II. BASIC BOILER WATER PROBLEMS, OXYGEN CONTROL EQUIPMENT and CHEMISTRIES
Industrial Boiler Water Treatment

BOILER WATER TREATMENT -

A SPECIALIZED STEAM SYSTEM MANAGEMENT SERVICE

1. Utilizes External Water Pretreatment Equipment and Internal Feedwater Management Chemicals.

2. Water Analyses, Problem Solving, and Technical Advice.

3. Serious Problems Occur in the Absence of Adequate Treatment and Control!
OBJECTIVES:

1. Keep All Boiler Steam and Waterside Surfaces Clean and Free of Foulants, Deposits, and Corrosion.


3. Limit Unnecessary Downtime and Maintenance.

4. Preserve and Extend Equipment Asset Life.
Observations

Boiler Plants Operate Most Effectively When the Feedwater and Boiler Water Chemistries are Constant and Predictable.

Pretreatment Equipment is Needed to Level Out Daily Variations in Feedwater Qualities.

A Water Softener is the Minimum Requirement.

In Most Plant Operations, More Extensive Pretreatment Equipment is Required, Especially at Higher Operating Pressures.

Mechanical Deaeration is Required in Virtually All Steam Plant Operations, Especially Those At Higher Pressures.
Observations, contd.

Higher Feedwater and Boiler Water Qualities can be Achieved by Improving Makeup Water Quality and Returning More Condensate.

BENEFITS INCLUDE –

• Less Blowdown Saving Heat and Treated Water
• Reduced Chemical Consumption
• Higher Quality Steam
• Reduced Risk of Corrosion and Deposition
• Higher Cycles of Concentration

Boiler Water Cycles are determined based on Operating Pressures, Silica, Alkalinity, and Total Dissolved Solids, and Steam Purity Demands.
Observations, contd.

- FEEDWATER QUALITY ... dictated by Boiler Pressure, Design, Application, and Heat Flux.

- HIGHER PRESSURE / HIGHER OUTPUT / SPECIAL USE BOILERS ... require Greater Feed Water Purities for More Efficient Steam/Water Separation without the Risk of Carryover!

- DEMINERALIZATION ... Required When a Lower Total Dissolved Solids, Silica or Sodium Feedwater is Needed.

- CONDENSATE POLISHING ... May be Required to Reduce a Feed water's Metal Content (Iron, Copper, Nickel, Chromium, etc.).
Boiler Operational Problems
Combustion / Gas Side Problems

- Tube Ties Broken
- Buckled Tubes
<table>
<thead>
<tr>
<th>Component</th>
<th>Damage Type</th>
<th>Failure Cause</th>
<th>Inspection/NDT Technique</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feedwater Piping</td>
<td>Wall thinning</td>
<td>Erosion-Corrosion, Oxygen pitting</td>
<td>UT thickness, Internal video</td>
<td>Monitoring, Feedwater control</td>
</tr>
<tr>
<td>Economizer Inlet Header</td>
<td>Ligament cracking, Tube stub thinning</td>
<td>Thermal/corrosion fatigue, Erosion-corrosion</td>
<td>Internal video, UT thickness</td>
<td>Monitoring, Eventual replacement</td>
</tr>
<tr>
<td>Economizer Outlet Piping</td>
<td>Internal cracking</td>
<td>Thermal (shock) fatigue</td>
<td>Internal video</td>
<td>Monitoring of components and temperatures</td>
</tr>
<tr>
<td>Downcomer piping</td>
<td>Damaged supports and attachments</td>
<td>Corrosion, Abnormal events, Thermal expansion</td>
<td>Visual inspection, Magnetic particle examination</td>
<td>Monitor, Repair</td>
</tr>
<tr>
<td>Lower Water Wall Headers</td>
<td>Tee cracking, Tube stub cracking</td>
<td>Thermal expansion fatigue, Thermal/corrosion fatigue</td>
<td>MT examination, Internal video</td>
<td>Repair, Replacement</td>
</tr>
<tr>
<td>Steam Drum Nozzles</td>
<td>Attachment weld cracking</td>
<td>Fabrication defect, Thermal expansion or erosion fatigue</td>
<td>MT examination, UT shear wave, Replication, Hardness testing</td>
<td>Repair</td>
</tr>
<tr>
<td>Attemporator Assemblies</td>
<td>Spray nozzle and liner assembly cracking</td>
<td>Thermal/erosion fatigue</td>
<td>Dye penetrant testing, Internal video</td>
<td>Replacement, Repair, Add dual spray</td>
</tr>
</tbody>
</table>
# Fire Side Temperatures and Problems

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>GAS TEMP</th>
<th>OUTER METAL TEMP</th>
<th>DEPOSIT TEMP</th>
<th>PROBLEMS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FLAME</strong></td>
<td>2500-3100</td>
<td></td>
<td></td>
<td>Combustion</td>
</tr>
<tr>
<td><strong>FURNACE</strong></td>
<td>2000-2800</td>
<td>800</td>
<td>2000-2500</td>
<td>High temp corrosion, slag, spalling</td>
</tr>
<tr>
<td><strong>SUPER HEATERS &amp; REHEATERS</strong></td>
<td>1200-2000</td>
<td>1000</td>
<td>1000-2000</td>
<td>High Temp corrosion, slag, fouling</td>
</tr>
<tr>
<td><strong>CONVECTION</strong></td>
<td>900-1200</td>
<td>500-900</td>
<td>1000</td>
<td>Fouling</td>
</tr>
<tr>
<td><strong>ECONOMIZER</strong></td>
<td>600-1200</td>
<td>200-600</td>
<td></td>
<td>Low Temp corrosion, fouling</td>
</tr>
<tr>
<td><strong>AIR HEATER</strong></td>
<td>300-600</td>
<td>200-500</td>
<td></td>
<td>Low Temp corrosion, fouling</td>
</tr>
</tbody>
</table>
Cavitation – Feed Water Explosion

Cavitation – the explosive conversion of Feedwater to Steam in the Feedwater Pump causing physical damage to the pump internals.

Feedwater Pumps are designed to pump liquids, not steam.
Oxygen - The Principle Cause of Corrosion

- In most cases the presence of Oxygen will initiate corrosion.
- Heat in a Feedwater system accelerates corrosion.
- Mechanical Deaeration removes most of the oxygen.
- The addition of a Chemical Oxygen Scavenger removes the remaining oxygen.
- When properly applied, Oxygen Scavengers will prevent oxygen corrosion and pitting.
Causes of Oxygen Pitting

• The ability for oxygen to attack a metal and form a pit increases by a factor of two for every $10^0 \text{C} (18^0 \text{F})$ temperature increase.

• Oxygen is 512 times more aggressive at $212^0 \text{F} (100^0 \text{ C})$ than at $50^0 \text{F}(10^0 \text{ C}).$

• Oxygen must be vented out of a system or removed with a Chemical Oxygen Scavenger.
Oxygen Pitting Corrosion
Boiler Water Treatment – Protection Against Corrosion and Scale
Calcium Carbonate Scales and Deposits

Once Scale has formed on a metal surface, the Deposit will attract other charged particles in the Boiler Water.
Tricalcium Phosphate Deposits

Tricalcium Phosphate is formed from inadequate control of Internal Phosphate Treatment Programs.
Iron Deposits – Denser Than Calcium Deposits and Harder to Remove

- Boiler Iron-Based Deposits are more insulating than Calcium Carbonate and more difficult to remove.
- Iron originates from Condensate or Feedwater System Corrosion.
- The corrosion must be stopped before the Iron Deposition can be controlled!
Boiler Tube deposits can result in ‘Thin-’ or ‘Thick-Lip’ Bursts. An over-heated tube results in bulging and eventual bursting.

A high temperature Stress Crack caused by over-heating led to the failure on the right.
Other Problems

• Flow Assisted Corrosion (FAC) – very prevalent in Combined-Cycle Heat Recovery Steam Generators (HRSGs). Controlled by materials selection, changes in Feedwater quality, approach temperature, flow rate, etc.

• Hydrogen Embrittlement, Caustic Gouging, Stress Corrosion Cracking, Short/Long Term Overheating.

• $\text{SO}_2$ Emissions - controlled by burner modifications, wet/dry scrubbing, atmospheric circulating fluidized bed (ACFB).

• $\text{NO}_x$ Emissions – controlled by coal gasification/ selective non-catalytic reduction (SNCR), fuel switching, etc.
Other Problems, contd.

Accelerated Corrosion Due to Water Leakage

Carbon in Gas Pipe
Steam / Waterside Problems

- Broken Chemical Feed Line in Steam Drum
- Oxygen Corrosion in Steam Drum
Internal Chemical Treatment is Needed to Clean Up a Boiler!
Cycles of Concentration and Blowdown Calculations
Cycles of Concentration - COC


- As water is evaporated, all dissolved solids originally present stay in the Boiler Water. These minerals become more concentrated.

- COC must be balanced versus high alkalinities and the risk of carryover!
Calculations and Notes

\[ \text{CYCLES}_{\text{Feedwater}} = \frac{\text{Cl}_{\text{Boilerwater}}}{\text{Cl}_{\text{Feedwater}}} \]

\[ \% \text{ CONDENSATE RETURN} = 100 - \% \text{ MAKE-UP} \]

\[ \text{FEEDWATER (ppd)} = \text{STEAM (ppd)} + \text{BLOWDOWN (ppd)} \]

\[ \text{STEAM RATE} = \text{BHP} \times \% \text{ LOAD} \times 34.5 \text{ pph/BHP} \]

\[ \text{BLOWDOWN} = \frac{\text{STEAM RATE}}{\text{COC} - 1} \]

\[ \text{BLOWDOWN} = \frac{\text{TDS}_{\text{Feedwater}} \times 100}{\text{TDS}_{\text{Boiler Water}} - \text{TDS}_{\text{Feedwater}}} \]
Blowdown Calculation Examples

Where: TDS is expressed in ppm or mg/l.

\[ E = 10,000 \text{ pph.} \]

\[ \text{TDS}_{FW} = 200 \text{ ppm; } \text{TDS}_{BW} = 3,000 \text{ ppm.} \]

COC = Boiler Water Cycles of Concentration.

\[ \text{COC} = 3,000 \div 200 = 15.0. \]

\[
\text{Blowdown} = \frac{\text{TDS}_{FW} \times 100}{\text{TDS}_{BW} - \text{TDS}_{FW}} \\
= \frac{200 \times 100}{2,800} = 7.14\% \\
\]

\[
\text{Feedwater} = \frac{\text{TDS}_{FW} \times 100}{\text{TDS}_{BW}} \\
= \frac{200 \times 100}{3,000} = 6.67\% \\
\]

\[
\text{Blowdown} = \frac{E}{\text{COC} - 1} \\
= \frac{10,000}{15 - 1} = 714 \text{ pph} \\
\]
Feedwater and Boiler Water Control
# ASME Boiler and Feed Water Requirements

<table>
<thead>
<tr>
<th>Drum Operating Pressure</th>
<th>psig (MPa)</th>
<th>0 – 300 (0 – 2.07)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Feedwater</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DO ppm (mg/l) O₂ before oxygen scavenger</td>
<td>&lt;0.007</td>
<td></td>
</tr>
<tr>
<td>Total iron ppm (mg/l) Fe</td>
<td>&lt;0.1</td>
<td></td>
</tr>
<tr>
<td>Total copper ppm (mg/l) Cu</td>
<td>&lt;0.05</td>
<td></td>
</tr>
<tr>
<td>Total hardness ppm as CaCO₃</td>
<td>&lt;1.0</td>
<td></td>
</tr>
<tr>
<td>pH @ 25°C</td>
<td>8.3 to 10.5</td>
<td></td>
</tr>
<tr>
<td>Non-volatile TOC ppm (mg/l) C</td>
<td>&lt;10</td>
<td></td>
</tr>
<tr>
<td>Oily matter ppm (mg/l)</td>
<td>&lt;0.1</td>
<td></td>
</tr>
<tr>
<td><strong>Boiler Water</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silica ppm (mg/l) SiO₂</td>
<td>&lt;150</td>
<td></td>
</tr>
<tr>
<td>Total alkalinity ppm as CaCO₃</td>
<td>&lt;700</td>
<td></td>
</tr>
<tr>
<td>Free OH alkalinity ppm as CaCO₃</td>
<td>not specified</td>
<td></td>
</tr>
<tr>
<td>Conductance S/cm) @ 25°C</td>
<td>&lt;7000</td>
<td></td>
</tr>
</tbody>
</table>
# British Standard 2486: Recommended Water Characteristics for Shell Boilers (<25 Bar)

<table>
<thead>
<tr>
<th></th>
<th>Feed water</th>
<th>Boiler water</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total hardness in feed water, mg/l CaCO(_3) max.</strong></td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td><strong>Feed water</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH value</td>
<td>7.5 to 9.5</td>
<td>7.5 to 9.5</td>
</tr>
<tr>
<td></td>
<td>7.5 to 9.5</td>
<td>7.5 to 9.5</td>
</tr>
<tr>
<td>Oxygen</td>
<td>†</td>
<td>†</td>
</tr>
<tr>
<td>Total solids, alkalinity, silica</td>
<td>†</td>
<td>†</td>
</tr>
<tr>
<td>Organic matter</td>
<td>†</td>
<td>†</td>
</tr>
<tr>
<td><strong>Boiler water</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total hardness, mg/l in terms of CaCO(_3) max.</td>
<td>ND‡</td>
<td>ND</td>
</tr>
<tr>
<td>Sodium phosphate, mg/l as Na(_3)PO(_4) §</td>
<td>50 to 100</td>
<td>50 to 100</td>
</tr>
<tr>
<td>Caustic alkalinity, mg/l in terms of CaCO(_3) min.</td>
<td>350</td>
<td>300</td>
</tr>
<tr>
<td>Total alkalinity, mg/l in terms of CaCO(_3) max.</td>
<td>1200</td>
<td>700</td>
</tr>
<tr>
<td>Silica, mg/l as SiO(_2) max.</td>
<td>Less than 0.4 of the caustic alkalinity</td>
<td></td>
</tr>
<tr>
<td>Sodium sulfite, mg/l as Na(_2)SO(_3)</td>
<td>30 to 70</td>
<td>30 to 70</td>
</tr>
<tr>
<td><em>Or</em> Hydrazine, mg/l as N(_2)H(_2)</td>
<td>0.1 to 1.0</td>
<td>0.1 to 1.0</td>
</tr>
<tr>
<td>Suspended solids, mg/l max.</td>
<td>50</td>
<td>200</td>
</tr>
<tr>
<td>Dissolved solids, mg/l max.</td>
<td>3500</td>
<td>3000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2000</td>
</tr>
</tbody>
</table>
Feed Water pH

- Feed Water pH should be above 8.5 to prevent corrosion of iron within the system.

- Feed Water pH should be below 9.2 to prevent copper loss within the system.

- Optimum Feed Water pH should be 8.5-9.2.
Boiler Water Treatment Areas Requiring Control

- OXYGEN SCAVENGING
- pH and ALKALINITY
- HARDNESS and SCALE DEPOSITION
- SUPERSATURATION of DISSOLVED SOLIDS
- SLUDGE and FOULANT
- PASSIVATION and CORROSION
- STEAM and CONDENSATE SYSTEM CORROSION
- PRIMING and/or CARRYOVER
- CONTROL of SPECIFIC PROBLEMS
  (Silica; Process Contamination; Iron; Sodium; Chlorides; Stress and Short-/Long-Term Overheating)
Internal Boiler Water Treatments

- ANODIC PROGRAMS - NITRITE, SILICATE, and MOLYBDATE
- TANNIN PROGRAMS
- PRECIPITATING CARBONATE PROGRAMS
- PRECIPITATING PHOSPHATE PROGRAMS
- COORDINATED PHOSPHATE PROGRAMS
- CONJUNCTIONAL/EQUILIBRIUM PHOSPHATE PROGRAMS
- ALL-VOLATILE TREATMENTS
- AMMONIA and AMINES
- CHELANT PROGRAMS (EDTA and NTA)
- ALL-POLYMER PROGRAMS
- COMBINATIONS PROGRAMS (CHELANT/PHOSPHATE; PHOSPHATE/POLYMER; CHELANT/POLYMER)
# Basic Boiler Chemistry

<table>
<thead>
<tr>
<th>CATIONS (Positive Charge)</th>
<th>ANIONS (Negative Charge)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HYDROGEN  H⁺</td>
<td>ORTHOPHOSPHATE PO₄³⁻</td>
</tr>
<tr>
<td>SODIUM  Na⁺</td>
<td>SULFITE SO₃²⁻</td>
</tr>
<tr>
<td>CALCIUM Ca²⁺</td>
<td>SULFATE SO₄²⁻</td>
</tr>
<tr>
<td>MAGNESIUM Mg²⁺</td>
<td>CARBONATE CO₃²⁻</td>
</tr>
<tr>
<td>IRON (FERROUS) Fe²⁺</td>
<td>BICARBONATE HCO₃⁻</td>
</tr>
<tr>
<td>IRON (FERRIC) Fe³⁺</td>
<td>HYDROXIDE OH⁻</td>
</tr>
<tr>
<td>ALUMINUM Al³⁺</td>
<td>CHLORIDE Cl⁻</td>
</tr>
</tbody>
</table>

## REACTIONS

- **Bicarbonate Decomp:**  
  \[ \text{NaHCO}_3 + \text{HEAT} \rightarrow \text{Na}_2\text{CO}_3 + \text{CO}_2 + \text{H}_2\text{O} \]
- **Developed Alkalinity:**  
  \[ \text{Na}_2\text{CO}_3 + \text{HEAT} + 2\text{H}_2\text{O} \rightarrow 2\text{NaOH} + \text{CO}_2 + \text{H}_2\text{O} \]
- **Brining Reactions:**  
  \[ \text{CaCl}_2 + \text{Boiler Water} \rightarrow \text{CaSO}_4 + \text{CaSiO}_3 \]
- **Phosphate Reaction:**  
  \[ \text{Ca}_3(\text{PO}_4)_2 \text{ Tricalcium Phosphate [Low Alkalinity]} \]
- **Phosphate Reaction:**  
  \[ \text{Ca}_{10}(\text{OH})_2(\text{PO}_4)_6 \text{ Hydroxyapatite [Adequate Alkalinity]} \]
- **Magnesium Reaction:**  
  \[ \text{Mg}_3(\text{PO}_4)_2 \text{ Trimagensium Phosphate [Low Alkalinity]} \]
- **Magnesium Reaction:**  
  \[ \text{Mg}(\text{OH})_2 \text{ Magnesium Hydroxide [Adequate Alkalinity]} \]
Cure For Cavitation of Feed Water Pumps

• Cavitation is caused by the sudden release of steam in the Feed Water and is cured by the prevention of steam formation.

• Deaerator systems are placed up to 30 ft (9 m) above the Feed Water pump creating a Head Pressure over the pump. At 1 psi of Head for every 2.3 ft (68 cm) of height, 33 feet of height will yield approximately 15 psi (1 bar) of Head Pressure.

• In a system with a feed water tank instead of a DA, maintain the temperature below 200°F (93°C).

Another method for the prevention of Cavitation is the use of a slip stream. This system uses a side stream to recirculate feed water back to the suction side of the pump. This alleviates steam release in the feed water pump.
Passivation and Oxygen Removal
Oxygen Saturation In The Feed Water
Passivation in a Boiler

In the absence of Oxygen and at higher temperatures, corrosion is often self-limiting as a Passivated (Non-Corrosive) surface layer of Magnetite is formed.

$$3 \text{ Fe(OH)}_2 \rightleftharpoons \text{ Fe}_3\text{O}_4 + 2 \text{ H}_2\text{O} + \text{ H}_2\uparrow$$

Ferrous Magnetite Water Hydrogen
Hydroxide (black)
Deaeration Is Vital!
Saturated Steam Tables and Deaerators

• A Feedwater System’s efficiency is measured in its ability to mechanically bring the Feedwater up to the Saturated Steam Temperature.

• The Saturated Steam Temperature is the point where the Feedwater exists as liquid and gas.

<table>
<thead>
<tr>
<th>Pressure (lb/sq in)</th>
<th>Temperature (°F)</th>
<th>Heat Content (BTU/lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>212</td>
<td>180</td>
</tr>
<tr>
<td>2</td>
<td>218</td>
<td>187</td>
</tr>
<tr>
<td>4</td>
<td>224</td>
<td>190</td>
</tr>
<tr>
<td>6</td>
<td>230</td>
<td>198</td>
</tr>
<tr>
<td>8</td>
<td>235</td>
<td>203</td>
</tr>
<tr>
<td>10</td>
<td>239</td>
<td>208</td>
</tr>
<tr>
<td>12</td>
<td>244</td>
<td>210</td>
</tr>
</tbody>
</table>
In the Absence of a Deaerator - Feedtanks and Oxygen Scavengers

Oxygen Scavengers chemically remove oxygen from water:

- Catalyzed Sodium Sulfite (Powders or Liquids).
- DEHA – a Volatile Organic Oxygen Scavenger transported throughout the steam system.
- Erythorbate – a GRAS approved product.
- Carbohydrazide, MEKO, and other organic oxygen scavengers.
Atmospheric Feedwater Tank Specifications

- Oxygen scavenger is to be fed to the water section of the tank using a Stainless Steel Quill.
- The higher the temperature, the more efficient oxygen removal.
- In this type of system, if the tank temperature is held above 190°F (90°C) there exists the potential for Feedwater pump cavitation.
  - Temperature gauges invariably fail, so holding the tank at 200°F (94°C) may actually equate to higher temperatures.
  - When the Feedwater pump comes on, the boiling point of the water is reduced.
  - Deaerators use head pressure (1 psi for every 2.3 ft of height above the pump), whereas a Feedwater Tank is nominally 3 ft above the Feedwater pumps.
  - Closely monitor temperatures to prevent pump loss due to cavitation.
Oxygen Removal

Oxygen Content of Water ...

- = 6.0 ml/L (8.6 ppm) @ 50°F (10°C)
- = 4.3 ml/L (6.1 ppm) @ 110°F (43°C)
- = 2.5 ml/L (3.5 ppm) @ 160°F (71°C)
- = 1.6 ml/L (2.3 ppm) @ 190°F (88°C)

Mechanically Deaerated Water = 0.007 ppm

Sulfite Requirements = \[O_2 \text{ ppm} \times 7.88 + \text{Residual}] \div \text{COC}
(as dry Sodium Sulfite)

Typical Low Pressure Boiler Water Sulfite Residuals of 30-70 ppm as sulfite.
Oxygen Scavengers

1. SULFITE (including Bisulfite and Metabisulfite)

Na₂SO₃ + ½ O₂ = Na₂SO₄

Sodium Sulfite at 7.88 ppm per 1.0 ppm O₂

Catalyzed with 0.03-0.05% Cobalt Salts

Residual = 20-40 ppm (sometimes 50-100 ppm)

Sulfites add TDS to the Boiler Water

100% Powder or 30-40% Aqueous Solutions
Oxygen Scavengers, contd.

2. HYDRAZINE, $\text{N}_2\text{H}_4$
   
   Available as 15-, 35-, and 65% Solutions
   
   Need 100% in excess of Stoichiometric Dose
   
   Feedwater: $\text{N}_2\text{H}_4 + \text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{N}_2$
   
   Boiler: $6\text{Fe}_2\text{O}_3 + \text{N}_2\text{H}_4 \rightarrow \text{N}_2 + 2\text{H}_2\text{O} + 4\text{Fe}_3\text{O}_4$
   
   Steam: $3\text{N}_2\text{H}_4 \rightarrow 4\text{NH}_3 + \text{N}_2$

   Ammonia Liberated @ 334°F (100 psi)
   
   Slow Reaction Times, even when Catalyzed!
   
   Potential Carcinogen Risk
   
   Residual = <0.5 PPM
   
   Does not contribute to Boiler Water TDS
Oxygen Scavengers, contd.

3. **DIETHYLHYDROXYLAMINE (DEHA)**
   - 1.24 ppm DEHA per 1 ppm O₂
   - Practical Ratio is 3 : 1
   - No Ammonia @ 534°F (900psi)
   - Safe as a Neutralizing Amine Corrosion Inhibitor
   - Typically 25% Active
   - When Catalyzed, Reacts Rapidly
   - Desired Residual = <0.5ppm
Oxygen Scavengers, contd.

4. **OTHER ORGANIC O$_2$ SCAVENGERS:**

   Erythorbic Acid
   Hydroquinone
   Methylethylketoxime
   Gallic Acid
   Carbohydrazide
# Oxygen Scavenger Comparisons

<table>
<thead>
<tr>
<th>Oxygen Scavenger</th>
<th>Combining Ratio</th>
<th>Max. Pressure psig</th>
<th>Volatility/ Distrib. Ratio</th>
<th>Passivation ability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium sulfite as solid or 32% soln. Cat. = Co or Eryth.</td>
<td>10:1 Rapid scavenger</td>
<td>950 max. Risk of SO₂/H₂S</td>
<td>Not volatile DR = Nil</td>
<td>Limited, only over 300 psig</td>
</tr>
<tr>
<td>Sodium bisulfite Typical is 40% soln. Cat. = Co or Eryth</td>
<td>7:1 Rapid scavenger</td>
<td>950 max. Risk of SO₂/H₂S</td>
<td>Not volatile DR = Nil</td>
<td>Limited, only over 300 psig</td>
</tr>
<tr>
<td>Na metabisulfate 100% powder Cat. Co or Eryth.</td>
<td>5:1 Rapid scavenger</td>
<td>950 max. Risk of SO₂/H₂S</td>
<td>Not volatile DR = Nil</td>
<td>Limited, only over 300 psig</td>
</tr>
<tr>
<td>Hydrazine as 15 or 35% soln. Cat. = HQ</td>
<td>3:1 Rapid scavenger</td>
<td>2500+ Produces NH₃</td>
<td>Poor volatility DR = 0.1</td>
<td>Excellent for all system</td>
</tr>
<tr>
<td>DEHA as 17.5 to 30% soln. Cat. = HQ or Cu</td>
<td>3:1 Rapid scavenger</td>
<td>2500+ Some NH₃</td>
<td>Good volatility DR = 1.3</td>
<td>Excellent for all system</td>
</tr>
</tbody>
</table>

**NOTE:** 1 std. atm = 14.696 pounds per sq.inch absolute (psia or lbf/in²). 1 bar = 14.5 psia, or 1 kg/cm², or 100,000 Pascal, or 100 kPa, or 0.1 MPa
Oxygen Scavengers, contd.

5. SODIUM NITRITE

An Anodic Passivating Agent
Enhances the Formation of Magnetite Films
NaNO₂ – typically Buffered with Sodium Borate
May include Yellow Metal Inhibitors
Reducing Environment @ 500-700 ppm NO₂
Simple to Test
High Dosages Restrict to Small Boiler Systems
Oxygen Scavengers, contd.

6. **TANNINS**

Querqus (Oak), Acacia (Wattle), Schinopsis (Quebracho), etc.

*Hydrolyzable Tannins when heated degrade into Polyhydroxyphenols, Gallic Acid, and Ellagic Acid ... all Oxygen Scavengers*

*Non-Hydrolyzable (Condensed) Tannins when heated degrade into ortho-, meta-, and para- Dihydroxy Flavenoids (Anionic Polyelectrolyte Sludge Conditioners)*

Residual @ 10-15 ppm Tannin Reserve (Brown Color)

Good Performance Under Poor Conditions