



Tech Brief

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Pumps

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Summary

From start to finish, pumps play an important role in all water distribution systems. They are used to transfer raw water to the treatment plant; they supply water to sections of a distribution system where it is not possible to supply it by gravity; they add appropriate chemical doses during treatment; and they transfer sludge from settling chambers for further treatment and disposal. Pumps will provide long-term efficient service if they are properly operated and maintained.

Pumps in Water Distribution Systems

Pumps are an important part of any water distribution system. At the source, they help deliver raw water to the treatment plant. In the plant, pumps add chemical solutions at desired dosages for treatment processes, and other pumps remove sludge from sedimentation facilities for further treatment and disposal. Within distribution systems, pumps discharge water under pressure to the pipe network and lift water where it cannot go by gravity, especially to water towers.

Pump Applications

Different types of applications require different types of pumps. Pumps are selected based on system requirements, discharge pressure required, flow capacity required, and availability of space. The two most common pumps in the water industry are: centrifugal pumps, used most often in water distribution, and positive-displacement pumps, most commonly used in treatment plants for chemical dosing.

Types of Pumps Used in Water Supply

Three kinds of pumps are most often found in water distribution systems: the aforementioned centrifugal pumps, used to move water, vertical turbine pumps, used at the intake, and submersible pumps, used in wells.

Centrifugal Pumps

Centrifugal pumps are the most common type used in water distribution. Centrifugal pumps have a circular “fan/turbine-shaped” structure called an impeller that is mounted on a centrally supporting structure called the shaft. The motor rotates the shaft and can be powered by electricity or diesel fuel.

Water enters at an opening in the center called the suction. The rotating impeller imparts a high velocity to the water, and it is circulated and thrown outward. **(See figure 1.)** A circular-shaped covering called casing surrounds the impeller. The casing is shaped like a spiral so that the water slows down, and the velocity head is converted to pressure head as it flows out of the casing. At the junction of the casing and shaft, a seal or packing rings are provided to prevent leakage.

Glossary of Pump Terms

Head—(1) A measure of the energy possessed by water at a given location in the water system expressed in feet; (2) a measure of the pressure or force exerted by water expressed in feet.

Velocity Head—A measurement of the amount of energy in water due to its velocity or motion.

Pressure Head—A measurement of the amount of energy in water due to water pressure.

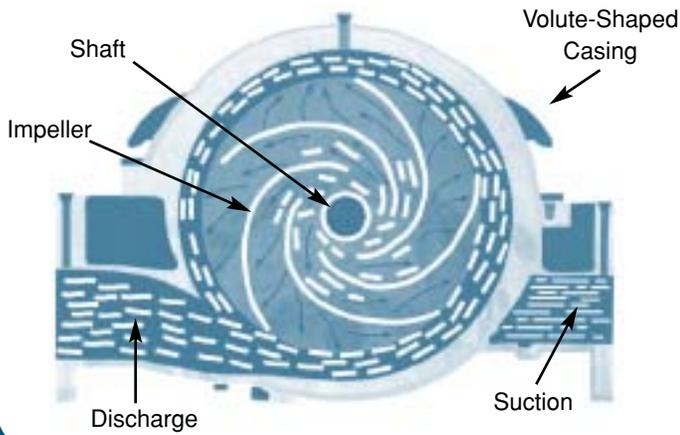
Impeller—The moving element in a pump that drives the fluid.

Efficiency—A ratio of total energy output to the total energy input expressed as a percent.

Priming—The action of starting the flow in a pump or siphon. With a centrifugal pump, this involves filling the pump casing and suction pipe with water.

Source: American Water Works Association. 1996. *Water Transmission and Distribution: Principles and Practices of Water Supply Operations*, 2nd edition. Denver, CO: AWWA

Figure 1: Volute Centrifugal Pump Schematic



Adapted from AWWA *Water Transmission and Distribution: Principles and Practices of Water Supply Operations*, 2nd edition.

A packing gland presses against the rings to maintain a tight seal.

Different flow rates and outlet pressures can be generated by this type of pump, depending on the size of the pump and the space between the casing and the impeller. Impellers can also have varying shapes. These pumps can be used either as a single unit or can be coupled with another similar pump in series to generate more output pressure. When more than one pump is used, it becomes a multistage pump. The pressure desired in the distribution system determines the number of stages required. If a single stage pump is not enough to supply water at adequate pressure, multiple stages are used. Centrifugal pumps can achieve an output pressure of up to 250 feet for each stage. Centrifugal pumps are used to supply large volumes of water at a constant output pressure. The pressure generated by a centrifugal pump is less compared to other types of pumps, such as a reciprocating (positive-displacement) pump.

According to the American Water Works Association's *Water Transmission and Distribution: Principles and Practices of Water Supply Operations*, some of the advantages of centrifugal pumps are:

- wide range of capacities that range from a few gallons per minute [gpm] to 50,000 gpm. Heads of five to 700 feet are generally available;
- uniform flow at constant speed and head;
- simple construction (small amounts of suspended matter in the water will not jam the pump);
- low to moderate initial cost for a given size;

- ability to adapt to several drive types—motor, engine, or turbine;
- moderate to high efficiency at optimal operation;
- no need for internal lubrication;
- little space required for a given capacity;
- relatively low noise level; and
- ability to operate against a closed discharge valve for short periods without damage.

Some of the disadvantages are:

- an efficiency that is limited to a narrow range of discharge flows and heads;
- low capacity that is greatly dependent on discharge pressure;
- generally no self-priming ability;
- potential for running backward if stopped with the discharge valve open; and
- potential for impeller to be damaged by abrasive matter in water, or clogged by large quantities of particulate matter.

During startup, centrifugal pumps require a procedure called “priming” in which the pump is filled with water before turning the switch on. This insures that when the impeller starts rotating it starts pumping water, and energy imparted to the impeller is not lost. If a centrifugal pump is not primed, it does not operate efficiently (i.e., it does not pump water even when it is turned on). Generally, pumps have an adjacent chamber, called the priming chamber, that sucks in water when the pump is turned on and keeps the impeller submerged.

Vertical Turbine Pumps

In vertical turbine pumps, the water flows vertically through a channel of uniform cross-sectional area. The impeller is positioned in the center along the axis in the channel. The blades of the impeller are shaped so that the water flows in a radial direction. (**See figure 2.**) The casing has diffuser vanes, shaped so that they guide water and make it flow either into the discharge or through diffuser bowls into inlets of succeeding stages. Vertical turbine pumps are used most often at raw water intakes and at booster stations in the distribution system to augment the pressure required for service. Vertical turbine pumps are relatively more expensive than centrifugal pumps for the same capacity and require more maintenance.

According to the American Water Works Association's *Water Transmission and*

Distribution: Principles and Practices of Water Supply Operations, some of the advantages of vertical turbine pumps are:

- uniform flow at constant speed and head;
- simple construction;
- individual stages capable of being connected in series, thereby increasing the head capacity of the pump;
- adaptability to several drive types—motor, engine, or turbine;
- moderate to high efficiency under the proper head conditions;
- little space occupied for a given capacity; and
- low noise level.

The main disadvantages are:

- high initial cost;
- high repair costs;
- the need to lubricate support bearings located within the casing;
- inability to pump water containing any suspended matter; and
- an efficiency that is limited to a very narrow range of discharge flow and head conditions.

Submersible Pumps

Submersible pumps, as the name implies, are placed below the water level. (See figure

3.) They are used mostly for pumping groundwater from wells. The pump is basically a multi-stage centrifugal pump. The impellers of the pump are mounted on a vertical shaft. Each impeller passes water to the next stage through a diffuser shaped so that the water flows vertically to the next diffuser. Each impeller and diffuser is called a stage. The desired output pressure determines the number of stages.

The pump is driven by an electric motor placed adjacent to the pump and is constructed for submerged operation. The wiring of the electric motor is such that it is waterproof. The motors are manufactured to ensure water does not cause it to fail by

grounding or shorting out. However, most failures of submersible pumps are due to electrical problems with the motors.

Positive-Displacement Pumps

Positive-displacement pumps are used in water supply operations for feeding chemicals at various stages of the treatment process. They displace a certain volume of water in each stroke as they operate. These pumps are not suitable for pumping large volumes of water, they are more suited for high pressure and low flow service. There are two types of positive-displacement pumps: reciprocating pumps and rotary pumps.

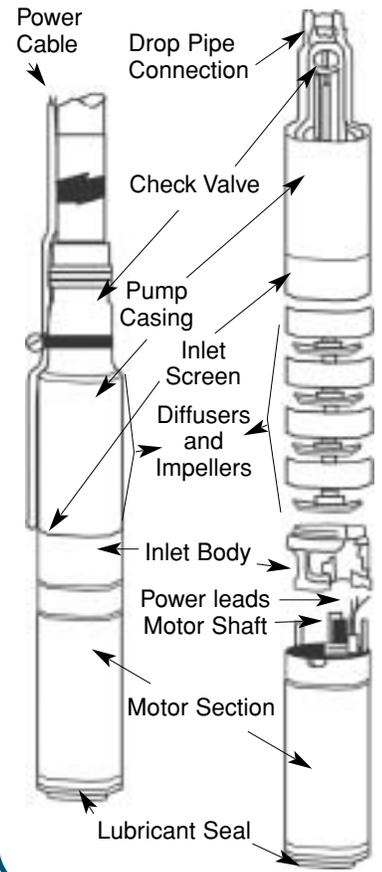
Reciprocating Pumps

Reciprocating pumps have a piston that moves back and forth in an enclosing cylinder. The arrangement of rotating shaft, connecting rod, and joint pushes the volume of the fluid in the cylinder through an outlet valve. The liquid enters and leaves the cylinder through check valves. Reciprocating pumps are suitable for applications where very high pressures are required, or where abrasive fluids, such as acids or viscous liquids, have to be pumped.

Rotary Pumps

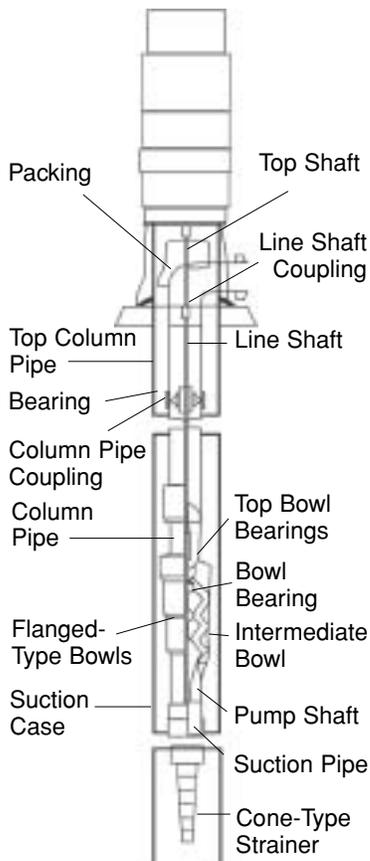
In rotary pumps, the impeller rotates within an enclosing structure and imparts energy to the water. The impeller can be in the shape of a gear, screw, or lobes. For rotary pumps, the output is continuous and smoother compared to reciprocating pumps. Rotary pumps are better suited for lower pressures than reciprocating pumps because of slippage at higher pressures. Rotary pumps can jam if any solids enter the small clearance spaces between the impeller and casing. Rotary pumps are suitable for handling fluids of varying viscosities and are used in water treatment for chemical dosing.

Figure 3: Submersible Pumps



Adapted from AWWA *Water Transmission and Distribution: Principles and Practices of Water Supply Operations*, 2nd edition.

Figure 2: Vertical Turbine Pump



Adapted from AWWA *Water Transmission and Distribution: Principles and Practices of Water Supply Operations*, 2nd edition.

Operation of Centrifugal Pumps

Because centrifugal pumps are so widely used in water distribution and because so many brands are available, the individual procedures for proper operation vary. Most manufacturers supply instructions, guidelines, or manuals with a new pump. Users must follow these instructions while operating pumps.

Pump Starting and Stopping

During pump startup, check the lubrication of the motor bearings and prime the pump. After priming, the pump must be started with the discharge valve fully closed. The discharge valve must then be opened slowly to allow any air in the system to escape. The pump discharge valve must be opened and closed slowly to prevent water hammer in the system. (For more information about water hammer, see the *Tech Brief* in the Winter 2003 *On Tap*.)

During power failure (when the motor stops running), the discharge valve can remain open. This might be a problem because the water can actually flow backward. On large pumps, emergency power operated valves are provided to prevent the impellers from running in reverse. On smaller pumps, check valves are provided.

If the pump will be shut down for longer periods, additional steps should be taken. In cold weather, for example, all water must be drained out from the pump to prevent freezing. The pump packing or seal must be removed if the pump is to be stored idle for longer periods.

Centrifugal Pump Maintenance

Centrifugal pumps require regular inspection and maintenance. Bearings on the motor may become worn and must be checked and kept well lubricated. The packing or seal can wear out due to friction resulting in leakage from the pump. These should be checked regularly. Bearing and motor temperatures must be monitored. If a surface is substantially hotter than normal, the unit should be shut down and the cause of excessive heat investigated. In case of any unusual noises or vibrations from the pump, it must be stopped and the cause investigated.

What about safety?

Safety instructions provided by the manufacturer must be followed. Pumps should always be switched off before any maintenance. All liquids must be drained out before servicing. People must stand away from any moving parts. Safety precautions

must be taken regarding electrical motors. Maintenance personnel must wear rubber gloves and use insulated tools while servicing electrical motors. A record of all maintenance work must be maintained.

Concern that the water supply could be vulnerable to terrorist attacks has understandably been heightened by recent world events. Knowledge, planning, and preparedness helps relieve this concern. It is crucial now to regularly inspect the location, accessibility, and operation of all the pumps in the distribution system. A large-scale disruption in water supply for a large water system can happen because of pump failure at a key location. After gathering complete and accurate information on all the pumps in the system, the utility manager can run through "what if" scenarios to determine where a contaminant is likely to move. Workers can also learn how water movement can be controlled by running or shutting down pumps or other utility operations.

Where can I find more information?

- American Water Works Association. 1996. *Water Transmission and Distribution: Principles and Practices of Water Supply Operations*, 2nd edition. Denver, CO: AWWA.
- American Water Works Association. 1999. *Design and Construction of Water Systems: An AWWA Small System Resource Book*, 2nd edition. Denver, CO: AWWA.
- Dickenson, T.C. 1995. *Pumping Manual*. Oxford, UK: Elsevier Advanced Technology.
- HDR Engineering, Inc. 2001. *Handbook of Public Water Systems*. New York: John Wiley and Sons, Inc.

For further information, to comment on this *Tech Brief*, or to suggest topics, contact Vipin Bhardwaj via e-mail at vbhardw2@wvu.edu.

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