CHAPTER – 10

SPILLWAY AND PUMPS

Dr. M. R. Kabir

Professor and Head, Department of Civil Engineering

University of Asia Pacific (UAP), Dhaka

LECTURE 26

Definition of Spillway

The spillways are openings provided at the body of the dam to discharge safely the excess water or flood water when the water level rises above the normal pool level.

Necessity of Spillway

- The height of the dam is always fixed according to the maximum reservoir capacity. The normal pool level indicates the maximum capacity of the reservoir. The water is never stored in the reservoir above this level. The dam may fail by over turning so, for the safety of the dam the spillways are essential.

- The top of the dam is generally utilized by making road. The surplus water in not be allowed to over top the dam, so to stop the over topping by the surplus water, the spillways become extremely essential.

- To protect the downstream base and floor of the dam from the effect of scouring and erosion, the spillways are provided so that the excess water flows smoothly.

Location of Spillway

Generally, the spillways are provided at the following places

- Spillways may be provided within the body of the dam.
- Spillways may sometimes be provided at one side or both sides of the dam.
- Sometimes by-pass spillway is provided which is completely separate from the dam.

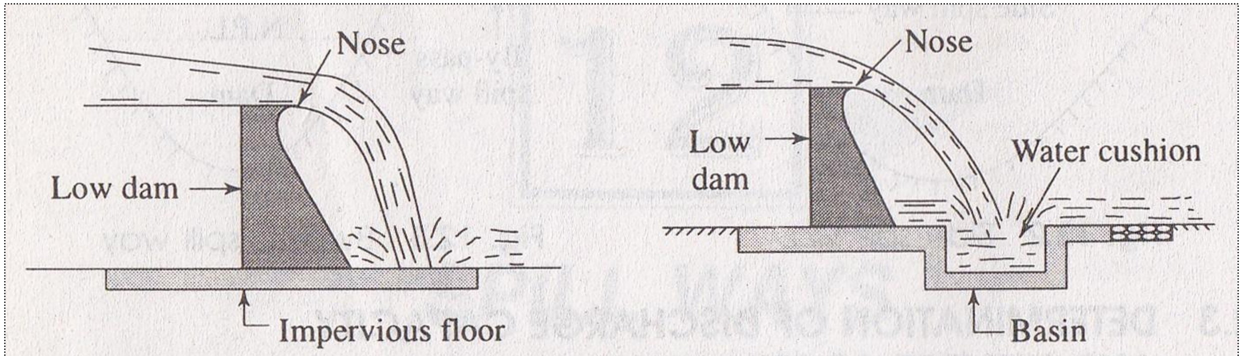
Determination of Discharge Capacity and Number of Spillway

- By studying the flood hydrograph of past ten years, the maximum flood discharge may be computed which is to be disposed off completely through the spillways.
- The water level in the reservoir should never be allowed to rise above the maximum pool level and should remain in normal pool level. So, the volume of water collected between maximum pool level and minimum pool level computed, which indicates the discharge capacity of spillways.
- The maximum flood discharge may also be computed from other investigation like, rainfall records, flood routing, empirical flood discharge formulae, etc.
- From the above factors the highest flood discharge is ascertained to fix the discharge capacity of spillways.
- The natural calamities are beyond the grip of human being. So, an allowance of about 25 % should be given to the computed highest flood discharge which is to be disposed off.
- The size and number of spillways are designed according to the design discharge.

Types of Spillway

- Drop Spillways
- Ogee Spillway
- Siphon Spillway
- Chute or Trough Spillway
- Shaft Spillway
- Side Channel Spillway

Drop Spillway



(a) Drop spillway with impervious apron
(b) Drop spillway with water cushion

- In drop spillway, the over flowing water falls freely and almost vertically on the downstream side of the hydraulic structure.
- The crest of the spillway is provided with nose so that the water jet may not strike the downstream base of the structure.
- To protect the structure from the effect of scouring horizontal impervious apron should be provided on the downstream side.

Ogee Spillway

- In Ogee Spillway, the downstream profile of the spillway is made to coincide with the shape of the lower nappe of the free falling waterjet from a sharp crested weir.
- In this case, the shape of the lower nappe is similar to a projectile and hence downstream surface of the ogee spillway will follow the parabolic path where "0" is the origin of the parabola.
- The downstream face of the spillway forms a concave curve from a point "*T*" and meets with the downstream floor.

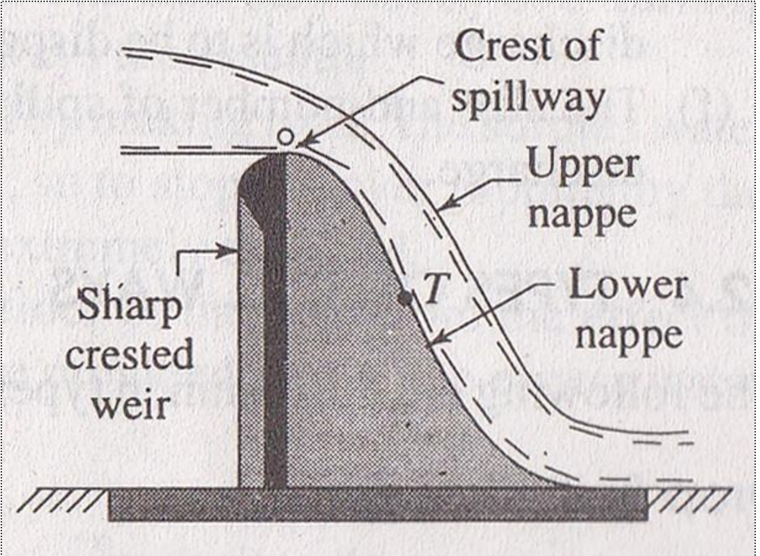


Fig: Ogee Spillway

The shape of the ogee spillway has been developed by U.S Army Corps Engineers which is known as "Water-way experimental station spillway shape". The equation given by them is, $X^n = K \times H^{n-1} \times Y$, where, *x* and *y* are the coordinates of a point *P* on the ogee profile taking *O* as origin. *K* and *n* are the constants according to the slope of the upstream face of the spillway (figure aside).

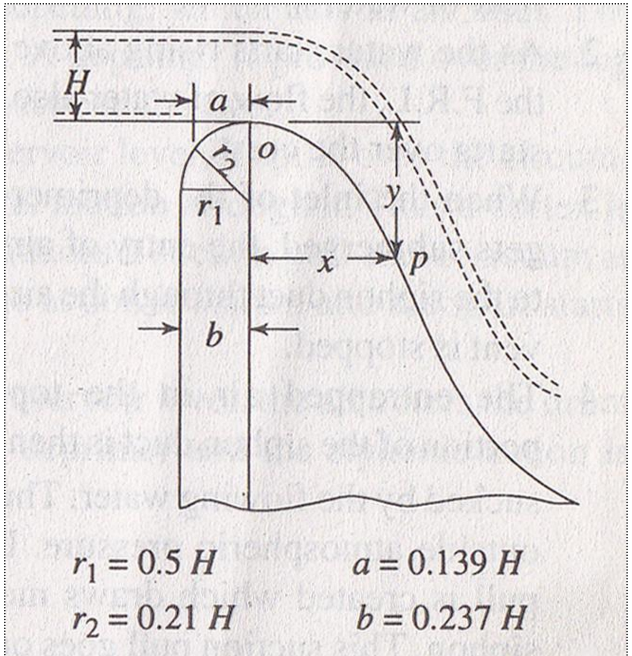


Fig: Shape of Ogee Spillway

The value of *K* and *n* are given as follow:

Shape of upstream face of spillway	K	n
Vertical	2.0	1.85
1:3 (H:V)	1.936	1.836
1:1½ (H:V)	1.939	1.810
1:1 (H:V)	1.873	1.776

LECTURE 27

Irrigation Pump

The mechanism by which the water is lifted from the under ground source to some height or to some place is known as pump

Pumping in ancient time

Pumping in modern time

Traditional irrigation system

Types of Pump

The Pumps may be of the following types:

- Reciprocating Pump
- Centrifugal Pump
- Turbine Pump
- Submersible Turbine Pump
- Rotary Pump
- Air Lift Pump

Reciprocating Pump

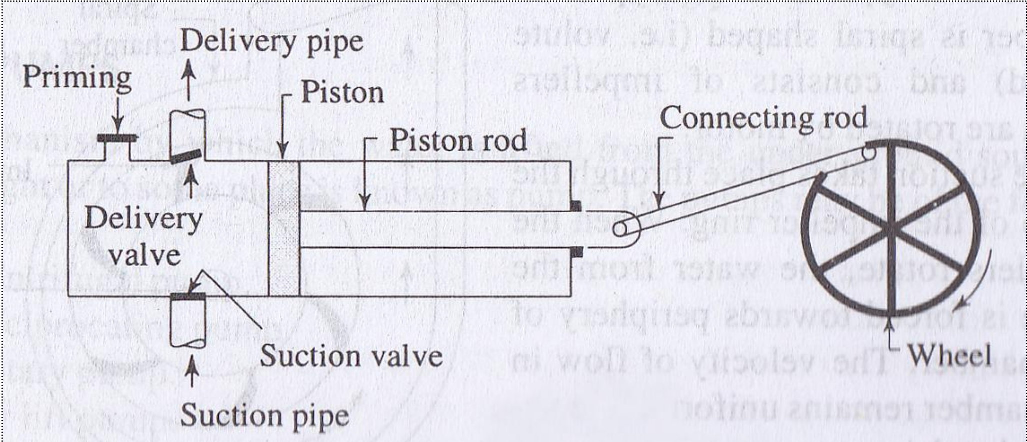


Fig: Reciprocating Pump

Components are:

- ❑Cylinder/piston
- ❑Suction Pipe
- ❑Delivery Pipe
- ❑Suction/inlet valve
- ❑Delivery/discharge valve

- ❑ A piston moves to and fro by a connecting rod.
- ❑ The connecting rod is again hinged with a wheel which is rotated by a motor.
- ❑ During the suction stroke, the suction valve is opened and delivery valve remains closed and water enters the cylinder.
- ❑ During the delivery stroke, the delivery valve is opened and suction valve remains closed and water is forced through the delivery pipe.
- ❑ An inlet is provided for the priming which is necessary for starting the pump.

Advantages of Reciprocating Pump

- It is suitable for large pumping units.
- It gives constant discharge.

Disadvantages of Reciprocating Pump

- It requires large space for installation.
- It is unsuitable for pumping water containing high sediment.

Centrifugal Pump

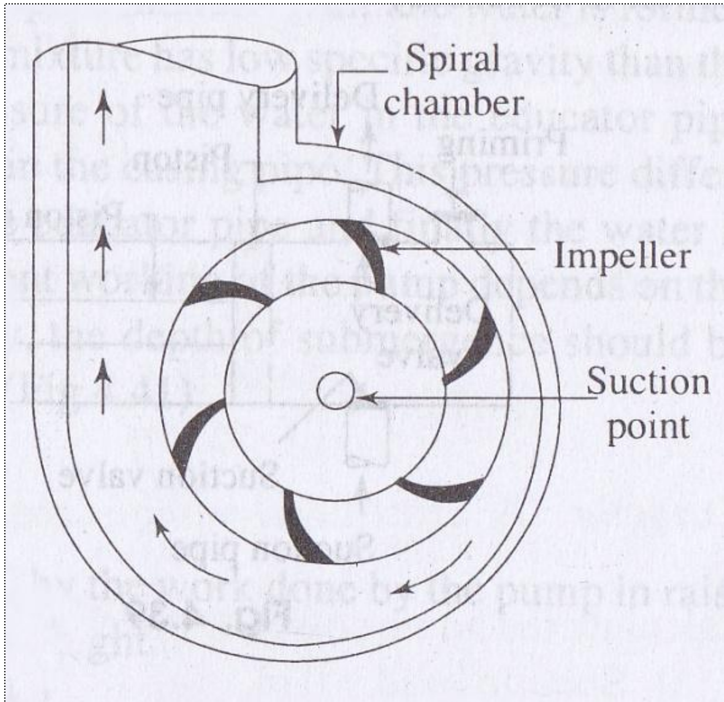


Fig: Centrifugal Pump (Volute Type)

- When the water in the chamber (casing) of a pump is rotated vigorously by the impellers about the central point, the centrifugal force develop which forces the water towards the periphery of the chamber.

- Thus the velocity head is converted to pressure head and this head forces the water through the delivery pipe.

- At the same time the water form the ground water source is lifted up by suction through the suction pipe.

Advantages of Centrifugal Pump

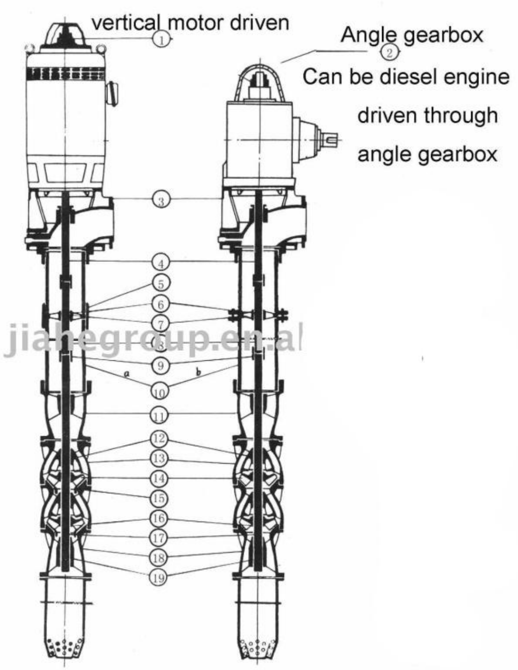
- It requires minimum space for installation as it is compact in design.
- It can be installed for high speed driving mechanism.
- The working is simple and there is no valve in the pump, hence it is reliable and durable

Disadvantages of Centrifugal Pump

- The pump will not work, if the chamber is not full of water. So, the priming should always be done before starting the pump
- The pump will not work if there is any leakage in the suction side.

Turbine Pump

- The impeller is surrounded by stationary guide vanes that reduce the velocity of water and convert velocity head to pressure head. The casting surrounding the guide vanes is usually circular and concentric with the impeller.
- A deep will turbine pump is a multi-stage pump that accommodates several impellers on a vertical shaft and stationary bowls pressing guide vanes.
- The two bowl assemblies are nearly always located beneath the water surface.
- The several bowls are connected in series to obtain the desired total head.



vertical turbine Long shaft deep well pump

Applicability:
Deep-well turbine pumps are used for irrigation when the water surface is below the practical lift of the centrifugal pump.
Q = 56 liter/sec, h = up to 300 m below ground level

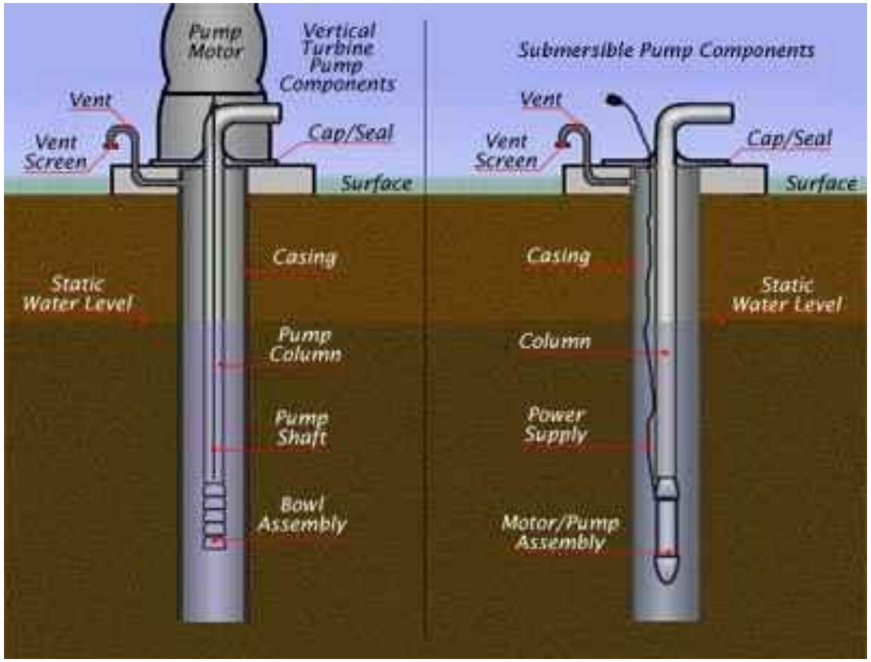
Advantages of Turbine Pump

- ❑ Priming is not required.
- ❑ Adapted to high lifts.
- ❑ Adapted to seasonal fluctuations in water level in the well

Disadvantages of Turbine Pump

- ❑ Operating parts are inaccessible and difficult to inspect
- ❑ Low efficiency is common
- ❑ Frequent shaft rupture
- ❑ Higher initial cost

Submersible Turbine Pump



- A submersible turbine pump is one in which the pump and the electric motor are placed below the water surface of a well. Delivery of water to the surface is through a riser pipe on which the assembly is suspended.

- The characteristics of the pump unit are similar to a conventional vertical turbine pump.

- They have been used in wells over 4000 meter deep. Units with more than 250 stages have been used.

Advantages of Submersible Turbine Pump

- It eliminates the long vertical shaft from the ground surface to the pump which reduces bearing friction and provides an unobstructed pipe for delivery of water to the surface.
- It can be used where the installation is flooded or where an above ground pump house would be inconvenient, unsightly or hazardous.

Disadvantages of Submersible Turbine Pump

- Operating parts are inaccessible and difficult to inspect

Rotary Pump

- It consists of tow cams which are pivoted in a casing.
- These cams rotate in opposite directions and thereby the suction takes place through the suction pipe.
- The rotation of the came pushes the water in upward direction through the delivery pipe.

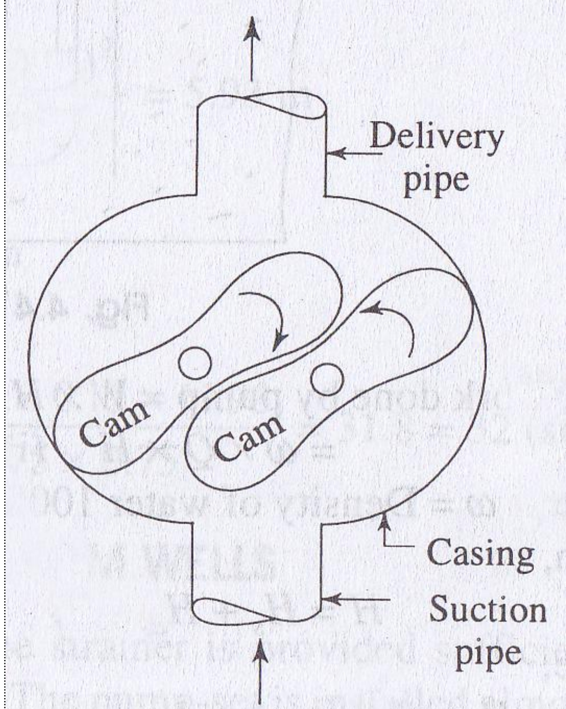


Fig: Rotary Pump

Advantages of Rotary Pump:

- The flow of water is uniform.
- No priming is required.
- It requires no valves and its operation is simple.

Disadvantages of Rotary Pump:

- It requires replacement of cams frequently and hence is involves more maintenance cost.
- It can not be used for pumping water containing high sediment.

Air Lift Pump

- When compressed air is forced through the air pipe, a mixture of air and water is formed and rises up in the form of bubbles.
- Thus the pressure of the water in the educator pipe becomes less than the pressure of water in the casing pipe.
- This pressure difference forces the water to rise through the educator pipe and finally the water is discharged through the outlet.

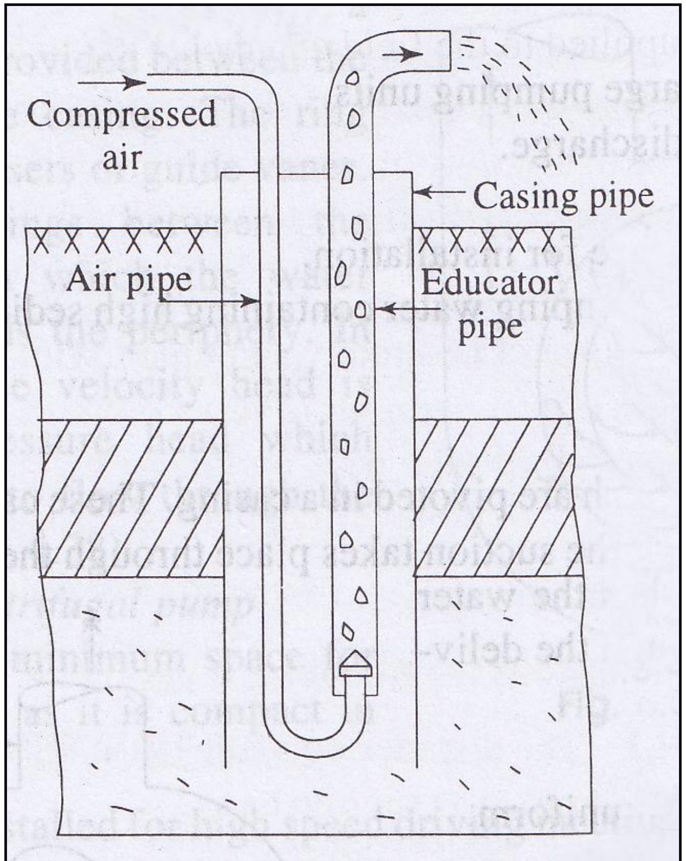
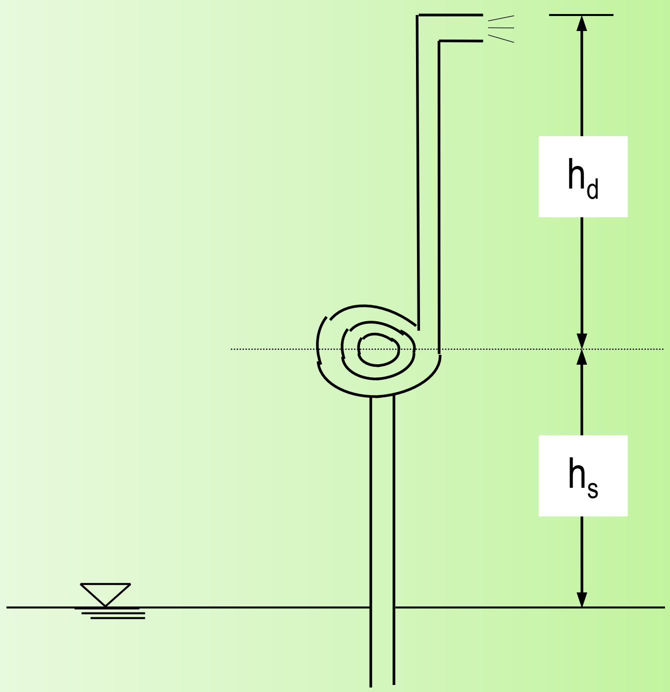


Fig: Air Lift Pump

LECTURE 28

Pumping Head



h_s = Static suction lift = vertical distance from the free suction water level to the centre line of the pump

h_d = Static discharge head = vertical distance from the centre line of the pump to the discharge water level

$h_s + h_d$ = Total static head = vertical distance from the suction water to the discharge water level

$h = h_s + h_d + d_f$ = Total pumping head

Where, h_f = Total frictional head loss in the suction and delivery pipes

Horse power of pump

The horse power of a pump is determined by work done by the pump in raising a particular quantity of water to some height.

Let, W = Quantity of water (kg)

H = Total head (m)

Then, work done by pump = $W \times H$

$= w \times Q \times H$ ------------- (i)

$[W = w \times Q]$

Where, w = Density of water (1000 kg/m^3)

Q = Discharge (m^3/s)

Again, $H = H_s + H_d + H_f$

Where, H_s = Suction head (m)

H_d = Delivery head (m)

H_f = Head loss due to friction (m)

The head lost by friction is given by,

$$H_f = \frac{f \times l \times Q^2}{3d^5}$$

Where, f = Coefficient of friction

l = Total length of pipe (suction and delivery)

d = Diameter of pipe (m)

From equation (i) $\Rightarrow$

$$\text{Water Horse Power (W.H.P)} = \frac{w \times Q \times H}{75}$$

Considering the coefficient of the pump as η, brake horse power

$$\text{Brake Horse Power (B.H.P)} = \frac{w \times Q \times H}{75\eta}$$

Problem-2:

A centrifugal pump is required to lift water at the rate of 100 lit/sec. Calculate the brake horse power of the engine from the following data when the water is directly supplies to the field channel.

(a) Suction head = 6 m

(b) Coefficient of friction = 0.01

(c) Efficiency of pump = 65%

(d) Water is directly supplied to the field channel

(d) Diameter of pipe = 15 cm

Solution:

$Q = 100$ lit/sec $= (100/1000)\ m^3/s = 0.1\ m^3/s$

Delivery head, $H_d = 0$ (As water is directly supplied to field)

$H = 5$ m

$f = 0.01$

$d = 15$ cm $= 0.15$ m

The length of the pipe where frictional effect may occur is taken equal to the suction head, so l = 6 m

$$H_f = \frac{f \times l \times Q^2}{3d^5} = \frac{0.01 \times 6 \times (0.1)^2}{3 \times (0.15)^5} = 2.63 \text{ m}$$

So, total head, $H = H_s + H_d + H_f$

$= 6 + 0 + 2.63$

$= 8.63$ m

Efficiency, η = 65% = 0.65

$$\text{Horse Power (H.P)} = \frac{w \times Q \times H}{75\eta} = \frac{1000 \times 0.1 \times 8.63}{75 \times 0.65}$$

= 17.70 ≈ 18 (Ans)

Power requirement

WHP (Water Horse Power) is the theoretical horse power required for pumping. It is the head and capacity of the pump expressed in terms of horse power.

$$WHP = Q \times h/76$$

Where, Q = Discharge (liter/sec)
h = Total pumping head (meter)

Efficiency is the ratio of the power output to power input

$$\therefore \text{Pump efficiency, } E_p = WHP/SHP$$

Where, SHP = Shaft horse power

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

$$BHP = SHP/E_d = WHP/(E_p \times E_d)$$

Where, E_d = Delivery efficiency

Horse Power input to electric motor = $WHP/(E_p \times E_d \times E_m)$

Kilowatt input to electric motor, KW = $(BHP/E_m) \times 0.746$

Pump characteristics

- The interrelations between speed, head, discharge and horse power of a pump are usually represented by curves which are designated as 'Characteristics curves'
- Knowledge of pump characteristics enables one to select a pump which fits operating conditions and thus attain a relatively high efficiency with low operating cost.
- As the discharge increases, the head decreases. The resulting efficiency is observed to increase from zero where the discharge is zero to a maximum of 82% when the discharge is 86 liter/sec and the head 23 m (and then found to decrease to zero at zero head).

Cont…. Pump characteristics

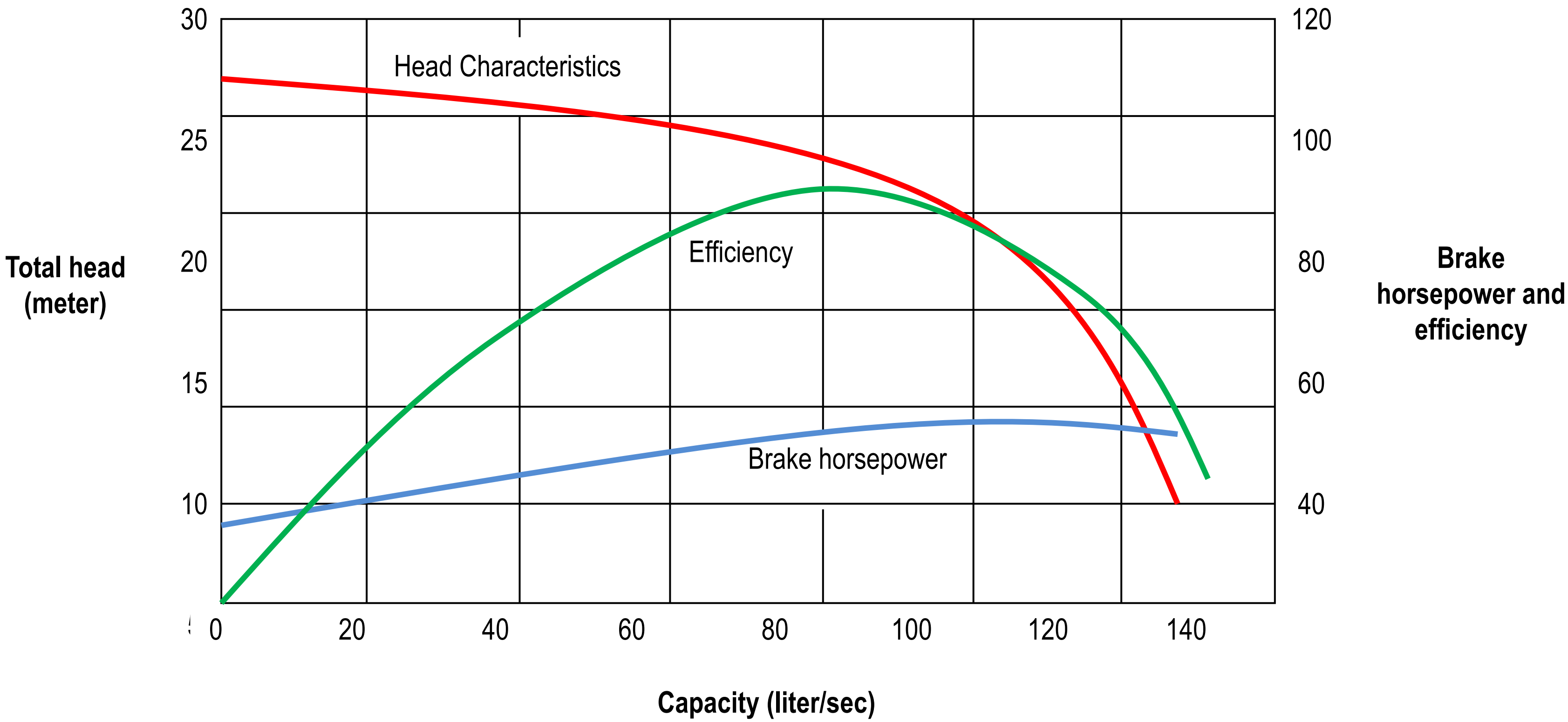


Fig: Pump characteristics curve

The BHP curve for a centrifugal pump usually increases over most of the range as the discharge increases, reaching a somewhat higher rate of discharge then that which produce maximum efficiency.

Selection of power plant

The power plant must be capable of delivering the required power under varying conditions. The factors are:

- Brake Horse Power required
- Initial cost
- Availability and cost of energy or fuel
- Depreciation
- Dependability of unit
- Portability required
- Maintenance and convenience of operation
- Labor availability and quality

Effect of speed and impeller diameter on pump performance

Effect of change of pump speed:

When the speed of a centrifugal pump is changed, the operation of the pump is changed as follows:

- ✓ The capacity varies directly as the speed.
- ✓ The head varies as the square of the speed.
- ✓ The brake horse power varies as the cube of the speed.

Expressed mathematically,

$$Q = Q_1 \times (n/n_1) \text{ ---------------- (i)}$$
$$H = H_1 \times (n/n_1)^2 \text{ --------------- (ii)}$$
$$P = P_1 \times (n/n_1)^3 \text{ --------------- (iii)}$$

From equation (i), (ii) & (iii) $\Rightarrow$

$$n/n_1 = Q/Q_1 = (H/H_1)^{1/2} = (P/P_1)^{1/3}$$

Where,

n = New speed desired, rpm

Q = Capacity at the desired speed n, liter/sec

H = Head at the desired speed n for capacity Q, meter

P = BHP at the desired speed n at H and Q

n_1= Speed at which the characteristics are known, rpm

Q_1 = Capacity at speed n, liter/sec

H_1 = Head at speed n_1 and capacity Q_1, meter

P_1 = BHP at speed n_1 at H_1 and Q_1

Effect of Change of Impeller Diameter

Changing the impeller diameter has the similar effect on the pump performance as changing the speed.

Thus, $D/D_1 = Q/Q_1 = (H/H_1)^{1/2} = (P/P_1)^{1/2}$

Where,

D = Changed diameter of impeller, mm

D_1 = Original diameter of impeller, mm

Pump and system characteristics

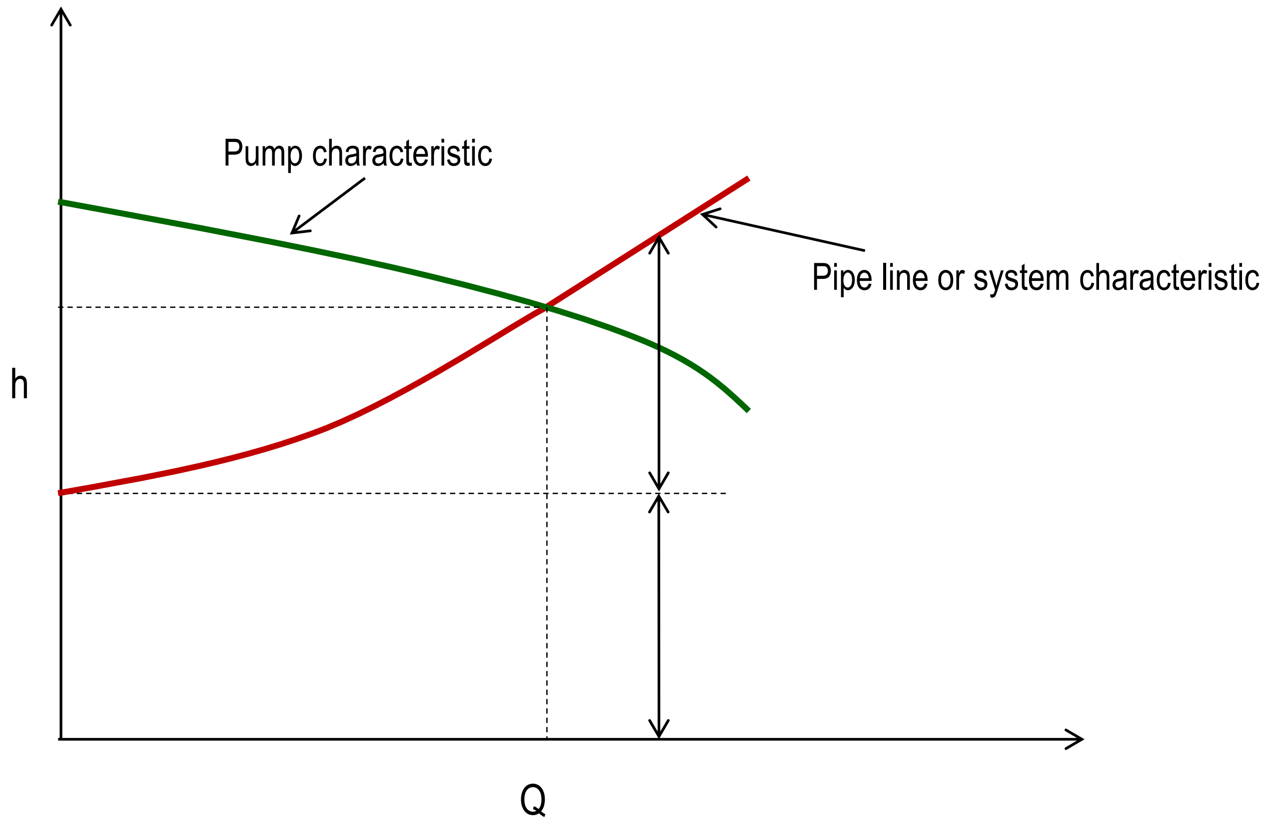


Fig: Graphical method for finding the operating condition of a pump and pipeline

If under this mode of operation the efficiency of the pump is not very high, an improvement in efficiency can be made by changing the speed of the pump or the impeller diameter or by selecting a different type of pump

Pumping Cost

Cost of pumping includes fixed cost and operating cost.

Fixed cost:

Total annual cost = capital cost 'X' CRF + annual O & M cost

Where,

CRF = Capital Recovery Factor

$$= \frac{i(1+i)^n}{(1+i)^n - 1}$$

i = Discount rate,

n = Project life, years

Operating cost:

Annual Operating cost = energy consumption rate X hours of operation X energy cost rate

End of Chapter – 10