

Chapter – 2

High Pressure Boilers

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Purpose of Boilers

- For generating power in steam engines or steam turbines.
- In textile industries for sizing and bleaching.
- For heating the buildings in cold weather and for producing hot water for hot water supply.
- In the Process industry like sugar, Fertilizers, Paper.
- Marine applications.
- Locomotives (it is now a day obsolete).

Boiler Classification

□ The boilers are classified based on the various criteria :

- Based on the contents of fluid :- - Fire tube Boilers - Water Tube Boilers
- Based on applications:- - Utility Boilers - Industrial Boilers - Marine Boilers
- Locomotive Boilers
- Based on Axis :- - Horizontal Boilers - Vertical Boilers
- Based on the fuel :- - Coal - Wood - Gas - Diesel
- Based on the Pressure:- - High Pressure Boilers ($P > 80$ bar). - Medium Pressure Boilers ($30 < P < 80$ bar). - Low Pressure Boilers ($P < 30$ bar).
- Based on Circulation of Water:- - Natural Circulation - Forced Circulation

Why the High Pressure Boiler ?

- Where 30 bar pressure & steam rate of 30 tones/hour is required the fire tube boilers are preferred due to lower cost.
- In the power plant it is necessary to produce the steam at high pressure , high rate and high efficiency.
- For the steam of 30 bar pressure & steam rate of 30 tones/hour is required then the water tube boilers are preferred.
- Modern high pressure boilers are generate stem at the rate of 30 to 650 tones/hour and pressure up to 225 bar and temp. of around 5500° C.

Advantages of High pressure Boilers

- Due to forced circulation of water, evaporative capacity of the boiler is increased and size of drum is reduced.
- Due to high velocity of water, chances of scale formation is reduced.
- Due to uniform heating there is less chances of overheating.
- High Temp. and Pressure increases the plant efficiency.
- The steam can be raised quickly to meet the variable load.
- It is using modified draught system which leads to reduction in the pollution.

Different High Pressure Boilers

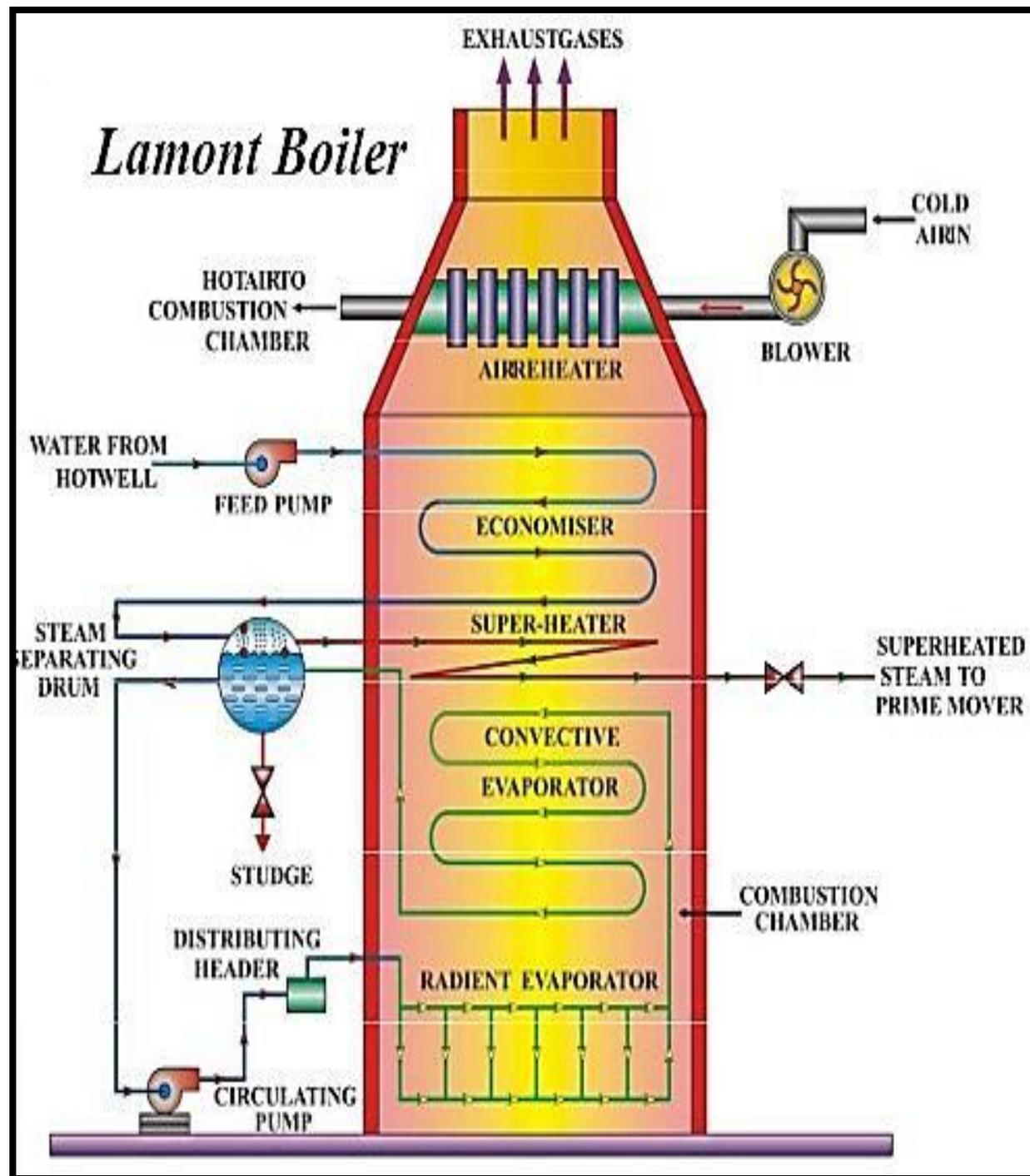
- La-Mont Boiler
- Benson Boiler
- Velox Boiler
- Loffler Boiler
- Schmidt-Hartmann Boiler
- Supercritical Boiler
- Supercharged Boiler
- Fluidized bed combustion Boiler

Specifications:

- Pressure 120 bar.
- Temperature up to 5000°C or above.
- Steam production rate: 45 to 50 tones/hour.

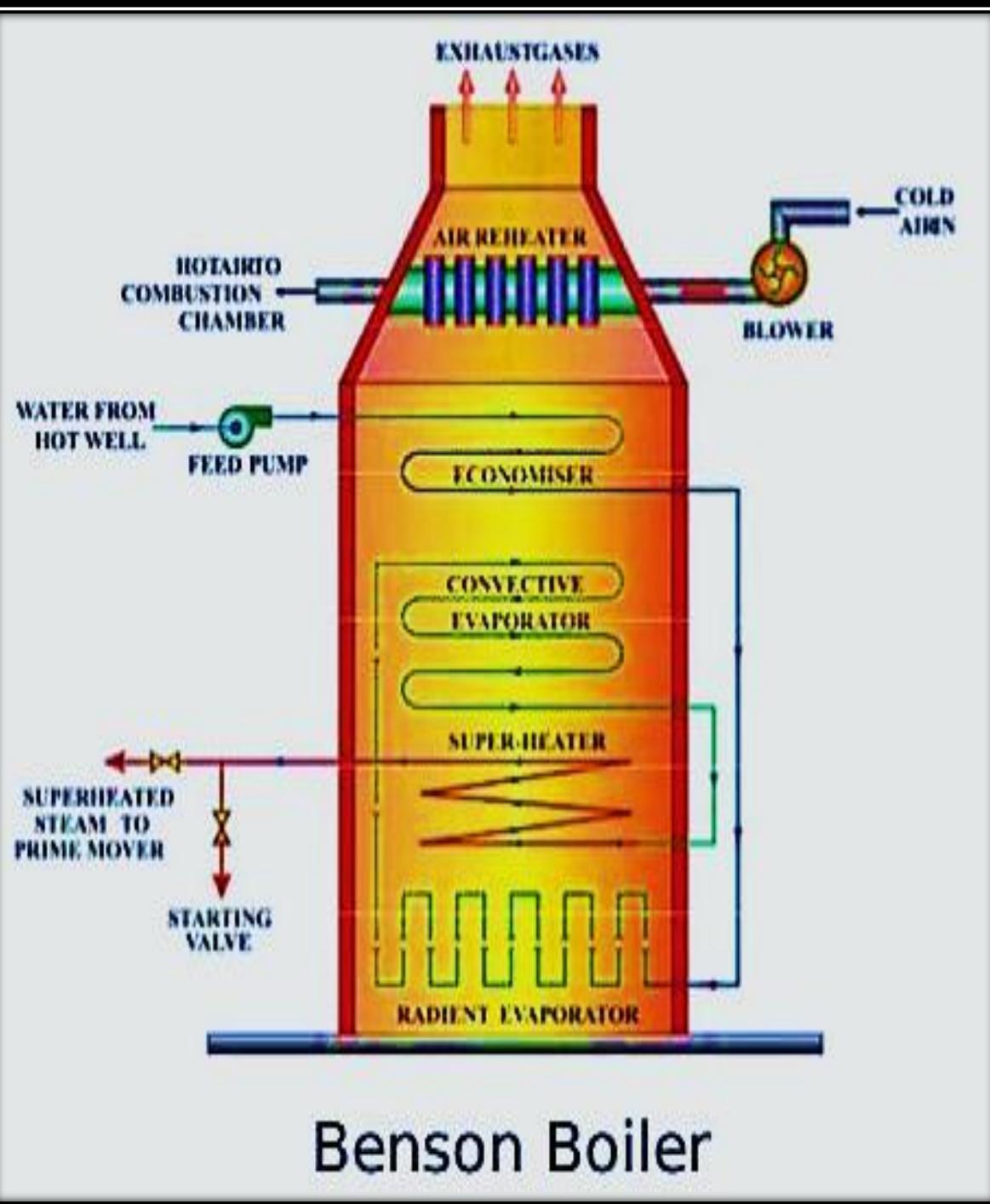
Difficulties:

- The deposition of salt and sediments on the inner surfaces of the water tubes, which reduces the heat transfer rate.
- There also formation of bubbling at the inner surfaces of water tubes.



Specifications:

- It was discovered based on the argument of “If the pressure of boiler is raised to the critical pressure of (225 bar), the steam and water have same density .”
- So, The danger of bubble formation can be easily eliminate.
- Temperature high up to 6500 C.
- Pressure 225 bar.
- Steam production rate : 150 tones/hour.

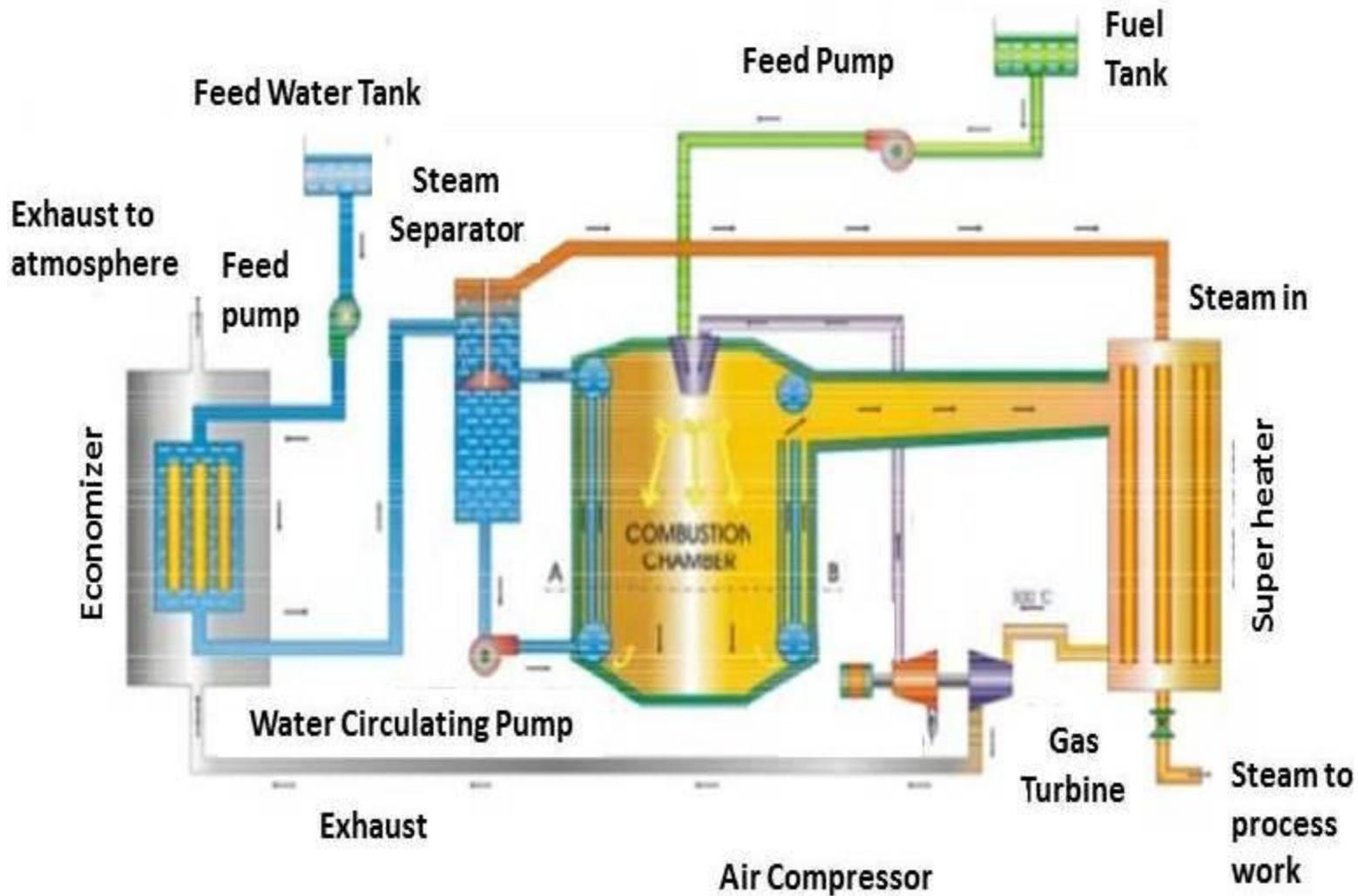


Advantages:

- It does not require drum it leads to the overall weight up to 20% and also reduction in cost also.
- At the overload it can be operated economically by changing pressure and temperature.
- There is no problem of bubbling.
- High steam generation rate. So, used for steam power plant.

Disadvantages:

- Salt deposition.
- Sediment on the inner surface of tube.
- Danger of over heating.



Velox Boiler

➤ Working:

- The air is compressed by air compressor driven by gas turbine driven.
- This compressed air passes from the combustion chamber, where more heat release by the fuel which increase the velocity of the flue gases up to sound velocity.
- From the bottom of combustion chamber, this flue gases pass from the fire tubes. These fire tubes surrounded by the evaporator water tubes.
- The water from the economizer passes from the evaporator tube force by a circulating pump.
- This water passes 15 – 20 time from the evaporator tube at very high speed. Due to this high speed circulation, heat is transfer from the gases to the water at very high rate.

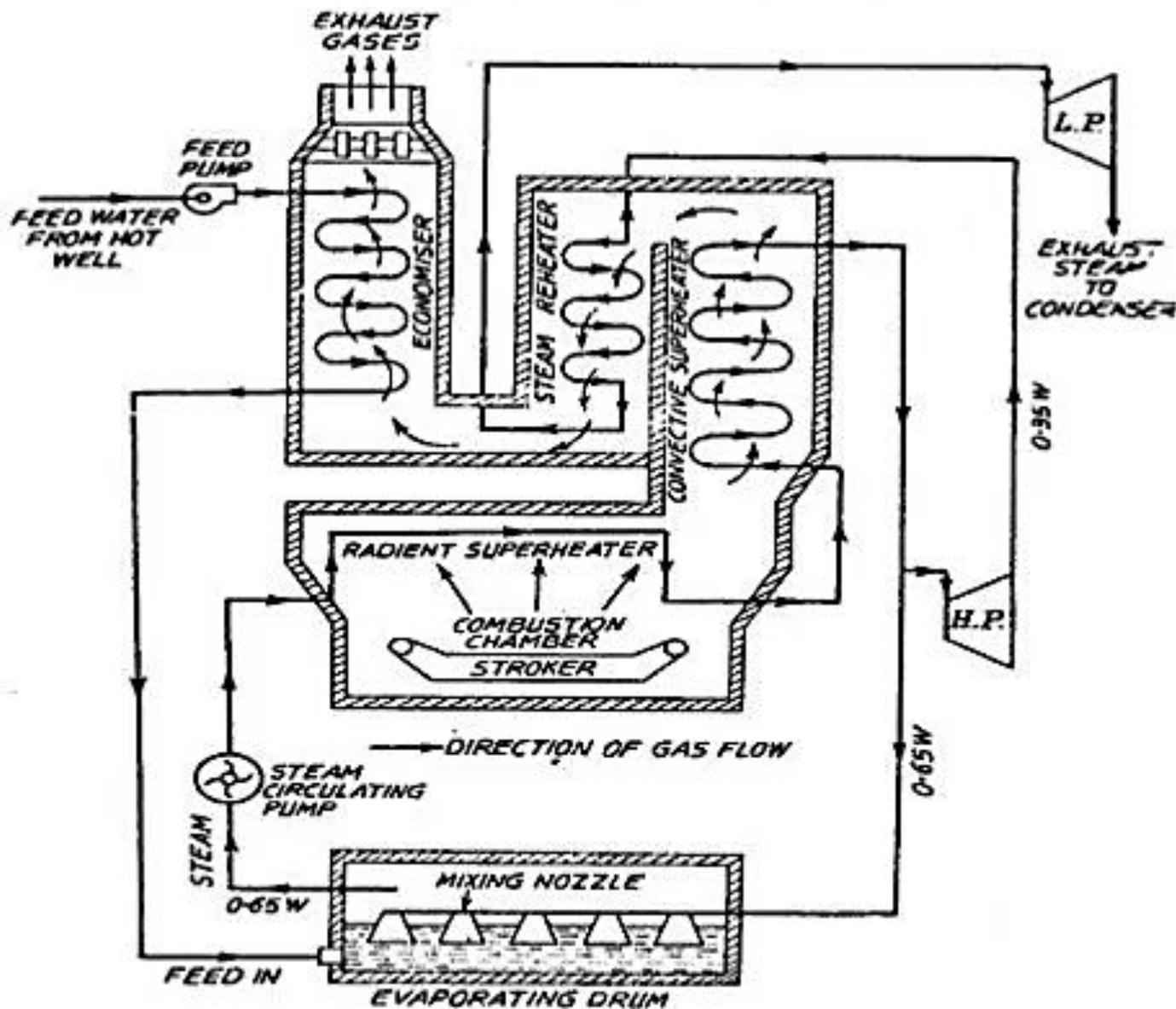
➤ Working:

- The mixture of water and steam is formed which further passes from the water and steam separator.
- The steam from the steam separator passes to the super heater and further for process work.
- The remaining water in the steam separator again passes from the evaporator tube.
- The flue gases from the fire tubes send to the super heater tubes, where it increases the steam temperature.
- The gas from the super heater sends to the turbine where it rotates the gas turbine and then passes from the economizer.

➤ Advantages:

- 1. This boiler has high heat transfer rate.
- 2. It has great flexibility.
- 3. it is compact in design.
- 4. It is easy to control. It is fully automatic.
- 5. It has great thermal efficiency of about 90 – 95%.

LOEFFLER BOILER



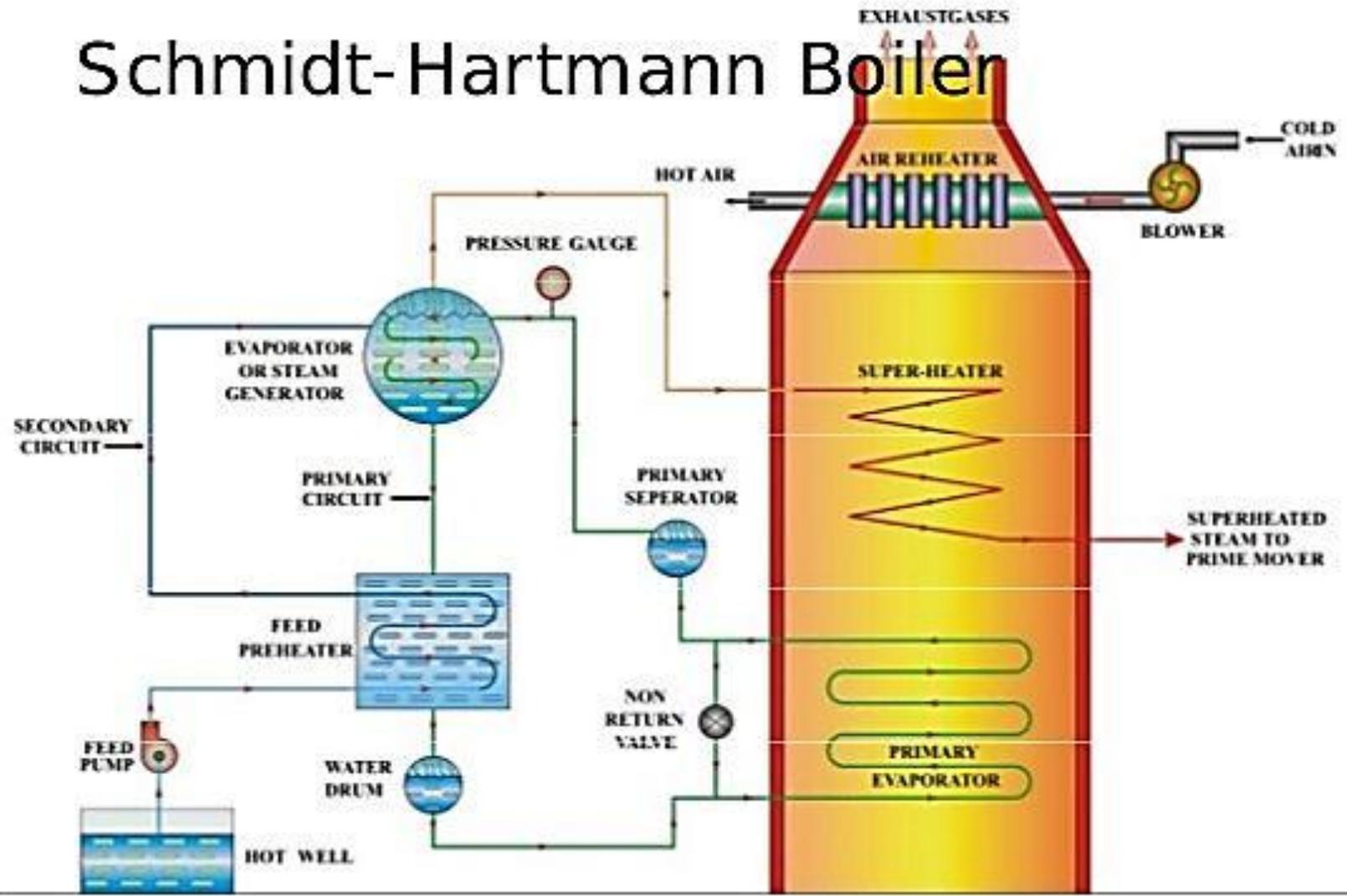
Specification:

- Forced circulation.
- Pressure 100 bar.
- Steam production rate : 100 tones/hour.

Working:

- The steam circulating pump draws saturated steam from evaporative drum.
- The steam passes through radiant and convective super heater.

Schmidt-Hartmann Boiler



- The most recent method to produce economical electric power is by the use of supercritical boiler in the power plant.
- In the supercritical boiler working under the pressure above critical pressure (221.2 bar), so the enthalpy of evaporation is becomes zero. and at the temperature of 3740 C. The problems of bubbling is solved.
- The once through boiler is only type suited to supercritical boiler.

➤ **Advantages:**

- Heat transfer rates are very high.
- There is no drum, so it weight is reduced.
- There is no two phase mixture. So, there is erosion and corrosion is minimized.

➤ **Disadvantages :**

- The high pressure and temperature restrict the use of it.
- The impurities remains in tubes after evaporation of water and blocks the flow passages.

Super Critical Boilers

- The term "supercritical" refers to main steam operating conditions, being above the critical pressure of water (221.2 bar).
- At critical pressure latent heat of vaporization becomes zero.
- It means saturated liquid is directly converted into superheated steam.
- The separator vessel cannot be used in these boilers. These boilers are known as "drum less boilers".
- It works between 220 bar to 300 bar pressure and 374° C to 650 °C.

Super Critical Boilers

- A sub critical boiler usually consists of preheater, i.e. economizer, evaporator, and super heater.
- But a super critical boiler uses economizer and super heater only.
- Presently 250 bar pressure and 813 K temperature are used for unit size above 500MW capacity.
- ***Advantages:***
 - The rate of heat transfer is more.
 - The pressure is more stable.
 - Higher thermal efficiency.
 - More flexibility to load fluctuations.

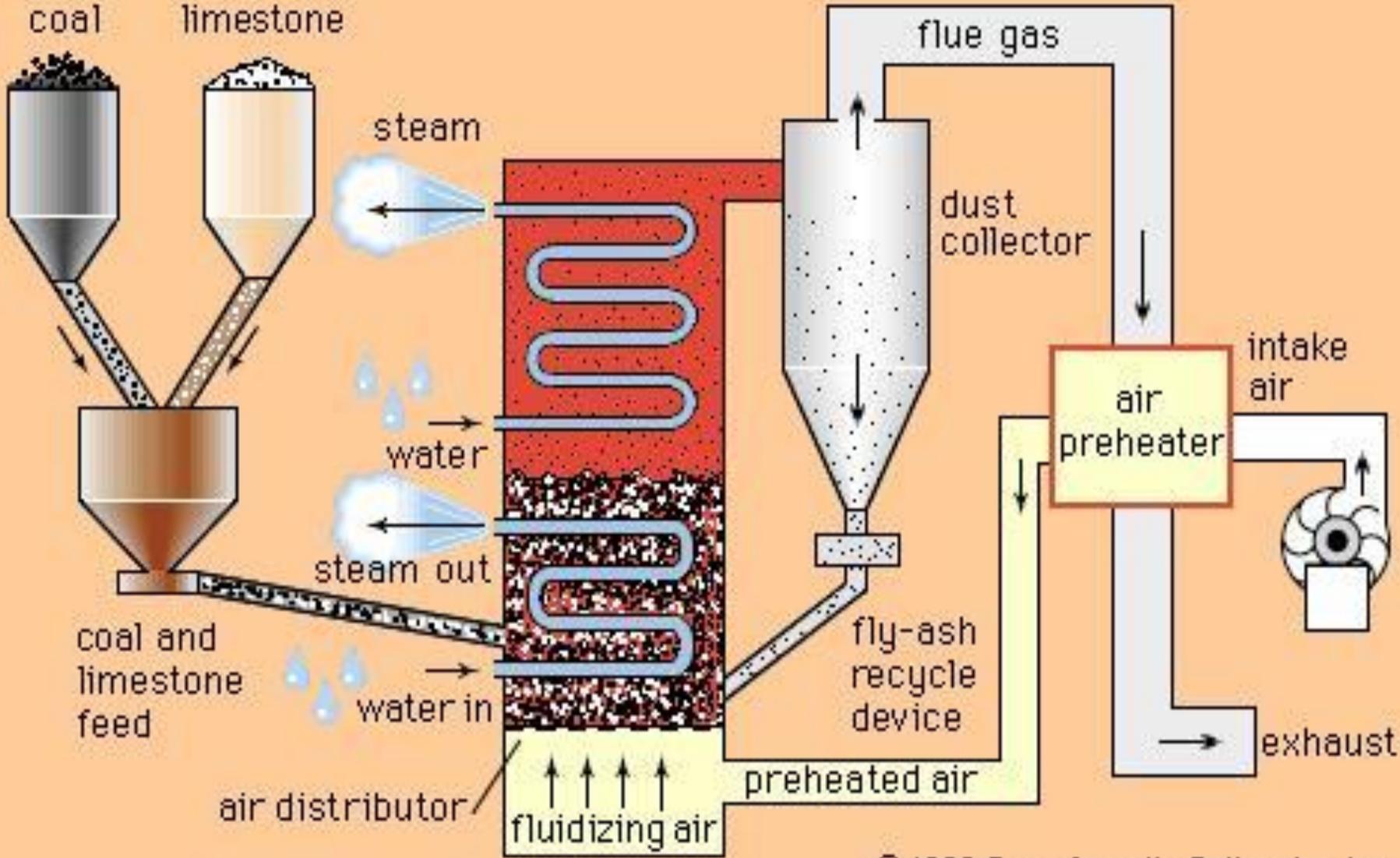
Super Charged Boilers

- The compressed air is supplied to combustion chamber.
- The exhaust gases from the combustion chamber are used to run the gas turbine as they are exhausted to high pressure.
- The gas turbine runs the air compressor to supply the compressed air to the combustion chamber.
- ***Advantages:***
 - Rapid start of the boiler is possible.
 - Power of gas turbine is partly used to run other components.
 - Heat transfer surface required is small compared to other conventional boilers.

Fluidized bed Combustion

- In 1921, the first fluidized bed being used successfully in Germany.
- Fluidized bed combustion has emerged as a feasible alternative and has significant advantages over conventional firing system and offers multiple benefits – compact boiler design, fuel flexibility, higher combustion efficiency and reduced emission of noxious pollutants such as SO_x and NO_x.
- The fuels burnt in these boilers include coal, watery rejects, rice husk, wood chips & other agricultural wastes.
- The fluidized bed boilers have a wide capacity range- 0.5 T/hr to over 100 T/hr.

Fluidized bed Combustion



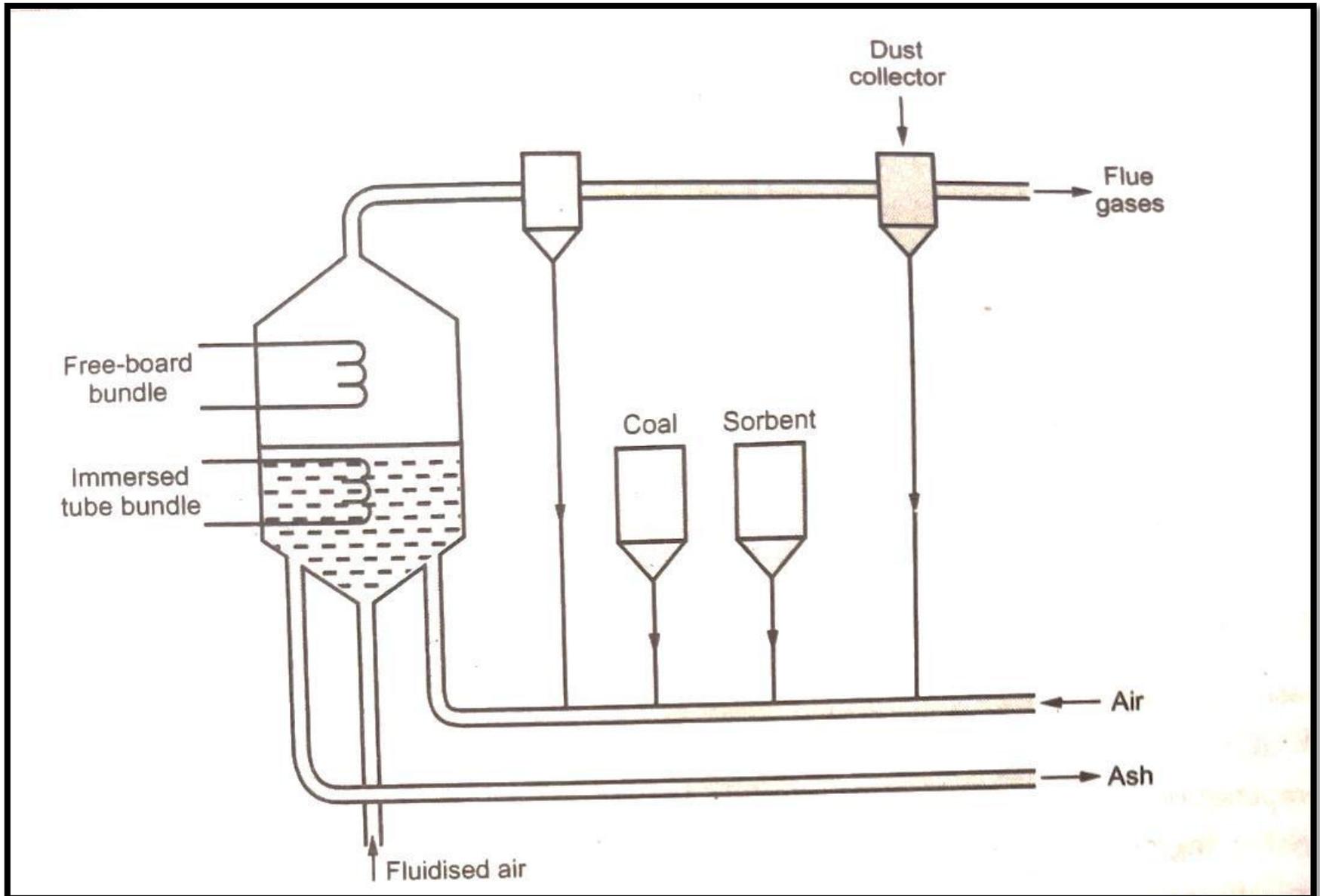
Fluidized bed Combustion

- Fluidized Bed Combustion takes place when the forced draught fan supplies air to the Furnace of the Boiler. In the furnace, and is (used for Bubbling phenomenon) placed on the Bed and is heated before fluidization, the air enters the bed from the nozzles fitted on the Furnace Bed. And above the nozzles; the sand opposes the upward motion of the air.
- But at sufficient velocities, when the pressure applied by the air becomes equal to the weight of the sand, fluidization of the sand occurs.
- Now the fuel supplied by fuel conveyor is fed to the preheated bubbling sand and gets combusted away. This phenomenon also ensures complete combustion of the Fuel.

Fluidized bed Combustion

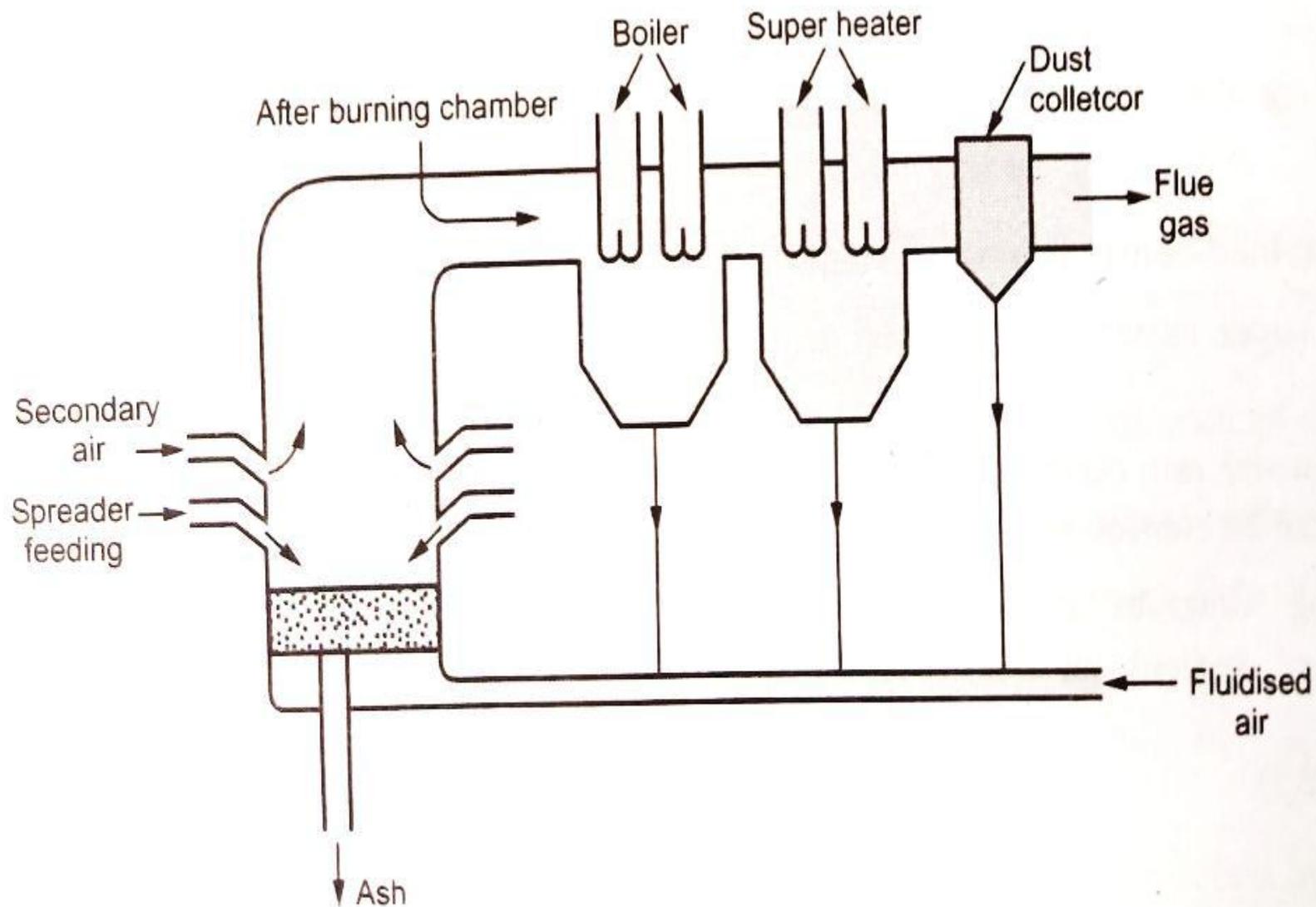
- The high velocity of air keeps the solid feed material in suspending condition during burning.
- During burning SO₂ is absorbed by dolomite and prevents its effect by the emission, also control bed temperature.
- As per cost economics a saving about 10% in operating and 15% capital costs could be achieved for unit rating of 120MW and may be higher for bigger units.
- There are **three basic types of fluidized bed combustion boilers:**
 - 1. **Atmospheric** classic Fluidized Bed Combustion System (AFBC)
 - 2. Atmospheric **circulating** (fast) Fluidized Bed Combustion system (CFBC)
 - 3. **Pressurized** Fluidized Bed Combustion System (PFBC).

Atmospheric Fluidized Bed Combustion System(AFBC)



UNDERFEED AFBC BOILER

Atmospheric Fluidized Bed Combustion System (AFBC)

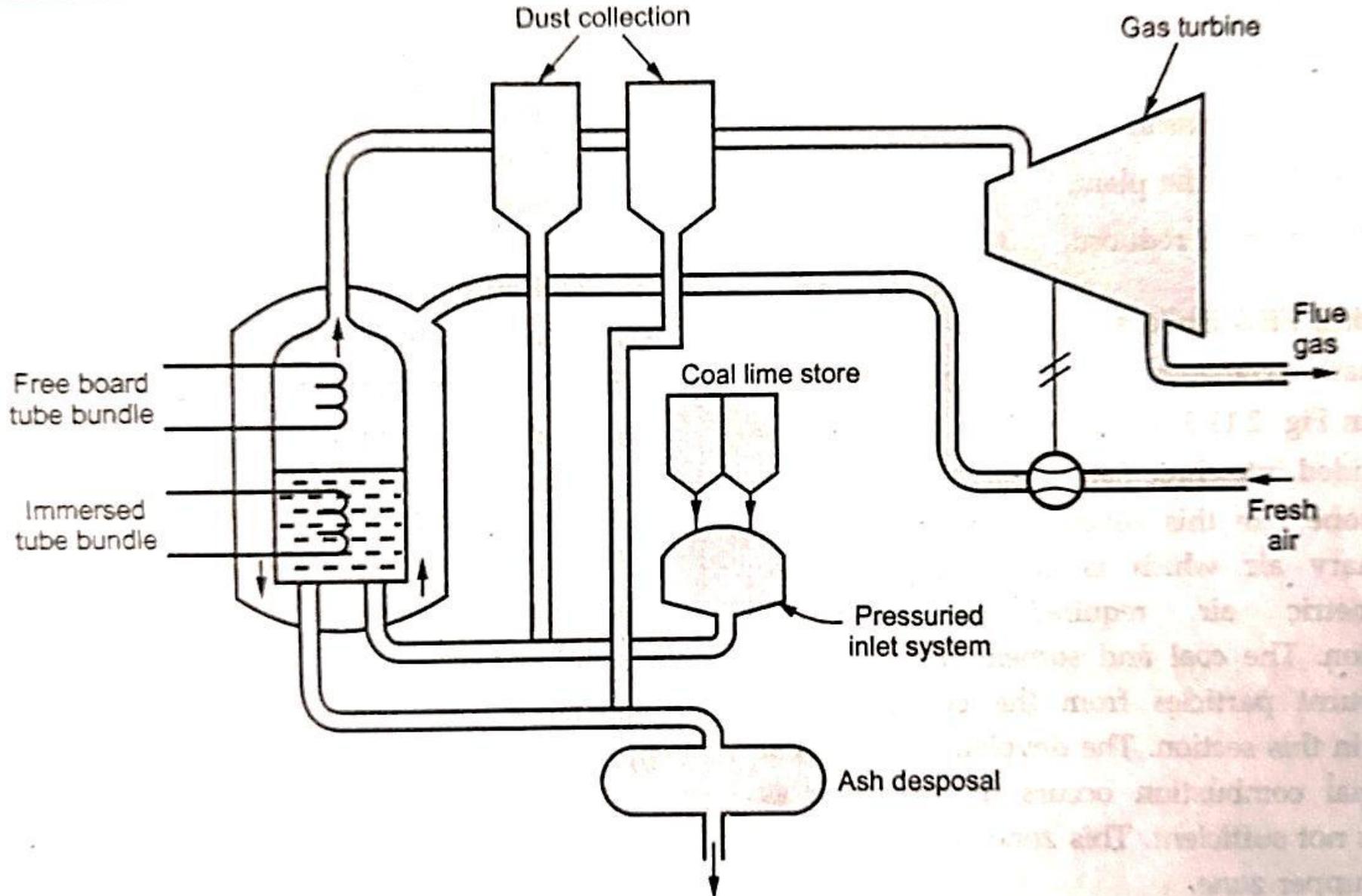


OVERFEED AFBC BOILER

Atmospheric Fluidized Bed Combustion System(AFBC)

- **Underfeed** provides a positive load and compact design, but costly in operation.
- **Overfeed** is simple and economical in operation but output is less compared to underfeed as pressure inside the bed is atmospheric. Also it shows lower desulphurization.

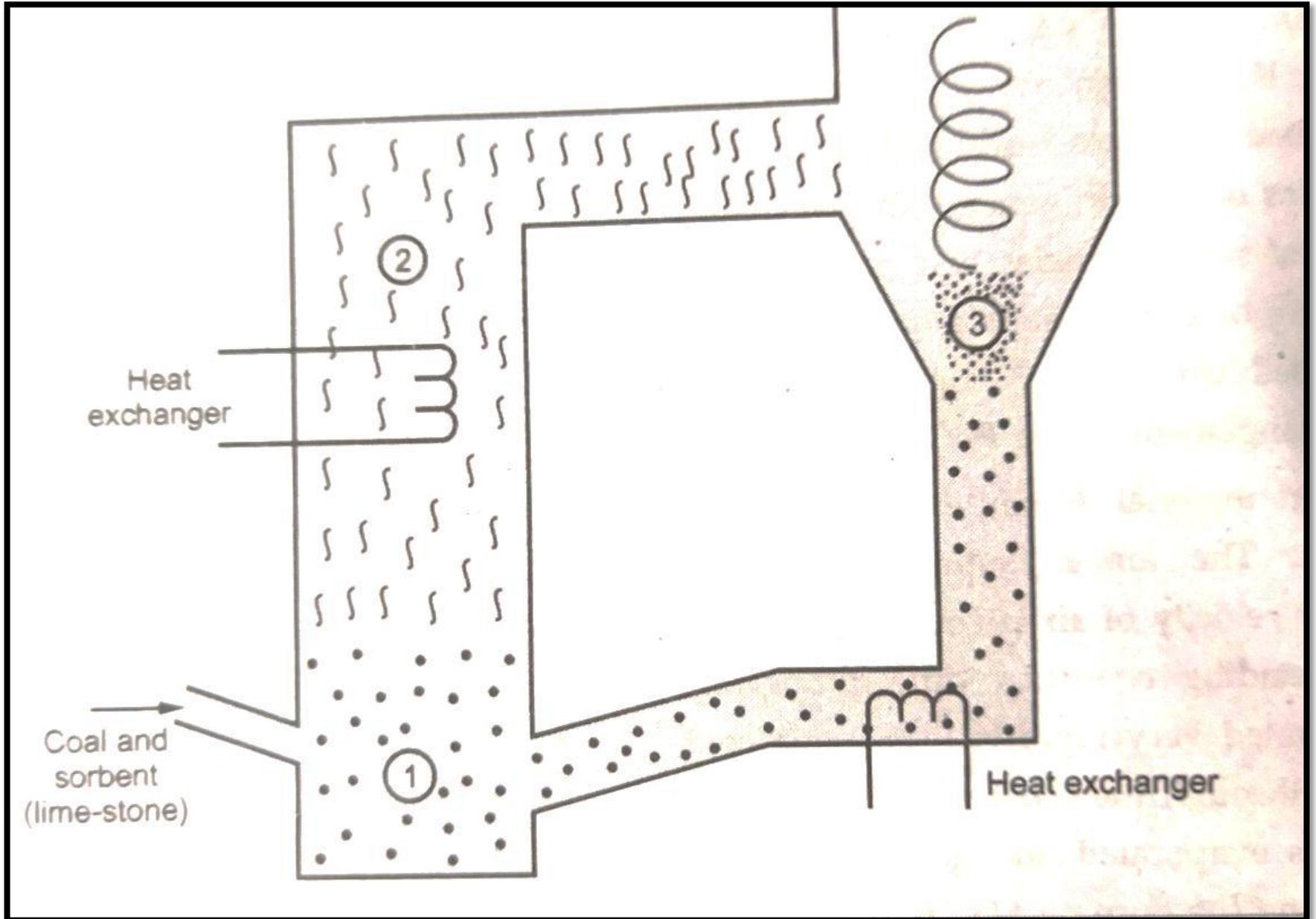
Pressurized Fluidized Bed Combustion System(PFBC)



Pressurized Fluidized Bed Combustion System(PFBC)

- In this boiler double shell design is used.
- The flue gas passed through the dust collector and then circulated through a gas turbine which drives the compressor.
- The compressor supplies pressurized air to fluidized bed combustor for fluidization and combustion.
- This double shell helps to separate the thermal reactor stress and pressure stress.
- **Advantages:**
 - It has low NO_x emission.
 - Cost of plant is reduced.
 - Desulphurization is improved.
 - Increase in coal loading.

Circulating Fluidized Bed Combustion System(CFBC)



Circulating Fluidized Bed Combustion System(CFBC)

- **1. Lower Zone:**
- In this zone the coal is fluidized by primary air which is 40 – 80 % of the stoichiometric air is required to complete combustion.
- The coal, sorbent and unburnt particles from the cyclone air is received in the section.
- The devolatilisation of coal and partial combustion occurs in this zone as oxygen is not sufficient.
- This zone is more denser than upper zone.

Circulating Fluidized Bed Combustion System(CFBC)

- **2. Upper Zone:**
- In this zone coal particles from lower zone is transported to upper zone where they completely burnt as amount of oxygen available is more.
- **3. Solid separator Zone:**
- The unburnt coal particles entering the refractory lined cyclone zone are taken back in this zone.
- In the cyclone the oxygen content in the air is lower therefore the combustion is less.
- The CO and volatiles are generally burnt in this zone.

Fluidized Bed Combustion System(FBC)

- **Advantages of FBC:**

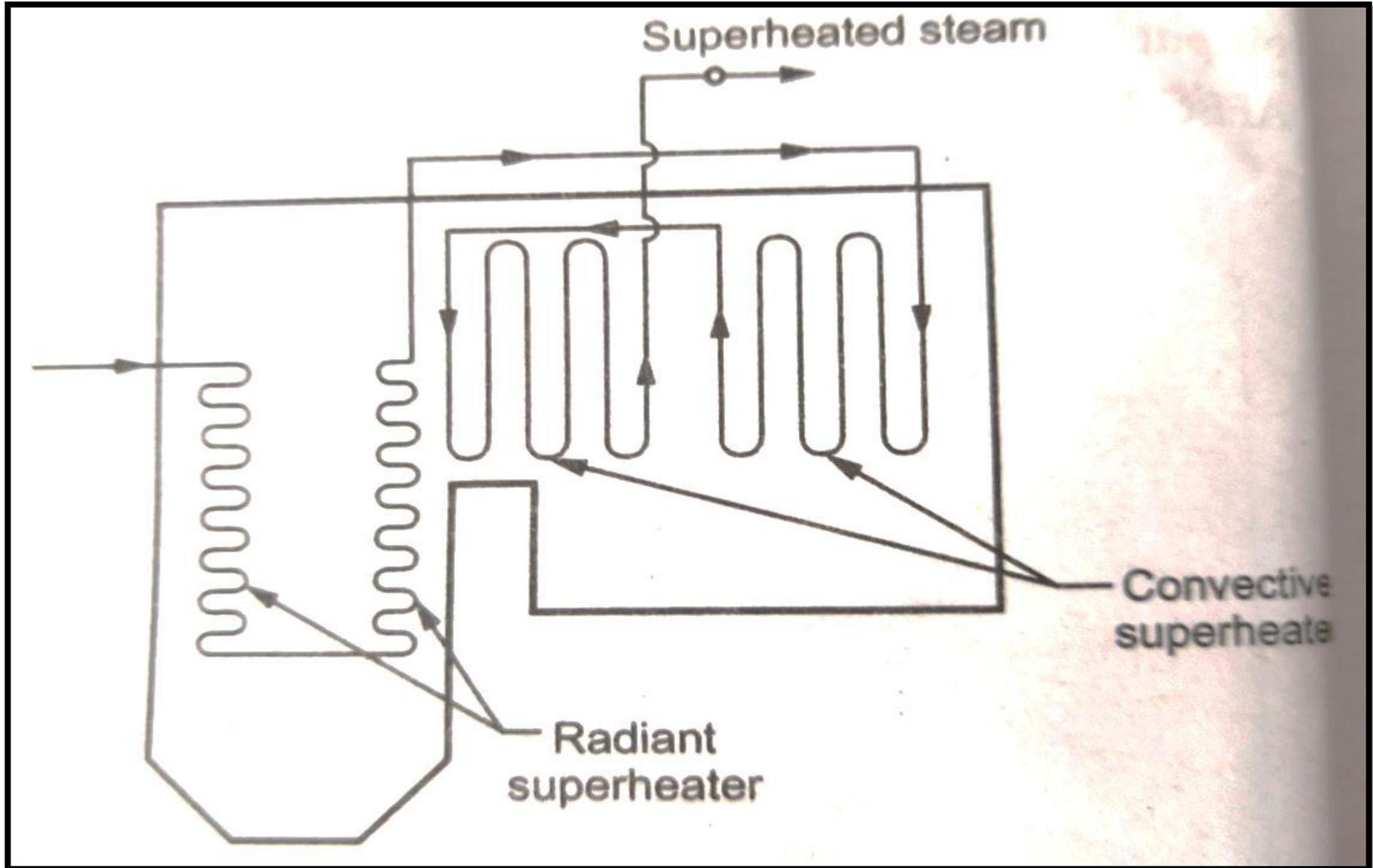
- Pollution is reduced.
- Combustion temperature can be controlled.
- Can use solid, liquid, or gaseous fuel or mix, as well as domestic and industrial waste can be utilized.
- Unit size and overall capital cost is reduced.
- Due to lower combustion temperature fouling and corrosion of tubes is reduced.

Method of Superheat Control

- To increase the plant efficiency superheated steam is required.
- If temperature of steam increases beyond design level overheating occurs.
- It cause damage of systems in power plant, hence controlling of temperature is required.
- It can be done by controlling the flow flue gases.

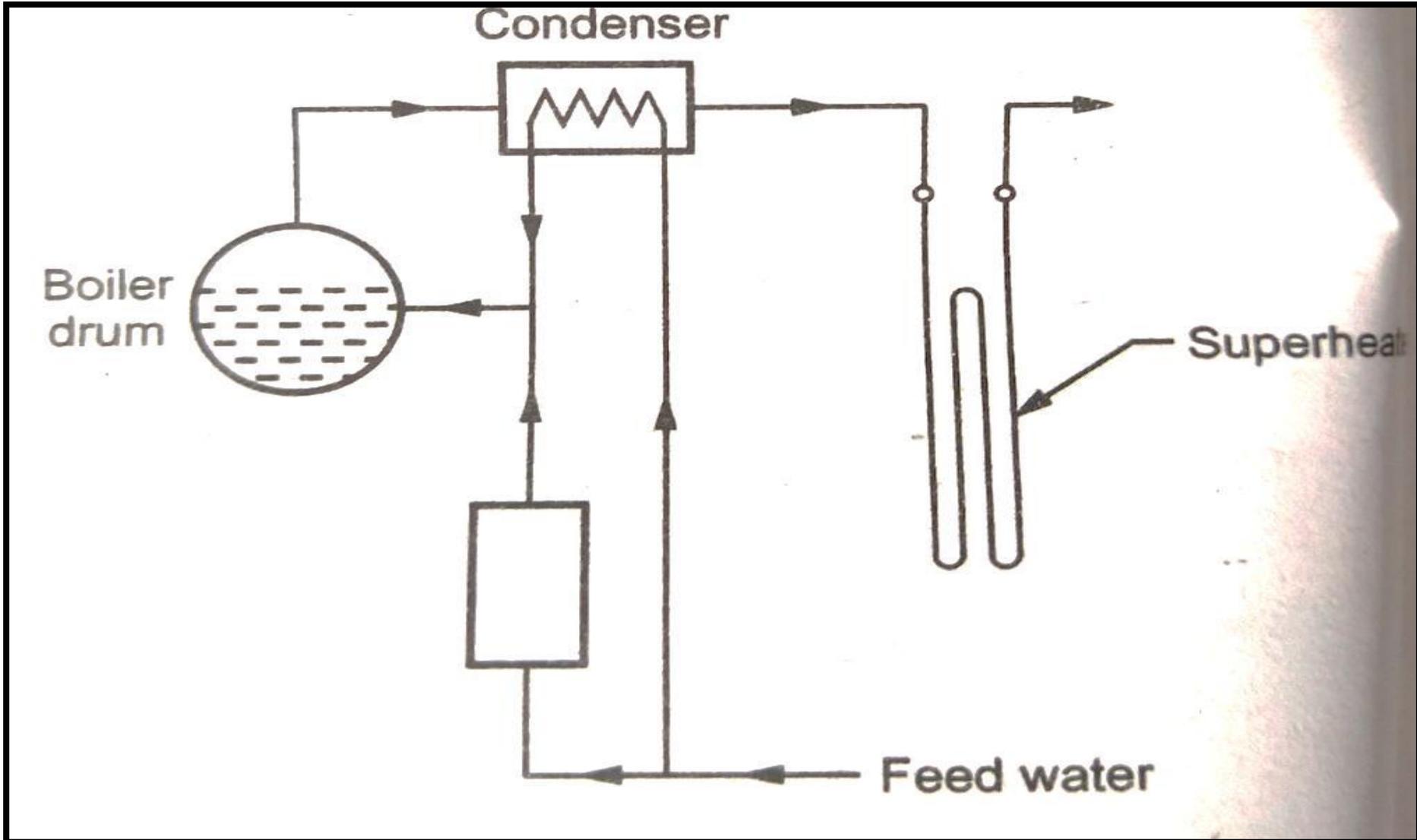
Method of Superheat Control

1. Combined-Convective super heaters



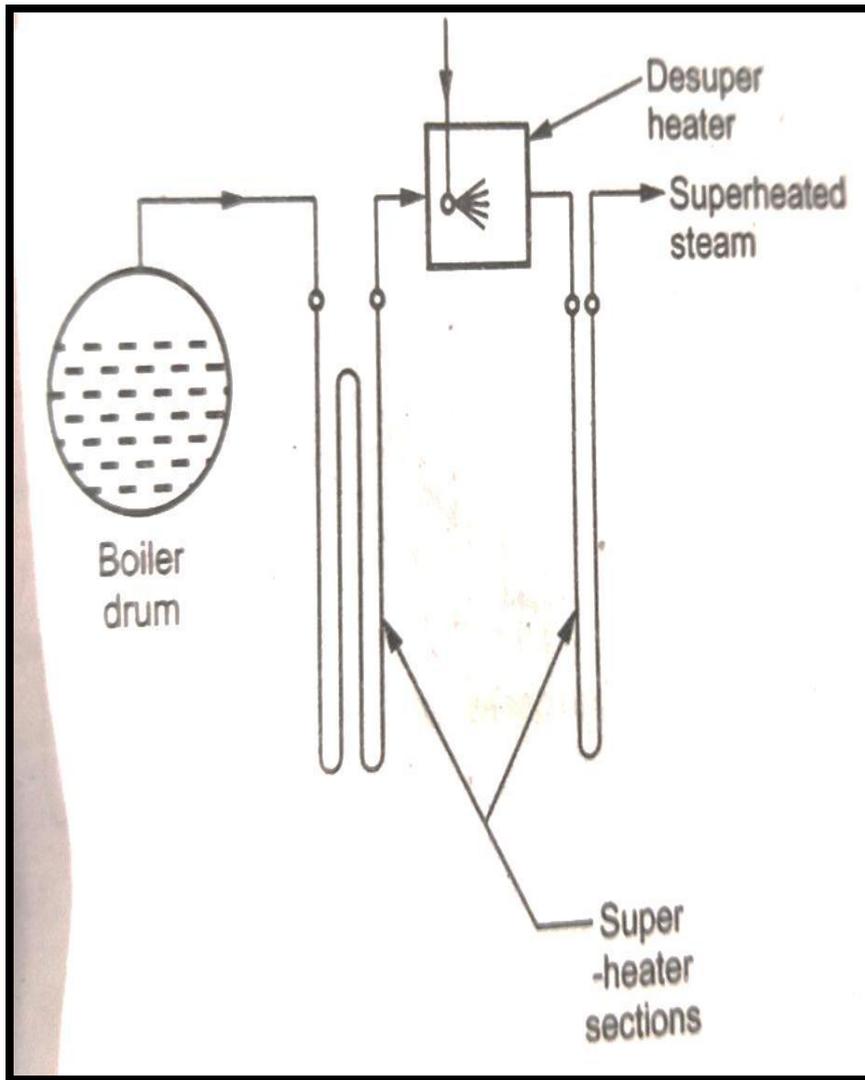
Method of Superheat Control

2. Pre Condensation Of Steam



Method of Superheat Control

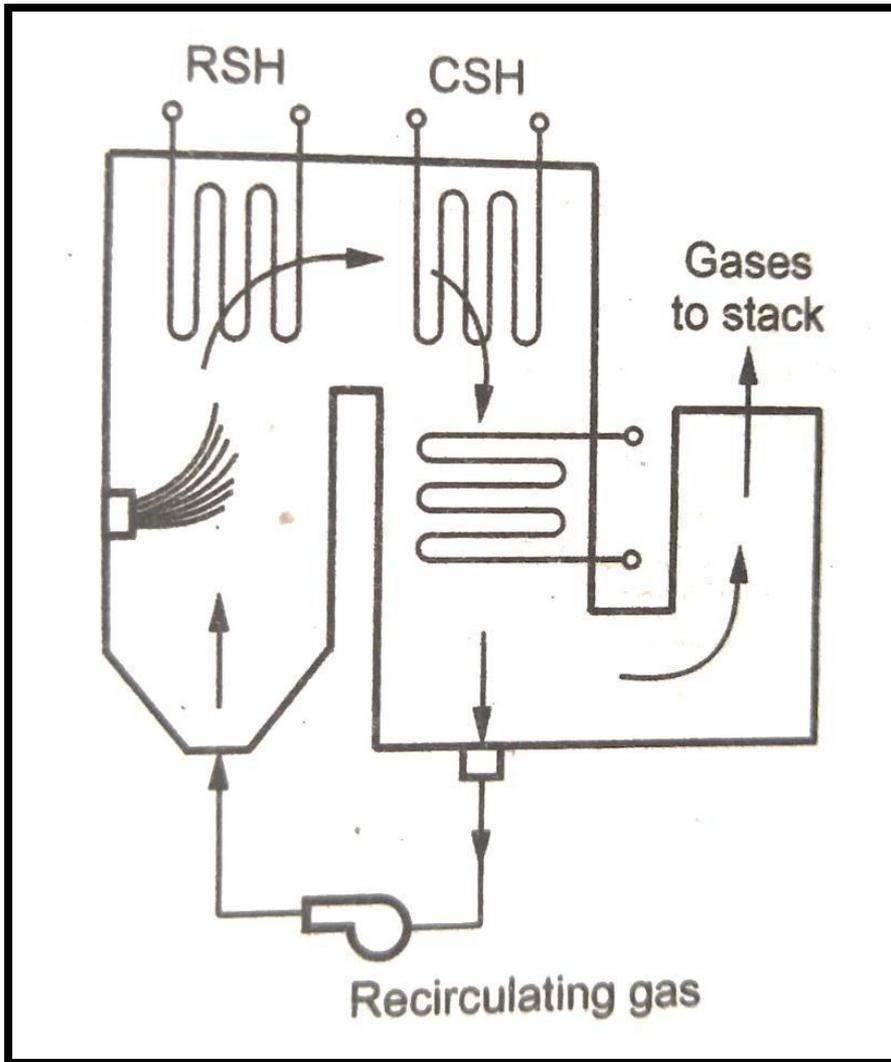
3. De-Superheating



- “Removal of small heat energy from a superheated steam.”
- It can be done by spraying water on the superheated steam and the sprayed water absorbs the heat energy and reduces the temperature of superheated steam.

Method of Superheat Control

4. Gas Circulation



- The gases coming out from the economizer, have less temperature.
- These gases are transferred to furnace to absorb the heat energy.

Method of Superheat Control

5. By passing the flue gases

- The gases coming from the furnace having high temperature.
- Some amount of gases are bypassed.
- As the mass flow rate decreases the temperature can be controlled.

Corrosion In Boilers

- The corrosion in boilers occurs due to salts and oxides. It reduces material strength and causes loss of material.
- It occurs on both inner (salt/low pH) and outer surfaces (ash) of tubes.
- Inner and outer surface corrosion occurs due to presence of O₂, CO₂, SO₂, chlorides, present in water.
- External surface due to presence of sodium and potassium sulphate in coal ash.

Preventive Measure of Corrosion In Boilers

- The use of FBC boiler decreases corrosion rate.
- The oxides are removed from the water by using scavengers.
- Proper water treatment plant to maintain pH value.
- The effect of CO₂ is controlled by adding ammonia in water.
- External coating are used to control deposition of scale or soot.
- Water can preheated properly to control corrosion in boiler.
- Economizer, Re-heater, Super-heater, can be used as effectively to overcome the corrosion in boilers.