REPORT ABOUT PUMP TYPS AND THEIR WORKING PRINCIPLES

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TYPES OF PUMPS AND THEIR WORKING PRINCIPLES

What is A Pump:

Definition: Pump is a mechanical device used to transfer different fluids from one position to another. It is a hydraulic device that lifts a fluid from a low to a high level and moves it from a low-pressure area to a high-pressure area. Pumps transfer fluids by converting the mechanical energy of the fluid into pressure energy (hydraulic energy).

Classification of pumps

Generally, Pumps classification done on the basis of its mechanical configuration and their working principle. Classification of pumps mainly divided into two major categories:

The following are some of the pumps under these two categories:

Classification of pumps:

Dynamic pumps **/** Kinetic pumps:

- Centrifugal pumps
- Vertical centrifugal pumps
- Horizontal centrifugal pumps
- Submersible pumps
- Fire hydrant system

Positive displacement pumps:

- Diaphragm pumps

- Gear pumps
- Peristaltic pumps
- Cam pumps
- Piston pumps

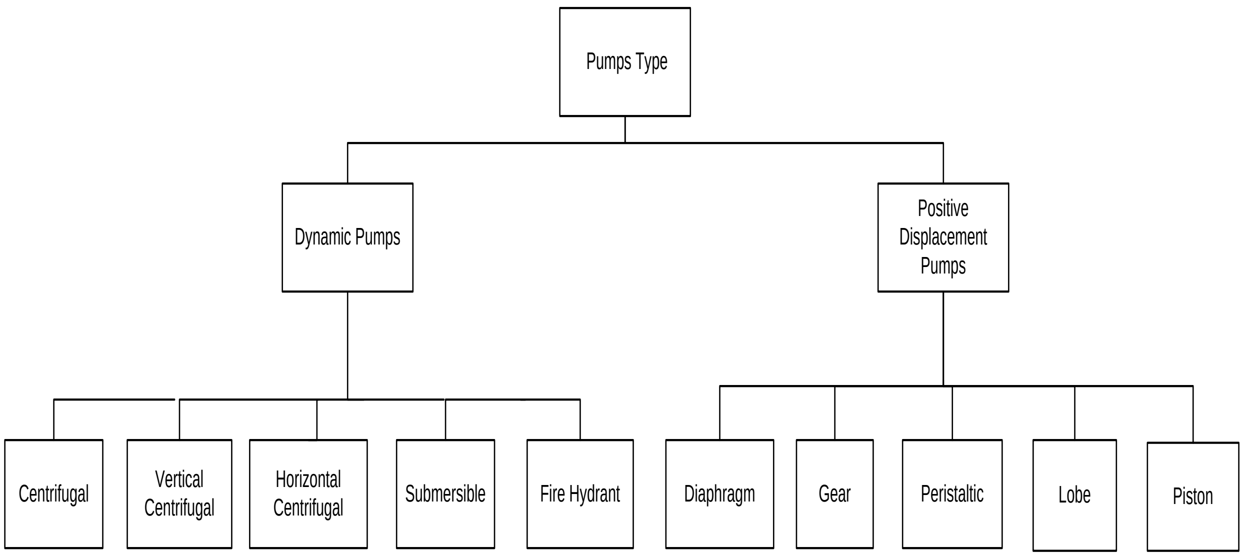


Figure 1-1 Pump Type Diagram

1- Dynamic Pumps

Dynamic pumps impart velocity and pressure to the fluid as it moves past or through the pump impeller and, subsequently, convert some of that velocity into additional pressure. It is also called Kinetic pumps Kinetic pumps are subdivided into two major groups and they are centrifugal pumps and positive displacement pumps.

There are different types of dynamic pumps, some of which will be discussed below, such as centrifugal pumps, vertical centrifugal pumps, horizontal centrifugal pumps, submersible pumps and fire hydrant systems.

1-1 Centrifugal Pumps

These types of pumps are the most commonly used in the world. The work is very simple, well described and carefully tested. These pumps are robust, efficient and fairly inexpensive to manufacture. Whenever the pump is running, the fluid pressure will increase from the pump's inlet to its outlet. The change in pressure will drive the fluid throughout the system. A centrifugal pump is a rotating machine in which flow and pressure are generated dynamically. The energy changes occur by virtue of two main parts of the pump, the impeller and the volute or casing. The function of the casing is to collect the liquid discharged by the impeller and to convert some of the kinetic (velocity) energy into pressure energy.

Figure 1-2 Centrifugal Pump

This pump produces an enhanced force by transferring the mechanical power of the motor to the fluid throughout the rotating impeller. The fluid flow will enter the center of the impeller and flow out with its vanes. Centrifugal force thus increases the velocity of the fluid and energy like kinetic energy can be changed into force.

Depending on the type of water flow they produce, centrifugal pumps can be divided into three subtypes. The flow pattern is determined by the impeller shape and the pump construction.

SUB-TYPE	DESCRIPTION	PERFORMANCE
Axial Flow Pump	Also known as a propeller pump, it produces water flow along the impeller shaft direction.	High flow rate Low pressure
Radial Flow Pump	This pump type produces flow in a direction perpendicular to the shaft (90° angle).	Low flow rate High pressure
Mixed Flow Pump **Components of Centrifugal Pumps** Every pump should have the following components: • Shaft • Impeller • Casing • Suction Pipe • Delivery Pipe	This pump type combines radial and axial flow, producing a conical flow pattern around the shaft.	Medium flow rate Medium pressure

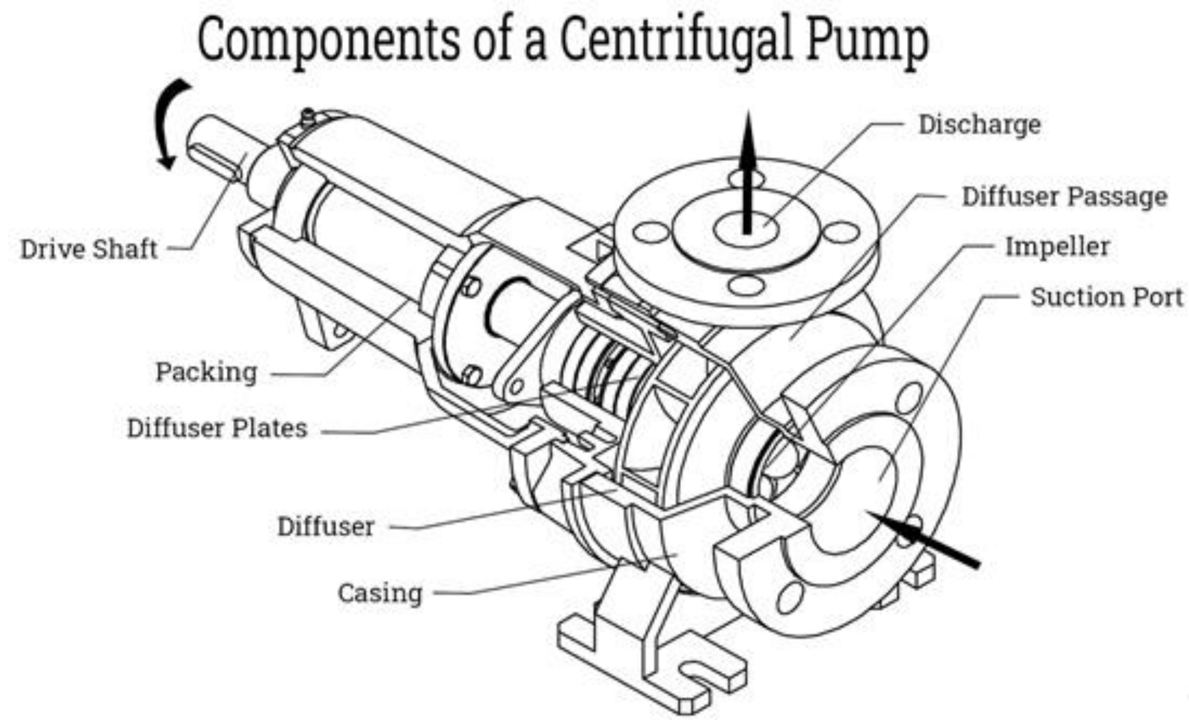


Figure 1-3 Centrifugal Pump Component

a) Centrifugal Pump Shaft

It is the central part of the pump which rotates together with the impeller when connected. The shaft is linked to the prime mover in order to get the power. The shaft fits perfectly with the ball bearing.

b) Centrifugal Pump Impeller

It comprises an arrangement of backward curved vanes. It is mounted to an electric motor's shaft. This is known as the rotating part of the centrifugal pump enclosed in a casing that is watertight. The impeller rotates and imparts velocity to a liquid.

c) Centrifugal Pump Casing

This is a passage surrounding the impeller, which will be airtight. It is made in such a way that the water's kinetic energy discharged at the outlet is changed to pressure energy before the water leaves the casing and is delivered into the delivery pipe. It works as a cover so that it protects the system. The casing transforms the velocity developed by the impeller into a stable flow. There are basically three types of casings in centrifugal pumps namely volute casing, vortex casing and casing with guide blades.

d) Volute Casing or Spiral Casing

The impeller surrounds this type of casing. Such a casing provides a successive increase in the area of flow and hence decreases the velocity of water and increases the pressure.

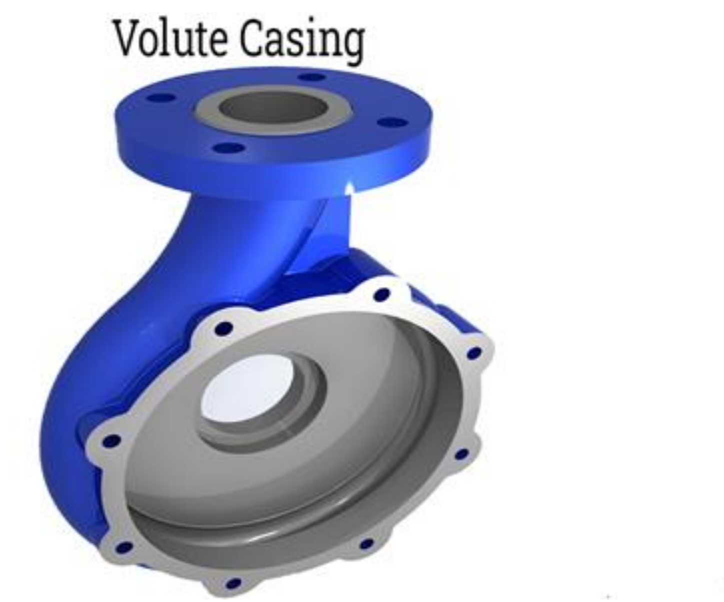


Figure 1-5 Volute Casing

e) Vortex Casing

This casing is a circular chamber that is introduced between the casing and impeller. The fluid from the impeller has to pass through the vortex chamber first and then through the volute casing. Velocity energy has been changed to pressure and has good efficiency compared to the volute casing.

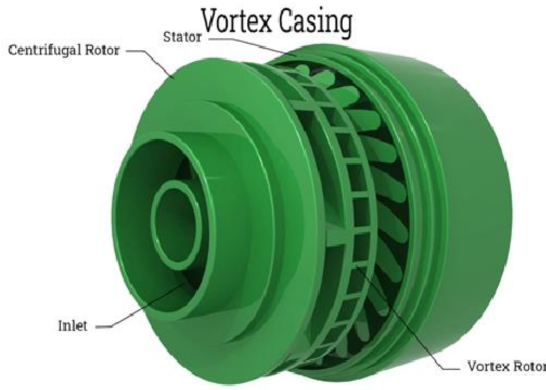


Figure 1-6 Vortex Casing

e) Casing With Guide Blades

In this type of casing, there are blades surrounding the impeller. These blades are arranged and designed in such a way that the water from the impeller passes through the guide vanes without shock and forms a passage of increasing area, through which the water passes through and reaches the delivery to leave with pressure.

f) Suction Pipe with a Strainer and Foot Valve

The suction pipe has two ends. The first end is connected to the pump's inlet and one end is dipped into the water in a slump. At the suction pipes' lower end, a foot valve is fitted. The valve only opens in an upward direction as it will be a one-way type. To prevent the entry of unknown and unwanted bodies into the suction pipe, a strainer is fitted at the end of the pipe.

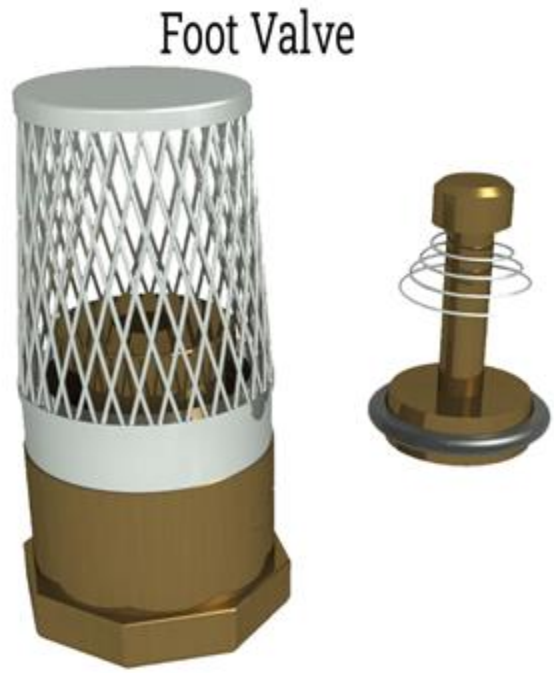
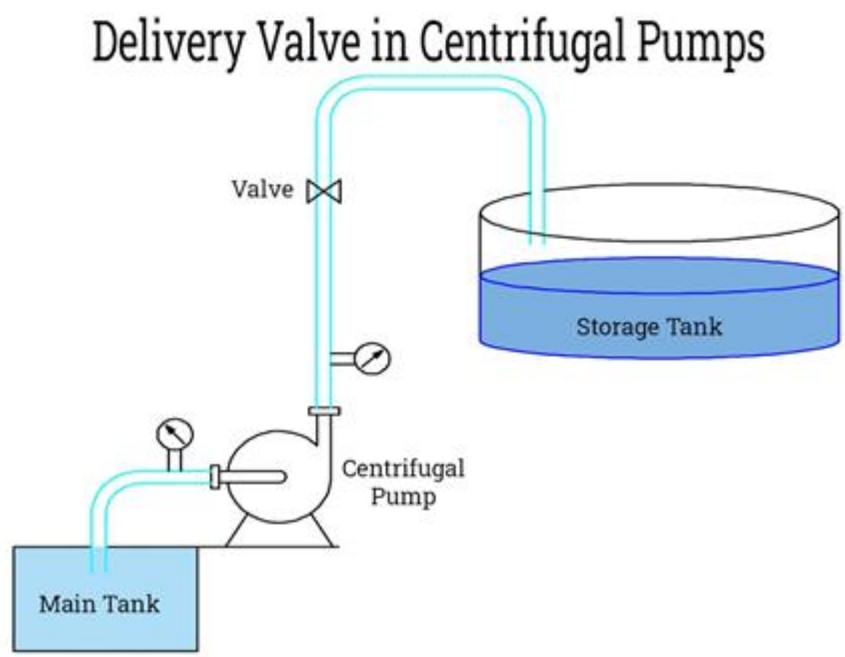


Figure 1-7 Foot Valve

g) Delivery Valve

The delivery valve also has two ends. One end is connected to the pump's outlet and the other end delivers the water at a required height.



h) Manufacture of Centrifugal Pumps

When selecting materials for centrifugal pumps, there are factors that need to be considered. These are strength, resistance to abrasive wear, corrosion resistance, casting and machining performance, repair and welding performance, and costs.

i) Materials Used in Centrifugal Pumps

Cast iron, cast steel, stainless steel, bronze, brass, carbon structural steel composite materials, alloy steel, and non-metallic materials are some of the materials used to make centrifugal pumps.

- Cast iron – This is the most common material used to make centrifugal pumps. It provides high tensile strength and abrasion resistance correlated to high-pressure ratings. It is also durable.

- Stainless steel - Austenitic stainless steel is the most common stainless steel that is used to make pumps. Stainless steel is usually used for chemical pumps as it is corrosion resistant. Its tensile strength is remarkably high.

- Cast steel – This material is suitable for high-pressure working conditions and has good mechanical properties. Though its corrosion resistance is not as good compared to other types of stainless steel used in corrosive and other chemical applications.

- Carbon structural steel – This material is widely used as pump shaft material where no corrosion is required.

- Alloy steel - It is usually used as a material in pump shafts for high-strength.

- Non-metallic materials – This material in pumps is mainly used for sealing purposes for example polytetrafluoroethylene, rubber, nitrile rubber, and fluorine. Polytetrafluoroethylene has excellent high temperature resistance and corrosion resistance. Is used for static seals of mechanical seals and chemical pump gaskets. It is advisable to use almost all chemical media within 250°C.

- Bronze – Can be used for the body of the pump. It helps the sealing of the pump body. For larger centrifugal pumps, tin bronze is used as a material for the body. Although nickel aluminum bronze is corrosion resistant and has the best mechanical properties it is expensive and incompetent.

- Composite materials - to improve the chemical resistance of the pump, a lining can be installed in the volute. The materials used for the lining can be rubber. Graphite monolithic ceramic and pumps are used in particular corrosive liquids, like hydrofluoric acid which is used in the pulp and paper industry and metal finishing industry. Composite materials are also used to make pump bodies.

Figure 1-8 Manufactured Centrifugal Pump

Criteria for Choosing Material

Considerations when choosing the centrifugal pump material include:

- Chemical compatibility - Pump parts that will be in contact with the pumped media can be made from chemically compatible materials that will not be contaminated or result in excessive corrosion or contamination. Consulting a metallurgist for proper metal selection is advised when dealing with corrosive media.

- Explosion proof - non-sparking materials are needed for operating on media or environments with the ability to catch fire or can explode.

- Sanitation- Pumps in the food and beverage industries require high density seals or unsealed pumps that are easy to sterilize and clean.

- Wear - Pumps that handle abrasives generally need materials with good wearing capabilities. Chemically resistant and hard surface materials are often incompatible. The housing and base materials should be of the right strength and also should be able to hold up against the conditions and environment being operated from.

1-2 Vertical Centrifugal Pumps

Vertical pumps were originally developed for well pumping. The bore size of the well limits the outside diameter of the pump and so controls the overall pump design.2.) Displacement Pumps / Positive displacement pumps

Vertical centrifugal pumps are also known as cantilever pumps. These pumps use a unique shaft and maintenance design that allows the volume to fall into the pit because the bearings are on the outside of the pit. This pump model does not use a filled container to cover the shaft, but uses a throttle bushing in its place. Parts washers are a common application for this type of pump.

Figure 1-9 Vertical Centrifugal Pumps

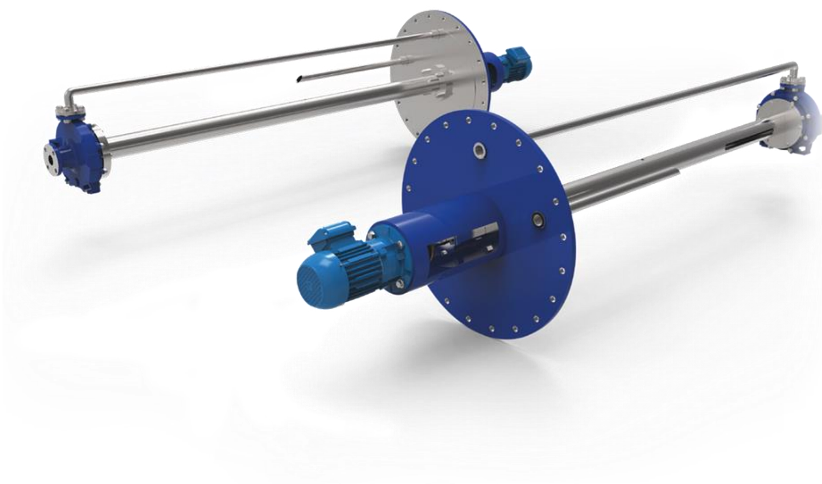


Figure 1-10 Vertical Centrifugal Pumps

1-3 Horizontal centrifugal pumps

These types of pumps include at least two otherwise more impellers. These pumps are used for pumping services. Each stage is basically a manifold pump.

Figure 1-11 Horizontal Centrifugal Pumps

All phases are in a similar bunker and mounted on a similar shaft. At least eight additional phases can be installed on separate horizontal shafts. Each phase enhances the head by approximately equal amounts. A multi-stage pump can also be a single-stage pump, or else a double suction pump on the first impeller. Various pumps have been supplied and repaired for this type of centrifugal pump.

1-4 Submersible Pumps

These pumps are also known as stormwater, sewage and septic pumps. Applications for these pumps include primarily building services, domestic, industrial, commercial, rural, municipal and stormwater recycling applications.

Figure 1-12 Submersible Pumps

These pumps are suitable for transferring stormwater, groundwater, sewage, blackwater, greywater, rainwater, trade waste, chemicals, bore water and food. These plumbing applications mainly include different impellers such as closed type pumps, convection pumps, vortex pumps, multistage pumps, single channel pumps, cutting pumps or grinder pumps. For different applications, a wide range of options are available, including high flow, low flow, low head or high head.

1-5 Fire hydrant system

Fire hydrant pump systems are also known as fire hydrant booster, fire pump and fire pump. These are high pressure pumps designed to increase the firefighting capacity of a building by increasing the force within the hydrant service, as the mains are not sufficient. Applications for this system include mainly irrigation and water distribution.

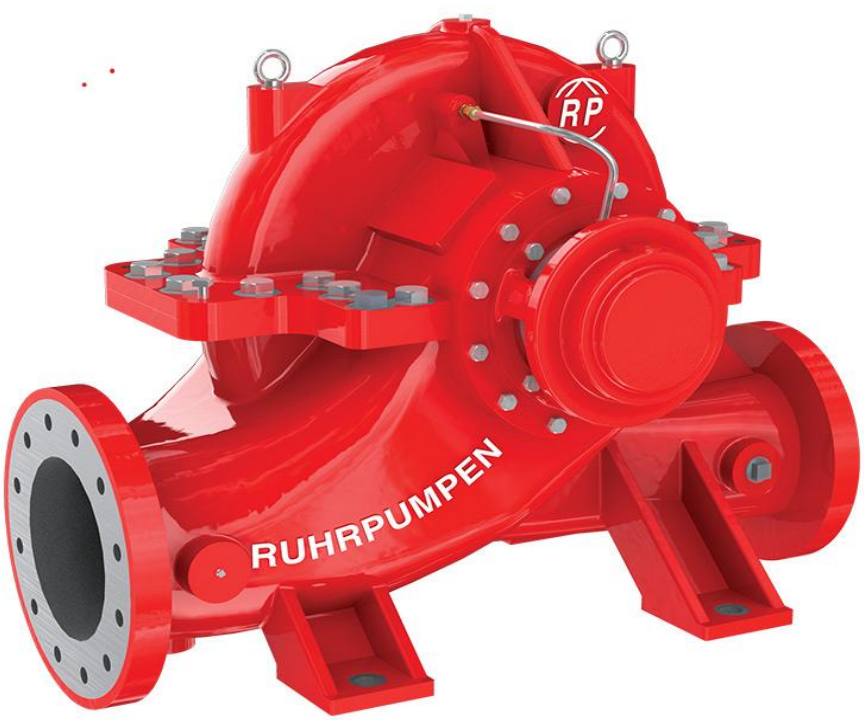


Figure 1-13 Fire Pump

2-Positive displacement pumps

There are different types of Positive displacement pumps (volumetric pumps), some of which will be discussed below, the moving element (piston, plunger, rotor, lobe, or gear) displaces the liquid from the pump casing (or cylinder) and, at the same time, raises the pressure of the liquid. So, displacement pump does not develop pressure; it only produces a flow of fluid.

2.1 Diaphragm Pumps

Figure 1-14 Diaphragm Pump

Figure 1-15 Diaphragm Pump

Figure 1-16 Diaphragm Pump

These pumps are response pumps that include two diaphragms driven by condensing air. The air portion of the transfer valve alternately applies air to both diaphragms; each diaphragm contains a set of ball valves or check valves.

2.2 Gear Pumps

These pumps are a rotating positive displacement pump, which means they produce a steady amount of fluid with each revolution. These pumps move the fluid by entering machinery inside and outside the network for a non-exciting pumping action. These pumps are capable of pumping at high forces and can efficiently pump highly concentrated fluids.

Gear pumps do not contain any valves that cause losses such as friction and high impeller speeds. Therefore, the pumps are suitable for handling thick fluids such as fuels and grease. These pumps are not suitable for driving solids and harsh liquids.

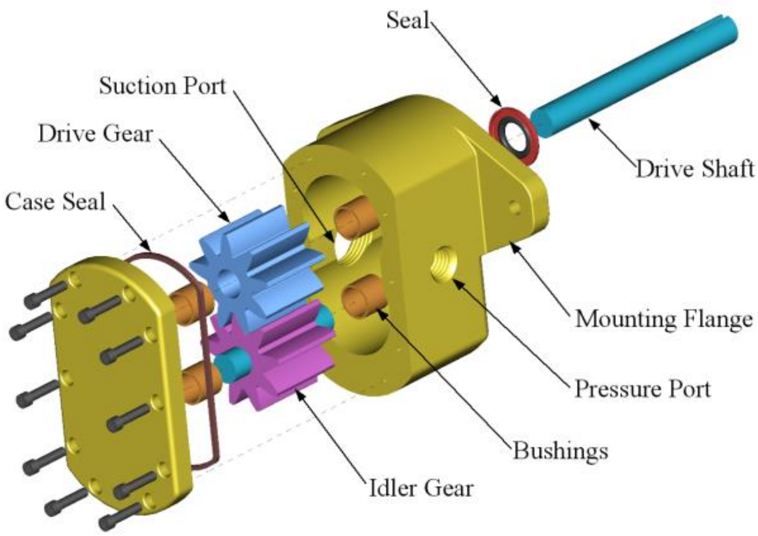


Figure 1-17 Gear Pump

2.3 Peristaltic pumps

Peristaltic pumps are also known as tube pumps and peristaltic dosing pumps. It is a volumetric pump and the applications of these pumps are mainly related to processing in the chemical, food and water treatment industries. It provides a steady flow for measuring and mixing and is also capable of pumping various liquids such as toothpaste and various chemicals.

2.3.1 In a reciprocating pump, a piston or plunger moves up and down. During the suction stroke, the pump cylinder fills with fresh liquid, and the discharge stroke displaces it through a check valve into the discharge line. Reciprocating pumps can develop very high pressures. Plunger, piston and diaphragm pumps are under these types of pumps.

2.3.2 Rotary Type Pumps
The pump rotor of rotary pumps displaces the liquid either by rotating or by a rotating and orbiting motion. The rotary pump mechanisms consisting of a casing with closely fitted cams, lobes, or vanes, that provide a means for conveying a fluid. Vane, gear, and lobe pumps are positive displacement rotary pumps.

Figure 1-18 Peristaltic Pump

2.4 Lobe Pumps

Lobe pumps are also called rotor pumps and these pumps have different characteristics such as excellent efficiency, rust resistance, sanitary quality, reliability etc. These pumps can handle highly concentrated fluids and solids without harming them. These pumps may work with gear pumps, except for the vanes that do not touch each other. In addition, these pumps have superior pumping chamber compared to gear pumps that allow them to move slurry. These are made of stainless steel and are very polished.

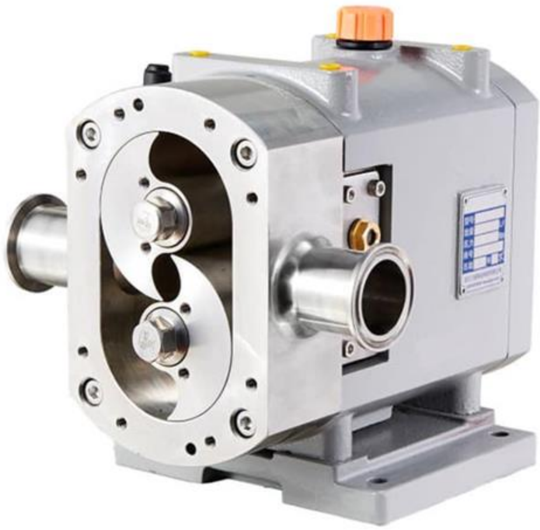


Figure 1-19 Lobe Pump

Figure 1-20 Lobe Pump

2.5 Piston Pumps

Piston pump is a positive displacement pump, also known as a plunger pump, in which a high-pressure seal responds through a piston. These pumps are often used for water irrigation, scenarios requiring high, reliable pressure and delivery systems for conveying chocolate, pastry, paint, etc.

Figure 1-21 Piston Pump

2- Maintenance Of Pumps

1. **Peristaltic Pumps:** These pumps use a series of rollers to squeeze fluid through a flexible tube. They are commonly used for pumping abrasive or viscous fluids.

2. **Jet Pumps:** These pumps use a jet of high-pressure fluid to create suction and move fluid through the pump. They are commonly used for pumping water from wells.

3. **Axial Flow Pumps:** These pumps use an impeller that creates a helical flow pattern to move fluid through the pump.

They are commonly used for high flow, low head applications such as water circulation in large bodies of water.

4. **Regenerative Turbine Pumps:** These pumps use multiple impellers to create a high-pressure flow. They are commonly used for high-pressure applications such as in boiler feed systems.

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These are just a few examples of the many types of pumps available. The choice of pump will depend on the specific application and requirements, including flow rate, pressure, viscosity, and other factors.

3- Which are the available pump designs?

As with the different technologies, the same also applies for design: The application stipulates the installation. While a **horizontal installation** may be able to simplify make for simpler maintenance, a **vertical installation** of the pump offers space advantages in narrow installations. Although the design of **single-stage pumps** is more maintenance-friendly and simpler, **multi-stage pumps** can build up higher pressure more easily.

Pumps that are mechanically sealed are used for many types of media and applications. If particularly aggressive, toxic or explosive fluids are handled, **seal-less, hermetic pumps** have to be used. There are also differences in suction characteristics: **Self-priming pumps** offer advantages for pumped fluids with high gas content, **immersed pumps** are often used in the water and wastewater sector.

Depending on pump technology and application, pump manufacturers have to ensure that various standards are being complied with. Important standards are issued, for example, by the **American Petroleum Institute (API)** and the **International Standards Organization (ISO)**. The **ATEX** directives of the **European Union for explosion protection** are also relevant for numerous industries.

The desired requirements for some applications can be fulfilled by standardized pumps. However, in some cases a standard pump is not suitable. For those purposes, well-known pump manufacturers offer custom-made designs that are specifically tailored to the medium and handling conditions. Particularly in industrial applications, most of the pumps are specifically dimensioned for the respective application since the requirements are very particular and can hardly be addressed with mass-produced standard pumps.

What materials are pumps made from?

Most of industrial pumps today are made of cast iron, but there are also numerous special designs with respect to the material. These always depend on the medium to be handled, the technical process conditions, the industry, and also applicable standards. In principle, a distinction is made between the pump housing material and the material of the components that come into contact with the media.

4- Examples of common materials for components in contact with media:

- Cast iron
- Metal
- Stainless steel, nickel-chromium steel, duplex, titanium, Hastelloy, bronze
- Ceramics
- PP, PFA, PVC, PVDF, PEEK, PTFE, UHMW-PE
- Synthetic carbon

Plastic pumps are often used as **acid pumps** or as **chemical pumps** or for other media that are very aggressive. Metal alloys such as Hastelloy can also be used in some cases, especially if high temperatures are achieved. Pumps whose components in contact with media are made of the relevant resistant materials, will also transport such media reliably and without additional maintenance effort.

Users in food production depend on stainless steel pumps for numerous primary processes: In contrast to a standard pump made of cast iron, they meet the industry's high hygiene requirements. For food and pharmaceutical applications, this also applies to the pump housing: It has to be easy to clean to ensure that there will be no contamination. Housings made of stainless steel are generally needed to meet this requirement.

What drive types are available for pumps?

In the industrial sector, the **electric motor** has become the absolute standard for driving pumps. It offers many advantages: It operates quietly and cleanly, and electricity is usually easily available in industrial installations. When it is equipped with a frequency converter, the pump's speed can be adapted easily to the handling requirements, thereby conserving energy and sparing wear on the installation.

5- What other drives besides the electric motor are available for pumps?

- Diesel engine
- Hydraulic motor
- Compressed air
- Magnetic coupling
- Solar drive

A **diesel engine** may be required in remote installations that are not connected to the power grid, for example, in water works. Compared with electric motors, drives with **compressed air** offer a high degree of explosion protection.

If an application requires that the pumped fluid be hermetically sealed against the environment (for example, due to high flammability or in case of particularly toxic media), then **magnetically coupled** pumps are required: Here, the motor is connected to the impeller via a magnetic drive system so that the product chamber is safely separated from the environment.

Depending on the application case, manufacturers also offer additional **special drives**, for example, an environmentally friendly **solar drive** – entirely according to the given conditions.

6- Pumps USED IN WATERWORKS AND WASTWATER SYSTEMS

In waterworks and wastewater systems, pumps are commonly installed at the source to raise the water level and at intermediate points to boost the water pressure. The components and design of a pumping station are vital to its effectiveness. Centrifugal pumps are most often used in water and wastewater systems, making it important to learn how they work and how to design them. Centrifugal pumps have several advantages over other types of pumps, including:

- Simplicity of construction – no valves, no piston rings, etc.;
- High efficiency;
- Ability to operate against a variable head;
- Suitable for being driven from high-speed prime movers such as turbines, electric motors, internal combustion engines etc.; and
- Continuous discharge.

A centrifugal pump consists of a rotating shaft that is connected to an impeller, which is usually comprised of curved blades. The impeller rotates within its casing and sucks the fluid through the eye of the casing (point 1 in Figure 10.1). The fluid's kinetic energy increases due to the energy added by the impeller and enters the discharge end of the casing that has an expanding area (point 2 in Figure 10.1). The pressure within the fluid increases accordingly.

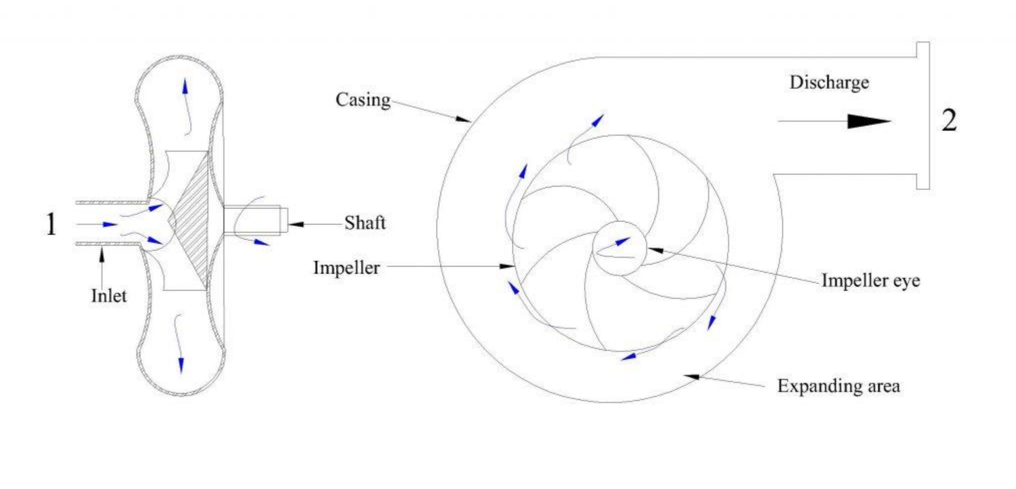

Figure 1-22 Schematic of a typical centrifugal pump

The performance of a centrifugal pump is presented as characteristic curves in Figure 10.2, and is comprised of the following:

- Pumping head versus discharge,

- Brake horsepower (input power) versus discharge, and
- Efficiency versus discharge.
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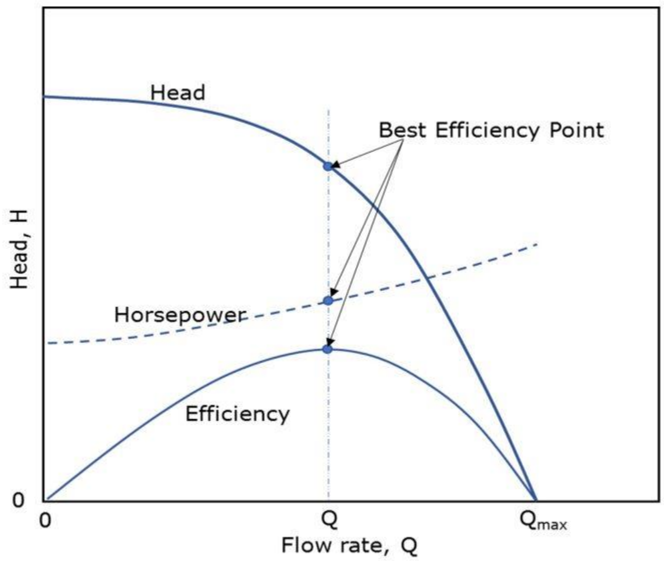

Figure 1-23 Typical centrifugal pump performance curves at constant impeller rotation speed. The units for H and Q are arbitrary.

The characteristic curves of commercial pumps are provided by manufacturers. Otherwise, a pump should be tested in the laboratory, under various discharge and head conditions, to produce such curves. If a single pump is incapable of delivering the design flow rate and pressure, additional pumps, in series or parallel with the original pump, can be considered. The characteristic curves of pumps in series or parallel should be constructed since this information helps engineers select the types of pumps needed and how they should be configured.

7- PRACTICAL APPLICATION

Many pumps are in use around the world to handle liquids, gases, or liquid-solid mixtures. There are pumps in cars, swimming pools, boats, water treatment facilities, water wells, etc. Centrifugal pumps are commonly used in water, sewage, petroleum, and petrochemical pumping. It is important to select the pump that will best serve the project's needs.

8- OBJECTIVE

The objective of this experiment is to determine the operational characteristics of two centrifugal pumps when they are configured as a single pump, two pumps in series, and two pumps in parallel.

9- METHOD

Each configuration (single pump, two pumps in series, and two pumps in parallel) will be tested at pump speeds of 60, 70, and 80 rev/sec. For each speed, the bench regulating valve will be set to fully closed, 25%, 50%, 75%, and 100% open. Timed water collections will be performed to determine flow rates for each test, and the head, hydraulic power, and overall efficiency ratings will be obtained.

10- EQUIPMENT

The following equipment is required to perform the pumps experiment:

- P6100 hydraulics bench, and
- Stopwatch.

11- EQUIPMENT DESCRIPTION

The hydraulics bench is fitted with a single centrifugal pump that is driven by a single-phase A.C. motor and controlled by a speed control unit. An auxiliary pump and the speed control unit are supplied to enhance the output of the bench so that experiments can be conducted with the pumps connected either in series or in parallel. Pressure gauges are installed at the inlet and outlet of the pumps to measure the pressure head before and after each pump. A watt-meter unit is used to measure the pumps' input electrical power [10].

12- THEORY

12-1 GENERAL PUMP THEORY

Consider the pump shown in Figure 10.3. The work done by the pump, per unit mass of fluid, will result in increases in the pressure head, velocity head, and potential head of the fluid between points 1 and 2. Therefore:

- work done by pump per unit mass = W/M
- increase in pressure head per unit mass
- increase in velocity head per unit mass
- increase in potential head per unit mass

in which:

W: work

M: mass

P: pressure

: density

v: flow velocity

g: acceleration due to gravity

z: elevation

Applying Bernoulli's equation between points 1 and 2 in Figure 10.3 results in:

Since the difference between elevations and velocities at points 1 and 2 are negligible, the equation becomes:

Dividing both sides of this equation by gives:

The right side of this equation is the manometric pressure head, H_m, therefore:

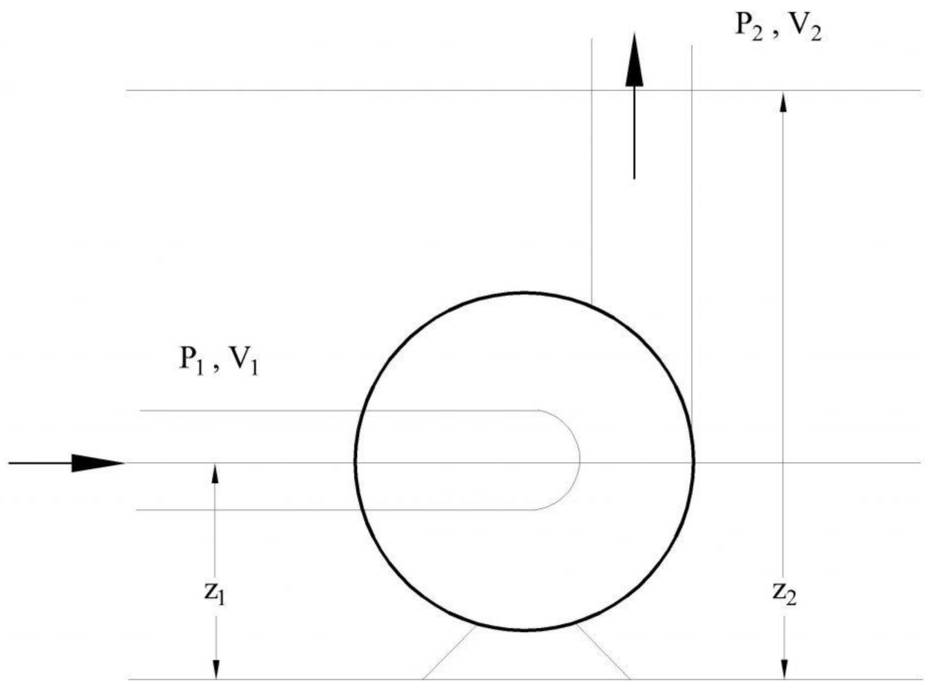

Figure 1-24 Schematic pump–pipe system

12-2 POWER AND EFFICIENCY

The hydraulic power (W_h) supplied to the fluid by the pump is the product of the pressure increase and the flow rate:

The pressure increase produced by the pump can be expressed in terms of the manometric head,

Therefore:

The overall efficiency ( ) of the pump-motor unit can be determined by dividing the hydraulic power (W_h) by the input electrical power (W_i), i.e.:

12-3 SINGLE PUMP – PIPE SYSTEM PERFORMANCE

While pumping fluid, the pump has to overcome the pressure loss that is caused by friction in any valves, pipes, and fittings in the pipe system. This frictional head loss is approximately proportional to the square of the flow rate. The total system head that the pump has to overcome is the sum of the total static head and the frictional head. The total static head is the sum of the static suction lift and the static discharge head, which is equal to the difference between the water levels of the discharge and the source tank (Figure 10.4). A plot of the total head-discharge for a pipe system is called a *system curve*; it is superimposed onto a pump characteristic curve in Figure 10.5. The operating point for the pump-pipe system combination occurs where the two graphs intercept [10].

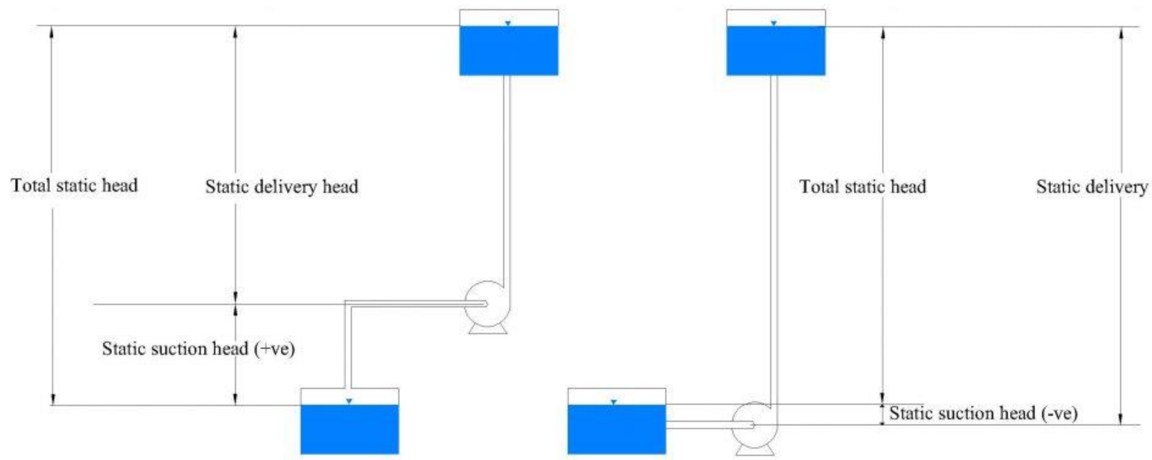

Figure 1-25 Pump and pipe system showing static and total heads: lift pump (left), pump with flooded suction (right)

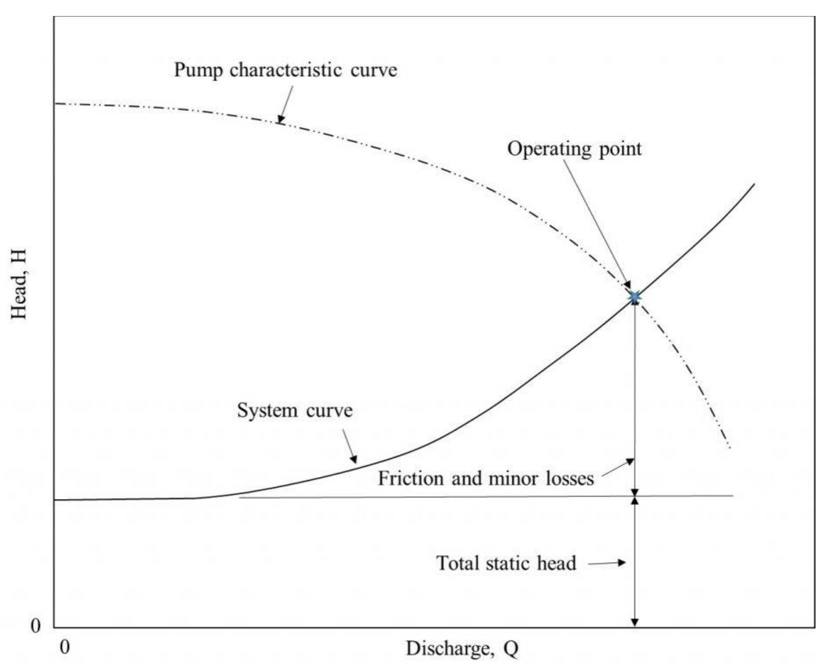

Figure 1-26 Pump-pipe system operating point

12-4 PUMPS IN SERIES

Pumps are used in series in a system where substantial head changes take place without any appreciable difference in discharge. When two or more pumps are configured in series, the flow rate throughout the pumps remains the same; however, each pump contributes to the increase in the head so that the overall head is equal to the sum of the contributions of each pump [10]. For n pumps in series:

The composite characteristic curve of pumps in series can be prepared by adding the ordinates (heads) of all of the pumps for the same values of discharge. The intersection point of the composite head characteristic curve and the system curve provides the operating conditions (performance point) of the pumps (Figure 10.6).

12-5 PUMPS IN PARALLEL

Parallel pumps are useful for systems with considerable discharge variations and with no appreciable head change. In parallel, each pump has the same head. However, each pump contributes to the discharge so that the total discharge is equal to the sum of the contributions of each pump [10]. Thus, for pumps:

The composite head characteristic curve is obtained by summing up the discharge of all pumps for the same values of head. A typical pipe system curve and performance point of the pumps are shown in Figure 10.7.

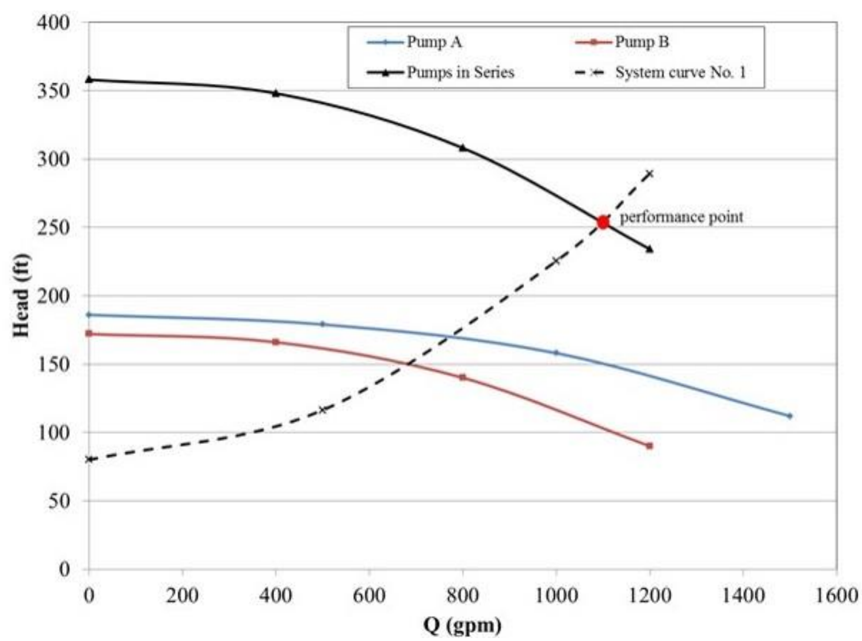

Figure 1-27 Characteristics of two pumps in series

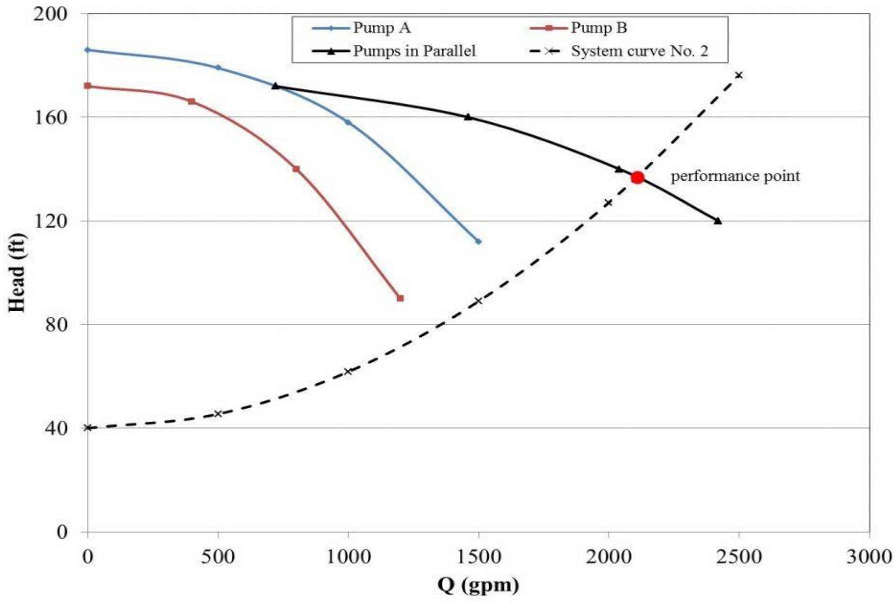

Figure 1-28 Characteristics of two pumps in parallel

12-6 EXPERIMENTAL PROCEDURE

12-6-1 EXPERIMENT 1: CHARACTERISTICS OF A SINGLE PUMP

a) Set up the hydraulics bench valves, as shown in Figure 10.8, to perform the single pump test.

b) Start pump 1, and increase the speed until the pump is operating at 60 rev/sec.

c) Turn the bench regulating valve to the fully closed position.

d) Record the pump 1 inlet pressure (P_1) and outlet pressure (P_2). Record the input power from the watt-meter (Wi). (With the regulating valve fully closed, discharge will be zero.)

e) Repeat steps (c) and (d) by setting the bench regulating valve to 25%, 50%, 75%, and 100% open.

f) For each control valve position, measure the flow rate by either collecting a suitable volume of water (a minimum of 10 liters) in the measuring tank, or by using the rotameter.

g) Increase the speed until the pump is operating at 70 rev/sec and 80 rev/sec, and repeat steps (c) to (f) for each speed.

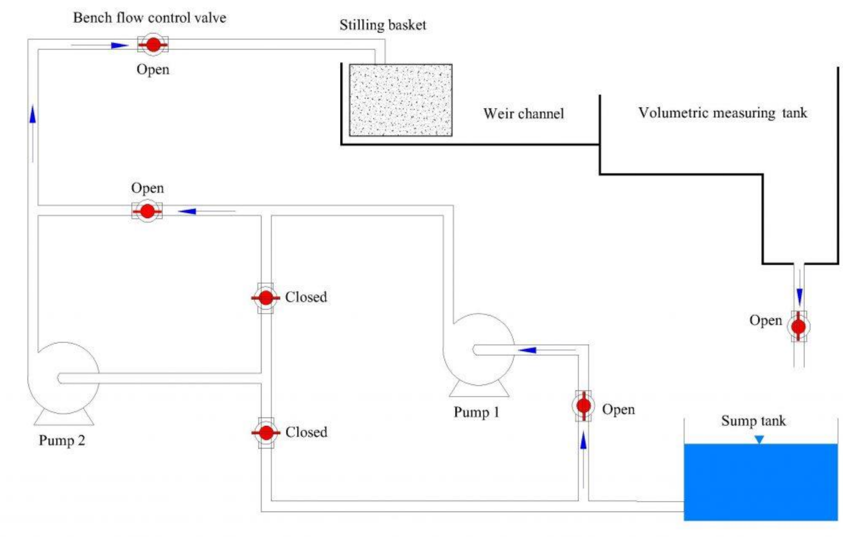

Figure 1-29 Configuration of hydraulics bench valves for the single pump test.

12-6-2 EXPERIMENT

CHARACTERISTICS OF TWO PUMPS IN SERIES

a) Set up the hydraulics bench valves, as shown in Figure 10.9, to perform the two pumps in series test.

b) Start pumps 1 and 2, and increase the speed until the pumps are operating at 60 rev/sec.

c) Turn the bench regulating valve to the fully closed position.

d) Record the pump 1 and 2 inlet pressure (P_1) and outlet pressure (P_2). Record the input power for pump 1 from the wattmeter (Wi). (With the regulating valve fully closed, discharge will be zero.)

e) Repeat steps (c) and (d) by setting the bench regulating valve to 25%, 50%, 75%, and 100% open.

f) For each control valve position, measure the flow rate by either collecting a suitable volume of water (a minimum of 10 liters) in the measuring tank, or by using the rotameter.

g) Increase the speed until the pump is operating at 70 rev/sec and 80 rev/sec, and repeat steps (c) to (f) for each speed.

Note: Wattmeter readings should be recorded for both pumps, assuming that both pumps have the same input power.

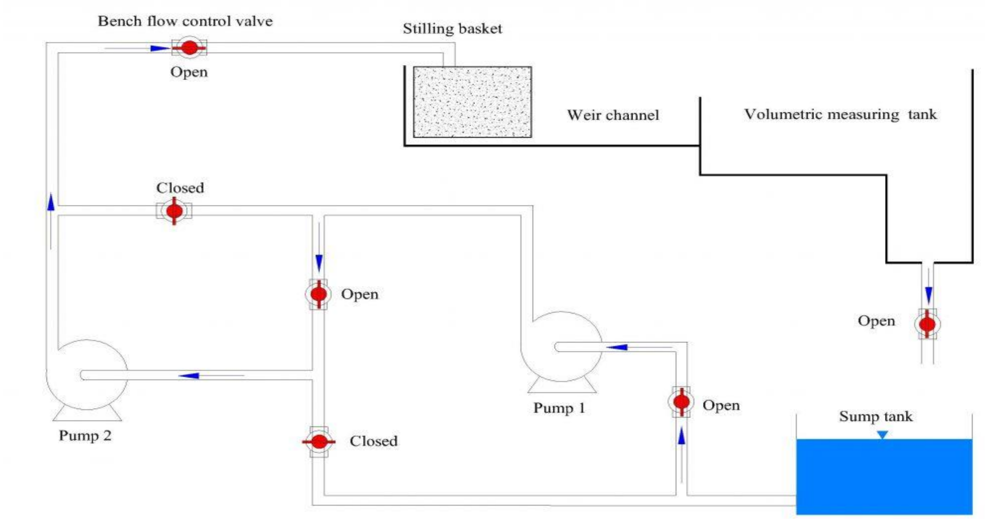

Figure 1-30 Configuration of hydraulics bench valves for pumps in series test.

12-6-2 EXPERIMENT

CHARACTERISTICS OF TWO PUMPS IN PARALLEL

a) Configure the hydraulic bench, as shown in Figure 10.10, to conduct the test for pumps in parallel.

b) Repeat steps (b) to (g) in Experiment 2.

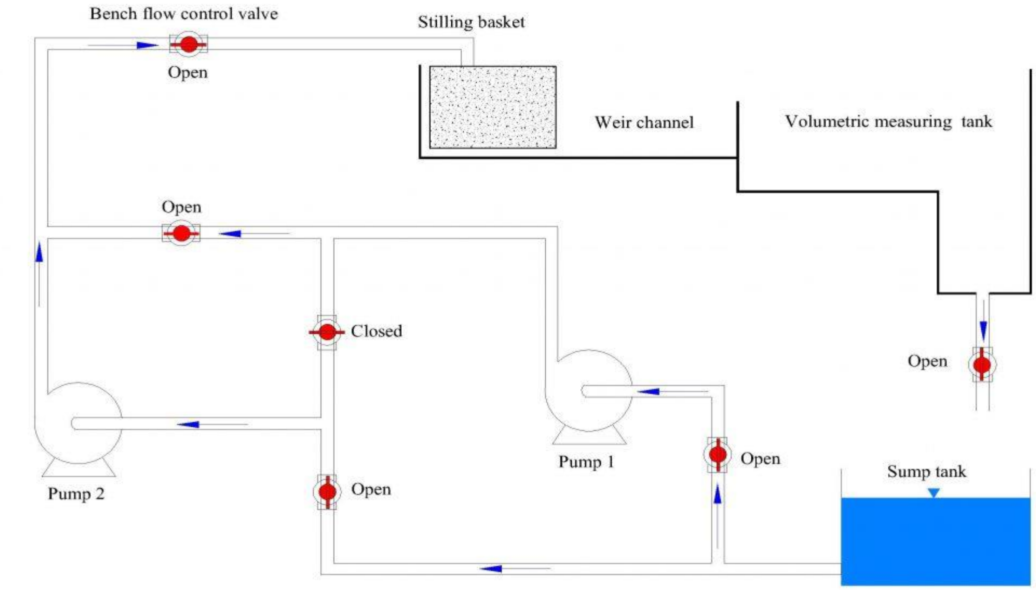

Figure 1-31 Configuration of hydraulic bench valves for pumps in parallel

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2- **انواع المضخات و كيف تعمل للمؤلف حسن علاوي**
3- **Pump Handbook 4Th Edition By Igor Karassik (Author), Joseph Messina (Author), Paul Cooper (Author), Charles Heald (Author)**
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