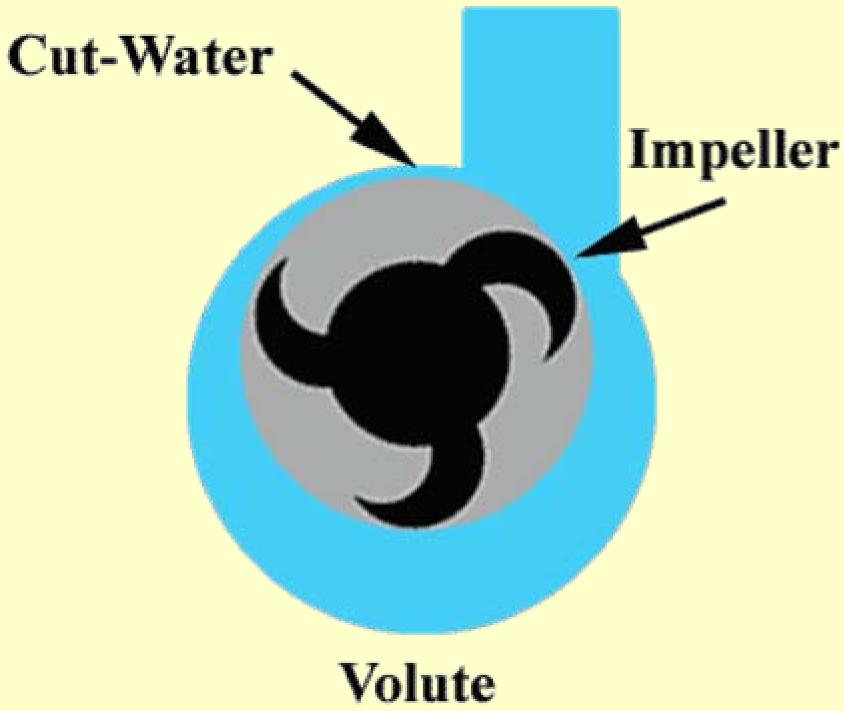
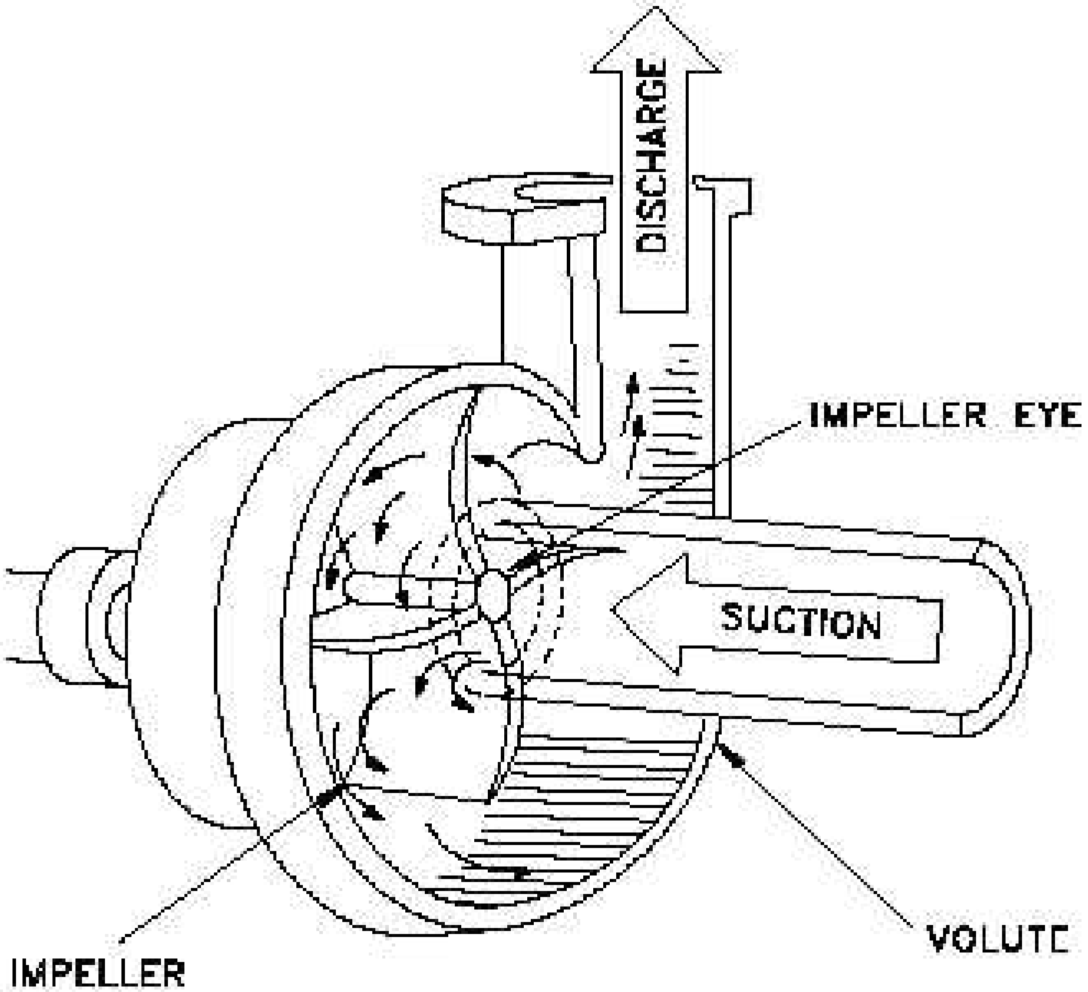
Pumps and Pumping Systems



6.1 Centrifugal Pumps



Centrifugal Pump

- Water enters the eye of the Impeller & exits the impeller with the help of Centrifugal Force.
- As water leaves the eye of the impeller a low pressure area is created, causing more water to flow into the eye (Atmospheric pressure & centrifugal force causes this to happen).
- Velocity is developed by the spinning impeller.
- Water velocity is collected by the diffuser & converted into the pressure by specially designed pathway.

Centrifugal Pumps ……

- The pressure (Head) developed is in direct relation to the Impeller dia., no. of Impellers,Size of Impeller Eye & Shaft Speed.
- Capacity is determined by the exit width of the Impeller.
- Head & Capacity are the main factors affecting Horse Power size of the Motor required.
- More the quantity of water to be pumped , more the energy required.
- Centrifugal pump will not pump the same volume always. Greater the depth lesser the flow.Higher the pressure lesser the flow.

Hydraulic power, pump shaft power and electrical input power

- **Hydraulic power P_h** = $\dfrac{Q\ (m^3/s) \times \text{Total head},\ h_d - h_s\ (m) \times \rho\ (kg/m^3) \times g\ (m^2/s)}{1000}$

Where h_d - discharge head, h_s – suction head, ρ - density of the fluid, g – acceleration due to gravity

- **Pump shaft power P_s** = $\dfrac{\text{Hydraulic power, } P_h}{\text{pump efficiency, } \eta_{Pump}}$

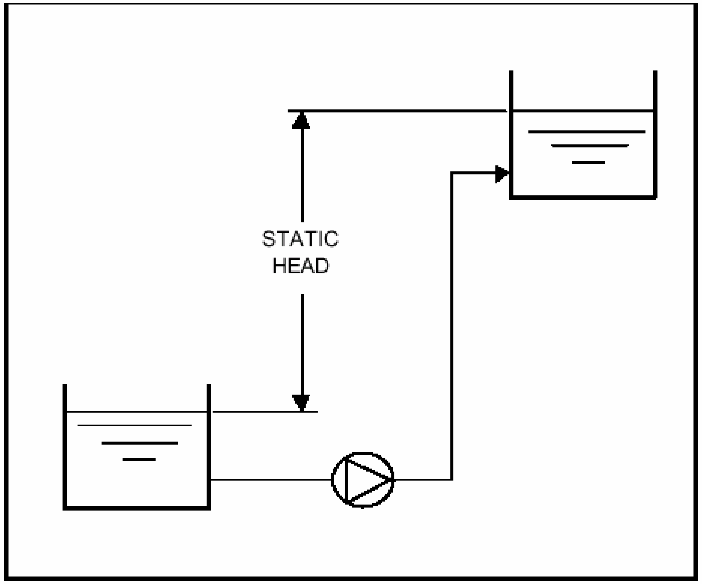
- **Electrical input power** = $\dfrac{\text{Pump shaft power } P}{\eta_{Motor}}$

System Characterstics

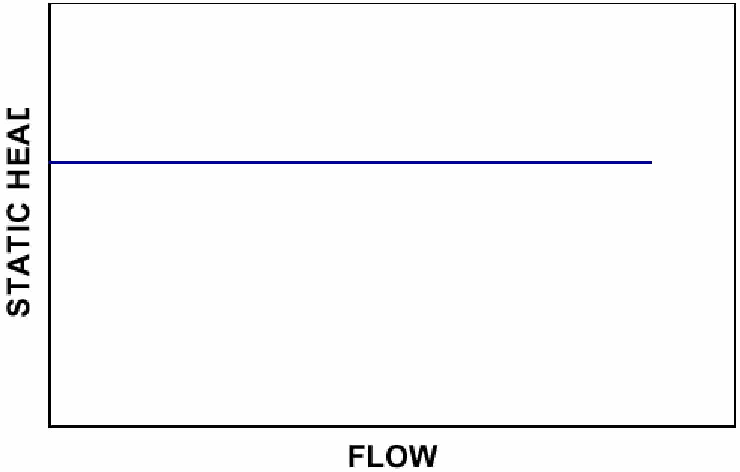
- A pressure is needed to overcome losses in the system i.e. Static & Friction losses.
- Static Head : Difference between the heights of the Supply & Destination Reservoirs.Static Head is independent of Flow.
- Friction Head : Losses in piping system & equipments. Friction losses are proportional to the square of the flow rate.

6.2 System Characteristics

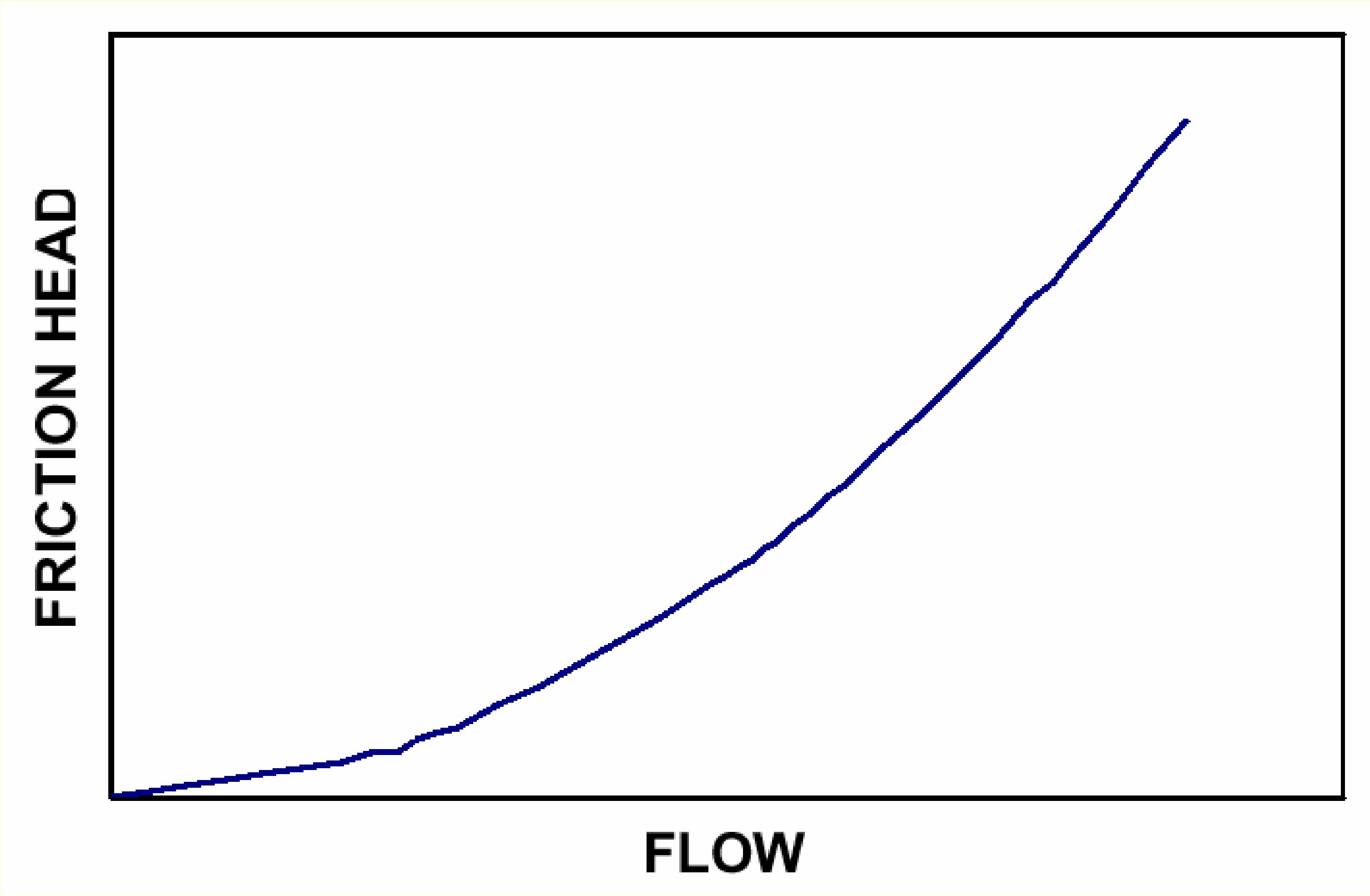
Static Head



Static Head vs. Flow

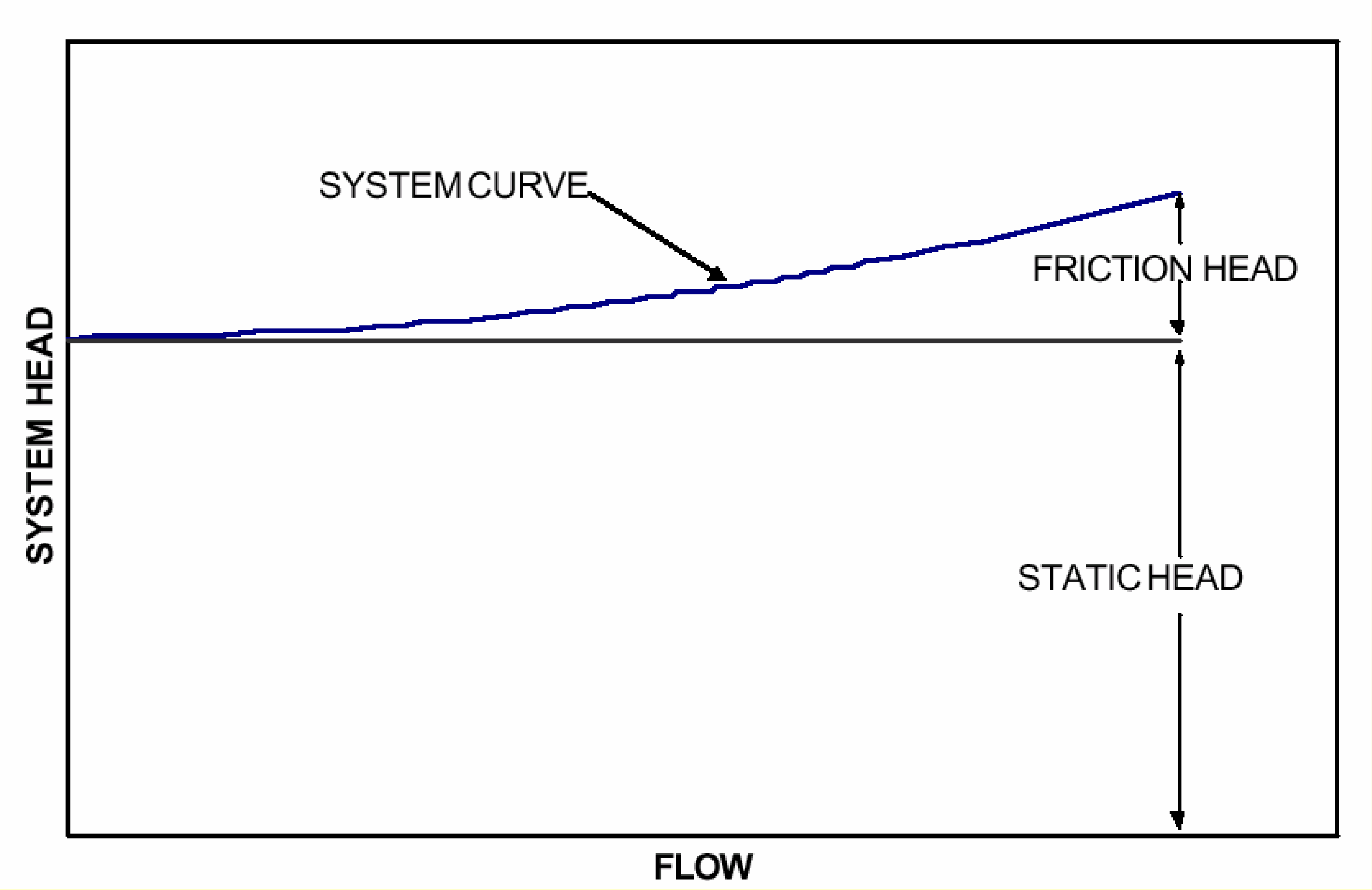


Dynamic (Friction) Head

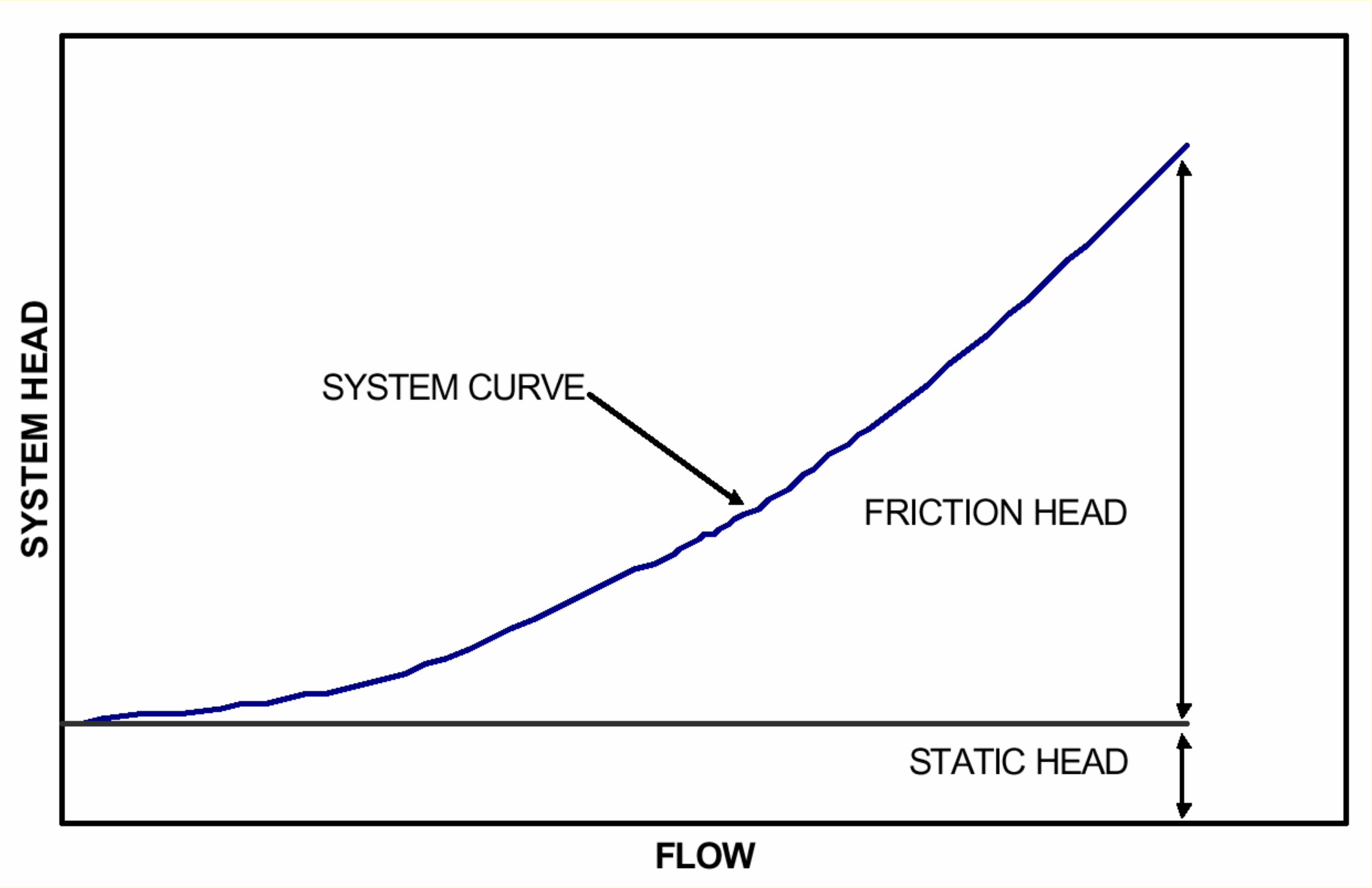


Friction Head vs. Flow

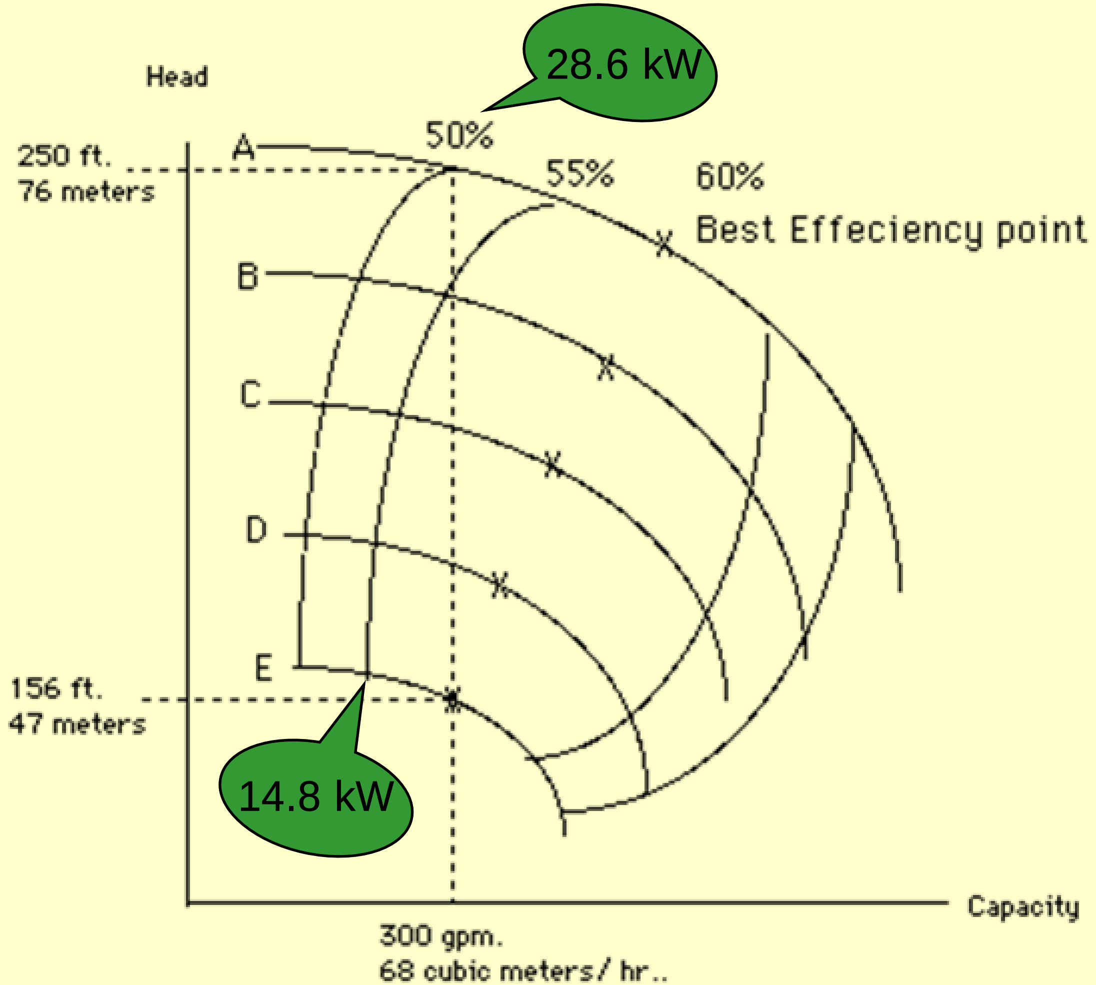
System with high static head



System with low static head



ENERGY LOSS IN THROTTLING



If we select E, then the pump efficiency is 60%

- Hydraulic Power = $\frac{Q\ (m^3/s) \times \text{Total head, } h_d - h_s\ (m) \times \rho\ (kg/m^3) \times g\ (m^2/s)}{1000}$

$$= \frac{(68/3600) \times 47 \times 1000 \times 9.81}{1000}$$

= 8.7 kW

- Shaft Power - 8.7 / 0.60 = 14.5 Kw
- Motor Power - 14.8 / 0.9 = 16.1Kw (considering a motor efficiency of 90%)

If we select A, then the pump efficiency is 50%

- Hydraulic Power = $\frac{Q\ (m^3/s) \times \text{Total head, } h_d - h_s\ (m) \times \rho\ (kg/m^3) \times g\ (m^2/s)}{1000}$

$$\frac{(68/3600) \times 76 \times 1000 \times 9.81}{1000}$$

= 14 kW

Shaft Power - 14 / 0.50 = 28 Kw

Motor Power - 28 / 0.9 = 31 Kw (considering a motor efficiency of 90%)

Using oversized pump !

As shown in the drawing, we should be using impeller "E" to do this, but we have an oversized pump so we are using the larger impeller "A" with the pump discharge valve throttled back to 68 cubic meters per hour, giving us an actual head of 76 meters.

- Hence, additional power drawn by A over E is 31 –16.1 = 14.9 kW.
- Extra energy used - 8760 hrs/yr x 14.9 = 1,30,524 kw.

= Rs. 5,22,096/annum

In this example, the extra cost of the electricity is more than the cost of purchasing a new pump.

Flow vs Speed

If the speed of the impeller is increased from N_1 to N_2 rpm, the flow rate will increase from Q_1 to Q_2 as per the given formula:

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

The affinity law for a centrifugal pump with the impeller diameter held constant and the speed changed:

Flow: is proportional to Speed

$Q1 / Q2 = N1 / N2$

Example: $100 / Q_2 = 1750/3500$

$Q_2 = 200\ m^3/hr$

Head Vs speed

The head developed(H) will be proportional to the square of the quantity discharged, so that

$$\frac{H_1}{H_2} = \frac{{Q_1}^2}{{Q_2}^2} = \frac{{N_1}^2}{{N_2}^2}$$

Head:

$$H1/H2 = (N1^2) \; / \; (N2^2)$$

Example: $100 / H_2 = 1750\ 2 \; / \; 3500$

$H_2 = 400$ m

Power Vs Speed

The power consumed(W) will be the product of H and Q, and, therefore

$$\frac{W_1}{W_2} = \frac{Q_1^3}{Q_2^3} = \frac{N_1^3}{N_2^3}$$

Power(kW):

kW1 / kW2 = $(N1^3)$ / $(N2^3)$

Example: 5/kW_2 = 17503 / 35003

kW_2 = 40

Effects of Impeller Dia. Change

Flow:

Q1 / Q2 = D1 / D2

Example: 100 / Q2 = 8/6

Q2 = 75 m^3/hr

Head:

H1/H2 = (D1) x (D1) / (D2) x (D2)

Example: 100 /H2 = 8 x 8 / 6 x 6

H2 = 56.25 m

Horsepower(BHP):

kW1 / kW2 = (D1) x (D1) x (D1) / (D2) x (D2) x (D2)

Example: 5/kW2 = 8 x 8 x 8 / 6 x 6 x 6

kW2 = 2.1 kW

Reducing impeller diameter

- Changing the impeller diameter gives a proportional change in peripheral velocity
- Diameter changes are generally limited to reducing the diameter to about 75% of the maximum, i.e. a head reduction to about 50%
- Beyond this, efficiency and NPSH are badly affected
- However speed change can be used over a wider range without seriously reducing efficiency
- For example reducing the speed by 50% typically results in a reduction of efficiency by 1 or 2 percentage points.
- It should be noted that if the change in diameter is more than about 5%, the accuracy of the squared and cubic relationships can fall off and for precise calculations, the pump manufacturer's performance curves should be referred to

ENERGY CONSERVATION IN PUMPING SYSTEM

- Ensure availability of instruments like Pressure Gauge,Flow meters etc.
- Operate pump near best efficiency point.
- Modify pumping system & pump losses to minimize throttling.
- Use booster pumps for small loads requiring high pressures.
- Increase Fluid temperature diffrentials to reduce pumping rates in heat exchangers.
- Repair Seals & packing to minimize water loss by dripping.

ENERGY CONSERVATION IN PUMPING SYSTEM

- Optimize Flow requirements & reduce pump power requirements.
- Conduct water balance to minimise water consumption.
- In multiple pump operation , carefully combine the operation of pump to avoid throttling.
- Replace old pumps & motors by Energy efficient pumps.

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