Post-Combustion Dry Reagent Injection For Acid Gas Mitigation Boilers and Cement Kilns
Discussion

- Trona Basics
- Mobile DRI Systems
- Results
  - 550 MW Utility Boiler
  - 150 kpph Industrial Boiler
  - 950 tpd Cement Kiln
Dry Reagent Injection

**Trona**

SO$_2$ Stoic Ratio = 2.35 lb trona/lb SO$_2$

HCl Stoic Ratio = 2.07 lb trona/lb HCl

\[ \text{Na}_2\text{CO}_3 \cdot \text{NaHCO}_3 \cdot 2\text{H}_2\text{O} \]
Dry Reagent Injection

**Normalized Stoichiometric Ratio (NSR)**

\[
NSR = \left( \frac{\text{mass of trona injected}}{\text{mass of acid gas entering system}} \right) \times \left( \frac{\text{stoichiometric mass of trona}}{\text{unit mass of acid gas}} \right)
\]
Parameters Affecting Acid Gas Removal by DRI

- Sorbent particle size (trona as received – 35 µm D50)
- Sorbent residence time in the flue gas stream
- Sorbent dispersion within the flue gas
- Particulate control device used
- Other acid gases (e.g., high SO2 concentration)

SO2 %RE and NSR are functions of these parameters
Mobile DRI Systems

- Modular – setup in 1 – 2 days
- Milling on-site
- Silos
- Bulk Trailers
- Supersack systems
550 MW Utility Boiler w/ ESP - SO₂/HCl vs. NSR

- Up to 18 tons/hr
- In-line Milling
- D₅₀ to 12 µm
- Removed 1,950 lb/hr SO₂ at max rate
Dry Reagent Injection

**550 MW Coal w/ESP - Trona Feed Rate vs. HCl %RE**

- **HCl Removal Efficiency**
- **HCl (lb/MMBtu)**
- **EU MATS HCl Limit = 0.002 lb/MMBtu**

### Graph Details:

- **Y-axis:** HCl Removal Efficiency (%)
- **X-axis:** Avg. Sorbent Feed Rate (lb/hr)
- Data points indicate the relationship between HCl removal efficiency and the feed rate of the sorbent (trona).
- A horizontal line at 0% HCl removal efficiency represents the EU MATS HCl Limit.

The graph visualizes how varying feed rates affect HCl removal efficiency, highlighting the optimal feed rate for HCl removal efficiency within the EU MATS HCl Limit.
Dry Reagent Injection

SO$_2$ and HCl Removal vs. Trona Injection Rate
150 kpph Boiler Biomass/SW with ESP

SO$_2$ Removal Efficiency

HCl Limit = 10 tpy

400 lb/hr Injection Rate

2.5 tpy

Trona Rate [lb/hr]

SO$_2$  HCl

0  200  400  600  800  1000  1200

0  20  40  60  80  100%

0.0  5.0  10.0  15.0  20.0  25.0  30.0  35.0

HCl [ton/yr]

2.5 tpy

SOUTHERN AIR SOLUTIONS CORP

EDMONTON, AB
Dry Reagent Injection

PM Emissions vs. Trona Injection Rate
150 kpph Steam Boiler with ESP

PM Limit = 0.029 lb/MMBtu

400 lb/hr Injection Rate
Dry Reagent Injection

PM Emissions and HCl Removal vs. Trona Injection Rate
150 kpph Boiler with ESP

PM Limit = 0.029 lb/MMBtu
HCl Limit = 10 tpy

0.025 lb/MMBtu PM
2.5 tpy HCl

HCl (ton/yr)

PM (lb/MMBtu)

Trona Rate (lb/hr)

HCl  FPM

SOUTHERN AIR SOLUTIONS CORP
SO\textsubscript{2} and HCl Removal vs. Trona Injection Rate
150 kpph Boiler Biomass/SW with ESP

- 2.5 tpy HCl
- \approx 25\% additional SO\textsubscript{2} Removal
Milled Trona SO2 %RE vs. NSR for Cement Kiln with FFBH

Removal Efficiency (%) vs. NSR

- Red line: SO2
- Green line: HCl by M26A
## Dry Reagent Injection

<table>
<thead>
<tr>
<th>Operating Unit</th>
<th>Kiln A</th>
<th>Kiln B</th>
<th>Kiln C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sorbent</td>
<td>Trona</td>
<td>Trona</td>
<td>Trona</td>
</tr>
<tr>
<td>APCD</td>
<td>FFBH</td>
<td>FFBH</td>
<td>FFBH</td>
</tr>
<tr>
<td>Moisture Content at Stack (%vol)</td>
<td>33.5%</td>
<td>11.5%</td>
<td>16.0%</td>
</tr>
<tr>
<td>SO\textsubscript{2} at Stack (ppmvd)</td>
<td>900</td>
<td>110</td>
<td>300</td>
</tr>
<tr>
<td>HCl at Stack (ppmvd)</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Flue Gas Temperature (F)</td>
<td>350</td>
<td>310</td>
<td>310</td>
</tr>
<tr>
<td>Flue Gas Flow Rate (acfm)</td>
<td>160,000</td>
<td>220,000</td>
<td>150,000</td>
</tr>
<tr>
<td>Flue Gas Flow Rate (scfm)</td>
<td>104,691</td>
<td>151,429</td>
<td>103,247</td>
</tr>
<tr>
<td>Flue Gas Flow Rate (dscfm)</td>
<td>69,620</td>
<td>134,014</td>
<td>86,727</td>
</tr>
<tr>
<td>Clinker Produced (ton/day)</td>
<td>950</td>
<td>1,100</td>
<td>1,900</td>
</tr>
<tr>
<td>CKD Collection Rate (ton/hr)</td>
<td>5.0</td>
<td>3.5</td>
<td>6.0</td>
</tr>
<tr>
<td>CKD Recycled (%)</td>
<td>40%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>SO\textsubscript{2} (lb/hr)</td>
<td>625.0</td>
<td>147.0</td>
<td>259.5</td>
</tr>
<tr>
<td>HCl (lb/hr)</td>
<td>5.93</td>
<td>11.42</td>
<td>12.32</td>
</tr>
<tr>
<td>HCl (ppmvd @ 7% O\textsubscript{2})</td>
<td>14.0</td>
<td>14.0</td>
<td>23.3</td>
</tr>
<tr>
<td>HCl - %RE required to Comply with PC MACT</td>
<td>79%</td>
<td>79%</td>
<td>87%</td>
</tr>
</tbody>
</table>
Dry Reagent Injection

Milled Trona SO2 %RE vs. NSR for Cement Kiln with FFBH

Removal Efficiency (%) vs. NSR

- SO2
- HCl by M26A
## Dry Reagent Injection

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<th>Kiln C</th>
</tr>
</thead>
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<tr>
<td>SO₂ NSR Required</td>
<td>0.45</td>
<td>0.45</td>
<td>0.45</td>
</tr>
<tr>
<td>SO₂ - Corresponding %RE</td>
<td>40%</td>
<td>40%</td>
<td>40%</td>
</tr>
<tr>
<td>TOTAL TRONA NEEDED (lb/hr)</td>
<td>672</td>
<td>176</td>
<td>297</td>
</tr>
<tr>
<td>Clinker Production (lb/hr)</td>
<td>79,167</td>
<td>91,667</td>
<td>158,333</td>
</tr>
<tr>
<td>CKD Recycled (%)</td>
<td>40%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>CKD Rate Recycled (lb/hr)</td>
<td>4,000</td>
<td>7,000</td>
<td>12,000</td>
</tr>
<tr>
<td>Na₂SO₄ Formed (lb/hr)</td>
<td>555</td>
<td>130</td>
<td>230</td>
</tr>
<tr>
<td>NaCl Formed (lb/hr)</td>
<td>10</td>
<td>18</td>
<td>20</td>
</tr>
<tr>
<td>Na from Trona Into CKD (lb/hr)</td>
<td>82</td>
<td>54</td>
<td>91</td>
</tr>
<tr>
<td>Na Recycled to Kiln (lb/hr)</td>
<td>33</td>
<td>54</td>
<td>91</td>
</tr>
<tr>
<td>Na In Clinker from Trona (%wt)</td>
<td>0.041%</td>
<td>0.059%</td>
<td>0.057%</td>
</tr>
<tr>
<td>Na₂O Equivalent in Clinker from Trona (%wt)</td>
<td>0.056%</td>
<td>0.079%</td>
<td>0.077%</td>
</tr>
</tbody>
</table>
Considerations

- Failed fly ash TCLP for selenium
  - High Se bearing coal
  - High trona injection rates
- Greatly reduced trona usage with baghouse
- Plume coloration at high trona injection rates (NO2)
- Can boost native Hg removal
- Can increase Hg emissions
- Inorganic CPM emissions increase (CPM expected to be regulated from EU boilers as PM2.5)
- Land-filling considerations
Conclusions

- Trona has high reactivity with HCl and SOx compounds
- Greatly reduced trona usage with baghouse and milling
- Trona can be a solution for EU MATS and Boiler MACT for HCl
- For moderate to low SO2 flue gases trona may be a solution for PC MACT compliance for kilns recirculating up to 100% of CKD
- For high SO2 flue gases trona may be a solution but may require wasting more CKD