Chapter 5

Steam Generator

5.1 INTRODUCTION

Boiler is an apparatus to produce steam. Thermal energy released by combustion of fuel is transferred to water, which vaporizes and gets converted into steam at the desired temperature and pressure. The steam produced is used for:

(*i*) Producing mechanical work by expanding it in steam engine or steam turbine.

(*ii*) Heating the residential and industrial buildings

(*iii*) Performing certain processes in the sugar mills, chemical and textile industries.

Boiler is a closed vessel in which water is converted into steam by the application of heat. Usually boilers are coal or oil fired. A boiler should fulfill the following requirements

(*i*) **Safety.** The boiler should be safe under operating conditions.

(*ii*) **Accessibility.** The various parts of the boiler should be accessible for repair and maintenance.

(*iii*) **Capacity.** The boiler should be capable of supplying steam according to the requirements.

(*iv*) **Efficiency.** To permit efficient operation, the boiler should be able to absorb a maximum amount of heat produced due to burning of fuel in the furnace.

(*v*) It should be simple in construction and its maintenance cost should be low.

(*vi*) Its initial cost should be low.

(*vii*) The boiler should have no joints exposed to flames.

(*viii*) The boiler should be capable of quick starting and loading.

The performance of a boiler may be measured in terms of its evaporative capacity also called power of a boiler. It is defined as the amount of water evaporated or steam produced in kg per hour. It may also be expressed in kg per kg of fuel burnt or kg/hr/m^2 of heating surface.

5.2 TYPES OF BOILERS

The boilers can be classified according to the following criteria.

According to flow of water and hot gases.

1. Water tube.
2. Fire tube.

In water tube boilers, water circulates through the tubes and hot products of combustion flow over these tubes. In fire tube boiler the hot products of combustion pass through the tubes, which are surrounded, by water. Fire tube boilers have low initial cost, and are more compacts. But they are more likely to explosion, water volume is large and due to poor circulation they cannot meet quickly the change in steam demand. For the same output the outer shell of fire tube boilers is much larger than the shell of water-tube boiler. Water tube boilers require less weight of metal for a given size, are less liable to explosion, produce higher pressure, are accessible and can response quickly to change in steam demand. Tubes and drums of water-tube boilers are smaller than that of fire-tube boilers and due to smaller size of drum higher pressure can be used easily. Water-tube boilers require lesser floor space. The efficiency of water-tube boilers is more.

Water tube boilers are classified as follows.

1. Horizontal straight tube boilers

(*a*) Longitudinal drum (*b*) Cross-drum.

2. Bent tube boilers

(*a*) Two drum (*b*) Three drum

(*c*) Low head three drum (*d*) Four drum.

3. Cyclone fired boilers

Various advantages of water tube boilers are as follows.

(*i*) High pressure of the order of 140 kg/cm^2 can be obtained.

(*ii*) Heating surface is large. Therefore steam can be generated easily.

(*iii*) Large heating surface can be obtained by use of large number of tubes.

(*iv*) Because of high movement of water in the tubes the rate of heat transfer becomes large resulting into a greater efficiency.

Fire tube boilers are classified as follows.

l. External furnace:

(*i*) Horizontal return tubular

(*ii*) Short fire box

(*iii*) Compact.

2. Internal furnace:

(*i*) Horizontal tubular

(*a*) Short firebox (*b*) Locomotive (*c*) Compact (*d*) Scotch.

(*ii*) Vertical tubular.

(*a*) Straight vertical shell, vertical tube

(*b*) Cochran (vertical shell) horizontal tube.

Various advantages of fire tube boilers are as follows.

(*i*) Low cost

(*ii*) Fluctuations of steam demand can be met easily

(*iii*) It is compact in size.

According to position of furnace.

(*i*) Internally fired (*ii*) Externally fired

In internally fired boilers the grate combustion chamber are enclosed within the boiler shell whereas in case of extremely fired boilers and furnace and grate are separated from the boiler shell.

According to the position of principle axis.

(*i*) Vertical (*ii*) Horizontal (*iii*) Inclined.

According to application.

(*i*) Stationary (*ii*) Mobile, (Marine, Locomotive).

According to the circulating water.

(*i*) Natural circulation (*ii*) Forced circulation.

According to steam pressure.

(*i*) Low pressure (*ii*) Medium pressure (*iii*) Higher pressure.

5.3 COCHRAN BOILER

This boiler consists of a cylindrical shell with its crown having a spherical shape. The furnace is also hemispherical in shape. The grate is also placed at the bottom of the furnace and the ash-pit is located below the grate. The coal is fed into the grate through the fire door and ash formed is collected in the ash-pit located just below the grate and it is removed manually. The furnace and the combustion chamber are connected through a pipe. The back of the combustion chamber is lined with firebricks. The hot gases from the combustion chamber flow through the nest of horizontal fire tubes (generally 6.25 cm in external diameter and 165 to 170 in number). The passing through the fire tubes transfers a large portion of the heat to the water by convection. The flue gases coming out of fire tubes are finally discharged to the atmosphere through chimney (Fig. 5.1).

The spherical top and spherical shape of firebox are the special features of this boiler. These shapes require least material for the volume. The hemi spherical crown of the boiler shell gives maximum strength to withstand the pressure of the steam inside the boiler. The hemi-spherical crown of the fire box is advantageous for resisting intense heat. This shape is also advantageous for the absorption of the radiant heat from the furnace.

Coal or oil can be used as fuel in this boiler. If oil is used as fuel, no grate is provided but the bottom of the furnace is lined with firebricks. Oil burners are fitted at a suitable location below the fire door. A manhole near the top of the crown of shell is provided for cleaning. In addition to this, a number of hand-holes are provided around the outer shell for cleaning purposes. The smoke box is provided with doors for cleaning of the interior of the fire tubes.

The airflow through the grate is caused by means of the draught produced by the chimney. A damper is placed inside the chimney (not shown) to control the discharge of hot gases from the chimney and thereby the supply of air to the grate is controlled. The chimney may also be provided with a steam nozzle (not shown; to discharge the flue gases faster through the chimney. The steam to the nozzle is supplied from the boiler.

The outstanding features of this boiler are listed below:

1. It is very compact and requires minimum floor area.
2. Any type of fuel can be used with this boiler.
3. It is well suited for small capacity requirements.

4. It gives about 70% thermal efficiency with coal firing and about 75% with oil firing.

5. The ratio of grate area to the heating surface area varies from 10: 1 to 25: 1.

It is provided with all required mountings. The function of each is briefly described below:

1. Pressure Gauge. This indicates the pressure of the steam in the boiler.

2. Water Level Indicator. This indicates the water level in the boiler The water level in the boiler should not fall below a particular level otherwise the boiler will be overheated and the tubes may burn out.

3. Safety Valve. The function of the safety valve is to prevent the increase of steam pressure in the holler above its design pressure. When the pressure increases above design pressure, the valve opens and discharges the steam to the atmosphere. When this pressure falls just below design pressure, the valve closes automatically. Usually the valve is spring controlled.

4. Fusible Plug. If the water level in the boiler falls below a predetermined level, the boiler shell and tubes will be overheated. And if it is continued, the tubes may burn, as the water cover will be removed. It can he prevented by stopping the burning of fuel on the grate. When the temperature of the shell increases above a particular level, the fusible plug, which is mounted over the grate as shown in the Fig. 4.1, melts and forms an opening. The high-pressure steam pushes the remaining water through this hole on the grate and the fire is *extinguished.*

5. Blow-off Cock. The water supplied to the boiler always contains impurities like mud, sand and, salt Due to heating, these are deposited at the bottom of the boiler, and if they are not removed, they are accumulated at the bottom of the boiler and reduces its capacity and heat transfer rates. Also the salt content will goes on increasing due to evaporation of water. These deposited salts are removed with the help of blow off cock. The blow-off cock is located at the bottom of the boiler as shown in the figure and is operated only when the boiler is running. When the blow-off cock is opened during the running of the boiler, the high-pressure steam pushes the water and the collected material at the bottom is blown out. Blowing some water out also reduces the concentration of the salt. The blow-off cock is operated after every 5 to 6 hours of working for few minutes. This keeps the boiler clean.

6. Steam Stop Valve. It regulates the flow of steam supply outside. The steam from the boiler first enters into an ant-priming pipe where most of the water particles associated with steam are removed.

7. Feed Check Valve. The high pressure feed water is supplied to the boiler through this valve. This valve opens towards the boiler only and feeds the water to the boiler. If the feed water pressure is less than the boiler steam pressure then this valve remains closed and prevents the back flow of steam through the valve.

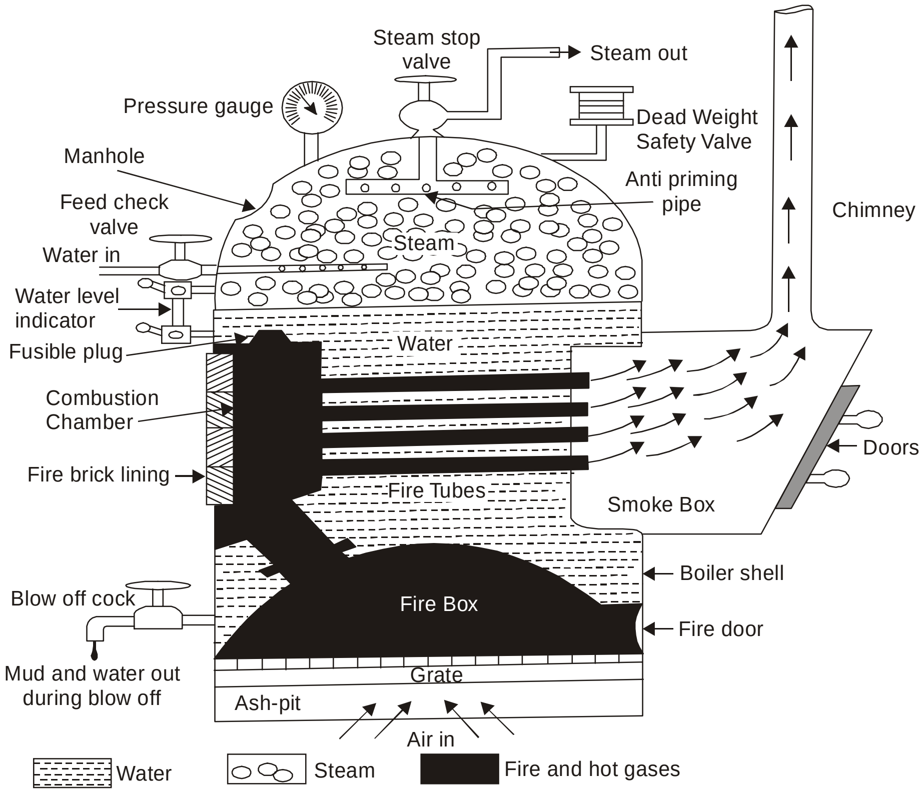


Fig. 5.1. Cochran Boiler.

5.4 LANCASHIRE BOILER

It is stationary fire tube, internally fired, horizontal, natural circulation boiler. This is a widely used boiler because of its good steaming quality and its ability to burn coal of inferior quality. These boilers have a cylindrical shell 2 m in diameters and its length varies from 8 m to 10 m. It has two large internal flue tubes having diameter between 80 cm to 100 cm in which the grate is situated. This boiler is set in brickwork forming external flue so that the external part of the shell forms part of the heating surface.

The main features of the Lancashire boiler with its brickwork shelling are shown in figure. The boiler consists of a cylindrical shell and two big furnace tubes pass right through this. The brick setting forms one bottom flue and two side flues. Both the flue tubes, which carry hot gases, lay below the water level as shown in the Fig. 5.2.

The grates are provided at the front end of the main flue tubes of the boiler and the coal is fed to the grates through the fire doors. A low firebrick bridge is provided at the end of the grate, as shown in the Fig. 5.2, to prevent the flow of coal and ash particles into the interior of the furnace tubes. Otherwise, the ash and coal particles carried with gases form deposits on the interior of the tubes and prevent the heat transfer to the water. The firebrick bridge also helps in deflecting the hot gases upward to provide better heat transfer:

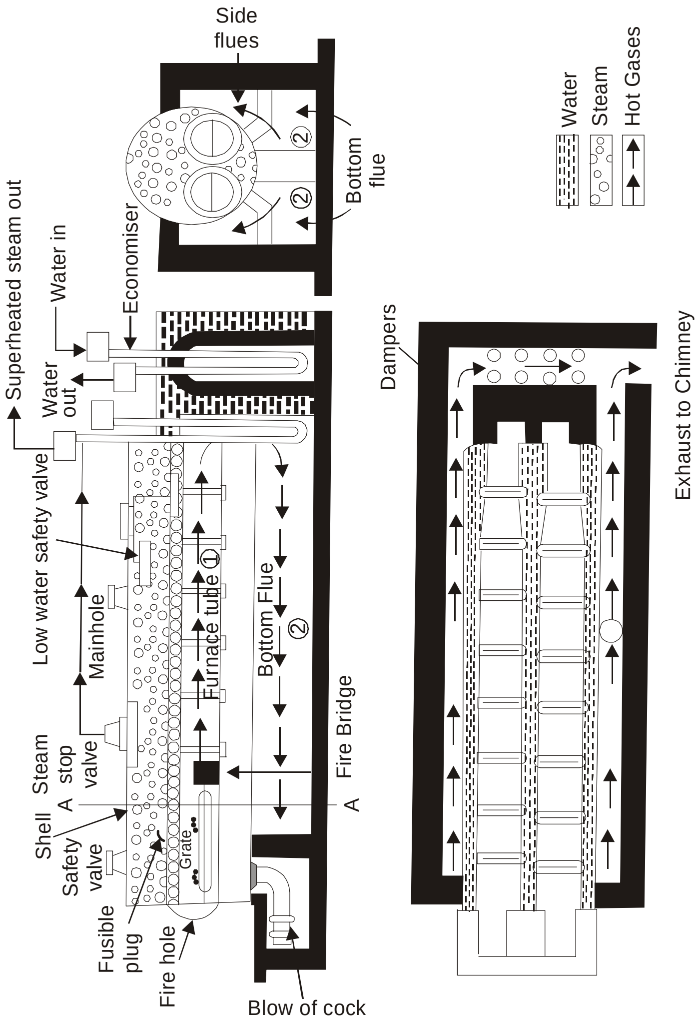


Fig. 5.2. Lancashire Boiler.

The hot gases leaving the grate pass up to the back end of the tubes and then in the downward direction. They move through the bottom flue to the front of the boiler where they are divided into two and pass to the side flues as shown in the figure. Then they move along the two-side flues and come to the chimney as shown in the figure.

With the help of this arrangement of the flow passages of the gases, the bottom of the shell is first heated and then its sides. The heat is transferred to the water through surfaces of the two flue tubes (which remain in water) and bottom part and sides of the main shell. This arrangement increases the heating surface to a large extent.

Dampers in the form of sliding doors are placed at the end of side flues to control the flow of gases. This regulates the combustion rate as well as steam generation rate. These dampers are operated by chains passing over a pulley at the front of the boiler. This boiler is fitted with usual mountings. The pressure gauge and water level indicator are provided at the front whereas steam stop valve, safety valve, low water and high steam safety valve and manhole are provided on the top of the shell.

The blow-off cock is situated beneath the front portion of the boiler shell for the removal of sediments and mud. It is also used to empty the water in the boiler whenever required for inspection.

The fusible plugs are mounted on the top of the main flues just over the grates as shown in the figure to prevent the overheating of boiler tubes by extinguishing the fire when the water level falls below a particular level. A low water level alarm is usually mounted in the boiler to give a warning in case the water level going below the precast value.

A feed check valve with a feed pipe is fitted on the front end plate. The feed pipe projecting into the boiler is perforated so that the water is uniformly distributed into the shell.

The outstanding features of this boiler are listed below:

1. Its heating surface area per unit volume at the boiler is considerably large.

2. Its maintenance is easy.

3. It is suitable where a large reserve of hot water is needed. This boiler due to the large reserve capacity can easily meet load fluctuations.

4. Super-heater and economizer can be easily incorporated into the system, therefore; overall efficiency of the boiler can be considerably increased (80-85%).

The super-heater is placed at the end of the main flue tubes. The hot gases before entering the bottom flue are passed over the super-heater tubes as shown in the figure and the steam drawn through the steam stop-valve are passed through the super-heater. The steam passing through the super-heater absorbs heat from hot gases and becomes superheated.

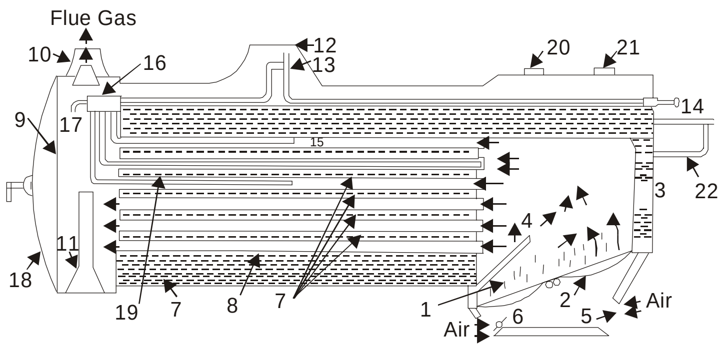
The economizer is placed at the end of side flues before exhausting the hot gases to the chimney. The water before being fed into the boiler through the feed check valve is passed through the economizer. The feed water is heated by absorbing the heat from the exhaust gases, thus leading to better boiler efficiency. Generally, a chimney is used to provide the draught.

5.5 LOCOMOTIVE BOILER

Locomotive boiler is a horizontal fire tube type mobile boiler. The main requirement of this boiler is that it should produce steam at a very high rate. Therefore, this boiler requires a large amount of heating surface and large grate area to burn coal at a rapid rate. Providing provides the large heating surface area a large number of fire tubes and heat transfer rate is increased by creating strong draught by means of steam jet.

A modern locomotive boiler is shown in Fig. 5.3. It consists of a shell or barrel of 1.5 meter in diameter and 4 meters in length. The cylindrical shell is fitted to a rectangular firebox at one end and smoke box at the other end. The coal is manually fed on to the grates through the fire door. A brick arch as shown in the figure deflects the hot gases, which are generated due to the burning of coal. The firebox is entirely surrounded by narrow water spaces except for the fire hole and the ash-pit. The deflection of hot gases with the help of brick arch prevents the flow of ash and coal particles with the gases and it also helps for heating the walls of the firebox properly and uniformly. It also helps in igniting the volatile matter from coal. The walls of the firebox work like an economizer. The ash-pit, which is situated below the firebox, is fitted with dampers at its front and back end shown in the figure to control the flow of air to the grate.

The hot gases from the firebox are passed through the fire tubes to the smoke box as shown in the figure. The gases coming to smoke box are discharged to the atmosphere through a short chimney with the help of a steam jet. All the fire tubes are fitted in the main shell. Some of these tubes (24 in number) are of larger diameter (13 cm diameter) fitted at the upper part of the shell and others (nearly 160 tubes) of 4.75 cm in diameter are fitted into the lower part of the shell. The shell contains water surrounding all the tubes. The top tubes are made of larger diameter to accommodate the super-heater tubes. Absorbing heat from the hot gases flowing over the tubes superheats the steam passing through the super-heater tubes. The steam generated in the shell is collected over the water surface. A dome-shaped chamber, known as steam dome, is fitted on the top of the shell. The dome helps to reduce the priming as the distance of the steam entering into the dome and water level is increased. The steam in the shell flows through a pipe mounted in the steam dome as shown in the figure into the steam header which is divided into two parts. One part of the steam header is known as saturated steam header and the other part is known as superheated steam header. The saturated wet steam through the steam pipe enters into the saturated steam header and then it is passed through the super-heater tubes as shown in the figure. The superheated steam coming out of super-heater tubes is collected in the superheated header and then fed to the steam engines. A stop valve serving also as a regulator for steam flow is provided inside a cylindrical steam dome as shown in the figure. This is operated by the driver through a regulator shaft passing from the front of the boiler.



1. Fire box
2. Grate
3. Fire hole
4. Fire bride arch
5. Ash pit
6. Damper
7. Fine tubes
8. Barrel or shell
9. Smoke box
10. Chimney (short)
11. Exhaust steam pipe
12. Steam dome
13. Regulator
14. Lever
15. Superheater tubes
16. Superheater header
17. Superheater exist pipe
18. Smoke box door
19. Feed check valve
20. Safety valve
21. Whistle
22. Water gauge

Fig. 5.3. Locomotive Boiler.

The supply of air to the grate is obtained by discharging the exhaust steam from the engine through a blast pipe which is placed below the chimney. The air-flow caused by this method is known as induced draught. A large door at the front end of the smoke box is provided which can be opened for cleaning the smoke box and fire tubes.

The height of the chimney must be low to facilitate the locomotive to pass through tunnels and bridges. Because of the short chimney, artificial draught has to be created to drive out the hot gases. The draught is created with the help of exhaust steam when locomotive is moving and with the help of live steam when the locomotive is stationary. The motion of the locomotive helps not only to increase the draught, but also to increase the heat transfer rate.

The pressure gauge and water level indicators are located m the driver's cabin at the front of the fire box as shown in the figure. The spring loaded safety valve and fusible plug are located as shown in the figure. Blow-off cock is provided at the bottom of the water wall to remove the debris and mud.

The outstanding features of this boiler are listed below :

1. Large rate of steam generation per square metre of heating surface. To some extent this is due to the vibration caused by the motion.

2. It is free from brickwork, special foundation and chimney. This reduces the cost of installation.

3. It is very compact.

The pressure of the steam is limited to about 20 bar. The details of W.G.Type Locomotive

Diameter and length of shell Ordinary tubes

Large size tubes

Pressure and temperature of steam Grate area

Heating surface area = 270 m^2.

The capacity of this boiler under normal load is 8500 kg/hr at 14.76 bar and 370°C burning 158.5 kg of coal per hour/m^2 of grate area.

Boiler manufactured at Chittaranjan are listed below : = 208.5 cm and 520.7 cm

= 116 and 57.15 mm in diameter = 38 and 114.3 mm in diameter = 14.76 bar and 370°C

= 4.27′11^2

5.6 BABCOCK WILCOX BOILER

As classified earlier, in a water tube boiler, the water is inside the tubes and hot gases flow over the tubes. Babcock and Wilcox original model is a straight water tube boiler. A simple stationary boiler of this type is described here.

The boiler with its parts is shown in Fig. 5.4. The boiler shell known as water and steam drum is made of high quantity steel. It is connected by short tubes with the uptake header or riser and by longer tubes to the down take header. The water level in the drum is slightly above the center. The water tubes are connected to the top and bottom header and are kept inclined at an angle of 15° to the horizontal. The headers are provided with hand holes in the front of the tubes and are covered with caps. This arrangement helps in cleaning of the tubes. The inclined position helps the flow of water.

The furnace is arranged below the uptake header. Coal is fed to the grate through the fire door. Two firebrick baffles are arranged in such a manner that the hot gases from the grate are compelled to move in the upward and downward directions. First the hot gases rise upward and then go down and then rise up again and finally escape to the chimney through the smoke chamber.

The outer surface of the water tubes and half of the bottom cylindrical surface of the drum form the heating surface through which heat is transferred from the hot gases to the water.

The front portion of the water tubes come in contact with the hot gases at higher temperature. So the water from this portion rises in the upper direction due to decreased density and passed into the drum through the uptake header. Here the steam and water are separated and the steam being lighter is collected in the upper part of the drum. From the back portion of the drum, the water enters into the water tubes through the down take header. Thus, a continuous circulation of water from the drum to the water tubes and water tubes to the drum is maintained. The circulation of water is maintained by convective currents and is known as natural circulation.

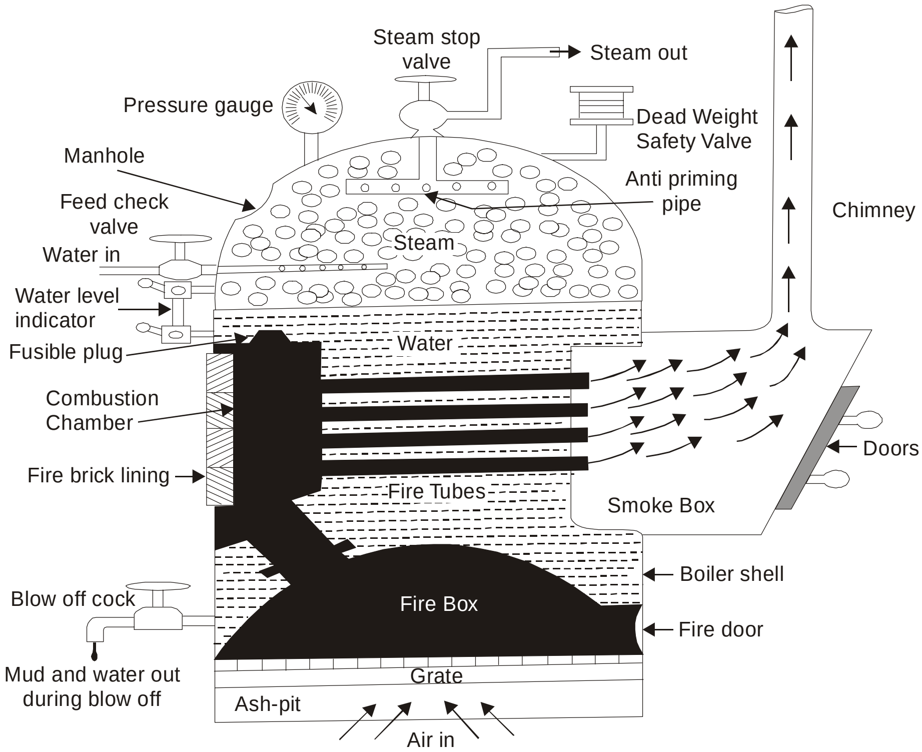


Fig. 5.4. Babcock Wilcox Boiler.

A super-heater is placed between the drum and water-tubes as shown in the figure. During the first turn of the hot gases, the gases are passed over the super-heater tubes and the steam is passed through the super-heater and becomes superheated steam. The steam is taken into the super-heater from the steam space of the drum through a tube as shown in the figure. The superheated steam coming out through super-heater is supplied through steam-pipe and steam stop valve to the turbine. When the steam is being raised from cold boiler, the super-heater is filled with water to the drum water level. This is essential to prevent the overheating of the super-heater tubes. The super-heater remains flooded with water until the steam reaches the working pressure. Once the rated pressure of steam is achieved in the boiler, then the water from the super-heater is drained and steam is fed to it for superheating purposes.

A mud box is fitted to the down header as shown in the figure. The impurities and mud particles from the water are collected in the mud box and they are blown-off from time to time by means of a blow off valve as shown in the figure.

The access to the interior of the boiler is provided by the doors. This is necessary for cleaning the tubes and removing the soots from their surfaces. The draught is regulated by a damper which is provided in the back chamber as shown in the figure. The damper position is controlled with the help of chain connected to it from the pulley as shown in figure.

The outstanding features of this boiler are listed below :

1. The evaporative capacity of this boilers is high compared with other boilers (20,000 to 40,000 kg/hr). The operating pressure lies between 11.5 to 17.5 bar.

2. The draught loss is minimum compared with other boilers.

3. The defective tubes can be replaced easily.

4. The entire boiler rests over an iron structure, independent of brick work, so that the boiler may expand or contract freely. The brick walls which form the surroundings of the boiler are only to enclose the furnace and the hot gases.

5.7 INDUSTRIAL BOILERS

The boilers are generally required in chemical industries, paper industries, pharmaceutical industries and many others. Efficiency, reliability and cost are major factors in the design of industrial boilers similar to central stations. Boiler’s capacity varies from 100 to 400 tons of steam per hour. Industrial companies in foreign countries with large steam demands have considerable interest in cogeneration, the simultaneous production of steam and electricity because of federal legislation. High temperature and high pressure boilers 350°C and 75 ata) are now-a-days used even though high pressure and temperature are rarely, needed to. process requirement but they are used to generate electricity to surging prices of the oil, most of the industrial boilers are designed to use wood, municipal - pulverized coal, industrial solid waste and refinery gas few industrial boilers which are in common use are discussed below.

Packaged Water-tube Boilers. The boilers having a capacity of 50 tons/hr are generally designed with water cooled furnaces. Advantages of this design include minimum weight and maintenance as well rigidity and safety. Presently the boilers are also designed to burn coal, wood and process waste also. The much larger furnace volumes required in units designed for solid fuels restrict the capacity of packaged units to about 40 tons/hr or about one-third of a oil-gas fired unit that can be shipped by railroad.

5.8 MERITS AND DEMERITS OF WATER TUBE BOILERS OVER FIRE TUBE BOILERS MERITS

1. Generation of steam is much quicker due to small ratio of water content to steam content. This also helps in reaching the steaming temperature in short time.
2. Its evaporative capacity is considerably larger and the steam pressure range is also high-200 bar.
3. Heating surfaces are more effective as the hot gases travel at right angles to the direction of water flow.
4. The combustion efficiency is higher because complete combustion of fuel is possible as the combustion space is much larger.
5. The thermal stresses in the boiler parts are less as different parts of the boiler remain at uniform temperature due to quick circulation of water.
6. The boiler can be easily transported and erected as its different parts can be separated.
7. Damage due to the bursting of water tube is less serious. Therefore, water tube boilers are sometimes called safety boilers.
8. All parts of the water tube boilers are easily accessible for cleaning, inspecting and repairing.
9. The water tube boiler's furnace area can be easily altered to meet the fuel requirements.

Demerits :

1. It is less suitable for impure and sedimentary water, as a small deposit of scale may cause the overheating and bursting of tube. Therefore, use of pure feed water is essential.
2. They require careful attention. The maintenance costs are higher.
3. Failure in feed water supply even for short period is liable to make the boiler over-heated.

5.9 REQUIREMENTS OF A GOOD BOILER

A good boiler must possess the following qualities :

1. The boiler should be capable to generate steam at the required pressure and quantity as quickly as possible with minimum fuel consumption.

2. The initial cost, installation cost and the maintenance cost should be as low as possible.

3. The boiler should be light in weight, and should occupy small floor area.

4. The boiler must be able to meet the fluctuating demands without pressure fluctuations.

5. All the parts of the boiler should be easily approachable for cleaning and inspection.

6. The boiler should have a minimum of joints to avoid leaks which may occur due to expansion and contraction.

7. The boiler should be erected at site within a reasonable time and with minimum labour.

8. The water and flue gas velocities should be high for high heat transfer rates with minimum pressure drop through the system.

9. There should be no deposition of mud and foreign materials on the inside surface and soot deposition on the outer surface of the heat transferring parts.

10. The boiler should conform to the safety regulations as laid down in the *Boiler Act.*

5.10 HIGH PRESSURE BOILERS

In all modern power plants, high pressure boilers (> 100 bar) are universally used as they offer the following advantages.

In order to obtain efficient operation and high capacity, forced circulation of water through boiler tubes is found helpful. Some special types of boilers operating at super critical pressures and using forced circulations are described in this chapter.

I . The efficiency and the capacity of the plant can be increased as reduced quantity of steam is required for the same power generation if high pressure steam is used.

2. The forced circulation of water through boiler tubes provides freedom in the arrangement of furnace and water walls, in addition to the reduction in the heat exchange area.

3. The tendency of scale formation is reduced due to high velocity of water.

4. The danger of overheating is reduced as all the parts are uniformly heated.

5. The differential expansion is reduced due to uniform temperature and this reduces the possibility of gas and air leakages.

6. Some special types of high pressure supercritical boilers are described in this chapter.

5.10.1 LA MONT BOILER

A forced circulation boiler was first introduced in 1925 by La Mont. The arrangement of water circulation and different components are shown in Fig. 5.5.

The feed water from hot well is supplied to a storage and separating drum (boiler) through the economizer. Most of the sensible heat is supplied to the feed water passing through the economizer. A pump circulates the water at a rate 8 to 10 times the mass of steam evaporated. This water is circulated through the evaporator tubes and the part of the vapour is separated in the separator drum. The large quantity of water circulated (10 times that of evaporation) prevents the tubes from being overheated.

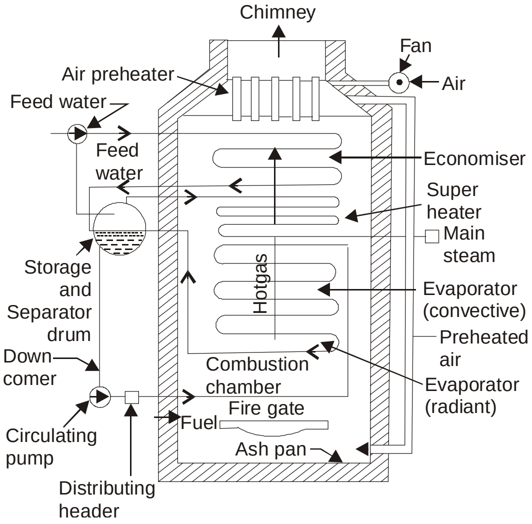


Fig. 5.5. La Mont Boiler.

The centrifugal pump delivers the water to the headers at a pressure of 2.5 bar above the drum pressure. The distribution headers distribute the water through the nozzle into the evaporator.

The steam separated in the boiler is further passed through the super-heater.

Secure a uniform flow of feed water through each of the parallel boiler circuits a choke is fitted entrance to each circuit.

These boilers have been built to generate 45 to 50 tonnes of superheated steam at a pressure of 120 bar and temperature of 500°C. Recently forced circulation has been introduced in large capacity power ?

5.10.2 BENSON BOILER

The main difficulty experienced in the La Mont boiler is the formation and attachment of bubbles on the inner surfaces of the heating tubes. The attached bubbles reduce the heat flow and steam generation as it offers higher thermal resistance compared to water film

1. Benson in 1922 argued that if the boiler pressure was raised to critical pressure (225 atm.), the steam and water would have the same density and therefore the danger of bubble formation can be completely

2. Natural circulation boilers require expansion joints but these are not required for Benson as the pipes are welded. The erection of Benson boiler is easier and quicker as all the parts are welded at site and workshop job of tube expansion is altogether avoided.

3. The transport of Benson boiler parts is easy as no drums are required and majority of the parts are carried to the site without pre-assembly.

4. The Benson boiler can be erected in a comparatively smaller floor area. The space problem does not control the size of Benson boiler used.

5. The furnace walls of the boiler can be more efficiently protected by using small diameter and close pitched tubes.

6. The superheater in the Benson boiler is an integral part of forced circulation system, therefore no special starting arrangement for superheater is required.

7. The Benson boiler can be started very quickly because of welded joints.

8. The Benson boiler can be operated most economically by varying the temperature and pressure at partial loads and overloads. The desired temperature can also be maintained constant at any pressure.

9. Sudden fall of demand creates circulation problems due to bubble formation in the natural circulation boiler which never occurs in Benson boiler. This feature of insensitiveness to load fluctuations makes it more suitable for grid power station as it has better adaptive capacity to meet sudden load fluctuations.

10. The blow-down losses of Benson boiler are hardly 4% of natural circulation boilers of same capacity.

11. Explosion hazards are not at all severe as it consists of only tubes of small diameter and has very little storage capacity compared to drum type boiler.

During starting, the water is passed through the economiser, evaporator, superheater and back to the feed line via starting valve A. During starting the valve B is closed. As the steam generation starts and it becomes superheated, the valve A is closed and the valve B is opened.

During starting, first circulating pumps are started and then the burners are started to avoid the overheating of evaporator and superheater tubes.

5.10.3. LOEFFLER BOILER

The major difficulty experienced in Benson boiler is the deposition of salt and sediment on the inner surfaces of the water tubes. The deposition reduced the heat transfer and ultimately the generating capacity. This further increased the danger of overheating the tubes due to salt deposition as it has high thermal resistance.

The difficulty was solved in Loeffler boiler by preventing the flow of water into the boiler tubes. Most of the steam is generated outside from the feedwater using part of the superheated steam coming out from the boiler.

The pressure feed pump draws the water through the economiser and delivers it into the evaporator drum as shown in the figure. About 65% of the steam coming out of superheater is passed through the evaporator drum in order to evaporate the feed water coming from economiser.

The steam circulating pump draws the saturated steam from the evaporator drum and is passed through the radiant superheater and then connective superheater. About 35% of the steam coming out from the superheater is supplied to the H.P. steam turbine. The steam coming out from H.P. turbine is passed through reheater before supplying to L.P. turbine as shown in the figure.

The amount of steam generated in the evaporator drum is equal to the steam tapped (65%) from the superheater. The nozzles which distribute the superheated steam through the water into the evaporator drum are of special design to avoid priming and noise.

This boiler can carry higher salt concentration than any other type and is more compact than indirectly heated boilers having natural circulation. These qualities fit it for land or sea transport power generation. Loeffler boilers with generating capacity of 94.5 tonnes/hr and operating at 140 bar have already been commissioned.

5.10.4. SCHMIDT-HARTMANN BOILER

The operation of the boiler is similar to an electric transformer. Two pressures are used to effect an interchange of energy.

In the primary circuit, the steam at 100 bar is produced from distilled water. This steam is passed through a submerged heating coil which is located in an evaporator drum as shown in the figure. The high pressure steam in this coil possesses sufficient thermal potential and steam at 60 bar with a heat transfer rate of 2.5 kW/m^2-°C is generated in the evaporator drum.

The steam produced in the evporator drums from impure water is further passed through 'the superheater and then supplied to the prime-mover. The high pressure condensate formed in the submerged heating coil is circulated through a low pressure feed heater on its way to raise the feed water temperature to its saturation temperature. Therefore, only latent heat is supplied in the evaporator drum.

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

In normal circumstances, the replenishment of distilled water in the primary circuit is not required as every care is taken in design and construction to prevent leakage. But as a safeguard against leakage, a pressure gauge and safety valve are fitted in the circuit.

Advantages

1. There is rare chance of overheating or burning the highly heated components of the primary circuit as there is no danger of salt deposition as well as there is no chance of interruption to the circulation either by rust or any other material. The highly heated parts run very safe throughout the life of the boiler.

2. 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.

3. The wide fluctuations of load are easily taken by this boiler without undue priming or abnormal increase in the primary pressure due to high thermal and water capacity of the boiler.

4. The absence of water risers in the drum, and moderate temperature difference across the heating coil allow evaporation to proceed without priming.

5.10.5. VELOX-BOILER

Now, it is known fact that when the gas velocity exceeds the sound-velocity, the heat is transferred from the gas at a much higher rate than rates achieved with sub-sonic flow. The advantages of this theory are taken to effect the large heat transfer from a smaller surface area in this boiler.

Air is compressed to 2.5 bar with an help of a compressor run by gas turbine before supplying to the combusion chamber to get the supersonic velocity of the gases passing through the combustion chamber and gas tubes and high heat release rates (40 MW/m^3). The burned gases in the combustion chamber are passed through the annulus of the tubes as shown in figure. The heat is transferred from gases to water while passing through the annulus to generate the steam. The mixture of water and steam thus formed then passes into a separator which is so designed that the mixture enters with a spiral flow. The centrifugal force thus produced causes the heavier water particles to be thrown outward on the walls. This effect separates the steam from water. The separated steam is further passed to superheater and then supplied to the prime-mover. The water removed from steam in the separator is again passed into the water tubes with the help of a pump.

The gases coming out from the annulus at the top are further passed over the superheater where its heat is used-for superheating the steam. The gases coming out of superheater are used to run a gas turbine as they carry sufficient kinetic energy. The power output of the gas turbine is used to run the air-compressor. The exhaust gases coming out from the gas turbine are passed through the economiser to utilise the remaining heat of the gases. The extra power required to run the compressor is supplied with the help of electric motor. Feed water of 10 to 20 times the weight of steam generated is circulated through the tubes with the help of water circulating pump. This prevents the overheating of metal walls.

The size of the velox boiler is limited to 100 tons per hour because 400 KW is required to run the air compressor at this output. The power developed by the gas turbine is not sufficient to run the compressor and therefore some power from external source must be supplied as mentioned above.

Advantages

1. Very high combustion rates are possible as 40 MJ/m^3 of combustion chamber volume.
2. Low excess air is required as the pressurised air is used and the problem of draught is simplified.
3. It is very compact generating unit and has greater flexibility.
4. It can be quickly started even though the separator has a storage capacity of about 10% of the maximum hourly output.

EXERCISES

1. State how the boilers are classified ?

2. Explain the principle of fire tube and water tube boilers.

3. Describe with a neat sketch the working of Cochran boiler. Show the position of different mountings and explain the function of each.

4. Describe, giving neat sketches, the construction and working of a Lancashire boiler. Show the positions of different mountings and accessories.

5. Sketch and describe the working of a Locomotive boiler. Show the positions of fusible plug, blow off cock, feed check valve and superheater. Mention the function of each. Describe the method of obtaining draught in this boiler.

6. Give an outline sketch showing the arrangement of water tubes and furnace of a Babcock and Wilcox boiler. Indicate on it the path of the flue gases and water circulation. Show the positions of fusible plug, blow off cock and superheater. Mention the function of each.

7. Explain why the superheater tubes are flooded with water at the starting of the boilers ?

8. Mention the chief advantages and disadvantages of fire tube boilers over water tube boilers.

9. Discuss the chief advantages of water tube boilers over fire tube boilers.

10. What are the considerations which would guide you in selecting the type of boiler to be adopted for a specific purpose ?

11. Distinguish between water-tube and fire-tube boilers and state under what circumstances each type would be desirable.