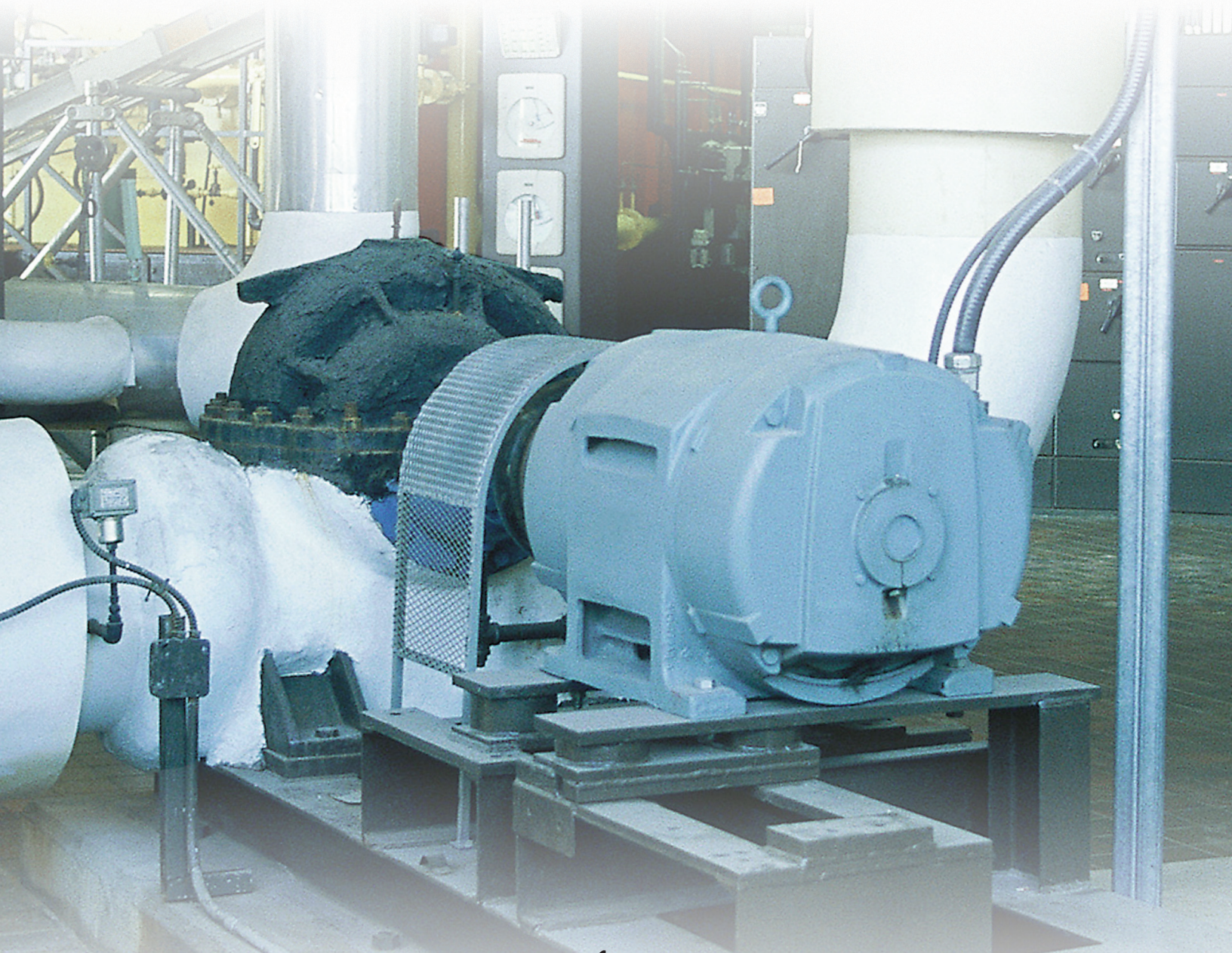
pumps



for

UNITED ASSOCIATION

JOURNEYWORKERS & APPRENTICES

INTERNATIONAL Pipe Trades JOINT TRAINING COMMITTEE, INC.

PUMPS

INTERNATIONAL
Pipe Trades
JOINT TRAINING COMMITTEE, INC.

Published by

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Under the Direction
of the
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This training manual has been prepared for the use of United Association journeyworkers and apprentices. It was compiled from information sources which the International Pipe Trades Joint Training Committee, Inc. believes to be competent. However, recognizing that each type of piping system and mechanical equipment installation must be designed to meet particular needs and code requirements, the Committee assumes no responsibility or liability of any kind in connection with this training manual or its use by any person or organization and makes no representations or warranties of any kind hereby.

This manual contains instructions for the safe use of various types of tools and equipment that are used in the installation, testing and repair of pumps. Those instructions, along with the tables, charts, drawings and photographs which appear in this training manual, are *not* intended to set standards for their use and application and manufacturers' type. Rather, they are designed to familiarize journeyworkers and apprentices with some of the factors and considerations involved in the installation, use and principles of pump operation.

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FOREWORD

The United Association journeyworkers, through the course of their career, will be called upon to install a large variety of pumps. These pumps could range from small circulating pumps to very large centrifugal pumps sending out thousands of gallons of water and other kinds of fluids through various types of piping systems.

Pumps have contributed greatly to modern civilization, allowing large cities to be built far away from the natural sources of water. Entire cities can be supplied with hot water and chilled water generated at a single facility.

Ever increasing public demands and uses for water causes reductions in pressure in municipal water supply systems. With each additional new building unit that is constructed, there may be a permanent or temporary water pressure problem created. Where these situations exist, they must be corrected. Generally, pumps are installed at these locations to alleviate these problems.

Although there are numerous applications of pumps in the mechanical systems UA journeyworkers install and service, pumps are also found in a great number of applications they as private citizens encounter in everyday living; the fuel pump and water pump in their autos, the drain pump in automatic washing machines, the air compressor and gasoline pump at gas stations, bicycle pumps, squirt type oil cans, and even in garden sprayers, etc.

All pumps, from the smallest and simplest to the largest and most complex, are constructed and operated in accordance with certain basic principles. Even though there are many different manufacturers of this equipment and many different sizes and capacities within each type of pump, after studying this manual you should be able to apply the principles covered to almost any type or make of pump you may encounter in your work.

Chapter 1, “Pump Theory,” provides an understanding of the fundamental principles of pump operation. Chapter 2, “Types of Pumps,” explains the variety of pumps there are, how they work, and how they are used. Chapter 3, “Pump Installation,” describes the correct procedures for the installation of various types of pumps necessary for a sound installation. Chapter 4, “Pumps in Systems,” is an in-depth explanation of selected piping systems and where pumps are used.

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The International Pipe Trades Joint Training Committee, Inc. wishes to acknowledge the organizations listed below for their generous and constructive contributions toward the preparation of this publication. Their courtesy and spirit of cooperation is merely a further indication of their continuing dedication to the highest standards of craft training and service to the public.

This Training manual was developed in 2000 under the direction of George H. Bliss, III, Director of Training, United Association; Peter G. Marzec, Special Representative, United Association Training Department; Herbert L. Fishpaw, Plumbers and Steamfitters Local Union #486, Baltimore, Maryland in cooperation with Eric L. Packard, Sprinklerfitters Local Union #669, Columbia, Maryland and John W. Miller, Plumbers Local Union #1, New York, New York. The authors of this training manual are John W. Miller and Herbert L. Fishpaw.

This training manual was updated in 2007, under the direction of Michael P. Arndt, Director of Training, United Association, and James G. Pavesic, Training Specialist, United Association Training Department.

This training manual was reprinted in 2009, under the direction of Michael P. Arndt, Director of Training, United Association, and James G. Pavesic, Administrative Assistant to the UA Director of Training.

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CONTENTS

CHAPTER		PAGE(s)
1	Pump Theory	1-7
2	Types of Pumps	9-35
3	Pump Installation	37-51
4	Pumps in Systems	53-84
GLOSSARY		G-1 – G-4
APPENDIX — General Pump Instructions		A-1 – A-15
INDEX		I-1 – I-4

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CHAPTER

1

Pump Theory

Procedure: Study the pages which have been assigned by your instructor and answer the questions on the assignment sheet(s) which will be distributed to you.

All pumps, from the smallest and simplest to the largest and most complex, are constructed and operated in accordance with certain basic principles. And although there are many different manufacturers of this equipment and many different sizes and capacities within each type of pump, after studying this text you should be able to apply the principles covered to almost any type or make of pump you may encounter in your work.

What is a pump?

A *pump* is a device through which an external source of power is used to apply a force to a fluid in order to move the fluid from one place to another. A pump develops no energy of its own; it merely transforms energy from the external source, its power end, (electric motor, steam turbine, etc.), into mechanical kinetic energy, which is manifested by the motion of the fluid. This kinetic energy is then utilized to do work. Each pump also has a fluid end, where the fluid enters (suction) and leaves (discharges) the pump.

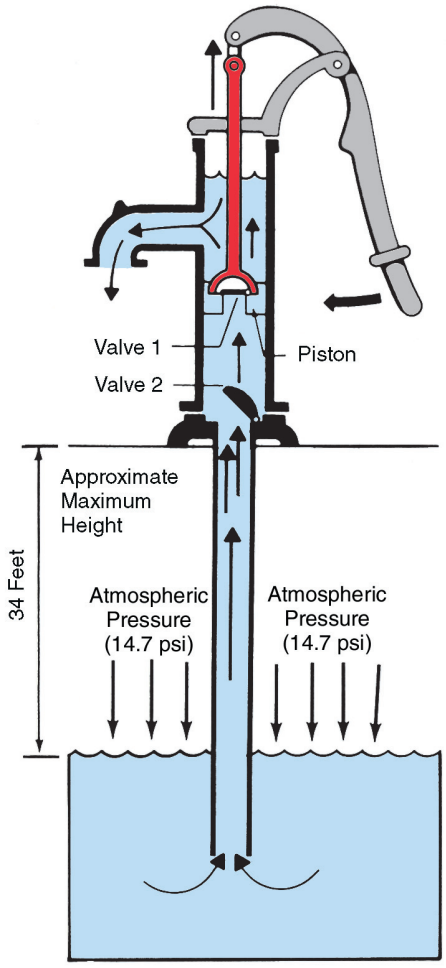
One example of using a pump in a piping system is to move water from a well to plumbing fixtures. List five more examples of the use of pumps in piping systems.

1. To transfer fuel oil from a storage tank to a boiler.
2. To circulate chilled water.
3. To circulate water in a hot water heating system.
4. To raise water or sewage from sumps up to a point of gravity drainage.
5. To return steam condensate back to a boiler.

What are two ways liquids can be raised?

Liquids can be raised by *suction* or by pushing with *positive* pressure. The first method (suction) is limited by atmospheric pressure (14.7 psi). When a pump is used to raise a liquid by suction, the actual force causing the liquid to rise in the suction pipe is atmospheric pressure. Pumps do not actually suck up liquids.

A pump located above the level of the reservoir from which water is being drawn creates a partial vacuum at the suction inlet. See **Figure 1-1**.



Effect of Force of Atmospheric Pressure

Fig. 1-1

Theoretically water can be pulled (raised) approximately 34' vertically. The positive atmospheric pressure forces the liquid up the suction pipe towards the lower pressure at the pump suction connection.

$$\frac{\text{Atmospheric press. (14.7 psi)}}{\text{Weight of column of water 1' high (.433 lb per foot)}} = 33.95\ (34)\ \text{ft.}$$

The partial vacuum in a pump is created by the piston in reciprocating pumps, by the cam or gear action in rotary pumps, and in centrifugal pumps by the liquid being forced away from the center. The maximum practical suction lift on positive displacement pumps is 22' and on centrifugal pumps it is 15'.

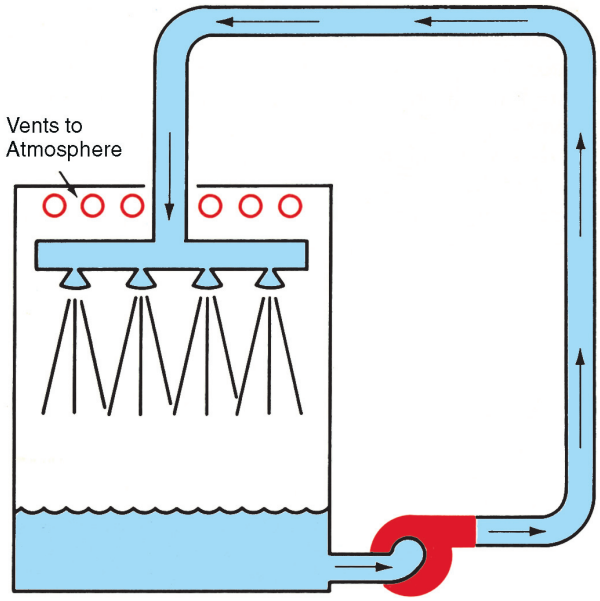
A maximum suction lift of 22' or 15' means that these figures are the total of two factors. These two factors are (1) the vertical distance the pump is above a liquid known as static suction lift, and (2) frictional resistance in these suction pipe.

For example, with a reciprocating pump where the maximum lift is 22', a table of friction losses would show that the friction loss in the suction piping is 5'. This means that the vertical distance of the pump above the liquid cannot exceed 22' minus 5' or 17'.

The forces generated by pumps are used to raise, transfer, compress, create a vacuum, or circulate fluids. Piping systems, which are exposed to atmospheric pressure at some point within the system, are known as *open systems*. In open systems, pumps are used not only to supply the pressure necessary to overcome the resistance of the piping, but also to lift the liquid to a higher elevation.

Some examples of how and where pumps are used in open systems are:

1. Water pumped from a well.
2. Condensate from steam systems that is pumped from condensate receivers (which are vented to the atmosphere) back to a boiler.
3. Drainage which has accumulated in a vented sump and is lifted by a pump to a higher point of entry into a drainage system.
4. Dishwasher water which is pumped during the washing cycle. See **Figure 1-2**.



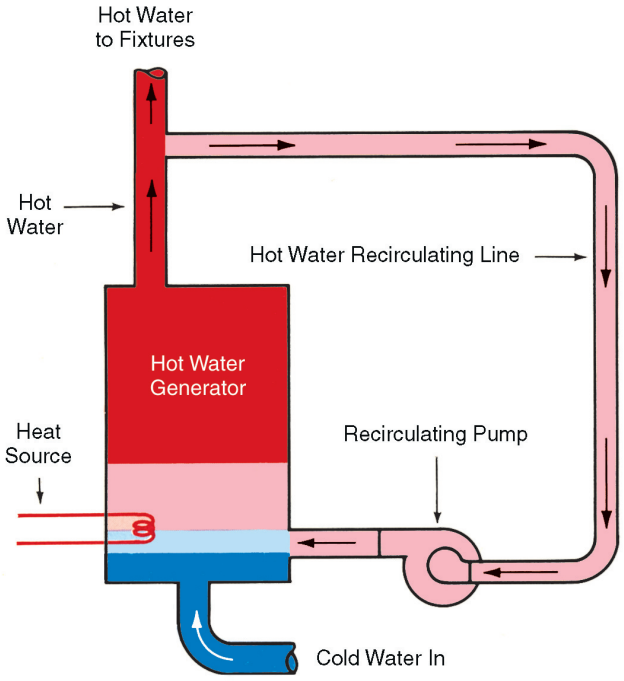
Dishwasher

Fig. 1-2

"Closed systems" are piping systems which are completely sealed from atmospheric pressure throughout the entire system.

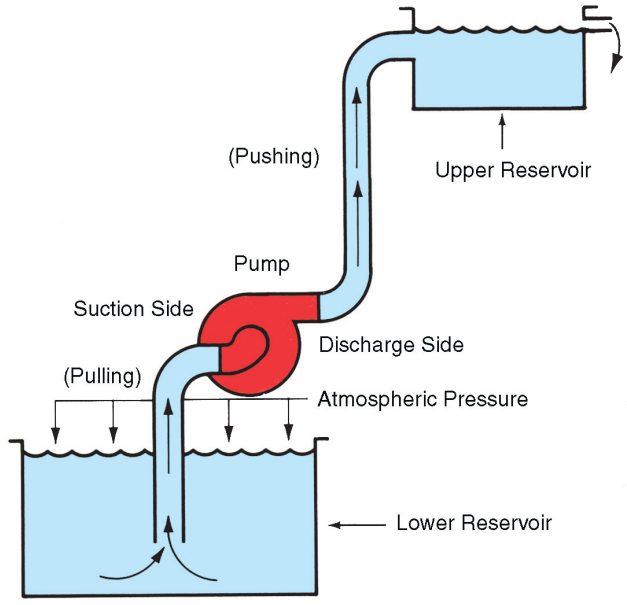
In closed systems, as shown in **Figure 1-3**, pumps supply the pressure necessary to circulate the liquid within the system. Because the pump does no net lifting, that is, whatever liquid is lifted is counter balanced by the equal height of the liquid returning to the pump, the pressure added by the pump is used simply to overcome the friction losses within the piping system.

In **Figure 1-4** the pump has lifted the water from the lower reservoir to the level of the pump. As the liquid, (raised from the lower reservoir) starts to pass through the pump, energy is added to the flowing liquid in the form of an



Example of a Domestic Hot Water Closed System

Fig. 1-3



Water in an Open System Being Lifted
to a Higher Elevation

Fig. 1-4

increase in pressure. This additional pressure at the discharge side of the pump now pushes the liquid up, to discharge at the level of the upper reservoir.

What is the difference between pounds of pressure and pounds of weight?

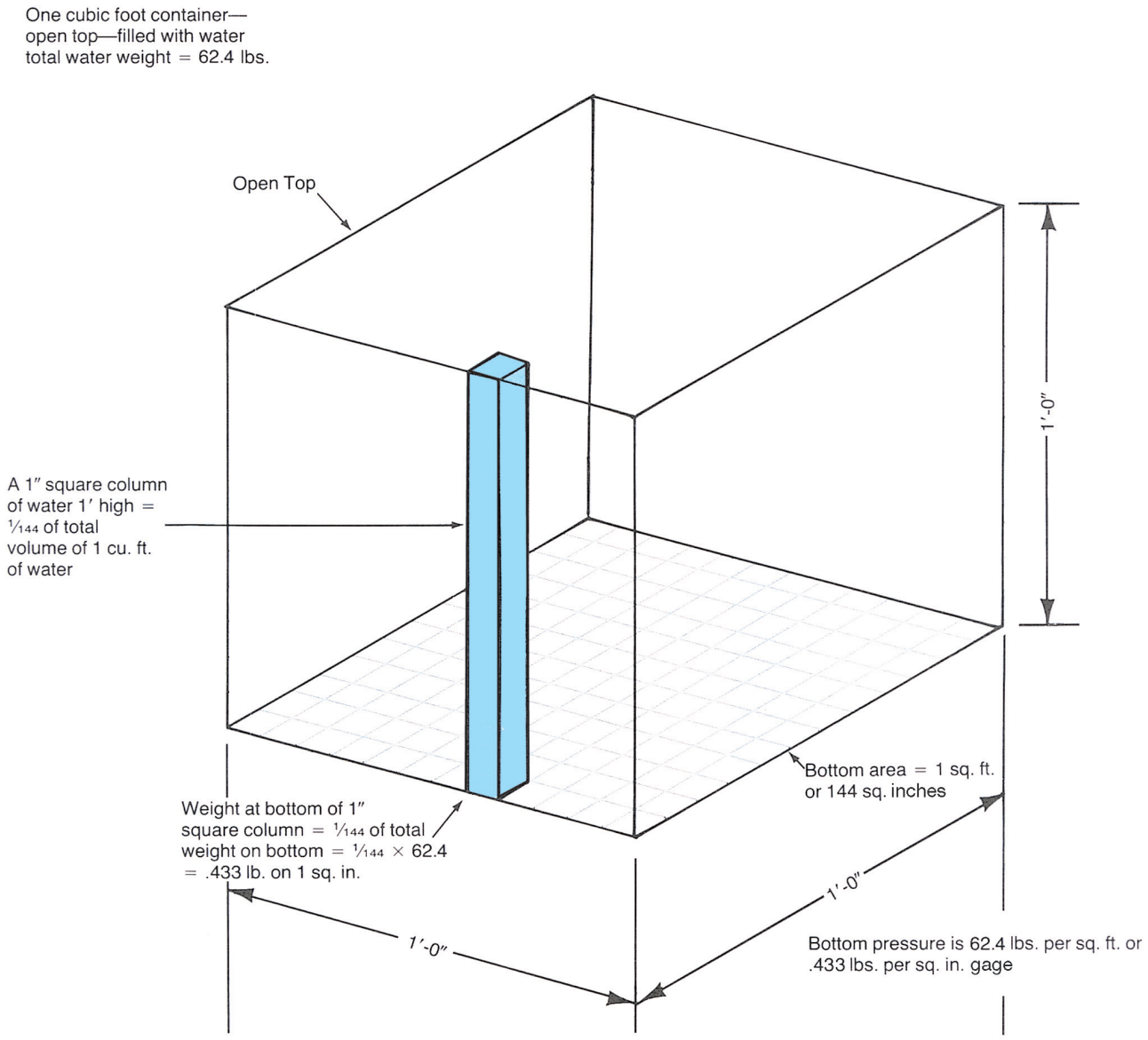
Pounds of weight is the measure of total heaviness of a substance as it is read on a scale. A cube of water in an open top container measuring 1' in each direction will weigh about 62.4 lb, not counting the weight of the container. This is *pounds of weight*. See **Figure 1-5**.

Pounds of pressure is the designation for *pounds of weight* bearing on a specific area. Pressure is usually expressed in pounds of weight on each square inch, called *pounds per square inch*. The symbol for this is *psi*. Pressure can also be expressed as pounds per square foot, grams per square centimeter, or any other unit of weight per unit of area. The cube of water shown in **Figure 1-5** measuring 1' in each direction will have a pressure on the bottom surface of 62.4 lb *per square foot* because the total weight is exerted on the 1 sq. ft. of bottom surface.

If you divide the bottom surface into square inches, you will find there are 144 sq. in. in a square foot (12" long x 12" wide). Each of these individual square inches supports the weight of 1/144 of the total 62.4 lb of weight. Therefore, 1/144 of 62.4 equal .433 lb bearing on each square inch of bottom surface, or .433 psig. The actual pressure at the bottom of the cube remains the same. It is simply expressed in terms of different units of area, in one case, square inches (pounds per square inch), and in the other case square feet (pounds per square foot).

Therefore, a pressure of .433 lb per square inch is equal to a pressure of 62.4 lb per square foot. And most important, these equal pressures are created by the *height* (1') of the water column alone and have nothing to do with how wide (1 sq. in. or 1 sq. ft.) the column is.

Pressure according to the height of a liquid is called *head* and is expressed in units of length. So you can say for water that both .433 psig and 62.4



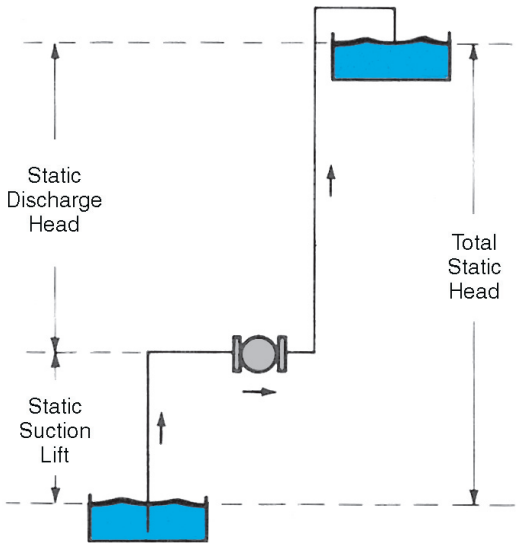
Pressure Exerted by Column of Water

Fig. 1-5

psf are equal to 1' of head. The vertical distance from the point of pressure measurement to the surface determines the pressure. The deeper you go, the greater the pressure.

The terms head and total head are closely associated with pumps. What relationship do these terms have to pumps?

The term head is used to describe the amount of force required to lift a column of water. It is expressed in feet of vertical height of water column. It requires 0.433 psig to lift water one foot. When you multiply head pressure by 0.433 psig/ft., you convert from head pressure to psig, or if you divide a pressure in psig by 0.433 psig/ft. you convert from psig to head pressure. Total head equals the total suction lift plus the total discharge head of a pump. See **Figure 1-6**.



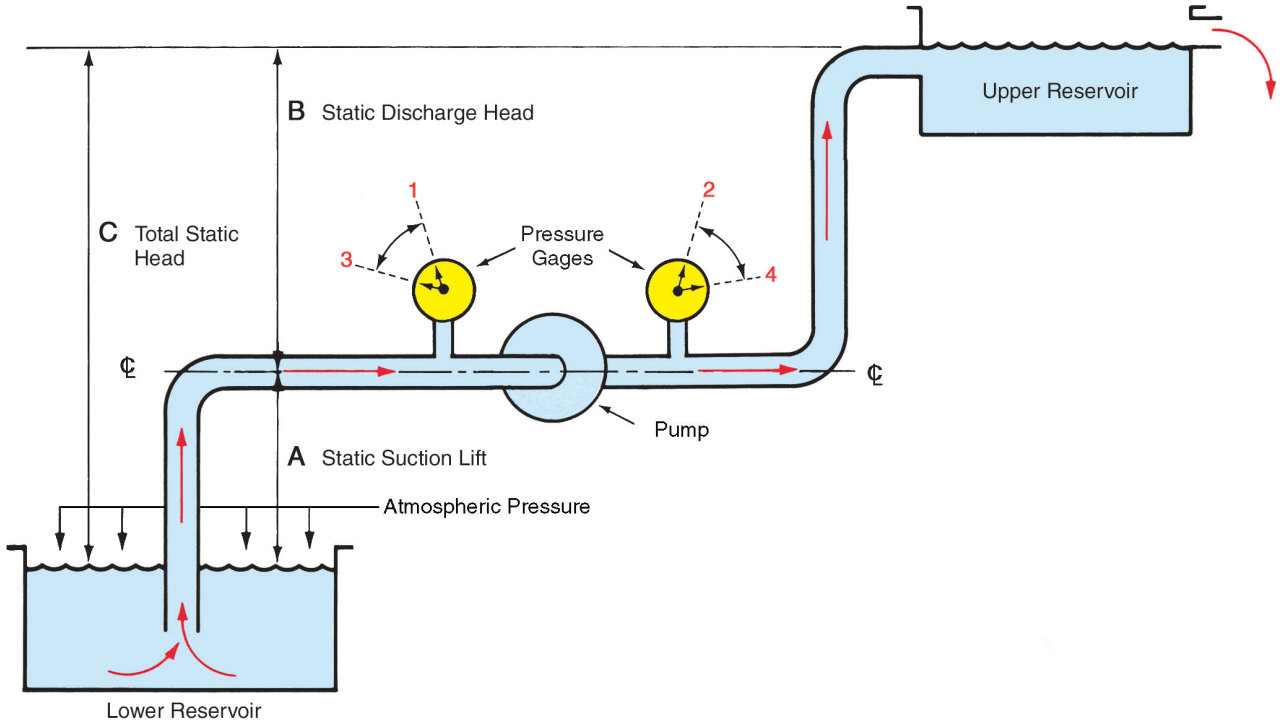
Total Head Equals Total Suction Lift Plus Total Discharge Head

Fig. 1-6

Describe the various head pressures illustrated in Figure 1-7.

1. Head A — *static suction lift* is the vertical distance liquid is raised by atmospheric pressure, from the surface of the supply reservoir to the centerline of the pump suction connection. This liquid is under a partial vacuum created by the pump.
2. Head B — *static discharge head* is the vertical distance the liquid is being pushed, as measured from the centerline of the pump discharge connection to the point of open discharge into the upper reservoir.
3. Head *C* — *total static head* is the overall vertical distance the liquid is being raised, from the level of the lower reservoir to the point of open discharge at the upper tank.

These measurements of head are equivalent to the pressures required to support these liquid columns if the systems were under no-flow (sta-



Open System — Supply *Below* Pump

Fig. 1-7

tic) conditions. They would be represented by the pressure indicated on the suction gage as "1," and on the discharge gage as "2" in **Figure 1-7**.

Determine the total static head of the system in Figure 1-7, if A = 4' and B = 56'.

The total static head C, is the sum of the static suction lift A plus the static discharge head B. The total static head is 60'.

C (total static head) = A (static suction lift) + B (static discharge head).

C = "1" + "2"

C = 4' + 56'

C = 60'

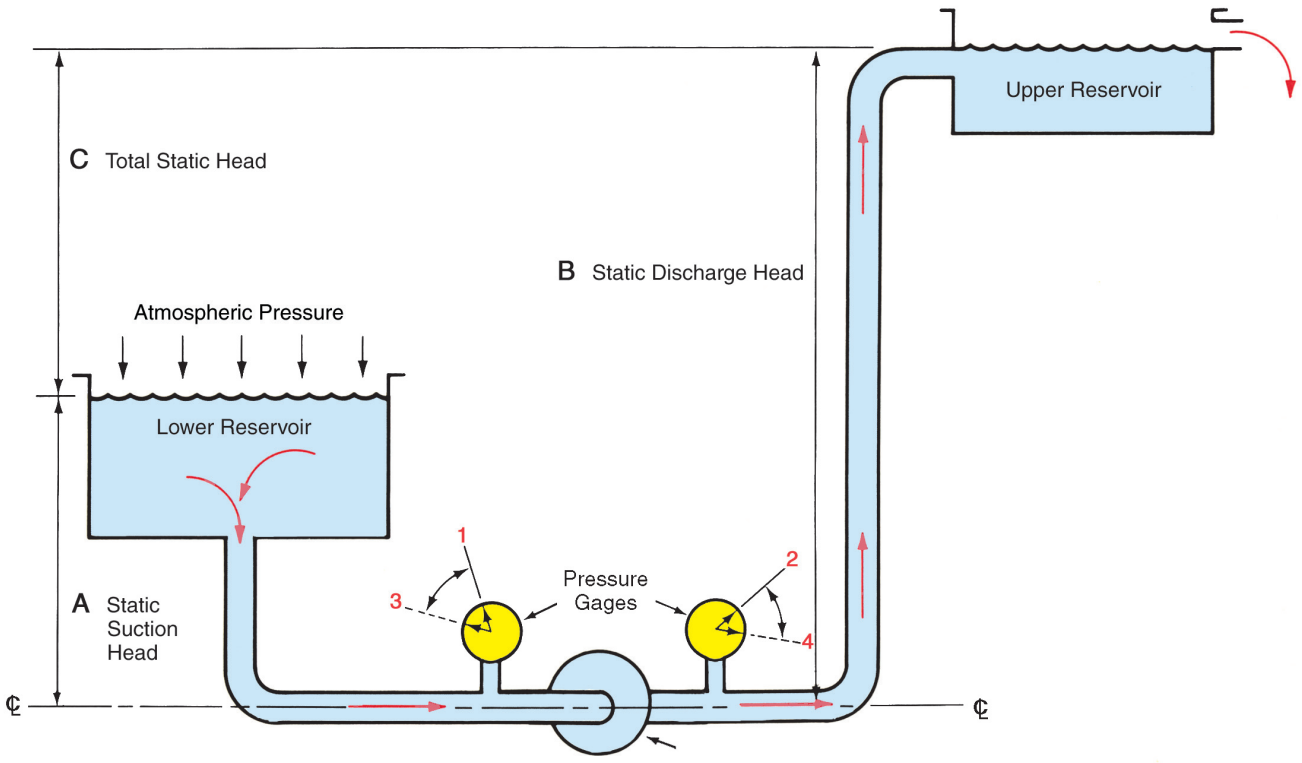
To convert the 60' of *total static head* to psig, multiply:

60' x .433 psig/ft. = 25.98 psig.

Figure 1-8 shows a system similar to that in Figure 1-7 except that the supply reservoir is now above the level of the pump. Describe the various head pressures illustrated.

1. Head A — this system is *static suction head* (instead of the static suction lift as in **Figure 1-7** when the reservoir was below the pump). It is the vertical distance between the surface of the liquid in the supply reservoir and centerline of the pump suction connection and therefore creates a *positive* pressure.

2. Head B — *static discharge head* is the vertical distance the pump pushes the liquid from the centerline of the pump discharge connection to the point of open discharge at the upper reservoir (similar to the corresponding discharge line in **Figure 1-7**).



Open System — Supply *Above* Pump

Fig. 1-8

3. Head C — *total static head* is the net vertical distance the liquid is being raised from the supply reservoir to the point of open discharge at the upper reservoir. (not the total vertical height as shown in **Figure 1-7**.)

In Figure 1-8 the value for B is the same as in Figure 1-7 (56') while the value for A (4') represents the distance above rather than below the pump. What is the total static head (in psig) in Figure 1-8?

The total static head is 22.52 psig.

C (total static head) = B (static discharge head) – A (static suction head)

C = "2" – "1"

C = 56' – 4'

C = 52'

C = 52' x .433 psig/ft.

C = 22.52 psig

What does the difference in pressure between the two gages shown in Figure 1-8 represent?

The gage on the suction side of the pump has its pointer at "1" which represents the pressure in psig equivalent to the *static suction head.* The position of the pointer at "2" on the discharge gage represents the pressure in psig equivalent to the *static discharge head.* The difference in pressure between the two gages represents the *total static head* which was calculated previously as 22.52 psig.

The conditions represented in Figures 1-7 and 1-8 have illustrated the impact of static pressures, meaning pressures in a system without flow. In these examples, the pumps are running at a rate which would barely maintain the pressures shown (there is no appreciable flow in the systems). What would happen to the system pressures if a significant flow were to be established while the levels of the reservoirs remained constant?

There is a pressure loss due to friction within piping systems when fluids are flowing through them. As the pump flow rates are increased in both **Figures 1-7** and **1-8**, you would observe the suction gages showing a lower pressure as the pointer moves from the pressure at "1" to a lower pressure at "3." Likewise, you would observe the discharge pressure gages increasing from the discharge pressure "B" to a new higher discharge pressure "4." See **Figures 1-7** and **1-8**.

The two changes in pressure represent the additional pressure the pump had to add to the system to overcome the *friction loss* due to higher flow rates. The number of psig the suction gage *moved* plus the number of psig the discharge gage *moved* is the total of the two changes in pressure. And this total of the two changes in pressure is equivalent to the additional energy added by the pump as the liquid began moving from a static condition to its present flow rate.

CHECKPOINT 1

At this point go back to page 1 for a review to see how thoroughly you have learned the material presented. This review is important to help you understand and retain what you have studied. When satisfied that you understand the material covered, answer the questions on the assignment sheet.

NOTES

CHAPTER

2

Types of Pumps

Procedure: Study the pages which have been assigned by your instructor and answer the questions on the assignment sheet(s) which will be distributed to you.

This chapter will discuss various types of pumps, how they work, and some of their uses.

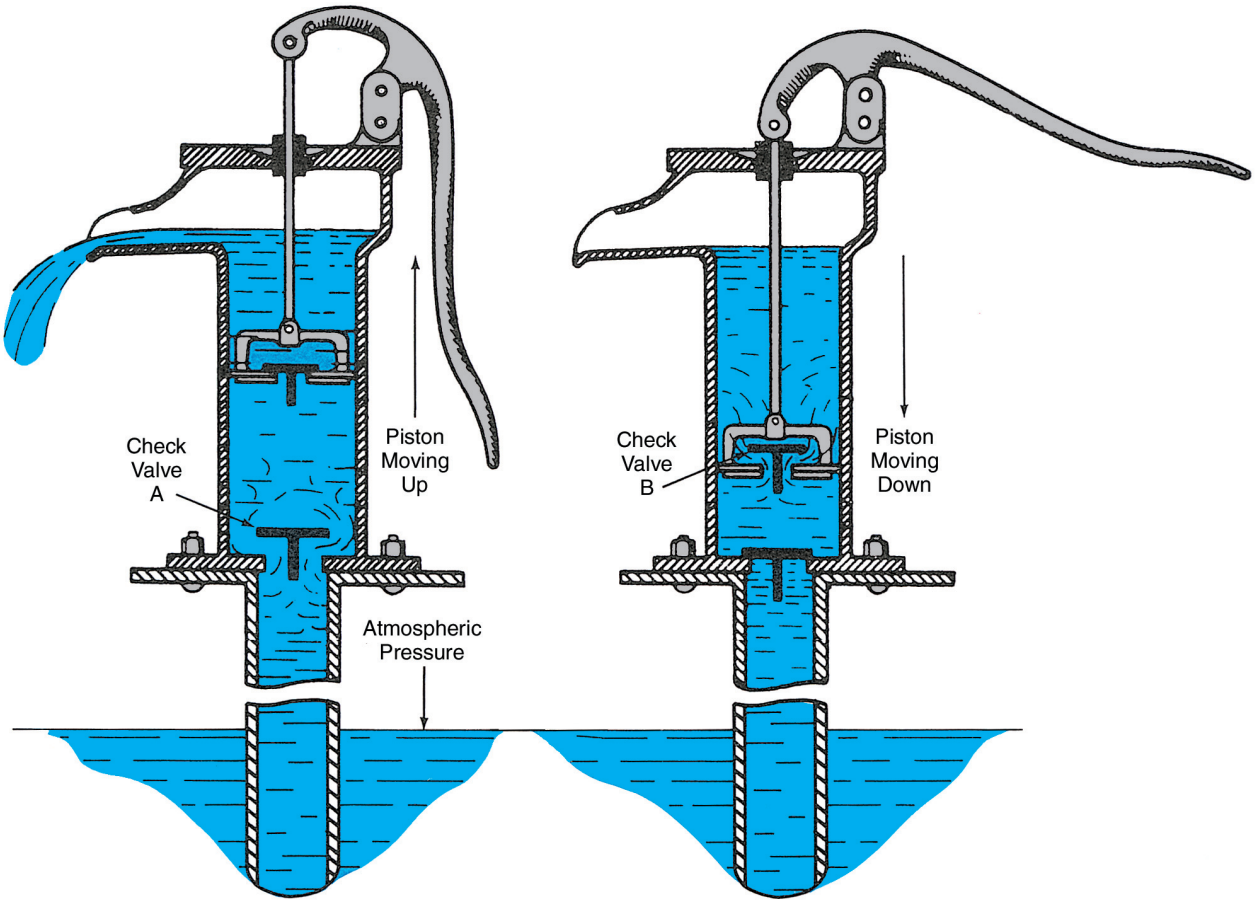
Two basic classifications of pumps are:

1. Positive displacement;
2. Non-positive displacement.

A *positive displacement* pump discharges a definite quantity of liquid for each operating cycle. As the name implies these pumps work on the principle of displacement. Liquid enters the pumps through the suction port and is ejected forcibly out of the discharge port by displacement. Reciprocating pumps and rotary pumps are of this type.

A piston type lift pump commonly known as a pitcher pump is shown in Figure 2-1. Describe the operation of a piston type lift pump.

The operation of a piston type lift pump is an example of how atmospheric pressure causes liquids to rise in exhausted tubes. **Figure 2-1** shows that

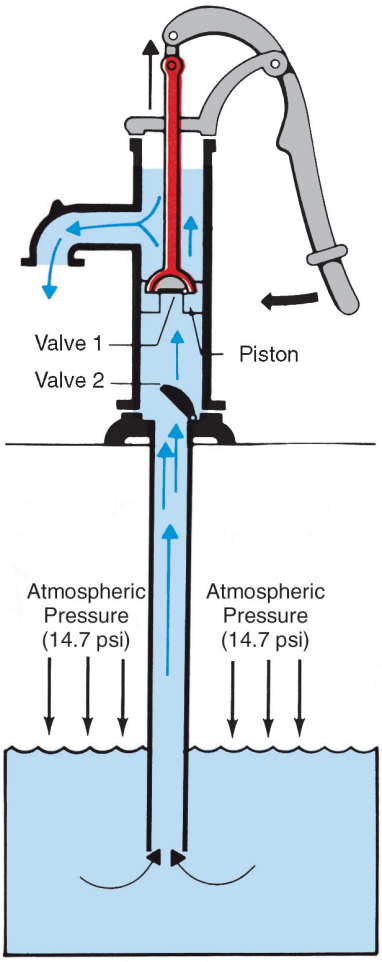


Piston Type Lift Pump

Fig. 2-1

as the handle of the pump is pushed downward, the piston moves upward and causes a reduction in pressure inside the cylinder. The pressure of the atmosphere acting on the surface of the water in the well is greater than the air pressure inside the pump and the water flows up the suction pipe. After several strokes the water will reach the pump body and enter the cylinder through check valve *A*. When the pump handle is pulled up, the pressure inside the cylinder will increase, causing the water to flow out of the pump through check valve *B* on top of the piston. It is actually the atmospheric pressure that is doing the lifting of the water, and not, as some people mistakenly believe, the partial vacuum created inside the cylinder of the pump.

The pitcher pump shown in **Figure 2-2** is an example of a positive displacement pump. Each full stroke displaces an equal amount of water.



Pitcher Pump

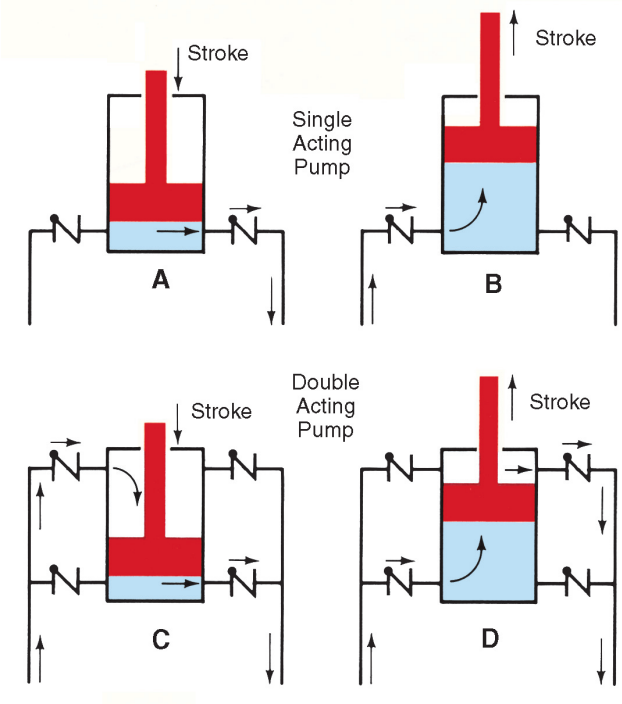
Fig. 2-2

It is a type of positive displacement pump called a *reciprocating* pump. Reciprocating pumps can be described as pumps that have a backward and forward or an upward and downward motion.

Other types of reciprocating pumps similar in operation to the pitcher pump are:

1. Air compressors;
2. Boiler feed pumps;
3. Deep well piston pumps (for water or oil);
4. Hydraulic power pumps;
5. Vacuum pumps;
6. Diaphragm type ditch pumps;
7. Hydrostatic test pumps.

The rate of discharge in reciprocating pumps can be varied. Using the pump illustrated in **Figure 2-3-A** and **B** as an example, you can see that both the length of the stroke of the piston and the number of strokes per minute would change the



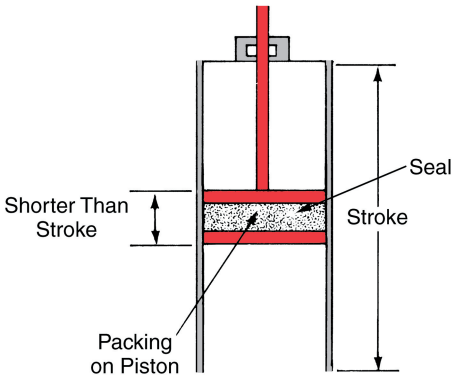
Reciprocating Pumps

Fig. 2-3

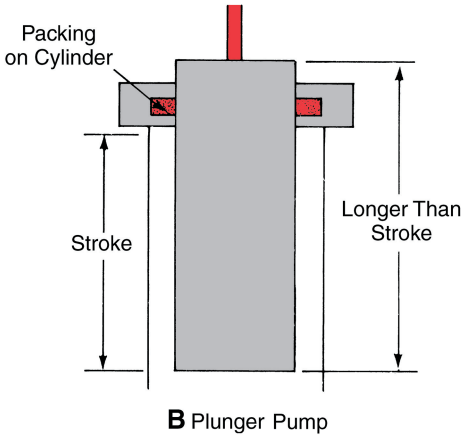
rate of discharge. Also, if multiple pistons were built into a single pump, the capacity could be increased. If the valves and piping are arranged to allow a positive discharge on the return stroke as well as the primary stroke makes it a *double acting pump*. See **Figure 2-3-C** and **D**. This also could increase the pumping capacity.

A piston pump and a plunger pump are examples of a reciprocating pump. What are the differences between a piston pump and a plunger pump?

The differences are: (1) the piston on a piston pump is shorter than the stroke and the plunger on a plunger pump is longer than the stroke; (2) the seal (packing) on the piston pump is on the piston while the seal on the plunger pump is on the cylinder. See **Figure 2-4**.



A Piston Pump

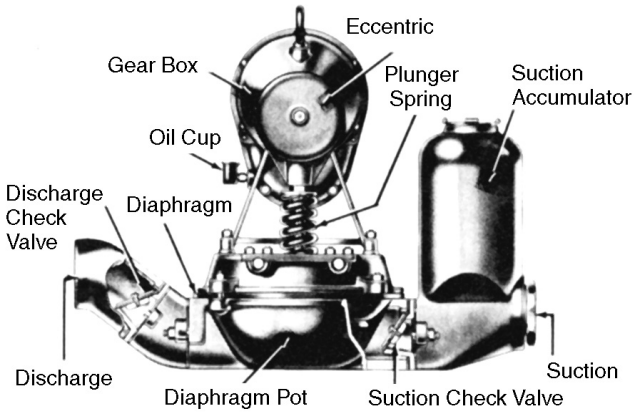


B Plunger Pump

Piston Pump and Plunger Pump

Fig. 2-4

A diaphragm pump is shown in **Figure 2-5**. The diaphragm type pump employs a substance such as rubber or neoprene in place of a piston or plunger. This type of pump is used to remove water from trenches, flooded foundations, drains and other places where there is a high proportion of mud, silt or sand to water.

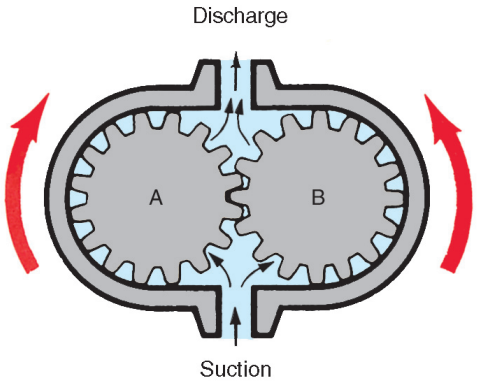


Diaphragm Type Pump

Fig. 2-5

Although reciprocating pumps have the advantage of being able to provide very high pressures, they discharge fluids in a pulsating flow. What type of positive displacement pump discharges fluids in a smooth flow?

The *rotary* gear pump shown in **Figure 2-6** is a positive displacement pump which discharges fluids in a smooth flow. It is simple in design, has few



Rotary Gear Pump

Fig. 2-6

parts and, like a reciprocating pump, is positive acting. It is called a rotary pump because a rotary motion carries the fluid from the inlet to the outlet.

One common use of rotary gear pumps is to pump fuel oil in oil burners. They can develop the stable high pressures needed to create the proper spray patterns when fuel oil is forced through the burner nozzles.

Another common use of rotary gear pumps is in the pumping of the high pressure hydraulic fluid which provides the power to operate hydraulic pistons on backhoes, loaders and other hydraulic equipment. These rotary gear pumps generate thousands of pounds of pressure under the steady conditions needed to move heavy loads under smooth and safe control.

Although rotary pumps are available in a wide variety of designs, most operate on the principle illustrated in Figure 2-6.

Gears A and B rotate in opposite directions as shown in **Figure 2-6**, one of which is turned from an outside source of power, trapping fluid between the teeth of the gears and moving it along the outer edges of the pump body to the upper chamber. As the fluid is moved ahead of the gear teeth into the upper chamber it is forced out the discharge opening.

As liquid becomes trapped between the gear teeth, and then discharged, a lower pressure is created in the suction chamber drawing in additional fluid from the suction piping. This operation produces an even and continuous flow. As in the case of reciprocating pumps, the capacity delivered is constant, regardless of pressure. Due to the necessary close clearance and metal-to-metal contact, such units naturally work best and last longer when pumping liquids having lubricating qualities. Rotary pumps are designed to operate at relatively slow speeds in order to maintain these clearances.

There are numerous other types of rotary pumps which operate on a similar principle as the rotary gear pump shown in **Figure 2-6**. They simply use other configurations for the rotating components, such as meshing screws, lobes, sliding vanes, etc. See **Figure 2-7**. These positive displacement pumps can maintain fairly even discharge rates over a wide range of pressures. They are often used for pumping viscous fluids. The lobe and sliding vane type rotary pumps are often used in refrigeration systems.

In both types of pumps, reciprocating and rotary, for every movement of the pump, a specific amount of liquid is discharged. For that reason they are grouped as positive displacement pumps. What is another classification of pumps?

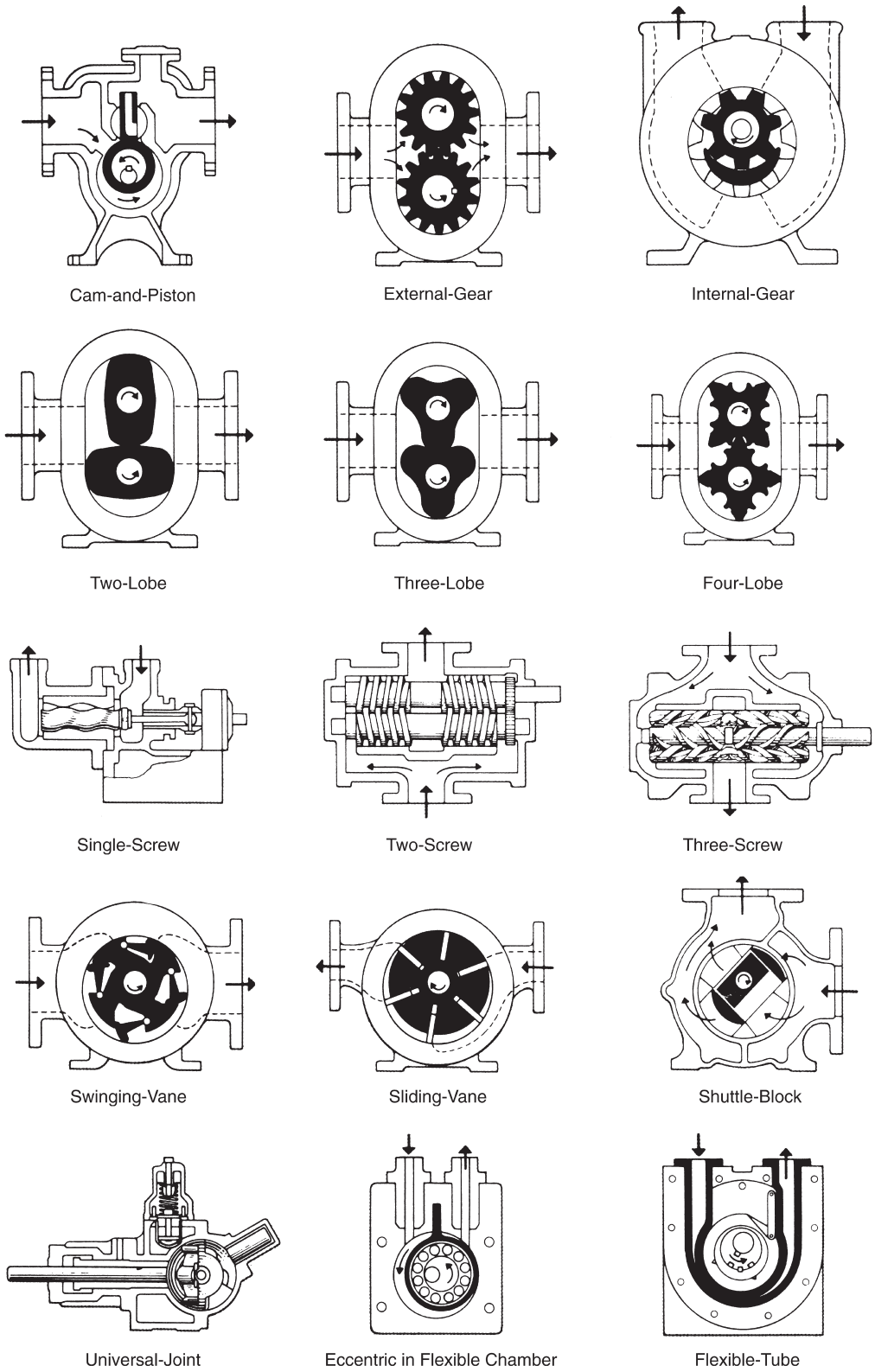
Another classification of pumps is *non-positive displacement* pumps. This would include centrifugal pumps, propeller pumps, and special pumps such as jet pumps and hydraulic rams, etc.

The common characteristic of non-positive displacement pumps is that they do not deliver a specific amount of fluid for every movement of the pump. Their discharge rates are directly affected by the amount of pressure in the systems they are supplying.

The most common type of non-positive displacement pump found in piping systems installed and serviced by UA journeyworkers is the centrifugal pump. See Figure 2-8. What are the characteristics of a centrifugal pump which make it so popular for use in piping systems?

There are a number of varieties available for the many different types of systems they may be used in. As a class they generally cost less and perform economically and reliably throughout various pressures and flow rates. They can produce up to several thousand feet of head, they can handle liquids up to 1000°F, and they can pump abrasives and solids.

They have few moving parts and if properly installed and serviced, will last a long time with little maintenance. See **Figure 2-9-A, B** and **C**. They also can be easily modified to change their performance if necessary. And they can tolerate considerable corrosion and erosion before their performance is substantially affected, depending on their use and in the type of piping system in which they are installed.

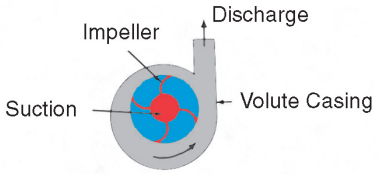


Types of Rotary Pumps

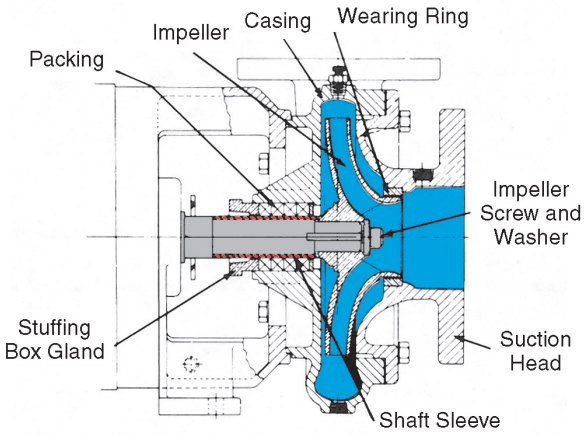
Fig. 2-7

Centrifugal Pump

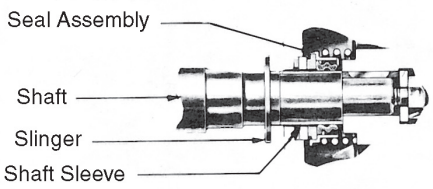
Fig. 2-8



A Volute-Type Centrifugal Pump



B Centrifugal Pump With Packing and Gland



C Centrifugal Pump With Mechanical Seal

Typical Construction of Centrifugal Pumps

Fig. 2-9

Never install an iron body in-line circulator or booster (centrifugal) pump in a potable water system. Because of air (oxygen) entrainment in a potable water system, a circulating pump with a bronze body must be used. However, in-line circulating pumps with an iron body can be used in a closed hot water (hydronic) heating system or in a combination heating/cooling system. How can oxygen cause corrosion in a domestic hot water supply system?

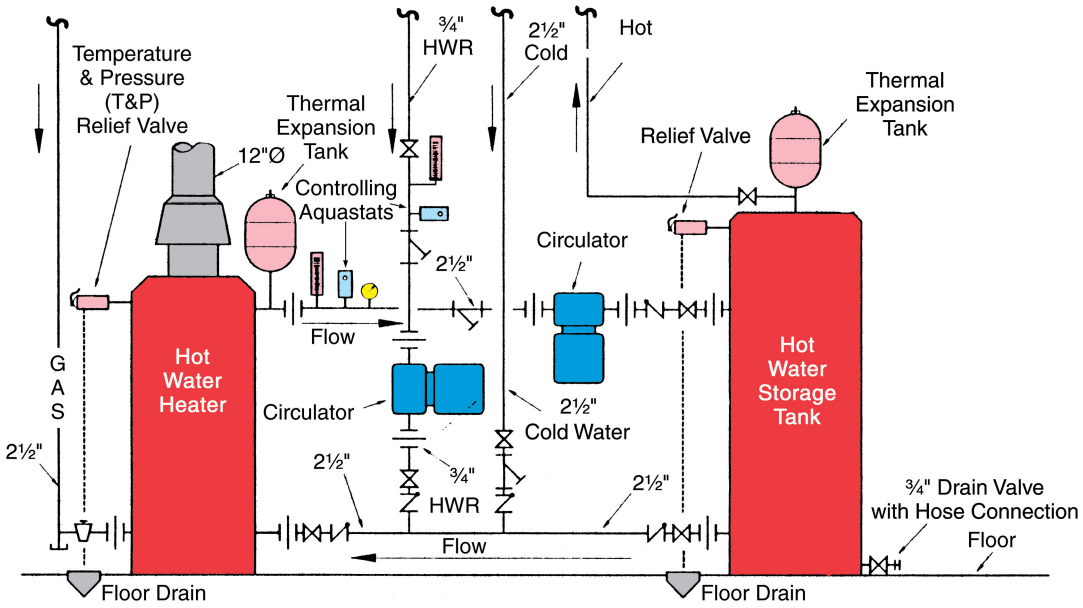
The building water supply can contain different minerals and dissolved gases, depending on the location and temperature of the water source. The gases can make the water corrosive and will, over a period of time, create the formation of rust on the inside of an iron body pump. As a result, rust will continue to accumulate and can stop the pump impeller from turning, thereby rendering it inoperable.

Air dissolved in water consists of about 30% oxygen the remainder is non-corrosive nitrogen). Given time, oxygen degrades ferrous metals through an electro-chemical process of internal oxidation. The metal gradually gets converted to an oxide, becoming thinner and weaker in the process. This results in rust, grooving and pitting, hot wall effect and fatigue, which are but a few ill effects of the overall process.

Four examples of systems using centrifugal (circulating) pumps are:

1. Hydronic hot water heating
2. Chilled water
3. Domestic hot water
4. Condenser water

See **Figure 2-10** for a typical application of centrifugal pumps in a domestic hot water system.



Centrifugal Pumps (Circulators) in Domestic Hot Water System

Fig. 2-10

Although there are many variations of centrifugal pump designs, they all employ centrifugal force to operate. What is centrifugal force?

Centrifugal force is the force generated by rotation which acts directly outward from the center of rotation. There are many examples of centrifugal force: one is the whirlpool created in the center of a spinning liquid; another is illustrated by the tendency for an automobile to move to the outside of a curve. A simple example is shown in **Figure 2-11**, where water remains in the bucket even when the bucket reaches the upside-down position.

Assume that you have a number of buckets rotating around a center, as in **Figure 2-12**, and that these buckets are bottomless. The result is a continuous pressure from the liquid in the buckets against the casing. In **Figure 2-13** the buckets are pie-shaped and in effect form a paddle wheel. As the wheel rotates, the liquid is forced to the outside causing pressure to be exerted on the casing. If you add an inlet and outlet, this force can be used to pump liquids.

Fig. 2-11

A centrifugal pump takes its liquid at the center of rotation of the impeller. The liquid is picked up by the impeller vanes and thrown outward, away from the center of rotation, into a casing or volute. See **Figure 2-14**.

The effectiveness of the vanes in a centrifugal pump is improved by shaping them with a curved backward slope as shown in **Figure 2-15**. The connected vanes are known as the impeller.

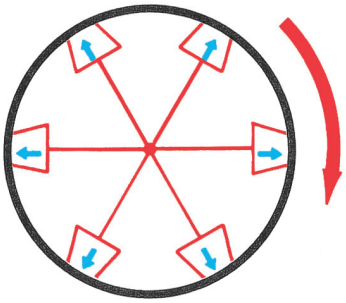


Fig. 2-12

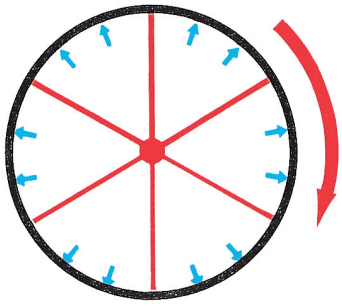


Fig. 2-13

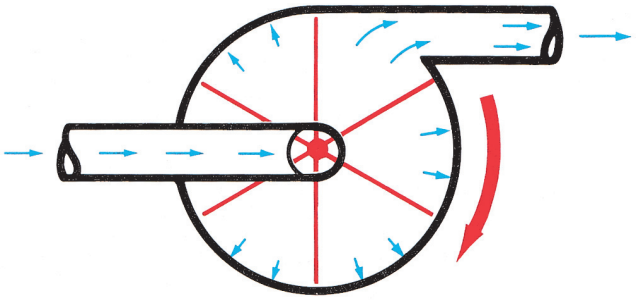


Fig. 2-14

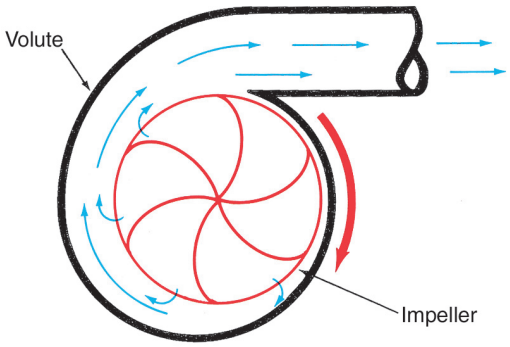


Fig. 2-15

Notice that the casing of the centrifugal pump shown in **Figure 2-16** expands gradually in the direction of rotation. This gradually expanding passage causes the flow velocity to be reduced as the fluid flows toward the pump discharge connection. This expanding casing, called a *volute* makes the pump operate more efficiently and gives the name to the *volute centrifugal* pump which is widely used throughout the piping industry.

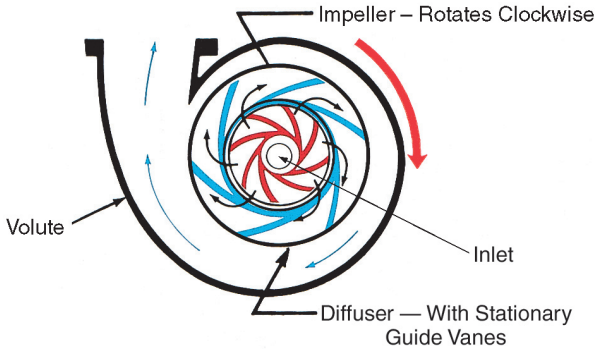


Fig. 2-16

Compare the inside of the casing of the pump in Figure 2-16 to the diffuser pump casing illustrated in Figure 2-17. What is the major difference in the design?

Diffusion or *turbine* type centrifugal pumps are applied to high pressures and, at times, in combination with high temperatures. They differ from the volute type in that the rotating impeller is surrounded within the casing by stationary guide vanes as shown in **Figure 2-17**. The diffusion vanes provide gradually expanding passages in which the direction of flow is sharply changed.

The velocity head becomes pressure head before the water reaches the circumference of the casing, and flows toward the discharge outlet. In the diffuser type casing, velocity head is thus more completely converted into pressure head than in the volute type, and its efficiency therefore may be slightly higher. The quantity of water pumped depends on the size of the suction and discharge lines, the size of the impeller and its speed.

Turbine pumps have long been recognized for their effectiveness in the areas of low flow, high head application. The turbine pump offers higher heads than centrifugal pumps.

Conventional centrifugal pumps, in contrast, must operate close to shutoff or operate at high speed to meet these high head, low flow requirements. This misapplication can cause high vibration, mechanical damage, frequent maintenance, and excessive energy use.

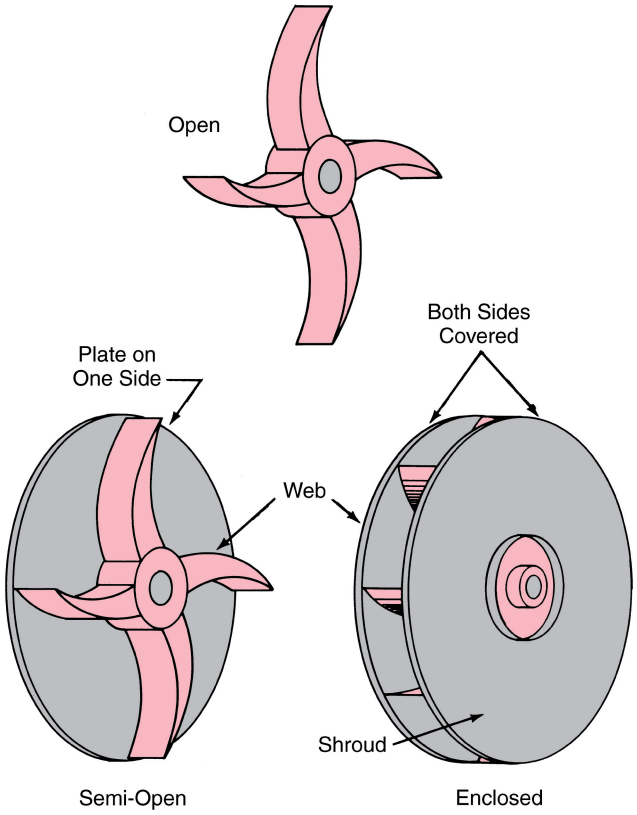
Turbine pumps having top centerline discharge are self-venting and have the ability to handle vapors without vapor lock. This characteristic allows handling of boiling liquids and liquefied gases at suction heads slightly over the vapor pressure.

Three kinds of impellers used in centrifugal pumps are shown in Figure 2-17.

The open impeller shown in **Figure 2-17** consists only of blades attached to a hub. The semi-open is constructed with a circular plate (the web) on the inside edge of the blades. The web adds strength and makes it possible to use thinner blades.

An enclosed impeller has, in addition to a *web*, a shroud attached to the outside of the blades. The liquid is held between the *shroud* and the *web*. This action reduces friction loss in the pump.

Although there are several other variations in impeller design, as in **Figure 2-18**, the three types shown in **Figure 2-17** are among the most commonly used. The enclosed impeller is more efficient and can create higher pressure. See **Figure 2-19**. However, it is limited to the pumping of relatively clear liquids. The semi-open and open, while each progressively less efficient, are capable of handling fluids with suspended solids such as might occur in pumping mud and water from a ditch or in pumping sewage.



Typical Impellers

Fig. 2-17

Open End Suction | Semi-Enclosed End Suction | Enclosed End-Suction | Enclosed Double-Suction | Paper Stock

Types of Centrifugal Pump Impellers

Fig. 2-18

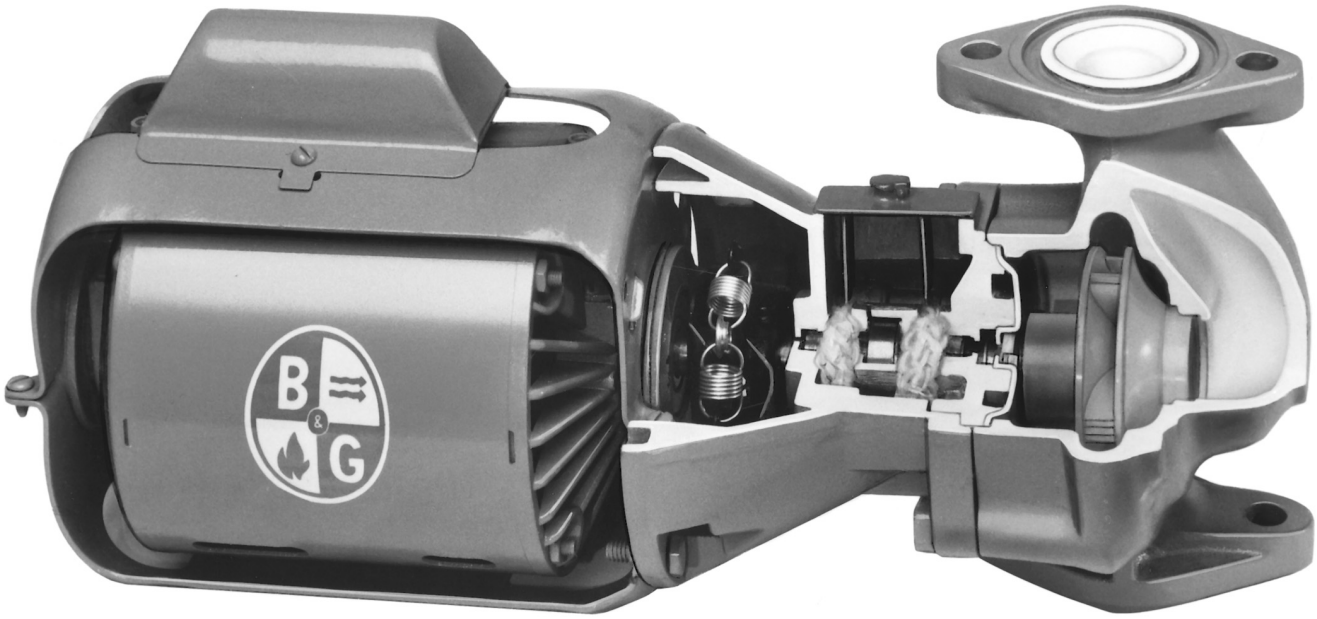


Illustration of Impeller in Centrifugal Booster Pump

Fig. 2-19

In order to begin pumping action the impellers must begin revolving (rotating) at the proper speed. If the pump has only air being rotated between the impeller blades, very little centrifugal force will be generated and very little suction or discharge force will be developed. In order for pumping action to begin the pump must first be primed, that is, the impeller must be immersed in liquid. Once the pump is primed, centrifugal action will generate the suction and discharge forces needed to pump the liquid.

The simplest priming occurs if the pump impeller is located below the suction piping. In that instance, when the suction piping is filled, the liquid will automatically flow into the *pump* casing as air is vented from it.

Where suction piping is below the level of the pump, the pump casing has to be filled by a separate source of liquid either piped to the empty chamber under pressure or manually filled through a priming connection above the level of the impeller.

In many water wells, the suction line is extended down vertically below the pump. How is the suction pipe kept full of water in order to maintain the prime?

Many shallow well installations have foot valves at the end of the suction pipe. There are many types of foot valves; the one selected for each installation should have a clear passage for water that is at least of the same area as the suction pipe. Basically, a foot valve is a check valve, sometimes located within a brass strainer body, at the foot (bottom) of the suction pipe. See **Figure 2-20**.

As previously stated, theoretically, water cannot be lifted by suction more than 34'. How then can a pump be made to retain its prime if the level of the water is below that limit?

This can be accomplished by the use of a deep well pump. For deep well pumping, the device

Typical Combination Foot Valves and Strainers

Fig. 2-20

which creates the suction must be immersed in the liquid. Three examples of deep well pumps are:

1. a *submersible* pump
2. a *reciprocating* pump
3. a *jet* pump

How does a submersible pump retain its prime?

As implied by its name, a submersible pump, including the motor, is completely immersed within the liquid it is pumping and, therefore, the impeller is always filled with liquid. It will retain its prime as long as the liquid being pumped is above the level of the pump suction inlet. Because pumped liquid lubricates and cools the submersible pump, it may become seriously damaged if allowed to run dry for any significant length of time. **Figure 2-21-A** shows a typical *deep well* submersible pump.

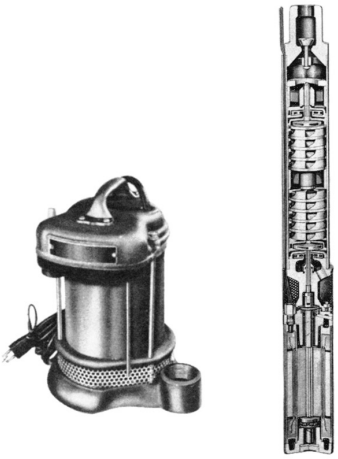
Describe the operation of a reciprocating pump.

A reciprocating pump (pump jack) similar to the one shown in **Figure 2-21-B**, creates suction inside of a drop pipe. Deep well reciprocating pumps are sometimes called *sucker rod pumps*, *stroke pumps*, *or working heads*. A working head is the most frequently used term. It has a v-belt driven gear box which contains the power end of the pump.

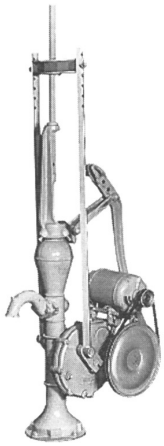
The gears transmit power from either an electric motor, or gas engine, mounted on the jack, to a lever which has one end projecting from the side of the working head. The outer end of the lever moves up and down making various length strokes. The stroke length, such as *8-inch stroke*, determines the size of the working head. A rod is connected to the lever which extends down in the well to a plunger. The plunger can be found in a cylinder located below the pumping water level. A check valve is located at the bottom of the cylinder. A drop pipe connects the working head to the cylinder. See **Figure 2-21-C**. The air pump shown in this illustration helps to prevent water logging of a pneumatic tank.

Sections of wooden rods (called pump or sucker rods) of various lengths and diameters as needed, are connected to each other by the use of threaded rod couplings. The rods are located inside of a drop pipe; one end connects to a plunger at the top of a cylinder and the opposite end is connected to the working head. See **Figure 2-21-D** and **E**.

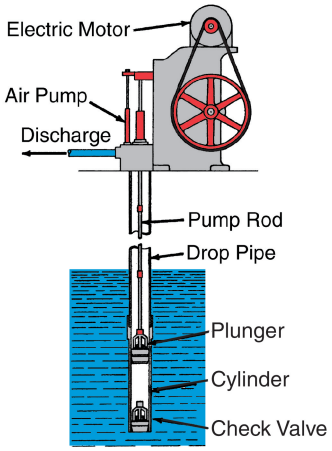
The up and down movement of the wooden rods makes the upper and lower plunger and check valve open and close simultaneously allowing water to enter the drop pipe. See **Figure 2-21-F**. The buildup of water inside the drop pipe due to this action is forced up through the drop pipe to the discharge outlet on the working head. The water in the drop pipe also serves the purpose of priming the pump. The pump jack shown in **Figure 2-21-B** is a pumping unit which consists of a helical gear speed reducer, driving two pumping arms (cranks). The arms are connected to the pump rod by two pumping angles and a crosshead.



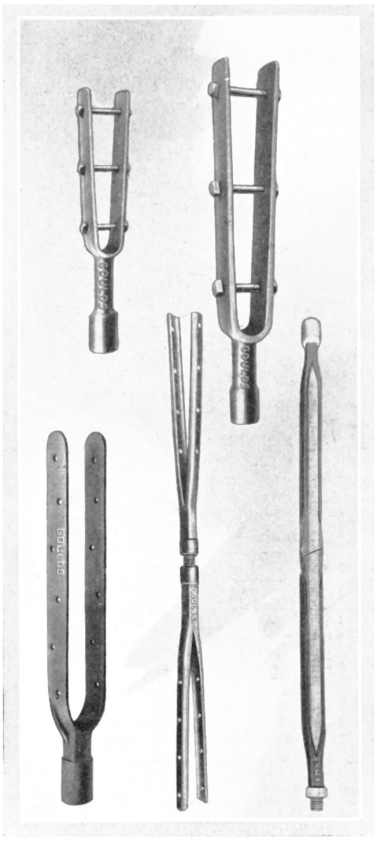
A Submersible Pump



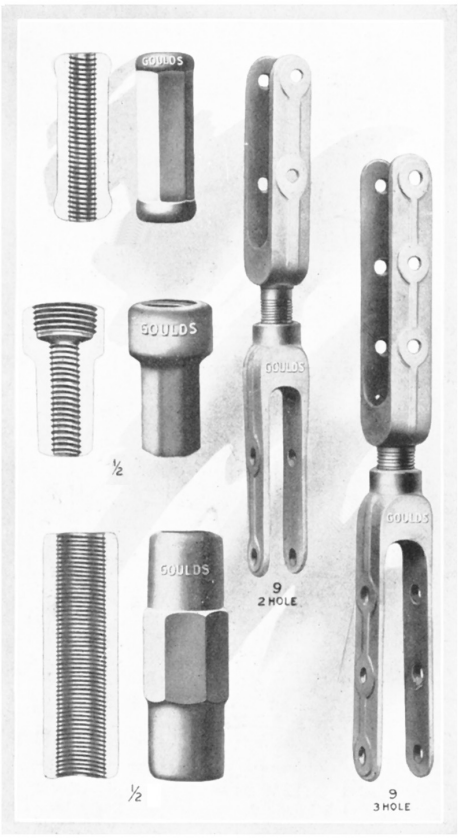
B Pump Jack



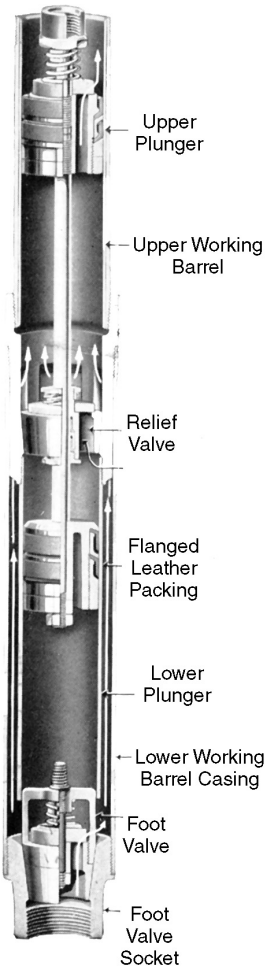
C Typical Reciprocating Pump Installation



D Wood Rod and Wood Rod Couplings



E Iron and Wood Rod Couplings



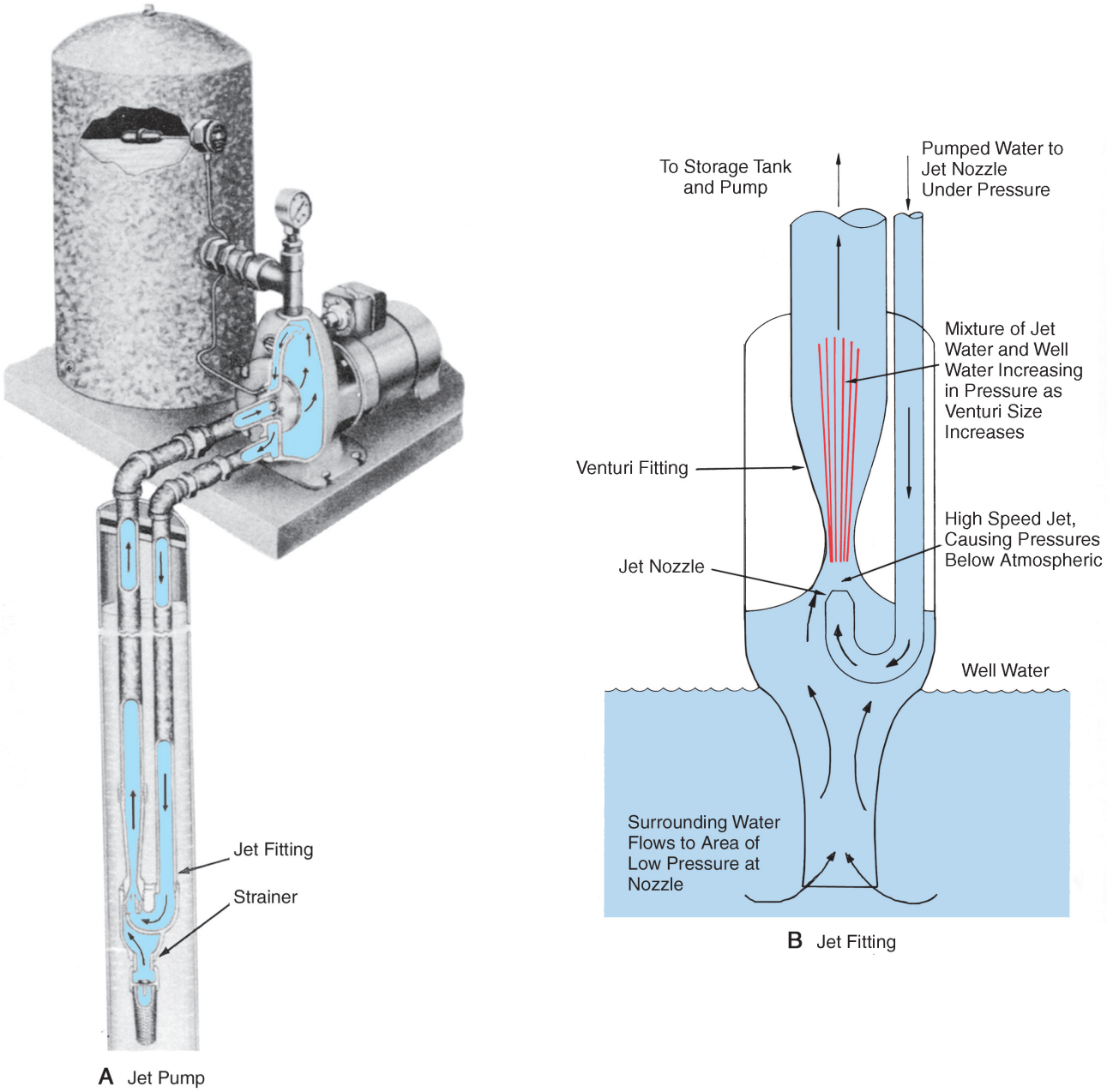
F Double Acting Deep Well Cylinder

Examples of the Components of Deep Well Pumping Units

Fig. 2-21

Jet pumps function by use of a suction creating device (the jet fitting) within the liquid being pumped as illustrated in Figure 2-22. Describe the operation of a jet pump.

Figure 2-22-A shows a typical jet pump where the centrifugal pump sends a portion of its discharge to the jet fitting where, as illustrated in **Figure 2-22-B**, a partial vacuum is formed by the high velocity fluid discharge from the jet nozzle. After the water passes through the restriction into the expanding venturi fitting the velocity decreases with a corresponding increase in pressure. This increase in pressure is used to push the water to within the limits of the centrifugal pump suction lift.



A Jet Pump

B Jet Fitting

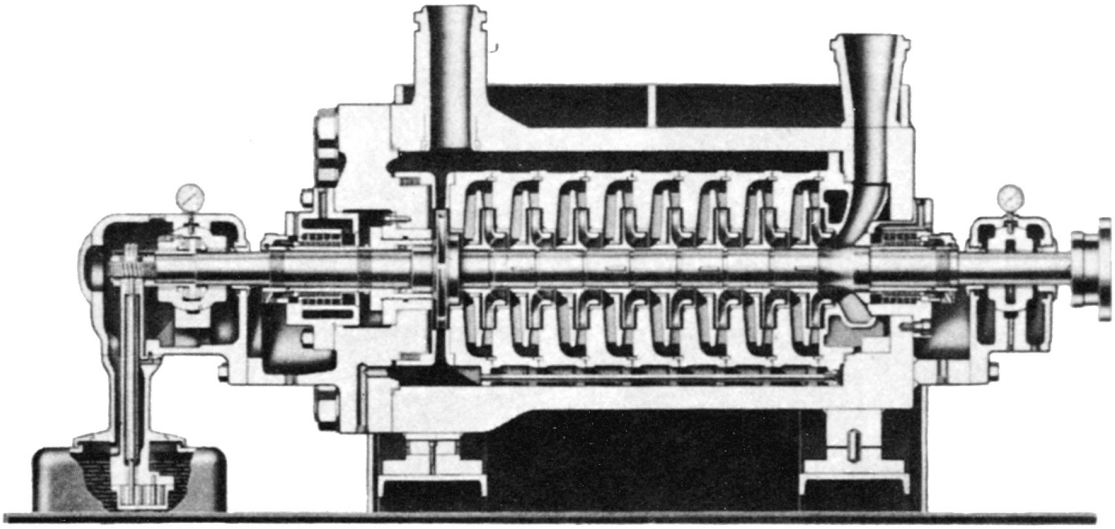
Typical Jet Pump and Jet Fitting

Fig. 2-22

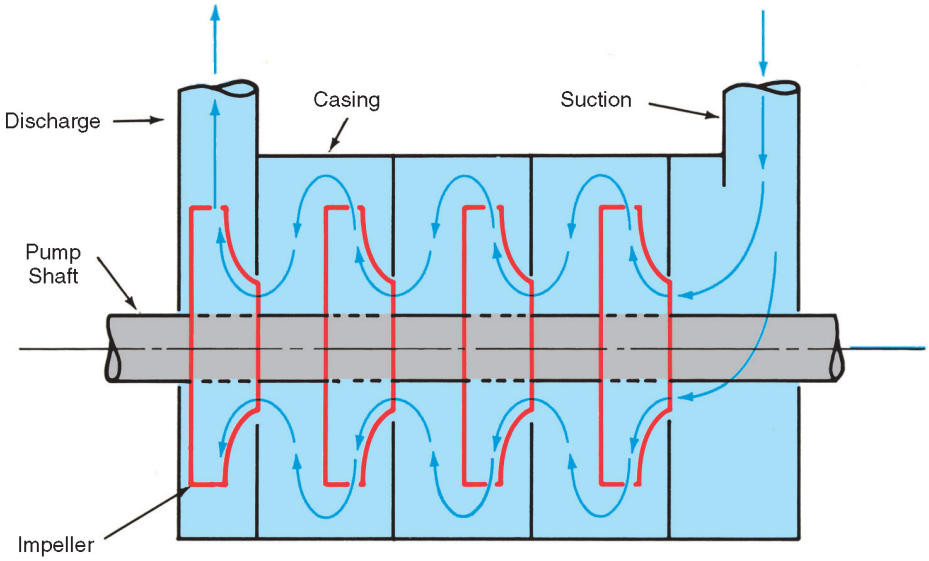
Figure 2-23-A illustrates a typical high pressure multistage pump. What is a multistage pump?

A multistage centrifugal pump is essentially a high head or high-pressure pump; it consists of two or more stages, depending on the pressure that is required in the system. Each stage is essentially a separate pump, they are located in the same housing and the impellers are attached to the same shaft. Two or more stages may be found in a single housing.

The initial or first stage receives the water directly from the source through the suction pipe, builds the pressure up to the correct single-stage pressure, and passes it onward to the succeeding stage. In each succeeding stage, the pressure is in-



A High Pressure Multistage Boiler Feed Pump



B Flow Schemetic of Multistage Pump

Example of a Multistage Pump

Fig. 2-23

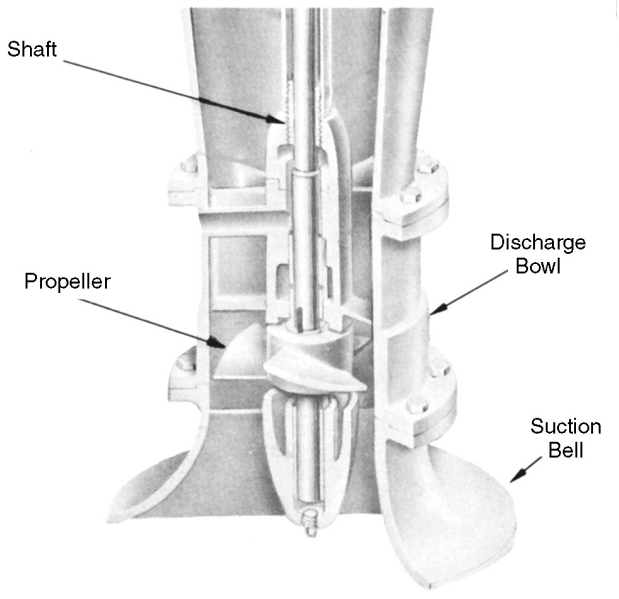
creased or built up until the water is delivered from the final stage at the pressure and volume the pump is designed to deliver. See **Figure 2-23-B**.

Multistage pumps are used for continuous high pressure and high capacity service such as for handling hot or cold liquids, industrial, process piping and boiler feed water.

When the name propeller pump was adopted it probably had reference to the similarity in appearance and function between the pump's impeller (propeller) and a ship's propeller. Explain.

In the first propeller pumps, the liquid entered the pump parallel to the shaft or axis of the pump, passed through the impeller axially and left through the discharge still in an axial direction. The pressure of the liquid was increased by the propelling or lifting effect of the vanes of the impeller on the liquid.

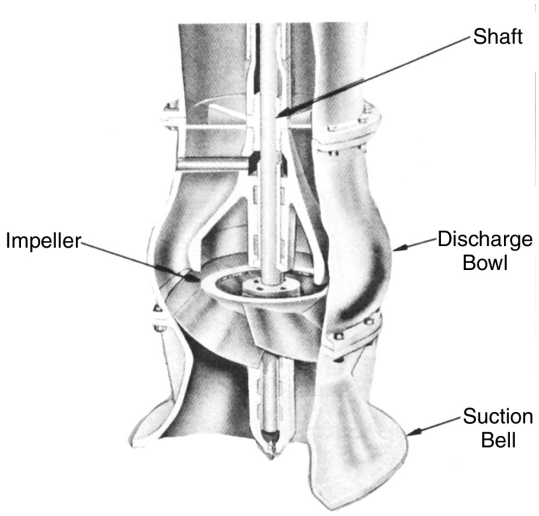
The present day axial flow propeller pump, shown in **Figure 2-24**, still functions in this manner. The pressures developed by such a pump are low. To increase the pressure capability of the propeller pump, it is necessary to have part of the energy imparted to the liquid by centrifugal force.



Axial Flow — Propeller Pump

Fig. 2-24

In such a pump the liquid no longer moves straight axially through the pump but, when passing through the impeller, the liquid moves axially away from the center of rotation. To differentiate this design from the axial flow type, it is called a mixed flow propeller pump and is illustrated in **Figure 2-25**.



Mixed Flow — Propeller Pump

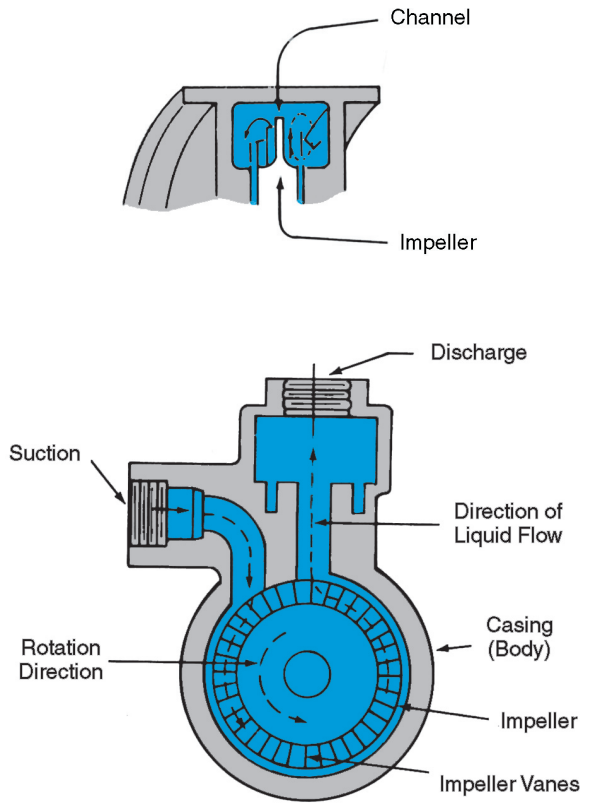
Fig. 2-25

A schematic drawing of a peripheral pump is shown in Figure 2-26. Give a brief description concerning the operation of a peripheral pump.

In this type pump, the liquid does not enter at the center of rotation but at the periphery of rotation and all the energy is imparted to the liquid at the periphery. It is, therefore, classified as a non-positive displacement pump, peripheral type. The liquid enters the impeller at its periphery opposite the suction opening of the pump.

The short impeller vane, operating in the channel in the body of the pump, causes the liquid to be thrown away from the center of rotation by centrifugal force. The channel reverses this flow and again the liquid is fed into the impeller vane farther around the channel in the direction of rotation.

The result is that the liquid flows through the pump in a circular spiral pattern continuously receiving energy and building up pressure as it moves from the suction toward the discharge of the pump.



Peripheral Pump

Fig. 2-26

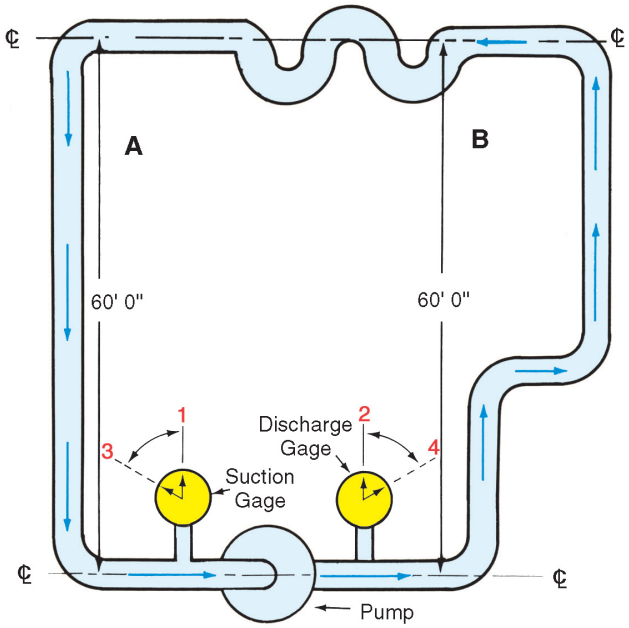
CHECKPOINT 1

At this point go back to page 9 for a review to see how thoroughly you have learned the material presented. This review is important to help you understand and retain what you have studied. When satisfied that you understand the material covered, answer the questions on the assignment sheet and then proceed to checkpoint 2.

The closed system shown in Figure 2-27 is similar to the systems shown in Figures 1-6 and 1-7 in Chapter 1, that were open to atmospheric pressure. In the open system the pressure gages on either side of the pump had different readings. What is the relationship between the readings on the suction and discharge gages in Figure 2-27?

Because both the discharge piping and the suction piping are connected into a closed loop or system, and the system is static (no flow) the pressure on both sides of the pump illustrated as heads "1" and "2" are the same, and the pressures at "1" and "2" on the gages will read the same.

When there is no flow (static conditions) in a system, there obviously is no friction loss. As flow occurs there is a corresponding friction loss which must be overcome by the pump. Therefore, in **Figure 2-27**, under flow conditions (dynamic) you would see the discharge pressure *increase* from point "2" to point "4" on the discharge gage. And simultaneously the suction pressure *would decrease* from point "1" to point "3" on the suction gage.



Relationship Between Suction and Discharge on a Closed System

Fig. 2-27

What can you tell from these changes in pressure at the suction and discharge gages?

In the closed loop system, in **Figure 2-27**, the total of the changes in pressure on the pump gages is equal to the *additional* head developed under flow conditions due to friction losses within the

system. Since both gages start at the same pressure, simply add the change at the suction gage to the change at the discharge gage to arrive at a single total change in pressure across the pump.

The symbol for this change in pressure between the suction and discharge of the pump is ΔP. (Δ is the Greek letter *delta* and it is used here to represent *change* in pressure). In a closed system ΔP represents the increase in head generated by the pump in order to overcome the resistance (or pressure drop) throughout the entire system due to friction loss.

In Figure 2-27, under static conditions, what is the pressure on the suction and discharge gages?

Because it is a closed system, the *static suction head* "A," and *static discharge head* "B" are equal. Therefore, the reading on both the suction and discharge gages would be the same; the head on both the suction and discharge side of the pump equals 60: the equivalent of 60' head in psig, or, 60' x 0.433 psig/ft. = 25.98 *psig*.

With each pressure gage reading 25.98 psig there is no ΔP (no pressure change) across the pump, and this indicates a no-flow condition.

What is the total change in head, if the system in Figure 2-27 is under flow conditions and the suction gage reads 7 psig lower (point "1" to point "3"), and the discharge gage reads 10 psig higher (point "2" to point "4")?

The total change in head would be the sum of the two changes in pressure.

Suction pressure change	=	7 psig
Discharge pressure change	=	10 psig
Total change in pressure	=	17 psig

This total change in pressure is the ΔP across the pump caused by the flowing liquid generating a friction loss in the system.

How can the friction loss within the system in Figure 2-27, be calculated without knowing the static pressure?

Since the suction and discharge pressures were equal under static conditions, simply calculate the difference between the operating pressure indicated on the suction head gage and the operating pressure on the discharge head gage. This difference is the ΔP or pressure change.

The ΔP expressed as head is 39.26'.

$$\frac{17 \text{ psig } (\Delta P)}{.433 \text{ psig/ft.}} = 39.26'$$

The head of 39.26' is equal to the friction head of the entire system shown in **Figure 2-27**. It is also the head produced by the pump to overcome that friction head (loss), and is known as the *total dynamic head* (TDH).

This TDH is a direct representation of the performance of the pump at a specific flow rate and is a very useful tool during start-up, testing and balancing and in troubleshooting pump performance.

Note: Although there may be some change in velocity head due to the discharge pipe being a smaller size than the suction pipe, for practical purposes these head changes can usually be considered negligible.

How do variations in head pressure affect the flow rate of a pump?

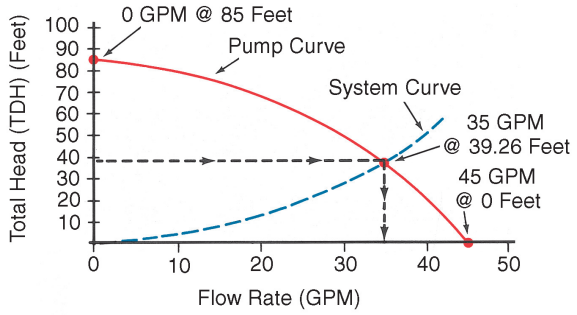
It is readily discernible that as total head increases, flow rate decreases. Conversely, as the total head becomes lower, the flow rate increases. The discharge rate of centrifugal pumps will vary according to the amount of system pressure being pumped against (ΔP). This relationship of flow to system pressure is described graphically for each individual pump through a diagram called a *pump curve*.

The line designated as *pump curve* in **Figure 2-28**, is simply the connection of a number of points the pump would operate at for a certain constant speed of rotation. This line shows the pump varying from zero gpm flow rate at 85' of head to 45

gpm flow rate at zero feet of head. Pump curves are developed by the manufacturer by testing each particular size and type of pump, and this information is published in catalog data for use by designers and operators of this equipment.

From the closed system in Figure 2-27, you determined that the pump was producing a ΔP of 39.26'. If the pump curve in Figure 2-28 represents the performance characteristics of the pump in Figure 2-27, what is the flow rate within the system?

Using the typical pump curve in **Figure 2-28**, first plot the 39.26' ΔP on the total head scale and then read across the chart (see dashed line) until the head reading intersects with the *pump curve*. From that point of intersection, read down to the flow scale. The flow rate is 35 gpm.



Typical Centrifugal Pump Performance Curve

Fig. 2-28

Note: Figure 2-28 is a theoretical pump curve for illustration purposes only. It is intended to indicate trends of performance of a theoretical centrifugal pump, not the actual performance of any pump.

By determining ΔP (change in pressure) and plotting this information on a performance curve of the pump being installed or serviced, the journeyworker can readily determine the flow rate being developed. This information is useful in analyzing the performance of pumping systems.

System resistance (which is the total resistance of a piping system) can be calculated from the length of the pipe and the number and style of fittings. However, the actual system resistance is often different than the calculated system resistance due to changes in piping arrangements in the as-built system. How can the actual system resistance be determined?

The previous information discussed how the actual pump capacity can be determined by measuring the ΔP (pressure change) across the pump. This pressure differential is also a direct measurement of the actual system resistance being developed at the particular flow rate the pump is producing.

In the piping system illustrated in **Figure 2-27**, this *system resistance* would be the sum of the resistances of all the piping, fittings, and equipment (coil), from the pump discharge connection throughout the entire loop back to the pump suction connection. Because this resistance varies with the flow rate, the various system resistance points for each flow rate can be plotted on the pump curve diagram.

When all of the resistance flow points are connected this line becomes the *system curve*. As shown in **Figure 2-28**, the system resistance varies from 39.26' at 35 GPM to 0' at 0 GPM for the actual piping system illustrated in **Figure 2-27**.

Frequently a pump selected for the designed system resistance may not operate at the designed flow capacity. How can the performance of a centrifugal pump be altered to provide the specified flow?

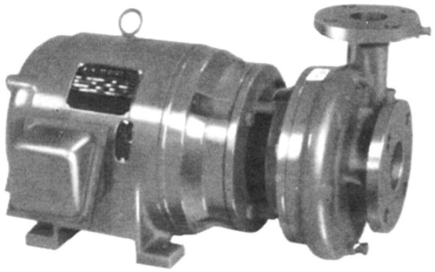
1. By changing the rotational speed (RPM)
2. By changing the diameter of the impeller
3. By changing the style of the impeller

Although centrifugal pumps operate in a similar manner, there are a great many variations in how they are constructed and mounted in a piping system. Give a brief description of the different styles of pumps shown in Figure 2-29-A through F.

A

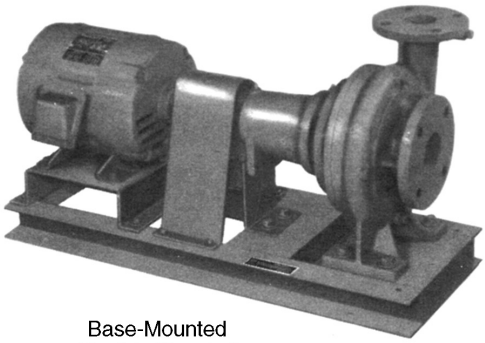
Close Coupled In-Line
Circulator

B



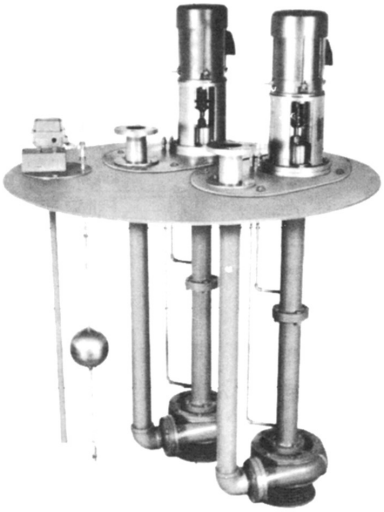
Close Coupled
Base-Mounted Pump

C



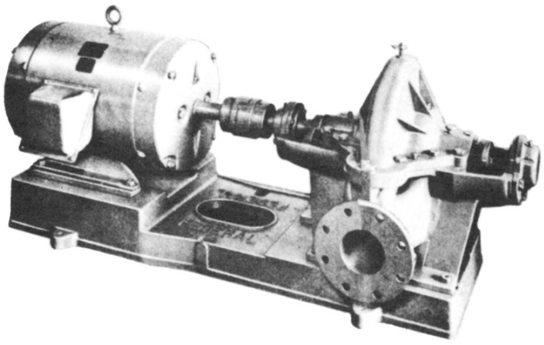
Base-Mounted
Flexible Coupled
Vertical Split Case Pump

D



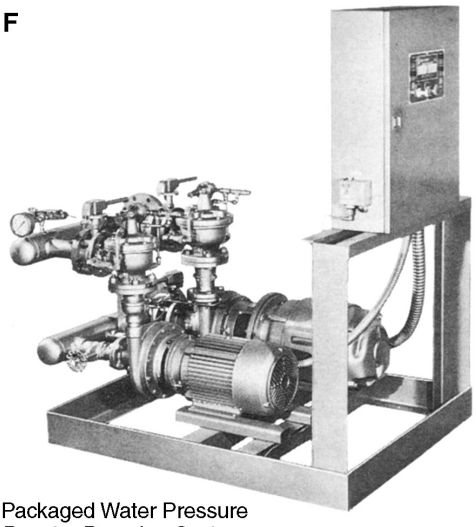
Wet Pit Pumps

E



Multistage Pump With Horizontally Split Case

F



Packaged Water Pressure
Booster Pumping System

Different Styles and Applications of Centrifugal Pumps

Fig. 2-29

Figure 2-29-A shows a pump which is mounted directly to the motor on a common shaft. It also mounts directly in the pipeline. Thus, the name *close coupled in-line* circulator.

Figure 2-29-B shows another close coupled pump, but one which mounts on a base rather than being supported by the piping.

Figure 2-29-C shows a larger style centrifugal pump which has a separate motor shaft which transmits its driving force to the pump shaft through a flexible coupling. This type of pump is frequently mounted on a special foundation as discussed in the next chapter.

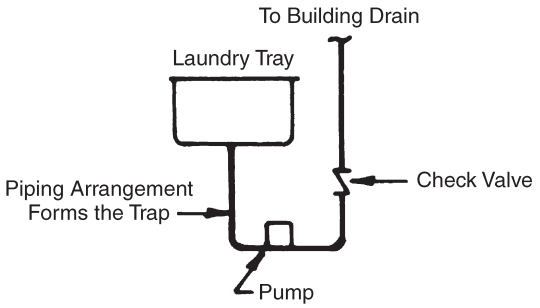
Figure 2-29-D shows a style of pump where the body of the pump is immersed in the liquid in a pit, and is connected by a long shaft to the motor which is mounted above the pit. This type is used for sump pumps, sewage pumps, condensate pumps, etc.

Figure 2-29-E shows a large base mounted pump with the casing split horizontally for easy access to the impeller for service.

Figure 2-29-F shows a packaged water pressure booster pumping system which includes two (duplex) centrifugal pumps, control valves, piping and electrical controls. This type of pumping system is used to boost the pressure in domestic water systems when the pressure in the public water mains is not high enough to supply the building adequately.

Provide an explanation concerning the installation and use of an individual fixture ejector or pump.

Individual fixtures other than water closets, urinals, or similar fixtures may discharge directly into an approved fixture mounted ejector or approved pump, or into receptors with ejectors or pumps. The discharge piping from the ejector or pump must have a check valve to prevent the discharged water from returning to the ejector or pump. The discharge piping shall be sized on a hydraulic basis consistent with the ejector or pump capabilities to the point where the discharge enters the gravity drainage system. Direct mounted equipment may be manually or automatically operated. Installation of either type of equipment is usually *not* subject to venting requirements, but subject only to venting necessary for proper operation of the equipment; the vent on the fixture side of the trap may terminate locally in the area served. If the equipment provides a proper waterseal, additional traps are not required. See **Figure 2-30**. Check state, local or provincial code requirements.



Example of a Laundry Tray with Pump

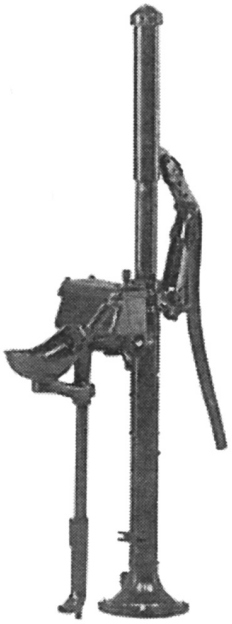
Fig. 2-30

Provide a list of several types and styles of pumps used in piping systems which were not mentioned earlier in this chapter. Include a brief description of their application in piping systems.

The drinking fountain pump shown in **Figure 2-31** is used on golf courses, campgrounds, roadside parks and picnic areas. A few strokes of the handle fills a reservoir with water which, without further pumping becomes a smooth flowing drinking fountain. A spring-loaded hand-lift valve allows water from the reservoir to flow out a hydrant for filling a jug or bucket. The pump stand is secure from contamination. All interior surfaces are inclined for complete drainage. All access holes are screened for vermin resistance. The drain pipe is anchored at ground level, into the pumps concrete foundation, to prevent abuse.

The hand pump shown in **Figure 2-32-A** is for windmill, pump jack or hand pump use. These lift pumps have adjustable strokes. They can be used to depths of 200'. This pump is recommended for shallow wells less than 25', has a 6" stroke only and a multi-position cap.

The closed spout cast iron cistern pump shown in **Figure 2-32-B** can be used for shallow pumping applications.



Drinking Fountain Pump

Fig. 2-31

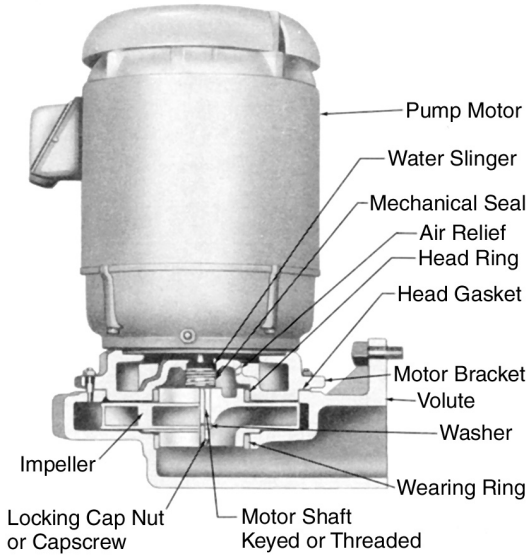
A Pump Jack

B Cistern Pump

Types of Hand Pumps

Fig. 2-32

See **Figure 2-33**. Mechanical seal type centrifugal pump. These close coupled vertical centrifugal pumps are equipped with mechanical seals. If system has not been properly cleaned prior to installation of pump, foreign matter such as dirt, pipe scale, core sand, etc. may clog the impeller and damage the seal. A strainer is recommended in return line to pump. *Pump must not be operated dry*. Seals may be damaged if operated without water present.



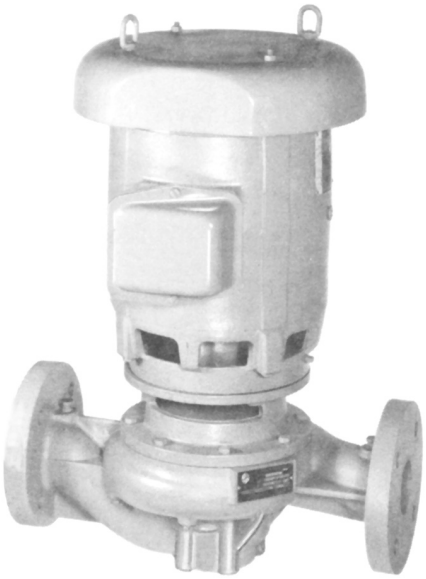
Cutaway View of Mechanical Seal Type Centrifugal Pump

Fig. 2-33

See **Figure 2-34**. In-line mounted centrifugal pump with flange connections. This centrifugal pump is a close coupled pump which features high efficiency, rugged construction and in-line mounting.

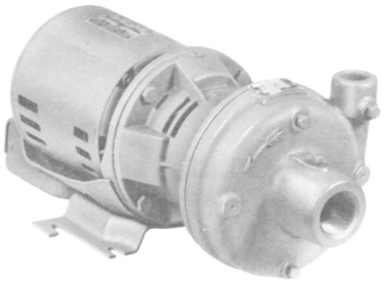
See **Figure 2-35**. Base mounted end suction centrifugal pump with threaded connections. The pump should be placed as near as possible to the source of supply, particularly when operating with a suction lift and located to permit installation with the fewest possible number of bends or elbows in the suction pipe. The maximum suction-lift should not exceed 15', including friction losses.

See **Figure 2-36**. Base mounted end suction centrifugal pump with threaded connections. This is a close coupled pump which features foot



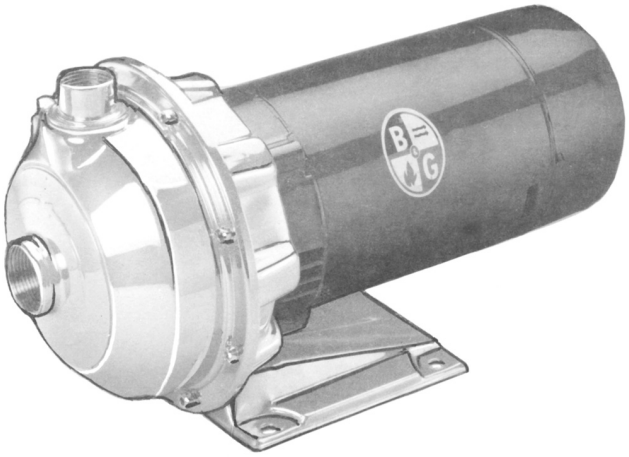
In-Line

Fig. 2-34



Base Mounted — End Suction

Fig. 2-35



Base Mounted — End Suction

Fig. 2-36

Bottom-Side Suction/Top-Side Discharge

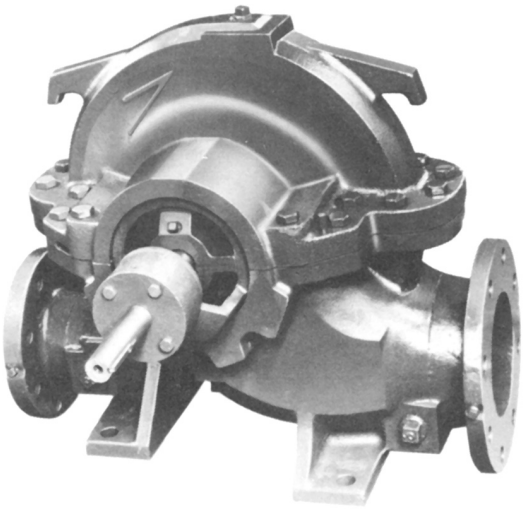
Fig. 2-37

mounting, light weight design, pump casing with top centerline discharge and self flushing mechanical seal. These features make installation, operation and service easy to perform. It's stainless steel construction makes it ideal for service with the following liquids: domestic water, fresh water, boiler feed water, condensate, hydronic cooling or heating, pressure boosting, general pumping and benign liquids.

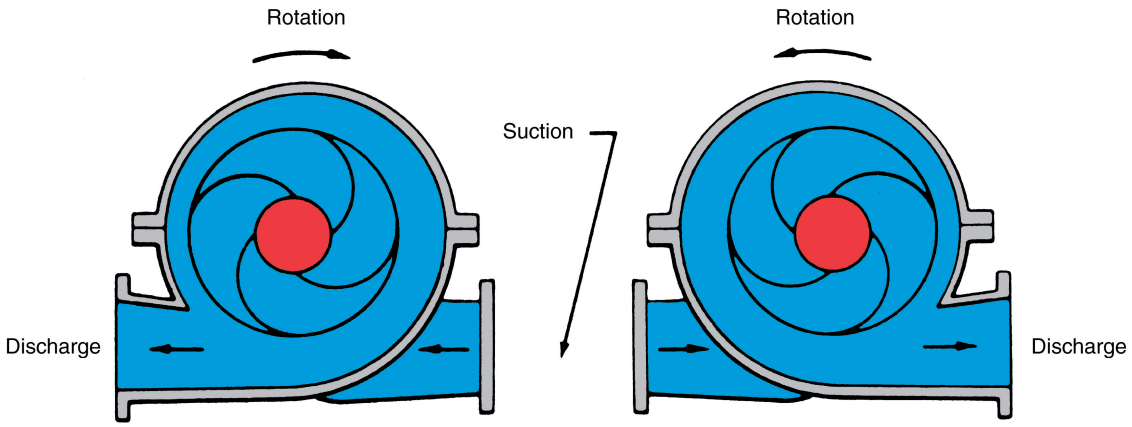
See **Figure 2-37**. Bottom (side) suction with top (side) discharge type centrifugal pump. If this pump is *not* installed in a closed system, it should be placed as near as possible to the source of supply, and located to permit installation with the fewest number of bends or elbows in the suction pipe.

A base mounted centrifugal pump with flanged suction and discharge openings is shown in **Figure 2-38-A**. This pump can be operated clockwise or counterclockwise when viewed from the pump end of the pump. If you wish to reverse the suction and discharge nozzles as shown in **Figure 2-38-B** and **C**, this can be accomplished as follows:

1. Remove the impeller from the shaft, turn it 180° and replace it on the shaft.
2. With the rotating element out of the casing, remove the casing from the bedplate and turn 180°.



A Base Mounted Centrifugal Pump



B Left Hand Rotation Viewed from the Pump end

C Right Hand Rotation Viewed from the Pump end

Reversing Suction and Discharge Nozzles

Fig. 2-38

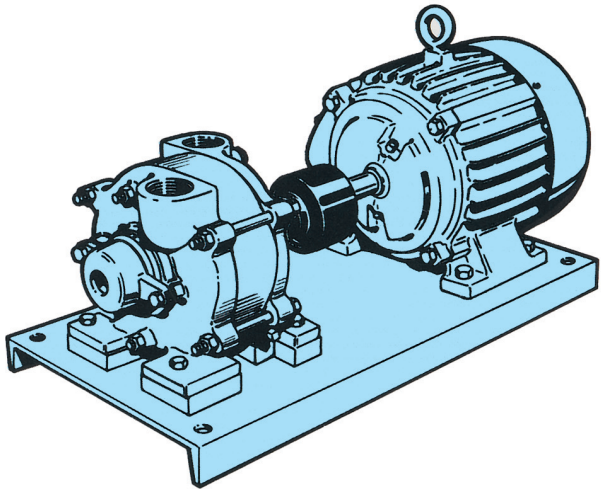
3. Set the rotating element back in the casing and reassemble the pump.

It should be located on a concrete floor with subsoil underneath and with plenty of room for inspection, maintenance and service. If the use of a hoist or tackle is needed allow sufficient head room.

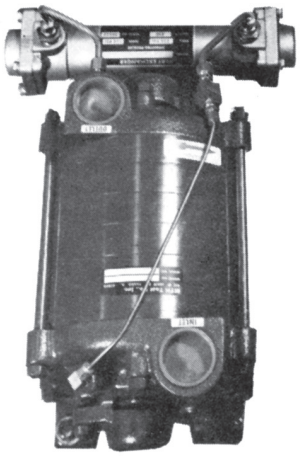
The turbine pumps shown in **Figure 2-39-A** through **E**, are available in single, two, three or four stage models. They are generally used for low flow applications involving high pressures such as boiler feed water systems, etc. See **Figure 2-39**.

What type pump is used by pipe trades journeyworkers to extract air from a vessel or system?

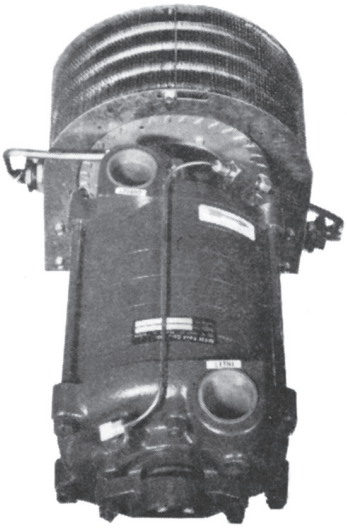
A vacuum pump is used to exhaust air from a vessel or system to create a pressure condition below that of the atmosphere. Vacuum pumps, such as the one shown in **Figure 2-40** are used to evacuate refrigeration systems. Vacuum pumps used for this purpose are usually of the piston or vane type. In the latter type, displacement is accomplished by means of sliding vanes. As **Figure 2-40** shows, these vanes seal against the cylinder. As the rotor turns, the air is compressed and forced out through the discharge port. At the same



A Regenerative Turbine Pump



B



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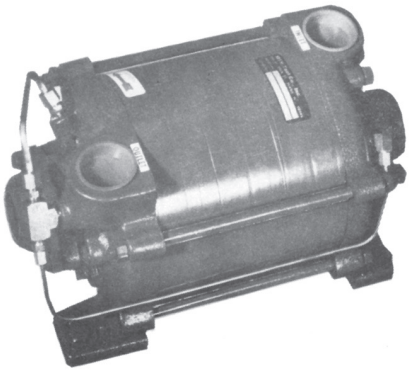

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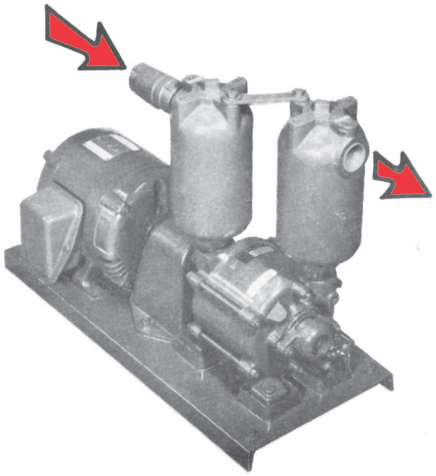
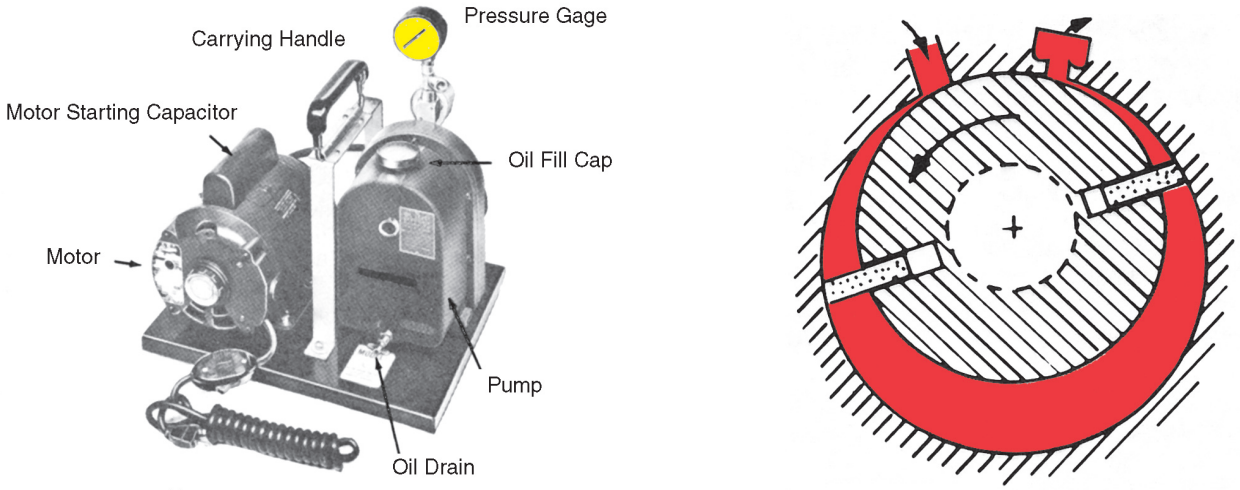


E

Types of Turbine Pumps

Fig. 2-39



A Vacuum Pump for Evacuation of Refrigeration System

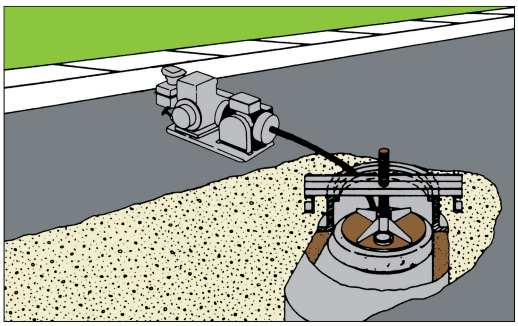
B Sliding Vane

Typical Vacuum Pump used to Evacuate a Refrigeration System

Fig. 2-40

time, the suction air is flowing into the cylinder. As the shaft rotates, the vanes move in and out always separating the suction from the discharge air.

Leak testing of a manhole can be accomplished using a vacuum pump. See Figure 2-41. Hydraulic pressure or hydrostatic test pumps are used to test piping systems installed by pipe trades journeyworkers. Describe the operation and use of a power driven hydrostatic and a hand operated test pump.

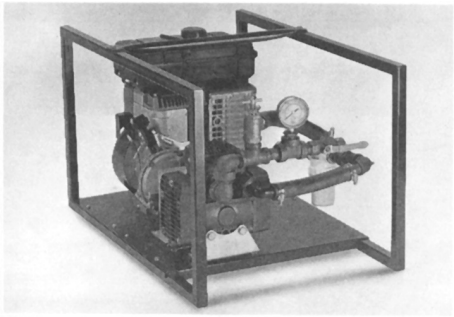


Manhole Leak Testing with a Vacuum Pump

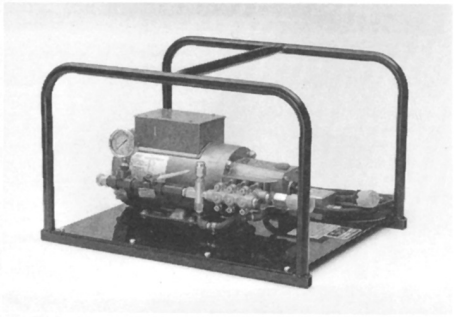
Fig. 2-41

The power driven hydrostatic test pumps shown in **Figures 2-42-A** and **B**, can be used to test newly installed or repaired water lines, commercial sprinkler systems, pressure vessels, etc.

1. Read manufacturing data on the engine, relief valve, and surge tank as applicable.
2. Check oil level in crank case.
3. Do *not* use test pump to fill pipe that is to be tested. The line should be filled by some other means.
4. Do *not* use water from a muddy ditch or rusty barrel. Do not remove intake line strainer except to clean. Sand and other contaminants will damage pump.
5. When drawing from a drum, be sure the intake hose is *not* resting against the wall of the drum, restricting the intake suction.
6. Do *not* use hose or fittings which are rated for less than the test pressure being used.
7. Do *not* run pump dry.
8. Do *not* tamper with engine setting.



A Gasoline Engine Powered



B Electric Motor Powered

Power Driven Hydrostatic Test Pumps

Fig. 2-42

9. Do *not* pump chlorine solutions unless unit is designed for use with chlorine. Chlorine can damage the pump and valve seals.
10. Connect water source to intake side and high pressure hose provided with unit to the pressure side.
11. Open all valves and purge air out of system. Prime pump if you are drafting water out of a tank.
12. Start engine. As pressure builds, adjust relief/unloader valve for desired test pressure, as indicated on the pressure gage. If you turn the relief hand valve screw clockwise, it increases the pressure. If it is turned counterclockwise, it decreases the pressure.
13. When you reach the desired pressure, close the ball valve and shut off engine.
14. System is *not* isolated and leaks can be detected by watching the gage for pressure drop.
15. Do *not* use test pressure higher than unit rating.
16. When you have finished using the unit and are going to store it until the next job, run a 50/50 water/anti-freeze solution through it. This will lubricate the pump and prevent rust.

Hand operated hydrostatic test pumps are shown in **Fig. 2-43-A** and **B**. They can be used for testing residential water lines and pressure testing small pressure tanks, sprinkler, hydronic heating and solar piping systems.

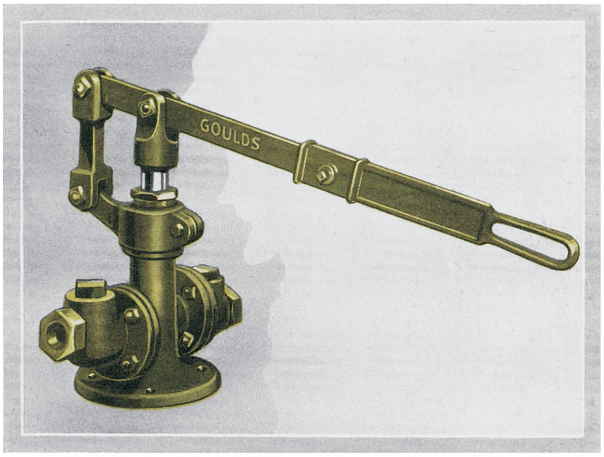
Siphon Method

1. Use a filtered hose.
2. Fill the water line to be tested.
3. Place the intake hose into your source, and pump (the unit is self-priming). Continue to pump until you see water coming out of the outlet, with little or no air mixed with it.
4. Connect the output hose to the water line. Continue with Step 5 below.

City Water Method

1. Connect the output hose to water line being tested.
2. Connect input hose to city water.
3. Open valve and turn on water.
4. Bring line to pressure by pumping handle.
5. Watch the gage while pumping. Close the valve about 90 degrees when approaching the desired pressure. As soon as the desired pressure is reached, shutoff the valve completely.
6. If pressure drops off, there is a leak in the line.

Caution: This pump is designed for water only! If the relief valve becomes stuck (water comes out of the relief valve while pumping, without building up pressure); close the valve and pump the handle quickly (be careful *not* to pump too fast as you might spike the gage) until pressure can increase without water being released from the relief valve.



A Hand Operated Hydraulic Pressure Test Pump

B Hand Operated Test Pump

Hand Operated Test Pumps

Fig. 2-43

CHECKPOINT 2

Go back to checkpoint 1 for a review as previously instructed. When satisfied that you understand the material covered, answer the questions on the assignment sheet.

NOTES

CHAPTER

3

Pump Installation

Procedure: Study the pages which have been assigned by your instructor and answer the questions on the assignment sheet(s) which will be distributed to you.

The first consideration for locating a pump is elevation. The lowest possible elevation is usually the best. This should *not* be in conflict, however, with the second recommendation that suction piping be as short as possible. Questions regarding possible locations should be resolved by checking inlet head calculations including all friction losses.

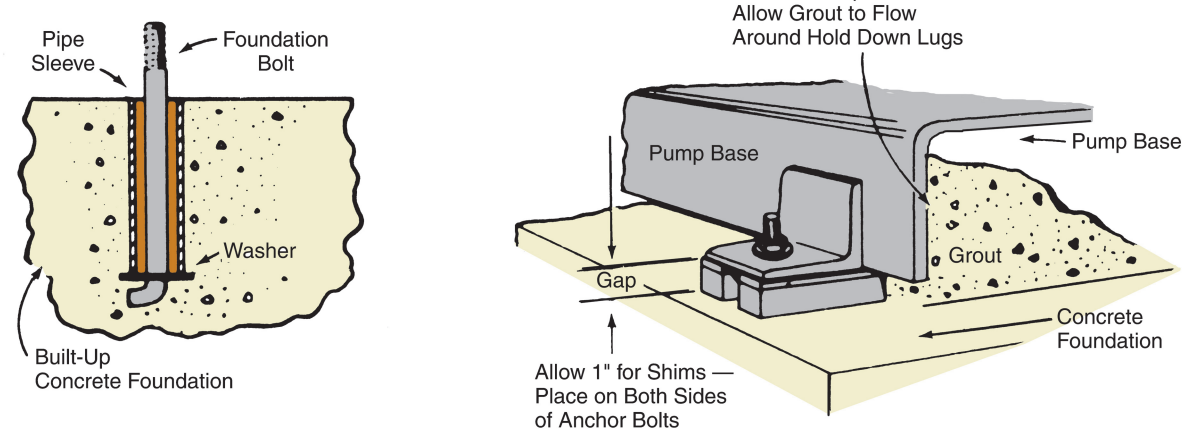
The one producing the highest inlet pressure, other things being equal, should be selected. There are a number of reasons for this precaution. The greater the inlet pressure, the less likelihood of *net positive suction head* (NPSH) problems. A flooded suction is particularly helpful on startup when many seals and sometimes entire pumps are ruined before they are properly primed and purged of air.

A dry, easily accessible location is also important. Allow ample clearance around the unit for free air circulation. Place the pump on a foundation, so that it can easily be inspected and serviced during operation. Head room should be provided, particularly where it is likely that lifting devices will be used for heavier assemblies.

What is the purpose of a pump foundation?

The purpose of a pump foundation is to rigidly support the baseplate to maintain alignment of the installed unit. Baseplates alone are not rigid enough to maintain alignment and for this reason they should be grouted to the foundation. If the baseplate is to be grouted to the foundation, it may be necessary to place a dam or form around the foundation to hold the grout in place until it hardens. *Do not grout unit to foundation until it has been properly aligned.*

The foundation should be a permanent rigid installation of concrete or other material of sufficient mass to absorb all normal vibrations. Foundation bolts should be located or embedded in the concrete by layout or template in relation to the suction and discharge piping. If concrete is used, foundation bolts of the specified size may be enclosed in a pipe sleeve *two* or *three* diameters



A Installation of Foundation Bolts

B Leveling of Pump Base on Concrete Foundation

Pump Foundation

Fig. 3-1

larger than the bolts to compensate for minor variations in alignment. See **Figure 3-1**.

Close coupled pumps may be mounted on a steel base prior to installation or mounted directly to the foundation. Shims should be placed under one or more of the motor feet so that strain and distortion will not result when mounting bolts are tightened.

Large pumps are often placed on a foundation sufficiently substantial to absorb vibration caused by the pump. Explain.

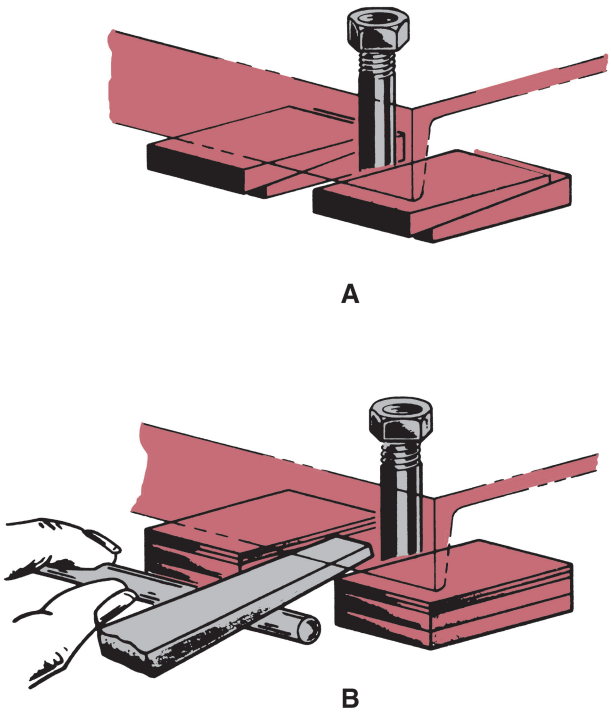
To eliminate *noise* in a piping system caused by pump *vibration*, a concrete foundation on a soil base can be used. Foundations made of reinforced concrete should be poured in advance of the installation to allow proper time for drying and curing.

Foundation bolts should be embedded in the concrete, and pipe sleeves slipped over the bolt to allow for movement in the final positioning of the bolts. Before setting the unit, thoroughly clean the top of the foundation. Break off any loose pieces of concrete and roughen the foundation top with a chisel to provide a good binding surface for the grout.

Some circumstances require that vibration elimination devices be placed between the pump base and the concrete foundation. When installing a pump on steelwork or other types of such a structure, it should be placed directly over the supporting members, such as bearing walls or beams.

What should be done when the unit is received?

When the unit is received with the pump and driver mounted on the baseplate, it should be placed on the foundation and the coupling halves disconnected. The coupling should not be reconnected until the alignment operations have been completed. The baseplate should be supported on metal shims or wedges having a small taper. See **Figure 3-2-A**. Some should be placed close to the foundation bolts. Others should be nearest to the greatest weight and spaced to give uniform support to the base.



Leveling Unit

Fig. 3-2

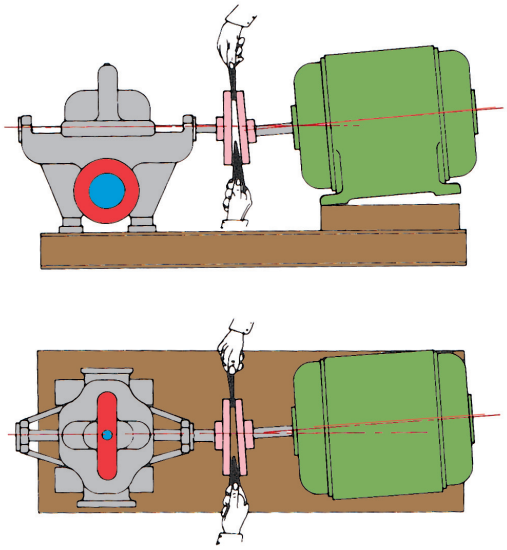
Adjust these supports until the shafts of the pump and driver are level. Check coupling alignment with a straight edge. A section of pipe can be used to determine if inlet and discharge openings are vertical and properly located. Correct the positions, if necessary, by adjusting the shims. See **Figure 3-2-B**.

Before grouting the space between the pump base and the foundation, alignment of the pump and power unit should be checked. Can a flexible coupling be used to compensate for misalignment?

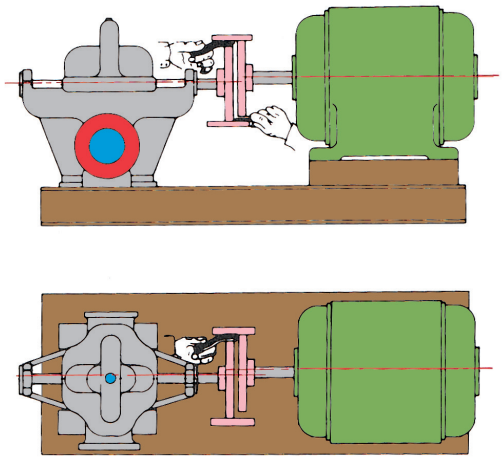
No. Flexible couplings are used to compensate for small movements of the shafts and to compensate for expansion due to change in temperature.

There are two kinds of misalignment that must be checked for. See **Figure 3-3-A** and **B**. They are: *angular* misalignment, where the ends of the shafts meet but are not parallel; and *par-*

allel misalignment, where the shafts are parallel but the ends do *not* meet. Pumps and drivers (power driven unit) shipped from the factory with both machines already mounted on a common baseplate were accurately aligned before shipment. However, because all baseplates are to some extent flexible, they must *not* be relied upon to maintain the factory alignment. It is likely that strains during transit to the jobsite have altered this alignment.



A Angular Misalignment



B Parallel Misalignment

Checking Flexible Coupling Misalignment

Fig. 3-3

Realignment is necessary after the complete unit has been leveled on the foundation, and again after the grout has set and the foundation bolts are tightened. The alignment should be checked after the unit is piped, and rechecked periodically.

The faces of the coupling halves should be spaced within the manufacturer's recommendations and far enough apart so that they cannot strike each other when the driver rotor is moved hard toward the pump. Allowance should be made for wear of the thrust bearings. The necessary tools for making an approximate check of the alignment of a flexible coupling are a straightedge and a taper gauge or feeler gauges. See **Figure 3-3-A** and **B**.

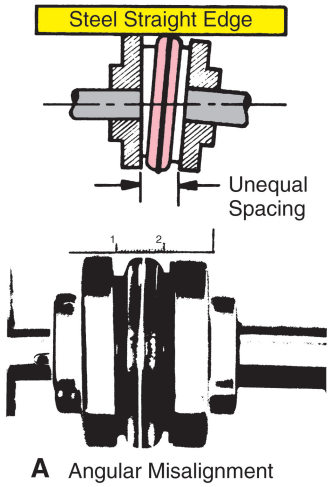
To check for angular alignment, insert a taper or feeler gauge at four points between the coupling faces and then compare the distances. If the unit is not in angular alignment, the measurements between the faces will differ. How can the pump and power unit be checked for angular and parallel alignment using a straight edge?

Place a straight edge across both halves of the coupling when checking the parallel alignment. The pump and power unit will be in parallel alignment if the straight edge rests evenly on the coupling rim at all positions. See **Figure 3-4-A, B** and **C**.

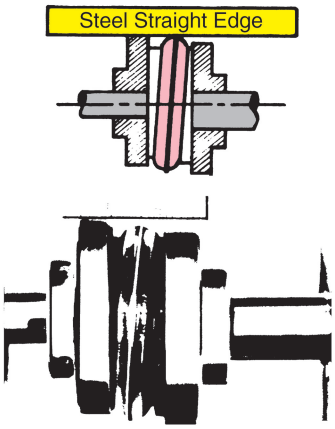
Caution: Be sure the coupling halves are of the same outside diameter and the straightedge is parallel to the shafts.

Proper alignment is the most important consideration in pump installation. Coupling manufacturers' instruction sheets are sent with each coupling from the factory. These sheets should be studied before installing, aligning, or servicing a coupling.

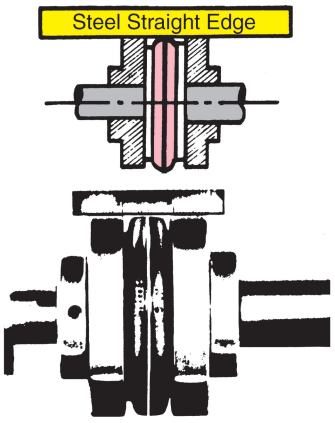
A standard coupling of the type shown in **Figure 3-4**, is supplied with pumps which use an elastomer member between internally serrated flanges. They have smooth outsides of equal diameter. These surfaces may be used for alignment purposes. A straight edge held against one or both surfaces should be used to visually determine



A Angular Misalignment



B Parallel Misalignment



C Correct Alignment

Checking Alignment between Couplings which Contain an Elastometer Member

Fig. 3-4

both angular and parallel misalignment. See **Figure 3-4-A, B** and **C**. Metal shims are placed under motor or pump feet to make corrections. If misalignment is of major proportion, this indicates that the baseplate is distorted. In that event, use a longer straight edge to correct the baseplate first. It is advisable to tighten either the pump or motor and adjust the other component. Final torquing of the hold down bolts alters the alignment which must then be compensated for. Torquing both at the same time is quite difficult.

What is the next step after the alignment is correct and the installation of the pump is complete?

When the alignment is correct and the installation of the pump is complete, the foundation bolts should be tightened evenly but not too firmly. Grout may then be placed between the pump base and the top of the concrete foundation. The underside of the base should be completely filled with grout, and it is desirable to grout the leveling pieces, shims or wedges in place at the same time. See **Figure 3-5**.

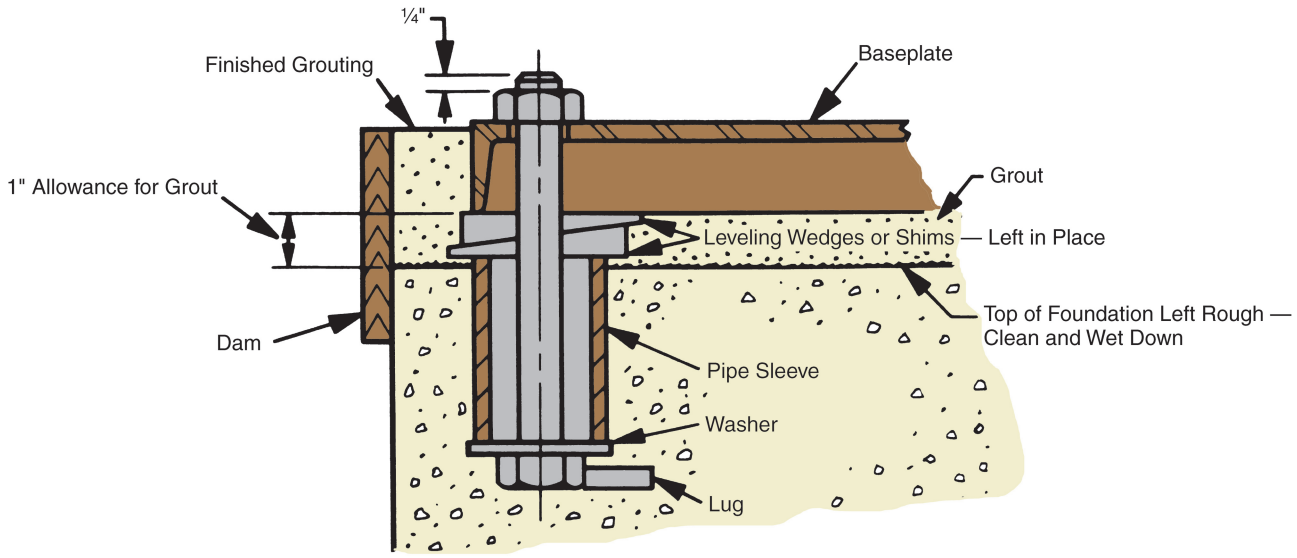
A recommended grout mixture is one part cement to two parts clean, sharp sand, wet enough to flow freely. The grout should be thoroughly stirred during the pour to insure the elimination of all air pockets.

After the grout has hardened, recheck the alignment. If no misalignment is present, the foundation bolts may be securely tightened. If misalignment is present, it should be corrected as outlined in the earlier discussion of coupling alignments before the foundation bolts are tightened firmly.

Caution: At least 48 hours should be allowed for the grout to set before the foundation bolts are given their final tightening.

Before connecting piping to a pump, take an inventory of tools and materials used during the installation. Explain.

Quite often, tools are forgotten, and, if left in the suction or discharge nozzles of the pump, they may be drawn into the pump when first started,



Example of a Foundation with Finished Grouting

Fig. 3-5

usually causing damage to the pump. If doubt exists as to the freedom of the pump and piping from tools, rags, bolts, nuts, welding slag and etc., much time and expense may be saved by checking the piping before connecting it to the pump.

What other precautions must be taken in pump installation?

As shown in **Figure 3-6** both the suction and discharge pipes should be supported independently and near the pump, so that when the flange bolts are tightened, no strain will be transmitted to the pump. Expansion joints, bends or loops, and hangers should be provided to prevent strain on the pump nozzles. Never draw the flanges into alignment with the flange bolts.

A pump with threaded connections should *never* be allowed to support piping. Other means should be provided for carrying the piping to avoid misalignment and distortion. Consideration should be given to thermally induced expansion and contraction, particularly in long runs of straight pipe. See **Figure 3-7**.

Full line size pipe and trim including valves, strainer and flexible connector should be used with the reduction to pump suction size. This reduction should be made through an eccentric reducer at the pump suction with the taper on the bottom. It is desirable to use a concentric reducer at the pump discharge to step up to full line size. All valves and fittings should be full line size.

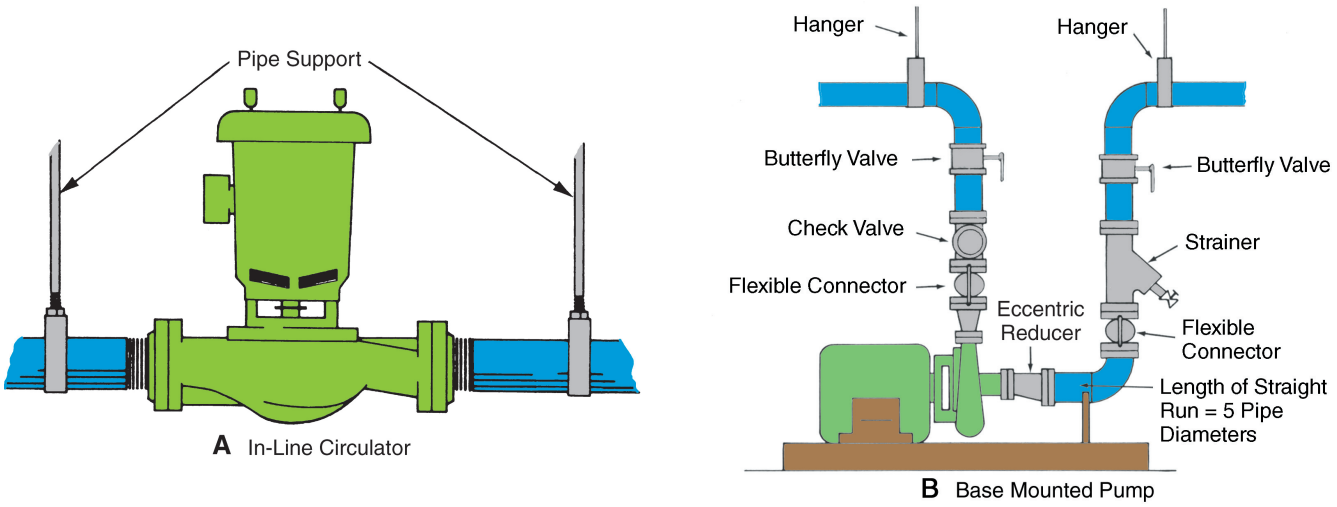
The pump suction straight run pipe length should be at least five diameters of suction pipe size to insure good pump entry conditions. See **Figure 3-7**.

Piping should line up naturally for the same reasons that the piping should be supported properly; to assure that strain is not placed on the pump casing.

It is important that all piping be lined up and not forced into place.

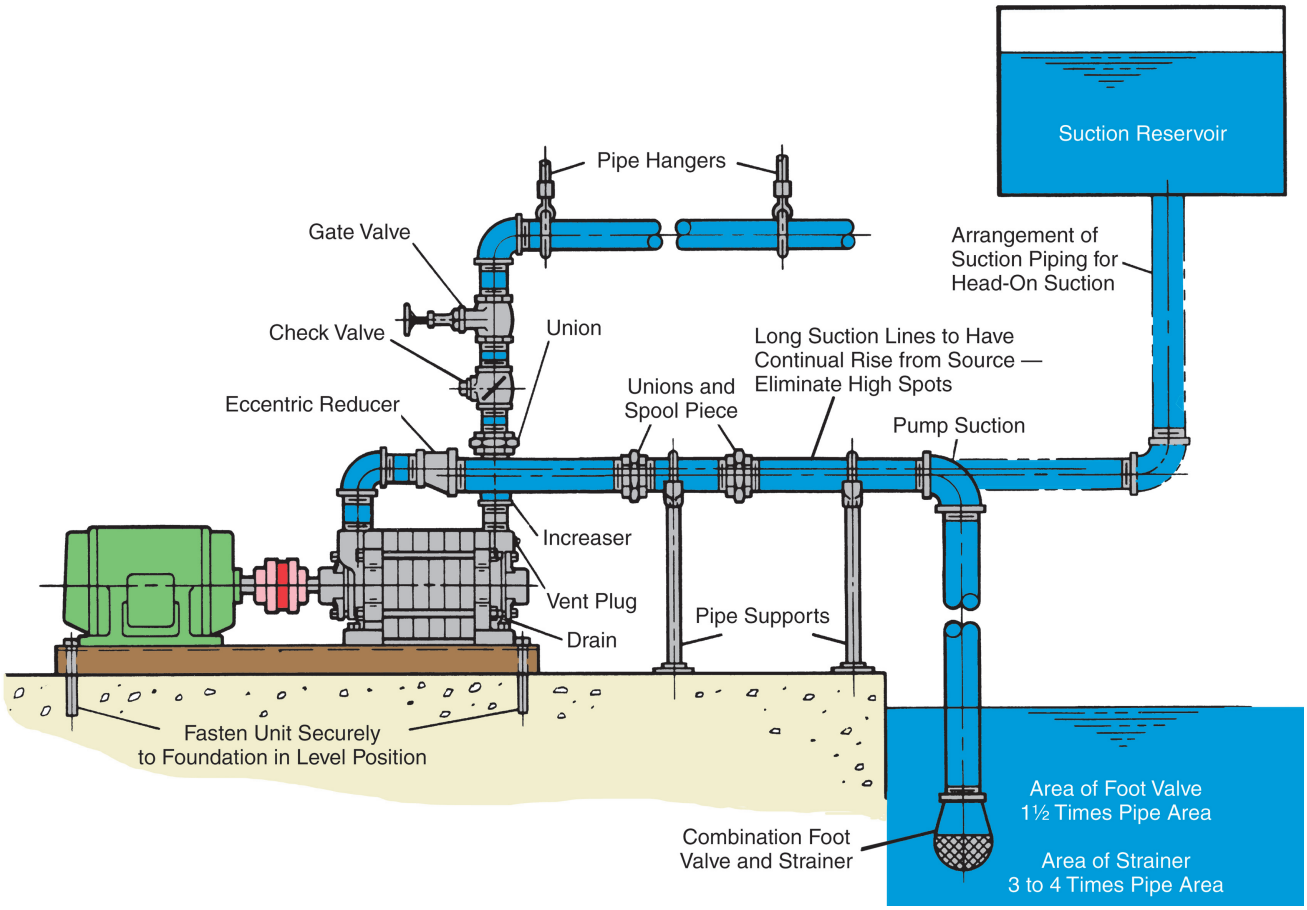
It is best to begin piping at the pump. When the lines are ended at the pump, particularly if the last piece is cut a little too short or long, the pump will be forced to meet the pipe and strain or distortion will result.

Caution: Avoid using in-line strainers with fine mesh strainer baskets. They could cause a pressure drop in the suction line to a pump. Strainer holes should be not less than 3⁄16". Be sure that the strainer is installed so that the basket can be removed.



Piping to Pump must be Supported Independently

Fig. 3-6

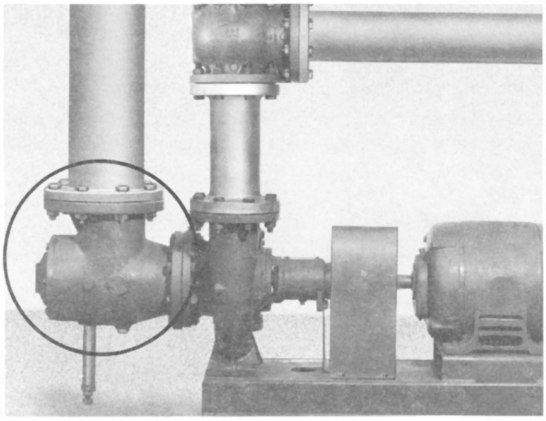


Pump Installation with Piping Supports

Fig. 3-7

A suction diffuser similar to the one shown in Figure 3-8 can be used in place of a basket strainer. Explain.

A support leg is required between the suction diffuser and the support foot to support the suction diffuser and prevent strain on the pump. Bosses are provided on the suction diffuser to locate the support leg and facilitate mounting the suction diffuser in any of three positions. The length of the support leg will vary depending on the pump centerline to mounting surface dimension. The support leg can be made of Schedule 40 pipe.



Installation of a Suction Diffuser

Fig. 3-8

Suction diffuser blowdown is best accomplished with the system connection in the 12 o'clock position. Blowdown will be less effective with the system connection in the 3 and 9 o'clock positions. Also, the magnetic trap will be less effective. The 16 mesh bronze start up strainer must be removed from the suction diffuser after the initial circulation and cleaning of the system. A pressure gage installed in the suction diffuser will warn of a blockage.

Why is the sizing and installation of pump suction piping extremely important?

It must be selected and installed so that pressure losses are minimized and sufficient liquid will flow into the pump when started and operated. Many NPSH (Net Positive Suction Head) problems can be directly attributed to improper suction piping systems. See **Figure 3-9**.

Suction piping should be short in length, as direct as possible, and never smaller in diameter than the pump suction opening. If the suction pipe is short, the pipe diameter can be the same size as the suction opening. If longer suction pipe is required, pipes should be one or two sizes larger than the opening depending on piping length.

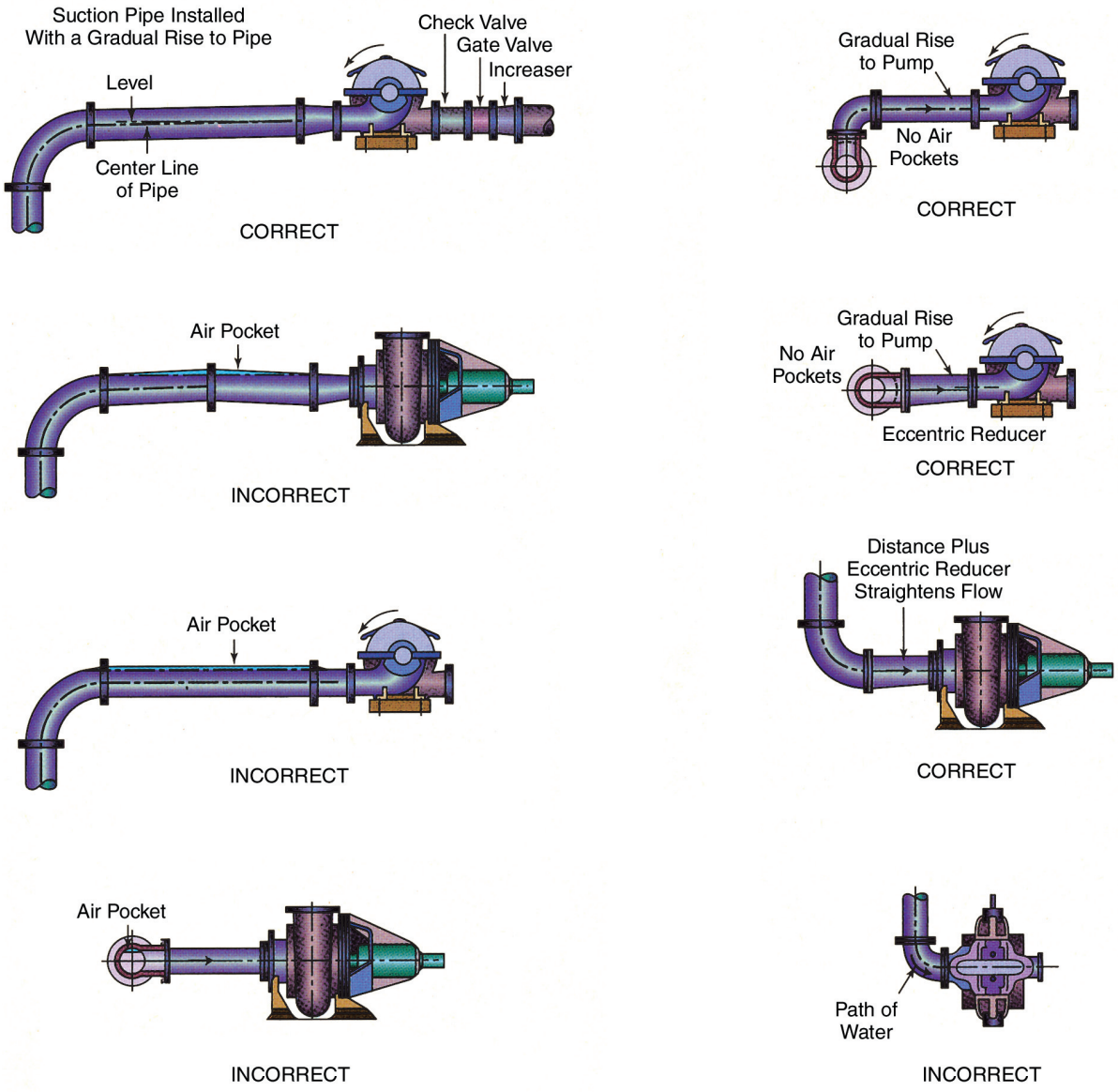
Suction piping for horizontal double suction pumps should not be installed with an elbow close to the suction flange of the pump except when the suction elbow is in the vertical plane. A suction pipe of the same size as the suction nozzle approaching at any angle other than straight up or straight down must have the elbow located 10 pipe diameters from the suction flange of the pump. Vertical mounted pumps and other space limitations require special piping.

There is always an uneven turbulent flow around an elbow and when it is in a position other than the vertical it causes more liquid to enter one side of the impeller than the other. See **Figure 3-10**. This results in high unequalized thrust loads that will overheat the bearings and cause rapid wear in addition to affecting hydraulic performance.

When operating on a suction lift, the suction pipe should slope upward to the pump nozzle. A horizontal suction line must have a gradual rise to the pump. Any high point in the pipe will become filled with air and thus prevent proper operation of the pump. When reducing the piping to the suction opening diameter use an eccentric reducer with the eccentric side down to avoid air pockets.

Note: When operating on suction lift *never* use a straight taper reducer in a horizontal suction line, as it tends to form an air pocket in the top of the reducer and the pipe.

To facilitate cleaning the pump liquid passage without dismantling the pump, a short section of pipe (Dutchman or spool piece) so designed that it can be readily dropped out of the line can be installed adjacent to the suction flange. With this arrangement, any matter clogging the impeller is accessible by removing the nozzle (or pipe section).

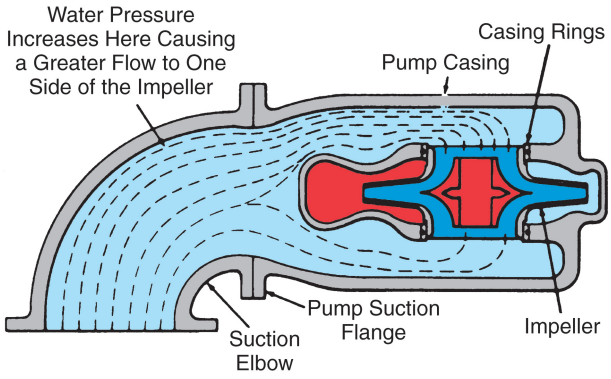


Suction Pipe Installations (Piping Supports not Shown)

Fig. 3-9

When installing valves in the suction piping, observe the following precautions.

1. If the pump is operating under static suction lift conditions, a foot valve may be installed in the suction line to avoid the necessity of priming each time the pump is started. This valve should be of the flapper type, rather than the multiple spring type, sized to avoid excessive friction in the suction line. (Under all other conditions, a check valve, if used, should be installed in the discharge line.)
2. When foot valves are used, or where there are other possibilities of *water hammer*, close the discharge valve slowly before shutting down the pump.
3. Where two or more pumps are connected to the same suction line, install gate valves so that any pump can be isolated from the line.



Unbalanced Loading of a Double Suction Impeller due to Uneven Flow around an Elbow Adjacent to the Pump.

Fig. 3-10

Gate valves should be installed on the suction side of all pumps with a positive pressure for maintenance purposes. Install gate valves with stems horizontal to avoid air pockets. Globe valves should not be used, particularly where NPSH is critical.

4. The pump must never be throttled by the use of a valve on the suction side of the pump. Suction valves should be used only to isolate the pump or maintenance purposes, and should always be installed in positions to avoid air pockets.

5. A pump drain valve should be installed in the suction piping between the isolation valve and the pump.

Where should pressure gages be installed?

Properly sized pressure gages should be installed on both the suction and discharge nozzles. The gages will enable you to easily observe the operation of the pump, and also determine if the pump is operating in conformance with the performance curve. If cavitation, vapor binding, or other unstable operation should occur widely fluctuating discharge pressure will be noted.

The valve on the suction side of a pump should be fully open. Never throttle flow through the pump with the suction valve. It could cause cavitation. What is cavitation?

Cavitation is the flashing of a pumped liquid into vapor bubbles and the subsequent violent collapsing of those bubbles as the liquid moves from suction to discharge through a pump. It can be extremely damaging to the pump internally, as well as to the piping and pump mountings. It can cause the pump to vibrate and shake erratically Cavitation can cause a sound like gravel passing through the pump.

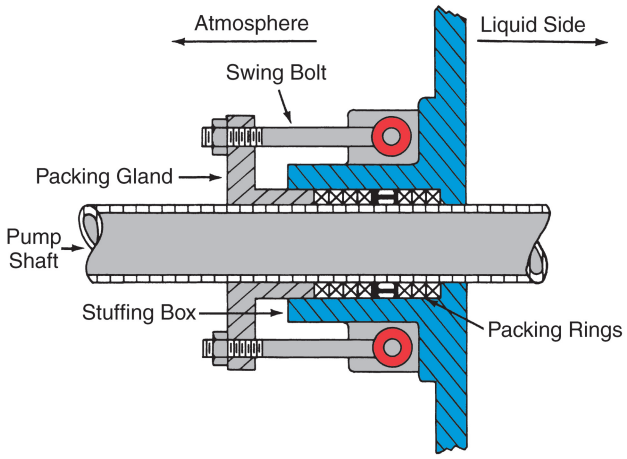
Cavitation can be caused by suction pressure which is too low (insufficient static pressure in the system) or by excessive flow through the pump (which can be corrected by throttling the discharge valve) or by the fluid being too hot. If cavitation cannot be corrected quickly, the pump should be turned off to prevent damage.

What are four items which should be checked after a pumping unit is properly installed and piped?

1. Stuffing boxes,
2. Mechanical seals,
3. Oil-lubricated sleeve bearings,
4. Antifriction bearings.

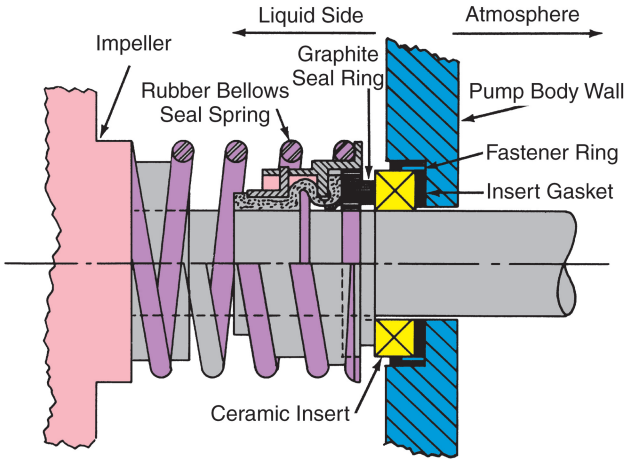
The point at which the pump shaft enters a pump body is provided with a seal. The two most commonly used sealing methods are the packing type seal (stuffing box) shown in Figure 3-11 and the mechanical seal shown in Figure 3-12. Following is information from a Bell & Gossett engineering design manual for centrifugal pumps explaining the construction of packing type pump seals. Describe the operation of the sealing methods shown in Figures 3-11 and 3-12.

Figure 3-11 shows a typical stuffing box with the packing in place. The packing rings are made of graphite impregnated cord or other resilient ma-



Packing Type Pump Seal

Fig. 3-11



Mechanical Pump Seal

Fig. 3-12

terial formed into properly sized split rings. These are compressed into the stuffing box by means of a packing gland. This packing gland is pulled up by means of a pair of gland nuts which are threaded on their respective swing bolts as shown in **Figure 3-11**. It is important that the tension on the packing gland be such that the packing drips steadily.

Too much packing pressure will not allow leakage and causes scoring of the pump shaft and overheating of the packing. After a period of time, the packing will be compressed and loses its resilience. This is evidenced by overheating of the stuffing box and excessive leakage if the gland is backed off to allow cooler operation. At this point, the packing should be replaced with the proper type and in the proper sequence as called for in the manufacturer's instructions.

Figure 3-12 shows a typical mechanical seal. These seal sets consist of a stationary member which is usually made of a very hard ceramic material. This stationary ring fits into a recess in the pump body and has a rubber gasket behind it to form a water-tight seal at that point. This ceramic material is kept from turning by means of a fastener ring pressed into the recess which engages flats on each side of a ring.

A molded graphite seal ring rotates against the lapped face of the ceramic material and forms the actual water seal at this point. The graphite seal ring is backed up by a rubber bellows which fits tightly on the pump shaft and is held tightly forward against the graphite ring by means of the seal spring. This spring keeps the graphite rotating ring tightly against the stationary ceramic seal and pushes it forward to make up for wear. No maintenance or adjustments are needed. In the event that the seal becomes worn and leaks, it is replaced.

Before a pump is put into use, oil lubricated sleeve bearings should be filled with the proper type and amount of lubricant recommended by the manufacturer.

Antifriction bearings must also be lubricated. Explain.

Fill antifriction bearings fully. If grease is the recommended lubricant, use the grade specified by the manufacturer. Do not overfill with grease as overheating may be caused by too much grease. *Lubricants containing graphite must not be used.*

What are the three steps which should be taken before starting a pump?

1. Make sure pump is primed,
2. Check rotation,
3. Check valve positions.

Before starting any pump, the casing and suction line must be filled (primed) with liquid. Pumps should not be operated unless they are completely filled with liquid, as there is a danger of injuring some parts of the pump which depend upon liquid for their lubrication. Impellers tend to seize quickly when the pump is run dry. Seal faces are easily damaged from heat buildup without lubrication.

Pumps are easily primed with a vacuum pump. An ejector or liquid ring vacuum pump is best because they are not damaged in the event liquid enters them. If other vacuum pumps are used, the system should be designed to prevent water from entering. Connect the vacuum line to the discharge side of the pump, either in the discharge opening or the drain tap. A foot valve is not necessary when this kind of a device is used.

When a vacuum pump is not practical, a foot valve in the suction inlet can be used to prevent liquid from running out. The pump and suction line can then be filled completely from an outside source. A vent opening will be necessary during filling to let air escape. A tight foot valve will keep the pump constantly primed so that automatic operation is possible. The valve should be inspected regularly to see that it does not develop leaks and allow the pump to run dry.

Self priming attachments are available for some pump types, to allow priming when neither a vacuum pump or foot valve is possible. There are three components to the self primer. A check valve is necessary to maintain a vacuum in the suction line as surging occurs in the pump, an air eliminator is used on the discharge side to separate air from liquid so that the liquid may be used again and again as air is carried through the pump. A recirculating line carries liquid from the air eliminator back to the suction. A fluid chamber is sometimes added on the inlet side to provide an additional supply of fluid to speed up priming.

Small suction lines are desirable to minimize priming time. Using the self priming attachments, it is only necessary to open the plugs in both inlet and outlet chambers and pour fluid in one until both are full. Tighten both plugs tightly. Turn on the pump. Priming time is dependent on lift, volume of air in the suction line and the size of the regenerative turbine pump selected.

If priming time is long and the pump becomes warm, it may be advisable to refill the priming chambers with fresh liquid. Most turbine pumps will pull 26" to 28" of mercury vacuum with cold water in the pump but have very little capacity and therefore are not very practical at lifts over 22'.

The best way to prime a pump and keep it primed is to use a flooded suction. While this is not always practical, it does provide a number of advantages. The likelihood of pump damage from dry running is all but eliminated. Suction lines may be large thus reducing line losses and minimizing the potential of cavitation damage. There are no check valves or other priming devices to fail or require maintenance. Whenever possible, design pumping systems with a flooded suction.

The proper direction for pump rotation is usually indicated by an arrow on the pump casing. After priming, *bump* (a short burst of power) the starting switch for the pump to determine direction of rotation.

The standard direction of pump rotation is usually right handed, or clockwise when looking at the end of the pump with the driving shaft. A rotation arrow is normally located on the pump to indicate the correct direction of rotation. How can improper rotation of an electric driven unit be corrected?

Since there are substantial performance variations and the potential of pump damage from operation in reverse, always confirm correct motor rotation prior to connection of the coupling. If this is not possible, or a final rotation check is being performed, jog the motor briefly. Observe rotation as it comes to a stop. Rotation should be in the direction the rotation arrow points.

If the motor operates in the wrong direction, interchange any two leads on three phase motors. Single phase motors will require wiring changes as indicated inside the connection box cover. Some single phase motors may not be reversible. *Extreme caution must be taken if it is necessary for you to make the change.*

Some centrifugal pumps can be operated clockwise or counterclockwise when viewed from the pump end of the pump. If you wish to reverse the suction and discharge nozzles, this can be accomplished with the pump shown in **Figure 3-13**, as follows:

1. Remove the impeller from the shaft, turn it 180° and replace it on the shaft.
2. With the rotating element out of the casing, remove the casing from the bedplate and turn 180°.
3. Set the rotating element back in the casing and reassemble the pump.

Note: The impeller and casing are in the same relationship to each other as they were originally. The shaft and motor are also in the same relationship as they were originally.

4. Reassemble the pump and realign the coupling as called for in the alignment instructions.
5. The rotation of the motor must be charged by switching the motor leads.

Note: Unless the motor rotation is reversed the impeller will run backward.

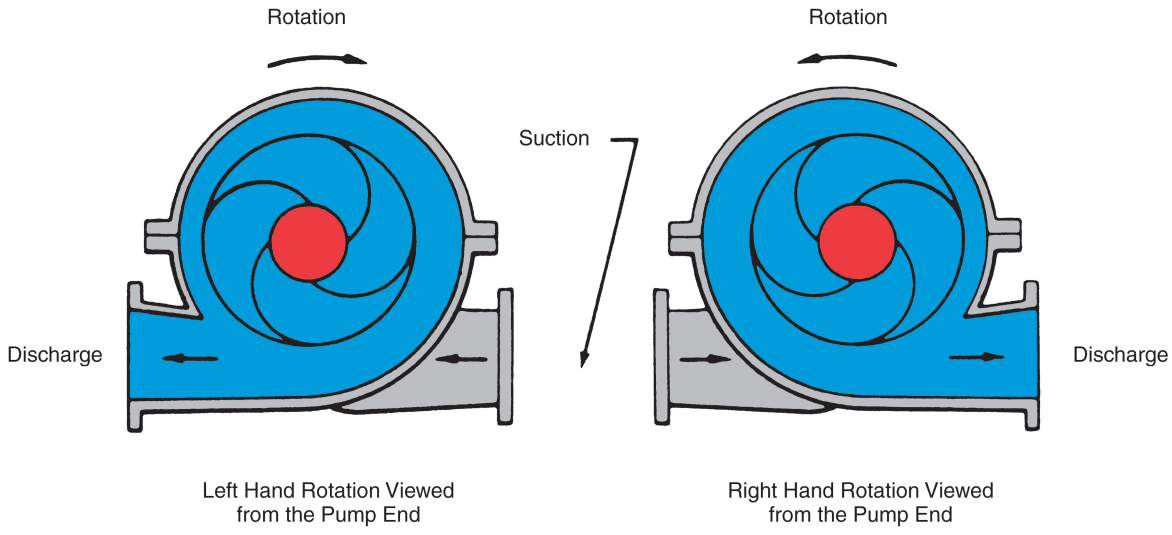
What is the normal position of the shutoff valve in the pump suction and in the pump discharge pipe?

The valve on the suction side of the pump should be fully open. The discharge valve should also be open. In the case of high head centrifugal pumps, the discharge valve can be closed during start up (less power is required) and then gradually opened.

What method(s) should be used if it is necessary for you to raise or lift a pump with lifting equipment?

If lifting of the entire pump is required, do so with slings placed around the pump assembly as shown in **Figure 3-14-A** and **B**. Use the same method if you are required to lift a base mounted pump. Place the slings around the entire base as illustrated in **Figure 3-15**.

Figure 3-16 illustrates typical positions that can be used for the installation of centrifugal booster pumps. They can be installed to discharge up or down, horizontally, left or right, but the oiling ports must always be in the 12 o'clock position (on top) with the motor and bearing assembly in a horizontal position. The arrow on the body must point in the direction of flow. See **Figure 3-16**.



Correct Relationship of Impeller and Casing

Fig. 3-13

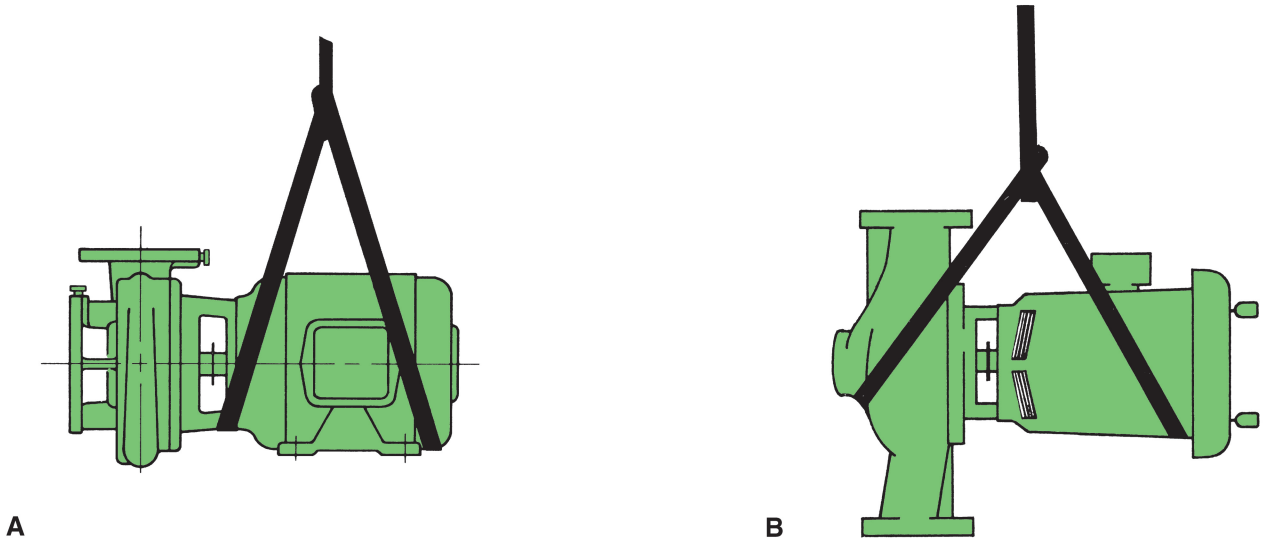


Fig. 3-14

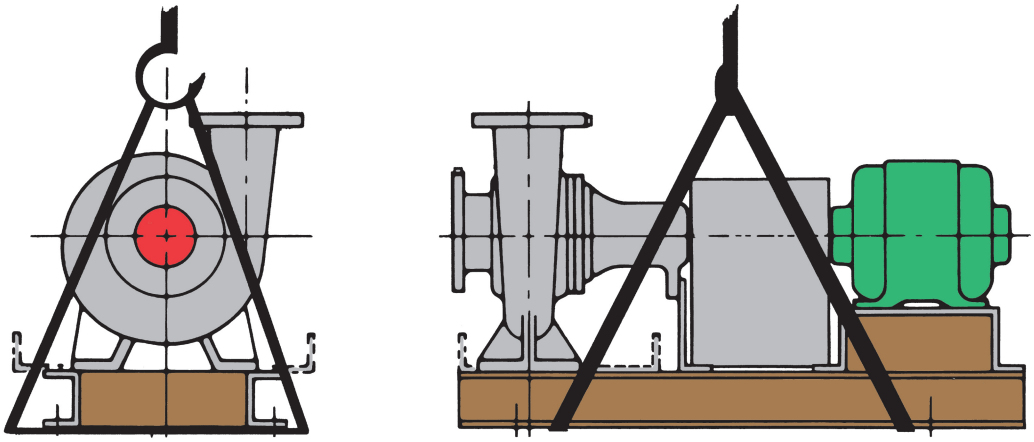


Fig. 3-15

After start up, if there is a problem, it is likely to be one of those shown in the following list.

No Discharge

Lack of discharge from a pump may be caused by any of the following conditions:

Pump not primed

Speed too low.

Discharge head too high

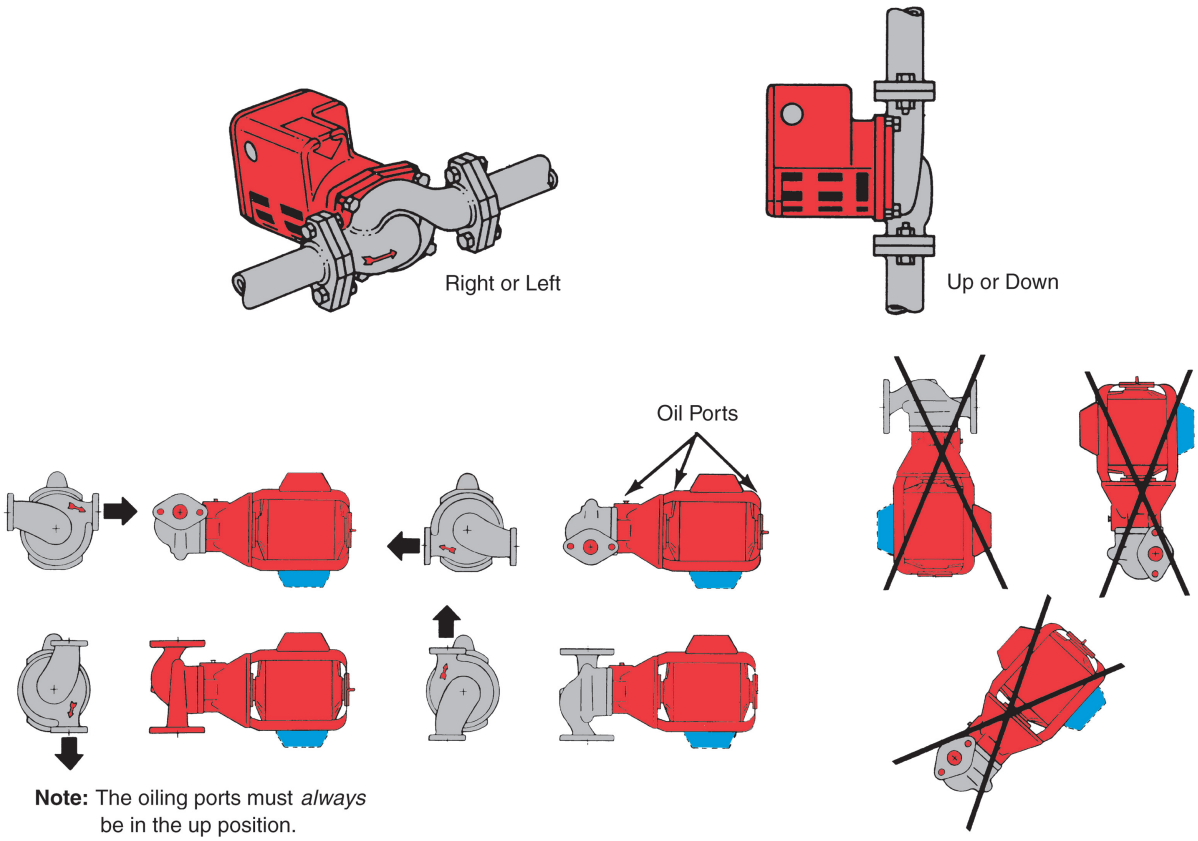
Suction lift higher than that for which pump is designed

Impeller completely plugged

Wrong direction of rotation

Insufficient Discharge

Insufficient discharge from a pump may be caused by any of the following conditions:



Typical Installation Positions of Centrifugal Booster Pumps

Fig. 3-16

Air leaks in suction line or stuffing boxes

Speed too low

Discharge head higher than anticipated

Suction lift too high. Check with gages; check also for clogged suction line or screen

Impeller partially plugged

Not enough suction head for hot or volatile liquids

Mechanical defects:

- Wearing rings worn
- Impeller damaged
- Foot valve too small
- Foot valve or suction opening not submerged deeply enough
- Impeller installed backwards
- Wrong direction of rotation

Insufficient Pressure

Insufficient pressure from a pump may be caused by any of the following conditions:

Speed too low

Air or gases in liquid

Mechanical defects:

- Wearing rings worn
- Impeller damaged
- Impeller diameter too small
- Impeller installed backwards
- Wrong direction of rotation

Loss of Suction Following Period of Satisfactory Operation

Loss of suction under these conditions may be caused by any of the following conditions:

Leaking suction line

Waterseal plugged

Suction lift too high

Casing gasket defective

Excessive Power Consumption

Excess power consumption may be caused by any of the following conditions:

Speed too high

Head lower than rating; pumps too much liquid

Specific gravity or viscosity of liquid pumped is too high

Mechanical defects:

- Shaft bent
- Rotating element binds
- Stuffing boxes too tight
- Wearing rings worn

If the problem is caused by the speed being too slow, you must determine whether or not the motor is across the line and receives full voltage when the pump is connected directly to the electric motor. When directly connected to a steam turbine, make sure the turbine receives full steam pressure.

CHECKPOINT 1

At this point go back to page 37 for a review to see how thoroughly you have learned the material presented. This review is important to help you understand and retain what you have studied. When satisfied that you understand the material covered, answer the questions on the assignment sheet.

NOTES

CHAPTER

4

Pumps in Systems

Procedure: Study the pages which have been assigned by your instructor and answer the questions on the assignment sheet(s) which will be distributed to you.

Pumps are the heart of many piping systems, and understanding how they work is the purpose of this chapter. U.A. journeyworkers must be able to apply their skills and knowledge in the installation, maintenance, and repair of any kind of pumping system they may encounter.

A private water system is usually made up of a pump, a storage tank and accessories to operate the system automatically. A typical arrangement is shown in Figure 4-1. The pump delivers the water from the well or other water sources to a tank where it is held under pressure. Describe the operating cycle of an automatic water system.

In an automatic water system, a pressure tank is used for the storage of water. Unlike air, water cannot be compressed or squeezed into a smaller volume. In a pressure tank, air is compressed by the rising water level in the tank as a means of storing energy. The compressed air in the top of the tank acts like a coiled spring, pushing down on the water in the tank. The pump delivers water under pressure to the tank and as the tank fills, air over the water is compressed. If no water is being used, delivery to the tank continues until the pressure reaches a set value, usually 40, 50 or 60 pounds per square inch gage (psig). A pressure switch then opens the electrical circuit to the motor and the pump stops.

When a valve is opened in the system, air pressure in the upper part of the tank forces the water to flow out of the tank and into the system. The pressure falls as the water flows out of the tank. When it drops to the cut-in setting of the pressure switch, usually 20, 30 or 40 psig, the latter closes the circuit and the pump starts.

The installation of a submersible well pump must be made in accordance with the manufacturer's instructions. List four preliminary steps which should be taken when installing a submersible well pump.

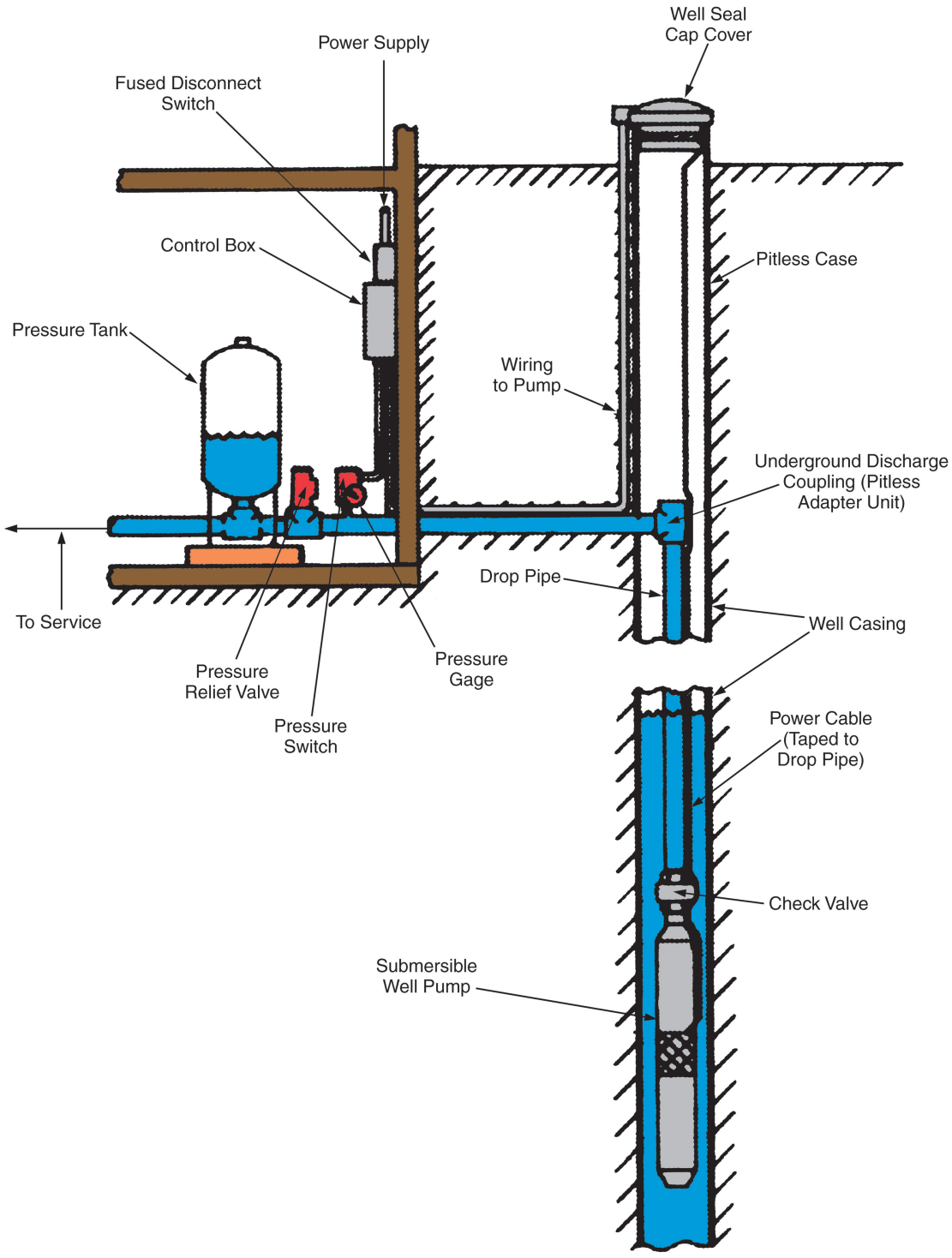
1. Remove the pump from its shipping carton and check it for damage.
2. Check the nameplate against the intended specification for the well.
3. Examine the check valve to make certain it will function correctly and close of its own weight or by spring pressure.
4. Check the electrical supply. The power source should be checked for proper fusing and wire size, grounding and transformer size, all as recommended by the manufacturer. Be sure to check the color coding of wires on single phase three wire units.

Important: All electrical equipment and wiring must comply with national, state local or provincial electrical codes. If a submersible pump or motor is tested or installed in any location where it or surrounding water can be contacted, it must be grounded to prevent electrical shock hazards. This can be done by connecting the motor frame to the power supply grounding terminal with a copper wire no smaller than the power cable wires.

In any pump installation, all of the *above ground* metal piping and equipment must be connected to the power supply ground as required by electrical codes to prevent electrical shock hazard. If a pump is tested outside the well, make sure it is properly grounded.

What is the next step by step procedure which should be followed when installing a submersible well pump? See Figure 4-1.

1. The well should be chlorinated before installing the pump. Check state, local or provincial codes or health department re-



Typical Installation of a Submersible Well Pump and Automatic Water System

Fig. 4-1

quirements. This prevents contamination and the growth of iron bacteria.

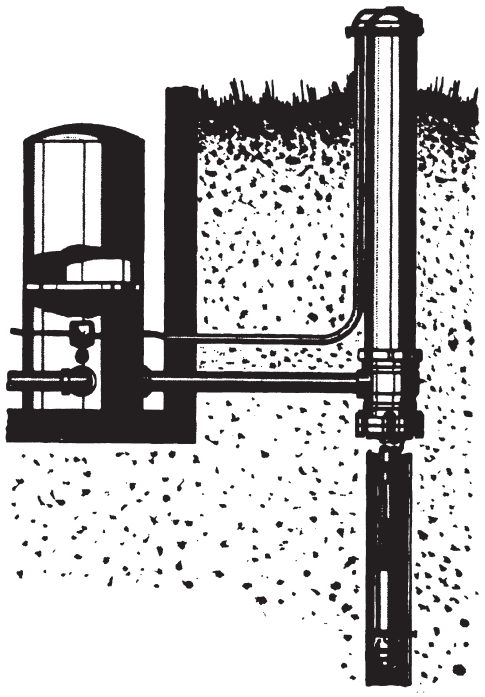
2. The top edge of the well casing should be checked for smoothness; sharp or jagged edges could cut or scrape the electric cable and cause it to break.

3. Attach the pump to the drop pipe. Screw the pump into the pipe and tighten. When using a pipe wrench on the pump, put it at or near the threads on the outlet casting not on the pump body. In some areas, it is recommended that an insulated or *dielectric* union be installed between the pump and the first section of galvanized iron pipe. The purpose is to prevent electrolytic corrosion between a bronze pump head and the iron pipe.

4. Next lower the pump into the well. The drop pipe is normally threaded lengths of galvanized steel or plastic, or one continuous length of flexible plastic pipe. Use an OSHA approved hoist or some other safe method to lower the pump and drop the pipe into the well, making sure it is supported at all times to prevent injury and to avoid dropping the pump. Feed the cable into the well as the pump is lowered, being careful to prevent damage to the cable and make sure it is fastened securely to the pipe every 10' or less.

5. Most present-day water systems use captive-air pressure tanks, which require no recharging to maintain the correct air volume in the tank. If a system uses a plain pressure tank which requires air recharge, install an air charger in the pump delivery line in accordance with the manufacturer's instructions.

6. Many state, local and provincial plumbing codes, health officials and water quality regulators require the use of underground discharge connectors (pitless adapters) to prevent freezing and to minimize the potential for contamination, physical damage and vandalism above ground. See **Figure 4-2**. Follow the manufacturer's instructions and applicable codes for their installation. If a pitless adapter is not required by local codes, construct the pipe and cable system at the well head to properly support the pump and comply with all other code requirements.



General Arrangement of a Pitless Adapter Unit with Tank Located in Building

Fig. 4-2

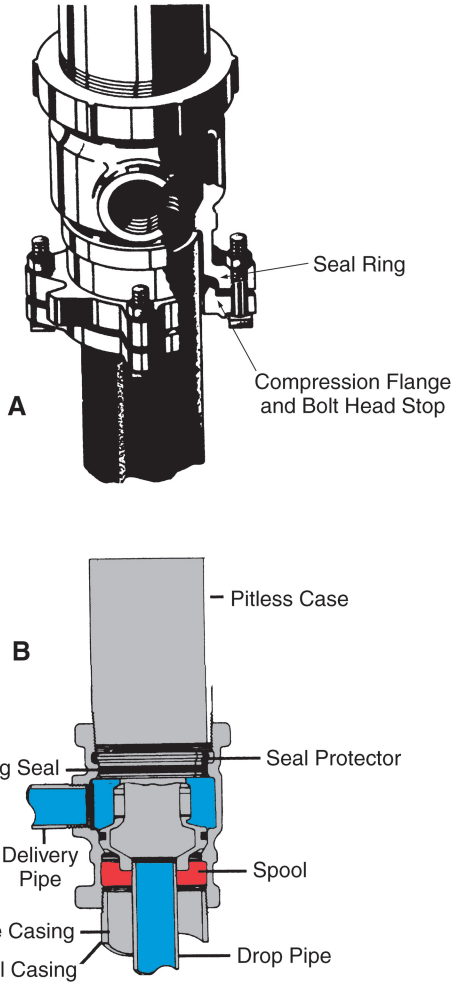
7. After the pump is installed it should be wired and the electrical work completed in accordance with code requirements.

The use of a pitless adapter was mentioned earlier. A pitless adapter forms an unbroken extension of a well. Give a brief description concerning the installation of a pitless adapter.

The pitless adapter unit extends from below the frostline to above the ground. The unit attaches to the well casing below the frostline. The water service line is attached to the unit (below the frostline) and is buried permanently. Electrical wire or conduit is also buried at the well to provide power for the pump.

A cap is placed on the top of the unit to keep contaminants out of the well. See **Figure 4-2**. Two types of standard domestic pitless adapter units are shown in **Figure 4-3-A** and **B**. The unit

shown in **Figure 4-3-A** can be installed using a compression flange and seal ring. The unit shown in **Figure 4-3-B** can be installed using a threaded well connection along with an O-ring seal and seal protector.

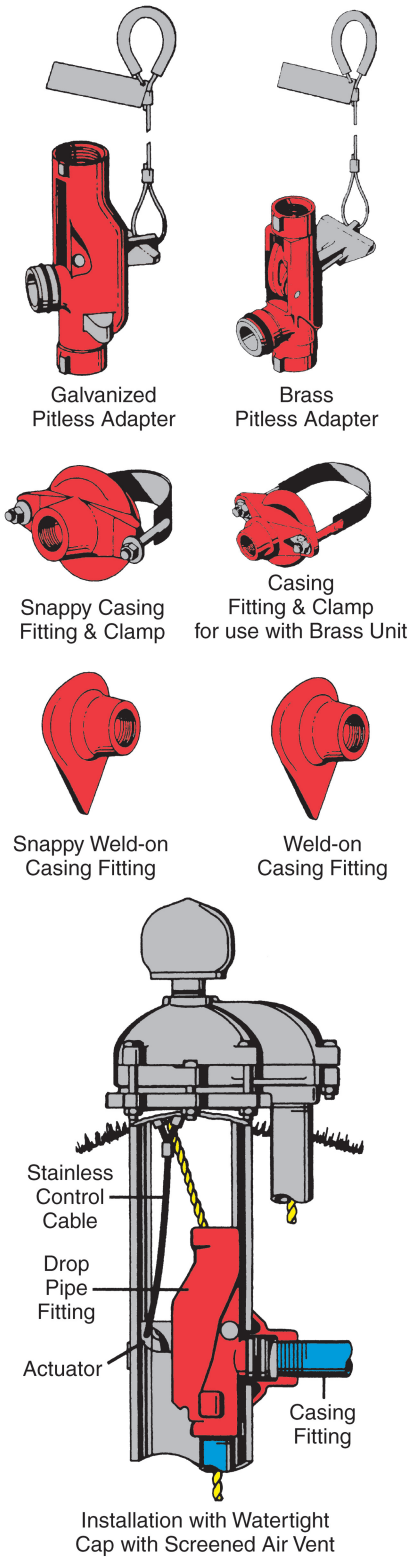


Two Types of Pitless Adapter Unit Connections

Fig. 4-3

How would the pitless adapter units shown in Figure 4-4 be installed in a submersible pump installation?

In a submersible pump installation using a snappy or bulldog pump, an excavation is made around the well casing and a hole is cut in the casing below the frostline. The casing fitting for either a galvanized or brass unit is then attached to the casing around the hole to provide a water service connection. See **Figure 4-4**.



Snappy and Bulldog units with Well Casing Fittings and Clamps

Fig. 4-4

The pump, suspended from the drop pipe fitting, is lowered into the well with the neck of the drop pipe fitting pointed toward the casing fitting. When the neck reaches the level of the casing fitting, the actuator automatically inserts the neck with an O-ring seal into a socket in the casing fitting and locks it there. This provides both a support for the drop pipe and the pump within the well and a fluid tight conduit between the drop pipe and the discharge pipe.

To remove the pump, the drop pipe fitting is first supported with a hoist. Then the neck of the drop pipe fitting is unlocked, and withdrawn from the socket by a manual pull on the control cable. This releases the drop pipe fitting from the casing fitting so that the pump can be lifted out with the hoist.

The unit shown in Figure 4-3-A is connected by slipping the unit onto the top of a well casing and tightening the compression flange bolts. The threaded pitless adapter unit similar to the one shown in Figure 4-3-B requires the top of the well casing to have a male thread of the proper size. This can be done by threading the well casing, or by using a certain type fitting. List five types of fittings which are sometimes used to connect pitless adapter units to a well casing.

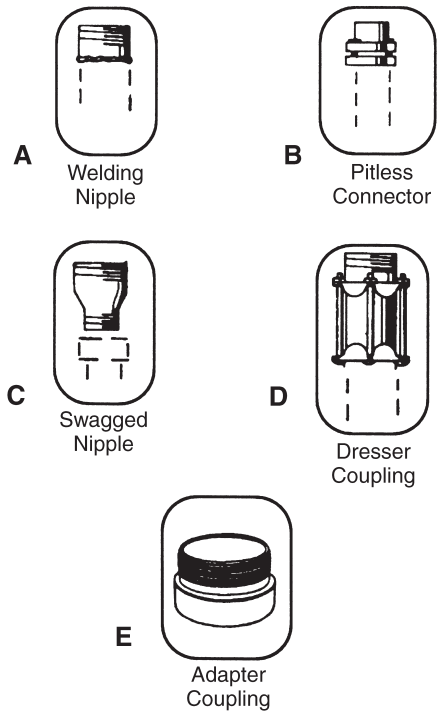
1. The welding nipple shown in **Figure 4-5-A** is male threaded on one end and chamfered on the other for welding to the top of the casing.

2. The pitless connector is female threaded on top and is slipped onto the top of the well casing and held in place by a neoprene seal ring which clamps against the casing. See **Figure 4-5-B**.

3. The swagged nipple is male threaded both ends and screws into the coupling on top of the casing to increase casing size. See. **Figure 4-5-C**.

4. The Dresser coupling as in **Figure 4-5-D**, is slipped onto the top of the well casing. A half nipple is inserted into the top of the coupling and the bolts are tightened to complete the joint. See **Figure 4-5-D**.

5. The adapter coupling shown in **Figure 4-5-E** is designed for use with pitless units having a female threaded connection, the other end is a collar for welding inside and outside.



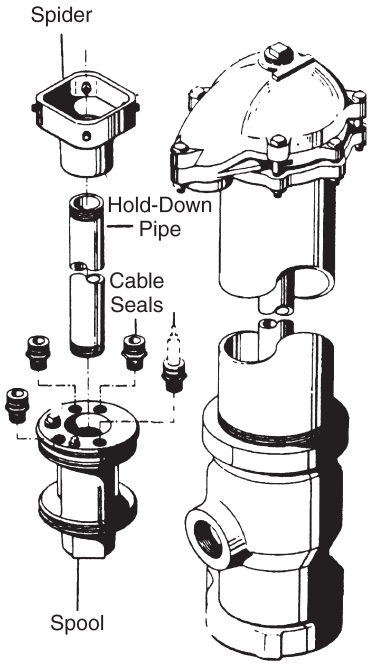
Types of Fittings used to Connect Pitless Adapter Units to a Well

Fig. 4-5

The unit shown in **Figure 4-6** is designed for use on 4", 5", and 6" well casing sizes with a threaded attachment to the casing. Submersible model pitless units as in **Figure 4-6** are available with a special spool for sealing wells where the well water rises above frost level.

A hold-down spider with set screws, attached to the lift-out pipe holds the spool in position in the discharge body, preventing the spool from rising from hydraulic pressure. The special spool is tapped for four water-tight cable seals.

Another type pitless unit designed for use on jet pump driven well installations 2" and smaller forms a watertight extension of the well casing



Pitless Unit for use where Water Rises Above Frost Level.

Fig. 4-6

from below the frostline (where it is buried permanently) to above ground. These units which can be used for shallow well and single-pipe deep well jet applications also have a back tapping.

What is the purpose of the back tapping?

When the inner well assembly is removed, a threaded casing of the same diameter as the well casing and about the same length as the pitless unit can be screwed into the back tapping to isolate the well from the upper case. See **Figure 4-7-A** and **C**. This isolation, during such well operations as jetting, sterilizing, and redrilling, protects the spool sealing surfaces from mechanical damage and prevents the entry of mud and/or well chemicals into the upper case and connecting passages and pipes.

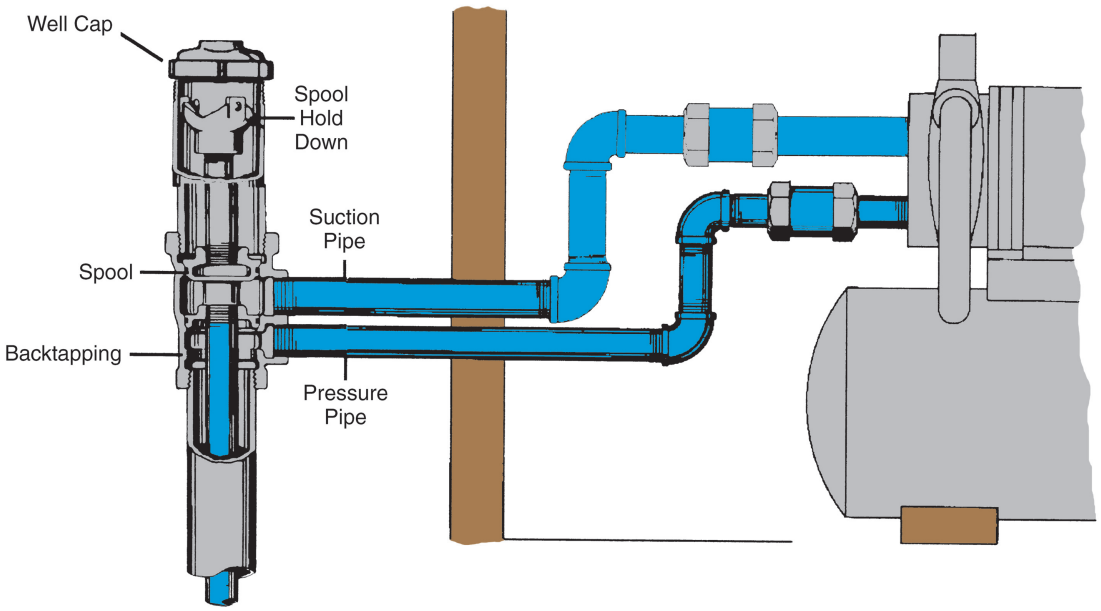
A pitless unit for a jet pump parallel piping installation is shown in Figure 4-7-A. The single-pipe deep well unit spool shown in Figure 4-7-A, is tapped for the suction drop pipe. Because the well casing is under system pressure, there is no pressure equalizing passage in the spool and a spool hold down is provided to prevent upward movement of the inner well assembly. The discharge body is tapped for the suction and pressure pipes, which are respectively connected to the pump suction and pressure ports. What is the difference between a shallow well unit and a single-pipe deep well unit?

On the shallow well pitless unit for jet pump concentric pipe installations the unit spool is tapped for a suction drop pipe. It has a vertical passage which equalizes the upper case and well casing pressures. The discharge body is tapped for the suction and concentric pressure pipes which are respectively connected to the pump suction and pressure ports. There is no passage extending from the pressure pipe to the well casing. See **Figure 4-7-B**.

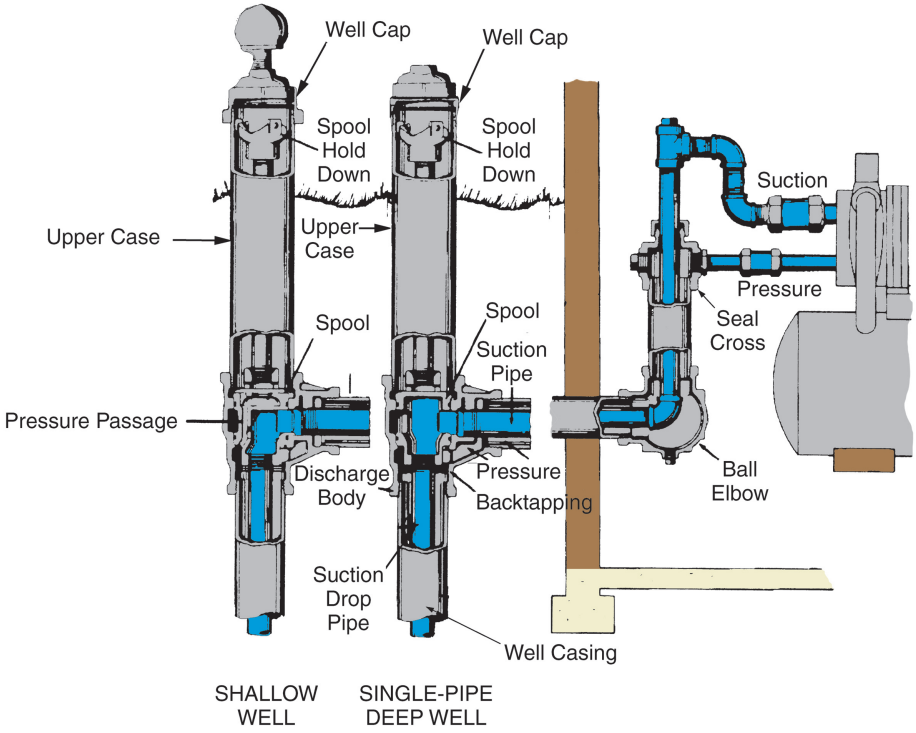
The single-pipe deep well unit spool is also tapped for the suction drop pipe. Because the well casing is under system pressure, there is no pressure equalizing passage in the spool. A spool *hold down* is provided to prevent upward movement of the inner well assembly.

The discharge body is tapped for the suction and concentric pressure pipes, which are respectively connected to the pump suction and pressure ports. A passage in the discharge body conducts water from the pressure pipe to the well casing. See **Figure 4-7-C**.

A typical galvanized storage tank along with several components of a submersible well water pump piping system is shown in Figure 4-8. The use of galvanized tanks to provide the storage of water under pressure allows air to enter the tank by means of an air volume control. There is no separation between the air and the water in the tank. See Figure 4-9. What effect does this have on the water stored in the tank?

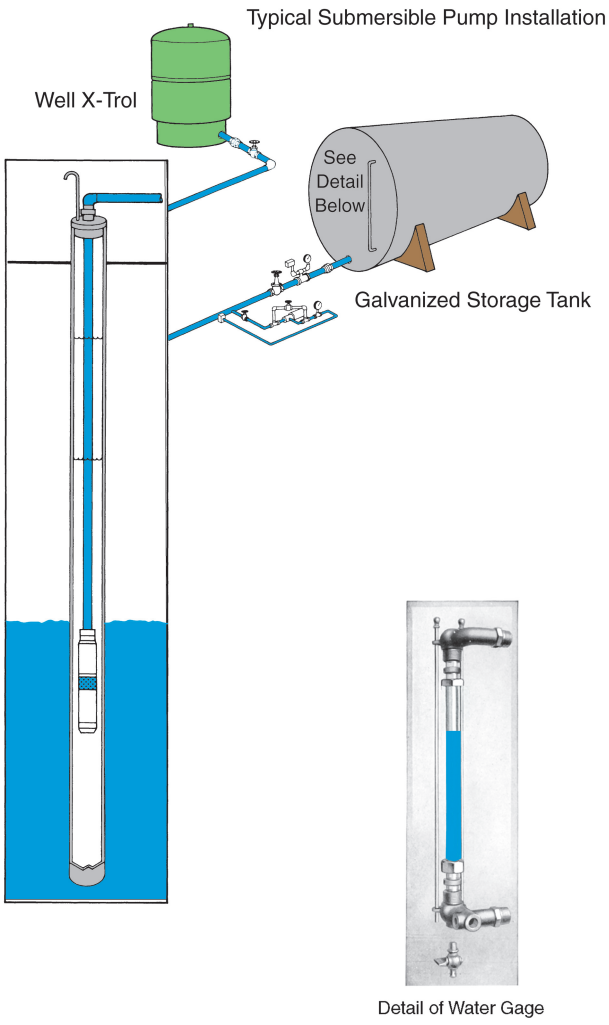


A Single-Pipe Deep Well Jet Pump Parallel Piping Installation



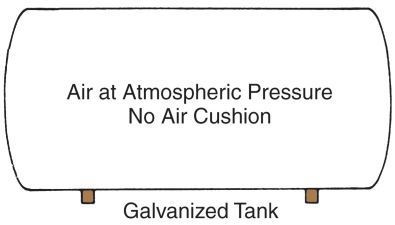
B Shallow Well and Single-Pipe Deep Well Concentric Installations

Fig. 4-7



Typical Galvanized Storage Tank along with Several Components of a Submersible Pump Installation

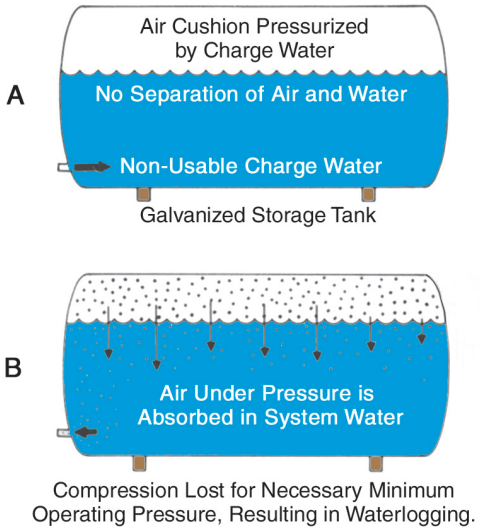
Fig. 4-8



Galvanized Tank without Separation of Air and Water

Fig. 4-9

It is possible that air under pressure in a well water system storage tank can be absorbed in the system water. The result is the storage tank will become waterlogged and the necessary compression required for the minimum operating pressure in the system is lost. Waterlogging usually occurs in storage tanks more rapidly at high pressure ranges. See **Figure 4-10-A** and **B**.

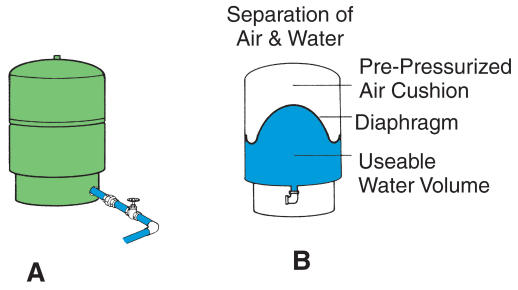


Pressurized Well Water Storage Tanks

Fig. 4-10

A device (well-x-trol tank) sometimes used in place of a pressurized storage tank is shown in **Figure 4-11-A** and **B**. The *well-x-trol* tank operates on the principle of the separation of air and water in a pre-pressurized hydro-pneumatic tank. The well-x-trol design provides a sealed-in air cushion to control operating pressures within designed units while also providing space to accept the desired usable water volume to maintain proper run time on a well pump.

Because the well-x-trol separates the necessary air volume from usable system air volume, it can be pre-pressurized to minimum system pressure (usually pump cut-in pressure) eliminating the need for non-usable charge water required by the plain galvanized hydro-pneumatic tanks. This separation of air and water feature offers several advantages over galvanized tanks used on well systems.



Typical Well-X-Trol Tanks

Fig. 4-11

What are five advantages in the use of a well-x-trol tank on a well water system?

1. It prevents waterlogging indefinitely. Since air and water do not interface as they do in a galvanized tank, air *cannot* be absorbed by system water left in the tank.
2. It allows the use of much smaller well tanks. Since the sealed-in air cushion can be pressurized it does not need large volumes of non-usable charge water to develop pressure as the air cushion in a galvanized tank does. Well-x-trol tanks can handle system pressurization and control in sizes one-fourth to one-fifth the size of galvanized tanks.
3. It can utilize varying pressure tanks to accommodate a great variety of applications. Because air absorption is eliminated, a well-x-trol can be used with higher operating pressures and wider pressure differentials than galvanized tanks.
4. It simplifies installation on large jobs. Since the well-x-trol can be much smaller than bulky galvanized tanks, and needs no exterior provision for air volume control or precharging, installation requires a minimum of handling and rigging, and no complex field support structures. It also requires a fraction of the space in the installation than large galvanized tanks do.
5. It reduces maintenance and replacement costs to a minimum. Because the water reservoir in a well-x-trol tank is completely non-metallic, aggressive action by corrosive water on the inner tank is eliminated, preventing corrosion and leakage.

A vacuum pump is of primary importance to a vacuum return heating system. Explain.

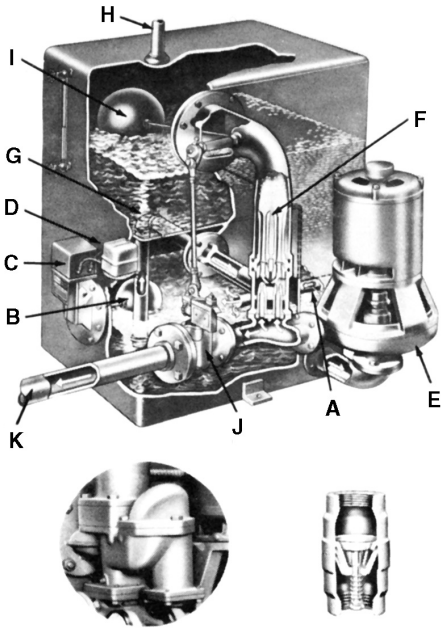
This pump must be capable of creating a vacuum for moving steam, air and condensate through the system piping. At the same time, it must be able to create the positive pressure needed to return condensate, from radiators, coils, pipe, etc., to a boiler operating at pressures up to 15 psig, or to the receiver of a boiler feed pump. These pumps normally maintain a vacuum on the return piping from 3" Hg to 8" Hg.

Describe the operation of a jet type vacuum pump capable of performing these functions.

In the cutaway view in **Figure 4-12**, it can be seen that the pump consists of two tanks, one on top of the other and separated by a metal wall. The smaller rectangular tank is called the accumulator tank, while the larger L-shaped tank which extends across the top and down one side is called the air separating tank. When the system is first put into operation the accumulator is empty and the pressure inside the tank is atmospheric. The air separating tank must be primed.

The centrifugal pump *E*, when started, will draw water out of the air separating tank. The water from the pump discharge passes through jet nozzles *F* where the velocity of flow is increased many times. With the increase in velocity there is a decrease in pressure at the nozzle outlet causing air and condensate to flow from the accumulator tank through the connecting pipe *G* and into the chamber housing the jet nozzles. The air and condensate are carried along with the high velocity jets of water and into the air separating tank.

Vent pipe *H* allows the air to be vented to the atmosphere and the condensate collects in the tank. As the level of water in the air separating tank increases, float *I* will rise causing discharge valve *J* to open, allowing water to return to the boiler through discharge pipe *K*.



Cutaway view of internal mechanism of suction valve assembly. Water passing from accumulator tank through suction tube assembly travels through heavy cast iron housing and quiet suction check valve on its way to exhauster assembly.

Jet Type Vacuum Pump

Fig. 4-12

When the vacuum switch turns off the centrifugal pump, condensate returning to the accumulator tank by gravity could cause the tank to become flooded. To prevent this from happening, float *B* measures the condensate level and condensate flow through float switch *C* starts and stops the pump.

Vacuum pump operation is dependent therefore on both the quantity of condensate returning from the system and the reduced vacuum pressure in the return main.

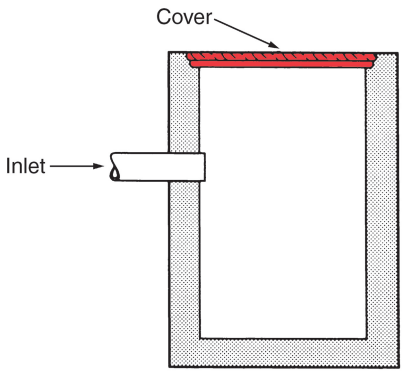
CHECKPOINT 1

At this point go back to page 53 for a review to see how thoroughly you have learned the material presented. This review is important to help you understand and retain what you have studied. When satisfied that you understand the material covered, answer the questions on the assignment sheet and then proceed to checkpoint 2.

Occasionally fixtures or other sources of drainage must be located within a building at elevations lower than the available sewer mains.

In situations of this type, it is impossible to drain plumbing fixtures to the sewer mains by gravity, they must be pumped up to a level from which gravity drainage is possible.

A *sump* can be defined as a watertight pit or receptacle at a low elevation into which liquid wastes or liquid carried wastes are drained. It is a tank or pit, sometimes called a sump pit that receives sewage or liquid waste, located below the normal grade of gravity system, and must be emptied by mechanical means. See **Figure 4-13**.



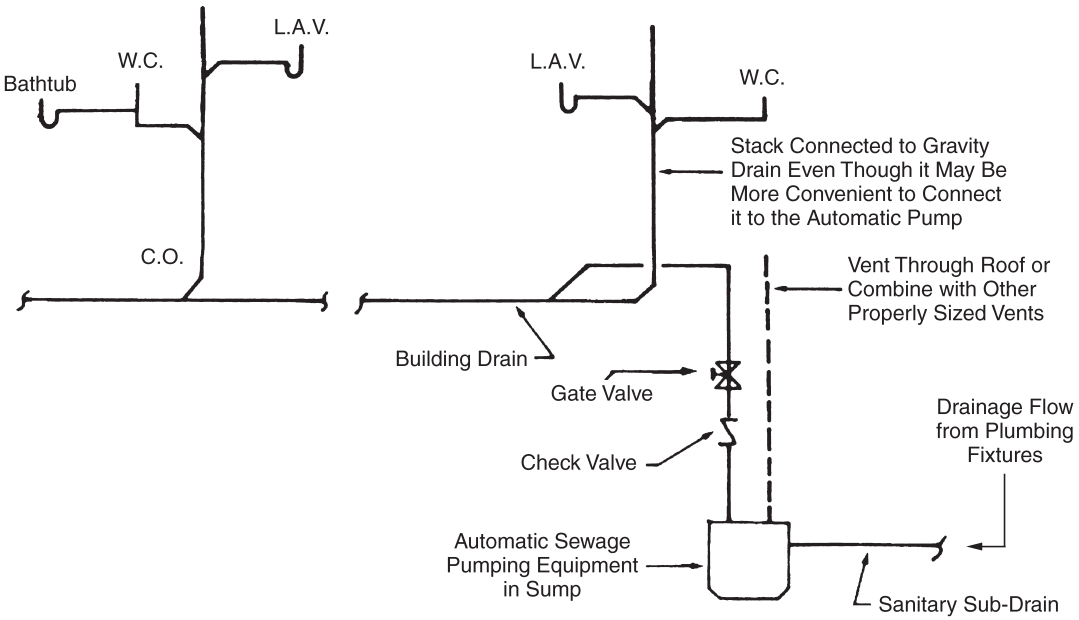
Sump

Fig. 4-13

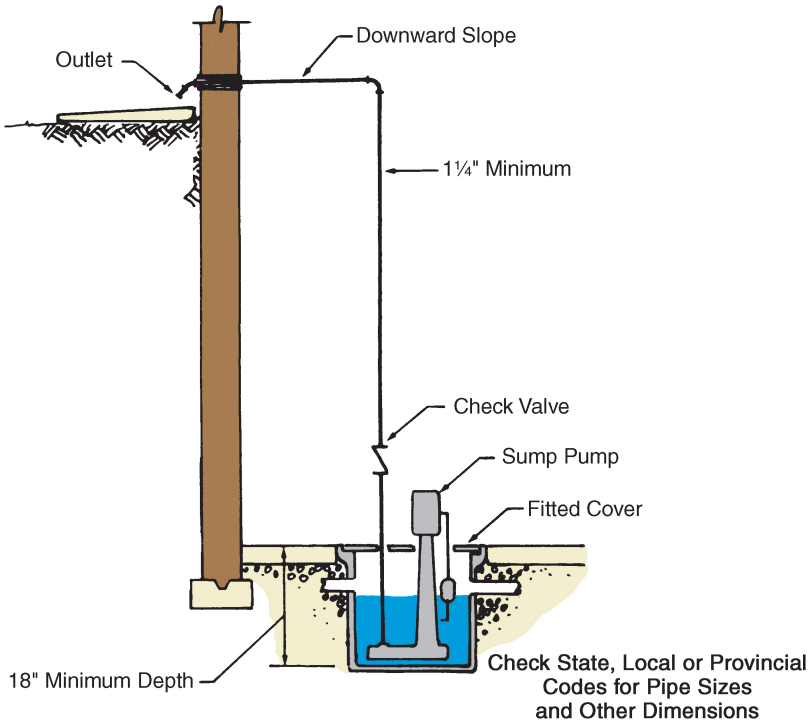
The pumping device used to pump sanitary drainage from plumbing fixtures to a higher elevation is called a *sewage ejector*, as shown in **Figure 4-14-A** and for nonpolluted drainage from floor drains or other clear water sources a similar, but simpler device called a *sump pump* is used. See **Figure 4-14-B**.

The terms sump pump and sewage ejector often are used interchangeably. What are the similarities between a sewage ejector and a sump pump?

Both sewage ejectors and sump pumps are basically composed of a receiving basin (or sump) designed to collect the drainage, and to house the



A Example of Sanitary Subdrain Below Gravity Building Drain



B Example of Sump Pump, Sump Pit and Discharge Piping

Typical use of Pumping Equipment to Lift Sanitary and Clear Water Drainage to a Higher Elevation

Fig. 4-14

pumping equipment used to pump liquids and wastes from the basin to a point of connection with a gravity drainage system. Both use automatic controls which activate the pumping equipment when the basins become filled, and stop it when the basins are emptied to predetermined levels. The design of sewage ejectors and sump pumps are generally of the centrifugal type.

They are both generally wet-pit mounted vertical pumps, but they are very different in function, design and purpose. Sewage ejectors are non-clogging-type pumps designed for transferring sewage containing insoluble solids from sanitary plumbing fixtures in buildings. They have specially designed impellers and volutes and usually are not furnished with suction strainers.

Sump pumps usually handle only waste or storm water with few or no solids. Most plumbing codes require vents on sewage ejectors but seldom require them on sump pumps unless they are handling sewage. Wherever excessive depth, cost or space becomes a problem, submersible-type pumps are available for both clean water and sewage applications. With submersible pumps, the motor and pump are below water level and are usually more efficient in operation because they are usually of close-coupled construction.

Figure 4-15 illustrates a duplex sewage ejector. Why do some codes require the use of a duplex sewage ejector?

In order to provide for short periods of high flow, maintenance, or pump failure, some codes require the installation of two (duplex) pumps.

According to one recognized plumbing code, a duplex sewage ejector is required whenever a pit or basin services more than 6 water closets. Each pump in a duplex system must be large enough to handle the entire flow by itself. This is a safety precaution in the event of failure of one of the pumps. Pumps that will handle solids up to 3" size are recommended.

Both pumps do not operate simultaneously. A control device causes the pumps to be activated alternately. Both pumps operate only if there is more flow into the basin than one pump can handle.

What are six important factors concerning the installation of the basin?

1. Depth of basin
2. Distance between top of basin and basin inlet
3. Size of basin
4. Solid vibration free foundation
5. Size of piping
6. Elimination of noise

Many basins are made of cast-iron and may be constructed in more than one section (sections are bolted together to form basin). The journeyworker must know the depth of the basin in order to provide a solid foundation to support the basin.

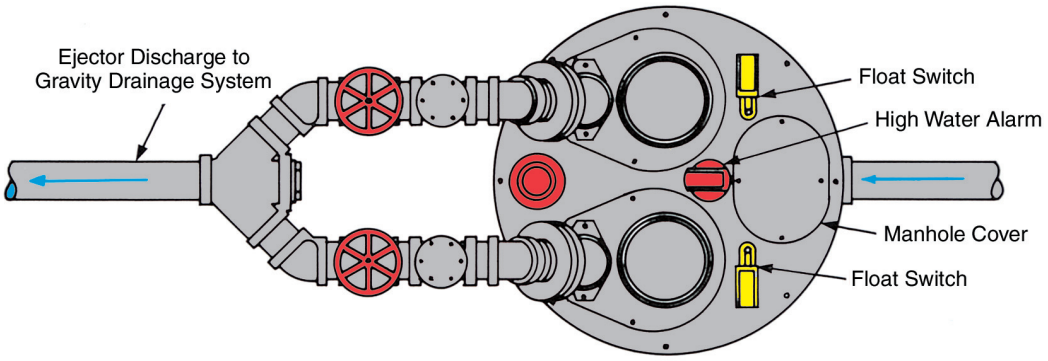
A basin is normally custom-made for each installation. The journeyworker must determine the location of the inlet below the top of the basin and order the basin to coincide with those dimensions. More than one inlet may be used.

Minimum recommended sump diameters are usually specified by the manufacturer for both single and duplex pump installations. Sump depths are determined by the lowest line entering the sump, incremental pump depths (usually 6"), and minimum recommended clearances below the pump suction (usually one and a half to two times the pipe diameter).

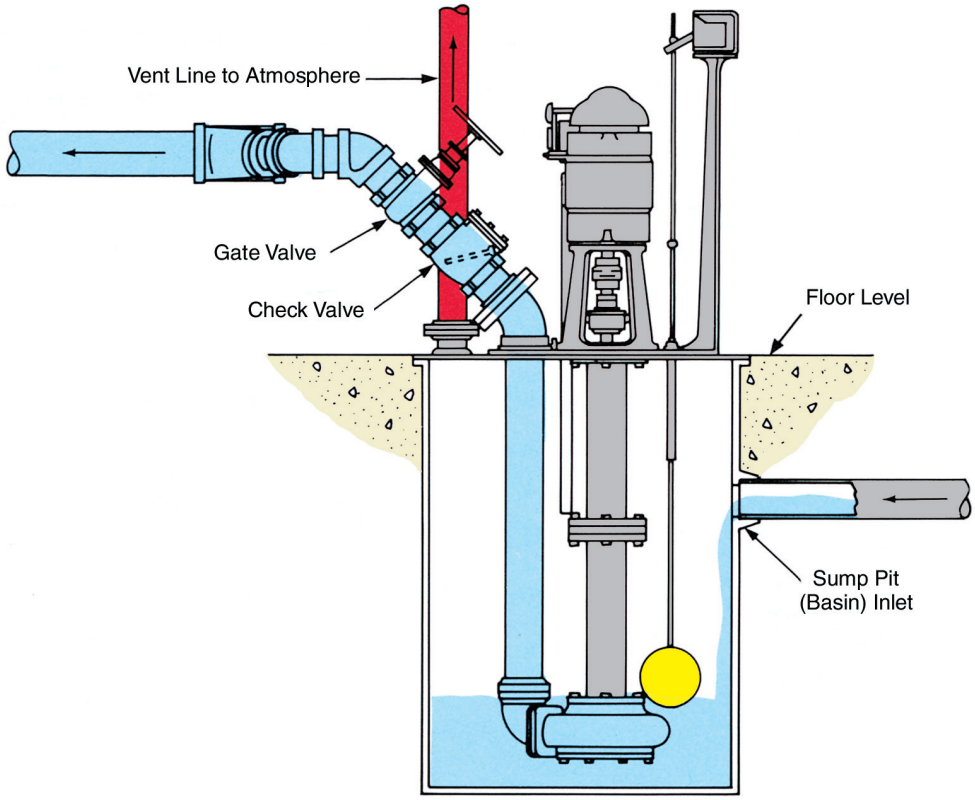
Submersible pumps can be located on the bottom of the sump. A minimum of 3'0" should be provided from the invert of the lowest line entering the bottom of the sump to minimize excessive pump cycling and back pressure on the inlet sewer.

The distance between the maximum liquid level and the basin cover should be ⅓ of the storage area between the high and low liquid levels, but not less than 2'.

Air may be entrained in the pumped liquid if the pump suction is located too close to the free liquid surface in the suction source. Pumping liquid with entrained air can cause a reduction of capacity, vibration, loss of efficiency and wasted power.



Plan View



Note: Additional basin inlet connections can be furnished, if required. Type, size, location and number of inlet connections determined by job conditions.

Elevation View

Example of a Duplex Sewage Ejector Installation

Fig. 4-15

When installing the sump pump or sewage ejector, ample room must be allowed above the pump for removal. Care must be exercised when installing the sump near foundation walls. Piping should be arranged with a union located clear of the pump removal area for ease of replacement.

Discharge piping must always be as large or larger than the size of the pump connection, as short and direct as possible to minimize friction losses, and supported independently of the pump. Any reducers required should be eccentric for complete drainage.

A check valve should be installed to prevent backflow and a gate valve for maintenance of the pump and check valve. Weighted-lever check valves are used to ensure positive shut-off. Resilient-type or aluminum-flapper check valves can be used where noise may be a problem.

Also to help eliminate noise in critical areas, the pump base plate should be installed on rubber or another resilient isolation material and flexible connectors installed in discharge piping.

Why are check valves and gate valves located in the pump discharge piping?

Because the discharge from the two pumps is yoked together into a single pipe line, check valves must be installed to prevent the discharge from one pump entering the other discharge line.

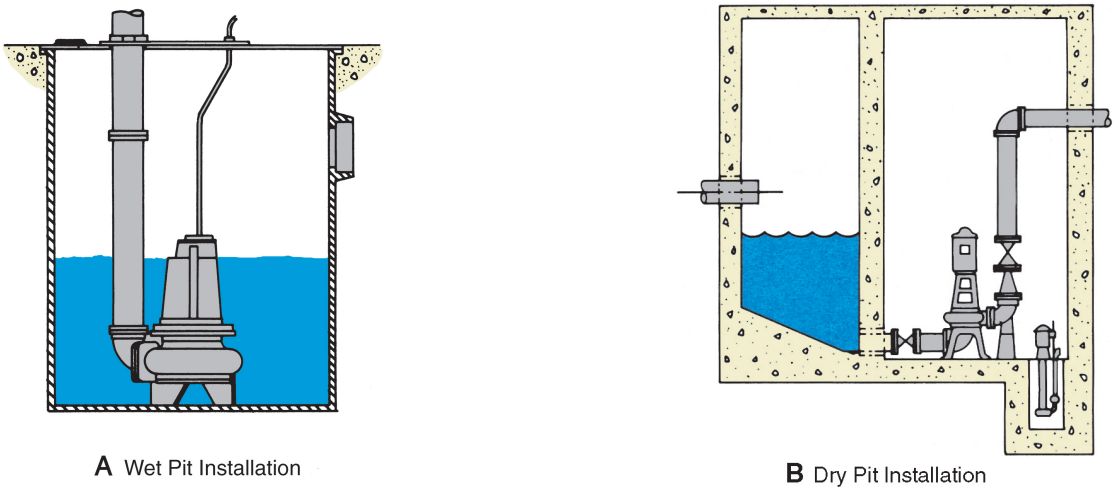
Gate valves are installed in the discharge piping to aid in pump maintenance. The gate valves location on the discharge side of the check valve assures that the check valve can be isolated from the discharge of the other pump.

Figure 4-16 shows two different types of sewage ejector installations.

A in **Figure 4-16** illustrates a typical wet pit installation using a submerged non-clog sewage pump. It features a pump and motor with a sealed housing, helping to insure a long service life. The suction inlet is on the bottom. See **Figure 4-17** for an illustration of a typical non-clog pump assembly.

B in **Figure 4-16** shows a dry pit installation. Neither the pump nor the driver is submerged. This unit is vertically mounted with an elevated driver coupled directly to the pump. It is used where floor space is limited and flooding is marginal. Note the installation of a sump pump in the dry pit.

There are various types of controls used to switch the pumps on and off. The controls must be installed and adjusted



A Wet Pit Installation

B Dry Pit Installation

Types of Sewage Ejector Installations

Fig. 4-16

Residential and Light Commercial Applications

Typical Non-Clog Pump Assembly

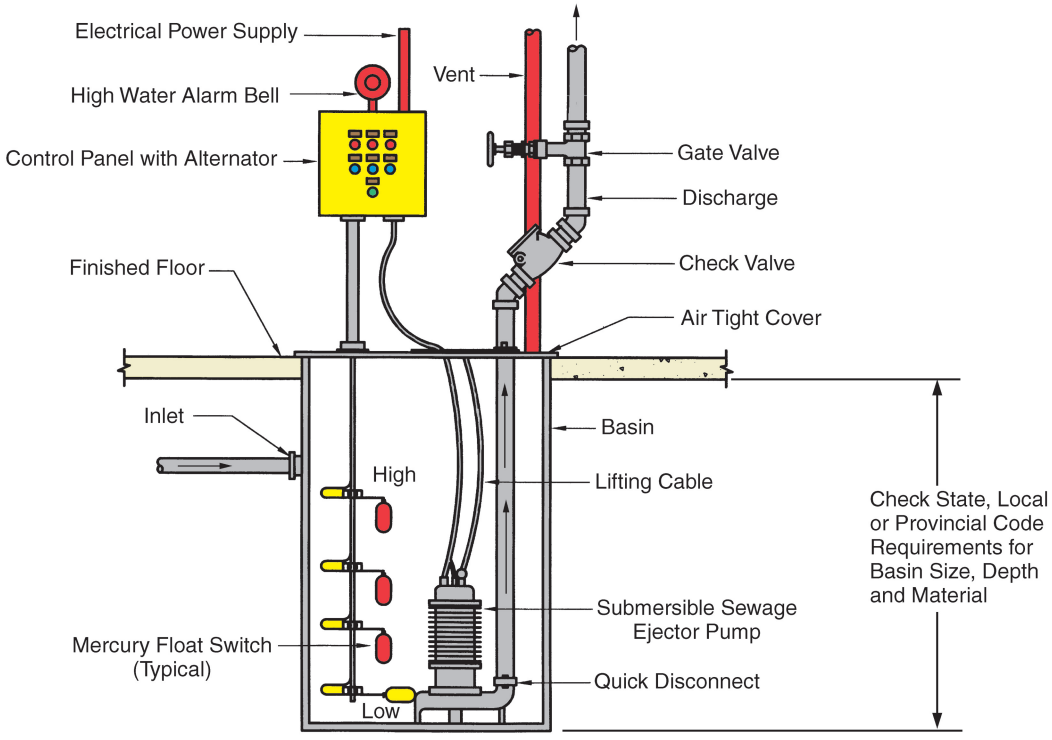
Fig. 4-17

according to the manufacturer's specifications. Describe the purpose and function of three types.

See **Figure 4-18**. Generally pumps are float-controlled, whereby a floating ball and rod, micro switch, mercury float switch or water-level detector starts and stops the pump at different adjustable water levels. They should not start more often than every 3 to 5 minutes and operate for 10 minutes. In critical applications, a high-water level alarm that activates an alarm device when the water level rises above a predetermined point is used.

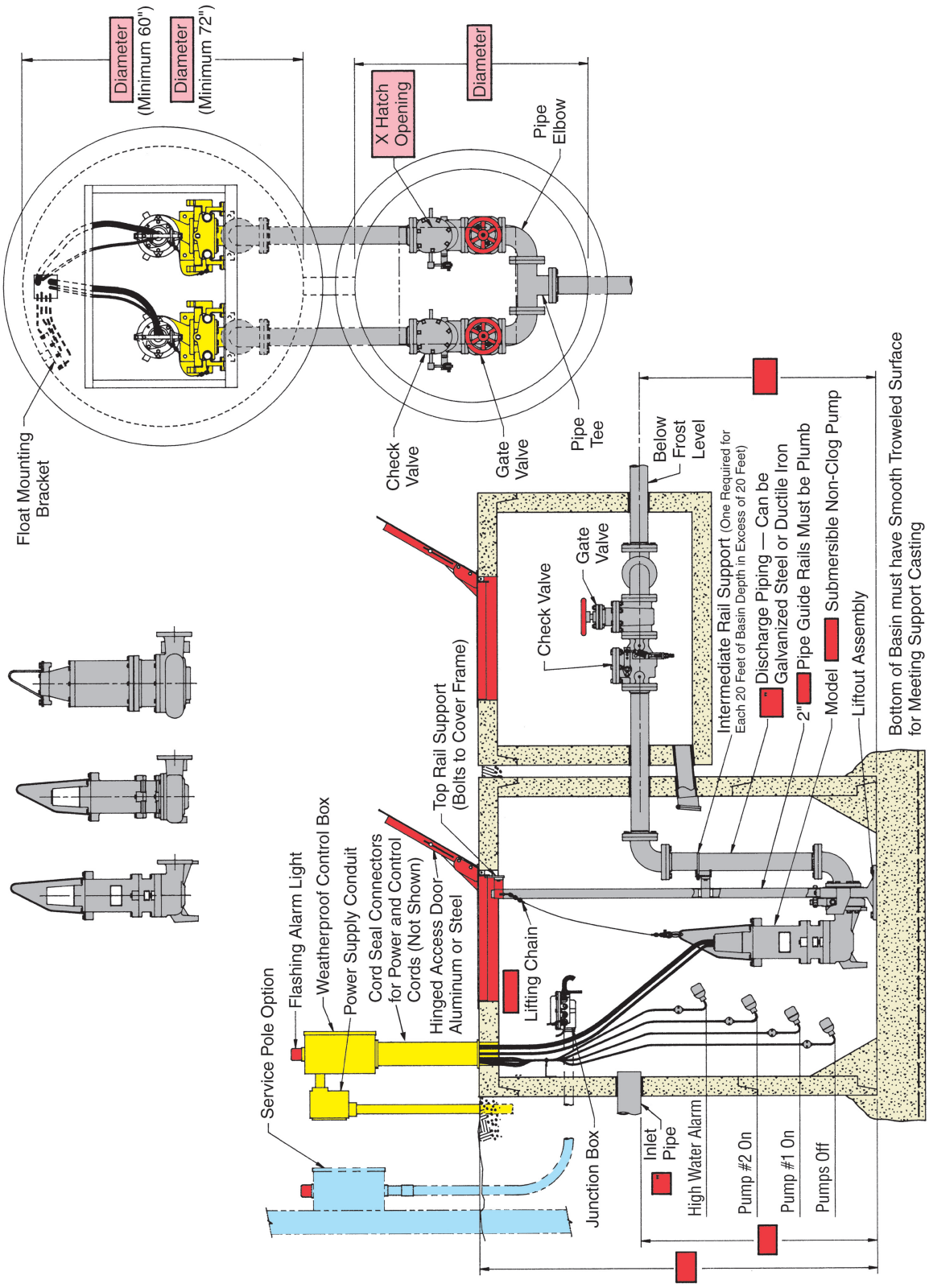
Duplex pump installations as in **Figure 4-19**, may be installed to operate in parallel from one float device, operate separately from different water levels, alternate periodically, or operate in a lead-lag arrangement to prolong the life of each pump.

A float switch assembly which consists of a float, float rod, rod guide, adjusting stops, gas tight pedestal and float switch. This unit serves as a pilot



Typical Submersible Sewage Ejector Installation

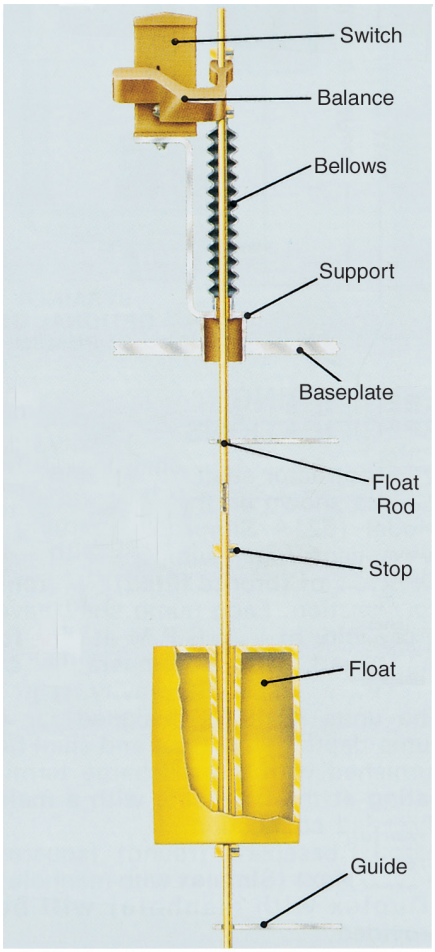
Fig. 4-18



Typical Installation of a Duplex 4" Submersible Non-Clog Sewage Pump

Fig. 4-19

device for the magnetic motor starter. It is mounted on the basin cover as shown in **Figure 4-20**. The two float stops are adjustable to the desired high and low level pumping levels. The float slides along the float rod between the float stops. The float rod is balanced with a counterweight on the switch arm for quick response. Explosion-proof switches are available for use in hazardous conditions.



Typical Float Switch Assembly

Fig. 4-20

Mechanical alternators are designed to provide a positive means of alternating the operation of the two pumps on a duplex system. For unusual or peak loads, both pumps are automatically placed in operation and will continue until the service flow can again be handled by a single pump. At that time, alternate cycling is automatically resumed. Only one float switch assembly is needed.

What must be done before a sewage pumping system is put into operation?

Before a sewage pumping system is put into operation, be sure that lubrication of the pump and driver is performed, all valves are in their normal operating position and the basin has been cleaned of debris.

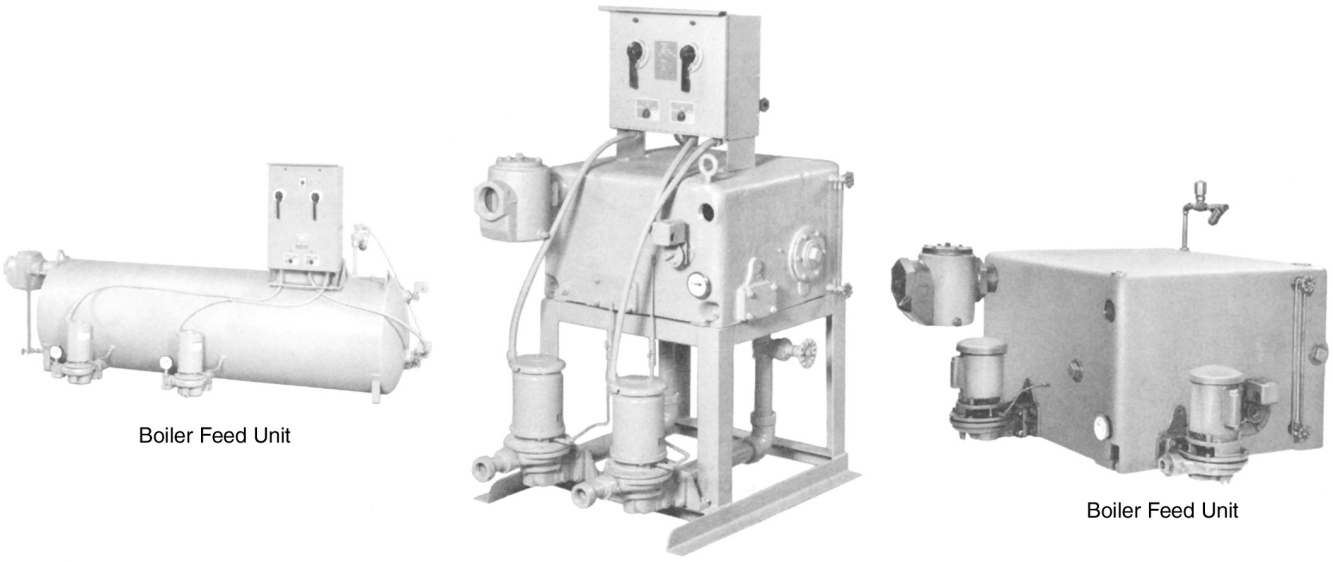
Boiler feed pumps are predominately of the centrifugal type, single diffuser type for low capacity and multi-stage for high pressure and high capacity installations. What is the function of a boiler feed pump?

The function of a boiler feed pump is to supply the water to a boiler in sufficient quantity and pressure to maintain a safe water level in the boiler. Obviously, the pressure which the pump produces must exceed the boiler pressure. This differential must also take into consideration the various resistances that the water will be subjected to as it leaves the pump outlet on its way to the boiler, such as pipe, valves, fittings, one or more feed water heaters, etc.

Vented boiler feed units of the types shown in **Figure 4-21-A, B** and **C** are designed to pump water into an operating boiler. The pumps are controlled by level controls on the boiler. They are normally sized to accommodate system surges and also to provide for the addition of fresh water as required. Low water cut-off switches and alarms are often included in the boiler feed system.

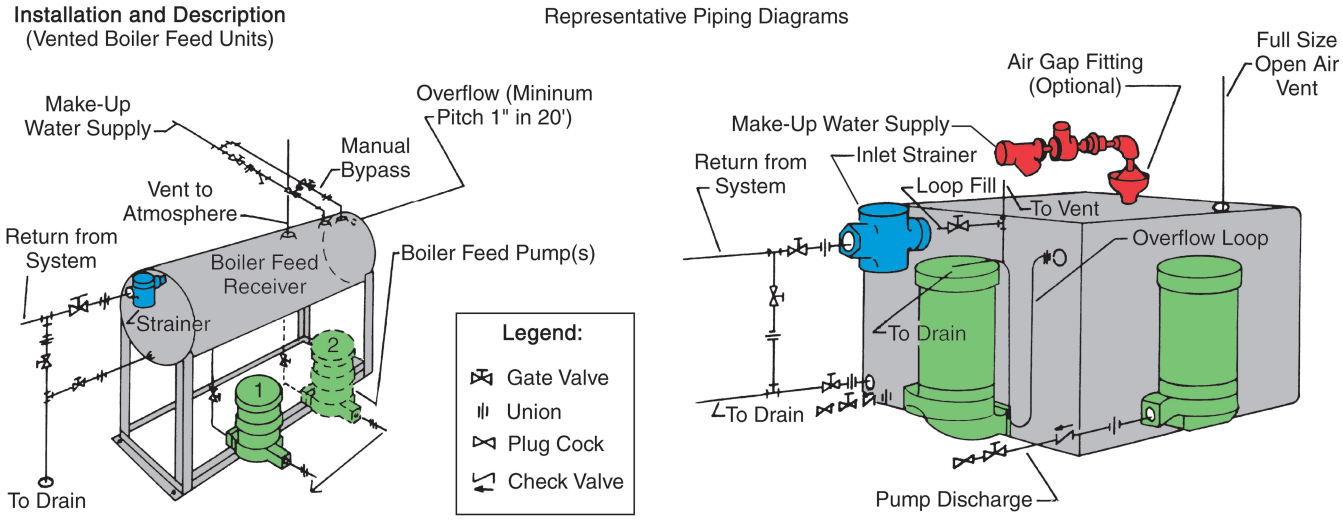
Typical piping diagrams for the vented boiler feed units shown in **Figure 4-21** are illustrated in **Figure 4-22-A** and **B**. Check state, local or provincial code requirements concerning the installation of approved backflow protection on the make-up water supply to boiler feed units.

Any training manual on pumps must also include information about compressors whether they are used in refrigeration systems, in medical gas systems, in compressed air systems, in pneumatic



Types of Vented Boiler Feed Units

Fig. 4-21



Typical Piping Diagrams for Vented Boiler Feed Units

Fig. 4-22

control systems or simply used for testing purposes. Explain.

An air compressor provides a source of energy in the form of compressed air. The controller, usually a device that regulates pressure, varies the amount of compressed air passing through a circuit of the system. Because of the expanding characteristics of air, it may be compressed at one location and used to do work at another location.

Strictly speaking, the term *compressor* is the pump, or compressor proper. Generally, the term compressor is taken to mean the complete unit consisting of the compressor and the motor which drives it.

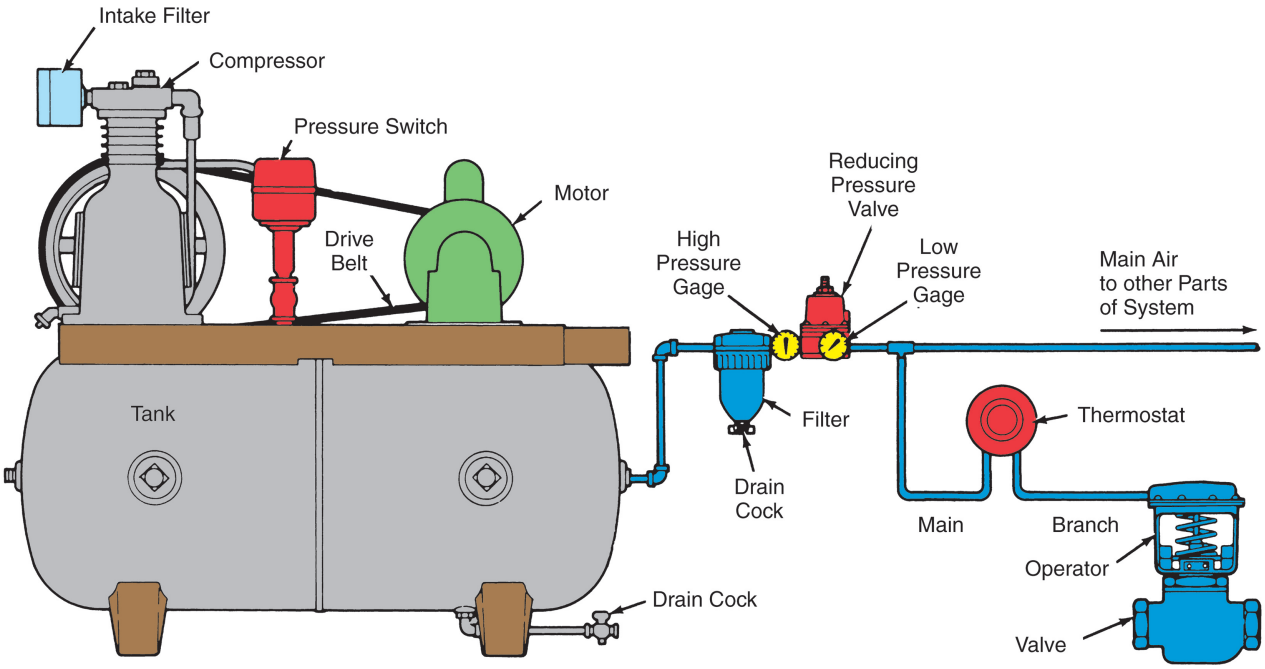
Compressed air is used for automatic controls on heating, cooling, ventilating and air conditioning equipment. In its most simple form an air compressor along with several components of a pneumatic control system is shown in **Figure 4-23**. A reciprocating compressor provides a source of energy in the form of compressed air. The controller, a thermostat for instance, varies the amount of compressed air passing through a circuit of the system. This compressed air operates the controlled devices, valves or damper operators in a building, on demand of the thermostat.

The basic operation of a piston type reciprocating compressor (compression pump) is illustrated in Figure 4-24. Describe the operation of the compression cycle shown in Figure 4-24.

On the downstroke of the piston a partial vacuum is created inside the cylinder and atmospheric pressure causes air to force the suction valve open and fill the cylinder. See **Figure 4-24-A**. The pressure in the discharge line holds the discharge valve closed. On the upward stroke of the piston, the air is compressed and the pressure inside the cylinder increases. This holds the suction valve closed and forces the air to flow out of the cylinder past the discharge valve and into the discharge pipe. See **Figure 4-24-B**.

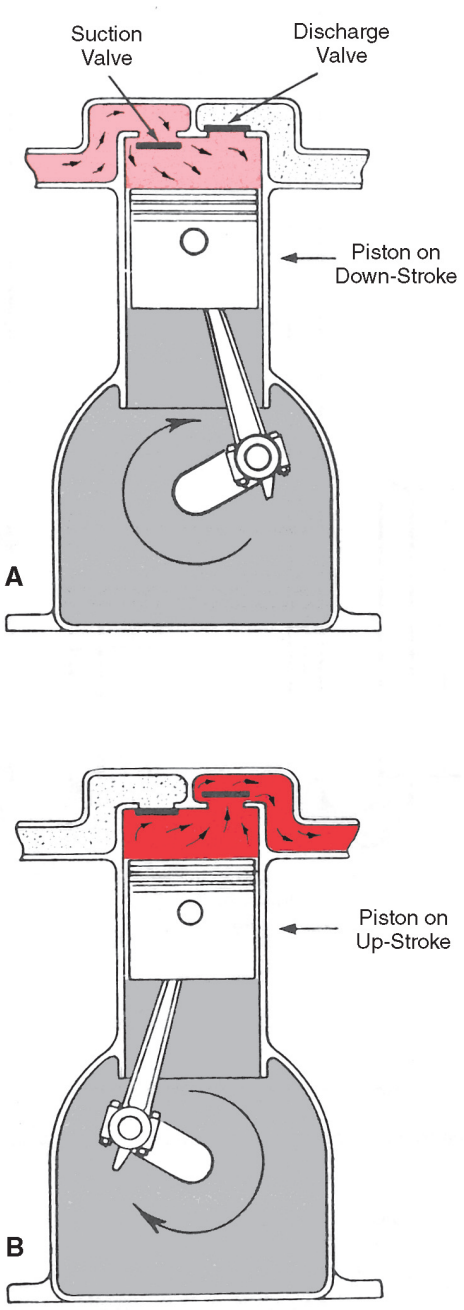
The installation and servicing of medical air compressors is one of the most critical tasks a U.A. journeyworker must do. Explain.

The main requirement for air compressors in a Level 1 (hospital) installation is to supply air with no added contamination. The air is used to support life and when mixed with other gases, the proper results can be achieved. The air in a medical gas system can be used for no other purpose than direct patient therapy. That is why the cleanliness and efficiency is so critical. The accepted authority on medical gas installations in health care facilities in the United States is The National Fire Protection Association Standard NFPA-99. Canada has a similar standard called CAN/CSA-Z305. Nonflammable Medical Gas Piping Systems.



Component of an Air Compressor for use with a Pneumatic Control System

Fig. 4-23



Operating Cycle of a Reciprocating Compressor

Fig. 4-24

As a compressed air supply source, a medical air compressor should *not* be used to supply air for other purposes because such use could increase service interruptions, reduce service life, and introduce additional opportunities for contamination.

There are two basic types of compressors used in medical gas systems.

One type is an *oil-less* with no oil anywhere in the compressor. This is to eliminate the addition of gaseous or liquid hydrocarbons to the air stream from the compressor itself.

The other type is *oil-free* and has a physical separation (air break) plus seals to limit the possibility of oil migration into the compression chamber. As you can see the *oil-less* is more desirable and is used whenever possible and practical. There are different styles of both types. They can be air-cooled or water-cooled and all have their individual manufacturer recommendations that must be followed.

Conventional lubricated piston compressors have oil-filled crankcases; thus oil vapor is always present in the compression chamber and discharge line. Filtration, the common solution, is expensive and requires constant maintenance. In commercial and industrial application, a conventional lubricated compressor is acceptable; in medical air systems, they are prohibited.

Oil-free piston compressors (Type B) contain an oil lubricated crosshead piston and crank mechanism, and a dry cylinder compression chamber that are isolated by means of at least two seals. These seals ensure a 99.99% possibility of oil-free air. However, with wear of the seals, oil migration into the discharge line will possibly increase. It is required, therefore, in these compressors, that the interconnecting shaft be open for visual inspection.

An oil-less piston compressor is one way to meet the goal of 100% oil-less air. Oil-less compressors use self-lubricated pistons and skirts, as well as sealed for life bearings. Since there is no oil in the crankcase, the crank mechanism operates in what amounts to a *dry state*, assuring no oil in the discharge line.

What is another method of delivering 100% oil-less air?

Another method of delivering 100% oil-less air is by using a liquid ring compressor. This system draws air through a filter into the inlet of the com-

pressor and discharges the air through a dryer into a receiver tank, using water to compress the air. Liquid ring compressors provide the added benefit of cleaning the air with the water used for compression, making the discharge air cleaner than the air entering the compressor.

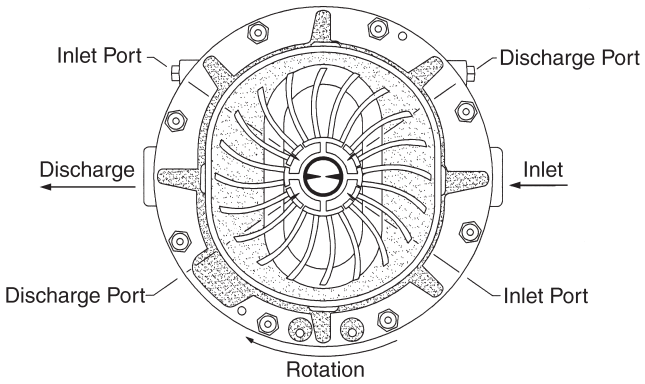
There is only one moving part, the impeller, and no metal to metal contact. The service water enters the compressor after passing through a strainer, solenoid valve, flow control valve, backflow preventer and dielectric fitting. The water combined with the spinning impeller compresses the air and discharges both water and air.

The impeller is located at the center of the pump body, which has, however, an internal periphery that is elliptical (oval) in shape. Due to centrifugal action of the spinning impeller, the water assumes the elliptical shape of the internal periphery, forming the liquid ring. By controlling the depth of the water, the impeller blades are totally submersed at the location of the discharge port and only partially (the blade tips) exposed at the inlet port. The converging casing of the compression sector forces the water back into the impeller at the discharge port.

As water recedes from the impeller at the inlet sector, the water is replaced by air drawn through an inlet port that connects to the compressor inlet. As the impeller turns, and water is forced, again, by the casing back into the impeller, the air that has filled the chamber is forced through discharge ports in the conical casting to the compressor or discharge.

This action causes a lower pressure (vacuum) to be formed in the lines connected at the compressor inlet and compressed air to be forced out of the compressor discharge. Each chamber fills and empties twice each revolution, balancing lateral forces to reduce deflection. See **Figure 4-25**.

During the compression cycle, heat is being transferred to the water, which is carried away by the introduction of more water. The amount of coolant supplied is equal to the amount discharged to the separators. A separator is used on the discharge to separate the water from the air with any condensate being removed by a filter. The air is then dried and stored in a receiver tank for use.



Compressor Operation

Fig. 4-25

In a liquid ring compressor, with water used as the liquid ring, no other internal lubrication is required. No contamination is added to the compressed air. It is 100% free of hydrocarbons.

In all types of installations, monitors with alarms are required to insure against high temperatures, high water levels (in liquid ring compressors), dewpoint, carbon monoxide and other gases. Installation will involve two or more compressors, running alternately, with dedicated disconnect switches.

CHECKPOINT 2

Go back to checkpoint 1 for a review as previously instructed. When satisfied that you understand the material covered, answer the questions on the assignment sheet and then proceed to checkpoint 3.

What are some of the installation requirements concerning the use of pipe, pipe fittings and valves in a fire protection system?

When installing pumps in a fire protection system, steel pipe must be used above ground. The only exception to this requirement is when you connect to underground suction and underground discharge piping.

To prevent tuberculation (small knobs or buttons of rust on the inside of the pipe) where corrosive water conditions exist, steel suction pipe shall be galvanized, or painted on the inside, prior to installation, with a paint recommended for submerged surfaces. Thick bituminous linings are *not* permitted. Sections of steel piping are joined by means of screwed, flanged (with flanges welded to pipe preferred), mechanical grooved joints, or other approved fittings.

How can pipe breakage caused by movement be lessened?

Pipe breakage caused by movement can be greatly lessened, and in many cases prevented, by increasing flexibility between major parts of the piping. Flexibility can be provided by the use of flexible couplings at critical points, and by allowing clearances at walls and floors.

A listed check valve must be installed in the pump-discharge assembly. Explain.

Large systems and systems in high buildings can experience objectionable water hammer when an automatically controlled fire pump shuts down. When such conditions are expected, a listed (approved) check valve must be installed in the pump discharge piping and it should be of the anti-water hammer type. A listed indicating gate or butterfly valve must be installed on the system side of the check valve.

A number of connections and fittings are usually needed to complete the installation of a centrifugal fire pump. These include pressure gages, relief valves, water measuring devices, hose valves, meters, and jockey pumps. See Figures 4-26 and 4-27. Give a brief description of the use of these items in a fire sprinkler system.

1. *Pressure gages*. A pressure gage with a dial not less than 3½" in diameter shall be connected near the discharge casing along with a ¼" gage valve or cock. The dial must indicate pressure at least twice the rated working pressure of the pump, but not less than 200 psig.

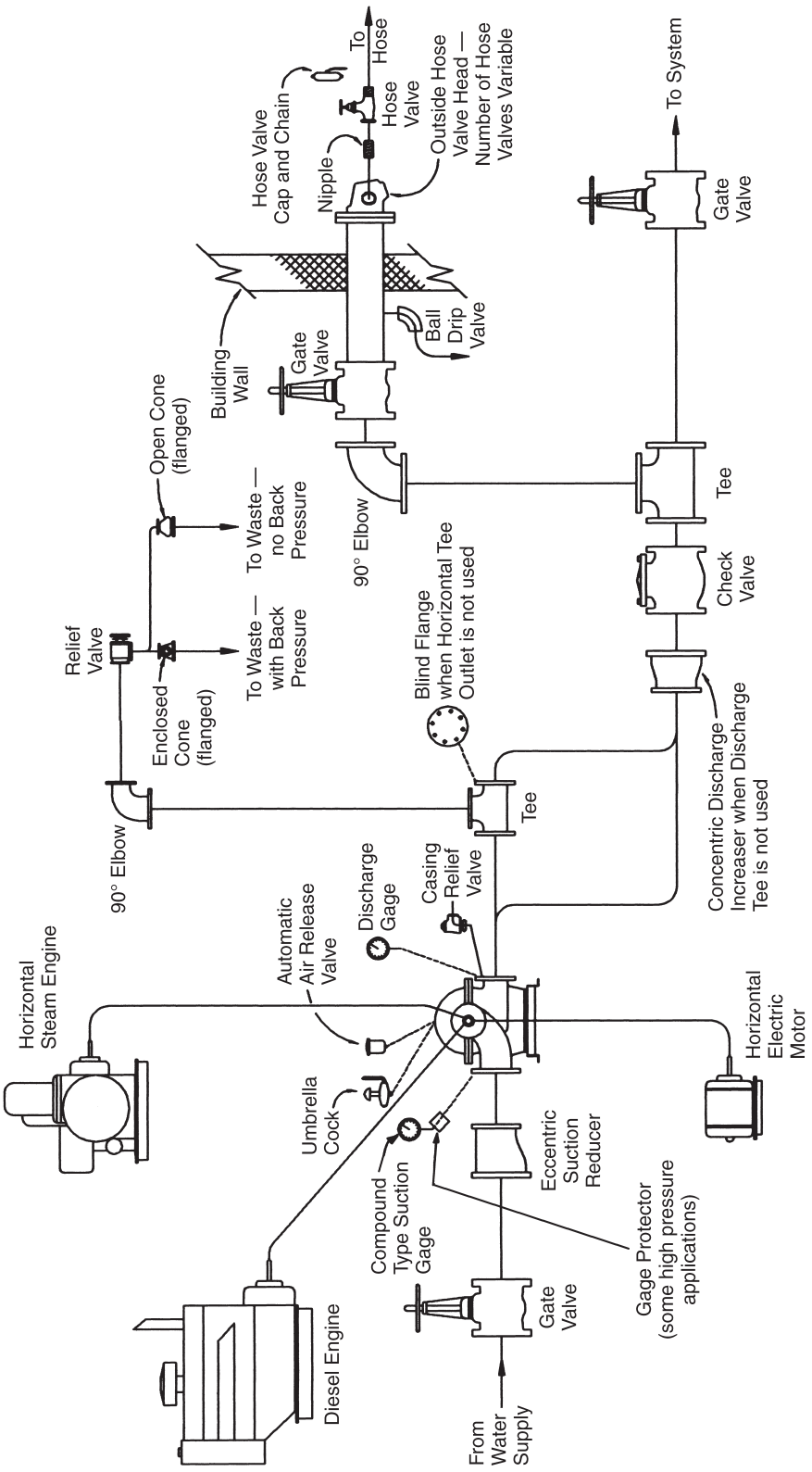
   A compound pressure and vacuum gage, with a dial not less than 3½" in diameter must be connected to the suction pipe near the pump along with a one-quarter inch gage valve or gage cock. The face of the dial can read in inches of mercury (Hg) or pounds per square inch for the suction range.

2. *Circulation relief valve (casing relief valve)*. Each pump driven by an electric motor shall be provided with an automatic relief valve listed for fire pump service and set below its shutoff or churn-pressure at minimum expected suction pressure. It must provide circulation of sufficient water to prevent the pump from overheating when operating with no discharge, which could otherwise cause the bearings to seize.

3. *Relief valves*. Pumps connected to adjustable-speed drivers (diesel or steam engines) shall be equipped with an approved relief valve. Where pumps are driven by constant-speed motors (electric), and the pump shutoff pressure plus the static suction pressure exceeds the pressure for which the system components are rated, relief valves are required.

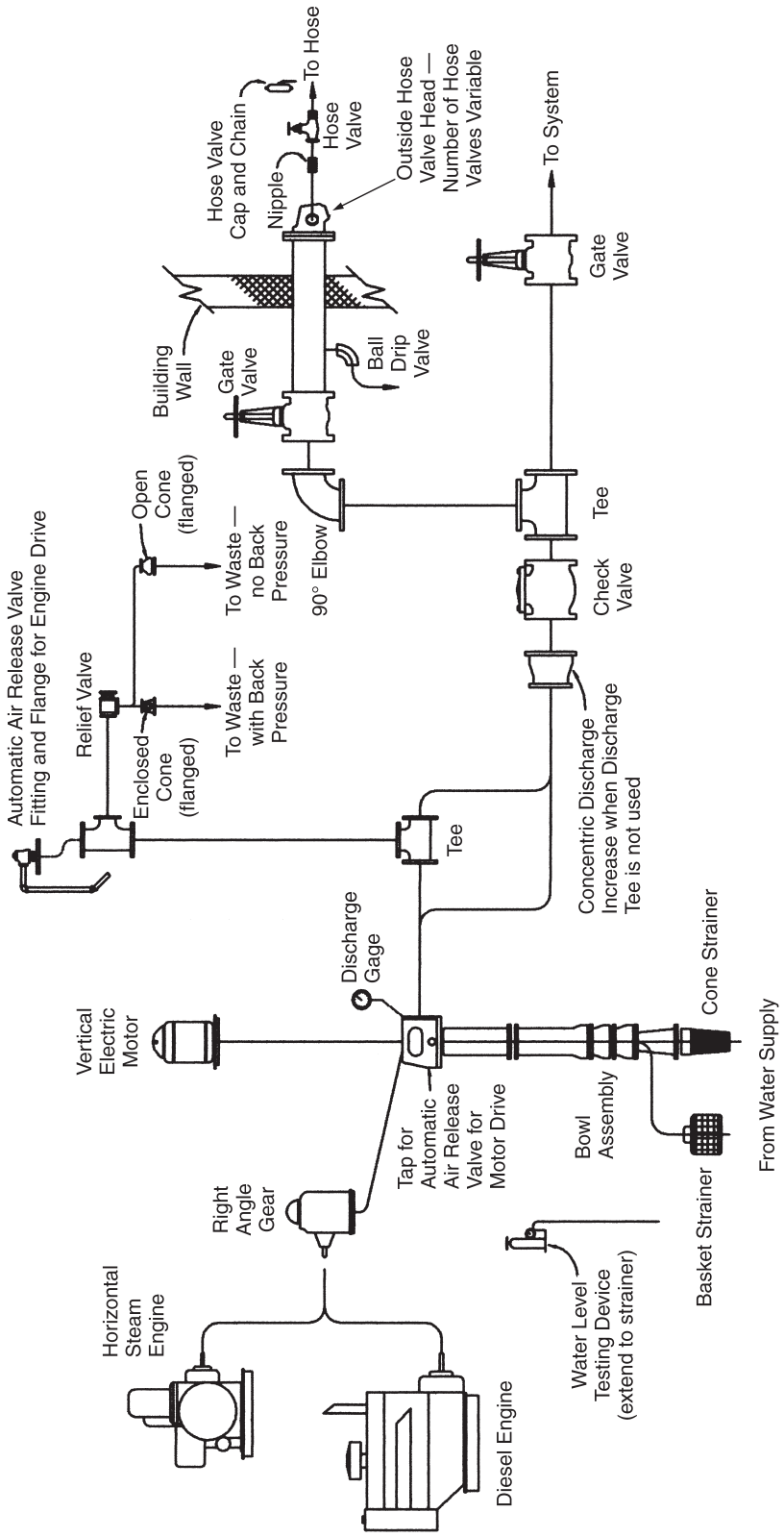
   The pressure developed by a fire pump, when the flow rate is below the rated capacity of the pump, is in excess of the pump's rated pressure. Maximum pressure is developed at a zero flow rate. This condition is referred to as *shutoff pressure*. Thus, if a pump is supplied by a city main with a suction pressure of 60 psig, and the pump has a shutoff pressure of 120 psig, the sprinkler system will be subjected to a pressure of 180 psig (60 psig from the source, plus 120 psig developed by the pump [60 + 120 = 180]). This, of course, exceeds the 175 psig sprinklers can be subjected to. Pumps supplying standpipe systems to which sprinklers are not connected do not generally require relief valves.

   The relief valve must be set to prevent pressure on the fire-protection system exceeding what the system is designed to with-



Schematic Diagram of a Horizontal Pump and System Components

Fig. 4-26



Schematic Diagram of a Vertical Pump and System Components

Fig. 4-27

stand. The relief valve must be located between the pump and the pump-discharge check valve and be so attached that it can be readily removed for repairs without disturbing the piping.

4. *Water measuring devices.* A water-measuring device must be provided to test the pump and the suction supply at the maximum flow available from the fire pump.

5. *Hose valves.* The most common devices for testing pump discharge capacity are listed hose valves mounted on a header. The hose valve piping connects to the pump discharge piping between the discharge check valve and the discharge gate valve.

   Hose valves should be located so as to avoid any possible water damage to the pump driver or controller. Further, they should be outside the pump room or pump house. If there are other adequate pump testing facilities, such as yard hydrants, wall hydrants, or standpipe hose valves, the hose valve header may be omitted when its main function is to provide a method of pump and suction pipe testing.

6. *Meters.* Metering devices for pump testing shall be listed and capable of waterflow of not less than 175 percent of the pump's rated capacity. The minimum size meter for a given pump capacity may be used where the meter system piping does not exceed one hundred feet equivalent length (length of straight pipe plus equivalent length in fittings, elevation, and loss through meter). Where metered system piping exceeds one hundred feet equivalent, the next larger size piping shall be used to minimize friction loss.

7. *Jockey pump.* A jockey pump, sometimes referred to as a *pressure maintenance* or *make-up pump* is usually required with automatically controlled fire pumps. A jockey pump is a high-pressure, low capacity pump. It is used to replenish system pressure lost through system leaks without undue wear on the fire pump. In a jockey pump system a small pump, motor, and controller/pressure switch is installed in the piping system.

What is the difference between a horizontal pump and a vertical pump?.

Probably the easiest way to differentiate between the two is to note that the supply to a horizontal pump is piped from a water source (a city connection or a tank) while the impellers of a vertical pump sit in the supply (a wet pit or a well).

Horizontal pumps used in fire sprinkler systems are of three designs.

1. The *horizontal-shaft split-case* pump is the one most commonly used. These pumps are specially tested for fire service applications where reliability of performance is of vital importance. They are characterized by easy access to all working parts, rugged construction, liberal water passages, and efficient operation. It has one flanged fitting for connection to the water supply and another for connection to the fire protection system. A shaft extends out one end to connect to the power source.

2. Another variation of the horizontal-shaft pump is referred to as an *end-suction* pump. As the name implies, the water inlet is at the end of the pump rather than on the side. The discharge may be out either side or the top of the pump unit.

3. The *in-line* type is a variation of the end-suction style with the inlet and outlet connections in a straight line for installation in a straight run of piping. The motor is mounted directly on the pump so that no baseplate, coupling, etc. are needed. The motor is mounted vertically over the pump so that a minimum of floor space is required.

What are some of the installation requirements of the suction pipe and fittings?

The suction pipe must be capable of maintaining a gage pressure of at least zero at the pump suction flange, with all pumps connected to the supply pipe operating at 150 percent of their rated capacity. For example, if you had a supply pipe

connected to ten pumps, each rated for 1,000 gpm, the pipe would have to be large enough to supply all ten pumps operating at 150 percent of rated capacity. This arrangement can be expressed in the following formula:

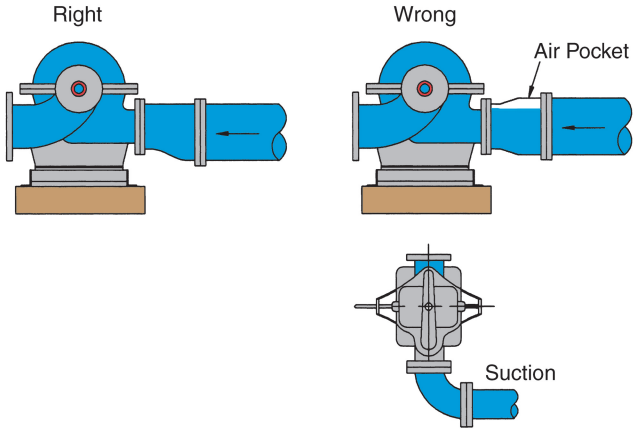
supply pipe = gpm per pump x 150% of rated capacity x number of pumps

supply pipe = 1,000 gpm/pump x 150% x 10 pumps = 1,000 x 1.5 x 10 = 15,000 gpm

Note: This must be done without pulling a vacuum.

When the supply pipe has enough pressure to be of value without the pump, such as in a connection to city water, a by-pass at least as large as the pipe size required for the discharge pipe must be incorporated in the installation.

Air pockets can seriously effect the operation of a pump. They can be avoided by good workmanship when the suction pipe is installed and by using an eccentric tapered reducer (make sure the flat side is on top) when the suction pipe is not the same size as the pump suction flange. See **Figure 4-28**.



Right and Wrong Pump Suction Installation

Fig. 4-28

Elbows with a centerline plane parallel to the pump shaft must be avoided, unless the distance between the flange of the suction inlet and the elbow is greater than ten times the suction pipe diameter. Horizontal shaft pumps are usually of the double suction volute type, in which water enters the impeller from each side. This balances out the thrust, minimizing the strain on the bearings. As you can see in **Figure 4-28**, incorrect elbow installation will not give the required balanced flow into the impeller.

What type of control valve must be used on the suction supply?

The suction supply control valve must be a listed OS&Y valve. While butterfly valves are permitted on the pump discharge, they must not be installed on the supply side of a fire pump or jockey pump within 50' of the pump suction flange. Turbulence caused in water passing a butterfly valve would cause cavitation. Where the suction supply is from public water mains, the gate valve should be located as far as is practical from the suction flange on the pump. Where it comes from a stored water container, the gate valve should be located at the outlet of the container.

Except as indicated below, no device or assembly (including, but not limited to, backflow prevention devices or assemblies) that will stop, restrict the starting, or restrict the discharge of a fire pump shall be installed in the suction piping. The exceptions are:

1. Shutoff valve.
2. Check valves and backflow prevention devices and assemblies required by other NFPA standards or by the authority having jurisdiction.
3. Pressure sensitive flow control valves listed for fire pump service where the authority having jurisdiction requires that positive pressure be maintained on the suction piping.

Suitable devices may be installed in the suction supply piping or stored water supply as long as they are arranged to activate an alarm if the pump suction pressure or water level falls below a predetermined minimum.

Pumps which are automatically controlled must be provided with an approved float-operated air release not less than ½" in size to release air from the pump automatically. This is *not* required for end suction pumps with a top centerline discharge, or on in-line pumps.

Pumps are designated having either a clockwise (CW), or right-hand, rotation, or a counterclockwise (CCW), or left-hand, rotation. Diesel engines are commonly stocked and supplied with clockwise rotation. How can the rotation of a horizontal pipe be determined?

The rotation of a horizontal pump can be easily determined. Stand at the driver end and facing the pump. If the top of the shaft revolves from the left to the right, the rotation is clockwise. If the top of the shaft revolves from right to left, the rotation is counterclockwise.

The turbine pump is a vertical-shaft centrifugal pump with rotating impellers suspended from the pump head by a column pipe. This column pipe also serves as a support for the shaft and bearings.

The turbine pump is particularly suitable for fire pump service when the water source is located below ground, or where it would be difficult to install any other type of pump below the minimum water level. Turbine pumps were originally designed for installation in drilled wells, but are most commonly used with a below-grade reservoir.

Both oil-lubricated enclosed-line-shaft and water lubricated open-line-shaft pumps are available. See **Figure 4-29-A** and **B**. Vertical-shaft pumps have the same characteristics and requirements as horizontal-shaft pumps.

Suction from wells is acceptable if the adequacy and reliability of the well is established and the entire installation conforms to the NFPA Fire Pump Standard.

What are two means of providing the necessary submergence for vertical-shaft turbine pumps?

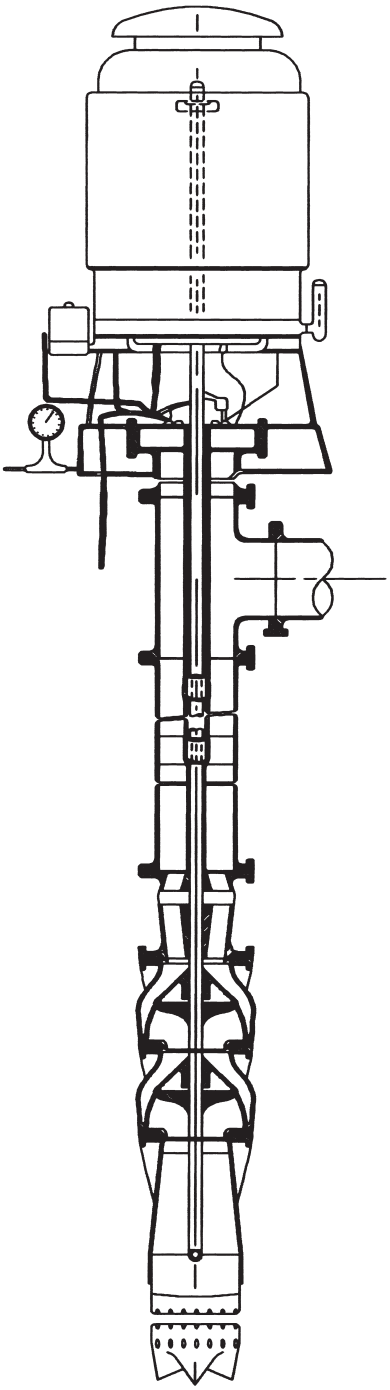
1. *Well installation.* For *well installations*, in order to provide for reliable operation of the fire-pump unit, submergence of the second impeller from the bottom of the pump-bowl assembly shall be *not* less than 10' below the pumping water level at 150 percent of rated capacity. See **Figure 4-30**. The submergence must be increased by 1' for each 1,000' of elevation the installation is above sea level.
2. *Wet pit installations.* In order to provide submergence for priming in a *wet-pit installation*, the elevation of the second impeller from the bottom of the pump-bowl assembly shall be such that it is below the lowest pumping water level in the open body of water supplying the pit. See **Figure 4-31**. For pumps with rated-capacities of 2,000 gpm or greater, additional submergence may be required to prevent the formation of vortices and/or prevent excessive cavitation. The required submergence shall be obtained from the pump manufacturer.

A typical vertical-shaft turbine pump consists essentially of five elements.

1. A motor head or right-angle gear drive
2. A column pipe and discharge fitting
3. An open or enclosed drive shaft
4. A bowl assembly (containing the impellers)
5. A suction strainer

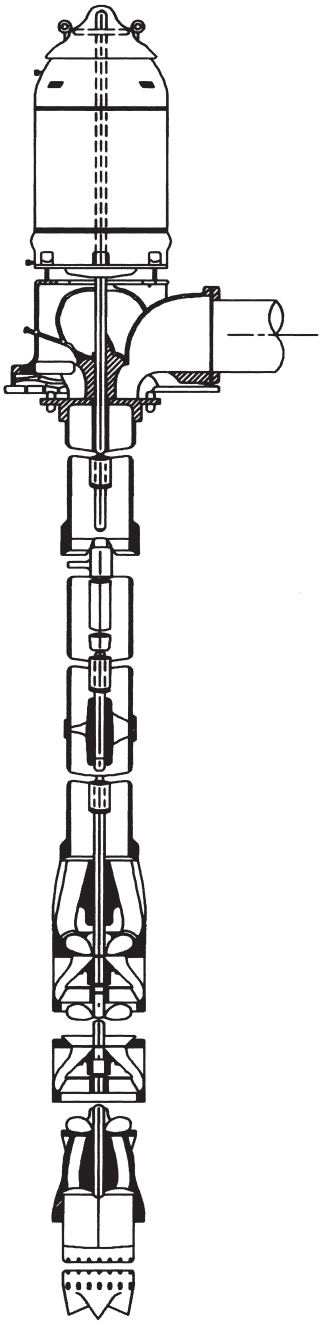
Note: The bowls containing the impellers are connected in series.

A 1½" or larger automatic air-release valve is required to vent air from the column and the discharge head upon the starting of a pump. This valve will also admit air to the column to dissipate the vacuum at that location there when the pump stops. It must be located at the highest point in the discharge line between the fire pump and the discharge check valve. A check valve mounted vertically in the inverted position is commonly used. Air will pass through the check valve, but water pressure will close its clapper.



A

Oil Lubricated
Enclosed-Line Shaft Pump
Underground Discharge
Flanged Column and Bowls

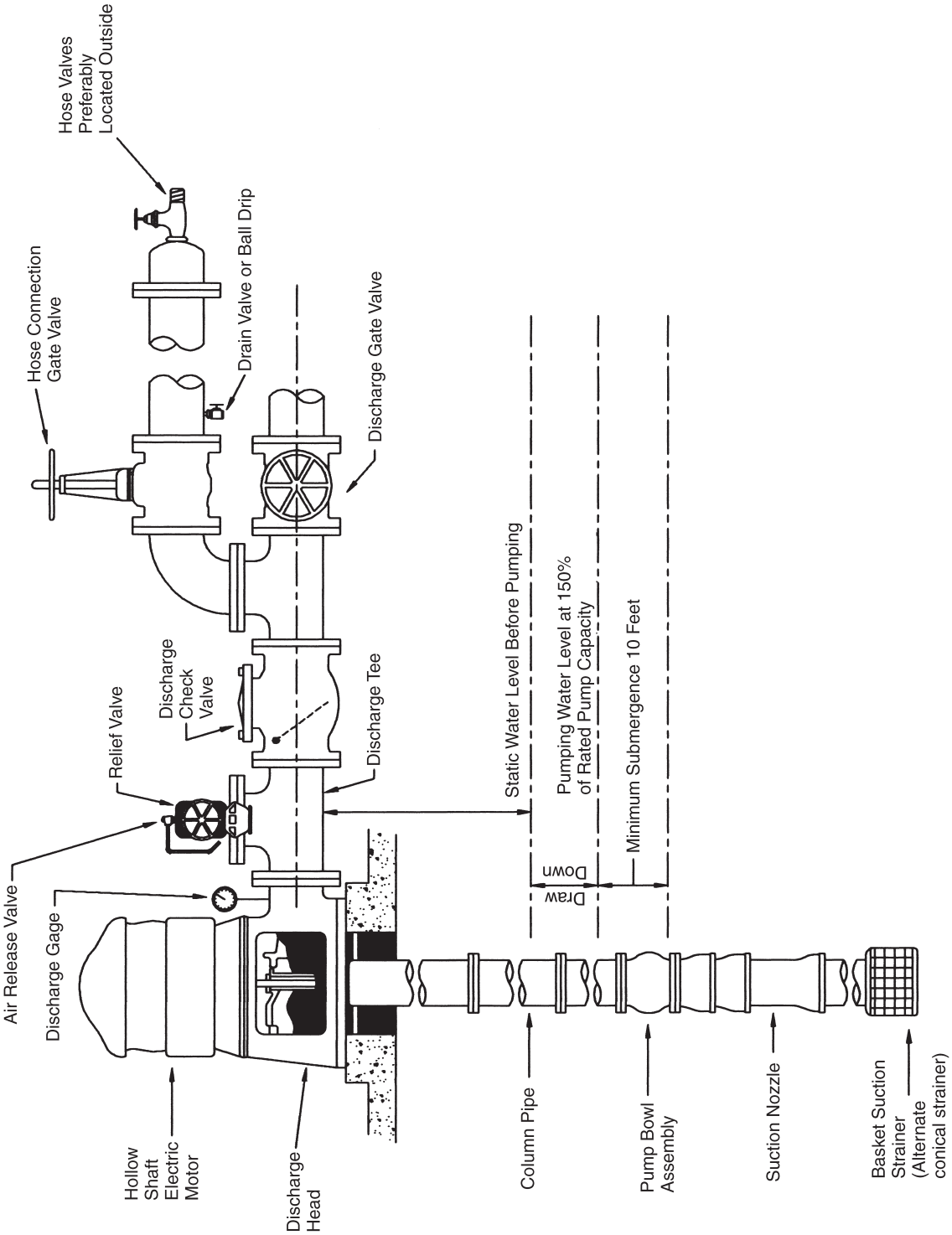


B

Water Lubricated
Open-Line Shaft Pump
Surface Discharge
Threaded Column and Bowls

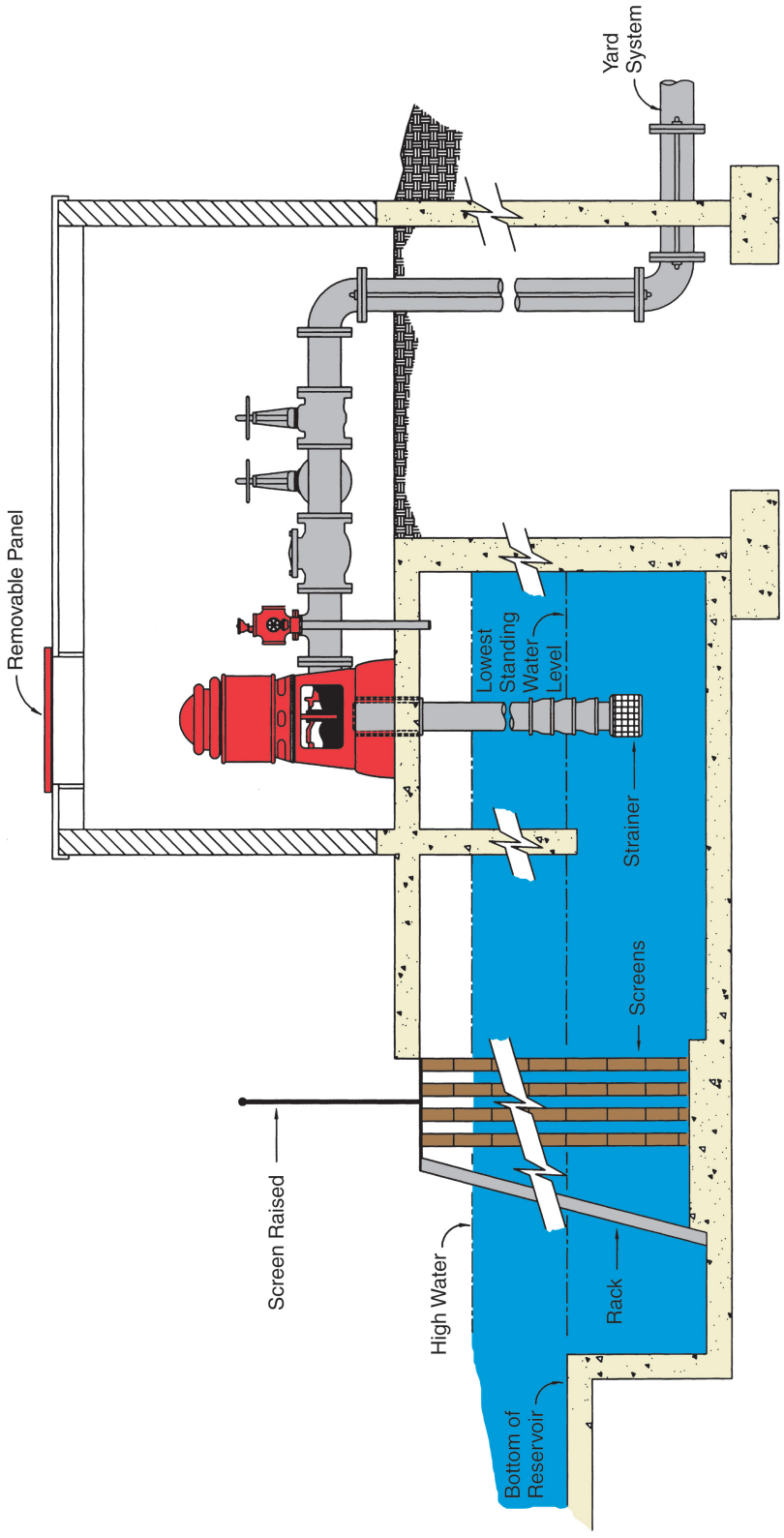
Vertical Shaft Pumps

Fig. 4-29



Vertical-Shaft Turbine Pump Installation in a Well

Fig. 4-30



Wet Pit Installation

Fig. 4-31

Each well installation shall be equipped with a suitable water-level detector. If a permanently installed air-line is used, it shall be of corrosion-resistant metal, such as copper, and be strapped to the column pipe at ten foot intervals. A satisfactory method of determining the water level involves the use of an air-line of small pipe or tubing with known vertical length, a pressure gage, and an ordinary bicycle pump. The air-line pipe of known length extends beyond the lowest anticipated water level in the well.

Several methods of installing a vertical-shaft turbine pump may be used, depending upon the location of the well or wet pit and the kind of facilities available. Since most of the unit is underground, extreme care must be used in assembling and installing the pump and in thoroughly checking the work as it progresses. The following three step method is the one most commonly used.

1. Construct a lifting device such as a tripod or portable derrick and use two sets of installing clamps over the open well or pump house. After the lifting device is in place, the alignment should be checked carefully with the well or wet pit to avoid any trouble when setting the pump.

2. Attach a set of clamps to the suction pipe on which the strainer has already been placed and lower it into the well or wet pit until the clamps rest on a block beside the well casing or on the pump foundation.

3. Attach clamps to the pump-stage assembly and bring it over the well casing. Install pump stages to suction pipe, etc., until each piece has been installed in accordance with the manufacturer's instructions.

Where the pump is mounted over a sump or pit, I beams may be used. When you are using a right-angle gear to connect the pump to its driver, install the driver parallel to the beams.

Vertical pumps are usually driven by electric motors or diesel engines. Explain.

Electric motors mount directly on the top of the pump discharge base fitting. They sit in a vertical position and are bolted directly to the pump. No alignment check is necessary.

However, due to the construction of the pump bowl, the position of the impellers in the pump unit is controlled by an adjustment of the coupling at the motor. This is referred to as the *lateral adjustment*. It must be made prior to start up. *Failure to set this properly will cause immediate damage to the pump.*

Correct procedures for making lateral adjustment vary with make and type. In all instances, however, it is absolutely necessary that the coupling be adjusted, as necessary, before checking rotation of the motor or running the pump.

When diesel engines are used to drive vertical fire pumps, a right-angle gear drive is usually used to connect the vertical pump shaft to the horizontal diesel engine shaft. The right-angle gear mounts on the pump discharge base in the same manner as an electric motor.

The *lateral adjustment* is the same as for an electric motor and must be done prior to start-up or damage to the pump will result.

The horizontal shaft of the gear is normally connected to the diesel engine by a flexible shaft and universal joint arrangement. Alignment of these shafts differs from usual in that perfect alignment is not correct.

There should be misalignment of these shafts, as specified by the pump's manufacturer, to ensure proper operation. Exact procedures are available from the manufacturers and should be followed.

All vertical pump installations are equipped with a non-reverse ratchet. If a pump lacks such a ratchet, receding water in the pump columns when the driving power ceases would cause backspin. The pump could be damaged if started while it is in such reverse rotation.

What precautions must be taken prior to putting a unit in operation?

Before starting the unit for the first time, all field installed electrical connections, as well as the discharge piping from the pump must be checked. With the top drive coupling removed, the drive shaft must be centered in the top drive coupling for proper alignment, and the motor shall be operated for a moment or two to ensure that it rotates in the proper direction.

The rotation of a vertical pump can be determined by looking down at the top of the pump. If the point of the shaft revolves from left to right, the rotation is right-hand or clockwise (CW). If the point of the shaft revolves from right to left, the rotation is left-hand or counterclockwise (CCW). With the impellers set for proper clearance, the top drive coupling shall then be reinstalled.

Setting the impellers should be undertaken only by a representative of the pump manufacturer. Improper setting will develop excessive friction loss by rubbing of impellers on pump seals, with resultant increase in power demand. If the setting is adjusted too high, there will be a loss in capacity. *Full capacity is vital for fire pump service.* The top shaft nut should be locked or pinned after proper setting.

With the above precautions taken, the pump shall be started and allowed to run. The operation is to be observed for vibration while running and also for any malfunctioning of the pump driver.

Pumping units are checked at the factory for smoothness of operation and should perform satisfactorily on the job. If excessive vibration is present, several conditions may be causing the trouble. List them.

1. a bent pump or column shaft
2. impellers not properly set within the pump bowls
3. pump not hanging freely in the well
4. strain transmitted through the discharge piping

Excessive motor temperature is generally caused by either a maintained low voltage of the electric service or an improper setting of impellers within the pump bowls.

CHECKPOINT 3

Go back to checkpoint 2 for a review as previously instructed. When satisfied that you understand the material covered, answer the questions on the assignment sheet.

GLOSSARY

Administrative Authority — The individual official, board, department, or agency established and authorized by a state, county, city, or other political subdivision created by law to administer and enforce the provisions of the plumbing code. Also known as *authority having jurisdiction*.

Alarm — 1. Any audible or visible signal indicating existence of a fire or emergency requiring evacuation of occupants and response and emergency action on the part of the firefighting service. 2. The alarm device(s) by which fire and emergency signals are received.

Alarm Check Valve — A check valve, equipped with a signaling device, that will annunciate a remote alarm when a sprinkler head(s) is discharging.

Alignment — The act of forming a straight line, either horizontal, vertical, or at a given angle.

Approved Testing Laboratory or Agency — Refers to an accredited laboratory or agency having capabilities for both the laboratory and field evaluation of backflow prevention assemblies or devices.

ASHRAE — Abbreviation for the American Society of Heating, Air Conditioning and Refrigerating Engineers.

ASME — Abbreviation for American Society of Mechanical Engineers.

Atmospheric Pressure — The weight of air bearing down on the surface of the earth that causes pressure of about 14.7 lbs. to be exerted on each square inch at sea level.

Authority Having Jurisdiction — The organization, office, or individual responsible for approving equipment, materials, installation, or procedure.

AWWA — Abbreviation for American Water Works Association.

Cavitation — A formation of partial vacuums in a swiftly moving liquid which causes the pitting and wearing away of solid surfaces as a result of the collapse of these vacuums in the surrounding liquid.

Cavitation Damage — Deterioration of a surface caused by cavitation (sudden formation and collapse of cavities in a liquid).

Centrifugal Force — The force which tends to impel a thing or parts of a thing outward from a center of rotation.

Circulator — A pump to force the circulation of liquid in a system.

Code — An authoritative book of rules and regulations. Those regulations, subsequent amendments thereto, or any emergency rule or regulation which the administrative authority having jurisdiction may lawfully adopt.

Compressor — A mechanical device for increasing the pressure of air or gas.

Cup Washer, Leather, Rubber — 1. A gasket or washer in the form of a disc with a hole in its center and raised out peripheral edge. 2. Shaped like a cup, may be rubber or other material.

Department Having Jurisdiction — The administrative authority and any other law enforcement agency affected by any provision of a code, whether such agency is specifically named or not.

Discernible — To detect or perceive something obscure or concealed.

Discharge Head, Dynamic — Static discharge plus pressure need at the end of a pipe, less the frictional resistance of the discharge pipe.

Discharge Head, Static — The vertical distance from the outlet of a pump to the point at which liquid leaves a pipe.

Displacement Pump — A pump such as an air lift that raises or transfers a fluid by direct displacement with no transformation of energy due to the fluids motion into pressure.

Dry-Pipe Valve — A valve used with a dry-pipe sprinkler system where water is on one side of the valve and air is on the other side. When a sprinkler head's fusible link melts, releasing air from the system, this valve opens, allowing water to flow to the sprinkler head.

Fire Pump Types

Can Pump — A vertical-shaft, turbine-type pump in a can (suction vessel) for installation in a pipeline to raise water pressure.

Centrifugal Pump — A pump in which the pressure is developed principally by the action of centrifugal force.

End-Suction Pump — A single-suction pump having its suction nozzle on the opposite side of the casing from the stuffing box and having the face of the suction nozzle perpendicular to the longitudinal axis of the shaft.

Excess Pressure Pump — UL-listed and/or FM-approved, low-flow, high-head pump for sprinkler systems not being supplied from a fire pump. the pump pressurizes the sprinkler system so that the loss of water supply pressure will not cause a false alarm.

Fire Pump — UL-listed and/or FM-approved pump with driver, controls, and accessories used for fire protection service. Fire pumps are of the centrifugal or turbine type and usually have an electric-motor or diesel-engine driver.

Horizontal Pump — A pump with the shaft normally in a horizontal position.

Horizontal Split-Case Pump — A centrifugal pump characterized by a housing that is split parallel to the shaft.

In-Line Pump — A centrifugal pump in which the drive unit is supported by the pump, having its suction and discharge flanges on approximately the same center line.

Pressure Maintenance (Jockey) Pump — Pump with controls and accessories used to maintain pressure in a fire protection system without the operation of the fire pump. Does not have to be a listed pump.

Vertical Shaft Turbine Pump — A centrifugal pump with one or more impellers discharging into one or more bowls and a vertical educator or column pipe used to connect the bowl(s) to the discharge head on which the pump driver is mounted.

Friction — Resistance of the relative motion between two bodies in contact with one another. In piping systems resistance creates a decrease in the velocity of a fluid at the surface with which it is in contact.

Gage Pressure — The pressure at a point in a fluid above that of the atmosphere; measured where atmospheric pressure is considered as 0.

gpm — Gallons per minute.

Head — The difference in elevation between two points in a body of fluid with the resulting pressure of the fluid at the lower point expressible at the height or pressure of the fluid.

Hydrostatic — A term (in piping systems) used to describe a system under pressure but at rest (not flowing).

Hydrostatic Test — Type of test used to locate leaks in a pressurized piping system.

Impeller — A blade type device that provides flow within a centrifugal pump by using centrifugal force.

Invert — The lowest portion of the inside of any horizontal pipe.

Invert Elevation — The elevation of the inside bottom of a pipe or conduit.

Kinetic Energy — Energy possessed by a body in motion.

Listed — Term describing equipment and materials included in a list published by an organization acceptable to the authority having jurisdiction and concerned (a listing agency).

Listing Agency — An agency accepted by the administrative authority that lists or labels certain models of a product and maintains a periodic inspection program on the current production of listed models. It makes available a published report of its listing, including information indicating that the products have been tested, comply with generally accepted standards, and are found safe for use in a specified manner.

Lubricant — Any substance which reduces the friction between moving solid surfaces.

Negative Pressure — Pressure less than atmospheric pressure.

NFPA — Abbreviation for "National Fire Protection Association."

OS & Y — Outside screw and yoke.

Piston Pump — A pumping machine in which either pressure or suction is the result of the movement of a piston type plug or plunger.

Positive Displacement — A term used to describe a type of pump which delivers the same amount of fluid for each pumping cycle.

Pressure — Force acting on a specific area usually measured in psig.

Pressure Drop — Loss of pressure due to friction as a fluid flows through piping.

psi — Pounds per square inch.

psig — Pounds per square inch gage.

Pump — 1. A device or machine that raises, transfers, or compresses fluids or that attenuates gases especially by suction or pressure or both. 2. Apparatus for raising, exhausting, driving or compressing fluids, air or gases by means of a piston, plunger, or rotating vanes. 3. To work a pump, raise or move a fluid with a pump. To move up and down like a pump handle.

Pump, Jockey — A small usually high pressure pump used to maintain the design system pressure in a fire protection (sprinkler or standpipe) system.

Pump Gage — An instrument to measure pressure of flow associated to a pump.

Pumps, Non-Positive Displacement — Liquid enters at the center of rotation of a pump impeller and is thrown outward into a casing or volute. (Volute and diffuser centrifugal, multistage, propeller, peripheral)

Pumps, Positive Displacement — Liquid enters a pump through the suction port and is ejected forcibly out of the discharge port by displacement.

Rate of Flow — A term used to describe the volume of a moving fluid related to time. Measured in gpm, cu. ft./min., etc.

Residual Pressure — Pressure available under full flow conditions.

Sewage Ejector — A device for lifting and discharging sewage; a device for moving sewage by entraining it on a high velocity stream, air or water jet.

Siamese Connection — A flush or exposed divider on a building having two or three hose threaded inlets feeding a single outlet, and serves as part of that building's fire protection system.

Sprinkler System — An integrated system of underground and overhead piping designed in accordance with fire protection engineering standards. The installation includes one or more automatic water supplies. The portion of the sprinkler system above ground is a network of specially sized or hydraulically designed piping installed in a building, structure, or area, generally overhead, and to which sprinklers are attached in a system-

atic pattern. The valve controlling each system riser is located in the system riser or its supply piping. Each sprinkler system riser includes a device for actuating an alarm when the system is in operation. The system is activated by heat from a fire and discharges water over the fire area.

Sprinkler System Classification

Automatic sprinkler system types

1. Wet-pipe systems
2. Dry-pipe systems
3. Pre-action systems
4. Deluge systems
5. Combined dry-pipe and pre-action systems

Static Pressure — The pressure within a system under no flow conditions (at rest).

Suction Lift, Dynamic — Static suction lift less the frictional resistance of the suction pipe of a pump.

Suction Lift, Static — The vertical distance from the free surface of a liquid to the inlet of a pump.

Sump — Water tight receptacle placed at a low elevation so that liquids or liquid waste can be drained into and retained for removal usually to a higher elevation by use of a pump or pumps.

Sump Pump — A mechanical device for removing liquid from a sump or pit.

Total Dynamic Head (TDH) — The pressure or head developed by a pump to overcome friction loss under flow conditions.

Tuberculation — Small knobs or buttons of rust on the inside of a pipe.

Turbulence — A state of fluid flow in which the instantaneous velocities and pressures exhibit irregular and random fluctuation, as produced by an obstruction of friction.

Upstream — Term referring to a location in the direction of flow before reaching a referenced point.

Vacuum — A pressure less than atmospheric pressure. It is usually measured by the number of inches of mercury below atmospheric pressure.

Vapor — A diffused matter suspended floating in the air and impairing its transparency, a substance in a gaseous state as distinguished from a liquid or solid state, or a gaseous substance that is at a temperature below its critical temperature and, therefore, liquefiable by pressure alone.

Vaporization — The process of converting a liquid into a vapor (boiling, evaporation, and flashing).

Velocity, Liquids — The rate at which liquids move through a piping system usually measured in feet per second.

Volute — A spiraling passageway inside of a centrifugal pump discharge casing.

APPENDIX

General Pump Instructions

PAGE(s)

Section 1 — Introduction

1-A Purpose A-2
1-B Pump Identification A-2

Section 2 — Installation

2-A Receiving Pump A-2
2-B Temporary Storage A-2
2-C Location A-3
2-D Foundation A-3
2-E Base Plate Setting . . . . . A-3 – A-4
2-F Grouting Procedure A-4
2-G Alignment Procedure . . . . . A-4 – A-5
2-H Doweling A-5
2-I Suction and Discharge Piping . . . . . A-6 – A-8
2-J Seal Lubrication A-8
2-K Mechanical Seals A-8

Section 3 — Operation

3-A Pre-Start Checks . . . . . A-8 – A-9
3-B Priming A-9
3-C Starting A-9
3-D Operating Checks A-9
3-E Freezing Protection A-9
3-F Field Tests . . . . . A-9 – A-11

Section 4 — Troubleshooting — Causes — Corrective Action

4-A No Liquid Delivered A-12
4-B Not Enough Liquid Delivered A-12
4-C Not Enough Pressure A-13
4-D Pump Operates for Short Time — Then Stops A-13
4-E Pump Takes Too Much Power A-13

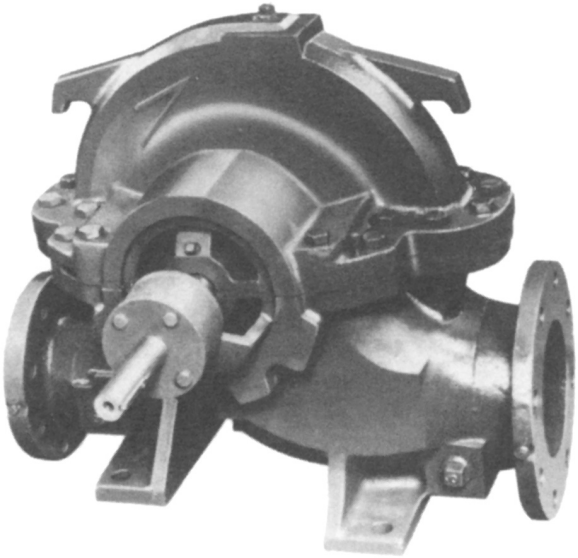
Section 5 — Maintenance

5-A General Maintenance A-14
5-B Maintenance of Pump Due to Flood Damage A-14
5-C Bearing Lubrication - Grease A-14
5-D Mechanical Shaft Seals . . . . . A-14 – A-15
5-E Cleaning Without Dismantling Pump A-15

Section 1 — Introduction

1-A – PURPOSE

Appendix A is included in this manual to acquaint journeyworkers and apprentices with some of the practical ways to install, operate, and maintain pumps similar to the type shown in **Figure A-1**. Read it completely before doing any work on a pump unit and keep it handy for future reference.



Example of Base Mounted Centrifugal Pump

Fig. A-1

Equipment cannot operate well without proper care. To keep a pump operating at top efficiency, follow the recommended installation and servicing procedures outlined in this appendix.

1-B – PUMP IDENTIFICATION

All pumps are designated by Serial Number, Model Number, Size and Type. This information is stamped on an identification plate which is mounted on the pump.

Section 2 — Installation

2-A – RECEIVING PUMP

Check pump for shortages and damage immediately upon arrival. An absolute must. Prompt reporting to the carrier's agent, with notations made on the freight bill, will expedite satisfactory adjustment by the carrier.

Warning: When unloading horizontal pumps, lift equally at four or more points on the baseplate. Do not lift on the driver or pump. Do not lift by flanges or by the eyebolts found on the motor. Be very careful not to damage any auxiliary piping or controls when moving pumps. Failure to follow these instructions could result in injury or death.

Horizontal pumps and drivers are normally shipped from the factory mounted on a baseplate and painted with primer and one finish coat. Couplings may either be completely assembled, or have the coupling hubs mounted on the shafts and the connecting members removed. When the connecting members are removed, they will be packaged in a separate container and shipped with the pump, or attached to the baseplate.

Shafts are in alignment when unit is shipped; however, due to shipping, the pumps may arrive misaligned and, therefore, *alignment must be established during installation.* Manufacturer's have determined that proper and correct alignment can only be made by accepted erection practices.

2-B – TEMPORARY STORAGE

If the pump is not to be installed and operated soon after arrival, store it in a clean, dry place having slow, moderate changes in ambient temperature. Rotate the shaft periodically to coat the bearings with lubricant. This will help retard oxidation, corrosion, and to reduce the possibility of false brinelling of the bearings.

2-C – LOCATION

The pump should be installed as near the suction supply as possible, but no less than five suction diameters, with the shortest and most direct suction pipe practical. The total dynamic suction lift (static lift plus friction losses in suction line) should not exceed the limits for which the pump was sold.

The pump must be primed before starting. Whenever possible, the pump should be located

below the fluid level to facilitate priming and assure a steady flow of liquid. This condition provides a positive suction head on the pump. It is also possible to prime the pump by pressurizing the suction vessel.

When installing the pump, consider its location in relation to the system to assure that sufficient Net Positive Suction Head (NPSH) at pump suction is provided. Available NPSH must always equal or exceed the required NPSH of the pump.

The pump should be installed with sufficient accessibility for inspection and maintenance. A clear space with ample head room should be allowed for the use of an overhead crane or hoist sufficiently strong to lift the unit.

Note: Allow sufficient space to be able to dismantle pump without disturbing the pump inlet and discharge piping.

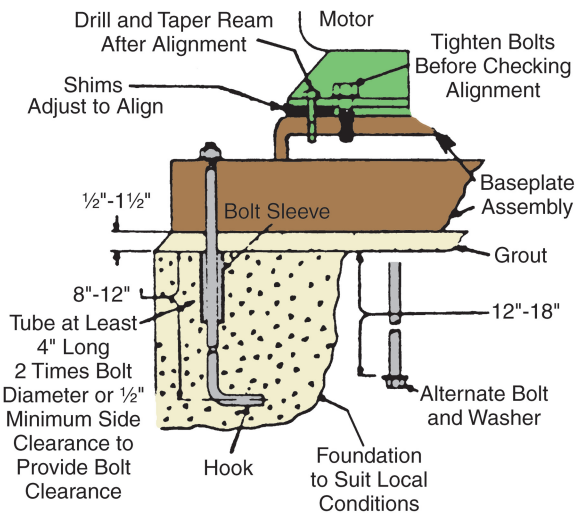
Select a dry place above the floor level wherever possible. Take care to prevent pump from freezing during cold weather when not in operation. Should the possibility of freezing exist during a shut-down period, the pump should be completely drained, and all passages and pockets where liquid might collect should be blown out with compressed air.

Make sure there is a suitable power source available for the pump driver. If motor driven, electrical characteristics should be identical to those shown on motor data plate.

2-D – FOUNDATION

A substantial foundation and footing should be built to suit local conditions. It should form a rigid support to maintain alignment.

Horizontal Pumps — The foundation should be poured without interruption to within ½ to 1½ inches of the finished height. The top surface of the foundation should be well scored and grooved before the concrete sets; this provides a bonding surface for the grout. Foundation bolts should be set in concrete as shown in **Figure A-2**. A 4-inch long tube around the bolts at the top of the concrete will allow some flexibility in bolt alignment to match the holes in the baseplate. Allow enough bolt length for grout, shims, lower baseplate



Foundation

Fig. A-2

flange, nuts and washers. The foundation should be allowed to cure for several days before the baseplate is shimmed and grouted.

2-E – BASEPLATE SETTING: (Before Piping)

Note: This procedure assumes that a concrete foundation has been prepared with anchor or hold down bolts extending up ready to receive unit. It must be understood that the pump and motor have been mounted and rough aligned at the factory. If the motor is to be field mounted, consult a manufacturer's representative for recommendations.

1. Use blocks and shims under the base for support at anchor bolts and midway between bolts, to position the base approximately 1" above the concrete foundation with studs extending through holes in the baseplate.
2. By adding or removing shims under the base, level and plumb the pump shaft and flanges. The base plate does not have to be level.
3. Draw anchor nuts tight against the base, and observe the pump and motor shafts or coupling hubs for alignment. Temporarily remove coupling guard for checking alignment.

4. If alignment needs improvement, add shims or wedges at appropriate positions under the base so that retightening of anchor nuts will shift shafts into closer alignment. Repeat this procedure until a reasonable alignment is reached.

   Note: Reasonable alignment is sometimes defined as that which the contractor and the accepting facility (final operator) mutually agree upon. Final alignment procedures are covered under "Alignment Procedures."

5. Check to make sure the piping can be aligned to the pump flanges without placing pipe strain on either flange.

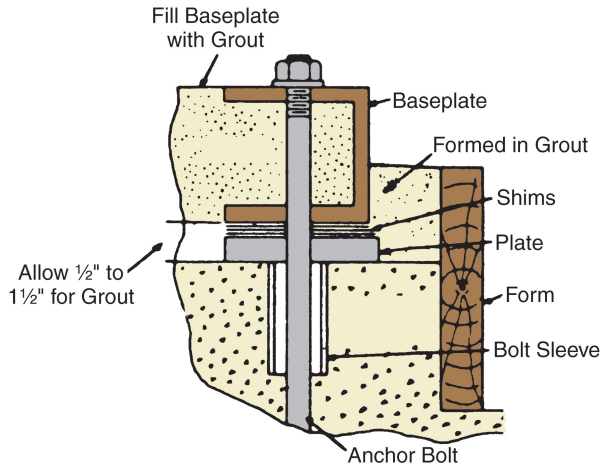
6. Grout baseplate in completely, see "Grouting Procedure," and allow grout to dry thoroughly before attaching piping to pump. (24 hours is usually sufficient time with an approved grouting procedure.)

2-F – GROUTING PROCEDURE

Grout compensates for uneven foundation, distributes weight of the unit, and prevents shifting. Use an approved, non-shrinking grout, after setting and leveling unit. See **Figure A-3**.

1. Build a strong form around the foundation to contain grout.

2. Soak top of concrete foundation thoroughly, then remove surface water.



Setting Baseplate and Grouting

Fig. A-3

3. Baseplate should be completely filled with grout and if necessary, temporarily use air relief tubing or drill vent holes to remove trapped air.

4. After the grout has thoroughly hardened, check the foundation bolts and tighten them if necessary.

5. Check the alignment after the foundation bolts are tightened.

6. Approximately 14 days after the grout has been poured or when the grout has thoroughly dried, apply an oil base paint to the exposed edges of the grout to prevent air and moisture from coming in contact with the grout.

2-G – ALIGNMENT PROCEDURE

Note: A flexible coupling will only compensate for small amounts of misalignment. Permissible misalignment will vary with the make of coupling. Consult coupling manufacturer's data when in doubt.

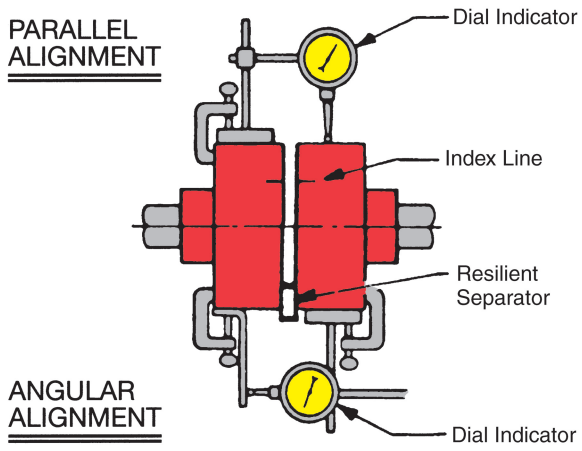
Allowances are to be made for thermal expansion during cold alignment so that the coupling will be aligned at operating temperatures. In all cases, a coupling must be in alignment for continuous operation. Even though the coupling may be lubricated, misalignment causes excessive wear, vibration, and bearing loads which result in premature bearing failure and ultimate seizing of the pump. Misalignment can be angular, parallel, or a combination of these, and in the horizontal and vertical planes. Final alignment should be made by moving and shimming the motor on the baseplate until the coupling hubs are within the recommended tolerances measured in total run-out. All measurements should be taken with the pump and motor foot bolts tightened. The shaft of sleeve bearing motors should be in the center of its mechanical float.

Note: Proper alignment is essential for correct pump operation. This should be performed after baseplate has been properly set and grout has dried thoroughly according to instructions. Final alignment should be made by shimming driver only. Alignment should be made at operating temperatures.

Warning: Disconnect and lockout power before servicing. Failure to follow these instructions could result in injury or death.

The following alignment procedure is recommended where precise alignment is necessary or desirable:

1. Make sure each hub is secured to its respective shaft and that all connecting and/or spacing elements are removed at this time.
2. The gap between the coupling hubs is set by the manufacturer before the units are shipped. However, this dimension should be checked. Refer to the coupling manufacturer's specifications suppled with the unit.
3. Scribe index lines on the coupling halves as shown in **Figure A-4**.



Single Element Couplings

Fig. A-4

4. Mount the dial indicator on one hub as shown for parallel alignment. Set dial to zero.
5. Turn both coupling halves so that index lines remain matched. Observe dial reading to see if driver needs adjustment. See item 9 below.
6. Mount dial indicator on one hub as shown for angular alignment. Set dial to zero.
7. Turn both coupling halves so that the index lines remain matched. Observe dial reading to see if the driver needs adjustment. See item 9 below.
8. Assemble coupling. Tighten all bolts and set screw(s). It may be necessary to repeat steps 3 through 6 for a final check.
9. For single element couplings, a satisfactory parallel misalignment is .004" T.I.R., while a satisfactory angular misalignment is .004" T.I.R. per inch of radius R. See **Figure A-4**.

Final Alignment

Final alignment cannot be accomplished until the pump has been operated initially for a sufficient length of time to attain operating temperature. When normal operating temperature has been attained, secure the pump to recheck alignment and compensate for temperature accordingly.

Warning: Do not operate pump without all guards in place. Failure to follow these instructions could result in injury or death.

Optional Alignment Procedure

After final alignment, it is necessary to dowel driver feet and pump to the baseplate. Drill and ream diagonal feet of both for dowels. See Doweling.

Caution: Eye protection required during this procedure. Failure to follow these instructions could result in personal injury.

Note: Pump may have been doweled to base at factory.

2-H – DOWELING

Caution: Eye protection is required during this procedure. Failure to follow these instructions could result in personal injury.

Dowel the pump and driving unit as follows:

1. Drill holes through diagonally opposite feet and into the base. Holes must be 1/64 inch less than the diameter of the dowel pins. Clean out the chips.
2. Ream the holes in the feet and base to the proper diameter for the pins (light push fit). Clean out the chips.
3. Insert pins to be approximately flush with the feet.

2-I – SUCTION AND DISCHARGE PIPING

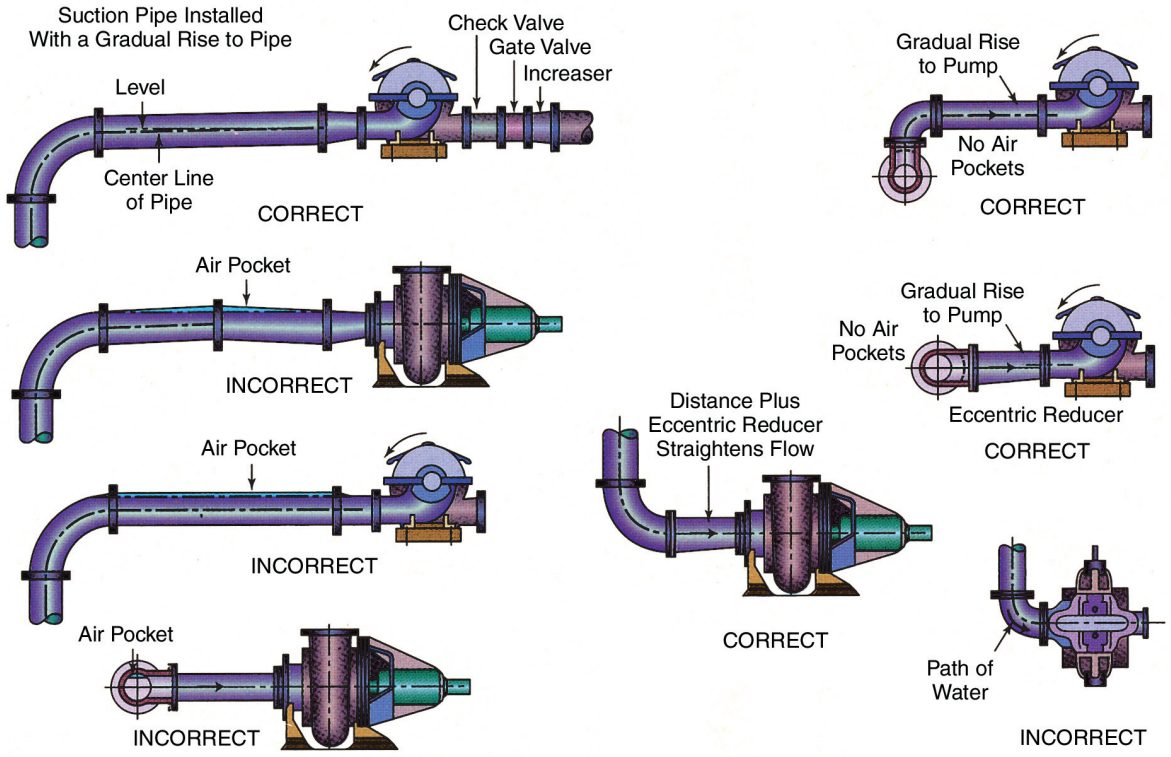
General

When installing the pump piping, be sure to observe the following precautions:

1. Piping should always be run to the pump.
2. Do not move pump to pipe. This could make final alignment impossible.
3. Both the suction and discharge piping should be independently supported near the pump, and properly aligned so that no strain is transmitted to the pump when the flange bolts are tightened. Use pipe hangers or other supports as necessary to provide support. When expansion joints are used in the piping system, they must be installed beyond the piping supports closest to the pump. Tie bolts should be used with expansion joints to prevent pipe strain. Do not install expansion joints next to the pump, or in any way that would cause a strain on the pump, resulting from system pressure changes. It is usually advisable to increase the size of both the suction and discharge pipes at the pump connections to decrease the loss of head from friction.
4. Install piping as straight as possible, avoid unnecessary bends. Where necessary, use 45-degree elbows or long radius 90-degree fittings to decrease friction losses.
5. Make sure that all piping joints are air-tight.
6. Where flanged joints are used, assure that inside diameters match properly.
7. Remove burrs and sharp edges when making up joints.
8. Do not "spring" piping when making connections.
9. Provide for pipe expansion when hot fluids are to be pumped.

Suction Piping

When installing the suction piping, observe the following precautions: See **Figure A-5**.



Suction Pipe Installations (Piping Supports Not Shown)

Fig. A-5

1. The sizing and installation of the suction piping is extremely important. It must be selected and installed so that pressure losses are minimized and sufficient liquid will flow into the pump when started and operated. Many (NPSH) problems can be directly attributed to improper suction piping systems.

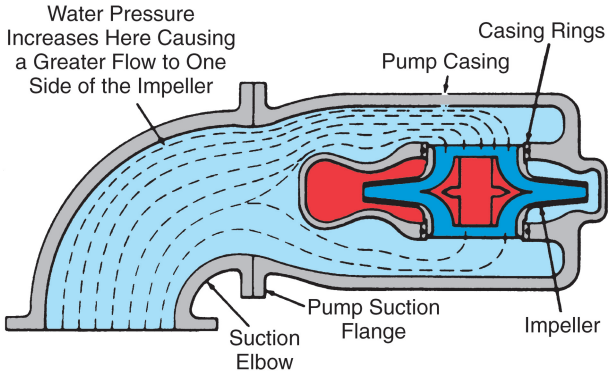
2. Suction piping should be short in length, as direct as possible, and never smaller in diameter than the pump suction opening. If the suction pipe is short, the pipe diameter can be the same size as the suction opening. If longer suction pipe is required, pipes should be one or two sizes larger than the opening, depending on piping length.

3. Suction piping for horizontal double suction pumps should not be installed with an elbow close to the suction flange of the pump, except when the suction elbow is in the vertical plane. A suction pipe of the same size as the suction nozzle approaching at any angle, other than straight up or straight down, must have the elbow located 10 pipe diameters from the suction flange of the pump. Vertical mounted pumps and other space limitations require special piping.

4. There is always an uneven turbulent flow around an elbow and when it is in a position other than the vertical, it causes more liquid to enter one side of the impeller than the other. See **Figure A-6**. This results in high unequalized thrust loads that will overheat the bearings and cause rapid wear in addition to affecting hydraulic performance.

5. When operating on a suction lift, the suction pipe should slope upward to the pump nozzle. A horizontal suction line must have a gradual rise to the pump. Any high point in the pipe will become filled with air and thus prevent proper operation of the pump. When reducing the piping to the suction opening diameter, use an eccentric reducer with the eccentric side down to avoid air pockets.

   Note: When operating on suction lift, never use a straight taper reducer in a horizontal suction line, as it tends to form an air pocket in the top of the reducer and the pipe.



Unbalanced Loading of a Double Suction Impeller Due to Uneven Flow Around on Elbow Adjacent to the Pump

Fig. A-6

6. To facilitate cleaning the pump liquid passage without dismantling pump, a short section of pipe (Dutchman or spool piece), so designed that it can be readily dropped out of the line, can be installed adjacent to the suction flange. With this arrangement, any matter clogging the impeller is accessible by removing the nozzle (or pipe section).

Valves in Suction Piping

When installing valves in the suction piping, observe the following precautions:

1. If the pump is operating under static suction lift conditions, a foot valve may be installed in the suction line to avoid the necessity of priming each time the pump is started. This valve should be of the flapper type, rather than the multiple spring type, sized to avoid excessive friction in the suction line. Under all other conditions, a check valve, if used, should be installed in the discharge line. See "Valves in Discharge Piping" below.

2. When foot valves are used, or where there are other possibilities of "water hammer," close the discharge valve slowly before taking the pump out of service.

3. Where two or more pumps are connected to the same suction line, install gate valves so

that either pump can be isolated from the line. Gate valves should be installed on the suction side of the pumps with a positive pressure for maintenance purposes. Install gate valves with stems horizontal to avoid air pockets. Globe valves should not be used, particularly where NPSH is critical.

4. The pump must never be throttled by the use of a valve on the suction side of the pump. Suction valves should be used only to isolate the pump, or for maintenance purposes, and should always be installed in positions to avoid air pockets.

5. A pump drain valve should be installed in the suction piping between the isolation valve and the pump.

Discharge Piping

If the discharge piping is short, the pipe diameter can be the same as the discharge opening. If the piping is long, the pipe diameter should be one or two sizes larger than the discharge opening. On long horizontal runs, it is desirable to maintain as even a grade as possible. Avoid high spots, such as loops, which will collect air and throttle the system or lead to erratic pumping.

Valves in Discharge Piping

A triple duty valve should be installed in the discharge piping. The triple duty valve placed on the pump protects the pump from excessive back pressure, and prevents liquid from running back through the pump in case of power failure.

Pressure Gages

Properly sized pressure gages should be installed in both the suction and discharge nozzles in the gage taps (which are provided on request). The gages will enable the operator to easily observe the operation of the pump, and also determine if the pump is operating in conformance with the performance curve. If cavitation, vapor binding, or other unstable operation should occur, widely fluctuating discharge pressure will be noted.

2-J – SEAL LUBRICATION

Internal Liquid Lubricant

Pumped liquid may be used to lubricate the seal when the following conditions prevail:

1. Liquid is clean, free from sediment and chemical precipitation and is compatible with seal materials.
2. Temperature is above 32°F and below 160°F.
3. Suction pressure is below 75 psig.
4. Liquid has lubricating qualities.
5. Liquid is non-toxic and non-volatile.

2-K – MECHANICAL SEALS

Mechanical seals are preferred over packing on some applications because of better sealing qualities and longer serviceability. Leakage is eliminated when a seal is properly installed, and normal life is much greater than that of packing on similar applications. A mechanical shaft seal has been supplied with pump shown in **Figure A-1**.

Single Mechanical Seal

Pumps containing single mechanical seals normally utilize the pumped liquid to lubricate the seal faces. This method is preferred when the pumped liquid is neither abrasive nor corrosive.

Section 3 — Operation

3-A – PRE-START CHECKS

Before initial start of the pump, make the following inspections:

1. Check alignment between the pump and the motor.
2. Check all connections to the motor and the starting device with wiring diagram. Check voltage, phase, and frequency on the motor nameplate with line circuit.
3. Check suction and discharge piping and pressure gages for proper operation.
4. Check impeller adjustment.

5. Turn rotating element by hand to assure that it rotates freely.
6. Check driver lubrication.
7. Make sure pump bearings are properly lubricated.
8. Make sure the coupling is properly lubricated, if required.
9. Make sure the pump is fill of liquid, and all valves are properly set and operational, with the discharge valve closed, and the suction valve open. See 3-B – Priming.
10. Check rotation. Be sure that the driver operates in the direction indicated by the arrow on the pump casing, as serious damage can result if the pump is operated with incorrect rotation. Check rotation each time the motor leads have been disconnected.

    Caution: Rotation should be checked with coupling disconnected on coupled units. Failure to follow these instructions could result in personal injury or property damage.

3-B – PRIMING

If the pump is installed with a positive head on the suction, it can be primed by opening the suction and vent valve and allowing the liquid to enter the casing.

If the pump is installed with a suction lift, priming must be done by other methods such as foot valves, ejectors, or by manually filling the casing and the suction line.

Caution: Under either condition, the pump must be completely filled with liquid before starting. The pump must not be run dry in the hope it will prime itself. Serious damage to the pump may result if it is started dry. Failure to follow these instructions could result in personal injury or property damage.

3-C – STARTING

1. Close drain valves and valve in discharge line.
2. Open fully all valves in the suction line.
3. Prime the pump.

   Note: If the pump does not prime properly, or loses prime during start-up, it should be shutdown and the condition corrected before the procedure is repeated.
4. When the pump is operating at full speed, open the discharge valve slowly. This should be done promptly after start-up to prevent damage to the pump by operating at zero flow.

3-D – OPERATING CHECKS

1. Check the pump and piping to assure that there are no leaks.
2. Check and record pressure gage readings for future reference.
3. Check and record voltage, amperage per phase, and kw if an indicating wattmeter is available.
4. Check bearings for lubrication and temperature. Normal temperature is 180°F maximum.

   Caution: Make all pump output adjustments with the discharge valve. Do not throttle the suction line to adjust the pump output. Failure to follow these instructions could result in personal injury or property damage.

3-E – FREEZING PROTECTION

Pumps that are shut down during freezing conditions should be protected by one of the following methods.

1. Drain the pump; remove all liquids from the casing.
2. Keep fluid moving in the pump and insulate or heat the pump to prevent freezing.

   Caution: If heat is used to keep the pump from freezing, do not let the temperature rise above 150°F. Failure to follow these instructions could result in personal injury or property damage.

3-F – FIELD TESTS

Performance Curve

A typical performance curve for a specific pump can be obtained from the manufacturer of the pump. This can be used in conjunction with a

field test, if one is required. All pump tests, and curves, are usually based on the "Hydraulic Institute Standards." All field tests must be conducted according to these Standards.

Unless otherwise specifically agreed, all capacity, head, and efficiencies are based on shop tests when handling clear, cold, fresh water at a temperature not over 85°F and under suction conditions as specified.

To aid in calculating pump performance, the following test information and definitions are included for reference.

Gage Datum

The datum for all gage readings is taken as the centerline of the pump shaft for all horizontal shaft pumps, and as the eye of the impeller for vertical pumps.

Head Measurement

The unit for measuring head should be feet; therefore, all pressure readings of the pumped liquid should be converted to feet. The relationship between a pressure expressed in pounds per square inch (psi) and that expressed in feet of head is:

$$\text{Head in feet} = \frac{\text{psi x } 2.31}{\text{sg}}$$

Where sg = specific gravity of the liquid pumped

Where sg = 1.0 for water at 60°F

Total Head

Total head is the algebraic difference between the total suction and the total discharge heads.

1. Where suction lift exists, total head is the sum of the total discharge head and the suction lift.
2. Where positive suction head exists, the total head is the total discharge head minus the total suction head.

Suction Lift

Suction lift exists where the total suction head is below atmospheric pressure. Total suction lift is the reading of a liquid monometer at the suction nozzle of the pump, converted to feet of liquid, and referred to the datum minus the velocity head at the point of gage attachment.

Positive Suction Head

Suction head exists when the total suction head is above atmospheric pressure. Total suction head is the reading of a gage at the suction of the pump, converted to feet of liquid, and referred to datum plus the velocity head at the point of gage attachment.

Velocity Head

Velocity head is figured from the average velocity obtained by dividing the discharge flow (in cubic feet per second) by the actual area of the pipe cross-section (in square feet), and is determined at the point of gage connection. It is expressed by the formula:

$$h_v = \frac{V^2}{2g}$$

Where g = the acceleration due to gravity, and is 32.17 feet per second squared at sea level and 45 degrees latitude.

V = velocity in the pipe in feet per second.

Volume Measurement

The method of volume measurement should be made by some accurate and accepted method and converted to gallons per minute. For easy reference, refer to the following:

1. The standard U.S. gallon contains 231 cubic inches.
2. One cubic foot equals 7.4805 gallons.
3. The specific weight of water at a temperature of 60°F shall be taken as 62.4 lb/cu ft.

Horsepower

1. The formula for horsepower required at the pump shaft is:

$$\text{Bhp} = \frac{\text{Total head x GPM}}{\text{3960 x Eff.}} \text{ x specific gravity}$$

2. The true motor brake horsepower, once the efficiency is determined from dynamometer tests, can also be calculated from the following formula:

$$Bhp = \frac{\text{kw input} \times \text{Eff.}}{0.746}$$

Where Bhp = Brake horsepower delivered
kw input = Real input power (kw)
Eff. = Motor efficiency

Pump Efficiency

Pump efficiency can be calculated by the formula:

$$\text{Pump efficiency} = \frac{\text{Total head} \times \text{GPM}}{3960 \times \text{Bhp}} \times \text{specific gravity}$$

Motor Controls – General

Motor controls should conform to all the electrical data stamped on the motor data plate. Complete instructions for installation, operation, and maintenance are included with the controlling device.

External Wiring

Wiring to the motor should be installed in conformance with the National Electrical Code and all local and state codes.

See the following two pages for Section 4 — Troubleshooting

Section 4 — Troubleshooting

Be alert for signs of motor or pump trouble at all times. Correct any trouble immediately. AVOID COSTLY REPAIR AND SHUTDOWN.

4-A – No Liquid Delivered

	CAUSES	CORRECTIVE ACTION
1.	Lack of prime.	Fill pump and suction pipe completely with liquid.
2.	Loss of prime.	Check for leaks in suction pipe joints and fittings; vent casing to remove accumulated air.
3.	Suction lift too high.	If no obstruction at inlet, check for pipe friction losses. However, static lift may be too great. Measure with mercury column or vacuum gage while pump operates. If static lift is too high, liquid to be pumped must be raised or pump lowered.
4.	Discharge head too high.	Check pipe friction losses. Large piping may correct condition. Check that valves are wide open.
5.	Speed too low.	Check whether motor is directly across-the-line and receiving full voltage. Or frequency may be too low; motor may have an open phase.
6.	Wrong direction of rotation.	Check motor rotation with directional arrow on pump casing.
7.	Impeller completely plugged.	Dismantle pump and clean impeller.

4-B – Not Enough Liquid Delivered

8.	Air leaks in suction piping.	If liquid pumped is water or other non-explosive, and explosive gas or dust is not present, test flanges for leakage with flame or match, or by plugging inlet and putting line under pressure. A gage will indicate a leak with a drop of pressure.
9.	Speed too low.	See item 5.
10.	Discharge head too high.	See item 4.
11.	Suction lift too high.	See item 3.
12.	Impeller partially plugged.	See item 7.
13.	Cavitation; insufficient NPSH (depending on installation)	a. increase positive suction head on pump by lowering pump. b. Sub-cool suction piping at inlet to lower entering liquid temperature. c. Pressurize suction vessel.
14.	Defective impeller.	Inspect impeller, bearings and shaft. Replace if damaged or vane sections are badly eroded.
15.	Foot valve too small or partially obstructed.	Area through ports of valve should be at least as large as the area of the suction pipe — preferably 1½ times. If a strainer is used, net clear area should be 3 to 4 times area of suction pipe.
16.	Suction inlet not immersed deep enough.	If inlet cannot be lowered, or if eddies through which air is sucked persist when it is lowered, chain a board to suction pipe. It will be drawn into eddies, smothering the vortex.
17.	Wrong direction of rotation.	Symptoms are an overloaded drive and about ⅓ rated capacity from pump. Compare rotation of motor with directional arrow on pump casing.
18.	Too small impeller diameter (probable cause if none of above).	Check with manufacturer's representative to see if a larger impeller can be used; otherwise, cut pipe losses or increase speed — or both, as needed. Be careful not to overload the drive.

4-C – Not Enough Pressure

	CAUSES	CORRECTIVE ACTION
19.	Speed too low.	See item 5.
20.	Air leaks in suction piping.	See item 8.
21.	Mechanical defects.	See time 14 and 15.
22.	Obstruction in liquid passages.	Dismantle pump and inspect passages of impeller and casing. Remove obstruction.
23.	Air or gases in liquid. (Test in laboratory, reducing pressure on liquid to pressure in suction line Watch for bubble formation.)	May be possible to overrate pump to point where it will provide adequate pressure despite condition. Better to provide gas separation chamber on suction line near pump, and periodically exhaust accumulated gas. See item 13.
24.	Too small impeller diameter. (Probable cause if none of above.)	See item 18.

4-D – Pump Operates For Short Time, Then Stops

25.	Incomplete priming.	Free pump, piping and valves of all air. If high points in suction line prevent this, they need correcting. See page 19.
26.	Suction lift too high.	See item 3.
27.	Air leaks in suction piping.	See item 8.
28.	Air or gases in liquid.	See time 23.

4-E – Pump Takes Too Much Power

29.	Head lower than rating; thereby pumping too much liquid.	Machine impeller's OD to size advised by factory.
30.	Cavitation.	See item 13.
31.	Mechanical defects.	See items 14 and 15.
32.	Suction inlet not immersed enough.	See item 16.
33.	Liquid heavier (in either viscosity or specific gravity) than allowed for.	Use larger driver. Consult manufacturer's representative for recommended size. Test liquid for viscosity and specific gravity.
34.	Wrong direction of rotation.	See item 6.
35.	Casing distorted by excessive strains from suction or discharge piping.	Check alignment. Examine pump for friction between impeller and casing. Replace damaged parts.
36.	Shaft bent due to damage — through shipment, operation, or overhaul.	Check deflection of rotor by turning on bearing journals. Total indicator runout should not exceed 0.002 on shaft and 0.004 inch on impeller wearing surface.
37.	Mechanical failure of critical pump parts.	Check bearings and impeller for damage. Any irregularity in these parts will cause a drag on shaft.
38.	Misalignment.	Realign pump and driver.
39.	Speed may be too high (brake hp of pump varies as the cube of the speed; therefore, any increase in speed means considerable increase in power demand).	Check voltage on motor.
40.	Electrical defects.	The voltage and frequency of the electrical current may be lower than that for which motor was built; or there may be defects in motor. The motor may not be ventilated properly due to a poor location.
41.	Mechanical defects in turbine, engine or other type of drive exclusive of motor.	If trouble cannot be located, consult manufacturer's representative.

Section 5 — Maintenance

5-A – GENERAL MAINTENANCE

Operating conditions vary so widely that to recommend one schedule of preventive maintenance for all centrifugal pumps is not possible. Yet some sort of regular inspection must be planned and followed. It is suggested a permanent record be kept of the periodic inspections and maintenance performed on pumps. This recognition of maintenance procedure will keep pumps in good working condition, and prevent costly breakdown.

One of the best rules to follow in the proper maintenance of a centrifugal pump is to keep a record of actual operating hours. Then, after a predetermined period of operation has elapsed, the pump should be given a thorough inspection. The length of this operating period will vary with different applications, and can only be determined from experience. New equipment, however, should be examined after a relatively short period of operation. The next inspection period can be lengthened somewhat. This method can be followed until a maximum period of operation is reached, which should be considered the operating schedule between inspections.

5-B – MAINTENANCE OF PUMP DUE TO FLOOD DAMAGE

Bearings are of primary concern on pumping units. First, dismantle the bearings; clean and inspect them for any rusted or badly worn surfaces. If bearings are free from rust and wear, reassemble and relubricate them with one of the recommended pump lubricants. Depending on the length of time the pump has remained in the flooded area, it is unlikely that bearing replacement is necessary; however, in the event that rust or worn surfaces appear, it may be necessary to replace the bearings.

Next, inspect the stuffing box, and clean out any foreign matter that might clog the box. Mechanical seals should be cleaned and thoroughly flushed.

Couplings should be dismantled and thoroughly cleaned.

Any pump that is properly sealed at all joints and connected to both the suction and discharge should exclude outside liquid. Therefore, it should not be necessary to go beyond the bearings, stuffing box, and coupling when servicing the pump.

5-C – BEARING LUBRICATION — GREASE

Grease lubricated ball bearings are packed with grease at the factory and ordinarily will require no attention before starting, provided the pump has been stored in a clean, dry place prior to its first operation. The bearings should be watched the first hour or so after the pump has been started to see that they are operating properly.

The importance of proper lubrication cannot be over emphasized. It is difficult to say how often a bearing should be greased, since that depends on the conditions of operation. It is well to add one ounce of grease at regular intervals, but it is equally important to avoid adding too much grease. For average operating conditions, it is recommended that 1 oz. of grease be added at intervals of three to six months, and only clean grease be used. It is always best if unit can be stopped while grease is added to avoid overloading.

Note: Excess grease is the most common cause of overheating.

Do not use graphite. A grade No. 1 or 2 grease is generally satisfactory for operation at ordinary temperatures, the lighter grease for operation at high speed or low room temperature.

Mineral grease with a soda base is recommended. Grease made from animal or vegetable oils are not recommended due to the danger of deterioration and forming of acid.

The maximum desirable operating temperature for ball bearings is 180°F. Should the temperature of the bearing frame rise above 180°F, the pump should be taken out of service. It must not be placed back in service until the cause of the temperature rise has been determined and corrective action is taken.

5-D – MECHANICAL SHAFT SEALS

General instructions for operation of the various mechanical sealing arrangements are

included below. It is not feasible to include detailed instructions for all mechanical seals in this manual because of the almost unlimited number of possible combinations and arrangements. Instead, pump seal manufacturer's instructions are usually included in the literature provided with a pump.

1. Mechanical seals are precision products and should be treated with care. Use special care when handling seals. Clean parts are essential to prevent scratching the finely lapped sealing faces. Even light scratches on these faces could result in leaky seals.

2. Normally, mechanical seals require no adjustment or maintenance, except routine replacement of worn, or broken parts.

3. A mechanical seal which has been used should not be put back into service until the sealing faces have been replaced or relapped. Relapping is generally economical only in seals two inches in size and above.

5-E – CLEANING WITHOUT DISMANTLING PUMP

A short section of pipe so designed that it can be readily dropped out of the line can be installed adjacent to the suction flange. With this arrangement, any matter clogging the impeller is accessible by removing the pipe section.

If the pump cannot be freed of clogging after the above methods have been tried, dismantle the unit as previously described to locate the trouble.

NOTES

NOTES

INDEX

A

Accumulator tank, 61, 62

Air release, 79

Air separating tank, 61

Alignment, coupling, 38, 39, 40, 84

Atmospheric pressure, 1, 2, 9, 24

Axial flow pump, 23

B

Backflow prevention devices, 78

Bearings, pump, 43, 45, 74, 79
- antifriction, 45, 46
- sleeve, 45, 46

Booster, circulator, 14

Box, stuffing, 45, 46, 50, 51

C

Cavitation, 45, 47, 78

Centrifugal force, 15
- defined, 15
- in peripheral pump, 23

Centrifugal pump, 2, 12, 14, 15, 17, 25, 26, 28-30, 45, 48, 61, 79
- diffuser type, 16
- multistage, 22
- turbine type, 16
- volute type, 16

Circulating pump, 14

Circulator; *see also* Pump(s), 14, 15, 28
- close coupled in-line, 28

Compressors, 69-73
- liquid ring, 73
- oil-free, 72
- oil-less, 72
- piston type, 71

Concentric reducer, 41

Condensate, in vacuum pump, 61, 62

Couplings, 19, 77, 83, 84
- flexible, 28, 38, 39, 74

D

Diaphragm pump, 11

Diffuser; *see* Pump, diffuser

Diffuser-type pump, 16, 69

Discharge head, 4-7, 49, 50

Discharge, rate of; *see* Pump, rate of discharge

Discharge valve, 44, 45, 48, 71

Displacement, in pumps, 9, 31

Dryer, 73

E

Eccentric reducer, 43

Ejector, 28, 47, 62-67

Energy; *see also* Kinetic energy,

Engines, diesel, 79, 83

F

Fittings, 26
- in pumps, 41, 57

Float, 61, 62, 67, 69
- in vacuum pumps, 62, 67

Flow, 7, 11, 12, 16, 17, 23, 24, 43, 45, 48, 61, 73, 74, 77, 84
- in vacuum pumps, 62, 64
- pump rate of, 25, 26

Fluids, hydraulic, 12

Foundation, 11, 28, 64, 66, 83
- for pump installations, 37-41

Friction, 2, 7, 17, 24, 25, 29, 37, 44, 66, 77, 84

G

Gage, 7, 24, 25, 50
compound, 74
pressure, 7, 25, 34, 43, 45, 74, 83
vacuum, 74

Grease, bearing, 46

Grouting, in pump installations, 38-41

H

Head, 3, 4, 24, 25, 37
discharge, 4, 5, 25, 49, 50
feet of, 12, 26
pressure, 4, 16, 25
pump, 55, 79
static discharge, 5-7, 25
static suction; *see also* Lift, static suction, 5-7, 25
total dynamic, 25
total static, 5-7
velocity, 16, 25

Hose, 33, 34

I

Impeller, 14, 15-18, 22, 23, 26, 28, 29, 30, 43, 47-50, 64, 73, 77-79

J

Jet nozzles, 21, 61

K

Kinetic energy, 1

L

Lateral adjustment, 83

Lift, static suction, 5-7, 25

Lobe pump, 12

Lobes, 12

M

Motors, electric, 1, 51, 83

Multistage pump, 22, 23

N

Non-positive displacement pump, 9, 12, 23

Nozzle, jet, 21, 61

P

Pipe,
discharge, 25, 48, 57, 61, 78
galvanized steel, 55
in pump installation, 41-44, 55
plastic, 55
suction, 1, 2, 10, 18, 22, 29, 43, 44

Piston-type lift pump, 9

Pit, 28, 64, 66, 77, 79, 82, 83
ejector, 62
sump, 62

Pitless adapter, 55-57

Power consumption, excessive, 51

Pressure; *see also* Head,
atmospheric, 1, 2, 9, 24
changes in, 3, 7, 21, 24, 26
conversion of to psig, 3
head, 4, 16, 25
insufficient, 45, 50
shutoff, 74
static, 7, 25, 45
tank, 34, 53, 55

Pressure sensitive flow control, 78

Pump(s),
alignment, 37-40, 83
as a circulator, 14, 15, 28
axial flow, 23
boiler feed, 10, 31, 61, 69
booster, 14
capacity, 26, 77
centrifugal type, 16-18, 22, 25-30, 48, 61, 64, 69, 74, 79
circulating, 14

classifications of, 9
close coupled in-line, 28
compression, 71
condensate, 28, 61
deep well, 10
definition of, 1
diaphragm, 11
diaphragm type ditch, 10
diffuser, 16, 69
duplex, 64, 67
ejector, 28, 47, 62, 64
electrical controls, 28
end suction, 29, 77, 79
flow capacity of, 26
for fire protection, 73-78
horizontal-shaft, 77, 78
hydraulic power, 10
hydrostatic test, 10
in closed systems, 2, 3, 14, 24, 26, 30
in open systems, 2, 3, 24
installation of, 28-30, 37-51
jet, 12, 19, 21, 57, 58, 61, 62
jockey, 74, 77, 78
lobe, 12
mounting, 29, 38, 43, 45
multistage, 22, 23
non-positive displacement, 9, 12, 23
peripheral, 23, 24
piston, 9, 11, 31, 71
pitcher, 9, 10
plunger, 11
positive displacement, 2, 9-12
power consumption, 51
propeller, 12, 23
priming, 18, 19, 44, 47, 79
rate of discharge, 10
reciprocating, 2, 10-12, 19
rotary, 2, 9, 11-13
rotation of,25, 26, 46-50, 79, 84
sewage, 28
shallow well, 28, 58
sliding vane, 12, 31
submersible, 19
sump, 28, 64
turbine, 16, 17, 31, 32, 47, 79, 81, 83
types of, 9-35
use of, 1, 12, 18, 28
vacuum, 10, 31, 33, 47, 61, 62
vertical-shaft, 79, 81, 83
vibration of, 37, 38, 45, 64, 84
volute centrifugal, *see also* Pumps, centrifugal, 16
well, 1, 2, 10, 18-20, 28, 53-61, 81, 83, 84

Pump base, 38, 40, 66, 84

Pump curve, 25, 26

R

Ratchet, non-reverse, 83

Receiver tank, 73

Reciprocating pumps, 2, 10-12, 19

Reducers,
concentric, 41
eccentric, 43, 66, 78
in pumps, 19

Relief valve, casing, 74

Rotary pumps, 11, 12

S

Screw, meshing, 12

Seal, mechanical, 29, 45, 46

Separator, 73

Shim, 38, 40

Shroud, 17

Static head; *see* Head, static

Static suction lift; *see* Lift, static suction

Strainer, for valves, 18, 41, 73

Suction, loss of, 50, 51

Suction lift, 2, 4-6, 21, 29, 43, 49, 50, 51

Sump, 1, 2, 28, 62, 64, 66, 83

Switch, pressure, 53, 77

Systems,
closed, 2, 3, 14, 24-26, 30
open, 2, 3, 5, 6, 24

T

Tank, pressurized, 60, 61

TDH; *see* Head, total dynamic

Throttling, 45

Tuberculation, 74

Turbine-type pump, 16, 17, 31, 32, 47, 79, 81, 83

V

Vacuum, 1, 2, 5, 10, 21, 73

Vacuum pumps, 10, 31, 33, 47, 61, 62, 79

Valves,
- anti-water hammer, 74
- butterfly, 74, 78
- check, 10, 18, 19, 28, 47, 53, 62, 66, 74, 77-79
- flow control, 73, 78
- foot, 18, 19, 44, 47, 50
- hose, 77
- outside screw and yoke (OS&Y), 78
- relief, 34, 74, 77
- solenoid, 73
- suction, 45, 62

Vanes,
- in pump, 12, 15, 16, 23, 33

Velocity,
- in jet pump, 21
- vacuum pump, 16, 61

Vibration, in pumps, 38, 64, 84

Volute, 64

Volute-type pump, 16, 78

W

Water hammer, 44, 74

Well(s), 1, 2, 10, 18, 53-61
- deep, 10, 18-20, 58
- shallow, 18, 28, 58

Well casing, 55-58, 83
- adapter, 55
- adapter coupling, 57
- dresser coupling, 57
- fittings, 56
- pitless connection, 56, 57
- swagged nipple, 57
- welding nipple, 57

Well seal, 57

Wet-pit, 64, 66, 77, 79, 82, 83

2000