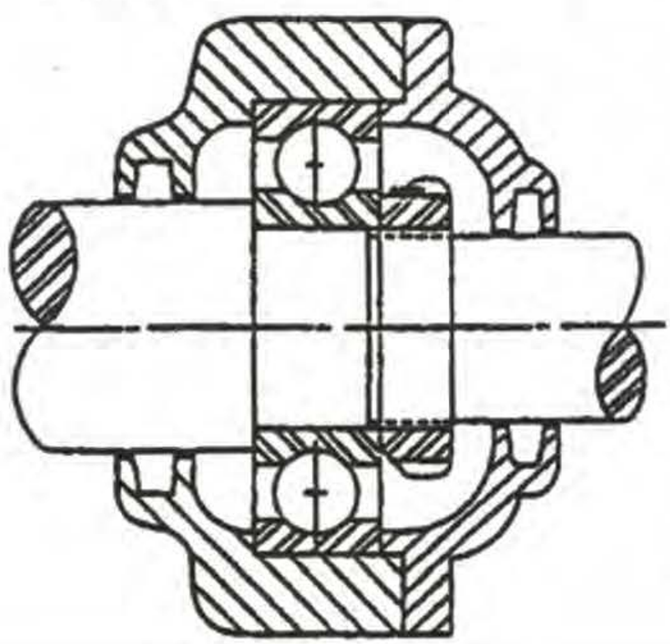


FIGURE 9-14—Grease Lubricated Ball Bearing

This housing has no provision for periodic greasing and is often used in those applications where speeds are low, the loads light and the service intermittent. Such service requires a charge of lubricant at very infrequent intervals and the bearing is therefore lubricated only when the unit is disassembled for overhaul or inspection. At such times a cleaning of housing and bearing are usually necessary.

If quite frequent lubrication is necessary it may be advisable to drill and tap the end cover for a grease fitting and drain hole during one of these disassembly periods.

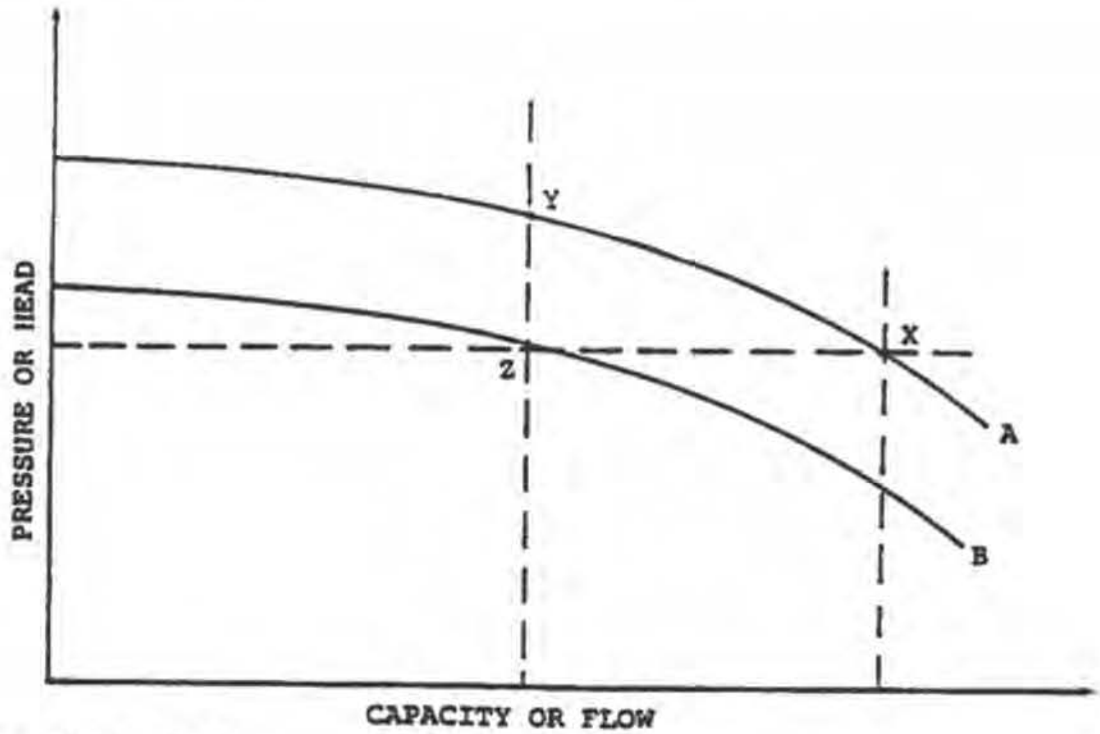


Figure 9-15 Pump Curve

The difference in pressure across the device produces a strong force toward the discharge end of the pump. This force balances out the thrust due to the impellers. The low pressure side of the balancing chamber is usually connected to the pump suction through an orifice. The pressure drop across the orifice is usually indicated and is used as a good measure of pump internal condition. Any large change in this pressure drop should be investigated. While small single stage pumps do not experience very large axial forces, they can develop quite large unbalanced radial forces. A volute type pump, particularly when operating at reduced capacity, is subjected to these forces. They result from the unequal pressure distribution around the volute.

These radial forces can be large enough to bend the pump shaft. Operation of volute type pumps at reduced capacities should be limited to as short a time as possible.

PUMP OPERATION

The operation of the various pumps in a power plant depends to a great extent on the particular pump and its related piping system. There are some general operating principles, however, that apply to all pumps. These general principles are discussed below.

Depending on its design and construction, every pump has certain characteristics. The pump characteristic curve relates the flow or capacity of the pump to the pressure or head it produces. A typical curve of this type for a centrifugal pump is shown in Figure 9-15. The curve A shows the pressure versus flow characteristic for one constant speed of the pump. Most pumps are driven by electric motors, which means they operate at essentially constant speed. As long as the speed is constant, the pump must operate at some point on this curve.

The exact operating point is determined by the pressure in the system. Flow is changed by making a change in pressure, usually by adjusting a valve in the discharge piping. If, for example, the pump is operating at point X and the discharge valve is then closed a bit, the pressure will increase. This will cause the pump's operating point to move along the curve to point Y. The flow at point Y is less than at point X. This is the most common method of flow control for centrifugal pumps. Another common method of flow control requires changing the speed of the pump. Curve B on the same figure represents a lower speed. This method is used when the pump is driven by a steam turbine or fluid coupling. If the pump is operating at point X and we wish to reduce the flow to that at point Y, we slow down the pump and it will now operate on curve B. The pressure has not changed, and the pump will now be operating at point Z on curve B. Another method of flow control which is occasionally used. This method maintains a constant flow through the pumps at all times but bypasses the unneeded portion of the flow back to the pump suction. By operating a valve in the bypass line more or less of the total flow can be bypassed, thereby controlling the flow to the system. The last method is changing the suction pressure. Increasing the suction diameter increases the discharge pressure while decreasing the suction diameter decreases the discharge pressure. Regardless of which method is used, it is this ability to change flow that makes centrifugal pumps so useful.

In order for a centrifugal pump to operate satisfactorily it must be completely filled with water prior to starting and must remain full during operation. In general, if the pump suction is under a positive pressure, there is no problem. It is only necessary to open the suction valve and the pump casing vent valve. Water from the suction supply will fill the casing and force all the air out the vent. It is helpful to close and open the vent valve several times to insure that all the air is removed. No special precautions are required while the pump is running since the entire pump casing is pressurized which precludes the possibility of air entering.

In cases where the pump suction is under a vacuum, as with condensate pumps, more precautions are necessary. The condensate pumps are always located at an elevation lower than the hotwell. The pump cannot be vented to atmosphere since this would only result in pulling air into the condenser. Condensate pumps are always vented to the main condenser. Considerable care must be exercised when filling a pump to be sure that the air vented from the casing does not upset the other condensate pumps. This is particularly important when a common vent line is used. Since it does vent back to the condenser in a closed system, it is not possible to observe when a condensate pump is filled; therefore, sufficient time should be allowed to insure that all the air is removed. While running, the pump suction remains under a vacuum and care must be taken to prevent air in leakage. This requires careful adjustment of the packing and a positive supply of sealing water. A frequent source of leakage is the pump suction valve packing which should be inspected frequently. In some cases this packing is also water-sealed. In some installations a small, operating vent to the main condenser is provided. This vent should remain open at all times to prevent the accumulation of air in the pump casing.

Another filling situation arises when the pump is located at an elevation above its suction supply. In this case the suction pipe extends down from the pump to the suction supply. Some means of getting water up into the pump casing must be provided. There are two general methods of accomplishing this requirement. On smaller pumps, an automatic valve, known as a foot valve is installed at the bottom of the suction pipe below water level. The foot valve is essentially a check valve that allows flow up the suction pipe toward the pump but prevents flow down the pipe away from the pump. A separate supply of water is provided to initially fill the suction pipe and pump for starting. This is known as priming the pump. Once the pump is running, it will maintain its own prime providing no air leaks are present since the pump suction is under a vacuum. When the pump is shut down, it will stay full of water since the foot valve prevents drainage. If the pump remains shut down for some time, it may be necessary to prime it again due to slight leakage past the foot valve. On larger pumps it is impractical to use a foot valve, and a vacuum priming system is used. This system includes a vacuum priming tank which is maintained at a high vacuum by a mechanical vacuum pump. The tank is connected to the pump casing. To fill the pump for starting, a valve in the line from the pump to the tank is opened. This puts the pump casing under a vacuum and draws water up the suction pipe and into the pump. Once the pump is full and running, it will maintain its own prime. In some cases an automatic float valve is used to provide continual removal of air from the pump casing. This valve allows air to pass freely to the vacuum priming tank from the pump but shuts off when water enters the valve.

Pumps handling hot water should always be warmed up slowly prior to starting. This prevents the possibility of high thermal stresses due to rapid temperature changes. Warmup is usually accomplished by circulating a small flow of hot water through the pump. Prior to starting the pump, metal temperature should be within 100°F of the water temperature. The warming supply usually comes from the pump discharge, flows through the pump, and returns to the pump suction. It is important that the suction valve be open while warming up to insure a flow and prevent overpressurizing the suction piping.

For any centrifugal pump there is a definite minimum flow that must be maintained. If flow is reduced below this minimum, excessive churning of the water occurs which results in heating up the water. Continued operation under these conditions can result in vaporizing the water to steam. This is known as flashing the pump and must be avoided. When a pump flashes, it becomes vapor-bound and ceases to operate. It is also very likely to overheat and result in rubbing or even seizing. A satisfactory minimum flow is best assured by providing an automatic recirculation system. This system automatically opens a recirculation valve in a line which leads from the pump discharge back to the suction. When flow decreases to the minimum allowable value, the recirculation valve automatically opens and maintains at least minimum flow. When flow to the system increases to above the minimum, the valve automatically closes. In smaller pumps where an automatic system is not practical, a permanent, always open, recirculation line is frequently provided.

Most centrifugal pumps are provided with a check valve in the discharge piping. When a pump is shut down, the check valve should close and prevent reverse flow through the pump. Reverse flow can cause the pump to rotate backwards and result in considerable damage to the pump or the driver. When shutting down a pump, it is good practice to observe the pump shaft to insure that the check valve has closed and the pump is not running backwards. If the check valve does stick and the pump starts to run backwards, it should not be restarted since this would overload and possibly damage the driver. In this case the discharge stop valve should be closed as quickly as possible.

Section 9
PUMPS
Study Questions

1. All pumps have one basic purpose. That purpose is ____________________________

   ____.

2. Two types of Positive Displacement Pumps are the Reciprocating type and the Rotary type.
   True \ False

3. In a reciprocating pump, a piston moves ____________________.

   a. up and down c. in a circular motion

   b. back and forth d. none of these

4. The flow from a rotary pump is pulsating, while the flow from a reciprocating pump is fairly steady. True \ False

5. Name at least three (3) rotary type positive displacement pumps.

   a.

   b.

   c.

6. Reciprocating pumps are most efficient for relatively small flow rates and high pressures.
   True \ False

7. Because of their simplicity, compactness, low cost, and ability to operate under a wide variety of conditions, ____________________________________ pumps are one of the most popular types.

8. Rotary pumps may be classified according to the number of pistons used. True \ False

9. An essential part of a centrifugal pump is a rotating member with vanes called the ______________________.

10. If the discharge valve of a centrifugal pump is closed, the pump will stop or something will burst. True \ False

11. In the axial flow pump, the flow of liquid is________________.
    a. around the axis of rotation c. both of these
    b. parallel to the shaft

12. Pumps that combine the radial flow of centrifugal pumps with axial flow and are frequently used for circulating water pump service in power plants are called ______________________.

13. What is the purpose of a shaft sleeve?

14. Sleeve bearings may be lubricated by either oil or grease while ball and roller bearings are always oil lubricated. True \ False

15. The most common method for maintaining hydraulic balance within a centrifugal pump is to provide a ____________________ ____________________ at the discharge end of the pump.

16. For the centrifugal pump to operate satisfactorily, it must ___________________.
    a. have pump suction under a positive pressure.
    b. be full of water during operation
    c. be filled with water prior to starting
    d. all of the above

17. When a pump flashes, it becomes vapor-bound and ceases to operate. True \ False