Using Dry Sorbent Injection to Meet the Utility MACT

Curt Biehn
Mississippi Lime Company
Overview

• Regulatory

• Options for Dry Sorbent Injection

• $\text{SO}_3$ and $\text{HCl}$ removal rate examples

• Material Handling
Regulatory Reasons for Acid Gas Mitigation (Pre-MACT)

• Offset additional SO$_3$ generated from SCR installation

• Control blue plume at stack from Wet FGD addition
  – Appearance
  – Local concerns
Regulatory
Acid Gas Mitigation Outlook

• Consent decree on Acid gases
  – Specified amount at the stack
    ➢ Limitations of Method 8A

• Particulate
  – 0.030 lb/MM Btu (filterable and condensable)

• HCl as acid gas surrogate
  – 0.002 lb/mmBTU (~3ppm)

• Consistency and OST of mitigation system will be critical
Regulatory Options to meet requirements

• Fuel switch
• Equipment additions
  – Wet ESPs
• Dry scrubber
  – Unit size
  – Fuel

Dry Sorbent Injection
Many will opt for some form of alkaline injection to neutralize the acid gases
Regulatory
Most commonly selected options for DSI

• **Hydrated lime**
  - High BET surface area (> 20 m²/g)
  - Fine particle size ($D_{50}$ of 2-4 microns)

• **Trona**
  - Larger particle size (40-60 microns)
  - On site milling to 15-25 microns
Questions to answer

• Where are you and where do you have to get with pollutants?
  – Potential side benefits of acid gas mitigation

• What will your injection system look like?
  – Expectations on Operations and Maintenance

• Implications of sorbent choice
  – Supply
  – Logistics
  – Ash
**Removal - Consider working your way backwards**

**Example for SO$_3$ mitigation**

- **Stack limit:** 5 ppm maximum

**Diagram:**
- **Boiler**
- **SCR**
- **APH**
- **Particulate Collection**
- **FGD**
- **Sorbent**

**Inlet Concentrations:**
- **APH inlet:** 8-13 ppm
- **Part. Coll inlet:** 7-10 ppm
- **wFGD inlet:** 6-8 ppm SO$_3$
Removal
Consider additional benefits of early removal

• Pre-SCR
  – Minimum operating temperature
  – Reduce arsenic poisoning of catalyst (calcium)

• Pre-APH
  – Corrosion protection
  – ABS control
  – Heat rate

• Particulate collection
  – Corrosion
  – Operational

• Wet FGD
  – Corrosion
  – Effects of HCl on scrubber and wastewater treatment
ESP - “It depends…”

• Some SO$_3$ aids resistivity of ash
• Ash resistivity
  – Sodium reduces; Calcium increases
• Unit specific issues
  – Existing ash properties
  – ESP size and efficiency
    ➢ Particulate loading with added sorbent
  – Residence time
    ➢ Short -> more sorbent
    • Manage with split injection?
  – Best to test

• Lodge Cottrell presentation from 2011 APC conference
  – Reinholdenvironmental.com library section
Air Preheater

Moving sorbent injection up in the process offers additional benefits:

- **Better utilization of sorbent**
  - Longer reaction time

- **APH operation**
  - Eliminate ABS buildup from ammonia slip
  - Flexibility on SCR operation

- **Lower heat rate**
  - Reduce acid dew point through APH

Courtesy BreenES
Using Sorbent Prior to APH

• Neutralization of SO$_3$ will occur at Pre-APH temperatures
• Sodium sorbents:
  – Byproducts and intermediates can form without temperature and concentration control
  – URS reported on Pre-SCR injection of SBS

• Calcium sorbents
  – No issues with reaction byproducts or intermediates
  – Multiple trials of Pre-APH since ’09
  – Utility – Pre-APH since 2010
    ➢ No issues reported
Hydrated Lime Data
Pre-APH removals from 2009 trial

- Injection of hydrate at SCR outlet
  - 2 sec residence time before first Breen probe (Pre-APH)
  - Post-APH Breen probe

- Took periods of stabilized operation of feed system and boiler
  - Varied from 1-24 hours
  - Averaged data from Breen probes
  - Hydrate feed rates varied
    - Stoich ratios from 3 to 6 mol Ca/mol SO$_3$
    - Unit load varied as well
Demonstrated Reductions Using In-line Breen Probes

- Good reduction from injection point to Pre-APH measurement point
- In-flight capture results are very good

<table>
<thead>
<tr>
<th></th>
<th>$SO_3$ (ppm)</th>
<th>% Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-APH</td>
<td>Post-APH</td>
</tr>
<tr>
<td>baseline</td>
<td>31.5</td>
<td>22.5</td>
</tr>
<tr>
<td>With hydrate</td>
<td>2.7</td>
<td>&lt;1</td>
</tr>
<tr>
<td>treatment</td>
<td>2.9</td>
<td>&lt;1</td>
</tr>
<tr>
<td></td>
<td>3.8</td>
<td>&lt;1</td>
</tr>
<tr>
<td></td>
<td>4.4</td>
<td>1.1</td>
</tr>
<tr>
<td></td>
<td>3.2</td>
<td>&lt;1</td>
</tr>
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</table>
Removal Rates
Full Scale $SO_3$ Mitigation with Hydrated Lime

Stack to Stack Removal Rates

SO$_3$ Removal % with Hydrated Lime
(stack to stack comparison)

SO$_3$ Contact: Residence time, location, temperature, duct dispersion, SO$_3$ concentration

Charge by volume or weight?

Measurement:
Stack to stack or removal from inlet SO$_3$?
Testing protocol?
## SO$_3$ Mitigation with Hydrated Lime

### Individual Examples

<table>
<thead>
<tr>
<th>Plant</th>
<th>Location</th>
<th>SO$_3$ APH</th>
<th>SO$_3$ Untreated Stack</th>
<th>mol Ca: mol SO$_3$</th>
<th>lb Ca: lb SO$_3$</th>
<th>Removal Stack</th>
</tr>
</thead>
<tbody>
<tr>
<td>550 MW</td>
<td>Pre-Wet FGD</td>
<td>20 ppm</td>
<td>12 ppm</td>
<td>4.2 : 1</td>
<td>3.9 : 1</td>
<td>92%</td>
</tr>
<tr>
<td>1300 MW</td>
<td>Pre-ESP</td>
<td>30 ppm</td>
<td>20 ppm</td>
<td>4.2 : 1</td>
<td>3.9 : 1</td>
<td>83%</td>
</tr>
<tr>
<td>704 MW</td>
<td>Post-ESP</td>
<td>35 ppm</td>
<td>21 ppm</td>
<td>3.8 : 1</td>
<td>3.5 : 1</td>
<td>83%</td>
</tr>
<tr>
<td>1150 MW</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Case Study -
High Opacity with pre-ESP injection

- Cold side ESP not capable of handling of sorbent injection / increased loading
  - Cyclone-fired boiler
    - ESP designed for ~20% fly ash
  - Sorbent injection increases ash by another 5%
    - Overwhelms ESP (since designed for low fly ash loading)
    - Opacity concerns

- Injected hydrated lime post ID fan, after the ESP
  - Achieved good removal of SO$_3$
  - Stack particulate emissions were not negatively affected

<table>
<thead>
<tr>
<th>Load (MW)</th>
<th>NSR</th>
<th>Stack Particulate (lb/MMBtu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1039</td>
<td>2.54</td>
<td>x</td>
</tr>
<tr>
<td>1030</td>
<td>4.75</td>
<td>0.40x</td>
</tr>
</tbody>
</table>

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## Baghouse Removal Data

- Midwestern Utility; med-high sulfur coal
- Injection post APH using temporary injection system
- Test runs measured at baghouse outlet

<table>
<thead>
<tr>
<th></th>
<th>Content, ppm</th>
<th>Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$SO_3$</td>
<td>$HCl$</td>
</tr>
<tr>
<td><strong>baseline inlet</strong></td>
<td>25</td>
<td>24</td>
</tr>
<tr>
<td><strong>baghouse outlet</strong></td>
<td>16</td>
<td>22.5</td>
</tr>
<tr>
<td><strong>lb Ca: lb SO$_3$</strong></td>
<td>2.15</td>
<td>4.9</td>
</tr>
<tr>
<td></td>
<td>2.70</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>3.24</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>

Reduced sorbent usages vs ESP

**Lower emissions**
Baghouse Follow-up Testing
Mercury and HCl

• Hg Removal = ~ 40% removal from coal to Particulate Collection outlet (no carbon injection)
  – 3% LOI
  – Baseline (no hydrate injection, 2008): No Hg removal with 10% LOI

• HCl Removal (SCR outlet ~45 ppm Cl)
  – Under typical conditions of 3 – 4 Ca / S ratios, little HCl removal was detected
  – On over-injection conditions (mid-load, high Ca / S ratios), some HCl removal in flight was detected, about 20 – 30%.
  – Similar to results from a Southern Co. test program at Mercury Research Center
Hydrated Lime for HCl Removal
Trial at Shawnee

Summary from report by Brian Williams (TVA) to PCUG, July 2011
Hydrated Lime Injection Demonstration

Goals

- Low Cost HCl Control Desired to Avoid Expediting Scrubber Installation

- Hydrated Lime Injection Testing Program Chartered to:
  - Determine if Hydrated Lime Injection System can Achieve Proposed HAPs HCl Limits
  - Evaluate BOP Impacts on Baghouse and Ash Removal System if Lime Injection Reduces HCl Emissions
  - Evaluate Additional Total Particulate Margin Recovered from Reduced Condensable PM
    - Provides Filterable PM Margin to Allow Maximum Usable Bag Life (current bag life ~ 8 years per unit)

- **CHALLENGING TEST** – The Last Few PPMs Are The Hardest To Remove
Project Overview and Regulatory Drivers

Shawnee Plant Background

- Nine (9) 150-MW wall-fired units equipped with Baghouses
- Currently Burning up to 50% PRB Blended with Low Sulfur Colorado Coal
- Unit 6 Holds National Continuous Run Record of 1,093 days set in 2006

<table>
<thead>
<tr>
<th>Emission</th>
<th>Proposed HAPs Limit</th>
<th>Shawnee U6-10 Stack Baseline (05/2011)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Particulate (lb/MMBTU)</td>
<td>0.03</td>
<td>0.016 Total</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.004 filterable</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.012 condensable</td>
</tr>
<tr>
<td>Mercury (lb/TBTU)</td>
<td>1.0</td>
<td>&lt; 0.5</td>
</tr>
<tr>
<td>Acid Gas Surrogate - SO₂ OR HCl (lb/MMBTU)</td>
<td>0.2 SO₂ OR 0.002 HCl</td>
<td>0.63 SO₂ 0.003 HCl</td>
</tr>
</tbody>
</table>
Emissions Control

- HCl controlled, especially after one day seasoning of baghouse
- No balance of plant impacts in baghouse operations
- Particulate emissions reduced by 44%

<table>
<thead>
<tr>
<th>Hydrate Injection Rate</th>
<th>HCl (lb/MMBTU)</th>
<th>HF (lb/MMBTU)</th>
<th>H$_2$SO$_4$ (ppmvd)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 lb/hr - Baseline</td>
<td>0.0030</td>
<td>0.0045</td>
<td>1.3</td>
</tr>
<tr>
<td>350 lb/hr</td>
<td>0.0005</td>
<td>0.0006</td>
<td>0.37</td>
</tr>
<tr>
<td>350 lb/hr</td>
<td>0.0007</td>
<td>0.0007</td>
<td>0.35</td>
</tr>
<tr>
<td>300 lb/hr</td>
<td>0.0008</td>
<td>0.0006</td>
<td>0.35</td>
</tr>
</tbody>
</table>
Objective 2 - Balance of Plant Impacts

Baghouse and Ash System Performance – No Issues Identified

- Full Pressure Loss Recovery Achieved (~4.4 in H₂O,g)
- The DP Cleaning Cycle Dwell Time Shortened (~2hrs to ~1.5 hrs) as expected
- No Ash Handling System Impacts (Hoppers Pulling Empty)
Conclusions and Path Forward

• Shawnee can achieve compliance with proposed HAPs regulations via a low cost hydrated lime injection system
  – Postpones unit idling/retirement or FGD installation.

• Hydrated Lime System
  – Can later be used with SCR installation to mitigate SO$_3$
  – Consider longer term (~2 month) demonstration on temporary system with HCl CEMS
    ➢ Longer-term BOP issues
    ➢ Process variability to minimize project and operational risk.

• Consider Clean Air Strategy changes at other sites slated for dry scrubbers.
Material Handling
Dense vs. Dilute Phase Conveying

• Dense Phase Conveying
  – Material: Air of 99 to 6.2 (two phase) or 1,239 to 62 (piston) lbs material/lb of air
  – Truck Unloading

• Dilute Phase Conveying
  – Material: Air 6.2 to 0.10 lbs material/lb of air
  – Pneumatic Injection Systems

Source: Solt, P. E., Pneumatic Points to Ponder, Powder and Bulk Engineering
Dry Sorbent Injection System

- Flue injection performed at multiple ports in each injection location
- Sites can injection in one or multiple locations
- System OST and flue coverage are key for high removal rates

Residence time
System Installation

• Wet air
  – Conveying
  – Rotary Airlock seals

• Piping joints
  – Shelf

• Field modifications
  – Added bends
Design Challenges – Understanding Air Dilute Phase Systems

• Flue coverage
  – High # of injection lances

• Two sorbent option
  – Different properties and system requirements

• Alternate fuels
  – Oversized equipment

• Inflexible equipment
  – Single speed blowers

• Conveying distance and pathway
  – # of bends require increased air
Questions

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Possible Explanations for Reduced PM Measured During Hydrated Lime Testing

- Triboelectric theory (Observed at Widows Creek, etc.)
  - Friction causes particles to become charged
  - One material positively charged, other material negatively charged
  - Fly ash (alumina and silica oxides) are typically negative
  - Hydrated lime, pneumatically conveyed, should be positive
  - Opposite charges attract, agglomerating fine particulate
- Measurement of Condensables on Particulate Filters (at Paradise)
  - Prescribed filter bake times do not eliminate all acid condensables
  - Baseline PMs include high acid concentrations
  - Hydrated lime injection PMs reduce acid on filters, lowering PMs
- Combination of the above and other unknown effects