Red Hot Video
of Combusting Liquor & Smelt
at Primary Airports

Black Liquor Colloquium - Utah

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Overview

• Background to Boiler Video Camera Probe

• Observations
  – Lifespan of a Combusting Particle
  – Coating of Tubes
  – Two Steady States

• Activity not causing >500°C excursions

Why Build a Camera Probe?

• Cracking of composite tubes at primary airports
• Associated with temperature excursions & cycling
• Cause of high temperatures - Unknown
• Since Feb.2001: Five successful camera probe variations
• ~ 35+ hours Video from 5 trips to 3 mills
• One design selected: “Boiler View”
## Black Liquor Life Span

**Hupa & Frederick 1987**

<table>
<thead>
<tr>
<th>Stage &amp; Temperatures (°C)</th>
<th>Droplets</th>
<th><strong>PAPRICAN’S OBSERVATIONS</strong></th>
<th>Eg.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Drying</strong> &lt;= 300</td>
<td>Droplets swell ~1.5x</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td><strong>Devolatilization</strong> 300 &gt; 800</td>
<td>Puffs up, bright yellow flame produced</td>
<td>Gray and Swelling</td>
<td><img src="image1.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>Char Burning</strong> 800 &gt; 1200</td>
<td>Particle shrinks, mainly C &amp; Na salts</td>
<td>Hollow – White: Large or Medium reducing to Solid – White: Small or Tiny</td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>Smelt</strong></td>
<td>Molten Salts - C depleted</td>
<td>Clear Liquid or Clear with fine black particles</td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
</tbody>
</table>

**Boiler-View Clip: Swelling Particles**
Boiler-View clip: Medium to Large Particles

Boiler-View clip: Small to Tiny Particles
Is there something on the tubes?

• Yes - all fireside tube surfaces are coated
• ~ 2 mm thick below 1° and fairly uniform
• Coating either ductile or brittle

Recognition of Two Steady States

• Expanded time scale revealed two dominant temperatures:
  24 hr

• Video revealed two associated physical states:
  5 hr
  – Coated
  – Protected
  1 hr
Coated Steady State (CSS)

Very Few Particles & Bed Low:

- Tubes coated in a uniform “white” layer
- Temperatures on tube bends steady (+1 - 3°C)
- Range 390° - 410°C; Average may drift over hours
- May have clear liquid flow over surface

Example Video:

Baseline

Boiler-View clip: Coated Steady State
Protected Steady State (PSS)

Char Bed Particulate Covering Tube Bends:

- Temperature steady @~320°C
- High stable bed of compact particulate over coated thermocouples
- Particulate excluding radiation & atmosphere
- Example Video: High Bed

Boiler-View clip: Protected Steady State
What Seems to Protect Thermocouples from Radiation and Atmosphere?

- Some protection provided by coating on tubes
- Most Effective Protection:
  - A high compact bed of particles, usually grey, over coating
    -> "Char Bed" Protected Steady State (PSS)
- Two Other Conditions Approach PSS:
  - Sticky grey particles forming a layer over coating on tubes, above bed level
  - A buildup of fine black particles, produced as particles melt, washed down the tubes and deposited by liquid at bed interface

Cross Section at Thermocouple (TC)
What Items Are Not the Sole Cause of > 500°C on tube bends?

- Medium to tiny white particles landing
- Surface washed with liquid or left dry
- Bed surface rising & lowering
- Darkening surface deposits
- Primary or Secondary port rodding

Summary

- Tubes are normally coated on the fireside with a thin, adherent, white coating
- Protection of the coated tubes from radiation and atmosphere, may occur 3 ways:
  - High compact char bed against the wall (most effective)
  - Sticky particle layer on the tube surface, above the char bed
  - “Black fines” deposited to form a smooth dense dark layer
- *When the Bed was low, and the thermocouples not impacted by particulate, no temperatures above 500°C were noted*