Amended Silicates™ for Removing Mercury from Power Plant Flue Gas

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Presentation Outline

- ADA Mercury control experience
- Intro to Amended Silicate sorbents
- Lab test results
- Pilot test results on flue gas slipstream
- Status of development project
- Plans for commercial-scale demonstration
ADA Mercury Control History

- Nine years developing mercury control solutions
- $9 million in government and industrial funding
- Wide range of technologies conceived, developed, evaluated, commercialized
- Bench-top to pilot-scale systems designed, built, operated in the field
## ADA Mercury Control Technologies Development

<table>
<thead>
<tr>
<th>Technology</th>
<th>Gas</th>
<th>Liquid</th>
<th>Solid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disposable Sorbent</td>
<td>P,R</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>Regen. Sorbent</td>
<td>P,R</td>
<td>P,R</td>
<td></td>
</tr>
<tr>
<td>Photocatalyst</td>
<td></td>
<td>P</td>
<td></td>
</tr>
<tr>
<td>Reagent</td>
<td>C</td>
<td>P,C</td>
<td></td>
</tr>
</tbody>
</table>

**R:** Current Research and Development Project  
**P:** Pilot Demonstration  
**C:** Commercial Product
Pilot Testing of Activated Carbon for Hg Capture

- Multi-year ADA project funded by DOE
- Slipstream pilot unit installed at plant burning PRB coal
- Activated carbon injection evaluated in ESP & baghouse configurations
- Limitations of activated carbon identified
- Stimulated search for alternative sorbents at ADA
Features of Sorbents for Mercury Control

- Low capital cost
- Easy to retrofit
- Control is simple
- Minimal impact on plant operation
- Hg removal rate proportional to sorbent injection
- Applicable to all coals, some more difficult
- Ongoing need for sorbent
- Sorbent collected with fly ash
Injected Sorbents for Mercury Control

[Diagram showing the process of injecting sorbents into the boiler system to control mercury emissions.]
Amended Silicates™: A new sorbent approach

- Amended Silicates™ are inexpensive, non-carbon substrates amended with mercury-binding sites
- Silicate-based substrate, chemically similar to the native fly ash- no impact on sale of fly ash
- Sites react with elemental and oxidized mercury species to bind the mercury to the sorbent
- ADA developing two formulations funded by DOE, EPA (internal competition)
- Patent pending
Laboratory Tests of Amended Silicate™ Formulations
Simulated Flue Gas Composition for Lab Tests

- \( \text{SO}_2 \): 1,600 ppm
- \( \text{NOx} \): 400 ppm
- \( \text{CO}_2 \): 12%
- \( \text{N}_2 \): Balance
- Water vapor at 2%
- Elemental mercury vapor at 30-80 µg/m³
- No HCl in majority of tests - better simulation of Lignite flue gas
Sorbet Capacity Results

Hg Capacity (mg/g)

| Amended Silicate Formulation | CB-AA-X001 | CB-DA-X001 | CC-AA-X001 | CH-AA-X001 | CN-AA-X001 | UC-AA-X001 | UC-AA-X002 | UC-AA-X003 | UC-BA-X001 | UC-DA-X001 | UC-DA-X002 | UP-AA-X001 | UP-AA-X002 | UP-DA-X001 | UP-DA-X002 | UV-AA-X001 | UV-BB-X001 | UV-BA-X001 | UV-DA-X001 |
|-----------------------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|

Typical Carbon Capacity*
Lab Test Results

- Demonstrated mercury capacity of 2-5 times that of activated carbon
- No effect of acid gas on performance of Amended Silicate™ sorbents
- Captures elemental and oxidized mercury with equal efficiency
- Multiple variants carried forward to pilot testing
Pilot Plant for ADA AS Sorbent Evaluation

- Operates on slipstream at Xcel Energy Comanche Station
- Unit configured with baghouse for particulate control
- Temperature control of flue gas (heat or cool)
- Several injection ports to study residence time effect
- Mercury measurement upstream and downstream of injection
Initial Pilot Results

<table>
<thead>
<tr>
<th>Msmt. Condition</th>
<th>Sorbent Injection Rate (lb/MMACF)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.5</td>
</tr>
<tr>
<td>Total Hg baseline</td>
<td>7.32</td>
</tr>
<tr>
<td>Baseline Vapor</td>
<td>7.02</td>
</tr>
<tr>
<td>Pre-Baghhouse Hg</td>
<td>5.61</td>
</tr>
<tr>
<td>Post-Baghhouse Hg</td>
<td>3.26</td>
</tr>
<tr>
<td>% Removal</td>
<td>55.5%</td>
</tr>
</tbody>
</table>

Note: Concentration units [µg/Nm³]
In-Flight Hg Removal Rates

Sorbent Injection Rate (lb/MMACF)

1.4 second contact time (In-Flight) for all tests

Texas Lignite (Pilot)
PRB (slipstream)
Amended Silicates™ Impact on Fly Ash Salability

- Substrate materials are silicates, similar to fly ash composition > Expect no effect on reuse of fly ash
- Tested properties of fly ash plus sorbent at Boral
  - Prepared sample of Arapahoe ash with 0.7% sorbent (equivalent to 5 lb. sorbent/MMACF)
  - Results showed no effect on air entrainment for sorbent plus fly ash sample compared to neat fly ash sample
  - At a lower loading of activated carbon, fly ash was rendered unsalable at other test sites
Cost Impact of Lost Fly Ash Sales - 500 MW Plant

<table>
<thead>
<tr>
<th></th>
<th>Amended Silicate™</th>
<th>AC with lost fly ash sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yearly delivered sorbent</td>
<td>$3.0 Million</td>
<td>$3.0 Million</td>
</tr>
<tr>
<td>Maint., labor, power</td>
<td>$0.2 Million</td>
<td>$0.2 Million</td>
</tr>
<tr>
<td>Lost fly ash revenue</td>
<td></td>
<td>$2.6 Million</td>
</tr>
<tr>
<td>Fly ash disposal</td>
<td></td>
<td>$1.3 Million</td>
</tr>
<tr>
<td>Debt Service</td>
<td>$0.1 Million</td>
<td>$0.1 Million</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$3.3 Million</td>
<td>$7.2 Million</td>
</tr>
</tbody>
</table>
Target Markets

• Plants that wish to continue to sell collected fly ash plus sorbent
• Plants with limited lifetime→ low capital investment for mercury control
• Plants burning low-chloride coals, especially lignite and PRB
• Plants with existing or planned dry scrubbers (spray dryers)
Amended Silicate™ Development Milestones

- Identified promising sorbent formulations in lab testing - two substrate families
- Best sorbents now being tested in power plant slip stream (PRB coal)
- ADA partnered with CH2M Hill for commercialization of technology
- Optimizing sorbent preparation process
- Interest in pilot testing in coal-fired flue gas streams
- Plans for evaluation on a commercial scale
Commercial-Scale Demonstration Objectives

• Show capability to make Amended Silicate™ sorbent at ton/day rate

• Demonstrate sorbent performance at commercial scale:
  – Testing at plants that represent target markets
  – Testing on eastern bituminous, lignite and low-sulfur western coals

• Make quantities of Amended Silicate™ sorbent available for evaluation by interested parties

• Build and lead consortium to promote technology and cooperate on testing
Summary- Attributes of Amended Silicates™

• Application via injection as a dry powder: low capital-cost option
• Higher Hg-capacity than activated carbon
• Not affected by moisture or acid gas components
• No impact on the sale of fly ash as a concrete additive
• Per-lb sorbent cost equal to activated carbon, with significantly lower cost per lb mercury removed
• Performance not affected by low chlorine coals
Aknowledgements

• Development funding from US DOE, US EPA, CH2M Hill
• In-Kind contributions from Xcel Energy, Boral Materials Technologies