CHAPTER

STEAM BOILER & ITS CLASSIFICATION

Introduction

A boiler is defined as a closed vessel in which water is converted into steam by burning of fuel in presence of air at desired temperature, pressure and at desired mass flow rate.

A boiler is defined as "a combination of apparatus for producing, finishing or recovering heat together with the apparatus for transferring the heat so made available to the fluid being heated and vaporized.

Boiler or a steam generator is example of heat exchanger. (Heat exchangers are defined as a mechanical device for exchanging heat between hot fluid and cold fluid with maximum rate, with minimum investment and with minimum running cost).

Principle:

In case of boiler, any type of fuel burn in presence of air and form flue gases which are at very high temperature (hot fluid). The feed water at atmospheric pressure and temperature enters the system from other side (cold fluid). Because of exchange of heat between hot and cold fluid, the cold fluid (water) temperature raises and it form steam. The flue gases (hot fluid) temperature decreases and at lower temperature hot fluid is thrown into the atmosphere via stack/chimney.

The function of boiler is to facilitate the generation of steam by providing the necessary heat transfer surfaces, space for storage of water and steam, furnace for burning the fuel and necessary equipments for control of safe operation The large variety of available boilers have cylindrical drum or shell and tubes except for the once through boilers in which drum is not used.

Function of a boiler

The steam generated is employed for the following purposes:

- Used in steam turbines to develop electrical energy.
- Used to run steam engines
- In the textile industries, sugar mills or in chemical industries as a cogeneration plant
- Heating the buildings in cold weather
- Producing hot water for hot water supply

Boiler properties:

- Safety: The boiler should be safe under operating conditions.
- Accessibility: The various parts of the boiler should be accessible for repair and maintenance.

- Capacity: Should be capable of supplying steam according to the requirements.
- Efficiency: Should be able to absorb a maximum amount of heat produced due to burning of fuel in the furnace.
- It should be simple in construction.
- Its initial cost and maintenance cost should be low.
- The boiler should have no joints exposed to flames.
- Should be capable of quick starting and loading.

Components of Steam Boiler

- Boiler drum, tubes, furnace
- Boiler mountings
- Boiler Accessories

Boiler mountings are devices which are required for proper operation, safety and control of the boiler. Examples are water level indicator (WLI), pressure gauges (PGs), steam stop valve, safety valves, fusible plug, feed-check valve, blow-off cock, manhole and mudhole, etc.

Boiler accessories are devices which are used to increase the efficiency of a boiler. Examples are air preheater, economizer, superheater, feedpump or injector, baffles, etc.

Classification of boiler

The different ways to classify the boilers are as follows

1. According to location of boiler shell axis

- Horizontal
- vertical
- Inclined boilers.

When the axis of the boiler shell is horizontal the boiler is called horizontal boiler. If the axis is vertical, the boiler is called vertical boiler and if the axis of the boiler is inclined it is known as inclined boiler.

Horizontal boiler: Lancashire boiler, Locomotive boiler, Babcock and Wilcox boiler etc.

Vertical boiler: Cochran boiler, vertical boiler etc.

2. According to the flow medium inside the tubes

- Fire tube
- Water tube boilers.

The boiler in which hot flue gases are inside the tubes and water is surrounding the tubes is called fire tube boiler.

When water is inside the tubes and the hot gases are outside, the boiler is called water tube boiler.

Examples

Fire tube boilers: Lancashire, locomotive. Cochran and Cornish boiler

Water tube boiler: Simple vertical boiler, Babcock and Wilcox boiler.

3. According to Boiler Pressure

According to pressure of the steam raised the boilers are classified as follows

- Low pressure (3.5 - 10 bar)
- Medium pressure (10-25 bar)
- High pressure boilers(> 25 bar)

Examples

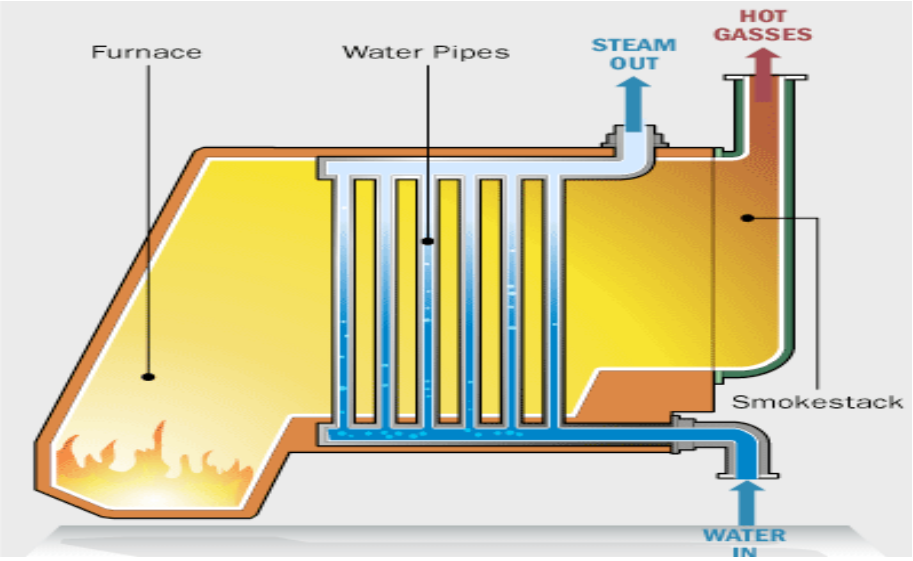
Low pressure: Cochran and Cornish boiler

Medium pressure: Lancashire and Locomotive boiler

High pressure: Babcock and Wilcox boiler.

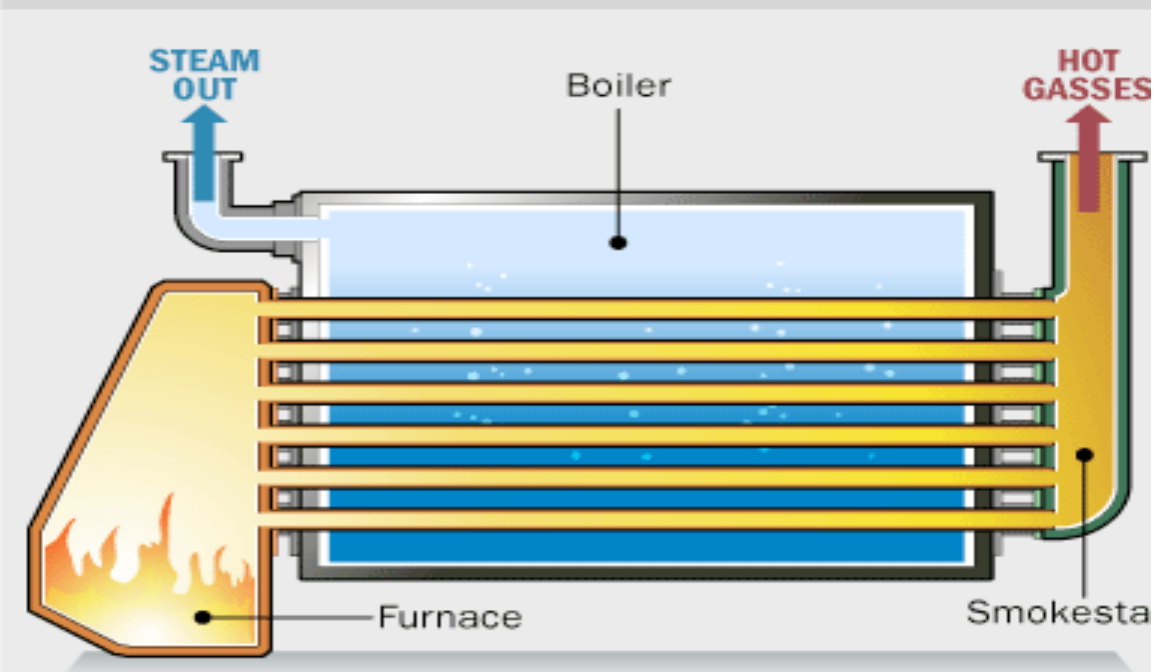
Water Tube Boiler

A water tube boiler is a type of boiler in which water circulates in tubes heated externally by the fire. Fuel is burned inside the furnace, creating hot gas which heats water in the steam-generating tubes. In smaller boilers, additional generating tubes are separate in the furnace, while larger utility boilers rely on the water-filled tubes that make up the walls of the furnace to generate steam.



Fire Tube Boiler

A fire-tube boiler is a type of boiler in which hot gases pass from a fire through one or (many) more tubes running through a sealed container of water. The heat of the gases is transferred through the walls of the tubes by thermal conduction, heating the water and ultimately creating steam.



MERITS OF WATER TUBE BOILERS OVER FIRE TUBE BOILERS

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 OF WATER TUBE BOILERS OVER FIRE TUBE BOILERS

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.

DIFERANCE BETWEEN WATER TUBE AND FIRE TUBE BOILER

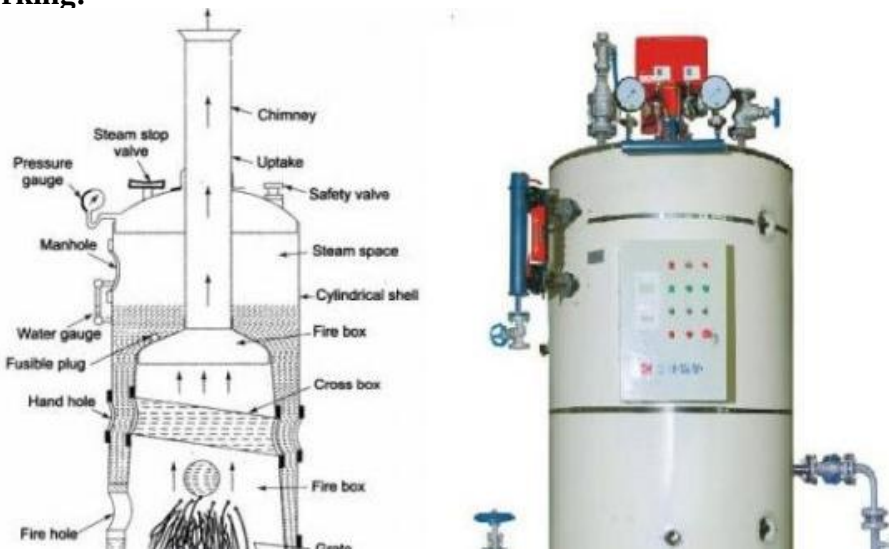
Criterion	Fire Tube	Water tube
1. Flow of hot gases and water	Gases in tubes surrounded by water outside	Water in tubes and gases flow outside
2. Location of furnace	Internal	External
3. Floor area for given output	Large	Small
4. Capacity	10000kg/hr	50000kg/hr
5. Evaporation	Slow	Fast
6. Pressure range	15 to 20 bar	170 to 200 bar
7. Efficiency	80%	92%
8. Safety	Large water content and low steam so better safety	Small water content and large steam generation. Needs expert attention.
9. Explosion	Lesser risk due to lower P	Higher risk due to higher P
10. Application	Not suitable for large power plant	Suitable
11. Skill	Less	More
12. Water Treatment	No	Yes
13. Construction	Difficult	Simple
14. Shell Diameter	More	Less
15. Transportation	Difficult	Simple

Simple Vertical Boiler

Classification of boiler

Vertical, natural circulation, natural draft, single turbular, stationary, medium pressure, solid fuel fired, fired tube boiler with internally located furnace.

Construction and working:



- It has a cylindrical fire box surrounded by a cylindrical water shell connected by one inclined cross tube for improved water circulation. It is provided with standard safety control and inspection mountings.

- Boiler drum is filled with water, the flue gas from the furnace rise in the tube.
- The exchange of heat takes place between water and flue gases.
- The water temperature raises and it converts into steam. The flue gases temperature drops and low temperature flue gases enter into environment via chimney.
- Due to provision of cross tube, the total heat transfer area increases and more amount of steam is available with the same amount of flue gases.
- They can built for small capacity and occupy small space.

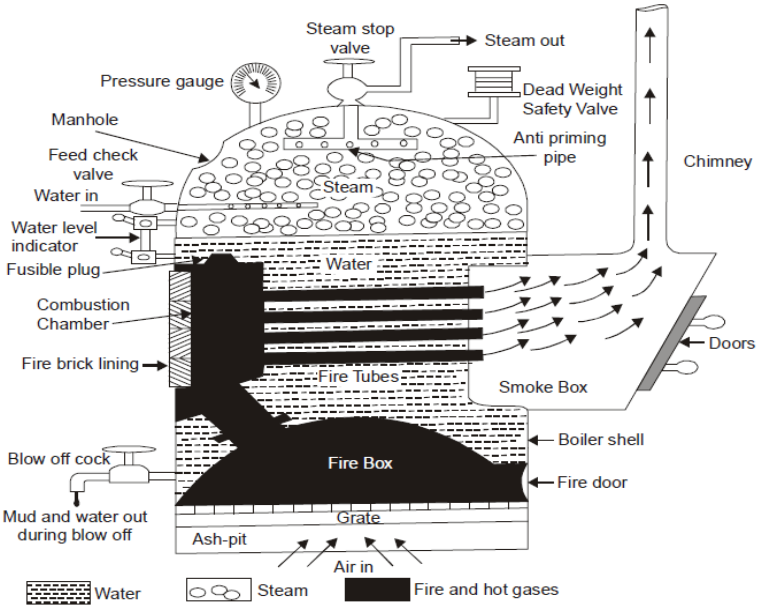
Cochran Boiler

Classification of boiler

Vertical drum axis, natural circulation, natural draft, multi tubular, low pressure, solid fuel fired fire tube boiler with internally located furnace.

Construction and working of boiler

- It is a modified form of simple vertical boiler. It has a hemispherical crown to given maximum space for steam and very high strength to withstand high steam pressure.
- Generated flue gas from the furnace pass through large number of smaller diameter tubes located horizontally in the boiler drum. The large heat transfer area is available for exchange of heat between water and flue gases. Total heating surface area is about 10-25 times the grate area.
- The water is converted into steam from the steam space it is supplied to the plant where the steam is required. Low temperature flue gases enter the environment via chimney.
- The advantages of this boiler are its low chimney height, portability, high beaming rate and burning of clay kind of solid as well as liquid fuel. But it has poor efficiency for smaller unit, high head space, difficult to inspect and uneconomical in operation.



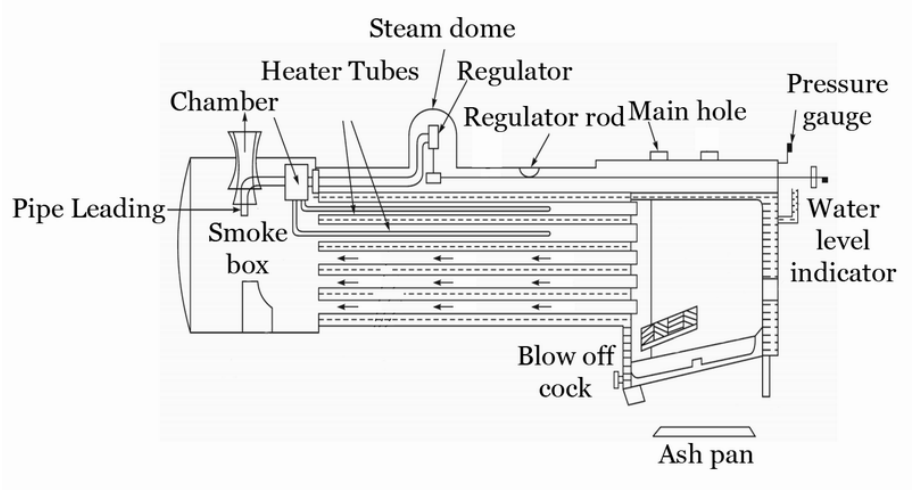
Locomotive boiler

Classification of boiler

Horizontal drum axis, natural circulation, artificial draft, multi-tubular, medium pressure, mobile, solid fuel fired, fired tube boiler with furnace located in tubes.

Construction and working

- It is multi-tubular boiler used in railway engines. It is a mobile boiler and steam generation rate is higher.
- The boiler consists of large number of smaller diameter tubes located in a cylindrical shell along with a rectangular fire box at one end and a smoke box at the other end. Fuel burn on the inclined grate and flue gases enter into the tubes because of fire bridge arch.
- The flue gases pass through number of tubes. Water is surrounded to the tubes. There is an exchange of heat between water and flue gases. The water convert into steam and the flue gases at lower temperature enter into chimney. The steam enters the super heater and the superheated steam is supplied to the steam engine via steam stop valve. The draft created in above case is of artificial type.
- The chimney of this boiler is very short. As such enough draft cannot be created by chimney. The draft is obtained by passing the steam exhausted from the engine through a blast -pipe located in the smoke box. The steam passing through the nozzle above the blast pipe creates enough suction to draw in the air through the tubes. A circular door is provided at the end of smoke box for inspection and cleaning.
- The rate of steam generation accelerated due to vibrations caused by the movement of the boiler. The boiler has a very low efficiency and cannot carry high overloads without suffering heavy damage due to overheating.

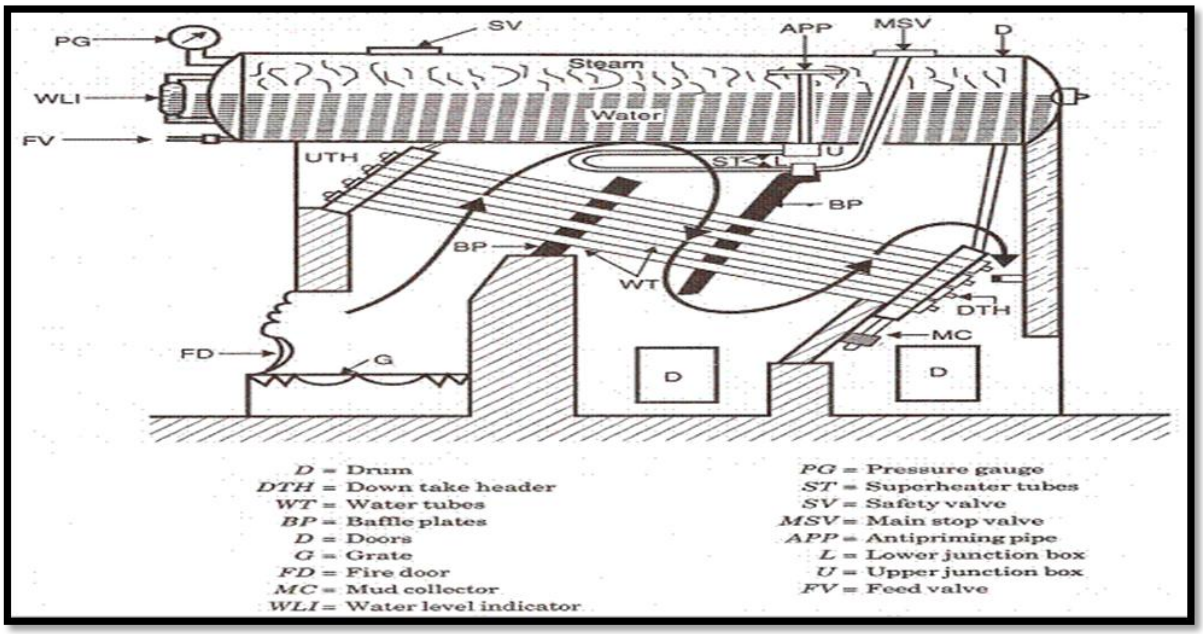


Babcock and wilcox boiler

Classification of boiler

Horizontal drum axis, natural circulation, natural draft, multitubular, high pressure, stationary, solid fuel fired, water tube boiler with furnace located externally.

Construction and working



- This is high pressure boiler used in power plants. It consists horizontal boiler drum connected by uptake header and down take header which in turn are connected by number of inclined tubes of water. The flue gases are exchange the heat with the water.
- The position of baffles cause the gas to move in zigzag way and more heat transfer is possible.
- A counter flow heating is used. The draft is regulated by dempers.
- The water enters the tube through down take header. Due to inclined tubes, the entire tube is not filled with the water.
- Due to exchange of heat, the steam is separated from the water and through uptake header, it enter the steam space inside the boiler drum. Anti priming pipe is provided to ensure that only the dry saturated steam enter the super heater via steam stop valve.
- It can be built for any width and height because of sectional construction, good circulation, rapid steaming,, safe and free from explosion, fast response to overloads, ease of repair, maintenance and cleaning. It is costlier and fluctuation in water level.

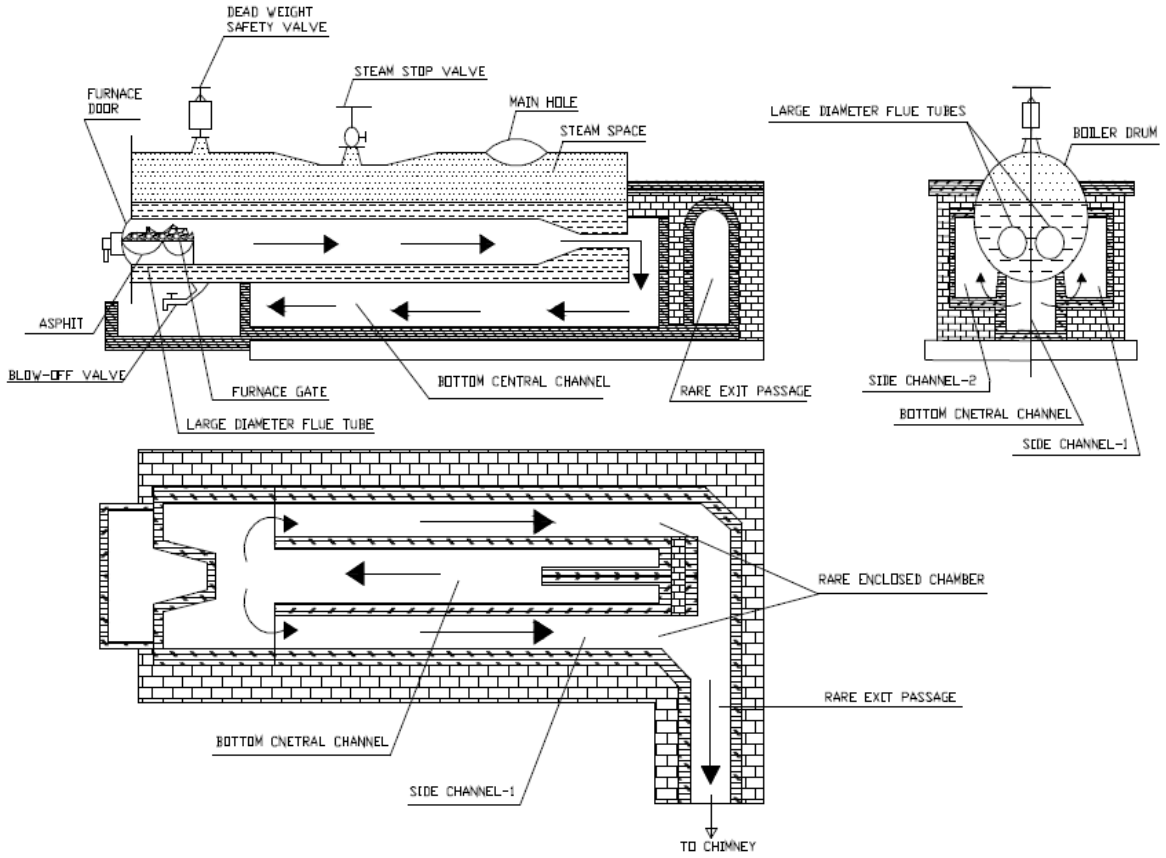
Lancashire Boiler

Classification of boiler

Horizontal drum axis, natural circulation, natural draft, two-tubular, medium pressure, stationary, fire tube boiler with furnace located internally.

Construction and working

- Figure shows the constructional details of Lancashire boiler along with different boiler mountings, brick work, path of flue gases, furnace etc.
- Fuel is burnt on the grate and the flue gases can flow from one furnace end to other end of tubes (i.e. from front side to back side of furnace). This is first pass of flue gas through the boiler tubes.
- The water is surrounded to the tube. The heat between the water in the boiler drum and the flue gases inside the tube. So the steam is formed.
- Flue gases available at the backside of the furnace can be diverted in the downward direction due to presence of brick work. (Brick is a very poor conductor of heat energy and can works as insulating material for a given system). So the flue gases can flow from the bottom part of the boiler drum and exchange the heat with water. This is second pass of flue gases outside the tube. So the flue gases are available at front side.
- From front, because of brick work, they are divided into two side flues and once again flow backward from the sides of boiler drum and finally are expelled out to stack chimney through main flue.
- Dampers are provided at the end of side flues to regulate the flow of flue gases.



Advantages of Lancashire Boiler

(1) It is economical, easy to operate, clean and inspect.

(2) Low maintenance cost.

(3) Load fluctuations can be easily met due to large water storage.

(4) Overall efficiency is as high as 80 to 85% due to super heater and economizer.

Disadvantages

(1) Steam generation is slow (9000kg/hr)

(2) Occupies more space (about 40m_2 for 5000kg/hr capacity)

(3) Maintenance of brick work is tedious.

(4) The grate area is limited to the small diameter of the fire tubes.

(5) Low pressure Boiler (upto 20 bar only)