2

HIGH PRESSURE BOILER

Course Contents

2.1 Introduction

Efficiency of any cycle can be increased by increasing the temperature of source or temperature of heat supplied. So, efficiency of the thermal power plant can be increased by increasing temperature of the steam supplied to the turbine. With development of the material, it is possible to supply high temperature steam to turbine. So to increase the efficiency of the plant it is necessary to use high pressure boiler.

2.2 Unique Features of High Pressure Boiler

2.2.1 Method of water circulation

The water may be circulated through the boiler by natural circulation due to density difference or by forced circulation with the help of pump.

In all modern thermal power plants forced circulation is used. But with increase of pressure, density difference decreases and at critical pressure it becomes zero. Thus the natural circulation ceases. Therefore, in high pressure boiler, it is necessary to use forced circulation. Further, heat transfer rate can also be increased by increasing the velocity of water with the help of pump.

2.2.2 Types of Tubing

In most of high pressure boiler, the water is circulated through the tubes and outer surface of tubes are exposed to the gases. If the water is circulated through the one continuous tube, large pressure drop will take place. To minimize the pressure drop, water is circulated through parallel system of tubing.

2.2.3 Improved Method of Heating

The heat transfer from the hot gases to water can be increased by using following methods:

i. At critical pressure, water is directly converted into steam. So, by increasing the pressure above the critical pressure latent heat of vaporization can be saved.
ii. If water is supplied to the boiler at high temperature, then efficiency of heat supplied can be increased. So, by using the feed water heater, temperature of feed water can be increased.
iii. The overall heat transfer coefficient can be increased by increasing velocity of water inside the tube or by increasing the velocity of gases.

2.3 Advantages of High Pressure Boiler

i. Scale formation is avoided due to the use of high velocity of water.
ii. Light weight tubes can be used.
iii. Reduction in number of tubes used.
iv. Boilers are capable of meeting rapid load changes.
v. Completely eliminates the high head which is needed for natural circulation.
vi. Since all parts are heated uniformly, eliminates danger of overheating and setting up thermal stresses.

vii. Construction time required is less

2.4 La-Mont Boiler:

Construction and Working

The arrangement of water circulation and different components is shown in figure 2.1.

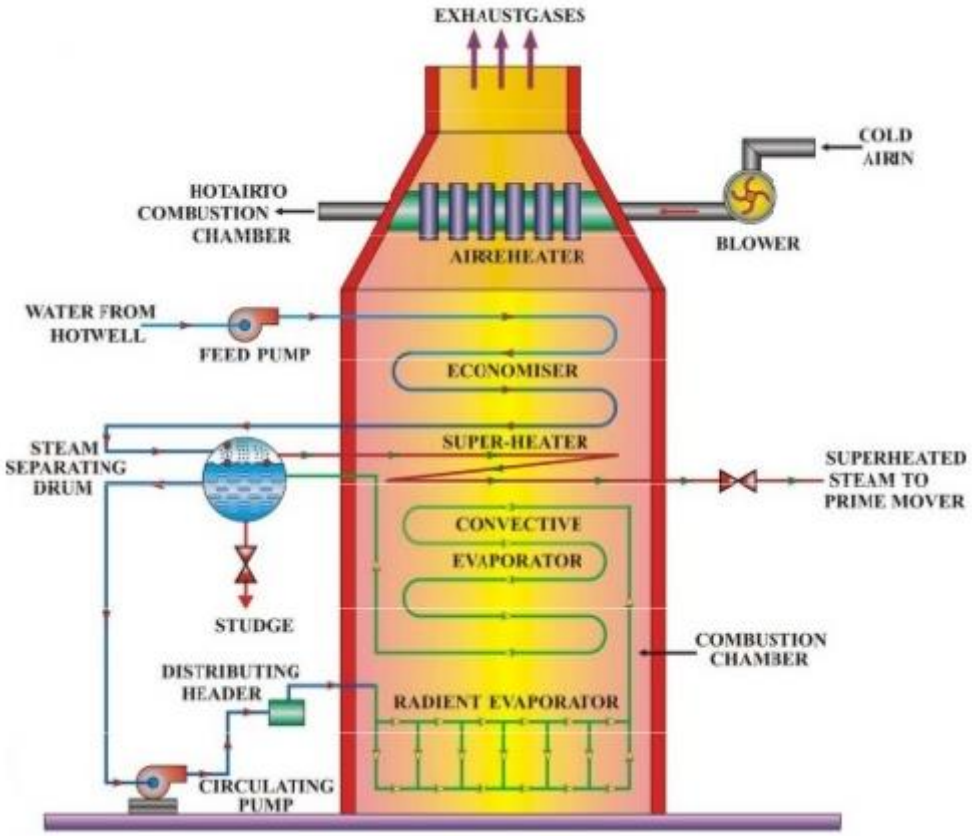

Fig. 2.1 La-Mont Boiler

The feed water from the hot well is supplied to a storage and separating drum through economizer. The most of the sensible heat is supplied to feed water through economizer. Water from the storage drum is circulated through the radiant evaporator and convective evaporator with the help of circulating pump. Circulation of water through evaporator is 8 to 10 times the weight of steam evaporated. Such large quantity of water circulation through evaporator tubes prevents the tube from overheating. Part of the water evaporated, as it pass through evaporator, is separated in the separating drum. Dry and saturated steam from the separating drum is passed through the super-heater before supply to prime mover. Distributing headers are used to distribute the water into radiant evaporator through nozzles.

Note: - In the radiant evaporator, heat is transferred by radiation so it is called radiant evaporator, whereas in convective evaporator, heat is transferred by convection. In modern high pressure boiler, furnace wall is covered with the water tube, so heat transfer in furnace is by radiation. This water tubes also protect the furnace wall from overheating.

Problem with La Mont Boiler and its Solution

The main difficulty experience in the La Mont boiler is the formation and attachment of bubbles on the inner surface of the heating tubes. As the attached bubbles offers high thermal resistance to heat transfer compare to water film, it reduce the heat transfer and steam generation. It also increases the thermal stresses.

This problem can be reduced by increasing the pressure inside the boiler upto the critical pressure. At the critical pressure, water and steam have same density, so formation of bubble can be eliminated.

2.5 Benson Boiler:

To avoid the formation and attachment of bubbles inside the water tube, Benson boiler is operated at critical pressure. The arrangement of the boiler components is shown in figure 2.2.

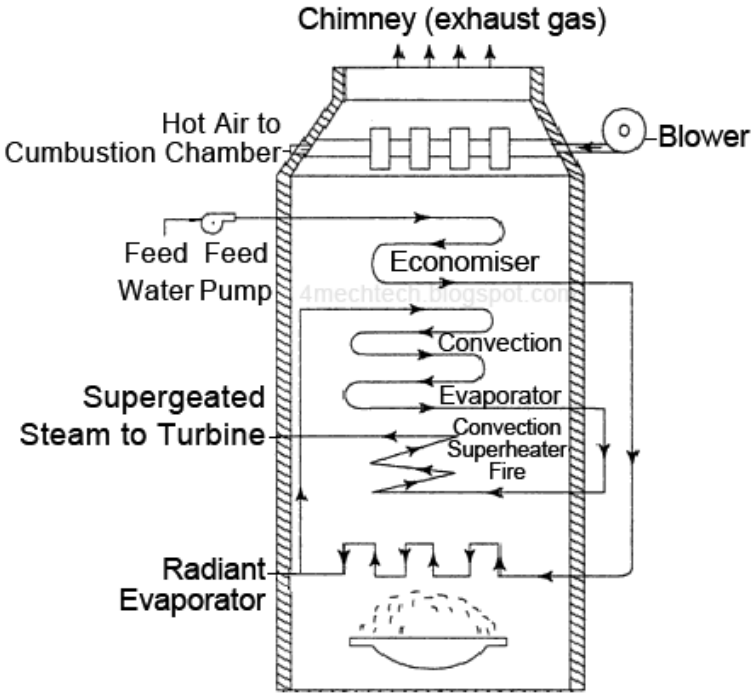

Fig. 2.2 Benson Boiler

Construction and Working

Water from the hot well is passed through the economizer where sensible heat is supplied to the water. Part of the water is evaporated when it passes through the radiant evaporator and remaining water is evaporated as it passes through the convective evaporator. Then dry and saturated steam from the convective evaporator is passed through the super-heater before supply to prime mover.

Starting of the Benson Boiler

First circulating pumps are started then burners are started. During starting water from super heater is supplied back to economizer with the help of valve A. During starting valve B is closed. Once generation of superheated steam starts, valve A is closed and valve B is opened.

Advantages

i. No drum so light weight
ii. Transportation of boiler is easy
iii. Erection is easy and can be carried out at plant site
iv. Furnace wall can be protected by small diameter tubes
v. Quick start because of the welded joint

Problem with Benson Boiler and its Solution

Major problem with the Benson boiler is deposition of salt in the transformation zone when all remaining water is converted into steam. This deposited salt offers the resistance to heat transfer and reduces the steam generation. It also causes the overheating of the tube.

To avoid this difficulty, the boiler is normally flashed out after every 4000 working hours to remove the salt.

2.6 Loeffler Boiler:

The major difficulty experienced in Benson boiler is deposition of salt on the inner surface of the tubes. This difficulty was solved in Loeffler boiler by preventing the circulation of water through the tubes. The arrangement of the components of boiler is shown figure 2.3.

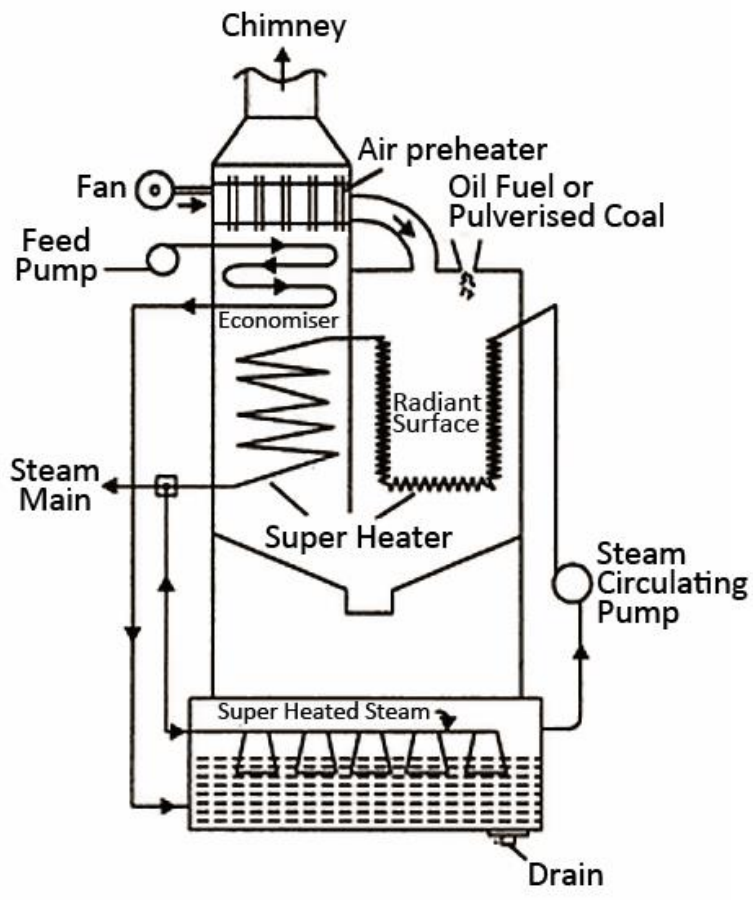

Fig. 2.3 Loeffler Boiler

Construction and Working

The water from the hot well is supplied to the evaporating drum through economizer. About 65% of the steam coming from the super-heater is supplied to the evaporating drum for evaporation of the feed water from the economizer. Steam is generated by mixing of the super-heated steam to the feed water in evaporating drum. Dry and saturated steam generated in the evaporating drum is circulated through the radiant super-heater and convective super-heater with the help of steam circulating pump. About 35% of super-heated steam generated in the super-heater is supplied to the H.P. turbine and remaining is supplied to evaporating drum. Exhaust steam from the H.P. turbine is reheated in the re-heater before supplied to the L.P. turbine.

For distribution of super-heated steam throughout the water into evaporator, special design nozzles are used which reduce the priming and noise. Higher salt concentration water can be used in this boiler.

2.7 Schmidt-Hartmann Boiler:

The operation of the boiler is similar to an electric transformer. The arrangement of the boiler components are shown in figure 2.4.

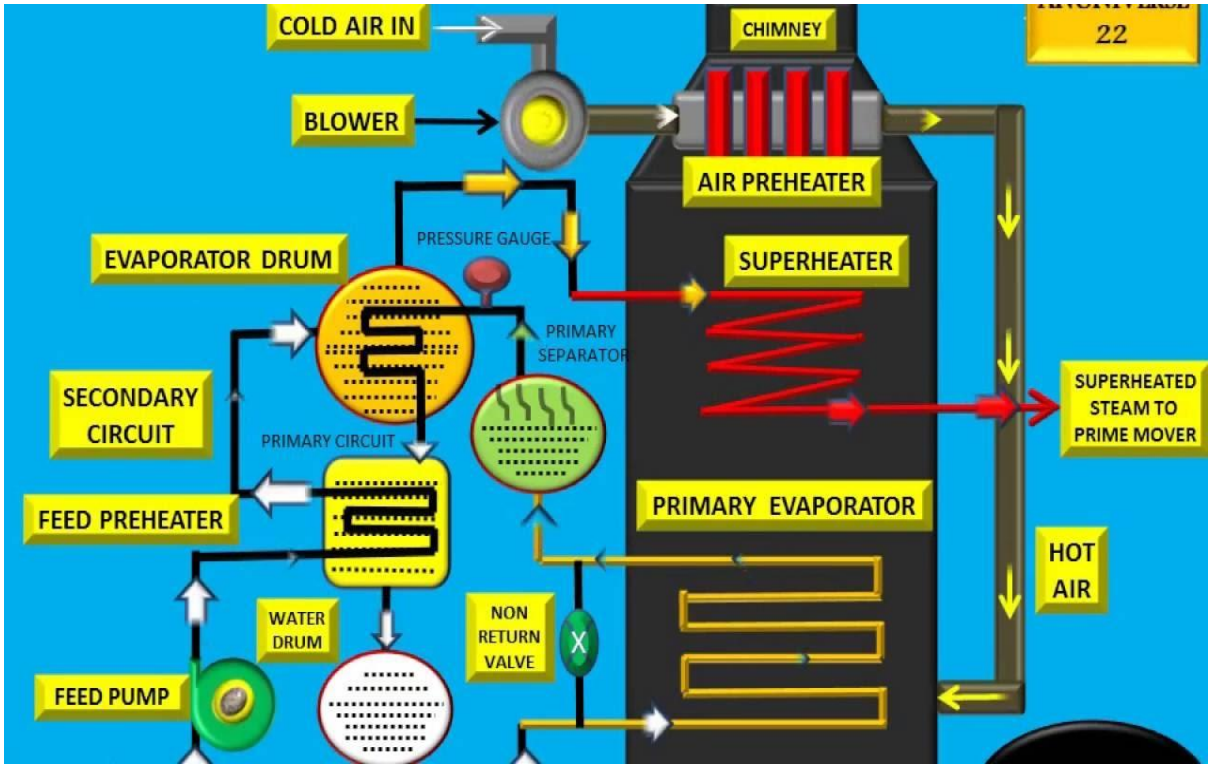

Fig. 2.4 Schmidt-Hartmann Boiler

Construction and working

The boiler consists of two circuits. In the primary circuit, steam is generated from the distilled water at 100 atm. The generated steam is passed through the coil submerged in the evaporating drum. Evaporating drum contains the impure water at 60 atm. so, in the evaporating drum, steam is generated at 60 atm. and high pressure steam is

condensed. Steam generated in evaporating drum is passed through the super-heater before supply to the prime mover.

The high pressure condensate produced in the submerged coil is passed through the feed pre-heater to raise the temperature of impure water to its saturation temperature. So, only latent heat is supplied in the evaporator drum.

Natural circulation is used in the primary circuit and this is sufficient for desired rate of heat transfer and to overcome the thermo-siphon head of about 2 to 10 m.

Every care is taken in design and construction to prevent the leakage of distilled water in the primary circuit, so in normal circumstances, make up water is not required. For safety of operation pressure gauge and safety valve are fitted in the primary circuit.

Advantages

i. There is a rare chance of overheating or burning the highly heated components of primary circuit as there is no chance of obstruction to the circulation by impurities.
ii. The salt deposited in the evaporator drum due to the circulation of impure water can be easily brushed off just by removing the submerged coil from the drum or by blowing off the water.
iii. The wide fluctuations of load are easily taken by this boiler without priming problem.
iv. The absence of water risers in the drum, and moderate temperature difference across the heating coil allows evaporation to proceed without priming.

2.8 Velox Boiler:

High rate of heat transfer can be achieved by increasing the velocity of the flue gases over the velocity of the sound. In the velox boiler, velocity of the gases is more than velocity of the sound. The arrangement of components of the boiler is shown in figure 2.5.

Construction and Working

Air is compressed to 2.5 bar with the help of the compressor driven by the turbine. That high pressure air is supplied to combustion chamber to get supersonic velocity of the gases. The supersonic gases are passed through the combustion chamber and gas tubes to achieve high heat transfer rate.

The burned gases in the combustion chamber are passed through the annulus of the tubes as shown in figure 2.5. Heat is transfer from the gases to water while passing through the annulus to generate the steam. The mixture of water and steam formed in the water tube is passed to the separator which is design so that the mixture enters with spiral flow. Due to the centrifugal force, heavier water particles are thrown outward on the wall which separates the steam from water.

The gases coming out from the annulus at the top is further passed over the super-heater to super heat the steam. The gases coming out from the super-heater is passed through the turbine to utilize the kinetic energy of the gases. The power output of the

turbine is used to run the compressor. The exhaust gases coming out from the turbine are passed through the economizer to utilize the heat of exhaust gases. The extra power required to drive the compressor is supplied with the help of electric motor.

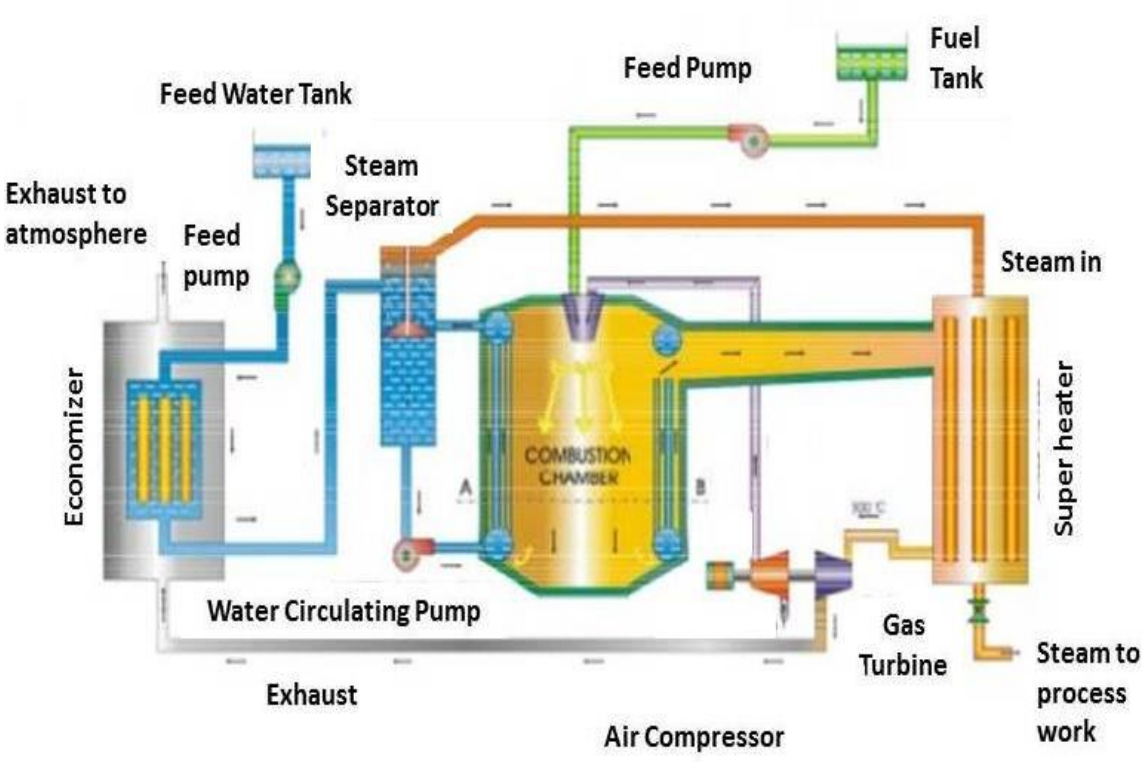

Fig. 2.5 Velox Boiler

Advantages

i. Very high rate of combustion is possible.
ii. It is very compact and has greater flexibility.
iii. Low excess air is required as pressurized air is used and draught problem is simplified.
iv. It can be quickly started from the cold.

2.9 Super Critical Boiler:

The efficiency of the plant can be increased by increasing the pressure of the steam. So in the modern power plants super critical boilers are used. Boiler which operates above the critical pressure is called super critical boiler.

Note:-

Critical state: State of a substance beyond which there is no clear distinction between the liquid and gaseous phase

A point where saturated liquid and dry saturated vapour lines meet so that latent heat is zero, is called Critical Point (figure 2.6).

For water, Critical Point is given by:

Pressure: 221 bar Temperature: 374.15 0C

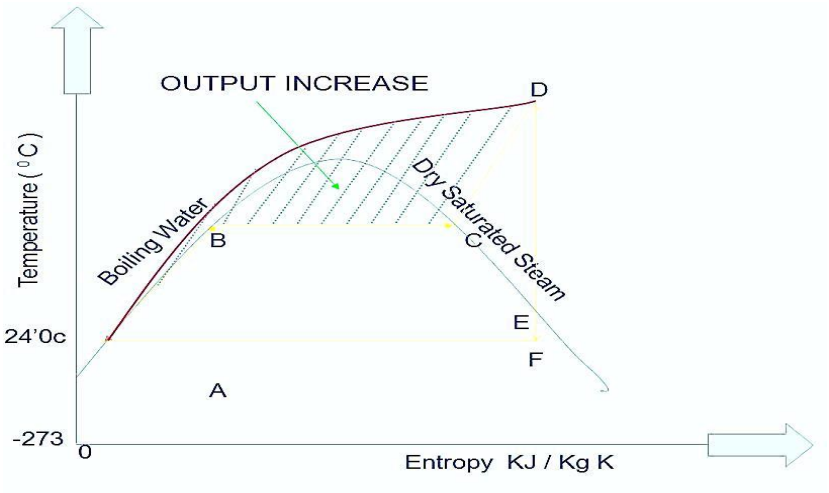

Fig. 2.6 T-S Diagram of Rankine Cycle

Super critical boiler is also called once through boiler as the water is converted into super-heated steam in single continuous pass. It does not required steam separating drum.

Design consideration of super critical boiler

Above super critical pressure, there is no density difference between the steam and water so forced circulation is necessary.

There is no steam drum so no blow down therefore extremely pure water must be used for which require high quality water treatment plant.

Boiler tubes must be made of high strength austenitic steels or super alloys to withstand high temperature.

Normally 3 steps of feed heating are required due to high pressure and to avoid excessive moisture at turbine exhaust.

Advantages

i. The heat transfer rate is considerable large compare to sub critical boiler.
ii. The pressure level is more stable due to less heat capacity of the boiler therefore give better response.
iii. Higher thermal efficiency of power plant can be achieved.
iv. The problems of erosion and corrosion are minimized in as two phase mixture does not exist.
v. The turbo generators connected to super-critical boilers can generate peak loads by changing the pressure of operation.
vi. It gives better response to load fluctuation.

Disadvantages

i. Feed pump is necessary.
ii. More reheats are required, hence increased complexity of the plant and maintenance.
iii. High capital involved.

2.10 Super-Charged Boiler:

In the super-charged boiler combustion of the fuel is carried out under the high pressure.

Construction and working

The arrangement of the different components is shown in figure 2.7. Air from the atmosphere is supplied to combustion chamber at high pressure with the help of the compressor. In the combustion chamber, combustion is carried out under the high pressure. The exhaust gases from the combustion chamber are used to run the gas turbine as they are exhausted at high pressure and the power produced by the gas turbine is used to run the compressor to compressor the air. The exhaust gases from the turbine are further used to preheat the feed water in the economizer.

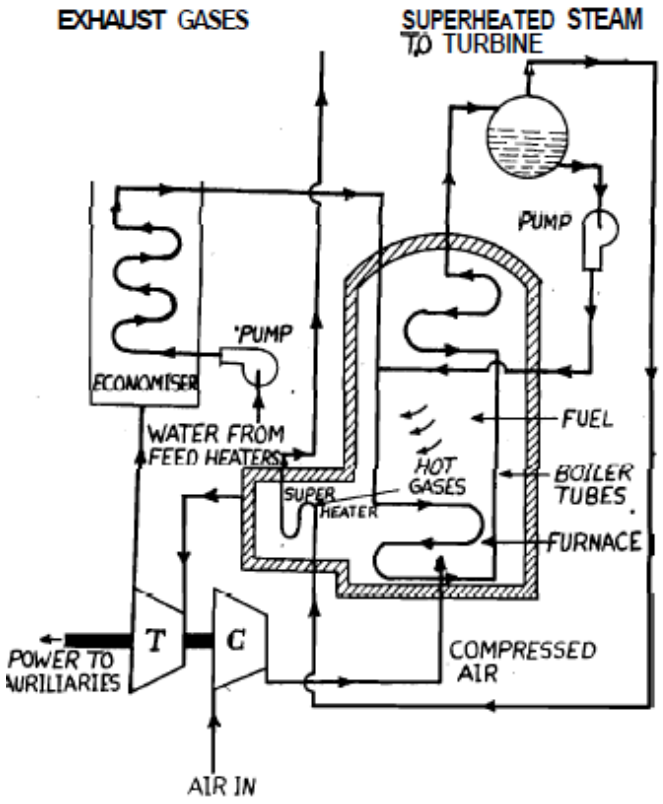

Fig. 2.7 Super charged Boiler

Advantages

i. High heat transfer rate can be achieved as combustion is carried under the high pressure.
ii. Rapid start of the boiler is possible as the boiler is compact.
iii. It gives the better response to load fluctuation due to small heat storage capacity.
iv. The part of the gas turbine output can be used to drive other auxiliaries.

Disadvantages

i. The tightness of high pressure gas passage is essential.
ii. Capital cost of the boiler is high.

2.11 Things to Think About

- List the different types of boilers and its application
- Compare the unique features of the different types of boilers

Assignment

1. Explain the constructional difference between Low pressure and High pressure boiler.
2. Explain with neat sketch construction and working of La Mont Boiler.
3. Draw a neat line diagram of a Benson boiler. State the main difficulty experienced in the La Mont boiler and how it is prevented. Explain its advantages.
4. Explain construction and working of Loeffler boiler. Also explain starting of Loeffler boiler.
5. With neat sketch explain construction and working of Schmidt-Hartmann boiler.
6. Draw line diagram of Velox boiler. Indicate all part of it. How it different from the other type of high pressure boiler?
7. What is subcritical and supercritical boiler?
8. Explain the working of pressurized fluidized bed combustion boiler with help of neat sketch. List its advantages and limitations.
9. Convection and radiant super heaters have opposite characteristics of temperatures v/s load- Explain.
10. With neat sketch explain different types of super heaters.
11. Write different methods of controlling temperature of superheated steam.
12. Distinguish between superheater, reheater and air preheater.