Chapter 8

Irrigation Pumping Systems

Kashif Mahmood and Tajammal Hussain[*]

Abstract

Pumping systems play important role in providing energy to the fluids in domestic, commercial and agricultural services. In addition, they are extensively utilized in municipal water and waste water services as well as in the industrial services for food processing, chemical, petrochemical, pharmaceutical processing and mechanical industries. The focus in this chapter, however, remains on the use of pumping systems in irrigation and agricultural production. Therefore, emphasis has been given on basic concept of pumping, components of a pump, various types of pumps impellers used for irrigation, need of pumping system in agriculture, pump characteristics, pumping efficiency, affinity laws, pump selection, Trouble shootings and solutions, pump maintenance and pump industry in Pakistan. The readers will therefore be benefitted with basic concepts related to operational characteristics of irrigation pumps, their design, selection, installation and diagnoses with possible remedies.

Keywords: Pump, Pump Characteristics, Pump Selection and Installation, Pumping Energy, Pumping Efficiency

Learning Objectives

- To provide an overview about pumping industry in Pakistan and various types of pumps used for irrigation.

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- To familiarize the reader with basic concept related to operational characteristics of irrigation pumps, their design, selection, installation and diagnoses with possible remedies.
- Use of pumps in tube wells and other installations for industry and domestic purposes.

8.1 Introduction

Groundwater has been a source of irrigation water since ancient times. Even after the introduction of canal irrigation in the Indus Basin groundwater has played an important role in supplementing the available water supplies. With the growth of population, the increasing demand for irrigation water to accelerate agricultural production could only be met with the use of groundwater. Controlling water logging in the country has further emphasized the need for pumping groundwater.

Over the time the method of extraction of groundwater has changed from digging wells and manual techniques to mechanized pumping using tubewell technology powered by engine or electric motors. Installation of tubewell in the Indus Basin started primarily in the public in the early 20th century to control the problem of water logging. In 1994 installation of about 1800 tubewells were initiated in Rechna Doab under Rural Tubewell scheme to control water logging (Planning and DDvelopment Division, 1991). At the time of independence, Pakistan had only a few thousand of tube wells mainly in Rechna and Chaj Doabs. About 200 tubewells were installed by Soil Reclamation Board from 1952 to 1960. The Salinity Control and Reclamation Project (SCARP) was the first reclamation project where high capacity deep well turbine pumps were installed. By 1992 almost 40 SCARP'S have been completed. The numbers of public tubewells installed in the country have been estimated to about 15650 (Planning and Development Division, 1991).

A significant growth in the number of tubewells has been observed particularly in private sector. In 1964 about 23,000 tubewells were operating which increased to more than 183,000 by 1981 indicating an increasing of about 9,500 private tubewells per year. About 2, 86,300 private tubewells are estimated to be operating in the country by 1988 (Planning and Development division, 1991). These tube wells include both shallow tubewells (up to 30 m depth) with smaller capacity 14 to 28 lps as well as deeper tubewells (54 to 60 m depth) with capacity ranging from 28 to 140 lps. The shallow tube wells which are mostly privately owned by the farmers are centrifugal pumps and are operated by diesel engines, tractors P.T.O or electric power. About 56 percent of private tubewells are diesel operated while the remaining are electric operated (Ahmad and Choudhry, 1988 and Planning and Development Division, 1991).

According to an estimate from one of the canal commands in the Punjab, out of 36.5 percent of the requirements were met from canal water while 20.6 percent from rainfall and 42.9 percent from groundwater. Therefore, groundwater serves as a major source of irrigation water in sweet water canal commands. Moreover, pumping has been found to be indispensable for profitable agriculture in the Indus Basin (Choudhry, 1987). According to an estimate, the total number of tubewell in Pakistan are more than one million (12, 29,000) in which some are diesel operated (5, 45,000), electricity operated (84000) and tractor operated tubewells are 600000 to meet the water requirement of different crops.

There are mainly two types of irrigation systems for providing water to crops. The gravity flow irrigation system and pressurized irrigation system. In gravity flow irrigation system, water is conveyed to the crops under gravitational forces and no pumping is required. In pressurized irrigation systems, water is conveyed through some external pressure and pumps are an integral part of this system. Tubewell irrigation, lift irrigation systems, sprinkler irrigation system and drip irrigation system are its typical examples.

8.1.1 Concept of a Pump

The primary function of a pump is to impart energy to the fluid. The power source is supplied by a separate unit, which may be a motor or an engine. A pump is a device, which converts mechanical energy (in case of engine) or electrical energy (in case of motor) into hydraulic energy (Karassik, 2001).

8.1.2 Energy

According to Bernoulli's theorem, the energy at any point of the system relative to datum can be expressed as:

$$\mathrm{H} = \frac{\mathrm{V}^2}{2\mathrm{g}} + \frac{\mathrm{P}}{\mathrm{r}} + \mathrm{z} \qquad (14)$$

Where

H = Total energy or head, m

$\frac{V^2}{2g}$ = velocity head, m

$\frac{P}{r}$ = pressure head, m

z = potential or elevation head, m

r= unit weight of liquid being pumped

The energy developed by the pump indicates the work done by the pump on the fluid, which may include the increase in elevation (h_e), pressure (h_p) or velocity (h_v) of the fluid being pumped. Thus, total energy or total head (H) produced by the pump may be given as:

$$\mathrm{H} = h_e + h_p + h_v$$

The corresponding examples may include rising of water from ground level to the top of a building, operating sprinklers at a given pressure or converting pressure into a high velocity jet.

8.2 Components of a Pump

There are several components of a pump as given in Fig. 8.1 and are explained below:

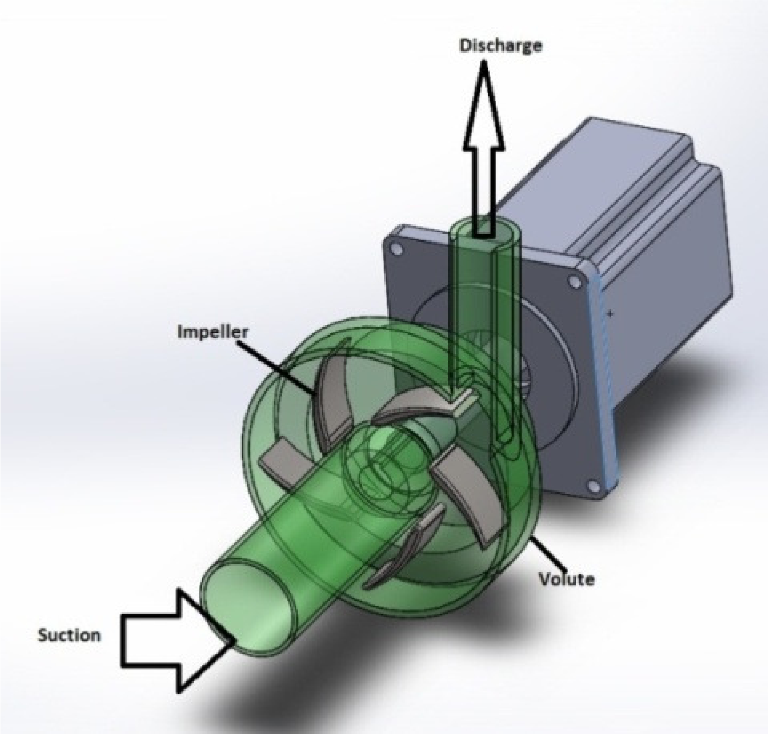


Fig. 8.1 Components of a Pump

8.2.1 Impeller

It is rotating part of pump or turbine that provides centrifugal acceleration to the fluids and is called an impeller. Thus, an impeller is a circular metallic disc with a built-in-passage for the flow of fluid.

An impeller can be further classified as closed, Semi Open and Open impellers.

8.2.1.1 Semi-open Impeller

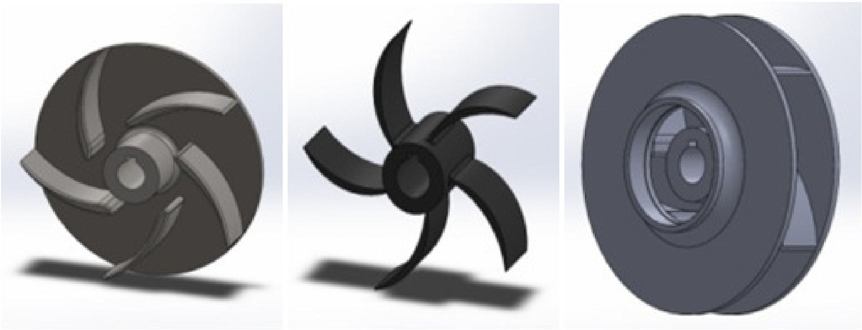
If the vanes of the impeller are enclosed by shrouds only on back side then it is termed as semi-open impeller, as shown in Fig. 8.1. It can work at higher speed. Such impellers must be adjusted so that the clearance between the open side of impeller vanes and bowls or volute face is within a tolerance of 0.1 mm.

8.2.1.2 Open Impeller

If an impeller has no shrouds on its both ends, it is known as open impeller, as shown in Fig. 8.2. The open impeller is less likely to be clogged with solids, but if it does, it is easy to clean it. Therefore, they are suitable to pump liquids carrying organic matter, paper pulp or other dense material such as sewage water.

8.2.1.3 Closed Impeller

If the vanes of the impellor are surrounded by shrouds on both sides then it is called closed impeller, as shown in Fig. 8.2. These impellers can clog if solids or "stringy materials" are pumped. It's difficult to clean out these solids from between the shrouds and vanes. Therefore, these are used to pump clear fluids such as clean water.



Semi-Open Impeller Open Impeller Closed Impellers

Fig. 8.2 Types of Impeller

8.2.2 Shaft

The shaft transfers the torque from motor to the impeller during startup and operation of pump.

8.2.3 Eye of Impeller

When the pump operates, water from the source enters the Eye of Impeller. It is located at the end of suction line before the start of wanes of impeller.

8.2.4 Stuffing Box

The portion of pump that houses the packing or mechanical seal is called stuffing box. It is usually referred to as dry portion of pump. The stuffing box is in the back of the impeller and around the shaft.

8.2.5 Casing

The main function of casing is to enclose the impeller from suction to delivery and therefore, it forms a pressure vessel for the fluid being pumped. The other function includes the provision of support and bearing medium for the shaft and impeller.

There are two types of casings:

(i) Volute casing has impellers that get fitted inside the casings. Its main purpose is to help balancing the hydraulic pressure on the shaft of the pump.
(ii) Circular casing has stationary diffusion vanes surrounding the impeller periphery that converts speed into pressure energy. These casings are mostly used for multi-stage pumps and can be designed as solid casing (one fabricated piece) or split casing (two or more parts together)

8.3 Need of Pumping System

A pumping system is required at various places for different purposes such as to:

- Lift water from one elevation to another elevation
- Move water from one point to another point.
- Circulate water around the cooling system.
- Develop pressure to operate sprinklers or Drip Irrigation System.

8.4 Pumping System Environment

Pumping Systems are operated to provide municipal water and wastewater services, and industrial services for food processing, chemical, petrochemical, pharmaceutical, and mechanical industries.

8.5 Classification of Pumps

The classification of pumps may be based on the following factors:

- Energy imparted to the fluids
- Position of pump
- Number of stages
- Geometry of impeller
- The materials or liquids being handled

8.5.1 Method of Imparting Energy to Fluids

8.5.1.1 Positive Displacement Pumps

A pump in which measured quantity of fluid is physically entrapped in a space, its pressure is raised and then it is delivered through the delivery pipe, is called as positive displacement pump. Hand pump is a good example of positive displacement pump. These pumps may be categorized as Reciprocating pumps and Rotary Pumps. Under reciprocating type, the displacement of water takes place by reciprocation of piston plunger. These pumps discharge the same quantity of water independent of head against which they operate. Reciprocating pumps are of 2 types *viz.*, 1) Single Suction Impeller, 2) Double Suction Impeller

An impeller that allows the liquid to enter the center of the vanes from only one direction or if suction takes place with one forward or backward stroke of the piston, it is termed as single suction. An impeller that allows the liquid to enter the center of the vanes from both sides simultaneously or if suction takes place with two forward and two backward strokes of the piston, it is termed as double suction. A double suction impeller is preferred because greater suction area permits the pump to operate with less net absolute suction head. If the displacement of water is by rotary action of gears or lobs, it is called a rotary pump.

8.5.1.2 Centrifugal Pumps

The Centrifugal Pumps utilize Centrifugal force to impart energy to the fluid, which is created through rotation of the impeller, which in turn moves the fluid in radial direction imparting centrifugal force to the fluid. These pumps are mostly used in lift irrigation systems. The prime mover, which may be an engine or an electric motor, provides rotational speed to the impeller. When the impeller rotates the fluid, accelerating it radial direction outward to the surrounding volute casing, creates centrifugal force in the fluid. The Principle of operation of a centrifugal pump may be explained as: The liquid is forced into the eye of the impeller by atmospheric pressure. Then vanes of the impeller pass Kinetic energy to liquid, thereby causing the liquid to rotate. The liquid leaves the impeller at high velocity. The impeller is surrounded by volute casing which converts kinetic energy into pressure energy. Centrifugal pump can be classified as single stage pumps and multistage pumps. Both types of pumps will be explained in section 8.5.3.

8.5.1.3 Jet Pumps

Jet pumps are low capacity pumps, which are seldom used for irrigation purposes. It combines two principle of pumping – that of the centrifugal pump and that of an injector (nozzle and venturi assembly) as shown in Fig. 8.3. Under jet action, some of the water discharged by the impeller passes out of the pump. The rest is re-circulated through the drive line to the injector in the well where the nozzle and venturi create vacuum, which draws water from the lower depth of well, through foot valve. As the water passes through the venture tube into the suction line, the pressure is increased sufficiently to force the water to the pump impeller.

8.5.2 Position of Pump

8.5.2.1 Deep Well Turbine Pumps

One impeller rotating inside a bowl and mounted on a vertical or horizontal shaft is called as a stage or a bowl assembly of the turbine. When a number of such bowl assemblies are coupled together on a line shaft such that the lower impeller imparts energy to the fluid and move it upward to the upper impeller that adds to the total head generated by the pump, it is called Multistage Deep Well Turbine Pump as shown in Fig. 8.4.

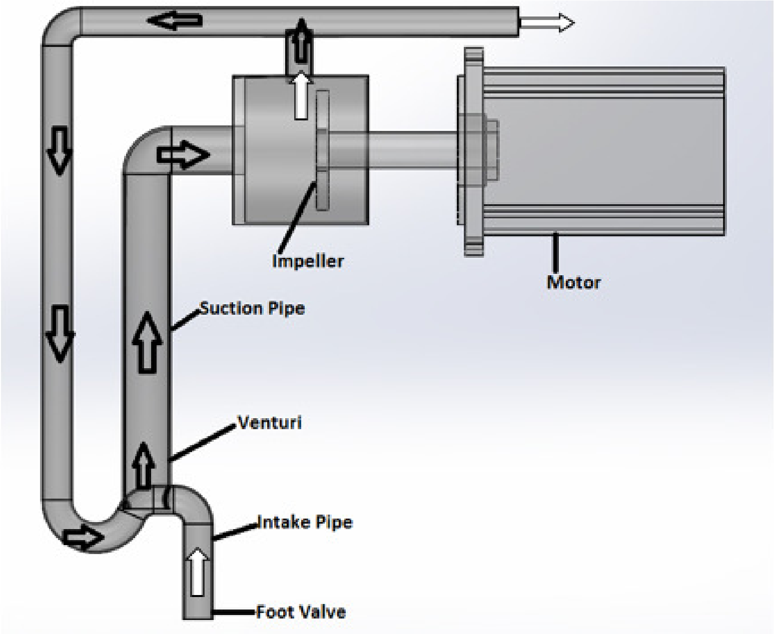


Fig. 8.3 Working principle of Jet Pump

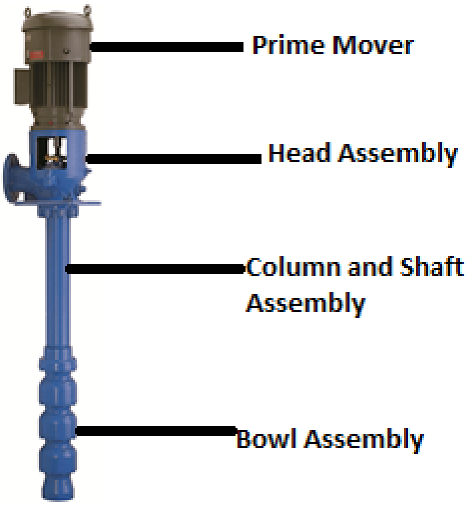


Fig. 8.4 Schematic Diagram of a Deep Well Turbine Pump

8.5.2.2 Submersible Pumps

A submersible pump is a device which has a sealed motor close-coupled to the pump body. The whole assembly is submerged in the water to be pumped. The main advantage of this type of pump is that it prevents pump cavitations. Submersible pumps are more efficient than jet pumps.

8.5.3 Number of Stages of Pumps

As each bowl assembly connected in series to the other bowl assemblies indicates the number of stages of the tubewell, the pumps may be classified as single stage or multistage depending on the number of bowl assemblies as given below. The purpose of increasing the bowl assemblies is to increase total dynamic head developed by the pump.

8.5.3.1 Single Stage Pumps

One impeller rotating inside a bowl and mounted on a vertical or horizontal shaft is called a stage and such type of the pump is termed as single stage pump.

8.5.3.2 Multistage Pumps

When several bowl assemblies are coupled together on a line shaft such that the lower impeller imparts energy to the fluid and moves it upward to the upper impeller, the pump is called multistage pump.

8.5.4 Geometry of Impeller

Based on the geometry of the impeller, the pumps may be classified as Axial Flow, Mixed Flow and Radial Flow as detailed below.

8.5.4.1 Axial flow pumps

These pumps push water along the axis perpendicular to the plane of rotation. These are generally used to pump at high flow rates against low heads. Capacities generally range from 40 to 6000 lps and total dynamic head range from 1 to 10 meters. The specific speed remains above 8000.

8.5.4.2 Mixed flow pumps

These pumps accelerate fluids at some angle or move water in a direction between the axial and radial flow pumps. These pumps can handle wide range of flows with capacity ranging from 40 to 6000 lps. In these types of pumps, there is less danger of cavitation.

8.5.4.3 Radial flow pumps

These pumps push water along the axis parallel to the plane of rotation of impeller. These pumps usually develop high head, low discharge and lower efficiency. They exhibit an efficiency of 50 to 80 percent and specific speed of 500 to 3000.

8.5.5 Materials or Liquids Being Handled

8.5.5.1 Irrigation Pumps

These pumps are used in semi-arid areas where the canal supply is insufficient to meet water requirements of various crops.

8.5.5.2 Drainage Pumps

These pumps are utilized in humid areas where water table is shallow which affects agriculture in the area.

8.5.5.3 Sewage Pumps

These are used to displace sewerage water from one point to the other point.

8.6 Pump Connections

The multiple pump units may be connected in parallel or in series arrangement depending on whether higher capacity at a constant head or higher head at constant capacity respectively, is required for the system under consideration. In planning such installation, a combined system head-capacity curve must be developed to select the right number of pumping units.

8.6.1 Pumps in parallel

Two or more pumps are connected in parallel to discharge into a single pipe line where the system requires wide variation in discharge for approximately same head. A group of pumps operating at a pumping station feeding the same supply line are good examples of pump in parallel. In an irrigation system, it is desirable to vary the discharge by putting limited number of pumps in operations to meet varying water requirements during rainy and dry seasons or operating a limited number of sprinklers in an irrigation system. However, to select such multiple pump units, their combined operating characteristics must be developed and compared with the system head curve to determine the range of head, discharge and efficiency in which the pump will operate. The method of developing a combined TDH-Q curve for the pumps A and B connected in parallel can be explained as follows:

$$\text{Combined discharge } Q_{A+B} = Q_A + Q_B \qquad (1)$$

$$\text{Combined Head } H_{A+B} = H_A = H_B \qquad (2)$$

$$\text{Combined Power } BP_{A+B} = BP_A + BP_B \qquad (3)$$

Therefore, combined efficiency for both the pumps would be given as:

$$E_{PARALLEL} = \frac{(Q_A + Q_B) * H_{A+B}}{102\,(BP_A + BP_B)} \qquad (4)$$

Where Q_A and Q_B are in liters per second (lps), H is in meters and BP_A and BP_B are in kilowatts. The combined H, BP and E are calculated and plotted against Q to develop combined characteristics curves for both pumps A and B as shown in Fig. 8.5 If both pumps are not taking water from the same source, different heads may be developed by each pump. The consequence is that the pump producing higher head would tend to suppress the discharge of the pump producing lower head, thus making its operation inefficient or stop it pumping water. Therefore, it is important that the pump should be selected such that they produce same head under given discharge condition.

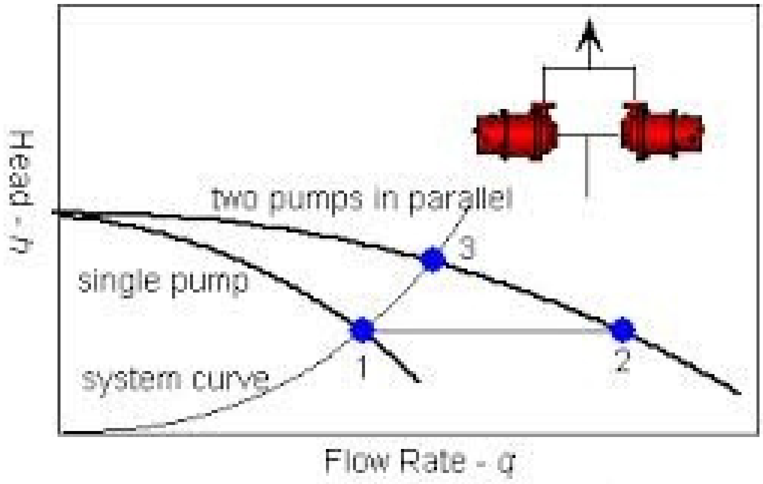


Fig. 8.5 Pumps in Parallel Combination

8.6.2 Pumps in Series

Two or more pumps connected in series may produce different heads but would produce the same discharge as they direct the flow through the same pipe line. However, heads produced by individual pumps would be added up to get the combined head. A good example of pumps in series is the multistage pump or a deep well turbine pump. The centrifugal pumps installed at the boosting stations also considered to be connected in series as the second pump boosts the pressure for use in sprinkler or municipal water supply systems. As shown in Fig. 8.7. The procedure to draw pump characteristics curves for pump A and B is given below:

By selecting several discharge and corresponding head values for both the pumps A and B, the combined discharge, head and power can be calculated using the following equations.

$$Q_{A+B} = Q_A = Q_B \quad (5)$$

$$H_{A+B} = H_A + H_B \quad (6)$$

$$BP_{A+B} = BP_A + BP_B \quad (7)$$

Therefore, combined efficiency for both the pumps would be given as:

$$E_{SERIES} = \frac{Q_{A+B} * (H_A + H_B)}{102\ (BP_A + BP_B)} \quad (8)$$

If all the pumps in series are identical then combined E-Q curve for both pumps would almost be the same as that of pump A or pump B. In case the two pumps are different, the resulting combined E-Q curve would be different than that of each pump as shown in Fig. 8.6.

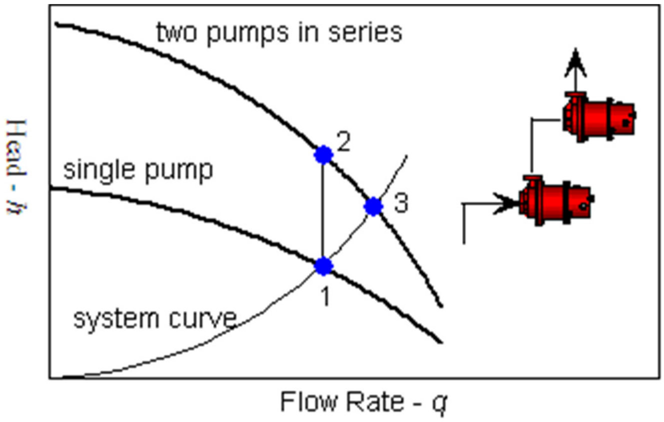


Fig. 8.6 Pumps in Parallel combination

8.7 Affinity Laws

The affinity laws describe the impact of changes in speed or impeller diameter on pump flow, head, and HP. They are useful tools in predicting changes in pump performance when speed or impeller diameter is changed. Such applications are important when variable speed drives are employed or impellers are trimmed. The pump manufactures cannot possibly develop characteristic curves for all ranges of diameter and speed; it would therefore be worth developing one's own curves as desired. The governing laws that provide such relations are called affinity laws which are described below.

8.7.1 Affinity Law I

The affinity law I states that flow rate/discharge (Q) will change directly when there is a change in speed (N), heads (H) will change as the square of a change in speed (N) and BP will change as the cube of a change in speed (N). As formulae, Affinity Law I is expressed as follows.

$$\frac{Q_1}{Q_2} = \frac{N_1}{N_2} \tag{9}$$

$$\frac{H_1}{H_2} = \left(\frac{N_1}{N_2}\right)^2 \tag{10}$$

$$\frac{BP_1}{BP_2} = \left(\frac{N_1}{N_2}\right)^3 \tag{11}$$

Where Q is discharge, N is speed, BP is the Brake horse power and H is the total dynamic head.

The subscript 1 indicates “existing conditions”; the subscript2indicates “new” conditions.

8.7.2 Affinity Law II

The Affinity Law II states that flow rate/discharge (Q) will change directly when there is a change in diameter (D), heads (H) will change as the square of a change in diameter (D) and BP will change as the cube of a change in diameter (D). As formulae, Affinity Law II is expressed as follows.

$$\frac{Q_1}{Q_2} = \frac{D_1}{D_2} \tag{11}$$

$$\frac{H_1}{H_2} = \left(\frac{D_1}{D_2}\right)^2 \tag{12}$$

$$\frac{BP_1}{BP_2} = \left(\frac{D_1}{D_2}\right)^3 \tag{13}$$

Where Q is discharge, N is speed, BP is the Brake horse power and H is the total dynamic head.

The subscript 1 indicates “existing conditions”; the subscriptindicates “new” conditions.

8.8 Pumping Energy

The energy that a pump imparts to the liquid during pumping operation is known as pumping energy. The work done by a pump or the amount of energy added into the liquid is the difference of energies between the point where the liquid leaves the pump and the point where the liquid enters the eye of impeller. The energy at any point of the pumping system is measured relative to an arbitrary or selected datum. An incompressible liquid such as water can have energy component in the form of velocity, pressure or elevation. Thus, energy can conveniently be expressed as the force or pressure developed per unit weight of the liquid, such as ft-lbs/s.

8.9 Irrigation System Head Requirement

The total system head requirements relate to the total energy or head that must be developed by a pump to overcome static lift, static discharge, good drawdown, operating pressure at discharge point and friction losses through the pumping system. These friction losses include all the losses taking place through pumping system components including well piping, valves, fittings, nozzles, weirs, meters, suction pipe, sprinkler units and pump itself. The total system head is, therefore, site specific and a pump with a given characteristics must be chosen to meet the head-capacity requirements of the system in which the pump must operate.

8.9.1 Static Head (H_{stat})

It is the summation of the static discharge (h_d) and the static suction heads (h_s) or it is different in height between source and destination of the pumped liquid. It is independent of flow rate.

$$H_{stat} = h_s + h_d \qquad (15)$$

8.9.1.1 Static Suction Lift (h_s):

It is the difference in elevation between the static liquid level and the centerline of the pump impeller when pump is not operating. If the pump is located at an elevation below the water surface, the static lift is negative and therefore is sometimes referred as a static head. In case the pump is located right at the water surface the suction lift is zero.

8.9.1.2 Static Discharge Head (h_d)

It is the difference in elevation between the centerline of the pump impeller and ultimate discharge point. In case the pump discharges directly into atmosphere at the same elevation as the delivery pipe of the pump, the static discharge head is considered zero. It is also independent of flow rate.

8.9.1.3 Drawdown

When a pump is installed in an aquifer, a cone of depression in water table develops as the pump operates. The maximum elevation between the static water table and the cone of depression at the well is called well drawdown. The well drawdown depends upon the discharge, aquifer characteristics, well radius and pumping period.

8.9.1.4 Operating Head

If the pump discharges into an open channel, the operating head may be considered zero. However, to operate the sprinklers, certain operating pressure is required at the discharge point which is called as operating head. This operating head may be converted into velocity head when sprinklers discharge into atmosphere. The operating head is required to attain the proper drop size and effective coverage of area.

8.9.1.5 Friction Losses

When water moves through the pipe system, loss of head due to friction takes place through suction pipe, pump components, pipes, flanges, elbows, joints and drippers. This head loss can be calculated using Darcy-Weisbach equation or William Hazen formula. Estimates of losses through various components of the system can be obtained from the manufacturers specifications as well.

8.9.1.6 Pump Size

The size of a pump depends upon the design discharge and head against which it must work. The total head (H_t) consists of the following

(a) Elevation Head (Vertical distance from the center line of the pump to the highest field)

(b) Friction losses
(c) Pump suction lift
(d) Minor losses A Fig. of 10% to 15% of (b) above is normally used
(e) Factor of safety

H_t = Suction + Static Lift+Pressure Head+Friction Losses+Factor of Safety

With Q and total head (H_t) known, the inspection of pump characteristics curves will indicate the size of pump to be selected.

8.10 Pump Characteristic Curves

The pump characteristics relate to operating characteristics of an individual pump independent of the pumping system requirement. These characteristics are built in the design of a pump by manufacturer to meet the given system requirements. These characteristics include the following relationships as shown in Fig.8.7 and 8.8.

- ✓ Total Dynamic Head Vs Discharge Rate (TDH-Q) Curve
- ✓ Break Power Vs Discharge (BP-Q) curve
- ✓ PumpEfficiency Vs Discharge (E-Q) curve
- ✓ Net positive suction head Vs discharge (NPSHR-Q) curve

When a pump is to be purchased, the manufacturers rating of pump characteristics should be consulted to select a pump which should be able to deliver the desired flow rate under given system head. After the most suitable type, the pump has been determined from the available information as described above; a specific pump is selected mating pump characteristics with system head curve. Some manufacturers use tabulated information while others give curves to show relationship between operational variables and the range of their performance.

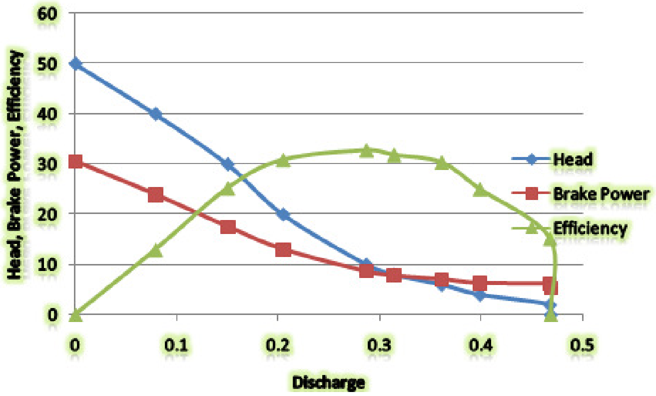


Fig. 8.7 Pump Characteristics Curves for Turbine Pump

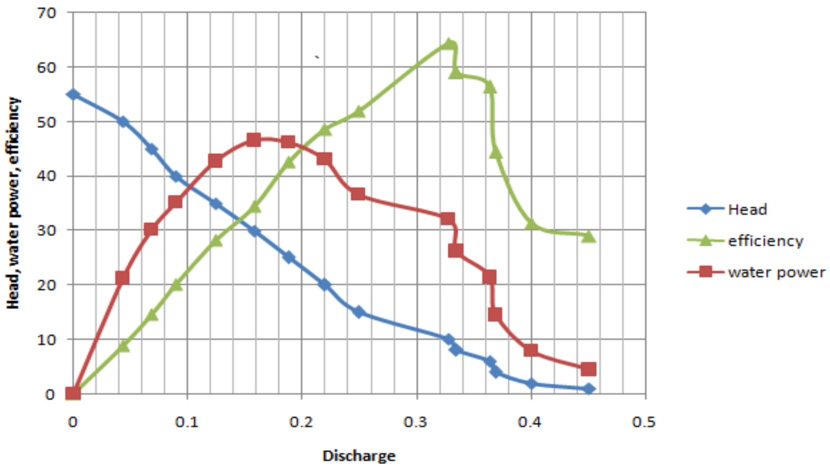


Fig. 8.8 Pump Characteristics Curves for Gear Pump

8.10.1 TDH-Q Curve

This is a curve that relates the head to the discharge of the pump. It shows that the same pump can provide different combinations of discharge and head. It is also noticeable that as the head increases the discharge decreases and vice versa. The point at which the discharge is zero and the head at maximum is called shut off head. This happens when a pump is operating with a closed valve outlet. As this may happen in the practice, knowledge of the shut off head (or pressure) of a particular pump would allow the engineer to provide for a pipe that can sustain the pressure at shut off point if necessary.

8.10.2 E-Q Curve

This curve relates the pump efficiency to the discharge. The materials used for the construction and the finish of the impellers, the finish of the casting and the number and the type of bearings used affect the efficiency. As a rule larger pumps have higher efficiencies.

Efficiency is defined as the output work over the input work.

$$E_P = \frac{\mathrm{Output}}{\mathrm{Input}} = \frac{\mathrm{WP}}{\mathrm{BP}} = \frac{\mathrm{Q*TDH}}{\mathrm{C*BP}} \qquad (16)$$

E_P= Efficiency of pump

BP =Brake power (kW or hp = 1.34 kW), energy imparted by the prime mover to the pump

WP = Water power (kW), energy imparted by the pump to the water

Q = Discharge (l/s or m^3/hr)

TDH = Total Dynamic Head (m)

C = Coefficient to convert work into energy units equals - 102 if Q is measured in l/s or 360 and is 360 if Q is measured in m^3/hr

Efficiency of motor is the ratio of brake horsepower and input horse power and given mathematically below:

$$E_m = \frac{\text{Output}}{\text{Input}} = \frac{\text{BP}}{\text{IHP}} * 100 \qquad (17)$$

E_m = Efficiency of motor

IHP = Input Horsepower measured by voltage and ampere taken the motor.

Efficiency of pumping plant is the ratio of water horsepower and input horsepower and is given by:

$$E_{Pp} = \frac{\text{Output}}{\text{Input}} = \frac{\text{WHP}}{\text{IHP}} * 100 \qquad (18)$$

8.10.3 BP-Q Curve

The brake power is the output power of the prime mover or the input power to the pump. With increasing discharge, the brake power increases in the beginning and then falls off to some extent at higher discharge. Even at shut off head (zero discharge) same input energy is needed. In some pumps, the brake power will be higher at lowest discharge.

8.10.4 NPSHR-Q Curve

At sea level, atmospheric pressure is 100 kPa or 10.33 m of water. This means that if a pipe was to be installed vertically in a water source at sea level and a perfect vacuum created, the water would rise vertically in the pipe to a distance of 10.33 m. Since atmospheric pressure decreases with elevation, water would rise less than 10.33 m at higher altitudes. A suction pipe acts in the manner of the pipe mentioned above and the pump creates the vacuum that causes water to rise in the suction pipe. Of the atmospheric pressure at water level, some is lost in the vertical distance to the eye of the impeller, some to frictional losses in the suction pipe and some to the velocity head. The total energy that is left at the eye of the impeller is termed the Net Positive Suction Head.

The amount of pressure (absolute) or energy required to move the water into the eye of the impeller is called the Net Positive Suction Head Requirement (NPSHR). It is a characteristic of the pump and a function of the pump speed, the shape and the discharge of the impeller. Manufacturers establish the NPSHR-Q curves for the different models after testing. If the energy available at the intake side is not sufficient to move the water to the eye of the impeller, the water will vaporize and the pumps will cavitate. To avoid cavitations, the NPSHA should be higher than the NPSHR required by the pump under consideration.

8.11 Pump Selection

Pump characteristics curves can be used as a basis for selecting the pump to provide the required head and capacity for the range of operational conditions at or near maximum efficiency. It is not always possible to select a pump, which meets the required head- capacity needs at high efficiency because there is only one capacity and one head conditions for every pump where high efficiency is obtained. It is also not possible for pump manufacturers to design as many pumps as many operating conditions. They usually design series of pumps covering a range of heads, capacities and efficiencies.

For selection of a specific pump design, the TDH-Q curve should be superimposed on system head curve which determines the head and discharge that can be developed by the pump under consideration. The point where the TDH-Q and system head curves intersect would be the actual operating point (Fig. 8.9).

It is however desirable that the operating point should fall to the right side of the peak efficiency for efficient performance even after sustained operation. At point of intersection of the two curves, the head developed by the pump is equal to the head required by the system at flow rate. If the system demands a different flow rate, a different pump should be tried.

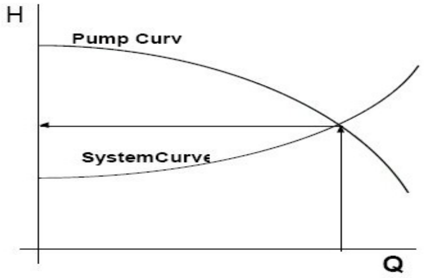


Fig. 8.9 Selection of Pump by Curves Match

The system head curves are time dependent due to variation in well drawdown, friction, operating conditions, static water level, wear of pumping components and well interface, etc. The pump must be selected to operate efficiently, satisfying the two extremes of low and high system head curves (curves S1 and S2 respectively). If curves A and B are characteristics curves for two different pumps, both pumps produce different ranges of discharge and head for high and low system curves. The pump B with steepest TDH-Q curve will result in least fluctuation in discharge but higher fluctuation in heads. On the other hand, the pump A with relatively flat TDH-Q curve produces higher fluctuation in discharge and least fluctuation in head. The operational requirements (constant head or constant discharge) will however help selecting the right pump design to match the moving system requirements.

8.12 Pump Trouble and Solutions

Table 8.1 Proposed Diagnosis of Trouble Shootings in Pumping Systems

Observed Troubles	Possible Diagnosis
Pump does not deliver water	Pump does not primed Leakage in suction line Suction lift too high
Insufficient flow rate	Air pockets in suction line Insufficient priming Air leaks into pump through stuffing box
Loss of pressure	Excessive air in liquid System head higher than designed head Speed too low
Loss of pressure	Excessive air in liquid System head higher than designed head Speed too low
Excessive power consumption	Speed too high Higher specific gravity of liquid System head lower than pump designed
Pump vibrates or noisy	Cavitation occurring Excessive air in liquid Food valve partially clogged
Pump overheats	Pump not primed Incorrect Alignment

8.13 Tubewell

A long pipe or tube which is bored or drilled deep into the ground intercepting one or more water bearing stratum. Larger discharge can be obtained by getting a larger velocity and larger cross sectional area.

8.13.1 Tubewell Components

Various components of tubewell are given below:

a) Prime movers

A tubewell utilizes diesel engines or electrical motors as power units. A prime mover provides mechanical energy to drive the pump through drive shaft. It is usually placed on the ground surface.

b) Suction Pipe

This is a pipe, which runs from pump to the source of water. It carries groundwater from aquifer to the center line of pump. It consists of two parts.

c) Blind Pipe

The pipe from strainer to eye of impeller is called blind pipe.

d) Strainer

A porous medium used ahead of equipment to filter out harmful solid object from the fluid stream. Important properties of the screen are that it prevents sand and fine material from entering the well during pumping, it has a large percentage of open area to minimize head loss and entrance velocity, supports the wall of the well against collapse, and is resistant to chemical and physical corrosion by the pumped water. The strainer used in Punjab/Pakistan is slotted strainers.

e) Discharge/delivery pipe

This pipe delivers water from the pump to the destination, which may be an overhead tank or a channel. Delivery pipe usually placed above ground to allow free fall of discharging.

f) Check Valve or foot valve:

The function of this valve is to allow the flow in one direction only. This is installed at the food of the pipe to allow entry of water in suction line and prohibit the flow of water back from the pump to aquifer or water body, when pump is stopped.

8.13.2 Pump/Tubewell Industry in Pakistan

With the increasing groundwater demand to meet the crop water requirement, several companies have developed, which manufacture different types of pumps in Pakistan. These include KSB, PECO, MECO, Grandfos and Golden Pumps. They produce different sizes of pumps to be used for Irrigation and Drainage purpose. KSB Pump Company is manufacturing a variety of local pumps which include the following:

- ✓ Low pressure Centrifugal Pump
- ✓ Vertical Non Clogging Centrifugal pumps
- ✓ Axial Flow Propeller pumps
- ✓ Multistage High Pressure Centrifugal Pumps
- ✓ Submersible Pumps
- ✓ Deep well turbine Pumps
- ✓ Non Clogging Pumps

8.14 Solar Pumping in Pakistan

Pakistan is an energy deficient country, where a large fraction of the population still does not have access to modern day energy services such as electricity. This is due to very limited fossil fuel resources and poor economy, which restrains the import of fossil fuels on a large scale. To overcome energy shortage, Pakistan needs to develop its indigenous energy resources like hydropower, solar and wind. Pakistan lies in an area of one of the highest solar insulation in the world. This vast potential can be exploited to produce electricity, which could be provided to off-grid communities in the northern hilly areas and the southern and western deserts. Applications other than electricity production such as solar water heaters and solar cookers also have vast applications. Solar water pumping also consumes a lot of fossil fuels and electricity.

Solar pumpsare generally designed to operate on DC power produced through solar panels. These pumps are getting popular wherever electricityiseither not available or unreliable. Solar pumps are becoming popular to replace diesel pumps.

8.14.1 Advantages

In addition to the environmental advantages of solar power, solar pumps offer the following advantages.

- **Low operating cost:** Since there is no fuel required for the pump like electricity or diesel, the operating cost of solar pumps is minimal.
- **Low maintenance:** A well designedsolarsystemrequireslittlemaintenance except cleaning of the panels once a week and normal maintenance of panels.
- It gives maximum water output when it is most needed i.e. in hot and dry months. Slow solar pumping allows us to utilize low-yield water sources
- The panels need not be right beside the well. Theycanbeanywhereup to 20 meters away from the well, or anywhere you needthewater. So, it offers freedom regarding the placement of panels.
- These pumps can also be turned on and off as per the requirement, provided the period between two operations is more than 30 seconds.

8.14.2 Limitation

- Solar pumping is not advisable where water requirement is very high. The maximum capacity available with solar is 2HP. However, the output of the 2HP pump is equivalent to a normal pump of 4HP.
- The water yield of the solar pump is variable and changes according to the sun light.

  It is highest around noon and least in the early morning and evening.
- The submersible pump has an in-built protection against dry run. However, the surface pumps are very sensitive to dry run. A dry run of 15 minutes or more can cause considerable damage to a surface pump.
- As with any other pump, solar pumps work best if the water is clean, devoid of sand or mud. However, if the water is not so clean, it is advisable to clean the well before installation or use a good filter at the end of the immersed pipe.
- The solarpanelscanbe stolen, which may be a problemin remote areas. Therefore, the farmers need to take necessary precautions for security. Ideally, the solar system should be insured against theft as well as natural hazards.

8.14.3 Design of Solar Pump

Following are the design steps

- Site Selection and Visit
- Determination of Water table depth
- Water requirements of farmer

- Site location (Latitude/Longitude)
- Shading effect
- Orientation of panels
- Theft protection measures
- Calculation of the Motor HP according to the depth of the W.T.
- Find safe places for Electrical appliances.
- Designed the Possible structure of PV array according to requirements of the site
- Designed the arrays according to the electrical devices.
- Make the connections Of the PV arrays with the electrical devices
- Make use of safety devices

8.14.4 Case Study-I

- A solar tubewell was installed at Mari Kot by Energy Alternatives. The following data were collected for installation purpose.
- Depth of water table = 50 ft
- Discharge of tubewell = 0.75 cusec
- Strainer start at 70 ft
- Total bore length = 150 ft
- Total number of pannels = 48 (250 Wp, 24 V)
- Total pannel capacity = 12 kW
- 3 phase Invertor (VFD) of capacity 15 kW
- Safety devices (breaker, fuses and change over)
- Pump type= Centrifugal

8.14.5 Case Study-II

- A solar tubewell was installed at Chiniot by Energy Alternatives. The following data were collected for installation purpose.
- Depth of water table = 50 ft
- Discharge of tubewell = 1 cusec
- Strainer start at 70 ft
- Total bore length = 150 ft
- Total number of panels = 80 (20KW, 24 V)
- Total panel capacity = 20 kW
- Number of batteries for back up=40
- 3 phase Invertor (VFD) of capacity 25 kW
- Safety devices (breaker, fuses and change over)

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