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SUBJECT:POWER STATION ENGINEERING

SUBJECT CODE: TH - 3

COURSE OBJECTIVES:

At the end of the course the students will be able to:

1. Understand the generation of power by utilizing various energy sources.
2. Understand the use of steam, its operation in thermal power stations.
3. Understand the nuclear energy sources and power developed in nuclear power station.
4. Understand the basics of diesel electric power station and hydroelectric power station.
5. Understand the basics of gas turbine power station

STEAM POWER PLANT:

LAYOUT OF STEAM POWER PLANT:

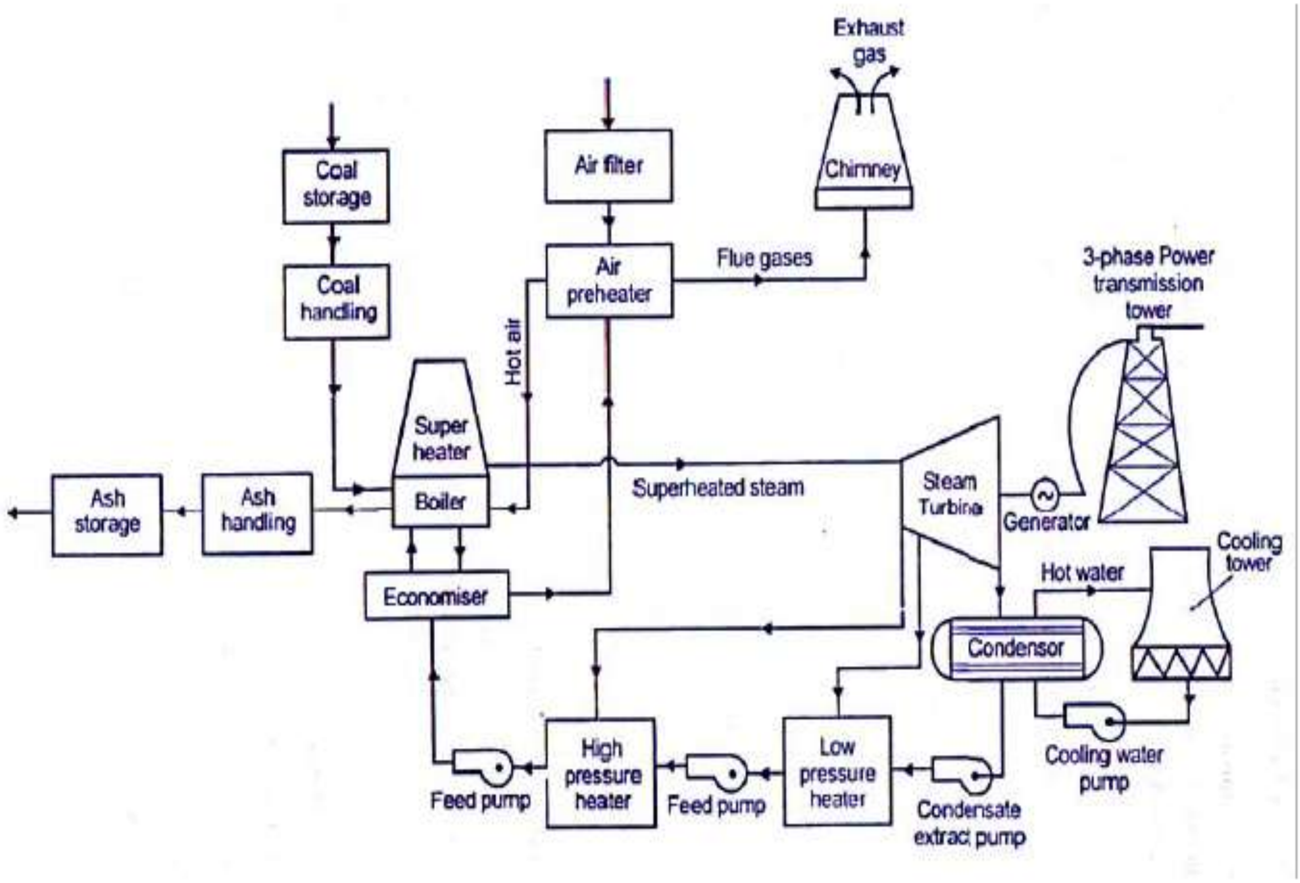
The main circuits thermal power plant layout are,

1. Air and Gas Circuit

2. Feed Water and Steam Circuit.

3. Coal and Ash Circuit

4. Cooling Water Circuit



1.Air and Gas Circuit

Atmospheric air is made to supply into the furnace through the air preheated by the action of a forced draught fan or induced draught fan. The dust from the air is removed before it enters the combustion chamber. The exhaust gases from the combustion chamber enters into super heater, economiser and air pre heater and finally escape into the atmosphere.

2.Feed Water and Steam Circuit

Steam is generated in the boiler and is being supplied to the turbine for power generation. The steam that is expelled by the prime mover in the thermal power plant is then condensed in a condenser. The condensed water is forced through a pump into the feed water heaters where it is heated using the flue gas from the furnace. To make up for the lost steam and water while passing through the various stages,feed water is supplied through external sources like river.

3.Coal and Ash Circuit

In a thermal power plant layout coal is feeding to the boiler from the coal handling for combustion of fuel. The ash that is generated during combustion is collected at the back of the boiler and removed to the ash storage.

4.Cooling Water Circuit

Adequate quantity of water is supplied from a water source like lake or river to cool the steam. After its purification, it is passed through the condenser where the steam is condensed. The water is finally discharged back into the water source after cooling. Cooling water circuit can also be a closed system where the cooled water is sent from the cooling towers by the help of pumps to the economiser.

ADVANTAGES AND DISADVANTAGES OF STEAM POWER PLANTS

Advantages of Steam Power Plants :

1. They can respond to rapidly changing loads without difficulty.
2. A portion of the steam generated can be used as a process steam in different industries.
3. Can be located very conveniently near the load centre.
4. As these plants can be set up near the industry transmission costs are reduced.
5. Steam engines and turbines can work under 25 per cent of overload continuously.
6. Fuel used is cheaper.
7. Less space is required in comparison with that for hydroelectric plants.
8. Cheaper in production cost in comparison with that of diesel power stations.
9. Cheaper in initial cost in comparison with that of diesel power stations.

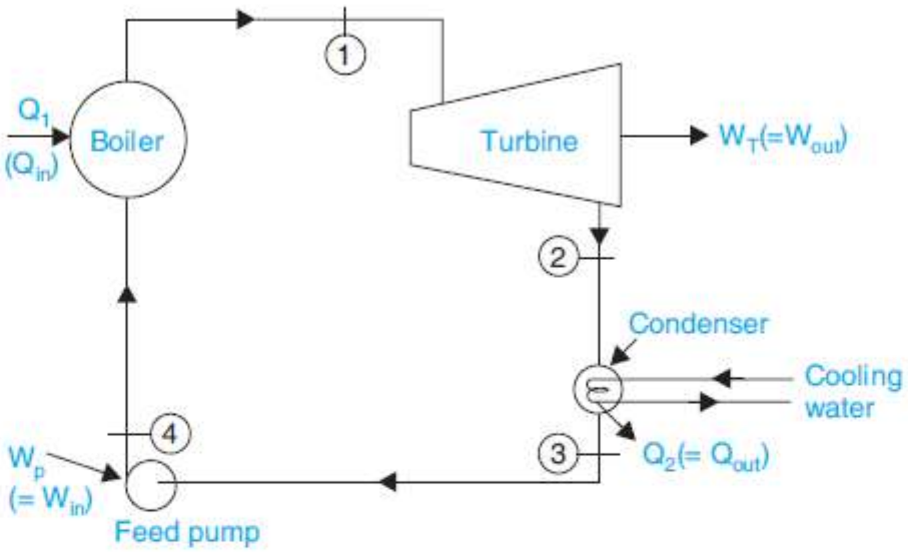
Disadvantages :

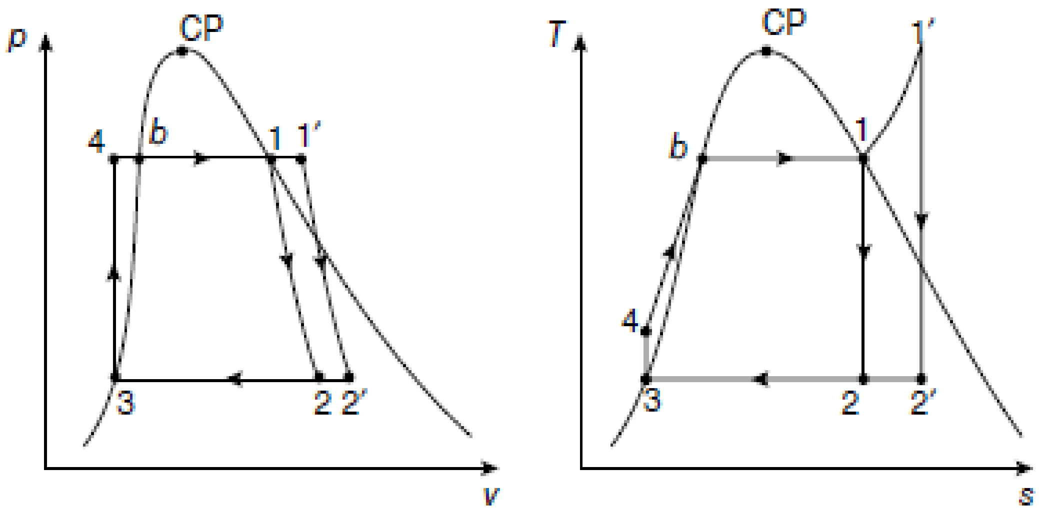
1. Maintenance and operating costs are high.
2. The cost of plant increases with increase in temperature and pressure.
3. Long time required for erection and putting into action.
4. A large quantity of water is required.
5. Great difficulty experienced in coal handling.
6. The plant efficiency decreases rapidly below about 75 per cent load.
7. Presence of troubles due to smoke and heat in the plant.

Rankine Cycle

The fig. below shows a Rankine cycle. In this cycle, feed water is supplied by a feed pump is raised into steam in a boiler. The high-pressure steam is expanded in the turbine, generating work. After expansion, the steam is condensed in a condenser and the cycle repeats. In a real cycle, due to irreversibility, losses are present and the cycle efficiency decreases. The figure below shows a simple Rankine cycle on p–V and T–s diagrams.

Cycle 1–2–3–4–*b*–1 is a saturated Rankine cycle .





Following reversible processes are discussed below.

a. 1–2 , adiabatic reversible expansion through the turbine.

b. 2–3 Heat is rejected in the condenser at constant pressure.

c.3–4 Adiabatic reversible compression.

d. 4–1 Heat is added at constant pressure in the boiler.

Let,

h1 = enthalpy of saturated vapour at 1

$h2$ = enthalpy of steam vapour at 2
$h3 = hf\ 3$ = enthalpy of water at point 3
$h4 = hf\ 4$ = enthalpy of water at point 4
$hb = hf\ b$ = enthalpy of water at point b

Heat added per unit mass at constant pressure process 4–b–1 is,
$qA = h1 - hf\ 4$ kJ/kg saturated vapour cycle
Heat rejected at constant pressure process 2–3
$qR = h2 - hf\ 3$ kJ/kg saturated vapour cycle
Turbine work during the process 1–2
$wT = h1 - h2$ kJ/kg saturated vapour cycle
Pump work during the process 3–4
$wp = hf\ 4 - hf\ 3$ kJ/kg
$= v3\ (p4 - p3)$ kJ/kg

Net work done Net work for saturated vapour cycle
Heat added − Heat rejected $= (h1 - hf\ 4) - (h2 - hf\ 3)$
$= (h1 - h2) - (hf\ 4 - hf\ 3)$ kJ/kg
$= (h1 - h2) - wp$

Thermal efficiency
Thermal efficiency is given by **=** $\frac{\text{Net Work done}}{\text{Heat Supplied}}$

$$= \frac{(h1-h2)-Wp}{h1-hf4}$$

$$= \frac{(h1-h2)}{h1-hf4}$$, Neglecting pump work

The ***work ratio*** is defined as the ratio of net work output to turbine work output.
Work ratio = $\frac{Wnet}{Wp} = \frac{WT-WP}{WT}$

PROBLEM.

A steam turbine receives steam at 15 bar and 350°C and exhausts to the condenser at 0.06 bar. Determine the thermal efficiency of the ideal Rankine cycle operating between these two limits.

Solution.

Pressure of steam at the entry to the steam turbine,
*p*1 = 15 bar, 350°C
Condenser pressure, *p*2 = 0.06 bar
Rankine efficiency :
From steam tables,
At 15 bar, 350°C : h = 3147.5 kJ/kg,
s = 7.102 kJ/kg K
At 0.06 bar : hf = 151.5 kJ/kg,
hfg = 2415.9 kJ/kg
sf = 0.521 kJ/kg K,
sfg = 7.809 kJ/kg K
Since the steam in the turbine expands isentropically,
s1 = s2 = sf2 + x2sfg2
7.102 = 0.521 + x_2 × 7.809

$$x_2 = \frac{(7.102-0.521)}{7.809} = 0.843$$

h1 = 3147.5 kJ/kg,
h2 = hf2 + $x_2 S_{fg2}$
= 151.5 + 0.843 × 2415.9
= 2188.1 kJ/kg

ηRankine $= \frac{(3147.5-2188.1)}{3147.5-151.5}$ = **0.32 or 32%. (Ans.)**

PROBLEM

In a steam turbine steam at 20 bar, 360°C is expanded to 0.08 bar. It then enters a condenser, where it is condensed to saturated liquid water. The pump feeds back the water into the boiler. Assume ideal processes, find per kg of steam the net work and the cycle efficiency.

Solution.

Boiler pressure, p_1 = 20 bar (360°C)

Condenser pressure, p_2 = 0.08 bar

From steam tables,

At 20 bar, 360°C :

h_1= 3159.3 kJ/kg

s_1= 6.9917 kJ/kg K

At 0.08 bar :

h_3 = 173.88 kJ/kg,

s_3 = 0.5926 kJ/kg K

hfg2 = 2403.1 kJ/kg,

S_2 = 8.2287 kJ/kg K

V_{f2} = 0.001008 m3/kg

S_{fg2} = 7.6361 kJ/kg K

Now,

$s_1 = s_2$

6.9917 = $s_3 + x_2\ S_{fg2}$

= 0.5926 + x_2 × 7.6361

$$x_2 = \frac{(6.9917-0.5926)}{7.6371} = 0.838$$

h_2 = 173.88 + 0.838 × 2403.1

= 2187.68 kJ/kg.

Wpump = 0.00108 (m3/kg) × (20 – 0.08) × 100 kN/m2

= 2.008 kJ/kg

Wturbine = h1 – h2 = 3153.9 – 2187.68

= 971.62 kJ/kg

∴ Wnet = 971.62 – 2.008

= **888.94 kJ/kg. (Ans.)**

Q1 = h1 – hf4

= 3159.3 – 175.89
= 2983.41 kJ/kg

Cycle efficiency

ηRankine = $\frac{888.94}{2983.41}$ = **0.325 or 32.5%. (Ans.)**

BOILER ACCESSORIES:

Economiser

Economiser is a device in which the waste heat of the flue gases is utilised for heating the feed water.

Types of Economiser

1. Independent type.
2. Integral type.

1.Independent type.

It is installed in chamber apart from the boiler setting. The chamber is situated at the passage of the flow of the flue gases from the boiler or boiler to the chimney.

2.Integral type.

It is a part of the boiler heating surface and is installed within the boiler setting. It is employed for boilers of medium pressure range up to about 25 bar. It Consists of a large number of vertical cast iron pipes which are connected with two horizontal pipes, one at the top and the other at the bottom. The flue gases move around the pipes in the direction opposite to the flow of water. Consequently, heat transfer through the surfaces of the pipes takes place and water is thereby heated. A blow-off cock is provided at the back of end vertical pipes to remove sediments deposited in the bottom boxes. The soot of the flue gases which gets deposited on the pipes reduces the efficiency of the economiser. To prevent the soot deposit, the scrapers move up and down to keep the external surface of the pipe clean for better heat transfer.

Air Preheater

The function of the air preheater is to increase the temperature of air before it enters the furnace. It is generally placed after the economiser. So the flue gases pass through the economiser and then to the air preheater.

An air preheater consists of plates or tubes with hot gases on one side and air on the other. It preheats the air to be supplied to the furnace. Preheated air accelerates the combustion and facilitates the burning of coal.

Degree of preheating depends on :
1. Type of fuel
2.Type of fuel burning equipment
3. Rating at which the boiler and furnace are operated.
There are *three* types of air preheaters :
1. Tubular type
2. Plate type
3. Storage type.
In the tubular type air preheater, after leaving the boiler or economiser the gaseous products of combustion travel through the inside of the tubes of air preheater in a direction opposite to that of air travel and transfer some of their heat to the air to be supplied to the furnace. Thus the air gets initially heated before being supplied to the furnace. The gases reverse their direction near the bottom of the air heater, and a soot hopper is fitted to the bottom of air heater casing to collect soot.
In the plate type air preheater the air absorbs heat from the hot gases being swept through the heater at high velocity on the opposite side of a plate.

Superheater

The function of a superheater is to increase the temperature of the steam above its saturation point. The superheater is very important accessory of a boiler and can be used both on fire-tube and water-tube boilers. The small boilers are not commonly provided with a superheater.
Superheated steam has the following advantages :
(i) Steam consumption of the engine or turbine is reduced.
(ii) Losses due to condensation in the cylinders and the steam pipes are reduced.
(iii) Erosion of turbine blade is eliminated.
(iv) Efficiency of the steam plant is increased.
Superheaters are located in the path of the furnace gases so that heat is recovered by the superheater from the hot gases.
There are two types of superheaters :
1. Convective superheater
2. Radiant superheater.
Convective superheater makes use of heat in flue gases whereas a radiant superheater is placed in the furnace and wall tubes receives heat from the burning fuel through radiant process. The radiant type of superheater is generally used where a high amount of superheat temperature is required.
Sugden’s superheater installed in a Lancashire boiler. It consists of two steel headers to which are attached solid drawn ‘U’ tubes of steel. These tubes are arranged in groups of four and one pair of the headers generally carries ten of these groups or total of forty tubes.
The steam from the boiler enters and leaves the headers.

Definition and Classification of Draught

The small pressure difference which causes a flow of gas to take place is termed as a **draught.** The function of the draught, in case of a boiler, is to force air to the fire and to carry away the gaseous products of combustion. In a boiler furnace proper combustion takes place only when sufficient quantity of air is supplied to the burning fuel.