Engineering Chemistry – Unit 2 Premium Notes

Boiler Problems & Softening Methods

RGPV Engineering Chemistry Notes

Unit Overview

This unit is one of the most important units in Engineering Chemistry because questions related to:

- Boiler Troubles
- Water Softening Methods
- Numerical Problems

are frequently asked in RGPV examinations.

This chapter is very important for:

- Semester Exams
- Viva Questions
- Competitive Exams
- Industrial Knowledge

Introduction to Boilers

A boiler is a closed vessel in which water is heated to produce steam.

Steam produced in boilers is used in:

- Power Plants
- Industries
- Textile Industries
- Chemical Industries
- Steam Turbines
- Railway Engines

For proper functioning of boilers, water should be free from impurities.

Impure water causes many boiler problems.

Boiler Troubles

Boiler troubles are problems caused due to impurities present in water.

Main boiler troubles are:

1. Sludge and Scale Formation
2. Priming and Foaming
3. Boiler Corrosion
4. Caustic Embrittlement

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1. Sludge and Scale Formation

Definition

When hard water is heated inside a boiler, dissolved salts separate out and deposit on the inner walls of the boiler.

These deposits are called:

- Scale n- Sludge

Scale

Definition

Scale is a hard, sticky and insoluble deposit formed inside boilers.

Causes of Scale Formation

Scale is formed due to decomposition of salts like:

- Calcium bicarbonate
- Magnesium bicarbonate
- Calcium sulphate

Reactions

Formation from Calcium Bicarbonate

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

Formation from Magnesium Bicarbonate

$Mg(HCO_3)_2 \rightarrow Mg(OH)_2 + 2CO_2$

Disadvantages of Scale

1. Wastage of Fuel

Scale is a poor conductor of heat.

More fuel is required to heat water.

2. Decrease in Efficiency

Heat transfer decreases.

3. Boiler Explosion

Excessive heating may cause bursting of boiler.

4. Choking of Pipes

Steam flow becomes difficult.

Prevention of Scale Formation

- Use soft water
- Regular cleaning
- Blow-down operation
- Water softening before use

Sludge

Definition

Sludge is a soft, loose and slimy deposit formed in colder parts of boilers.

Causes

Formed due to salts like:

- Magnesium chloride
- Magnesium sulphate
- Calcium chloride

Differences Between Scale and Sludge

Scale	Sludge
Hard deposit	Soft deposit
Difficult to remove	Easy to remove
Forms in hot region	Forms in cold region
Reduces heat transfer	Chokes pipes

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2. Priming and Foaming

Priming

Definition

The process in which water droplets are carried along with steam is called priming.

Causes of Priming

- High steam velocity
- High water level
- Sudden boiling
- Presence of dissolved salts

Disadvantages of Priming

- Wet steam formation

- Damage to turbines
- Salt deposition in pipes

Prevention of Priming

- Maintain proper water level
- Use anti-priming devices
- Reduce steam velocity

Foaming

Definition

Formation of stable bubbles or foam on water surface is called foaming.

Causes

- Presence of oil
- Presence of grease
- Alkaline substances

Prevention of Foaming

- Remove oil from water
- Use anti-foaming chemicals
- Maintain proper alkalinity

Difference Between Priming and Foaming

Priming	Foaming
Carrying water with steam	Formation of bubbles
Caused by high velocity	Caused by oil and grease
Produces wet steam	Produces foam

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3. Boiler Corrosion

Definition

Destruction of boiler material due to chemical or electrochemical reactions is called boiler corrosion.

Causes of Boiler Corrosion

1. Dissolved Oxygen

Oxygen reacts with iron.

Reaction

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

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2. Carbon Dioxide

CO_2 forms carbonic acid.

$CO_2 + H_2O \rightarrow H_2CO_3$

This attacks boiler metal.

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3. Acidic Water

Acids corrode metal surfaces.

Prevention of Boiler Corrosion

- Remove dissolved oxygen
- Use corrosion inhibitors
- Maintain proper pH
- Use deaeration process

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4. Caustic Embrittlement

Definition

Cracking of boiler metal due to high concentration of sodium hydroxide is called caustic embrittlement.

Causes

Na_2CO_3 hydrolyses to form NaOH.

$Na_2CO_3 + H_2O \rightarrow 2NaOH + CO_2$

NaOH enters cracks and weakens metal.

Prevention of Caustic Embrittlement

- Use phosphate conditioning
- Avoid excess sodium carbonate
- Maintain proper alkalinity

Water Softening Methods

Hard water must be softened before using in boilers.

Main softening methods are:

1. Lime Soda Method
2. Zeolite Method
3. Ion Exchange Method

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1. Lime Soda Method

Principle

Hardness causing salts are removed by adding:

- Lime [$Ca(OH)_2$]

- Soda ash [Na_2CO_3]

Lime Removes

- Temporary hardness
- Magnesium salts

Soda Removes

- Permanent calcium hardness

Important Reactions

Temporary Hardness Removal

$Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3 + 2H_2O$

$Mg(HCO_3)_2 + 2Ca(OH)_2 \rightarrow Mg(OH)_2 + 2CaCO_3 + 2H_2O$

Permanent Hardness Removal

$CaSO_4 + Na_2CO_3 \rightarrow CaCO_3 + Na_2SO_4$

Advantages of Lime Soda Method

- Economical
- Removes temporary and permanent hardness
- Suitable for large industries

Disadvantages

- Large amount of sludge formed
- Requires skilled operation
- Time consuming

2. Zeolite Method

Principle

Hard water is passed through sodium zeolite.

Calcium and magnesium ions are replaced by sodium ions.

Reaction

$Na_2Z + Ca^{2+} \rightarrow CaZ + 2Na^+$

$Na_2Z + Mg^{2+} \rightarrow MgZ + 2Na^+$

Where:

Z = Zeolite

Regeneration of Zeolite

Used zeolite is regenerated using NaCl solution.

$CaZ + 2NaCl \rightarrow Na_2Z + CaCl_2$

Advantages

- Easy operation
- Efficient softening
- Compact plant

Disadvantages

- Not suitable for acidic water
- Water should be clear

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3. Ion Exchange Method

Principle

Uses ion exchange resins to remove ions from water.

There are two resins:

1. Cation Exchange Resin
2. Anion Exchange Resin

Cation Exchange Resin

Replaces positive ions with H^+ ions.

$2RH + Ca^{2+} \rightarrow R_2Ca + 2H^+$

Anion Exchange Resin

Replaces negative ions with OH^- ions.

$R'OH + Cl^- \rightarrow R'Cl + OH^-$

Formation of Pure Water

$H^+ + OH^- \rightarrow H_2O$

Advantages of Ion Exchange Method

- Produces completely demineralized water
- High efficiency
- Suitable for high pressure boilers

Disadvantages

- Expensive method
- Requires maintenance

Numerical Problems

Numerical 1 – Hardness Calculation

Question

50 mL hard water sample required 10 mL EDTA solution. Normality of EDTA = 0.01N. Find hardness.

Formula

Hardness = (V × N × 50,000) / Volume of sample

Solution

= (10 × 0.01 × 50,000) / 50

= 100 ppm

Final Answer

Hardness = 100 ppm

Numerical 2 – Lime Requirement

Question

Calculate lime required for temporary hardness.

Temporary hardness = 100 ppm.

Formula

Lime Required = Temporary Hardness × 74 / 100

Solution

= 100 × 74 / 100

= 74 ppm

Viva Questions

Q1. What is scale?

Hard insoluble deposit inside boiler.

Q2. What is sludge?

Soft loose deposit in boiler.

Q3. What is priming?

Carrying water droplets with steam.

Q4. Which method produces demineralized water?

Ion exchange method.

Q5. Which chemical regenerates zeolite?

NaCl solution.

Most Important Exam Questions

7 Marks Questions

1. Explain boiler troubles in detail.
2. Differentiate scale and sludge.
3. Explain priming and foaming.
4. Explain boiler corrosion and prevention.
5. Explain caustic embrittlement.
6. Explain lime soda method.
7. Explain zeolite process.
8. Explain ion exchange method.
9. Numerical problems on hardness.

Quick Revision Sheet

Boiler Troubles

- Scale
- Sludge
- Priming
- Foaming
- Corrosion
- Caustic Embrittlement

Water Softening Methods

- Lime Soda Method
- Zeolite Method
- Ion Exchange Method

Important Formula

Hardness = (V × N × 50,000) / Sample Volume
