Chapter 6

STEAM BOILERS

6.1 INTRODUCTION

- A boiler may be defined as a closed vessel in which steam is produced from water by combustion of fuel at the desired temperature and pressure.
- According to the Indian Boiler Regulations — 1950 (I.B.R.), a boiler is a closed pressure vessel with capacity exceeding 22.75 litres used for generating steam under pressure. It includes all the mountings fitted to such vessels which remain wholly or partly under pressure when steam is shut off.
- According to American Society of Mechanical Engineers (A.S.M.E.), a steam generating unit is defined as :

  "A combination of apparatus for producing, furnishing or recovering heat together with the apparatus for transferring the heat so made available to the fluid being heated and vaporised".
- The difference between a steam boiler and a steam generator is that a steam boiler consists only of the containing vessel and convection heating surfaces, whereas a steam generator covers the whole unit including water wall tubes, superheater, airheat and economiser.
- The steam generated is employed for the following purposes :
  1. Generating power in steam engines and steam turbines.
  2. Process heating in textile, sugar mills, chemical industries, etc.
  3. Heating of buildings in cold weather and producing hot water for hot water supply.
- The primary requirements of boilers or steam generators are :
  1. The water must be contained safely.
  2. The steam must be safely delivered in desired condition, *i.e.*, pressure, temperature, quality and mass flow rate.

Steam generator=steam boiler + its mountings&accessories

6.2 CLASSIFICATION OF STEAM GENERATORS

Steam generators may be classified on the following basis :

1. Water tube and fire tube,
2. Natural/forced circulation,
3. Horizontal, vertical or inclined,
4. Single/ multiple tube(s),
5. Stationary/mobile
6. Internally/externally fired
7. Source of heat

1. In a water tube boiler, water or steam flows through the tubes and heat is supplied to outside surface. Babcock and Wilcox and Stirling boilers are of this category.

   In case of fire tube boiler, hot gases flow through the tubes and water circulates outside the tubes. There may be one large tube surrounded by water as in Cornish boiler, or two large tubes

surrounded by water in a big tube of water as in the case of Lancashire boiler. There may be many smaller tubes through which hot gases pass and all surrounded by water as in the case of vertical Cochran or Locomotive boiler.

2. Natural circulation of water takes place by natural convection currents produced by application of heat as in the case of Lancashire boiler and Babcock and Wilcox boiler.

   In forced circulation, the fluid is forced 'once through' or controlled with partial recirculation as in the case of Lamont boiler, Velox boiler and Benson boiler.

3. The disposition on the principal axis of the boiler decides whether the boiler is horizontal, vertical or inclined.
4. A boiler may have only one fire/water tube or multiple tubes.
5. The boilers are called either stationary (land) or mobile (marine and locomotive). Stationary boilers are used for power plant steam generation. Mobile boilers are portable boilers.
6. The boiler is said to be external combustion takes place outside the region of boiling water. The boiler is said to be internal combustion boiler, if the furnace region is completely surrounded by water-cooled surface as in the case of Lancashire boiler.
7. Boilers may be classified according to the source from which heat is supplied to water for evaporation. For example, coal fired, oil fired, gas fired, electrical energy or nuclear energy.

6.3 COMPARISON OF FIRE TUBE AND WATER TUBE BOILERS

	Criteria	Fire tube Boilers	Water tube Boilers
1.	Raising of steam	Less rapid	More rapid
2.	Suitability for large power plants	Unsuitable because of lower rate of steam raised.	Suitable because of higher rate of steam raised
3.	Operating pressure	≤ 25 bar	> 125 bar
4.	Floor area required per kg of steam	Less	More
5.	Reliability and cost	Greater reliability and low cost	Require careful attention and maintenance costs are higher
6.	Suitability for rapid changes in load	Suitable	Unsuitable
7.	Damage due to failure in feed water supply	No damage to boiler as it contains large quantity of water	The boiler shall be overloaded
8.	Risk of damage to property in case of bursting.	Serious because of its large water capacity	Less serious
9.	Transportation	Very inconvenience because of large size	Can be easily transported and erected as various parts can be separated.
10.	Chances of bursting	Less	More
11.	Maintenance	Difficult for maintenance	All parts are easily accessible for cleaning, inspection and repairing.
12.	Treatment of feed water	Not essential	Essential

6.7.1 Fire Tube Boilers

1. Simple Vertical Boiler. A simple vertical boiler is shown in Fig. 6.1. It consists of a cylindrical shell the greater portion of which is full of water and remaining is the steam space. At the bottom of the fire box is grate on which fuel is burnt and the ash from it falls in the ash pit. The fire box is provided with two cross tubes. This increases the heating surface and the circulation of water. The cross tubes are fitted inclined for efficient circulation of water. At the ends of each cross tube are provided hand holes to give access for cleaning these tubes. The combustion gases after heating water and converting it into steam escape to the atmosphere through the chimney. Manhole is provided to clean the interior of the boiler and exterior of the combustion chamber and chimney. The various mountings are : pressure gauge, water level indicator, safety valve, steam stop valve, feed check valve, and blow-off cock.

The rate of steam generation of such a boiler does not exceed 2500 kg/h and pressure is generally limited to 7.5 to 10 bar. The efficiency of this boiler is also low. However, it is very compact, occupies less space and easy to transport.

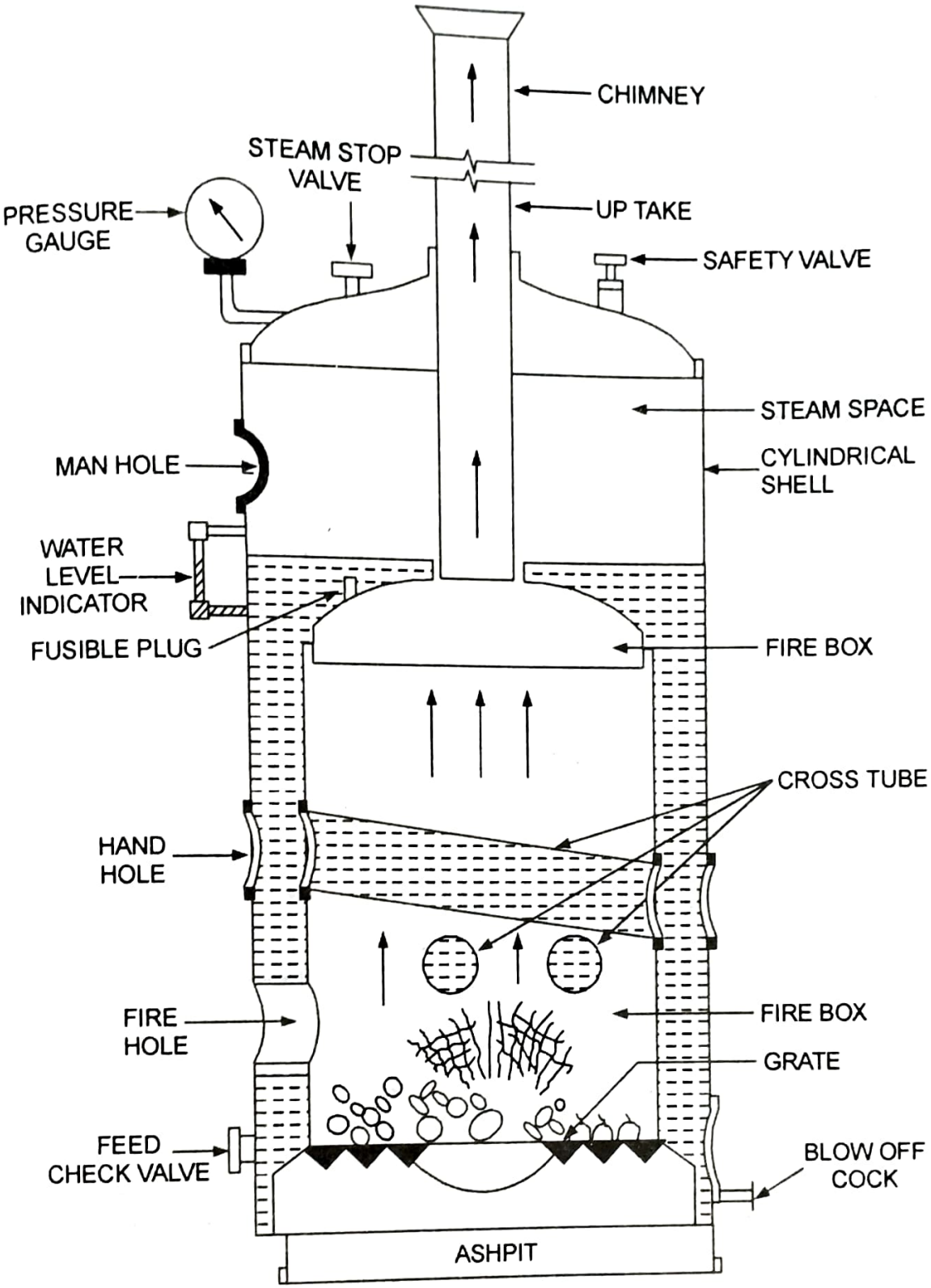

Fig. 6.1 Simple Vertical Boiler

6.7.2 Water Tube Boilers

For pressures above 10 bar and capacities in excess of 7000 kg of steam per hour, the water tube boiler is used almost exclusively.

1. Babcock and Wilcox Boiler. Fig 6.7 shows a stationary type Babcock and Wilcox boiler. It consists of a large number of parallel tubes inclined at an angle which varies from 5° to 15° to the horizontal which connect the uptake header with the down take header. Both of these are connected to the shell having a substantial quantity of water in it. The uptake header is connected to the shell, through a short tube while a long tube is employed to connect the down take header with the shell. The coal is fed through the fire hole on to the chain grate stoker. The velocity of the chain is so adjusted as to ensure complete combustion of coal by the time it reaches the other end of the grate. The flue gases first rise up then move down and once again rise up due to the presence of the baffles. The hot water and steam moisture rise up through the uptake header into the boiler shell, where steam separates from water and collects in the steam space. The cold water flows down into the tubes through the down take header. Thus a continuous circulation of water is maintained by the convection currents set up.

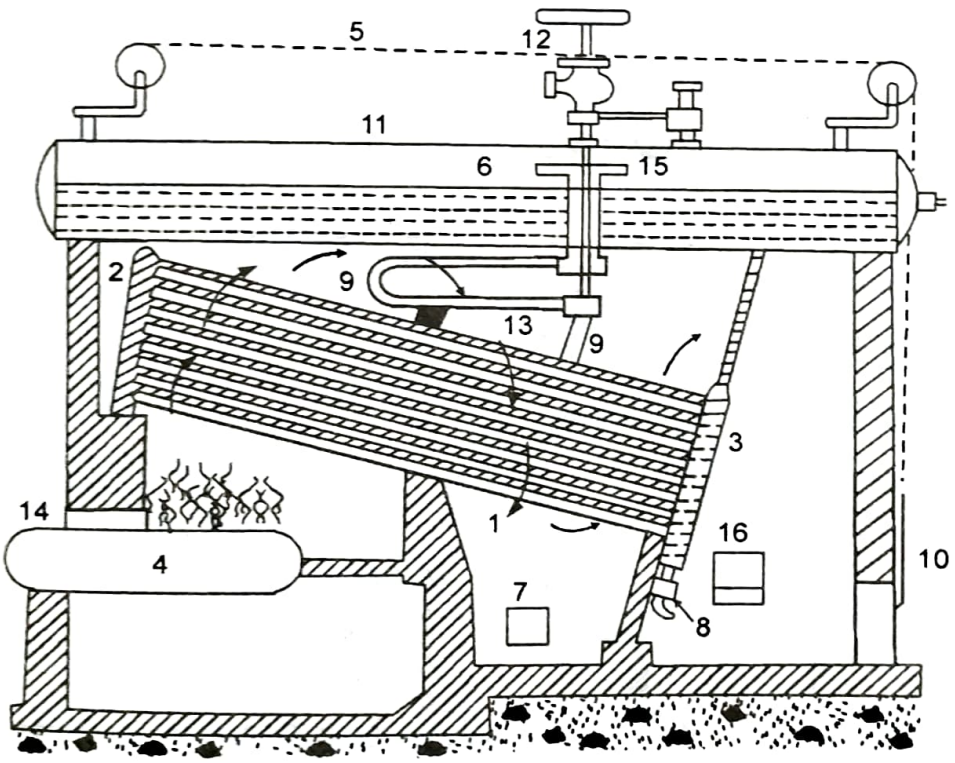

Fig. 6.7 Babcock and Wilcox boiler

Legend

1. Water tubes
2. Uptake header
3. Downtake header
4. Grate
5. Damper chain
6. Steam pipe
7. Soot doors
8. Mud box
9. Baffles
10. Damper
11. Shell
12. Stop valve
13. Super heater tubes
14. Fire hole
15. Tube
16. Side flue

Super heater — A set of super heater tubes is provided to superheat steam which enters these tubes from the steam space in the boiler shell. The superheated steam can be taken out to the steam stop valve, through the steam pipe. The lower part of the down take header has a mud box attached to it to collect the sediments. The damper chain controls the quantity of air flowing through the boiler. Two soot doors are provided for internal cleaning of boiler.

Its steaming capacity is 40,000 kg/h at a maximum pressure of 40 bar. It is used in large power stations due to greater operational safety and lesser space area required as compared to fire tube boilers to generate steam at the same pressure.

Advantages :

1. Both solid and liquid fuels can be burnt.
2. Minimum draught losses.
3. High evaporation capacity.
4. Natural water circulation.
5. Defective tubes can be easily replaced.