BOILER FEED WATER AND ITS TREATMENTS

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Contents

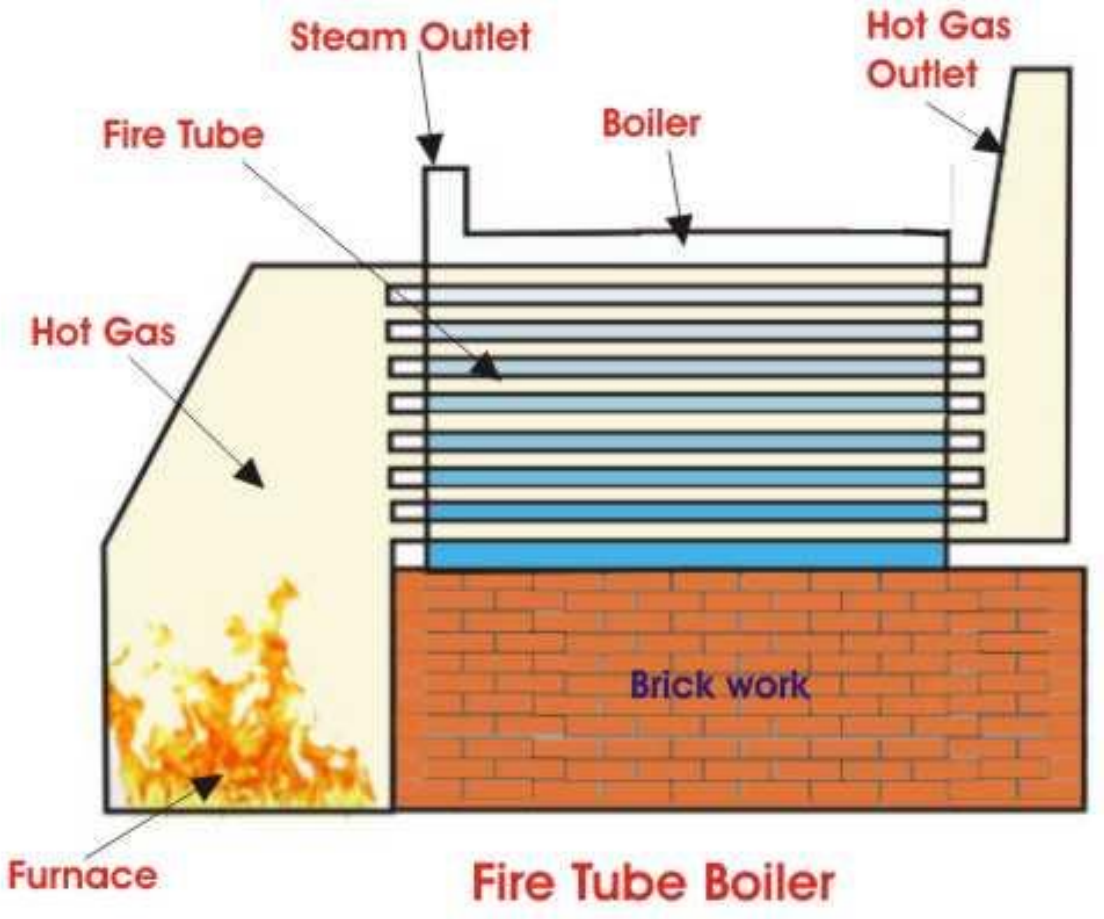
- Boiler Feed water
- Major Problems in Boiler
    - Scaling
    - Boiler corrosion
    - Caustic embrittlement
    - Foaming & priming

Boiler Feed Water

- A boiler is a device for generating steam
- Consists of two main parts:
  - Furnace and Boiler proper
  - ❑ Furnace provides heat, usually by burning a fuel
  - ❑ Boiler proper, a device in which the heat changes, from water into steam
- The steam or hot fluid is then recirculated out of the boiler for use in various processes in heating applications

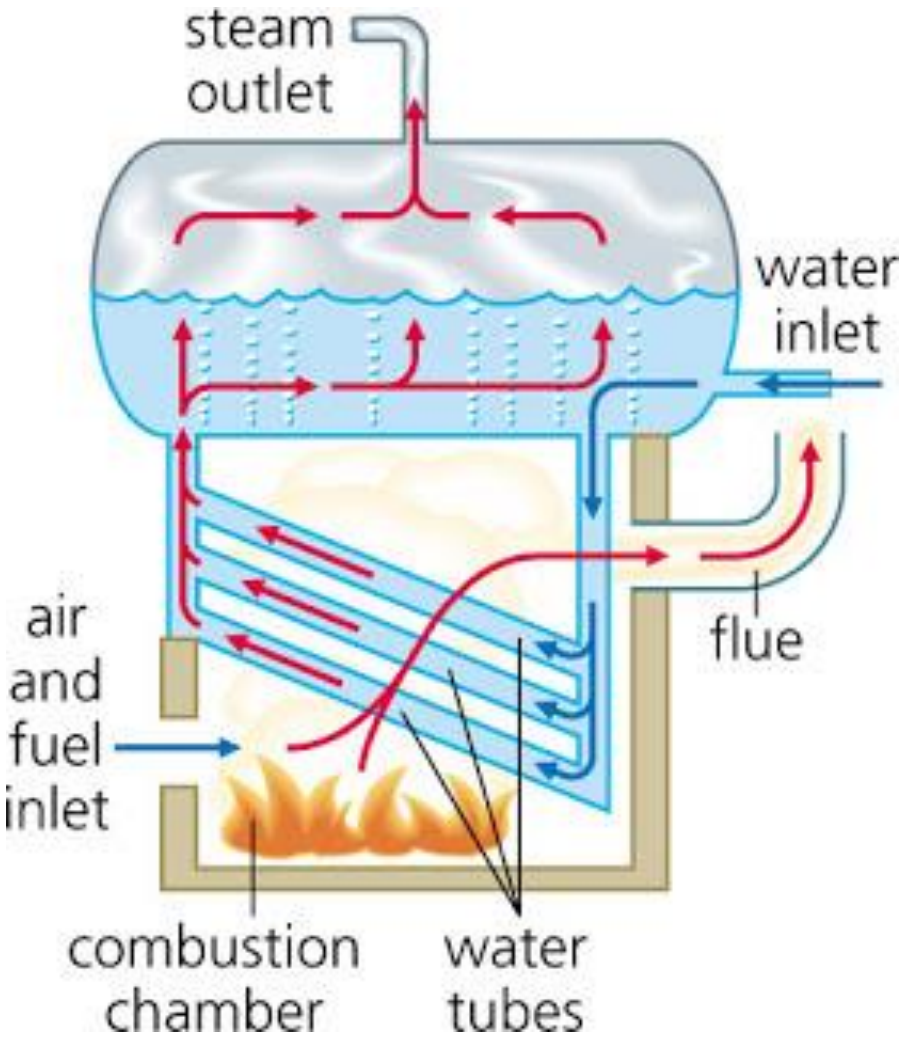
Fire-Tube Boiler

consists of a tank of water perforated with pipes. The hot gases from a coal or wood fire run through the pipes to heat the water in the tank



Water-Tube Boiler

water circulates in tubes heated externally by the fire



- Boiler receives feed water in the form of
  - Fresh water (make up water: purified in varying degrees or natural water in its raw state)
  - Recovered condensed water (return water)
- Feed-water composition therefore depends on the quality of the make-up water and the amount of condensate (**return water**) returned to the boiler
- Steam which is coming out from the boiler, contains liquid droplets as well as gases
- Water remaining in the liquid form at the bottom of the boiler picks up all the impurities from any form of water
- The impurities must be ***blown down*** by the discharge of water from the boiler to the drains

- Proper treatment of boiler feed water is an important part of operating and maintaining the boiler system
- **As steam is produced, dissolved solids become concentrated and deposited inside the boiler**
- This leads to poor heat transfer and reduces the efficiency of the boiler
- Dissolved gases such as oxygen, carbon dioxide will react with the metals in the boiler system and lead to **boiler corrosion**.
- **In order to protect the boiler from these contaminants, they should be controlled or removed, through external or internal treatment**

I. Scaling

- In boiler, water is continuously converted into steam
- Increasing the concentration of salts.
- Concentrates changes into loose and slimy precipitates called **sludge** and
- if these are become hard and adherent, called **scales**.
- Scales are hard deposits, which stick very firmly to the inner surface of the boiler.
- Types of the scale, depends upon the chemical composition of the concentrated water
  - Scale due to calcium and magnesium
  - Scale due to iron oxide
  - Scale due to copper
  - Scale due to silica

Effect of Scale or Sludge Formation

- The thermal conductivity of scale is very low (similar to insulating brick).
- The scale acts as an insulating layer and prevents an efficient transfer of heat through the tubes to the circulating water.
- The reduction in thermal conductivity means lower boiler efficiency which in turn leads to overheating and may result in the softening, bulging or even fracturing of the boiler tubes
- Boiler scale can also cause clogging or partial obstruction of circulating water tubes in a boiler, which again causes overheating of the tubes.
- It increases the maintenance and operating costs
- Scales also cause **corrosion** (serious problems in boiler operation)

Prevention of Scale or Sludge Formation

External pretreatment of feed water with water softeners, demineralizers, or reverse osmosis to remove minerals before enter into boiler

- Scale/sludge is prevented by introducing the kerosene, colloidal substances (tannins, lingo-sulphonates, polyacrylates, maleic-acrylate co-polymer, maleic-styrene co-polymer, polystyrene sulphonates)
- These **colloids get coated over the scale and forming particles and are suspended** in water which can easily blown-off from the boiler
- Internal treatment using chemical conditioning

  carbonate conditioning

  phosphate conditioning

  calgon conditioning

  into boiler feedwater to keep the scale forming materials in **dissolved form**

Carbonate Conditioning Process

- Sodium carbonate is added into the boiler water
- Scales react with it and form insoluble calcium carbonate

$$CaSO_4 + Na_2CO_3 \rightarrow CaCO_3\downarrow + Na_2SO_4$$

- Used only for low pressure boilers
- In high pressure boilers the **excess** of sodium carbonate get converted into sodium hydroxide due to hydrolysis and causes caustic embrittlement

Calgon Conditioning Process

- Calgon [sodium hexametaphosphate, $(NaPO_3)_6$] is added to boiler water
- forms the sludge $[Na_4P_6O_{18}]^{2-}$ and prevents the scale formation by forming the soluble complex compounds

$$Na_2[Na_4(PO_3)_6] \rightarrow 2Na^+ + [Na_4P_6O_{18}]^{2-}$$

$$[Na_4P_6O_{18}]^{2-} + 2CaSO_4 \rightarrow [Ca_2P_6O_{18}]^{2-} + 2Na_2SO_4$$

II. Boiler Corrosion

- Destructive attack or decay of boiler material or metal by chemical or electrochemical reaction with its environment
- Main responsible for corrosion in boiler:
  - ❑ Dissolved Oxygen
  - ❑ Dissolved Carbon dioxide
  - ❑ Acids from dissolved salts

Dissolved oxygen (D.O)

- Water usually contains about 8 ml D.O/L at room temperature
- D.O in water and presence of high temperature attacks boiler material

$$2Fe + 2H_2O + O_2 \rightarrow 2Fe(OH)_2 \downarrow$$

$$4Fe(OH)_2 \downarrow + O_2 \rightarrow 2[Fe_2O_3.2H_2O] \downarrow$$

Ferrous hydroxide **(Rust)**

Removal of Dissolved oxygen (D.O)

- By mechanical deaeration
- Chemically, oxygen is removed by adding oxygen scavenger or absorbing chemicals in a calculating amount such as sodium sulphite or hydrazine or sodium sulphide
  - If only small quantities of oxygen is present, the addition of sodium sulphite is practical , in large quantities causes **foaming**
  - Hydrazine is used in large utility boilers to remove dissolved oxygen but not recommended for heating boilers because it must be closely controlled because of **explosive nature** of hydrazine and if used excess, it decomposes to produce **ammonia which again cause corrosion**

Dissolved carbon dioxide

- Carbon dioxide in presence of water forms carbonic acid (H_2CO_3)

$$CO_2 + H_2O \rightarrow H_2CO_3$$

- Carbon dioxide is also released inside the boiler, if water used for steam generation contains bicarbonates

$$Mg(HCO)_3 \rightarrow MgCO_3 + H_2O + CO_2$$

- Slow corrosive effect on the boiler material

Removal of Dissolved Carbon Dioxide

- By adding calculated amount of ammonia

$$2NH_4OH + CO_2 \rightarrow (NH_4)_2CO_3 + H_2O$$

- By mechanical deaeration process, reduces CO_2 concentration to 5-10 ppm

Acids from dissolved salts

- Water containing dissolved magnesium salts liberate acids on hydrolysis

$$MgCl_2 + 2H_2O \rightarrow Mg(OH)_2 \downarrow + 2HCl$$

- The liberated acids reacts with iron (of the boiler) producing HCl again and again

III. Caustic Embrittlement

- Caustic embrittlement is a type of boiler corrosion caused by using highly alkaline water in the boiler.
- During softening process by lime-soda processes, free sodium carbonate is present
- sodium carbonate decomposes to give carbon-dioxide and sodium hydroxide (**caustic**)

$$Na_2CO_3 + H_2O \rightarrow 2NaOH + CO_2$$

- sodium hydroxide containing water flows into the minute hair-line cracks by capillary action
- water evaporated and the dissolved caustic soda concentration increases gradually
- caustic soda attacks the surrounding area, thereby dissolving iron of boiler as sodium ferrate
- This causes **embrittlement** of boiler parts

Prevention of Caustic Embrittlement

- By using sodium phosphate as softening agent instead of sodium carbonate
- By adding tannin or lignin to boiler water
- By adding sodium sulphate to boiler water, blocks hair cracks in the boiler
- By adjusting the pH of boiler water to 8.0–8.5

IV. Priming and Foaming

Priming

- When a boiler is producing steam very rapidly some particles of the water carried along with the steam. This process of 'Wet Steam' formation is called ***priming***.
- It is caused by:
  - presence of large amount of dissolved solids such as alkali sulphate and chlorides
  - sudden boiling
  - improper boiler design
  - sudden increase in steam-production rate

Disadvantage of Priming

- Reduces the efficiency of boiler
- Decrease the life of the machinery part
- maintenance cost increases

Prevention of Priming

- By improving the designing of boiler
- By addition fitting of mechanical steam purifiers
- By maintaining low water level in the boilers.
- By using softwater.
- By decreasing the amount of dissolved salts present in the feed-water.

Foaming

- Foaming is the persistent formation of bubbles or foam in the boiler
- which do not break easily.
- It is due to the presence of oily substances in water.
- These oily substances reduce the surface tension of water in boiler

Disadvantage of Foaming

- Actual height of the water column cannot be judge
- Dissolved salts in water carried by the wet steam may damage the machinery parts especially turbine blades.
- Boiler pressure cannot be maintained

Prevention of Foaming

- By the addition of anti-foaming agents such as castor oil, Gallic acid, tannic acid etc.

- By adding compounds like sodium aluminate for removing oil from boiler water.