Boiler Feed Water

- An important application of water is in steam production for electricity generation.
- For this water is fed to industrial boilers.
- Boiler is a heat exchanger which uses radiant heat and hot flue gases, liberated from burning fuel, to generate steam and hot water for heating and processing loads.

Boiler Feed Water

Boiler feed water should:

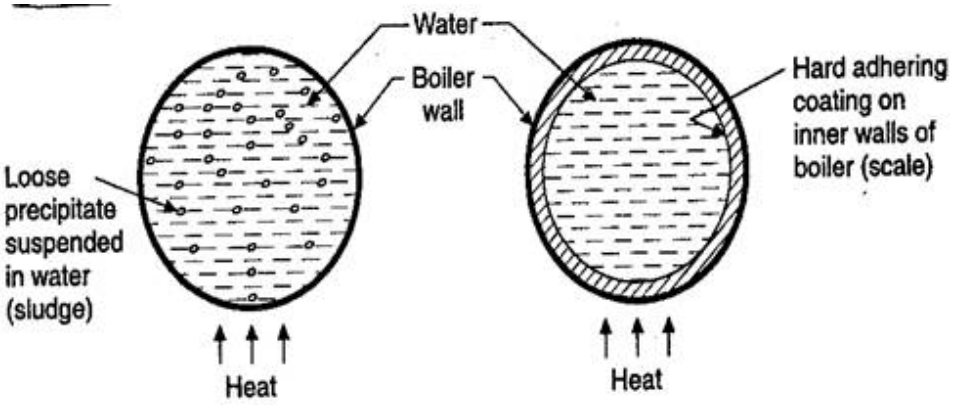
- hardness below 0.2 ppm
- OH^- alkalinity between 0.15 and 0.45 ppm
- Na_2CO_3 alkalinity between 0.45 and 1 ppm.

Excess of impurities may lead to the following problems:

- Scale and Sludge Formation.
- Priming and Foaming
- Boiler Corrosion
- Caustic Embrittlement

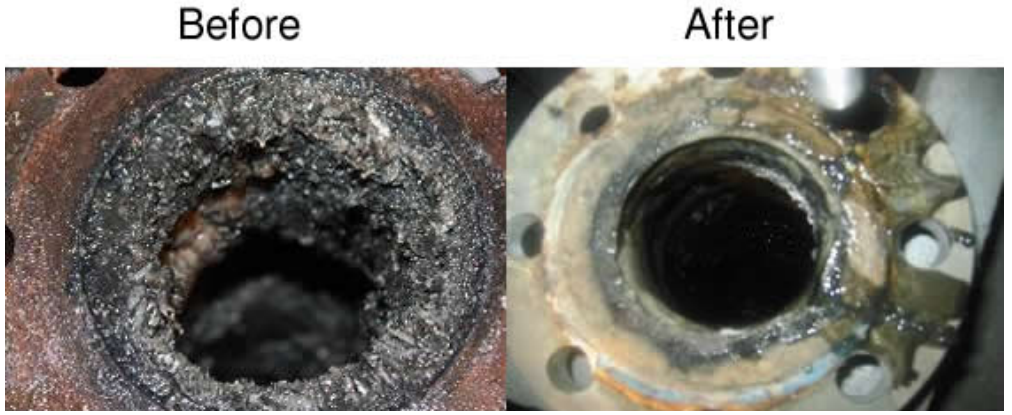
Scale And Sludge Formation

- When water containing impurities is used for generating steam, the concentration of the dissolved salts increases.



- If dissolved salts takes place in the form of loose, non adherent, slimy precipitates, it is called **sludge**.

- Sludge can be removed easily.



Sludge

Sludge are formed by the substances having greater solubilities in hot water than in the cold water e.g. $MgCO_3$, $MgCl_2$, $CaCl_2$, $MgSO_4$ etc.

Disadvantages of Sludge Formation

- Poor conductor of heat so it tends to waste lot of amount of heat, thus decreasing the efficiency of the boilers.
- Slows down the water circulation as it cause choking of pipes.

Prevention of Sludge Formation

- By using softened water.
- By frequently carrying out the cleaning operations *(blow-down)*: partial removal of concentrated water through a tap at the bottom of boiler.

Scale

If the precipitates form hard, adhering coating on the inner walls of the boilers, it is called *scale*.

Causes:

- *Decomposition of bicarbonates*: When water containing bicarbonates is heated in the boiler, the bicarbonates present are converted into insoluble $CaCO_3$.

$$Ca(HCO_3)_2 \rightarrow CaCO_3 + CO_2 + H_2O$$

- *Hydrolysis of Mg Salts*: Dissolved magnesium salts undergo hydrolysis forming precipitates of $Mg(OH)_2$.

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

- $CaSO_4$ is less soluble in hot water so it forms hard scale on the heated portions of the boiler. $CaSO_4$ is the main cause of scale formation in high pressure boilers.
- Silica Salts like calcium silicate, magnesium silicate are completely insoluble in hot water. So they form hard scale on inner boiler surface and are very difficult to remove.

Scale

Disadvantages:

- *Wastage of Fuel:* Because of low thermal conductivity of the scales, more heat is supplied to the boiler to maintain the supply of steam leading to wastage of fuels.
- *Bagging*: The distortion of boiler material is known as bagging. The superheating of the boiler leads to the distortion of the boiler material. Due to overheating, it causes thinning of the boiler material.
- *Danger of Explosion*: The uneven expansion of the scale may lead to the cracking of the scale.

Scale

Removal:

- Soft scales are removed with the help of scrapper or wire brush or by frequent blow-down operation.

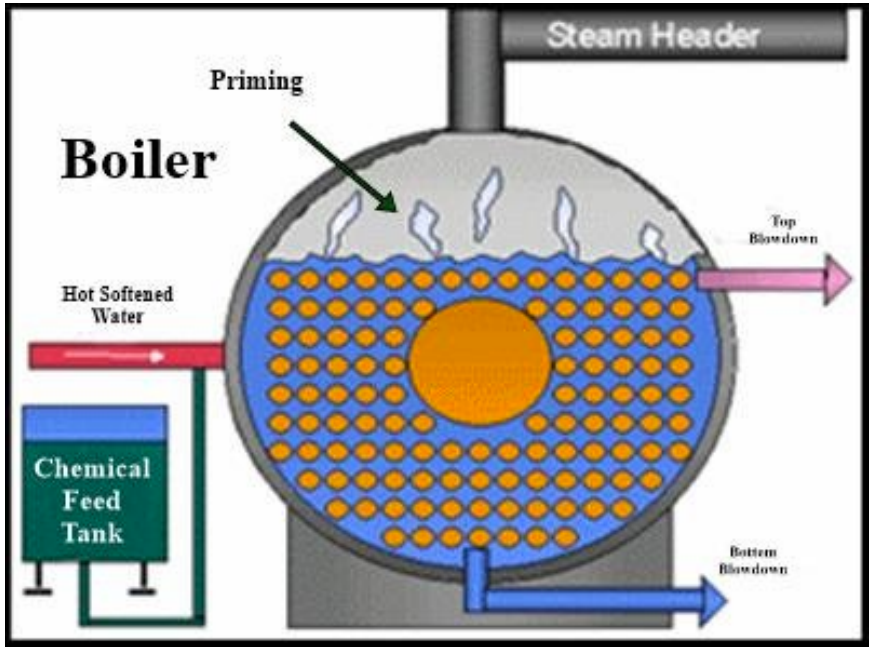
- Brittle or hard scales can be removed by giving thermal shocks i.e. heating the boiler and suddenly cooling with cold water.

- Scales can also be dissolved in certain chemicals and hence can be removed along with water.

For e.g. $CaCO_3$ scales can be dissolved by using 5-10% HCl. Similarly EDTA can also be used to dissolve $CaSO_4$, with which it forms soluble complexes.

Priming

- Steam formed due to the extremely rapid boiling of water in the boiler carries away some water droplets with it. Formation of this *wet steam* is called priming.
- Refers to the propulsion of water into the steam drum by extremely rapid boiling of water at the heating surfaces.
- If steam contains 0.5% moisture, its steam quality will be reported as 99.5% (percentage by weight of steam).



Priming

- Causes
  - The high steam velocities.
  - Very high water level in the boiler.
  - Faulty boiler design.
  - Presence of suspended and dissolved impurities in water.

- Prevention
  - Controlling rapid change in steaming velocities.
  - By blowing off sludge or scale regularly
  - Ensuring efficient softening.
  - Proper boiler design.
  - Filtration of the boiler-water carried over to the boiler.

Foaming

- Foaming is the formation of small persistent bubbles at the surface of water in the boiler.

- Any material, such as oil or alkalis, which lowers the surface tension of the water will collect at the interface and thus increase the foaming.

- The substances which increase the viscosity of the surface film also increase foam forming tendency.

Foaming

- Prevention

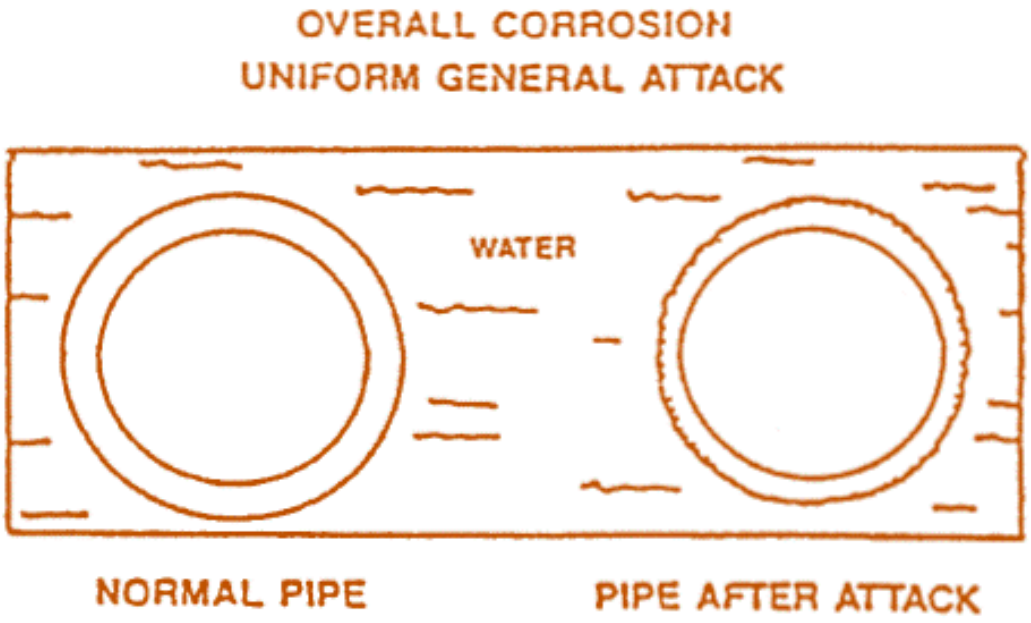
- *Adding anti-foaming chemicals*: Chemicals, such as polyamide antifoamers, counteract the reduction in surface tension, e.g. Castor oil spreads on the surface of water, neutralizes the surface tension reduction and prevents foaming.
- Removing oil from boiler water also prevents foaming.
- Oil and grease can be removed by addition of coagulants such as sodium aluminate, ferrous sulphate etc.

Disadvantages of Priming and Foaming

- Priming and foaming are often occur together.
- These are highly objectionable because impurities with the steam goes to super heaters or turbine blades, where they get deposited as the water evaporates.
- These deposits reduce their efficiency by hindering the flow of steam.
- Dried salts may be deposited on the engine valves decreasing their life.
- Water in the steam may lead to corrosion in the super heaters.
- Height of the water column cannot be judged properly due to foaming, thereby making the maintenance of the boiler pressure difficult.

Boiler Corrosion

- Decay of boiler material due to the attack of certain chemicals on its surface.
- The material of the boiler thus gets dissolved and rusted, thereby reducing the life of the boiler.



Boiler Corrosion

Disadvantages:

- Shortening of boiler life
- Leakages of the joints and rivets
- Increased cost of repairs and maintenance

Main reasons for boiler corrosions are:

- Presence of dissolved oxygen.
- Presence of dissolved carbon dioxide.
- Presence of Mineral Acids.

Dissolved Oxygen

- O_2 is introduced through the raw water supply.
- Water usually contains about 8 ppm of dissolved O_2 at RT.
- The solubility of oxygen in water is dependent on the temperature of the water – the solubility of gases in water decreases with increase in temperature.
- When water containing dissolved oxygen is heated in the boiler, evolved free gas with high temperature of boiler attacks the Fe of the boiler material.

$$4\,Fe + 2H_2O + 2O_2 \rightarrow 4Fe(OH)_2$$

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

RUST

Dissolved Oxygen

Removal of dissolved Oxygen:

Chemical Means: Oxygen can be removed by adding calculated amounts of certain chemicals such as Na_2SO_3, Na_2S and N_2H_4.

$$N_2H_4 + O_2 \rightarrow N_2 + 2\ H_2O$$

$$2Na_2SO_3 + O_2 \rightarrow 2Na_2SO_4$$

Mechanical Means: Mechanical deaeration involves, injecting hot feed-water, as a fine spray, into a vacuum chamber heated externally by steam. The chamber is fitted with perforated plates to provide large surface area. Large exposed surface, high temperature, and vacuum reduces the solubility of the gas, the water free of dissolved oxygen is collected at the bottom.

Dissolved CO_2

- CO_2, in addition to being present in raw water, is formed by the decomposition of dissolved bicarbonates at high temperature of boiler.

$$Mg(HCO_3)_2 \rightarrow MgCO_3 + CO_2 + H_2O.$$

- CO_2 forms carbonic acid in presence of water which has slow corrosive effect on boiler material.

$$CO_2 + H_2O \rightarrow H_2CO_3$$

Removal of dissolved CO_2:

Chemical means: By addition of calculated amount of NH_4OH.

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

Mechanical means: Similar process as discussed in removal of oxygen.

Presence of Acids

- Free mineral acids, present in boiler water, reacts with iron material in the following way:

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

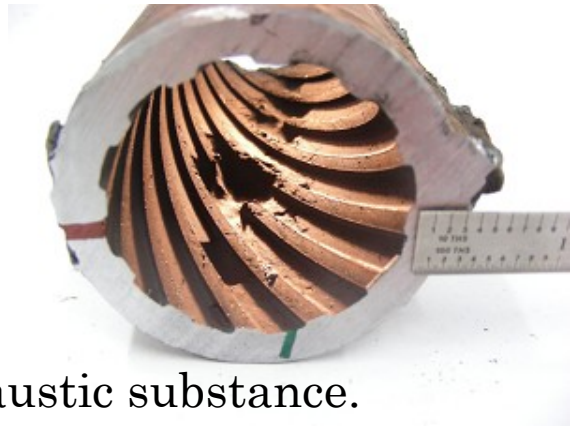
$$Fe + 2HCl \rightarrow FeCl_2 + H_2$$

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

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

- Thus a small amount of HCl may lead to corrosion to a great extent.
- If the water is acidic, calculated amount of alkali is added to neutralize it.

Caustic Embrittlement



- Boiler corrosion due to high alkaline water in the boiler.
- Boiler material becomes brittle due to accumulation of caustic substance.
- During the softening of water by lime-soda process a slight excess of Na_2CO_3 is used for the complete removal of calcium and magnesium salts.
- In low pressure boilers, treatment with Na_2CO_3 is quite satisfactory but in high pressure boilers the free Na_2CO_3 present forms NaOH as

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

- NaOH makes the boiler water *caustic* and attacks the minute hair cracks, riveted seams, bends and joints.
- Thereby corroding the boiler material or dissolving the iron of the boiler as Na_2FeO_2.

$$Na_2FeO_2 + 4H_2O \rightarrow 6NaOH + Fe_3O_4 + H_2$$

Caustic Embrittlement

Prevention of Caustic Embrittlement:

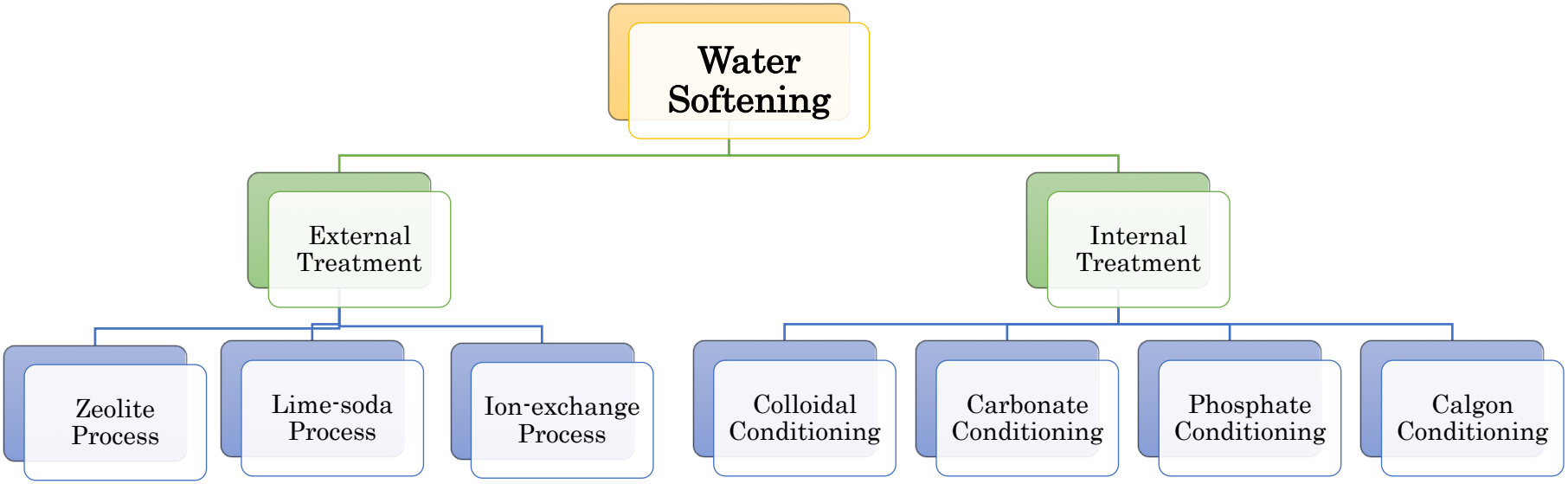
- Using sodium phosphate as softening reagent instead of sodium carbonate.
- By adding liquids or tannin to boiler water. These block up the hair cracks, thus preventing the infiltration of NaOH.
- Boiler waters containing Na_2SO4 or Na_3PO_4 block capillaries, thereby preventing the infiltration of caustic soda solution to these.
- The concentration of Na_2SO4:NaOH are maintained at 1:1, 2:1 or 3:1 for operating pressures of 10, 20 and > 20 atmospheres respectively to check the embrittlement.
- However, it is preferable to use Na_3PO_4 instead of Na_2SO_4. It is over 300 times as effective as Na_2SO_4 in suppressing embrittlement.

Water Softening

- Process to remove or reduce the hardness of water.
- Both temporary and permanent hardness.
- Essential for domestic and industrial uses.

Water Softening

- The scale formation can be minimized by subjecting the boiler feed water to certain treatments



- External treatment: treatment of water before its entry into the boiler.
- Internal Treatment: treatment of water in the boiler itself.