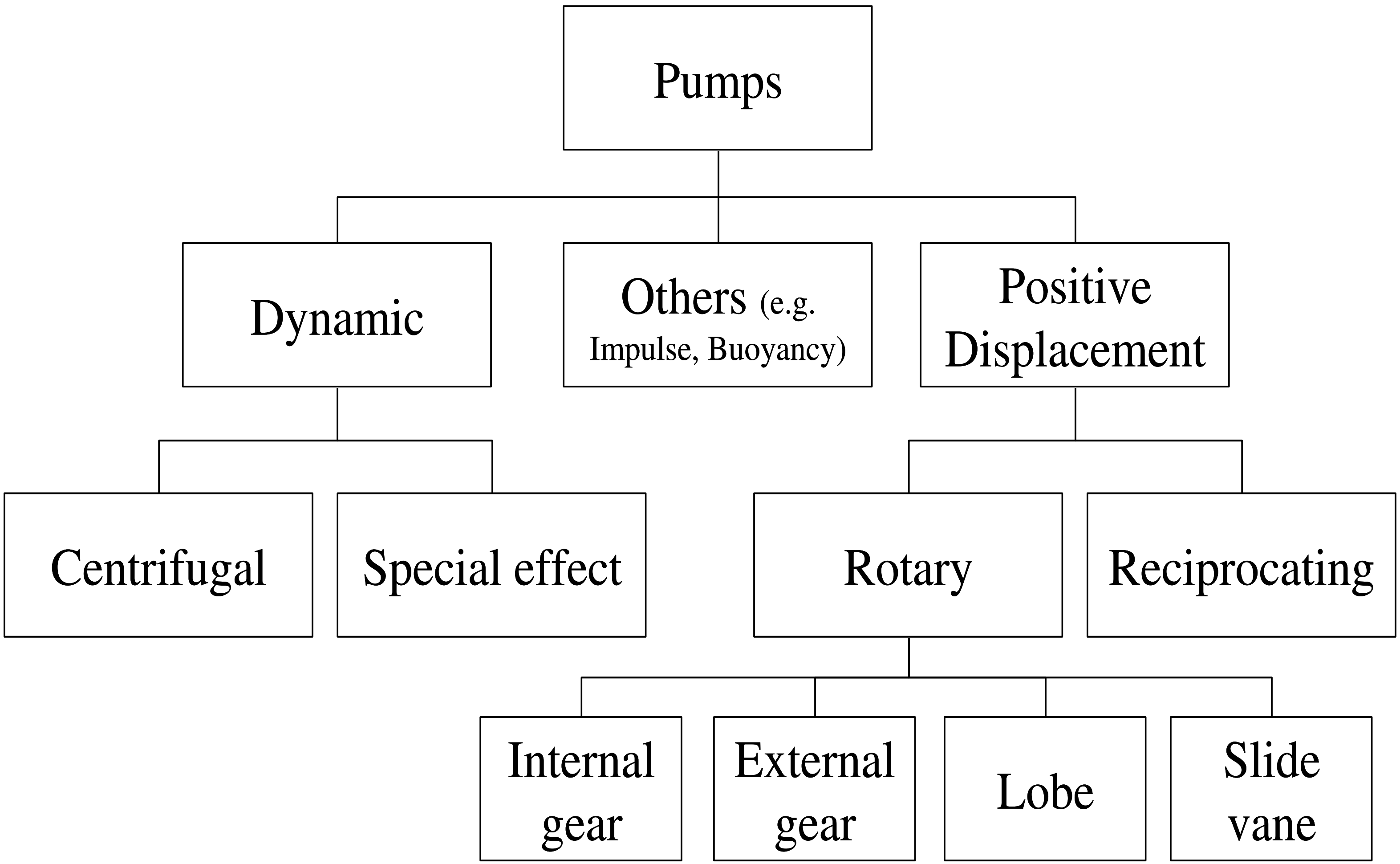
UNIT-IV

Centrifugal Pump

Type of Pumps
Pump Classification



Positive Displacement Pumps

- These pumps operate on the principle of a definite quantity of liquid is discharged or displaced due to the positive or real displacement of working element like piston, plunger, gears, etc..

- **Reciprocating pump:-**
    1. Piston pumps:
        1. Single cylinder single acting or double acting.
        2. Double cylinder single acting or double acting.
    2. Plunger pumps
    3. Bucket pump-Hand pump

- **Rotary pump**
    1. Displacement by rotary action of gear, cam or vanes
    2. Several sub-types
    3. Used for special services in industry

2. **<u>Dynamic pump</u>:**

These pumps operate on the principle of the rise in pressure energy of liquid by dynamic action of liquid. The dynamic action of liquid is carried by revolving wheel which ha curved vanes on it. This wheel is known as impeller.

1. **Radial flow pump**:

   In this pump, addition of energy to the liquid occurs when the flow of liquid in radial path.

   1. **Centrifugal pumps:**
      1. Single stage
      2. Multi stage

1. **Axial flow pump**:

   In this pump, addition of energy to the liquid occurs when the flow of liquid in axial direction.

1. **Mixed flow pump**:

   In this pump, addition of energy to the liquid occurs when the flow of liquid in axial as well as radial directions.

3. Other type of pumps:

This types of pumps does not belongs to the category of positive displacement or roto-dynamic type pumps as follows:

1. Jet pump
2. Air lift pump

INTRODUCTION

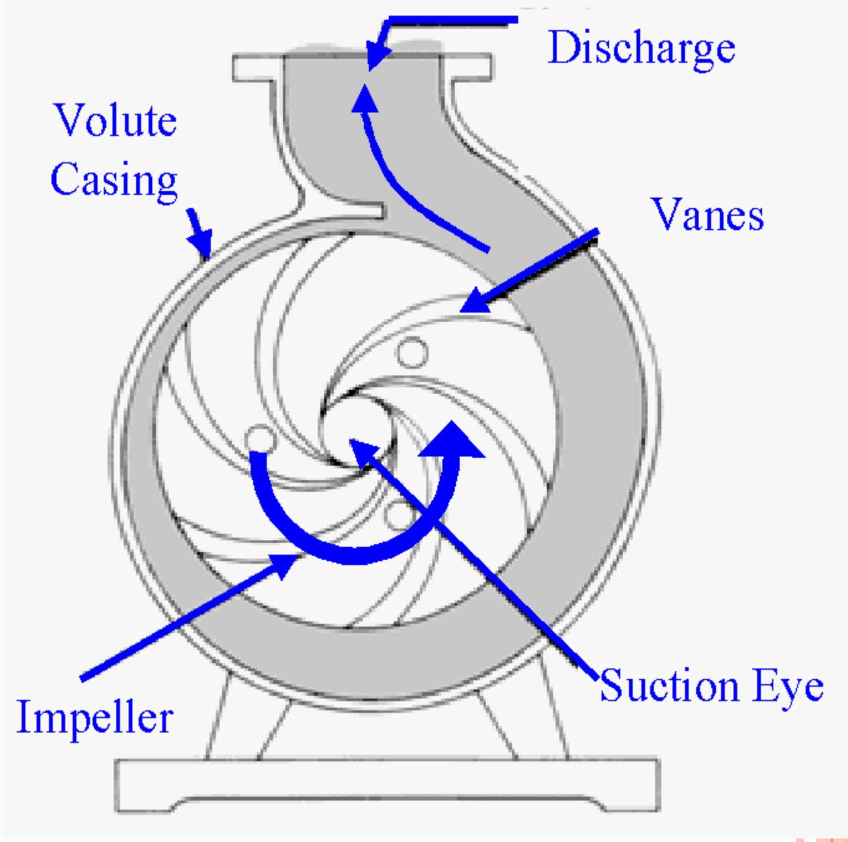
- It converts mechanical energy into hydraulic energy (pressure energy) by virtue of centrifugal force.
- Flow is in radial outward direction.
- It works on principle of forced vortex flow.
- Common uses include water, sewage, petroleum and petrochemical pumping.

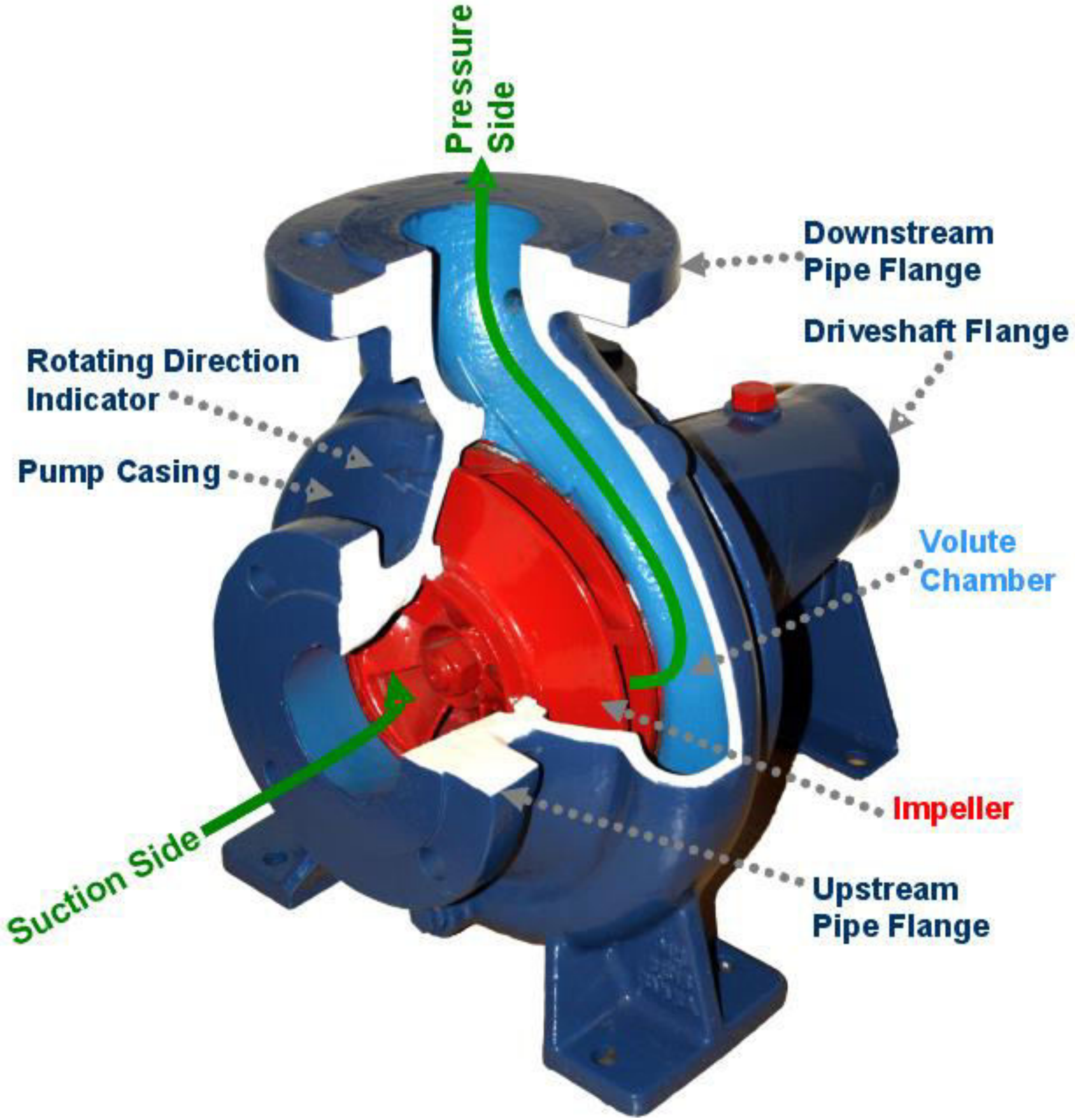
PRINCIPLE

- It works on the principle of forced vortex flow means when a certain mass of fluid is rotated by external torque rise in pressure head takes place.
- Conversion of energy occur by virtue of two main parts of the pump:
  a) Impeller
  b) Casing.
- Impeller converts driver energy into the kinetic energy & diffuser converts the kinetic energy into pressure energy.

COMPONENTS

- Impeller
- Casing
- Suction pipe
- Foot valve and strainer
- Delivery pipe




Pressure Side
Downstream Pipe Flange
Driveshaft Flange
Rotating Direction Indicator
Pump Casing
Volute Chamber
Impeller
Upstream Pipe Flange
Suction Side

- A centrifugal pump has two main components:

    I. A rotating component comprised of an impeller and a shaft.

    II. A stationary component comprised of a casing, casing cover, and bearings.

ROTATING COMPONENTS

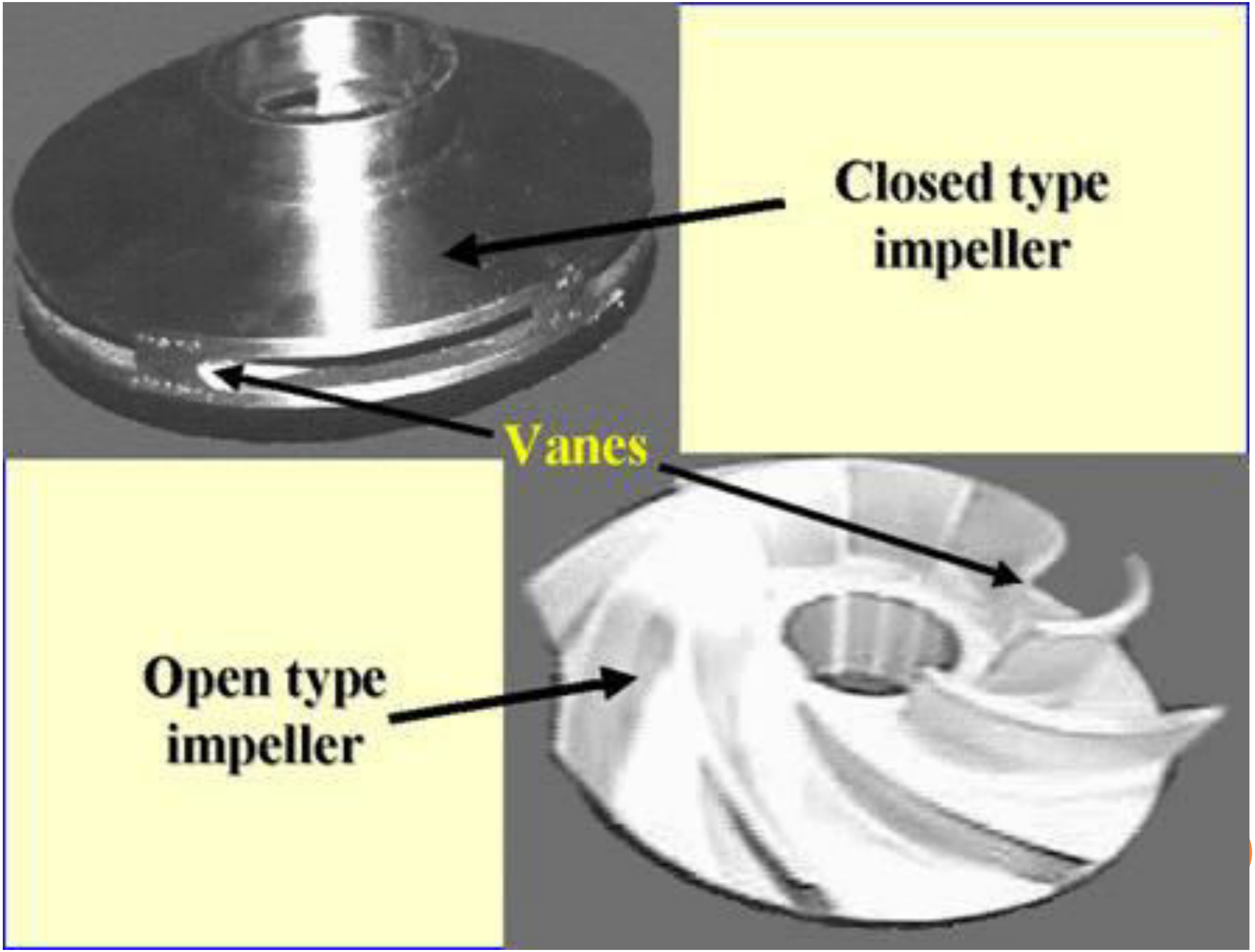
- Impeller:

  The impeller is the main rotating part that provides the centrifugal acceleration to the fluid.

- Shaft:

  Its purpose is to transmit the torques encountered when starting and during operation.

  Supports the impeller & other rotating parts.


Closed type
impeller
Vanes
Open type
impeller

STATIONARY COMPONENTS

- Casing:

The main purpose of casing is to convert kinetic energy into pressure energy.

Casings are generally of three types:

a) Volute : Used for higher head, eddy currents formed
b) Vortex : Eddy currents are reduced.
c) Circular : Used for lower head.

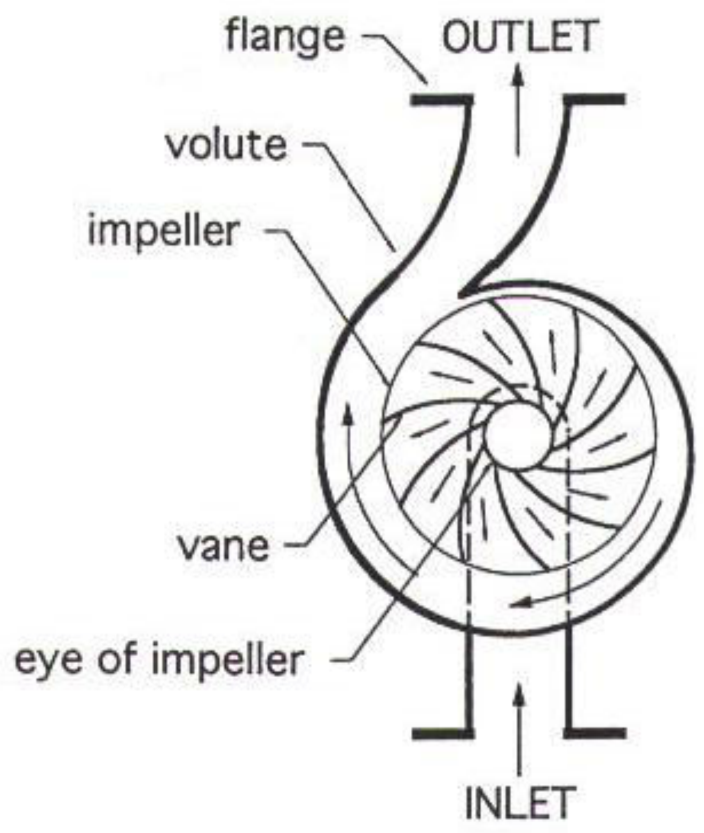
- A *volute* is a curved funnel increasing in area to the discharge port. As the area of the cross-section increases, the volute reduces the speed of the liquid and increases the pressure of the liquid.

- **Vortex Casing :**
- A circular chamber is introduced between casing and impeller. Efficiency of pump is increased.

- **Circular casing** have stationary diffusion vanes surrounding the impeller periphery that convert velocity energy to pressure energy.
- Conventionally, the diffusers are applied to multi-stage pumps.

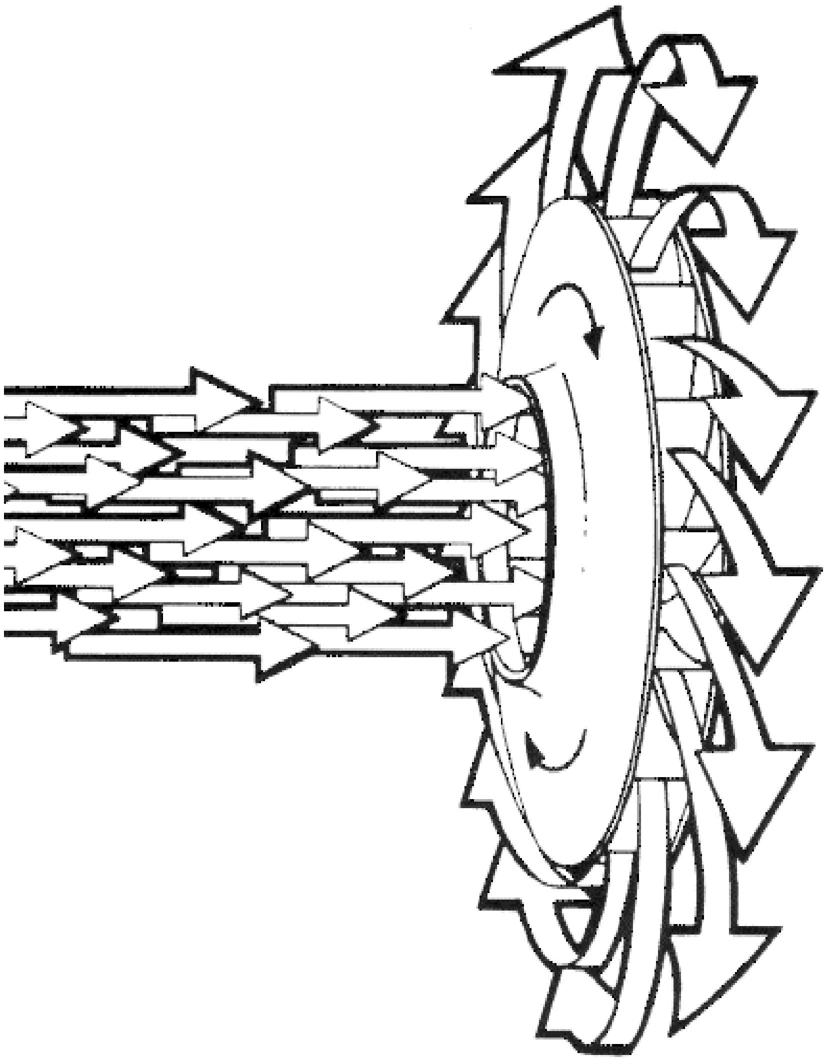
HOW DO THEY WORK?

- Liquid forced into impeller
- Vanes pass kinetic energy to liquid: liquid rotates and leaves impeller
- Volute casing converts kinetic energy into pressure energy



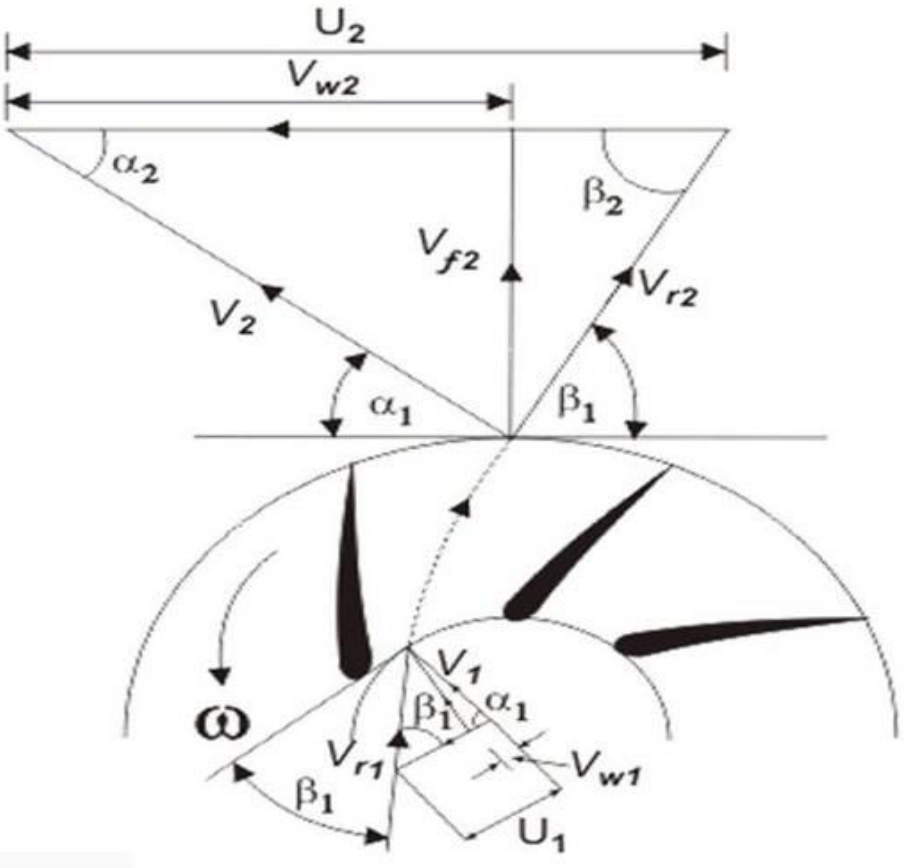
- It consists of an *IMPELLER* rotating within a casing.

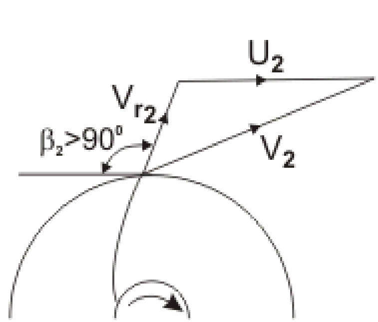
- Liquid directed into the center of the rotating impeller is picked up by the impeller’s vanes and accelerated to a higher velocity by the rotation of the impeller and discharged by centrifugal force into the casing .



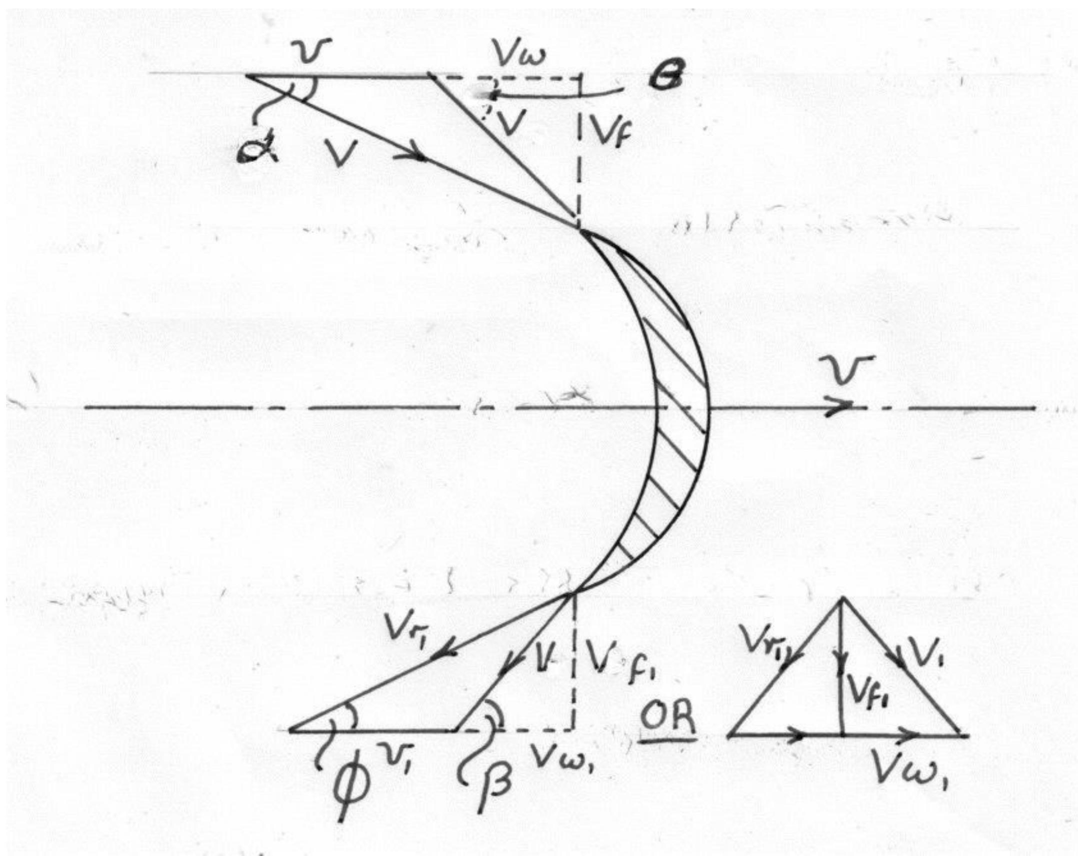
VELOCITY TRIANGLE

Velocity triangles for centrifugal pump Impeller





(a) Forward-facing vanes (b) Radial vanes (c) Backward-facing vanes



WORK DONE

- Work is done by the impeller on the water

$$W=[V_{w2}U_2-V_{w1}U_1]/g$$

where,

W=work done per unit wg. of water per sec.

V_{w2}=whirl component of absolute vel. of jet at outlet.

U_2=tangential vel. of impeller at outlet.

V_{w1}=whirl component of absolute vel. of jet at inlet.

U_1=tangential vel. of impeller at inlet.

- As water comes radially :

  Guide blade angle at inlet $\alpha=90^0$

  $V_{W1}=0$

  then

  $W=V_{w2}U_2/g$

HEADS IN CENTRIFUGAL PUMP

- Suction Head:-

  Vertical height of center line of centrifugal pump above the water surface to the pump from which water to be lifted.

- Delivery Head:-

  Vertical distance between center line of the pump and the water surface in the tank to which water is delivered.

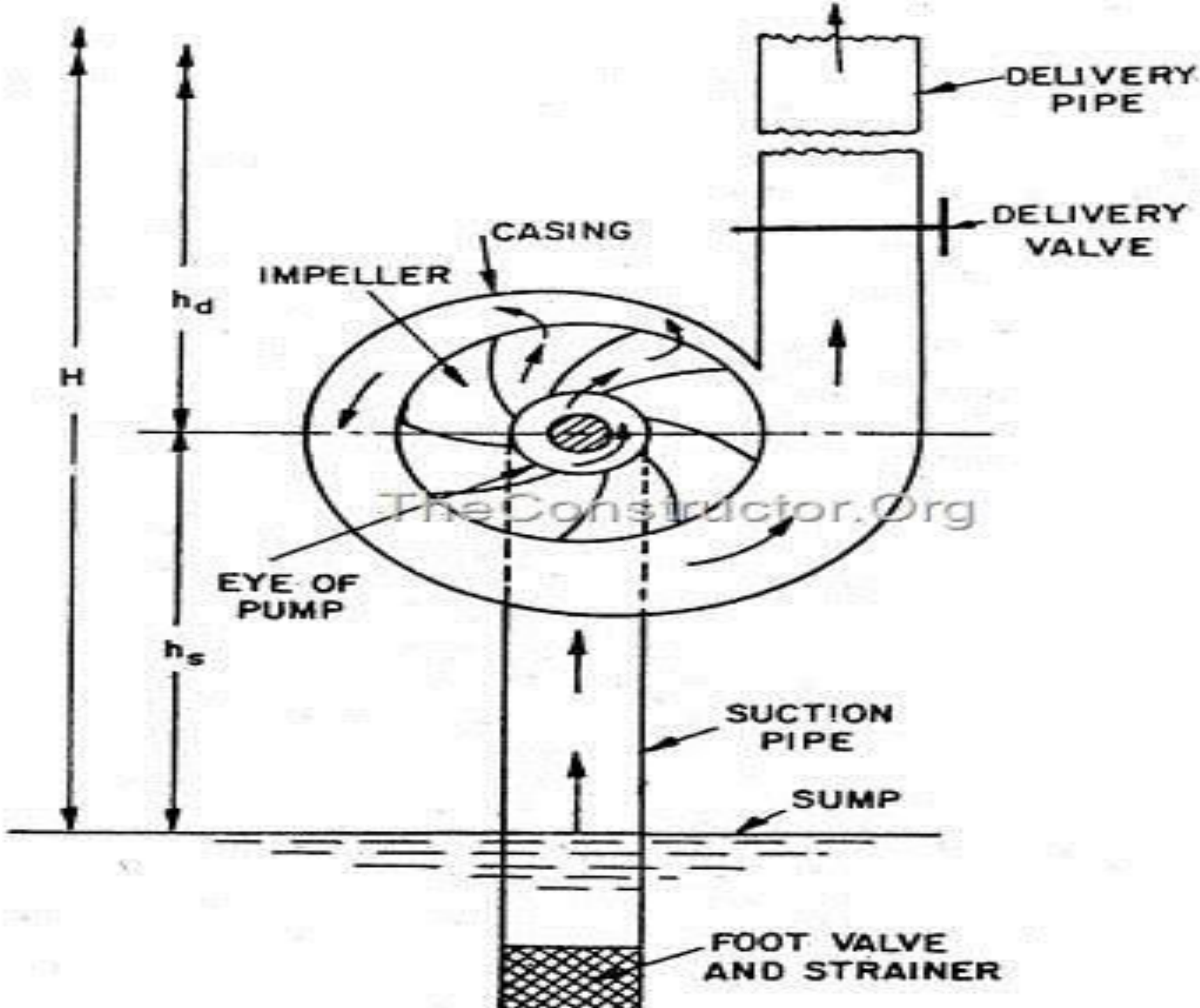
- Static Head:-

  Sum of suction head and delivery head.

- Manometric Head:-

  The head against which a centrifugal pump has to work.

$$H_m = h_s + h_d + h_{fs} + h_{fd} + (V_d * V_d)/2g$$


DELIVERY
PIPE
DELIVERY
VALVE
CASING
IMPELLER
h_d
H
EYE OF
PUMP
h_s
SUCTION
PIPE
SUMP
FOOT VALVE
AND STRAINER

EFFICIENCES

- Manometric efficiency:-

  The ratio of manometric head to the head imparted by impeller.

  $$=H_m/(V_{w2}\ u_2/g)$$

- Mechanical efficiency :-

  The ratio of power delivered by the impeller to the liquid to the power input to the shaft.

  $$=(WV_{w2}u_{2/}g)/(\text{power input to the pump shaft})$$

- Overall Efficiency:-

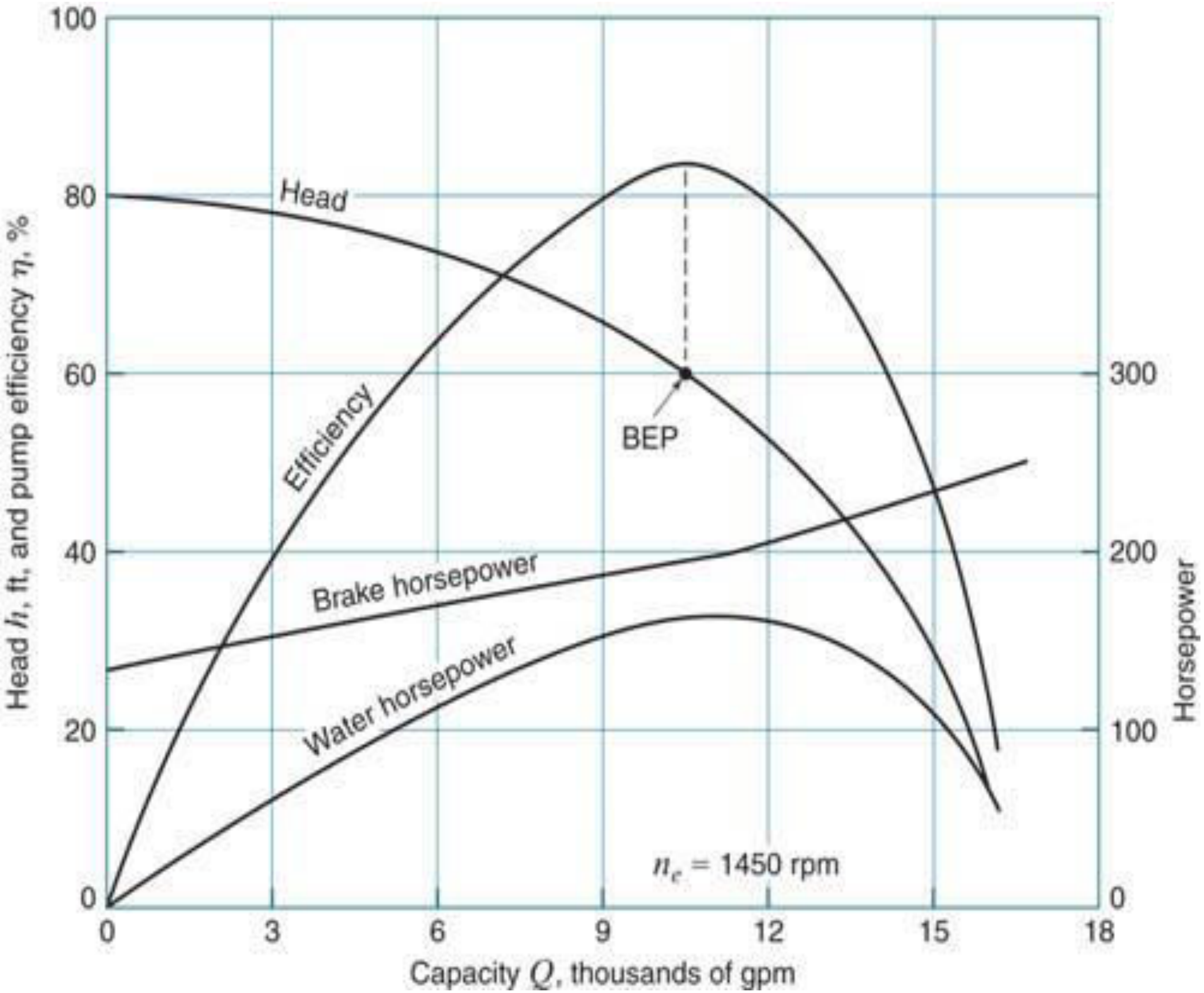
  Ratio of power output of the pump to power input to the pump or shaft.

$$= wQH_m/P$$

$$=WH_m/P$$

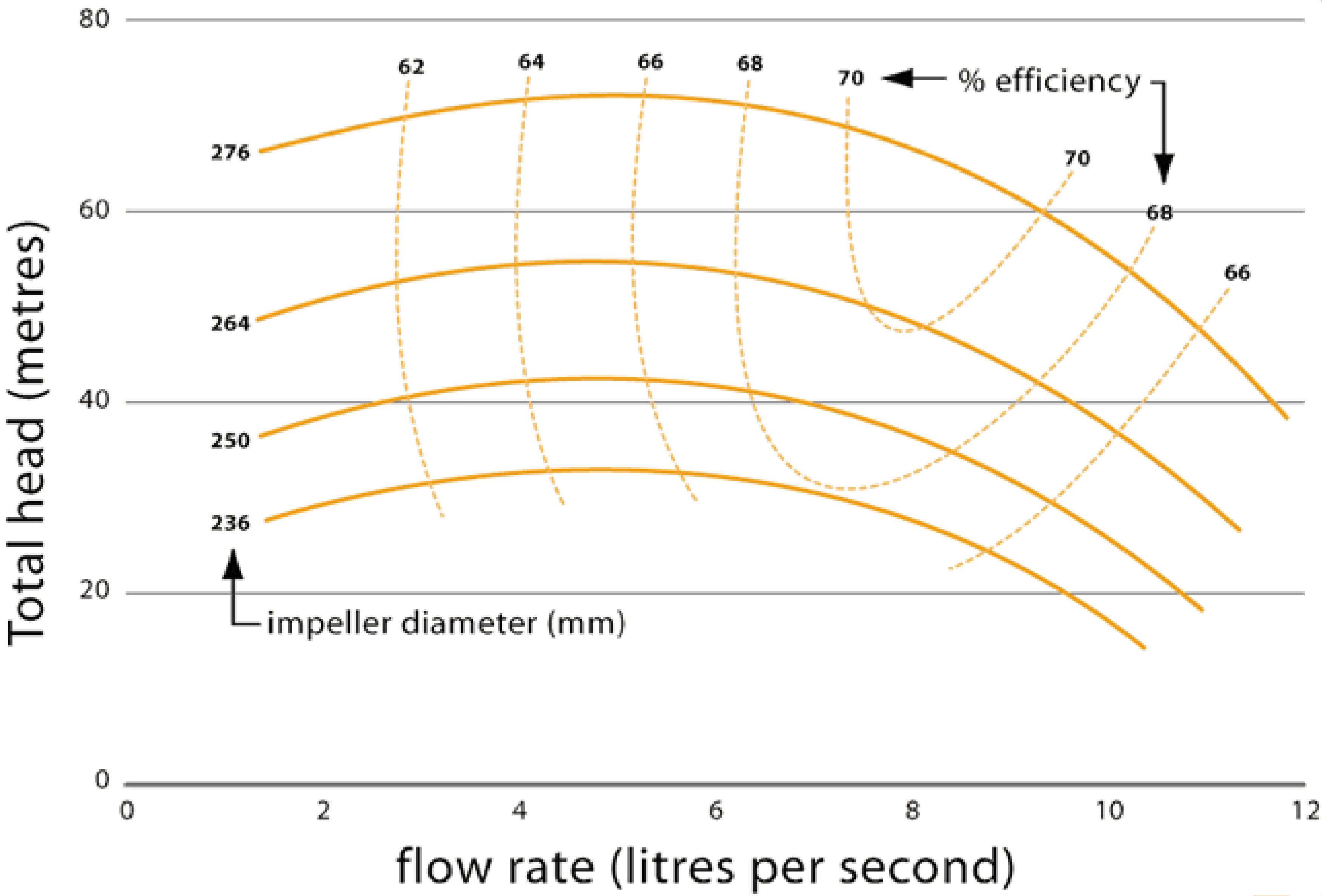
CHARACTERISTICS CURVE

- These are required to predict the performance & behavior of pump working under different head, flow rate & speed.
- Following are the important curves:
  a) Main characteristic curve.
  b) Operating characteristic curve.
  c) Muschel or constant efficiency curve.



$NQ^{1/2}/H_m^{3/4}=C$
$P/(D^5N^3)=C$
$\eta=\rho QgH/S.P.$

Operating characteristic curve



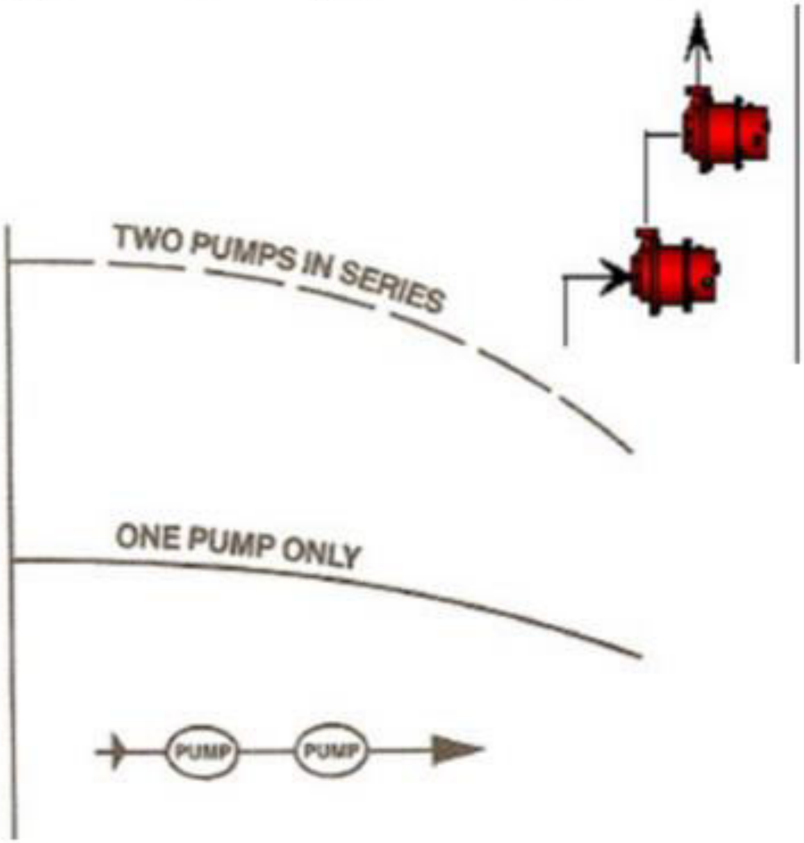
Constant efficiency curve

MULTISTAGE CENTRIFUGAL PUMP

- It consists of two or more impellers.
- There are two types as follows:
  a) SERIES :To produce high head.
  b) PARALLEL :To discharge large quantity of liquid.

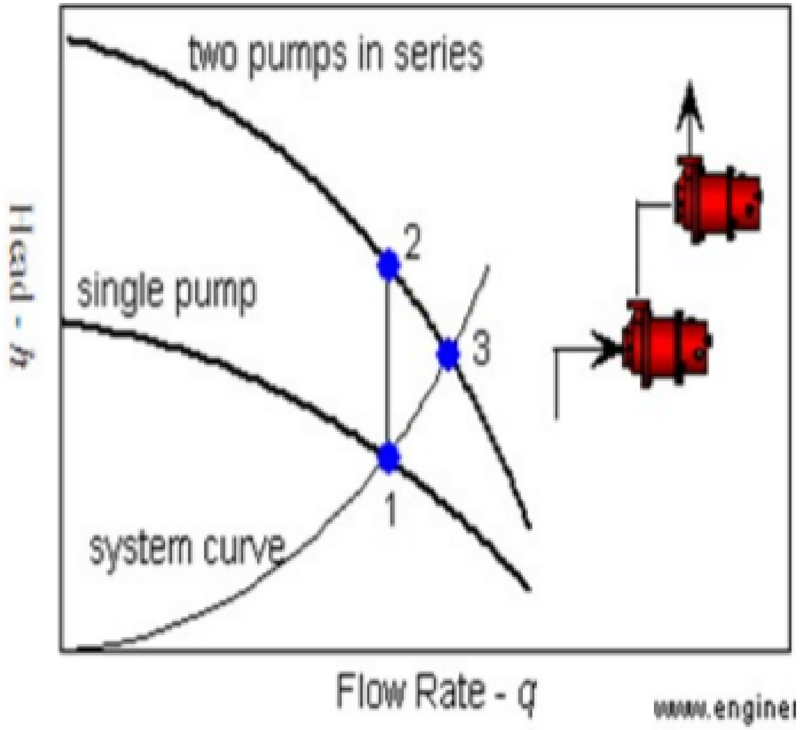
Running Centrifugal Pumps in Series

- Centrifugal pumps are connected in series if the discharge of one pump is connected to the suction side of a second pump. Two similar pumps, in series, operate in the same manner as a two-stage centrifugal pump.
- Each of the pumps is putting energy into the pumping fluid, so the resultant head is the sum of the individual heads.
- There is no change in the quantity discharged



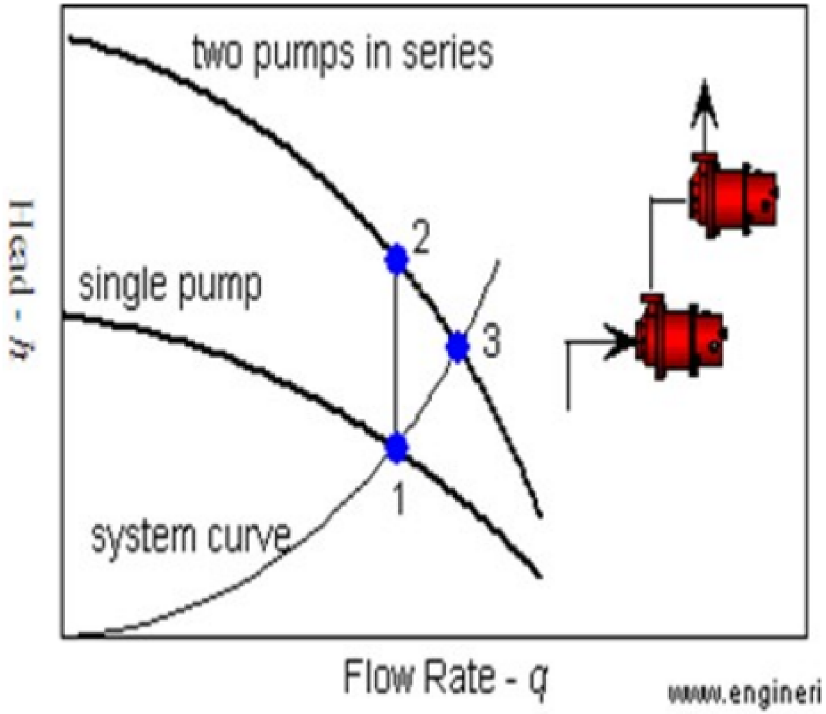
Running Centrifugal Pumps in Series

- When two (or more) pumps are arranged in series, their resulting pump performance curve is obtained by adding their heads at same flow rate as indicated in the figure below.
- If one of the pumps in series stops, the operation point moves along the system resistance curve from point 3 to point 1 - the head and flow rate are decreased.



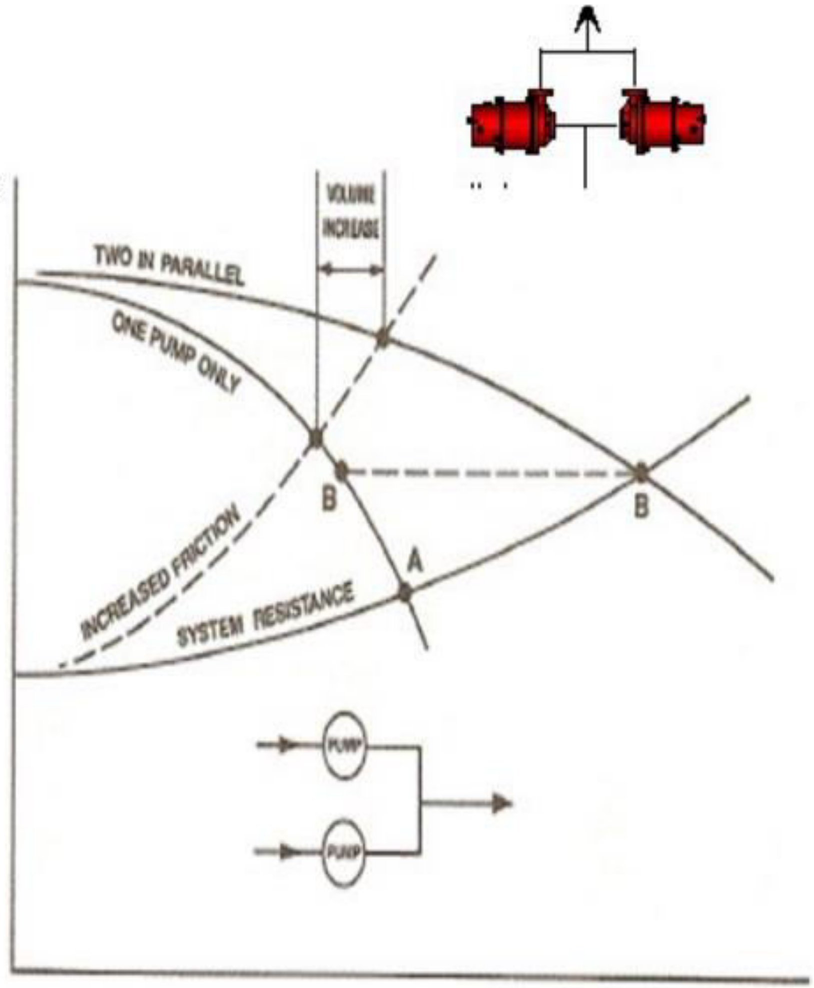
Running Centrifugal Pumps in Series

- Centrifugal pumps in series are used to overcome larger system head loss than one pump can handle alone. For two identical pumps in series, the head will be twice the head of a single pump at the same flow rate. With constant flowrate the combined head moves from 1 to 2. In practice the combined head and flow rated moved along the system curve to 3.
- The first pump acts like a booster pump

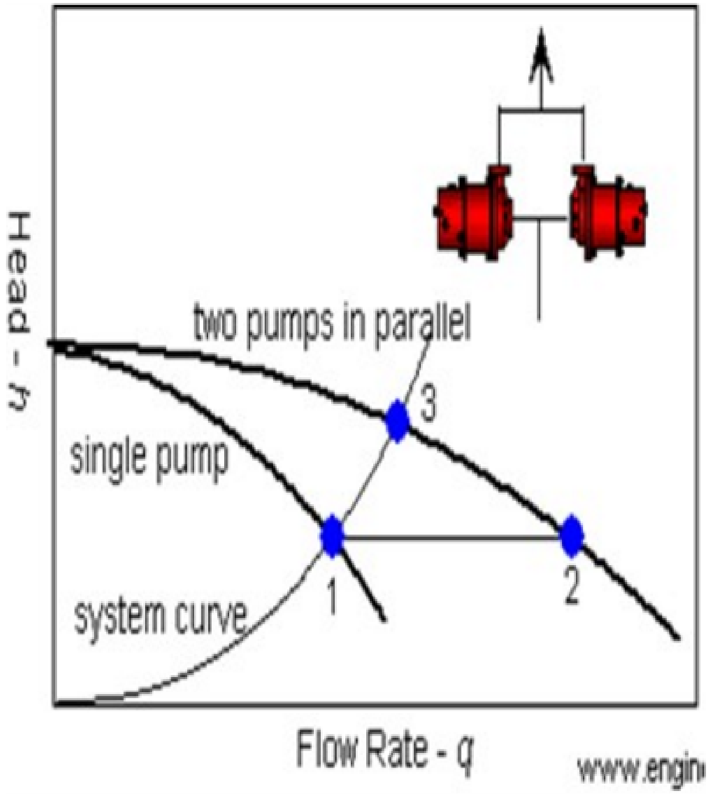


Running Centrifugal Pumps in Parallel

- Pumps are operated in parallel when two or more pumps are connected to a common discharge line, and share the same suction conditions.
- When two or more pumps are arranged in parallel their resulting performance curve is obtained by adding their flowrates at the same head as indicated in the figure.

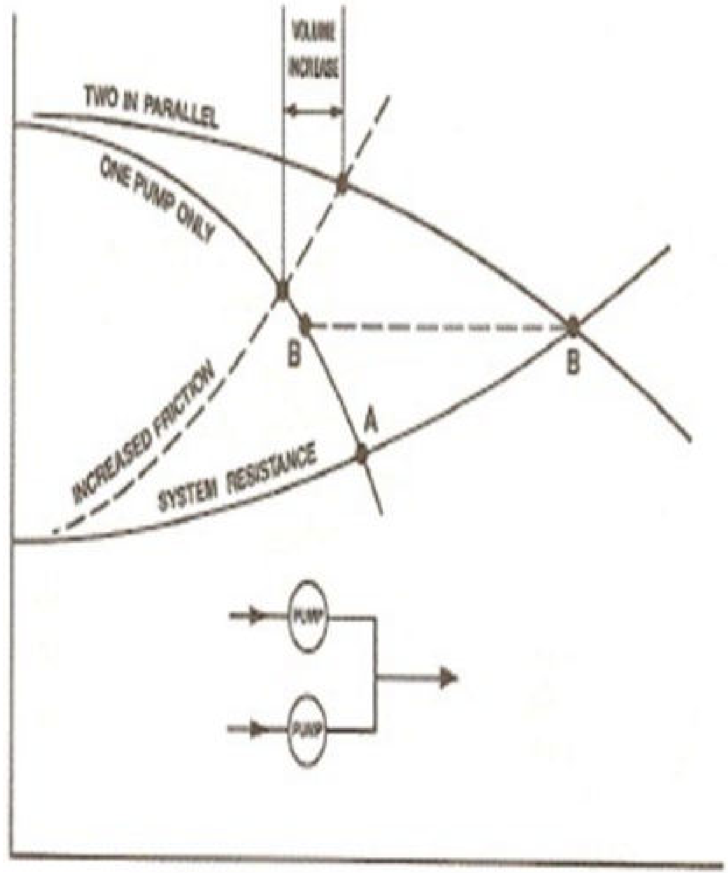


Running Centrifugal Pumps in Parallel



- Centrifugal pumps in parallel are used to overcome larger volume flows than one pump can handle alone. For two identical pumps in parallel the flowrate will double (moving from 1 to 2) compared to a single pump if head is kept constant. In practice the combined head and volume flow moves along the system curve as indicated from 1 to 3.
- If one of the pumps in parallel or series stops, the operation point moves along the system resistance curve from point 3 to point 1 - the head and flow rate are decreased.

Parallel Running of Centrifugal Pumps



- Both pumps must produce the same head this usually means they must be running at the same speed, with the same diameter impeller.
- Two pumps in parallel will deliver less than twice the flow rate of a single pump in the system because of the increased friction in the piping.
- The shape of the system curve determines the actual increase in capacity. If there is additional friction in the system from throttling (see dotted line in the following diagram), two pumps in parallel may deliver only slightly more than a single pump operating by its self.

PRIMING

- It is the process of filling suction pipe, casing and delivery pipe upto delivery valve with water.
- Used to remove air from these parts.
- It is of 2 types:

a) Positive Priming:-The one which speeds up processing.

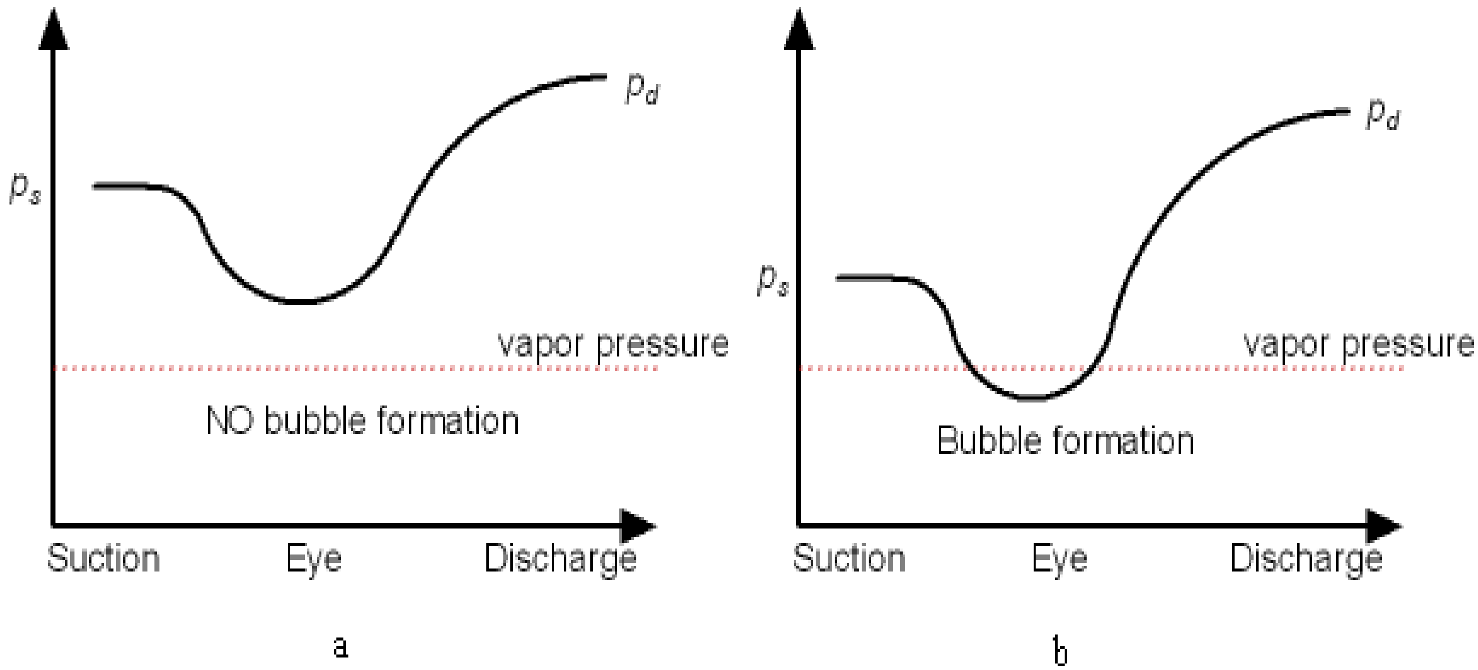
b) Negative Priming:-The one which slows down the processing.

CAVITATION

- It is a phenomena of formation of vapour bubble where the pressure falls below the vapour pressure of flowing liquid .
- Collapsing of vapour bubble causes high pressure results in pitting action on metallic surface.
- Erosion, noise & vibration are produced.

The concept of NPSH

- Cavitation
  - Vapour Pressure is the pressure req. to boil a liquid at a specific temperature.
  - Can be avoided if the pressure of the liquid at all points within the pump is above the atm. pressure.

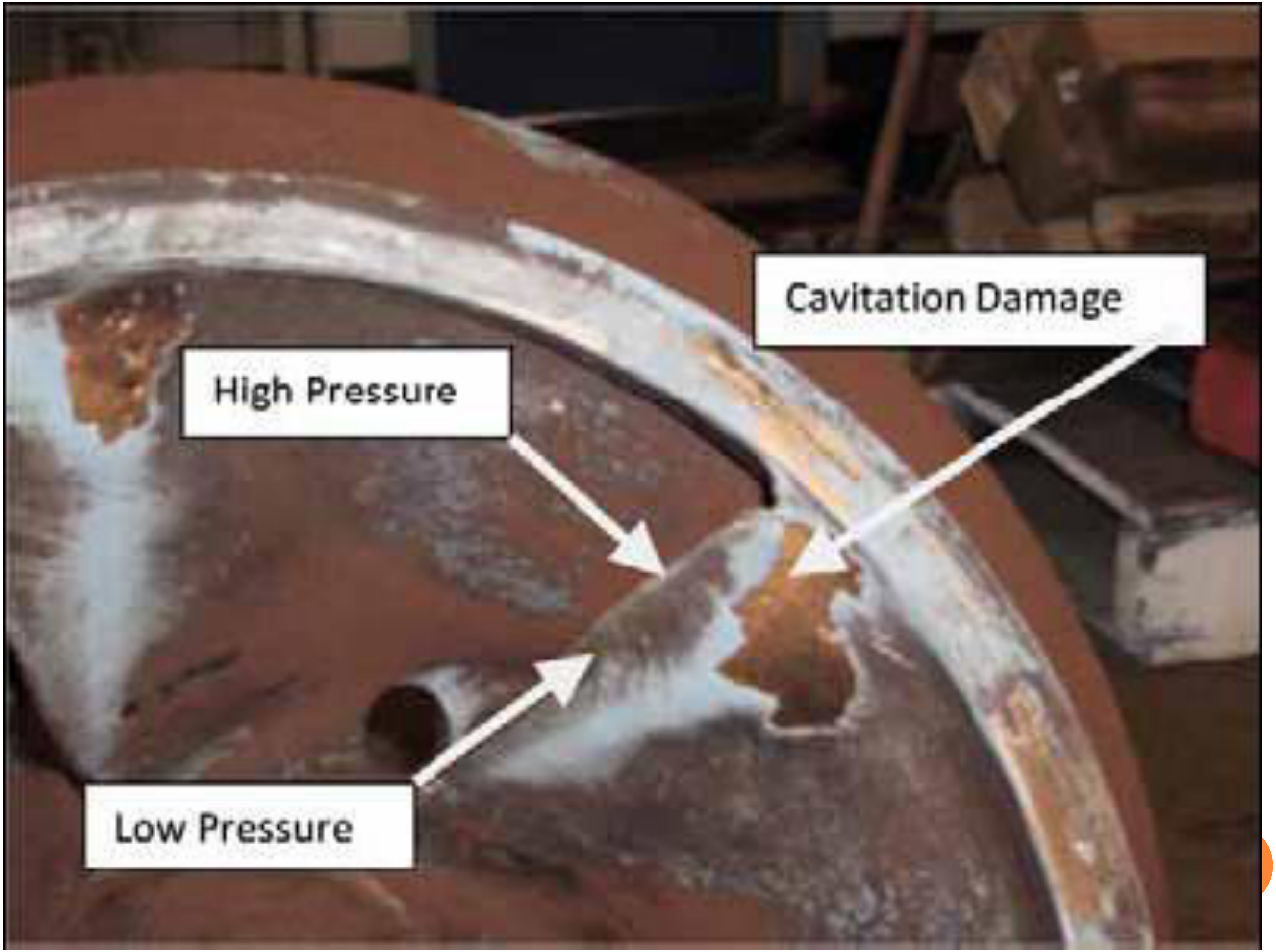


THE CONCEPT OF NPSH

- Two NPSH parameters:-

  i) available and

  ii) required.
- NPSHA: Difference between the pressure at the suction of the pump & the saturation pressure of the liquid being pumped.
- NPSHR: Min. net positive suction head req. to avoid cavitation.
- NPSHA $\geq$ NPSHR
- General requirement: NPSHA is at least 2.0m of liquid greater than the pump manufacturer requires under the worst pump operating conditions.


Cavitation Damage
High Pressure
Low Pressure

EFFECT OF CAVITATION

- Metallic surface are damaged & cavities are formed.
- Efficiency of pump decreases.
- Unwanted noise and vibrations are produced.

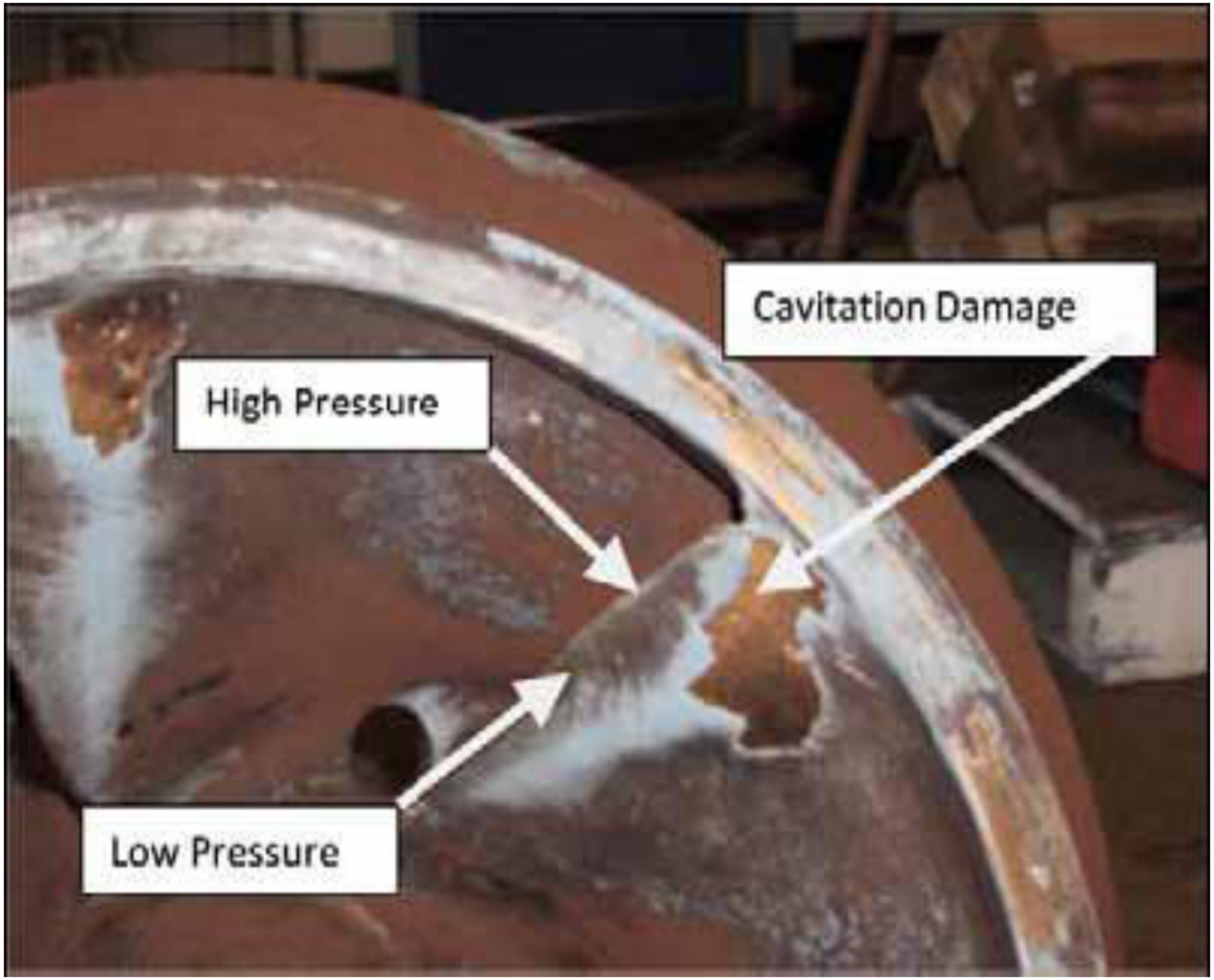
THOMA'S CAVITATION FACTOR

- The cavitation factor(σ) is defined as the ratio of total inlet head above the vapor pressure at the suction side of the pump to the head developed by the pump.

$$\sigma = \frac{\text{Total head above the vapour pressure at the pump inlet}}{\text{Head developed by the pump}}$$

$$\text{Therefore, } \sigma = \frac{(p_s/\rho g) + (V_s^2/2g) - p_{Vap}/\rho g}{H_m} = \frac{NPSH}{H_m}$$

Cavitation Damage



SELECTION OF PUMPS.

Capacity – No. of pumps in parallel

Total Head – No. of stages

Physical, Chemical properties of Liquids

Viscosity @ Frictional Loss @ Power Required

Corrosive Fluid @ MOC

Site conditions

Source of Power

Type	Capacity	Head	Viscosity	Solid	% Gas
Centrifugal	Upto 7500 m^3/h	Upto 105 m	< 200 cSt	Upto 20%	< 2%
Rotary	< 350 m^3/h	1050 m	Max	< 5%	> 2%
Positive Displacement	< 300 m^3/h	10500 m	< 600 cSt	< 25%	> 2%
Peristaltic	Upto 1 m^3/h	< 25 m	< 200 cSt		

THANK YOU