

Evaluation of Mercury Emissions from Coal-Fired Facilities with SCR-FGD Systems



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Outline

- **Background**
- **Previous Work by CONSOL**
- **Program Objectives and Approach**
- **Results**
- **Summary**



Background

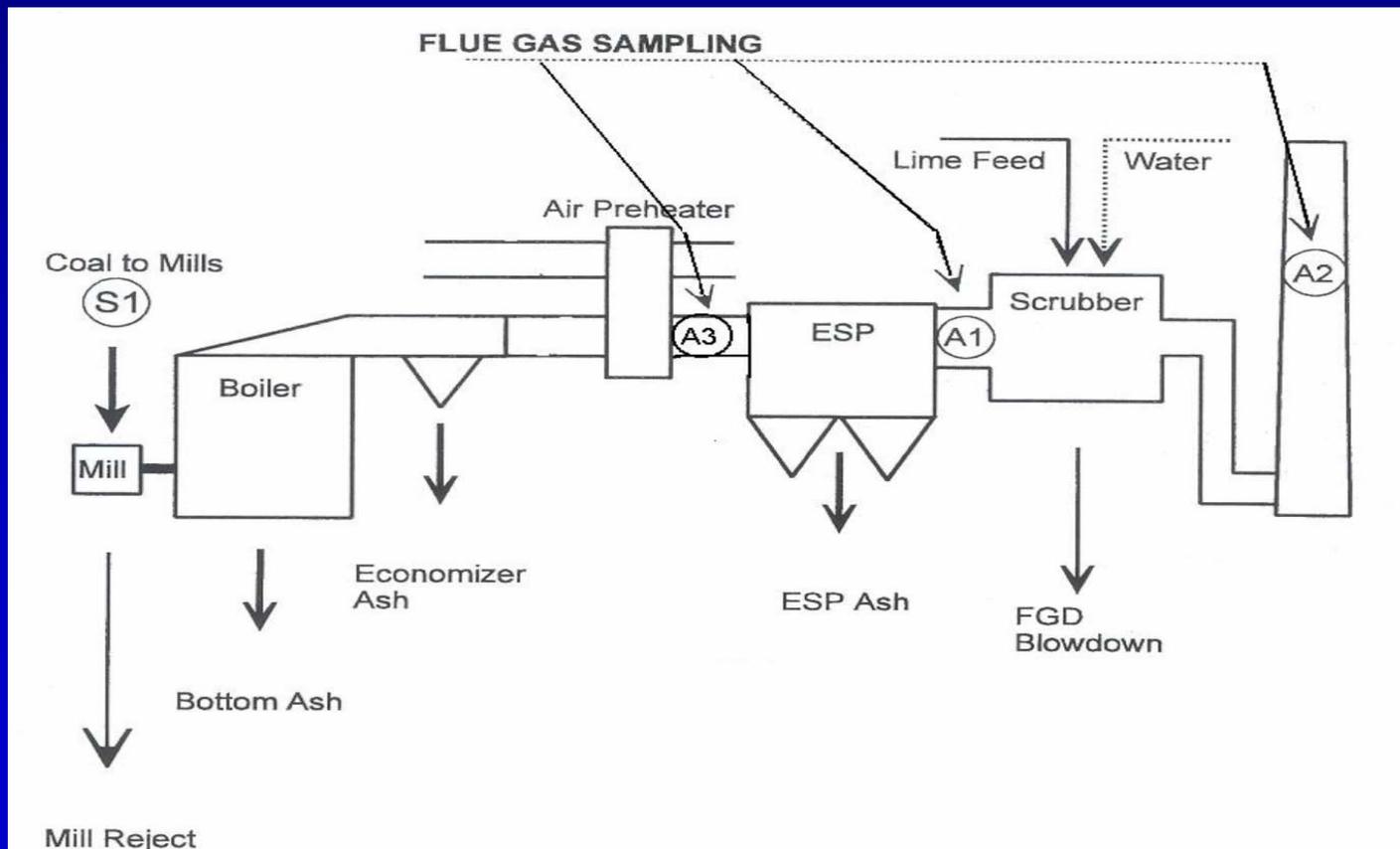
- Typical mercury concentration in coal is 0.08 to 0.20 $\mu\text{g/g}$
- Volatilized during combustion, exits boiler in flue gas
 - Particulate mercury (Hg^{Part})
 - Oxidized mercury (Hg^{++})
 - Elemental mercury (Hg^0)
- ESP/FGD or SDA/FF mainly remove oxidized and particle-bound mercury



Previous Studies

Mercury Removal in ESP/FGD

Samples at 5 utility boilers and 1 industrial boiler, all with ESP-FGD but none with SCR at the times of testing



Previous Studies

Mercury Removal in ESP/FGD

- Average Hg removal across FGD: $54\pm 7\%$
- Average Hg removal across ESP-FGD: $67\pm 6\%$
- Average Hg mass balance closure: $103\pm 8\%$
- $\text{Hg}^{++}:\text{Hg}^0$ – ca. 80%:20% ratio at air heater outlet (ESP inlet) for bituminous coal
- 80% to 95% of Hg^{++} removed by ESP-FGD



Current Program

- Evaluate the mercury removal co-benefits achieved by the SCR-FGD combination
- 10 SCR / FGD equipped units:
 - 3 SCR-SDA-baghouse units
 - 4 SCR-ESP-wet limestone FGD units
 - 3 SCR-ESP-wet lime FGD units
- 9 units fire bituminous coal
- 1 unit fires subbituminous coal
- 6 ozone and 4 year-round units



Objectives

- **Evaluate the effects of:**
 - SCR / air preheater system on Hg speciation
 - SCR / FGD system on Hg capture
- **Collect data to provide insights into:**
 - The nature of Hg chemistry in flue gas,
 - The effect of SCR / air heater systems on Hg speciation, and
 - The capture of Hg by different FGD technologies.



Host Site Information

| Site # | MW | Air Pollution Control Devices | Coal | Ozone Unit |
|----------|-------|---|------|------------|
| 1 | 330 | SCR / Spray Dryer / Baghouse | Bit | year round |
| 2 | 130 | SCR / Spray Dryer / Baghouse | Bit | year round |
| 3 | 550 | SCR / Spray Dryer / Baghouse | Sub | year round |
| 4 | 468 | SCR / ESP/ Limestone FGD, natural oxidation | Bit | year round |
| 5 Unit 1 | 1,300 | SCR / ESP/ Limestone FGD, in-situ oxidation | Bit | yes |
| 5 Unit 2 | 1,300 | ESP/ Limestone FGD, in-situ oxidation | Bit | yes |
| 6 | 544 | SCR / ESP/ Limestone FGD, ex-situ oxidation | Bit | yes |
| 7 | 566 | SCR / ESP/ Limestone FGD, ex-situ oxidation | Bit | yes |
| 8 | 684 | SCR / ESP / Lime FGD, ex-situ oxidation | Bit | yes |
| 9 | 640 | SCR / ESP/ Lime FGD, inhibited oxidation | Bit | yes |
| 10 | 1,300 | SCR / ESP/ Lime FGD, natural oxidation | Bit | yes |



Sampling Locations

- **Flue gas**
 - SCR inlet
 - SCR outlet
 - Air heater outlet
 - FGD inlet
 - Stack

- **Process Streams**
 - Coal
 - Bottom ash
 - Baghouse or ESP hopper ash
 - Scrubber sludge
 - FGD reagent (lime or limestone slurry)
 - FGD makeup water
 - FGD mist eliminator wash water



Current Status

- Pre-sampling visits to all sites except Site #3
- Sampling completed at 4 sites: #1, #2, #5 (units 1 and 2), and #8
- Site #9 will be tested next week.
- Sites #6, #7, and #10 will be tested next month.
- Sites #3 and #4 are scheduled for Q3/Q4 2004.



Sites Tested

Site 1: SCR Inlet, Air Heater Outlet, Stack

Site 2: SCR Inlet, Air Heater Outlet, Stack

Site 8: SCR Inlet, Air Heater Outlet, Stack

**Site 5 Unit #1: SCR Inlet, SCR outlet, Air Heater Outlet,
FGD inlet, Stack**

Site 5 Unit #2: FGD inlet, Stack

All burned bituminous coal.



Plant Comparison

| | Site 1 | Site 2 | Site 8 | Site 5, Unit 1 | Site 5, Unit 2 |
|------------------------------------|---------------------|---------------------|---|--|--|
| FGD Type | Lime Spray Dryer | Lime Spray Dryer | Lime, Ex- Situ Oxidation Wet FGD | Limestone In-Situ Oxidation Wet FGD | Limestone In-Situ Oxidation Wet FGD |
| SCR Catalyst Type | Plate | Honeycomb | Plate | Honeycomb | (none) |
| Capacity, MW | 330 | 130 | 684 | 1300 | 1300 |
| Plant Load During Test | 215 | 130 | 650 | 1296 | 1313 |
| SCR Inlet Temperature, °F | 630 | 760 | 680 | 642 | NA |
| Air Heater Exit Temperature, °F | 255 | 350 | 335 | 315 | NA |
| Stack Temperature, °F | 190 | 180 | 150 | 127 | 130 |
| % Oxygen at SCR Inlet | 5.0 | 4.0 | 3.1 | 4.7 | NA |
| % Oxygen at AH Exit | 7.0 | 5.1 | 5.3 | 5.0 | NA |



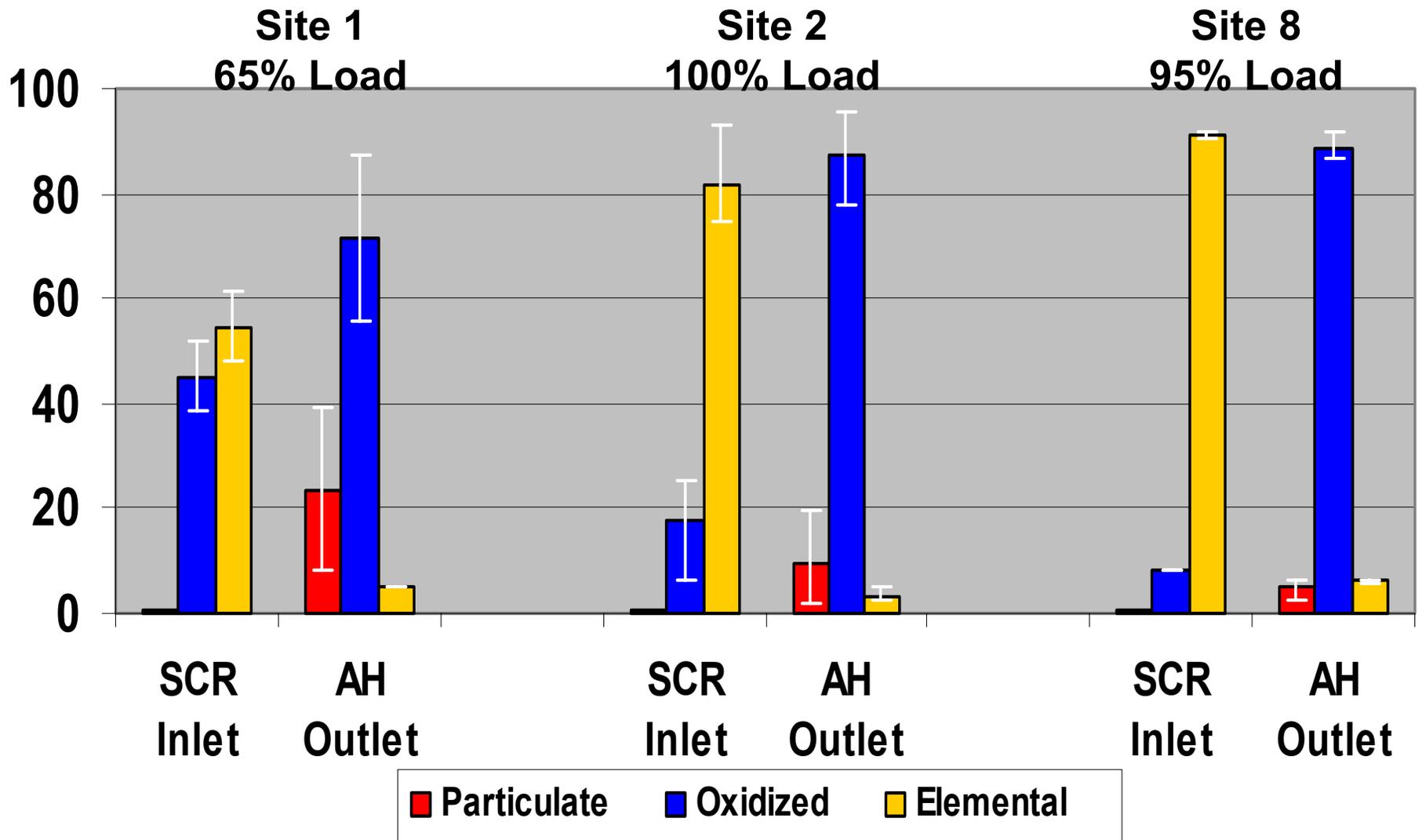
Coal Analyses

(Units are % dry basis, unless noted otherwise)

| Site No. | 1 | 2 | 8 | 5 Unit #2 |
|---------------------------|--------|--------|--------|-----------|
| Carbon | 75.1 | 77.9 | 73.6 | 73.0 |
| Volatile Matter | 36.6 | 38.0 | 39.8 | 39.3 |
| Ash | 10.1 | 7.2 | 9.5 | 9.8 |
| Sulfur | 1.0 | 1.9 | 4.7 | 3.3 |
| Hydrogen | 4.9 | 4.9 | 5.0 | 5.0 |
| Nitrogen | 1.6 | 1.5 | 1.5 | 1.5 |
| Oxygen | 7.2 | 6.7 | 5.8 | 6.3 |
| | | | | |
| Chlorine | 0.10 | 0.10 | 0.05 | 0.16 |
| | | | | |
| Mercury [ppm] | 0.11 | 0.11 | 0.10 | 0.09 |
| | | | | |
| Moisture, (as determined) | 2.1 | 2.1 | 2.3 | 4.6 |
| Heating Value [Btu/lb] | 13,390 | 14,000 | 13,370 | 13,108 |



Distribution of Hg Species (%)



Hg Speciation at Air Heater Outlet

| Site No. | | 1 | 2 | 8 |
|-------------------------|---|------|------|------|
| Particulate Mercury (%) | | 24 | 10 | 7 |
| Oxidized Mercury (%) | | 71 | 87 | 88 |
| Elemental Mercury (%) | | 5 | 3 | 6 |
| Coal Parameters | Chlorine, dry wt % | 0.10 | 0.10 | 0.05 |
| | Sulfur, dry wt % | 1.0 | 1.9 | 4.7 |
| | Coal Ash SiO ₂ , % | 54 | 48 | 39 |
| | Coal Ash Al ₂ O ₃ , % | 26 | 24 | 19 |
| | Coal Ash Fe ₃ O ₄ , % | 9 | 18 | 32 |
| Boiler Parameters | % Load | 65% | 100% | 95% |
| | SCR Inlet Temperature, °F | 630 | 760 | 680 |
| | AH Outlet Temperature, °F | 255 | 350 | 335 |
| | % O ₂ at SCR Inlet | 5.0 | 4.0 | 3.1 |
| | % O ₂ at AH Outlet | 7.0 | 5.1 | 5.3 |



Hg Removal

| Site # | Hg Flowrate (mg/sec) | | | Coal-to-Stack Hg Removal (%) | Coal-Air Heater Outlet Hg Material Balance Check (%) |
|--------------|----------------------|----------------------|-------|------------------------------------|--|
| | Coal | Air Heater Outlet | Stack | | |
| 1 | 1.9 | 1.9 | 0.21 | 89 | 100 |
| 2 | 1.7 | 1.6 | 0.09 | 95 | 94 |
| 8 (a) | 5.3 | 5.0 | 1.45 | 72 | 94 |
| 5 Unit 2 (b) | 11.7 | N/A | 6.20 | 47 | N/A |

Notes: (a) 15% of flue gas by-passed FGD; Hg removal in the scrubbed portion of the flue gas was 84%
 (b) Flue gas was sampled at FGD inlet and stack.



Hg Removal

| Site No. | 1 | 2 | 8 | 5 Unit #2 |
|---|----------------|----------------|--------------------------|------------------------------|
| Coal-to-Stack Hg Removal (%) | 89 | 95 | 72 (84 for gas scrubbed) | 47 |
| Air Pollution Control Devices After Air Heater | SDA & Baghouse | SDA & Baghouse | ESP & Lime Wet Scrubber | ESP & Limestone Wet Scrubber |
| Boiler Load | 65% | 100% | 95% | 100% |
| AH Outlet Temperature | 255 | 350 | 335 | N/A |
| Stack Temperature | 190 | 180 | 150 | 127 |
| % C in ESP/Baghouse Ash | 5.1 | 6.3 | 5.4 | 2.2 |
| Particulate Loading to Baghouse or ESP, gr/dscf | 6.0 | 5.5 | 2.4 | N/A |



Comparison with Previous Results

| | | Mercury Speciation at Air Heater Outlet (%) | | % Hg Removal |
|--------------------------|------------------------------------|---|------------------------|----------------|
| | | Elemental | Particulate + Oxidized | |
| Units without SCR | | | | |
| | Scrubber Type | | | |
| Site A | Mg-Lime In-Situ Oxidation | 20 | 80 | 66 |
| Site B | Limestone In-Situ Oxidation | 19 | 81 | 56 |
| Site C | Limestone Natural Oxidation | 11 | 89 | 72 |
| Site D | Chiyoda Limestone | 32 | 68 | 75 |
| Site E | Limestone Natural Oxidation | 21 | 79 | 67 |
| Site F | Mg-Lime In-Situ Oxidation | 27 | 73 | 63 |
| Site 5, Unit 2 | Limestone In-Situ Oxidation | NA | NA | 47 |
| Units with SCR | | | | |
| Site 1 | Lime Spray Dryer (Baghouse) | 5 | 95 | 89 |
| Site 2 | Lime Spray Dryer (Baghouse) | 3 | 97 | 95 |
| Site 8 | Mg-Lime Ex-Situ Oxidation | 6 | 95 | 72 (84) |



Conclusions

Based on tests conducted at 3 sites with SCR/FGD

- **The SCR/air heater combination effectively oxidized Hg**
 - At all three units, flue gas exiting the air heater contained only 3% to 6% Hg⁰
- **On a coal-feed basis, Hg removals were:**
 - 89% and 95% for the lime spray dryer units
 - 84% for the lime wet scrubber unit (accounting for 15% flue gas bypass).



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