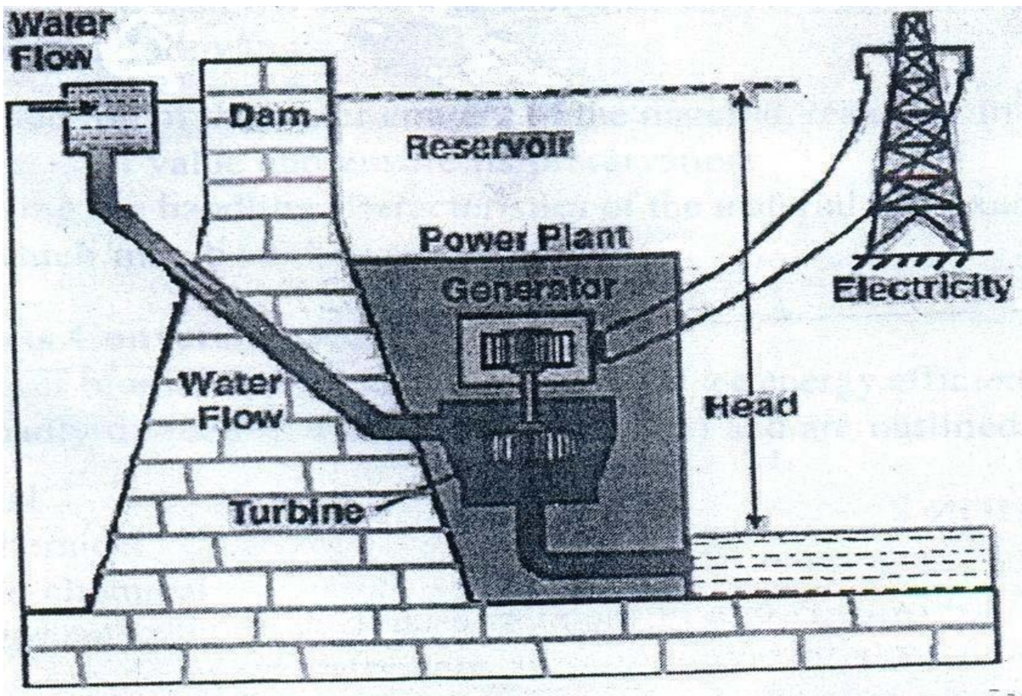
UNIT 1

HYDRO ELECTRIC POWER STSTION & HYDRAULIC TURBINES

HYDROPOWER

Hydro-energy is known as traditional renewable energy source. It is based on natural circulating water flow and its drop from higher to lower land surface that constitutes the potential. In order to convert this potential to applicable electric energy, water flow should be led to and drive a hydraulic turbine, transforming hydro energy into mechanical energy, the latter again drives a connected generator transforming the mechanical energy into electric energy. As hydro energy exploitation and its utilization are completed at the same time. I.e. the exploitation of first energy source and the conversion of secondary energy source occur simultaneously, unlike the coal power generation which should have two orders; first order is exploitation of fuel, second order is generation, so hydropower has the advantages over thermal power generation.

Mankind has used the energy of falling water for many centuries, at first in mechanical form and since the late 19th century by further conversion to electrical energy. Historically, hydropower was developed on a small scale to serve localities in the vicinity of the plants. With the expansion and increasing load transfer capability of transmission networks, power generation was concentrated in increasingly larger units and to benefit from the economies resulting from development on a larger scale.



General Layout of a dam based hydroelectric plant

Sites selected for development tended to be the most economically attractive; in this regard, higher heads and proximity to load centers were significant factors. For this reason, development was not restricted to large sites, and hydro stations today range from less than 1 MWe capacity to more than 10,000 MWe. The efficiency of hydroelectric generation is more than twice that of competing thermal power stations.

TYPES OF PROJECT

Capacity, unit size and selection of Equipment, their Characteristics and Specifications for design of hydro power station depend upon type of hydroelectric development and classification with respect to head and size. There are three main types of hydropower schemes that can be categorized in terms of how the flow at a given site is controlled or modified. These are:

Run-of-river plants (no active storage); and

Plants with significant storage
Pumped storage

In a run-of-river project, the natural flow of the river is relatively uncontrolled. In a storage project, the filling and emptying of the impounded storage along with the pattern of the natural stream flow controls the flow in the river downstream from the storage impoundment.

Run-of-river plants can be located at the downstream end of a canal fall, open flume, or pipeline diverting the stream’s flow around a water supply dam or falls. The available flow governs the capacity of the plant. The plant has little or no ability to operate at flow rates higher than that available at the moment.

In a conventional plant, a dam, which stores water in a reservoir or lake impoundment, controls the river flows. Water is released according to electric, irrigation, water supply, or flood control needs. Constructing a dam and storage reservoir can increase the percentage of time that a project can produce a given level of power. Base load plants-those operated at relatively constant output-may have either a small capacity relative to the river flow or may have a significant storage reservoir. Storage reservoirs can be sized for storing water during wet years or wet seasons. Alternatively, they can be sized to provide water for weekly or daily peak generation. A storage reservoir allows using available energy that might otherwise be wasted as spill.

Plants with storage at both head and tailrace are pumped storage project.

Run of the River Schemes or Diversion Schemes

This type of development aims at utilizing the instantaneous discharge of the stream. So the discharge remains restricted to day to day natural yield from the catchments; characteristics of which will depend on the hydrological features. Diurnal storage is sometime provided for optimum benefits. Development of a river in several steps where tail race discharges from head race inflows for downstream power plants forms an interesting variation of this case and may require sometimes special control measures.

Small scale power generation also generally fall in the category and may have special control requirement especially if the power is fed into a large grid.

Storage Schemes

In such schemes annual yield from the catchment is stored in full or partially and then released according to some plan for utilization of storage. Storage may be for single purpose such as power development or may be for multi purpose use which may include irrigation, flood control, etc. therefore, design of storage works and releases from the reservoir will be governed by the intended uses of the stored water. If the scheme is only for power development, then the best use of the water will be by releasing according to the power demand. Schemes with limited storage may be designed as peaking units. If the water project forms a part of the large grid, then the storage is utilized for meeting the peak demands. Such stations could be usefully assigned with the duty of frequency regulation of the system.

Pump Storage Scheme

Principle

The basic principle of pumped storage is to convert the surplus electrical energy available in a system in off-peak periods, to hydraulic potential energy, in order to generate power in periods when the peak demand on the system exceeds the total available capacity of the generating stations.

By using the surplus scheme electrical energy available in the network during low-demand periods, water is pumped from a lower pond to an upper pond. In periods of peak demand, the power station is operated in the generating mode i.e. water from the upper pond is drawn through the same water conduit system to the turbine for generating power.

There are two main types of pumped storage plants:

Pumped-storage plants and

Mixed pumped-storage plants.

Pump-storage plants: In this type only pumped storage operation is envisaged without any scope for conventional generation of power. These are provided in places where the run-off is poor. Further, they are designed only for operation on a day-to-day basis without room for flexibility in operation.

Mixed pumped-storage plants: In this type, in addition to the pumped storage operation, some amount of extra energy can be generated by utilizing the additional natural run-off during a year. These can be designed for operation on a weekly cycle or other form of a longer period by providing for additional storage and afford some amount of flexibility in operation.

CLASSIFICATION OF HYDROPOWER PLANTS

As such there are no hard and fast rules to classify Hydro power plants. Some of the basis is as follows:

Based on Hydraulic Characteristics

Based on Head

Based on Capacity

Based on Turbine Characteristics

Based on Load Characteristics

Based on Interconnection

Hydropower Project based on Hydraulic Characteristics:

Run off river plant (Diversion plant)

Storage plant (Impoundment plant)
Pumped storage plant
Tidal plant

Run off River Plant (Diversion Plant)

In some areas of the world, the flow rate and elevation drops of the water are consistent enough that hydro electric plants can be built directly in the river.

The water is utilized as it comes in the river.

Practically, water is not stored during flood periods as well as during low electricity demand periods, hence water is wasted.

Run off river plant may be without pondage or with pondage.

The plants with pondage are provided with a barrage to store the water, to take care of daily variation.

During good flow conditions – can supply base load and during low flow conditions - can supply peak load

Seasonal changes in river flow and weather conditions affect the plant's output; hence it is in limited use unless interconnected with grid.

flows that occur in the stream at the intake and flows downstream of the powerhouse are virtually identical to pre-development flows.

Run-of-river facilities use low dams to provide limited storage of water– at most daily pondage.

In a run-off river SHP scheme, through diversion structure water is diverted to water conductor system to the powerhouse.

Water impounded in dam for storage and released in phased manner to generate power and further used for irrigation is shown in (figure 1.5.1).

Site Selection for Hydropower Plants

- **Availability of Water:** Run-off data for many years available
- **Water Storage:** for water availability throughout the year
- **Head of Water:** most economic head, possibility of constructing a dam to get required head
- **Geological Investigations:** strong foundation, earthquake frequency is less
- **Water Pollution:** excessive corrosion and damage to metallic structures
- **Sedimentation:** capacity reduces due to gradual deposition of silt
- **Social and Environmental Effects:** submergence of areas, effect on biodiversity (e.g. western ghat), cultural and historic aspects
- **Access to Site:** for transportation of construction material and heavy machinery new railway lines or roads may be needed
- **Multipurpose:** power generation, irrigation, flood control, navigation, recreation; because initial cost of power plant is high because of civil engineering construction work

Classification of Hydropower Plants

According to water flow regulation:

1. Runoff river plants without pondage
2. Runoff river plants with pondage
3. Hydroelectric plants with storage reservoir

According to Load:

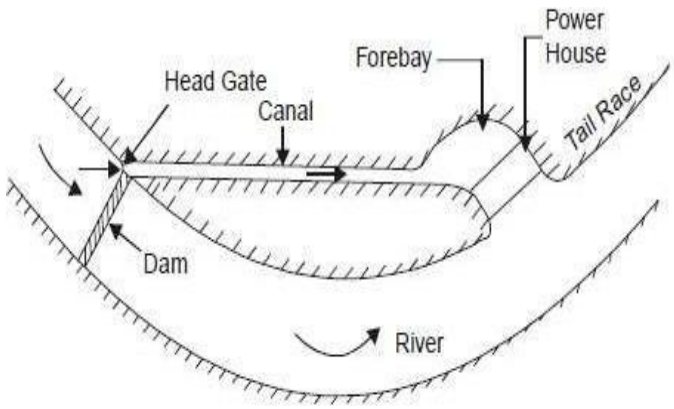
1. Base load plants
2. Peak load plants
3. Pumped storage plants

According to head:

1. High head plants (>100m)
2. Medium head plants (30-100 m)
3. Low head plants (<30 m)

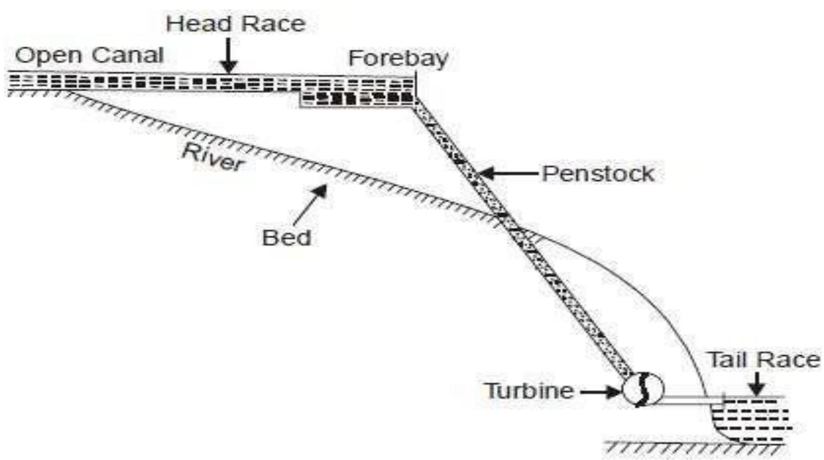
Low head plant

- Operating head is less than 15m.
- Vertical shaft Francis turbine or Kaplan turbine.
- Small dam is required.



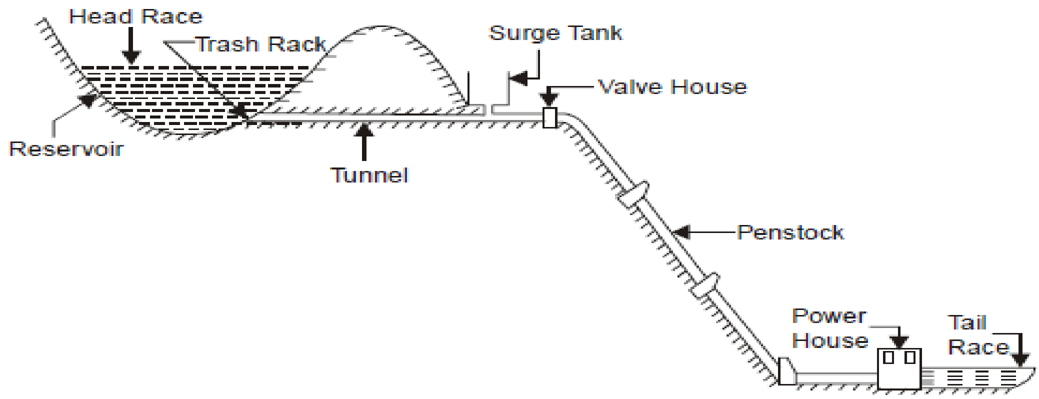
Medium head plant

- Operating head is less than 15 to 50m.
- Francis turbines.
- Forebay is provided at the beginning of the penstock.



High head plant

- Operating head exceed 50m.
- Pelton turbines.
- Surge tank is attached to the penstock to reduce water hammer effect onthe penstock.



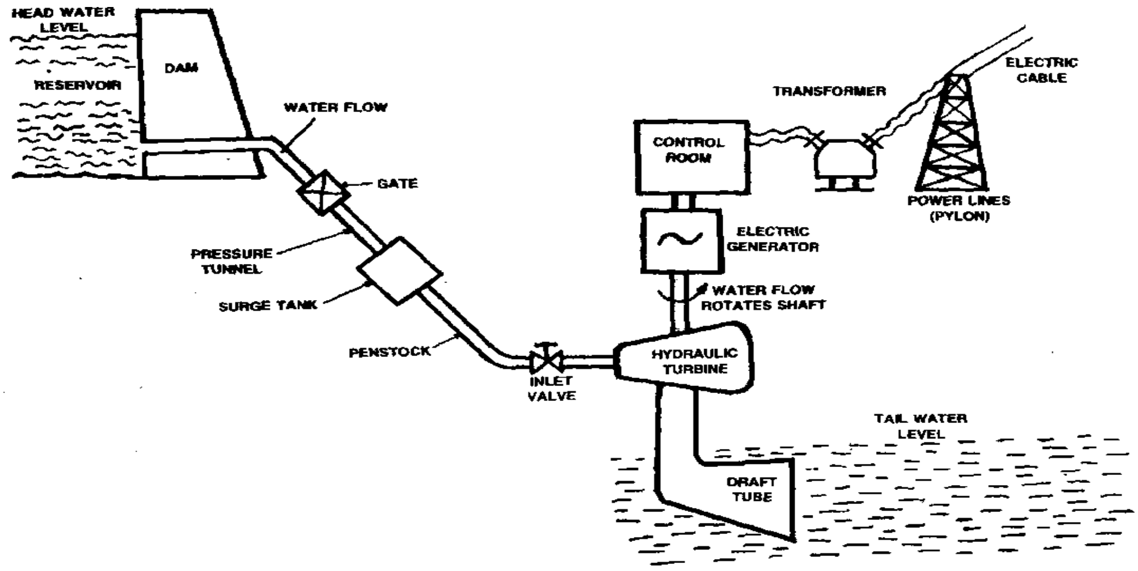


FIG. 3.6: LAYOUT OF HYDRO-ELECTRIC POWER PLANT

Components of a HPP

Schematic of a Hydropower Plant

The various components of HPP are as follows:

1. Catchment area
2. Reservoir
3. Dam
4. Spillways
5. Conduits
6. Surge tanks

7. Draft tubes
8. Power house
9. Switchyard for power evacuation

Dam

- Develops a reservoir to store water
- Builds up head for power generation

Spillway

- To safeguard the dam when water level in the reservoir rises

Intake

- Contains trash racks to filter out debris which may damage the turbine

Forebay

- Enlarged body of water just above the intake

Forebay Conduits

- Headrace is a channel which lead the water to the turbine
- Tailrace is a channel which carries water from the turbine
- A canal is an open waterway excavated in natural ground following its contour.
- A flume is an open channel erected on a surface above ground.
- A tunnel is a closed channel excavated through an obstruction.
- A pipeline is a closed conduit supported on the ground.
- **Penstocks** are closed conduits for supplying water "under pressure" from head pond to the turbines.

Surge Tank

- A surge tank is a small reservoir in which the water level rises or falls to reduce the pressure swings so that they are not transmitted to the penstock.
- Water Hammer
    - Load on the turbine is suddenly reduced
    - Governor closes turbine gates
    - Sudden increase of pressure in the penstock
- Negative Pressure
    - Load on the generator is suddenly increased
    - Governor opens the turbine gates
    - Tends to cause a vacuum in the penstock
- When the gates are closed, water level rises in the surge tank and when the gates are suddenly opened, surge tank provides the initial water supply.

Surge Tank Draft Tubes

The function of the draft tube is to

- To reduce the velocity head losses of the water
- To allow the turbine to be set above the tailrace to facilitate inspection and maintenance

Tailrace:

- A tailrace is required to discharge the water leaving the turbine into the river.
- The design of the tail race should be such that water has a free exit.

Power House

1. Hydraulic turbines
2. Electric generators
3. Governors
4. Gate valves
5. Relief valves
6. Water circulation pumps
7. Air ducts
8. Switch board and instruments
9. Storage batteries
10. Cranes

Switchyard

1. Step up transformers
2. Instrument transformers
3. Transmission lines

Advantages of hydro power plant:

- Water is a renewable energy source.
- Maintenance and operation charges are very low.
- The efficiency of the plant does not change with age.
- In addition to power generation, hydro-electric power plants are also useful for flood control, irrigation purposes, fishery and recreation.
- Have a longer life (100 to 125 years) as they operate at atmospheric temperature.
- Water stored in the hydro-electric power plants can also be used for domestic water supply.
- Since hydro-electric power plants run at low speeds (300 to 400 rpm) there is no requirement of special alloy steel construction materials or specialised mechanical maintenance.

Disadvantages of hydro power plant:

- The initial cost of the plant is very high.
- Since they are located far away from the load centre, cost of transmission lines and transmission losses will be more.
- During drought season the power production may be reduced or even stopped due to insufficient water in the reservoir.
- Water in the reservoir is lost by evaporation.

PUMP STORAGE SCHEME

Principle

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Pumped Storage Plant

Water is utilized for generation of power during peak demand, while same water is pumped back in the reservoir during off peak demand period, when excess power is available for this purpose.

If turbine is reversible, it can be used as a pump to supply water back to reservoir, otherwise separate pump can be used.

Based on operating cycle it can be classified as:

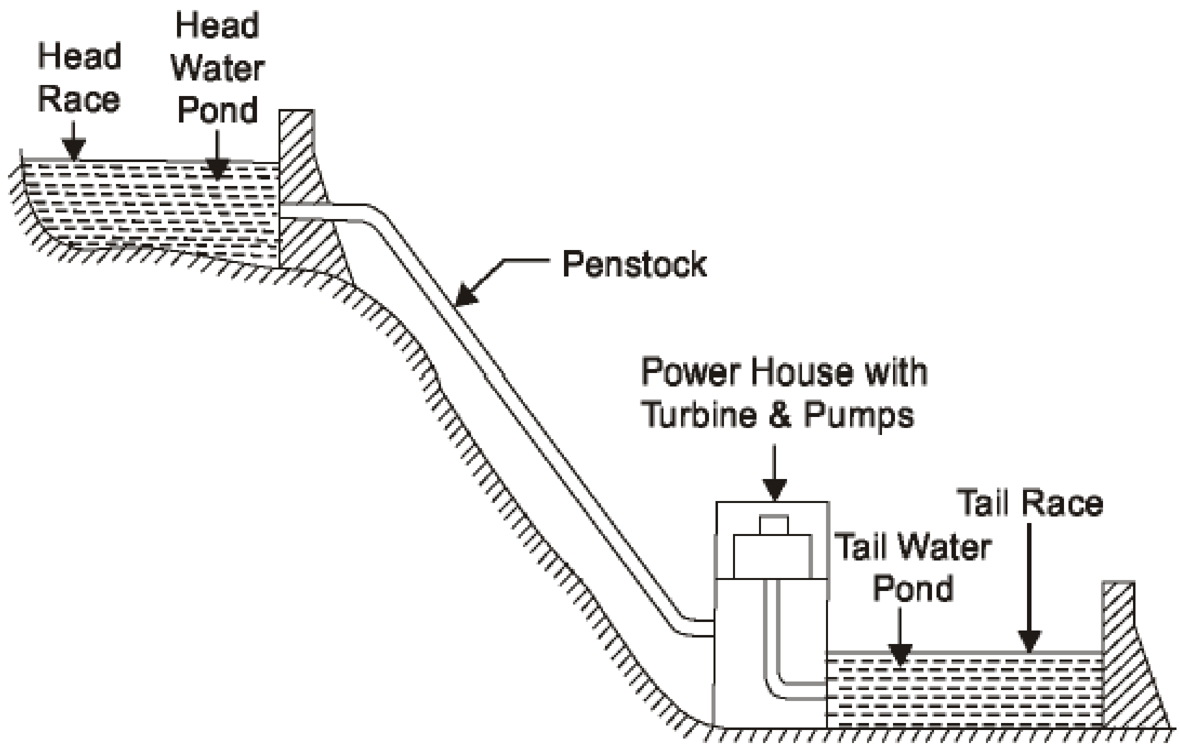
Plant with a daily cycle: water is pumped up from mid night to early morning as well as near lunch time.

Plant with a weekly cycle: water is pumped up during weekend.

Plant with a seasonal cycle: water is pumped up in the winter continuously for several days to be utilized for a continuous power generation in the high demand summer period.

PUMPED STORAGE POWER PLANTS

These plants supply the peak load for the base load power plants and pump all or a portion of their own water supply. The usual construction would be a tail water pond and a head water pond connected through a penstock. The generating pumping plant is at the lower end. During off peak hours, some of the surplus electric energy being generated by the base load plant is utilized to pump the water from tail water pond into the head water pond and this energy will be stored there. During times of peak load, this energy will be released by allowing the water to flow from the head water pond through the water turbine of the pumped storage plant. These plants can be used with hydro, steam and i.e. engine plants. This plant is nothing but a hydraulic accumulator system and is shown. These plants can have either vertical shaft arrangement or horizontal shaft arrangement. In the older plants, there were separate motor driven pumps and turbine driven generators. The improvement was the pump and turbine on the same shaft with the electrical element acting as either generator or motor. The latest design is to use a Francis turbine which is just the reverse of centrifugal pump. When the water flows through it from the head water pond it will act as a turbine and rotate the generator. When rotated in the reverse direction by means of an electric motor, it will act as a pump to shunt the water from the tail water pond to the head water pond



Pumped Storage Plant

Power Estimation

The potential electric power of the water in terms of flow and head can be calculated from the following equation.

$$KW = 9.81 \times Q \times H \times \eta$$

Where,

kW = electric power in kW

Q = quantity of water flowing through the hydraulic turbine in cubic meters per second. Discharge (quantity of water) flowing in a stream and available for power generation has daily and seasonal variation. Optimum discharge for power generation is determined on the basis of energy generation cost.

H = Net available head in meters (gross head – losses)

= overall efficiency of the hydro power plant. For general estimation purposes, η is normally taken as 0.85

Hydrology

- First requirement – Q (discharge)
- Hydrology deals with occurrence and distribution of water over and under earth's surface.
  - Surface Water Hydrology
  - Ground Water Hydrology
- **Watershed, catchment area or drainage area:** length of the river, size and shape of the area it affects, tributaries, lakes, reservoirs etc.
- Investigation of **run-off** for past few years is required for power potential studies of a HPP.

Objectives of Hydrology

- To obtain data regarding the stream flow of water that would be available,
- To predict the yearly possible flow
- To calculate the mean annual rainfall in the area under consideration from a record of the annual rainfall for a number of years, say 25 to 30
- To note the frequency of dry years
- To find maximum rainfall and flood frequency

Various terms related to Hydrology

- Rainfall is also known as precipitation and can be measured by rain gauges.
- Some part of precipitation is lost due to evaporation, interception and transpiration.
- **Transpiration:** Plants absorbing moisture and giving it off to the atmosphere
- Stream flow = precipitation – losses
- Stream flow = surface flow + percolation to ground
- Surface flow is also known as **run-off.**
- **Hydrograph:**
  - Shows the variation of stream flow in m^3/s with time for a particular river site. The time may be hour, week, month or a year.
  - The area under hydrograph gives the total volume of flow

- **Flow duration curve:**
  - Shows the percentage of time during the period when the flow was equal to greater than the given flow.
  - The area under FDC gives the total quantity of run-off during a period

- **Mass curve**
  - Indicates the total volume of run-off in cubic meters up to a certain time.
  - the slope of the curve at any point shows the rate of flow at that time
  - Used for estimating the capacity of storage reservoir
- **Storage:**
  - to ensure water availability during deficient flow and thus increasing the firm capacity

  - Storage also results in more energy production
- **Pondage:**
  - Storing water in small ponds near the power plant as the storage reservoir is away from plant
  - To meet the power demand fluctuations over a short period of time e.g. 24 hours

- **Primary Power:** power that will be available 90 % of the time
- **Secondary Power:** power that will be available 75 % of the time
- **Dump Power:** power that will be available 50 % of the time.
- **Maximum flow estimation:** gives estimation of floods and helps in design of dam and spillway.

HYDROGRAPH & FLOW DURATION CURVE:-

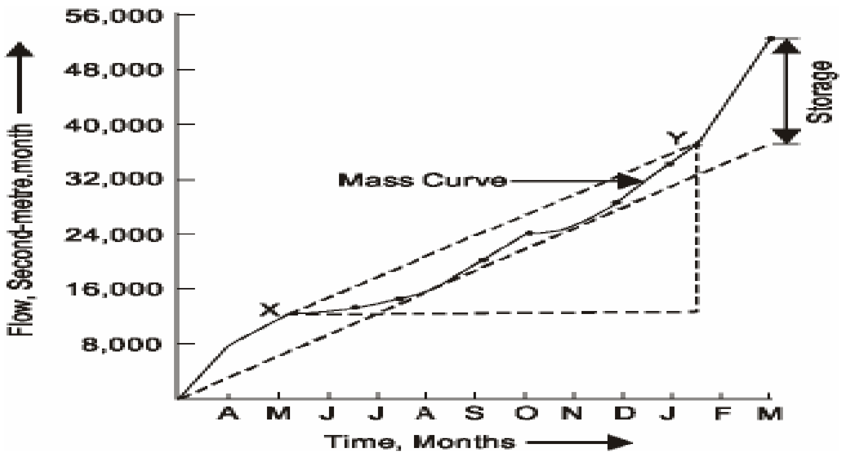
- A hydrograph indicates the variation of discharge or flow with time. It is plotted with flows as ordinates and time intervals as abscissas. The flow is in m^3/sec and the time may be in hours, days, weeks or months.

- A flow duration curve shows the relation between flows and lengths of time during which they are available. The flows are plotted as the ordinates and lengths of time as abscissas. The flow duration curve can be plotted from a hydrograph.

THE MASS CURVE:-

The use of the mass curve is to compute the capacity of the reservoir for a hydro site. The mass curve indicates the total volume of run-off in second meter-months or other convenient units, during a given period. The mass curve is obtained by plotting cumulative volume of flow as ordinate and time (days, weeks by months) as abscissa. Fig. 11.2 shows a mass curve for a typical river for which flow data is given in Table 11.2. The monthly flow is only the mean flow and is correct only at the beginning and end of the months. The variation of flow during each month is not considered. Cumulative daily flows, instead of monthly flows, will give a more accurate mass curve, but this involves an excessive amount of work. The slope of the curve at any point gives the flow rate in second- meter. Let us join two points X and Y on the curve. The slope of this line gives the average rate of flow during the period between X and Y. This will be = (Flow at Y-Flow at X)/Time Span Let the flow demand be, 3000 sec-meter. Then the line X-Y may be called as `demand line' or „Use line‟. If during a particular period, the slope of the mass Curve is greater than that of the demand line, it means more water is flowing into the reservoir than is being utilized, so the level of water in the reservoir will be increasing during that period and vice versa. Upto point X and beyond point Y the reservoir will be overflowing. Being full at both X and Y.

The capacity of the reservoir is given by the maximum ordinate between the mass curve and the demand line. For the portion of mass curve between point X and Y, the storage capacity is about 4600 sec-meter-month. However, considering the entire mass curve, storage capacity will be about 15,400 sec-meter-months.



UNIT-1

THERMAL POWER STATIONS

INTRODUCTION:

- Thermal energy is the major source of power generation in India. More than 60% of electric power is produced by steam plants in India. India has large deposit of coal (about 170 billion tones), 5^{th} largest in world. Indian coals are classified as A-G grade coals.
- In Steam power plants, the heat of combustion of fossil fuels is utilized by the boilers to raise steam at high pressure and temperature. The steam so produced is used in driving the steam turbines or sometimes steam engines couples to generators and thus in generating electrical energy.
- Steam turbines or steam engines used in steam power plants not only act as prime movers but also as drives for auxiliary equipment, such as pumps, stokers fans etc.
- Steam power plants may be installed either to generate electrical energy only or generate electrical energy along with generation of steam for industrial purposes such as in paper mills, textile mills, sugar mills and refineries, chemical works, plastic manufacture, food manufacture etc.
- The steam for process purposes is extracted from a certain section of turbine and the remaining steam is allowed to expand in the turbine. Alternatively the exhaust steam may be used for process purposes.
- Thermal stations can be private industrial plants and central station.

Coal Classification

Coal Type	kJ/kg	kWh/kg	kCal/kg
Peat	8000	28800000	1912
Lignite	20000	72000000	4780
Bituminous	27000	97200000	6453
Anthracite	30000	108000000	7170

Advantages and Disadvantages of a Thermal Power Plant

Advantages:

- Less initial cost as compared to other generating stations.
- It requires less land as compared to hydro power plant.
- The fuel (i.e. coal) is cheaper.

- The cost of generation is lesser than that of diesel power plants.

Disadvantages:

- It pollutes the atmosphere due to the production of large amount of smoke. This is one of the causes of global warming.
- The overall efficiency of a thermal power station is low (less than 30%).
- Requires long time for erection and put into action.
- Costlier in operating in comparison with that of Hydro and Nuclear power plants.
- Requirement of water in huge quantity.

Selection of site for thermal power plant

- **Nearness to the load centre:** The power plant should be as near as possible to the load centre to the centre of load .So that the transmission cost and losses are minimum. This factor is most important when Dc supply system is adopted. However in the case of AC supply when transformation of energy from lower voltage to higher voltage and vice versa is possible power plants can be erected at places other than that of load provided other conditions are favorable.
- **Water resources:** For the construction and operating of power plant large volumes of water are required for the following reasons
  - To raise the steam in boiler.
  - For cooling purpose such as in condensers
  - As a carrying medium such as disposal of ash.
  - For drinking purposes.
  - This could be supplied from either rivers or underground water resources. Therefore having enough water supplies in defined vicinity can be a factor in the selection of the site.
- **Availability of Coal:** Huge amount of coal is required for raising the steam. Since the government policy is to use the only low grade coal with 30 to 40 % ash content for power generation purposes, the steam power plants should be located near the coal mines to avoid the transport of coal & ash.
- **Land Requirement:** The land is required not only for setting up the plant but for other purposes also such as staff colony, coal storage, ash disposal etc.

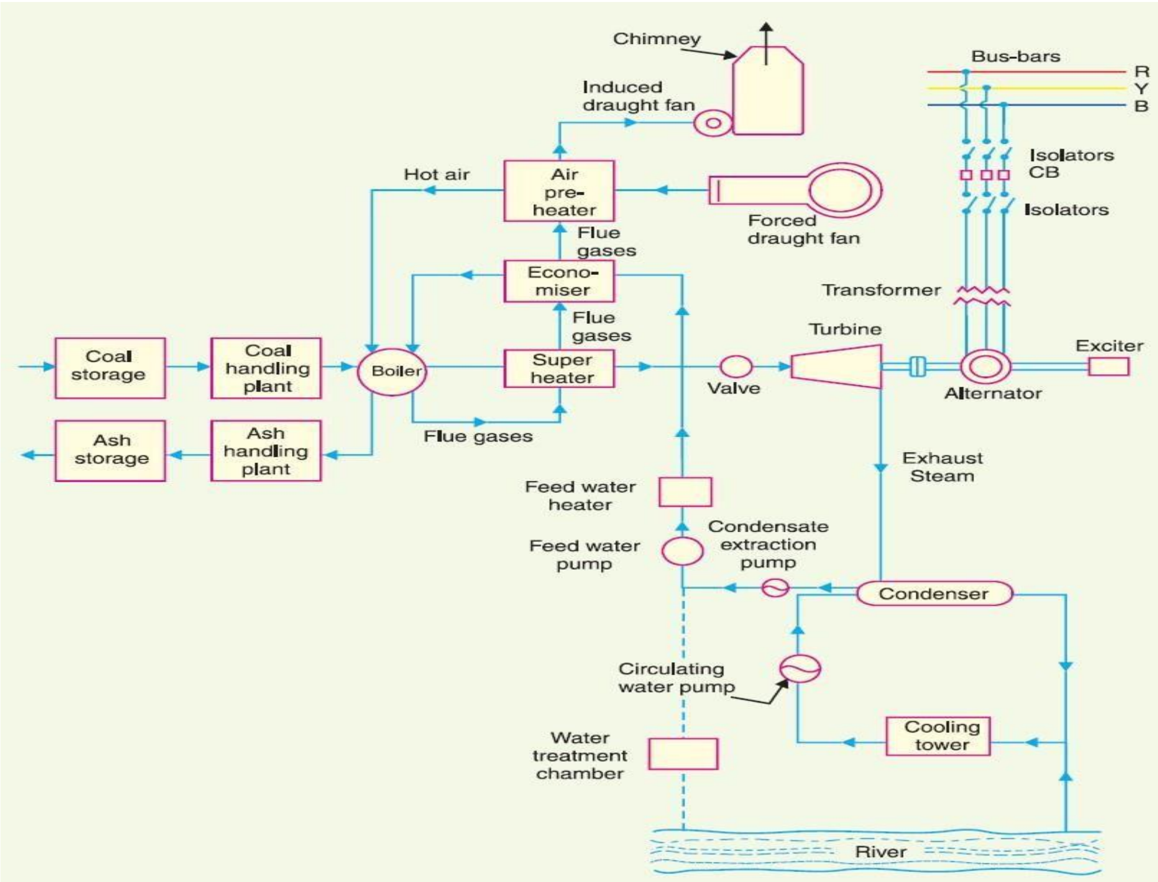
- **Eg:** For 2000MW plant, the land requirement may be of the order of 200-250 acres. As the cost of the land adds up to the final cost of the plant, it should be available at a reasonable price. Land should be available for future extension.

- **Transportation Facilities**: The facilities must be available for transportation of heavy equipment and fuels e.g near railway station.
- **Labour supplies:** Skilled and unskilled laborers should be available at reasonable rates near the site of the plant.
- **Ash Disposal:** Ash is the main waste product of the steam power plant and with low grade coal, it may be 3.5 tones per day , some suitable means for disposal of ash should be though of. It may be purchased by building contractors, or it can be used for brick making near the plant site. If the site is near the coal mine it can be dumped into the disused mines. In case of site located near a river,sea or lake ash can be dumped into it.
- **Distance from populated area:** The continuous burning of coal at the power station Produces smoke, fumes and ash which pollute the surrounding area. Such a pollution due to smoke is dangerous for the people living around the area. Hence, the site of a plant should be at a considerable distance from the populated area.

Major Components of a Thermal Power Plant

- **Coal Handling Plant**
- **Pulverizing Plant**
- **Draft or Draught fan**
- **Boiler**
- **Ash Handling Plant**
- **Turbine and Generator**
- **Condenser**
- **Cooling Tower And Ponds**
- **Feed Water Heater**
- **Economiser**

- **Super heater and Reheater**
- **Air pre heater**
- **Alternator with Exciter**
- **Protection and control equipment**
- **Instrumentation**



Schematic arrangement of Steam Power Station

- A boiler (or steam generator) is a closed vessel in which water, under pressure, is converted into steam. The heat is transferred to the boiler by all three modes of heat transfer i.e. conduction, convection and radiation.
- Major types of boilers are: (i) fire tube boiler and (ii) water tube boiler

- Generally water tube boilers are used for electric power stations.

Fire Tube Boiler

- The boiler is named so because the products of combustion pass through the tubes which are surrounded by water.
- Depending on whether the tube is vertical or horizontal the fire tube boiler is divided into two types
    - Vertical tube boiler
    - Horizontal tube boiler
- A fire tube boiler is simple, compact and rugged in construction. Its initial cost is low.
- Water being more and circulation being poor they cannot meet quickly to changes in steam demand.
- As water and steam, both are in the same shell, higher pressure of steam are not possible, the maximum pressure which can be had is 17.5 kg/cm^2 with a capacity of 15,000kg of steam per hour.
- For the same output the outer shell of a fire tube boiler is much larger than that of a water tube boiler.
- In the event of a sudden and major tube failure. Steam explosions may be caused in the furnace due to rush of high pressure water into the hot combustion chamber which may generate large quantities of steam in the furnace.
- Fire tube boilers use is therefore limited to low cost small size and low pressure plants.

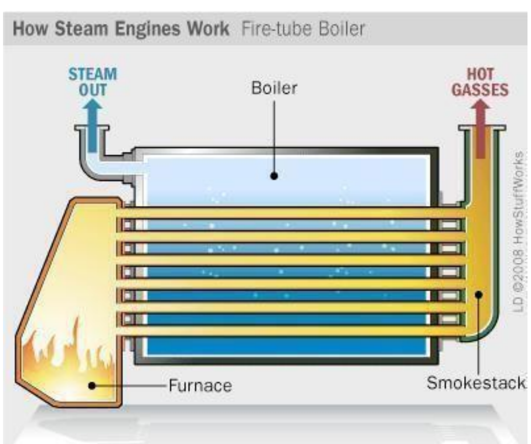


Figure: Fire Tube Boiler

Water Tube Boilers

- In this boiler, the water flows inside the tubes and hot gases flow outside the tube.
- Water tube boiler are classified as
- Vertical tube boiler
- Horizontal tube boiler
- Inclined tube boiler
- The circulation of water in the boiler is may be natural or forced.
- For Central steam power plants large capacity of water tube boilers are used.
- The tubes are always external to the drum they can be built in smaller size and therefore withstand high pressure.
- The boiler drum contains both steam and water, the former being trapped from the top of the drum where the highest concentration of dry steam exists.

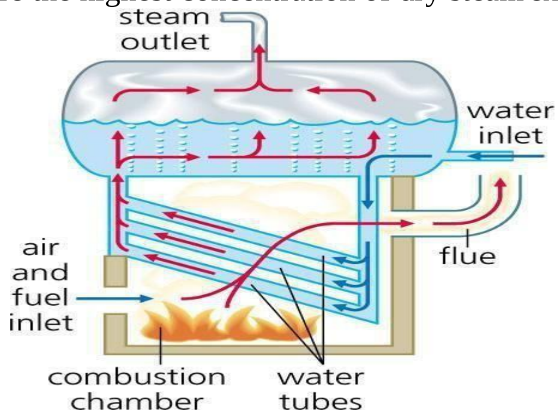


Figure: Water tube boiler

SUPERHEATER AND REHEATERS

- The function of the super heater is to remove the last trash of moisture from the saturated steam leaving the boiler tubes and also increases its temperature above the saturation temperature.
- For this purpose the heat of the combustion gases from the furnace is utilized.
- Super heated steam is that steam which contains more heat than the saturated steam at the same pressure. The additional heat provides more energy to the turbine hence

power output is more.

- Superheated steam causes lesser erosion of the turbine blades and can be transmitted for longer distance with little heat loss
- A super heater may be convention type, radiant type or combination. However, convention super heaters are more commonly used.

Figure: Super heaters

REHEATER

- In addition to super heater modern boiler has reheater also. The function of the reheater is to superheat the partly expanded steam from the turbine, this ensure that the steam remain dry through the last stage of the turbine.
- A reheater may be convention type, radiant type or combination.

Feed Water Heaters: These heaters are used to heat the feed water by means of blend steam before it is supplied to the boiler. Necessity of heating feed water before feeding it back to the boiler arises due to the following reasons.

- Feed Water heating improve overall efficiency.
- The dissolved oxygen which would otherwise cause boiler corrosion are removed in the feed water heater.
- Thermal stresses due to cold water entering the boiler drum are avoided.
- Quantity of steam produced by the boiler is increased.

❖ Some other impurities carried by steam and condensate, due to corrosion in boiler and condenser, are precipitated outside the boiler.

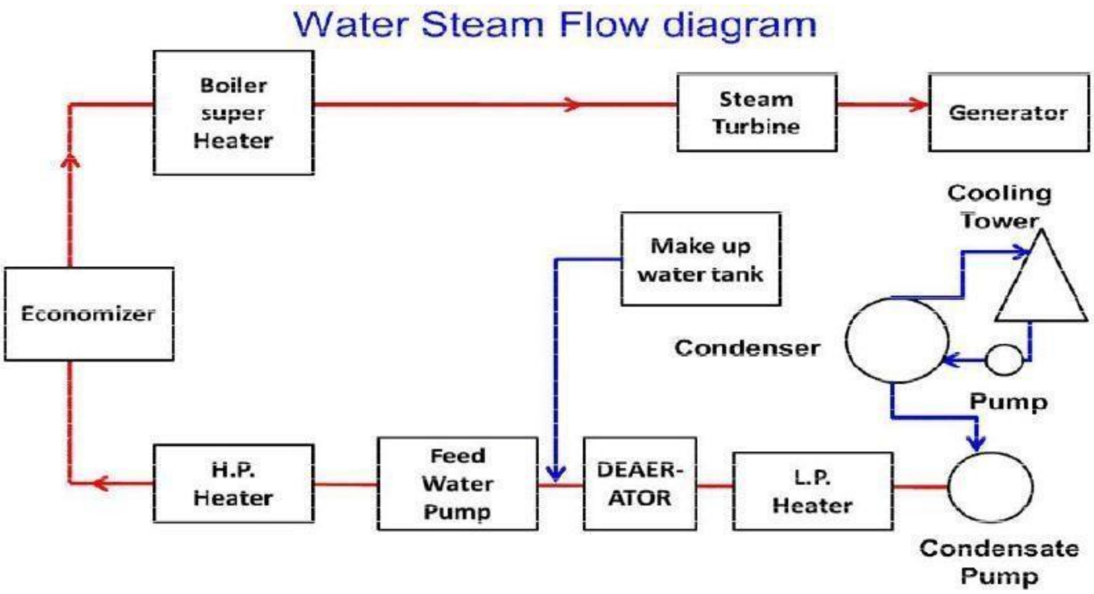


Figure: Water steam flow diagram

ECONOMIZER

❖ Boilers are provided with economizer and air pre-heaters to recover heat from the flue gases. An increase of about 20% in boiler efficiency is achieved by providing both economizer and air pre-heaters.

❖ Economizer alone gives only 10-12% efficiency increase, causes saving in fuel consumption 5-15 %. The feed water from the high pressure heaters enters the economizer and picks up heat from the flue gases after the low temperature super heater.

❖ Economizer can be classified as an inline or staggered arrangement based on the type of tube arrangement.

❖ For pressure of 70 Kg/cm^2 or more economizer becomes a necessity.

❖ The tubes are arranged in parallel continuous loops.

- Feed water flows through the tubes and the flue gases outside the tubes across them.

The feed water should be sufficiently pure not to cause forming of scales and cause internal corrosion and under boiler pressure.

- The temperature of the feed water entering the economizer should be high enough so that moister from the flue gases does not condense on the economizer tubes.

AIR PREHEATERS

- After the flue gases leave economizer, some further heat can be extracted from them and is used to heat the incoming air for combustion.
- Air preheaters may be of following types:
  - Plate type
  - Tubular type
  - Regenerative type
- Cooling of flue gases by 20^0increase the efficiency of the plant by 1%.
- The use of air preheaters is more economical with pulverized fuel boilers because the temperature of flue gases going out is sufficiently large and high air temperatures (250 to 350^0 C) is always desirable for better combustion.
- Air preheaters should have high thermal efficiency, reliability of operation, less maintenance charges, should occupy small space, should be reasonable in initial cost and should be accessible.
- In order to avoid corrosion of the air preheaters, the flue gases should not be cooled below the dew point.

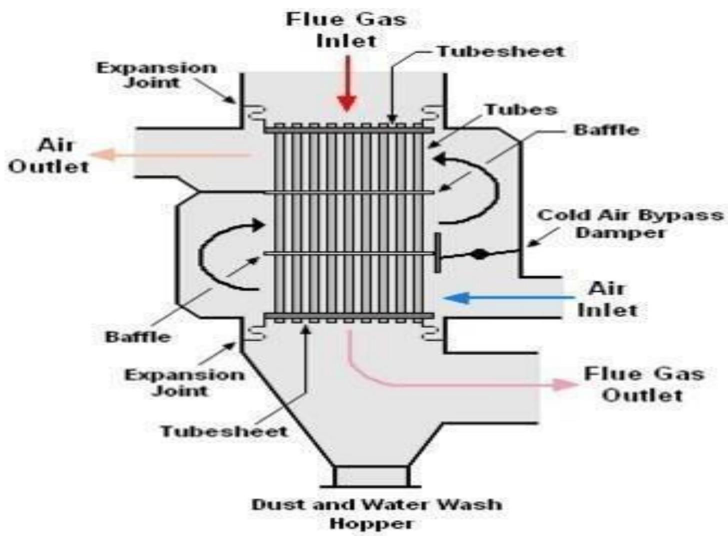


Figure: Air Preheater

STEAM TURBINES

- Steam entering from a small opening attains a very high velocity.
- The velocity attained during expansion depends on the initial and final content of the steam.
- The difference in initial and final heat content represent the heat energy to be converted to kinetic energy.

There are two types of steam turbines:

1) Impluse turbine and 2)Reaction Turbine

Impuse Turbine:

- In this turbine there are alternate rows of moving and fixed blades. The moving blades are mounted on the shaft and fixed blades are fixed to the casing of the turbine.
- A set of fixed nozzle is provided and steam is passed through these nozzles. The in steam due to pressure and internal energy is converted to K.E. The steam comes out of the nozzles with very high velocity and impinges on the rotor blades.
- The direction of steam flow changes without changing its pressure.
- Thus due to the change in momentum the turbine rotor starts rotating.

Reaction Turbine:

- Reaction turbine have no nozzles. These two have alternate rows of moving and fixed blades. The moving blades are mounted on shaft, while fixed blades are fixed in casing of turbine.
- When high pressure steam passes through fixed blades, then steam pressure drops down and velocity of steam increases.
- As steam passes over moving blades, the steam expands and imparts energy,resulting in reduction in pressure and velocity of steam.

Note: Turbines used in thermal power stations are Impuse, Reaction or combined.
Generally multistage turbines are used. H.P steam after doing work in the H.P stage passes over
stage . more workis extracted thereby, with consequent increase in thermal efficiency.

Compounding of steam turbines:

Single stage turbines are of low efficiency.

In compounding, a number of rotors are connected or keyed to the same shaft

Two types of compounding are used: velocity compounding and pressure compounding

Governing of steam turbines:

Governing signifies the process of controlling the volume of steam to meet the load fluctuation.

Figure: Steam Turbines

CONDENSERS

The function of the condenser is to condense the steam exiting the turbine. The condenser helps maintain low pressure at the exhaust.

Two types of condensers are used.

Table: Jet and Surface Condensers

Jet condenser (contact type)	Surface condenser (non-contact type)
Exhaust steam mixes with cooling water.	Steam and water do not mix.
Temperature of the condensate and cooling water is same while leaving the condenser.	Condensate temperature higher than the cooling water temperature at outlet.
Condensate cannot be recovered.	Condensate recovered is fed back to the boiler.
Heat exchanged by direct conduction	Heat transfer through convection.
Low initial cost	High initial cost.
High power required for pumping water.	Condensate is not wasted so pumping power is less.

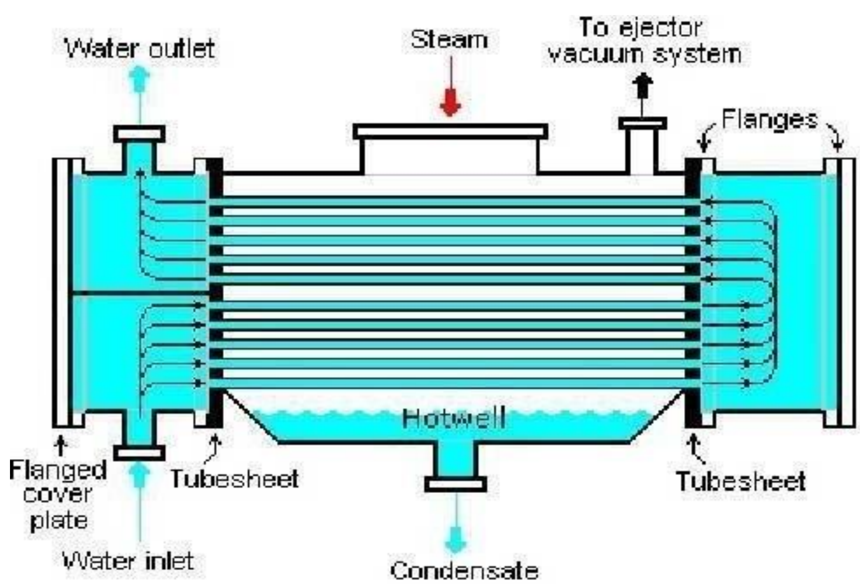
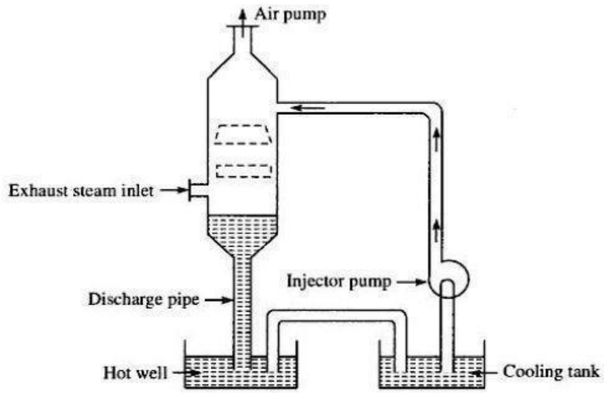


Figure: Surface Condenser



DEAERATORS

- A deaerator is a device that is widely used for the removal of oxygen and other dissolved gases from the feed water to steam-generating boilers.
- In particular, dissolved oxygen in boiler feed waters will cause serious corrosion damage in steam systems by attaching to the walls of metal piping and other metallic equipment and forming oxides (rust).
- There are two basic types of deaerators,
  1. the tray-type an
  2. the spray-type
- The tray-type (also called the cascade-type) includes a vertical domed deaeration section mounted on top of a horizontal cylindrical vessel which serves as the deaerated boiler feedwater storage tank.
- The spray-type consists only of a horizontal (or vertical) cylindrical vessel which serves as both the deaeration section and the boiler feed water storage tank.

COOLING TOWERS AND SPRAY PONDS

- Condensers need huge quantity of water to condense the steam.
- Water is led into the plants by means of circulating water pumps and after passing through the condenser is discharged back into the river.
- If such a source is not available closed cooling water circuit is used where the

warm water coming out of the condenser is cooled and reused.

- In such cases ponds and cooling towers are used where the water loses heat to the atmosphere.

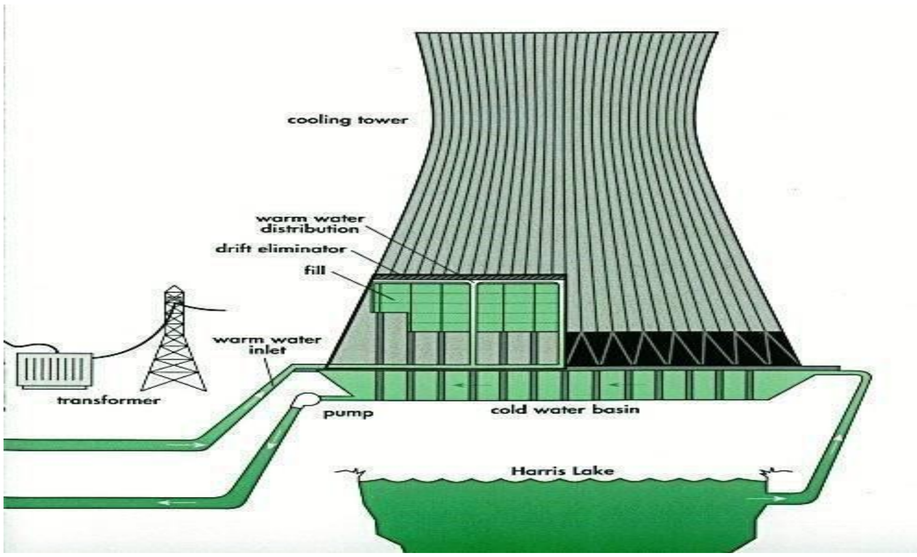
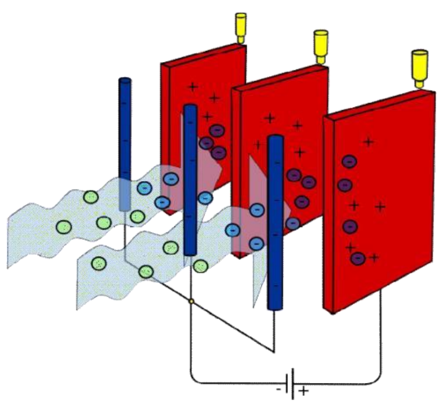


Figure : Cooling Tower

ELECTROSTATIC PRECIPITATORS

- ❖ An electrostatic precipitator (ESP), or electrostatic air cleaner is a particulate collection device that removes particles from a flowing gas (such as air) using the force of an induced electrostatic charge.



- ❖ the basic idea of an ESP:
- ❖ *Charging*
- ❖ *collecting.*
- ❖ *removing*

- Every particle either has or can be given a charge—positive or negative.
- We impart a negative charge to all the particles in a gas stream in ESP.
- Then a grounded plate having a positive charge is set up.
- The negatively charged particle would migrate to the grounded collection plate and be captured.
- The particles would quickly collect on the plate, creating a dust layer. The dust layer would accumulate until we removed it.
- The structural design and operation of the discharge electrodes (rigid-frame, wires or plate) and collection electrodes.
  - tubular type ESP
  - plate type ESP
- The method of charging
  - single-stage ESP
  - two-stage ESP
- The temperature of operation
  - cold-side ESP
  - hot-side ESP
- The method of particle removal from collection surfaces
  - wet ESP
  - Dry ESP

Ash Handling Plant

In Thermal Power Plant's coal is generally used as fuel and hence the ash is produced as the byproduct of Combustion. Ash generated in power plant is about 30-40% of total coal consumption and hence the system is required to handle Ash for its proper utilization or disposal. The steam power plant produces 5000 of tons ash daily (2000MW)

The ash may be

- ❖ Fly Ash (Around 80% is the value of fly ash generated)
- ❖ Bottom ash (Bottom ash is 20% of the ash generated in coal based power stations.

Fly Ash

Ash generated in the ESP which got carried out with the flue gas is generally called Fly ash. It also consists of Air pre heater ash & Economizer ash (it is about 2 % of the total ash content).

Bottom ash

Ash generated below furnace of the steam generator is called the bottom ash.

The operation of ash handling plants is…….

- ❖ Removal of ash from the furnace ash hoppers
- ❖ Transfer of the ash to a fill or storage
- ❖ and disposal of stored ash

The ash may be disposed in the following way…….

- ❑ Waste land site may be reserved for the disposal of ash.
- ❑ Building contractor may utilize it to fill the lowlying area.
- ❑ Deep ponds may be made and ash can be dumped into these ponds to fill them completely
- ❑ When sea born coal is used, barrage may take the ash to sea for disposal into water grave.

The modern ash handling system usually used in large steam power plants are …….

- Belt conveyor system
- Pneumatic system
- Hydraulic system
- Steam jet system

Belt conveyor system

❑ In this system the ash is made to flow through a water seal over the belt conveyor in order to cool it down and then carried out to a dumping site over the belt.

❑ It can deliver 3 tonnes of ash per hour with a speed of 0.3m/minute.

- The life of belt is 5 years. it is used in small power plant

Pneumatic system

- In this system air is employed as a medium to driving the ash through a pipe over along distance.
- This system can handle 5-30 tonnes of ash per hour
- This is used for disposal of fly ash

Hydraulic system

- In this system a stream of water carries ash along with it in a closed channel and disposed it off to the proper site.
- It is of two types high pressure system and low pressure system.

Steam jet system

- This system employs jets of high pressure blowing in the direction of ash travel through a conveying pipe in which ash from the boiler ash hopper is fed.
- It is employed in small and medium size plant
- Steam consumption is 110 kg per tonne of material conveyed.