Steam Boiler

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Steam Boiler

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Steam Boiler

A steam boiler is a closed vessel, generally made of steel, in which water is heated by some source of heat produced by combustion of fuel and ultimately to generate steam. The steam produced may be supplied at low pressure for industrial process work in cotton mills, sugar industries etc. and for producing hot water which can be used for heating installations at much low pressure.

Logically a steam boiler should have a minimum capacity of containing 10 liters of water and its minimum working pressure should be 3.4 Kgf/cm^2.

Steam

Steam is the gas formed when water passes from the liquid to the gaseous state. At the molecular level, this is when H_2O molecules manage to break free from the bonds (i.e. hydrogen bonds) keeping them together. In liquid water, H_2O molecules are constantly being joined together and separated. As the water molecules are heated, however, the bonds connecting the molecules start breaking more rapidly than they can form. Eventually, when enough heat is supplied, some molecules will break free. These 'free' molecules form the transparent gas we know as steam, or more specifically dry steam.

Steam is used in a wide range of industries. Common applications for steam are, for example, steam heated processes in plants and factories and steam driven turbines in electric power plants, but the uses of steam in industry extend far beyond this.

Classification of Boiler

Boilers can be classified in a number of ways, but the following are important from the subject point of view:

1. Horizontal, vertical and inclined boilers
2. Stationary, portable and marine boilers
3. Water tube and fire tube boilers
4. Single tube and multi tube boilers
5. Internally fired and externally fired boilers
6. Naturally circulated and forced circulated boilers
7. Source of heat (solid fuel, liquid and gaseous fuel, electrical and nuclear energy)
8. Low pressure, medium pressure and high pressure boilers

Difference between fire tube boiler and water tube boiler

S. No	**Fire tube boiler**	**Water tube boiler**
1.	In this boiler the hot flue gases is present inside the tubes and water surrounds them	The water is present inside the tubes and the hot flue gases surrounds them
2.	They are low pressure boilers. The operating pressure is about 25 bar	They are high pressure boilers and the operating pressure is about 165 bar
3.	The steam generation rate in fire tube boiler is low, i.e.9 tonne per hour	Steam generation rate in water tube boiler is high i.e. 450 tonne per hour
4.	For a given power the floor area required for steam generation is more i.e. 8 m^2 per tonne per hour	The floor area required for the steam generation is less, i.e. 5 m^2 per tonne per hour
5.	The transportation and erection in this type of boiler is difficult	The transportation and erection is easy as its parts can be separated
6.	The overall efficiency of this boiler is upto 75%	The overall efficiency is upto 90% with the economizer
7.	It can works on fluctuating loads for shorter period of time	It works on fluctuating loads all the times
8.	The direction of water circulation in fire tube boiler is not well defined	The direction of water circulation in water tube boiler is well defined i.e. a definite path is provided for the circulation of water
9.	Operating cost is low	Operating cost is high
10.	Bursting chance is less in fire tube boiler	Bursting chance in water tube boiler is more
11.	Due to bursting, there is a greater risk to the damage to the boiler	The bursting in this boiler does not produce any major destruction to the whole boiler
12.	It can be operated with less skilled person	A skilled person is required to operate this boiler
13.	Low maintenance cost	High maintenance cost
14.	They are light in weight	They are heavy in weight
15.	It is suitable for small power plant	It is suitable for large power plant

Fire tube boiler vs water tube boiler

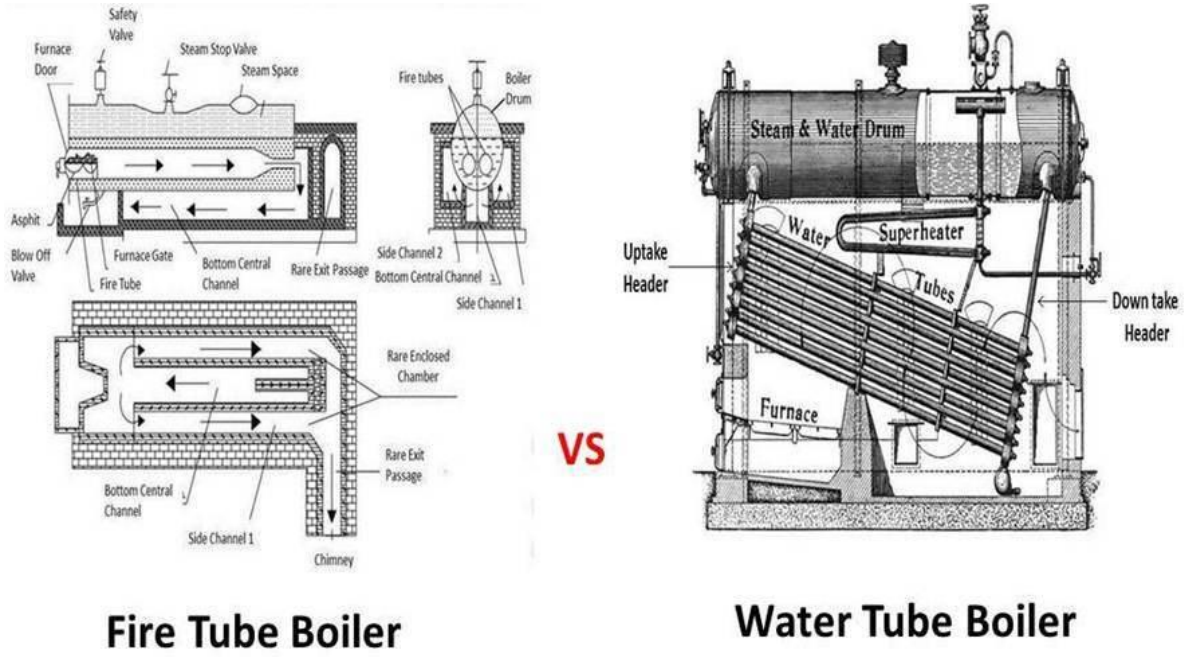
Fire tube boiler

- It is a boiler in which the hot flue gases are present inside the tubes and the water surrounds these tubes. As fire is present insides the tubes, hence it is called as fire tube boiler.
- The steam produced by these boilers has pressure of about 25 bar and that's why they fall under the category of low pressure boilers.
- The steam generation rate in these boilers are low i.e. 9 tonnes per hour.
- For a given power the floor area required for steam generation is more and it is about 8 m^2 per tonne per hour.
- The erection and transportation of these boilers are not easy. And this is because their parts cannot be separated.
- If we talk about the efficiency then the overall efficiency of fire tube boilers is about 75%.
- The direction of the water circulation is not well defined i.e. a definite path is not provided for the circulation of water.
- The operating cost of this boiler is low.
- The bursting chance is less. The bursting produces greater risk to the damage of the boiler.
- It is not suitable for large power plants but used in small power plants.

Water tube boiler

- It is a boiler in which the water is present inside the tubes and the hot flue gases surrounds the tubes. Since the water is present insides the tubes hence these boilers are called water tube boiler.
- High pressure steam is produced by these boilers. The pressure of the steam is about 165 bar. These boiler falls under the category of high pressure boiler.
- The steam generation rate in water tube boiler is high i.e. 450 tonnes per hour.
- For a given power the floor area required for the generation of steam in this boiler is less i.e. 5 m^2 per tonne per hour.
- The erection and transportation is easy as its parts can be separated.

- The overall efficiency of water tube boiler with economizer is upto 90%.
- The direction of the water circulation is well defined i.e. a definite path is provided for the circulation of water.
- The operating cost is high.
- The bursting chance is high because of its high steam pressure. The bursting does not cause any destruction to the whole boiler.
- It is suitable for the large power plant.



Fire Tube Boiler

Water Tube Boiler

Constructional Futures of Boilers

Cochran Boiler

This is a vertical, fire tube boiler commonly used for small capacity steam generation. It is an improved type of simple vertical boiler in order to minimize heating surface. Total heating surface area is 10-25 times the grate area and the working pressure is upto Kgf/cm^2 and steam generating capacity from 20 Kg/hrs to 3000 Kg/hrs. Boiler has dimensions ranging from 1 m diameter and 2 m height to 2 m diameter and 6 meter height.

Working

Cochran boiler consists of an external cylindrical shell. Basically, the construction of Cochran boiler can be divided into three parts such as fire box, combustion chamber and steam space. The shell and fir box are both hemispherical shape. The hemispherical crown of the boiler shell gives maximum space and strength to withstand the pressure of steam inside the boiler. Fire box is also hemispherical in shape, and advantages for resisting intense heat. Flue gases flow from fire box to refractory material linked combustion chamber through a flue pipe. These flue gases flow through a number of smoke tubes. The gases from the smoke box pass to atmosphere through a chimney. A manhole near the top of crown on the shell is provided for cleaning. At the bottom of the fire box, there is a grate and the coal fed through the fire hole. If the boiler is used for oil firing, than no grate is provided, but the bottom of the fire box is linked with fire bricks. It is provided with all required mountings as:

- Pressure gauge
- Water level indicator
- Safety valve
- Fusible plug
- Blow off cock
- Steam stop valve
- Feed check valve

This boiler has the following important classification:

- It is a vertical boiler
- It is a multi tube boiler
- It is a fir tube boiler
- It is an internally fired boiler
- It is low pressure boiler
- It is a stationary boiler
- It is a naturally circulated boiler
- It is solid or liquid fuel burning boiler
- Shell diameter : 2.75 m Height : 6 m

- Steam generation capacity 3000 – 4000 Kg/hr
- Working pressure 7 bar (max 15 bar)
- Efficiency of boiler 70 to 75%
- Tube diameter : 6.25 cm (external diameter)
- No of tubes : 165 – 170 numbers
- Provided main hole at the top for cleaning purpose
- Commonly used for small capacity steam generation
- **Uses of Cochran boiler**. The **Cochran boiler** was produced by **Cochran** & Co. of Annan, Scotland. It is widely **used** in marine practice, either fired directly by coal or oil fuels, or else **used** for heat recovery from the exhaust of large diesel engines. The **boiler** is a cylindrical vertical water drum with a hemispherical domed top.

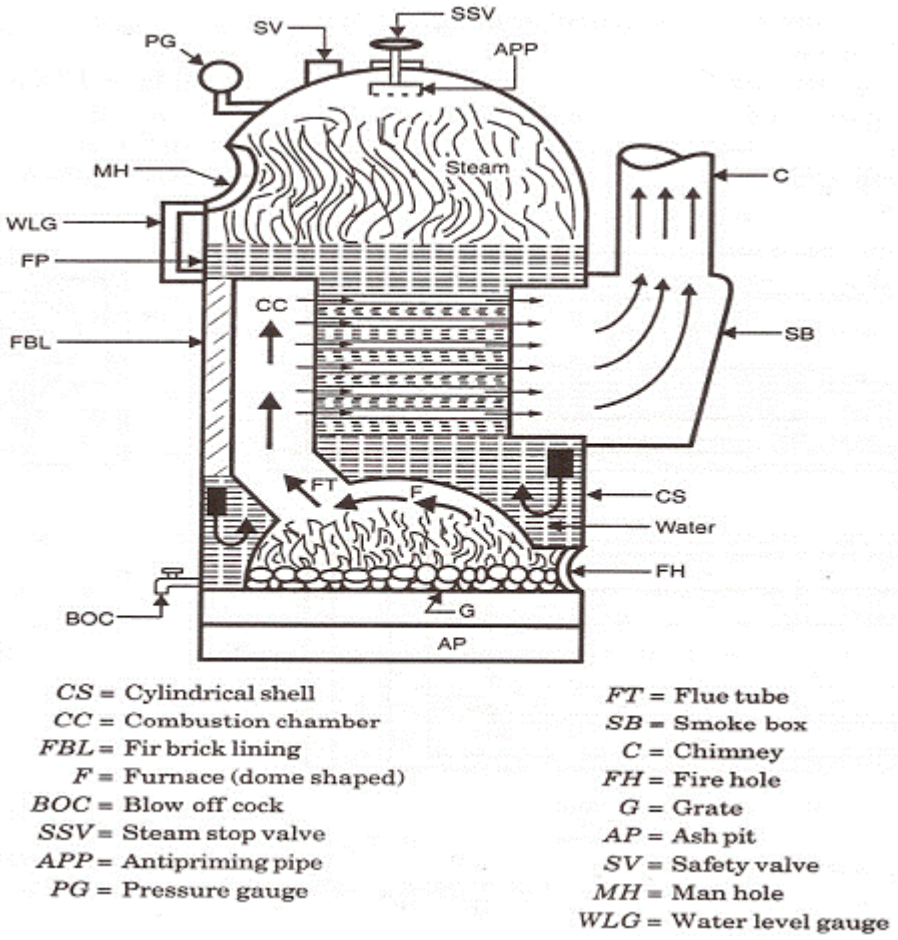


Figure 1 Cochran Boiler

Lancashire Boiler

It is a stationary, fire tube, internally fired, horizontal and natural circulated boiler. It is where working pressure and power required are moderate. These boilers have a cylindrical shell of 2 m in diameter and its length varies from 8 m to 10 m. two fire tubes run throughout the length of the boiler. Fire tubes are of diameter less than half the diameter of shell. This boiler is mounted on brick work setting with front end of shell sloping about 1:250 for empty shell.

Fire bridge is provided to prevent fuel from falling over end of furnace. Hot gases start from grate area, enter into fire tubes and come out at back of boiler from where these gases flow towards the front of boiler through bottom flue. Upon reaching the front these hot gases flow through the side flues and enter the main outlet. 85% of actual heat is transferred through surface of fire tube while 15% is transferred through bottom and side flues. Figure 2 explain the furnace, different fire tubes, bottom flues, side flue etc. other mountings and accessories are shown in Figure 2.

Working pressure in these boilers is in the range of 0.7 Mpa to 2 Mpa and efficiency of the boiler is about 65% - 70 %. Generally a chimney is used to provide the draught. The features of this boiler are:

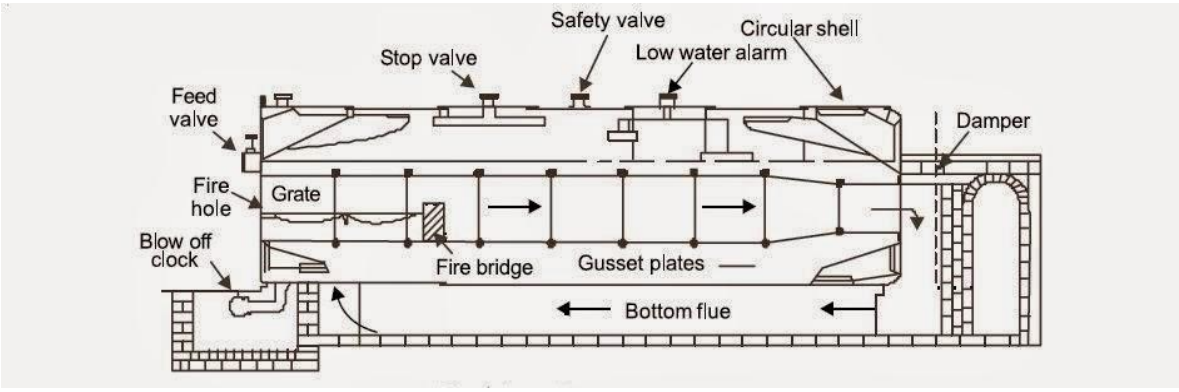
- Its maintenance is easy
- It is suitable where a large reserve of hot water is needed
- Superheated and economizer can be easily incorporate into the system to improve the efficiency of the boiler. This boiler is used in sugar mills and textile industries

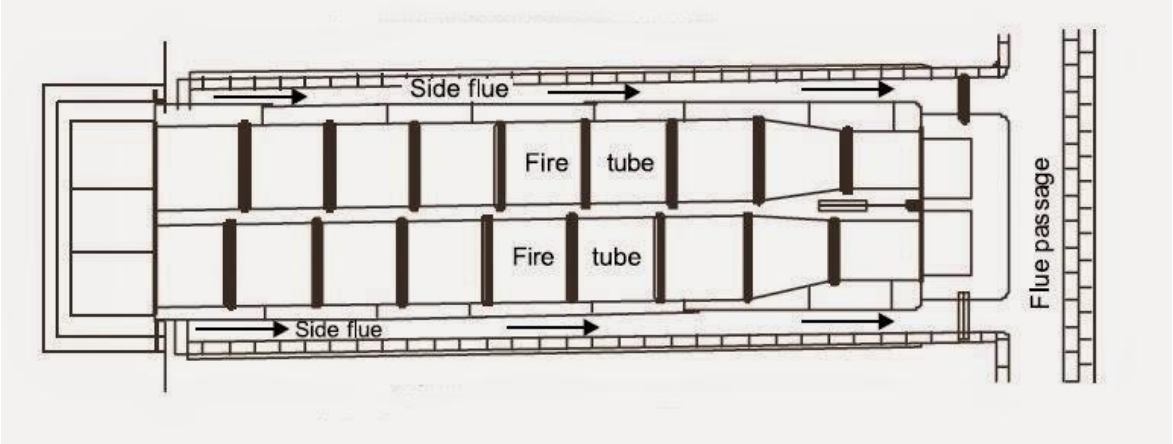
It is provided with all required mountings as:

- Pressure gauge
- Water level indicator
- Safety valve
- Fusible plug
- Blow off cock
- Steam stop valve
- Feed check valve
- Combined high steam low water safety valve

This boiler has the following important classification:

- It is a horizontal boiler
- It is a multi tube boiler (two tubes)
- It is a fir tube boiler
- It is an internally fired boiler
- Boiler have cylindrical shell
- It is a stationary boiler
- It is a naturally circulated boiler
- diameter of boiler shell : 1.74 to 2.75 m
- Length of boiler shell : 7.25 m to 9 m
- Steam generation capacity 8500 Kg/hr
- Working pressure 7 bar to 20 bar
- Efficiency of boiler 65 to 70%
- Tube diameter : 6.25 cm (external diameter)
- No of tubes : 165 – 170 numbers
- This boiler mounted on brick work
- Chimney is used for smoke
- Slop of shell 1:250





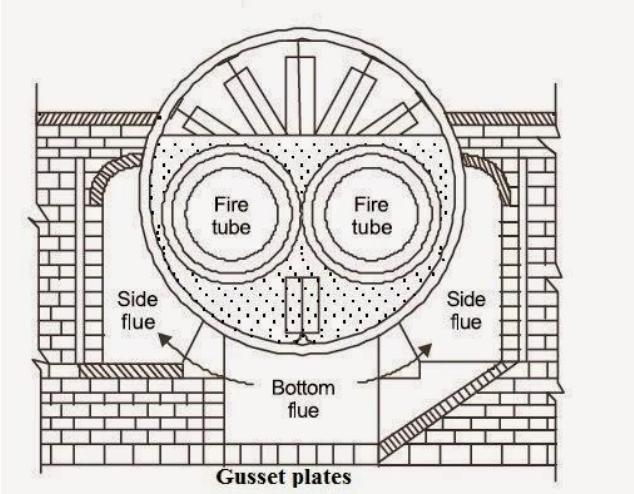


Figure 2 Lancashire Boiler

Babcock and Wilcox Boiler

It is a straight tube, stationary type water tube boiler. This boiler can generate steam at a pressure varying from 11.5 Kgf/cm^2 to 17.5 Kgf/cm^2. It can generate steam at the rate from 20,000 Kg/hr to 40,000 Kg/hr. Figure 3 shows the Babcock and Wilcox Boiler. It was discovered by George Herman Babcock and Stephen Wilcox in the year 1967. And it was named after its discoverer as Babcock and Wilcox boiler.

It has three main parts:

- Steam and water drum
- Water tubes
- Furnace

Steam and water drum

Steam and water drum is a long drum fabricated using small shells riveted together. End cover plates can be opened as and when required. Drum is followed by water tubes which are arranged below the drum, and connected to one another and drum through headers. Below off cock for blowing out the sediments settled in mud box is shown in Figure 3. Super heater tubes are also shown in arrangement, which are U – shape tubes placed horizontally between drum and water tubes. Below the super heater and water tubes is the furnace, at the front of which fuel feed hopper is attached. Bridge wall and baffles made of fire resistant bricks are constructed so as to facilitate hot gases moving upwards from grate area then downwards. A smoke box is put at the back of furnace through which smoke goes via chimney. A damper is used for regulating pressure difference causing expulsion of hot gases. A Babcock and Wilcox boiler fitted with the following mountings for safe working of the boiler:

- Pressure gauge
- Water level indicator
- Safety valve
- Fusible plug
- Blow off cock
- Steam stop valve
- Feed check valve

Working:

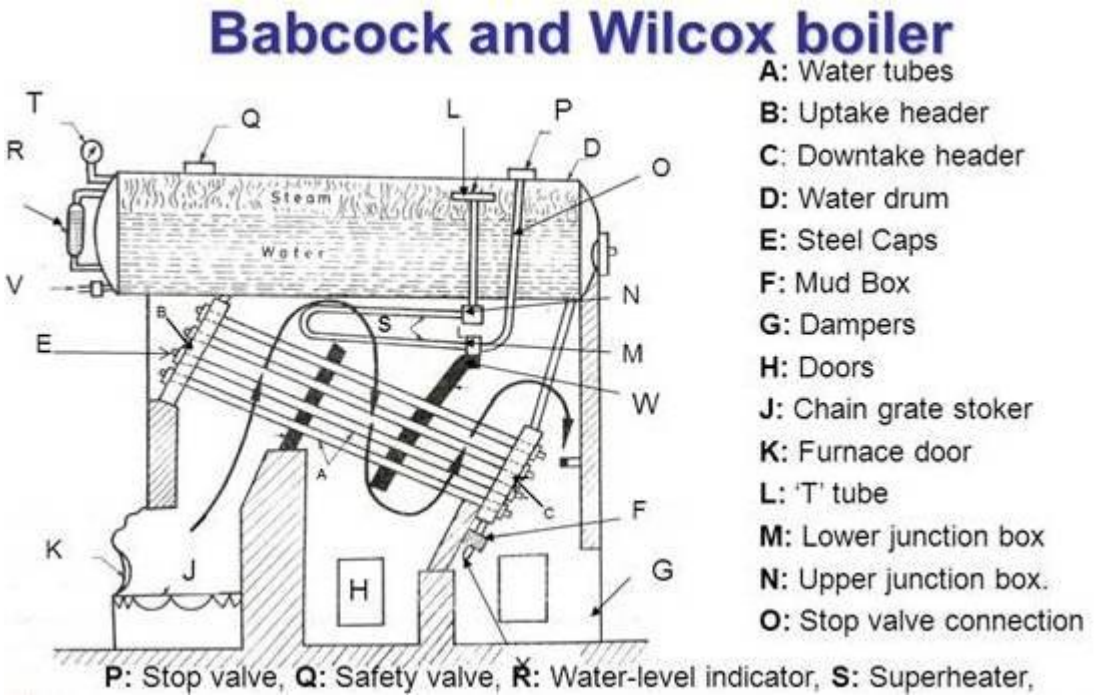
- First the water starts to come in the water tubes from drum through down take header.
- The water present in the inclined water tubes gets heated up by the hot flue gases. The coal burning on the grate produces hot flue gases and it is forced to move in zigzag way with the help of baffle plates.
- As the hot flue gases come in contact with water tubes, it exchanges the heat with water and converts it into steam.
- The steam generated is moved upward and through up take header it gets collected at upper side in the boiler drum.
- An anti-priming pipe is provided in the drum. This anti-priming pipe filters the water content from the steam and allows only dry steam to enter into superheater.
- The superheater receives the water free steam from the anti-priming pipe. It increases the temperature of steam to desired level and transfers it to the steam stop valve.
- The superheated steam from the steam stop valve is either collected in a steam drum or made to strike on the steam turbine for electricity generation.

This boiler is a large sized boiler and cannot be easily transported from one place to the other. It is very popular boiler to be used in power station.

This boiler has the following important classification:

- It is a horizontal boiler
- It is a multi tube boiler
- It is a water tube boiler
- It is an externally fired boiler
- It is a stationary boiler
- It is a naturally circulated boiler
- It is a medium/high pressure boiler
- Diameter of boiler drum : 1.2 to 1.8 m
- Length of boiler shell : 6 m to 9 m
- Steam generation capacity 40000 Kg/hr

- Working pressure up to 40 bar
- Efficiency of boiler 60 to 80%
- Tube inclined at an angle of 15 ^{0}C
- Drum fitted with water up to ⅔ part
- Boiler drum is made of steel
- The Babcock and Wilcox boiler are generally used to produce high pressure steam in power generation industries. The high pressure steam so generated is used to produce electricity.



T: Pressure gauge, **V:** Feed check valve, **W:** Baffles, **X:** Below off cock

Figure 3 Babcock and Wilcox boiler

Locomotive Boiler

- It is a horizontal boiler
- It is a multi tube boiler
- It is a fire tube boiler
- It is an internally fired boiler
- It is a portable boiler
- It is a naturally circulated boiler
- It is a low pressure boiler
- Size and number of tubes: 14 cm and 38 numbers
- Steam generation capacity: 9000 Kg/hr
- Working pressure: 14 bar
- Maximum steam pressure: 20 bar
- Rate of evaporation: 55 to 70 Kg/s
- Heating surface and grate area: 271 m^2 and 4.2 m^2
- Dom is provided in which steam regulator is there
- Company made locomotive boiler is Chitranjan

Construction

1. Multi tubular barrel containing an envelope of water in which fire tubes are immersed
2. Fire box which has flat side. This forms a combined grate and combustion chamber. Grate is a platform in the combustion chamber upon which fuel is burnt.
3. Smoke box equipped with a very short chimney. The coal introduced into the fire box through the fire hole, is burnt on the grate which slopes downwards towards the front. The boiler also provides manhole for cleaning purposes and a large door for excess to the smoke box and tubes for cleaning.

Working

The coal is fed through the fire hole and it burns on a grate. Below the grate there is an ash pit. Air is supplied through the damper hole into the ash pit. The flue gases are formed due to combustion of coal in presence of air. This hot flue gases raising from the grate are deflected by a fire brick arch for their proper distribution to the smoke tubes.

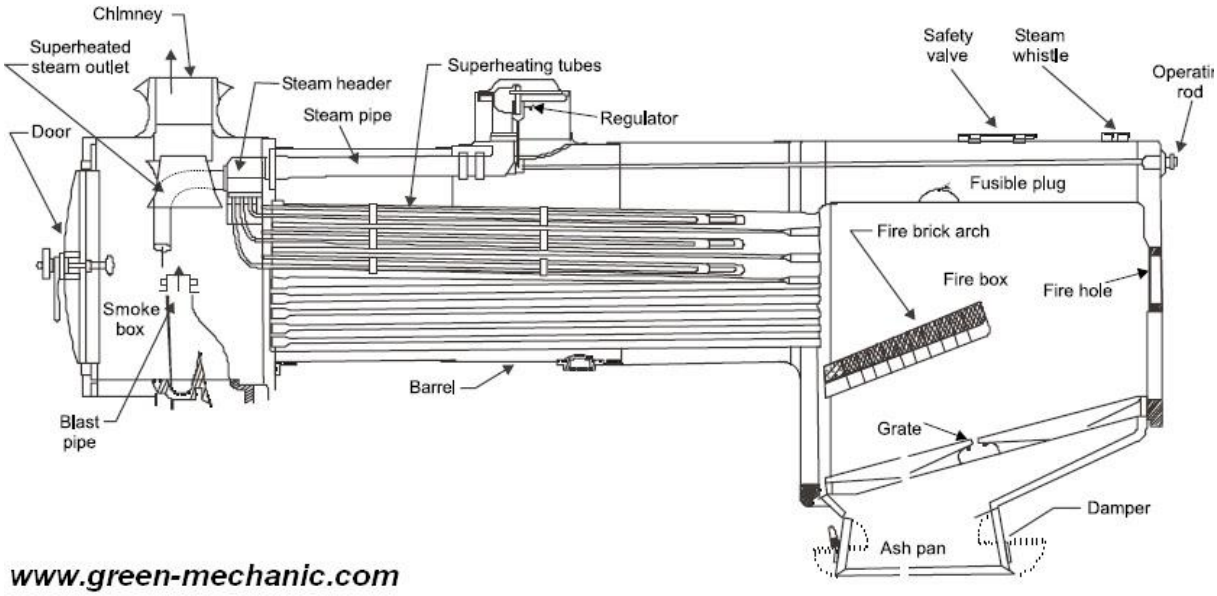
The hot flue gases while passing through the fire tubes impart their heat energy to surroundings water and are ultimately led to smoke box and then discharged to atmosphere through a short chimney. The steam generated collects in the steam dome. The dome is provided to increase the steam release capacity. The driver from the cab operates the regulator by turning a lever and the dry saturated steam is led to engine for expanding and doing work.

The superheated steam is supplied to the engine through superheated steam pipe, which is obtained the steam is taken to super heater header.

Draught in this boiler is provided due to exhaust steam from the cylinder which is discharged into the smoke box through the exhaust pipe also called blast pipe, situated axially below the chimney.

Application

Locomotive boiler is used in railways as well as road rollers. This boiler is also used in agriculture fields, saw mill plant and stationary power service.

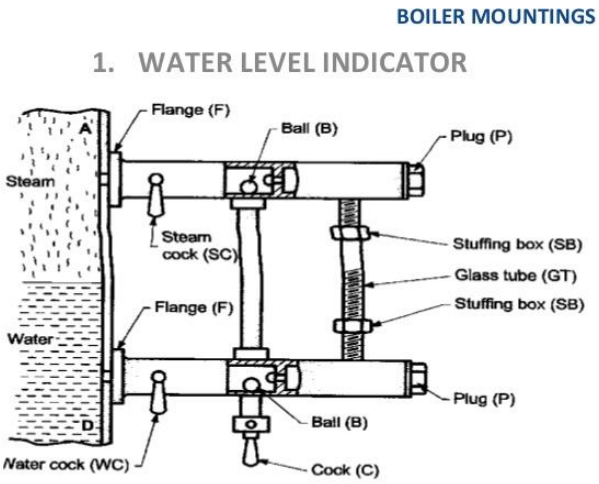


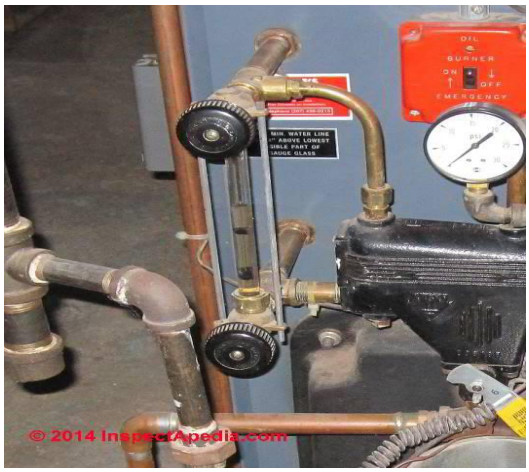
Boiler Mountings

Different fittings and devices necessary for the operation and safety of a boiler are known as boiler mountings. Important mountings which are generally fitted on a boiler are given below:

Water level indicator

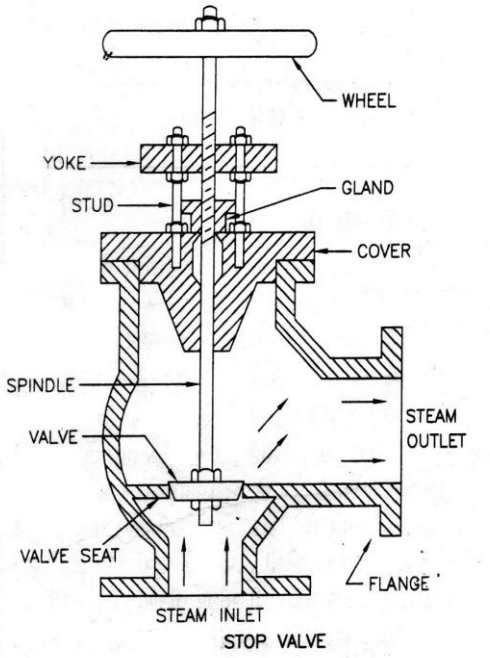
It is an important fitting, which indicates the water level inside the boiler to an observer. It is a safety device, upon which the correct working of the boiler depends. This fitting may be seen infront of the boiler. It is mostly employed in the steam boiler. It has a strong glass tube fitted to two hollow gun metal castings with the help of stuffing box. The lower end of this indicator communicates with water and the upper end with steam in the boiler.





Steam stop valve

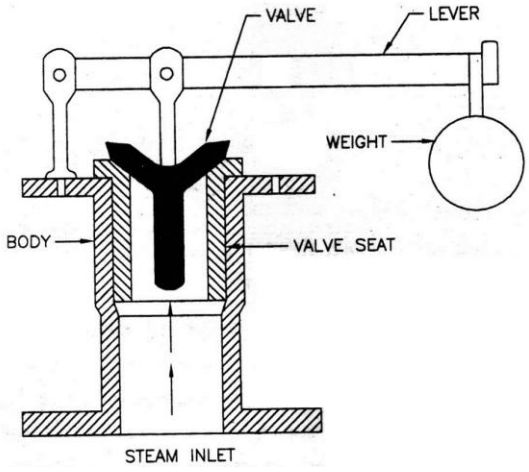
It regulates the flow of steam from a boiler. This is generally mounted on the highest part of boiler shell and performs function of regulating the flow of steam from boiler. Steam stop valve generally has main body of cast steel. Valve, valve seat and nut etc. are of brass. It can be easily operated by rotating the hand wheel which causes lifting or lowering of spindle, thus causing opening or closing of valve

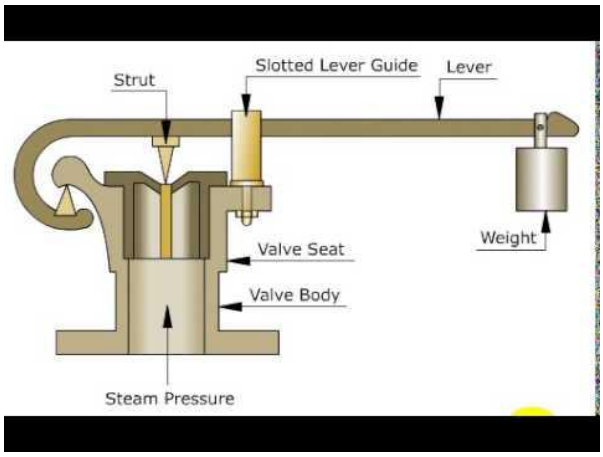


Safety valves

These are the devices attached to the steam chest for preventing explosions due to excessive internal pressure of steam. A steam boiler is usually provided with two safety valves. These are directly placed on the boiler. The function of a safety valve is to below off the steam when the pressure of steam inside the boiler exceeds the working pressure. There are four types of safety valves usually used in boilers:

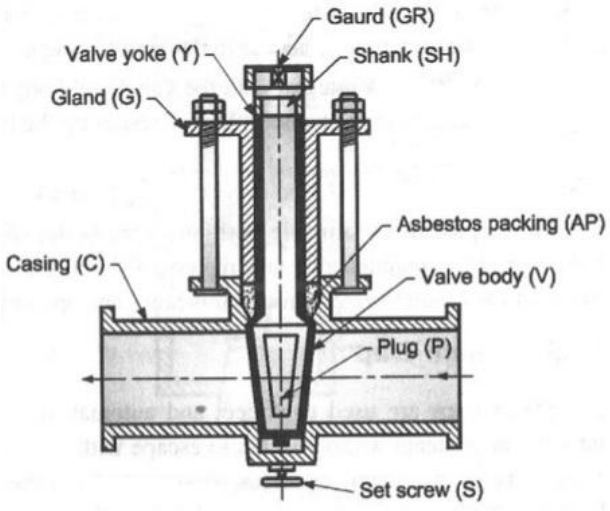
1. Lever safety valve
2. Dead weight safety valve
3. Spring loaded safety valve
4. High steam and low water safety valve





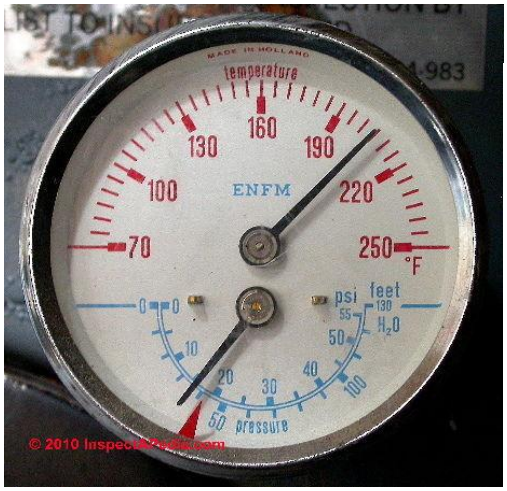
Below off Cock

It is used for periodical cleaning by discharging the water and sediments from bottom of boiler. It is fitted to the bottom of boiler shell. Below off cock has a plug of conical type put into the mating casing. Plug position is altered for opening and closing the flow. It also helps in regulating the salt concentration as frequent draining helps in throwing out the salt deposited over period of time. It is also used for emptying the boiler when ever boiler is to be cleaned



Pressure Gauge

A pressure gauge indicates the pressure of steam in a boiler. It is mounted at front top. Generally Bourdon type pressure gauge is being used for pressure measurement. Pressure is continuously monitored so as to avoid occurrence of over shooting of boiler pressure. Although safety devices to protect boiler against pressure rising beyond a limit are provided but pressure gauges are also used for monitoring pressure.



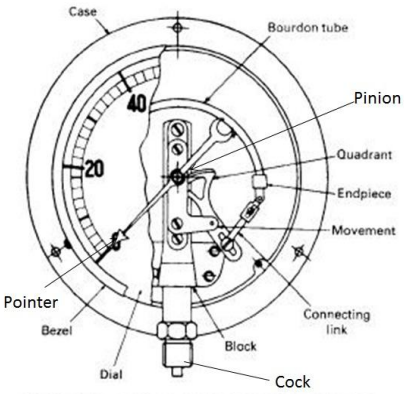


FIGURE 1 – Typical arrangement of Bourdon gauge.

C = cock
B = Block
P = Pinion
L = Connecting link
H = Hinge Point
S = Bourdon Tube
T = Quadrant
N = Pointer

Feed Cheek Valve

It is a non return valve at the end of delivery pipe from feed water pump and is placed on boiler shell slightly below normal water level. It has a check valve whose opening and closing are regulating by the position of spindle. Feed check valve permits unidirectional flow of water from feed pump to be boiler shell. It is used to feed and control the flow of

water from feed pump into the boiler. While during the non working of feed pump the pressure in the boiler shell is more and so the feed check valve gets closed.

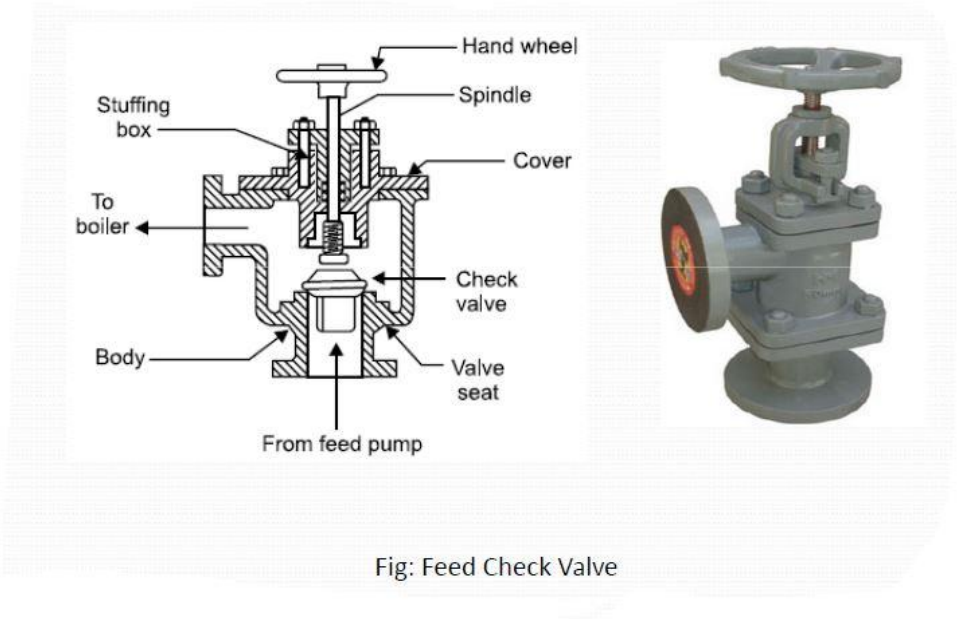
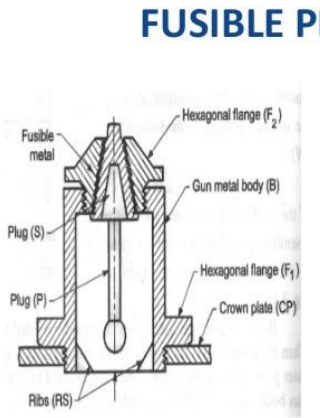


Fig: Feed Check Valve

Fusible Plug

It is a safety device used for preventing the level of water from going down below a critical point and thus avoids overheating. It is fitted to the crown plate of the fire box. It has gun metal body and a copper plug put with fusible metal at interface of copper plug and gun metal body. A fusible plug must be kept in a good condition and replaced annually.



Boiler Accessories

The accessories fitted with the boiler are the devices which are responsible for increasing the efficiency of the boiler. The important accessories fitted to the boiler are:

Super heater

It is an important device of steam generating unit. Generally boiler generates wet steam. By heating further it can be converted into dry-saturated steam. The steam temperature can further be increased to any desired degrees by passing it through super heater. The super heater receives heat from furnace itself. Since the temperature of superheated steam is more, it can do more mechanical work. Therefore, a super heater increases the efficiency of the boiler.

Economizers

An economizer is used to heat the water which is being fed into the boiler shell. The heat required for this purpose is extracted from the waste flue gases going out of the boiler. It is also a type of heat exchanger having exhaust gas and feed water. It also help in removal of dissolved gases by preheating of water and thus minimizing tendency of corrosion. It is placed between the exits of the furnace and entry into the chimney. Thus economizer increases the efficiency of the boiler.

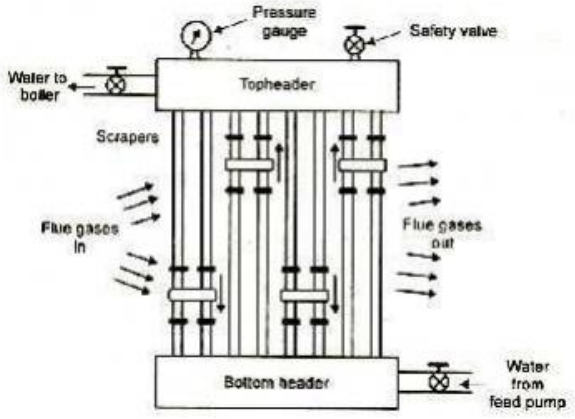


Fig. Economizer

Feed Pump

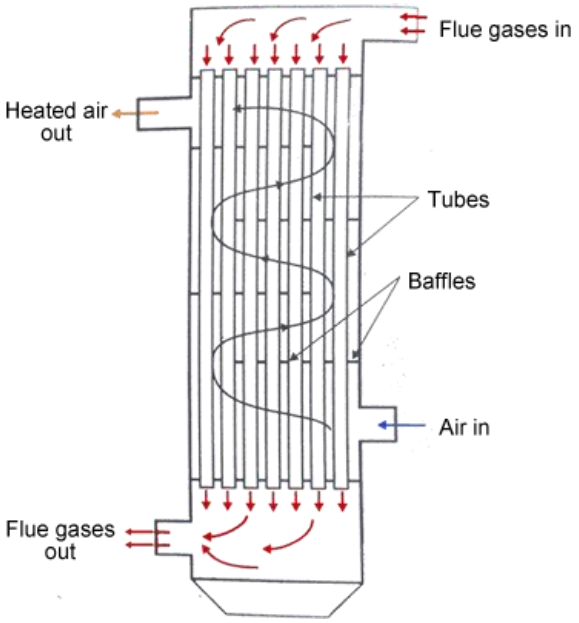
The function of feed pump is to feed water to the boiler at the pressure at which steam generation takes place. It is generally of three type's i.e. centrifugal pump, reciprocating pump and injectors. In boiler the pumps raise feed water pressure to the valve more than the height operating pressure of boiler. Pump also has capacity to deliver feed water in excess to the maximum evaporating rate of boiler. This excess capacity of feed pump is generally 15-20%. Now a day's multistage centrifugal type pumps are used which have favorable pressure.

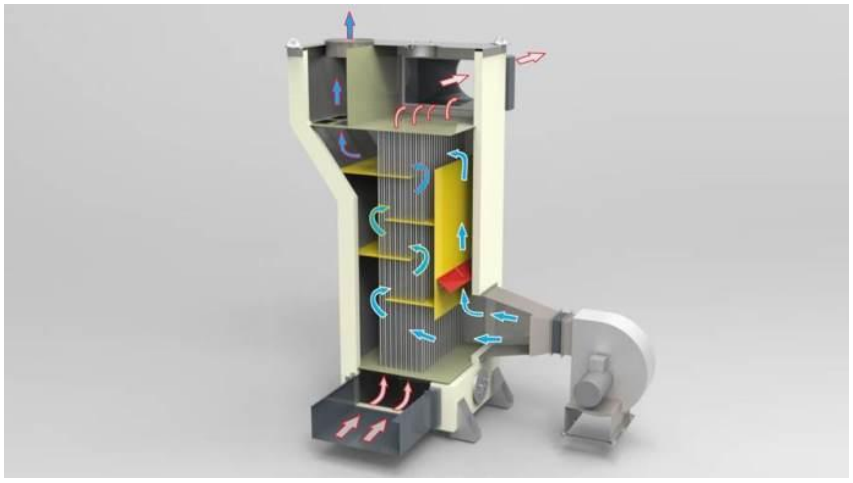
Air Pre heater

The function of an air pre heater is to heat the air before it is supplied to the furnace of the boiler. It is placed near chimney and above economizer. There are three types of air pre heater:

1. Tubular type
2. Plate type
3. Regenerative type

It is also uses the heat of the waste flue gases.





Steam Injector

A steam injector is used to feed the water into the boiler shell with the help of the jet of the steam. The steam used for this purpose is the exhaust steam from a steam engine.

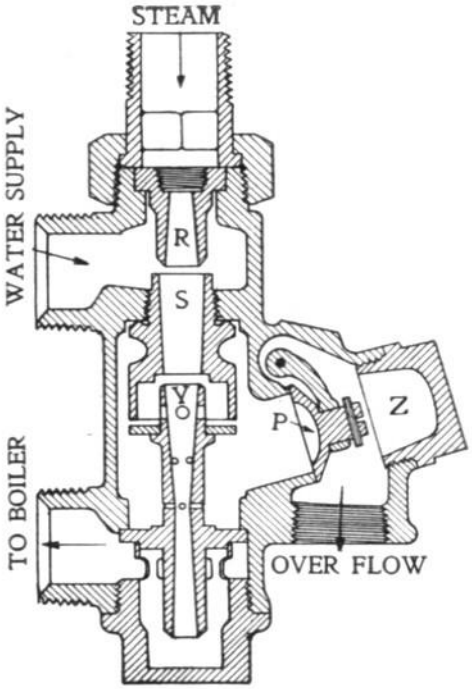


FIG. 5. SECTIONAL VIEW OF INJECTOR

Introduction of Fuel for Boiler

Common Fuels

The fuel is substance containing combustible elements which on combining with oxygen generate heat. In other words, any material that can be burned to release thermal energy is called a fuel. It is further defined as the source of heat energy which is released in a reactive system by chemical reaction. A fuel is a substance which belongs to the hydrocarbon family in which main constituents are carbon and hydrogen. Also have sulphur and non combustible substance like nitrogen, water vapour and ash.

- Fuel can be defined as the source of heat energy which is released in a reactive system by chemical reaction
- Fuel represents a combustible substance which one raised to ignition temperature, continues to burn without any external support, provided a sufficient quantity of oxygen is available for combustion. Example: wood, Coal, Petrol diesel, producer gas, oil gas etc.

The fuels may be classified as:

1. Solid fuel
2. Liquid fuel
3. Gaseous fuel

Solid Fuel

It may be

Natural Solid: Wood and coals (Peat, lignite, Bituminous, Anthracite)

Artificial: Char coal, Cock, Pulverized coal, Bagasse

Major Source of Solid Fuel

Coal: Coal is high carbonaceous matter that has been formed. It contains varying amount of oxygen, hydrogen, nitrogen, sulphur, moisture and ash. The coals are recognized on the basis of rank.

Peat coal, lignite coal, Sub-Bituminous coal, Bituminous coal, Semi-Bituminous coal, Semi-Anthracite coal, Anthracite coal and Super Anthracite coal are the different types of coal. Anthracite is the highest rank of coal.

Anthracite coal is a form of coal that is almost made entirely of carbon. Anthracite coal is much harder than other forms of coal such as bituminous, and is usually found in areas surrounding mountains or deep valleys. Anthracite is considered the cleanest burning coal available. It produces more heat and less smoke than other coals and is widely used in hand-fired furnaces. Some residential home heating stove systems still use anthracite, which burns longer than wood. Anthracite has been nicknamed hard coal especially by locomotive engineers who used it for fueling trains.

Anthracite contains a high amount of fixed carbon 80 to 95 percent and very low sulfur and nitrogen less than 1 percent each. Volatile matter is low at approximately 5 percent, with 10 to 20 percent ash possible. Moisture content is roughly 5 to 15 percent. The coal is slow burning and difficult to ignite because of its high density, so few pulverized, coal fired plants burn it.

The quality of coal depends on:

- Moisture content (5% to 15%)
- Calorific value (3500Kcal/kg)
- Hydrogen, oxygen, nitrogen and sulphur contents

Liquid Fuels

Most of the liquid fuels are obtained from natural petroleum which is a mixture of many hydrocarbons together with small amounts of organic compounds containing oxygen,

nitrogen and sulphur. It obtained from oil wells in form of crude oil under the earth crest in the different parts of the world such as Iraq, Saudi Arabia, Russia, America and India. When crude petroleum is refined by boiling at different temperatures it gives liquid fuels like:

Petrol: High volatile, inflammable and used in internal combustion engine and aeroplane

Diesel: Used in diesel engine for road and rail transport

Kerosene Oil: Used for domestic fuel

Artificial Oils: Coal tar, Tar oil, Shale oil, Natural gas oil

Advantages: Higher calorific value, undergo complete combustion

Gaseous Fuels

Natural gas is produced from gas wells or oil wells rich in natural gas. It is composed mainly of methane but also contains small amounts of ethane, hydrogen, helium, carbon dioxide, nitrogen, hydrogen sulfate and water vapour.

Types of Gases

1. **Natural gas:** Obtained from well dug in the petroleum – bearing field
2. **Coke oven gas:** Got after burning of bituminous coals and used for industrial heating and power generation
3. **Coal gas:** Obtained when coal is heated in the absence of air at about 1300 ^{0}C used for street and domestic lighting, heating etc.
4. **Producer gas:** Obtained by passing air – water blast over a bad of red hot coal at 1100 ^{0}C in a special reactor. Cheap, clean, easily preparable gas. It is used mostly for heating open hearth furnace

Equivalent Evaporation

It is the amount of water that would be evaporated from water at 100 ^{0}C by same amount of heat which was actually absorbed by water and steam under operating conditions. Therefore, equivalent evaporation of boiler is defined as the weight of water evaporated

from water at 100 ^{0}C to dry and saturated steam at 100 ^{0}C by utilizing the same amount of heat as would have been used under the actual working conditions.

This may be expressed in Kg/Kg of fuel or per hour

The equivalent evaporation at 100 ^{0}C/ Actual evaporation x F

Heat absorbed by water

$W_e = Wa\ (h - h_f)/h_{fg}$

$W_e = Wa\ (h - h_f)/2258$

h = Total heat of steam at the working pressure

h_f = Sensible heat of feed water

h_{fg} = Latent heat of steam at atmospheric pressure and is equal to 2258 KJ

Wa = Weight of water actually evaporated, into steam per Kg of fuel at the working pressure

W_e = Equivalent evaporation in Kg per Kg of fuel

$h = h_f + Xh_{fg}$ (If steam is wet with dryness fraction X)

$h = h_f + h_{fg}$ (If steam is dry saturated)

$h = h_f + h_{fg} + C_p\ (t_s - t)$ (If steam is superheated)

Boiler Efficiency

It is the ratio of the heat actually utilized in generation of steam to the heat supplied by the fuel in the same period

Boiler Efficiency = $Wa\ (h - h_f)/C$

Where Wa = Weight of water actually evaporated into steam into steam per Kg of fuel at the working pressure

C = Calorific value of fuel in KJ/Kg