PUMPS AND PUMPING STATIONS

AAiT, Civil Engineering Department
Zerihun Alemayehu

PUMPING

- The operation of lifting water or any fluid is called pumping
- **Pump**, a mechanical machine, is used for lifting water or any fluid to a higher elevations or at higher pressures.

Purposes of Pumping

- To increase the water pressure at certain points in the distribution system.
- To lift treated water to elevated storage tanks→ flow automatically under gravity into distribution system.
- To lift raw river water to carry it to treatment plant.
- To lift water available from wells to an elevated storage tank in stages.
- To pump water directly into the distribution system.
- To take out water from basins, sumps, tanks etc.

Types of pumps

- Classification based on mechanical principle of operation
  (i) Displacement pumps
  (ii) Centrifugal pumps
  (iii) Air lift pumps
  (iv) Miscellaneous pumps
- Classification based on type of power required
  (i) Steam engine pumps
  (ii) Diesel engine pumps
  (iii) Electrically driven pumps
- Classification based on the type of service called for
  (i) Low lift pumps
  (ii) High lift pumps
  (iii) Deep well pumps
  (iv) Booster pumps

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Selection of pump

- Capacity of pump
- Number of pump units required
- Suction conditions
- Lift (total head)
- Discharge conditions and variations in load
- Floor space requirement
- Flexibility of operation
- Starting and priming characteristics
- Type of drive required
- Initial costs and running costs.

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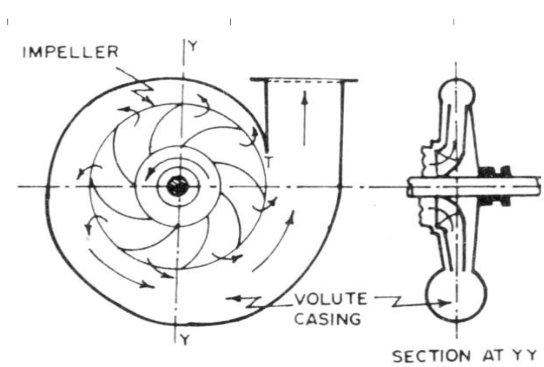
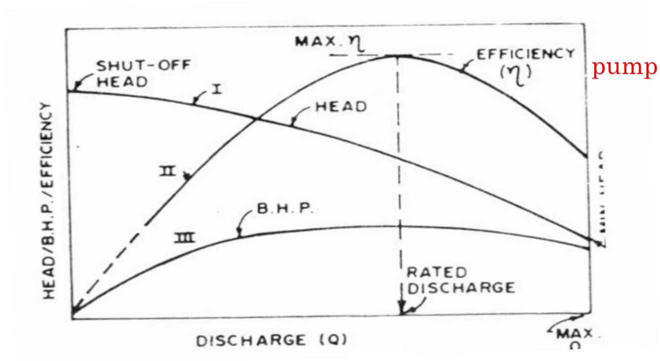
Centrifugal pumps

- Rotodynamic pumps which convert Mechanical energy into Hydraulic energy by centripetal force on the liquid.



Centrifugal pumps…

- key performance parameters of centrifugal pumps are capacity, head, BHP (Brake horse power), BEP (Best efficiency point) and specific speed.



pump operating curve

Pumping terms

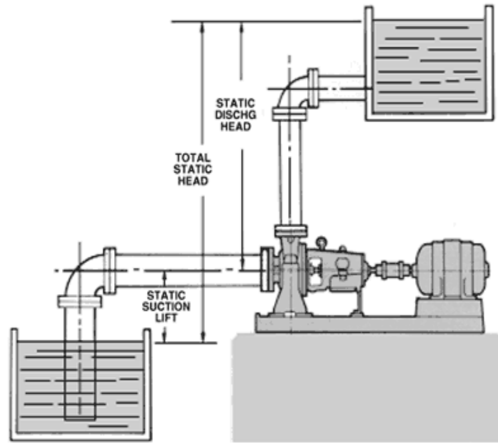
- *Head:* A Centrifugal pump → velocity energy to a liquid → pressure energy.

- $$Head = H = \frac{v^2}{2g}$$

$$peripheral\ impeller\ velocity = v = \frac{RPM \times D}{60}$$

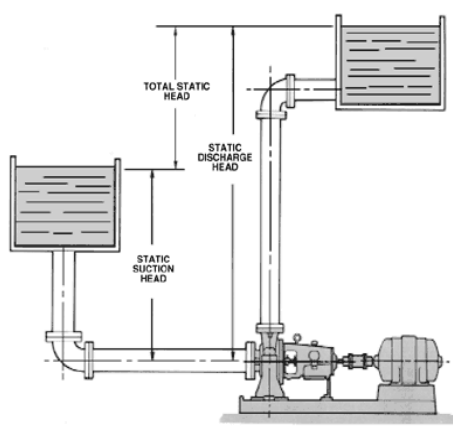
PUMPING TERMS…

- *SUCTION LIFT* exists when the source of supply is below the center line of the pump.
- *STATIC SUCTION LIFT* is the vertical distance in meter from the centerline of the pump to the free level of the liquid to be pumped.



PUMPING TERMS…

- *STATIC DISCHARGE HEAD* is the vertical distance between the pump centerline and the point of free discharge
- *TOTAL STATIC HEAD* is the vertical distance between the free level of the source of supply and the point of free discharge or the free surface of the discharge liquid.



Pumping terms…

- FRICTION HEAD (h_f) is the head required to overcome the resistance to flow in the pipe and fittings.
- TOTAL DYNAMIC SUCTION LIFT (hs) is the static suction lift minus the velocity head at the pump suction flange plus the total friction head in the suction line.
- TOTAL DYNAMIC SUCTION HEAD (hs) is the static suction head plus the velocity head at the pump suction flange minus the total friction head in the suction line.

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Pumping terms…

- TOTAL DYNAMIC DISCHARGE HEAD (hd) is the static discharge head plus the velocity head at the pump discharge flange plus the total friction head in the discharge line.
- HEAD (H) or TOTAL Dynamic HEAD (TDH)
  - **TDH = $h_d + h_s$ (with a suction lift)**
    TDH = $h_d - h_s$ (with a suction head)

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Power and Efficiency

- The work performed by a pump is a function of the total head and the weight of the liquid pumped in a given time period.
- Work done by the pump = W x H m-kg/sec = γ x Q x H m-kg/sec
- Pump input or brake horsepower (BHP) is the actual horsepower delivered to the pump shaft.
- Pump output or hydraulic horsepower (WHP) is the liquid horsepower delivered by the pump.

$$WHP = \frac{Q \times TDH \times Sp.\ Gr.}{75}$$

$$BHP = \frac{Q \times TDH \times Sp.Gr.}{75 \times Pump\ Efficiency}$$

$$Pump\ Efficiency = \frac{WHP}{BHP} = \frac{Q \times TDH \times Sp.\ Gr.}{75 \times BHP}$$

Example 1

Population of a city is 120,000 and rate of water supply per head per day is 200 liters. Calculate the BHP of motor to raise the water to an overhead tank 50 m high. Length and diameter of the rising main is 200 m and 40 cm, respectively. Assume motor efficiency 90 % and the of the pump 60 %. Take *f* = 0.01 and peak hourly demand as 1.5 times the average demand.

Solution of example 1

- Average demand = 120,000 x 200
  = 24 x 10^6 L/day
  = 24000 m^3/day (0.28 m^3/sec)
- Peak hr demand = 1.5 x 0.28 m^3/sec = 0.42 m^3/sec
- Weight of liquid delivered by the pump
  =1000 kg/m^3 x 0.42 m^3/sec = 420 kg/sec
- Total static head = 50 m

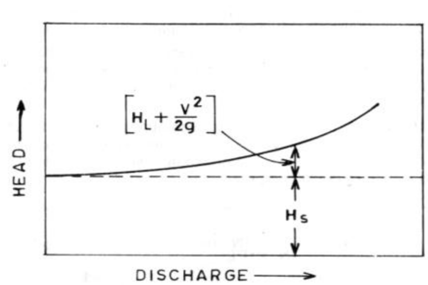
$$h_f = \frac{flQ^2}{12.1D^5} = \frac{0.01 \times 200 \times 0.42^2}{12.1 \times 0.2^5} = 2.85\ m$$

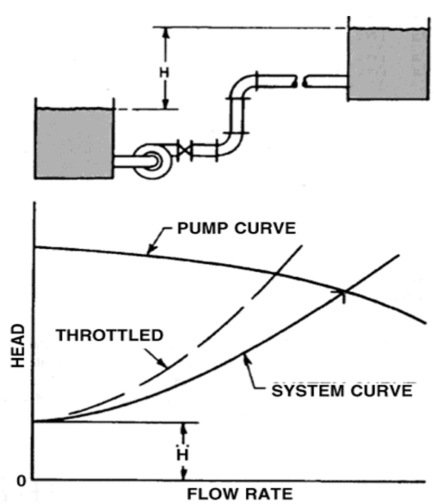
$H = h_s + h_f = 50 + 2.85 = 52.85$ m
$\eta = 0.9 \times 0.6 = 0.54$

$$BHP = \frac{WH}{75\eta} = \frac{420 \times 52.85}{75 \times 0.54} = 548\ Hp$$

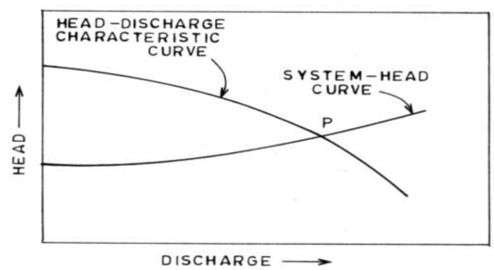
System-head curve

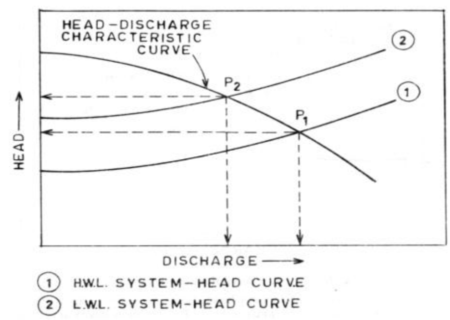
- System Head Curve: the relationship between *flow and hydraulic losses* in a system





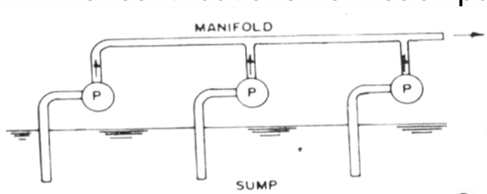
System-head curve

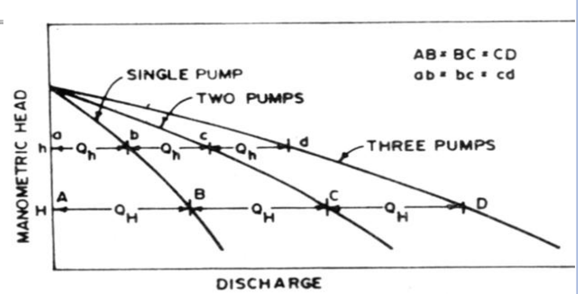




Pumps operating in parallel

- for a purpose of increasing the total discharge.
- Pumps should deliver the same head.
- The total system flow rate is equal to the sum of the flow rates of contributions from each pump.





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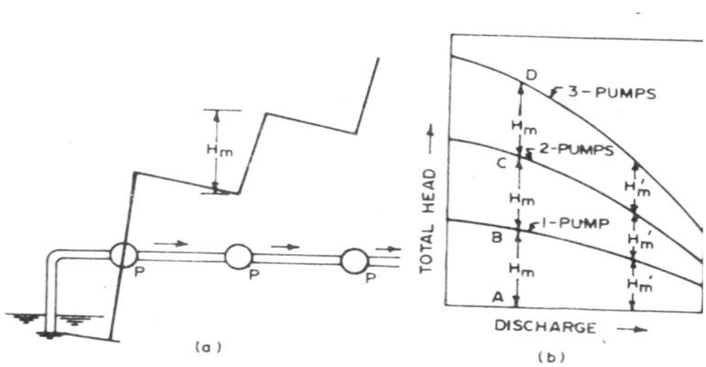
PUMPS OPERATING IN SERIES

- for a purpose of increasing the total head.
- the pumps connected should deliver the same discharge.
- The total system head is equal to the sum of the contributions from each pump.



CAVITATION

- Cavitation is a phenomenon of cavity formation or the formation and collapse of cavities.
- Cavities develop when the absolute pressure in a liquid reaches the vapor pressure related to the liquid temperature.
- When the net positive suction head (NPSH) is reduced → NPSHmin → detrimental cavitation
- The minimum static lift is given as

$$Z_{min} = \frac{p_a - p_v}{\gamma} - NPSH_{min} - h_{ls}$$

Where p_a is atmospheric pressure, p_v is vapor pressure of fluid and h_{ls} head loss in the suction pipe
NPSH is obtained from manufuctures

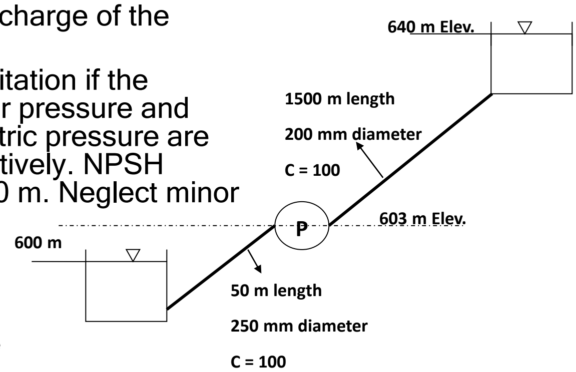
Examples 2

The pump shown in the figure below has a head characteristics that can be expressed by

$H = 100 - 6000Q^{1.85}$

Where H = pump head in meters and Q = discharge in m^3/s.

a. Calculate the head and discharge of the pump.
b. Check the potential for cavitation if the anticipated maximum vapor pressure and minimum absolute barometric pressure are 0.40 m and 9.70 m, respectively. NPSH required for the pump is 3.0 m. Neglect minor head losses.



Solution of Example 2

- First calculate the TDH
- TDH = Hs + h_{ld}+ h_{ls}
- Hs = 640 - 600 = 40 m

$$h_l = \frac{6.78L}{D^{1.165}}\left(\frac{V}{C}\right)^{1.85} = \frac{10.6L}{D^{4.865}}\left(\frac{Q}{C}\right)^{1.85}$$

❑ After inserting D and L we get

TDH = 40 +8067.66 $Q^{1.85}$

❑ Since the TDH and the head delivered by the pump has to be the same we have:

$100-6000\ Q^{1.85} = 40 + 8067.66\ Q^{1.85}$

→ Q = 0.0523 m3/sec and H = 74.45 m

Solution of Example 2

- H_{abs} = 9.70 m, H_{vap} = 0.40 m and NSPH = 3.0 m
- NPSH = H_{abs} - (H_{vap} + h_{ls} + suction lift)
  - Suction lift = 603-600 =3 m

$$h_{ls} = \frac{10.6x50}{0.25^{4.865}}\left(\frac{0.0523}{100}\right)^{1.85} = 0.3824\ m$$

- NSPH = 9.7 - (0.4 + 0.3824 + 3)

  = 5.92 > 3 → no cavitation

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