Connecting the Dots between Process Operation and Materials Failures in Kraft Recovery Boilers

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7th Black Liquor Colloquium, Jyväskylä Finland, July 31 – August 2, 2006
Presentation Outline

• Motivation & Methodology
• Case Study 1 Results – Boiler A
• Case Study 2 Results – Boiler B
• Case Study 3 Results – Boiler C
• Critical Factors for Thermal Excursions
• “Connecting the Dots” Conclusions
Motivation & Methodology

• Primary Air Port Tube Cracking
  – Corrosion fatigue cracking mechanism
  – Thermal cycling a critical factor
  – Reduce thermal cycling to mitigate cracking

• What process changes will achieve that goal?
  – Installation of thermocouples
  – Normalizing process changes
  – In-situ imaging
  – Inspection results
Case Study 1 – Boiler A

- 1997; 2½” on 3” membrane construction; sloped floor
- 3.6 Mlbs BLDS/d; 600,000 lb/h steam; 1525 psig
- Softwood liquor; 73-75% solids
Cracking and Thermal Fluctuations

Large Thermal Fluctuations = High Excursions AND High Cycles
Thermal Cycling and Operation

Before Trial I

After Trial II

Time (h)

Temperature (°C)
## Trials I and II Operating Parameters

<table>
<thead>
<tr>
<th>Operating Parameter</th>
<th>Trial Ia Initial Mode</th>
<th>Trial Ib Final Mode</th>
<th>Trial Ila Initial Mode</th>
<th>Trial IIB Final Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature, °C (as-fired)</td>
<td>120</td>
<td>120</td>
<td>121</td>
<td>120</td>
</tr>
<tr>
<td>Pressure, kPa (as-fired)</td>
<td>296</td>
<td>305</td>
<td>251</td>
<td>208</td>
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<tr>
<td>Flow Rate (DS), kg/h</td>
<td>71,009</td>
<td>71,277</td>
<td>78,152</td>
<td>67,378</td>
</tr>
<tr>
<td>Soap In Combination</td>
<td>No</td>
<td>No</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Nozzle Type</td>
<td>Wedge</td>
<td>Wedge</td>
<td>Wedge</td>
<td>Splashplate</td>
</tr>
<tr>
<td>Nozzle Diameter</td>
<td>2-#30, 2-#32</td>
<td>2-#30, 2-#32</td>
<td>4-#30</td>
<td>4-#28</td>
</tr>
<tr>
<td>Splashplate Angle, Degrees</td>
<td>49</td>
<td>49</td>
<td>49</td>
<td>49</td>
</tr>
<tr>
<td>Tilt Angle, Degrees (F/RH/R/LH)</td>
<td>n/a</td>
<td>n/a</td>
<td>-5/-5/-5/-5</td>
<td>-9/-5/-5/-5</td>
</tr>
<tr>
<td>Total Air Split, PA/SA/TA</td>
<td>30/51/19</td>
<td>35/35/30</td>
<td>37/35/28</td>
<td>38/38/24</td>
</tr>
<tr>
<td>PA Split, % (F/RH/R/LH)</td>
<td>18/30/26/26</td>
<td>25/26/23/27</td>
<td>20/24/31/25</td>
<td>21/25/24/30</td>
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<tr>
<td>SA Split, % (F/RH/R/LH)</td>
<td>17/35/15/33</td>
<td>11/38/5/46</td>
<td>6/41/2/51</td>
<td>8/46/11/35</td>
</tr>
<tr>
<td>SA Interlaced Pattern</td>
<td>4-Wall Mismatch</td>
<td>2-Wall Mismatch</td>
<td>2-Wall Mismatch</td>
<td>2-Wall Mismatch</td>
</tr>
</tbody>
</table>
Key Changes

• Dramatic reduction in large thermal fluctuations observed in the recovery boiler
  – Increased primary air jet momentum
  – Switched from wedge to splashplate nozzle
  – Burned soap in combination with liquor

• How do these global changes affect local environment in and around primary air ports?
Case Study 2 – Boiler B

- 2001; 2½” on 3” membrane construction; decanting floor
- 3.5 Mlbs BLDS/d; 500,000 lb/h steam; 900 psig; 900 °F
- Softwood liquor; 73-75% solids
Cracking and Operation

**REAR WALL**

- **Before Changes**
- **After Changes**

**RIGHT-HAND WALL**

- **Before Changes**
- **After Changes**

**FRONT WALL**

- **Before Changes**
- **After Changes**

**LEFT-HAND WALL**

- **Before Changes**
- **After Changes**

**Inspection Period (mm-yr)**

7th Black Liquor Colloquium, Jyväskylä Finland, July 31 – August 2, 2006
Thermal Cycling

Before 2004 Changes

After 2004 Changes

7th Black Liquor Colloquium, Jyväskylä Finland, July 31 – August 2, 2006
## Operating Parameters

<table>
<thead>
<tr>
<th>Operating Parameter</th>
<th>Initial Mode</th>
<th>Normalized Mode</th>
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</thead>
<tbody>
<tr>
<td>Temperature, °C</td>
<td>123 – 128</td>
<td>126</td>
</tr>
<tr>
<td>Pressure, kPa (psig)</td>
<td>Δ 180 (26)</td>
<td>180 (26)</td>
</tr>
<tr>
<td>Flow Rate, (Dry Solids) kg/h</td>
<td>65,000</td>
<td>65,000</td>
</tr>
<tr>
<td>Soap In Combination</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Nozzle Type</td>
<td>Splashplate</td>
<td>Splashplate</td>
</tr>
<tr>
<td>Nozzle Diameter, mm (F/RH/R/LH)</td>
<td>27/27/24/27</td>
<td>27/27/24/27</td>
</tr>
<tr>
<td>Splashplate Angle, Degrees</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Tilt Angle, Degrees (F/RH/R/LH)</td>
<td>-7/-7/-5/-4</td>
<td>-7/-7/-5/-4</td>
</tr>
<tr>
<td>Total Air Split, % (PA/SB/LSA/USA/TA)</td>
<td>25/12/39/9/15</td>
<td>36/7/33/8/16</td>
</tr>
<tr>
<td>PA+SB Split, % (F/RH/R/LH)</td>
<td>16/36/17/31</td>
<td>22/28/23/27</td>
</tr>
<tr>
<td>LSA Split, % (RH/LH)</td>
<td>55/45</td>
<td>52/48</td>
</tr>
<tr>
<td>USA Split, % (F/R)</td>
<td>29/71</td>
<td>38/62</td>
</tr>
<tr>
<td>SA Interlaced Pattern</td>
<td>4-Wall Mismatch</td>
<td>4-Wall Interlaced</td>
</tr>
</tbody>
</table>
Key Process Changes

• Dramatic reduction in cracking indications observed in the recovery boiler
  – Increased primary air jet momentum
  – Balanced combustion air system (central chimney)
  – Stabilized as-fired liquor temperature

• How do these global changes affect local environment in and around primary air ports?
Case Study 3 – Boiler C

- 2004; 2½” on 3” membrane construction; sloped floor
- 3.9 Mlbs BLDS/d; 400,000 lb/h steam; 625 psig; 752 °F
- Softwood liquor; 66-68% solids
# Cracking and Operation

## LEFT-HAND WALL

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<thead>
<tr>
<th>Studs</th>
<th>Apr-06</th>
<th>Dec-05</th>
<th>May-05</th>
<th>Jun-04</th>
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<tr>
<td></td>
<td>1 2 3 4</td>
<td>5 6 7 8</td>
<td>9 10 11 12</td>
<td>13 14 15 16</td>
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</tbody>
</table>

## RIGHT-HAND WALL

<table>
<thead>
<tr>
<th>Studs</th>
<th>Jun-04</th>
<th>May-05</th>
<th>Dec-05</th>
<th>Apr-06</th>
<th>Studs</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>1 2 3 4</td>
<td>5 6 7 8</td>
<td>9 10 11 12</td>
<td>13 14 15 16</td>
<td>17 18 19 20</td>
</tr>
</tbody>
</table>

FW

RW

7th Black Liquor Colloquium, Jyväskylä Finland, July 31 – August 2, 2006
Thermal Cycling

Before 2005 Changes

After 2005 Changes
## Operating Parameters

<table>
<thead>
<tr>
<th>Operating Parameter</th>
<th>Initial Mode</th>
<th>Normalized Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature, °C</td>
<td>115</td>
<td>116</td>
</tr>
<tr>
<td>Pressure, kPa (psig)</td>
<td>112-126 (16-18)</td>
<td>120 (17)</td>
</tr>
<tr>
<td>Flow Rate, (Dry Solids) kg/h</td>
<td>68,000</td>
<td>68,000</td>
</tr>
<tr>
<td>Soap In Combination</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Nozzle Diameter (F/RH/R/LH)</td>
<td>#40/#40/#40/#40</td>
<td>#40/#40/#40/#40</td>
</tr>
<tr>
<td>Splashplate Angle, Degrees</td>
<td>49</td>
<td>49</td>
</tr>
<tr>
<td>Tilt Angle, Degrees (F/RH/R/LH)</td>
<td>-8/-24/-22/-21</td>
<td>-19/-17/-20/-17</td>
</tr>
<tr>
<td>Total Air Split, % (PA/SA/TA)</td>
<td>34/40/26</td>
<td>40/45/15</td>
</tr>
<tr>
<td>PA Split, % (F/RH/R/LH)</td>
<td>22/27/25/26</td>
<td>24/26/23/27</td>
</tr>
<tr>
<td>SA Split, % (RH/LH)</td>
<td>48/52</td>
<td>49/51</td>
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<tr>
<td>SA Interlaced Pattern</td>
<td>Weak 2-Wall Interlaced</td>
<td>Strong 2-Wall Interlaced</td>
</tr>
</tbody>
</table>
Key Process Changes

• Will changes reduce cracking occurrence?
  – Increased primary air jet momentum
  – Increased secondary air jet momentum
  – Lower liquor gun tilt angles

• If yes, how do these global changes affect local environment in and around primary air ports?
Critical Conditions

Char Bed Contacting Port Tube

Droplets Contacting Port Tube [Dehydration or Devolatilization Incomplete]

Low Primary Air Jet Momentum

Large Thermal Fluctuations
In-Situ Imaging (High T Cycle)

Temperature Rising
~575°C to 600°C

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Acknowledgements

• Mill Personnel of Boiler A, B & C
  – Francois Jetté (Domtar)

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  – Jerry Yuen (PSL)
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  – RWDI
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  – Craig Reid (Acuren)
  – Acuren (Canspec)