UNIT -4
CENTRIFUGAL PUMPS

Course Objectives:

CO4:Understand and Analyze the centrifugal pump performance characteristics and the importance of velocity head, the discharge head and the suction lift.

Topics

1. Centrifugal Pumps- Main Components, Working
2. Priming
3. Work done and Velocity Triangle
4. Heads in Centrifugal Pumps
5. Efficiency
6. Characteristics Curves
7. Multistage Pumps
8. Characteristics Curves
9. Axial Flow Pumps

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:

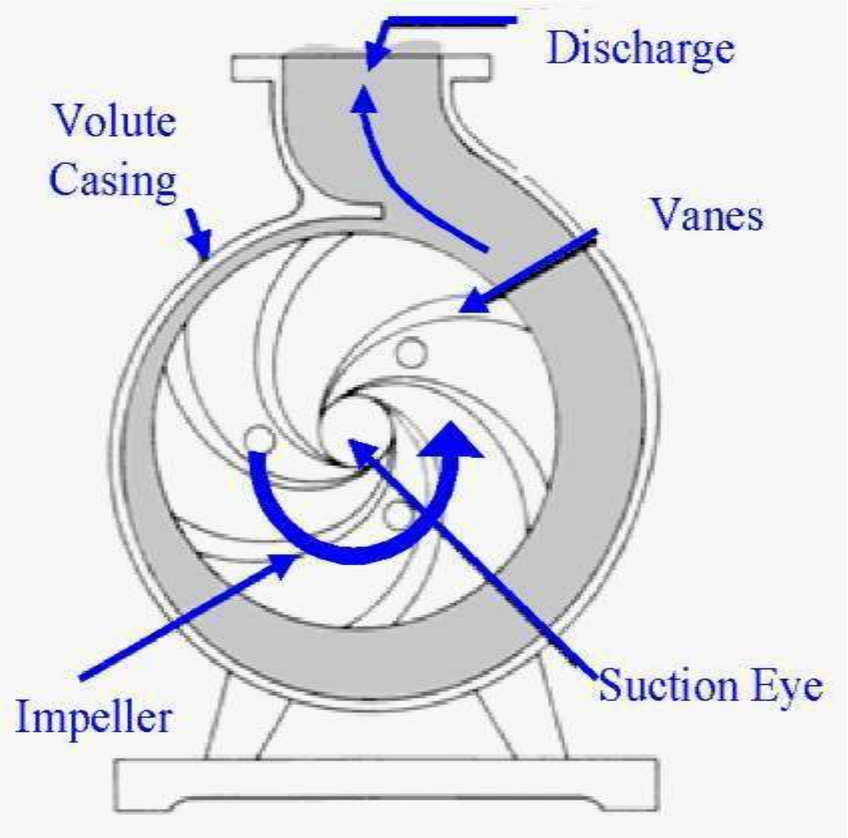
a) Impeller

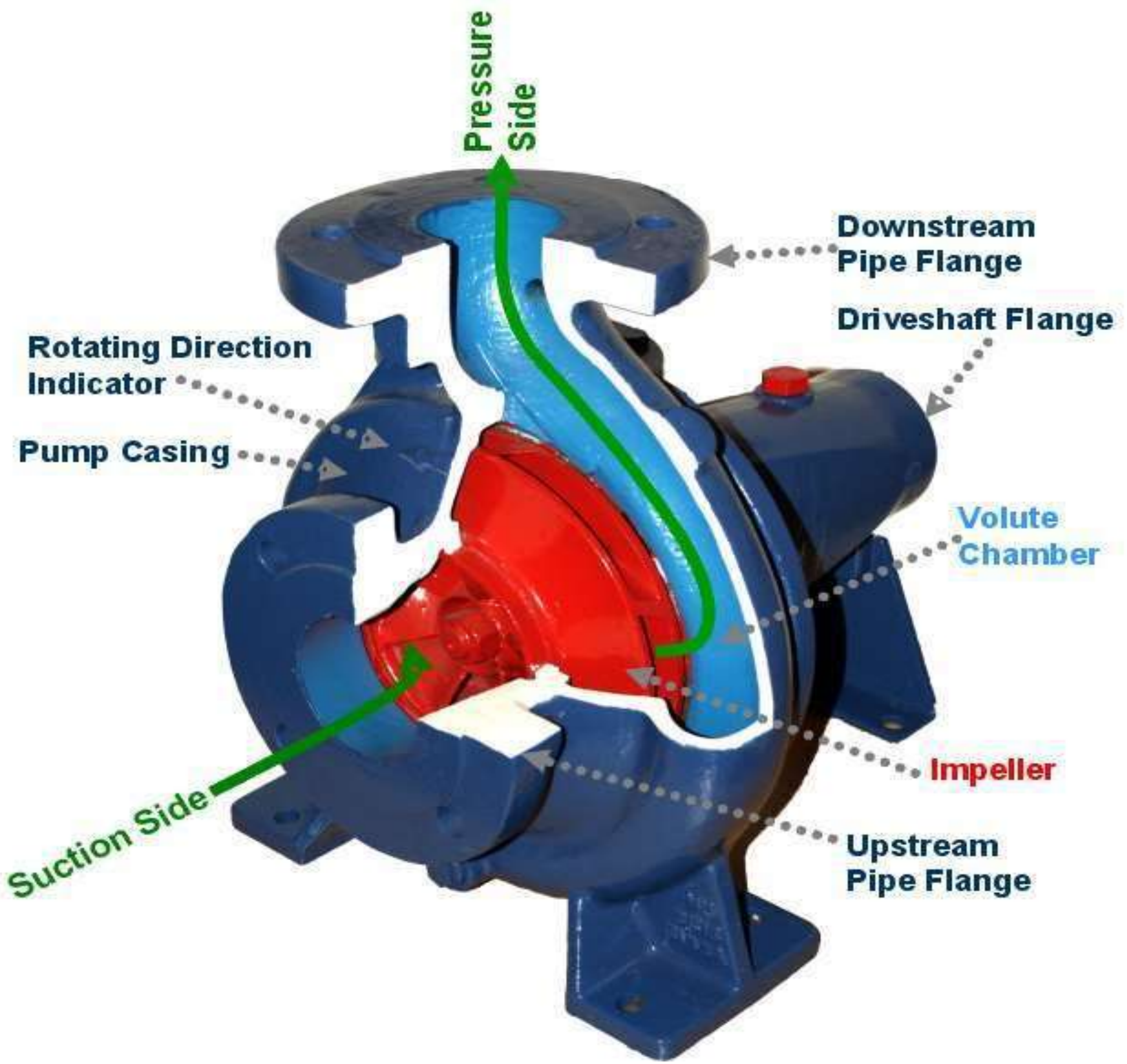
b) Casing.

- 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:

A rotating component comprised of an impeller and a shaft.

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

ROTATING COMPONENTS

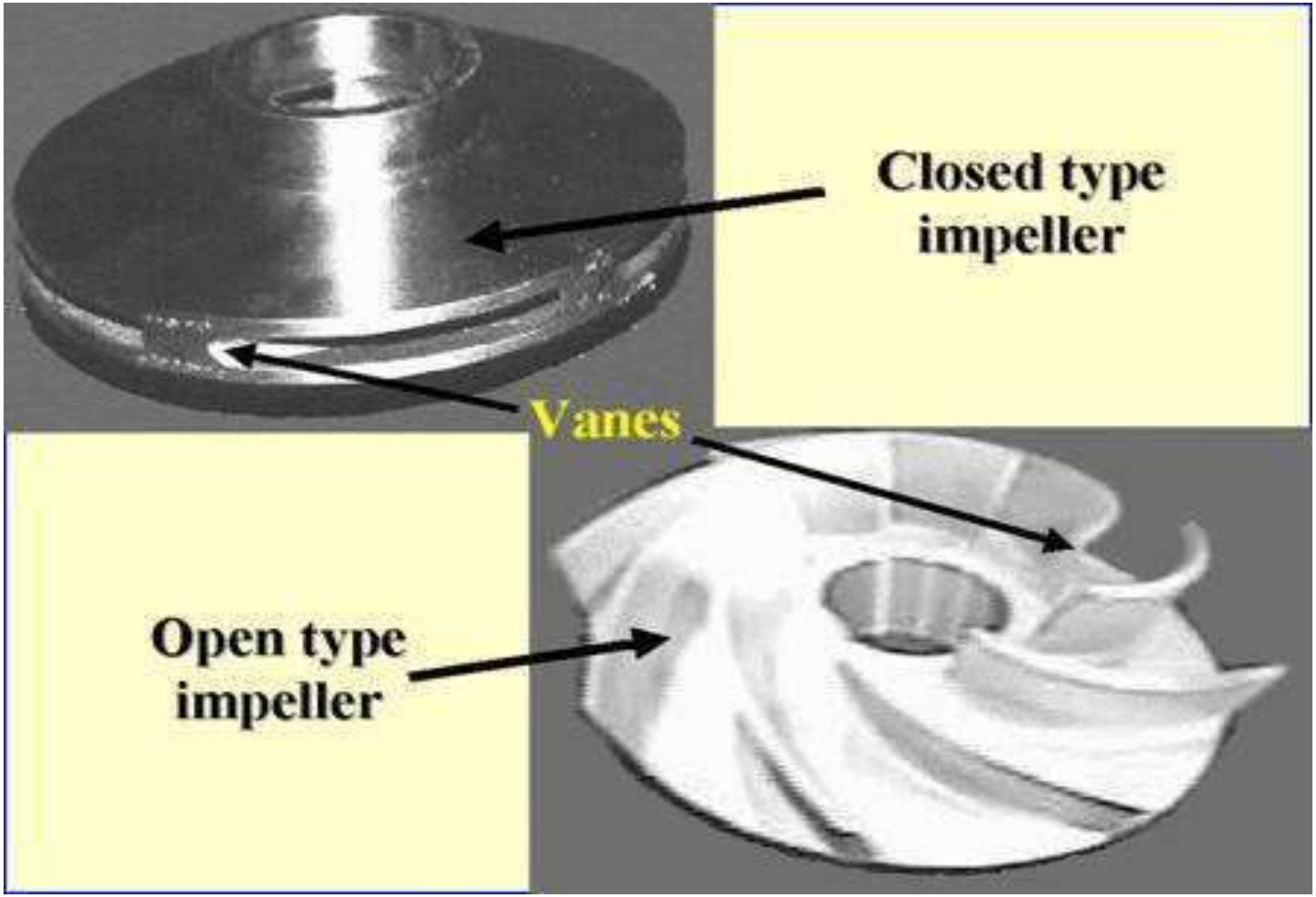
- Impeller:

  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.

PRIMING

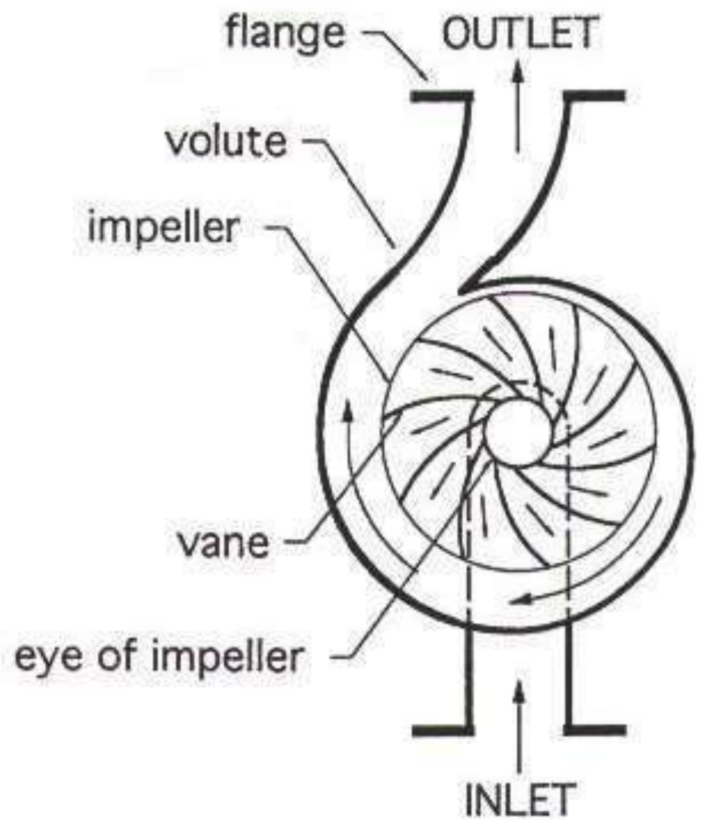
- It is the process of filling suction pipe, casing and delivery pipe upto delivery valve with water.
- Used to remove air from these parts.
- It is of 2 types:

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

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

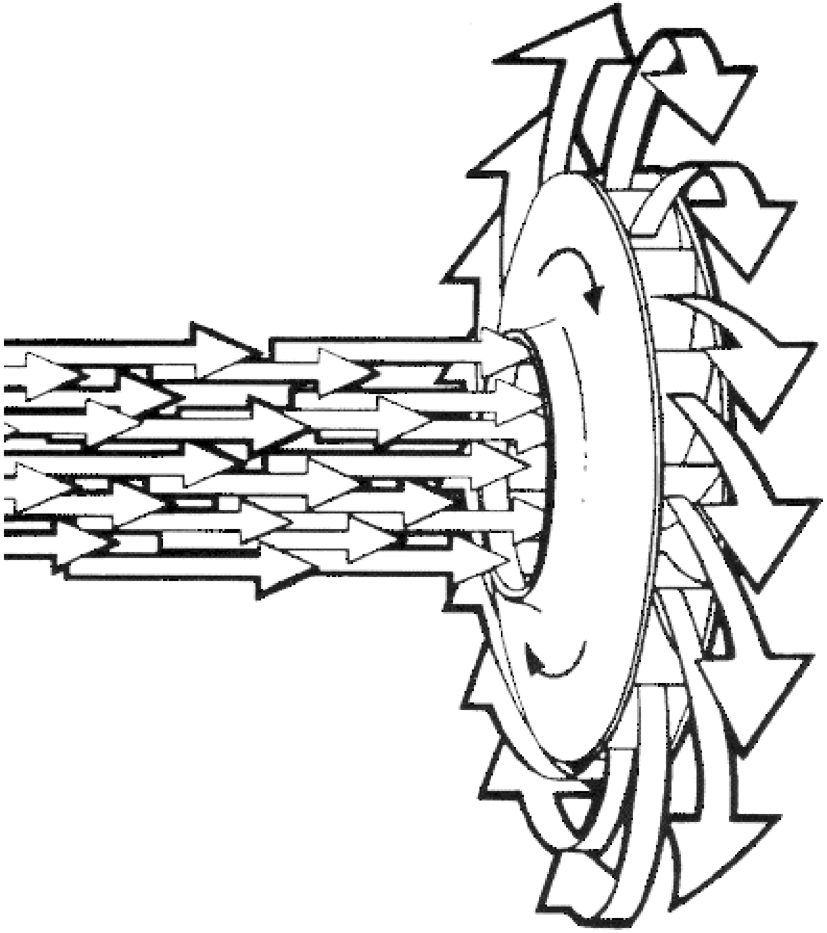
HOW DO THEY WORK?

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

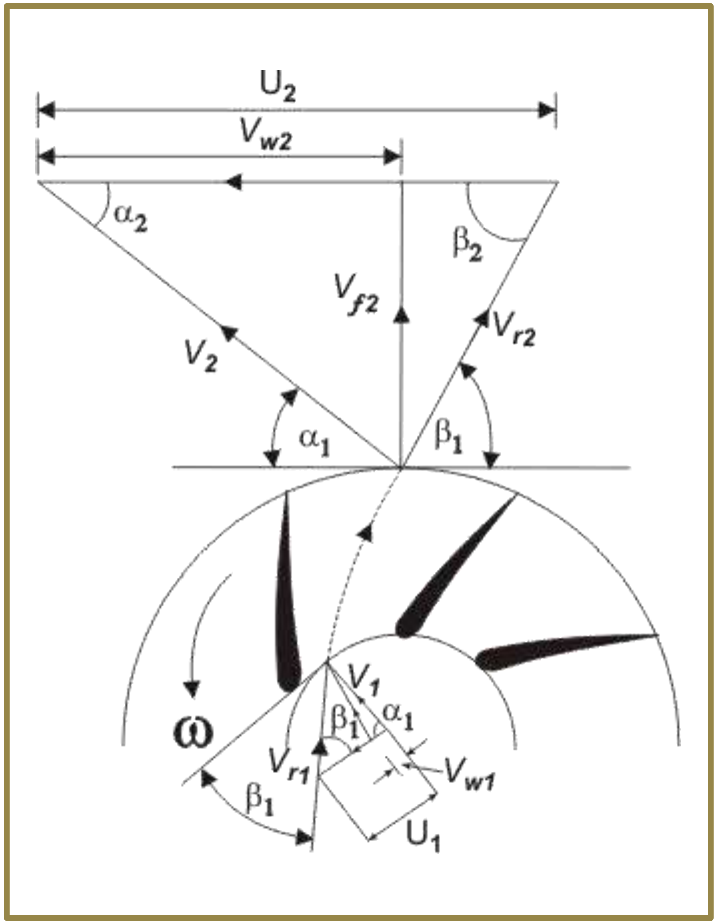


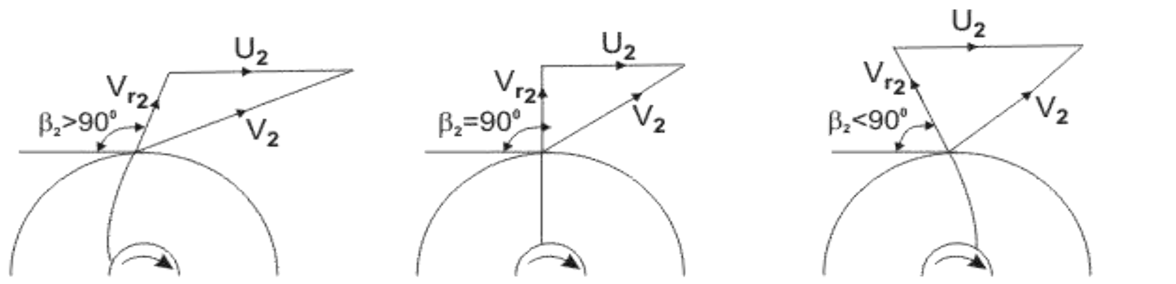
It consists of an *IMPELLER* rotating within a casing.

- 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 .

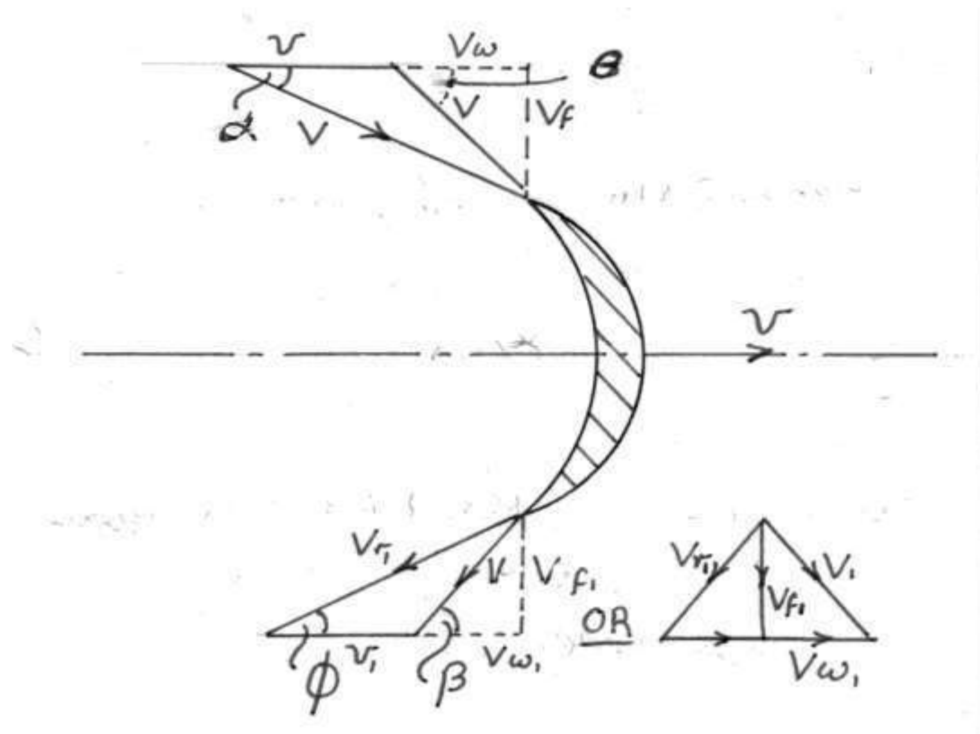


VELOCITY TRIANGLE





(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 $\alpha=90^0$

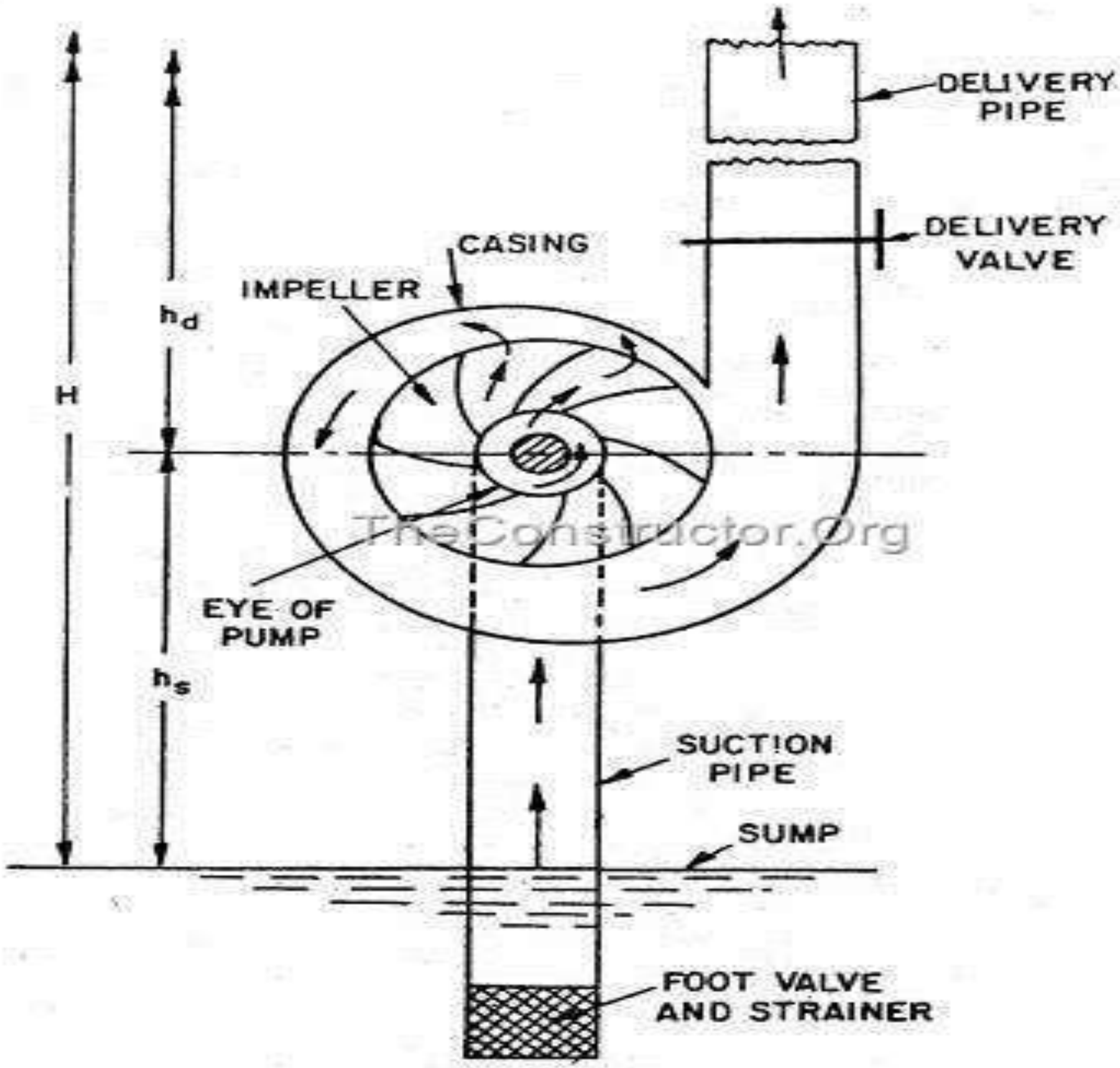
$V_{W1}=0$

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
TheConstructor.Org

EFFICIENCIES

- 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.

$$= wQH_m/P$$

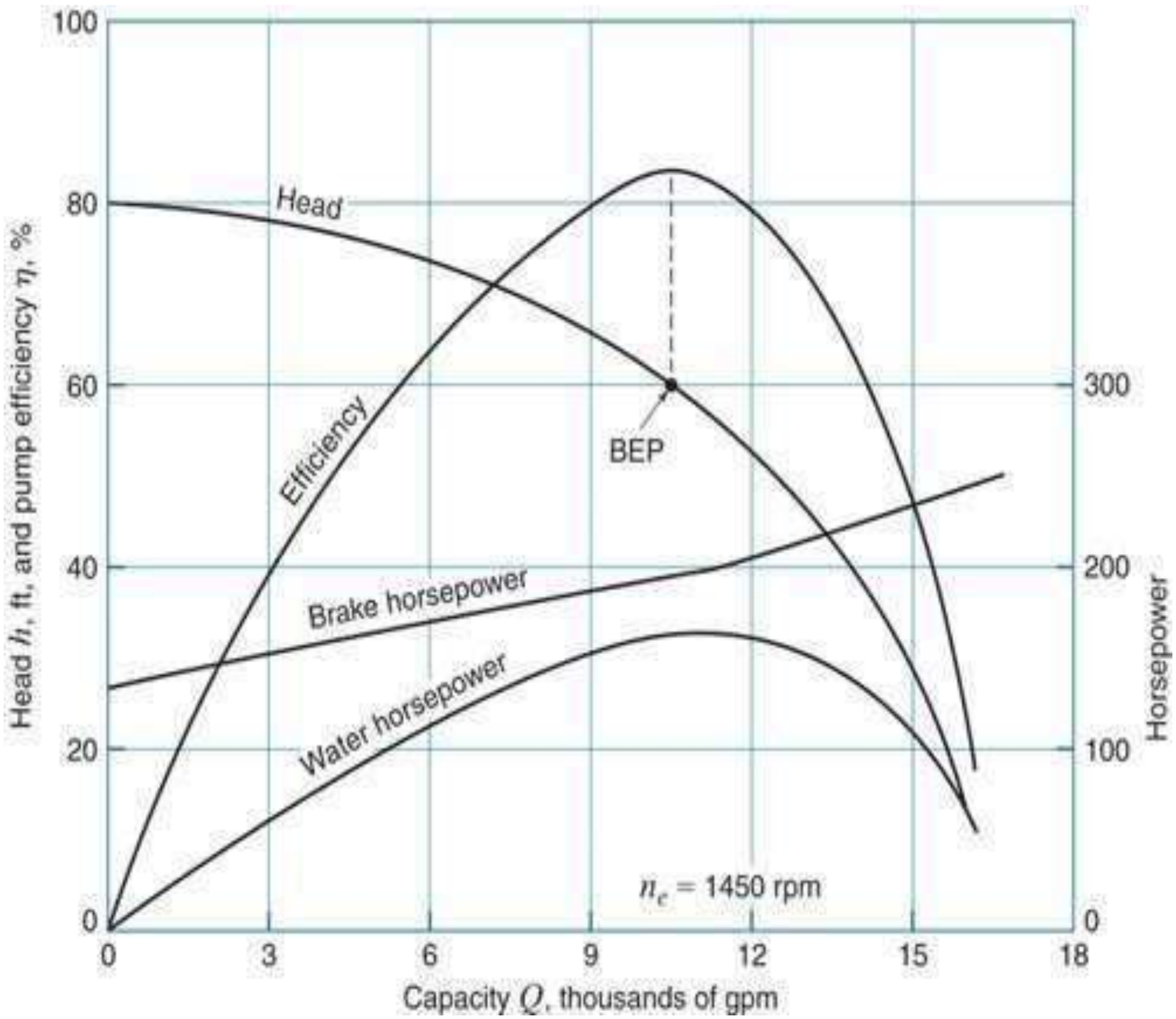
$$=WH_m/P$$

CHARACTERISTICS CURVES

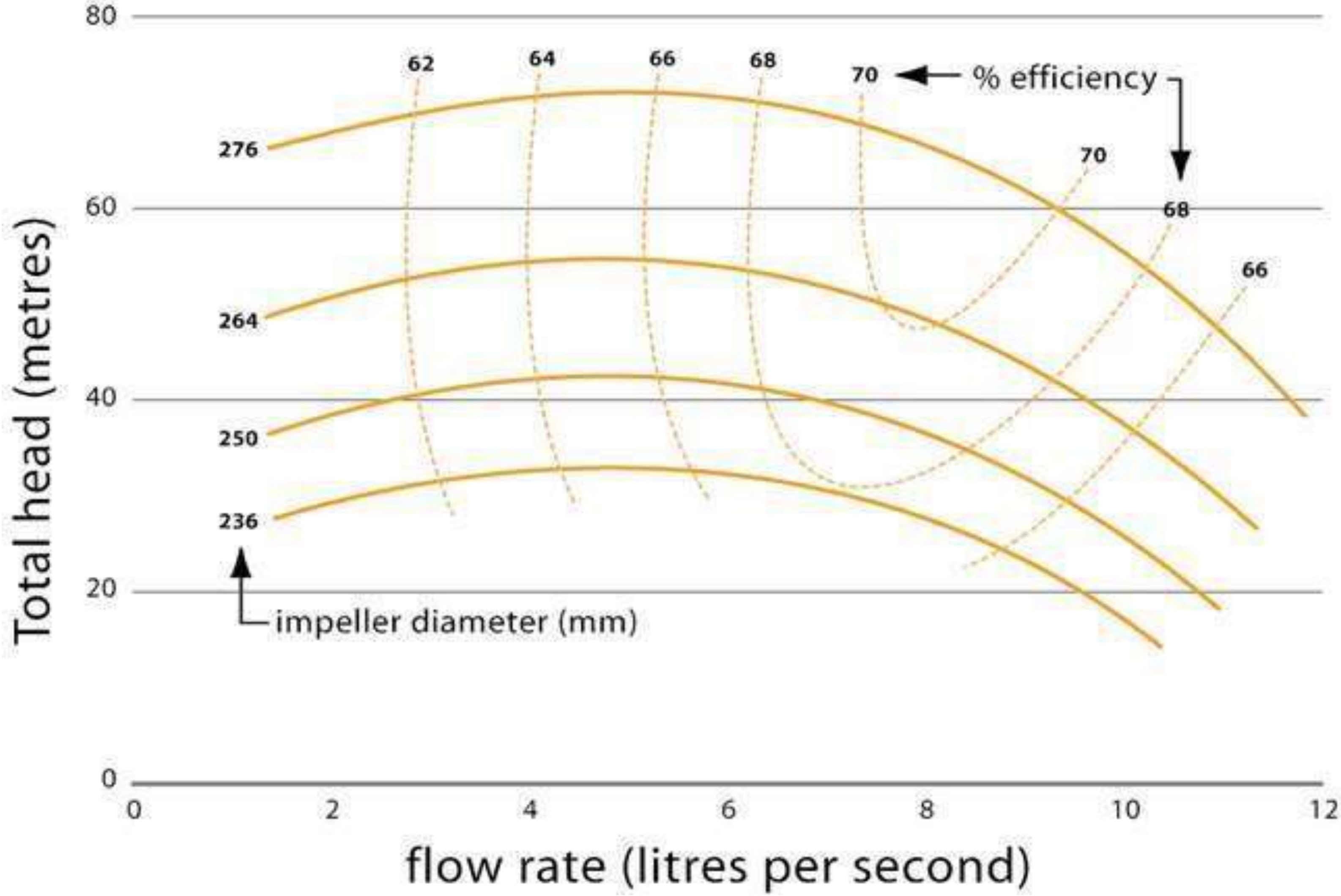
These are required to predict the performance & behavior of pump working under different head, flow rate & speed.

Following are the important curves:

a) Main characteristic curve.
b) Operating characteristic curve.
c) Muschel or constant efficiency curve.



Operating characteristic curve



Constant efficiency curve

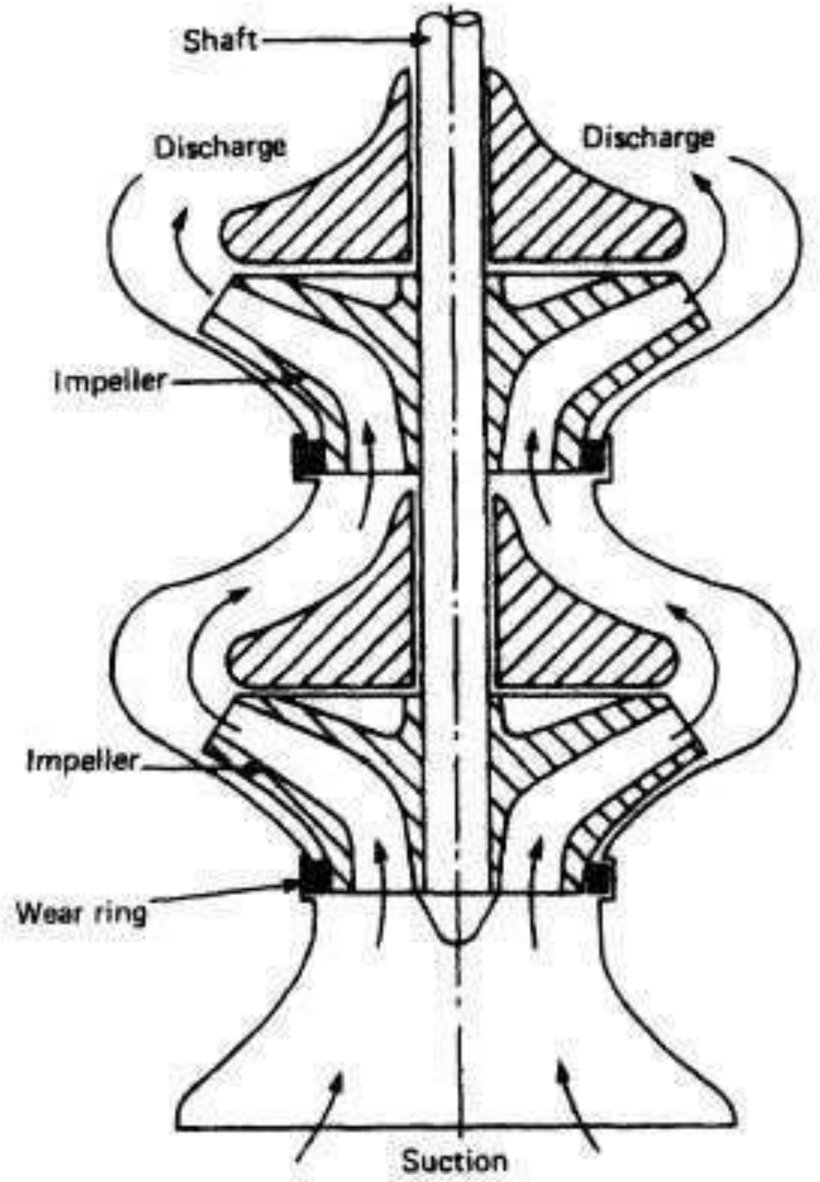
MULTI STAGE CENTRIFUGAL PUMPS

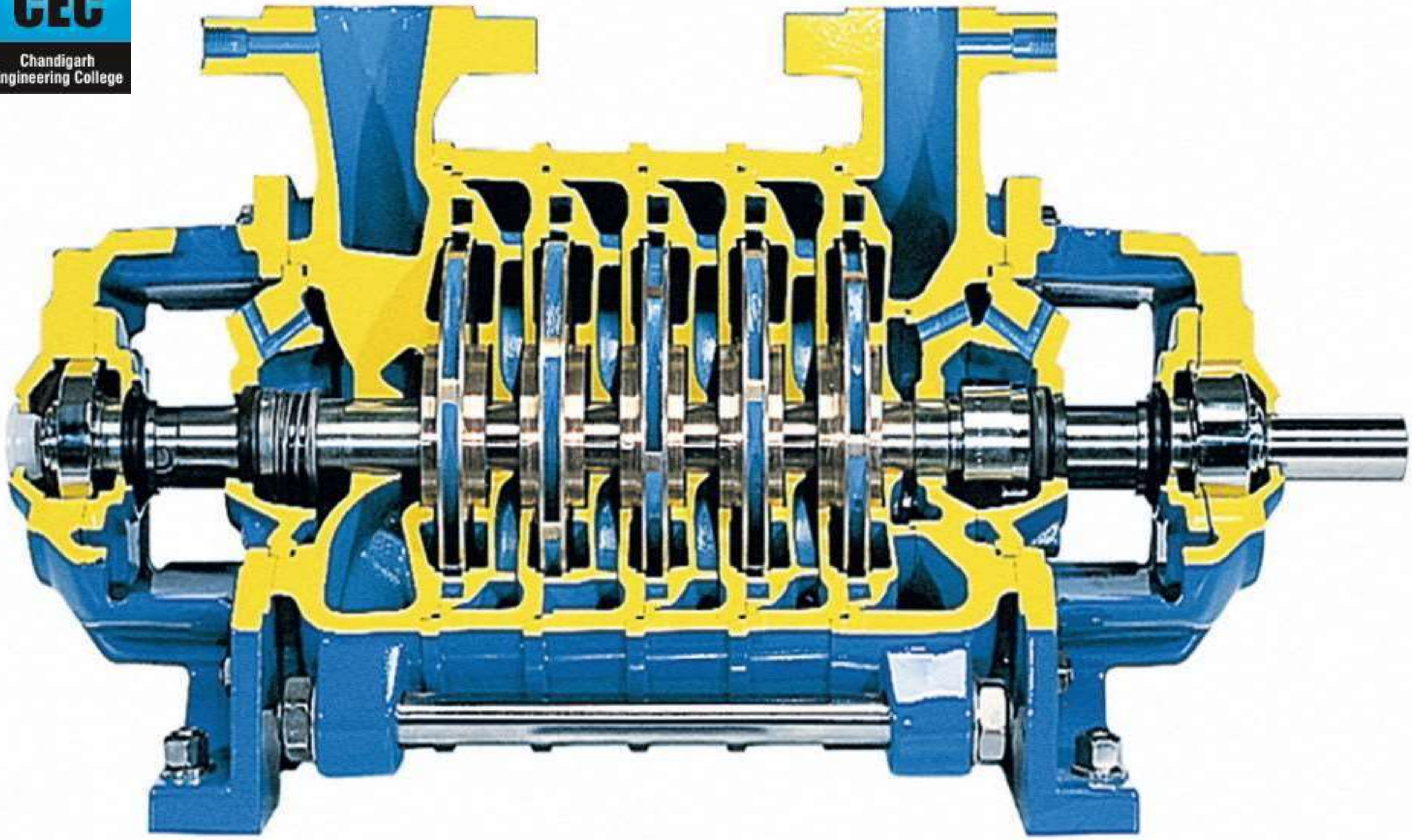
- It consists of two or more impellers.
- There are two types as follows:

a) SERIES :To produce high head.

b) PARALLEL :To discharge large quantity of liquid.

Series combination for high head





Parallel combination for high discharge

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.

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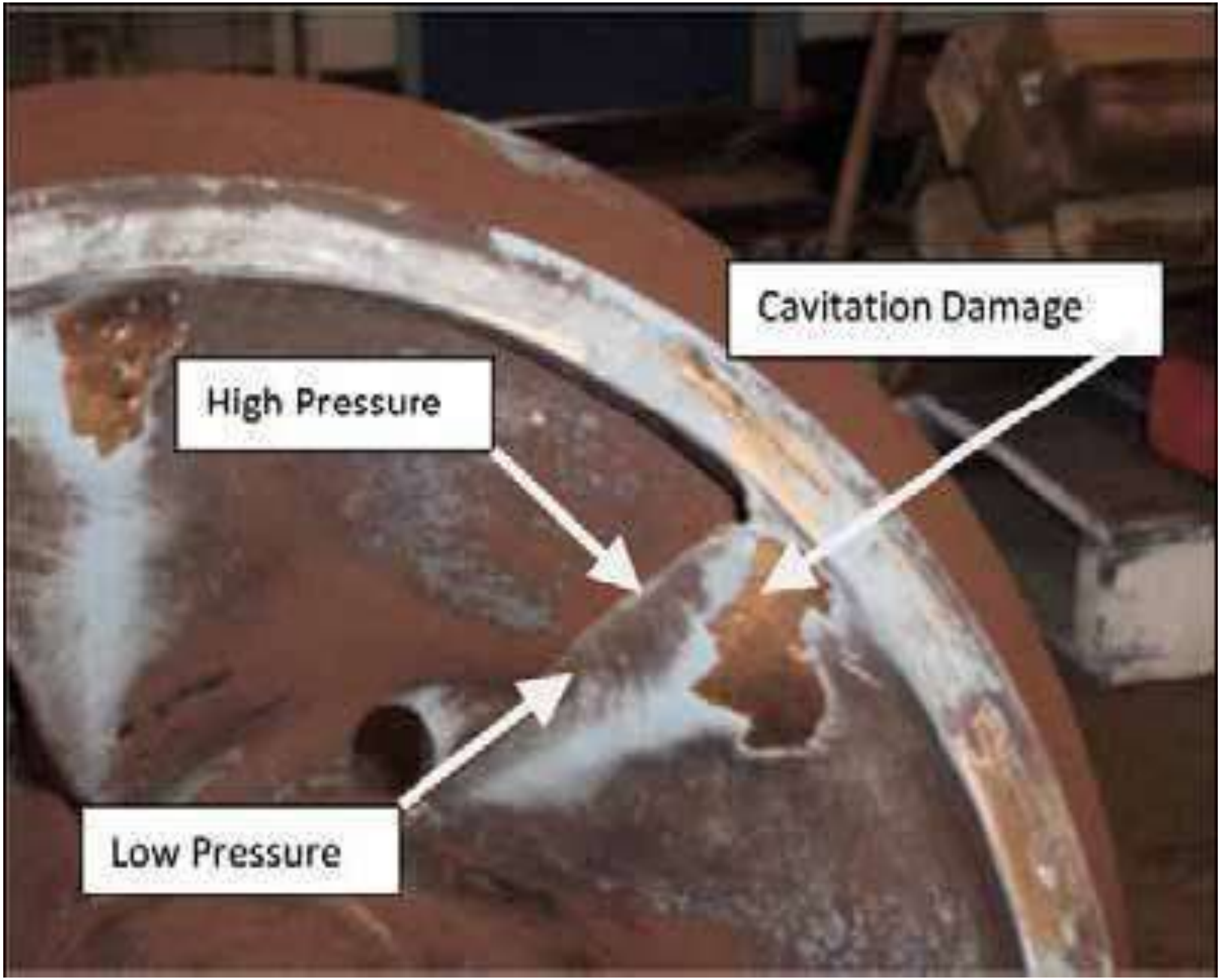

EFFECT OF CAVITATION

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

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AXIAL FLOW PUMPS

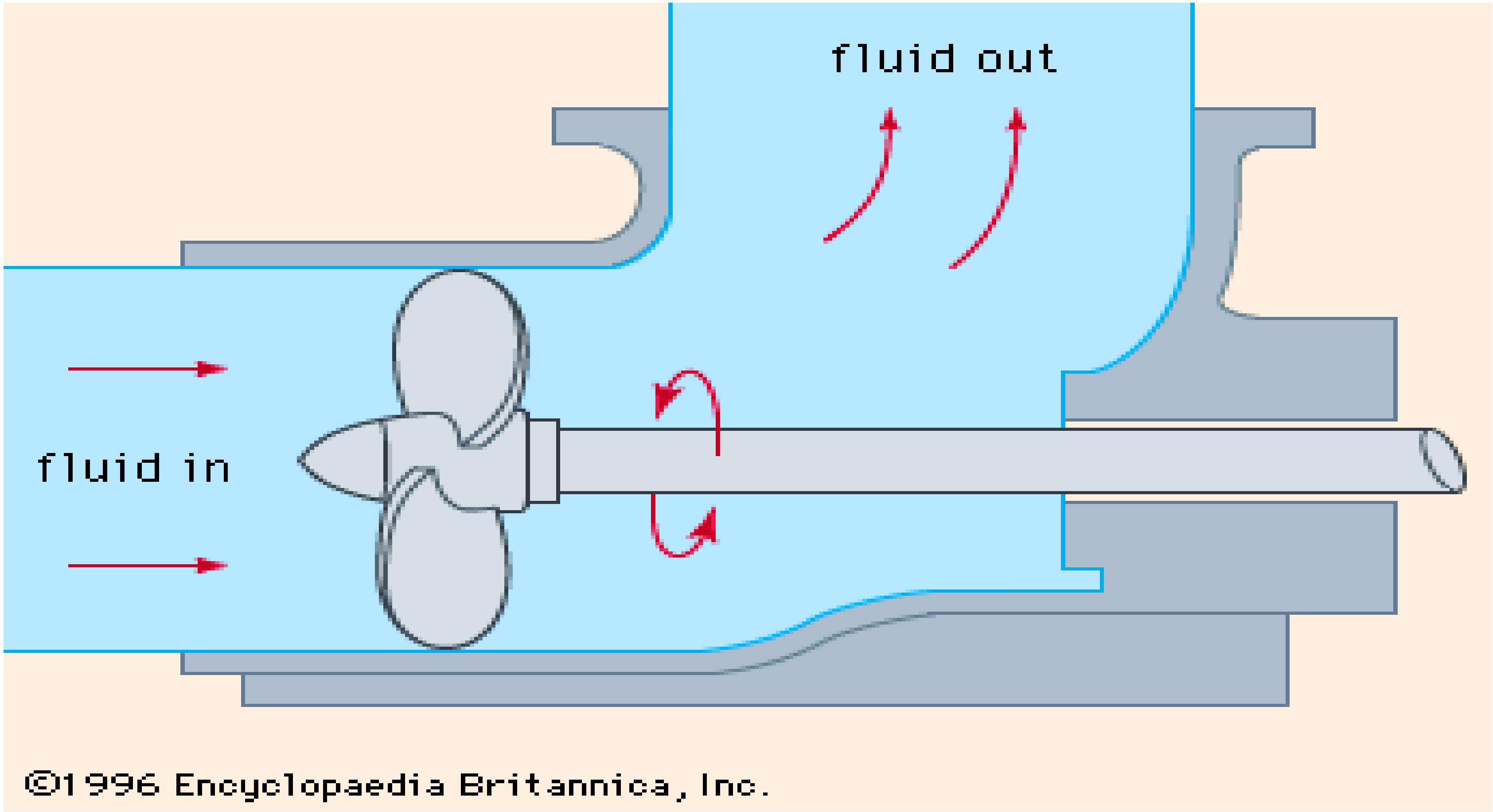
INTRODUCTION

- An **axial flow pump**, or AFP, is a common type of pump for water that essentially consists of a propeller in a pipe. The propeller can be driven directly by a sealed motor in the pipe or mounted to the pipe from the outside or by a right-angle drive shaft that pierces the pipe.
- These pumps have the smallest of the dimensions among many of the conventional pumps and are more suited for low heads and higher discharges.

INTRODUCTION

- **Axial Flow Pumps** or Propeller Pumps allow fluid to enter the impeller axially.
- They discharge fluid nearly axially, pumping the liquid in a direction that is parallel to the pump shaft.
- An axial flow pump is also called a propeller pump because the impeller works much like the propeller of a boat. The propeller is driven by a motor that is either sealed directly in the pump body or by a drive shaft that enters the pump tube from the side.
- Axial flow pumps use the propelling action of the impeller vanes on the liquid to develop pressure.

AXIAL FLOW PUMP



AXIAL FLOW PUMP

- Axial flow pumps use the propeller action to draw water into the pump by suction. An axial flow pump can be designed as a suction pump that draws water in through one end and discharges it out the top of the pump.
- However, axial flow pumps are not typically used for suction lift applications. Axial flow pumps used for pumping clear water or storm water may also be submersible. A submersible pump that uses an axial flow design is common in irrigation and drainage applications.
- Axial flow pumps may also be used as a sump pump in some industrial applications to circulate slurries or wastewater or to drain storm water from sump pits or waste storage lagoons.
- Axial flow pumps are typically used in high flow rate, low lift applications. A mixed flow pump similar to a turbine pump may be used as a well pump provided the well is not too deep.

AXIAL FLOW PUMP

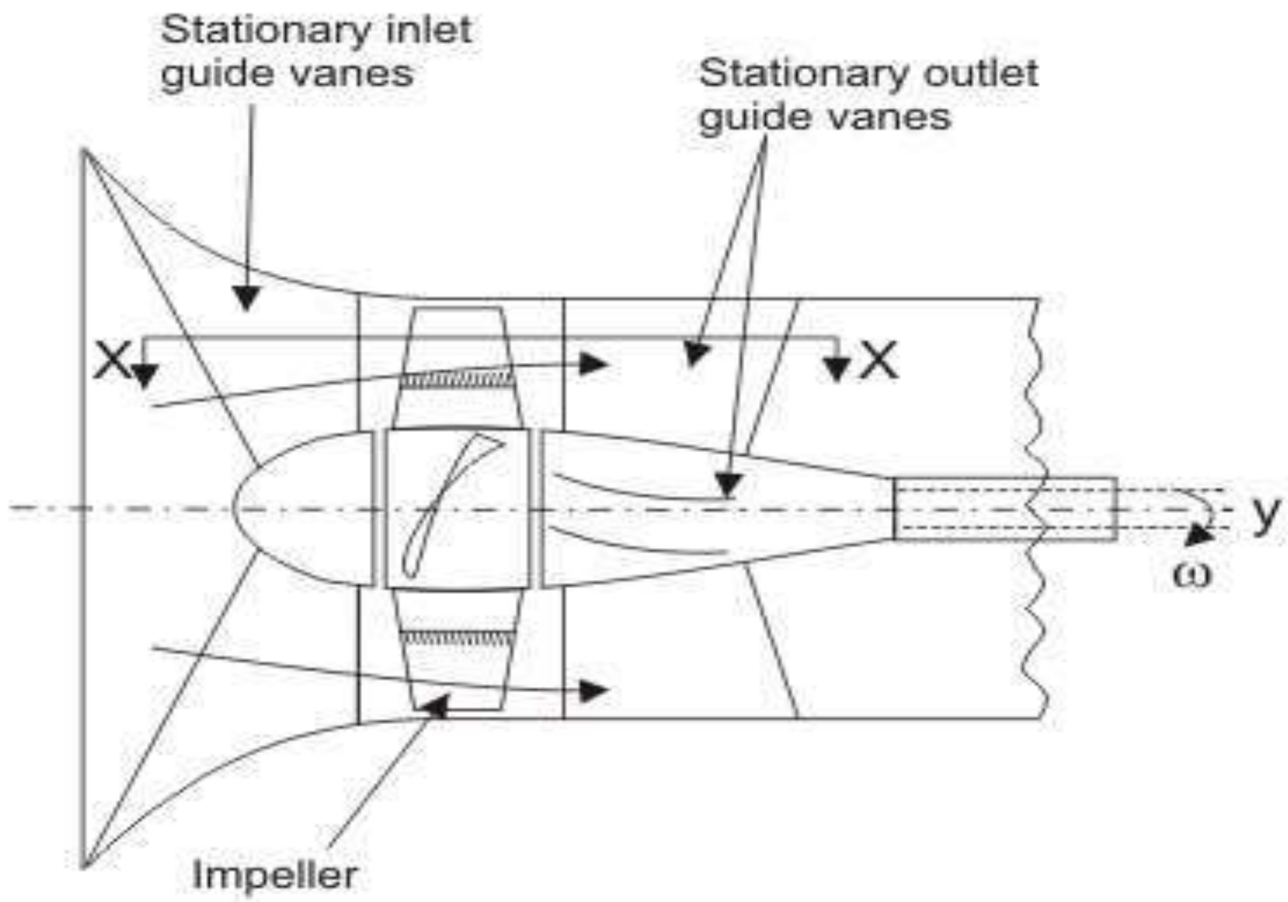
- An axial flow pump consists of a propeller type impeller running in a casing with fine clearances between the blade tips and the casing inner walls.
- The fluid essentially passes almost axially through alternate rows of the fixed stator blades and moving rotor blades in a multistage axial flow pump.
- The inlet guide vanes guide the fluid to enter the rotor with a purely axial velocity. The impeller blades, however impart a whirl component to the fluid. The outlet guide vanes eliminate the swirl on the outlet side and turn the flow towards the axis. To ensure a smooth flow without shock at the design condition, the blades of the impeller must be twisted.

AXIAL OR PROPELLER PUMP

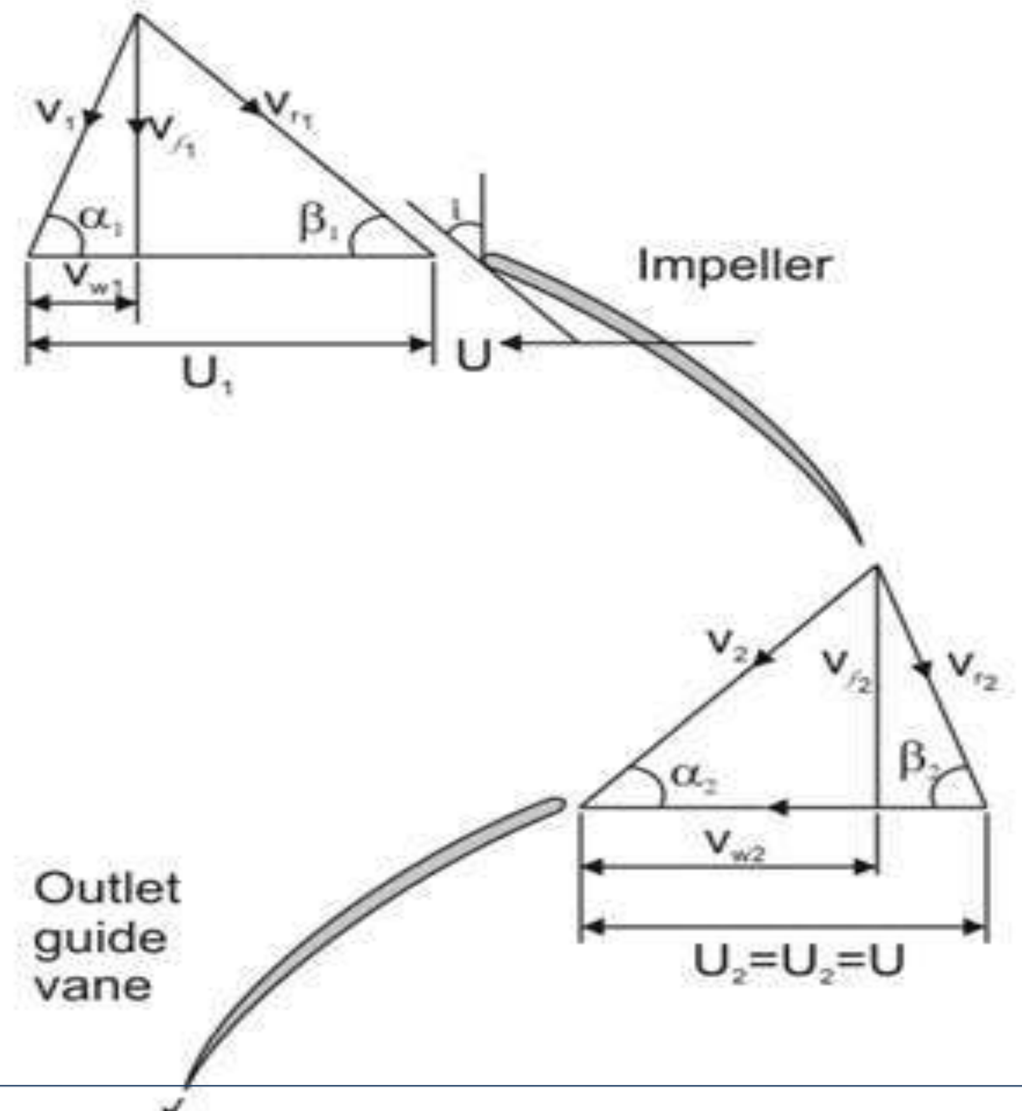
- The axial flow or propeller pump is the converse of axial flow turbine and is very similar to it an appearance. The impeller consists of a central boss with a number of blades mounted on it. The impeller rotates within a cylindrical casing with fine clearance between the blade tips and the casing walls.
- Fluid particles, in course of their flow through the pump, do not change their radial locations. The inlet guide vanes are provided to properly direct the fluid to the rotor.
- The outlet guide vanes are provided to eliminate the whirling component of velocity at discharge. The usual number of impeller blades lies between 2 and 8, with a hub diameter to impeller diameter ratio of 0.3 to 0.6.

AXIAL FLOW PUMP

AXIAL OR PROPELLER PUMP



VELOCITY TRIANGLE



WORK DONE

- The blade has an aerofoil section. The fluid does not impinge tangentially to the blade at inlet, rather the blade is inclined at an angle of incidence to the relative velocity at the inlet . If we consider the conditions at a mean radius r_m then

$$u_2 = u_1 = u = w r_m$$

where ω is the angular velocity of the impeller

Work done on the fluid per unit weight = $u(V_{w2} - V_{w1})/g$

For maximum energy transfer , $V_{w1} = 0$, i.e $\alpha_1 = 90^0$

WORK DONE

Again , from the outlet velocity triangle

$$V_{w2} = u - V_{f2} \cot \beta_2$$

Assuming a constant flow from inlet to outlet $V_{f1} = V_{f2} = V_f$

Then, we can write

Maximum energy transfer to the fluid per unit weight

$$= u(u - V_f \cot \beta_2) / g$$

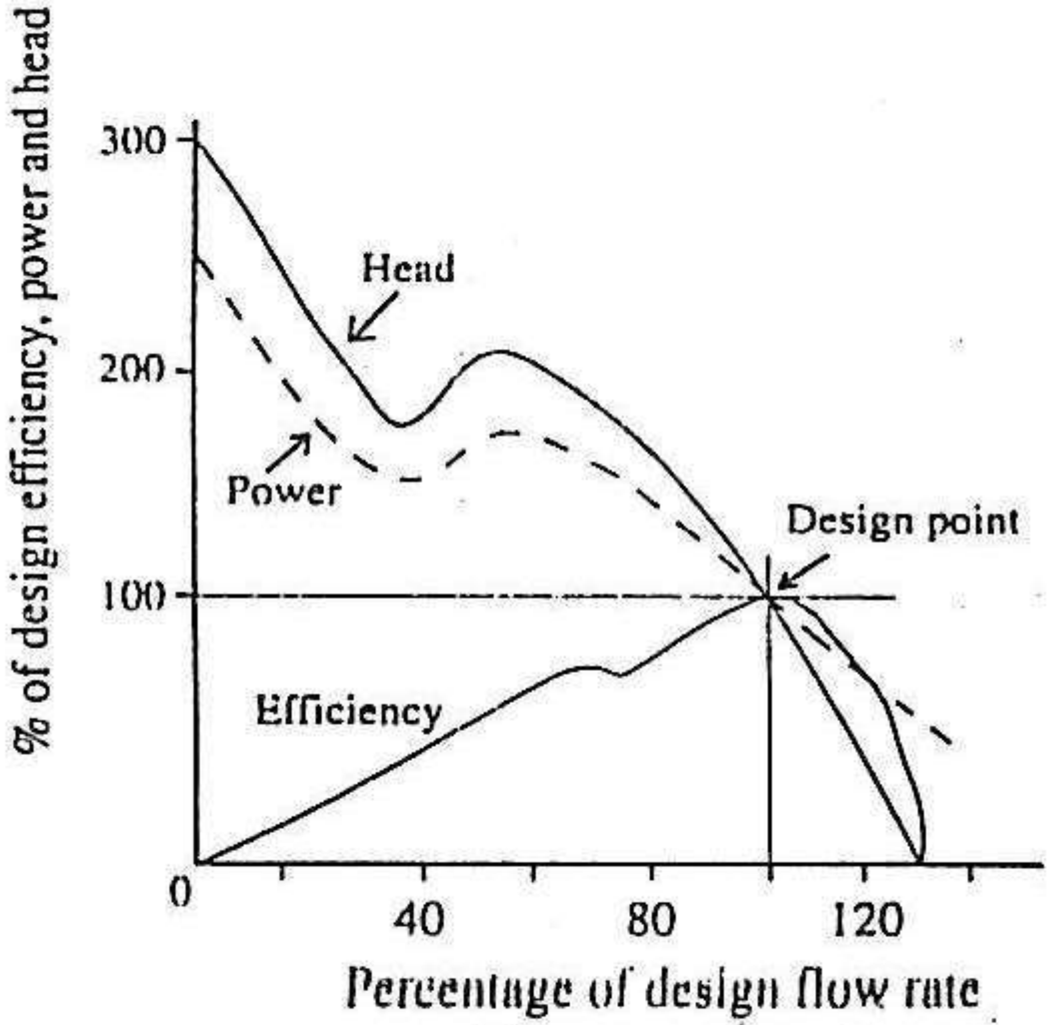
For constant energy transfer over the entire span of the blade from hub to tip , the right hand side of Equation has to be same for all values of r

WORK DONE

It is obvious that u^2 ncreases with radius , r therefore an equal increase in $uV_f \cot \beta_2$ must take place, and since V_f is constant then $\cot \beta_2$ must increase.

Therefore , the blade must be twisted as the radius changes.

AXIAL PUMP CHARACTERISTICS



AXIAL PUMP CHARACTERISTICS

- A steep negative slope is evident on the head and power curves at low flow rates. Work done E $= u(u - V_f \cot \beta_2)/g$
- Since discharge Q α V_f, therefore dE/dV_f α dE/dQ α $(-u^*\cot \beta_2)$
- For axial flow at inlet, β_2 is relatively small for a given pump at a given speed, the head-flow relationship has a steep slope.
- The power curve is similarly very steep, the power requirement at shut off being 2 – 2.5 times that required at the design point.
- The power and head curves are seen to enter a region of instability at about 50% of the design flow rate. This is due to V_f becoming increasingly small and thereby increasing the angle of incidence of flow onto the blade until separation and stalling of blade occurs.
- Further head rise at even lower flow rates and the consequent power rise is due to the recirculation of the fluid around the blade.

References

- **A Textbook of Fluid Mechanics and Hydraulic Machines**
Dr. R. K. Bansal, Laxmi Publications

- **NPTEL VIDEO LECTURES**