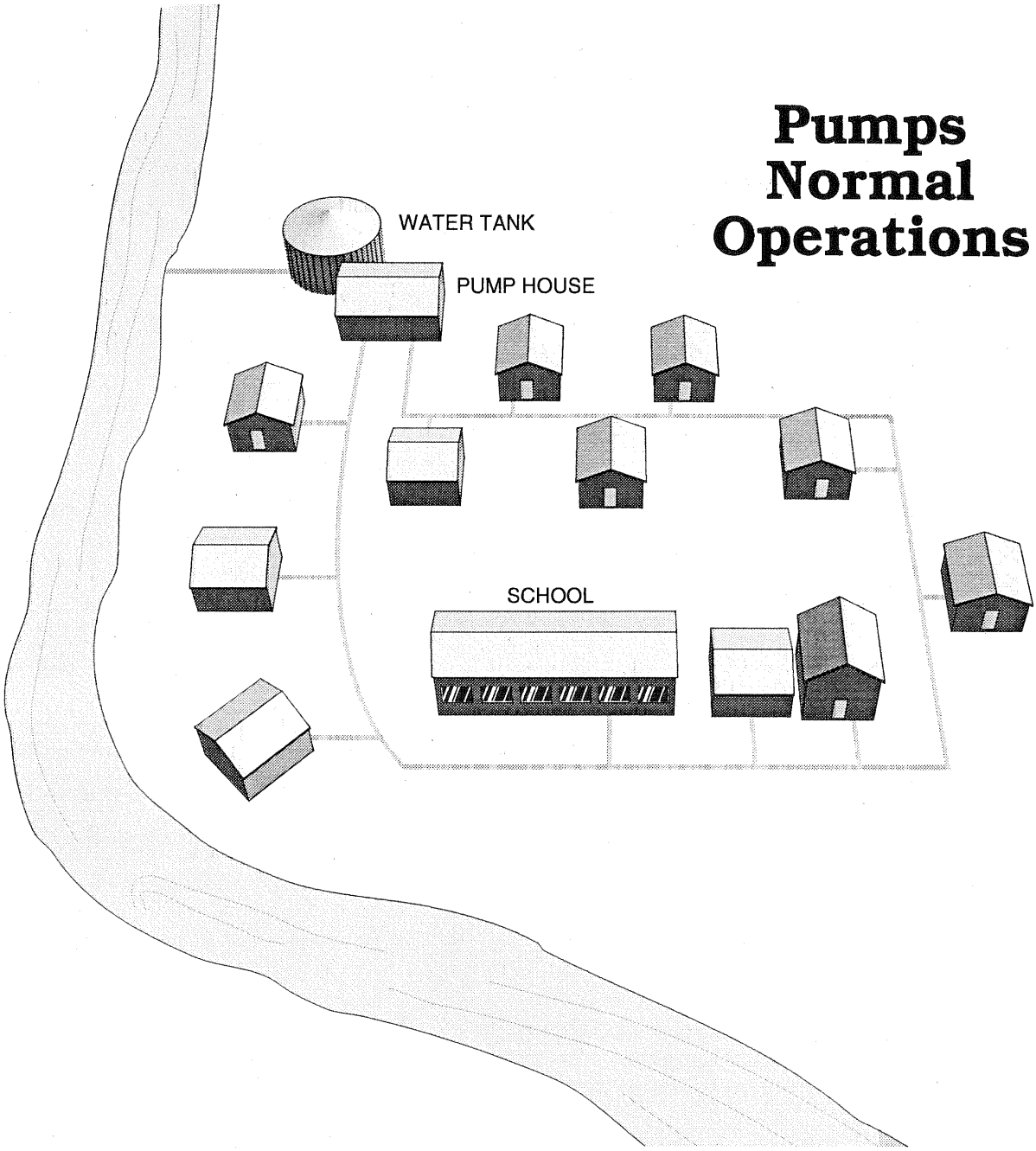
O & M of Small Water Systems



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O & M of Small Water Systems

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ACR Publications, Inc.
1298 Elm Street SW
Albany, Oregon
(503) 928-5211

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PUMPS - NORMAL OPERATION

WHAT IS IN THIS MODULE?

1. The primary uses of pumps in water systems in rural Alaska.
2. The two typical suction conditions.
3. The five major components of any pumping system.
4. Major components of a typical well with submersible pump.
5. The major components of a lineshaft turbine installation.
6. The major components of a non-well installed submersible turbine.
7. The major components of a submersible pump and pressure tank system.
8. The major components of a self-priming pump, pumping installation.
9. The major components of an end-suction centrifugal pump, pumping installation.
10. A method of priming a pump.
11. Proper routine operation of a seal water system.
12. Proper operation of a typical pumping installation.
13. Routine inspection requirements for a pumping station.
14. The components of a mechanical seal.
15. How a mechanical seal works.
16. How to change a mechanical seal.

KEY WORDS

- Amperage
- Backflow
- Bellows seal
- Cartridge seal
- Cross connection
- Double seal
- Elastomer
- Elevation head
- End play
- End-suction centrifugal
- External seal
- Fretting
- Friction drive seals
- Headloss
- Heaters
- Internal seal
- Lineshaft turbine
- Mechanical seal
- Pitless adapter
- Pressure Head
- Runout
- Seal water
- Single seal
- Submersible turbine
- Suction head
- Suction lift
- Three phase
- Velocity head
- Volute case
- Voltage

MATH CONCEPTS DISCUSSED

- Flow
- Conversion of psi to feet of head
- Horsepower
- Static Head
- Ohms law
- Efficiency

SCIENCE CONCEPTS DISCUSSED

- Ohms Law
- Compression of air
- Hydraulics
- Three phase power

SAFETY CONSIDERATIONS

- Measuring amperage & voltage
- Coupling shrouds
- Confined space

MECHANICAL EQUIPMENT DISCUSSED

- Submersible turbines
- End-suction centrifugal pumps
- Wide body globe valve
- Magnetic breaker
- Foot valve
- Level controls
- Air level controls
- Flow meter
- Mechanical seals
- RPZ
- Lineshaft turbines
- Check valve
- Butterfly valve
- Magnetic starter
- Pressure switch
- Snifter valve
- Pressure relief valve
- Packing
- Gate valve
- Air gap

PUMP STATIONS - NORMAL OPERATIONS

INTRODUCTION

Alaska

The primary emphasis of this module to focus on the operation and basic maintenance of pumps used in rural Alaska. Centrifugal pumps are used in small Alaska communities to remove water from wells, lakes, streams and other surface water sources. Centrifugal pumps are also used by communities to provide pressure to the system, circulate water in the system and in individual home services to prevent freezing as well as circulation of glycol through heating systems.

Content of the Module

This module discusses the use of centrifugal pumps in water systems in rural Alaska. At the heart of the module are those pumps used to remove water from wells and surface water sources. Secondarily, but discussed, are those pumps used to circulate water and glycol as well as pumps used to maintain system pressure. The module deals with system components, operation and basic maintenance of centrifugal pumps.

HYDRAULIC CONSIDERATIONS

Introduction

In order to understand how a pump responds to various pumping conditions it is necessary to have a basic understanding of pump hydraulics. The following is a brief discussion of those hydraulic items that impact pump performance. A more detailed explanation can be found in the section on hydraulics.

Suction Conditions

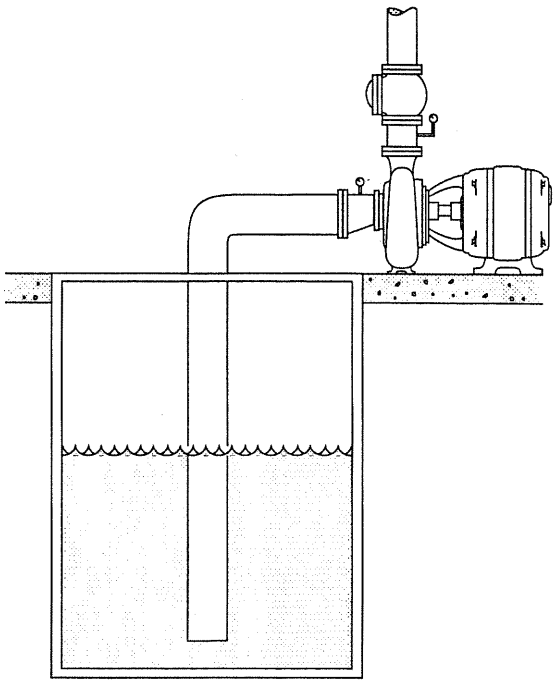
The proper operation of a centrifugal pump is impacted by its suction condition more than any other single factor. There are two suction conditions, **suction lift**[1] and **suction head**[2]. Understanding the differences and the impacts of these conditions is important to the operator who is attempting to resolve typical pumping problems.

Suction Lift

The most common suction condition is the suction lift condition. This condition exists any time the eye of the impeller is above the water that is being pumped. The suction condition requires that the pump, designed to pump water, pumps air and develops a vacuum at the eye of the impeller. This condition gives the greatest number of operational problems. These problems include the loss of prime and cavitation. When possible, suction lift conditions should be avoided.

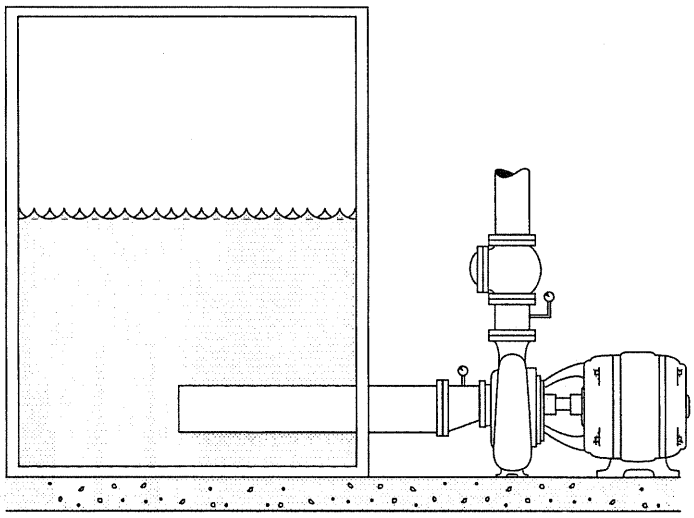
[1] **Suction Lift** - A pumping condition where the eye of the impeller of the pump is above the surface of the water that the pump is pumping from.

[2] **Suction Head** - A pumping condition where the eye of the impeller of the pump is below the surface of the water the pump is pumping from.



Suction Head

Suction head conditions exist any time the eye of the impeller is below the water that is being pumped. Suction head conditions are commonly the most efficient and provide the least number of operational problems. Examples of suction head conditions are; **lineshaft turbines**[3], submersible pumps, and pumps with a positive pressure on the suction, such as recirculation pumps.



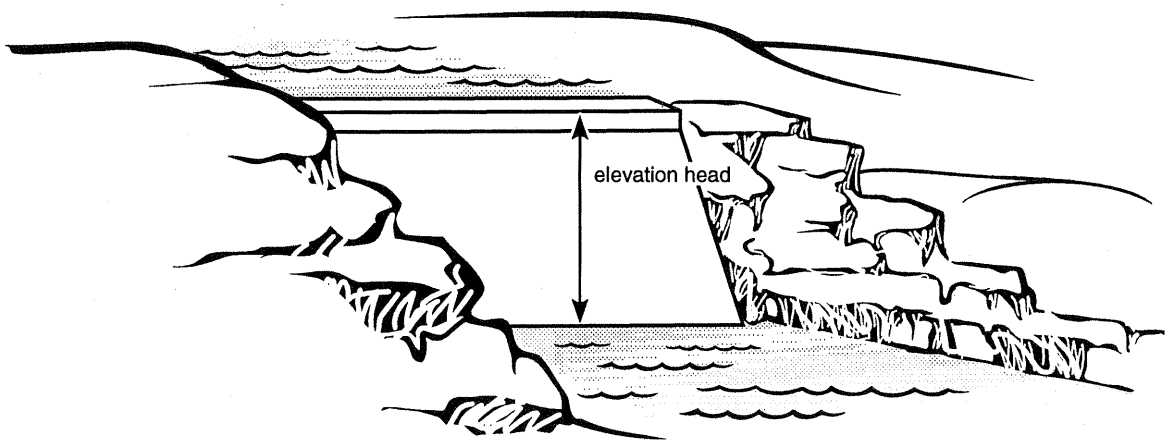
[3] **Lineshaft Turbine Pumps** - A type of vertical turbine. With this type of vertical turbine the motor is mounted above the ground and the pump unit is mounted below the water surface. A column extends from the pump to a discharge head that is mounted above the ground just below the motor. A shaft extends on a straight line from the center of the motor to the pump. The pump may be mounted a few feet away from the motor or several hundred feet away.

Measurements of Energy

In a pumping installation the energy is often measured in feet of head. One foot of head is the pressure exerted by a column of water one foot tall (0.433 psi/ft). There are four classic measurements of head in a pumping system; **elevation head**[4], **pressure head**[5], **velocity head**[6] and **head loss**[7].

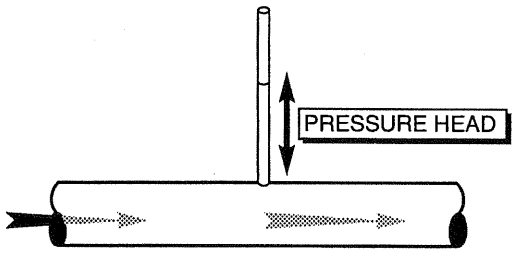
Elevation Head

Elevation head is the physical distance between two levels of water measured in feet. In the drawing below the physical distance between the two water levels is elevation head. It makes no difference if reservoirs are close together or a great distance apart. Elevation head is the vertical distance between them.



Pressure Head

Pressure head is the pressure that is measured on a gauge. This pressure can be converted to feet of head by dividing by 0.433 psi/ft. Pressure head is the vertical distance that the water would rise in a line inserted in a pipe. Pressure head can result from a transfer from elevation head or as a result of a pump.



Velocity Head

Velocity head is the amount of energy that is required to start the water to move and bring it up to some velocity. This is the energy required to overcome inertia. Velocity head is expressed in feet and commonly shown in hydraulic text books as $V^2/2g$, ("V" squared,

[4] **Elevation Head** - The energy possessed per unit weight of a fluid because of its elevation.
[5] **Pressure Head** - The head exerted by water expressed in psi. 1 foot of water exerts a pressure of 0.433 psi.
[6] **Velocity Head** - The amount of energy required to bring a fluid from a standstill to its velocity. For a given quantity of flow, the velocity head will vary indirectly with the pipe diameter.
[7] **Head loss** - The loss of energy commonly expressed in feet as a result of friction. The loss is actually a transfer to heat.

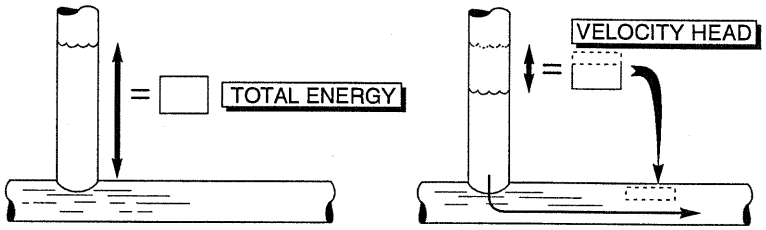
divided by two "g". Where the velocity is feet per second and "g" is the acceleration due to gravity (32.2 ft/sec^2). Velocity head is seldom more than one foot.

Example - Find the velocity head when the velocity is 8 ft/sec.

$V^2 = 8\ ft/sec\ X\ 8\ ft/sec\ = 64\ ft/sec^2$

$$V^2/2g = \frac{64\,ft^2/sec^2}{2X32.2\,ft/sec^2} = \frac{64\,ft^2/sec^2}{64.4\,ft/sec^2} = 0.99 \text{ or } 1\ ft/sec$$

What this means is that the amount of energy required to start the water to move and to brink it up to a velocity of one foot per second is the same amount of energy that would be required to lift this quantity of water straight in the air one foot.



Headloss

Headloss is the energy lost to heat as a result of friction. Headloss is commonly expressed in feet. When a person says that the headloss in a pipe is 40 feet, it means that the energy required to overcome the friction in the pipe and fittings is the same amount of energy that would be required to lift the water straight in the air 40 feet. There are several equations available to calculate the headloss in a system. While this is an engineering function and not an operator function, we will share one of the equations as a means of clarifying headloss.

Darcy-Wiesbach

One of the equations that can be used to calculate headloss is the Darcy-Wiesbach equation:

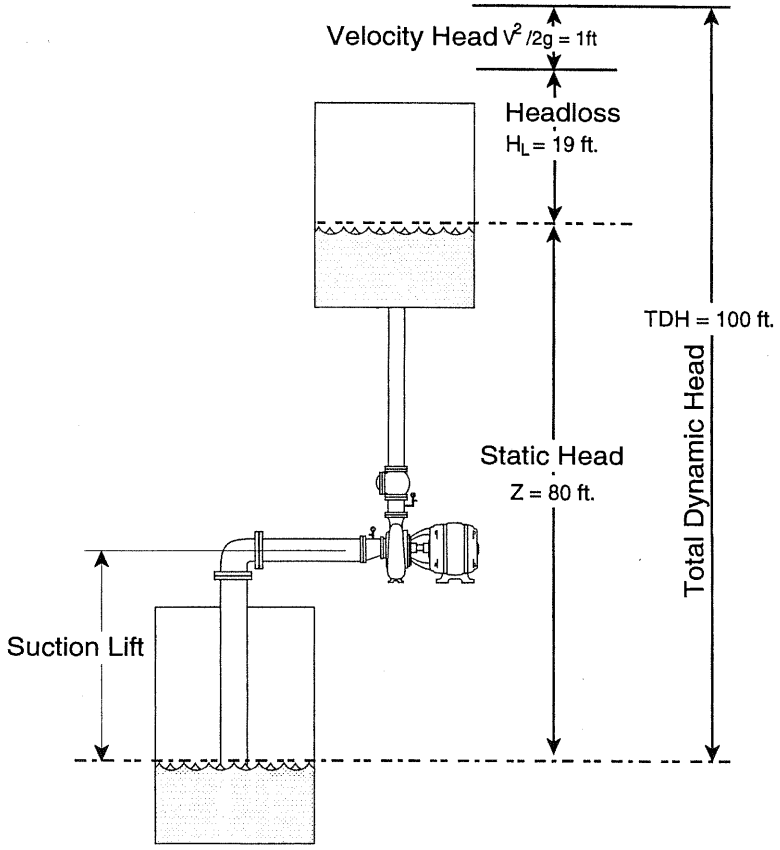
$$H_L = \frac{LV^2}{D\,2g}$$

Explanation of Darcy-Wiesbach

We are not interested in using the calculation, but in observing it in order to understand how pipe length, pipe diameter and velocity impact headloss. If we double the length of pipe we can see that the headloss is doubled. If we double the diameter of the pipe, and everything else remains the same, we cut the headloss in half. However, if the velocity is doubled, the headloss is increased by a factor of four (2 X 2 = 4). As you can see the velocity, more than any other single factor impacts headloss. The easiest way to reduce velocity in a pumping installation is to increase pipe size.

Total Dynamic Head

In the diagram below, the elevation head is 80 feet, the velocity head is one foot and the headloss is 19 feet. The theoretical distance that the water must be pumped is now 100 feet. This distance is called Total Dynamic Head. (TDH = elevation head, velocity head and headloss).



TDH & Flow

The flow of a pump is impacted by total dynamic head (TDH). As the TDH goes up the flow goes down and as TDH goes down the flow goes up. This relationship is shown graphically on the pump curve. Pump curves are explained in more detail in the section on hydraulics.

TDH, Flow and Horsepower

The pump curve is not a straight line. With most centrifugal pumps used in the water and wastewater field small changes in TDH can make dramatic changes in flow. The amount of work being done by a pump is a reflection of the TDH and flow (Q). With most pumps used in the water works industry, as the TDH goes up, flow goes down and the horsepower requirements also go down. Notice that the horsepower curve shown below slopes upward with an increase in flow. (If you are not familiar with how to read pump curves, please refer to the section on hydraulics.)

Horsepower and Amperage

Because the **amperage**[8] is a direct reflection of the work being done, amperage changes will follow changes in horsepower requirements. When the horsepower is reduced the amperage is reduced and likewise, when the horsepower is increased the amperage is increased.

Impeller Changes

For a specific pump, the thing that impacts the quantity (Q), head (H) and horsepower (Hp) of a pump more than any other single factor is the peripheral speed of the impeller. (How fast the outside edge of the impeller turns.) There are two things that impact peripheral speed, impeller diameter and rpm of the motor. With electric motors the rpm is constant, regardless of the load. Therefore, changes in impeller diameter is a key to changing pump performance characteristics.

Results of Impeller Diameter

As the diameter of an impeller wears down, the flow, pressure and horsepower (amperage) of the pump are reduced. The item that shows the greatest change is amperage. For instance, if an impeller were to be cut to half of its original diameter, the flow would be cut in half, the TDH would be cut by a factor of four, but the amperage would be reduced by a factor of eight.

Measuring Amperage

As you can see, reading and recording amperage readings of a pumping installation can give you a great deal of information about the pump performance.

PUMPING SYSTEM COMPONENTS

Five Sets

There are five sets of components in any pumping station; the building, the pump, the piping and valves associated with the pump, the electrical system and the control system. How these are arranged and what actual components are involved depends on the configuration. The configurations discussed below include; wells with **submersible turbines**[9], surface water intakes using submersible turbines, well and pressure tank systems, surface water intakes using **end-suction centrifugal**[10] pumps, lineshaft turbines, and pressure and recirculation systems.

[8] **Amperage** - The measurement of electron flow.
[9] **Submersible Turbine Pumps** - A style of vertical turbine pump in which the entire pump assembly and motor are submersed below the water. The motor is commonly mounted below the pump.
[10] **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.

WELLS - SUBMERSIBLE TURBINES

Pump Types

In Alaska the most common submersible turbine used to pump from a well is the Jacuzzi. Red Jacket and Peerless pumps are used to a lesser degree.

MAJOR COMPONENTS

Motor

The submersible pump is driven by an electric motor placed below the pump. The most common electric motor used is the Franklin. To remove heat away from the motor and thus prevent damage the motor must be kept submerged any time it is running. Motors for most of the small pump installations can be single or **three phase**[11]. The motor horsepower, **voltage**[12], number of phases and original amperage draw are key pieces of data that the design engineer should have provided at the conclusion of installation.

Pump

Most of the submersible turbine pumps used in small communities in Alaska are four or six inch pumps. This means that the outside diameter of the pumping assembly is approximately four or six inches. The impellers and pump bowls are commonly plastic on the four inch pumps and bronze on the six inch.

Plastic Impellers

While the pumps with plastic impellers are less expensive to purchase they are more prone to wear when the water contains sand, silt or other fine abrasive material.

Multistage

The number of bowl assemblies (bowl and impeller) that are used in the pump is dependent on the TDH that was calculated by the design engineer. The addition of stages increases pressure but does not change the flow of the pump. The pressure increase is linear, that is, two stages will double the pressure over one stage and three stages will triple the pressure, etc. The quantity that the pump will pump (gpm) is dependent on the capabilities of the first impeller. Adding impellers will not impact the flow of the pump.

Casing

While casings can be made from steel or PVC the most common casing material is welded steel pipe. The casing protects the bore hole from caving in and has no impact on the pumping installation.

Riser

The line leading from the pump to the well head is called the riser. The most common materials for risers are galvanized steel, PVC and HDPE. The steel pipe can corrode and acquire tuberculas thus increasing headloss and reducing flow. PVC and HDPE pipes require there be a cable attached to the top of the well casing to support the weight of the pump and motor.

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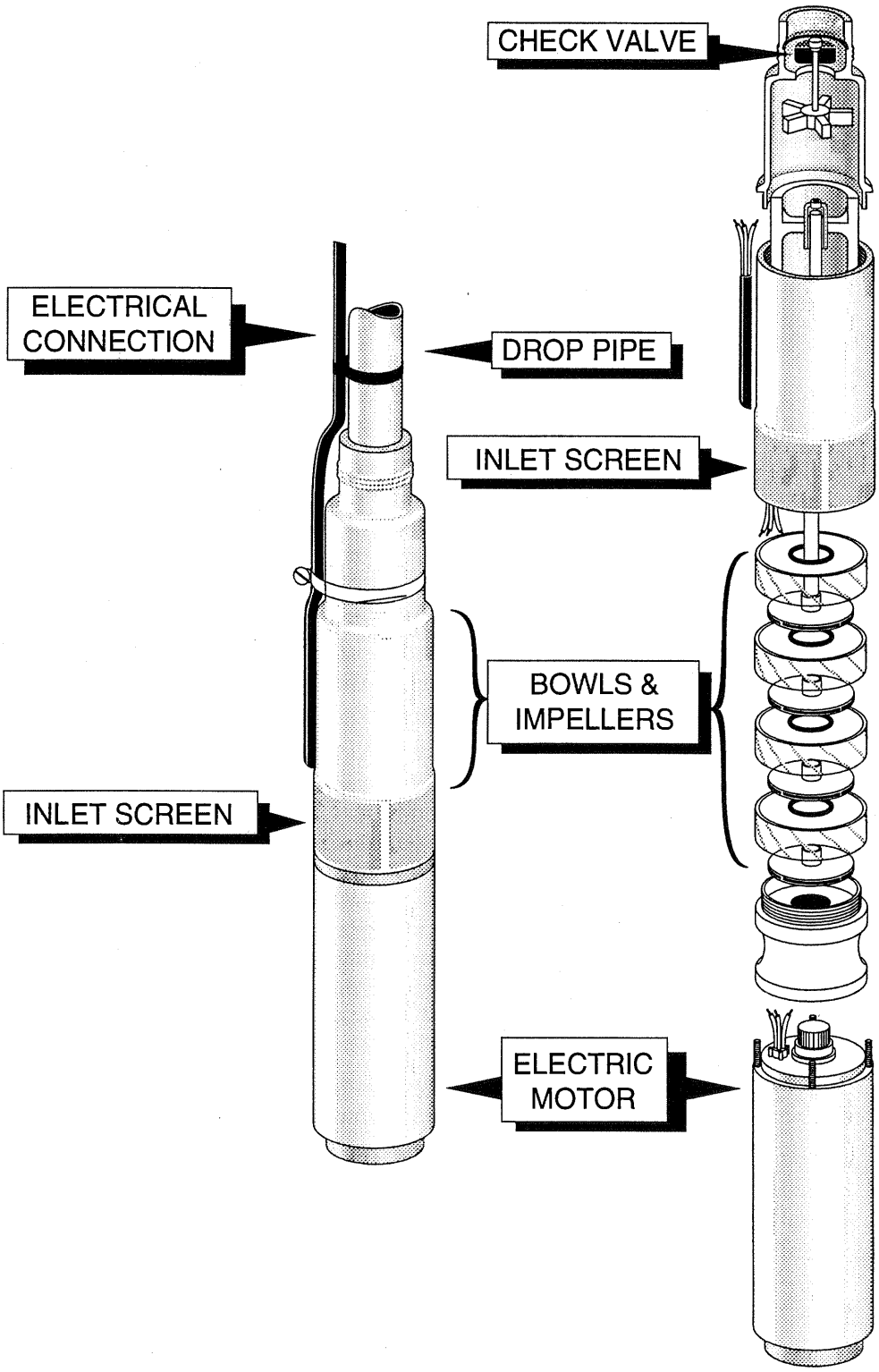
[11] **Three Phase Power** - A circuit or generator in which three power sources 120° out of phase with each other are produced.

[12] **Voltage** - The measurement of EMF between two points.



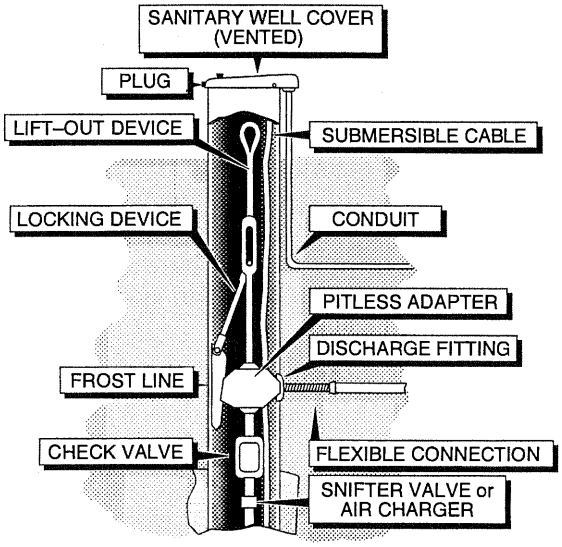
Check Valves

Most small submersible turbines have a check valve installed in the top of the pump. In deep installations there may be other check valves installed in the riser. These valves prevent water from running back through the pump and thus damaging the pump or motor. More details on the location and use of the

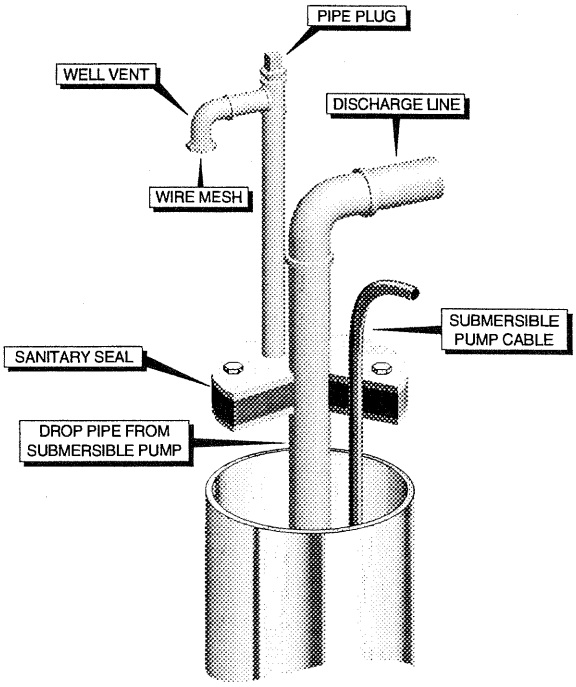
check valves can be found in the module on O & M of Groundwater.

Electric Drop

The electrical connection to the pump is composed of three sections of wiring. The first is the section that comes with the motor. This section is connected to the drop, which is attached to the riser. The connection between the drop and the motor is protected from the water with heat shrink tape. The connection at the well head is made inside of a junction box with wire nuts or just under the sanitary seal using the heat shrink tape process. Regardless of the type of connection the conduit and/or junction box should be water resistant. This requires NEMA 4 boxes and electrical connections.



Pitless Adapter



Well Head

The well head contains the casing vent, sanitary seal and discharge piping or **pitless adapter**[13] and discharge piping. The sanitary seal and pitless adapter are portions of the well and discharge piping system and are not normally considered part of the pumping process. However, if the casing does not have an adequate working vent the pump performance may be affected. When the pump starts, water in the well casing drops. Without a vent in the casing, the pressure in the casing can become a vacuum, causing the casing to collapse and/or reducing the pressure at the eye of the first impeller, resulting in cavitation.

[13] **Pitless adapter** - A devices used to discharge water from below the frost line of a well without the use of a pit. With a pitless adapter the well casing extends to the surface. Removal and installation of the pump is through the well casing.

Operations

The submersible pump installation is difficult to observe for proper performance. The keys to proper operation are, identifying the type and brand of pump, depth, operation of the vent and discharge pressure. It is also desirable to know the number of bowls, motor brand and motor horsepower. This data can be important in identifying and solving pumping problems.

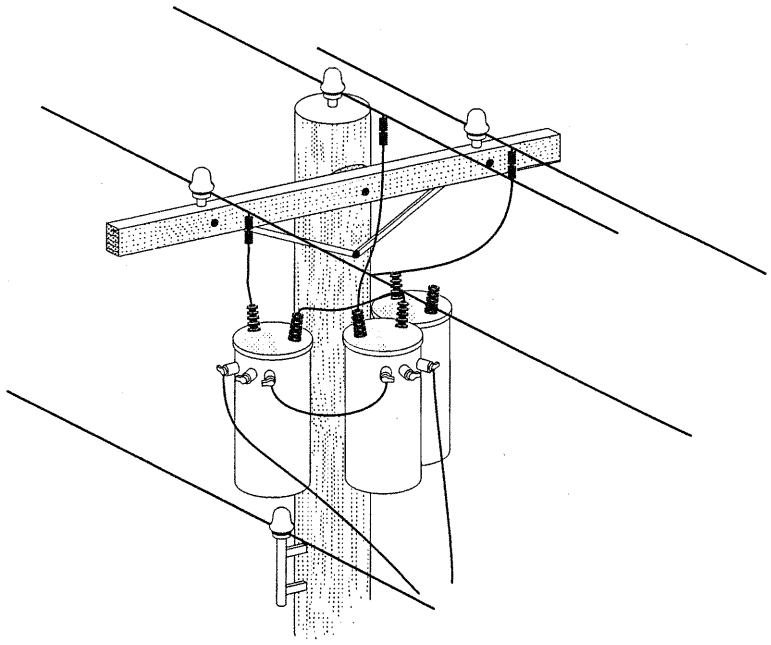
ELECTRICAL SYSTEM

Operational Need

While it is not necessary for the operator to be versed in electrical theory, and electrical maintenance it is desirable for each operator to be able to identify basic electrical components and describe their functions. Therefore, the following discussion is provided.

Phase

The first electrical consideration is to determine the number of phases being used. Is the system single phase or three phase? The easiest way to make this determination is to observe the number of transformers on the pole and the number of wires (the drop) leading from the transformer to your weather head. If there are three or four transformers and there are four wires leading from the transformers to the weather head then the possibility is high that the system is three phase. If there is one or two transformers and there are only three wires in the drop the system is most likely single phase.



Breaker

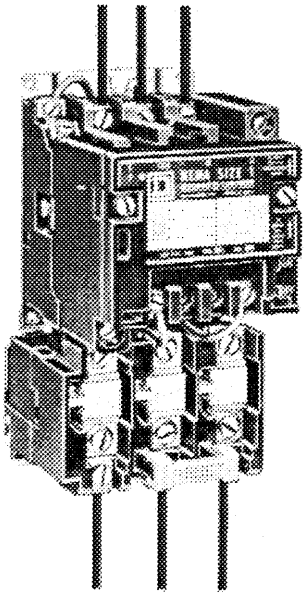
Each pump must have some type of disconnect. This is used to allow power to be disconnected so that electrical work can be performed safely. In small systems the disconnect is also the breaker. The breaker also is used to protect the wiring in the building should a short circuit occur in the motor or wiring. Identify the breaker for each motor and note the amperage rating.

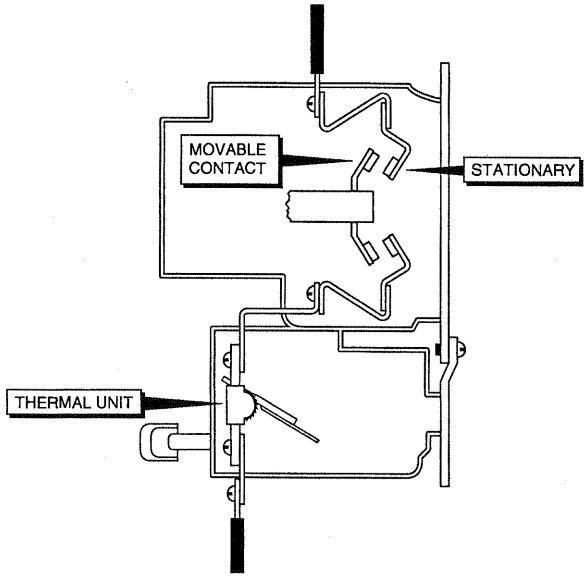
Lock-out

Each breaker must have a method of allowing a padlock to be placed on the breaker whenever the breaker is placed in an off position. Placing a padlock on the breaker along with a tag explaining the reason for the shut-down is an OSHA requirement.

Magnetic Starter

The magnetic starter is a large switch operated by an electromagnetic, The magnetic starter is used to start and stop the pump. The magnetic starter may also contain extra contacts called auxiliary contacts that can be used to turn on and off chemical feed pumps and lights.





Capacitors

Single phase electric motors need capacitors to help them start. These are typically mounted on the side of the motor. However, with submersible pumps the capacitor is mounted in the control panel. It may appear as a small round tube with two wires.

Heaters

As a part of or placed below the magnetic starter are the **heaters**[14] or thermal overloads. This may be a single device in a single phase motor or a bank of three devices with a three phase motor. The heaters protect the motor from excessive amperage draw. It is important to remember that it commonly takes 20 to 60 seconds of overload before a heater will trip.

Reset Button

The easiest way to identify thermal overloads, (heaters), is to find the red button marked "Reset." When there is an overcurrent condition the heaters will "trip", pressing the "reset" will reset the heaters. **Before pressing the reset button always return the Hand-Off-Auto switch to the OFF position.** This will prevent premature failure to the thermal overload system.

[14] **Heater** - A device designed for overload protection of electric motors. The device is heat sensitive and is placed in the power circuit with an electrical connection to the control circuit.

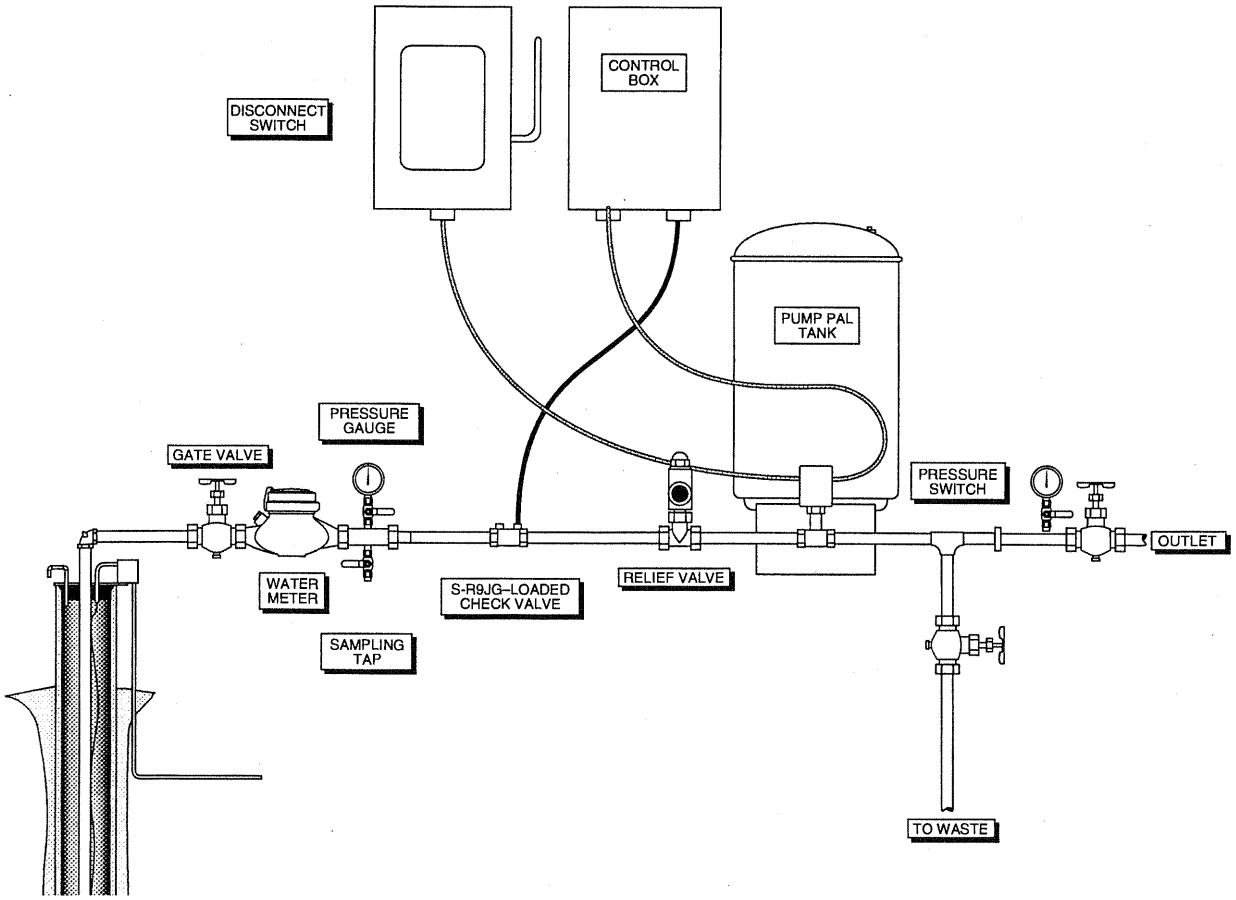
CONTROL SYSTEM

Function

Every pumping system has some type of control system. In order understand the operation of a specific pump installation it is necessary to observe and understand the basic functions of the control system. Typical functions include **backflow**[15], pressure regulation, level controls, flow controls and water depth indication.

Backflow Prevention

Once water is pumped into a tank or distribution system it is desirable to prevent it from running back through the pump at shut-down. The most common method of preventing this backflow is with a check valve on the discharge line.

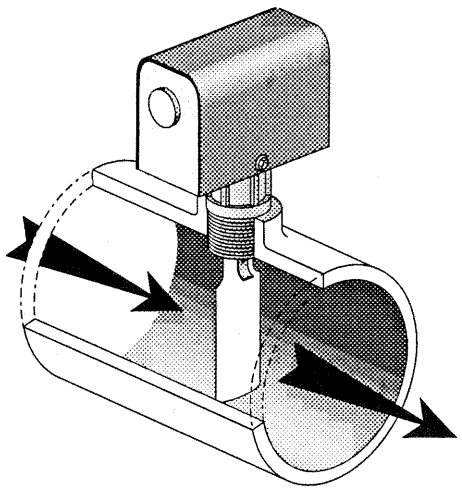


Flow Indication

When chemical feed pumps, such as chlorine and fluoride pumps are connected to a well system it is desirable to have them only operate when it is assured that the pump is pumping. This can be accomplished by placing a flow switch in the pump discharge line. The flow switch is wired into the electrical system in such as way as to prevent the chemical feed pumps from operating until a flow is detected.

[15] **Backflow** - A reverse flow condition, created by a difference in water pressures, which causes nonpotable water to flow into a potable water system.

Flow Switch



On and Off

The most common on and off control is the H-O-A (hand, off, auto) switch. Placing this switch in the "hand" position disconnects all of the level, pressure and flow controls. Selecting hand allows the operator to determine if a pumping problem is in the control system or the pump motor. *Placing the switch in the "hand" position, should not allow the operator to override the flow safety switch for the chemical feed pumps.*

Pressure Control - Reservoir

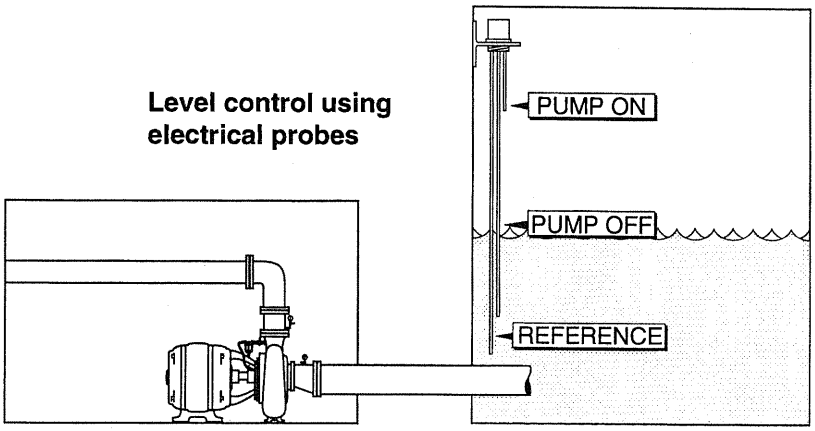
One method of determining when a pump should come on is to respond to pressure changes. A pressure control system may be tied directly to a reservoir or to the distribution system. As the water level in the reservoir drops the pressure would drop and the pump would come on. When the pressure in the reservoir reached full the pressure would increase and the pump would shutdown. The low pressure to depth ratio, 0.433 psi per foot, associated with water makes this process difficult to use for small reservoir height changes.

System Pressure

One of the more common methods of pressure control is to respond to system pressure. When the system pressure drops below some set point the pump comes on, when pressure rises to a predetermined point the pump is shut off. This process, while more popular than identifying reservoir level, suffers from the same difficulty of attempting to respond to small changes. This type of system often suffers from frequent pump start stop cycles. This results in premature pump motor failure.

Level Controls

One of the most popular pump control systems is the level control. Level measuring devices such as probes, sonic devices and floats are used to detect reservoir level. When the level drops to a predetermined point the pumps come on and pump until the "full" level is reached.



Level control using electrical probes

Pressure Gauges

A pressure gauge on the discharge of a submersible turbine pump is not part of the typical control system. However, it is an important tool for the operator to use to determine pump performance. The pump discharge pressure should be read and recorded on a regular basis.

Flow Meter

The flow meter, like the pressure gauge, is not normally used as part of the pump control system. Also, like the pressure gauge the flow meter can be very useful in determine pump performance. The flow meter should be read and recorded regularly.

Water Depth

The depth of water in the well should be observed and recorded on a regular basis. This can be accomplished with a bubbler tube, electric tape or sonic device. The process of obtaining this data is discussed in the module on O & M of Groundwater.

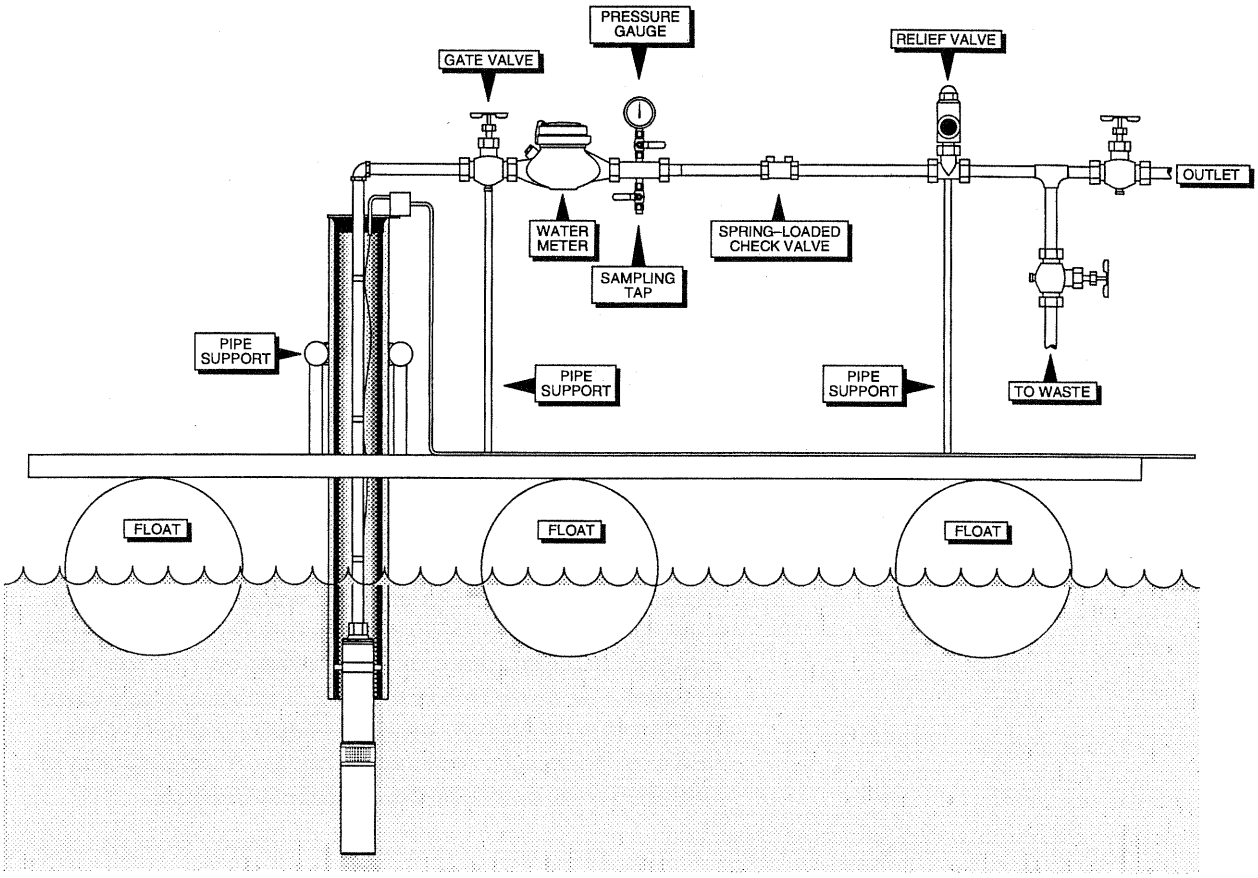
BUILDING

The building used to house a submersible pump pumping from a well should be designed to be vandal resistant, heated and properly insulated to protect the piping from winter temperatures. A detailed discussion of this type of building can be found in the module on O & M of Groundwater.

SURFACE WATER - SUBMERSIBLE TURBINE

Unique

One of the unique uses of submersible pumps in Alaska is to hang the pump from a float placed in the river. When winter arrives either the reservoir is filled and no water is pumped until spring or the pump is installed through the ice.



Transition Problems

The biggest operational problem with this type of installation is dealing with the spring and fall transition periods. These transition periods often require the operator to become very innovative. Innovative techniques, range from filling the reservoir and asking for voluntary water conservation to making special platforms that can withstand the ice conditions.

Major Components

With few exceptions, the components associated with this type of installation are the same as those associated with a well that was described above.

Vertical Position

While these processes work quite effectively, it is important that the submersible turbine be maintained in a vertical position during its operation. The bearing used in the pumps were not designed to handle radial loads and will wear prematurely if the pump is not hanging vertically.

Piping Connection

The piping connection between the float and the shore must be flexible and should be designed for easy connection and disconnection. Commonly the piping used includes fire hoses, PVC and HDPE pipe. Because hose offers a high headloss and PVC is easily broken HDPE is the most logical choice. The HDPE pipe is connected to the pump riser using a short piece of hose with Kamlock™ connections.

Electrical Connection

The electrical connection for this type of installation needs to be designed for easy connection and disconnection. Typical is a water resistant twist lock plug. Most operators find it is best to wrap the connection with plastic and seal with duct tape.

Electrical Components

There are two electrical systems used with this type of installation. One houses the breaker, magnetic starter and other control devices in a control panel based on shore. The second places the electrical control system in a panel located on the float. With few exceptions, some noted below, the electrical system for this type of pumping installation is the same as was discussed above with the well system.

Electrical Drop

The wire running between the shore and the float is commonly called the "drop." Because this wire is exposed to the weather and the water it will deteriorate. Deterioration takes two forms, reduction in the insulation capabilities of the coating on the wire and breakage of the strands of wire. The insulation capabilities can be tested using a megger, a device that tests resistance in millions of ohms. A description of this device is found in the electrical module.

WELL AND PRESSURE TANK SYSTEM

Introduction

Pressure tanks, called hydropneumatic tanks, are added to well pumping systems to maintain system pressure and to reduce the frequency that the pump operates.

Tank

The discussion of how the tank operates and how the air volume is controlled is discussed in the reservoir module.

SYSTEM COMPONENTS

Pump & Motor

The pump and motor used in this system is either the submersible turbine system discussed above or the end-suction centrifugal pumps discussed below.

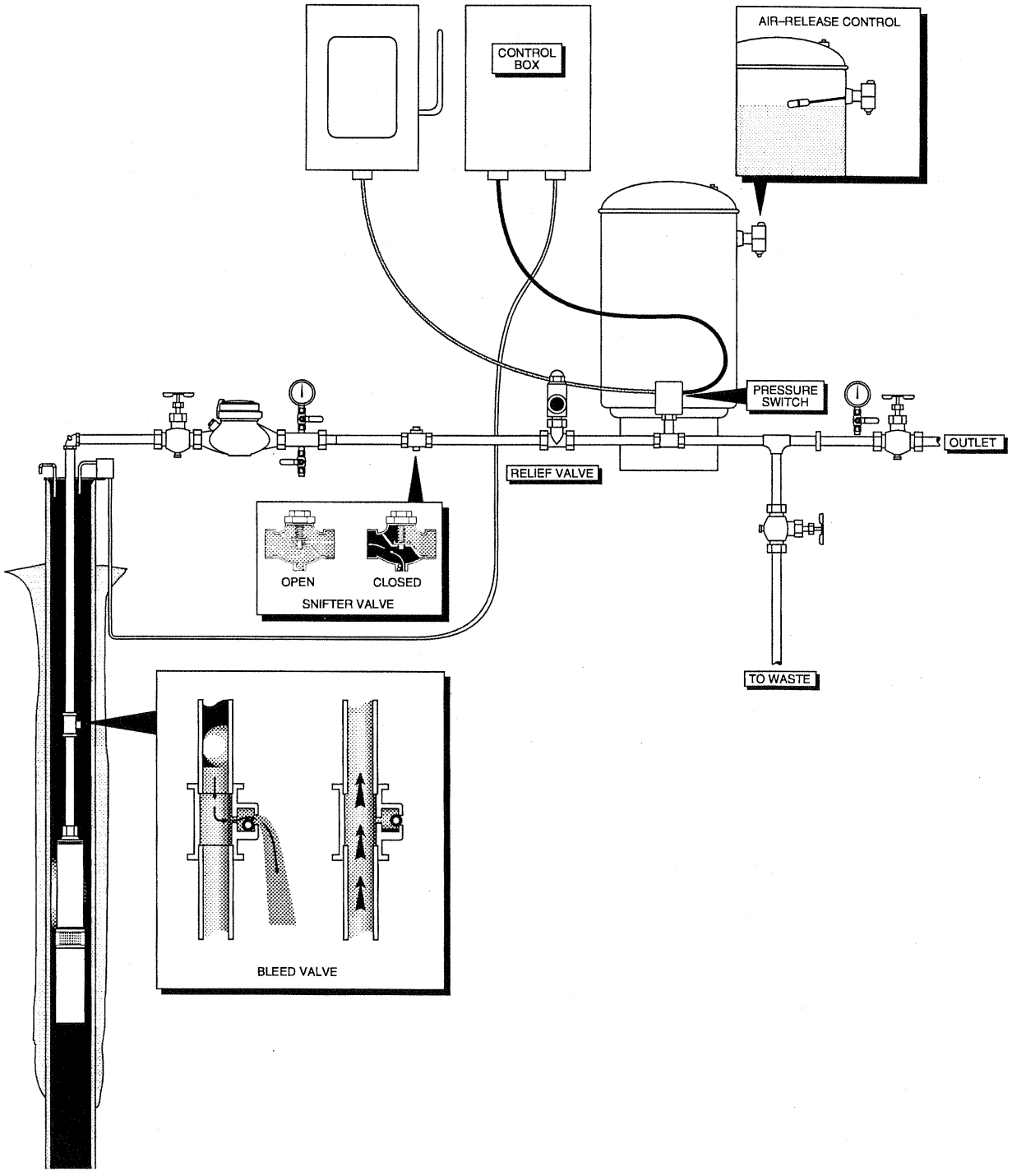
Air Control

What makes this system unique is the air control system. While there are a wide variety of air control systems available, the most common with the submersible turbine is the snifter and bleed valve combination. The snifter valve allows air to enter the line

anytime there is negative pressure in the line. The bleed valve allows water to escape from the riser pipe.

Operation

When the pump shuts down, the water between the discharge check valve and the bleed valve leaks back into the well. As the water leaks from the line a vacuum is formed, opening the snifter valve and allowing air to enter the line. Upon starting the pump this air is pumped into the hydropneumatic tank to maintain the air supply.



Compressors

With larger systems an air compressor is often used to supply air to the hydropneumatic tank thus eliminating the need for the snifter and bleed valves.

Pressure Relief

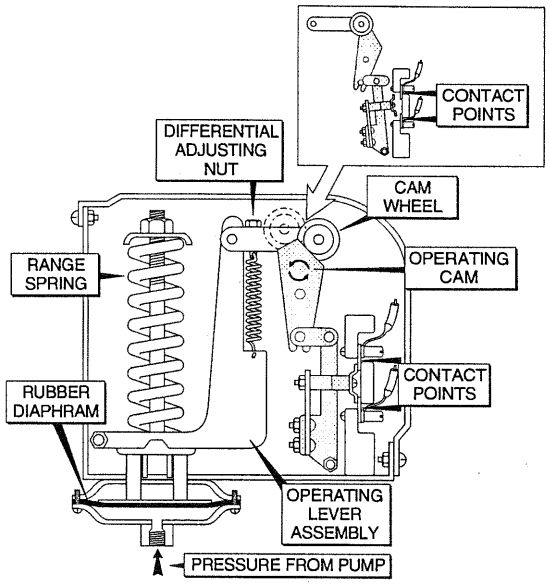
It is common with this type of system to have a pressure relieve valve installed in the discharge line. This valve is usually installed between the well head and the isolation valve. Should the isolation valve become closed, the system pressure could exceed the capacity of the piping system. The pressure relief valve, commonly set to relive any time the pressure exceeds normal working pressure plus 10%, would open and exit water to waste.

Cross-Connection

It is important that the discharge of the relief valve exit near the floor but not be directly connected to the floor drain or building sewer. To prevent a **cross-connection**[16], the discharge must be two pipe diameters or a minimum of 1 inch above the floor drain.

Pressure Controls

The pump usually operates on a demand provided by a pressure switch or a set of pressure controls. On small systems a standard pressure control switch is used. This is a diaphragm operated switch that physically closes contacts when the pressure reaches a low point and opens the contracts when the pressure reaches the high point. These contacts are wired into the control system that operates the motor starter.



Dual Controls

On larger systems, it is normal to utilize two pressure switches. One turns the pump on and the second turns it off. This system usually provides the operator with the widest range of pressure options.

Pressure Range

While the pressure range is commonly set by the design engineer based on system requirements, the typical range is 20 to 40 psi.

[16] **Cross-connection** - Any physical arrangement whereby a public water supply is connected, directly or indirectly, with a non-potable or unapproved water supply or system.

Pressure Gauge

In order to determine if the pressure controls are operating properly and to make adjustments, it is necessary to have a pressure gauge on the discharge line of the pump. This gauge should have a ball, or other isolation valve between the gauge and the line. This valve will allow the gauge to be changed without shutting down the system.

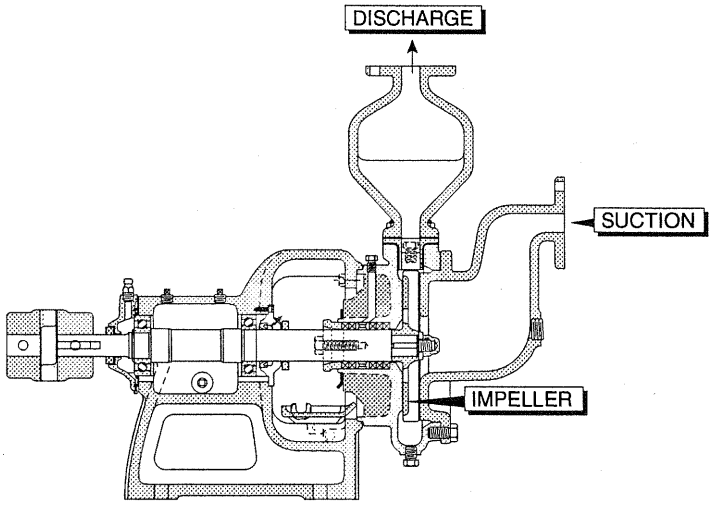
PUMPING FROM SURFACE WATER - END-SUCTION CENTRIFUGAL PUMPS

Pump Types

The most common end-suction centrifugal pumps used to pump surface water in Alaska are the Gorman Rupp, Homelite and Wisconsin. These pumps are all classified as self-priming pumps. In this situation self-priming describes a special **volute case**[17] configuration and does not describe the function of the pump. No centrifugal pump is self-priming. That is, no centrifugal pump when installed in a suction lift condition can start with a dry volute case and suction line and pump water. They all need to be primed first.

What is Self-priming

Self-priming describes a pump classification that requires the suction piping connection to be above the eye of the impeller. Also, most self-priming pumps have a large cavity on the discharge of the pump. When the volute case is filled with water, the impeller is immersed. Thus, when the pump starts the pump is already "primed." The Gorman Rupp has an additional by-pass between the discharge and the volute case. This allows water to be circulated between the discharge and volute case, thus improving the possibility that the pump will pump when started.



Other End-Suction

When self-priming pumps are not used, the PACO or Burke end-suction centrifugal is typically selected.

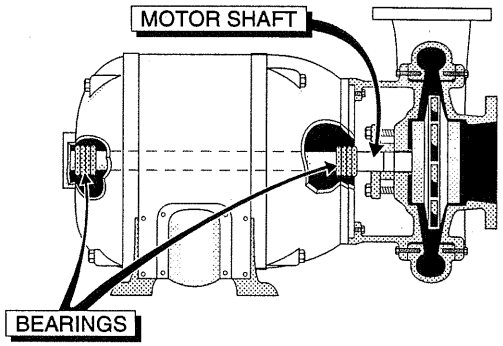
MAJOR COMPONENTS

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

HYDRAULIC SYSTEM

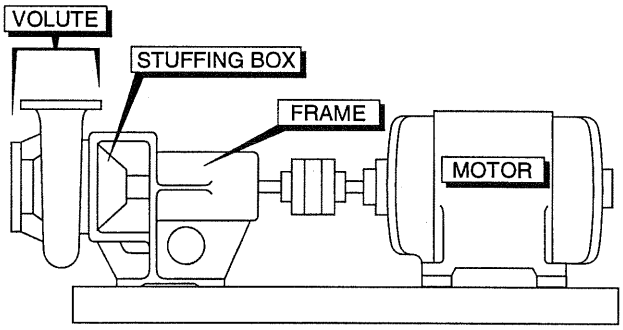
Pump

End-suction centrifugal pumps can either be close-coupled or frame mounted. A close coupled pump uses the motor bearings and motor shaft as the pump bearings and pump shaft. There is no coupling between the motor and pump of a close coupled end-suction centrifugal pump.



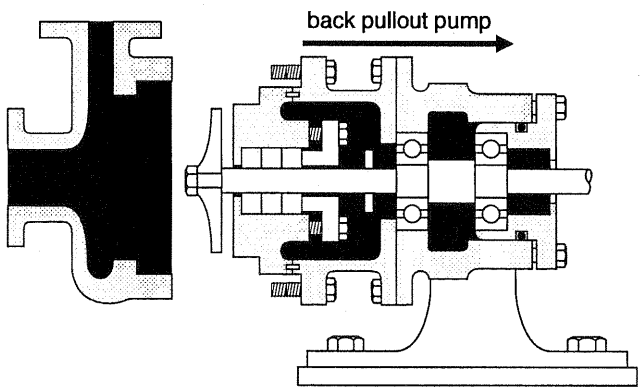
Frame Mounted

Frame mounted pumps have pump shafts and bearings separate from the motor shaft and bearings. A coupling must be installed between the motor and pump in order to transfer energy from the motor to the pump.



Back-pull out

End-suction centrifugal pumps can be either back-pull-out or nonback pull out. Back pull out pumps allow the pump impeller to be removed from the back of the volute case. This allows the suction and discharge piping and valves to remain attached to the case during repairs, reducing repair time and cost.



Suction Piping

When a pump is in a suction lift condition the suction piping more than any other single factor affects pump performance. Therefore, to reduce headloss the suction piping should be one pipe size larger than the pump suction connections, made of round, smooth straight pipe, and any elbows should be the long radius type. The suction piping should slope upward toward the pump.

Reducer

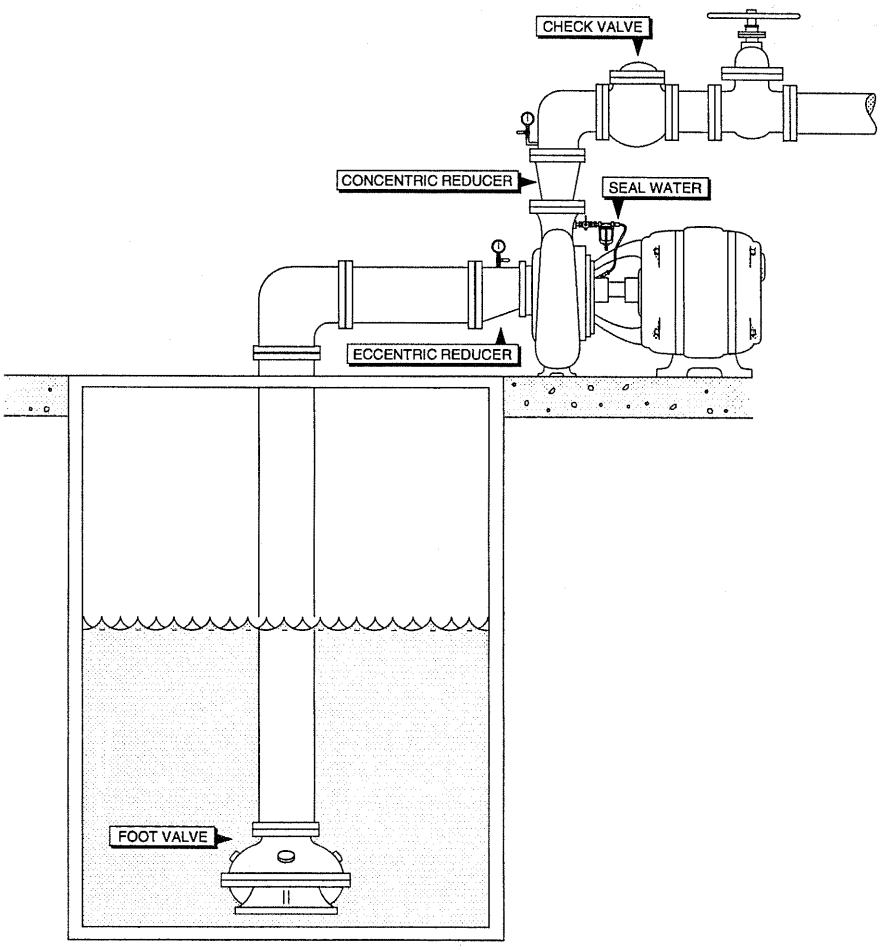
There should be an eccentric reducer installed just before to reduce the piping to match the pump. This reducer should be flat on the top and sloped on the bottom. This will reduce air entrapment in the reducer and thus reduce cavitation possibilities.

Support

The suction piping should not be supported by the pump. The weight of the piping can cause excessive vibration and premature pump and motor bearing failure.

Foot Valve

When not using a self-priming pump a foot valve must be installed at the end of the suction line. To reduce headloss this valve should be one pipe size larger than the suction piping or be the angel cut low headloss type of valve.



Isolation Valve

Under suction lift conditions no isolation valve is necessary on the suction side of the pump.

Discharge Piping

In order to reduce headloss, the discharge piping should be round smooth pipe, one pipe size larger than the pump discharge with long radius elbows.

Concentric Reducer

The connection between the discharge piping and the pump should be made using a concentric reducer.

Check Valve

To prevent water from running back though the pump and having to be pumped again, a check valve is installed in the discharge piping. This valve may be a swing check, silent check or an automatic check valve. The most common automatic check valves are the wide body globe valves.

Isolation Valve

In order to work on the pump an isolation valve is installed on the discharge piping. While butterfly valves are often used for this purpose, the gate valve offers less headloss.

Spool

In order to reduce the amount of time necessary to repair a pump, and thus reduce maintenance cost, a flange by flange spool is placed in the discharge line, between the reducer and the isolation valve.

ELECTRICAL SYSTEM

The electrical system associated with end-suction centrifugal pump installations is same as that found with the submersible turbine pumping instllations used in wells. This system is explained on pages 12 - 16.

SURFACE WATER - LINESHAFT TURBINE

Pump Types

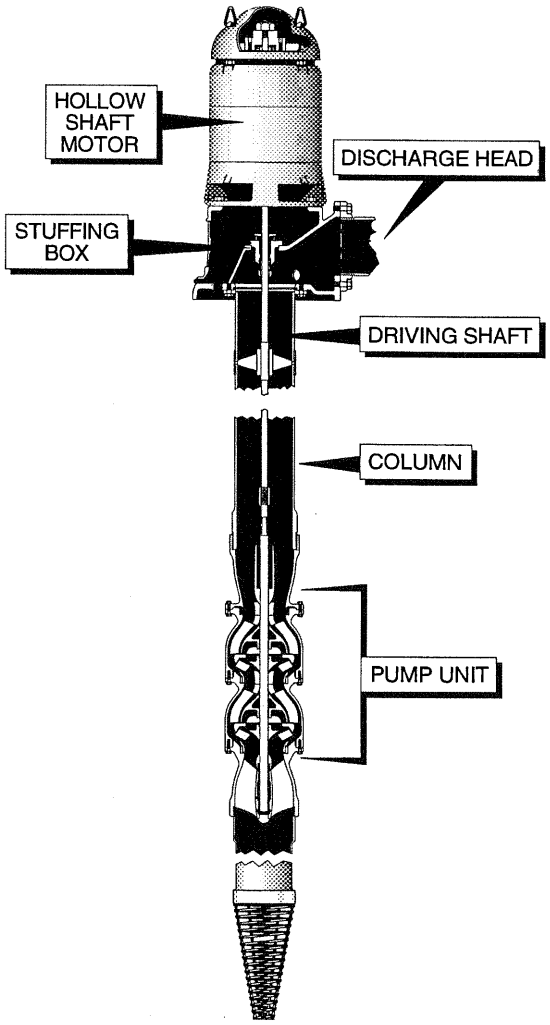
In Alaska, very few systems use lineshaft turbines to pump groundwater or surface water. Lineshaft turbines are used in wells in Anchorage to pump from the water plant at Craig and to pump from the lake at Kotzebue.

MAJOR COMPONENTS

HYDRAULIC SYSTEM

Pump & Column

The pump in a lineshaft turbine installation is placed in the well casing toward the bottom of the well. Water is pumped from the pump up through pipe called a column.

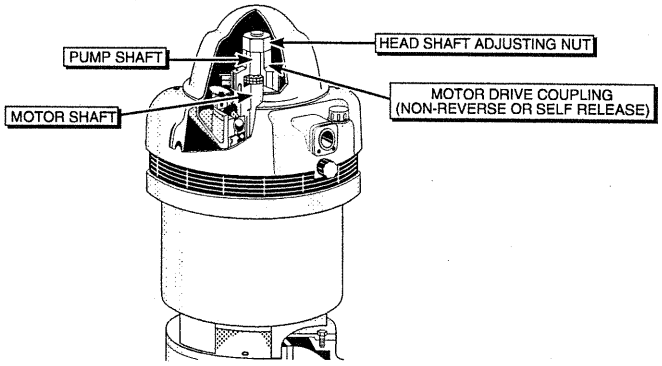


Impellers

Lineshaft turbines can be installed with closed or semi-open impellers. The semi-open impellers offer the advantage of allowing the clearance between the impellers and the bottom of the pump bowls to be adjusted to change opening capabilities of the pump. Under normal conditions the impellers will wear, reducing flow, pressure, and amperage draw. By lowing the impellers closer to the bowl the pump performance can be improved.

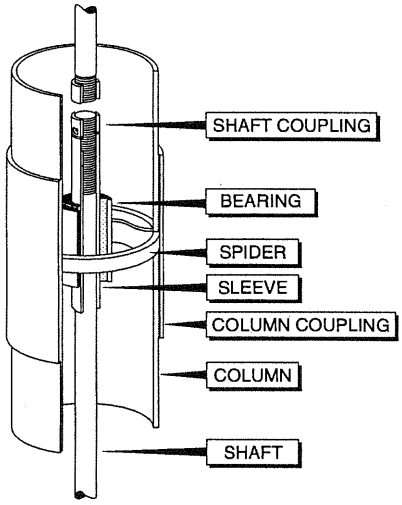
Head Nut

The adjustment of the impeller clearance is accomplished by backing off on the head nut and lowering the impellers closer to the pump bowls.



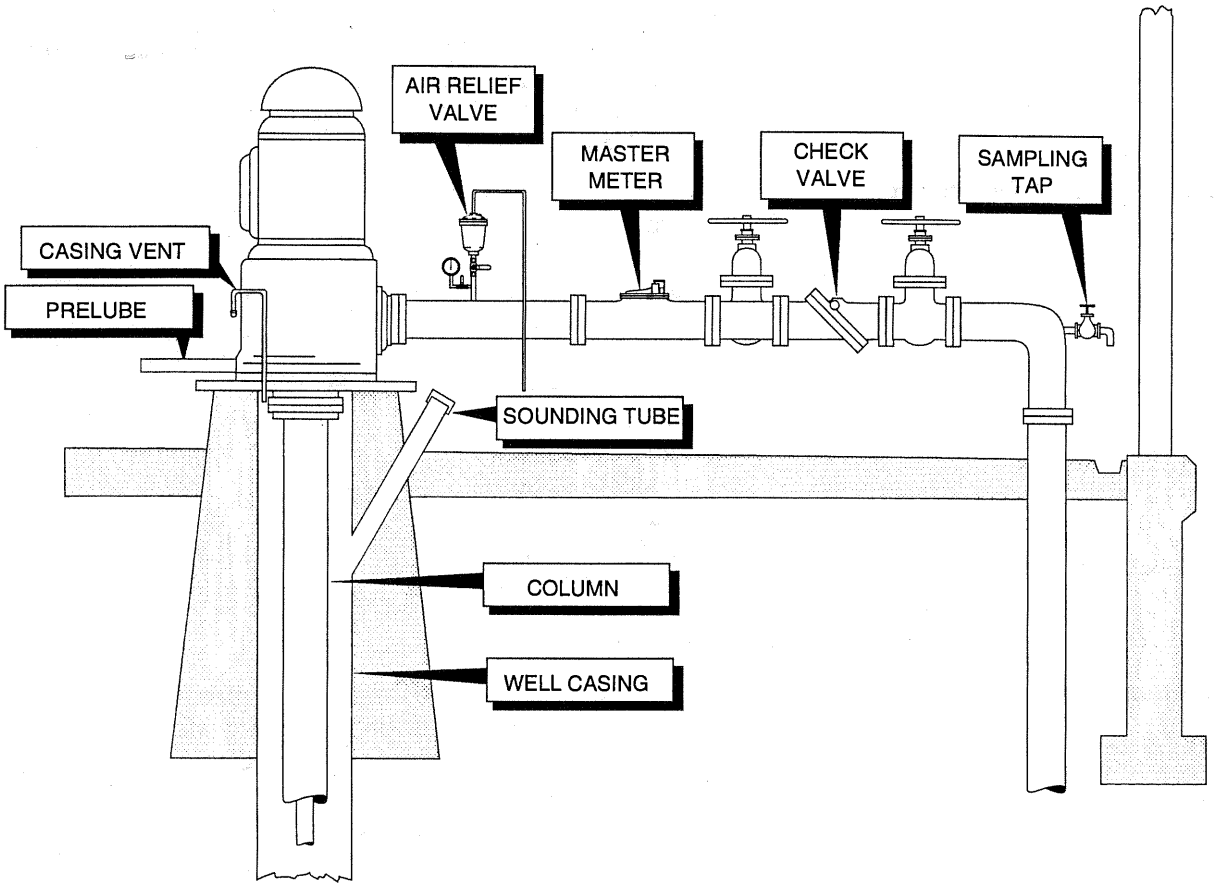
Shaft

Power is supplied to the pump by the motor, which is setting above the ground. This shaft has radial support bearings every 5, 10 or 20 feet depending upon the design. The bearings and shaft may be housed inside of a second column. In this case the bearings are normally made of bronze and are oil lubricated. When the bearings are exposed to the flow of water they are said to be water lubricated. The water lubricated bearings are most often made of a rubber like material and are housed in a bronze bracket called a "spider."



Prelude

To prevent damage to the bearings when water lubricated bearings are used they must be wet before the shaft turns. The normal method of wetting the bearings is with a water line attached to the back of the discharge head. This water is called the prelude. The line is connected to a water source, sometimes just past the check valve, and controlled with a solenoid valve. When there is a demand for water the prelude line will open for a predetermined time before the pump starts. After the pump starts the valve will close. On very deep wells the prelude may run all of the time that the pump is off.

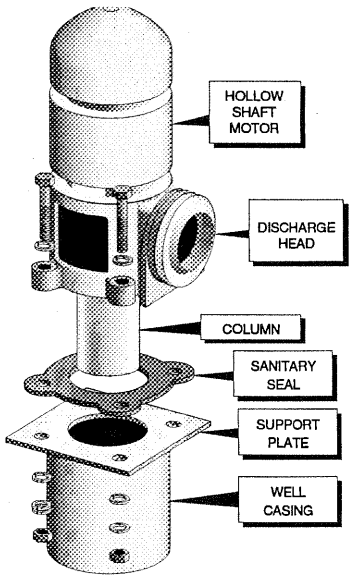


Support Plate

The well casing usually extends above the floor, as required by the regulations, and is encased in concrete, forming a concrete pedestal. Secured in the pedestal and welded to the well casing is a steel support plate.

Discharge Head

Fastened to the support plate with bolts is the pump discharge head. The discharge head holds the stuffing box and forms the 90 degree bend needed to get the water from the column into the discharge piping. The motor is mounted on top of the discharge head.



Sanitary Seal

A rubber like gasket is placed between the discharge head and the support plate and forms the sanitary seal for the well.

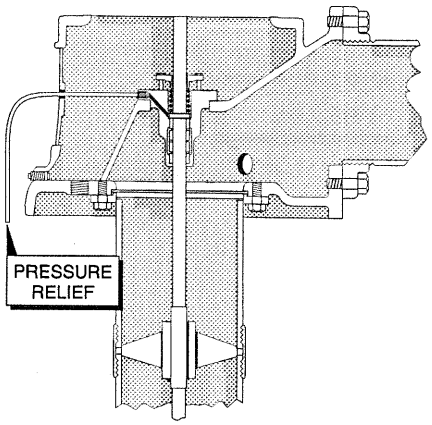
Well Vent

As with the submersible pump, the well casing must be vented to prevent collapse and "sucking back" of

contaminated water from around the well head, or stuffing box. This vent can be through the casing or through the discharge head. The vent should be turned downward and be covered with a #24 mesh stainless steel screen.

Packing Water Discharge

When a lineshaft turbine has packing in the stuffing box there will be leakage through the packing. To prevent this water from running back down into the well, all holes in the discharge head should be plugged and the water piped away from the well head.



Discharge Piping

The discharge piping is connected directly to the discharge head and contains the related valves and fittings. To prevent vibration the weight of the discharge piping should not be on the pump discharge head but supported by pipe supports to the floor.

Isolation Valve

In order to work on the pump it must be isolated from the system. A gate or butterfly valve is often installed on the discharge line as an isolation valve.

Sampling Tap

In order to obtain samples of the raw water a raw water sampling tap should be installed. This tap must be far enough away from the injection of any chemicals to prevent the chemicals from showing up in the sample.

Spool

In order to reduce long term maintenance cost and make maintenance easier a flange by flange spool is often placed in the discharge line before the isolation valve. The spool is easy to remove and install, reducing down time.

ELECTRICAL SYSTEM

Operational Need

While it is not necessary for the operator to be versed in electrical theory and electrical maintenance, it is desirable for each operator to be able to identify basic electrical components and describe their functions. Therefore, the following discussion is provided.

Phase

The first electrical consideration is to determine the number of phases being used. Is the system single phase or three phase? The easiest way to make this determination is to observe the number of transformers on the pole and the number of wires (the drop) leading from the transformer to your weather head. If there are three or four transformers and there are four wires leading from the transformers to the weather head then the possibility is high that the system is three phase. If there is one or two transformers and there are only three wires in the drop the system is most likely single phase.

Breaker

Each pump must have some type of disconnect. This is used to allow power to be disconnected so that electrical work can be performed safely. In small systems the disconnect is also the breaker. The breaker also is used to protect the wiring in the building should a short circuit occur in the motor or wiring. Identify the breaker for each motor and note the amperage rating.

Lock-out

Each breaker must have a method of allowing a padlock to be placed on the breaker whenever the breaker is placed in an off position. Placing a padlock on the breaker along with a tag explaining the reason for the shut-down is an OSHA requirement.

Magnetic Starter

The magnetic starter is an large switch operated by an electromagnetic, The magnetic starter is used to start and stop the pump. The magnetic starter may also contain extra contacts called auxiliary contacts that can be used to turn on and off chemical feed pumps and lights.

Capacitors

Single phase electric motors need capacitors to help them start. These are typically mounted on the side of the motor. However, with submersible pumps the capacitor is mounted in the control panel. It may appear as a small round tube with two wires.

Heaters

As a part of or placed below the magnetic starter are the heaters or thermal overloads. This may be a single device in a single phase motor or a bank of three devices with a three phase motor. The heaters protect the motor from excessive amperage draw. It is important to remember that it commonly takes 20 to 60 seconds of overload before a heater will trip.

Reset Button

The easiest way to identify the thermal overloads, (heaters), is to find the red button marked "Reset."

When there is an overcurrent condition the heaters will "trip". Pressing the "reset" will reset the heaters. **Before pressing the reset button always return the Hand-Off-Auto switch to the OFF position.** This will prevent premature failure to the thermal overload system.

Motor

VHS Motor

There are two types of motors used with lineshaft turbines, VHS and VSS. The VHS motor is a vertical hollow shaft motor. With this motor the drive shaft of the pump extends up through the hollow shaft of the motor and connects to the top of the motor. This type of motor is often used with a pump that utilizes semi-open impellers. The VHS allows for easy adjustment of impeller clearance in the pump bowls and thus allows the operator to adjust for impeller wear. This helps to maintain the proper performance of the pump.

VSS Motor

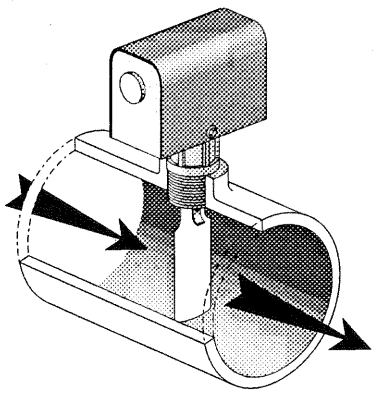
The second motor type used in lineshaft turbine installations is the VSS or vertical solid shaft motors. This motor is connected to the pump shaft using a traditional coupling and making the connection just below the motor. The VSS motor is primarily used on lineshaft turbines that utilize closed impellers. This type of installation does not require adjustment of the impeller clearance.

CONTROL SYSTEM

Meters

In the better installations the control panel holds a motor hour meter as well as amperage and voltage meters. Reading, recording and analyzing the data from these meters can help you determine the potential failure of an electric motor before it happens.

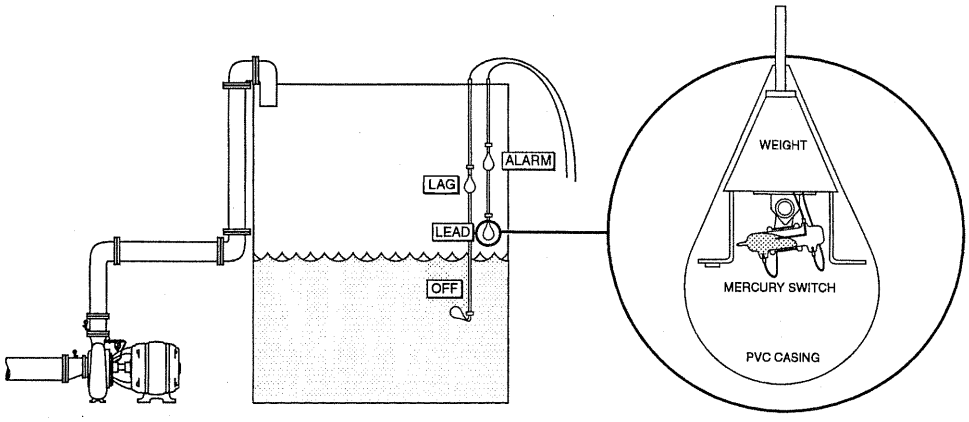
Flow Indicators



In systems with where chemical feed pumps are required to come on when the well comes on, a fail safe flow indicator switch is often installed in the discharge piping. The flow switch utilizes a reed that is placed in the flow. When flow exists the reed moves and closes a set of contacts on top of the switch. By connecting chemical feed pumps to this set of contacts, they can be prevented from operating except when there is actually a flow through the discharge piping. This process can be very helpful in preventing an accidental overdose of a chemical.

Level Controls

Each well installation must have some method of turning the pump on and off. Common methods are to use reservoir height or system pressure. With the reservoir height situation, the level of the water in the reservoir may be measured with an electrical probe, float or by using a pressure switch in the line below the reservoir. When the level drops to a predetermined point the pump comes on and pumps until the water level reaches an upper point.



Pressure Controls

The pressure control system uses a pressure switch, which could be a bellows operated switch, mercury switch or electric transducer. This process requires a switch with a high and low setting or two switches. The two settings or switches are used to turn the pumps on and off.

Signal

The signal from the level or pressure switches is connected to the electrical control circuit that controls the electromagnet on the motor starter. By energizing the electromagnet on the motor starter the pump will start.

Discharge Pressure Gauge

Regardless of pump type it is an operational requirement to have a gauge on the discharge of the pump. Reading, recording and analyzing the data from this gauge, along with other operational data can help the operator identify pump problems long before there is a pump failure.

Air Vent

With most lineshaft turbines, when the pump is shut off water runs back down the column and into the well casing. When this happens a vacuum is created inside the column pipe and discharge piping. This could cause damage to the piping, "suck" water back in around the packing or leaks at one or more fittings. To prevent damage, an air vent is placed on the discharge piping. This vent allows air to be brought into the column at pump shutdown. When the pump is restarted, the same vent is used to allow air to be discharged from the column. This reduces water hammer at the discharge check valve and air intrusion into the line.

Air Intrusion Problems

If air is allowed to be forced into the line it will cause numerous customer complaints. The complaints will take the form of "milky" water and air exiting the tap with such force as to blow a glass out of someone's hand.

Flow Meter

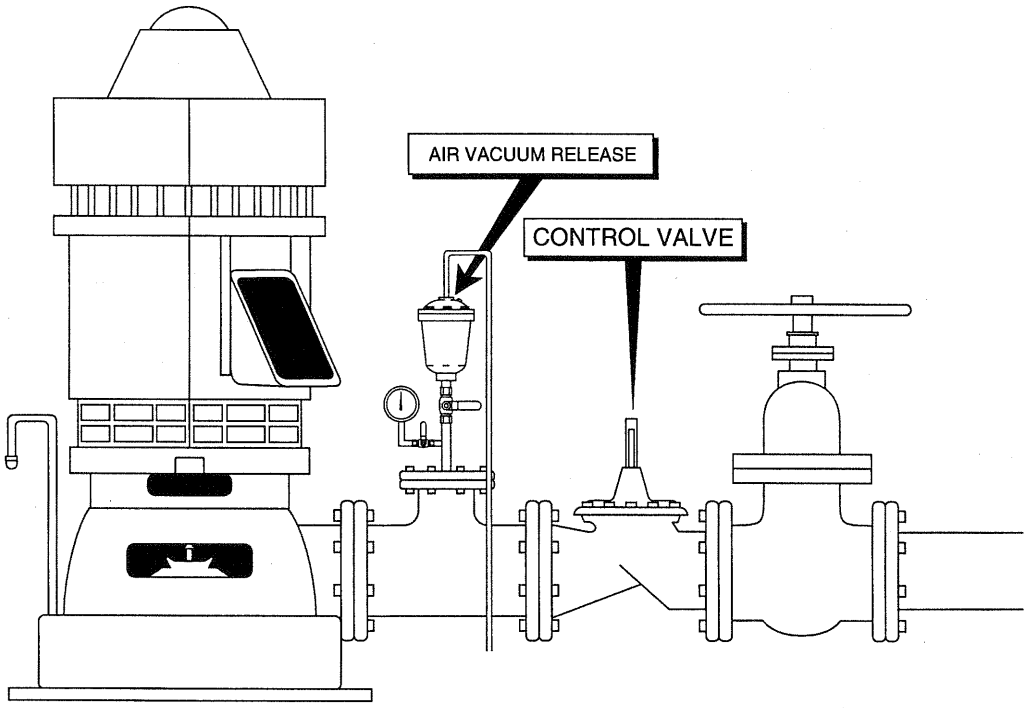
In order to determine how the pump is performing as well as determine the water demand, a flow meter should be installed on each and every well discharge. By reading, recording and analyzing the flow demand data an operator can, with the help of other data, determine pumping and consumption problems long before a failure or crisis has occurred.

Pump to Waste

While not a requirement in all states a pump to waste line and valve make good operational sense. With this line placed after the flow meter, pumping tests can easily be conducted. The line can also be used to exercise the pump under stand-by conditions as well as to pump water from the well when attempting to deal with a contamination problem or allowing the well to be pumped after a long shut-down without placing any accumulated debris into the system.

Check Valve

When a lineshaft turbine is being used to pump against a low head a common swing check or silent check valve can be used to prevent the entire system from running back down through the pump and into the well.



Surge Control

When the pump is pumping against a high head the check valve would cause excessive water hammer at shutdown and could cause the piping to break. To

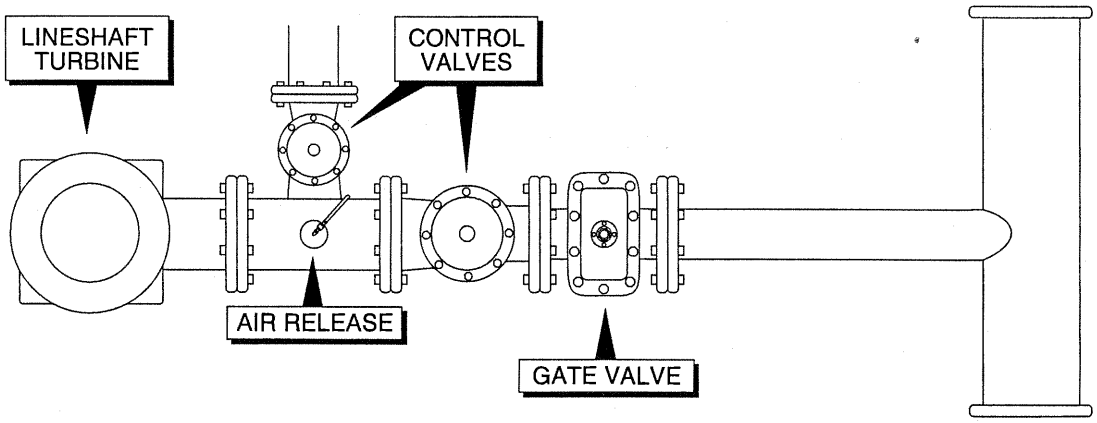
prevent this there are two common techniques. The most common is the single surge control valve. The most common surge control valve is a wide body control valve like a Clay or Ross installed in the discharge line. This valve is closed at start-up. As the pressure on the pump side reaches the pressure on the down stream side of the valve the valve slowly opens and allows the pump to deliver water into the system.

Shutdown with Control Valve

When there is no longer a demand for the pump, the control valve begins to slowly close. As the valve reaches the closed position, a micro switch is triggered by a rod extending from the top of the valve and a signal is sent to stop the pump.

Double Control Valves

The second common method used to control water hammer works similar to the one just discussed except two control valves are used. The second control valve is smaller than the first and placed on the discharge of a tee, which is placed upstream of the main control valve. When the pump is off the large control valve is closed and the small valve is open. At start-up the small valve begins to close and the large valve opens. When the large valve is fully opened the small valve is closed.



Shutdown - 2 Control Valves

At shutdown the large valve begins to close, as the pressure between the pump and the control valve increases to a predetermined level the small valve begins to open. When the small valve is fully opened the large valve is closed. At this point a micro switch that senses the valve position sends a signal to the motor to shutdown. This process produces very little water hammer as well as allowing the pump to reach operating RPM very quickly and thus reducing torque and stress on the pump shaft and reducing the amount of time that the motor is drawing high amperage.

Reversal of Flow

There is usually a control valve or check valve on the discharge line of a line shaft turbine. When the pump has been pumping and the motor is shut off, all of the

water on the pump side of the check valve will fall back towards the water in the well. This flow will cause the pump to turn backwards. A backward rotation could cause the column shafts, which are in sections, to come unscrewed. It could also cause the motor to turn at too high of an RPM, causing damage to the pump and motor bearings. And finally, if it turns at a high enough speed, the steel plates in the motor rotor may be thrown out of alignment. This is normally not a problem unless the column is more than 40 feet long

Non-reversing Ratchet

To prevent the line shaft turbine from turning backwards and damaging the motor or pump, a non-reversing ratchet is installed at the top of the motor. The non-reversing ratchet is composed of free-floating balls or pegs. As the pump turns in a forward direction, the balls or pegs are lifted upwards by centrifugal force. Should the pump reverse directions, the balls or pegs drop down against a stop, preventing back rotation.

Change of Direction

With low horsepower (less than 100 hp) units, the non-reversing ratchet can prevent rotation when there is a reversal of phase. In large horsepower units, the non-reversing ratchet is often destroyed during a reversal of phase.

PRESSURE AND RECIRCULATION SYSTEMS

Pumps - Pressure Recirculation

The two most common brands of pumps used in small communities in Alaska for recirculation and/or the maintenance of system pressure are the PACO and Burks pumps.

Heat Exchanger

The most common recirculation pumps used to circulate water or glycol between the boiler and heat exchanger are Bell and Gosset and Gounfos.

Pump Configuration

The PACO, Burks, and Gounfos pumps used are commonly close coupled, back pullout, end-suction centrifugals. The B & G used on most boiler systems is usually a frame mounted, back pullout, end-suction centrifugal.

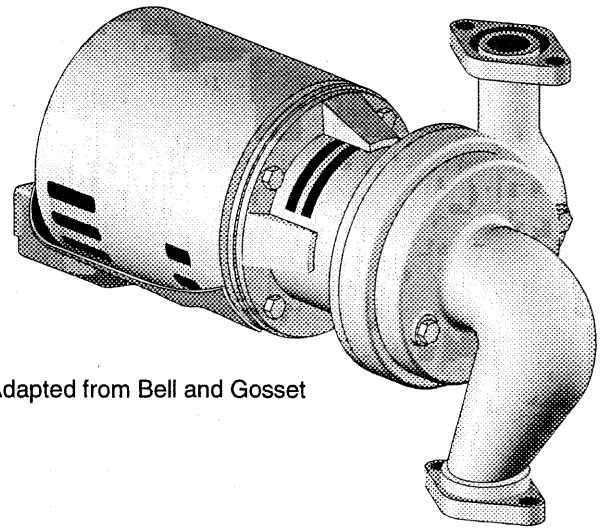
Major Components

The end-suction centrifugal pumps used for pressure and recirculation, with few exceptions, have similar piping, electrical and control configurations as described above in the "Pumping from Surface Water - end-suction Centrifugal Pumps" section.

Suction Valve

One of the exceptions is an isolation valve on the suction side of the pump. Any time a pump is in a suction head condition it is necessary to have an isolation valve in the suction line. This valve should be a gate valve. Butterfly and globe valves offer excessive resis-

tance and turbulence which can contribute to cavitation problems.



Adapted from Bell and Gosset

START-UP

Assumptions

The following start-up procedure describes the sequence that is typical for starting up a pumping system that has been off line for an extended period of time due to maintenance or as a result of a seasonal operation. It is assumed that this system has previously been in operations and it is not a new system.

Steps

Start by making a careful observation of the facility and equipment. The details of this inspection will be different for each type of pump used. The information below includes the three types pumps described in this module. Select those activities that fit your facility.

- Check the power pole fuses - make sure they are all engaged.
- Place the disconnect in an off position & lock-out the system.
- Open the panel door and look for rodent nests.
- Vacuum dust from panel.
- Check voltage at top of breaker or disconnect - compare to previous data.
- Check the water level that you are pumping from.
- With lineshaft turbines - change oil in motor, replace packing, check prelube for operation, if oil lubricated bearings - fill the oil reservoir and check drip rate (normal drip rate is 8 to 13 drops per minute) and make sure that the motor and pump shaft will rotate freely.

- Prime pump if necessary - see priming sequence below.
- If available, open pump to waste valve 1/2 open and close discharge isolation valve.
- Remove lock-out.
- Place H-O-A switch in Hand.
- As soon as possible after the pump is running, check amperage, discharge pressure and flow. If amperage and flow are below normal, open the waste valve until normal flow is observed. Recheck amperage.
- With lineshaft turbines - check and adjust packing.
- Run pump for 15 to 20 minutes.
- Slowly open isolation valve and close pump to waste valve. Observe operation of any automatic surge control valves. Observe system pressure, flow and amperage.
- Turn H-O-A switch to off.
- Turn switch to Auto and observe operation sequence.
- Record data and any actions taken.
- Read and record, power meter, hour meter and flow totalizer.
- Collect any routine operational water quality data.

PRIMING CONSIDERATIONS

Importance

Second in importance only to suction piping conditions is the problem of removing air from the volute case of the pump. The impeller has no way to draw water into the eye of the impeller until the volute case is full of water. Frequently an operator will think that opening the suction valve on a flooded suction pump will prime it. This practice usually traps air in the volute case of the pump. Air should be carefully bled from the highest point on the volute case or discharge piping. This point must be above the eye of the impeller.

Priming Systems

The common piping systems used to remove air from the volute case of a pump are found in module 7 "Pump Piping System."

Observations

It is very common to find pumping installations that have no flow meters. This is common in wastewater collection systems. In these pumping installations it may be difficult to determine if a pump has lost its prime and is not pumping. Common methods of determining if a pump has lost its prime include:

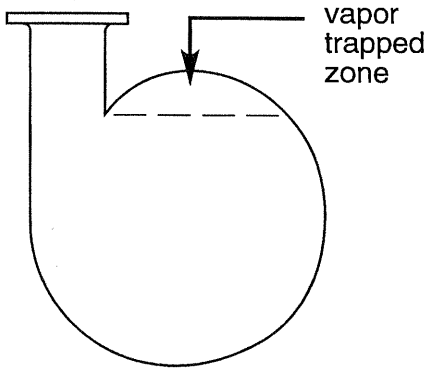
- Listening to the sound that the pump makes when it is operating normally and comparing this sound on each inspection visit. A pump that has lost its prime runs much smoother than one that is actually pumping.
- When a pump looses its prime and stops pumping it is doing little or no work. Therefore, the pump amperage would drop to minimum.
- If there is a swing check valve, observing the position of the arm can be a clue to determine if the pump is actually moving any water.

Routine Operations

On end suction and split case pumps, the operator should routinely open a pet-cock at the top of the pump case to remove any air accumulated. Many times this entrapped air will not clear itself as one might assume. In some applications it may be desirable to run a small pipe from the top of the pump case to a floor drain. By means of a valve in the drain line, the flow can be adjusted down to provide a small continuous stream of water. Such a line is mandatory on distribution system booster pumps provided with automatic shut-down and re-start on low suction pressure.

Air Binding

When cold water is allowed to stand for several hours in a volute case the temperature may increase. When the temperature increases gases held in solution will be released and will displace water in the volute case. In extreme conditions this situation can cause a loss of prime. This condition is often referred to as air binding.



Start-up

Most centrifugal pumps are not difficult to prime and put into operation if the following steps are taken:

1. Open suction valve and close discharge valve.
2. With pump motor stopped, fill volute case with water.
3. Bleed air out of top of case until all bubbles are gone. Close air bleed.
4. Start motor.
5. Slowly open the discharge valve listening to the sound of the pump. Rough, turbulent sound is to be expected. If the pump suddenly runs quietly, prime may have been lost. In this case, shut off the motor and

check suction conditions; i.e., leaks, height of lift, etc. Close discharge valve and refill volute case with water.

6. Once pumping has started, open a bleed valve on the volute case and allow some water to drain to waste. This will remove any small air pockets that may have accumulated in the pump case.

NOTE: This procedure should only be used on centrifugal type pumps. Serious damage can result in starting a positive displacement pump against a closed valve. If you are not sure of the type of pump you have, a call to the pump manufacturer or supplier could be very worthwhile.

NORMAL OPERATIONS

Routine

The normal operations of a pumping station require making routine inspections, collecting and analyzing data on pump performance and performing maintenance as required.

INSPECTIONS

STUFFING BOX & FLUSH WATER

Normal Conditions

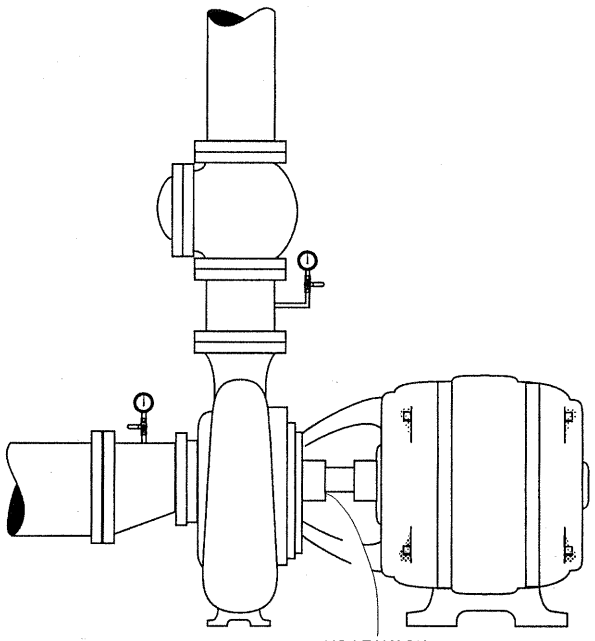
Under normal conditions the stuffing box should not be any warmer than the fluid that is being pumped. If the stuffing box is warmer than the volute case it is an indication that the packing gland is too tight or the **mechanical seal**[18] is about to fail.

Leakage - Packing

When using packing the leakage from the stuffing box should be sufficient to assure that the temperature of the box does not exceed the volute temperature. Normally this is a leakage of 5 to 20 drops per minute for non-synthetic packing. When using Teflon™ or Kevlar based packing the leakage rate must be increased to 30 drops per minute per inch of shaft diameter. That means that a two inch shaft would require 60 drops per minute. This rate of leakage is required to prevent the packing from over heating and damaging the shaft or shaft sleeve.

Mechanical Seals

There should be no visible leakage from the stuffing box of a pump with a mechanical seal. Leakage from the stuffing box is an indication of seal failure.



[18] **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 tolerances as to prevent the passage of water between them.

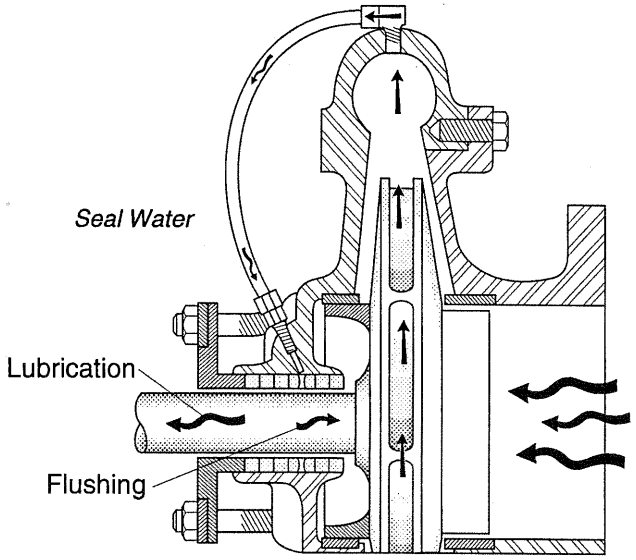
Flush Port

Some pumps with a mechanical seal have a flush port on the stuffing box. This port allows the operator to flush debris from the stuffing box. The port should be opened once a week and allowed to run until the water is clean.

External Seal Water

Most pumps used to pump drinking water either obtain **seal water**[19] directly from the volute case or allow water to flow from the volute back into the stuffing box. There are three conditions that require an external source of clean seal water:

- When the suction lift is greater than 15 feet.
- When the discharge pressure is less than 10 psi.
- When pumping dirty or gritty water.



Seal Water Pressure

When an external source of seal water is used it must be 10 to 15 psi greater than the pressure on the suction side of the volute case.

Cross-connection

If the pump is pumping raw water, glycol or any other non-potable water and the seal water is connected to the potable water source there is a cross-connection. To prevent backflow through this cross-connection a reduced pressure backflow prevention device (RPZ) or an air gap should be installed in the seal water system.

LUBRICATION

LUBRICANT SELECTION

Basic Criteria

Lubricants are selected on the basis of load, operating speed and environmental conditions for a specific type of rolling element. We have described a more detailed selection process at the end of this section.

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

Use Oil or Grease?

Normally, oil is used for high RPM's (above 12,000 1n/min) and grease for slower speeds (less than 100 RPM), heavy loads, and in damp or dusty conditions. Be sure to check with the bearing and lubricant manufacturer to determine the proper oil or grease for a given situation.

LUBRICATION FREQUENCY

Basic Criteria

Lubrication frequency is based on operating speed, horsepower and environmental conditions. Normally, an increase in operating speed, higher horsepower and poor environmental conditions requires more frequent lubrication practices.

Quantity

When you use oil, it should come halfway up the lowest ball. The grease housing should be filled 1/3 full and the bearing completely full.

Impact of Temperature

The item that dictates lubricating frequency more than any other is operating temperature. At 140 degrees F and in a clean environment, oil changes once a year can be tolerated. At 212 degrees F, the oil must be changed every two months. As a general rule, the life expectancy of an oil is cut in half for every 20 degrees F over 140 degrees.

General Recommendations

When an electric motor is less than 20 horsepower most manufacturers recommend that the bearings in the motor and the pump be lubricated every three (3) years with a #2 lithium based grease.

DETERMINING FREQUENCY

Cause of Bearing Failure

The most common cause of premature bearing failure is from over lubrication. A review of existing literature is often as confusing as talking with other maintenance personnel about methods for determining frequency. In one review we found that a lubricant company recommended 1 oz of grease be administered for every 3 to six months of continuous operation.

Example

A quality example provided by one motor manufacturer gives a range based on environmental conditions, horsepower and operating time. The motor sizes range from 1.5 hp to 150 hp. The lubrication frequency ranges from once every three months to once every 10 years.

Common Practice

It is common practice in most industries where lubrication frequency has been studied to install sealed bearings in small horsepower motors and pumps (less than 20 hp) and replace the bearings on a three to five year schedule. It has been determined by several studies that the motor and bearing failure rate when using the sealed bearings was dramatically less than when a standard lubrication schedule was used.

Data Base

A technique that we have found very useful with clients in developing a lubrication schedule is to place

specific lubrication information into a computer data base and then share this information with a bearing supply house and a lubrication supplier. Based on their feedback develop a reasonable lubrication schedule.

Data Base Fields

Common data base fields used are:

- Bearing type
- RPM
- Horsepower
- Special load considerations - thrust and radial
- Run time - hours per day
- Environmental conditions
- Manufacturer's recommended frequency & type
- Bearing supplier's recommendations
- Lubrication supplier's recommendations

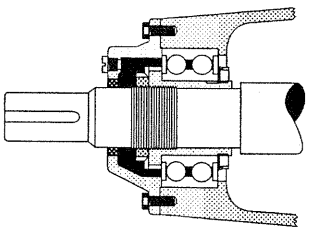
LUBRICATION SYSTEMS

Types

There are four types of grease lubrication systems and four basic oil systems, each of which perform well under set conditions. You should be familiar with the basics of each.

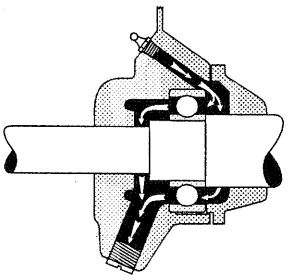
Sealed Bearings

These are bearings with seals or shields on both sides. No lubrication is required or recommended. The life expectancy of the bearing should be documented so that they can be scheduled for replacement prior to failure.



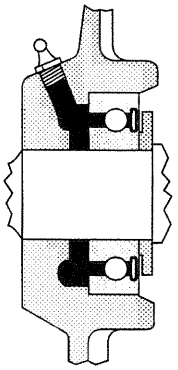
Drain Fittings

Some bearing housings are equipped with a drain plug opposite the grease fitting. This drain is removed during lubrication to remove entrapped air and prevent over lubrication.



Contained Housings

Some bearing housing are not equipped with any drain or relief plug. This type of system often contains a bearing with a seal on one side or the housing has a grease seal to prevent grease from escaping the bearing. Lubrication of this type of system requires extreme caution. It is very easy to over lubricate this type of system or to damage the grease seal if one exists.



Relief Port

A few bearing housing are designed with a special grease relief port. These ports are designed to relieve excess grease and prevent over lubrication. However, the port opening can become clogged with old grease and the bearing be over lubricated. Care must be taken when lubricating a bearing in this system to be assured that the relief port is open.

PUMP AND MOTOR DATA

Data Cards

Having pump and motor data available makes ordering parts much easier. It is simpler to look on a printed listing than to try to read, dirty, painted over name plates that are often placed in dark places with difficult access. This data can be written on cards or placed in a computer. Either process is useful. The following data cards can be used to gather name plate data.

Motor Data Card

Location _____ Asset ID# _____

Brand _____ Frame _____ Heater No. _____

Model _____ Class Design _____ S.F. _____

Hp _____ Volts _____ Starter Size _____

Serial No. _____ Amps _____ Lubricant _____

Type _____ Frequency _____ Lube Frequency _____

Code _____ Phase _____

Outboard or Upper Berg _____ Inboard or Lower Berg _____

Date Installed _____

Cost _____ Vendor _____

Date Removed _____ Reason for Removal _____

Notes : _____

Pump Data Card

Location _____ Asset ID# _____

Brand _____ No. of Stages _____ Packing Size _____

Model _____ Column Size _____ No. of Stages _____

Configuration _____ Suction Size _____ Impeller Type _____

Serial No. _____ Discharge Size _____ Impeller ID _____

Shaft size _____ Column Size _____ Lubricant _____

Shutdown Head _____ gpm _____ Lube Frequency _____

Outboard or Upper Berg _____ Inboard or Lower Berg _____

Date Installed _____

Cost _____ Vendor _____

Date Removed _____ Reason for Removal _____

Notes: _____

SPARE PARTS

How Critical

In order to determine what spare parts should be on hand first determine how critical a failure of the pump would be and how difficult it is to obtain parts. If the pump is the primary means of obtaining water, or it is the primary means of operating the circulating system then the pump should be considered critical.

Redundant

If the pumping system has built in redundancy (there is a piped in stand-by) then the following spare parts list is recommended.

No Redundancy

If the pump is critical and there is no redundancy then it is best to keep a spare pump and motor on hand.

Storage Considerations

Spare pumps and motor shafts should be rotated several turns by hand at least once a month. This will prevent the bearings from becoming damaged.

Parts List

- One set of pre-cut packing for each pump.
- One mechanical seal for each pump.
- Spare gasket set.
- Spare set of volute case bolts.

- Spare shaft sleeve for pumps with packing.

BUILDING INTERIOR

Storage

The room that houses the pump(s) should only be used to store parts and supplies associated with the pump. Storing chemicals in the room with electrical equipment is never recommended. A small release of chlorine or fluoride can over time destroy an electric motor or control panel.

Appearance

The pump room and piping system should be kept clean, dry and painted. When the piping is allowed to rust and deteriorate it becomes difficult to work on. Rusty bolts and nuts are hard to remove and increase down time and increase maintenance cost.

ROUTINE INSPECTION

Frequency

Visit each pumping installation at least 3 times a week. Use your senses to check the following:

Item	Frequency
Air temperature	Each visit
Building temp	Each visit
Water temp	Each visit
Pump pressures	Each visit
Power meter reading	Once a week
Suction water level	Each visit
Level of water in well	Once a month
Hour meter	Each visit
Temp of motor - check with back of hand	Each visit
Stuffing box leakage	Each visit
Stuffing box temp	Each visit
Building appearance	Each visit
Leaks	Each visit
Vibration and noise	Each visit
Position of HOA switches	Each visit
Bleed air from volute case	Once a week
Measure amperage and voltage on motors	Once each quarter
Touch up paint	Once each year

Recording Data

The information concerning pumping conditions should be recorded at each visit.

Data Analysis

In order to obtain the greatest benefit from the data collected at a pumping station the number of hours of operation, horsepower required and kilowatts per 1000 gallons pumped should be calculated each time the appropriate data is collected.

EQUATIONS ASSOCIATED WITH PUMPING

CONVERSIONS

1 HP = 746 watts

1 KW = 1000 watts

1 ft water = 0.433 psi

Efficiency of Station

$$\text{Station Efficiency} = \frac{\text{Water Hp}}{\text{Electrical Hp}}$$

Efficiency of Pump

$$\text{Pump Efficiency} = \frac{\text{Water Hp}}{\text{Brake Hp}}$$

Converting pressure to feet of head

$$\text{Feet of head} = \frac{\text{psi}}{0.433\ \text{ft/psi}}$$

Inches of mercury to feet of water

$$\text{Feet of water} = \frac{\text{inches of Hg x } 13.55}{12\ \text{"/ft}}$$

The specific gravity of mercury is 13.55.

Electrical Power to Hp

1 Hp = 746 watts. To find electrical horse power divide the power in watts by 746.

HORSEPOWER

Water Horsepower

$$\text{WHP} = \frac{\text{TDH x Q x } 8.34\ \text{lbs/gal}}{33{,}000\ \text{ft-lbs/min/Hp}}$$

Where:

WHP = Water Horse Power

TDH = Total dynamic Head in feet

Q = Flow in gpm

Electrical Hp from Meter Readings

or $$\text{EHP} = \frac{4.826 \times R \times Kh \times M}{t}$$

Where:

M = Multiplier of electrical meter

Kh = Watts/rev of meter - should be on name plate

R = Revolutions of meter disk

t = Time in seconds

Electrical Power for 3 Phase

P = V x A x 1.73 x P.F.

Where:

P = Power in watts

V = Average voltage of all three legs

A = Average amperage of all three legs

1.73 = The impact of three phases on power

P.F. = The power factor

TDH CALCULATIONS

Suction Head Condition

$$TDH = \frac{\text{Discharge psi} - \text{Suction psi}}{0.433 \text{ psi/ft}}$$

Suction Lift with Vacuum Gauge

$$TDH = \frac{\text{Discharge psi}}{0.433 \text{ psi/ft}} + \text{suction vacuum Inches of Hg X 1.13 in/ft}$$

Suction Lift

$$TDH = \frac{\text{Discharge psi}}{0.433 \text{ psi/ft}} + \text{Suction Lift in feet}$$

Line Shaft Turbine

$$TDH = \frac{\text{Discharge psi}}{0.433 \text{ psi/ft}} + \text{Distance from center of discharge pipe to suction water level}$$

Electrical Powered Pump Standards - from Pacific Gas and Electric Co.

Motor Size (Nameplate Hp)	Rating (Percent Efficiency) Low	Fair	Good	Excellent
3 - 5	41.9 or less	42 - 42.9	50 - 54.9	55 or above
7.5 - 10	44.9 or less	45 - 52.0	53 - 57.9	58 or above
15 - 30	47.9 or less	48 - 55.9	56 - 60.9	61 or above
40 - 60	52.9 or less	53 - 59.9	60 - 64.9	65 or above
75 and up	55.9 or less	56 - 62.9	63 - 68.9	69 or above

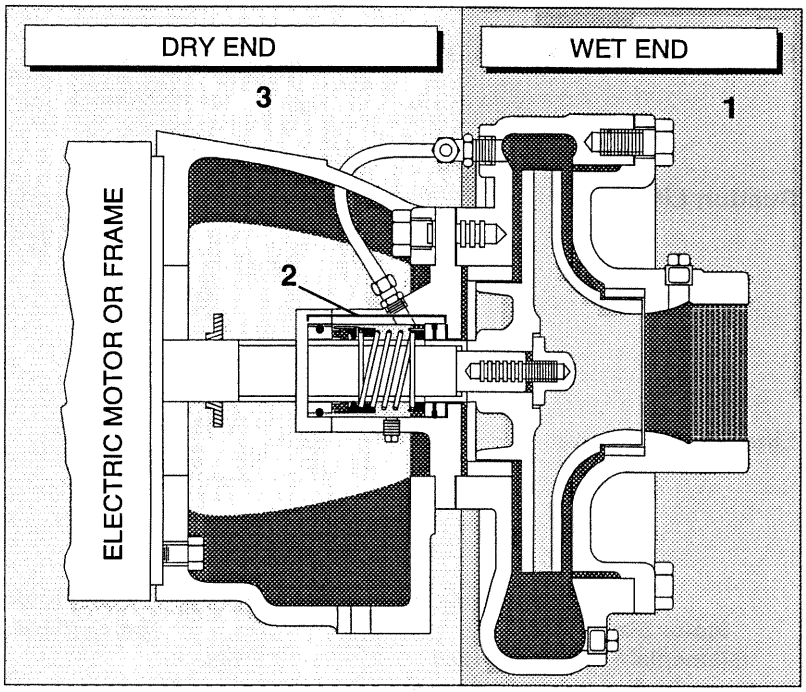
TYPICAL REPAIRS

MECHANICAL SEALS

PURPOSE

Location and Function

Mechanical seals are located in or adjacent to the stuffing box separating the wet end of the pump (1) from the dry end of the pump (3). The main purpose of the mechanical seal (2) is to control leakage from the stuffing box and prevent air leakage into the volute case when the pump is in a suction lift condition.



Compared to Packing

The main advantages that mechanical seals have over packing are that when properly installed, mechanical seals have a much longer life and almost all leakage from the stuffing box is eliminated. However, their initial cost and installation cost is considerably higher than packing.

Cost & Leakage Comparison

Financial evaluations by several utilities have indicated that there is a significant long term savings in maintenance cost. This is primarily due to their long life. An additional advantage is the reduction of leakage. Utilities that have switched over with sewage lift stations have found that the reduction in leakage represents a real savings in cleanup time.

Impact in Technology

These advantages have prompted numerous water and wastewater utilities to switch many of their pumps to mechanical seals. This interest in the use of mechanical seals comes at a time when there are numerous changes taking place in the mechanical seal market. It is impossible for text material like this to keep up with the rate of change. However, what we can do is give

you the basics for understanding the differences in mechanical seals. This information will allow you to make informed decisions about the type of seals that you want to use.

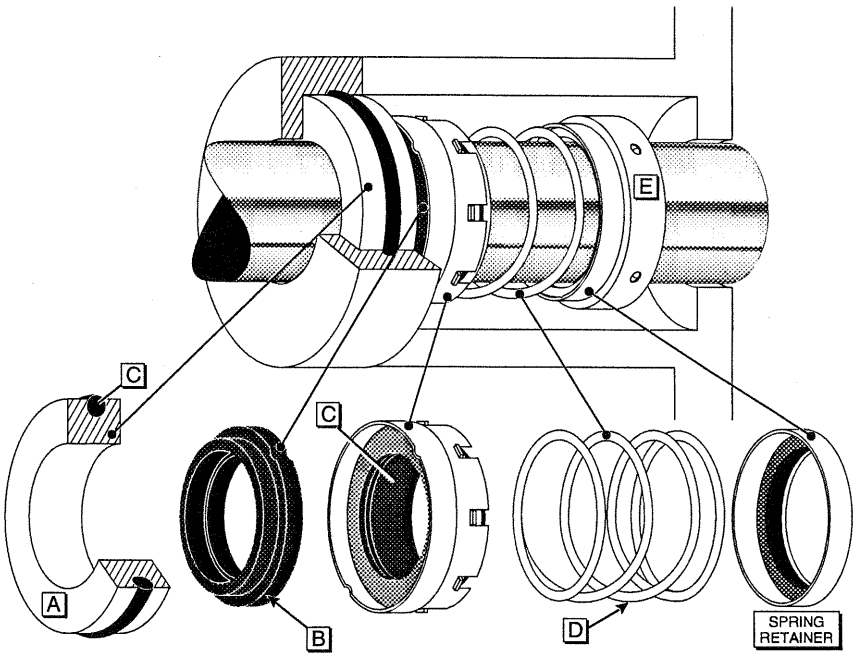
DESCRIPTION

Components

All mechanical seals are composed of two primary elements and three secondary elements.

Primary Elements

The two primary elements are: (A) a stationary component, typically made of some hard material such as ceramic, stellite, tungsten carbide, silicon carbide, cast iron or tooled steel and (B) a rotating component, usually made of a material softer than the stationary component. Common materials include carbon, bronze, phenolic, tooled steel and silicon carbide. The rotating component is secured to the shaft and turns with it.



Common Materials

The vast majority of the seals used in the water and wastewater industry use ceramic for the stationary component and carbon for the rotating component.

Use of Exotic Materials

The other materials are typically used in pumping corrosive and abrasive materials. Typical installation of mechanical seals using some of the above exotic metals would be in the pulp and paper industries.

Cost Advantages

Fortunately, ceramic and carbon seals are the most common seals made by the various seal manufacturers. This means that the price of these seals is less than it would be if they were the minority of seals produced rather than the majority.

Rotating Ceramics

Although stationary ceramics and rotating carbons are the most common configuration of mechanical seals, they are available in the reverse order. That is, they can be purchased with a stationary carbon and a rotating ceramic.

Secondary Elements

Besides the two primary elements, the mechanical seal contains three secondary components. (1) A spring (D) helps keep the two primary components together and helps take up for the wear of the surfaces of the two primary elements.

Secondary Seals

(2) The secondary seals (C) are composed a various **elastomers**[20] and may also include gaskets. In the drawing on the previous page, the secondary seals are the O-ring and the two gaskets. The O-ring rotates with the shaft and prevents water from leaking along the shaft. The gaskets are stationary and cushion the stationary element and prevent water from leaking between the stuffing box and the seal gland. The elastomer may consist of a flexible boot, Teflon™ V-wedge or U-cup.

Holding Element

(3) Some type of collar (E) or metal shell. This collar may hold set screws that are used to position the mechanical seal or its only function may be to hold an elastomer or the spring in place.

HOW MECHANICAL SEALS WORK

Smooth & Flat Faces

The primary elements, which are the stationary and rotating components of the mechanical seal, are manufactured to such a degree of tolerance in both flatness and smoothness that a water molecule can just squeeze between the two. It is the combination of both flatness and smoothness that allows the seal to perform. By flatness, we mean flat like a table is flat. That is, the entire surface of the sealing face is on the same plane. By smoothness, we are talking about surface irregularities. The seal face must be smooth like a ball bearing is smooth (only much smoother). The tolerances that we are talking about are measured in millionths of an inch. The tolerance between these two surfaces is the critical point in the operation of the mechanical seal. The tolerance is the same, regardless of the seal price or the type of seal face materials.

Lubricating the Faces

Although the faces meet incredibly close tolerances, a small amount of water must pass across the faces. This is the primary means of lubricating the faces. Without a slight leakage across the faces, the seal would soon fail.

[20] **Elastomer** - A natural or synthetic material which is elastic in the generally accepted sense. That is, it will return immediately and rapidly to its original shape after distortion. Common elastomers used in mechanical seals are bellows and O-rings.

TYPES OF SEALS

Focus of Section

When we hear about mechanical seals, we often hear them referred to in terms of single, double, balanced, unbalanced, internal, external, bellows, boot type and more recently cartridge, split and symmetrical seals. In this section we will attempt to take the mystery out of these terms and give you the basic information you need to identify the various types of seals.

Four General Categories

There are four general categories of mechanical seals: single, double, unbalanced and balanced. However, a multitude of variations of each of these can be found. All of the above mentioned seals and many more fit into these categories. We will not attempt to explain all the variations, but instead keep this discussion limited to the basic categories and the common adaptation.

Criteria for Classification

At a basic level, mechanical seals are placed in the above categories based first on the number of sealing faces and then on the position of these sealing faces in relationship to the stuffing box. The categories of balanced, unbalanced, cartridge, etc. are sub-categories of the above.

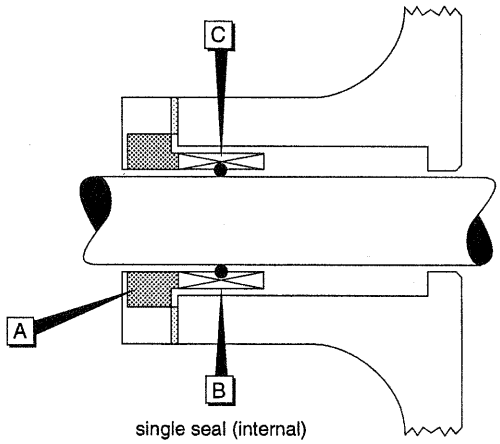
SINGLE SEAL

Location of Faces

A **single seal**[21] is a seal with only one set of sealing faces. These faces can be placed inside the stuffing box or outside the stuffing box. When the faces are inside the stuffing box, the seal is referred to as an **internal seal**[22]. When the faces are placed outside the stuffing box, the seal is referred to as an **external seal**[23]. In an external seal, it is the rotating element that is outside of the stuffing box.

Internal Seals

The internal single seal is the most common of all of the mechanical seals and makes up the vast majority of seals sold and installed in the water and wastewater industry.

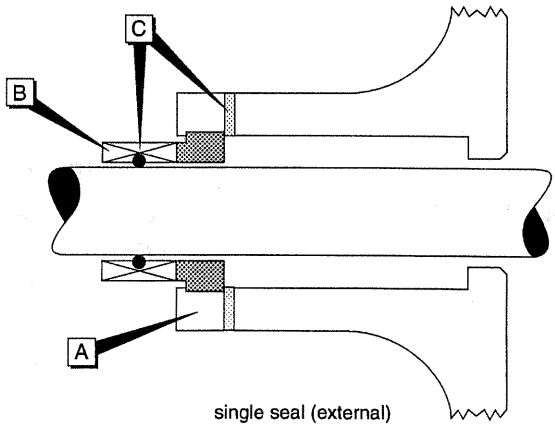


single seal (internal)

[21] **Single seal** - A mechanical seal with one set of sealing faces.
[22] **Internal seal** - A mechanical seal whose sealing faces are placed inside of the stuffing box.
[23] **External seal** - A mechanical seal whose sealing faces are placed outside of the stuffing box.

External Seals

The external seal, while not as popular, has certain advantages. The primary advantage is that the seal can be adjusted after installation. This is extremely important when installing a seal on a pump with adjustable impellers (line shaft turbines). Another advantage this seal has is that the rotating element is not in contact with the material being pumped. This allows the use of less expensive holding collars and springs. An application of this seal would be in pumping a concentrated chlorine solution or lime slurry.

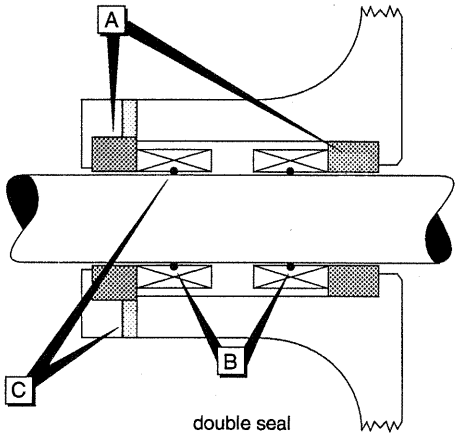


single seal (external)

DOUBLE SEAL

General Description

The **double seal**[24] has the same components as the single seal except there are two sealing surfaces. This is a very common seal in wastewater pumps.



double seal

The Use of Seal Water

With this seal, seal water may be injected in the stuffing box between the two faces. The pressure of this seal water should be 10 to 15 psi above the normal stuffing box pressure. This will cause a small flow of water past the faces for lubrication. In using the seal water for lubrication, the springs and holding collar do not need to withstand the corrosiveness of the material being pumped. Also, an important point with

[24] **Double seal** - A mechanical seal with two sets of sealing faces.

wastewater pumps is that this flow of water prevents grit from entering from the volute case into the seal. A small amount of grit on the faces of the seal will quickly destroy the seal.

Reduces Contamination of Product

This seal can also be used to pump material that you do not wish to have contaminated or diluted by the seal water. Examples would be concentrated chemical solutions and return sludge at a wastewater treatment plant.

Used with Hazardous Liquids

In other industries, the double seal is commonly used where hazardous liquids are handled or when there is a high vacuum on the suction.

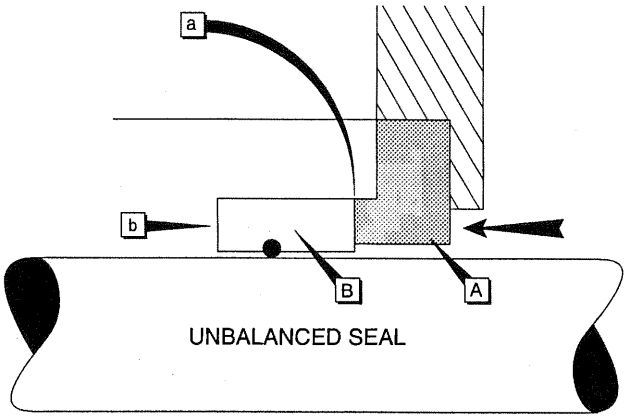
UNBALANCED SEALS

Lubrication of Faces

In order for a seal to receive cooling and lubrication, there must be some leakage across the sealing faces. This leakage is related to the difference in pressure between the stuffing box and the atmospheric pressure outside. As the liquid enters between the sealing faces, it forms a wedge which tends to drive the faces apart (a). The force created by this wedge is partially counter-acted by the force on the end of the rotating element (b) caused by the spring pressure of the seal. The remaining force is the resulting force holding the two faces together. This force must be sufficient to hold the faces together but not so great as to prevent a small amount of water from passing across the faces. The amount of water that passes across the faces should be small enough so that it evaporates before it can be seen by the operator.

What Can Stop the Lubrication

There are two situations that can prevent sufficient water from flowing across these faces. One is high pressure; the second is high RPM.



UNBALANCED SEAL

Results of High Pressure

With high pressure applications, the pressure in the stuffing box, coupled with the spring pressure on the end of the rotating element, may overcome the force of the wedge of water. At this point, lubrication of the

faces stops and the seal life is shortened.

Results of High RPM

With high RPM applications, the same centrifugal force that helps the centrifugal pump to work throws water away from the seal and thus prevents it from entering between the faces. At this point, lubrication of the faces stops and the seal life is shortened. This type of seal is referred to as an unbalanced seal. That is, it is unbalanced hydraulically.

Maximum Pressure

The maximum amount of pressure that can be pumped with an unbalanced seal without failure is determined by the differences in two opposing forces, force at A and force at B, shown in the figure at the bottom of this page. This difference depends upon the pressure inside and outside the stuffing box, the cross-sectional area of surface on the back of the holding collar, shaft speed, material of the sealing faces and the type of liquid being pumped. The American Petroleum Institute has set the following limits for use of unbalanced seals:

Shaft Size	**1800 RPM**	**3600 RPM**
1/2" to 2"	100 psi max.	50 psi max.
2" to 4"	50 psi max.	25 psi max.

These pressures are operating pressures at the stuffing box and are guidelines.

BALANCED SEALS

Function of the Balanced Seal

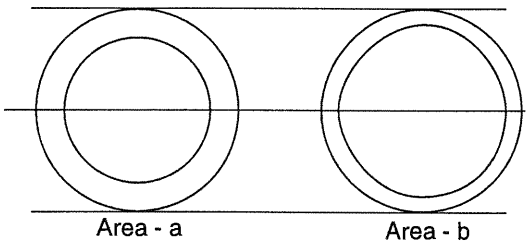
To overcome the pressure problems occurring with high pressure high RPM applications, many manufacturers have developed what is called the balanced seal. The balanced seal is designed to reduce the resulting force between the sealing surfaces. This is done by utilizing the stuffing box pressure and some geometry.

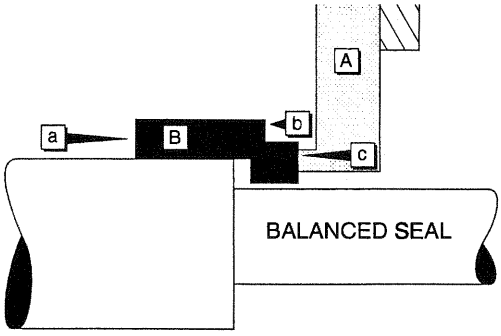
How it Works

Consider the seal configuration where the seal cage or shaft provides a step in the rotating element. The primary force driving the two faces together comes from the internal stuffing box pressure. The stuffing box pressure is applied to surface A as well as surface B.

Relationship of Force & Pressure

Force = Pressure X Area. Notice that the area of B is less than the area of A. Therefore, the force applied to area A is greater than the force applied to area B. The





result is a reduction of the force at the sealing surface C. Thus, the seal is said to be balanced hydraulically.

Results of Various Pressures

The amount of force applied to the sealing faces will remain relatively constant over a wide variety of stuffing box pressures.

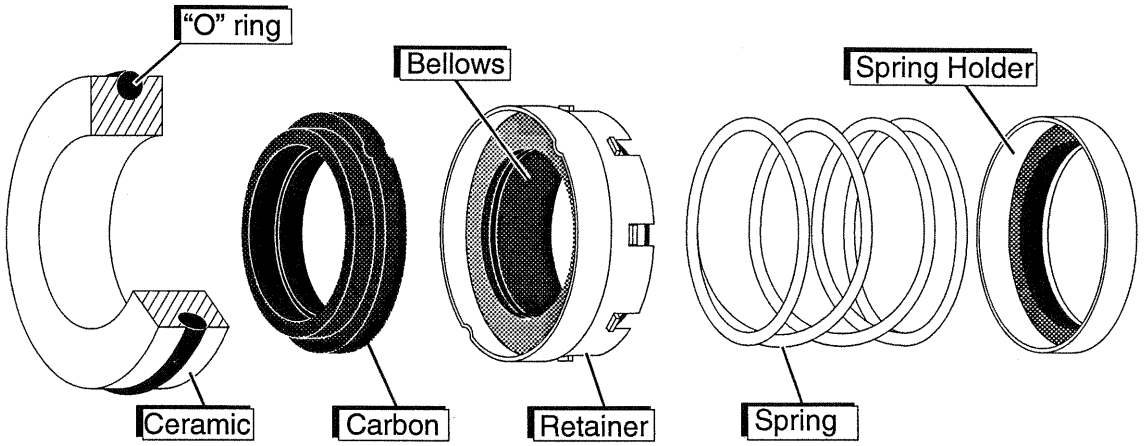
When to Use Which Seal

The overall result of this change in the geometry is that the balanced seal will last much longer under high pressure conditions than the unbalanced seal. However, in low pressure and low RPM conditions the opposing forces created within the balanced seal will not allow the two faces to be held together with sufficient force to keep the seal from leaking. Therefore we have a rule: balanced seals for high pressure/high RPM conditions and unbalanced seals for low pressure/low RPM conditions.

BELLOWS SEALS

Components

The most common single seal is the so-called "bellows" or "boot" seal. With this seal, the secondary seal on the rotating element is a synthetic rubber bellows that is compressed during installation and is used to hold the sealing faces together.



Shaft Connection

Seals that use this type of arrangement are also referred to as **friction drive seals**[25]. This means that the rotating element is held to the shaft by friction. The other means of holding the rotating element to the shaft involves some type of mechanical device, commonly one or more set screws. This is referred to as a mechanical drive seal.

Availability

The **bellows seal**[26] is the most common seal used in the US. It is available in both a single and double seal as well as balanced and unbalanced. This seal is normally one of the least expensive types of seals.

[25] **Friction drive seals** - Mechanical seals using friction and usually a synthetic rubber material to hold the rotating element to the shaft.

[26] **Bellows seal** - A seal using an elastomer to secure the rotating element to the shaft.

Not the Metal Bellows Seal

This type of seal should not be confused with the metal bellows seal. This seal is explained in the section below on springs.

MECHANICALLY MOUNTED SEALS

Comparison to Boot Seals

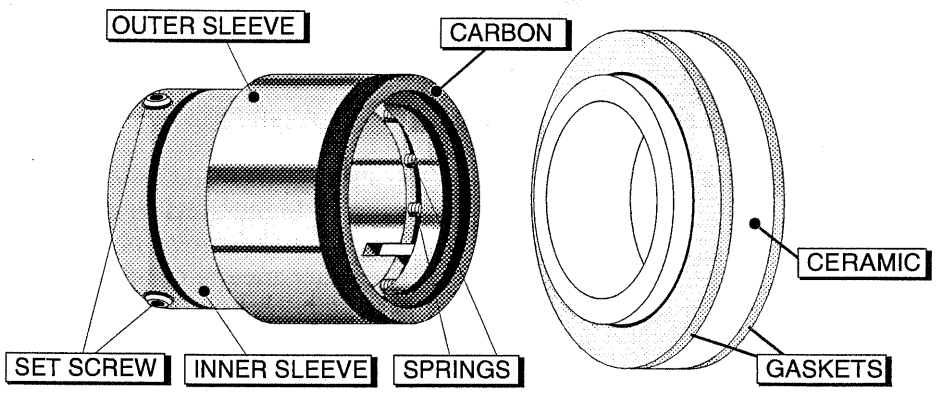
The mechanically mounted seals are considered "high end" seals. While they normally cost more than bellows seals they have the same major components. The difference is the mechanically mounted seal has a housing composed of at least two components, the rotating element is held to the shaft with a series of set screws and a series of springs is used to hold the faces together. Common brands of mechanically mounted seals include, Chesterton, Durametallic and John Crane-Houdaille.

Springs

When a single spring is compressed the force exerted by the spring is not evenly distributed. This can cause the two faces to be pressed together harder in one area than another causing uneven wear. A series of matched springs provides a much more even distribution of force between the two faces.

Shaft Damage

When an "O"-ring or "V"-wedge is placed against a shaft under pressure and a slight end movement is present the O-ring or V-wedge will have a tendency to indent the shaft. This is called **fretting**[27]**.** The rotating element of the mechanically mounted seal is made from two sleeves. An elastomer is placed between the inside sleeve and the shaft to prevent leakage along the shaft. A second elastomer is placed between the two sleeves. The seal is designed to allow the end movement of the rotating element to take place between the two sleeves thus reducing the possibility of fretting.



Rebuilding

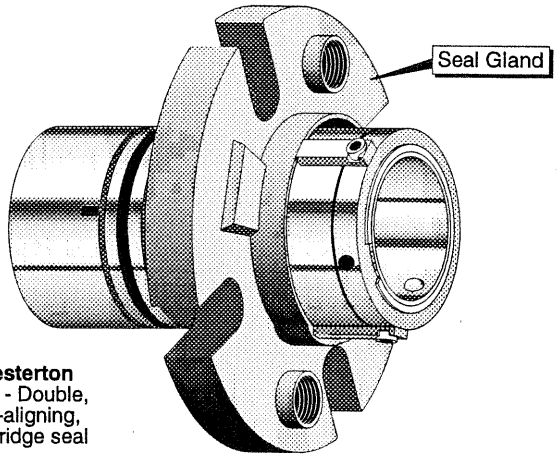
Most of the major manufacturers of mechanically mounted seals will rebuild a worn seal for approximately one-half of the purchase price of a new seal. When using large expensive seals this can be a real cost savings.

[27] **Fretting** - An indentation made in a shaft by an elastomer. The indentation results from constant small movement of the elastomer back and forth on the shaft.

CARTRIDGE SEALS

Single Unit

Cartridge seals[28] are seals designed to be installed as a single unit. The unit is placed over the pump shaft and attaches to the back of the stuffing box. Set screws hold the rotating element to the shaft and the stationary element is housed in the piece that is attached to the back of the stuffing box. An elastomer is used to prevent leakage along the shaft.



Chesterton
241 - Double, self-aligning, cartridge seal

Advantages

This type of seal, while expensive, offers the advantage of easy installation. There is no need to make any measurements other than shaft size and stuffing box housing size.

Configuration

These seals are available as either single or double seals. Most of the cartridge seals are balanced seals. Their ease of installation, resulting in a reduction of down time and seal failures, has made them very popular with the wastewater industry.

SEAL SPRINGS

Types Available

There are three common spring types used in mechanical seals: the single spring, spring sets and metal bellows.

Single Spring

The single spring is by far the most popular. The difficulty with the single spring concept is that it is difficult to obtain an even distribution of force on the entire sealing face with a single compression spring.

Multi-spring

The multi-spring seals use a set of evenly matched compression springs. These springs are evenly spaced around the seal collar and improve the distribution of force around the faces.

Metal Bellows

The metal bellows spring mechanism is found in expensive seals used in situations with extreme high or low temperatures. The bellows give an excellent distribution of force on the faces.

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[28] **Cartridge seal** - A mechanical seal made so that the elements are all contained in one housing. This housing can be fastened to the back of the stuffing box. No positioning or adjustment of the sealing faces is necessary.

REPLACEMENT OF MECHANICAL SEALS - GENERAL INFORMATION

The Approach

Because of the wide variety of mechanical seals, it is not practical for us to attempt to discuss the individual steps involved in the installation of each brand and style. Instead we will concentrate on giving general information on the installation procedure that should be followed for installing two general types of mechanical seals: friction-mounted and mechanically-mounted. We highly recommend that you contact the seal manufacturer for specific recommendations associated with their seal.

Six Steps

Regardless of the type of mechanical seal to be installed or replaced, the mechanical seal replacement procedure can be divided into six steps. The steps are: preparation, pump shutdown, disassembly, checking pump condition, installation and start-up.

PREPARATION

Review Information

Before the installation or replacement of a mechanical seal is undertaken, a careful evaluation of the seal manufacturer's and pump manufacturer's drawings is a must. Determine that the correct seal has been purchased. Identify any special precautions that the seal manufacturer has about the installation and start-up processes. Thoroughly study the seal location measurements.

Tool Requirements

After you have determined that you have the correct seal and understand the steps and measurements necessary, you are ready to gather the correct tools. The tool list should include:

- A dial indicator to determine the **runout**[28] and **end play**[29] of the shaft.
- A dial caliper or outside micrometer to determine the roundness of the shaft.
- Disposable rubber or plastic gloves. These will be used to protect the mechanical seal faces during installation.
- Container of dish detergent and water in a 1:5 mixture. This will be used to clean and lubricate the seal faces.
- Lubricant to allow the seal to be installed. Some manufacturers supply a lubricant with the seal. Others recommend the use of water, oil or grease. These recommendations are not universal, and we highly recommend that you check with the seal manufacturer. Some oils may damage the elastomer. With boot seals the best lubrication is the dish detergent and water mixture discussed above.
- Lint free rags to allow the work area to be kept clean. Disposable paper shop towels work well.

[29] **Runout** - The amount of axial movement of a shaft.
[23] **End play** - The amount of radial movement of a shaft.

PUMP SHUTDOWN PROCEDURE

Lock-out - Tag-out

The power should be shut off, locked out and tagged (OSHA 29 CFR 1010.147). This will prevent someone from engaging the pump while you are working on it. The water to both the suction and discharge should be shut off.

INSTALLATION PROCEDURE - FRICTION-MOUNTED SEALS

Assumptions

The following is a list of general steps to be followed during the installation of a friction-mounted mechanical seal. It is assumed that the pump preparation and shutdown steps described above have been completed. It is further assumed that the type of pump that this seal is being installed in is the style that has no seal gland. The only seal that can be installed in this type of pump is the friction-mounted seal.

General Instructions

Each manufacturer of mechanical seals has its own instruction for replacement. However, there are a few general instructions which should apply to all seal installations.

DISASSEMBLY

Component Removal

The pump volute case, impeller and stuffing box must be removed. If you are replacing packing with a mechanical seal, the shaft sleeve must be replaced. If this is merely a seal replacement, then the old seal must be removed from the shaft. In order to remove friction-mounted seals, it is often necessary to use side cutters or a hack saw to cut the collar and then tear the old boot from the shaft.

Remove Stationary Element

The stationary element must be removed from the stuffing box. The stuffing box should be thoroughly cleaned with solvent and then rinsed with clean water and allowed to dry.

Clean the Shaft

The shaft should be cleaned with automotive cleaning solvent and fine emery or a "Scotch" pad. Do not attempt to clean the shaft too completely. A change in the texture of the shaft surface may make it difficult for the boot to adhere.

CHECK PUMP CONDITIONS

Fretting and Burrs

Inspect the sleeve for fretting. If the shaft is fretted, it must be replaced. Check the front edge of the shaft sleeve for burrs. If present, they should be removed with a fine file.

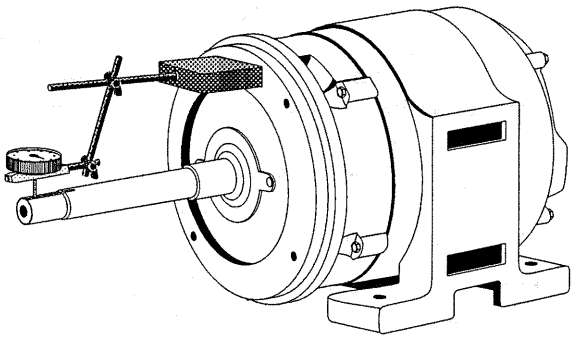
Shaft Roundness

Check the roundness of the shaft at the point that the collar will attach. If the shaft is out of round, it will show up as run out and could cause you to replace

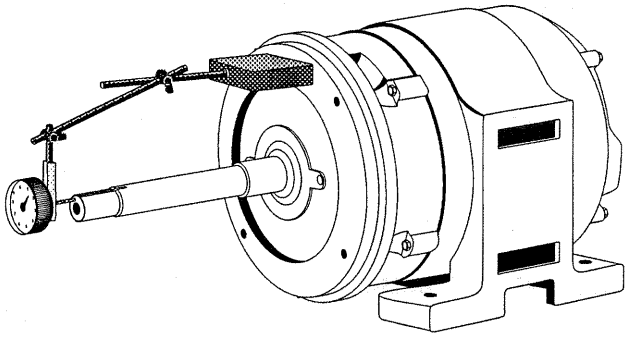
the bearing when the problem was the shaft itself. The out-of-roundness of the shaft should not exceed the recommendation for runout.

Runout & End Play

If the shaft is round, place a dial indicator at this same point and check shaft runout. Then check shaft end play.



Checking Runout



Checking End play

Allowable Tolerance

The allowable tolerance for end play and runout differs slightly from seal manufacturer to seal manufacturer. For instance, Chesterton recommends that the end play of the shaft not exceed 0.005" and runout not exceed 0.001" per inch of shaft diameter. John Crane, on the other hand, recommends that neither of these dimensions be exceeded by 0.002". We highly recommend that you check with the seal manufacturer and follow their recommendations.

Primary Cause of Seal Failure

We realize that these tolerances may seem excessive. However, research on seal failures indicates that by far the most common cause of premature seal failure is the pump condition itself. If you cannot meet the recommended tolerances, then you are wasting your time and money installing a mechanical seal. Repair the shaft and/or bearings before proceeding.

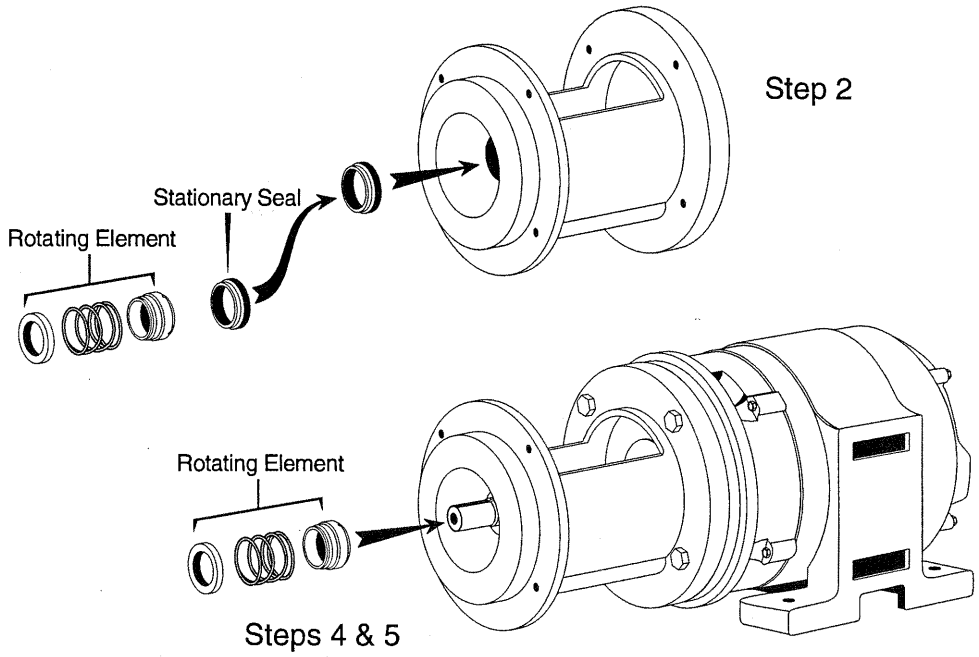
SEAL INSTALLATION

The installation process should follow these steps:

1. Put on the disposable gloves, open the seal box and spread the components onto a lint free cloth.
2. The stationary element on this type of seal is usually held in place in the stuffing box by an "L" shaped elastomer. Lubricate this elastomer with the soap/water solution and place the stationary component into the stuffing box. Make sure that the component fits evenly at the bottom of the box.
3. Reinstall the stuffing box.
4. The spring and spring holder are often not attached to the collar and rotating element. If this is the case,

then work with only the collar and rotating element. Lubricate the elastomer and the seal faces with the soap/water solution. Force the collar onto the shaft. Be careful not to damage the elastomer as it goes over the chamfer of the shaft.

5. Push the collar and rotating element so that the seal faces make contact. You may need to use a hammer handle or stick to help push the collar into place. Do not hit or strike the collar or in any way cause the faces to strike one another as they meet.



6. Quickly, before the elastomer in the collar seizes to the shaft, place the spring, spring holder, impeller thrust washer (if there is one) and impeller on the shaft.

7. Tighten the impeller; hold down bolt or nut. While this is being done, turn the shaft. This will help the two faces align to one another.

8. Reinstall the volute case and piping.

WHY SEALS FAIL

Normal Wear & Excessive Heat

Original installation of mechanical seals usually fail only from normal wear and/or excessive heat. The excessive heat is usually caused by the loss of seal water.

Four Common Causes

However, the failure of replacement seals in less than normal time is usually caused by one of four items: condition of the pump, seal installed in the wrong position, cutting or damaging of the secondary seal or elastomer during installation or warped or scratched seal faces.

Preventing Failure

Here are some suggestions for preventing these four things from happening to the seals that you install.

CONDITION OF THE PUMP

Run-out & End Play

Whenever a seal is changed, the runout and end play of the shaft must be checked. The end play should not exceed 0.005" and the runout should not exceed 0.001" per inch of shaft diameter. This is 0.002" maximum for both dimensions with John Crane Seals.

End-play Problems

If the end play is too great, the natural thrust developed will allow the pressure on the seal to decrease. This will allow water containing grit to flow from the stuffing box and go between the seal faces. The seal faces will become scratched as a result.

Run-out Problems

If the runout of the shaft is too great, the movement of the two faces against one another will allow the rotating face to pick up grit from the exposed portions of the stationary face. This grit then becomes embedded in the rotating face and works as sandpaper against the stationary face.

Other Conditions

The other pump conditions that cause seal failure are vibration, which could be due to misalignment, bad bearings, unbalanced impeller or a number of other items.

Shaft Sleeve Leakage

The operator should also check to see if he can find signs of leakage under the shaft sleeve.

SEAL INSTALLED IN THE WRONG POSITION

Rotating Element Position

Each seal manufacturer packages the seal with a drawing that shows the proper placement of the rotating element. It is essential that the distance given be adhered to.

Too Much Pressure

If the seal faces are too close together, too much heat will be produced. This excessive heat can cause failure of the secondary seal and checking of the seal faces.

Not Enough Pressure

If the rotating portion of the seal is placed too far on the shaft, there will not be enough pressure on the seal faces to keep excessive water from leaking past them.

Always check the seal drawing for proper installation position.

CUTTING OR DAMAGING OF THE SECONDARY SEAL OR ELASTIMA DURING INSTALLATION

When placing the rotating portion of the seal on the shaft, the secondary seal (O-ring, Teflon V-wedge, or U-cup), is often scratched or cut by burrs on the shaft or from the sharp edge of the shaft sleeve. Burrs on keyways and set screws are common culprits. The shaft and shaft sleeve should be closely inspected and smoothed where necessary. Keyways can be covered with masking tape until the rotating element is installed.

WARPED OR SCRATCHED SEAL FACES

Packaging & Handling

Seal faces are often warped or scratched from poor packing and/or handling practices during installation.

Poor Packaging

If the seal is loose in its container when the container is rattled, the faces may become warped.

Improper Handling

If you drop one of the faces on the floor, it should not be installed. These faces are very fragile and should be handled with the greatest of care. If the face of a seal should become soiled, it should be cleaned with water only and then coated with light oil. Do not wipe the face with a cloth. It only takes a few particles of dust to cause a seal to leak.

PUMPS - NORMAL OPERATIONS

WORKSHEET

1. If the water that a pump is pumping is below the eye of the pump impeller the pump is in what type of pumping condition?

   _____ a. Static condition

   _____ b. Suction head condition

   _____ c. Suction velocity lifting condition

   _____ d. Velocity head condition

   _____ e. Suction lift condition

2. Submersible turbines and lineshaft turbines are always in a suction _____ condition.

   _____ a. Pressure

   _____ b. Lift

   _____ c. Head

   _____ d. Velocity

   _____ e. Dynamic

3. Using the diagram below, compare the items indicated with the listing.

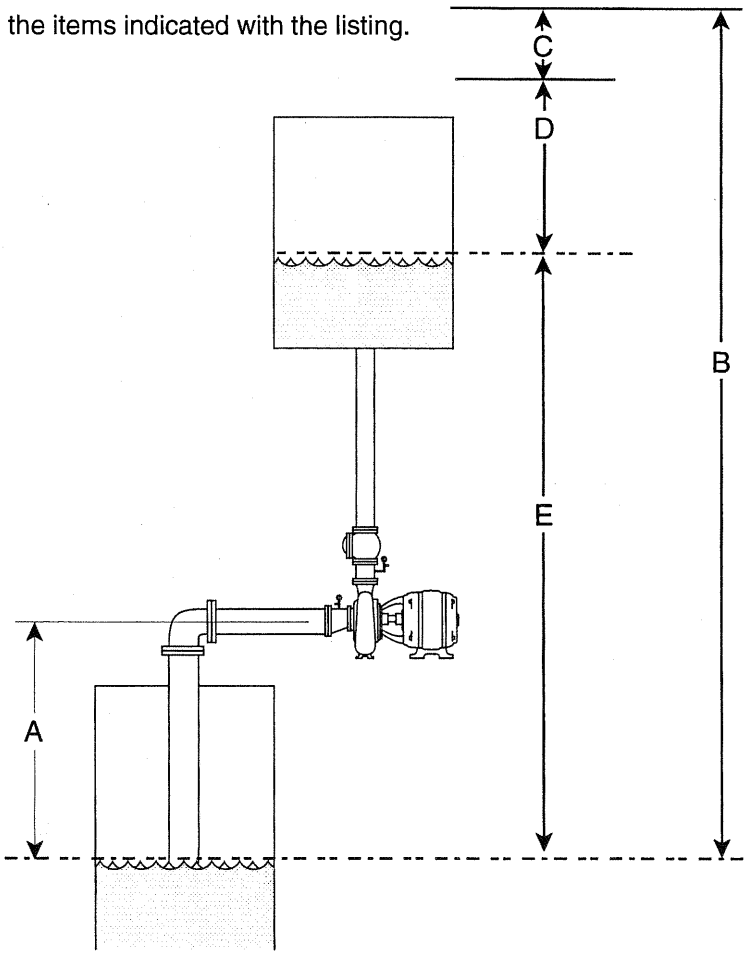
   _____ a. TDH

   _____ b. Velocity Head

   _____ c. Elevation Head

   _____ d. Head Loss

   _____ e. Suction Lift



4. As the horsepower requirements of a pump were to increase you would expect the:

_____ a. Amperage to go up

_____ b. Amperage to go down

5. As an impeller wears down you would expect:(two answers)

_____ a. Amperage to drop

_____ b. Amperage to increase

_____ c. Flow to increase

_____ d. Flow to decrease

_____ e. Flow to remain the same

6. The most common pump used in wells in small communities in Alaska is the _____ _____.

_____ a. Submersible turbine

_____ b. Lineshaft turbine

_____ c. Can turbine

_____ d. End-suction centrifugal

_____ e. Self priming turbine

7. When the thermal overload (heater) has tripped, what should be done before you press reset?

_____ a. Turn the H-O-A switch to auto

_____ b. Check to see that the fuses are OK

_____ c. Check pump pressure

_____ d. Turn the H-O-A to off

_____ e. Do nothing, press the reset

8. Before working on any pump you should shut off the power and _____. This meets the OSHA requirements.

_____ a. Press the reset button

_____ b. Lock- out and tag breaker

_____ c. Place the starter in the off position

_____ d. Fasten the panel door open with a bungie cord

_____ e. Make a voltage measurement at the starter "Terminal" connections

9. Submersible turbines should be installed in a _____ position.

_____ a. Horizontal

_____ b. Angular

_____ c. Deep

_____ d. Vertical

_____ e. Lateral

10. The problem with using a hose or other flexible connection on the discharge of a pump is ....

_____ a. It requires a great deal of support

_____ b. High headloss

_____ c. It is difficult to make the connection

_____ d. Hoses and other flexible connections may not be safe for drinking water

_____ e. It does not offer the proper support for the pump

11. Match the items indicated on the drawing with the list below.

_____ a. Air release control valve

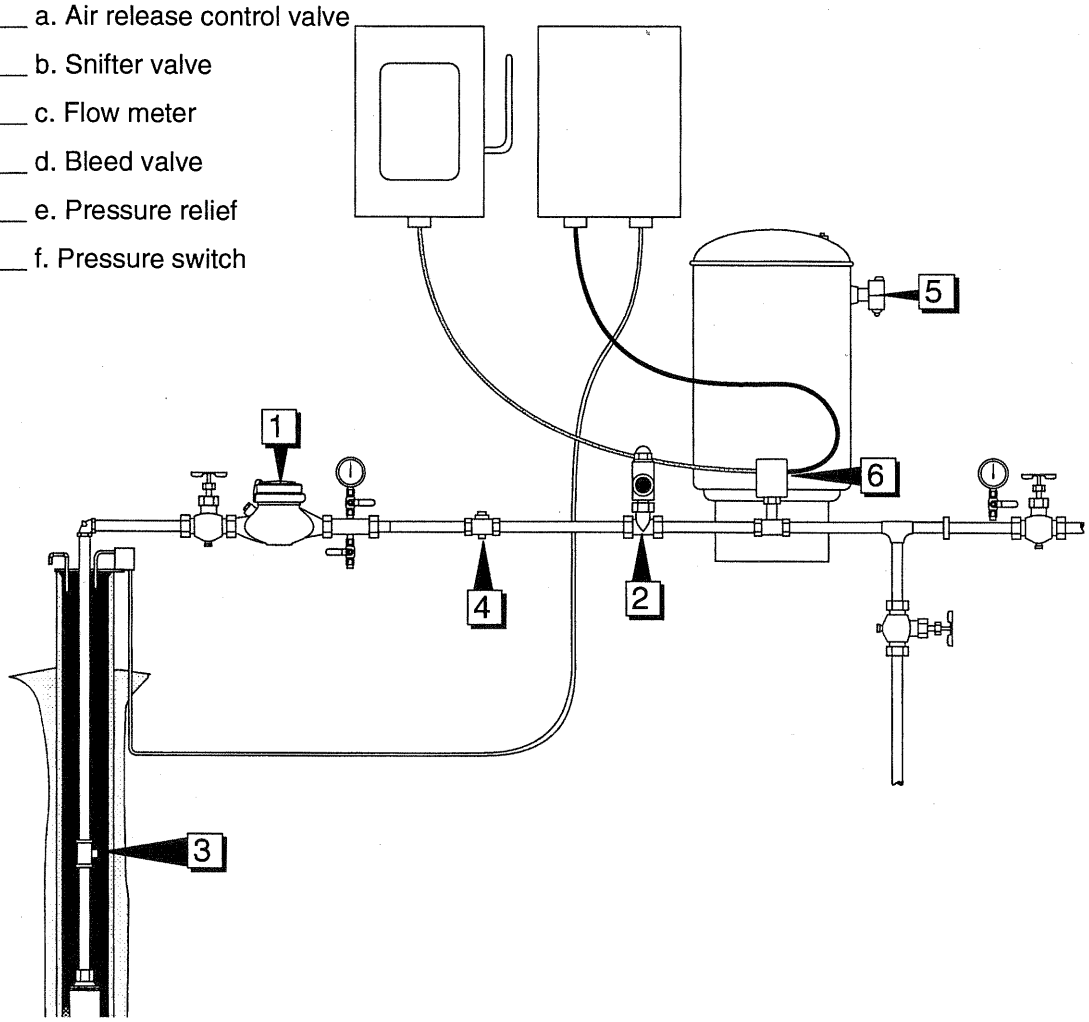
_____ b. Snifter valve

_____ c. Flow meter

_____ d. Bleed valve

_____ e. Pressure relief

_____ f. Pressure switch



11. On a pumping system with a hydropneumatic tank the common pressure range between pump off and pump on is ....

_____ a. 10 psi - 35 psi

_____ b. 20 psi - 60 psi

_____ c. 20 psi - 40 psi

_____ d. 30 psi - 60 psi

_____ e. 30 psi - 50 psi

12. Pressure gauges are installed on pumping systems in order to...

_____ a. Determine the pumping efficiency

_____ b. Determine if the pump is running

_____ c. Determine impeller size

_____ d. Evaluate pump type

_____ e. Evaluate operating conditions

13. For the pump in the drawing below, identify which of the following match.

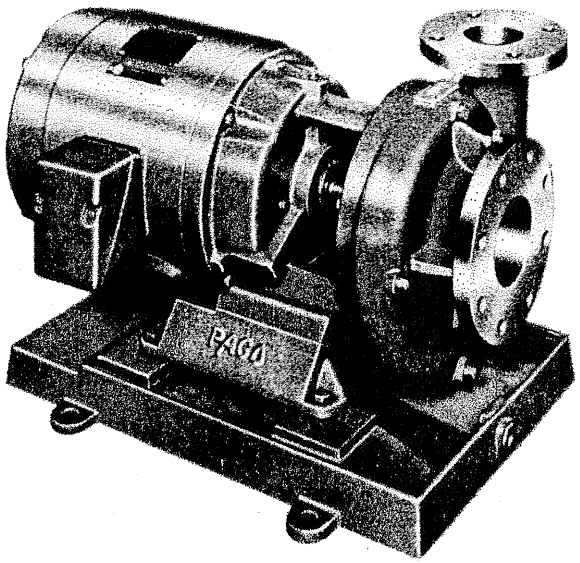
_____ a. End-suction centrifugal, frame mounted

_____ b. Counterclockwise rotation

_____ c. Non-back pull-out

_____ d. Back pull-out

_____ e. Clockwise rotation



14. On an end-suction centrifugal pump a _____ reducer is used on the suction side of the pump.

_____ a. Eccentric

_____ b. Large

_____ c. Bell

_____ d. Concentric

_____ e. Flange

15. On a end-suction centrifugal pump a _____ reducer is commonly used on the discharge of the pump.

_____ a. Eccentric

_____ b. Large

_____ c. Bell

_____ d. Concentric

_____ e. Flange

16. The most common pump used for distribution circulation loops in small communities is the ....

_____ a. Submersible turbine

_____ b. Caned turbine

_____ c. Split case

_____ d. End-suction centrifugal

_____ e. Lineshaft turbine

17. The function of the spool in the piping system is to ....

_____ a. Make the operators job easier

_____ b. Reduce maintenance cost

_____ c. Reduce vibration

_____ d. Reduce cavitation

_____ e. Increase piping harmonics

18. The thermal overloads (heaters) function is to protect the....

_____ a. Building wiring

_____ b. Pump

_____ c. Motor

_____ d. Breaker

_____ c. Capacitor

19. The magnetic breaker and fuses function is to protect the....

_____ a. Building wiring

_____ b. Pump

_____ c. Motor

_____ d. Breaker

_____ e. Capacitor

20. A lineshaft turbine with adjustable impellers usually is using a _____ motor.

_____ a. Large

_____ b. VSS

_____ c. VHS

_____ d. Single phase

_____ e. Horizontally mounted

21. Prelube is used on what type of pump?

_____ a. Submersible turbine

_____ b. End-suction centrifugal - frame mounted

_____ c. Can Turbine

_____ d. Split case

_____ e. Lineshaft turbine

22. To prevent a lineshaft turbine from turning backwards at shutdown, a _____ is installed.

_____ a. Check valve

_____ b. Non-reversing ratchet

_____ c. Backflow preventer

_____ d. Hollow shaft motor

_____ e. Head nut

23. When a pump uses packing to control leakage from the stuffing box, common drip rates for water from the stuffing box should range between _____ and _____ drops per minute.

_____ a. 5 to 100

_____ b. 30 drops per minute per inch of shaft diameter

_____ c. 10 to 30

_____ d. 5 to 20

_____ e. 10 to 40

24. When external seal water is used on a centrifugal pump it should be _____ to _____ psi above the suction volute pressure.

_____ a. 5 to 40

_____ b. 20 to 40

_____ c. 30 to 60

_____ d. 5 to 20

_____ e. 10 to 15

25. Typical lubrication frequency for electric motors of 20 hp and smaller, and their associated pumps is...

_____ a. Once every 3 years

_____ b. Once every month

_____ c. Twice a month

_____ d. Once a quarter

_____ e. Once every five years

26. The purpose of the mechanical seal is to _____ leakage.

_____ a. Stop

_____ b. Divert

_____ c. Control

_____ d. Reduce

_____ e. Eliminate

27. The major advantage to using mechanical seals is.....

_____ a. Cost

_____ b. Ability to control leakage

_____ c. Their life expectancy

_____ d. Ease of installation

_____ e. The improvement in pump performance

28. When should a mechanical seal be replaced?

_____ a. When leakage occurs from the volute

_____ b. Every 3 to 5 years

_____ c. When the amperage goes up

_____ d. Only when the pump is rebuilt

_____ e. When leakage occurs from the stuffing box

29. In order for a mechanical seal to last its expected life the runout of the shaft should not exceed how many inches per inch of shaft diameter?

_____ a. 0.001

_____ b. 0.002

_____ c. 0.003

_____ d. 0.004

_____ e. 0.005

30. Identify the seal components below by matching the number with the list provided.

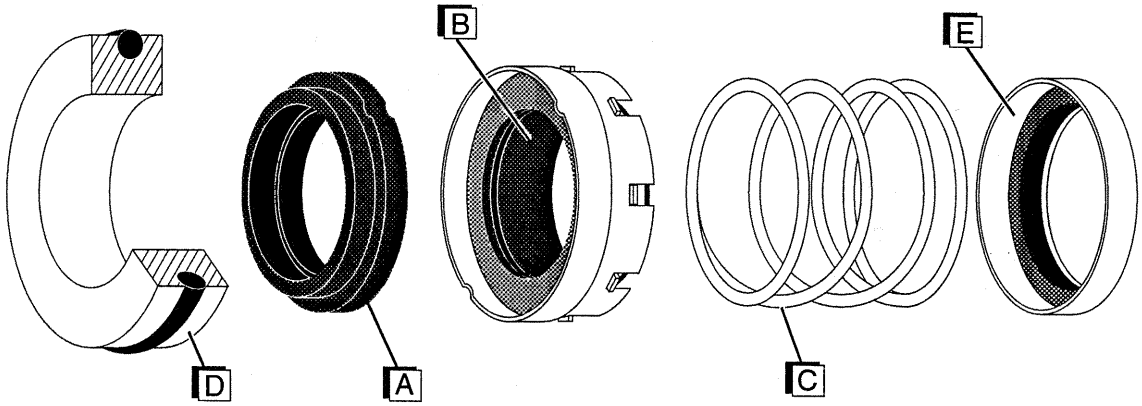
_____ a. Ceramic

_____ b.Spring holder

_____ c. Spring

_____ d. Carbon

_____ e. Boot



31. In order for a mechanical seal to last its expected life the end-play of the shaft should not exceed ....

_____ a. 0.001

_____ b. 0.002

_____ c. 0.003

_____ d. 0.004

_____ e. 0.005