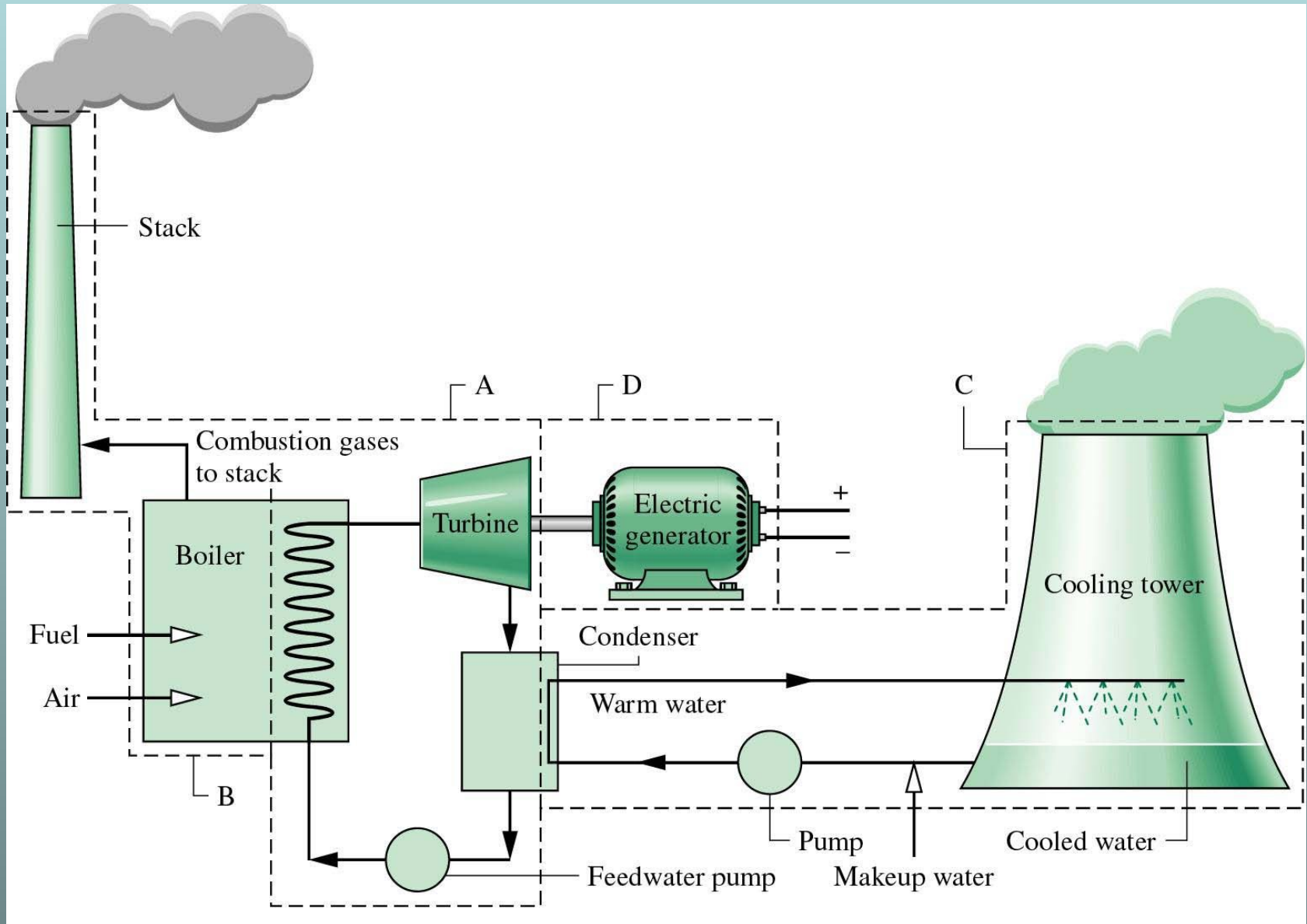


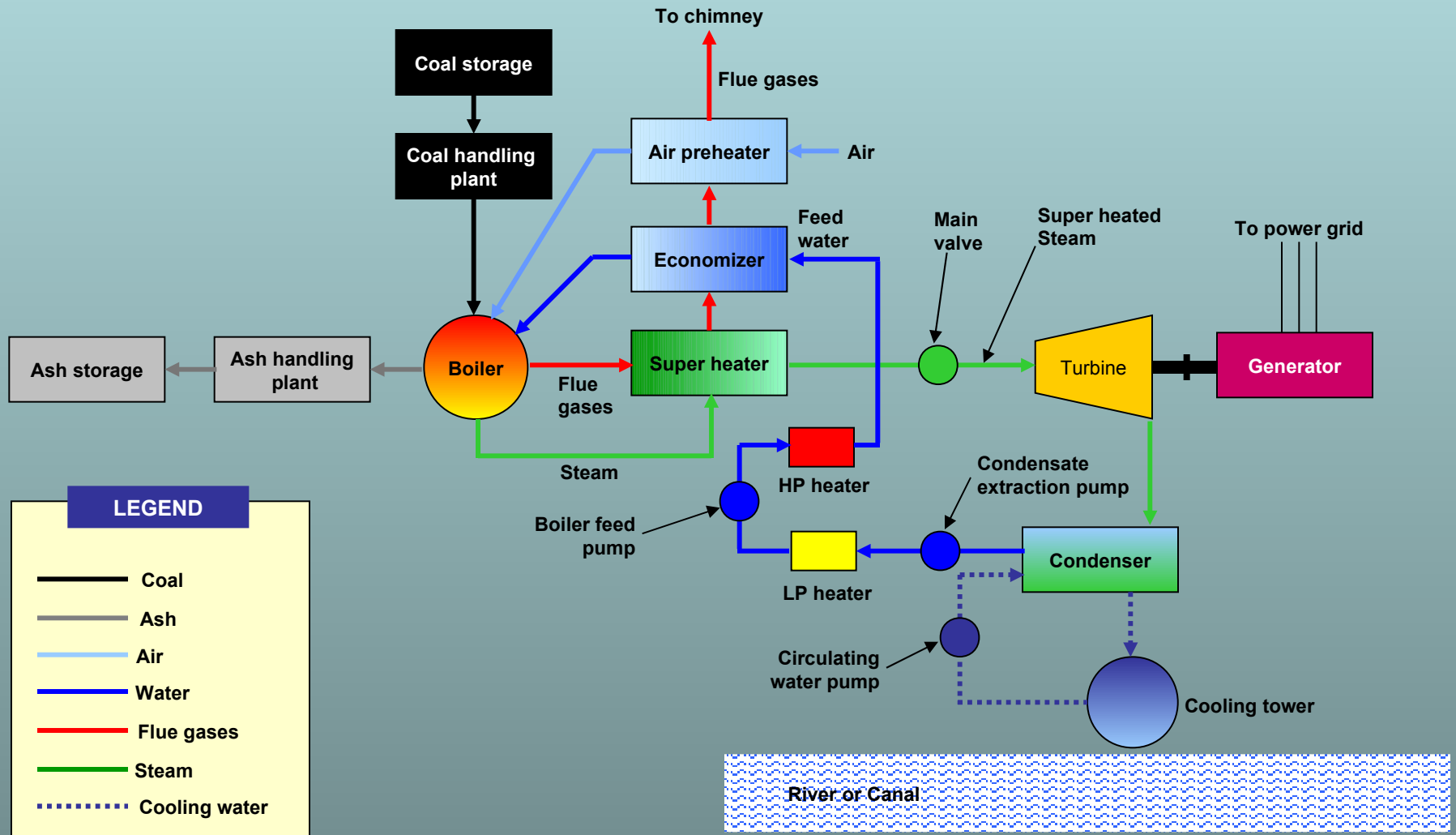
# **Energy Conversion Engineering**

## **Steam Power Plants**

# General layout of steam power plant



# Schematic diagram of coal based steam power plant



# How coal power plants produce electricity

The conversion from coal to electricity takes place in three stages.

## Stage 1

The first conversion of energy takes place in the boiler. Coal is burnt in the boiler furnace to produce heat. Carbon in the coal and Oxygen in the air combine to produce Carbon Dioxide and heat.

## Stage 2

The second stage is the thermodynamic process. The heat from combustion of the coal boils water in the boiler to produce steam. In modern power plant, boilers produce steam at a high pressure and temperature. The steam is then piped to a turbine. The high pressure steam impinges and expands across a number of sets of blades in the turbine. The impulse and the thrust created rotates the turbine. The steam is then condensed to water and pumped back into the boiler to repeat the cycle.

## Stage 3

In the third stage, rotation of the turbine rotates the generator rotor to produce electricity based on Faraday's Principle of electromagnetic induction.

# **General layout of coal based steam power plant**

**The different types of systems and components used in steam power plants are:**

- High pressure boiler**
- Prime mover**
- Condensers and cooling towers**
- Coal handling system**
- Ash handling system**
- Draught system**
- Feed water treatment plant**
- Pumping system**
- Air preheater, super heater, feed water heater**

# General layout of coal based steam power plant

Though each plant is unique in itself in terms of specific features and functionalities, there are four main circuits in any thermal power plant:

**1. Coal & Ash Circuit** – This circuit deals mainly with feeding the boiler with coal for combustion purposes and taking care of the ash that is generated during the combustion process and includes equipment and peripherals that is used to handle the transfer and storage of coal and ash.

**2. Air & Gas Circuit** – Since lots of coal is burnt inside the boiler it needs a sufficient quantity of air which is supplied using either forced draught or induced draught fans. The exhaust gases from the combustion are in turn used to heat the incoming air and water through heat exchangers before being let off in the atmosphere. The equipment which handles all these processes fall under this circuit.

# General layout of coal based steam power plant

**3. Feed Water & Steam Circuit** – This section deals with supplying of steam generated from the boiler to the turbines and to handle the outgoing steam from the turbine by cooling it to form water in the condenser so that it can be reused in the boiler plus making good any losses due to evaporation etc.

**4. Cooling Water Circuit** – This part of the thermal power plant deals with handling of the cooling water required in the system. Since the amount of water required to cool the outgoing steam from the boiler is substantial, it is either taken from a nearby water source such as a river, or it is done through evaporation if the quantity of cooling water available is limited.

*A power plant using steam as working substance works basically on Rankine cycle. For plants operating with steam at subcritical pressures (less than 221 bar) and steam temperatures of 570 °C, the Rankine cycle efficiency is around 43 %. For the state of the art plants running at greater than supercritical pressure and steam temperatures near to 600 °C, the efficiency is around 47 %.*

# Why is the efficiency low for thermal plant?

- The heating value or the energy available in the coal, is in the range of 10,500 kJ/kg to 27,000 kJ/kg. A heating value of 20,000 kJ/kg is equivalent to 5.56 kwh of electrical energy. In practice the effective conversion is only around 43% to 47% of the theoretically possible value.

## Reasons for low thermal efficiency:

- Due to practical limitations in heat transfer, all the heat produced by combustion is not transferred to the water; some is lost to the atmosphere as hot gases. Moisture in coal vapourises taking latent heat from the combustion heat and exits the boiler along with the hot gases. This is a loss.
- The steam is condensed for re-use. During this process the latent heat of condensation is lost to the cooling water. This is the major loss and is almost 40 % of the energy input. Losses in the turbine blades and exit losses at turbine end are some of the other losses.
- The Rankine cycle efficiency is dictated by the maximum temperature of steam that can be admitted into the turbine. Due to metallurgical constraints steam temperatures are at present limited to slightly more than 600 °C.
- Various auxiliary equipment like pulverizers, fans, pumps and precipitators in large power plants consume around 6 % of the generator output for internal consumption.



# Fuels used for steam generation

- The primary fuels which are burned to release heat and generate steam in boilers are the fossil fuels – coal, fuel oil and natural gas.
- Besides these, industrial wastes like blast furnace gas, coke oven gas, refinery gas, bagasse, saw mill wood dust, rice husk etc. are also used to boost primary fossil fuels in the form of combination firing.

## Coal

- In India, coal is the main source of energy because of its large deposits and availability.
- Coal originates from millions of years old vegetable matter transformed by subterranean heat and soil pressure. The vegetable decay first produces peat bogs, which after distillation of its moisture by subterranean forces hardens to brown coal or lignite. Continuing metamorphosis produces higher grade coals.

# Fuels used for steam generation

## Coal (contd..)

- According to geological order of formation, coal may be of the following types with increasing carbon content:
  - Peat
  - Lignite
  - Sub-bituminous
  - Bituminous
  - Sub-anthracite
  - Anthracite
  - Graphite
- Each type of coal has a certain set of physical parameters which are mostly controlled by moisture, volatile content (in terms of aliphatic or aromatic hydrocarbons) and carbon content.
- Peat contains up to 90% moisture and is not attractive as a utility fuel. Coal 'Ranking' is a measure of carbon content in the coal. Lignite is considered to be low rank and anthracite to be high rank.

# Coal analysis

- Coal ranking is made based on coal analysis. Basically there are two types of coal analysis:
  - Proximate analysis
  - Ultimate analysis

## Proximate analysis

- The objective of coal proximate analysis is to determine the amount of fixed carbon (FC), volatile matters (VM), moisture (M), and ash (A) within the coal sample.

$$\text{FC} + \text{VM} + \text{M} + \text{A} = 100\% \text{ by mass}$$

- The variables are measured in weight percent (wt. %) and are calculated in several different bases as follows.
  - As Received (AR)
  - Air Dried (AD)
  - Dry Basis (DB)
  - Dry Ash Free (DAF)
  - Dry Mineral Matter Free (DMMF)

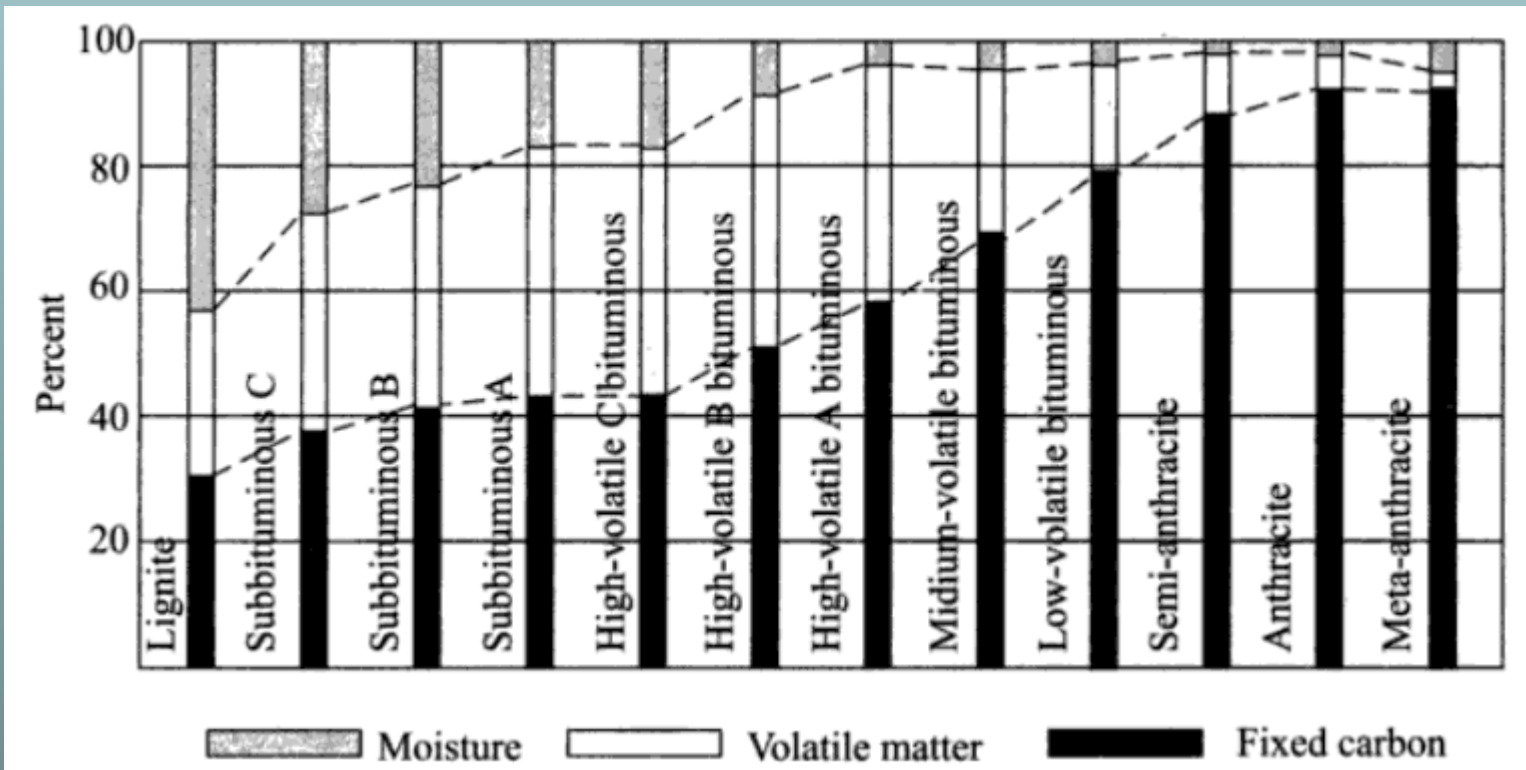
# Coal analysis

- AR (as-received) basis is the most widely used basis in industrial applications. It takes all variables into consideration and uses the total weight as the basis of measurement.
- AD (air-dried) basis neglects the presence of moisture other than inherent moisture.
- DB (dry-basis) leaves out all moistures, including inherent moisture.
- DAF (dry, ash free) basis neglects all moisture and ash constituent in coal
- DMMF (dry, mineral-matter-free) basis leaves out the presence of moisture and mineral matters in coal like quartz, pyrite, calcite, etc.
- A typical proximate analysis of coal looks like this:

Proximate analysis	Unit	AR	AD	DB	DAF
Moisture	(wt. %)	3.30	2.70		
Ash	(wt. %)	22.10	22.20	22.80	
Volatile Matter	(wt. %)	27.30	27.50	28.30	36.60
Fixed Carbon	(wt. %)	47.30	47.60	48.90	63.40

# Coal analysis

- Figure below shows the trend in moisture, volatile matter and fixed carbon expressed on DAF basis.
- With increasing rank, there is an increase of heating value and carbon content with a corresponding decrease of moisture and VM.
- Lower rank coals also contain greater oxygen, which helps combustion



Coal rank compared with proximate analysis

# Coal analysis

## Ultimate analysis

- Similar to coal proximate analysis, the objective of coal ultimate analysis is to determine the constituent of coal, but in a form of its basic chemical elements.
- The ultimate analysis determines the amount of carbon (C), hydrogen (H), oxygen (O), sulphur (S), and other elements within the coal sample. These variables are also measured in weight percent (wt. %) and are calculated in the bases explained above.

$$C + H + O + N + S + M + A = 100\% \text{ by mass}$$

- A typical ultimate analysis of coal looks like this:

Ultimate analysis	Unit	AR	AD	DB	DAF
Carbon (C)	(wt. %)	61.1	61.5	63.2	81.90
Hydrogen (H)	(wt. %)	3.00	3.02	3.10	4.02
Nitrogen (N)	(wt. %)	1.35	1.36	1.40	1.81
Total Sulphur (S)	(wt. %)	0.40	0.39	0.39	
Oxygen (O)	(wt. %)	8.80	8.80	9.10	

# Coal ranking

<b>Rank of Coal</b>	<b>Fixed Carbon*</b>	<b>Volatile Matter*</b>	<b>Moisture*</b>
<b>Lignite</b>	<b>29</b>	<b>26</b>	<b>46</b>
<b>Subbituminous</b>	<b>42</b>	<b>34</b>	<b>23</b>
<b>Low-rank/volatile bituminous</b>	<b>47</b>	<b>41</b>	<b>12</b>
<b>Medium-rank/volatile bituminous</b>	<b>54</b>	<b>41</b>	<b>5</b>
<b>High-rank/volatile bituminous</b>	<b>65</b>	<b>32</b>	<b>3</b>
<b>Low-rank/volatile semibituminous</b>	<b>75</b>	<b>22</b>	<b>3</b>
<b>Semianthracite</b>	<b>86</b>	<b>12</b>	<b>3</b>
<b>Anthracite</b>	<b>96</b>	<b>1.2</b>	<b>3</b>

\* Figures indicate weight by percentage

# Boilers

- **Boiler is an apparatus to produce steam. Thermal energy released by combustion of fuel is transferred to water, which vapourises and gets converted to steam at the desired temperature and pressure.**
- **The performance of a boiler is measured in terms of its evaporative capacity which is also called as “Boiler Power”. It is defined as the amount of steam produced in kg/hour. It may also be expressed in kg of steam per kg of fuel burnt or kg/hr/m<sup>2</sup> of heating surface.**
- **Boilers are classified according to the following criteria:**
  - **According to flow of water and hot gases.**
    - **Water tube**
    - **Fire tube**

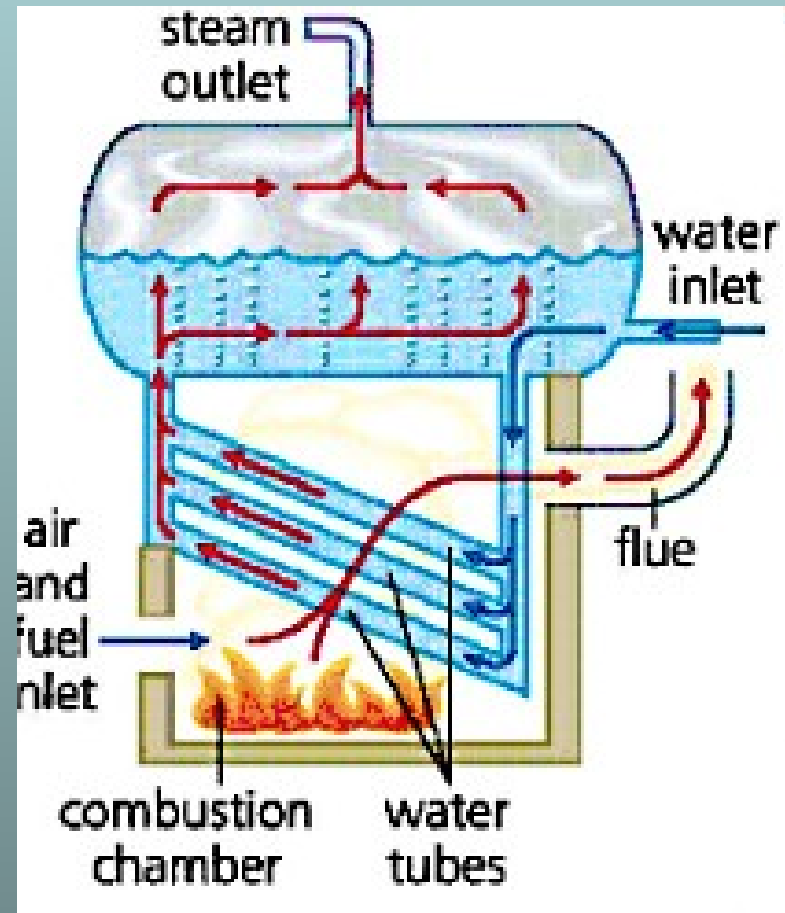


# Boilers

- **According to flow of water and hot gases.**
  - Water tube
  - Fire tube
- **According to position of furnace**
  - Internally fired
  - Externally fired
- **According to the position of the principle axis**
  - Vertical
  - Horizontal
  - Inclined
- **According to application**
  - Stationary
  - Mobile (Marine, Locomotive...)
- **According to circulating water**
  - Natural circulation
  - Forced circulation
- **According to steam pressure**
  - Low pressure
  - Medium pressure
  - High pressure

# Water Tube Boilers

In water tube boilers, water is circulated through tubes and hot products of combustion flow over these tubes



# Water Tube Boilers

**Water tube boilers can further be classified as follows:**

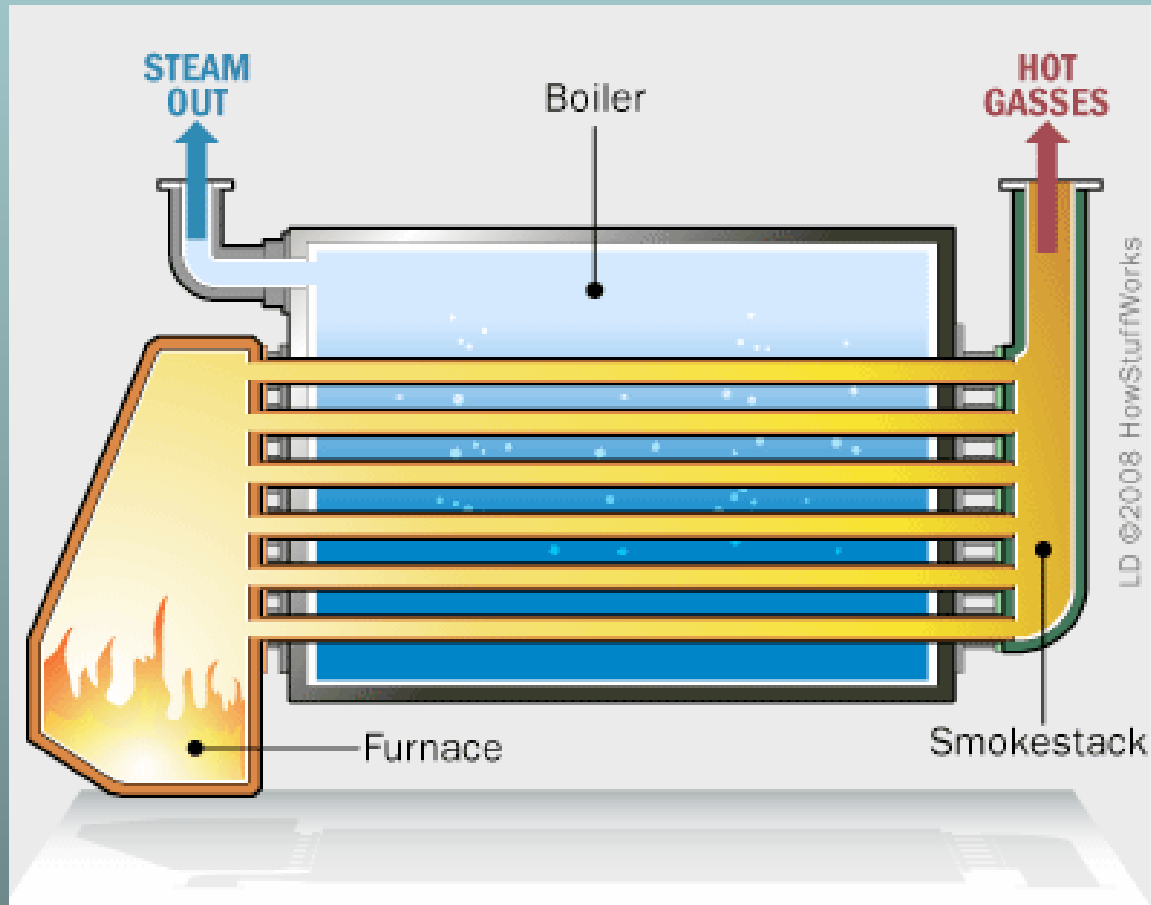
- **Horizontal straight tube boilers**
- **Bent tube boilers**
- **Cyclone fired boilers**

**Water tube boilers have the following advantages:**

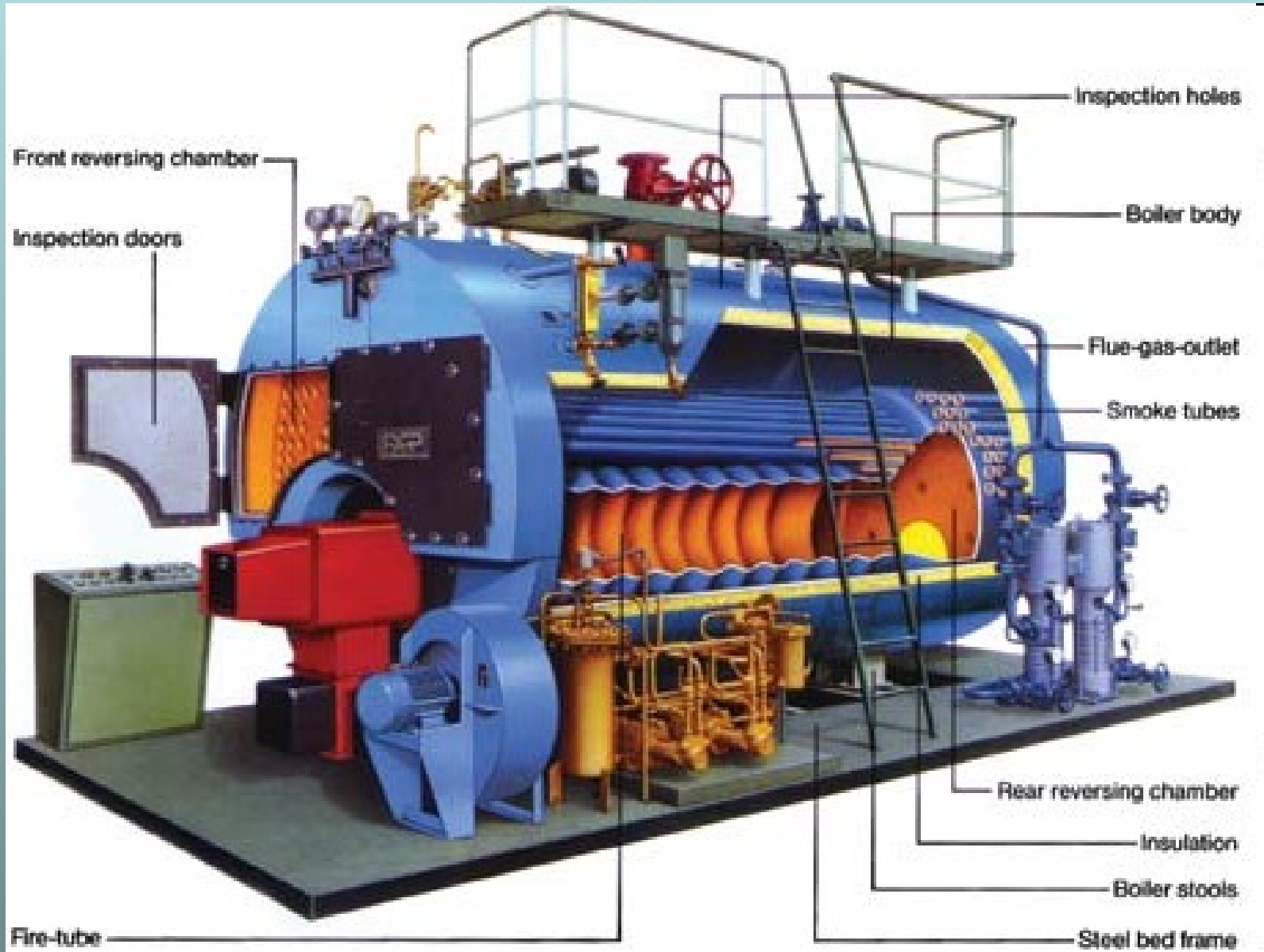
- **High pressures (about 140 kg/cm<sup>2</sup>) can be obtained**
- **Large heating surfaces can be obtained by use of large number of tubes – therefore steam can be generated easily.**
- **Efficiency is higher because of high velocity of water in tubes which improves heat transfer.**

# Fire Tube Boilers

In fire tube boilers, the hot combustion gases pass through the tubes, which are surrounded by water.



# Fire Tube Boilers



# **Fire Tube Boilers**

**Fire tube boilers can further be classified as follows:**

- **External furnace**
- **Internal furnace**

**Fire tube boilers have the following advantages:**

- **Low cost**
- **Fluctuations of steam demand can be easily met**
- **Compact in size**

**Disadvantage of fire tube boilers is that they contain more water in the drum and if the flue gas circulation is poor, they can not quickly meet the steam demand. For the same output, the outer shell of fire tube boiler is much larger than the shell of a water tube boiler.**

# **Combustion equipment for burning coal**

**Coal burning methods are classified into two types:**

- Stoker firing – used for solid coal**
- Pulverized fuel firing – used for pulverized coal**

**Selection of one of the above methods depends upon**

- Characteristics of the coal available**
- Capacity of the plant**
- Load fluctuations**
- Efficiency / Reliability of combustion equipments**

**The boiler furnaces that burn coal can be classified as follows:**

- Fuel bed furnaces (coarse particles)**
- Pulverized coal furnaces (fine particles)**
- Cyclone furnaces (crushed particles)**
- Fluidized bed furnaces (crushed small particles)**

# **Stoker firing**

**In small boilers, coal is fed manually on to a stationary grate. But in large boilers, to attain uniform operating condition, higher burning rate and better efficiency, mechanical stokers are employed. A stoker consists of a power operated coal feeding mechanism and grate.**

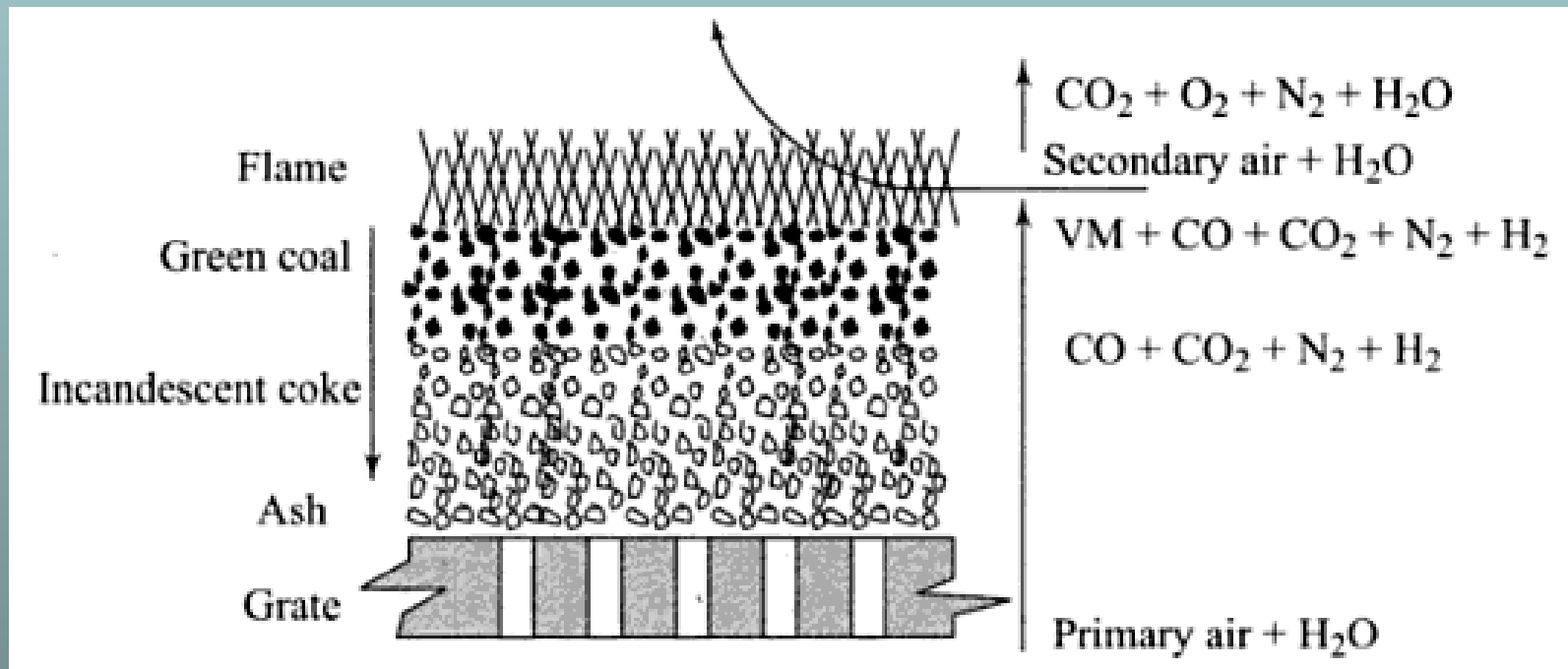
**Mechanical stokers are of two types:**

- 1. Overfeed stoker**
- 2. Underfeed stoker**



# Overfeed stoker

Overfeed stokers are used for large capacity boilers where coal is burnt as lumps (i.e., without pulverization). In this type of stoker, the fuel bed receives fresh coal on top surface; ignition plane lies between green coal and incandescent coke.

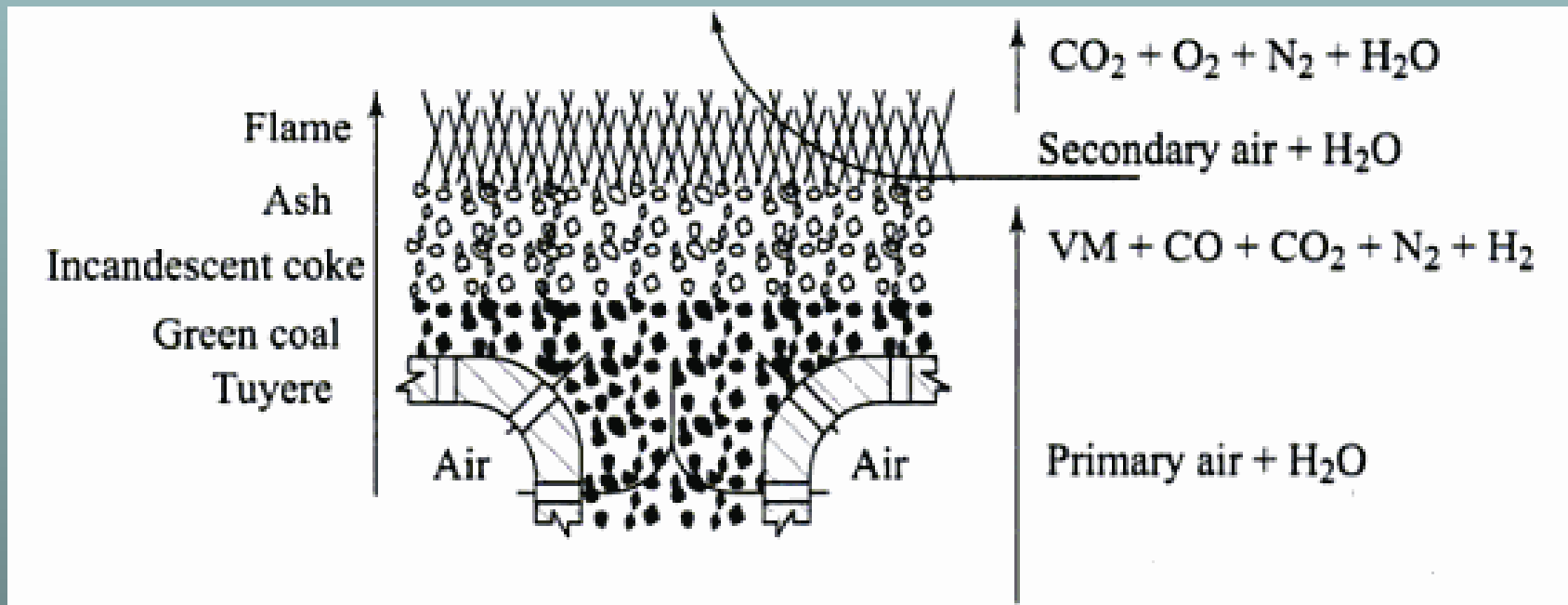


# Overfeed stoker - Processes

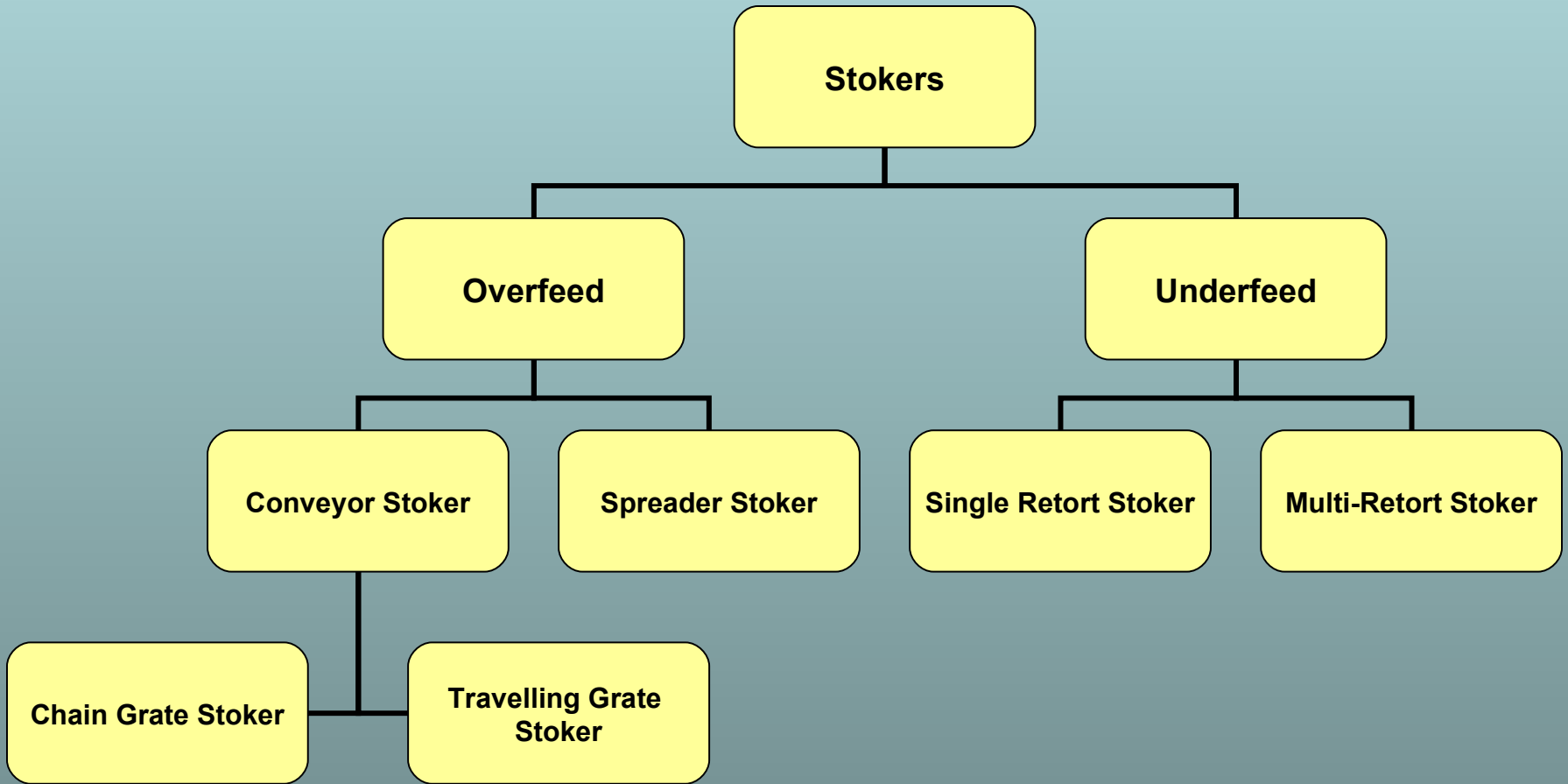
- In the first layer (top layer), fresh coal is added
- Second layer is the drying zone, where coal loses moisture
- Third layer is distillation zone, where coal loses volatile matter
- Fourth layer is the combustion zone, where the fixed carbon in coal is consumed.
- Fifth layer is the ash cooling zone.

# Underfeed stoker

In the case of underfeed stoker, the coal is fed into the grate below the point of air admission, or air entering the stoker comes in contact with fresh coal before reaching the incandescent coke.



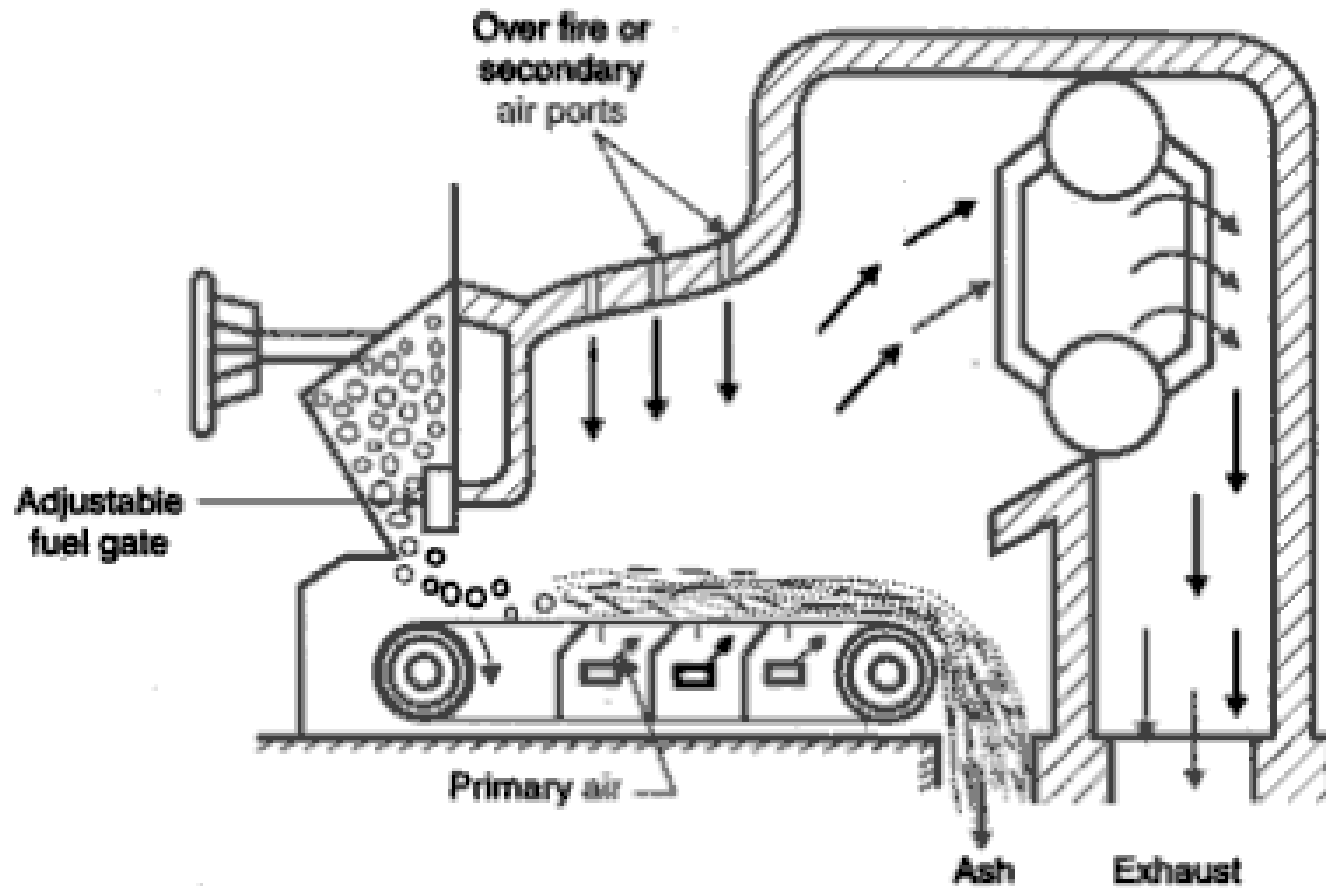
# Types of stokers



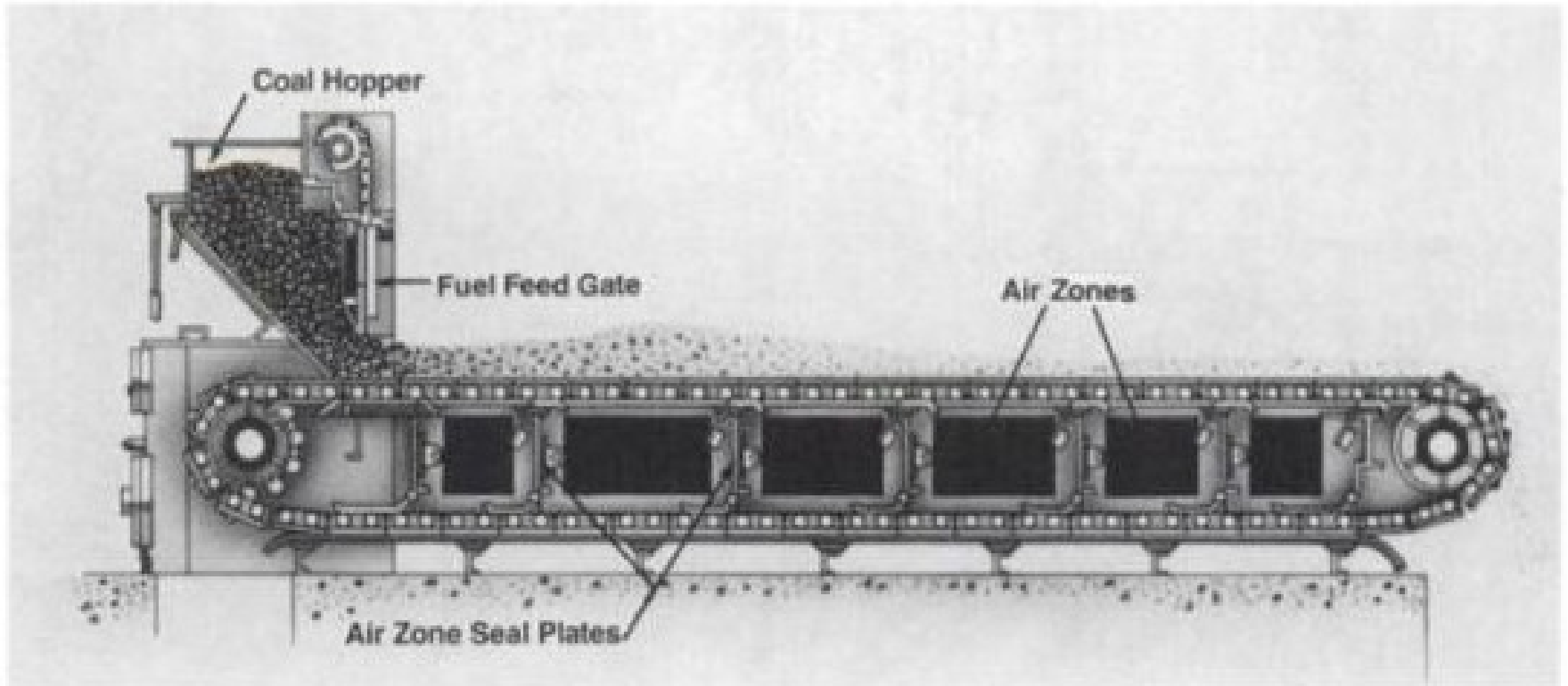
# Travelling or Chain Grate stokers

- **Traveling or chain grate stokers feed coal out onto a rotating metal belt that supports the fire.**
- **Coal is fed from a hopper.**
- **Grate speed is automatically controlled to maintain desired steam pressure.**
- **Burning progresses as the belt moves from front to back of furnace.**
- **Combustion is essentially complete at the back end of belt, and ash is dumped off into an ash pit.**
- **Can burn all coals, except strongly caking bituminous coal. Caking coals tend to block the flow of air through fuel bed and cause loss of carbon in ash.**

# Chain Grate stokers

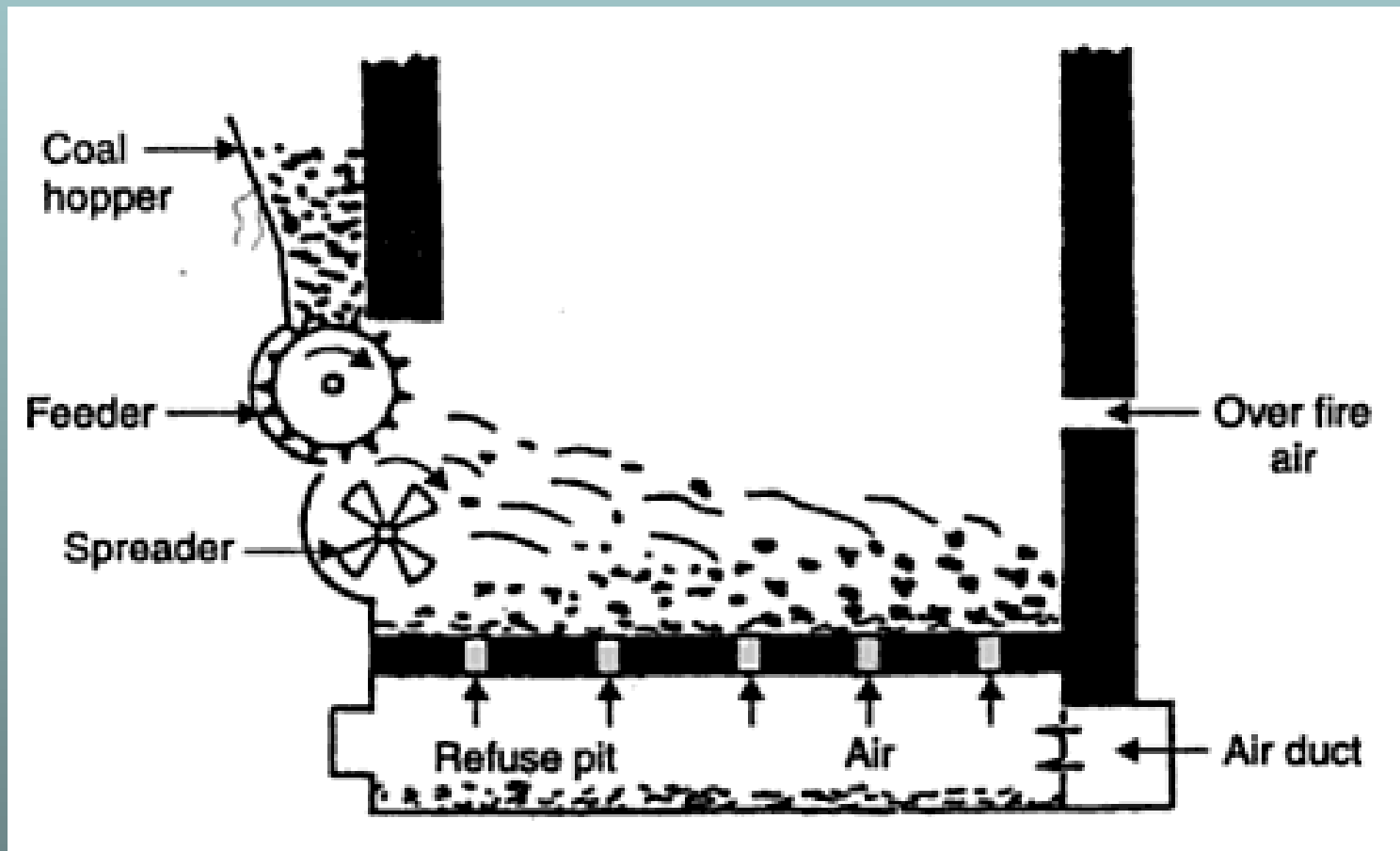


# Chain Grate stokers



# Spreader stokers

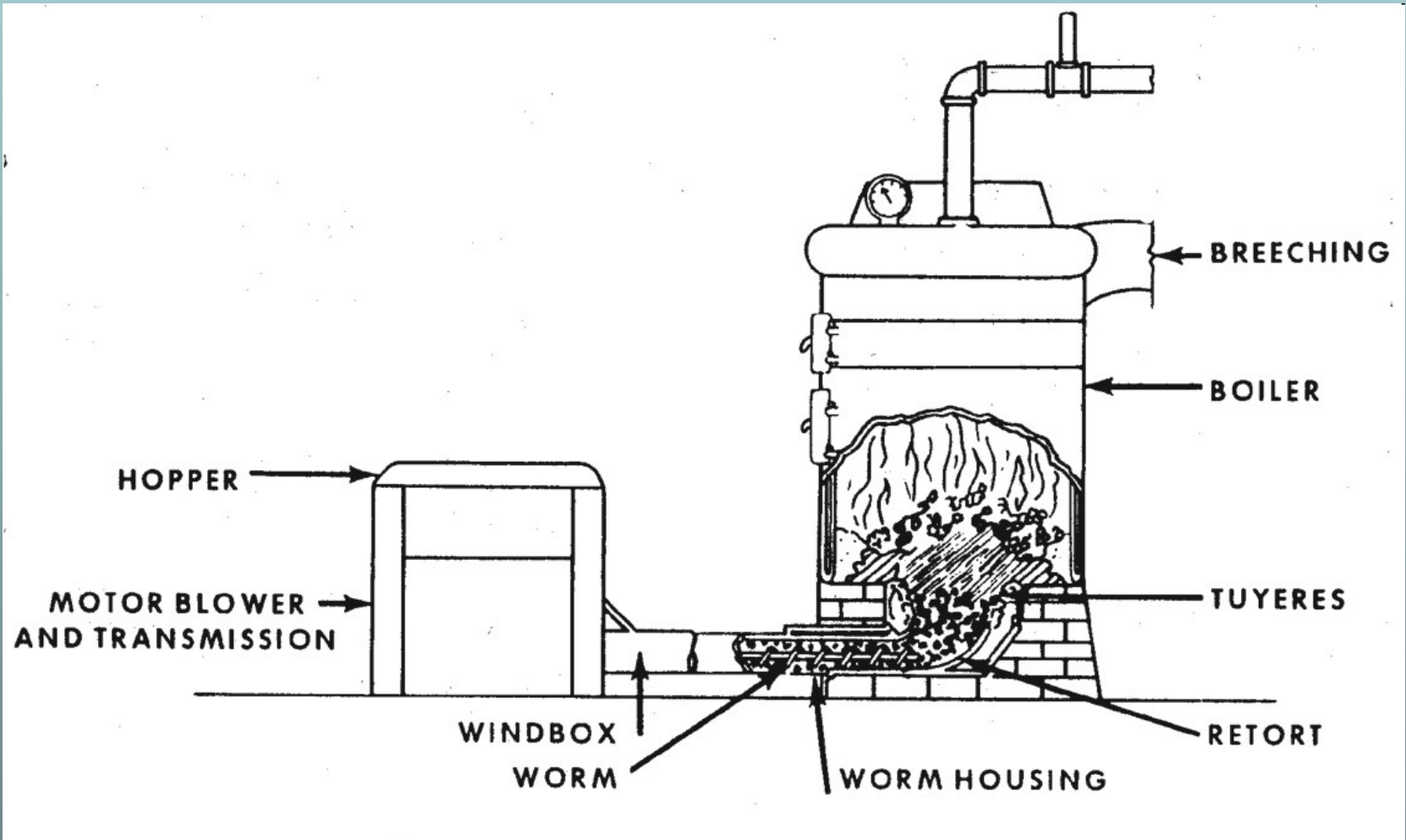
- Coal from hopper is fed into the path of a rotor by a conveyor, and is thrown into the furnace by the rotor and the coal is burnt in suspension.
- Spreader stokers can burn any type of coal





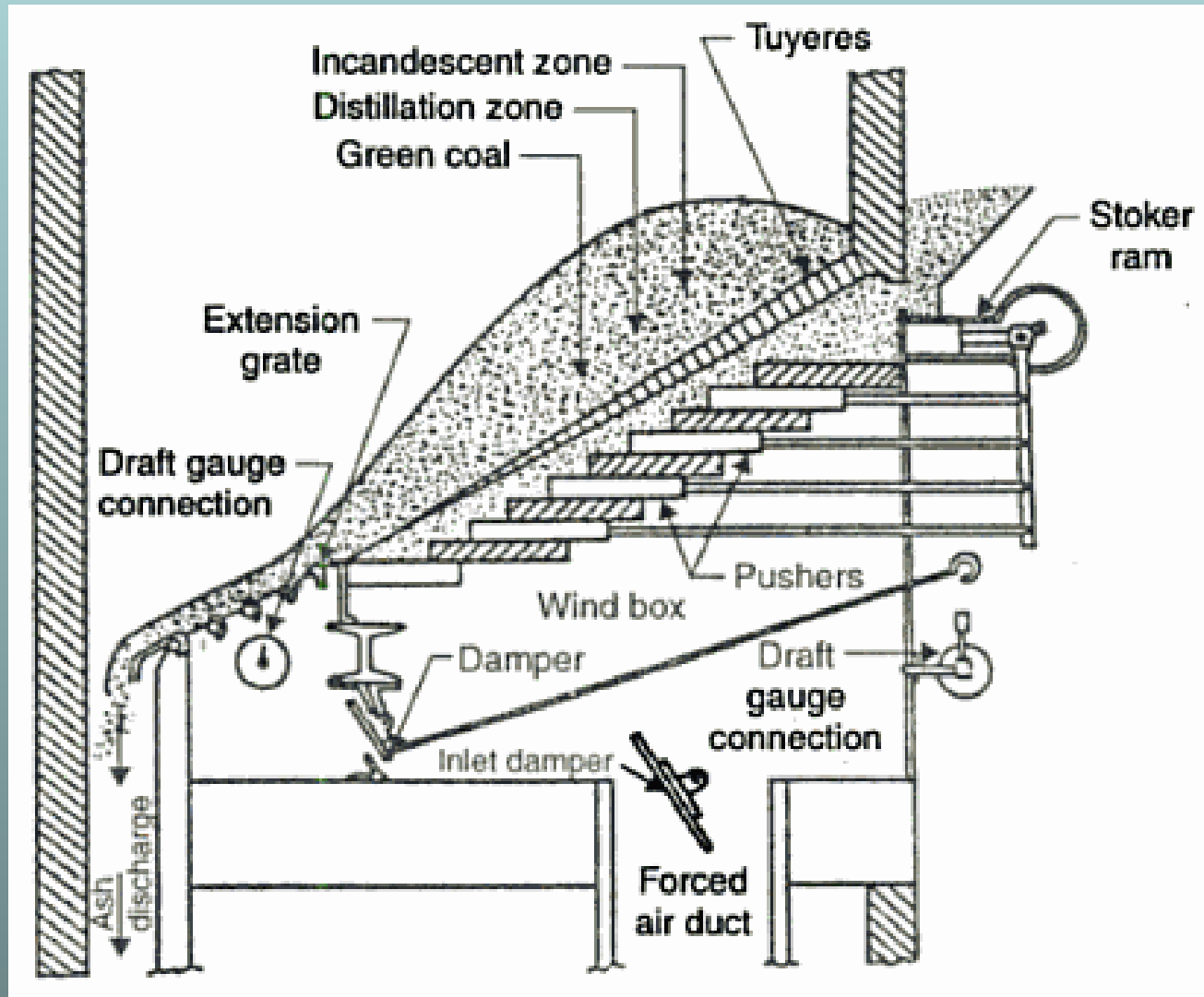
# Single retort stokers

- A screw conveyor or a ram transfers coal to the furnace. Surrounding the conveyor or ram is the primary air duct.



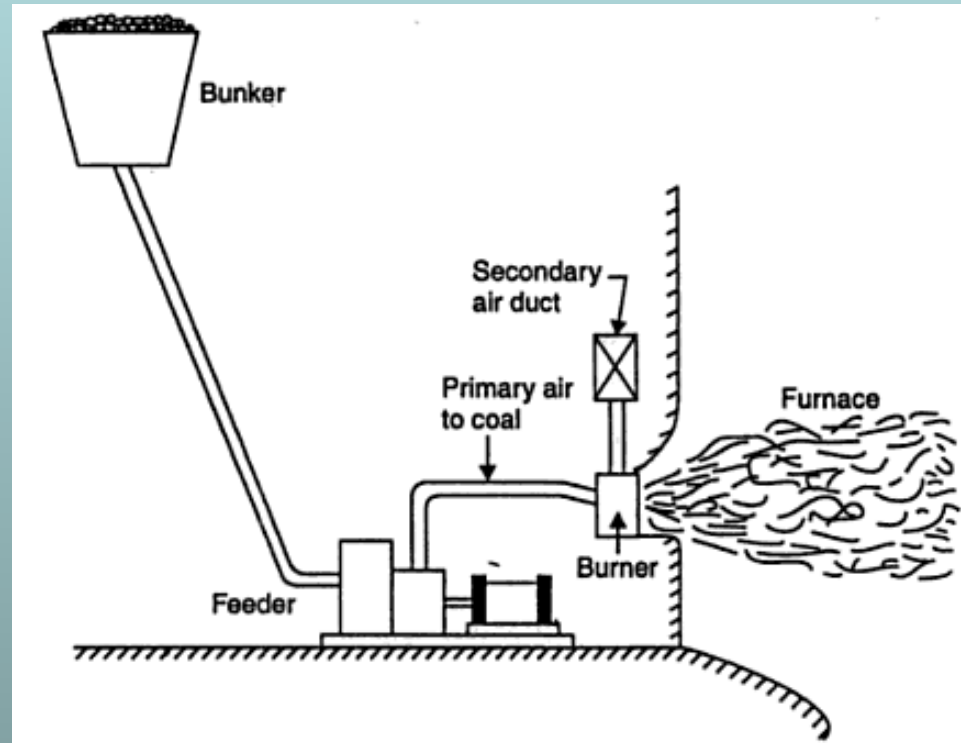
# Multi retort stokers

- The stoker consists of a series of sloping parallel troughs called retorts. Reciprocating rams push the coal into the retort.



# Pulverized coal firing system

- In the pulverized coal firing system, the coal is reduced to a fine powder with the help of grinding mill and then admitted into the combustion chamber with the help of primary hot air.
- The primary air also helps to dry the coal before entering the combustion chamber.
- Secondary air required to complete the combustion process is supplied separately to the combustion chamber.
- The resulting turbulence in the combustion chamber helps in uniform mixing of fuel and air and good combustion.



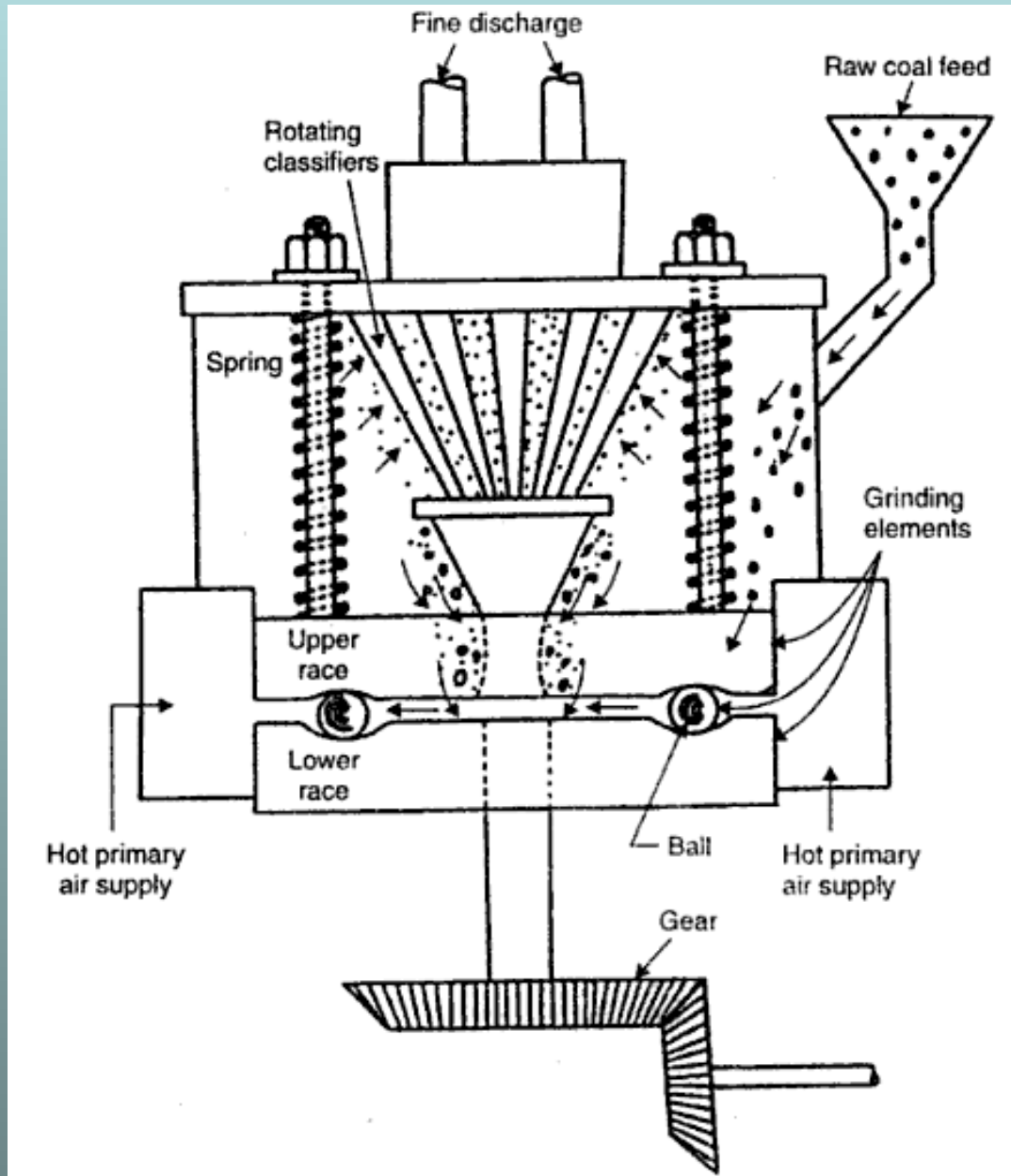
Elements of a pulverized coal firing system

# Pulverized coal

- Coal is pulverized (powdered) to increase its surface area (and therefore exposure) thus permitting rapid combustion.
- The pulverized coal is obtained by grinding the raw coal in pulverizing mills. Various types of pulverizing mills are:
  - Ball mill
  - Ball and race mill
  - Hammer mill
  - Bowl mill
- Essential functions of pulverizing mills are:
  - Drying of the coal
  - Grinding
  - Separation of particles of a desired size.

Coal pulverizing mills reduce coal to powder by any (or all) action such as *Impact, Abrasion and Crushing*

# Ball and race mill for pulverizing coal



# **Advantages of Pulverized coal firing system**

- **Any grade of coal can be used because coal is powdered before use.**
- **Rate of feed of fuel can be easily regulated – better fuel economy.**
- **Since there is almost complete combustion of fuel, there is increased rate of evaporation and hence better boiler efficiency.**
- **Greater capacity to meet peak load.**
- **System is free from sagging and clinkering troubles associated with lump coal.**
- **Practically no ash handling problems.**
- **No moving parts within the furnace that is subjected to high temperatures.**
- **This system works successfully in combination with gas and oil.**
- **Requires much less air compared to stoker firing**
- **Furnace volume is considerably small.**

# **Disadvantages of Pulverized coal firing system**

- **High capital cost.**
- **Lot of fly-ash in the exhaust – removal of fine dust is expensive.**
- **Possibility of explosion is high because pulverized coal burns like gas.**
- **Maintenance of furnace brickwork is costly because of high temperatures.**
- **Special equipments required to start the system.**
- **Skilled operators are required.**
- **Separate coal preparation plant is necessary.**
- **Periodic maintenance of pulverized coal dispensing system is needed.**

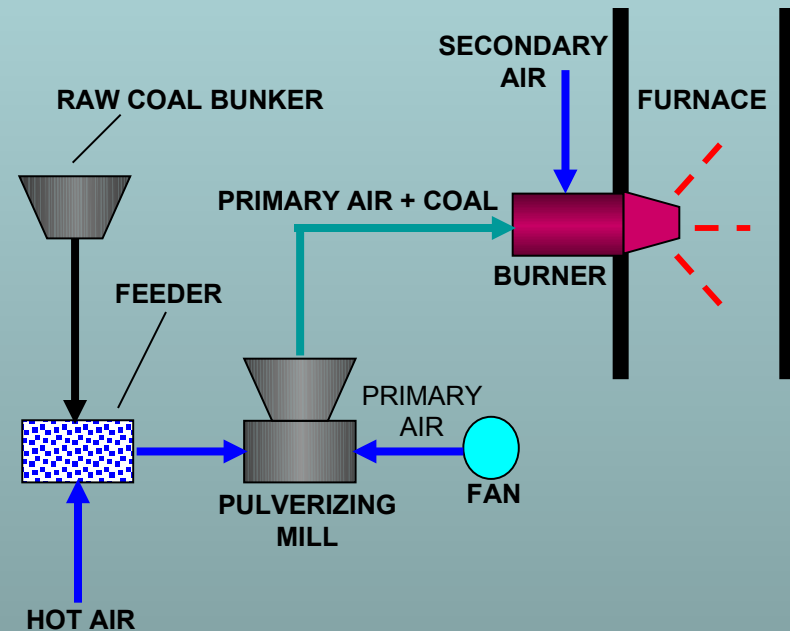
# Pulverized coal firing

- Basically, pulverized fuel plants may be divided into two systems based on the method used for firing the coal:

- Unit System or Direct System
- Bin System or Central System

**Unit or Direct System:** This system works as follows:

- Coal from bunker drops on to the feeder.
- Coal is dried in the feeder by passage of hot air.
- The coal then moves to a mill for pulverizing.
- A fan supplies primary air to the pulverizing mill.
- Pulverized coal and primary air are mixed and sent to a burner where secondary air is added.



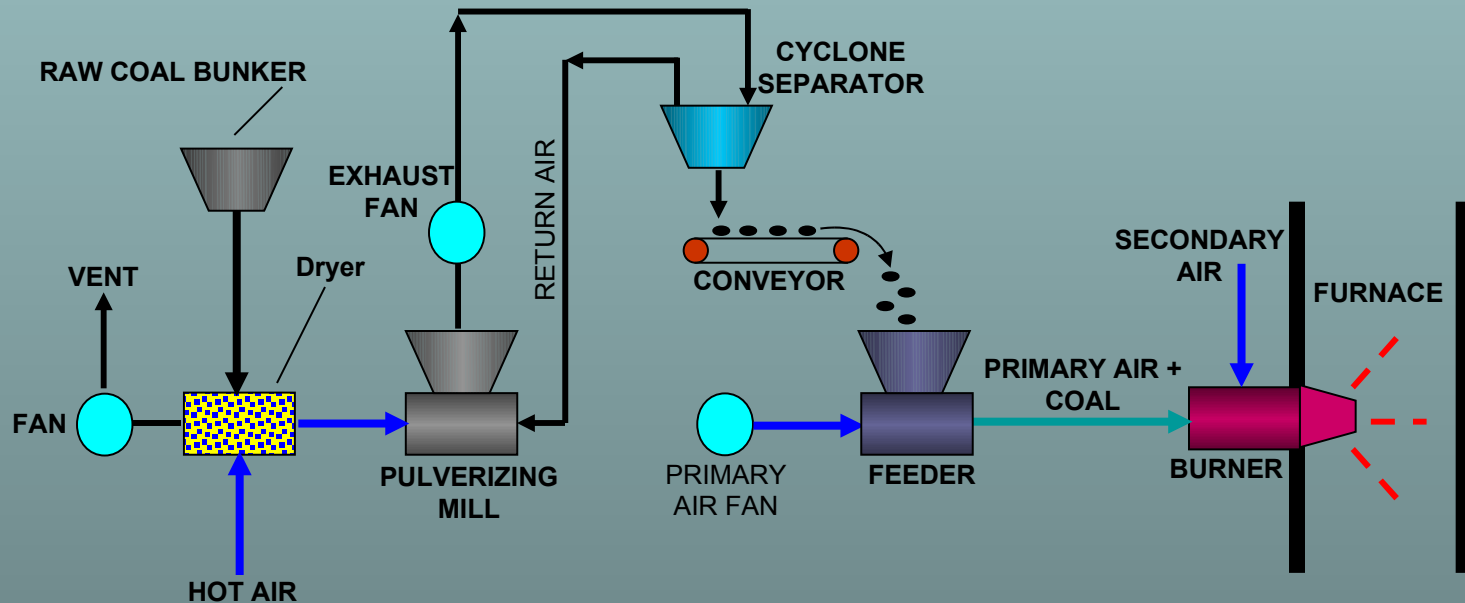
It is called Unit System because each burner or a group of burners and pulverizer constitute a unit.



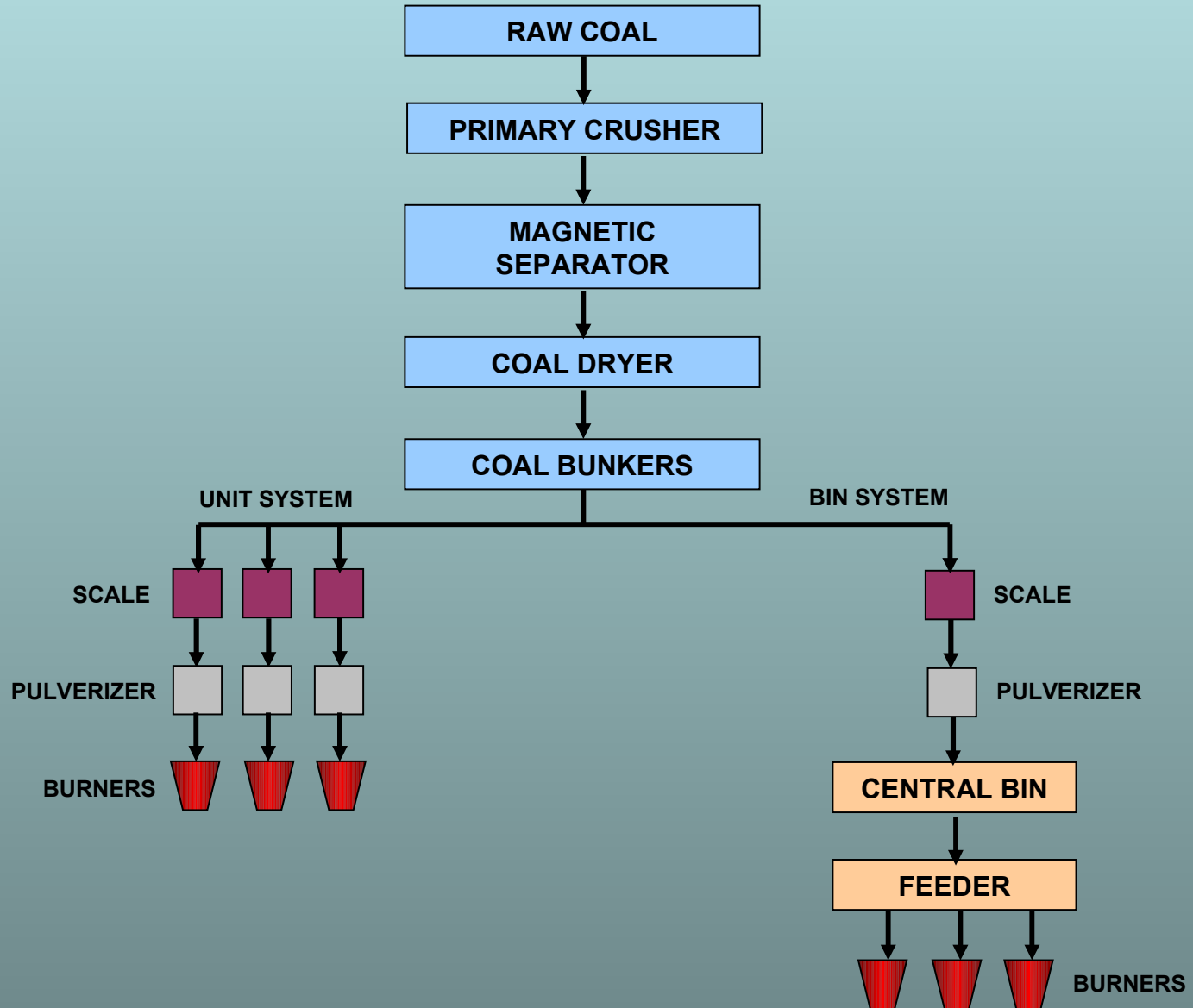
# Pulverized coal firing

## Bin or Central System:

- Coal from bunker is fed by gravity to a dryer where hot air is admitted to dry the coal.
- Dry coal is then transferred to the pulverizing mill.
- Pulverized coal then moves to a cyclone separator where transporting air is separated from coal.
- Primary air is mixed with coal at the feeder and supplied to the burner.
- Secondary air is supplied separately to complete the combustion.



# Equipments for Unit and Bin Systems



# Pulverized Coal Burners

Burners are used to burn pulverized coal. Burner configurations differ in the rapidity with which air-coal mixing (turbulence) takes place.

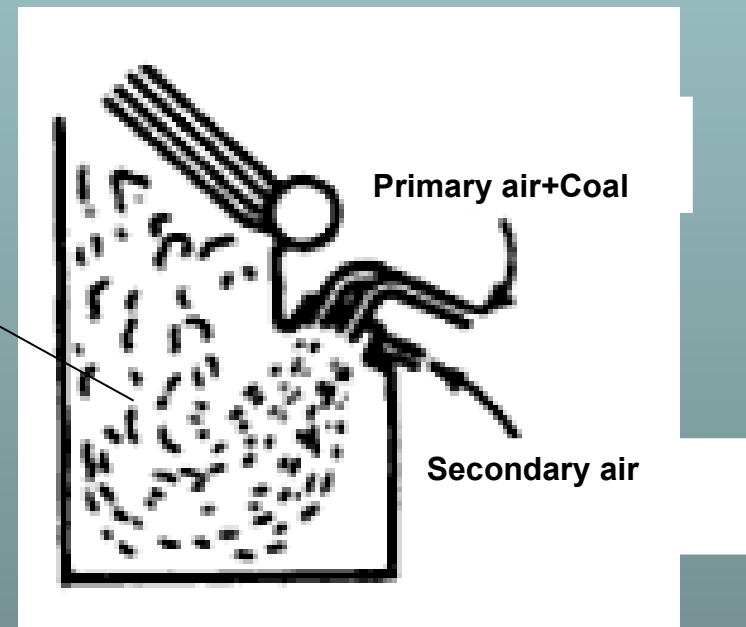
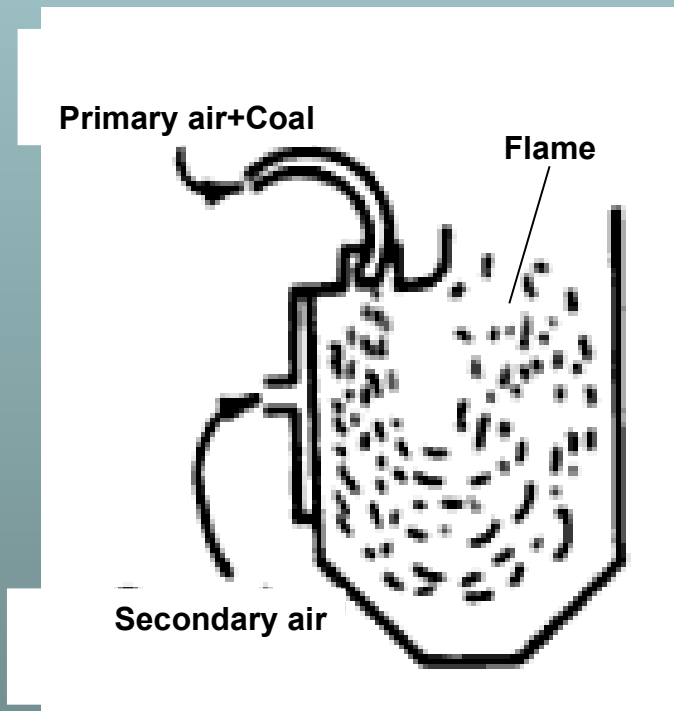
## Requirements of pulverized coal burners:

- Mix coal and primary air thoroughly before secondary air is added.
- Deliver air to the furnace in the right proportion and maintain stable ignition of coal-air mixture.
- Control the shape and travel of flame within the furnace. The flame shape is controlled by the secondary air vanes and their control adjustments incorporated into the burner. Too much of secondary air may cool the mixture and prevent ignition.
- Control the rate of travel of coal-air mixture away from the burner to avoid flash back into the burner.

# Types of Burners for Pulverized Coal

Various types of burners are used for combustion of pulverized coal.

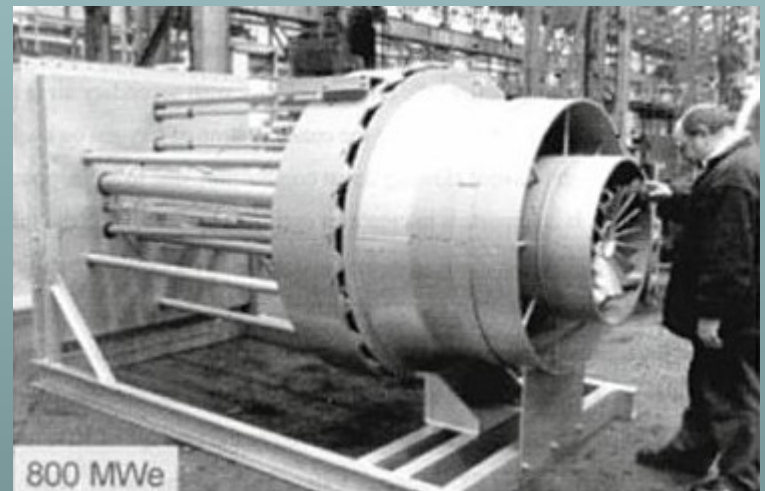
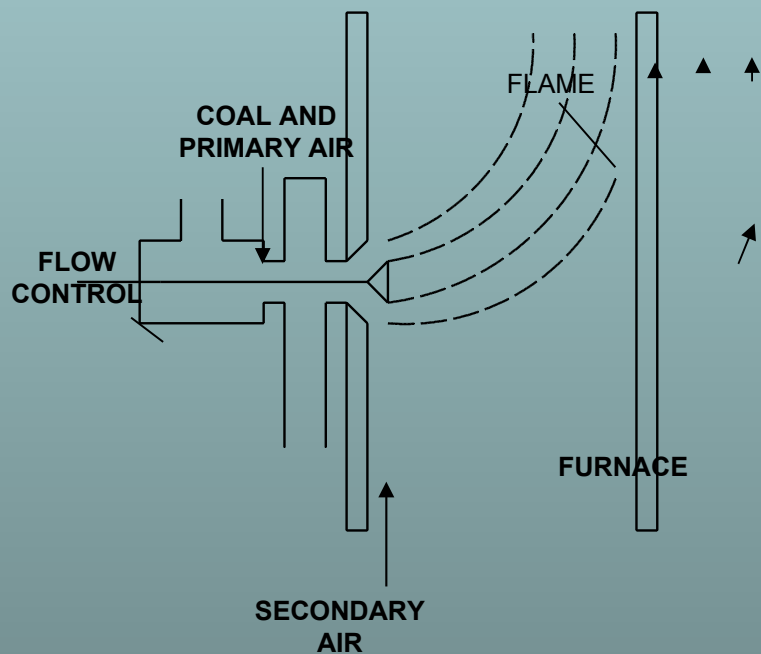
- **Long Flame (U-Flame) Burner:** In this burner, air and coal mixture travels a considerable distance thus providing sufficient time for complete combustion.



Long Flame Burners

# Types of Burners for Pulverized Coal

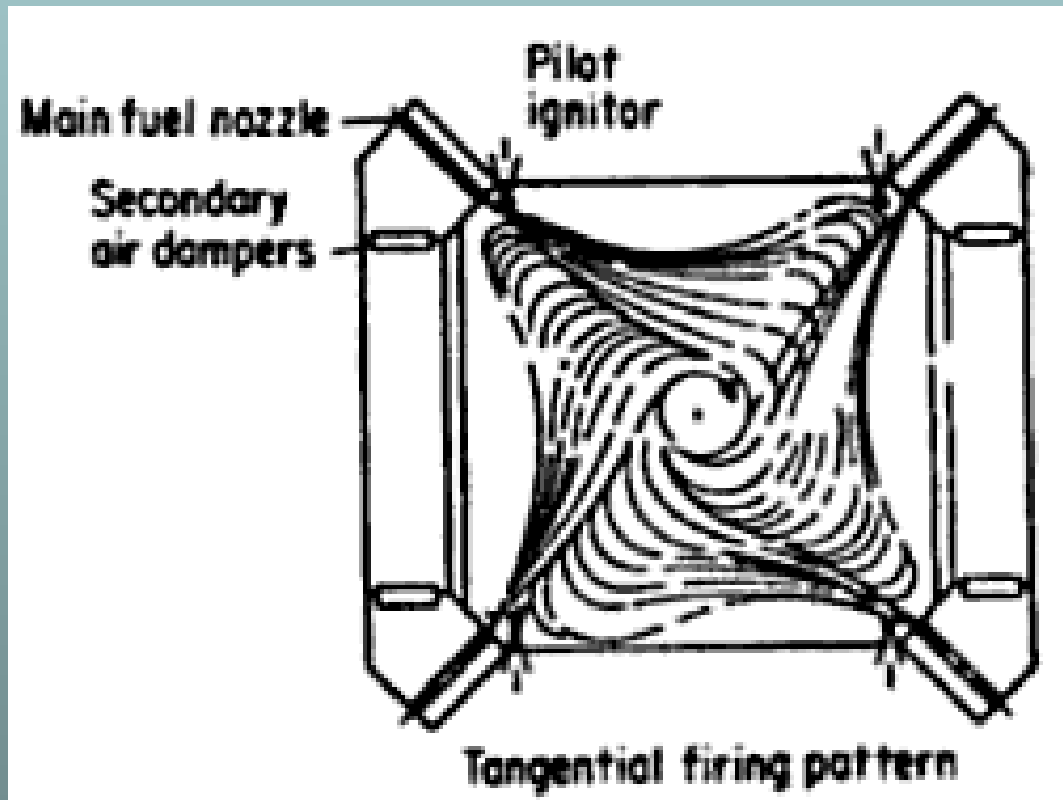
- **Short Flame (Turbulent) Burner:** The burner is fitted in the furnace wall and the flame enters the furnace horizontally with great turbulence.



Short Flame Burner

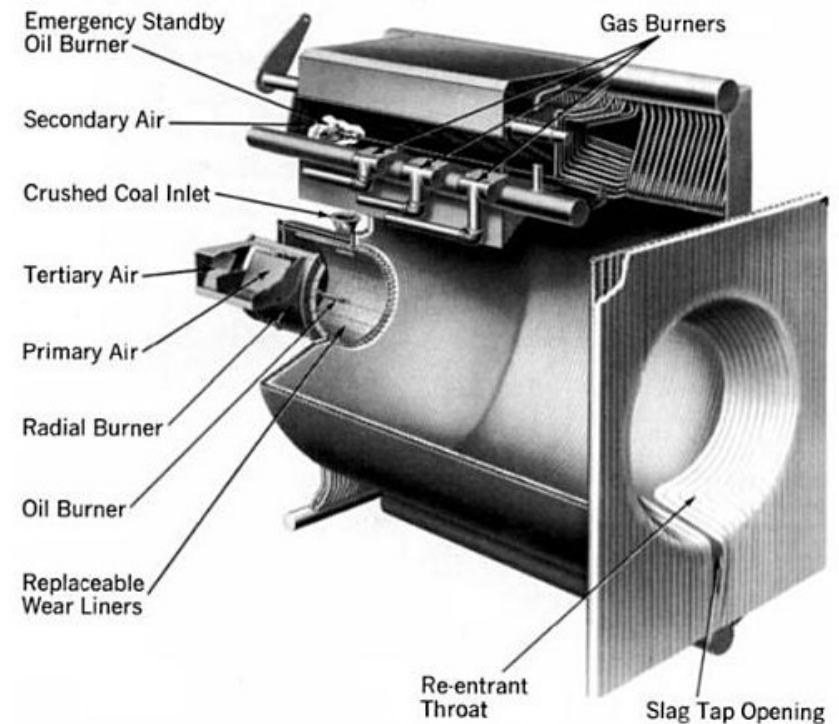
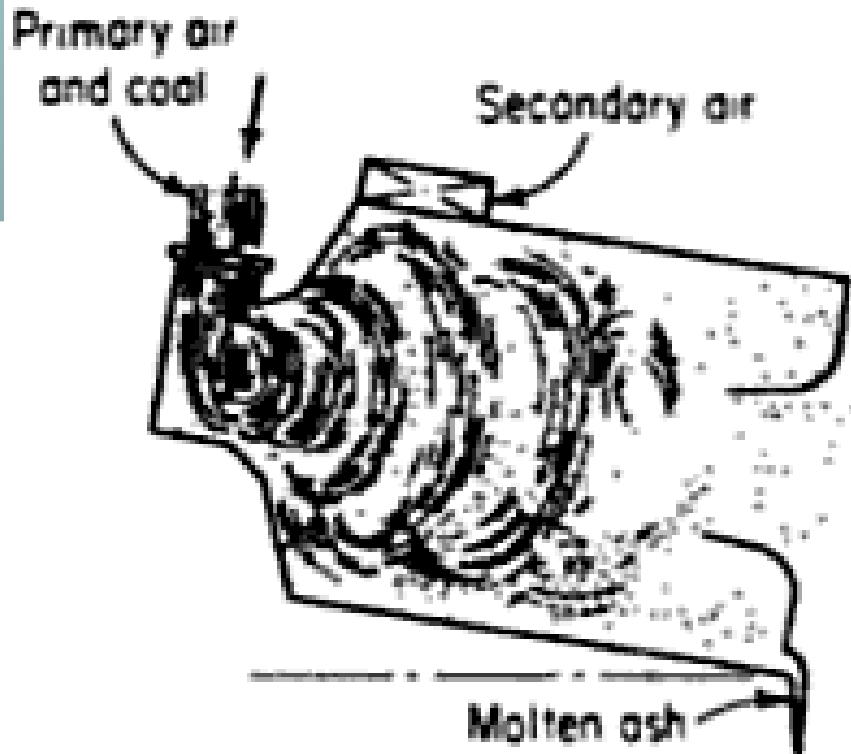
# Types of Burners for Pulverized Coal

- **Tangential Burner:** In this system, one burner is attached at each corner of the furnace. The inclination of the burners is so made that the flame produced is tangential to an imaginary circle at the centre.

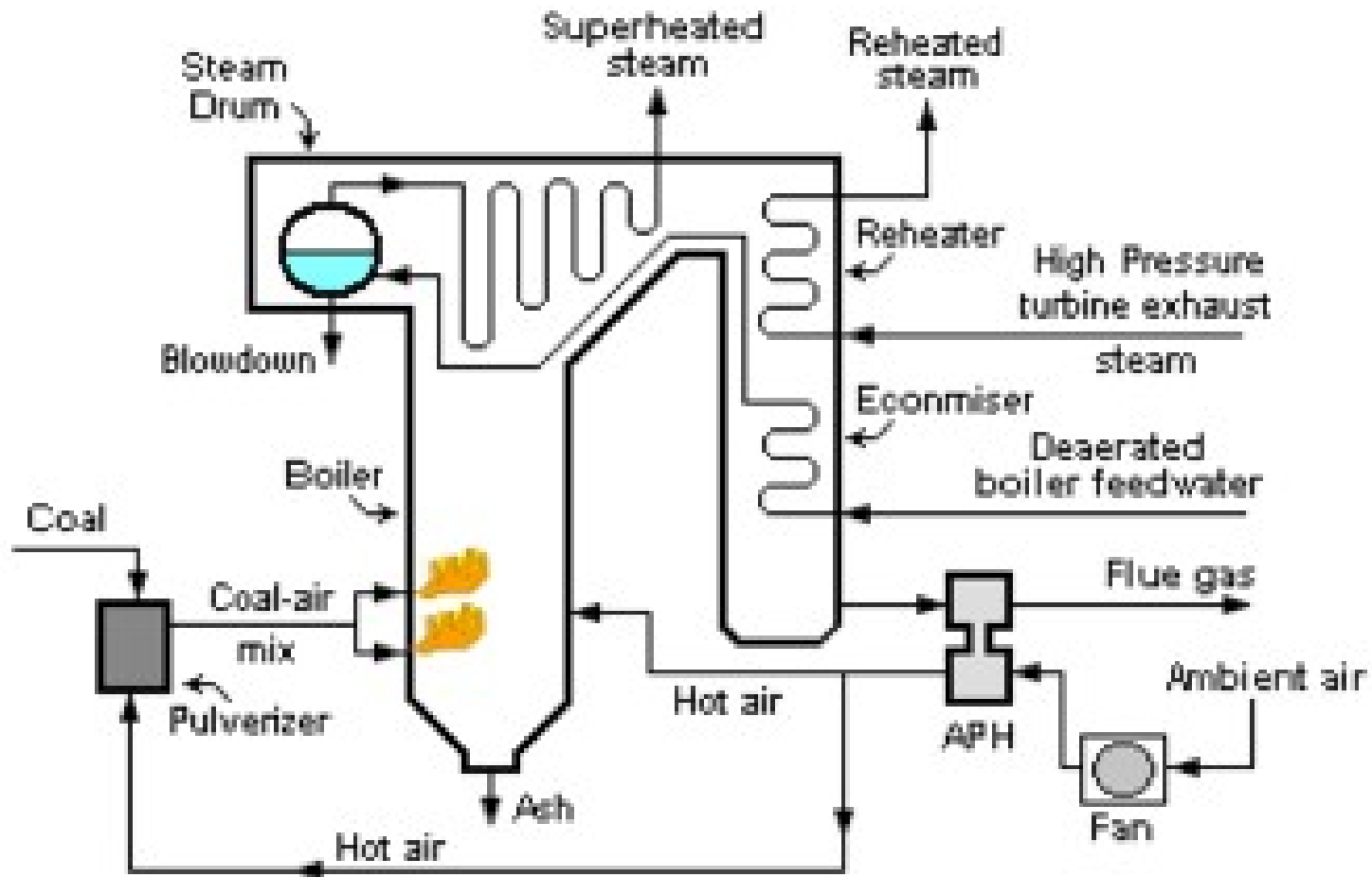


# Types of Burners for Pulverized Coal

- **Cyclone Burner:** In this system, the cyclonic action whirls coal and air against the wall of the furnace to facilitate thorough mixing of coal and air. Advantage of this burner is that it can also use crushed coal in addition to pulverized coal thus providing an option. When crushed coal is used, ash is collected in molten form for easy disposal.



# Typical Pulverized Coal Boiler

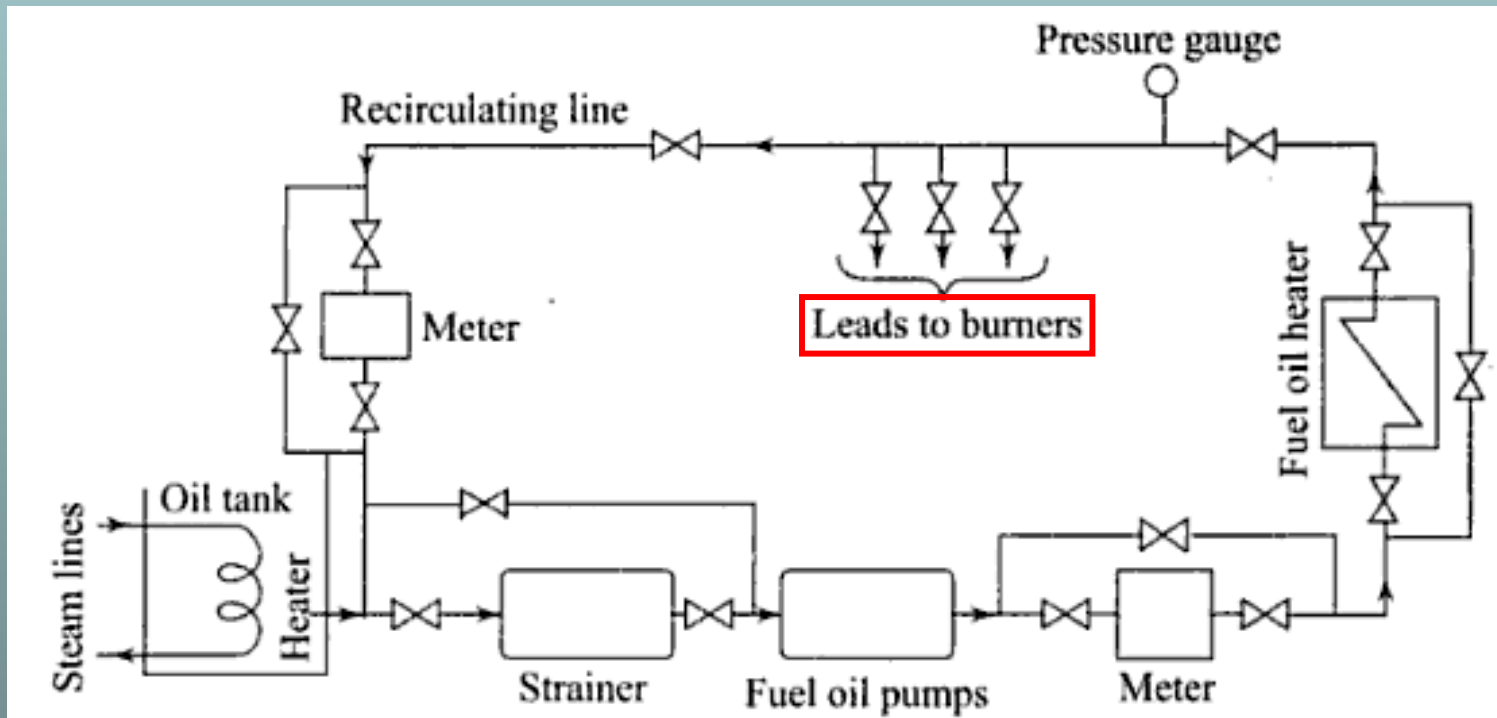


Note: APH is the air preheater



# Oil and Gas Burners

Thermal power plants can also be operated on oil and gas in addition to coal. Highly volatile petroleum fuels are too expensive for boiler firing. Therefore, heavy fuel oils (left after refining of crude petroleum) are used. Schematic of an oil burning system is depicted below:



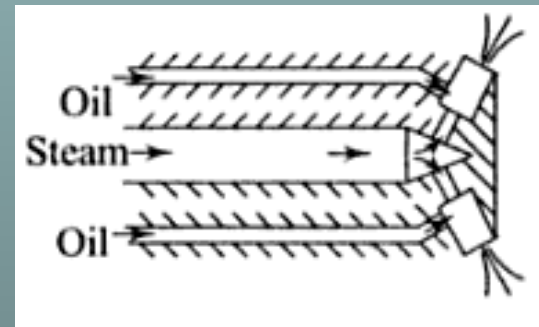
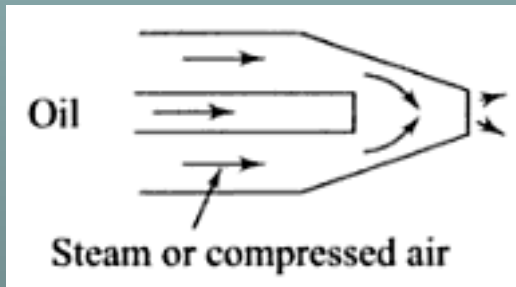
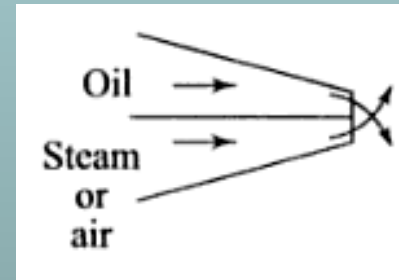
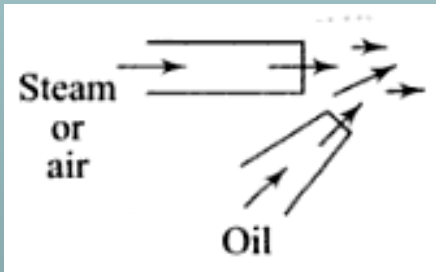
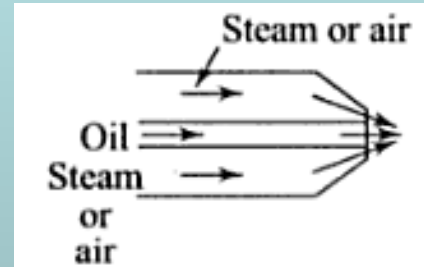
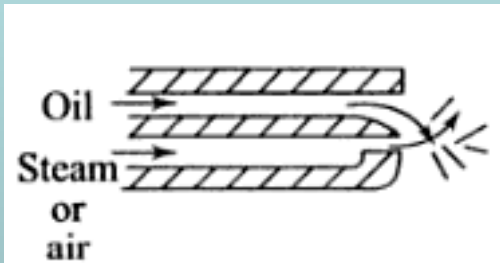
# Combustion of fuel oil

- Because of high viscosity of fuel oil, steam heating coils are installed in the oil tank to reduce viscosity and facilitate pumping.
- Reciprocating type pumps receive oil from filters and discharge it to the burners through heaters and a flow measuring system.
- Oil temperature is generally controlled between 65°C and 115°C for obtaining a good spray pattern. Higher temperatures may cause vapourization of oil or may lead to decomposition of oil.
- Recirculation of oil is necessary initially to purge the pipe lines so that heavy oil does not collect and plug the passages. Usually a light oil is used for some time during starting and stopping the boiler to wash the pipes clean of heavy oil.

# Oil Burners

- **The major parts of an oil burner are:**
  - **Atomizer**
  - **Air register**
  - **Oil lines with filters and valves**
- **Atomization of fuel oil exposes more surface area per unit mass, thus promoting ignition and complete combustion.**
- **Atomization of fuel oil is accomplished mechanically or with steam or air.**
- **In twin-fluid burners, high pressure steam or air is used to break up oil drops to fine droplets, enabling better mixing with air for combustion.**
- **For large boilers, oil burners with pressure atomization are suitable. Oil under pressure (6 – 20bar) is atomized by ejecting the oil through very small oil injector orifices.**

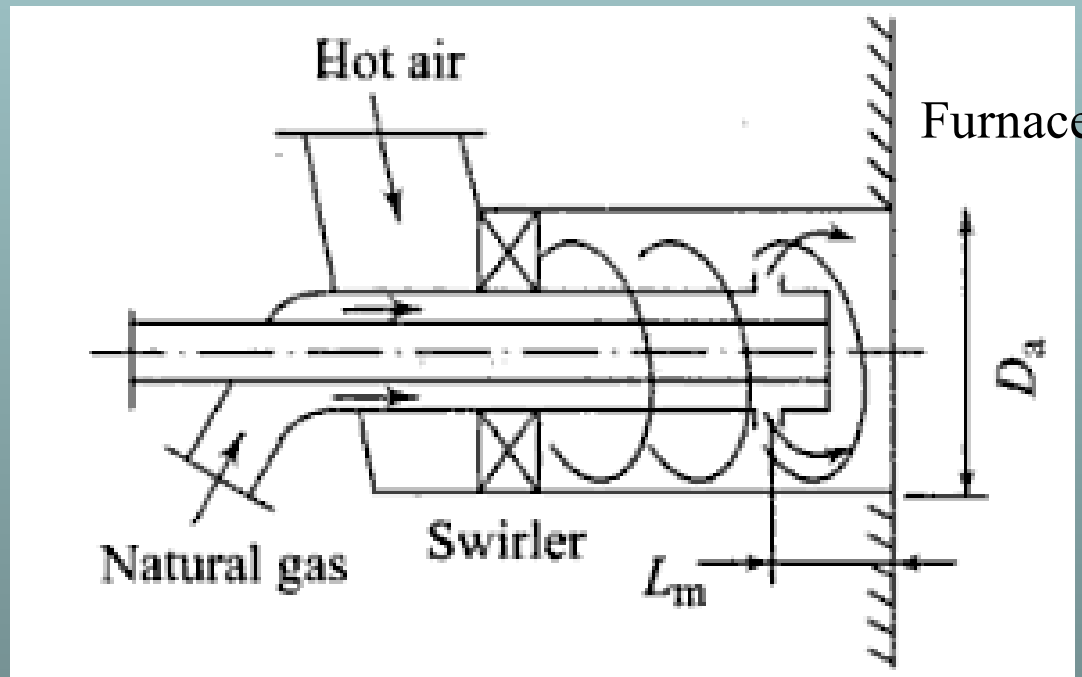
# Oil Burners



Typical configurations of Steam or Air atomized oil burners

# Gas Burners

Burning of gas is easy and clean. There is no need for atomization. Combustion of  $1\text{m}^3$  of natural gas requires about  $20\text{m}^3$  of hot air. Proper mixing of gas and air can be achieved by introducing gas into a swirling air flow in the form of thin jets.



# Ash Handling

- Large power plants produce a huge quantity of ash, sometimes as much as 10 to 20% of the coal burnt per day. Therefore, mechanical devices are used for effective collection and disposal of ash.
- Ash handling includes:
  - Removal of ash from furnace
  - Loading to conveyors and delivery to fill or dump from where it can be disposed off.
- Handling of ash is a problem because it is too hot when it comes out of furnace, dusty and sometimes poisonous and corrosive. Ash needs to be quenched before handling due to following reasons:
  - Quenching reduces corrosive action of ash
  - It reduces the dust accompanying the ash
  - It reduces the temperature of ash
  - Fused clinkers will disintegrate making it easier to handle

# Ash Handling Equipment

A good ash handling equipment should have the following characteristics:

- It should have enough capacity to cope with the volume of ash that may be produced in a station.
- It should be able to handle large clinkers, boiler refuse, soot etc., with little attention from workers.
- It should be able to handle hot and wet ash effectively and with good speed.
- It should be possible to minimise the corrosive or abrasive action of ash.
- Operation of the plant should be easy, economical, simple and noiseless.
- It should be able to operate effectively under all variable load conditions.
- It should also remove fly ash and smoke to control air pollution.

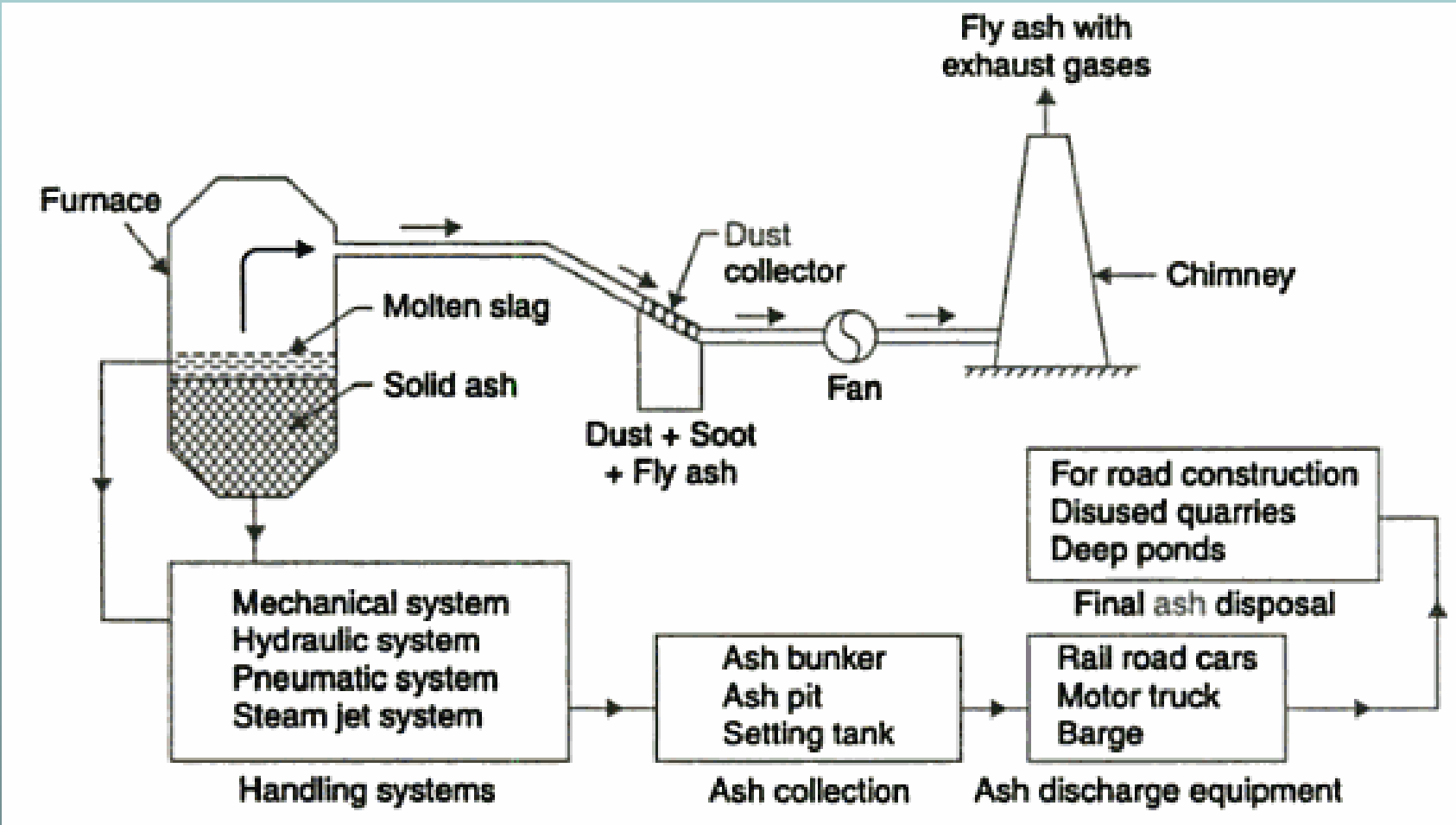
# Ash Handling Equipment

The commonly used equipment for ash handling in large and medium size plants may comprise of:

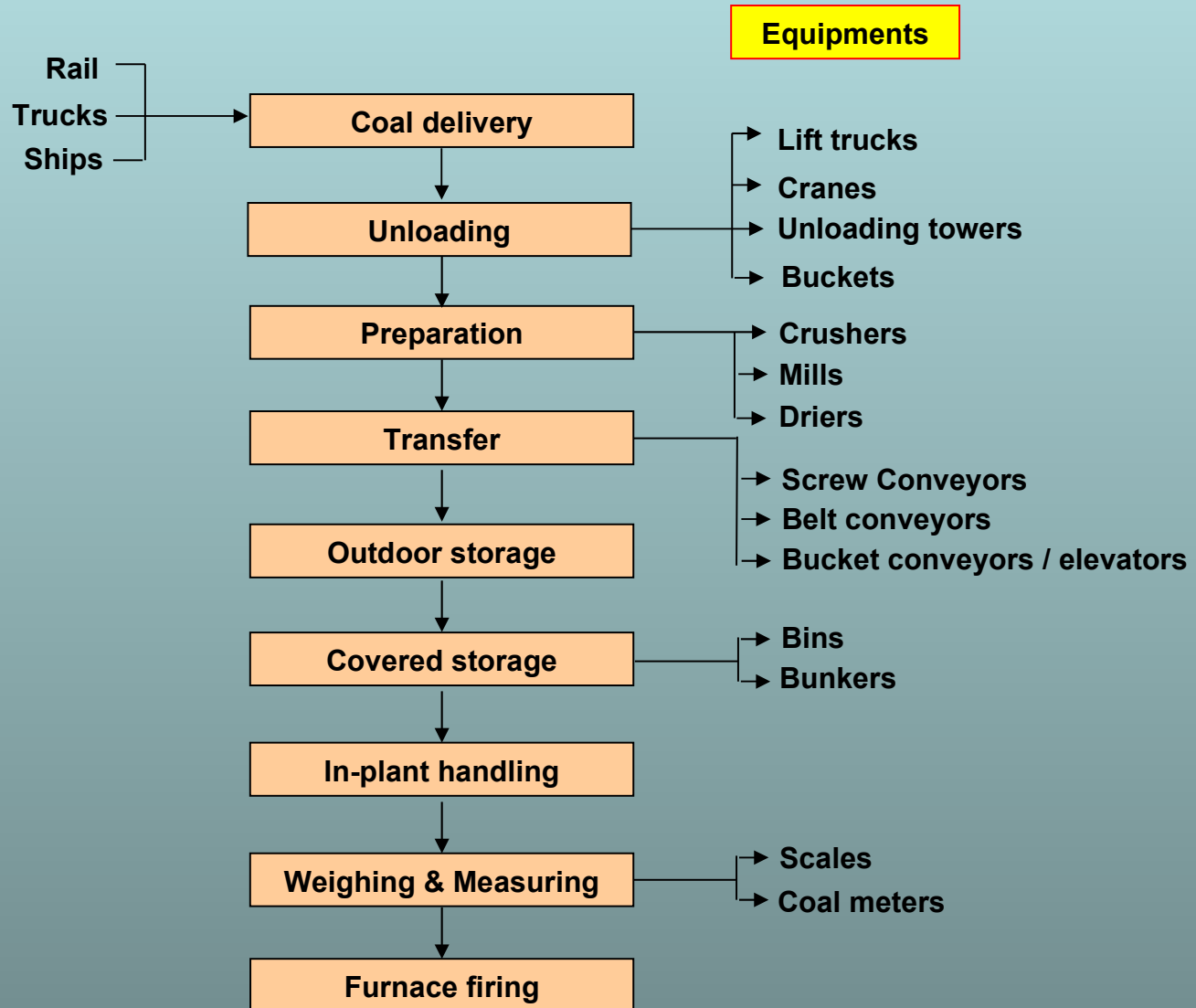
- **Bucket elevator**
- **Bucket conveyor**
- **Belt conveyor**
- **Pneumatic conveyor**
- **Hydraulic sluicing equipment**
- **Trollies and Rail cars etc.**
- **These are mainly classified into:**
  - **Mechanical handling systems**
  - **Hydraulic systems**
  - **Pneumatic systems**
  - **Steam jet systems**



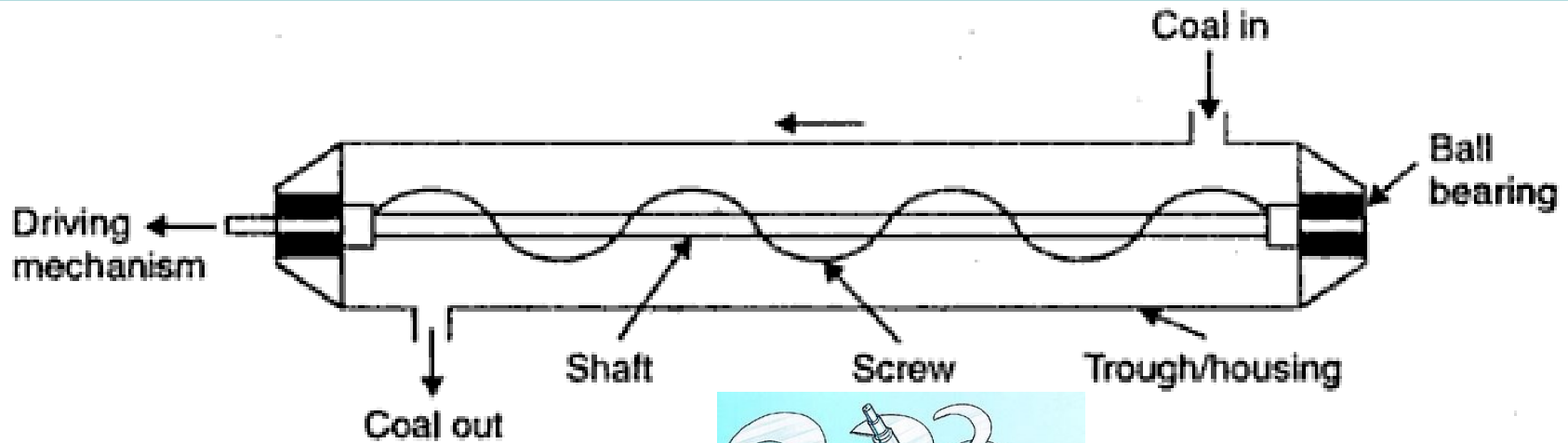
# Ash Collection and Transportation



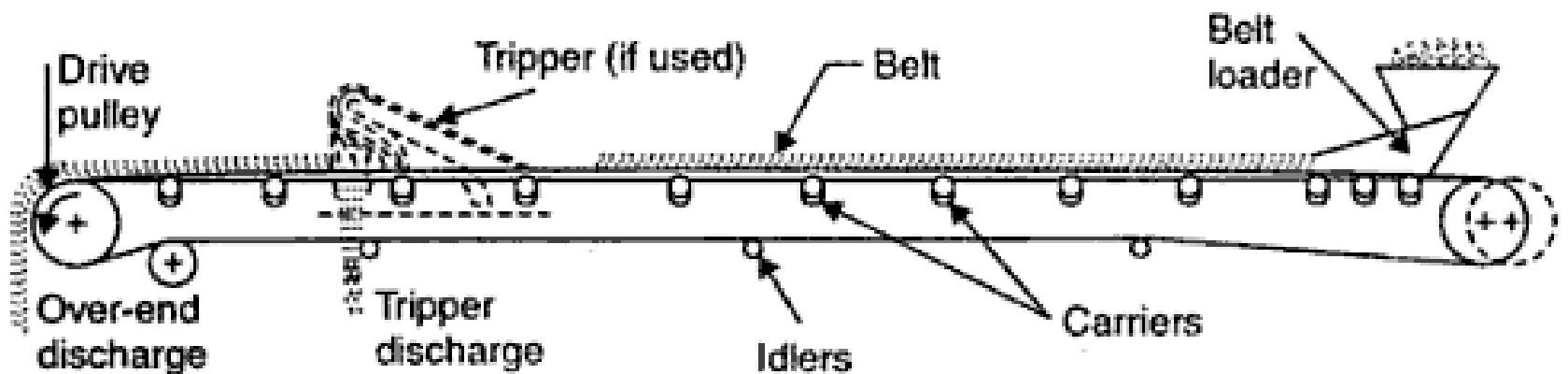
# Coal Handling System



# Coal Handling System

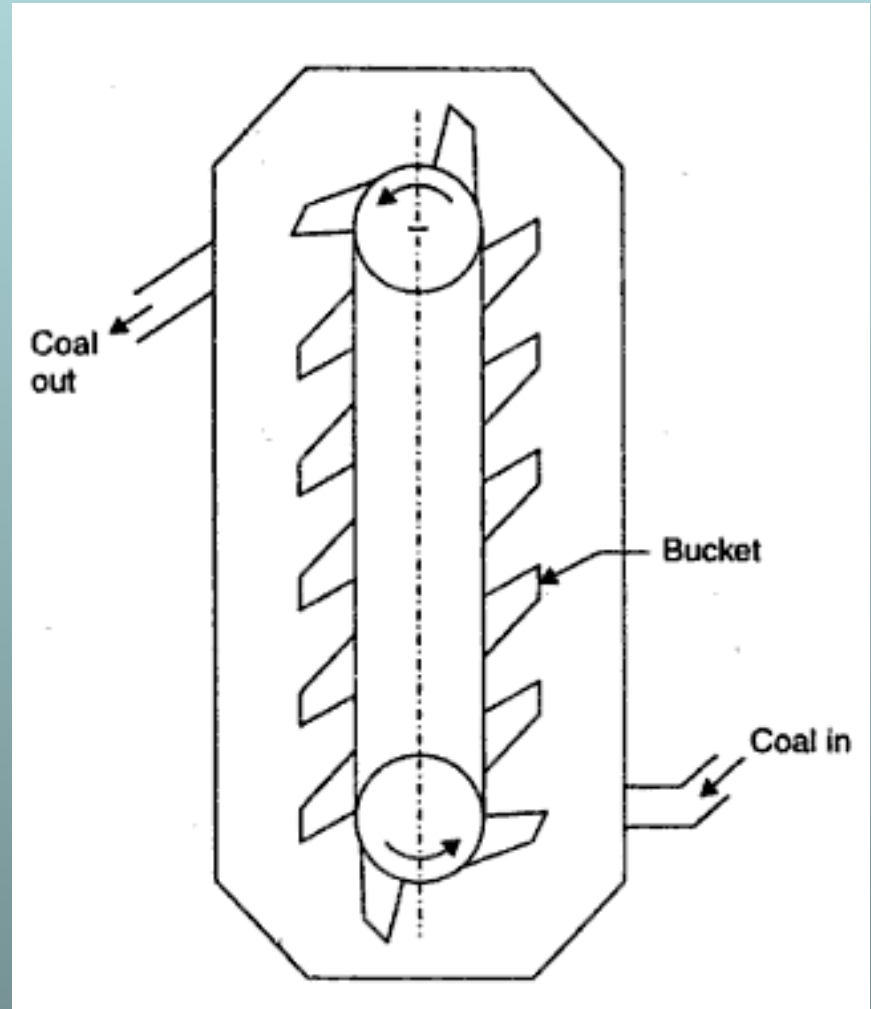
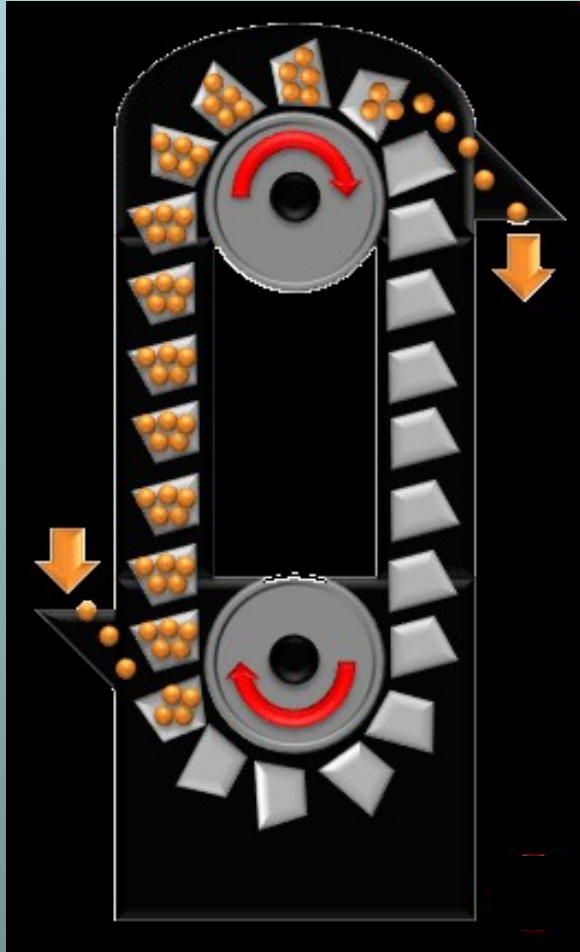


Screw Conveyor



Belt Conveyor

# Coal Handling System

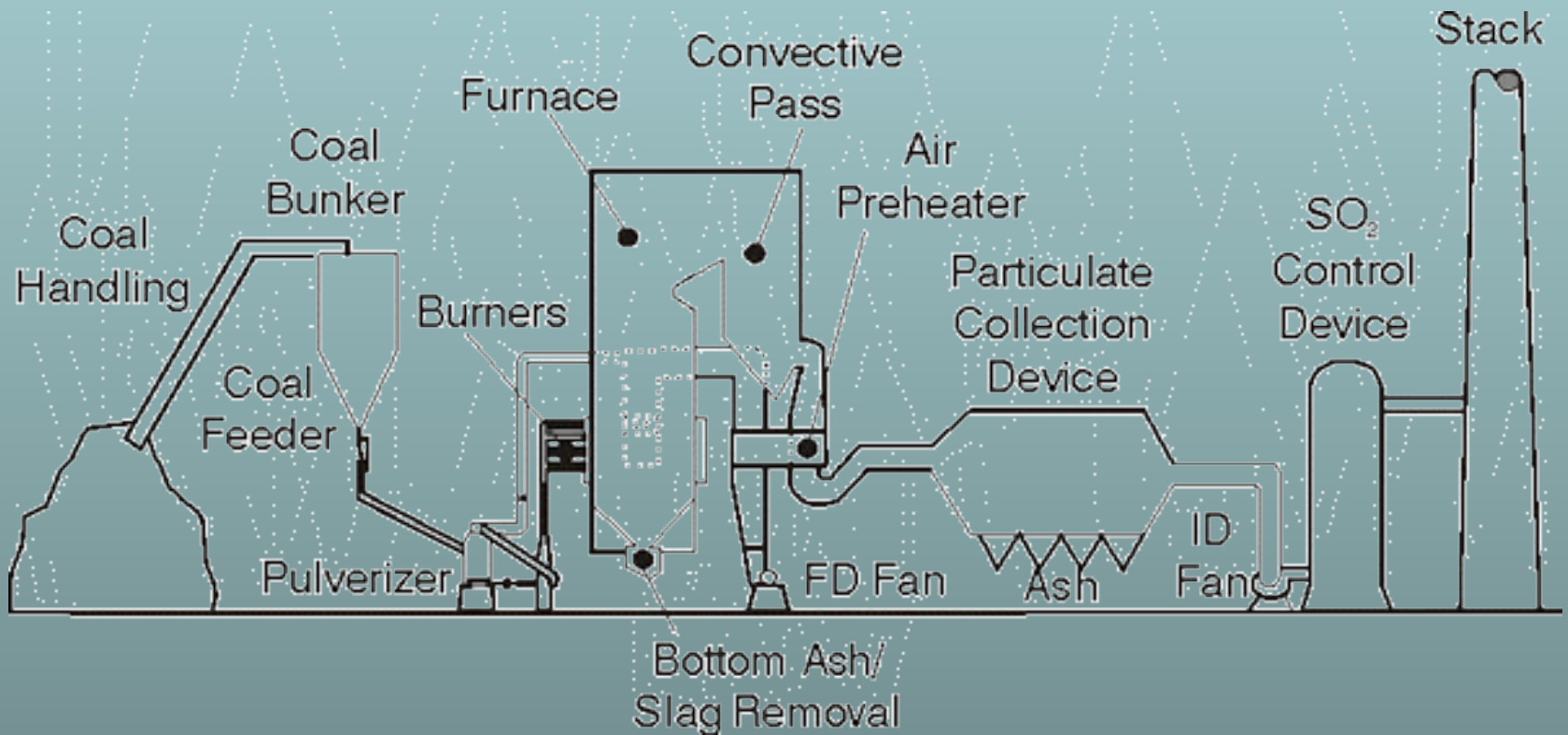


Bucket Elevator

# Typical input and output for a 500 MW boiler

- **225 tons/hr coal**
- **5400 tons/day coal (54 rail cars)**
- **Bottom Ash – 108 tons/hr**
- **Fly Ash – 432 tons/hr**
- **SO<sub>x</sub> – 228 tons/day**
- **NO<sub>x</sub> – 20 tons/day**
- **Steam – 2000 tons/hr**

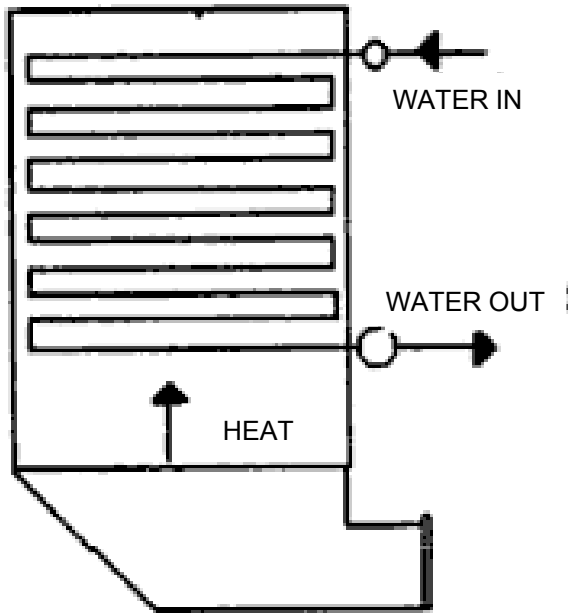
# Coal and Ash handling in a typical coal fired power plant



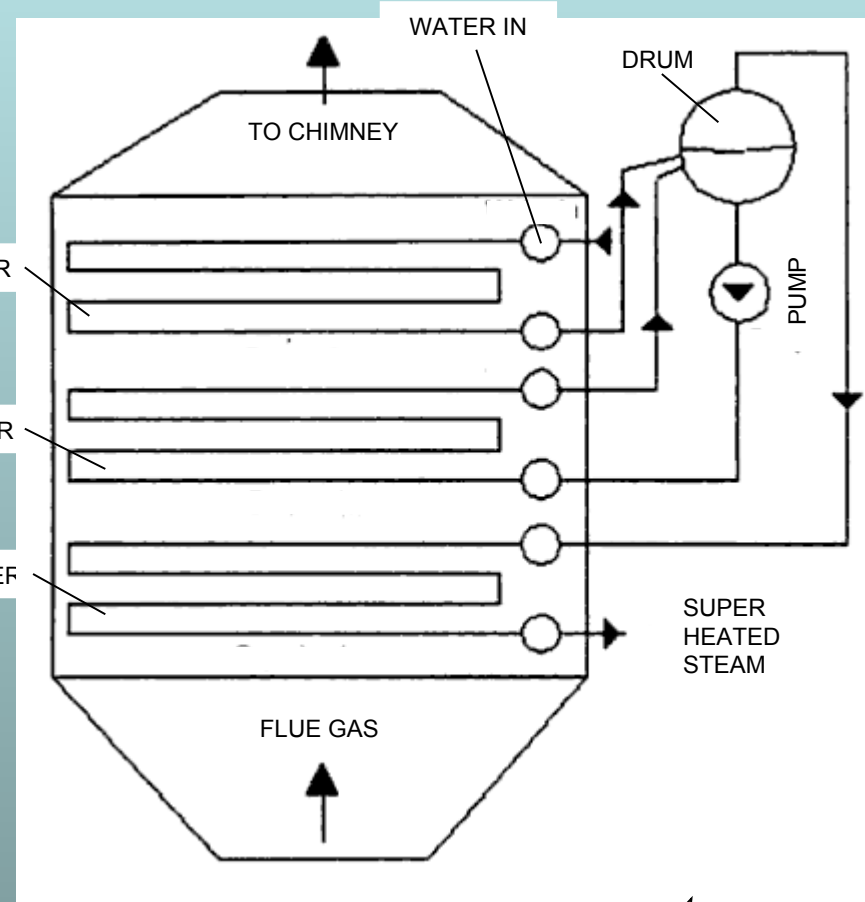
# High Pressure Boilers

- In all modern power plants, high pressure boilers ( $> 100$  bar) are invariably used due to their inherent advantages.
- If high pressure steam is used, plant efficiency is increased because lesser quantity of steam is required for generating a given power; i.e., work done per unit mass of steam is higher.
- Forced circulation of water can be used which helps arrangement of furnace and water surfaces and reduction of heat exchange area.
- Tendency for scale formation is reduced due to high velocity of water.
- Danger of overheating is reduced as all parts are more uniformly heated.
- Differential expansion is less due to more uniform temperature distribution thus reducing possibility of gas and air leakages.
- Following types of high pressure boilers are generally used:
  - La Mont Boiler
  - Benson Boiler
  - Loeffler Boiler
  - Schmidt-Hartmann Boiler

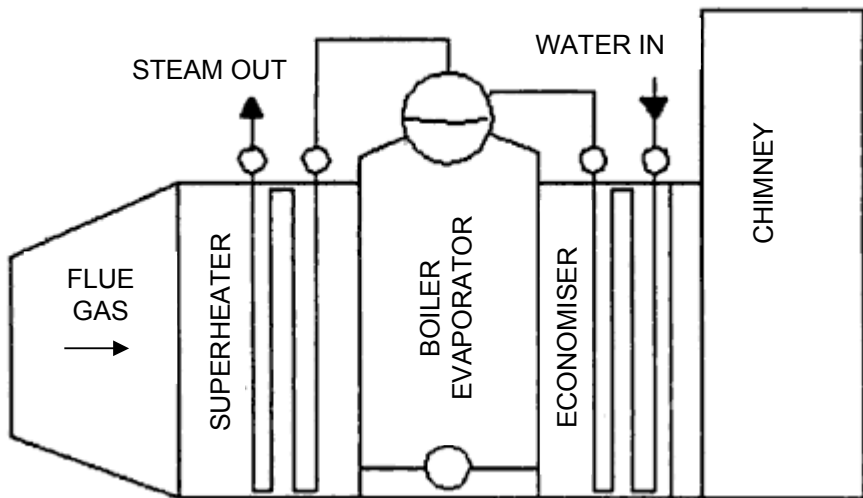
# Water Circulation in Boilers



Once through circulation



Forced circulation



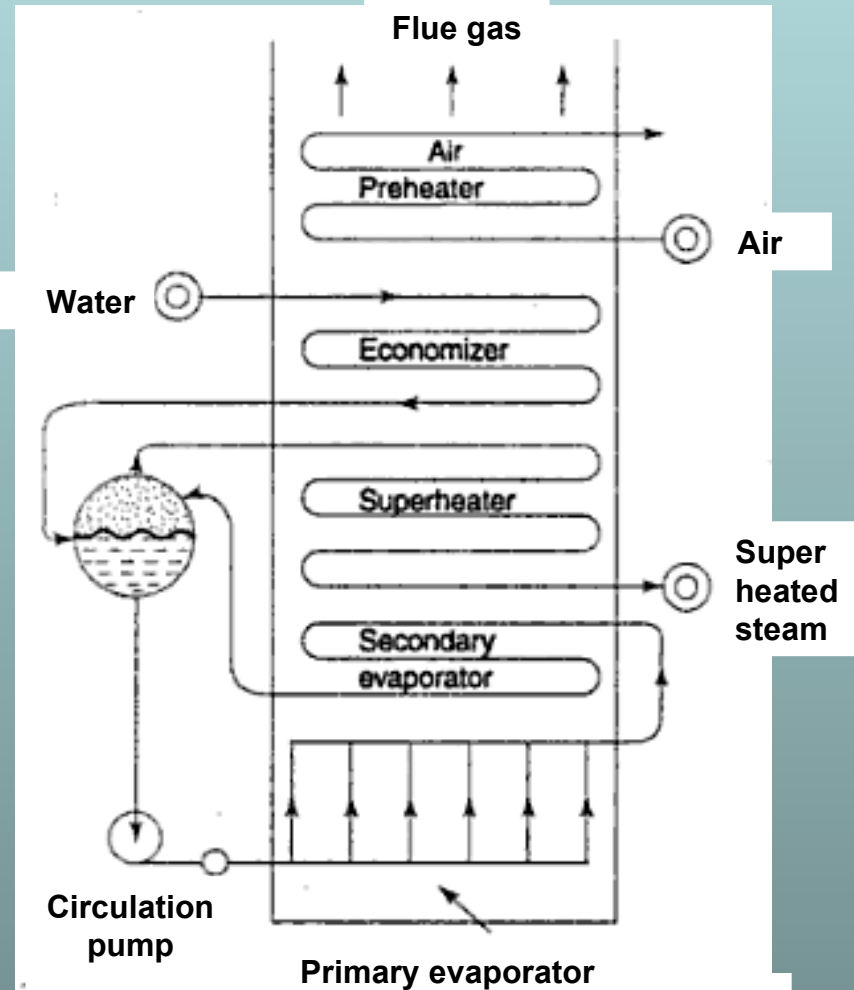
Natural circulation

Forced circulation is generally used in high pressure boilers



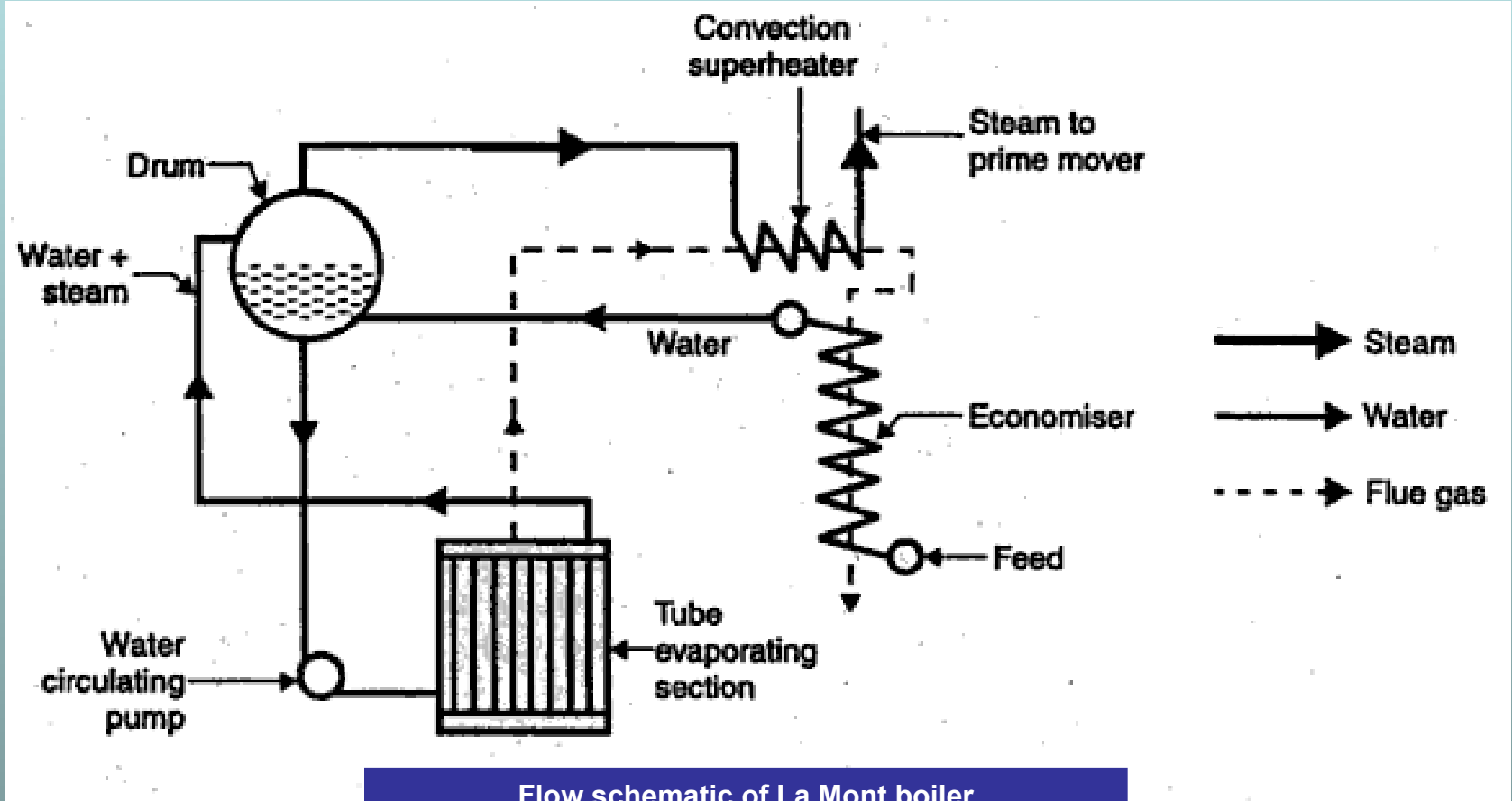
# La Mont Boiler

- Feed water is supplied to the boiler drum through an economiser.
- A pump circulates water at 8 to 10 times the mass of steam evaporated.
- The large quantity of water circulated prevents overheating of tubes.
- The pump delivers water to headers at a pressure of 2.5 bar above the drum pressure and the distribution headers distribute the water through nozzles into the evaporators.
- The steam separated in the boiler is further passed through the super heater.
- This type of boiler can generate 45 to 50 tonnes of superheated steam at 120 bar and 500°C



Schematic representation of La Mont Boiler

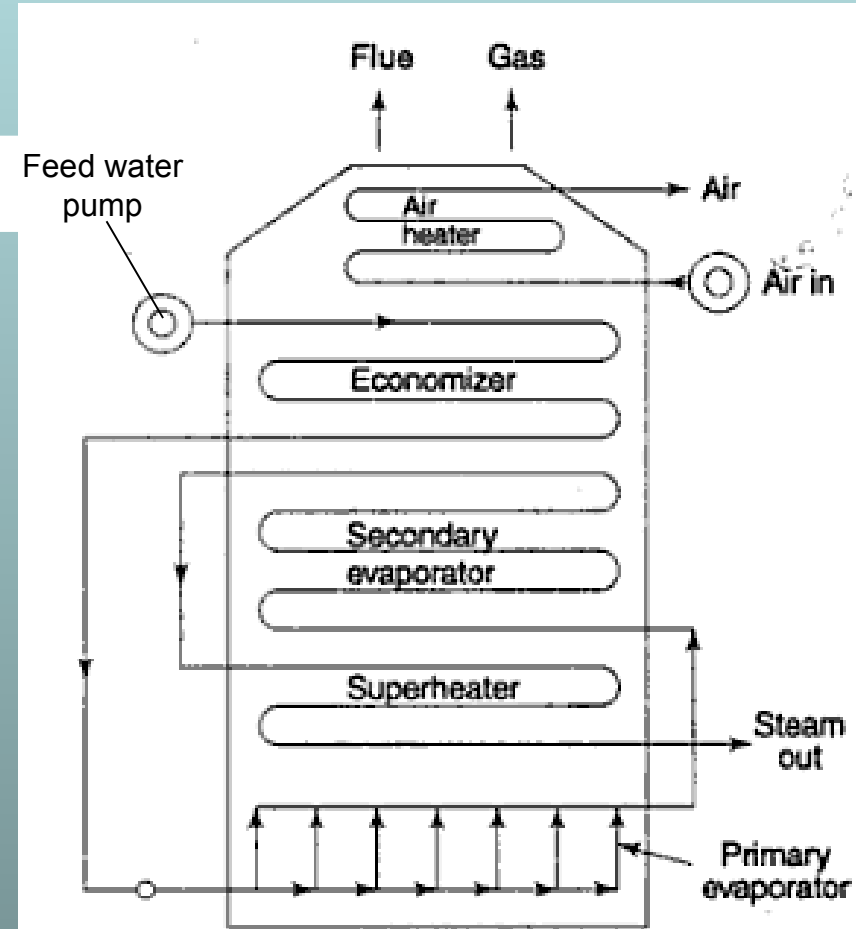
# La Mont Boiler



The main difficulty experienced in the La Mont boiler is the formation and attachment of bubbles on the inner surface of tubes. These bubbles reduce the heat flow and steam generation as it offers higher thermal resistance compared to water film.

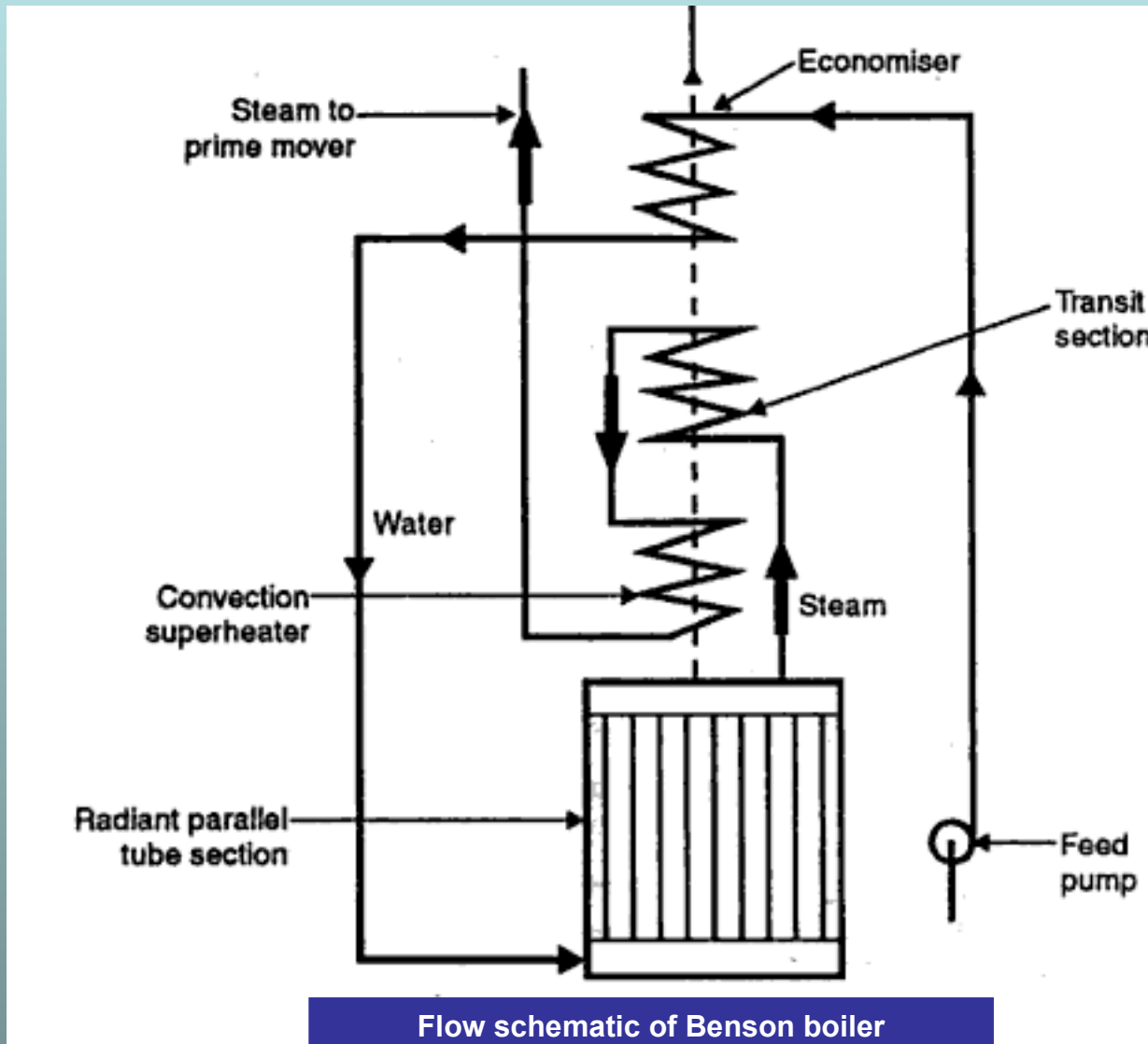
# Benson Boiler

- It is a water tube boiler capable of producing steam at super critical pressure ( $> 225$  bar).
- At super critical pressure, water flashes into steam without any latent heat requirement. Therefore steam generation is faster.
- Above critical point, water transforms into steam without boiling and without change in volume. i.e., same density.
- Super critical steam generation does not have bubble formation and consequent pulsations.
- Materials of construction should be strong to withstand high pressure and temperature.
- 130 – 135 tonnes of steam per hour is generated at  $> 225$  bar and  $\sim 90\%$  thermal efficiency.



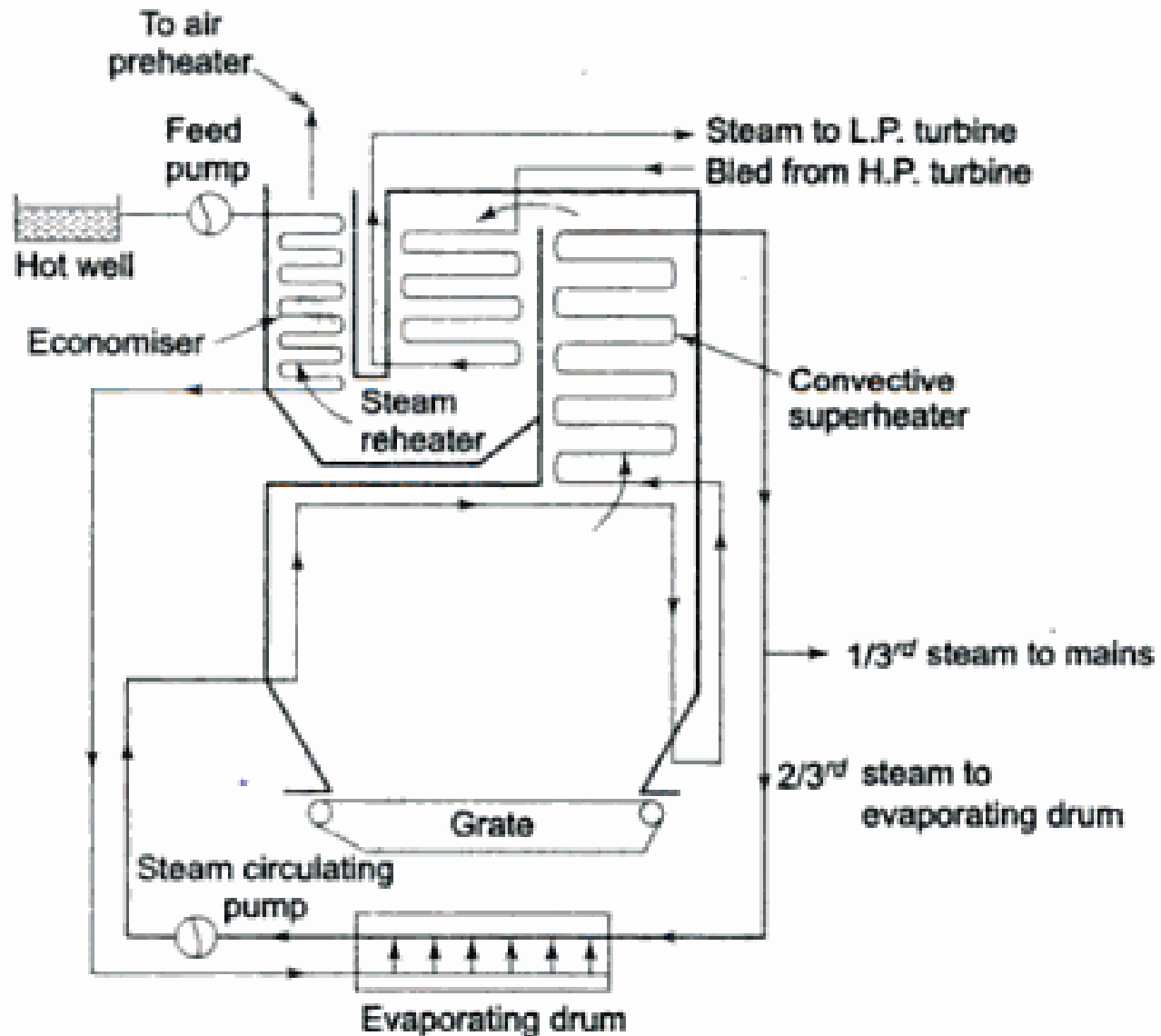
Schematic representation of Benson boiler

# Benson Boiler



The main drawback of Benson boiler is deposition of salt and sediment on the inner surface of water tubes which offers high thermal resistance.

# Loeffler Boiler

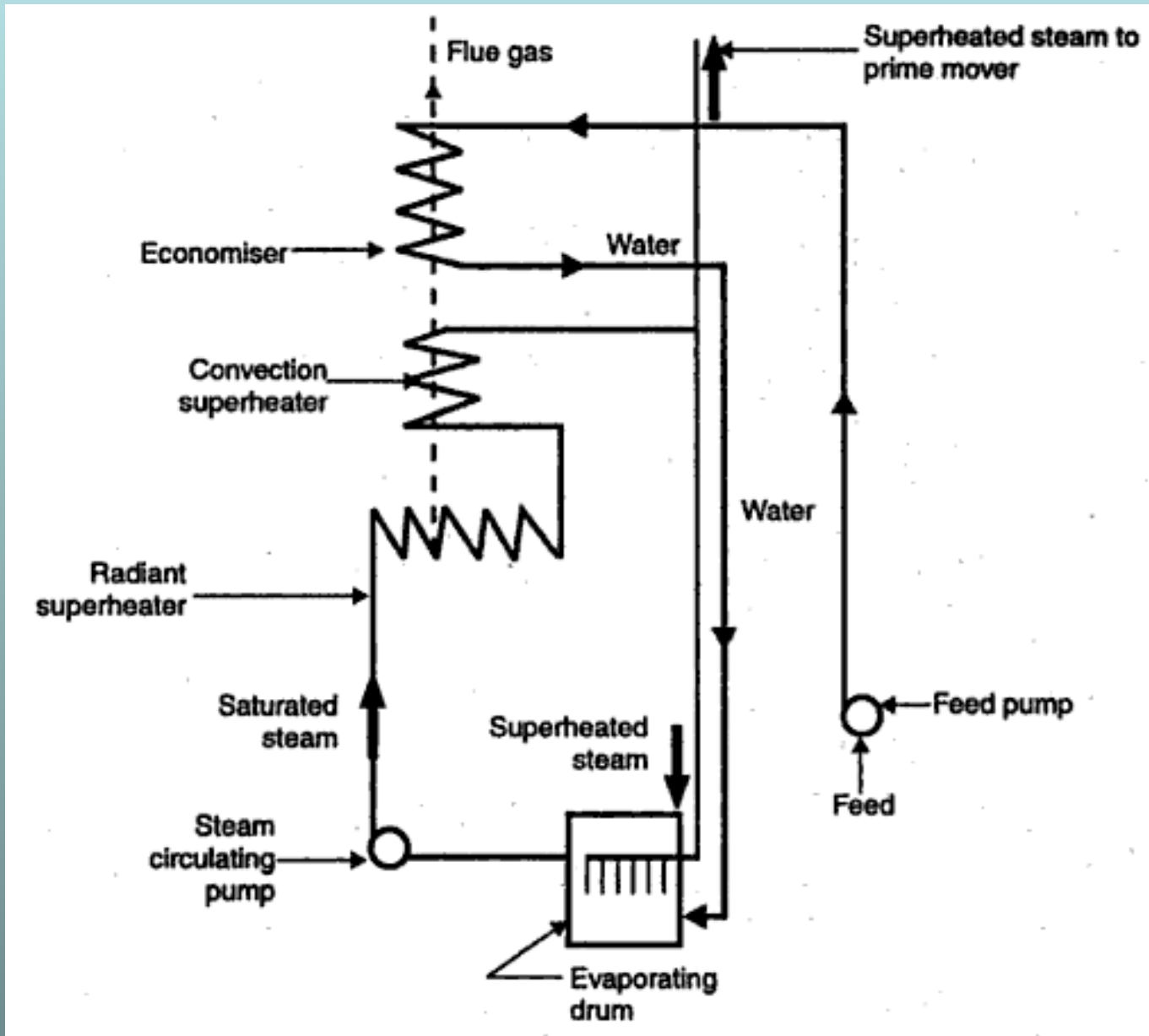


Schematic representation of Loeffler boiler

# Loeffler Boiler

- The limitation of Benson boiler is the deposition of salts on water tube walls. This is solved in Loeffler boiler by evaporation of feed water by means of superheated steam from the super heater.
- Loeffler boiler uses forced circulation and the hot gases from the furnace are primarily used for superheating purposes.
- The high pressure feed pump draws water through the economiser and delivers it to the evaporating drum.
- The steam circulating pump draws saturated steam from the drum and passes it through convective and radiative superheaters where steam is heated to required temperature.
- From the superheater, about 35% of the superheated steam goes to the turbine and the remaining 65% passes through water in the evaporating drum to evaporate feed water.

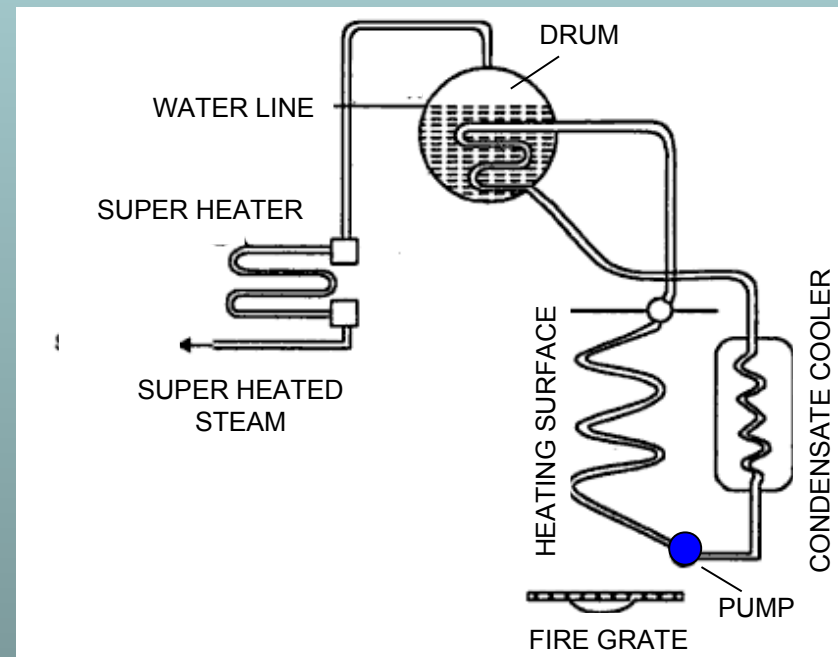
# Loeffler Boiler



Flow schematic of Loeffler boiler

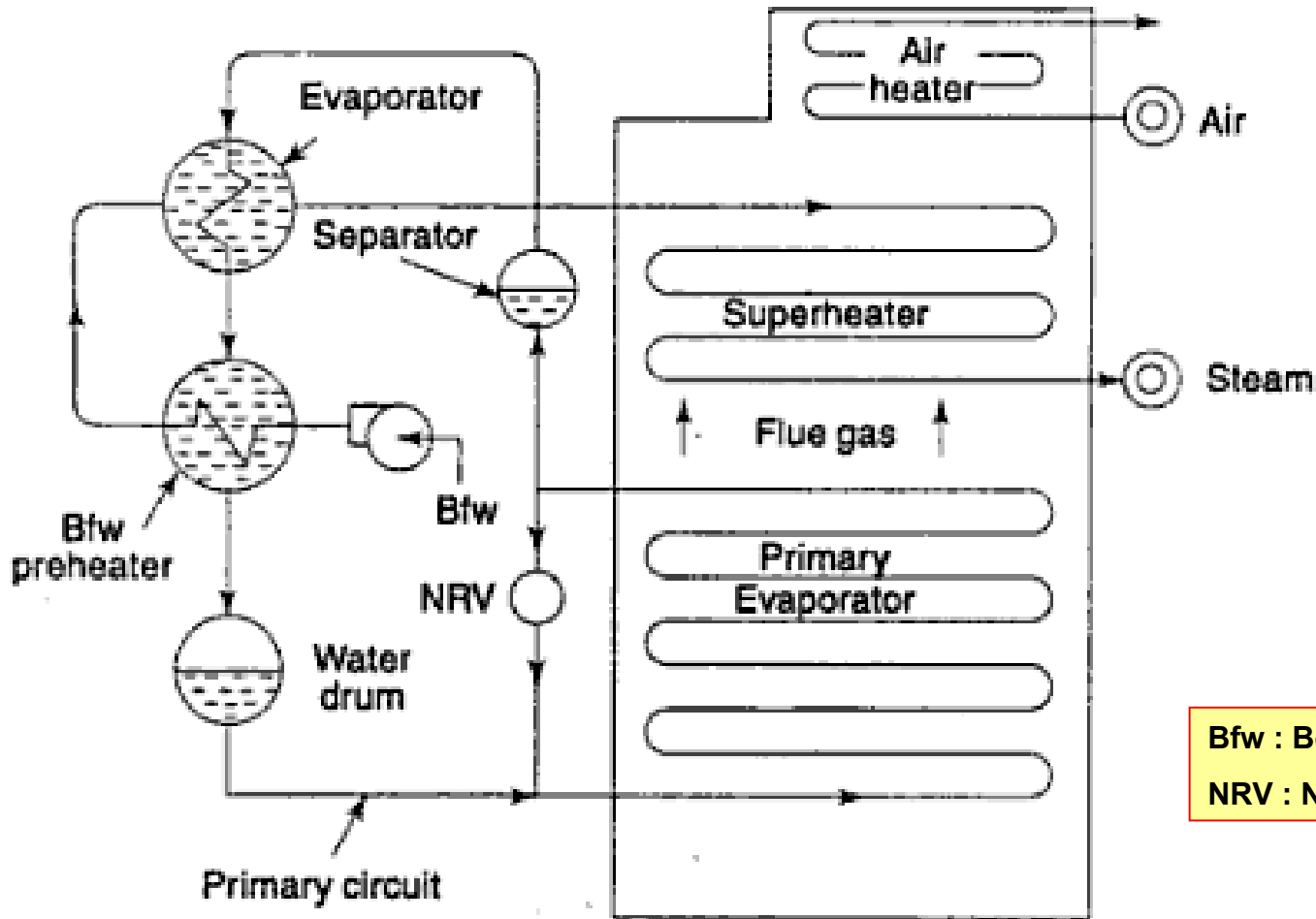
# Schmidt-Hartmann Boiler

- There are two pressure circuits in this boiler
  - Primary circuit
  - Secondary circuit
- Primary circuit uses distilled water that goes from the drum to primary evaporator kept at the furnace. Steam generated is passed through a submerged heating coil kept inside the drum. It loses heat to water in secondary circuit and condenses. A condensate pump maintains primary water circulation.
- In the secondary circuit, normal water is pumped to evaporator drum which picks up heat from steam in submerged coils.
- Steam thus produced is superheated and passed on to the turbines.





# Schmidt-Hartmann Boiler



Flow schematic of Loeffler boiler