Effect of SCR Catalyst on Mercury Speciation

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Combined Power Plant Air Pollutant Control Mega Symposium
August 30 - September 2, 2004, Washington, DC

Background

- Speciation influences emissions control
  - Wet FGD captures high percentage of ionic Hg^{2+}
  - Volatile elemental Hg^0 is difficult to capture
- Many Selective Catalytic Reduction (SCR) units are meeting stringent NO_X regulations
  - 100 GW coal-fired capacity will employ SCR by 2005
  - Oxides of vanadium/titanium (V_2O_5/TiO_2) catalyst
  - Ammonia (NH_3) or urea (NH_2CONH_2) reductant
- SCR has an impact on mercury speciation
  - Limited field data in Europe and U.S.
  - Increase in Hg^{2+} across SCR reactor

Hg Chemistry in SCR Systems

- Apparent dependence on coal type
  - Higher Hg^{2+} across SCR for bituminous coal-fired boilers
  - Little change in Hg speciation across SCR for sub-bituminous (Powder River Basin, [PRB]) coal-fired boilers

- Possible effects of SCR system
  - Changes in flue gas chemistry (NO_X, NH_3, SO_3)
  - Catalytic oxidation by vanadium based catalysts

- Effects of SCR catalyst age and residence time on Hg^0 oxidation are not well understood
  - Important for SCR to be a viable technology for Hg speciation modification

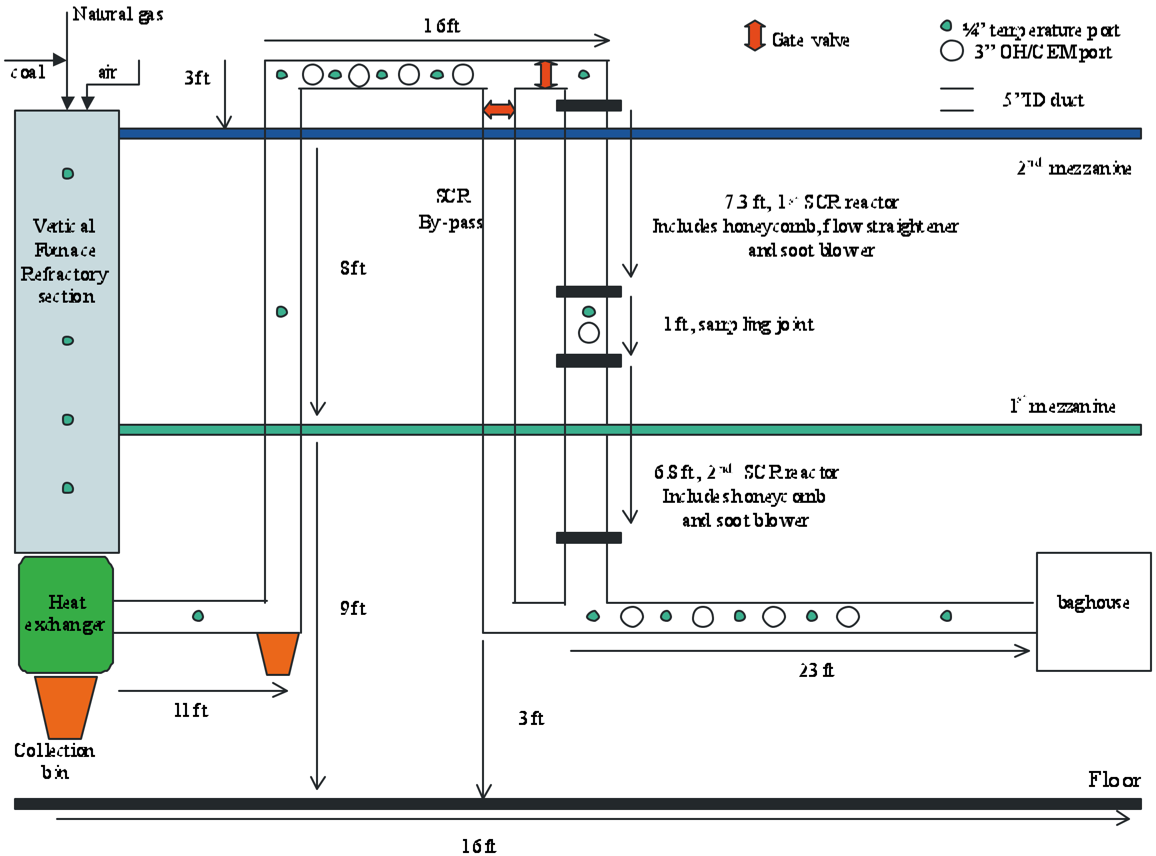
Objectives

- Evaluate Hg speciation effects of SCR technology for Illinois bituminous and PRB coal combustion flue gases
  - No prior SCR Hg field studies on Illinois coals
- Understand the effects of SCR catalyst age and residence time on Hg^0 oxidation

Approach

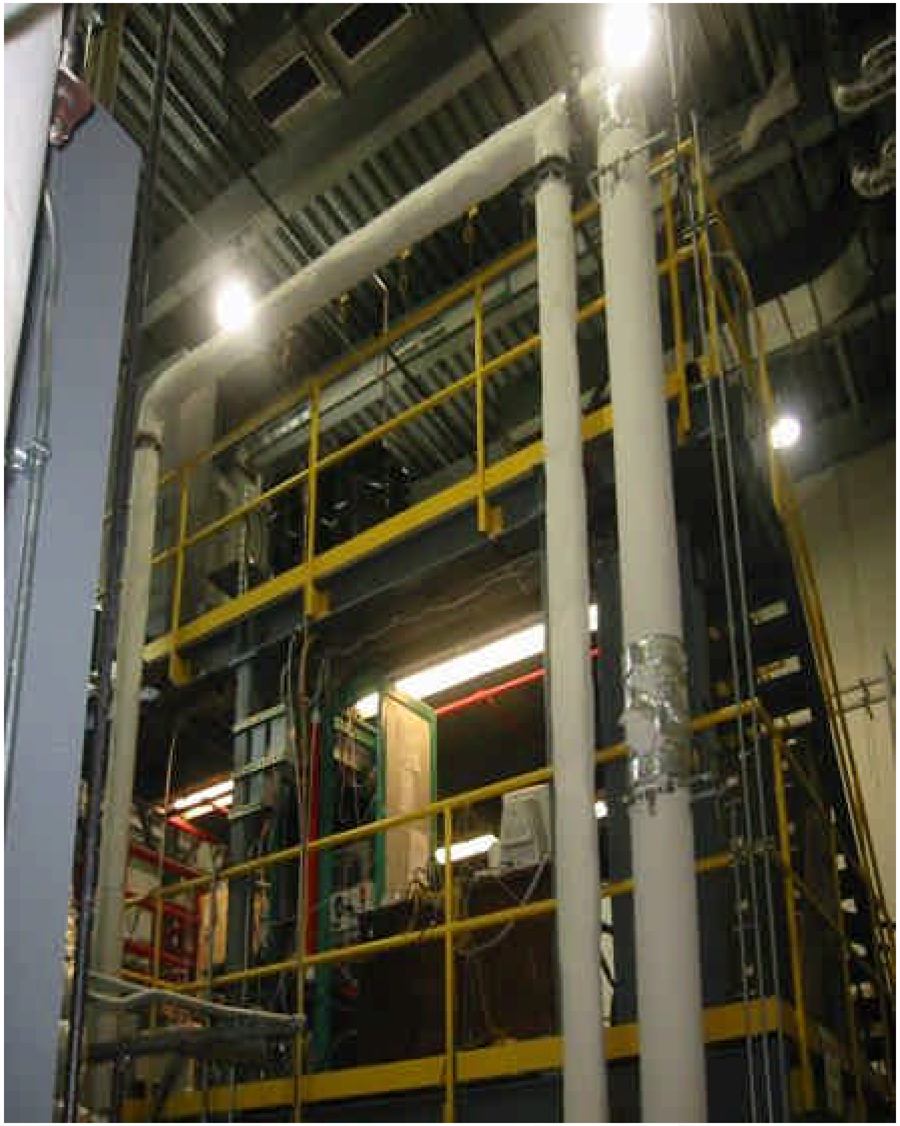
- Pilot-scale SCR experiments
  - Assess Hg^0 oxidation during firing of Illinois and PRB coals with Ontario Hydro (OH) method
- Bench-scale SCR experiments
  - Fresh and aged catalyst from bituminous coal-fired utility power plant
  - Field-aged sample collected after 2 ozone seasons
  - Residence time studied by varying catalyst length (at constant flow)
  - Simulated flue gas and SCR operating conditions
  - Triplicate run with on-line Hg^0 analyzer (Seefelder)

Pilot-Scale Coal Combustion and SCR System



- Vertical down-fired combustor (6"ID X 13'L)
- 150 kBtu/hr firing rate
- Two SCR catalysts (1.25 m each)
- 2 Sootblowers
- SV: ~ 3000 hr^{-1}
- OH sampling at SCR inlet and outlet

Pilot-Scale SCR Reactor



Characteristics of Coals Tested

Content	PRB Black Thunder	Turris (Illinois) (Medium S/Cl)	Crown II (Illinois) (High S/low Cl)	Galatia (Illinois) (Low S/high Cl)
% Moisture	14.00	16.99	16.07	11.33
% Ash	5.92	9.26	7.34	6.29
% Volatile	37.33	33.89	37.05	34.16
% Fixed C	42.76	39.85	39.55	48.22
HV (Btu/lb)	9,903	10,531	10,877	12,179
%C	59.71	59.00	60.48	68.31
%H	3.83	4.32	4.70	4.50
%N	0.82	1.19	1.07	1.50
%S	0.29	3.11	3.48	1.13
%O	15.44	5.96	5.73	6.94
%Cl	NA	0.17	0.13	0.29
Hg, ppmw	NA	0.07	0.07	0.09

NA: not available

Pilot-Scale SCR Test Conditions

Parameter	Turris	Galatia	Crown II	PRB
Coal feed rate, lb/hr	14.0	11.5	13.4	15.7
Firing rate, Btu/hr	147,540	140,424	145,208	155,873
Total air flow, scfm	28.6	28.2	28.4	28.9
Excess air, %	11	18	11	5
CO, ppm (dry)	38	30	40	0
Uncontrolled NO_x, ppm (dry)	960	850	650	525
SO_2, ppm (dry)	2921	929	2739	222
Air in-leakage (calculated), %	4	4	11	16

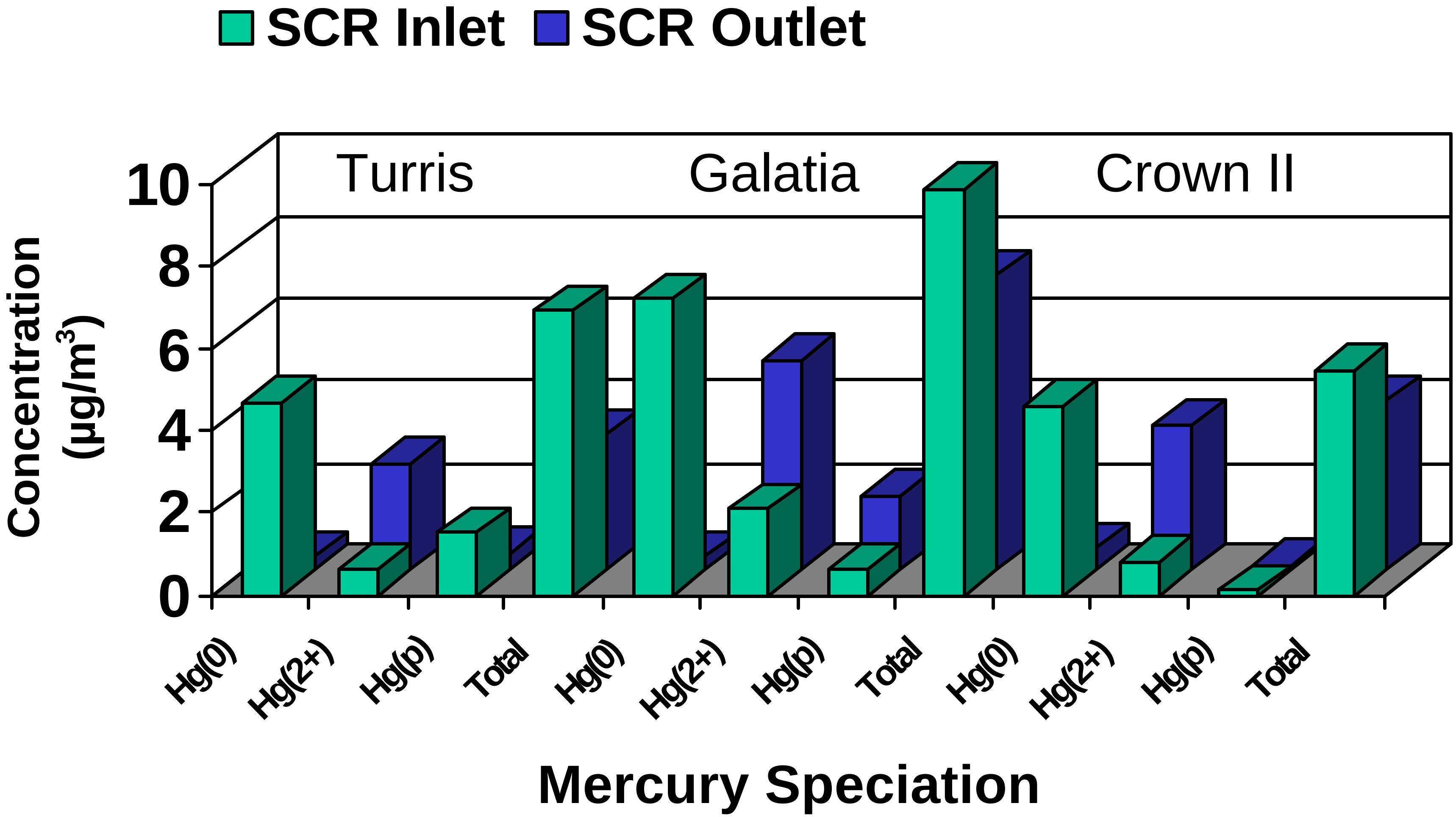
Pilot-Scale SCR Test Conditions (Continued)

Parameter	Turris	Galatia	Crown II	PRB
Temperature, °C	365	342	352	364
NOx reduction across SCR, %	90	86	90	90
HCl (measured), ppm (wet)	NM	246	NM	NM
HCl (calculated), ppm (wet)	141	208	96	7.9
PM at SCR inlet*, mg/dscm	5863	3070	3946	2418
PM at SCR outlet*, mg/dscm	3506	1735	2560	1606

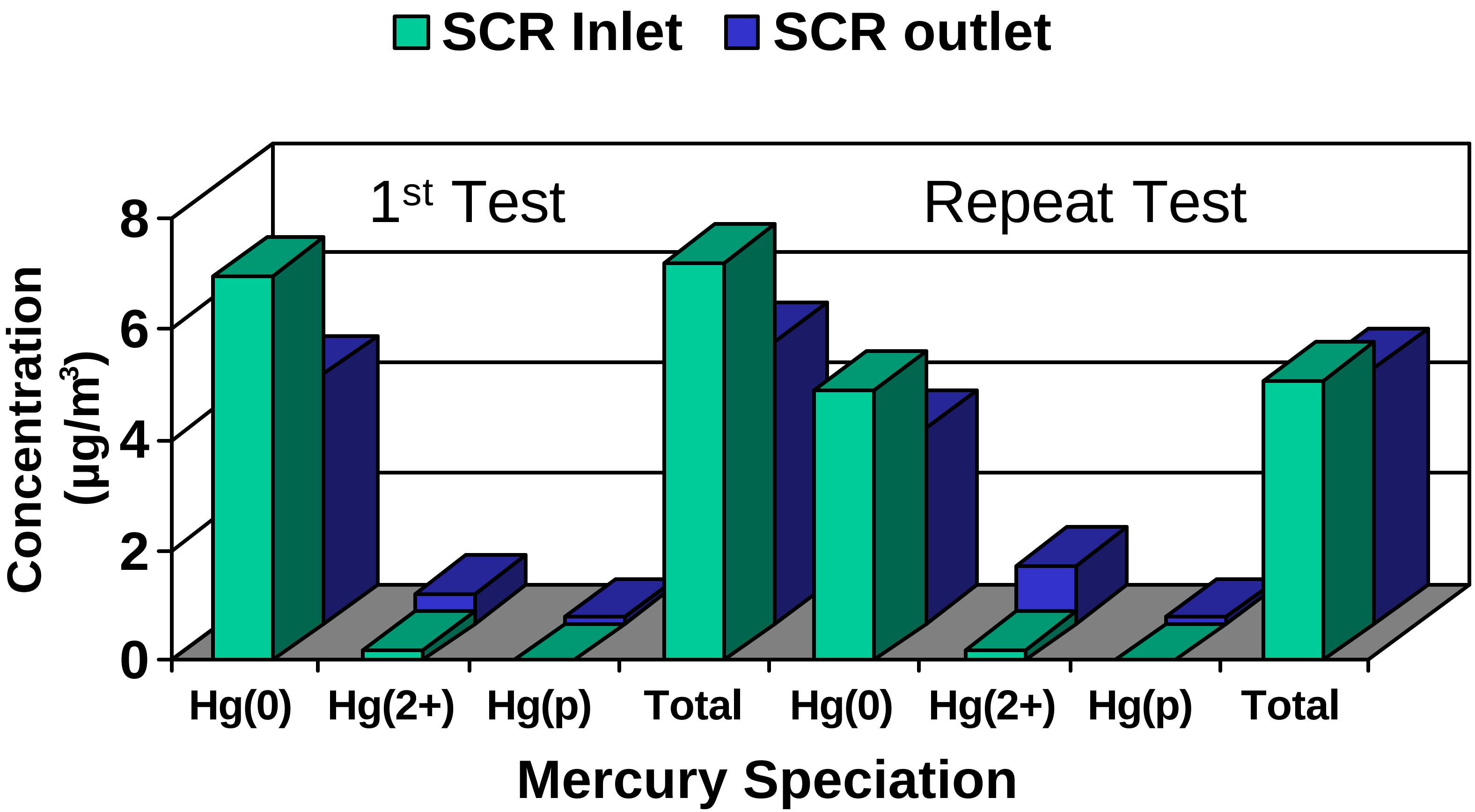
NM: Not Measured

* Measured using the filter weight of the isokinetic OH method at the inlet and outlet of the SCR

Illinois Bituminous Coal Test Results



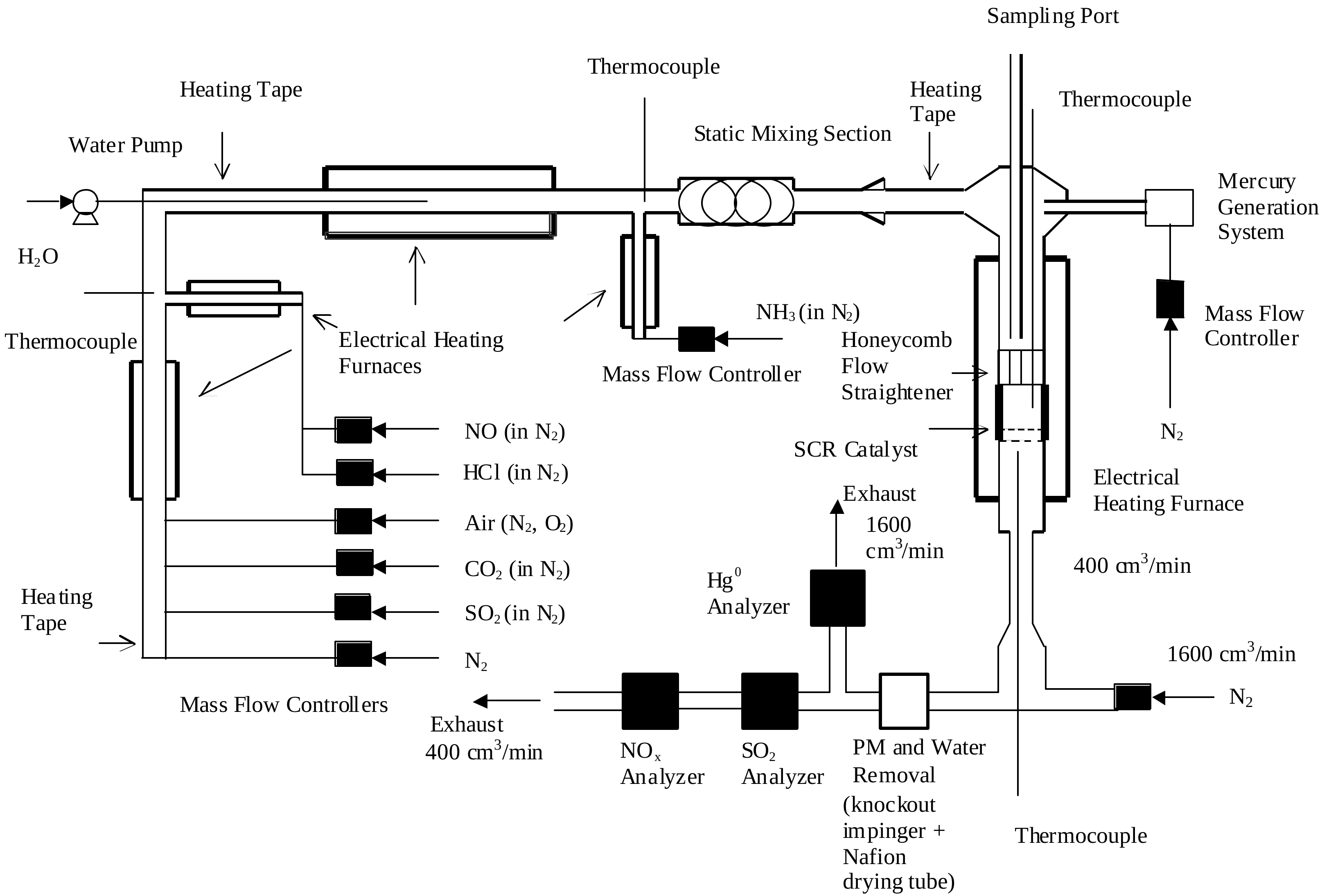
Black Thunder (PRB) Test Results



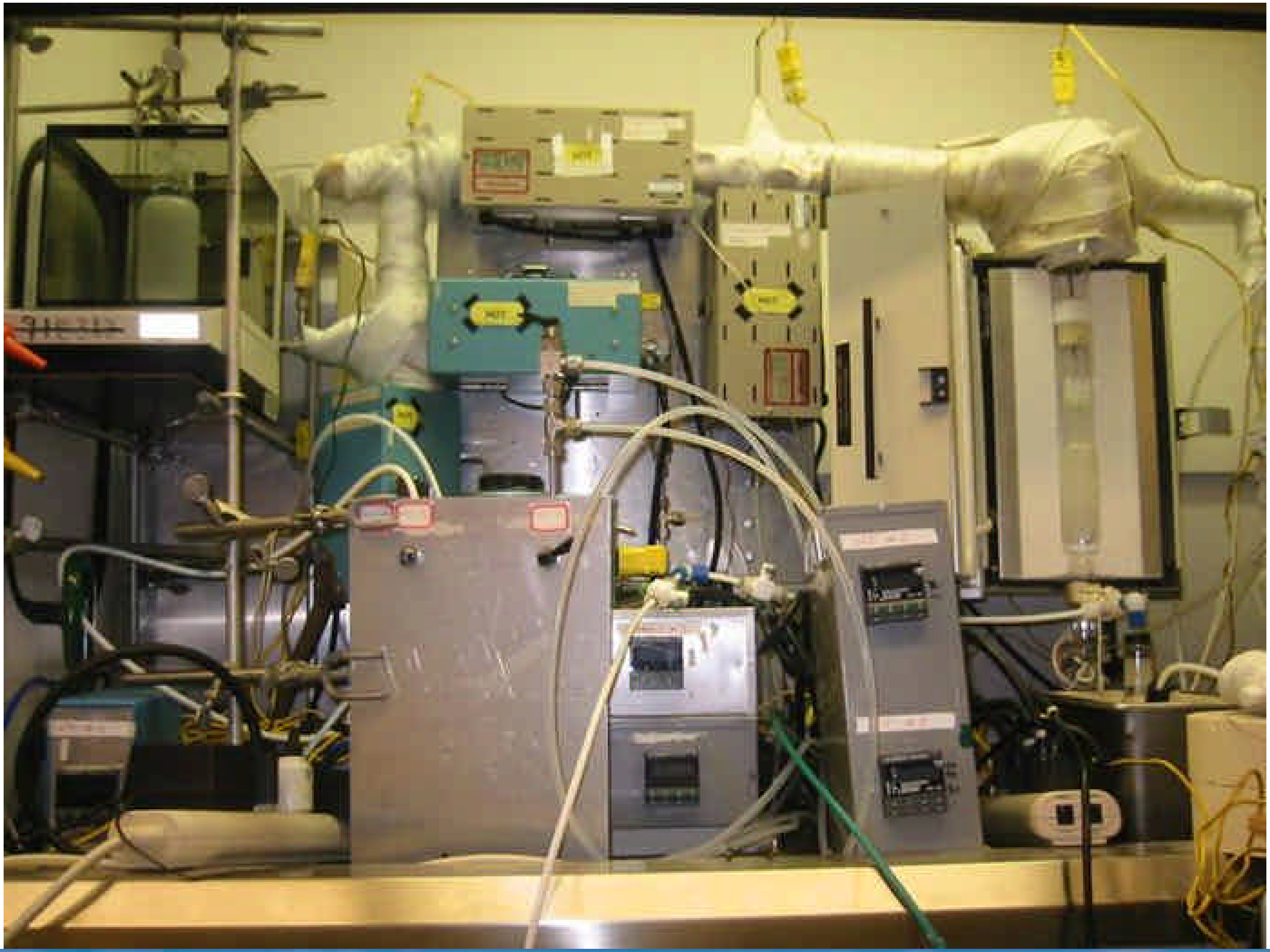
Summary of Pilot Results

	Turris	Galatia	Crown II	PRB	PRB Repeat
% Hg^0 at SCR inlet	68	73	84	97	96
% Hg^0 at SCR outlet	9	4	12	88	76
% Oxidation	87	94	85	9	21

Bench-Scale SCR Reactor



Bench-Scale SCR Reactor



Experimental Procedures

- Thermal pre-treatment of catalyst
  - Heating of catalyst overnight at 425 °C under N_2 flow
  - Minimize residual effect from previous experiment
- Catalyst pre-conditioning
  - Passing SO_2 and HCl through catalyst overnight at levels for next day's experiment
- Add Remaining flue gas components (O_2, CO_2, H_2O, NO, NH_3, Hg^0) before experiment

Simulated Bituminous Bench-Scale Results

	Design SV		High SV	
	Fresh	Aged	Fresh	Aged
Space Velocity (hr^{-1})	2263	2263	3031	3031
NO_x Reduction (%)	84	90	92	90
	87	86	91	92
	87	85	91	92
Average Reduction (%)	85 $\pm$ 2	87 $\pm$ 3	91 $\pm$ 1	91 $\pm$ 1
Hg^0 Oxidation (%)	87	84	74	70
	88	86	78	68
	89	85	77	68
Average Oxidation (%)	88 $\pm$ 1	85 $\pm$ 1	76 $\pm$ 2	69 $\pm$ 1

- Aged catalyst sample: collected in the field after 2 ozone seasons (ca. 8000 hr)
- Operating conditions: 365 °C, 2250 ppm SO_2, 590 ppm NO_X, 531 ppm NH_3, 40 ppm HCl, 20 ppb Hg^0, 4.2% O_2, 13.2% CO_2, 7.1% H_2O

Conclusions

- Heterogeneous reactions over SCR catalyst promote Hg^0 oxidation
- Pilot studies confirm coal type dependence
  - Illinois bituminous coal - high levels of Hg^0 oxidation
  - PRB coal - low Hg^0 oxidation at test conditions
- Bench-scale studies show sustained Hg^0 oxidation
  - Field-aged and fresh SCR samples - high Hg^0 oxidation
  - Slight aging effect seen at high space velocity
- Implications
  - Illinois/bituminous - SCR + FGD is a practical option
  - PRB/sub-bituminous - SCR oxidation needs improvement

Acknowledgement

This project is supported, in part, by grants made possible by the Illinois Department of Commerce and Economic Opportunity through the Office of Coal Development and Illinois Clean Coal Institute