

Steam Power Plant



Contacts:

Mail: poddar05@gmail.com

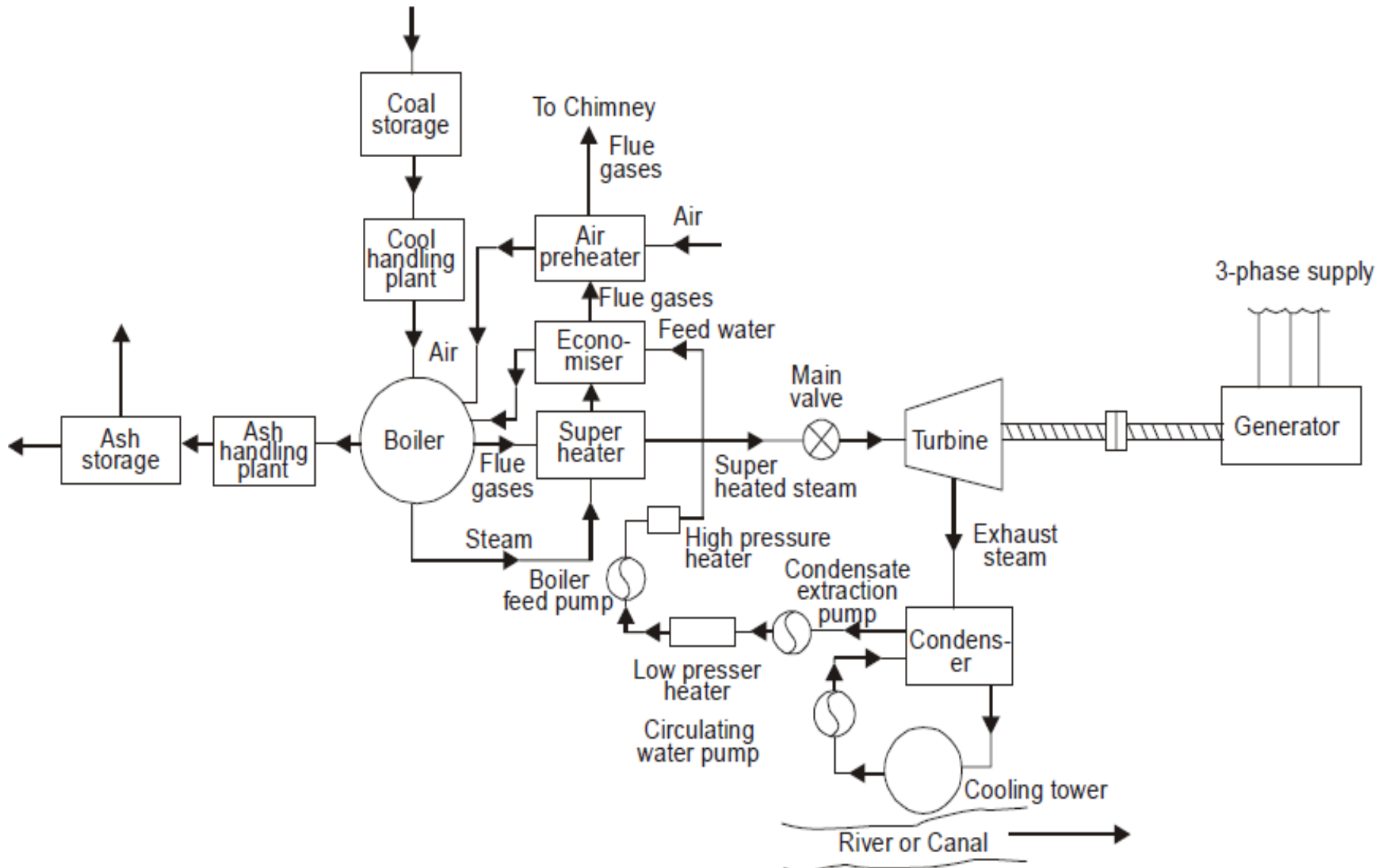
Web: <http://www.ajourneywithtime.weebly.com/>

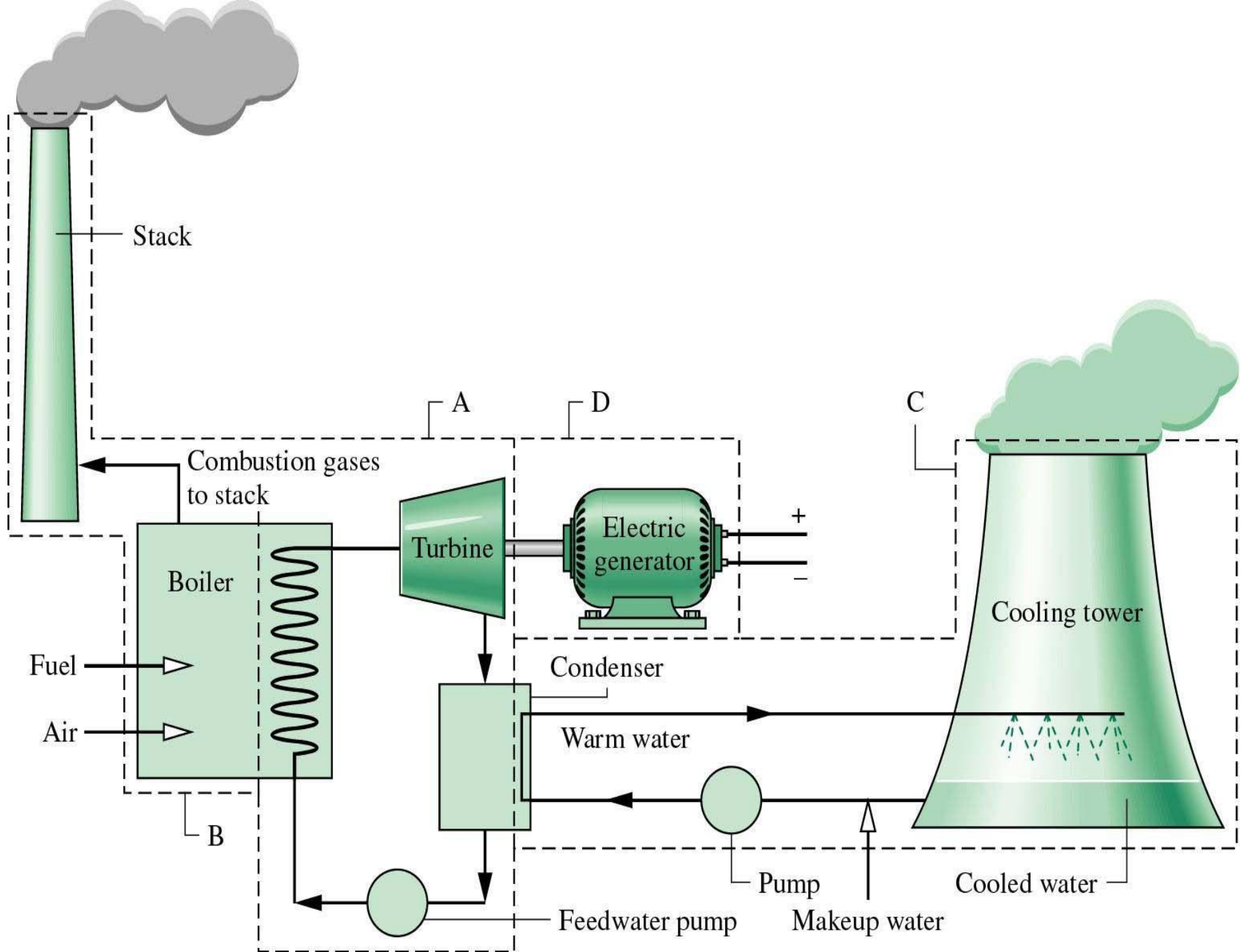
Contents:

- General layout of steam power plant
- Power plant boilers
- Boilers mountings and accessories
- Combustion Systems
- Turbine auxiliary systems
- Operation and maintenance of steam power plant
- Heat balance and efficiency
- Site selection of a steam power plant

General layout of steam power plant

A steam power plant must have following equipments :





Power plant boilers or steam generator

Boiler: it is defined as an enclosed vessel in which steam is produced from water by application of heat. Usually boilers are coal or oil fired. A boiler should fulfil the following requirements.

- Safety
- Accessibility
- Capacity
- Efficient
- Simple in construction & low maintenance cost

Performance of the boiler may be measured in term of its evaporative capacity also called power of a boiler. It is defined as the amount of water evaporated or steam produced in Kg/hr or Kg/Sec

Basic Components of Boiler system

- Boiler feed water heaters or furnace and fuel burning equipment, water walls, boiler surface (drum and tube), Super heater, air heater (pre-heater) , Economizer (feed water heating) and several accessories.
- In addition, there are sets of controls to monitor water and steam flow, fuel flow, airflow and chemical treatment additions.

Classification of Boilers or Steam generator

Based on application of boiler

- Utility Steam Generator
- Industrial Steam Generator
- Marine Steam Generator

Based on relative flow of flue gases and water

- Fire tube Boiler
- Water tube boiler

Based on circulation of water

- Forced circulation
- Natural Circulation

Based on the pressure of steam production

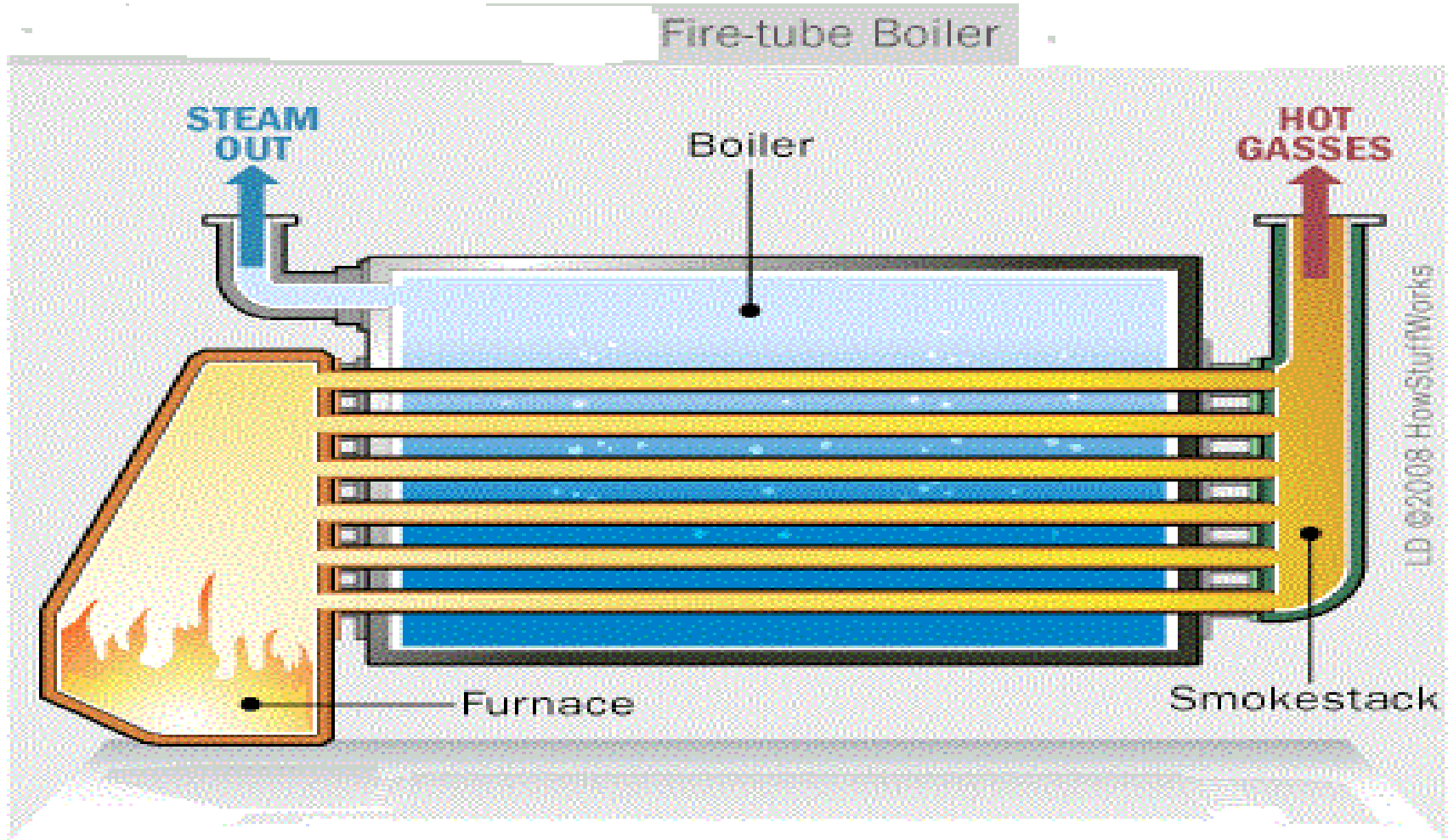
- High pressure boiler
- Low pressure boiler

Classification of Boilers or Steam generator cont...

Based on Steam Delivery Condition

- Wet
- Dry saturated
- Super heated

Fire tube Boiler



Exp: Cochran, Lancashire and locomotive boiler

Fire tube Boiler

In this type, the hot combustion gases are passed inside the tubes, and the tubes are surrounded with water.

The fire-tube boilers may be classified in several ways:

- 1- Externally or internally fired.
- 2- Horizontal, vertical or inclined.
- 3- Direct tube or return tube.

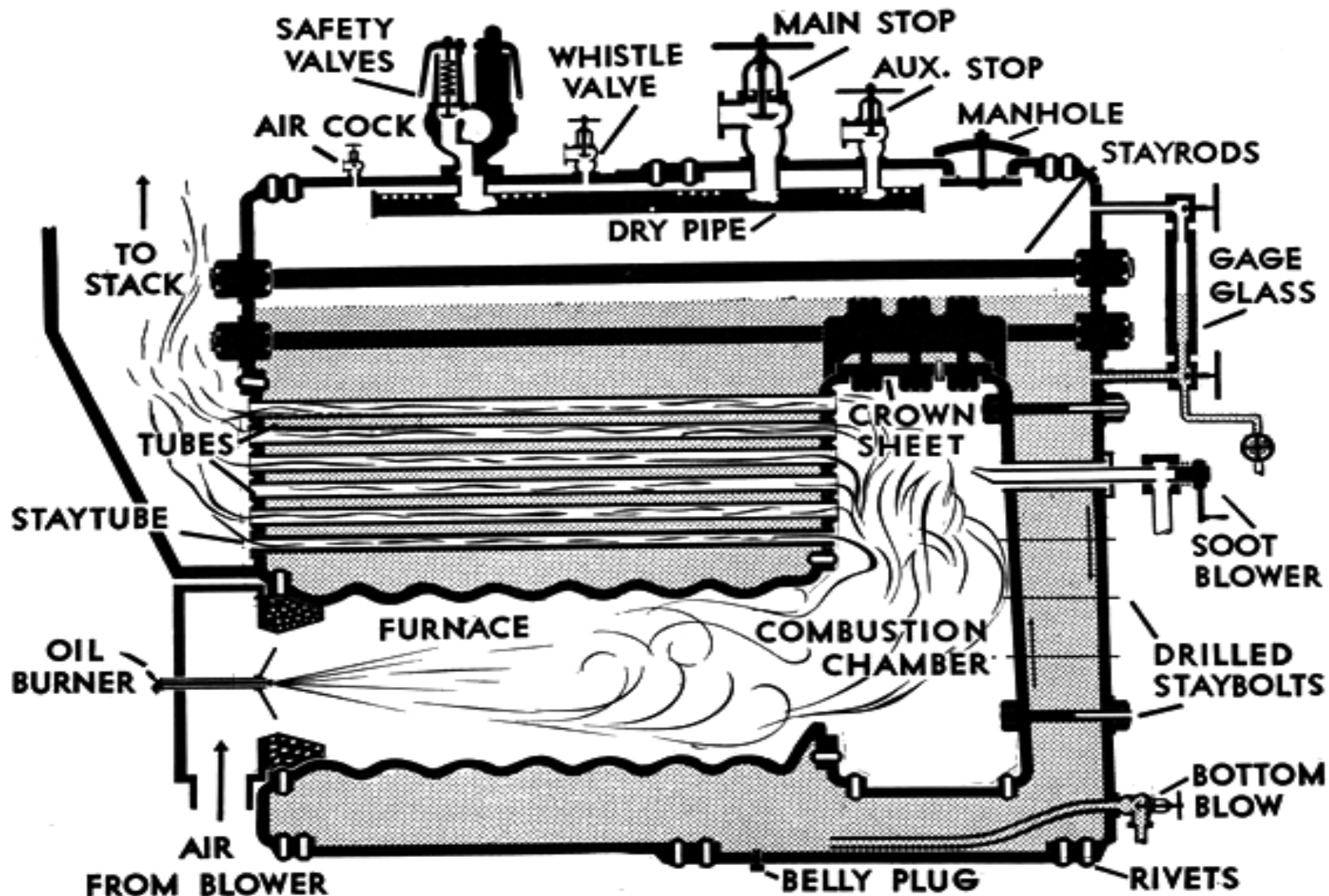
Disadvantages:

1. Since the water and steam are held in a drum, an increase of working pressure need using of thicker plat sections for construction. The max. pr. Is limited.
2. Longer time is required for steam rising due to large quantity of water in the drum.

Advantages:

1. Fire tube boilers are cheaper for smaller pressure and they are capable of meeting large fluctuations in steam demands due to grater water storage in the drum.
2. Doors in the front and rear of the boiler drum provide access to the tubes for cleaning.

Oil fired fire tube boiler

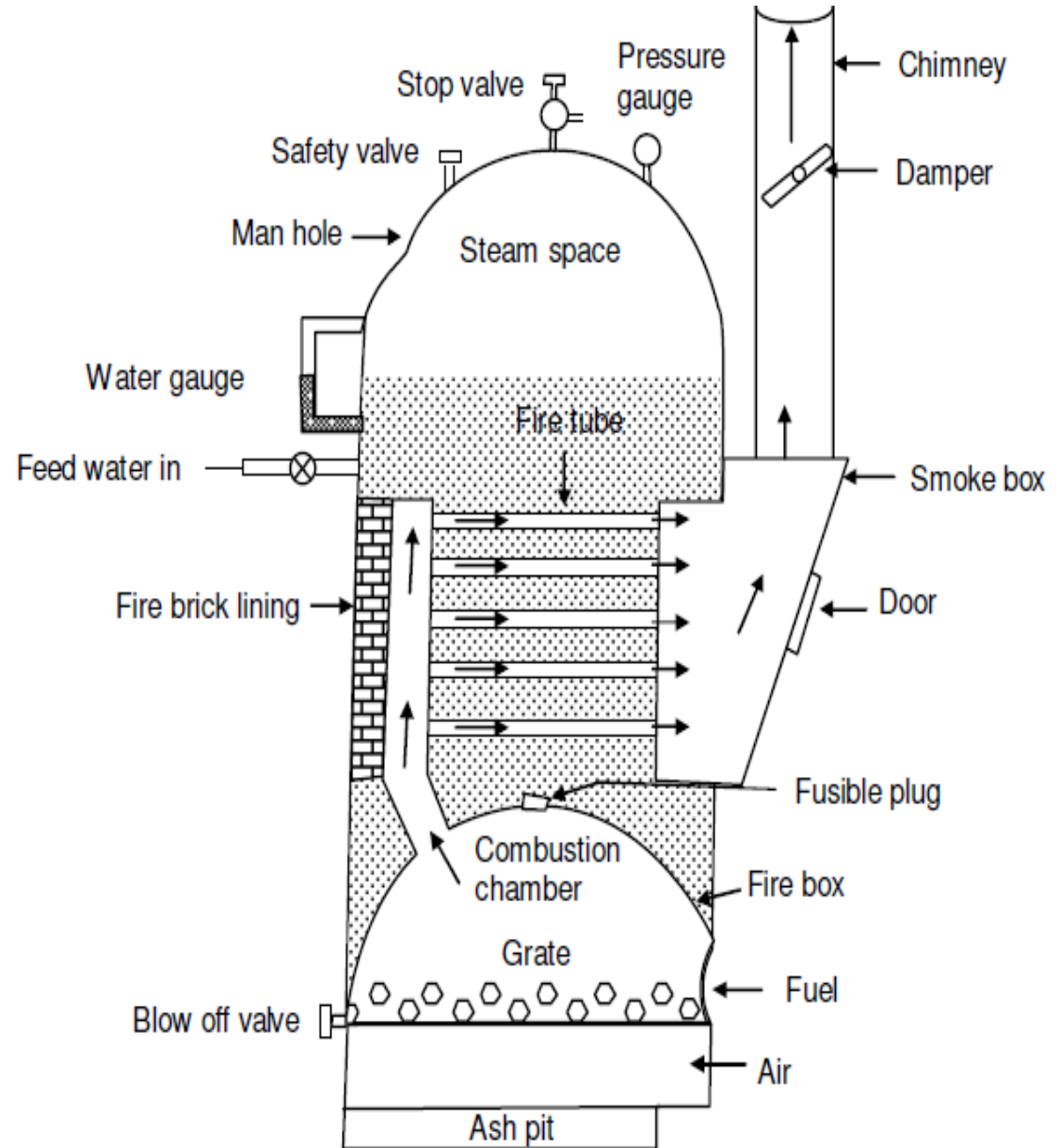


Cochran Boiler

- Vertical multi-tubular boiler has horizontal fire tube

Specifications:

- Shell dia: 2.75 m
- Height: 5.79
- Working Pressure: 6.5 bar
- Steam Capacity: 3500 Kg/hr (max up to 4000 kg/hr)
- Efficiency: 70 to 75 %

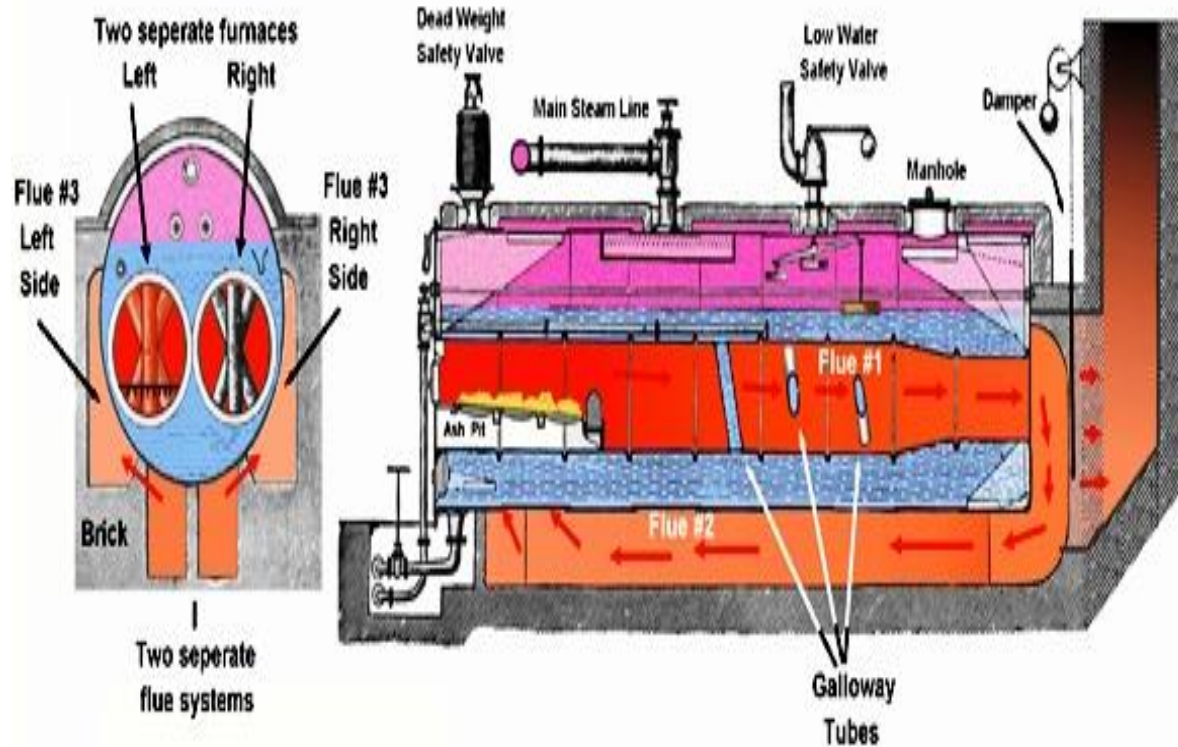


Lancashire Boiler

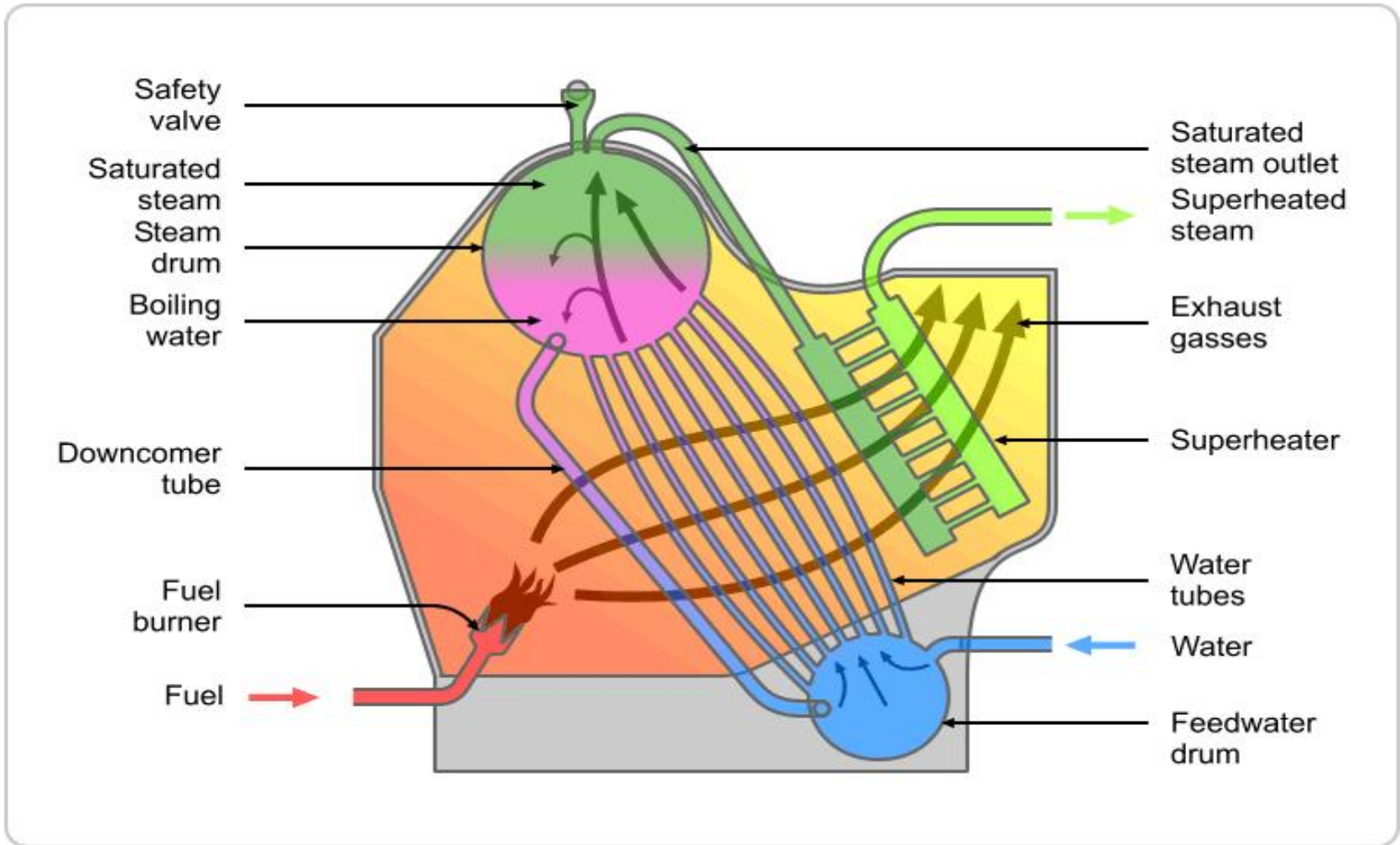
Specifications:

- Max working pressure: 16 bar
- Steam Capacity: 9000 Kg/hr
- Efficiency: 50 to 70 %

Lancashire Boiler cross section views



Water tube boiler



Babcock and Wilcox,
Stirling boiler

Water tube boiler

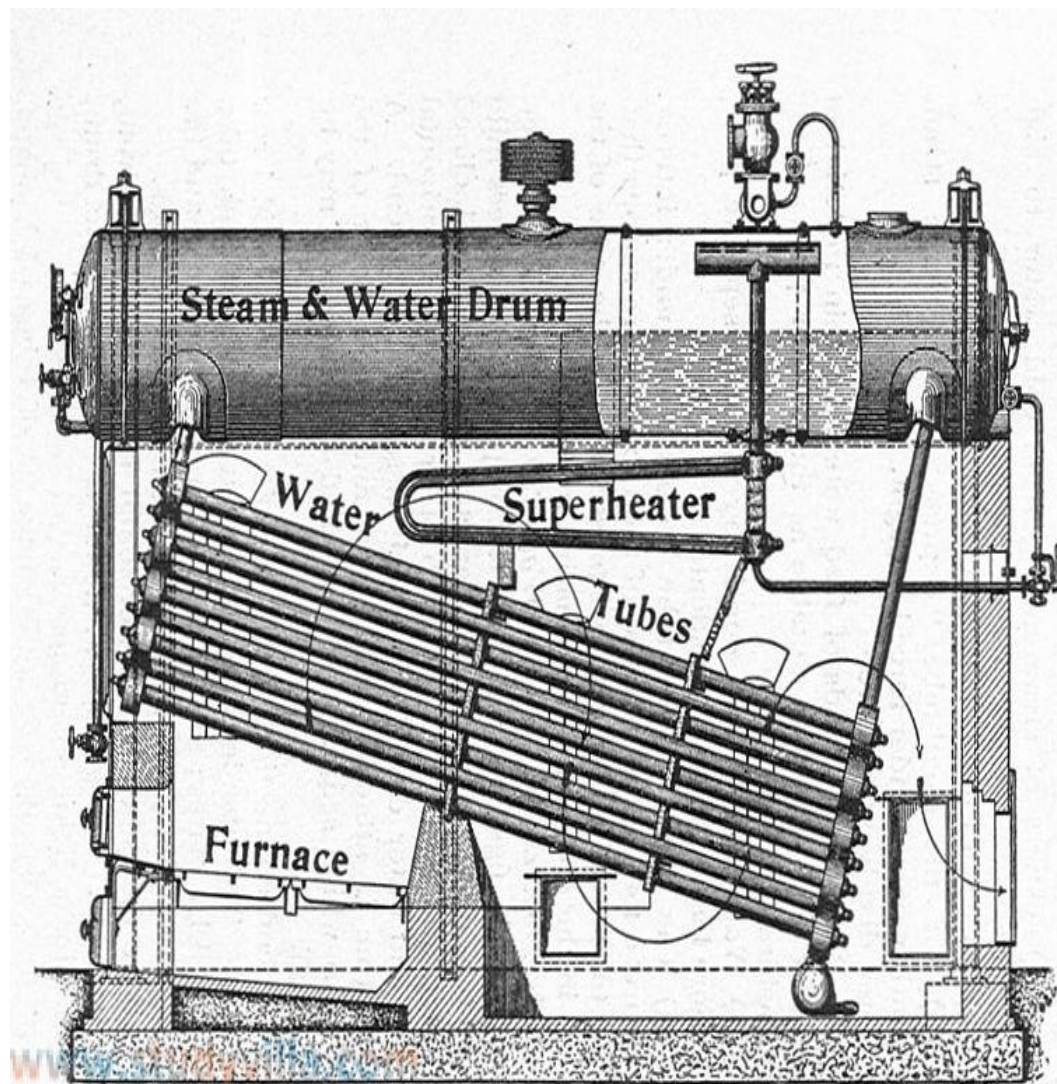
- **For central steam P.P. with large capacities, the water-tube boilers are universally used (pressure is above 17 bar and steam generation is more than 7000 kg/hr). In these boilers, water flows inside tubes and drums, and receives heat by radiation and conduction from combustion gases flowing over the tube surface. Water- tube boilers may be classified in several ways:**
- **Straight or bent tube.**
- **Longitudinal or cross tube**
- **Sectional or box header.**
- **One or more drums.**
- **Horizontal, vertical and inclined tubes.**
- **Forced or natural circulation.**

Advantages:

- **Lower manufacturing and erecting cost.**
- **Ease of inspection.**
- **Ease of cleaning.**

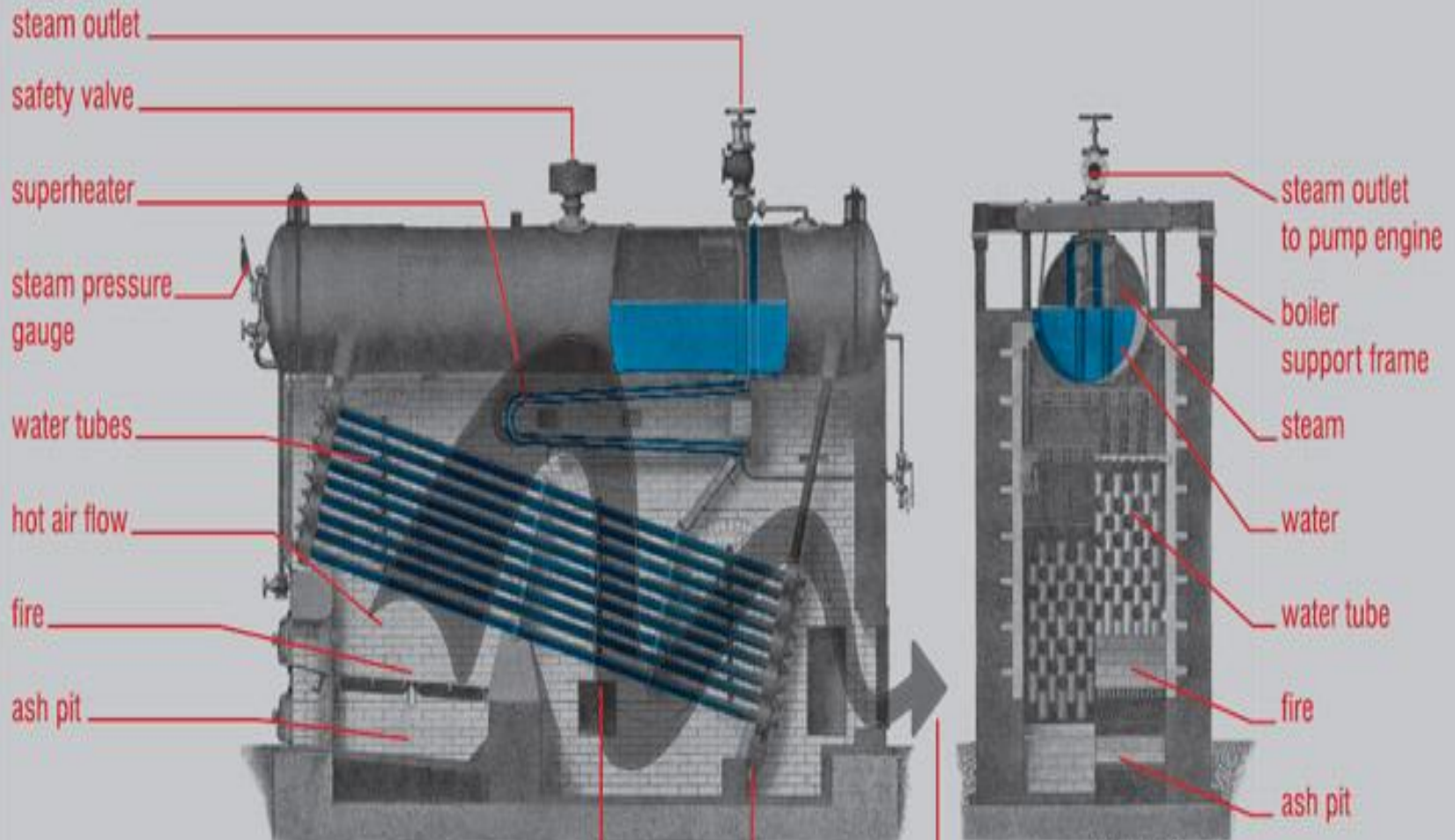
Babcock and Wilcox

- Longitudinal Drum Type
- Straight tube
- Pressure: 12-23 bar
- Steam capacities: 0.63-10 kg/sec
- Efficiency: 60-80%



Straight tube

longitudinal drum boiler with superheated tubes. The straight inclined parallel tubes are rolled into header at each end, and placed below the longitudinal drum. The drum may be placed cross-wise with respect to the tubes. Incline tubes in parallel connect the two headers (box header). The rear header is provided at the bottom, called the mud drum, to collect solids in the boiler water.



steam outlet

safety valve

superheater

steam pressure gauge

water tubes

hot air flow

fire

ash pit

steam outlet to pump engine

boiler support frame

steam

water

water tube

fire

ash pit

BABCOCK & WILCOX PATENT WATER-TUBE BOILER, FITTED WITH PATENT SUPERHEATER (INTEGRAL WITH BOILER)

Babcock & Wilcox Ltd

hot air flow over tubes + superheaters

mud drum

exhaust to chimney via economiser

Longitudinal section of boiler

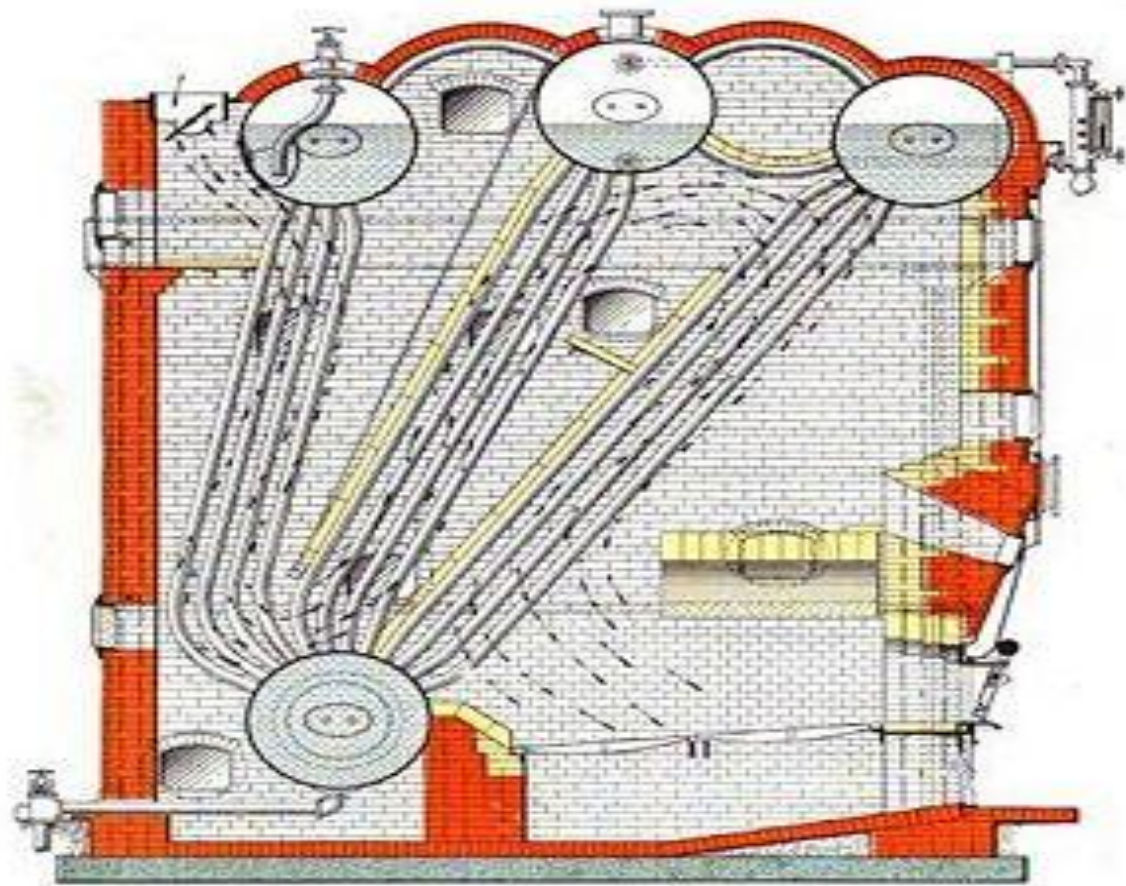
Cross section of boiler

Babcock and Wilcox contd....

- Cross-drum type
- Pressure: 12-100 bar
- Steam capacity; 0.63-63 kg/sec

Stirling boiler

- Bent-tube boiler
- Pressure: 60 bar and more
- Steam capacities: 12 kg/se and more

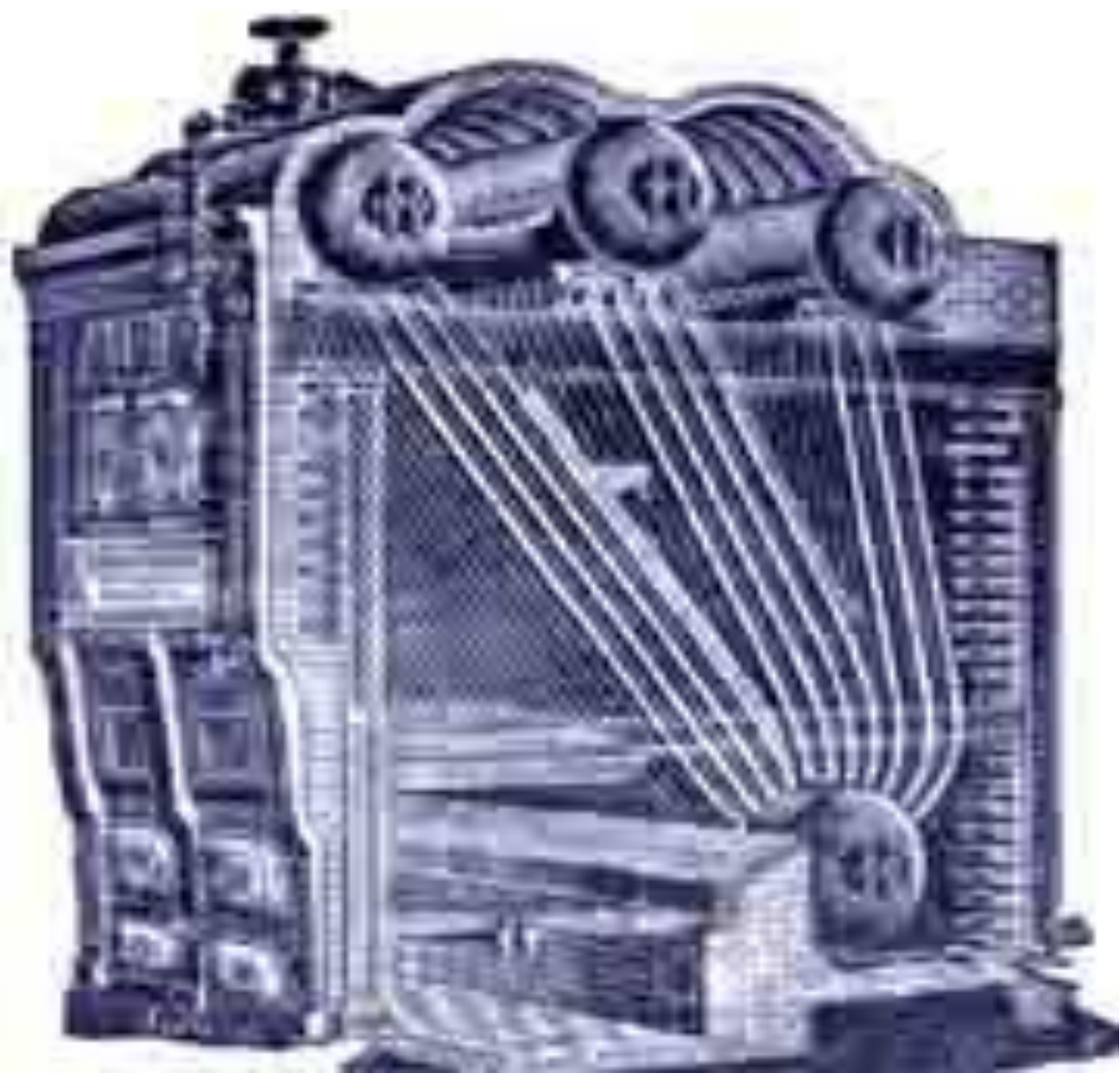


Stirling Water-tube Boiler with Four Cross-Drums

The red, yellow and blue sections are red brick, fire brick and concrete

The bent tube boiler is one of the most commonly used due to its simplicity. The headers are eliminated there by reducing maintenance costs. The bent tubes inter directly into the drum. They are arranged to give good circulation. As shown in the following fig. , three drums are used, each at a different levels. Water circulates from the upper most drum to the lower most drum, then into intermediate drum, and finally to the upper drum which contains the direct steam.

- Tubes are cleaned from inside the drums, and only one or two manholes need be removed to get inside.
- This design is used for pressure of 32 bar and for capacities of about 18000 kg/hr.
- Water walls are used in these boilers to increase combustion rates and steaming capacity.



Q. Compare Fire tube and water tube boilers

Fire Tube Boiler	Water Tube Boiler
Hot gases pass through the tubes which are surrounded by water.	Water passes through the tube and hot gases surround the tube and heat it from outside
Any leak of water into tube will lead to explosion.	Leakage of water cannot cause service damage.
Because smoke or fire tubes are subjected to compressive stresses maximum pressure is restricted	Water/steam can be at very high pressures and tube failure rarely occurs
Suitable for low capacity	Suitable for large – very large capacity.
Efficiency is low	Efficiency is high.
Periodic tube cleaning is necessary to remove the deposits to enhance the heat transfer rate.	With the use of boiler feed water tube inside cleaning is not needed.

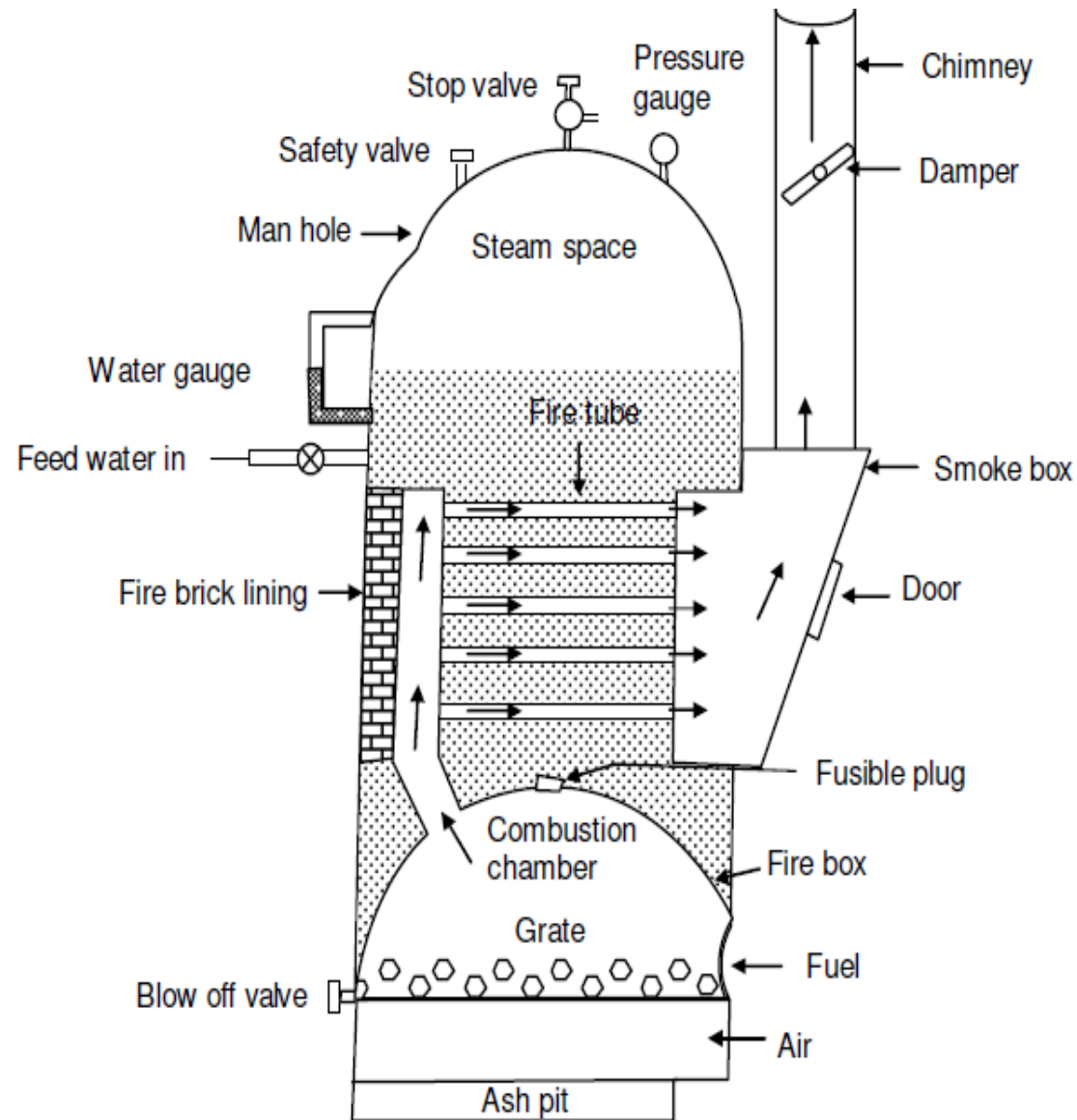
Boilers mountings and accessories

Boilers mountings: The boiler mountings are the part of the boiler and are required for proper functioning. In accordance with the Indian Boiler regulations, of the boiler mountings is essential fitting for safe working of a boiler.

- Safety valve
- Pressure gauge
- Water gauge
- Steam stop valve
- Feed check valve
- Fusible plug, and
- Blow off cock

Boilers mountings contd...

- **Safety valve:** Safety valves are located on the top of the boiler. They guard the boiler against the excessive high pressure of steam inside the drum.
- These are available in three designs :
 - (a) Dead weight,
 - (b) Lever loaded, and
 - (c) **Spring loaded.**All high pressure boilers have spring loaded safety valves.



Safety valve contd....

➤ It is provided to keep the boiler pressure within the safety limit.

➤ The spring is set in such a way that the upward thrust of the steam is balanced by the downward thrust of the spring. If the operating steam pressure exceeds this value, the difference in the thrust opens the lid upward as a result of which steam will be released with hissing sound, the steam pressure inside the shell will go down till the lid is forced down to be back on its seat or initial place

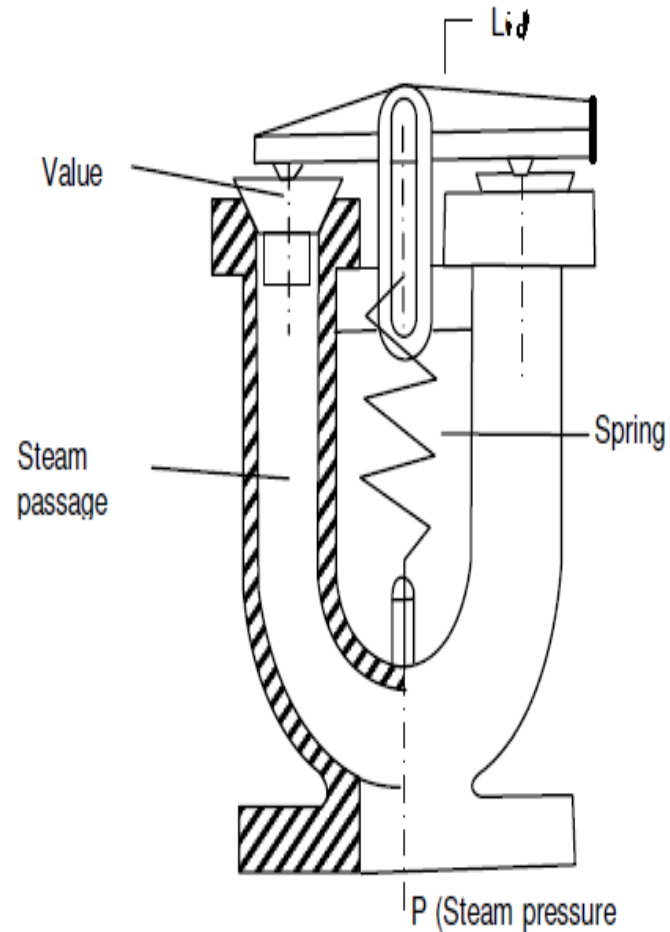
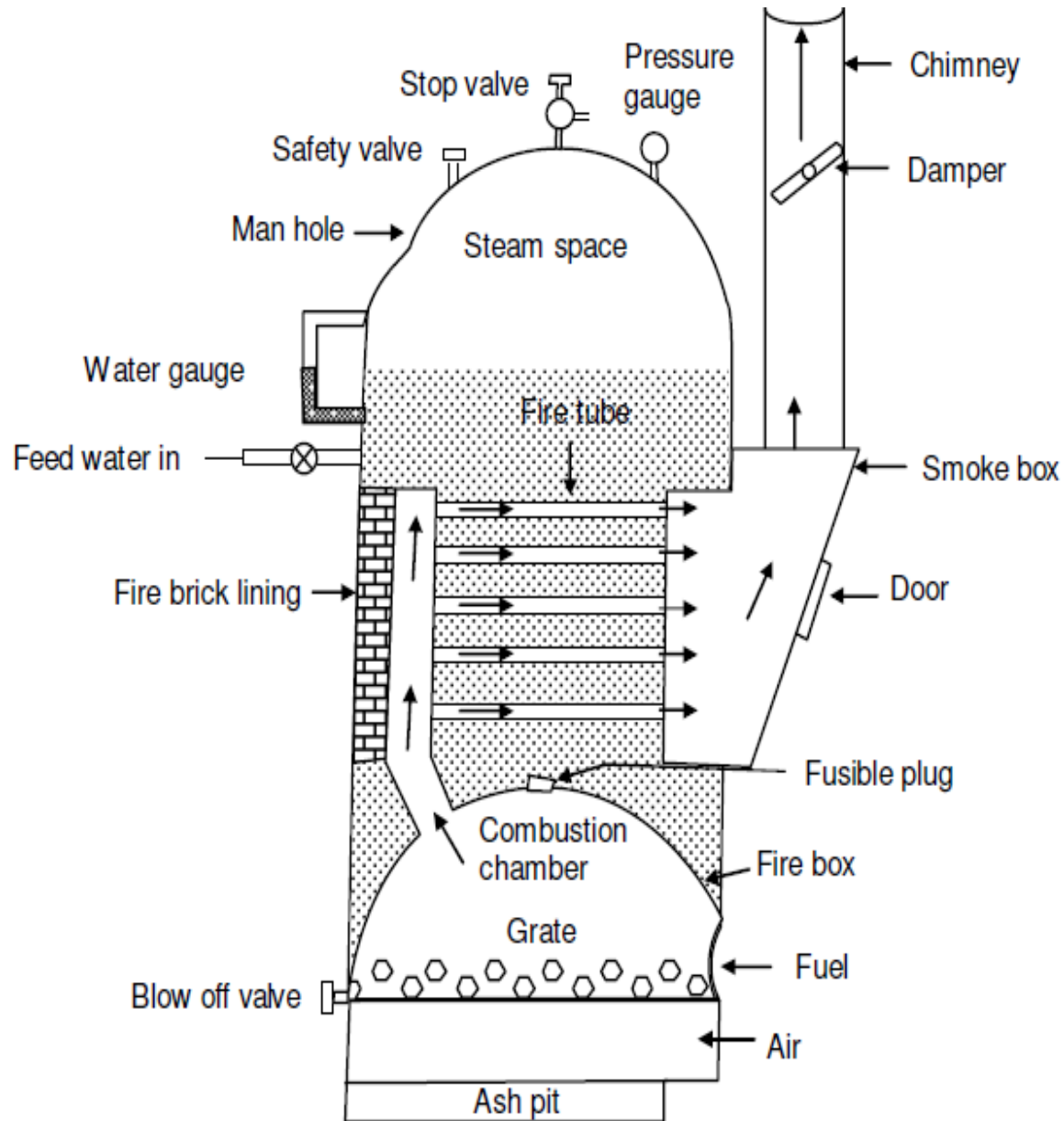


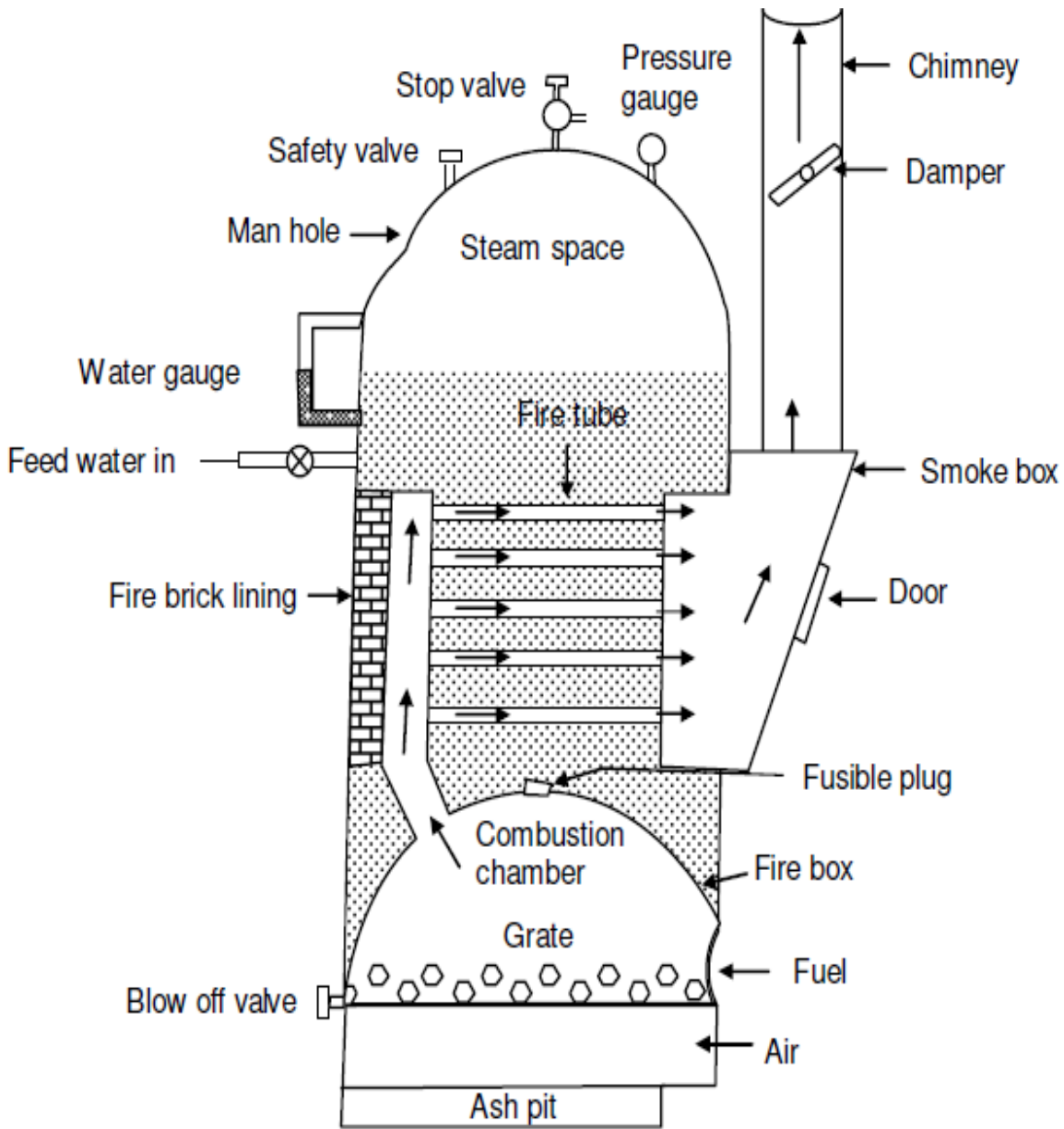
Fig: Spring Loaded Safety Valve

- **Pressure gauge:** A pressure gauge is fitted in front of boiler in such a position that the operator can conveniently read it. It reads the pressure of steam in the boiler and is connected to steam space by a siphon tube.

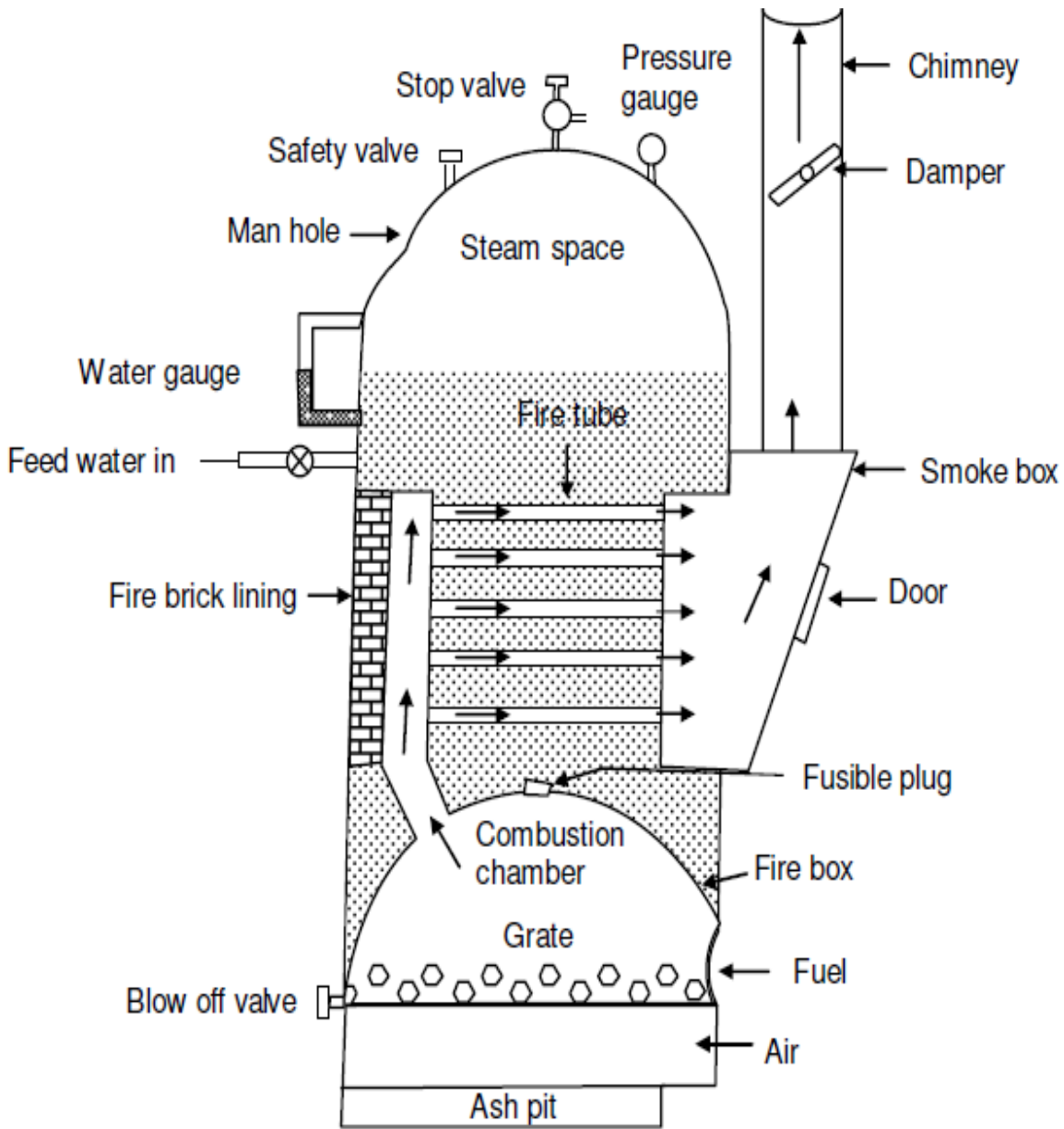


Water gauge or water level indicator:

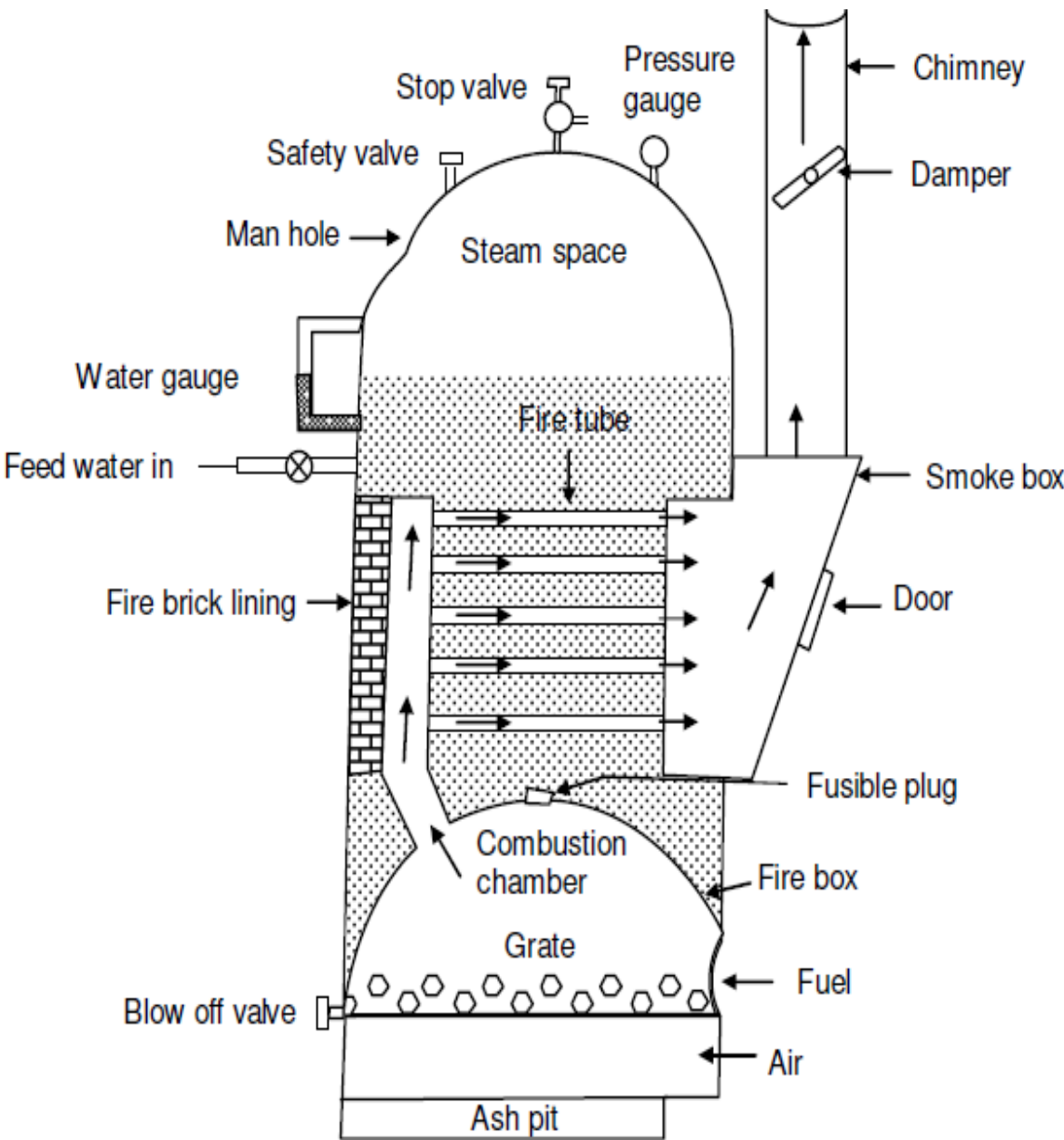
Water level indicator is located in front of boiler in such a position that the level of water can easily be seen by attendant.



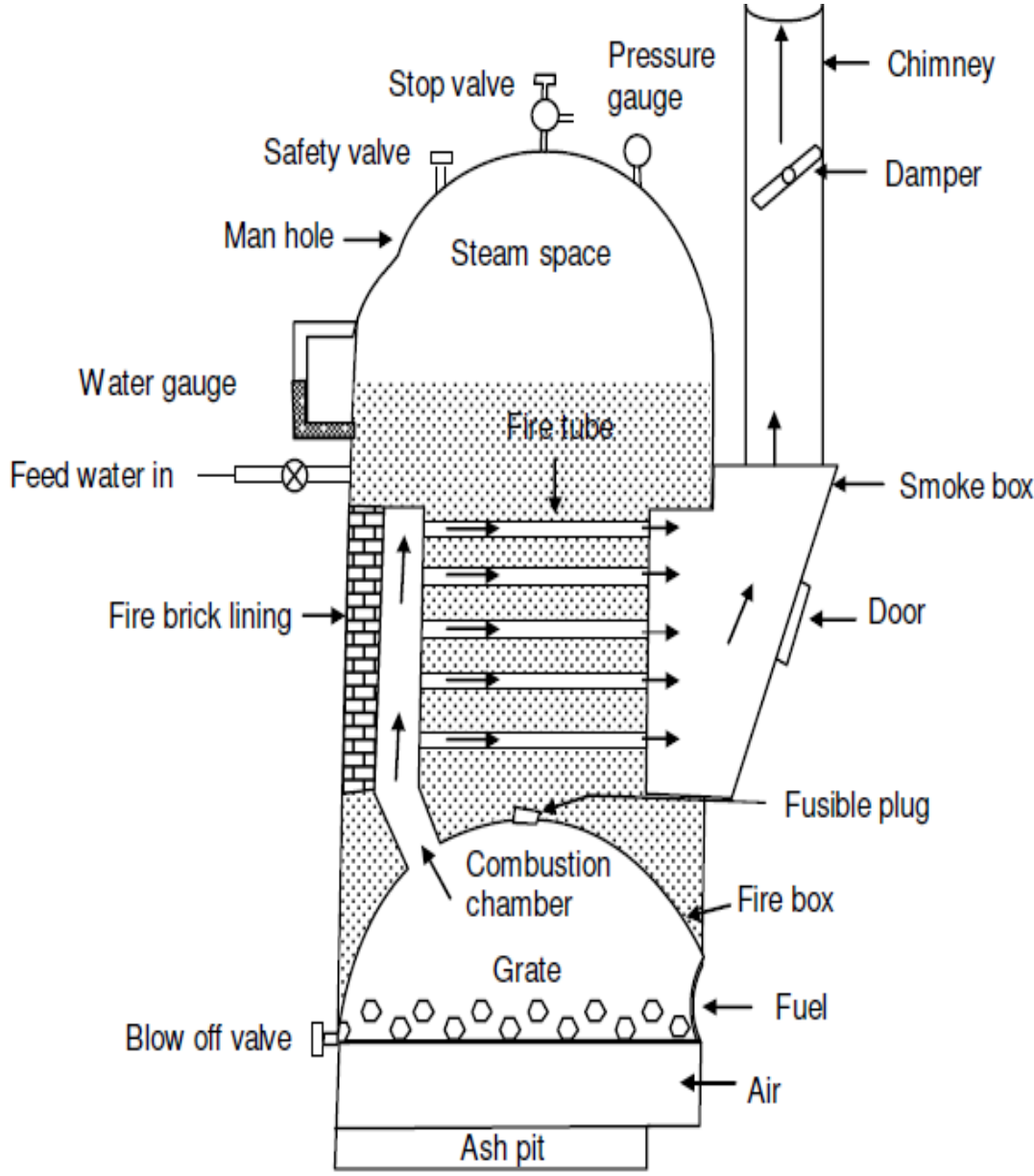
- Steam stop valve:** The steam stop valve is located on the highest part of the steam space. It regulates the steam supply to use. The steam stop valve can be operated manually or automatically.



- **Fusible plug:** It is very important safety device, which protects the fire tube boiler against overheating. It is located just above the furnace in the boiler.



Blow off cock : The function of blow-off cock is to discharge mud and other sediments deposited in the bottom most part of the water space in the boiler, while boiler is in operation. It can also be used to drain-off boiler water. Hence it is mounted at the lowest part of the boiler. When it is open, water under the pressure rushes out, thus carrying sediments and mud.



Boilers accessories

- Air Pre Heater
- Economiser
- Super Heater
- Feed Water Pump
- Condenser
- Evaporator

Boilers accessories

To increase the efficiency of boilers equipment like economiser, air pre heater and super heater are added to the boiler. These are known as boiler accessories.

Air Pre Heater:

It is a heat exchanger used to heat the air entering furnace by extracting heat from flue gas. Combustion of fuel using hot air improves furnace temperature and also improves the thermal efficiency of the boiler.

Economiser:

This is also a heat exchanger but heats the feed water again using flue gases. It is placed in the path of flue gas just ahead of the air pre heater.

Super Heater

The function of a superheater is to increase the temperature of the steam above its saturation point.

There are two type of superheaters:

1. Convective superheater
2. Radiant superheater

Superheated steam has the following advantages:

- Steam consumption of the turbine is reduced.
- Losses due to condensation in the cylinders and steam pipes are reduced.
- Erosion of turbine blade is eliminated.
- Efficiency of the steam plant is increased.

Feed Water Pump

- It forces the feed water into the boiler at the desirable operating pressure

There are two type of pumps used as a feed pumps:

1. Reciprocation pump: The reciprocating pump consists of a pump cylinder and a piston. Inside the cylinder reciprocates a piston which displaces water.
2. Rotary pump: Rotary feed pump are centrifugal type and are commonly run either by a small steam turbine or by an electric motor.

Condenser:

This is another type of heat exchanger used to condense exhaust steam from engine or turbine.

Evaporator: Found only in ships. It is used to get pure water from available sea (salt) water

Evaluation of Performance of boilers

The performance of boiler may be measured in term of its evaporative capacity also called power of boiler. It is defined as the amount of water evaporated or steam produced in Kg/hr or Kg/sec

It may be expressed as in

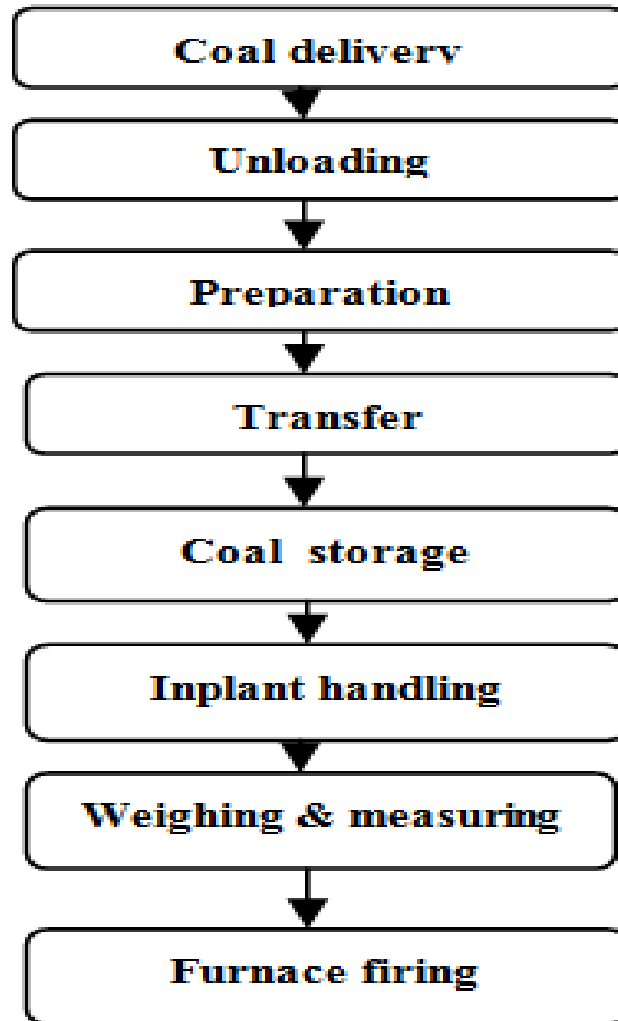
- Kg of steam/hr/m²
- Kg of steam/kg of fuel fired

Equivalent Evaporation:

- Generally the different boilers generate steam at different pressure and temperature and as such have different amount of heat. Hence to compare the evaporative capacity or performance of different boilers working under different conditions it become imperative to provide a common base so that water be supposed to be evaporated under standard conditions.
- The standard conditions adopted are: temperature of feed water $100\text{ }^{\circ}\text{C}$ and converted into dry and saturated steam at $100\text{ }^{\circ}\text{C}$. as per these standard conditions 1 kg of water at $100\text{ }^{\circ}\text{C}$ necessitates 2257 kJ to get converted to steam at $100\text{ }^{\circ}\text{C}$
- So **Equivalent Evaporation** may be defined as the amount of water evaporated from water at $100\text{ }^{\circ}\text{C}$ to dry and saturated steam at $100\text{ }^{\circ}\text{C}$

Coal handling system

The following Stages are involved in handling the coal



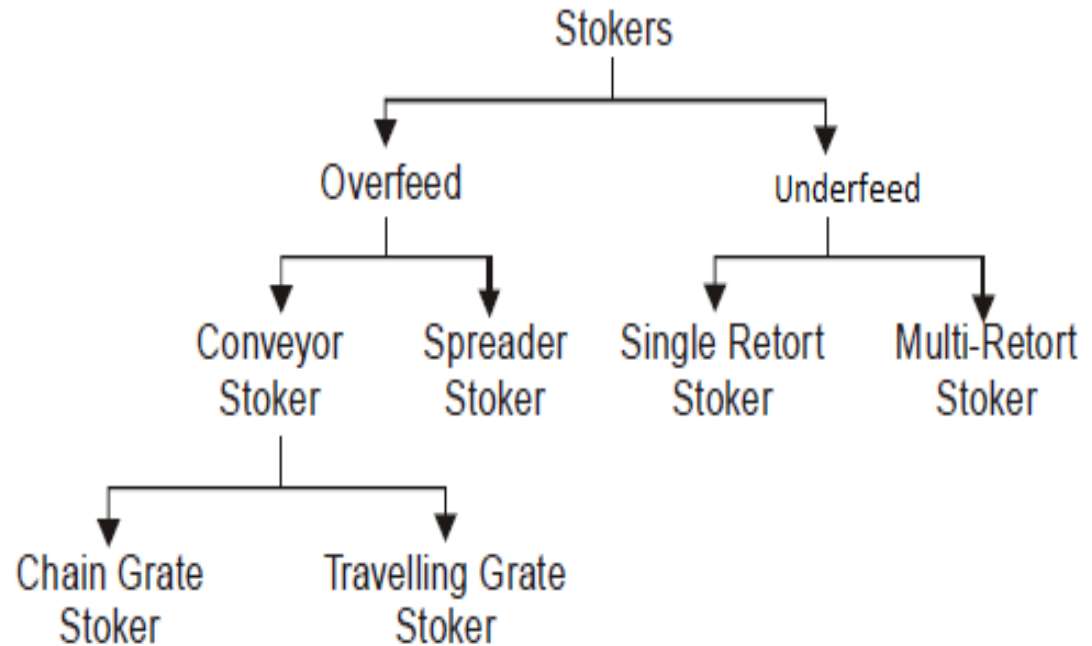
Burning or firing of Coal

The solid fuels are fired into the furnace by the following methods :

- Hand firing
- Mechanical firing(Stokers)
- Pulverized fuel firing

Mechanical stokers are commonly used to feed solid fuels into the furnace in medium and large size power plants.

Types of Stokers:

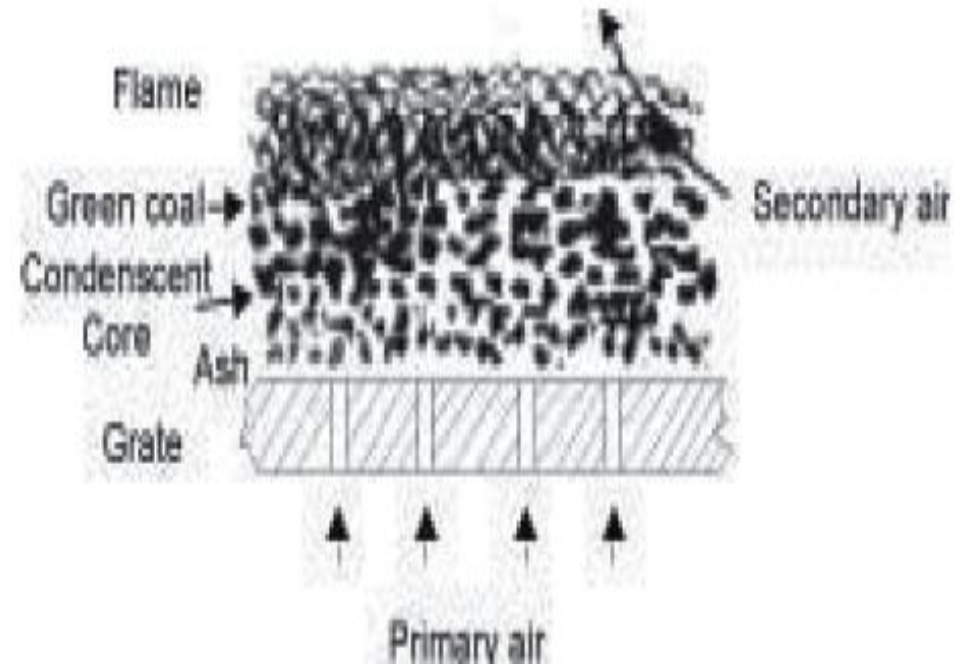


Principles of Stokers

The working of various types of stokers is based on the following two principles:

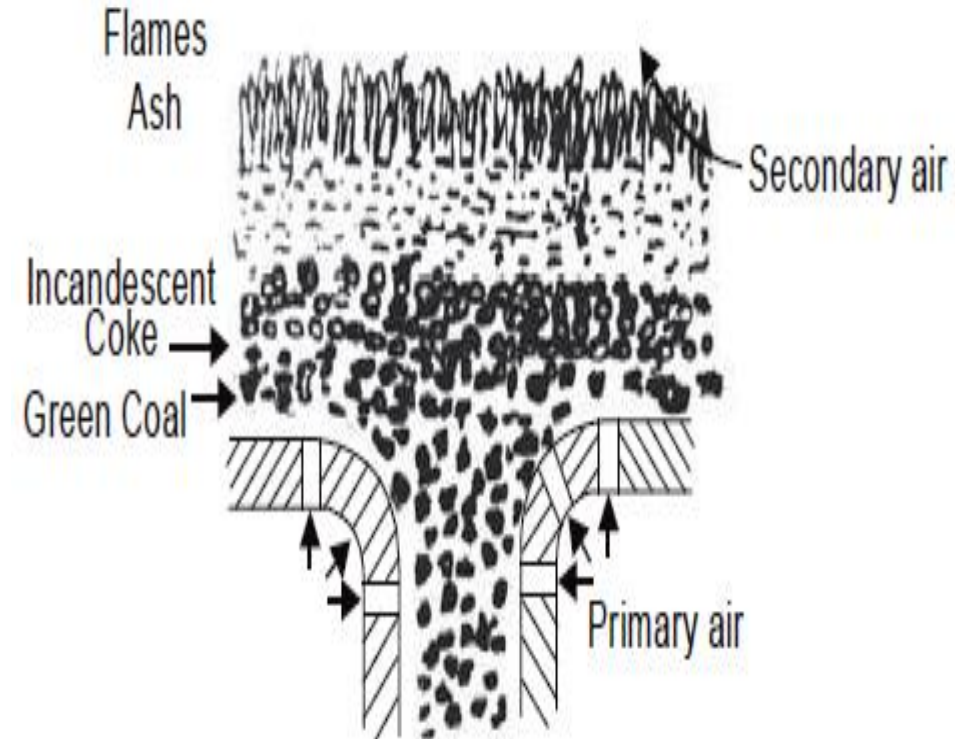
Overfeed Principle:

- According to this principle the primary air enters the grate from the bottom. The air while moving through the grate openings gets heated up and the grate is cooled. The hot air that moves through a layer of ash and picks up additional energy. The air then passes through a layer of incandescent coke where oxygen reacts with coke.
- The combustion gases entering the boiler consist of N_2 , CO_2 , O_2 and H_2O



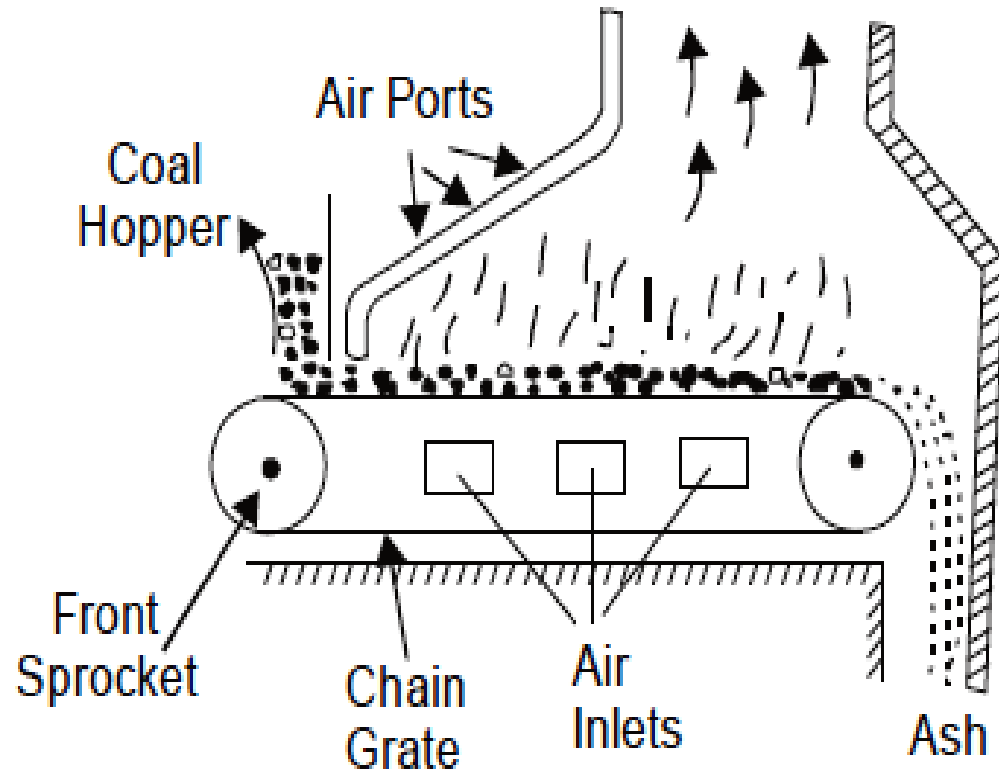
Underfeed Principle

- In underfeed principle air entering through the holes in the grate comes in contact with the raw coal. Then it passes through the incandescent coke where reactions similar to overfeed system take place. The gases produced then pass through a layer of ash. The secondary air is supplied to burn the combustible gases. Underfeed principle is suitable for burning the semi-bituminous and bituminous coals.



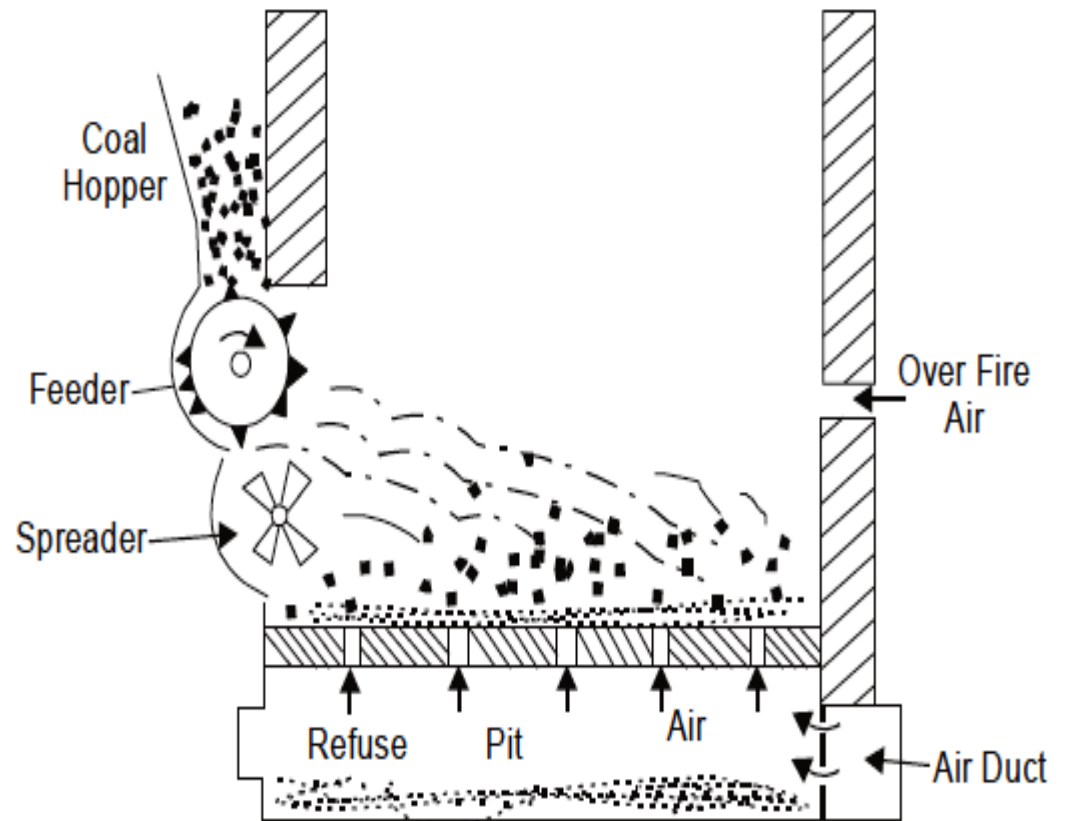
Chain Grate Stoker

- A chain grate stoker consists of an endless chain which forms a support for the fuel bed. Primary air Secondary air Incandescent Coke Green Coal
- The traveling chain receives coal at its front end through a hopper and carries it into the furnace. The ash is tipped from the rear end of chain.



Spreader Stoker

In this stoker the coal from the hopper is fed on to a feeder which measures the coal in accordance to the requirements. Feeder is a rotating drum fitted with blades. Feeders can be reciprocating rams, endless belts, spiral worms etc. From the feeder the coal drops on to spreader distributor which spread the coal over the furnace. The spreader system should distribute the coal evenly over the entire grate area.

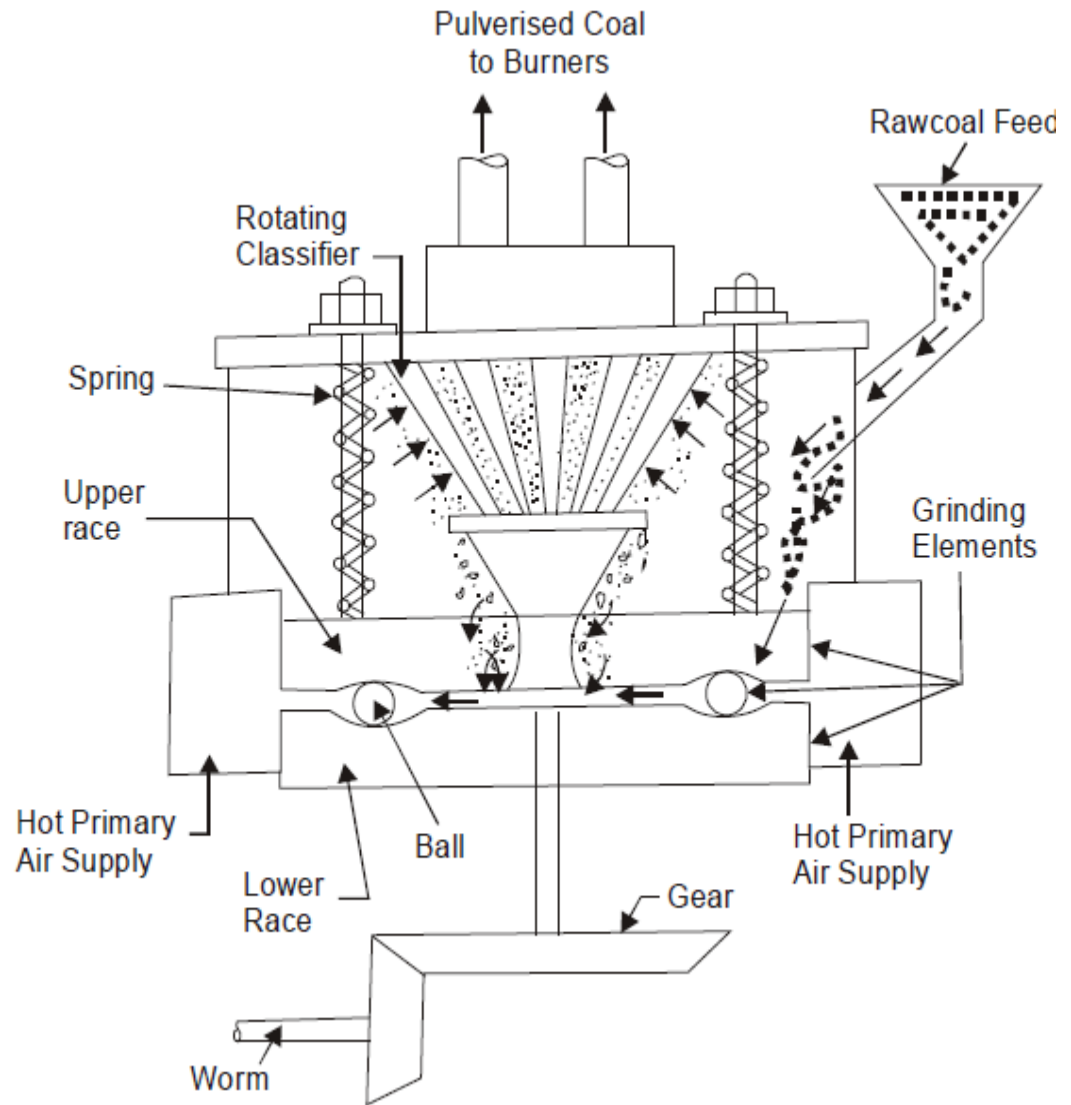


Pulverizers

- **PULVERIZED COAL:** Coal is pulverized (powdered) to increase its surface exposure thus permitting rapid combustion. The use of pulverized coal has now become the standard method of firing in the large boilers. The pulverized coal burns with some advantages that result in economic and flexible operation of steam boilers.
- For large scale generation of energy the efficient method of burning coal is confined still to pulverized coal combustion. The pulverized coal is obtained by grinding the raw coal in pulverising mills. The various pulverising mills used are as follows: (i) Ball mill (ii) Hammer mill (iii) Ball and race mill (iv) Bowl mill.
- The essential functions of pulverising mills are as follows:
 - (i) Drying of the coal (ii) Grinding (iii) Separation of particles of the desired size.
- The coal pulverising mills reduce coal to powder form by three actions as follows:
 - (i) Impact (ii) Attrition (abrasion) (iii) Crushing.

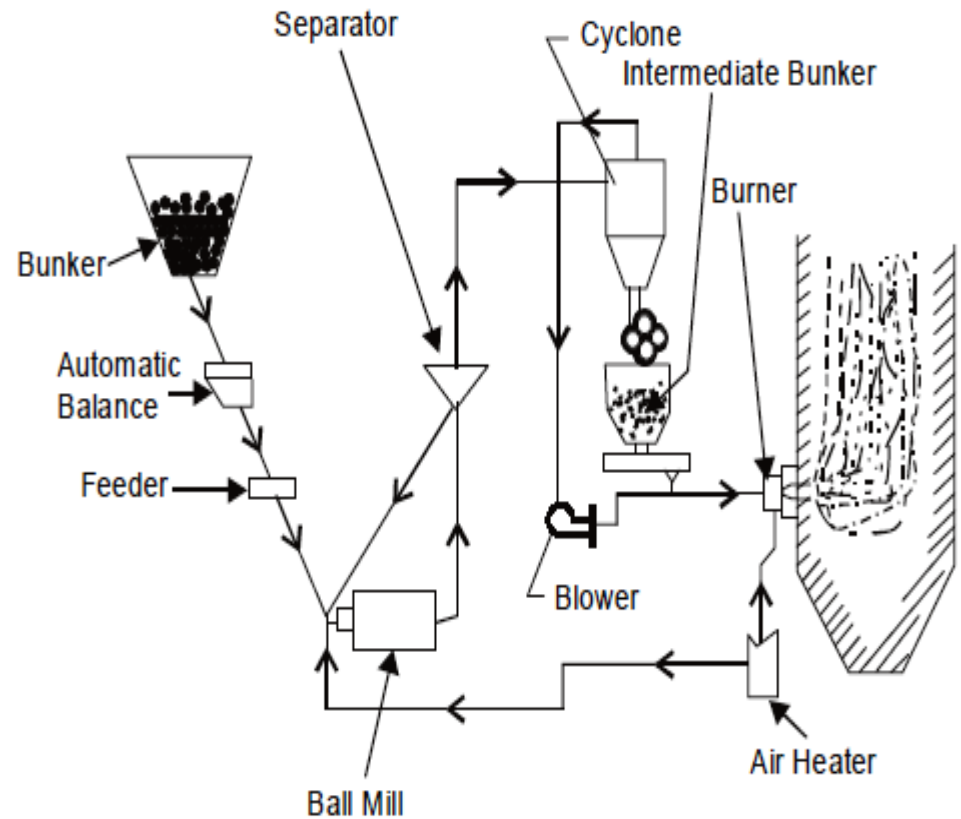
BALL MILL

- It consists of a slowly rotating drum which is partly filled with steel balls. Raw coal from feeders is supplied to the classifiers from where it moves to the drum by means of a screw conveyor.
- As the drum rotates the coal gets pulverized due to the combined impact between coal and steel balls. Hot air is introduced into the drum. The powdered coal is picked up by the air.
- The coal air mixture from the classifier moves to the exhauster fan and then it is supplied to the burners.

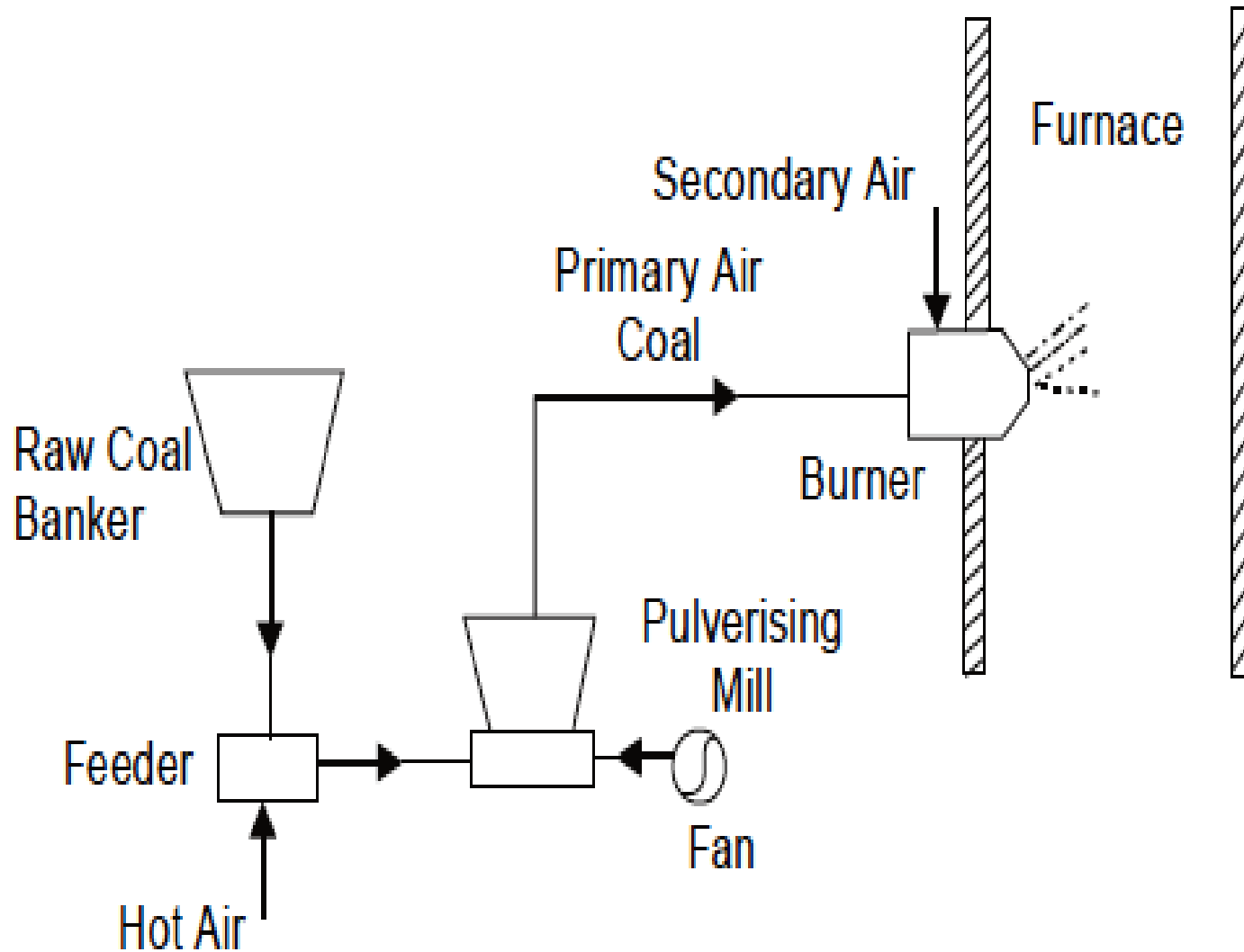


BALL AND RACE MILL

- The fuel moves to the automatic balance and then to the feeder and ball mill through which hot air is blown. It dries the pulverized coal and carries it from the mill to separator.
- The air fed to the ball mill is heated in the air heater. In the separator dust (fine pulverized coal) is separated from large coal particles which are returned to the ball mill for regrinding. The dust moves to the cyclone. Most of the dust (about 90%) from cyclone moves to bunker. The remaining dust is mixed with air and fed to the burner.



PULVERISED COAL FIRING



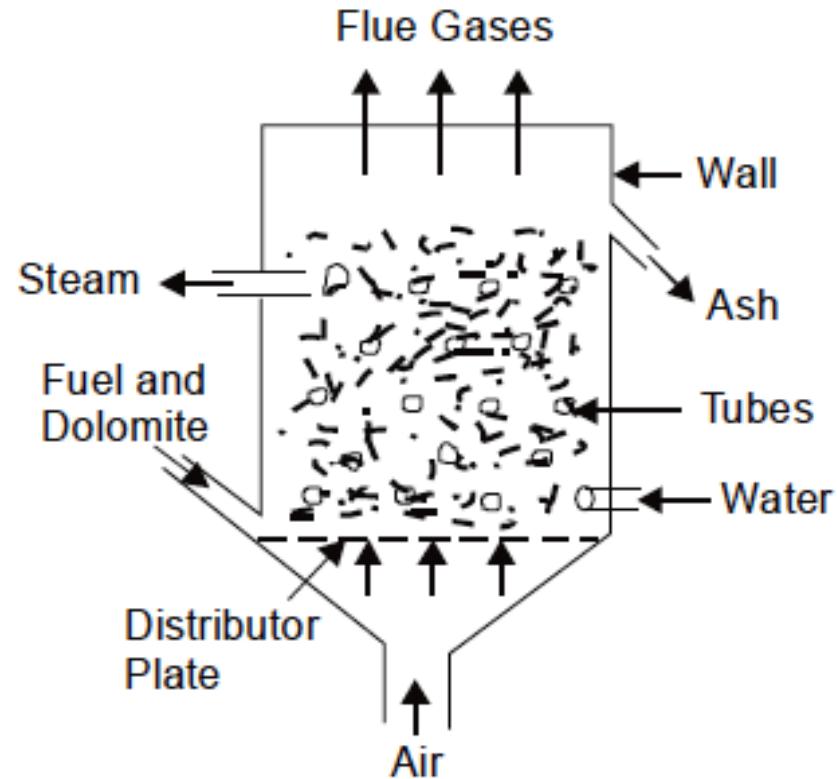
FLUIDISED BED COMBUSTION (FBC)

➤ A fluidised bed may be defined as the bed of solid particles behaving as a fluid.

➤ **Principle of FBC:**

When a gas is passed through a packed bed of finely divided solid particles, it experiences a pressure drop across the bed. At low gas velocities, this pressure drop is small and doesn't move the particles. But if gas velocity is increased further, a state is reached, when particles are suspended in the gas stream and the packed bed becomes a fluidised bed. With further increase in gas velocity, the bed becomes turbulent and rapid mixing of particles occurs.

➤ In general, the behavior of this mixture of solid particles and gas is like a fluid. Burning of a fuel in such a state is known as a fluidised bed combustion.



Various advantages of FBC system are as follows:

- (i) FBC system can use any type of low grade fuel including municipal wastes and therefore is a cheaper method of power generation.
- (ii) It is easier to control the amount of SO₂ and NO_x, formed during burning. Low emission of SO₂ and NO_x. will help in controlling the undesirable effects of SO₂ and NO_x. during combustion. SO₂ emission is nearly 15% of that in conventional firing methods.
- (iii) There is a saving of about 10% in operating cost and 15% in the capital cost of the power plant.
- (iv) Ability to burn coal especially of high ash content, and inferior coals.
- (v) Reduced environmental impact in terms of air pollution.
- (vi) Reduced water requirement.
- (vii) Higher reliability and availability

Ash handling system

- **ASH DISPOSAL:**

A large quantity of ash is, produced in steam power plants using coal. Ash produced in about 10 to 20% of the total coal burnt in the furnace. Handling of ash is a problem because ash coming out of the furnace is **too hot**, it is **dusty** and irritating to handle and is accompanied by some **poisonous gases**.

- Handling of ash includes its removal from the furnace, loading on the conveyors and delivered to the fill from where it can be disposed off.

- **ASH HANDLING EQUIPMENT:**

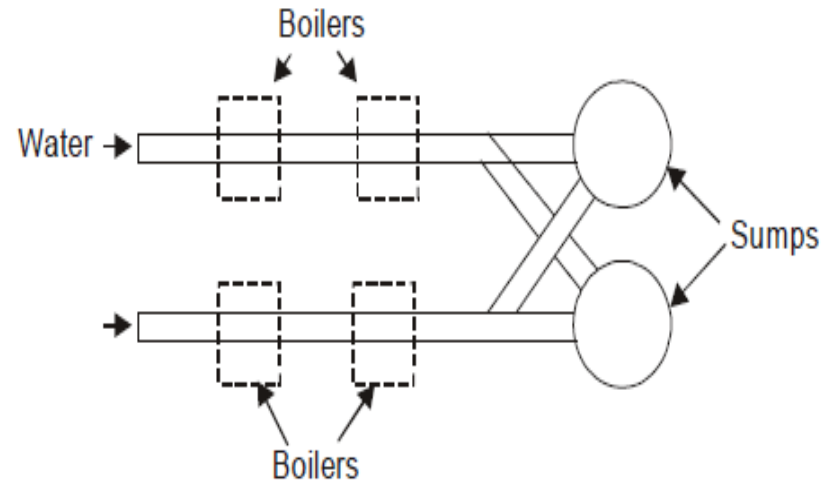
The commonly used ash handling systems are as follows :

- (i) Hydraulic system
- (ii) pneumatic system
- (iii) Mechanical system.

Contd in next classes.....

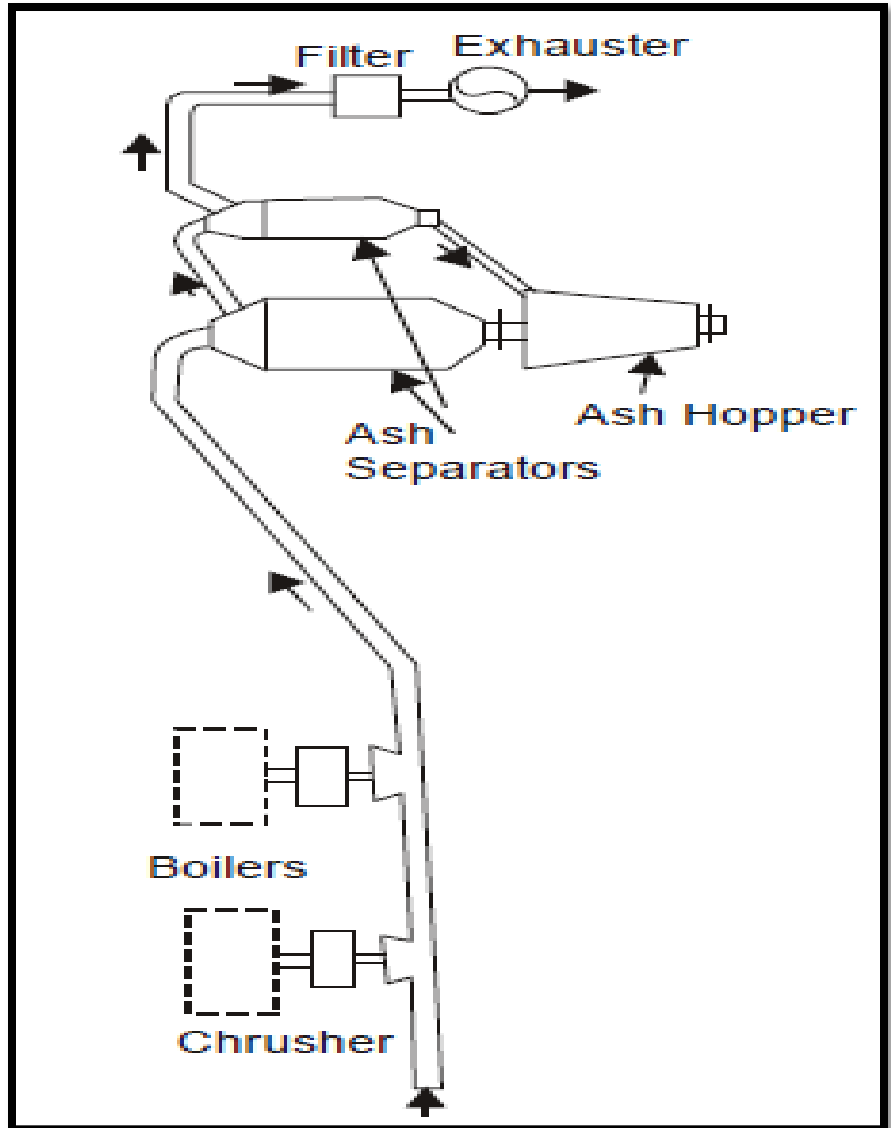
Hydraulic System

- In this system, ash from the furnace grate falls into a system of water possessing high velocity and is carried to the sumps.
- It is generally used in large power plants.
- In this method water at sufficient pressure is used to take away the ash to sump. Where water and ash are separated. The ash is then transferred to the dump site in wagons, rail cars or trucks.



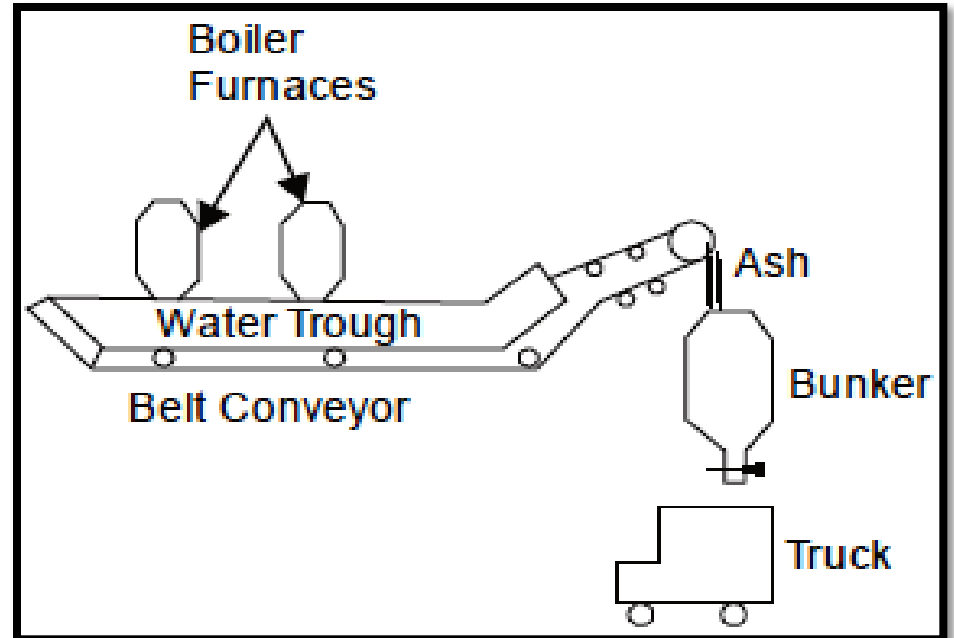
Pneumatic system

- In this system ash from the boiler furnace outlet falls into a crusher where larger ash particles are crushed to small sizes. The ash is then carried by a high velocity air or steam to the point of delivery. Air leaving the ash separator is passed through filter to remove dust etc. so that the exhauster handles clean air which will protect the blades of the exhauster.



Mechanical ash handling system

- In this system ash cooled by water seal falls on the belt conveyor and is carried out continuously to the bunker. The ash is then removed to the dumping site from the ash bunker with the help of trucks.



Dust collection system

- In coal fed furnaces the products of combustion contain particles of solid matter floating in suspension. This may be smoke or dust.
- The production of smoke indicates that combustion conditions are faulty and amount of smoke produced can be reduced by improving the furnace design.

The disposal smoke to the atmosphere is not desirable due to the following reasons :

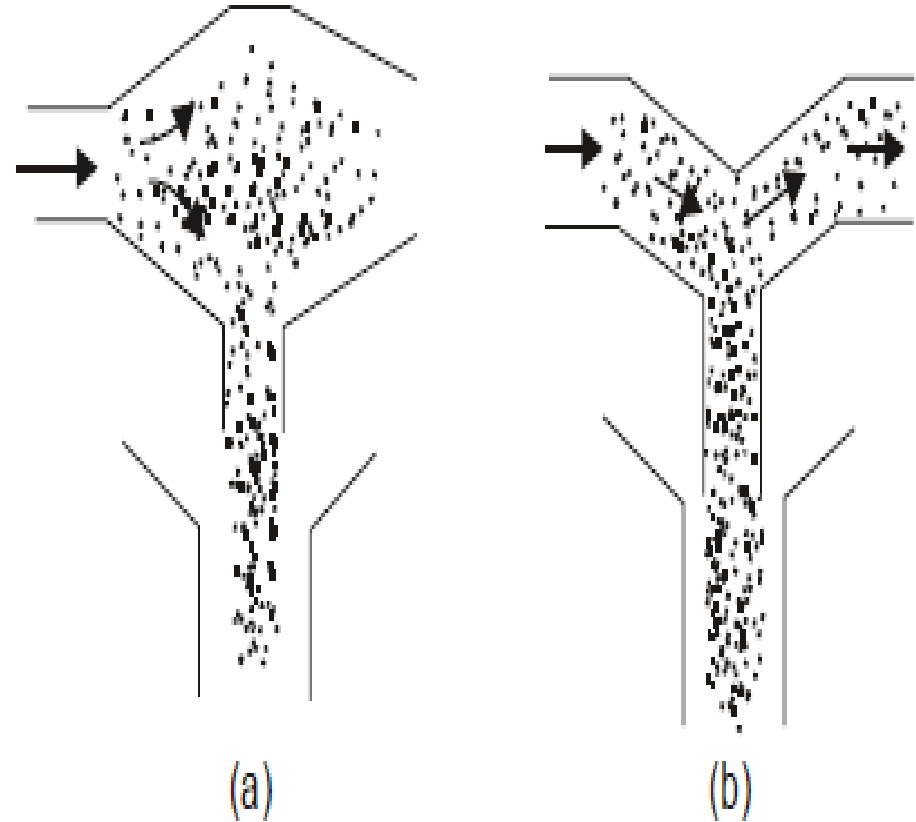
1. A smoky atmosphere is less healthful than smoke free air.
 2. Smoke is produced due to incomplete combustion of coal. This will create a big economic loss due to loss of heating value of coal.
 3. In a smoky atmosphere lower standards of cleanliness are prevalent. Buildings, clothings, furniture etc. becomes dirty due to smoke. Smoke corrodes the metals and darkens the paints.
- **To avoid the atmospheric pollution the fly ash must be removed from the gaseous products of combustion before they leaves the chimney.**

TYPES OF DUST COLLECTORS

1. Mechanical dust collectors.
2. Electrical dust collectors.

Mechanical dust collectors

The basic principles of mechanical dust collectors are shown in Fig. (a) by increasing the cross-sectional area of duct through which dust laden gases are passing, the velocity of gases is reduced and causes heavier dust particles to fall down. Changing the direction of flow Fig.(b) of flue gases causes the heavier particles of settle out.



Electrical dust collectors

- **Electrostatic Precipitators:**

- It has two sets of electrodes, insulated from each other that maintain an electrostatic field between them at high voltage. The flue gases are made to pass between these two sets of electrodes. The electric field ionises the dust particle; that pass through it attracting them to the electrode of opposite charge.
- The electrostatic precipitator is costly but has low maintenance cost and is frequently employed with pulverised coal fired power stations for its effectiveness on very fine ash particles and is superior to that of any other type.

Feed water treatment

- Water used for steam plants contains impurities which must be treated before use.
- **Classification of impurities**
 1. **Visible impurities:** Suspended insoluble matter
 2. **Dissolved gas:** oxygen, carbon dioxide, nitrogen, methane, hydrogen sulphide
 3. **Minerals and salts:** sodium and potassium salts, iron & manganese, fluorides, silica
 4. **Mineral acids:** their presence in water is always undesirable as it may result in the chemical reaction with the boiler material.
 5. **Hardness:** the salts of calcium and magnesium as bicarbonates, chlorides, sulphates etc are mainly responsible for the formation of a very hard surface which resists heat transfer and clogs the passages in pipes. Presence of these salts is known as hardness.

Feed water treatment

Effects of impurities in water

➤ **Scale formation:**

- > Formation of scale reduces heat transfer and simultaneously raises the temperature of the metal wall.
- > scale is due to mainly the salts of calcium and magnesium.

➤ **Corrosion**

- > Corrosion in power plant equipment produces pits, grooves and cracks or wastage of wall material. Allowed to continue corrosion ultimately makes metal parts fail.
- > presence of oxygen and carbon dioxide is mainly responsible for corrosion among all other factors

➤ **Carry over**

- > water solid carried over in the steam leaving a boiler-drum are called “carry-over”

➤ **Embrittlement**

- > Presence of certain concentration of sodium hydroxide cause Embrittlement
- > it is the weakening of boiler steel as a result of inner crystalline cracks.

Methods of feed water Treatment

- Mechanical treatment
- Thermal treatment
- Chemical Treatment
- Demineralisation
- Blow down

Mechanical treatment

- **Sedimentation:** In this process the water is allowed to stand at stand still in big tanks so that solid matter settle down. These solid matter settle down could be removed from the bottom either periodically or continuously. Clear water is then drained out from the tank surface.
- **Coagulation:** Coagulation of colloidal suspensions make them settle out easily. Adding a coagulation like aluminum sulphate or sodium aluminates improve the sedimentation or filtration process.
- **Filtration:** The suspended matter can't be removed during sedimentation are removes with the help of filtration. The water is allowed to pass through a bed of fine sand or graded sand and then a larger of gravels etc. the suspended matter adheres to the filter material leaving the water clear as it drained from the bottom

Thermal treatment

- **Deaeration:** The process of removing dissolved oxygen is known as deaeration. This is done in a deaerating heaters. If the water is heated to a temp. of about 110 °C with subsequent agitation, the dissolved oxygen is expelled.
- **Distillation by evaporators:** An evaporator's function is to produce from raw water, vapor that can be condensed to distilled water for boiler feed make-up

Demineralisation: The mineral content of water may be removed by evaporation or by series of cation and anion exchangers to produce essentially distilled water

Blow down:

Condenser

- A Steam condenser is a device or an appliance in which steam condenses and heat released by steam is absorbed by water. It supplies to the boiler pure and hot feed water as the condensed steam which is discharged from the condenser and collected in a hot well, can be used feed water for boiler.
- A steam condensing plant mainly consists of the following elements:
 1. Condenser (to condense the steam)
 2. Supply of cooling water
 3. Wet air pump
 4. Hot well

Classification of condenser



Jet Condenser: The exhaust steam and water come in direct contact with each other and temperature of the condensate is the same as that of cooling water leaving the condenser. The cooling water is usually sprayed into the exhaust steam to cause rapid condensation.

Surface Condenser: The exhaust steam and water do not come into direct contact. The steam passes outer surface of the tube through which a supply of cooling water is maintained. It is most commonly used because the condensate obtained is not thrown as a waste but return to the boiler

Compare between surface and jet condenser

Jet Condenser	Surface Condenser
Low manufacturing Cost	High manufacturing Cost
Require small floor space	Require large floor space
The condensate can't be used as feed water in the boiler unless the cooling water is free from impurities	Condensate can be reused as a feed water as it does not mix with the cooling water.
More auxiliary power required	Less auxiliary power needed

Cooling ponds and cooling Tower

Cooling ponds: A cooling pond consists of a large, shallow pool into which the hot water is allowed to come in contact with atmospheric air.

Cooling pond is suitable where sufficient supply of circulating water is not available.

Cooling Tower: In power plant hot water from condenser is cooled in cooling tower, so that it can be reused in condenser for condensation of steam

- Natural draught cooling tower
- Mechanical draught cooling tower