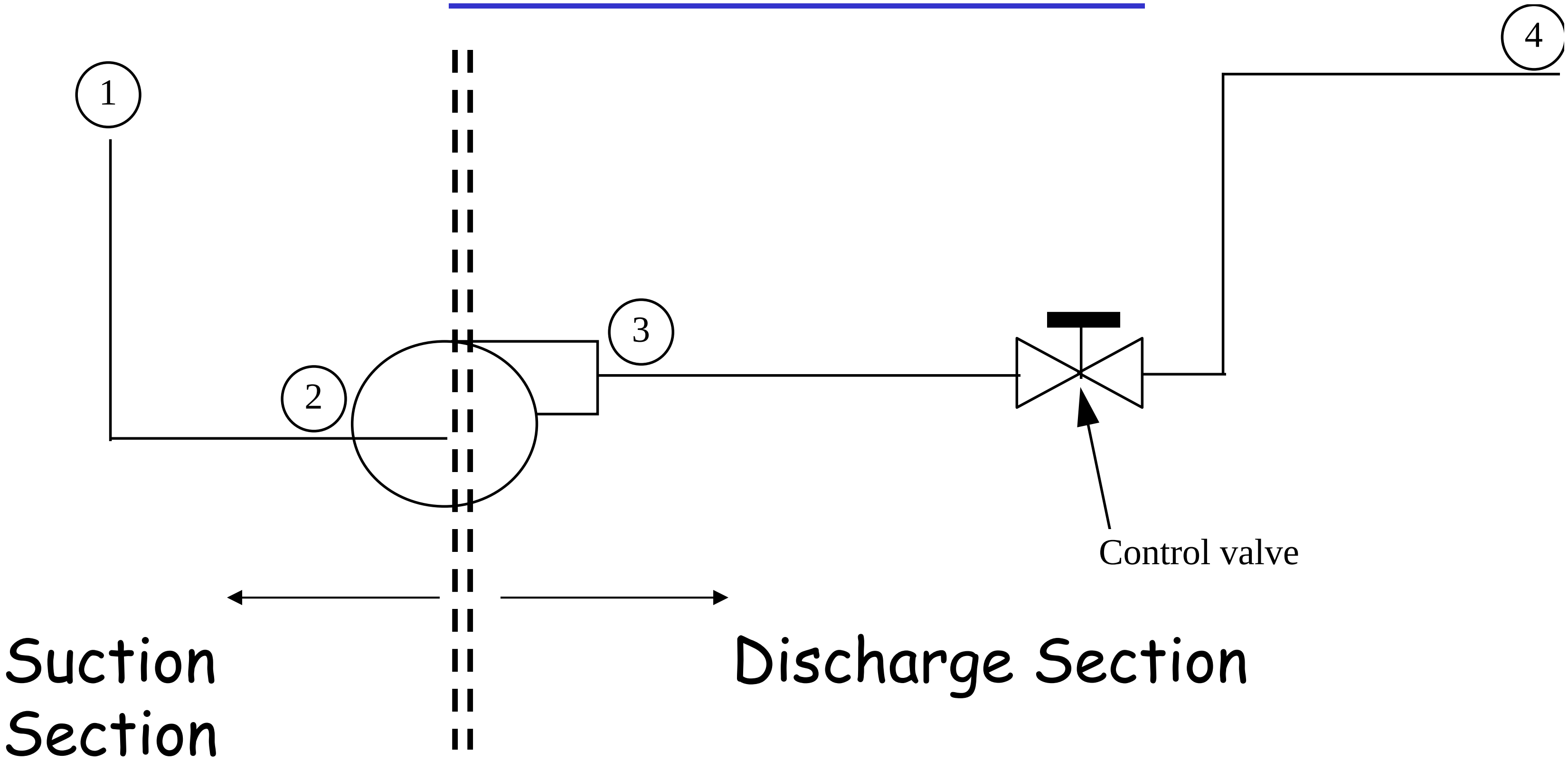
FLUID FLOW - PUMPS



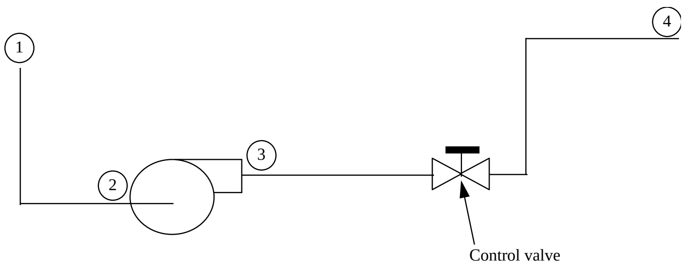
Two main types of pumps:

- **Positive Displacement pumps**
- **Centrifugal pumps**

FLUID FLOW - PUMP PERFORMANCE

Mechanical Energy Balance:

$$g\Delta Z + \int \frac{dp}{\rho} + \Delta\left(\frac{V^2}{2}\right) = W_o - \sum F$$



Between points 1 and 2 (note that these are 1 and 4 in previous slide):

$$g(Z_2 - Z_1) + \left(\frac{p_2}{\rho_2} - \frac{p_1}{\rho_1}\right) + \left(\frac{V_2^{\,2} - V_1^{\,2}}{2}\right) = \Delta W_o - \sum F$$

Divide by g to get units of length.

$$\left(Z_2 + \frac{p_2}{g\rho_2} + \frac{V_2^{\,2}}{2g}\right) - \left(Z_1 + \frac{p_1}{g\rho_1} + \frac{V_1^{\,2}}{2g}\right) = \Delta h - h_f$$

FLUID FLOW - PUMP PERFORMANCE

$$\left(Z_2 + \frac{p_2}{g\rho_2} + \frac{V_2^{\ 2}}{2g}\right) - \left(Z_1 + \frac{p_1}{g\rho_1} + \frac{V_1^{\ 2}}{2g}\right) = \Delta h - h_f$$

Z: Potential or static Head
$P/\rho g$: Pressure head

$\frac{V_1^{\ 2}}{2g}$: Velocity head

Δh: Total head of the pump
h_f: Head loss due to friction

Note: Total head of the system: Solution of the MEB eqn.
Total head of the pump: The manufacturer provides it.

FLUID FLOW - PUMP PERFORMANCE

Total Dynamic Head, TDH

$$TDH = P_d - P_S$$

P_d = discharge pressure
P_s= suction pressure

Hydraulic Horsepower

$$W_h(hp) = \frac{Q(gpm)TDH(psi)}{1714.3}$$

Shaft Efficiency

$$\eta = \frac{W_h}{W_b}$$

W_h = theoretical required power (hp)
W_b= actual shaft work or brake-horsepower
Note: $\eta < 1$ because there are friction losses inside the pump.

FLUID FLOW - PUMPS

Positive Displacement pumps

Used in cases when large pressure heads are needed.

1. Rotary pumps (rotating gears, lobes or screws).
2. Reciprocating pumps (pistons).
3. Miscellaneous (e.g. peristaltic pumps).

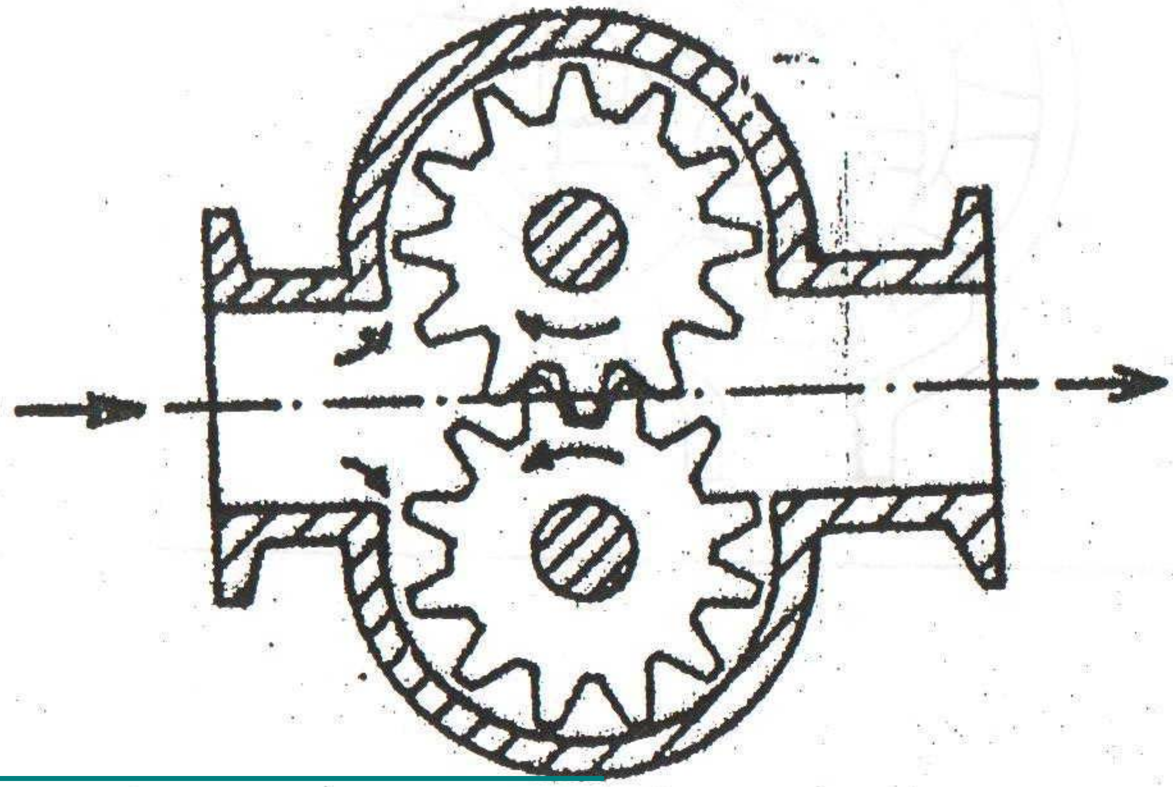
ADVANTAGES:

- Self-priming.
- Can work in two directions.
- Can pump liquids with gases for a small amount of time.

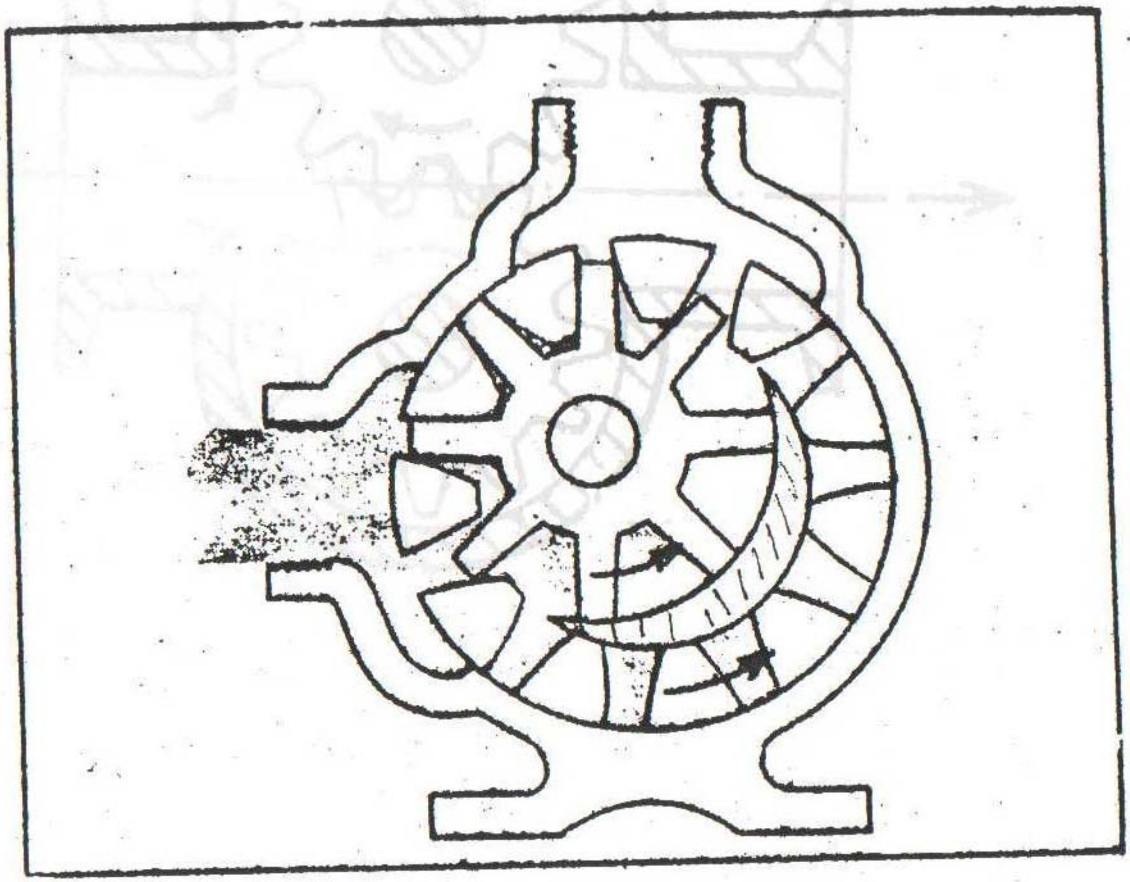
DISADVANTAGES:

- Most of them cannot operate with closed discharge.
- Might produce oscillations in discharge.

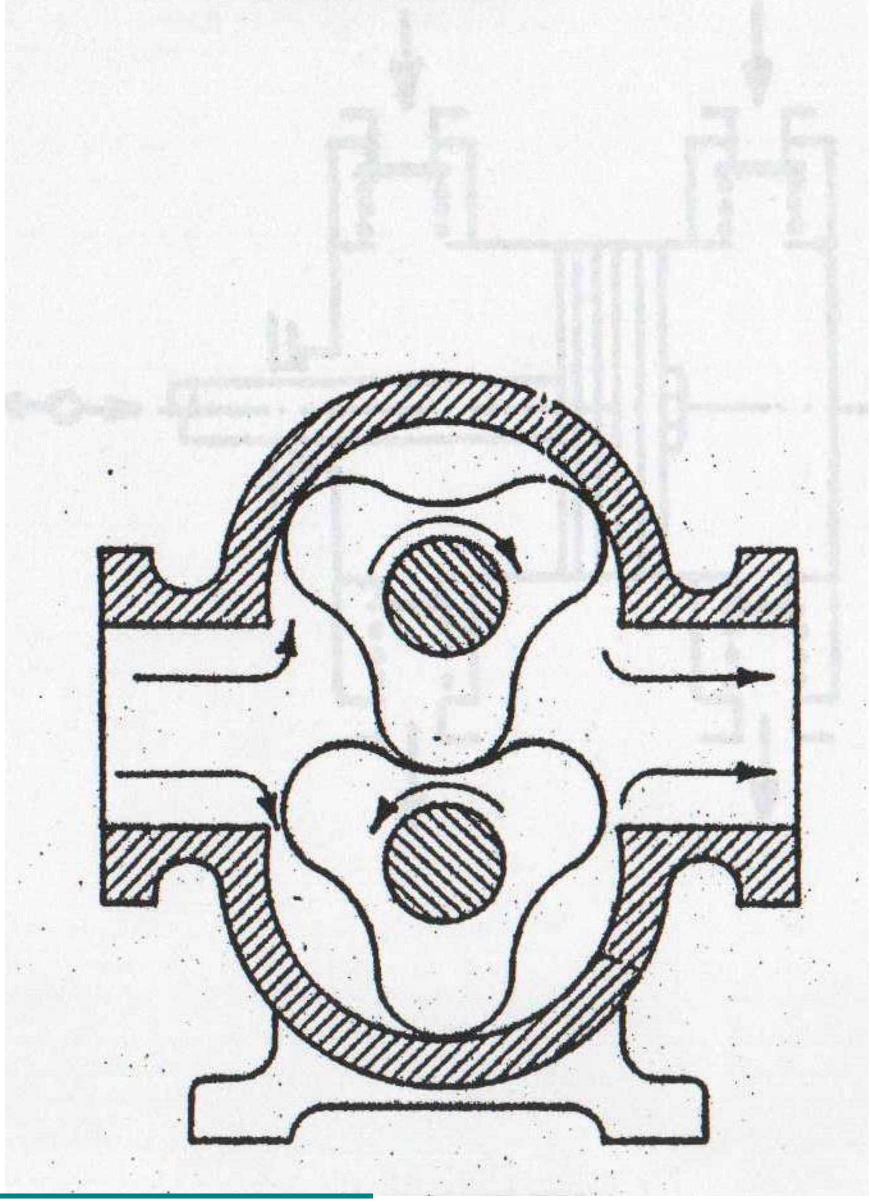
External Gear Pump



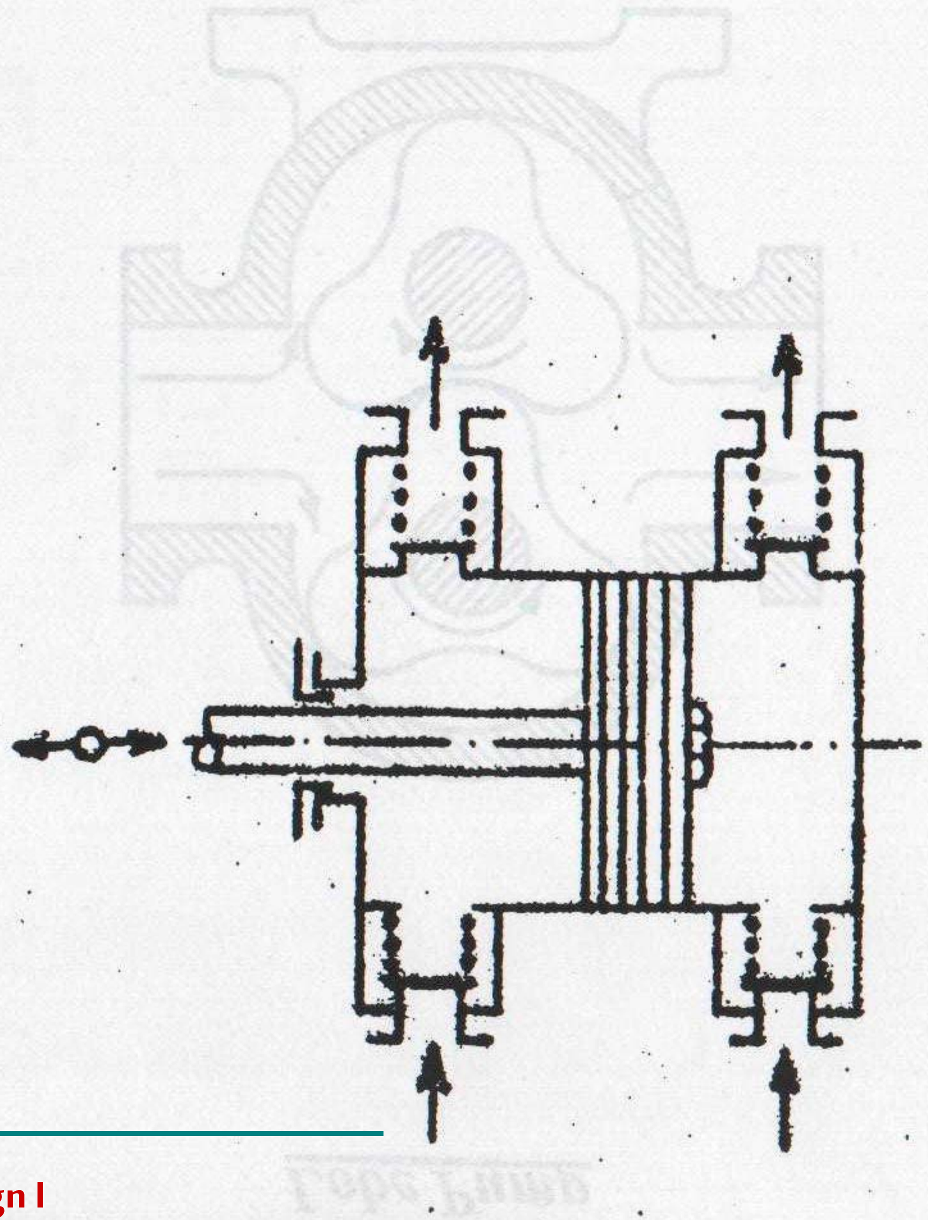
Internal Gear Pump



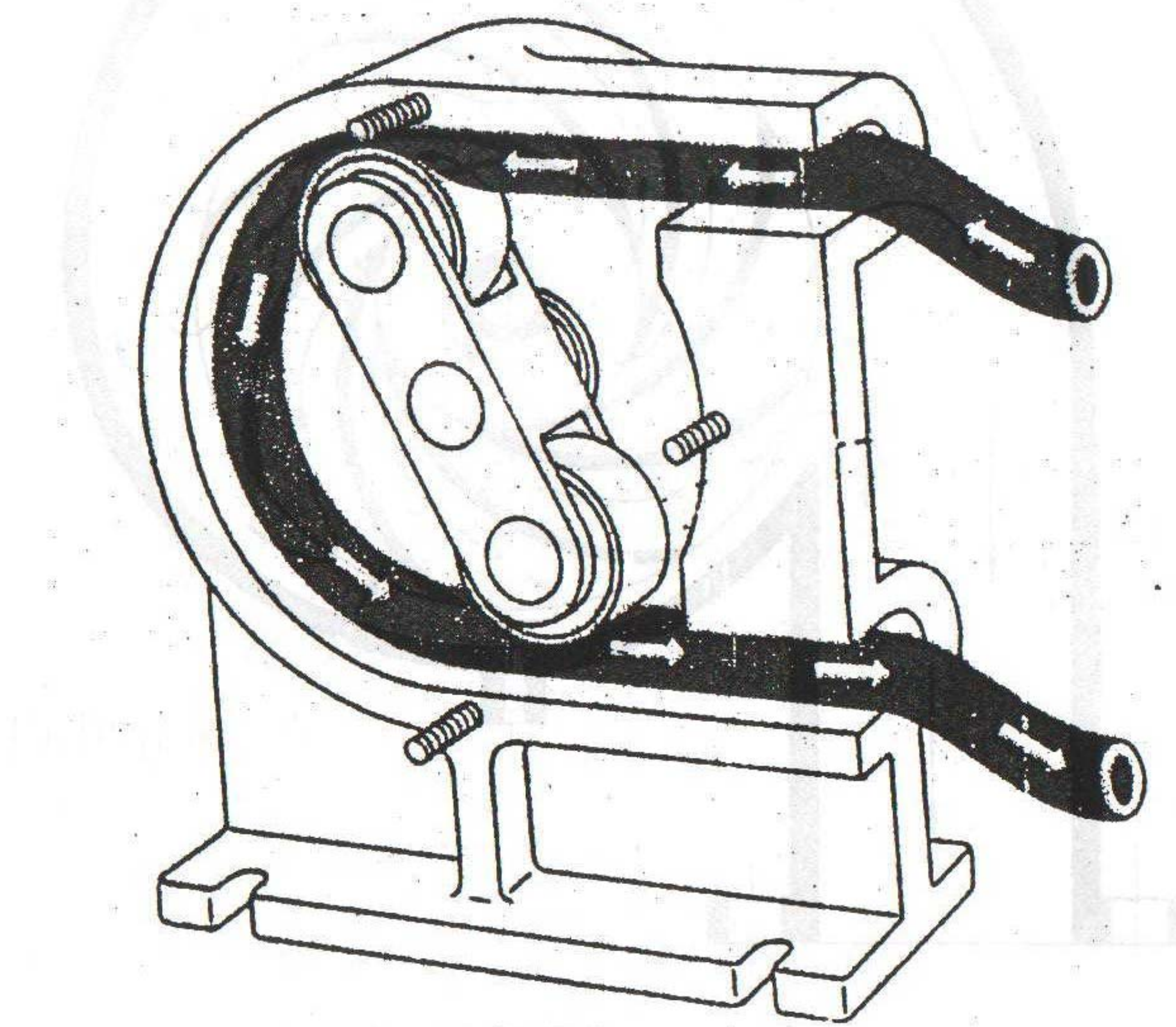
Lobe Pump



Piston pump



Peristaltic Pump



FLUID FLOW - PUMPS

Centrifugal pumps

1. Volute pumps (shell and simple impeller).
2. Diffuser pumps (diffuser vanes around the impeller).
3. Turbine pumps.
4. Propeller pumps.

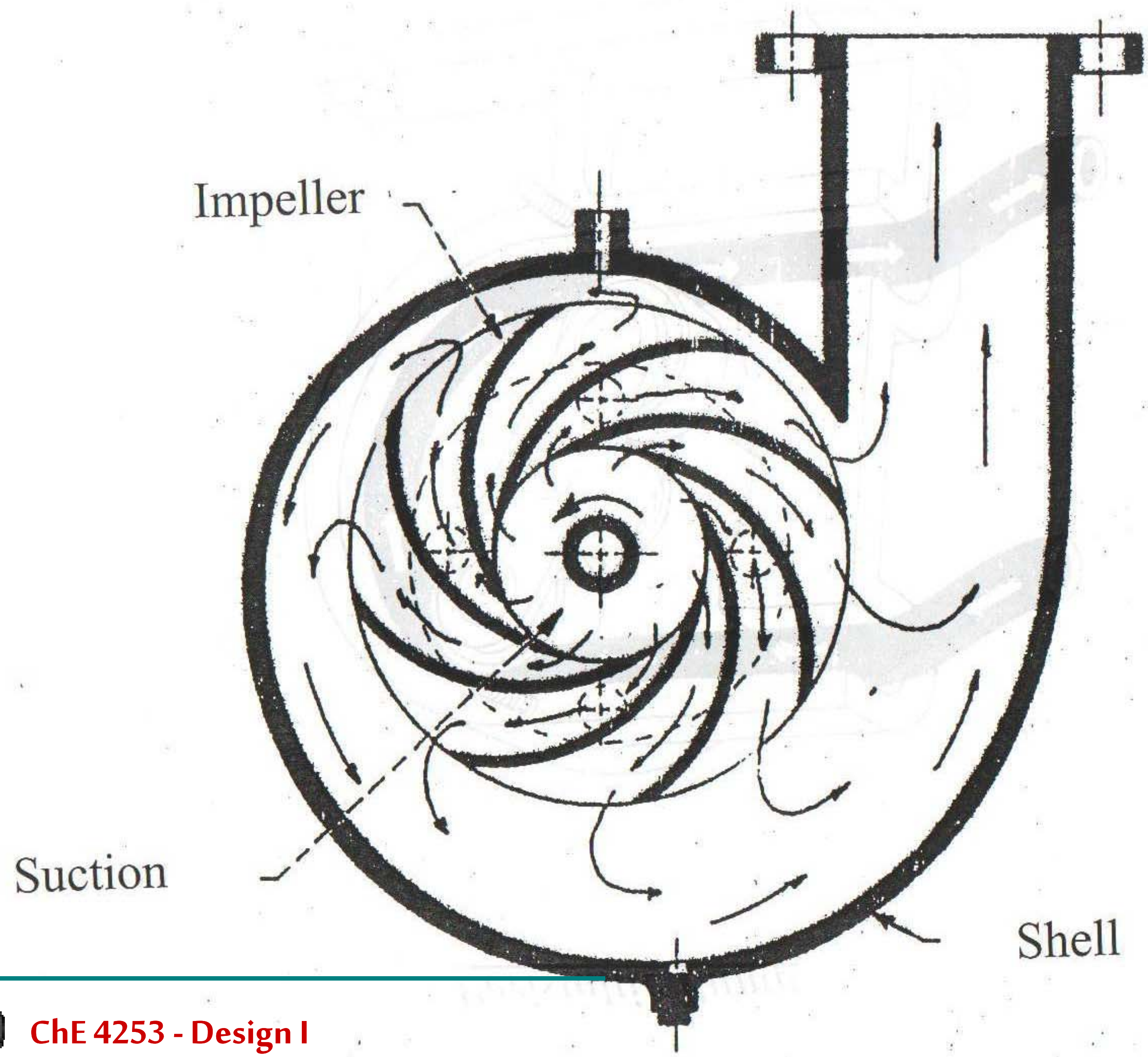
ADVANTAGES:

- Low cost - easy maintenance.
- Do not produce a lot of noise.
- Uniform discharge (no oscillations).

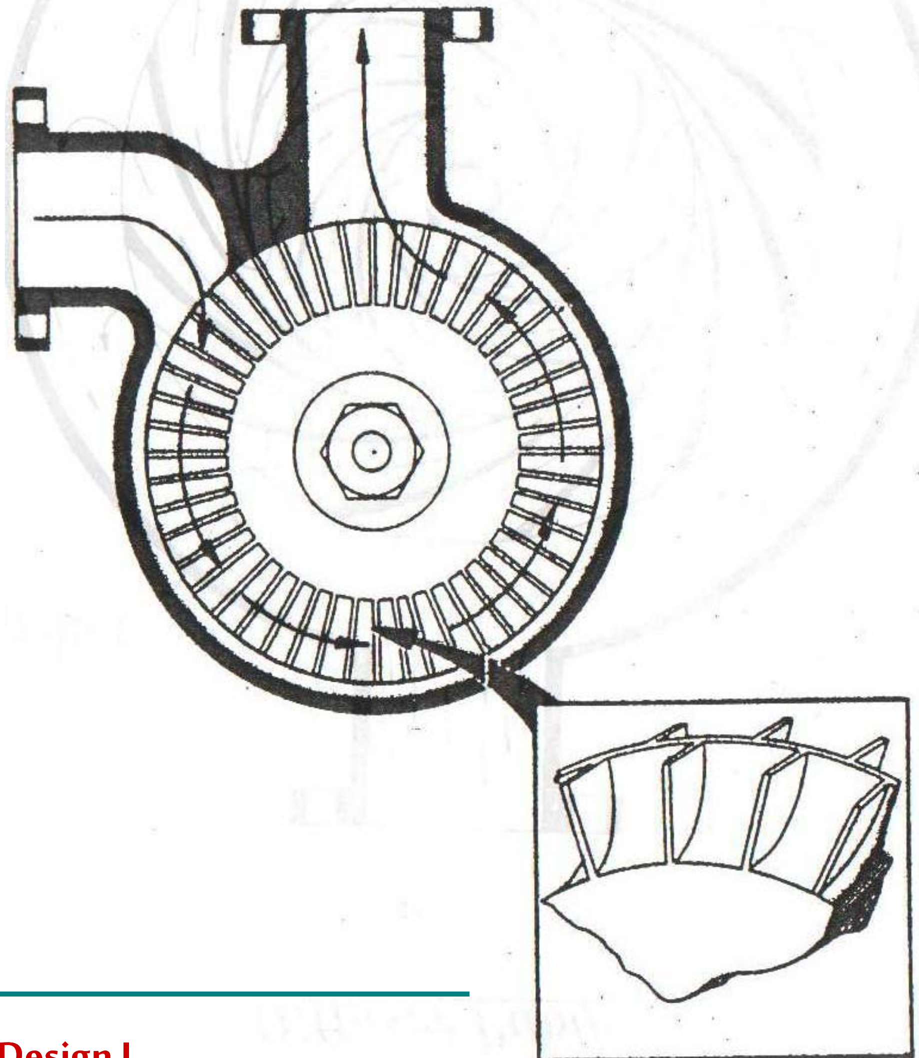
DISADVANTAGES:

- Do not produce large heads.
- Do not work well with high viscosity fluids.

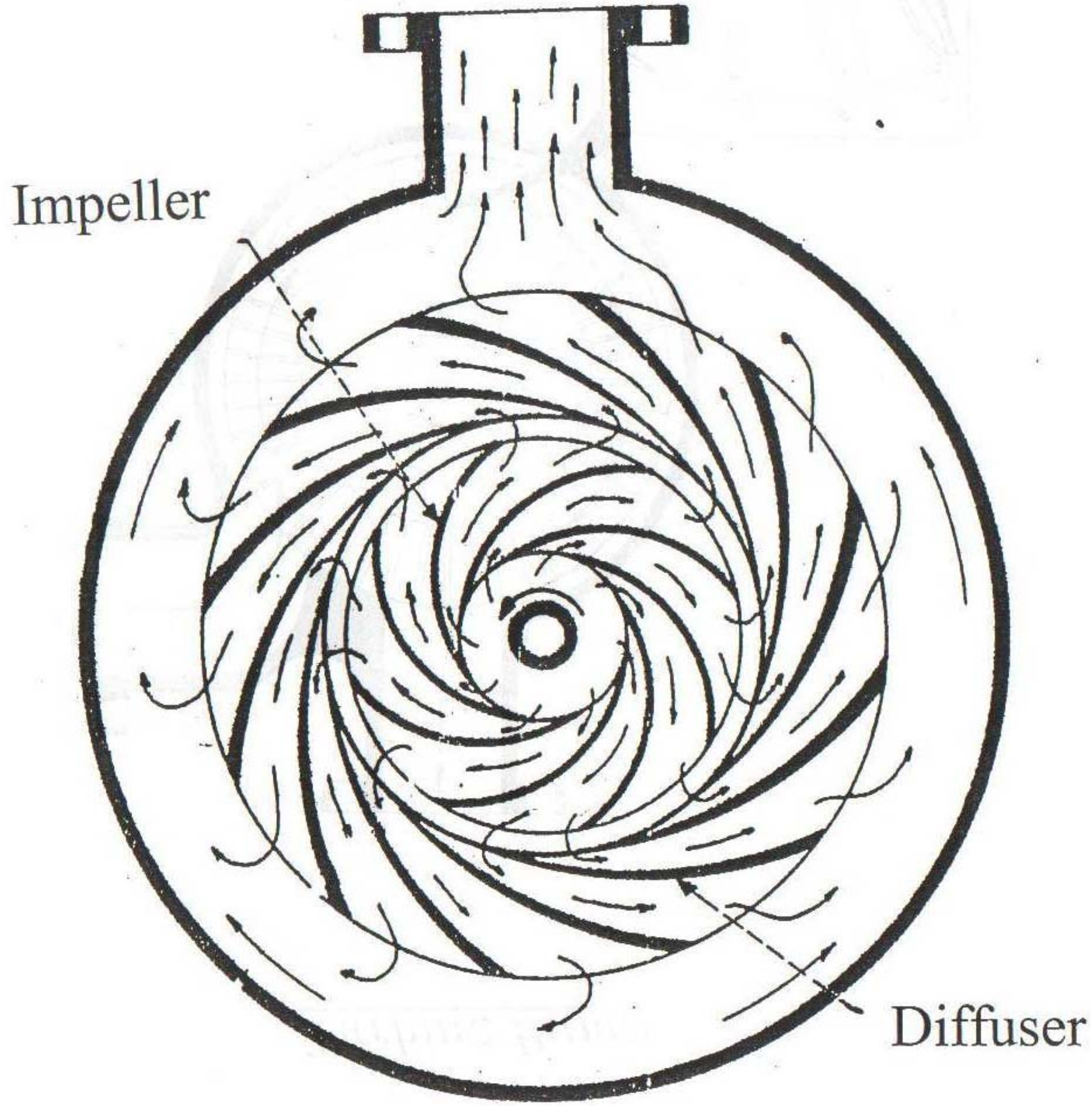
Volute Pump



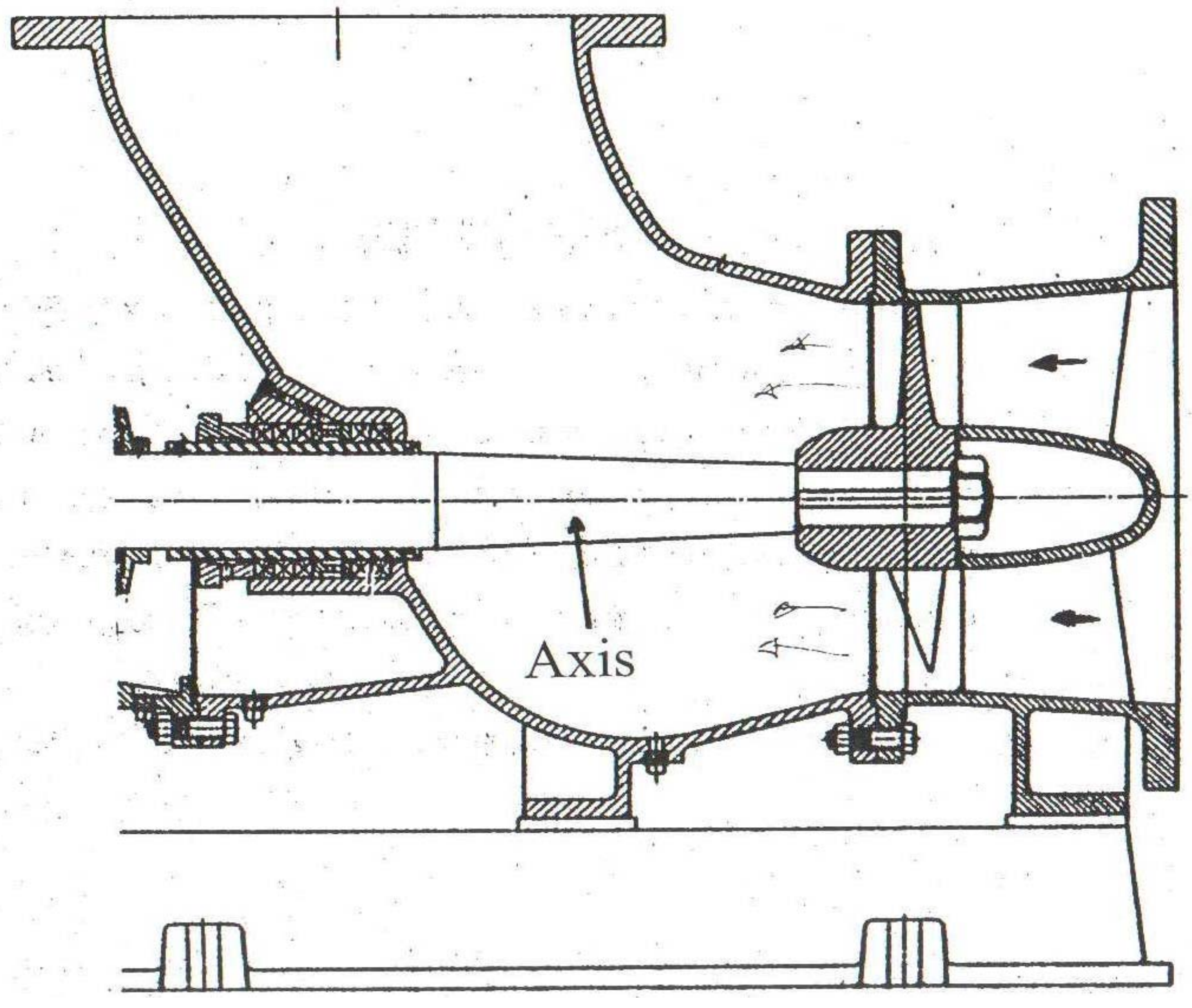
Turbine Pump



Diffuser Pump



Propeller Pump



Centrifugal pumps- Advantages and dissadvantages

Advantages	**Volute pumps**	**Diffuser pumps**	**Turbines**	**Propeller pumps**
Simple construction	X			X
Quiet operation	X	X	X	X
Long life-time	X	X		
Capable of pumping fluids with particles	X	X		X
Capable of pumping fluids with gases or vapors			X	
Self-priming			X	
No need for variable rpm motor	X	X	X	X
Disadvantages				
Not good for high viscosity fluids	X	X	X	X
Low discharge head	X	X	X	X
Accurate machining for rotor-shell required			X	

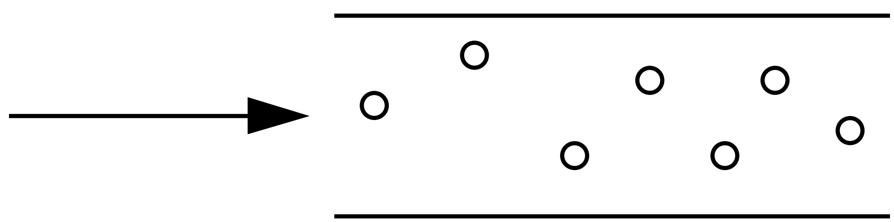
Fluid Flow - Pumps

Available Net Positive Suction Head

$$NPSHA = \frac{P_S}{\rho g} - \frac{P_V}{\rho g}$$

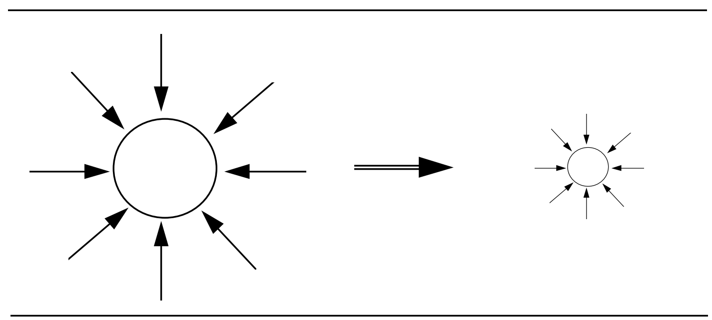
P_s= suction pressure
P_v= vapor pressure of fluid

NPSHA has to be positive. Otherwise, the fluid enters the pump with bubbles.



NPSHA:

As pressure increases inside the pump the bubbles collapse.



This phenomenon is called CAVITATION and it

- Reduces capacity
- Damages the pump

Fluid Flow - Pumps

Net Required Positive Suction Head (NPSHR)

Ideal pumps will not cavitate if NPSHA is positive.

However a small pressure decrease can take place in a pump due to internal losses close to the suction.

====> if NPSHA = 0 bubbles can form and cavitation takes place.

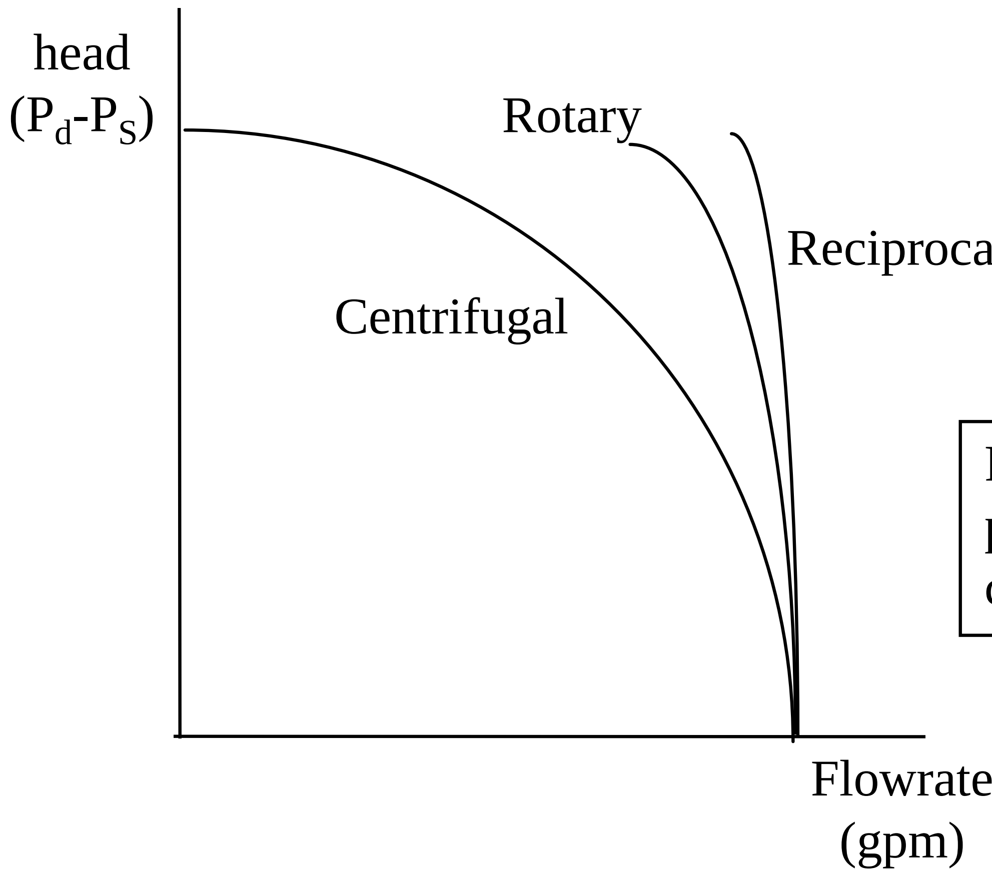
====> NPSHR is a required value suggested by the manufacturer

Specification Criteria

NPSHA > NPSHR

Fluid Flow - Pumps

Head Capacity Curves

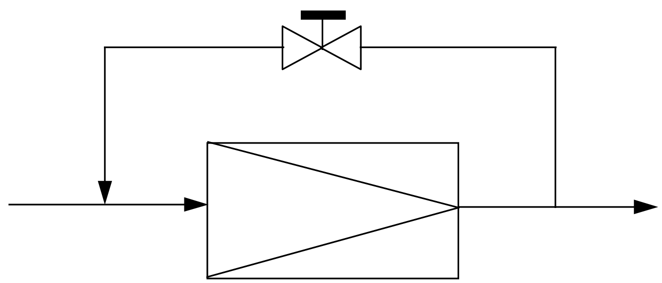


Positive displacement pumps give an approximate constant flow

Fluid Flow - Pumps

Thus, centrifugal pumps are chosen because they can operate in a wider range of flowrates (better control and process flexibility).

If you are stuck with a positive displacement pump, the following diagram shows how you can regulate flow.

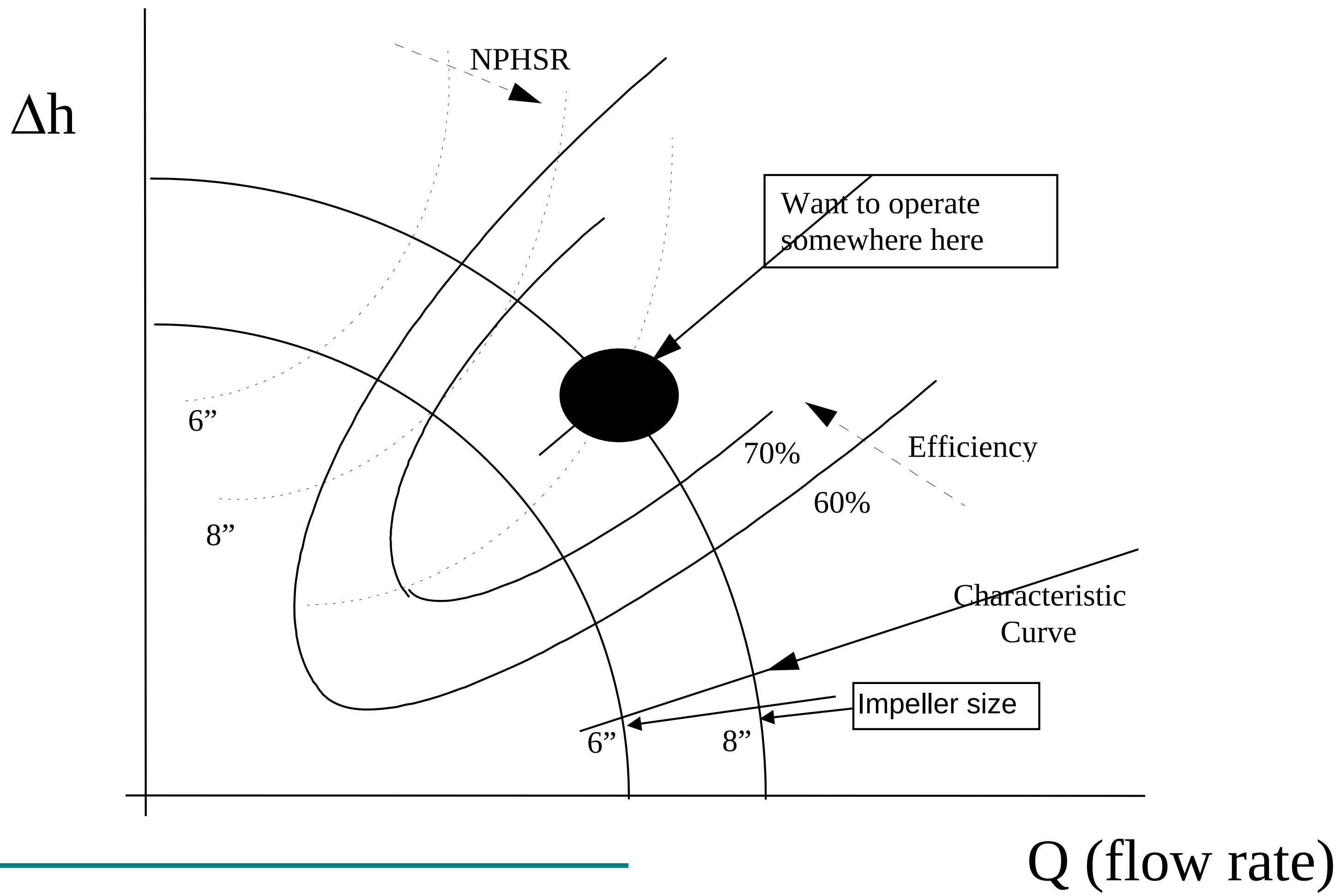


However, this arrangement will:

- use more energy
- heat up the fluid

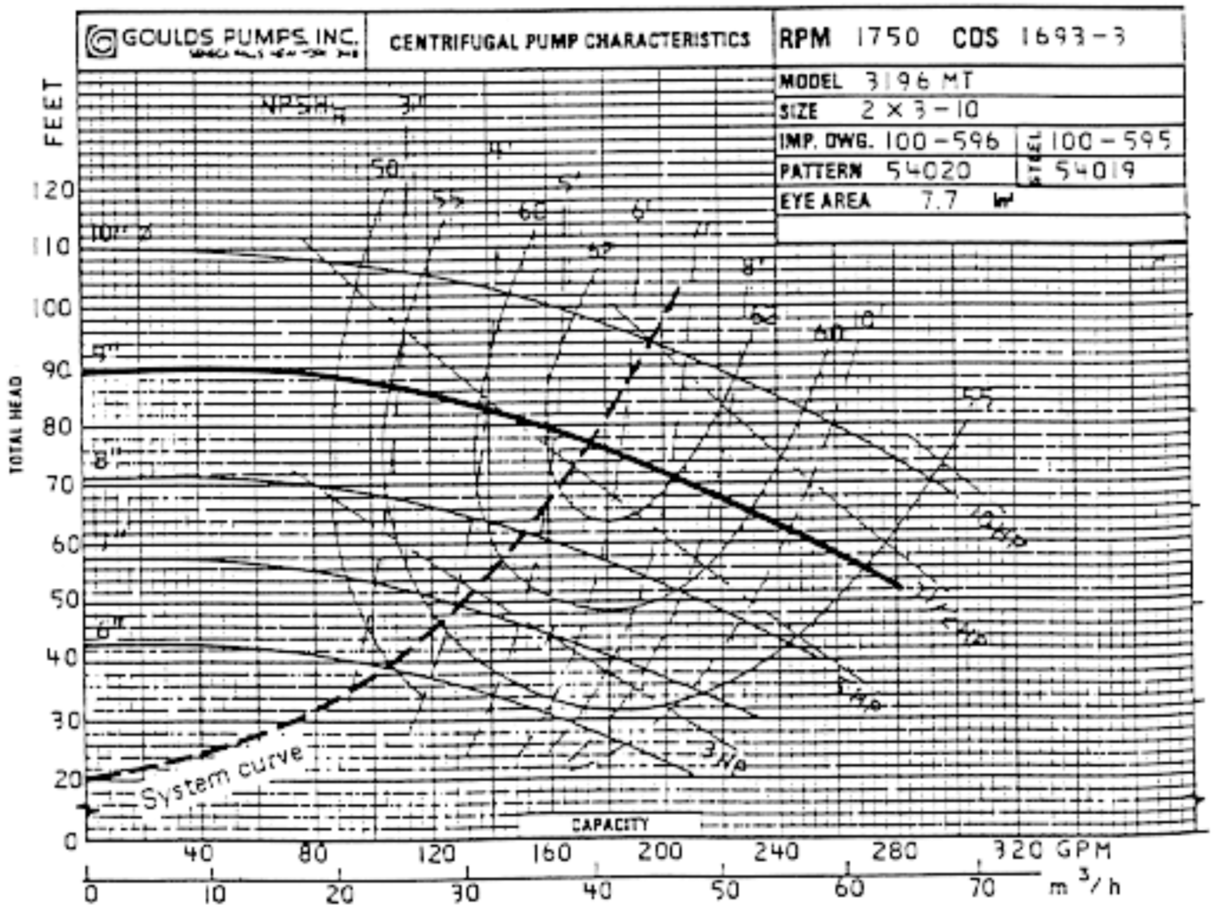
Fluid Flow - Pumps

Centrifugal Pump Performance Curves

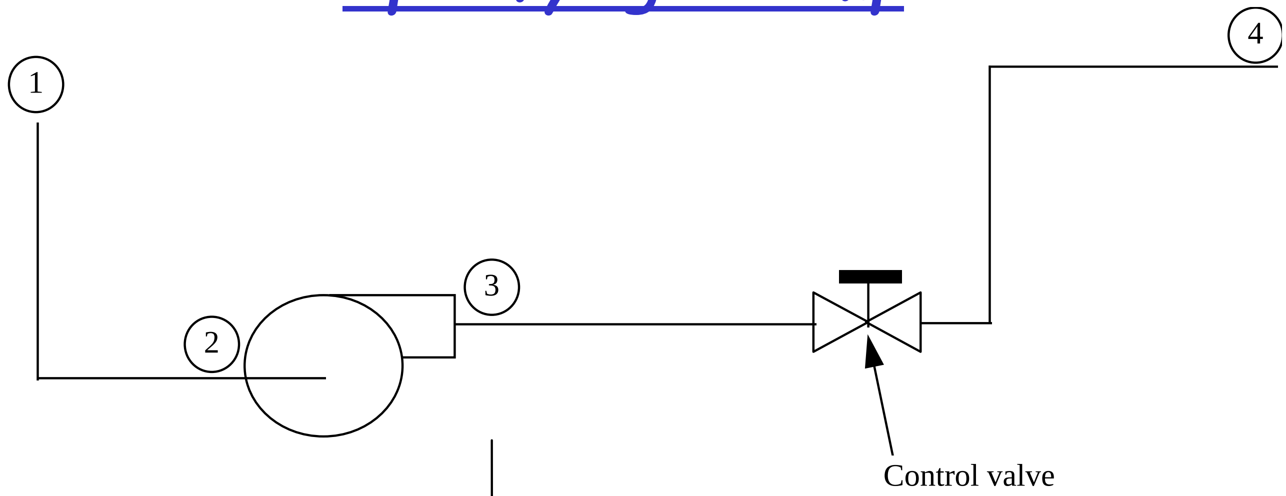


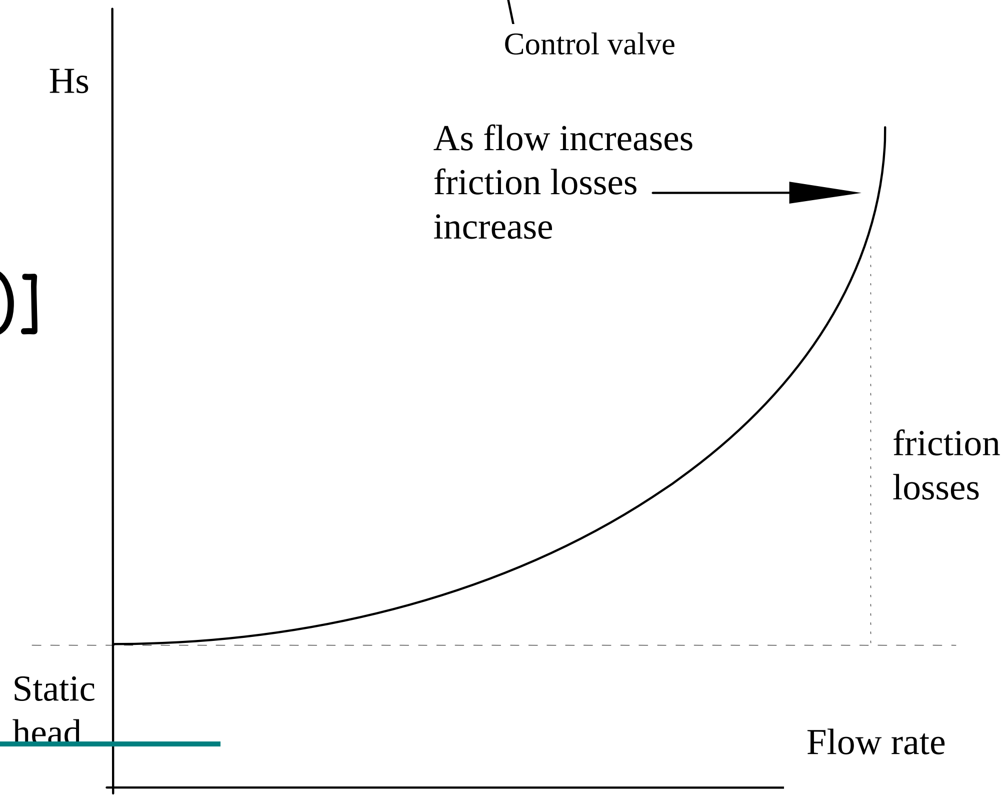
Specifying a Pump

Parameters you can control when selecting the pump:
impeller diameter, speed (not very common), the model
Things to look for: Maximum efficiency, NPSHA > NPSHR



Specifying a Pump

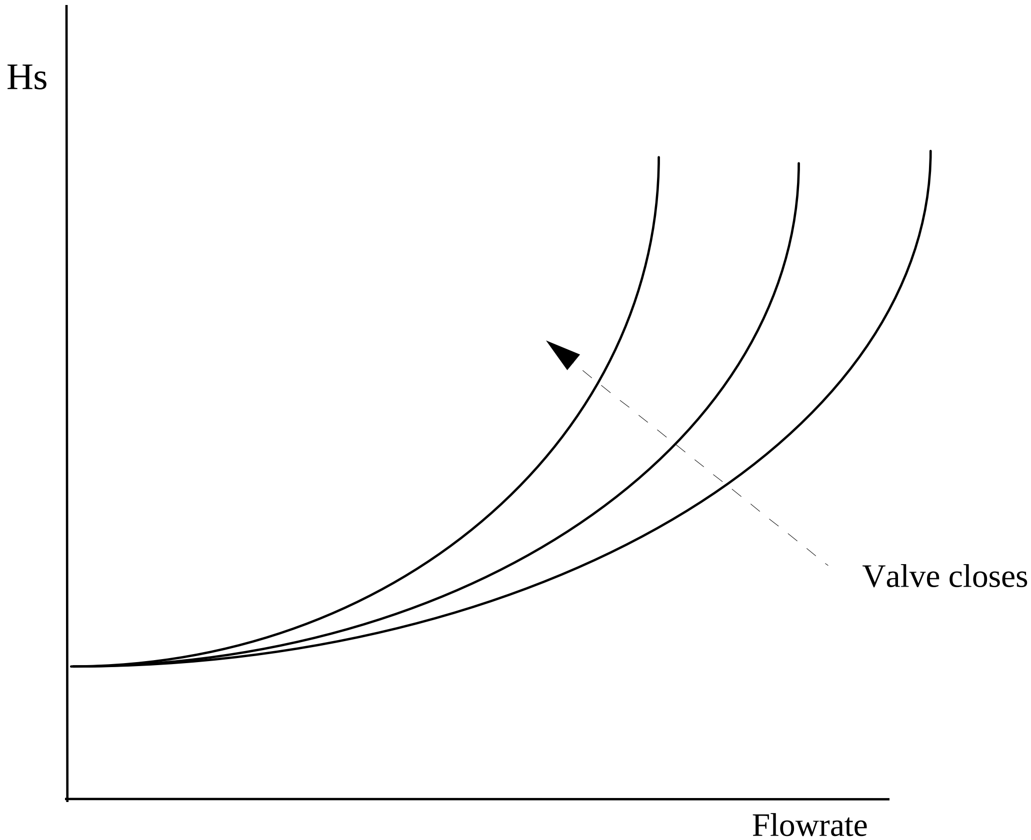




Need to calculate:
System head
$H_S = -[(P_4-P_3)+(P_2-P_1)]$
Pump head: Hp

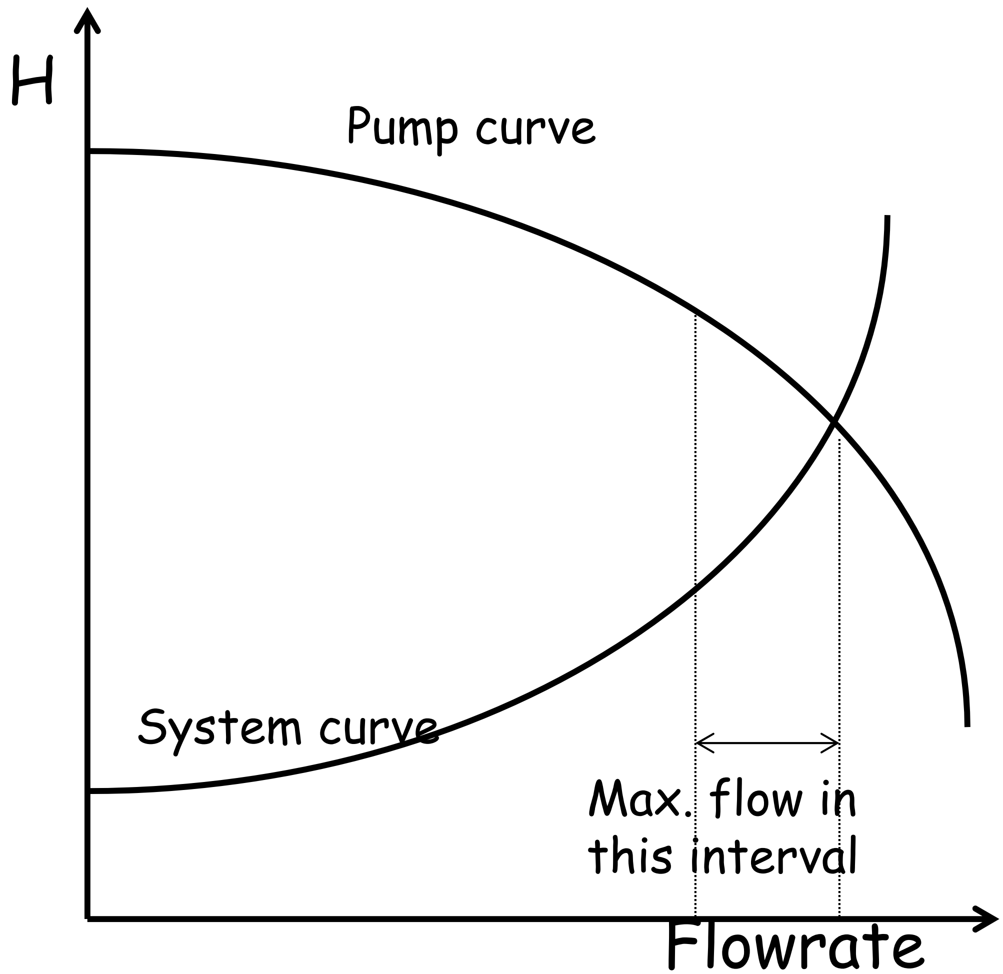
But: **Hp = Hs**

Specifying a Pump



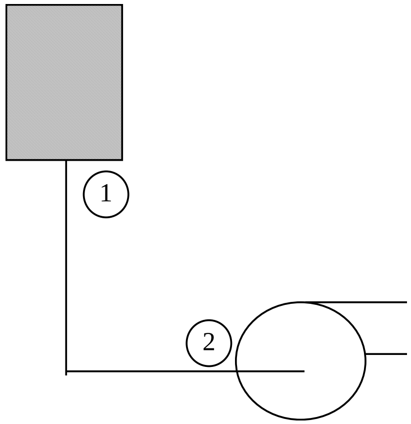
Effect of throttling a valve.

Specifying a Pump



Since Hs = Hp , pick the Hs curve close to 80% open, at maximum flow

What to do if NPSHA is too low



$$NPSHA = (P_2 - P_V)/rg$$

Increase P_2 !!! (How?)
Increase Z_1

This is the reason why pumping fluids that are close to saturated conditions require that the vessel upstream be elevated. Flash tanks are typical examples of this.

Pumps that return flow from the reboiler to distillation columns need to be bellow the column level.

Fluid Flow - Pumps

Pumps in parallel:

Total head: $\Delta h_{tot}=\Delta h_1=\Delta h_2$

Total flow rate: $Q_{tot}=Q_1+Q_2$

Pumps in series:

Total head: $\Delta h_{tot}=\Delta h_1+\Delta h_2$

Total flow rate: $Q_{tot}=Q_1 = Q_2$

REFERENCES

Pumps

•McCabe, W.L., Smith, J.C., and P. Harriott, "Unit Operations of Chemical Engineering," 5th edition, McGraw-Hill, New York, 1993. (good for pumps and other unit ops equipment)