9
Chapter

PUMPS

9.1 INTRODUCTION

Pump is a mechanical device to increase the pressure energy of a liquid. In most of the cases, a pump is used for raising fluids from a lower to a higher level. This is achieved by creating a low pressure at inlet or suction end and high pressure at the outlet or delivery end of the pump. Due to the low inlet pressure the fluid rises from a depth where it is available and the high outlet pressure forces it up to a height where it is required. Work has to be done by a prime-mover on the pump to enable it to impact energy to the fluid.

9.2 CLASSIFICATION OF PUMPS

The pumps may be classified as shown in Fig. 9.1.

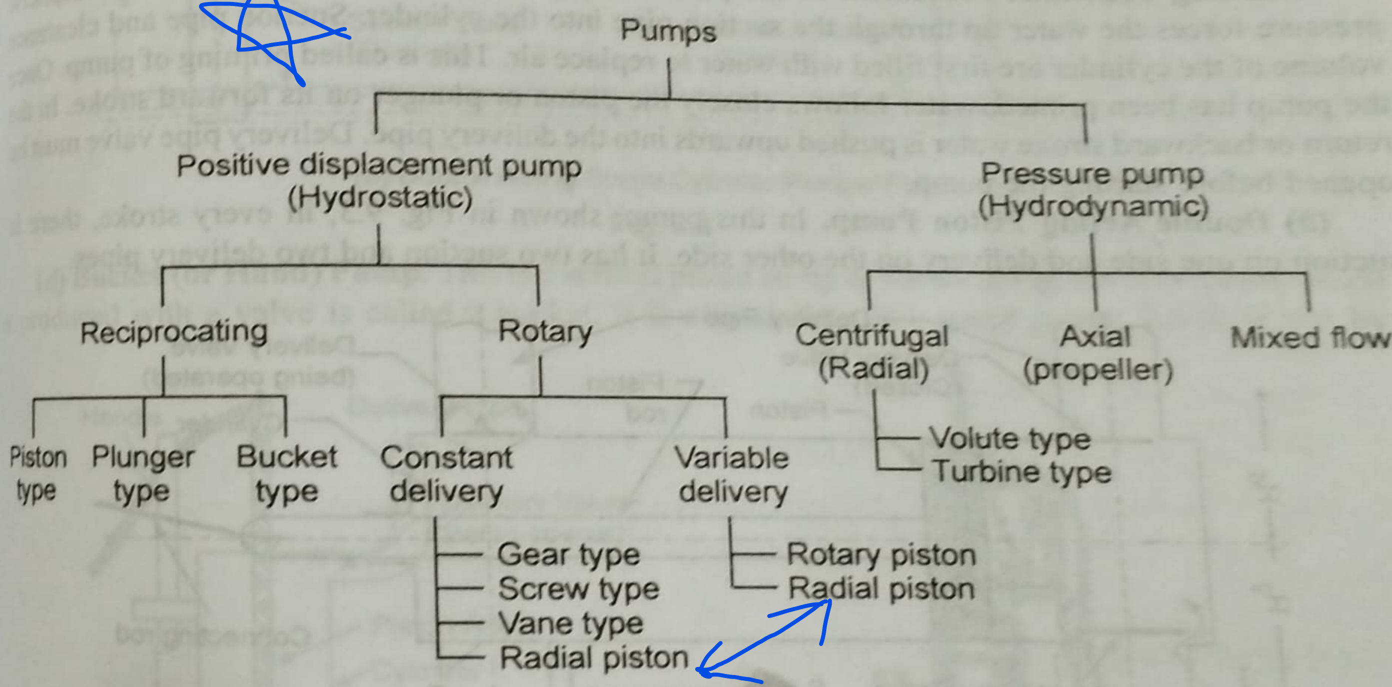


Fig. 9.1 Classification of pumps

9.3 RECIPROCATING PUMPS

(a) Single Acting Piston Pump. A reciprocating pump shown in Fig. 9.2 consists primarily of a piston or a plunger reciprocating inside a close fitting cylinder, thus performing the suction and delivery strokes. It is a positive acting type which means that it is a displacement pump which creates lift and pressure by displacing liquid with a moving member or piston. The chamber or cylinder is alternately filled and emptied by forcing and drawing the liquid by mechanical motion. This type is called the positive displacement pump. Suction and delivery pipes are connected to the cylinder. Both the pipes are provided with non-return values which ensure unidirectional flow of liquid. Volume of fluid delivered is constant regardless of pressure, and is varied only by speed changes. They operate at small speeds. They are used generally for pneumatic pressure systems, feeding small boilers condensate return and light oil pumping.

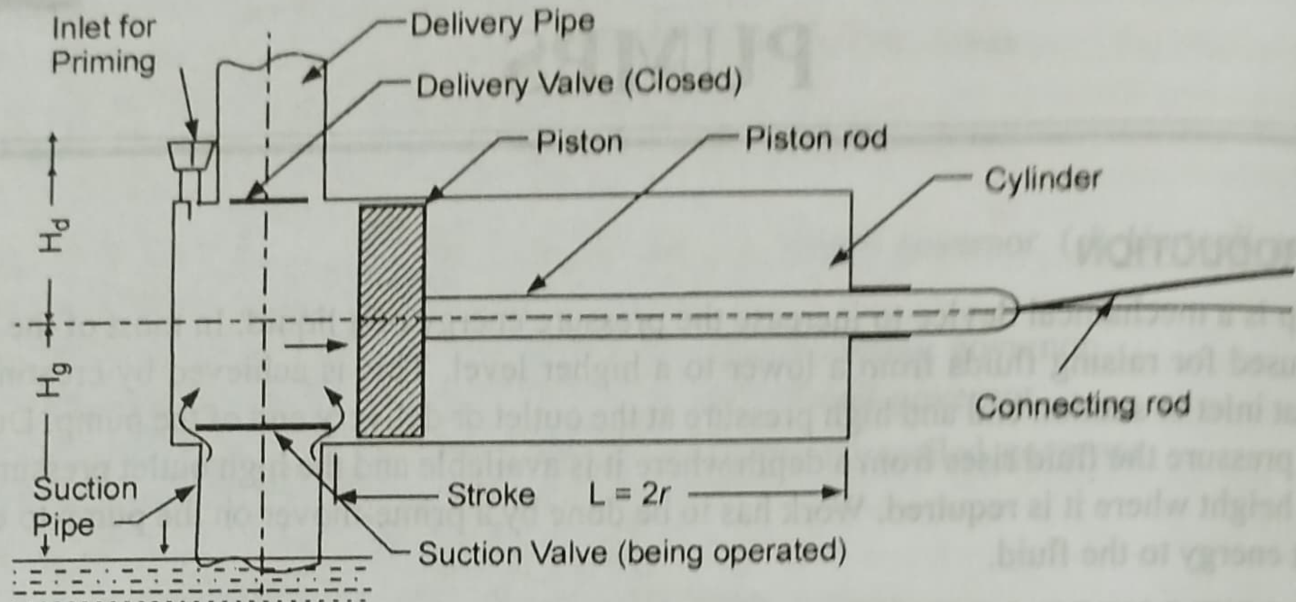


Fig. 9.2 Reciprocating Single Acting Piston Pump

Working Principle. Movement of the piston or plunger creates a vacuum and atmospheric pressure forces the water up through the suction pipe into the cylinder. Suction pipe and clearance volume of the cylinder are first filled with water to replace air. This is called priming of pump. Once the pump has been primed, water follows closely the piston or plunger on its forward stroke. In the return or backward stroke water is pushed upwards into the delivery pipe. Delivery pipe valve must be opened before starting the pump.

(ii) Double acting pump : (June 2012, Dec. 2013)

- In double acting reciprocating pump, liquid acts on both side of the piston. In this pump, suction and delivery strokes occur simultaneously.
- Fig. 8.4 shows double acting pump. When the piston moves towards the right side of the cylinder, the liquid is sucked from sump through suction valve S_1. Simultaneously, built up of high pressure on the right side of the piston opens the delivery valve D_2 and the liquid is pumped in to the discharge tank till the end of the stroke. When piston moves towards the left side of the cylinder, the liquid is sucked through suction valve S_2 and simultaneously delivered to the discharge tank through delivery valve D_1 till the end of the stroke. Double acting pump gives more uniform discharge compared to single acting pump.

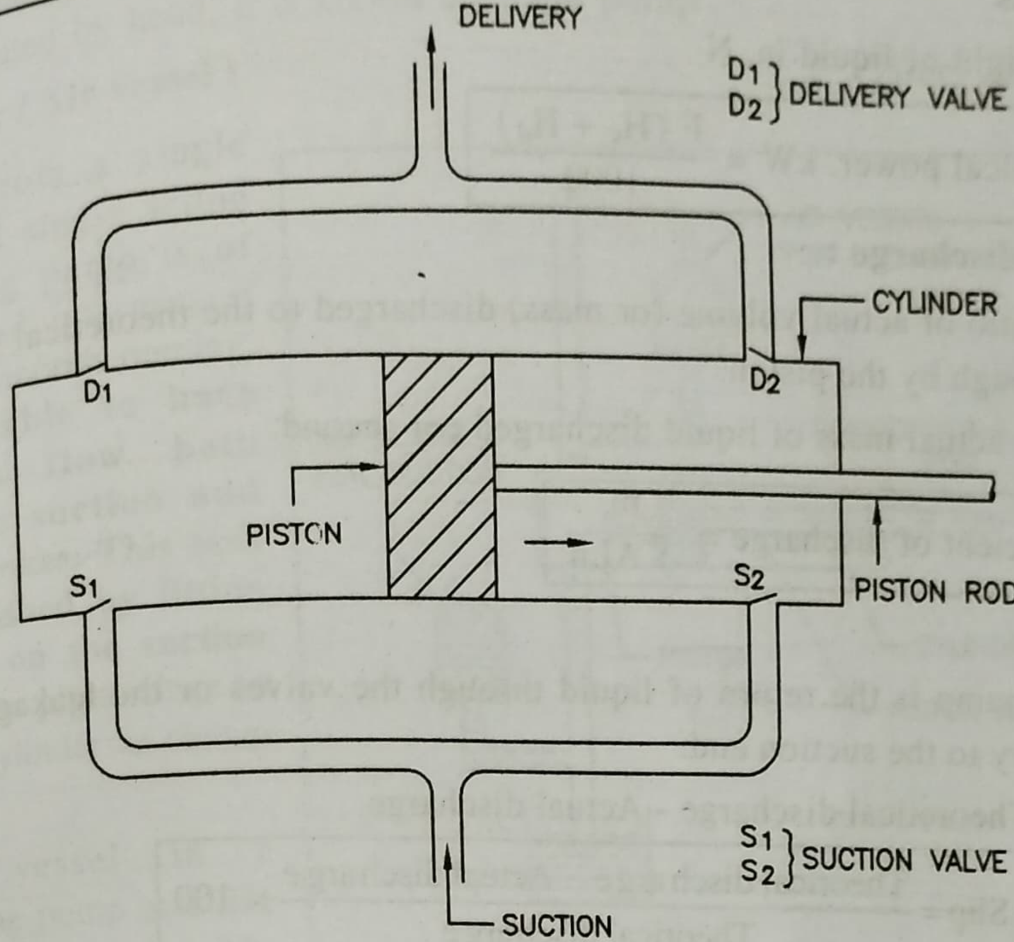


FIG. 8.4 DOUBLE ACTING RECIPROCATING PUMP

9.6 CENTRIFUGAL PUMP

A centrifugal pump is a device to raise liquids from a lower to a higher level by creating the required pressure with the help of centrifugal action. In general, it can be defined as a machine which increases the pressure energy of a fluid. Whirling motion is imparted to the liquid by means of backward curved blades mounted on a wheel known as the impeller. Liquid enters the impeller at the eye of the pump and discharges into the casing surrounding the impeller, as shown in Fig. 9.8. The pressure head developed by centrifugal action is entirely due to the velocity imparted to the liquid by the rotating impeller.

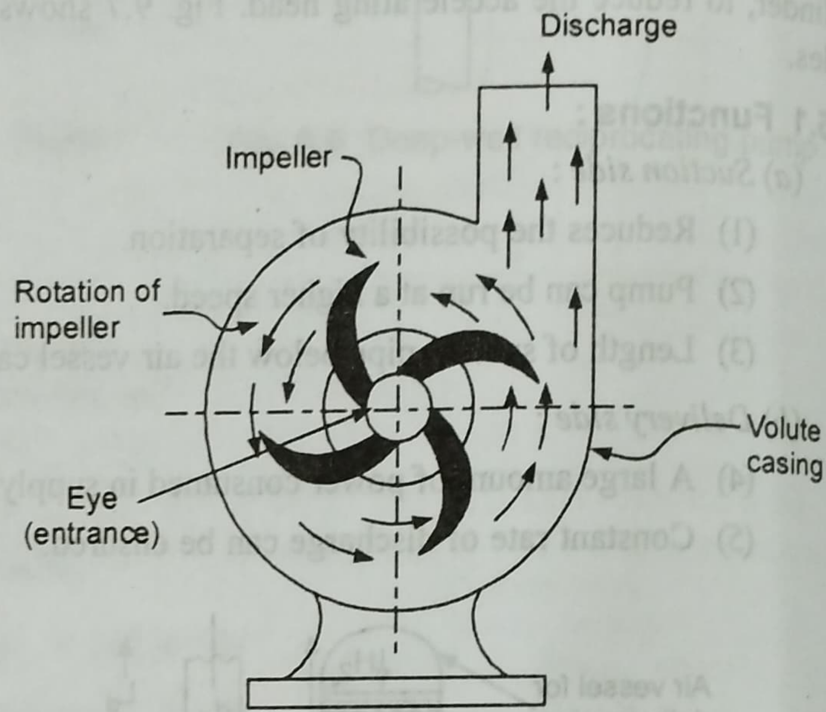


Fig. 9.8 Principle of centrifugal pump

9.6.1 Principle of Operation

First of all priming of the pump is carried out. The power source is switched on and the revolution of the pump impeller inside the casing full of water produces a forced vortex which is responsible for imparting a centrifugal head to water. Rotation of impeller effects a reduction of pressure at the centre. This causes the water in the suction pipe to rush into the eye.

9.6.2 Classification of Centrifugal Pumps

The centrifugal pumps may be classified based on the following characteristic features :

1. Working head.
2. Type of casing.
3. Number of impellers per shaft.
4. Relative direction of flow through impeller.
5. Number of entrances to impeller.

5. Disposition of shaft.
7. Liquid handled.
8. Specific speed.

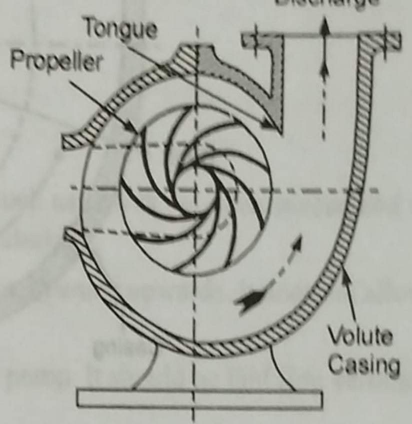
1. Working head

Low lift : upto 15 m.
Medium lift : upto 40 m.
High lift : above 40 m.

2. Type of Casing

The casings are of two types : Volute and turbine or diffusion type.

(*a*) **Volute Pump.** A volute casing type of pump is shown in Fig. 9.9(*a*). It has a volute casing into which the impeller discharges water at a high velocity. Volute is of a spiral form and the cross-sectional area of the moving stream gradually increases from the tongue towards the delivery pipe. The cross-sectional area at any point is therefore proportional to the quantity of water flowing across that section and therefore the mean velocity remains constant. This eliminates the possibility of loss of kinetic head.



(*a*) Volute Pump

The functions of volute casing are :

(*i*) To collect water from the periphery of impeller and to transmit it to the delivery pipe at a constant velocity.

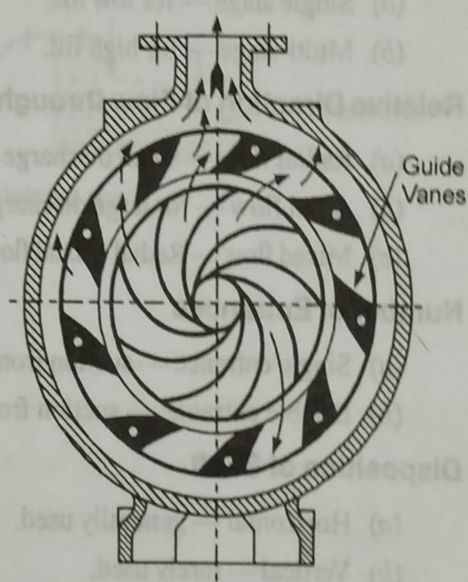
(*ii*) To eliminate the loss of velocity head.

(*iii*) To increase the efficiency of the pump by eliminating loss of velocity head.

(*b*) **Turbine or Diffusion Pump.** This pump as shown in Fig. 9.9(*b*) consists of an impeller surrounded by a guide wheel consisting of a number of stationary vanes or diffusers. The diffusers provide outlets with cross-section gradually enlarging towards the periphery. Water emerging from the impeller flows past the guide vanes and as the area across flow increases, velocity decreases and pressure increases.

Diffusion pumps may be either horizontal or vertical shaft type. They are used in narrow wells and mines etc.

(*c*) **Vortex Casing.** The vortex or whirlpool chamber type casing is shown in Fig. 9.9(*c*). This is an improved type of volute chamber where an annular space is provided between the volute and impeller forming a combination of spiral and circular chamber. This arrangement reduces prices to a considerable extent and improves the performance of the pump.



(*b*) Turbine Pump or Diffusion Pump

9.6.4 Submersible Pump

In a submersible pump, the pump and the electric motor are placed below the water surface of a well. Delivery of water to the surface is through a vertical pipe on which the assembly is suspended. An advantage of the submersible pump is the elimination of the long drive shaft from the ground surface to the pump. This helps in reducing bearing friction and provides an unobstructed pipe for delivery of water to the surface.

9.6.5 Important Terms and Formulae in Centrifugal Pump

Suction head, H_s — It is the vertical height of the centre line of pump shaft above the surface of liquid from which it is being raised.

Delivery head, H_d — It is the vertical height measured from the centre line of pump shaft to where the liquid is delivered.

Static head, H_{stat} — It is the sum of static and delivery heads.

$$H_{stat} = H_s + H_d$$

Manometric head, H_{mano} — It is the head measured across the pump inlet and outlet flanges. It expresses the increase in pressure energy per unit weight of liquid handled by the impeller.

$$H_{mano} = \frac{p_d - p_s}{\gamma} + h_g$$

$$= (H_{mano})_d - (H_{mano})_s + h_g$$

where h_g = vertical distance between the pressure tappings for the suction and delivery gauges.

Total, Gross or Effective head, H — This is the actual head against which the pump has to work. It expresses the increase in total energy of the liquid between inlet and outlet.

$$H = H_{mano} + \frac{v_d^2 - v_s^2}{2g}$$

where v_d, v_s = velocity of liquid in delivery and suction pipes respectively.

Power required to drive the pump,

$$P = \frac{\gamma Q H_{mano}}{10^3 \times \eta_{overall}} \text{ kW}$$

where γ = specific weight of liquid handled, N/m^3

Q = discharge, m^3/s

H_{mano} = manometric head, m

$\eta_{overall}$ = overall efficiency of pump

9.7 PRIMING OF PUMP

Priming. Before starting a pump, its impeller and suction pipe have to be filled with water in order to remove any air, gas or vapour from the waterways of the pump. If a centrifugal pump is not primed before starting, air pockets inside the impeller may give rise to vortices and cause discontinuity of flow. The wearing rings may rub and seize causing serious damage if the pump is allowed to run dry. It is also essential that packing be lubricated by liquid leaking past it.

Originally, priming is done by pouring water through a funnel, displaced air being allowed to escape through air vents. When a pump is being primed or stopped, the delivery valve should be kept closed.

Necessity of priming is the main disadvantage of a centrifugal pump. To overcome this difficulty, the following methods are employed in practice :

(*a*) the pump is installed below the suction water level;

(*b*) the pump is equipped with one of the priming or self-priming devices given in the next article.

9.7.1 Priming Devices —

(*a*) *Pouring Water.* Water is poured in the pump through priming funnel. Air vent is opened to provide exit to the air. It is closed after the priming is over.

(*b*) *Connection with City Water Main.* The pump may be connected with the city water main which can be opened to fill the impeller and the suction pipe in order to prime the pump.

(*c*) *Priming Chamber.* In small pumps a priming chamber may be used on the delivery side of the impeller. When the pump is stopped, some water is stored in the tank and this can be used to fill the impeller and suction line before restarting. Normally, the capacity of the tank is about three times the volume of the suction pipe.

(*d*) *Vacuum Producing Devices.* With such devices the suction line and pump are exhausted of all air so that atmospheric pressure at the sump, forces the water up into the pump. An ejector using high pressure water, steam or compressed air is employed to create vacuum at the top of the casing (refer Fig. 9.11) so that water is sucked into the suction pipe and the impeller.

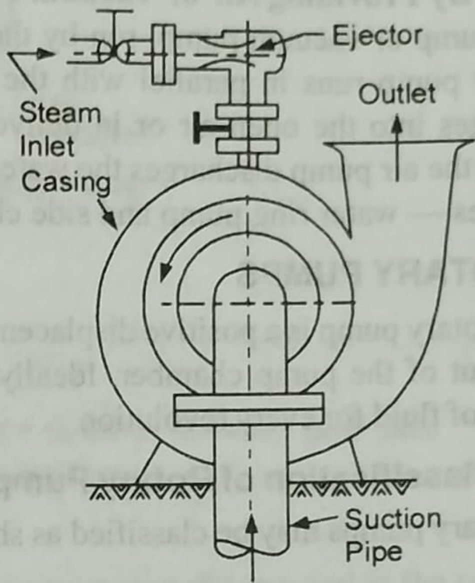


Fig. 9.11 Priming of Centrifugal Pump

9.8 ROTARY PUMPS

A rotary pump is a positive displacement pump with a circular motion. It continuously scoops the liquid out of the pump chamber. Ideally speaking a positive displacement pump delivers a given volume of fluid for every revolution.

9.8.1 Classification of Rotary Pumps

Rotary pumps may be classified as shown in Fig. 9.13.

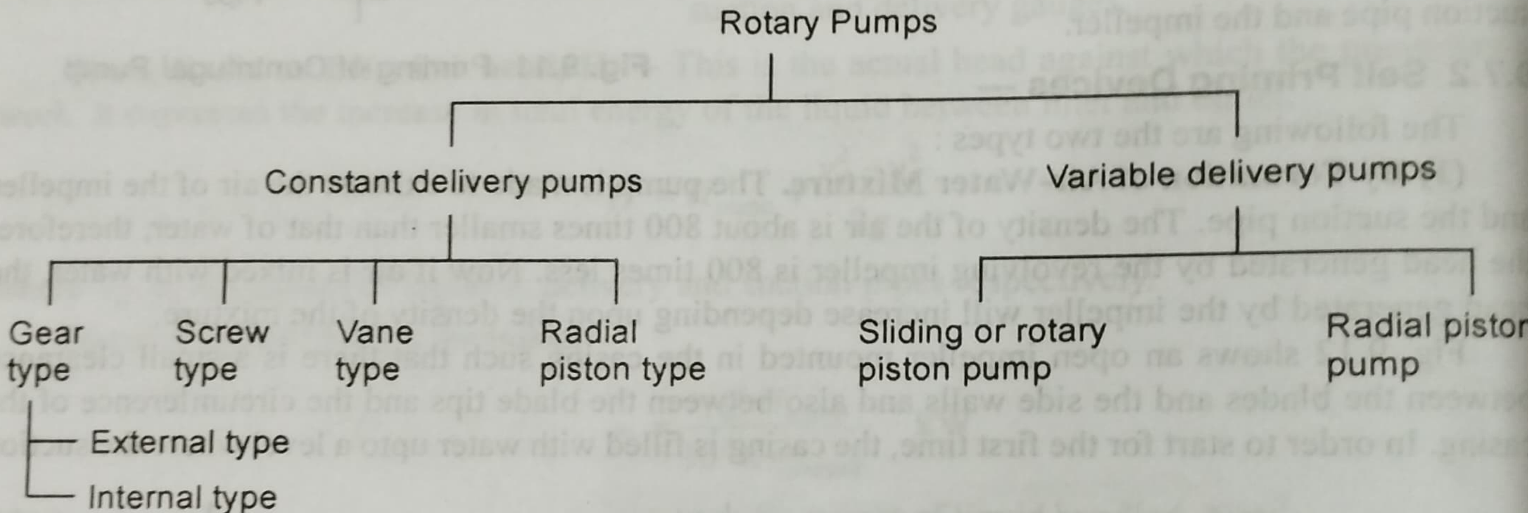


Fig. 9.13 Classification of rotary pumps

Constant delivery pumps give continuous discharge of liquid at a uniform rate of flow whereas variable delivery pumps has a continuous discharge of liquid at rates of flow varied as required. The construction of variable delivery pumps is complex and as such are more costly than constant pumps.