BOILER TROUBLES

Scale And Sludge Formation In Boilers

In boilers, water evaporates continuously and the concentration of the dissolved salts increases progressively. When their concentrations reaches saturation point, they are thrown out of water in the form of precipitates which stick to the inner walls of the boiler. If the precipitation takes place in theform of loose or slimy precipitate it is called sludge. On the other hand, if the precipitated matter forms a hard adhering crust/ coating on the inner walls of the boiler, it is a scale. Sludge is a soft, loose and slimy precipitate formed within the boiler. Sludge can be easily scrapped off with a wire brush. It is formed at comparatively colder portions of the boiler and collects in areas of the system, where the flow rate is slow at bends. Sludges are formed by substances which have greater solubilities in hot water than in cold water. Examples are $MgCO_3$, $MgCl_2$, $CaCl_2$, $MgSO_4$ etc.

Differences between scale and Sludge.

S.No.	Scale	Sludge
1.	Scale is hard and adherent .	Sludge is loose , slimy and non –adherent.
2.	formed by the salts like Calcium bicarbonate , Calcium sulphate , etc.	formed by the salts like magnesium Sulphate magnesium carbonate , etc,
3.	Scale*formation can be prevented by* dissolving scale using dilute acids like HCl , H_2SO_4 .	*formation of sludge can be prevented by* i periodically removing the concentrated water by fresh water ii. taking soft water

Formation of scales may be due to

1. Decomposition of calcium bicarbonate

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

However, scale composed chiefly of calcium carbonate is soft and is the main cause of scale formation in low pressure boilers. But in high pressure boilers $CaCO_3$ is soluble.

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

2. Decomposition of calcium sulphate:

The solubility of calcium sulphate in water decreases with increase in temperature. Thus, solubility of calcium sulphate is 3,200 ppm at 15 oC and it reduces to 55 ppm at 230 oC and 27 ppm at 320 oC. In other words, calcium sulphate is soluble in cold water, but almost completely insoluble in superheated water. Consequently calcium sulphate gets precipitated as hard scale on the heated portions of the boiler. This is the main cause in the high pressure boilers.

3. Hydrolysis of magnesium salts:
Dissolved magnesium salts undergo hydrolysis at prevailing high temperatures in the boiler forming magnesium hydroxide precipitate, which forms a soft type of scale.
$MgCl_2 + 2H_2O \rightarrow Mg(OH)_2 + 2HCl$

4. Presence of silica: (SiO_2), even if present in small quantities, deposits as calcium silicate ($CaSiO_3$) and/ or magnesium silicate ($MgSiO_3$). These deposits stick very firmly to the inner walls of the boiler surface and are very difficult for removal. One important source of silica in water is the sand filter used.

Disadvantages of scale formation:
Sludge is poor conductors of heat, so they tend to waste a portion of heat used. If sludge is formed along with scales, the former get entrapped in the later and both get deposited as scales. Excessive sludge formation disturbs the working of the boiler. It settles in the regions of poor water circulation such as pipe connection, plug opening, gauge glass connection thereby causing even chocking of the pipes.

1. Wastage of fuels: Scales have a low thermal conductivity, so the rate of transfer of heat from boiler to inside water is largely decreased. In order to provide a steady supply of heat to water, excessive or over heating is done which causes unnecessary increase in fuel consumption. Thickness of the scale (mm) 0.325 0.625 1.25 2.5 12 Wastage of fuel 10% 15% 50% 80% 150%

2. Lowering of boiler safety:
Due to scale formation, over-heating of the boiler has to be done in order to maintain a constant supply of steam. The over-heating of the boiler tube makes the boiler material softer and weaker and this causes distortion of the boiler tube and makes the boiler tube unsafe to bear the pressure of the steam especially in high-pressure boilers.

3. Decrease in efficiency:
Scales may sometimes get deposited in the valves and condensers of the boiler and choke them partially or totally. This results in decrease the efficiency of the boiler.

4. Danger of explosion:
When thick scales crack due to uneven expansion, the water comes in contact with the overheated iron plates. This causes a release of a large amount of steam suddenly, developing a high pressure, which may cause explosion in the boiler.

Prevention of sludge formation:
1. By using well softened water.
2. By a frequent blow down operation, i.e., drawing off a portion of the concentrated water Scales are hard deposits, which stick very firmly to the inner surface of the boiler. Scales are very difficult to remove even with the help of hammer and chisel. Scales are the main source of boiler troubles.

Removal of scales:

1. With the help of scraper or piece of wood or wire brush, if they are loosely adhering.
2. By giving thermal shocks like heating the boiler and suddenly cooling it with cold water.
3. Dissolving scales by adding suitable chemicals, if they are adherent and hard. Thus calcium carbonate scales can be dissolved by the addition of 5% HCl. Calcium sulphate scales can be dissolved by the addition of EDTA (ethylene diamine tetra acetic acid), with which they form complexes.
4. By frequent blow down operation, if the scales are loosely adhering.

CAUSTIC EMBRITTELMENT

Caustic embrittlement is a type of boiler corrosion, caused by using highly alkaline water in the boiler. During softening process by lime- soda process, free sodium carbonate is usually present in small proportion in the softened water. In high pressure boilers, sodium carbonate decomposes to give sodium hydroxide and carbon dioxide, and their presence makes the boiler water caustic.

$Na_2CO_3 + H_2O \rightarrow NaOH + CO_2$

The water containing sodium hydroxide flows into the minute hair cracks always present, by capillary action in to the inner sides of the boiler. Here as water evaporates the dissolved caustic soda concentration increases progressively. This concentrated caustic soda attacks the surrounding area dissolving inner iron side of the boiler by forming sodium ferroate. This causes the embrittlement of the boiler parts, particularly stressed parts such as bends, joints, rivets etc., causing even failure of the boiler operations. Caustic cracking can be explained by the following concentration cell Iron at Bends, rivets and joints

The iron surrounded by the dilute NaOH becomes the cathodic surface and the iron present with the high concentration of NaOH becomes anodic which is consequently dissolved or corroded.

Caustic embrittlement can be avoided by

1. By using sodium phosphate as a softening agent instead of sodium carbonate.
2. By adding tannin or lignin to the boiler water, since these substances block the hair cracks, thereby preventing the infiltration of the caustic soda solution in to these.
3. By adding sodium sulphate to boiler water: Sodium sulphate blocks the hair cracks preventing the infiltration of caustic soda solution in to these. It has been observed that caustic cracking can be prevented, if sodium sulphate is added to the boiler in the ratio of Na2SO4 : NaOH as 1:1; 2:1; 3:1 in boilers working respectively at pressures up to 10, 20 and above 20 atmospheres.

BOILER CORROSION

Boiler corrosion is the decay of boiler material (iron) either by chemical or electro chemical attack of its environment.

Main reasons for the boiler corrosion are:

Dissolved oxygen:
Water usually contains 8 mg of dissolved oxygen per liter at room temperature. Dissolved oxygen in water in the presence of prevailing high temperature of the boiler, attacks the boiler material as

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

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

Removal of the dissolved oxygen:
a. By adding calculated amount of sodium sulphite or hydrazine or sodium sulphide.

$2Na_2SO_3 + O_2 \rightarrow 2\ Na_2SO_4$

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

$Na_2S + O_2 \rightarrow Na_2SO_4$

b. Mechanical de-aeration:
In this process water is sprayed in to a tower fitted with perforated plates (Fig), heated from sides and connected to vacuum pump. High temperature, low pressure and large exposed surface
area reduce the dissolved oxygen in water.

Dissolved carbon dioxide:
Carbon dioxide dissolved in water forming carbonic acid, has a slow corrosive effect on the boiler material. Carbon dioxide is also released inside the boiler, if water, containing bicarbonates is used for steam generation

$CO_2 + H_2O \rightarrow H_2CO_3$

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

Removal of dissolved carbon dioxide: a. By adding calculated amount of ammonia

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

b. By mechanical de-aeration process along with oxygen (described above)

Acids from dissolved salts:
Water containing dissolved salts of magnesium liberates acids on hydrolysis.

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

The liberated acid reacts with the iron material of the boiler in chain like processes, producing HCl again and again.

$Fe + 2HCl \rightarrow FeCl_2 + H_2$

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

Consequently, presence of even small amount of magnesium chloride will cause corrosion to a large extent and may cause damage to the boiler material. Removal of acids: a) Softening boiler water to remove magnesium chloride, if any. b) By frequent blow down operation of removal of concentrated water with fresh soft water. c) Addition of inhibitors as sodium silicate/sodium phosphate/sodium chromate, which protect the boiler material against acid attack.

PRIMING AND FOAMING
When a boiler is producing steam rapidly, some particles of the condensed liquid water are carried along with the steam. The process of wet steam formation is called priming. Priming is

causedby
1. The presence of large amounts of dissolved solids
2. High steam velocities
3. Sudden boiling
4. Improper boiler design
5. Sudden increase in the steam production rate.

Foaming is the production of persistent foam or bubbles in boilers, which do not break easily. Foaming is due to the presence of substances like oils in water, which reduce the surface tension
of water.Priming and foaming usually occur together. They have to be eliminated because

a. Dissolved salts in boiler water are carried by the wet steam to super heater and turbine blade,
where they get deposited as water evaporates. This deposit reduces the efficiency of the boiler.

b. Dissolved salts may enter the other parts of the machinery, where steam is being used, thereby
decreasing the life of the machinery

c. Actual height of the water column cannot be judged properly making the maintenance of the boiler pressure difficult.

Priming can be avoided by fitting mechanical steam purifiers, avoiding the rapid change in steaming rate, maintaining low water levels in boilers, efficient softening and filtration of the boiler feed water. Foaming can be avoided by adding anti foaming chemicals like castor oil, or removing oil from boiler water by adding compounds like sodium aluminate.