SCR Catalyst Selection and Management for Improved Hg Oxidation Performance

Christopher T. Reeves, Christopher J. Bertole, Chris E. DiFrancesco, Scot G. Pritchard, Katsumi Nochi
Cormetech, Inc.
Background

- SCR co-benefit for Hg oxidation is a key component of MATS Hg compliance strategies.
- Catalyst management now has to consider Hg oxidation performance threshold along with DeNOx performance.
- Catalyst management for Hg oxidation is analogous to DeNOx
  - added complexity due to the nature of Hg oxidation kinetics.
- COMET™ technology
  - Characterization and modeling tools
  - Advanced Hg oxidation catalyst
  - Tools for analyzing and defining catalyst management strategies.
Key Differences for Hg vs. NOx
More Factors Influence Hg Oxidation

DeNOx
– Key Parameters
  • NOx inlet
  • Efficiency
  • Slip
  • Temperature
  • O₂, H₂O, SO₂ (lower impact)
  • SO₂ conversion (formulation)
  • Fuel → contaminants → K/Ko
  • Reactor condition

Hg
– Key Parameters
  • Hg oxidation → Performance Threshold
  • NOx inlet
  • Efficiency
  • Slip
  • Layer position (NH₃)
  • Halogen (Fuel or additive)
  • Temperature
  • CO
  • O₂, H₂O, SO₂ (can be larger impact)
  • SO₂ conversion (formulation)
  • Fuel → contaminants → K/Ko
  • Reactor condition
Key Differences for Hg vs. NOx
Hg Ox Catalyst Potential, K/AV

- **Hg Oxidation** $K_{HgOx}/AV$ defines:
  - Capacity for X% Hg oxidation

- **Activity, $K_{HgOx}$, depends on:**
  - Catalyst composition and age
  - Flue gas conditions (+HCl, HBr, NH$_3$, CO, SO$_2$, HC)

- **AV = Area Velocity = (Gas Flow) / (Total GSA)**

- First order rate equation can be applied for Hg oxidation tests, *but be careful! This K value is strongly condition dependent!*

\[
\frac{K_{HgOx}}{AV} = -\ln \left[ -\eta_{HgOx} \right]
\]

\[
\eta_{HgOx} = fraction\ of\ Hg^0\ oxidation
\]
MHI Semi-Bench Reactor – reflects years of experience

- Collected Hg oxidation data for development, designs, deactivation studies, and quality assurance since 2002.
- Total system testing (fresh and deactivated) up to 4 layers

![Diagram of MHI Semi-Bench Reactor](image-url)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Measurement Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hg and Hg$^{2+}$</td>
<td>Ontario Hydro Method</td>
</tr>
<tr>
<td>SO$_2$, SO$_3$, HCl, NH$_3$</td>
<td>Wet Chemical Analysis</td>
</tr>
<tr>
<td>NO$_x$, O$_2$</td>
<td>CEMs</td>
</tr>
</tbody>
</table>

Courtesy of: Mitsubishi Heavy Industries, Ltd. Technical Headquarters
**Mercury Assurance Testing Reactor**

Versatile and fully-automated for efficient data collection. CEMS for Hg, NO\textsubscript{x}, SO\textsubscript{2} Allows us to measure Hg oxidation under a full range of conditions to develop catalysts and management strategies.

Capable of characterizing any catalyst type/vintage.
Cormetech Bench Reactor

- Added Bench scale Hg oxidation testing capability.
  - Construction complete
  - Validation testing underway

- Full size element testing
- Individual element and multi-layer testing
- Any catalyst type or combination
- Fresh or deactivated
- HCl/HBr, O₂, H₂O, SO₂, SO₃, NOₓ, CO, HC
Catalyst characterization

% Hg Oxidation vs. HCl [ppmvda] for different temperatures and MR values:
- 400°C, MR = 0.2
- 400°C, MR = 0.9
- 340°C, MR = 0.2
- 340°C, MR = 0.9

**Layer Dependency:**
- MR = 0.9 represents the top layer
- MR = 0.2 represents a lower layer
**Catalyst Type Dependency**

**PRB Unit - Lab Testing Case Study:** COMET™ vs Standard

At same SO2 oxidation rate.

**Constants**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Temp C</td>
<td>403</td>
</tr>
<tr>
<td>NOx ppm</td>
<td>107</td>
</tr>
<tr>
<td>O₂ %</td>
<td>3.5</td>
</tr>
<tr>
<td>H₂O %</td>
<td>14</td>
</tr>
<tr>
<td>SO₂ ppm</td>
<td>345</td>
</tr>
<tr>
<td>HCl ppm</td>
<td>8</td>
</tr>
</tbody>
</table>

80% higher Hg ox Activity at design case! (Range: 50% - 400%)
Integrated Approach to Solutions

- Understand the needs & options
- Define SCR requirement

- Obtain and test catalyst samples
- Use COMET™ modeling technology
- Evaluate against available field data

- Evaluate multiple scenarios
- Develop management plans
- Select catalyst type:
  - Standard, or
  - COMET™ Advanced Hg Ox Catalyst
- Set SCR performance guarantees.
Case study: System characterization and analysis

- Evaluation of impacts to Hg oxidation and DeNOx performance for catalyst replacement options.
- 4 layer system – replacement of first and last layer
  - Layer 1: Honeycomb A
  - Layer 2: Honeycomb B
  - Layer 3: Honeycomb B
  - Layer 4: Plate
- Layer 1 – replace with fresh catalyst (already purchased)
- Options for Layer 4 replacement:
  - Regenerated honeycomb (from layer 1)
  - Fresh COMET™ catalyst
Case study (cont.)

- Lab tested 7 samples of field and fresh catalyst
  - MR = 0, 0.2, 0.3
  - over 60 tests completed.
- Validated lab data against model
  - Average absolute deviation within 3% across range of MR
- Field data in good agreement
- Options analyzed and management plan developed.

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Option 1</th>
<th>Option 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Layer 4</td>
<td>Existing</td>
<td>Fresh Regen</td>
<td>Fresh COMET</td>
</tr>
<tr>
<td>Hg Oxidation</td>
<td>40%</td>
<td>55%</td>
<td>70%</td>
</tr>
<tr>
<td>(System)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Higher oxidation can be achieved with additional COMET layers.
Summary

• Hg oxidation is influenced by multiple factors.
  – Layer dependency
  – More factors in setting design conditions
  – Impacts of catalyst type & formulation

• Cormetech has developed testing capabilities needed to characterize performance under all operating conditions.

• COMET™
  – testing and modeling technology allows us to predict system performance and evaluate options for catalyst actions.
  – advanced Hg oxidation catalyst can significantly improve SCR co-benefit for Hg oxidation.
  – Used in combination to provide optimal solutions.
Thank You!

Questions/Discussion