Demonstration of Mer-Cure™ Technology for Enhanced Mercury Control

(DOE Cooperative Agreement DE-FC26-07NT42776)

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and
Pieri Noceti
DOE/NETL
Outline

• Background

• ALSTOM Mer-Cure™ Technology

• Project Objectives and Plan
  – Budget Period 1 – LCRA short-term demo
  – Budget Period 2 – LCRA long-term, Reliant Energy demo

• Budget Period 1 Test Results from LCRA
  – Baseline measurements
  – Parametric testing
  – Ash evaluation
  – Balance of plant impact

• Summary

• Acknowledgements
Background

- No “one-size-fits-all” solution for mercury control
  - Each plant has its own unique opportunities/challenges
  - Fuel type, boiler operation, and backend configuration
  - System-wide control strategy
    - CAMR vs. state regulations

- ALSTOM has developed diverse mercury control options in order to meet unique challenges of customers
  - Coal additives for co-benefits
  - Activated Carbon Injection (ACI) + Baghouse installation
  - “Enhanced” sorbent injection – Mer-Cure™

- ALSTOM Mer-Cure™ technology development target
  - Easy retrofit solution for boilers (mainly with ESP only)
  - Low capital investment
  - Low operating cost
  - Removal efficiency greater than 90%
1. Proprietary sorbent design
   - Accelerated oxidation/capture
   - Mitigate SO₃ impact/improved stack opacity
   - Prepared for high-temp application

2. On-line processing of sorbent
   - Uniform dispersion
   - Maximum surface area
   - Removed mass transfer limitations

3. Injection upstream air heaters
   - High temperature
   - Longer residence time
   - Above acid dew point
   - More internal duct area
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Project Team

Department of Energy/NETL

Alstom Power Inc.

Lower Colorado River Authority

Reliant Energy

Envergex, LLC

UND EERC
Project Goals:

DOE Phase III:
• Full-scale demonstration of a mercury control technology capable of
  – 90% capture above baseline, i.e., uncontrolled mercury emissions;
  – At 50% or less of the baseline cost ($50,000/lb Hg removed)
  – Various plant configurations
• Longer-term demonstration

LCRA:
• Allow continued ash utilization
  – Reduced consumption of sorbent due to co-benefit from FGD
  – New sorbent formulations

Reliant Energy:
• Reduce sorbent consumption under high SO$_3$ environment
  – SO$_3$-tolerant sorbent formulations
### LCRA Fayette Unit 3

<table>
<thead>
<tr>
<th>Utility</th>
<th>LCRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Host site</td>
<td>Fayette Unit 3</td>
</tr>
<tr>
<td>Size (MW gross)</td>
<td>480</td>
</tr>
<tr>
<td>Location</td>
<td>La Grange, TX</td>
</tr>
</tbody>
</table>

**Fuel**
- %S: 0.6
- %ash: 7.6
- ppm Cl: 49
- ppm Hg: 0.09+/−0.02

**Air heaters**
- Ljungstrom™

**Particulate control**
- CS-ESP

**SOx control**
- Wet FGD
# Test Plan (3/5/07 through 4/8/07)

<table>
<thead>
<tr>
<th>Sun</th>
<th>Mon</th>
<th>Tue</th>
<th>Wed</th>
<th>Thu</th>
<th>Fri</th>
<th>Sat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3/1</td>
<td>3/2</td>
<td>3/3</td>
</tr>
<tr>
<td>2/25</td>
<td>2/26</td>
<td>2/27</td>
<td>2/28</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3/8</td>
<td>3/9</td>
<td>3/10</td>
</tr>
<tr>
<td>Baseline mercury measurement (no injection of sorbents)</td>
<td>Mer-Cure installation week</td>
<td>Kick-off Meeting</td>
<td>Parametric testing (injection of various sorbents at several injection rates)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ash evaluation starts (continuous injection of sorbents at a fixed lb/MMacf for sampling of representative bulk ash)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>day 1 MerClean</td>
<td>day 2 MerClean</td>
<td>day 3 MerClean</td>
<td>day 4 MerClean</td>
<td>day 5 MerClean</td>
<td>day 6 MerClean</td>
</tr>
<tr>
<td></td>
<td>day 7 MerClean recovery, PM</td>
<td>day 1 eSorb 11</td>
<td>day 2 eSorb 11</td>
<td>day 3 eSorb 11</td>
<td>day 4 eSorb 11</td>
<td>day 5 eSorb 11</td>
</tr>
<tr>
<td></td>
<td>day 6 eSorb 11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4/1</td>
<td>4/2</td>
<td>4/3</td>
<td>4/4</td>
<td>4/5</td>
<td>4/6</td>
<td>4/7</td>
</tr>
<tr>
<td>forced outage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demobilize mobile unit</td>
<td>Demobilize</td>
<td>Demobilize</td>
<td>Demobilize</td>
<td>Demobilize</td>
<td>Demobilize</td>
<td></td>
</tr>
</tbody>
</table>
Fayette 3 Plant and Sampling Layout

- **Coal sample**
- **Solid sample**
- **Sorbent injection**
- **Mercury measurement**

- **Fayette 3**
- **Ljungstrom™ APH**
- **ESP**
- **Fly Ash**
- **Silo B ash**
- **Wet scrubbers**
- **FGD samples**

- **Bypass (15-25%)**

- **805°F, 3.3%O2**
- **330°F, 6.8%O2**
- **145°F, 7%O2**

- **184°F, 3.3%O2**
- **330°F, 6.8%O2**
Mer-Cure™ Equipment Layout in Fayette 3

From trailer on ground

Injection lances
Injection Deck
Solids Sampling Locations

South
side

North
side

A11A12A13A14A15
A21A22A23
A31A32A33
A41A42A43
A51A52A53
A61A62A63
Computational Fluid Dynamics (CFD) Modeling

- Identify gas sampling location – wet FGD vs stack
- Identify sorbent injection location – vs. O2 probes
- Design sorbent injection lances – number of lances, nozzle size, etc.
FPP3 Backpass CFD Study for Lance Design

Contours of Velocity Magnitude (ft/s)

FLUENT 6.2 (3d, segregated, ske)

Oct 03, 2006

DOE Phase III - P 15
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• ALSTOM Mer-Cure™ Technology
• Project Objectives
• LCRA Test Results
  – Baseline measurements
  – Parametric testing
  – Ash evaluation
  – Balance of plant impact
• Summary
• Acknowledgements
AH inlet CMM vs Hg from coal analysis

Calculated from mercury content in coal

Continuous Mercury Monitor (CMM) readings

Calculated from mercury content in coal

- CMM readings and calculated Hg concentrations are in general agreement
Baseline Measurements – all three locations

- Air Heater Inlet
- ESP Outlet
- Stack
- Capture across AH/ESP
- Capture across FGD

Hg (total, ug/m³, corrected to 3%O₂)


Time
Baseline Measurements - Speciation

- ESP Outlet - total
- ESP Outlet - elemental
- Stack - total
- Stack - elemental

Hg (elemental and total, μg/m³, corrected to 3% O₂)

Time:
- 3/4
- 3/5
- 3/6
- 3/7
- 3/8
- 3/9
- 3/10
- 3/11
- 3/12
### Baseline Measurements - Summary

(at 3% O2)

<table>
<thead>
<tr>
<th>Measurement location</th>
<th>total</th>
<th>elemental</th>
<th>oxidized</th>
<th>% oxidized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Heater inlet</td>
<td>11.7</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>ESP outlet</td>
<td>8.5</td>
<td>1.7</td>
<td>6.8</td>
<td>80% oxidized</td>
</tr>
<tr>
<td>Stack</td>
<td>5.9</td>
<td>4.2</td>
<td>1.7</td>
<td>28% oxidized</td>
</tr>
</tbody>
</table>

- About 50% of AH inlet mercury inherently captured by boiler:
  - 27% across AH and ESP
  - 23% across FGD modules

- Not all of oxidized mercury was captured across FGD!!

- A significant amount of oxidized mercury was reduced to elemental mercury in FGD
Parametric Testing

• Tested four (4) sorbents for mercury reduction:
  – ALSTOM’s Mer-Clean™ 8, Envergex’s eSorb™ 11, 13 and 18
  – Constructed performance curve: injection rate vs. % removal

• Constructed foam index chart with simulated ash-sorbent mixture:
  – Mixed LCRA ash with a small amount of sorbent at various proportions
  – Foam index-tested ash-sorbent mixtures
  – % carbon (sorbent) in ash vs. drops (foam index value)
Parametric Testing – Typical Run

- **Mer-Clean 8 at 1.3 lb/MMacf**
- **0.36 μg/m³**

- **Sorbent turned on**
- **Air Heater Inlet**
- **ESP Outlet**
- **Stack**
Definitions of Mercury Capture Efficiencies

- **Coal**
- **ESP**

**Input mercury**

- **AH**
  - "Inherent" capture
  - Uncontrolled mercury emissions

- **Sorbent injection**
- **FGD**
  - ESP outlet for injection concentration (lb/MMacf) calculation
- **Stack**

**Gaseous mercury concentration**

- 10
- 5
- 0

**Boiler location**

- Input mercury
- "Inherent" capture
- Uncontrolled mercury emissions
- Stack mercury with injection
ALSTOM’s Mer-Clean sorbent:
90% achieved at 0.8 lb/MMacf (85 lb/hr);
→ carbon in ash increases by 0.25% pts
Parametric Testing – foam index test performance

![Graph showing foam index test performance with trend lines and data points.]

- **y = 1450.5x + 156** with $R^2 = 0.9619$
- **y = 1108.4x + 156** with $R^2 = 0.99$
- **y = 554.3x + 156** with $R^2 = 0.74$

**Legend:**
- MerClean 8
- eSorb 11
- eSorb 13
- eSorb 18

**Notes:**
- Ash may not be sold at the threshold.
- Ash may be sold above the threshold.
Ash Evaluation Testing – Mer-Clean™ Sorbent

Foam index values:
- 375
- 562
- 531
- 562 (→ silo B ash)

Baseline = 5.8 μg/m³
Avg. = 0.59 μg/m³ (or 90% of uncontrolled Hg)

Sorbent on
Sorbent off


Power Systems
ALSTOM
Ash Evaluation Testing – eSorb™ 11 Sorbent

Foam index value: 468 468 (silo B ash)

Baseline = 5.8 μg/m³
Avg. = 0.6 μg/m³ (or 90% of uncontrolled Hg)

Sorbet on

Forced outage
Sorbet off
Ash Evaluation Testing – foam index test performance

Ash may not be sold

threshold

Ash may be sold

Carbon increase in LCRA ash due to sorbent injection, % points

Foam Index Value

y = 1450.5x + 156
R² = 0.9619

y = 1106.4x + 156
R² = 0.99

y = 554.3x + 156
R² = 0.74

0.12

MerClean 8
esorb 11
esorb 13
esorb 18
Ash Evaluation Testing – Hg capture performance

~75% reduction of uncontrolled mercury level while still selling ash
On Input Mercury Basis...

Mer-Clean: ~88% reduction of input mercury level while still selling ash
## Ash Leaching Test Results – No Detectable Leaching

<table>
<thead>
<tr>
<th>PPL#</th>
<th>Sample location</th>
<th>Date</th>
<th>Time</th>
<th>mg Hg/l</th>
<th>TCLP Extraction (mg/liter)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>As</td>
</tr>
<tr>
<td>7-2676-M</td>
<td>Reclaim Pond</td>
<td>3/12</td>
<td>8:57</td>
<td>&lt;0.2</td>
<td></td>
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<tr>
<td>7-2677-M</td>
<td>LS slurry tank</td>
<td>3/12</td>
<td>8:28</td>
<td>&lt;5</td>
<td></td>
</tr>
<tr>
<td>7-2586-A</td>
<td>Silo ash</td>
<td>3/13</td>
<td></td>
<td>&lt;1</td>
<td>3.5</td>
</tr>
<tr>
<td>7-2587-A</td>
<td>Silo 3B-01</td>
<td>3/23</td>
<td>17:15</td>
<td>&lt;1</td>
<td>3.3</td>
</tr>
<tr>
<td>7-2588-A</td>
<td>Silo 3B-02</td>
<td>3/23</td>
<td>17:15</td>
<td>&lt;1</td>
<td>2.9</td>
</tr>
<tr>
<td>7-2589-A</td>
<td>Silo 3B-01</td>
<td>3/30</td>
<td>16:15</td>
<td>&lt;1</td>
<td>4.3</td>
</tr>
<tr>
<td>7-2590-A</td>
<td>Silo 3B-02</td>
<td>3/30</td>
<td>16:15</td>
<td>&lt;1</td>
<td>3.6</td>
</tr>
<tr>
<td>7-2616-A</td>
<td>Silo B</td>
<td>3/28</td>
<td>15:05</td>
<td>&lt;1</td>
<td>3.7</td>
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<tr>
<td>7-2617-A</td>
<td>Silo B</td>
<td>3/29</td>
<td>11:35</td>
<td>&lt;1</td>
<td>3.6</td>
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<tr>
<td>7-2618-A</td>
<td>Silo B</td>
<td>3/30</td>
<td>9:00</td>
<td>&lt;1</td>
<td>3.6</td>
</tr>
</tbody>
</table>

Analysis conducted by Alpha Analytical
No change in stack opacity during sorbent injection
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Summary

• Baseline measurements
  – Native capture is 50% - 27% by AH/ESP and 23% by FGD
  – Not all of oxidized mercury was captured by FGD
  – A large amount of oxidized mercury was reduced to elemental in FGD

• Parametric testing during sorbent injection
  —90% of uncontrolled mercury emission was captured at 0.8 lb/MMacf
  —90% of input mercury was captured at 0.5 lb/MMacf
  —No capture was observed by FGD

• Balance-of-plant impact
  —No stack opacity increase during injection
  —No leaching of mercury from flyash

• Continued ash sales/utilization
  —75% of uncontrolled mercury can be removed before ash sales loss
  —88% of input mercury may be removed before ash sales loss
Acknowledgements

Department of Energy/NETL – financial support

Lower Colorado River Authority – host site

Envergex, LLC – specialized sorbents

UND EERC – measurement services