Introduction to Fluid Machinery
(Turbines, Pumps, Blowers and Compressors)

Fluid Machines (machines are energy conversion devices) are called **Turbo-machinery** which transfers energy between a fluid system and its mechanical system (e.g. rotor).

Two primary categories of Turbo-machinery are:

1. Turbines which extract hydraulic energy available in a fluid and convert it into mechanical energy (power) to rotate a shaft.
2. Pumps, Fans, Blowers and Compressors which impart hydraulic energy to a fluid by converting the mechanical energy available in a shaft.

A fluid contains hydraulic form of energy:
Hydraulic Energy (Power) = Pressure Energy (Potential) + Velocity Energy (Kinetic)
= Pressure x Flowrate = $\underline{\gamma\ HQ}$
A rotating shaft contains mechanical form of energy:
Mechanical Energy (Power) = Torque x Angular Speed = $\underline{T\ \omega}$

Depending on the Energy conversion mechanism Turbines are classified into two groups according to "Degree of Reaction" :

1. Impulse Turbine: Pelton Wheels (used for high head, low discharge installations)
2. Reaction Turbine: Kaplan Turbine (used for low head, high discharge installations)

Degree of Reaction (DR) is the ratio of static pressure drop (pressure energy converted) in the rotor to the total pressure drop (total hydraulic energy available) in the turbine.

[DR <0.5 indicates an impulse turbine and DR>0.5 indicates a reaction turbine]

Depending on the Energy conversion mechanism Pumps/Fans/Blowers/Compressors are classified into two groups:

1. Rotodynamic Type: Centrifugal Pump, Submersible Pump (high discharge, low head)
2. Positive Displacement Type: Reciprocating Pump, Gear Pump (low discharge, high head)

[Pumps can be arranged in series to add head and in parallel to add discharge]

Performance Parameters/ Technical Specifications:

Turbine		**Pump/Fan/Blower/Compressor**	
Reaction type	**Impulse type**	**Rotodynamic type**	**Positive Displacement type**
1. Power output, P_o Torque, T	Power output / Torque	1. Discharge, Q	Head
2. Speed, n	Speed	2. Head, H	Discharge
3. Efficiency, η	Efficiency	3. Efficiency	Efficiency
4. Discharge, Q	Head	4. Power input, P_i	Power input
5. Head, H	Discharge	5. Speed, n	Speed

Rotodynamic Pumps

Pump: A device which converts mechanical energy from a shaft into hydraulic (pressure) energy of a liquid. A pump is a device used to move fluids, such as liquids or slurries. A pump displaces a volume by physical or mechanical action. Pumps fall into two major groups: **positive displacement pumps and rotodynamic pumps**. For example, reciprocating pumps and gear pumps are positive displacement pumps whereas centrifugal pumps and submersible pumps are rotodynamic pumps.

Centrifugal pump

A centrifugal pump is a rotodynamic pump that uses a rotating impeller to increase the pressure and flowrate of a fluid. Centrifugal pumps are the most common type of pump used to move liquids through a piping system. The fluid enters the pump impeller along or near to the rotating axis and is accelerated by the impeller, flowing radially outward or axially into a diffuser or volute chamber, from where it exits into the downstream piping system. Centrifugal pumps are typically used for large discharge through smaller heads.

Identification of different major parts of a centrifugal pump:

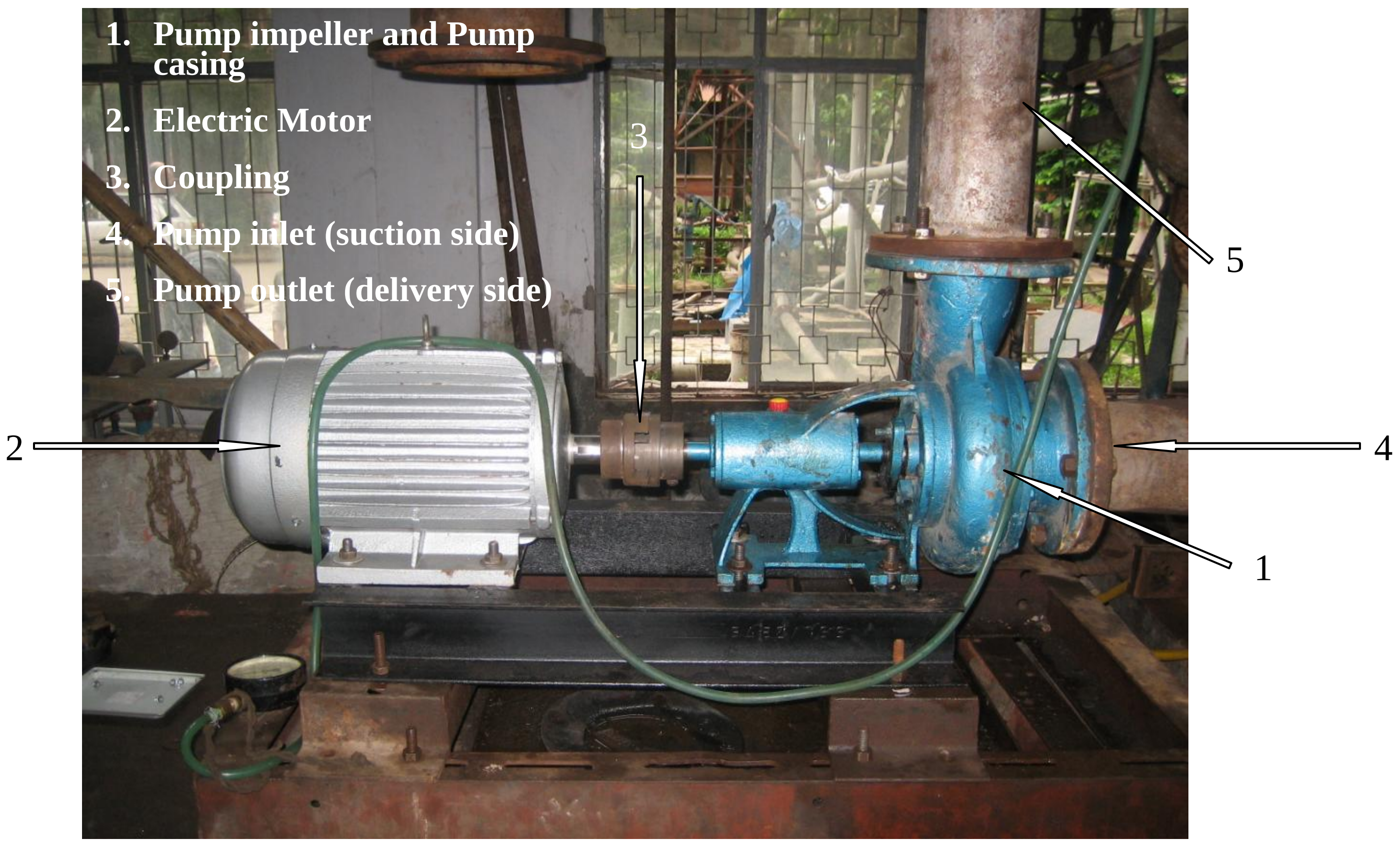


Fig. – 1: A centrifugal Pump

(a) **(b)**

Fig-2 A centrifugal pump casing (a) with impeller (b) without impeller

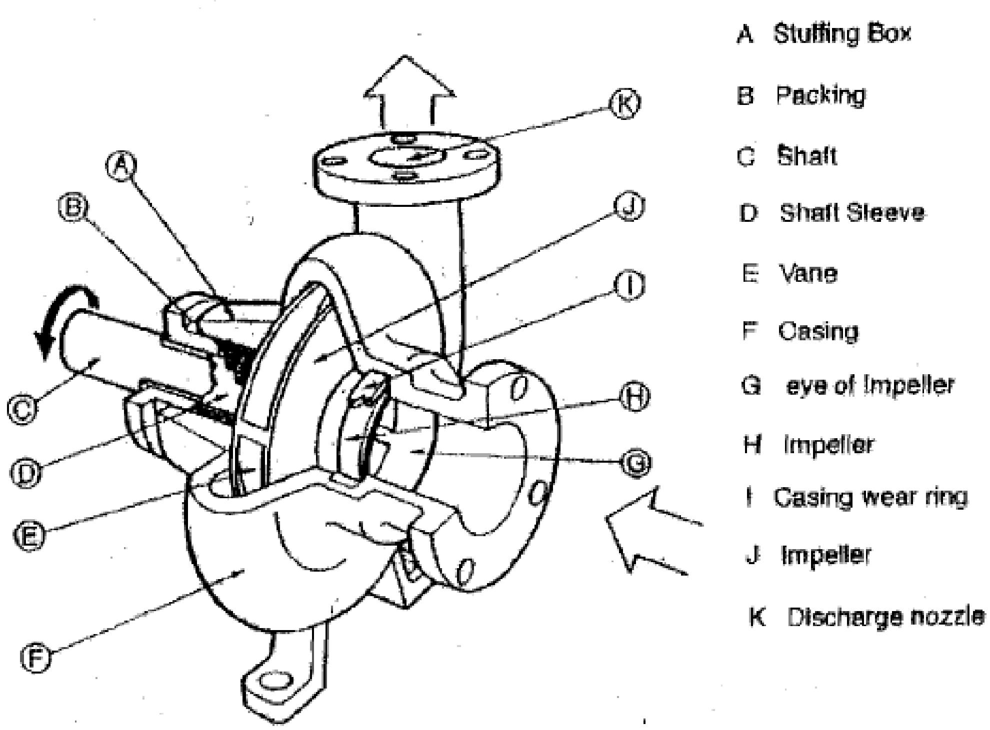
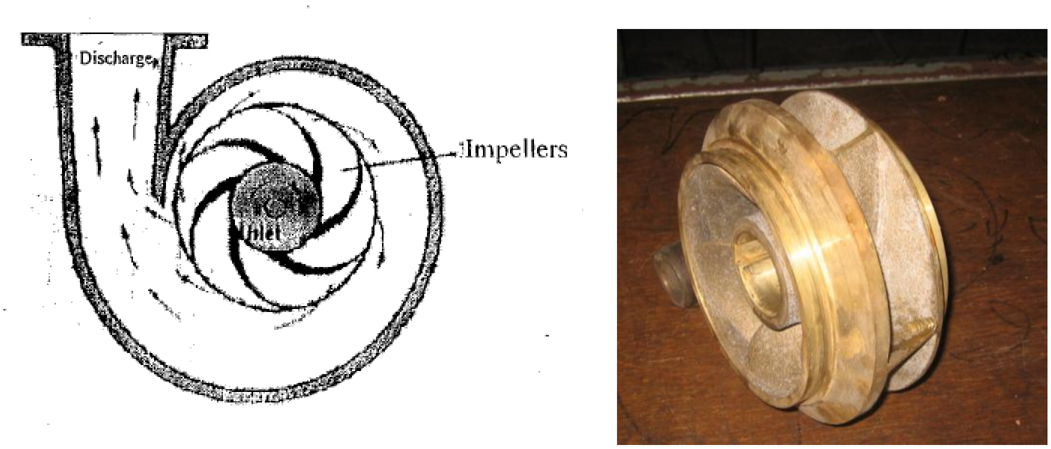


Fig-3 Schematic diagram of a centrifugal pump with a prime mover



(a) **(b)**

Fig-4 (a) Sectional view of a centrifugal pump casing; (b) Photograph of closed type centrifugal pump impeller

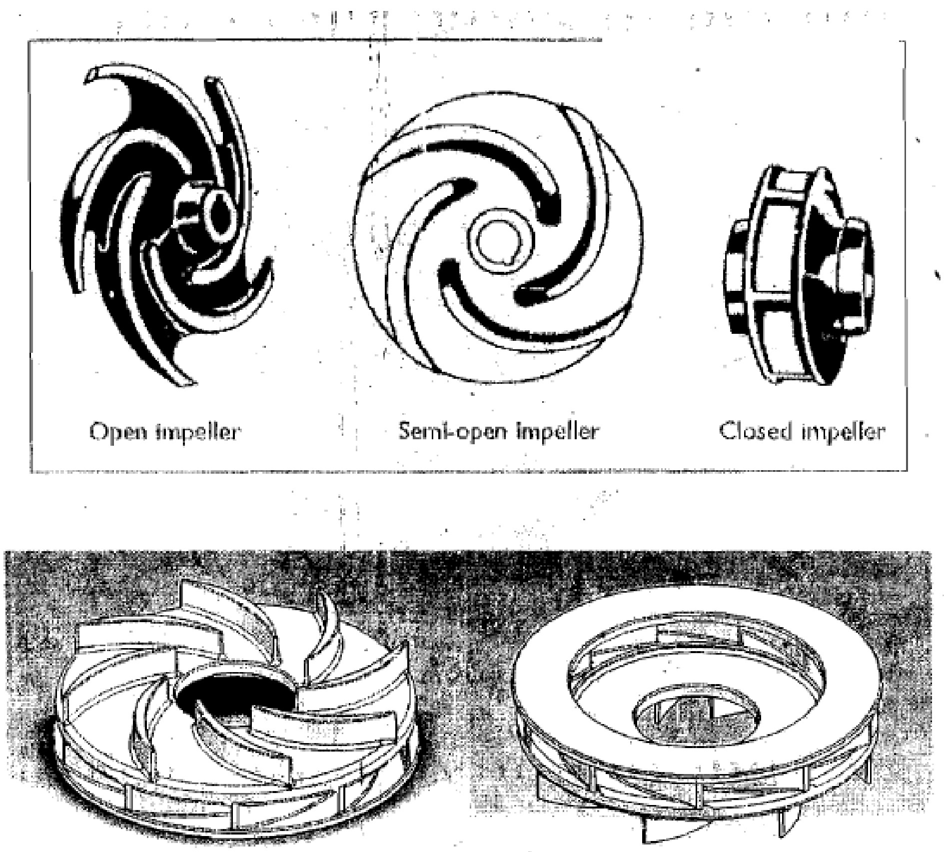


Fig-5 Different types of centrifugal pump impellers

Application of Centrifugal Pumps:

Centrifugal pumps are used throughout society for a variety of purposes. the pump is used for irrigation, water supply, gasoline supply, air conditioning systems, chemical movement, sewage movement, flood control, marine services, metering for gasoline and additives, etc.

Specifications

Pumps are commonly rated by horsepower, flow rate, outlet pressure in feet (or metres) of head, inlet suction in suction feet (or metres) of head.

Submersible pump

A submersible pump is a pump which has a hermetically sealed motor close-coupled to the pump body. The whole assembly is submerged in the fluid to be pumped. The main advantage of this type of pump is that it prevents pump cavitation, a problem associated with a high elevation difference between pump and the fluid surface. Cavitation results in damage to the pump and occurs where pressure at the pump inlet is too low causing the fluid to vapourise inside the pump body. Submersible pumps also are easily primed (removing air from the suction line) compared to other alternatives. A system of mechanical seals are used to prevent the fluid being pumped from entering the motor and causing a short circuit.

Applications

Submersible pumps are found in many applications. Single stage pumps are used for drainage, sewage pumping, general industrial pumping and slurry pumping. They are also popular with aquarium filters. Multiple stage submersible pumps are typically lowered down a borehole and used to lift water from underground or from water wells.

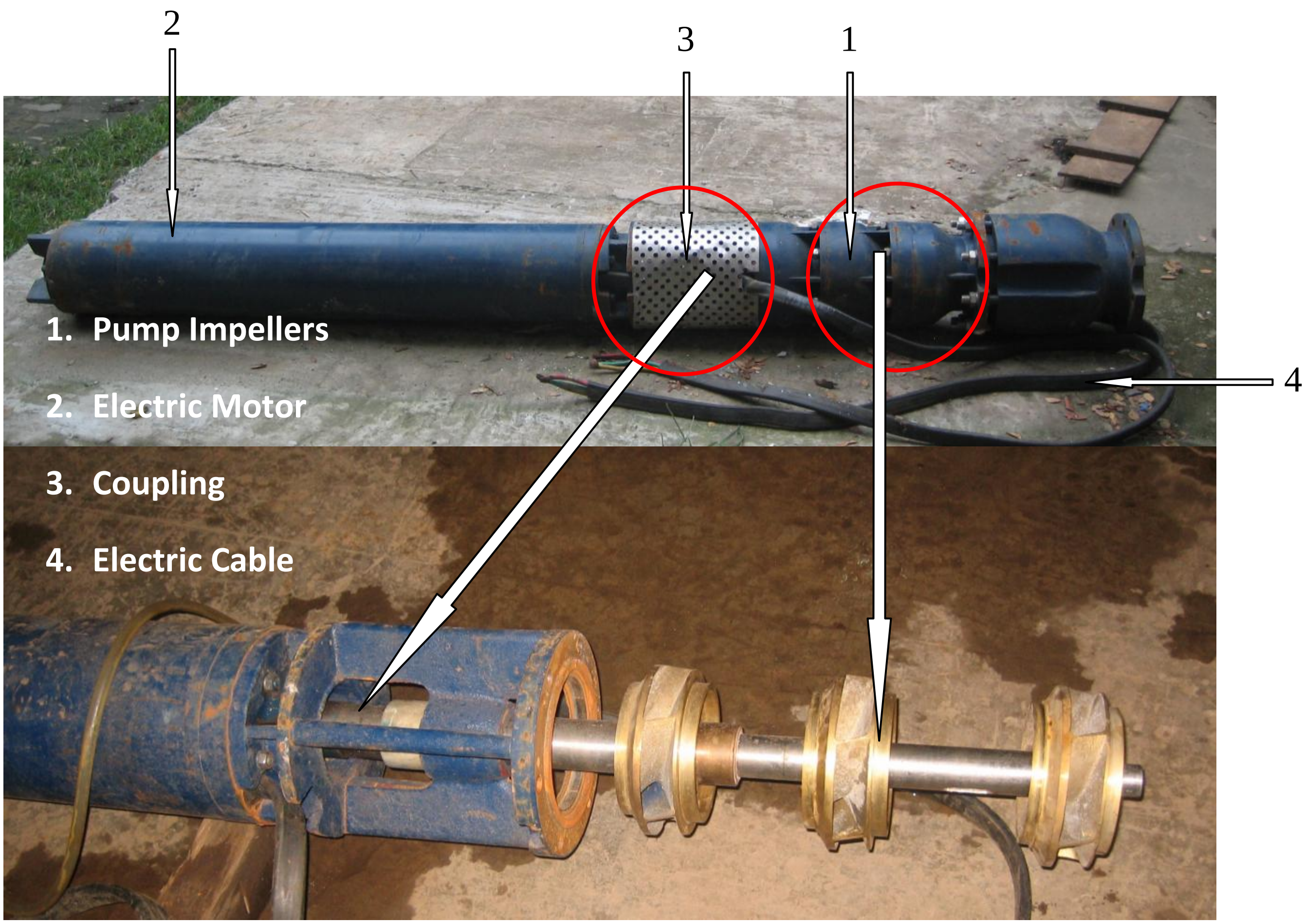


Fig-6 A submersible pump

Submersible pump impeller housing assembly

Foot Valve Assembly

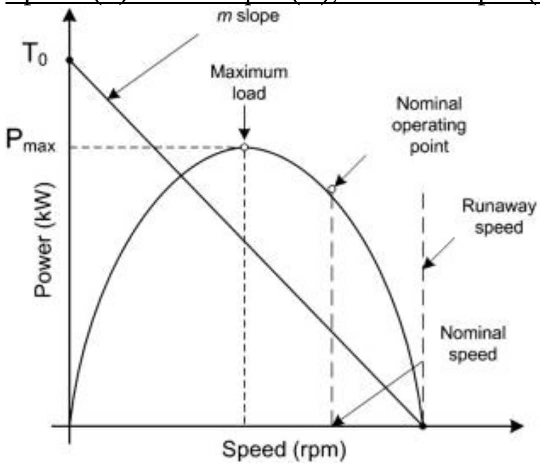
Foot Valve (exposed)

Strainer

<u>**Performance Curves:**</u>

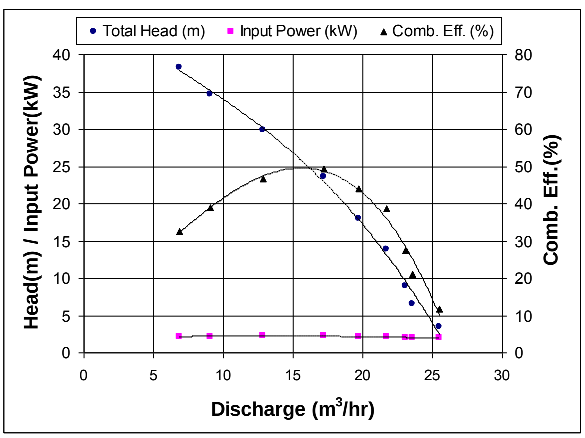
For Turbines:

Speed (n) vs. Torque (T), Power output (P_o) and Efficiency (η)



For Pumps:

Discharge (Q) vs. Total Head (H), Power input (P_i), and Efficiency (η)



<u>Specific Speed, (N_s):</u>

- Calculated at the best efficiency point (<u>varies with the type of unit used</u>)
- Indicates the shape of the turbine/pump (used for comparison between different sized machines)
- Also used for the selection of the machine type for a particular hydro site.

For Turbines: $N_s = \dfrac{N\sqrt{P_o}}{H^{\frac{5}{4}}}$	$N_s = 0.2626\dfrac{N\sqrt{P_o}}{H^{\frac{5}{4}}}$
N_s = Specific Speed (Dimensionless)	The factor 0.2626 (might be omitted) is used to compare the value obtained with that obtained from US customary unit.
N = Speed in rpm	N = Speed in rpm
P_o = Power output in hp	P_o = Power output in kW
H = Head in ft	H = Head in m
<u>In US Customary Unit (FPS)</u>	If the factor 0.2626 is omitted, the calculated specific speeds will be larger.
Pelton Wheel : 1 to 10	
Francis Turbine: 10 to 100	
Kaplan Turbine: 100 or more	

For Pumps: $N_s = \dfrac{N\sqrt{Q}}{H^{\frac{3}{4}}}$	$N_s = 0.861\dfrac{N\sqrt{Q}}{H^{\frac{3}{4}}}$
N_s = Specific Speed (Dimensionless)	The factor 0.861 (might be omitted) is used to compare the value obtained with that obtained from US customary unit.
N = Speed in rpm	N = Speed in rpm
Q = Discharge in US gallons per minute	Q = Discharge in m^3/hr
H = Head in ft	H = Head in m
[1 US gallon = 3.785 Liters]	
<u>In US Customary Unit (FPS)</u>	If the factor 0.861 is omitted, the calculated specific speeds will be larger.
Reciprocating Pump : 50 to 500 Centrifugal Pump: 500 to 10000	
Radial Flow Pump : 500 to 4000	
Mixed Flow Pump : 2000 to 8000	
Axial Flow/Propeller Pump: 7000 to 20000	

Net Positive Suction Head (NPSH)

NPSH = Suction Pressure – Vapor Pressure

For Pump Installation : $\mathbf{NPSH_{available}}$ (at the installation site) > $\mathbf{NPSH_{required}}$ (for pump)

in order to avoid **cavitation** (i.e. bubble formation and collapsing of bubbles in the flow resulting in damage to the fluid machines). $NPSH_{required}$ is usually given for a particular pump for its installation without cavitation. $NPSH_{available}$ is to be calculated at the installation site.

Differences among Pumps, Fans, Blowers and Compressors

Fluid Machines	Fluid Type	Output Pressure	Output Velocity
Pump	Liquid	High / Medium /Low	Low / Medium / High
Fan	Gas / Vapor	Low	Moderate
Blower	Gas / Vapor	Moderate	High
Compressor	Gas / Vapor	High	Moderate