out of the runner possesses a large amount of kinetic energy and the pressure at the runner outlet is less than the atmospheric pressure. This kinetic energy of water is converted into potential energy by allowing it to flow through a gradually diverging tube called draft tube.

The draft tube employed in reaction turbines have different shapes and a few of them have been illustrated in Fig. 14.

5.14 PUMPS

The hydraulic machines which convert the mechanical energy into hydraulic energy are called pumps.

Pump is a mechanical device which is used to increase the pressure of a liquid. It is also used for raising fluid from a lower level to a higher level. Pump is used to increase the pressure energy of a liquid. The pressure energy is increased by creating a region of low pressure (usually lower than the atmospheric pressure) near the inlet of the pump and a higher pressure at the outlet of the pump. Due to this low inlet pressure, the liquid rises to the pump from a low level reservoir (sump) and the high pressure created inside the pump forces the liquid out of the pump to be delivered to the reservoir.

5.15 CLASSIFICATION OF PUMP

Pumps can be broadly classified into two categories, i.e.

1. Rotodynamic or dynamic pressure pump.
2. Positive displacement pump.

1. Rotodynamic or dynamic pressure pump

In rotodynamic or dynamic pressure pumps the liquid is subjected to whirling motion by an impeller (a rotating disc having a finite number of blades similar to the runner of a turbine) and gain in the kinetic energy of the liquid is converted into the pressure energy inside the pump.

In these pumps the dynamic pressure is developed to lift the liquids from a lower to a higher level. The basic principle is based on centrifugal force developed during rotation of a liquid by an external force. Since, these pumps perform the lifting of the liquid mainly due to centrifugal force. These are also called as centrifugal pumps.

2. Positive displacement pump

In a positive displacement pumps the liquid is sucked or taken inside the pump and displaced or forced out of the pump under pressure.

The liquid inside a positive displacement pump may be subjected either to a reciprocating motion (a reciprocating pump) or to a rotary/circular motion (gear pump, screw pump etc.)

Rotodynamic pumps (centrifugal pumps) may be classified as:

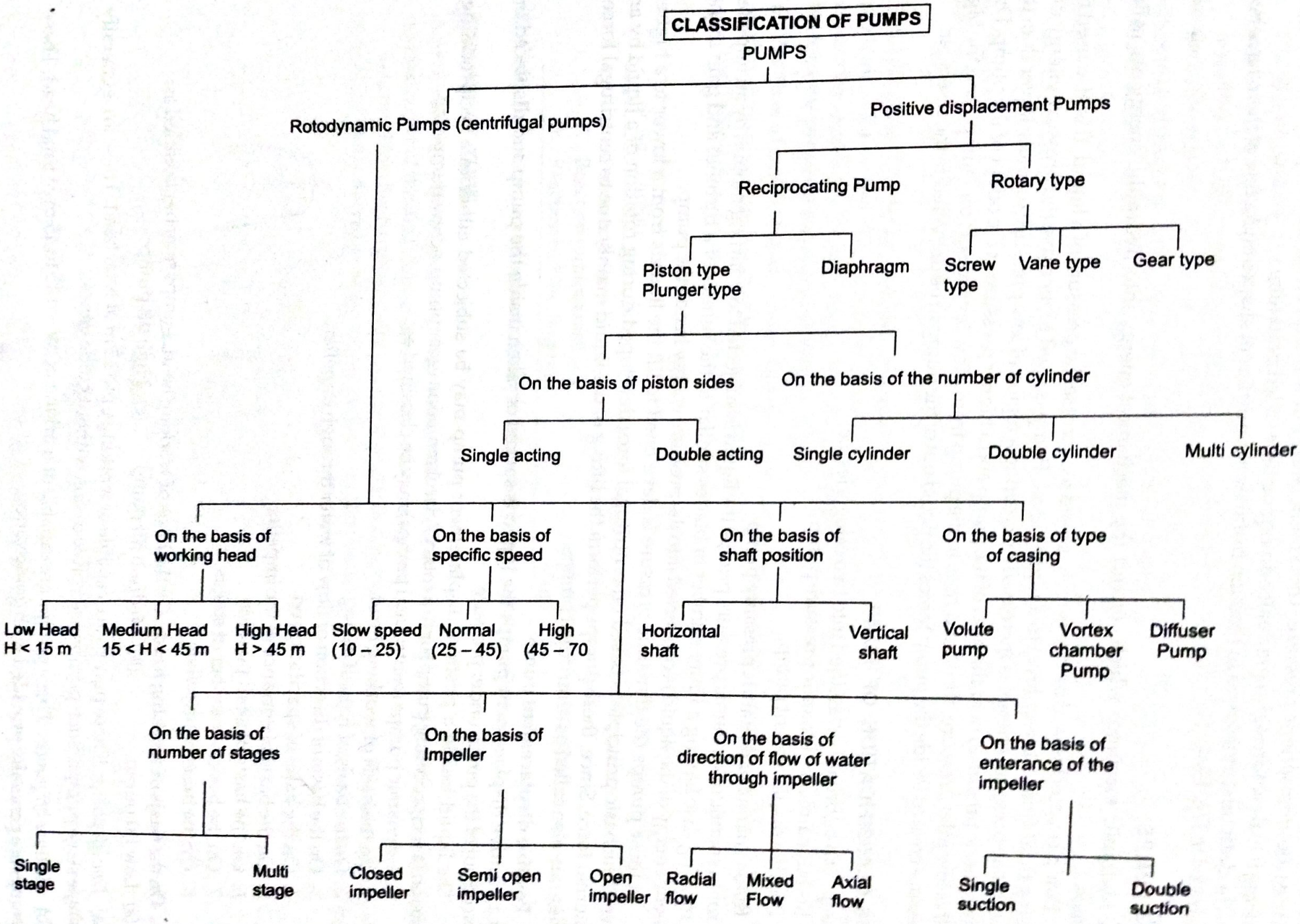
1. On the basis of working head
2. On the basis of type of casing
3. On the basis of direction of flow of water through impeller.
4. On the basis of specific speed
5. On the basis of entrance of the impeller
6. On the basis of shaft position
7. On the basis of number of stages
8. On the basis of Impeller.

1. On the basis of working head: On the basis of working head, pumps may be classified as:

(a) Low lift pump (b) Medium lift pump (c) High lift pump

(a) *Low lift pump*: These pumps are capable of working upto 15 m of total head. These are generally single stage pumps. Such pumps use volute casing without guide vanes.

(b) *Medium lift pump*: These pumps are capable of working between 15 to 45 m of total head. These pumps are generally provided with guide vanes.


CLASSIFICATION OF PUMPS
PUMPS
Rotodynamic Pumps (centrifugal pumps)
Positive displacement Pumps
Reciprocating Pump
Rotary type
Piston type
Plunger type
Diaphragm
Screw type
Vane type
Gear type
On the basis of piston sides
On the basis of the number of cylinder
Single acting
Double acting
Single cylinder
Double cylinder
Multi cylinder
On the basis of working head
On the basis of specific speed
On the basis of shaft position
On the basis of type of casing
Low Head H < 15 m
Medium Head 15 < H < 45 m
High Head H > 45 m
Slow speed (10 – 25)
Normal (25 – 45)
High (45 – 70
Horizontal shaft
Vertical shaft
Volute pump
Vortex chamber Pump
Diffuser Pump
On the basis of number of stages
On the basis of Impeller
On the basis of direction of flow of water through impeller
On the basis of enterance of the impeller
Single stage
Multi stage
Closed impeller
Semi open impeller
Open impeller
Radial flow
Mixed Flow
Axial flow
Single suction
Double suction

(c) *High lift pump*: These pumps are capable of working above 45 m of total head. These pumps are generally multistage pumps with guide vanes.

2. On the basis of type of casing: On the basis of type of casing, pump may be classified as:
(a) Volute chamber pump (b) Vortex chamber pump (c) Diffuser pump

(a) *Volute chamber pump:* It has a spiral form and its cross-sectional area uniformly increases from the tongue to the delivery pipe. The increasing cross-sectional area is provided to accommodate more and more quantity of water coming out of the impeller vanes, so that the mean velocity of flow at any cross-section is the same. The casing has to be properly designed so that there is no loss of head due to change in velocity. A volute casing is shown in Fig. 15.

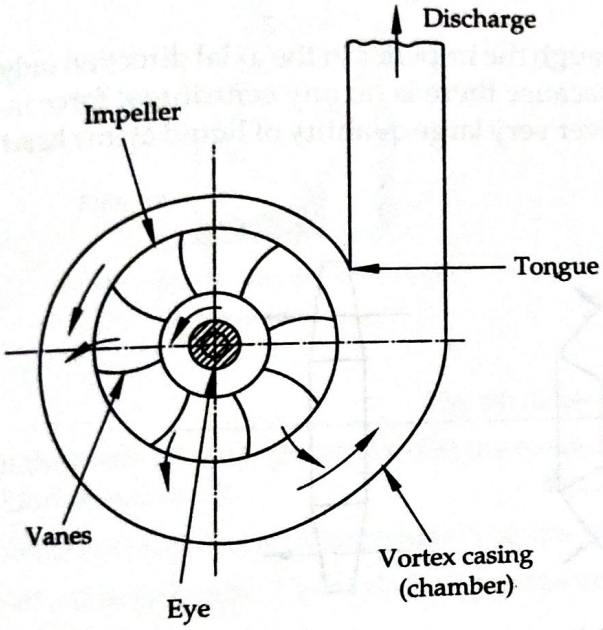


Fig. 15 Volute casing

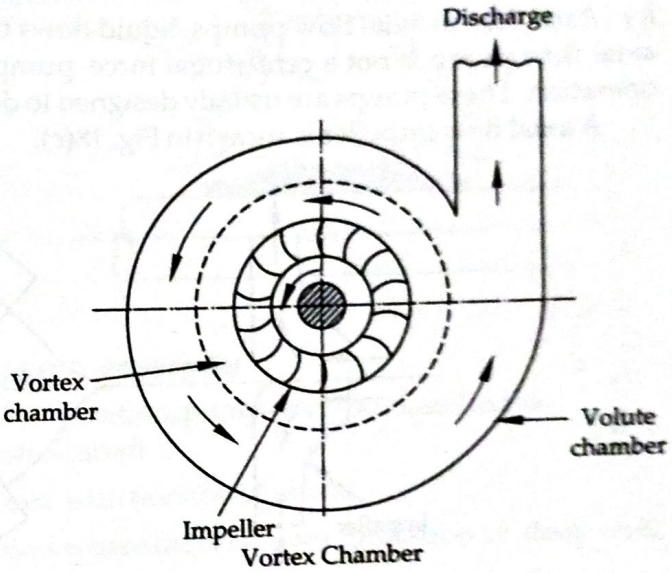


Fig. 16 Vortex chamber

(b) *Vortex chamber pump*: It is a pump of vortex chamber with volute casing. Vortex or whirlpool chamber means Annular space is provided between the volute and Impeller. This arrangement reduces the formation of eddies and gives the improved performance. A vertex chamber is shown in Fig. 16.

(c) *Diffuser pump*: In a diffuser pump, guide vanes are provided at the outlet of impeller vanes. The water coming out of the impeller vanes flows through the guide vanes, its velocity decreases and pressure energy increases. The guide vane angle at inlet coincides with the direction of absolute velocity at the impeller outlet.

A collecting volute of uniform or varying cross-sectional area is provided outside the guide vanes. Guide vanes provide better guidance to flow, eddy losses are reduced which increase the efficiency.

A diffuser pump is shown in Fig. 17.

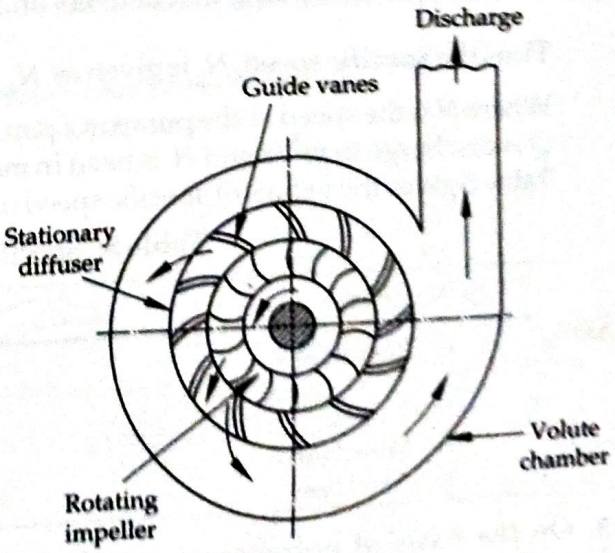


Fig. 17 Diffuser pump

3. On the basis of direction of flow of water through impeller: On the basis of direction of flow of water, pumps may be classified as:

(a)Radial flow (b) Mixed flow (c) Axial flow

(a) *Radial flow*: In radial flow pump, liquid flows through the impeller is in the radial direction only.

This type of pump is most suitable for high head and low discharge. Ordinarily all the centrifugal pumps are manufactured with radial flow impeller. A radial flow impeller is shown in Fig. 18(a).

(b) *Mixed flow*: In mixed flow pump, liquid flows through the impeller axially as well as radially that is there is a combination of radial and axial flows. These pumps are most suitable for irrigation purpose where a medium quantity of water is required at a medium head. A mixed flow impeller is shown in Fig. 18(b)

(c) *Axial flow*: In axial flow pumps, liquid flows through the impeller in the axial direction only. The axial flow pump is not a centrifugal force pump because there is no any centrifugal force in their operation. These pumps are usually designed to deliver very large quantity of liquid at low head.

A axial flow impeller is shown in Fig. 18(c).

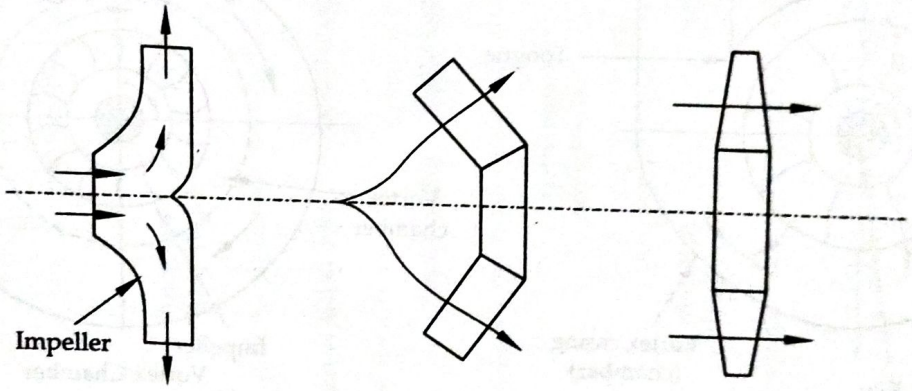


Fig. 18 Different impeller shapes

4. On the basis of specific speed: The specific speed of a pump is defined as the speed of a geometrically similar pump that delivers units discharge under units head.

Thus the specific speed, N_s is given as $N_s = \frac{N\sqrt{Q}}{H^{3/4}}$

Where N is the speed of the pump in r.p.m.

Q is discharge in m^3/s and H is head in metres.

Table 5 gives the values of specific speed of different types of pump.

Table 5: Specific speed of centrifugal pump

Sr No.	*Pump*	*Speed*	*Specific speed*
1.	Radial flow	Slow	10 – 30
		Medium	30 – 50
		High	50 – 80
2.	Mixed flow		80 – 160
3.	Axial flow		160 – 425

5. On the basis of entrance of Impeller: On the basis of entrance of impeller pumps may be classified as:

(a) Single suction pump (b) Double suction pump

(a) *Single suction pump*: Pumps which have suction pipe only on one side of the impeller are called single suction pump. It is shown in Fig. 19(a).

(b) *Double suction pump*: In double suction pumps, the suction is made from both sides of the impeller. It is shown in Fig. 19(b). The double suction pumps are suitable for pumping large quantities of liquid and have the added advantages that there is no axial thrust.

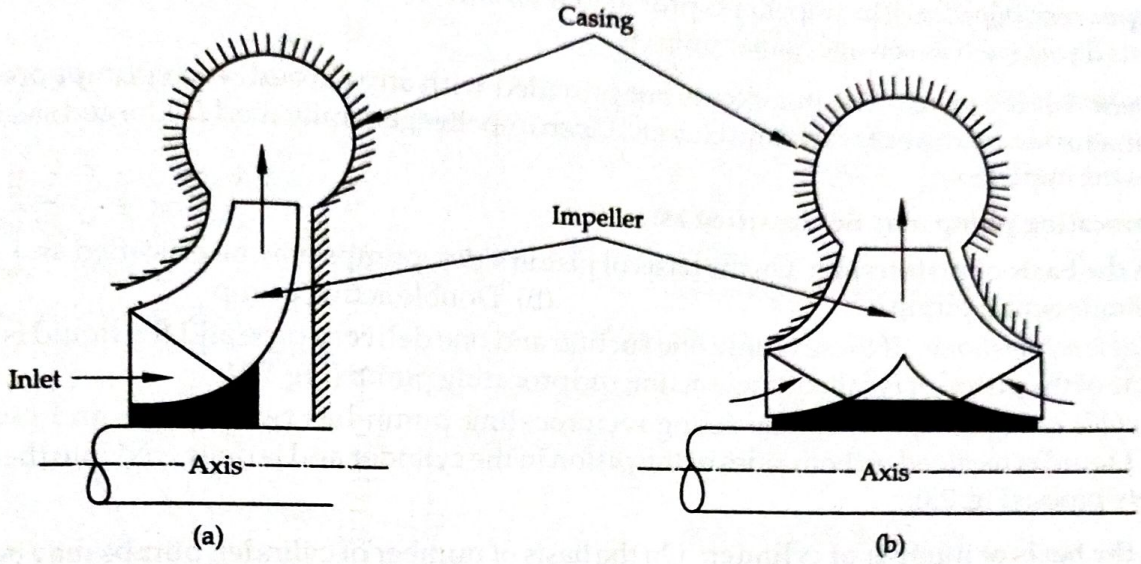


Fig. 19 Single and double entry impeller

6. On the basis of shaft position: On the basis of shaft position, pumps may be classified as:
(a) Horizontal shaft (b) Vertical shaft

(a) *Horizontal shaft Pump*: Centrifugal pumps are used with horizontal shafts.

(b) *Vertical shaft Pump*: Vertical shaft pumps are used where there is space limitation *i.e.* deep well, mines etc.

7. On the basis of number of stages: On the basis of number of stages, pumps may be classified as:
(a) Single stage pump (b) Multistage pump

(a) *Single stage pump*: It has one impeller keyed to the shaft.

(b) *Multistage pump*: It has two or more impellers keyed to a single shaft enclosed in the same casing. Pressure is built up in steps.

8. On the basis of impeller: On the basis of impeller, pumps may be classified as:
(a) Closed impeller (b) Semi-open impeller (c) Open impeller

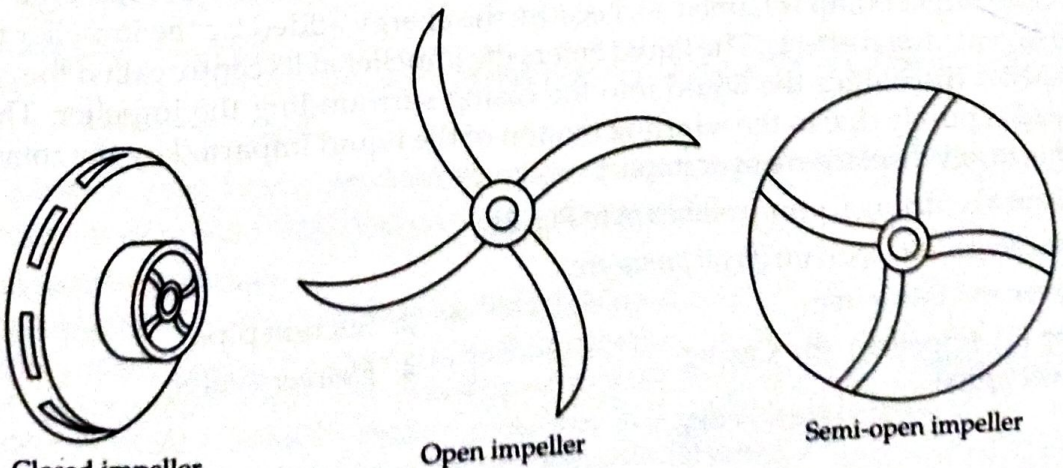


Fig. 20

(a) *Closed impeller*: An ordinary centrifugal pump is equipped with a closed impeller in which the vanes are covered with shrouds (covere) on both sides. This type is meant to handle non-viscous liquid such as ordinary water, hot water, hot oils and chemicals like acid etc. The material of the impeller should be selected according to the chemical properties of liquid used. For hot water at temperature exceeding 150°C Cast steel impeller is recommended.

(b) *Semi-open impeller*: The impeller is provided with shroud on one side only. This pump is used for viscous liquid such as sewage, paper pulp etc.

(c) *Open impeller pump*: The impeller is not provided with any shroud, such pumps are used in to handle slurries, mixture of water and clay etc. Open impeller generally made of forged steel. Figure 20 shows the impellers.

Reciprocating pump may be classified as:

1. On the basis of piston side: On the basis of piston sides, pumps may be classified as:
(a) Single acting pump (b) Double acting pump

(a) *Single acting pump*: If these is only one suction and one delivery pipe and the liquid is filled only one side of the piston, it is called single acting reciprocating pump (Fig. 22).

(b) *Double acting pump*: A double acting reciprocating pump has two suction and two delivery pipes. Liquid is received on both sides of the piston in the cylinder and is delivered into the respective delivery pipes. (Fig. 23).

2. On the basis of number of cylinder: On the basis of number of cylinder, pumps may be classified as:
(a) Single cylinder pump (b) Double cylinder pump
(c) Multi-cylinder pump

(a) *Single cylinder pump*: A reciprocating pump having only one cylinder is known as single cylinder pump. It may be either single acting or double acting pump.

(b) *Double cylinder pump*: A double cylinder pump consists of two cylinders connected to the same shaft. Each cylinder has its own suction and delivery pipes. Each piston is connected by cranks which are set at 180° to each other. Thus, when there is suction stroke in one pump in the other it is delivery stroke. So liquid is delivered to the delivery pipe during each stroke of the piston.

(c) *Multi-cylinder pump*: Pumps having more than one cylinder are known as multi-cylinder pumps.

5.16 CENTRIFUGAL PUMP

A centrifugal pump is a rotodynamic or dynamic pressure pump where the working fluid or liquid is subjected to whirling motion by means of backward curved blades mounted on a wheel called *impeller*. A centrifugal pump is named so, because the energy added by the impeller to the fluid is largely due to centrifugal effects. The liquid enters the impeller at its centre called the *eye of the pump* and the impeller discharges the liquid into the casing surrounding the impeller. The developed pressure head is purely due to the whirling motion of the liquid imparted by the rotating impeller and is not due to any displace-ment or impact.

A layout of a centrifugal pump is shown in Fig. 21.

The main components of a centrifugal pump are:

1. Strainer and foot valve
2. Suction pipe
3. Pump (a) Impeller (b) Casing
4. Delivery valve
5. Delivery pipe