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STEAM BOILERS



A *steam boiler or generator* is a closed vessel in which the steam at the desired pressure and temperature is generated from water by the application of heat. The steam thus generated may be used for the following purposes.

1. To generate power as in the case of steam engines and steam turbines.
2. For process work in cotton mills, sugar mills, paper mills, breweries, chemical industries, etc.
3. For home heating in cold countries.

Classification of boilers

The important classifications of steam boilers are as follows :

1. According to relative position of water and hot gases:

- (i) Fire tube or smoke tube boiler, and (ii) Water tube boiler.

In fire tube boiler, the hot flue gases from the boiler furnace flow through the tubes, which are surrounded with water (refer fig. 3.1a). Examples of fire tube boiler are Cochran, Lancashire, Cornish, locomotive, Scotch marine, etc.

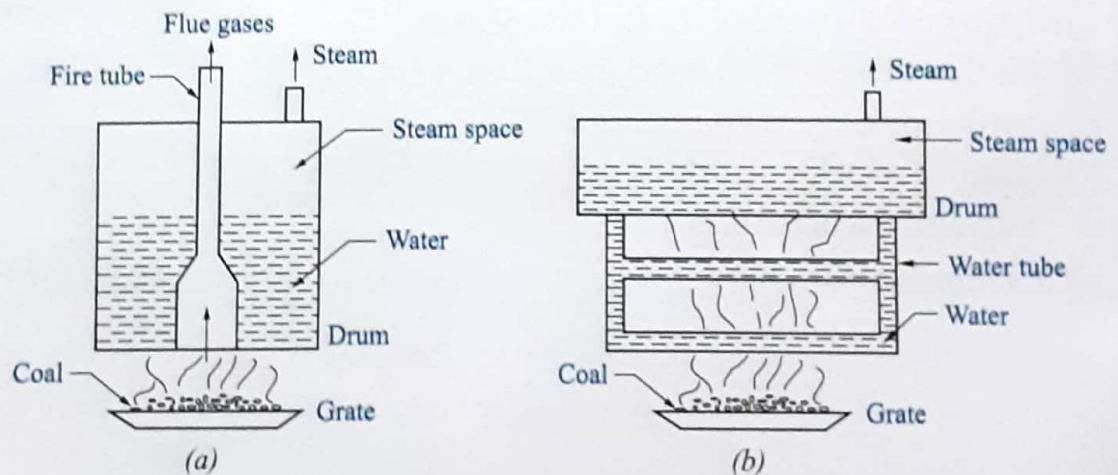


Fig. 3.1 (a) Fire tube boiler (b) Water tube boiler

In water tube boiler, the water flows within the tubes, which are surrounded by hot flue gases from the boiler furnace (refer fig. 3.1b). Examples of water tube boiler are Babcock and Wilcox, Stirling, La Mont, etc.

2. According to the location of furnace:

- (i) Internally fired, and (ii) Externally fired.

In internally fired boiler the furnace is provided inside the boiler shell. Most of the fire tube boilers are internally fired. In externally fired boilers, the furnace is provided outside the boiler shell. Water tube boilers are always externally fired.

3. *According to the axis of the shell:*

- (i) Vertical, and (ii) Horizontal.

In vertical steam boilers, the axis of the shell is placed vertical. Examples of this type are vertical, Cochran, etc. In horizontal steam boilers, the axis of the shell is placed horizontal. Examples of this type are Cornish, Lancashire, locomotive, etc.

4. *According to the method of circulation of water and steam:*

- (i) Natural circulation, and (ii) Forced circulation.

In natural circulation boilers, water is circulated by natural convection currents, which are set up due to the temperature difference. Most of the conventional boilers are natural circulation type. In forced circulation boilers water is circulated with the help of a pump. Forced circulation is used in high pressure boilers such as La Mont, Loeffler, Benson, etc.

5. *According to the number of tubes:*

- (i) Single tube boiler, and (ii) Multi-tubular boiler.

In single tube boilers there is only one fire tube or water tube whereas in multi-tubular boilers there are two or more fire tubes or water tubes.

6. *According to the use:*

- (i) Stationary, (ii) Locomotive, (iii) Marine, (iv) Portable, etc.

7. *According to the source of heat:*

Boilers may be classified according to the source of heat for generating steam. Such source may be from the combustion of solid, liquid or gaseous fuel, hot waste flue gases, electrical energy, nuclear energy, etc.

Requirements of a boiler:

The following are the general requirements in boiler selection;

1. It should generate high rate of steam with minimum fuel consumption.
2. It should be able to meet wide fluctuations of steam load.
3. Components should be easily accessible for maintenance and replacements.
4. Suitable for different types of fuel.
5. Less cost and less floor space requirement.

Lancashire boiler

Lancashire boiler is a horizontal type fire tube boiler. It is used for supplying steam to stationary engines in factories and power stations. Fig. 3.2 shows a Lancashire boiler. It consists of a horizontal cylindrical shell with flat or dished ends. There are two flues or furnace tubes, which extend over the entire length of the boiler. The flue tubes are built up of several cylindrical rings or of corrugated in construction (not shown). The flue tubes are made large in diameter at the front to accommodate the furnace and are tapered to a smaller diameter at the rear end. There are two grates one for each flue tube

and two fire holes. At the back end of the grate is a low firebrick bridge. The function of the bridge is to prevent the entry of unburned fuel and ash particles into the flue tubes and also helps in deflecting the hot gases upwards to provide better heat transfer. The boiler is set in a brickwork forming one bottom flue and two side flues so that the external shell forms a part of heating surface. A man hole is provided at the top of the shell for cleaning the boiler and inspection or repairs. A mud hole is provided at the bottom of the shell to remove the sediment, which gets accumulated.

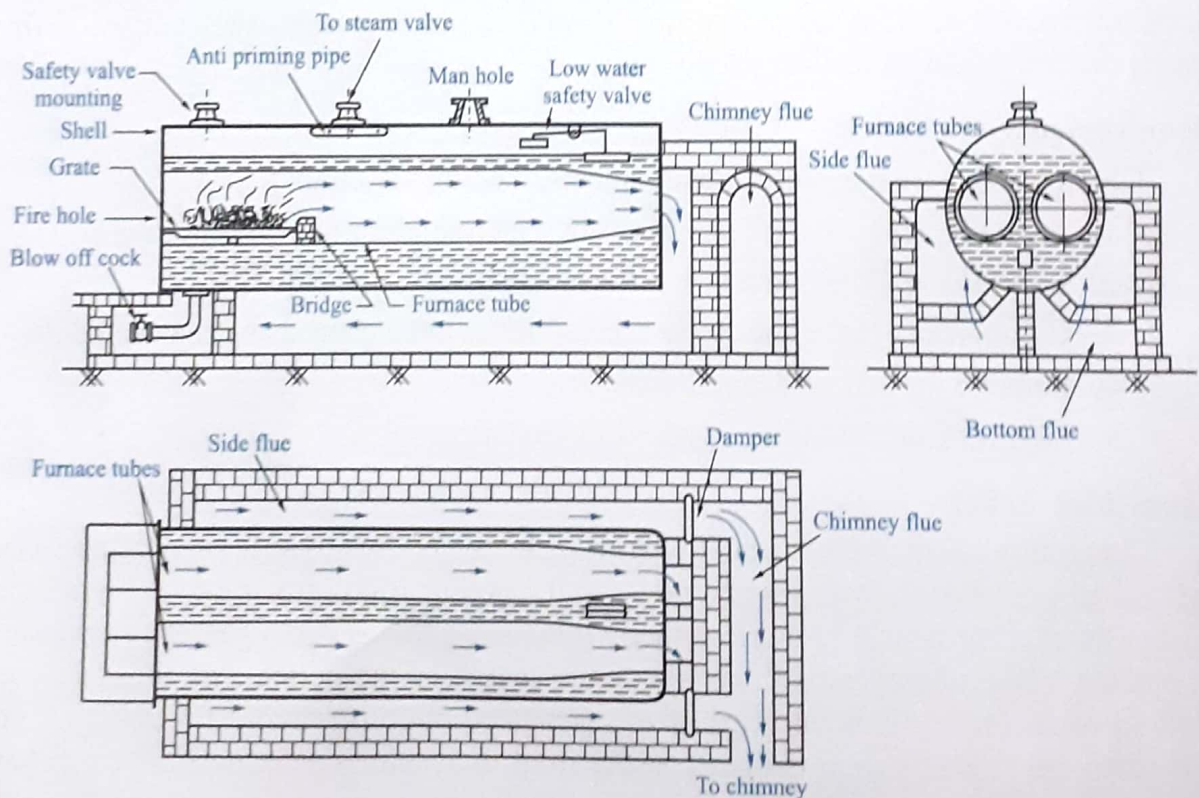


Fig. 3.2 Lancashire boiler

Working : The boiler is filled with substantial quantity of water. The fuel is charged through the furnace doors. The fuel burns in the grates. The product of combustion pass first through the flue tubes, then return along a brick built flue under the boiler to the front end. Here the hot gases divide and flow along the two side flues to the rear end and then pass to the chimney. The steam is accumulated in the steam space above the surface of water and can be tapped off through the steam stop valve connected to an anti-priming tube.

Advantages and disadvantages of Lancashire boiler

Advantages:

1. It is simple in design and reliable.
2. It is easy to operate.
3. It is easy to clean and inspect.
4. Less maintenance.
5. Heating surface area per unit volume of the boiler is considerably large.
6. It can meet sudden demands of steam.

Disadvantages:

1. It occupies more floor space.
2. The shell construction restricts the maximum working pressure.
3. The brickwork setting is expensive and troublesome in maintenance.
4. The grate area is restricted by the diameter of the flue tubes.
5. It takes more time to generate steam initially.

Babcock and Wilcox boiler

This is one of the most popular type of water tube boiler employed both for large as well as small power stations. A simple land type Babcock and Wilcox straight tube boiler is shown fig. 3.3. It consists of a steam and water drum, in which the water level being kept at about the middle of the drum, the remainder being the steam space. The steam and water drum is suspended from iron girders resting on iron columns. A number of horizontally inclined straight water tubes are connected to the front headers forming uptakes at the front end (on the left hand side of the figure), and to the rear headers forming down takes at the rear end. The headers are in turn connected to the boiler drum by means of steel tubes to complete the water circuit. The headers are fitted with covered inspection holes for cleaning of water tubes periodically. A mud box is attached to the bottom of the down take header in which sediment collects, and from which it may be blown off by means of a blow-off valve. A superheater is placed between the drum and water tubes for the purpose of superheating the steam. The steam is taken from the steam space through a perforated pipe (anti-priming pipe) and downwards into the superheater, entering the superheater at the upper part. The steam leaving the superheater at the lower part is carried by a pipe to the stop valve from where it is delivered to the engine.

The furnace is placed below the uptake header. Baffles are introduced across the water tubes to act as deflectors, which cause the furnace gases to cross the tubes three times before leaving the boiler. The boiler is surrounded on all four sides by firebrick walls. Doors are provided for a man to enter for repairing and cleaning.

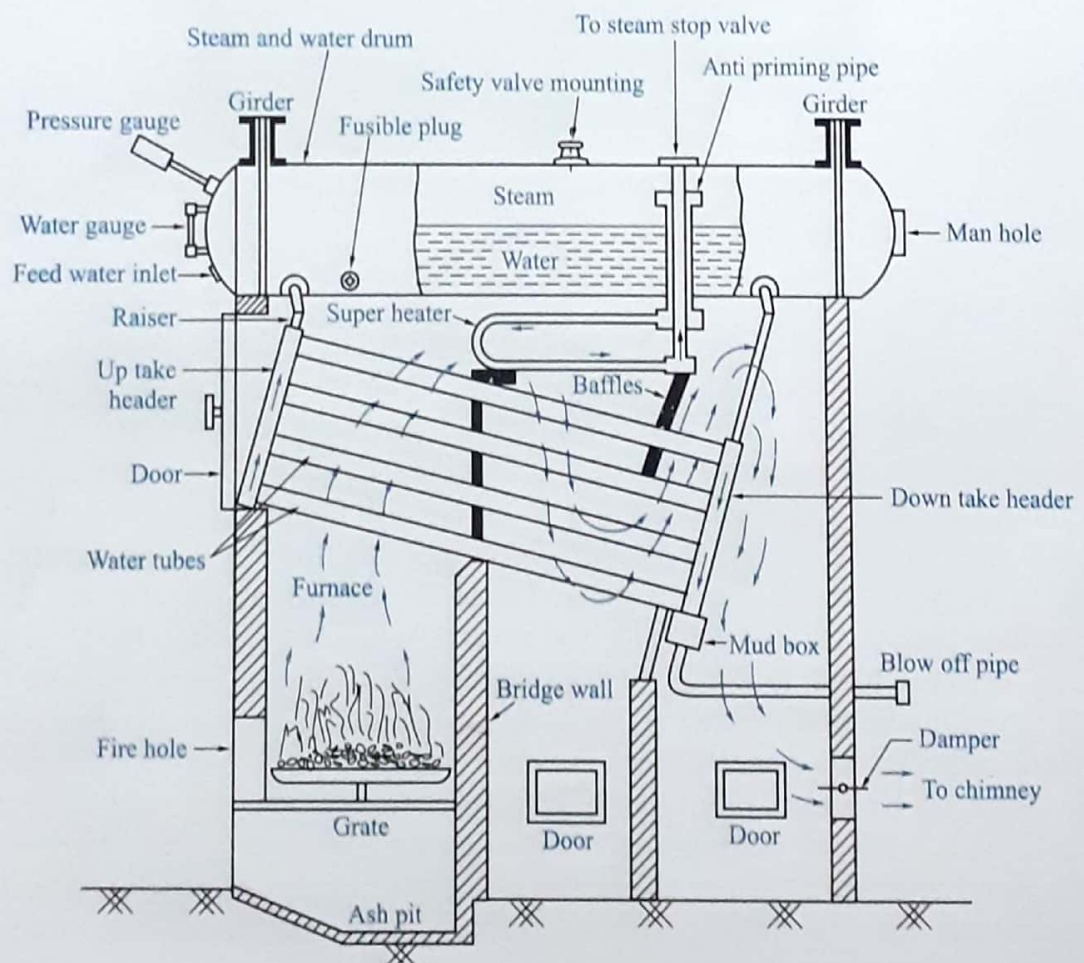
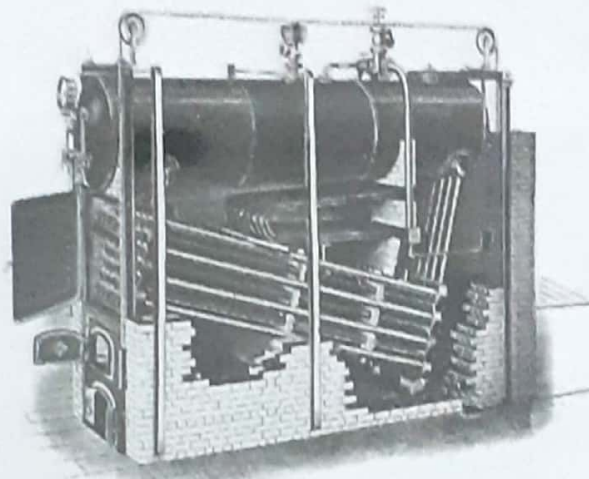


Fig. 3.3 Babcock and Wilcox boiler

Working: The boiler is filled with substantial quantity of water. The coal is charged through the fire hole. The coal burns in the grate. The hot gases of combustion first rise up, then move down and once again rise up due to the presence of baffles. It finally escapes to the chimney through the smoke chamber. 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. From the steam space the steam is led to the superheater tubes and the superheated steam can be tapped off through the steam stop valve.

Advantages and disadvantages of Babcock and Wilcox boiler:

Advantages:

1. The steam generating capacity is very high.
2. It can meet sudden fluctuation of load.
3. Ease of maintenance.
4. The boiler may expand and contract freely due to flexible support structure.
5. Minimum draft loss.

Disadvantages:

1. High initial and maintenance cost.
2. Most of the parts need to be assembled at the site.

Comparison between fire tube boilers and water tube boilers

<i>Fire tube boilers</i>	<i>Water tube boilers</i>
1. The hot flue gases flows through the tubes that are surrounded with water.	Water flows within the tubes and are surrounded by hot flue gases.
2. Internally fired boilers.	Externally fired boilers.
3. Low evaporating capacity, hence it takes more time to generate steam.	High evaporating capacity, hence the generation of steam is quicker.
4. For the given power, it occupies more space.	It occupies less space.
5. Various parts are not so easily accessible for cleaning and inspection or repair.	All the parts are easily accessible for cleaning and inspection or repair.
6. Suitable for less impure feed water.	Require feed water treatment plant.
7. Bursting of fire tube boilers cause less risk.	Bursting of water tube boilers become very serious.
8. Operating pressure is limited to 20 bar.	Can work under high pressure (100 bar).
9. Less maintenance cost.	Operation and maintenance costs are higher.
10. Suitable for small power plants and locomotives.	Suitable for large power plants.

Boiler mountings and accessories

The proper and satisfactory functioning of a steam boiler depends upon certain mountings and accessories, which must be fitted to it. Boiler mountings are required to provide the safety of the boiler and to control the process of steam generation. Generally mountings are mounted over the boiler shell. The mountings commonly fitted on a boiler are; water level indicator, pressure gauge, stop valve, feed check valve, blow off cock, fusible plug, and safety valve.

Accessories are required to increase the efficiency of the boiler and for the proper working of the plant. Generally accessories are not mounted directly on the boiler. The principal accessories are economiser, air pre-heater, superheater, injector, feed pump, steam separator and steam trap.

Boiler mountings

Water level indicator or water gauge: The object of water gauge is to indicate the level of water in the boiler so as to enable the attendant to regulate the supply of feed water.

Pressure gauge: A pressure gauge is used to measure the pressure of steam inside the boiler. It is fitted in front of a boiler in such a position that the operator can conveniently read it. The most commonly used pressure gauge is the Bourdon pressure gauge.

Steam stop valve: The function of the stop valve is to regulate the flow of steam. When it is mounted over the boiler to control the flow of steam from the boiler, it is called a *junction valve*. If the valve is placed near the engine or between the steam pipes it is called *stop valve*.

Feed check valve: The feed check valve is used to control the supply of water to the boiler and to prevent the escaping of water from the boiler when the pump pressure is less than the boiler pressure. It is fitted over the shell below the normal water level of the boiler.

Blow-off cock: It is fitted at the lower part of the boiler. The functions of a blow off cock are:

1. To empty the boiler while it is to be cleaned or inspected.
2. To discharge the mud, scale or sediments collected at the bottom of the boiler.

Fusible plug: The fusible plug is used to protect the boiler against the damage due to overheating for low water level. It is fitted over the furnace crown.

Safety valve: Safety valve is a device attached to the steam chest of the boiler for preventing explosions due to excessive internal pressure of steam. A good safety valve is one, which will not permit the pressure in the boiler to rise above a fixed value and having reached that value will allow excess of steam to escape as fast as it is generated by the boiler. Usually two safety valves are fitted on the top of the boiler. The most commonly used safety valves are:

1. Dead weight safety valve,
2. Lever safety valve,
3. Spring loaded safety valve, and
4. High steam and low water safety valve.

Dead weight safety valve: A dead weight safety valve is used for stationary boiler. It has the following disadvantages:

1. Heavy weight

2. Not suitable for locomotive and marine boiler as they are subjected to vibration

Lever safety valve: A lever safety valve is suitable for stationary boiler only as it is affected by vibration.

Spring loaded safety valve: Spring loaded safety valve is suitable for locomotive or marine boiler where it is subjected to jerks and vibration. The most commonly used valve is the Ramsbottom spring loaded safety valve. Spring loaded safety valve have the following advantages over the dead weight and lever safety valves.

1. Elimination of heavy weight.
2. Easy examination and maintenance.
3. In case of locomotive and marine boiler the load on the valve is not affected due to jerks, pitching and rolling.

One disadvantage of the spring loaded safety valve is that the load on the valve increases as the valve lifts, so that the pressure required just to lift the valve is less than that required to open it fully.

High steam and low water safety valve: It is a combined safety arrangement against high steam pressure and low water level. This type of safety valve is generally used in Lancashire and Cornish boilers.

Boiler accessories

Economiser: An economiser is a device used to heat the feed water by utilising the heat in the exhaust flue gases before leaving the chimney. It is placed in the flue between the boiler and the chimney. The advantages gained by installing an economiser are:

1. Fuel economy,
2. Increase in steam generation rate, and
3. Long life of the boiler.

Air pre-heater: The function of an air pre-heater is to transfer heat from the flue gases to the air fed to the furnace for combustion purpose. It is installed between the economiser and the chimney. The advantages gained by installing an air pre-heater are:

1. Fuel economy.
2. Inferior grades of coal can be burnt efficiently.
3. Better combustion conditions and less smoke.
4. Increase in steam generation rate.

Superheater: A superheater is used in the boiler to increase the temperature of the saturated steam without increasing its pressure. It is placed in the path of hot flue gases from the furnace. The advantages gained by fitting a superheater are:

1. It reduces the specific steam consumption of the engines and turbines.
2. It reduces condensation losses in the pipe and engine cylinder.
3. It eliminates the erosion of turbine blades.
4. It increases the efficiency of the steam plant.

Injector: The function of an injector is to feed water to the boiler with the help of a steam jet. The injector is operated by steam from the same boiler into which it is required to feed water from a feed tank.

Feed pump: The function of a feed pump is to pump water into the water space of a boiler. Pumps are classified as reciprocating, rotary and centrifugal. Reciprocating pumps are continuously run by the steam from the same boiler to which the water is to be fed. Rotary pumps are either driven by electric motors or by small steam turbines.

Steam separator: A steam separator is used to separate the water particles present in the steam before it enters the engine.

Steam trap: Steam trap is a device intended to drain off water accumulated in the steam pipe or from steam separator, without allowing the steam to escape through it.

Choose the correct answer:

1. Device used to generate steam at high pressure and temperature is known as
(a) Steam injector (b) Steam turbine (c) Steam engine (d) Steam boiler
2. In fire tube boiler,
(a) Hot flue gases flow through the flue tubes which are surrounded with water
(b) The water flows through the water tubes, which are surrounded by hot flue gases
(c) Forced circulation occurs
(d) None of the above
3. When the water in the boiler is circulated due to temperature difference, then the boiler is known as
(a) Natural circulation boiler (b) Forced circulation boiler
(c) Externally fired boiler (d) Internally fired boiler
4. Lancashire boiler is a
(a) Stationary fire tube boiler (b) Horizontal boiler
(c) Internally fired boiler (d) All of the above
5. The boiler to meet sudden demands of steam is
(a) Lancashire boiler (b) Babcock and Wilcox boiler
(c) Cornish boiler (d) Cochran boiler

6. The position of water tubes in Babcock and Wilcox boiler is
(a) Vertical (b) Horizontal (c) Inclined (d) Zig-zag form
7. One of the boiler mounting is
(a) Economiser (b) Super heater (c) Feed pump (d) Water level indicator
8. The mounting used to prevent over heating for low water level is known as
(a) Safety valve (b) Blow-off cock (c) Fusible plug (d) Injector
9. The mounting used to prevent explosion due to excessive internal pressure of steam is called
(a) Water level indicator (b) Stop valve (c) Blow-off cock (d) Safety valve
10. The boiler accessory is
(a) Economiser (b) Feed check valve (c) Safety valve (d) Stop valve
11. A steam separator is used to
(a) Drain water in the steam pipe
(b) Separate the water particles present in the steam
(c) Feed water to the boiler
(d) Increase the steam generation
12. The function of an economizer in a boiler is to increase
(a) Fuel economy (b) Steam generation rate
(c) Life of a boiler (d) All of the above
13. The function of a super-heater in a boiler is
(a) Increase the specific steam consumption
(b) Increase the condensation losses
(c) Increase the erosion of turbine blades
(d) Increase the efficiency of steam plant
14. The condition of steam in boiler drum is always,
(a) Dry (b) Wet (c) Saturated (d) Superheated
15. Blow off valve is used
(a) To reduce steam pressure (b) To stop steam supply
(c) To remove sediments collected at the bottom of the boiler
(d) To remove excess steam from boiler
16. Super heater is used
(a) Inside the boiler drum (b) To convert steam into dry steam
(c) In the path of flue gases to increase volume of steam
(d) To increase temperature of steam above saturation temperature

Review questions

1. What is a steam boiler? How are boilers classified?
2. Explain the principles of fire tube and water tube boilers.
3. Differentiate between the following:
 - (i) Internally fired and externally fired boilers.
 - (ii) Fire tube and water tube boilers.
4. Describe with the aid of a neat diagram, the construction and working of Lancashire boiler. (VTU, June 2010)
5. Explain with a neat sketch the working of Babcock and Wilcox boiler.
6. What are the merits and demerits of water tube boilers over fire tub boilers?
7. Differentiate between boiler mountings and boiler accessories.
8. Name the important mountings on a steam boiler and state their functions.
9. What are the advantages of lever safety valve over dead weight safety valve?
10. What are boiler accessories?
11. Describe the functions of the following boiler accessories:
 - (i) Economiser, (ii) Air pre-heater, and (iii) Superheater.
12. What is the function of steam separator?
13. What is the function of a feed pump?
14. What is the function of an injector?
15. What is the function of a steam trap?
16. Differentiate between the following (i) Safety valve and stop valve (ii) Injector and feed pump (iii) Pressure gauge and water gauge (iv) Economiser and pre-heater.
17. State any five differences between water tube boiler and fire tube boiler. (VTU, Mar 2000)
18. Sketch and explain Babcock and Wilcox boiler. Show the path of the flue gases and water. (VTU, July 2008)
19. Differentiate between boiler mountings and accessories. Give two examples for each. (VTU, July 2000)
20. Explain with a neat sketch the working of a Lancashire boiler and state its advantages. (VTU, Mar 2001)
21. What are the advantages of superheated steam? (VTU, Aug 2003)
22. List the boiler mountings and accessories and also mention their uses. (VTU, Feb 2005)