Oxidation of Mercury Across SCR Catalysts in Coal-Fired Power Plants Burning Low Rank Fuels

(DE-FC26-03NT41728)

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Project Objectives

- Gather data on the behavior of mercury across SCR catalysts
  - Increase understanding of Hg behavior
  - New model
- Measurements at one power plant burning bituminous/subbituminous blend
- Slipstream reactor with six catalysts
  - One blank honeycomb
  - Three commercial honeycomb catalysts
  - Two commercial plate catalysts

Project Organization

- Slipstream reactor built under catalyst deactivation program (DE-FC26-00NT40753; Bruce Lani, COR)
- Mercury testing carried out under separate program (DE-FC26-03NT41728; José Figueroa, COR)
- Additional support from EPRI and Argillon GmbH
- Field test support from AEP

Project Team

REI: Planning/analysis, slipstream reactor operation

- Connie Senior, Temi Linjewile, Darren Shino, Dave Swensen

URS: Mercury measurement and analysis

- Carl Richardson, Mandi Richardson, Tom Mahalek

AEP: Field test support and program review

- Steve Pfeister, Steve Batie
- Gary Spitznogle, Aimee Toole

Program review

- José Figueroa, Bruce Lani, Lynn Brickett (DOE-NETL)
- Chuck Dene (EPRI)
- Jeanette Bock (Argillon GmbH)

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Testing Summary

- Rockport:
  - Two 1300 MW_e B&W opposed wall-fired, supercritical boilers
  - Testing on Unit 1 across air preheater
- Burn a bituminous-subbituminous blend
- Two test series (March and August)
- FIRST TEST SERIES:
  - Boiler held at full load, 7:00 to 19:00 during test days
  - Ontario Hydro measurement at inlet to SCR reactor (3/28/03)
  - SCEM measurements made 3/28-4/2/03
  - Coal and ash samples collected

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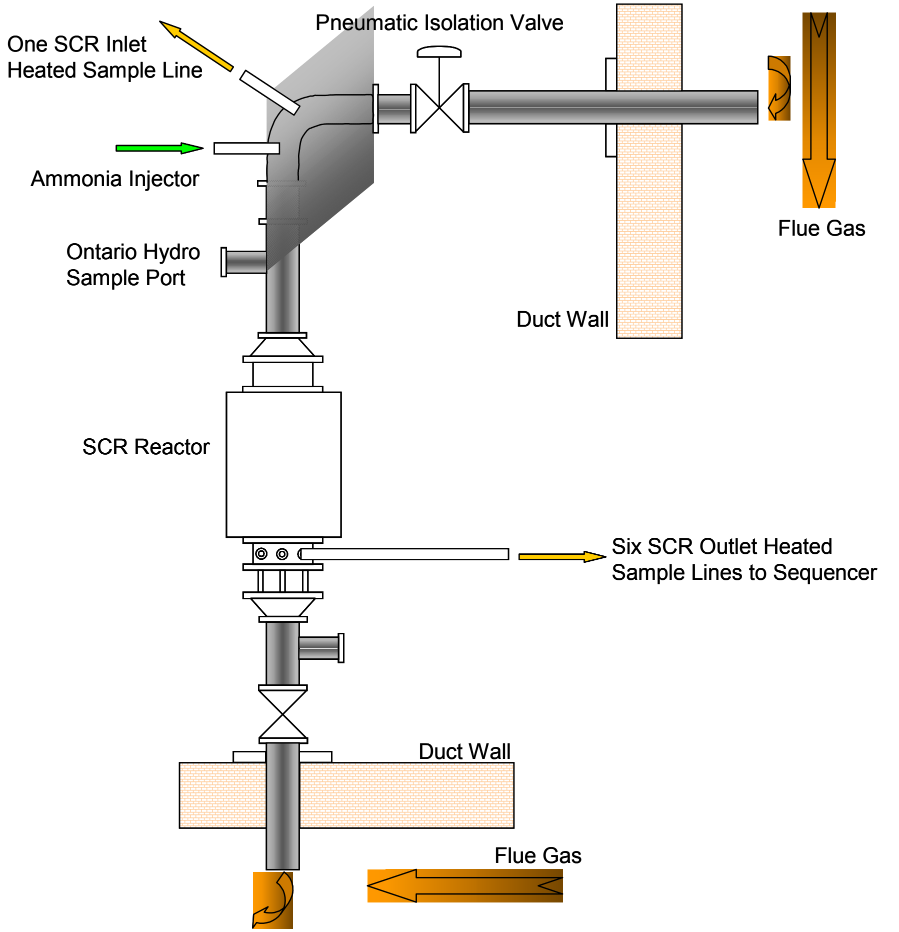
Multi-catalyst Slipstream Reactor



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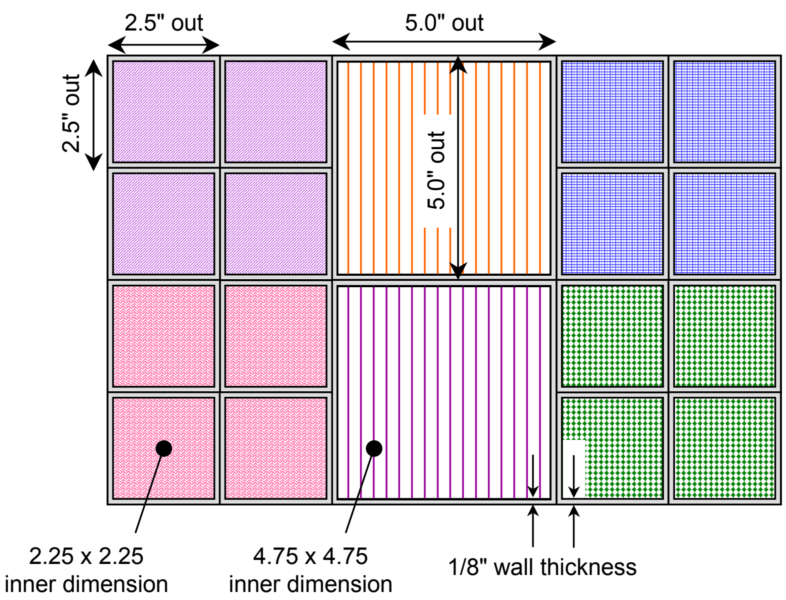
Catalyst Dimensions

Chamber:	1 (Blank)	2	3	4	6	5
Catalyst type:	Monolith	Monolith	Plate	Plate	Monolith	Monolith
Chamber porosity:	58.7%	70.0%	85.0%	86.9%	70.0%	68.3%
Length of catalyst in chamber (inch):	24.40	21.50	39.25	43.25	20.06	19.75



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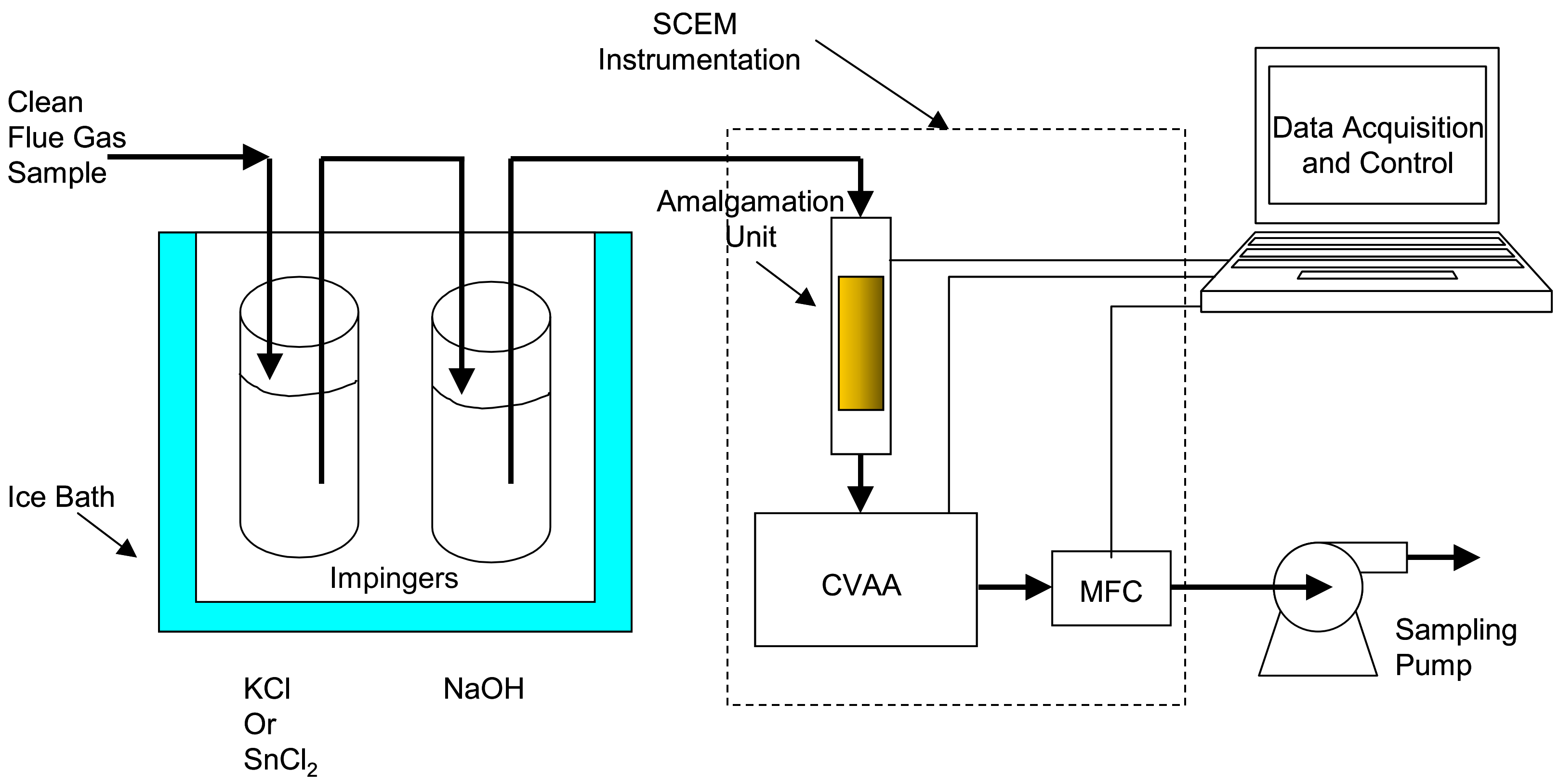
Semi-continuous Hg Monitor (URS)



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Coal Properties

Date	3/28/03	4/1/03	4/2/03
(As Received):			
Carbon	50.67	51.80	51.75
Hydrogen	3.51	3.64	3.46
Oxygen	10.89	11.04	11.18
Nitrogen	0.76	0.78	0.75
Sulfur	0.32	0.30	0.37
Ash	5.12	5.99	6.10
Moisture	28.74	26.45	26.39
HHV	8,723	8,989	8,989
(Dry Basis):			
Hg, ug/g	0.088	0.118	0.091
Cl, ug/g	120	160	200
SO_2, lb/MBtu	0.74	0.67	0.82
Hg, lb/TBtu	10.10	13.13	10.13
Hg, ug/dnm^3 (5%O_2)	8.02	10.82	8.46

- Coal blend – mostly subbituminous
- Higher Cl than typical subbituminous
- 8-10 μg/dnm^3 Hg (gas-phase equivalent)
- Ash contains ~6 wt% Fe_2O_3, ~16 wt% CaO

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Flue Gas Composition

Est. Gas Composition	3/28/03	4/1/03	4/2/03
Excess Air	35%	35%	35%
O_2	4.0%	4.0%	4.0%
CO_2	13.3%	13.4%	13.5%
H_2O	10.6%	10.2%	10.0%
N_2	72.0%	72.3%	72.4%
SO_2 [ppm]	317	292	360
HCl [ppm]*	7.5	10.1	12.8
NO_x [ppm]*	400	400	400

*Estimated

- Calculated from coal analysis and measured O_2, except NO_x

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Hg and Cl in ash

Ash sample	Date	LOI, wt%	Hg, ug/g	Cl, ug/g	% Hg in Ash	% Cl in Ash
Economizer	3/28/03	0.08%	0.0053	28.6	0.03%	1.71%
ESP, silos 3&4	3/28/03	0.31%	0.0809	20.2	0.41%	1.21%
ESP, silos 3&4	3/31/03	0.37%	0.118	24.6	--	--
ESP, silos 3&4	4/1/03	0.31%	0.127	23.6	0.44%	1.20%
ESP, silos 3&4	4/2/03	0.34%	0.101	26.8	0.55%	1.11%

- Economizer ash has 10-20 times less Hg than ESP ash
- ESP ash has very little Hg, ~0.5% of coal Hg
- Cl content of ash is similar in economizer and ESP, ~1.5% of coal Cl

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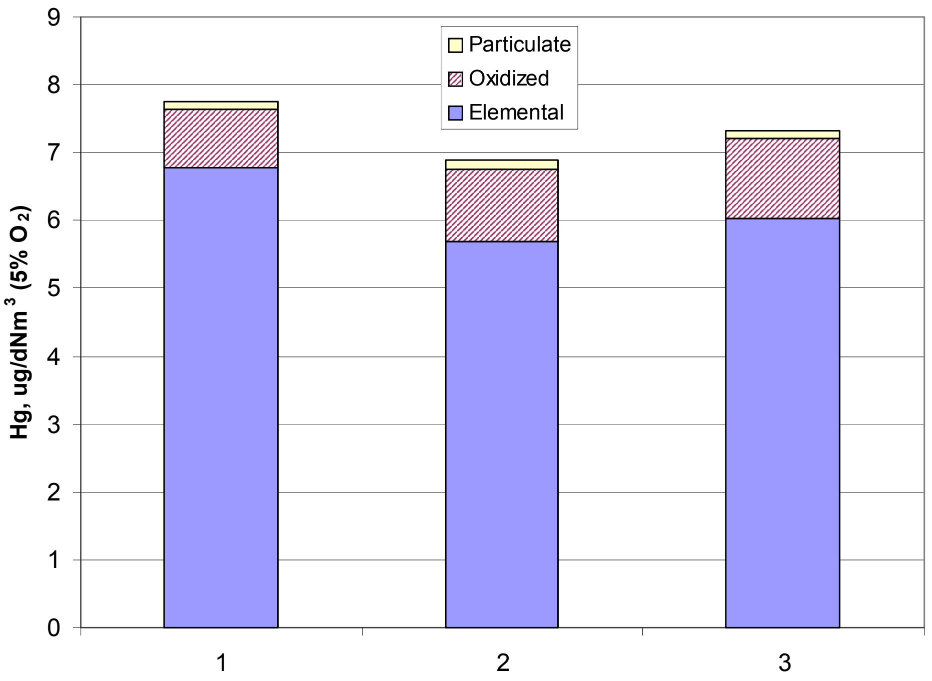
Ontario Hydro Data



- Hg conc. in ash higher than in ESP fly ash
- BUT fraction of Hg in ash very low
- 81% elemental Hg

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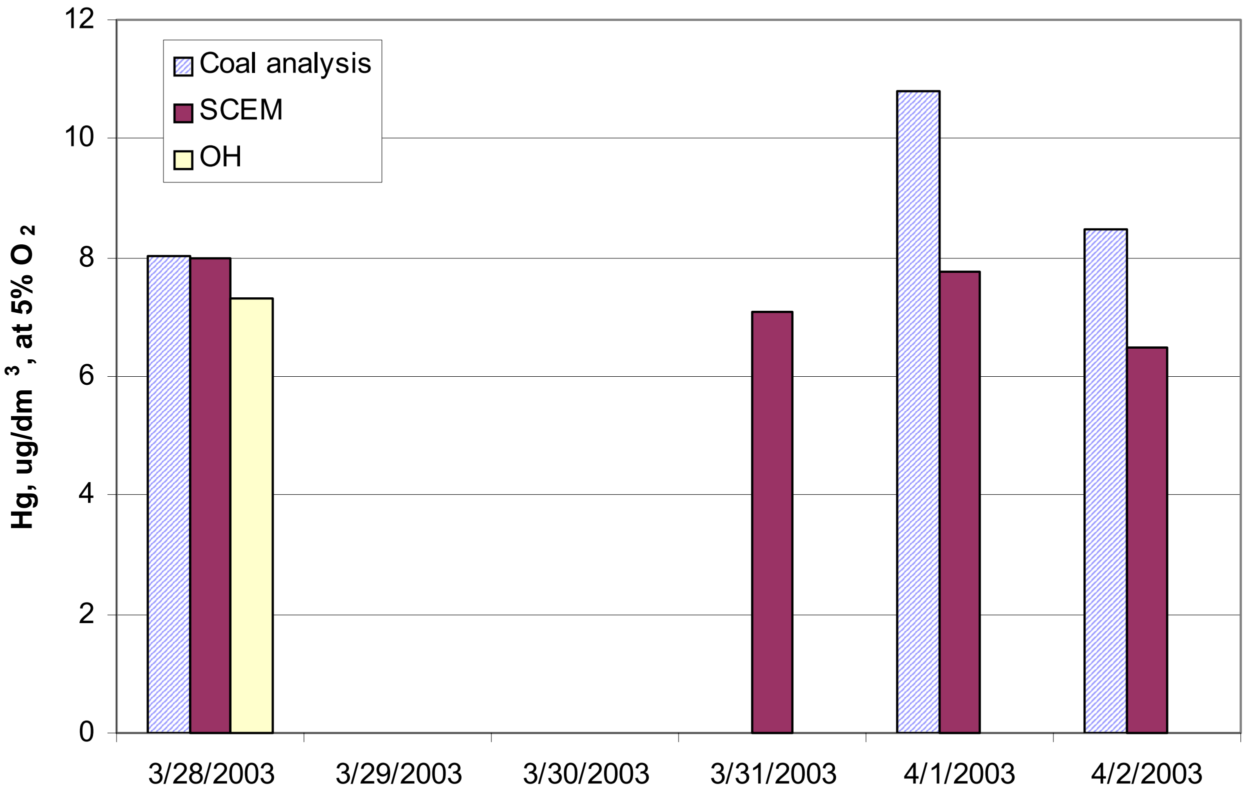
Comparison of Hg: Coal v. SCEM



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Testing Summary: Reactor and Flue Gas

	Temperatures, F					Inlet Mercury		
Date	Boiler Duct	Entrance	Chamber	Space Velocity	NH_3 (avg) ppm	Hg^0, ug/Nm^3, 5% O_2	Hg_T, ug/Nm$_3$, 5% O_2	%Elemental Hg
3/28/03						**6.17**	**7.64**	**81%**
3/28/03	727	651	657	medium	408	5.88	8.00	74%
3/31/03	719	631	657	medium	452	5.00	7.00	71%
4/1/03	719	602	657	low	555	4.82	7.75	56%
4/1/03	717	625	656	medium	523		7.82	
4/2/03	724	641	662	medium	0	6.04	6.47	93%
4/2/03	726	658	667	high	435	4.81	6.47	80%

Space velocities (1/hr):
“low” ~ 3,000
“medium” ~ 6,000-8,000
“high” ~ 12,000-14,000

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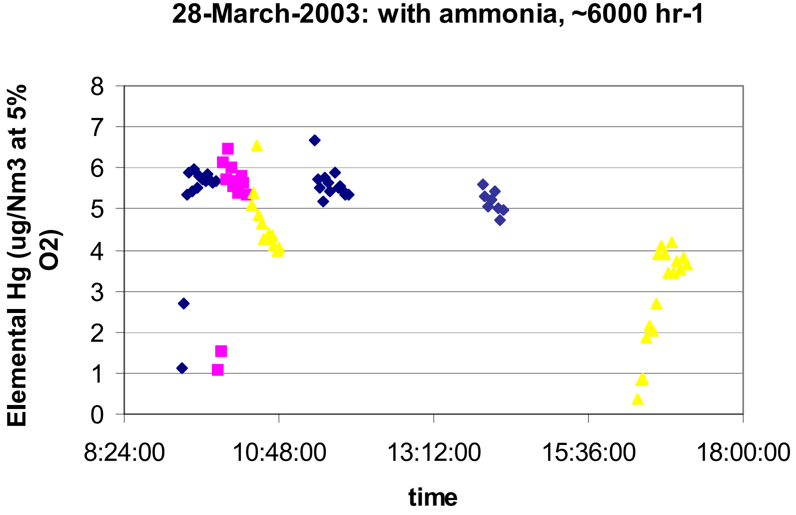
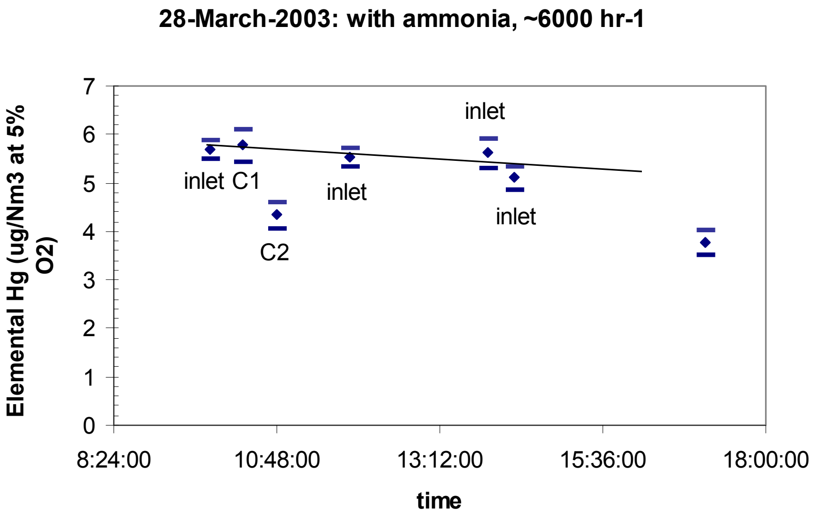
28 March, Hg^0: 6,000 hr^{-1}, with ammonia





- Initial data points not used to calculated standard deviation (right-hand graph)
- Inlet elemental Hg consistent over time
- C1 (blank) did not show oxidation
- C2 showed oxidation

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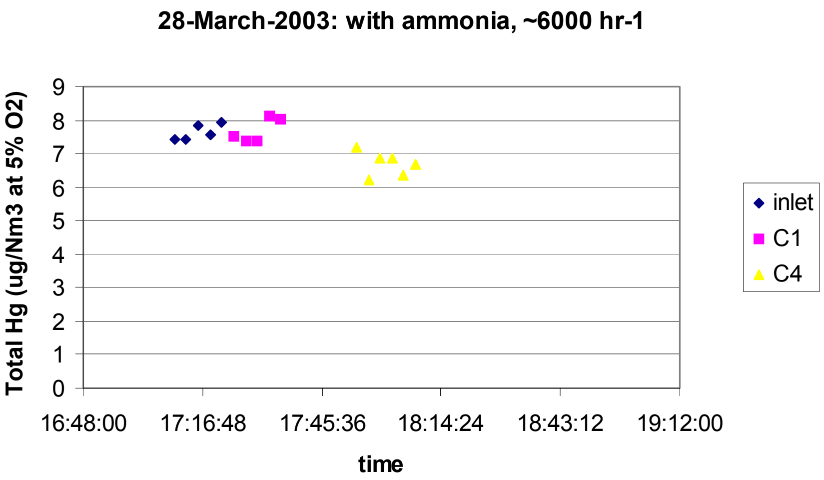
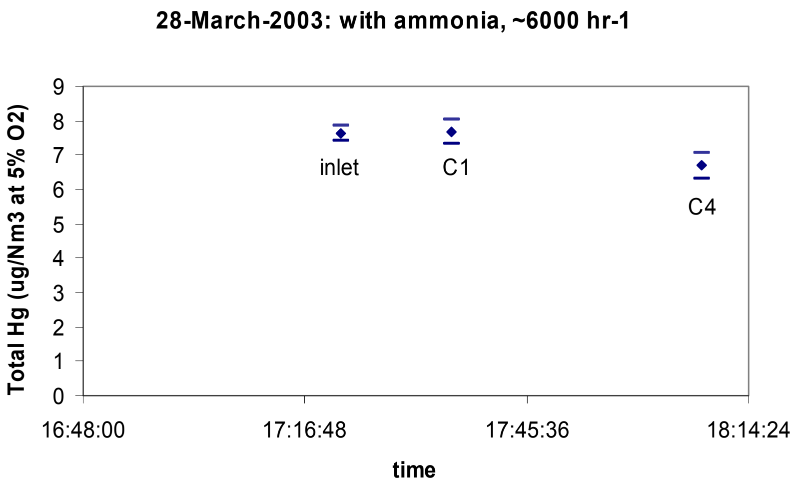
28 March, Hg_T: 6,000 hr^{-1}, with ammonia





- Initial data points not used to calculated standard deviation (right-hand graph)
- Total mercury the same at inlet and outlet of C1 (blank)
- C4 may indicate loss of Hg across catalyst

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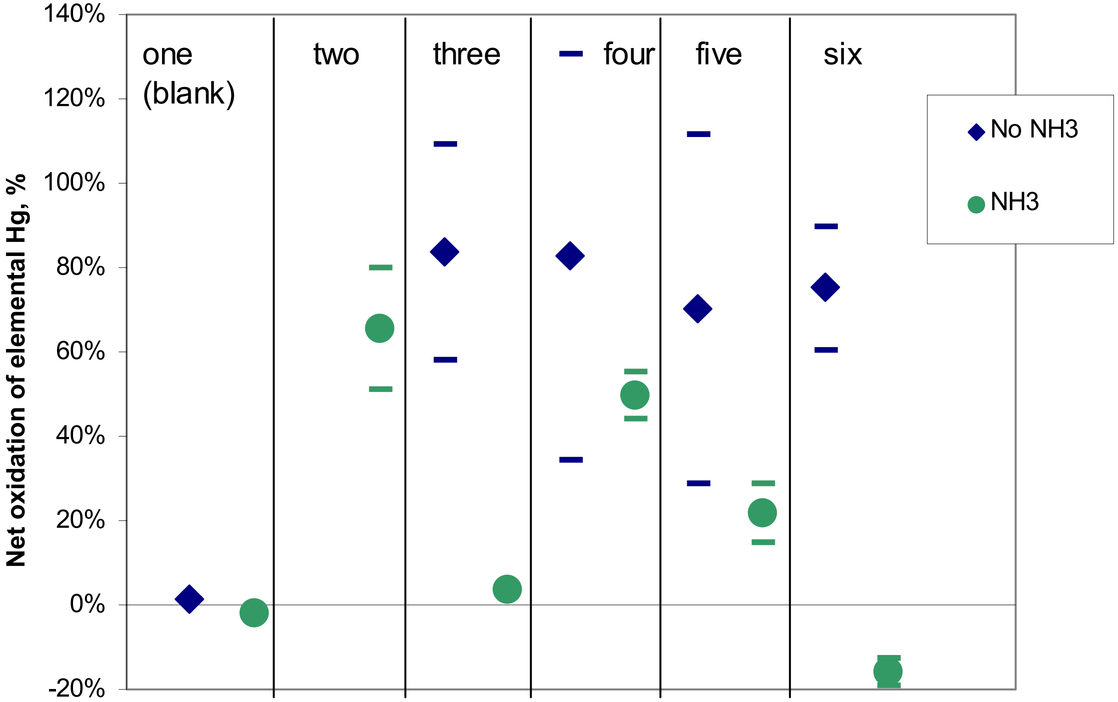
Oxidation of Hg^0 Across Catalyst



- No oxidation across blank
- Some increase in oxidation w/o NH_3
- SV ~ 7,000 hr^{-1}
- T ~ 660 F
- 380-450 ppm NH_3
- Errors estimated from quadratic eqn.

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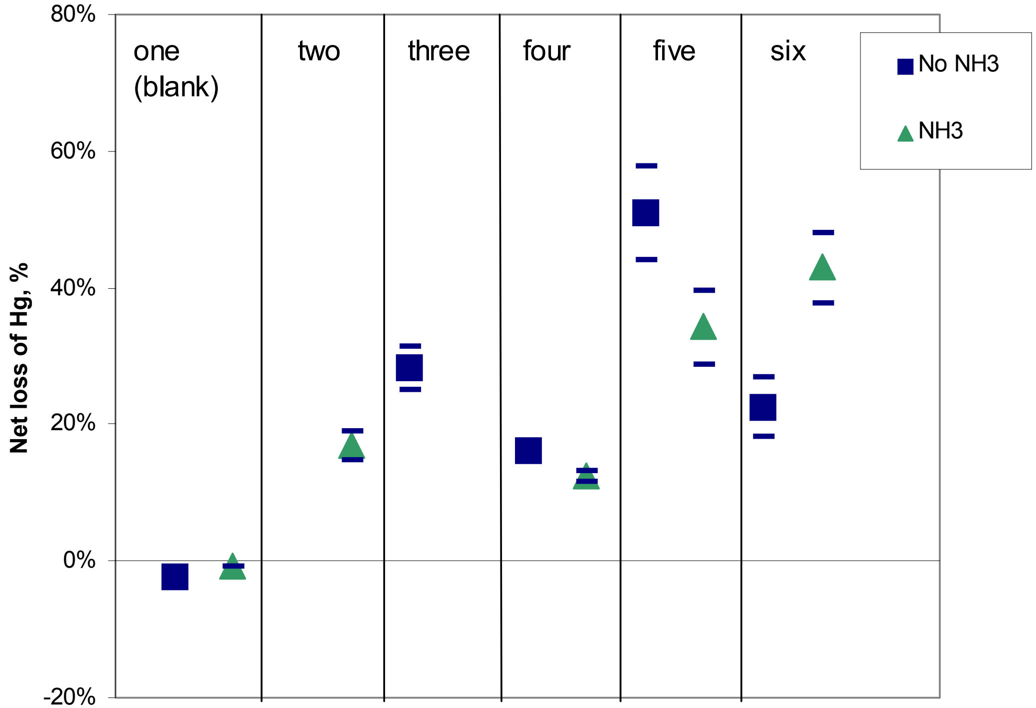
Loss of Hg_T Across Catalyst



- Loss of Hg across commercial catalysts observed
- No loss across blank
- No clear effect of NH_3
- SV ~ 7,000 hr^{-1}
- T ~ 655 F
- 420-540 ppm NH_3
- Errors estimated from quadratic eqn.

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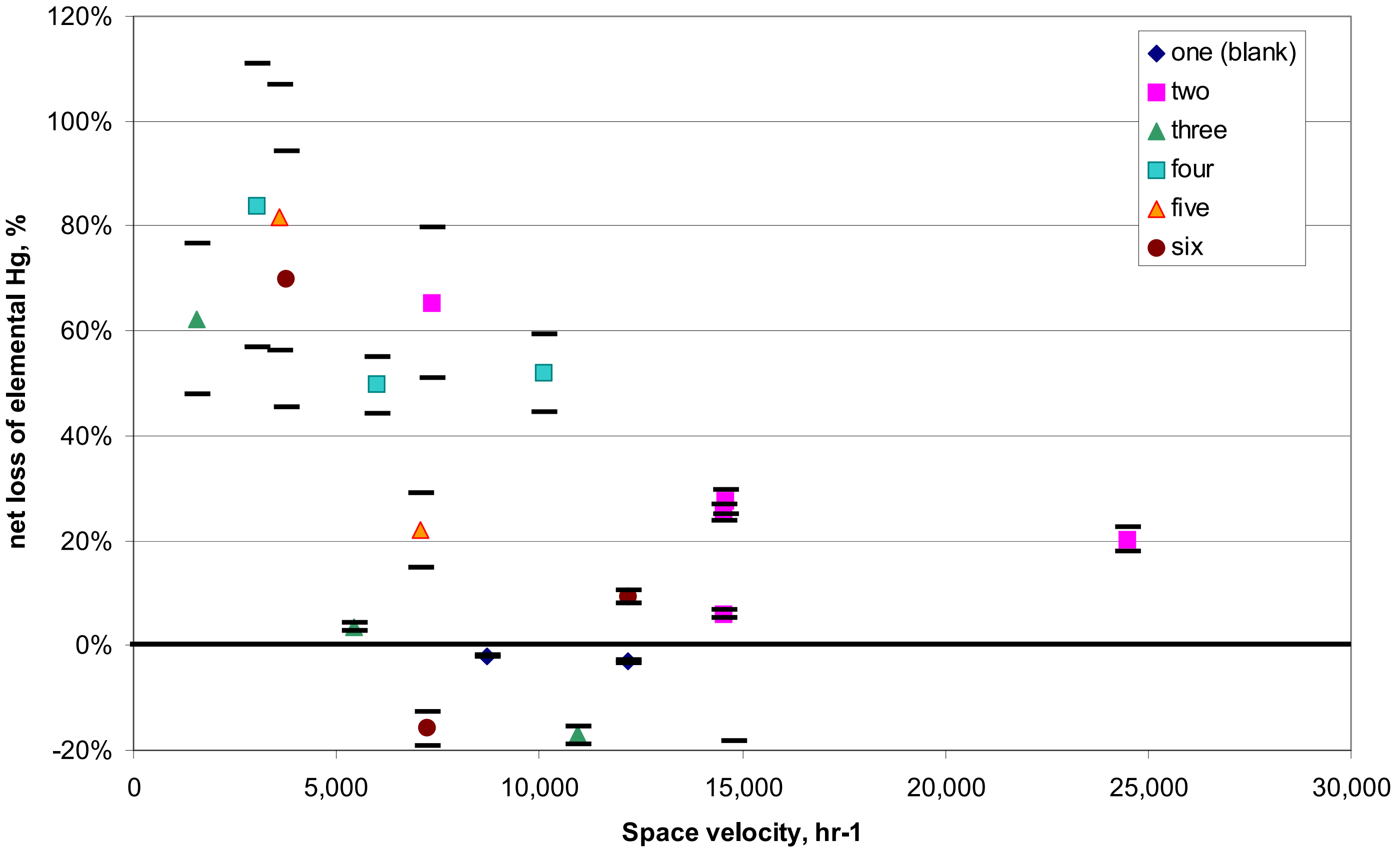
Loss of Elemental Hg as a Function of Space Velocity



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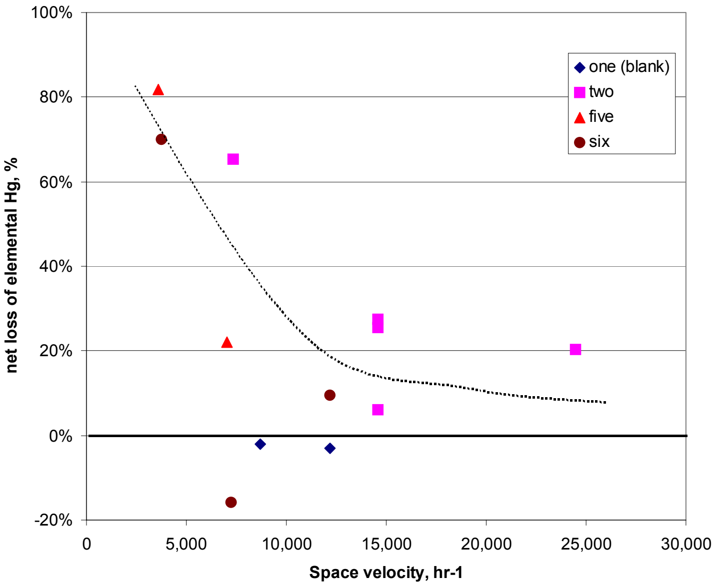
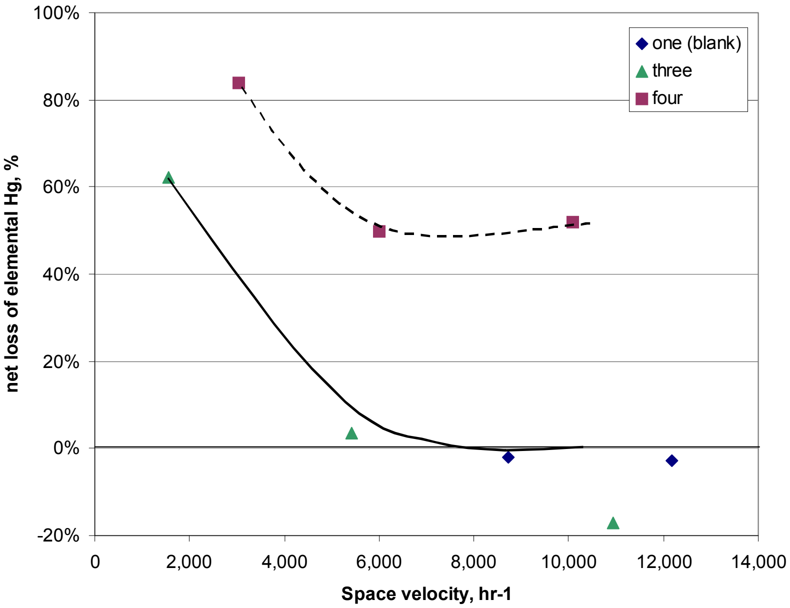
Catalyst Types





Honeycomb Catalysts

Plate Catalysts

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Conclusions

- Blank monolith did not oxidize Hg^0
- Commercial catalysts oxidized Hg^0
- Oxidation of Hg^0:
  - Function of space velocity (at constant T)
  - Monoliths generally had same behavior vs. SV
  - Plate catalysts behaved differently
- Loss (adsorption?) of Hg:
  - No loss of Hg across blank
  - Some loss of Hg_T across catalysts, but no clear effect of NH_3
  - No clear effect of catalyst pressure drop
  - Assumption that lost Hg^0 was oxidized
  - Sampling system problems? Loss of Hg^{+2}?

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Next Test Series: Priorities and Plans

- In progress (August 7 – August 15)
- Make gas-phase Cl measurements
- Make simultaneous NO_x measurements
- Look at transients with sample line switch and ammonia on/off
- Repeat Hg^0 measurements at one SV
  - With and without ammonia
  - NH_3/NO ~ 0.9, maybe lower
  - Determine whether oxidation changes with aging
- Look at possible sampling system effects on loss of Hg

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