

# Steam Boilers

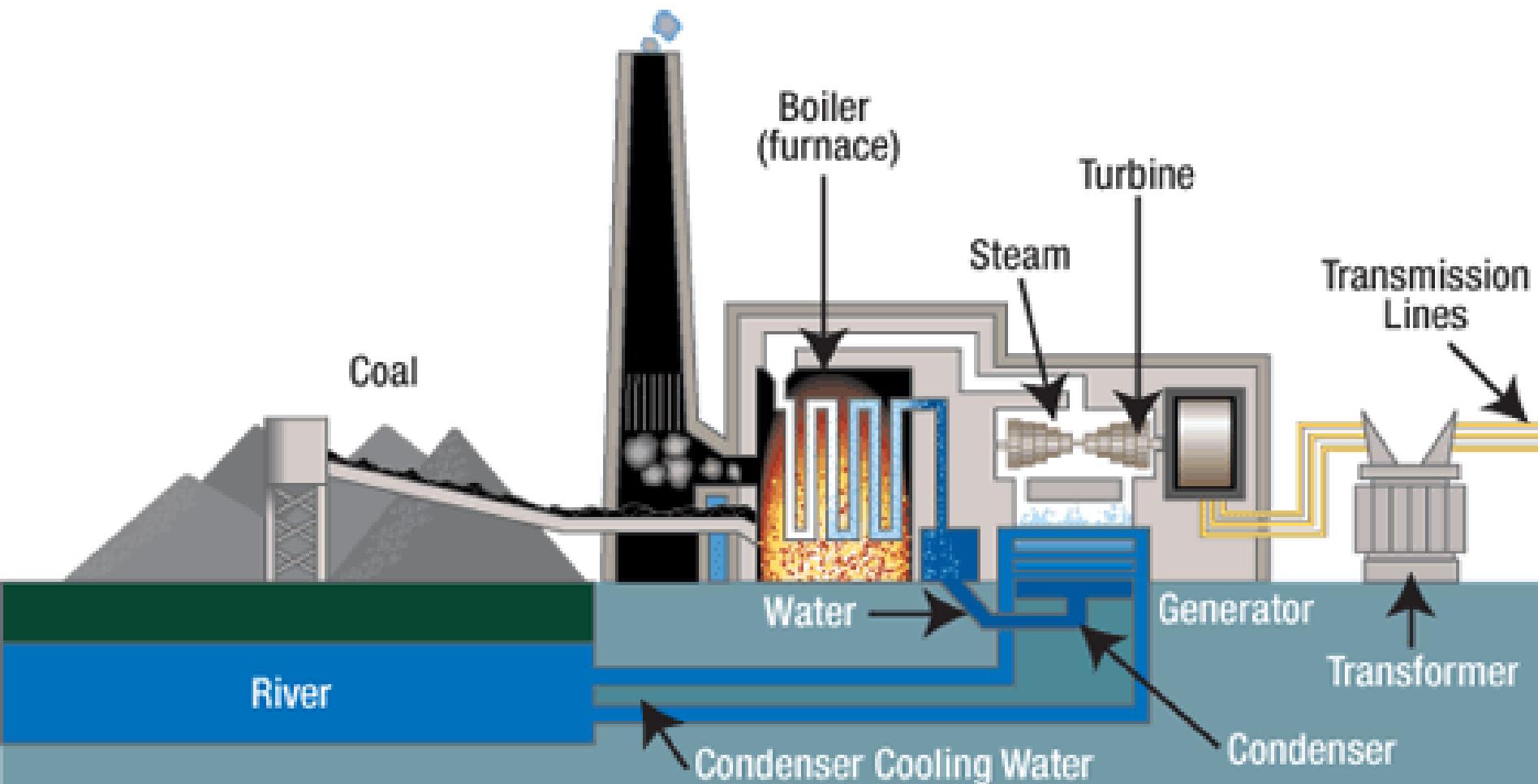
- Definition of a Boiler

Boiler is defined as a closed metallic vessel in which the water is converted into steam above the atmospheric pressure by the application of heat generated by the combustion of fuels.

- Function of a Boiler

The function of a boiler is to generate & supply the steam at the required constant pressure with its quality either dry, wet or superheated.

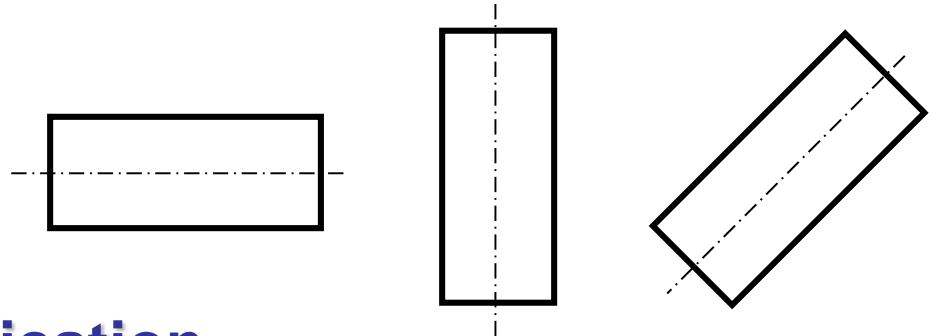




# Classification of Boilers

## 1. According to the axis of the shell:

- a. Horizontal boiler
- b. Vertical boiler
- c. Inclined boiler

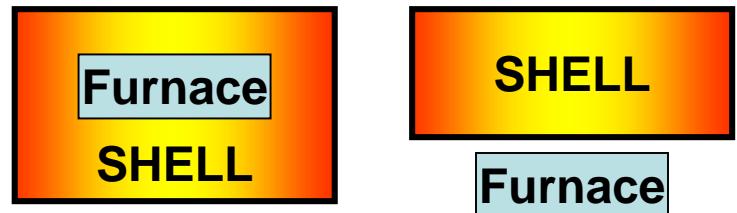


## 2. According to the application

- a. Stationary boiler
- b. Mobile boiler

## 3. According to the location of the furnace

- a. Internally fired boiler
- b. Externally fired boiler



#### **4. According to the type of fuel used**

- a. Solid fueled boiler
- b. Liquid fueled boiler
- c. Gaseous fueled boiler

#### **5. According to the method of circulation of water**

- a. Natural circulation boiler (circulation of water due to difference in temperature)
- b. Forced circulation boiler (pumps are used)

#### **6. According to the flow of water and flue gases**

- a. Fire tube boilers
- b. Water tube boilers

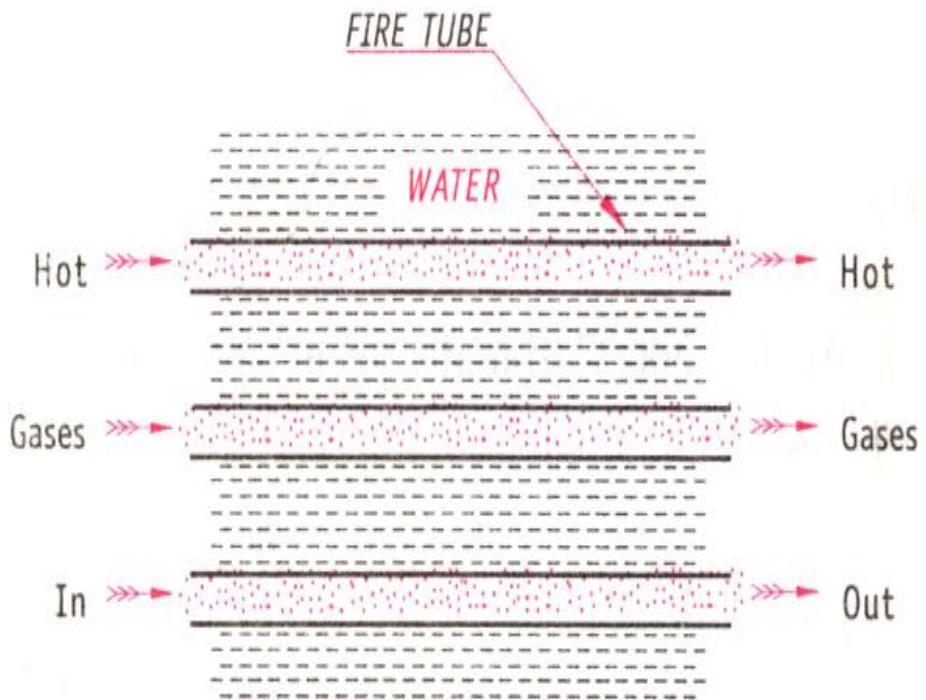


# ***Fire Tube Boiler:***

In the fire tube boilers, the hot flue gases produced by the combustion of fuels are led through a nest of tubes around which the water circulates.

**Example:**

**Lancashire boiler.**

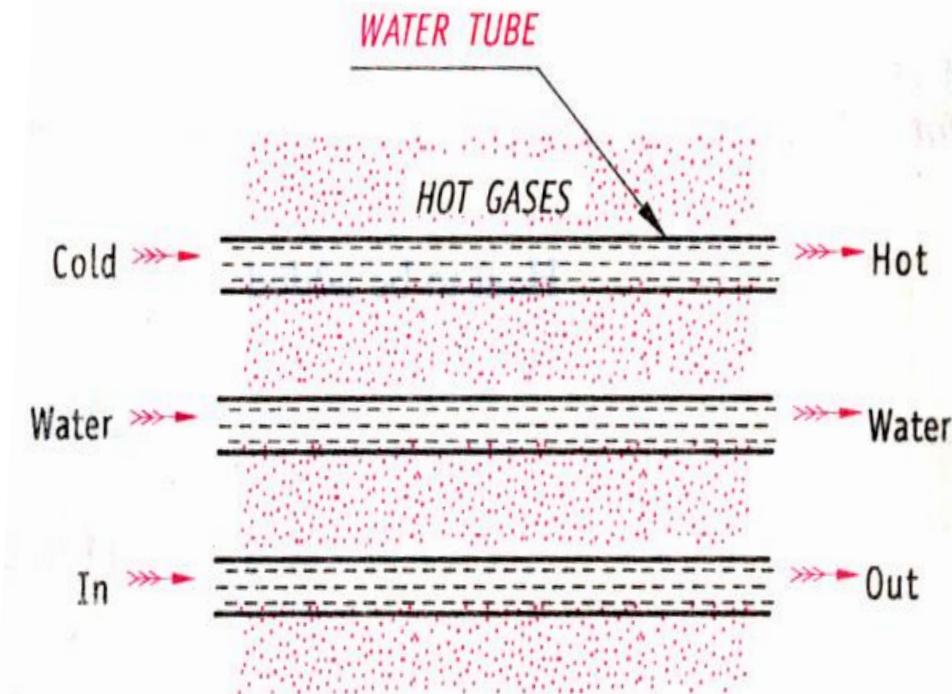


# **Water Tube Boiler:**

In the water tube boilers, the water flows through the tubes while the hot gases produced by the combustion of the fuels pass around them externally

**Example:**

**Babcock and Wilcox**



# **Babcock & Wilcox boiler**

## **(Water tube boiler)**

It is a horizontal, stationary, externally fired, natural circulation, water tube boiler.

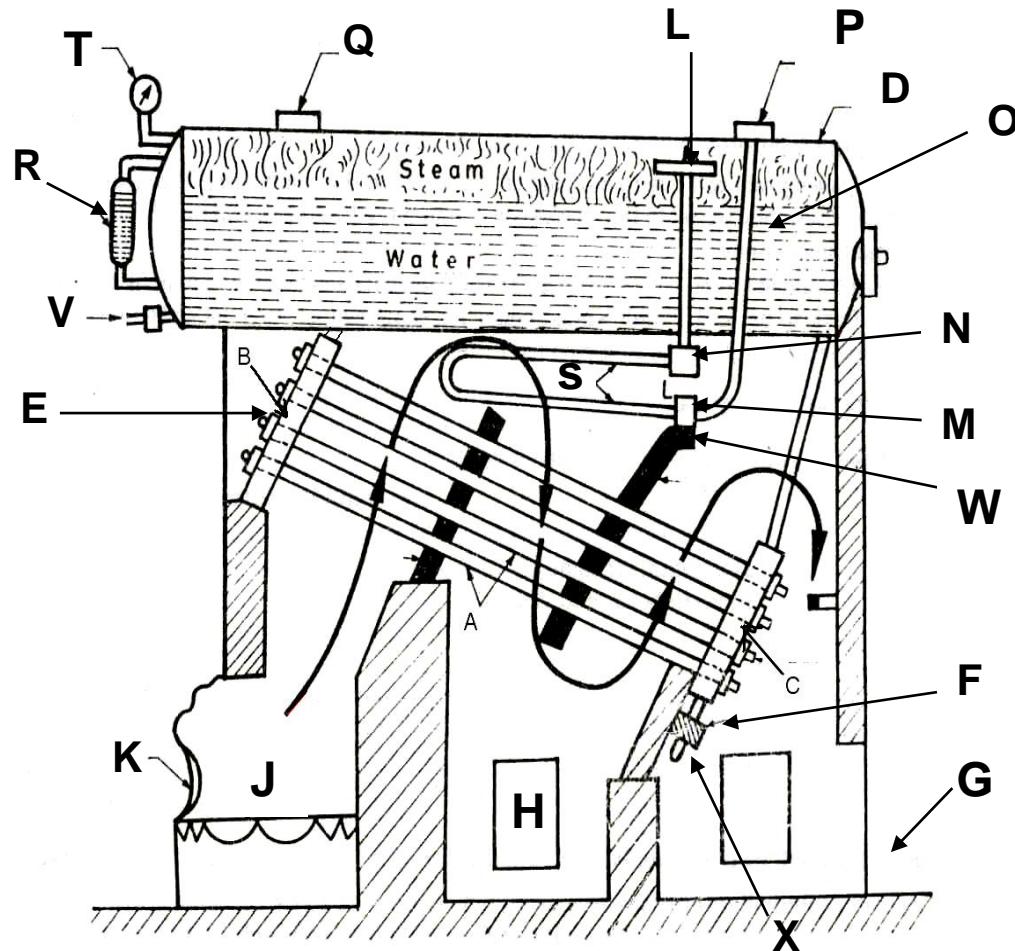
By using this boiler, we can get steam up to a pressure of **75 – 80 bar**.

### **Application:**

It is widely used in thermal power stations.



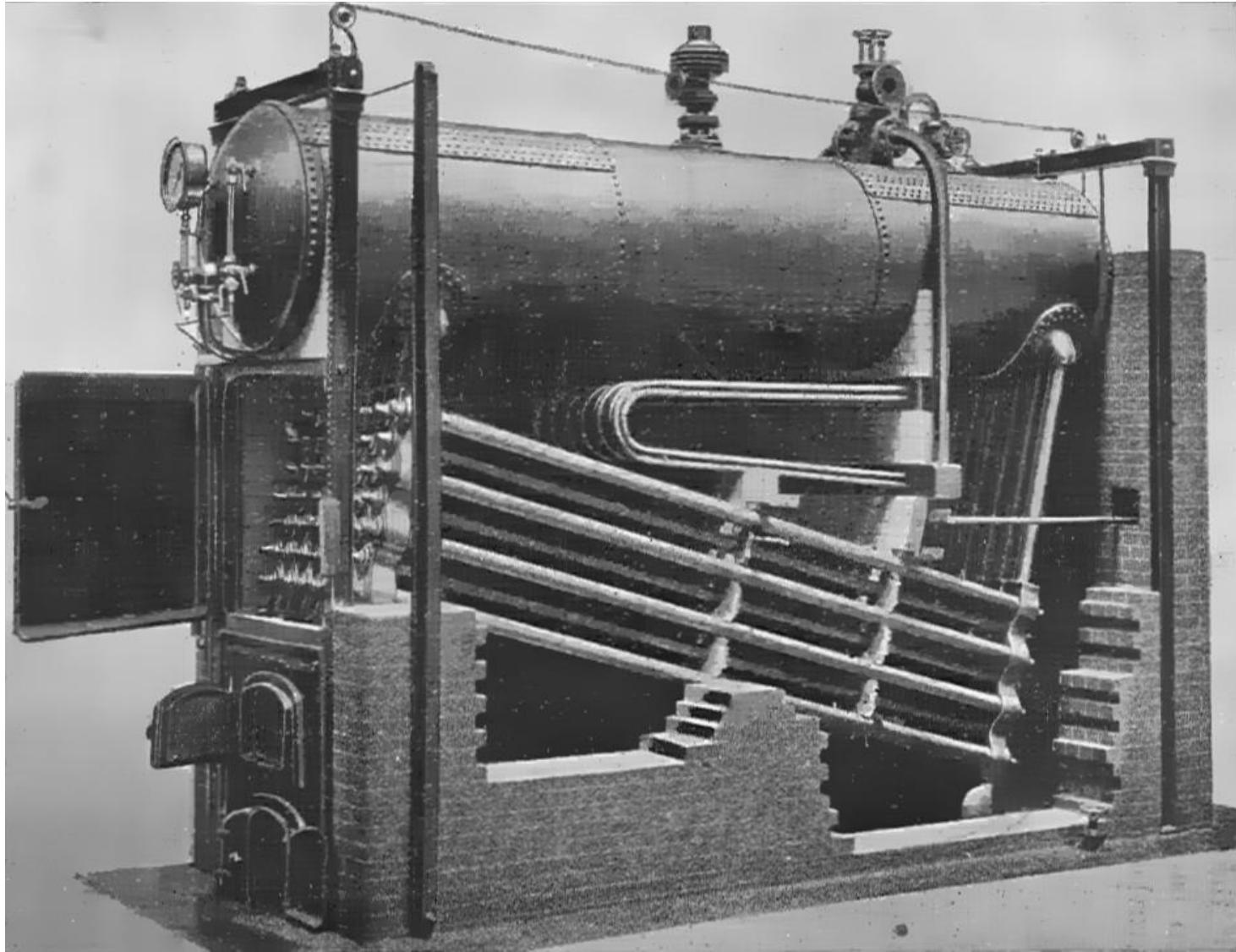
# Babcock and Wilcox boiler



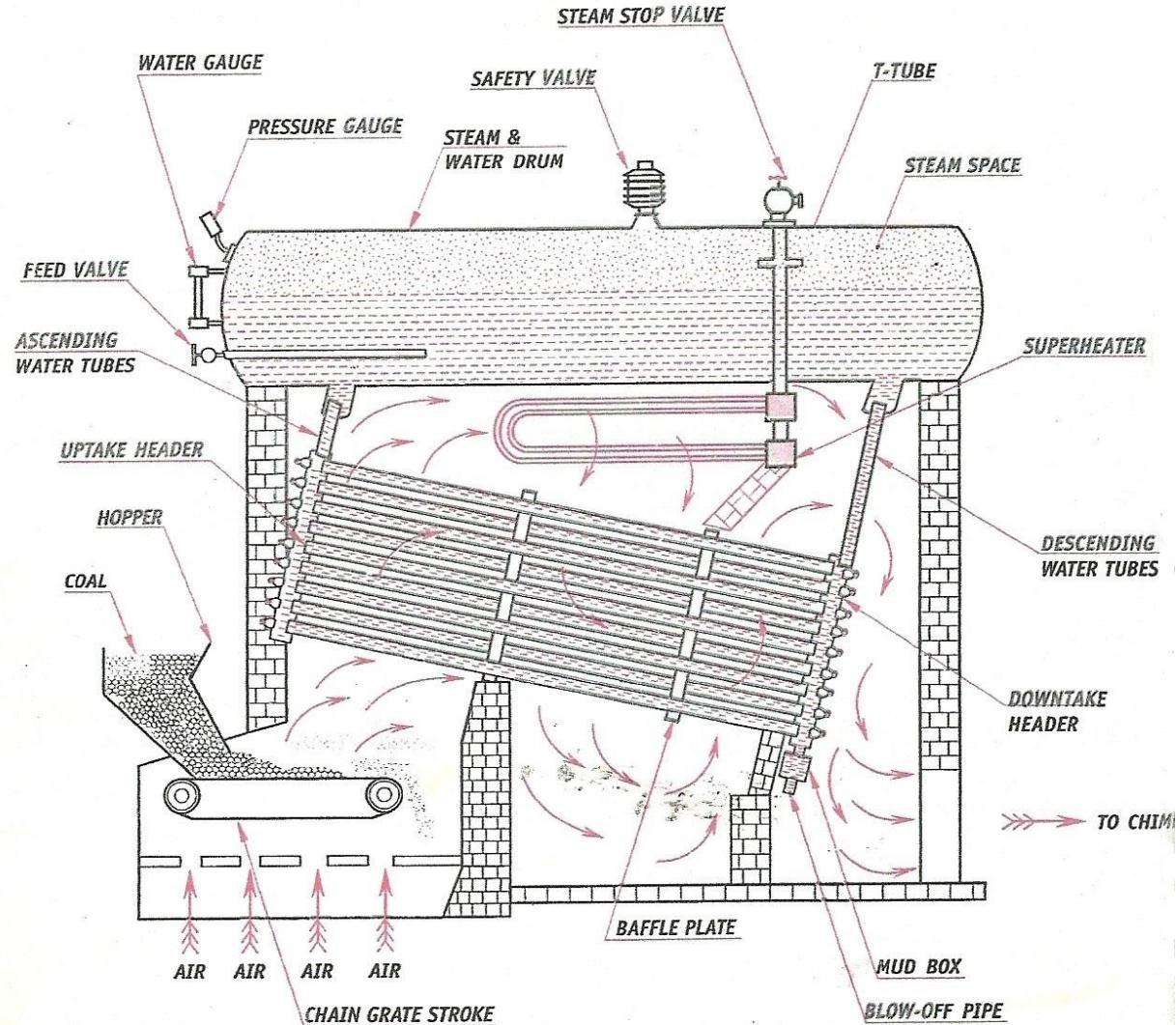
- A: Water tubes
- B: Uptake header
- C: Down take header
- D: Boiler drum
- E: Steel Caps
- F: Mud Box
- G: Dampers
- H: Doors
- J: Chain grate stoker
- K: Furnace door
- L: 'T' tube
- M: Lower junction box
- N: Upper junction box.
- O: Stop valve connection

P: Stop valve, Q: Safety valve, R: Water-level indicator, S: Super heater,  
T: Pressure gauge, V: Feed check valve, W: Baffles, X: Blow off valve

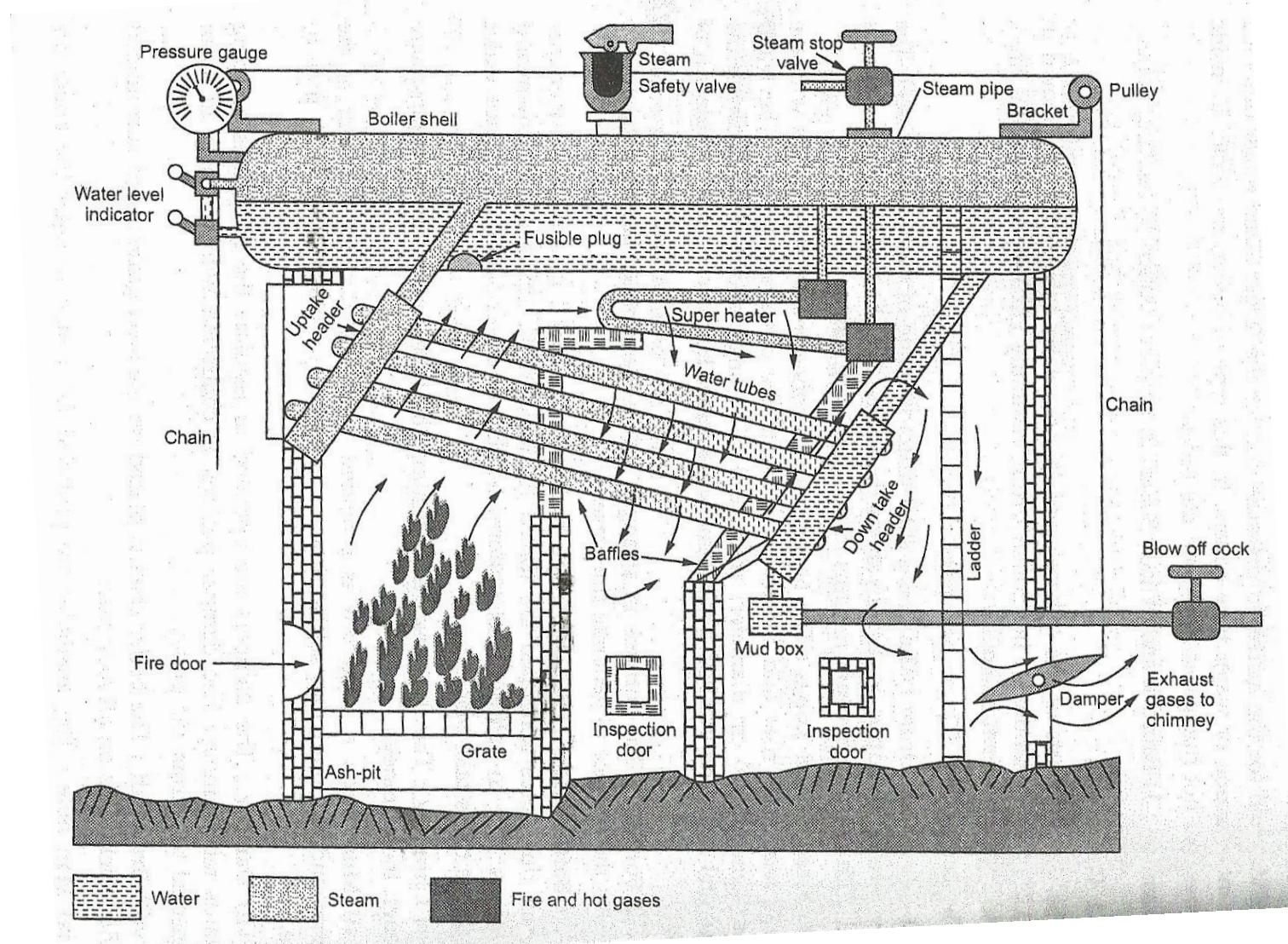
# Babcock and Wilcox boiler



# Babcock and Wilcox boiler



# Babcock and Wilcox boiler



# Construction:

It mainly consists of 4 parts

- Boiler drum
  - Water tubes
  - Chain grate stoker
  - Super heater
- Boiler drum is supported by iron channels.
- A number of inclined water tubes at a very low inclination are connected at right angles to the end boxes called headers.



- The water tubes are arranged in a number of vertical rows, each row consisting of 4 to 5 tubes.
- There will be a number of such vertical rows one behind the other.
- Each row of such inclined water tubes are connected to one set of **headers** on either side.
- Header shown at the right end of the water tube is called **down take header** and the other shown at the left end of the water tubes is called **uptake header**.
- Each set of header is in turn connected to the boiler drum by a set of inclined tubes.



- A mud box is provided just below the down take header.
- Any sediments or impurities collected in the mud box are blown off from time to time through the blow off pipe.
- A chain grate stoker is provided to feed the coal to the combustion zone and to ensure uniform combustion of the coal. The speed of chain grate stoker can be adjusted depending upon the quality of the coal.
- The boiler is fitted with a superheater consisting of a number of horizontal 'U' tubes secured to upper and lower junction boxes and are located in the combustion chamber underneath the boiler drum just above the water tubes.



# **Advantages of Water Tube Boilers over Fire Tube Boilers**

1. *Rapid steam generation*
2. *Generation of steam at higher pressures*
3. *Higher steam generation capacity*
4. *Sediment deposition is less*
5. *Suitable for any type of fuel*
6. *Occupies less space per unit power generation*
7. *Easy maintenance.*



# **Disadvantages of Water Tube Boilers over Fire Tube Boilers**

- Not suitable for mobile application
- Treatment (Filtering/Softening) of water is necessary
- High initial cost



## Differences / Comparison between Fire tube and Water tube boilers

Particulars	Fire tube	Water tube
<b>Flow of water &amp; hot gases</b>	Hot gases inside the tubes and water outside the tubes	Water inside the tubes and hot gases outside the tubes
<b>Mode of firing</b>	Internally fired	Externally fired
<b>Operating pressure</b>	Low (Up to 15 bar)	High ( Up to 75 bar)
<b>Rate of steam production</b>	Low	High



# Differences / Comparison

Particulars	Fire tube	Water tube
<b>Applications</b>	Suitable for chemical & sugar industries & not for power generation	Ideally suitable for power generation plants.
<b>Safety</b>	Safe, due to low pressure	Not safe, due to high pressure
<b>Treatment of water</b>	Not essential	Essential
<b>Shell diameter</b>	Large for given capacity	Small for given capacity



# **Boiler Mountings and Accessories**

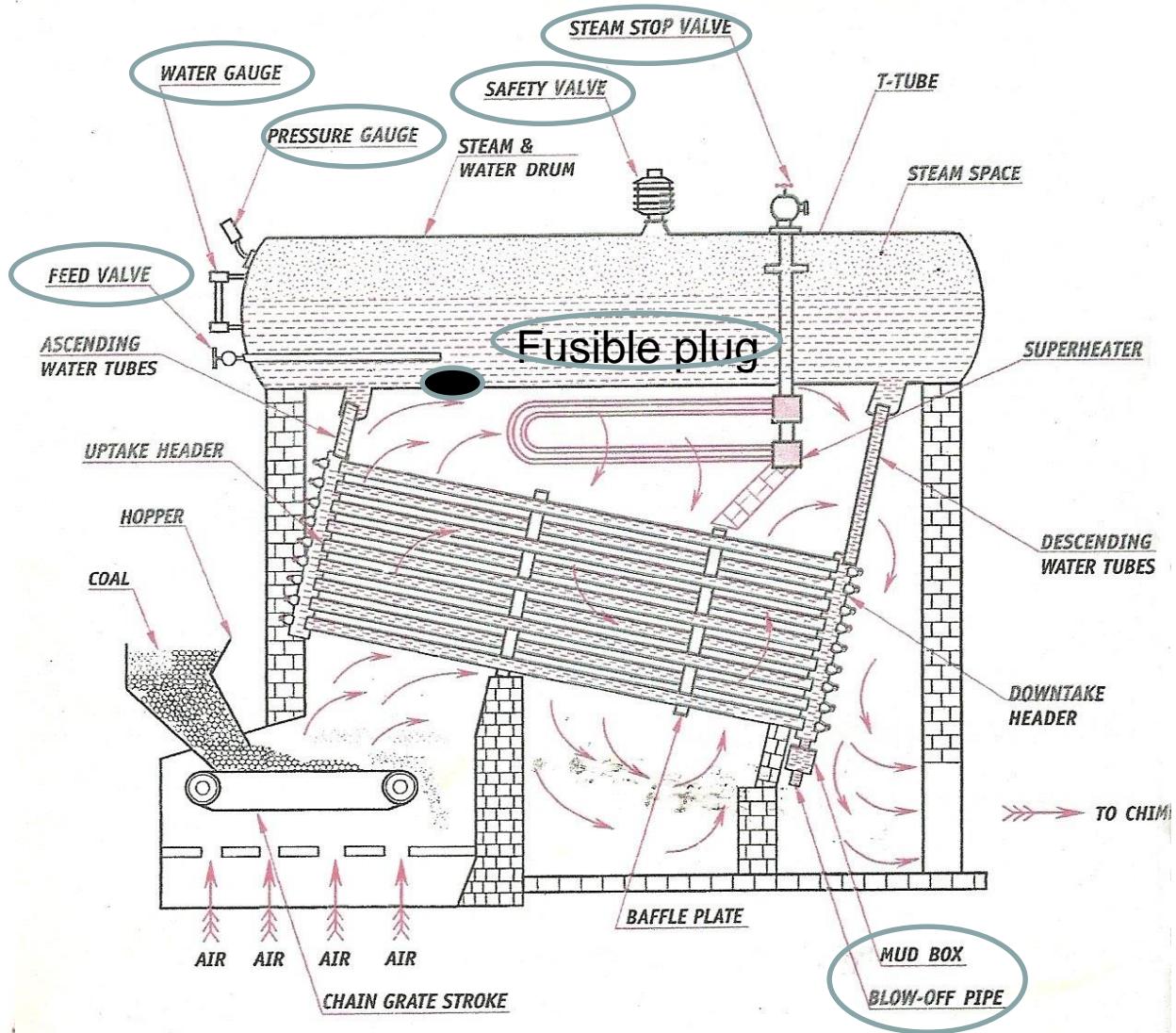
***BOILER MOUNTINGS***, are mandatory and are required

- To have complete control over the steam generation,
- Measurement of some of the important steam properties,
- To provide safety to the boiler.

They are mounted directly on the boiler and become an integral part of the same.



# Boiler Mountings



**Water level indicators**

**Pressure gauge**

**Safety valves**

**Steam stop valve**

**Blow-off valve**

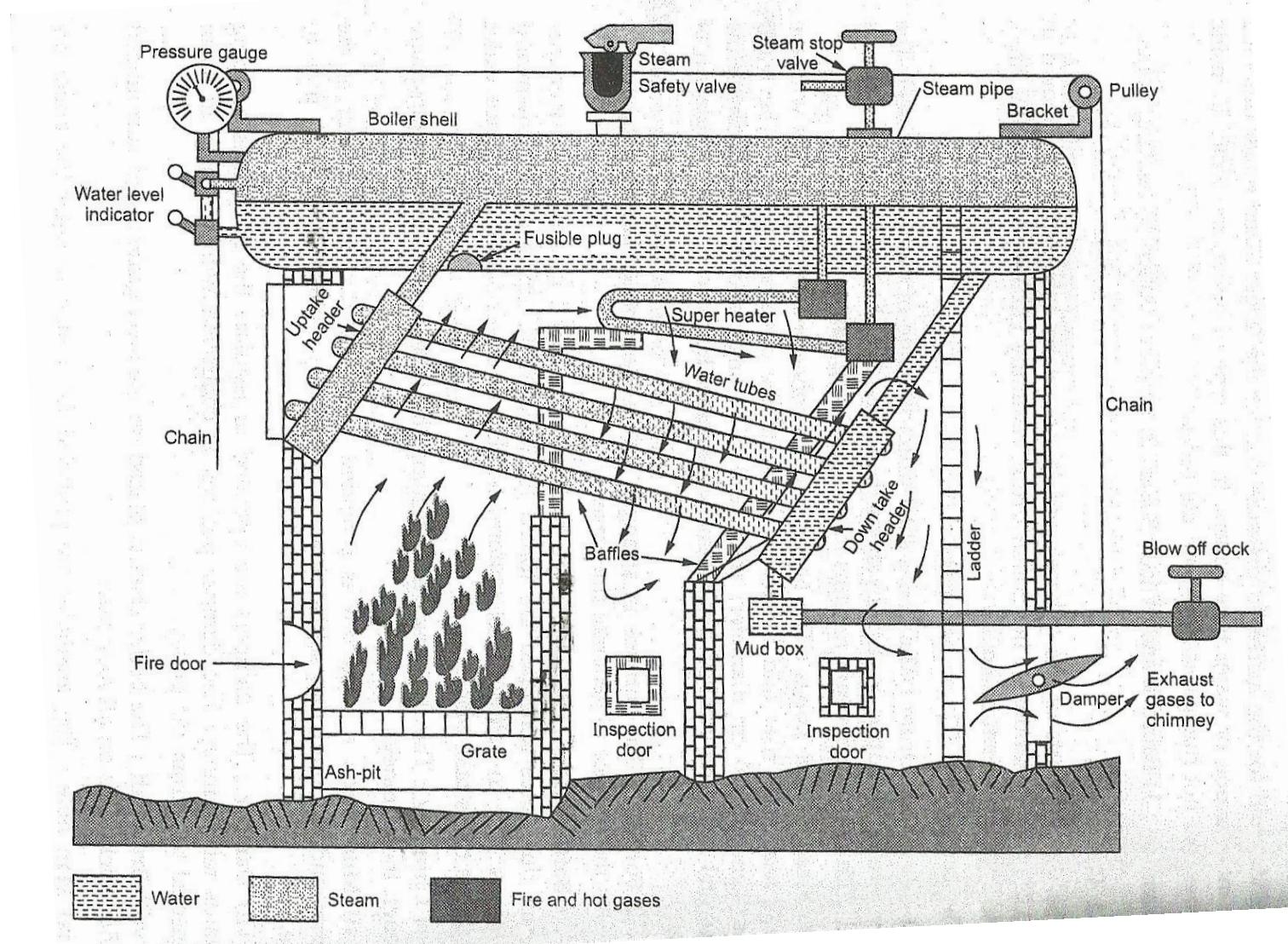
**Feed check valve**

**Fusible plug**

**Manhole & Mud Box**



# Babcock and Wilcox boiler



**BOILER ACCESSORIES:** They are used to **improve the efficiency** of the boiler and hence the steam power plant. They are not mandatory and are not mounted directly on the boiler. The essential boiler accessories are

1	<i>Economizer</i>
2	<i>Air Preheater</i>
3	<i>Super Heater</i>
4	<i>Steam Separator</i>
5	<i>Steam Trap</i>



# Reasons for using Boiler Mountings & Accessories

- Continuous production of steam.
- Closed shell- Water level is not seen and can not be controlled manually – Level may fall to a danger limit.
- High Temperature -Operator can not stand near the boiler.
- High Pressure in the boiler- Possibility of explosion - Necessary to maintain pressure at the required operating pressure.
- High Pressure & Closed container- water can not be poured.
- Water is pumped from river – May contain mud and sediments.



# Reasons for using Boiler Mountings & Accessories

- Falling water level - Fire can not be extinguished manually.
- Superheated steam - The quality of steam leaving the boiler is wet (at the most dry), hence enthalpy is less. Therefore improvement in quality is required- Can not be produced inside the boiler.
- Temperature of flue gases leaving the boiler is high - Large amount of heat is wasted.
- Steam while flowing through the pipes may get condensed and water will be collected on the walls of pipe line. This water mixes with steam flowing through the pipe and decreases the enthalpy of the steam.



# Functions of Boiler Mountings

## ● **Water Level Indicator:**

- It is used to indicate the level of water inside the boiler drum, and thereby guide the boiler attendant to maintain a constant level of water in the boiler drum.
- It is mandatory to use **two water level indicators**. Because **there could be blockage in the water level indicator** due to mud & other impurities getting pumped along with water. This can be noticed only if two water level indicators are used. Any difference in the water level reflects a faulty indicator and alarms the operator to shut down the boiler and reset the water level indicator. Only when both the indicators show the same level , the reading is accepted.



# Functions of Boiler Mountings

## ● **Pressure Gauge:**

- It is used to indicate the pressure of steam inside the boiler drum so that the same can be set to the required operating pressure.
- A **pressure gauge having a range double that of operating pressure is used in the boiler so that the needle of the pressure gauge stays vertical** at the operating pressure. The operator adjusts the flow through the stop valve so that the needle stays vertical.



# Functions of Boiler Mountings

## ● **Safety Valve:**

- The function of the safety valve is to **prevent the steam pressure in the boiler from exceeding a certain predetermined value.** It instantly blows off the excess steam from the boiler and shuts off automatically thereby restoring the normal working pressure.
- Sometimes the steam pressure exceeds the required value either due to reduced outflow of steam from the boiler or because of rapid steam generation due to low water level or rapid combustion of coal. This sudden rise in pressure affecting the safety of the boiler drum is restored by a safety valve.



# Functions of Boiler Mountings

## ***Steam Stop Valve:***

It is used to regulate the flow of steam from the boiler drum through the super heater to the steam pipe leading to the steam turbine.

## ● ***Blow off Valve:***

The function of the blow off valve is to remove the sediments collected at the bottom of the boiler periodically while in operation & also to empty water from the boiler for carrying out periodical cleaning and maintenance. It is located at the lowest portion of the boiler assembly.



## ● **Feed Check Valve:**

It is a non return valve and performs the dual function of regulating the flow of water to the boiler when the level of water inside the boiler drum falls and prevents the return flow of water from the boiler drum when the feed pump stops or in the event of failure of feed pump.

Since **water is pumped into the boiler during the running condition, to prevent the return flow of water it acts like a non return valve.**



## ● **Fusible Plug:**

It is used to extinguish the fire in the furnace of the boiler when the water level falls too much below the normal level. It protects the boiler against damage due to over heating caused by low water level. It is mounted at the crown of the fire box.

The plug has an annulus of fusible metal having a low melting point. Normally the plug is covered by water inside the boiler drum which keeps the temperature of the plug below its melting point.

As the water level falls below the minimum level, the plug is uncovered and the fusible metal melts as it gets exposed to steam space instead of water, which is not able to keep it cool. The plug drops down facilitating the steam and residual water present in the boiler drum to rush out into the combustion zone and put out the fire.



## **Manhole:**

It is an opening in the boiler shell through which a person can go in for periodic inspection and cleaning. It is elliptical in shape.

Since the lid of the man hole has to be closed from inside, enabling the steam pressure to **hold it tight** it is made elliptical in shape. The larger size elliptical cover with the minor axis less than the major axis of the smaller hole can be easily inserted inside the boiler, turned by 90 degrees and closed.

## **Mud Box:**

Mud box is located at the bottom portion of the down take header for collecting the mud particles present in the water. The blow off valve is connected to the mud box.



**BOILER ACCESSORIES:** They are used to improve the efficiency of the boiler and hence the steam power plant. They are not mandatory and are not mounted directly on the boiler. The essential boiler accessories are

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# Functions of Boiler Accessories

## ● **Economizer:**

The function of the economizer is to increase the temperature of feed water. It is a device in which the waste heat of the flue gases is utilized for preheating the feed water thereby increasing its sensible heat.

## ● **Air preheater:**

It is a accessory which is used for preheating the air supplied to the furnace of the boiler. It uses the waste heat of the flue gases for preheating the air, which accelerates the combustion process of the fuel thereby improving the boiler efficiency.



# Functions of Boiler Accessories

- ***Super heater:***

It is used to increase the temperature of the steam beyond the saturation temperature thereby increasing its enthalpy. It is fitted outside the boiler drum. Generally it uses the same heat source of the boiler.

- ***Steam Separator:***

It separates the water particles from the steam flowing in the pipe lines. It is installed very close to the turbine room.



## ● ***Steam trap:***

It is a device which is used to drain off the condensed water accumulating in the steam pipe lines or steam separators while at the same time ensuring that the high pressure steam does not escape out of it.



# Differences between Boiler mountings & Accessories

Boiler mountings	Boiler accessories
They are mandatory	They are optional
They are related to proper functioning, maintenance and safety of the boilers.	They are related to efficiency & economy of the boilers.
They are fitted directly on the boiler drum.	They are not fitted directly on the boiler drum
They are also used to measure some of the important properties	They are used to improve some of the important properties



## *f) Boiler Efficiency*

- Boiler efficiency is defined as the ratio of heat energy utilized from the boiler to the heat energy supplied to the boiler.



## f) Boiler Efficiency

$$\eta = \frac{Q(h_s - h_w) * 100}{m_{fu} * GCV}$$

Where

$Q$ = Quantity of steam generated per unit time(kg/hr.)

$h_s$  = Enthalpy of steam generated (kJ/kg)

$h_w$  = Enthalpy of feed water (kJ/kg)

$m_{fu}$  = Quantity of fuel consumed per unit time(kg/hr.)



$GCV$ = Gross calorific value of the fuel (kJ/kg)

7) A chemical company planning to install a coal fired boiler in its plant for process heating is weighing different technical options due to investment constraints. The steam generation capacity required is 5000kg per hour at a pressure of 0.56MPa and at a temperature of 220°C. The feed water is available from a nearby reservoir at an average temperature 30°C. The coal consumption is 1500 kg/hr, having a calorific value of 24MJ/kg. Assess the improvement in boiler efficiency if the following accessories are used.

- i) Economizer which will increase the feed water temperature by 58°C and reduce the coal consumption by 14%.
- ii) Air Preheater which will reduce the coal consumption by 20%.
- iii) Both Economizer and Air Preheater whose combined effect will reduce the coal consumption by 30%.

Assume specific heat of water and superheated steam as 4.187kJ/kg K and 2.25kJ/kg k respectively



8) A restaurant, daily uses 600 kg of 95% dry steam produced at a pressure of 3bar. The boiler is fitted with an economizer which increases the feed water temperature to  $94^{\circ}$  C and is fired using wood and paddy husk in equal proportions. The gross calorific values of wood and paddy husk are 15500 kJ/kg and 12600 kJ/kg respectively. The boiler has been operating with an average efficiency of 78%. Calculate the daily consumption of wood and paddy husk?

