PUMP EQUIPMENT

WHAT IS IN THIS SECTION?

1. The function of pumping systems
2. Common pump types
3. Basic theory of operation of centrifugal pumps
4. The basic theory of operation of diaphragm pumps
5. The major components of a pumping system, including the building and piping system
6. The terms used to identify common pumps and their components
7. The function of the major components of a centrifugal pump
8. The pumping process used by a pneumatic ejector
9. The components of an air lift pump

KEY WORDS

- Centrifugal force
- Centrifugal pump
- Close-coupled pumps
- Concentric reducer
- Displacement pumps
- Dynamic pumps
- Energy
- Eccentric reducer
- End suction centrifugal pumps
- Frame-mounted pumps
- Impeller
- Mechanical seal
- Packing
- Seal water
- Shroud
- Stuffing box
- Volute

PUMPING EQUIPMENT

INTRODUCTION

Section Content & Purpose

This section is intended to provide an overview of the major pumping related components found in small wastewater systems. The focus of the lesson will be on basic theory, descriptions of components, common names of components and their general functions.

PUMP SYSTEM USES

Functions

Wastewater pumping systems in small communities are used to:

- Pump wastewater through portions of the collection system - a lift station
- Pump wastewater from an individual house into a pressure collection system
- Pump wastewater effluent from the plant or septic tank to a receiving body
- Pump wastewater from a major collection point into a treatment facility
- Circulate glycol through a heat exchanger or heating loop
- Pump chemicals into the system

MAJOR COMPONENTS

A pump station is composed of four sets of components:

- The structure, including the wet well;
- The hydraulic system; the pump and related piping.
- The electrical system; the motor and its related components.
- The control system; pressure, flow and level switches.

STRUCTURE/BUILDINGS

Introduction

In a wastewater system the most common pumping structure is the lift station. This is typically a concrete or steel structure placed in the ground with a fiberglass or wooden building placed over the wet well. Having a building over the wet well provides improved access to the equipment during the months of bad weather.

Basic Consideration

Regardless of the design, most lift station buildings are designed with the door opening out. This allows access should there be a broken discharge line in the building. The buildings should be vandal resistant, well heated in the winter and properly vented in the summer.

HYDRAULIC SYSTEM

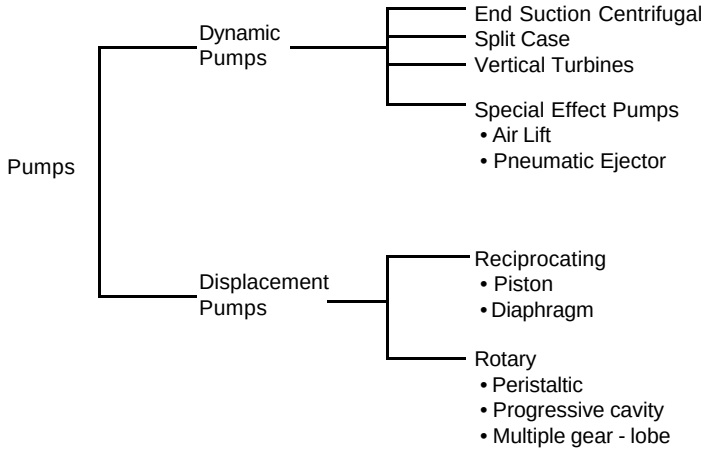
PUMP TYPES

Two Types

The pumps used in small wastewater systems can be divided into two general categories; dynamic pumps[1] and displacement pumps[2]. One type of dynamic pump, centrifugal pumps, are the most common pumps used in wastewater systems. Displacement pumps are also called positive displacement pumps. The most common positive displacement pump is the diaphragm pump used to pump chlorine solutions.

Special Pumps

Collection systems may also use a special pumping device called a pneumatic ejector. Small wastewater treatment plants often use air lift pumps for pumping return activated sludge and waste activated sludge.



Dynamic Pumps

The basic differences between the two pump types have to do with their response to changes in discharge pressure. Dynamic pumps are used in conditions where high volumes are required and a change in flow is not a problem. As the discharge pressure on a dynamic pump is increased the quantity of wastewater pumped is reduced. Dynamic pumps can be operated for short periods of time with the discharge valve closed.

Displacement Pumps

Displacement pumps are used in conditions where relatively small, but precise volumes are required. Displacement pumps will not change their volume with a change in discharge pressure. Operating a displacement pump with the discharge valve closed will damage the pump.

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[1] **Dynamic Pumps -** Pumps in which the energy is added to the water continuously and the water is not contained in a set volume.

[2] **Displacement Pumps -** Pumps in which the energy is added to the water periodically and the water is contained in a set volume.

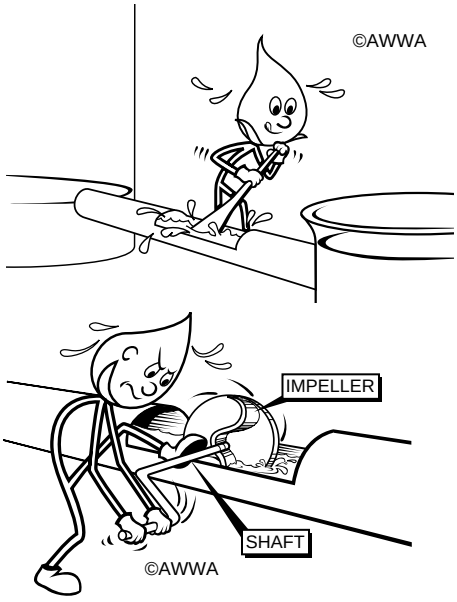
CENTRIFUGAL PUMP THEORY

Energy Input Device

A pump is a device that puts energy[3] into the wastewater. This energy can be expressed in two ways; an increase in pressure or an increase in flow.

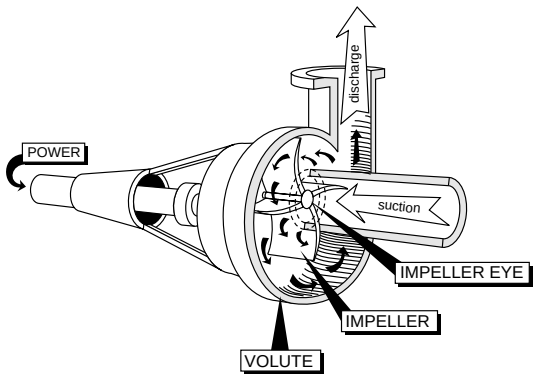
Centrifugal Pumps - Energy Input

If we cut a section out of the top of a pipe and used a canoe paddle to move the wastewater we would have a pump. It would not be very efficient but we would be inputting energy into the wastewater. If the paddle were reshaped into an impeller[4] we would be able to place more energy into the wastewater. The energy is transferred from the impeller to the wastewater due to the friction between the impeller and the wastewater. However, notice that a lot of the wastewater would splash out onto the floor. This is because centrifugal force[5] causes the wastewater to fly outward away from the impeller.



The Pump Case

If we surround the impeller with a case we can control the wastewater and obtain a more efficient energy transfer. The case that is used is shaped like a spiral and is called a volute. Volute[6] is a geometrical shape; like a circle, a square, etc. A snail shell is volute shaped. The shape of the case helps us to determine the direction of rotation of the pump.



[3] **Energy -** The ability to do work. Energy can exist in one of several forms, such as heat, light, mechanical, electrical or chemical. Energy can neither be created nor destroyed, but can be transferred from one form to another. Energy also can exist in one of two states - either potential or kinetic.

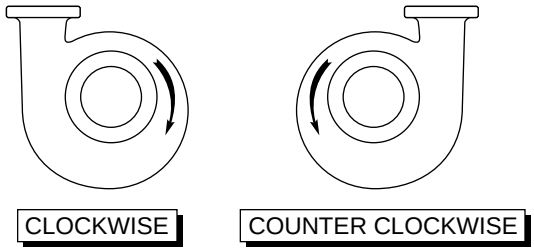
[4] **Impeller** - A rotating set of vanes designed to impart rotation to a mass of fluid.

[5] **Centrifugal Force** - The force that when a ball is whirled on a string, pulls the ball outward. On a centrifugal pump, it is the force which throws water from the spinning impeller.

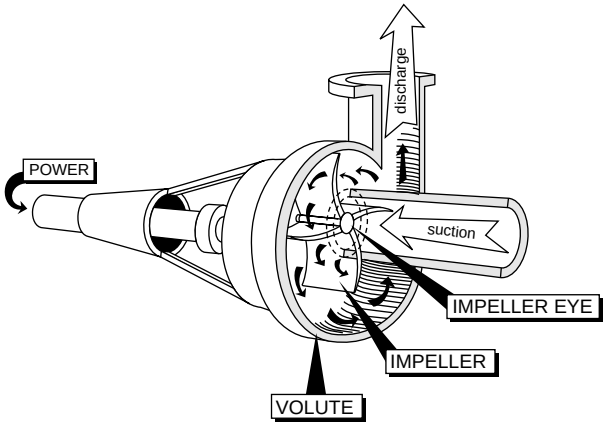
[6] **Volute** - The spiral shaped casing surrounding a pump impeller that collects the liquid discharged by the impeller.

Pump Rotation

The direction of rotation should be determined when we are looking into the suction side of the volute case.



Observing the case below, the direction of rotation is counter clockwise.



Summary

In summary, there are two theories that explain how a centrifugal pump[7] works. They are: energy transfer, the transfer of energy from the shaft to the impeller and from the impeller to the wastewater; and centrifugal force, the force used to throw the wastewater from the impeller.

CENTRIFUGAL PUMP CONFIGURATION

Three Different Configurations

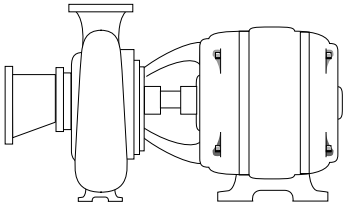
Centrifugal pumps can be divided into one of three classifications based on their configuration. The three are: end suction centrifugal[8], split case [9]and vertical turbine[10]. Split case and vertical turbine pumps are seldom found in wastewater systems and therefore will not be discussed in this lesson.

[7] **Centrifugal Pump** - A pump consisting of an impeller fixed on a rotating shaft and enclosed in a casing, having an inlet and discharge connection. The rotating impeller creates pressure in the liquid by the velocity derived from centrifugal force.

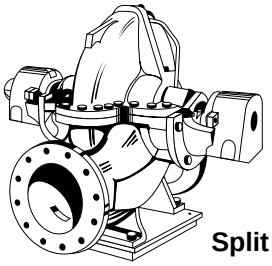
[8] **End Suction Centrifugal Pumps** - The most common style of centrifugal pump. The center of the suction line is centered on the impeller eye. End suction centrifugal pumps are further classified as either frame-mounted or close-coupled.

[9] **Split Case Pumps** - A centrifugal pump designed so that the volute case is split horizontally. The case divides on a plane that cuts though the eye of the impeller.

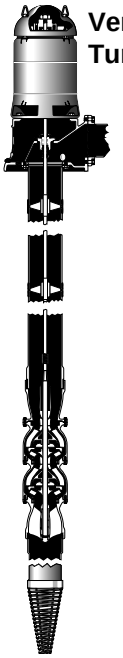
[10] **Vertical Turbine Pumps** - A classification of centrifugal pumps that are primarily mounted with a vertical shaft; the motor is commonly mounted above the pump. Vertical turbine pumps are either mixed or axial flow devices.



End-suction Centrifugal



Split Case



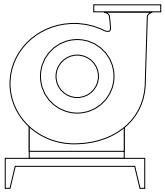
Vertical Turbine

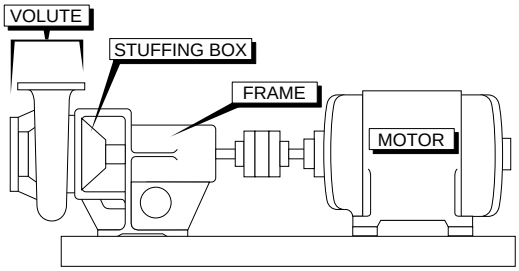
End-Suction Centrifugal - Types

The end-suction centrifugal pump is the most common centrifugal pump and is the one we usually picture in our mind when we think about centrifugal pumps. There are two types of end-suction pumps; close-coupled[11] and frame mounted[12].

Frame Mounted

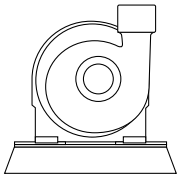
The frame mounted pump has a shaft and bearings separate from the motor. A coupling is required to get the energy from the motor to the pump.

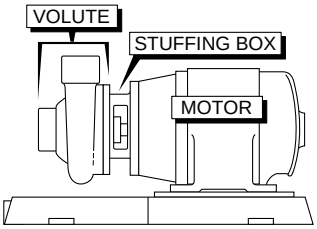




Close-coupled

A close coupled pump has only one shaft and one set of bearings; the motor shaft and bearings. The pump impeller is placed directly onto the motor shaft. Close-coupled pumps require less space and are less expensive than frame-mounted pumps.



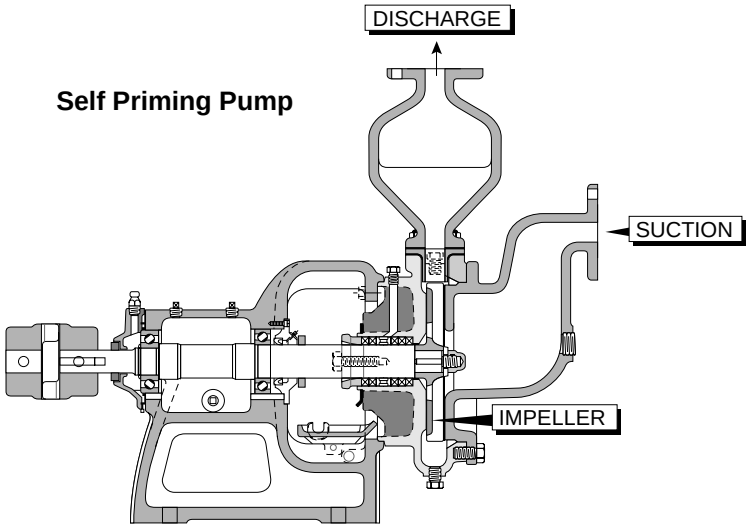


[11] **Close-coupled Pumps** - End suction centrifugal pumps in which the pump shaft and motor shaft are the same shaft. The pump bearings and motor bearings are also the same. The impeller is attached directly onto the end of the motor shaft.

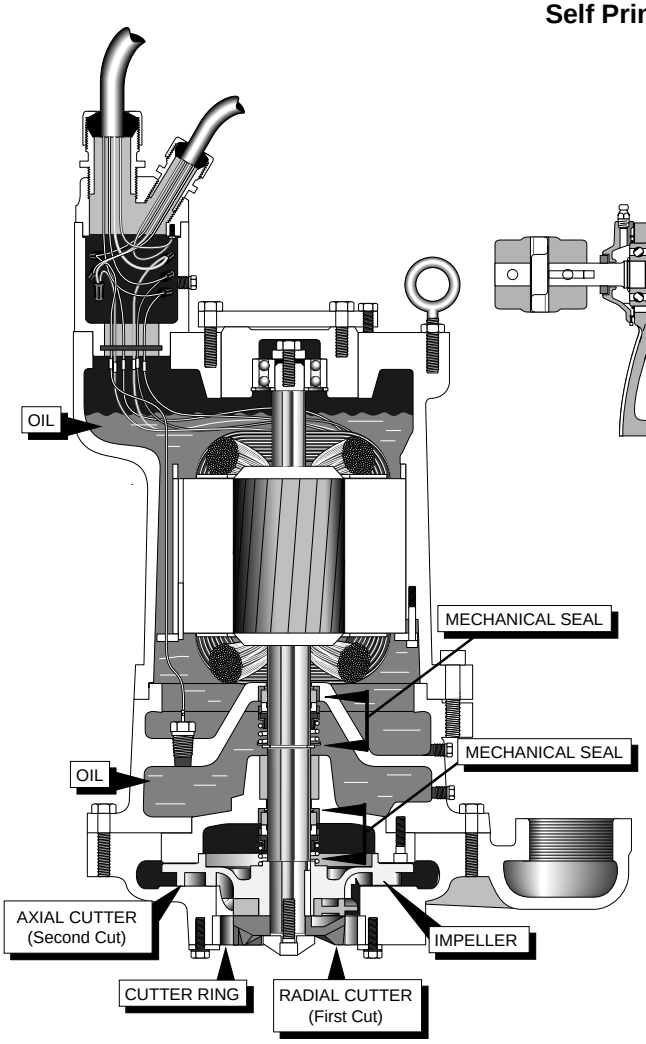
[12] **Frame-mounted Pumps -** End suction centrifugal pumps designed so that the pump bearings and pump shaft are independent of the motor. This type of pump requires a coupling between the pump and the motor in order to transfer energy from the motor to the pump.

Special Wastewater Configurations

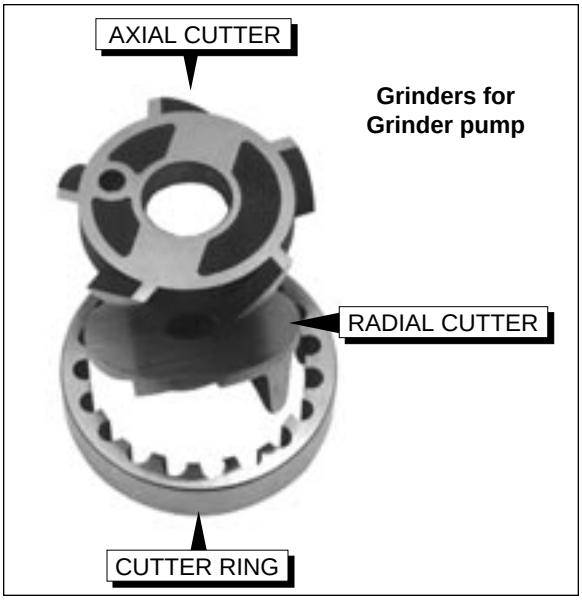
There are two special configurations commonly used in wastewater lift stations, they are the self-priming and submersible pumps. Both pumps are end-suction centrifugal pumps. The self priming pump has the suction connection attached above the impeller eye helping to maintain a level of water in the volute case. The submersible pump is a close coupled end-suction pump that uses a motor that can be submersed in water. One common variation of the submersible pump is the grinder pump. This is a standard submersible pump with a grinder built into the volute case. The grinder pump is used to reduce the size of solids in the system and thus reduce damage to the pump and piping system.



Self Priming Pump



Grinder Pump

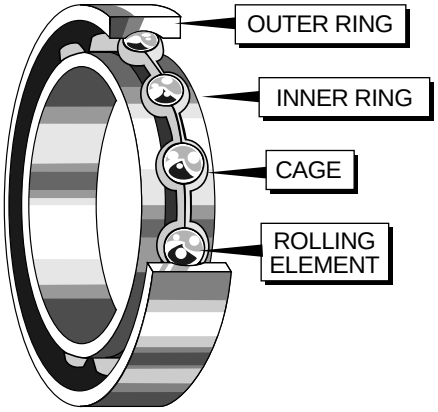


Grinders for Grinder pump

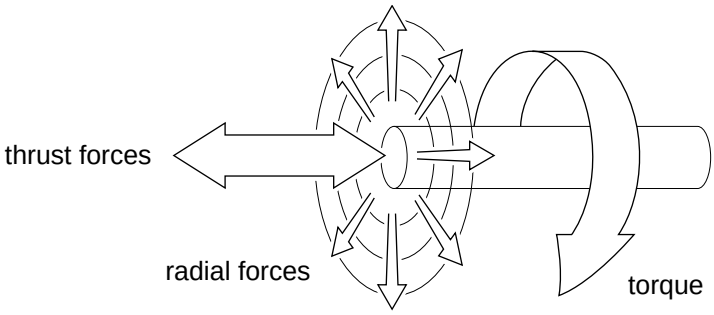
END-SUCTION CENTRIFUGAL PUMP COMPONENTS

Shaft & Bearings

The shaft is used to transfer energy from the motor to the impeller. The most common shaft materials are high carbon steel and stainless steel. Each shaft is supported by bearings which must support loads along the shaft, called thrust loads, and loads at right angles to the shaft, called radial loads.

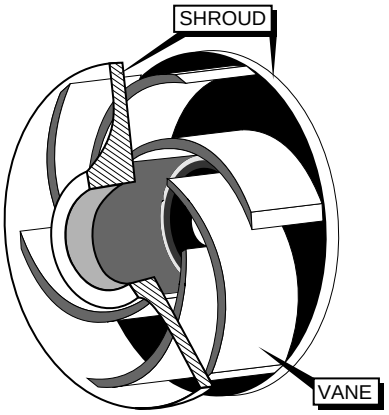


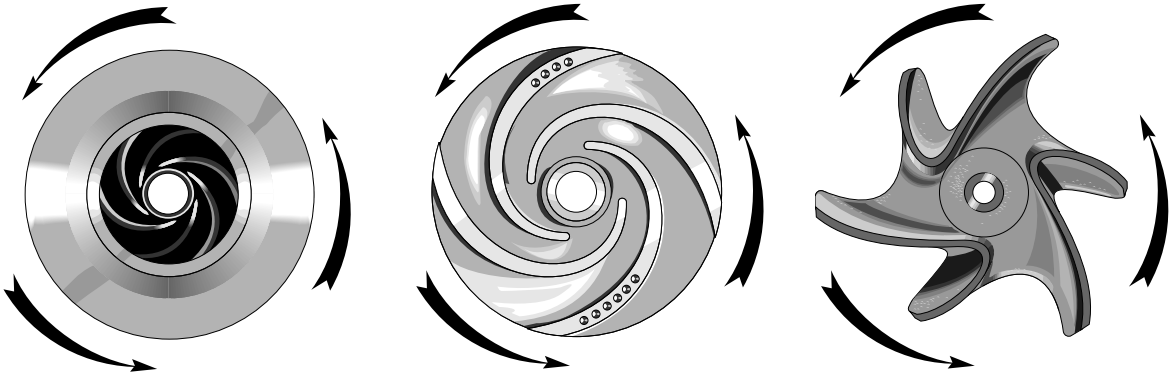
Single row deep groove ball bearing



Impellers

The energy is transferred from the shaft to the impeller and from the impeller to the water. There are three classes of impellers based on the position and number of shrouds[13]. When an impeller has a shroud in the front and in the back it is called a closed impeller. When there is only a shroud in the back of the impeller, it is a semi-open impeller and when there are no shrouds, the impeller is an open impeller. The impeller type is selected by the pump manufacturer to meet specific conditions.





Closed **Semi-open** **Open**

[13] **Shroud** - The front and /or back of an impeller.

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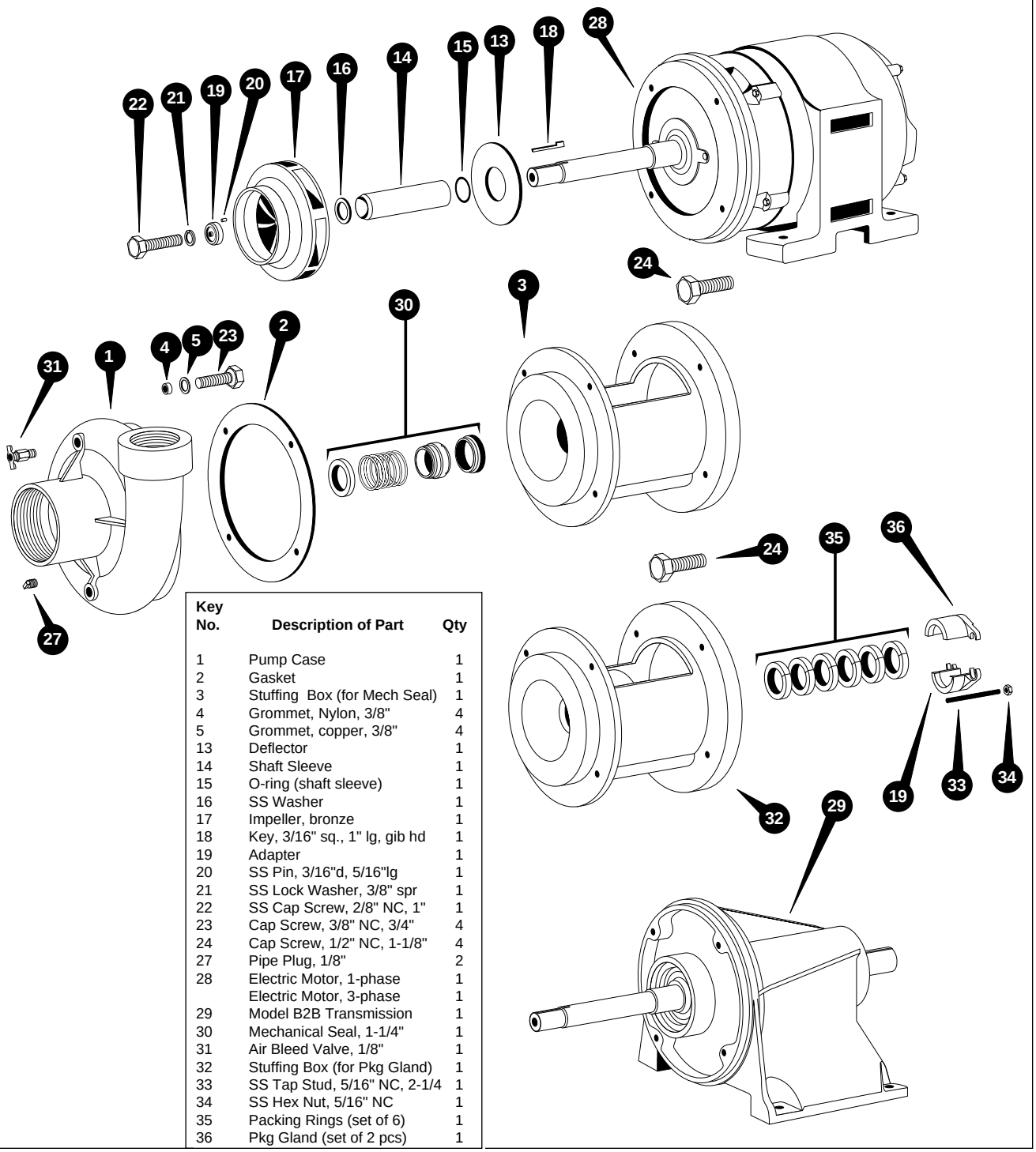
R E P A I R P A R T S

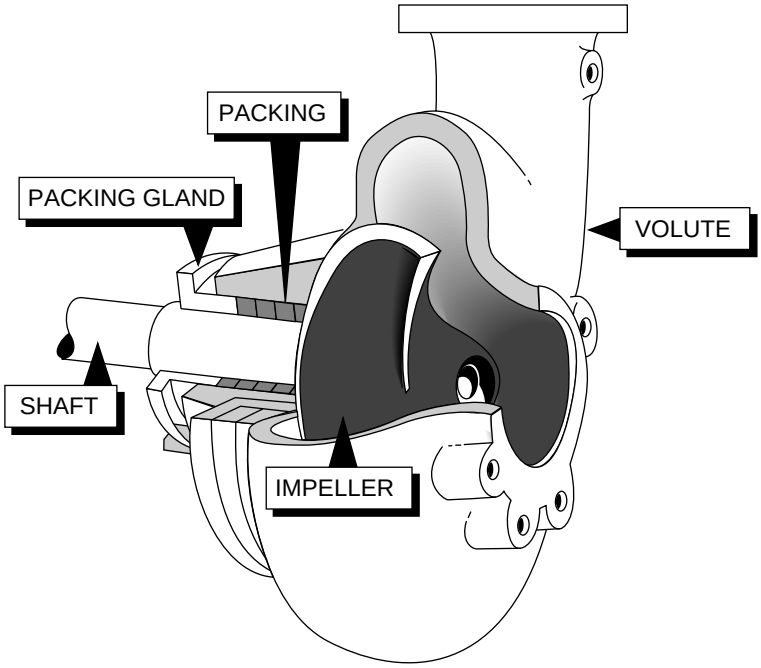
Jacuzzi
JACUZZI BROS. INC.

Series D

with Integral HP Close-coupled Pump Motors
and Model B2B Transmission Heads

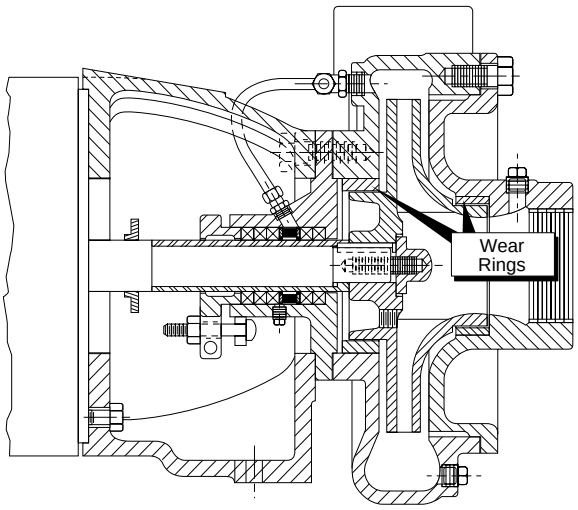


Key No.	Description of Part	Qty
1	Pump Case	1
2	Gasket	1
3	Stuffing Box (for Mech Seal)	1
4	Grommet, Nylon, 3/8"	4
5	Grommet, copper, 3/8"	4
13	Deflector	1
14	Shaft Sleeve	1
15	O-ring (shaft sleeve)	1
16	SS Washer	1
17	Impeller, bronze	1
18	Key, 3/16" sq., 1" lg, gib hd	1
19	Adapter	1
20	SS Pin, 3/16"d, 5/16"lg	1
21	SS Lock Washer, 3/8" spr	1
22	SS Cap Screw, 2/8" NC, 1"	1
23	Cap Screw, 3/8" NC, 3/4"	4
24	Cap Screw, 1/2" NC, 1-1/8"	4
27	Pipe Plug, 1/8"	2
28	Electric Motor, 1-phase	1
	Electric Motor, 3-phase	1
29	Model B2B Transmission	1
30	Mechanical Seal, 1-1/4"	1
31	Air Bleed Valve, 1/8"	1
32	Stuffing Box (for Pkg Gland)	1
33	SS Tap Stud, 5/16" NC, 2-1/4	1
34	SS Hex Nut, 5/16" NC	1
35	Packing Rings (set of 6)	1
36	Pkg Gland (set of 2 pcs)	1



Wear Rings

With closed impellers the impeller fits very close to the case. As a result, the case is worn by material passing from the high pressure side of the impeller to the low pressure side. To protect the case brass or stainless steel wear rings are inserted into the case.



Volute Case

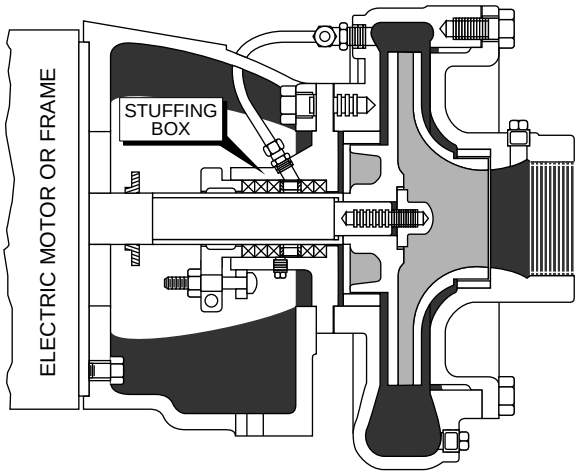
Around the impeller is the volute case. The volute case gathers the water that is being thrown from the impeller and directs it in a single direction.

Backing Plate

Behind the volute case is the backing plate. The backing plate forms the back of the volute case.

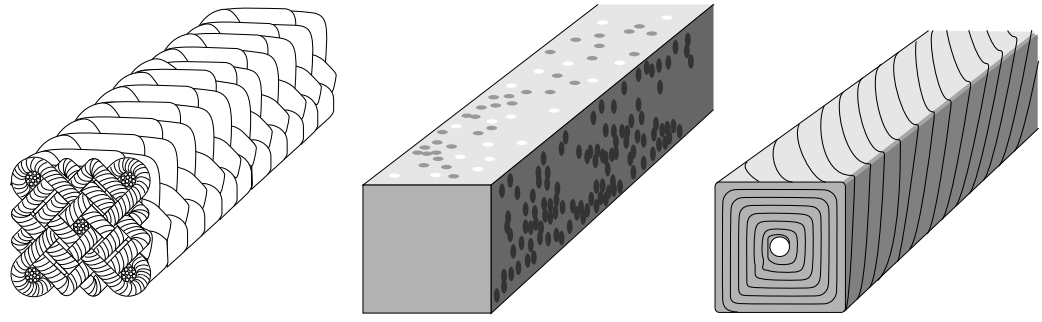
Stuffing Box

Attached to, and sometimes part of, the backing plate is the stuffing box[14]. The stuffing box is where we place material that controls the leakage of water from around the shaft. The material that is placed in the stuffing box is either packing[15] or a mechanical seal[16].



Packing

Packing is installed in the stuffing box to control leakage of water out of the stuffing box and air into the volute case. Three of the common packing configuration are; braided, formed and compressed metal. The most common type of packing used in wastewater systems is braided. Braided packing is composed of some type of fiber, like cotton and some type of lubricant, like graphite or Teflon™.



BRAIDED FABRIC

PLASTIC

METAL FOIL

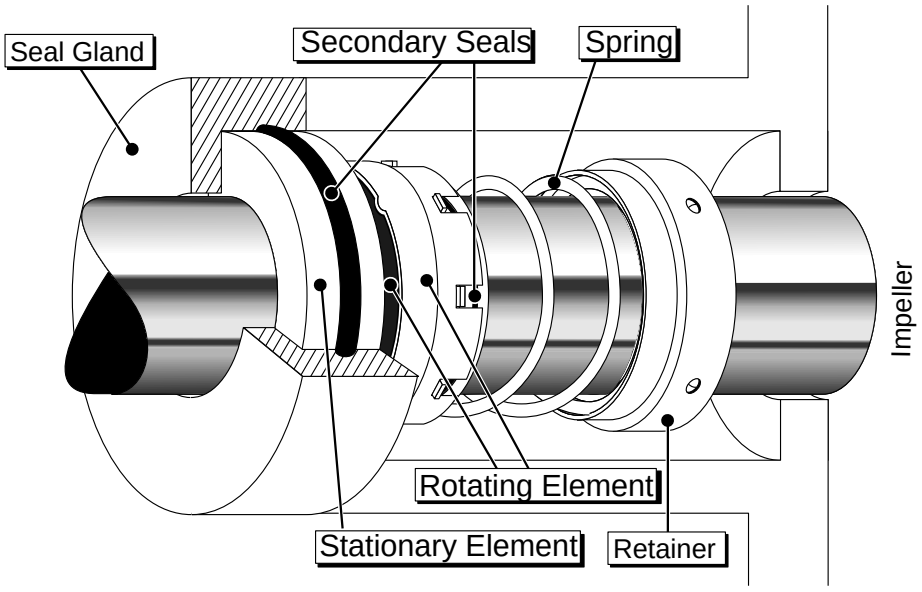
14 **Stuffing Box -** That portion of the pump which houses the packing or mechanical seal. Usually referred to as the dry portion of the pump, the stuffing box is located in back of the impeller and around the shaft.

15 **Packing -** Material made of woven animal, plant, mineral or metal fiber and some type of lubricant, placed in rings around the shaft of a pump and used to control the leakage from the stuffing box.

16 **Mechanical Seal** - A mechanical device used to control leakage from the stuffing box of a pump. Usually made of two flat surfaces, one of which rotates on the shaft. The two flat surfaces are of such close tolerances as to prevent the passage of water between them.

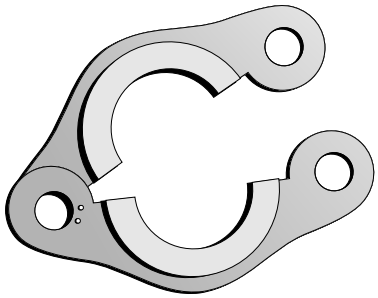
Mechanical Seals

Mechanical seals are installed in the stuffing box for the same purpose as packing, to control leakage through the stuffing box. A mechanical seal is composed of two sets of components, primary components and secondary components. The primary components are made up of two pieces, a rotating component and a stationary component. One of these must be made of a hard material (usually ceramic) and one of a soft material (usually carbon). One component must be stationary and the other must rotate on the shaft. The tolerance between these two faces prevents water from passing. The secondary portion of the mechanical seal is composed of secondary seals that prevent water from leaking along the shaft, a spring or set of springs that provide pressure on the faces and some type of retainer used to hold the rotating element on the shaft.



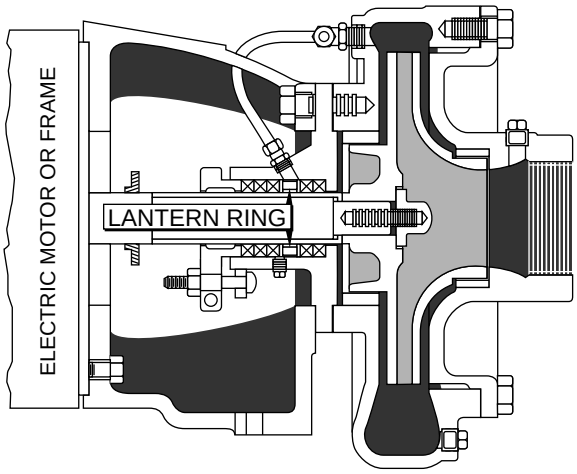
Packing Gland/Seal Gland

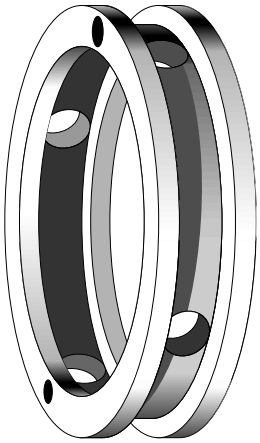
In order to control leakage with packing, pressure must be placed on the packing. This pressure is applied by the packing gland, two pieces of metal at the back of the stuffing box. When a pump uses a mechanical seal this component is called a seal gland.



Lantern Ring

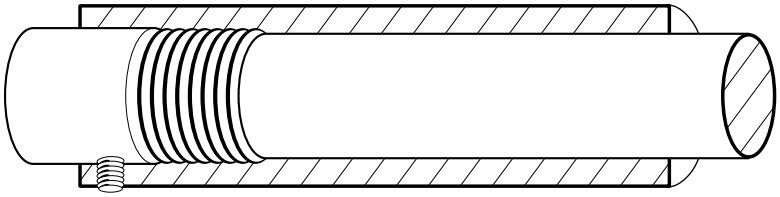
It is often desirable to lubricate and cool the packing with external water or oil. When water is used it is called seal water[17] or flush water. The seal water is distributed into the stuffing box through the lantern ring. The lantern ring is commonly a brass ring with holes that allow the water to easily pass.





Shaft Sleeve

To protect the shaft from damage due to the packing, a shaft sleeve can be installed. A shaft sleeve is a brass or stainless steel sleeve that fits tightly over the shaft.



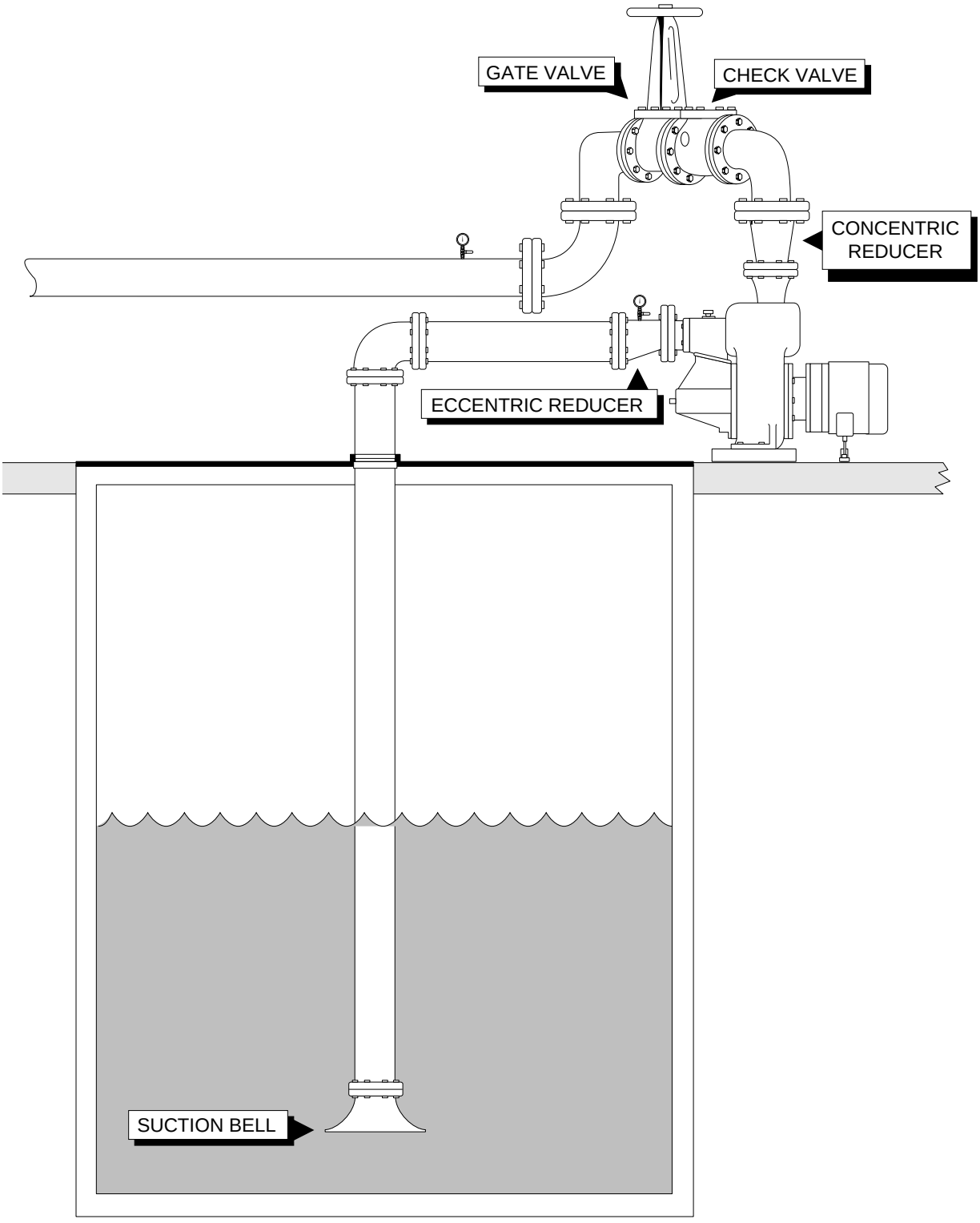
[17] **Seal Water -** The water supplied to the stuffing box to lubricate and flush the packing or the mechanical seal.

END-SUCTION CENTRIFUGAL PUMP - PIPING SYSTEM

Suction Piping	The suction piping more than any other external factor can impact pump performance. In order to reduce the impact of the piping system the suction piping is usually designed one pipe size larger than the inlet of the pump, with smooth piping material and fittings. Isolation valves on the suction side of a pump should only be knife gate or plug valves. As the piping reaches the pump it is reduced to meet the pump connection using an eccentric reducer[18]. The eccentric reducer prevents air accumulation in the piping.
Discharge Piping	The discharge side of a pump usually starts with a concentric reducer[19] taking the pipe up to one pipe size larger than the pump discharge. An isolation valve, preferably a knife gate or plug valve, is normally installed on the discharge. To reduce repair cost a flange by flange spool or expansion joint is placed between the isolation valve and the pump.
Check Valve	To prevent the flow of water back through the pump a check valve is often placed in the discharge line. The check valve could be a swing check or ball check.
Gauges	In order to evaluate pump operating conditions, pressure gauges are placed on the suction and discharge sides of a pump. Ball valves are installed at the base of the gauges to allow easy replacement and to shut the gauges off when not in use, extending their life.
Seal Water	Seal water is used to cool packing and prevent material from entering the stuffing box from the volute case. When the pump utilizes a mechanical seal rather than packing, the seal water is used to lubricate the faces of the seal. Seal water is supplied from the discharge of the volute case or an external source. A pressure gauge should be installed in the seal water line in order to assure that flow of seal water is into the stuffing box. If the seal water source is the drinking water system then an air gap must be placed between the drinking water system and the wastewater pump. This air gap prevents contamination of the drinking water system as a result of backflow from the wastewater pump.
More Information	Additional information on the piping system found in a typical lift station can be found in the lesson on collection systems.

[18] **Eccentric Reducer -** A device used to connect a large pipe to a smaller pipe so that one edge of both pipes is aligned.

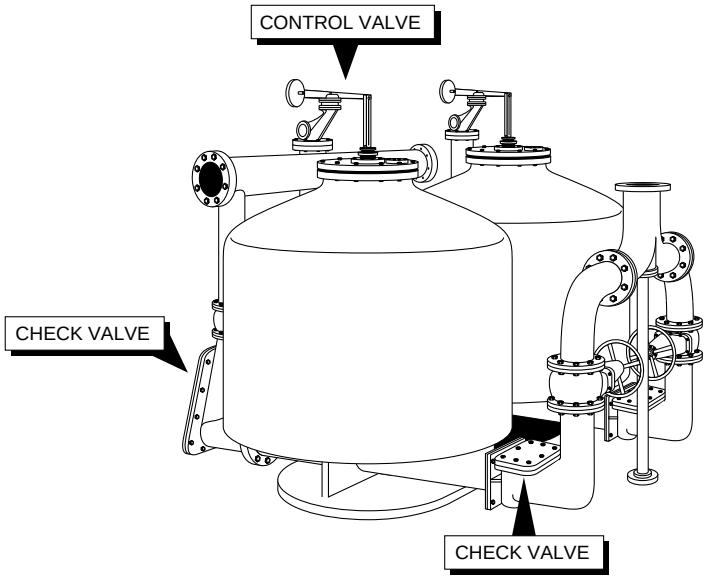
[19] **Concentric Reducer** - A device used to connect a large pipe to a smaller pipe so that the center lines of both pipes are aligned.


GATE VALVE
CHECK VALVE
CONCENTRIC REDUCER
ECCENTRIC REDUCER
SUCTION BELL

PNEUMATIC EJECTOR

Configuration

The pneumatic ejector consists of one or two steel or cast iron pots, which receive wastewater by gravity. When the pots become full, air is introduced into the top of the pots, displacing the sewage. These devices are available in sizes from 20-80 gpm and deliver heads of approximately 80 feet, with an efficiency of 15% or less.



NOMENCLATURE

Pots

The sealed pots may be constructed of steel or cast iron. The pot size determines both capacity and flow capacity in gpm; that is, a 30 gallon pot is a 30 gpm device. When two 30 gallon pots are used, the system is still a 30 gallon system or can be described as a 30 gpm ejector system with a duplex pot arrangement.

Check Valves

Swing type check valves are placed on the inlet and discharge piping of the pots. These valves control the direction of flow. During the fill cycle, the inlet valve is open and the discharge valve is closed. Air pressure applied to the pot causes the discharge valve to open and the inlet valve to close. When air pressure is discontinued, back pressure of sewage closes the discharge valve. The inlet valve is opened by head developed from sewage in the inlet piping.

Controls

Liquid level in the pots is sensed by mechanical or electrical control.

Air

Air is supplied by an air compressor. In some cases, an air storage tank is used in conjunction with the air compressor, this allows the use of a low volume low voltage air compressor allowing the device to be used in remote locations.

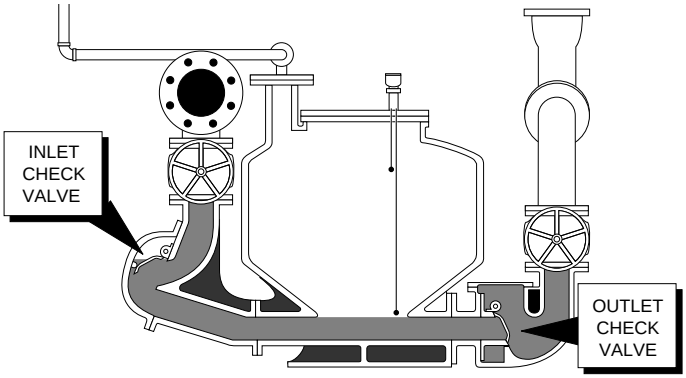
OPERATION SEQUENCE

Three Steps

The operation of the ejector is relatively simple and involves three basic steps–filling, filled and discharge.

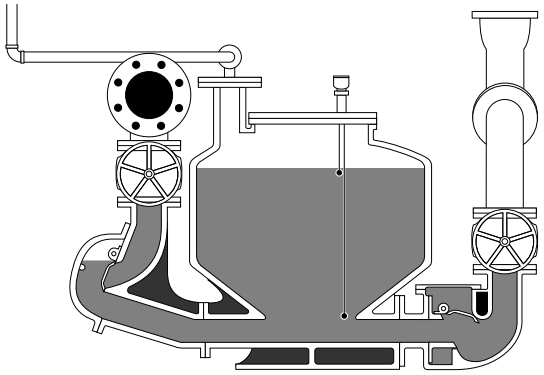
Filling

During the filling stage, the discharge check valve is held closed by a downstream head above the valve. The inlet valve is forced open by incoming sewage. Air in the pot is vented to the upstream manhole through the air inlet line.



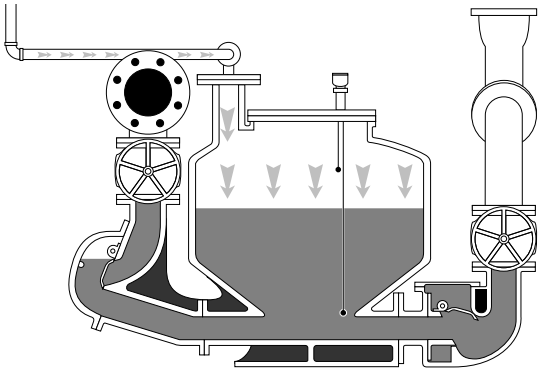
Full

When the tank becomes full, the air control valve shuts off the vent line and allows air into the pot.



Discharging

As the air pressure in the pot increases, the inlet check valve is closed and the sewage is forced out past the discharge valve.



AIR LIFT PUMPS

Configuration

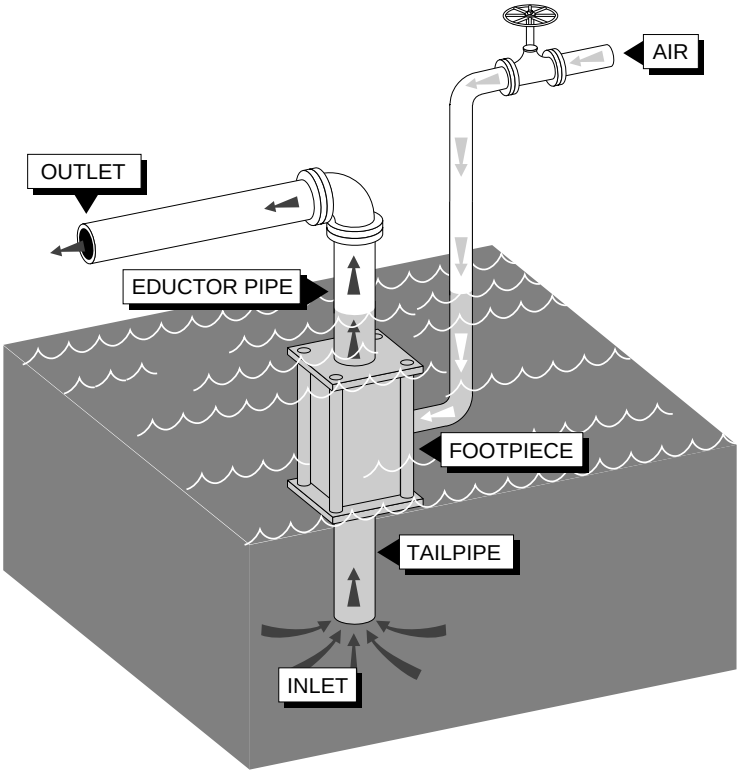
The air lift pump is relatively simple, consisting of a large pipe extending into a fluid and an air supply that introduces air into the pipe below the water level. This air supply pipe may extend down inside or outside the pump pipe.

Use

Air lift pumps are used as the return and waste sludge pump on many small activated sludge treatment plants.

COMPONENTS

The main components of an air lift pump include an air supply, air inlet line and control valve. The air inlet line is connected to a footpiece. Below the footpiece is the fluid inlet pipe called the tailpipe. Above the footpiece is the eductor pipe and outlet piping.



THEORY OF OPERATION

Drop in Specific Gravity

As air is introduced into water inside the pump, the specific gravity of the wastewater inside is reduced below that of the wastewater outside the pump. This difference in specific gravity causes the wastewater on the outside of the pump to rush into the pipe, thus pushing the wastewater in the pipe up and out.

Velocity Carries Solids

As the wastewater approaches the entrance of the pump, its velocity carries large amounts of solids through the pump.

POSITIVE DISPLACEMENT PUMPS

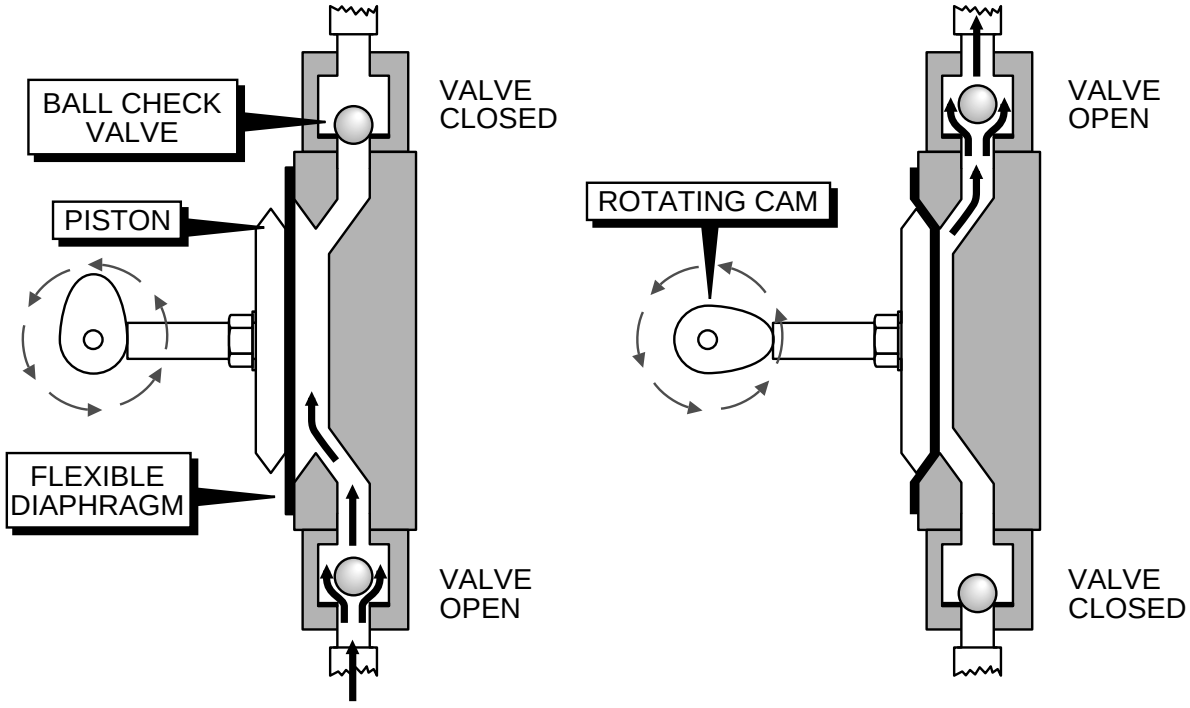
Major Components

While there are several different types of positive displacement pumps available, this discussion will be limited to diaphragm pumps. Diaphragm pumps are used to pump chlorine solutions for disinfection. The diaphragm pump is composed of:

- A chamber used to pump the fluid
- A diaphragm that is operated by either electric or mechanical means
- Two valve assemblies - a suction and a discharge valve assembly.

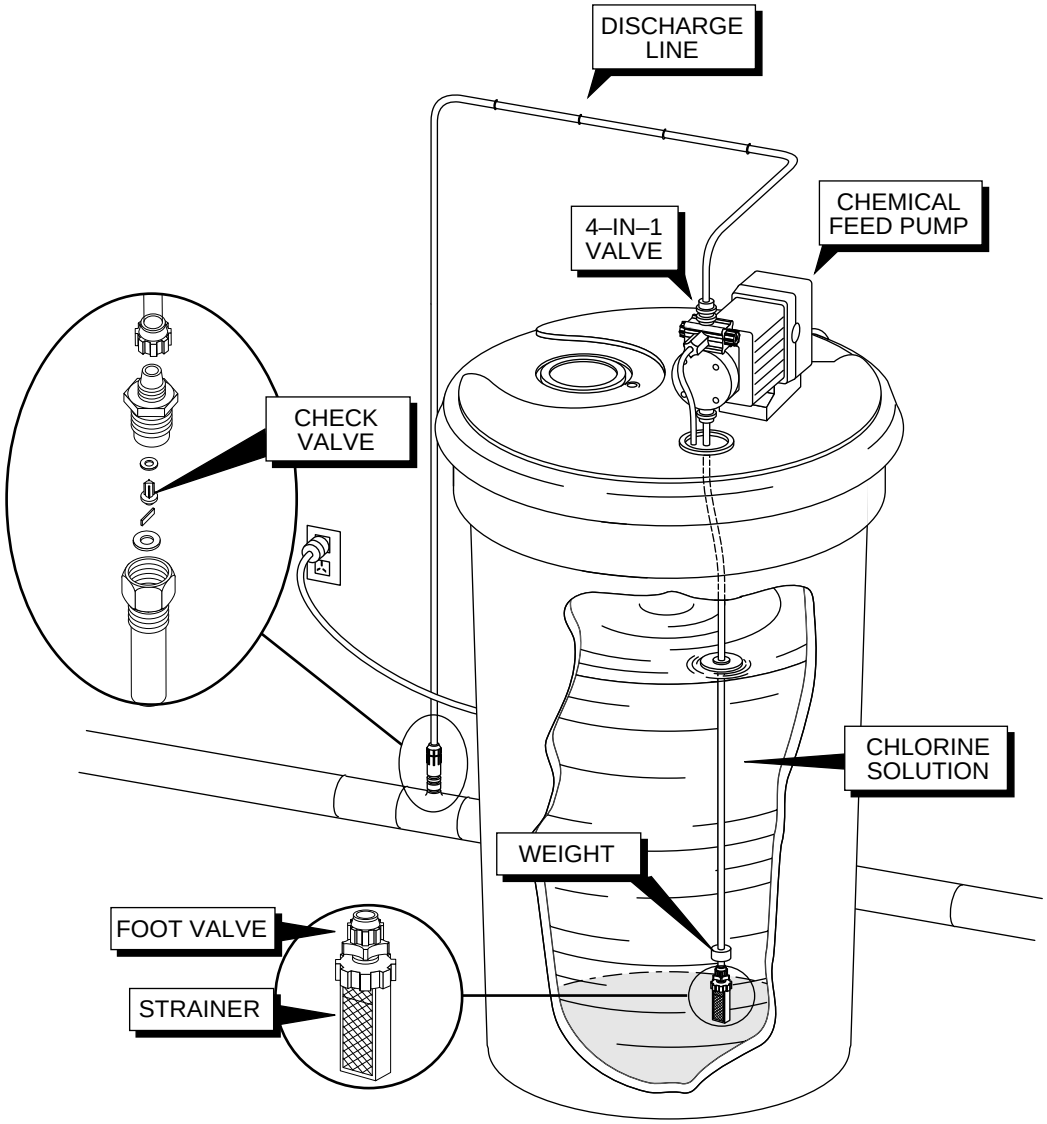
Operation

When the diaphragm is pulled back a vacuum is created in the chamber in front of the diaphragm. This vacuum causes the discharge valve to be forced closed against its seat. The vacuum allows atmospheric pressure to push fluid up against the outside of the suction valve opening the valve and filling the chamber. When pressure is returned to the diaphragm, forcing it toward the front of the chamber, the increased pressure causes the suction valve to be forced closed and the discharge valve to be forced open. The fluid is pushed out of the chamber and the pumping cycle starts over.



Piping System

The piping system for diaphragm pumps, used to pump chemicals includes a foot valve and screen on the suction line and a check valve on the end of the discharge line. The foot valve prevents loss of prime. The discharge check valve prevents the system water from flowing back into the chemical feed tank.



PUMPING EQUIPMENT

WORKSHEET

1. What are the two major categories of pumps?

   a. _____

   b. _____

2. How is energy transferred from the impeller of a centrifugal pump to the water?

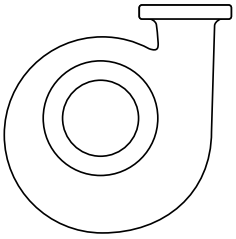
3. The two theories that are used to explain why a centrifugal pump works are:

   a. _____ transfer, and

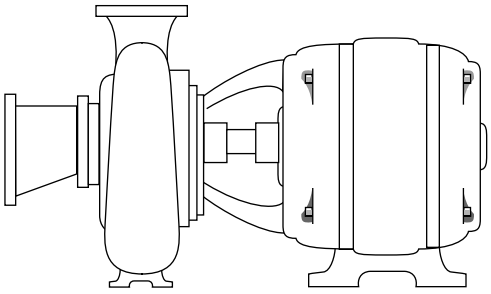
   b. _____ force.

4. The energy placed into the water by a pump can be expressed as an increase in _____ and an increase in _____.

5. Observe the volute case below. What is the proper direction of rotation?



6. Describe the pumps below by configuration.



7. Identify the components indicated in the drawing below. Compare the numbers on the drawing to the list provided.

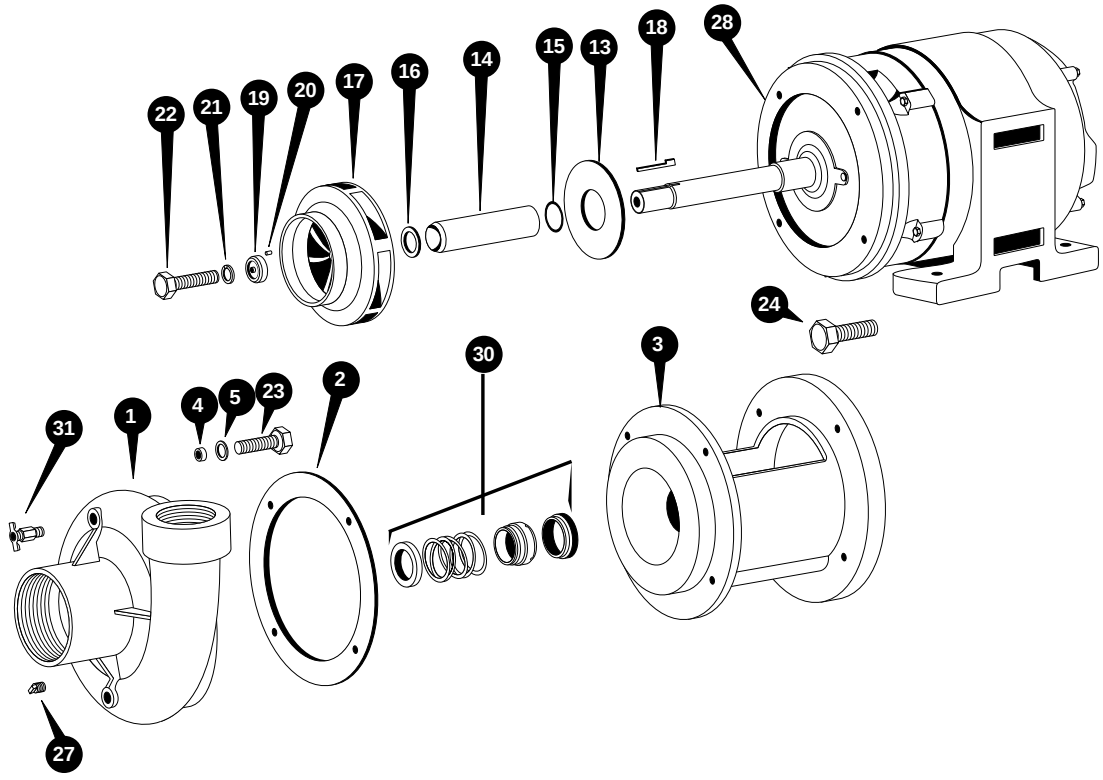
_____ a. Volute case

_____ b. Mechanical seal

_____ c. Impeller

_____ d. Stuffing Box

_____e. Shaft sleeve



8. What is the energy source used to operate a pneumatic ejector?

9. Pumps are rated in _____ per _____.

10. There are two items in a centrifugal pump that are designed to wear out and at the same time protect a portion of the pump. They are:

a. The _____ _____ - designed to protect the shaft.

b. The _____ _____ - designed to protect the volute.

11. Identify the components indicated in the drawing below. Compare the numbers on the drawing to the list provided.

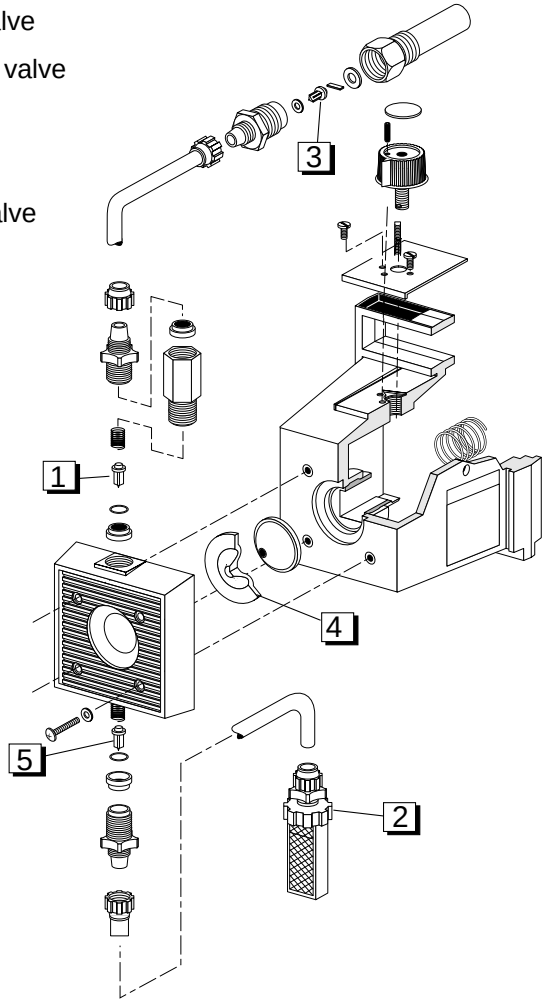
_____ a. Pumps suction valve

_____ b. Pumps discharge valve

_____ c. Diaphragm

_____ d. Foot valve

_____ e. Injection check valve



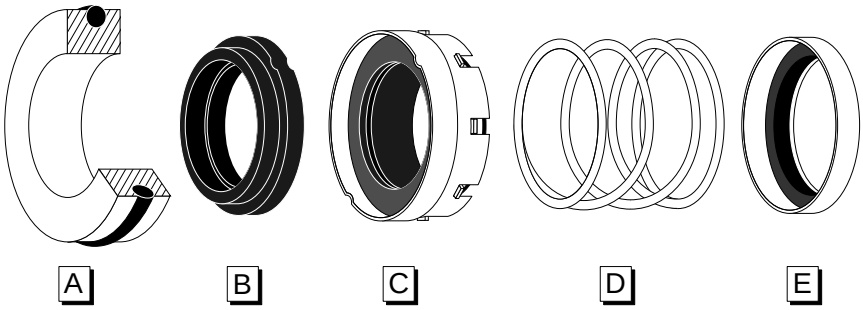
12. Identify the components in the drawing below. Compare the letters on the drawing to the list provided.

_____ a. Boot or secondary seal

_____ b. Spring

_____ c. Stationary component

_____ d. Carbon face - rotating component



13. _____ water is used to cool the packing and provide lubrication to the mechanical seal.

14. Packing and mechanical seals serve the same purpose, _____ leakage through the stuffing box.

15. Identify the components indicated in the drawing below. Compare the letters on the drawing to the list provided.

_____ a. Eductor pipe

_____ b. Tailpipe

_____ c. Air supply

_____ d. Footpiece