REACTION
ENGINEERING
INTERNATIONAL

Oxidation of Mercury Across SCR Catalysts in Coal-Fired Power Plants

C. L. Senior and T. Linjewile
Reaction Engineering International

REACTION
ENGINEERING
INTERNATIONAL

Project Objectives

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

REACTION ENGINEERING INTERNATIONAL

Project Organization

- Slipstream reactor built under catalyst deactivation program (DOE- NETL)
- Mercury testing carried out under separate program (DOE – NETL)
- Additional support from EPRI and Argillon GmbH
- Field test support from AEP

REACTION ENGINEERING INTERNATIONAL

Project Team

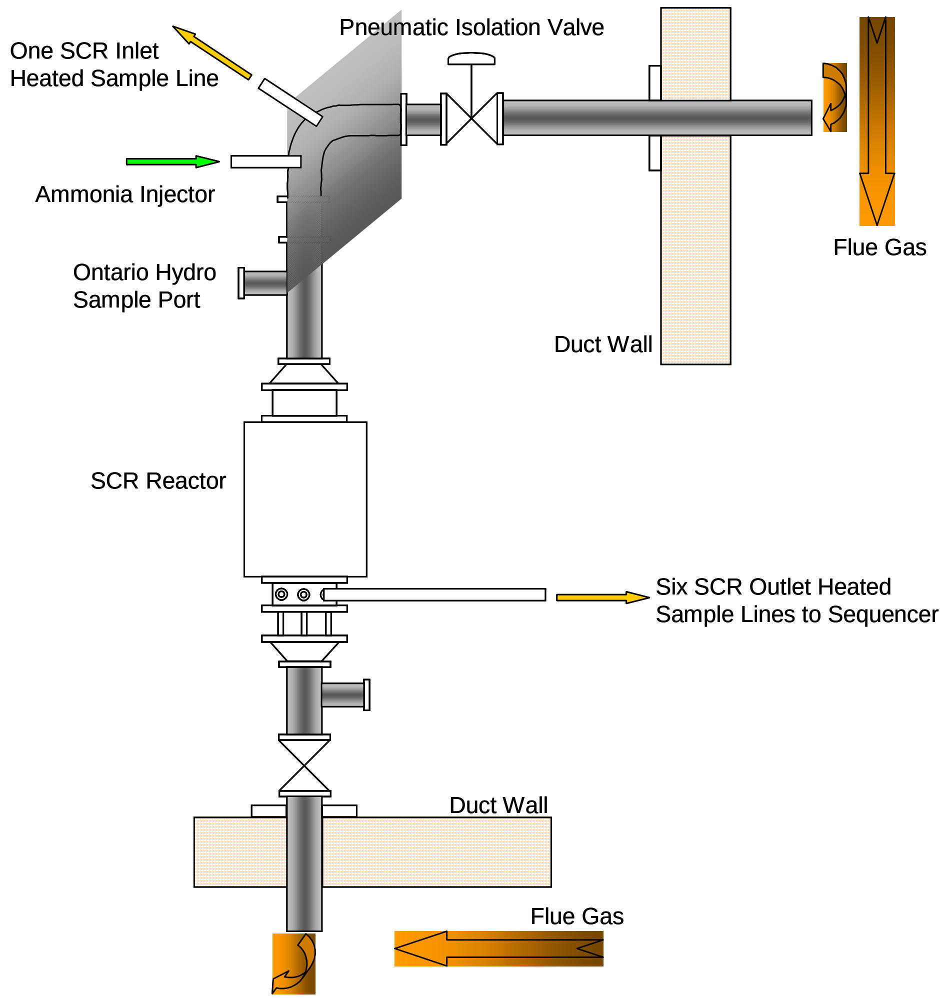
REI: Planning/analysis, slipstream reactor operation
- Connie Senior, Temi Linjewile, Darren Shino, Dave Swensen

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

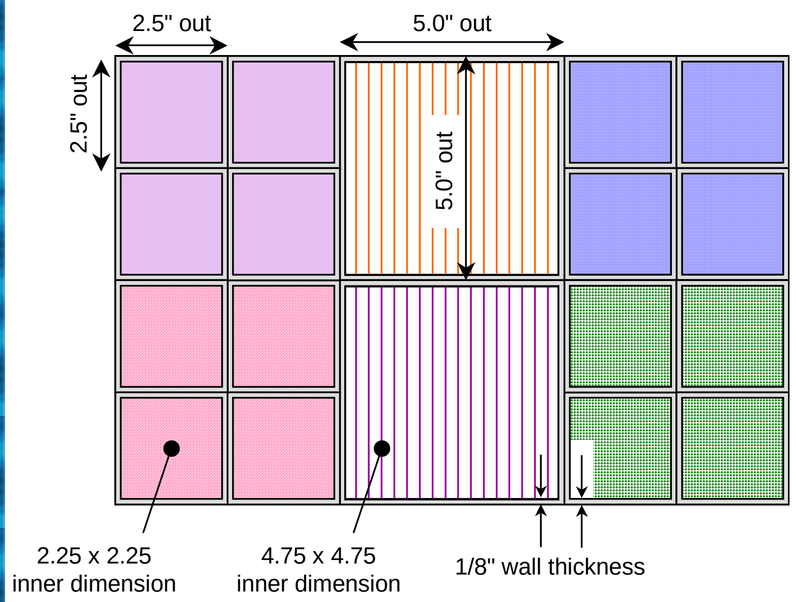
Program review
- José Figueroa, Bruce Lani, Lynn Brickett (DOE-NETL)
- Chuck Dene (EPRI)
- Jeanette Bock (Argillon GmbH)

Multi-catalyst Slipstream Reactor



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



- Five commercial catalysts
- One blank cordierite honeycomb

REACTION
ENGINEERING
INTERNATIONAL

Testing Summary

- AEP Rockport:
  - Two 1300 MW_e B&W opposed-wall, supercritical boilers
  - Testing on Unit 1 across air preheater
  - Burn a subbituminous-bituminous blend
- Two test series (March and August)
- Measurements
  - Coal, economizer ash, ESP ash composition
  - Ontario Hydro measurements at inlet to slipstream
  - SCEM measurements at inlet/outlet of catalyst chambers
  - NO_x and O_2 at inlet/outlet of catalyst chambers
  - Carbon trap and acid gas measurement at inlet of catalyst

REACTION ENGINEERING INTERNATIONAL

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

REACTION ENGINEERING INTERNATIONAL

Flue Gas Composition

(Inlet to Slipstream Reactor)

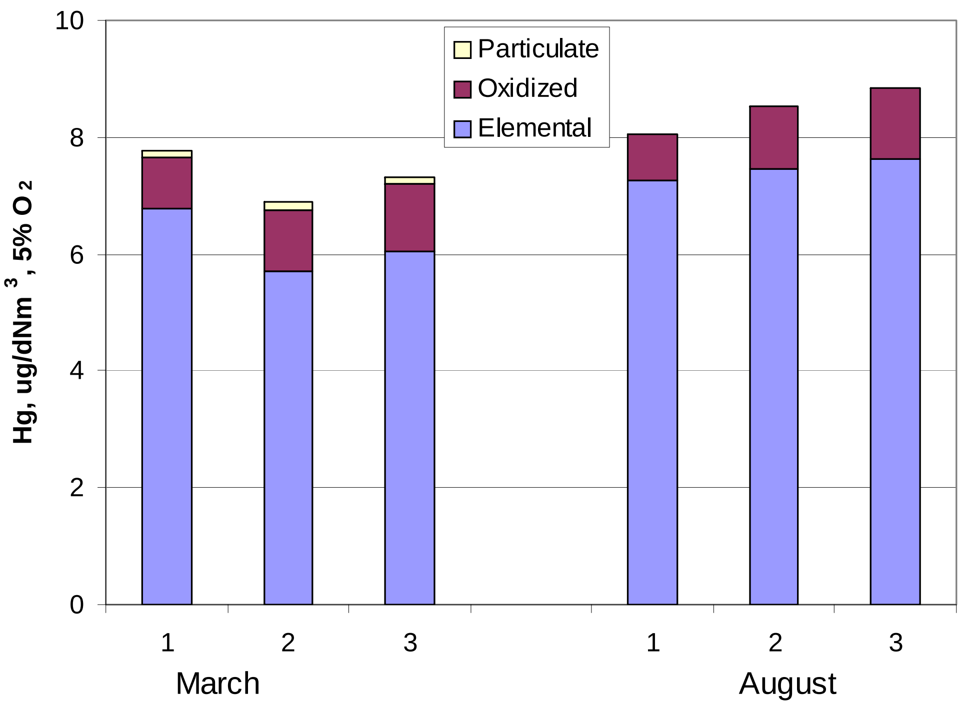
Calculated from coal:

HCl	6-12 ppm (5% O_2)
SO_2	275-325 ppm (5% O_2)

Measured:

NO_x	300-350 ppm (5% O_2)
Total Hg	7-9 ug/dNm^3 (5% O_2)

Ontario Hydro Data



- Hg concentration in OH ash higher than in ESP fly ash BUT fraction of Hg in particulate very low
- 80-90% elemental Hg at inlet to catalysts

Hg and Cl in ash

Date	LOI, wt%	Hg, ug/g	Cl, ug/g
Economizer			
3/28/03	0.08%	0.005	29
8/11/03	0.00%	0.005	<5
8/15/03	0.00%	0.000	<5
ESP Hopper			
3/28/03	0.31%	0.081	20
3/31/03	0.37%	0.118	25
4/1/03	0.31%	0.127	24
4/2/03	0.34%	0.101	27
8/7/03	0.06%	0.034	21
8/11/03	0.30%	0.050	21
8/15/03	0.13%	0.055	23

- Economizer ash has 10-20 times less Hg than ESP ash
- Little Cl on economizer ash
  - Expect most Cl in gas phase at inlet to slipstream
  - Not consistent with gas sampling

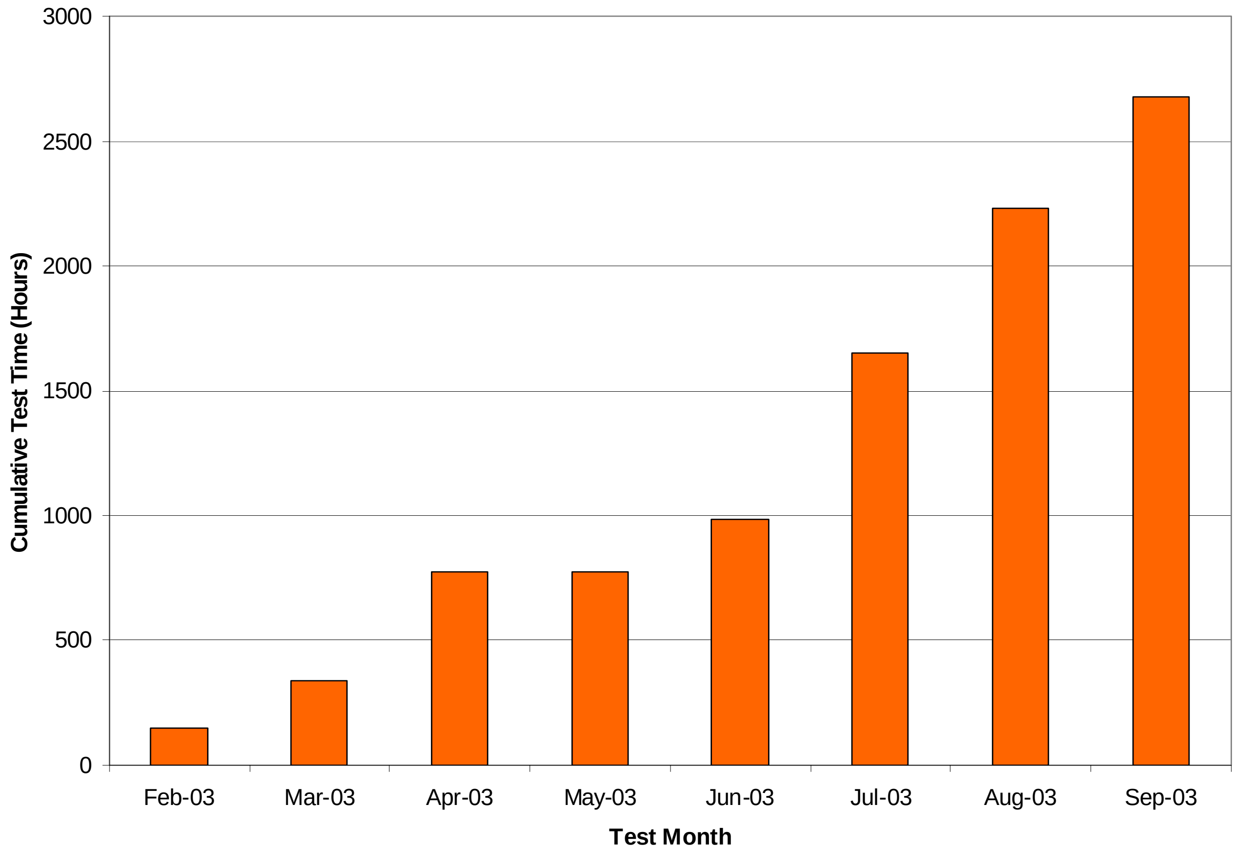
REACTION ENGINEERING INTERNATIONAL

Hg and Cl in ash

Date	LOI, wt%	Hg, ug/g	Cl, ug/g
Economizer			
3/28/03	0.08%	0.005	29
8/11/03	0.00%	0.005	<5
8/15/03	0.00%	0.000	<5
ESP Hopper			
3/28/03	0.31%	0.081	20
3/31/03	0.37%	0.118	25
4/1/03	0.31%	0.127	24
4/2/03	0.34%	0.101	27
8/7/03	0.06%	0.034	21
8/11/03	0.30%	0.050	21
8/15/03	0.13%	0.055	23

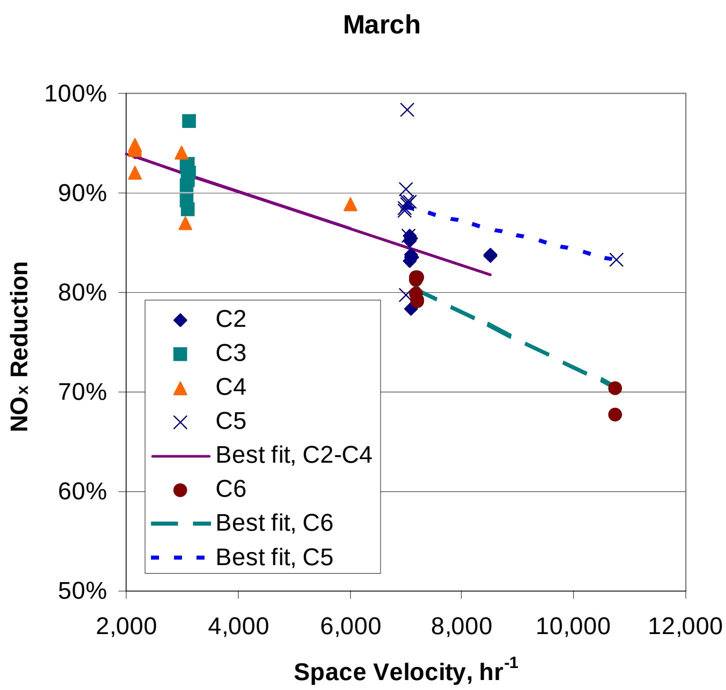
- Low LOI in ESP ash
  - Predominantly PRB
- ESP ash has very little Hg, ~0.5% of coal Hg (consistent with OH data)
- Cl content of ESP ash low
  ~1.5% of coal

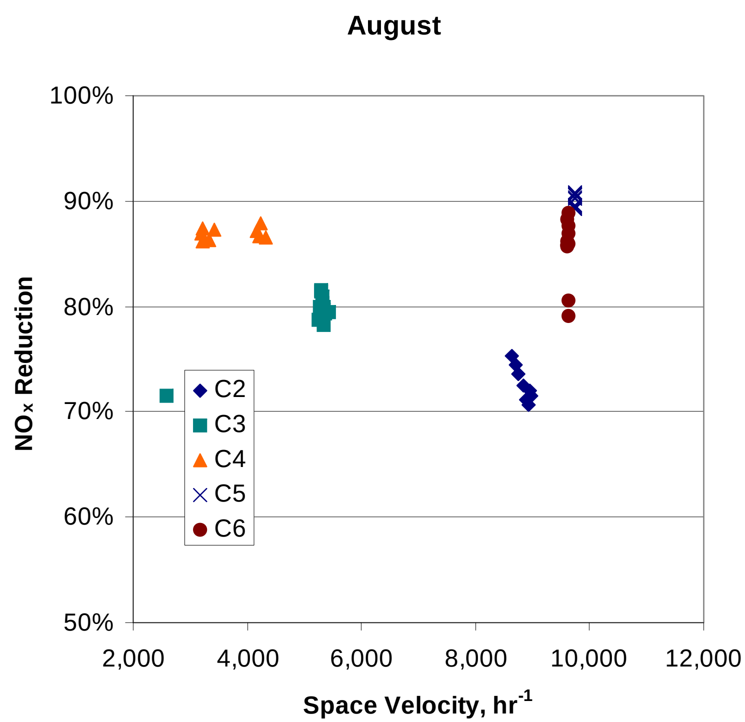
Operating Experience



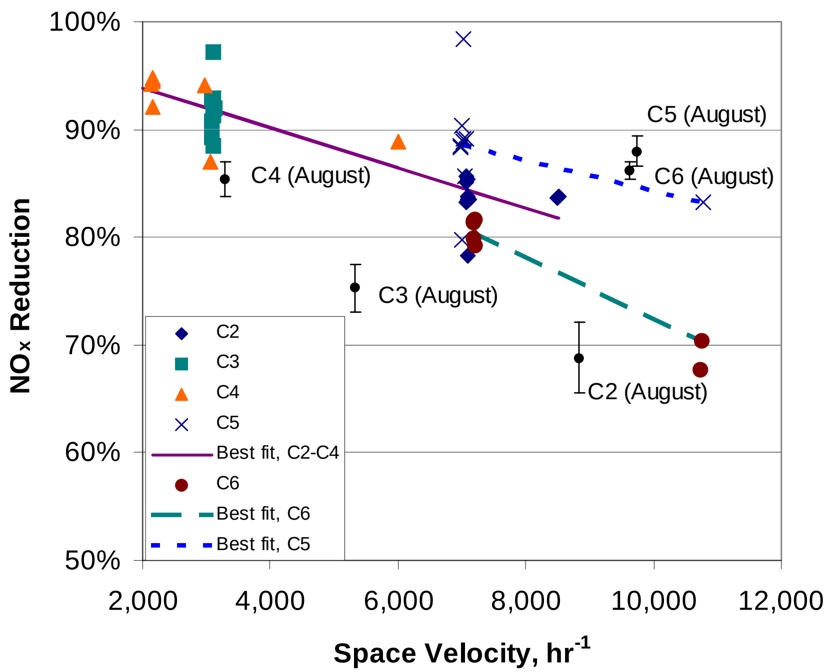
~2700 hours of cumulative flue gas exposure

NO_x Reduction





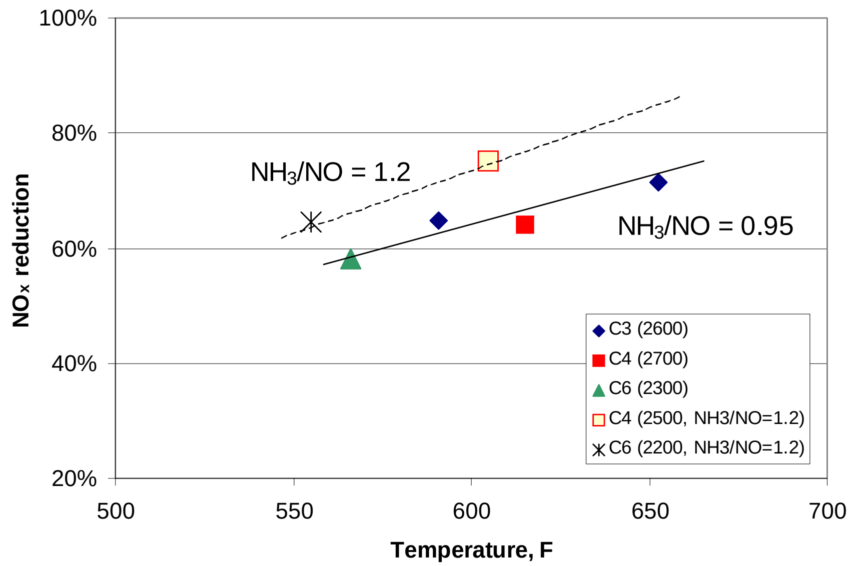
Change in NO_x Activity



- Activity decreased for catalysts C2, C3, C4
- Activity about the same for C5
- C6 appears higher?
  - Extrapolation of data to different temperature range

Hg Testing: Temperatures

- Temperatures for August testing (500-550 F) lower for than March testing (570-660 F)
- NO_x reduction decreases at lower T, as expected

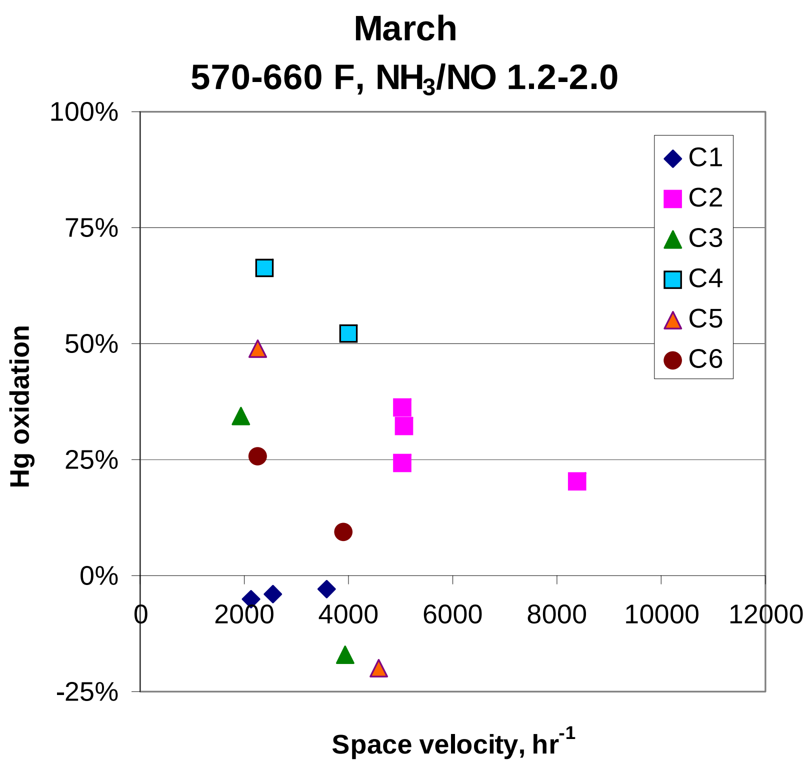


- Hg effect?
  - Other lab, slipstream data[1] suggests Hg oxidation increases as temperature decreases

---

[1]Richardson, et al., AQIII Conference

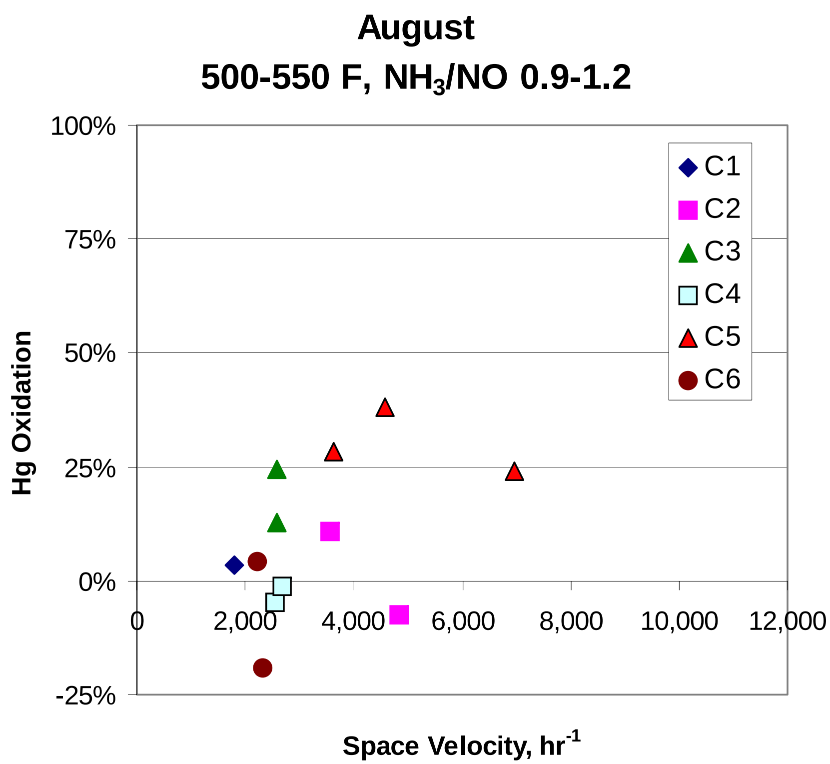
Oxidation of Hg^0



- Blank (C1) does not show oxidation
- March data in same range as previous pilot-scale data

REACTION
ENGINEERING
INTERNATIONAL

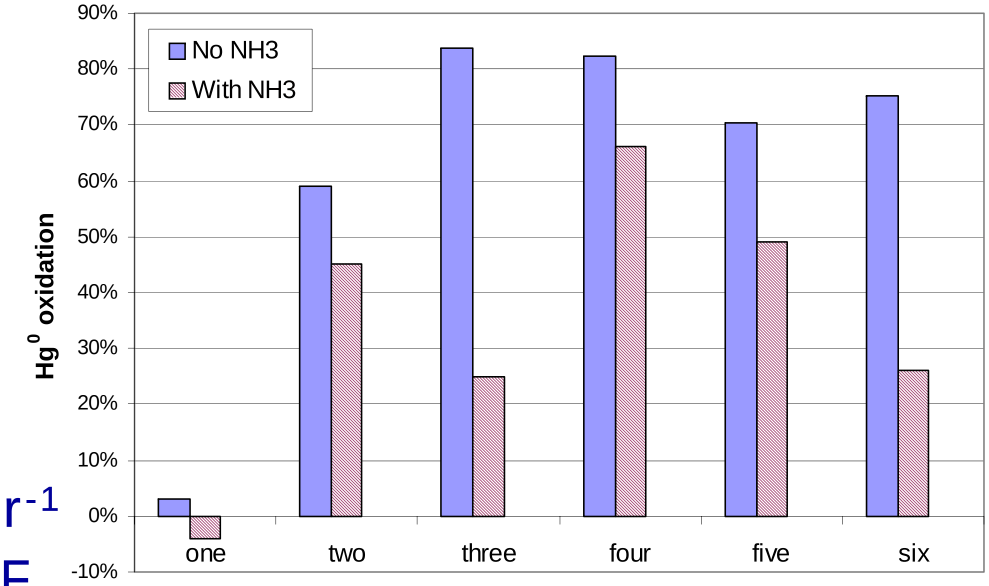
Oxidation of Hg^0



- Blank (C1) does not show oxidation
- August data show some decrease in oxidation relative to March

Effect of Ammonia

- No ammonia vs. excess ammonia (NH_3/NO ~ 2)
- March:
  - SV ~ 2,500 hr^{-1}
  - T ~ 610-630 F

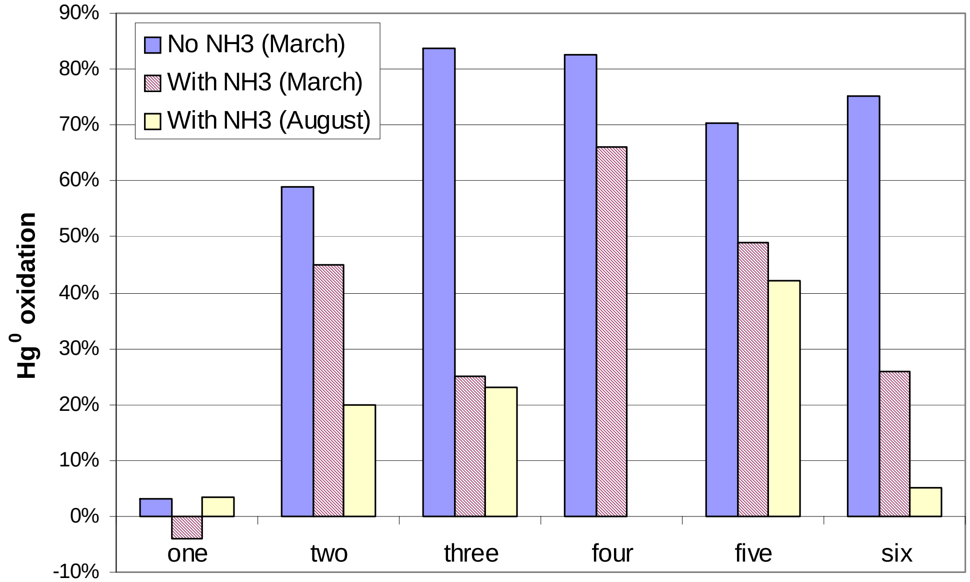


- Oxidation decreased in presence of ammonia
- No effect of blank monolith (C1)

REACTION
ENGINEERING
INTERNATIONAL

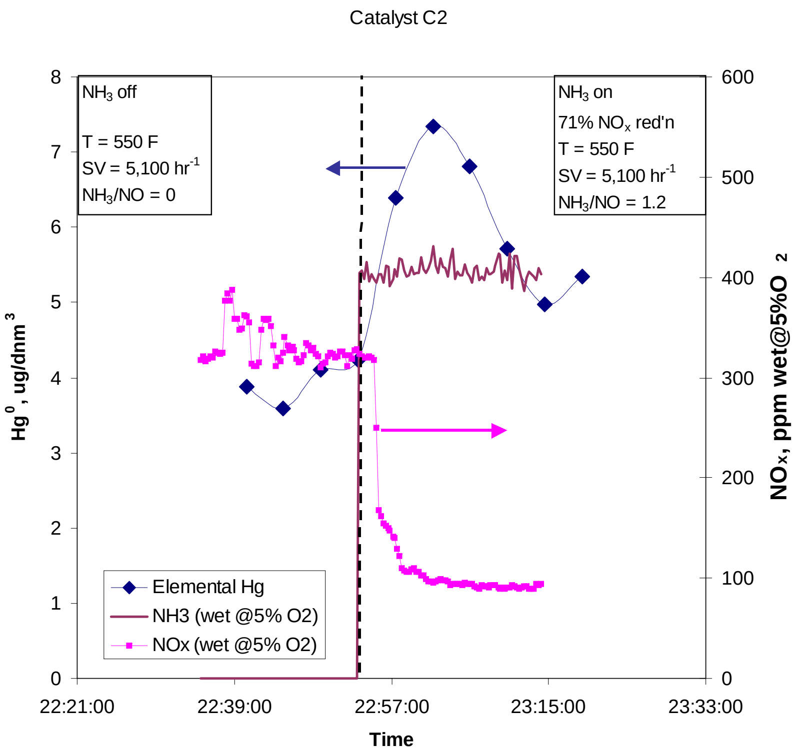
Effect of Aging

- August:
  - SV ~ 2,500 hr^{-1}
  - T ~ 500-550 F
  - NH_3/NO ~ 0.9-1.2
- Two catalysts (C3 and C5 show little effect of aging on oxidation



- Other catalysts had decrease in oxidation
- No effect of blank monolith (C1)

Transients



Elemental mercury and NO_x as a function of time for catalyst C2; T=550 F, SV=5,100 hr^{-1}.

- After ammonia turned off, concentration of elemental mercury initially increased, and then dropped
- Less oxidation with ammonia
- Time scale on the order of 10-20 minutes

Conclusions

- Blank monolith showed no oxidation at 300 hours (March) or 2,200 hours (August)
- Oxidation of mercury increased without ammonia present
- Catalysts C3 (plate) and C5 (monolith) showed comparable oxidation in March and August
  - no loss of activity toward elemental mercury after ~2000 hours of exposure to flue gas.
- Other commercial catalysts exhibited less oxidation in August test series
- Hg oxidation not always correlated with NO_x reduction
- Transient experiments: Hg desorption when ammonia turned on