Hitachi Power Systems America, Inc.

Babcock-Hitachi K.K.

McIlvaine Hot Topic Hour

Catalyst Selection

Presented by:

Stephen Guglielmo
SCR Product Manager
October 21, 2010
Outline

- Regulations and Market Drivers
- Catalyst Selection
- Latest Catalyst Developments
Regulations and Market Drivers
Federal Air Regulatory Drivers

- Transport Rule 1 (CAIR replacement)
- Transport Rule II – (NOx)
- National Ambient Air Quality Standards (NAAQS)
  - SO₂, Ozone, PM
- New Source Performance Standards (NSPS)
- Maximum Achievable Control Technology (MACT)
- New Source Review (NSR) – i.e. consent decrees
- Clean Air Mercury Rule (CAMR)
- Greenhouse Gas Regulations/Legislation (GHG)

The U.S. has a Complicated Network of Overlapping Rules and Regulations for Emissions
Notes: The 28 states subject to annual SO \(_2\) standards are grouped into two tiers. The 15 dotted states above belong to the more stringent tier (Group–1) and are subject to a substantial increase in their SO \(_2\) reduction requirement beginning in 2014. As compared to CAIR, the Transport Rule ozone season NO \(_x\) program would include Georgia, Kansas, Oklahoma, and Texas but exclude Iowa, Massachusetts, Missouri, and Wisconsin. Similarly, the Transport Rule annual SO\(_2\) and NO\(_x\) programs would include Connecticut, Kansas, Massachusetts, Minnesota, and Nebraska but exclude Mississippi and Texas.
Transport Rule 1 (TR-1) will impact the existing coal market. Most at risk are some 30 gigawatts worth of units without SO₂ controls. Expect the heaviest hit states would be KY, OH, PA and WV.

TR-1 will end multi-state cap-and-trade programs to control sulfur dioxide (SO₂) and nitrogen oxide (NOₓ) emissions.

TR-1 will not carry banked allowances forward.

TR-2 proposal due in summer 2011 and final rule expected summer 2012 – will tighten NOx standards where TR-1 did not.

3 GW coal units already shut down, more to follow suit.
Summary Timeline for Environmental Regulatory Requirements for the Utility Industry

CAIR Phase I
Seasonal NOx Cap

Beginning CAIR Phase I Annual NOx Cap

NOx Primary NAAQS

SO2 Primary NAAQS

SO2/NO2

PM-2.5 NAAQS

Next PM-2.5 NAAQS Revision

HAPS MACT proposed rule

HAPS MACT final rule expected

PM-2.5 SIPs due ('06)

SO2/NO2 Secondary NAAQS

New PM-2.5 NAAQS Designations

Beginning of CAIR Phase II Annual SO2 & NOx Caps Expected

CO2 Regulation Expected

TR 1 - Final CAIR Replacement Issued, TR-II Issued

TR 1 - Final CAIR Replacement issued July 6, 2010

CO2

CO2 Regulation Expected

TR-II Final Expected

CO2

Beginning of CAIR Phase II Annual SO2 & NOx Caps Expected

HAPS MACT Compliance 3 yrs after final rule

HAPS MACT

PM2.5

Hg / HAPS

How Will Catalyst Management Play a Role in Meeting These New Challenges by Regulation?
Specifying the Correct Catalyst to Provide the Most Operational Flexibility and the Lowest Overall Lifecycle Cost:

- What’s your budget?
- What kinds of fuel are you burning?
- What is your outage cycle?
- How does your unit operate?
- How much NOx removal and/or $K_0/K_e$ do you need?
- What are your SO$_2$ to SO$_3$ conversion limitations?
- What are your DP limitations?
- What level of Hg oxidation do you need?
- Future Regulations?
- Other Considerations?
Factors that impact catalyst performance and Cost:

- Catalyst Pitch (Hydraulic Diameter)
- Catalyst Volume/Height
- Catalyst Formulation
- Disposal of Spent Catalyst
## Variation of Catalyst Pitch

<table>
<thead>
<tr>
<th>Catalyst Pitch (mm)</th>
<th>10</th>
<th>7</th>
<th>6</th>
<th>5.7</th>
<th>5.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catalyst Volume</td>
<td>Maximum</td>
<td>Minimum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure Loss</td>
<td>Minimum</td>
<td>Maximum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dust Plugging</td>
<td>Minimum</td>
<td>Maximum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Note</td>
<td>Additional Catalyst Layer Required for Initial Installation</td>
<td>Fair for Application</td>
<td>Precaution for Pop-Corn Ash Required</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note:**
- Additional Catalyst Layer Required for Initial Installation
- Fair for Application
- Precaution for Pop-Corn Ash Required
## Hydraulic Diameter

### Table: Comparison of Plate, Honeycomb, and Corrugated Types

<table>
<thead>
<tr>
<th>Metric</th>
<th>Plate (mm)</th>
<th>Honeycomb (mm)</th>
<th>Corrugated (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Pitch</td>
<td>5.7 (7.0)</td>
<td>6.9 (9.0)</td>
<td>6.5 (9.0)</td>
</tr>
<tr>
<td>a</td>
<td>5.7 (7.0)</td>
<td>6.9 (9.0)</td>
<td>6.5 (9.0)</td>
</tr>
<tr>
<td>b</td>
<td>62 (85)</td>
<td>6.9 (9.0)</td>
<td>6.5 (9.0)</td>
</tr>
<tr>
<td>$D_h$, mm</td>
<td>9.25 (11.7)</td>
<td>6.2 (8.0)</td>
<td>5.06 (7.0)</td>
</tr>
<tr>
<td>Difference vs. Plate</td>
<td>--</td>
<td>-33% (-14%)</td>
<td>-45% (-24%)</td>
</tr>
</tbody>
</table>

### Formula

$$D_h = 4 \times \frac{\text{Cross Sectional Area (mm}^2\text{)}}{\text{Perimeter (mm)}}$$

### Diagrams

- **Plate type**
- **Honeycomb type**
- **Corrugated type**
## Typical Catalyst Deactivation Factors

<table>
<thead>
<tr>
<th>Deactivation Factor</th>
<th>Effect on Catalyst</th>
<th>Types of Fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic (As)</td>
<td>Deactivates Sites</td>
<td>Bituminous</td>
</tr>
<tr>
<td>Alkaline metals (K₂O, Na₂O)</td>
<td>Deactivates Sites</td>
<td>Biomass</td>
</tr>
<tr>
<td>Phosphorus (P₂O₅)</td>
<td>Deactivates Sites</td>
<td>PRB</td>
</tr>
<tr>
<td>Iron (Fe₂O₃)</td>
<td>Produced by catalyst wetting due to tube leakage etc.</td>
<td>Increase SO₂ conversion rate</td>
</tr>
<tr>
<td>Calcium (CaO)</td>
<td>Covers Active Sites</td>
<td>PRB</td>
</tr>
<tr>
<td>Ash Content / Silica</td>
<td>Erosion</td>
<td>Lignite</td>
</tr>
<tr>
<td>Vanadium</td>
<td>Increase SO₂ conversion rate</td>
<td>Pet Coke</td>
</tr>
</tbody>
</table>
Plate type catalyst is the only catalyst that can be recycled.

Recycling can be done by a steel mill for no cost to you.
Latest Catalyst Developments
CM Catalyst

Combines High NOx Reduction with:

- Longest Catalyst Life: Lifecycle Cost
- Low SO2 → SO3 Conversion: SO₃ Mitigation Consumption
- Excellent Hg Oxidation: Activated Carbon Consumption

Compared to Conventional Catalysts

Excellent DeNox performance and lower operating costs.
Newly developed CM catalyst deactivates slower than conventional or regenerated catalyst, therefore providing longer service life.
Economics of Regenerated vs. New CM Catalyst

Based on our experience, DeNOx activity of Regenerated catalyst is lower than that of new catalyst. Therefore, Regenerated catalyst has a shorter lifetime than new catalyst, if catalyst volume is constant and deterioration rate is the same for both cases. The economics should be evaluated for a long term operation prior to application of regenerated catalyst.
### Economics of Conventional vs. New CM Catalyst

<table>
<thead>
<tr>
<th>Catalyst Type</th>
<th>Required number of replacement for 12 years</th>
<th>Catalyst volume ratio to be replaced</th>
<th>Unit price</th>
<th>Total price for Catalyst</th>
<th>Removal &amp; Installation cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Unused</td>
<td>4</td>
<td>Base:100 %</td>
<td>Base:100 %</td>
<td>Base:100%</td>
<td>4 Times</td>
</tr>
<tr>
<td>Conventional Regenerated</td>
<td>6</td>
<td>150 %</td>
<td>60 %</td>
<td>90%</td>
<td>6 Times</td>
</tr>
<tr>
<td>New CM Unused</td>
<td>3</td>
<td>75%</td>
<td>100%</td>
<td>75%</td>
<td>3 Times</td>
</tr>
</tbody>
</table>

Based on the deactivation tendencies of CM catalyst vs. conventional or regenerated conventional, the extended life allows for longer time between catalyst change outs of catalyst, therefore making it more economical over the lifetime of the SCR.
Enhanced Mercury Oxidation Catalyst

Mercury Oxidation Catalyst: **TRAC®**
*(TRiple Action Catalyst)*

- Equivalent performance to CM Catalyst but with enhanced mercury oxidation.
- Increased mercury oxidation rate of 90% at the SCR outlet.

**Excellent DeNox performance and lower operating costs.**
Characteristics of TRAC®

Sub-bituminous | Bituminous (Eastern)

Mercury Oxidation (%)

HCl Concentration (ppm)

New Catalyst

Conventional Catalyst

Without Catalyst

Temperature 662 F

Hg 10 ng/l
Typical Performance of TRAC®

TRAC® – TRiple Action Catalyst*

Activity Ratio (-)

Hg Oxidation
SO2 to SO3 Oxidation
NOx Removal

Conventional
TRAC

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Why Oxidize Mercury in the SCR?

- **Co-Benefit**…Utilization of SCR to reduce NOx and oxidize Hg
- In Hitachi WFGD, removal of 90+% of the oxidized mercury can be achieved
- Hg Removal efficiency of Dry FGD System can be improved with more oxidized Hg
- **Significantly reduce** use of additives such as ACI

![Graph showing Hg removal efficiency](image)
### Estimation of TRAC® Economics

#### PRB Applications

<table>
<thead>
<tr>
<th></th>
<th>3 N/T Layers</th>
<th>Existing 2 Layers + TRAC® 1 Layer</th>
<th>TRAC® 3 Layers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxidized Hg (%) (W/O Br Injection)</td>
<td>41%</td>
<td>56%</td>
<td>71%</td>
</tr>
<tr>
<td>Br Concentration</td>
<td>25 ppm</td>
<td>4 ppm</td>
<td>3 ppm</td>
</tr>
<tr>
<td>Expected for 90% oxidation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Halogen Cost</td>
<td>$0.18M / year</td>
<td>$0.03M / year</td>
<td>$0.02M / year</td>
</tr>
</tbody>
</table>

N/T = Non-TRAC® Catalyst

Flue gas temp. at SCR inlet: 741 Deg.F

After a half year operation

For PRB applications, some halogen injection may be required to achieve 90% mercury oxidation at AH outlet.

TRAC® is effective to reduce operation cost by lowering the amount of halogen injection required.
## Eastern Bituminous Applications

<table>
<thead>
<tr>
<th></th>
<th>3 N/T Layers</th>
<th>2 N/T Layers + 1 TRAC®</th>
<th>3 Layers of TRAC®</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACI injection, # / MMACF</td>
<td>2.6</td>
<td>1.8</td>
<td>0</td>
</tr>
<tr>
<td>ACI Cost (Millions per year)</td>
<td>$2.6</td>
<td>$1.8</td>
<td>n/a</td>
</tr>
<tr>
<td>HG Oxidation(@ APH outlet), (%)</td>
<td>(90% removal)</td>
<td>95</td>
<td>95</td>
</tr>
</tbody>
</table>

N/T = Non-TRAC® Catalyst

For Bituminous applications, TRAC® is effective to reduce operation cost by lowering or even eliminating ACI injection.
Summary

• New regulations are creating new challenges for SCR operations. Hitachi continues to develop new solutions minimizing the operational impact to the unit providing the flexibility required.

• Newly developed CM and TRAC® catalysts can be applied for both PRB and E.B. coals.

• Both are able to achieve less than 0.25% of SO₂ / SO₃ oxidation rate per layer for E.B.

• Both reduce the need for sorbent injection for SO₃ mitigation.

• TRAC® enhances Hg oxidation capability with 95% Hg oxidation possible at A/H outlet to avoid ACI for E.B. coal, and PRB with minimal or no Halogen Injection required.

Development continues thru Hitachi’s R&D efforts to further enhance our SCR catalyst performance.
Questions?

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