Pumps[1]

There are various types of fluid machinery. Among them are those that transfer fluid energy (***torque converters***), those that convert mechanical energy to fluid energy (***pumps***), and those that convert fluid energy to mechanical energy (***turbines***). The conversion of mechanical energy to fluid energy is accomplished by pumps for the case of incompressible fluids, and by ***blowers, fans,*** and ***compressors*** for the case of compressible fluids. In this chapter we shall confine our discussion to pumps. In Secs. 6.11–6.14 there is a discussion of flow through rotating machinery and rotating conduits; we suggest the reader review that material before proceeding further. Since pumps are much more prevalent than turbines, we discuss pumps first. We shall deal with ***centrifugal and axial-flow pumps,*** but shall not discuss positive displacement pumps such as reciprocating piston and rotary types.

15.1 Description of Centrifugal and Axial-Flow Pumps

The rotating element of a centrifugal pump is called the ***impeller*** (Fig. 15.1). The impeller may be shaped to force water outward in a plane at right angles to its axis (***radial flow***), to give the water an axial as well as radial velocity (***mixed flow***), or to induce a spiral flow on coaxial cylinders in an axial direction

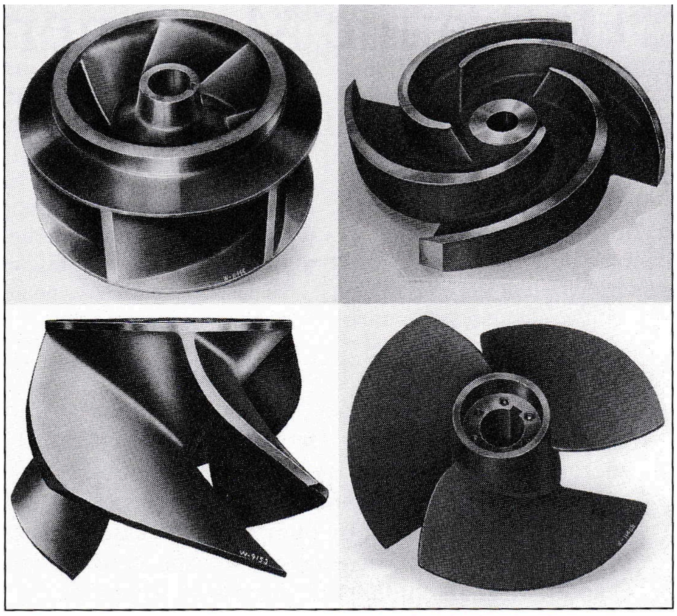

Figure 15.1
Types of pump impellers. Top left: closed or shrouded radial. Top right: open or unshrouded radial. Bottom left: mixed flow. Bottom right: propeller. (Worthington Pump Co.)

(***axial flow***). Radial-flow and mixed-flow machines are commonly referred to as centrifugal pumps, while axial-flow machines are called axial-flow pumps or ***propeller pumps.*** Radial- and mixed-flow impellers may be either open or closed. The open impeller consists of a hub to which vanes are attached, while the closed impeller has plates (or ***shrouds***) on each side of the vanes. The open impeller does not have as high an efficiency as the closed impeller, but it is less likely to become clogged and hence is suited to handling liquids containing solids.

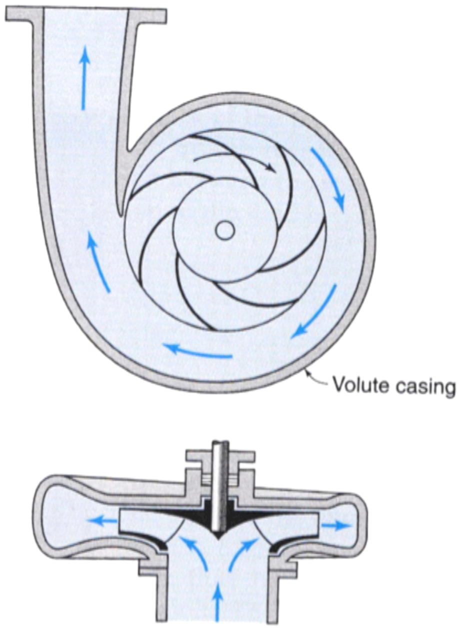

Figure 15.2
Radial-flow centrifugal pump with volute casing.

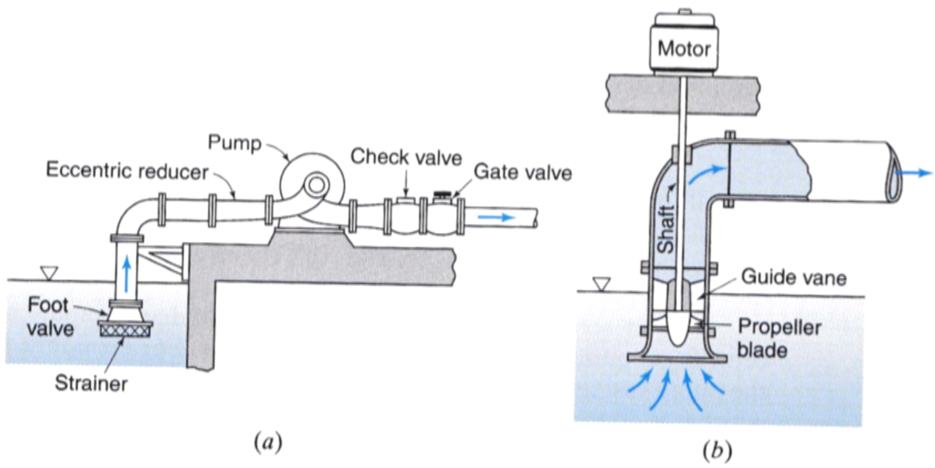

Figure 15.3
(*a*) Typical centrifugal pump installation. (*b*) Typical axial-flow pump installation.

Typical centrifugal-flow and axial-flow pump installations are shown in Fig. 15.3. Pumps can be ***single-stage*** or ***multistage.*** A single-stage pump has only one impeller, while a multistage has two or more impellers arranged in such a way that the discharge from one impeller enters the eye of the next impeller. Deep-well pumps (Fig. 15.4), a type of turbine pump, are usually multistage, having

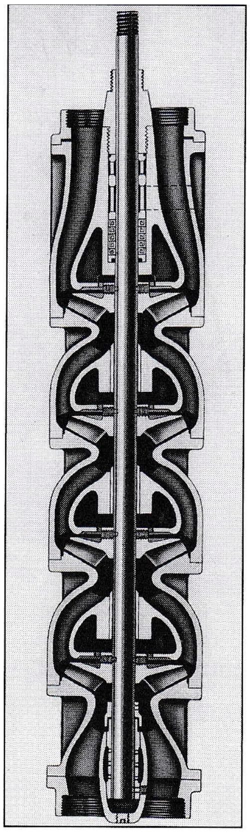

Figure 15.4
Deep-well multistage mixed-flow turbine pump. (Courtesy of Byron Jackson Company)

several impellers on a vertical shaft suspended from a prime mover, usually an electric motor, located at the ground surface. Each impeller discharges into a fixed-vane diffuser, or bowl, coaxial with the drive shaft, which directs water to the next impeller.

Proper arrangement of the suction and discharge piping is necessary if a centrifugal pump is to operate at best efficiency. For economy, the diameter of the pump casing at suction and discharge is often smaller than that of the pipe to which it is attached. If there is a horizontal reducer between the suction and the pump, we should use an ***eccentric reducer*** (Fig. 15.3*a*) to prevent air accumulation. A ***foot valve*** (check valve) can be installed in the suction pipe to prevent water from leaving the pump when it is stopped. The discharge pipe is usually provided with a check valve and a gate valve. The ***check valve*** prevents backflow through the pump if there is a power failure. Suction pipes taking water from a sump or reservoir are usually provided with a screen to prevent entrance of debris that might clog the pump.

Axial-flow pumps (Fig. 15.3*b*) usually have only two to four blades and, hence, large unobstructed passages that permit handling of water containing debris without clogging. The blades of some large axial-flow pumps are adjustable to permit setting the pitch for the best efficiency under existing conditions.

15.3 Pump Efficiency

As liquid flows through a pump, only part of the energy imparted to the shaft of the impeller is transferred to the flowing liquid. There is friction in the bearings and packings, not all liquid passing through the pump is effectively acted upon by the impeller, and there is substantial loss of energy due to fluid friction which has a number of components including shock loss at entry to the impeller,[2] fluid friction as the fluid passes through the space between the vanes or blades, and head loss as the fluid leaves the impeller. The efficiency of a pump is quite sensitive to the conditions under which it is operated, as will be discussed in Sec. 15.5.

The power input to the pump, delivered to the pump shaft by the motor, is called the ***shaft power*** or the ***brake power.*** The power output from the pump, delivered to the fluid, usually water, is called the ***fluid power*** or the ***water power.*** From Eq. (5.42) then, the efficiency η (eta) of a pump is given by

$$\eta = \frac{\text{output power}}{\text{input power}} = \frac{\text{fluid power}}{\text{shaft (brake) power}} = \frac{\gamma Q h}{T\omega} \qquad (15.2)$$

where γ, Q, and h are defined in the usual fashion; T is the torque exerted on the shaft of the pump by the motor that drives the shaft, and ω is the rate of rotation of the shaft in radians per second.

Also, γ is the specific weight of the fluid being pumped (in lbs/ft^3), Q is the fluid discharge (in ft^3/sec, cfs), and h is the head (in ft) developed by the pump. It is given that γ of water is 62.4 lbs/ft^3.

Sample Problem 15.2 A small pump serving as a model has a diameter of 7.4 in. When tested in the laboratory at 3600 rpm, it delivered 3.0 cfs at a head of 125 ft. (*a*) If the efficiency of this model pump is 84%, what is the horsepower input to this pump? (

(*a*) From Eq. (15.2): $P_m = T\omega = \gamma Qh/550\eta$ hp

$$P_m = 62.4(3)125/[550(0.84)] = 50.6 \text{ hp} \qquad \textbf{\textit{ANS}}$$

[1] This is part of a chapter in the book **Fluid Mechanics With Engineering Applications,** J. Finnemore and J. Franzini, McGraw Hill, 2002, 790 pages.