Scaling in boilers

Boiler scale is caused by impurities being precipitated out of the water directly on heat transfer surfaces or by suspended matter in water settling out on the metal and becoming hard and adherent. Evaporation in a boiler causes impurities to concentrate. This interferes with heat transfers and may cause hot spots. Leading to local overheating. Scaling mechanism is the exceeding of the solubility limits of mineral substances due to elevated temperature and solids concentration at the tube/water interface. The deposition of crystalline precipitates on the walls of the boiler interferes with heat transfer and may cause hot spots, leading to local overheating. The less heat they conduct, the more dangerous they are.

Common feed water contaminants that can form boiler deposits include calcium, magnesium, iron, aluminum, and silica. Scale is formed by salts that have limited solubility but are not totally insoluble in boiler water. These salts reach the deposit site in a soluble form and precipitate.
The values corresponding to their thermal conductivity are:

Steel 15 kcal/m^2.h per degree C
$CaSO_4$ 1-2 kcal/m^2.h per degree C
$CaCO_3$ 0.5-1 kcal/m^2.h per degree C
SiO_2 0.2-0.5 kcal/m^2.h per degree C

Scaling is mainly due to the presence of calcium and magnesium salts (carbonates or sulphates), which are less soluble hot than cold, or to the presence of too high concentration of silica in relation to the alkalinity of the water in the boiler.
A **carbonate deposit** is usually granular and sometimes of a very porous nature. The crystals of calcium carbonate are large but usually are matted together with finely divided particles of other materials so that the scale looks dense and uniform. Dropping it in a solution of acid can easily identify a carbonate deposit. Bubbles of carbon dioxide will effervesce from the scale.
A **sulphate deposit** is much harder and more dense than a carbonate deposit because the crystals are smaller and cement together tighter. A Sulphate deposit is brittle, does not pulverize easily, and does not effervesce when dropped into acid.
A **high silica deposit** is very hard, resembling porcelain. The crystal of silica are extremely small, forming a very dense and impervious scale. This scale is extremely brittle and very difficult to pulverize. It is not soluble in hydrochloric acid and is usually very light coloured.
Iron deposits, due either to corrosion or iron contamination in the water, are very dark coloured. Iron deposits in boilers are most often magnetic. They are soluble in hot acid giving a dark brown coloured solution.


Boiler scaling on boiler tubes in composite boiler

If unchecked, scaling causes progressive lowering of the boiler efficiency by heat retardation, acting as an insulator. Eventually, scale built-up will cause the tube to overheat and rupture.
Boiler deposits can also cause plugging or partial obstruction of corrosive attack underneath the deposits may occur. In general, boiler deposits can cut operating efficiency, produce boiler damage, cause unscheduled boiler outages, and increase cleaning expense.

The first anti-scaling preventative measure is to supply good quality demineralised water as make–up feed water. The purer the feed water is, the weaker the driving mechanism to form scale. Scale-forming minerals that do enter the boiler can be rendered harmless by internal chemical treatment. A long-established technique is to detach the hardness cations, magnesium and calcium, from the scale forming minerals and to replace them with sodium ions.

Boiler scale on water side

Images Source: http://www.aalborg-industries.com/ifs/files/AI/eng/Presentation/Website/Downloadablefiles/pdf/Aalborg_Solutions_download/aal_sol_6_mar04.pdf

Presence of Silica

Silica can vaporize into the steam at operating pressures as low as 28 bars. Its solubility in steam increases with increased temperature; therefore, silica becomes more soluble as steam is superheated. The conditions under which vaporous silica carryover occurs have been thoroughly investigated and documented. Researchers have found that for any given set of boiler conditions using demineralized or evaporated quality make-up water, silica is distribute between the boiler water and the steam in a definite ratio. This ratio depends on two factors: boiler pressure and boiler water pH. The value of the ratio increases almost logarithmically with increasing pressure and decreases with increasing pH.
If the silica enters the boiler water, the usual corrective action is to increase boiler blowdown, to decrease it to acceptable levels and then to correct the condition that caused the silica contamination.

For further information check our web page about silica scaling in boilers.

Find information about the other main problems occurring in boilers: foaming and priming, corrosion.
For a description of the characteristics of the perfect boiler water click here.
Check also our web page about boiler water treatment, in particular through deaeration (deaerating heaters or membrane contractors).

References

‘*Water treatment handbook’* Vol. 1-2, Degremont, 1991
‘Industrial water conditioning’, BeltsDearborn, 1991
http://www.thermidaire.on.ca/boiler-feed.html