TYPES AND SELECTION OF PUMPS

The mechanical device or arrangement by which water is caused to flow at increased pressure is known as a ***pump*** and the process of using a pump for this purpose is known as ***pumping.*** Irrigation pumps, in general, are driven either by engines or electric motors. Basically, the following four principles are involved in pumping water. Atmospheric pressure, centrifugal force, positive displacement and movement of columns of fluid caused by differences in specific gravity. Pumps are classified on the basis of mechanical principles of operation as

Positive Displacement Pumps

(a) Reciprocating Pump

(b) Rotary Pump

Variable Displacement Pumps

(a) Centrifugal Pump

(b) Turbine Pump

   a. Deep well turbine

   b. Submersible pump

(c) Propeller Pump

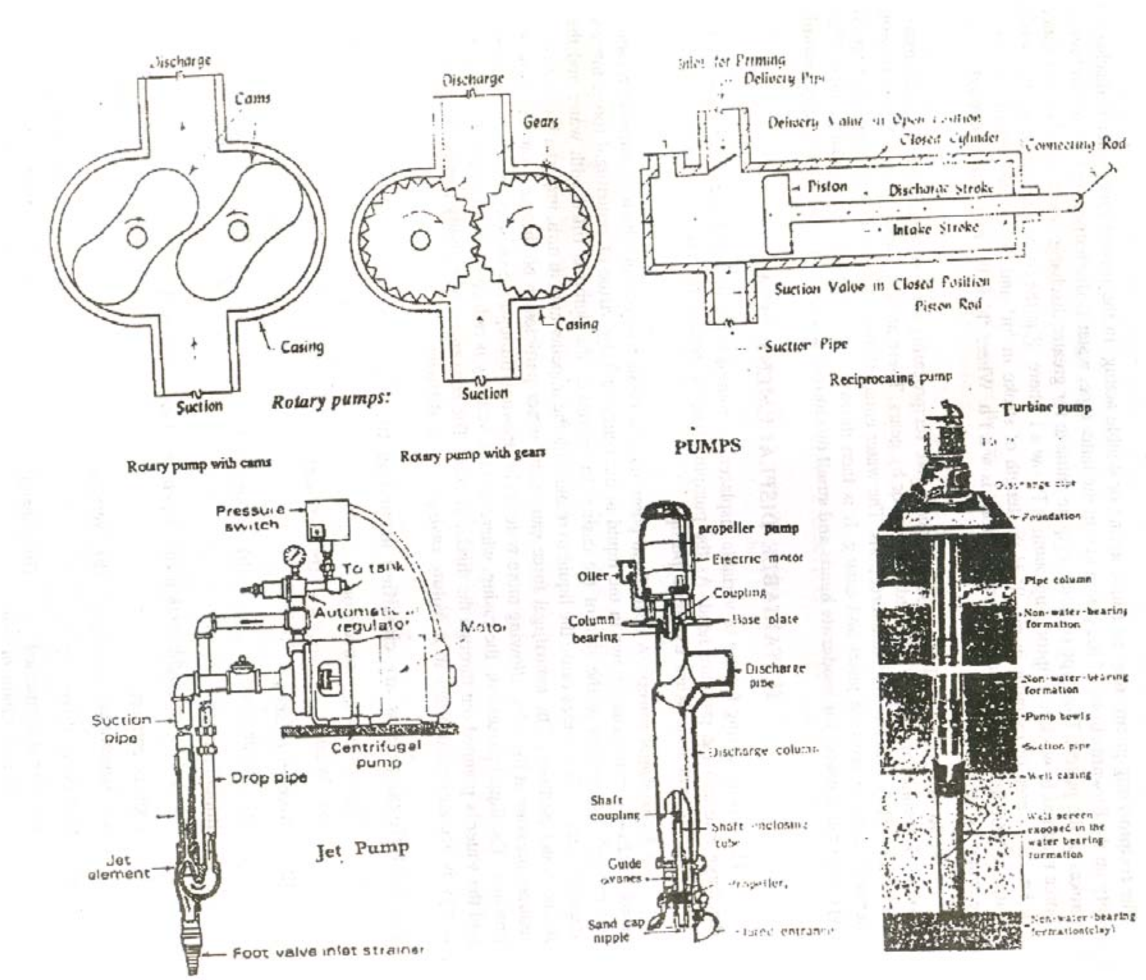
(d) Jet Pump

(e) Air Lift Pump

Positive Displacement Pump

In a positive displacement pump, the fluid is physically displaced by mechanical devices such as the plunger, piston, gears, cams, screws etc. In this type of pump, a vacuum is created in a chamber by some mechanical means and then water is drawn in this chamber. The volume of water thus drawn in the chamber is then shifted or displaced mechanically out of chamber,

(a) ***Reciprocating Pumps:*** In this type of pump, a piston or a plunger moves inside a closed cylinder. On the intake stroke, the suction valve remains open and allows water to come into the cylinder. The delivery valve remains closed during intake stroke. On the discharge stroke, the suction valve is closed and water is forced in delivery pipe through delivery pipe through delivery valve which opens during discharge stroke.



The reciprocating pumps may be single acting or double acting. In the former type water is discharged only on the forward stroke of the piston and in the latter type, water is discharged on forward and return strokes of the piston. This type of pump is quite suitable for greater discharge under high head of water. Force required to work a reciprocating pump is P = w*a*1 where, ‘P’ is the force required to lift the piston in kg, ‘a’ is area of cylinder in m^2, ‘l’ is the length of stroke in m and ‘w’ is the specific weight of water is 1000 kg m^{-3}. Work done in one upstroke is w*a*1*h, where ‘h’ is the total height through which the water is raised, m.

(b) ***Rotary Pumps*:** In this type of pump, the reciprocating motion is substituted by the rotary motion. The rotary motion is achieved by cams or by gears. There are two cams or gears which fit with each other. They rotate in opposite directions. The water enters through the suction pipe and it is trapped between cams or teeth of gears and casing. It is then thrown with force into the discharge pipe. This type of pump is useful for moderate heads and small discharges not greater than 40 litres per second.

Variable Displacement Pump

The distinguishing feature of variable displacement pumps is the inverse relationship between the discharge rate and the pressure head. As the pumping head increases, the rate of pumping decreases. They are also termed as ***Roto Dynamic Pumps*.**

(a) ***Centrifugal Pump*:** A centrifugal pump may be defined as one in which an impeller rotating inside a close – fitting case draws in the liquid at the centre and, by virtue of centrifugal force, throws out through an opening at the side of the casing. In operation, the pump is filled with water and the impeller rotated. The blades cause the liquid to rotate with the impeller and, in turn, import a high velocity to the water particles. The centrifugal force causes the water particles to be thrown from the impeller reduces pressure at the inlet, allowing more water to be drawn in through the suction pipe by atmospheric pressure. The liquid passes into the casing, where its high velocity is reduced and converted into pressure and the water is pumped out through the discharge pipe. The conversion of velocity energy into pressure energy is accomplished either in a ***Volute casing* or in a *Diffuser*.**

The centrifugal pumps are classified according to

1. Type of energy conversion:

(a) Volute	(b) Diffuser	

2. Number of stages

(a) Single stage	(b) Multi stage	

3. Impeller types

(a) Single or double action	(b) Open, semi-open or closed	

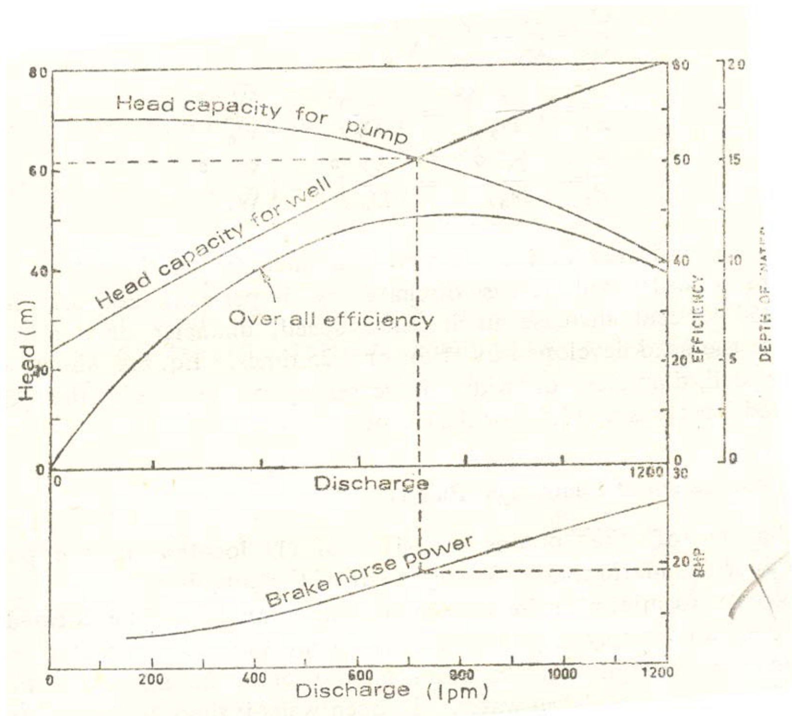
4. Axis of rotation

(a) Horizontal	(b) Vertical	

5. Method of drive

(a) Direct connected	(b) Geared	(c) Belt or chain driven

Selection of centrifugal pumps are based on the characteristic curves namely (1) ***Head capacity curve*** which shows how much water a given pump will deliver with a given head at one particular speed. (2) ***Overall efficiency curve*** represents the relationship between the efficiency of the pump and the discharge for different speeds and (3) ***Break-Horse Power curve*** gives the relation between the discharge, speed and horse power. In case a centrifugal pump has to be selected for pumping from an open water source, the total head has to be calculated for selecting the suitable pump. In case of wells, the head capacity curve of the well is matched with the pump head-efficiency-horse power curves and the pump is selected.



Priming: While positive displacement pumps, especially piston pumps, can move and compress all fluids, including air, centrifugal pumps are very limited in their capacity to do so. Hence they are to be primed, or filled with water upto the top of the pump casing to initiate pumping priming is done by using (i) a foot valve to hold the water in the pump (ii) an auxiliary piston pump to fill the pump (iii) connection to an outside source of water under pressure for filling the pumps and (iv) use of a self priming construction.

Common troubles and their remedies for a centrifugal pump are as follows:

1. ***Pump fails to deliver water:*** (i) Air leak in suction line, mainly in threaded connections are to be located with white lead (ii) Gaskets admitting air should be tightened (iii) Defective foot valve should be checked for its flap and replaced.

2. ***Pump fails to develop sufficient pressure or capacity:*** (i) Pump speed should be checked and corrected (ii) Suction line and foot valve clogging to be checked (iii) Check the suction lift (iv) Check for worn out impeller.

3. ***Pump takes for much power:*** (i) Speed may be high (ii) Head may be lower and pumping too much water (iii) Mechanical defects in installation.

4. ***Pump leaks excessively at the stuffing box:*** (i) Worn out packing or incorrectly inserted packing (ii) Worn out shaft to be renewed.

5. ***Pump is noisy:*** (i) Too high suction lift (ii) Mechanical defects such as bent shaft, broken bearing etc.

(b) **Turbine Pumps:** Turbine pumps consist of impellers placed below the water level and are driven by a vertical shaft rotated by an engine or motor placed at the ground level or under the water.

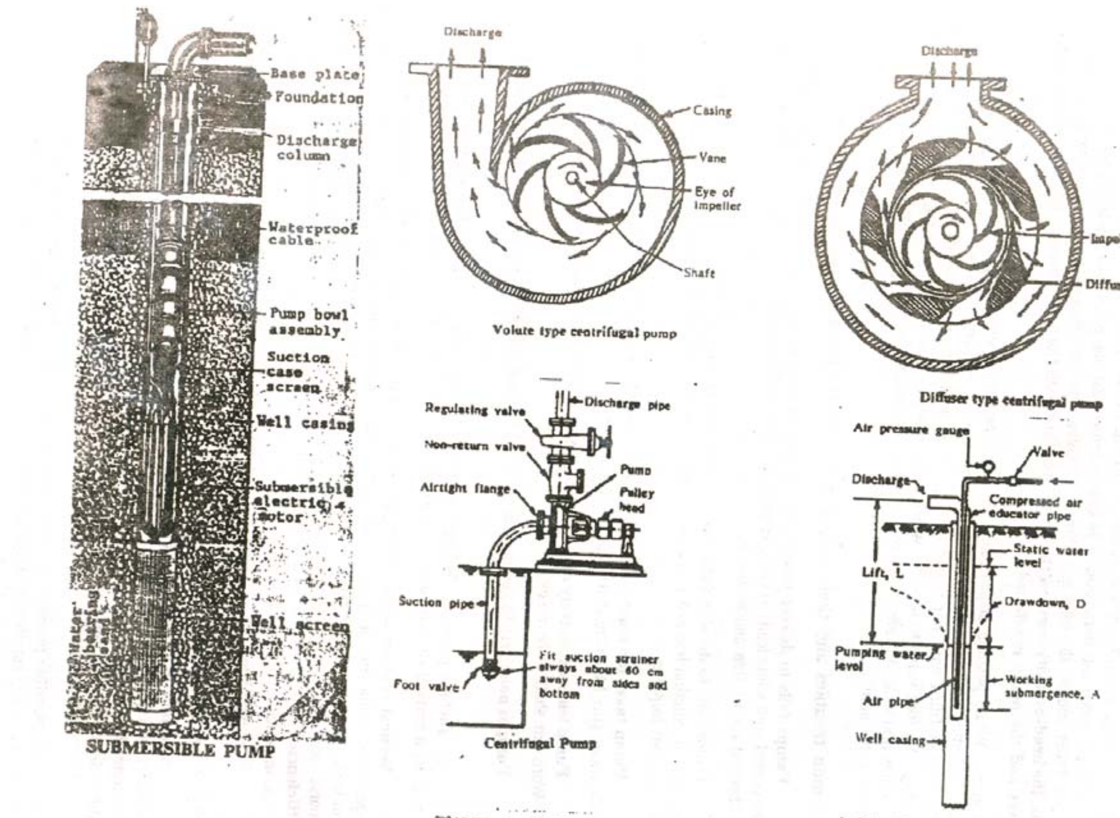
1. ***Vertical Turbine Pump (or) Deep well Turbine Pump:*** is a vertical axis centrifugal or mixed flow type pump comprising of stages which accommodate rotating impellers and stationary bowls possessing guide vanes with the motor fixed on the ground level. The pump bowl is surrounded by a screen to keep coarse sand and gravel away from entering the pump. These pumps are adopted to high lifts and high efficiencies under optimum operating conditions. The pressure head developed depends on the diameter of the impeller and the speed at which it is rotated. Since the pressure head developed by a single impeller is not great, additional head is obtained by adding more bowl assemblies or stages. Turbine pumps could be water lubricated or oil lubricated. It is preferable to use oil lubricated pumps for wells giving fine sand along with water.

Selection of Turbine Pumps: Characteristics curves giving the relationship among the head capacity, efficiency, horse power and speed are available for turbine pumps also. For turbine pump selection accurate data about the well is essential. Besides the head capacity curve of the well, the seasonal fluctuations of water table should also be known so that the pump bowls are installed such that they are always under water.

2. ***Submersible Pump*** is a turbine pump coupled to a submersible electric motor. A cable passing through the water supplies power to the motor. Both the pump and the motor are suspended and operate under the water, pumping water through the discharge column. The pump eliminates the long shaft and bearings that are necessary for a vertical turbine pump. Submersible pumps are cheaper than the vertical turbine pumps. Suitable for deep settings and also for crooked wells which are not perfectly vertical. The installation of the pup is easy and the initial cost of installation low. The repair of the submersible pumps, when they go out of order is not easy and require technical skill. Submersible pump requires little maintenance, after 6000 hours of operation or two years of service life, it may be necessary to with draw the pump from the bore hole and overhaul it. Selection of the submersible pump is mainly depending upon the bore well size, type, well discharge etc.

3. ***Propeller Pumps:*** The principal parts of the propeller pumps and method of operation are similar to the turbine pumps. The main difference is in design of the impellers, which give high discharges at low heads. Two types of impellers *i.e.* axial flow type and mixed flow type are used in this pump. In single stage pumps only one impeller is used and in multistage pumps more than one impeller is used. The selection of a propeller pump is done based on the characteristic curves compared with the well discharge and head.

4. ***Jet Pumps:*** Consist of a combination of a centrifugal pump and a jet mechanism or ejector. Jet pump is used when the suction lift of the centrifugal pump exceeds the permissible limits. A portion of the water from the centrifugal pump is passed through the drop pipe to the nozzle of the jet assembly. This water is forced through the throat opening of the diffuser, creating a vacuum which causes water to be drawn from the well. The water mixed with the boost water is carried up through the diffuser where the high velocity energy is converted into useful pressure energy, forcing the water up through the delivery pipe to the centrifugal pump.



TYPES OF PUMPS

Principles of operation of an air-lift pump

5. ***Air-lift Pump*** operates by the injection of compressed air directly into the water inside a discharge or eductor pipe at a point below the water level in the well. The injection of the air results in a mixture of air bubbles and water. This composite fluid is lighter in weight than water so that the heavier column of water around the pipe displaces the lighter mixture facing it upward and out of the discharge pipe. The piping assembly consists of a vertical discharge pipe called the eductor pipe – and a smaller air pipe. Air-lift pumping is extensively used in the development and preliminary testing and cleaning of tube wells. The advantages of air-lift pumps are simplicity, tube well need not be perfectly straight or vertical, and impure water will not damage the pump. The main disadvantage is its low efficiency about 30 per cent.

Specific Speed of a pump may be defined as the speed of a geometrically similar pump when delivering one $m^3\ s^{-1}$ of water against a total head on one metre. The value of specific speed is useful in comparing the performance of different pumps.

Specific Speed (rpm), $n_s = \dfrac{n * Q^{1/2}}{H^{3/4}}$

where, n = Pump speed (rpm); Q = Pump discharge ($m^3 s^{-1}$); H = Total head (m).

POWER REQUIREMENTS FOR PUMPING

1. ***Water Horse Power (WHP)*** is the theoretical horse power required for pumping.

$$\text{WHP} = \frac{\text{Discharge (litres sec}^{-1}) * \text{Total head (m)}}{75}$$

2. ***Shaft Horse Power*** is the power required at the pump shaft.

$$\text{Shaft Horse Power} = \frac{\text{Water Horse Power}}{\text{Pump Efficiency}}$$

3. ***Pump Efficiency*** = $\dfrac{\text{Water Horse Power}}{\text{Shaft Horse Power}} * 100$

4. ***Brake Horse Power (BHP)*** is the actual horse power required to be supplied by the engine or electric motor for driving the pump.

(i) For direct driven pump, BHP = Shaft Horse Power

(ii) With belt or indirect drives, BHP = $\dfrac{\text{Water Horse Power}}{\text{Pump Efficiency} * \text{Drive Efficiency}}$

5. ***Horse Power Input to electric motor*** =

$$\frac{\text{Water Horse Power}}{\text{Pump Efficiency} * \text{Drive Efficiency} * \text{Motor Efficiency}}$$

6. ***Kilowatt Input to electric motor (or) Energy Consumption in Kilowatt Hours***

$$\text{Energy in Kilowatts} = \frac{\text{Brake Horse Power} * 0.746}{\text{Motor Efficiency}}$$

7. Cost of operation for electric motor

= Energy in Kilowatts*Hours of pumping*Cost per Kilowatt Hour

The pump efficiency of most of the pumps generally ranges from 60 to 70 per cent and the drive efficiency of motor is about 80 per cent. The overall efficiency of the system may be approximately 50 to 55 per cent.

General maintenance of pumps for maximum working efficiency

1. The suction lift should be periodically checked and it should be within the permissible limits.
2. The gland packing in the pump should be checked and replaced if necessary. The water should drip through the packing at a rate of 15 to 30 drops minute.
3. Periodical inspection of impeller of the pump is necessary for wear.
4. The rpm of the prime mover should be at the rated valve.
5. The alignment of the pimp and motor shaft should be checked.

EXERCISE

1. A centrifugal pump delivering 851.25 litres per minute irrigates 1.619 hectares working 8 hours in a day. What is the depth of irrigation per day?
2. A pump delivers 22,730 litres of water to a height of 45.6 metres in every five minutes. If the efficiency of the pump is 75 per cent, what is the horsepower required to drive the pump?
3. A pump driven by an electric motor delivers 454.6 litre of water to a height of 30.4 metres in every minute. If the efficiency of the pump is 70 per cent and the motor takes 19 amps at 200 volts, what is the efficiency of the motor?
4. A centrifugal pump driven by an oil engine delivers 851.25 litres per minute. If the pump works for 10 hours a day how many hectares of paddy crop can be irrigated by the discharge, interval of irrigation being 10 days and depth of irrigation being 2.54 cms.
5. Calculate the cost of pumping 4 million litres of water from a well with a centrifugal pump from the following data.

Suction head = 3 metres; Delivery head = 7 metres; Friction head = 1.5 metres

Output of the pump = 40,000 litres/ hour; Pump efficiency = 70 per cent

Motor efficiency = 85 per cent; Cost of electricity = 10 paise per unit.