Advancements in Boiler Water Internal Treatment Chemistry

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Agenda

- The Problem of Boiler Waterside Deposition
- A Short History of Boiler Internal Treatments
- Advancements in Boiler Internal Treatment Technology
- A Case Study of Boiler Deposition Control
Boiler Waterside Deposition – What Goes in Must Come out!

BFW
1 kg/day of contaminant (Ca, Mg, Fe, etc)

Blowdown
1 kg/day of contaminant
Boiler Waterside Deposition – Where did the contaminant go?

BFW
10 kg/day of contaminant (Ca, Mg, Fe, etc)

Blowdown
5 kg/day of contaminant
What Creates These Deposits?

- All deposition can be tracked back to the boiler feedwater (BFW)
- 99% of work needs to be focused on BFW
- Important to understand BFW quality 24/7
We rarely, if ever, have zero contaminants in the feedwater.

How do we get this contaminant to transport thru?
- Bottom Blowdown
- Continuous Blowdown
- Chemical Treatment

Last resort....
- Aqua blasting
- Chemical Cleaning
Impacts of Boiler Waterside Deposition

Fireside

Waterside

Scale

> 850°F

Without Scale

With Scale

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Composition</th>
<th>Maximum Recommended Service Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA-178, SA-210</td>
<td>Carbon Steel</td>
<td>850 F</td>
</tr>
<tr>
<td>SA-209 T1</td>
<td>0.5% Mo</td>
<td>900 F</td>
</tr>
<tr>
<td>SA-213 T11</td>
<td>1.25% Cr, 0.5% Mo</td>
<td>1025 F</td>
</tr>
<tr>
<td>SA-213 T22</td>
<td>2.25% Cr, 1.0% Mo</td>
<td>1075 - 1100 F</td>
</tr>
</tbody>
</table>
Impacts of Boiler Waterside Deposition

Element | Weight Percent
--- | ---
Calcium | 51.2
Phosphate | 21.6
Iron | 13.6
Silicon | 3
Copper | 2.9
Manganese | 2.3
Aluminum | 2.2
Sulfur | 1.2
Sodium | 1.1

<table>
<thead>
<tr>
<th>DWD Section</th>
<th>DWD (g/ft²)</th>
<th>Internal Surface Deposit Thickness</th>
<th>Wall Thickness</th>
<th>Internal Pit Depth – Max. (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Side I</td>
<td>194</td>
<td>0.016</td>
<td>0.028</td>
<td>0.135</td>
</tr>
<tr>
<td>Side II</td>
<td>197</td>
<td>0.023</td>
<td>0.033</td>
<td>0.132</td>
</tr>
</tbody>
</table>
Impacts of Boiler Waterside Deposition

![Graph showing typical energy loss vs. scale thickness](image)

- **Iron & Silica**
- **High Iron**
- **Hardness and Iron**

- Energy Loss (%)
  - 0% to 8%
- Scale Thickness
  - 0
  - 1/64
  - 1/32
  - 3/64
  - 1/16
Polymer components make the backbone of today’s internal treatment

Prior to 2000’s, many boiler systems were treated using other treatment strategies:

- Sludge conditioning
  - Carbonate cycle (1900’s)
  - Phosphate precipitation (1920’s)
- Complexation
  - Chelants (1950’s)
- First generation synthetic polymers (1970’s)
Today’s industry has refined 3rd generation boiler polymers.

The latest internal treatment programs are:

- Performant and easy to use
- Cost effective
- Safe… to the users, the metallurgy and the environment!
Internal Treatment Chemistry Advancements

Performance:

- Cleaner surfaces
- Better heat transfer
- Lower fuel consumption
- Lower risk of failure
- Less maintenance (reactive and planned)

![Ion Transport - 300 psig](chart.png)
Ease of use:

- Safe for the user
- Can be fed to any part of the system
- Works without constant proportional injection

Deposit formed under upset conditions without treatment

Same tube as above – After 3rd generation polymer applied (upset recovery)
Case Study – 3rd generation polymer field application

- Heavy industrial facility @ 650 PSIG steam (4 boilers)
- Zeolite Softener Pretreatment - Hardness leakage in BFW
  - <50% Hardness transport
- One tube failure per month on average
  - Overheating and/or under deposit corrosion
- Phosphate precipitating internal treatment program
  \[
  \text{Ca} + \text{PO}_4 + \text{OH} \rightarrow \text{Ca(OH)PO}_4
  \]
  Calcium   Phosphate   Hydroxide   Hydroxyapatite
Case Study – 3rd generation polymer field application
### Case Study – 3rd generation polymer field application

#### Boiler Internal Treatment Advancements – CampusEnergy2020

<table>
<thead>
<tr>
<th>Element</th>
<th>Top ID Deposit (wt %)</th>
<th>Bottom ID Deposit (wt %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na</td>
<td>3.2</td>
<td>5.2</td>
</tr>
<tr>
<td>Mg</td>
<td>11.4</td>
<td>4.5</td>
</tr>
<tr>
<td>Al</td>
<td>3.2</td>
<td>1.1</td>
</tr>
<tr>
<td>Si</td>
<td>13.1</td>
<td>9.9</td>
</tr>
<tr>
<td>P</td>
<td>9.0</td>
<td>1.3</td>
</tr>
<tr>
<td>S</td>
<td>1.9</td>
<td>-</td>
</tr>
<tr>
<td>K</td>
<td>6.4</td>
<td>1.1</td>
</tr>
<tr>
<td>Ca</td>
<td>20.5</td>
<td>2.2</td>
</tr>
<tr>
<td>Fe</td>
<td>31.3</td>
<td>74.7</td>
</tr>
</tbody>
</table>
# Case Study Problem Example

<table>
<thead>
<tr>
<th>Parameter</th>
<th>DA 2</th>
<th>Boiler 4</th>
<th>Cycles</th>
<th>% Transport</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfur</td>
<td>3.3</td>
<td>53</td>
<td>16</td>
<td>100%</td>
</tr>
<tr>
<td>Silica</td>
<td>2</td>
<td>34</td>
<td>17</td>
<td>106%</td>
</tr>
<tr>
<td>Hardness</td>
<td>0.3</td>
<td>3.1</td>
<td>10</td>
<td>65%</td>
</tr>
<tr>
<td>Calcium</td>
<td>0.16</td>
<td>1.9</td>
<td>12</td>
<td>74%</td>
</tr>
<tr>
<td>Magnesium</td>
<td>0.14</td>
<td>1.2</td>
<td>9</td>
<td>54%</td>
</tr>
<tr>
<td>Chloride</td>
<td>1.9</td>
<td>32</td>
<td>17</td>
<td>105%</td>
</tr>
<tr>
<td>Iron</td>
<td>0.02</td>
<td>0.21</td>
<td>11</td>
<td>66%</td>
</tr>
<tr>
<td>Phosphate</td>
<td>16.9</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[
\% \text{ Ion Transport} = \frac{\text{ppm ion in Boiler blowdown}}{\text{ppm in Feedwater} \times \text{Cycles of Concentration}} \times 100
\]
Case Study Problem Example

↓ BFW TH and ↑ Treatment = 100+% Transport

↑ Hardness = ↑ Treatment required

Treatment underfeed = <50% Transport

↓ BFW TH = >100% Transport

Applied Treatment adequate for Hardness in BFW
Case Study Problem Example

2015 Inspection – Mud Drum

2018 Inspection – Mud Drum
Case Study Problem Example

2015 Inspection - Mud Drum Third Row Tube

2018 Inspection - Mud Drum Third Row Tube
Case Study Problem Conclusions

- Hardness recovery from <50% to 120%
- Complete elimination of monthly boiler tube failures
- Greatly improved boiler waterside cleanliness
  - Heat transfer efficiency gain
Treatment significantly outperforms dated phosphate/polymer chemistry:
- From <50% to 120% Hardness Transport

Treatment must be fed proportional to contaminant load to maintain 100% contaminant transport.

Treatment exhibits forgiving capabilities:
- Ability to recover from hardness excursion and disperse existing scale
QUESTIONS?
THANK YOU

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