Air Cooled Condenser Users Group: Corrosion Product Transport Monitoring

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Topics

• Why Monitor Corrosion Product Transport?
• Creating a Monitoring Program
• Sampling and Sample Methods
• Iron Monitoring Methods
• Costs and Time Commitments
Why Monitor Corrosion Product Transport?

- Protects people
  - Minimizes equipment failures and hazards

- Protects plant equipment
  - FIRST line of defense in problem detection
  - Protects ACC, feedwater, HRSGs and turbines
  - Predicts and minimizes cleaning needs and frequency

- Allows performance monitoring of the steam-condensate-feedwater cycle
  - Provide data to operating & chemistry personnel for detection of any deviations from control specs.
  - Allows corrective action

Boiler chemical cleaning tank farm
Creating a Monitoring Program

- Sample Locations and Limits
- Sample Frequency
- Interpreting Data
- Recommended Tests
Creating a Monitoring Program: Sample Locations and Limits
Creating a Monitoring Program: Frequency

• Normal Operation
  - Daily (to start) – all locations (include RACs if equipped)
  - Adjust schedule based on results

• Startup and Shutdown Profiles
  - Specific schedule important
  - Sample every 15 minutes for first 6 hours (or until levels stabilize)
  - Perform quarterly and after major maintenance
  - Determines “crud burst” duration and magnitude
Creating a Monitoring Program: Interpreting Data

Interpret data carefully

- Most transport occurs during transients
- S/U and S/D important

Particle index (discussed later) and ORP on plant startup
Creating a Monitoring Program: Recommended Tests

- Total, Soluble, and Filtered Tests to start
- Continue for 30-60 data sets (60 preferred)
- Analyze for consistency and trends
- Soluble test frequency decreases to monthly if results consistently non-detect
- Total (wet test) frequency to weekly if consistent with filtered results
Sampling and Sample Methods

- Continuously running
- SS lines, $\frac{1}{4}$ to $\frac{3}{8}$-inch
- Minimize line lengths
  - Minimizes lag time
  - Minimizes iron loss (through sample line deposition)
- Cooled to $< 90^\circ$F
- Flow rate 4-6 FPS
- Isokinetic samples best, but most plants don’t have them (continuous flow especially important)
Sampling and Sample Methods

- **Key Monitoring Parameters**
  - pH
  - Total Iron (wet test)
  - Soluble Iron (wet test)
  - Suspended Iron (Millipore filter test)
  - Dissolved Oxygen
  - Treatment Chemical (oxygen scavenger, if used)

- **Influencing Parameters**
  - Na leakage from demineralizers and polishers
  - Alkalinity (CO2 source) and TOC
  - Cation and Specific Conductivity of feedwater, condensate and steam
  - NH3 and dissolved CO2
  - Silica
  - Hardness
  - Na and hydrogen in the steam
  - Flow rates, temperatures and pressures
# Iron Monitoring Methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Soluble Iron</th>
<th>Total Iron</th>
<th>Digestion Required</th>
<th>Test Type</th>
<th>Detection Limit (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TNTplus</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Grab / Wet</td>
<td>200</td>
</tr>
<tr>
<td>FerroVer</td>
<td>X</td>
<td>X</td>
<td></td>
<td>Grab / Wet</td>
<td>20</td>
</tr>
<tr>
<td>TPTZ</td>
<td>X</td>
<td>X</td>
<td></td>
<td>Grab / Wet</td>
<td>10</td>
</tr>
<tr>
<td>1-10, Phenanthroline</td>
<td>X</td>
<td></td>
<td></td>
<td>Grab / Wet</td>
<td>20</td>
</tr>
<tr>
<td>FerroZine</td>
<td>X</td>
<td>X</td>
<td></td>
<td>Grab / Wet</td>
<td>10</td>
</tr>
<tr>
<td>Titraver</td>
<td>X</td>
<td></td>
<td></td>
<td>Grab / Titration</td>
<td>10,000</td>
</tr>
<tr>
<td>FerroMo</td>
<td>X</td>
<td>X</td>
<td></td>
<td>Grab / Wet</td>
<td>10</td>
</tr>
<tr>
<td>Test Strips</td>
<td>X</td>
<td></td>
<td></td>
<td>Grab / Strips</td>
<td>150</td>
</tr>
<tr>
<td>Millipore (Suspended Iron)</td>
<td>X</td>
<td></td>
<td></td>
<td>Grab / Filter</td>
<td>10*</td>
</tr>
<tr>
<td>Composite Sampler</td>
<td>X</td>
<td></td>
<td></td>
<td>Composite / Filter</td>
<td>1</td>
</tr>
<tr>
<td>Off-site Lab</td>
<td>X</td>
<td>X</td>
<td></td>
<td>Grab / Off-site Lab</td>
<td>3</td>
</tr>
<tr>
<td>Particle Analysis</td>
<td>X</td>
<td></td>
<td></td>
<td>Continuous / Online</td>
<td>N/A (Particle Index)</td>
</tr>
<tr>
<td>Deposit Weight Density</td>
<td>X</td>
<td></td>
<td></td>
<td>Destructive</td>
<td>N/A</td>
</tr>
</tbody>
</table>

*Can lower detection limit with larger sample*
Iron Monitoring Methods – Wet Tests

- Hach tests shown (typical)
- Specialty chemical suppliers may have their own
- Detection limit usually too high (minimum is 10 ppb)
- Require digestion (complicated and time consuming)
- Requires spectrophotometer
- Suspended iron test is better, but early testing should include wet tests
Iron Monitoring Methods – Suspended Iron

- Millipore filter test (filter through 0.45 micron filter)
- More accurate than wet tests
  - Wet test methods don’t accurately measure total iron in drums
  - Iron changes form and does not show up on the traditional wet tests unless digested
- Uses B&W comparison chart
- Detection limit of 10 ppb for 1L sample
- Lower detection limit by increasing sample size
- 5L sample lowers detection limit to 2 ppb
- Manual filtering of 5L of sample impossible
  - Use a vacuum pump and filter assembly to accomplish this task
Iron Monitoring Methods – Suspended Iron

This chart is for suspended Black Iron Oxide (Fe₃O₄) only and is based on a passage of one liter of water containing the indicated concentration of Fe₃O₄ in terms of parts per billion... iron (Fe) through a 0.45μm pore size membrane filter.

MEMBRANE FILTER COMPARISON CHART
(Fe₃O₄)

THE BABCOCK & WILCOX CO.
POWER GENERATION DIVISION

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Iron Monitoring Methods – Suspended Iron

5L Sample Reservoir

Filter Assembly and 5L Receiver

Vacuum Pump
Iron Monitoring Methods – Composite Sampling

- Millipore test uses visual comparison
- Composite sampling uses same filter, but off-site analysis provides greater accuracy
- Known volume of water passes through filter
- Corrosion products accumulate
- Filter removed and weighed after exposure
- Weight of iron (in mg) divided by total flow (in L) to provide result in mg/L or ug/L
- Additional analyses (like X-ray diffraction) can provide data on oxide composition
Iron Monitoring Methods – Composite Sampling
Iron Monitoring Methods – Off-site Lab

- Field test accuracy not the best (high detection limits)
- Off-site samples confirm field test results
- Should be obtained quarterly for all streams of interest (see diagram)
- Include soluble and total iron
- Samples must be preserved to ensure accuracy
- Pull samples when field grab samples are pulled
- Compare results to confirm accuracy
- Costly ($250-$400 per sample)
Iron Monitoring Methods – Particle Analysis

- Traditional monitoring of metal transport and generation in the steam cycle relies primarily on periodic wet tests
- Wet tests valuable, but leave significant holes in the data stream
- Every thermal, chemical, or hydraulic event liberates or generates metal oxides in the steam cycle
- These events occur often and cannot be scheduled - they occur as the plant operates
Iron Monitoring Methods – Particle Analysis

- Time-based testing (iron sampling at a specific frequency) important, but it cannot detect the majority of these events
- Particle analysis provides a window into metal liberation and transport as it occurs
- Two different technologies that can be used - particle size analysis and particle counts
Iron Monitoring Methods – Particle Analysis – Particle Counter or Particle Monitor

- PC reports counts in different size ranges
  - Requires 4 DCS inputs for each sample
  - Provides more data than PM, but requires more storage and data infrastructure

- PM provides only one reading – “index”
  - Only 1 DCS input/PI tag per sample
  - Index represents the total surface area of all particles passing through the sensor
Iron Monitoring Methods –
Particle Analysis – Particle Counter or Particle Monitor

- Both may be useful
- Testing indicates that the majority of iron transport occurs as particles < 5 microns in size
- Most iron transport occurs as particles of similar and smaller size
Iron Monitoring Methods – Particle Analysis – Particle Counter or Particle Monitor

Condensate After Chemical Feed Particle Distribution  
LP Economizer Outlet Particle Distribution
Iron Monitoring Methods – Particle Analysis – Particle Counter or Particle Monitor

Good agreement between PC and PM

**Comparison of Particle Counts and Particle Index**

- CACF Total Particle Count
- CACF Particle Index

Date and Time:
- 12/16/08 12:00 AM
- 12/16/08 2:24 AM
- 12/16/08 4:49 AM
- 12/16/08 7:12 AM
- 12/16/08 9:36 AM
- 12/16/08 12:00 PM
- 12/16/08 2:24 PM
- 12/16/08 4:49 PM
- 12/16/08 7:12 PM
- 12/16/08 9:36 PM

Particle Counts/100 ml Particle Index
- 150,000
- 140,000
- 130,000
- 120,000
- 110,000
- 100,000
- 90,000
- 80,000
- 70,000
- 60,000

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Iron Monitoring Methods: Deposit Weight Density (DWD)

- Measures the amount of deposit on both the hot and cold side of a boiler tube.
  - NACE TM0199-99: Bead Blasting Method
  - Mechanical method, so follow B&W Cleaning Guidelines

- Sample from high heat release zone
  - Conventional unit: water wall approximately the centerline of the highest burner elevation
  - HRSG: HP evaporator, first row

- Used to determine need to clean boiler
  - Need to clean will be unit specific, as heat release and circulation play an important role in deposition on, and cooling of, the boiler tubes
Iron Monitoring Methods: Deposit Weight Density (DWD)

DWD tube Sample (before cleaning)
- Weigh each side
- Clean
- Reweigh each side
- Difference is DWD
Iron Monitoring Methods: Deposit Weight Density - Chemical Cleaning Guidelines

- Follows B&W Guidelines
- Based on mechanical cleaning (bead blasting or scraping)
- Need to clean will be unit specific.

<table>
<thead>
<tr>
<th>US Units</th>
<th>Metric Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>psi</td>
<td>g/ft²</td>
</tr>
<tr>
<td>&lt; 1000</td>
<td>10 – 40</td>
</tr>
<tr>
<td>1000 – 2000</td>
<td>12 – 20</td>
</tr>
<tr>
<td>&gt; 2000</td>
<td>10 - 12</td>
</tr>
</tbody>
</table>
Iron Monitoring Methods – Using the Tools

- Conventional testing and DWD provide quantification
- Particle analysis technology provides visibility to previously undetectable events.
- The two approaches can be used to correlate particle index to metal transport (iron) test results
- Combining particle counts with wet test results "closes the loop" on steam cycle metal transport. The combination offers three windows into the process
  - Wet tests correlate particle index to iron transport
  - Particle index provides real-time, continuous indication of amount of iron moving through the system
  - DWD confirms amount of deposition on tubes
# Costs and Time Commitments (Approximate)

<table>
<thead>
<tr>
<th>Method</th>
<th>Cost (per test)</th>
<th>Cost (initial setup)</th>
<th>Time Required</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet Tests</td>
<td>$1.00</td>
<td>$0</td>
<td>Approximately 1 hour per day</td>
<td>3 minutes per test, but 3-5 tests per day (condensate, FW, drums)</td>
</tr>
<tr>
<td>(assumes existing spectro-photometer and glassware)</td>
<td></td>
<td></td>
<td>(concurrent with other sampling)</td>
<td></td>
</tr>
<tr>
<td>Millipore Filtered Iron Test</td>
<td>$0.40-$0.50</td>
<td>$1,500</td>
<td>Approximately 2 hours per day</td>
<td>Operators fill reservoir with sample, start vacuum pump, read result later</td>
</tr>
<tr>
<td>(Reservoir, vacuum pump, tubing, filter, etc.)</td>
<td></td>
<td></td>
<td>(concurrent with other sampling)</td>
<td></td>
</tr>
<tr>
<td>Off-site Lab</td>
<td>$250-$400</td>
<td>$0</td>
<td>Approximately 4 hours per quarter</td>
<td>Performed quarterly and only on select samples</td>
</tr>
<tr>
<td>Off-site Lab</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Particle Analysis</td>
<td>$0</td>
<td>$15,000</td>
<td>None – online analyzer with input to DCS</td>
<td>Assumes 2 particle monitors, 2 sample streams to each</td>
</tr>
<tr>
<td>Deposit Weight Density</td>
<td>$15,000 every 3 years</td>
<td>$0</td>
<td>Approximately 2 days every 3 years</td>
<td>Includes cost to cut and reweld sample.</td>
</tr>
</tbody>
</table>
What a good iron monitoring program can prevent