Bundling Technologies for Cost-effective NO\textsubscript{x} Control

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March 26, 2015
Changing NO\textsubscript{x} Control Market

- New limits may involve installation of advanced combustion controls and/or SNCR, \textit{but}
- Some units being forced as low as 0.05 lb/MMBtu NO\textsubscript{x}, often leaving choice between SCR and retirement
- SCR is less desirable because marketplace has changed
  - Lower baseline NO\textsubscript{x} and lower capacity factors make SCR less cost-effective
  - Large capital investments are no longer desirable due to market uncertainties
- Life extension need of existing fleet requires cost-effective alternatives to SCR
Non-SCR NO\textsubscript{x} Reduction Strategy

- Minimize baseline emissions by applying advanced combustion controls, as ROFA\textsuperscript{®} and Rotamix\textsuperscript{®} at Fiddler’s Ferry

- Implement LoTOx\textsuperscript{™} (low-temperature ozone injection) to achieve cost-effective “SCR-like” NO\textsubscript{x} emissions
Unit Description

- SSE’s Fiddlers Ferry Unit 2 in UK
- 500 MWe supercritical unit
- Twin tangential furnace
- Equipped with CCOFA and SOFA
- Burning blends of Columbian, Russian, and U.S. coal
- Baseline Avg. NOx: 0.44 lb/mmBtu
## Operating Conditions and Fuel Analysis

<table>
<thead>
<tr>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Firing Rate (based on NCV)</td>
<td>[MW\textsubscript{th}]</td>
</tr>
<tr>
<td>System Load</td>
<td>[MW\textsubscript{e gross}]</td>
</tr>
<tr>
<td>System Excess Air</td>
<td>[%]</td>
</tr>
<tr>
<td>System Excess O\textsubscript{2}</td>
<td>[% dry]</td>
</tr>
<tr>
<td>System Excess O\textsubscript{2}</td>
<td>[% wet]</td>
</tr>
<tr>
<td>System Fuel Flow</td>
<td>[kg/s]</td>
</tr>
<tr>
<td>System Air Flow</td>
<td>[kg/s]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>[%wt]</td>
</tr>
<tr>
<td>Ash</td>
<td>[%wt]</td>
</tr>
<tr>
<td>Volatile Matter</td>
<td>[%wt]</td>
</tr>
<tr>
<td>Fixed Carbon</td>
<td>[%wt]</td>
</tr>
<tr>
<td>Carbon</td>
<td>[%wt]</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>[%wt]</td>
</tr>
<tr>
<td>Oxygen</td>
<td>[%wt]</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>[%wt]</td>
</tr>
<tr>
<td>Sulphur</td>
<td>[%wt]</td>
</tr>
<tr>
<td>Chlorine</td>
<td>[%wt]</td>
</tr>
<tr>
<td>GCV</td>
<td>[kJ/kg]</td>
</tr>
<tr>
<td>NCV</td>
<td>[kJ/kg]</td>
</tr>
</tbody>
</table>
Integrated NOx Reduction System

- Rotating Opposed Fire Air (ROFA)
  - Two ROFA fans
  - 12 ROFA boxes
  - Modulated dampers
  - Ductwork
- Rotamix SNCR
  - Rotamix fan
  - Rotamix boxes
  - Urea solution handling and dilution
  - Injection lances and devices
- Burner modifications
- Keep existing SOFA/CCOFA

Presented at Reinhold Environmental 2015 NOx/Combustion Round Table & Expo
**17-Days Trial Test Results**

- NOx reduced from around 0.44 lb/mmBtu to below 0.16 lb/mmBtu. Averaged NOx after modifications is 0.153 lb/mmBtu.
- CO reduced from up to 1000 ppm to below 400 ppm.
LoTOx® NO$_x$ Control Technology

- Low-temperature oxidation
- Offered by Linde Group
- NO$_x$ scrubbing
- Widely used in refining industry with ~30 FCCU installations
- 25 MW coal-fired institutional boiler installation
- EPRI pilot demonstration at Coal Creek
- 90% NO$_x$ removal

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Reaction Kinetics

- **NO\(_x\) scrubbing**
  - Inject ozone downstream of air heater
  - Convert insoluble NO\(_x\) to highly-soluble N\(_2\)O\(_5\)
  - Requires ½ second residence time at 300ºF
  - Capture in scrubber

- **No SO\(_2\) oxidation to SO\(_3\)**

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Rate constants @ 25ºC</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO + O(_3) ⇒ NO(_2) + O(_2)</td>
<td>62,500</td>
</tr>
<tr>
<td>2 NO(_2) + O(_3) ⇒ N(_2)O(_5) + O(_2)</td>
<td>125</td>
</tr>
<tr>
<td>CO + O(_3) ⇒ CO(_2) + O(_2)</td>
<td>1</td>
</tr>
<tr>
<td>SO(_2) + O(_3) ⇒ SO(_3) + O(_2)</td>
<td>5</td>
</tr>
</tbody>
</table>
Performance and Operational Advantages

- **NO\textsubscript{x} Performance**
  - Capable of 90% removal
  - Select % removal by treating fraction of gas flow

- **Multi-pollutant control**
  - 50-70% Hg oxidation
  - Offset CaBr\textsubscript{2} addition rate

- **Ozone supply flexibility**

- **Advantage over SCR**
  - No MOT constraints
  - No AH fouling
  - No catalyst deactivation
Utility Boiler Applications - What’s Changed?

- Lower NO$_x$ baselines
- Smaller units
- Reduced capacity factors
- Improved utilization of oxygen in ozone production
- More flexible ozone delivery options
- Effluent regulations driving more plants to ZLD
- FCCU long-term operation
'Over the Fence' Ozone Supply Cost Model

Plant supplies electricity to gas company under multi-year contract to supply ozone

- Low NOx Burners (20-30%)
- Over Fire Air (25-35%)
- SNCR/Rotamix (15-35%)
- LNB + OFA (35-45%)
- ROFA (45-65%)
- ROFA + Rotamix (65-80%)
- ROFA + Rotamix Combined with LoTOx (80-95%)
- SCR (70-90+%)

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Summary and Conclusions

- Non-SCR boilers are being pushed to further reduce NO\textsubscript{x} emissions
- ROFA and Rotamix are cost-effective, but cannot achieve SCR-like emissions reductions
- LoTOx is best-suited to applications with low baseline NO\textsubscript{x} emissions
- The combination of ROFA and LoTOx provides a cost-effective alternative to SCR, with fewer operational constraints

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