UNIT 1

PUMPS

Unit Outcome

When you complete this unit you will be able to…

Describe the various types of pumps found in buildings and industrial plants.

Lesson Objectives

Here is what you will be able to do when you complete each lesson.

1. List common applications of pumps in the power industry.
2. Define the terms associated with pump performance.
3. Sketch and describe the common types of pumps used in the power industry.

Introduction

One of the first pieces of powered machinery to be invented at the dawn of the industrial age was a crude form of pump. The pump has since evolved into an endless variety of types, sizes, and applications. This unit will give an overview of the general types of pumps that are in common use in buildings and industrial plants.

Operators should become familiar with the diversity of pumps that are in existence as they may be required to safely operate pumps in the normal course of their daily routines. A functional understanding of pumps, their use, and application, is essential to understanding how most processes are handled in plants today.

LESSON 1

Definition, Application and Location

1- Definition

A pump is a mechanism that is used to transfer a liquid from one place to another by imparting energy to the liquid being transferred.

2- Applications

Pumps are used in numerous locations for many purposes. A car may contain several different types of pumps: one pumping fuel, one pumping lubricating oil, one pumping engine coolant, possibly another pumping high pressure hydraulic fluid for power steering, and a hydraulic pump attached to a foot-pedal which activates the brakes.

Pumps are employed to move materials ranging from molten metals at very high temperatures, to cryogenic materials at extremely low temperatures. They are used to generate pressures so small as to be barely perceptible or pressures so high that the liquid being pumped is capable of cutting through material as though it were a saw. Also, they are designed to supply quantities from as small as one drop per day to four billion litres per day. They have power requirements from a few watts to nearly 75 megawatts.

Some of the more common types of pumps required in industrial plants are:

1. Boiler feedwater pump - supplies the boiler with feedwater as required. It must be capable of forcing this water into the boiler against the pressure existing in the boiler.
2. Fuel oil pump - used in oil-fired boilers to pump fuel oil to the burners.
3. Lubricating oil pump - used to circulate oil to the bearings of a machine such as a turbine, engine, pump, or compressor.
4. Circulating water pump - also called a cooling water pump. It is used to pump water through a heat exchanger such as a condenser or an oil cooler.
5. Chemical feed pump - small capacity units are used to pump chemicals into boilers; larger units are used as process pumps.
6. Fire pump - used to supply water to plant fire lines.
7. Domestic water pump - used to supply water to plant washrooms, etc.

3- Pump Location

Pumps may be small enough to be suspended by the pipework that they are servicing, but are usually anchored to a firm location. Large pumps are supported by reinforced concrete foundations for stability and vibration control. Pumps are generally located where they can be easily accessed for operation and maintenance, however, some pumps may be on the bottom of a lake, down a well, or on the inside of a pipeline or vessel.

4- Pump Drives

The source of power for a pump could be an electric motor, a gas or diesel internal combustion engine, a gas, water, or steam turbine, a steam engine, or a steam operated piston. Small pumps may be operated by hand or foot, by air pressure or another fluid pressure, or an electromagnet.

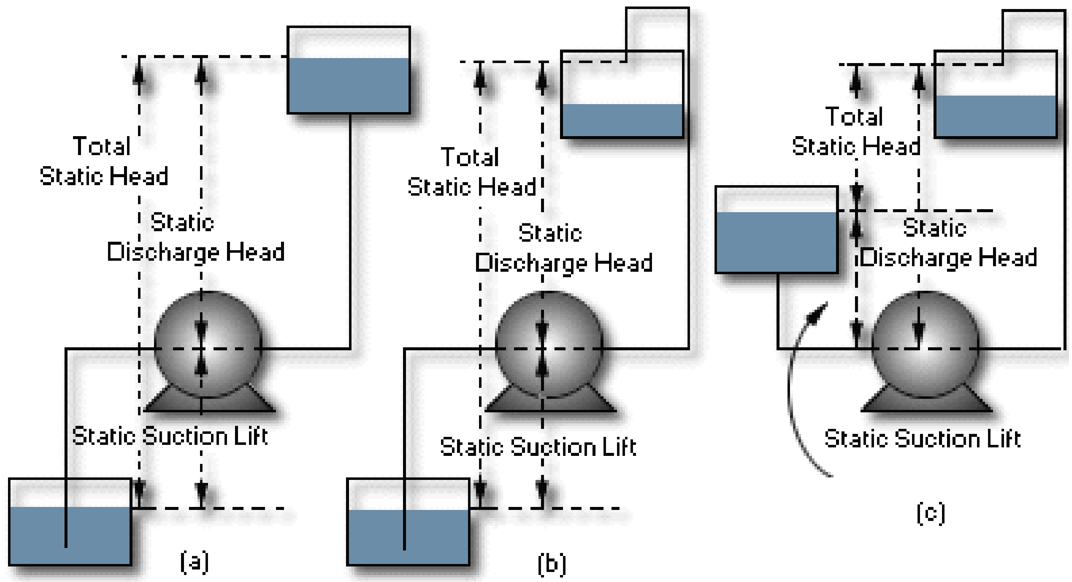
LESSON 2

Theory of Pumping

1- Static Suction Lift

Let us assume that a pump is used to move a certain amount of water and that this pump is located above its source of supply which may be a pond, tank or other source (Fig. 1(a)). The pump has to lift the water through the suction line. The distance, measured vertically, that the intake of the pump is placed above the surface of the water is called the static suction lift.

Figure 1. Static Suction Lift



The pump is able to lift water because of the downward pressure of the air or atmosphere on the surface of the water in the supply tank or pond.

When a pump is started, the plungers or pistons, moving to and fro, exhaust the air from the pumps body and create a partial vacuum in the pump cylinders and suction pipe whereupon the atmospheric pressure on the surface of the water in the supply tank, being now unbalanced, forces water up the suction pipe and into the pump.

The revolving impellers in a centrifugal pump also exhaust the air from the pump body and suction pipe to some extent but, as they are not an airtight fit, the vacuum obtained is not very high, hence the reason for placing centrifugal pumps either close to or below the surface level of the water supply.

Rotary pumps, due to the close clearances between the casing and the lobes, vanes, etc., are quite efficient in regard to lifting water.

We have learned that the atmospheric pressure varies with the altitude or height above sea level. At sea level, the pressure is approximately 101.3 kilopascals (14.7 psi) or 760 millimetres of mercury (30 inches) which is equivalent to the pressure exerted by a column of water 10.34 metres (34 feet) high. At an altitude of 1100 metres (3600 ft) the atmospheric pressure is only approximately 89 kpa (12.9 psi) or 667.7 mm Hg (26.35 inches of mercury) which is equivalent to approximately 9.1 metres (29.8 feet) of water.

Theoretically, the maximum lift of a pump figures out at 10.34 metres at sea level and 9.1 metres at 1100 metres altitude, but in practice this cannot be attained because of friction in the pump and piping, and leakage past the piston or plunger and valves. At this high altitude, a reciprocating pump would be doing very well to lift water 6 metres, (say 20 feet) but no pump should be set very high above the water supply if it is at all possible to set it lower. Centrifugal pumps, particularly, have a much poorer suction than piston or plunger pumps and should always be placed close to, or preferably below the water supply.

2- Static Discharge Head

The vertical distance, in metres or in feet, from the centre line of the pump to the free surface of the water in the discharge tank is called the static discharge head.

3- Total Static Head

The vertical distance from the surface of the source of supply to the surface of the water in the discharge tank is called the total static head. This is the sum of static suction lift plus static discharge head, thus it is the total height the water is raised by the pump.

When the water is discharged above the level of the water in the tank, the discharge head is measured from the centre line of the pump to the point of free discharge (Fig. 1(b)).

4- Static Suction Head

In many pump systems the source of supply is located above the pump and the water flows toward the pump by gravity (Fig. 1(c)). The distance from the free surface of the supply tank to the centre line of the pump is called the static suction head and the total static head is then the difference between static discharge head and static suction head.

5- Friction Head

When the pump puts the water in motion, this water will meet resistance in the pipes, valves and fittings. To overcome this resistance a certain amount of pressure is required. This pressure is called the friction head and is also expressed in metres or feet of water.

6- Velocity Head

A force is required to put the water in motion. This is called the velocity head.

7- Pressure or Equivalent Head

When the pump discharges the water into a vessel under pressure, such as a boiler, it has to impart additional pressure to the water in order to overcome the boiler pressure. This extra pressure is called the pressure or equivalent head.

8- Dynamic Head

Friction, velocity and pressure head are required to move the water from the source of supply into the discharge vessel. For this reason we call the sum of these heads the dynamic (force in motion) head.

9- Total Head

The total head required to move the water from the source of supply to the point of discharge is the sum of static and dynamic head.

The power required to drive a pump is determined by the amount of liquid pumped and the total head against which the pump operates.

LESSON 3

Types of pumps

Pumps can be broadly classified into three groups: reciprocating, rotary, and centrifugal.

1- Reciprocating Pumps

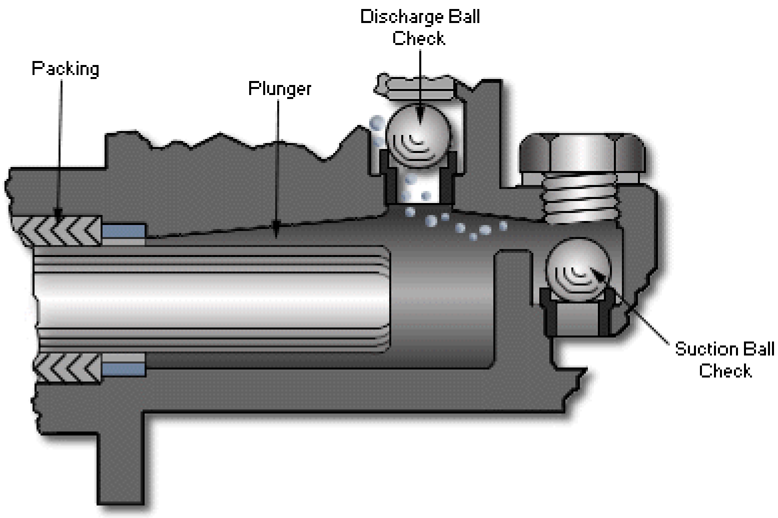
In this type of pump the pumping action is produced by the to and fro (reciprocating) movement of a piston or plunger within a cylinder. The liquid being pumped is drawn into the cylinder through one or more suction valves and then forced out through one or more discharge valves by direct contact with the piston or plunger.

Fig. 2 illustrates a plunger type reciprocating pump while Fig. 3 shows the piston type.

Referring to Fig. 2, when the plunger moves from right to left the liquid is drawn into the cylinder through the suction ball check. When the plunger reverses and moves from left to right, the liquid is forced out through the discharge ball check. The discharge ball check is forced open by the pressure of the liquid and, at the same time, the suction ball check is forced closed.

The movement of the plunger in the cylinder in one direction is called the stroke of the plunger. The distance the plunger moves in and out of the cylinder is called the length of the stroke.

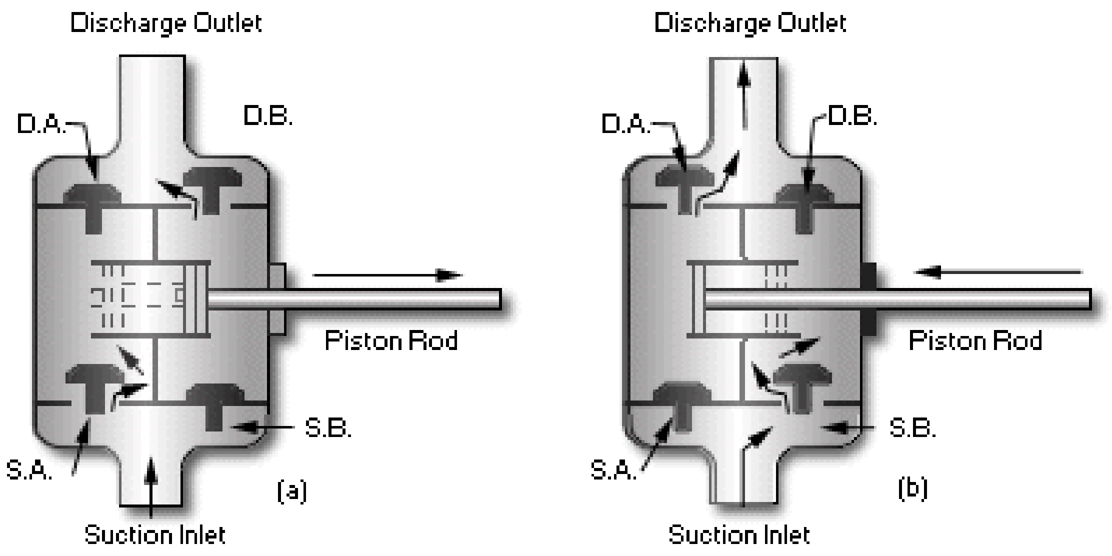
Figure 2. Single-Acting Pump



As can be seen in the sketch, only one side of the plunger takes part in the pumping action and water is discharged only during one out of every two strokes. For these reasons the pump is called single-acting.

Fig. 3 shows a basic diagram of a double-acting, piston type reciprocating pump. The pump has two discharge valves D.A. and D.B. and two suction valves S.A. and S.B. When the piston moves from left to right as shown in Fig. 3(a), the liquid will be drawn in through the suction valve S.A., while at the same time liquid is being forced out through the discharge valve D.B. Then when the piston reverses and moves from right to left as in Fig. 3(b), liquid is drawn in through the suction valve S.B. and at the same time, liquid is being forced out through the discharge valve D.A.

Figure 3. Double-Acting Pump



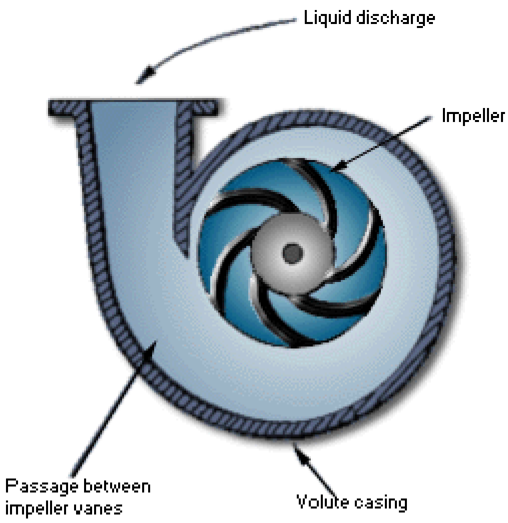
With this arrangement both sides of the piston take part in the pumping action and liquid is discharged when the piston moves in either direction, hence it is called double-acting.

2- Centrifugal Pumps

A centrifugal pump may be defined as a pump which uses centrifugal force to develop velocity in the liquid being handled. The velocity is then converted to pressure when the liquid velocity decreases. As kinetic energy is decreased, pressure is increased. Centrifugal pumps can be subdivided into the following types: volute, diffuser, axial flow, mixed flow, and regenerative. Although the regenerative pump is not truly a centrifugal pump, it will be considered in this classification.

The general construction of the volute centrifugal pump is shown in Fig. 4. The liquid being pumped is drawn into the centre or eye of the impeller and is discharged from the impeller periphery into the volute casing. The volute casing has an increasing cross-sectional area as it approaches the pump discharge. In this area, the velocity of the liquid discharged from the impeller is lowered and converted to pressure. To make the conversion from velocity to pressure more effective, stationary diffuser vanes can be installed around the rim of the impeller. This construction gives rise to the term diffuser centrifugal pump as shown in Fig. 5.

Figure 4. Volute Centrifugal Pump



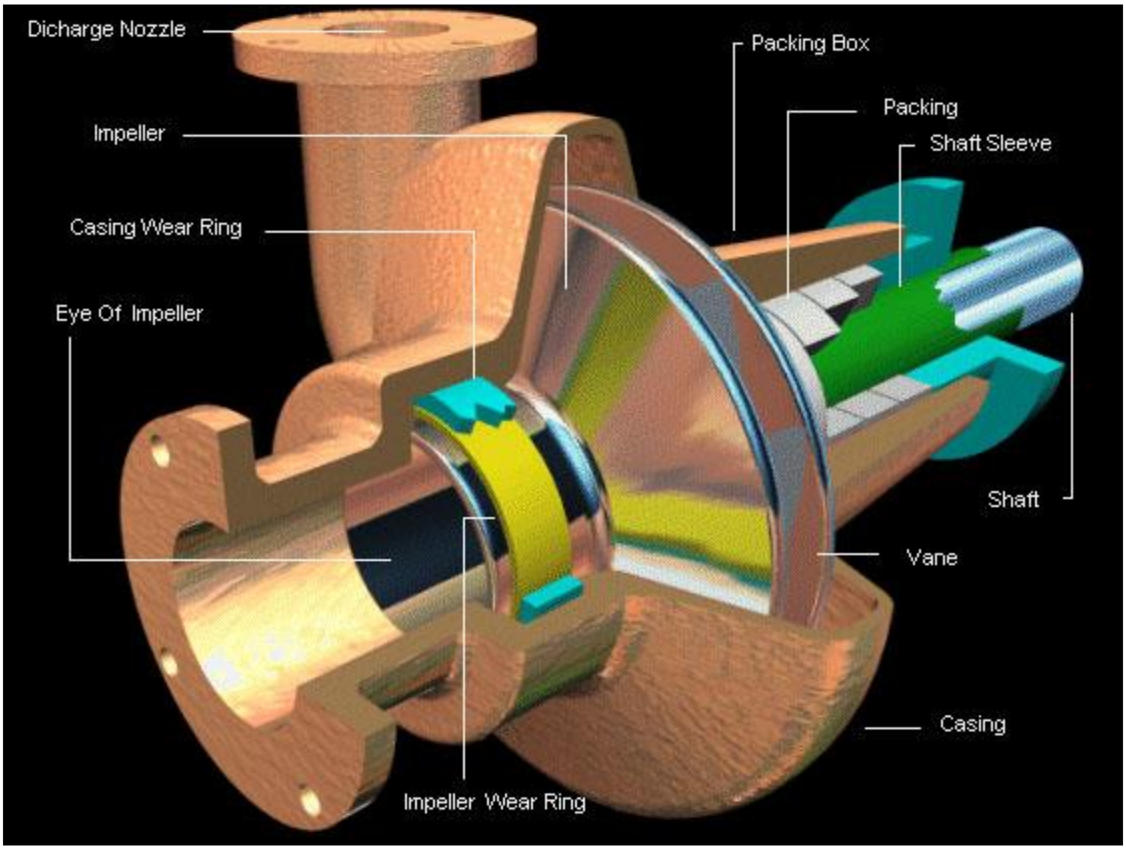
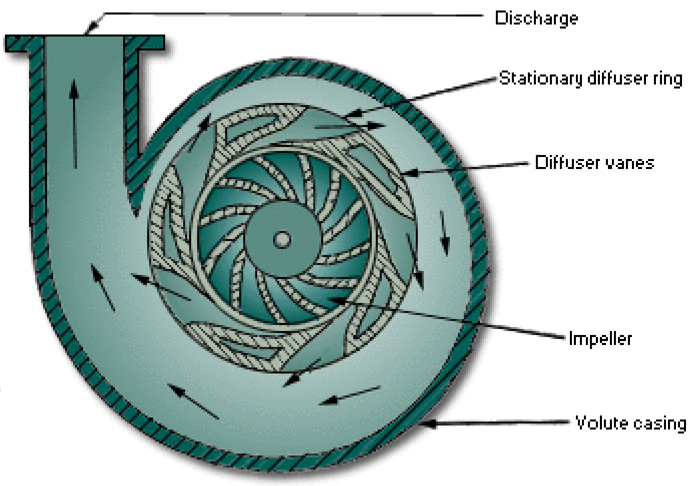
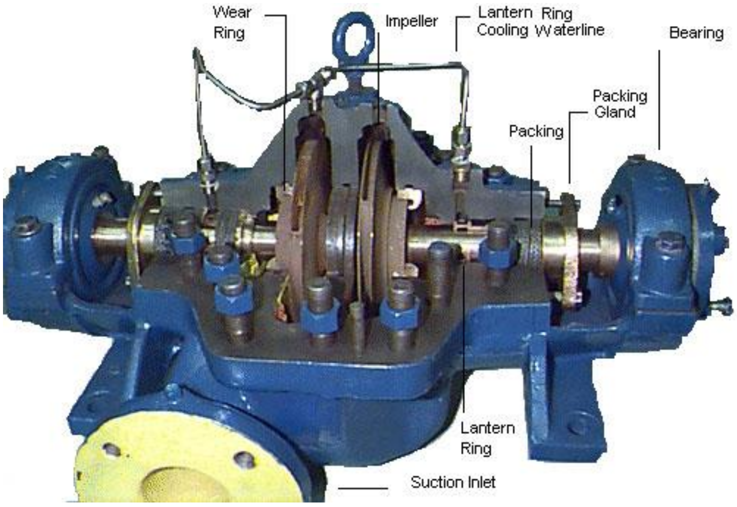
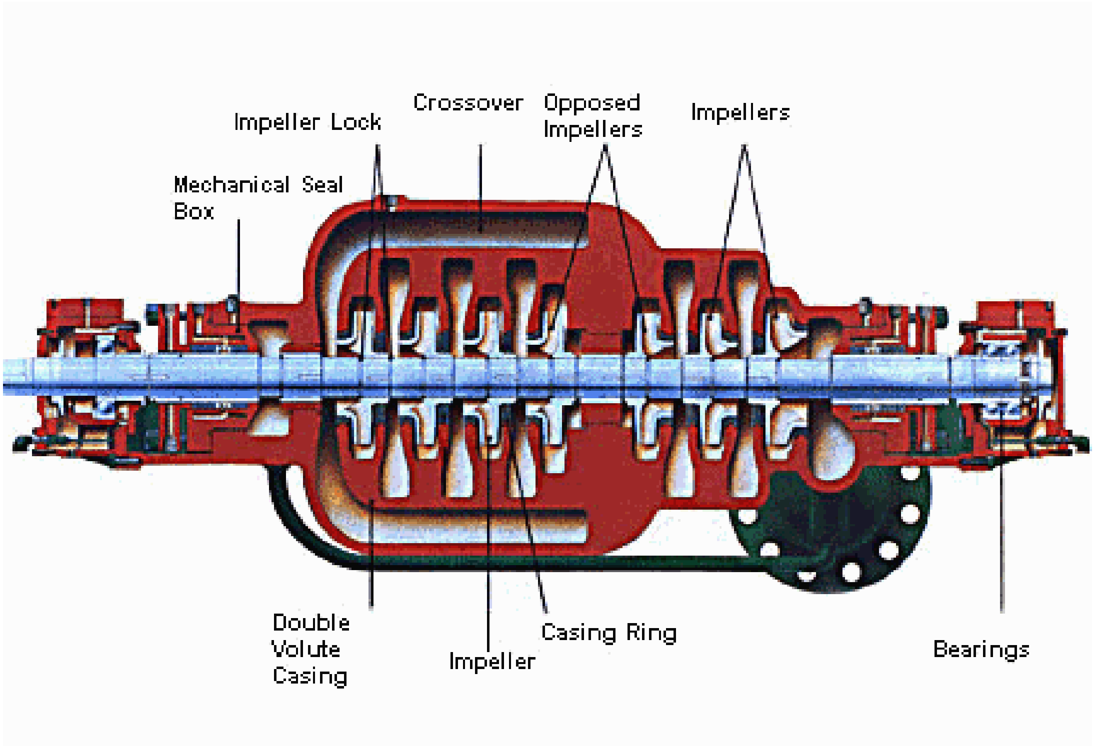
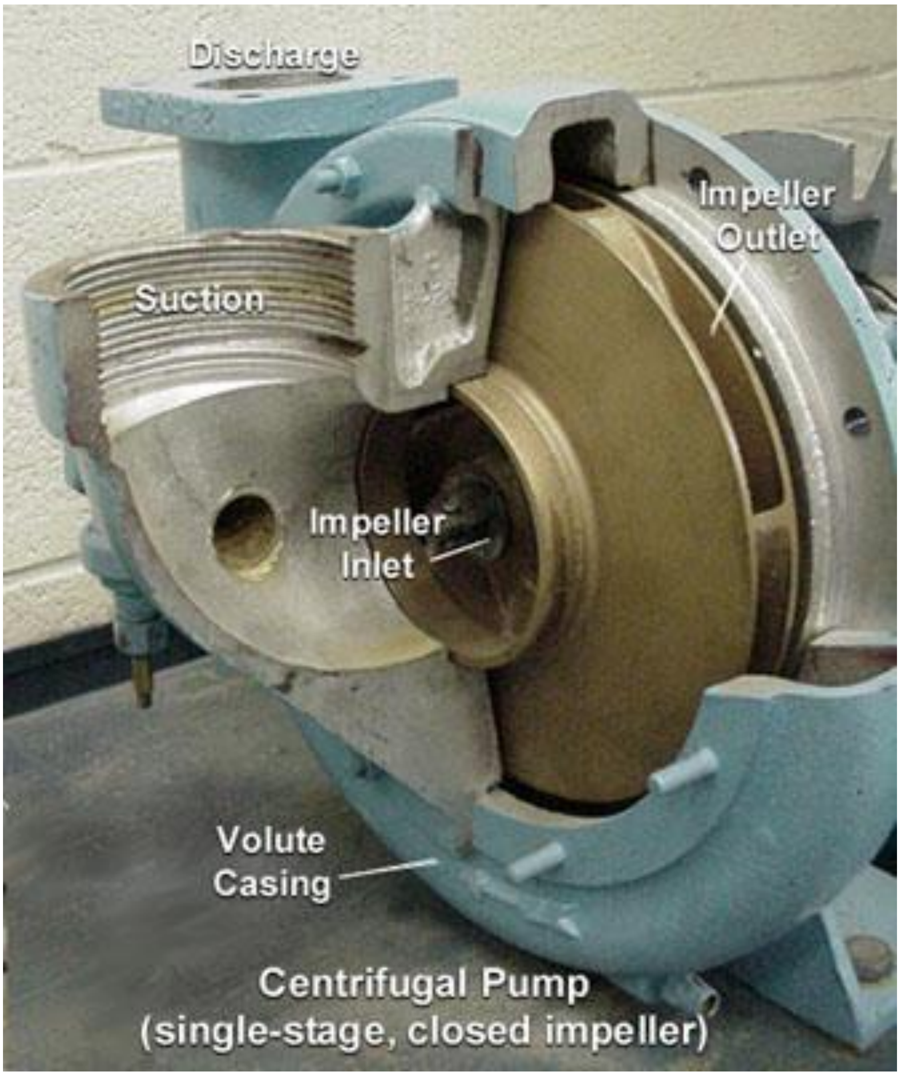


Figure 5. Diffuser Centrifugal Pump




Wear Ring
Impeller
Lantern Ring Cooling Waterline
Bearing
Packing Gland
Packing
Lantern Ring
Suction Inlet


Impeller Lock
Crossover
Opposed Impellers
Impellers
Mechanical Seal Box
Double Volute Casing
Impeller
Casing Ring
Bearings



The combination of centrifugal force and pressure created by velocity decrease accounts for the total pressure developed by the volute or diffuser pumps.

A very popular pump used to provide forced circulation in hot water heating and chilled water cooling systems of small and medium capacity is illustrated in Fig. 6. It is known in the trade as a circulator. The pump is driven by an electric motor attached by means of a flexible coupling to the pump frame. The pump is directly installed in the piping and, therefore, is also known as an in-line pump. A circulator must be capable of operating quietly and reliably for long periods of time without shut down.

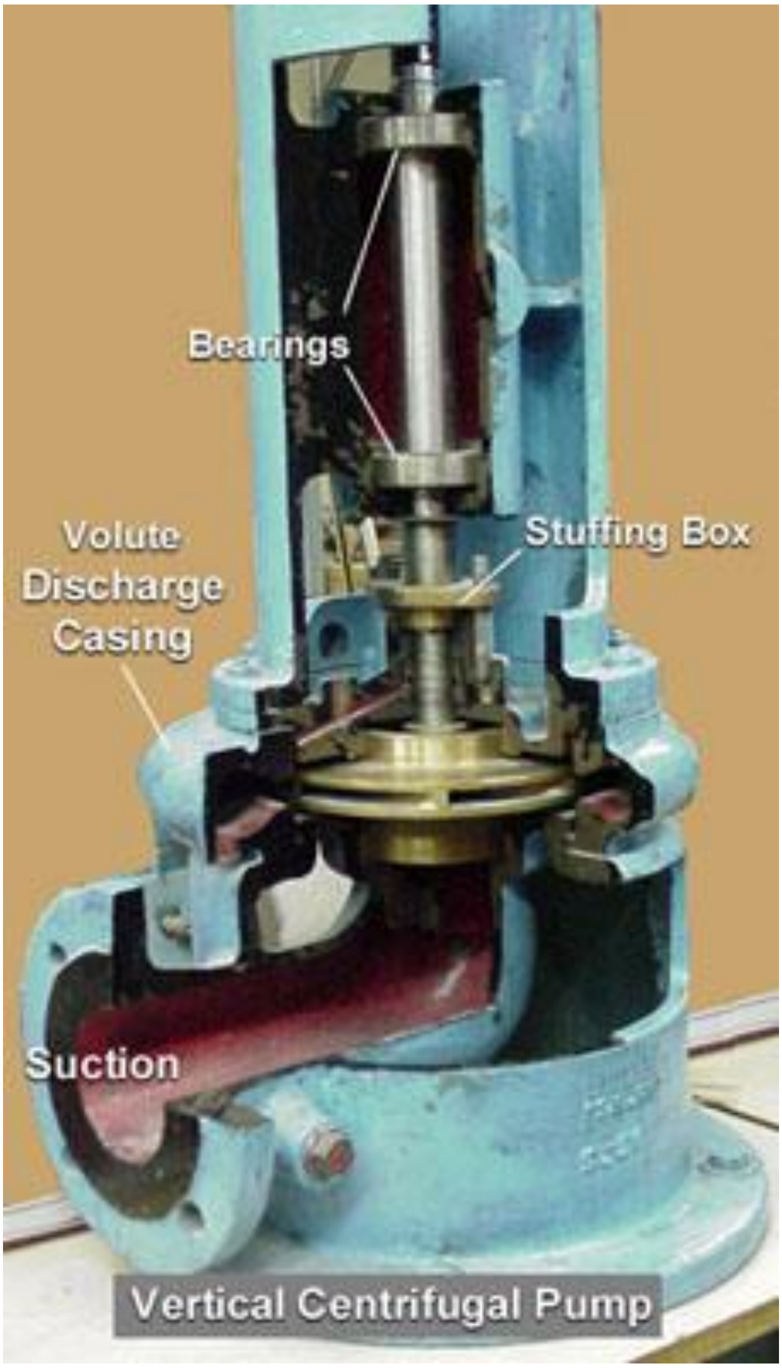
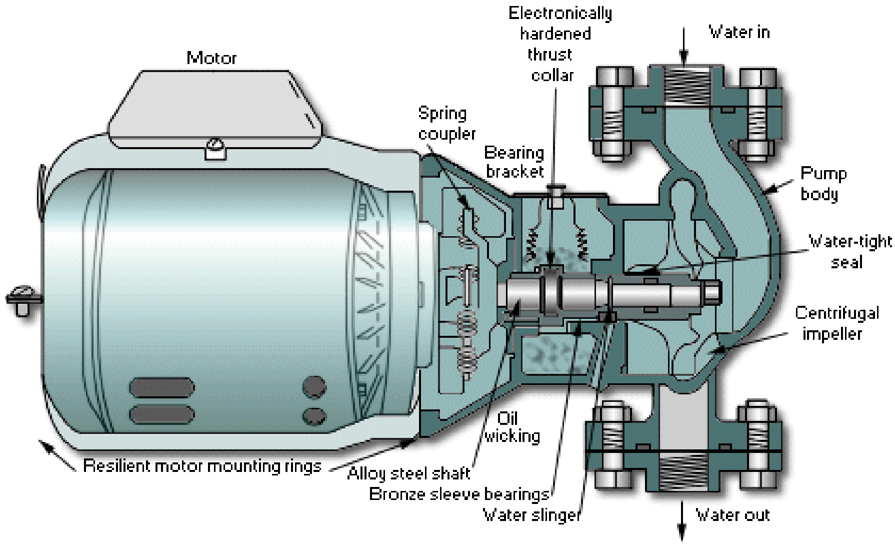


Figure 6. Centrifugal Circulator



Centrifugal Pump Characteristics

Reciprocating and rotary pumps are classified as positive displacement pumps, which means that at a constant speed they move a specific amount of liquid regardless of pump head. The capacity of a centrifugal pump, however, changes with a change in head, thus this pump is not a positive displacement pump.

When the head is increased, the capacity of the centrifugal pump decreases and when the head is lowered, the capacity increases. When the head is increased so much that it exceeds the design head for the pump, the output drops to zero.

It is, therefore, vitally important that the designer of a pumping system carefully calculates the total head of the system in order to be able to select a centrifugal pump that can deliver the required amount of liquid against this head.

The flow of a centrifugal pump can be regulated by adjusting the discharge valve. Throttling the discharge valve increases the flow resistance, thus enlarges the friction head, and the flow will be reduced. The discharge pressure gage on the pump will show an increase in pressure, however this increase is moderate and there will be no danger to the pump as with positive displacement pumps. Even with the discharge valve completely closed the pressure build-up will be well within safe limits.

When the flow is throttled down, the power requirement of the pump is also reduced, notwithstanding the resulting pressure increase. We take advantage of this fact by starting large centrifugal pumps with a closed discharge valve. Since the no-flow power requirement is relatively small, excessive power surging during start-up of the pump can be avoided. This is very important in buildings with a large electric light load, such as large office buildings, where severe dimming of lights due to a power surge can be disturbing.

CAUTION:

1. Never run a centrifugal pump continuously with the discharge valve completely closed. The mechanical power applied to the impeller is dispelled as friction to the water trapped and churned about in the casing. This friction causes overheating of the water to the point where it turns into steam which may result in damage to the pump.

2. Always operate a centrifugal pump with its suction valve wide open. Never use it for flow control. Throttling or closing of this valve starves the impeller of its water supply and the casing becomes partially empty resulting in excessive vibration which may ruin the bearings. The lack of liquid also affects stuffing boxes and seals which require a certain amount of liquid for lubrication and cooling.

Cavitation

When the pressure at any point inside a pump drops below the vapour pressure corresponding to the temperature of the liquid, the liquid will vaporize and form vapour bubbles. These bubbles are carried along with the flow until they reach a region of higher pressure where they collapse, producing a shock wave. This phenomenon is called cavitation. When the bubbles are carried onto the surface of the impeller and collapse there, the impact will damage the metal surface. When this action is repeated in rapid succession, the metal is worn away and other mechanical effects, such as noisy operation and vibration will also be produced. This may result in the mechanical destruction of the pump. Cavitation occurs mainly on the suction side of the pump or in the inlet portion of the impeller.

3- Turbine (Regenerative) Pump

Fig. 7 shows a regenerative pump or turbine pump as they are also called. The liquid being pumped enters at the pump suction and is circulated almost 360 degrees by the impeller to the pump discharge. The impeller vanes travel through a channel in the pump casing. The liquid being pumped receives continuous impulses from the fast moving vanes, and the pressure increases substantially as the liquid approaches the pump discharge. The regenerative pump can develop pressures several times that of a centrifugal pump of similar size and speed.

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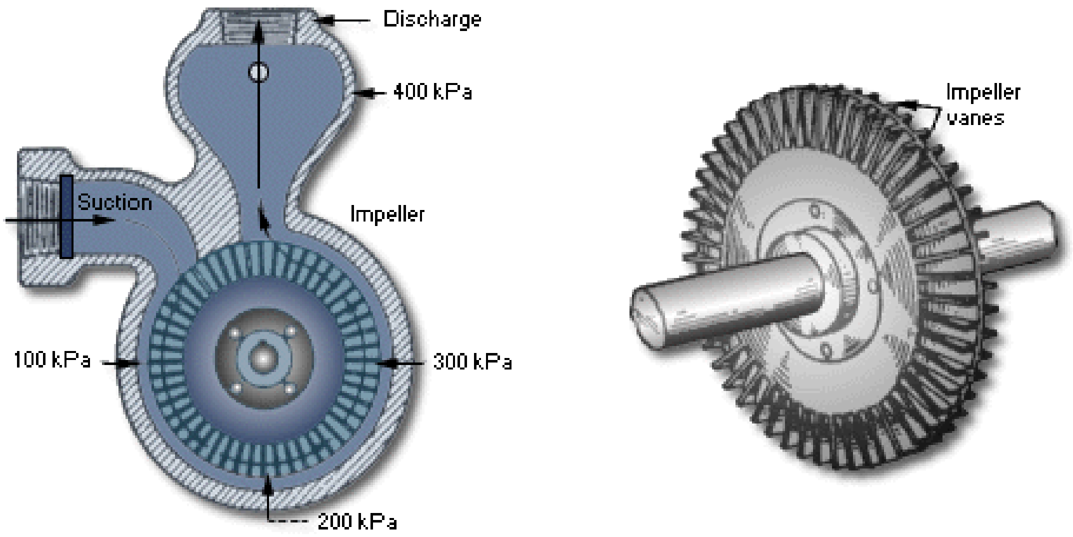
Figure 7. Turbine Pump Casing and Impeller



NOTE: In this introductory unit, the discharge from pumps has been referred to as pressure. In future unit's the term head will be more accurately applied, meaning the differential pressure between the pump intake and the pump discharge.

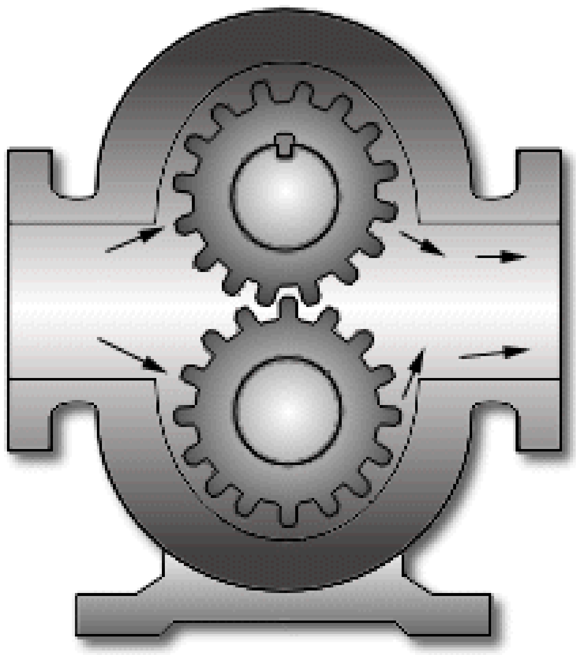
To produce high head, it is usually necessary to direct the discharge from one impeller into the intake of another impeller. This is called staging. A pump with three impellers is referred to as a three stage pump. Staging is used for increased differential pressure; the more stages, the greater the pressure.

4- Rotary Pumps

Unlike the centrifugal pumps discussed previously, rotary pumps are positive displacement pumps. Instead of propelling the liquid, most rotary pumps transfer pockets of liquid from the low pressure side of the pump to the high pressure side where the pockets are forced to empty themselves and return to the low pressure side for refilling. The capacity of rotary pumps is much less than that of centrifugal pumps. Some common rotary pumps are gear pumps, lobe pumps, and sliding vane pumps.

Fig. 8 shows a gear pump, also called a spur gear pump or an external gear pump. The pump consists of a housing, a driving gear, and an idler gear. Arrows indicate the direction of rotation of the gears. As the gears rotate, they convey pockets of liquid to the discharge side of the pump. The liquid is expelled from the pockets as the teeth of the gears mesh, because the liquid and the tooth cannot be in the pocket at the same time. Further rotation of the gears causes the teeth to unmesh on the suction side of the pump. Liquid flows in to fill the void created as the gear teeth come out of the pockets. Gear pumps are used for pressures up to 10 000 kPa.

Figure 8. Gear Pump



Lobe pumps are similar to gear pumps in theory, as liquid is transferred around the outside of rotating lobes and expelled by the meshing of the lobes. One difference is that the lobes are both driven by external gears which keep the lobes synchronized. Fig 9 shows a lobe pump.

Figure 9. Lobe Pump

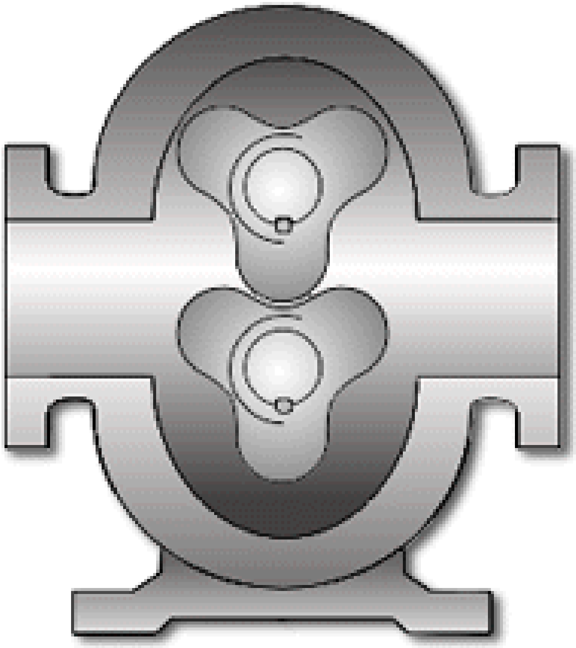
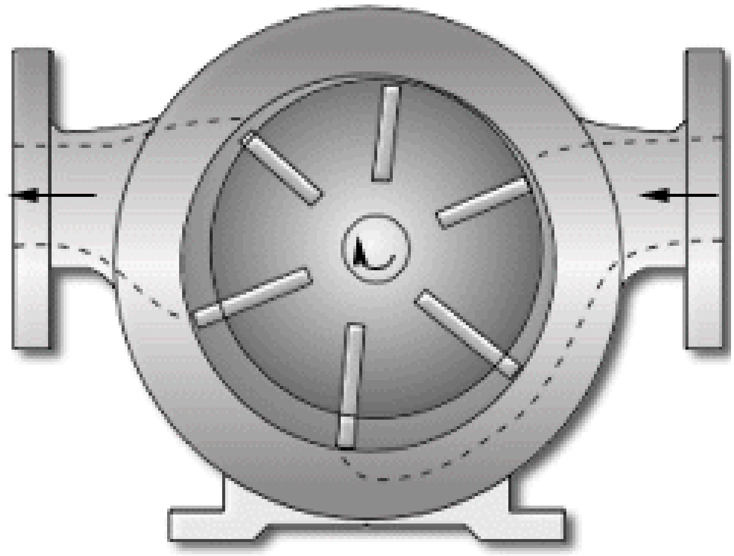


Fig. 10 shows a sliding vane pump. The sliding vane pump consists of a rotor, sliding vanes held in the rotor, and an eccentric casing. As the vanes are caused to rotate by the rotor, the vanes slide in and out to conform to the changing proximity of the pump casing. Pockets of liquid are transferred as indicated by the arrows. As the vanes are forced to retract by the diminishing clearance with the pump casing, the size of the pockets is decreased and the liquid is forced out of the pockets. As the vanes rotate past the minimum clearance with the pump casing, the size of the pockets begins to increase again and the liquid on the intake side of the pump flows in to fill the increasing void.

Figure 10. Sliding Vane Pump



Rotary pumps deliver high pressure liquid without the pulsations that occur in reciprocating pumps. Where positive displacement pumps are installed, a means of pressure relief should be installed in the discharge line before the discharge valve. If the discharge valve is inadvertently closed, excessively high pressures could be produced, which could cause damage to the pump or piping.

This unit deals with common types of pumps. Pumps are made for a great variety of applications, and specialty pumps are discussed in other units.

UNIT 2

PUMP OPERATION AND MAINTENANCE

Learning Outcome

When you complete this unit you will be able to…

Describe all details pertaining to pump operation and various maintenance procedures performed on pumps.

Lesson Objectives

Here is what you will be able to do when you complete each lesson.

1. Describe the construction and function of pump wearing rings.
2. Discuss pump shaft sealing, and describe the process that is followed when replacing compression type packing.
3. Sketch and describe the standard types of mechanical seals
4. Describe pump bearings and shaft alignment equipment and procedures.
5. Describe pump start-up and priming procedures.
6. Apply pump troubleshooting steps.

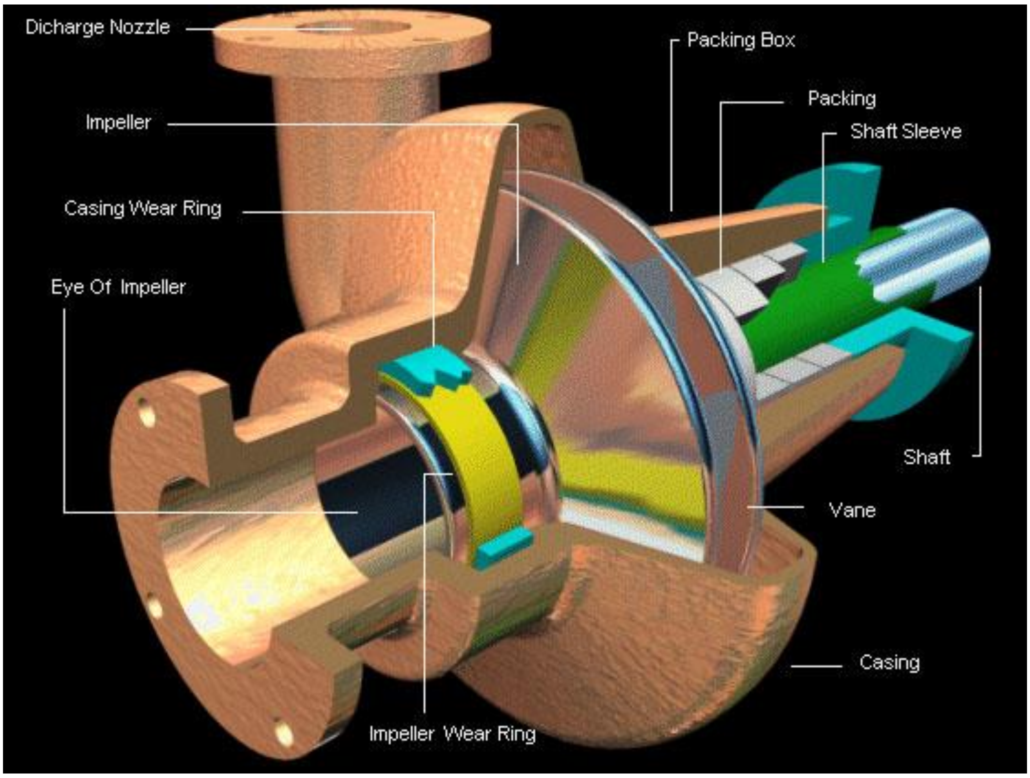
Introduction

This unit discusses the operation of the various types of pumps found in use in power and heating plants; as well as explains the various maintenance procedures performed on these pumps.

LESSON 1

Wearing Rings

In order to prevent leakage between the rotating impeller and the stationary parts of the pump, wearing rings are used. These rings are installed on the impeller or the casing or both. They reduce the clearance between the rotating impeller and the stationary casing to a very small amount. The smaller the clearance, the smaller the amount of water leaking from the discharge side of the pump to the suction side and the higher the pump efficiency will be. The rings also prevent wear of impeller and casing (hence their name). When the wearing rings themselves wear, they are easily and cheaply replaced.



Usual materials favored for wearing rings are bronze and cast iron which tend to wear in a smooth manner.

Figure 11. Impeller and casing wearing rings.

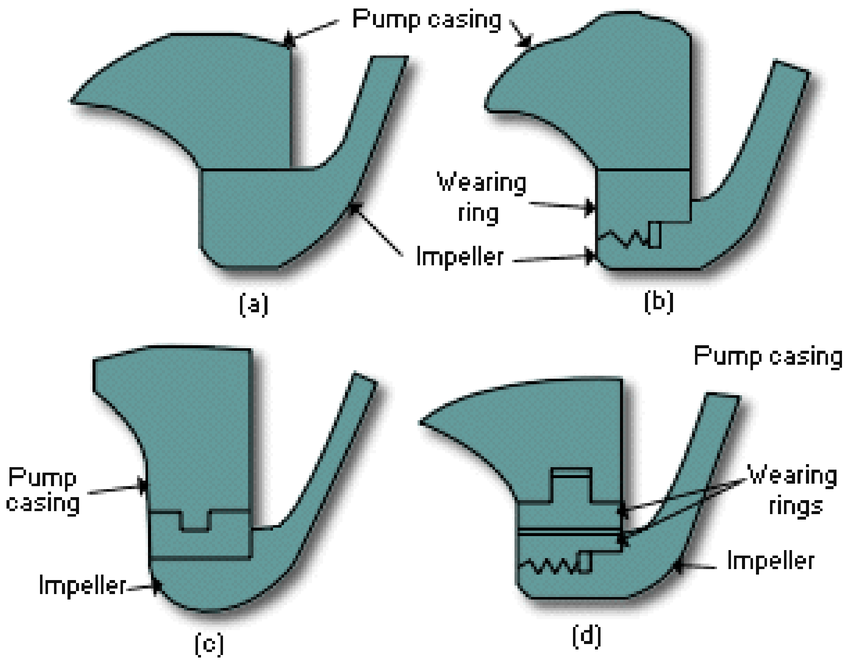


Fig.11(a) illustrates the clearance space between the pump casing and impeller of a low cost pump without wearing rings. When wear enlarges the clearance to the point that the pump efficiency drops off drastically, both casing and impeller have to be replaced. Fig. 11(b) shows a single flat wearing ring threaded on the eye of the impeller, while in Fig. 11(c) a wearing ring is fitted onto a ridge on the casing. Both rings form a flat sealing joint similar to Fig. 11(a), but the wearing ring can be readily renewed to restore the original clearance. Fig. 11(d) shows the arrangement with renewable wearing rings for casing as well as impeller.

Wearing rings are installed on the hub of the impeller by either threading or shrinking. Casing wearing rings consist of either a continuous ring or two half rings which are pressed into place. The continuous ring is used with vertically split casings while horizontally split casings are equipped with wearing rings consisting of two halves. Split rings can be fitted onto a ridge or into a groove of the casing which will prevent any axial movement should the rings work loose.

LESSON 2

Pump Shaft Sealing

In order to reduce leakage around the pump shaft where it passes through the casing, two means of sealing are presently available. These two means are:

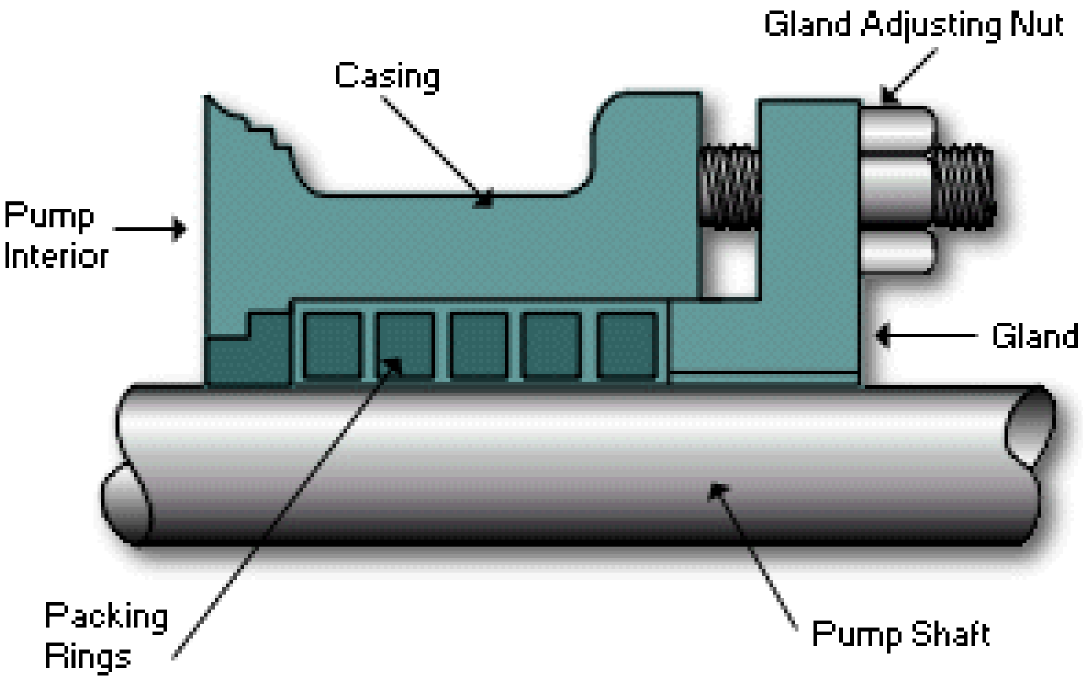
1. Compression or jam type packing
2. Mechanical seals

1- Compression Type Packing

Rings of packing, made of a soft, pliable yet durable material, are placed in the stuffing box through which the shaft leaves the housing. The packing bears against the pump shaft and the stuffing box walls and so reduces leakage around the shaft.

Packing is made from a wide variety of materials, some of which are asbestos, nylon, flax, Teflon, lead, copper and aluminum. Frequently a lubricating material, called the saturant, such as graphite or grease, is incorporated into the packing material.

Figure 12. Stuffing box and packing.



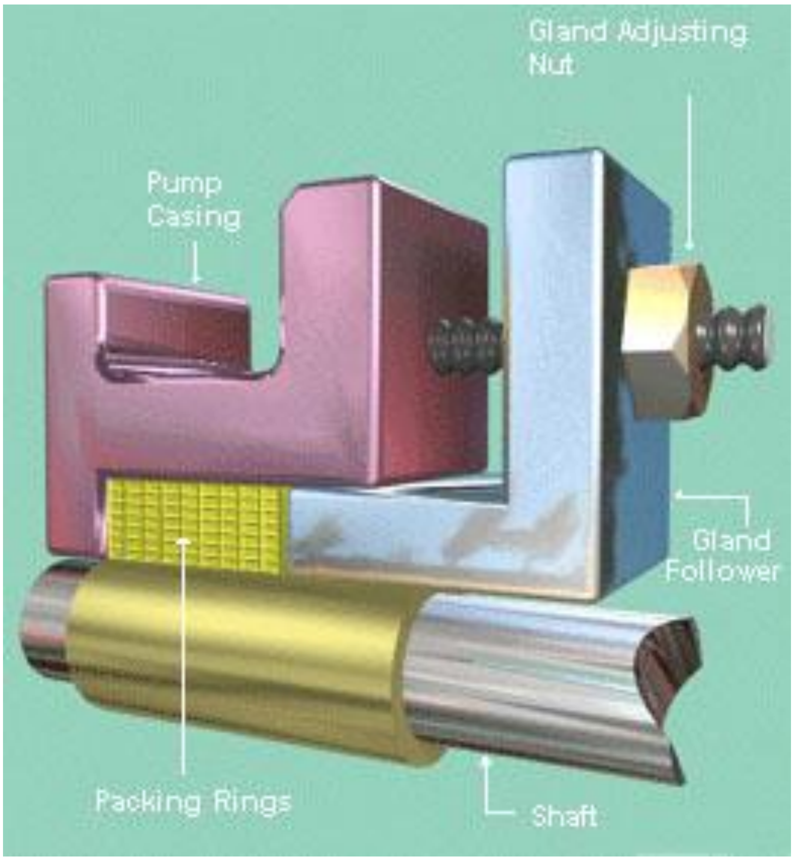
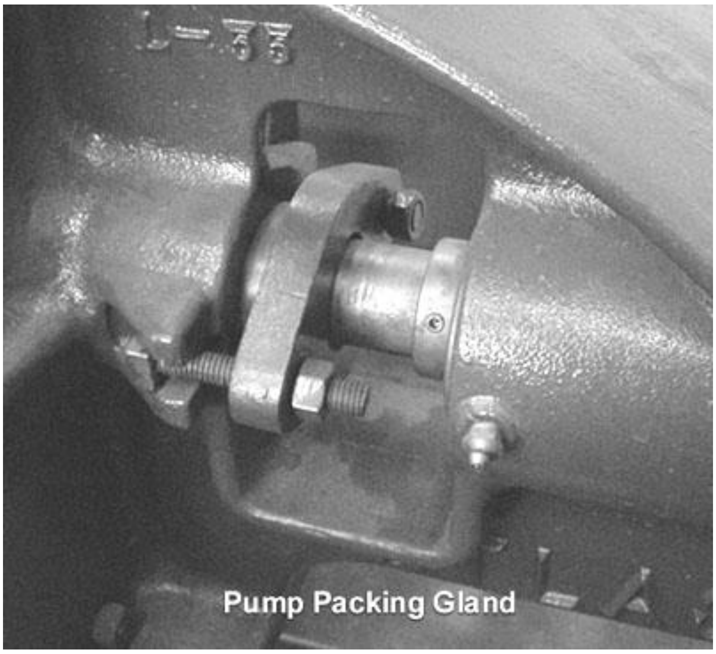


Fig. 12 shows the basic construction of a stuffing box which holds five rings of packing. The gland holds the rings in place and can be adjusted to put pressure on the packing by tightening of the adjusting nuts.

The sealing of the rotating pump shaft by means of packing is no easy matter. As long as the shaft is perfectly round, has a smooth finish, and is running dead true, no great difficulty will be encountered. But shafts usually run out a few thousands of an inch due to clearance in the bearings. Grooves on the shaft make sealing a really tough job regardless of the high quality of the packing.

Packing in the stuffing boxes of a centrifugal pump is not supposed to stop leakage entirely, it only should throttle the fluid. The reason for this is that the packing acts as a bearing and must be lubricated as such. Lubrication comes from slight leakage of fluid from the pump or, in emergency, from a lubricant in the packing. It is sometimes necessary to provide lubricant from an outside source.

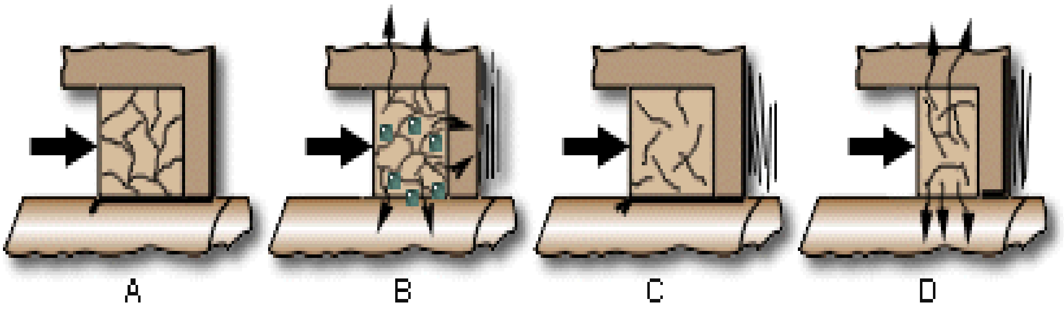


It is vitally important that the operator has a good understanding of the basic principle of the sealing action of jam packing. If this principle is not fully understood, wasted packing, scored shafts, excessive down-time and expensive repair may result.

Sketch A, Fig. 13, shows a ring of new packing before the gland has been tightened. When saturant is lost, the packing shrinks away from the shaft since its volume is reduced. This, of course, increases the fluid leakage along the shaft. Should the operator now tighten the gland so that he stops all fluid flow, no fluid lubrication will be available, Sketch B, and the shaft and packing will heat up through friction. This will cause the lubricant in the packing to go to work. The high temperature developed by the friction starts to melt the lubricant out of the packing which then lubricates the shaft for this emergency. Because this lubricant leaves the packing, the space taken by the packing is reduced and the liquid from the casing will start flowing again, supplying the needed lubrication and carrying away the heat, Sketch C.

The emergency is now over, but here is where trouble may start. A slight leakage is needed to lubricate shaft and packing but should the operator tighten the gland again in the mistaken idea that the packing should be leakproof, the same procedure described above will take place again. However, packing only contains a limited amount of lubricant and tightening up can only be repeated a limited number of times before the point will be reached where all saturant has left the packing and its volume cannot be reduced anymore.

Figure 13. Gland packing.



When the gland is tightened again to stop leakage, the excessive heat caused by the friction will burn up the packing and score the shaft, Sketch D. A full understanding of this simple principle will stop the operator from over-tightening the gland and will help him to get the maximum service expected from the packing.

Often the pressure inside the pump at the stuffing box is below atmospheric pressure and instead of water leaking out through the packing, the tendency is for air to leak in. When this is the case the stuffing box is provided with a sealing water connection and a lantern ring as shown in Fig.14

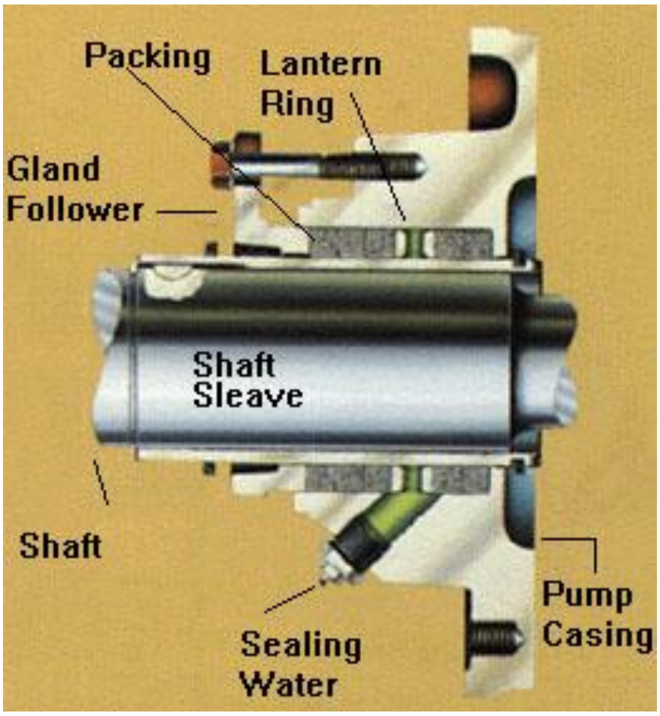
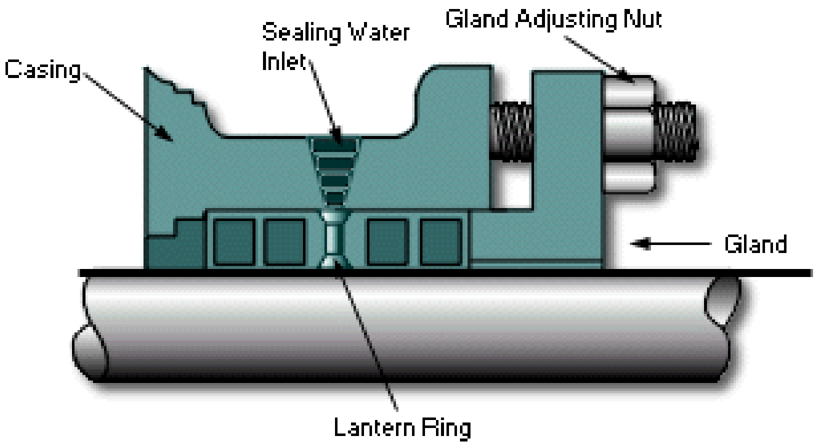
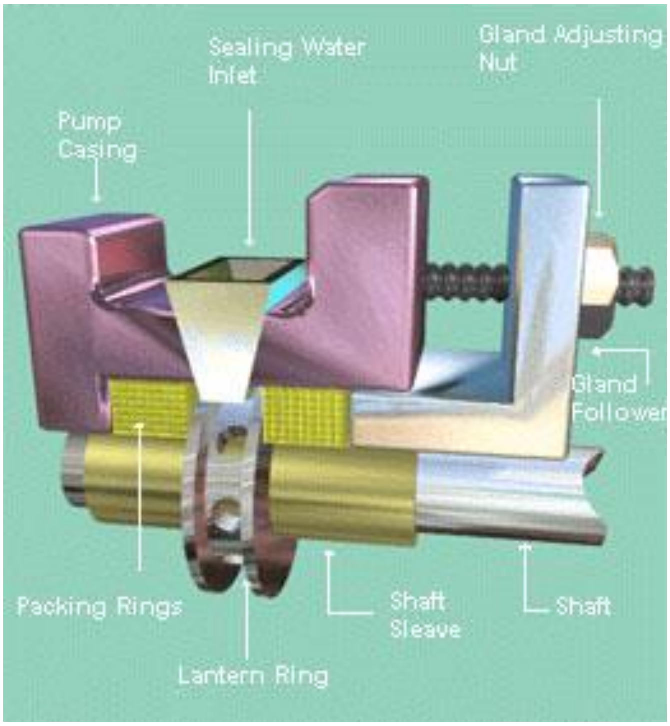


Figure 14. Stuffing box with lantern ring.





The lantern ring (also called the seal cage) is a metal ring having radial holes and it serves to distribute the sealing water to the packing. The sealing water not only helps to prevent air leakage but also lubricates the packing and this water is usually supplied from a higher pressure section of the pump. In cases where the pump is pumping water containing sand or grit or other abrasives, then clean sealing water may be supplied from a separate source.

Replacing Pump Packing

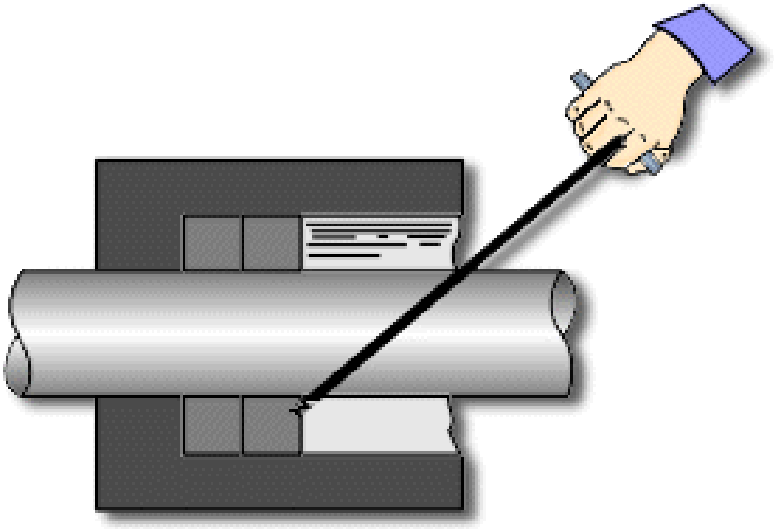
Pump packing has to be replaced periodically due to its deterioration from being compressed and from loss of saturant. How often this has to be done will depend upon the operating conditions of the pump, the quality of the packing used, and the care with which the packing was installed and adjusted. The frequency of replacement of the packing may vary between a matter of months in the case of severe operating conditions, to several years under more moderate conditions.

The recommended steps for replacing packing are as follows:

1. Shut down, isolate and drain pump. Make sure pump motor switch is locked open or fuses removed and switch tagged with a "Do Not Operate" warning tag.

2. Remove gland adjusting nuts and slide gland away from the stuffing box. Then remove all the old packing using some type of packing hook (Fig. 15). Make sure the stuffing box is thoroughly clean and free from any small pieces of old packing. Check that the sealing water connection to stuffing box is clear.

Figure 15. Removing packing.



3. Check the conditions of the shaft or the shaft sleeve if a sleeve is installed over the shaft. If the surface is grooved or scored, then it should be replaced as any rough surface will damage the packing.

4. To determine the correct size (thickness) of packing to use, measure the bore of the stuffing box and subtract the diameter of the pump shaft and divide the difference by two.

Example:

The stuffing box bore on a pump is 76.2 mm (3 in) and the shaft diameter is 57.2 mm (2 1/4 in). What size packing should be used?

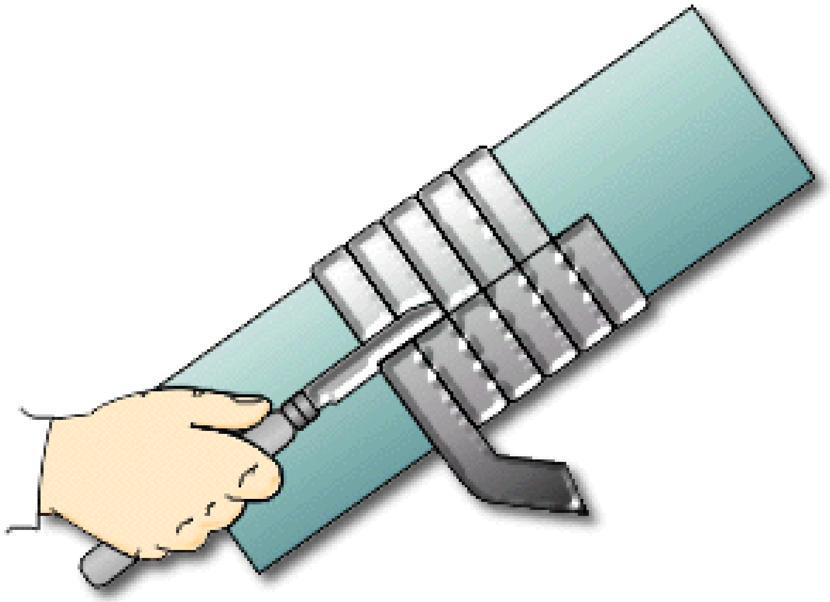
Solution:

Difference between stuffing box bore and shaft diameter:

76.2 – 57.2 mm	=	19 mm (3/4 in)
Packing size (thickness) 19 mm/2	=	**9.5 mm (3.8 in)** (Ans.)

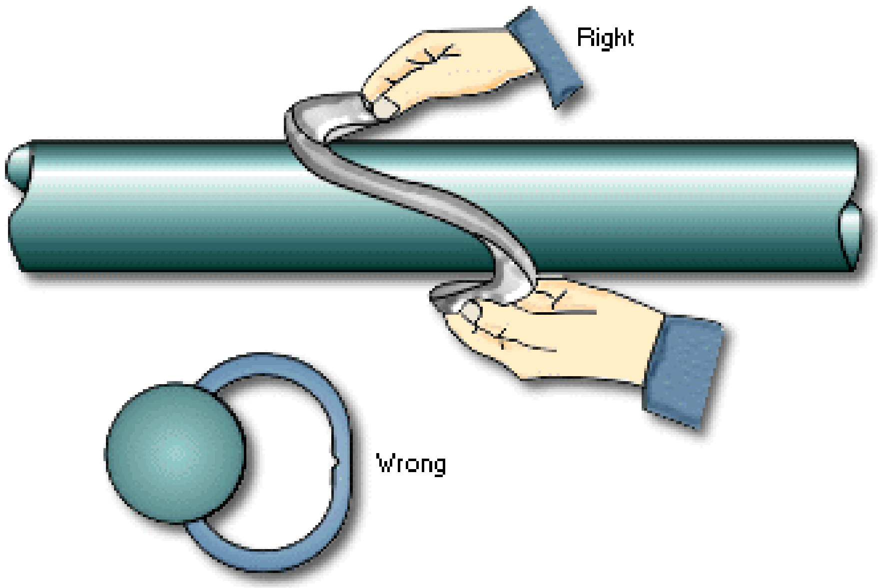
5. Then wrap a coil of the correct size packing around a rod (same diameter as shaft and held in a vise) and cut through each turn as shown in Fig. 16. If the packing is slightly too large, never flatten it with a hammer. Place each turn on a clean surface and roll it out with a piece of pipe.

Figure 16. Cutting packing ring.



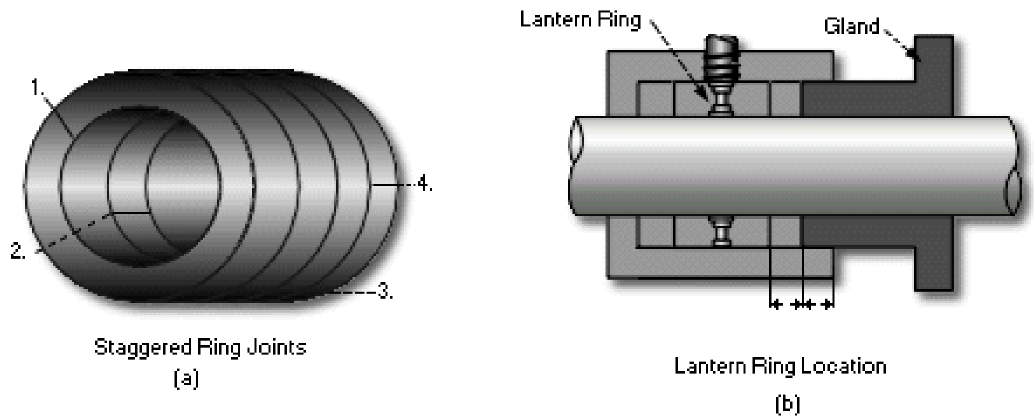
6. Install the packing rings one at a time after putting a light coating of oil or grease on the inner diameter of each ring. Slide each ring sideways over the shaft as shown in Fig. 17 to prevent breaking of the ring.

Figure 17. Sliding Ring onto shaft.



7. Tamp the rings into place one at a time using a split wooden bushing or metal ring to push each ring into the stuffing box. Make sure the ring joints are staggered and the lantern ring lines up properly with the sealing water inlet. See Fig. 18.

Figure 18. Lanturn rings.



8. Put packing follower in place and compress the packing slightly by tightening the gland nuts. Then slacken off to just finger tight to allow for packing expansion. In the case of small pumps the shaft should turn freely by hand.

9. The packing should be allowed to leak freely when the pump is first started. After about twenty minutes of running the follower should be gradually tightened until only the necessary operating leakage is apparent.

The above method of installation of packing in stuffing boxes is essentially the same for centrifugal, rotary and reciprocating pumps.

2- Mechanical Seals

Instead of employing a stuffing box with packing, many pumps use mechanical seals to prevent leakage along the shaft. Mechanical seals have the following advantages over packing.

1. They require much less maintenance.
2. They do not produce wear of shafts or shaft sleeves as do packing rings.
3. They reduce leakage to a minimum.
4. They can be designed to work under very high temperatures and pressures.

On the other hand, mechanical seals have a greater first cost than packing, and when they fail, the pump must be taken out of service for a longer period to replace the seal than would be necessary with the simple stuffing box and packing method.

All types of mechanical seals feature two flat sealing faces which are at right angles to the pump shaft. One of these faces is called the sealing ring and it is held in position by a spring. The other sealing face, which is in contact with the sealing ring, is called the mating ring.

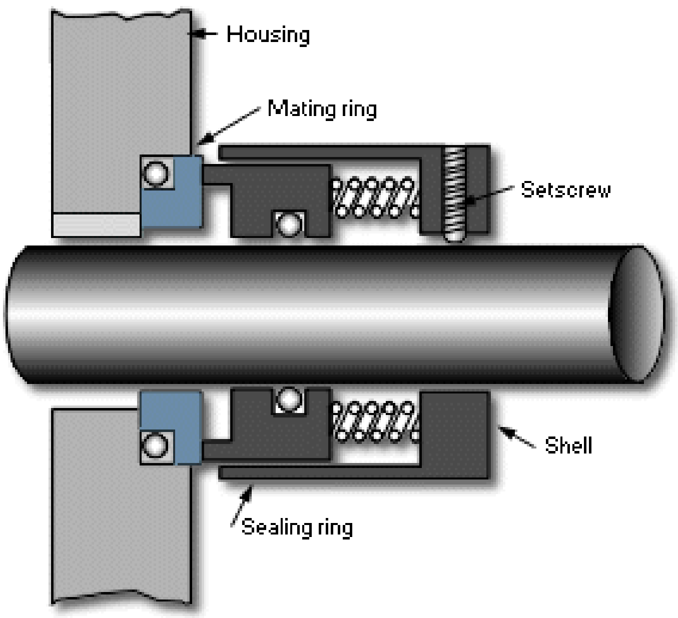
Mechanical seals may be divided into two general types, the rotating seal and the stationary seal.

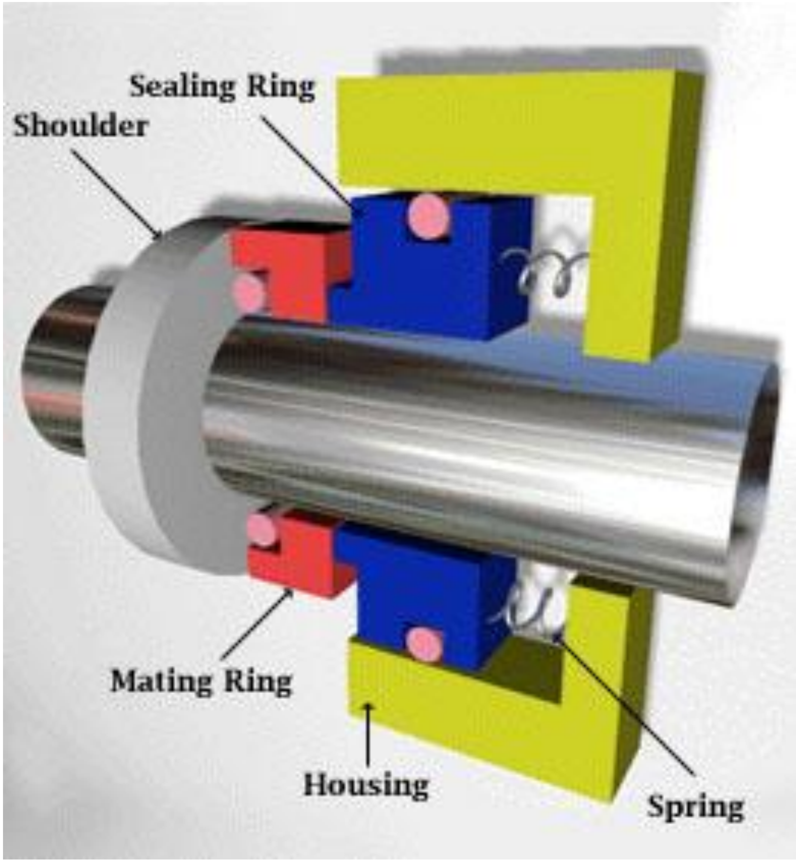
2.1 Rotating Mechanical Seal

In the rotating seal sketched in Fig. 19, the sealing ring and spring are held in place by a shell which is fastened to the pump shaft with a set screw. Therefore the sealing ring will turn with the shaft. The mating ring, however, is held stationary within the pump casing.

As the pump shaft turns, the rotating sealing ring is forced against the mating ring, thus preventing leakage between the faces. "O" ring type gaskets prevent leakage between the casing and the mating ring and between the shaft and the sealing ring.

Figure 19. Rotating seal.

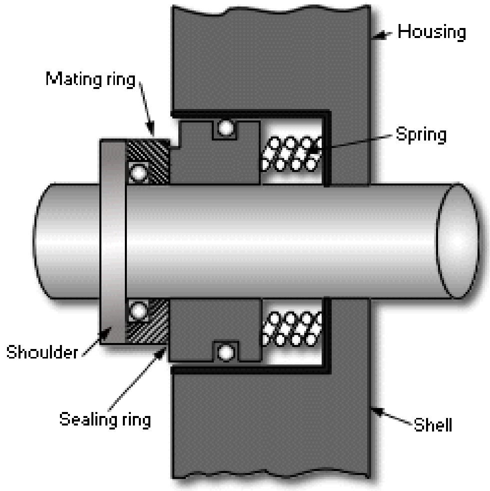




2.2 Stationary Mechanical Seal

In this type of seal, which is sketched in Fig. 20, the sealing ring assembly is held stationary within the pump housing. The mating ring is fastened rigidly to the shaft, usually against a shoulder. As the pump shaft turns, so does the mating ring. The stationary sealing ring bears against the rotating mating ring and leakage between the two faces is prevented. "O" ring gaskets are used to stop leakage between the shaft and mating ring and between the sealing ring and housing.

Figure 20. Stationary seal.



Sealing Ring Materials

The materials chosen for the sealing and mating rings depend upon such things as the type of liquid being pumped, its temperature, its pressure, pump speed and seal design. Materials frequently used by various seal manufacturers are bronze, carbon graphite, ceramics, stellite, and tungsten carbide.

Care of Mechanical Seals

It is extremely important that the seals never run in a dry condition, otherwise the faces will become grooved and scored. The following precautions should therefore be followed:

1. Never run the pump in a dry condition even for a few minutes.
2. Vent any air present from the seal housing before start up.
3. Make sure an adequate flow of quenching or cooling liquid is flowing to the seal.

A squealing sound is an indication of a dry seal but this sound is not always present if the seal runs dry.

A leaking seal may be caused by the following:

1. Seal faces scored or grooved.
2. Seal housing bolts too tight, causing distortion of rings.
3. "O" ring gaskets cut or nicked during installation.
4. Misalignment of piping, causing distortion of pump parts.
5. Excessive pump shaft vibration.

LESSON 3

Pump Bearings

The only moving parts of a centrifugal pump are the impeller and the shaft on which it is mounted. The shaft is held in place and supported by its bearings which allow it to rotate with a minimum of friction. Pump bearings can be divided into the following two general classes:

1. Shell or sleeve bearings
2. Ball or roller bearings

Pump Alignment and Flexible Couplings

The majority of the centrifugal pumps used for various purposes in buildings are driven by electric motors. Nearly all these motors drive the pumps directly. This means that pump and motor shafts are coupled together so that pump operates at the same speed as the motor. Direct drive requires the pump and motor to be lined up in such away that the centre line of both shafts are exactly in line. This is called a perfect alignment. If perfect alignment could be achieved and maintained during operation, the shafts could be connected together by a rigid coupling. Unfortunately, perfect alignment is very difficult to obtain and practically impossible to maintain.

Two forms of shaft misalignment are illustrated in Fig. 21. Fig. 21(a) shows angular misalignment. The motor and pump shaft are in line looking down from the top, but looking from the side the centre lines are at an angle (the angle is exaggerated for the sake of clarity).

Figure 21. Shaft misalignment.

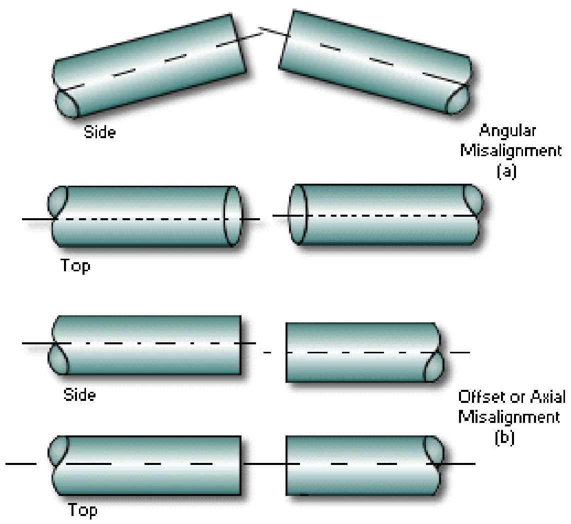


Fig. 21(b) shows axial misalignment. The shafts are parallel but their axes are beside each other. Angular and offset misalignment can also appear in combination with each other.

Misalignment of shafts connected by rigid couplings causes overheating and excessive wear of the bearings, increased power consumption, severe bending stresses in the shafts which may lead to shaft failure, vibrations and noise.

The causes of misalignment are various. Poor installation or assembly is one of the main reasons of unsatisfactory service. Bearing wear, thermal expansion and flexing of shafts cause misalignment during operation even though the original installation was all right.

To protect the machinery against any of the dire results of misalignment, pump and motor are connected by a flexible coupling. This coupling should not be considered a cure-all for misalignment due to poor workmanship, proper alignment is still vitally important, but rather as a corrective means for the unavoidable misalignment that may develop during operation.

Most flexible couplings allow a limited amount of angular as well as offset misalignment, they dampen vibration and allow a certain amount of end float of the shafts.

Flexible couplings can be divided into two basic groups. The first group contains couplings consisting of two rigid coupling flanges mounted on the shafts connected together by a flexible yielding member. The second group contains rigid coupling parts only, but through mechanical design a certain amount of flexibility is made possible.

Fig. 22 shows a few of the many different types of flexible couplings available on the market.

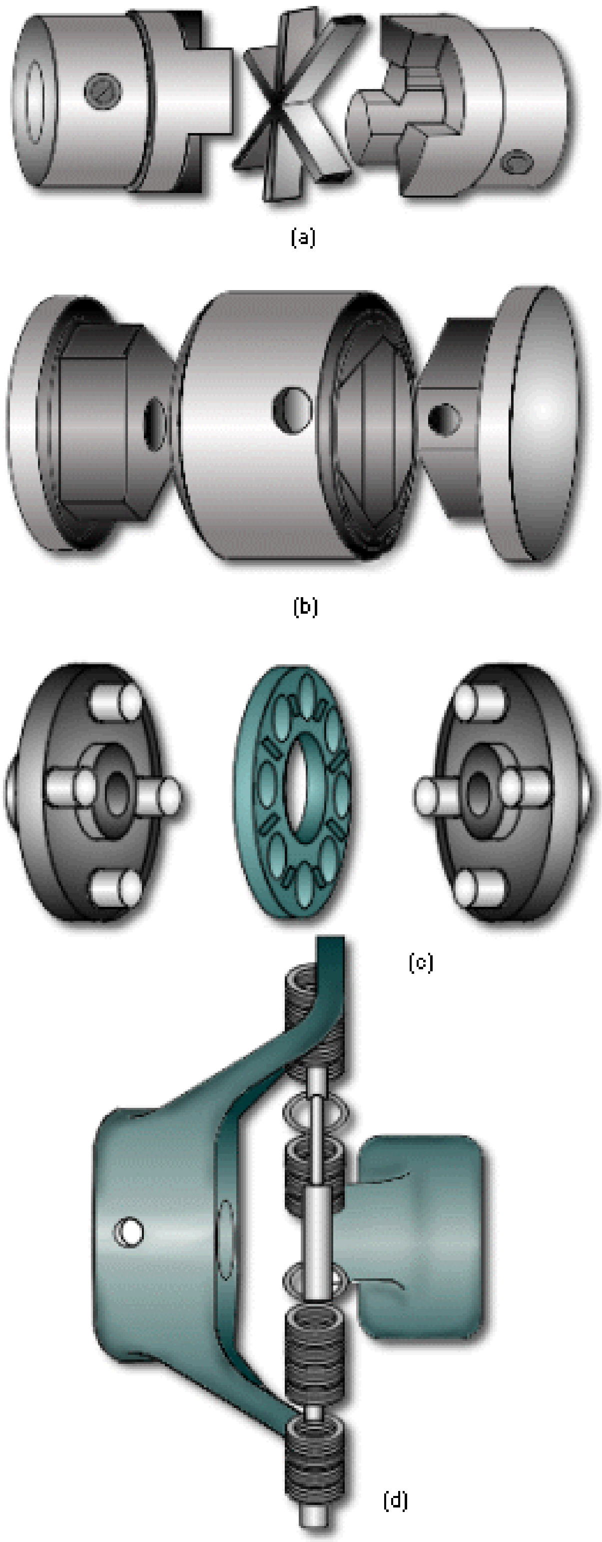
Fig. 22 (a) shows a jaw type coupling with a non-metallic spider-like insert with four, six or eight arms. This insert may be of synthetic rubber, laminated leather or bakelite.

Figure 22a. Flexible coupling

Figure 22b. The triangular coupling members fit into the ends of a rubber-lined metal sleeve.

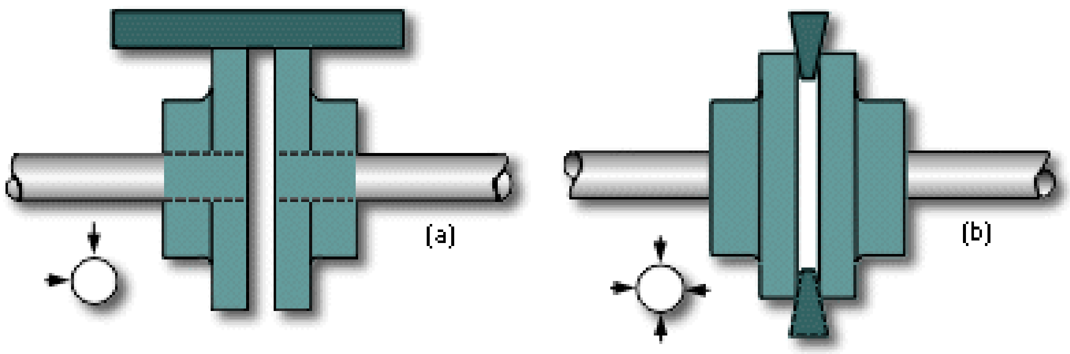
Figure 22c. The coupling flanges are fitted with pins which fit into the holes of the leather disk which forms the yielding member.

Figure 22d. The fork-like coupling flanges are connected by springs.



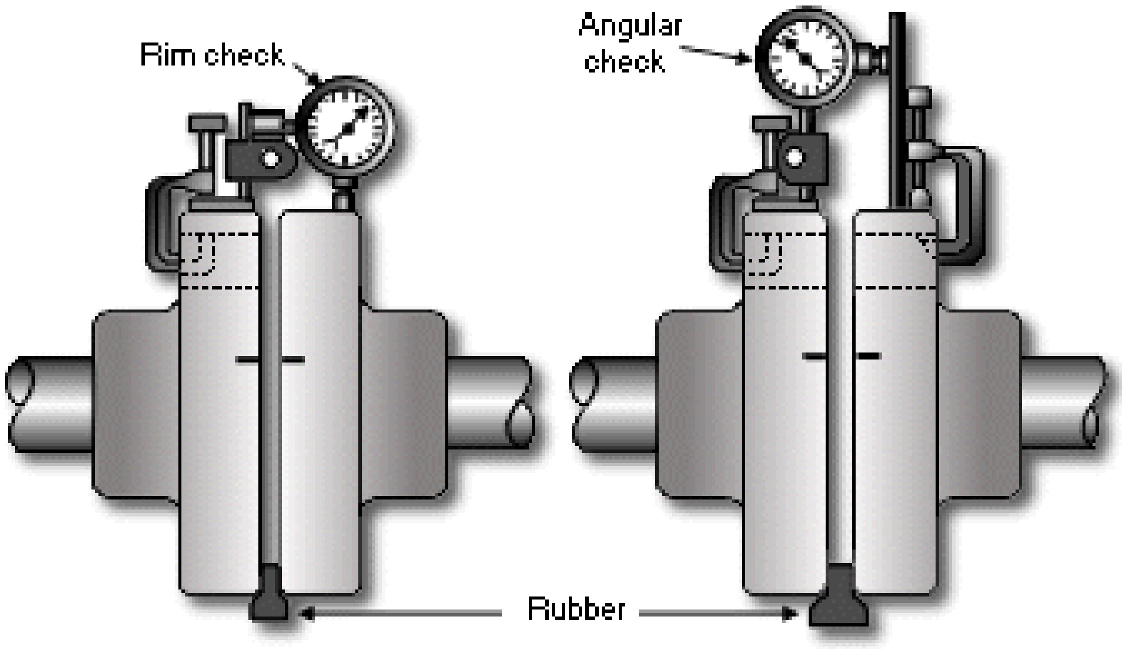
It was mentioned before that proper alignment of pump and motor drive is necessary even when a flexible coupling is used. Serious misalignment of equipment connected by a flexible coupling may not only damage the coupling but it also may result in damage to bearings, vibration and noise. For couplings with hubs or flanges of the same diameter and with suitable machined faces, a straight edge can be used to check offset or axial alignment (Fig. 23(a)). The measurement is taken along the top and side of the flanges. To check the angular alignment a tapered feeler gage is used (Fig. 23(b)). When the faces of the flanges are exactly parallel, the measurement at each 90° of the circumference should be the same. Raise or lower the pump or motor, as necessary, during alignment by inserting shims under the feet of either unit. Make sure to check the alignment again after the adjustments are made.

Figure 23. Checking alignment.



The use of straight edge and tapered feelers for alignment will give fairly accurate results, however, this method cannot be used for all types of couplings due to their design. A more accurate method of alignment suitable for all types of couplings uses a dial indicator which measures in thousandths of an inch. Fig. 24 shows how this indicator is used to measure offset and angular misalignment. The coupling halves should be marked and a piece of rubber should be placed between them at the centre to hold them apart. Set the dial at 0 at the top. Rotate the two halves together and take readings at each 90° angle. If the alignment is out, the amount of misalignment is indicated by the gage and adjustments can be made accordingly.

Figure 24. Dial indicator.



LESSON 4

Centrifugal Pump Priming and Starting

The term priming, used in connection with pumps, simply means to fill the pump casing and suction line with water or with whatever liquid is being pumped.

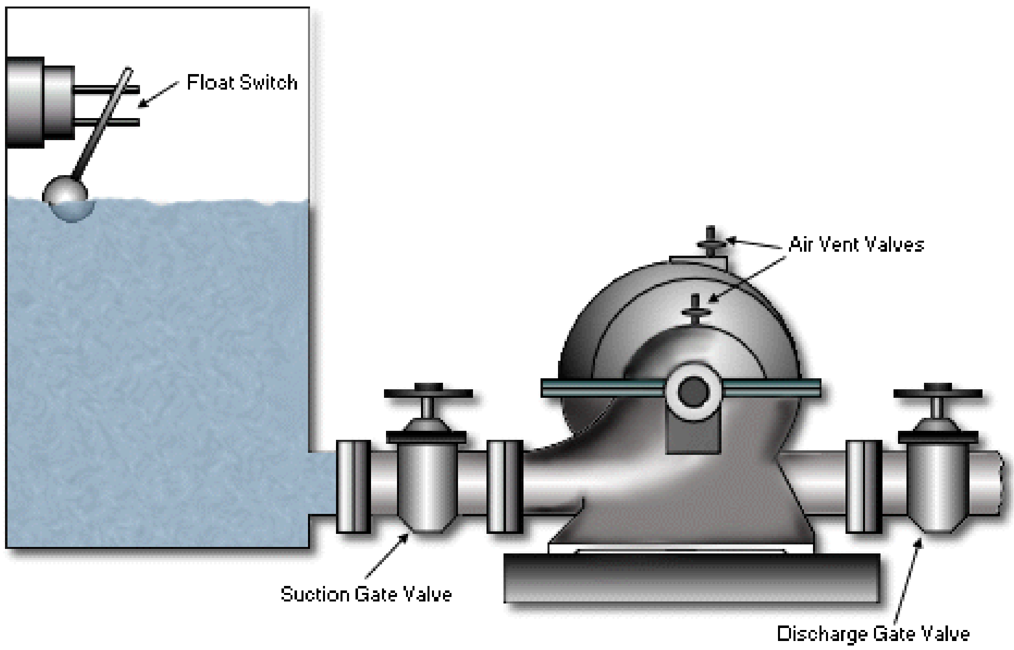
Before starting a centrifugal pump, it must be primed, otherwise the impeller will simply churn air and will not produce any suction. In addition, the wearing rings will have no liquid to lubricate them and they may seize. Also, as mentioned previously, mechanical seals and packing will be damaged by dry running.

Methods of Priming

In the case where the pump is below the source of supply, as in Fig. 25, the pump is primed in the following manner.

Close the discharge valve and open the suction valve. Then open the air vent valves to allow the air in the pump casing to escape. When water flows from the vents, they can be closed and the pump is then in a primed condition and ready for starting.

Figure 25. Flooded suction method.

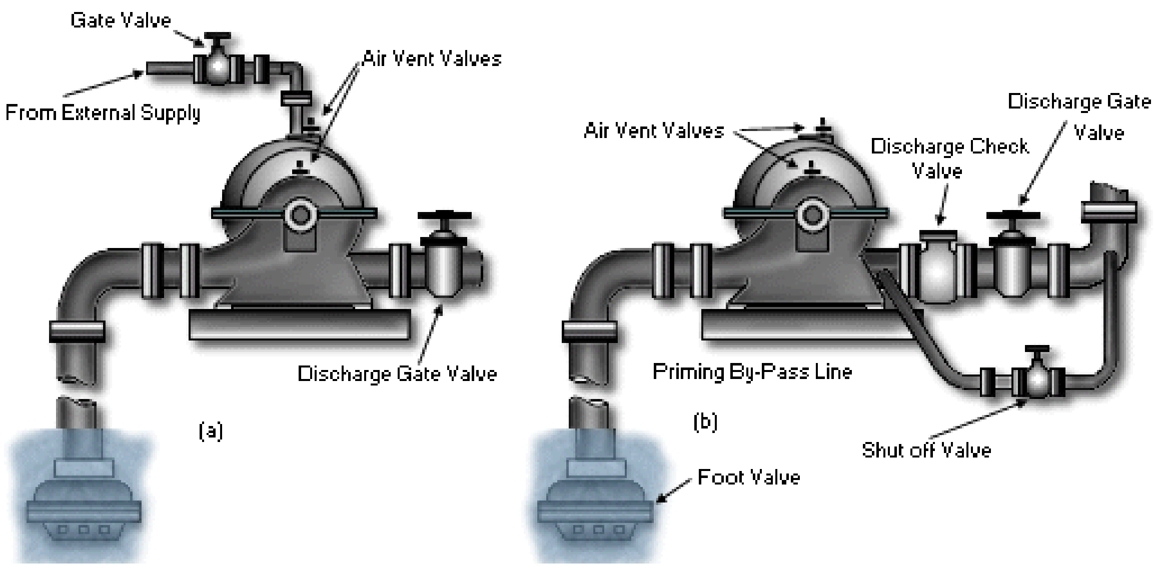


When the pump is located above the source of supply (pump has a suction lift), various methods of priming can be used and in each of these the pump suction line is equipped with a foot valve. The foot valve is a flap type valve which allows water to enter the suction line but prevents the water from flowing back out of the suction line.

In Fig. 26(a) the priming water comes from an external source. To prime the pump, the discharge valve is closed and the external supply valve is opened as are the vent valves. The water flows into the pump and then into the suction line where it is prevented from escaping by the foot valve. The water fills the suction line and then the pump casing. When water flows from the vent valves, they and the external supply valve are closed and the pump is ready for starting.

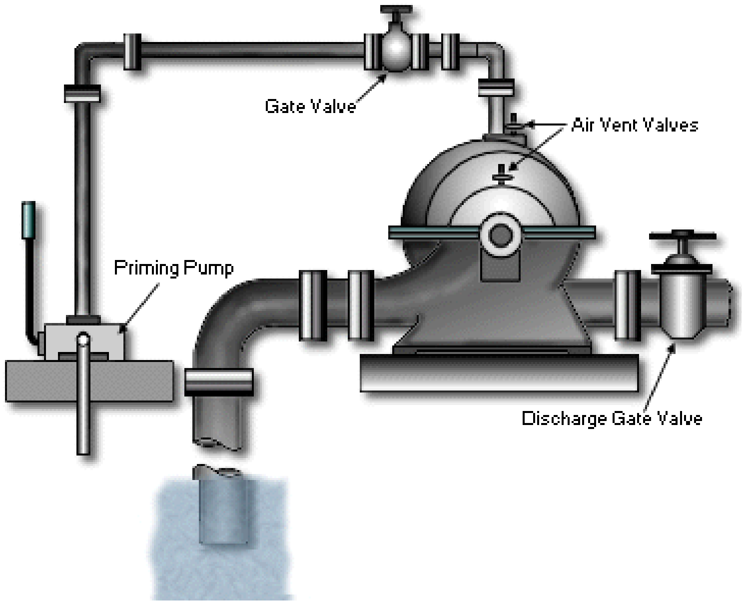
In Fig. 26(b) the pump is primed by water which is supplied from the pump discharge line. The discharge valve is shut and the priming valve and the air vents are opened. Water from the discharge line fills the pump casing and the suction line. When water issues from the vents the vent valves and the priming valve are closed and the pump is ready for starting.

Figure 26. Priming methods.



In Fig. 27 a separate hand-operated priming pump is used. The main pump discharge valve is shut and the priming pump valve is opened. The pump is operated and it exhausts air from the main pump casing and suction line thus causing water to fill them. When water issues from the priming pump discharge, then the priming pump valve is shut and the main pump is ready for starting.

Figure 27. Suction lift methods.



Installation

Although proper placement of pump and driver on their foundation, alignment and installation of the connecting piping are the responsibility of the contractor, it is advisable that the building operator makes himself familiar with these procedures. In many new plants, troubles develop after a short period of operation which are due to improper installation.

The best way to become familiar with the proper installation procedures for any particular type of equipment is by studying the instruction manual supplied with this equipment by the manufacturer.

Initial Start

Starting a centrifugal pump for the first time can be a troublesome experience unless a thorough check of the unit is made during and after installation. More trouble develops during initial starting of a pump than at almost any other time. Factors that should be considered before starting the pump are:

1. **Pipe Cleanliness**

Many single-stage pumps have close-clearance running parts which must be protected from abrasive particles often found in new piping systems. To prevent the larger particles from reaching the pump, install a flat or conical strainer made of 1.5 mm or 1/16 inch mesh screen backed with 6 mm or 1/4 inch mesh screen in the suction line as close as possible to the pump suction nozzle. When starting the pump for the first time, watch the suction gage. When suction pressure drops, it indicates that the screen is clogging. Stop the pump, remove the screens, clean and re-install them. It may be necessary to clean the screens several times during the first few days of operation. The screens can be removed permanently if no more clogging occurs.

2. **Pump Alignment**

The pump and its driver, usually an electric motor in small and medium sized heating and cooling systems, should be aligned before the pump is put into operation for the first time. Then, after the pump has run a short while and motor and pump have assumed their normal operating temperatures, the alignment should be rechecked. The change in temperature may have changed the alignment. Make sure the connected piping is properly supported. Its weight should never be supported by the pump. Turn the pump over by hand. It should turn freely, without binding, scraping or making any noise. Inspect pump footings to see that any devices for expansion of the casing are free and in good working condition.

3. **Rotation**

Always check the driver and pump rotation. Touch the starter button just long enough to make the motor turn a few revolutions. The pump shaft should turn in the direction of the arrow on the casing.

4. **Bearings**

Before any pump is started, its bearings must be carefully inspected, cleaned and lubricated. With oil lubricated sleeve bearings, remove the cap, linings, and drain plug. Flush the housing with solvent. Wash bearing parts thoroughly and reassemble them in the housing. Flush the bearing and housing with lubricating oil. Replace the drain plug, caps and other parts and fill the bearing as directed by the manufacturer. Grease-lubricated ball, roller, and needle bearings are usually packed with grease at the factory. Therefore no lubrication may be necessary before starting the pump, but it is advisable to check the condition of the grease by removing the bearing housing cover.

Starting the Pump

To start a centrifugal pump in good operating condition, the following sequence can be followed:

1. Turn on the cooling-water system for pump bearings, stuffing boxes, and mechanical seals, if these parts are liquid cooled.
2. Check the oil level in bearing housing if pump is equipped for oil lubrication.
3. Open the suction valve and close or open the discharge valve, depending on the starting procedure to be followed.
4. Close all drains in the casing, suction and discharge piping.
5. Make sure the pump is properly primed.
6. Start the pump and bring it up to speed.
7. If the pump is started with a closed discharge valve, open this valve slowly.
8. Check leakage from the stuffing boxes.
9. Adjust the sealing-liquid flow to ensure packing lubrication.
10. Check the oil rings on sleeve bearings. They must be turning freely.
11. Check the suction and discharge pressures.
12. Feel the pump bearings for overheating.

LESSON 6

Troubleshooting guide

Centrifugal pumps

1- COMPLAINT: No liquid delivered

Possible Causes

- *Lack of prime*
- *Speed of pump driver too low*
- *Discharge head too high*
- *Suction lift too high*
- *Impeller plugged*
- *Wrong direction of rotation*
- *Plugged suction strainer*

2- COMPLAINT: Not enough liquid delivered.

Possible Causes

- *Causes under "No liquid delivered"*
- *Air leaks in suction line and stuffing boxes*
- *Suction head too low*
- *Worn wearing rings*
- *Damaged impeller*
- *Undersized foot valve*
- *Suction bay disturbances*
- *Oil viscosity-too high*
- *Worn gaskets*

3- COMPLAINT: Pump discharge pressure low.

Possible Causes

- *Speed too low*
- *Worn wearing rings*
- *Damaged impeller*
- *Worn packing*
- *Gas or air in liquid*
- *Pump water passages obstructed*

- *Impeller diameter too small*
- *Wrong direction of rotation*

4- COMPLAINT: Pump loses prime after starting

Possible Causes

- *Incomplete priming*
- *Suction lift too high*
- *Air leaks in suction pipe or packing glands*
- *Gas or air in liquid*
- *Suction line not filled completely*
- *Inlet not completely submerged*
- *Suction head too low*
- *Plugged seal-liquid piping*
- *Lantern ring in stuffing box out of place*

5- COMPLAINT: Pump overloads driver

Possible Causes

- *Discharge head too low resulting in excessive capacity*
- *Wrong liquid, viscosity too high*
- *Speed too high*
- *Wrong direction of rotation*
- *Packing too tight*
- *Distorted casing*
- *Bent shaft*
- *Mechanical failures*
- *Misalignment*

6- COMPLAINT: Stuffing box overheats

Possible Causes

- *Packing too tight*
- *Insufficient packing lubricant*
- *Wrong grade of packing*
- *Insufficient seal lubricant*
- *Incorrect installation of packing*

7- COMPLAINT: Excessive vibration

Possible Causes

- *Gas or air in liquid*
- *Insufficient suction head*
- *Pump misalignment*
- *Worn or loose bearings*
- *Unbalanced rotor (plugged or damaged)*
- *Bent shaft*
- *Non-rigid foundation*

8- COMPLAINT: Bearings overheat

Possible Causes

- *Oil level too low*
- *Poor or wrong grade of oil*
- *Dirt in bearings or oil*
- *Moisture in oil*
- *Clogged or scaled cooler*
- *Insufficient cooling water*
- *Bearings too tight*
- *Too much grease in bearings*
- *Misalignment*
- *Oil seals fitted too closely*

9- COMPLAINT: Bearings wear rapidly

Possible Causes

- *Misalignment*
- *Bent shaft*
- *Vibration*
- *Excessive thrust due to mechanical failure*
- *Lack of lubrication*
- *Wrong bearings*
- *Dirt in bearings*
- *Moisture in oil*
- *Excessive cooling of bearings*