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 µg/g
- Volatilized during combustion, exits boiler in flue gas
  - Particulate mercury
  - Oxidized mercury
  - Elemental mercury
- ESP/FGDs mainly remove oxidized and particle-bound mercury

Background

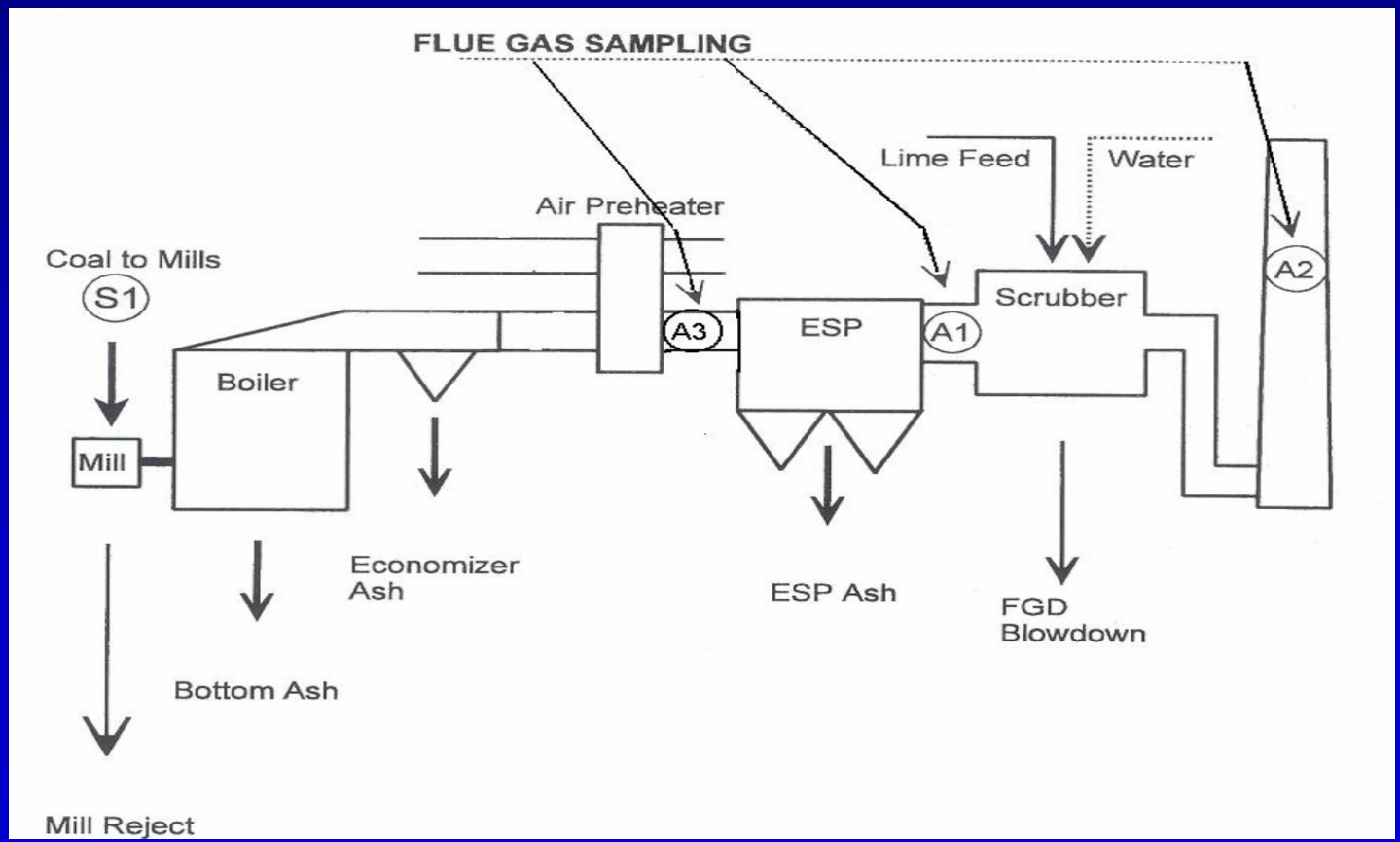
- **EPA: Coal-fired utilities – largest single-source contributor of mercury emissions**

- **EPA's initial assumptions**
  - **FGD scrubbers remove 80% of total Hg**
  - **SCR/FGD combination removes 95% of total Hg**

Previous Studies

Mercury Removal in ESP/FGD

Samples at 5 utility boilers and 1 industrial boiler, all with ESP-FGD



Previous Studies

Mercury Removal in ESP/FGD

- Average Hg removal across FGD: 54±7%
- Average mercury removal across ESP-FGD: 67±6%
- Average Hg mass balance closure: 103±8%
- Oxidized Hg:elemental Hg – ca. 80%:20% ratio at air heater outlet (ESP inlet) for bituminous coal
- 80% to 95% of oxidized Hg removed in ESP-FGD

Current Program

- Evaluate the mercury removal co-benefits achieved by the SCR-FGD combination
- 10 SCR-FGD equipped plants:
  - 3 SCR-SDA-baghouse plants
  - 4 SCR-ESP-wet lime FGD plants
  - 3 SCR-ESP-wet limestone FGD plants
- 9 bituminous coal-fired plants

  1 subbituminous coal-fired plant

Objectives

- Evaluate the effects of:
  - SCR catalyst / air preheater combination on mercury speciation
  - SCR on mercury capture in the ESP-FGD combination
  - low-load operation on mercury capture in an SCR-FGD system

- Collect data to provide insights into:
  - the nature of mercury chemistry in flue gas
  - the effect of SCR/air heater systems on Hg speciation
  - the capture of mercury by different FGD technologies

Sampling Locations

- Flue gas
  - SCR inlet
  - SCR outlet (if ports are available)
  - Air pre-heater outlet
  - Stack

- Solids
  - Coal
  - Bottom ash
  - Baghouse or ESP hopper ash
  - Scrubber sludge
  - FGD reagent (lime, limestone)

QA/QC

- Duplicate analysis of all process stream samples and mercury impinger samples (+/- 20%)
- Field blank and reagent blank analyses
- Spike sample recovery determination on 20% of the impinger samples (+/- 30%)
- NIST SRM (+/- 10%)
- Mercury mass balance (+/- 20%)

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	1,300	SCR / ESP/ wet Lime FGD, natural oxidation	Bit	yes
5	460	SCR / ESP/ wet Limestone FGD, natural oxidation	Bit	year round
5a	460	ESP/ wet Limestone FGD, natural oxidation	Bit	N/A
6	1,300	SCR / ESP / LSFO-gypsum wet FGD	Bit	yes
7	684	SCR / ESP / wet Lime - gypsum FGD, ex-situ oxidation	Bit	yes
8	509.5	SCR / ESP/ wet Limestone FGD, inhibited oxidation	Bit	yes
9	184.5	SCR / ESP/ wet Lime FGD, natural oxidation	Bit	yes
10	640	SCR / ESP/ wet Lime FGD, natural oxidation	Bit	yes

Current Status

- Pre-sampling visits to 6 sites
- Sampling completed at 3 sites
- Next plant in December or January

Results

- Plants 1, 2, and 7
  - Plant 1: 2 runs
  - Plant 2: 4 runs
  - Plant 7: 2 runs
- Eastern bituminous coal
- SCR Inlet, Air Heater Outlet, Stack

Plant Comparison

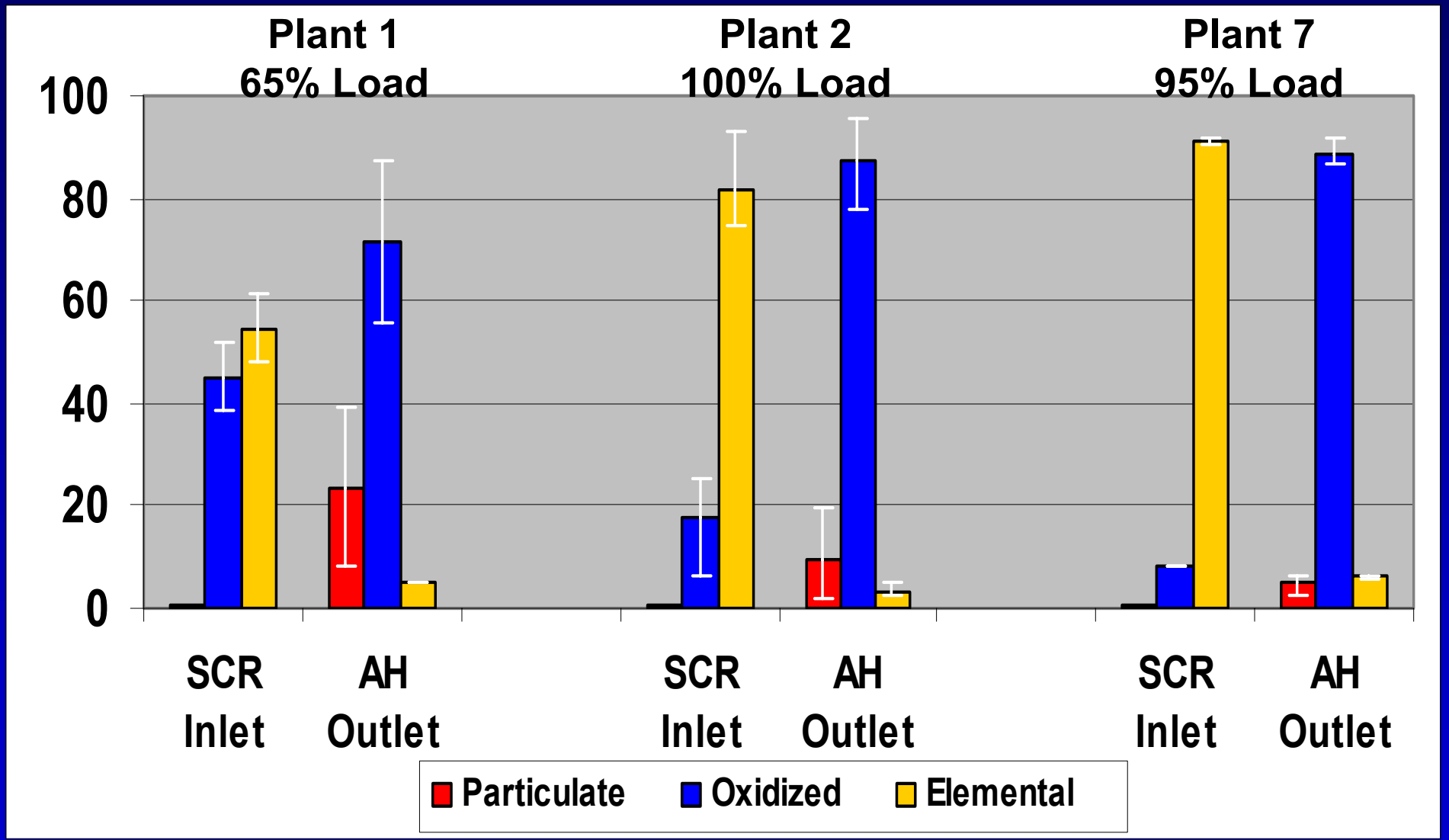
	Plant 1	Plant 2	Plant 7
FGD Type	Lime Spray Dryer	Lime Spray Dryer	Lime, Ex-Situ Oxidation Wet FGD
SCR Catalyst Type	Plate	Honeycomb	Plate
Capacity, MW	330	130	684
Plant Load During Test	215	130	650
SCR Inlet Temperature, °F	630	760	680
Air Heater Exit Temperature, °F	255	350	335
Stack Temperature, °F	190	180	150
% Oxygen at SCR Inlet	5.0	4.0	3.1
% Oxygen at AH Exit	7.0	5.1	5.3

Coal Analyses

(Units are % dry basis, unless noted otherwise)

	Plant 1	Plant 2	Plant 7
Carbon	75.1	77.9	73.6
Volatile Matter	36.6	38.0	39.8
Ash	10.1	7.2	9.5
Sulfur	1.0	1.9	4.7
Hydrogen	4.9	4.9	5.0
Nitrogen	1.6	1.5	1.5
Oxygen	7.2	6.7	5.8
Chlorine	0.10	0.10	0.05
Mercury [ppm]	0.11	0.11	0.10
Moisture (as determined)	2.1	2.1	2.3
Heating Value [Btu/lb]	13,390	14,000	13,370

Distribution of Hg Species (%)



Hg Removal

Plant Number	Hg Flowrate (mg/sec)			Coal-to-Stack Hg Removal (%)	Coal-Air Preheater Outlet Hg Material Balance Check (%)
	Coal	Air Preheater Outlet	Stack		
1	1.9	1.9	0.21	89	100
2	1.7	1.6	0.09	95	94
7 (a)	5.3	5.0	1.45	73	94

Notes: (a) 15% of flue gas by-passed FGD; equivalent Hg removal without bypass was 83%

Hg Speciation at Air Heater Outlet

	Plant Number	1	2	7
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 SiO2, %	54	48	39
	Coal Ash Al2O3, %	26	24	19
	Coal Ash Fe3O4, %	9	18	32
Boiler Parameters	% Load	65%	100%	95%
	SCR Inlet Temperature, °F	630	760	680
	AH Outlet Temperature, °F	255	350	335
	% O2 at SCR Inlet	5.0	4.0	3.1
	% O2 at AH Outlet	7.0	5.1	5.3
	SCR Type	Plate	Honey-comb	Plate

Hg Removal

Plant Number	1	2	7
Coal-to-Stack Hg Removal (%)	89	95	73 (no bypass = 83)
Air Pollution Control Devices After Air Heater	Spray Dryer & Baghouse	Spray Dryer & Baghouse	ESP & Lime Wet Scrubber
Boiler Load	65%	100%	95%
AH Outlet Temperature	255	350	335
Stack Temperature	190	180	150
% C in ESP/Baghouse Ash	5.1	6.3	5.4
Particulate Loading to Baghouse or ESP, gr/dscf	6.0	5.5	2.4

Comparison with Previous Results

Units without SCR		Mercury Speciation at Air Heater Outlet (%)		% Hg Removal
		Elemental	Particulate + Oxidized	
	Scrubber Type			
Plant A	Mg-Lime	20	80	66
Plant B	Limestone Forced Oxidation	19	81	56
Plant C	Limestone Natural Oxidation	11	89	72
Plant D	Chiyoda Limestone	32	68	75
Plant E	Limestone Natural Oxidation	21	79	67
Plant F	Mg-Lime	27	73	63
Units with SCR				
Plant 1	Lime Spray Dryer (Baghouse)	5	95	89
Plant 2	Lime Spray Dryer (Baghouse)	3	97	95
Plant 7	Lime Forced Oxidation	6	95	73 (83)

Conclusions

Based on tests conducted at 3 sites with SCR/FGD

- The SCR/air heater combination effectively oxidized mercury
  - At all three units, flue gas exiting the air heater contained only 3% to 6% elemental mercury
- On a coal-feed basis, Hg removals were:
  - 89% and 95% for the lime spray dryer units
  - 83% for the lime wet scrubber unit (accounting for 15% flue gas bypass).

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