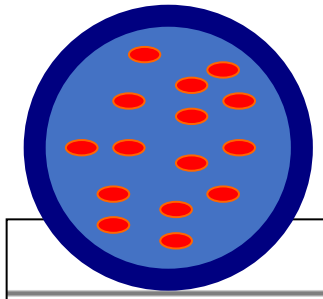
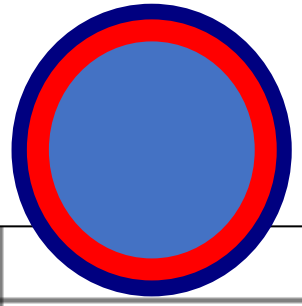
Sludge vs. Scale





Sludge	Scale
Loose, slimy , non-adherent precipitate	Hard, thick , strong adherent precipitate
Due to salts like $MgSO_4$, $MgCl_2$	Due to salts like $CaSO_4$, $Ca(HCO_3)_2$
Due to poor conductance, they decrease the boiler efficiency to lesser extent and causing chocking in the pipelines.	Due to poor conductance, they decrease the boiler efficiency to maximum extent, cause reduced fuel economy , improper boiling, boiler explosion etc.,
It can be prevented by periodical replacement of concentrated hard water by fresh water. This process is known as "blow down" method.	It can be prevented by special methods Like: i)external treatment of ion exchange , ii)Internal carbonate, phosphate, Calgon conditioning iii)Mechanical hard scrubbing methods.

✓ **Prevention of scales formation**

\# **External treatment:** Softening of water by Soda-lime process, Zeolite (permutit) process, Ion exchange process

\# **Internal treatment (also called sequestration):** Changing original character of the hardening chemicals via

Precipitation of the scale forming impurities/Converting them into water soluble compounds

- ❑ Colloidal conditioning
- ❑ Carbonate conditioning
- ❑ Phosphate conditioning
- ❑ Calgon conditioning
- ❑ $NaAlO_2$ treatment
- ❑ Electrical conditioning
- ❑ Radioactive conditioning
- ❑ Complex metric method

Prevention of Scale Formation

Colloidal conditioning

- Colloidal conditioning is a mixture in which one substance of microscopically dispersed insoluble particles is suspended throughout another substance
- In low-pressure boilers, scale formation can be avoided by adding organic substances like kerosene, tannin, agar-agar (a gel), etc. These get coated over the forming precipitates, thereby yielding non-sticky and loose deposits
- These lose deposits can easily be removed by pre-determined blow-down operations.

Carbonate conditioning

- Performed in low-pressure boilers. Scale-formation is avoided by adding sodium carbonate to boiler water
- $CaSO_4$ is converted into calcium carbonate

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

- Deposition of $CaSO_4$ as scale does not take place and calcium is precipitated as loose sludge of $CaCO_3$, which can be removed by blow-down operation
- Excessive Na_2CO_3 can result in caustic embrittlement

Phosphate conditioning

- Performed in high-pressure boilers
- Scale formation can be avoided by adding sodium phosphate
- Mg^{2+} and Ca^{2+} salts are converted to non-adherent and easily removable, soft sludge of calcium and magnesium phosphates. The sludge can be removed by blow - down operation

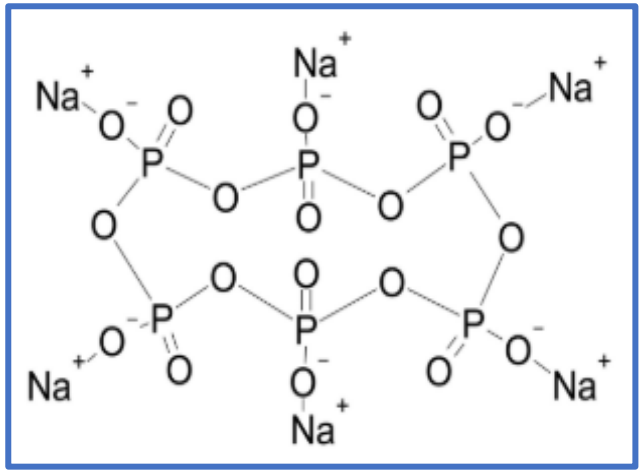
$$3\,CaCl_2 + 2\,Na_3PO_4 \rightarrow Ca_3(PO_4)_2 \downarrow + 6\,NaCl$$

- NaH_2PO_4 (acidic); Na_2HPO_4, (weakly alkaline); Na_3PO_4, (alkaline) are used for this purpose
- Choice of the phosphate depends of the alkalinity of the boiler feed water

Prevention of Scale Formation

Calgon conditioning

- Involves in adding calgon [sodium hexametaphosphate ($Na_6P_6O_{18}$) to boiler water.



- It prevents the scale and sludge formation by forming soluble complex compound with $CaSO_4$. Soluble complex $Na_2[Ca_2P_6O_{18}]$ can be easily removed

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

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

$NaAlO_2$ treatment

- Sodium aluminates gets hydrolyzed yielding NaOH and a gelatinous precipitate of aluminium hydroxide

$$NaAlO_2 + 2H_2O \rightarrow NaOH + Al(OH)_3$$

- The sodium hydroxide, so-formed, precipitates some of the magnesium as $Mg(OH)_2$

$$MgCl_2 + 2\ NaOH \rightarrow Mg(OH)_2 + 2\ NaCl$$

- The flocculent precipitate of $Mg(OH)_2$ plus $Al(OH)_3$, produced inside the boiler, entraps finely suspended and colloidal impurities, including oil drops and silica.
  - The loose precipitate can be removed by pre-determined blow-down operation

Electrical conditioning:

Sealed glass bulbs, containing mercury connected to a battery, are set rotating in the boiler. When water boils, mercury bulbs emit electrical discharges, which prevents scale forming particles to adhere /stick together to form scale

Radioactive conditioning:

Tablets containing radioactive salts are placed inside the boiler water at a few points. The energy radiations emitted by these salts prevent scale formation

Prevention of Scale Formation

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Complexometric method

- Involves addition of alkaline (pH = 8.5) solution of EDTA to feed-water. The EDTA binds to the scale-forming cations to form stable and soluble complex. As a result, the sludge and scale formation in boiler is prevented.
- Moreover, this treatment :

(1) prevents the deposition of iron oxides in the boiler,

(2) reduces the carryover of oxides with steam, and

(3) protects the boiler units from corrosion by wet steam

➢ Caustic Embrittlement

This type of boiler corrosion is caused by using highly alkaline water generated by lime-soda process – free Na_2CO_3 is usually present in small proportion in the softened water.

In high pressure boilers, Na_2CO_3 decomposes to NaOH and carbon dioxide and this makes the boiler water alkaline

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

The NaOH containing water flows into the minute hair-cracks present in the inner side of boiler and dissolving iron of boiler as sodium ferroate (Na_2FeO_2) this causes embrittlement of boiler parts, particularly stressed parts (like bends, joints, rivets, etc.)

$$Fe + NaOH \rightarrow 2\,Na_2FeO_2 + H_2$$

❑ Prevention of Caustic embrittlement

✓ by using sodium phosphate as softening agent, instead of sodium carbonate

✓ by adding tannin or lignin to boiler water, since these blocks the hair-cracks, thereby preventing infiltration of caustic soda solution in these

✓ by adding sodium sulphate to boiler water. Na_2SO_4 also blocks hair-cracks, thereby preventing infiltration of caustic soda solutions.

Boiler Troubles: Dissolved gas

- It's a decay of boiler material by chemical or electro-chemical attack by its environment
- Main reasons for boiler corrosion are: Dissolved oxygen
  - Water usually contains about 8 ppm of dissolved oxygen at room temperature.
  - Dissolved oxygen in water, in presence of prevailing high temperature, attacks boiler material:

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

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

✓ Removal of dissolved oxygen

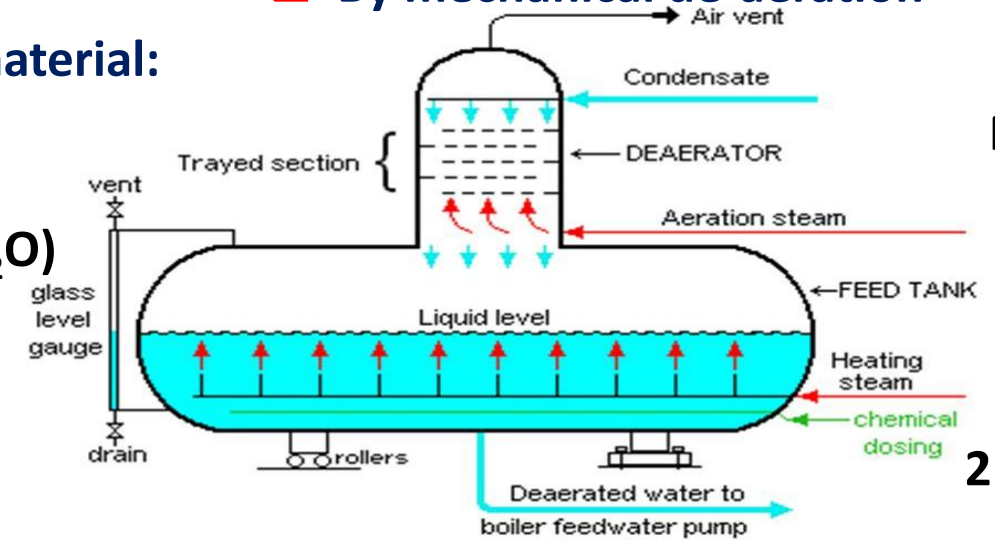
- By adding calculated quantity of Sodium sulphite or Hydrazine or Sodium sulphide

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

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

$$Na_2S + 2\,O_2 \rightarrow Na_2SO_4$$

- By mechanical de-aeration



Dissolved carbon dioxide

- CO_2 is reacts with water to form carbonic acid (H_2CO_3) which has a slow corrosive effect on the boiler material
- CO_2 is released inside the boiler, if water used for steam generation contains bicarbonate

$$CO_2 + H_2O \rightarrow H_2CO_3$$

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

✓ Removal of CO_2

- By adding calculated quantity of ammonia

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

- By mechanical-aeration process

Boiler Troubles

❑ Acids from dissolved salts

- Water containing dissolved magnesium salts liberate acids on hydrolysis

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

- The liberated acid reacts with iron of the boiler in chain-like reactions producing HCl.

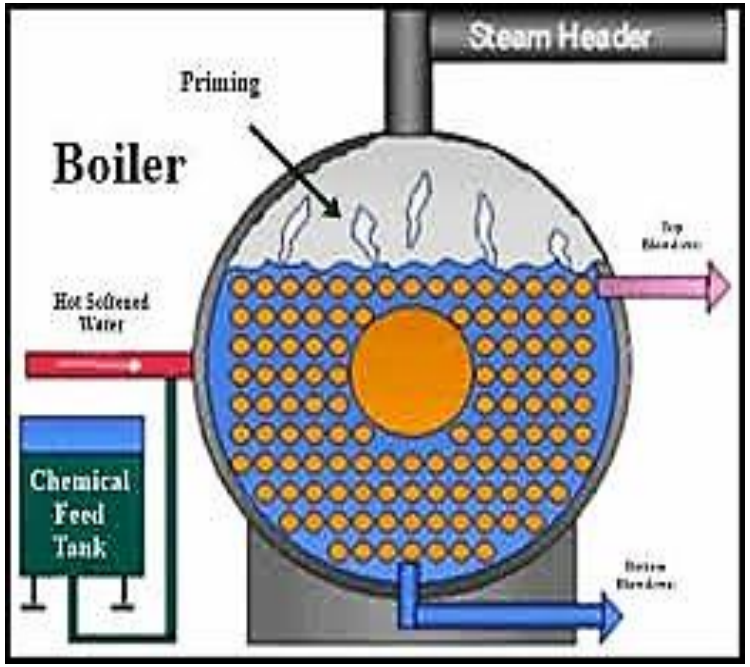
$$Fe + 2\,HCl \rightarrow FeCl_2 + H_2$$

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

- As a result presence of even a small amount of $MgCl_2$ will cause corrosion of iron to a large extent

❑ Priming

- When a boiler is producing steam rapidly, some particles of the liquid water are carried along-with the steam. This process of 'wet steam' formation is called priming.



- Priming is caused by:
  - Presence of a large amount of dissolved solids
  - high steam velocities
  - sudden boiling
  - improper boiler design
  - sudden increase in steam-production rate