MODULE 2

MODULE-2

Contents:

Boilers; Introduction to boilers, classification, Lancashire boiler, Babcock and Wilcox boiler. Introduction to boiler mountings and accessories

Turbines: Hydraulic turbines-classification and specification, principles and operation of Pelton wheel turbine, Francis turbine and Kaplan turbine

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

Web links:

https://in.search.yahoo.com/yhs/search;_ylt=AwrxgvmoGYdefGEArwN9TbYF;_ylc=X1MDOTU4MzM0NjkEX3IDMgRmcgN5aHMtb21yLTAwMQRncHJpZANQWGtiWWlTX1RnS181dXBhY
https://www.quora.com/How-does-a-centrifugal-pump-work
https://theconstructor.org/practical-guide/reciprocating-pump-components-working-uses/2914/

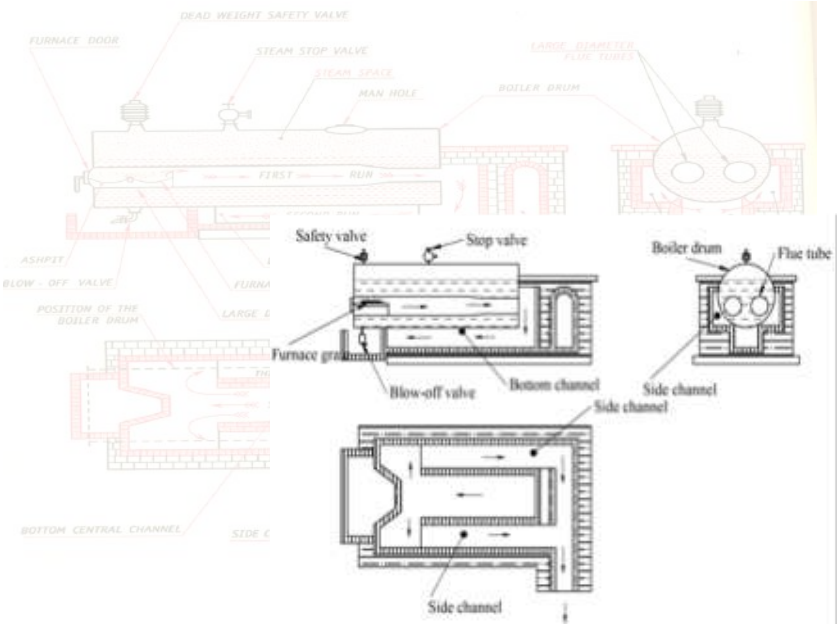
STEAM BOILERS

- Steam boiler is a closed vessel, which is used to convert water into steam at required temperature and pressure by the application of heat.

Classification of Boilers:

- Horizontal, vertical or inclined
- Fire tube boiler & water tube boiler
- Internally fired & externally fired boiler
- Forced circulation & natural circulation
- High pressure boiler & low pressure boiler
- Single tube & multi tube boiler
- Stationary & portable (locomotive) boiler

LANCASHIRE BOILER



Construction:

- It is a horizontal type fire tube boiler. It is used for supplying steam to stationary engines in factories and power stations.
- It consists of a horizontal cylindrical shell. There are two flue tubes which extend over the entire length of the boiler and are tapered to a smaller diameter at the rear end.
- There are two grates and two fire holes and a firebrick bridge at the back end of grate to prevent the entry of unburnt fuel into the flue tubes.
- A manhole is provided at the top of the boiler for cleaning, inspection and repair of the boiler. A mud hole is provided at the bottom to remove the sediments.

Working

- The boiler is filled with substantial quantity of water.
- The fuel is charged through the furnace door which burns in the grates.

- The product of combustion first passes through the flue tubes and return along the brick built flue under the boiler to the front end.
- Here the hot gases divide and flow along the two side flues to the rear end and then pass through the chimney.
- The steam is accumulated at the steam space above the surface of the water and can be tapped off through the steam stop valve.

BABCOCK AND WILCOX BOILER

Construction:

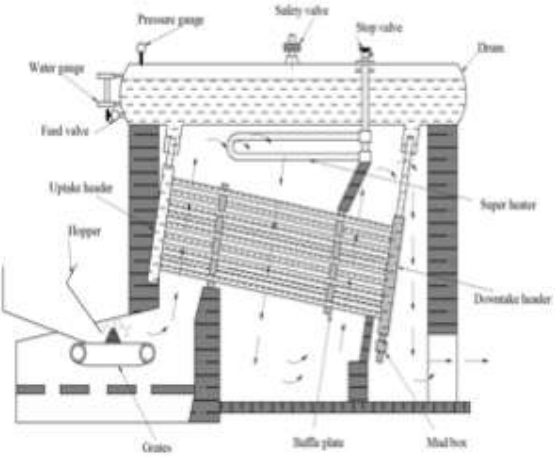
- It consists of a steam and water drum in which the water level being kept at about the middle of the drum. The drum is suspended from iron girders
- A number of horizontally inclined straight water tubes are connected to the front headers, forming the uptake and to the rear headers, forming the down takes. The headers are in turn connected to the boiler drum by means of steel tubes to complete the water circuit.
- A mud box is attached to the bottom of the down take headers to collect the sediments.
- A super heater is placed between the drum and water tubes to obtain superheated steam.
- The furnace is placed below the uptake header. Baffle plates are attached to the water tubes to act as deflectors of flue gases so as the flue gases come in maximum contact with the water tubes.
- The boiler is surrounded on all four sides by firebrick walls. Doors are provided for a man to enter for repairing and cleaning.

Working

- The boiler is filled with substantial quantity of water.
- The coal is charged through the hopper and it burns on the grate.
- The hot gases of combustion first rises up, then move down and again rise up due to the presence of baffle plates. It finally escapes through the chimney.
- The hot water and steam moisture rise up through the uptake header into the boiler shell where steam separates from water and collects in the steam space.
- From the steam space the steam is led to the super heater tubes and the super heated steam can be tapped off through the steam stop valve.

Advantages of water tube boilers over fire tube boilers.

- Steam can be raised more quickly
- Steam at higher pressures can be produced
- Higher rate of evaporation
- Sediment deposition is less
- Suitable for any type of fuel and method of firing
- More effective heat transfer
- Failure of water tubes will not affect the working of boiler
- Occupies less space
- Easy maintenance
- Easy transportation



Disadvantages

- Not suitable for ordinary water.
- Not suitable for mobile application.
- High initial cost and hence not economical

COMPARISON BETWEEN FIRE TUBE AND WATER TUBE BOILERS

FIRE TUBE BOILERS	WATER TUBE BOILERS
Hot flue gases flow within the tubes and is surrounded by water.	Water flows within the tubes and is surrounded by flue gases.
Internally fired boilers.	Externally fired boilers.
Suitable for small power plants and locomotives.	Suitable for large power plants.
For given power, it occupies more space.	It occupies less space.
Furnace is within the boiler shell.	Furnace is situated outside the boiler shell.
Water circulation is within the drum itself.	Water will be in continuous circulation between the drum and the tubes.
Low evaporating capacity. Hence it takes more time to generate steam.	High evaporating capacity. Hence the generation of steam is quicker.

LIST OF BOILER MOUNTINGS AND ACCESSORIES

For the satisfactory functioning, efficient working, easy maintenance and the safety of the boilers, they are equipped with some type of fittings and appliances.

- **Boiler mountings** are mainly fittings required for the complete controlling of the steam generation, measurement of some of the important steam properties and to provide safety to the boiler.
    - Two water level indicators
    - Pressure gauge
    - Two safety valves
    - Steam stop valve
    - Blow off cock
    - Feed check valve
    - Fusible plug

- **Boiler accessories** are mainly appliances required to improve the efficiency of steam power plant and to enable for the proper working of the boiler.
    - Economizer
    - Air preheater
    - Super heater
    - Feed pump
    - Steam separator
    - Steam trap

Two water level indicators:
It indicate the level of water inside the water drum. This enables the operator to control the flow of water into the drum as and when desired.
Pressure gauge:
It indicated the pressure of the steam developed inside the boiler
Safety valves:
A safety valve is used to maintain a constant safe pressure inside the boiler. When the pressure of steam exceeds the design pressure, the safety valve automatically opens and discharges the excess steam to the atmosphere.
Steam stop valve/junction valve:
The function of this device is to control the flow of steam from the boiler to the steam pipes.
Blow off valve:
To empty the boiler, when the boiler has to be cleaned or inspected.
To remove the sediments collected at the bottom of the boiler during operation
Feed check valve:
The function of feed check valve is to control the supply of water into the boiler and also to prevent any water escaping back from the boiler in the event if failure of feed pump.
Fusible plug:
The function of fusible plug is to extinguish the fire in the furnace when the water level falls much below the normal level.

Boiler accessories, mainly appliances are required to improve the efficiency of steam power plant and to enable for the proper working of the boiler.

Economizer:
An economizer is a device used to heat the feed water by extracting the heat from the gasses that are passing out of the chimney. The economizer is placed in between the boiler exit and the chimney entrance.
Air preheater:
The air preheater is to extract the heat from the gases that are passing out of the chimney. This is utilized for heating the air that is supplied for the combustion of fuel in the furnace.
Superheater:
Superheater is to increase the temperature of steam above its saturated temperature.
Feed pump:
It is to pump the water at high pressure into the boiler drum. The commonly used feed pumps are reciprocating pump and centrifugal pump.

Steam separator:

It is a device, which is used to separate the water particles in suspension present in the steam before it enters the turbine or engines.
Steam trap:
It is a type of automatic valve, used to drain off the condensed water accumulated in the steam pipes and steam separator without allowing the escape of high pressure steam from it.

TURBINES

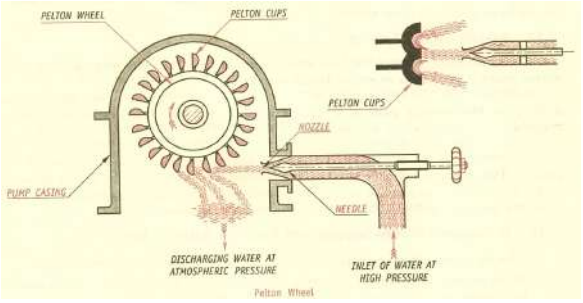
WATER TURBINES:

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.

CLASSIFICATION BASED ON THE ACTION OF WATER ON THE MOVING BLADES

1. IMPULSE TURBINES
2. REACTION TURBINES

IMPULSE TURBINE OR PELTON WHEEL:



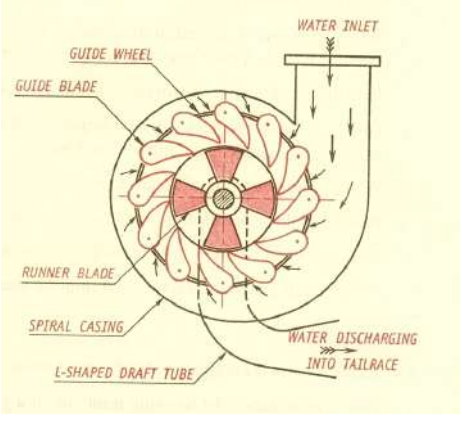
1. It requires high head and low flow rate.
2. Pressure energy of water is converted entirely into kinetic energy in a nozzle.
3. Water coming out of nozzle at the end of penstock is made to strike a series of buckets or hemispherical cups fitted on the periphery of a wheel or runner.
4. The impulsive force of the jet striking the pelton cups sets up the pelton wheel to rotate in the direction of the impinging jet.
5. Majority of impulse turbines are horizontal shaft turbines.
6. Suitable when water flows with high velocity and for high heads.
7. Needle valve is used to control the water flow to the turbine.
8. Quantity of water required is less.

REACTION TURBINES:

FRANCIS TURBINE

1. Most preferred hydraulic turbines since they can operate in wide range of operating conditions.
2. Most important part of a Francis turbine is its runner. Since water enters the runner radially and leaves axially, they are also called mixed flow turbines.
3. Before entering the turbine water has both the pressure energy and kinetic energy.
4. When water flows over the runner blades, both the kinetic and pressure energy of water will be reduced.
5. Guide blades are used to control the flow rate of water to meet the power demand. Guide blades also control the flow angle of water.
6. Runner is connected to the generator via a shaft for electricity production.
7. The runner and guide blades are together fitted in a spiral casing.
8. Water after doing work, is discharged into the tail-race through a draft tube which has increasing diameter to reduce effect of cavitations.

KAPLAN TURBINES



➢ Kaplan turbines are suitable when water is available at low head and high flow rate.
➢ The runner of the turbine looks like a propeller of a ship. Hence it is also known as propeller turbine
➢ Before entering the turbine water has both the pressure energy and kinetic energy.
➢ In Kaplan turbine blades are mounted on the boss (hub) so that the blade angles can be adjusted while the machine is in operation. The rotation of the runner is transferred to a generator via a shaft for

electricity production.

➢ Kaplan turbines are axial flow turbines where the velocity of the flow is along the axis of the runner.

➢ Depending on the fluctuation of the power demand, a governing mechanism opens and closes the guide blades depending on the demand.

➢ Guide vanes are used to control water flow rate. They also help in controlling the swirl of flow or turbulence of water.

➢ Number of blades on the runner is very less (3 to 6).

➢ Water after doing work, is discharged into the tail-race through a draft tube which has increasing diameter to reduce effect of cavitation.

HYDRAULIC PUMPS

Introduction

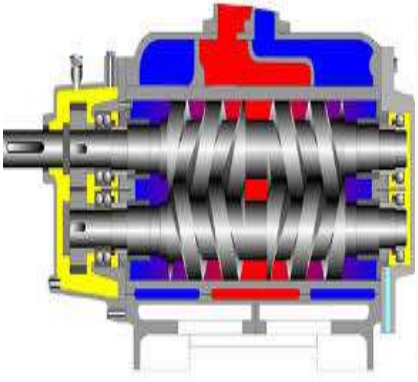
A hydraulic pump is a device that transfer energy to raise liquid from a lower level to a higher level, or circulate in a closed system.

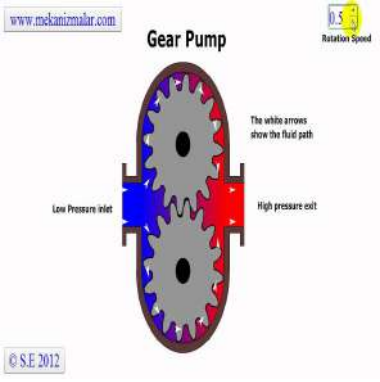
Eg: pumping of water from a sump to on overhead tank

Circulating a coolant or lubricant oil to various moving parts of a machine

Classification of pumps

- **Centrifugal pump:** which makes use of the centrifugal force of a rotary element known as impeller to impart energy to the liquid.
- **Reciprocating pump:** which imparts energy to the liquid by the reciprocating action of a piston or plunger inside the cylinder.
- **Rotary pump:** which consists of rotating members, traps fluid in its closed casing thereby building and raising the pressure of the fluid, and in turn discharges the high pressure fluid. The rotating members may be gears, vanes, screws

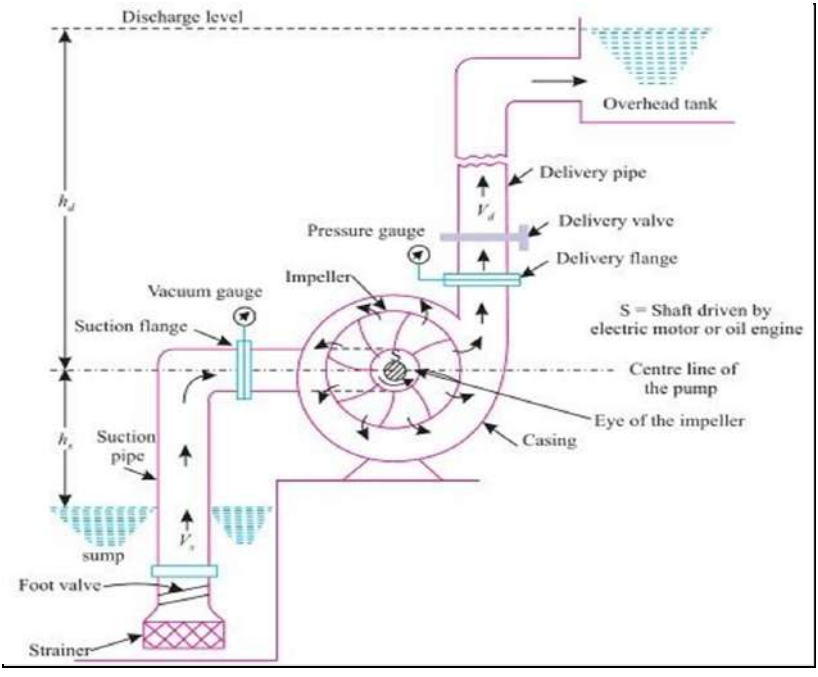




Specification of pumps

- Maximum discharge pressure
- Maximum discharge flow
- Discharge size: outlet connection
- Horse power :used to express the rate at which mechanical energy is expended
- Pumps type & its features: centrifugal, pump, piston, gear, vane
- Power source: AC, DC power, air/pneumatic, hydraulic etc.
- Housing material: aluminium, cast iron, stainless steel etc.

Centrifugal pumps



Construction and Working of a Centrifugal Pump:
What are the parts of a centrifugal pump?

- Impeller
- Casing
- Suction pipe with a foot valve and strainer
- Delivery pipe

The impeller and shaft are the rotating parts of the pump that converts driver energy into kinetic energy.

Another important rotating component is the shaft whose basic purpose is to transmit the torque that is encountered during operation

The volute or diffuser along with casing, casing cover, and bearings form the stationary parts of the centrifugal pump and are responsible for converting the kinetic energy into pressure energy.

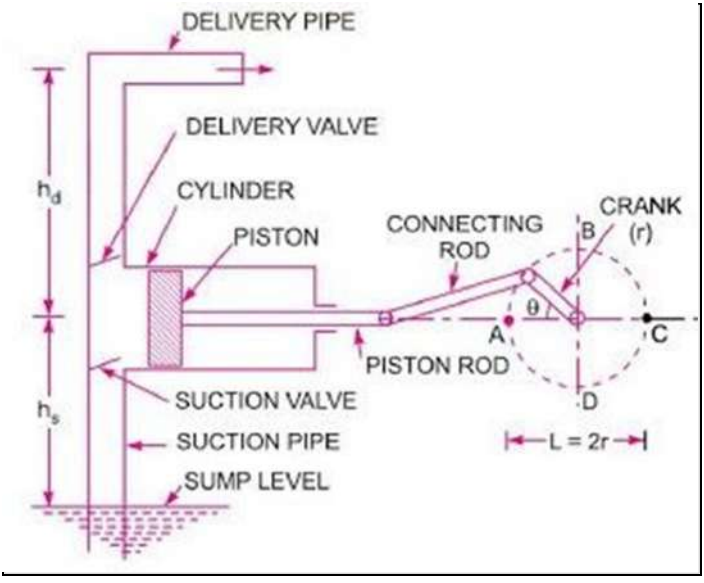
Working Principle of Centrifugal Pump The pump works on the principle of the force vortex flow. it means when a mass of liquid is rotating by an external torque, the rise in pressure head of the rotating liquid takes places. The rises in pressure head at any point is directly proportional to the velocity of the liquid at that point.

Centrifugal pumps operate by transferring energy (angular momentum) from a rotating impeller to the fluid,

which is inside a casing. Fluid enters the rapidly rotating impeller along its axis and is cast out by centrifugal force along its circumference through the impeller's vane tips. The action of the impeller increases the fluid's velocity and pressure and also directs it towards the pump outlet.

- **Advantages :**
- Suitable for all types of fluids
- Simple and compact
- Delivers uniform flow. Output flow is steady and consistent
- Can be mounted horizontally or vertically
- Easy maintenance
- **Disadvantages:**
- Relatively poor suction power
- Develops cavitation resulting in structural failure of impeller blades
- Not suitable for air/gases

Reciprocating pumps:



Components of Reciprocating Pump

The main components of reciprocating pump are as follows:

1. Suction Pipe
2. Suction Valve
3. Delivery Pipe
4. Delivery Valve
5. Cylinder
6. Piston and Piston Rod
7. Crank and Connecting Rod
8. Strainer
9. Air Vessel

Working of Reciprocating Pump

The working of reciprocating pump is as follows:

- When the power source is connected to crank, the crank will start rotating and connecting rod also displaced along with crank.
- The piston connected to the connecting rod will move in linear direction. If crank moves outwards then the piston moves towards its right and create vacuum in the cylinder.
- This vacuum causes suction valve to open and liquid from the source is forcibly sucked by the suction pipe into the cylinder.
- When the crank moves inwards or towards the cylinder, the piston will move towards its left and compresses the liquid in the cylinder.
- Now, the pressure makes the delivery valve to open and liquid will discharge through delivery pipe.
- When piston reaches its extreme left position whole liquid present in the cylinder is delivered through delivery valve.
- Then again the crank rotate outwards and piston moves right to create suction and the whole process is repeated.
- Generally the above process can be observed in a single acting reciprocating pump where there is only one delivery stroke per one revolution of crank. But when it comes to double acting reciprocating pump, there will be two delivery strokes per one revolution of crank.

Uses of Reciprocating Pump

Reciprocating pump is mainly used for

- Oil drilling operations
- Pneumatic pressure systems
- Light oil pumping
- Feeding small boilers condensate return

• **Advantages:**

• High discharge pressure can be obtained

• Provides high suction lift

• Priming is not required

• Can be used to pump air or any other gas

• **Disadvantages:**

• High maintenance due to reciprocating parts

• Low flow rate

• Heavy and bulky in size

• High cos

Cavitation

Cavitation occurs on the suction side of the pump as lowest pressure exists just below the pump on the suction side. Due to height of installation of the above the sump, the pressure on the suction side is below the atmospheric value. Bubble formation occur at the inlet to runner. Thus formed bubbles moves at very high velocity to the more pressure side of the impeller blade, and strikes the surface of the blade and collapse there. This causes erosion and pitting, forming cavities on blades. This damages centrifugal pump. This phenomenon called cavitation.

Effects of cavitation

The metallic surfaces are damaged and cavities are formed on the impeller surface.

2. Noise and vibration are produced due to the sudden collapse of vapour bubble.

3. Efficiency of the machine reduces.

4. Head and discharge decrease.

Priming

Priming is the process of removing the air present in the suction pipe and impeller casing. To remove the air the suction pipe, casing of the pump and of the delivery pipe are completely filled with water before starting the pump.