The SCR Toolbox for Mercury Emission Management

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2015 Reinhold NOx-Combustion Round Table

Agenda

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- **Background**
  - The SCR's role in Hg control
  - Quantifying and testing SCR catalyst potential
- **Review the factors that affect the SCR catalyst potential for Hg oxidation**
  - Flue gas conditions
    - Hg^0, Hg^{2+}, O_2, H_2O, NO, Molar Ratio, Temperature, CO, SO_2
  - Halogens
    - HCl, HBr, HI
  - Catalyst
    - Traditional
    - Advanced

SCR Catalyst Functionality

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- **Reduce NOx**

$$4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$$

$$2NO + 2NO_2 + 4NH_3 \rightarrow 4N_2 + 6H_2O$$

- **Minimize undesirable side reaction**

$$2SO_2 + O_2 \rightarrow 2SO_3$$

- **Oxidize elemental Hg**

$$2Hg + 4HCl + O_2 \rightarrow 2HgCl_2 + 2H_2O$$

SCR Hg Mass Balance

- **At the SCR inlet, Hg is present in three forms:**

$$\mathrm{Hg_{in}^{total}} = \mathrm{Hg_{in}^{0}} + \mathrm{Hg_{in}^{2+}} + \mathrm{Hg_{in}^{particulate}}$$

Particulate Hg is not affected by the SCR

- **Hg mass balance across SCR (at steady state):**

$$\mathrm{Hg_{in}^{0}} + \mathrm{Hg_{in}^{2+}} = \mathrm{Hg_{out}^{0}} + \mathrm{Hg_{out}^{2+}}$$

$$2Hg + 4HCl + O_2 \rightarrow 2HgCl_2 + 2H_2O$$

- **Quantify Hg oxidation by the SCR:**

$$\eta_{\mathrm{HgOx}} = \frac{\mathrm{Hg_{in}^{0}} - \mathrm{Hg_{out}^{0}}}{\mathrm{Hg_{in}^{0}}}$$

$$\%\ \mathrm{Oxidized} = \frac{\mathrm{Hg_{out}^{2+}}}{\mathrm{Hg_{out}^{0}} + \mathrm{Hg_{out}^{2+}}}$$

The SCR's Role in Hg Removal

Oxidize Hg for Downstream Capture!

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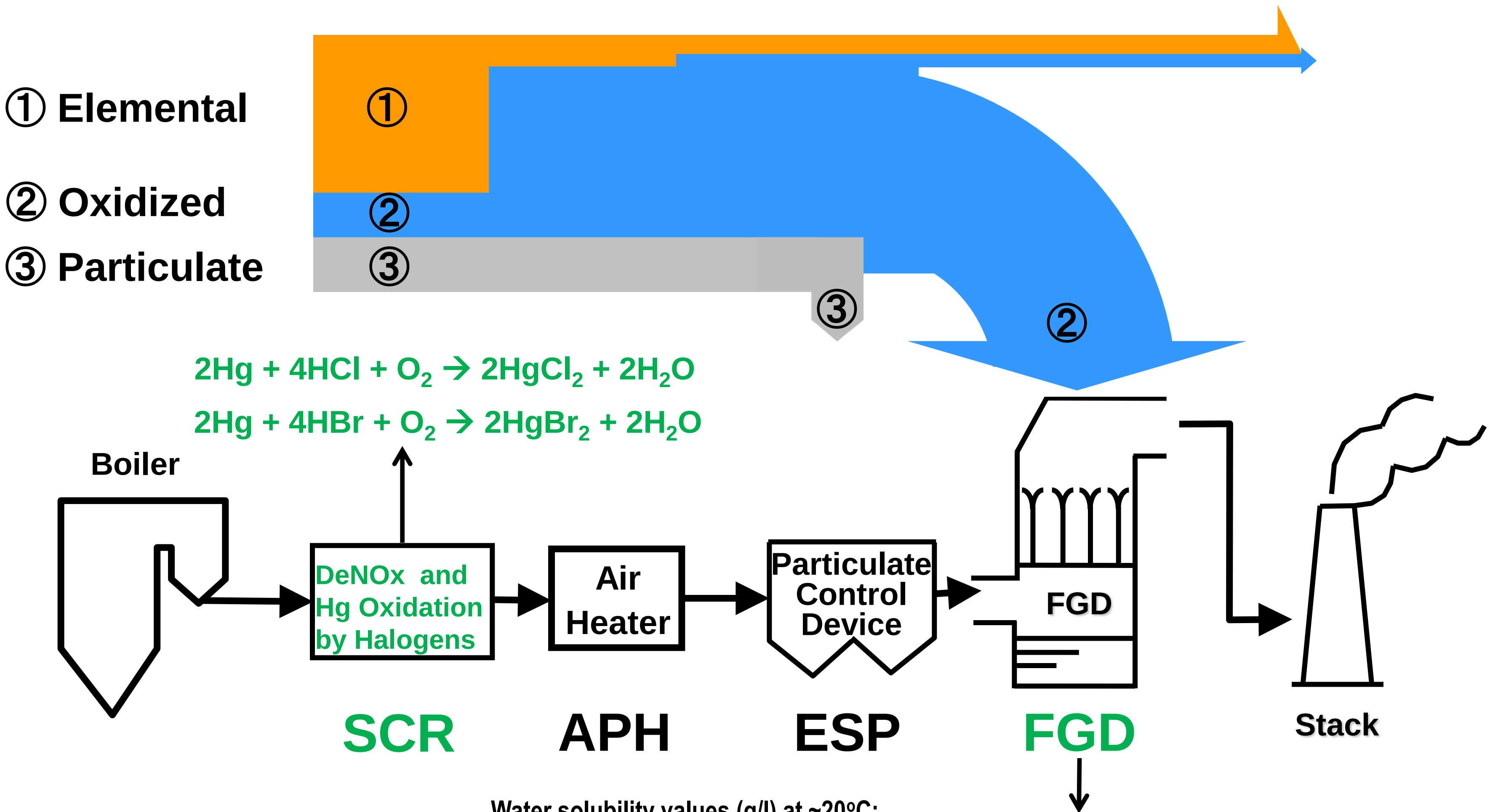


Water solubility values (g/l) at ~20°C:
Hg = 5.6×10^{-5}, HgO = 5.3×10^{-2}, $HgCl_2$ = 74

Plant Hg Removal Strategy

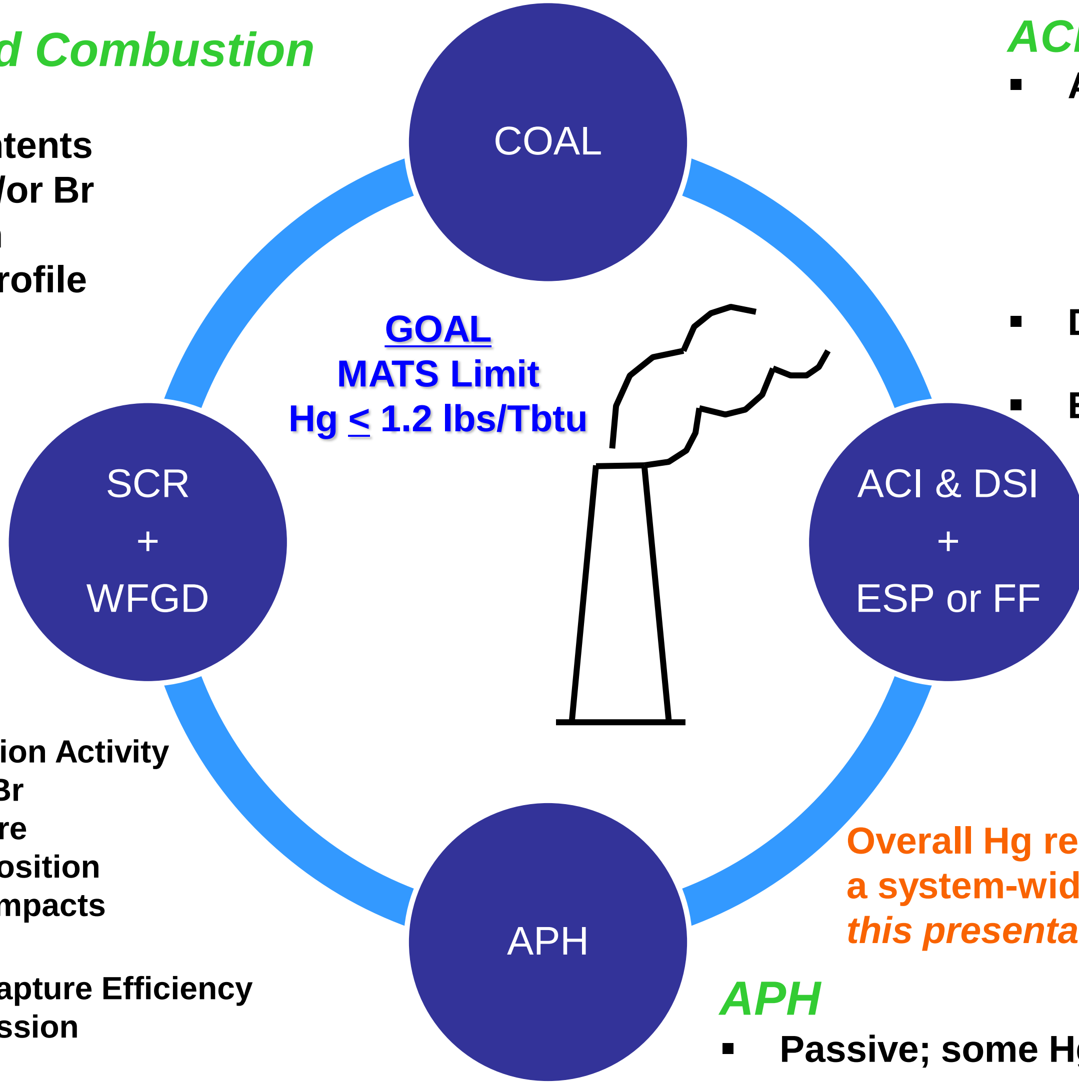
Site Specific. Includes All or Some Components.

Coal Type and Combustion

- **Hg Content**
- **Cl and Br Contents**
- **Added Cl and/or Br**
- **LOI in Fly Ash**
- **Boiler Load Profile**

ACI & DSI + ESP or FF

- **ACI:**
  - **Hg Capacity**
  - **Temperature**
  - **SO_3 Concentration**
  - **HCl and HBr**
  - **Sorbent Injection Rate**
- **DSI:**
  - **SO_3 Mitigation**
- **ESP or FF:**
  - **ACI, DSI Capture**
  - **Ash Capture (Hg on LOI)**



SCR + WFGD

- **SCR:**
  - **Hg^0 Oxidation Activity**
  - **HCl and HBr**
  - **Temperature**
  - **Gas Composition**
  - **Seasonal Impacts**
- **WFGD:**
  - **Hg^{2+} Net Capture Efficiency**
  - **Hg^0 Reemission**

Overall Hg removal strategy requires a system-wide perspective. *Focus of this presentation is on the SCR.*

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- **Passive; some Hg Oxidation**

SCR Catalyst Potential

$$\frac{K}{AV} = \text{Catalyst Potential}$$

$$AV = \frac{\text{Gas Flow}}{\text{Total GSA}}$$

$$\frac{K}{AV} = \text{Catalyst Potential for X\% DeNOx}$$

$$\frac{K_{HgOx}}{AV} = \text{Catalyst Potential for Y\% Hg Oxidation}$$

$$\frac{K_{SO2Ox}}{AV} = \text{Catalyst Potential for Z\% } SO_2 \text{ Oxidation}$$

SCR Catalyst Potential

$$\frac{K}{AV} = -\ln(1-\eta_{NOx})$$

Activity, K, depends on:

- Catalyst composition and age
- Flue gas conditions
  - Temperature
  - MR (NH_3), O_2, H_2O, SO_2, SO_3

$$\frac{K_{HgOx}}{AV} = -\ln(1-\eta_{HgOx})$$

K_{HgOx} is strongly condition dependent, but it's still a useful parameter!

Activity, K_{HgOx}, depends on:

- Catalyst composition and age
- Flue gas conditions
  - Temperature
  - MR (NH_3), O_2, H_2O, SO_2, SO_3
  - +HCl, HBr, HI, CO, HC

$$\frac{K_{SO2Ox}}{AV} = -\ln(1-\eta_{SO2Ox})$$

Activity, K_{SO2Ox}, depends on:

- Catalyst composition, ρ_{bulk} and age
- Flue gas conditions
  - Temperature
  - MR (NH_3), SO_2, SO_3

Measuring SCR Hg Oxidation

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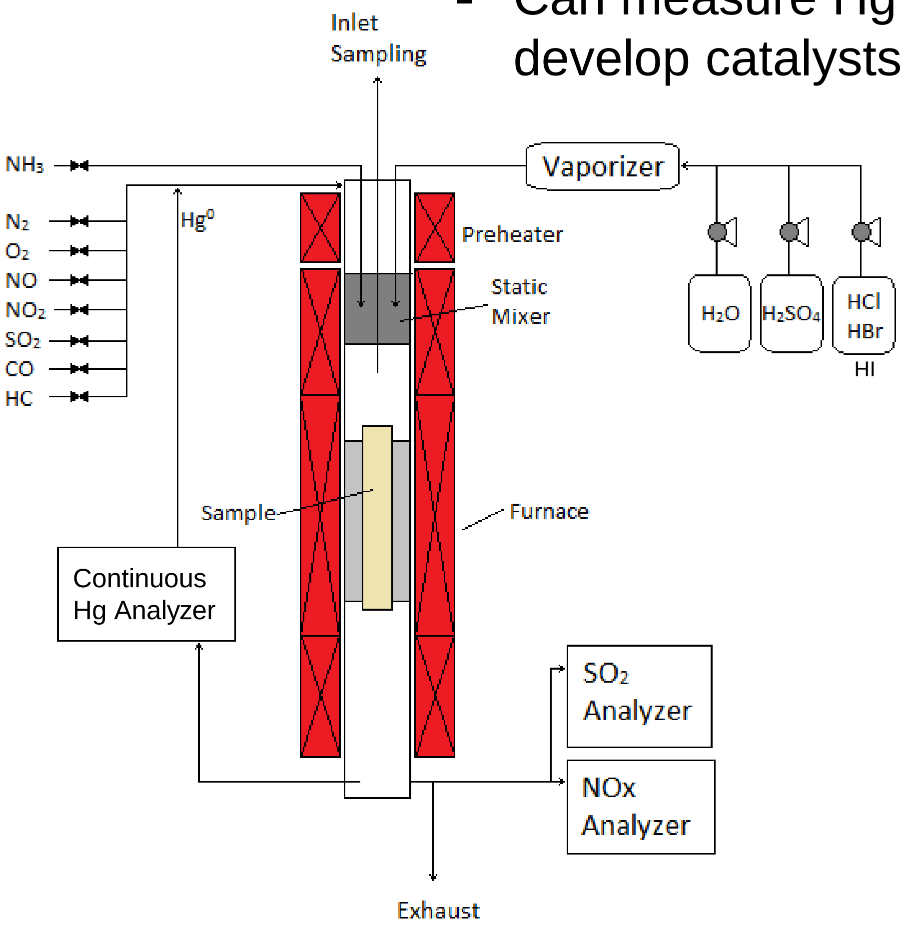
- **Measure Hg^0 and Hg^{2+}**
  - CEMS
  - Sorbent traps
- **Lab-scale catalytic reactors**
  - Micro reactor
  - Bench reactor
- **Field (full scale reactor)**
  - SCR inlet and outlet measurements
    - Particulate challenge (high dust difficult to measure)
  - Stack measurements
    - Final system performance
    - SCR contribution combined

Lab Reactors

- *Each reactor type can be used to generate quality data.*
- *Each reactor type has it's own advantages and limitations.*
- **Micro is well-suited for parametric studies**
  - Automation can help rapidly test a large set of conditions
- **Bench is well-suited for field audit testing**
  - **Full size element**
    - Catalyst poisons not evenly distributed throughout log.
    - Micro may require multiple samples to fully characterize log.
  - **Multi-layer system test**
    - System and individual layer performance in a single test
    - Micro may need multiple step-wise tests using results of upper layers to set conditions for lower layers.
  - Aging times are similar to micro scale

Micro Reactor

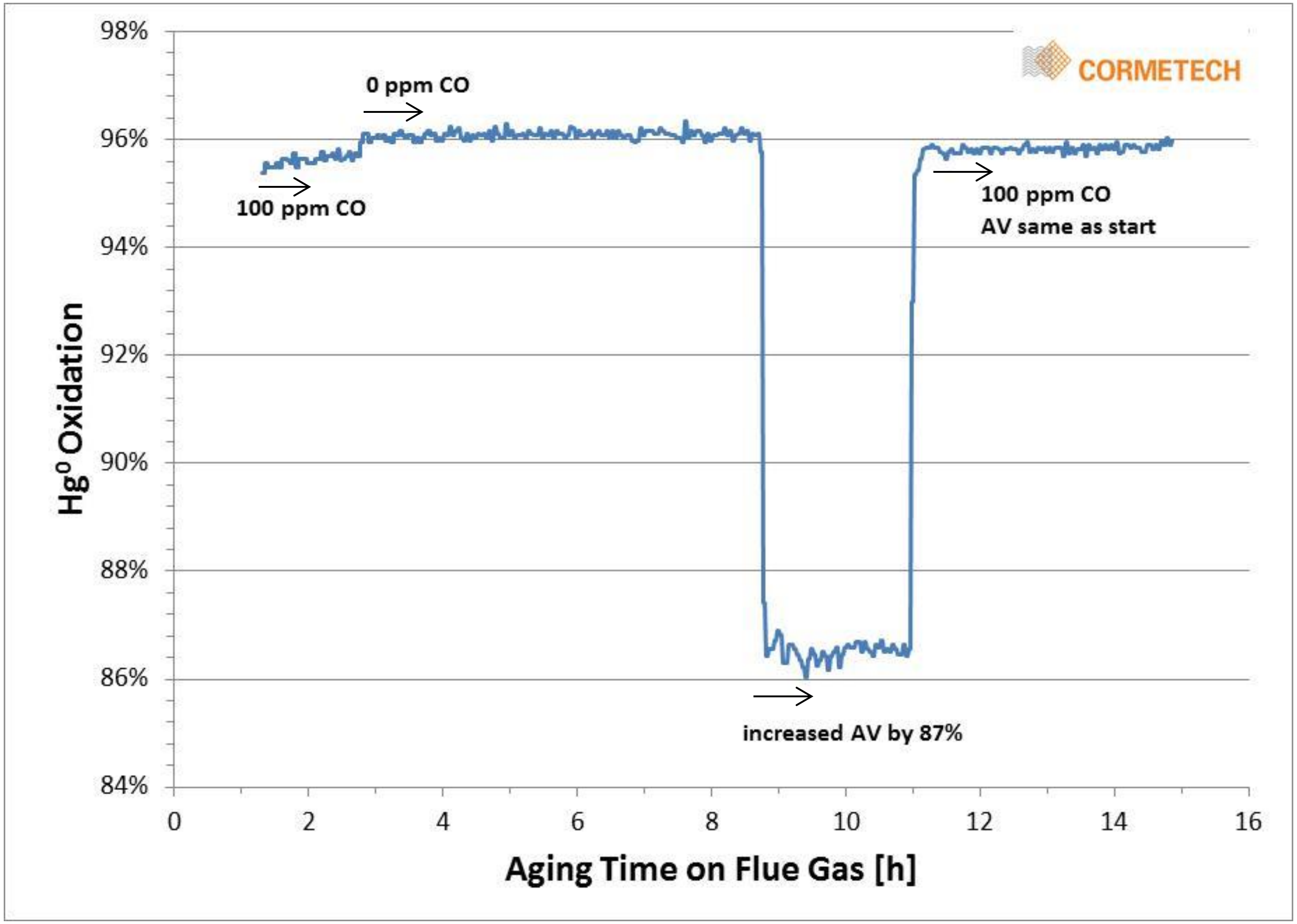
- Example shown is fully-automated for efficient data collection.
  - Can measure Hg oxidation under a full range of conditions to develop catalysts and assist with management strategies.



Micro Reactor: Aging Times

Fresh Catalyst

Transients are typically short. Steady state for this test is achieved is < 1 hour.

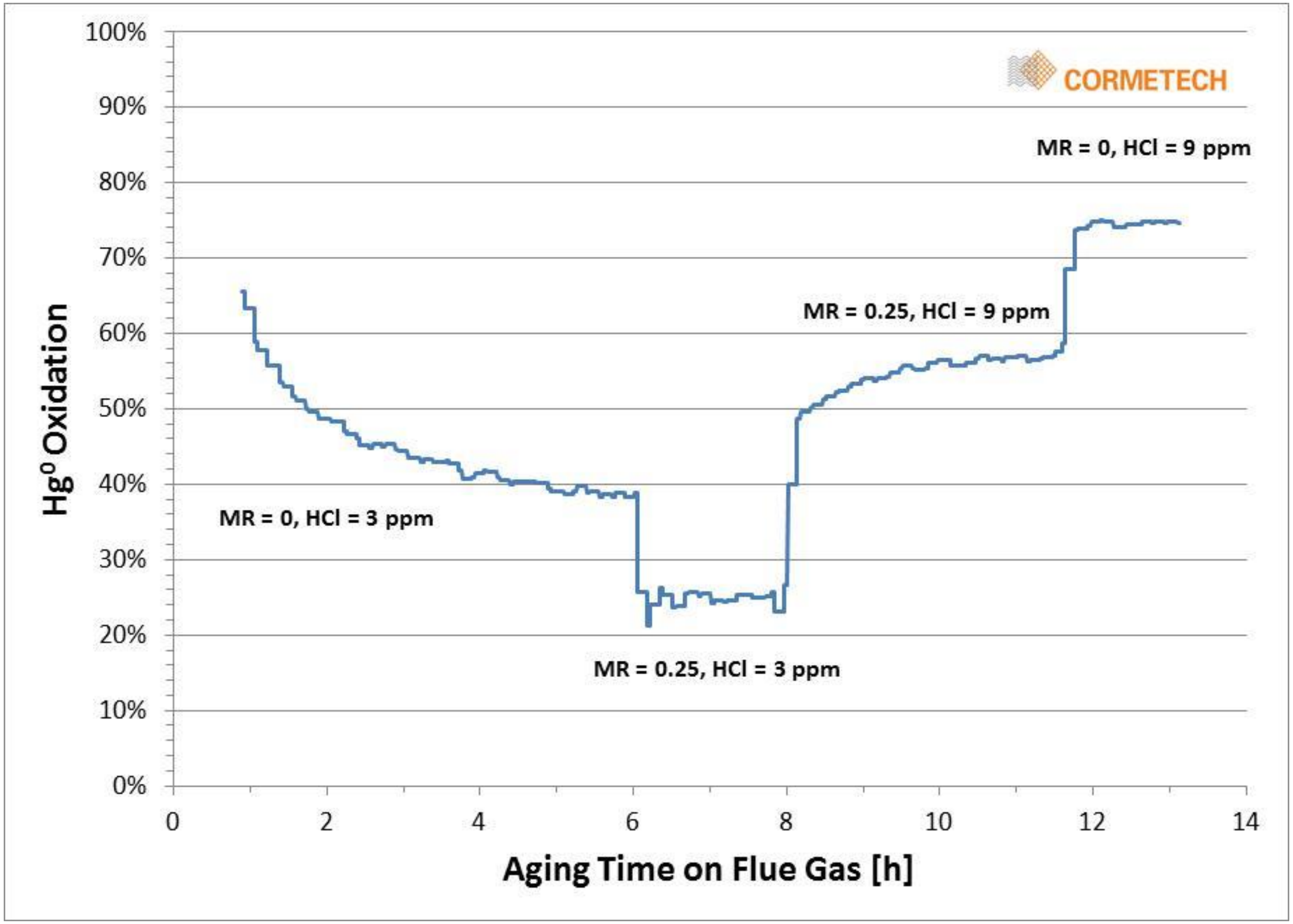


357^{o}C, 5.4% O_2, 9.7% H_2O, 46 ppm HCl, 1450 ppm SO_2, 15 ppm SO_3, 0 or 100 ppm CO, 275 ppm NO, MR = 0

Micro Reactor: Aging Times

Fresh Catalyst

Transients can be longer when HCl is < 10 ppm. Steady state for this series is achieved in < 5 hours.

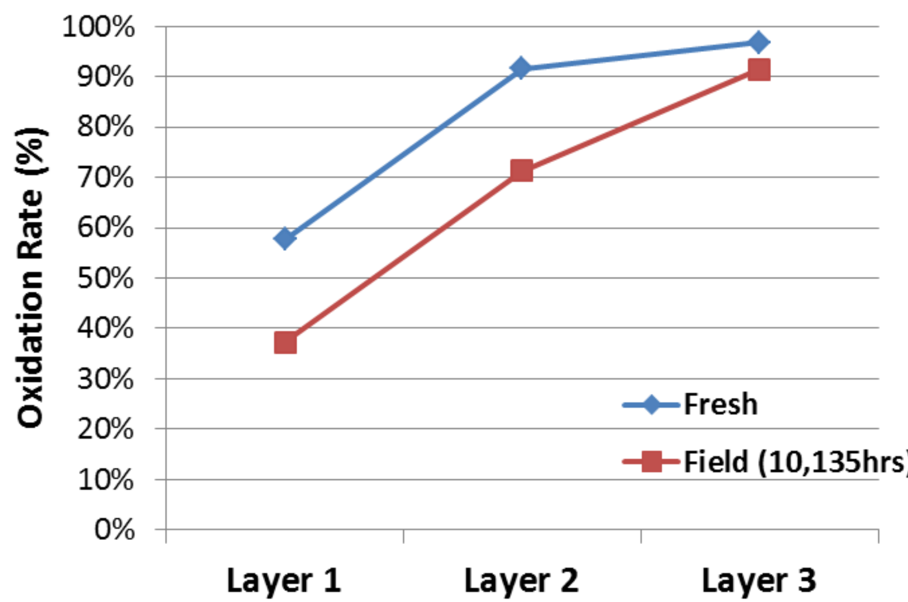


400ºC, 3.3% O_2, 11% H_2O, 3 or 9 ppm HCl, 490 ppm SO_2, 5 ppm SO_3, 50 ppm CO, 375 ppm NO, MR = 0 or 0.25

Bench Reactor

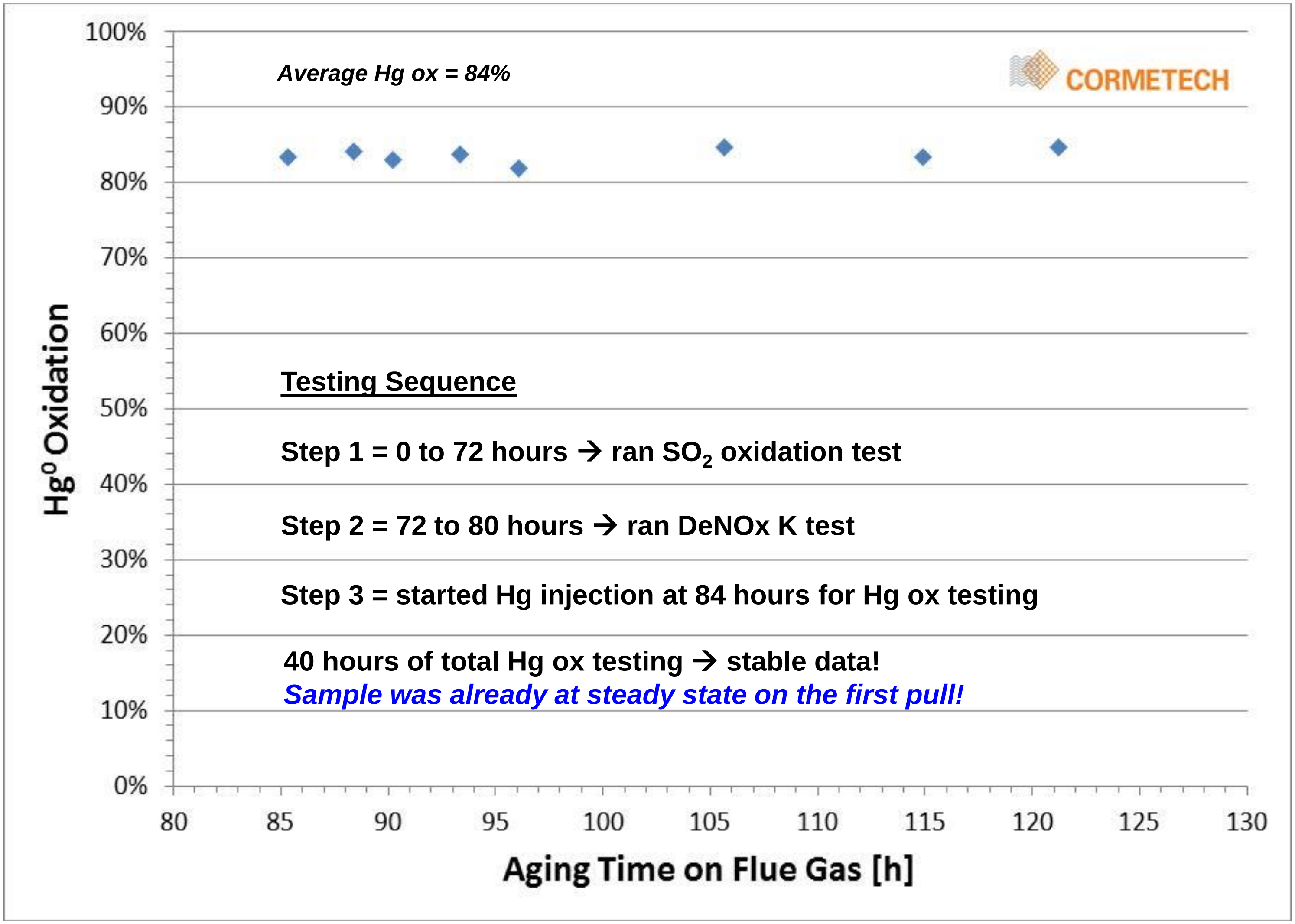
- Bench scale allows full-size element testing (single or multi-layer).
- Test fresh or deactivated catalyst.
- Inject HCl/HBr, O_2, H_2O, SO_2, SO_3, NOx, CO, HC.
- Full H_2O concentration control

Hg oxidation performance measured on bench reactor



Bench Reactor Data

New Catalyst



371°C, 4.3% O_2, 8.5% H_2O, 58 ppm HCl, 850 ppm SO_2, 9 ppm SO_3, 100 ppm CO, 300 ppm NO, 11 ppm NH_3

Main Presentation Focus…

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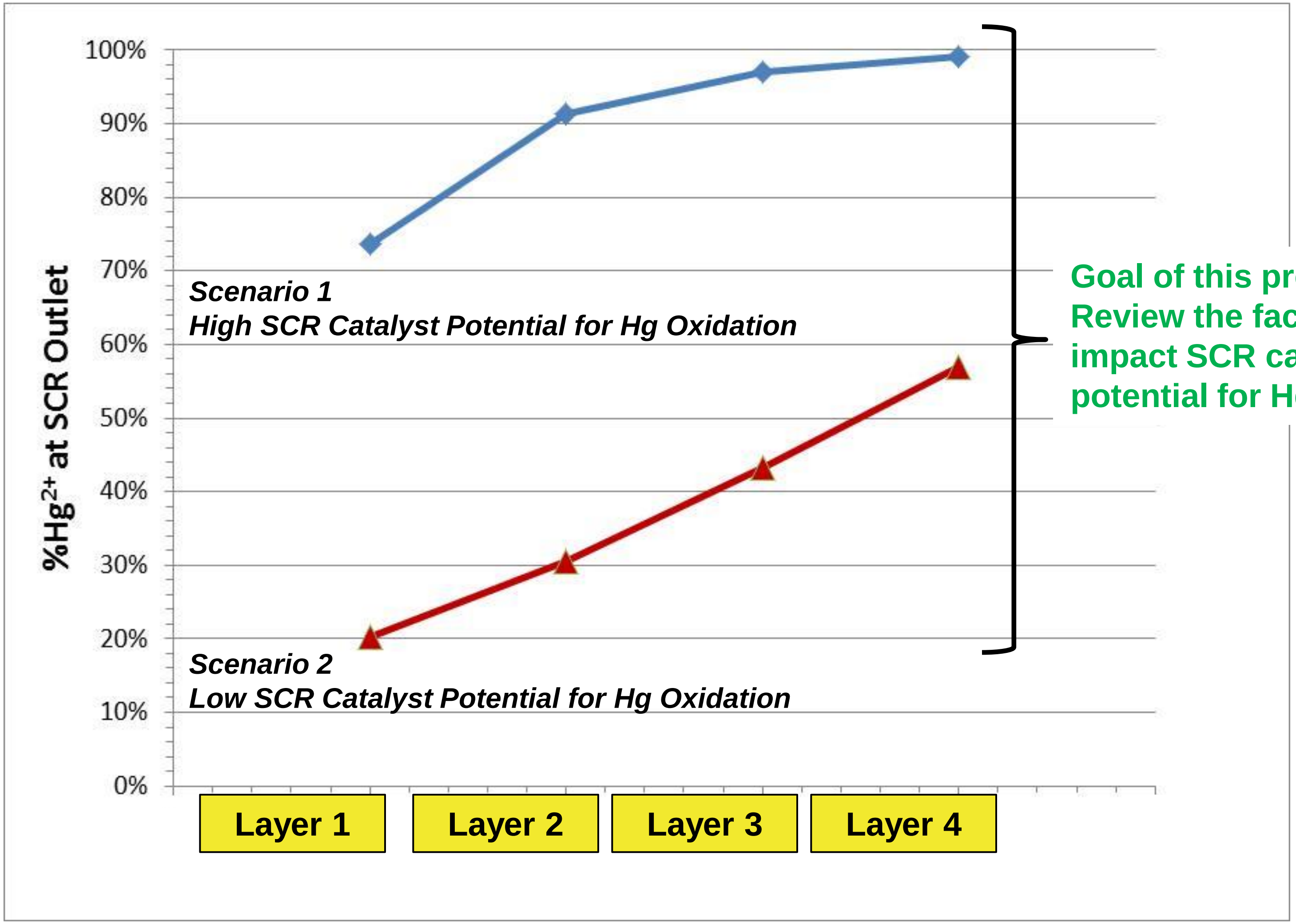

Goal of this presentation: Review the factors that impact SCR catalyst potential for Hg oxidation

Summary of Factor Impacts
Positive Correlations

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Factor	Hg Oxidation Correlation with Increasing Factor Value	Note
HCl	↑	Strong interdependence with T and concentration
HBr	↑	Strong interdependence with T and concentration
HI	↑	Strong interdependence with T and concentration
O_2	↑	
Catalyst surface area	↑	Determined by layer length and Ap/pitch selection
Catalyst V_2O_5	↑	
Advanced catalysts	↑	Improve Hg ox at constant DeNOx and SO_2 ox
Hg^0	○	No impact: kinetics are first order in Hg^0

Summary of Factor Impacts
Negative Correlations

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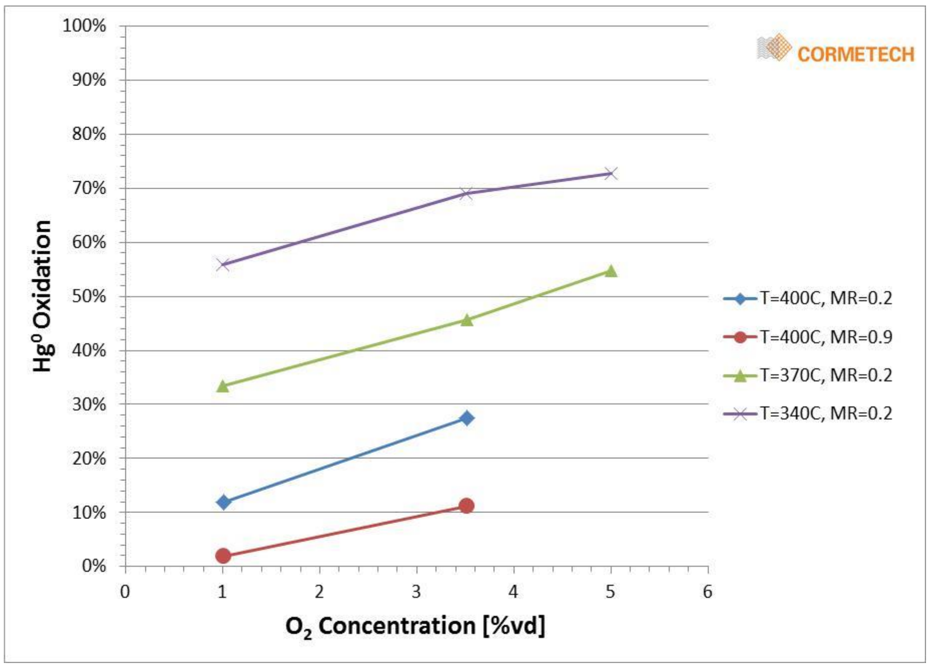
Factor	Hg Oxidation Correlation with Increasing Factor Value	Note
Hg^{2+}	○ ↓	Impact depends on re-reduction activity
Temperature	↓	Strong interdependence with HCl, HBr, NH_3, catalyst
NH_3	↓	Strong interdependence with T, HCl, HBr, catalyst
NO	↓	Impact is cross-correlated through NH_3
H_2O	↓	
SO_2	↓	
SO_3	↓	
CO	↓	Strong interdependence with T, HCl, HBr, catalyst
Hydrocarbons	↓	
Catalyst Age	↓	Strong interdependence with catalyst type

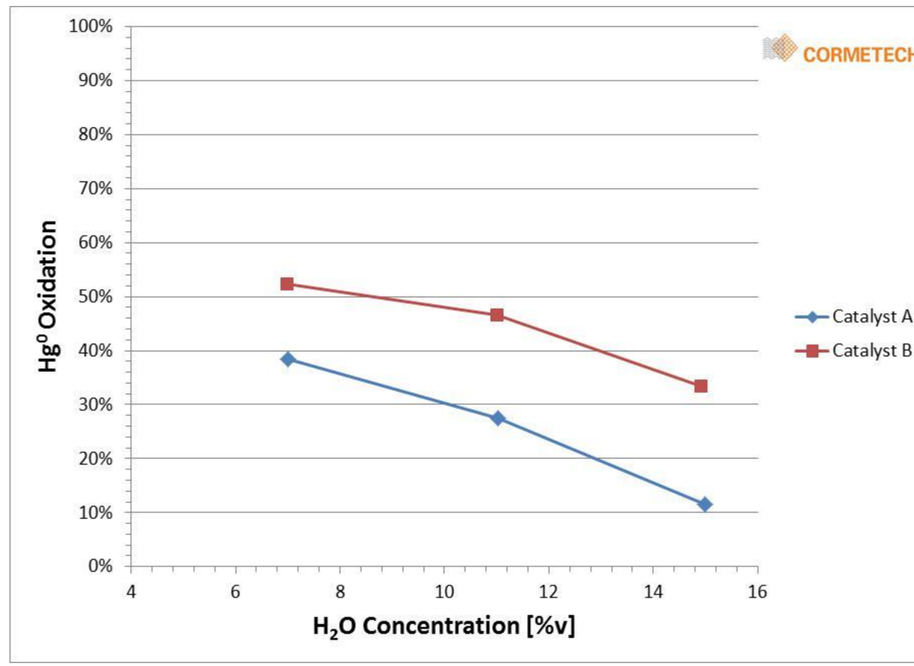
Impact of O_2 and H_2O

Hg Oxidation Activity

O_2 and H_2O both have a significant impact on Hg oxidation activity. In comparison, these parameters have a much smaller impact on DeNOx or SO_2 oxidation rates.



11% H_2O, 350 ppm NO, 0.2 Molar Ratio, 1000 ppm SO_2, 10 ppm SO_3, 100 ppm CO, 11 ppm HCl



400°C, 3.5% O_2, 350 ppm NO, 0.2 Molar Ratio, 1000 ppm SO_2, 10 ppm SO_3, 100 ppm CO, 11 ppm HCl

Impact of Hg^0

Hg Oxidation Activity

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Steady state data reveal that the Hg oxidation reaction is 1st order in Hg^0 → Hg oxidation is constant with varied inlet Hg^0 concentration.

Inlet NH_3/NOx	HCl [ppmvd]	Hg Oxidation with inlet Hg 21 μg/Nm^3	Hg Oxidation with inlet Hg 11 μg/Nm^3
0.2	11	28%	27%
0.9	11	11%	14%
0.2	56	81%	81%
0.9	56	58%	61%

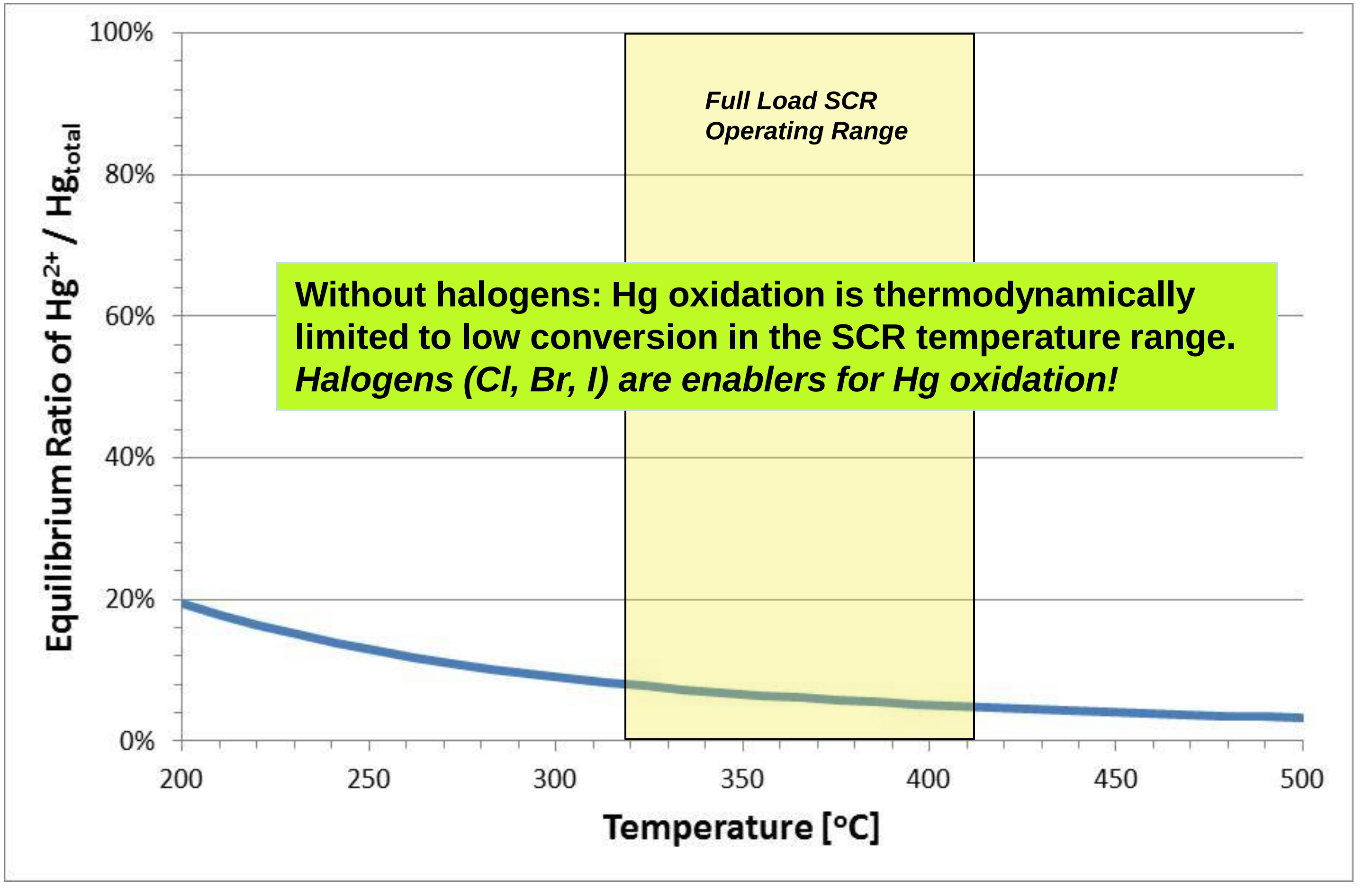
400^{o}C, 3.5% O_2, 11% H_2O, 350 ppm NO, 1000 ppm SO_2, 10 ppm SO_3, 100 ppm CO

The overall kinetic rate law, however, is more complex, and includes the kinetic effects of HCl and O_2, and inhibition effects of H_2O, NH_3, CO and SO_2.

Why are Halogens Needed?

(No halogens included).

$$2Hg^0 + O_2 \rightarrow 2Hg^{2+}O$$



Why are Halogens Needed?

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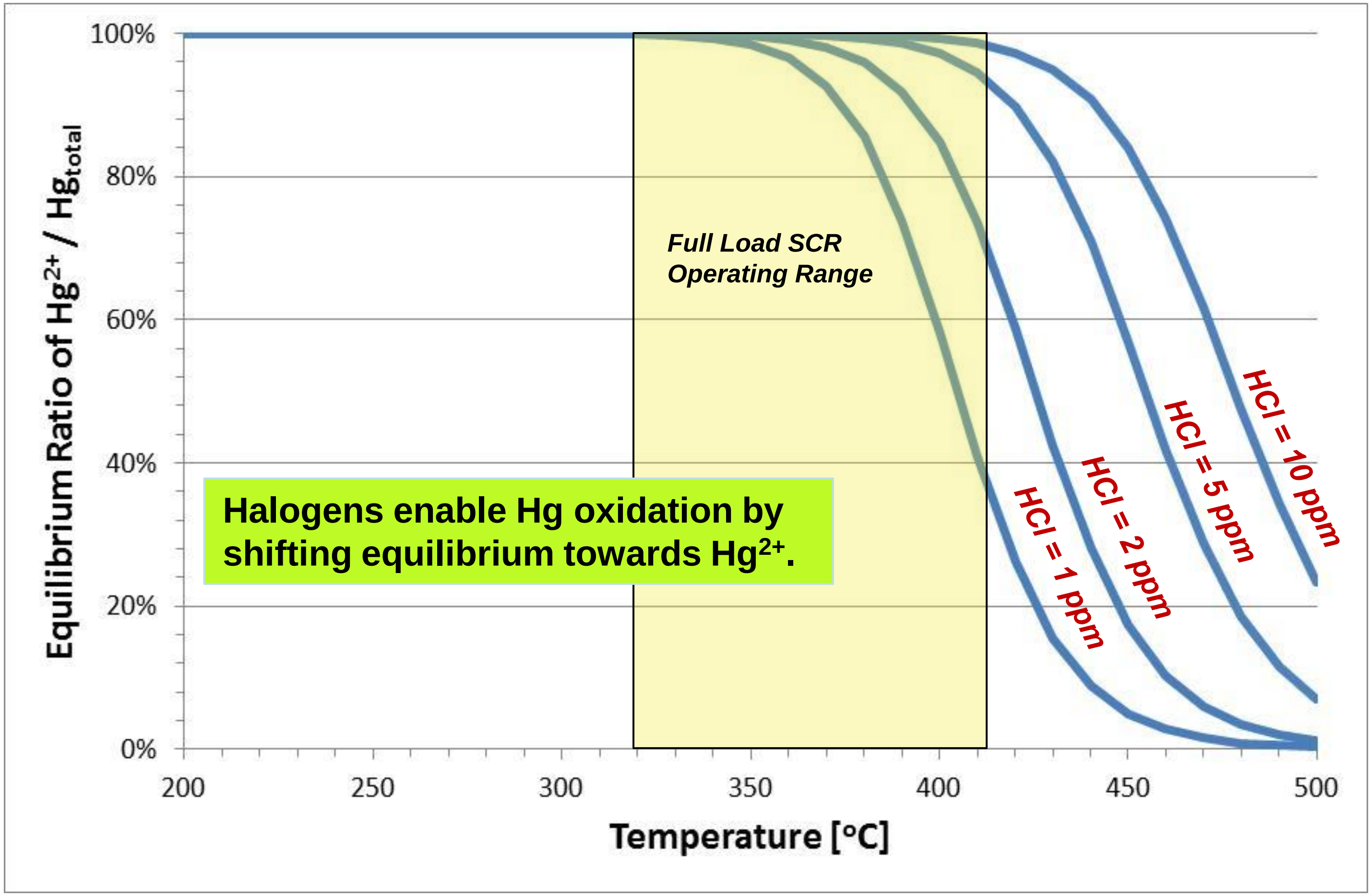
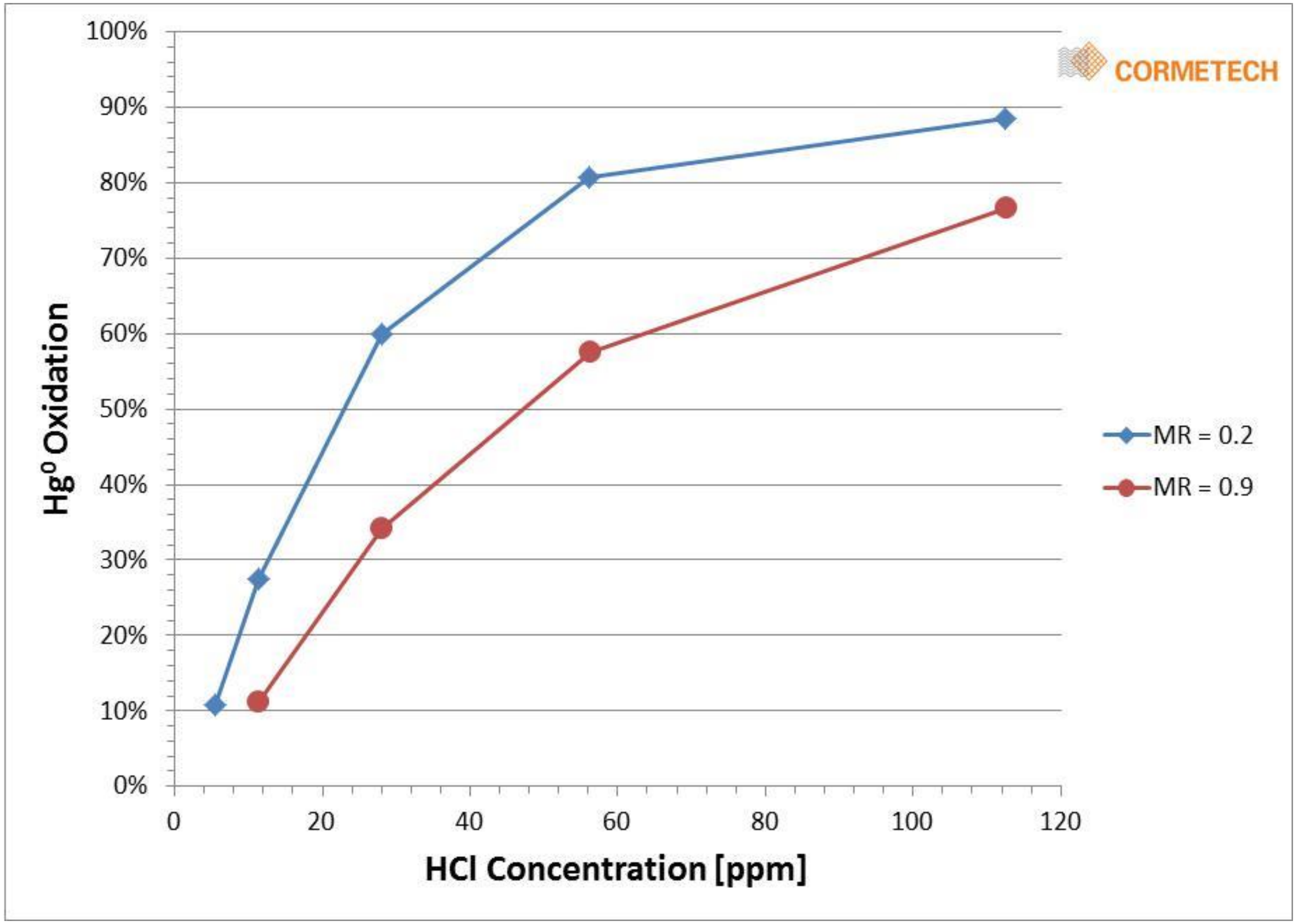
(With Cl included). $$2Hg^0 + 4HCl + O_2 \rightarrow 2Hg^{2+}Cl_2 + 2H_2O$$



Impact of HCl

Hg Oxidation Activity

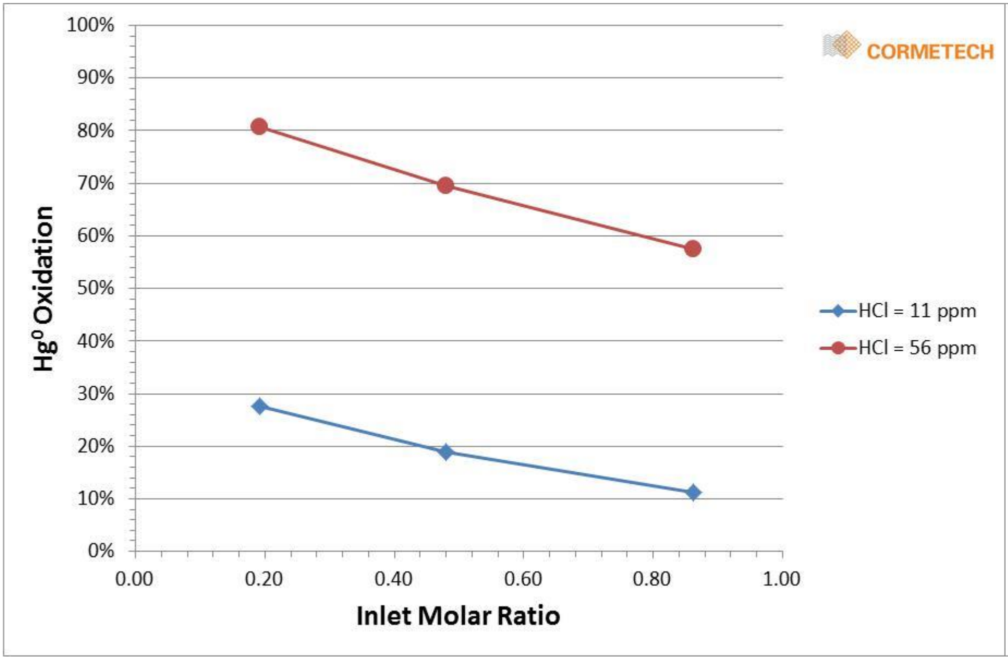
The kinetic data are consistent with a mechanism where HCl adsorbs on the catalyst. NH_3 can significantly inhibit Hg oxidation activity.

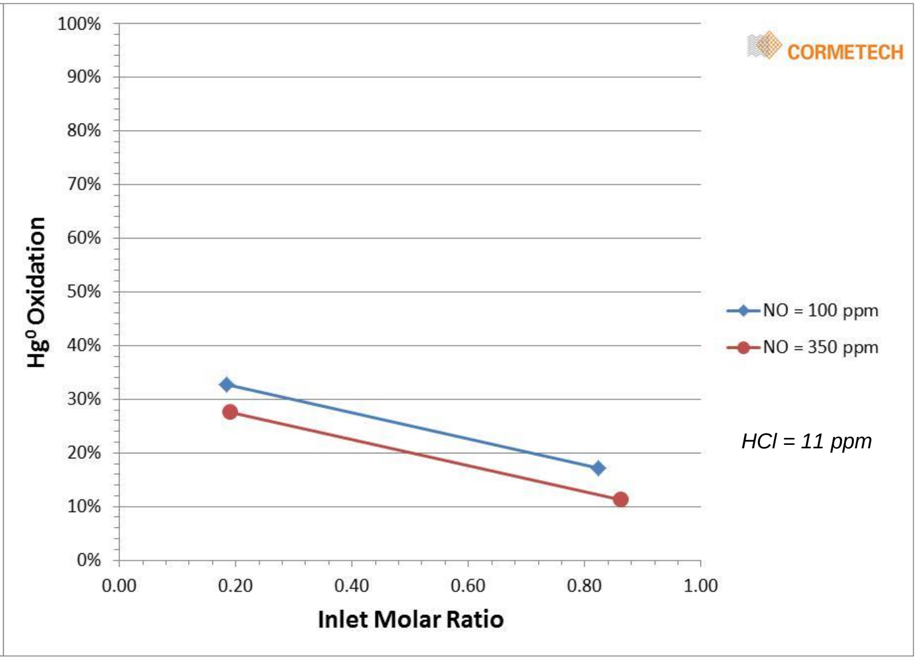


400°C, 3.5% O_2, 11% H_2O, 350 ppm NO, 1000 ppm SO_2, 10 ppm SO_3, 100 ppm CO; MR = Inlet Molar Ratio

Impact of NH_3 and NOx
Hg Oxidation Activity

NH_3 can significantly inhibit Hg oxidation activity. Negative impact of higher inlet NOx is caused by higher inlet NH_3 (we tested at fixed molar ratio values).



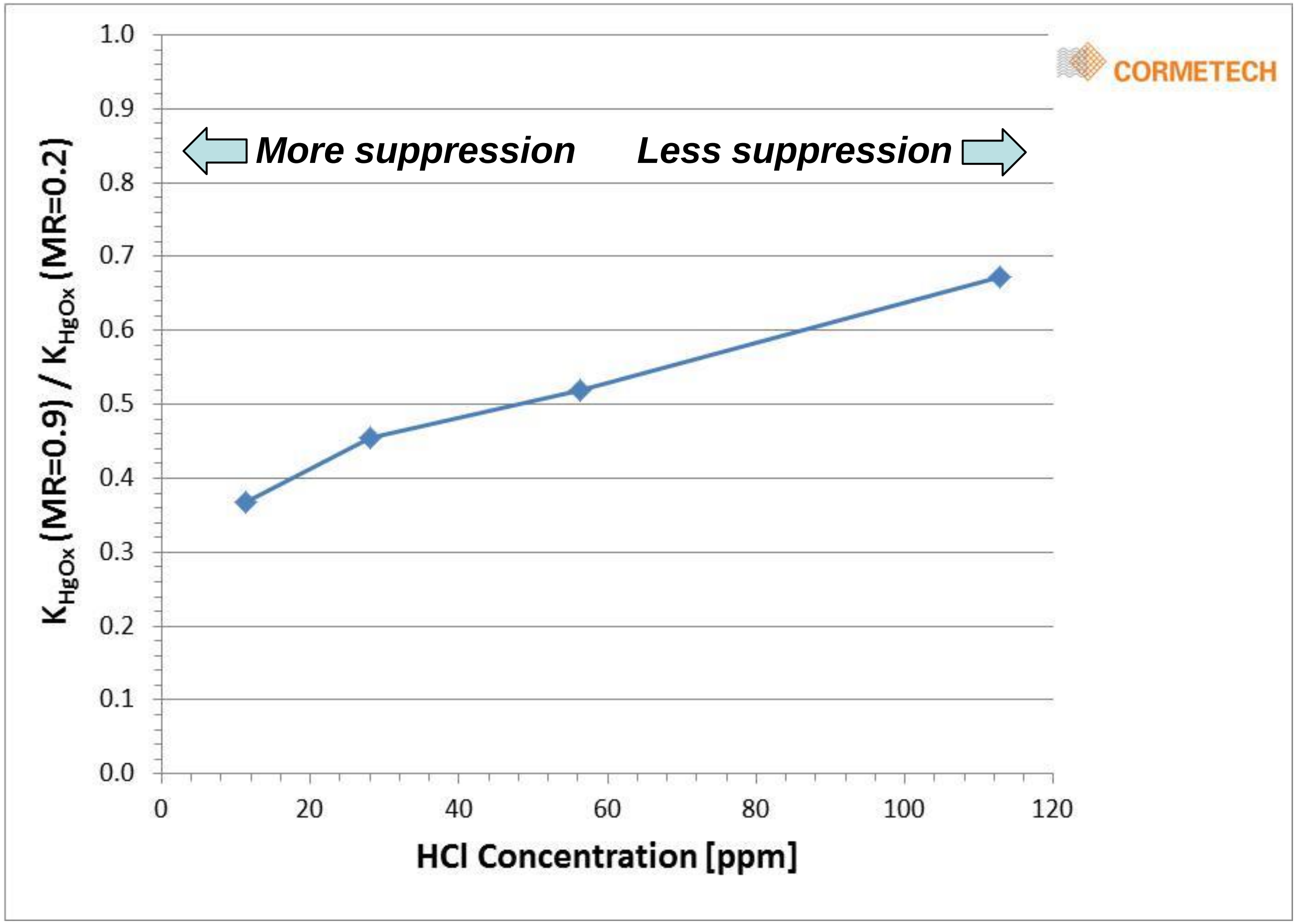


400ºC, 3.5% O_2, 11% H_2O, 350 ppm NO, 1000 ppm SO_2, 10 ppm SO_3, 100 ppm CO

Impact of HCl on NH_3 Inhibition
Hg Oxidation Activity

There is a strong Interdependence between the HCl concentration and the degree of NH_3 suppression of the Hg oxidation rate.

K ratio on y-axis!



400ºC, 3.5% O_2, 11% H_2O, 350 ppm NO, 1000 ppm SO_2, 10 ppm SO_3, 100 ppm CO; MR = Inlet Molar Ratio

Impact of HCl on NH_3 Inhibition

First Layer vs. Lower Layer Performance

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Strong interdependence between the HCl content and the degree of NH_3 suppression of the Hg oxidation rate → one implication is that layer 1 catalyst can contribute more to overall Hg oxidation under higher HCl conditions!

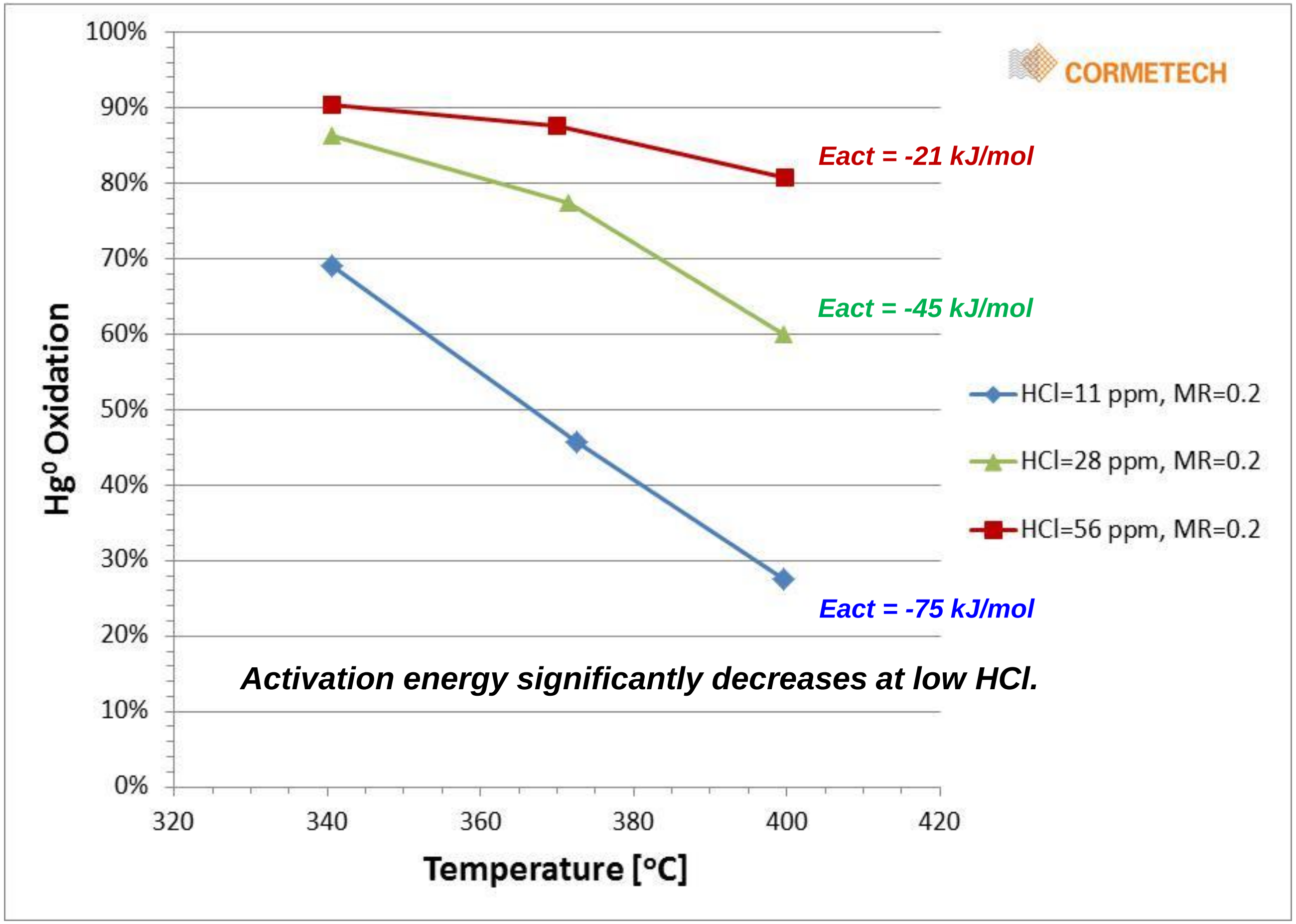
Single Layer Performance Example					
Position	**Case**	**MR**	**HCl [ppm]**	**Layer Hg Ox**	**Hg Ox Delta Layer 1 vs. Lower Layer**
Layer 1	Low HCl	0.9	28	36%	-27%
Lower Layer	Low HCl	0.2	28	63%	
Layer 1	High HCl	0.9	113	79%	-11%
Lower Layer	High HCl	0.2	113	90%	

400ºC, 3.5% O_2, 11% H_2O, 350 ppm NO, 1000 ppm SO_2, 10 ppm SO_3, 100 ppm CO; MR = Inlet Molar Ratio

Impact of Temperature (MR=0.2)

Hg Oxidation Activity

Listed activation energy values are for the overall Hg oxidation reaction. Values are negative because the rate decreases as temperature increases.

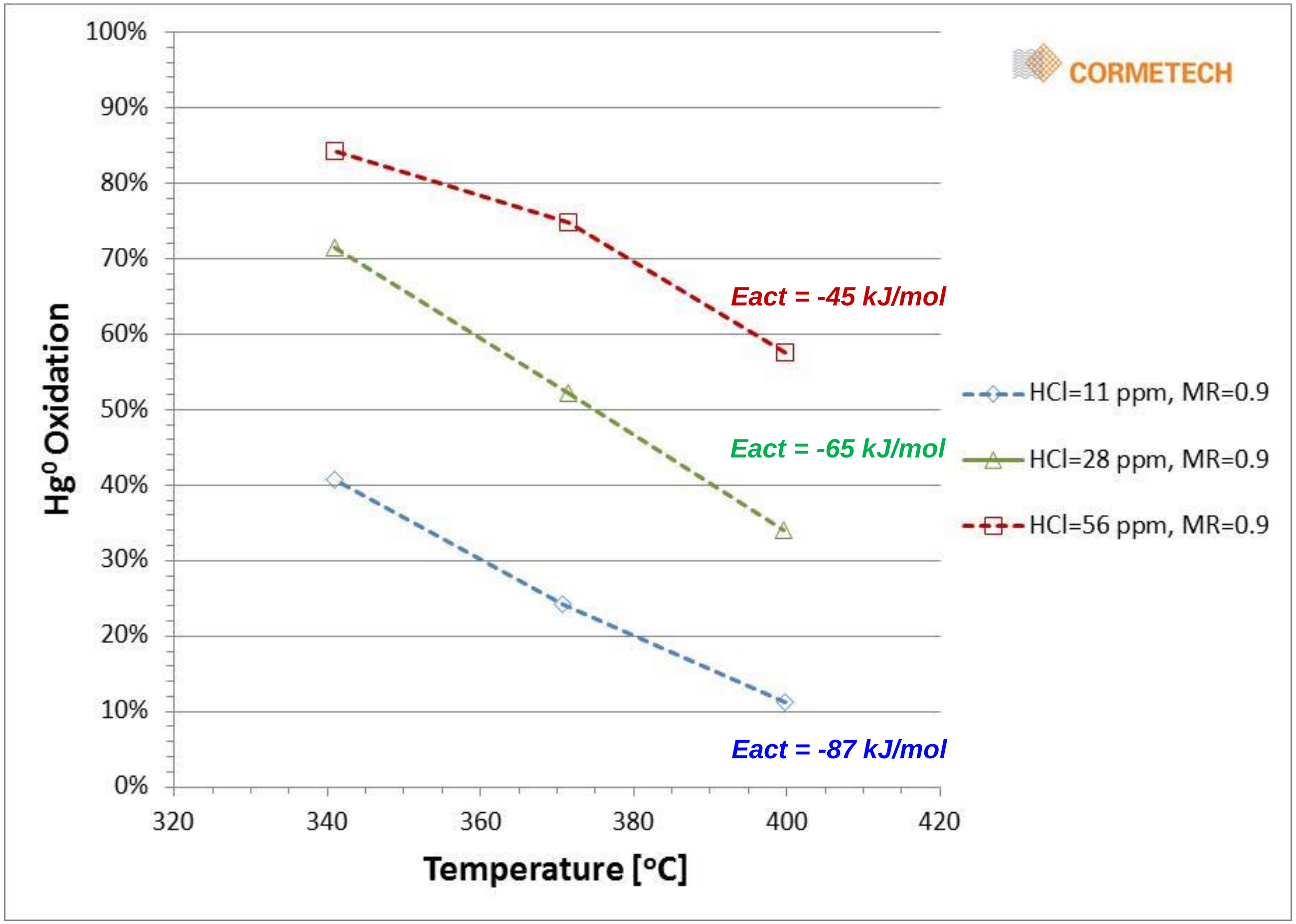


3.5% O_2, 11% H_2O, 350 ppm NO, 1000 ppm SO_2, 10 ppm SO_3, 100 ppm CO; MR = Inlet Molar Ratio

Impact of Temperature (MR=0.9)

Hg Oxidation Activity

With high inlet NH_3, the activation energy decreases for constant HCl, which indicates that NH_3 inhibition can become more pronounced at high temperature.

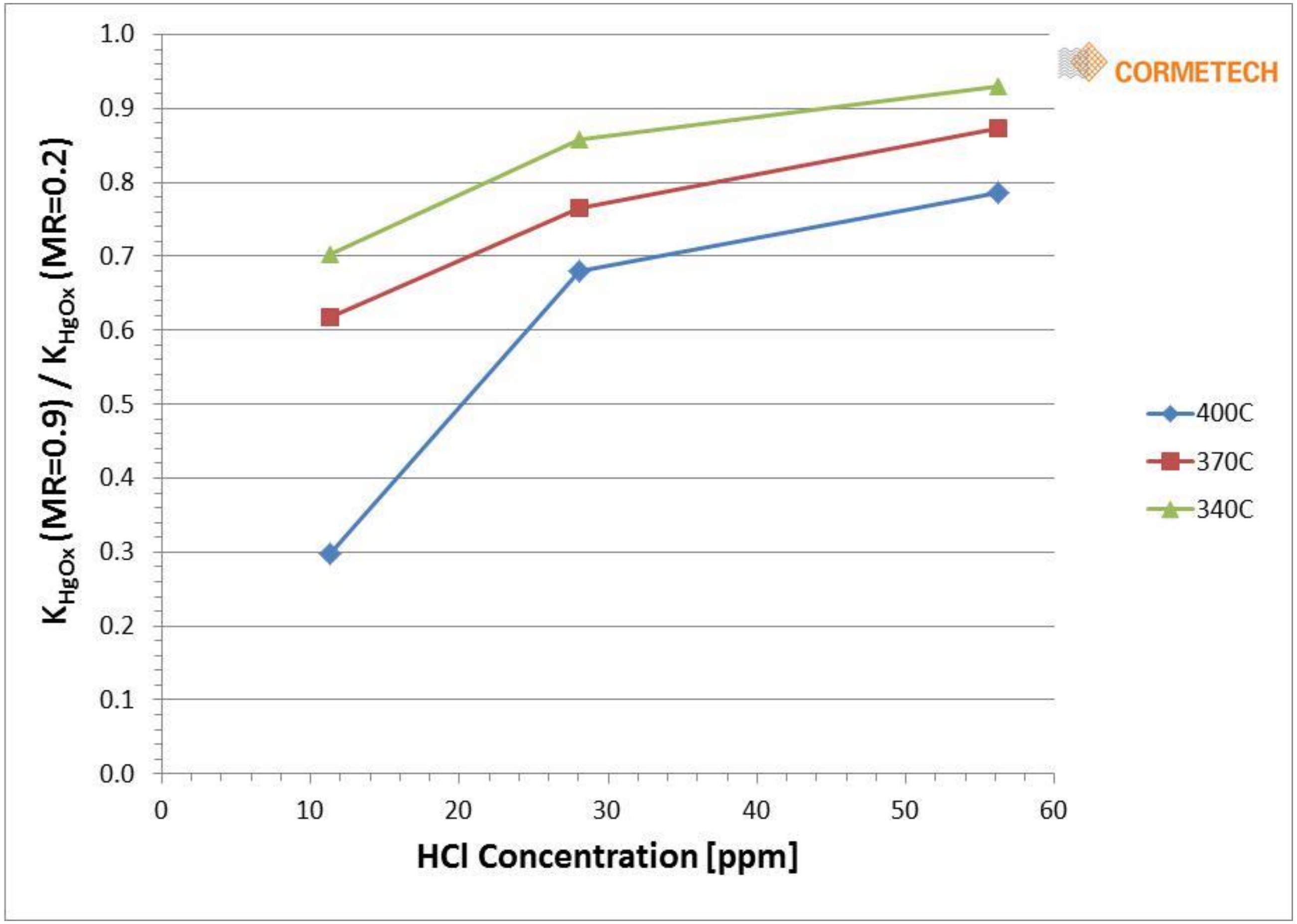


3.5% O_2, 11% H_2O, 350 ppm NO, 1000 ppm SO_2, 10 ppm SO_3, 100 ppm CO; MR = Inlet Molar Ratio

Impact of Temperature

Hg Oxidation Activity

Increasing HCl can reduce the amount of NH_3 suppression across the temperature range.

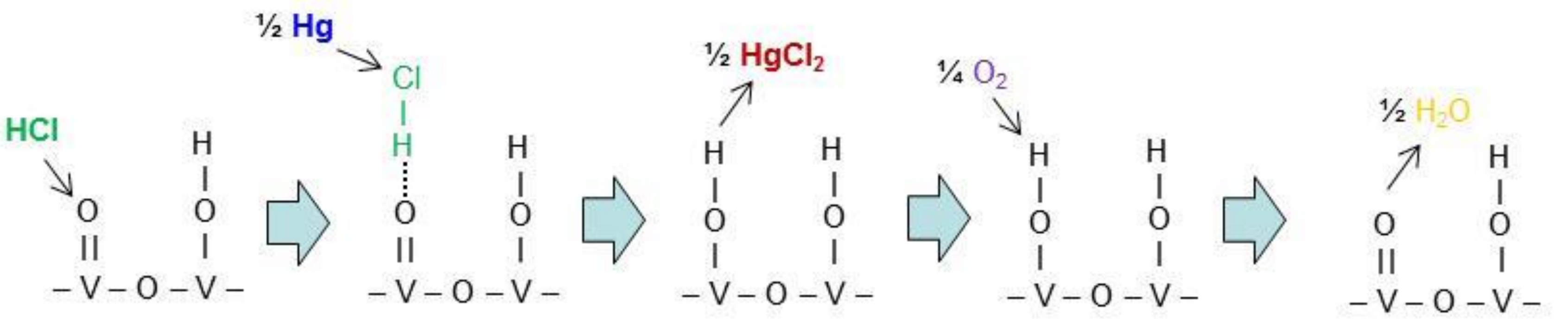


3.5% O_2, 11% H_2O, 350 ppm NO, 1000 ppm SO_2, 10 ppm SO_3, 100 ppm CO; MR = Inlet Molar Ratio

Reaction Mechanism

Several Hypotheses in the Literature

One example: Eley – Rideal (HCl adsorbs, Hg reacts from gas phase)



Two other examples (both include Hg adsorption steps):

- **Langmuir – Hinshelwood (both HCl and Hg adsorb before reaction occurs)**
- **Mars – van Krevelen (reaction of adsorbed Hg with lattice chloride)**

How NH_3 Inhibits Hg Oxidation

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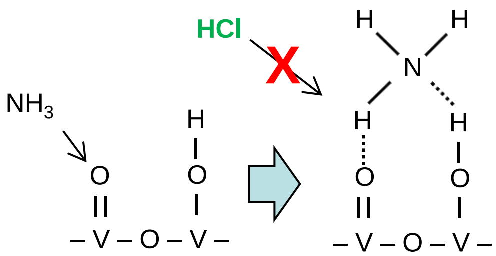
1. Competitive adsorption of HCl and NH_3:

(more significant at lower temperature)



We verified that $HgCl_2$ reduction by NH_3 occurs by running experiments with 100% Hg^{2+} injection and measuring the Hg^0 that formed.

	MR	Hg0 in	Hg2+ in	Hg0 out	Hg2+ out	Delta Hg0	Delta Hg2+	Hg Ox
with Hg2+ injection	0.0	0.0	19.7	1.7	18.0	1.7	-1.7	-9%
with Hg2+ injection	0.9	0.0	19.7	3.8	15.9	3.8	-3.8	-19%

400°C, 4% O_2, 11% H_2O, 350 ppm NO, 1000 ppm SO_2, 10 ppm SO_3

2. Re-reduction of $HgCl_2$ by NH_3:

(more significant at higher temperature)

$$2NH_3 + 3HgCl_2 \rightarrow 3Hg + 6HCl + N_2$$

What will happen on a more detailed level (simplified):

$$2NH_3 + 3V^{5+}O \rightarrow N_2 + 3H_2O + 3V^{3+}$$

$$3V^{3+} + 3HgCl_2 + 3H_2O \rightarrow 3V^{5+}O + 3Hg + 6HCl$$

Coal-type SCR has a low activity for NH_3 oxidation.

Impact of Reducing Agents

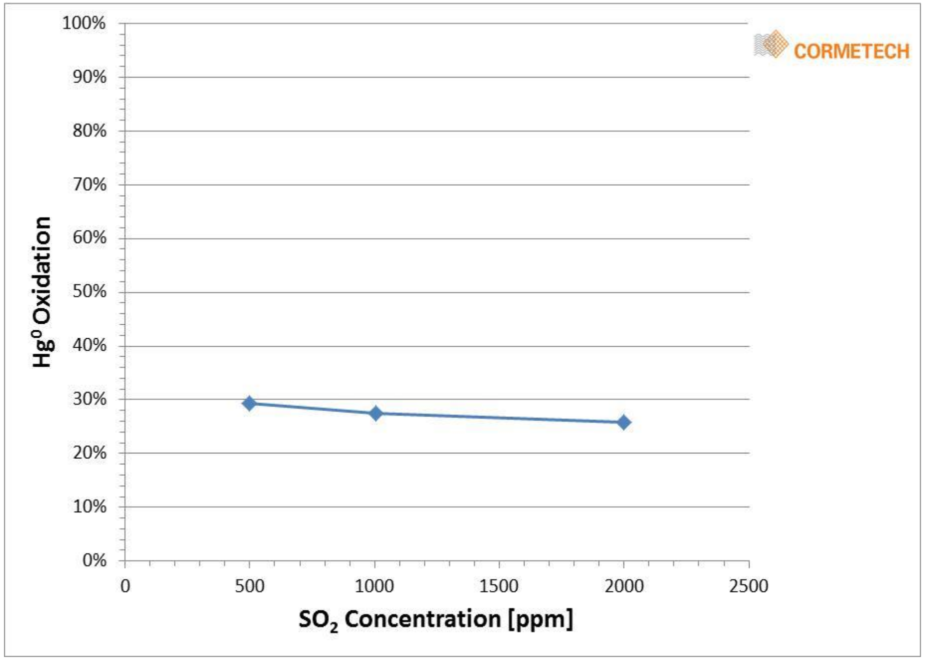
Hg Oxidation Activity

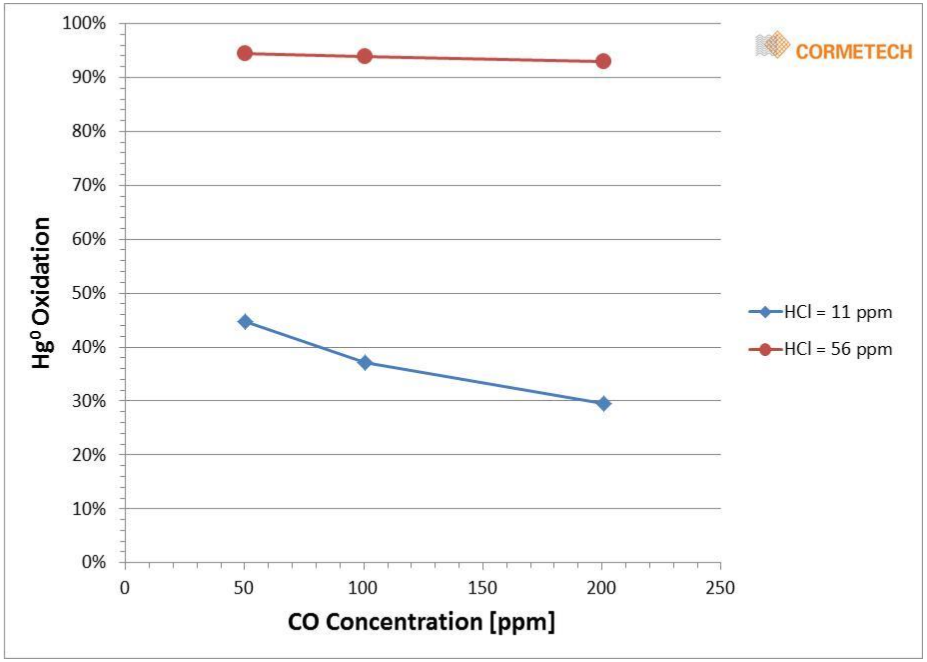
In addition to NH_3, there are additional flue gas species that can act as catalyst reducing agents and inhibit Hg oxidation by reduction of $HgCl_2$.

SO_2: $$SO_2 + HgCl_2 + H_2O \rightarrow Hg + 2HCl + SO_3$$

CO: $$CO + HgCl_2 + H_2O \rightarrow Hg + 2HCl + CO_2$$

Hydrocarbons can oxidize over SCR catalyst and partially reduce V^{5+} sites, but the hydrocarbon concentration in coal flue gas tends to be fairly low.



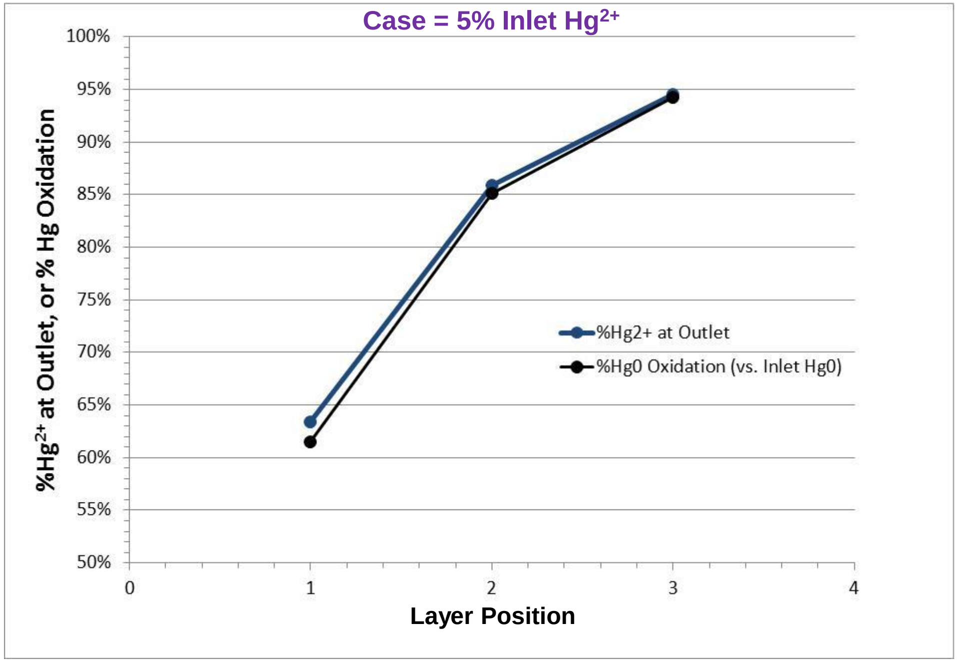


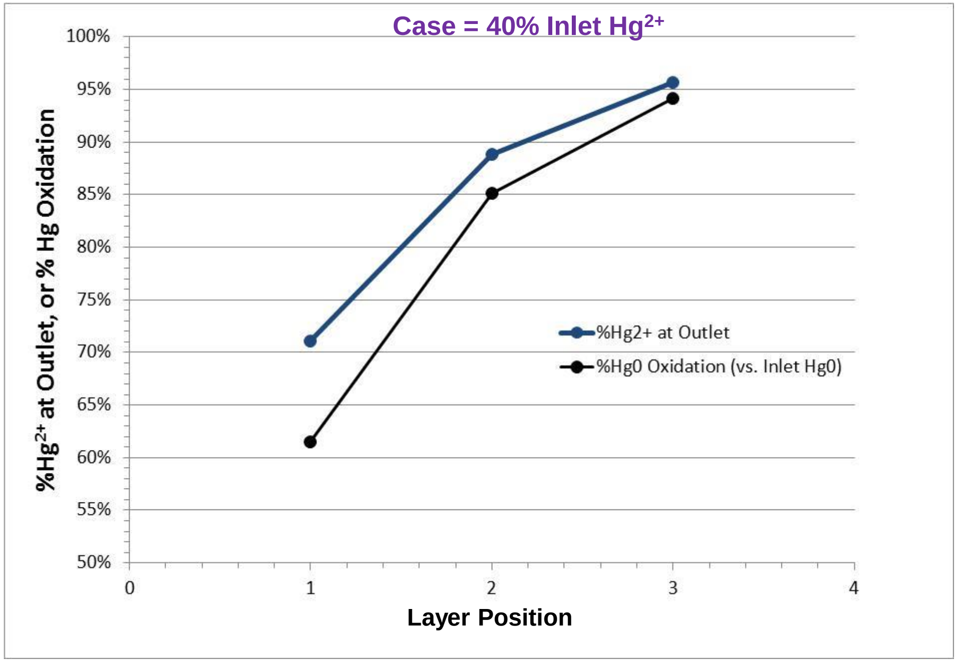
400°C, 3.5% O_2, 11% H_2O, HCl = 11 ppm or as specified, 350 ppm NO, 0.2 MR, SO_2 = 1000 ppm or as specified, SO_3 = 1% of SO_2, CO = 100 ppm or as specified

Impact of Inlet Hg Speciation

Model Simulation

Hg oxidation reactivity held constant. Hg^{2+} reduction activity by NH_3 set at 0 (inactive).

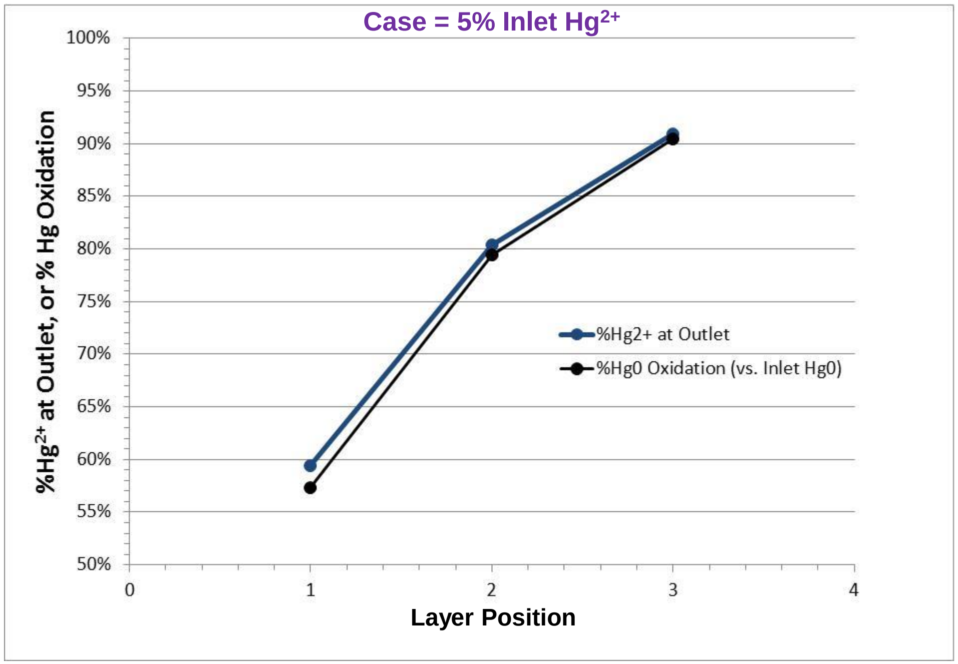


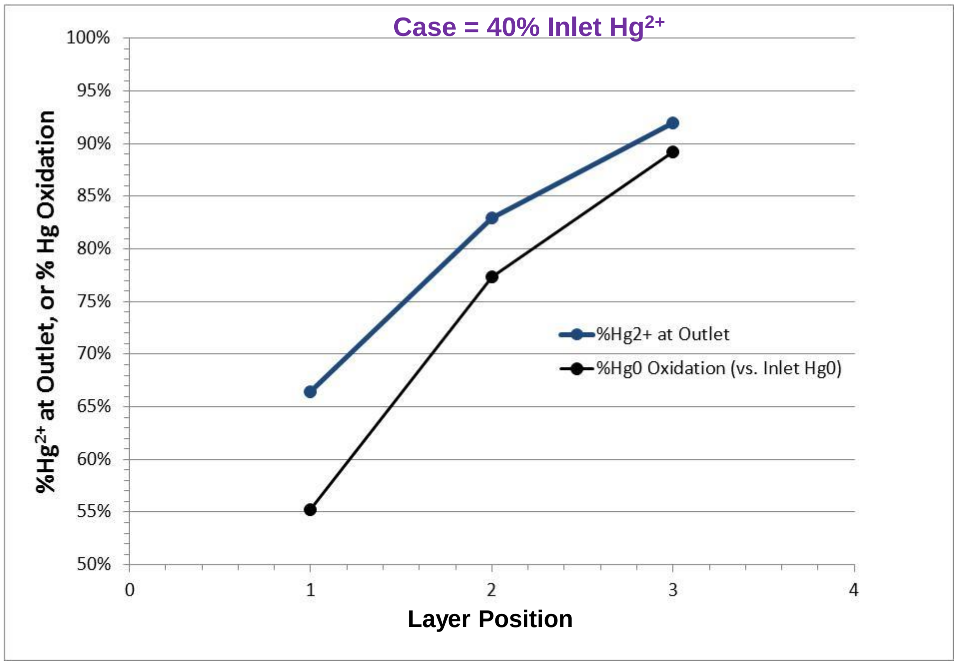


In the limit where Hg^{2+} reverse reactions are inactive → Hg oxidation is independent of inlet Hg^{2+} speciation, and the outlet % oxidized Hg^{2+} is effectively additive (= inlet Hg^{2+} + amount of Hg^0 oxidized in the SCR)

Impact of Inlet Hg Speciation
Model Simulation

Hg oxidation reactivity held constant. Hg^{2+} reduction activity by NH_3 set at a low value.

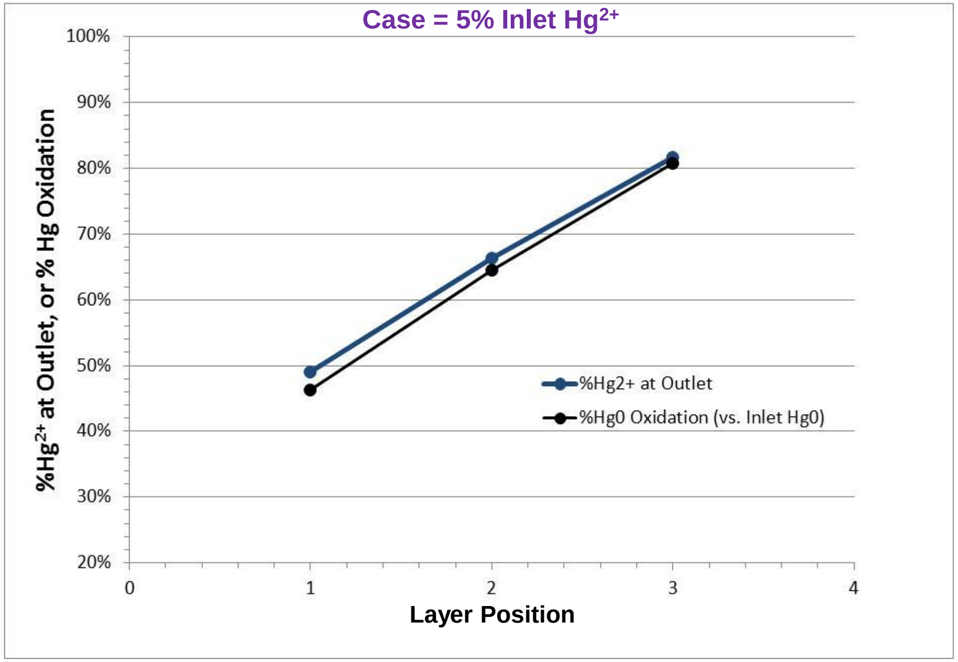


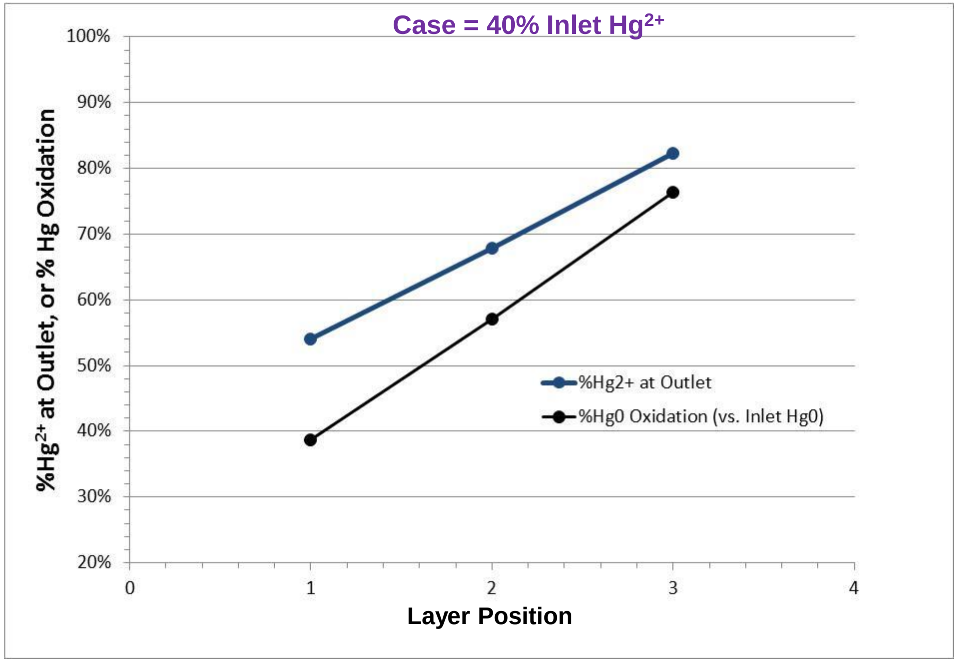


Higher inlet Hg^{2+} decreases the effective Hg oxidation due to reverse reactions. Note that the outlet $\%Hg^{2+}$ for the 40% inlet oxidized case is higher than the 5% inlet oxidized case.

Impact of Inlet Hg Speciation
Model Simulation

Hg oxidation reactivity held constant. Hg^{2+} reduction activity by NH_3 further increased.





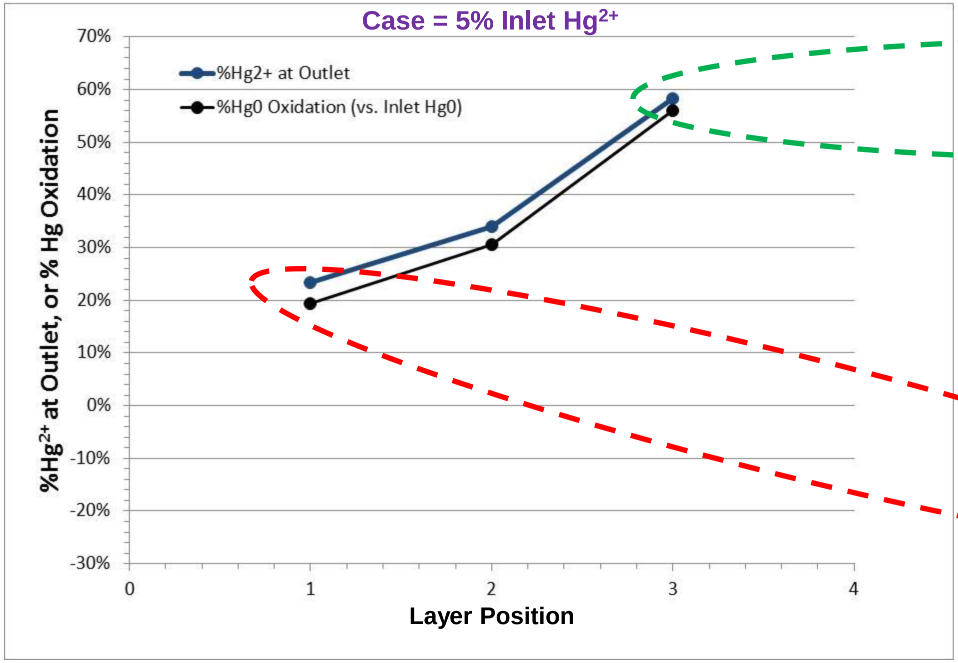
Higher inlet Hg^{2+} decreases the effective Hg oxidation due to reverse reactions. Note that the outlet $\%Hg^{2+}$ for the 40% inlet oxidized case is still higher than the 5% inlet oxidized case (but the difference is becoming smaller).

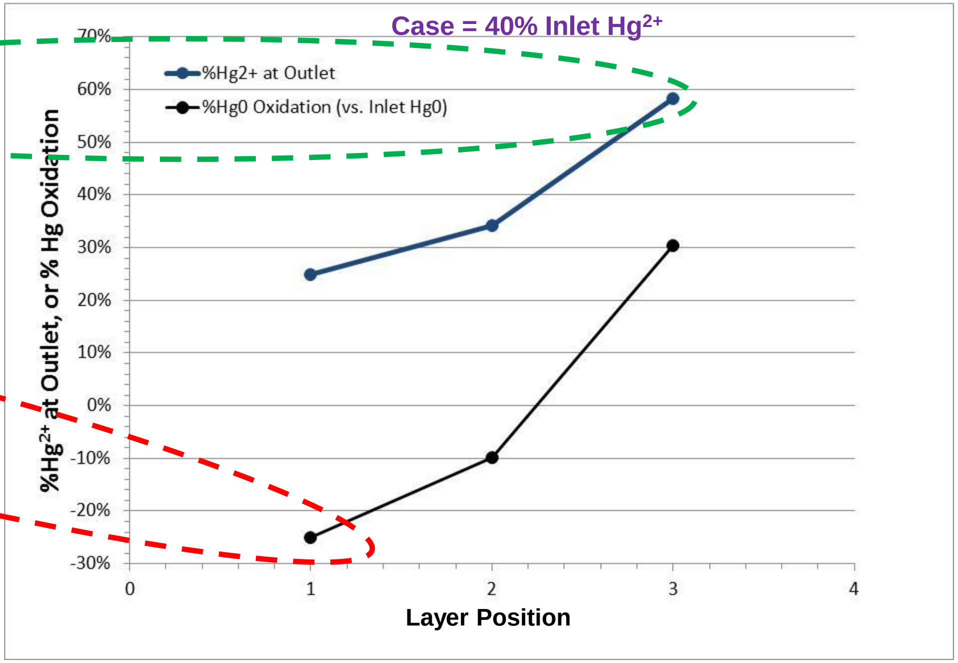
Impact of Inlet Hg Speciation

Model Simulation

Hg oxidation reactivity held constant. Hg^{2+} reduction activity by NH_3 increased again.

In the limit where reverse reactions are dominant, the %outlet Hg^{2+} achieved is independent of the %inlet Hg^{2+}.



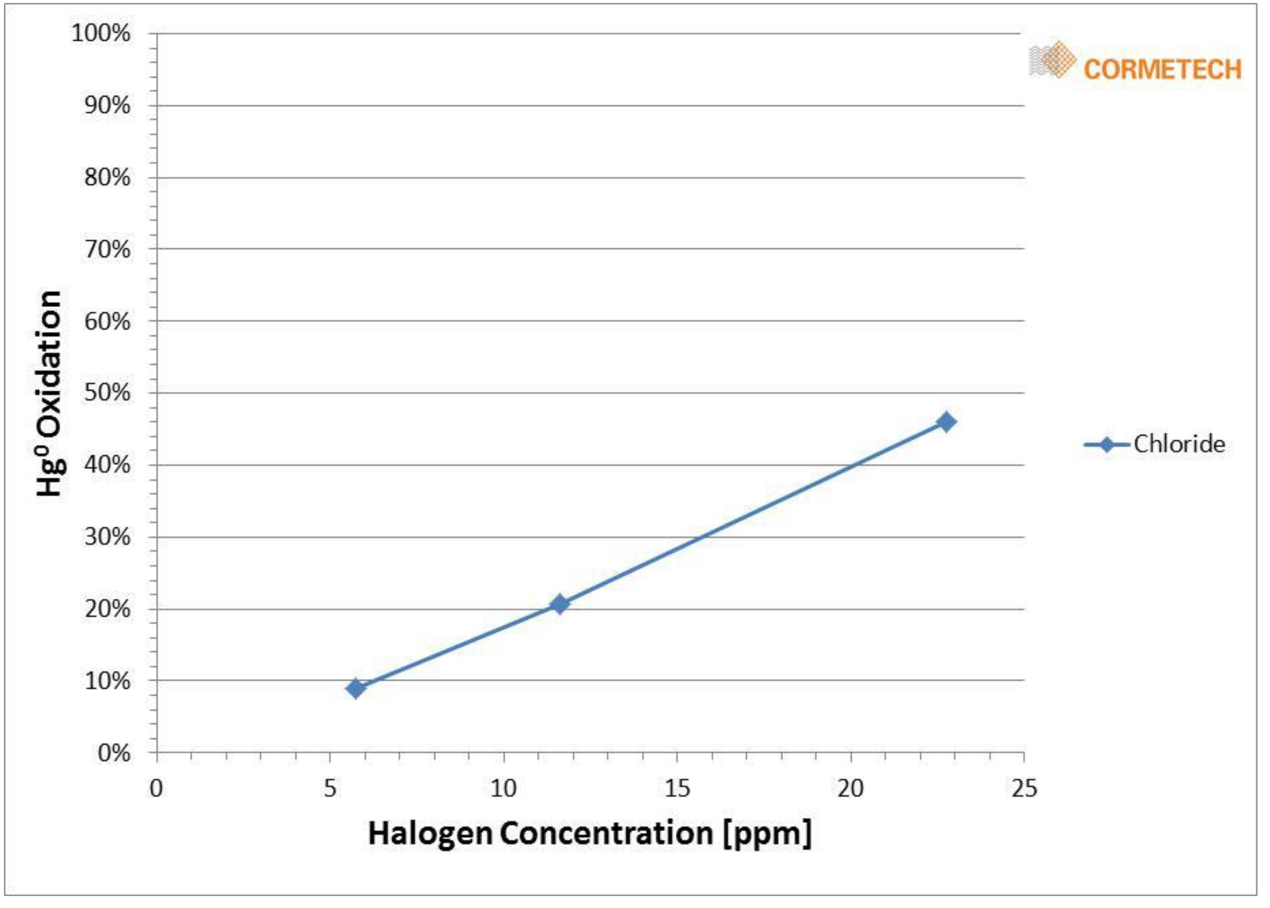


In the limit where reverse reactions are dominant, Hg oxidation of top layers can become negative for high %inlet Hg^{2+}.

Halogens: Cl vs. Br vs. I

Hg Oxidation Activity

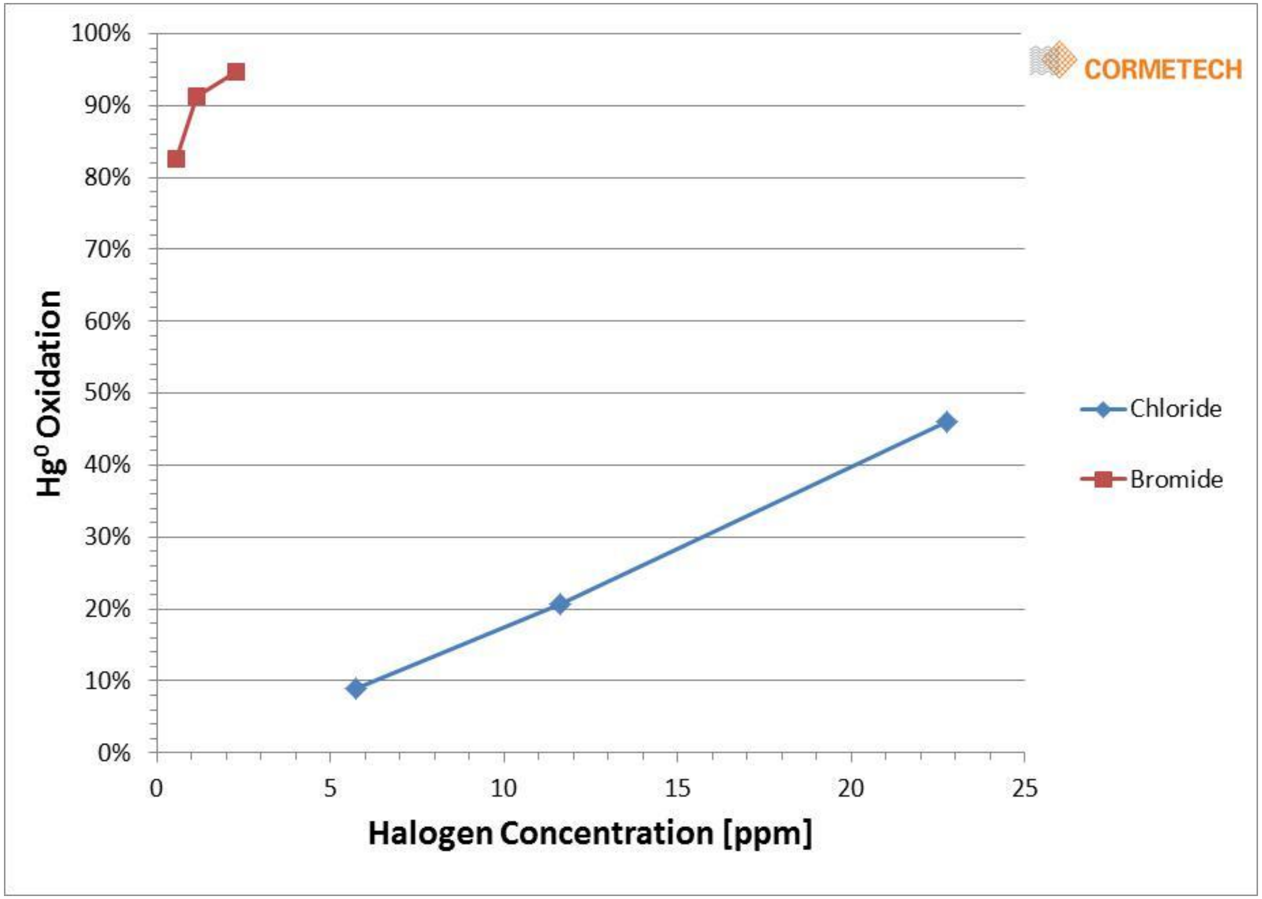
Baseline with chloride only. Challenging Hg oxidation condition.



400ºC, 350 ppm NO, 0.9 MR, 3.5% O_2, 12% H_2O, 1000 ppm SO_2, 11 ppm SO_3, 100 ppm CO.

Halogens: Cl vs. Br vs. I
Hg Oxidation Activity

Bromide is much more effective than chloride for Hg oxidation.



400ºC, 350 ppm NO, 0.9 MR, 3.5% O_2, 12% H_2O, 1000 ppm SO_2, 11 ppm SO_3, 100 ppm CO.

Halogens: Cl vs. Br vs. I

Hg Oxidation Activity

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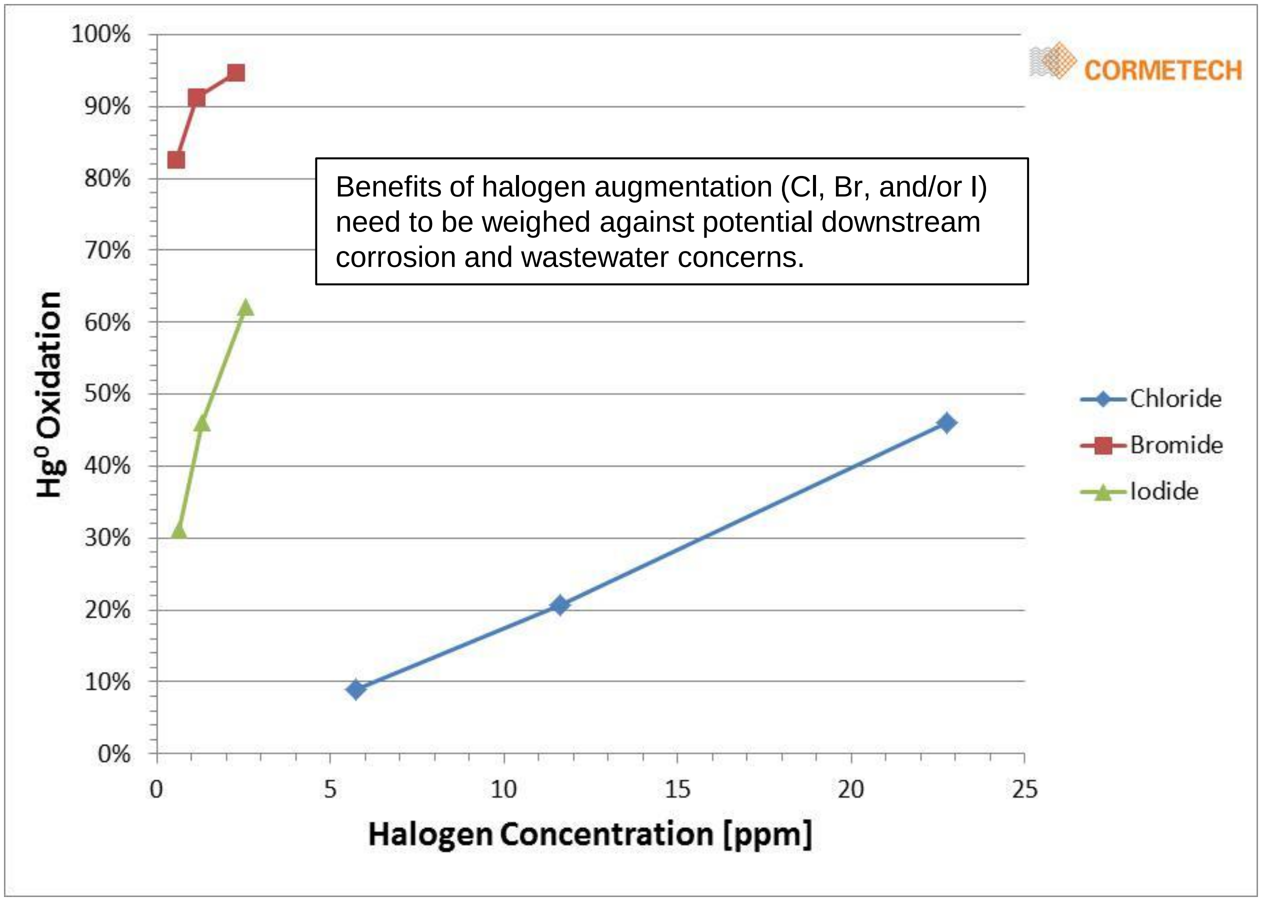
Rank of halogen effectiveness for Hg oxidation: Br > I > Cl.



400ºC, 350 ppm NO, 0.9 MR, 3.5% O_2, 12% H_2O, 1000 ppm SO_2, 11 ppm SO_3, 100 ppm CO.

HBr Impact on NH_3 Inhibition

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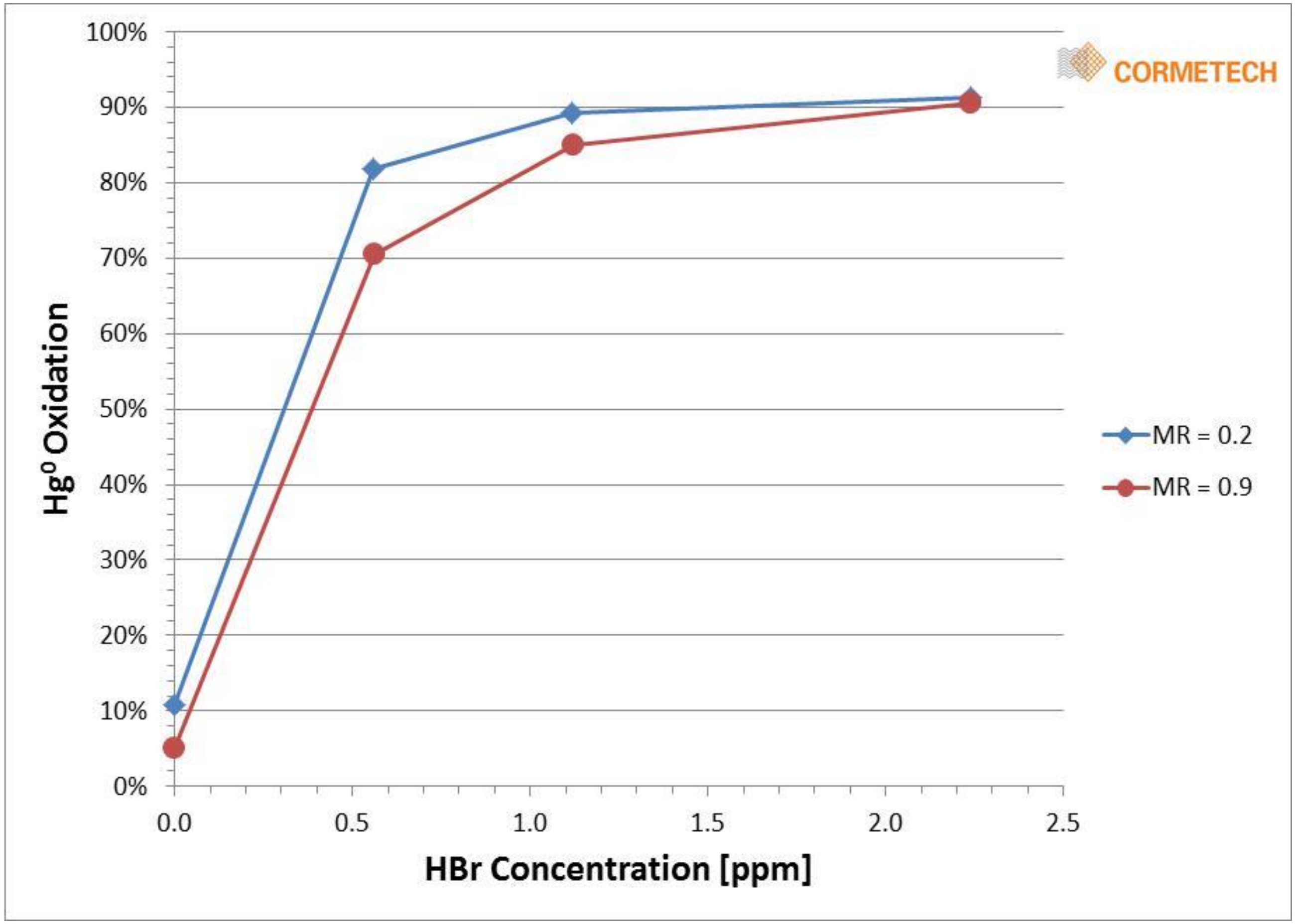
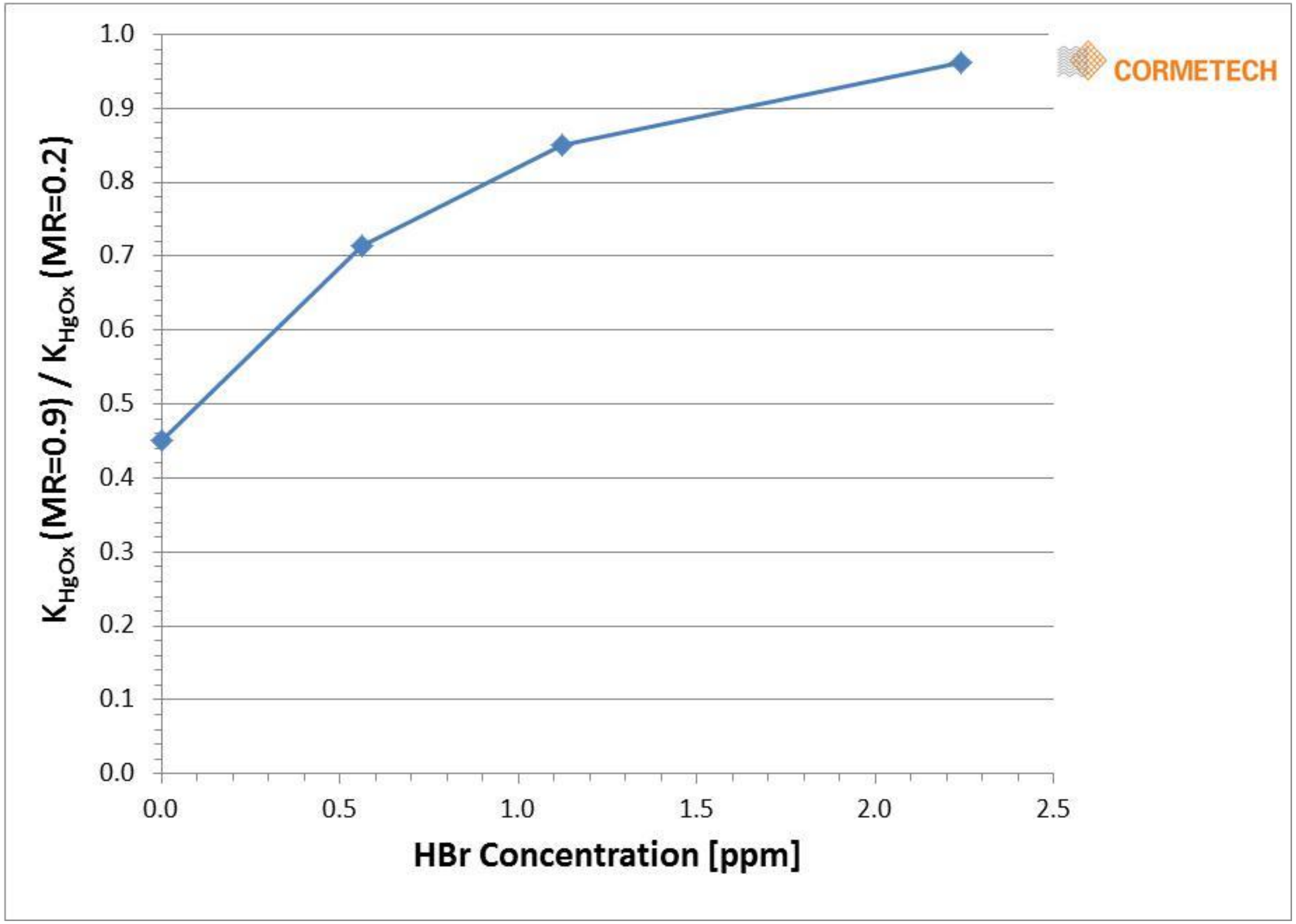
Testing data set at MR = 0.2 and MR = 0.9.



400°C, 3.5% O_2, 11% H_2O, 1000 ppm SO_2, 10 ppm SO_3, 100 ppm CO, HCl = 5 ppm; MR = Inlet Molar Ratio

HBr Impact on NH_3 Inhibition

The catalyst's Hg oxidation activity is much less sensitive to NH_3 at high HBr concentration (almost no inhibition at 2 ppm HBr).



400°C, 3.5% O_2, 11% H_2O, 1000 ppm SO_2, 10 ppm SO_3, 100 ppm CO, HCl = 5 ppm; MR = Inlet Molar Ratio

Impact of HBr on NH_3 Inhibition

First Layer vs. Lower Layer Performance

Strong interdependence between the HBr content and the degree of NH_3 suppression of Hg ox rate → as with higher HCl, the layer 1 catalyst will contribute more to overall Hg oxidation with HBr injection!

Single Layer Performance Example						
Position	Case	MR	HCl [ppm]	HBr [ppm]	Layer Hg Ox	Hg Ox Delta Layer 1 vs. Lower Layer
Layer 1	no HBr	0.9	6	0	5%	-6%
Lower Layer	no HBr	0.2	6	0	12%	
Layer 1	HBr = 1	0.9	6	1	87%	-4%
Lower Layer	HBr = 1	0.2	6	1	91%	
Layer 1	HBr = 2	0.9	6	2	92%	-1%
Lower Layer	HBr = 2	0.2	6	2	93%	

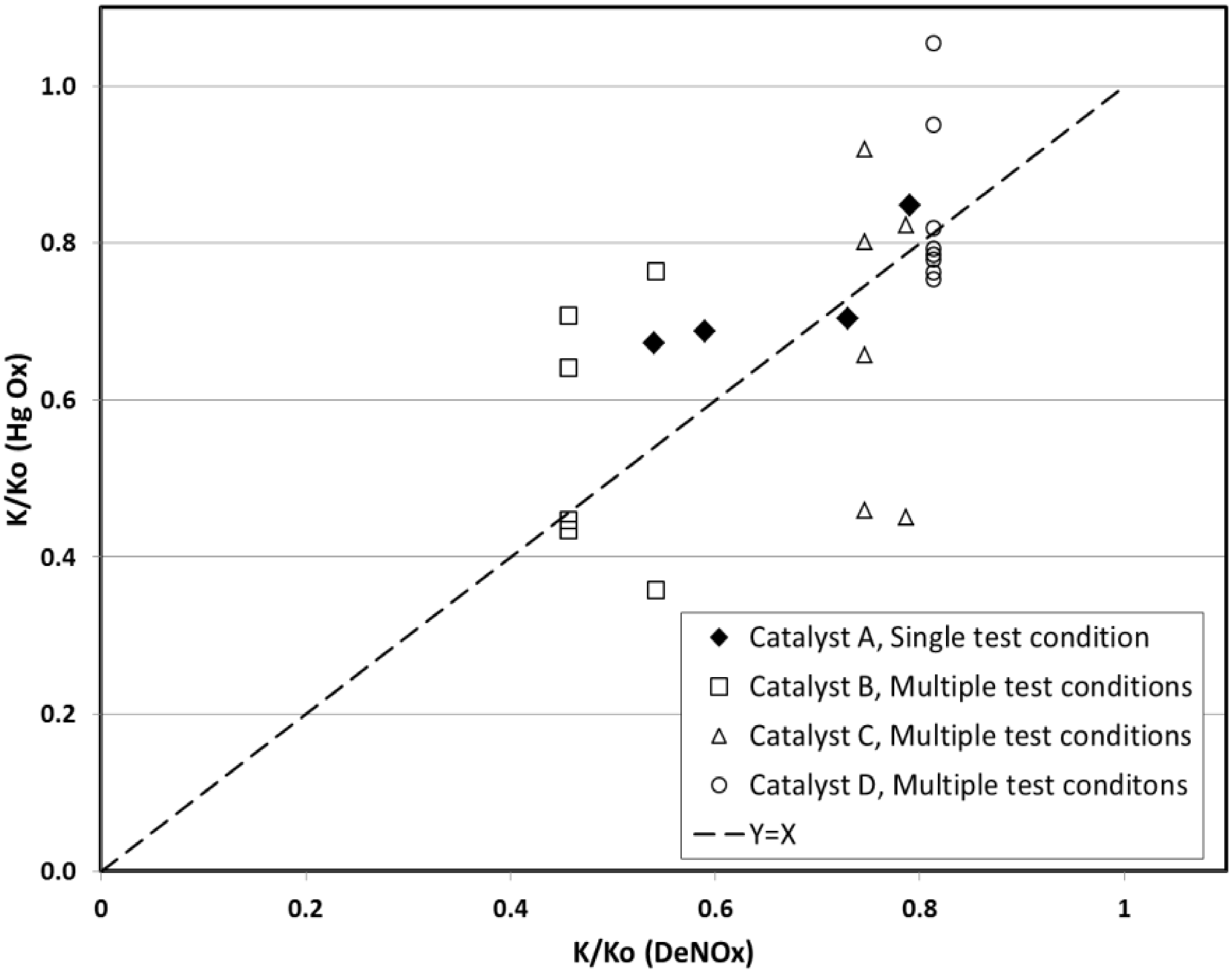
400°C, 3.5% O_2, 11% H_2O, 1000 ppm SO_2, 10 ppm SO_3, 100 ppm CO, HCl = 5 ppm; MR = Inlet Molar Ratio

Catalyst Management

- **Including Hg is analogous to DeNOx…**
  - *With the caveats for K_{HgOx} previously outlined*
- **DeNOx or Hg oxidation establishes the design minimum volume**
  - *Depends on the relative catalyst potential and performance requirements for each reaction*
- **Considerations**
  - Layer auditing (lab reactor testing)
  - Catalyst action selection (traditional, regen, advanced)
  - Halogen augmentation potential

Catalyst Deactivation

Correlation with DeNOx Deactivation



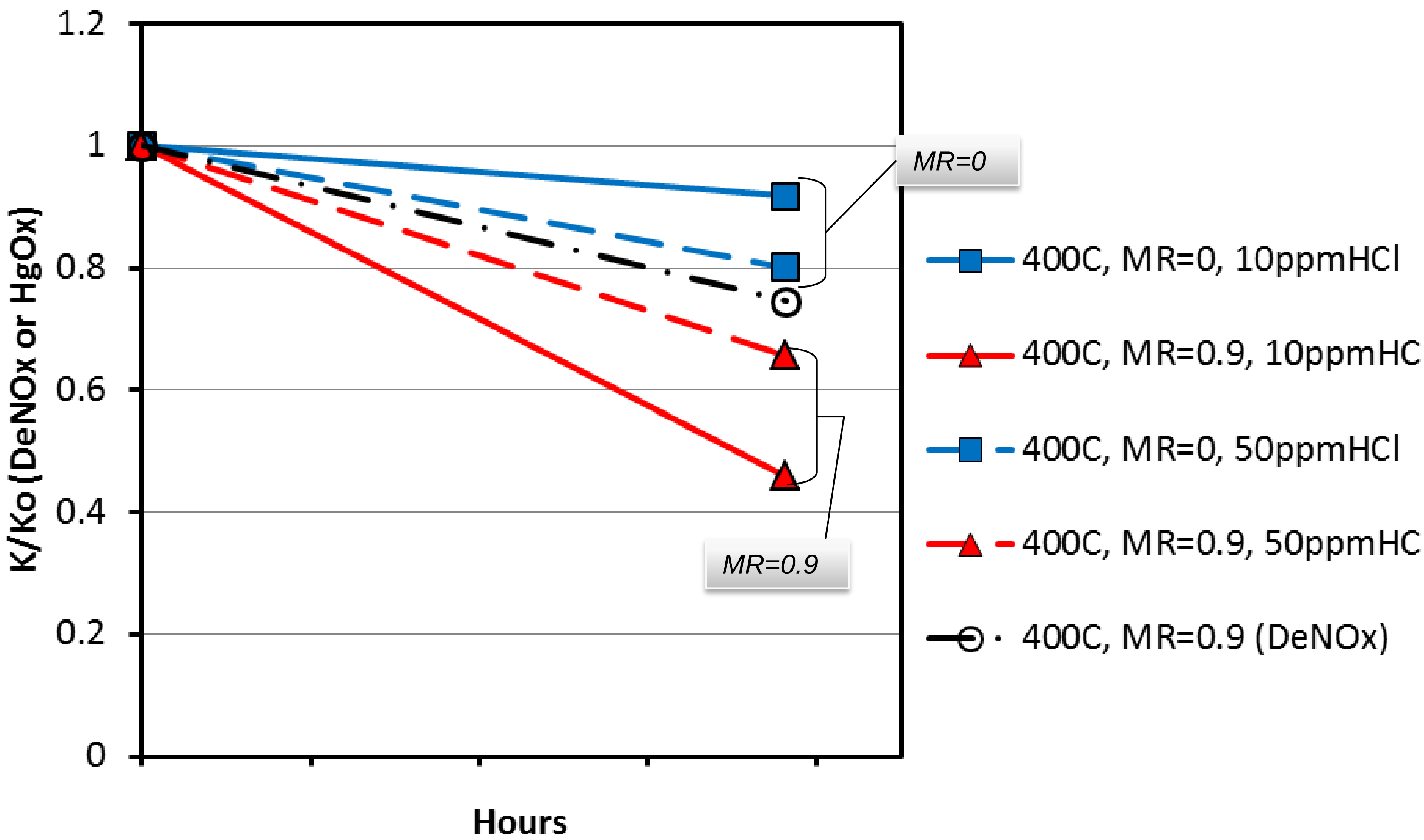
Hg oxidation deactivation generally correlates with DeNOx deactivation.

The extent of deactivation for the two reactions may not be equivalent:

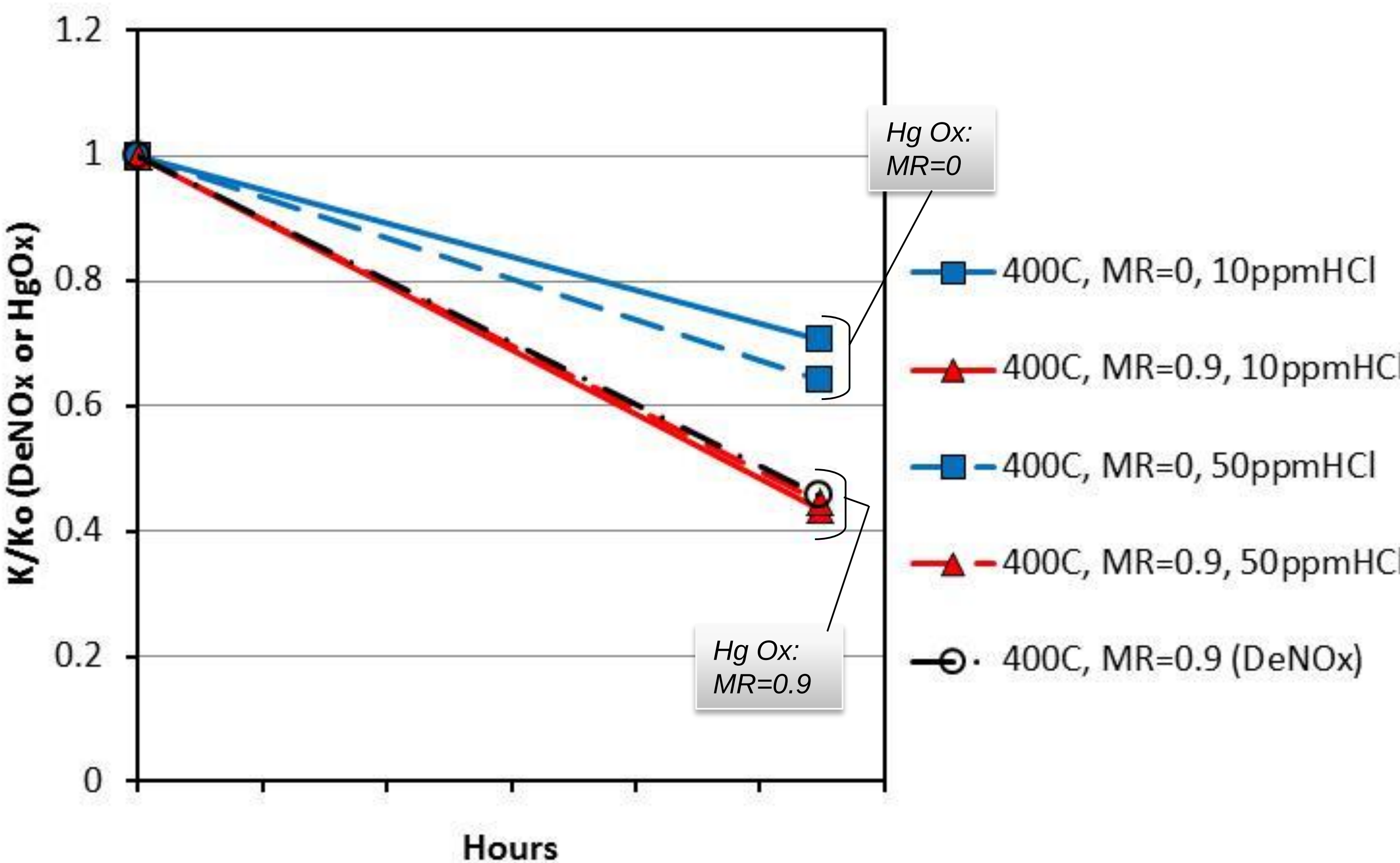
K/Ko (Hg Ox) is sensitive to operating conditions (especially NH_3, HCl, temperature, and catalyst type).

Catalyst Deactivation

PRB-Firing Unit Example (Ca, P)

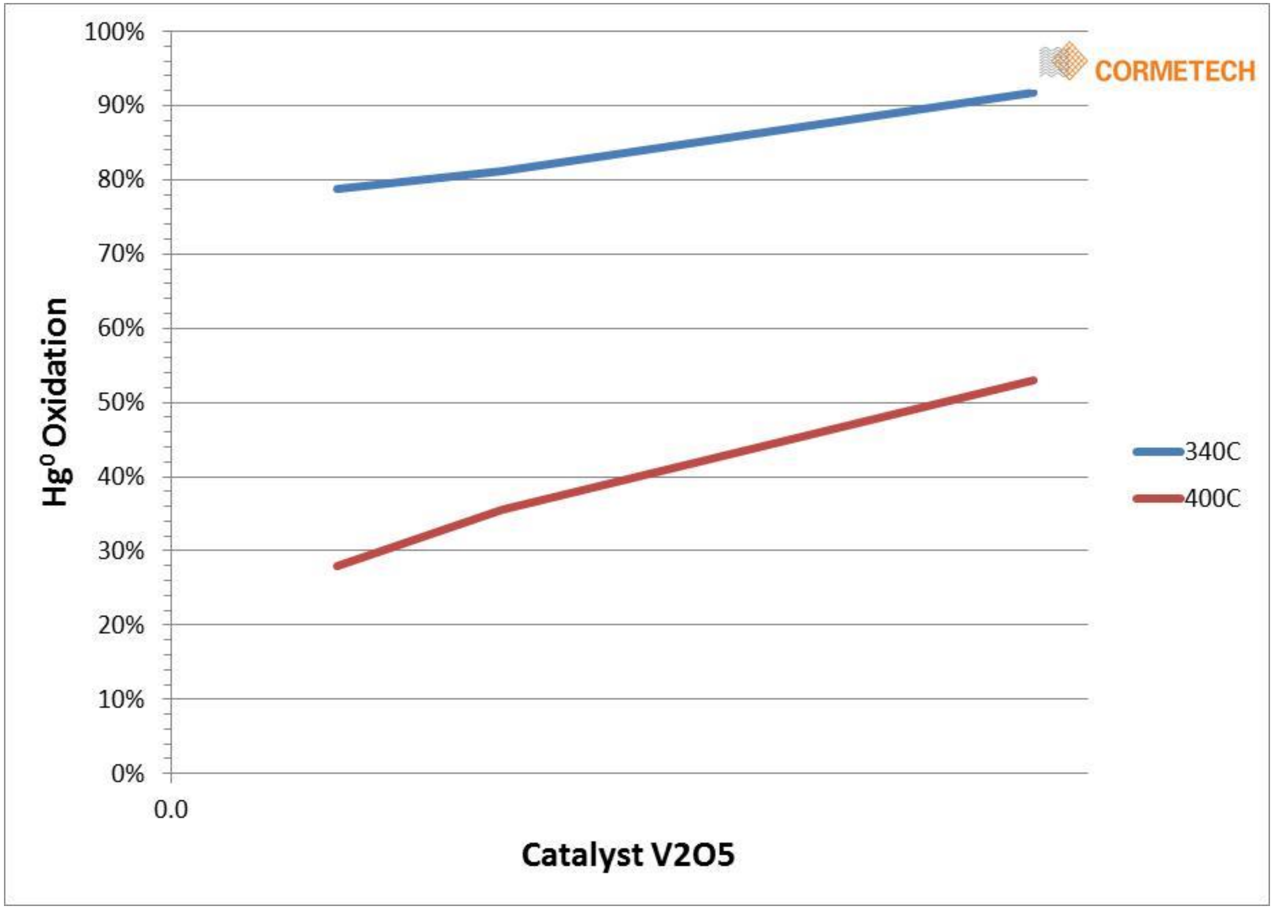


Catalyst Deactivation
Bituminous-Firing Unit Example (As)



Impact of Catalyst V_2O_5 Content

Higher V_2O_5 improves Hg oxidation and DeNOx, but it must be balanced relative to SO_2 oxidation constraints (e.g., PRB vs. bituminous, SO_3 mitigation).



400ºC, 3.5% O_2, 11% H_2O, 1000 ppm SO_2, 10 ppm SO_3, 100 ppm CO, HCl = 11 ppm; MR = 0

SCR Catalyst: Design Approach

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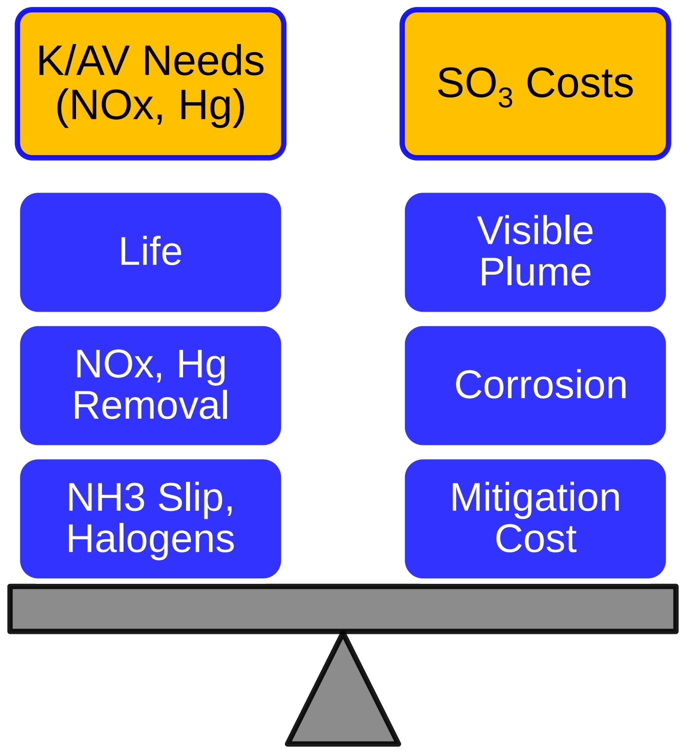
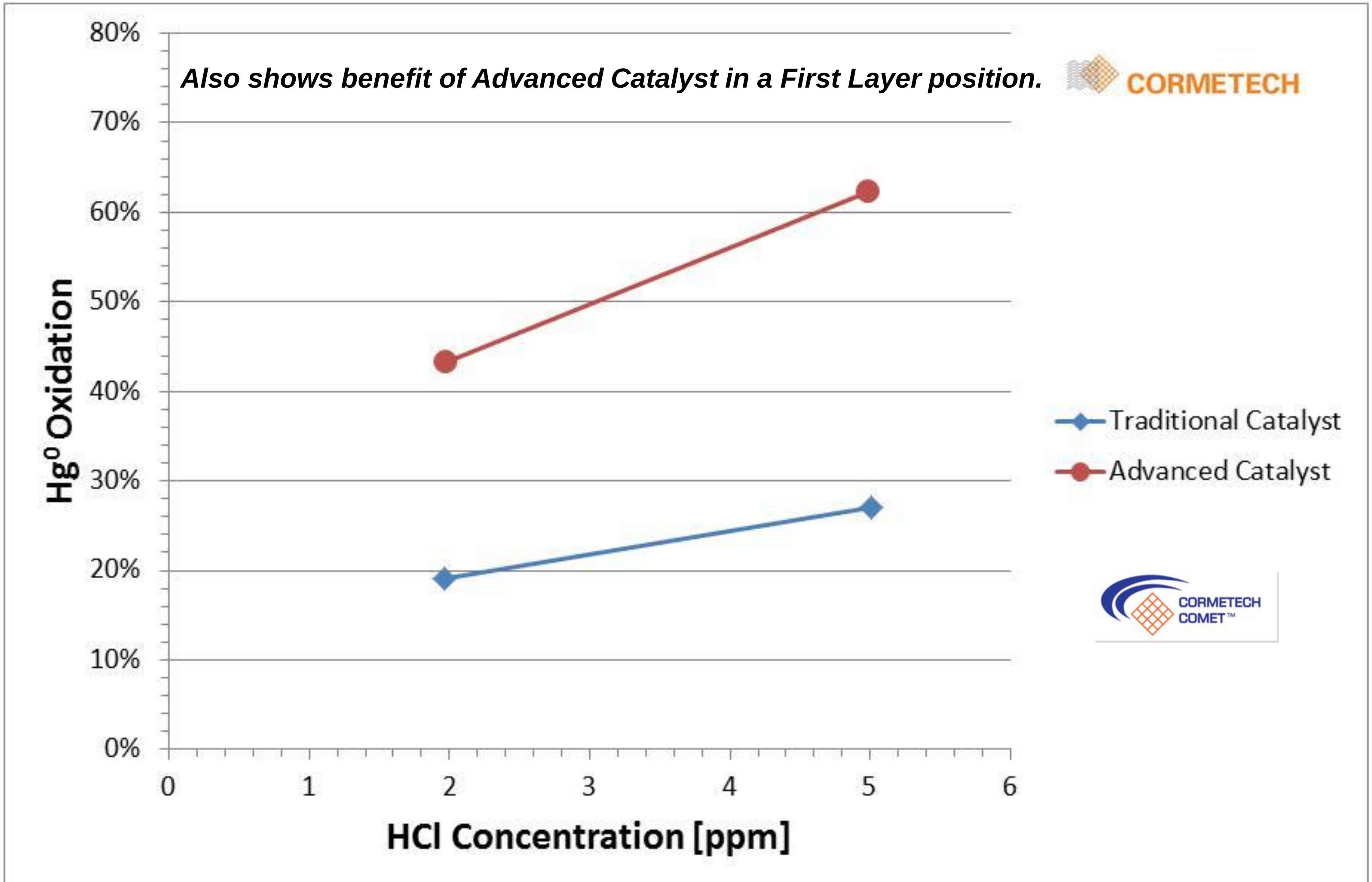
SCR catalyst is formulated to achieve DeNOx and Hg oxidation requirements, while meeting SO_2 oxidation constraints. Either DeNOx or Hg oxidation will be controlling for catalyst volume; the other will have excess potential.



Advanced Catalyst

- **For challenging conditions, such as…**
  - Lower HCl, and/or
  - Higher temperature, and/or
  - Higher concentration of reducing agents (NH_3, CO, SO_2)
- **…we can modify catalyst formulation and processing to improve Hg oxidation relative to DeNOx and SO_2 oxidation**

Advanced Catalyst: Low HCl



370°C, 250 ppm NO, 0.9 MR, 4% O_2, 14% H_2O, 400 ppm SO_2, 4 ppm SO_3, 100 ppm CO

Advanced Catalyst: NH_3 Impact

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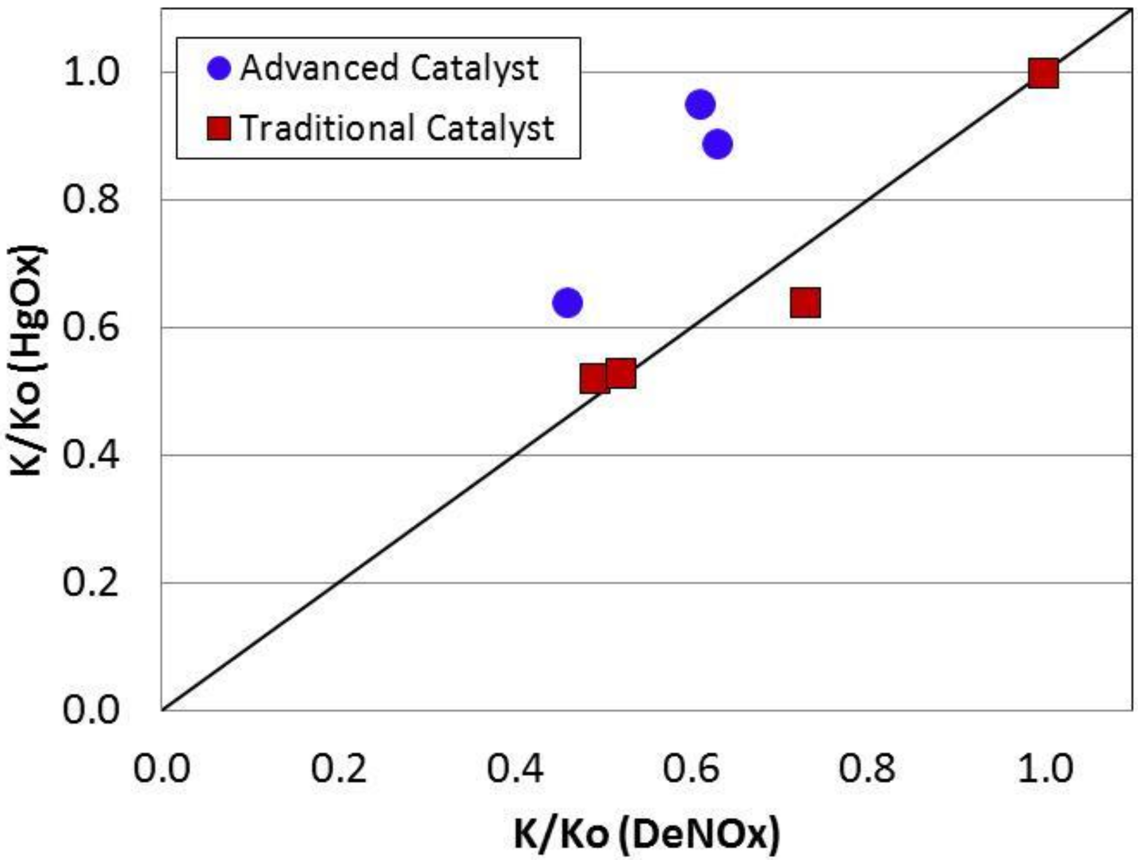
Advanced Catalyst also has a performance benefit in the First Layer position for higher HCl cases.

Single Layer Performance Example					
Position	**Case**	**MR**	**HCl [ppm]**	**Layer Hg Ox**	**Hg Ox Delta Advanced vs. Traditional**
Layer 1	Traditional Catalyst	1.0	58	53%	
Layer 1	Advanced Catalyst	1.0	58	72%	18%

371°C, 305 ppm NO, 1.0 MR, 4.3% O_2, 8.5% H_2O, 850 ppm SO_2, 8 ppm SO_3, 100 ppm CO.

Advanced Catalyst: K/Ko



400°C, 350 ppm NO, 0.9 MR, 3.5% O_2, 12% H_2O, 1000 ppm SO_2, 10 ppm SO_3, 100 ppm CO, 56 ppm HCl

Summary

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- **SCR Hg oxidation is influenced by multiple factors**
  - Layer dependency
  - More factors in setting design conditions
  - Interdependencies between factors
  - Impacts of catalyst type & formulation

Understand these factors and incorporate them into the design process to optimize the SCR for Hg oxidation, maintain NOx reduction and manage SO_2 oxidation.

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Thank You!

Questions?

Christopher Bertole

Cormetech, Inc.

2015 Reinhold NOx-Combustion Round Table