Total Dissolved Solids (TDS)

VIT
Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

Total dissolved solids (TDS) is the amount of particles dissolved in water

- They come from a) **Organic sources** (leaves), b) **Silt**, c) **Industrial wastage and sewage** as well as runoff from urban sources, fertilizers and pesticides, d) **Inorganic materials**
- A constant level of minerals, eg. Phosphorous, nitrogen and sulphur, is necessary for aquatic life.
- Concentration of dissolved solids **should not be too high or too low** which can affect the growth and leads to death of many aquatic organisms.
- High concentration of dissolved solids reduces the clarity of water and can decrease the photosynthesis and raises the water temperature.
- It can be determined taking a known amount (say 100 mL) of water and by evaporating the contents carefully to dryness. The residue (W/g) left after evaporation of the filtered sample shows the total dissolved solids present in that articular water sample.

- Recommended TDS for drinking water is 25-250 mg/L
- At any cost drinking water TDS should not exceed 500 mg/L
- TDS for distilled water will be 0.5-1.5 mg/L
- TDS ranges from 100-20,000 mg/L in river water and will be generally higher in ground water
- Sea water will have 3500 mg/L of TDS
- Lakes and streams will have a TDS of 20-250 mg/L

Hard Water: Problems

➢ For Domestic Use

a) Washing:

- Hard water, when used for washing purposes, does not lather freely with soap.
- It produces sticky precipitates of calcium and magnesium soaps.
- Bathing – can cause skin problem

b) Cooking:

- Due to the presence of dissolved hardness producing salts the boiling point of water is elevated & more fuel is and time are required.

c) Drinking:

- Hard water causes bad effect on our digestive system.
- The possibility of forming calcium oxalate crystals in urinary tracks is increased (Kidney stones).

➢ For Industrial Use

- **Paper Industry:** Presence of Ca/Mg make impact on the properties and quality of paper and their products
- **Textile industry:** Hard water cause waste of soap. During dyeing process, Ca/Mg salts present in water make the quality of the shades very poor.
- **Sugar industry:** If nitrates, sulphates of Ca/Mg are present, they cause hindrance to crystallization of sugar
- **Concrete making:** Water containing chlorides and sulphates, if used for concrete making, affects the hydration of the cement and the final strength of the hardened concrete.
- **In steam generation in boilers:** If the hard water fed directly to the boilers - lead many problems such as formation of scales which corrodes the boiler, wastage of fuel etc.

Boiler Troubles: Sludge

- These deposits may consist of minerals, oils, and other matter. Sludge can stick to the boiler walls and continue to grow in size over time, causing clogs and other issues

- Sludge's are formed by substances which have greater solubility in hot water than in cold water, e.g., $MgCO_3$, $MgCl_2$, $CaCl_2$, $MgSO_4$, etc

✓ **Prevention of sludge formation**

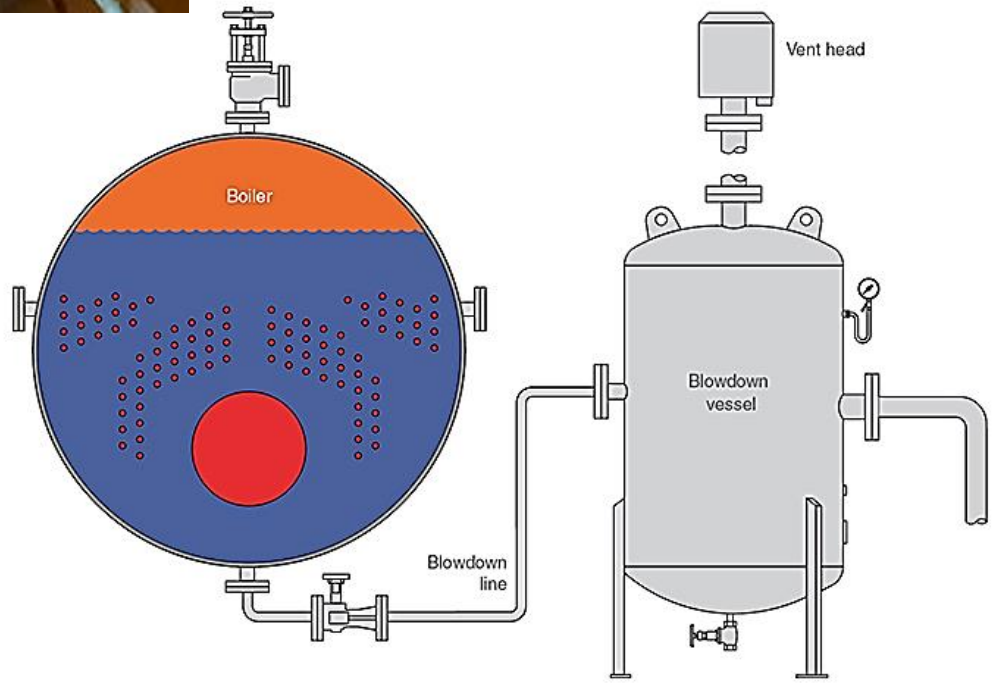
- By using well softened water
- Frequently 'blow-down operation', i.e., drawing off a portion of the concentrated water.

Disadvantages of sludge formation

⇒ Sludges are poor conductor of heat, so they tend to waste a portion of heat generated.

⇒ If sludges are formed along with scales, then former gets entrapped in the latter 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, they even choke the pipes.



Blow-down vessel installation

Boiler Troubles: Scale

- Scales are hard deposits, which stick very firmly to the inner surfaces of the boiler.
- Scales are difficult to remove, even with the help of hammer and chisel.
- These are the main source of troubles.
- Hard, adherent coating forms due to presence of salts like $Mg(HCO_3)_2$, $MgCl_2$, $Mg(OH)_2$, $Ca(HCO_3)_2$, Fe_2O_3, CuO, $CaSO_4$, Complex Silicates of Magnesium, Iron, Sodium, and Aluminium

⇒ **Decomposition of calcium bicarbonate**

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

- However, scale composed chiefly of calcium carbonate is soft and is the main cause of scale formation in low-pressure boilers.
- In high-pressure boilers, $CaCO_3$ becomes soluble due to the formation of $Ca(OH)_2$

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

⇒ Dissolved magnesium salts undergo hydrolysis (at prevailing high temperature inside the boilers) forming magnesium hydroxide precipitate, which forms a soft type of scale

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

⇒ Presence of silica in small quantities deposits as calcium silicate ($CaSiO_3$) or magnesium silicate ($MgSiO_3$). These deposits stick very firmly on the inner side of the boiler surface and are very difficult to remove.

Boiler Troubles: Scale

➢ Disadvantages of scale formation

Wastage of fuel:

Scales have a low thermal conductivity. So rate of heat transfer from boiler to inside water is greatly decreased. In order to provide a steady supply of heat to water, excessive or over heating is carried out and this causes increase in fuel consumption.

Lowering of boiler safety :

Due to scale formation, over-heating of boiler is 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. This causes distortion of boiler tube and makes the boiler unsafe to bear the pressure of the steam, especially in high-pressure boilers.

Decrease in efficiency:

Scales may sometimes deposit in the valves and condensers of the boiler and choke them partially. This results in decrease in efficiency of boiler.

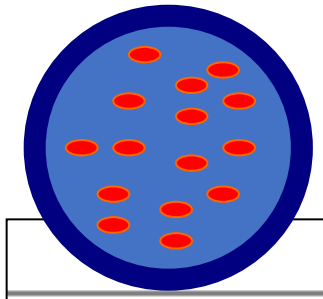
Danger of explosion:

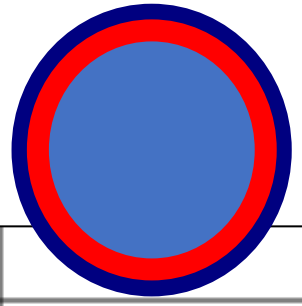
When thick scales crack, due to uneven expansion, the water comes suddenly in contact with over-heated iron plates. This may even cause explosion of the boiler.

✓ Removal of Scales

- With the help of scraper or piece of wood/wire brush, if they are loosely adhering.
- If they are brittle, by giving thermal shocks –heating the boiler and then suddenly cooling with cold water.
- By dissolving them by adding them chemicals, if they are adherent and hard. Thus, $CaCO_3$ scales can be dissolved by using 5-10% HCl. $CaSO_4$ scales can be dissolved by adding EDTA, with which they form soluble Ca-EDTA complexes.
- By frequent blow-down operation, if the scales are loosely adhering.

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