McIlvaine
NOx Reduction Innovations for Coal Fired Plants

Mark Ehrnschwender
November 6th, 2014
STEAG Group

STEAG GmbH

- Power Operations and Engineering Services
  - Power O&M services Worldwide
  - Operations in India, Spain, Brazil, Colombia, Philippines, etc.
  - Ownership & Operations of solar, wind, fossil fuel, natural gas, biogas and geothermal
  - Over 20,000 MW's of operation worldwide

STEAG Energy Services GmbH

- Engineering and Consulting Services
  - Complete Plant Integration Services
  - Owners A/E Services
  - Operations in Europe, India, Turkey, South Africa and the US

STEAG Energy Services LLC

- Engineering and Consulting Services (USA)
  - Worldwide STEAG group NOx Expert
  - HQ and Plants in NC - Offices in PA, IL, DC
  - 500,000 ft² of warehouse space
  - 60,000 m³ regenerated, 4,000 XRF’s annually,
  - 2 x 2013 VGB certified bench scale reactors
**The Basics**
The SCR Catalyst / Reactor

**Catalyst Oxidation Reactions**
- NOx Reaction - \( \text{NH}_3 + \text{NO (NO}_2) \rightarrow \text{H}_2\text{O} + \text{N}_2 \)
- SOx Reaction – \( \text{SO}_2 + \text{O}_2 \rightarrow \text{SO}_3 \)
- Mercury Reaction – \( \text{Hg} + \text{O}_2 \rightarrow \text{HgO} \)

**Where / When do the reactions occur?**
- NOx Reaction – Quick Reaction
- SOx Reaction – Slow Reaction
- Mercury Reaction – Quick Reaction – NO\(_x\) is preferential

**What is STEAG Doing on it’s Units for Mercury**
- Primary Mercury oxidation is layer
- Secondary is Bromide Addition
- Re-emission is by PAC into the FGD Unit
“The Basics”
Catalyst Regeneration

- Chemically removing De-activating compounds

Small Fly Ash Particles
Dense Second-phase Coating
Pore System
Catalyst Surface
Active Sites

i.e. Fly Ash
i.e. Calcium, Magnesium
i.e. Arsenic, Phosphorus, Sodium, Potassium

PRB

- Removal of Chemicals and Ions from Catalyst
- Addition of the activating compound (Vanadium) and strength metals (Tungsten or Molybdenum) back onto the catalyst
“The Basics”
Longevity of Catalyst

- STEAG has catalyst that has been regenerated 7 time (26 years in operation)
- What should a customer buy?

<table>
<thead>
<tr>
<th></th>
<th>Honeycomb</th>
<th>Plate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall Thickness</td>
<td>&gt; 0.8 mm</td>
<td>&gt; 0.7 mm</td>
</tr>
<tr>
<td>Tungsten or Molybdenum</td>
<td>&gt;7%</td>
<td></td>
</tr>
<tr>
<td>Metal Substrate</td>
<td>N/A</td>
<td>Austenitic Stainless</td>
</tr>
</tbody>
</table>

- Anything less will lead to throw away catalyst!
- Catalyst Disposal Issues:
  - Ash disposed of as non-hazardous (40 CFR)
  - Ceramic Material Non-hazardous
  - Metal recycled. China working on ceramic recycle
  - Future CCP could affect this!
Innovation:
Co-coupling of SCR & SNCR

STEAG is working on Strategy on STEAG units for co-coupling of SNCR with SCR.

- Need for additional removal on STEAG units 60% to 80% or 80% to 90%.

<table>
<thead>
<tr>
<th>Case 1: Stretching the SCR</th>
<th>Case 2: Stretching the SCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>No SNCR</td>
<td>Typical SNCR</td>
</tr>
<tr>
<td>Boiler Inlet</td>
<td>250</td>
</tr>
<tr>
<td>SNCR Reduction</td>
<td>0%</td>
</tr>
<tr>
<td>SCR Inlet</td>
<td>250</td>
</tr>
<tr>
<td>SCR reduction</td>
<td>60%</td>
</tr>
<tr>
<td>NOx Outlet</td>
<td>100</td>
</tr>
<tr>
<td>Total Reduction</td>
<td>60%</td>
</tr>
</tbody>
</table>

How to achieve 50% reduction with SNCR?

- More injectors
- Live CFD modeling (STEAG Powitec System)
Innovation:
In-situ Dry Cleaning in the Reactor

United States Patent No 8,268,743 B2

<table>
<thead>
<tr>
<th>Removal Systems</th>
<th>Benefits</th>
<th>Challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vacuuming</td>
<td>Large ash removal</td>
<td>Top ash only</td>
</tr>
<tr>
<td>Air Lancing</td>
<td>Mechanical/light ash removal</td>
<td>Only 4-6 inches of pluggage removal</td>
</tr>
<tr>
<td>Mechanical Shakers</td>
<td>Large ash removal</td>
<td>On-site plate removal&lt;br&gt;Honeycomb “verboten”</td>
</tr>
<tr>
<td>Reactor Shakers</td>
<td>Large ash removal</td>
<td>Unknown long-tern reactor effects</td>
</tr>
<tr>
<td>Scraping / Poking</td>
<td>Mechanical/light ash removal</td>
<td>Damages the catalyst surface – Logs normally need to be replaced before regeneration</td>
</tr>
<tr>
<td>High Pressure Wash</td>
<td>Large ash removal</td>
<td>Water reacts with SO₃ to form sulfuric acid, which deteriorates the metal substrate in plate, solidifies any remaining ash and releases iron oxide in ash to increase SO₂/SO₃ conversion rate</td>
</tr>
<tr>
<td>Dry Ice Blasting</td>
<td>Mechanical cleaning for all types of catalyst</td>
<td>Unable to undo damages caused by other cleaning techniques</td>
</tr>
</tbody>
</table>

- Most effective and very safe cleaning method
- Our process has reduced pluggage from 100% down to < 5%
- Savings in Pressure Drop alone provides 6 to 8 month payback
- Successful performed on all Catalyst Types
• **Catalyst Re-calcination**
  - Heat treatment above 800 °F but below 850 °F
  - Time is 9 to 12 hours
  - Regain strength, bond material and eliminate inherent water

• **Single Impregnation of Vanadium (activating compound) with tungsten or molybdenum (strength metals)**

• **Mercury Testing**
  - STEAG has acquired the testing facility from Martin Luther University (Halle-Wittenberg) – Research before 2002
  - STEAG continues the work and has several testing contracts

• **What is STEAG doing on it’s Units for Mercury**
  - Primary Strategy - Mercury oxidation is lower layer of catalyst
  - Secondary Strategy – Trim with Bromide Addition
  - Capture Oxidized Mercury in the wFGD with Re-emission is by PAC into the FGD Unit
  - STEAG has Patented Mercury removal technology for wFGD water