# UNIT - I / WATER AND ITS TREATMENT

## BOILER FEED WATER AND BOILER TROUBLES

### 1.3 BOILER FEED WATER

**Requirements of boiler feed water**

**Specifications of boiler feed water**

### 1.3.1 BOILER TROUBLES

**Scale & Sludge formation**

**Priming &Foaming**

**Caustic Embrittlement**

**Boiler Corrosion**

## 1.3 BOILER FEED WATER

- The water fed into the boiler for the production of steam is called boiler feed water.
- Boiler feed water should be free from dissolved salts, suspended impurities, silica, turbidity,oil, alkali and hardness producing substances.

### REQUIREMENTS OF BOILER FEED WATER

Any natural source of water does not supply a perfectly suitable boiler feed water. The boiler feed water must have the following requirements.

| TYPES | AMOUNT |
|---|---|
| Hardness | < 0.2 ppm. |
| Soda alkalinity | 0.15-1.0 ppm |
| Caustic alkalinity | 0.15-0.45 ppm |
| Excess soda ash | 0.3-0.55 ppm |
| Dissolved gases like oxygen, carbon dioxide | 0 ppm |

### Specifications of boiler feed water

| S. NO | SPECIFICATIONS | DISADVANTAGES |
|---|---|---|
| 1. | Boiler feed water should have zero hardness. | Scale and Sludge's will be produced, which prevents efficient heat transfer. |
| 2. | It must be free from dissolved gases like O2, CO2. | It leads to boiler corrosion. |
| 3. | It should be free from dissolved salts and alkalinity. | Produces caustic embrittlement, which causes brittlement of boiler parts. |
| 4. | It should be free f rom oil and turbidity. | Produces priming and foaming. |
| 5. | It should be free from suspended | Produces wet steam. |

| | | |
|---|---|---|
| | impurities. | |
| 6. | It should befree from total dissolved solids. | Produces priming, foaming and caustic embrittlement. |

## 1.3.1 BOILER TROUBLES (OR) DISADVANTAGES OFUSING HARD WATER IN BOILERS

Presence of impurities in boiler feed water may lead to the following problems:

- Sludge and scale formation
- Priming and foaming (carry over)
- Caustic embrittlement
- Boiler corrosion

### SLUDGE AND SCALE FORMATION IN BOILERS

- When water is evaporated in boilers to produce steam continuously, concentration of dissolved salts present in water increases progressively.
- When the concentration of the salts reaches their saturation point, they are thrown out ofwater in the form of precipitates on the inner walls of the boilers.
- The least soluble one gets precipitated first.

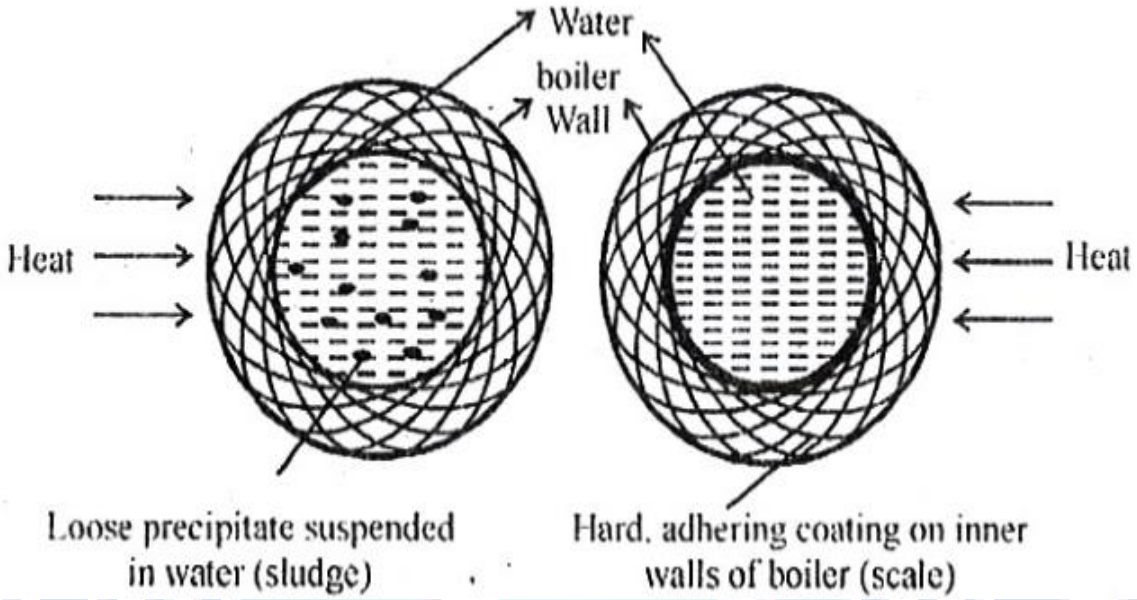


***Figure 1.3.1 Scale and Sludge in Boilers***

***[Source: https://www.rgpvonline.com/answer/chemistry/10.html]***

## SLUDGE FORMATION

- If the precipitate formed inside the boiler is soft, loose and slimy it is known as sludge.
- Sludge's are formed by substances like $MgCO_3$, $MgCl_2$, $MgSO_4$ and $CaCl_2$.
- They have greater solubility in hot water than cold water.

## DISADVANTAGES

- Sludge's are poor conductors of heat which results in wastage of fuel.
- Excess of sludge formation decreases the efficiency of boiler (i.e.) it disturbs thefunctioning of boiler.

## PREVENTION

- Sludge formation can be prevented by using softened water.
- It can be removed by "blow down operation". It is a process of removing a

portion of concentrated water frequently from the boiler during steam production.

**SCALE FORMATION**

- Scales are hard deposits formed by the evaporation of hard water in boilers.
- If the precipitate forms a hard and adherent coating on the inner walls of the boiler, it isknown as scale.
- Scales are formed by substances like $Ca(HCO_3)_2$, $CaSO_4$ and $Mg(OH)_2$.

**DISADVANTAGES**

- Scales decrease the efficiency of the boiler.
- Scales are poor conductor of heat. Therefore, it causes decrease in evaporative capacity of the boiler and increase in the fuel consumption.
- When the scale cracks, water suddenly comes in contact with the overhead boiler metal. This causes the formation of a large amount of steam suddenly. So, sudden high pressure is developed, which may even cause the explosion of the boiler. (any crack developed on the scale leads to explosion.)

**PREVENTION**

- Scale formation can be prevented by treating water in two ways:
  - External treatment
  - Internal treatment
- Scale formation can be prevented by dissolving it using acids like HCl and $H_2SO_4$.
- They can also be removed by applying thermal shocks, scrapers, wire brush, etc.

**REMOVAL OF SCALE FROM BOILERS**

1. At the initial stage, scales can be removed using scraper, wire brush etc.
2. If scales are brittle, they can be removed by thermal shocks.
3. By using suitable chemicals like dil. acids, EDTA with which form suitable complexes.
4. If the scales are loosely adhering, they can be removed by frequent blow down operation.

## DISADVANTAGES OF SCALE FORMATION

### 1. WASTEGE OF FUELS

Scale have low thermal conductivity, so the heat transfers from boiler to inside water is not efficient. In order to provide steady supply of heat to watt, overheating is done and this causes wastage fuel. The wastage of fuel depends on the thickness and nature of the scale, which is shown in the table.

| Thickness of scale(mm) | 0.325 | 0.625 | 1.25 | 2.5 | 12 |
|---|---|---|---|---|---|
| Wastage of fuel | 10% | 15% | 50% | 80% | 150% |

### 2. DECREASE IN EFFICIENCY

Scales sometimes deposit in the valves and condensers of the boiler and choke. This results in decrease efficiency of the boiler.

### 3. BOILER EXPLOSION

Sometimes due to overheating the thick scales may crack and causes sudden contact of high heated boiler material with water. This causes formation of a large amount of stem and high pressure is developed which may lead to explosion.

**Differences between Slugde and Scale**

| S.No. | Sludge | Scale |
|---|---|---|
| 1. | Sludge is a loose, slimy and non-adherent precipitate | Scale is a hard, adherent coating |
| 2. | The main sludge forming substances are $MgCO_3$, $MgCl_2$ , $MgSO_4$ and $CaCl_2$ etc | The main scale forming substances are $Ca(HCO_3)_2$,$CaSO_4$, $Mg(OH)_2$ |
| 3. | **Disadvantages:** Sludge's are poor conductors of heat. Excess of sludge formation decreases the efficiency of boiler. | **Disadvantages:** Scales act as thermal insulators. It decreases the efficiency of boiler. Any crack developed on the scale, leads to explosion. |
| 4. | **Prevention**<br>(i)Sludge formation can be prevented by using softened water.<br>(ii)Sludge's can also be removed by blow-down operation.<br>(iii) Blow-down operation is a process of removing a portion of concentrated water by fresh water frequently from the boiler during steam production. | **Prevention**<br>(i) Scale formation can be prevented by dissolving using acids like HCl, $H_2SO_4$<br>(ii) Scale formation can be removed by (a)External treatment. (b)Internal treatment.<br>(iii) They can also be removed by applying thermal shocks, scrapers, wire brush, etc. |

**Priming and Foaming:**

**Priming**

Due to rapid boiling, the steam may carry some water droplets along with it. This is called wet steam .The process of wet steam production is called Priming. It can reduce the heat of the steam and cause corrosion in the pipelines.

Priming is due to:

a) Improper design of boiler

b) High water level

c) High velocity of steam

d) Uneven boiling

Priming can be controlled by

i) Proper boiler design

ii) Maintaining proper water level

iii) Proper boiling

**Foaming**

If oil and grease are present, they produce stable bubbles on the water surface. This will increase the wet steam production. This is known as "Foaming".

Foaming is prevented by adding

i) Anti foaming agents (e.g.) synthetic polyamides, castor oil

ii) Coagulants (e.g.) Aluminium hydroxide

***Foaming and priming are collectively known as "Carry over".***

**Caustic Embrittlement: (Inter crystalline cracking of boiler metal)**

It is the inter- crystalline cracking of boiler due to the presence of $Na_2CO_3$. In high pressure, $Na_2CO_3$ undergoes hydrolysis to produce NaOH. This makes water caustic (alkaline). The NaOH content in water flows into the minute hair-cracks in the boiler.

$$Na_2CO_3 + H_2O \longrightarrow 2\ NaOH + CO_2 \uparrow$$

This NaOH occupies the hair line cracks of boiler metal and converts the insoluble Fe into soluble Sodium Ferroate. Thus it makes the cracks bigger in bents, joints and crevices.

$$\underset{\text{(Insoluble)}}{Fe} + 2\ NaOH \longrightarrow \underset{\text{(Soluble)}}{Na_2FeO_2} + H2 \uparrow$$

**Prevention of caustic embrittlement:**

1. As softening agent, we can use sodium phosphate instead of sodium carbonate.
2. The hair line cracks can be sealed by waxy materials like Tannin and Lignin.

**Boiler Corrosion**

It may be due to three major reasons:

i) Dissolved Oxygen

ii) Dissolved $CO_2$

iii) Dissolved salts like $MgCl_2$

**Corrosion Due to dissolved oxygen:**

Dissolved oxygen present in water, causes corrosion.

$$4Fe + 6H_2O + 3O_2 \longrightarrow 4Fe(OH)_3$$

(Rust)

**Prevention from oxygen:**

**a) Chemical method**

i) **Adding Sodium Sulphite:** $2\ Na_2SO_3 + O_2 \longrightarrow 2Na_2SO_4$

This method results in other precipitates which can have some side effects. So this method is less preferred.

ii) **Adding Hydrazine:** $N_2H_4 + O_2 \longrightarrow N_2 + 2H_2O$

This method results in inert gas and pure water, and has no side effects. So it is preferred.

**b) Mechanical deaeration method:**

1. This is based on the principle that at high temperature, low pressure and high exposed area, the solubility of gases in water is decreased. So, the gases can be expelled easily.
2. Here, the water is fed into the mechanical deaerator which is provided with vacuum pump, heaters and perforated plates.
3. The out coming water will be free from dissolved gases.

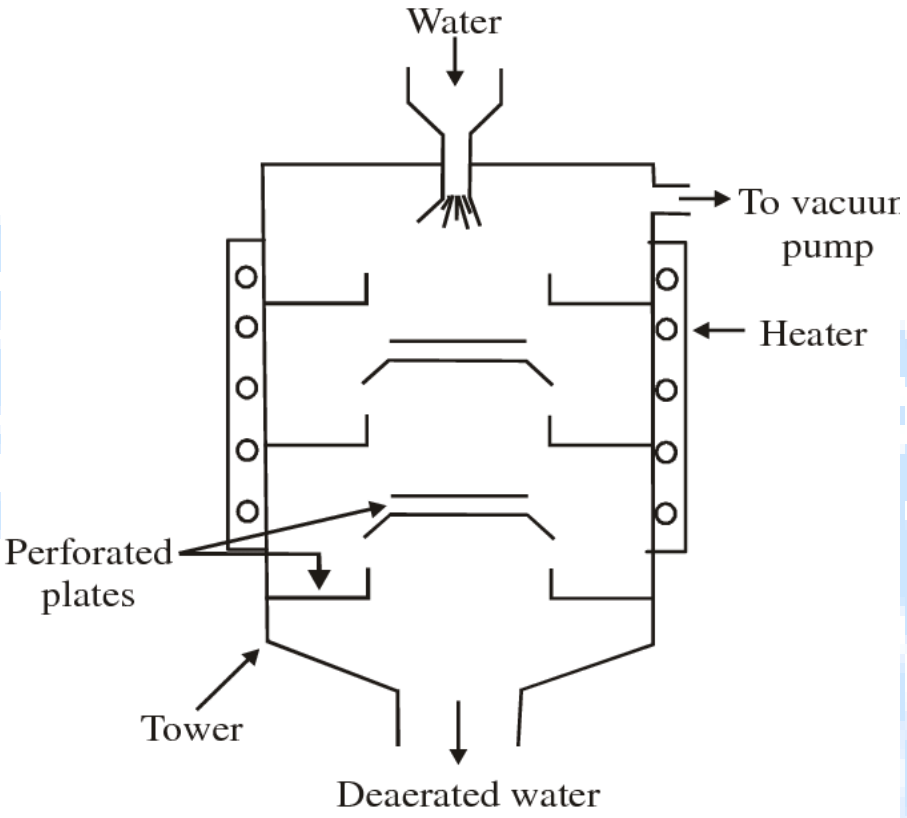


***Figure 1.3.2- Mechanical deaerator***

***[Source:Dr.RaviKrishnan,Sri Krishna publications]***

**Corrosion due to dissolved $CO_2$:**

Salts like Calcium bicarbonate on heating produces $CO_2$. $CO_2$ dissolves in water to form carbonic acid which corrodes the boiler metal.

$$Ca(HCO_3)_2 \xrightarrow{\Delta} CaCO_3 + H_2O + CO_2$$

$$H_2O + CO_2 \longrightarrow H_2CO_3 \text{ (carbonic acid)}$$

**Removal of dissolved $CO_2$**

1. **Chemical method:** By adding calculated amount of ammonium hydroxide

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

2. **Mechanical deaeration method** (similar to oxygen method)

**Corrosion due to Dissolved salts like $MgCl_2$:**

Dissolved salts like $MgCl_2$ results in acid formation. This will be prevented by alkali

neutralization.

$$MgCl_2 + 2\ H_2O \longrightarrow Mg(OH)_2 + 2\ HCl\ (\text{Corrosive acid})$$

**Neutralization:**

Excess acidic nature is neutralized by adding alkalis and vice versa.

$$HCl + NaOH \longrightarrow NaCl + H_2O.$$