Mercury Control In Wet FGD Systems on Coal-Fired Utility Boilers

Kevin Redinger
Babcock & Wilcox
Mercury Control Technology

8 year $14 million development effort leads to mercury control technology
- Timely
- Cost effective
- Retrofittable
- Integrates with WFGD

B&W's pathway to commercialization

55 MWe long term demonstration at MSCPRA, Endicott Station -- May '01

1300 MWe full-scale demonstration at the Zimmer Plant -- Fall '01 (Cinergy, DP&L, AEP)

Development/Demonstration Partners: OCDO & US DOE

US Department of Energy / Ohio Coal Development Office
Babcock & Wilcox / McDermott Technology Inc

Wet FGD Mercury Control for Coal-Fired Utility Boilers
Wet FGD – Flue Gas Desulfurization

Primary SO\textsubscript{2} Control for US Utility Industry
- 95,000 MW or about 85% of all US FGD installations
- About 25% of US generating capacity (220 installations)
- Well proven technology – 30+ years
- Several major system suppliers

Co-control of mercury as a secondary benefit
- Control efficiency dependent on form of mercury
- System design and operation also play a role
Typical Wet FGD Installation
B&W Wet SO₂ Scrubber

Flue Gas Inlet

Limestone or Lime Slurry

Spent Slurry or Gypsum

Flue Gas Outlet

Limestone or Lime Slurry Spray
B&W / MTI Pilot Tests Showed:

System design and operation impacted mercury emissions control
- 78% at L/G ratio of 40 vs. 94% at L/G of 120
- Oxidized Hg removal of 85 to 98%
- Limited impact on elemental Hg
- Favorable Hg$^{++}$ / Hg$^{0}$ does not assure high removal efficiency

Additives effective in preventing reduction and release of Hg$^{0}$
- Effective, convenient technique for addition
- Safe, stable, low-cost reagents
B&W / MTI Pilot Testing - mid 1990’s

Total Inlet Mercury = 14.8 ± 2.1 ug/dscm

Hg Emissions [ug/dscm]

L/G Ratio [gpm/kacfm]

Tray
No Tray

FGD Design and Operation Impacts Mercury Control

Wet FGD Mercury Control for Coal-Fired Utility Boilers
Additive to Control Release of Hg$^0$

Effective reagent / minimal FGD process impact
Full Scale Demonstration Tests

Mercury Removal
Chemical Addition

Wet FGD Mercury Control for Coal-Fired Utility Boilers
MSCPA Endicott - 55 MW / Limestone / In-situ oxidation

Design L/G ~ 80 gal/kacf, 90 to 93% SO$_2$ Removal
Endicott – Initial Tests

Wet FGD Mercury Control for Coal-Fired Utility Boilers
Endicott – Performance Over 4 Months

Average Removal: 79%

Test ID 24 25 26 27 28 29
Gas Phase Hg Concentration, µg/dscm

78% 83% 81% 77% 77% 79%

Endicott – Performance Over 4 Months

Wet FGD Mercury Control for Coal-Fired Utility Boilers
Cinergy Zimmer - 1300 MW / Thiosorbic Lime / Ex-situ oxidation

Design L/G ~ 20 gal/kacf, 90 to 92% SO₂ Removal

Wet FGD Mercury Control for Coal-Fired Utility Boilers
Zimmer Results

Mercury emissions reduction

- Total across FGD averaged 51%
- Oxidized mercury species averaged 87%
- $\text{Hg}^0$ at FGD outlet greater than inlet in each test

Reagent or approach was not effective at this site

- Different scrubber chemistry
- Different operating conditions
# B&W Full-Scale Demonstration Summary

<table>
<thead>
<tr>
<th></th>
<th>Endicott</th>
<th>Zimmer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FGD System Gas Phase</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hg Removal, %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>79</td>
<td>51</td>
</tr>
<tr>
<td>Range</td>
<td>67 to 84</td>
<td>38 to 69</td>
</tr>
<tr>
<td><strong>Average Coal Mercury, lb/10^{12} Btu</strong></td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>Stack Hg Emissions, lb/10^{12} Btu</td>
<td>1.1 to 5.3</td>
<td>3.6 to 8.4</td>
</tr>
</tbody>
</table>
Fate of Mercury - FGD Byproducts

Mercury found mainly in solid byproducts

- Filtrate samples – ND (< 0.0005 mg/l)
- Byproduct solids
  - Fly ash  0.2 – 0.4 ppmd  0.01 – 0.04
  - Gypsum  0.7 – 1.1 ppmd  0.05 – 0.07

Suggests mercury not in soluble form (not HgCl₂)

- Mercury concentrated in fine solids

MTI Thermal Dissociation Tests

- Possible mercury compounds in the byproduct include HgO, HgS and HgSO₄
Wet FGD Mercury Control for Coal-Fired Utility Boilers
Thermal Dissociation Test (TDT) for Hg Standards
TDT for Endicott Gypsum Solids

Endicott - Gypsum
0.9959g Test 050901-1B
1.1025g Test 071001-21A

Temperature, °C

Hg Concentration

Oven Temp
Test-1B
Test-21A
**EPA ICR Data – PC Boiler / Baghouse / WFGD**

<table>
<thead>
<tr>
<th>Bituminous Coal Sites</th>
<th>Clover</th>
<th>Intermountain Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tower Design</td>
<td>Open</td>
<td>Open</td>
</tr>
<tr>
<td>Reagent</td>
<td>Limestone</td>
<td>Limestone</td>
</tr>
<tr>
<td>Slurry Oxidation</td>
<td>Natural</td>
<td>Natural</td>
</tr>
<tr>
<td>L / G, gal/kacf</td>
<td>100</td>
<td>45 -70</td>
</tr>
<tr>
<td>pH</td>
<td>5.3 – 5.4</td>
<td>5.6 – 5.7</td>
</tr>
<tr>
<td>SO₂ Removal, %</td>
<td>96</td>
<td>90</td>
</tr>
<tr>
<td>Hg Removal, %</td>
<td>75 (58 – 86)</td>
<td>68 (59 – 76)</td>
</tr>
<tr>
<td>Inlet Speciation , % Hg⁺⁺ / Hg⁰</td>
<td>49 / 51</td>
<td>84 / 16</td>
</tr>
</tbody>
</table>
### EPA ICR Data – PC Boiler / Cold ESP / WFGD

<table>
<thead>
<tr>
<th>Bituminous Coal Site</th>
<th>Cayuga</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tower Design</td>
<td>Open</td>
</tr>
<tr>
<td>Reagent</td>
<td>Limestone / Formic Acid</td>
</tr>
<tr>
<td>Slurry Oxidation</td>
<td>Forced</td>
</tr>
<tr>
<td>L / G, gal/kacf</td>
<td>138</td>
</tr>
<tr>
<td>pH</td>
<td>NA</td>
</tr>
<tr>
<td>SO$_2$ Removal, %</td>
<td>92 - 94</td>
</tr>
<tr>
<td>Hg Removal, %</td>
<td>64 (62 – 68)</td>
</tr>
<tr>
<td>Inlet Speciation, % Hg$^{++}$ / Hg$^0$</td>
<td>70 / 30</td>
</tr>
</tbody>
</table>
### EPA ICR Data – PC Boiler / Hot ESP / WFGD

<table>
<thead>
<tr>
<th>Bituminous Coal Site</th>
<th>RD Morrow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tower Design</td>
<td>Venturi</td>
</tr>
<tr>
<td>Reagent</td>
<td>Limestone</td>
</tr>
<tr>
<td>Slurry Oxidation</td>
<td>Natural</td>
</tr>
<tr>
<td>L / G, gal/kacf</td>
<td>50</td>
</tr>
<tr>
<td>pH</td>
<td>5.4</td>
</tr>
<tr>
<td>SO$_2$ Removal, %</td>
<td>61</td>
</tr>
<tr>
<td>Hg Removal, %</td>
<td>49 (45 – 53)</td>
</tr>
<tr>
<td>Inlet Speciation , % Hg$^{++}$/Hg$^{0}$</td>
<td>69 / 31</td>
</tr>
</tbody>
</table>
EPA View of Wet FGD Mercury Control Potential

Current Level of Control (ICR Data)

<table>
<thead>
<tr>
<th>Type</th>
<th>Bituminous</th>
<th>Sub-bituminous</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP &amp; WFGD</td>
<td>80</td>
<td>0</td>
</tr>
<tr>
<td>FF &amp; WFGD</td>
<td>90</td>
<td>75</td>
</tr>
</tbody>
</table>

Near-Term Potential (2007 -2008)

<table>
<thead>
<tr>
<th>Type</th>
<th>Bituminous</th>
<th>Sub-bituminous</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP &amp; WFGD</td>
<td>90</td>
<td>50</td>
</tr>
<tr>
<td>FF &amp; WFGD</td>
<td>90</td>
<td>85</td>
</tr>
</tbody>
</table>


Wet FGD Mercury Control for Coal-Fired Utility Boilers
OEM View of Wet FGD Mercury Control Potential

FGD mercury control variation reflects:
- Coal / mercury speciation differences
- System design differences (tower configuration, SO₂ removal, L/G)
- System chemistry (forced oxidation / natural / inhibited)

Enhanced FGD is cost effective approach for co-control
- Limited additional hardware
- Low reagent use rate

Mercury control efficiency
- 90% possible for bituminous coal – but it’s a stretch currently
- 50 to 70% readily achievable for bituminous coal sites
- Integrated Hg⁰ oxidation – catalytic or chemical?
- Must control re-emission of Hg⁰
OEM Perspective –
Mercury Control Technology Application

Inherent performance variability
- Variable coal mercury and chlorine content
- Combustion system performance

Technical and commercial guarantee risks
- Risk exposure not yet established in the market – “best efforts” basis
- Mercury emissions measurement technique uncertainty
- Liquidated damages?
- Performance fixes?