DEPARTMENT OF MECHANICAL ENGINNERING

POWER STATION ENGINEERING

OF

6^{th} SEM

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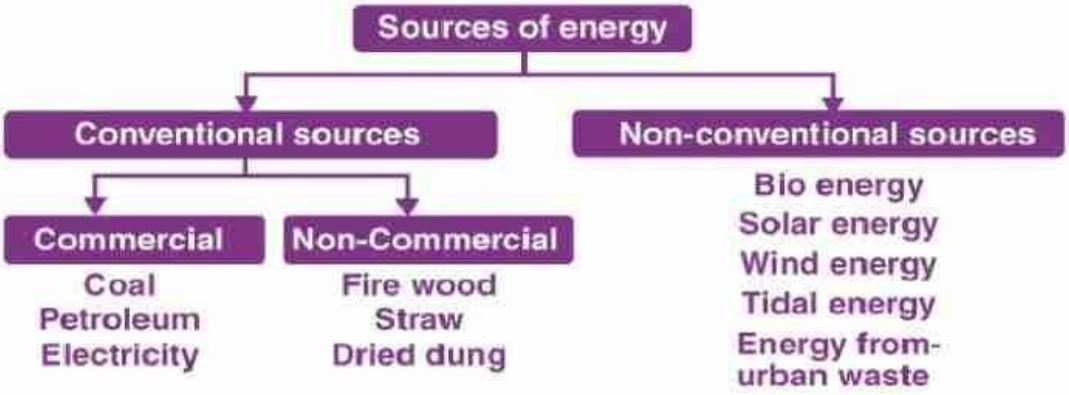
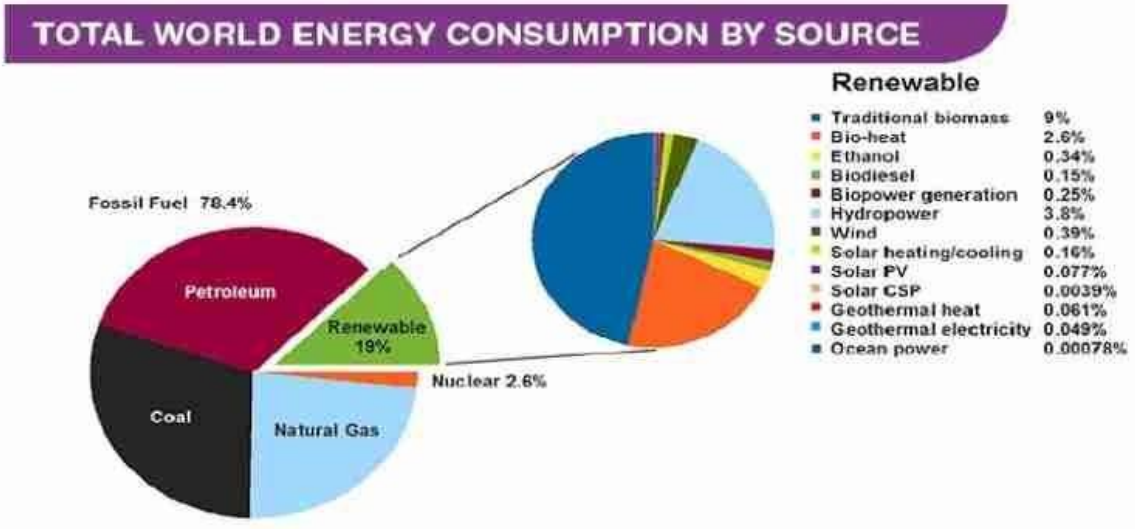
INTRODUCTION:-

Sources of Energy:-

The three major categories of energy for electricity generation are fossil fuels (coal, natural gas, and petroleum), nuclear energy, and renewable energy sources. Most electricity is generated with steam turbines using fossil fuels, nuclear, biomass, geothermal, and solar thermal energy.



Conventional Source	Non-Conventional Source
Conventional sources of energy refer to traditional sources of power like charcoal, firewood, coal, petroleum, etc.	Non- conventional sources of energy are recently developed sources of energy from Sun, wind, water, tides, geothermal, etc.
These sources of energy are non renewable.	These sources are renewable.
Generation of energy is expensive.	Initial cost of generation is high but cheaper in the long run.
They cause large scale pollution.	They are Eco friendly sources of energy.



Captive Power Generating plant or Captive Power Station:-

It means a power plant set up by any person to generate electricity primarily for his own use and includes a power plant set up by any co-operative society or association of persons for generating electricity primarily for use of members of such co-operative society or association.

A group of industries can set up a big generating station for their groups use and sell excess power. They are mostly meant by in-house power generation for industry and not selling the power to grid of electricity boards

Advantages of Captive power plant:-

- It is close to the load centre and hence reduction in the fixed cost of electricity generated due to lesser stranded assets.
- Reduced transmission and distribution losses.
- Grid is strengthened at multiple points, even at the tail- ends.
- Higher thermal efficiency, due to waste heat recovery by method of cogeneration.
- Distribution of environmental impact.
- Shorter gestation period to set up power plants .
- Captive power plants have modular designs and hence can match the load profile.

Central Power Station:-

Centralized power plant is one that generates large amount of energy and distributes it to many users via the power grid. Terms such as transmission, distribution etc. are all related to a centralized power plant. This is also the conventional method of generating power.

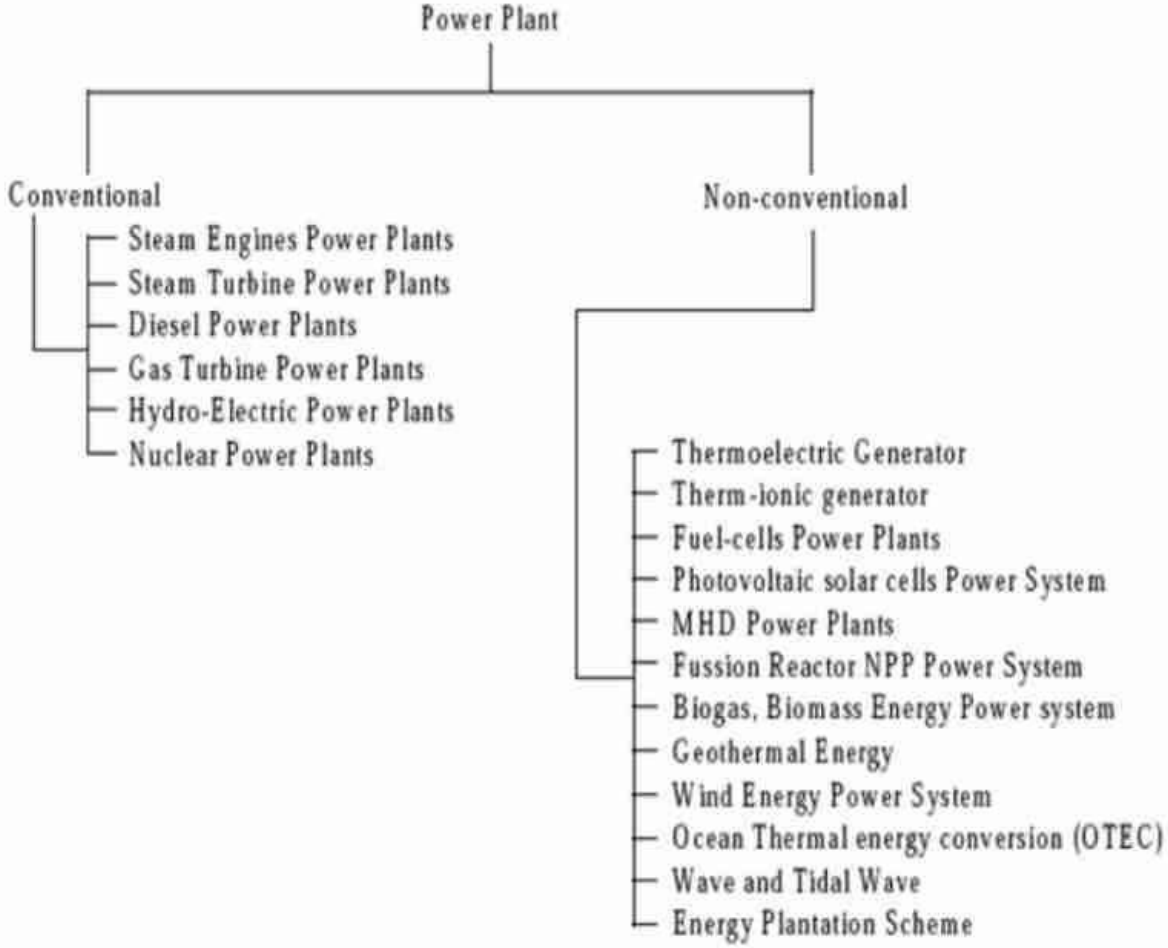
Centralized generation facilities include fossil-fuel-fired power plants, nuclear power plants, hydroelectric dams, wind farms, and more.

Advantages of Centralized System:-

- Central power plant is flexible and changes can be made to accommodate quick changes in demand.
- There is always a supply of fuel available in reserve in the boiler bunkers. Since any mill can be used to supply to any boiler, the outage of parts of the mills or even a short outage of entire pulverizing plant will not cause a boiler plant outage.
- Capacity produced is much more as compare to captive system.
- Economical benefit is more.

Classification of Power Plants:-

Power plants are classified into those using traditional and nontraditional energy resources. The different types of power plants are classified depending on the type of fuel used. For the purpose of bulk power generation thermal, nuclear, and hydropower are the most efficient.



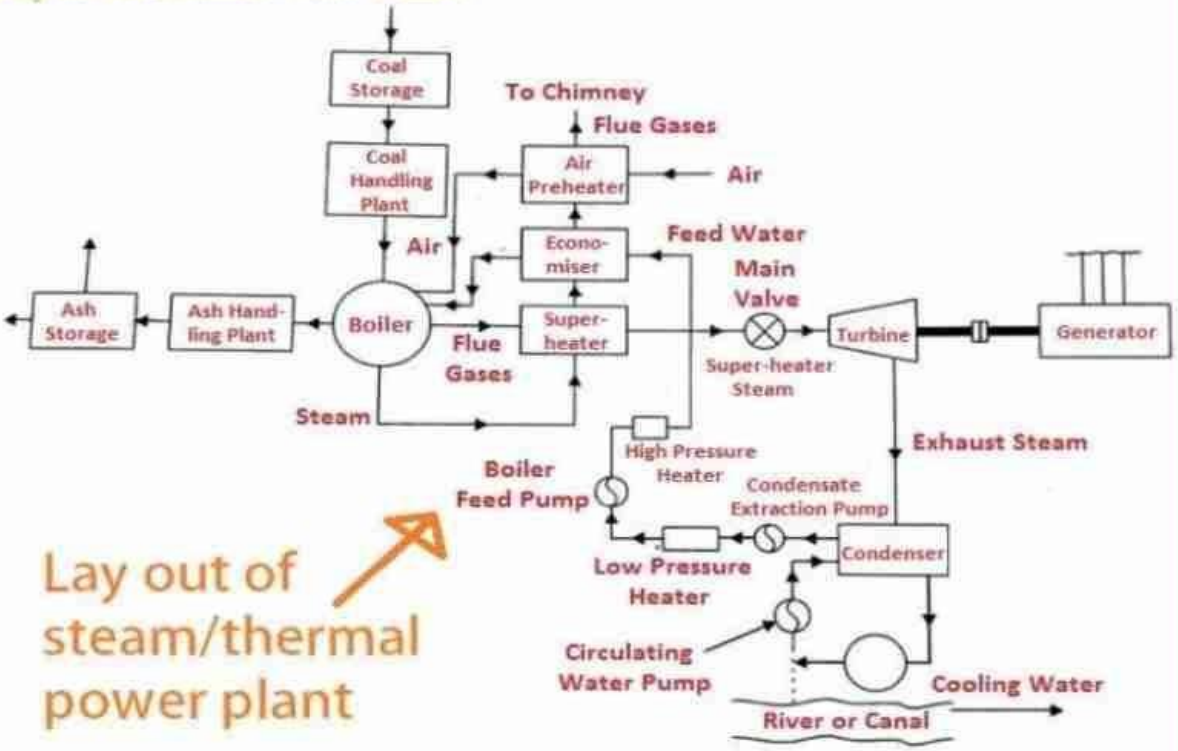
Non conventional energy of power generation and can be classified as:-

- Solar power generation. (making use of the available solar energy)
- Geo-thermal power generation. (Energy available in the Earth's crust)
- Tidal power generation.
- Wind power generation (energy available from the wind turbines)

STEAM POWER PLANT:-

A steam power plant consists of a boiler, steam turbine, condenser, pump and generator, with other auxiliaries. The boiler generates steam at high pressure and high temperature. The steam turbine converts the heat energy of steam into mechanical energy. The generator then converts the mechanical energy into electric power.

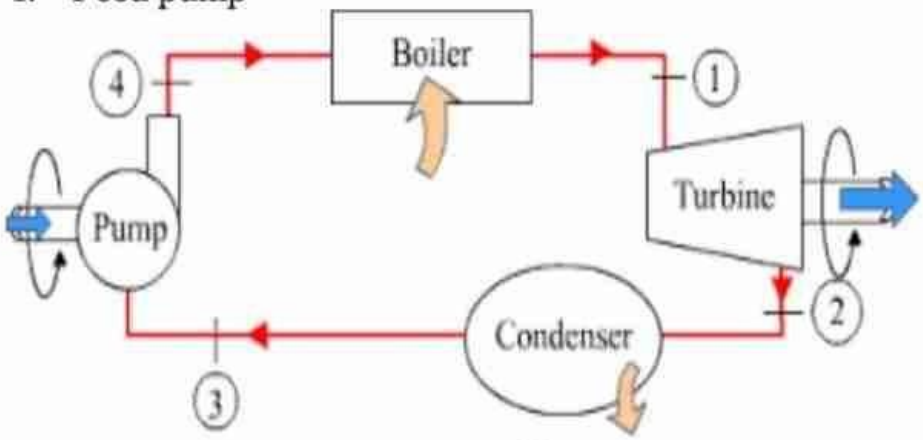
Layout of Steam Power Plant:-



In steam power cycle the working fluid changes from liquid to vapour and back to liquid state.

The elements of steam power plants are as follows:

1. Boiler
2. Steam turbine
3. Condenser
4. Feed pump



Rankine Cycle:-

The Rankine cycle was named after him and describes the performance of steam turbine systems, though the theoretical principle also applies to reciprocating engines such as steam locomotives.

→In general, the Rankine cycle is an idealized thermodynamic cycle of a constant pressure heat engine that converts part of heat into mechanical work.

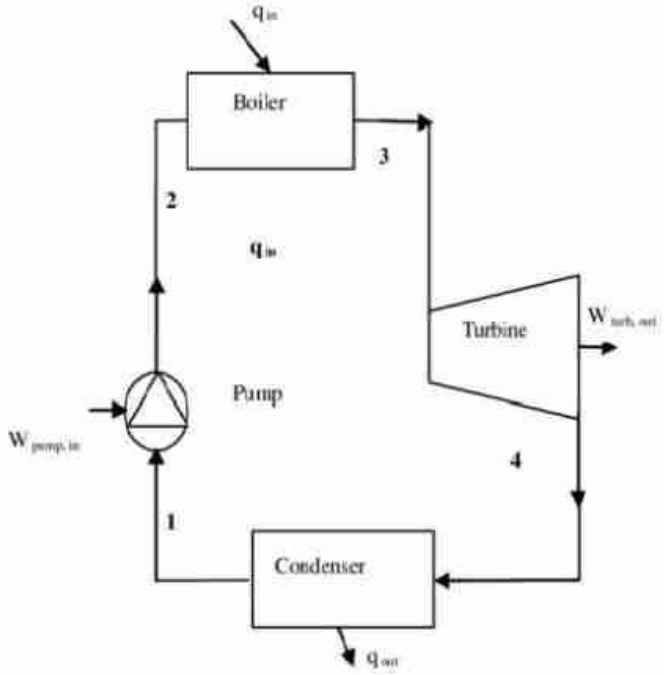
→ The ideal Rankine cycle consists of four internally reversible processes:

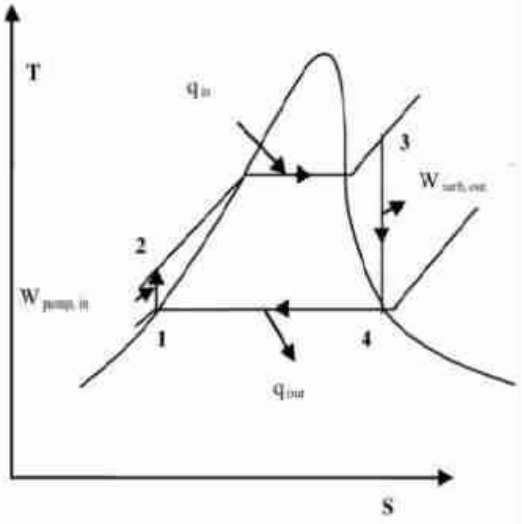
Process 3-4: Isentropic expansion through the turbine

Process 4-1: Heat transfer from the working fluid passing through the condenser at constant pressure

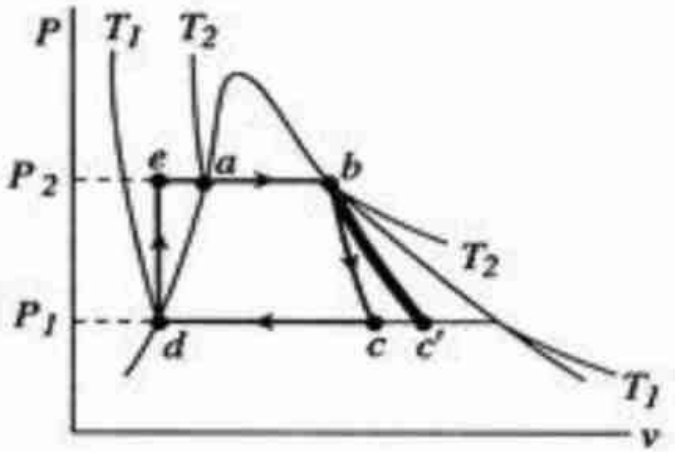
Process 1-2: Isentropic compression in the pump

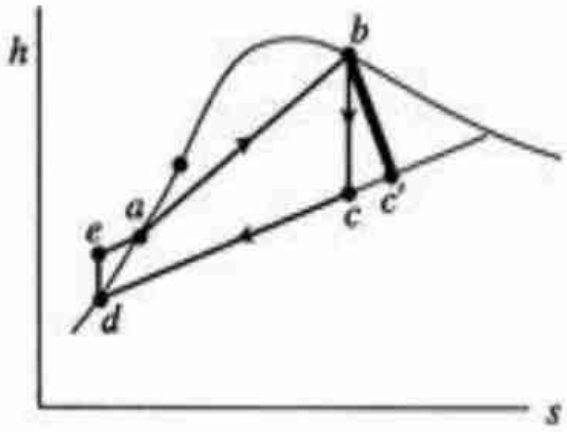
Process 2-3: Heat transfer to the working fluid passing through the boiler at constant pressure





T-S diagram





- $d \rightarrow e$: Cold liquid at initial temperature T1 is pressurized reversibly to a high pressure by a pump. In this process, the volume changes slightly.
- $e \rightarrow a$: Reversible constant pressure heating in a boiler to temperature T2 .
- $a \rightarrow b$: Heat added at constant temperature T2 (constant pressure), with transition of liquid to vapor.
- $b \rightarrow c$: Isentropic expansion through a turbine. The quality decreases from unity at point b to Xc < 1 .
- $c \rightarrow d$: Liquid-vapor mixture condensed at temperature T1 by extracting heat.

Thermal Efficiency of Rankine Cycle:-

In general the thermal efficiency, ηth, of any heat engine is defined as the ratio of the work it does, Wnet= W_T - W_P, to the heat input at the high temperature, $q_{in} = q_1$.
Also Wnet= W_T - W_P = $q_1 - q_2$

Net work done, Wnet = W_T - W_P

Work Ratio:-

It is defined as the ratio of net work done to turbine work

$r_w = W_{net} / W_T$

Back Work Ratio:-

It is defined as the ratio of pump work to turbine work

$r_{bw} = W_p / W_T$

$r_w = 1 - r_{bw}$

Work done on pump, per kg of water, $W_P = h_2 - h_1$

Energy added in steam generator, $q_1 = h_3 - h_2$

Work delivered by turbine, $WT = h_3 - h_4$

Energy rejected in the condenser, $q_2 = h_4 - h_1$

The thermal efficiency of the Rankine cycle is given by,

$$\eta = \frac{q_1 - q_2}{q_1} = \frac{(h_3 - h_2) - (h_4 - h_1)}{h_3 - h_2} = \frac{(h_3 - h_4) - (h_2 - h_1)}{h_3 - h_2}$$

Methods to increase efficiency

1. Lowering the condenser Pressure:-
2. Superheating the steam to high temperatures:-

   The average temperature at which heat is added to the steam can be increased without increasing the boiler pressure by superheating the steam to high temperatures.

   Superheating the steam to higher temperatures has another very desirable effect: It decreases the moisture content of the steam at the turbine exit.

3. Increasing the Boiler pressure

Heat Rate:-

It is defined as the ratio of heat input to the power developed.

$HR = m_s \cdot q_{in} / m_s \cdot W_{net} = q_{in} / W = 1/\eta$

Specific Steam Consumption:-

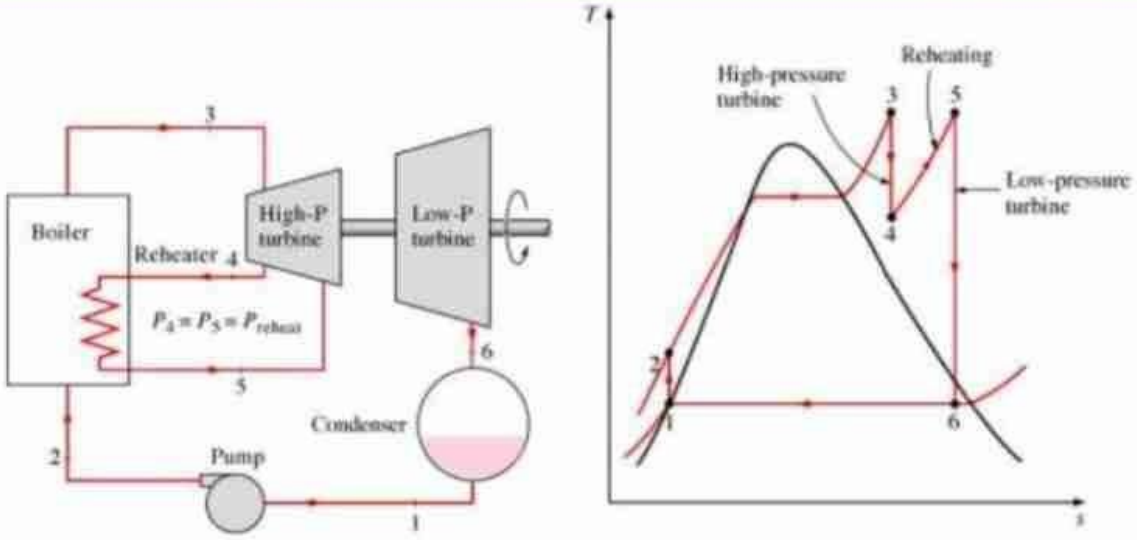
It is defined as the ratio of mass rate of steam to the unit power developed.

$SSC = m_s / \text{Power}$

$SSC = 3600 / W_{net}$ kg/ kWh

Reheat Rankine Cycle:-

The moisture content of the steam is increased to unacceptable level when the boiler pressure is increased. By utilizing a reheat process inside the Rankine cycle, it could practically solve the excessive moisture problem in the turbines. This technique is commonlyused in modern steam power plants. Figure below indicates the ideal reheat Rankine cycle and T-S diagram of the cycle



In ideal reheat Rankine cycle, the expansion process takes place in two stages. In first stage (the high pressure turbine), steam is expanded isentropically to an intermediate pressure and sent back to the boiler where it is reheated at constant pressure, usually to the inlet temperature of the first turbine stage. Steam then expands isentropically in the second stage (low pressure turbine) to the condenser pressure. This improves the cycle efficiency by 4 to 5 percent by increasing the average temperature at which heat is transferred to the steam. The reheat stages can be increased to increase the efficiency; however the gain is too small to justify the added cost and complexity.

Note:-

Here $q_{in} = (h3 - h2) + (h5 - h4)$

$W_T = (h3 - h4) + (h5 - h6)$

Regenerative Rankine Cycle:-

There is a way to overcome this problem by raising the temperature-of the working fluid (water) before it enters into the boiler and this process is called regeneration in steam power plants.

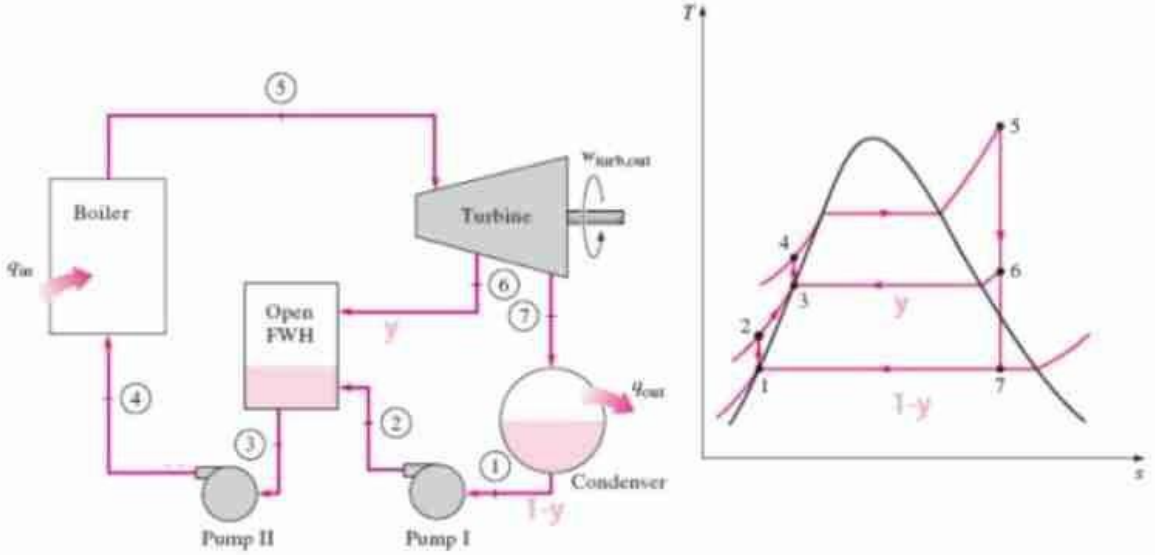
→Conventional way of doing regeneration in a power plant is by extracting the steam from the turbine after partial expansion or partial work done. This steam is used to heat the feed water and the device in which it happens is called a feed water heater or a regenerator.

→Regeneration improves the cycle efficiency by increasing the initial feed water temperature before the water, water enters the boiler and also helps in controlling the large the large flow rate of steam at the turbine exhaust.

→Regeneration is commonly used in all power plants where efficiency is of importance and fuel saving is the motto.

→A feed water heater is basically a heat exchanger where heat is transferred to the feed water by extracting the partially expanded steam from the turbine to heat the feed water. Heating of feed water can be done by:

- Directly heating (in a tank)- Direct heating of feed water is performed in tanks or vessel also called open feed water heaters; or
- By indirect heating (in shell and tube type heat exchanger)- Indirect heating of steam and water is performed on shell and tube type closed heaters



Note:-

Here $q_{in} = h5 - h4$

$W_T = (h5 - h6) + (1-y)(h6 - h7)$

$Q_{out} = (1-y)(h7 - h1)$

$W_p = W_{P1} + W_{P2}$

$= (1-y)(h2 - h1) + (h4 - h3)$

Also $W_{P1} = V_1 (P2 - P1)$

$W_{P2} = V_3 (P4 - P3)$ Where $P2 = P3$

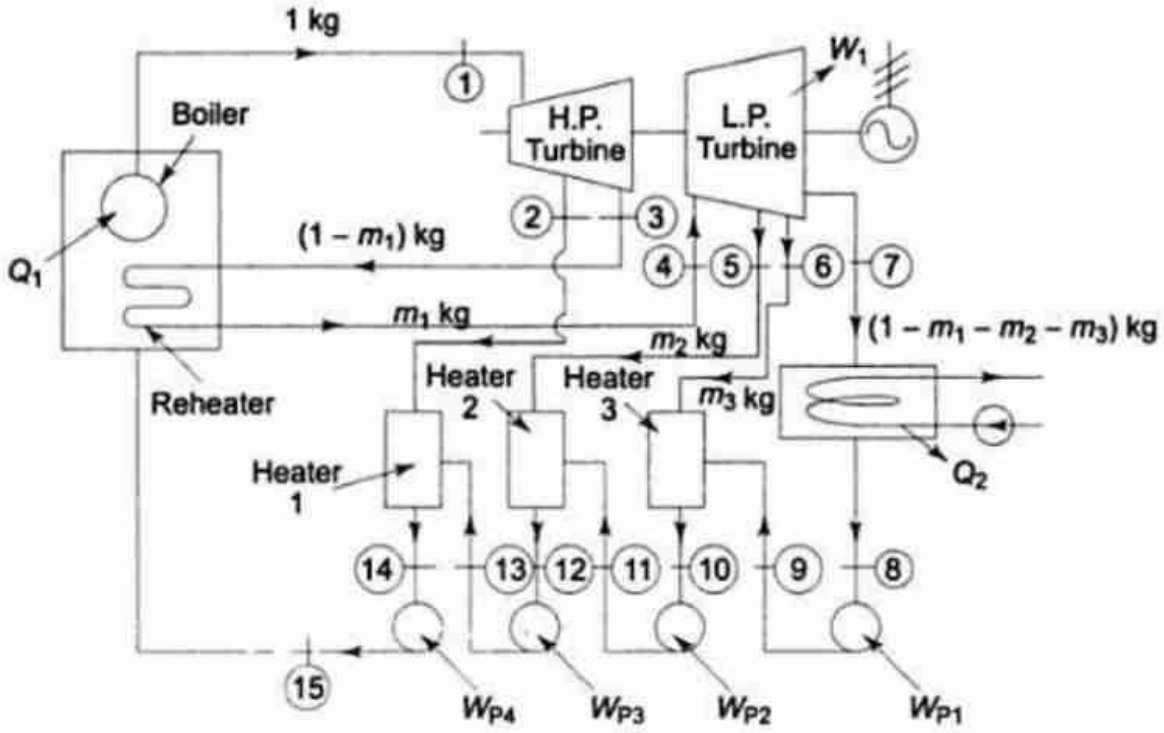
Combination of ReheatAnd Regenerative Cycle:-

These days, modern steam power units are operated with the Reheat-regenerative cycle and we will see here the basic concept of Reheat-regenerative cycle in this post.

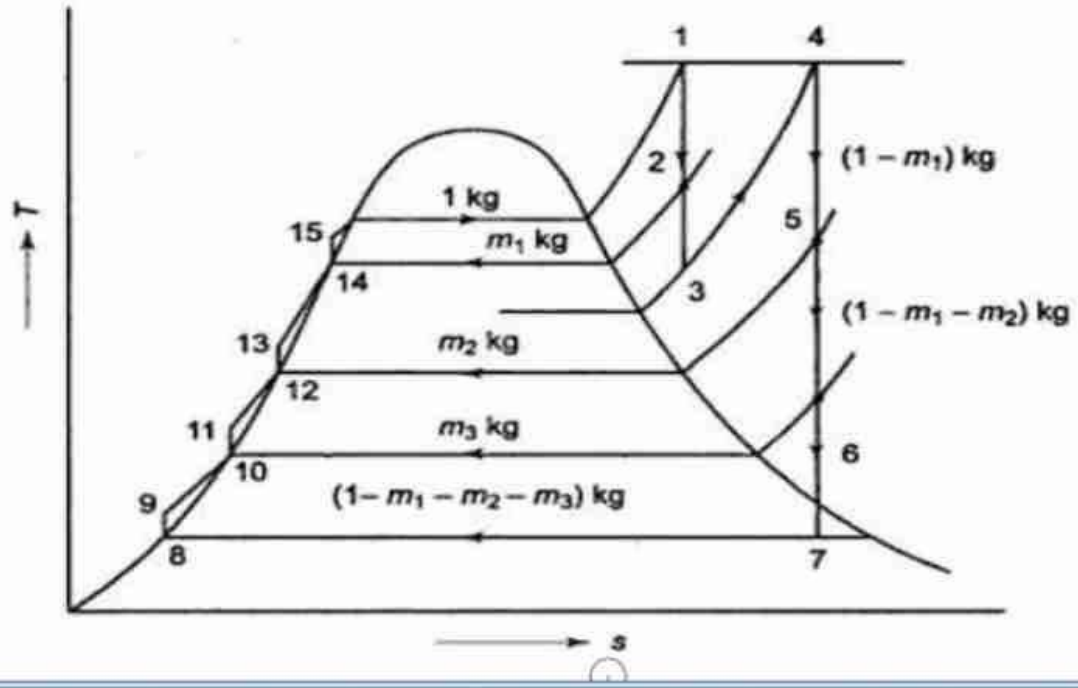
Let us see here the basic block diagram and TS diagram also for steam power cycle with three stages of feedwater heating.

As we can see in block diagram, high pressure and high temperature steam enters to the high pressure turbine at state 1 and as we are also considering here the concept of regeneration hence we must note it here

that all steam will not be expanded through the high pressure turbine up to pressure corresponding to state 3 but also certain quantity of steam will be extracted from the high pressure turbine and its state is displayed by state 2



Expanded steam from high pressure turbine will enter in to the reheater at state 3 and reheater, as shown in figure, will use the heat energy from boiler for reheating the steam coming from high pressure turbine. In simple way we can say that steam will be reheated in reheater coil tube by receiving heat energy from boiler. Steam will be heated in reheater up to a temperature of T4 as displayed in figure by process 3-4.



→Steam coming from reheater will enter to the low pressure turbine at state 4 and similarly as studied earlier certain quantity of steam will be extracted here from low pressure turbine before the complete expansion of steam up to the condenser pressure.

→So as shown in figure, steam will be extracted from low pressure turbine at state 5 and state 6 and rest quantity of steam will be expanded up to the condenser pressure i.e. up to state 7.

→Steam will enter to the condenser at state 7 and will go undergo condensation process during the process 7 to 8. Now working fluid will be pumped with the help of feed pump by process 8-9.
Now extracted steam at state 6 and working fluid (pumped by the feed pump WP1) at state 9 will exchange heat energy with each other in to the feedwater heater 3.

→Therefore, working fluid will be heated in to the feedwater heater and we have displayed this process of heat energy addition to the working fluid in feedwater heater 9-10.

→Similarly working fluid will secure heat energy during the process 11-12 and 13-14 in feewater heater 2 and feedwater 1 respectively.
Process 15-1 will indicate here the heat energy addition to the working fluid in boiler and we will consider this heat energy addition as input energy addition. Working fluid will also secure heat energy in reheater during the process 3-4 and hence heat energy added during the process 3-4 will also be taken as input heat energy.

→However we have recently studied that heat energy will also be added to the working fluid during the process of feedwater heater but that heat energy addition will be internal as that heat energy addition will be done by the concept of regeneration process.

Work done by the turbine:

$$W_T = (h_1 - h_2) + (1 - m_1)(h_2 - h_3) + (1 - m_1)(h_4 - h_5) + (1 - m_1 - m_2)(h_5 - h_6) + (1 - m_1 - m_2 - m_3)(h_6 - h_7)$$

Work required by the pump:

$$W_P = (1 - m_1 - m_2 - m_3)(h_9 - h_8) + (1 - m_1 - m_2)(h_{11} - h_{10}) + (1 - m_1)(h_{13} - h_{12}) + 1(h_{15} - h_{14})$$

Heat energy addition as input energy to the working fluid:

$$Q_1 = (h_1 - h_{15}) + (1 - m_1)(h_4 - h_3)$$

Heat energy rejected:

$$Q_2 = (1 - m_1 - m_2 - m_3)(h_7 - h_8)$$

Rankine Thermal Efficiency will be:

$$\eta = (W_T - W_P) / Q1$$

Boiler Accessories:-

The boiler accessories are not the integral parts of the boiler. They are used in the boiler to improve its efficiency.

1. Air pre-heater
2. Superheater
3. Economiser
4. Feed pump
5. Electrostatic precipitator

1. Air preheater

It is used to recover heat from the exhaust gases.

→It is installed between the economiser and the chimney.

2. Superheater

It is placed in the path of hot flue gases from the furnace.

→A superheater is an important accessory used in the boiler. Its main function is to increase the temperature of saturated steam without raising its pressure.

3. Economiser

It is used to heat the feedwater by the utilization of heat from the hot fuel gases before it leaves the chimney.

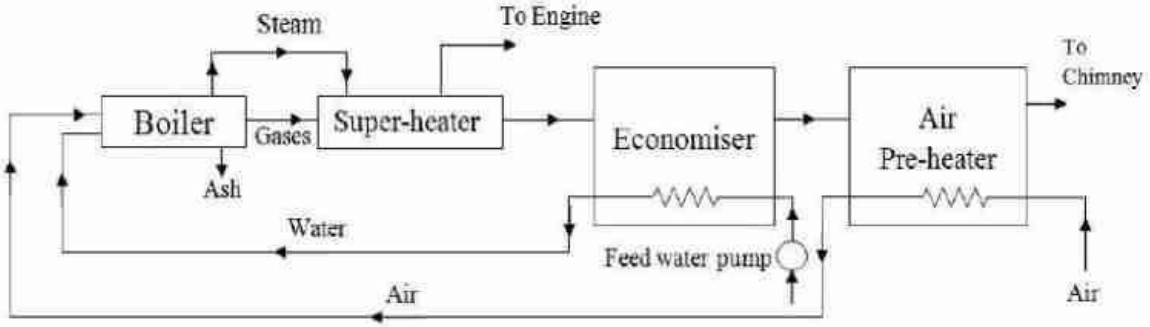
→A economiser improves the economy of the steam boilers.

4. Feed pump

It is used to deliver water to the boiler.

5. Electrostatic precipitator (ESP)

Electrostatic precipitator electrically charges the ash particles and imparts a strong electric field in the flue gas to collect and remove them. An ESP is comprised of a series of parallel, vertical metallic plates (collecting electrodes) forming lanes through which the flue gas passes. Centered between the collecting electrodes are discharge electrodes which provide the particle charging and electric field.



Boiler Mountings:-

The boiler mountings are the integral parts of the boiler. They are used in the boiler for safety purpose.

1. Water level indicator (Water level gauge)
2. Pressure gauge
3. Safety valves
4. Stop valve
5. Blow off Valve
6. Feed check valve
7. Fusible plug

Sl. No.	Boiler Mountings	Boiler Accessories
1	Mountings are fitted for the safety of the boiler.	Accessories are fitted to increase the efficiency
2	They form integral parts of the boiler	They are not integral part of the boiler
3	They are usually mounted on the boiler shell	They are usually installed outside the boiler shell
4	A boiler should not be operated without mountings	A boiler can be operated without accessories

Boiler Draught:-

Boiler draught is the pressure difference between the atmosphere and the pressure inside the boiler.

The draught is one of the most essential systems of the thermal power plant which support the required quantity of air for combustion and removes the burnt products from the system. To move the air through the fuel bed and to produce a flow of hot gases through the boiler economiser, preheater and chimney require a difference of pressure.

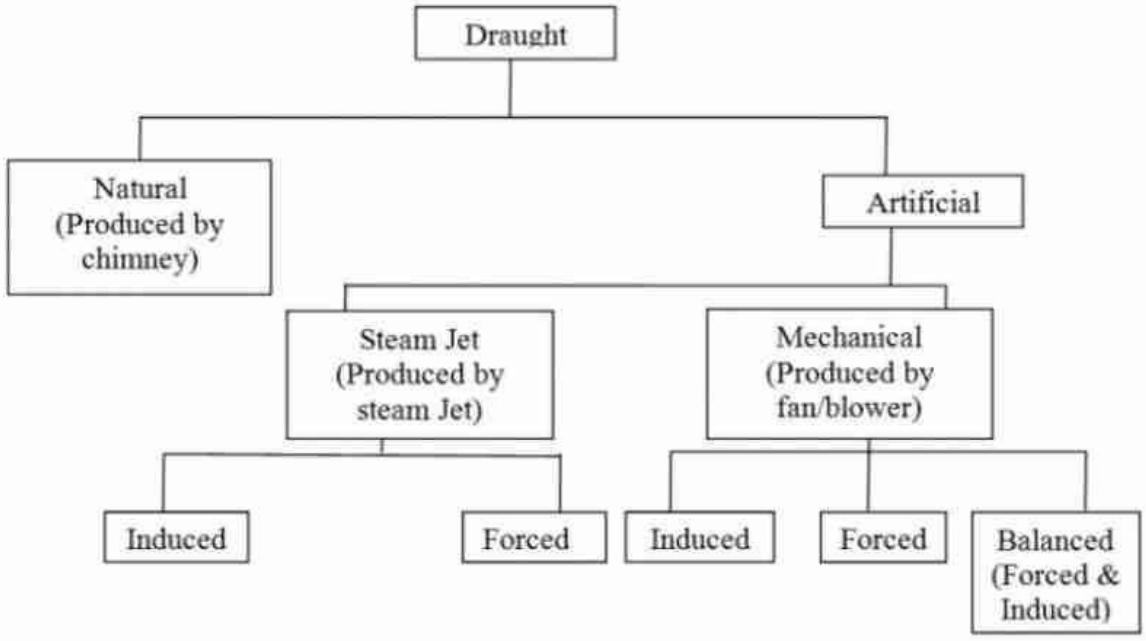
This difference of pressure to maintaining the constant flow of air and discharging the gases through the chimney to the atmosphere is known as draught. Draught can be achieved by the use of chimney, fan, steam or air jet or a combination of these.

When the draught is produced with the help of chimney only, it is known as Natural Draught and when the draught is produced by any other means except chimney it is known as Artificial Draught.

Purpose of Boiler Draught:-

- To provide an adequate supply of air for fuel combustion.
- For throw out the exhaust gases of combustion from the combustion chamber.
- To discharge these gases to the atmosphere through the chimney.

Classification of Boiler Draught:-

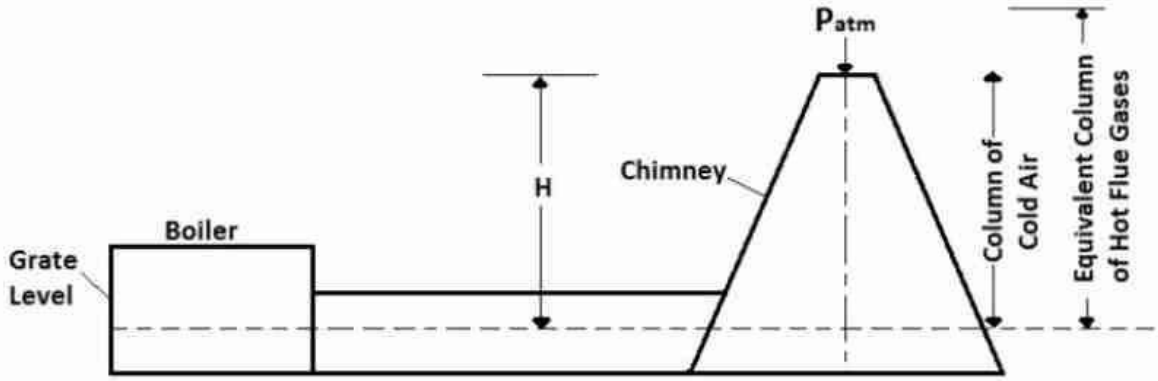


In general, the draughts may be classified into the following two types,

1. Natural Draught
2. Artificial Draught

1. Natural Draught:-

Natural draught system employs a tall chimney as shown in the figure. The chimney is a vertical tubular masonry structure or reinforced concrete. It is formed for enclosing a column of flue gases to produce the draught.



Natural Draught

It removes the gases high enough to prevent air pollution. The draught is produced by this tall chimney due to the temperature difference of hot gases in the chimney and cold external air outside the chimney.

Advantages of Natural Draught:-

- It does not require any external power for producing the draught.
- The capital investment is less. The maintenance cost is low as there is no mechanical part.
- Chimney keeps the flue gases at a high place in the atmosphere which prevents the contamination of the atmosphere.
- it has a long life.

Disadvantages of Natural Draught:-

- The maximum pressure available for producing natural draught by the chimney is hardly 10 to 20 mm of water under the normal atmospheric and flue gas temperatures.
- The available draught reduces with increases in outside air temperature and for generating enough draught, the exhaust gases have to be discharged at relatively high temperatures resulting in the loss of overall plant efficiency. Thus maximum utilization of Heat is not possible.

2. Artificial or Mechanical Draught:-

It has been seen that the draught produced by the chimney is affected by the atmospheric conditions. It has no flexibility, poor efficiency and tall chimney are required. In most of the modern power plants, the draught applied must be freedom of atmospheric condition, and It should have more flexibility (control) to bear the fluctuation loads on the plant.

The artificial is produced by a fan.

Advantages of Artificial or Mechanical Draught:-

- It is more economical and its control is easy.
- The desired value of draught can be produced by mechanical means which cannot produced by means of natural draught.
- It increases the rate of combustion by which low-grade fuel can also be used.
- It reduces the smoke level and increases the heat transfer co-efficient no flue gases side thus increases the thermal efficiency of the boiler.
- In mechanical draught, It saves the energy and the heat of flue gases can be best utilized by it.
- In this way, it reduces fuel consumption and makes boiler operation cheaper.
- It reduces the height of chimney which now is only controlled by the requirement of pollution norms.

Disadvantages of Artificial or Mechanical Draught:-

- The initial cost of mechanical draught system is high.
- Running cost is also high due to the requirement of electricity but that is easily compensated by the savings in fuel consumption.
- Maintenance cost is also at a higher rate.
- Noise level of boiler is also high due to noisy fan/blower etc.

Types of Artificial or Mechanical Draught:-

The following are the two types of Artificial or Mechanical draught:

I. Steam jet draught
II. Mechanical or fan draught

I. Steam Jet Draught:-

It is a very simple and easy method of producing artificial draught without the need for an electric motor. It may be forced or induced depending on where the steam jet is installed. Steam under pressure is available in the boiler.

When a small position of steam is passed through a jet or nozzle, pressure energy converts to kinetic energy and steam comes out with a high velocity. This high-velocity steam carries, along with it, a large mass of air or flue gases and makes it flow through the boiler. Thus steam jet can be used to produce draught and it is a simple and cheap method.

→Actually the steam jet is directed towards a fix direction and carries all its energy in kinetic form. It creates some vacuum in it's surrounding and

attracts the air of flue gases either by carrying along with it. Thus it has the capacity to make the flow of the flue gases either by carrying or including towards chimney. It depends on the position of the steam jet.

Types of Steam Jet Draught:-

The following are the main two types of steam jet draught:

a) Induced steam jet draught.
b) Forced steam jet draught.

Advantages of Induced Steam Jet Draught:-

- It is quite simple and cheap.
- The induced steam jet draught has the capability of using low-grade fuels.
- It occupies very less space.
- It is quite simple and cheap.
- The initial cost is low.
- Maintenance cost is low.
- Exhaust steam from the steam engine or turbine can be used easily in the steam jet draught.

Disadvantages of Steam Jet Draught:-

- It can operate only when some steam is generated.
- Draught produced very low.

II. Mechanical or Fan Draught:-

The draught, produced by means of a fan or blower, is known as mechanical draught or fan draught. The fan used is, generally, of centrifugal type and is driven by an electric motor.

→In an induced fan draught a centrifugal fan is placed in the path of the flue gases before they enter the chimney. It draws the flue gases from the furnace and forces them up through the chimney. The action of this type of draught is similar to that of the natural draught.

→In case of forced fan draught, the fan is placed before the grate, and the air is forced into the grate through the closed ash pit.

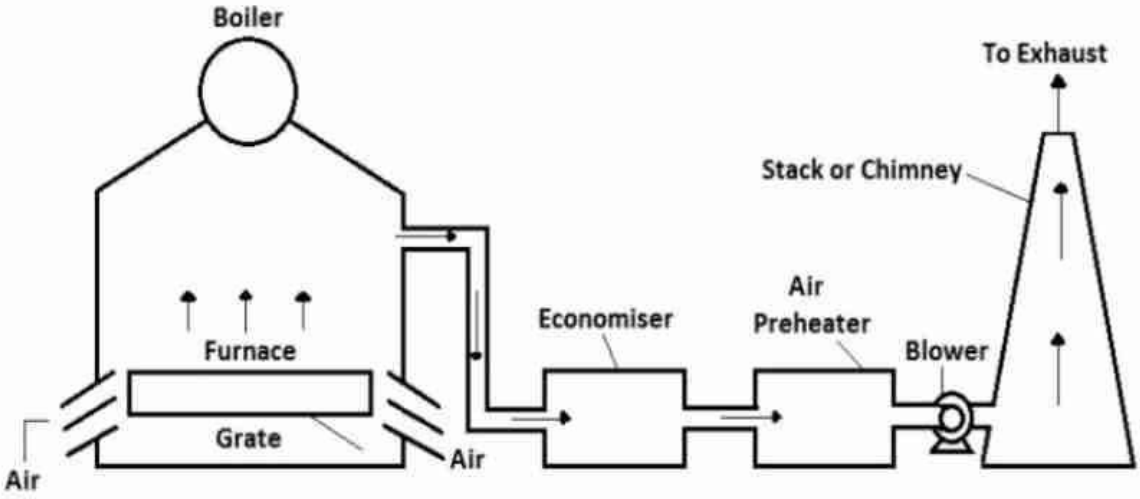
Types of Mechanical or Fan Draught:-

The following are the three types of mechanical or fan draught:

a) Induced draught.
b) Forced draught.
c) Balanced draught.

a) Induced draught

In induced draught, the blower is placed near the base of the chimney instead of near the grate. The air is absorbed in the system by decreasing the pressure through the system below the atmosphere. The induced draught fan sucks the burned gases from the furnace and the pressure inside the furnace is reduced below atmosphere and includes the atmospheric air to flow through the furnace.

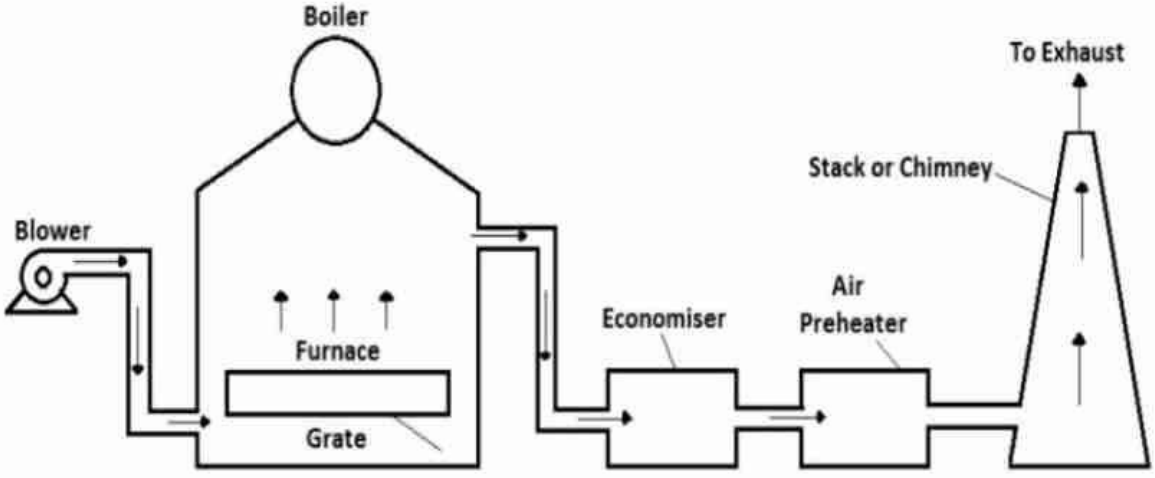


Induced Draught System

→The action of the induced draught is related to the action of the chimney. The draught produced is free from the temperature of the hot gases, therefore, the gases may be released as cold as possible after recovering as much heat as possible in air-preheater and economiser.

b) Forced Draught

In a forced draught system, a blower is installed near the base of the boiler and air is forced to pass through the furnace, flues, economiser, air-preheater and to the stack



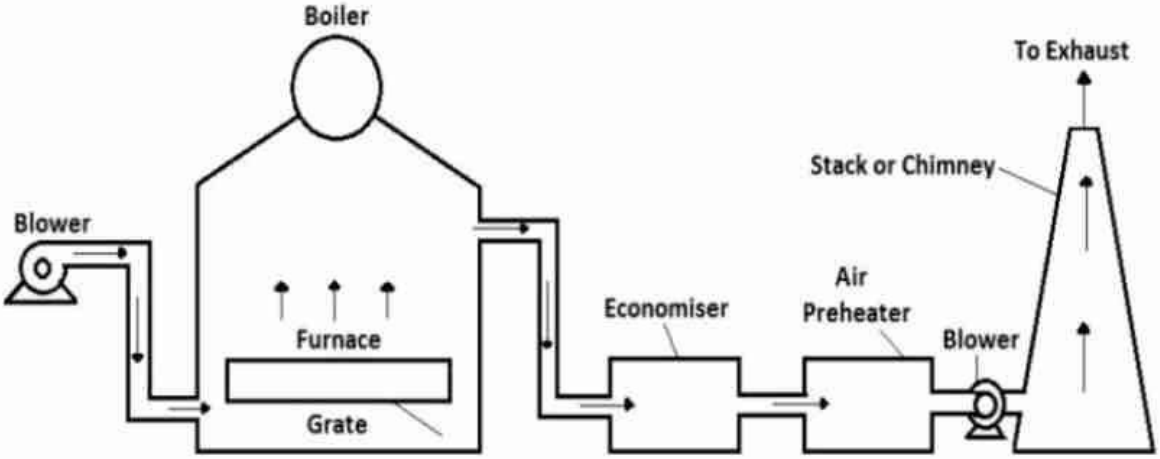
Forced Draught System

→This draught system is known as positive draught system or forced draught system because the pressure and air are forced to flow through the system.

→The arrangement of the system is shown in the figure. A stack or chimney is also in this system as shown in the figure but its function is to discharge gases high in the atmosphere to prevent the contamination. It is not much significant for producing draught, therefore, the height of the chimney may not be very much.

c) Balanced Draught

It is always better to use a combination of forced draught and induced draught instead of forced or induced draught alone. If the forced draught is applied alone, the furnace cannot be opened for firing or inspection because high-pressure air inside the furnace will quickly try to blow out and there is every possibility of blowing out the fire completely and furnace stops.



Balanced Draught System

If the induced draught is used alone, then also furnace can not be opened either for firing inspection because the cold air will try to rush into the furnace as the pressure inside the furnace is under atmospheric pressure. This reduces the effective draught and dilutes the combustion.

Forced Draught	Induced Draught
1) Fan or blower is placed before grate or situated within the oil burner assembly in case of an oil fired boiler.	The fan or blower is placed after the grate or after the flue passages and before chimney.
2) Pressure inside the flue passages is slightly more than atmospheric pressure.	Pressure inside the flue passages is slightly less than atmospheric pressure.
3) Due to the above reason, there is the serious danger of fire to come out and injure someone if any leakage in boiler flue passage take place.	Due to the above reason, there is no danger of fire to come out from boiler flue passage in case of a leakage. Hence Induced draught is safer.
4) It forces fresh air into the combustion chamber, which helps in burning of fuel and production of hot combustion gases. Due to this force, the hot flue gases are further pushed through the flue passages in the boiler.	It sucks the hot flue gases from the combustion chamber through flue passages and then passes on these to economizer, air preheater and chimney. Due to this suction, fresh air is also sucked into the combustion chamber.
5) Forced draught fan require less power because it has to handle cold and dense air, the volume per unit mass of which is less.	Induced draught fan requires more power because it has to handle hot flue gases, the volume per unit mass of which is more.
6) The flow of flue gases through the boiler is more uniform.	The flow of flue gases is less uniform

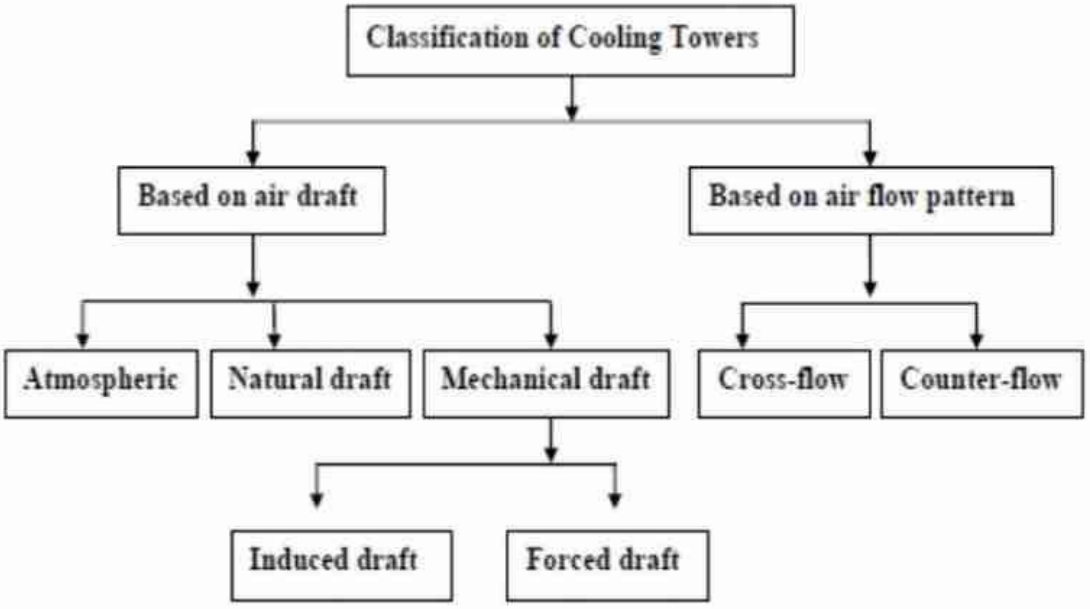
Cooling Tower:-

Functions of cooling tower:-

Cooling tower is an important part of power plant. The basic working principle of cooling tower is to cool the hot water with the help of atmospheric air. Though it is widely used in different engineering sector and other refrigeration plant. The height of the cooling tower in thermal power plant is about 9 feet or above from the ground level. A water store unit called pond is placed at the base of the cooling tower. In steam power plant, cooling tower first collects hot water from the condenser at a certain height from the ground level, after that the hot water falls down by the radial spray. The atmospheric air which is comparatively cool enters at the bottom of the tower. Now the hot air in the cooling tower expose in the atmospheric air which reduces the temperature of the hot water by partial evaporation. This cooled water is collected in the pond at the base of the tower and pumped into the condenser for further use. Doing so, limited quantity of water can be used again and again. It is used such type of power plant where supply of water is limited.

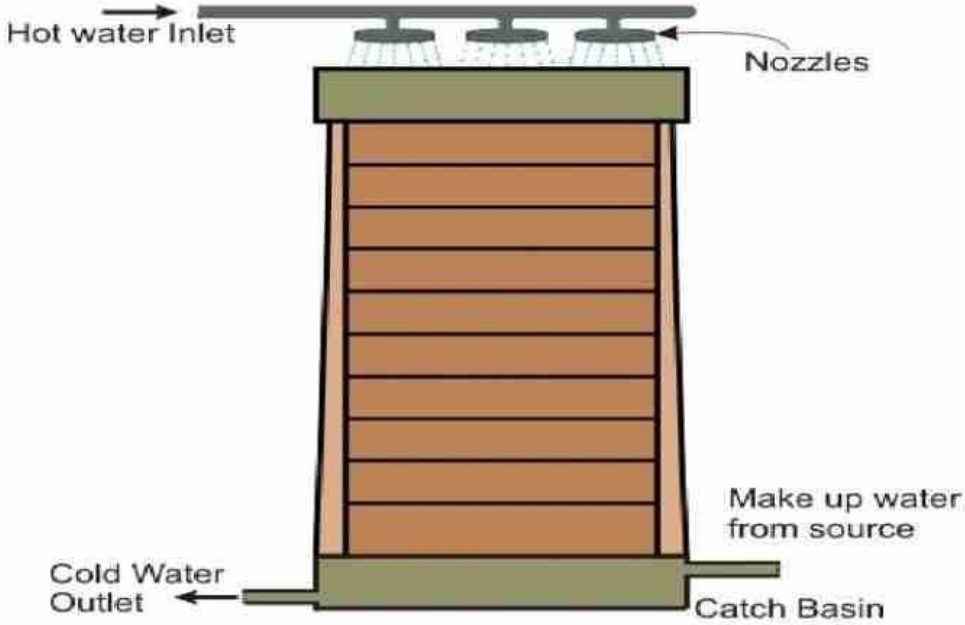
Some important factors which is essential for cooling tower to cool the water:-

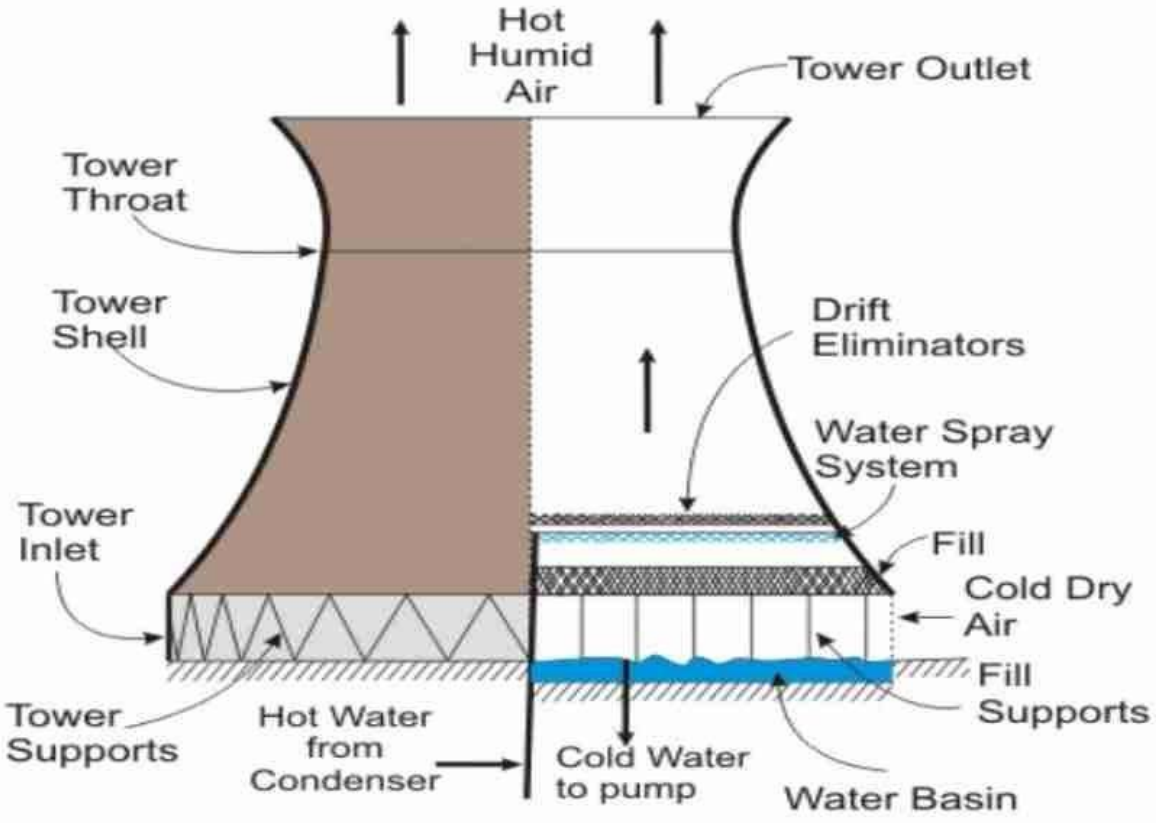
1. Size and height of the cooling tower.
2. Temperature of the air.
3. Humidity of the air.
4. Arrangements of plate in the cooling tower.
5. Velocity of air entry of the cooling tower.
6. Accessibility of air to all parts of the cooling tower.



1) Natural Draught Cooling Tower:

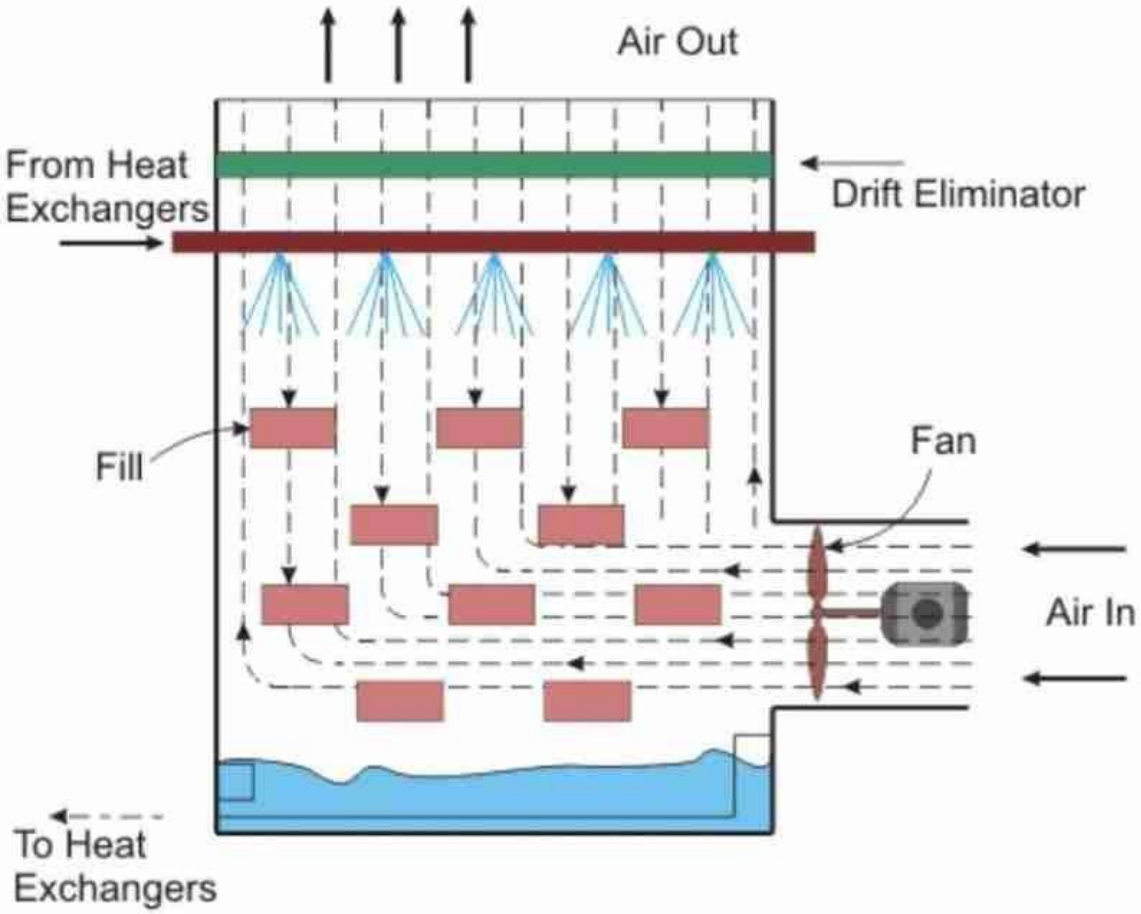
In this type of cooling tower, fan is not used for circulating air but here, by enclosing the heated air in the chimney and it will create pressure difference between heated air and surrounding air. Because of this pressure difference air enters in to the cooling tower. It requires large hyperbolic tower, so capital cost is high but operating cost is low because of absence of electrical fan. There are two types of natural draught cooling tower, rectangular timber tower and reinforced concrete hyperbolic tower.

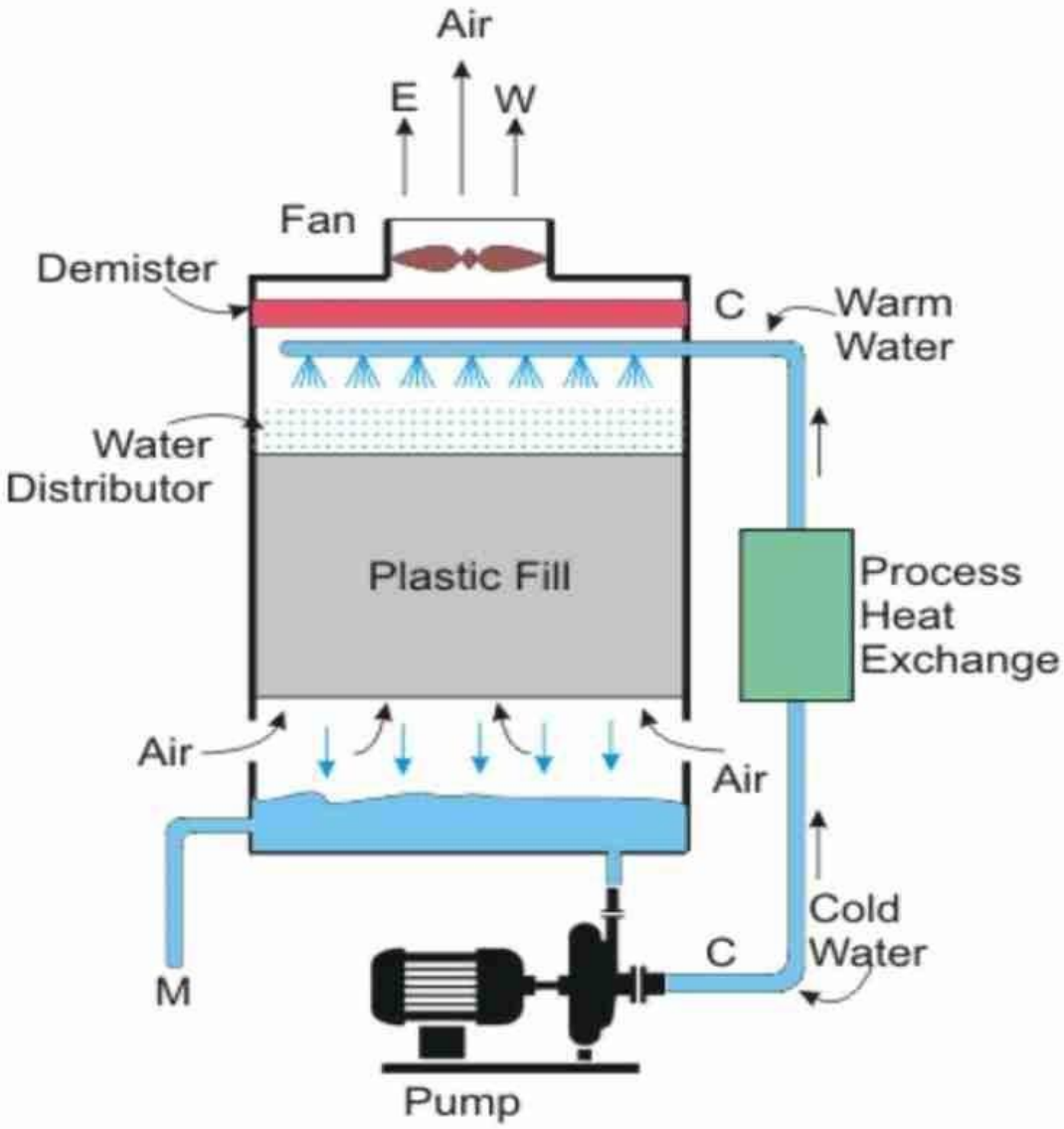




2) Mechanical or Forced Draught Cooling Tower:

In this type of cooling tower, fan is used to circulate the air. When power plant runs on peak load, it requires a very high rate of cooling water. To rotate fan, it uses motor with speed around 1000 rpm. Working principle is same as natural draught cooling tower, only difference is that here fan is mounted on the cooling tower. If fan is mounted on the top of the tower is called as induced draught cooling tower which is most popular for very large capacity installation and requires large capacity of fan. So, forced draught cooling tower contains horizontal shaft for the fan and it is placed at bottom of the tower and induced draught cooling tower contains vertical shaft and it is placed at top of the cooling tower.




Air
E
W
Fan
Demister
C
Warm
Water
Water
Distributor
Plastic Fill
Process
Heat
Exchange
Air
Air
Cold
Water
C
M
Pump

Steam Turbine:-

A steam turbine is a device which converts thermal energy of steam into mechanical energy. This mechanical energy is generally used further to generate electricity. It is invented by sir Charles Parsons in 1884.
→It is also called as steam prime mover.

Types of Steam Turbines:-

They are basically classified into two types

1. Impulse Turbine
2. Reaction Turbine

A turbine composed of blades alternating with fixed nozzles is called an impulse turbine example: Curtis turbine, Rateau turbine, or Brown-Curtis turbine.
A turbine composed of moving nozzles alternating with fixed nozzles is called a reaction turbine example: Parsons turbine.

Failure of Steam Turbine:-

- Over speeding of turbine.
- Low condenser vacuum.
- Lubricating system failure.
- High vibrations in turbine.

Advantages of Steam Turbine:-

They have following advantages:

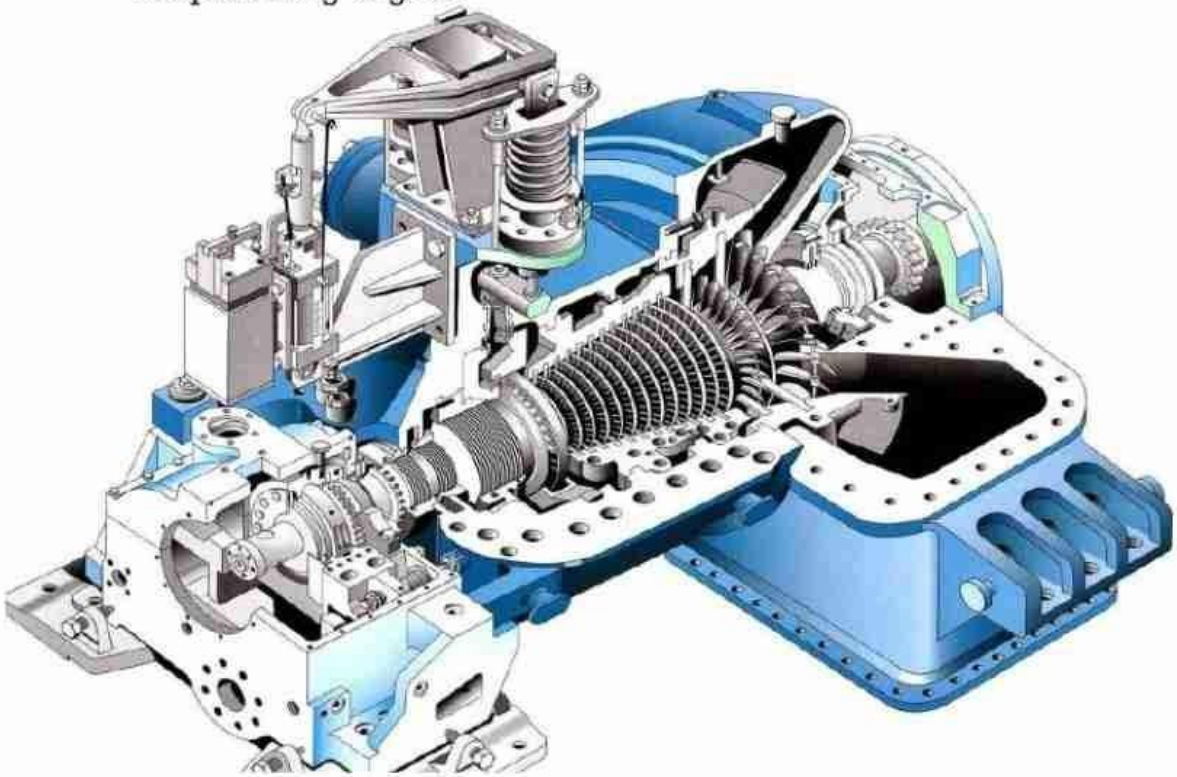
- They have high reliability especially in the cases where sustained high-power output is needed.
- They have less vibrations when compared to reciprocating engines.
- They require less mass flow rates compared to gas turbines.
- They have very high power to weight ratio when compared to reciprocating engines.
- Thermal efficiency is usually high compared to reciprocating engines.
- Since it is a rotary engine hence it is more suitable to drive an electricity generator.

Disadvantages of Steam Turbines:-

They have following disadvantages:

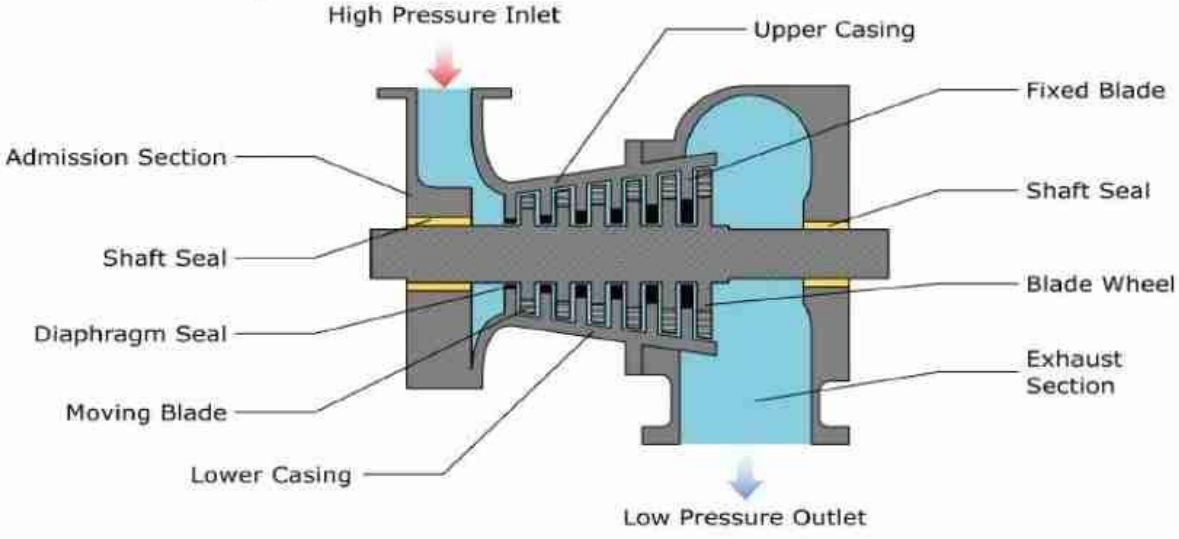
- They are less responsive to change in power demand compared to reciprocating engines.
- They take long startup time compared to gas turbines and reciprocating engines.

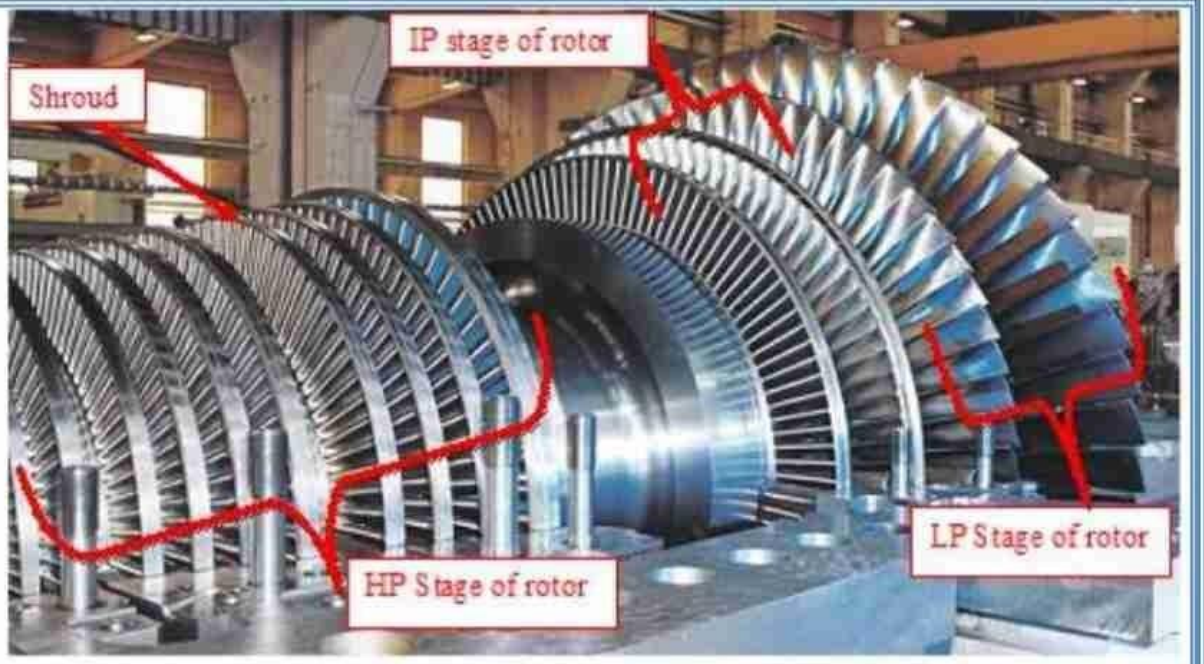
- In part load operations steam turbine is less efficient than reciprocating engine.



Elements of Steam Turbine:-

- Casing
- Rotor
- Blades(fixed and moving)
- Stop and control valve
- Shaft seal
- Governor
- Bearing(general and thrust bearing)
- Gear box
- Oil pumps





Compounding of Steam Turbine:-

If the steam pressure drops below boiler pressure to the condenser pressure in a single stage, then exit velocity of steam from nozzle becomes very high .As turbine speed is proportional to steam velocity turbine blades may get damaged because of centrifugal stresses caused by high speed and energy of steam is not utilized effectively. So to avoid the damages and increase efficiency it's necessary to reduce turbine speed by using compounding method.

So basically, it is the "Method of reducing blade speed for given overall pressure drop by extracting the energy of steam in a more than one stage".

Basically there are 3 types of compounding.

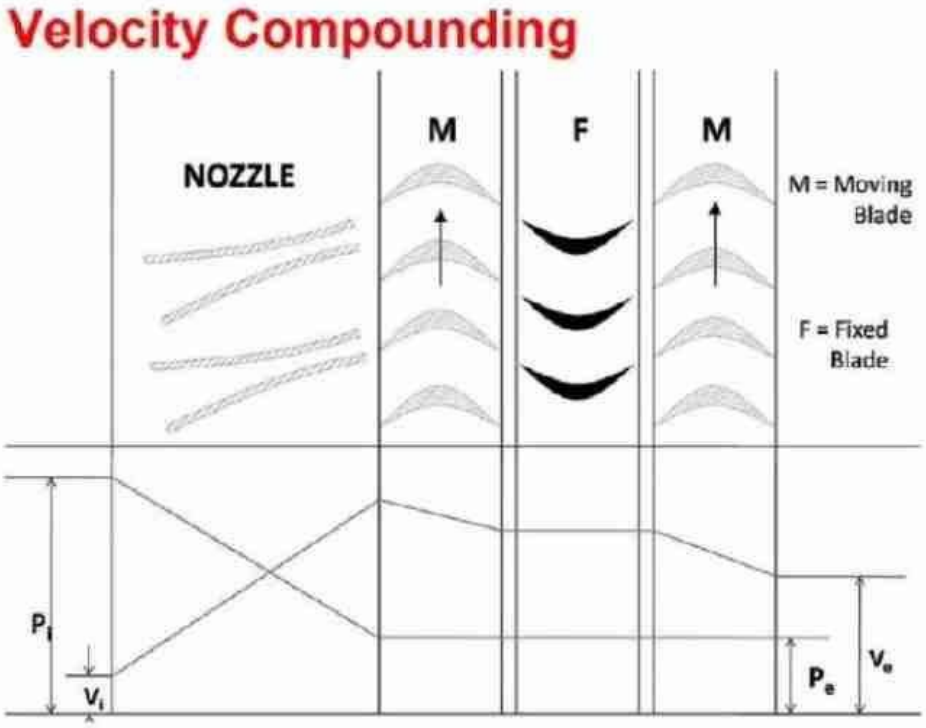
1. Velocity compounding.
2. Pressure compounding.
3. Pressure-velocity compounding.

1. Velocity Compounding:-

The velocity compounded impulse turbine has moving and fixed blades. The moving blades are keyed to turbine shaft and fixed blades are fitted to casing. The high pressure steam from boiler is expander in nozzle where pressure energy is converted into kinetic energy.

→The high velocity steam is directed on first set of moving blades and as steam flows over the blade it imparts some of its momentum to blades and loses some velocity. Some part of high K.E is absorbed by blades and there is no change in velocity of steam as it passes through fixed blades. The steam then goes to next set of moving blades and this process is

repeated until all the energy of steam is absorbed. The figure below shows the velocity compounding of impulse turbine.



Here: Pi and Pe are pressure of steam at inlet and exit and Vi and Ve are velocities of steam at inlet and exit.

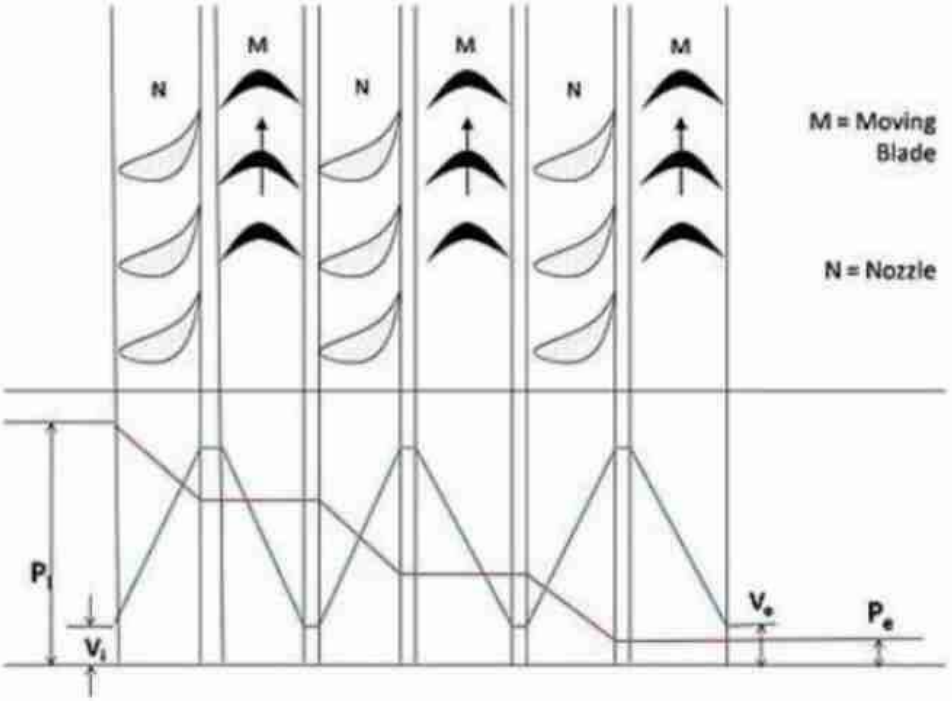
2. Pressure Compounding:-

This is used to solve the problem of high blade velocity in the single stage-impulse-turbine.

→It consists of alternate rings of nozzles and turbine blades. The nozzles are fitted to the casing and the blades are keyed to the turbine shaft. In this type of compounding, steam is expanded more than once(as in velocity compounding).

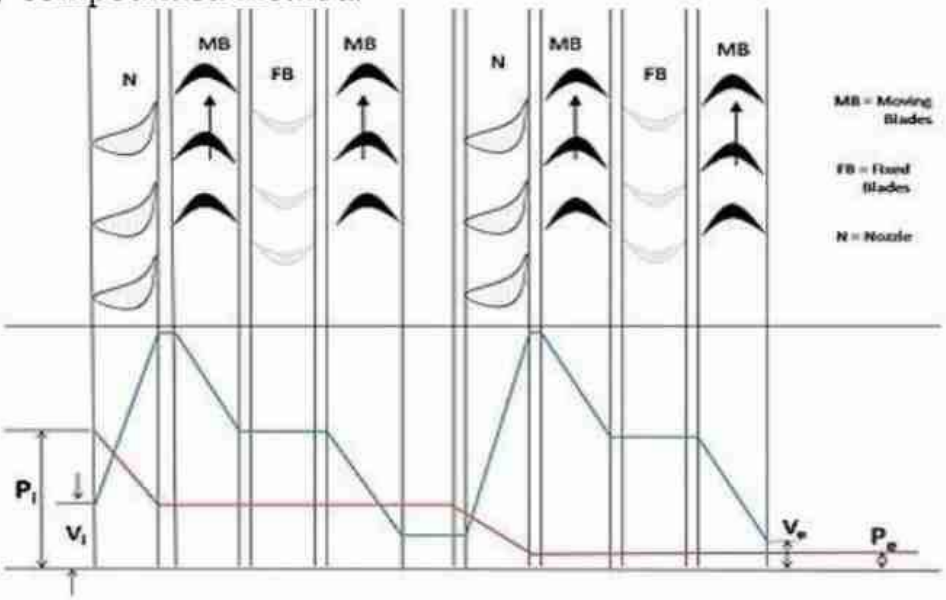
→ Here the high pressure steam is fed to nozzle where it is partially expanded i.e pressure decreased velocity increased and when this steam is passed over the set of blades, where almost all its velocity is absorbed and pressure remains constant during this period and this process is repeated until condenser pressure is achieved.

Pressure Compounding



3. Pressure-Velocity Compounding:-

This method is the combination of both pressure and velocity compounding. Here the set of nozzle rings is fixed at the beginning of each stage and pressure remaining constant of each stage. Diameter is comparatively large in stage for increasing the volume of steam at lower pressure. The total pressure drop of the steam is divided into stages and velocity obtained in each stage is also compounded. A pressure velocity compounded turbine allows a bigger pressure drop in each stage. That's why pressure velocity compounded method need less stage as compared to the other method. A CURTIS TURBINE is an example of pressure velocity compounded method.



Velocity Compounding	Pressure Compounding
Not equal velocity drop for each stage	Equal velocity drop for each stage
No pressure drop per stage	Not equal pressure drop per stage
Non equal power per stage	Equal power per stage
High friction losses due to high velocities	Low friction losses due to reduced steam velocity
Not recommended for more than two stages	Recommended for multistage
No problem with steam leak	Larger steam leak
Suitable for small turbines as well as only for the first stage in large turbine	Suitable for large turbines

Impulse turbine	Reaction Turbine
The entire available energy of the water is first converted into kinetic energy.	The available energy of the water is not converted from one form to another.
The water flows through the nozzles and impings on the buckets, which are fixed to the outer periphery of the wheel.	The water is guided by the glide blades to flow over the moving vane.
The water impings on the buckets with KE	The water glides over the moving vanes with PE.
The pressure of the flowing water remains unchanged and is equal to the atmospheric pressure.	The pressure of the flowing water is reduced after gliding over the vane.
It is not essential that the wheel should run full.	It is essential that the wheel should always run full and kept full of water.
It is possible to regulate the flow without loss.	It is not possible to regulate the flow without loss.
Impulse Turbine has more hydraulic efficiency.	Reaction Turbine has relatively less efficiency.
Impulse Turbine operates at high water heads.	Reaction turbine operates at low and medium heads.
Example of Impulse turbine is Pelton wheel.	Examples of Reaction Turbine are Francis turbine, Kaplan and Propeller Turbine, Deriaz Turbine, Tubuler Turbine, etc.

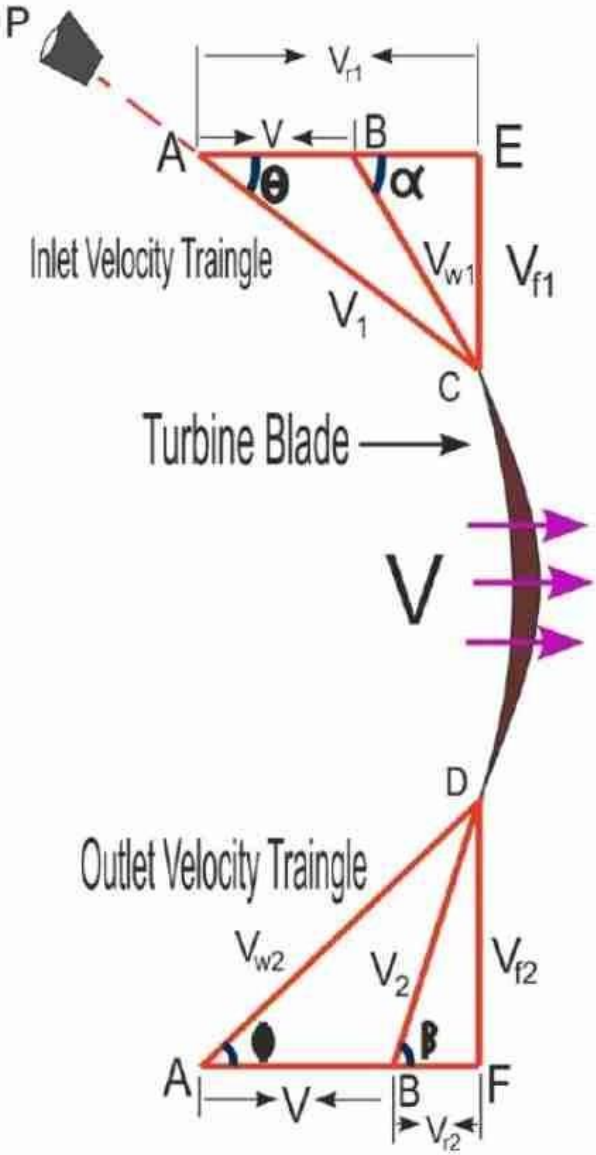
Performance of Steam Turbine:-

Steam turbine is a heat engine that converts heat energy of the high temperature and pressure steam to kinetic energy and then kinetic to mechanical energy in two stages and/or electrical energy with alternators.
→Therefore, the maximum thermal efficiency conditions have to take into account while steam turbines design.

Thermal Efficiency:- (ηth)

It is defined as the ratio of the net work done W net to the heat input at the high temperature, q_{in}.

$$\eta th = W net / q_{in} = (W_T - W_P) / q_{in}$$



P = Nozzle
V = Linear velocity of blades in m/s (AB)
V_1 = Absolute velocity of steam entering the moving blades in m/s (AC)
V_2 = Absolute velocity of steam leaving the moving blades in m/s (DB)
V_{w1} = Velocity of whirl at entry of moving blades,it is a tangential component of V_1 (BC)
V_{w2} = Velocity of whirl at exit of moving blades,it is a tangential component of V_2 (DA)
V_{f1} = Velocity of flow at entrance,it is an axial component of V_1 (EC)
V_{f2} = Velocity of flow at entrance,it is an axial component of V_2 (DF)
V_{r1} = Velocity of steam relative to moving blades at entrance (AE)
V_{r2} = Velocity of steam relative to moving blades at exit (BF)
α = Angel of entering steam makes with the tangent of wheel at entrance
β = Angel of discharging steam makes with the tangent of wheel at exit
θ = Inlet angel of moving blades
ϕ = Exit angel of moving blades

Steam Turbine Velocity Diagram

Diagram Efficiency or Blade Efficiency of Steam Turbine:-

It is the ratio of work done on the blades to the energy supplied to the blades.

Let

V1 = Absolute velocity of inlet steam in m/s, m = Mass of steam supplied in kg/s,

Vr1 = Velocity of steam relative to moving blades at entrance.

Vr2 = Velocity of steam relative to moving blades at exit.

So, energy supplied to the blade/sec,

$$= \frac{m v_1^2}{2} \quad J/S$$

As we all know that the work done on the blades per second,

$$= m\,(V_{r1} + V_{r2})\,V \quad J/s$$

So, Diagram or blade efficiency equation of steam turbine is,

$$\eta_b = \frac{m\,(V_{r1} + V_{r2})\,V}{m\,V^2/2} = \frac{2\,(V_{r1} + V_{r2})\,V_b}{V^2} \quad J/s$$

Nozzle Efficiency of Steam Turbine:-

Nozzle efficiency of steam turbine is the ratio of energy supplied to the blades per kg of steam to the total energy supplied per stage per kg of steam.

The energy supplied to the blades per kg of steam,

$$= \frac{V_1^2}{2}\ (injoules)$$

So, Nozzle Efficiency equation of steam turbine is,

$$\eta_n = \frac{V_1^2\,/\,2}{1000\,h_d} = \frac{V_1^2}{2000\,h_d}$$

Gross or Stage Efficiency of Steam Turbine:-

Gross efficiency of steam turbine or stage efficiency of steam turbine is the ratio of the work done on the blades per kg of steam to the total energy supplied per stage per kg of steam.

calculation of gross or stage efficiency of steam turbine is,

Let, h1 = Enthalpy or total heat of steam before expansion through the nozzle in kJ/kg of steam, h2 = Enthalpy or total heat of steam after expansion through the nozzle in kJ/kg of steam,

Enthalpy or heat drop in the nozzle ring of an impulse wheel,

$$h_d = h_1 - h_2 \ (in\ kJ/kg)$$

Total energy supplied per stage = 1000 hd J/kg of steam

Work done on the blade per kg of steam,

$$= 1\,(V_{r1} + V_{r2})\,V \ \ J/kg\ of\ steam$$

Gross or stage efficiency,

$$\eta_s = \frac{(V_{r1} + V_{r2})\,V}{1000\,h_d} = \frac{(V_{r1} + V_{r2})\,V}{1000\,(h_1 - h_2)}$$

We know that the Gross efficiency is the multiplication of blade efficiency and stage efficiency,

$$\textbf{Stage Efficiency} = \textbf{Blading Efficiency} \times \textbf{Nozzle Efficiency}$$

Note:- All the above, steam turbine efficiency formula are important for both impulse and reaction turbine.

Steam Condenser:-

In thermal power plants, the purpose of a surface condenser is to condense the exhaust steam from a steam turbine to obtain maximum efficiency, and also to convert the turbine exhaust steam into pure water (referred to as steam condensate) so that it may be reused in the steam generator or boiler as boiler feed water.

Function of the Condenser:-

- The main purposes of the condenser are to condense the exhaust steam from the turbine for reuse in the cycle and to maximize turbine efficiency by maintaining proper vacuum.
- It creates a vacuum by condensing steam.
- Removing dissolved non-condensable gases from the condensate.
- Providing a leak-tight barrier against air, preventing excess back pressure on the turbine.

Classification of Condenser:-

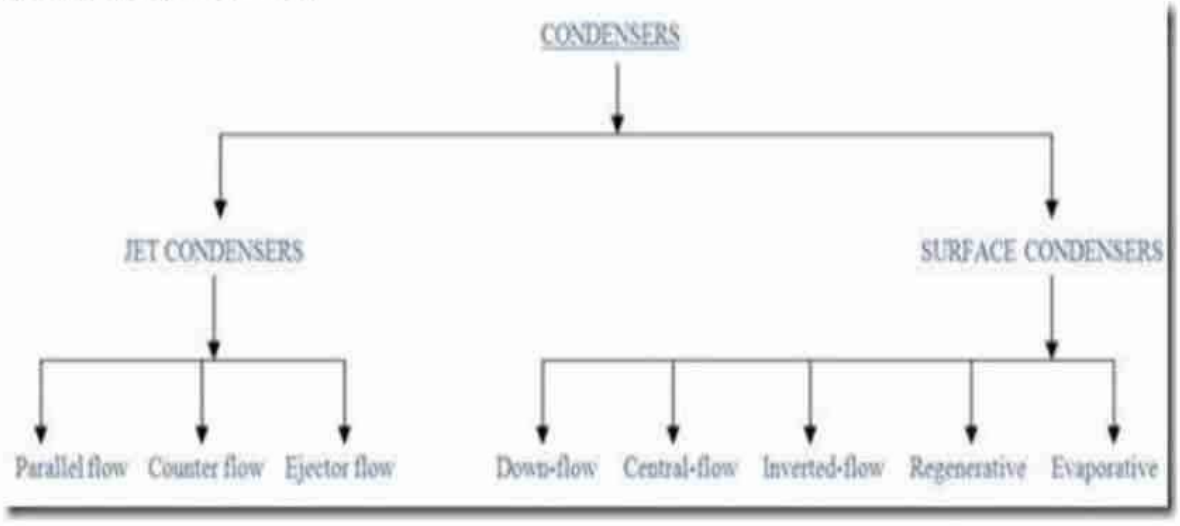
1. Jet condensers
2. Surface condenser

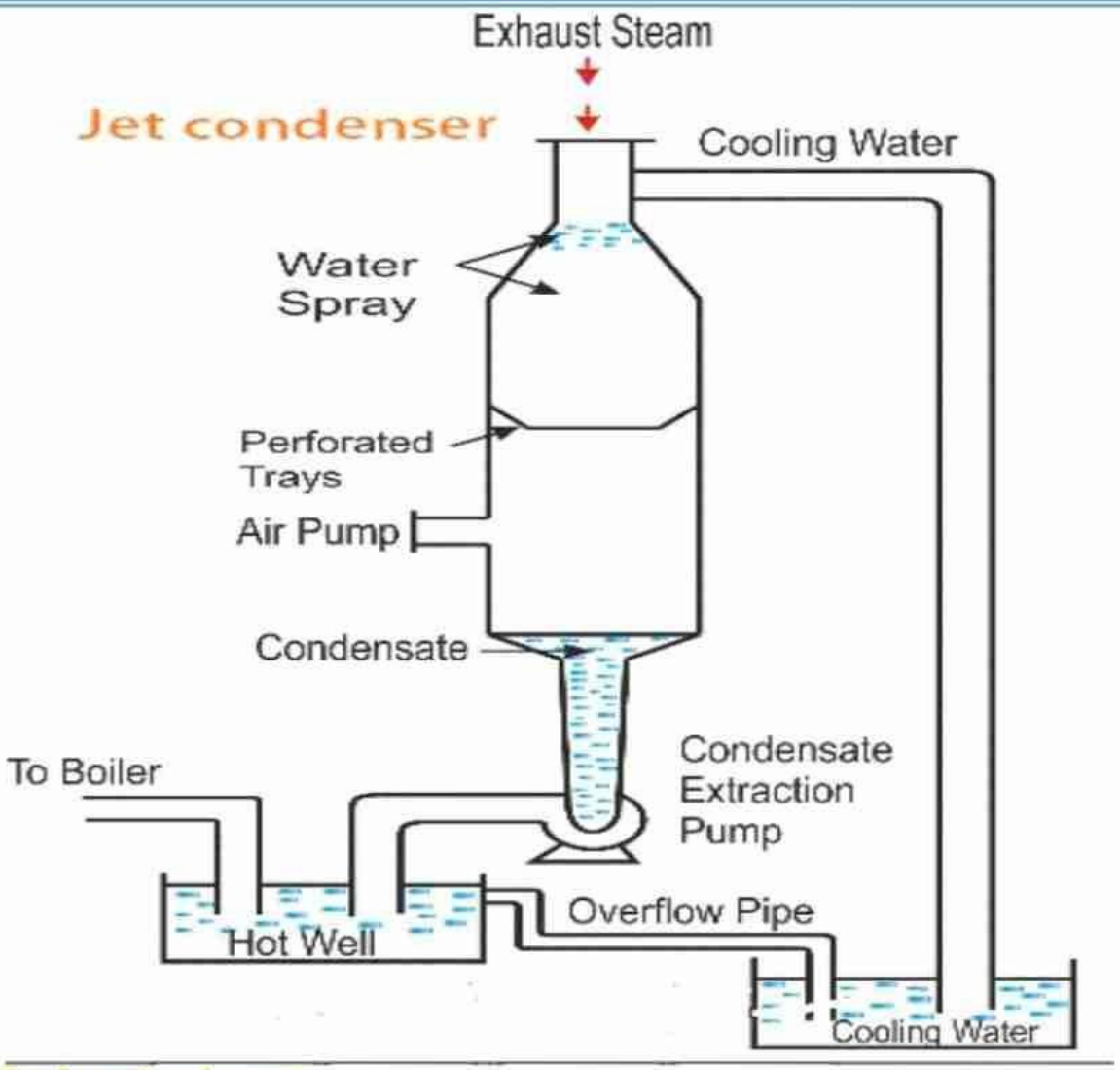
Jet Condensers:-

The exhaust steam and water come in direct contact with each other and temperature of the condensate is the same as that of cooling water leaving the condenser. The cooling water is usually sprayed into the exhaust steam to cause, rapid condensation.

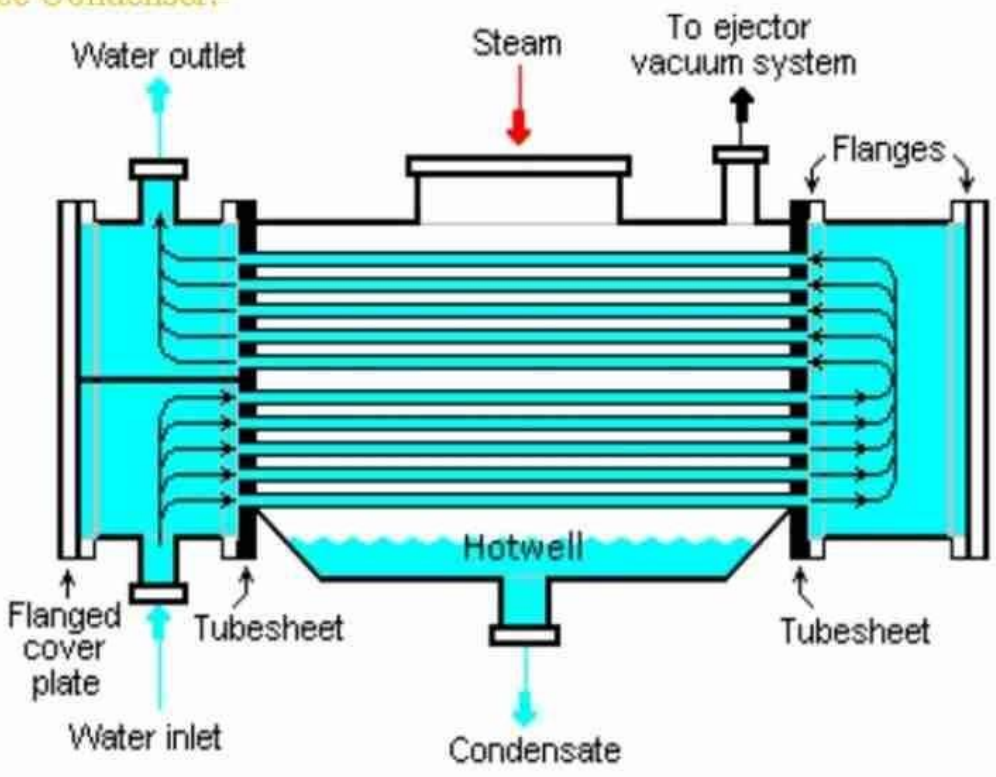
Surface Condensers:-

The exhaust steam and water do not come into direct contact. The steam passes over the outer surface of tubes through which a supply of cooling water is maintained.





Surface Condenser:-

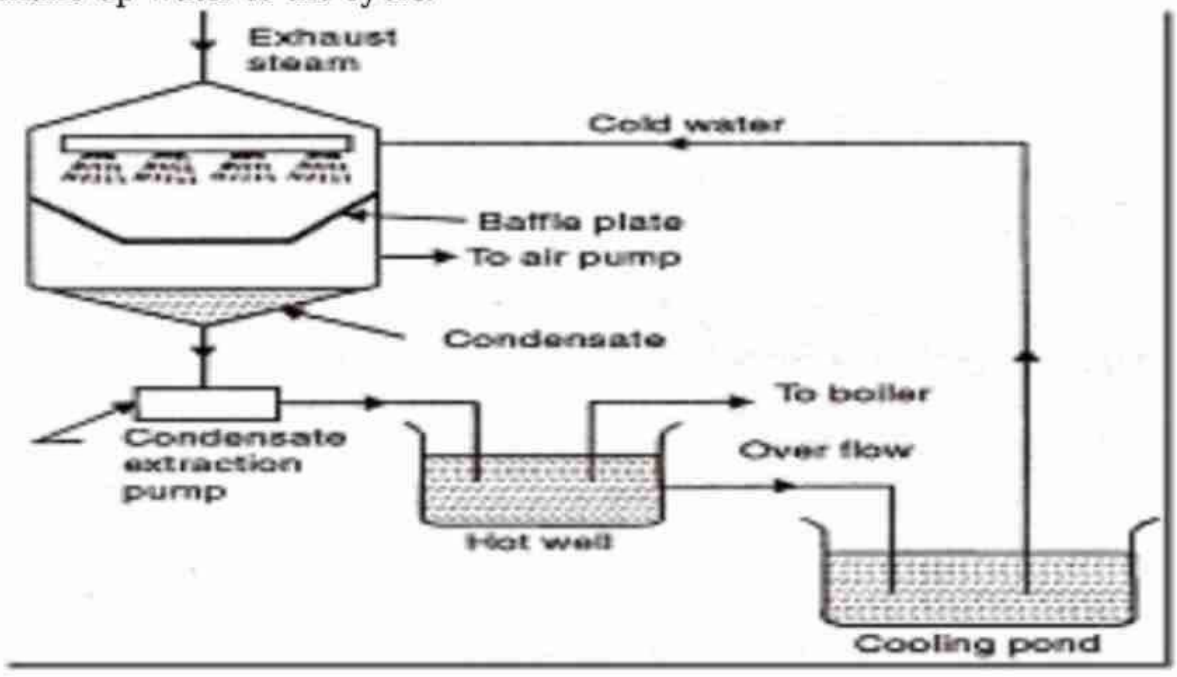


Jet condenser	Surface condenser
Direct contact	Indirect contact
Condensation due to mixing	Condensation due to heat transfer by conduction and convection
Maintenance cost is low	Maintenance cost is high.
Less Vacuum created	More Vacuum created
Small floor space required	Large floor space required
Condensate can not be directly used as feed water	Condensate can be directly used as feed water
Less power for pumping	More power for pumping
Less quantity of cooling water required	Large quantity of cooling water required
Suitable for low capacity plants	Suitable for large capacity plants

Hot well:-

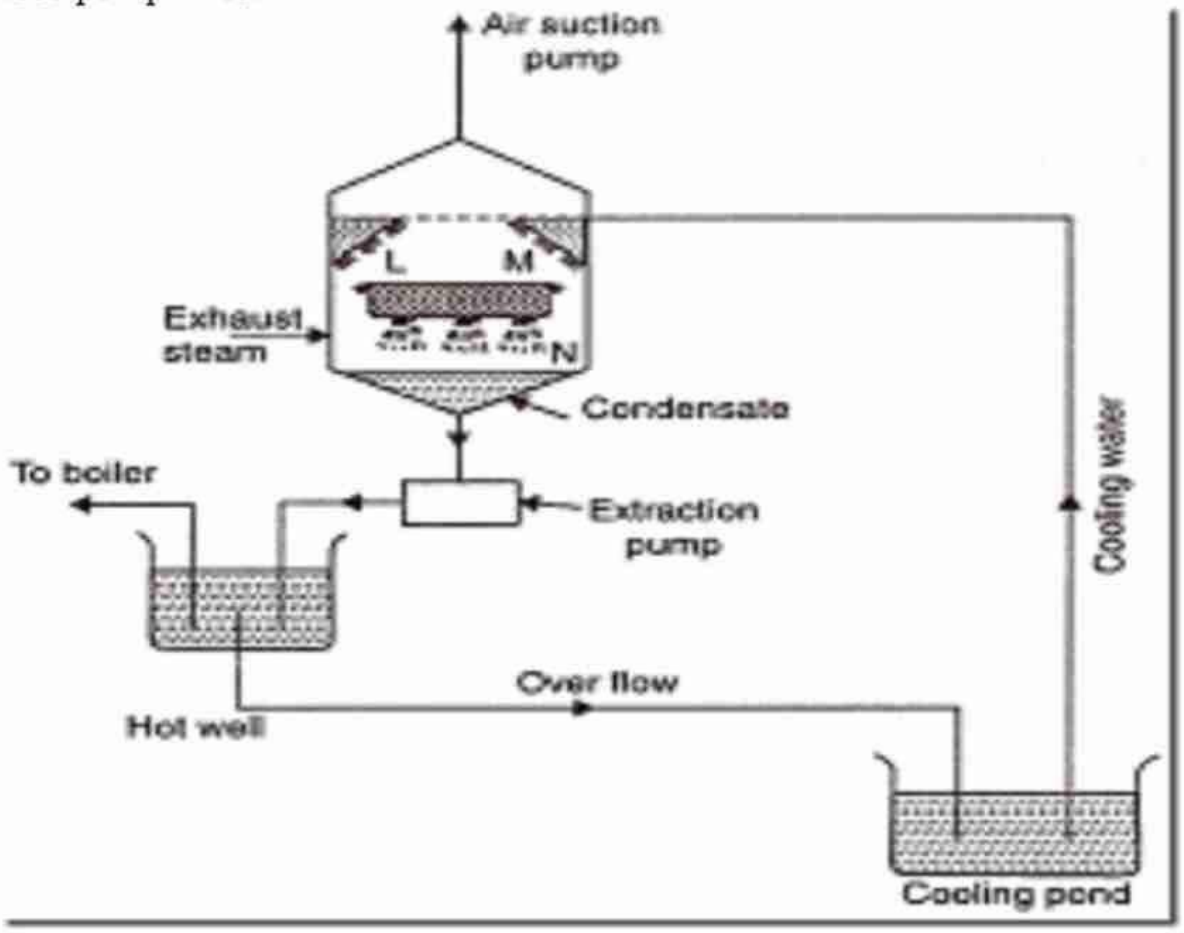
The water droplets fall like rain from the tube surfaces into the hot well situated at the bottom of the condenser. This hot well is essentially a large basin that serves as a collection point for the condensed water, otherwise known as condensate.

→The condenser hot well serves as a water reservoir for the turbine cycle. When hot well level reaches the low point, a valve opens to supply make-up water to the cycle.



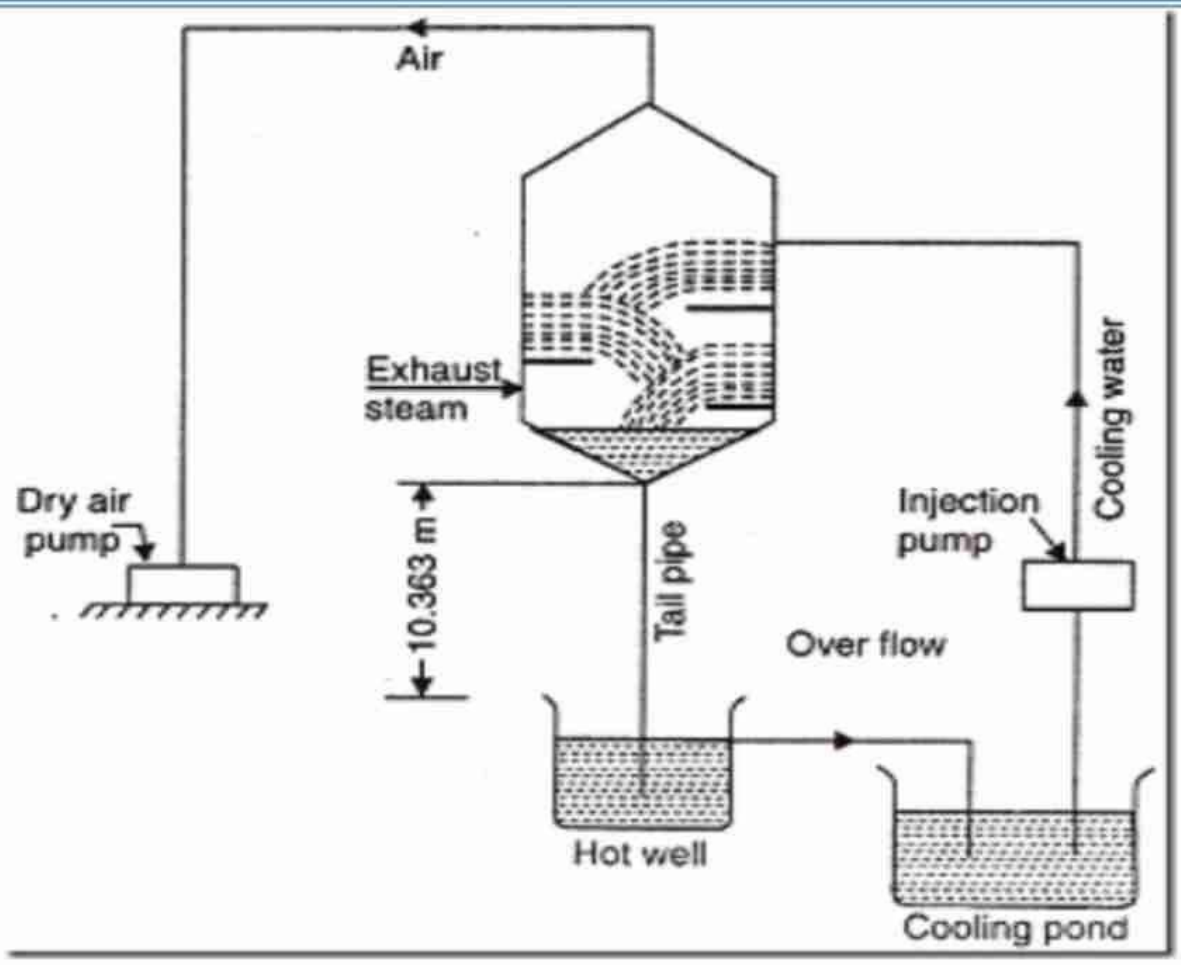
Extraction Pump:-

An extraction pump is an important part of a feed water system. Generally, fitted in between the condenser and de-aerator, the extraction pump works as an excellent tool for generating the requisite pressure, to deliver the feed water from a condenser under vacuum to de-aerator or a feed pump inlet.



Air Extraction Pump:-

It is a machine which is used in the condenser to remove condensate air from the condenser. Basically Air pump creates a vacuum in the condenser as nearly as possible, corresponding to exhaust steam temperature. It is used in the condenser to remove both air and condensate from the condenser.

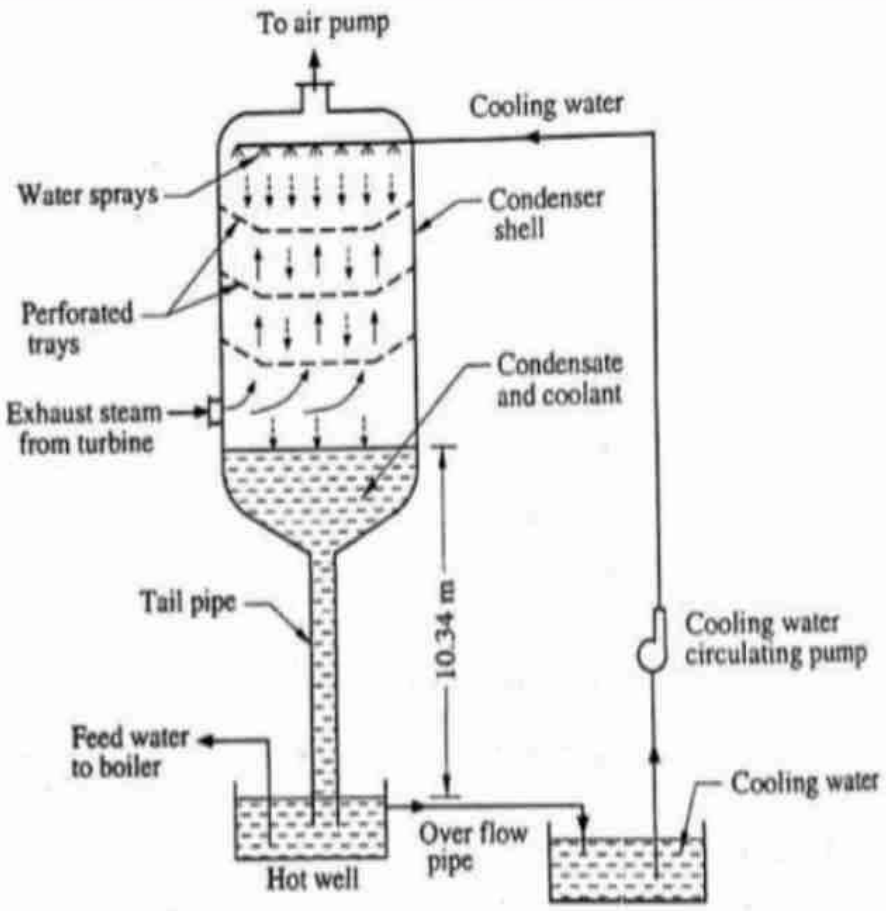


Cooling Water:-

They exchange heat by removing heat from one fluid and transferring it to another fluid. A water-cooled condenser is a heat exchanger that removes heat from refrigerant vapor and transfers it to the water running through it. In doing so, the vapor condenses and gives up heat to the water running inside the tube.

Circulating Pumps:-

It delivers cool water from freshwater sources near the power plant and pump it through the condenser to condense exhaust steam from the turbine. These pumps can be either located in dry pits or wet pits. If they are in wet pits, then they are a vertical design.


To air pump
Cooling water
Water sprays
Condenser shell
Perforated trays
Condensate and coolant
Exhaust steam from turbine
Tail pipe
10.34 m
Cooling water circulating pump
Feed water to boiler
Cooling water
Over flow pipe
Hot well

NUCLEAR POWER PLANT :-

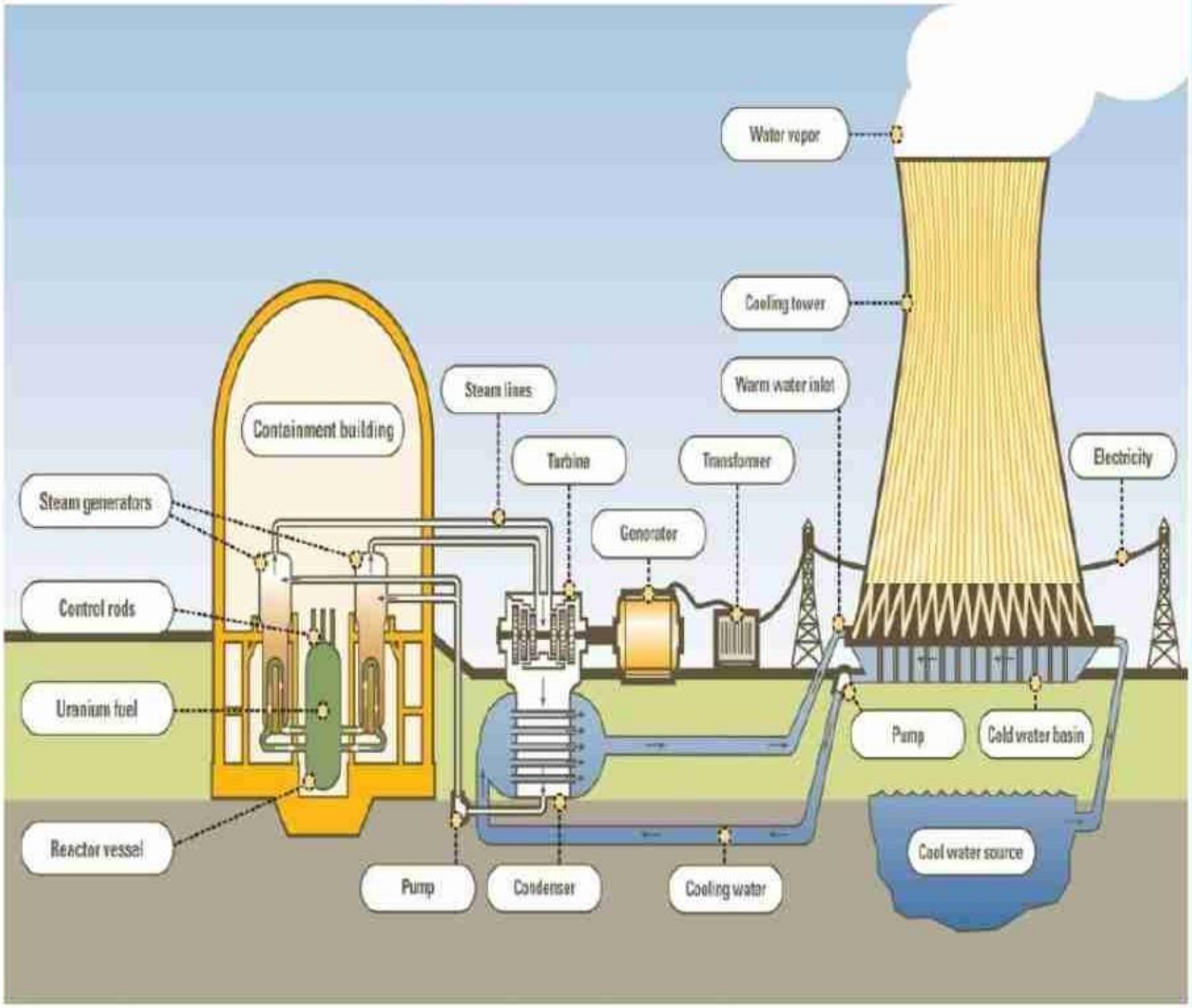
The Power Plant which uses nuclear energy of radioactive material (Uranium or Thorium) converted into Electrical Energy is known as Nuclear Power Plant.

Every power plant has its own basic principal, on the basis of this the plant works. The Basic Principal of Nuclear Power Plant is given below:

CE↔HE ↔KE ↔ME ↔EE

As we know that, the freely moving neutrons bombarded with radioactive material (U^{235} or Th^{232}) the heat energy produced, with the help of this heat energy & water a steam produced at high pressure & temperature. High pressure steam passes towards turbine where kinetic energy (KE) is converted to mechanical energy (ME). We know that, turbine & generator are mechanically coupled through this combination an Electrical Energy (EE) is produced in Nuclear Power Plant.

→Look below the simple layout diagram of nuclear power plant.



List of Nuclear Power Plant in India:-

Place	State	Type of Reactor	Total Installed Capacity
Kaiga	Karnataka	PHWR	880 MW
Kakrapar	Gujarat	PHWR	440
Madras	Tamil Nadu	PHWR	440
Narora	Uttar Pradesh	PHWR	440
Rawatbhata	Rajasthan	PHWR	1180
Tarapur	Maharashtra	PHWR BWR	1440
Kudankulam	Tamil Nadu	PHWR	1000

Atom:-

The smallest particle of a nucleus is known as atom.

→The nucleus is present in every atom central part. These nucleuses consist of number of protons & neutrons. Out of that the protons are positively charges & neutrons are negatively charged (electrically neutral).

→These nucleus carries positively charged (protons) & the electrons revolving in elliptical orbit. If the number of protons is equal to number of neutrons then the atoms are stable.

Mass Number & Atomic Number:-

Mass number is defined as the sum of atomic number & number of neutrons in the nucleus.

Atomic number is defined as the number of protons present in the nucleus. Mass number (A) = Atomic number (Z) + Number of neutrons in nucleus.

For example ${}_{2}^{4}He$ Helium having Mass Number = 4 &
Atomic Number = 2

Isotopes:-

Isotopes are defined as the atoms consist of same number of protons but different number of neutrons in the nucleus is known as isotopes.

Radioactive Isotopes:-

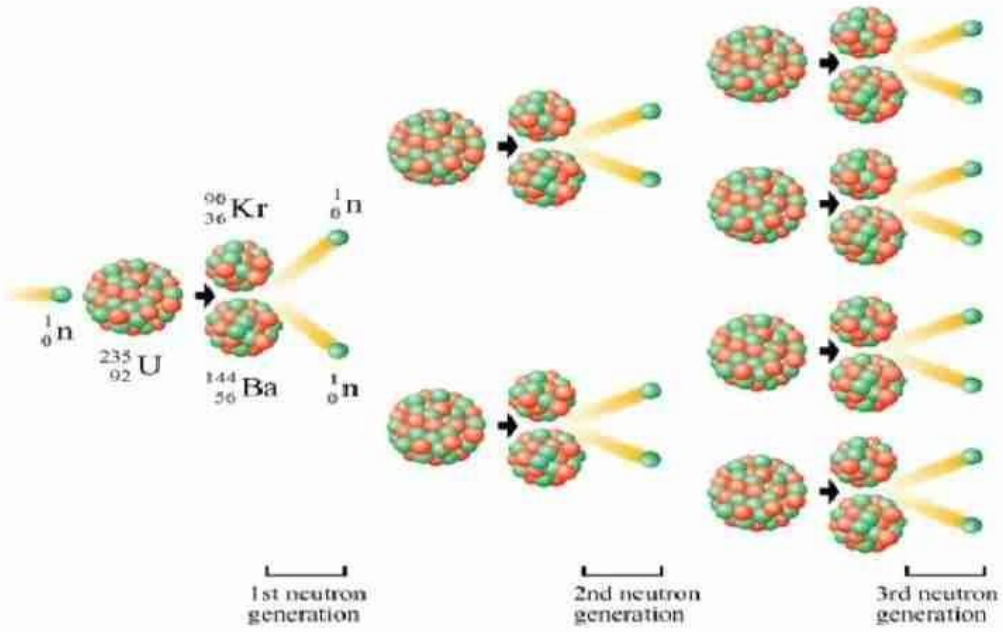
If the number of protons are not equal to the number of neutrons in the nucleus, then the atoms are unstable this is known as radioactive isotopes. For e.g. the radioactive material uranium, thorium are don't have same number of protons & neutrons because in this material too many or too few neutrons in their nucleus.

Mass Energy Equivalence:-

Mass-energy equivalence states that mass are concentrated energy.
In his theory of special relativity Einstein formulated the equation E=mc^2. There is a tremendous amount of energy in mass.
→Nuclear reactions can be understood to release so much more energy than chemical reactions because of the mass changes.

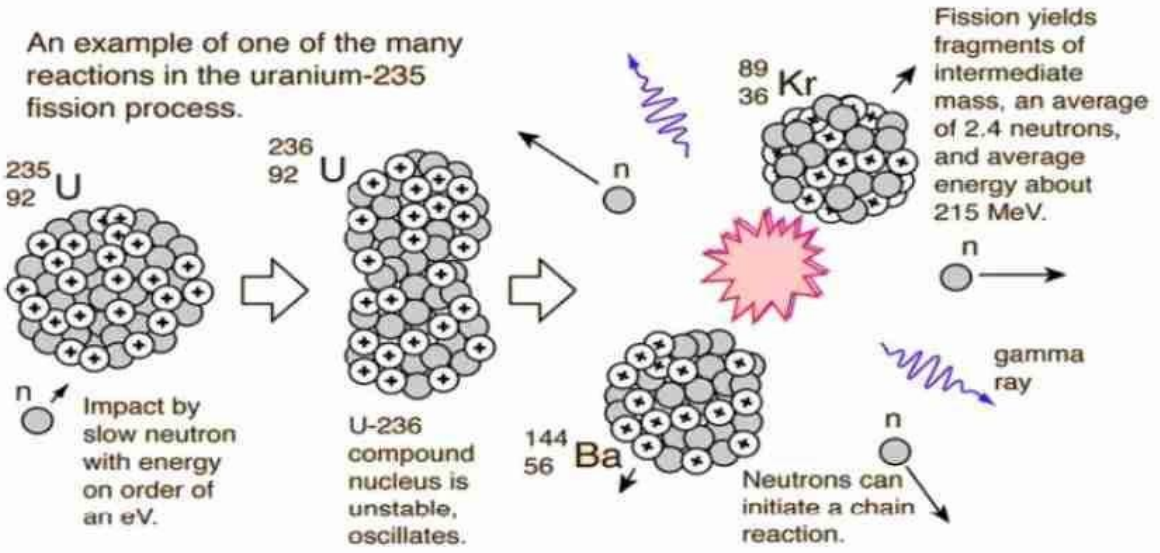
Nuclear Chain Reaction:-

The nuclear chain reaction states that: if slow moving neutrons hits (or bombarded) with the heavy or unstable nucleus, then the neutrons are absorbed & this nucleus splits into two equal or similar parts due to this process a lot of kinetic energy released in the form of heat. This process is continued, it is known as nuclear chain reaction.
→Nuclear chain reaction is possible only with heavy nucleus such as uranium, thorium & plutonium etc. because these heavy nucleuses are more unstable.



Nuclear Fission:-

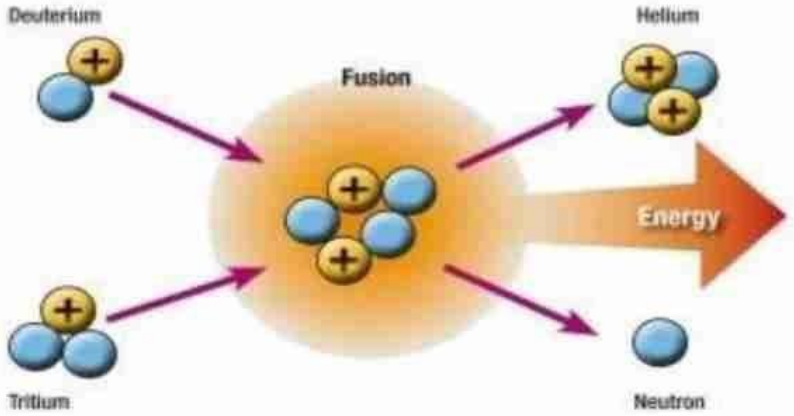
It is a process by which the nucleus of an atom is split into two or more smaller nuclei, known as fission products like uranium, thorium etc.



- It is the process of breaking the heavier nucleus.
- It emits radioactive rays
- Occurs at ordinary temperature
- Chain reaction takes place
- Emits neutrons
- It can be controlled
- Example in atom bomb

Nuclear Fusion:-

It is the process of releasing huge amount of heat energy after combining lighter nuclei to form a heavy nucleus is known as nuclear fusion.



- It is the process of combination of lighter nuclei.
- Does not emit radioactive rays.

- At high temperature(>10^6K).
- No chain reaction.
- Emits positrons.
- Cannot be controlled.
- Example in sun, stars and hydrogen bomb.

NUCLEAR FISSION	NUCLEAR FUSION
A heavy nucleus breaks up to form two lighter nuclei.	Two light nuclei combine to form a heavy nucleus.
It involves a chain reaction.	Chain reaction is not involved.
The heavy nucleus is bombarded with neutrons.	Light nuclei are heated to an extremely high temperature.
We have proper mechanisms to control fission reaction for generating electricity.	Proper mechanisms to control fusion reaction are yet to be developed.
Disposal of nuclear waste is a great environmental problem.	Disposal of nuclear waste is not involved.
Raw material is not easily available and is costly.	Raw material is comparatively cheap and easily available.

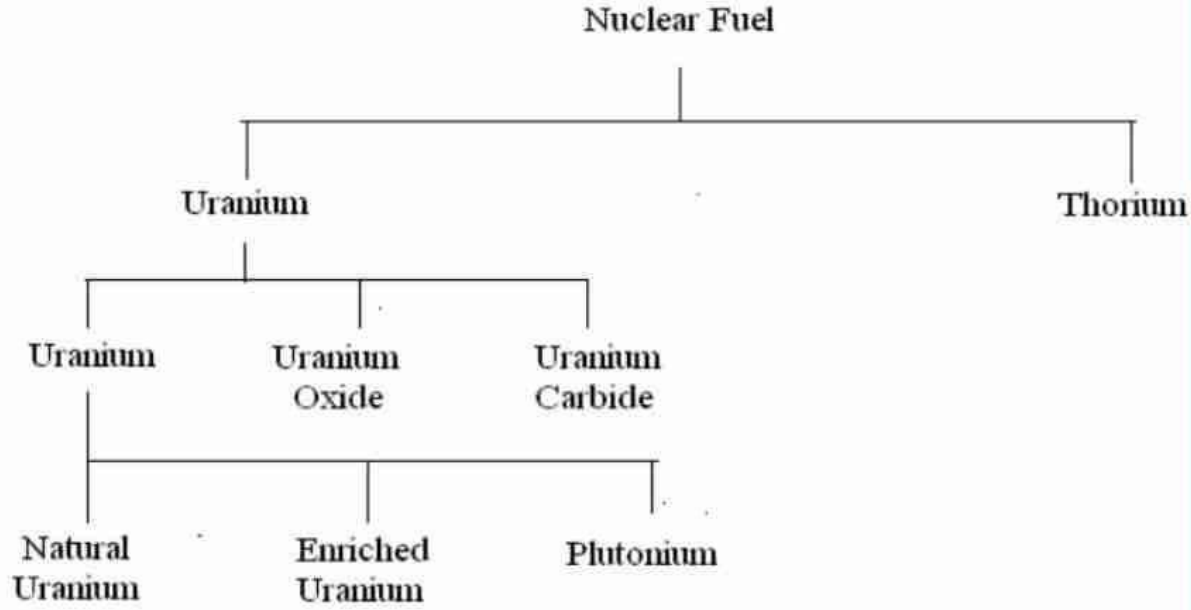
Fissile Material:-

In nuclear engineering, fissile material is material that is capable of undergoing fission reaction after absorbing thermal (slow or low energy) neutron. These materials are used to fuel thermal nuclear reactors, because they are capable of sustaining a nuclear fission chain reaction.
→List of fissile materials:
Uranium-235 which occurs in natural uranium and enriched uranium.
Plutonium-239 bred from uranium-238 by neutron capture.
Plutonium-241 bred from plutonium-240 by neutron capture.
The 240Pu comes from 239Pu by the same process.
Uranium-233 bred from thorium-232 by neutron capture

Fertile Material:-

Fertile material is a material that, although not itself fissionable by thermal neutrons, can be converted into a fissile material by neutron absorption and subsequent nuclei conversions.
In nuclear engineering, fertile material (nuclide) is material that can be converted to fissile material by neutron transmutation and subsequent nuclear decay.
→The process of the transmutation of fertile materials to fissile materials is referred to as fuel breeding.

→There are two basic fertile materials: 238U and 232Th.

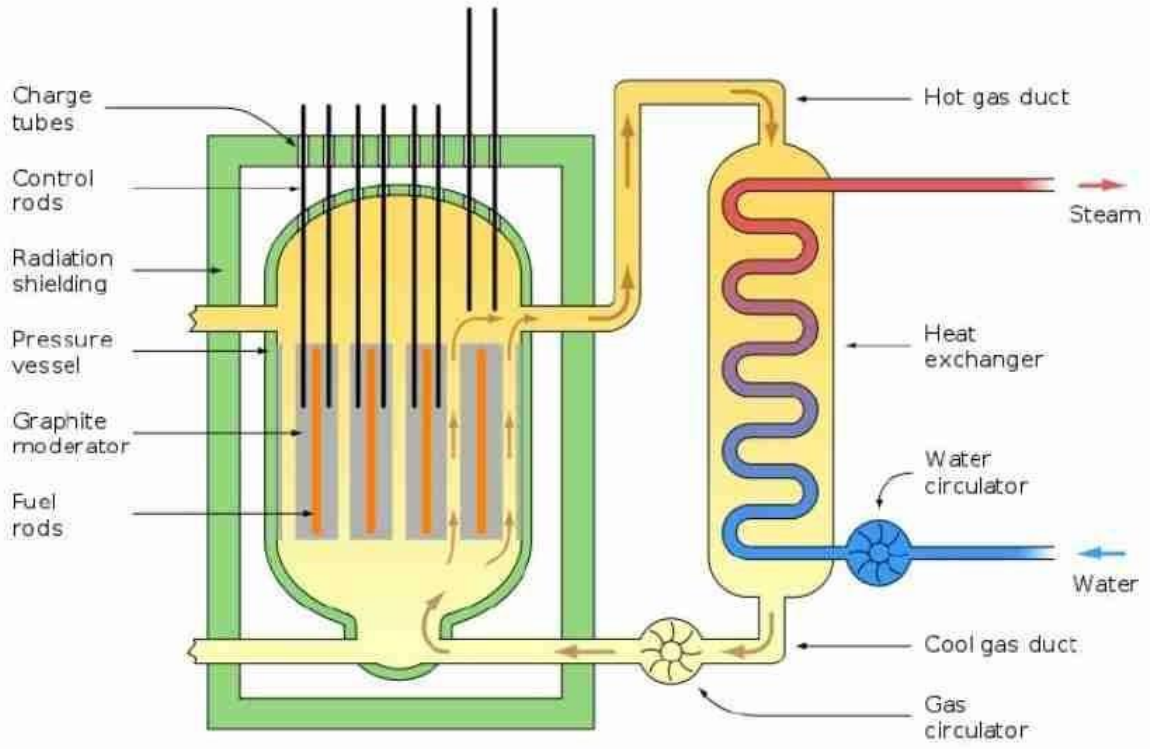


Enriched Uranium:-

The Process used to increase the percentage of U-235 is known as enrichment. This will help us to maintain chain reaction

Main Parts of Nuclear Reactor:

- Nuclear Fuels.
- Moderator.
- Control rods.
- Reflectors.
- Shielding.
- Reactor vessel.
- Heat Exchanger.
- Coolant.
- Turbine.
- Condenser.
- Cooling Tower.
- Water Treatment Chamber.



Nuclear Fuels:-

The fuel is required in nuclear power plant to produce a huge amount of heat energy. The fuel are inserted in fuel rod, these fuel rods are bombarded with slow moving neutrons. Separate provision provided for bombarded or hits the neutron to the fuel rod, this device is known as neutron bombardment device.

Moderator:-

In nuclear power plant, moderator is a device, of rod shaped. Moderator is placed near the nuclear fuel rod.

→The main function of moderator in nuclear power plant is to reduce the speed of neutrons (neutron at slower speed is required to produce fission) & increases the fission processes. Moderator rod is made up of graphite or heavy water or beryllium material.

Control Rods:-

In nuclear power plant, the control rods are placed in between nuclear fuel rod, moderator and then control rod. These control rods are operated either automatically or manually. (To start or stop the chain reaction).

→In nuclear power plant the main function of control rod is to control the chain reaction. If the control rod is inserted then it absorbs the freely moving neutrons & stop the chain reaction, if it is no inserted chain reaction is in process, means chain reaction continued.

→The steady rate or to stop the chain reaction is maintained through control rods. The control rods are made up of cadmium, boron (alloyed with steel or aluminum).

Reflector:-

Before shielding, the reflector is placed. The reflector is used to surround the reactor core. The reflector will also help to bounce the escaping neutrons back to the reactor core & it conserve the nuclear fuel.

Shielding:-

Shielding is the also important part of nuclear power plant, shielding is in other words protecting. In nuclear reactor, first one is nuclear fuel rod then moderator, control rod & reflector. Through this shielding is provided. When the chain reaction starts, heat energy start to produce. During this period lots of radiation or rays are produced, these are very harmful; to avoid this shielding is provided in reactor.

Reactor Vessel:-

After shielding the next layer is a reactor vessel. This vessel encloses reactor core, reflector, shielding. It is used to protect complete nuclear reactor. Few holes are provided in the top portion of reactor vessel to insert control rods & at lower side of this vessel fuel & moderator assembly are placed.

Heat Exchanger:-

The main function of heat exchanger in nuclear power plant is the boiled the cold water and produces steam at high temperature & pressure.
Heat exchanger is used in nuclear power plant, to exchange the heat i.e. it consists of one input to feed the cold water & output to flow of hot steam.
→The heat exchanger receives the heat from reactor, this heat is continuously circulated through pipe, before it is re-entered to the reactor it is filted.
→By using this heat a heat exchanger boils the cold water produces steam at high temperature & Pressure. Further this steam passes to the steam turbine for generation of electrical power.

Coolant:-

The coolant becomes a cold metal. In coolant the gases are used like carbon dioxide, air, hydrogen etc. the heats from the heat exchanger are re-circulated to the reactor through pump after filtration. During filtrations the unwanted impurities in the coolant are removed.

Turbine:-

We know that, the turbine is a mechanical device and it is mechanically coupled with alternator. In case of nuclear power plant turbine receives steam from heat exchange at high pressure, and it rotates at high speed then alternator also rotates, this way electrical power produced. The exhaust steam from turbine passes to condenser for further use.

Condenser:-

The condenser receives an exhaust hot steam from turbine; with the help of water it is cooled. Water taken from available water sources e.g. river and is filtered in water treatment plant. This water is re-circulated to heat exchanger through feed water heater & Pump.

Cooling Tower:-

The cooling towers are used to convert the hot water or steam exhausted from turbine into normal water. That is, its temperature decreases at normal temperature.

Water Treatment Chamber:-

The water treatment chamber provides filter water to the cooling tower, condenser through available water source. It also reduces unwanted impurities in the stored water.

Types of Nuclear Reactor:-

The nuclear reactors are classified into four types. These are mentioned below:

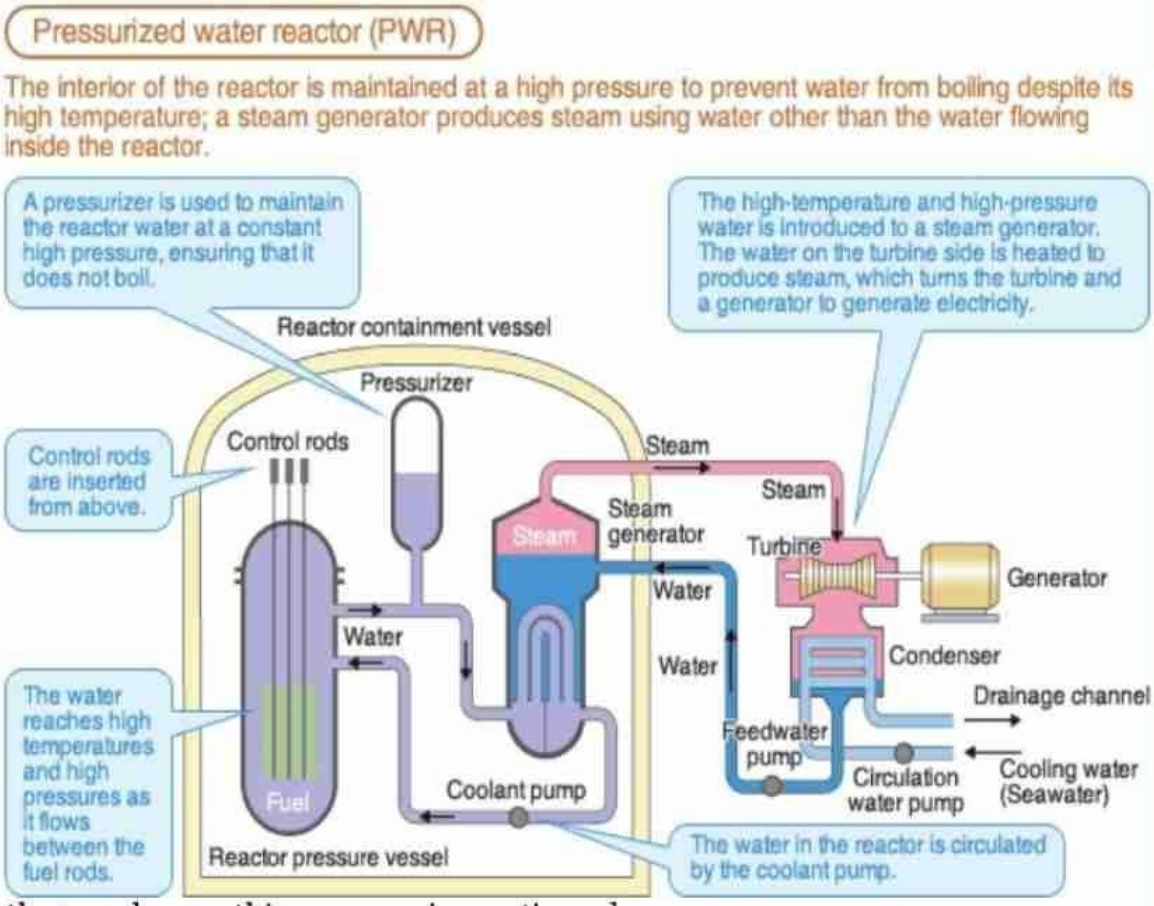
1. Pressurised Water Reactor (PWR).
2. Boiling Water Reactor (BWR).
3. Advanced Gas Cooled Reactor (AGCR).
4. Fast Breeder Reactor (FBR).

Pressurised Water Reactor (PWR):-

In PWR the enriched uranium fuel is used. When the chain reaction starts the reactor core produces heat energy at high temperature. This produced heat energy passes to the heat exchanger. We have passed the hot metal to the heat exchanger, this metal is also radioactive, and that's why heat exchanger also requires shielding.

→The pressure equalizer uses to maintain the pressure of hot metal. In heat exchanger, other side tubes of water are inserted. This will help us to boil the water & Produces steam at high pressure.

→This steam passes to the steam turbine for the generation of electrical energy with the help of alternator. After that the exhausted steam passes

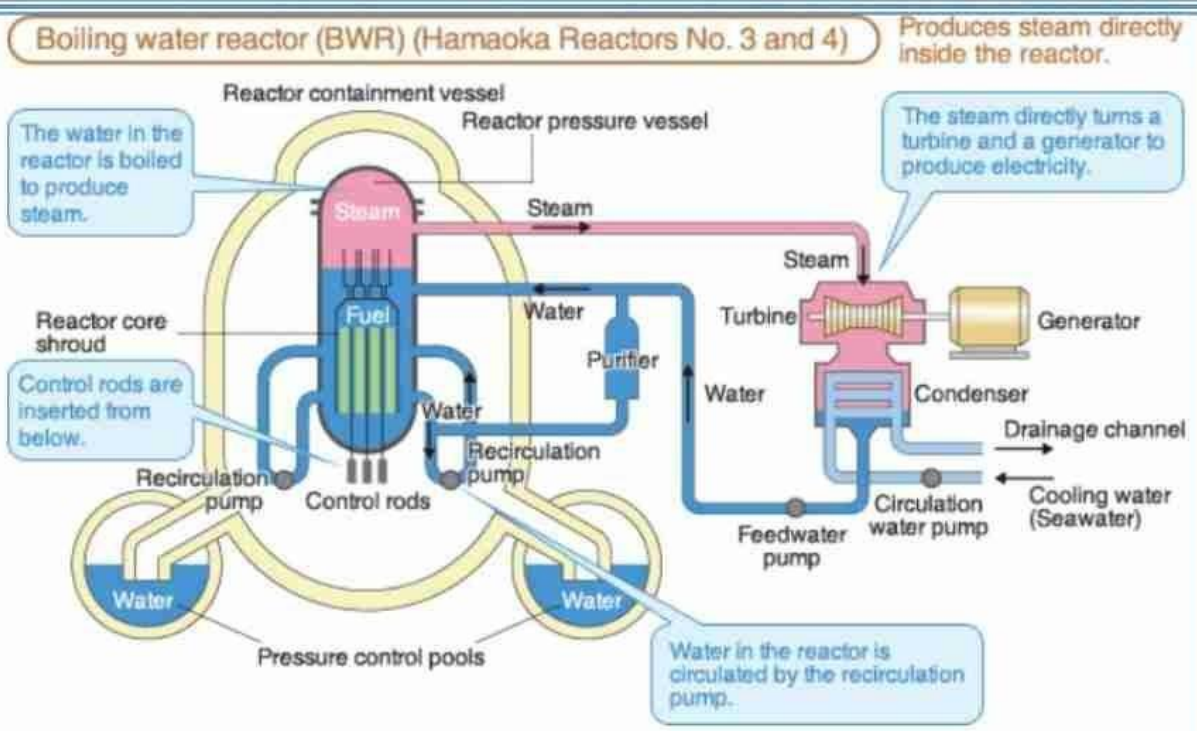


to the condenser this process is continued.

Boiling Water Reactor (BWR)

In BWR, the enriched uranium fuel is used in reactor. In this type of reactor water is directly passes to the bottom of reactor core. When the chain reaction starts, the reactor core produces a heat energy, which is help full to boiled the water & produced steam at high temperature & Pressure.

→This steam passes to the turbine, through turbine-alternator combination electrical power produced. The exhausted steam from the steam turbine passes to the condenser. Where it is condensed, and again passes to the reactor core through pump.



	BWR	PWR
Thermodynamic Cycle	Single loop (turbine steam directly from reactor) - lower capital cost	Two loops - higher capital cost
	Lower pressure (7 MPa) decreases capital cost	Higher pressure (15 MPa) increases capital cost
Power Density (kW/liter)	Low power density due to boiling moderator	High power density
	Better power distribution	Must use zone loading to flatten power distribution
Major Equipment	Larger pressure vessel (due to low power density)	Smaller pressure vessel
	Thinner vessel walls (lower pressure)	Thicker vessel walls (higher pressure)
	Steam separators	Steam generator, pressurizer
Control	Control by rods and burnable poison	Control by rods, burnable poison, and chemical shim
	Use jet pumps to load follow	Natural ability to load follow
Core Design	Larger fuel pins, smaller burnup	Smaller diameter fuel pins, larger burnup
Materials Problems	Lower temperatures	Higher temperatures
	Little control over coolant purity	Good control over coolant purity

Disposal of Nuclear Waste:-

Based on this means the level of radioactivity material or radiations, nuclear waste management is classified into three types:

1. Low Level Waste (LLW)
2. Intermediate Level Waste (ILW)
3. High Level Wastage (HLW)

LLW (Low Level Waste):-

In case of low level waste, the (% Content of Radioactivity) radioactive level is very less. Normally, this type of waste comes from industries, hospitals, small nuclear plant. At the time of handling & transport the low level waste, it does not require shielding. The low level waste buried in land with suitable depth at the time of disposal.

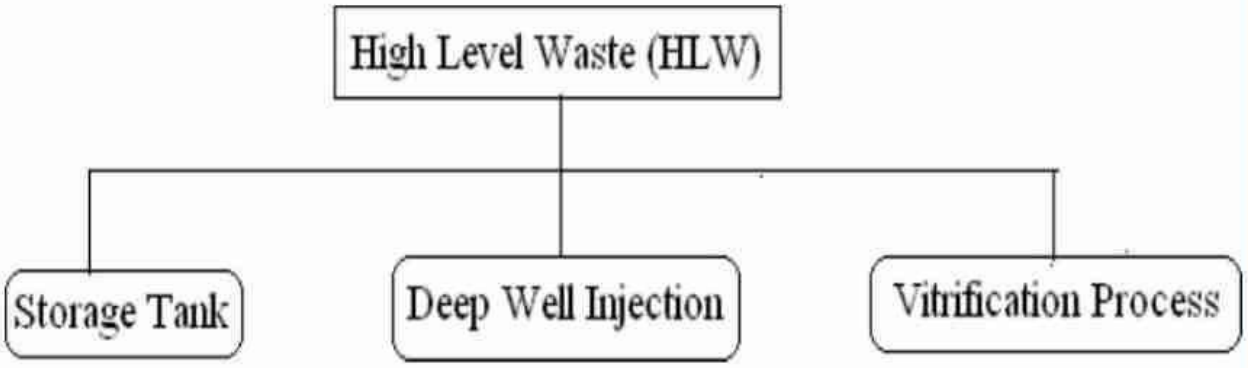
ILW (Intermediate Level Waste):-

The percentage of radioactivity is higher as compared with low level waste. At the time of handling & transportation shielding is required because, the produce radioactive are very difficult. It means that it's affected to human health. At the time of ILW disposal first up all it is placed in concrete container, after that it is well sealed. Finally the ILW is buried in underground facility.

HLW (High Level Waste):-

As compared with LLW & ILW, the HLW is very dangerous to handling as well as it is directly affected to human health. Most of accidents in nuclear power plants are occurred due to this HLW. At the time of handling it requires shielding as well as cooling. The HLW mainly comes from reprocessing of nuclear fuel in the reactor. The HLW is obtained in liquid form & the heat % is very high.

→ There are three ways to dispose the HLW.



With the help of Storage Tank:-

The agitator is placed, which is rotating type. In that agitator the high temperature liquid waste is kept. Due to its continuous rotation, & outer cooling, it will help to its high temperature is converter into its normal value. For the protection & leak proof purpose the closed vessel surrounded by stainless steel tank & concrete layer. Whenever the tank is full, it will be well sealed & buried underground.

Disposal through Deep Well Injection:-

In this method, first up all the high temperature liquid HLW is kept in storage tank. Then with the help of pumps these liquid HLW is sent to ground at high pressure. Its depth is normally 3500 to 16000 feet.

Vitrification Process:-

We know that, the HLW is liquid form & it is difficult to handling and disposal. To overcome this drawback in vitrification process first up all it is converted into solid form (the liquid form of HLW is converted into solid form is known as vitrification).

→Whenever the liquid HLW is kept with steel container, it is mixed with glass forming material through heating process. Due to this a solid glass is formed which is put in steel container, after that it is surrounded by reinforced concrete. These tanks are now ready for disposal.

There are two ways of disposing these solid waste tanks:

- It can be kept in trench deep underground.
- It can be suspended in sea beads.

Advantages of Nuclear Power Over Thermal Power Plant:-

- A nuclear power station occupies much smaller space compared to other conventional power station of same capacity.
- This station does not require plenty of water, hence it is not essential to construct plant near natural source of water.
- This also does not required huge quantity of fuel; for e.g. 1 kg of uranium produces a heat which is equivalent to 4300 tonnes of coal.
- It is possible to locate the plant near to load center
- If bulk power is produced it is economical.
- Clean operation.
- Area required is very less.
- Independent of geographical conditions.
- Saving of natural resources such as coal, oil, gas etc.

Disadvantages of Nuclear Power Over Thermal Power Plant:-

- The fuel is not easily available and it is very costly.
- Initial cost for constructing nuclear power station is quite high.
- Erection and commissioning of this plant is much complicated.
- The fission by products is radioactive in nature, and it may cause high radioactive pollution.
- The maintenance cost is higher and the man power required to run a nuclear power plant is quite higher since specialty trained people are required.

- Sudden fluctuation of load cannot be met up efficiently by nuclear plant.
- It is very big problem for disposal of this by products. It can only be disposed deep inside ground or in a sea away from sea share.
- Enrichment technology is essential for fuel processing & fabrication.
- Maintenance cost is very high.
- Waste disposal is problematic.
- For variable load it is not suitable.
- Construction is complicated.

DIESEL ENGINE POWER PLANT:

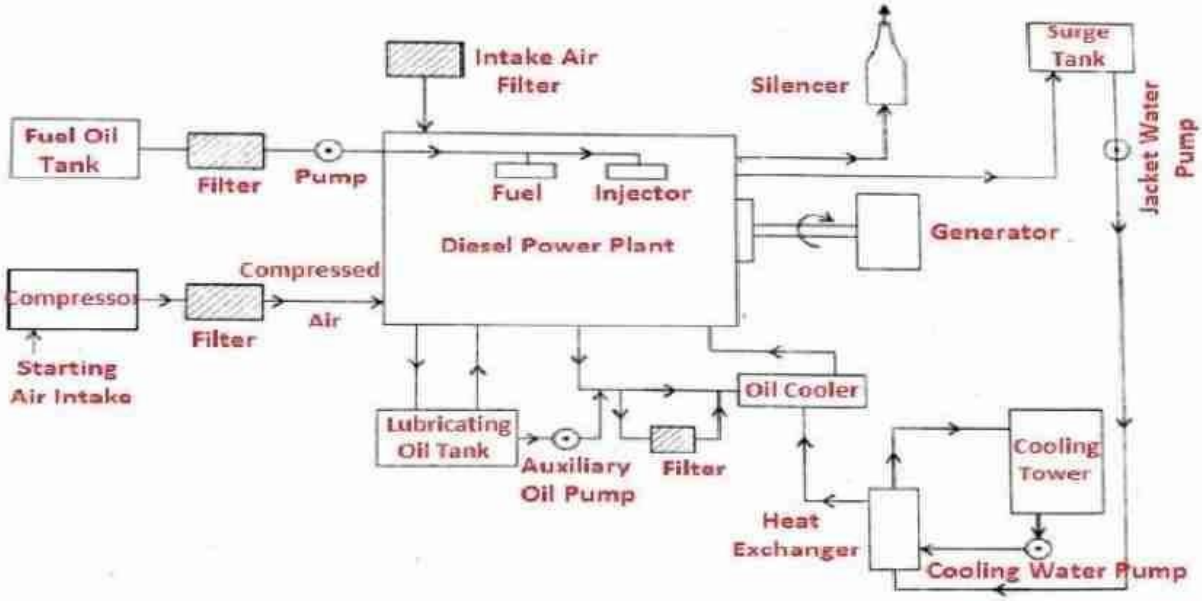
In a diesel power station, diesel engine is used as the prime mover. The diesel burns inside the engine and the products of this combustion act as the working fluid to produce mechanical energy. The diesel engine drives alternator which converts mechanical energy into electrical energy.

→As the generation cost is considerable due to high price of diesel, therefore, such power stations are only used to produce small power. Although steam power stations and hydro-electric plants are invariably used to generate bulk power at cheaper costs, yet diesel power stations are finding favour at places where demand of power is less, sufficient quantity of coal and water is not available and the transportation facilities are inadequate. This plants are also standby sets for continuity of supply to important points such as hospitals, radio stations, cinema houses and telephone exchanges.

Chemical Energy of Diesel ↔ Heat Energy ↔ Mechanical Energy ↔Electrical Energy

Main Components of Diesel Electric Power Plant:-

- Diesel Engine.
- Engine Fuel Supply System.
- Engine Air Intake System.
- Engine Exhaust System.
- Engine Cooling System.
- Engine Lubrication System.
- Engine Starting System.
- AC or DC Generators.
- Governing System.

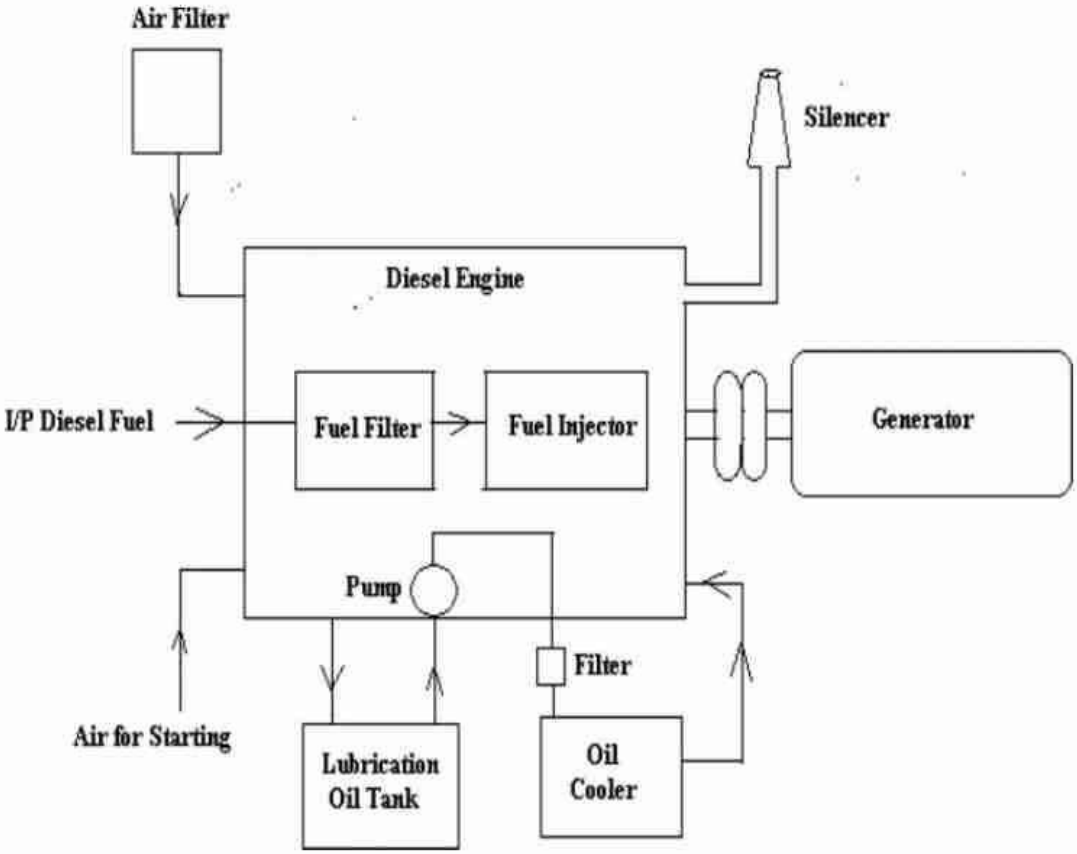


Schematic Diagram of Diesel Power Plant

Diesel Engine:-

It is the main components used in diesel electric power plant for developing mechanical power. This mechanical power we use to run the generator & produce electrical energy. For producing the electrical energy the diesel engine is mechanically coupled to generator.

When the diesel fuel burning inside the engine, its start to produce a mechanical power. The combustion of diesel fuel produces increased temperature & pressure inside the engine. Due to this pressure gases are formed, this gas pushes the piston inside the diesel engine, and then mechanical power is produced. With the use of this mechanical power the shaft of diesel engine starts rotating.

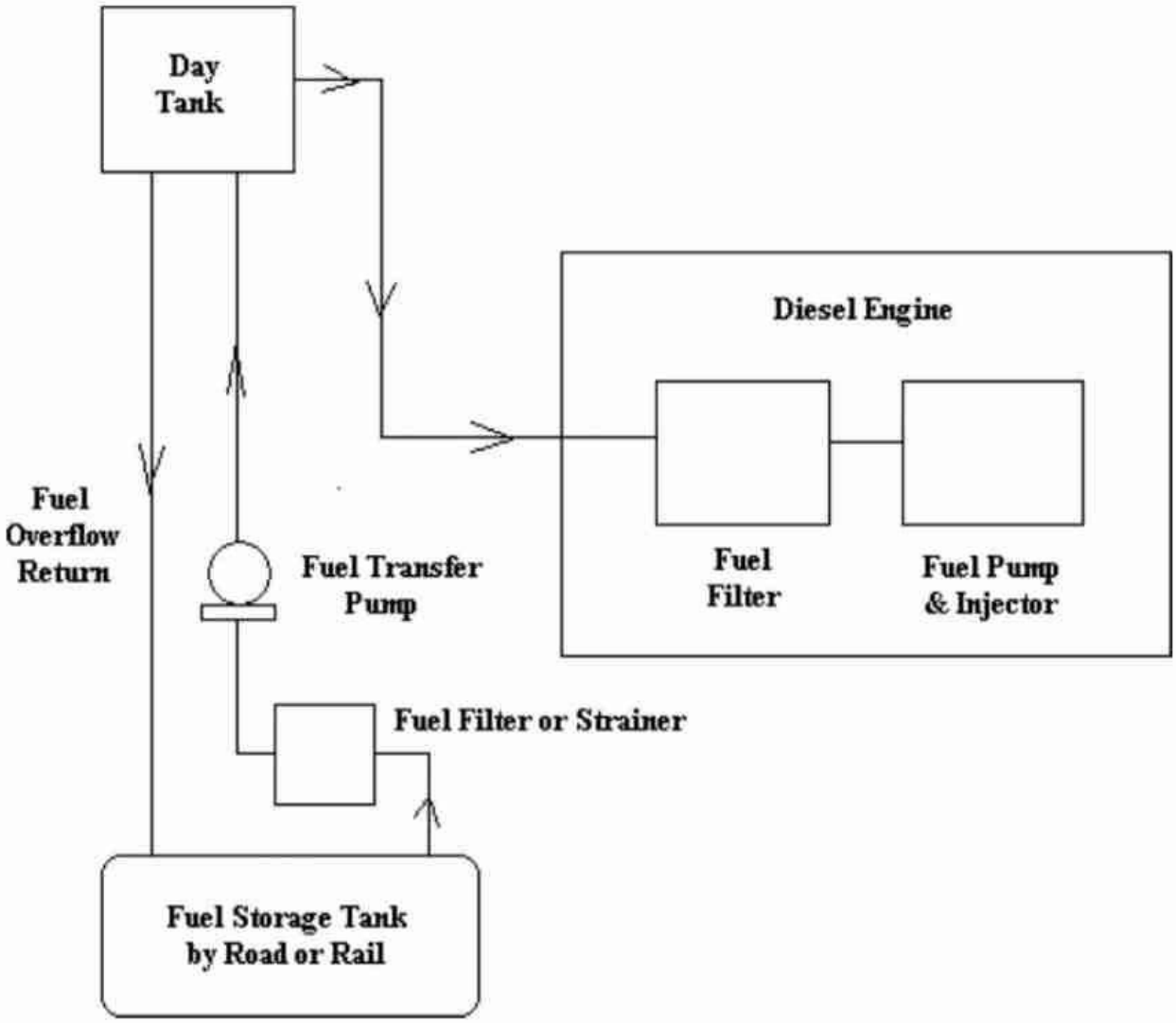


Engine Fuel Supply System:-

It consists of Fuel Storage Tank, Fuel Filter or Strainer, Fuel Transfer Pump, Day Tank, Heaters & Connecting Pipes.

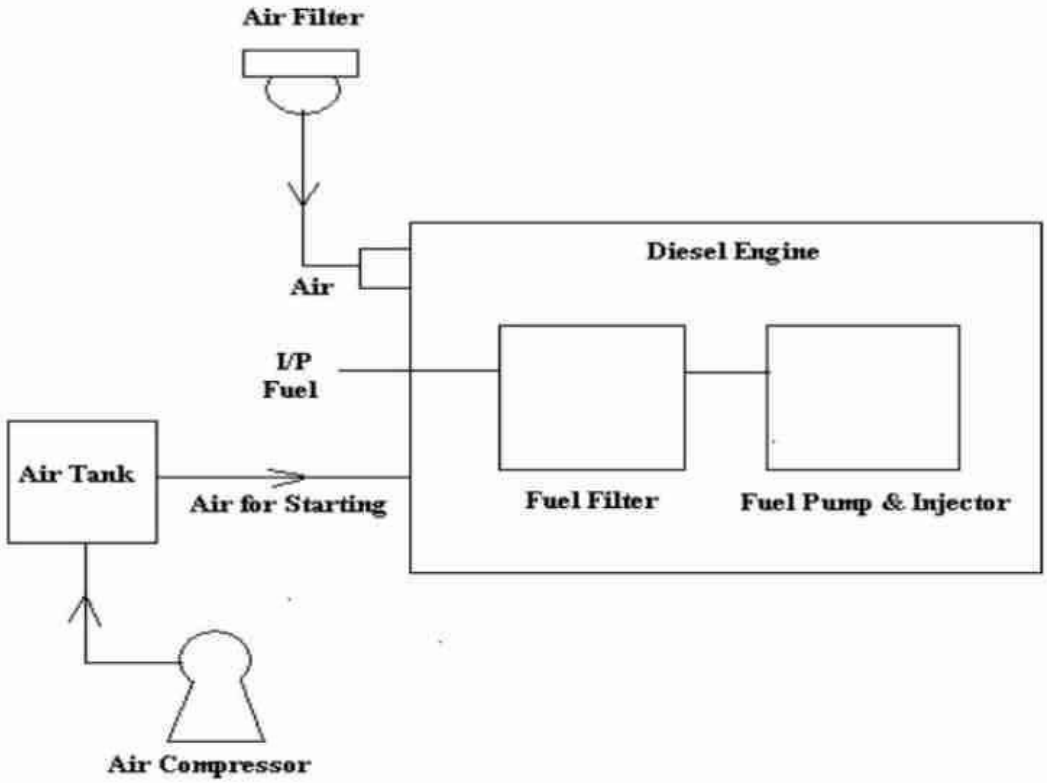
First up all with the help of transportation facility available (road, rail etc.) the diesel fuel stored in storage tank. Then this diesel fuel transfer to day tank, the function of day tank is how much quantity of diesel required for 24 hours is store. If the day tank is full or overflow occurs, then excessive diesel returned to storage tank. The filter or strainer is used to

purify diesel. With the help of fuel transfer pump the diesel is transfer to day tank.



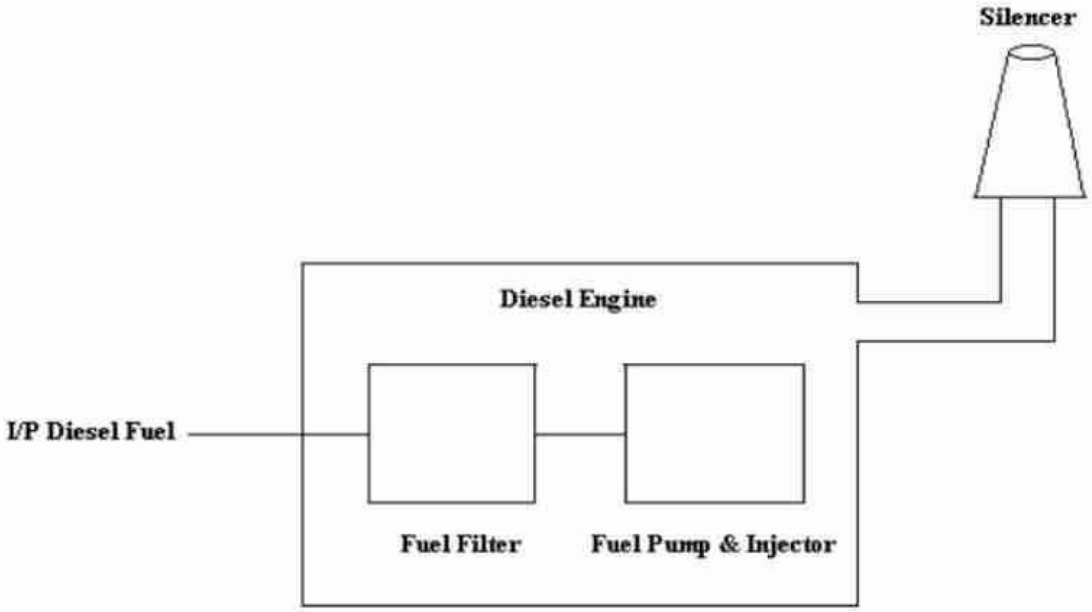
Engine Air Intake System:-

This System includes air filters, air tank, compressor & connecting pipes. The air filters are used to supply the fresh air to diesel engine for the purpose of combustion. Engine required fresh air because, if dust particles in the air entered into the engine will cause disastrous effect to valve, cylinder & pistons. The compressor or Supercharger is used to increase pressure of the air supplied to the engine. This will helps to increase the output power.



Engine Exhaust System:-

These systems consist of silencers & connecting ducts. As the temperature of the exhaust gases is sufficiently high, it is used for heating the fuel oil or air supplied to the diesel engine. The exhaust gas is removed from engine, to the atmosphere by means of an exhaust system. A silencer is normally used in this system to reduce noise level of the engine.



Engine Cooling System:-

The Diesel Engine Cooling System Consist of coolant pumps, water cooling towers or spray pond, water treatment or filtration plant & Connecting Pipe Works.

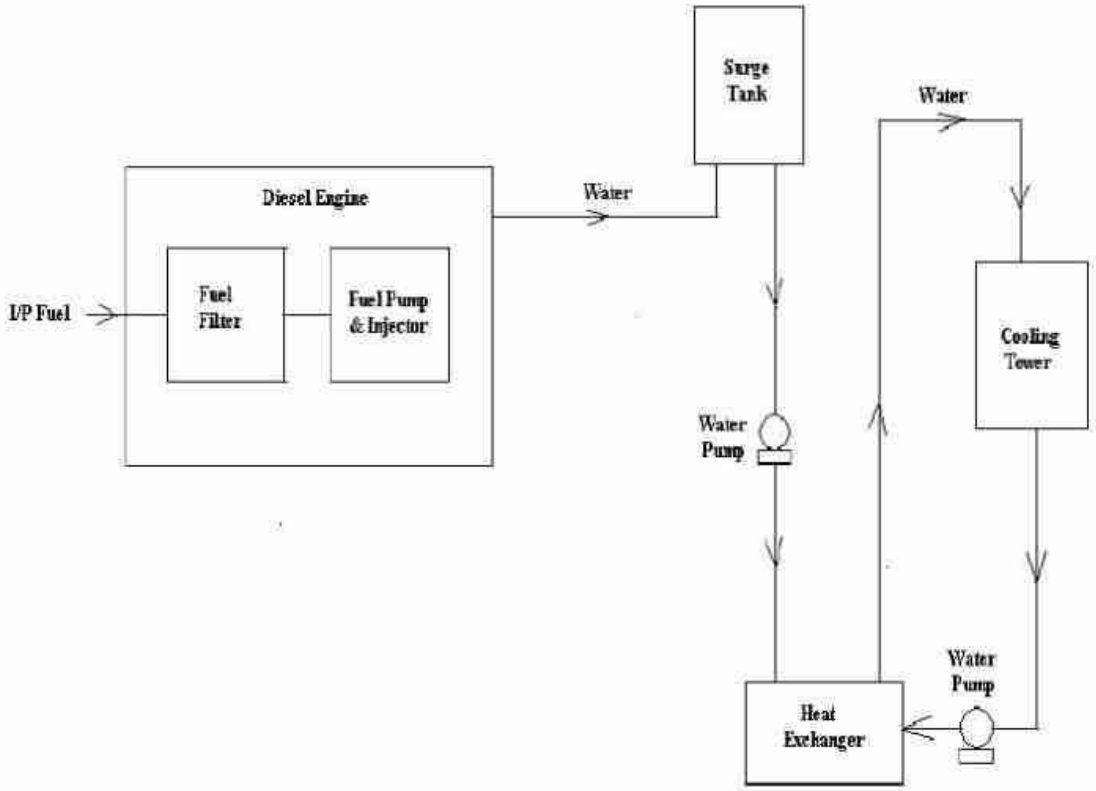
→The heat produced due to internal combustion, drives the engine. But some parts of this heat raise the temperature of different parts of the engine. High temperature may cause permanent damage to the machine. Hence, it is essential to maintain the overall temperature of the engine to a tolerable level. Cooling system of diesel power station does exactly so.

→The cooling system is required to carry heat from diesel engine to keep its temperature within safe limits. The water pump circulates water to cylinder of diesel engine to carry away the heat. The cooling tower is used for the same water reused.

→The cooling system requires a water source, water pump and cooling towers. The pump circulates water through cylinder and head jacket. The water takes away heat from the engine and it becomes hot. The hot water is cooled by cooling towers and is re-circulated for cooling.

The cooling system can be classified into two types:

- Open Cooling System:- A Plant near the river may utilize the river water for cooling & discharging again the hot water into river. This type of cooling system is known as open cooling system.
- Closed Cooling System:- The Cooling Water is circulated again & again and only water lost due to leakage, evaporation etc. is made up by taking make up water from supply source.

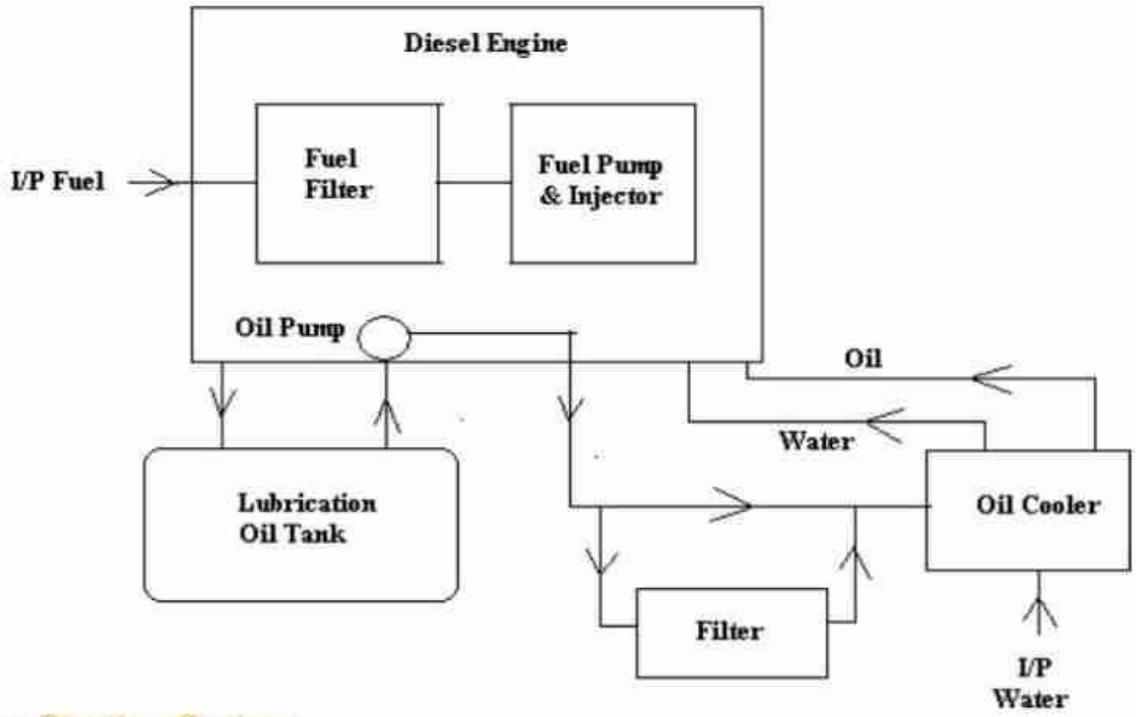


Engine Lubrication System:-

Engine lubrication system consists of lubricating oil pump, oil tanks, filters, coolers, purifiers & connecting pipes. This system provides lubricating oil to moving parts of the system to reduce the friction between them wear & tear of the engine parts.

→This system minimizes the water of rubbing surface of the engine. Here lubricating oil is stored in main lubricating oil tank. This lubricating oil is drawn from the tank by means of oil pump. Then the oil is passed through the oil filter for removing impurities. From the filtering point, this clean lubricating oil is delivered to the different points of the machine where lubrication is required the oil cooler is provided in the system to keep the temperature of the lubricating oil as low as possible.

→It is then cooled through heat exchanger by means of cold water and then it is fed to the engine.



Engine Starting System:-

The function of starting system is to start the engine form stand still or cold conditions by supplying compressed air.

→For starting a diesel engine, initial rotation of the engine shaft is required. Until the firing start and the unit runs with its own power. For small DG set, the initial rotation of the shaft is provided by handles but for large diesel power station. Compressed air is made for starting.

→This system includes storage compressed air tank, self starter, auxiliary engines & electrical motors (battery) etc.

AC or DC Generators:-

1) For Single Phase:

Single Phase, 230 Volts, and 50Hz frequency generators are used as per requirements of load.

2) For Three Phase:

Generally, three phase, 50Hz, salient pole type, the number of poles depends upon diesel engine speed. Generally, speeds of diesel engines are low that's why 6 or 8 poles generators used. Generators are coupled with the shaft of diesel engine. These generators are 3.3kV, 6.6kV or 11kV output capacities.

3) DC Generator:

Generally DC Compound generator is used, which help to develop an output voltage of 230 Volts.

Governing System:-

The function of the governing system is to maintain the speed of the engine.

→This is done generally by varying fuel supply to the engine according to load. It is achieved with use of governors.

Maintenance of Diesel Electric Power Plant:-

For diesel electric power plant, following points are considered during maintenance period.

- To maintain the operating condition of diesel engine at every half hour.
- To maintain the correct record of the instrument reading in log sheet.
- To maintain the record of instrument temperature, pressure, electrical load, flow etc.
- To check the level of fuel oil periodically.
- Filterized the fuel and remove unwanted impurities.
- Clean the fuel tank at regular interval.

Applications of Diesel Power Station:-

- The diesel oil is used as a fuel in power generation.
- It produces AC as well as DC Voltages.
- It is used where small power is generation is requirement.
- In case of any emergency diesel engines are used.
- It is also used for peal load during small period of time.
- It is used to restart the boilers.
- It is used in remote places.
- It can be used in areas having low load factor.

Advantages of Diesel Power Station:-

- This is simple in design point of view.
- Required very small space.
- It can also be designed for portable use.
- It has quick starting facility; the small diesel generator set can be started within few seconds.
- It can also be stopped as when required stopping small size diesel power station, even easier than it's starting
- As these machines can easily be started and stopped as when required, there may not be any standby loss in the system.
- Cooling is easy and required smaller quantity of water in this type power station.
- Initial cost is less than other types of power station.

- Thermal efficiency of diesel is quite higher than of coal.
- It requires less operating staff.
- The overall cost is much less than that of steam power station of same capacity.

Disadvantages of Diesel Power Station:-

- The cost of diesel is very high compared to coal.
- The plant generally used to produce small power requirement.
- Cost of lubricants is high.
- Maintenance is quite complex and costs high.
- The plant doesn't work satisfactorily under overload conditions for a longer period.
- The cost of lubrication is generally high.
- The maintenances charges are generally high

HYDEL POWER PLANT:-

A generating station which utilizes the potential energy of water at a high level for the generation of electrical energy is known as a hydro-electric power plant or hydel power plant.

(Potential Energy↔ Kinetic Energy ↔Mechanical Energy↔ElectricalEnergy)

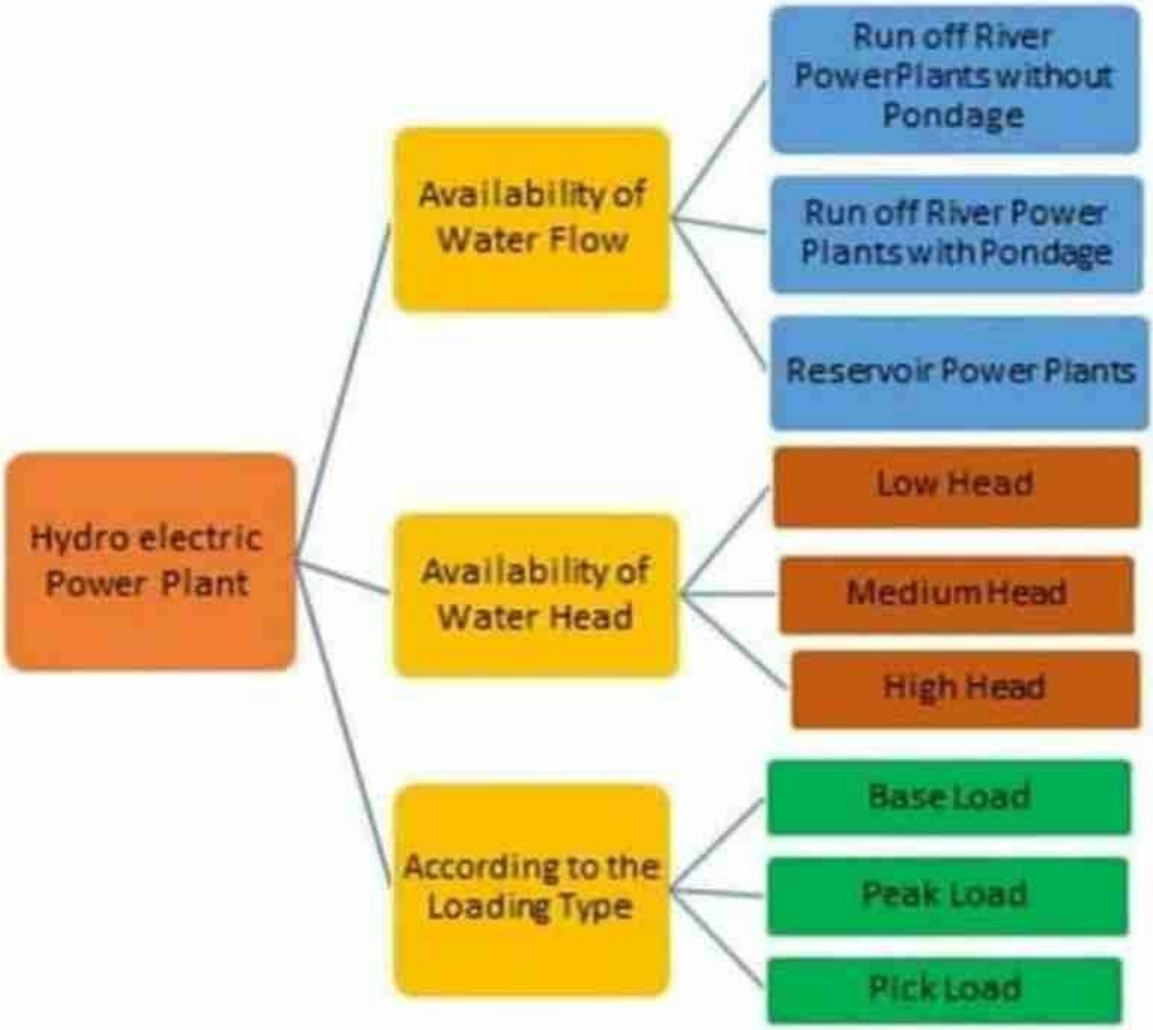
Advantages:-

- There is no fuel cost as water is available in nature.
- There is no fuel transportation cost.
- There is no necessity of fuel & ash handling equipment.
- There is no air pollution.
- It is very neat & clean plant.
- Operating & maintenance cost are very low.
- H.P.P can be put into service immediately.
- There are no standby losses.
- Efficiency of plant is highest and does not change with age.
- Power generation can be controlled quickly & rapidly without any difficult.
- This plant is suitable for supplying power to variable load.
- By controlling discharge of water precisely, constant speed & frequency can be maintained.
- The life of plant is longest.
- Generation cost per unit (KWH) is lowest.

Disadvantages:-

- High capital cost due to construction of dam.
- It depends on nature as it require huge amount of water which is store during rainy season.
- Firm power (Output) is totally depends on monsoon.
- It takes long time for complete erecting of power plant.
- It requires large area (catchment) area for storage of water.
- As sites are away from load centre, so cost of transmission and losses in it are more.

Classification of Hydroelectric Power Plant:-

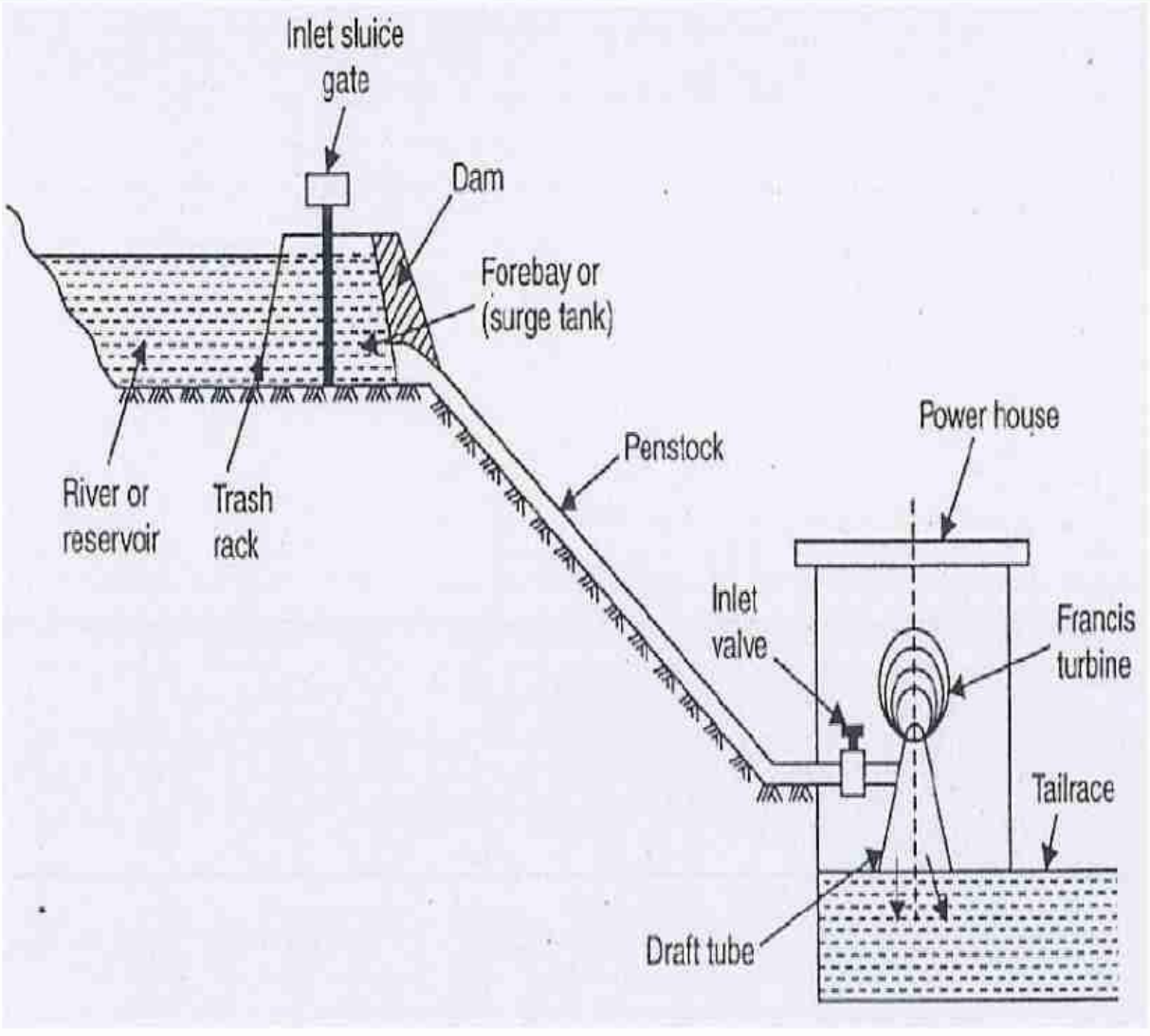


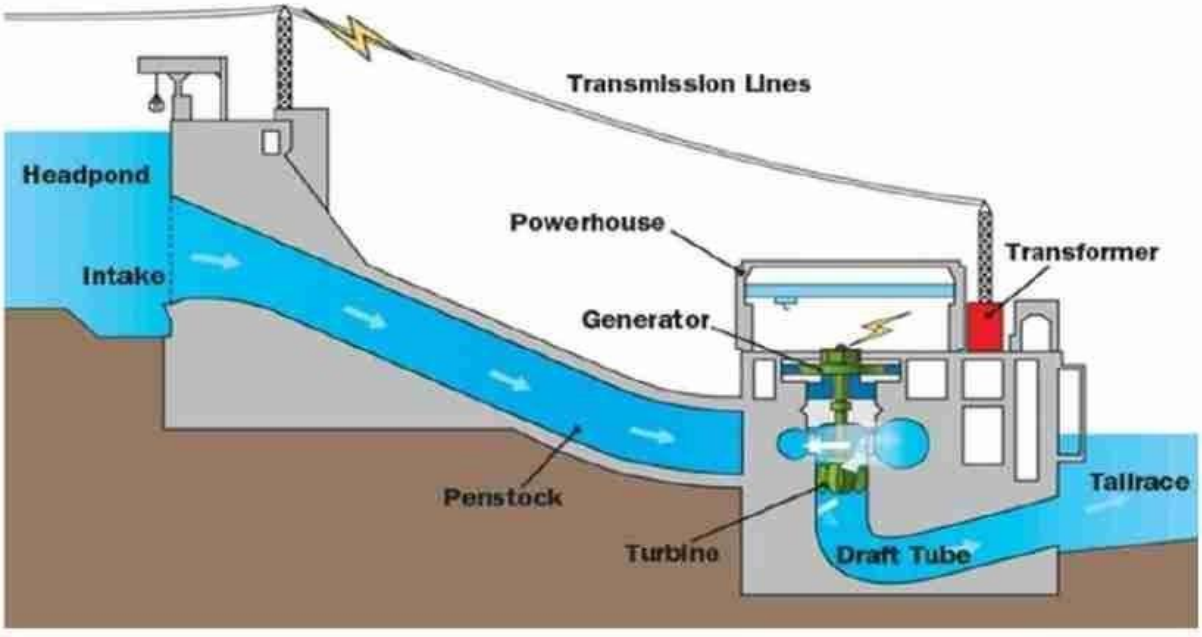
Storage Type Hydro Electric Power Plant:-

In this type of hydro-electric power plant, reservoir is provided. This reservoir is useful to store an ample quantity of water during rainy season, & this is useful throughout the year. Such type of power plant has better capacity. This type of hydro-electric power plant may be used as base load plant. Majority of the hydro-electric power plants are of this type.

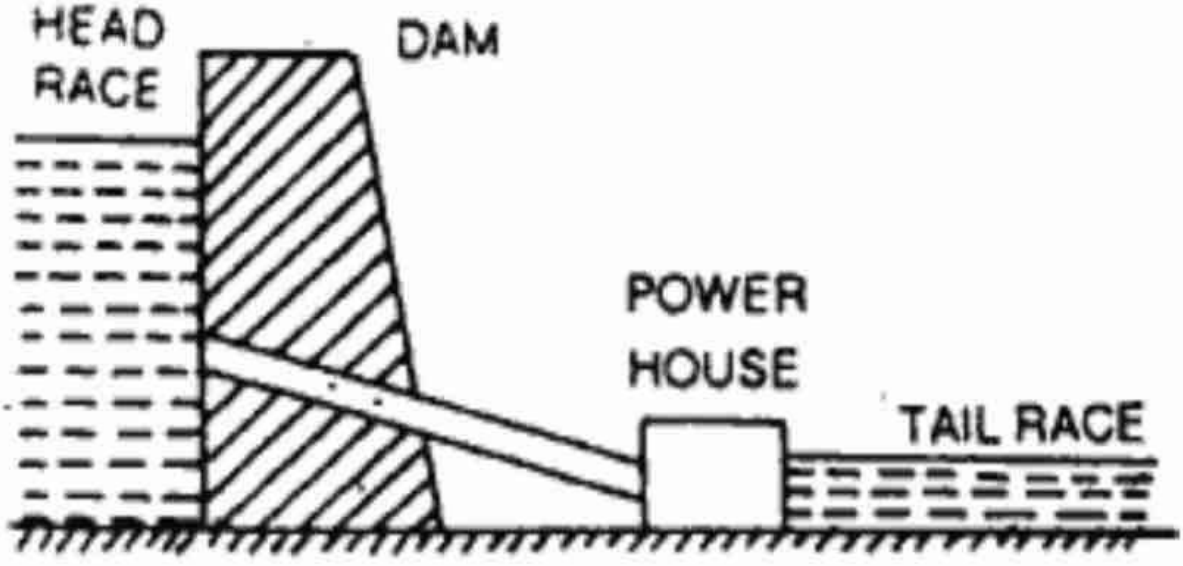
Working Principle Of Hydel Power Plant:-

We know that, water is stored in dam by using rain water. This stored water contains Potential energy, due to height or head of dam. When this water is flow towards turbine, at that time the Kinetic Energy is Converted into Mechanical Energy. The turbine or prime mover is mechanically coupled with generator. Whenever turbine starts to rotate with the help of high pressure water, automatically generator starts to rotate & it produced an electrical energy.


Inlet sluice gate
Dam
Forebay or (surge tank)
Penstock
Power house
River or reservoir
Trash rack
Inlet valve
Francis turbine
Tailrace
Draft tube

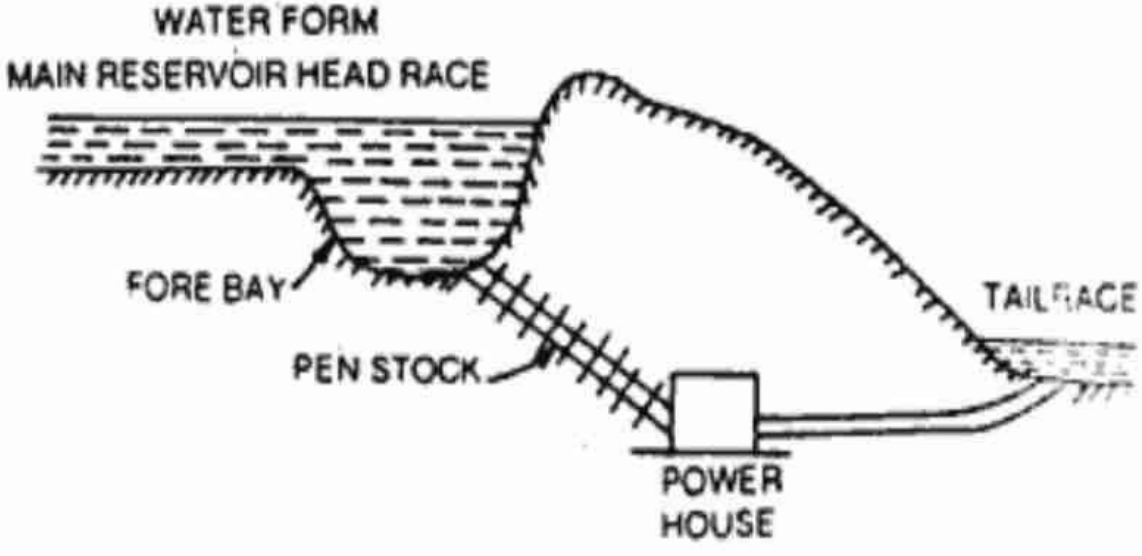

Transmission Lines
Headpond
Intake
Powerhouse
Transformer
Generator
Penstock
Turbine
Draft Tube
Tailrace

Low Head Plants:-



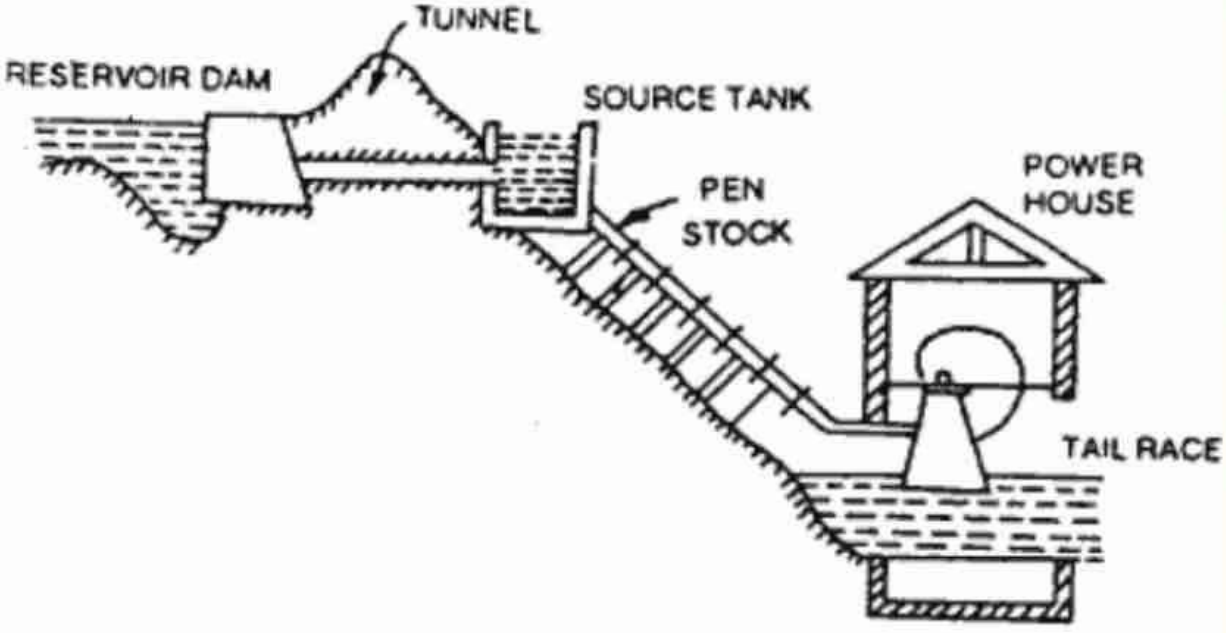
The low head plants have water head below 30m. A low head power plant store water by construction of dam across river or lake. The power house is installed near the base of dam on the downstream side. The barrages with regulating gates are provided to flow of excess water in river or lake. In low head hydro-electric power plant Kaplan turbines can be used.

Medium Head Plants:-



If the available water head is between 30 and 100 m, the plant is called a medium-head plant. Water is led to the turbines from the Forebay by the penstocks, which may be steel pipes. Forebay also stores the rejected water as the load on the turbine decreases. Francis turbines are normally used.

High Head Power Plant:-



If the available head is more than 300 m, the plant is called high-head plant. The civil works include a surge tank, the function of which is to meet the sudden changes in the requirement of water caused by the fluctuations in the system load.

INDIA'S MAJOR HYDROPOWER GENERATING UNITS

Name	State	Capacity (MW)
Bhakra	Punjab	1100
Dehar	Himachal Pradesh	990
Nagarjuna	Andhra Pradesh	960
Koyna	Maharashtra	920
Sharavathy	Karnataka	891
Kalinadi	Karnataka	810
Srisailam	Andhra Pradesh	770

List of Hpp In Odisha:-

- Hirakud Hydro Electric Project, HHEP(Burla)
- Chiplima Hydro Electric Project, CHEP(Chipilma)
- Balimela Hydro Electric Project, BHEP(Balimela),
- Rengali Hydro Electric Project, RHEP(Rengali),
- Upper Kolab Hydro Electric Project, UKHEP(Bariniput),
- Upper Indravati Hydro Electric Project, UIHEP(Mukhiguda)
- Upper Indravati Hydro Electric Project, UIHEP (Khatiguda)
- Machkund Hydro Electric Project, Onukudel

MCQ:-

1. Which element of hydroelectric power plant prevents the penstock from water hammer phenomenon?
a)Valves and Gates
b)Draft tubes
c)Spillway
d)✓SurgeTank

2. The pressure at the inlet or exit of the draft tube should not be _____
a)✓ less than one third of atmospheric pressure
b) greater than one third of atmospheric pressure
c) less than one atmospheric pressure
d) greater than one atmospheric pressure

3. Draft tube increases the operating head on the turbine.
a)✓ True
b) False

4. Governing mechanism used in case of Pelton wheel turbine is _____
a) guide vane
b) ✓nozzle needle
c) control valve
d) dam gates

5. The cheapest plant in operation and maintenance is.....
a)Staem power plant
b)Nuclear power palnt
c)✓Hydro-electric power plant
d)None of the above

6. The power output from a hydro-electric power plant depends on three parameters.....
a)Head,type and dam of discharge

b)✓Head,discharge and efficiency of the system
c)Efficiency of the system,type of draft tube and type of turbine used
d)Type of dam,discharge and type of catchment area

7. Location of the surge tank in a hydro-electric station is near to the.....
a)Tailrace
b)Turbine
c)✓Reservoir
d)None of the above

8. Francis,kaplan and propeller turbines fall under the category of.....
a)Impulse turbine
b)✓Reaction turbine
c)Impulse reaction combined
d)Axial flow

9. Gross head of a hydro power station is.....
a)✓The difference of water level between the level in the storage and tail race
b)The height of the water level in the river where the storage is provided
c)The height of the water level in the river where the tail race is provided
d)None of the above

10. Operating charges are minimum in the case of.....for same power output
a)Gas turbine plant
b)✓Hydel plant
c)Thermal plant
d)Nuclear plant