EEE 411
Power Station Engineering

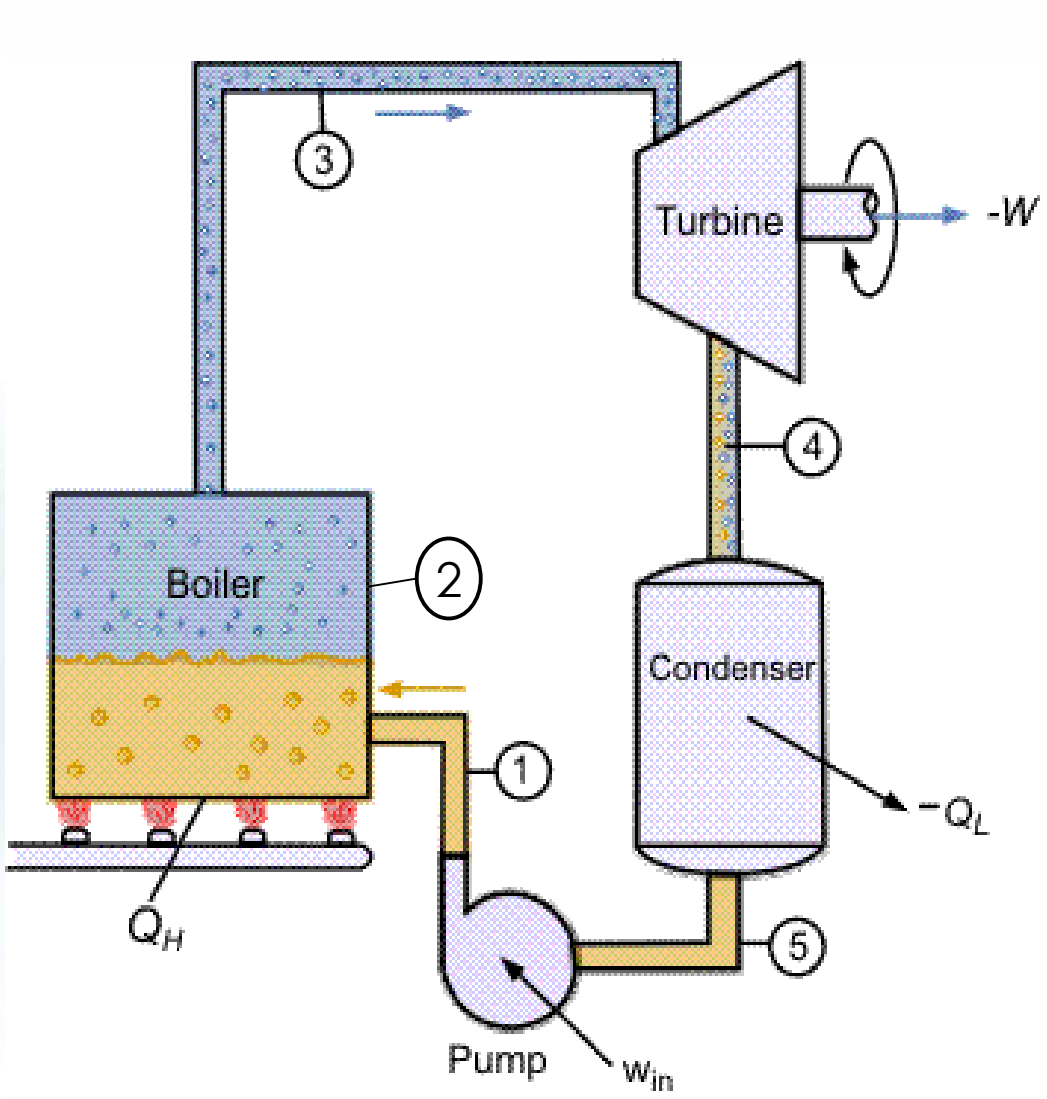
STEAM POWER PLANT

Steam Power Plant

- A generating station which converts heat energy of coal combustion into electrical energy is known as a steam power station.
- Heat energy converts to Mechanical energy first
- Mechanical energy converts to Electrical energy
- This plant is considered as Thermal Power Plant
- It basically works on the **Rankine Cycle.**

Source: Mehta chap 2

Simple Rankine Cycle



- **(1-2-3)**High pressure liquid enters the boiler from the feed pump. Steam is produced in the boiler by utilizing the heat of coal combustion.
- **(3-4)**The vapor is expanded in the turbine(prime mover) , thus producing work. This work rotates turbine and converts the mechanical energy to electrical output. Here Pressure and temperature decreases.
- **(4-5)** The exhaust leaving the turbine (4) is condensed at low pressure, using cooling water.
- **(5-1)**The pressure of the condensate is raised in the feed pump.

Components

1.Coal and ash handling plant.

•Coal is delivered to the **coal handling plant** where it is pulverized *(i.e., crushed into small pieces) in order* to increase its surface exposure. Thus, small quantity can produce larger amount of heat.

- The pulverized coal is fed to the boiler **by belt conveyors.**
- The coal is burnt in the **boiler.**
- The ash produced after the complete combustion of coal is removed to the **ash handling plant** delivered to the **ash storage plant** for disposal.
- The removal of the ash from the boiler furnace is necessary for proper burning of coal.

Components

2. Steam generating plant.

I. Boiler

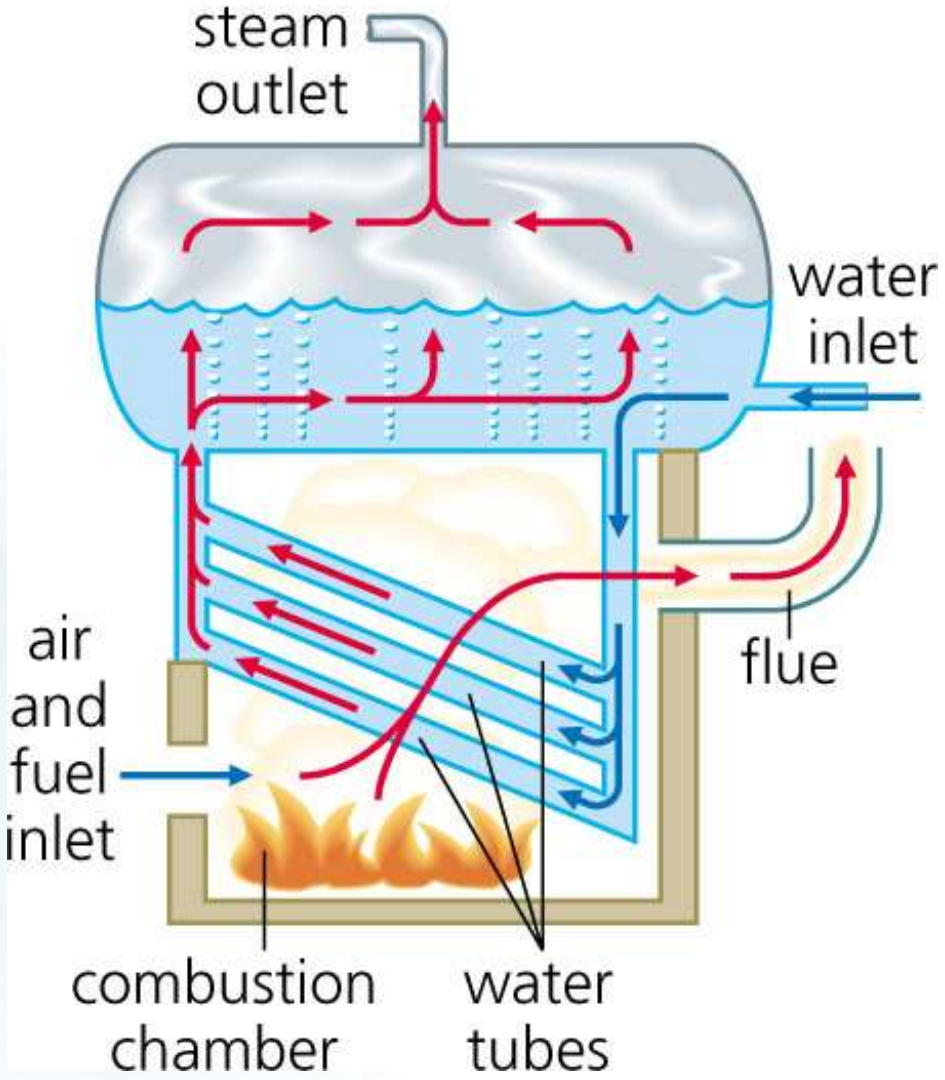
II. Superheater

III. Economizer

IV. Forced Draught Fans

V. Air preheater

Components



I. Boiler:

- Converts water into steam at high temperature and pressure
- Heat of combustion of coal is used for heating
- Besides steam, some amount of flue gases and ashes also produced

Components

II. **Superheater:** Superheated steam is a steam at a temperature higher than its vaporization (boiling) point. Steam temperature can be decreased without changing its states.

- steam produced in the boiler is wet and is passed through a **superheater** where it is dried and superheated by the **flue gases** on their way to chimney

-two advantages:

- ❑ The overall efficiency is increased
- ❑ Too much condensation in the last stages of turbine (which would cause blade corrosion) is avoided

-superheated steam fed into the steam turbine.

Components

iii. Economizer

-The feed water is fed to the economizer before supplying to the boiler

-economizer extracts a part of heat of flue gases to increase the feed water temperature.

iv. Forced Draught Fan

draws air from the atmosphere and passes to air preheater.

v. Air preheater

An air preheater increases the temperature of the air supplied for coal burning by deriving heat from flue gases.

Components

3. Steam Turbine

The heat energy of steam when passing over the blades of turbine is converted into mechanical energy.

4. Alternator

-Steam turbine is coupled to an alternator

-The alternator converts mechanical energy of turbine into electrical energy

5. Cooling arrangement

-To improve the efficiency of the plant, the steam exhausted from the turbine is condensed by means of a condenser

Components

5. Cooling arrangement

-Cooling towers used when scarcity of water prevails

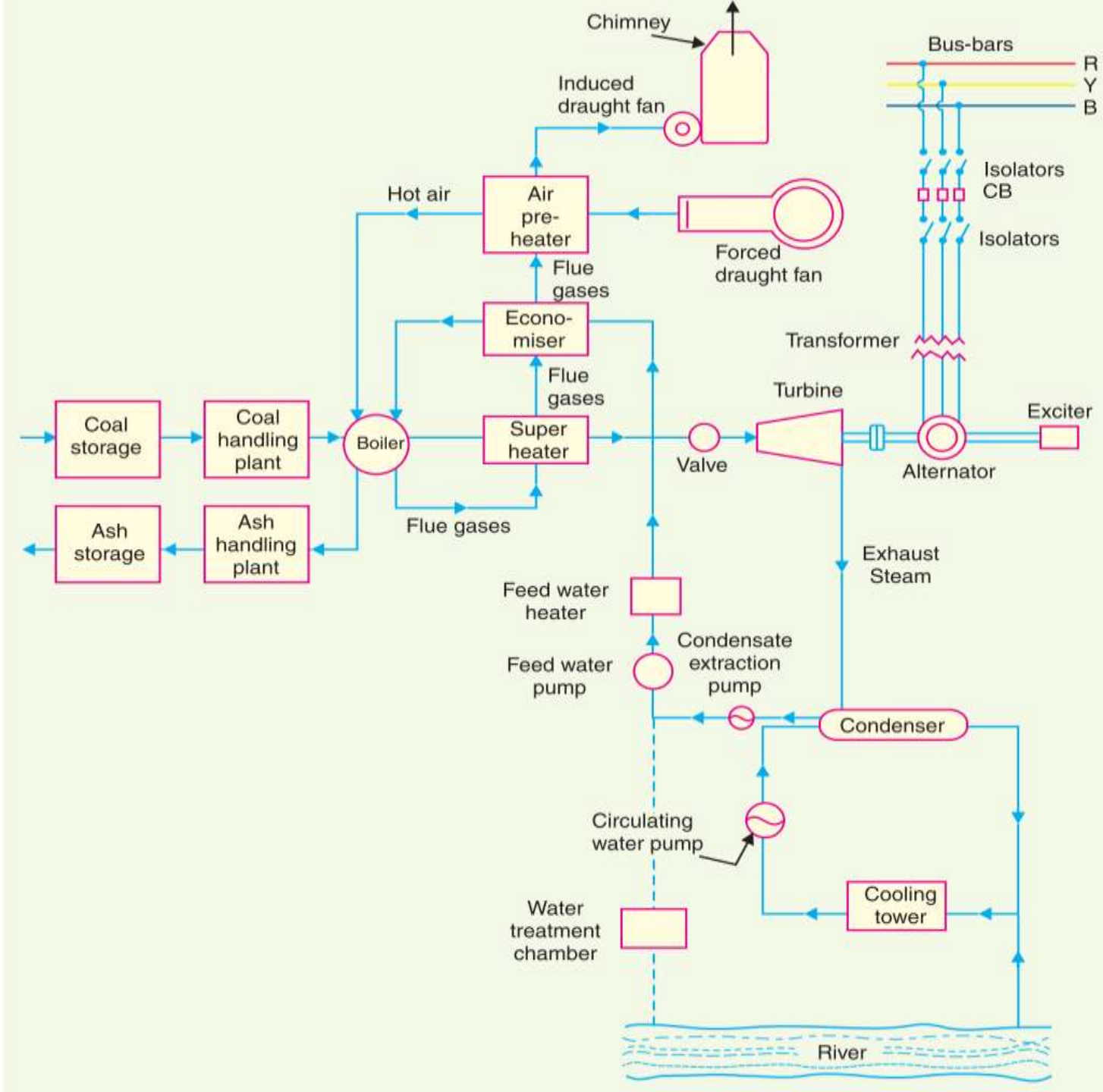
-Condensate water pump is used to pump the feed water from the condenser.

6. Boiler Feed Pump(BFP)

-High capacity induction motor is used to pump the condensate water to economizer.

-BFP highest power consumer. It consumes power from this plant.

7.Induced Draught Fan and Chimney: This fan draws flue gas from boiler to Chimney. Chimney then emits flue gas.


Chimney
Induced draught fan
Bus-bars
R
Y
B
Isolators
CB
Isolators
Hot air
Air pre-heater
Forced draught fan
Flue gases
Econo-miser
Transformer
Flue gases
Turbine
Exciter
Coal storage
Coal handling plant
Boiler
Super heater
Valve
Alternator
Ash storage
Ash handling plant
Flue gases
Exhaust Steam
Feed water heater
Condensate extraction pump
Feed water pump
Condenser
Circulating water pump
Cooling tower
Water treatment chamber
River

Operation

- **Boiler** produces steam which goes to the **superheater**. It also exhausts flue gases**. Induced draught fan** draws this flue gases to the **chimney** through the **superheater, economizer** and **air preheater** . **Chimney** emits the gas. Boiler emits ash to the **ash handling plant** also.
- Steam is produced by heating the water. Heat of combustion of the coal is used in this purpose.
- For combustion, Air is needed. **Forced draught fan** draws air from the atmosphere and passes it to the **air preheater.** In **air preheater**, Flue gas exchanges heat with the new fresh air.
- Steam produced in the **boiler** is superheated in the **superheater**.
- Superheated steam goes to **the steam turbine** and converts heat energy to the mechanical energy
- **The Turbine** converts the mechanical energy to the electrical energy with the help of coupled **alternator**.
- To reduce the costs, used steam then condensed in the **condenser** and passes to the **economizer** through the **condensate water pump** and **boiler feeder pump**.
- **Economizer** increases the feed water temperature

Electrical Equipments

i. **Alternators:**

-Each alternator is coupled to a steam turbine and converts mechanical energy of the turbine into electrical energy

-excitation is provided by means of main and pilot exciters directly coupled to the alternator shaft.

ii. **Transformers:**

-main step-up transformers which step-up the generation voltage for transmission of power of the turbine into electrical energy

-station transformers which are used for general service (*e.g., lighting) in the power* station.

Choice of Site for Steam Power Plant

- ✓***Supply of fuel*** : power station Should be near to the fuel source to minimize the transportation cost.
- ✓***Availability of water***
- ✓***Transportation facilities:*** adequate transportation facilities must exist
- ✓***Cost and type of land:*** The land should be cheap and extendable
- ✓***Nearness to load centers:*** In order to reduce the transmission cost
- ✓***Distance from populated area***: As coal burning is not environment friendly, distance from populated area is needed

Advantages

(*i*) The fuel (*i.e.,* coal) used is quite cheap.
(*ii*) Less initial cost as compared to other generating stations.
(*iii*) It can be installed at any place irrespective of the existence of coal. The coal can be transported to the site of the plant by rail or road.
(*iv*) It requires less space as compared to the hydroelectric power station.
(*v*) The cost of generation is lesser than that of the diesel power station.

Disadvantages

(i) It pollutes the atmosphere due to the production of large amount of smoke and fumes.

(ii) It is costlier in running cost as compared to hydroelectric plant.

Efficiency

The overall efficiency of a steam power station is quite low (about 29%) due to two reasons mainly:

Firstly, a huge amount of heat is lost in the condenser.
Secondly, heat losses occur at various stages of the plant

$$\text{Thermal efficiency, } \eta_{thermal} = \frac{\text{Heat equivalent of mech. energy transmitted to turbine shaft}}{\text{Heat of coal combustion}}$$

$$\text{Overall efficiency, } \eta_{overall} = \frac{\text{Heat equivalent of electrical ouput}}{\text{Heat of combustion of coal}}$$

$$\text{Overall efficiency} = \text{Thermal efficiency} \times \text{Electrical efficiency}$$

Mathematical Problems

Example 2.1. *A steam power station has an overall efficiency of 20% and 0·6 kg of coal is burnt per kWh of electrical energy generated. Calculate the calorific value of fuel.*

Example 2.3. *A steam power station spends Rs. 30 lakhs per annum for coal used in the station. The coal has a calorific value of 5000 kcal/kg and costs Rs. 300 per ton. If the station has thermal efficiency of 33% and electrical efficiency of 90%, find the average load on the station.*

Example 2.5. *A 100 MW steam station uses coal of calorific value 6400 kcal/kg. Thermal efficiency of the station is 30% and electrical efficiency is 92%. Calculate the coal consumption per hour when the station is delivering its full rated output.*