UNIT-I

INTRODUCTION

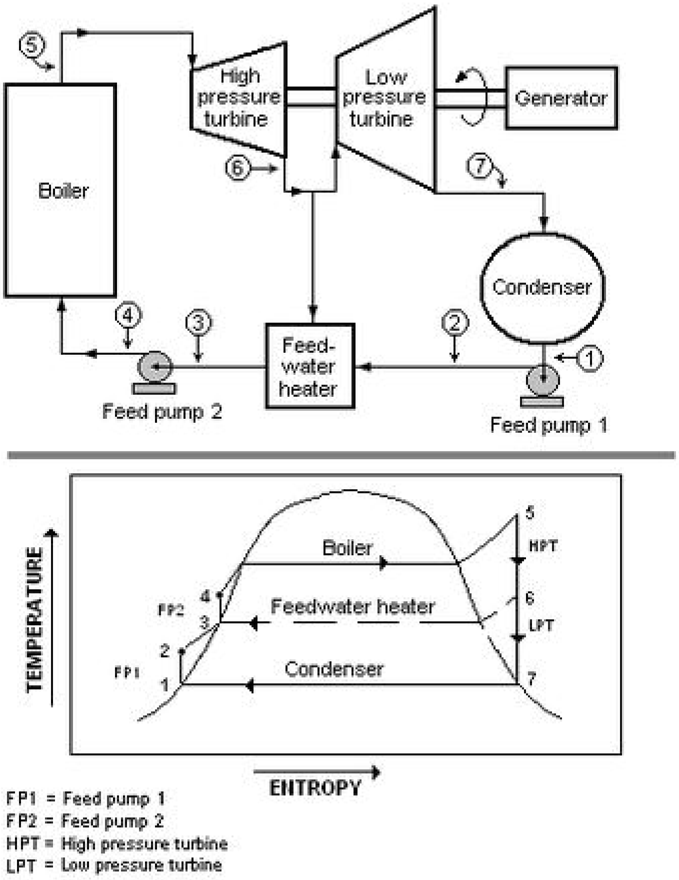
A station thermal power is a power plant in which the prime mover is steam driven. Water is heated, turns into steam and spins a steam turbine which drives an electrical generator. After it passes through the turbine, the steam is condensed in a condenser and recycled to where it was heated; this is known as a Rankine cycle. The greatest variation in the design of thermal power stations is due to the different fossil fuel resources generally used to heat the water. Some prefer to use the term *energy center* because such facilities convert forms of heat energy into electrical energy. Certain thermal power plants also are designed to produce heat energy for industrial purposes of district heating, or desalination of water, in addition to generating electrical power. Globally, fossil fueled thermal power plants produce a large part of man-made CO_2 emissions to the atmosphere, and efforts to reduce these are varied and widespread.

Almost all coal, nuclear, geothermal, solar thermal electric, and waste incineration plants, as well as many natural gas power plants are thermal. Natural gas is frequently combusted in gas turbines as well as boilers. The waste heat from a gas turbine can be used to raise steam, in a combined cycle plant that improves overall efficiency. Power plants burning coal, fuel oil, or natural gas are often called fossil-fuel power plants. Some biomass-fueled thermal power plants have appeared also. Non-nuclear thermal power plants, particularly fossil-fueled plants, which do not use co-generation are sometimes referred to as conventional power plants.

Commercial electric utility power stations are usually constructed on a large scale and designed for continuous operation. Electric power plants typically use three-phase electrical generators to produce alternating current (AC) electric power at a frequency of 50 Hz or 60 Hz. Large companies or institutions may have their own power plants to supply heating or electricity to their facilities, especially if steam is created anyway for other purposes. Steam-driven power plants have been used in various large ships, but are now usually used in large naval ships. Shipboard power plants usually directly couple the turbine to the ship's propellers through gearboxes. Power plants in such ships also provide steam to smaller turbines driving electric generators to supply electricity. Shipboard steam power plants can be either fossil fuel or nuclear. Nuclear marine propulsion is, with few exceptions, used only in naval vessels. There have been perhaps about a dozen turbo-electric ships in which a steam-driven turbine drives an electric generator which powers an electric motor for propulsion.

Combined heat and power plants (CH&P plants), often called co-generation plants, produce both electric power and heat for process heat or space heating. Steam and hot water lose energy when piped over substantial distance, so carrying heat energy by steam or hot water is often only worthwhile within a local area, such as a ship, industrial plant, or district heating of nearby buildings.

EFFICIENCY



A Rankine cycle with a two-stage steam turbine and a single feed water heater.

The energy efficiency of a conventional thermal power station, considered salable energy produced as a percent of the heating value of the fuel consumed, is typically 33% to 48%As with all heat engines, their efficiency is limited, and governed by the laws of thermodynamics. By comparison, most hydropower stations in the United States are about 90 percent efficient in converting the energy of falling water into electricity.

The energy of a thermal not utilized in power production must leave the plant in the form of heat to the environment. This waste heat can go through a condenser and be disposed of with cooling water or in cooling towers. If the waste heat is instead utilized for district heating, it is called co-generation. An important class of thermal power station are associated with desalination facilities; these are typically found in desert countries with large supplies of natural gas and in these plants, freshwater production and electricity are equally important co-products.

The Carnot efficiency dictates that higher efficiencies can be attained by increasing the temperature of the steam. Sub-critical fossil fuel power plants can achieve 36–40%

efficiency. Super critical designs have efficiencies in the low to mid 40% range, with new "ultra critical" designs using pressures of 4400 psi (30.3 MPa) and multiple stage reheat reaching about 48% efficiency. Above the critical point for water of 705 °F (374 °C) and 3212 psi (22.06 MPa), there is no phase transition from water to steam, but only a gradual decrease in density.

Currently most of the nuclear power plants must operate below the temperatures and pressures that coal-fired plants do, since the pressurized vessel is very large and contains the entire bundle of nuclear fuel rods. The size of the reactor limits the pressure that can be reached. This, in turn, limits their thermodynamic efficiency to 30–32%. Some advanced reactor designs being studied, such as the very high temperature reactor, advanced gas-cooled reactor and supercritical water reactor, would operate at temperatures and pressures similar to current coal plants, producing comparable thermodynamic efficiency.

ELECTRICITY COST

The direct cost of electric energy produced by a thermal power station is the result of cost of fuel, capital cost for the plant, operator labour, maintenance, and such factors as ash handling and disposal. Indirect, social or environmental costs such as the economic value of environmental impacts, or environmental and health effects of the complete fuel cycle and plant decommissioning, are not usually assigned to generation costs for thermal stations in utility practice, but may form part of an environmental impact assessment.

LOCATION OF POWER PLANTS:

The location of HydroElectric power plants is usually predetermined by the availability of water and the water head which is utilized

1. Availability of cooling water
2. Availability of Fuel
3. Distance from the center of gravity of load demand
4. Cost of land
5. Character of soil
6. Main wind directions and water currents in cooling water source in order to minimize air and water pollution and other ecological considerations.
7. With coal fired stations, disposal of ash
8. If the plant is erected far from the town, accommodation for staff.
9. Rail and road connections
10. Security considerations.

Q. What are the factors to be considered to install a typical 5 MW solar PV power plant?
A. Some of the factors to be considered to install a typical 5 MW solar PV power plant are as follows
1. Location of area in which the plant is to be installed.

2. Availability of the space.
3. PV module type to be installed.
4. Physical dimensions of the SPV module.
5. Method of mounting the panels.
6. Availability of power conditioning unit.
7. Electrical grid interconnection facility.
8. Annual energy generation capacity.
9. Duration of operation time.
10. Load supported by the plant.
11. Construction time.
12. Availability of the market for spares and components.

Q. In a steam power plant, a deaerator is located at elevated place. Justify.

A. In a steam power plant, a deaerator is located at an elevated place due to the following reasons:

1. To prevent vapour lock cavitation problems caused due to flashing of low pressure feed water into vapour.
2. To provide a new suction head for the boiler feed pump.
3. To prevent the feed pump from any damage.
4. To prevent the flashing of water into vapour by ensuring that temperature of feed water do not fall below the saturation temperature.

LOAD DURATION CURVES:

When planning a power plant,the two basic parameters to be decided are

1.Total power output to be installed(kW_{inst}).

2.Size of the generating units.

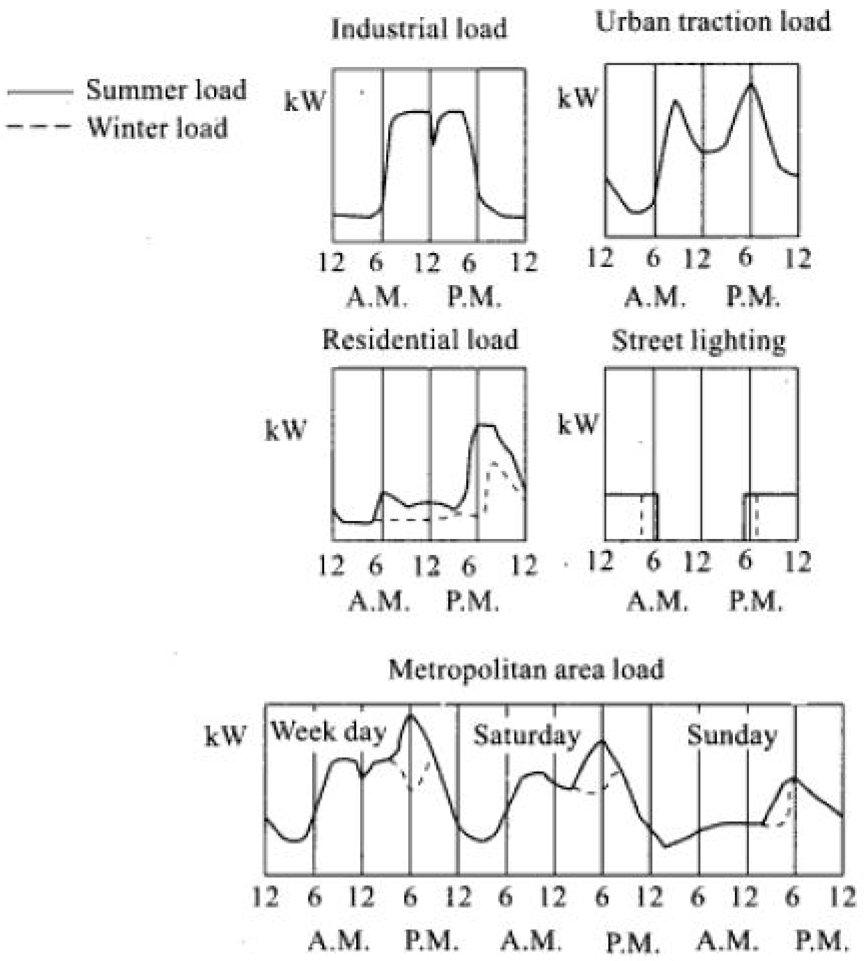
The total installed capacity required can be determined from

1.First demand estimated

2.growth of demand required

3.Reserve capacity required

For estimating the expected maximum load the hypothetical load curve should be drawn figure shows the hourly load curve.



Typical hourly variation in energy demand for different types of electrical load and curves of total load in a metropolitan area

<u>Different Types of Pollution and Methods of Control</u>

The intermixing of contaminants into the natural resources leading to their degradation is known as pollution. The problem of pollution has always been a major issue all around the globe and the need for proper steps to prevent and overcome it has been increasing and has also found some voices in the recent times. The ever increasing rate of pollution has caused severe damage to the ecosystems as can be seen from the rising global warming. Also, the pollution enhances human diseases and the death rates of various animals and plants leading to an imbalance in their population. The growing rate of industries and a higher rate of consumption of fossil fuels gives rise to this undesirable pollution. Constant efforts to bring about the decrement of this pollution so as to ensure a healthy environment is the need of the hour.

Pollution is a concept whose proper understanding requires the understanding of many other related concepts. While studying about pollution, we are going to deal with a number of terms related to chemistry. Different gases, minerals and compounds will form an active part of our discussion about pollution. Hence it would be a good idea to have some basic knowledge about the concepts of chemistry which will aid our study of the different types of pollution. This great course about the basics of chemistry will help you in getting familiar with the basic concepts and will enable you to understand the things being discussed here in a better way.

Here we are going to discuss the different types of pollution and how all these types differ from one another. We will study all these factors in detail and will also study about how we can prevent the pollution of the natural resources. We will try and understand how the pollution is caused and this in turn will help us in understanding how this pollution can be prevented and controlled.

AIR POLLUTION

Air pollution is the contamination of natural air by mixing up of it with many different contaminating particles including chemicals, harmful fumes etc. This type of pollution always behaves as a potential risk, leading to respiratory infections, heart diseases, strokes etc. Other health effects due to air pollution include asthma and cardiac conditions.

The pollutants for air pollution are divided into two categories. The first type of pollutants known as primary pollutants are those which are produced from a certain process like the smoke emitted from the vehicles. The second type of pollutants are termed as the secondary pollutants and these are the ones which are generated due to the reaction of primary pollutants with natural air.

Different pollutants affect the air in different forms. Like the reaction of sulfur oxides and nitrogen oxides results in the production of acid rain. The vehicles, from their exhaust systems, give out the component of carbon monoxide which has an adverse effect on the atmosphere. The ground level ozone which is the basis of certain regions of stratosphere can also act as an air pollutant which in high concentrations aids in the generation of smog. Coal is another source which contaminates the air. If the burning coal gets mixed up with the smoke from some other sources, it results in the generation of smog which is also a major type of air pollution.

Lack of ventilation inside the houses can also lead to health issues resulting from air pollution. For example, the pesticides and other chemicals, brought into use extensively in the homes, are required to be properly exhausted from the house, but this cannot be achieved as a result of improper ventilation. The same is inhaled by the inhabitants and thus leads to health issues. Air pollution is present everywhere and it is very important to protect yourself from the ill effects of this pollution and to remain healthy. This course about the 5 pillars of optimal health will give you some great and highly useful information about living a healthy and happy life.

WATER POLLUTION

It is defined as the constant addition of pollutants to the water bodies resulting in contamination of the water. This makes the concerned water unfavorable for the use for both humans and commercially and is left as a waste only. The contaminated water when mixed with a bigger water body results in the adverse impact on the aquatic species. The major role played in the contamination of water is by the various industrial chemicals and wastes that are thrown into the water body without adequate treatment and thus contaminating the water. The high temperature fluids adversely affect the thermal state of the water and lead to the discoloration of natural clean water.

The list of the contaminants of water also includes many other particles such as detergents being generated by the industries and also from the households which get readily mixed with the water bodies. Testing the extent of water pollution can be done in a number of ways including the physical testing which means to analyze the temperature, solids, concentration and other factors for a particular sample of water. You can check out this well-written blog post about the types of water pollution to get more information about this highly dangerous type of pollution.

SOIL POLLUTION

Basically, the soil pollution refers to the mixing up of soil with the materials which are potent enough to affect the natural soil when mixed up with it in more than adequate proportions. The addition of the contaminated particles to soil happens both due to the human and natural activities in which the former plays a major part.

The most important factor leading to soil pollution is the ever increasing number of construction sites in today’s world. The harmful chemicals which are used in these construction activities harm the environment both during the construction and also after the construction has been completed.

The other factors leading to soil contamination include the landfill and illegal dumping that is usually carried out in the outskirts of urban areas due to which the waste decomposed intermixes with the nutrients present in the soil in the initial phases and leads to its depletion.

The contaminated soil directly affects the human health either through the direct contact with it or by the inhalation of harmful soil contaminants which are vaporized. For example, the nitrate particles are highly dangerous to be dumped under the soil cover and thus are first mixed up with the ammonia to reduce their impact, but even after this the resultant mixture leads to highly dangerous health hazards. It is very important to stay protected from these hazards and to remain healthy. This course about how to achieve the perfect health will help you in understanding the concept of perfect health and the important steps that need to be taken to achieve it.

NOISE POLLUTION

Noise pollution is the generation of sounds that are irritating and have a high pitch as compared to the hearing capabilities of humans. The basic sources of this sort of pollution are the machines that are extensively found in the industries and the transportation systems. Also, the loud noise created by loud music and other building activities can also contribute to this pollution leading to cardiovascular effects and other undesirable health effects for the humans. The need for preventive measures for noise pollution has always been there and this in a way has resulted in the emergence of hybrid vehicles which are less noisy than other contemporary vehicles.

The concept of noise pollution is a very unique one, as sound is something which has the capability to have both good and bad effects on the health of humans. Undesirable noises, in the form of noise pollution, can cause many health problems, but at the same time some soothing sounds can have a positive effect on the mental as well as physical health of the humans. Here is a great course about the the positive effects of sound on human health, and this course will help you in understanding how sound can be a highly positive influence for the mind and the body if it is controlled properly.

THERMAL POLLUTION

The increase in the temperature of a water system by any means is termed as thermal pollution. The basic source of this type of pollution is through making use of water as a coolant in industries which includes the disposal of heat generated by the industrial processes to the water and thus resulting in the increase of temperature of this water.

The worst impact of this sort of pollution is witnessed in the aquatic systems where the level of dissolved oxygen is readily decreased by the abrupt increase in the water’s temperature and thus harming the life of aquatic species. The reduction in the oxygen level of the ecosystem is also witnessed due to the reduced lifespan of the primary producers.

POLLUTION CONTROL METHODS

The control of the emission of various particulates into the environment so as to bring down the level of the pollution is termed as pollution control. The main steps that can be followed in this regard include recycling and reusing the products that can be used a few times so that the waste produced from them does not deplete the environment. Also the waste water that is to be thrown into the water bodies from the industries should be treated first to bring down its hazardous nature which poses a threat to the aquatic natural species.

Moreover the amount of raw material that is to be used should be used in an adequate quantity so that it results in low generation of the waste amount which is mixed with the environmental agents later. Apart from these, proper noise and smoke precipitators should be used to bring down the amount of lethal smoke and noise produced to help protect the environment. Here is a great blog post which discusses some other very effective and useful methods to help and keep our environment clean and pollution free.

UNIT-II

Thermal power plant

LAYOUT OF STEAM POWER PLANT:

Introduction: Steam is an important medium for producing mechanical energy. Steam is used to drive steam engines and steam turbines. Steam has the following advantages.

1. Steam can be raised quickly from water which is available in plenty.
2. It does not react much with materials of the equipment used in power plants.
3. It is stable at temperatures required in the plant.

Equipment of a Steam Power Plant:

A steam power plant must have the following equipment.

1. A furnace for burning the fuel.
2. A steam generator or boiler for steam generation.
3. A power unit like an engine or turbine to convert heat energy into mechanical energy.
4. A generator to convert mechanical energy into electrical energy.
5. Piping system to carry steam and water.

Figure: shows a schematic layout of a steam power plant. The working of a steam power plant can be explained in four circuits. 1. Fuel (coal) and ash circuit 2. Air and flue gas circuit 3. Feed water and steam flow circuit 4. Cooling water flow circuit

1. Coal and Ash circuit:

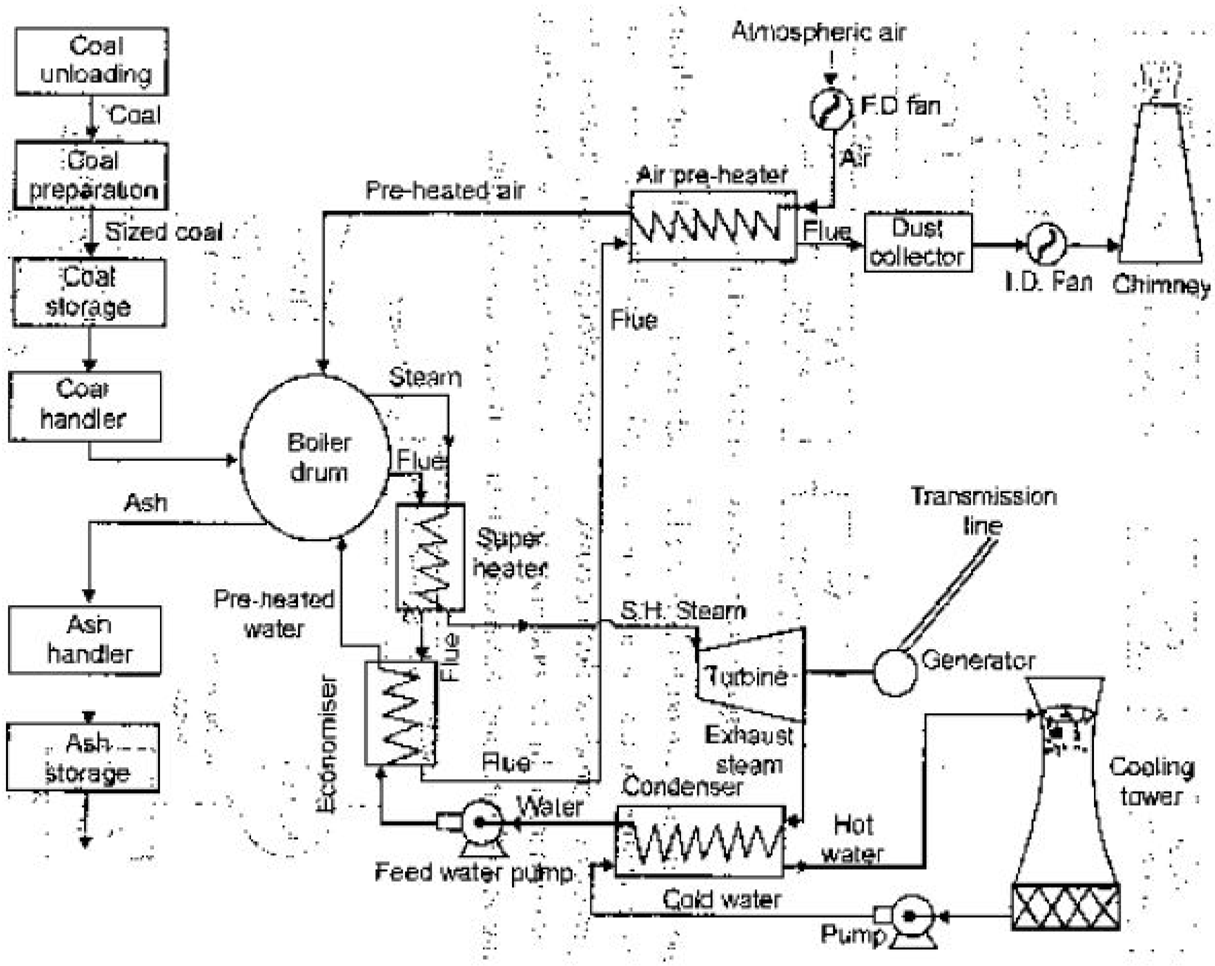


Fig: Layout of Steam Power Plant

This includes coal delivery, preparation, coal handling, boiler furnace, ash handling and ash storage. The coal from coal mines is delivered by ships, rail or by trucks to the power station. This coal is sized by crushers, breakers etc. The sized coal is then stored in coal storage (stock yard). From the stock yard, the coal is transferred to the boiler furnace by means of conveyors, elevators etc. The coal is burnt in the boiler furnace and ash is formed by burning of coal, Ash coming out of the furnace will be too hot, dusty and accompanied by some poisonous gases. The ash is transferred to ash storage. Usually, the ash is quenched to reduced temperature corrosion and dust content. There are different methods employed for the disposal of ash. They are hydraulic system, water jetting, ash sluice ways, pneumatic system etc. In large power plants hydraulic system is used. In this system, ash falls from furnace grate into high velocity water stream. It is then carried to the slumps. A line diagram of coal and ash circuit is shown separately in figure.

2. **Water and Steam circuit**

It consists of feed pump, economizer, boiler drum, super heater, turbine condenser etc. Feed water is pumped to the economizer from the hot well. This water is preheated by the flue gases in the economizer. This preheated water is then supplied to the boiler drum. Heat is transferred to the water by the burning of coal. Due to this, water is converted into steam.

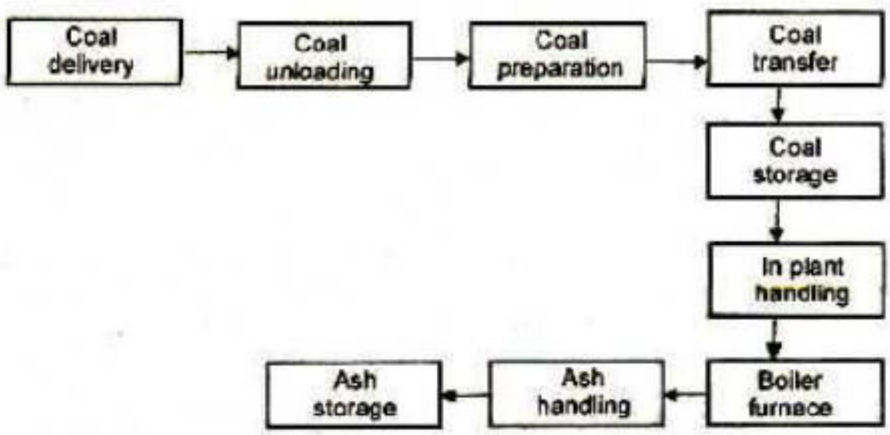


Figure: Fuel (coal) and ash circuit

The steam raised in boiler is passed through a super heater. It is superheated by the flue gases. The superheated steam is then expanded in a turbine to do work. The turbine drives a generator to produce electric power. The expanded (exhaust) steam is then passed through the condenser. In the condenser, the steam is condensed into water and recirculated. A line diagram of water and steam circuit is shown separately in figure.

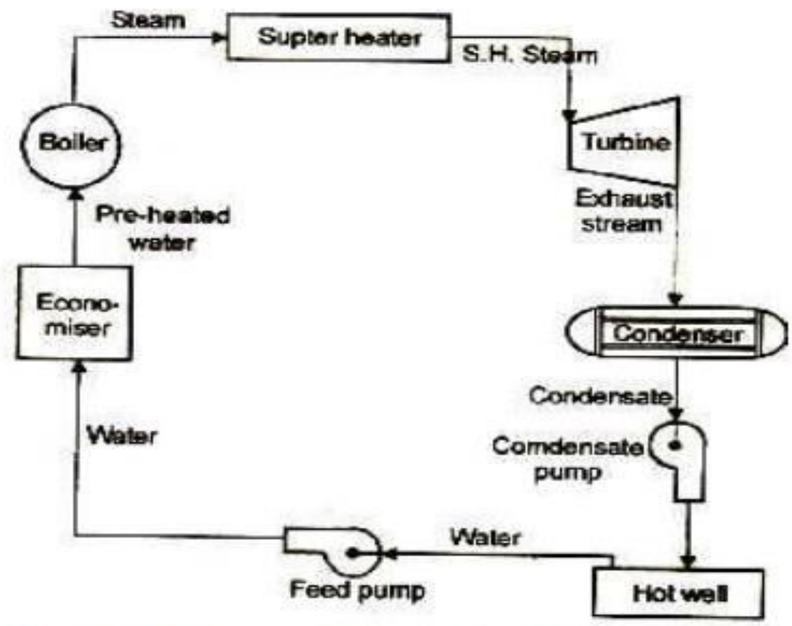


Figure: Water and Steam circuit

3. Air and Flue gas circuit

It consists of forced draught fan, air pre heater, boiler furnace, super heater, economizer, dust collector, induced draught fan, chimney etc. Air is taken from the atmosphere by the action of a forced draught fan. It is passed through an air pre-heater. The air is pre-heated by the flue gases in the pre-heater. This pre-heated air is supplied to the furnace to aid the combustion of fuel. Due to combustion of fuel, hot gases (flue gases) are formed.

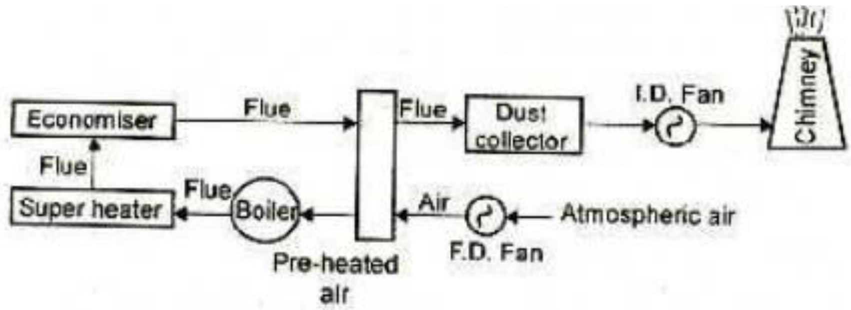


Figure: Air and flue gas circuit

The flue gases from the furnace pass over boiler tubes and super heater tubes. (In boiler, wet steam is generated and in super heater the wet steam is superheated by the flue gases.) Then the flue gases pass through economizer to heat the feed water. After that, it passes through the air pre-heater to pre-heat the incoming air. It is then passed through a dust catching device (dust collector). Finally, it is exhausted to the atmosphere through chimney. A line diagram of air and flue gas circuit is shown separately in figure.

4.Cooling water circuit:

The circuit includes a pump, condenser, cooling tower etc. the exhaust steam from the turbine is condensed in condenser. In the condenser, cold water is circulated to condense the steam into water. The steam is condensed by losing its latent heat to the circulating cold water.

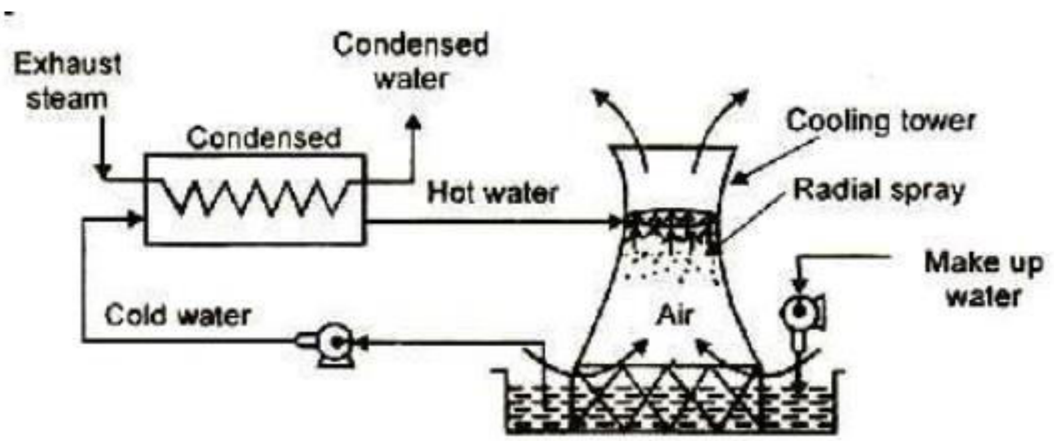


Figure: Cooling water current.

Thus the circulating water is heated. This hot water is then taken to a cooling tower, In cooling tower, the water is sprayed in the form of droplets through nozzles. The atmospheric air enters the cooling tower from the openings provided at the bottom of the tower. This air removes heat from water. Cooled water is collected in a pond (known as cooling pond). This cold water is again circulated through the pump, condenser and cooling tower. Thus the cycle is repeated again and again. Some amount of water may be lost during the circulation due to vaporization etc. Hence, make up water is added to the pond by means of a pump. This water is obtained from a river or lake. A line diagram of cooling water circuit is shown in figure separately.

Merits (Advantages) of a Thermal Power Plant

1. The unit capacity of a thermal power plant is more. The cost of unit decreases with the increase in unit capacity.
2. Life of the plant is more (25-30 years) as compared to diesel plant (2-5 years).
3. Repair and maintenance cost is low when compared with diesel plant.
4. Initial cost of the plant is less than nuclear plants.
5. Suitable for varying load conditions.
6. No harmful radioactive wastes are produced as in the case of nuclear plant.
7. Unskilled operators can operate the plant.
8. The power generation does not depend on water storage.
9. There are no transmission losses since they are located near load centres.

Demerits of thermal power plants

1. Thermal plant are less efficient than diesel plants
2. Starting up the plant and bringing into service takes more time.
3. Cooling water required is more.
4. Space required is more
5. Storage required for the fuel is more
6. Ash handling is a big problem.
7. Not economical in areas which are remote from coal fields
8. Fuel transportation, handling and storage charges are more
9. Number of persons for operating the plant is more than that of nuclear plants. This increases operation cost.
10. For large units, the capital cost is more. Initial expenditure on structural materials, piping, storage mechanisms is more.

HIGH PRESSURE BOILERS:-

In all the modern power plants, high pressure boilers (>100bar) are universally used as have following advantages.

1. Efficiency and Capacity of plant is increased if high pressure steam is used.
2. Forced circulation provides freedom in arrangement of furnace and walls, hence reduces heat exchange area.
3. Tendency of scale formation is reduced due to high velocity water.
4. Danger of overheating is reduced as all parts are uniformly heated.
5. Differential expansion is reduced due to uniform temperature, hence reducing gas and air leakage.

Type of high pressure supper critical boiler

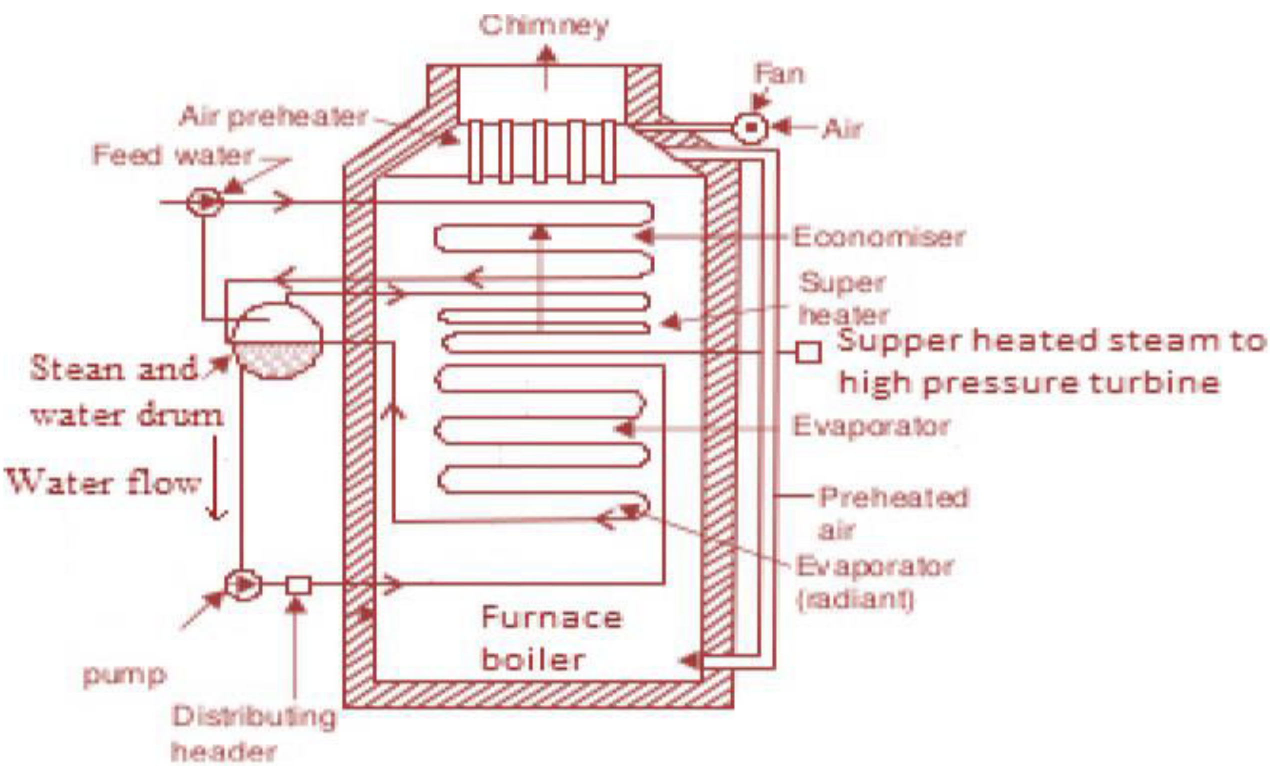
1. La mount boiler
2. Benson boiler
3. Loeffler boiler
4. Velox boiler
5. Schmidt Hartmann boiler
6. Ramson boiler

1. La Mont Boiler:-

A forced circulation boiler was first introduced by La Mount in 1925. The arrangement of water circulation and different component is as shown in figure.

The feed water from hot well is supplied to a steam and water drum through the economizer.

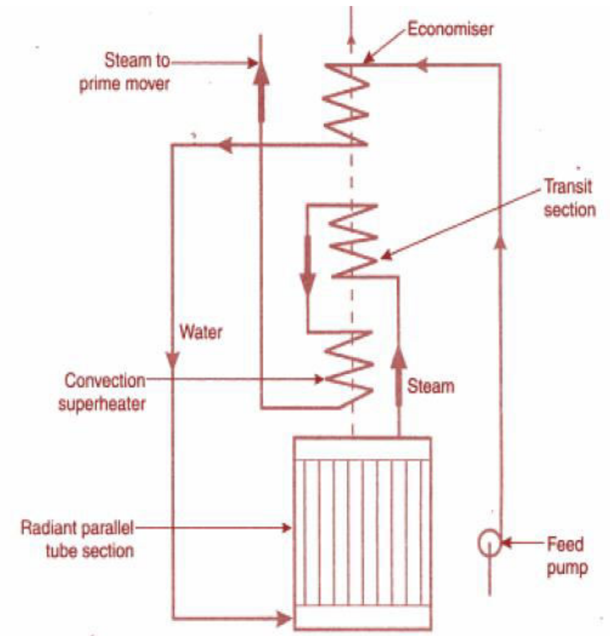
- Most of the sensible is supplied to feed water while passing through economizer.
- A pump is used to circulate the water through the evaporator tube and part of vapor separated into water drum.



Pump delivers water to header above drum pressure.

- Distribution header distributes water through nozzle into the evaporator.
- The steam separated in boiler is further passed through supper heater to generate 45to 50tone superheated steam at pressure 120bar and temperature 500^0C

2.Benson Boiler:-



Operations or working:

- During the starting of engine, the water from feed pump is fed into the economizer where the water is preheated.

- The preheated water from economizer is passed through evaporator where water is converted to steam by passing through heated tubes.
- The vapor from evaporator is passed through section or small tubes to attain maximum velocity
- Then it is passed through supper heater to supper heat the steam.
- The supper heated, high velocity then moved to the prime mover which is used to generate power.

Merits of Benson Boiler

1) The total boiler cost and weight is less as there is no steam drum.
2) A Benson boiler occupies lesser space area.
3) All the joints in Benson boiler are welded and because of lesser number of components the erection is faster.
4) As this boiler works at a high pressure of 250bars there is no danger of bubble formation even when sudden fall of demand occurs.
5) Possibility of explosion does not rise as there is no boiler drum.
6) Benson boiler can be started very quickly from cold.

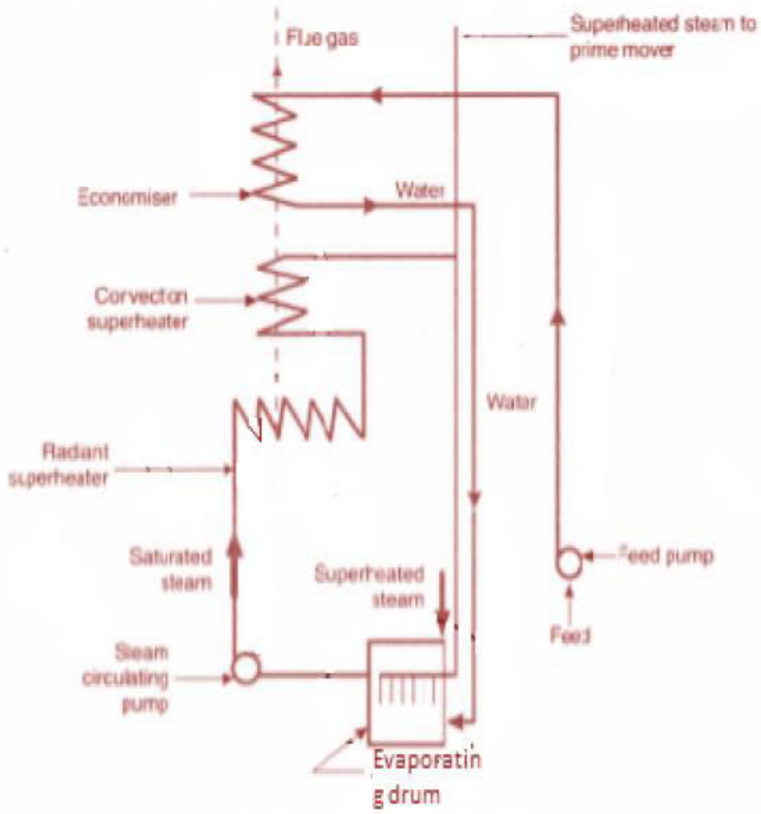
Demerits of Benson Boiler

1) It has low steam, capacity and hence not suitable for high power outputs.
2) There are possibilities of overheating of econ
water pump problems in running conditions.
3) It cannot meet sudden, raise, in demand.

3. Loeffler Boiler:-

The major difficulty experienced in Benson Boiler is the deposition of salt and sediment on the inner surfaces of the water tubes. The deposition reduced the heat transfer and ultimately the generating capacity. This further increased the danger of overheating the tubes due to salt deposition acid has high thermal resistance.

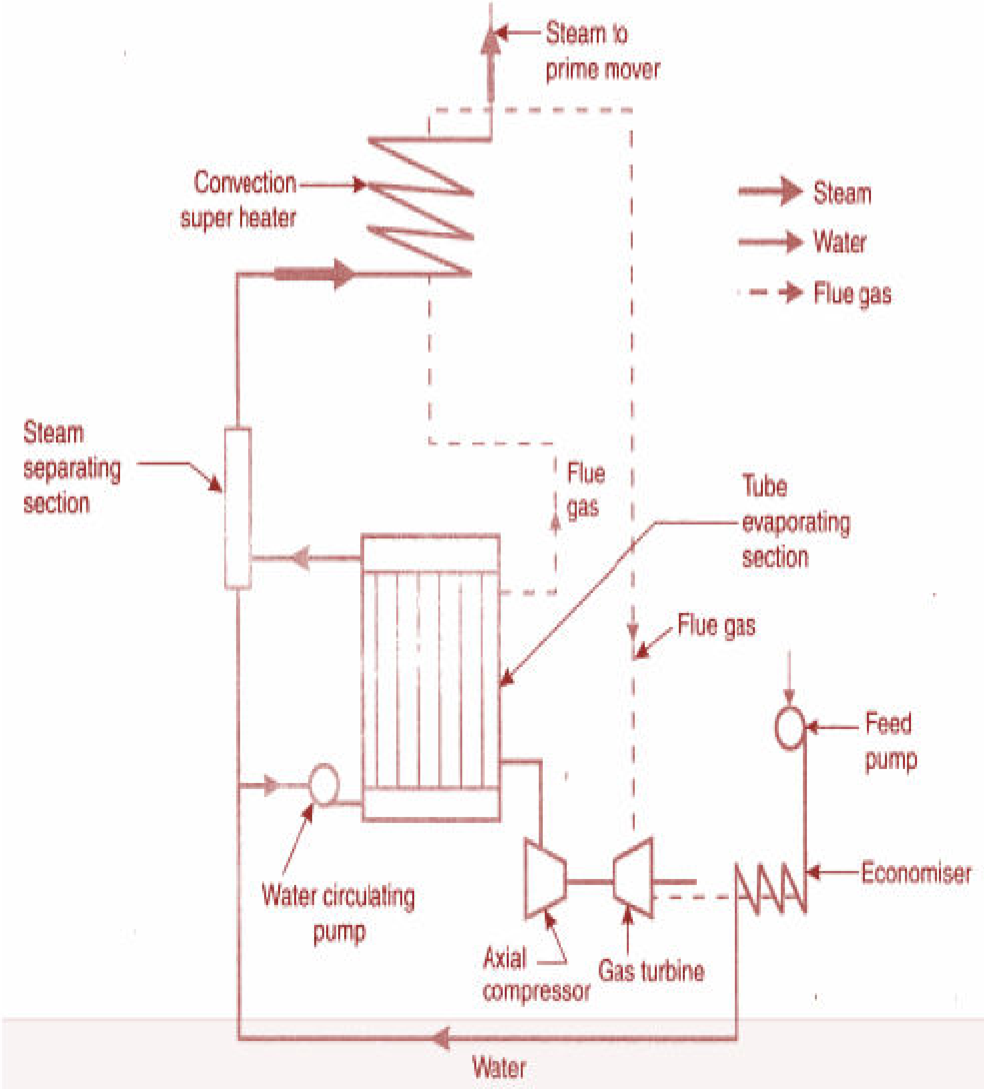
The difficulty was solved in Loeffler boiler by preventing the flow of water into the boiler tubes. Most of the steam is generated outside from the feed water using part of the super coming out from the boiler.The pressure feed pump draws the water through the economizer and delivers it into the evaporator drum as shown in the figure.



- The steam circulating pump draws the saturated steam from the evaporator drum and is through the radiant super heater and then connective super heater.
- About 35% of the steam coming out from the super heater is supplied to the High Pressure steam turbine and 65% of the steam coming out of super heater is passed through the evaporater drum in order to evaporate the feed water a coming from economiser.
- The steam coming out from high pressure turbine is passed through re heater before supplying to low pressure turbine.

This boiler can carry higher salt concentration than any other type and is more compact than indirectly heated boilers having natural circulation. These qualities fit it for land or sea transport power generation. Loeffler boilers with generating capacity of 94.5tonnes/hr and operating at 140bar have already been commissioned.

4.Velox Boiler



Operations:

• This boiler design makes use of pressurized combustion, to achieve a higher rate of heat transfer from a smaller surface area.

• The special feature of this boiler is that the flue gases are expanded in a gas turbine before being discharged to the atmosphere, which runs an axial flow compressor.

• The axial flow compressor is used to pressurize the atmospheric air to the operating furnace pressure to facilitate pressurized combustion.

• The compressor is driven by the gas turbine with reduction gears (as the turbine speed is very high).

• This system thus makes efficient use of the fuel in a smaller area for heat transfer.

• In the steam line, the feed water from the economizer pass through a steam separating unit

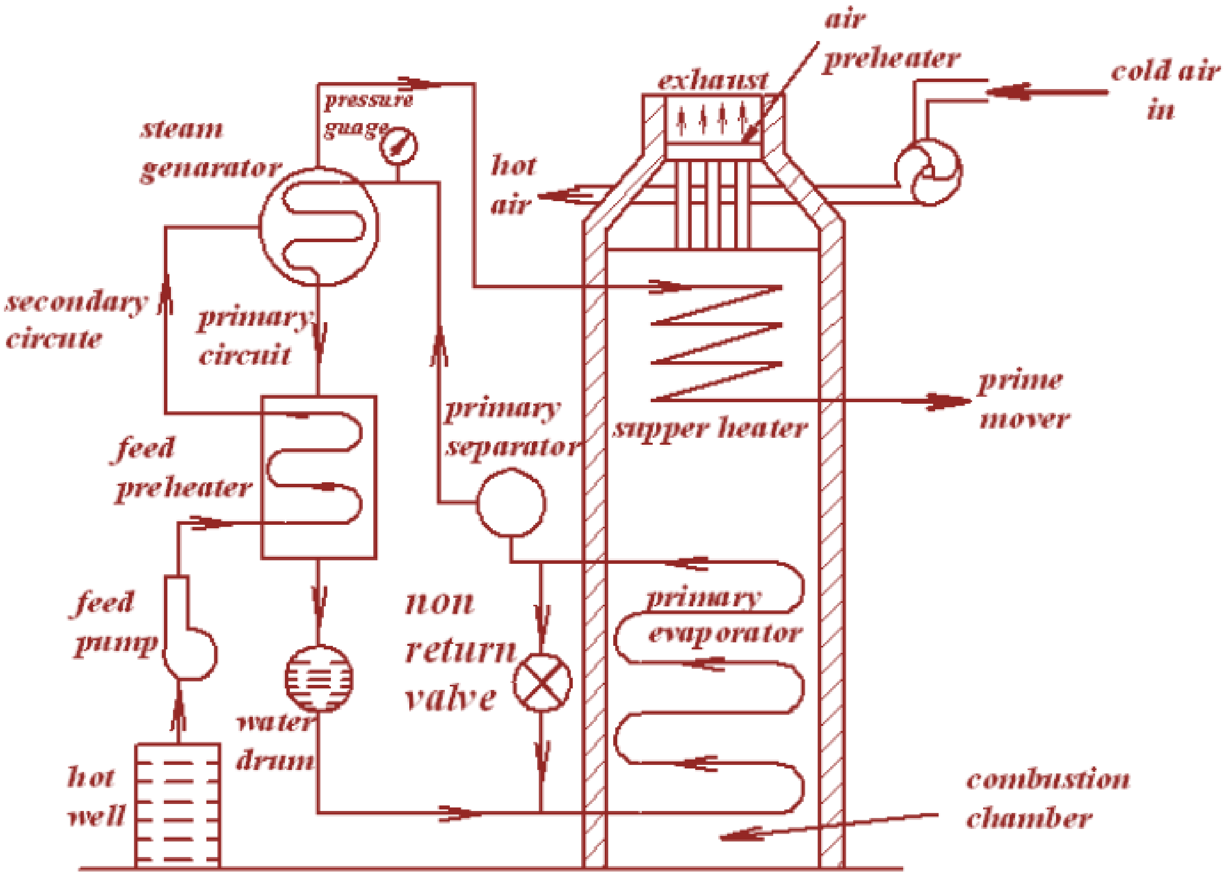
• The steam is separated due to the centrifugal effect of the water entering through the spiral flow arrangement.

• The separated water is then fed to the evaporator by a water circulating pump.

• The steam separated in the separator as well as the steam from the evaporator together enters the super heater.

• This superheated steam finally passes to the prime mover for operation

5. Schmidt Hartmann Boiler



Operation:

• This boiler makes use of two steam pressure circuits to raise the steam.

• A closed primary steam circuit is used to evaporate the water in the secondary circuit and the steam produced in the secondary circuit is used for running the prime mover.

• The closed primary circuit uses-distilled water and the steam are raised at a pressure of about 100bar.

• This steam is used to generate steam in the secondary or main evaporator.

• This is achieved by the submerged heating coils in the evaporator of the primary circuit

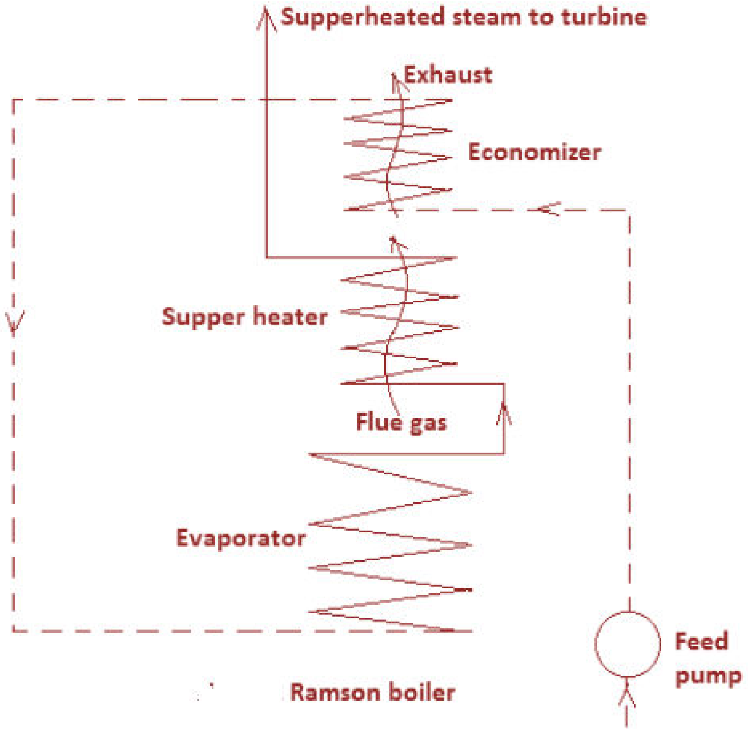
• Then the condensate of this circuit is used to preheat the feed water of the secondary circuit, and finally flows back to the primary evaporator.

• The primary circuit also includes a steam separator and a non-return valve as shown in figure.

• The preheated feed water in the secondary circuit then passes to the main evaporator and the generated steam at about 60bar is superheated in the super heater and finally passed to the prime mover.

• The flow in the primary circuit, however, takes place due to the natural circulation.

6. Ramson's once through boiler



- The boiler consists of inclined evaporator coil arranged in spiral.
- Forty such coils is paralleled around the furnace.
- Steam generated in evaporator flows into headers and then convection supperheaters.
- The superheated steam is utilized for power generation.

Advantages:

1. Heat transfer rate is large.
2. High thermal efficiency.
3. Problem of corrosion and erosion are minimized.
4. Adaptable to load fluctuations.

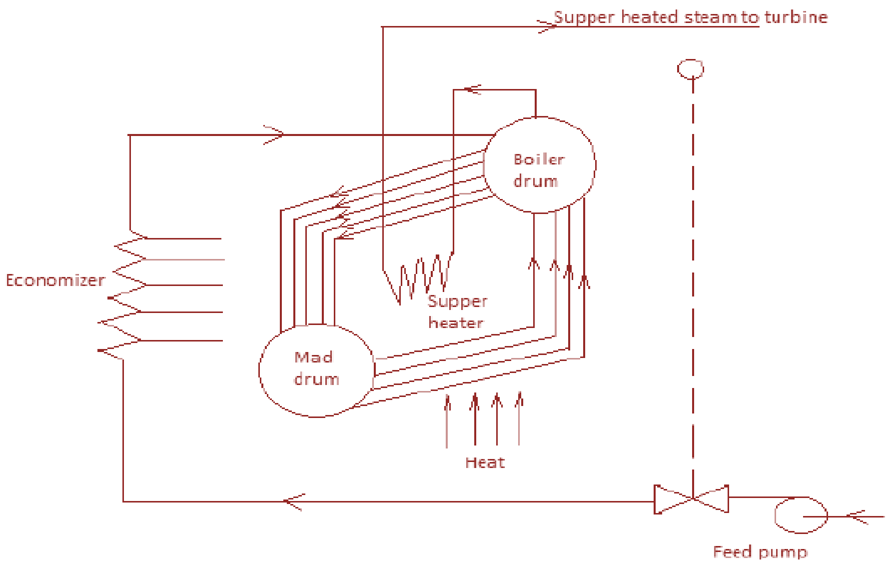
Disadvantages:

It is costly due to increased requirement for steel for heat transfer surface, pump and feed water piping. Generation of steam using forced circulation, high and supercritical pressure

High pressure boilers can be further classified into

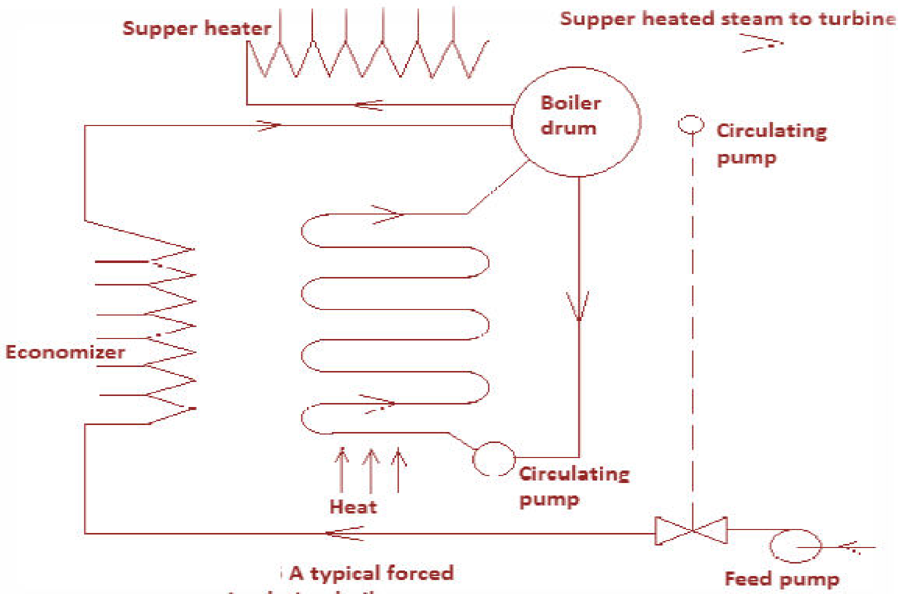
1. Natural circulation,
2. Forced circulation and
3. Once through boilers.

Natural circulation boilers



- A typical pattern of natural circulation boiler is as shown in figure.
- Here the water is circulated purely by density difference with most of the heat from the fuel flame is being radiated to the water walls directly.
- The steam pressure of such boiler is limited to 180bar, with water steam being separated in boiler drum.

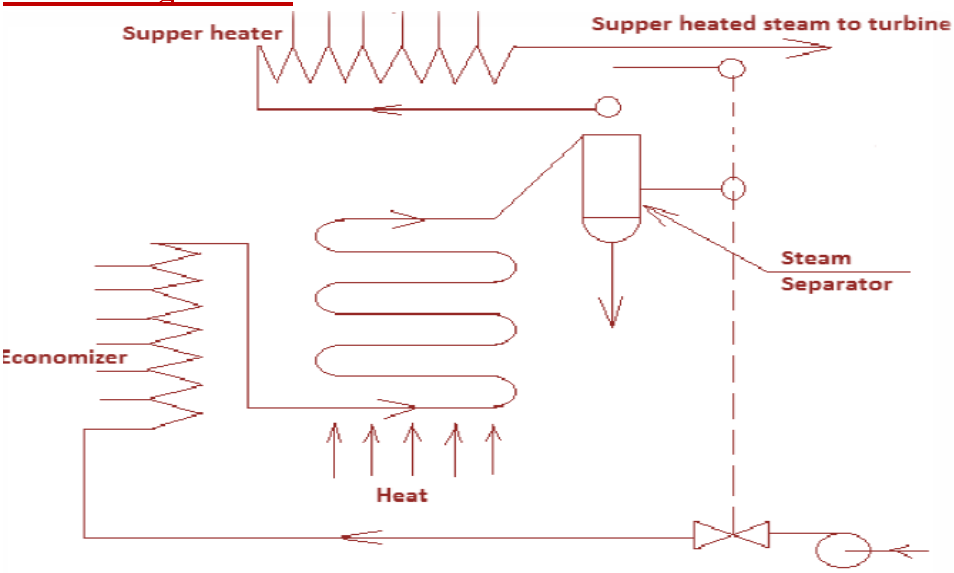
2. Forced circulation boilers



A typical forced circulation boiler

- Figure shows the flow pattern of forced circulation boiler.
- In these boilers water is circulated by using additional pump. These boilers often use orifice, which control which control flow circulation.
- Orifice is located at bottom of tubes that ensure eve distribution of flow through water wall tubes.
- These boilers can produce steam pressure up to 200bar.

Once through boilers



Flow diagram of once through boiler

- Figure shows the flow diagram of once through boilers.
- These boilers operate about critical pressure i.e. above 221bar.
- As density of water and steam is same above critical pressure, there will be no recirculation.
- In these boilers water enters bottom of the tubes and completely transforms into steam as it pass through tubes and reaches the top.
- Thus, these boilers does not require steam drum and hence referred to as drumless boilers.

Chimney:-

The most common method to achieve this difference in pressure, the draught, is to provide a chimney. Chimney is a tall hollow structure, which creates the required draught due to difference in pressure from the ground level to some altitude in the atmosphere.

- Chimneys are made of steel, bricks or concrete.
- Brick and concrete chimneys are generally used as they have a longer life.
- The average life of concrete chimneys is about 50 years.
- The life of steel chimneys is about 25 years, which depends upon the maintenance and care taken to prevent corrosion.
- Chimneys ere provided with lightning conductor to protect from thunder lightning and aircraft warning light as they are at higher altitudes.

Draught (or Draft) system:-

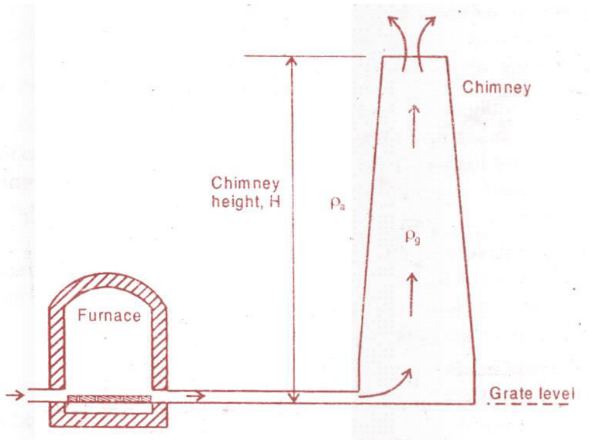
- Draught systems are essential **for flue gas propagation.**
- Flue gas propagation is the process of movement of the hot gases from the combustion chamber through boiler pipes, economizer, air pre-heater and finally to the chimney.
- The function of draught is to supply required quantity of air for combustion, propagate the flues and remove the flues from the system

- difference in pressure is required to move the air through the fuel bed to produce a flow of hot gases i.e., propagation of the flue gases through the boiler, economizer, pre heater and to the chimney by overcoming the pressure losses in the system
- This difference in pressure required maintaining a constant flow of air, through the boiler systems and finally to discharge the hot flues to the atmosphere through chimney is termed the draught

TYPES OF DRAUGHT SYSTEMS

- Natural Draught
- Mechanical Draught
- Forced Draught
- Induced Draught
- Balanced Draught

- **Natural Draught:-**



- The natural drought is produced by chimney or stack.
- It is caused by the density difference between atmospheric air and hot gas in the stack.
- For a chimney of height 'H' meter. The pressure difference is given by,

$$\Delta P = gH(\rho_{air} - \rho_{gas})$$

Where,

G = $9.81 ms^{-2}$ is acceleration due to gravity H is height of chimney (in m)
ρ_{air} is density of air (in kgm^{-3})
ρ_{gas} is density of gas inside chimney (in kgm^{-3})

Advantages of Natural Draught:-

- No external power is required to run the system.

- It requires small capital investment.
- Maintenance costs are minimum.
- The exhausts are discharged at a high altitude and -hence atmosphere pollution is less at lower levels.
- The system has a long life.

Limitations:-

- The maximum pressure created by natural draught is very low (20mm of water).
- For sufficient draught, the flue gases should be discharged at a higher temperature, which reduces the plant efficiency.
- Economizer and pre heater cannot be used to recover heat from the flue gases.
- The system will have poor combustion efficiency, since the velocity of air is low.
- It cannot produce higher draughts under peak loads, hence not flexible.

- **Mechanical Draught:-**
  - There are two types of mechanical draught systems, depending upon the type of fan used for creating the draught effect.
- If a forced draught fan is used it is termed a **forced draught** system, and if an induced draught fan is used it is termed an **induced draught** system.
- **Forced Draught:-**

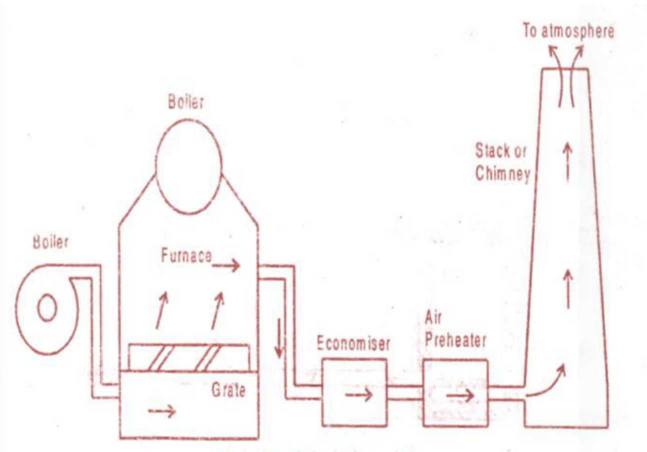


Fig. 2-37. Forced draught

- In this system, a blower is provided before the furnace.
- The blower forces the air through the furnace, economizer, air preheater and finally to the stack.
- This system is termed a positive or forced draught system, since the pressure throughout the system is above atmospheric, and the flues are force driven.
- The function of chimney in this arrangement is only to discharge the exhaust at high altitudes.

- The chimney has got nothing to do with draught creation and hence its height need not be too much, but a higher altitude is desirable to discharge the flues to minimize atmospheric pollution.
- **Induced Draught:-**

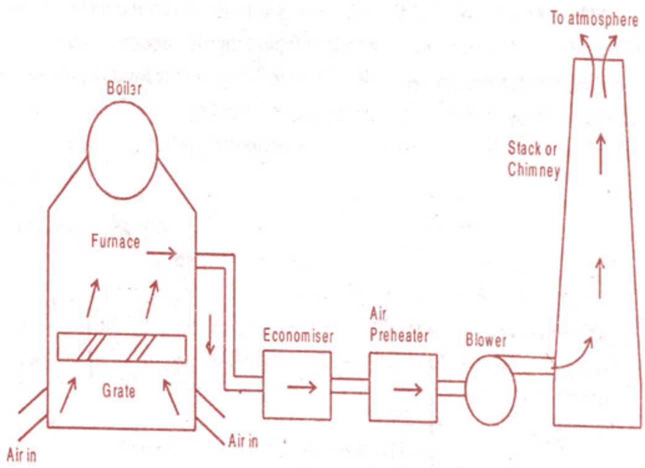


Fig. 2-38. Induced draught

- In this system, a blower is installed before the chimney which sucks air into the system and creates a low pressure condition below atmospheric pressure.
- This causes the air to be induced into· the furnace through the entrance ports and hot gases flow through the boiler, economizer, preheater, blower and· then finally to the chimney.
- The action of induced draught is similar to the action of natural draught chimney, but the draught produced it independent of the temperature of hot gases.
- Hence, maximum heat can be recovered in the air pre heater and economizer, and comparatively cooler gases can be discharged to the atmosphere.
- **Balanced Draught:-**

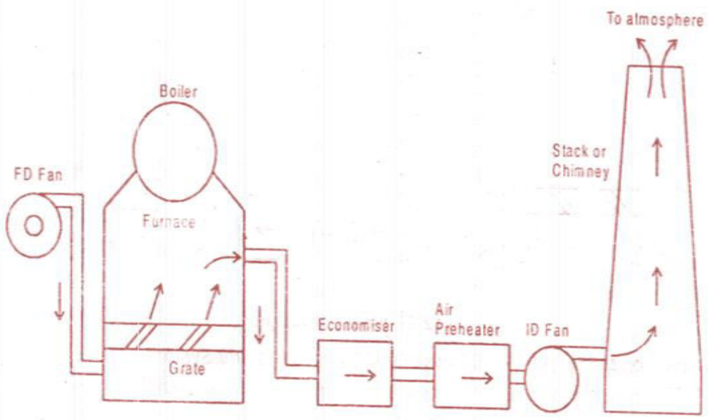


Fig. 2-39. Balanced draught

- Balanced draught is a combination of both forced draught and induced draught.
- In this system, both forced draught and induced draught fans are used, thus eliminating the difficulties of forced draught and induced draught systems.

- The forced draught fan provided at the entry to the furnace supplies the air through the fuel bed/grate, while the induced draught fan sucks in the hot flues from the furnace and discharges them at the chimney.
- Forced draught supplies sufficient air for combustion and induced draught prevents blow off flames when the doors are opened

Comparison between Forced Draught and Induced Draught Systems:-

- The induced draught handles a higher volume of gases at high temperature, therefore the size of fan required and power to drive it are larger as compared to· the forced draught system.
- Water cooled bearings are required in induced draught system since the hot gases come in contact with the fan.
- There are chances of air leakage in the forced draught system, since the pressure inside the furnace is above atmospheric. In the induced draught, the pressure is below atmospheric (suction), hence there are no chances of leakage.
- In the induced draught system, air flow is more uniform through the grate and furnace, as compared to the forced draught system.
- In an induced draught system, cold air may rush into the furnace while fuel charging doors are opened. This cold air rush will reduce the heat transfer efficiency.
- The fan blade wear is more in induced draught system as the blades come in contact with hot gases.

Advantages of Mechanical Draught over Natural Draught:-

- In a mechanical draught system, the rate of combustion is high since high draught is available.
- The rate of air flow, hence the combustion can be controlled by changing the draught pressures through the fan operations.
- The operation of the mechanical draught system does not depend on the environmental temperature. However, the natural draught is highly dependent on the environmental temperature.
- Low grade fuels can be easily burnt in mechanical draught system since a higher level of draught is available in a mechanical draught system.
- In mechanical draughts, maximum heat can be recovered and hence the overall efficiency is higher.
- The chimney height need not be as high as that of natural draught as its function is only to discharge the flues.

Boiler Accessories:-

- A boiler requires many accessories for continuous trouble-free functioning and steam generation.
- Some accessories are needed to increase the efficiency of the boiler.

- High economy in power generation can be achieved by utilizing the maximum extent.

Some of the essential boiler accessories **useful for waste heat recovery**, in the sequence, are as follows

- **Super heater**
- **Re heater**
- **Economizer**
- **Air pre heater**

Other essential accessories include:-

- **De super heater**
- **Soot blower**

- **Super heater:-**

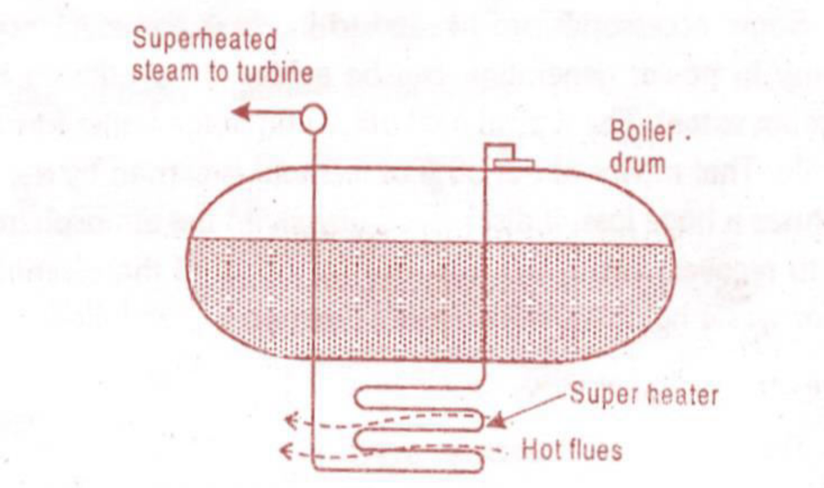


Fig. 2-40. Superheater

- As the name implies, the **function of a super heater is to superheat** the steam coming from the boiler.
- The steam generated in a boiler is not fully saturated, it contains some water particles (dryness fraction will be less than 1).
- If used directly, the water particles in the wet steam cause corrosion of the turbine blades, lead to reduced turbine efficiency, life and later failure of the blades itself
- The super heater completely saturates the wet steam (produces dry steam) and increases its temperature.
- A superheated steam has high heat content, and hence has an increased capacity to do work.
- This in turn improves the overall efficiency of the power plant.
- The super heaters are made of steel tubes of 25 to 50 mm diameter, and formed in series of U shapes.
- Super heaters can be classified based on the heat transfer method.
- There are three types of super heaters, as follows:

- **Convective super heater-**
- Absorbs heat from the hot gases by convection.
- This is the primary super heater that receives nearly saturated steam from the boiler drum.
- This super heater is located in the convective zone of the furnace, just before the economizer.

- **Radiant super heater -**
- Absorbs heat from the hot gases by radiation.
- This is the secondary super heater that receives steam from the primary super heater.
- This super heater is located in the radiant zone of the furnace, adjacent to tile water wall so that it absorbs heat by radiation.

- **Combined convective and radiant super heater -**
- Absorbs heat both by convection and radiation from the hot gases.
- This is also termed the pendant super heater, and is another secondary super heater used in steam power plants.
- Usually the steam from the radiant super heater passes through a de super heater, where high quality water is directly sprayed on to the steam.
- The de super heater maintains the required temperature in the steam after passing through the final stage or the pendant super heater.

- **Re-heater:-**

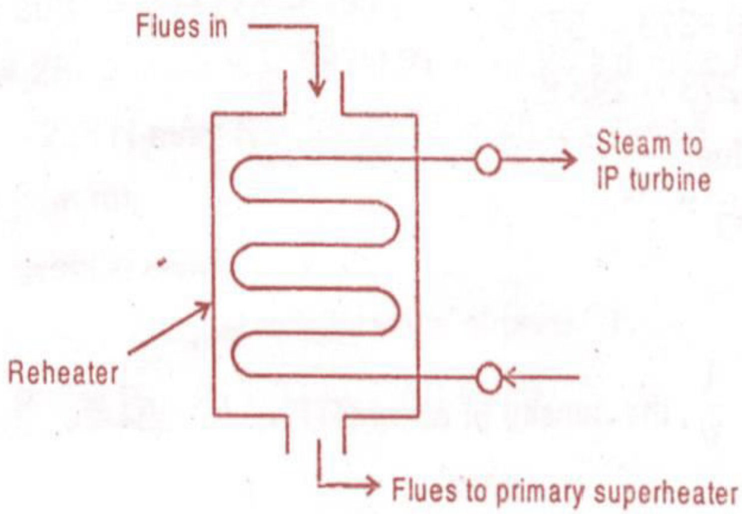


Fig. 2-41. Reheater circuit

- In a boiler, the super heaters are used to superheat the steam before being expanded in the high pressure (HP) turbine.
- The steam from the HP turbine loses the pressure and temperature.
- This steam before being sent to the next stage (intermediate IP or low pressure LP) turbine, it need to be improved again, this is done by passing this steam through a re heater.
- Thus, a re-heater is similar to a super heater, except that it adds heat to the steam coming out of the HP turbine, before being expanded in the IP or LP turbine.
- A re heater is generally located above the primary or convective super heater in the path of the hot flues.
- It is made of steel tubes mounted horizontally, perpendicular to the flue direction.
- **Economizer:-**

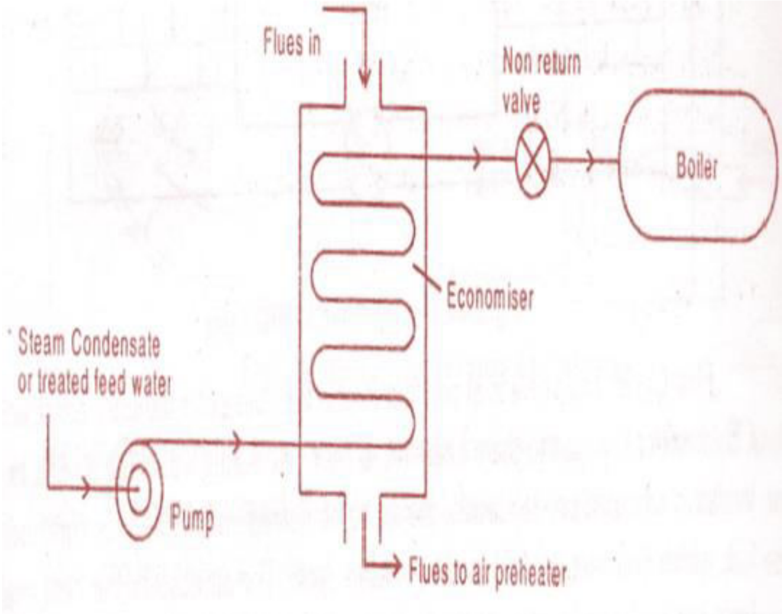


Fig. 2-42. Econimiser

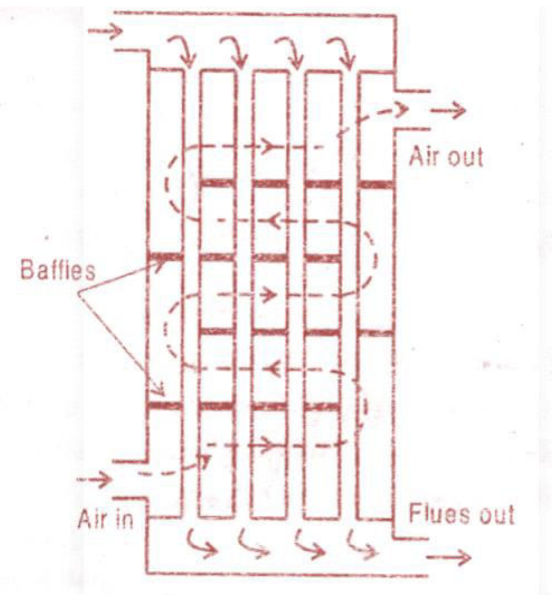
- The function of an economizer is to heat the feed water, before being supplied to the boiler, using the products of combustion discharged from the boiler.
- Generally feed water is heated 20-30°C below the boiling point.
- The economizer makes economizer. use of waste flues; recovers heat energy and hence the name
- Thus the economizer increases the boiler efficiency.
- As an approximation, it is shown that the boiler efficiency increases by 1% for every 6°C raise in the feed water temperature
- The flues passing throgh the economizer chamber transfer the heat energy to the water flowing through the steel tubes.
- The maximum temperature desirable is 20 – 30^0C below the boiling point, as at temperatures above 85°C the steam bubbles begin to form and the feed pump cannot supply steam-water mixture properly.

- To overcome this problem the feed water pump is generally located before the economizer.
- The feed water pump pumps either raw water (after proper treatment) or condensate from the condenser.
- The feed water flowing through the economizer gets heated and enters the boiler under pressure.
- A non-return valve is provided to avoid return flow of feed water or steam from the boiler, when the feed pump is not in operation.
- The pump pressure is always higher (about 2 bar more) the boiler pressure in operation.

Advantages of Economizer:-

- It recovers the waste heat to a greater extent.
- It reduces the fuel consumption per unit power produced.
- It improves the efficiency of the power plant.
- It reduces the soot and fly-ash being discharged to atmosphere to some extent.

- **Air pre heater:-**



(a) Tubular Type

- The function of an air preheater, as the name indicates, is to preheat the air being supplied to the furnace for combustion.
- This makes use of the flues discharged from the furnace and from the economizer.
- As this also recovers further heat from the flues, it increases the boiler efficiency.
- An increase in temperature of the 20°C increases the boiler efficiency by 1 %.

***Advantages*:-**

- Combustion efficiency is improved.
- Low grade fuels can be burnt successfully.
- Steam rising capacity is increased.
- Fuel consumption is reduced.

Special accessories,

- **Desuperheater:-**

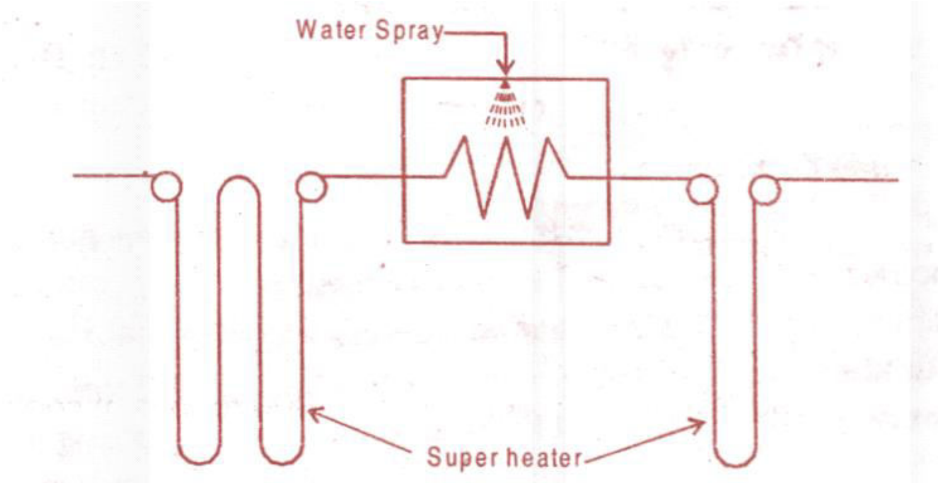


Fig. 2-46. Desuperheater

- It is essential to control the superheat temperature, otherwise it may lead to overheating of superheated tubes and initial stages of the turbine, causing operational problems.
- The device used to control the superheat temperature is termed a desuperheater.
- The various methods used to control the superheat temperatures are as follows:
- Bypassing the hot gases. When the temperature of the superheated steam raises sufficiently high, then the hot gases are bypassed with the help of dampers.
- Cooling water is essential in a steam power plant to condense the steam from the steam turbines.
- The quantity of cooling water required is so high that it cannot be let out after use.
- A 100 MW plant needs about 10,000 tones of cooling water per day.
- This necessitates the need for recirculation of the cooling water.

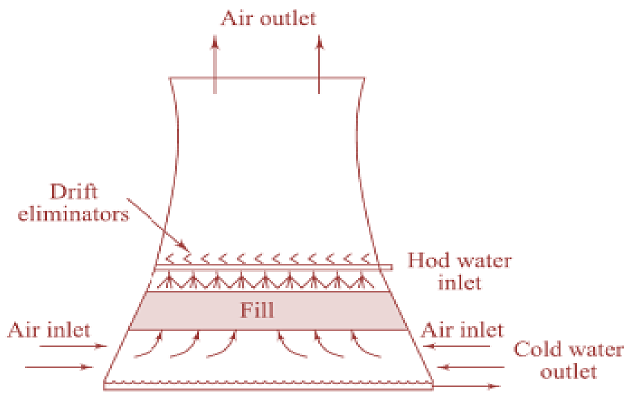
- The used water absorbs heat from the condenser and cannot be recirculated unless cooled to a minimum temperature.

Cooling Towers:-

The different types of cooling towers used in power plants are:

- **Wet type**
  - Natural draught cooling tower
  - Forced draught cooling tower
  - Induced draught cooling tower
- **Dry type**
  - Direct type
  - Indirect type

- **Wet type:-**
  - **Natural draught cooling tower:-**

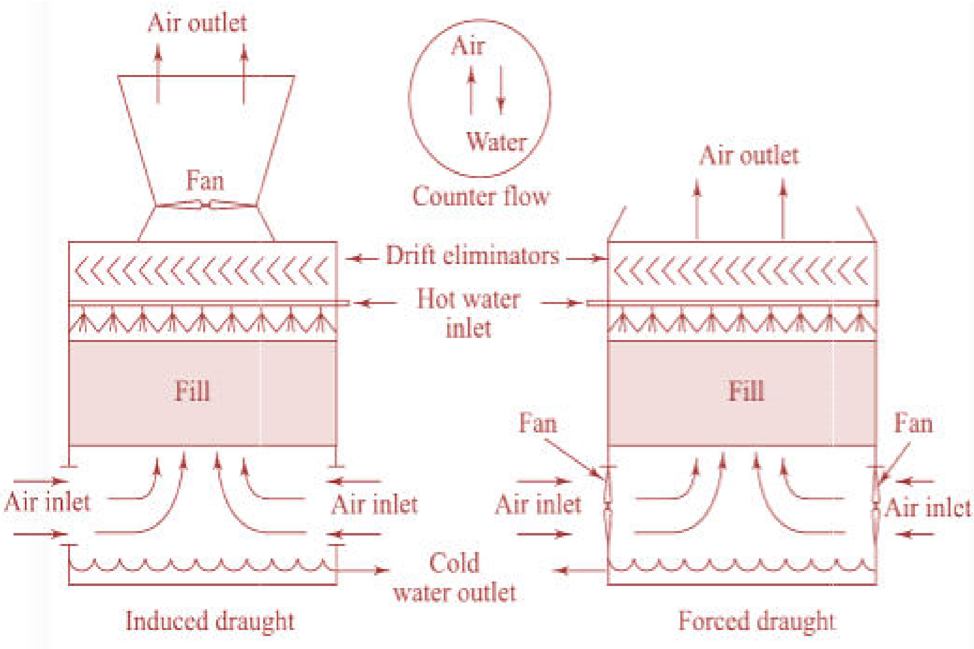


Counterflow hyperbolic natural draught cooling tower

- This is a wet type of cooling tower, and is generally used in large capacity power plants.
- It consists of a huge hyperbolic concrete structure, with openings at the bottom.
- At the lowest portion of the structure a water pond is constructed for the collection of the cooling water.
- In operation, the cooling water from the condenser is to the top of the cooling tower.
- The water is sprayed from the top, and falls sprinkles.
- Because of the height, natural draught is created and the air rises bottom.
- The falling water comes in contact with the rising air and gets cooled water is collected in the pond and pumped back to the condenser.
- Make up water is added to the pond periodically.

- The height of the cooling tower ranges from 50 m to 80 m, with base diameter up to 40 m.

Forced draught cooling tower:-



Induced draught counterflow cooling towers

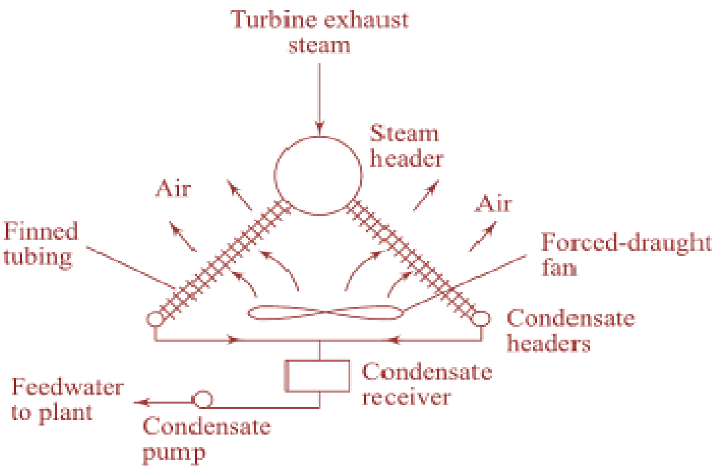
- Forced draught cooling towers are smaller in size and are used in small capacity power plants.
- Since the height of the cooling tower is smaller and it has a rectangular section, the natural draught created very low.
- Hence, to create a draught, a forced draught a fan is provided at the bottom
- The cooling tower is a rectangular section having baffles/obstruction at the centre.
- A forced draught fan is provided at the bottom, and it pressurizes the air.
- The hot water from the condenser is sprayed from the top and while falling through the baffles/obstacles it comes in contact with the raising forced draught air and gets cooled.
- The cooled water is collected in the pond and re circulated.
- Make up water is added to the pond periodically

Induced draught cooling tower:-

- This is similar in construction and operation to a forced draught cooling tower, except for the induced draught fan.
- This is suitable for small capacity power plants.
- It has a rectangular section with opening at the bottom for the air entry.

- In operation the induced draught fan sucks air through the baffles from the openings at the bottom of the tower.
- The hot water pumped from the condenser is sprayed at the top.
- The falling water comes in contact with the raising air and gets cooled.
- The cooled water is collected in the pond and pumped back to the condenser.
- Make up water is added periodically to the pond.

- **Dry type:-**
- **Direct type:-**



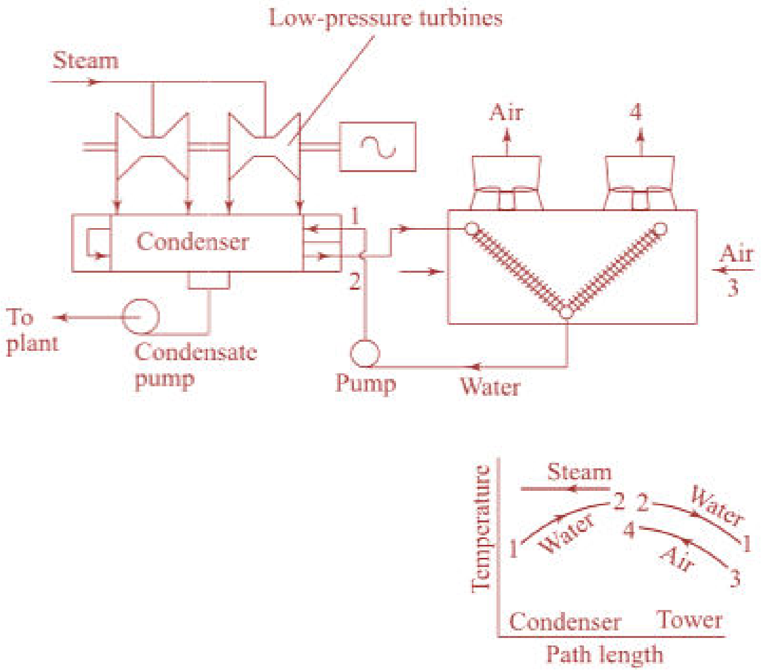
Schematic of a direct dry-cooling tower

- In this, the exhaust steam is collected in a large steam header at the top.
- A number of steel tubes are connected to the steam header, through which the steam is passed to the condensate header at the bottom.
- The steam tubes are provided with external fins, so as to increase the heat transfer rate and hence condense the steam in the tubes.
- The steam condenses as water in the condensate headers, and is collected in a condensate tank.
- From the tank the water is pumped to the feed water line.

- **Indirect type:-**

There are two types of indirect dry cooling towers.

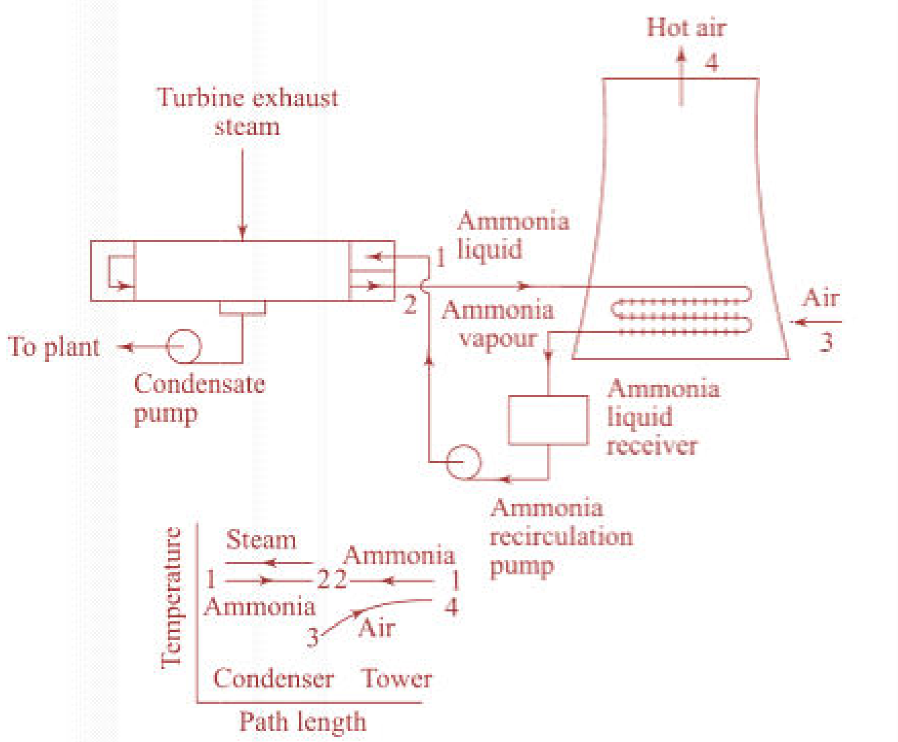
- **Indirect dry cooling tower with a conventional surface condenser**



Schematic of an indirect dry-cooling tower with a conventional surface condenser

- This cooling tower uses two heat exchangers in series.
- The first one is the conventional surface condenser, where the turbine exhaust steam is condensed using cooling water as the coolant.
- The condensate is used as feed water.
- The second heat exchanger is the hot water to air heat exchanger, in which the hot water from the surface condenser is cooled with the help of finned tubing similar to the dry cooling tower concept.
- The steam at temperature Ts from the turbine is first condensed in the surface condenser.
- At this heat exchanger by absorbing heat from steam, the water temperature raises from T1 to T2.
- The hot water is (at T2) then passed through a series of steel tubes in the dry cooling tower.
- The steel tubing is provided with external fins, so as to increase the heat transfer rate and hence cool the hot water in the tubes.
- The cooling is assisted in the tower with the help of two 10 fans (or a large hyperbolic natural draught tower can also be used, depending upon the cooling requirements).

- **Indirect dry cooling tower with a open type condenser**



Schematic of an indirect dry-cooling tower with a surface condenser having ammonia as the coolant

- The construction and operation of this cooling tower is same as the dry indirect cooling tower with surface condenser, except that it uses a open spray type condenser instead of the surface condenser.
- Thus this cooling tower also uses two heat exchangers in series.
- The first one is a direct contact spray type steam condenser, where the turbine exhaust steam is condensed using cooling water. The second heat exchanger is indirect type, the hot water to air heat exchanger, in which the hot water from the condenser is cooled with the help of finned tubing similar to the dry cooling tower concept.
- A part of the hot water is used as feed water.
- The steam at a higher condenser.
- At this heat exchanger by mixing with steam, the water temperature raises from T_1 to T_2 water-steam mixture attains the same temperature.
- The hot water is (at T_2) then passed through a series of steel tubes in the drying tower.
- The steel tubing are provided with external fins, so as to increase the transfer rate and hence cool the hot water in the tubes.
- The cooling is assisted in tower with the help of two ID fans (or a large hyperbolic natural draught tower also be used, depending upon the cooling requirements).

- At this cooling tower, the water temperature drops from T_2 to T_1.
- Since the heat is absorbed by the cooling he air gains temperature from T_3 to T_4.
- These temperature path lengths at the condenser and the cooling tower.

Pondage:-

It is defined as a regulating means of water, and is a small reservoir that is used for the collection of the excess flow water from the dam spill ways of the main reservoir or from/the river stream.

- It is basically a small pond or reservoir just behind the power house as shown in figure.
- The amount of regulation obtained with pondage usually involves storing water during low loads (during low power demand periods such as early morning hours and Sundays) to aid carrying peak loads during the week.
- The water that would go over the dam spill-way unused during low-loads can be released and added to normal river flow to supply peak loads, usually for a few hours of duration
- For fluctuating loads, pondage increases the maximum capacity that a plant can carry.
- Plants with reservoirs upstream can store excess water of spring floods for release during summer to supplement the low rates of flow during this dry season
- Reservoir water elevation will generally be lowest during the year at the end of the summer.
- Pondage increases the capacity of a river for a brief period only, like for 8 week.
- But, storage increases the capacity of a river over an extended period such like 6 months to 2 year.

TWO MARKS QUESTIONS:

1. What are the types of power plants?

1. Thermal Power Plant
2. Diesel Power Plant
3. Nuclear Power Plant
4. Hydel Power Plant
5. Steam Power Plant
6. Gas Power Plant
7. Wind Power Plant
8. Geo Thermal
9. Bio – Gas
10. M.H.D. Power Plant

2. What are the flow circuits of a thermal Power Plant?
1. Coal and ash circuits.
2. Air and Gas
3. Feed water and steam
4. Cooling and water circuits

3. List the different types of components (or) systems used in steam (or) thermal power plant?
1. Coal handling system.
2. Ash handling system.
3. Boiler
4. Prime mover
5. Draught system.
a. Induced Draught
b. Forced Draught

4. What are the merits of thermal power plants? Merits (Advantages) of Thermal Power Plant:
1. The unit capacity of thermal power plant is more. The cost of unit decreases with the increase in unit capacity
2. Life of the plant is more (25-30 years) as compared to diesel plant (2-5 years)
3. Repair and maintenance cost is low when compared with diesel plant
4. Initial cost of the plant is less than nuclear plants
5. Suitable for varying load conditions.

5. What are the Demerits of thermal power plants? Demerits of thermal Power Plants:
1. Thermal plant are less efficient than diesel plants
2. Starting up the plant and brining into service takes more time
3. Cooling water required is more
4. Space required is more.

6. What are the various steps involved in coal handling system?
1. coal delivery
2. Unloading,
3. Preparation
4. Transfer
5. Outdoor storage
6. Covered storage
7. In-Plant handling
8. Weighing and measuring
9. Feeding the coal into furnace

7. After coal preparation, How the coal transfer?

1. Belt conveyors
2. Screw conveyors
3. Bucket elevation
4. Grab bucket elevators
5. Skip hoists
6. Flight conveyor.

8. Write the advantages of belt conveyor?

1. Its operation is smooth and clean,
2. It requires less power as compared to other types of systems.
3. Large quantities of coal can be discharged quickly and continuously,
4. Material can be transported on moderate inclines.

9. What are the systems used for pulverized coal firing?

1. Unit system or Direct system
2. Bin or Central system

10. Write the classification of Mechanical Stokers?

1. Travelling grate stoker
2. Chain grate stoker
3. Spreader stoker
4. Vibrating grate Stoker
5. Underfeed stoker.

11. What are the three major factor consider for ash disposal system?

1. Plant site
2. Fuel source .
3. Environmental regulation

12. Write the classification of Ash handling system?

1. Hydraulic system,
2. Pneumatic system
3. Mechanical system

13. What are the Ash discharge equipments?

1. Rail road cars
2. Motors truck
3. Barge

14. Define Draught.

Draught is defined as the difference between absolute gas pressure at any point in a gas flow passage and the ambient (same elevation) atmospheric pressure.

15. What are the purpose of Draught.

(i) To supply required amount of air to the furnace for the combustion of fuel. The amount of fuel can be burnt per square foot of grate depends upon the quantity of air circulated through fuel bed.

(ii) To remove the gaseous products of combustion.

16. Define artificial draught?

If the draught is produced by steam jet or fan it is known as artificial draught.

17. Define Induced draught?

The flue is drawn (sucked) through the system by a fan or steam jet.

18. Define Forced draught?

The air is forced into the system by a blower or steam jet.

19. Write the merits of Natural Draught?

1. No external power is required for creating the draught
2. Air pollution is prevented since the flue gases are discharged at a higher level
3. Maintenance cost is practically nil since there are no mechanical parts
4. Its has longer life, 5. Capital cost is less than that of an artificial draught.

20. Write the De-merits of Natural Draught?

1. Maximum pressure available for producing draught by the chimney is less,
2. Flue gases have to be discharged at higher temperature since draught increases with the increase in temperature of flue gases.
3. Heat cannot be extracted from the fluid gases for economizer, superheater, air pre-heater, etc. Since the effective draught will be reduced if the temperature of the flue gases is decreased.

21. Write the merits of steam Jet draught?

1. This system is very simple and cheap in cost,
2. Low grade fuel can be used
3. Space required is less

22. Write the De-merits at steam jet draught?

1. It can be operated only when the steam is raised
2. The draught produced is very low

23. Define Condenser?

A condenser is a device in which the steam is condensed by cooling it with water. The condensed steam is known as condensate.

24. Write the essential elements of a steam condensing plant?

1. A closed vessel in which the steam is condensed.

2. A pump to deliver condensed steam to the hot well from the condenser.
3. A dry air-pump to remove air and other non-condensable gases,
4. A feed pump to deliver water to the boiler from hot well.

25. What are the sub division of jet condensers?

1. Low level counter flow jet condenser
2. High level (or) Barometric jet condenser
3. Ejector condenser.

26. Write the surface condenser?

1. Down flow condenser
2. Central flow condenser
3. Evaporative condenser

27. Write the advantages of surface condenser?

1. The condensate can be used as boiler feed water
2. Cooling water of even poor quality can be used because the cooling water does not come in direct contact with steam
3. High vacuum (about 73.5 cm of Hg) can be obtained in the surface condenser. This increases the thermal efficiency of the plant.

UNIT-III

Diesel Engine and Gas Turbine Power Plant

Application of diesel engine electric plant:-

Peak load plants: Diesel plants can be used in combination with thermal or hydro plants as peak load units. They can be easily started or stopped at short notice to meet the peak demand.

Mobile plants: Diesel plants mounted on trailer can be used for temporary or emergency purposes such as supplying power to large civil engineering works.

Standby unit: If the main unit fails or can't cope up with demand, a diesel plant can supply necessary power. For example, if the water available in the hydro plant is not adequately available due to less rainfall, the diesel station can operate in parallel to generate short fall of power.

Emergency plant: During power interruption in a vital unit like key industrial plant or hospital, a diesel electric plant can be used to generate the needed power.

Nursery station: In the absence of the main grid, a diesel plant can be installed to supply power in a small town. In course of time when electricity from main grid becomes available in the town, the diesel unit can be shifted to some other area which needs power in small scale. Such diesel station is called nursery station.

Starting station: Diesel units can be used to run auxiliaries (like FD & ID fans) for starting large steam power plant.

Central station: Diesel electric plant can be used as central station where power required is small.

Layout of a diesel power plant:-

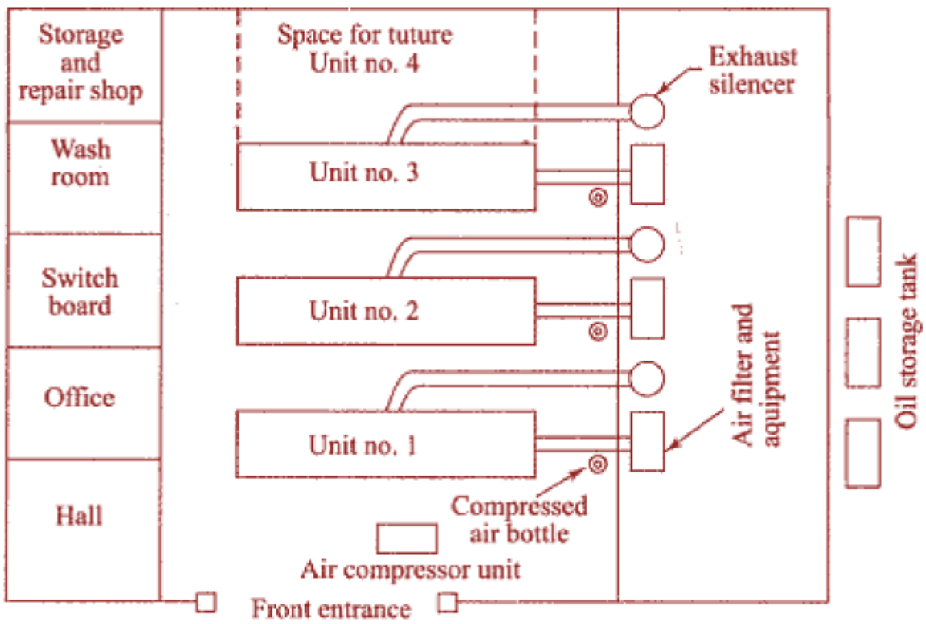


Fig. 11.37 *Typical layout of a diesel engine power plant*

The layout of a diesel engine power plant is shown in above figure.

Diesel engine units are installed side by side with some room left fur extension in the future.
The repairs and usual maintenance works require some space around the units.
The air intakes and filters are exhaust mufflers are located outside.
Adequate space for oil storage, repair shop and office are provided as shown.
Bulk storage of Oil may be outdoors.

Starting of engine:-

Following are the three common method of starting an engine.

By an auxiliary engine, this is mounted close to the main engine through a clutch and gears.
and drives the latter

By using an electric motor, in which a storage battery 12 to 36 volts is used to supply power to an electric motor that derives the engine.

By compressed air system, in which compressed air at about 17bar supplied from an air tank is admitted to a few engine cylinders making them work like reciprocating air motors to run the engine shaft. Fuel is admitted to the remaining cylinders and ignited in the normal way causing the engine to start. The compressed air system is commonly used for starting large diesel engines employed for stationary power plant service.

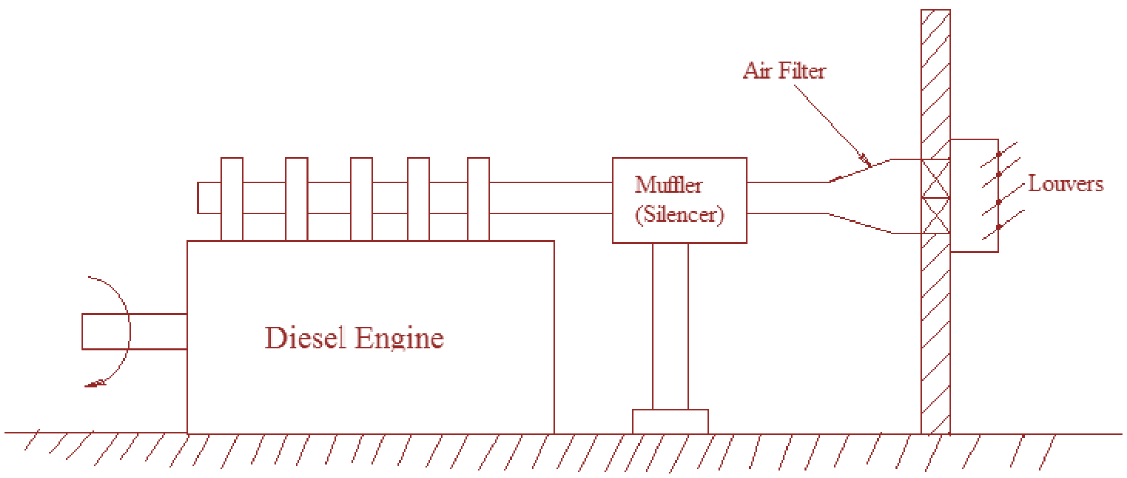
Essential component or element of diesel electric plant:-

Engine
Air intake system
Exhaust system
Fuel system
Cooling system
Lubrication system

Engine:-

It is the main component of the plant and is directly coupled to the generator.

Air intake system:-



It conveys fresh air through louvers and air filter that removes dirt, etc. causing wear of the engine. Supercharger, if fitted, is generally driven by the engine itself and it augments the power output of the engine.

Exhaust system:-

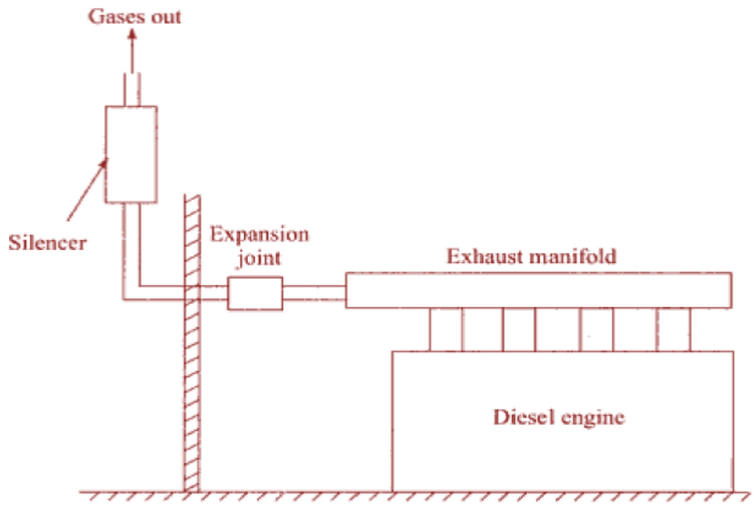


Fig. 11.3 *Diesel engine exhaust system*

- Exhaust system discharge the engine exhaust to the atmosphere.
- The exhaust manifold connects the engine cylinder exhaust outlets to the exhaust pipe which is provided with a muffler or silencer to reduce pressure on the exhaust line and eliminates most of the noise which may result if gases are discharged directly to the atmosphere.
- The exhaust pipe should have flexible tubing system to take up the effects of expansion due to high temperature and also isolate the exhaust system from the engine vibration.

There is scope of waste heat utilization from the diesel engine exhaust,

- By installing a waste heat boiler to raise low pressure steam which can be used for any process, purpose or for generating electricity.
- The hot exhaust may also be utilized to heat water in a gas-to-water heat exchanger which can be in the form of a water coil installed in the exhaust muffler.
- It can also be used for air heating where the exhaust pipe is surrounded by the cold air jacket.

Fuel system:-

Fuel oil may be delivered at the plant site by trucks, railway wagons or barges and oil tankers. An unloading facility delivers oil to the main storage tanks from where oil is pumped to small service storage tanks known as engine day tanks, which store oil for approximately eight hours of operation.

The fuel injection system is the heart of a diesel engine.

Engines driving electric generators have lower speeds and simple combustion chambers that promote good mixing of fuel and air.

Cooling system:-

The temperature of the gases inside the cylinder may be as high as 2750"C. If there is no external cooling, the cylinder walls and piston will tend to assume the average temperature of the gases which may be of the order of 1000° to I500°C. The cooling of the engine is necessary for the following reasons.

- The lubricating oil used determines the maximum engine temperature that can be used.
- Above these temperatures the lubricating oil deteriorates very rapidly and may evaporate and bum damaging the piston and cylinder surfaces.
- The strength of the materials used for various engine parts decreases with increase in temperature.
- High engine temperatures may result in very hot exhaust valve, giving rise to pre-ignition and
- detonation or knocking.
- Due to high cylinder head temperature, the volumetric efficiency and hence power outputs of the engine are reduced.

Following are the two methods of cooling the engine.

Air cooling:

Air cooling is used in small engines, where fins are provided to increase heat transfer surface area.

Water cooling:

Big diesel engines are always water cooled. The cylinder and its head are enclosed in a water jacket which is connected to a radiator. Water flowing in the jacket carries away the heat from the engine and becomes heated. The hot water then flows into the radiator and gets cooled by rejecting heat to air from the radiator walls. Cooled water is again circulated in the water jacket.

Various methods used for circulating the water around the cylinder are the following.

Thermosiphon cooling: In this method water flow is caused by density difference. The rate of' circulation is slow and insufficient.

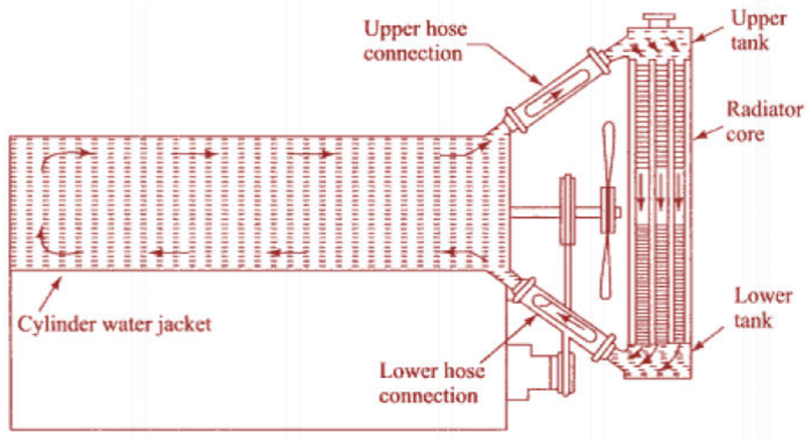


Fig. 11.11 *Thermosiphon cooling*

Forced cooling by pump: In this method a pump, taking power from the engine, forces water to
circulate, ensuring engine cooling under all operating conditions. There may be overcooling
which may cause low temperature corrosion of metal parts due to the presence of acids.

Thermostat cooling: This is a method in which a thermostat maintains the desired temperature and protects the engine from getting overcooled.

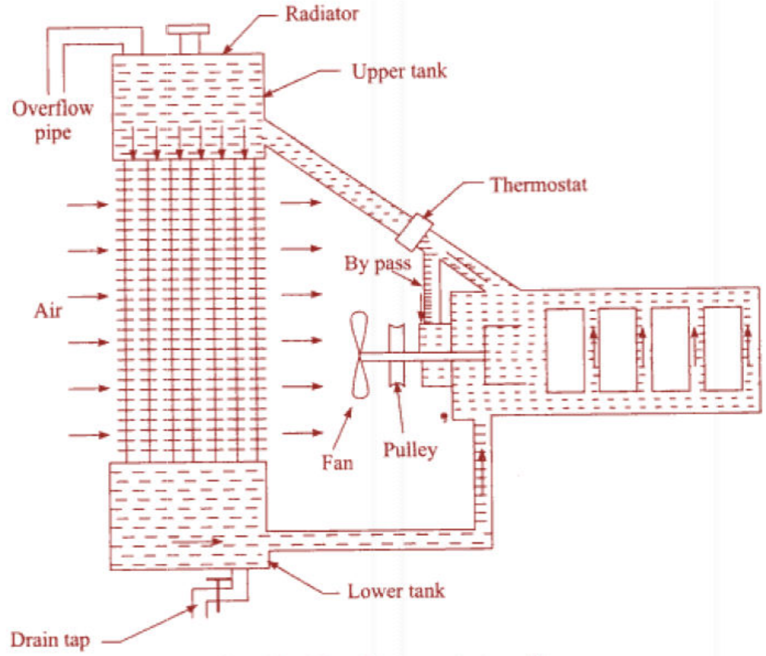


Fig. 11.12 *Thermostat cooling*

Pressurized water cooling: In this method a higher water pressure, 1.5 to 2 bar, is maintained to increase heal transfer in the radiator. A pressure relief valve is provided against any pressure drop or vacuum.

Evaporative cooling: In this method water is allowed to evaporate absorbing the latent heal of evaporation from the cylinder walls. The cooling circuit is such that the co and the steam flashes in a separate vessel.

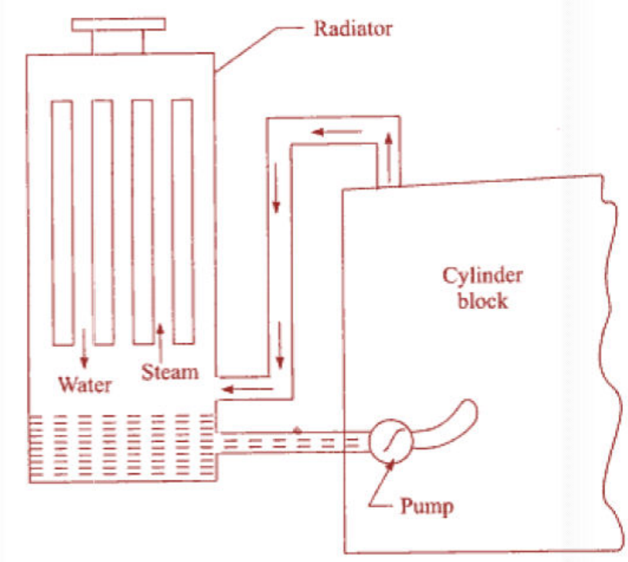


Fig. 11.13 *Evaporative cooling*

Lubrication system:-

Lubrication is the flow of oil between two surfaces having relative motion.
Following are the function of lubricating system.
Lubrication: To keep moving parts sliding freely past each other, thus reducing engine friction and wear.

- ***Cooling:*** To keep the surface cool by taking away a part of heat caused by friction.
- ***Cleaning:*** To keep bearing and friction ring clean of the product of wear and combustion by washing them away.
- ***Sealing:*** To form a good seal between the piston ring and cylinder wall.
- ***Reduce noise:*** To reduce noise of engine by absorbing vibration.

Lubrication system can be classified as,

(a) Mist lubrication system,

(b) Wet sump lubrication system and

(c) Dry sump lubrication system.

Mist lubrication system:-

This system is used for two stroke cycle engine which employs crankcase compression. Thus crankcase lubrication is not suitable in these engines.

Wet sump lubrication system:-

The bottom part of the crankcase, called sump, contains the lubricating oil which is pumped to the various part of the engine. There are three types of wet sump lubrication system; they are **Splash system, Modified splash system and Full pressure system**

Splash system:-

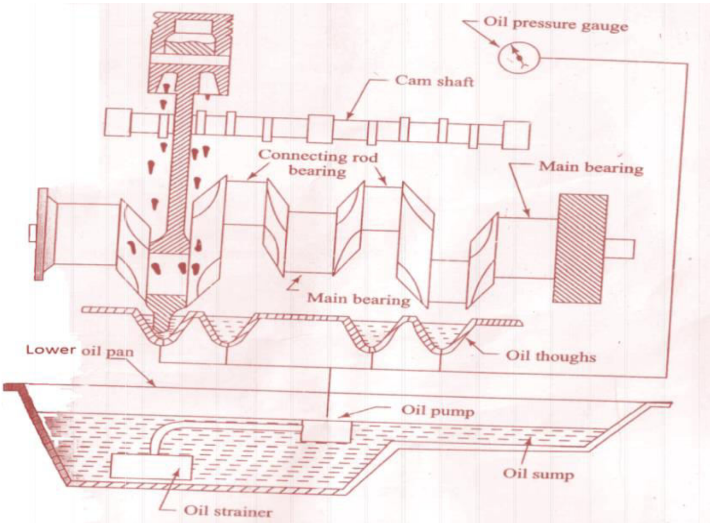


Fig. 11.14 *Splash lubrication system*

It is used for small four stroke stationary engines. The oil level in the sump is maintained in such a way that when the connecting rod's big end at its lowest position the dippers at the end strike the oil in the troughs which are supplied with oil from the sump by an oil pump. Due to striking of dippers oil splashes over various parts of engine like crank pin, bearing, piston ring, piston pin etc. Excess oil drips back into the sump.

Modified splash system:-

The splash system is not sufficient if the bearing loads are high. For such cases, the modified splash system is used, where main and camshaft bearings are lubricated by oil under pressure pumped by an oil pump. The other engine parts are lubricated by splash system as shown in above figure.

Full pressure system:-

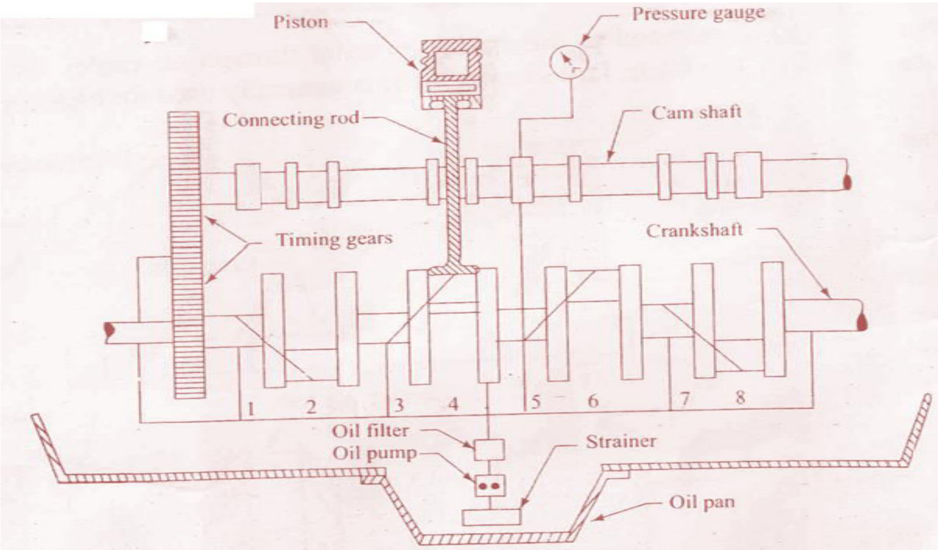


Fig. 11.15 *Full pressure lubrication system*

An oil pump is used to lubricate all the parts of the engine. Oil is pumped to the main bearing of the crankshaft and camshaft at pressure between 1.5bar to 4bar. Drilled passages are used to lubricate connecting rod end bearing.

A gear pump submerged in oil and driven by the camshaft draws the oil from the sump through a strainer. A pressure relief valve is provided on delivery side to prevent excessive pressure.

(c) Dry sump lubrication system:-

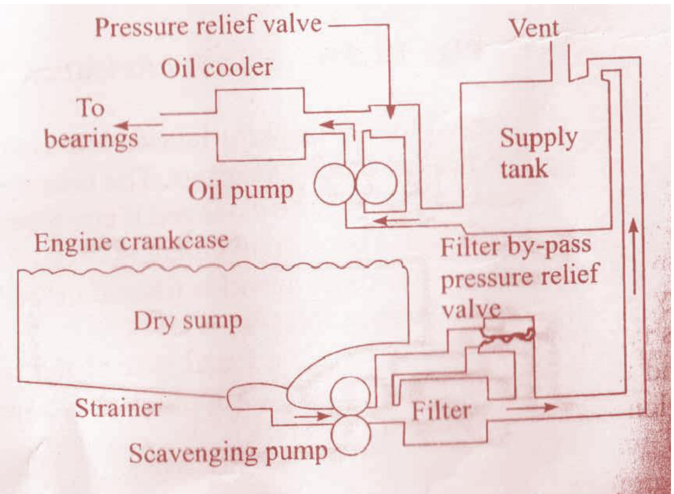


Fig. 11.17 *Full flow dry sump lubrication*

Oil from the sump is carried to a separate storage tank or supply tank outside the engine cylinder. The oil from the dry sump pumped through the filter to the storage tank. Oil from the supply tank is pumped to the engine cylinder through oil cooler. Oil pressure varies from 3bar to 8bar. Dry sump system is generally used for high capacity engine.

From the pump all the oil used for lubrication usually passes through an oil filter before it reaches engine bearing. The bearings are machined through very high tolerance and are likely to be damaged if any foreign material is allowed to the lubrication line.

Filter arrangement are of two types, they are **full flow type and bypass type**.
In full flow type, all the oil is filtered before it is fed to the bearings, as in dry sump lubrication (Fig 11.17).
In bypass flow type, only a small part of oil is passed through the filter and rest is directly supplied to the bearing, as in wet sump lubrication system (Fig. 11.18).

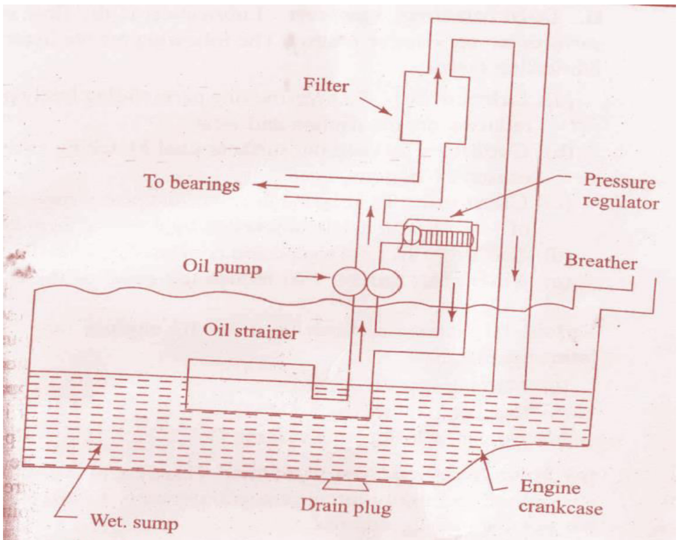


Fig. 11.18 *By-pass type wet sump lubrication*

TWO MARK QUESTIONS

1.Define heat engine?
Any type of engine or machine which derives heat energy from the combustion of fuel or any other source and converts this energy into mechanical work is termed as a heat engine.

2. What are the essential component of diesel power plants?
Essential components of a diesel power plant are:
(i) Engine
(ii)Air intake system
(iii)Exhaust system
(iv)Fuel system
(v) Cooling system
(vi) Lubrication system
(vii) Engine starting system
(viii) Governing system.

3. **What are the injection system's are used in diesel power plants?**
Commonly used fuel injection system in a diesel power station:

(i) Common-rail injection system
(ii) Individual pump injection system
(iii) Distribution system.

4. List the various Liquid Cooling System?
In liquid cooling following methods are used for circulating the water around the cylinder and cylinder head:
(i) Thermo-system cooling
(ii) Forced or pump cooling
(iii)Cooling with thermostatic regulator
(iv) Pressurized cooling
(v) Evaporative cooling.

5. What are the various Lubricating system's are used in I.C Engines?
Various Lubrications systems use for I.C. engines are:
(i) Wet sump lubrication system
(ii) Dry sump lubrication system
(iii) Mist lubrication system.

6. Mention three starting systems for Large and Medium size engines?
The following three are the commonly used starting systems in large and medium size engines:
(i) Starting by an auxiliary engine
(ii) Use of electric motors of self starters
(iii) compressed air system.

7. What is the purpose of super charging?
The purpose of supercharging is to raise the volumetric efficiency above that value which can be obtained by normal aspiration.

8. What are the classifications of Heat Engine?
Heat engines are classified into two types:
1) External combustion engines,
2) Internal combustion engines.

9. Define connecting rod?
It connects the piston and the crankshaft, thereby transmitting the force exerted on the piston to the crankshaft.

10.Define crankshaft?
It converts the reciprocating motion of the piston into the rotary motion of the output shaft. It is enclosed in the crankcase.
11.Define Flywheel?

It is a heavy wheel mounted on the crankshaft. It stores the excess energy delivered by the engine during power stroke and supplies the energy needed during other strokes. Thus it keeps the fluctuations in the crankshaft speed within desired limits.

12.What are the 2 – cooling Medium in cooling system?

The cooling medium used in the cooling system can be air or water. There are two types of cooling systems:

1) Liquid or indirect cooling system,
2) Air or direct cooling system.

13. Write the three types of liquid cooling systems?

This system can be classified under three types:

i) Natural circulation type or thermo syphon system,
ii) forced circulation system,
iii) Thermostatic cooling system.

14. Write the Disadvantages of over cooling of the Engine?

1) Engine starting is difficult,
2) Over-cooling reduces the overall efficiency of the system,
3) At low temperatures, corrosion assumes considerable magnitude that it may reduce the life of various components.

15. Write the advantages of Air cooling?

1. It occupies less space,
2. Air cooled engine are lighter than water-cooled engines. Hence used in two wheelers, agricultural sprayers, etc.
3. Engine warms up faster than water cooled engines,
4. Practically, there is no need for maintenance.

16. Write the advantages of Water cooling?

1) Cooling is more efficient,
2) Uniformity in cooling,
3) Engines cooled by water can be placed anywhere in the vehicle.

17. Write the function of Lubrication?

a. To reduce the wear and tear between the moving parts and thereby increasing the life of the engine.
b. The lubricating oil acts as a seal, i.e., it prevents the high pressure gases in the combustion chamber from entering the crankcase
c. To cool the surfaces.

18. What are the classifications of Lubrication system?

Classification of Lubrication System:

Some of the lubricating systems used for IC engines are:

i) Wet sump lubricating system,

ii) Mist lubricating system.

Wet sump lubricating system can be further classified as,

i) Splash type lubricating system,

ii) Pressure feed lubricating system.

19. What are the components of fuel injector?

The fuel injector or atomizer consists of:

1) Needle valve,

2) Compression spring,

3) Nozzle,

4) Injector body.

20. What are the duties of Air intake systems?

The duties of the air intake systems are as follows:

i) To clean the air intake supply,

ii) To silence the intake air,

iii) To supply air for super charging.

Gas Turbine (GT) Power Plant

Introduction:-

The gas turbine has low weight to power ratio hence gas turbines are extensively used to drive aviation system of all kind in aircraft system. It is also being increasingly used in land vehicles such as bus and truck and also to drive locomotives and marine ships. In oil and gas industries, the gas turbine is widely employed to drive auxiliaries like compressor blower and pumps.

Advantages of gas turbine power plant:-

Warm up time: Once the turbine is brought up to rated speed by starting the motor and fuel is ignited, the GT will accelerate to full load without warming up.

Low weight to size: The weight of GT per kW output is low, which is a favorable feature in all vehicles.

Fuel flexibility: Any hydrocarbon fuel from high octane gasoline to heavy diesel oil and pulverized coal can be used efficiently.

Floor space: Because of its small size, the floor space required for its installation is less.

Start up and shut down: A GT plant can be started up as well as shut down very quickly. Thus suitable for peak load demand for certain region.

High efficiency: Suitable blade cooling permits use of high GT inlet temperature yielding high thermal efficiency (around 30%).

Combined cycle mode: A GT power plant can be used in conjunction with a bottoming steam plant in combined cycle mode to yield overall fuel to electricity efficiency of 55%.

Cooling water: The cooling water requirement is not much. Hence water availability is not a restriction in installation of GT plant.

Ash disposal: In thermal power station ash disposal from site poses serious problem. This is not so in GT power plant.

Transmission loss: It can be located in the load center itself. Therefore transmission loss is minimal.

Installation cost: installation cost is less compared to thermal plant. Only foundation is required. The plant comes from the factory to site, almost fully assembled.

Scope of cogeneration: GT plants are used to produce process heat for various uses.

Low capital cost: The capital cost per kW is considerably less than a thermal plant.

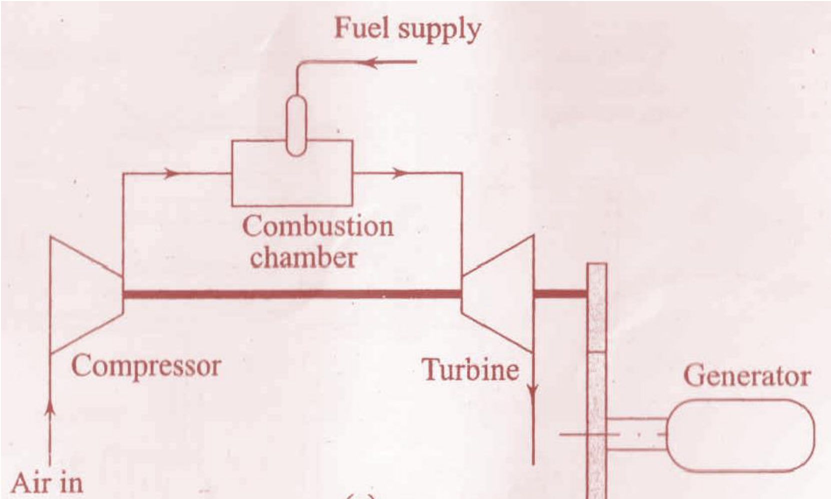
Disadvantages of gas turbine power plant:-

- Part load efficiency is low.
- Highly sensitive to component efficiency like compressor and turbine efficiency.
- The efficiency depends upon ambient condition (ambient temperature and pressure).
- High air rate is required to limit the maximum GT inlet temperature; as a result exhaust loss is high.
- Large compressor work is required, which tells upon efficiency of the plant.
- Air and gas filter should be off high quality so that no dust enters to erode or corrode turbine blade.

Open cycle and closed cycle gas turbine power plant:-

The Gas Turbine (GT) power plant could be either open cycle or closed cycle.

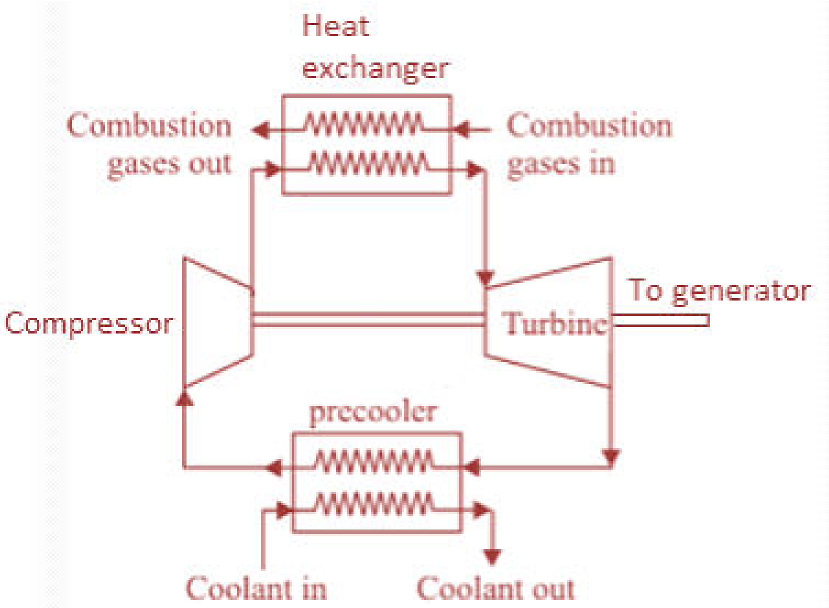
Open cycle gas turbine power plant:



(a)

- The open cycle power plants (as shown in fig.) are most widely used in majority of GT power plants.
- In open cycle GT power plants, atmospheric air is continuously drawn into the compressor and compressed to high pressure.
- The compressed air then enters the combustion chamber, where it is mixed with fuel and combustion occurs at constant pressure. The heated gases coming out of combustion chamber are then expanded in the gas turbine to produce mechanical work.
- The part of the mechanical work produced by the turbine is utilized to drive the compressor and other accessories and remaining is used for power generation.
- The gases leaving turbine are exhaust to surroundings.
- The working gas is air in open cycle GT power plant.

Closed cycle gas turbine power plant:



(b) Closed cycle GT power plant

- In a closed cycle GT power plants (as shown in fig.), the working gas coming out of compressor is indirectly heated at constant pressure in heat exchanger by an external heat source.
- The external heat source may be gas cooled nuclear reactor or flue gases resulting from the combustion chamber or furnace.
- The high pressure high temperature working gas coming from heat exchanger is expanded through the gas turbine.
- The working gas leaving the turbine after expansion is cooled in heat exchanger with help of surrounding and supplied to the compressor to repeat cycle of operation.
- The working gas may be air, helium, argon, carbon di oxide and so on.

The gases other than air, having more desirable property can be used to improve the performance. Performance of gas turbine depends on the ratio of specific heat of working gas which in turn depends on the nature of the gas. The thermal efficiency of the of GT power plant increases as pressure ratio increases. High pressure ratio is possible in closed cycle GT plants for same maximum and minimum temperature limit.

Essential component of GT power plant:-

The essential component of open cycle and closed cycle power plants are,

- Compressor
- Combustion chamber
- Turbine and
- Blades.

Compressor:-

The high flow rate of air through the turbine and relatively moderate pressure necessitate the use of rotary compressor.

The types of compressorcommonly used are

1. Centrifugal compressor and
2. Axial flow compressor

Centrifugal compressor:

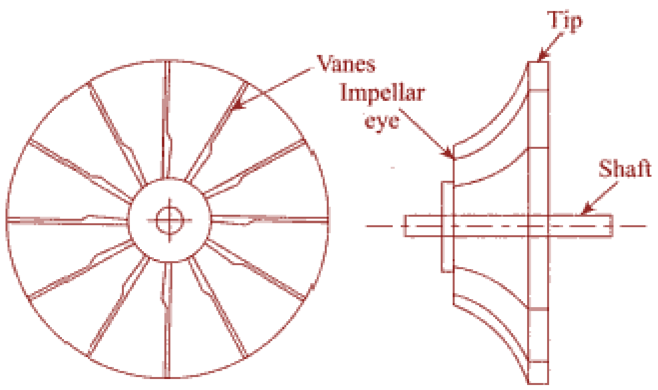


Fig. 11.53 *Centrifugal compressor impeller*

- A centrifugal compressor figure. connsists of an impeller with series of curved radial vanes as shown in
- Air is sucked inside near the hub called impeller eye and is whirled round at high speed by vane on the impeller.
- The static pressure of air increases from the eye to tip of the impeller.
- Air leaving at the tip flows through the diffuser passage which converts kinetic energy to pressure energy.
- The compressor might have single inlet or double inlet.
- In a double inlet impeller it will be having eye on both side of diffuser passage.

Axial flow compressor:

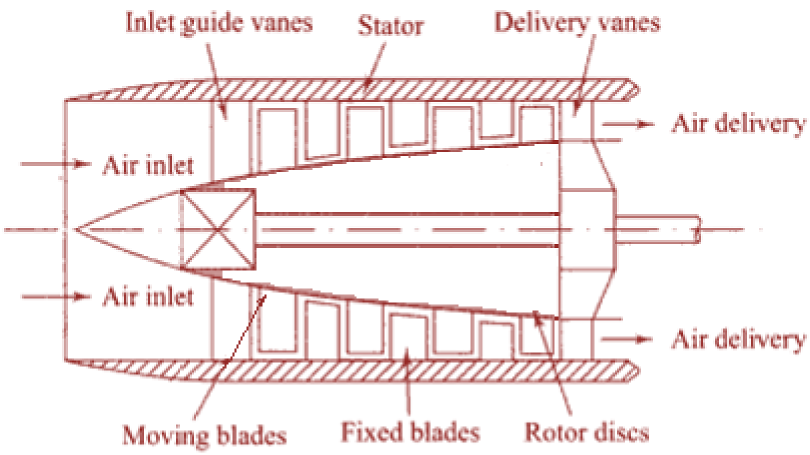


Fig. 11.58 *Axial flow compressor*

- An axial flow compressor is similar to that of an axial flow turbine with moving blades on the rotor shaft and fixed blades arranged around the stator.
- Air flows axially through the fixed and moving blades, with a diffuser passage through which continuously increase the pressure and decrease the velocity.

- Stationary guide vanes are provided at the entry to the first row of moving blades. The work input to the rotor shaft is transferred by moving blade to the air, thus accelerating it.
- The space between the moving blades and stator blades from diffuser passage decreases velocity and increases pressure.

Combustion chamber:-

In an open cycle GT plants combustion can be arranged to take place in one or two large cylindrical can type combustion chamber with ducting to convey hot gases to turbine. Combustion is initiated by an electrical spark and once the fuel start burning the flame is required to be stabilized. A pilot or re-circulated zone is created in main flow to establish a stable flame which helps to sustain combustion continuously. The common methods of flame stabilization are by swirl flow and by bluff body.

Gas turbine:-

Like steam turbine gas turbine are also axial flow types. The basic requirements of a turbine are light weight, high efficiency, reliability in operation and long working life. Large work output can be obtained per stage with high blade speeds when blades are designed to sustain high stresses. More stages are always preferred on gas turbine power plants because it helps to reduce stress on the blade and increases overall life of the turbine. Cooling of gas turbine blade is essential for long life as it is continuously subjected to high temperature gases.

Vortex blading:-

Vortex blading is the name given to the twisted blades which are designed by using three dimensional flow equations to decrease fluid flow losses.

TWO MARKS QUESTIONS

1.Define – open cycle gas turbine?

In the open cycle gas turbine, air is drawn into the compressor from atmosphere and is compressed. The compressed air is heated by directly burning the fuel in the air at constant pressure in the combustion chamber. Then the high pressure hot gases expand in the turbine and mechanical power is developed.

2.Define – closed cycle gas turbine?

In this, the compressed air from the compressor is heated in a heat exchange (air heater) by some external source of heat (coal or oil) at constant pressure. Then the high pressure hot gases expand passing through the turbine and mechanical power is developed. The exhaust gas is then cooled to its original temperature in a cooler before passing into the compressor again.

3. Write the few fuels for Gas turbine and why these fuels are use for gas turbine? Natural gas, last furnace gas, produce gas, coal gas and solid fuels distillate oils and residual oils paraffins used in gas turbine and methane, ethane, propane, octane. Important properties to be considered while selecting the fuel for gas turbine are as follows:

1) Volatility
2) Combustion products,
3) Energy contents,

4) Lubricating properties,
5) Availability.

4. Write the major field of application of gas turbines?

The major fields of application of gas turbines are:

i) Aviation
ii) Power generation
iii) Oil and gas industry
iv) Marine propulsion.

5. Define Gas turbine plant and write the working medium of this gas turbine? A gas turbine plant may be defined as one ‚in which the principal prime-mover is of the turbine type and the working medium is a permanent gas‛.

6. What are the components of gas turbine plant?

A simple gas turbine plant consists of the following:

i) Turbine
ii) Compressor
iii) Combustor
iv) Auxiliaries.

A modified plant may have in addition and intercooler, a regenerator, a reheater etc.

7. What are the methods to improving the thermal efficiency in open cycle gas turbine plant?

Methods for improvement of thermal efficiency of open cycle gas turbine plant are :

i) Inter cooling
ii) Reheating
iii) Regeneration

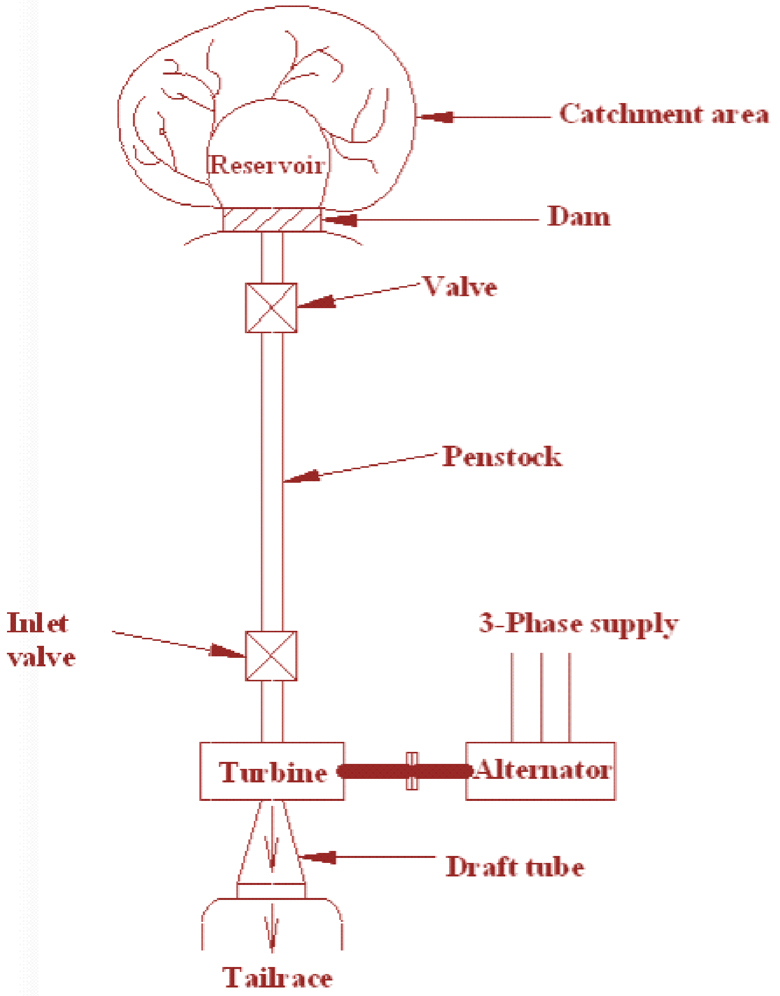
8. What is the main difference between free piston engine plants and conventional gas turbine plant?

Free-piston engine plants are the conventional gas turbine plants with the difference that the air compressor and combustion chamber are replaced by a free piston engine.

UNIT-IV

Hydro Electric Power Plant

General layout of Hydel power plant:-



The main components of a storage type hydel power plant are as follows:

- Catchment area
- Reservoir
- Dam
- **Penstock**
- Forebay
- **Power house**
- Draft tube
- Spill way
- **Surge tank**

- **Catchment Area:**

- The complete area around the reservoir, around the river and the river basins near the reservoir is termed the catchment area. A larger catchment area results in better run-off into the reservoir.
- The reservoir capacity and the dam size are dependent on the size of the catchment area.

- **Reservoir:**
  - The main purpose of reservoir is to store water during rainy season and supply the same during dry season.
  - The reservoir is located at a region of heavy rain fall; with sufficient catchment is intensity of the rainfall

- **Dam:**
  - The function of a dam is to increase the height of water level behind it, hence to increase the reservoir capacity.
  - The dam also helps to increase the working head of the power plant.

- **Penstock:**
- A pipe between the surge tank and prime mover is known as penstock.
  - The structural design of a penstock is same as other pipes, except for that it is made stronger inside, to withstand high pressures caused by water hammer during load fluctuations.
  - Penstocks are usually made of steel through.
  - Penstocks are equipped with head gates at the inlet which can be closed during repair of the penstocks.
  - In very cold weather conditions, it is better to bury the penstock to prevent the ice formation in the pipe and to reduce to number of expansion joints required.

- **Forebay:**
  - It serves as a regulating reservoir and temporary storage pond.
  - It receives the excess water when the load on the plant is reduced and provides water for initial increment of an increasing load, while the water in the canal is being accelerated.
  - Thus, forebay is a naturally provided storage which is able to absorb the flow variations.
  - This can also be considered as the naturally provided surge tank as it performs the work of a surge tank.

- **Power house:**
  - A power house should have suitable structure
  - Its layout should be such that there is adequate space is provided for convenient dismantling and repair.

- Some of equipment power house are turbines, pumps etc.

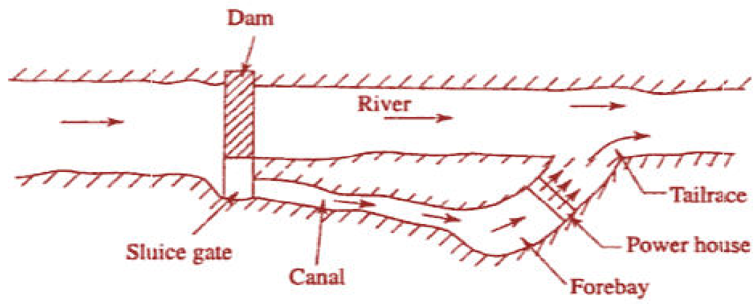
- **Draft tube:**
  - This essential part of reaction turbine installation.
  - It supplements the action of the runner by utilizing most of the remaining kinetic energy of the water at the discharged end of the runner.
- **Spill way:**
  - It is a safety device constructed with the dam. It functions when the dam faces flood problems.
  - It allows the passage of excess water from the reservoir, whenever the level rises above the predetermined safer level, thus avoiding the damage to the dam.
- **Surge Tank:**
  - A Surge tank is a small reservoir in which water level rises or falls to reduce the pressure swing so that they are not transmitted to penstock.
  - It is not required if the power house is at a short distance from reservoir such as in low head plants but it is required for high head turbines.
  - It is a protective device connected to the penstock.
  - It's function is to protect penstock against water hammer effects during low demand periods and avoid vacuum effect during high demand periods.
  - It achieves this by stabilizing the velocity and pressure in the penstock.

CLASSIFICATION OF HYDEL PLANTS:-

1. **According to Head of water,**
   - *Low head plant*
   - *Medium head plant*
   - *High head plant*
2. **According to Nature of load,**
   - *Base load plant*
   - *Peak load plant*
3. **According to Capacity of plant,**
   - *Low capacity plant (100-999 kW)*
   - *Medium capacity plant (1 MW-10 MW)*
   - *High capacity plant (above 10 MW)*
4. **According to Quantity of water available,**
   - *Run-off river plants without pondage*
   - *Run-off river plants with pondage*
   - *Pumped storage plant*

- **According to <u>Head</u> of water,**

<u>Low head hydel po wer plant</u>:-



Low head power plant

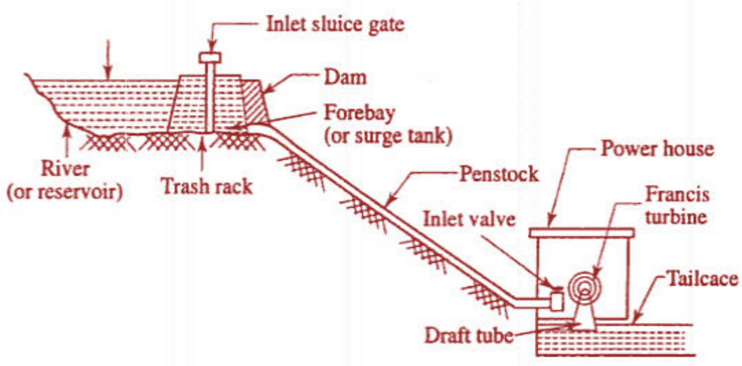
1.A hydel plant with a water head of less than 50 meters is termed a low head plant.

2.In such plants, a small dam is constructed across a river to obtain the necessary water head.

3.The excess water is allowed to flow over the dam, while the water head is made use to run a hydraulic turbine.

4.Francis or Kaplan turbine is used to generate power.

<u>Medium head hydel power plant:-</u>



Medium head power plant

Low Head Power Plants

1.A hydel plant with a water head of in the range of 30 to 100 meters is termed a medium head plant.

2.In this, the water is stored in a main reservoir.

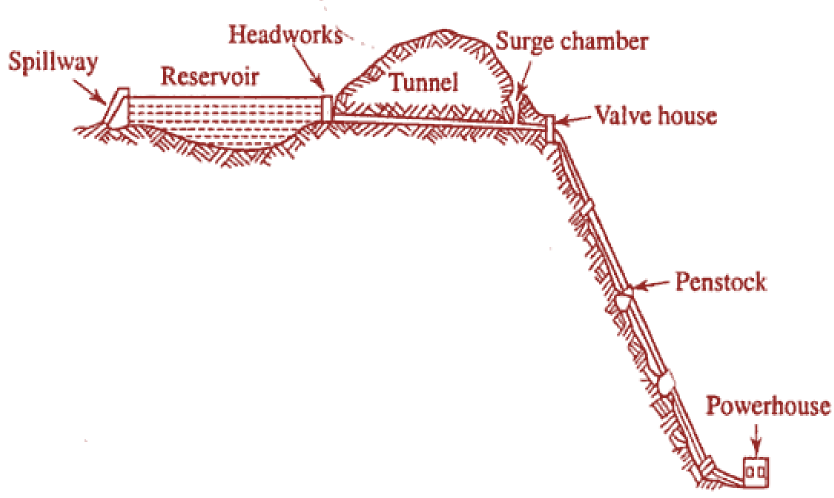
3.This water is allowed to a small pond or forebay through a canal

4.The water from the forebay is taken to the turbine through penstock.

5.In such plants the forebay itself acts as the surge tank, and hence receives the excess water during the low demand periods.

6.Francis turbine is most suitable for medium head hydel plants.

<u>High head hydel power plant</u>:-



High head power plant

1.A hydel plant with a water head of more than 100 meters is termed a high head plant.

2.In this case, the water from the main reservoir is carried through tunnels up to the surge tank, from where it is taken through the penstock.

3.Since the water head is very high, the effect of water hammer is too severe in such plants.

4.Thus, it is essential to provide a surge tank in the water line at appropriate location.

5.The surge tank takes care of the increasing and decreasing water levels during the low- demand and high demand periods, respectively.

6.The Francis and Pelton wheel turbines are most suitable for high head plants.

According to Nature of load,

- **Base load plant:-**

1.These plants are required to supply constant power in the grid.

2.They run continuously without any interruption and are mostly remote controlled.

- **Peak load plants:-**

1.They only work during certain hours of a day when the load is more than the average.

2.Thermal stations work with hydel plants in tandem to meet the basic load and peak load during various seasons.

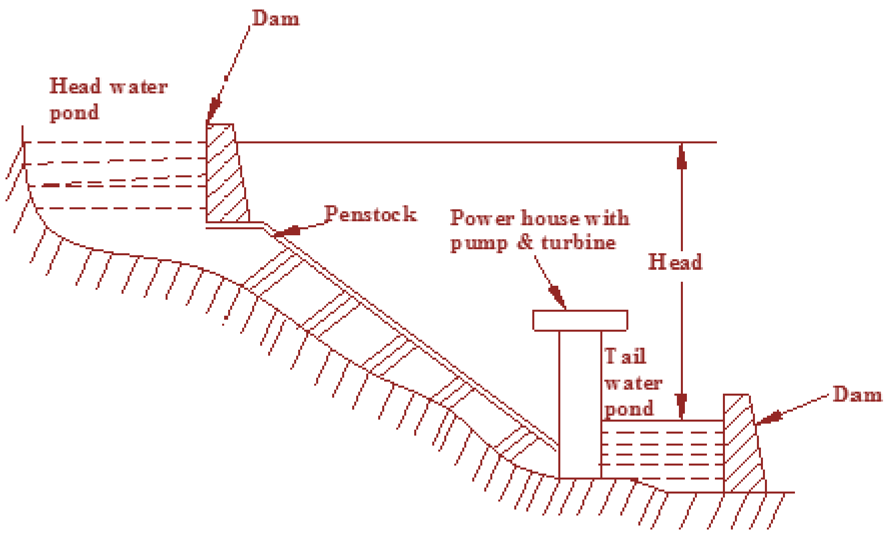
4. According to Quantity of water available,

- **Run-of-river plant without pondage:-**

- In such plants water is **not stored,** but only the running water is used for power generation.
- In such power plants the power generated directly depends upon the rate of flow available.
- Hence, during rainy seasons some excess quantity of water may run waste without doing any power generation.

- During dry periods the power production will be very poor, since the water flow rate will be low.
- **Run-of-river plant with pondage:-**
- In such plants, the excess water available during rainy seasons is stored in the reservoirs.
- The plant works with the normal run-off during the rainy season, while the stored water from the reservoir is utilised to supplement the low flow rate during dry periods.
- Power production will not be affected by the dry seasons.
- Hence, plants with pondage can generate a constant rate of power throughout the year.

- **Pumped storage plant:-**



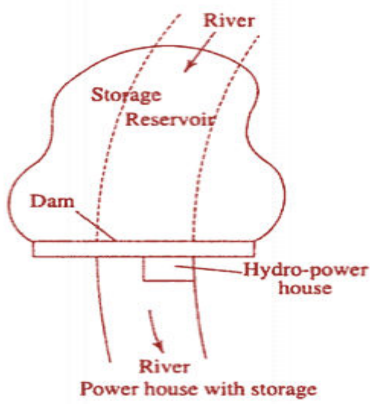
The schematic arrangement of pumped storage plant operating along with a thermal plant to meet the peak load demands, is shown in above figure

- Such plants are most suitable for supplying sudden peak load requirements.
- However, such demands can be met only for a short duration. In the normal operation they can meet the average demand only.
- Such type of plant consists of two storage reservoirs.
- The upstream reservoir is the main storage reservoir to which water flows from the catchment area
- The second reservoir is the downstream (tail race) reservoir, in which the used water from the upstream is collected.
- The water in the downstream reservoir is pumped back to the main upstream reservoir, during off peak periods.
- This facilitates making use of the excess water during peak hours
- A pumped storage plant is a peak load plant arid operates in combination with other base load plants such as a thermal power plant.

- The off peak load capacity of the thermal plant is used for pumping water from the downstream reservoir to the main upstream reservoir.

Storage & Pondage

1.Storage plants are the plants with facilities for storing water at their sites.
2.However, often such plants cannot store as much water as required for the full year operation.
3.For continuous operation, it is always preferred to have one upstream.
or more reservoirs

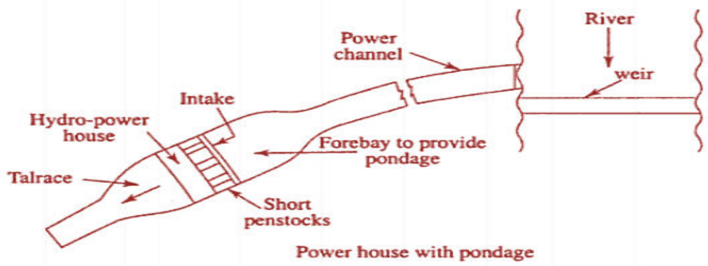


Hydro-power units with pondage and storage

4.Depending upon the place of storage and the function, the reservoirs are grouped as storage and pondage

Storage:

Storage can be defined as the collection of a large quantity of run-off during monsoon seasons, which is essentially used in the dry seasons for the plant operation.This is the main, or the upstream reservoir, made by the construction of a dam across the stream.



Power house with pondage

Pondage:-

1. It is defined as **a regulating means of water, and is a small reservoir that is used for the collection of the excess flow water from the dam spill ways of the main reservoir or from/the river stream**.
2. It is basically a small pond or reservoir just behind the power house.

3. The amount of regulation obtained with pondage usually involves storing water during low loads (during low power demand periods such as early morning hours and Sundays) to aid carrying peak loads during the week.
4. The water that would go over the dam spill-way unused during low-loads can be released and added to normal river flow to supply peak loads, usually for a few hours of duration
5. For fluctuating loads, pondage increases the maximum capacity that a plant can carry.
6. Plants with reservoirs upstream can store excess water of spring floods for release during summer to supplement the low rates of flow during this dry season
7. Reservoir water elevation will generally be lowest during the year at the end of the summer.
8. Pondage increases the capacity of a river for a brief period only, like for 8 week.
9. But, storage increases the capacity of a river over an extended period such like 6 months to 2 years.

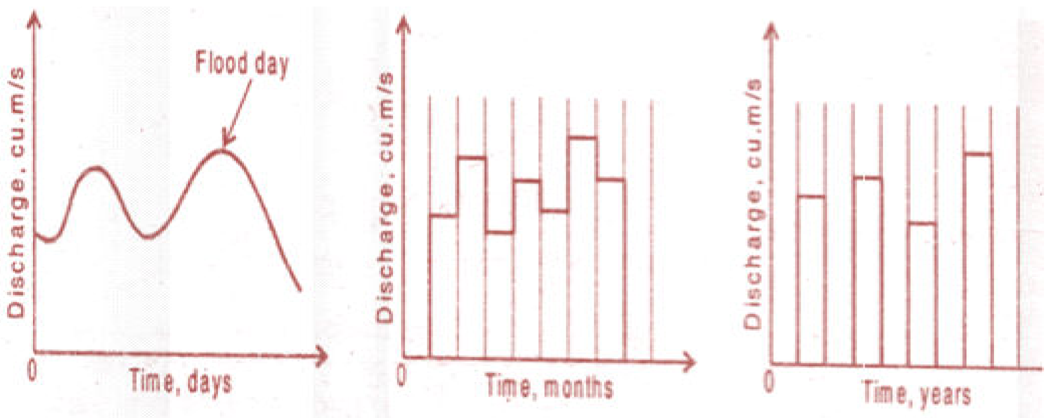
Hydrographs:-

1.It is a **graph representing** the **discharge** of flowing water with respect to time for a specific period.

2.The time axis may have units of hour, day, week or month.

3.The discharge units may be **m^3/sec, km^2-cm/hr or day-second-meter.**

4.Discharge hydrographs are also known as **flood or run-off hydrographs**.



Uses of a Hydrographs:

A hydro graph is useful to determine a number of parameters, such, as:

1.Rate of flow at any instant during the specific recorded period.

2.Total volume of flow in a given period, as the area under the hydrograph represents the volume of water in a given duration.

3.The mean annual run-off for any of the recorded period.

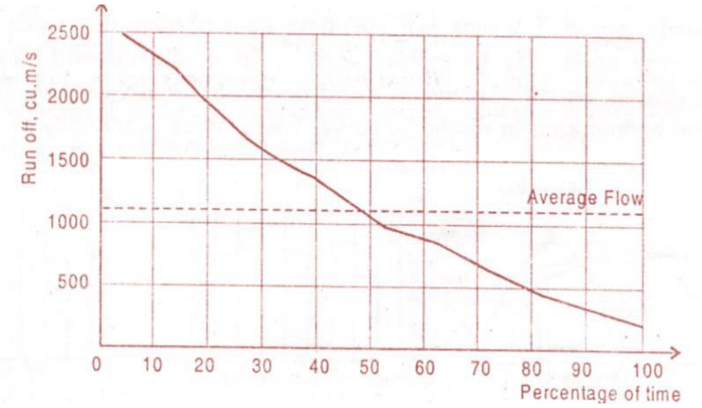
4.The **maximum and minimum run-off** for any selected period.

5.The **maximum rate of run-off** during the floods and duration of frequency of floods (peak of the curve indicates the flood).

Unit Hydrograph:-

A unit hydrograph is a hydrograph **with a volume of 1 cm of run-off** resulting from a rainfall of specified duration and a real pattern, which is constructed using the hydrograph data.

Flow Duration Curve:-



1. This is another **useful graphical representation** of the **run-off** for a given period.
2. The run-off data on the ordinate against the corresponding percentage of time on the abscissa represents a **Flow Duration Curve.**
3. Fig. shows a typical flow duration curve.
4. The flow may be **expressed as m^3/s/week** or any other convenient unit of time.
5. When the **available head** of water is known, then the total energy of flow can be computed
6. Thus, by flow duration curve it is **possible** to estimate the total power available at the site.
7. A **flow duration curve** can be used to determine the **minimum and maximum** conditions of flow of water.
8. If the **magnitude** on the ordinate is the estimated power contained in the stream flow **against** the corresponding percentage of time on the abscissa, then the curve is known as **Power Duration Curve**
9. If the head of discharge, **H** is known practically then power of plant, **P** can be obtained from following equation,

Where,

$$P = \rho g H Q \eta_0 \quad \text{(in W)}$$

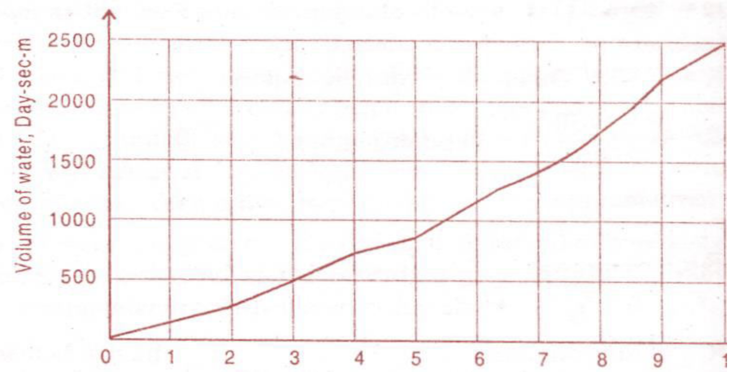
$\rho = 1000 kgm^{-3}$ is density of water

$g = 9.81 ms^{-2}$ is acceleration due to gravity

H is height of water in m **Q** is discharge in m^3/s η_0 is overall efficiency

Mass Curve:-

1. The graph representing the **cumulative values** of water **quantity (run-off)** against **time** is termed as the Mass Curve.
2. A reservoir is the means of **storing water** that is **available** during rainfall, from the catchment areas and/or from a river.
3. A mass curve is a **convenient method** of determining the **storage requirements** of a reservoir so as **to obtain** a satisfactory flow from the **fluctuating discharge** of a river.



Gates and valves:

Drum Gate:-

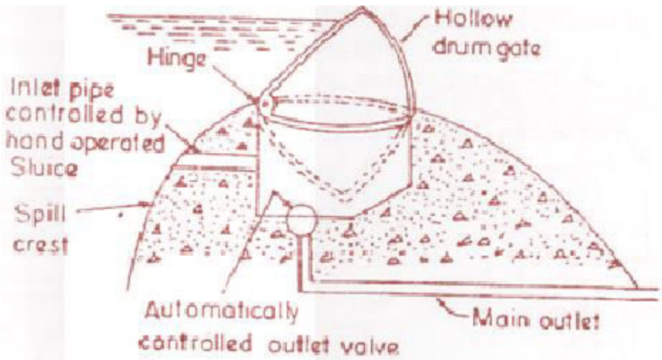


Fig. 4.13. Hollow drum gate.

4. Drum Gate. The cross-section of drum gate is shown in Fig. 4.13. This type of gate is al preferably adopted for long spans. This gate also consists of a segment of a hollow cylinder. Tl gate fits in a recess in the top of the spillway in open position. When the water is admitted und force to the recess, the hollow drum gate is forced upward to the closed position. The gate generally hinged at the upstream edge so that the buoyant force aids in its lifting. When the ga is lowered, it conforms closely to the shape of Ogee crest. They are not adopted to small dar because of large recess required by the drum gates in the lowered position.

TWO MARKS QUESTIONS:

1.Differentiate propeller and Kaplan turbine?

In the propeller turbine the runner blades are fixed and non-adjustable. In Kaplan turbine, which is a modification of propeller turbine the runner blades are adjustable and can be rotated about the pivots fixed to the boss of the runner.

2.What are the Element of Hydel Power Plant?

Elements of Hydel Power Plant:

1. Water reservoir,
2. Dam,
3. Spillway,
4. Pressure tunnel,
5. Penstock,
6. Surge tank,
7. Water turbine,
8. Draft tube,
9. Tail race.
10. Step-up transformer,
11. Power house.

3. Write the Advantages of Hydro-electric power plants?

1. Water is a renewable source of energy. Water which is the operating fluid, is neither consumed nor converted into something else,
2. Water is the cheapest source of energy because it exists as a free gift of nature. The fuels needed for the thermal, diesel and nuclear plants are exhaustible and expensive.
3. There is no ash disposal problem as in the case of thermal power plant.

4.Write the classification of Hydro turbines?

Hydraulic turbines are classified as follows:

1) According to the head and quantity of water available,
2) According to the name of the originator,
3) According to the action of water on the moving blades,
4) According to the direction of flow of water in the runner,
5) According to the disposition of the turbine shaft,
6) According to the specific speed N.

5.**Define Governing Mechanism?**

When the load on the turbine changes, the speed may also change. (i.e., without load the speed increases and with over load, the speed decreases). Hence, the speed of the runner must be maintained constant to have a constant speed of generator. This is done by controlling the quantity of water flowing on the runner according to the load variations. This speed regulation is known as governing and it is usually done automatically by a governor.

6. What are the functions of draft tubes?

1) Increase in efficiency,
2) Negative head.

7. Write the two types of Draft tubes?

The draft tubes are of the following three types:
1) Conical or divergent draft tube,
2) Elbow type draft tube,
3) Hydracone or Moody spreading draft tube.

8. Define Kaplan turbine?

The Kaplan turbine is an axial flow reaction turbine. It is suitable for relatively low heads. Hence, it requires a large quantity of water to develop high power. It operates in an entirely closed conduct from the head race to the rail race.

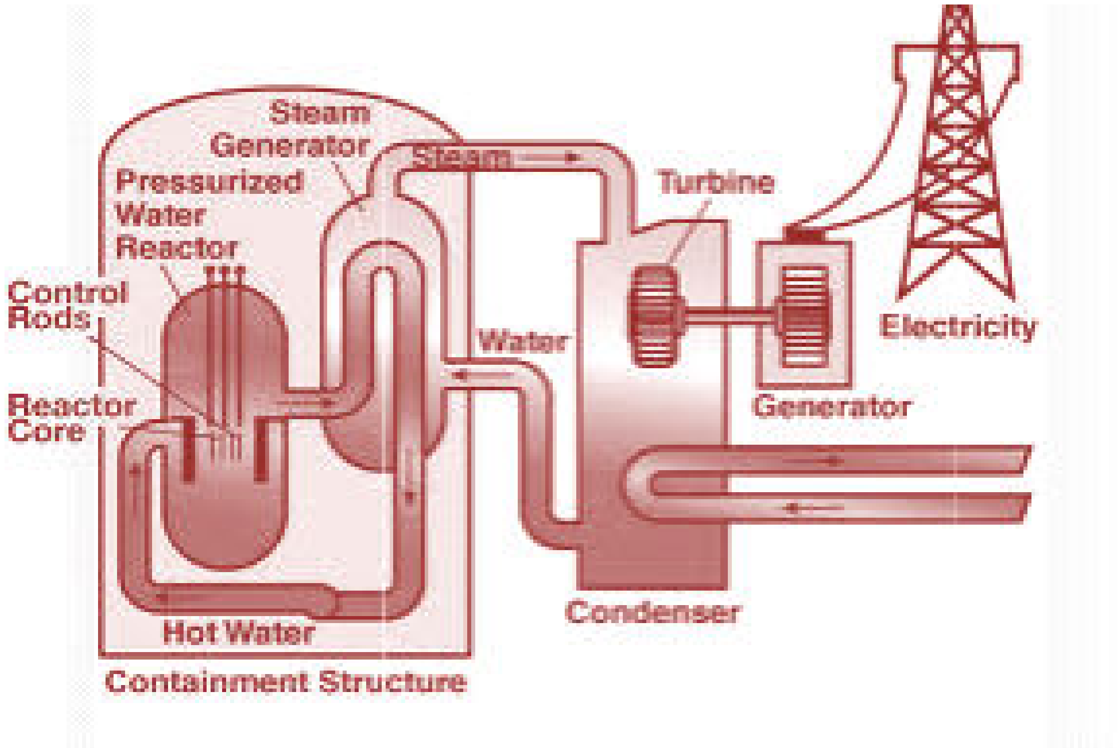
9.**Write the advantages of small Hydro-power plant (SHP)?**

a) Readily accessible source of renewable energy,
b) Can be installed making use of water head as low as 2 m and above,
c) Does not involve setting up of large dams,
d) Least polluting.

UNIT-V

Nuclear Power Plant

General Structure of Nuclear power plant:-



The main components of the power plant:

- **Reactor vessel (Shielding)**
- **Moderator**
- **Control rod**
- **Fuel rod**
- **Coolant**
- **Reflector**

- **Reactor vessel (Shielding):**
  - It is a strong steel container in which the fuel rods, moderator, control rods and the reflector are arranged properly.
  - It forms a strong structural support for the reactor core.

Moderator:

- **It is used to reduce the kinetic energy of fast neutrons into slow neutrons and to increase the probability of chain reaction**.
- Graphite, heavy water and beryllium are generally used as moderator
- The hydrogen moderator would slow the neutron from **2MeV** to **0.025eV.**

A moderator should possess the following properties:

- It should have high thermal conductivity
- It should be available in large quantities in pure form
- It should have high melting point in case of solid moderators and low melting point in case of liquid moderators.
- Solid moderators should also possess good strength and machinability.
- It should provide good resistance to corrosion.
- It should be stable under heat and radiation.
- It should be able to slow down neutrons.

Control rod:

- **Control rod is to regulate the rate of a chain reaction**.
- They are made of boron, cadmium or other elements which absorb neutrons.
- **Control rods should posses the following properties**,
- They should have adequate heat transfer properties.
- They should be stable under heat and radiation.
- They should be corrosion resistant.
- They should be sufficient strong and should be able to shut down the reactor almost instantly under all conditions.
- They should have sufficient cross sectional area for the absorption

Fuel rods:

- **Fuel rod tube like structure containing Nuclear Fuels** .
- Nuclear fuels are made in the form of capsules & inserted in the tubes.
- During nuclear reaction nuclear fuel will release energy to produce power.
- **Important properties of Fuel rods,**
- It should withstand high temperature.
- It should have high corrosion resistance.
- It should have good thermal conductivity.
- It should not absorb neutrons.
- It should withstand radiation effects.

Coolant:

- **Coolants are used to cool the reactor by carrying away the heat generated by the reactor**.

- There are many number of coolants are used some of them are water (H_2O), heavy water (D_2O), carbon-di-oxide (CO_2), liquid sodium (liq. Na), organic liquid etc.
- The coolants should have high latent heat of absorption.

Reflector:

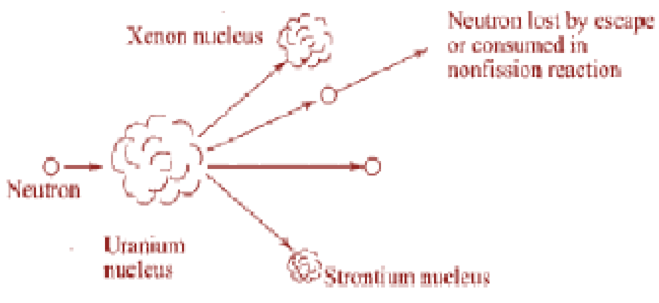
· Function of the reflector is to minimize the neutron leakage by reflecting them back into the reactor.
· Graphite and Beryllium are generally used as reflectors.
· The important properties of good reflectors material are:
i. It should have good thermal conductivity
ii. It should have good corrosion resistance
iii. It should have high stability under high temperature and pressure conditions
iv. It should not absorb neutrons
v. It should have good reflectivity.

Nuclear Energy:-

· Nuclear energy is the energy trapped inside each atom.
· Heavy atoms are unstable and undergo nuclear
· Nuclear reactions are of two types,
1. Nuclear fission…the splitting of heavy nucleus
2. Nuclear fusion…the joining of lighter nuclei

1. Fission:

· Fission may be defined as the **process of splitting an atomic nucleus into fission fragments**.
· The fission fragments are generally in the form of smaller atomic nuclei and neutrons.
· Large amounts of energy are produced by the fission process.
For eg.



A fission reaction

When neutron is bombarded into Uranium Uranium-235 (92U235) it will split into smaller nuclei
Xenon-140 & Strontium-94 with release of high energy in the form of neutron.

2. Fusion:-

- It is defined as nuclear reaction **whereby two light atomic nuclei fuse or combine to form a single larger, heavier nucleus**.
- The fusion process generates tremendous amounts of energy.
- For fusion to occur, a large amount of energy is needed to overcome the electrical charges of the nuclei and fuse them together.
- Fusion reactions **do not occur naturally** on our planet but are the principal type of reaction found in stars.
- The large masses, densities, and high temperatures of stars provide the initial energies needed to fuel fusion reactions.
- The sun fuses hydrogen atoms to produce helium, subatomic particles, and vast amounts of energy.

Comparison of fission and fusion:-

Sl. No.	Fission	Fusion
1	Splitting of heavy nucleus	Joining of light nuclei
2	Is a chain reaction	Is not a chain reaction
3	Can be controlled	cannot be controlled
4	Radiations are very harmful	Will not emit harmful

Multiplication Factor & Thermal Utilization Factor:-

1. Multiplication Factor, k:

It is the ratio of neutrons in generation to the preceding generation.

$$k = \frac{No.of\ neutrons\ in\ one\ generation}{No.of\ neutrons\ in\ preceding\ generation}$$

If $k<1$, subcritical
$k=1$, critical
$k>1$, supper critical

2. Thermal Utilization Factor:

It is the thermal Neutrons absorbed in the fuel to the thermal Neutrons absorbed in the entire core.

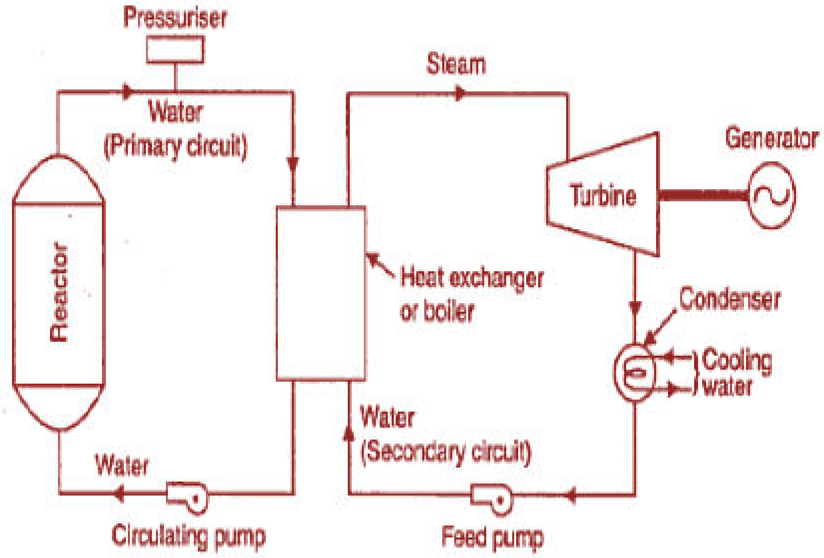
Classification of Reactors

Basis of classification	Types of reactors
Type of core used	• Homogeneous reactors • Heterogeneous reactors
Moderator used	• Graphite reactors • Beryllium reactors • Light water (ordinary) reactors • Heavy water reactors
Coolant used	• Ordinary water cooled reactors • Heavy water cooled reactors • Gas cooled reactors • Liquid metal cooled reactors • Organic liquid cooled reactors
Neutron energy	• Thermal reactors • Fast reactors
Fuel material used	• Enrich uranium • Natural uranium • Plutonium

Some of the reactors are,

1. Pressurized Water Reactor
2. Boiling Water Reactor
3. Liquid metal Fast breeder reactor or Sodium graphite reactor
4. Gas Cooled Reactor or Homogeneous graphite reactor

1. Pressurized Water Reactor(PWR)



Pressurised water reactor.

In a PWR the primary coolant (natural and highly enriched fuel or **water**) is pumped under high pressure to the reactor core where it is heated from 275 °C **to 315 °C by absorbing** energy generated by the **fission** of atoms. Then it moves to a pressurizer to maintain pressure of about **155bar** in Primary circuit.

- The heated water then flows to a heat exchanger (steam generator) where it transfers its thermal energy to a secondary system where steam is generated and flows to turbines which, in turn, spins an electric generator.

In contrast to a boiling water reactor, pressure in the primary coolant loop prevents the water from boiling within the reactor. All PWRs use ordinary **light water as both coolent and neutron moderator**.

- PWRs are the most common type of power producing nuclear reactor, and are widely used in power stations such as ships and submarines all over the world.
- More than 230 of them are in use in nuclear power plants to generate electric power, and several hundred more for marine propulsion in aircraft carriers, submarines and ice breakers.

Advantages:

1. PWR reactors are very stable since they produce low power.
2. Less fissile material can be used hence safe
3. Ordinary water as coolant is easily available.
4. Small number of control rods is required.
5. Fission products remain contained in the reactor

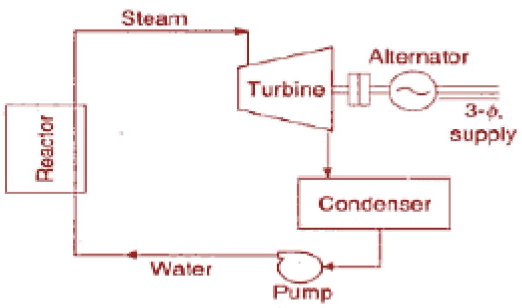
Disadvantages:

1. Cannot be refueled while operating it will take long period of time (some week).
2. Severe corrosion problem.
3. High initial cost.
4. High maintenance cost.

2. Boiling Water Reactor (BWR)

Boiling water reactor (BWR) is the simplest of all facilities. Water absorbs heat from the reactions in the core and is directly driven to the turbines.

- After condensing the water is pumped back to the reactor core. In a Boiling Water Reactor **enriched fuel** is used.
- The BWR uses de mineralized water (light water) as a coolant and moderator)
- Heat is produced by nuclear fission in the reactor core, and this causes the cooling water to boil, producing steam.
- The steam is **directly** used to drive a turbine, after which is cooled in a condenser and converted back to liquid water

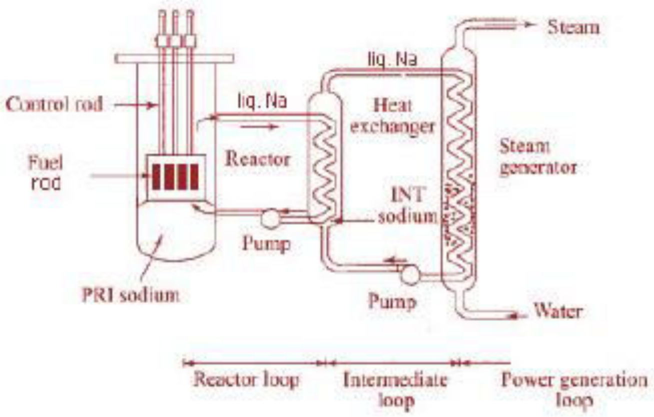


Schematic diagram of a BWR power plant.

- **Advantage:**
- 1. Uses ordinary water as coolant, moderator which is easily available.

- 2. High thermal efficiency.
- 3. No need of Pressurizer.
- 4. Thicker vessel is not required.
- 5. Metal Temperature remains low.
- 6. Outlet temp of steam is very high.
- **Disadvantages:**
- 1. Higher cost due to large pressure vessel.
- 2. Possibility of radioactive contamination in the turbine.
- 3. The possibility of "burn out" of fuel is more
- 4. More safety required.
- 5. Lower thermal efficiency.

3. Liquid metal Fast breeder reactor (Sodium Graphite reactor, LMFBR)



It is used to Produce, breed or generate fissile material like **plutonium-239** from non fissionable **uranium-238**.

· This reactor consists of **double circuit** coolant.

· Enriched **uranium** is used as the fuel.

· Liquid metal and alloys such as **sodium (and NaK)** as coolant. **Graphite** as the moderator

· Here **primary** circuit uses **sodium** as coolant absorbs the heat from core and transfer to the Na or **NaK** (uses an alloy as coolant) in the secondary circuit.

· Na or NaK transfers heat to the boiler to raise steam, which is used to run the turbine to generate power.

· **Sodium** has high **thermal conductivity** which is more than **100 times** that of water, hence increases the thermal efficiency of the plant.

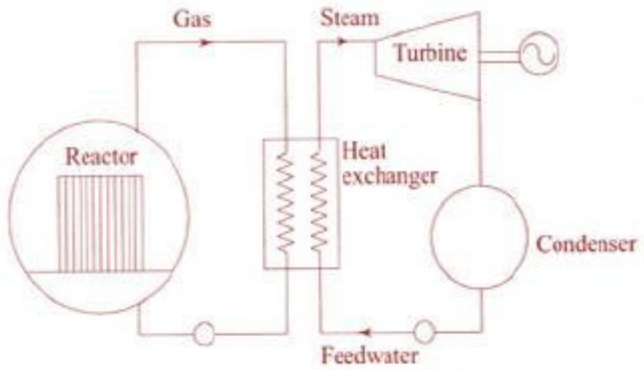
Advantage:

1. The moderator is not required.
2. High breeding is possible.
3. Small core is sufficient.
4. High burn-up of fuel is achievable.
5. Absorption of neutrons is low.
6. Thermal efficiency of the plant is very high.

Disadvantages:

1. Requires highly enriched fuel.
2. It is necessary to provide safety against melt-down.
3. Neutron flux is high at the centre of the core.
4. The specific power of reactor is low.
5. There is a major problem of handling sodium as it becomes hot and radioactive.
6. Plant cost is more due to costly coolants.

4. Gas Cooled Reactor (GCR) or Homogeneous graphite reactor:



The fuel used is natural uranium, clad with an alloy of magnesium called **graphite – moderated** systems.

· Gas-cooled reactor (GCR) system uses oxide UO2 as the fuel clad in stainless steel tubes with CO

· The GCR uses Uranium U-233 as the fissile material and thorium as fertile coolant and graphite as moderator.

· The gas-cooled reactor is designed to use U with U-235 until sufficient U material.

· Initially, the system would have to be fuelled **fertile spheres** for makeup fuel. Because of the very high melting point of graphite, these fuel elements can operate at very high temperatures, and it is possible to generate steam at conditions equivalent to those in modern coal-fired power plant.

· The basic fuel forms are small spheres of fissile and fertile material as carbides, UC2 or ThC2.

·

Advantage:

1. The processing of fuel is simpler.
2. No corrosion problem.
3. Graphite remains stable under irradiation at high temperature.
4. The use of CO2 as coolant completely eliminates the possibility of explosion in the reactor.

Disadvantages:

1. Power density is low (due to low heat transfer coefficient), therefore large vessel is required.
2. If helium is used instead of CO2, the leakage of gas is a
3. More power is required for coolant circulation (pumping cost is more).
4. Fuel loading is more elaborate and costly.

Effects of Nuclear Radiation (Radiation Hazards):-

1] Effects on the tissues:-

Radiations affect the tissues in 3 ways,

a) Ionization: Ion pair in the tissue causes complete damage of tissues of man, animals, birds.

b) Displacement: Displacement of an atom of the tissue from its normal lattice position causes adverse effects on the tissues.

c) Absorption: This result in formation of a radioactive nucleus in the cell thus altering its chemical nature .It causes cell damage and genetic modifications.

2] Effects on the cells (biological effects):-

a) **Somatic effects**:

This results blood cancer, lung cancer, thyroid cancer, bone cancer.

b) **Genetic effects:**

This results still births, growth and developmental abnormalities

Radioactive Waste Disposal Systems:-

The main objective in managing and disposing of radioactive (or other) waste is to protect people and the environment Seal it inside a corrosion-resistant container, such as stainless steel. A possibility for long term storage on the earth is burial in the sea bed. The rock formations in the sea bed are generally more stable than those on dry land reducing the risk of exposure from seismic activity. As well there is little water flow under the sea bed reducing the possibility of radioactive material escaping into the ground water. High level radioactive waste is generally material from the core of the nuclear reactor or nuclear weapon. This waste includes uranium, plutonium, and other highly radioactive elements made during fission. There are three types of radioactive wastes.

a] Disposal of low level solid waste:

· Primarily the low level solid waste is cast in cement in steel drum.

· After it is buried few meters below from the soil or kept on ocean bed.

· It gets diluted as it disperses.

b] Disposal of medium level solid waste:

· These wastes mainly contaminated with neutron activation product isotopes.

· This type of waste is primarily put in a cement concrete cylinder.

· Then it is buried few meters below from the soil or kept on ocean bed.

c] Disposal of high level liquid waste:

· High level liquid waste is stored in steel cylinder tanks with concrete.

· It is water cooled to keep the temperature at 50ºc.then this cylinder is stored in salt mine.

· The ocean is used for permanent storage of high level waste disposal.

· Long-term storage of radioactive waste requires the stabilization of the waste into a form which will not react, nor degrade, for extended periods of time. One way to do this is through **vitrification**.

Nuclear fuel:-

• It is a material that can be 'burned' by **nuclear fission** or **fusion** to derive **nuclear energy**.

• *Nuclear fuel* can refer to the fuel itself, or to physical objects (for example bundles composed of fuel rods) composed of the fuel material, mixed with structural, **neutron-moderating**, or neutron-reflecting materials.

- Most nuclear fuels contain heavy **fissile** elements that are capable of nuclear fission.
- When these fuels are struck by neutrons, they are in turn capable of emitting neutrons when they break apart.
- This makes possible a self-sustaining **chain reaction** that releases energy with a controlled rate in a **nuclear reactor** or with a very rapid uncontrolled rate in a **nuclear weapon**.

· The most common fissile nuclear fuels are **uranium-235** (235U) and **plutonium-239** (239Pu).

The actions of mining, refining, purifying, using, and ultimately disposing of nuclear fuel together make up the **nuclear fuel cycle**.

· Not all types of nuclear fuels create power from nuclear fission. **Plutonium-238** and some other elements are used to produce small amounts of nuclear power by **radioactive decay** in **radioisotope thermoelectric generators** and other types of **atomic batteries**. Also, light **nuclides** such as **tritium** can be used as fuel for **nuclear fusion**.

TWO MARKS QUESTIONS

1.Define Isotopes?

Those pairs of atoms which have the same atomic number and hence similar chemical properties but different atomic mass number are called isotopes.

2.Define Isobars?

Those atoms which have the same mass number but different atomic numbers are called isobars. Obviously, these atoms belong to different chemical elements.

3.Define Isomers?

Those pairs of atoms (nuclides) which have the same atomic number and atomic mass number but have different radioactive properties are called isomers and their existence is referred to as nuclear isomerism.

4.Define isotones?

Those atoms whose nuclei have the same number of neutrons are called isotones.

5.Define Radioactivity?

The phenomenon of spontaneous emission of powerful radiations exhibited by heavy element is called radioactivity. The radioactivity may be natural or artificial.

6.Write the types of Nuclear radiations?

The five types of nuclear radiations are :

(i) Gamma rays (or photons) : electromagnetic radiation.
(ii) Neutrons : uncharged particles, mass approximately 1.
(iii) (iii) Protons : + 1 charged particles, mass approximately 1.
(iv) Alpha particles : helium nuclei, charge + 2, mass 4.

(v) Beta particles : electrons (charge – 1), positrons (charge + 1), mass very small.

7. Define Fertile Materials?

It has been found that some materials are not fissionable by themselves but they can be converted to the fissionable materials, these are known as fertile materials.

8. Define Fission?

Fission is the process that occurs when a neutron collides with the nucleus of certain of heavy atoms, causing the original nucleus to split into two or more unequal fragments which carry-off most of the energy of fission as kinetic energy. This process is accompanied by the emission of neutrons and gamma rays.

9.Define Nuclear fusion?

Nuclear fusion is the process of combining or fusing two lighter nuclei into a stable and heavier nuclide. In this case large amount of energy is released because mass of the product nucleus is less than the masses of the two nuclei which are fused.

10.Define Nuclear Reactor?

A nuclear reactor is an apparatus in which nuclear fission is produced is the form of a controlled self-sustaining chain reaction.

11.Write the Essential components of a nuclear reactor?

Essential components of a nuclear reactor are: (i) Reactor core (ii) Reflector (iii) Control mechanism (iv) Moderator (v) Coolants (vi) Measuring instruments (vii) Shielding.

12.What are the main components of a nuclear power plant?

The main components of a nuclear power plant are:

(i) Nuclear reactor
(ii) Heat exchanger (steam generator)
(iii) Steam turbine
(iv) Condenser
(v) Electric generator

13. Mention some important reactors?

Some important reactors are :

(i) Pressurized water reactor (PWR)
(ii) Boiling water reactor (BWR)
(iii)Gas-cooled reactor
(iv) Liquid metal-cooled reactor
(v) Breeder reactor.

14. What are the factors are consider to selecting the site for Nuclear power plant?

Following factors should be considered while selecting the site for a nuclear power plant:

(i) Proximity to load centre

(ii) Population distribution
(iii) Land use
(iv) Meteorology
(v) Geology
(vi) Seismology
(vii) Hydrology

15. Write the types of Reactors?
1. On the basis of neutron energy.
2. On the basis of fuel used.
3. On the basis of Moderate used.
4. On the basis of coolent used.

16. What are the advantages of nuclear power plant?
1. It can be easily adopted where water and coal resources are not available.
2. The Nuclear power plant requires very small quantity of fuel. Hence fuel transport cost is less.
3. Space requirement is very less compared to other power plant of equal capacity.
4. It is not affected by adverse weather condition.

17. Mention any 3 fast breeder reactors?
1. Liquid Metal
2. Helium
3. Carbon dioxide

18. What are the ways the liquid wastes are dispose?
1. Dilution
2. Concentration to small volumes and storages.

19. Write the effects of Nuclear radiation?
Biological damage
1. Ionization
2. Displacement
3. Absorption

OCEAN THERMAL ENERGY CONVERSION (OTEC)

The ocean and seas constitute about 70% of the earth's surface area and hence they represent a large storage reservoir of the solar energy. In tropical waters, the surface water temperature is about 27□C and at 1 km directly below, the temperature is about 4□C. The reservoir of surface water may be considered a heat source and the reservoir of cold water (1 km below) is considered a heat sink. The concept of ocean thermal energy conversion is based on the utilization of temperature difference between the heat source and the sink in a heat engine to generate power. The temperature gradient present in the ocean is utilized in a heat engine to generate power. This is called OTEC. Since the temperature gradient is very small, even in the tropical region, OTEC systems have very low efficiencies and very high capital costs. There are two basic designs for OTEC systems. 1. Open cycle or Claude cycle. 2. Closed cycle or Anderson cycle.

Open cycle or Claude cycle

In this cycle, the seawater plays a multiple role of a heat source, working fluid, coolant and heat sink. Warm surface water enters an evaporator where the water is flash evaporated to steam under particle vacuum. Low pressure is maintained in the evaporator by a vacuum pump. The low pressure so maintained removes the non-condensable gases from the evaporator. The steam and water mixture from evaporator then enters a turbine, driving it thus generating electricity. The exhaust from the turbine is mixed with cold water from deep ocean in a direct contact condenser and is discharged to the ocean. The cycle is then repeated. Since the condensate is discharged to the ocean, the cycle is called 'open'.

Flash evaporation

In the evaporator the pressure is maintained at a value (0.0317 bar) slightly lower than the saturation pressure of warm surface water at 27□C (0.0356 bar). Hence, when the surface water enters the evaporator, it gets 'superheated'. This super heated water undergoes ,volume boiling‛ causing the water to partially flash to steam.

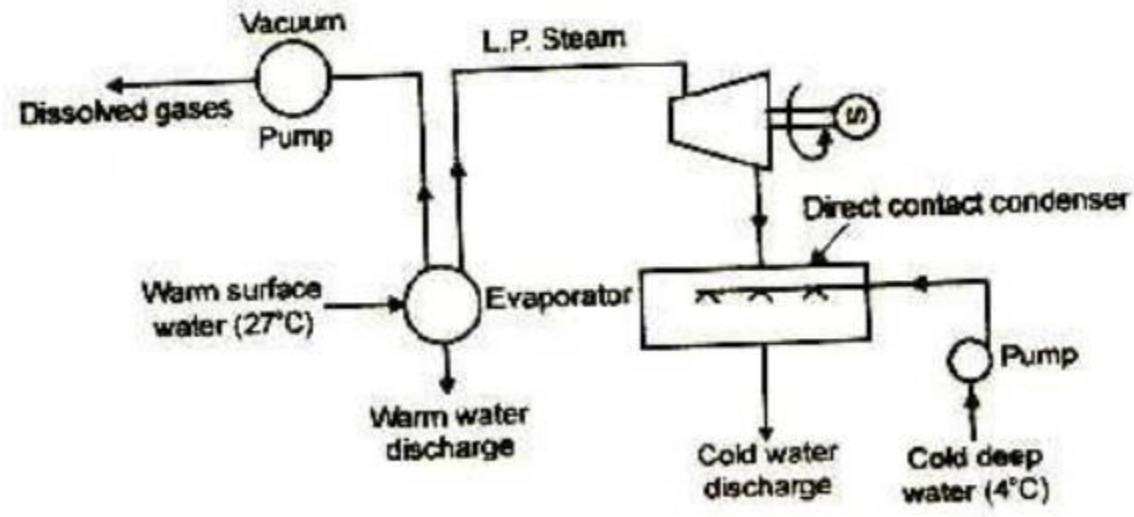


Figure: OTEC – open cycle.

Closed OTEC cycle

Here, a separate working fluid such as ammonia, propane or Freon is used in addition to water. The warm surface water is pumped to a boiler by a pump. This warm water gives up its heat to the secondary working fluid thereby losing its energy and is discharged back to the surface of the ocean. The vapours of the secondary working fluid generated in the boiler, drive a turbine generating power. The exhaust from the turbine is cooled in a surface condenser by using cold deep seawater, and is then circulated back to the boiler by a pump.

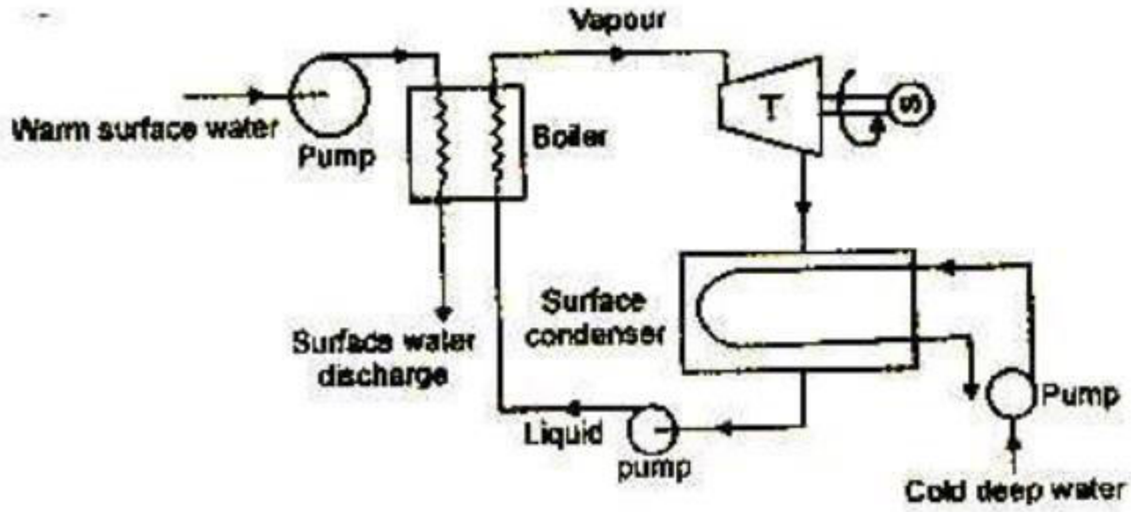


Figure: OTEC – closed cycle

Advantages of OTEC

1. Ocean is an infinite heat reservoir which receives solar incidence throughout the year.
2. Energy is freely available.

Disadvantage of OTEC

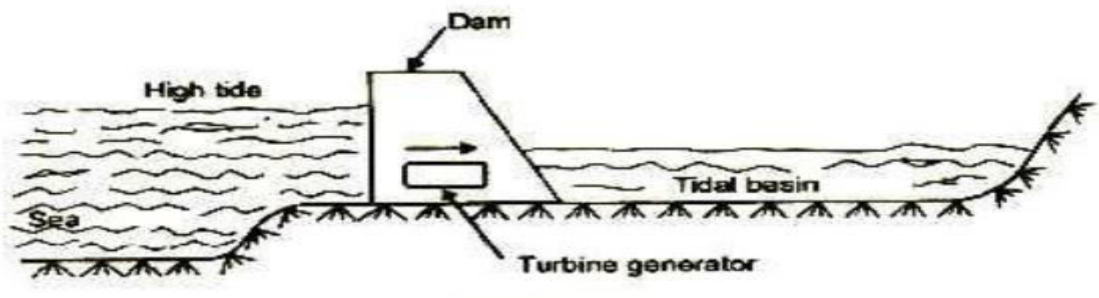
1. Efficiency is very low, about 2.5%, as compared to 30-40% efficiency for conventional power plants.
2. Capital cost is very high.

TIDAL POWER PLANTS

Tide or wave is periodic rise and fall of water level of the sea. Tides occur due to the attraction of sea water by the moon. Tides contain large amount of potential energy which is used for power generation. When the water is above the mean sea level, it is called flood tide. When the water level is below the mean level it is called ebb tide.

Working:

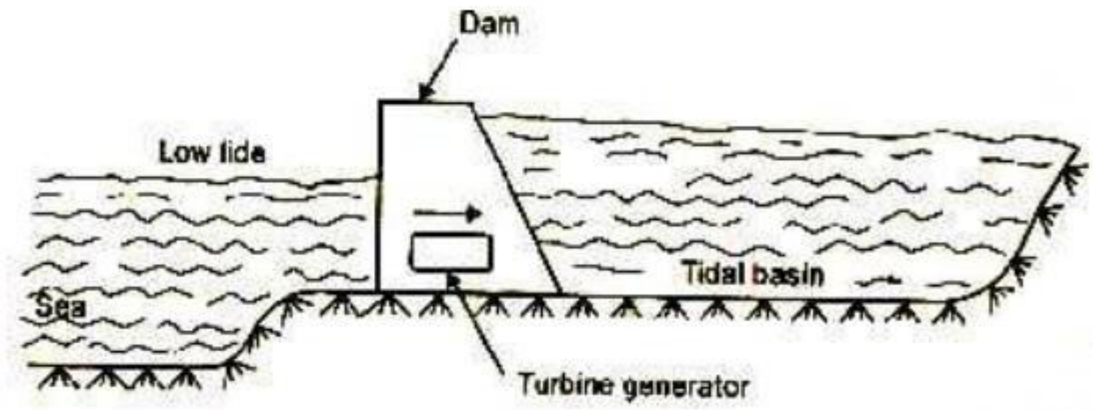
The arrangement of this system is shown in figure. The ocean tides rise and fall and water can be stored during the rise period and it can be discharged during fall. A dam is constructed separating the tidal basin from the sea and a difference in water level is obtained between the basin and sea.



(a) High tide

Figure: High tide

During high tide period, water flows from the sea into the tidal basin through the water turbine. The height of tide is above that of tidal basin. Hence the turbine unit operates and generates power, as it is directly coupled to a generator. During low tide period, water flows from tidal basin to sea, as the water level in the basin is more than that of the tide in the sea. During this period also, the flowing water rotates the turbine and generator power.



(b) Low tide

The generation of power stops only when the sea level and the tidal basin level are equal. For the generation of power economically using this source of energy requires some minimum tide height and suitable site. Kislaya power plant of 250 MW capacity in Russia and Rance power plant in France are the only examples of this type of power plant.

Advantages of tidal power plants.

1. It is free from pollution as it does not use any fuel.
2. It is superior to hydro-power plant as it is totally independent of rain.
3. It improves the possibility of fish farming in the tidal basins and it can provide recreation to visitors and holiday makers.

Disadvantages

1. Tidal power plants can be developed only if natural sites are available on the bay.

2. As the sites are available on the bays which are always far away from load centres, the power generated has to be transmitted to long distances. This increases the transmission cost and transmission losses.

Wind-Electric Generating power plant

Figure shows the various parts of a wind-electric generating power plant. These are:

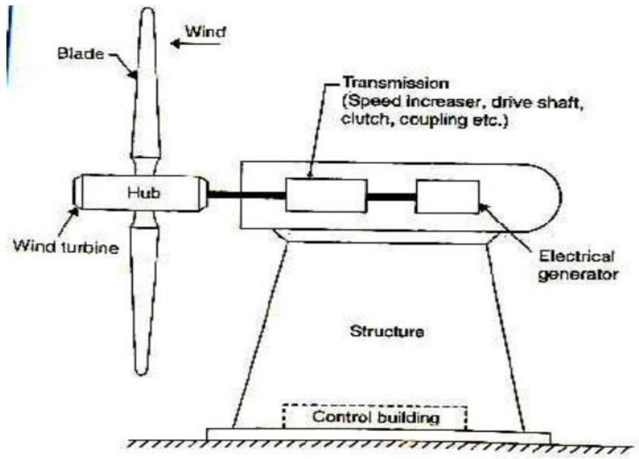


Figure: Wind-Electric generating power plant

1. Wind turbine or rotor.
2. Wind mill head – it houses speed increaser, drive shaft, clutch, coupling etc.
3. Electric generator. 4. Supporting structure.

The most important component is the **rotor**. For an effective utilization, all components should be properly designed and matched with the rest of the components.

The wind mill head performs the following functions:

(i) It supports the rotor housing and the rotor bearings.

(ii) It also houses any control mechanism incorporated like changing the pitch of the blades for safety devices and tail vane to orient the rotor to face the wind, the latter is facilitated by mounting it on the top of the supporting structure on suitable bearings.

- The wind turbine may be located either unwind or downwind of the power. In the unwind location the wind encounters the turbine before reaching the tower. *Downwind rotors are generally preferred especially for the large aerogenerators.*
- The **supporting structure** is designed to withstand the wind load during gusts. Its type and height is related to cost and transmission system incorporated. Horizontal axis wind turbines are mounted on towers so as to be above the level of turbulence and other ground related effects.

Types of Wind Machines

Wind machines (aerogenerators) are generally classified as follows:

1. Horizontal axis wind machines.
2. Vertical axis wind machines.

Horizontal axis wind machines.

Figure shows a schematic arrangement of horizontal axis machine. Although the common wind turbine with horizontal axis is simple in principle yet the design of a complete system, especially a large one that would produce electric power economically, is complex. It is of paramount importance's that the components like rotor, transmission, generator and tower should not only be as efficient as possible but they must also function effectively in combination.

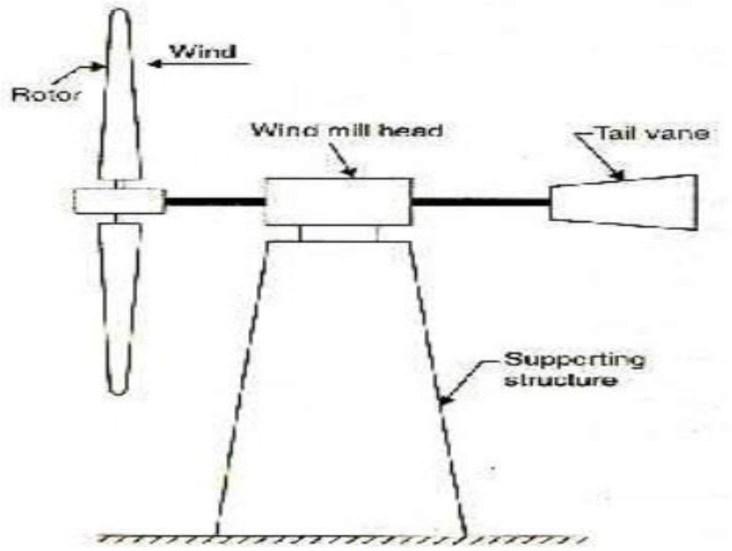


Figure: Horizontal axis wind machine.

Vertical axis wind machines. Figure shows vertical axis type wind machine. One of the main advantages of vertical axis rotors is that they do not have to be turned into the windstream as the wind direction changes. Because their operation is independent of wind direction, vertical axis machine are called panemones.

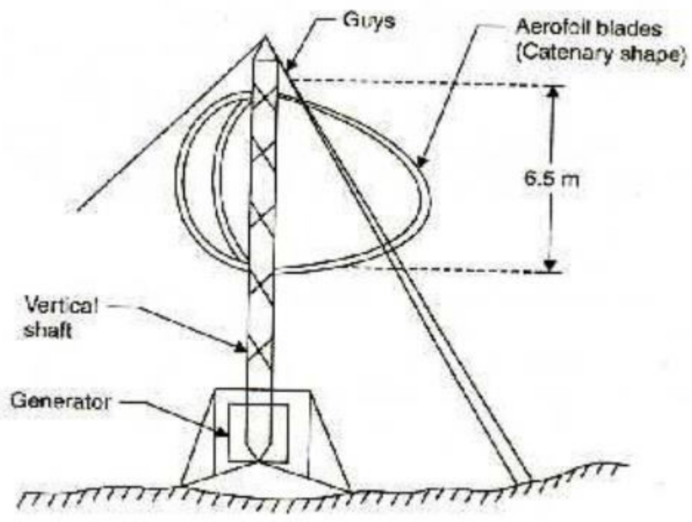


Figure: Vertical axis wind machine.

Radioactive waste

Radioactive waste is waste that contains radioactive material. Radioactive waste is usually a by-product of nuclear power generation and other applications of nuclear fission or nuclear technology, such as research and medicine. Radioactive waste is hazardous to most forms of life and the environment, and is regulated by government agencies in order to protect human health and the environment.

Radioactivity naturally decays over time, so radioactive waste has to be isolated and confined in appropriate disposal facilities for a sufficient period until it no longer poses a threat. The time radioactive waste must be stored for depends on the type of waste and radioactive isotopes. Current major approaches to managing radioactive waste have been segregation and storage for short-lived waste, near-surface disposal for low and some intermediate level waste, and deep burial or partitioning / transmutation for the high-level waste.

A summary of the amounts of radioactive waste and management approaches for most developed countries are presented and reviewed periodically as part of the International Atomic Energy Agency (IAEA) Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.

Classification of radioactive waste

Classifications of radioactive waste varies by country. The IAEA, which publishes the Radioactive Waste Safety Standards (RADWASS), also plays a significant role.

Low-level waste

Low level waste (LLW) is generated from hospitals and industry, as well as the nuclear fuel cycle. Low-level wastes include paper, rags, tools, clothing, filters, and other materials which contain small amounts of mostly short-lived radioactivity. Materials that originate from any region of an Active Area are commonly designated as LLW as a precautionary measure even if there is only a remote possibility of being contaminated with radioactive materials. Such LLW typically exhibits no higher radioactivity than one would expect from the same material disposed of in a non-active area, such as a normal office block.

Some high-activity LLW requires shielding during handling and transport but most LLW is suitable for shallow land burial. To reduce its volume, it is often compacted or incinerated before disposal. Low-level waste is divided into four classes: class A, class B, class C, and Greater Than Class C (GTCC).

Intermediate-level waste

Spent fuel flasks are transported by railway in the United Kingdom. Each flask is constructed of 14 in (360 mm) thick solid steel and weighs in excess of 50 tons

Intermediate-level waste (ILW) contains higher amounts of radioactivity and in general require shielding, but not cooling.[32] Intermediate-level wastes includes resins, chemical sludge and metal nuclear fuel cladding, as well as contaminated materials from reactor decommissioning. It may be solidified in concrete or bitumen for disposal. As a general rule, short-lived waste (mainly non-fuel materials from reactors) is buried in shallow repositories, while long-lived waste (from fuel and fuel reprocessing) is deposited in geological repository. U.S. regulations do not define this category of waste; the term is used in Europe and elsewhere.

High-level waste

High-level waste (HLW) is produced by nuclear reactors. The exact definition of HLW differs internationally. After a nuclear fuel rod serves one fuel cycle and is removed from the core, it is considered HLW. Fuel rods contain fission products and transuranic elements generated in the reactor core. Spent fuel is highly radioactive and often hot. HLW accounts for over 95 percent of the total radioactivity produced in the process of nuclear electricity generation. The amount of HLW worldwide is currently increasing by about 12,000 metric tons every year, which is the equivalent to about 100 double-decker buses or a two-story structure with a footprint the size of a basketball court. 1000-MW nuclear power plant produces about 27 tonnes of spent nuclear fuel (unreprocessed) every year.[35] In 2010, there was very roughly estimated to be stored some 250,000 tons of nuclear HLW, that does not include amounts that have escaped into the environment from accidents or tests. Japan estimated to hold 17,000 tons of HLW in storage in 2015, HLW have been shipped to other countries to be stored or reprocessed, and in some cases, shipped back as active fuel.

The ongoing controversy over high-level radioactive waste disposal is a major constraint on the nuclear power’s global expansion. Most scientists agree] that the main proposed long-term solution is deep geological burial, either in a mine or a deep borehole. However, almost six decades after commercial nuclear energy began, no government has succeeded in opening such a repository for civilian high-level nuclear waste, although Finland is in the advanced stage of the construction of such facility, the Onkalo spent nuclear fuel repository. Reprocessing or recycling spent nuclear fuel options already available or under active development still generate waste and so are not a total solution, but can reduce the sheer quantity of waste, and there are many such active programs worldwide. Deep geological burial remains the only responsible way to deal with high-level nuclear waste.[40] The Morris Operation is currently the only de facto high-level radioactive waste storage site in the United States.

Prevention of waste

A theoretical way to reduce waste accumulation is to phase out current reactors in favour of Generation IV Reactors or Liquid Fluoride Thorium Reactors, which output less waste per power generated. Fast reactors can theoretically consume some existing waste. The UK's Nuclear Decommissioning Authority published a position paper in 2014 on the progress on approaches to the management of separated plutonium, which summarises the conclusions of the work that NDA shared with UK government.

Management of waste

Modern medium to high level transport container for nuclear waste of particular concern in nuclear waste management are two long-lived fission products, Tc-99 (half-life 220,000 years) and I-129 (half-life 15.7 million years), which dominate spent fuel radioactivity after a few thousand years. The most troublesome transuranic elements in spent fuel are Np-237 (half-life two million years) and Pu-239 (half-life 24,000 years).[43] Nuclear waste requires sophisticated treatment and management to successfully isolate it from interacting with the biosphere. This usually necessitates treatment, followed by a long-term management strategy involving storage, disposal or transformation of the waste into a non-toxic form.[44] Governments around the world are considering a range of waste management and disposal options, though there has been limited progress toward long-term waste management solutions.[45]

In second half of 20th century, several methods of disposal of radioactive waste were investigated by nuclear nations,[46] which are :

"Long term above ground storage", not implemented.

"Disposal in outer space" (for instance, inside the Sun), not implemented - as it would be currently too expensive.

"Deep borehole disposal", not implemented.

"Rock-melting", not implemented.

"Disposal at subduction zones", not implemented.

Long-term storage of radioactive waste requires the stabilization of the waste into a form which will neither react nor degrade for extended periods. It is theorized that one way to do this might be through vitrification. Currently at Sellafield the high-level waste (PUREX first cycle raffinate) is mixed with sugar and then calcined. Calcination involves passing the waste through a heated, rotating tube. The purposes of calcination are to evaporate the water from the waste, and de-nitrate the fission products to assist the stability of the glass produced. The 'calcine' generated is fed continuously into an induction heated furnace with fragmented glass.[51] The resulting glass is a new substance in which the waste products are bonded into the glass matrix when it solidifies. As a melt, this product is poured into stainless steel cylindrical containers ("cylinders") in a batch process. When cooled, the fluid solidifies ("vitrifies") into the glass. After being formed, the glass is highly resistant to water.

After filling a cylinder, a seal is welded onto the cylinder head. The cylinder is then washed. After being inspected for external contamination, the steel cylinder is stored, usually in an underground repository. In this form, the waste products are expected to be immobilized for thousands of years.The glass inside a cylinder is usually a black glossy substance. All this work (in the United Kingdom) is done using hot cell systems. Sugar is added to control the ruthenium chemistry and to stop the formation of the volatile RuO_4 containing radioactive ruthenium isotopes. In the West, the glass is normally a borosilicate glass (similar to Pyrex), while in the former Soviet bloc it is normal to use a phosphate glass.] The amount of fission products in the glass must be limited because some (palladium, the other Pt group metals, and tellurium) tend to form metallic phases which separate from the glass. Bulk vitrification uses electrodes to melt soil and wastes, which are then buried underground. In Germany a vitrification plant is in use; this is treating the waste from a small demonstration reprocessing plant which has since been closed down.

Ion exchange

It is common for medium active wastes in the nuclear industry to be treated with ion exchange or other means to concentrate the radioactivity into a small volume. The much less radioactive bulk (after treatment) is often then discharged. For instance, it is possible to use a ferric hydroxide floc to remove radioactive metals from aqueous mixtures. After the radioisotopes are absorbed onto the ferric hydroxide, the resulting sludge can be placed in a metal drum before being mixed with cement to form a solid waste form.] In order to get better long-term performance (mechanical stability) from such forms, they may be made from a mixture of fly ash, or blast furnace slag, and Portland cement, instead of normal concrete (made with Portland cement, gravel and sand).

Synroc

The Australian Synroc (synthetic rock) is a more sophisticated way to immobilize such waste, and this process may eventually come into commercial use for civil wastes (it is currently being developed for US military wastes). Synroc was invented by Prof Ted Ringwood (a geochemist) at the Australian National University. The Synroc contains pyrochlore and cryptomelane type minerals. The original form of Synroc (Synroc C) was designed for the liquid high level waste (PUREX raffinate) from a light water reactor. The main minerals in this Synroc are hollandite ($BaAl_2Ti_6O_{16}$), zirconolite ($CaZrTi_2O_7$) and perovskite ($CaTiO_3$). The zirconolite and perovskite are hosts for the actinides. The strontium and barium will be fixed in the perovskite. The caesium will be fixed in the hollandite.

Long term management of waste

The time frame in question when dealing with radioactive waste ranges from 10,000 to 1,000,000 years,] according to studies based on the effect of estimated radiation doses. Researchers suggest that forecasts of health detriment for such periods should be examined critically. Practical studies only consider up to 100 years as far as effective planningand cost evaluations are concerned. Long term behavior of radioactive wastes remains a subject for ongoing research projects in geoforecasting.

Above-ground disposal

Dry cask storage typically involves taking waste from a spent fuel pool and sealing it (along with an inert gas) in a steel cylinder, which is placed in a concrete cylinder which acts as a radiation shield. It is a relatively inexpensive method which can be done at a central facility or adjacent to the source reactor. The waste can be easily retrieved for reprocessing.

Geologic disposal

On Feb. 14, 2014, at the Waste Isolation Pilot Plant, radioactive materials leaked from a damaged storage drum (see photo). Analysis of several accidents, by DOE, have shown lack of a "safety culture" at the facility.

The process of selecting appropriate deep final repositories for high level waste and spent fuel is now under way in several countries with the first expected to be commissioned some time after 2010. The basic concept is to locate a large, stable geologic formation and use mining technology to excavate a tunnel, or large-bore tunnel boring machines (similar to those used to drill the Channel Tunnel from England to France) to drill a shaft 500 metres (1,600 ft) to 1,000 metres (3,300 ft) below the surface where rooms or vaults can be excavated for disposal of high-level radioactive waste. The goal is to permanently isolate nuclear waste from the human environment. Many people remain uncomfortable with the immediate stewardship cessation of this disposal system, suggesting perpetual management and monitoring would be more prudent.

Because some radioactive species have half-lives longer than one million years, even very low container leakage and radionuclide migration rates must be taken into account. Moreover, it may require more than one half-life until some nuclear materials lose enough radioactivity to cease being lethal to living things. A 1983 review of the Swedish radioactive waste disposal program by the National Academy of Sciences found that country's estimate of several hundred thousand years—perhaps up to one million years—being necessary for waste isolation "fully justified. Ocean floor disposal of radioactive waste has been suggested by the finding that deep waters in the North Atlantic Ocean do not present an exchange with shallow waters for about 140 years based on oxygen content data recorded over a period of 25 years. They include burial beneath a stable abyssal plain, burial in a subduction zone that would slowly carry the waste downward into the Earth's mantle, and burial beneath a remote natural or human-made island. While these approaches all have merit and would facilitate an international solution to the problem of disposal of radioactive waste, they would require an amendment of the Law of the Sea.