Impact of Black Liquor Firing Characteristics on Recovery Boiler Operation

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7th Black Liquor Colloquium, Jyväskylä, Finland, July 31 – August 2, 2006
Factors That Affect Recovery Boiler Operation

The efficient operation of Kraft recovery boilers is greatly impacted by a number of factors including:

- Boiler design (aspect ratio, air system, liquor delivery system, materials, etc)

- Combustion air split and flow distribution

- Liquor quality (Heating value, viscosity, Inorganic to organic ratio, residual alkali content, swelling behavior, etc)

- Liquor firing characteristics (temperature, pressure, nozzle type, etc.)
Factors That Affect Black Liquor Sprays

- Liquor viscosity
  - Viscosity is a complex function of liquor chemistry (Alkali content, extractives, wood type), liquor solids, temperature, pulping and evaporation conditions.
- Liquor injection pressure
- Liquor nozzle type and opening size
  - Splash plates, wedge nozzles or V/U Jet nozzles
- Liquor gun angle and nozzle plate design
- Other liquor physical and chemical properties
  - Swelling behavior, soap content, inorganic to inorganic ratio, etc.
Scope of this Presentation

• Data and observations from 5 recovery boilers to assess the impact of liquor temperature, injection pressure, nozzle type and gun angles on recovery performance.

• Although, Paprican has access on data collected during optimization in 50 recovery boilers (42 in Canada and 8 in the USA).
  – Operations in 31+ of the Canadian recovery boilers, and 6 of the U. S. recovery boilers have been optimized.
  – Recovery boiler throughput was increased by 3 – 20%, while reducing the water wash frequency.
  – Optimisation is also being used in tackling the issue of material failure in Kraft recovery boilers (Primary Air Port Cracking, etc).
Performance indicators

- Amount of carryover
  - Indicator of fouling and plugging

- Chemical reduction efficiency

- Smelt quality and fluidity
  - Lack of fluidity has become a serious safety concern

- Boiler emissions (CO, SO$_2$, TRS, NOx, Particulate matter)
  - Symptomatic of other lower furnace issues

- Thermal Efficiency

- Char bed shape, size and temperature profile
  - Surrogate indicator of some of the above
# Characteristics of the Five Boilers

<table>
<thead>
<tr>
<th>Boiler</th>
<th>Type</th>
<th>Air levels</th>
<th>BLS Mlb/day</th>
<th>Solids %</th>
<th>Liquor pressure Psi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler 1</td>
<td>CE/ABB</td>
<td>3</td>
<td>4.2</td>
<td>68</td>
<td>18-24</td>
</tr>
<tr>
<td>Boiler 2</td>
<td>B&amp;W</td>
<td>3</td>
<td>3.95</td>
<td>68-70%</td>
<td>12-15</td>
</tr>
<tr>
<td>Boiler 3</td>
<td>B&amp;W</td>
<td>3</td>
<td>3.95</td>
<td>73-76</td>
<td>Up to 32</td>
</tr>
<tr>
<td>Boiler 4</td>
<td>CE/ABB</td>
<td>3</td>
<td>3.0</td>
<td>68-70</td>
<td>12-16</td>
</tr>
<tr>
<td>Boiler 5</td>
<td>CE/ABB</td>
<td>4 (2 levels of Secondary Air)</td>
<td>1.6</td>
<td>70</td>
<td>15</td>
</tr>
</tbody>
</table>
Impact of Shear Rate on Black Liquor Viscosity

Viscosity vs Shear Rate ACSFHBL- 31/01/2002 @ 68% Solids

![Graph showing the impact of shear rate on black liquor viscosity at 90°C, 100°C, and 110°C.](image-url)
Viscosity - Shear Profile at 120° C
Impact of Temperature and Liquor Solid Concentration on Viscosity

Viscosity measured at 250 s⁻¹ and for REA = 2.25%

7th Black Liquor Colloquium, Jyväskylä, Finland, July 31 – August 2, 2006
Impact of Temperature and Liquor Solid Concentration on Viscosity

Viscosity measured at 250 s\(^{-1}\) and for REA = 2.25%

7\(^{th}\) Black Liquor Colloquium, Jyvaskyla, Finland, July 31 – August 2, 2006
Effect of REA on BL Viscosity

72.2% S-fired BL at 110°C

Douglas Fir + Hemlock Black Liquor

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Impact of Liquor Temperature on Carryover

Mill 2: Splash plates; nozzles; Compromise is required between an acceptable carryover and good smelt flow and low emissions.
Impact of Liquor Pressure (Boiler 1)

![Graph showing the impact of liquor pressure on carryover across different tests.](image-url)
Impact of Liquor solids and temperature

72% solids
131 °C
210 kPa
(4 splash plates)

Carryover: 9.35 g
Flue gas temperature at bullnose: 967 °C
Bed is melting
Smelt is flowing but very viscous

75% solids
128 °C
214 kPa
(4 splash plates)

Carryover: 6.30 g
Flue gas temperature at bullnose: 905 °C
Large bed
Smelt spouts plugging

Later air flow distribution had to be modified to adjust bed shape and smelt flow.
Impact of Liquor Gun Inclination Angle on Carryover

**Boiler 2:** 4 Splash plates; 124 C; 14.5 psi; Same pattern observed at **Boilers 1 and 3**

Existence of an Optimum Gun angle?

Carryover in g/10 min vs. Liquor gun angles
Isothermal Cold Flow Velocity Profile (m/s) Before and After Optimization

Typical vertical velocity profile due to an imbalanced air flow distribution

Chimney pushed against front wall

Chimney re-centred after optimisation
Splashplate Nozzle Types

Conventional

Wedge

Different Spreading Angle
## Impact of gun angle and nozzle type on Boiler 5

<table>
<thead>
<tr>
<th>Changes</th>
<th>Carryover (g/10min)</th>
<th>Opacity</th>
<th>CO ppm</th>
<th>SO₂ ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Splash plates (F/R/B/L) -8°/-4°/-8°/-6°</td>
<td>3.5</td>
<td>44%</td>
<td>84</td>
<td>0.6</td>
</tr>
<tr>
<td>All lowered to -10</td>
<td>3.1</td>
<td>39%</td>
<td>387</td>
<td>1.2</td>
</tr>
<tr>
<td>All splash plates and -10</td>
<td>3.8</td>
<td>31%</td>
<td>44</td>
<td>9.2</td>
</tr>
<tr>
<td>Front and rear replaced by similar size wedge nozzles</td>
<td>2.2</td>
<td>44%</td>
<td>54</td>
<td>0.6</td>
</tr>
</tbody>
</table>

High opacity was found to be the result of a limited electrostatic precipitator. Splash plates were 45° plate from boiler supplier. Carryover low due to measurement location.
Wedges versus splash plates

• For same nozzle opening, wedge nozzles require higher liquor header pressure than splash plates. However nozzles resulted in lower carryover. Wedge nozzles tend to put more liquor on the boiler walls and in the corners. This may cause problems with smaller furnaces.
Nozzle arrangement For Boiler 6

Splash plate

Beer can nozzle

Splash plate

Splash plate

Beer can nozzle
## Impact of Nozzle type For Boiler 6

<table>
<thead>
<tr>
<th>Nozzle Configuration</th>
<th>Char bed T (°C)</th>
<th>Wall to Wall Max ΔT (°C) at bed</th>
<th>Flue Gas T at Tertiary air level (°C)</th>
<th>CO ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 splash plates (SP) SW liquor</td>
<td>1000</td>
<td>29</td>
<td>888</td>
<td>63</td>
</tr>
<tr>
<td>4 SP + 1 BC SW liquor</td>
<td>1037</td>
<td>28</td>
<td>863</td>
<td>NM</td>
</tr>
<tr>
<td>4 SP + 2 BC SW liquor</td>
<td>1059</td>
<td>67</td>
<td>863</td>
<td>33</td>
</tr>
<tr>
<td>4 SP + 2 BC Transition liquor (SW + HW)</td>
<td>1036</td>
<td>34</td>
<td>NM</td>
<td>66</td>
</tr>
</tbody>
</table>

“Beer can” nozzles supplied by Crenshaw Machinery for trial. Carryover was not an issue at this mill. Both types of nozzle yielded very low carryover.
Conclusion

• Many variables in black liquor firing can affect boiler operation.

• Understanding and controlling these variables can help in greatly improving boiler efficiency and throughput.
Acknowledgments

• Paprican
• Personnel at Mills 1-5
• Paprican Member Company mills