Chapter 16
Cooling Water and Boiler Water

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Topics

- How corrosion occurs with boiler feed water and cooling water
- Methods for removal of dissolved O_2
- Treatment of cooling water
- Methods for prevention of corrosion

Methods of removal of O_2

- Large amount of water is needed as boiler feed water and cooling water.
- Utmost care and steps are taken to reduce corrosion of pipes and equipment in the cooling water system.
- Similarly, constant attention is given to boiler feed water meet strict specifications to reduce corrosion in the boiler tubes, water and steam pipes and turbine blades.

Methods of removal of O_2 cont'd

Reduction of Dissolved O_2

Dissolved O_2 can be removed from water by:

1. Deactivation (chemically reacting the O_2)
2. Deaertion (distilling off in an appropriate equipment)

Deactivation

1. Deactivation (chemically reacting the O_2)

A) Sodium sulfite is employed to react with O2 in the weight ratio of 8:1

$$\mathbf{Na_2SO_3 + ½\ O_2 = Na_2SO_4}$$

- The reaction is slow at ordinary temperature, but can be made fast by adding catalysts such as Cu^{2+} or Co^{2+} (see Figure 1)
- Resulting Na_2SO_4 accumulates in the heated water and needs to be removed.

Deactivation cont'd

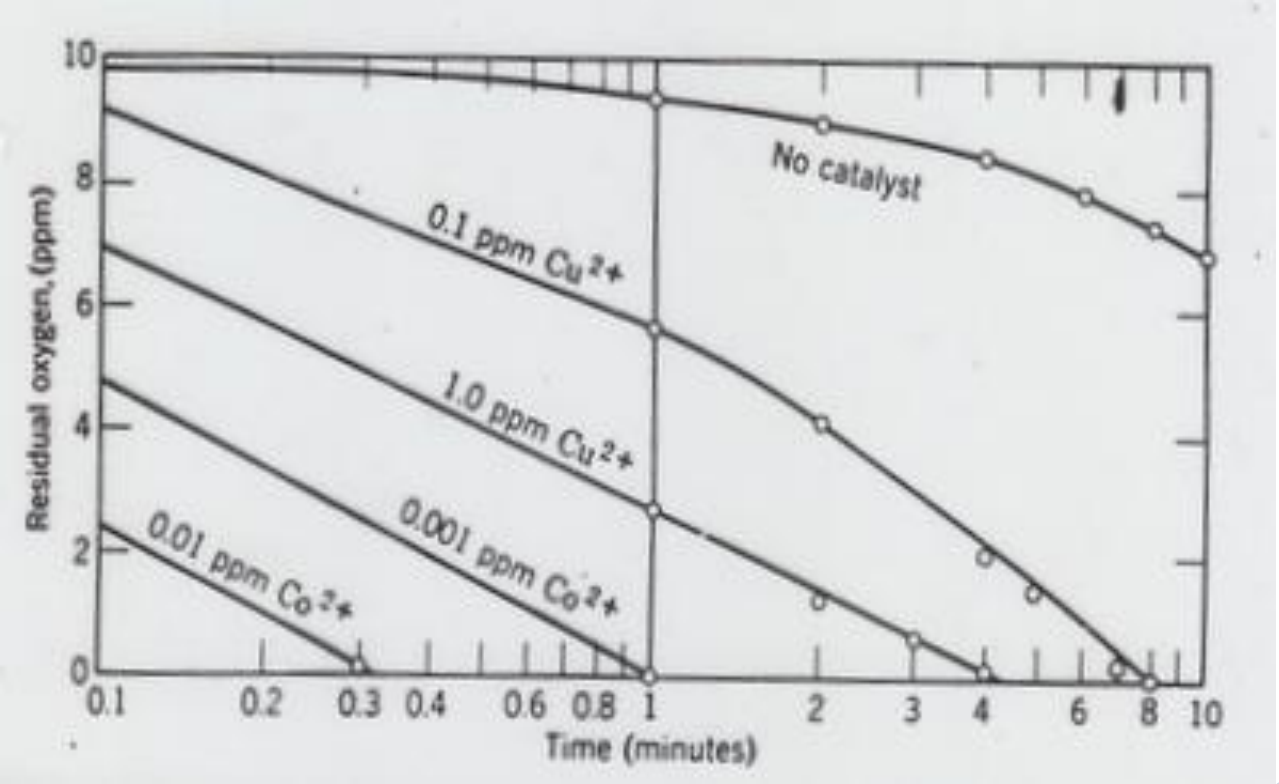

Figure 1: Effect of cobalt and copper salts on reaction rate of sodium sulfite with dissolved O_2

Deactivation cont'd

B) Hydrazine (N_2H_4) act as a conc. aq. solution reacts with dissolved O_2

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

- This reaction is also slow, but can be made faster by use of catalysts such as activated charcoal, metal oxides, etc. or by raising temperature.
- At 300° C another reaction sets in:

$$3N_2H_4 = N_2 + 4\ NH_3$$

- All the reaction products, N_2, H_2O and some NH_3 are volatile and salt accumulation is absent.

C) Appropriate Ion Exchange resins are also available for reducing dissolved O_2. The resins are generated by chemical treatment

Deaeration

2. Deaertion (distilling off in an appropriate equipment)

- As depicted in Figure 2, **Deaeration is achieved by spraying water over a large surface countercurrent to steam.**
- O_2 and some dissolved CO_2 distills off.
- Deaerated water gets heated in this process and is more suitable for boiler feed water.
- If cold deaerated water is needed, the dissolved gas can be distilled off by lowering the pressure(by steam ejector). This method is called **vacuum deaeration**.
- It is easy to remove the first 90-95% O_2 by distillation, but it is difficult to remove the remaining the O_2 specially at low temperature.

Deaeration cont'd

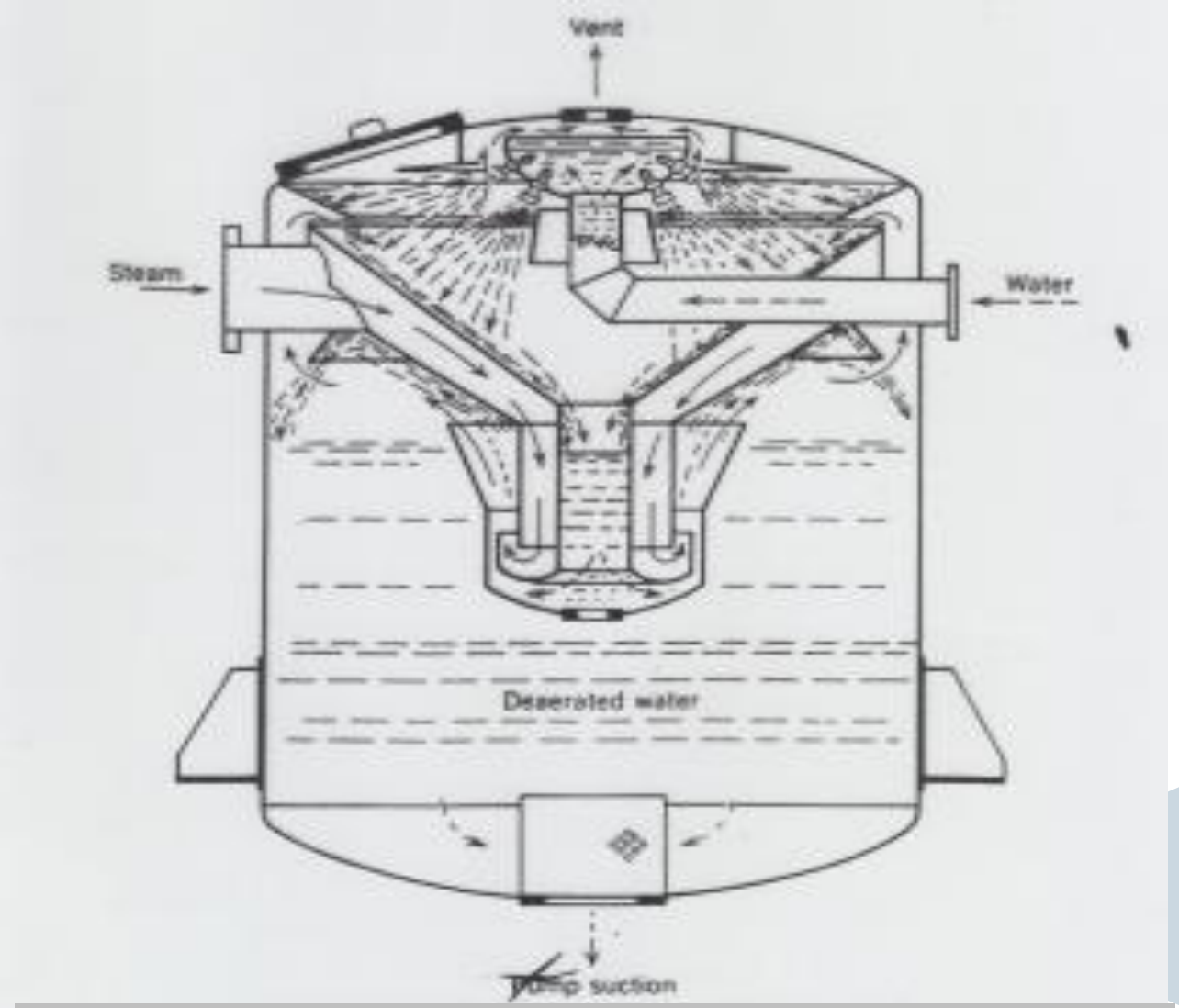

Figure 2: One type of steam Deaerator

Methods of removal of O_2 cont'd

1. Hot water Heating System
2. Municipal Water supplies(Potable water)
3. Cooling waters
4. Recirculating cooling waters
5. Boiler feed water/ Boiler water

Methods of removal of O_2 cont'd

1. Hot water Heating System

Because of the closed system of hot water heating system, corrosion cannot go on after all the dissolved O2 is used up.

Methods of removal of O_2 cont'd

2. **Municipal Water Supplies(Potable Water)**

- **Vacuum deaeration** would be ideal, but expensive and hence not taken.
- Potable water is **usually not treated chemically** for corrosion preventation for health reasons. But nontoxic chemicals like alkalies or lime may be added in small amounts.
- Corrosion is also reduced if the **water is moving** and the water is **aerated**.
- In stagnant zones there will be no effect of addition of polyphosphate(which otherwise reduces the red color from ferric salts or rust in water)
- Saturation Index may be increased to about 0.5 for soft water to reduce corrosion by addition of lime($Ca(OH)_2$) or soda ash(Na_2CO_3).
- 4-15 ppm SiO_2 reduces red water due to rust and eliminates blue staining of Cu/brass fitting.

Methods of removal of O_2 cont'd

3. Cooling waters

- Once through cooling waters are not usually treated with inhibitors for corrosion control because of **cost and pollution of water bodies**.
- Small amounts of sodium or Ca-polyphosphates are sometimes added to reduce corrosion of steel
- Disposal to water bodies may lead to eutrophication.
- **Eutrophication:** Excessive nutrients in a lake or other body of water, usually caused by runoff of nutrients (animal waste, fertilizers, sewage) from the land, which causes a dense growth of plant life; the decomposition of the plants depletes the supply of oxygen, leading to the death of animal life.
- Adjusting S.I is the better solution.

Methods of removal of O_2 cont'd

4. Recirculating cooling waters

- For industrial recirculatory cooling water, chromates were used widely.
- But because of pollution problem, alternates have been developed (e.g. organic phosphonic acids etc.)
- Sodium polyphosphates are also used. But they may cause scaling problem .
- Polyphosphates also favor algae growth.
- Polyphosphates in low concentration are not toxic.

Methods of removal of O_2 cont'd

5. Boiler feed water/Boiler water

- In modern boiler operation, dissolved O_2 is removed by **deaeration and deactivation**

Boiler Water Treatment

Purpose

1. Corrosion control

2. Prevention of scaling of boiler tubes due to inorganic deposits.

Steps for boiler water treatment

1. Removal of dissolved gases (O_2,CO_2)

2 .Alkali addition

3. Use of inhibitors

Boiler Water Treatment cont'd

1. **Removal of dissolved gases (O_2,CO_2)**

- O_2 removal is achieved by **steam deaeration** and then use of **O_2 scavenger** such as Na_2SO_3 or N_2H_4.
- O_2 conc. In feed water is lowered to about < 0.005 ppm O_2.CO_2 reduction also takes place.
- Sometimes feed water is acidified before deaeration to free carbonic acid from dissolved carbonates.

Boiler Water Treatment cont'd

1. Removal of dissolved gases (O_2,CO_2) cont'd

- At temperatures in the boiler following reaction also takes place:

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

- This causes **carbonic acid corrosion** of condenser and return lines.
- CO_2 accumulation is avoided by CO_2 release during boiler blowdown.

Boiler Water Treatment cont'd

2 .Alkali addition

- For most high pressure boilers, alkali addition is a standard practice,
- In high pressure boilers, sometimes NH_3 is added instead of NaOH for pH adjustment.
- NH3 is volatile , hence does not have the disadvantage of alkali concentration in the crevices.
- Addition of boiler water is based on the experiments of Berl & Taack (see Figure-3)

Boiler Water Treatment cont'd

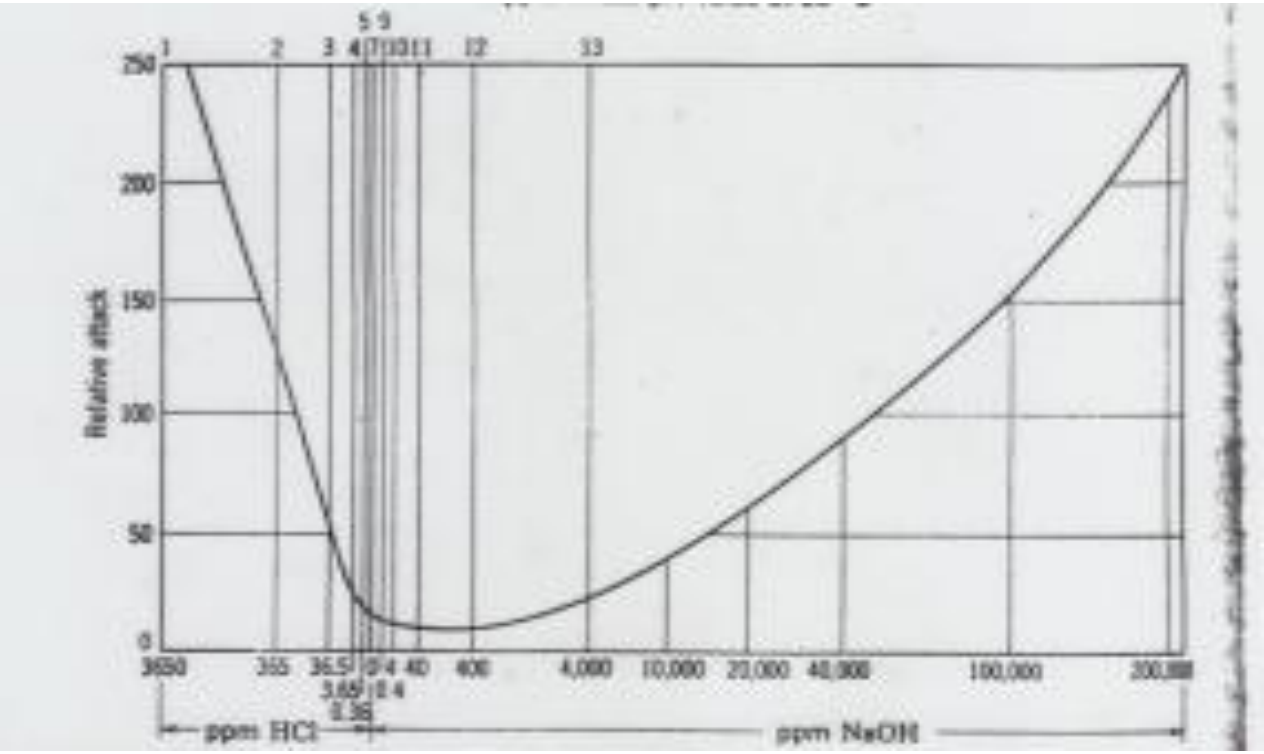

Figure 3: Corrosion of iron by water at 310 ° C

As evident from figure-3, pH value above 13 is also damaging. Hence buffer ion such as PO_4^{3-} in the form of Na_3PO_4 is also added which limits the pH of the boiler water.

Boiler Water Treatment cont'd

3 .Use of inhibitors

Inhibitors are added to boiler water to control

a. Stress corrosion cracking

b. Return-line corrosion

- **For SCC prevention:**

- Phosphate addition is done as discussed earlier
- Tannins from Quebracho extract(from extract of a South American tree) are also effective.
- Nitrates in the form of $NaNO_3$.

- Dissolved CO_2 in steam condensate is responsible for corrosion in the condensate return line. This is prevented by adding volatile amines.

End of Lecture