Presentation Format

- Objectives Of Treatment Program
- Steam/Water Cycle: Basic Components
- Top Routine Chemistry Parameters
- Summary
Objectives Of Treatment Program

<table>
<thead>
<tr>
<th>Component</th>
<th>Deposit</th>
<th>Corrosion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condensate System</td>
<td>--</td>
<td>Minor</td>
</tr>
<tr>
<td>Feedwater System</td>
<td>--</td>
<td>Minor</td>
</tr>
<tr>
<td>Boiler</td>
<td>Minor</td>
<td>0 or Minor</td>
</tr>
<tr>
<td>Superheaters</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Turbines</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Boiler Deposit Example

- Thick Nose Tube Deposits of Copper and Copper Oxides Over Mixed Iron Oxide, Hardness Phosphate and Carbon
Boiler Blistering Example

Boiler Corrosion Example

- Deposits After Brushing
- Under-Deposit Corrosion
Turbine Deposits Example

Superheater Corrosion Example
Steam/Water Cycle Diagram

Questions
Specific Conductivity

- Total Conductive Solids (Salts, Acids, Alkalis)
- High Levels Can Cause Foaming and/or Corrosion
- Units: Usually $\mu$S/cm
- Micromho ($\mu$mho/cm) = Microsiemen ($\mu$S/cm)
- Millimho (mmho/cm) = Millisiemen (mS/cm)
- 1 mS/cm = 1000 $\mu$S/cm (Beware of auto-switching ranges on meter!)

Specific Conductivity

<table>
<thead>
<tr>
<th>Sample</th>
<th>Normal Values, $\mu$S/cm</th>
<th>Main Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demineralized Water</td>
<td>0.05 – 5.0</td>
<td>NaOH Leakage</td>
</tr>
<tr>
<td>Condensate &amp; Feedwater</td>
<td>2.0 – 6.0</td>
<td>Amine Feed</td>
</tr>
<tr>
<td>Boiler Water</td>
<td>20 – 150 (a)</td>
<td>3 to 5 $\times$ PO₄</td>
</tr>
</tbody>
</table>

(a) Much Higher For Low Pressure Boilers On Softened Makeup
Example of Amine Blend Effect on Conductivity

![Graph showing the effect of amine blend on conductivity.](image)

**Specific Conductivity, µS/cm**

- **Trial A - Change in SC**
  - (33.9 - 35.7°C)

- **Trial B - Change in SC**
  - (34.0 - 36.3°C)

**pH (Relative Acidity and Alkalinity)**

- **Acid Units**
- **Base Units**

- **pH Scale**
  - 0: Neutral
  - 4% Sulfuric Acid
  - Lemon Juice
  - Condensate/Feedwater
  - Boiler Water
  - Household Ammonia
  - 4% Caustic Soda
Example of Amine Blend Effect on pH

Effect of pH on Copper Transport
Dissolved Oxygen

- Oxygen as O₂ (from air) dissolved in water. Corrodes copper and steel (economizer shown).
- 1 ppm O₂ =
  - 1 mg/L =
  - 1000 ppb =
  - 1000 µg/L

Dissolved Oxygen Effect on Copper Corrosion

Temperature °F vs. Corrosion Rate, mpy

- 70Cu/30Ni (Alloy 715) 3 ppb O₂ 100-200 ppb H
- 70Cu/30Ni (Alloy 715) 200 ppb O₂ 25 ppb H
- 90Cu/10Ni (Alloy 706) 3 ppb O₂ 100-200 ppb H
- 90Cu/10Ni (Alloy 706) 200 ppb O₂ 25 ppb H
Dissolved Oxygen

- **Normal Values**
  - Mill Water or Demineralized Water
    - Saturated (8,000 - 14,000 ppb)
  - Condensate: 10 - 100 ppb O₂
  - Feedwater: <5 - 10 ppb O₂

- **Sources**
  - Air Leaks
    - Where Water Leaks Out, Air Leaks In
  - Mill Water In-leakage
    - 0.1% Raw Water = 8 - 14 ppb O₂

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Dissolved Oxygen Control: Deaerator

- Water Inlet
- Distributor Nozzles
- Trays
- Steam Inlet
- Vent
Deaerator Spray Nozzles And Trays

Oxygen Scavengers – Carbohydrazide Example

- Oxygen Scavenging (Reduces Oxygen)
  - Oxygen + Carbohydrazide $\rightarrow$ Inerts + Carbonic Acid

- Passivation
  - Red Rust + Scavenger $\rightarrow$ Black Rust + Carbonic Acid
Oxygen Scavenger Feed

- **Underfeed**
  - Copper Corrosion in Steam/Condensate System
  - Pitting of Economizer

- **Overfeed**
  - FAC: Flow Accelerated Corrosion and Rupture of Steel Pipe Lines (e.g., Feedwater Line)
  - Decomposition Products

Questions
Hardness In Generation Bank Tube

- Hardness Scale In Generation Bank Tube, Dispersant Treatment
- Without Dispersants, Gray Mayonnaise Deposits Are In Drums

Hardness – Definition

- Mainly the Calcium (Ca) and Magnesium (Mg)
- Precipitates and Forms Hardness Scale In Boiler
- Precipitation Can Result in Decreased Boiler pH

<table>
<thead>
<tr>
<th>Hardness</th>
<th>+</th>
<th>Phosphate</th>
<th>→</th>
<th>Sludge</th>
<th>+</th>
<th>Salt</th>
<th>+</th>
<th>Acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td></td>
<td>Sulfate</td>
<td>→</td>
<td>Calcium</td>
<td></td>
<td>Phosphate</td>
<td>+</td>
<td>Sodium</td>
</tr>
<tr>
<td>CaSO_4</td>
<td></td>
<td>2Na_2HPO_4</td>
<td>→</td>
<td>Ca_3(PO_4)_2</td>
<td></td>
<td>2Na_2SO_4</td>
<td>+</td>
<td>H_2SO_4</td>
</tr>
</tbody>
</table>

\[
3\text{CaSO}_4 + 2\text{Na}_2\text{HPO}_4 \rightarrow \text{Ca}_3(\text{PO}_4)_2 + 2\text{Na}_2\text{SO}_4 + \text{H}_2\text{SO}_4
\]
Hardness - Limits

- Expected Values (ppm CaCO₃)
  - Feedwater and Turbine Condensate: 0.0
  - Process Condensate 0.0 – Trace

- Sources
  - Mill Water In Condensate/Feedwater
  - Problem In Makeup Demineralization System

Control of Hardness: Prevent Intrusion

![Diagram of control system](image)
Phosphate (PO₄)

- Amount of Sodium Phosphate Dissolved in Boiler Water
- Units: ppm PO₄ = mg/L PO₄
- Purpose:
  - Stabilizes pH
  - Precipitates Hardness as Softer Deposits
  - Backup Indication of Hardness Contamination

Phosphate/pH Control Curves

![Phosphate/pH Control Curves](image-url)
Phosphate Effect on Boiler Water pH

<table>
<thead>
<tr>
<th>Sodium-To-Phosphate Molar Ratio</th>
<th>Blowdown</th>
<th>NaOH</th>
<th>TSP</th>
<th>DSP (MSP)</th>
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</thead>
<tbody>
<tr>
<td>2.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Summary: What Should You Know?

- Top Chemistry Parameters in Steam/Water Cycle
  - Conductivity $\mu$S/cm
  - pH
  - Dissolved Oxygen, ppb $O_2$ (and Oxygen Scavengers)
  - Hardness, ppm $CaCO_3$
  - Phosphate, ppm $PO_4$
- Steam/Water Cycle, Basic Components
- Other (See Appendices)
Appendices

- A: Makeup Water Treatment
- B: Condensate Collection and Treatment
- C: Feedwater Treatment System
- D: Boiler Water Treatment
- E: Steam Purity Considerations
- F: Additional Chemistry Testing
- G: Preventive Maintenance
- H: Personnel Training
- I: Chemical Cleaning

For More Information

- TAPPI Technical Information Papers
  - TIP 0416-03 – Water Quality and Monitoring Requirements for Paper Mill Boilers Operating on High Purity Water, 1999
  - TIP 0416-05 – Response to Contamination of High Purity Boiler Feedwater, 2000
  - TIP 0416-06 – Keys to Successful Chemical Cleaning of Boilers, 2000