

Principles of Centrifugal Pump Construction

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PRINCIPLES OF CENTRIFUGAL PUMP OPERATION

A centrifugal pump is designed on the principle of imparting velocity to the liquid which it is handling, then directing the liquid with its acquired velocity to the point of use. Velocity is given to the liquid by using the "centrifugal force" which is generated whenever an object is rotated around a central axis. The object being rotated tends to fly away from the center of rotation due to its velocity. The centrifugal force increases proportionately with the speed of rotation.

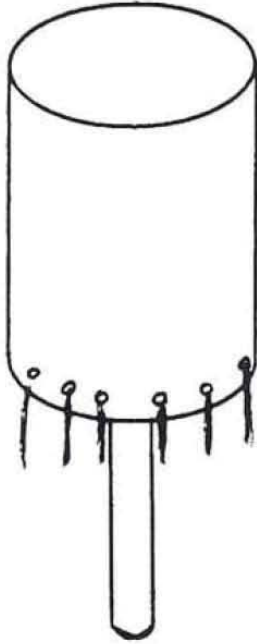


Figure 1

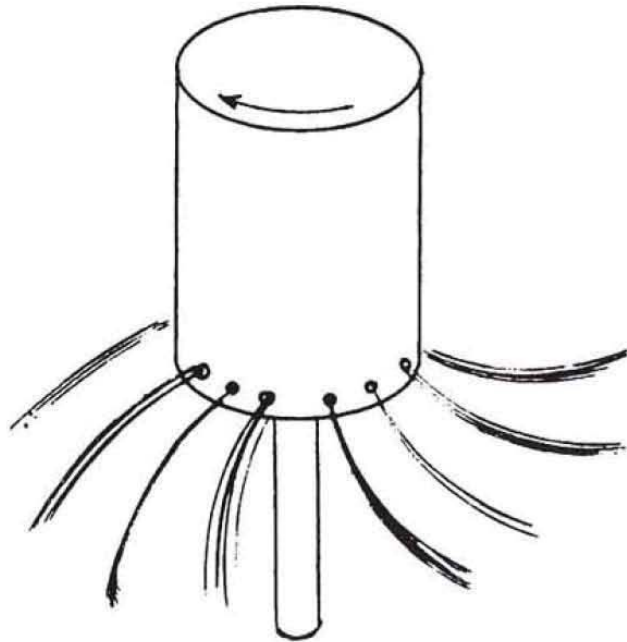


Figure 2

As an example, consider a can with a series of small holes around the rim at the bottom and with an axle mounted in its center as in Figure 1. If we fill the can with water, the water will drain by gravity from the holes. If we rotate the can slowly with a fresh filling of water, the inner walls of the can will impart velocity to the water and it will drain from the holes at an increased rate. The faster we turn the can, the more velocity energy is given to the water and the faster we drain the can. Figure 2 illustrates this fact. We can also increase the rate of drainage or "pumping" by increasing the diameter of the can, which in effect allows more velocity to be imparted to the water due to the increased speed at the can's rim. This rotating can represents the "impeller", the device which increases the velocity of water in a centrifugal pump.

Now, suppose we close up the opening on top of our can and place a compound pressure gauge in the cover. If we begin with a full can of water and are performing our

experiment at sea level, the gauge will read zero psi gauge pressure or 14.7 psi absolute pressure. With the can at rest, no water will leak out because a state of equilibrium exists between the pressures inside and outside the can. Water can't leave the bottom openings unless air can enter to displace it. If the can were now rotated, water would leave the holes as before due to the velocity imparted to it and the gauge in the cover would indicate a drop to below atmospheric pressure, a vacuum. Theoretically, we should be able to empty the can in this manner and create a perfect vacuum in the can. Of course, as soon as we pumped all the water from the can, air would enter the holes and break the vacuum, since the can would have nothing to pump but air at this point. Air, having very little density compared to water, cannot readily be pumped by a centrifugal pump impeller and centrifugal pumps are, for this reason, very inefficient air pumps. This is why a centrifugal pump must be "primed", or flooded with water, in order to pump at all. Vents are often included in the pump design to allow the operator to insure that all air is removed and the pump is completely flooded with water before putting it in operation. In order to vent a pump, turn it off then open the vent and allow system pressure or static head to push air from the pump body. If you try to vent a pump while it is running, water will come out of the vent due to centrifugal force, but any air will remain trapped around the center of the impeller.

To further explain the centrifugal pumping process, let us use our "can impeller" to construct a centrifugal pump. Figure 3 shows our impeller with its shaft supported by a bearing, being driven through a coupler by an electric motor. The impeller is installed in an enclosure, the "volute", which collects the water leaving the impeller and directs it out through the pump discharge. The impeller opening or "eye" is located at the pump suction opening. The entire apparatus is mounted securely on a steel base.

The suction opening of our pump is connected to the source of the fluid to be pumped and the discharge side is connected to the point of use. When the pump motor turns the shaft, fluid is delivered to the discharge opening and pressure in the inlet, or eye of the impeller drops. The pressure at the discharge rises because of the action of the impeller and volute. The pressure differential between the fluid source and the impeller eye causes fluid to enter the suction side of the pump at the same rate as the fluid leaving the pump discharge.

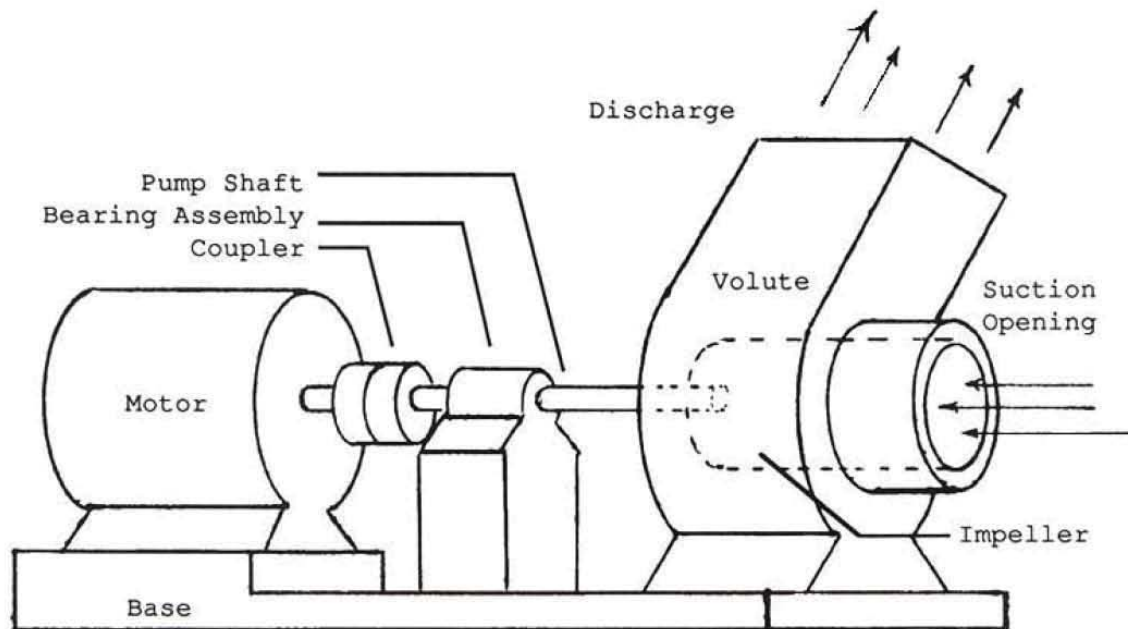
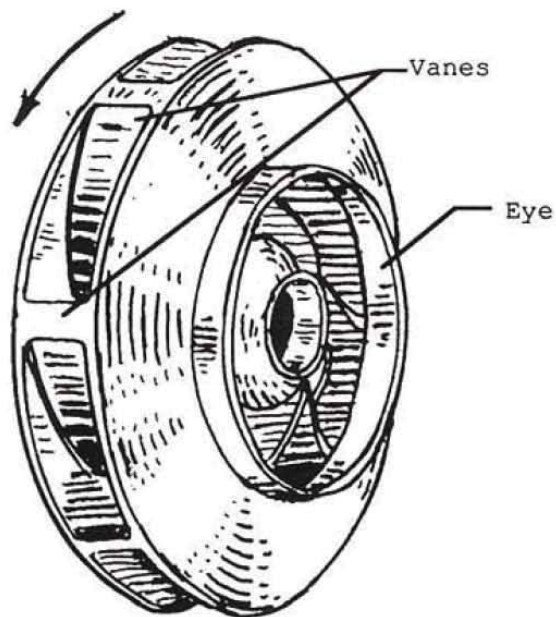


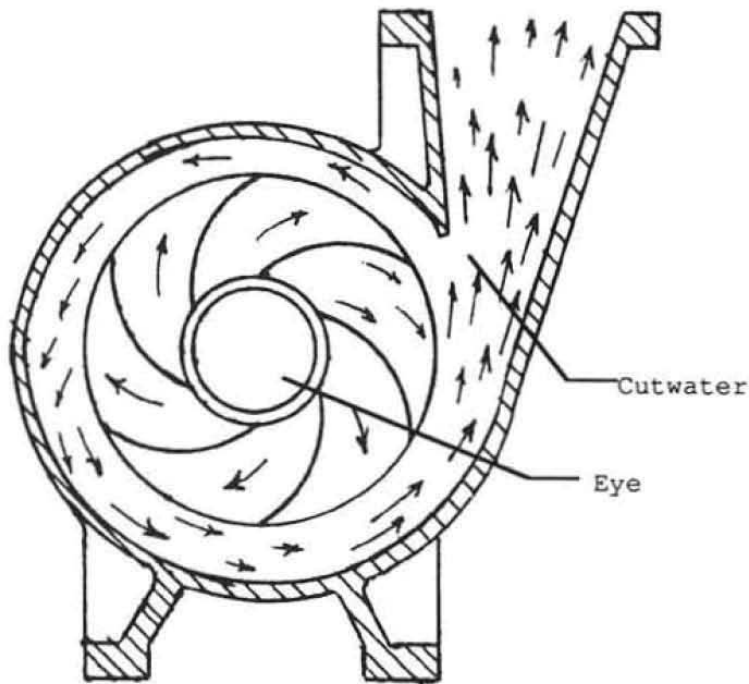
Figure 3



Single Suction Impeller

Figure 4

The rotating can impeller used in this illustration would be very inefficient and was used only to describe the principles involved. In actual practice, a number of curved blades or "vanes" are provided inside the impeller to pick up the fluid and increase its velocity. These blades are shaped to streamline the flow pattern, and minimize turbulence. Figure 4 shows a typical impeller with the proper direction of rotation. Notice that the blades or vanes always "slap" the water - they do not "dig in".



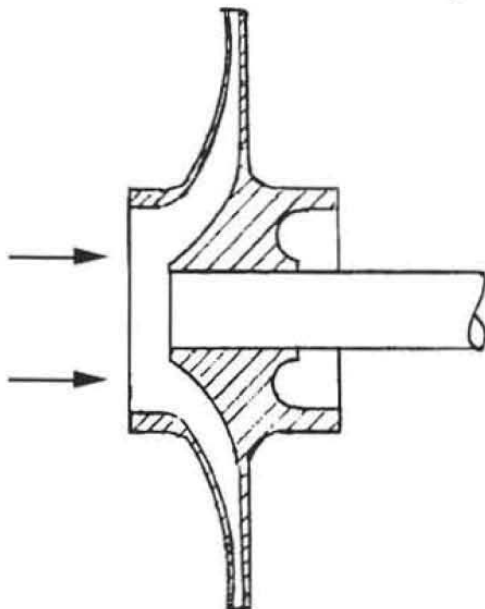
Impeller and Volute

Figure 5

Figure 5 shows the impeller inside the pump volute with arrows indicating the direction of water flow. The portion of the volute at the narrowest passage between the impeller and volute is called the "cutwater", where flow from the pump toward the discharge begins. Figure 5 illustrates why the impeller direction of rotation must be toward the discharge opening for proper operation. Reverse rotation of the impeller will greatly reduce the flow rate compared to forward rotation. Reverse rotation also increases turbulence and motor loading.

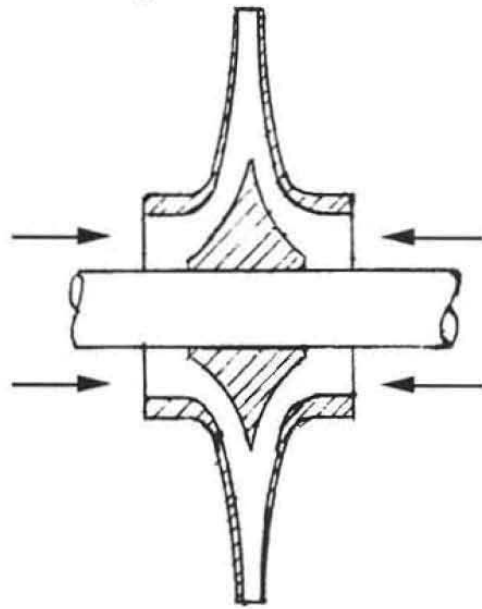
IMPELLERS

Impellers of the type just described are called "single suction", since all the water enters at one side of the impeller as shown in Figure 6.



Single Suction Impeller

Figure 6



Double Suction Impeller

Figure 7

In some cases, the pump impeller is constructed so that the water enters at both sides as in Figure 7. This is called a "double suction" impeller. Impellers like

these which have a wall or "shroud" enclosing the vanes on both sides are called "closed" impellers. Closed impellers are used whenever the pumped liquid is free of large particles which might clog the impeller passages. Where moderately sized particles are included in the pumped liquid, the front shroud is omitted and the impeller is called a "semi-open" impeller. In cases where larger solids must be handled with the liquid, such as in sewage pumping, both shrouds are omitted and the impeller is of the "open" type. For pumping relatively clean water, closed impellers are more efficient than open impellers.

Impellers can be made from a variety of materials such as cast iron, plastic, bronze, or stainless steel depending upon the type of fluid to be pumped, its temperature, and the amount of abrasive solids it might contain. They will always be designed with smooth surfaces and streamlined flow passages to cut down on friction losses.

SUCTION PIPING AND SUCTION LIFT

Because a centrifugal pump can elevate water in its suction line, it is sometimes said that the pump "lifts" the water. The pump does not actually lift the water, but makes it possible for atmospheric pressure to lift it. As we saw earlier, a decrease in pressure takes place in the eye of the impeller and the suction line when a pump operates. The liquid in the suction line rises in response to atmospheric pressure pushing it up the line.

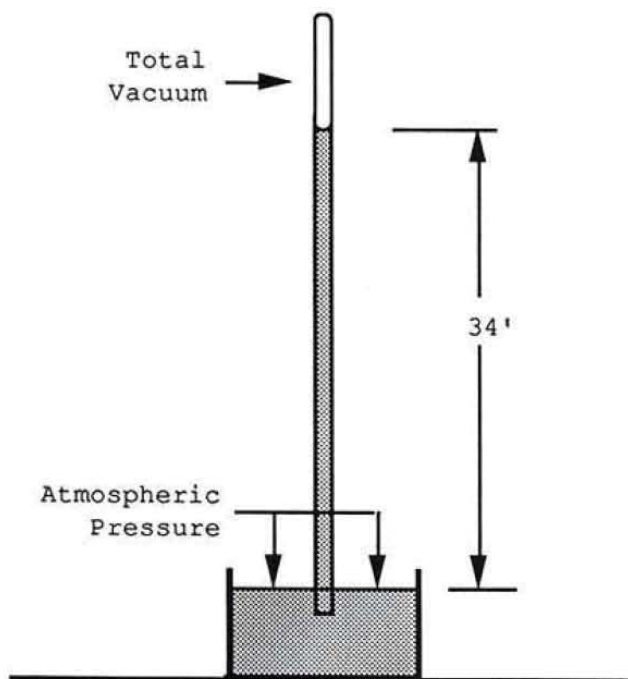


Figure 8

Figure 8 shows a closed tube that's been filled and inverted into a beaker of water. Using cold water at sea level, atmospheric pressure will support a column of water about 34 feet high. Therefore, a pump could lift water this high ("suction lift") if it were capable of pulling a total vacuum in its suction line. This is not possible due to the vapor pressure of the water and the fact that no pump can be 100% efficient. Some centrifugal pumps are capable of as much as 26 feet of suction lift at sea level at reduced efficiencies and assuming that the liquid vapor pressure is low enough, but most centrifugal pumps are

limited to a total suction lift of 15 feet when used with their published capacity curves. Keep in mind that friction losses in the suction piping will reduce even further the actual amount of suction lift that a given pump may be able to achieve.

Special priming systems or pump designs are required to keep a pump primed in the static suction lift situation. An example is shown in Figure 9.

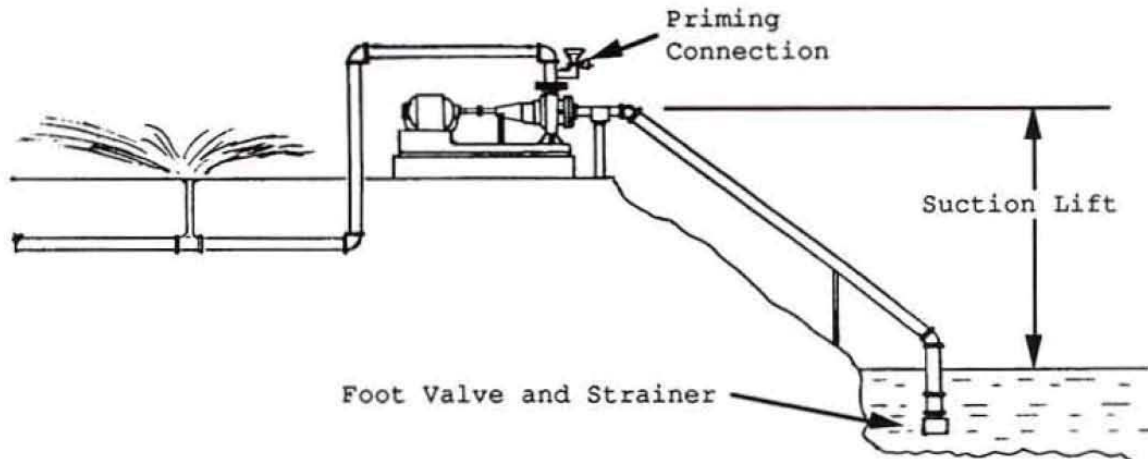
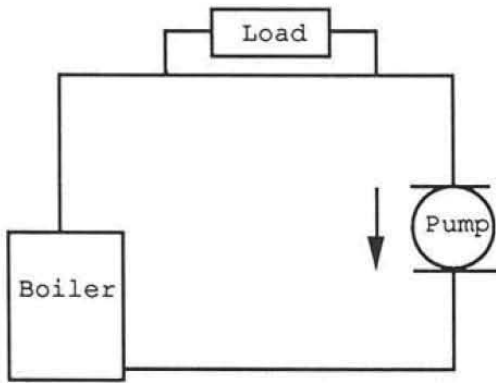


Figure 9

In order to cause flow under conditions of suction lift, the suction line as well as the pump body must be primed. This means that a type of check valve, sometimes called a "foot valve", must be installed at the inlet end of the suction line to hold the prime whenever the pump stops. A strainer is usually placed ahead of the foot valve to keep out trash which might cause leakage of the foot valve. Figure 9 shows the use of a centrifugal pump to raise water from a pond for irrigation, with the various components described above.

Since the pump must maintain a partial vacuum in its suction line to insure suction lift, it is vulnerable to any leaks in this line which will allow air to enter and break the vacuum. A small leak will greatly reduce pumping efficiency and a leak of any consequence will stop the flow altogether. An external priming connection can be used to refill the pump if it should lose its prime.

Where the liquid source is above the pump suction, a "static suction head" exists. As long as air is properly vented, the pump will always be primed and will deliver water whenever it operates.

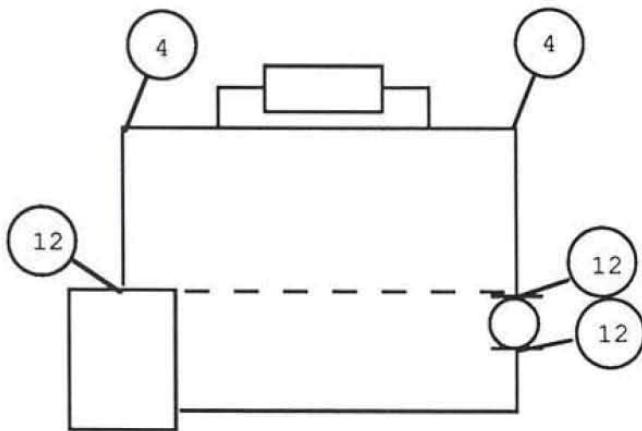


Closed System

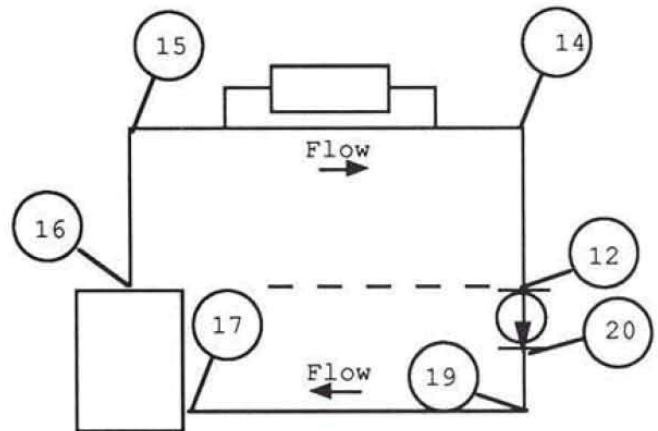
Figure 10

This is also true for a pump installed in a closed piping system, where the pump is always flooded and the pump head is used only to overcome the circuit pressure drop caused by friction losses. Figure 10 represents a closed system. When the pump in a closed system is not operating, only the static pressure, that is, the pressure due to the weight of the water plus any extra imposed pressure, will show on the gauges. This is illustrated

in figure 11 (Pump Off - Static Pressure Only), where 4 psi has been added to pressurize the highest point in the system, plus the static elevation of the system equals a total of 12 psi at the boiler. When the pump starts, the pressure readings change to show the additional pressure head created by the pump. The pump head is always completely used up by friction losses as water flows through the closed loop. The 20 psi discharge pressure shown on the right is equal to the 12 psi static pressure plus 8 psi caused by the head of the pump. As water flows through the system back to the pump suction, all the pump head is used up in causing flow and overcoming the pressure drop of the system. The pump suction gauge will continue to read 12 psi of static pressure only.



Pump Off - Static Pressure Only



Pump On - Static Plus Pump Head

Figure 11

MATERIALS USED IN PUMP CONSTRUCTION

Centrifugal pumps are constructed of various metals, alloys and other materials, depending on the fluid being pumped and its temperature. In this manual, we will limit our discussion to the materials commonly used in general pumping and HVAC applications.

Bronze Fitted Pumps

Bronze fitted pumps have a cast iron ("ferrous") pump body or volute, a steel shaft, and a bronze impeller. The metal parts of the seal assembly are made of brass or some other non corroding material. These pumps are used in closed heating or chilled water systems where very little or no make-up water is required. They hold up well in this service, since the water in a closed system quickly becomes chemically inert as far as corrosion of iron pump parts is concerned. With no free oxygen in the water, excessive corrosion of the volute is limited. The bronze impeller, the heart of the pump, is inherently resistant to corrosion. These pumps are also used for pumping fresh water at relatively low temperatures, since corrosive action on the ferrous pump parts drops off sharply with reduction in temperature. Typical examples are hydronic system pumps, irrigation pumps, cooling tower pumps, sump pumps and process pumps.

All Bronze Pumps

In these pumps, the volute, the impeller and all other wetted parts are made of bronze or other non ferrous materials. The steel pump shaft is equipped with a bronze sleeve at the impeller end to prevent contact with the water thus avoiding corrosion. Bronze pumps are used in higher temperature fresh water systems where the bronze fitted pumps would have their working parts and the cast iron pump body affected by corrosion. Typical examples are for recirculation lines in domestic hot water systems and pumping hot process water.

Stainless Steel Pumps

New methods of working with stainless steel have allowed the use of deep drawn stainless steel plate for pump volutes and impellers. The pump shaft can be stainless steel or carbon steel, and the seal components could be bronze or stainless steel. Since these materials are inherently resistant to corrosion, they are often used in many of the same applications as the all bronze pumps. They can also be used in place of the bronze fitted pump, or in applications where even a small amount of iron corrosion would be unacceptable, as in pumping inks or dyes. They are limited to applications where the pumped liquid will not cause damage to the stainless steel material.

PUMP MOTORS

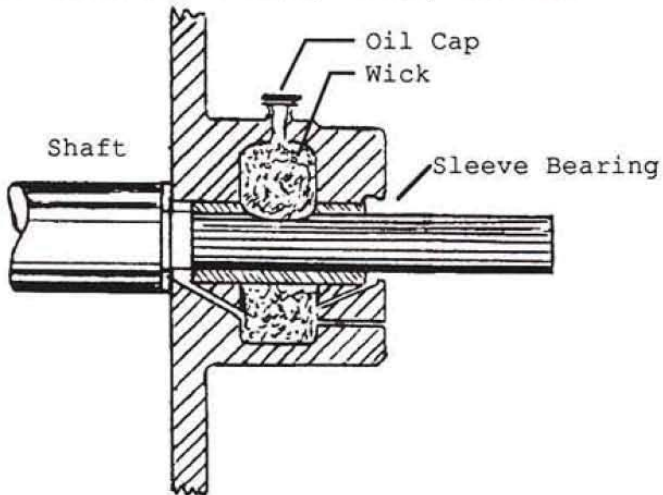
Any prime mover; a steam turbine, diesel engine, etc. could be used to drive a centrifugal pump. This manual is concerned only with pump applications that use electric motors.

Motors are enclosed in a casing that provides some protection from water and dirt. Most motors used with hydronic system pumps are "open, drip proof" designs, (abbreviated as ODP), which give minimum protection from spray and overhead drips. Other designs are available which give more protection, such as "totally enclosed, fan cooled", (TEFC), and "explosion proof".

Motors are available to operate in a variety of horsepower ratings, temperature ranges, and voltages. They can be constructed for use with 60 Hz current to drive pumps at one of a number of different constant speeds, for example, 1150, 1750 or 3450 rpm. Most common pump designs use one of these rotational speeds. Motors can also be equipped to provide variable speed to minimize pump operating costs. Although standard motors usually have good efficiency ratings, some people prefer to use special high efficiency motors.

PUMP BEARINGS

Like motors, pumps are equipped with various types of bearings to support the shaft with minimum friction, noise, and wear.



Oil Lubricated Sleeve Bearing

Figure 12

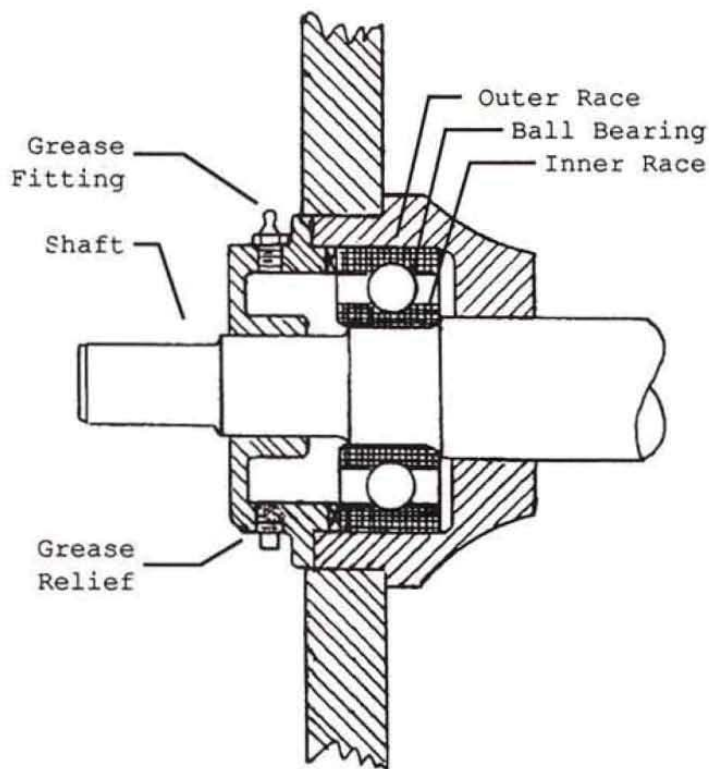
Sleeve Bearings

Figure 12 illustrates a typical lubrication system for a sleeve bearing. The wick lubricated bearing shown in Figure 12 uses the capillary action of a wicking material to feed oil to the bearing. Woolen wicks are the traditional material, although synthetic materials have also been developed which can absorb a great deal of oil. These wicks are packed in the oil reservoir, and oil is added until the wick is completely

oil-soaked, and the reservoir below the wick is full of oil. The wicking material carries oil to the top of the bearing, where a hole in the sleeve allows oil to coat the shaft. As the shaft rotates, it spreads the oil in a thin film between the

shaft and the stationary sleeve bearing. In effect, the shaft is supported on this oil film as it rotates, reducing friction and noise, and carrying away heat. Figure 12 shows a sleeve bearing used in small pumps. As a rule, the oil in these bearings is not changed, since the oil chamber is packed with wicking which tends to keep dirt and other foreign matter out of the oil. If the wick should become non-absorbent due to a build up of dirt, it can be replaced in many pump designs. Motor bearing wicks, and synthetic wicks rarely need to be replaced.

High grade non-detergent mineral oils or synthetic oils of the type and viscosity recommended by the manufacturer for the conditions under which the pump or motor is running are preferred. If these lubricants are not available, SAE 20W oil may be used with satisfactory results. A program to insure that these bearings are periodically lubricated will help avoid running the pump or motor without oil. This can cause overheating and ruin the shaft. Checking and lubricating these bearings twice a year, at the beginning and midway through the heating season for example, is often sufficient, but where a pump or motor is operating in a high temperature area, it may need oil more frequently.



Typical Ball Bearing

Figure 13

Ball Bearings

Figure 13 shows a typical ball bearing. The bearing inner ring or "race" rotates with the shaft usually by means of a tight press fit, while the bearing outer ring is stationary in the bearing housing. Rotation of the shaft is converted into rolling friction by the ball bearings that are held between the two rings. The snug, but not tight, fit of the outer race prevents stresses or binding of the bearing due to expansion of the shaft with heat. Some pumps or motors are equipped with "permanently lubricated" bearings and require no lubrication - they are simply replaced when they wear out. These

bearings are packed with grease and supplied with a shield on each side which retains the grease and keeps out dirt. The bearing in Figure 13 has a grease shield

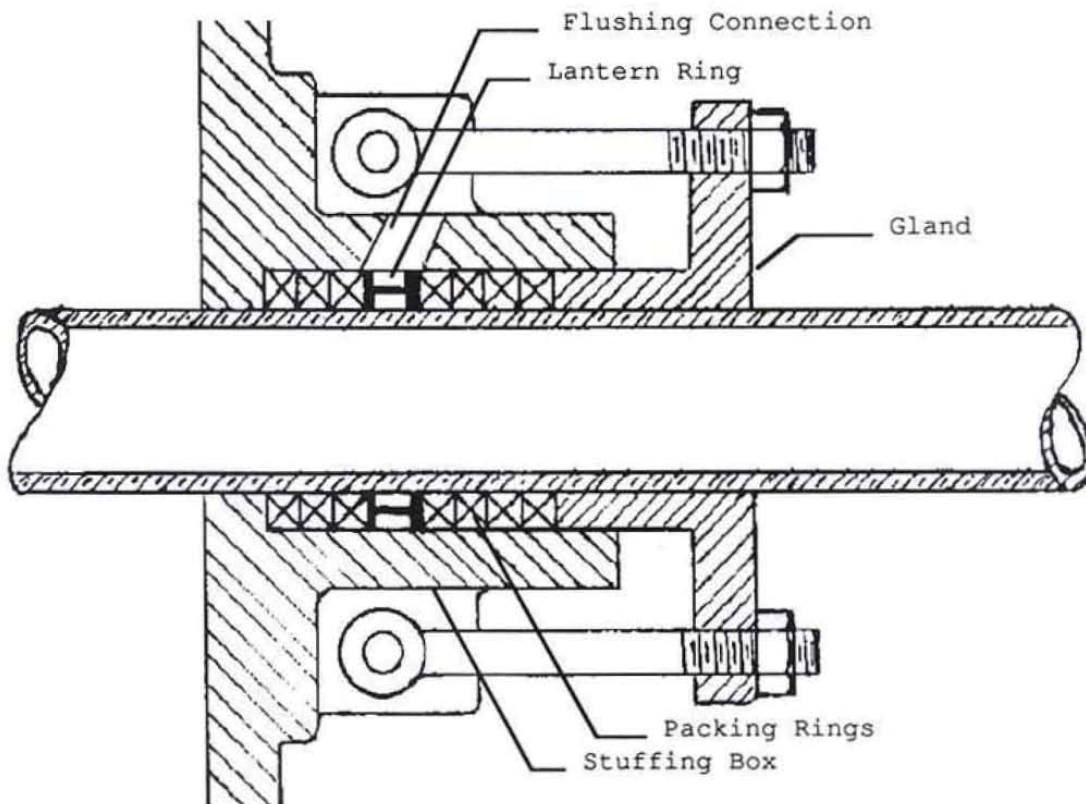
only on the inner side so it can be re-greased. The bearing housing is provided with a grease fitting and grease relief hole for that purpose. These bearings require lubrication at regular intervals to replace the old grease and its accumulated dirt with fresh, clean grease. This is done by removing the drain or relief plug from the bearing housing and adding grease until all the old, dirty grease is forced out of the relief hole. The shaft should be turning during this process. The relief plug should not be replaced until the bearing has cleared itself of all excess grease through the relief port. Greasing these bearings without opening the relief port will pack the bearing solidly with grease and cause overheating and possible bearing failure. That's why some designs don't include a plug for the relief hole.

PUMP SEALS

The point where the pump shaft enters the pump body must be provided with a seal to prevent leakage of water from the pump, or air into the pump. The two most commonly used sealing devices are mechanical seals and compression packing rings.

Compression Packing Ring Type Seals

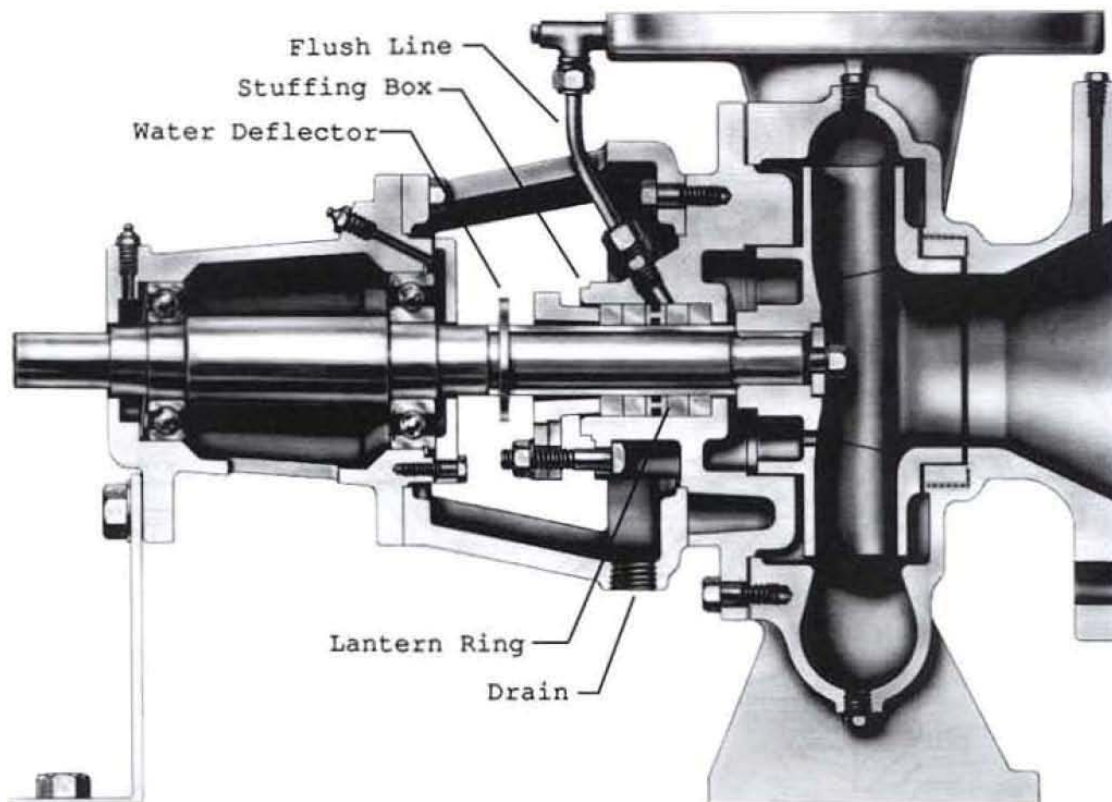
Figure 14 shows a stuffing box and packing rings.



Stuffing Box and Flushed Packing Rings

Figure 14

The stuffing box is part of the pump's backplate. The packing rings are made of graphite impregnated cord or Teflon formed into split rings that fit snugly around the shaft. They are compressed into the stuffing box by means of a packing gland which is pulled in by a pair of gland nuts and bolts as shown. The "lantern ring" in the center of the stuffing box distributes flushing water from the discharge of the pump throughout the stuffing box to cool and lubricate the shaft as it turns against the packing rings. It's important that the packing gland be loose enough so that the packing drips steadily. Too much packing pressure will reduce leakage, causing heat to build up in the stuffing box, hardening of the packing rings, and scoring of the shaft sleeve. In operation, the pump must be checked regularly and the packing adjusted to maintain a proper leakage rate as the rings wear and the lubricant is squeezed out of them. After a period of time, the packing will lose its resilience and lubrication. This is often accompanied by overheating of the stuffing box and excessive leakage if the gland is backed off to allow cooler operation. At this point, the packing must be replaced with the proper type and in the proper sequence as called for in the manufacturer's instructions. Earlier pump designs sometimes used the packing rings without a flushing connection. Cooling leak-off was simply flowed from the pump, past the rings of packing, to the gland.

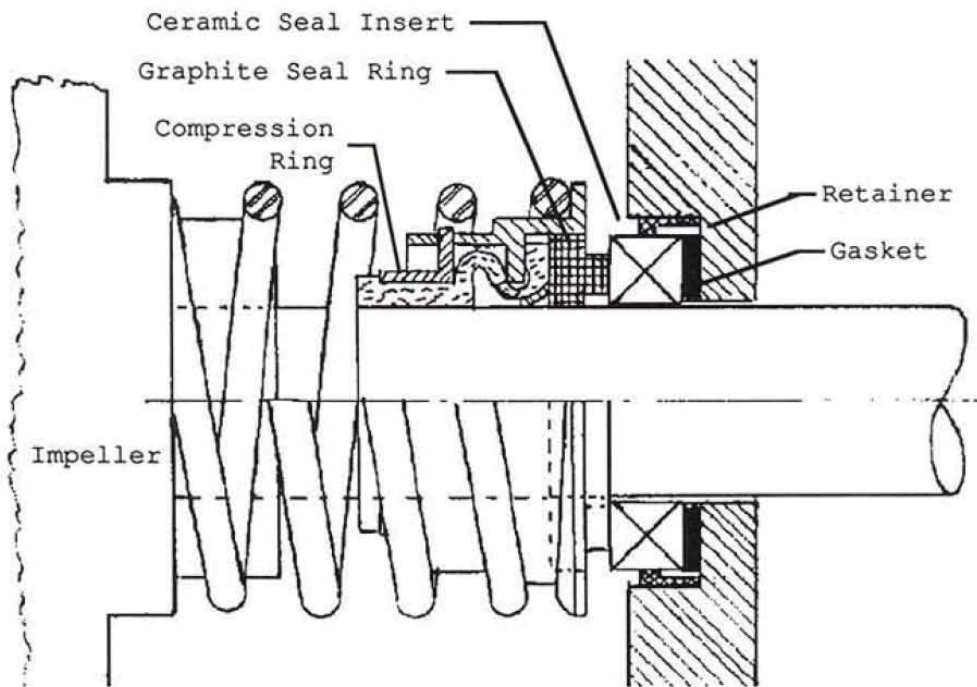


Bell & Gossett Series 1510 Pump With Stuffing Box Construction and Flushed Packing
Figure 15

Figure 15 shows a pump equipped with a stuffing box and flushed packing. Notice the flushing line that allows water from the discharge of the pump to cool and lubricate the rings in the stuffing box. There's a drain connection, and sometimes a shallow pan, to catch the leak-off from the stuffing box to avoid spilling water on the floor. Since the compression packing rings have a tendency to cut grooves in the pump shaft if they dry out and overheat, all pump shafts that use packing are equipped with replaceable shaft sleeves that rotate with the shaft and rub against the packing. If the packing should become dry, and score the sleeve, it's economical to replace the sleeve rather than the shaft.

A water deflector or "slinger ring" is a piece of composition material installed on the shaft between the stuffing box and the bearing. Its job is to intercept excess water that leaks from the stuffing box and throw it out at right angles to the shaft to keep the bearings from becoming wet. Water in the bearing oil or grease could cause corrosion and failure of the bearing.

Because of the constant leak-off from packed type pumps, make up water must be regularly added to the system. This water usually carries oxygen with it, causing corrosion and other system problems. In order to avoid these problems, most hydronic system pumps are equipped with mechanical seals instead of packing rings. One of the most important features of the mechanical seal is that it doesn't require any leak-off. Therefore, the amount of makeup water is greatly reduced thereby avoiding corrosion and air control problems. A mechanical seal goes a long way toward making the hydronic system a truly "closed system".



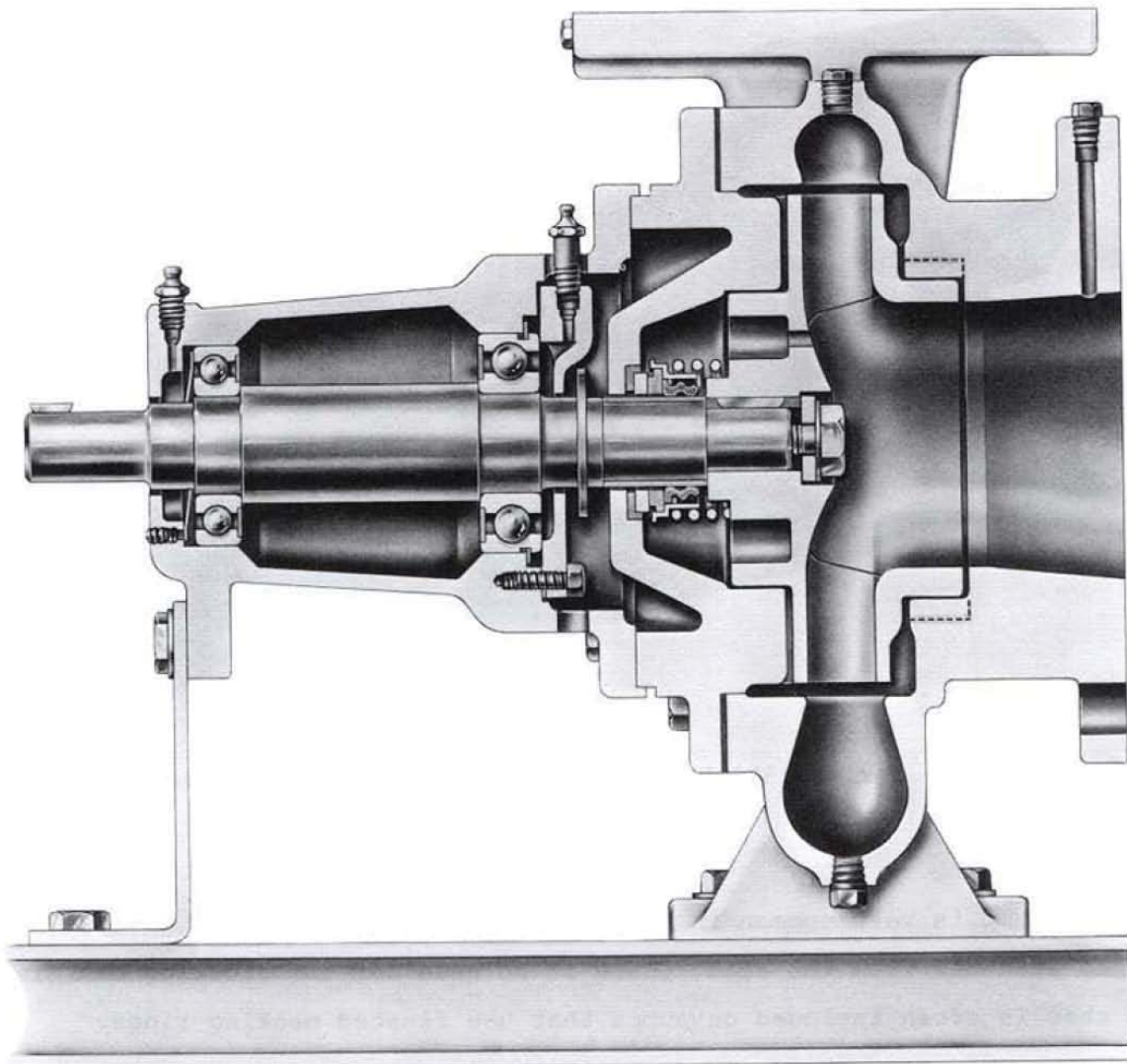
Internally Flushed Mechanical Seal

Figure 16

Mechanical Seals

Figure 16 shows a typical mechanical seal installed around the shaft instead of the stuffing box gland and packing rings. This seal has a hard ceramic ring around the shaft. This stationary ring, or "seal insert" fits into a recess in the pump body with a rubber gasket behind it to form a watertight seal. The insert is kept from turning by means of a retainer pressed into the recess which engages flats on each side of the ring, or in some designs, by an "L" shaped rubber cup or boot which acts to prevent both leakage and rotation. A "seal ring", often made of graphite, rotates against the lapped face of the ceramic and forms the primary seal. The graphite seal ring is backed up by a rubber bellows and compression ring which fits tightly on the pump shaft preventing leakage along the shaft, and insuring that the seal ring will rotate with the shaft. The rotating seal ring is held tightly against the stationary ring by means of the seal spring. The bellows allows the spring to push the seal ring forward to make up for wear without disturbing the compression ring on the shaft. System water always flows around and between the seal faces, carrying away the frictional heat that builds up as the seal rings rotate against each other. That's why a pump must never be run dry - lack of cooling water will destroy the seal faces in short order. Some of this flushing water evaporates in the process, and a tiny amount of vapor is lost from the pump. A shaft sleeve is sometimes installed under the compression ring to prevent pitting. These sleeves protect the shaft and are easily replaced if necessary. No maintenance or adjustments to the seal are needed. In the event that the seal becomes worn and leaks, it

is replaced. It's good practice to replace all seal parts. That's why most seal kits contain all the parts needed for a new seal. If a combination of new and old seal rings and seal inserts are installed together, they will probably leak because the old part takes up a certain wear pattern that can't be matched by the new part.

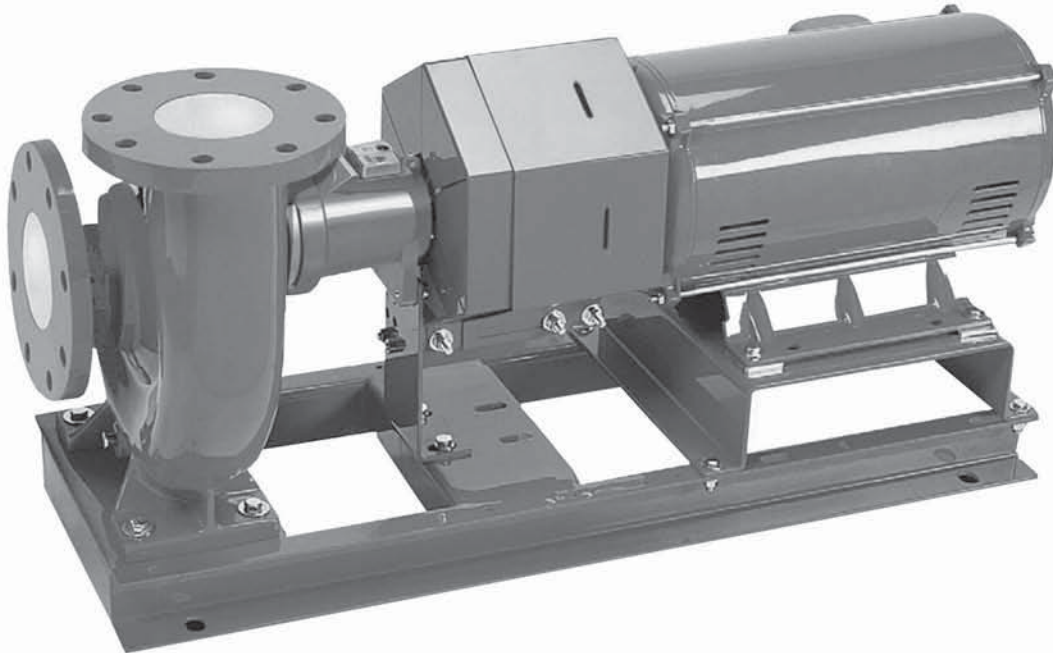


Bell & Gossett Series 1510 Pump With Internally Flushed Mechanical Seal

Figure 17

The pump in Figure 17 is the same pump that was shown before with the stuffing box and compression packing rings. The internally flushed mechanical seal does not require the stuffing box construction, so the volute cover plate is simpler in design, and often less expensive. The seal operates in a "seal cavity" formed by the cover plate and the back of the impeller. This cavity insures that the seal gets plenty of water circulation to keep it running cool. It's called an internally flushed seal because no external flush lines are needed. The volute, impeller, and base are essentially the same as in the packed type pump. A water slinger is installed

between the seal and bearings to protect the bearings from leakage if the seal should fail. The drain hole below the slinger is a good place to check for indications of seal failure.

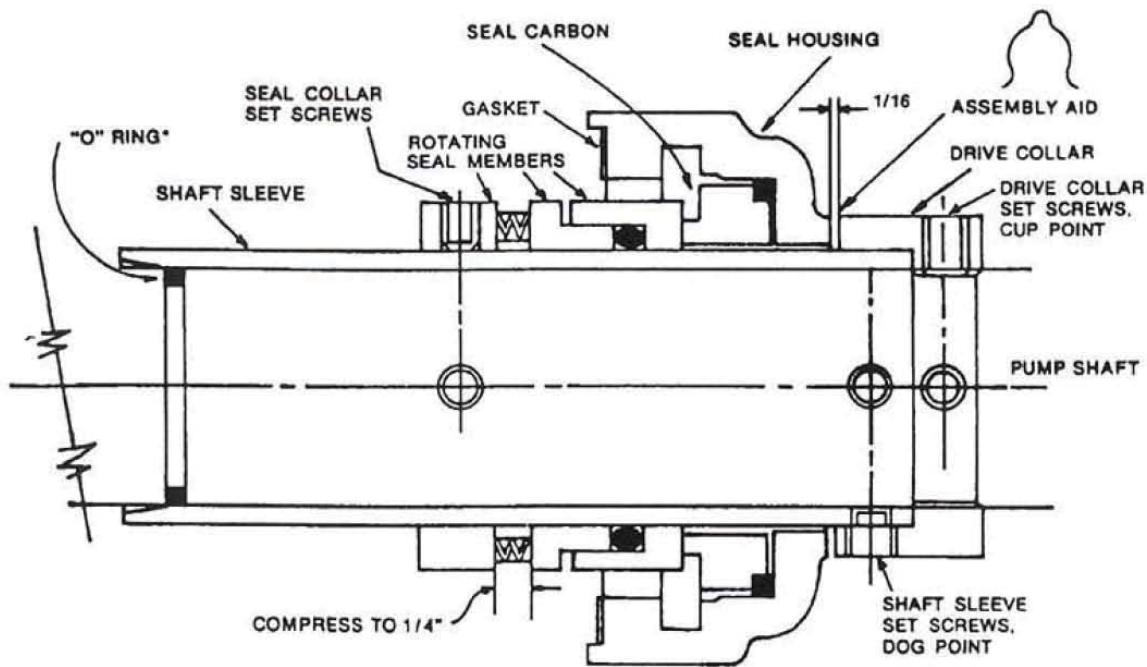


Bell & Gossett Series 1510 Pump with Internally Flushed Mechanical Seal

Figure 18

This type of pump is very common in HVAC and general pumping applications. Because there is no leak-off from the seal, there is no need for the stuffing box drain and drip pan that is often included on pumps that use flushed packing rings.

The bearing assembly in this "standard" design is slightly different from the bearing assembly used in the stuffing box construction. However, in both designs, the ball bearings in the bearing assembly are semi-sealed with a single grease seal. They are pressed onto the shaft so that the inner ring of the bearing rotates with the shaft. The shaft sleeve is made of a corrosion resistant high leaded tin bronze, and it's sealed to the shaft by means of an adhesive that insures the sleeve and shaft turn together, and prevents leakage between the shaft and the sleeve.



Typical Externally Flushed Mechanical Seal

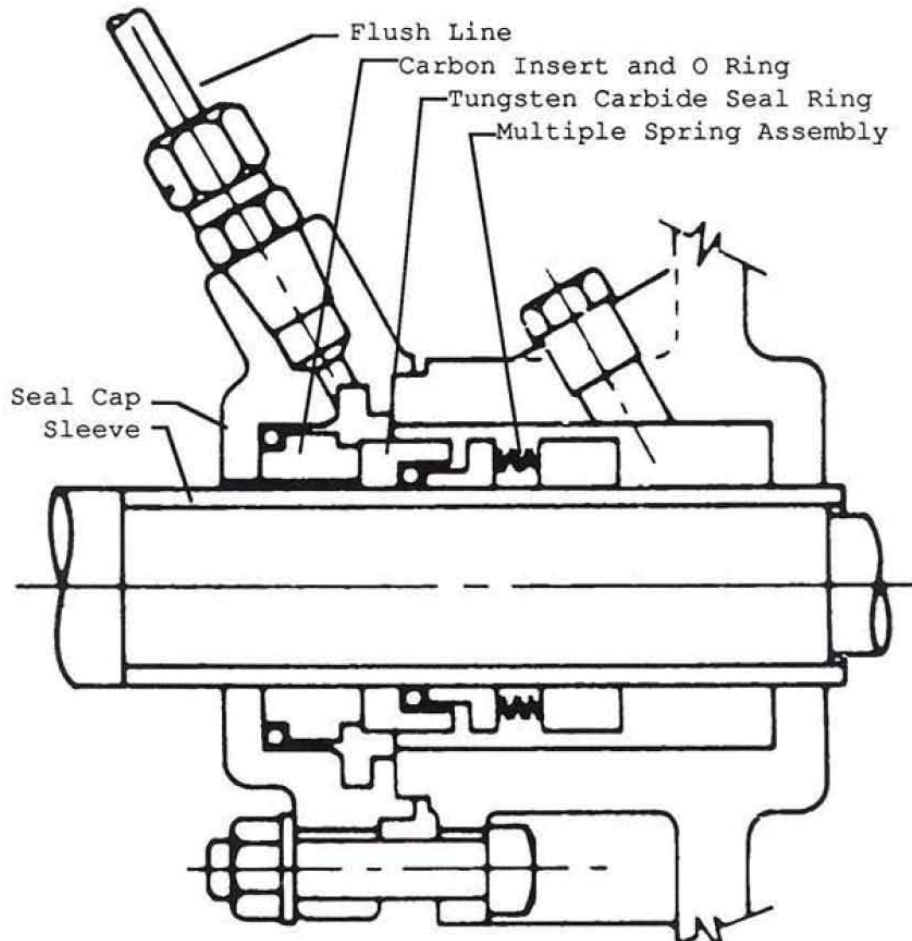
Figure 19

Another kind of mechanical seal is used where high system temperatures, high alkalinity, or high concentrations of water treatment chemicals might cause the internally flushed mechanical seal in Figure 16 to fail prematurely. The seal in Figure 19 has a stationary carbon insert, (seal carbon) backed up by an O ring in the seal housing, or "seal cap". The rotating seal ring is made of tungsten carbide, an extremely hard material, which has been lapped to a high degree of flatness. Instead of a compression ring, this seal uses an O ring to prevent leakage along the shaft, and a stainless steel collar and multiple spring assembly to drive the seal and hold the seal faces tightly together. Multiple springs provide a more constant sealing pressure compared to the single spring design. The whole seal is mounted on a shaft sleeve, and fits in the pump stuffing box. The stuffing box construction is required because this seal needs to be flushed by water from the discharge side of the pump. Unlike the packing ring construction, this seal has no leak-off out of the pump; all of the flush water goes back into the pump except for the tiny amount that evaporates in the process of cooling off the seal faces.

These seals are more expensive than the simpler, internally flushed seal, but they hold up longer in systems where high concentrations of chemicals would build up solids between the seal faces as the water evaporates, and act as an abrasive to ruin the seal faces.

In this seal, the shaft sleeve is often made of stainless steel, and is mechanically locked to the shaft by a drive collar, rather than the adhesive used in other pump designs.

Figure 20 shows how the externally flushed mechanical seal fits in the stuffing box in place of the packing, lantern ring, and gland.

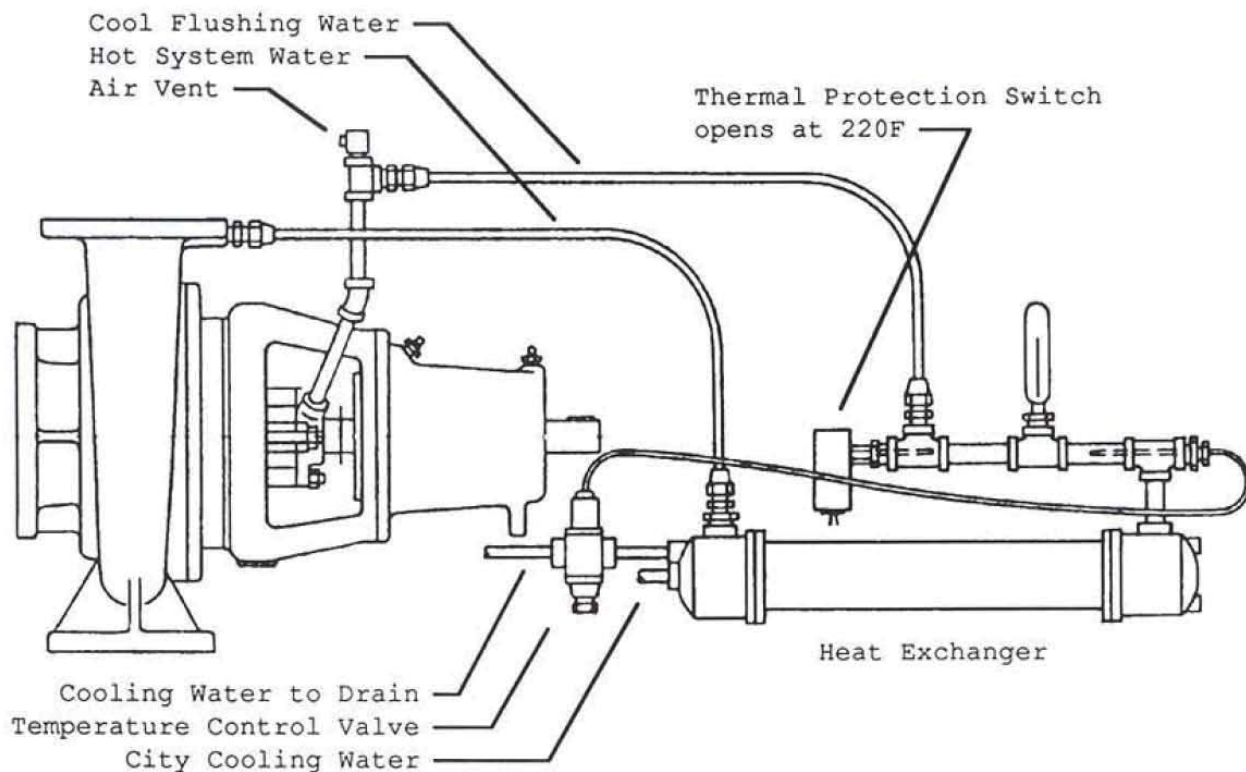


Externally Flushed Mechanical Seal

Figure 20

Notice that the flush line applies water directly to the seal face where the rotating and stationary rings make contact.

Although this mechanical seal is built to hold up under higher system temperatures, it lasts longer if the water in the seal chamber is cooled to about 180°F. This cooling can be accomplished by a heat exchanger which uses city water to cool the system seal flushing water as shown in figure 21.

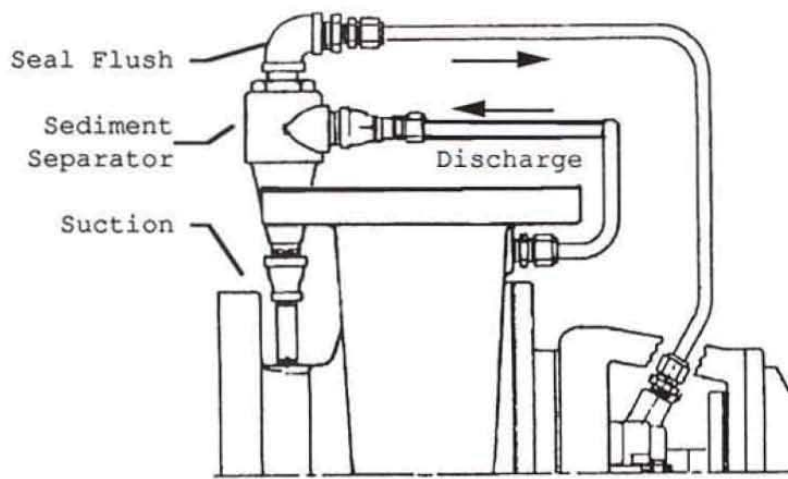


Heat Exchanger to Cool Seal Flushing Water

Figure 21

For a one gallon per minute flow of flushing water, and a system temperature of about 250°F, the heat exchanger would have to cool the flush water to about 125°F in order to get a temperature of about 180°F at the seal. A typical heat exchanger installation is shown in Figure 21. The temperature control valve varies the flow of city water to provide constant temperature flushing. The optional high temperature cut off switch will stop the pump motor if the flush water temperature gets too high. Since there is no leak-off, all the flushing water that leaves the pump to go to the heat exchanger returns to the system at the seal.

Seals of all designs can be damaged by suspended solids in the system water. These solids may be dirt or grit left over from system construction, or they may be magnetic iron oxide particles which result from corrosion of the piping. These solids are suspended in the water, they are not dissolved in it like water treatment chemicals. They can cause seal wear and failure by collecting between the seal faces and acting like an abrasive to score even the hard tungsten carbide seal ring material used in externally flushed seals. A sediment separator is sometimes installed on a pump that must handle water with large concentrations of these solids. A typical sediment separator is shown in Figure 22.



Sediment Separator Installation

Figure 22

Seal flushing water from the discharge of the pump is pumped to a conical sediment separator which gives it a whirling motion.

Centrifugal force acts on the heavier particles suspended in the water, hurling them to the rim of the separator, and back to the suction side of the pump. The relatively clean water from the center of the sediment separator is then sent to flush the seal as shown.

Many systems require water treatment chemicals. Closed systems that are clean and tight need relatively little treatment if they are properly cleaned on start up, but open systems like cooling towers sometimes require large doses of several different chemicals to control corrosion or algae growth. Boiler feedwater in steam systems usually requires significant treatment to avoid oxygen pitting and corrosion in the boiler. In these cases, it's best to mix the chemicals and inject them downstream of the pump discharge so they can mix with the system and become fully diluted. If chemicals are simply dumped into the pump suction, the high chemical concentration and abrasive action of undissolved chemicals can destroy the impeller and seal.

PUMP COUPLERS

The pump coupler is required to:

- (1) transmit power from the motor shaft to the pump shaft, and
- (2) compensate for minor misalignment between the pump and motor shafts.

While couplers will do this within the tolerances established by the coupler manufacturer, you should keep in mind that the closer the shaft alignment, the better and more quietly the pump will operate. Operating a pump with severe misalignment between the shafts will result in noisy operation, early coupler failure and possible pump or motor bearing failures.

Shaft alignment may be accomplished by means of a straightedge or dial indicator, depending on the coupler manufacturer's specifications. The straightedge method is acceptable for most small pumps. The dial indicator method is preferred for larger

pumps or where the coupler manufacturer requires it. Both methods are fully explained in other ITT Bell & Gossett publications. Shaft alignment for pumps operating at 3450 rpm is more critical than for pumps operating at 1150 or 1750 rpm.

Pump couplers are furnished in several basic types; the equalized spring type, the flexible disc type, and the drop out sleeve type.



Equalized Spring Coupler

Figure 23

Figure 23 shows the coupler used on small pumps where quiet operation is essential. The motor turns the pump shaft through four springs in tension, with the torque balanced on all springs by an equalizing bar. This coupler requires no maintenance and is trouble free provided alignment is proper. Shaft misalignment is the most common cause of coupler breakage and noise. Motors with resilient motor mounts are sometimes over oiled with excess oil spilling on the rubber mountings. Constant oil soaking

causes deterioration of the mounting and sagging of the motor shaft. Mountings should always be checked for this condition when coupler breakage occurs. This kind of coupler will usually break long before significant damage can occur to more expensive pump components like bearing assemblies or the impeller. Since these couplers are inexpensive, this offers low cost protection for the pump.



photograph courtesy of Lovejoy, Inc.

Flexible Disc Coupler

Figure 24

Figure 24 shows the typical flexible disc, or "jaw" type coupler. These are used on applications where extremely quiet operation is not required and for larger motors than the spring type coupler can handle. The motor drives the pump shaft through the flexible center member, or "spider", which absorbs misalignment or shock. The spider should be checked for wear if the pump vibrates, or is noisy. The flexible disc should never be tightly bound between the two

coupler halves. Maintain the slight clearance called for in the coupler specifications furnished by the manufacturer to allow for thermal growth of the shafts. Sleeve bearing motors which may have considerable end play should have this coupler clearance checked when the motor is at its magnetic center.



photograph courtesy of T.B. Wood's Sons Co.

Flexible Sleeve Coupling

Figure 25

The flexible sleeve coupler shown in figure 25 is used with even larger pumps and motors. The sleeve may be in two pieces held together by a wire ring as shown, it may be a single piece split to fit over shafts that are close together, or it may be a single, unsplit piece. The coupler flanges may fit directly on the shafts as shown, or they may bolt to hubs that fit on the shafts to form a "spacer coupling" as in Figure 26.



photograph courtesy of T.B.Wood's Sons Co.

Drop-Out Type Spacer Coupling

Figure 26

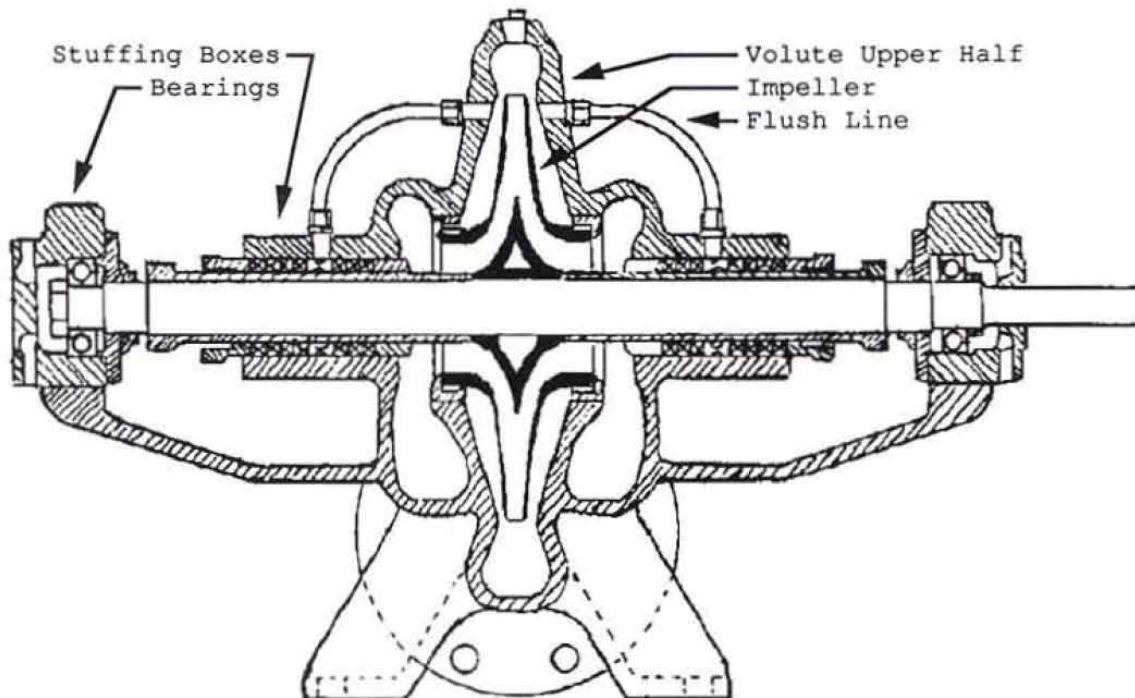
This coupler design is particularly important with base mounted pumps that can be serviced without moving the motor. These "true back pull out" pump designs save maintenance time by not requiring movement of the motor to replace the seal or bearings, or service the impeller, therefore extensive realignment of the shafts after service is not required. There are a number of different coupler sleeve materials in use. Be careful to replace a sleeve with the same kind of material as the original since other sleeve materials can cause problems in alignment

and sleeve wear. Pumps that require couplers are equipped with a coupler guard, either as a separate piece, or as part of the bearing assembly design. To avoid injury, always replace any removable guards after servicing the pump.

PUMP BODIES

Centrifugal pump bodies are manufactured in several types depending on the type of impeller to be used and the pump application. Pumps using single suction impellers may be "end suction", or "in-line" pumps. We've already seen examples of end suction pump bodies. Double suction impeller pumps may have horizontal split case or vertical split case bodies. The terminology refers to the manner in which the pump body opens for assembly or maintenance.

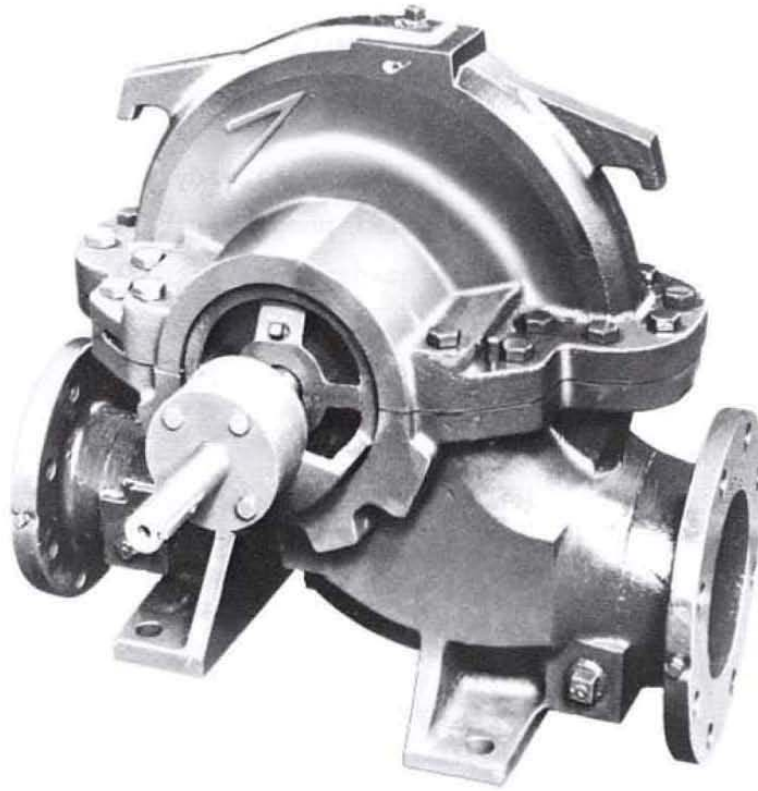
Horizontal Split Case Pumps



Typical Horizontal Split Case Pump

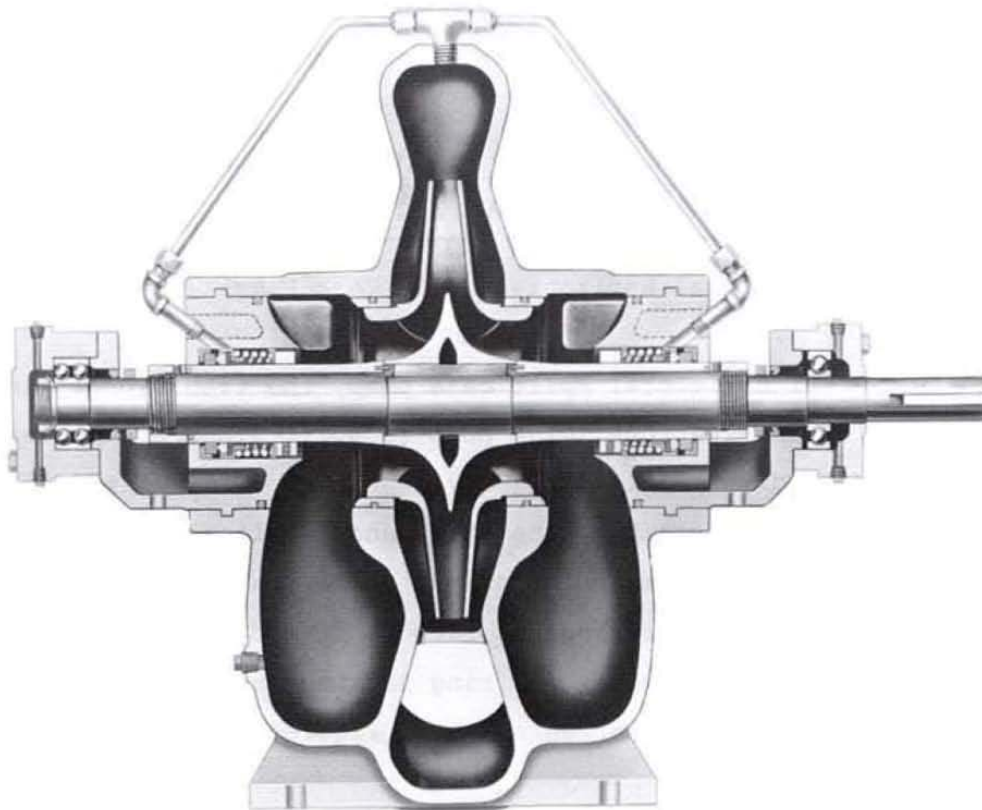
Figure 27

Figure 27 shows a typical horizontal split case pump, the traditional kind of pump used in many industrial applications. The pump is split along its horizontal axis at the pump shaft and is disassembled by removing the top half of the volute, which gives access to the rotating assembly, the shaft and impeller. The double suction impeller is mounted at about the midpoint of the shaft, making it necessary to have two seals or stuffing boxes and bearings at each shaft end. This drawing shows the stuffing box, flush lines, and compression ring packing, but pumps like this are also available with mechanical seals, as shown in Figures 28 and 29.



Bell & Gossett Horizontal Split Case Pump

Figure 28



Horizontal Split Case Pump with Externally Flushed Mechanical Seals

Figure 29

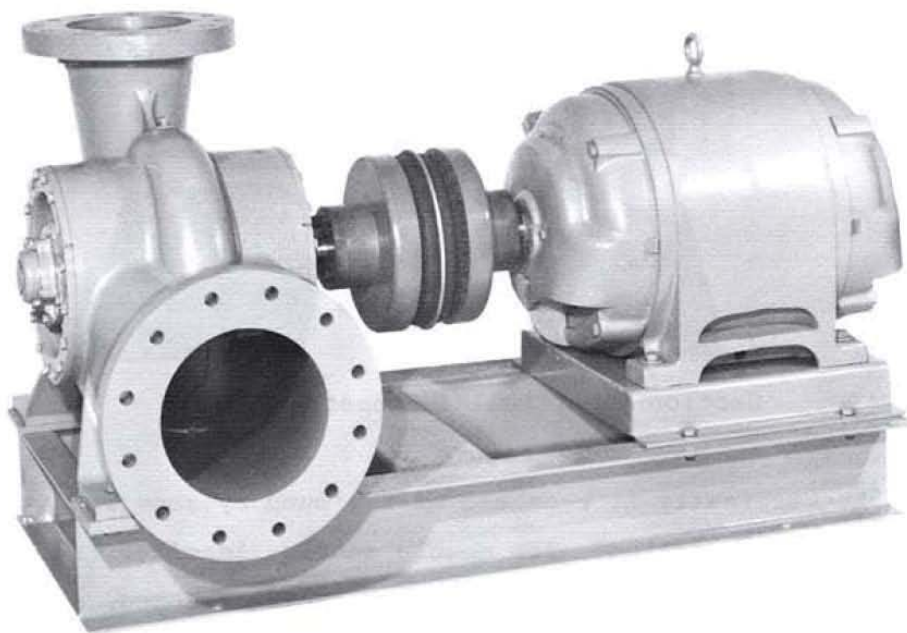
Vertical Split Case, Double Suction Pumps



Bell & Gossett Vertical Split Case Double Suction Pump

Figure 30

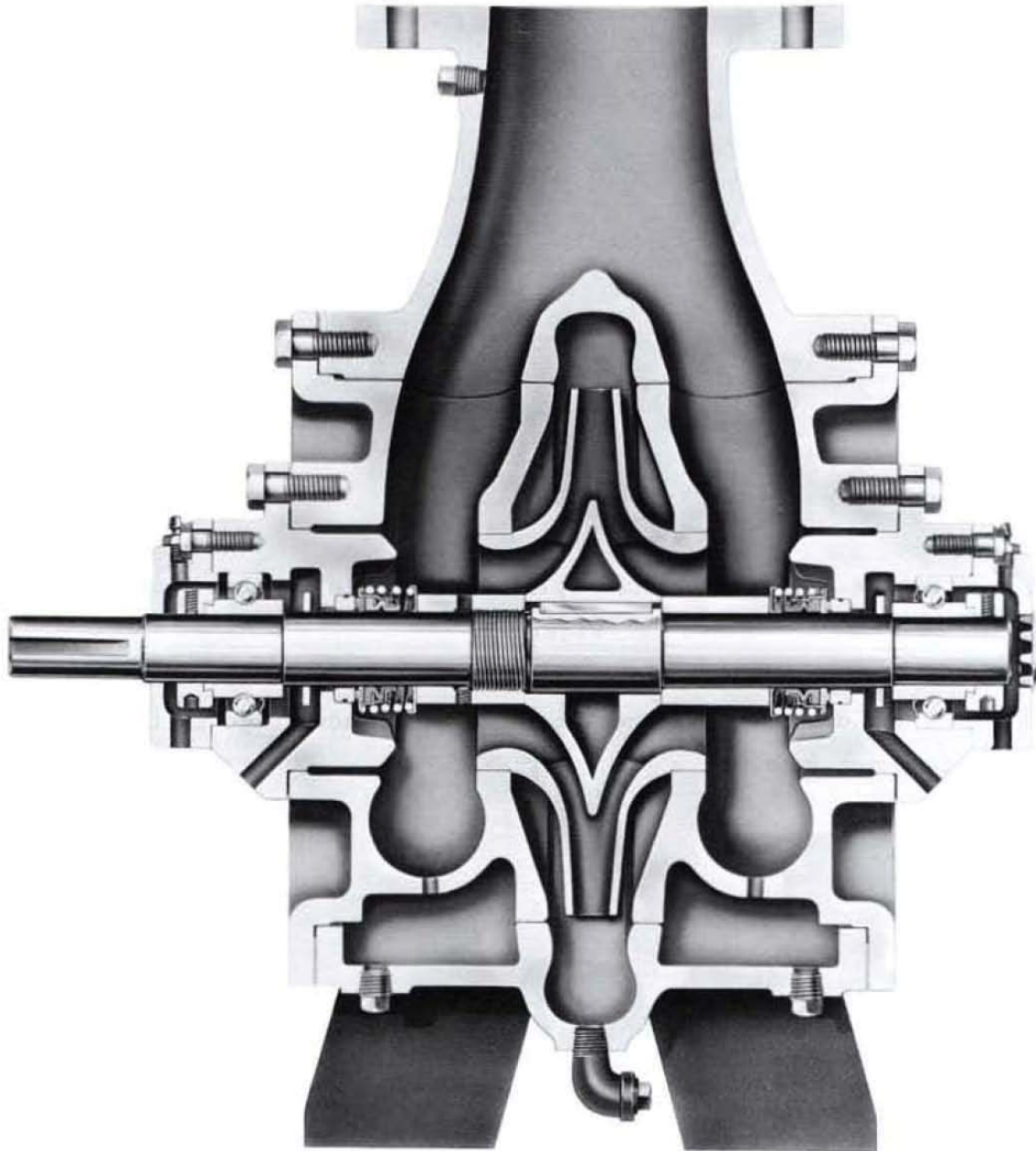
A vertical split case double suction pump is shown in Figure 30. This model has both the suction and discharge flanges at the top, an advantage in installing piping in a crowded equipment room.



Bell & Gossett Vertical Split Case, Side Suction Pump

Figure 31

In figure 31, the vertical split case pump has its suction flange rotated 90° to accommodate the larger suction pipe sizes required for the high flow rates that this pump can handle. In both versions of the vertical split case pump, the internal construction features are about the same as shown in the following section view.



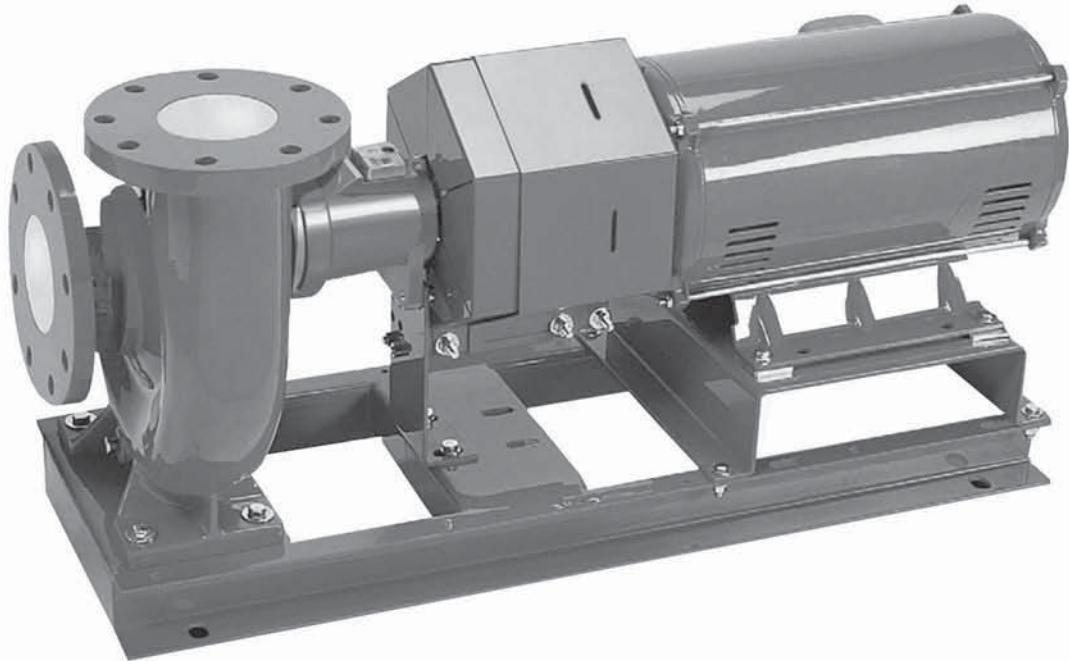
Section View, Bell & Gossett VSC Pump

Figure 32

The volute is split vertically at each end of the pump by removing two volute cover plates from the main pump casting. The double suction impeller is located in the middle of the pump, and it requires two seals or stuffing boxes, as well as two bearings. Like the horizontal split case pump, they are located on opposite sides of the impeller, but unlike the horizontal split case pump, they are closer to the

impeller, giving the pump shaft more support. Unlike the horizontal split case pump, servicing one bearing or seal does not disturb the other. Different seals are available for this pump, including compression rings, and the externally flushed mechanical seal. The internally flushed seal is the most popular since it is rated to handle the system temperature, alkalinity, and water treatment chemical concentrations most often found in closed heating and cooling systems.

End Suction Pumps.



Bell & Gossett Series 1510 End Suction Pump

Figure 33

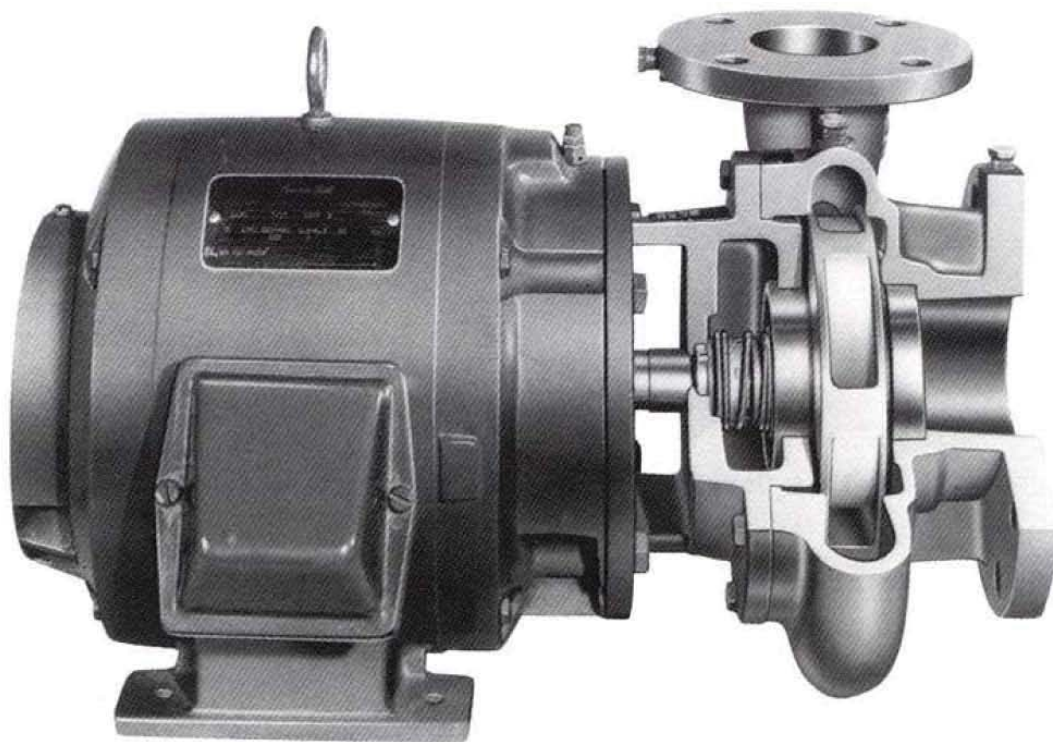
Figure 33 shows a single suction pump. Pumps like this are called "end suction" designs because the water enters the suction eye of the impeller at the end of the pump. In this case, the water leaves from a centerline discharge, which makes for easier venting. The single volute cover plate can be removed from the back of the pump for servicing the seal or removing the impeller. Leakage is prevented by an O ring around the cover plate. The stainless steel impeller is keyed to the shaft and held in place by means of a washer and capscrew. There's only one seal, because the shaft penetrates the pump in only one place. The bearing assembly consists of a casting which contains two bearings and the pump shaft. Notice that both bearings are on the same side of the impeller.

Piping connections differ between horizontal split case pumps and end suction pumps. The horizontal split case is "straight through", with suction in one end and

discharge out the other in the same plane, at right angles to the shaft. End suction pumps have the suction piping enter the pump's end and the discharge line at right angles to the suction line.

TYPES OF CENTRIFUGAL PUMPS

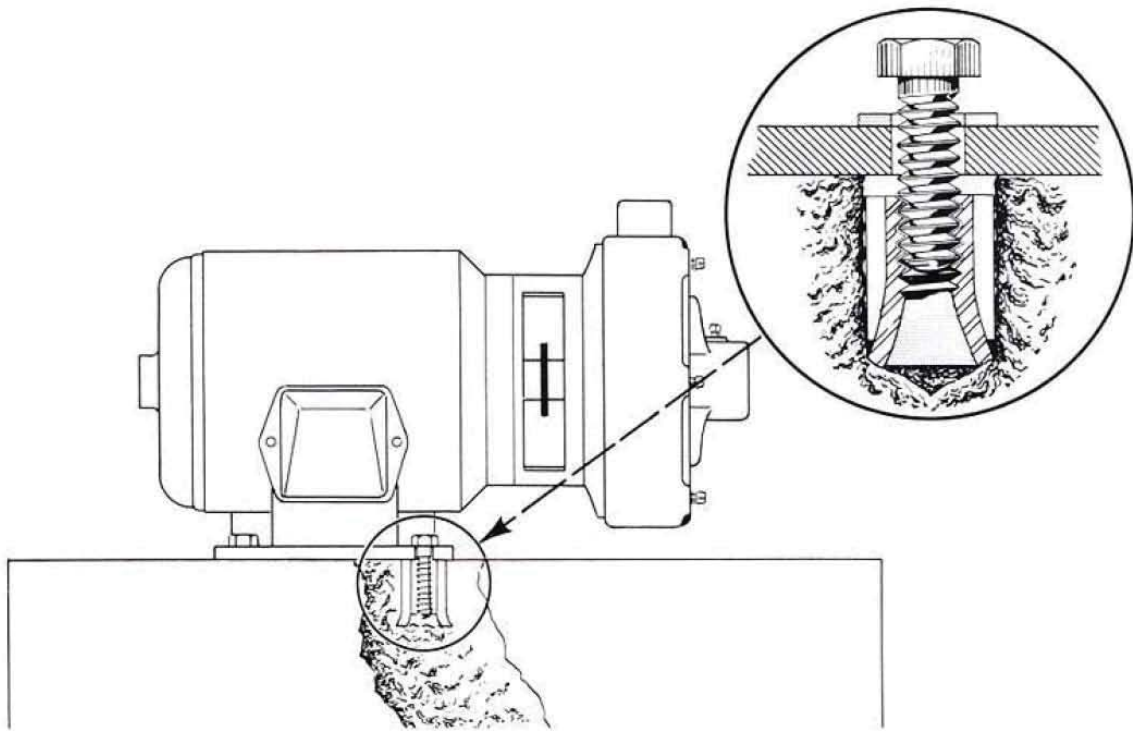
Centrifugal pumps may be "base mounted", like the one in Figure 33, where the pump, bearing assembly, and motor are all mounted on a common base ready for installation on a foundation. They may be "in-line" for installation directly in the pipe line without a base. Either of these may also have separate pump and motor shafts connected by a coupler, called "long coupled", or "flexibly coupled"; or the motor shaft may be common to both the motor and pump in which case the pump is called "close coupled". Finally, many of these pumps can be found with different seal options as already described.



Bell & Gossett Series 1531 Base Mounted, Close Coupled Pump

Figure 34

In Figure 34, the motor has an extended shaft which enters the pump body through an opening in the cover plate. The mechanical seal, shaft sleeve, and single suction impeller are mounted on the motor shaft so there is no coupler or pump bearing assembly. The motor bearings are usually grease lubricated ball bearings sized to carry the impeller load.



Close Coupled, Base Mounted Pump Installation

Figure 35

The motor and pump are attached by means of a combination coverplate and bracket. The pump can be mounted on a foundation by means of the motor legs with the pump body supported by the motor and bracket. Once the pump is installed in a piping system, you can get access to the seal and impeller by unbolting the coverplate, and sliding the motor and bracket back from the pump. That's why it's important to attach the motor to the foundation by using capscrews that extend down through the motor legs into threaded fittings in the foundation as shown in Figure 35, rather than studs that mount upward from the foundation into the motor legs. If studs and nuts are used, the motor will not slide back to allow pump service.

Although these close coupled pumps are more compact than base mounted pumps, they aren't necessarily smaller in capacity. In fact, many close coupled pumps use the same volute and impeller as the base mounted version, and therefore have about the same pumping capacity. Their advantage is in the compact size and smaller base required.

Horizontal Line Mounted Pumps

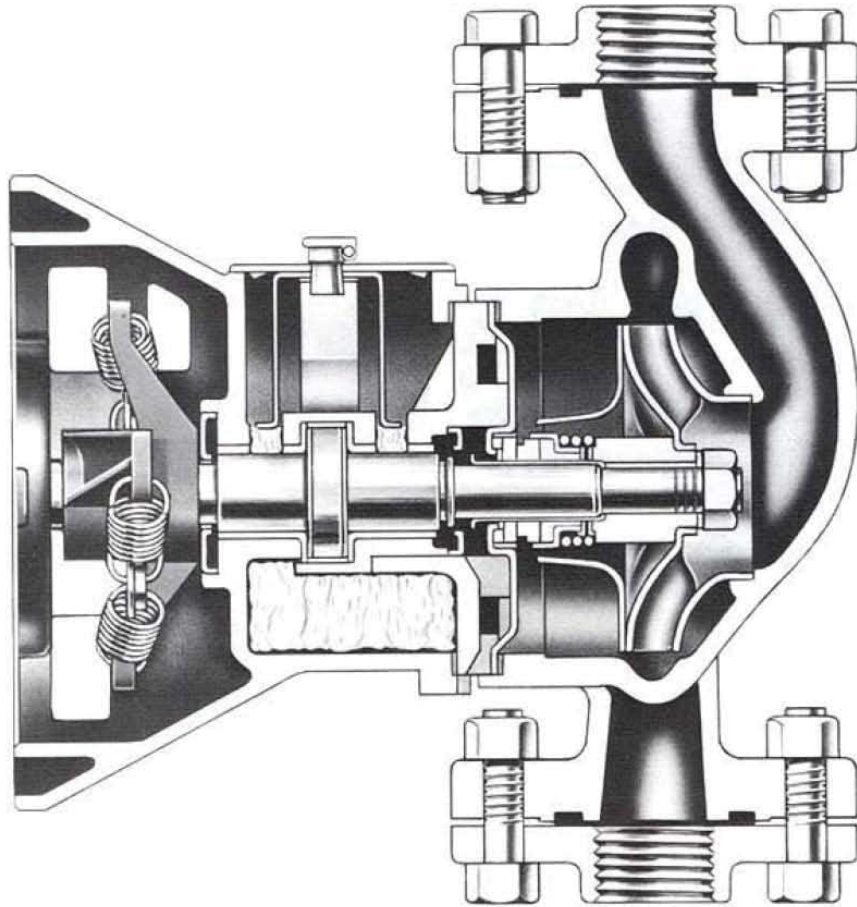


Bell & Gossett Series 100 "Booster"

Figure 36

"Circulators" are small pumps mounted with the shaft horizontal in the system piping. They are sometimes called "line mounted", or "in line" pumps because the piping supports the pump - no base is required. The B&G "booster" got its name because it was originally installed to aid, or "boost", the gravity circulation in older systems. Gravity systems are no longer being designed since pumped circulation is so much more efficient and economical, but the name has stuck. The Series 100 booster shown in Figure 36 is typical of the small, in line pumps used in closed heating or cooling systems to provide flow up to about 100 gpm. This pump has a single suction impeller mounted in an iron or bronze body, a bearing assembly, and a motor mounted in a bracket that bolts to the bearing assembly. Since the pump is used in applications where quiet operation is a requirement, it uses oil lubricated sleeve bearings in the motor and in the pump bearing assembly and a spring type coupler. The resilient motor mounts isolate motor noise or vibration from the system. It is designed with an internally flushed mechanical seal for simple maintenance and long life.

Bronze construction boosters are recommended for use in domestic, or fresh water, systems.

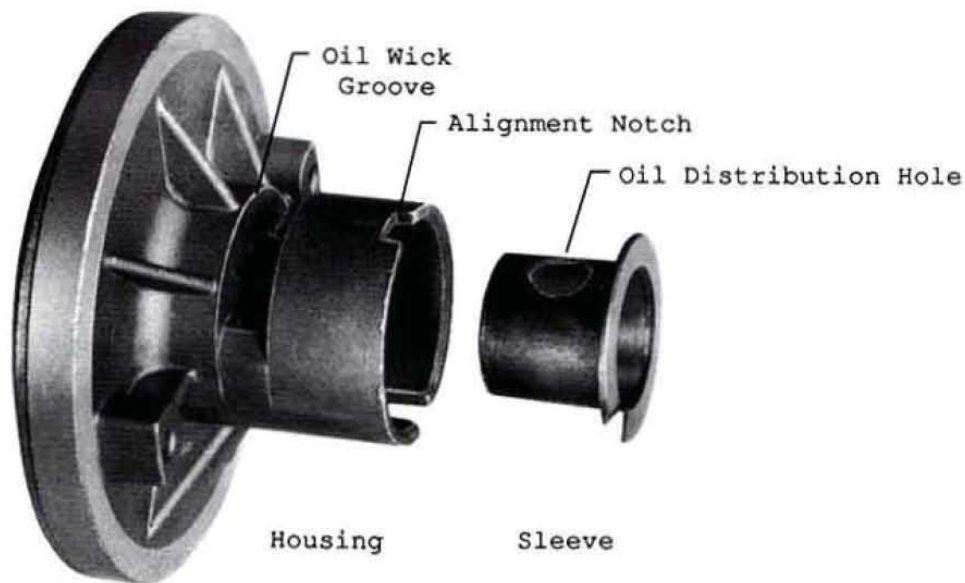


Series 100 Section View

Figure 37

Though these smaller pumps have many of the same design features as the larger ones, there are some differences.

The copper shaft sleeve is permanently pressed onto the shaft, so if it should get pitted or badly scratched, or if the bearing surfaces of the shaft should get scratched or burned, simply replace the whole shaft. The water slinger is built into the shaft sleeve as a small flair in the sleeve material. The pump seal is a smaller version of the internally flushed seal described before, and while there are no other seal design options available, a number of different seal kits containing parts made with different materials can be used in these small pumps to suit different system temperatures or chemical conditions. The impeller may be made of bronze, plated steel, or plastic depending on the age and size of the pump. Some impeller designs promote circulation around the seal by means of a shroud surrounding the seal as shown above. Some plastic impellers are built in two pieces.



Replaceable Front Bearing with Sleeve Removed

Figure 38

The front bearing is easily replaced, but the bearing closer to the coupler, the rear bearing, is not. In the unlikely event that the rear bearing should fail, simply replace the bearing assembly casting. Figure 38 shows the replaceable front bearing housing and sleeve. The sleeve bearing is shown separate from the bearing housing for clarity only. In practice, the sleeve is very accurately and permanently pressed into the housing. The hole at the top of the sleeve allows oil to form the film between the shaft and the sleeve that lubricates the shaft. The collar around the sleeve bearing is designed to carry thrust forces caused by slight movement of the shaft parallel to the shaft axis. The groove in the housing is where the wick lies. The little notch in the housing insures that the bearing is aligned properly in the housing, with the wick slot at the top.

This replaceable bearing is held in the bearing assembly by two bolts that screw into the bosses shown on each side of the housing. Be careful not to over tighten these bolts, since it is possible to pull the threads out of the housing material.



Bell & Gossett System Lubricated Circulator

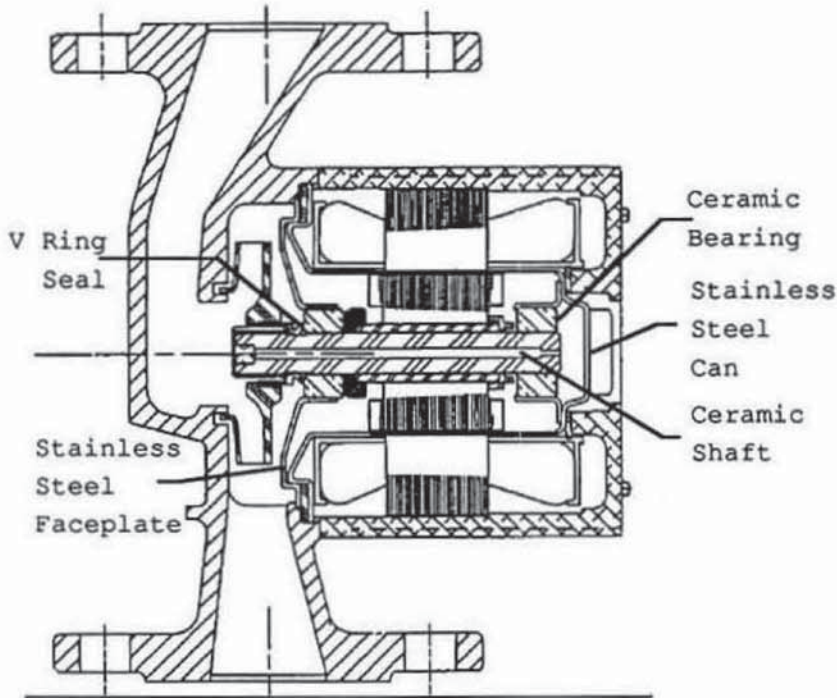
Figure 41

Close Coupled Booster Pumps.

The demand for maintenance free, very small circulators has led to the development of system lubricated pumps whose bearings use the system water itself rather than oil for cooling and lubrication.

These pumps are designed for use in typical closed systems, so their bearings will tolerate the small amount of grit that is bound to form due to corrosion. Of course, higher concentrations of dirt and grit will cause the bearings to wear faster. There is no service

required for this pump. If it should develop a problem, simply replace it.

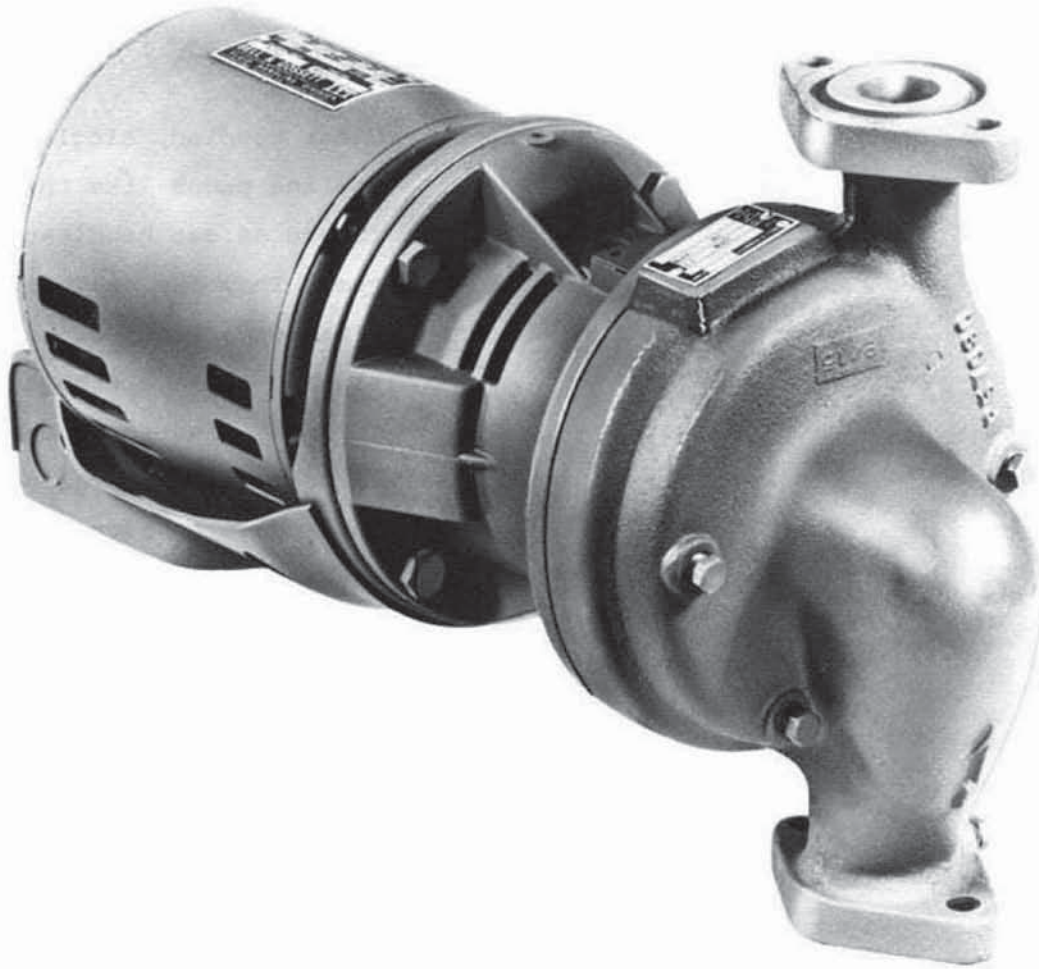


Section View

Figure 42

The system lubricated circulator is another example of a close coupled pump. The "V ring" seal and ceramic shaft provide circulation of filtered system water around the bearings, while keeping system grit in that area to a very low level. The combination of the stainless steel faceplate and can enclose and seal the wet rotor from the motor windings, which must remain dry. The impeller is a semi open design made of glass filled PES, another non-corroding

material which holds up very well to hydronic system service.



Bell & Gossett Series 60 Line Mounted Pump

Figure 43

Larger line mounted pumps like the one in Figure 43 are also installed directly in and supported by the piping system, so they don't need a base or foundation. Where extra support may be desirable, such as in copper tubing, or in an overhead location, an eyebolt may be attached to the bearing assembly and wired with a turnbuckle to an overhead support to carry some of the weight of the motor. Their most common application is the circulation of water in hydronic heating or cooling systems, up to about 160 gpm. The pump body may be installed to pump up, down, left to right, or right to left as required, as long as the bearing assembly is bolted to the pump body with its oil cap at the top. In line pumps always have the same size suction and discharge openings. This may be true for end suction and double suction pumps too, but it is more likely that those pumps would have different size suction and discharge openings. If they are different, then the suction opening will always be the larger of the two.

These pumps come equipped with internally flushed mechanical seals, sleeve bearings, and resilient motor mounts, so they don't require a great deal of attention beside periodic lubrication of the pump and motor bearings.

Vertical Line Mounted Pumps.

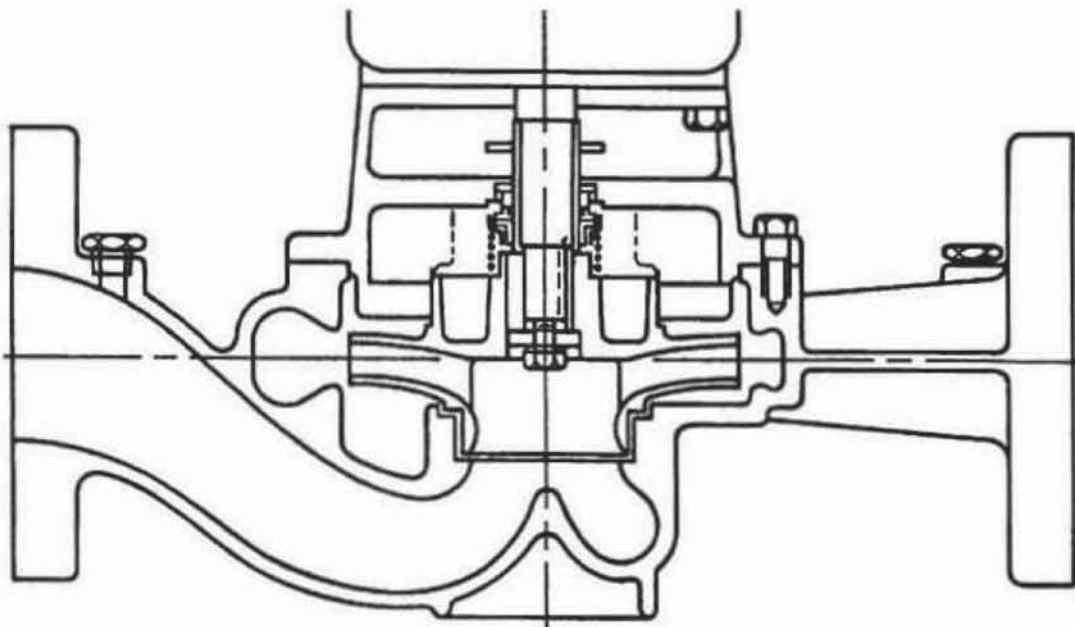


Bell & Gossett Series 80 In Line Pump

Figure 44

Close coupled, single suction in-line pumps like the one in figure 44 can handle up to 2500 gpm. They can be equipped with flushed packing, or externally flushed seals although the internally flushed mechanical seal is most common. These larger pumps must be supported by pipe hangers at the pump flanges, or by a base under the pump constructed to allow for thermal growth of the piping. The pump assembly should never be supported by the motor lifting rings provided on the motor. The motor should be mounted with the shaft above the pump, verti-

cally if possible, or no less than horizontal so that grit from the system will not collect around the seal.



Series 80 Section View

Figure 45

Xylem |'zīləm|

- 1) The tissue in plants that brings water upward from the roots;
- 2) a leading global water technology company.

We're 12,500 people unified in a common purpose: creating innovative solutions to meet our world's water needs. Developing new technologies that will improve the way water is used, conserved, and re-used in the future is central to our work. We move, treat, analyze, and return water to the environment, and we help people use water efficiently, in their homes, buildings, factories and farms. In more than 150 countries, we have strong, long-standing relationships with customers who know us for our powerful combination of leading product brands and applications expertise, backed by a legacy of innovation.

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