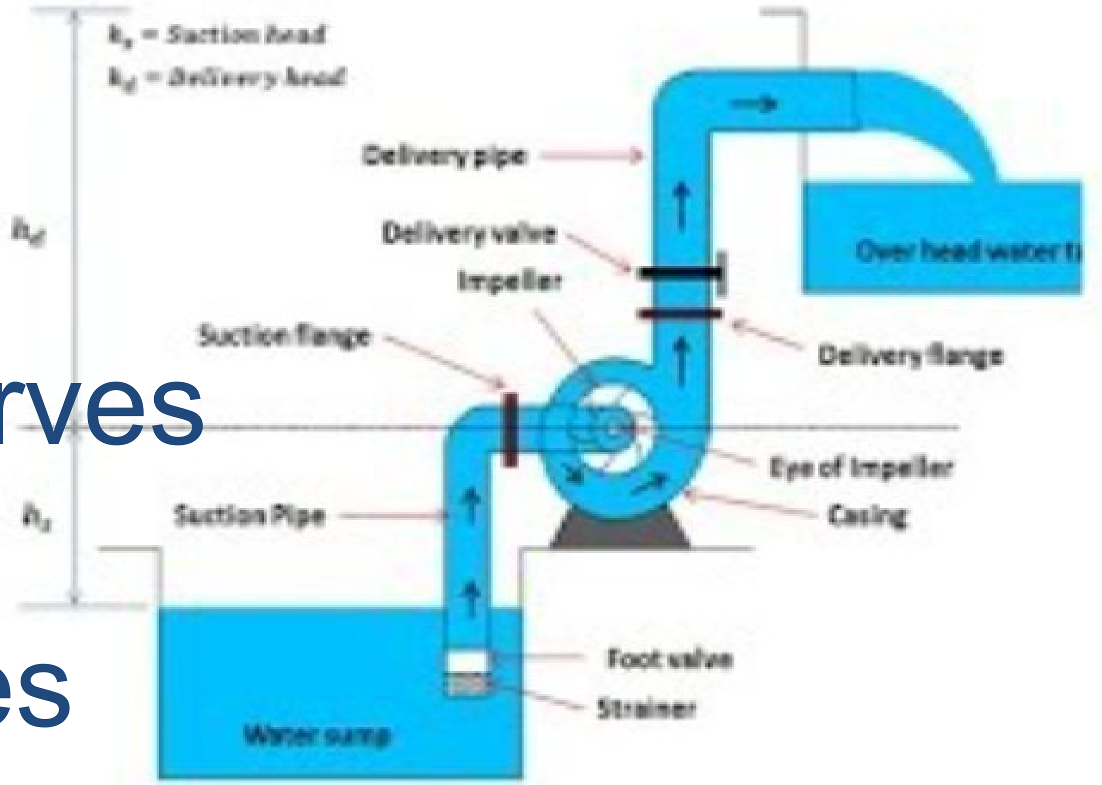
CENTRIFUGAL PUMP INTRODUCTION

- Introduction
- Principle
- Construction
- Performance curves
- NPSH
- Pump efficiencies



Introduction

What is pump?

PUMPS

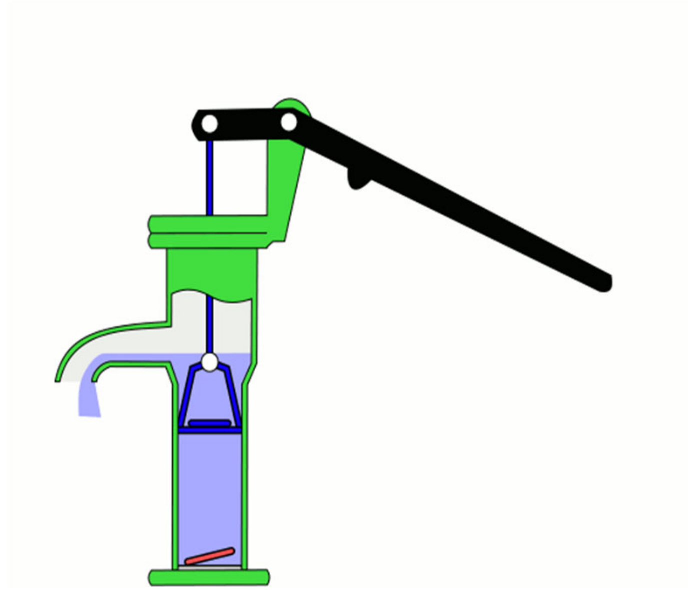
Machine that provides energy to a fluid in a fluid system.

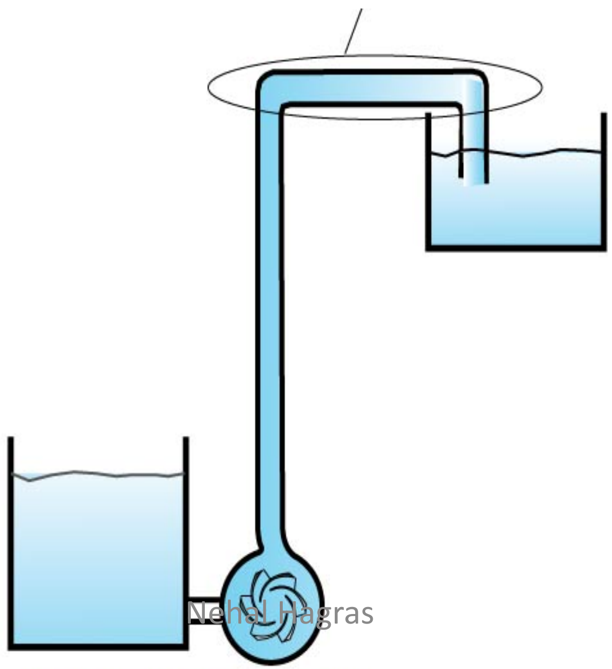
Converts the mechanical energy supplied to it externally to hydraulic energy and transfers it to the liquid flowing through a pipe Flow is normally from high pressure to low pressure

What pump can do?

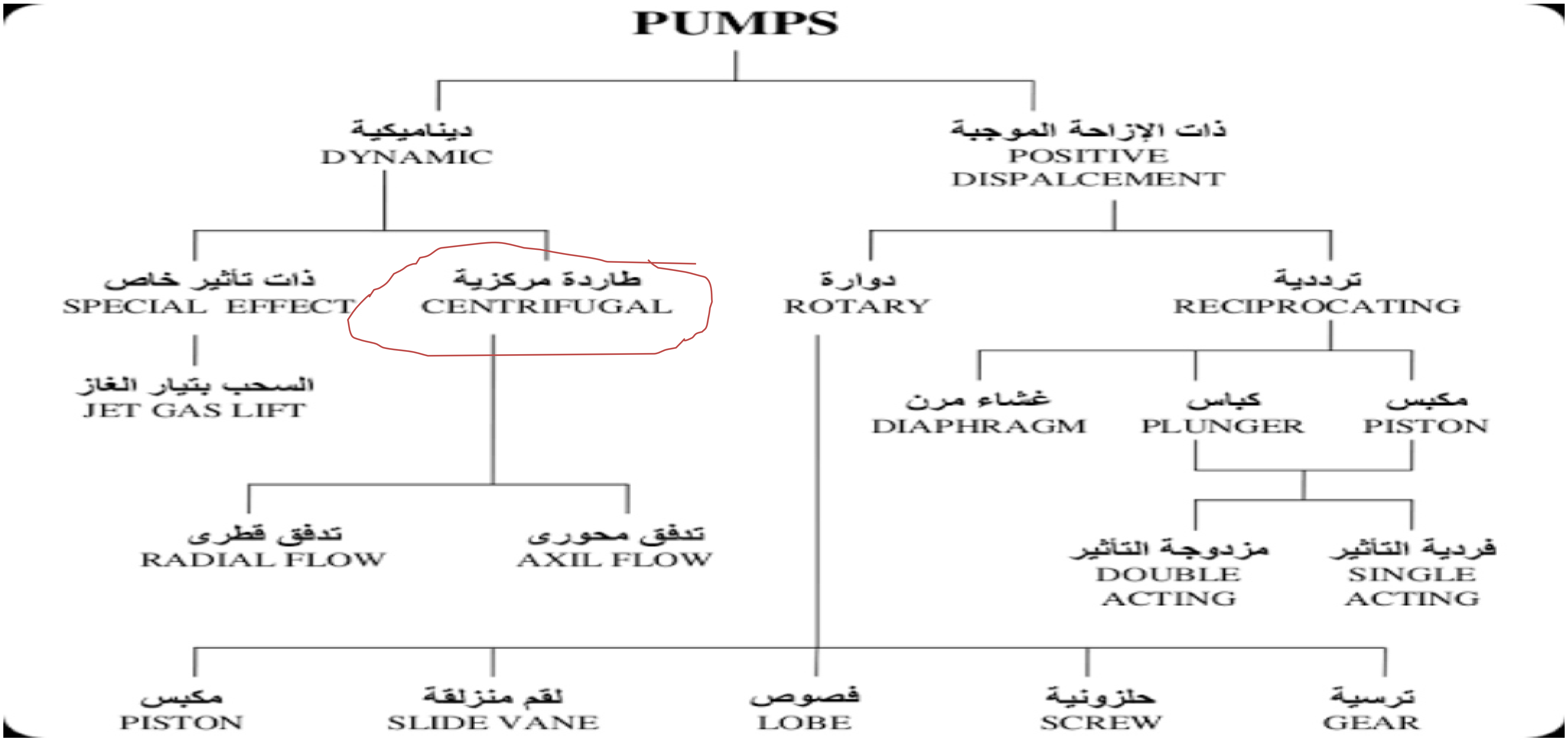
Pumps enables liquid to:-

- **Flow from low pressure aria to high pressure aria**
- **Form low level to high level**
- **Flow at higher flow rate**

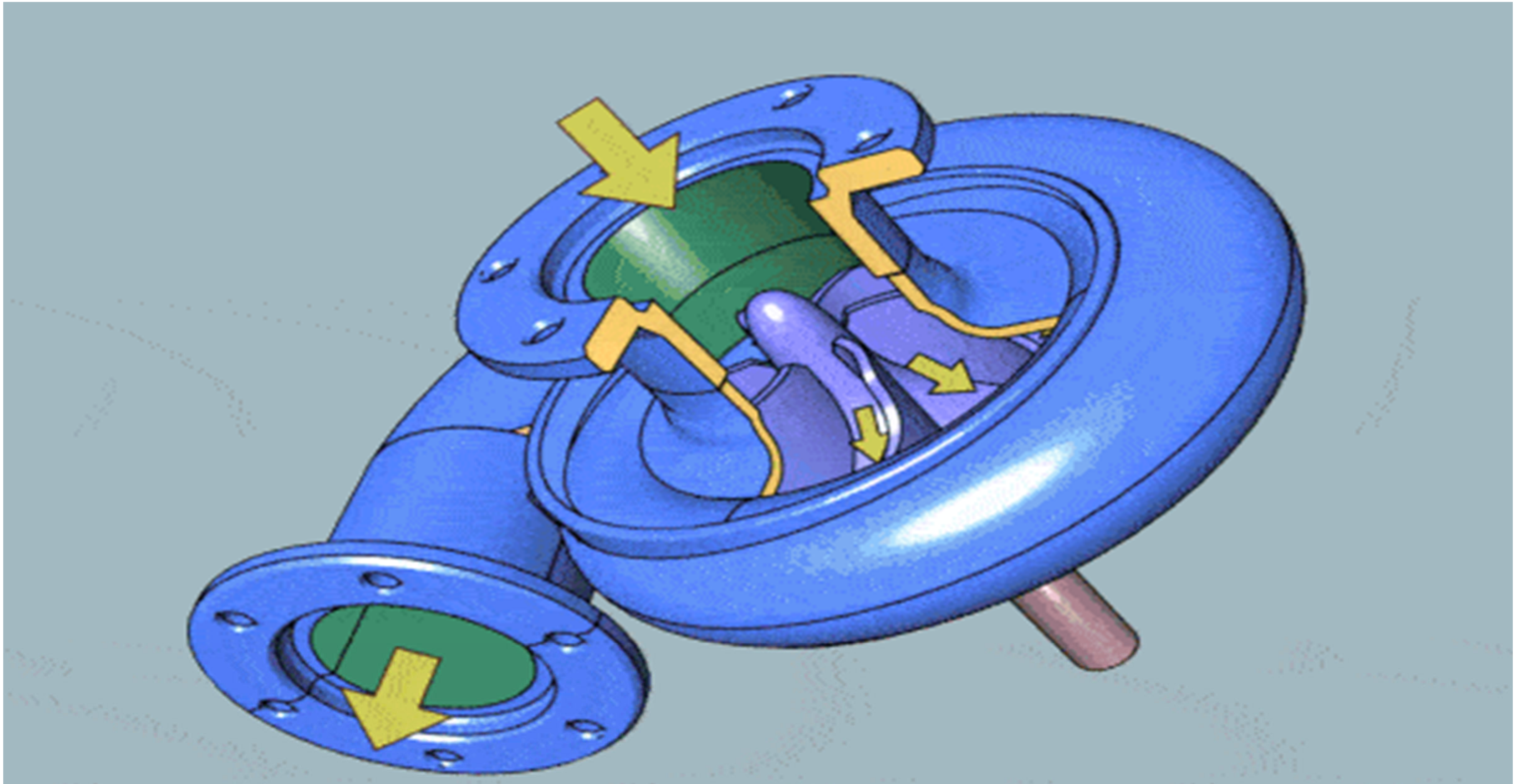




Main classification of pumps



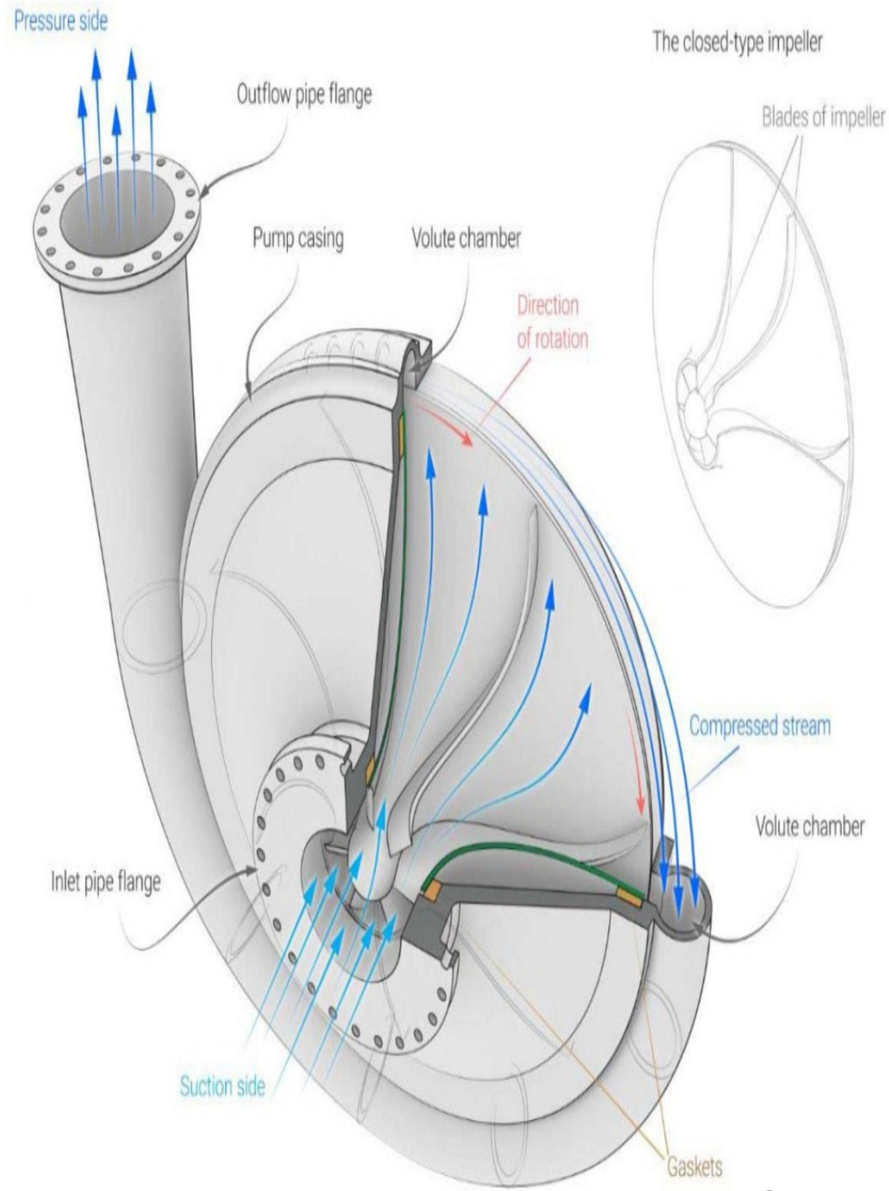
Operating principle



Construction of a centrifugal pump

Following are the main parts of the centrifugal pump:

- Impeller
- Casing
- Suction pipe
- Delivery pipe



Construction of a centrifugal pump

Impeller-

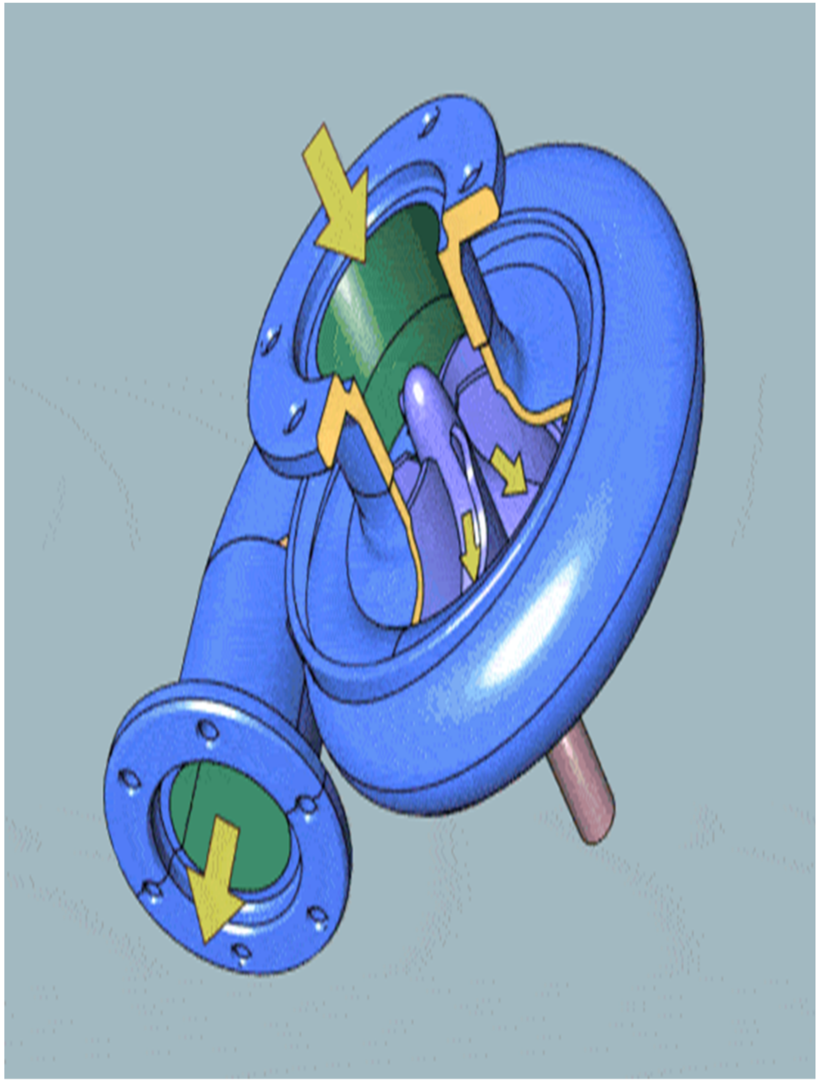
- An impeller is the most important part of a centrifugal pump. The rotating part of a centrifugal pump is called the impeller.
-
- It imparts kinetic energy to the fluid by rotating at a high r.p.m.
-
- It is mounted on a shaft coupled to a prime mover like an electric motor or an engine.
-
- The impeller consists of a number of backward curved vanes mounted on the circumference of the impeller.

Construction of a centrifugal pump

Casing-

The casing of a centrifugal pump is similar to the casing of a reaction turbine i.e. it is of volute shape.

It is an air-tight passage surrounding the impeller. The kinetic energy of liquid coming out of the impeller is converted into pressure energy by a casing.



Construction of a centrifugal pump

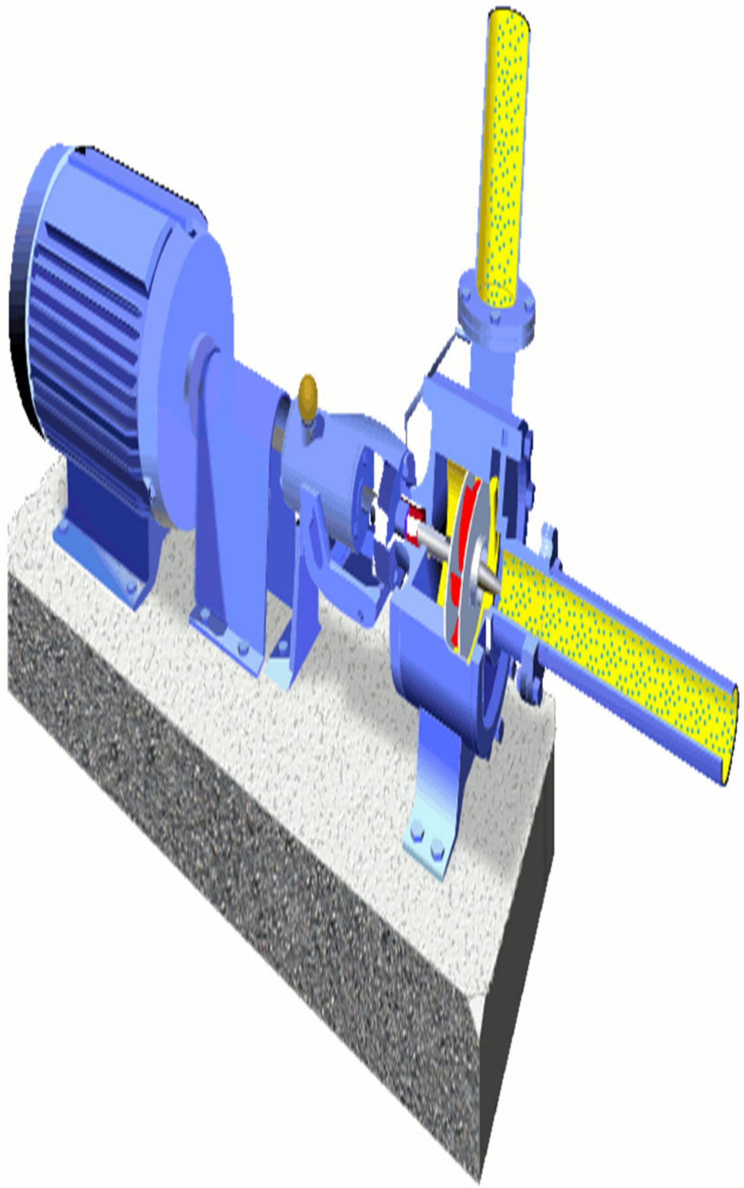
Suction pipe-

It is a pipe that is connected at its upper end to the inlet of the pump or to the centre of the impeller.
The lower end of the suction pipe dips into liquid in a suction tank or a sump from which the liquid is to be pumped or to be lifted up.

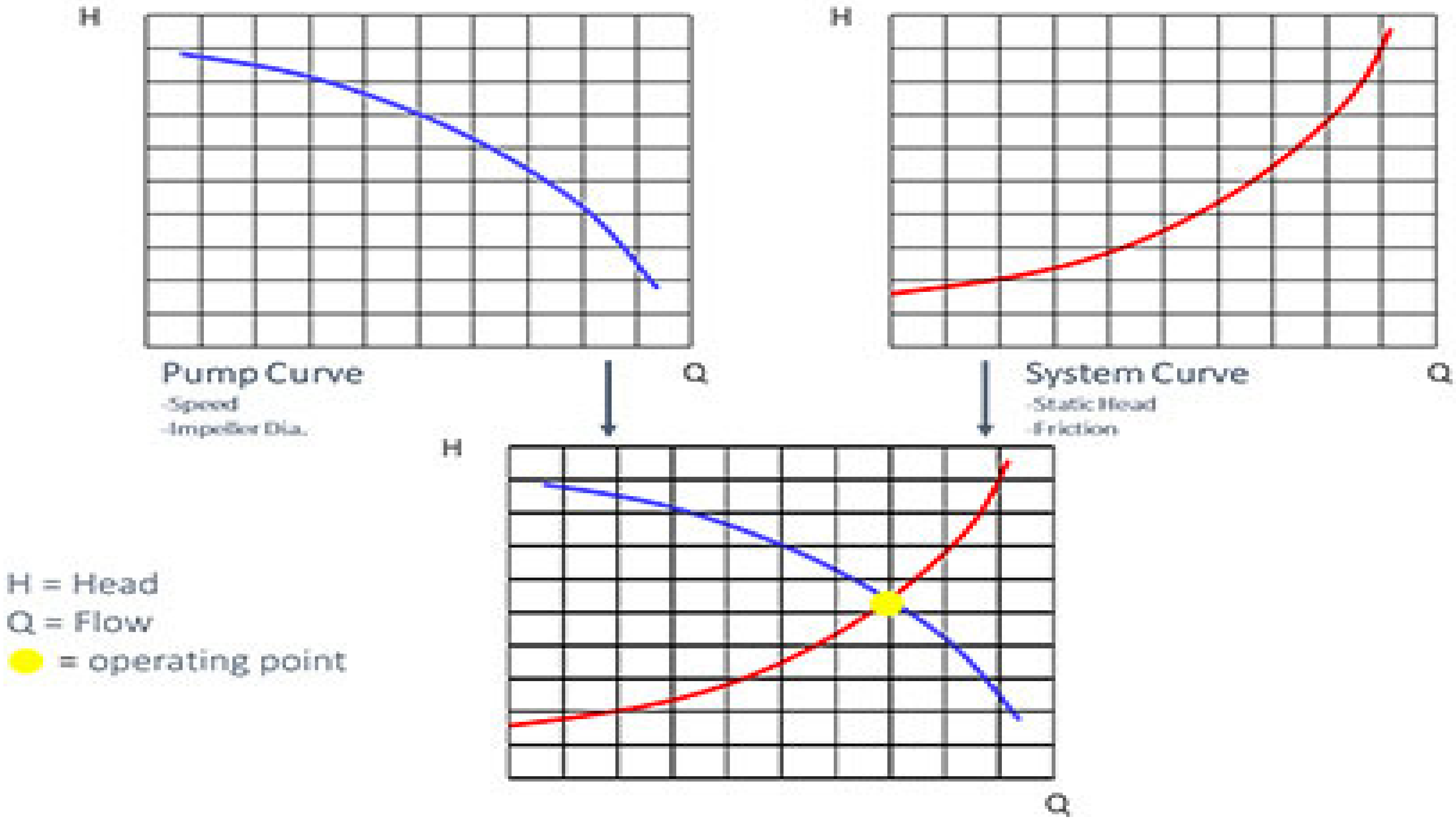
The diameter of a suction cup is kept larger than the delivery pipe to avoid cavitation.

Delivery pipe-

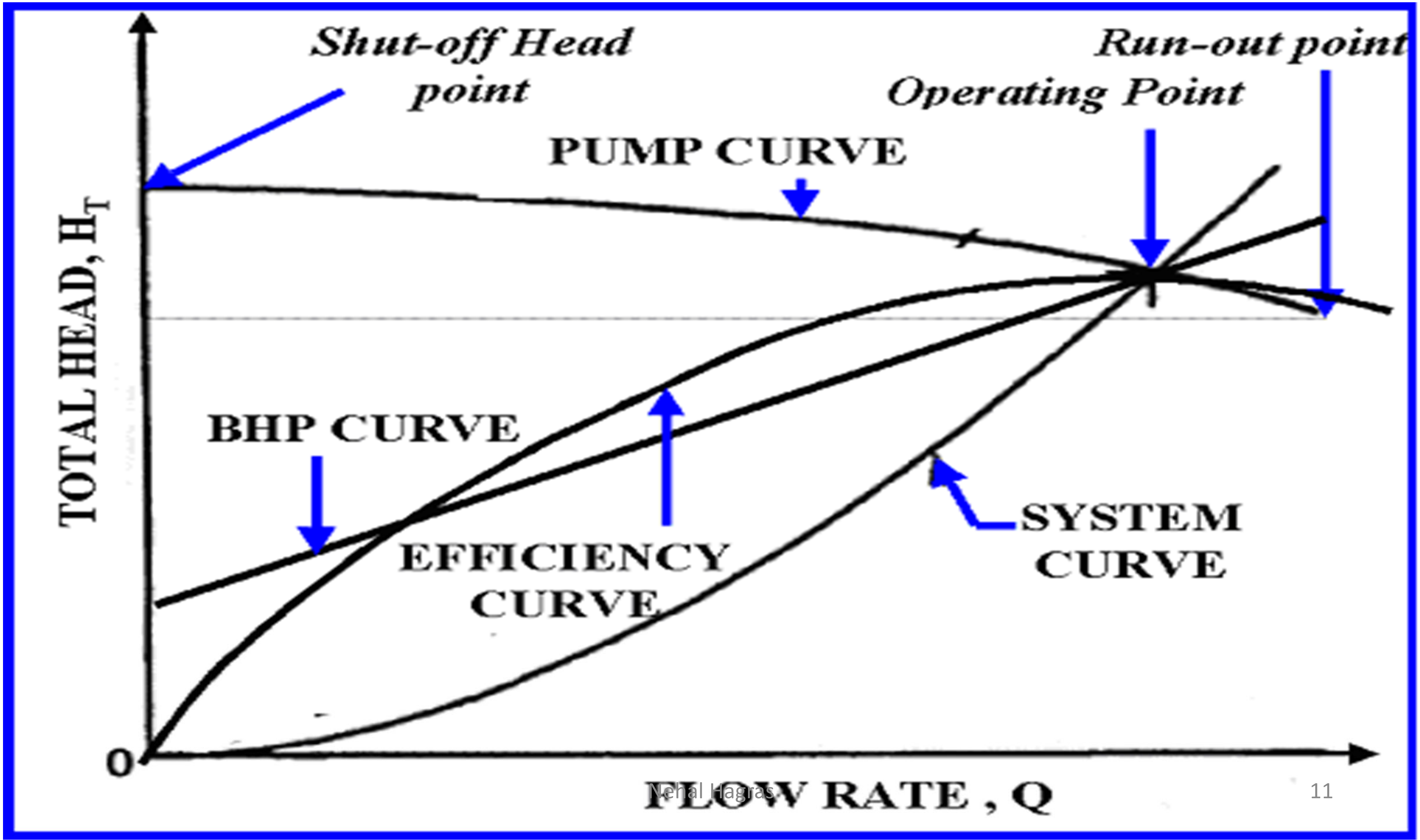
It is a pipe that is connected at its lower end to the outlet of the pump and it delivers the liquid to the required height.



PUMP PERFORMANCE CURVE



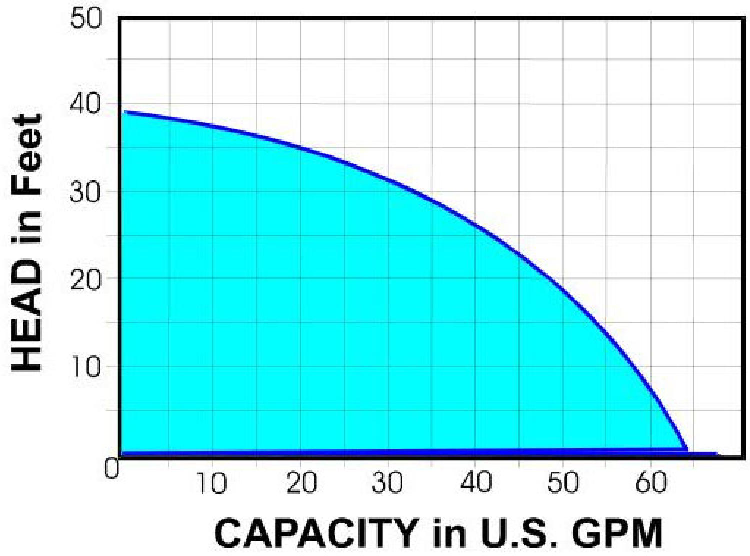
PUMP PERFORMANCE CURVES



Working of a centrifugal pump

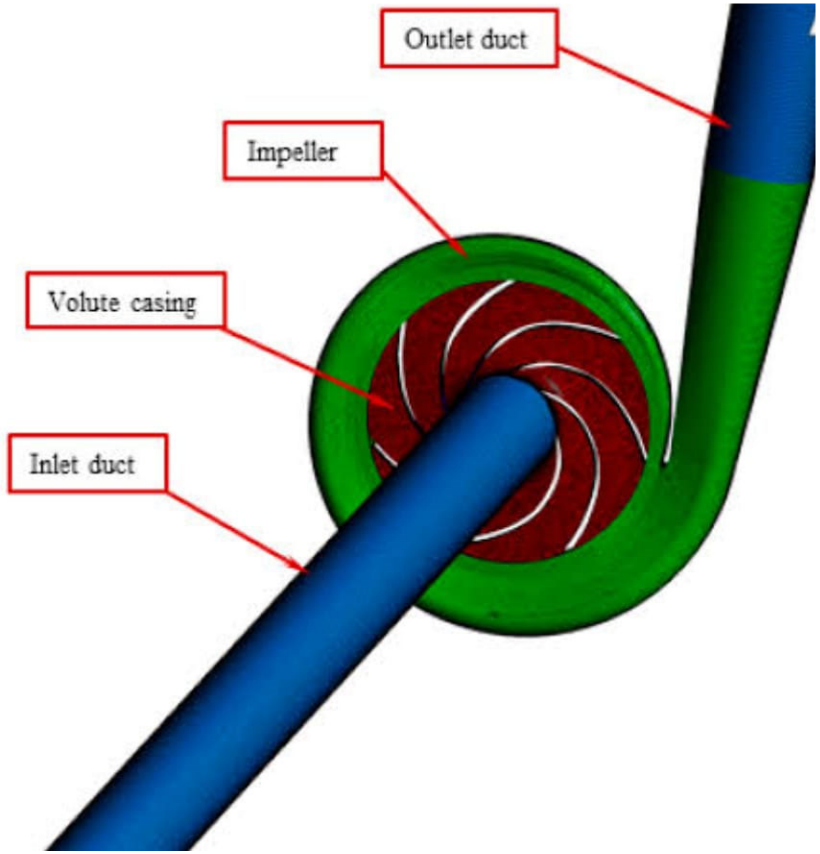
- The **head and flow** rate determine the performance of a **pump,** which is graphically shown in the figure as the performance curve or **pump** characteristic curve

A mapping or graphing of the pump's ability to produce head and flow



يحدد الضغط و التصرف أداء المضخة ، والذي يظهر بيانياً في الشكل على أنه منحنى الأداء أو منحنى خصائص المضخة.

PUMP DESIGN SCALING



Pump Flow rate

- Q2 = Q1 x [(D2xN2)/(D1xN1)]

Pump Head

- H2 = H1 x [(D2xN2)/(D1xN1)]2

Pump Brake Horse Power

- BHP2 = BHP1 x [(D2xN2)/(D1xN1)]3

- D = Impeller Diameter
- N = specific speed

$$Ns = \frac{N \times Q^{0.5}}{H^{0.75}}$$

where

- Q = Capacity at best efficiency point (BEP) at maximum impeller diameter,GPM
- H = Head per stage at BEP at maximum impeller diameter ,ft
- N = Pump speed, RPM

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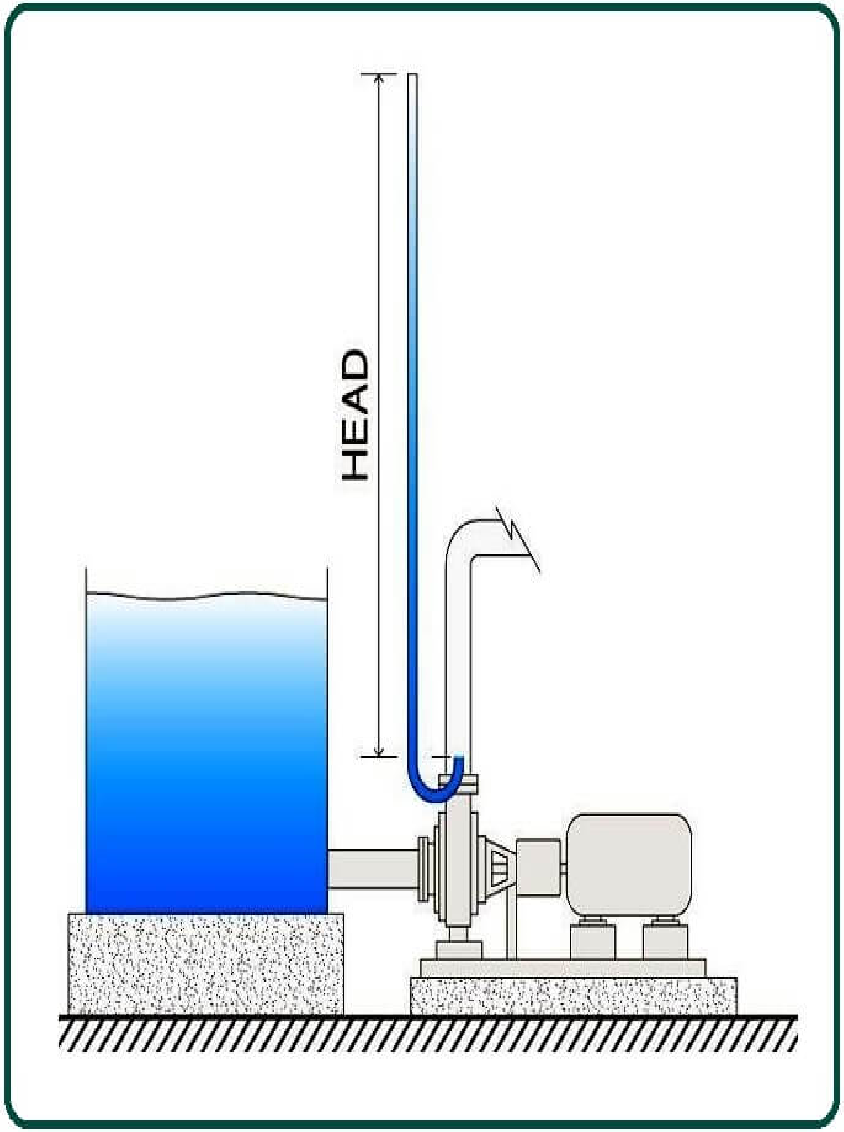
PUMP HEAD

What Is Head of a Pump?

- the head of pumps is the maximum height that the pump can achieve pumping against gravity. Intuitively, if a pump can generate more pressure, it can pump more water & produce a higher head. The purest examples of this are if you have verticals pipes running straight up from the discharge outlet.



PUMP HEAD

The head of a pump can be expressed in metric units as:

$$head = (p_2 - p_1)/(\rho g) + (v_2^2 - v_1^2)/(2g) + (z_2 - z_1)$$

where

h = total head developed (m)

p_2 = pressure at outlet (N/m^2)

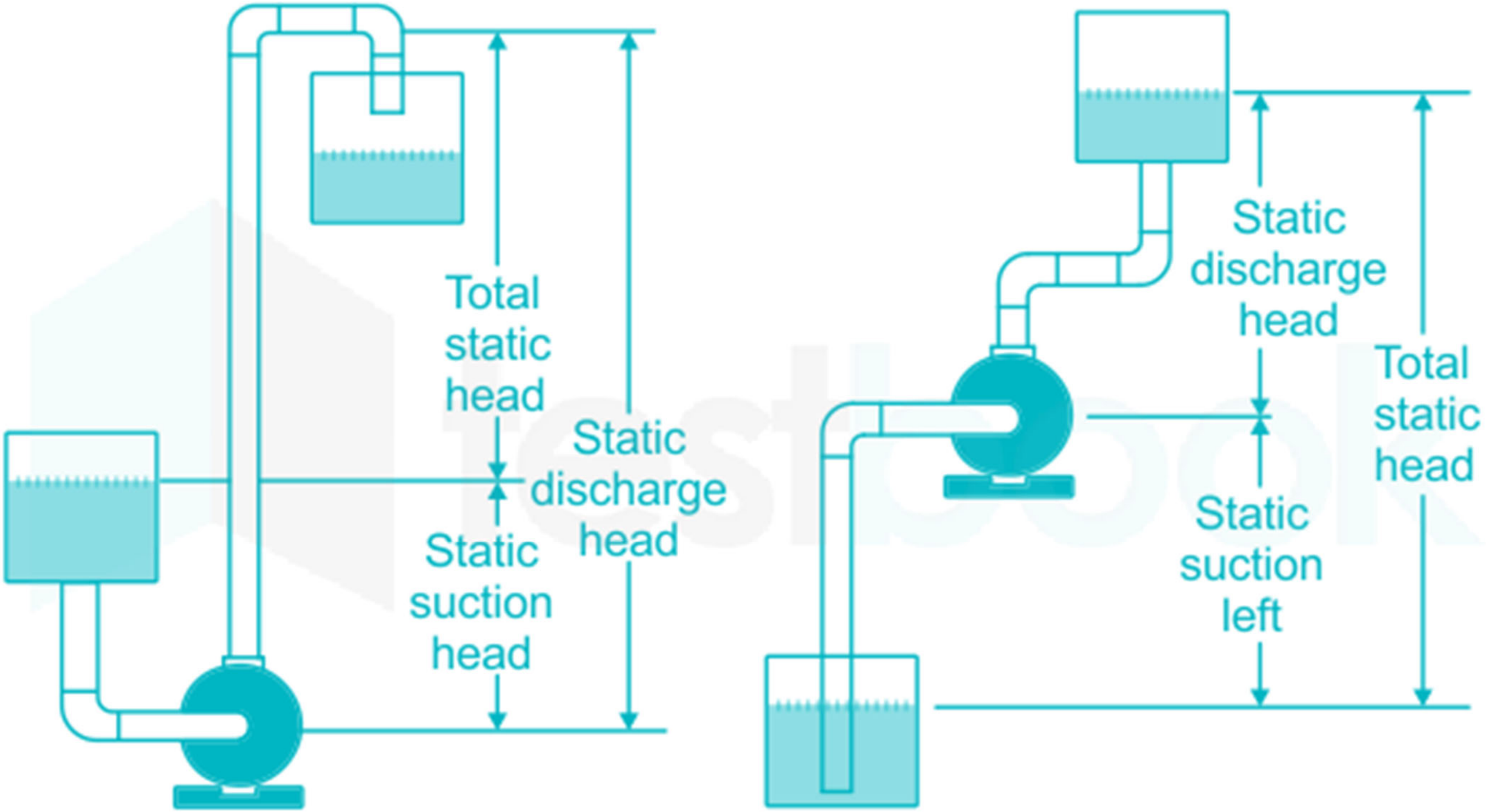
p_1 = pressure at inlet (N/m^2)

ρ = density of liquid (kg/m3)

g = acceleration of gravity (9.81) m/s^2

v_2 = velocity at the outlet (m/s)

TYPES OF PUMP HEAD



DIFFERENT TYPES OF PUMP HEAD

- **Total Static Head** - Total head when the pump is not running Total Dynamic Head (Total System Head) - Total head when the pump is running
- **Static Suction Head** - Head on the suction side, with pump off, if the head is higher than the pump impeller.
- **Static Suction Lift** - Head on the suction side, with pump off, if the head is lower than the pump impeller.
- **Static Discharge Head** - Head on discharge side of pump with the pump off Dynamic Suction Head/Lift - Head on suction side of pump with pump on Dynamic Discharge Head - Head on discharge side of pump with pump

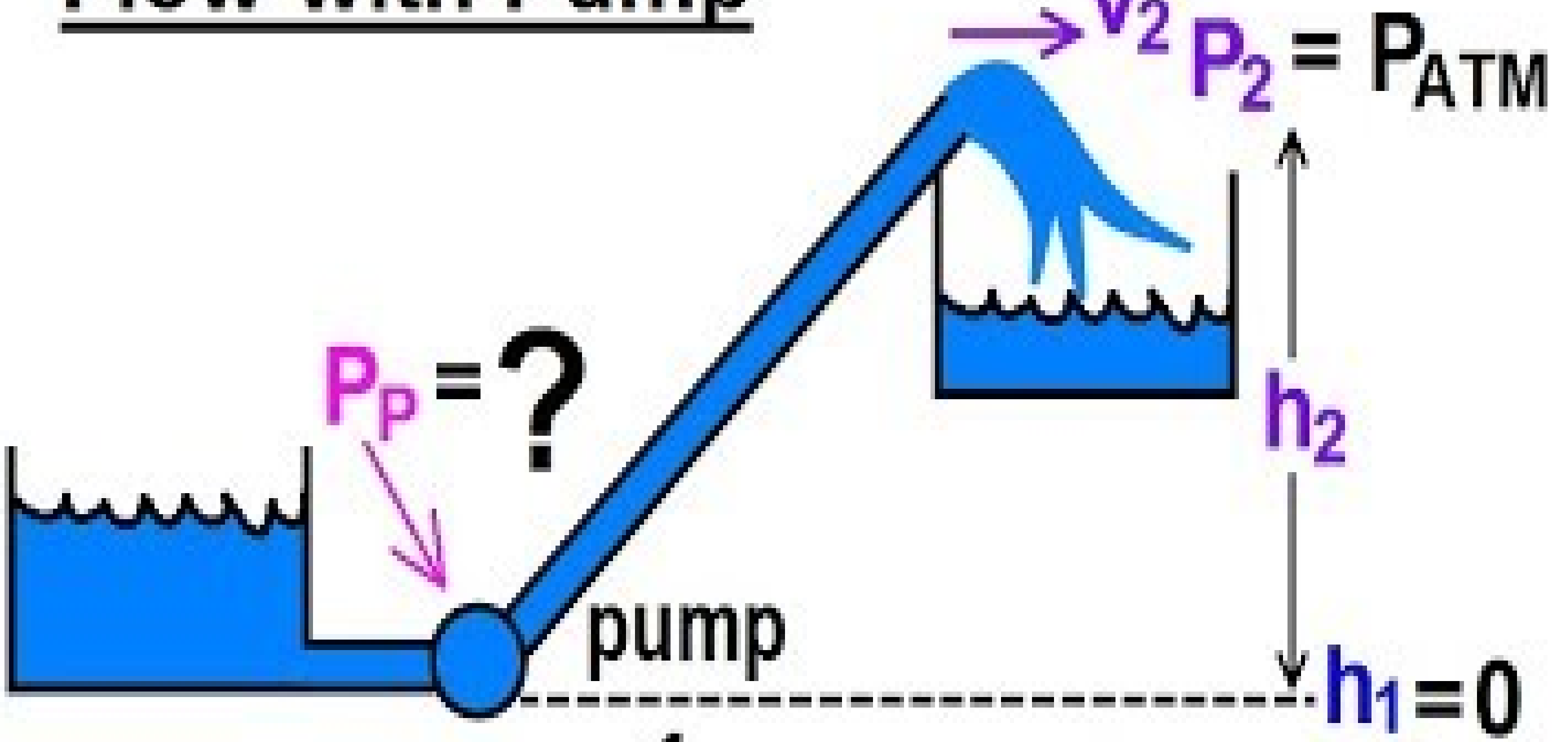
Flow with Pump

$$f_h = \frac{fLv^2}{2Dg}$$

$P_1 = P_{ATM}$

$v_1 = 0$

$h_1 = 0$



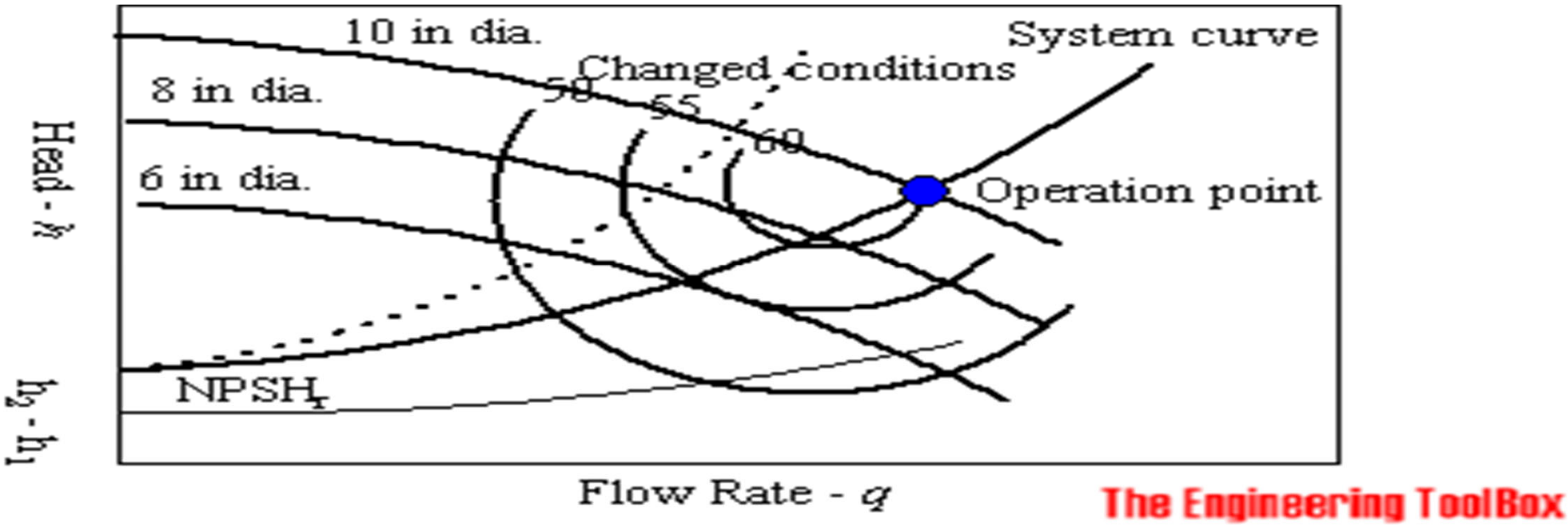
$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 + P_P = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2 + \rho g f_h$$

$$0 + 0 + 0 + P_P = 0 + \frac{1}{2}\rho v_2^2 + \rho g h_2 + \rho g f_h$$

$$P_P = \frac{1}{2}\rho v_2^2 + \rho g h_2 + \rho g f_h$$

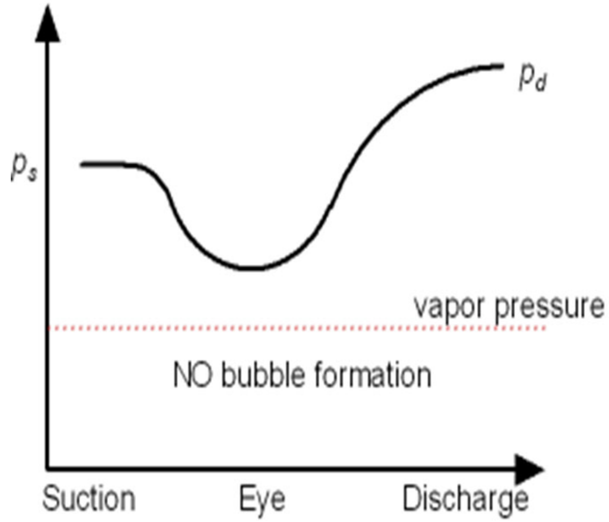
NET POSITIVE SUCTION HEAD-NPSH

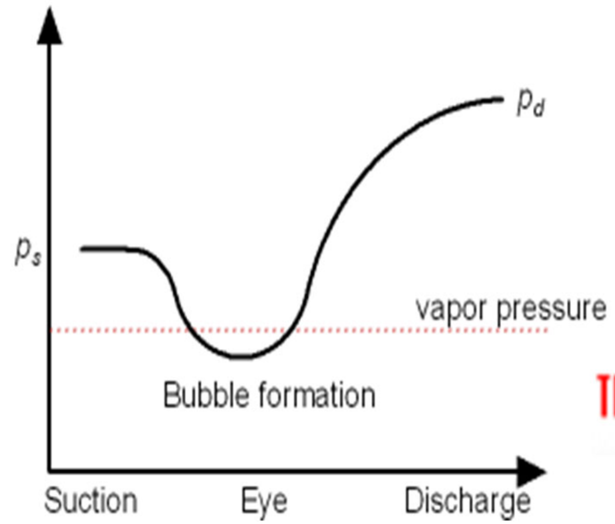
- Pumps can not pump vapors! The satisfactory operation of a pump requires that vaporization of the liquid being pumped does not occur at any condition of operation.

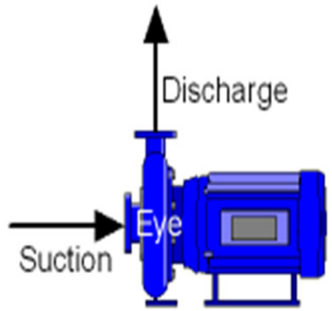


NET POSITIVE SUCTION HEAD-NPSH

- Low pressure at the suction side of a pump may cause the fluid to start **boiling** with
- **reduced efficiency**
- **cavitation**
- **damage**
- of the pump as a result. Boiling starts when the pressure in the liquid is reduced to the vapor pressure of the fluid at the actual temperature.







The Engineering ToolBox

NET POSITIVE SUCTION HEAD-NPSH

Suction Head

- Based on the Energy Equation - the **suction head** in the fluid close to the impeller*) can be expressed as the sum of
  the **static** and **velocity head**:
- $h_s = p_s / \gamma_{liquid} + v_s^2 / 2\, g$

We can not measure the suction head "close to the impeller". In practice we can measure the head at the pump suction flange.

NET POSITIVE SUCTION HEAD-NPSH

Liquids Vapor Head

- The **liquids vapor head** at the actual temperature can be expressed as:
- $h_v = p_v / \gamma_{vapor}$ (2)

where,,

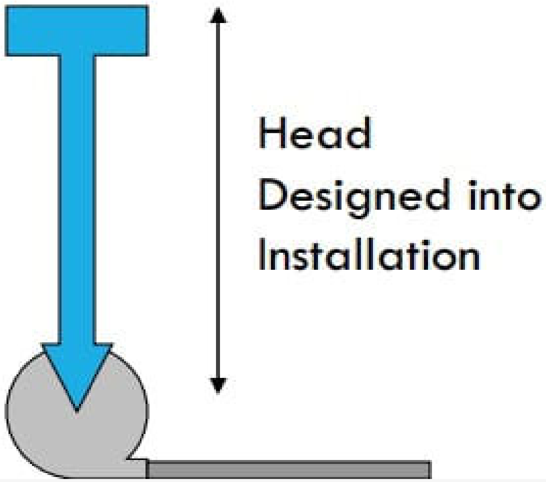
- γ_{vapor} = *specific weight of the vapor (N/m³, lb/ft³)*

Note! The vapor pressure in a fluid depends on the temperature. Water, our most common fluid, starts boiling at *20 °C* if the absolute pressure is *2.3 kN/m²*. For an absolute pressure of *47.5 kN/m²* the water starts boiling at *80 °C*. At an absolute pressure of *101.3 kN/m²* (normal atmosphere) the boiling starts at *100 °C*.

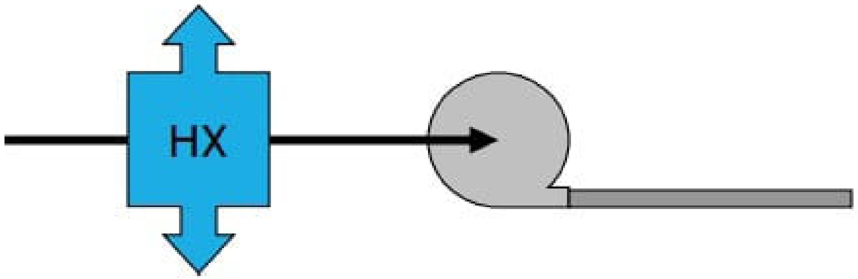
NET POSITIVE SUCTION HEAD AVAILABLE, $NPSH_A$

Net Positive Suction Head **Available** is a function of the system in which the pump operates. It is the excess pressure of the liquid in feet absolute over its vapor pressure as it arrives at the pump suction, to be sure that the pump selected does not cavitate.

Head to Feed Pump
To overcome suction head



Subcooling before Pump

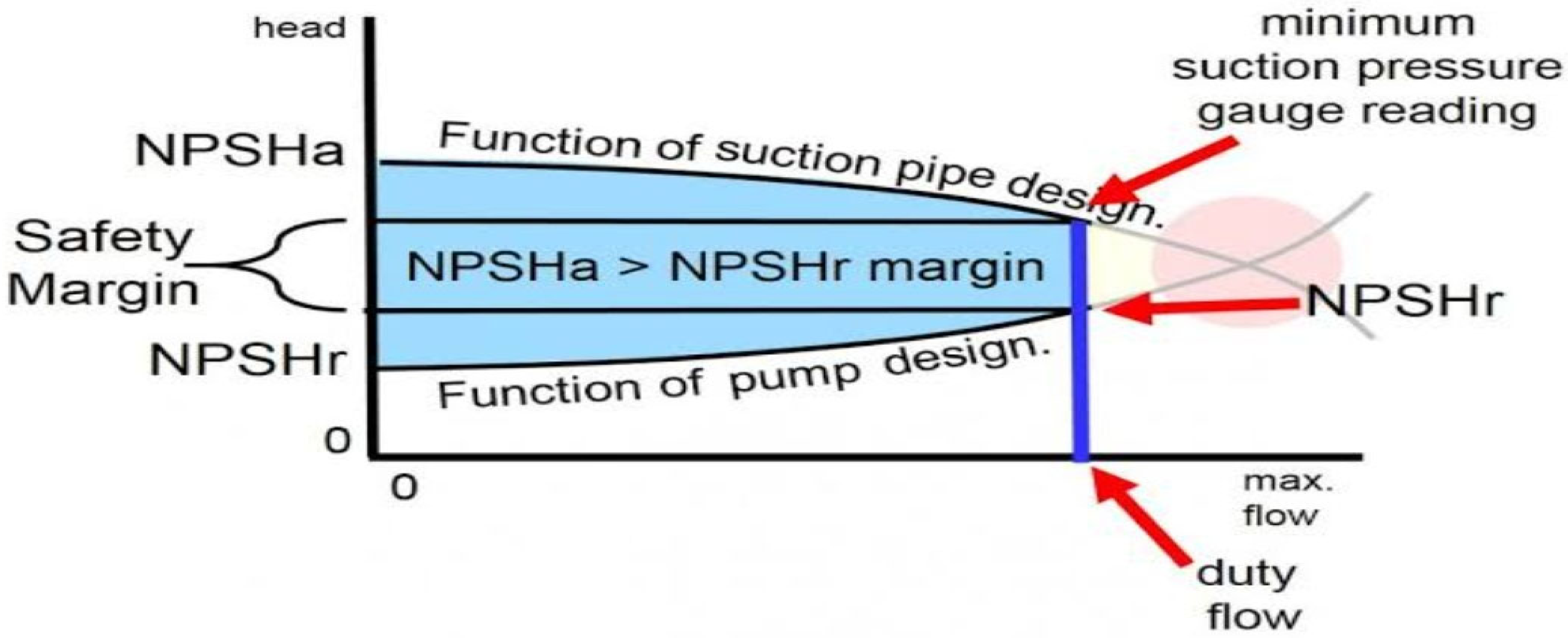


Cool a few Degrees
To overcome suction head

NET POSITIVE SUCTION HEAD-NPSH

the difference between the Suction Head, and the Liquids Vapor Headand can be expressed as

$$NPSH = h_s - h_v$$



NPSHa (available) is a property of the system and is calculated by the system designer giving a value of the pressure on the suction side of the pump.

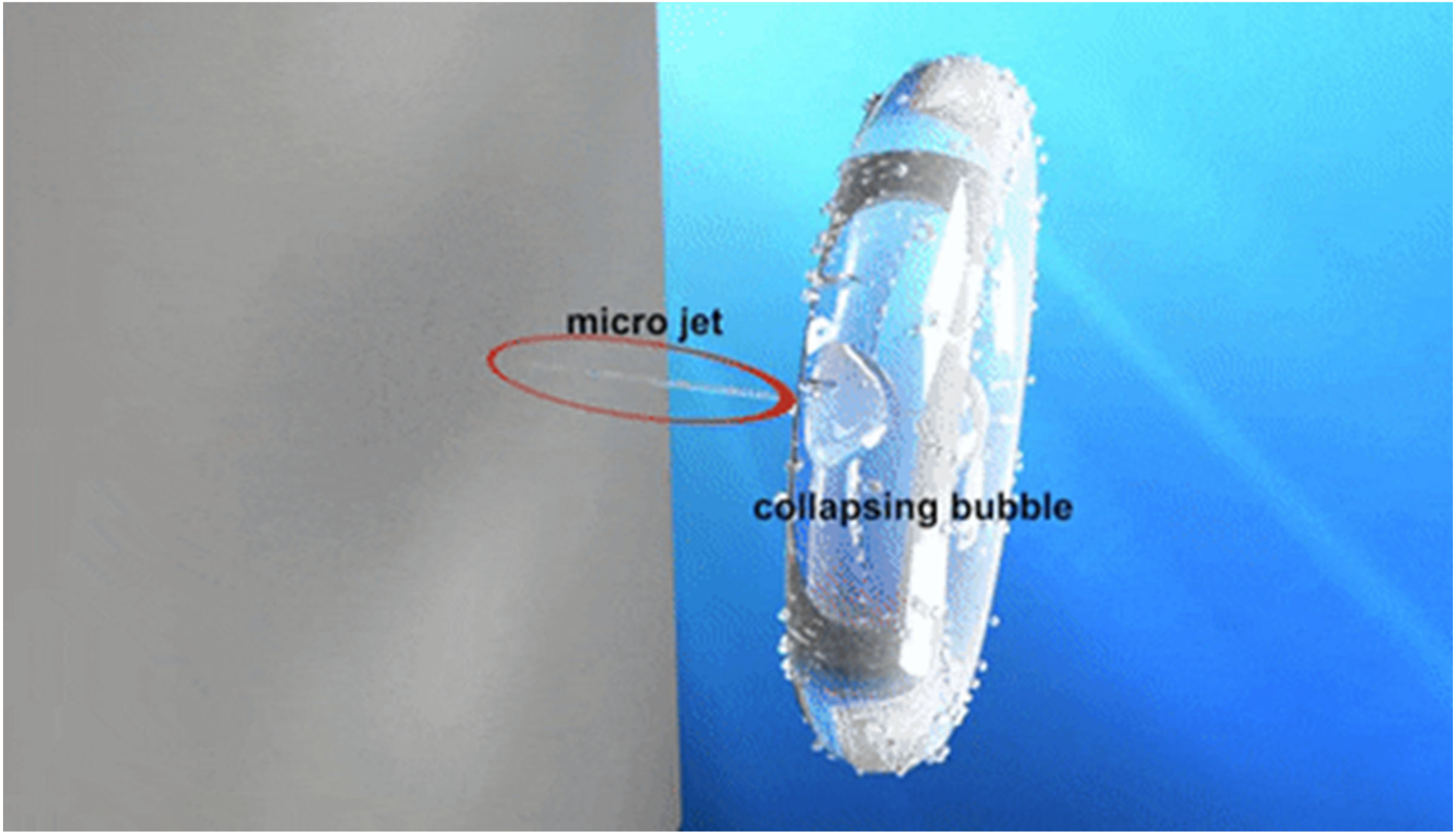
NPSHr(required) is a property of the pump.

CAVITATION

- Cavitation

is defined as phenomenon of formation of vapour bubbles of a flowing liquid in a region where the pressure of the liquid falls below its vapour pressure and collapsing of these vapour bubbles in a region of higher pressure.

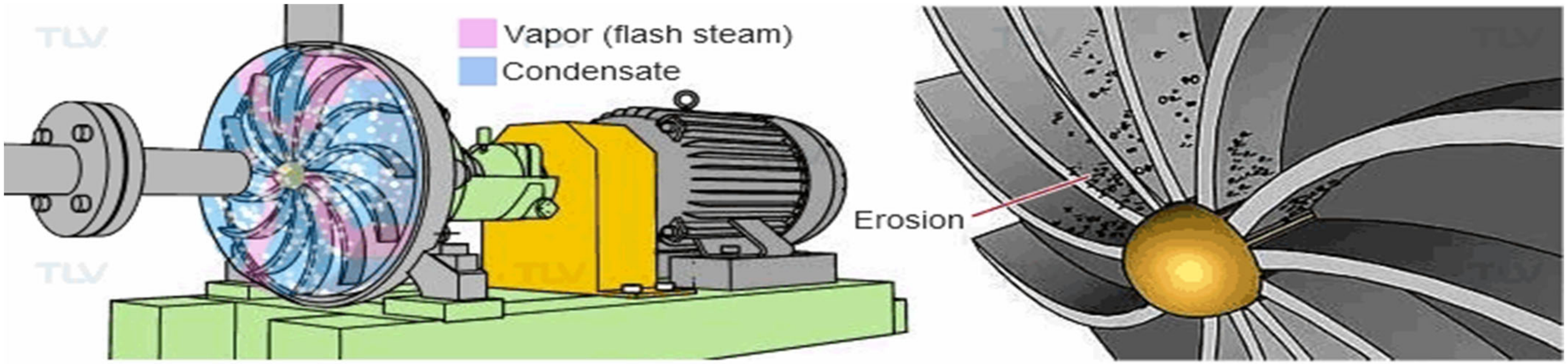
CAVITATION



CAVITATION

- Cavitation

When the vapour bubbles collapse and very high pressure is created, the metallic surface above which the liquid is flowing is subjected to these high pressures which cause pitting action on the surface, thus cavities are formed on metallic surface and also considerable nose and vibration created.



Pump oscillates due to cavitation

Damage caused to impeller

Precaution against cavitation

- The pressure of the flowing liquid in any part of the hydraulic system should not be allowed to fall below vapour pressure (NPSHA>NPSHR).
- The special material or coating such as aluminum bronze and stainless steel should be used.

Specific speed

Specific speed of a pump is defined as the speed of a geometrically similar pump which delivers unit discharge under unit head.

$N_s = N\sqrt{Q} / H^{3/4}$ --------------------------(10.4)

LOSSES AND EFFICIENCIES

1. Hydraulic Efficiency

Hydraulic losses are the losses the occur between the suction and the delivery ends of a pump.

Hydraulic efficiency varies from 0.6 to 0.9.

2. Manometric Efficiency

Manometric efficiency is defined as the hydraulic efficiency of an ideal pump.

HEADS OF A PUMP

3. Manometric Head

It is usually not possible to measure exactly the losses in the pump casing. So, a term known as manometric head is introduced. It is the rise in pressure energy of the liquid in the impeller of the pump.

If two pressure gauges are installed on the suction and the delivery sides as near to the pump as possible, the difference in their reading will give the change in the pressure energy in the pump or the manometric head.

H_m = Manometric head of the pump

H_{ms} = Reading of the pressure gauge on the suction side

H_{md} = Reading of the pressure gauge on the delivery side.

Then $H_m = H_{md} - H_{ms}$

4. Mechanical Efficiency

Mechanical losses in case of a pump are due to

(a) Friction in bearings

(b) Disc friction as the impeller rotates in liquid.

Mechanical efficiency is the ratio of the actual power input to the impeller and the power given to the shaft.

Let P = Total power input to the shaft

ΔP = Mechanical losses

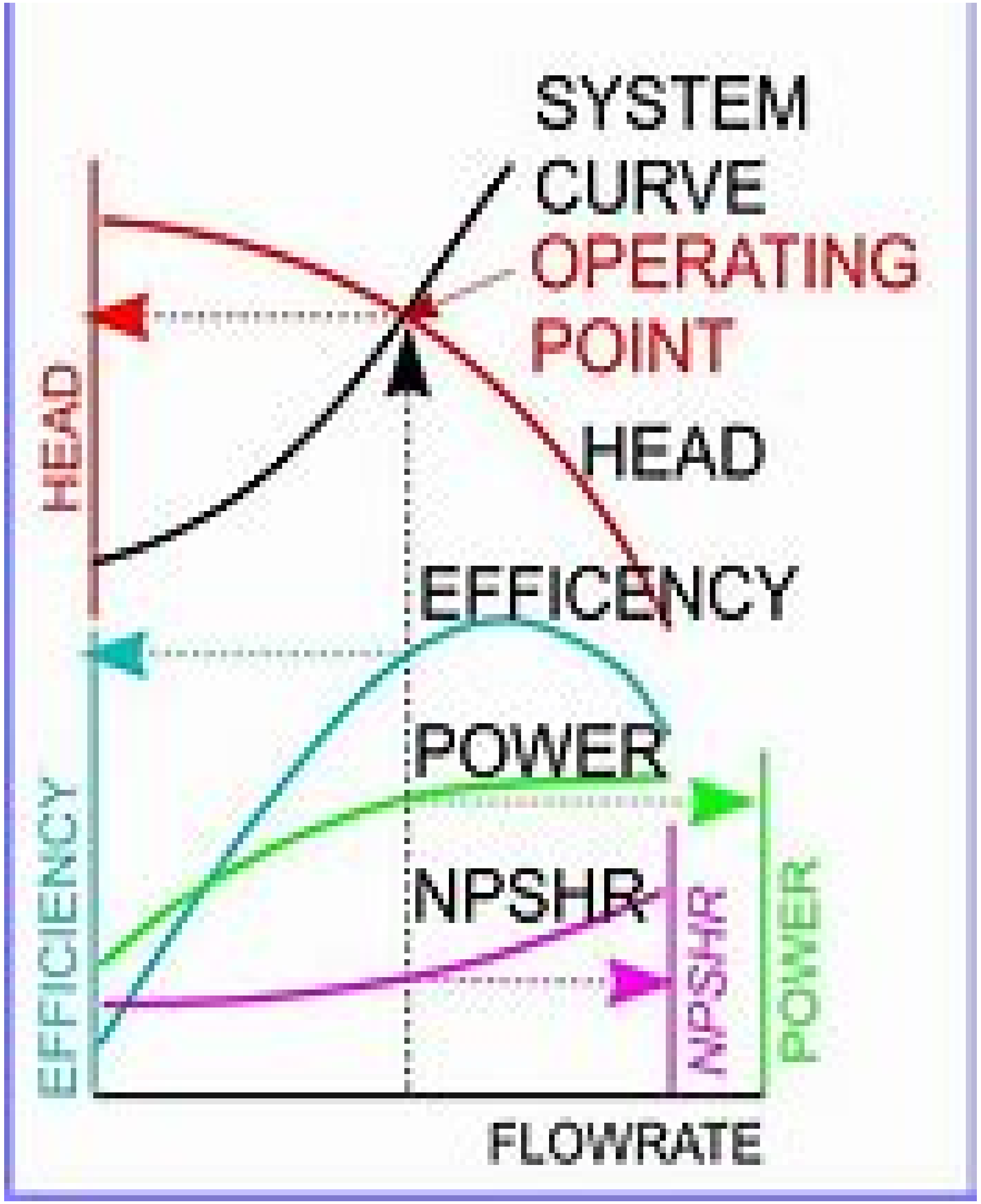
$$\eta_m = (P - \Delta P) / P$$

5. Overall Efficiency

It is the ratio of the total head developed by a pump to the total power input to the shaft.

$$\eta_o = (\rho Q g H) / P$$

Range of overall efficiency is between 0.71 to 0.86.

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Discussion
Time