**Lesson 19**

**Title of the Experiment:** Introduction to Pumps
(Activity number of the GCE Advanced Level practical Guide – 31 & 32)

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## Introduction

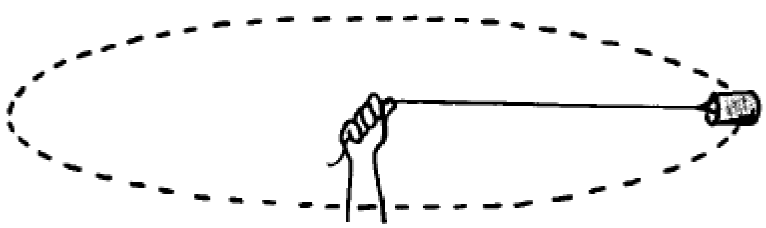
Pumps are in general classified as Centrifugal Pumps (or Roto-dynamic pumps) and Positive Displacement Pumps. The centrifugal or roto-dynamic pumps produce a head and a flow by increasing the velocity of the liquid through the machine with the help of a rotating vane impeller. Centrifugal pumps include radial, axial and mixed flow units. The positive displacement pump operates by alternating of filling a cavity and then displacing the given volume of liquid. The positive displacement pump delivers a constant volume of liquid for each cycle against a varying discharge pressure or head.

## Centrifugal Pump

As mentioned earlier centrifugal pump falls into the category of roto-dynamic pumps. There are many roto-dynamic pumps used in the agriculture and industrial sector. These pumps are popular in different names such as end suction pumps, in-line pumps, double suction pumps, vertical & horizontal multistage pumps, submersible pumps etc.

A centrifugal pump is developed after the positive displacement pump. Today most of the pumping applications are covered by this technology due its higher efficiency. In general large centrifugal pumps have more than 90% efficiency and fractional horsepower (small) pumps have at least 50% efficiency.

As mentioned in the name centrifugal pump operates due to the centrifugal force. A simple example for centrifugal force is bucket of water swinging in a circle as shown in figure 1.



(Evans, 2000)

**Figure 1:** Illustration of centrifugal force

Swinging the bucket around a circle (circular motion) generates a force to hold the water in the bucket. Water in the bucket may be thrown out of the bucket if there is a hole in the bottom of the bucket. The volumetric flow rate of water exit from the bucket depend on the radius of the circle and the velocity of the rotating bucket. In other words faster rotation of bucket generates greater centripetal force and hence produces a large volumetric flow rate.

Centrifugal pumps rely on centrifugal force as the fundamental operation principle. As explained earlier centrifugal force affects an object or material moving in a circular pattern by causing it to pull away from the central axis or center point of the path along which it travels. This force can be used to regulate the pressure and motion within a pumping unit, and when applied in combination with a number of other centrifugal pumping principles, forms an integral part of hydraulic mechanisms.

The centrifugal pump (figure 2) is the most used pump type in the world. The principle is simple, well-described and thoroughly tested, and the pump is robust, effective and relatively inexpensive to produce. There is a wide range of variations based on the principle of the centrifugal pump and consisting of the same basic hydraulic parts.

**Figure 2:** Centrifugal pump

**Parts of Centrifugal pump**

The pump is connected to the piping system through its inlet and outlet flanges. The design of the flanges depends on the pump application. Some pump types have no inlet flange because the inlet is not mounted on a pipe but submerged directly in the fluid. The inlet guides the fluid to the impeller eye. The design of the inlet depends on the pump type. The four most common types of inlets are inline, endsuction, doublesuction and inlet for submersible pumps, see figure 3. The design of the inlet depends on the pump type.

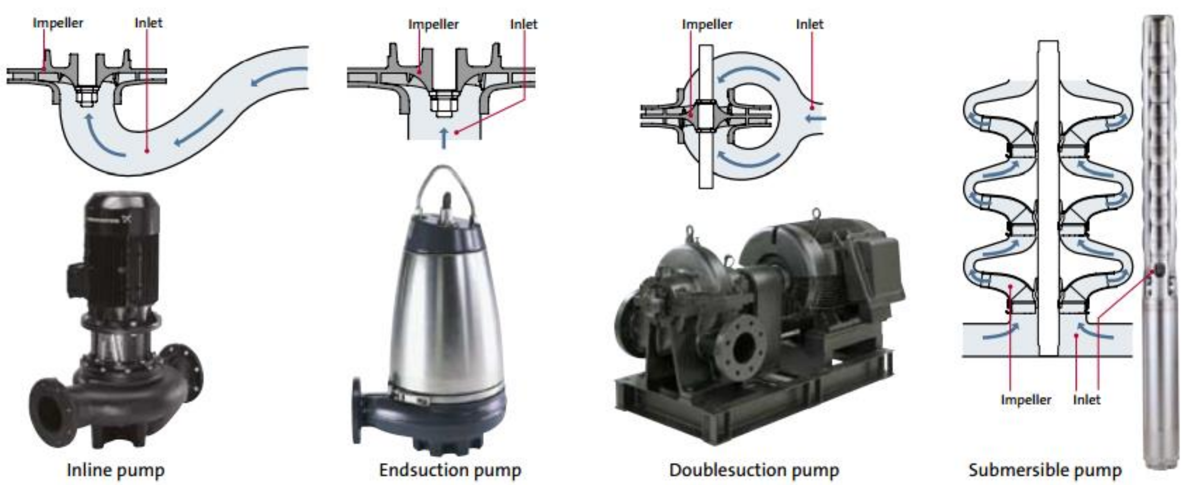



**Figure 3:** Centrifugal pumps with different inlets.

(Grounfos, 2009)

Parts of the centrifugal pump are illustrated in Figure. 4. The following discussion briefly explains the importance of each part illustrated in the figure.

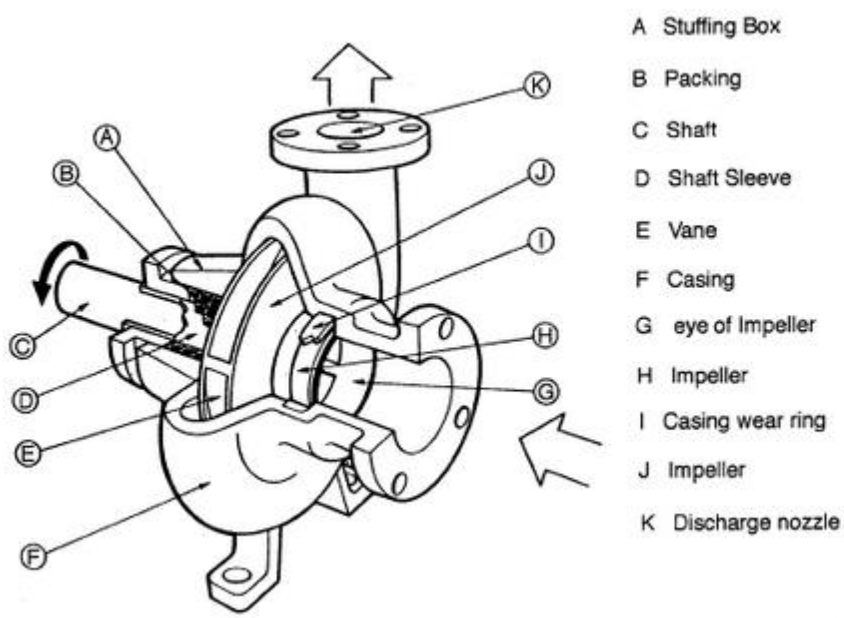



**Figure 4:** Parts of the centrifugal pump

The mechanical design of centrifugal pump is always challenging. A shaft (c) is used to connect the impeller and motor. Since water pressure inside the casing is huge, a proper sealing arrangement is imperative in arresting the water leakage through the shaft casing clearance. The stuffing box and packing (A &B) seals the fluid in the pump preventing leakage between the casing and the pump shaft.

The impeller (H &J) is a very important part in any centrifugal pump because it's primary component determines the performance of the pump. Impeller consists of a series of vanes (E).The impeller is always immersed in water and made to rotate. The blades of the rotating impeller transfer energy to the fluid there by increasing pressure and velocity. There are two types of vanes used in centrifugal pumps; straight vane and curved vane. The impellers used in this discussion are shown in figure 5.

As discussed earlier both kinetic energy (velocity) and the pressure of the fluid will rise when energy is transferred to the fluid. At the suction side (close to the eye) water is getting displaced and negative pressure is induced at the eye. The negative pressure sucks the fluid into the system. The negative pressure generated at the eye is not large enough to suck fluid if the system from the bottom to the impeller is not filled with fluid. Therefore the system should be initially filled with water before starting the motor or the water column has to be kept after stopping the motor for the next start. There is a special valve called a "foot valve" is placed at the end of the suction side pipe to keep this water column after stopping the motor. This is a one way valve and it can be opened by the negative pressure created at the eye. Once the motor stops this valve is closed due to the weight of the water column.

Pump casing (F) is a special design to improve the performance of the pump. The casing volume is increased with the flow direction. Less cross sectional area with high fluid flow rate will transfer to the high pressure fluid with low flow rates when it arrives to the discharge nozzle (K). In other words reduction in the flow velocity will result in an increase in the static pressure, which is required to overcome the resistance of the pumping system.

**Performance curves**

Performance curves are used by the customer to select pumps matching his requirements for a given application. Pump data sheets provides information about head and volumetric flow rate. In addition to above two parameters power, efficiency and NPSH (net positive suction head) also included in the data sheet. The NPSH curve shows the need for inlet head, and which requirements the specific system have to fulfill to avoid cavitation. If pressure at the suction side of impeller goes below the vapor pressure of the water a dangerous phenomenon called cavitation occurs. Typical performance curves for a centrifugal pump are shown in figure 6.

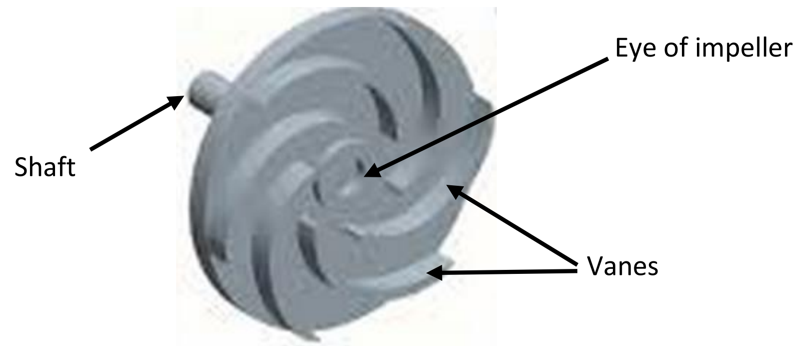
For example to find the head and efficiency at 70 $m^3$/h, locate 70$m^3$/h on abscissa and read the corresponding data on the ordinate.

The NPSH value is absolute and always positive. Available net positive suction head ($NPSH_A$) and required net position suction head ($NPSH_R$) are important terms when selecting a pump. To determine if a pump can safely be installed in a system $NPSH_A$ and $NPSH_R$ should be found for the largest flow and temperature within the operating range. At that point $NPSH_A$ must be greater than $NPSH_R$ and minimum 0.5m difference is recommended to avoid cavitation.

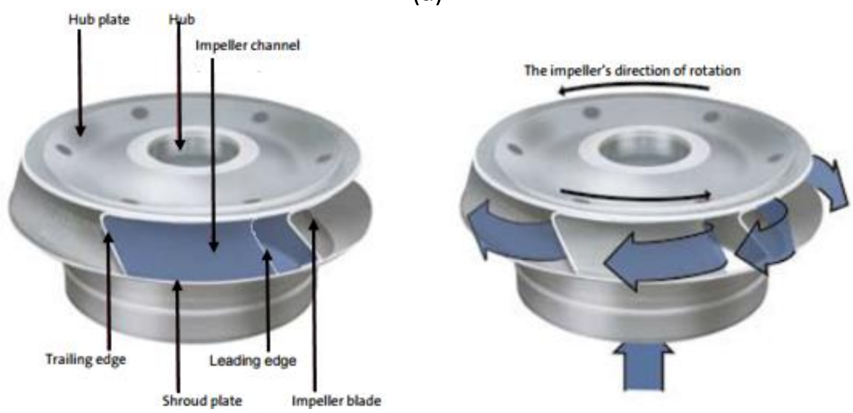
**Positive displacement pump**

The positive displacement pump delivers a constant volume of liquid for each cycle against varying discharge pressure or head. The positive displacement pump can be classified as:

- Reciprocating pumps - piston, plunger and diaphragm
- Power pumps
- Steam pumps
- Rotary pumps - gear, lobe, screw, vane, regenerative (peripheral) and progressive cavity




(a)




(b)

**Figure 5:** Close view of impellers

(Grounfos, 2009)

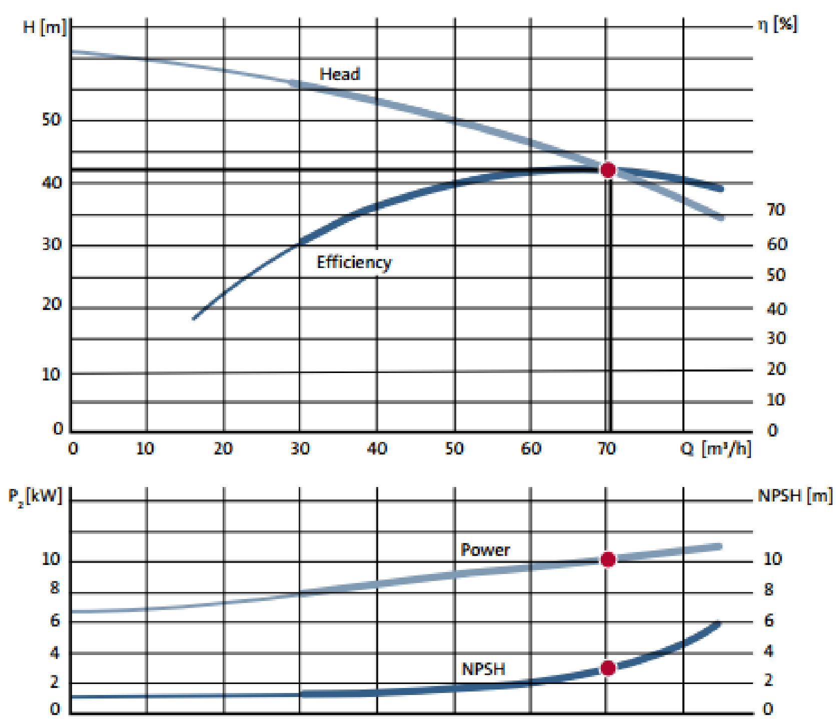



**Figure 6:** Performance curves

**Characteristics of Centrifugal pump and positive displacement pump**

**Table 1:** Pump comparison

| | Centrifugal pump | Positive displacement pump |
|---|---|---|
| **Capacity and viscosity** | flow is reduced when the viscosity is increased | flow is increased when viscosity is increased |
| **Mechanical efficiency** | Changing the system pressure or head has a dramatic effect on the flow rate | Changing the system pressure or head has little or no effect on the flow rate |
| **Flow rate & Pressure head** | varying flow depending on the system pressure or head | more or less a constant flow regardless of the system pressure or head. |
| **NPSH** | varies as a function of flow determined by pressure | varies as a function of flow determined by speed. |

It is really difficult to select a pump for a specific purpose but Table 1 provides a guideline for selecting a pump into some extent.

**Experiment 1**

Identify the parts of centrifugal pump.

**Theory**

Refer the section "parts of the centrifugal pump" in this document.

**Learning Outcomes**

At the end of the experiment, the student will be able to identify main parts of a centrifugal pump and explain their purposes.

**Materials and Equipment**

Centrifugal pump, suitable tool kit

**Observations**

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**Experiment 2**

Operating centrifugal pump system.

**Learning Outcomes**

At the end of the experiment, the student will be able to demonstrate skills on constructing and operating a centrifugal pump system.

**Materials and Equipment**

Centrifugal pump, suitable pipe, bends, foot valve

**Observations** (Draw the pump system)

**Experiment 3**

Identify the parts of piston pump (positive displacement pump)

**Learning Outcomes**

At the end of the experiment, the student will be able to identify main parts of the piston pump and explain their purposes.

**Materials and Equipment**

Piston pump, suitable tool kit

**Observations**

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**References**

Evans, E. (2000). *A brief introduction to centrifugal pumps*, Pacific Liquid and Air Systems, Honolulu

Grundfos. (2009). *The Centrifugal Pump.* Grundfos Management A/S; Grundfos research and Technology, Denmark