Pumps

Table of Contents

PUMPS

Lesson One

Pump Development and Application

TPC Training Systems

30501

Lesson

1 Pump Development and Application

TOPICS

The Development of Pumps
Pumping Systems
Water Pumping Systems
Chemical Pumping Systems
Waste Pumping Systems
High-Viscosity Material Pumping Systems
Solids Pumping Systems

OBJECTIVES

After studying this lesson, you should be able to…

- Describe dead-end and recirculating hot water distribution systems.
- List several special considerations involved in chemical pumping systems.
- Define the term viscosity and give examples of high-viscosity materials.
- Tell the effects of heat on the pumping of high-viscosity materials.
- List some special problems involved in the pumping of solids.

KEY TECHNICAL TERMS

Archimedean screw 1.01 a broad-threaded screw encased in a cylinder or in an open trough

Noria 1.02 a water-lifting device with open-ended tubes around the edge of a wheel

Viscosity 1.28 the property of a material that resists any flow-producing force

Pumps are used in almost every industrial plant. Water systems are the most common pumping systems in industry. Water supply and hot water distribution systems are two examples of water pumping systems. After studying this lesson, you will be able to explain how these systems work, including the differences between dead end systems and recirculating systems.

Chemical pumping systems have special design and construction requirements because of the nature of the materials they handle. Many factors must be considered when choosing the correct pump for such systems. This lesson will acquaint you with only some of the important factors.

High-viscosity material pumping systems have special requirements, as do solids pumping systems. This lesson covers some of the problems involved in these pump applications.

The Development of Pumps

1.01 One of the earliest pumping devices in recorded history is the *Archimedean screw,* developed in Greece in the third century BC. The device is simply a broad-threaded screw encased in a cylinder or in an open trough. In ancient times, an operator at the top of the screw turned a hand crank that turned the screw, raising the water higher with each revolution. The screw was used for irrigation purposes and for raising water from mines, ship holds, and other confined spaces. These devices are still used today in water treatment plants. Figure 1-1 shows several screws in use at the Indianapolis Advanced Water Treatment facility.

1.02 The first pumping device employing neither human nor animal power was probably developed in China. The device, called a *noria,* consisted of many open-ended bamboo tubes attached around the edge of a large wheel. As the current of a river caused the wheel to turn, each tube dipped into the river and carried a small amount of water up to a channel located near the top of the wheel. Here the tubes spilled their water and returned to the river.

1.03 An early modification of the noria is illustrated in Fig. 1-2 on the following page. This device employed free-swinging buckets attached to a wheel by pins. Their free-swinging nature prevented the

Fig. 1-1. Archimedean screws

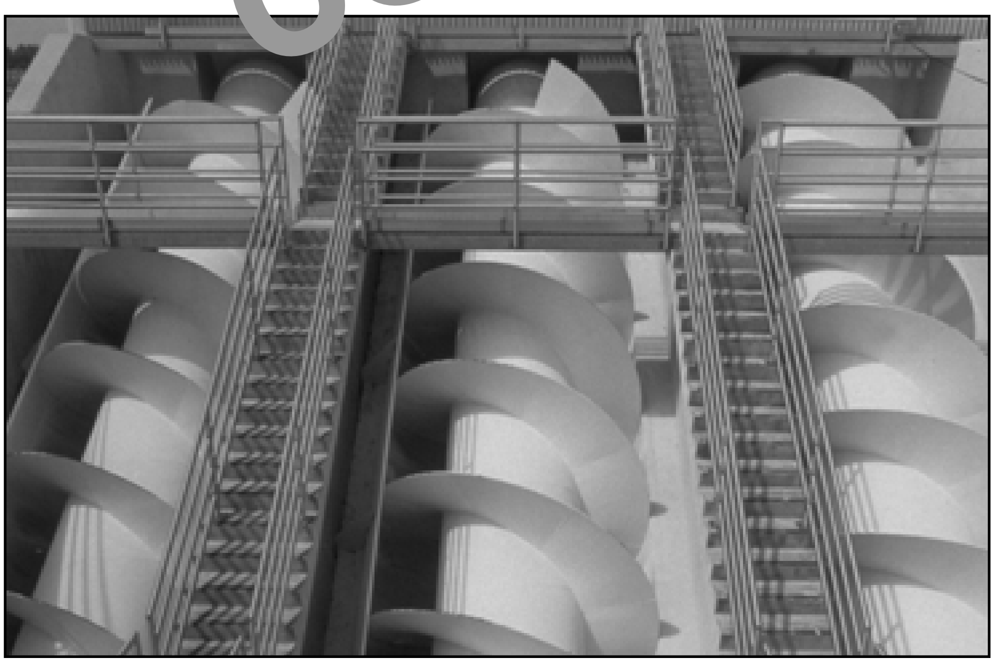


Fig. 1-2. Noria with free-swinging buckets

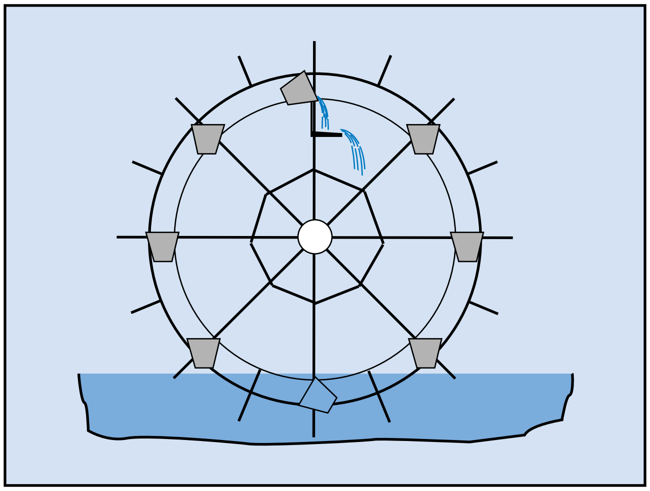
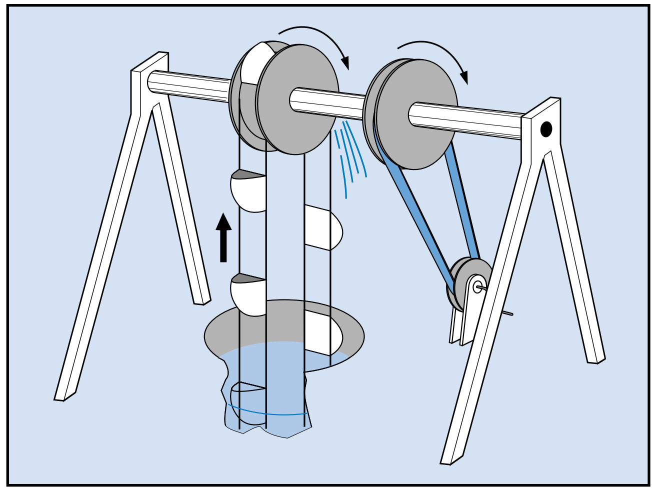


Fig. 1-3. Chain of pots



buckets from dumping their contents before reaching the top of the wheel. When a bucket reached the top of the wheel it struck a bar that caused it to tip and empty its contents into a trough. The maximum lift of the noria was limited by the diameter of the wheel, usually 30 to 40 ft. Use of the noria was also limited by the fact that it could not operate in wells or other confined spaces.

1.04 Ancient Egyptians are credited with inventing a device for pumping water from deep wells. It consisted of a series of buckets or pots mounted on an endless chain rather than on a wheel. The chain was driven by humans or by oxen. This device is shown in Fig. 1-3. Simple pumping machines like these are still used today for irrigation in areas of the Far East.

1.05 Figure 1-4 is a drawing of an early positive-displacement pump. A *positive-displacement pump* discharges a known quantity of fluid during a piston movement through a stroke distance. This pump remained substantially unchanged until the beginning of the Industrial Revolution in late eighteenth-century England. At this time, a steam-powered, positive-displacement pump was developed. The centrifugal pump first appeared in the mid 1800s.

1.06 In industry today, pumps are second only to electric motors as the most commonly used type of equipment. Pumps allow fluids to be moved through pipes, raised to higher elevations, or stored under pressure. Some pumps are even used to move cement and other solids. The remainder of this lesson describes several applications of modern pumps in typical pumping systems, perhaps like those used in your plant.

Pumping Systems

1.07 Nearly all industrial plants use pumps in some way. The pumping of materials can create many challenges for both operating and maintenance personnel.

1.08 Problems in pumping systems can usually be traced to the pump itself, but can also be the result of improper piping or poor selection of valves or accessories. Extending or modifying an existing piping system is a project often assigned to the maintenance department.

1.09 Some pumping systems described in this lesson probably resemble those located in your plant. Even if the systems are different, the basic principles and operating procedures will be similar. The main objective of this lesson is to describe various pump and piping systems used in industrial plants.

Water Pumping Systems

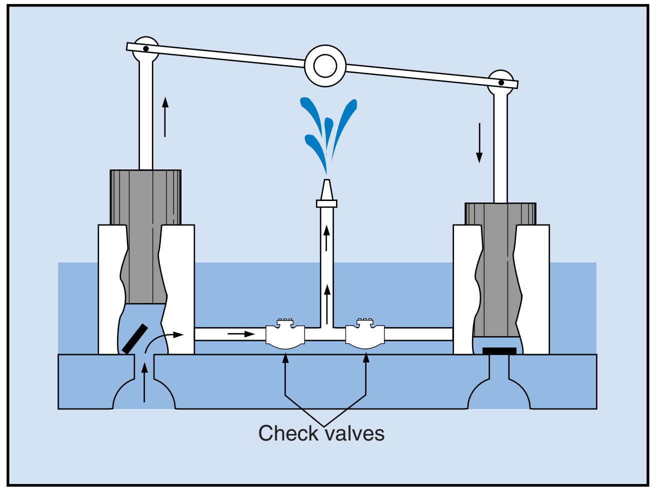
1.10 Water systems are the most common pumping systems in a plant. Although municipal water systems supply water to most plants, some plants have their own wells or other supply sources. Some plants have special requirements, such as water under high pressure, chemically treated water, or water circulation within the plant.

1.11 A typical direct water supply system is shown in Fig. 1-5. A pump withdraws water from a reservoir, lake, well, or other supply source. A centrifugal pump is usually used for this purpose. The water is then conditioned to make it usable for drinking and other purposes. Conditioning can include such processes as softening, filtering, settling, and chemical treatment. From the conditioning tanks, pumps raise the water to an elevated storage tank. After leaving the storage tank, a piping system distributes the water to the required points within the plant.

1.12 Plants with special water treatment requirements often use modifications of the system just described. For example, water might be treated for use with a specific piece of equipment and supplied directly to the equipment without passing through a conditioning tank. Boiler feedwater systems commonly use an arrangement similar to this. The necessary chemicals are added to the water in specific amounts just before the water is pumped into the boiler. The chemicals are often mixed in advance and held in a small storage tank until they are added to the boiler feedwater system.

1.13 Industrial plants use many types of chemical additive systems that resemble the boiler feedwater system. You might have one or more of these in your plant. The feed pumps used in additive systems are often metering pumps. If metering pumps are not used, some other means of control must be provided to regulate the flow of the chemicals or other additives.

Fig. 1-4. Early positive-displacement pump



1.14 The pumping systems just described are relatively easy to understand. Several application problems exist, however, even in these simple systems. One, of course, is choosing the right kind of pump. In addition, pump pressures must be sufficient to overcome changes in the elevation of the water and pressure in the piping. Also, the pumps and piping must be constructed of materials that are capable of han-

Fig. 1-5. Typical water supply system

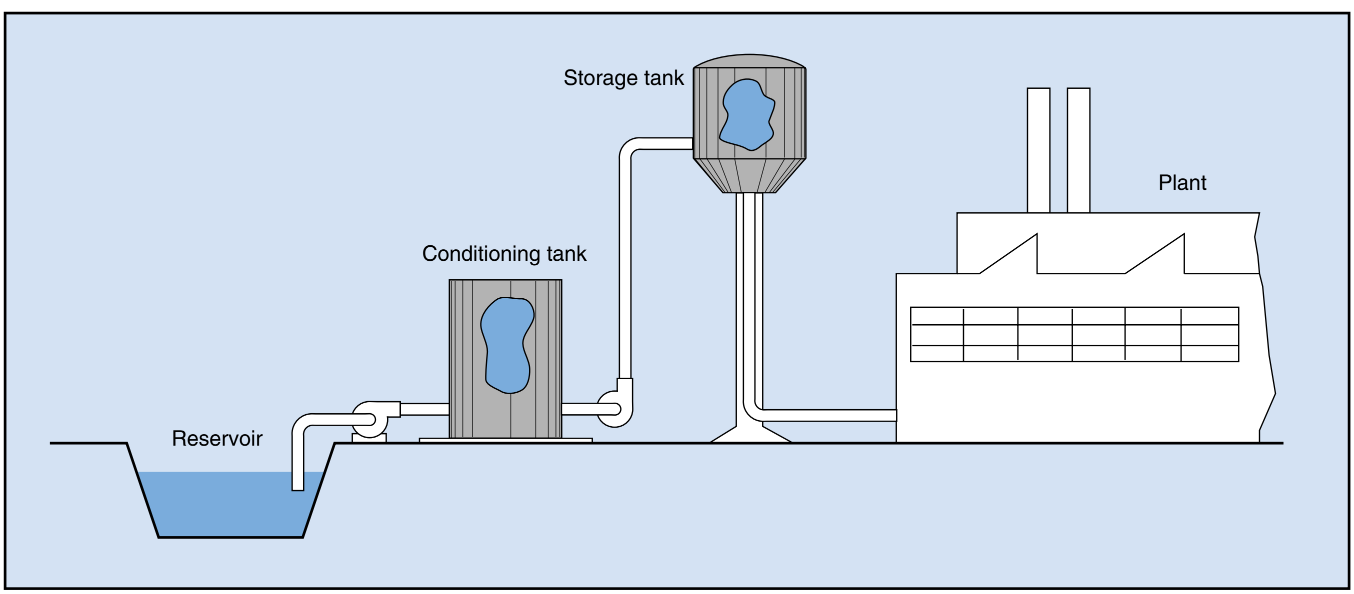
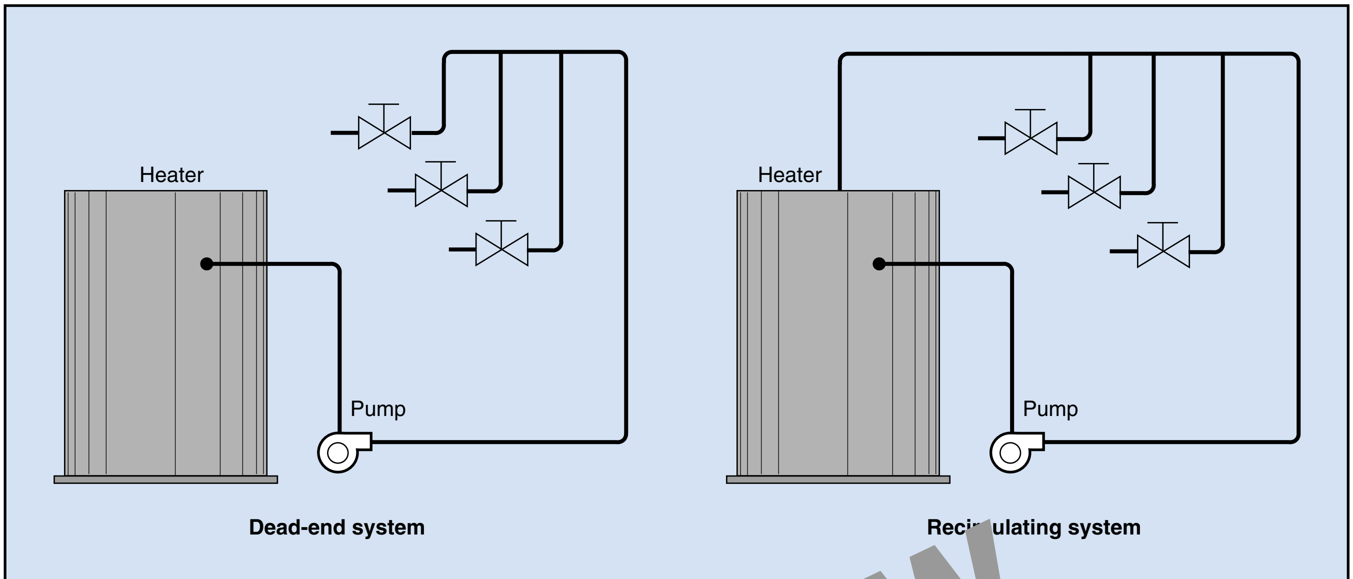


Fig. 1-6. Hot water distribution systems



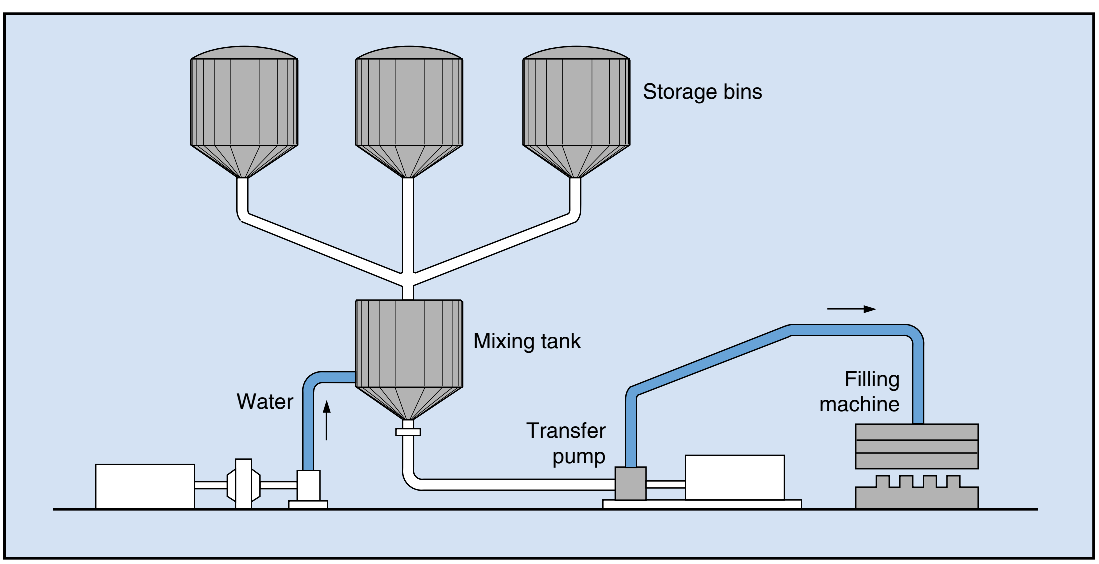
dling the water and chemical solutions without becoming damaged or corroded.

1.15 Another pumping system common to most industrial plants is the hot water distribution system. A hot water distribution system can be either a *dead-end system* or a *recirculating system.* Both types are shown in Fig. 1-6. The type used in a particular case depends upon plant requirements. If a large amount of hot water is required in one specific area, a dead-end system is probably the best choice. If hot water is required throughout the plant, a recirculating system might be more economical. In a recirculating system, unused hot water can be reheated along with a small amount of incoming cool water. This type of system not only eliminates the need to heat all cool water, but also saves heat that would be wasted as water cooled in the lines.

Chemical Pumping Systems

1.16 Chemical pumping systems are unique in their design. Most of their special construction and

Fig. 1-7. Chemical pumping system



design requirements are necessary because of the nature of the materials they handle. The chemicals handled in one area of a plant might not require the use of special corrosion-resistant materials. The corrosion-resistant material used in one pump for one chemical might not be suitable for use with another chemical. In such cases, two separate systems must be used. Piping requirements also vary with the material being pumped.

1.17 Another factor to be considered when selecting a pump is the flow resistance of the chemical. If the chemical is a slurry, it might be necessary to use a positive-displacement pump rather than a centrifugal pump. The viscosity (resistance to flow) of the chemical determines the kind of pump selected. Applications in which chemicals must be metered or pumped under high pressure require high-powered positive-displacement pumps.

1.18 Chemical pumping systems often require special gaskets, seals, and packing materials. The materials used to manufacture seals for pumps having a corrosion-resistant casing are not the same as those used for pumps without this casing. As a result, you must give special consideration to the seals used. They must not only withstand the corroding action of the chemical, but must also be compatible with the corrosion-resistant materials used in the pump.

1.19 Chemical handling, like water distribution, can involve a wide variety of pump and piping arrangements. The plant layout and the requirements of the particular application determine the arrangement. For example, one chemical pumping system might be an in-plant operation limited to only a small area, as shown in Fig. 1-7. In this case, dry chemicals are stored in elevated bins on the second floor of the plant. Feed spouts or chutes extend down to the first-floor mixing area. On the first floor, several dry chemicals are blended in a mixing tank, then combined with water or other liquids to produce the desired chemical solution. The chemical solution is then pumped to a filling machine, which dispenses it into bottles, cans, drums, or other containers. Similar operations take place in most bottling plants.

1.20 In another type of operation, a plant might manufacture chemicals in a process similar to the one just described. But instead of filling containers, pumps move the chemicals into large storage tanks that are located either outside the building or within. The fluid is later pumped from the storage tanks to rail cars or trucks for shipment to other plants, where it is processed further. Or, the chemicals might be pumped from one building to another within the plant complex for further processing to make a different product. A good example of this type of operation is an oil refinery.

1.21 Frequently, chemical products must remain within a specific temperature range while they are being pumped from one location to another. In such cases, the piping systems carrying the chemicals must be fully insulated to maintain the proper temperature. Insulated piping systems are also necessary for piping hot water or steam within an industrial plant complex.

The Programmed Exercises on the following page will tell you how well you understand the material you have just read. Before starting the exercises, remove the Reveal Key from the back of your book. Read the instructions printed on the Reveal Key. Follow these instructions as you work through the Programmed Exercises.

1-1. Fluids can be moved through pipes raised to higher elevations, or stored under pressure through the use of ________.	1-1. PUMPS Ref: 1.06
1-2. Maintenance problems in pumping systems are usually caused by the pump, but also can be the result of improper ________.	1-2. PIPING Ref: 1.08
1-3. What is the most common type of pumping system in industrial plants?	1-3. WATER SYSTEM Ref: 1.10
1-4. If a large amount of hot water is required in one specific area, a(n) ________ distribution system is the best choice.	1-4. DEAD-END Ref: 1.15
1-5. In a(n) ________ system, unused hot water is reheated along with cool incoming water.	1-5. RECIRCULATING Ref: 1.15
1-6. Applications in which chemicals must be metered or pumped under high pressure require high-powered ________ pumps.	1-6. POSITIVE-DISPLACEMENT Ref: 1.17
1-7. Chemical handling arrangements are determined by the plant ________ and the requirements of the particular ________.	1-7. LAYOUT; APPLICATION Ref: 1.19
1-8. Insulated piping systems are necessary for piping chemical products, ________, and ________ in an industrial plant.	1-8. HOT WATER; STEAM Ref: 1.21

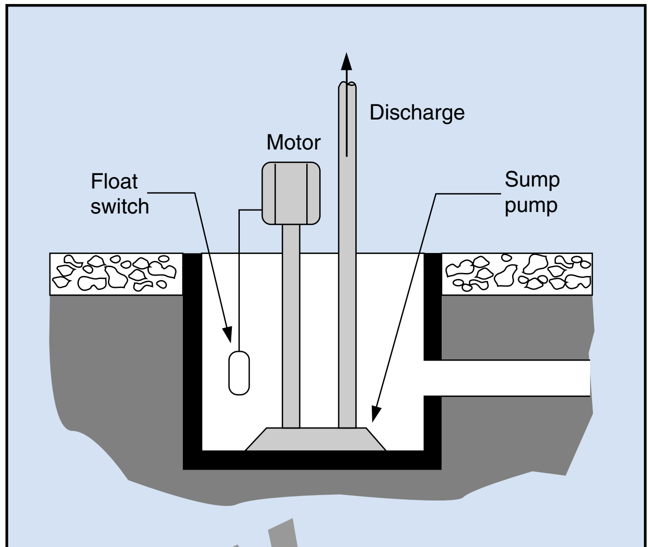
Waste Pumping Systems

1.22 Waste pumping systems, like chemical pumping systems, have a variety of applications. For example, one system might handle roof runoff water, another sewage wastes, and yet another chemical wastes and radioactive wastewater. Generally, centrifugal pumps are used to pump wastewater in a plant. The low-head pumping requirements and the pump's ability to pass small solid particles make the centrifugal pump well suited to these applications. Usually, the waste is piped directly to the pump. Often, the pump is completely submerged in the liquid it is pumping, like the sump pump shown in Fig. 1-8.

1.23 If the pump is handling corrosive waste, the pump impeller, housing, shaft, and supporting structure must be made of corrosion-resistant materials. If the pump is handling runoff water or other noncorrosive waste, it can be made of cast iron, bronze, or brass and will usually have good service life. When sump pumps are used, intake screens must be installed to keep large particles from reaching the pump impeller.

1.24 When pumping radioactive or chemical wastes, pumps are often connected to independent collection and discharge systems. Chemical wastes might be pumped through one system, while floor drainage and other wastewater are conveyed through a separate system to a second sump, as shown in Fig. 1-9. Since the chemical pump is located outside of the sump, only the internal parts of the pump come into contact with the waste. Therefore, only the internal pump parts must be able to withstand the action of the chemical. The pump discharges the waste into an elevated waste storage tank for temporary storage. From this point, the waste is picked up by truck, rail car, or other means and is disposed of where the waste chemicals will not harm or pollute any existing water sources or disposal facilities.

Fig. 1-8. Waste pumping arrangement



1.25 The pulp, paper, and canning industries offer many examples of special waste disposal facilities. These industries produce large amounts of wastewater in a short time. Because of the nature of the waste-

Fig. 1-9. Separate waste systems

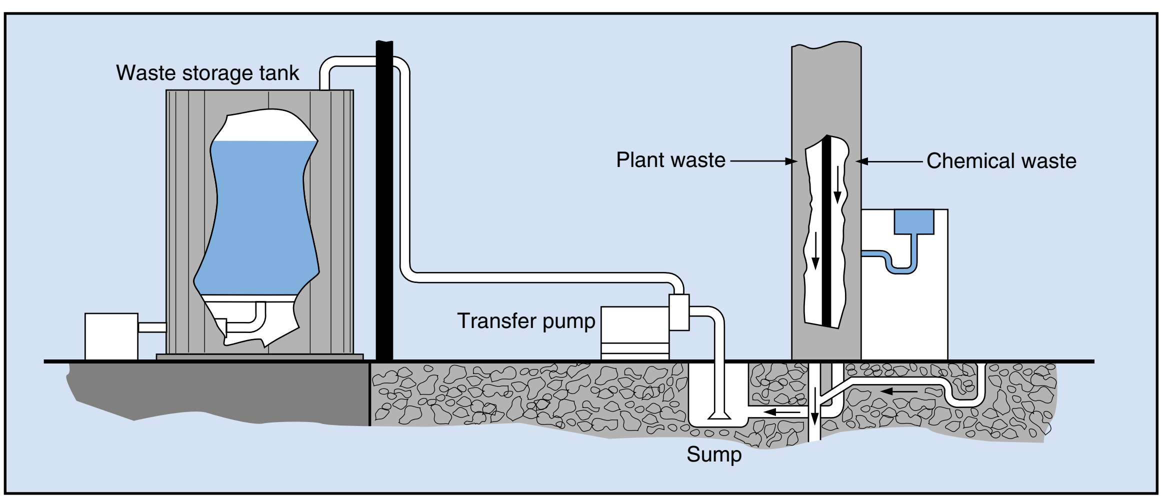
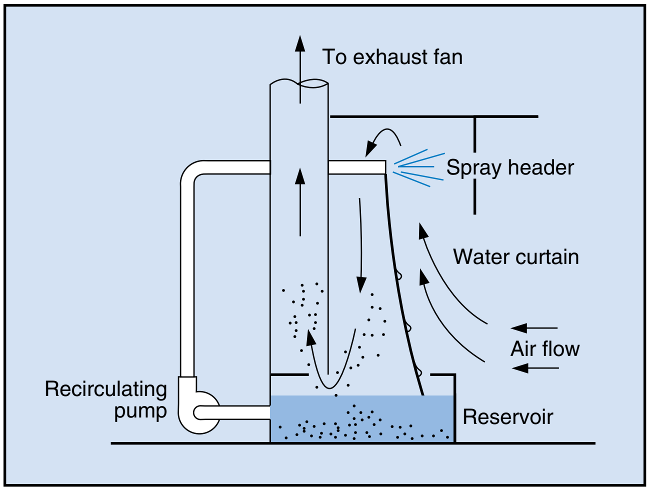


Fig. 1-10. Typical paint spray booth



water, it cannot be discharged into municipal sewage systems, rivers, or lakes. In these cases, companies usually have treatment plants installed on company property. The treatment plants process and purify the water before it is discharged into municipal sewage facilities or bodies of water.

1.26 Another example of chemical waste treatment is the paint spray booth shown in Fig. 1-10. Air passes through the painting area into the water curtains of the spray booth. As the air and paint pass through several curtains of water, the water collects the paint pigments. The water returns to the reservoir, where the paint pigments settle to the bottom. Water from the reservoir is supplied to the spray header pipe by a recirculating pump that is mounted outside of the spray booth. The paint spray booth is an example of a closed circulation system operating in a small area.

1.27 Because spray booths require large quantities of water, it is impractical to supply fresh, unused water continuously. By using a recirculating system, far less water is used. The water is changed at regular intervals, and the paint pigments are collected from the bottom of the reservoir.

High-Viscosity Material Pumping Systems

1.28 *Viscosity* is the property of a material that resists any flow-producing force. High-viscosity materials include syrups, oils, and light cement slurries. The degree of viscosity of materials varies from plant to plant. The materials covered in this section are fairly thick but still flow when pumped.

1.29 Positive-displacement pumps (both rotary and reciprocating) are generally used for pumping high-viscosity materials. The nature of the material being pumped frequently limits the area of system operation. The length of pipe runs is limited by the distance the material can be pumped without using booster pumps, which add to energy consumption. In some cases, the fluid being pumped can be heated to lower its viscosity and make it easier to pump. Pipe runs are then insulated to maintain the elevated temperature of the fluid.

Fig. 1-11. Paint spray systems

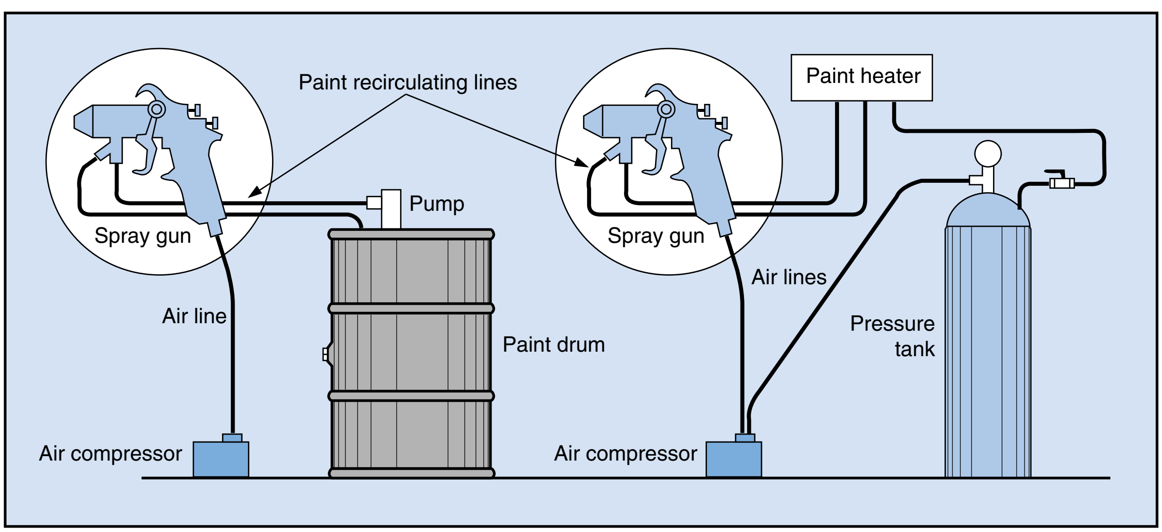
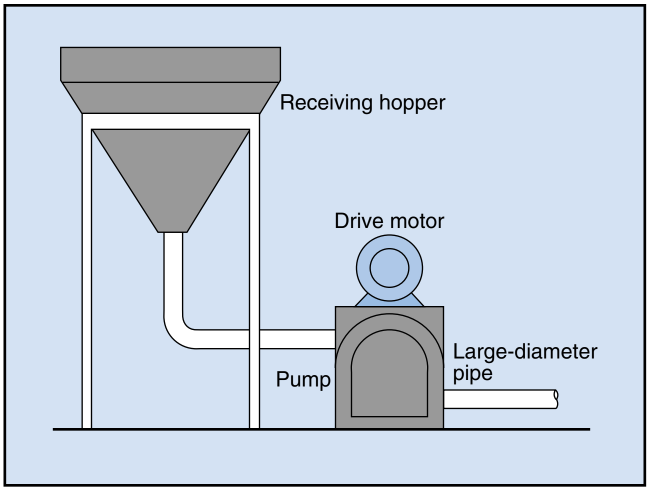


Fig. 1-12. Cement slurry pumping system



1.30 Paint is another example of a high-viscosity fluid. Piston pumps are usually used to handle paint. Often the paint is pumped directly from the drum, through a system of filters and strainers, to the spray gun, as shown in Fig. 1-11.

1.31 Some paint systems do not pump from a drum, but rather use compressed air to force the paint from a pressurized storage tank. This arrangement is also shown in Fig. 1-11. The paint moves through a heater and then to the spray gun. When heaters are used, they usually contain small, air-driven, circulating gear pumps to help keep the paint in motion.

1.32 One of the problems involved with paint pumping systems is the settling of pigments as they travel through the supply lines. To avoid pigment settling, the paint must be kept in motion and must move relatively quickly.

1.33 Another problem in spray paint systems involves the abrasiveness of paint pigment. Although paint feels slippery when you rub it between your fingers, the pigment that gives paint its color is very abrasive. This abrasiveness causes wear within the pump.

1.34 Light cement slurries and glue are usually pumped with piston pumps. In these applications, heat need not be added. Because of the high water content of these materials, they flow quite easily at room temperature. Heat applied to these materials tends to set them or dry them out, causing problems within the piping system.

1.35 Because of their weight, cement slurries are usually withdrawn from a holding tank or hopper located above the pump. Cement slurries can be pumped long distances without encountering many problems. The piping through which the materials flow should be large enough to allow them to flow with a minimum of friction. An example of a cement slurry pumping operation is shown in Fig. 1-12. Notice that the receiving hopper is located above the pump.

Solids Pumping Systems

1.36 Solids pumping systems are similar in nature to high-viscosity material systems. They differ only by the characteristics of the material being pumped. Solids pumping systems handle greases, heavy mastics, cement, concrete, and similar materials. The cement slurry pumping system previously described is equally effective for pumping dry cement.

1.37 When pumping concrete, a pump must be able to pass a large quantity of stone and gravel. For this reason, pumps must be heavily constructed with large suction and discharge ports. Because of the abrasiveness of the sand in the concrete, excessive wear is frequently a problem. Repair will therefore be easier if cylinder liners and other replaceable components are used.

1.38 Mastic and grease pumping systems are usually of the dead-end or noncirculating type shown at the right in Fig. 1-13 on the following page. Recirculating systems are sometimes used when several stations demand large quantities throughout the day. A recirculating system is shown at the left in Fig. 1-13.

1.39 Piston pumps are most often used to handle materials like these. One common problem encountered with a piston pump, however, involves the flow at the source of supply. The pump can usually withdraw the material (grease, for example) faster than the material can flow down to the pump, as shown in Fig. 1-14. To overcome this problem, grease drums using piston pumps are usually equipped with a *follower plate,* as shown. This follower plate rides on top of the material being pumped. The use of a follower plate is also shown in Fig. 1-14.

Fig. 1-13. Grease or mastic pumping systems

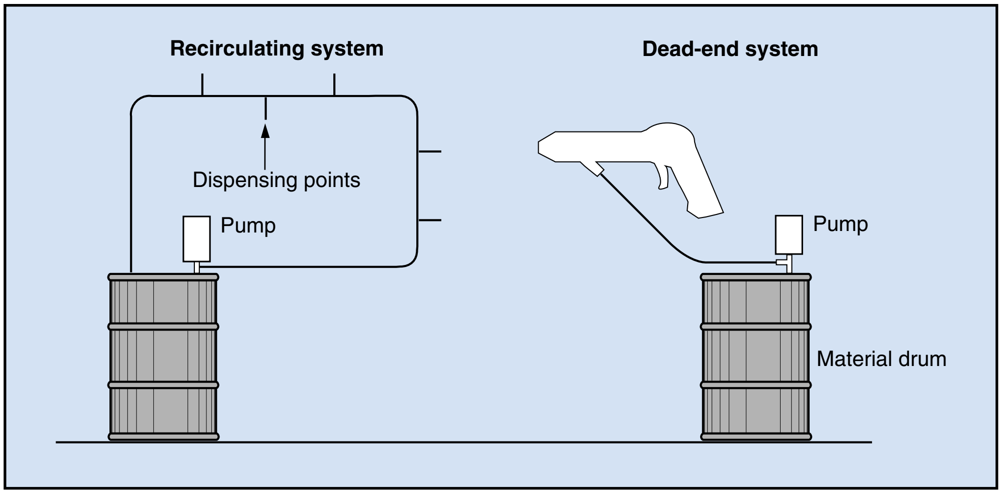
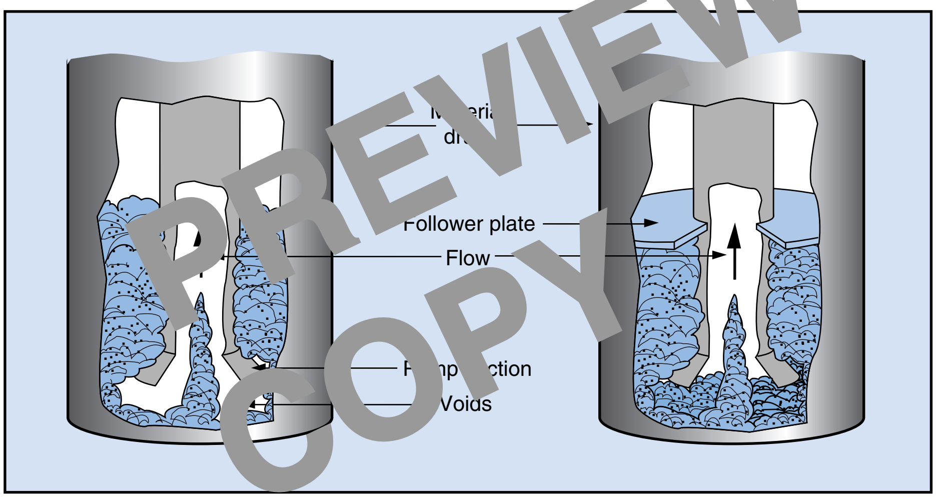


Fig. 1-14. Use of a follower plate



1.40 The suction of the pump draws the level of the grease or mastic down toward the bottom of the drum. The weight of the follower plate helps force the material down. The plate also prevents the formation of air pockets or voids between the pump suction and the grease surface. A rubber gasket placed around the outer edge of the plate scrapes the drum clean as it travels down and ensures that most of the grease gets to the pump.

1-9. When sump pumps are used, ________ must be installed to keep large particles from reaching the pump impeller.	1-9. INTAKE SCREENS Ref: 1.23
1-10. Because spray booths require large quantities of water, a(n) ________ systems is best for such applications.	1-10. RECIRCULATING Ref: 1.27
1-11. High-viscosity materials are materials that resist any ________ force.	1-11. FLOW-PRODUCING Ref: 1.28
1-12. What type of pump is usually used for pumping high-viscosity materials?	1-12. POSITIVE-DISPLACEMENT Ref: 1.29
1-13. In some cases, a fluid is ________ to lower its viscosity.	1-13. HEATED Ref: 1.29
1-14. Two problems encountered in paint pumping systems are the settling of ________ and pigment ________.	1-14. PIGMENTS; ABRASIVENESS Ref: 1.32, 1.33
1-15. Systems handling greases, heavy mastics, cement, and concrete are called ________ pumping systems.	1-15. SOLIDS Ref: 1.36
1-16. Repair of solids pumping systems is made easier if cylinder liners and other ________ components are used.	1-16. REPLACEABLE Ref: 1.37

Answer the following questions by marking an "X" in the box next to the best answer.

1-1. In boiler feedwater systems, metering pumps regulate the flow of

- ☐ a. chemicals
- ☐ b. solids
- ☐ c. steam
- ☐ d. water

1-2. Which type of distribution system is best suited for plants that require hot water throughout?

- ☐ a. Boiler
- ☐ b. Conditioning
- ☐ c. Dead end
- ☐ d. Recirculating

1-3. High-powered positive-displacement pumps are used to pump chemicals that are

- ☐ a. corrosive
- ☐ b. noncorrosive
- ☐ c. under high pressure
- ☐ d. used in water treatment

1-4. Insulated piping systems are *not* necessary for piping

- ☐ a. chemicals
- ☐ b. hot water
- ☐ c. slurries
- ☐ d. steam

1-5. When sump pumps are used in a waste pumping system, which of the following is used to keep large particles from reaching the impeller?

- ☐ a. Filter
- ☐ b. Intake screen
- ☐ c. Large discharge pipe
- ☐ d. Strainer

1-6. High-viscosity materials are

- ☐ a. combustible
- ☐ b. lumpy
- ☐ c. thick
- ☐ d. thin

1-7. If a liquid is heated to lower its viscosity, the pipe runs must be

- ☐ a. angled
- ☐ b. insulated
- ☐ c. made of aluminum
- ☐ d. short

1-8. To avoid pigment settling in paint pumping systems, the paint must be

- ☐ a. heated
- ☐ b. kept in motion
- ☐ c. pressurized
- ☐ d. strained

1-9. Adding heat to light cement slurries and glue

- ☐ a. destroys pipe insulation
- ☐ b. dries them out
- ☐ c. lowers their viscosity
- ☐ d. makes them flow more easily

1-10. Repair of solids pumping systems is easier if

- ☐ a. pipe runs are kept short
- ☐ b. replaceable components are used
- ☐ c. the system has small ports
- ☐ d. you work as a team

SUMMARY

Water systems are the most common pumping systems used in industry. The direct water supply system and its modifications are used to supply water to the plant. Metering pumps are often part of the system when chemicals must be added to the water. Hot water distribution systems can be either dead-end or recirculating systems, depending on how much water is needed in a given area.

Chemical pumping systems have special design and construction requirements. The viscosity of the chemical being pumped determines the type and energy requirements of the pump selected. Positive-displacement pumps are common in chemical pumping systems. Such systems also require special gaskets and seals, and some must be insulated.

Waste pumping systems generally use centrifugal pumps. Depending on the materials to be handled, the pumps may be made of corrosion-resistant materials and special screens may be used.

Positive-displacement pumps are often used to pump high-viscosity materials. Piston pumps are used to handle paint. Solids pumping systems are similar to high-viscosity materials systems except in the materials each carries. Cylinder liners and other replaceable components make repairs of solids pumping systems easier.

Answers to Self-Check Quiz

1-1. a. Chemicals. Ref: 1.13

1-2. d. Recirculating. Ref: 1.15

1-3. c. Under high pressure. Ref: 1.17

1-4. c. Slurries. Ref: 1.21

1-5. b. Intake screen. Ref: 1.23

1-6. c. Thick. Ref: 1.28

1-7. b. Insulated. Ref: 1.29

1-8. b. Kept in motion. Ref: 1.32

1-9. b. Dries them out. Ref: 1.34

1-10. b. Replaceable components are used. Ref: 1.37

Contributions from the following sources are appreciated:

Figure 1-1. RQAW and Associates, Consulting Engineers, Inc.