Production of Powdered Activated Carbon for Mercury Capture Using Hot Oxygen

2008 Annual ACERC Meeting
Provo, UT
Introduction

• Current focus on oxy-coal combustion is atypical of the typical use of oxygen in combustion systems

• Oxygen is usually used in combustion systems to ‘make the process better’
  — Improve efficiency (high stack temperature processes)
  — Increase throughput – often partial air replacement
  — Pollution control – Praxair’s Oxygen Enhanced Combustion for NOx control

• Activated carbon production is different in the oxy-coal flame is specifically used to create a separate product
Technology Development Drivers

• New and pending regulations will restrict mercury emissions from coal fired boilers in the U.S. and Canada

• Powder Activated Carbon shown to be effective for mercury capture
  — Doped carbons may be required with some fuels
  — Currently purchased from PAC suppliers

• Praxair process allows utilities to produce PAC onsite using the coals being fired by the plant
  — Cost reduced by ~ 40%
  — Helps ensure security of supply
**Hot Oxygen Burner**

- Patented burner is the basis of the PAC production process
- Fraction of $O_2$ burned to heat $O_2$ stream
- Hot gas exits nozzle to form high velocity jet
- Turbulent hot gas jet has high shear forces and entrainment rates
- Coal entrained into jet in mixing section
- Coal-hot oxygen mixture reacts in entrained flow reactor to form PAC

Praxair’s patented Hot Oxygen Burner
The Process

• Hot, oxygen rich, gas mixes with a pulverized feedstock and reacts in an entrained flow reactor
  — high temperature causes rapid heatup and devolatilization
  — oxidizing gas reacts with char to open pores
  — Syngas is formed

• A quench is introduced to cool the gas and solids

• Cooled particles (product) and syngas separated in a cyclone

• Syngas returned to utility boiler as fuel

• Product further cooled and sent to storage silo
  — Storage silo and injection grid is ‘standard’ equipment for activated carbon injection
Small-scale Production Rig

<table>
<thead>
<tr>
<th>Small scale system includes all key process components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Syngas Flare</td>
</tr>
<tr>
<td>Baghouse</td>
</tr>
<tr>
<td>Cyclone</td>
</tr>
<tr>
<td>Loss In Weight Feeder</td>
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<tr>
<td>Mixing Section (HOB Not Shown)</td>
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<tr>
<td>Entrained Flow Reactor</td>
</tr>
<tr>
<td>Sample Collection Drum</td>
</tr>
</tbody>
</table>
Work to Date

• Several years of optimization effort has provided insight on process
  — Key product qualities required for good mercury capture
  — Process parameters to control product quality and yield

• Previous scaling work showed process is scaleable

• Praxair approached for large samples (~1500 lb) for use in ongoing large-scale parametric testing
  — Led to over 200 hours of system operation on coal over approximately 6 weeks
  — Provided key information on long term operation of process and effect of coal type and variability
PAC Testing to Date

- Optimization using EPRI’s PoCT slipstream rig has shown steady improvement in mercury capture.
- Mercury capture >90% routinely achieved in slipstream testing with PRB-derived flue gas.
- 1 MW FF testing at SaskPower’s ECRF showed good capture on Lignite-derived flue gas.
- 1 MW ESP testing showed mercury capture rates similar to the commercial product.
Effect of Coal Type

• Utilities in general want to use the coal they have onsite

• Previous work showed good product could be produced with different coals

• Additional work done with new coals to evaluate system flexibility

• Recent work completed to understand how coal quality impacts process conditions required to produce good carbon
  — Coal type
  — Ash content and composition
  — Moisture content
## Coal Properties

<table>
<thead>
<tr>
<th></th>
<th>PRB 1</th>
<th>PRB 2</th>
<th>Bit. 1</th>
<th>Lig. 1</th>
<th>Lig. 2*</th>
<th>Lig. 3</th>
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<tbody>
<tr>
<td><strong>Ultimate Analysis</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Carbon</td>
<td>54.00</td>
<td>57.43</td>
<td>67.08</td>
<td>47.48</td>
<td>43.32</td>
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<tr>
<td>Hydrogen</td>
<td>3.90</td>
<td>3.97</td>
<td>5.03</td>
<td>3.38</td>
<td>3.07</td>
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<tr>
<td>Nitrogen</td>
<td>0.90</td>
<td>0.77</td>
<td>1.31</td>
<td>0.75</td>
<td>0.57</td>
<td>0.94</td>
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<tr>
<td>Sulfur</td>
<td>0.40</td>
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<td>0.46</td>
<td>0.83</td>
<td>0.78</td>
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<tr>
<td>Oxygen</td>
<td>13.70</td>
<td>13.46</td>
<td>10.88</td>
<td>14.25</td>
<td>11.96</td>
<td>12.15</td>
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<tr>
<td>Ash</td>
<td>6.00</td>
<td>6.00</td>
<td>12.87</td>
<td>8.33</td>
<td>26.30</td>
<td>18.70</td>
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<tr>
<td>Moisture</td>
<td>21.10</td>
<td>18.00</td>
<td>2.35</td>
<td>25.00</td>
<td>14.00</td>
<td>24.61</td>
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<td><strong>Proximate Analysis</strong></td>
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<tr>
<td>Fixed carbon</td>
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<td>44.08</td>
<td>32.70</td>
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<td>Volatile matter</td>
<td>33.4</td>
<td>34.73</td>
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* Sample ash content varied widely and much higher than normally produced at mine
Slipstream Testing Results

PRB-derived flue gas with 2 lb/MMacf injection and 4 sec residence time

Mercury Capture

- Lignite 1
- Bituminous 1
- PRB 1
Slipstream Testing Results

PRB-derived flue gas with 2 lb/MMacf injection and 2 sec residence time

Mercury Capture

Lignite 1  Lignite 2  Bituminous  PRB 1  PRB 2
Long Term System Operation

• Praxair was approached for large (~1500 lb) product samples (~1500 lb) for use in ongoing large-scale parametric testing
  — Mercury capture results to be presented by organizers/sponsors
  — Lignite 2 and PRB 2

• Samples produced in small-scale rig (~100 lb/coal per hour)
  — Led to over 200 hours of system operation on coal over approximately 6 weeks
  — Provided key information on long term operation of process and effect of coal type and variability

• Addition sample production runs are ongoing
  — Lignite 3
Learnings from Long Term Operation

- Process optimized to maximize yield and product quality
- Economic yields achievable
- Slag/ash control is critical — Primary cause of product loss
- Mixing chamber design critical

Data From PRB2 – Derived PAC Production

<table>
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<th>Parameter</th>
<th>Relative Deviation</th>
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<tr>
<td>Temperature</td>
<td>2.0%</td>
</tr>
<tr>
<td>Yield*</td>
<td>15.6%</td>
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<tr>
<td>Density</td>
<td>3.9%</td>
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</tbody>
</table>

*Process conditions intentionally changed to affect yield

Long term, stable operation achievable and β site engineering requirements identified
Reactor Temperature Response

- Reactor temperature was shown to decrease as the combustion stoichiometric ratio was decreased.

- Reactor temperature was shown to decrease as the firing rate was decreased.

Temperature follows normal combustion patterns.
Good Process Stability

- Rapid change out of sample drum (shown by spike in temperature) had relatively little impact on operation.

- Slow decrease in temperatures between drum changes due to refill cycle on feeder – not a process characteristic.

Data from typical production run with the PRB fuel.

Control parameters are well understood – allowing safe operation with wide range of coals.
Conclusions

• Process yields PAC with good mercury capture characteristics with a number of different coals
  — Variability in coal quality/type could be handled by changing process conditions

• Long term operation demonstrated
  — Process stable even with multiple restarts to empty sample drum
  — Product quality could be controlled to optimize quality and yield

• Engineering update underway for β-site plant
Acknowledgements

• SaskPower
• We Energies Pleasant Prairie
• Xcel Comanche and Pawnee
• Apogee Scientific
• EERC