Sub Name: ELEMENTS OF MECHANICAL ENGINEERING
Subject Code: ME201

UNIT – 1

Content:

Energy resources: Conventional; Fossil fuels, hydropower, nuclear, non-conventional: Solar, wind, geothermal, tidal and ocean thermal energy.

Steam boilers: Formation of steam at constant pressure, conditions of steam, properties of steam with simple problems, Boiler, boiler mountings, accessories and applications.

Steam turbine: Prime movers, Impulse and reaction turbine, Definition of compounding, methods of compounding.

Gas turbine: Classification, working principles and operations, open and closed cycle gas turbines.

Water turbine: Classification, working principle of Pelton, Francis and Kaplan turbines

10 Hours

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ENERGY RESOURCES

Energy is a fundamental concept in physics, with applications throughout the natural sciences.

Can you imagine life without lights, fans, cars, computers and television or, of fetching water from the well and river? This is what life would have been like mad man, if it is not discovered the uses of energy – both renewable and non renewable sources. Energy is the driving force for humans and machines, without energy the whole world will comes to stand still (halt).

The total energy of a system can be subdivided and classified in various ways. For example, it is sometimes convenient to distinguish kinetic energy from potential energy. It may also be convenient to distinguish gravitational energy, electrical energy, thermal energy, and other forms. These classifications overlap; for instance thermal energy usually consists partly of kinetic and partly of potential energy. Energy is the primary and most universal measure of all kinds of work by human beings and nature. Most people use the word energy for input to their bodies or to the machines.

Energy: Energy is defined as the capacity for doing the work. The SI unit of energy is Joule (J).

Energy forms: Although every energy form is physically invisible, is presence is always felt. Energy can exist in various forms such as

1) Mechanical energy 2) Electrical energy
3) Chemical energy 4) Heat energy
5) Nuclear energy 6) Sound energy

Potential energy: The potential energy possessed by a body is due to its position or elevation relative to some datum plane.

Kinetic energy: The kinetic energy possessed by a body is due to the reason of its motion.

A body of mass m kg moving with a velocity V m/sec possesses an amount of kinetic energy = $mv^2/2g_c$ in Nm.

Energy sources: Energy either exists in earth or come from outer space.

Capital energy: The energy existing in the earth is known as capital energy.

Ex: fossil fuels (coal, Petroleum based fuel and natural gases), Nuclear fuels and heat traps.

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Celestial energy or income energy: The energy comes from the outer space is called as celestial energy or income energy.

Ex: electromagnetic, gravitational and partical energy from stars.

❖ **NON RENEWABLE AND RENEWABLE ENERGY SOURCES**:

Non -Renewable energy Sources (conventional sources): The source which are formed in the earth crust over millions of year and which get depleted with their use are known as non-renewable or conventional energy sources.

Ex: fossil fuels (coal, Petroleum based fuel and natural gases), Nuclear fuels.

Renewable energy Sources (Non-Conventional): The sources which will not deplete with their use are known as renewable or non-conventional energy sources.

or

The energy resources which are produced continuously in nature and are essentially inexhaustible at least in the time frame of human societies.

Ex: solar energy, wind energy, tidal energy, hydal energy and ocean thermal energy.

Difference between Renewable and Non-Renewable source of energy

Renewable energy Sources	Non -Renewable energy Sources
1. The energy resources are non-exhaustible with their use.	The energy resources are exhaustible with their use
2. These are pollution free	Causes pollution
3. These are available at free of cost.	These are not directly available at free of cost
4. Initial cost to extract the energy source is more, but the maintenance cost is less	Initial cost is less but the maintenance cost is more.
5. The technology to extract the energy sources is not yet completely developed.	The technology to extract the energy sources is developed.
6. Ex: solar energy, wind energy, tidal energy, hydel energy etc.	Fossil fuels (coal, Petroleum based fuel and natural gases), Nuclear fuels.

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RENEWABLE ENERGY SOURCES

1. LIQUID FLAT PLATE COLLECTOR (SOLAR ENERGY)

Liquid flat plate collector: solar energy can directly converted into heat energy by using flat plate collector. Figure shows a schematic representation of liquid flat plate collector.

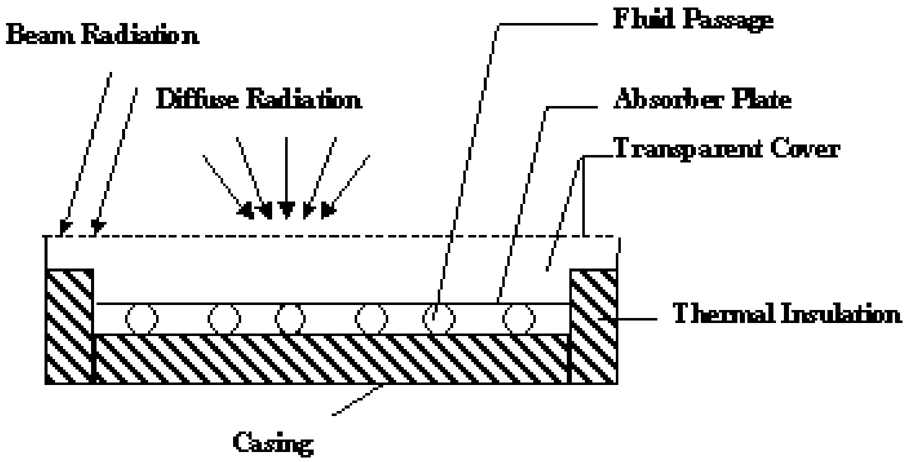

Fig. Liquid Flat Plate Collector

CONSTRUCTION: The majority of the flat plate collector has five main components as follows.

1. **Transparent cover**: A transparent cover which may be one or more sheets of glass or radiation transmitting plastic film.
2. **Absorber plate**: It basically consists of a flat surface with high absorptivity for solar radiation, called the absorbing surface. It is normally made of metallic or black surface. Usually metal plates are made of copper, steel or aluminium material with 1 to 2 mm thickness.
3. **Tubes, fins, fluid passages or channels:** These are integral with the collector absorber plate or connected by soldered, brazed or clamped to the bottom of the absorber plate. And tubes are made with copper having diameter ranges from 1 to 1.5 cm. Pitch ranging from 5 to 15 cm.
4. **Insulation:** Insulation should be provided at the back and sides to minimise the heat losses. Standard insulating materials such as fibre glass, glass wool are used for this purpose. Thermal insulation of 5 to 10 cm thickness is usually placed behind the absorber plate.
5. **Casing or Container:** casing or container which encloses the other components and protects them from the weather.

WORKING: In the liquid flat plate collector as shown in above fig. a blackened sheet of metal is used to absorb all the sunlight, direct and diffuse recitation. A sheet of metal coated in black has the property of absorbing the sunlight falling on it and convert it into heat. The heat generated in the sheet of metal is subsequently transferred to fluids like air and water etc through tubes wall. When the conduction, convection and radiation losses during absorption, generation and transfer are prevented, this method of solar energy conversion will have very high conversion efficiencies.

2. HYDRO POWER PLANT

Hydro power: principle of electric power generation from hydropower plants. Figure shows the schematic arrangement of commonly used hydro-plant.

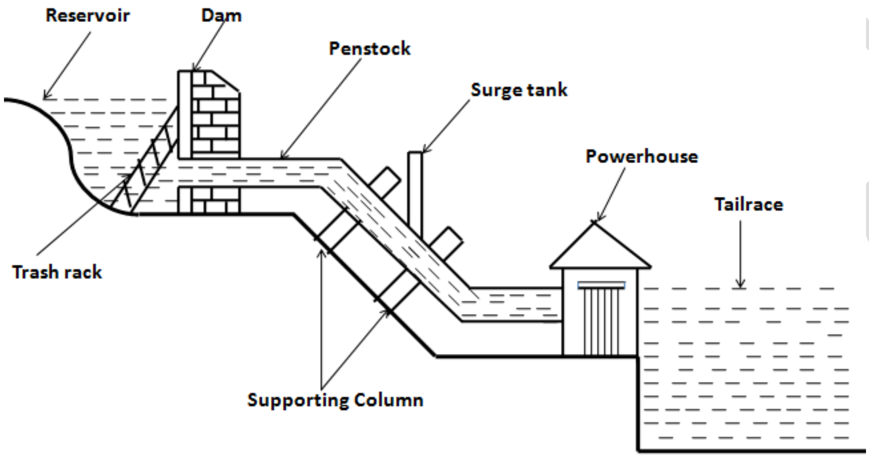

Fig. shows the schematic arrangement of commonly used hydro power-plant

CONSTRUCTION: The function of the different component used in hydro-power plants are

1. **Reservoir**: The purpose of the reservoir to store the water during rainy season and supply the same during summer when the runoff is low.
2. **Dam**: The purpose of the dam is creating the artificial reservoir and many times artificial head also.
3. **Trash rack**: The function of the trash rack is to prevent the flow of debris, sand and fishes to the prime mover. It is always located before the intake of the water from the reservoir.
4. **Penstock**: The penstock is a special pipe carrying the water from surge tank to the turbine. This is made of steel or reinforced concrete.
5. **Surge tank**: This keeps in reducing the pressure surges developed due to sudden backflow of water as load on the turbine is reduced.
6. **Prime mover**: The function of the prime mover is to convert the potential energy of water into mechanical energy. Which consist of turbine generator etc.
7. **Draft tube**: It is connected to the outlet of the reaction turbine which helps to increase the efficiency of the turbine by converting the part of kinetic energy into useful head.

8. **Generator**: The function of the generator is to generate electrical power using mechanical power of turbine.
9. **Step up transformer**: The function of step up transformer is to raise the voltage generated at the generator terminal.

WORKING: The water flow during peak rainy season is stored in the reservoir and it is carried to the prime mover through a penstock. The potential energy of the water is converted into mechanical energy as it passes through the water turbine. The mechanical energy of the water turbine in turn is used to generate electrical power. The electric power is transmitted through transformer to consumers.

❖ **WIND POWER PLANT**

Wind power: Wind energy is the energy contained in the force of the winds blowing across the earth's surface. When harnessed, wind energy can be converted into mechanical energy for performing work such as pumping water, grinding grain by wind mills and producing electrical energy by wind turbines. Figure shows the schematic arrangement of typical windmill.

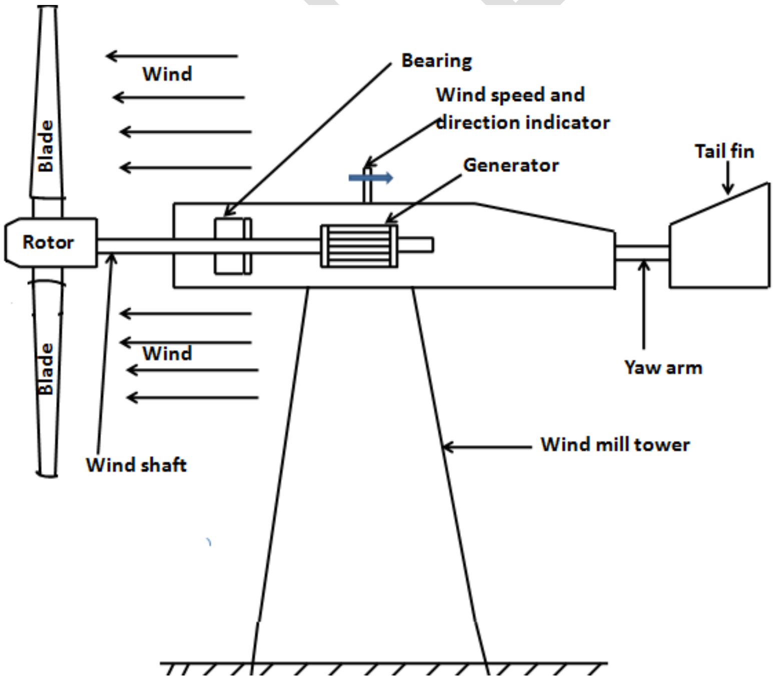

Fig. Wind mill

CONSTRUCTION: The function of the different component used in windmill is

1. **Blades**: Blades are usually made in aerofoil shape with light weight composite material.

2. **Rotor**: The rotor is usually one of the important components for effective utilization. Rotors are mainly of two types horizontal axis rotor and vertical axis rotor. The advantage of vertical axis machines is that they operate in all wind direction and thus need no yaw adjustment.
3. **Wind speed and direction indicator**: the purpose of indicator is to sense the wind speed, wind direction.
4. **Yaw Control**: Most of wind turbines are yaw active, that is to say, as the wind direction changes, a motor rotates the turbine slowly about the vertical axis so as to face the blades into the wind.
5. **Wind Mill Tower:** This supports the rotor, housing the rotor bearing. It also house many control mechanism incorporated like changing the pitch of the blades for safety devices and tail vane to orient the rotor to face the wind.

WORKING: wind energy is defined as the kinetic energy associated with the movement of large masses of air over the earth's surface. The circulation of air in the atmosphere is caused by the non-uniform heating of the earth's surface by the sun. The air immediately above a warm area expands and become less dense. It is then forced upwards by a cool denser air which flows in from the surrounding areas causing a wind. Then kinetic energy of wind can be converted into mechanical energy by rotating wind turbine blades.

❖ GEOTHERMAL POWER PLANT

Geothermal power plants can be divided into two main groups, steam cycles and binary cycles. Typically the steam cycles are used at higher well enthalpies, and binary cycles for lower enthalpies. The steam cycles allow the fluid to boil, and then the steam is separated from the brine and expanded in a turbine. Usually the brine is rejected to the environment (re-injected), or it is flashed again at a lower pressure. Here the Single Flash (SF) and Double Flash (DF) cycles will be presented.

A binary cycle uses a secondary working fluid in a closed power generation cycle. A heat exchanger is used to transfer heat from the geothermal fluid to the working fluid, and the cooled brine is then rejected to the environment or re-injected. The Organic Rankine Cycle (ORC) and Kalina cycle will be presented.

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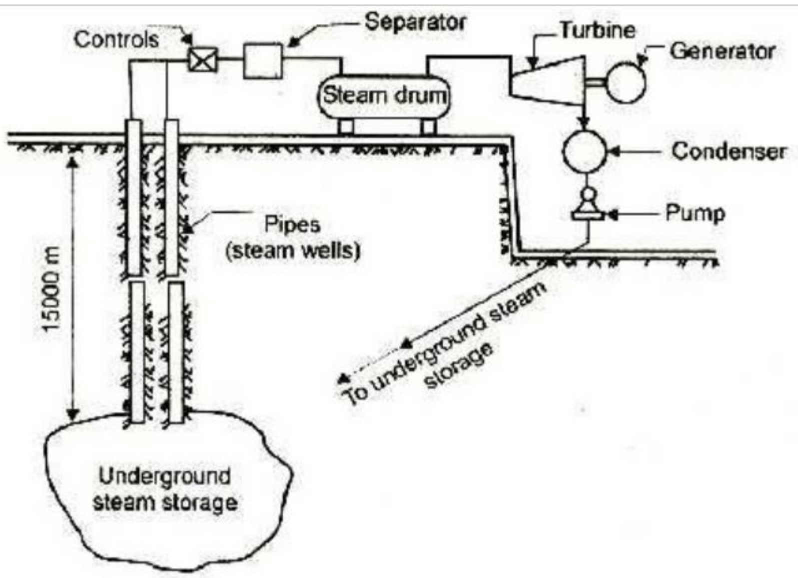

Figure: Geo-thermal power plant

Steam well

Pipes are embedded at places of fresh volcanic action called steam wells, where the molten internal mass of earth vents to the atmospheric with very high temperatures. By sending water through embedded pipes, steam is raised from the underground steam storage wells to the ground level.

Separator

The steam is then passed through the separator where most of the dirt and sand carried by the steam are removed.

Turbine

The steam from the separator is passed through steam drum and is used to run the turbine which in turn drives the generator. The exhaust steam from the turbine is condensed. The condensate is pumped into the earth to absorb the ground heat again and to get converted into steam.

Location of the plant, installation of equipment like control unit etc., within the source of heat and the cost of drilling deep wells as deep as 15,000 metres are some of the difficulties commonly encountered.

- **TIDAL ENERGY**

Tidal energy comes into existence due to rise and fall of tides when ocean surges. It is also a form of renewable energy and currently used to generate electricity.

Tidal energy or tidal power can be defined as the energy that is the result of the moon and the sun’s gravitaional influence on the ocean. Height differences between high and low tides create tidal currents in coastal areas, and these currents can be strong enough to drive turbines.

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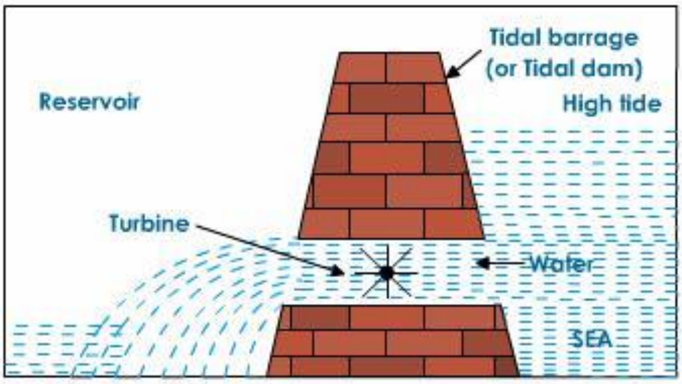
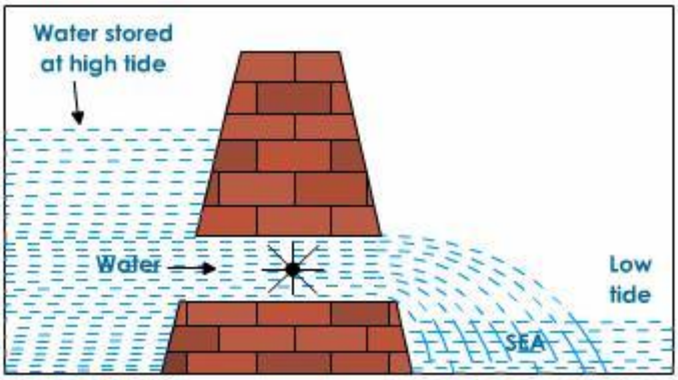
Working:

During high tide, when the level of water in the sea is high, sea-water flows into the reservoir of the barrage and turns the turbines. The turbines then turn the generator shaft to produce electricity.



At high tide, water flows from sea into reservoir and turns the turbine

During low tide, the sea-water stored in the barrage reservoir is allowed to flow out into the sea. This flowing water also turns the turbines and generates electricity. Thus, as the sea-water flows in and out of the tidal barrage during high and low tides, the turbines rotate continuously to generate electricity.



At low tide, stored water flows out from reservoir into sea and turns the turbine

❖ NUCLEAR POWER PLANT

Nuclear energy: Nuclear energy is the chemical energy released during the **fission (splitting) or fusion (combining)** of atomic nuclei.

1. **Fusion process**: In nuclear fusion process, small-atomic number nuclei are joined together to form larger nuclei. In the process an extremely small fraction of mass is converted into energy.
2. **Fission process**: In a fission process a nucleus explodes into two roughly equal size nuclei with generation of energy.

Principles of nuclear power plants: The figure shows the schematic diagram of nuclear power plant.

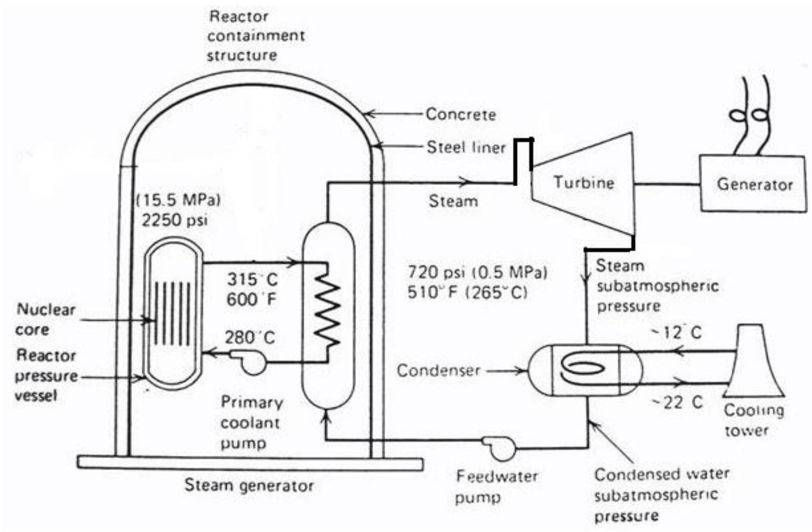


Fig. Nuclear Power Plants

CONSTRUCTION: The function of the different component used in nuclear power plants is

1. **Nuclear Reactor**: Is a device where nuclear chain reactions are initiated, controlled and also sustained at a steady rate
2. **Fuels**: The fuels which are commonly used are natural uranium containing 0.7% U^{235}.
3. **Coolant**: The purpose of the coolant is to transfer the heat generated in the reactor core and use it for steam generation.
4. **Control rods**: The purpose of the control rod is maintain the value of multifilication factor as one, that is to allow only neutron evolved in each fission to take part in further fission reaction.
5. **Moderator**: The function of the moderator is to reduce the energy of neutrons evolved during fission.

WORKING: high pressure cold water is pumped into the reactor core. It absorbs the heat energy generated due to nuclear fission. A pressuriser is used to increase the boiling point of water, which enables the water to absorb large amount of heat. High pressure, high temperature water from pressurizer enters into steam generator. Here hot water gives the heat to feed water, which turn gets converted into steam. The generated high pressure and high temperature steam is expanded by passing through steam turbine. Rotational energy of the turbine is converted into electrical energy by coupling a generator to the shaft of steam turbine.

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STEAM BOILERS

Steam is the gaseous phase of water. It utilizes heat during the process and carries large quantities of heat later. Hence, it could be used as a working substance for heat engines. Steam is generated in boilers at constant pressure. Generally, steam may be obtained starting from ice or straight away from the water by adding heat to it.

Formation of steam at constant pressure:

Consider a cylinder fitted with frictionless piston which, may be loaded to any desired pressure p bar as shown in fig. 3-1 (a). Now, assume for convenience that there is one kilogram of water initially at temperature O'C in the cylinder under the piston and the piston exerts a constant pressure p bar. Let the area of the piston be one square metre and the volume of one kilogram of water be vw m3, the length of the cylinder occupied by water will be vw m. Now, let heat be supplied to the water in the cylinder. The temperature of water will rise when sensible enthalpy be supplied. The rise in temperature will continue until the boiling point is reached, where it will remain constant. The temperature at which water boils depends upon the pressure on it. For any given pressure, there is one definite boiling point. The boiling point is called the saturation temperature (ts) or the temperature of steam formation. Water boils at 99-63‘C when the pressure on it is 1 bar, and at 18409'C when the pressure on it is 11 bar (these values are taken from steam tables).

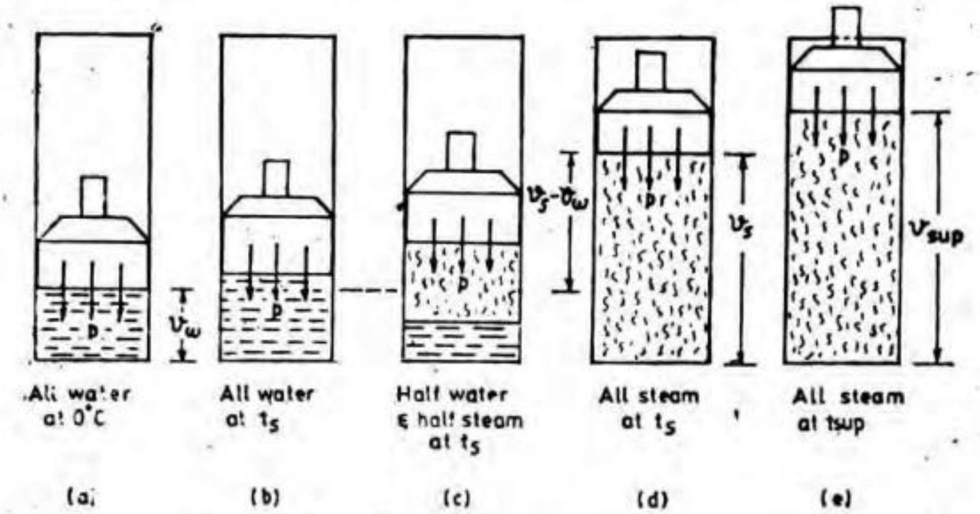
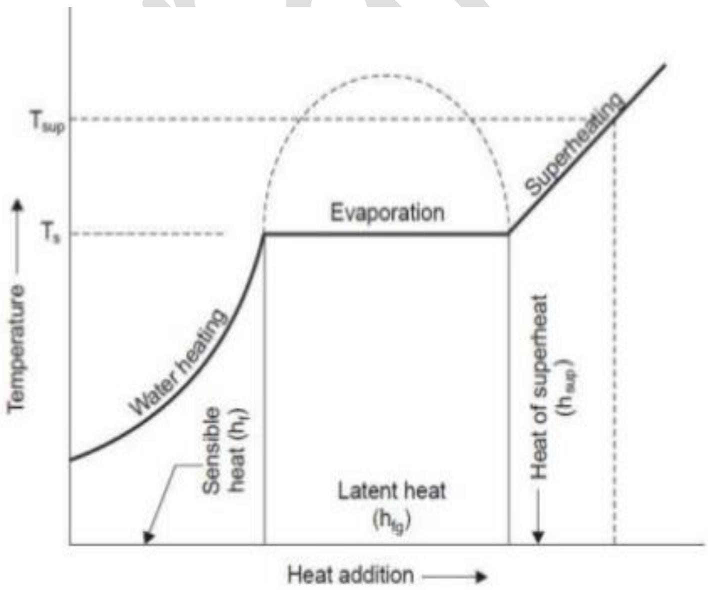


Fig. 3-1. Formation of steam at constant pressure.

The water will expand slightly during the rise of temperature. The increase in volume of water causes the piston to move up slightly as shown in the fig. 3-1 (b), thus, work is done in moving the piston against this pressure p. This work, however, is only a small portion of the heat added to water during the rise in temperature and may be neglected in general. Figure 3-1 (a) represents the condition before the first stage commences and fig. 3-1 (b) represents the condition at the end of the first stage. It will be noted that the piston is at slightly higher level at the end of operation. The next stage, as shown in fig. 3-1 (c), is the actual production of steam. If the heating of this one kilogram of water is continued after the boiling point is reached, it will be noticed that there is no further increase in temperature, as the pressure is maintained constant but steam begins to form and piston commences to ascend (rise) in the cylinder, rising higher and higher as more and more steam is formed. The heat absorbed is now utilised in converting water into steam and is known as evaporation enthalpy or latent heat. As long as there is some water left unevaporated in the cylinder, the steam formed will not be pure (dry) steam, but will have some water mixed with it. In fig. 3-1 (c), part of water is evaporated and the cylinder has in it, rAixture of water and steam (about half steam and half water). A mixture of steam and water is called wet steam. If the heating of this wet steam is further continued and as soon as last particle of water in suspension in wet steam disappears (evaporates), the steam produced is known as dry saturated steam. Figure 3-1 (d) shows that the process of formation of steam is completed.



Graphical representation of formation of steam

Conditions of steam: Steam exists in following states or types or conditions.

(i) **Wet steam**: When steam contains water particles then it is known as Wet steam

(ii) **Dry steam (dry saturated steam):** When wet steam is further heated then all water particles get converted into vapour and resulted steam is called dry steam.

(iii) **Superheated steam:** When dry saturated steam is heated to higher temperatures then steam obtained is in superheated state. This steam is mostly used in Power generation.

Dryness Fraction of Saturated Steam (x or q) It is a measure of quality of wet steam. It is the ratio of the mass of dry steam (mg) to the mass of total wet steam (mg +mf), where mf is the mass of water vapor.

Properties of steam: Properties of steam are listed below

1. Pressure,
2. Temperature,
3. Specific Volume,
4. Enthalpy, and
5. Entropy.

Simple problems: Problems are discussed in the class

STEAM BOILER: Boiler is a device which is used to produce steam at high pressure by supplying heat. Steam is being used in thermal power plant, textile industries and for domestic uses during winter to heat the room.

Classification of boilers or Types of boiler

1. **Horizontal, Vertical and Inclined boilers**

   If the axis of the boiler is horizontal, vertical or inclined then it is called horizontal, vertical or inclined boiler respectively

2. **Fire tube and water tube boiler**

   If hot gases are inside the tube and water is outside the tube, it is called fire-tube boiler.

   Examples: Cochran, Lancashire and locomotive boilers.

   If water is inside the tube and hot gases are outside the tube, it is called fire-tube boiler.

   Examples: Babcock and Wilcox, Sterling, Yarrow boiler etc.

3. **Externally fired and internally fired boiler**

   The boiler is known as externally fired if the fire is outside the shell.

Gururaj Lalagi

Examples: Babcock and Wilcox, Sterling

The boiler is known as internally fired if the furnace is located inside the boiler shell.

Examples: Cochran, Lancashire

4. **Forced circulation and natural circulation boiler**

   In forced circulation type of boilers, the circulation of water is done by a forced pump

   Examples: Velox, Lamont, Benson boiler

   In natural circulation type of boilers, circulation of water in the boiler takes place due to natural convection currents produced by the application of heat.

   Examples: Lancashire, Babcock and Wilcox

5. **High pressure and low pressure boiler**

   The boilers which produce steam at pressures of 80 bar and above are called high pressure boilers.

   Examples: Babcock and Wilcox, Velox, Lamont, Benson boilers.

   The boilers which produce steam at pressure below 80 bar are called low pressure boilers.

   Examples: Cochran, Cornish, Lancashire and locomotive boilers.

6. **Stationary and portable (moving) boiler**

   Stationary boilers are used for power plant-steam, for central station utility power plants, for plant process steam etc. Mobile or portable boilers include locomotive type, and other small unit for temporary use at sites.

7. **Single tube and multi tube boiler**

   The fire tube boilers are classified as single tube or multi-tube boilers, depending upon whether the fire tube is one or more than one.

   Examples of single tube boilers are Cornish and simple vertical boiler

BOILER MOUNTINGS: The device, which are used for safety operation of boiler are called mountings.

Important boiler mountings are as follows,

1. **Pressure gauge:** Fitted in front of the boiler to record the steam pressure at which steam is generated in the boiler. Two types of pressure gauges are being used in boiler operations. Diaphragm type Bourdon Tube
2. **Safety valves:** Safety valves are needed to blow off the steam when the pressure of the steam in the boiler exceeds the working pressure. It is placed on the top of the boiler.

Gururaj Lalagi

3. **Fusible plug:** To extinguish fire in the event of water level in the boiler shell falling below a certain specified limit. It is installed below boiler's water level on the crown plate
4. **Steam stop valve:** A valve is a device that regulates the flow of a fluid (gases ,fluidized solids slurries or liquids) by opening or closing or partially obstructing various passageways
5. **Feed check valve:** To allow the feed water to pass in to the boiler and to prevent the back flow of water from the boiler in the event of the failure of the feed pump
6. **Blow off cock:** To drain out water from the boiler for internal cleaning inspection or other purposes
7. **Mud and man holes:** To drain out mud, dirt other impurities from the boiler for internal cleaning inspection or other purposes
8. **Water level Indicator:** The function of water level indicator is to show level of water present in the boiler.

BOILER ACCESSORIES: Accessories are the devices being used to increase the efficiency of the boiler. A large amount of heat is being carried out by the flue gases, this is wastage of useful energy, which can be recovered.

Commonly used accessories are as follows,

1. **Steam Super heater:** The function of a super heater is to increase the temperature of steam above its saturation point

2. **Economizer:** In best way it is known as feed water heater, that refers heating of feed water, which is supplied to the boiler shell to get vaporized. It utilizes heat carried out but the waste furnace gases to heat the water before it enters boiler.
3. **Air preheater:** The function of an air preheater is to heat the inlet air before it is sent to the furnace. It is placed after economizer, flue gases coming from economizer is being utilized to heat air.
4. **Steam separator:** The basic work of steam separator is to ensure the quality of steam and removes water particles from steam.
5. **Feed Pump:** Feed pump is the device required to supply water to the boiler.

6. **Injector:** The basic work of an injector is to feed water to the boiler on high pressure; it finds its application in such places where there is no space to install feed pumps.

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WATER TUBE BOILER (BABCOK & WILCOX BOILER)

This is a type of water tube boiler used when pressure exceeds 10 bar and capacity 7000 kg per hour. Construction It consists of a horizontal high pressure drum, from each end of it connections are made with an uptake and a down take header. Headers are joined to each other by large number of water tubes inclined at an angle of 15 degree to provide water circulation. Hand holes are provided for the maintenance of tubes. The entire assembly of water tubes is hung in a room made of masonry work, lined with fire bricks to resist thermal expansion. As super heater additional U-shaped tubes are arranged between drums and water tubes. Furnace is arranged below the uptake header. Baffles are provided across the water tubes to guide flue gases. A Chimney is provided for exit of gases and a damper at the opening of chimney to provide draught. Cleaning doors are provided to access the tubes for cleaning and removal of soot and various mountings for successful operation.

Advantage of Babcock and Wilcox boiler

1. Suitable for all types of fuels and hand stokers for firing.
2. Draught loss is small.
3. All components are accessible for inspection during operation.
4. Expansion and contraction has no harm on masonry work(construction).
5. Replacement of defective tubes is easy.

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STEAM TURBINE

Prime mover: **"**A device which converts the available form of energy into the required form (useful form) is known as a **prime mover"**.

Turbine is a prime mover of rotating type having curved blades on it's periphery, it converts the kinetic energy into rotational motion (mechanical energy). When the turbine is coupled (connected) to a generator, the mechanical energy converted into electrical energy (useful energy).

The process of conversion is represented by a block diagram as shown

Kinetic/Pressure energy → **Rotational motion (Mechanical Energy)** → **Electrical energy**

- ➢ If the rotational motion is due to kinetic energy of steam, then the turbine is known as steam turbine
- ➢ If the rotational motion is due to pressure energy of hot gases, then the turbine is known a gas turbine
- ➢ If the rotational motion is due to kinetic energy of water, then the turbine is known as water turbine

Main parts of a steam turbine:-

Nozzle: In steam turbines, normally, convergent-divergent type of nozzles is used. When steam flows through the nozzles, there is a pressure drop, which is converted into velocity or kinetic energy. The nozzles also guide the steam in the proper direction to strike the blades. The nozzles are kept very close to the blades to minimize the losses.

Rotor: The rotor or runner consists of a circular disc fixed to a horizontal shaft.

Blade: On the periphery of the rotor, a large no of blades are fixed. The steam jet from the nozzles impinges on the surface of the blades due to which the rotor rotates.

Casing: It is a steam tight steel casing which encloses the rotor, blades etc. In a multistage turbine , the casing also accommodates the fixed blades

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CLASSIFICATION OF STEAM TURBINE

Steam turbines can be classified into two types.

i) **Impulse turbine** ex: Delaval's turbine

ii) **Reaction turbine** ex: Parson's turbine

PRINCIPLE OF OPERATION

Impulse turbine-These turbines works on the principal of impulse, in impulse turbine steam expands in the nozzle and its pressure does not change as it moves over the blade. The high velocity steam from the nozzle is directed over the blades of the turbine. The turbine is there by rotated and thus kinetic energy of the steam is converted into mechanical work. The velocity of the steam decreases and its pressure remains constant while passing through the blades.

Examples: Delaval turbine, Curtis, Reteau etc.

Reaction Turbine- In reaction turbine, gradual pressure drop takes place continuously over the fixed and moving blades thus, the rotation of shaft carrying the moving blades is the result of both impulse and reactive forces in the steam.

Examples: Parson's turbine.

Delaval turbine - Impulse turbine

The pressure energy is converted into velocity energy or kinetic energy by the expansion of steam through a set of nozzles. Normally, in steam turbines, convergent-divergent nozzles are used. The kinetic energy is converted into mechanical energy with the help of moving blades, fixed on the rotor. The rotor is connected to the output shaft. All these parts are enclosed in a casing.

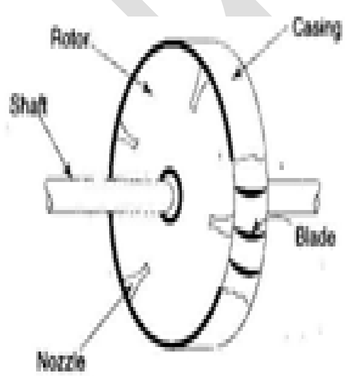

Fig.1 single stage Impulse turbine

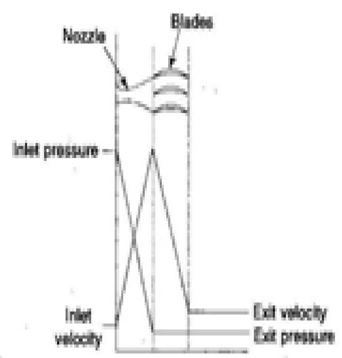

Fig.2 Pressure velocity diagram for

Impulse Turbine

Parson's turbine-Reaction turbine

The reaction turbine, as the name implies, is turned by reactive force rather than by a direct push or impulse. In reaction turbines, the blades that project radially from the periphery of the rotor are formed and mounted so that the spaces between the blades will have the nozzle shape. Since these blades are mounted on the revolving rotor, they are called moving blades. Fixed or stationary blades of the same shape as the moving blades are fastened to the casing in which the rotor revolves. The fixed blades guide the steam into the moving blade. A reaction turbine is moved by three main forces: (1) the reactive force produced on the moving blades as the steam increases in velocity as it expands through the fixed blades. (2) The reactive force produced on the moving blades when the steam changes its direction. **Fig**

Difference between impulse turbine and reaction turbine

Impulse turbine	**Reaction turbine**
Complete expansion of steam takes place in the nozzle	Partial expansion of steam takes place in the fixed blades and further expansion takes place in the moving blades.
Blades are symmetrical in shape	Blades are non symmetrical in shape i.e., aerofoil section
The rotor runs at higher speeds	The rotor runs at relatively low speed.
The impulse turbines are used for small power generation plant.	The reaction turbines are used in large power generation plant.
Less floor area is required.(small power plant)	More floor area is required.(Medium and large power plant)
The pressure of steam remains constant from inlet to the outlet of the blade.	The pressure of steam drops from inlet to the outlet of the blade

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Definition of compounding

Methods of compounding.

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GAS TURBINE

A gas turbine is a prime mover. Here a jet of burnt gases and air is made to flow over several wing of moving blades which are fixed to the rotor. The shapes of blades are almost similar to steam turbines. Kerosene, coal, bunker oil, coal gas, gasoline are used as fuel for gas turbines.

The first gas turbine was designed and manufactured in England by Stolze in 1872. In United States, Charles G. Curtis was the first to patent and develop a gas turbine in 1914. World war –1 and world war –2 have given a great boost for the development of the gas turbine. Frank whittle was a first scientist patented the design of the gas turbine aircraft engine. Gas turbine is used in wide range of applications like, aircraft, industrial, ship and power generation plants.

Main parts of a Gas turbine

1) **Compressor:-** The air compressor sucks the air from the atmosphere and compresses it, thereby increasing its pressure.
2) **Combustion chamber:-** In the combustion chamber, the compressed air combines with fuel and the resulting mixture is burnt.
3) **Turbine:-** The burning gases at very high pressure expand rapidly and made to pass over the rings of moving blades mounted on the turbine shaft.

PRINCIPLE OF OPERATION

A gas turbine essentially consist of three component are **compressor, combustion chamber** and **turbine.** First the atmospheric air is drawn and is compressed to a high pressure, the fuel is injected to the compressed air, the fuel burns and The burning gases at very high pressure expand rapidly and made to pass over the rings of moving blades mounted on the turbine shaft where it kinetic energy is absorbed by the moving blades imparting rotary motion to the turbine shaft.

CLASSIFICATION OF GAS TURBINES

1) Open Cycle Gas Turbine
2) Closed Cycle Gas Turbine

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1. Open Cycle Gas Turbine

The components of open cycle gas turbine are compressor (low or high pressure), combustion chamber and turbine.

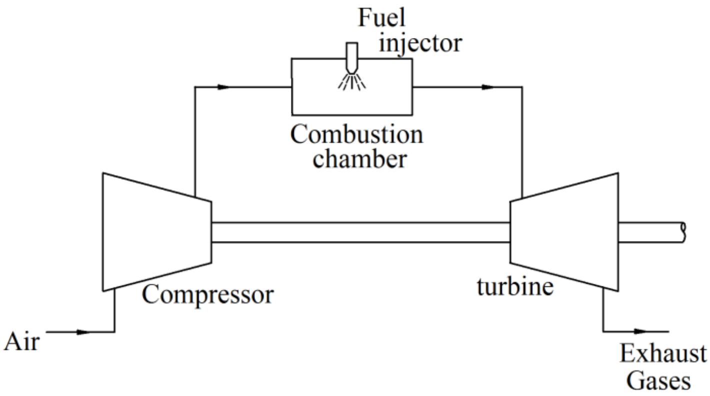

Fig. shows an open cycle gas turbine.

Working: A compressor which draws air at atmospheric pressure and compresses the air and delivered to a combustion chamber at high pressure. The fuel (liquid or gas) is injected into a stream of high-pressure air and the combustion takes place in a combustion chamber. The combustible gases releases tremendous amount of energy, which is used to rotate a turbine. The exhaust gases from the turbine are led to the atmosphere. **The exit gas from the turbine is not recycled back to the compressor hence it is known as open cycle gas turbine**, In open cycle gas turbine every cycle fresh air enters the compressor.

2. Closed Cycle Gas Turbine

The components of closed cycle gas turbine are compressor (low or high pressure), heating chamber, turbine and cooler. The closed cycle gas turbine is as shown in figure

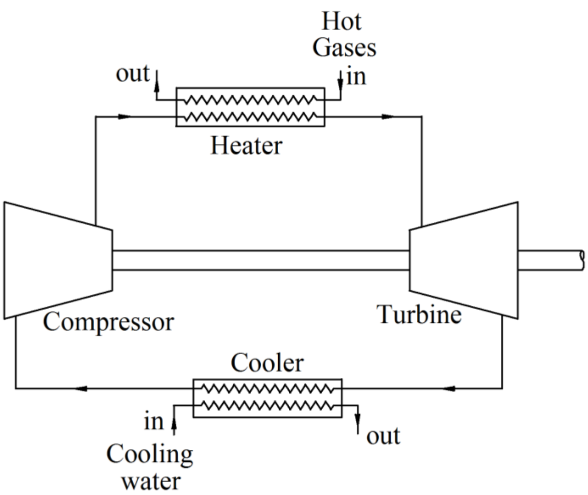

Fig. closed cycle gas turbine

The closed cycle gas turbine is as shown in figure. The rotary compressor compresses the air to very high pressure and delivers it to the heat exchanger, where heat transfer takes place at constant pressure. The high pressure and temperature gases are then expanded through the turbine doing mechanical work. **The exit gases from the turbine is cooled to ambient temperature in heat exchanger (cooler), this cooled gases fed back to the rotary compressor for the next cycle**. **Thus the same working fluid is circulated through the cycle**. The working fluid selected for closed cycle is helium.

Difference between Open cycle gas turbine and Closed cycle Gas turbine

Open cycle gas turbine	**Closed cycle Gas Turbine**
Fresh working fluid enters in every cycle	Same working fluid is continuously circulated in every cycle of operation.
The working substances comprises of the mixture of air and products of combustion of the fuel	Any fluid may be used as the working fluid
No cooling water is required as the exhaust gases are not cooled.	Large amounts of cooling water are required in the cooler.
There is mass transfer taking place in addition to heat and work transfer between the system and surrounding.	There is only heat and work transfer takes place between the system surrounding
Exhaust gases from the turbine exit to the atmosphere.	Exhaust gases from the turbine are fed back into the cycle.

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WATER TURBINE:

Water turbines were developed in the nineteenth century and were widely used for industrial power prior to electrical grids. Now they are mostly used for electric power generation. They harness a clean and renewable energy source.

The water at certain height possesses potential energy. This potential energy may be utilised to do some useful work when it flows from a higher to a lower level. **A device which can convert the potential and kinetic energy of water into mechanical energy is defined as water turbine**. This mechanical energy produced by turbine is converted into electrical energy by means of generator, which is mounted on the same shaft.

CLASSIFICATION OF WATER TURBINE

Water turbine are classified as follows

a) Based on action of flow of water

1. Impulse turbine ex: Pelton wheel, Bankine turbine
2. Reaction turbine ex: Francis turbine, Kaplan turbine

b) Based on head available at inlet of the turbine

1. Low head turbine ex: Kaplan turbine
2. Medium head turbine ex: Francis turbine
3. High head turbine ex: Pelton wheel

c) Based on direction of flow of water with respect to the manner

1. Tangential flow turbine ex: Pelton wheel
2. Radial flow turbine ex: Francis turbine
3. Axial flow turbine ex: Kaplan turbine
4. Mixed flow turbine ex: Modern Francis turbine

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PRINCIPLE OF OPERATION

Hydraulic or water turbines are the machine **which can convert the potential and kinetic energy of water into mechanical rotary motion or power**. In other words, this mechanical energy produced by turbine is converted into electrical energy by means of generator, which is mounted on the same shaft.

Principle and operation

Pelton Wheel-Impulse Turbine

Principle:- In impulse turbine a high-velocity jet of water hits a series of specially shaped cups on the runner. Impulse turbines change the velocity of a water jet. The jet impinges on the turbine's curved blades which reverse the flow. The resulting change in momentum (impulse) causes a force on the turbine blades. Since the turbine is spinning, the force acts through a distance (work) and the diverted water flow is left with diminished energy. Prior to hitting the turbine blades, the water's pressure (potential energy) is converted to kinetic energy by a nozzle and focused on the turbine. No pressure change occurs at the turbine blades, and the turbine doesn't require a housing for operation Pelton wheel, a type of impulse turbine, named after L. A. Pelton who invented it in 1880.

Operations: Water passes through nozzles and strikes cups arranged on the periphery of a runner, or wheel, which causes the runner to rotate, producing mechanical energy. The runner is fixed on a shaft, and the rotational motion of the turbine is transmitted by the shaft to a generator. Pelton turbines are suited to high head, low flow applications; they are used in storage power stations (dams) with downward gradients above 300 meters.

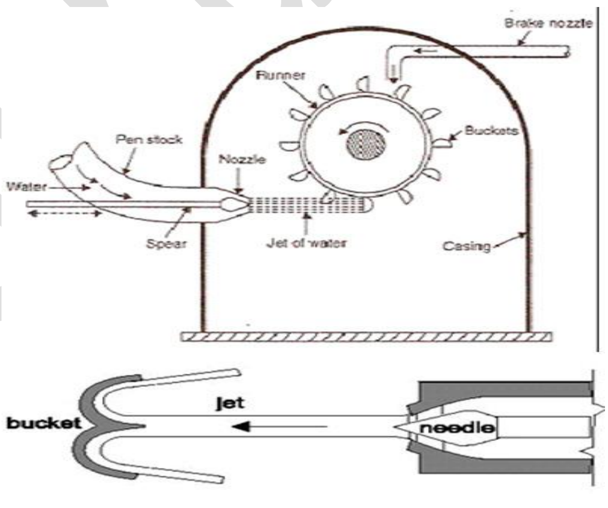
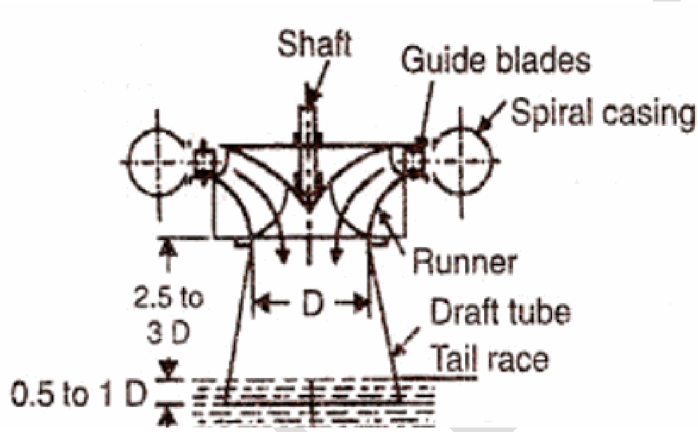


Fig. shows pelton wheel arrangement

Francis turbine-Reaction turbines:

Principle:-Reaction turbines are acted on by water, which changes pressure as it moves through the turbine and gives up its energy. They must be encased to contain the water pressure (or suction), or they must be fully submerged in the water flow. Newton's third law describes the transfer of energy for reaction turbines. Most water turbines in use are reaction turbines. They are used in low and medium head applications.



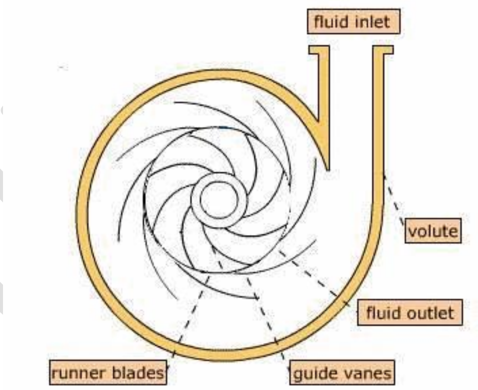


Fig. shows Francis turbine arrangement

Working: It is a reaction turbine working under medium head handling medium quantity of water. Francis turbines can either be volute-cased or open-flume machines. The spiral casing is tapered to distribute water uniformly around the entire perimeter of the runner and the guide vanes feed the water into the runner at the correct angle. Thus, water possessing pressure and kinetic energy enters the runner vanes in the radial direction and leaves in the axial direction. The runner blades are profiled in a complex manner and direct the water so that it exits axially from center of the runner. In doing so the water imparts most of its pressure energy to the runner before leaving the turbine via a draft tube.

Kaplan turbine-Reaction turbines:

The Kaplan turbine is an inward flow reaction turbine, which means that the working fluid changes pressure as it moves through the turbine and gives up its energy. The design combines radial and axial features. The inlet is a scroll-shaped tube that wraps around the turbine's wicket gate (guide vanes). Water is directed tangentially, through the guide vanes, and spirals on to a propeller shaped runner, causing it to spin. The outlet is a specially shaped draft tube that helps decelerate the water and recover kinetic energy. The turbine does not need to be at the lowest point of water flow, as long as the draft tube remains full of water. Variable geometry of the guide vanes and turbine blades allow efficient operation for a range of flow conditions. Kaplan turbine efficiencies are typically over 90%, but may be lower in very low head applications

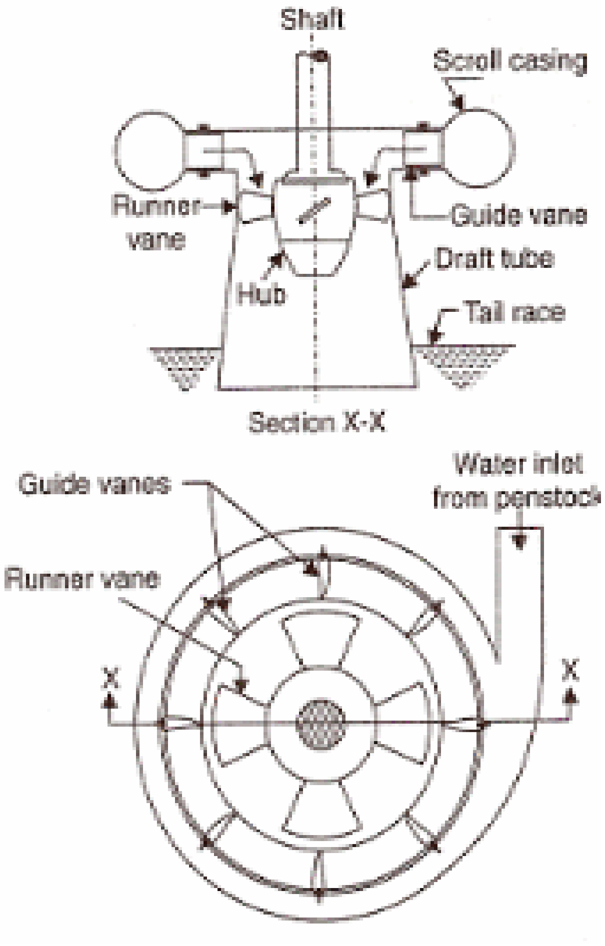


Fig. Shows Kaplan turbine arrangements