Boilers, Turbines and Hydraulic Pumps

SYLLABUS

Boilers: Introduction to boilers, classification, Lancashire boiler, Babcock and Wilcox boiler. Introduction to boiler mountings and accessories (no sketches).

Turbines: Hydraulic Turbines – Classification and specification, Principles and operation of Pelton wheel turbine, Francis turbine and Kaplan turbine (elementary treatment only).

Hydraulic Pumps: Introduction, classification and specification of pumps, reciprocating pump and centrifugal pump, concept of cavitation and priming.

Steam boilers

Definition of boilers:

Boiler is defined as a closed metallic vessel in which the water is heated beyond the boiling state by the application of heat liberated by the combustion of fuels to convert it into steam.

Function of a boiler:

The function of the boiler is to supply the steam at the required constant pressure with its quality either dry or as nearly as dry, or superheated. The steam can be supplied from the boiler at a constant pressure by maintaining the steam generation rate and the steam flow rate.

Classification of boilers:

• Boilers are classified based on the principle of working as:

- **Fire tube boilers.**
- **Water tube boilers**.

a. Fire Tube Boiler – hot flue gases are fed into tubes or nest of tubes around which water circulates. Examples: Lancashire boiler, Cornish boiler.

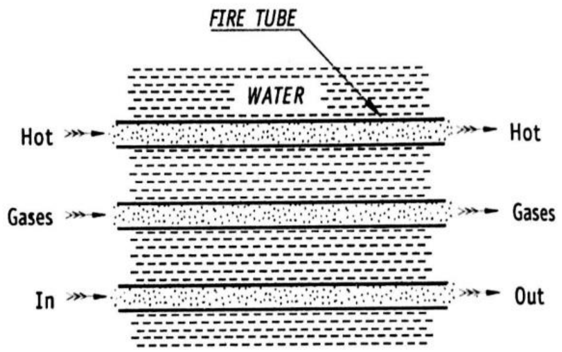


Fig.1. Fire tube Boiler

(b) Water Tube Boiler – water circulates in the tubes or nest of tubes, hot flue gases pass around them.

Examples: Babcock and Wilcox boiler, Stirling boiler.

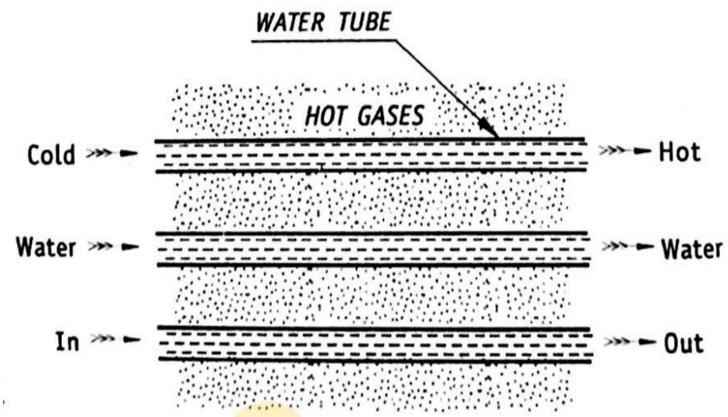


Fig2.Water Tube Boiler

Lancashire boiler:

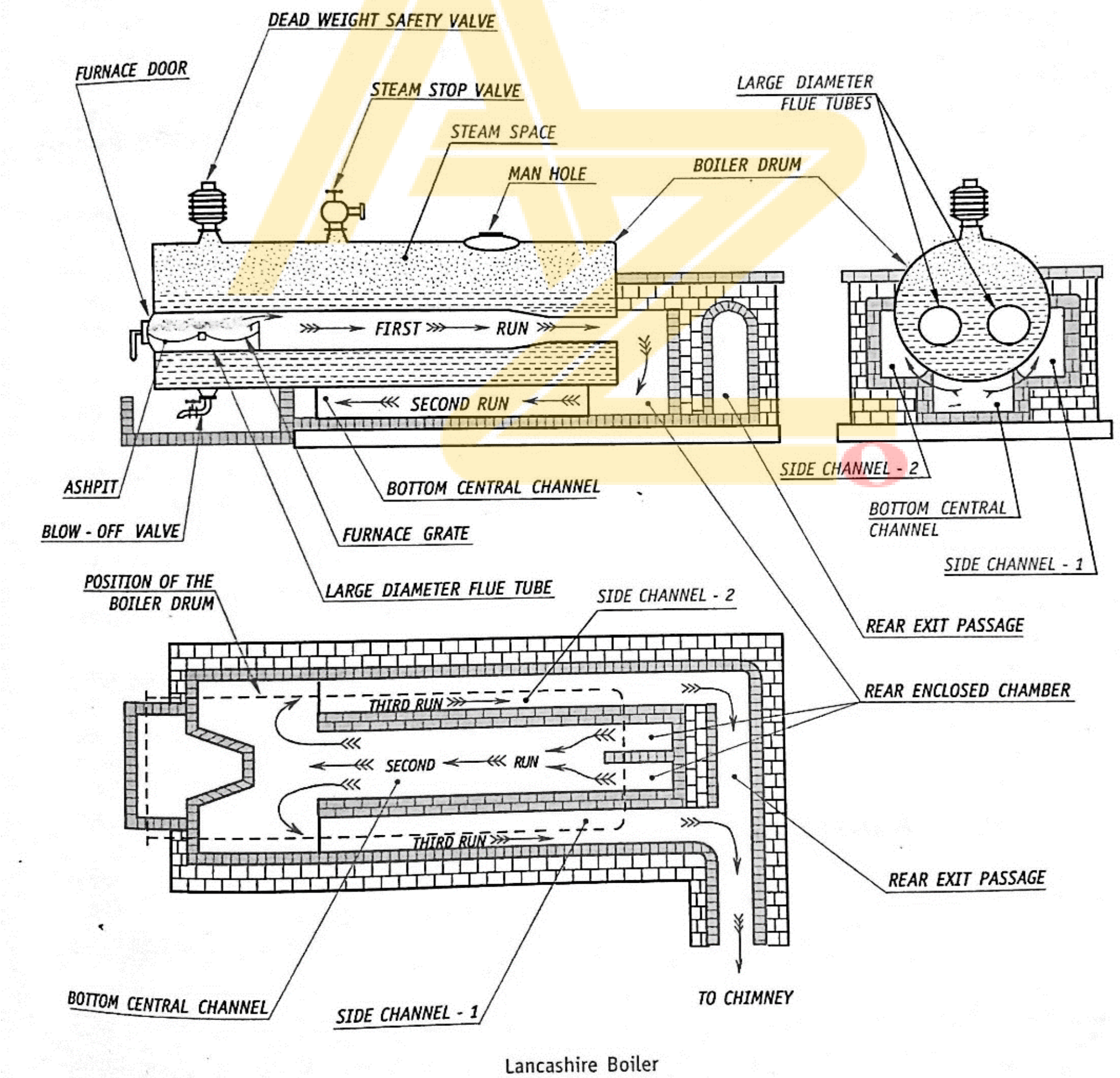


Fig.3 Lancashire boiler

Lancashire Boiler: It is a horizontal, internally fired, natural circulation, fire tube boiler.

• This boiler consists of a large horizontal cylindrical shell placed on the brick wall. Two large flue tubes are placed inside the shell, which carry the hot flue gases.

• The boiler shell is filled with water to three-fourths of its volume and the remaining space is the steam space.

• Hot flue gases from the combustion are made to pass through the flue tubes.

• In the first run it passes from the front end to the rear end of the boiler.

• At the rear end they are made to pass to the bottom central channel.

• In the bottom central channel the hot gases travel from rear end to the front end of the boiler. This is the second run.

• At the front end the hot gases enter into side channels 1 and 2 and travel to the rear end of the boiler. This is the third run.

• At the rear end hot gases coming out of channels 1 and 2 are made to exit to the chimney through the rear exit passage.

• During the first, second and third pass the heat transfer takes place between hot flue gases and the water in the shell, converting water into steam.

• The steam gets accumulated in the steam space at the top.

• Super heater (set of U-tubes) is placed at the rear end of the shell.

• For safety the boiler consists of safety valve, steam stop valve, blow-off valve, pressure gauge, etc.

Babcock & Wilcox Boiler

It is a horizontal, externally fired, natural circulation, water tube boiler.

It consists of mainly four parts:

- Steam and water drum – It is filled with three-fourths water. It stores the feed water and Steam.
- Water tubes – number of water tubes are connected through down take header and uptake header in which water circulates as shown in fig.
- Internal furnace– it burns the coal to produce hot flue gases.
- Super heater – it is set of U-tubes just below the boiler drum, it converts the steam into superheated steam.

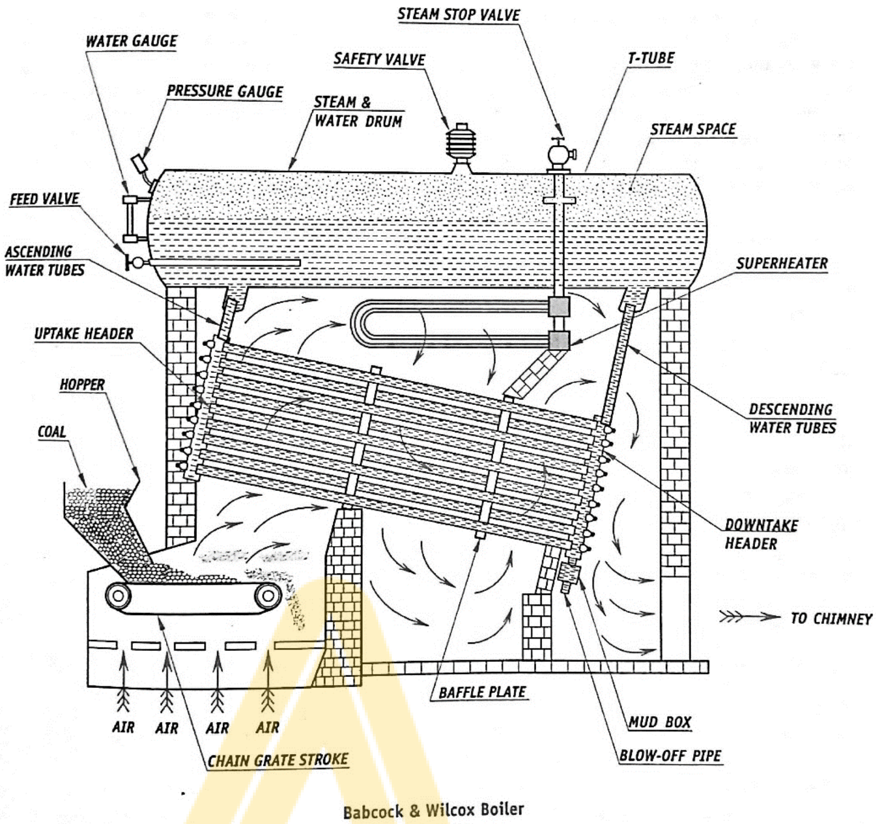


Fig.4. Babcock & Wilcox Boiler

Working:

• Water is introduced into the boiler drum through the feed valve. Water descends into the down take headers, into the water tubes and then into the uptake headers.

• The hot flue gases from the furnace pass over the water tubes. The path of the hot gases is guided by the baffle plates as shown in the fig., and passes out to the chimney.

• As the hot gases pass over the water tubes, the water gets converted into steam. This steam due to low density raises up the tube through the uptake headers and reach the top of boiler drum. This sets up a natural circulation of water.

• The steam collected in the boiler is wet. This is made to pass through the superheater U-tubes just below the boiler drum. The hot gases on their way out pass over these tubes hence converting the steam into superheated steam.

• The superheated steam in then passed out to the turbine through the steam stop valve.

• For safety the boiler consists of safety valve, steam stop valve, blow-off pipe, pressure gauge, etc.

Comparison between A Water Tube Boiler and a Fire Tube Boiler

S. No.	Parameter	Water tube boiler	Fire tube boiler
1	**Flow of water.**	Water flows through the tubes surrounded by hot gases.	Hot gases flow through the tubes and water in the drum surrounds the tubes.
2	**Water circulation**	Water circulates in a definite direction between the drum and water tubes.	There is no circulation of water in the drum.
3	**Bursting chances.**	Bursting chances of the water tubes are more.	Bursting chances are less.
4	**Space required**	The floor area required is less for a given capacity	The floor area required is more for a given capacity.
5	**Construction**	The construction is simpler and easy.	Initial cost is high and the construction is difficult and complicated
6	**Risk involved**	The risk involved in case of bursting is not high.	There is a greater risk of damage to the entire boiler in case of bursting.
7	**Transportation.**	The transportation is easier an convenient because of the smaller size of the boiler shell.	Transportation is difficult due to the large size of the drum.
8	**Treatment of water**	Feed water treatment is must as the scale formation in tubes may lead to bursting.	Feed water treatment is not necessary as the scale formation will not lead to bursting
9	**Rate of steam generation**	The rate of steam generation is as high as 450000 kg/hr.	The rate of steam generation is only upto 9000 kg/hr.
10	**Application**	Due to high rate of steam generation these boilers are suitable for large power plants.	These are suitable for industrial applications rather than power generation.
11	**Operating pressure**	Generates steam at very high pressure of the order of 125 bar.	It can generate steam only upto a pressure of 25 bar.

Function of Various Mountings and Accessories

Water level indicator

The function of the water level indicator is to indicate the level of water in the boiler drum and thus enables the operator to maintain the constant level of water in the drum. There exist two water level indicators in all the boilers. The water level indicators are fitted at the front end of the boiler so that the operator can easily see it.

Safety valve

Two safety valves are to be provided on a boiler as per the Indian Boiler act so that at least one of them is working. These are mounted on the top of the boiler. The function of the safety valve is to safeguard the boiler when the pressure inside boiler reaches above the working pressure. This is automatically done by opening of the valve and discharges of the steam to the atmosphere as soon as the pressure inside the boiler exceeds the working pressure. The commonly used safety valves include, Dead weigth safety valve, Spring loaded safety valve, and Lever safety valve.

Pressure Gauge

The pressure gauge is used to measure the pressure of the steam inside the boiler. The most common type of pressure gauge is the Bourdon gauge. It is fitted in the front of the boiler such that the boiler attendant can easily read it.

Stop (Junction) valve

Stop valve or junction valve is mounted directly on the boiler and is connected to the steam pipe which leads to the engine. It is operated by hand and its function is to regulate the amount of steam passing through the steam pipe and to shut it off when required. When there are a number of boilers delivering steam to a main pipe each boiler must have its own junction valve.

Feed check valve

The function of the feed check valve is to maintain the level of water in the boiler drum constant. It is fitted to the boiler slightly below the working level of water in the boiler. It is connected to the boiler end of the delivery pipe from the feed water pump. A feed check valve consists of two parts, feed valve, and check valve. The feed valve is operated by hand and its function is to allow or to stop the supply of water to the boiler. The check valve allows the water to flow in only one direction, from feed pump to the boiler. In the event of failure of feed pump, the boiler pressure becomes more than the feed pump side, this closes the check valve and prevents the back flow of water from the boiler.

Blow off cock

It is necessary to periodically empty the boiler in order to clean and inspect internally. It is also a common practice that a portion of water from the bottom of the boiler is periodically discharged so that any sediment deposited may be carried away. For these purposes a blow off valve or cock is fitted to the lowest part of the boiler.

Fusible plug

The crown of a furnace or combustion chamber should be fitted with a plug held in position by a fusible metal of alloy. The main object of the fusible plug is to put off the fire in the furnace of the boiler when the water level in the boiler falls below an unsafe level and thus avoid explosion which may take place due to overheating of the tubes and shell.

Man hole or Mud box

It is an elliptical shaped hole on the top of the boiler shell at a convenient position so that a man Can enter through it inside the boiler for cleaning and inspection purposes. Mud box is fitted at the bottom of the boiler to collect the mud. Normally blow off valve is connected to this box.

Super heater

Super heater is a device used to convert the dry steam generated by the boiler into superheated steam to increase the thermal efficiency of the boiler. It is a set of tubes placed in the path of the flue gases. The steam from the boiler shell is passed through the superheater where it absorbs heat from the flue gases and converted into superhested steam before it reaches the steam stop valve.

Economizer

Economizer is the heat exchanger that raises the temperature of the water before it enters the boiler drum. Its function is to extract heat from the outgoing flue gases before it enters the chimney and this heat is used to pre heat the feed water. Hence, most of the heat from the escaping gases is utilized and the thermal efficiency of the boiler increases. The pre heating of water also increases the fuel efficiency since the water is converted into steam with less heat input. Hence, the over all efficiency of the boiler increases. The economizer is mounted in the path of flue gases, just before the chimney and after the air pre heater.

Air preheaters

The air preheater is a device used to heat the air entering the combustion chamber. This preheated air eases the burning of the fuel and hence improves the efficiency of the boiler. It is mounted in the path of the outgoing flue gases before the economizer. As the air before entering the furnace passes through this preheater, it absorbs heat from the surroundings and its temperature increases.

Feed pump

A feed pump is an accessory required to deliver the feed water at high pressure into the boiler. The commonly used pumps are rotary pump, reciprocating pump, and injectors.

Steam drier or separator

A steam separator separates the suspended water particles in the steam before it enters the turbine. It is located very close to the turbine on the main supply pipe.

Steam trap

Steam trap is a device used to drain off the condensed water accumulated in the steam pipe lines while at the same time the high pressure steam do not escape out of it. It is connected to a small by-pass pipe which branches off from the main steam pipe line.

WATER TURBINES:

Hydraulic or water turbines are the machines which convert the kinetic and potential energies possessed by water into mechanical rotary motion or power. These are further coupled to electric generators to produce electric power. The water is stored in artificially created reservoirs by constructing dams across flowing rivers. Water from these reservoirs is carried through penstocks to the turbines, where hydraulic energy of water is converted into mechanical energy.

CLASSIFICTION BASED ON THE ACTION OF WATER ON THE MOVING BLADES:

1. IMPULSE TURBINES
2. REACTION TURBINES

IMPULSE TURBINE OR PELTON WHEEL: The pelton wheel is the most commonly used type of impulse turbine. It works under a high head and requires small quantity of water. Fig. shows a schematic sketch of a Pelton Wheel. The water from a high head source is supplied to the nozzle provided with a needle, which controls the quantity of water flowing out of the nozzle. The pressure energy of water is converted into velocity energy as it flows through the nozzle. The jet of water issuing out of the nozzle at high velocity impinges on the curved blades known as pelton cups, at the centre as shown in the adjoining figure. The impulsive force of the jet striking on the Pelton cups sets up the pelton wheel to rotate in the direction of the impinging jet. Thus the pressure energy of the water is converted into mechanical energy. The pressure inside the casing of the turbine will be at atmospheric pressure.

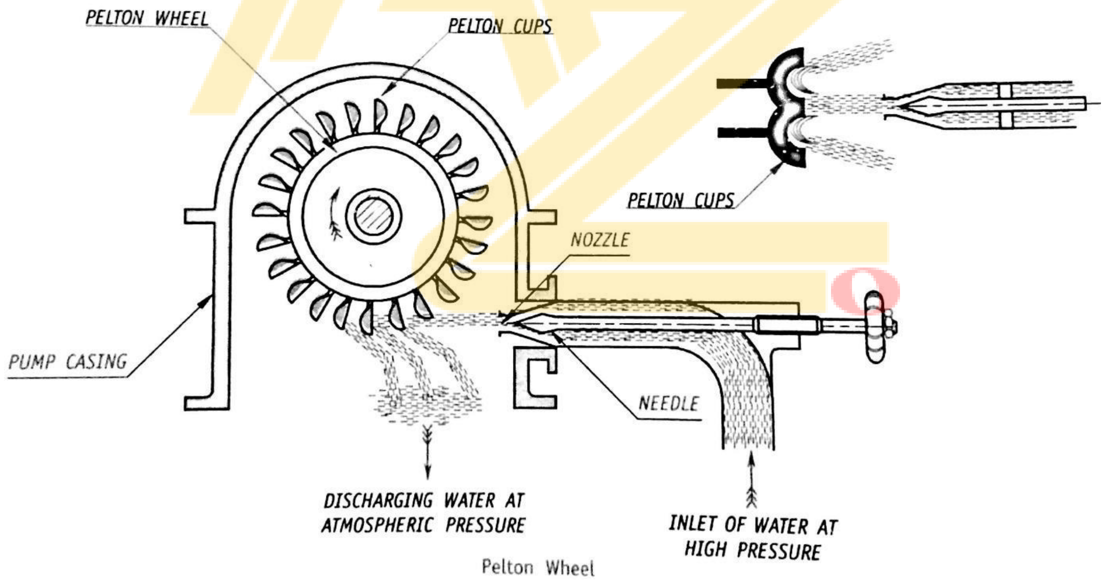


Fig.5.Pelton wheel Turbine

REACTION TURBINES:
FRANCIS TURBINE:

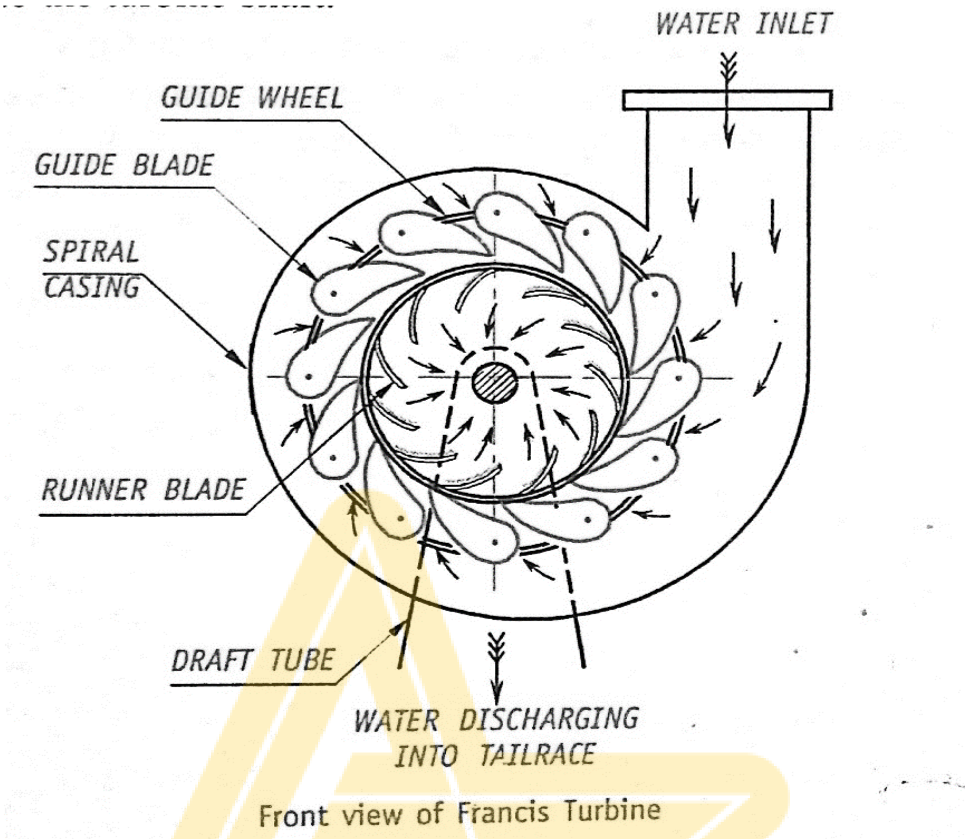


Fig.6.Francis Turbine

The Francis turbine is a medium head reaction turbine in which water flows radially inwards. Fig shows a simple schematic representation of the Francis turbine. It consists of a spiral casing enclosing a number of stationary guide blades fixed all-round the circumference of an inner ring of moving vanes forming the runner which is keyed to the turbine shaft. Water at high pressure enters through the inlet in the casing and flows radially inwards to the outer periphery of the runner through the guide blades. From the outer periphery of the runner the water flows inwards through the moving vanes and discharges at the centre of the runner at lower pressure. During its flow over the moving blades it imparts kinetic energy to the runner to set it into rotational motion. To enable the discharge of water at lower pressure, a diverging conical tube called draft tube is fitted at the centre of the runner. The other end of the draft tube is immersed in the discharging side of the water known as tail race.

KAPLAN TURBINES:

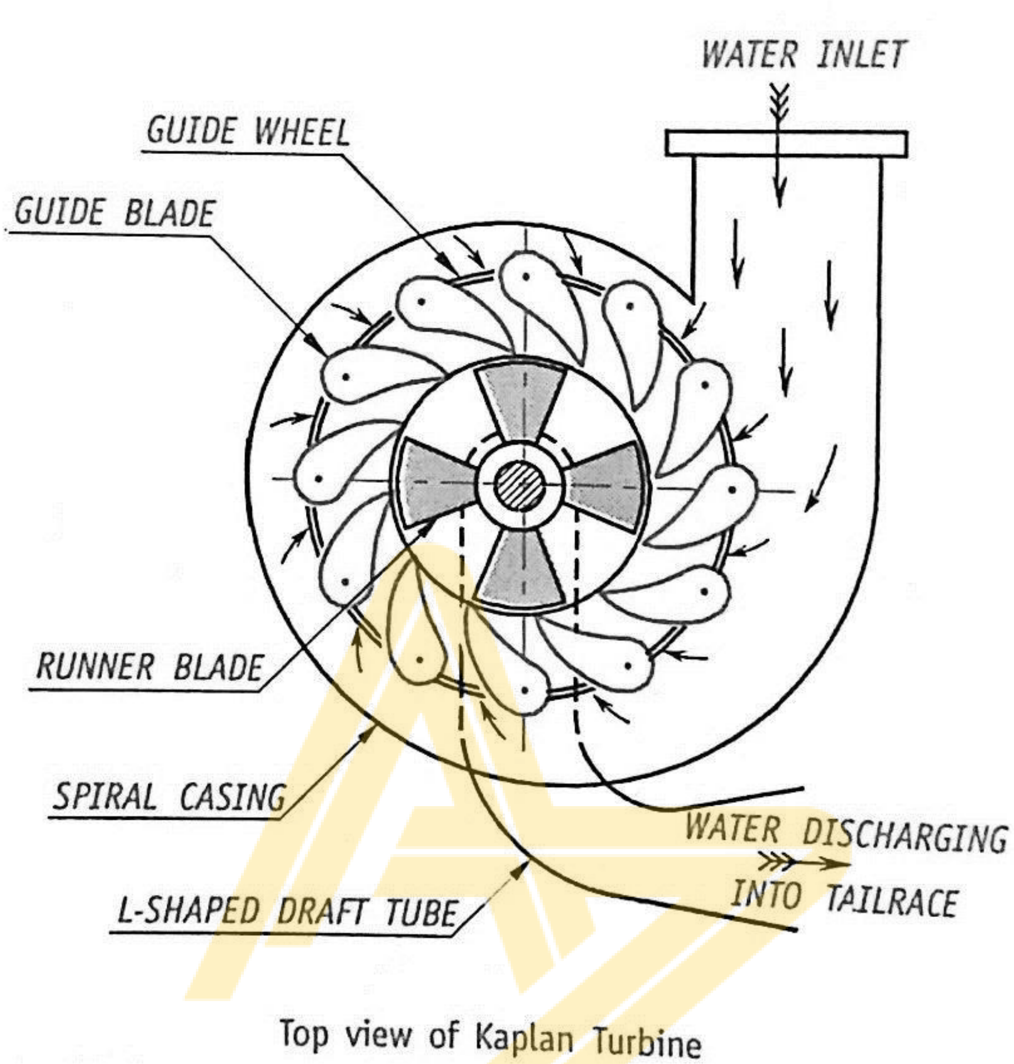


Fig.7.Kaplan Turbine

The Kaplan turbine is a low head reaction turbine in which water flows axially. Fig shows a simple schematic representation of a Kaplan turbine. All the parts of the turbine are similar to that of the Francis turbine except the runner and the draft tube. The runner of the Kaplan turbine resembles with the propeller of the ship, hence sometimes the Kaplan turbine is also called Propeller turbine.

The water at high pressure enters the turbine casing through the inlet and flows over the guide blades. The water from the guide blades strikes the runner blades axially imparting the kinetic energy to set it into rotational motion. The water discharging at the centre of the runner in the axial direction into the draft tube which is in L-shape having its discharging end immersed into the tail race.

Hydraulic Pumps

Introduction

The controlled movement of parts or a controlled application of force is a common requirement in the industries. These operations are performed mainly by using electrical machines or diesel, petrol and steam engines as a prime mover. These prime movers can provide various movements to the objects by using some mechanical attachments like screw jack, lever, rack and pinions etc. However, these are not the only prime movers. The enclosed fluids (liquids and gases) can also be used as prime movers to provide controlled motion and force to the objects or substances. The specially designed enclosed fluid systems can provide both linear as well as rotary motion. The high magnitude controlled force can also be applied by using these systems. This kind of enclosed fluid based systems using pressurized incompressible liquids as transmission media are called as hydraulic systems. The hydraulic system works on the principle of Pascal's law which says that the pressure in an enclosed fluid is uniform in all the directions. The Pascal's law is illustrated in figure. The force given by fluid is given by the multiplication of pressure and area of cross section. As the pressure is same in all the direction, the smaller piston feels a smaller force and a large piston feels a large force. Therefore, a large force can be generated with smaller force input by using hydraulic systems.

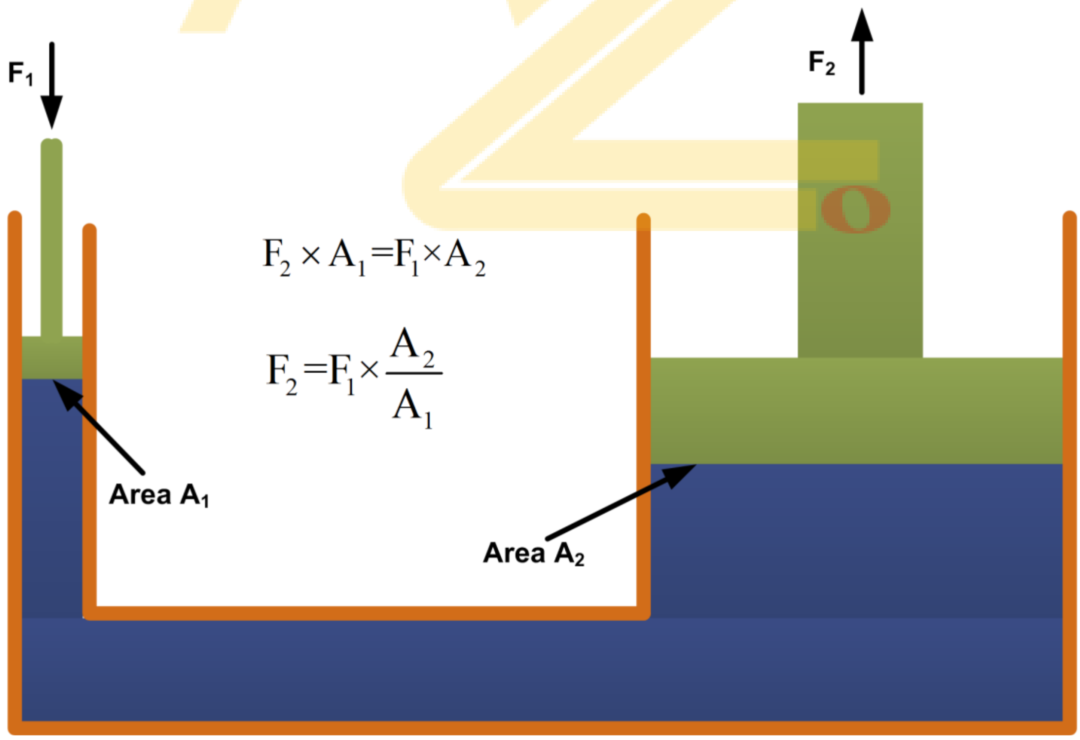


Fig.8. Principle of hydraulic system

PUMPING THEORY

Pumps operate on the principle whereby a partial vacuum is created at the pump inlet due to the internal operation of the pump. This allows atmospheric pressure to push the fluid out of the oil tank (reservoir) and into the pump intake. The pump then mechanically pushes the fluid out the discharge line.

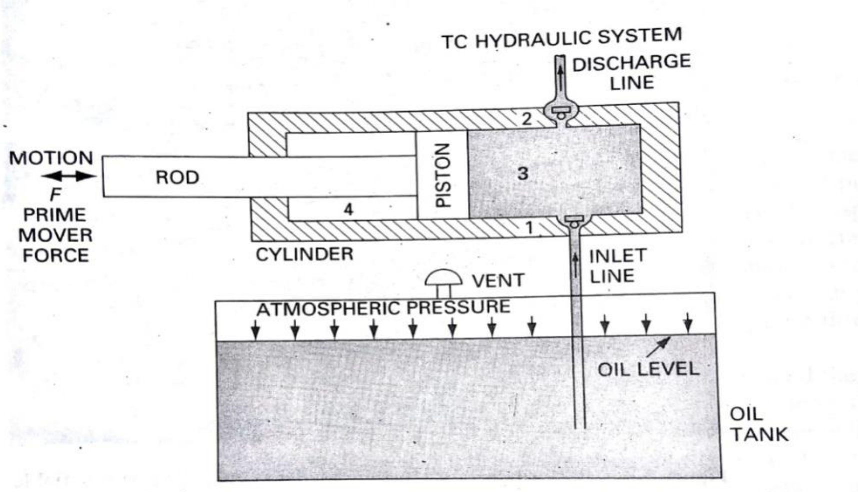
This type of operation can be visualized by referring to the simple piston pump of Figure. Note that this pump contains two ball check valves, which are de-scribed as follows:

• Check valve 1 is connected to the pump inlet line and allows fluid to enter the pump only at this location.

• Check valve 2 is connected to the pump discharge line and allows fluid to leave the pump only at this location.

As the piston is pulled to the left, a partial vacuum is generated in pump cavity 3, because the close tolerance between the piston' and cylinder (or the use of piston ring seals) prevents air inside cavity 4 from travelling into cavity 3. This flow of air, if allowed to occur, would destroy the vacuum. This vacuum holds the ball of check valve 2 against its seat (lower position) and allows atmospheric pressure to push fluid from the reservoir into the pump via check valve 1. This inlet flow occurs because the force of the fluid pushes the ball of check valve 1 off its seat.

When the piston is pushed to the right, the fluid movement closes inlet valve 1 and opens outlet valve 2. The quantity of fluid, displaced by the piston, is forcibly ejected out the discharge line leading to the hydraulic system. The volume of oil displaced by the piston during the discharge stroke is called the displacement volume of the pump.



Pumping action of a simple piston pump.

Fig.9.Pumping Theory

CLASSIFICATION OF PUMP

Non-Positive Displacement Pumps (or) Dynamic Pumps

These pumps are also known as hydro-dynamic pumps. In these pumps the fluid is pressurized by the rotation of the propeller and the fluid pressure is proportional to the rotor speed. These pumps can not withstanding high pressures and generally used for low-pressure and high-volume flow applications. The fluid pressure and flow generated due to inertia effect of the fluid. The fluid motion is generated due to rotating propeller. These pumps provide a smooth and continuous flow but the flow output decreases with increase in system resistance (load). The flow output decreases because some of the fluid slip back at higher resistance. The fluid flow is completely stopped at very large system resistance and thus the volumetric efficiency will become zero. Therefore, the flow rate not only depends on the rotational speed but also on the resistance provided by the system. The important advantages of non-positive displacement pumps are lower initial cost, less operating maintenance because of less moving parts, simplicity of operation, higher reliability and suitability with wide range of fluid etc. These pumps are primarily used for transporting fluids and find little use in the hydraulic or fluid power industries. **Centrifugal pump** is the common example of non-positive displacement pumps.

Positive displacement pump

These pumps deliver a constant volume of fluid in a cycle. The discharge quantity per revolution is fixed in these pumps and they produce fluid flow proportional to their displacement and rotor speed. These pumps are used in most of the industrial fluid power applications. The output fluid flow is constant and is independent of the system pressure (load). The important advantage associated with these pumps is that the high-pressure and low-pressure areas (means input and output region) are separated and hence the fluid cannot leak back due to higher pressure at the outlets. These features make the positive displacement pump most suited and universally accepted for hydraulic systems. The important advantages of positive displacement pumps over non-positive displacement pumps include capability to generate high pressures, high volumetric efficiency, high power to weight ratio, change in efficiency throughout the pressure range is small and wider operating range pressure and speed. The fluid flow rate of these pumps ranges from 0.1 and 15,000 gpm, the pressure head ranges between 10 and 100,000 psi and specific speed is less than 500.

It is important to note that the positive displacement pumps do not produce pressure but they only produce fluid flow. The resistance to output fluid flow generates the pressure. It means that if the discharge port (output) of a positive displacement pump is opened to the atmosphere, then fluid flow will not generate any output pressure above atmospheric pressure. But, if the discharge port is partially blocked, then the pressure will rise due to the increase in fluid flow resistance. If the discharge port of the pump is completely blocked, then an infinite resistance will be generated. This will result in the breakage of the weakest component in the circuit. Therefore, the safety valves are provided in the hydraulic circuits along with positive displacement **pumps. Important positive displacement pumps are gears** pumps, vane pumps and piston pumps.

1. **Gear pump**
    a. External gear Pump
    b. Internal Gear Pump
    c. Lobe Pump
    d. Screw Pump
2. **Vane Pump**
    a. Unbalanced vane pumps
    b. Balanced vane pumps
3. **Piston pump**
    a. Axial Design
    b. Radial Design

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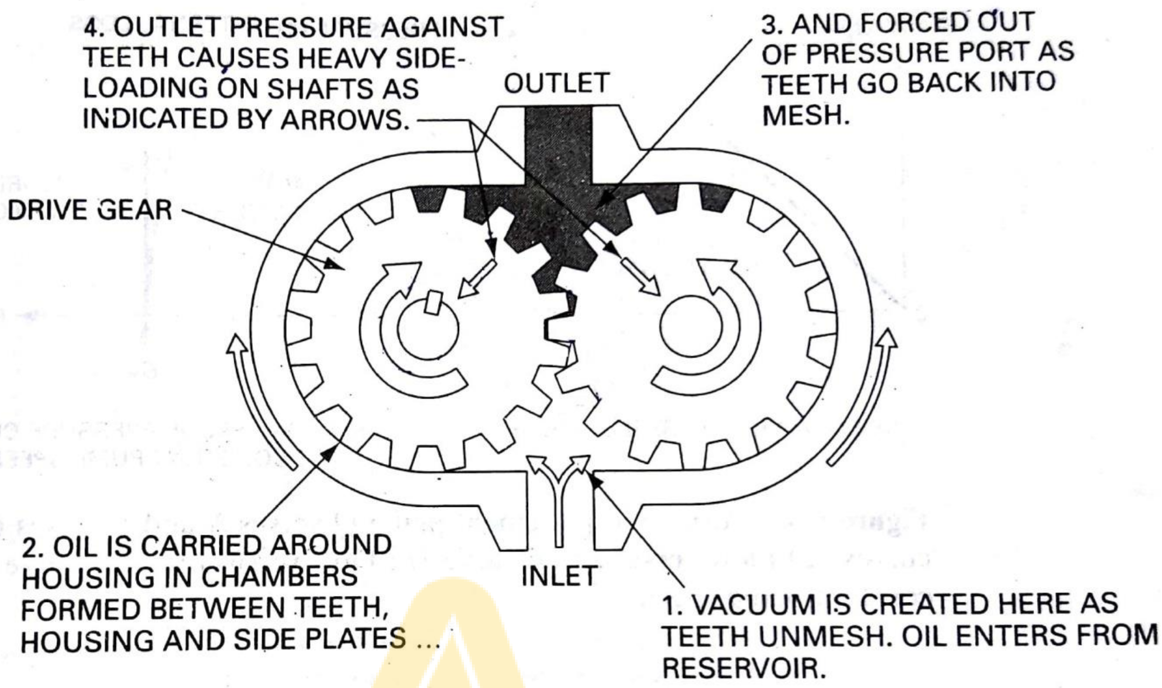
1. Gear pump

Gear pump is a robust and simple positive displacement pump. It has two meshed gears revolving about their respective axes. These gears are the only moving parts in the pump. They are compact, relatively inexpensive and have few moving parts.

a).External gear Pump

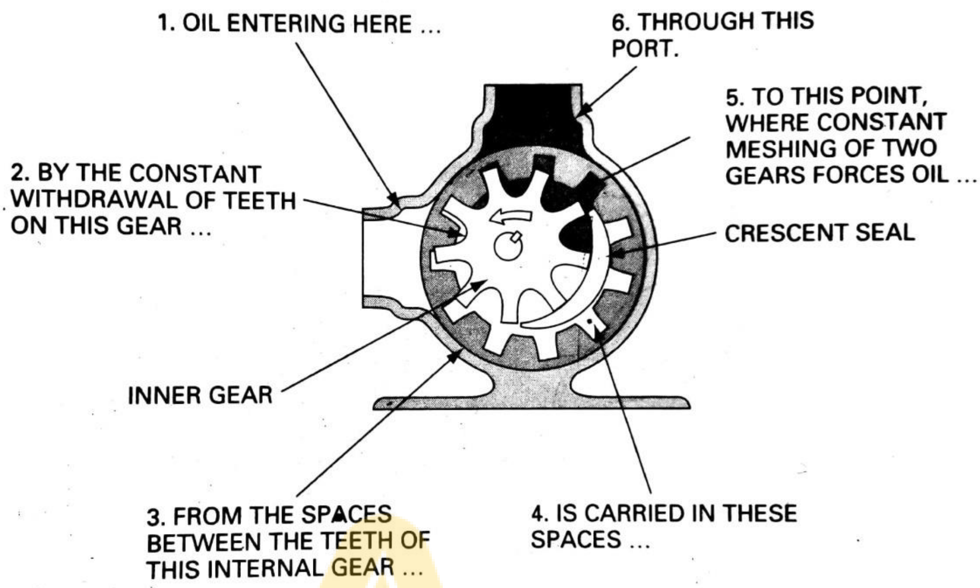


External gear pump operation.

Fig.10 External gear pump

The external gear pump consists of externally meshed two gears housed in a pump case as shown in figure. One of the gears is coupled with a prime mover and is called as driving gear and another is called as driven gear. The rotating gear carries the fluid from the tank to the outlet pipe. The suction side is towards the portion whereas the gear teeth come out of the mesh. When the gears rotate, volume of the chamber expands leading to pressure drop below atmospheric value. Therefore the vacuum is created and the fluid is pushed into the void due to atmospheric pressure. The fluid is trapped between housing and rotating teeth of the gears. The discharge side of pump is towards the portion where the gear teeth run into the mesh and the volume decreases between meshing teeth. The pump has a positive internal seal against leakage; therefore, the fluid is forced into the outlet port.

b). Internal Gear Pump



Operation of an internal gear pump.

Fig.11.Internal gear pump

Fig shows configuration and operation of the internal gear pump. This design consists of an internal gear, a regular spur gear, a crescent-shaped seal, and external housing. As power is applied to either gear, the motion of the gears draws fluid from the reservoir and forces it around both sides of the crescent seal, which acts as a seal between the suction and discharge ports. When teeth mesh on the side opposite to the crescent seal, the fluid is forced to enter the discharge port of the pump.

c).Lobe Pump

Lobe pumps work on the similar principle of working as that of external gear pumps. However in Lobe pumps, the lobes do not make any contact like external gear pump. Lobe contact is prevented by external timing gears located in the gearbox. Similar to the external gear pump, the lobes rotate to create expanding volume at the inlet. Now, the fluid flows into the cavity and is trapped by the lobes. Fluid travels around the interior of casing in the pockets between the lobes and the casing. Finally, the meshing of the lobes forces liquid to pass through the outlet port. The bearings are placed out of the pumped liquid. Therefore the pressure is limited by the bearing location and shaft deflection.

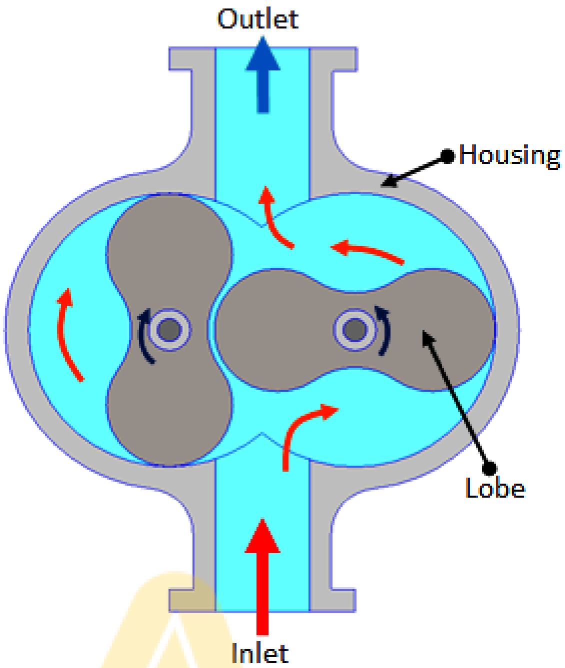


Fig.12.Lobe Pump

d).Screw Pump

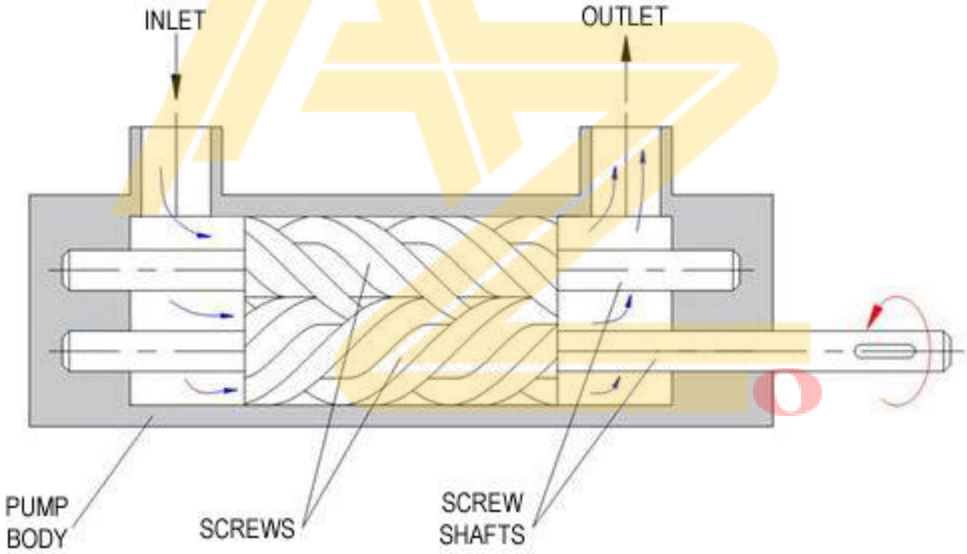


Fig.13 Screw Pump

The screw pump is an axial flow positive displacement unit. Three precision ground screws, meshing within a close-fitting housing, deliver nonpulsating flow quietly and efficiently. The two symmetrically opposed idler rotors act as rotating seals, confining the fluid in a succession of closures or stages. The idler rotors are in rolling contact with the central power rotor and are free to float in their respective housing bores on a hydrodynamic oil film. There are no radial bending loads. Axial hydraulic forces on the rotor set are balanced, eliminating any need for thrust bearings.

2. Vane Pump

Gear pumps have a disadvantage of small leakage due to gap between gear teeth and the pump housing. This limitation is overcome in vane pumps. The schematic of vane pump working principle is shown in figure Vane pumps generate a pumping action by tracking of vanes along the casing wall. The vane pumps generally consist of a rotor, vanes, ring and a port plate with inlet and outlet ports. The rotor in a vane pump is connected to the prime mover through a shaft. The vanes are located on the slotted rotor. The rotor is eccentrically placed inside a cam ring as shown in the figure. The rotor is sealed into the cam by two side plates. When the prime mover rotates the rotor, the vanes are thrown outward due to centrifugal force. The vanes track along the ring. It provides a tight hydraulic seal to the fluid which is more at the higher rotation speed due to higher centrifugal force. This produces a suction cavity in the ring as the rotor rotates. It creates vacuum at the inlet and therefore, the fluid is pushed into the pump through the inlet.

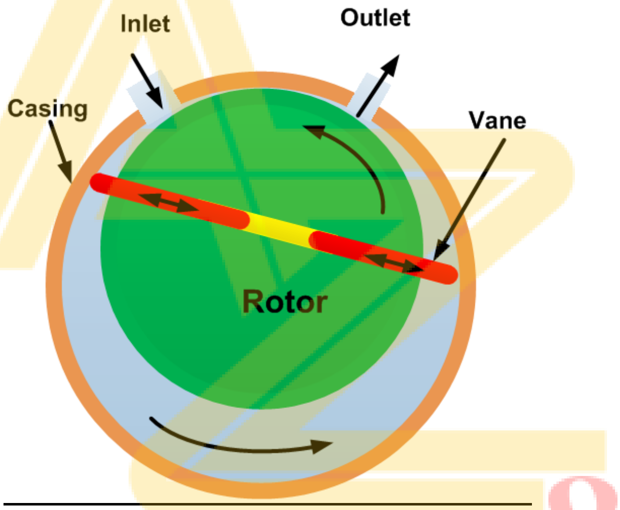


Fig.14.Vane Pump

a. Unbalanced vane pumps

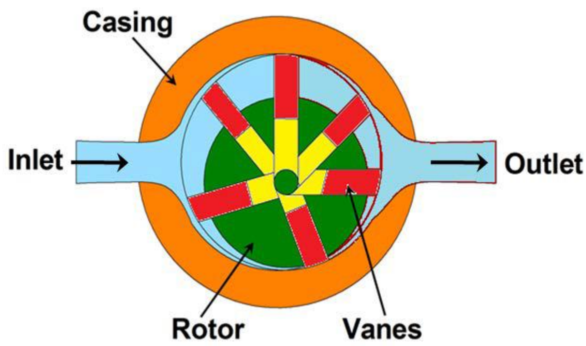


Fig.15 Unbalanced vane pumps

In practice, the vane pumps have more than one vane as shown in figure. The rotor is offset within the housing, and the vanes are constrained by a cam ring as they cross inlet and outlet ports. Although the vane tips are held against the housing, still a small amount of leakage exists between rotor faces and body sides. Also, the vanes compensate to a large degree for wear at the vane tips or in the housing itself. The pressure difference between outlet and inlet ports creates a large amount of load on the vanes and a significant amount of side load on the rotor shaft which can lead to bearing failure. This type of pump is called as unbalanced vane pump.

b. Balanced vane pumps

Figure shows the schematic of a balanced vane pump. This pump has an elliptical cam ring with two inlet and two outlet ports. Pressure loading still occurs in the vanes but the two identical pump halves create equal but opposite forces on the rotor. It leads to the zero net force on the shaft and bearings. Thus, lives of pump and bearing increase significantly. Also the sounds and vibrations decrease in the running mode of the pump.

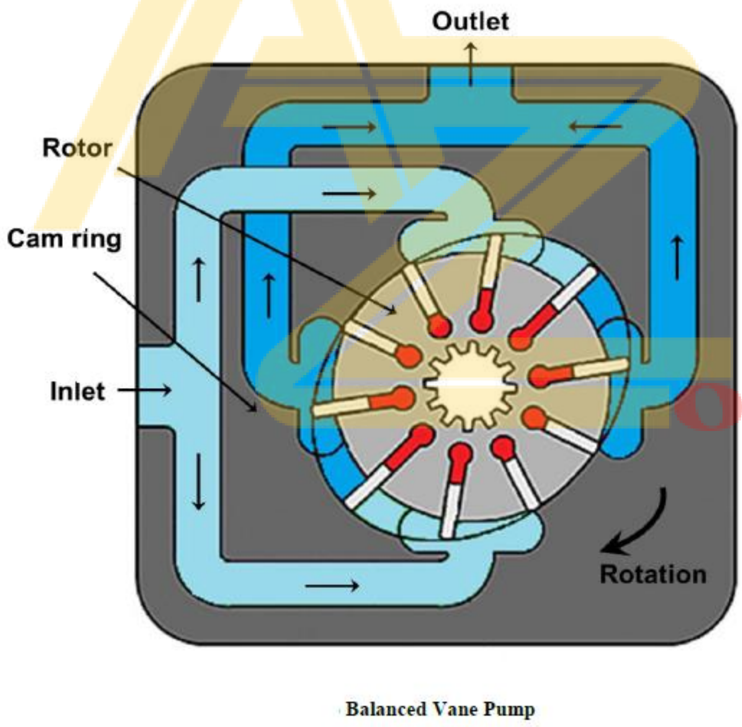


Fig.16.Balanced Vane Pump

4. Piston pump

Piston pumps are meant for the high-pressure applications. These pumps have high-efficiency and simple design and needs lower maintenance. These pumps convert the rotary motion of the input shaft to the reciprocating motion of the piston. These pumps work similar to the four stroke engines. They work on the principle that a reciprocating piston draws fluid inside the cylinder when the piston retracts in a cylinder bore and discharge the fluid when it extends.

a. Axial Design

Axial piston pumps are positive displacement pumps which converts rotary motion of the input shaft into an axial reciprocating motion of the pistons. These pumps have a number of pistons (usually an odd number) in a circular array within a housing which is commonly referred to as a cylinder block, rotor or barrel. These pumps are used in jet aircraft. They are also used in small earthmoving plants such as skid loader machines. Another use is to drive the screws of torpedoes. In general, these systems have a maximum operating temperature of about 120 °C. Therefore, the leakage between cylinder housing and body block is used for cooling and lubrication of the rotating parts. This cylinder block rotates by an integral shaft aligned with the pistons. These pumps have sub-types as:

I. **Bent axis piston pumps**
II. **Swash plate axial piston pump**

I. Bent-Axis Piston Pumps

Figure shows the schematic of bent axis piston pump. In these pumps, the reciprocating action of the pistons is obtained by bending the axis of the cylinder block. The cylinder block rotates at an angle which is inclined to the drive shaft. The cylinder block is turned by the drive shaft through a universal link. The cylinder block is set at an offset angle with the drive shaft. The cylinder block contains a number of pistons along its periphery. These piston rods are connected with the drive shaft flange by ball-and-socket joints. These pistons are forced in and out of their bores as the distance between the drive shaft flange and the cylinder block changes. A universal link connects the block to the drive shaft, to provide alignment and a positive drive.

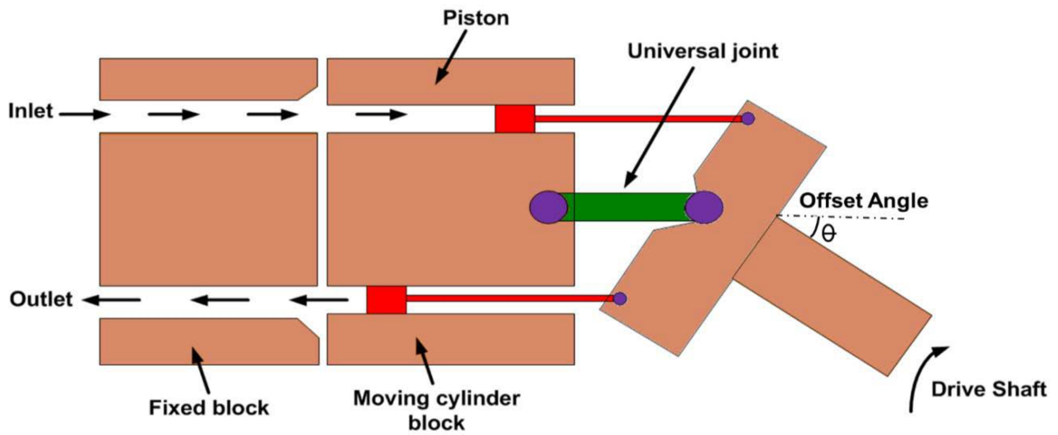
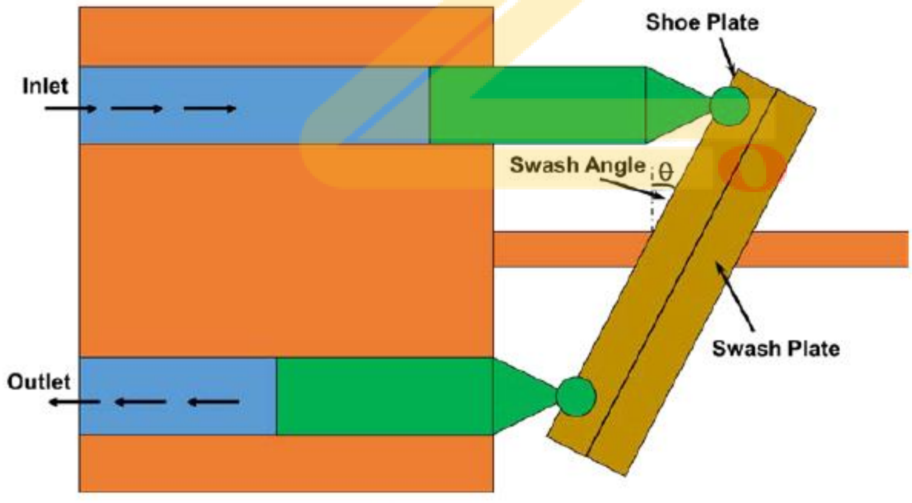


Fig.17. Bent-Axis Piston Pumps

II.Swash Plate Axial Piston Pump

A swash plate is a device that translates the rotary motion of a shaft into the reciprocating motion. It consists of a disk attached to a shaft as shown in Figure. If the disk is aligned perpendicular to the shaft; the disk will turn along with the rotating shaft without any reciprocating effect. Similarly, the edge of the inclined shaft will appear to oscillate along the shaft's length. This apparent linear motion increases with increase in the angle between disk and the shaft (offset angle). The apparent linear motion can be converted into an actual reciprocating motion by means of a follower that does not turn with the swash plate.



Swash plate piston pump

Fig.18.Swash Plate Axial Piston Pump

b. Radial Design

The typical construction of radial piston pump is shown in Figure 5.3.7. The piston pump has pistons aligned radially in a cylindrical block. It consists of a pintle, a cylinder barrel with pistons and a rotor containing a reaction ring. The pintle directs the fluid in and out of the cylinder. Pistons are placed in radial bores around the rotor. The piston shoes ride on an eccentric ring which causes them to reciprocate as they rotate. The eccentricity determines the stroke of the pumping piston. Each piston is connected to inlet port when it starts extending while it is connected to the outlet port when start retracting. This connection to the inlet and outlet port is performed by the timed porting arrangement in the pintle. For initiating a pumping action, the reaction ring is moved eccentrically with respect to the pintle or shaft axis. As the cylinder barrel rotates, the pistons on one side travel outward. This draws the fluid in as the cylinder passes the suction port of the pintle. It is continued till the maximum eccentricity is reached. When the piston passes the maximum eccentricity, pintle is forced inwards by the reaction ring. This forces the fluid to flow out of the cylinder and enter in the discharge (outlet) port of the pintle.

The radial piston pump works on high pressure (up to 1000 bar). It is possible to use

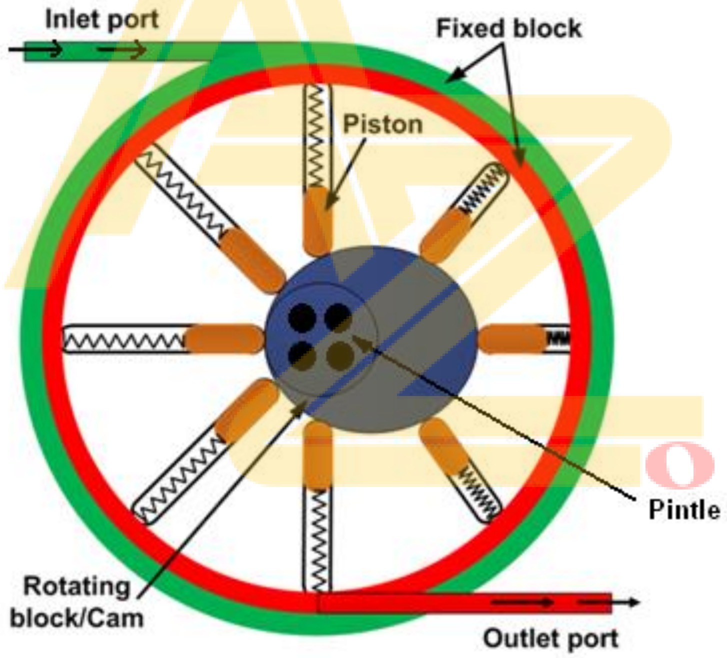


Fig.19. Radial Piston Pump

CENTRIFUGAL PUMP

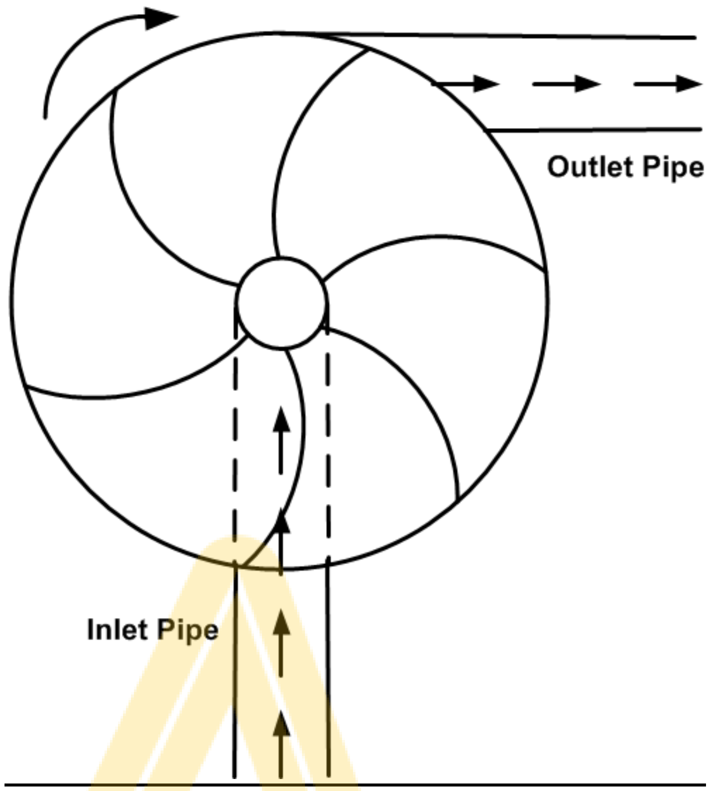


Fig.20.Centrifugal Pump

Centrifugal pump uses rotational kinetic energy to deliver the fluid. The rotational energy typically comes from an engine or electric motor. The fluid enters the pump impeller along or near to the rotating axis, accelerates in the propeller and flung out to the periphery by centrifugal force as shown in figure. In centrifugal pump the delivery is not constant and varies according to the outlet pressure. These pumps are not suitable for high pressure applications and are generally used for low-pressure and high-volume flow applications. The maximum pressure capacity is limited to 20-30 bars and the specific speed ranges from 500 to 10000. Most of the centrifugal pumps are not self-priming and the pump casing needs to be filled with liquid before the pump is started.

Reciprocating Pump

The reciprocating pump is a positive plunger pump. It is also known as positive displacement pump or piston pump. It is often used where relatively small quantity is to be handled and the delivery pressure is quite large. The construction of these pumps is similar to the four stroke engine as shown in figure. The crank is driven by some external rotating motor. The piston of pump reciprocates due to crank rotation. The piston moves down in one half of crank rotation, the inlet valve opens and fluid enters into the cylinder. In second half crank rotation the piston moves up, the outlet valve opens and the fluid moves out from the outlet. At a time, only one valve is opened and another is closed so there is no fluid leakage. Depending on the area of cylinder the pump delivers constant volume of fluid in each cycle independent to the pressure at the output port.

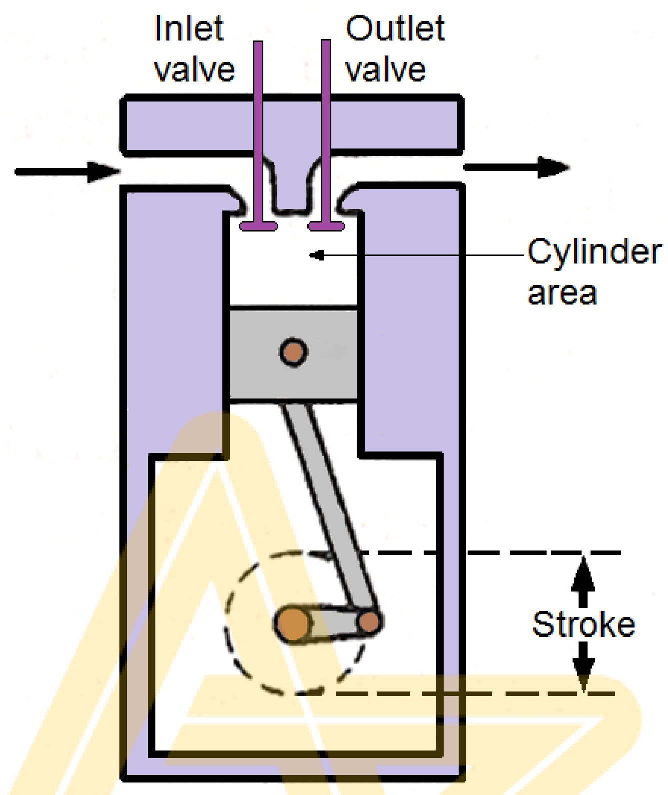


Fig.21. Reciprocating Pump

Pump Cavitation

Pump cavitation, can occur due to entrained air bubbles in the hydraulic fluid or vaporization of the hydraulic fluid. This occurs when pump suction lift is excessive and the pump inlet pressure falls below the vapor pressure of the fluid (usually about 5-psi suction). As a result, air or vapor bubbles, which form in the low-pressure inlet region of the pump, are collapsed when they reach the high-pressure discharge region. This produces high fluid velocity and impact forces, which can erode the metallic components and shorten pump life.

The following rules will control or eliminate cavitation of a pump by keeping the suction pressure above the saturation pressure of the fluid:

1. Keep suction line velocities below 4 ft/s (1.2 m/s).

2. Keep pump inlet lines as short as possible.

3. Minimize the number of fittings in the inlet line.

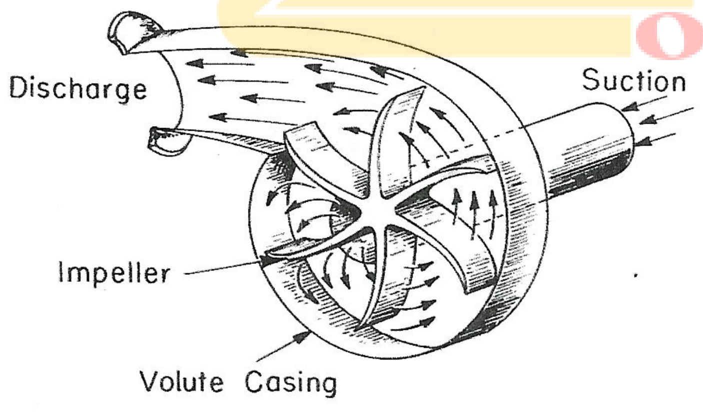
4. Mount the pump as close as possible to the reservoir.

5. Use low-pressure drop inlet filters or strainers. Use indicating-type filters and strainers so that they can be replaced at proper intervals as they become dirty.

6. Use the proper oil as recommended by the pump manufacturer. The importance of temperature control lies in the fact that increased temperatures tend to accelerate the liberation of air or vapor bubbles. Therefore, operating oil temperatures should be kept in the range of 120^0F to 150°F (50°C to 65°C) to provide an optimum viscosity range and maximum resistance to liberation of air or vapor bubbles to reduce the possibiiity of cavitation.

PUMP PRIMING

Positive displacement pumps, for the most part, will pull water or air into their suction side with nearly equal efficiency. In other words, positive displacement pumps are truly self priming. Centrifugal pumps, on the other hand, cannot produce areduced pressure on their suction side without the presenceof water inside the volute and so they have to be primed. Priming is the act of replacing the air inside the pumpvolute with water. Priming can be accomplished manuallyby the operator opening a valve, pouring with a bucket orautomatically by using priming assist equipment.



Technically, a centrifugal pump must have water up to the horizontal center line of the impeller in order to go dynamic when turned on. This is called the datum line. A line just above the center line is the datum + line and is the practical priming level. The datum line relies on all tolerances to be perfect inside the pump. The datum + line can allow for some inefficiency. Figure shows this on a standard centrifugal pump configuration. When the impeller starts to turn, water is moved around and outward inside the volute. This creates higher pressure on the outside of the impeller veins that at the center or eye of the impeller. The pressure difference causes water to be drawn into the pump suction where the pressure is lowest. This works fine as long as the pump is below the inlet water level and is called flooded suction. If the inlet water is below the pump, called a suction lift, the pump must be able to not only pull water into the suction, but release the air that is being moved up the suction line into the pump. The most common way to do this is to locate the impeller and volute inside a case called the priming case. When the priming case is filled with water up to the datum of the pump, there is sufficient volume of water available to the pump to keep it dynamic so that the suction side will maintain the lower pressure necessary to pull water or air into the inlet. When air enters the inlet it is separated from the water in the priming case and is vented out the pump discharge. This type of pump is commonly called a Self-Priming pump. More accurately, it should be called a Re-Priming pump because the pump must be manually primed before is it run.