Effect of Hard water on steam boilers

1. Sludge and Scale formation
2. Priming & Foaming
3. Caustic embrittlement
4. Boiler corrosion

2. Priming and Foaming:

a) Foaming:

- Foaming is the production of persistent foam or bubbles in boilers which do not break easily.
- This is because of presence of oils which reduce the surface tension of water.
- Can be avoided by removing oil from the boiler feed water by adding anti-foaming agents like sodium aluminate ($NaAlO_2$).

b) Priming:

- Along with steam, some particles of water are carried (**wet steam**) which is called priming.
- This is because of large amounts of dissolved salts, high steam velocities, sudden boiling, improper boiler design, sudden increase in steam production rate.
- **Priming can be avoided by**
  - **Efficient softening**
  - **Maintaining low water level in boilers**
  - **Avoiding rapid steam generation**
  - **Installing mechanical steam purifiers**

3. Caustic embrittlement:

- Caused by using highly alkaline water in boiler
- When water is softened by lime-soda process, free Na_2CO_3 is present in softened water.
- In high pressure boilers, this Na_2CO_3 decomposes to NaOH and CO_2

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

- This NaOH makes the water caustic.
- This NaOH flows through minute cracks present in the boiler by capillary action.
- As water is boiling it evaporates and the conc. of NaOH increases.
- This caustic soda attacks the boiler and forms sodium ferroate (Na_2FeO_2).
- This makes the boiler parts brittle (embrittlement).

Concentration cell representation of caustic embrittlement

Caustic attack on boiler parts can be represented as:

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Iron at rivets, bends, Joints etc.		Conc. NaOH soln.	‖	Dil. NaOH soln.		Iron at plane surfaces		

- The iron in contact with dil. NaOH becomes cathode and the iron in contact with conc. NaOH becomes anode.
- The anodic part slowly dissolves and corrodes.

Caustic embrittlement

- **Caustic embrittlement can be avoided:**
  - By using **sodium phosphate** as softening reagent instead of **sodium carbonate**
  - By adding tannin or lignin to boilers water, since it blocks the hair-cracks, thereby preventing infiltration of caustic soda
  - By adding sodium sulphate to boiler water – It also blocks the hairline-cracks and preventing infiltration of caustic soda.

4. Boiler corrosion:

- Decay of boiler material by chemical or electrochemical attack by surrounding environment.
- Reasons for boiler corrosion are:
  - a) Dissolved oxygen
  - b) Dissolved carbon dioxide
  - c) Acids from dissolved salts

a) Dissolved oxygen (DO):

$$2\,Fe + H_2O + O_2 \longrightarrow 2\,Fe(OH)_2$$

$$2\,Fe(OH)_2 + O_2 \longrightarrow 2\,Fe_2O_3.2H_2O\ (Rust)$$

- DO can be removed by adding calculated qty. of sodium sulphite or hydrazine or sodium sulphide:

$$2\,Na_2SO_3 + O_2 \longrightarrow 2\,Na_2SO_4$$

$$N_2H_4 + O_2 \longrightarrow N_2 + 2H_2O\ (best\ method)$$

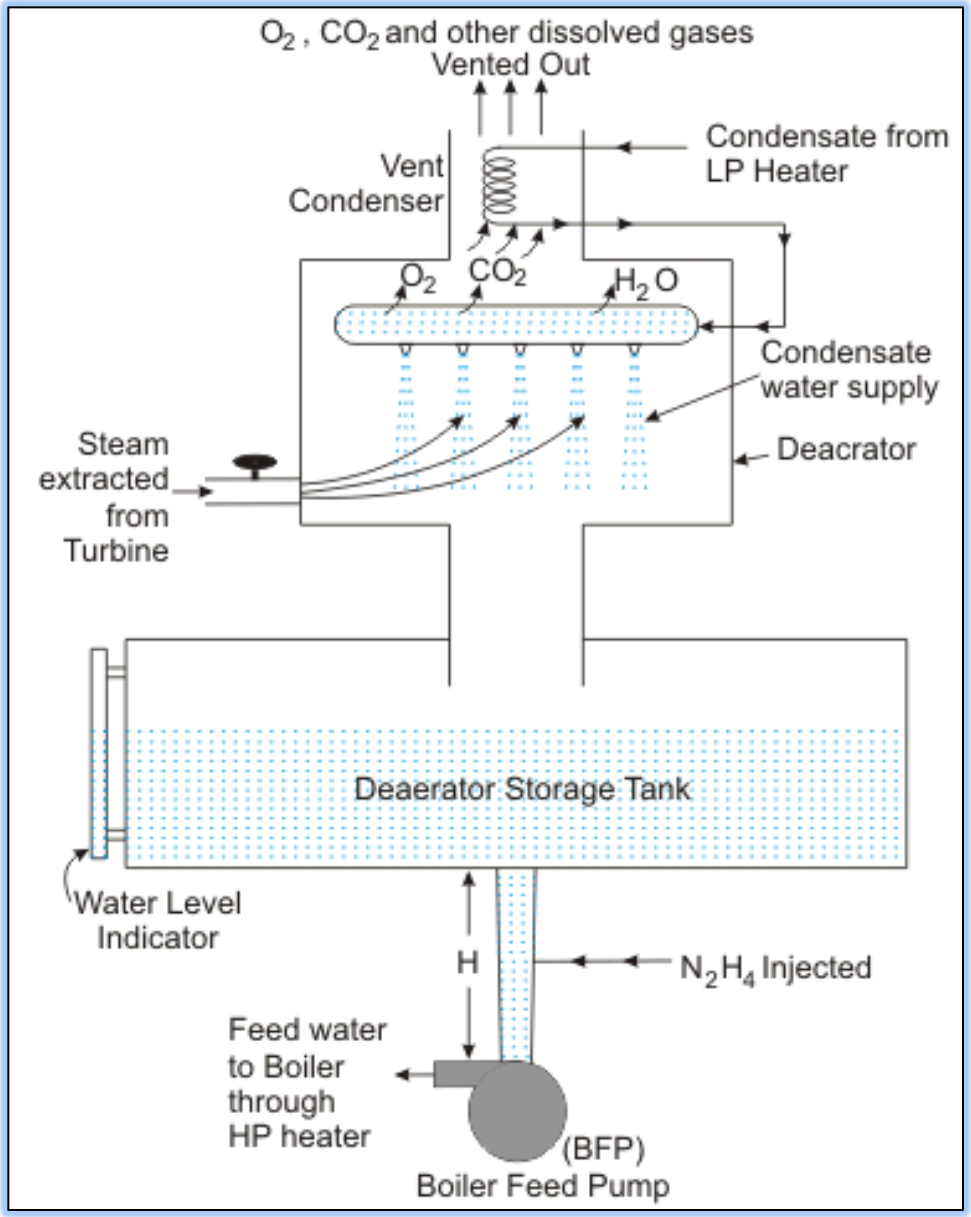
$$Na_2S + 2O_2 \longrightarrow Na_2SO_4$$

- DO can be removed by mechanical aeration also

Removal of dissolved oxygen by de-aeration

Water spraying in a perforated plate-fitted tower, heated from sides and connected to Vacuum pump. High temperature, low pressure and large exposed surface reduces dissolved oxygen in water

Most **Deaerators** are designed in such a way that dissolved oxygen content in Deaerator outlet must be within 5-10 ppb by wt%.



4. Boiler corrosion:

b) Dissolved CO_2:

- Dissolved CO_2 forms carbonic acid which corrodes the boiler slowly.

$$CO_2 + H_2O \longrightarrow H_2CO_3$$

- CO_2 is removed by adding calculated quantity of ammonia:

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

- It is also removed along with oxygen by mechanical aeration.

c) Acids from dissolved salts:

- Dissolved magnesium salts hydrolyze to form acids:

$$MgCl_2 + 2\,H_2O \longrightarrow Mg(OH)_2 + 2\,HCl$$

- This acid reacts with boiler and corrodes:

$$Fe + 2\,HCl \longrightarrow FeCl_2 + H_2$$

$$FeCl_2 + 2\,H_2O \longrightarrow Fe(OH)_2 + 2\,HCl$$

- The liberated acid reacts with iron of the boiler in chain-like reactions producing HCl again and again. As a result presence of even a small amount of $MgCl_2$ will cause corrosion of iron to a large extent.