

Course Material

Name of the Course : **Power Plant Engineering (PPE)**
Name of the Unit : **Thermal Power Plant**
Name of the Topic : Essential of steam power plant equipment -characteristics of steam power plant-layout

- Aim and Objectives: To understand the layout and various equipment of coal based thermal power plant

1. Outcomes: **Upon successful completion, the student should be able to understand the layout, construction and working principle of the components inside a thermal power plant.**

2. Pre-requisites: **To have a basic knowledge of Power Plants**

3. **Pre-Test-MCQ type:**

1. In steam power plant which of the following component needs more maintenance:

- a) Condenser
- b) Boiler
- c) Turbine
- d) Coal carrying system

Ans: b

2. In thermal power plants the condenser used is of:

- a) Surface type
- b) Jet type
- c) Can be both surface type and jet type
- d) None of the above

Ans: a

3. Which of the following equipment is installed in steam power plant to reduce air pollution:

- a) Air filter
- b) HEPA filter
- c) Electro static precipitator

d) All the above can be used

Ans: c

4. In India largest thermal power station is located at

- (a) Kota
- (b) Sarni
- (c) Chandrapur
- (d) Neyveli

Ans: c

5. In a super heater:

- a) Pressure rises and temperature drops
- b) Temperature rises and pressure drops
- c) Temperature rises and pressure remains unchanged
- d) Pressure rises and temperature remains the same

Ans: c

6. Steam turbine works on the principle of:

- a) carnot cycle
- b) brayton cycle
- c) rankine cycle
- d) None of the above

Ans: c

7. The steam power plant efficiency can be improved by:

- a) Using large quantity of water
- b) Burning large quantity of coal
- c) Using high temperature and pressure of steam
- d) Decreasing the load on the plant

Ans: c

8. As the size of the thermal power plant increases, the capital cost per kW of installed capacity:

- a) Increases
- b) Decreases
- c) Remains the same
- d) May increase and decrease

Ans: b

9. Equipment used for pulverizing the coal is:

- a) hopper
- b) Stoker
- c) Ball mill

d) Electro static precipitator

Ans: c

10. The purpose of Spray pond in Thermal power plant is:

a) To deposit the ash coming out of the thermal power plant

b) To cool the water coming out of condensate

c) To remove the dissolved gases in the feed water

d) None of the above

Ans: b

5. Steam Power Plant and its Equipments

- A Steam Power Plant converts the chemical energy of the fossil fuels (coal, oil, gas) or fissile fuels (Uranium, Thorium) into electrical energy.
- Steam is produced in the boiler by utilizing the heat of fuel combustion; thus steam is expanded through the steam turbines. The Steam turbine drives the generator which converts mechanical energy of the turbine into electrical energy.
- Steam Power Plant basically works on Rankine cycle.
- Equipment of a Steam Power Plant:

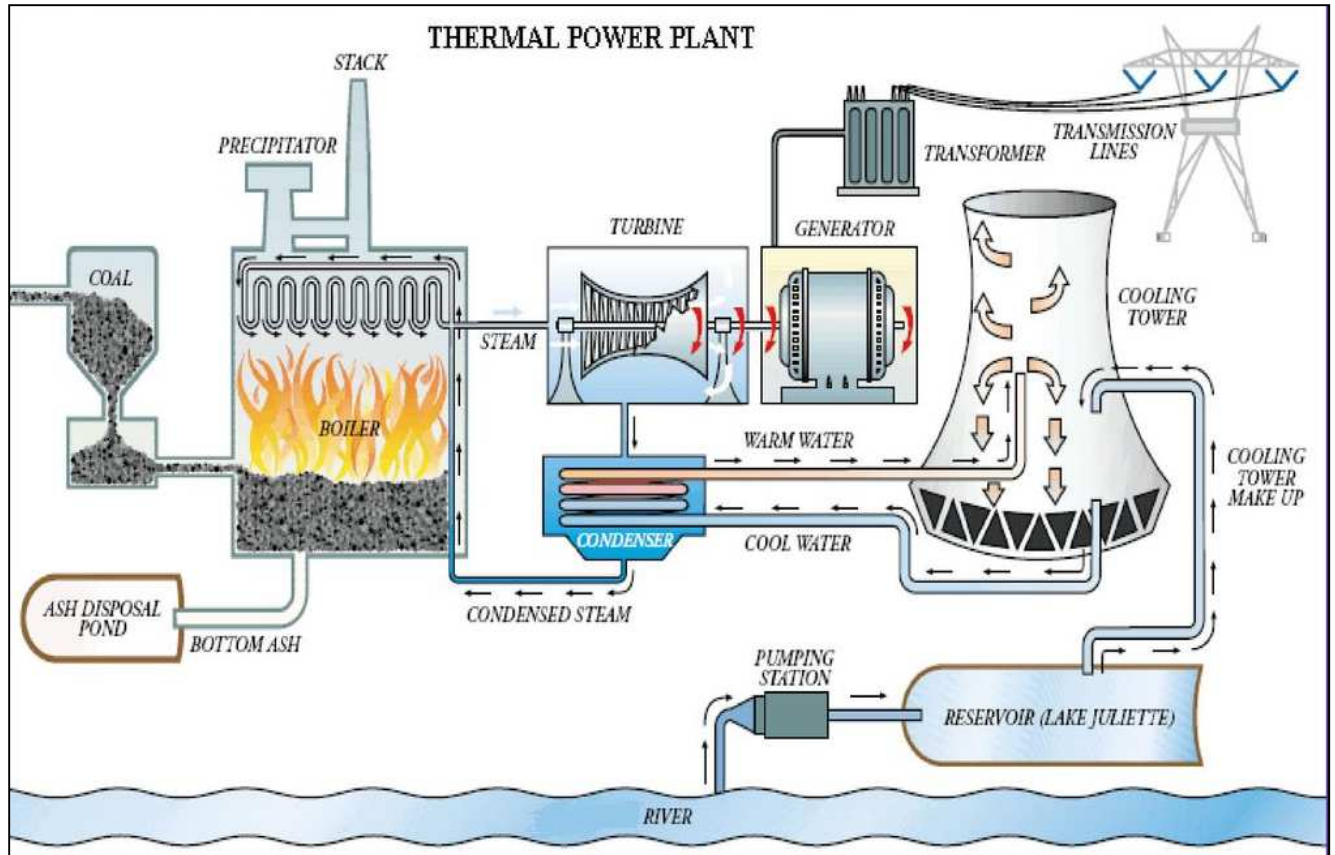
A steam power plant must have the following equipment

1. A furnace for burning the fuel.
2. A steam generator or boiler for steam generation.
3. A power unit likes 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.

Steam Power Plant Layout

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.



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:

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.

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.

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 re-circulated. A line diagram of water and steam circuit is shown separately in figure.

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.

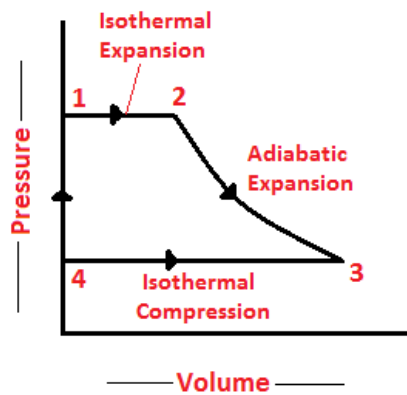
The flue gases from the furnace pass over boiler tubes and super heater tubes. (In boiler, wet steam is generated and in super heater the wet steam is superheated by the flue gases.) Then the flue gases pass through economizer to heat the feed water. After that, it passes through the air pre- heater 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:

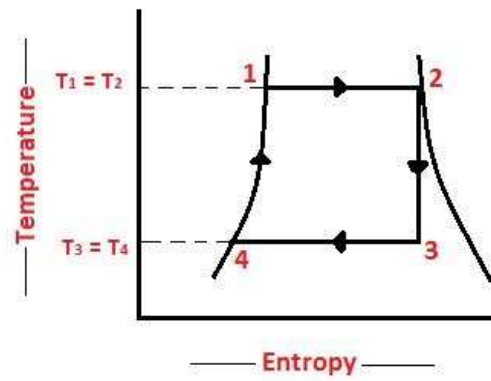
The circuit includes a pump, condenser, cooling tower etc. the exhaust steam from the turbine is condensed in condenser. In the condenser, cold water is circulated to condense the steam into water. The steam is condensed by losing its latent heat to the circulating cold water. Thus the circulating water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

6. Mechanism involved

- From laws of thermodynamics when heat is transferred to water its enthalpy and physical state change as heating takes place its temperature rises and density decreases the vapour formed in this process is called steam which is gaseous state but does not entirely follow the laws of perfect gas
- The Carnot cycle cannot be applied to steam turbine as compression phase does not exist hence a steam power plant works on rankine cycle
- The impracticalities associated with Carnot cycle can be eliminated by superheating the steam in the boiler and condensing it completely in the condenser. This cycle results as the Rankine cycle, which is the ideal cycle for vapour power plants
- The Rankine cycle consists of the following four processes: 1-2 : Isentropic compression in pump (compressors) 2-3 : Constant pressure heat addition in boiler 3-4 : Isentropic expansion in turbine 4-1 : Constant pressure heat rejection in a condenser



P-v Diagram of Rankine Cycle



T-s Diagram of Rankine Cycle

- The cycles encountered in actual devices are difficult to analyze because of the presence of complicating effects, such as friction and the absence of sufficient time for establishment of the equilibrium conditions during the cycle.
- The actual vapour power cycle differs from the ideal Rankine cycle, as a result of irreversibility's in various components. Fluid friction and heat loss to the surroundings are the two common sources of irreversibility's.

- Fluid friction causes pressure drop in the boiler, the condenser and the piping between various components. Also the pressure at the turbine inlet is somewhat lower than that at the boiler exit due to the pressure drop in the connecting pipes. To compensate for these pressure drops, the water must be pumped to a sufficiently higher pressure than the ideal cycle.

7. Merits of Thermal power plants

- The unit capacity of a thermal power plant is more. The cost of unit decreases with the increase in unit capacity.
- Repair and maintenance cost is low when compared with diesel plant.
- Initial cost of the plant is less than nuclear plants.
- Unskilled operators can operate the plant.
- The power generation does not depend on water storage.
- There are no transmission losses since they are located near load centres.

Test after completion

1. For the flue gas flow, tick the correct sequence:
 - a) Boiler-Air preheater- economizer- ID fan- Chimney
 - b) Boiler- ID fan -Air preheater- Economizer- Chimney
 - c) Boiler- Economizer- Air preheater- ID fan- Chimney
 - d) None of the above

Ans: c
2. Economizer is normally employed when boiler pressure exceeds:
 - a) 70 kg/cm²
 - b) 50 kg/cm²
 - c) 30 kg/cm²
 - d) Can be used for all pressures

Ans: a
3. Large size thermal power plants will be:
 - a) peak load plants
 - b) Base load plants

- c) Can be operate either as peak load or base load plants
- d) None of the above

Ans: b

4. Electrostatic precipitator is installed between:

- a) Induced fan and chimney
- b) air preheater and induced fan
- c) Economizer and air preheater
- d) Boiler furnace and economiser

Ans: b

5. For the same draught required, the power of forced draught fan will be __ than the induced draught fan:

- a) Higher
- b) Lower
- c) The same
- d) May be more or less

Ans: b

Conclusion

- More than 65% of India's electricity generation capacity comes from thermal power plants with 85% of the country's thermal power generation being coal-based.
- Thermal Power Plants constitute 75.43% of the total installed captive and non-captive power generation in India.
- No harmful radioactive wastes are produced as in the case of nuclear plant.
- Suitable for the varying load conditions.
- Life of the plant is more (25-30 years) as compared to diesel plant (2-5 years).

Demo Videos

<https://www.youtube.com/watch?v=IdPTuwKEfmA>

References

Thomas C. Elliott, Kao Chen and Robert C. Swanekamp, "Power Plant Engineering", Second Edition, Standard Handbook of Tata McGraw – Hill, 2nd edition, 2012.
G. R. NAGPAL, Power Plant Engineering, Khanna Publishers, Sixteenth edition, 1995

Assignment

1. In a boiler installation the natural draught is produced (a) due to the fact that furnace gases being light go through the chimney giving place to cold air from outside to rush in (b) due to the fact that pressure at the grate due to cold column is higher than the pressure at the chimney base due to hot column (c) due to the fact that at the chimney top the pressure is more than its environmental pressure (d) all of the above
- 2 Rankine cycle efficiency of a good steam power plant may be in the range of (a) 15 to 20 percent (b) 35 to 45 percent (c) 70 to 80 percent (d) 90 to 95 percent
3. It is important the heat the water before feeding to boiler because: a) The dissolved gases which corrodes the boiler are removed b) Thermal stresses arises due to the cold water entering the boiler can be reduced c) Some impurities carried by steam and condensate due to corrosion in boiler and condenser are precipitated outside the boiler d) All the above
4. Economizer of boiler has main function of: a) Heat up the incoming water with excess steam b) Heat up the pulverized fuel by exhaust gases c) Heat up the incoming air by exhaust gases d) Heat up the incoming water by exhaust gases
5. The auxiliary consumption of thermal power plants will be in the range: a) 2-5% of plant power generated b) 8-10% of power generated c) 15-20% of power generated d) 20-25% of power generated