REINHOLD ENVIRONMENTAL Ltd.

2015 NOx-Combustion Round Table & Expo Presentations

February 23 & 24, 2015, in Richmond, VA / Hosted by Dominion

2015 NOx Combustion/PCUG Conference

Monday, February 23, 2015

SCR Mercury Oxidation

Practical Guidance for Co-Benefit Mercury Control

W. Scott Hinton, Ph.D., P.E.

W. S. HINTON & ASSOCIATES

1612 Smugglers Cove Circle
Gulf Breeze, FL 32563
Tel: 850-936-0037
Fax: 850-936-0064
Cell: 850-261-5239
shinton@wshinton.com

Training Class Outline

1. Mercury Chemistry, Equilibrium, etc.
2. Fuel Impacts
3. SCR Mercury Oxidation
    a. operating conditions
    b. catalyst design
    c. aging
    e. catalyst management
    f. modeling efforts
4. Mercury Measurement Techniques
5. Laboratory Testing for Mercury Oxidation

Mercury Chemistry

1. Mercury Species
2. Equilibrium
3. Reaction Mechanism

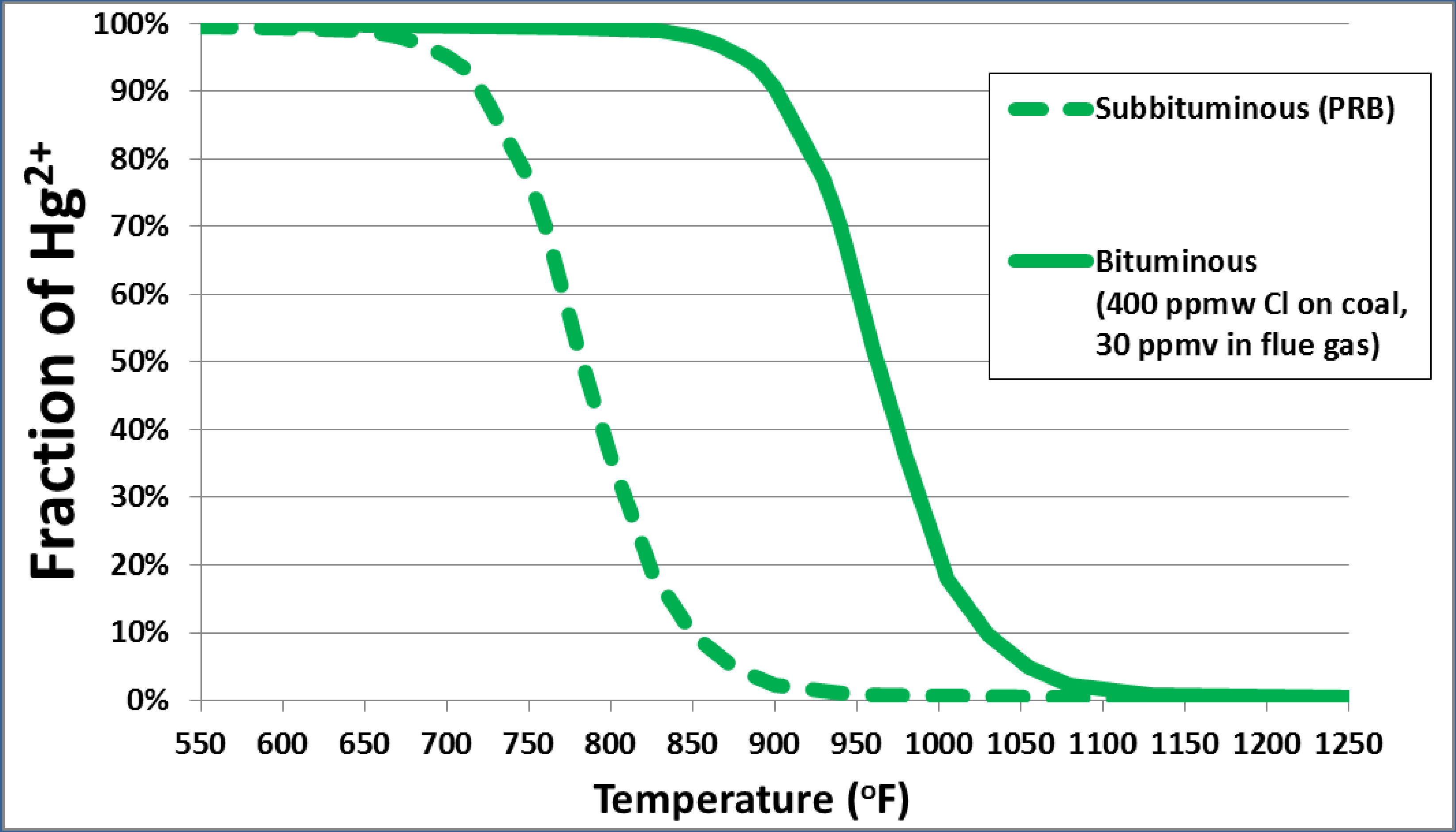
Mercury Species Designations

Species	Abbr.	Notes
Elemental Mercury	**Hg^0**	Elemental mercury denotes free unreacted mercury, typically present in the gas-phase of the flue gas.
Oxidized Mercury	**Hg^{2+}**	Oxidized mercury refers to any mercury compound that is formed, typically present in the gas-phase. The term implies the chemical oxidation reaction, rather than mercury oxide. The most common specific oxidized mercury species include $HgCl_2$ and $HgBr_2$.
Particulate Mercury	**Hg^P**	Particulate mercury refers to mercury that is associated with flue gas particulate and/or is captured in the measurement system as part of the particulate.
Vapor-Phase Mercury	**Hg^{vap}**	Not as commonly utilized as the other species designations, vapor-phase mercury refers to the combination of mercury species <u>excluding</u> particulate mercury. It is usually considered to be the sum of Hg^0 and Hg^{2+}.
Total Mercury	**Hg^T**	Total mercury typically refers to the combination of all mercury species present, i.e. $Hg^T = Hg^0 + Hg^{2+} + Hg^P$. However, depending on context and specific conventions, it may refer to only the vapor-phase species present, in which case it would be equivalent to Hg^{vap}

EQUILIBRIUM CURVES

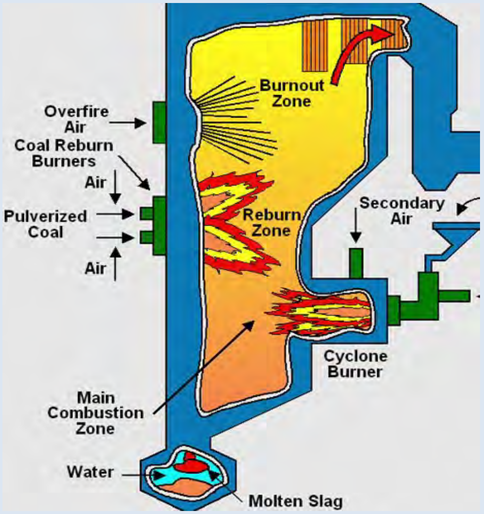
High temperature drives thermochemical equilibrium toward elemental mercury.

High halogens shift curve to the right (favoring oxidized mercury).



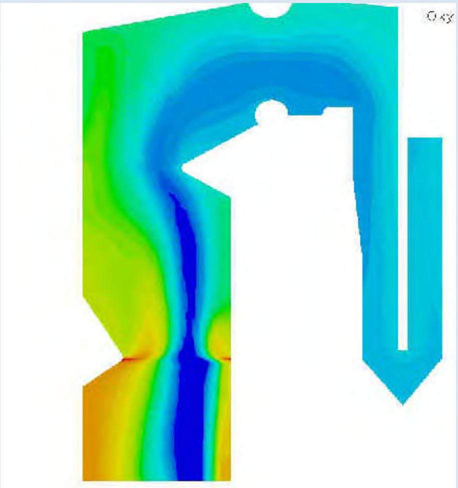
Flue Gas Train and Mercury Speciation

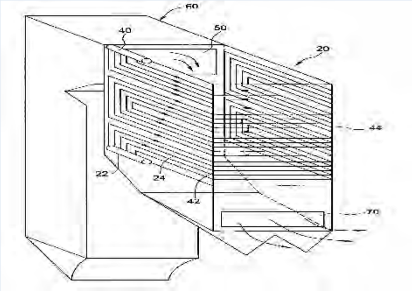
BOILER



Very high temperature converts all mercury to elemental form

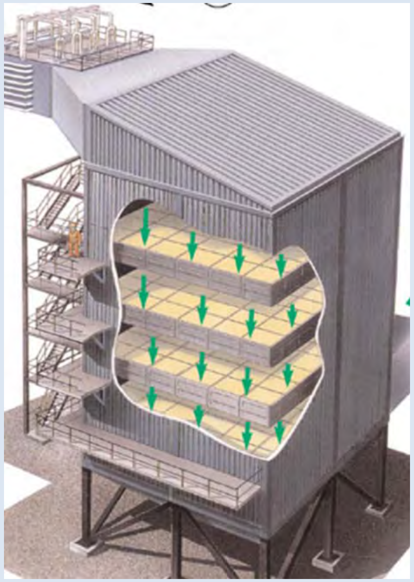
ECONOMIZER





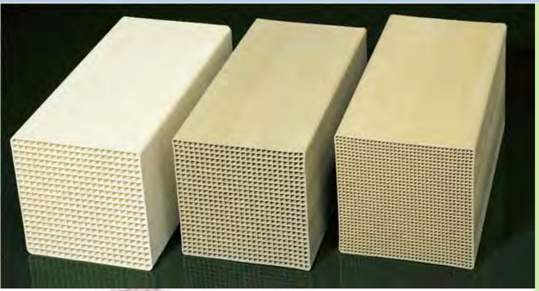
Lower temperature allows for some conversion of mercury, but very limited – low residence time a factor

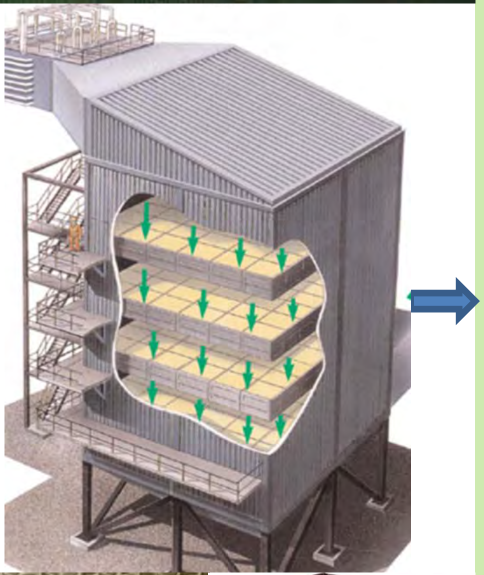
SCR

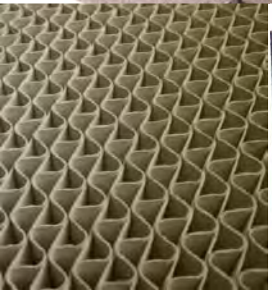


Lower temperature coupled with catalytic activity and residence time results in appreciable conversion

SCR: Catalyst drives the potential reactions forward







- Catalysts promote or “speed up” reactions. They are not consumed in the process – they are simply “expeditors”.
- For SCR catalyst, mercury oxidation is a beneficial side-reaction.
- SCR generally produces the largest mercury speciation change of any single device - it also changes the concentrations of many other species via chemical reactions (SO_3, NOx, possibly halogen form).
- Ammonia and NOx are “moving targets” in terms of concentrations as the gas moves through the reactor.

Conceptual Catalyzed Reaction Equation

elemental mercury reacts with chlorine to form oxidized mercury

complex intermediate species in
actual reaction mechanism

$$\mathrm{Hg}^0 + \mathrm{HCl} + \tfrac{1}{2}\mathrm{O}_2 \xrightarrow[\text{physical surface}]{\text{active site or}} \mathrm{HgCl}_2 + \mathrm{H}_2\mathrm{O}$$

Catalyzed reactions drive the mercury oxidation reaction forward

Mercury Oxidation Rate Equations

The “Hg^0 oxidation rate” is typically referred to simply as the “mercury oxidation rate”

Elemental Mercury Basis

$$Hg^0 \text{ Oxidation Rate} = \frac{Hg^0_{in} - Hg^0_{out}}{Hg^0_{in}}$$

Oxidized Mercury Basis

$$Hg^0 \text{ Oxidation Rate} = \frac{Hg^{2+}_{out} - Hg^{2+}_{in}}{Hg^0_{in}}$$

Normalized Basis

$$Hg^0 \text{ Oxidation Rate} = \frac{\%Hg^{2+}_{out} - \%Hg^{2+}_{in}}{\%Hg^0_{in}}$$

The above equation can also be written in a number of alternate mathematically equivalent ways since $\%Hg^0 = 100\% - \%Hg^{2+}$

Hg^0 = elemental Hg, µg/m^3

Hg^{2+} = oxidized Hg, µg/m^3

$\%Hg^0$ = % elemental Hg

$\%Hg^{2+}$ = % oxidized Hg

Mercury Oxidation Activity and Potential

$$K_{Hg} = -AV*\ln(1\text{-}Rate)$$

$$P_{Hg} = K_{Hg}/AV = -\ln(1\text{-}Rate)$$

Where;

Rate = mercury oxidation rate (as fraction)
P_{Hg}= mercury oxidation potential
K_{Hg}= mercury oxidation activity (m/hr^{-1})
AV= area velocity at standard conditions (m/hr^{-1})

Caution ! Mercury oxidation activity and potential are unique to the specific conditions of testing. Although similar in form to the bench-scale deNOx activity and field potential equations, they are used differently.

FUELS

single most important global driver of mercury behavior

1. Mercury and BTU Content
2. Halogen Content
3. Specific Coal Types (PRB, EB, etc.)
4. Fuel Effects at the SCR

Uncontrolled Mercury Emissions (lb/TBtu) as a Function of Coal Btu and Mercury Concentration

Coal Btu/lb (dry basis)

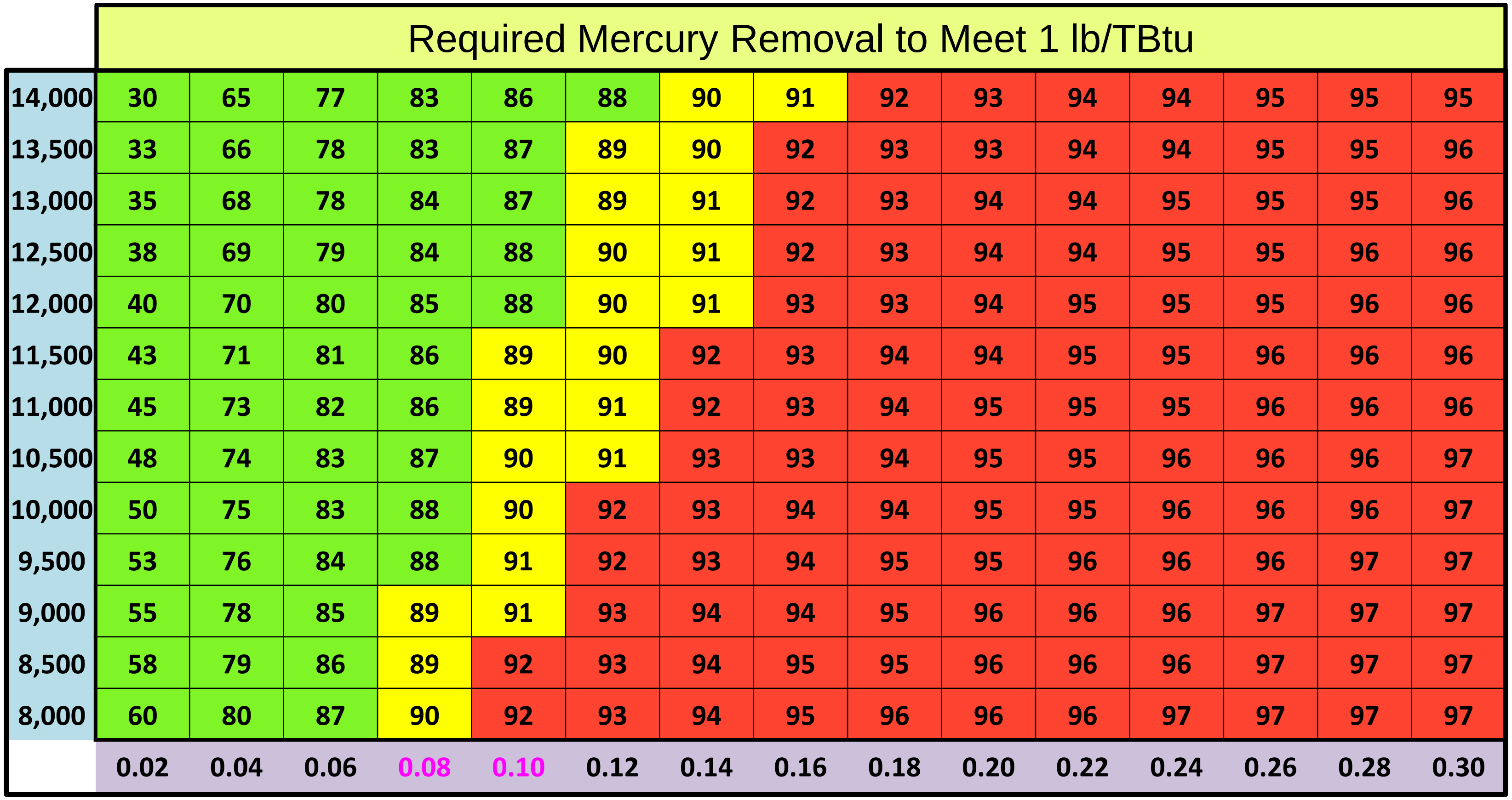
	Uncontrolled Hg^T Emissions (lb/TBtu)														
14,000	1.4	2.9	4.3	5.7	7.1	8.6	10.0	11.4	12.9	14.3	15.7	17.1	18.6	20.0	21.4
13,500	1.5	3.0	4.4	5.9	7.4	8.9	10.4	11.9	13.3	14.8	16.3	17.8	19.3	20.7	22.2
13,000	1.5	3.1	4.6	6.2	7.7	9.2	10.8	12.3	13.8	15.4	16.9	18.5	20.0	21.5	23.1
12,500	1.6	3.2	4.8	6.4	8.0	9.6	11.2	12.8	14.4	16.0	17.6	19.2	20.8	22.4	24.0
12,000	1.7	3.3	5.0	6.7	8.3	10.0	11.7	13.3	15.0	16.7	18.3	20.0	21.7	23.3	25.0
11,500	1.7	3.5	5.2	7.0	8.7	10.4	12.2	13.9	15.7	17.4	19.1	20.9	22.6	24.3	26.1
11,000	1.8	3.6	5.5	7.3	9.1	10.9	12.7	14.5	16.4	18.2	20.0	21.8	23.6	25.5	27.3
10,500	1.9	3.8	5.7	7.6	9.5	11.4	13.3	15.2	17.1	19.0	21.0	22.9	24.8	26.7	28.6
10,000	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0	22.0	24.0	26.0	28.0	30.0
9,500	2.1	4.2	6.3	8.4	10.5	12.6	14.7	16.8	18.9	21.1	23.2	25.3	27.4	29.5	31.6
9,000	2.2	4.4	6.7	8.9	11.1	13.3	15.6	17.8	20.0	22.2	24.4	26.7	28.9	31.1	33.3
8,500	2.4	4.7	7.1	9.4	11.8	14.1	16.5	18.8	21.2	23.5	25.9	28.2	30.6	32.9	35.3
8,000	2.5	5.0	7.5	10.0	12.5	15.0	17.5	20.0	22.5	25.0	27.5	30.0	32.5	35.0	37.5
	0.02	0.04	0.06	0.08	0.10	0.12	0.14	0.16	0.18	0.20	0.22	0.24	0.26	0.28	0.30

Coal Mercury Content (ppmw, dry)

Required Mercury Removal (%)

to meet 1 lb/TBtu - based on coal Btu and Hg content

Mercury conversion: 0.10 ppmw Hg in coal ≈ 12 µg/m^3 flue gas (dry, 32º F, 3% O_2)



Required Mercury Removal to Meet 1 lb/TBtu

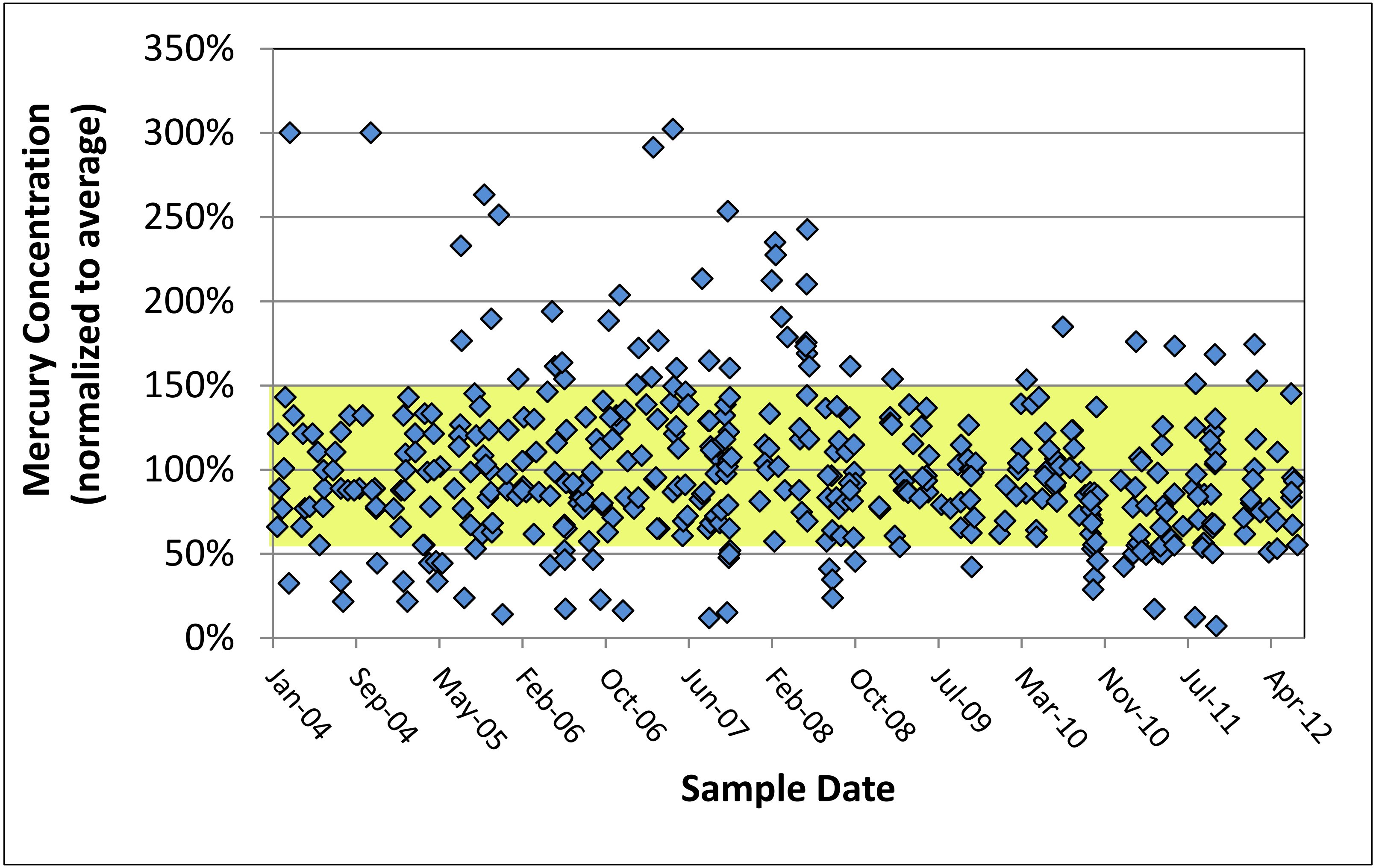
Coal Btu/lb (dry basis)	0.02	0.04	0.06	0.08	0.10	0.12	0.14	0.16	0.18	0.20	0.22	0.24	0.26	0.28	0.30
14,000	30	65	77	83	86	88	90	91	92	93	94	94	95	95	95
13,500	33	66	78	83	87	89	90	92	93	93	94	94	95	95	96
13,000	35	68	78	84	87	89	91	92	93	94	94	95	95	95	96
12,500	38	69	79	84	88	90	91	92	93	94	94	95	95	96	96
12,000	40	70	80	85	88	90	91	93	93	94	95	95	95	96	96
11,500	43	71	81	86	89	90	92	93	94	94	95	95	96	96	96
11,000	45	73	82	86	89	91	92	93	94	95	95	95	96	96	96
10,500	48	74	83	87	90	91	93	93	94	95	95	96	96	96	97
10,000	50	75	83	88	90	92	93	94	94	95	95	96	96	96	97
9,500	53	76	84	88	91	92	93	94	95	95	96	96	96	97	97
9,000	55	78	85	89	91	93	94	94	95	96	96	96	97	97	97
8,500	58	79	86	89	92	93	94	95	95	96	96	96	97	97	97
8,000	60	80	87	90	92	93	94	95	96	96	96	97	97	97	97

Coal Mercury Content (ppmw, dry)

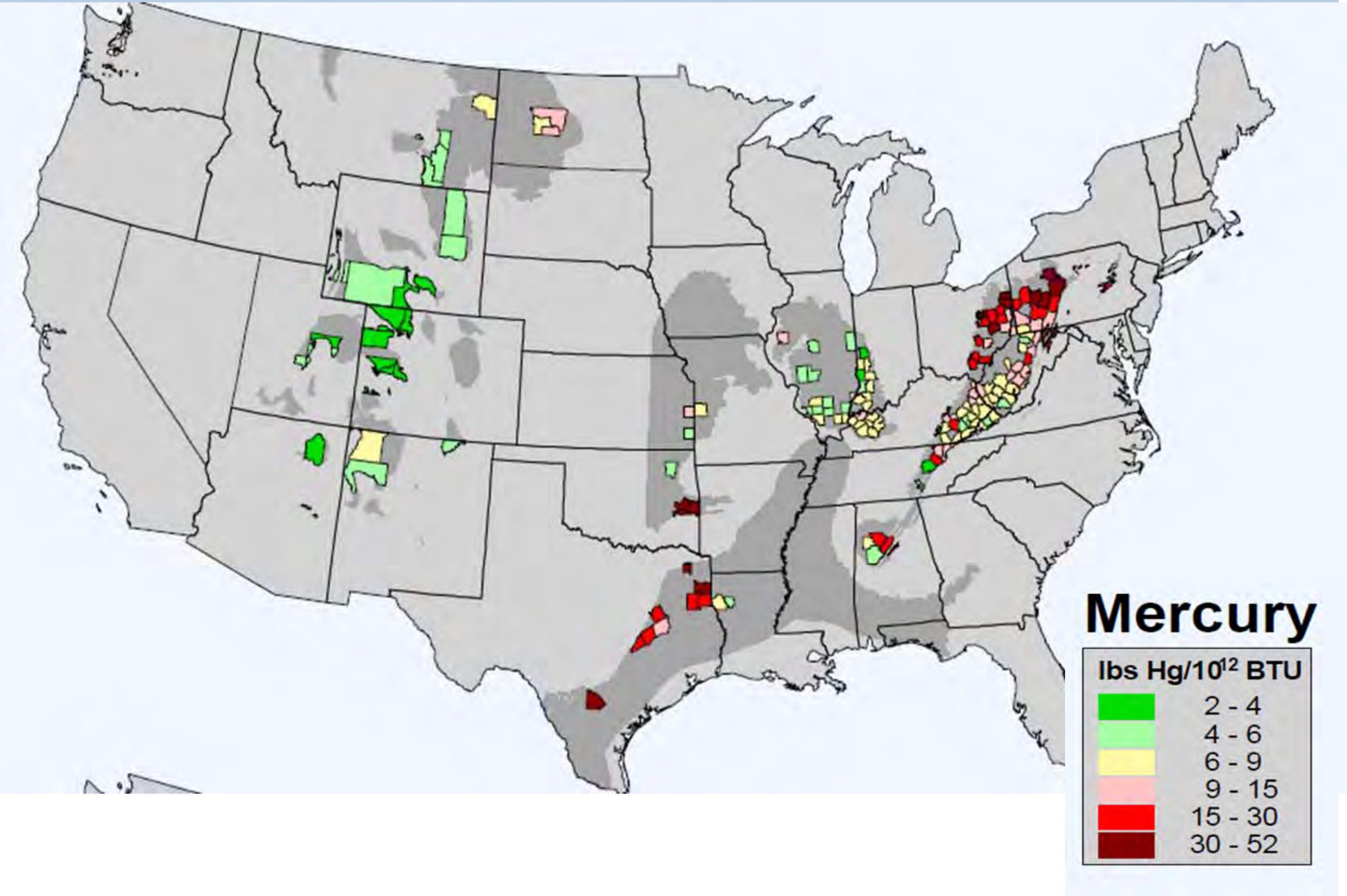
Example Coal Mercury Variability

large eastern bituminous plant

80% of data in 50% to 150% of average range

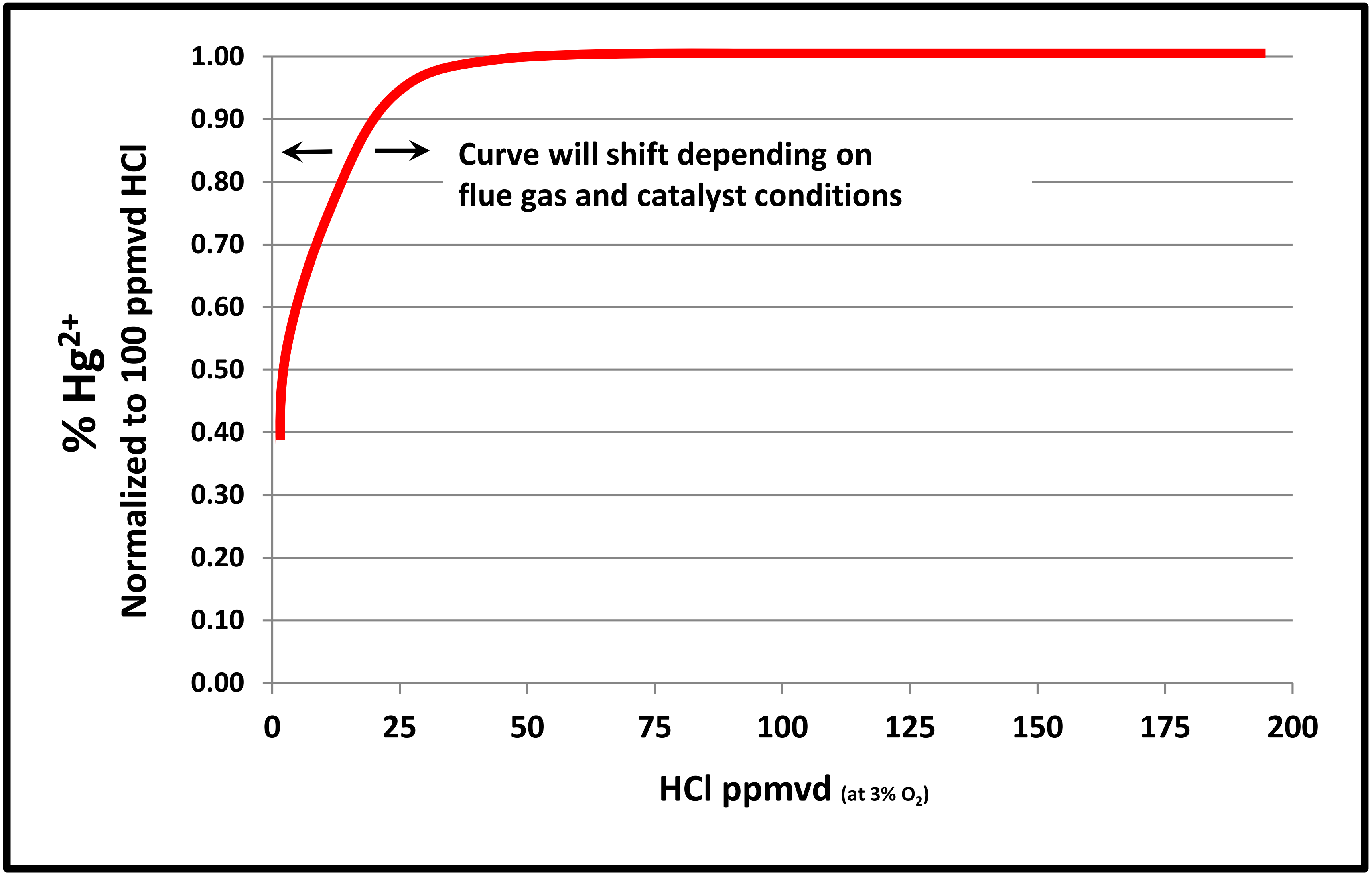


Fuel Composition – Distribution of Mercury



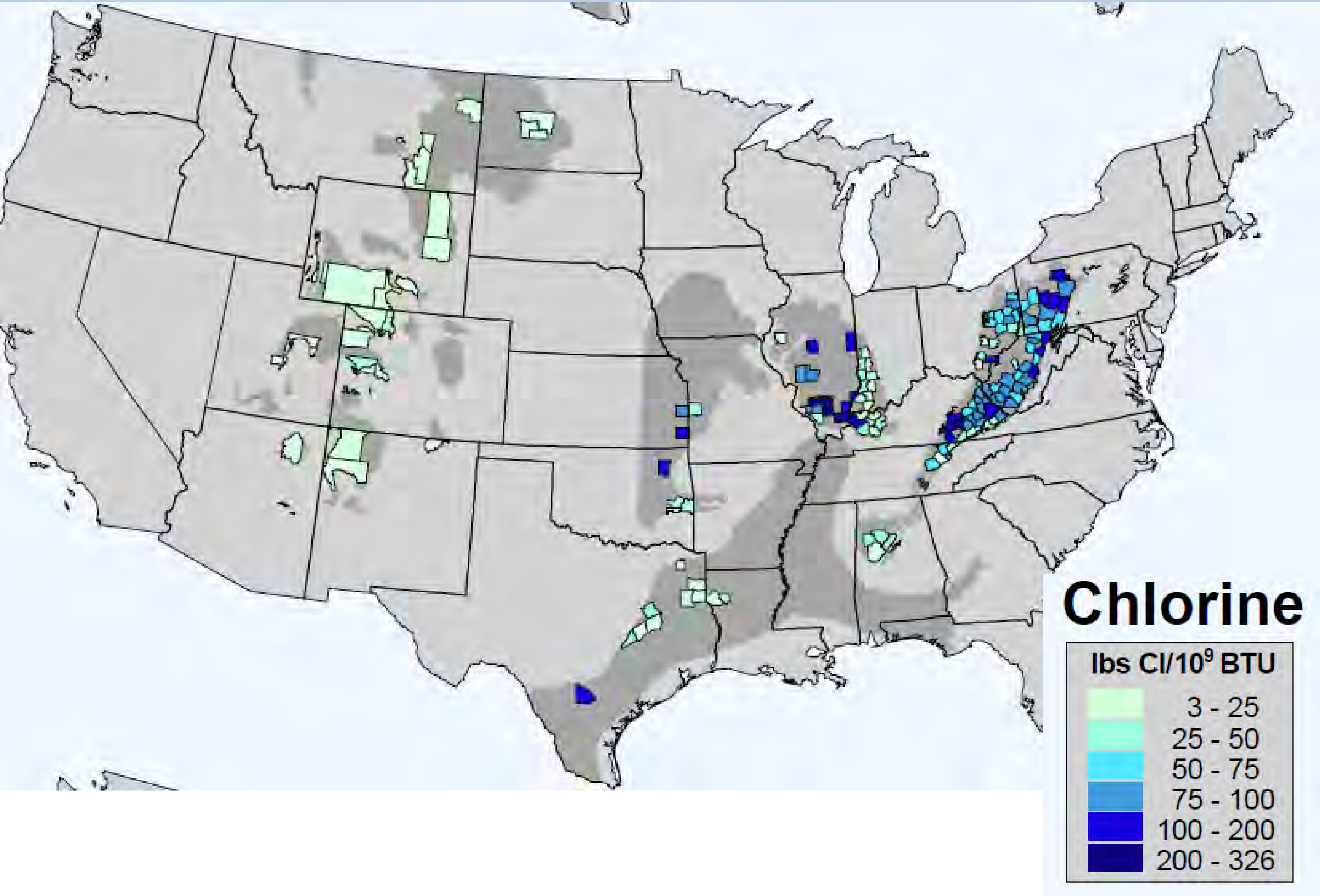
Conceptual Chlorine Effect Across SCR Catalyst

(1,000 ppmw on coal ≈ 70 ppmv in flue gas)



Curve will shift depending on flue gas and catalyst conditions

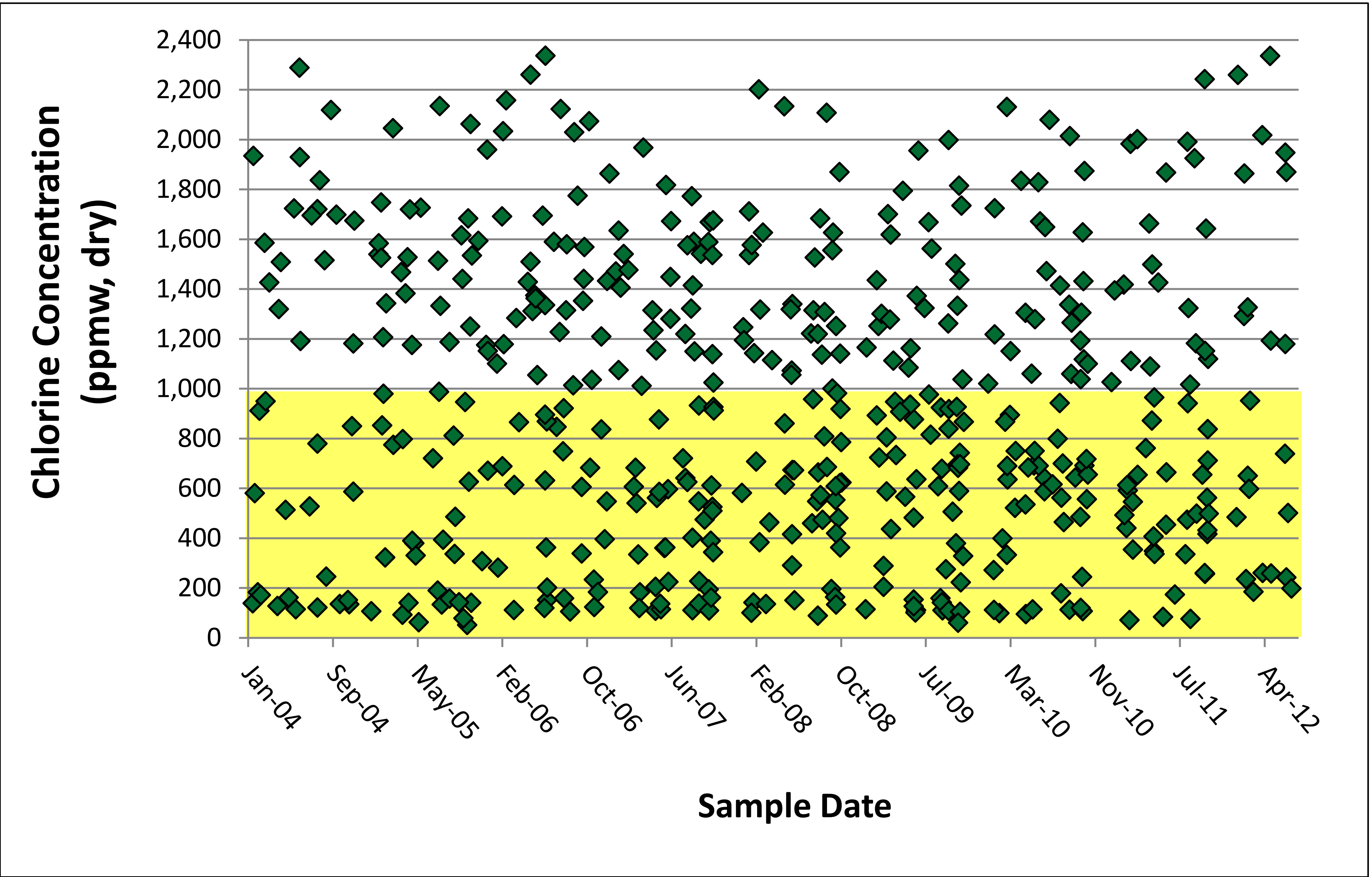
Fuel Composition – Distribution of Chlorine



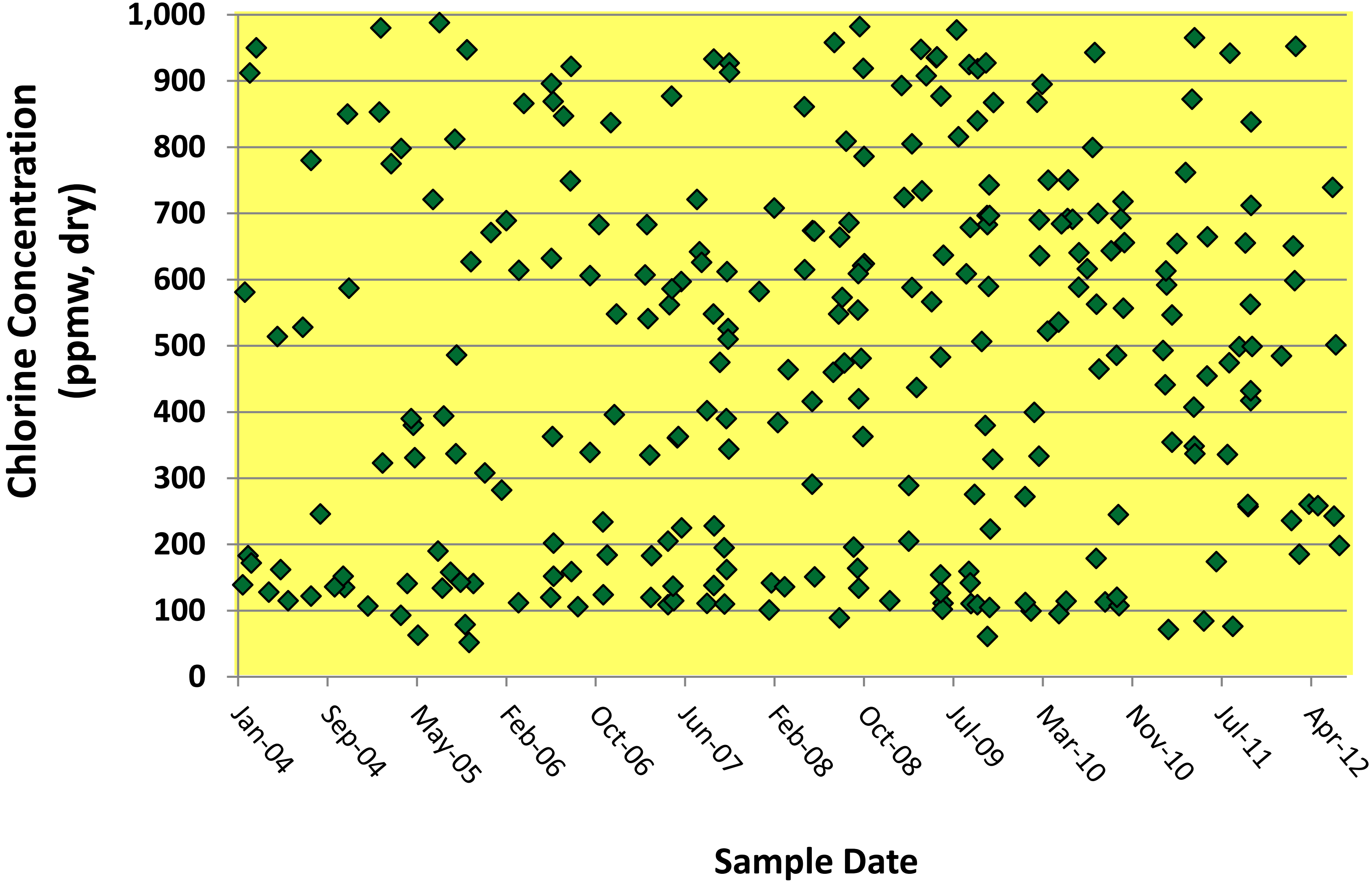
Example Chlorine Variability

large eastern bituminous plant

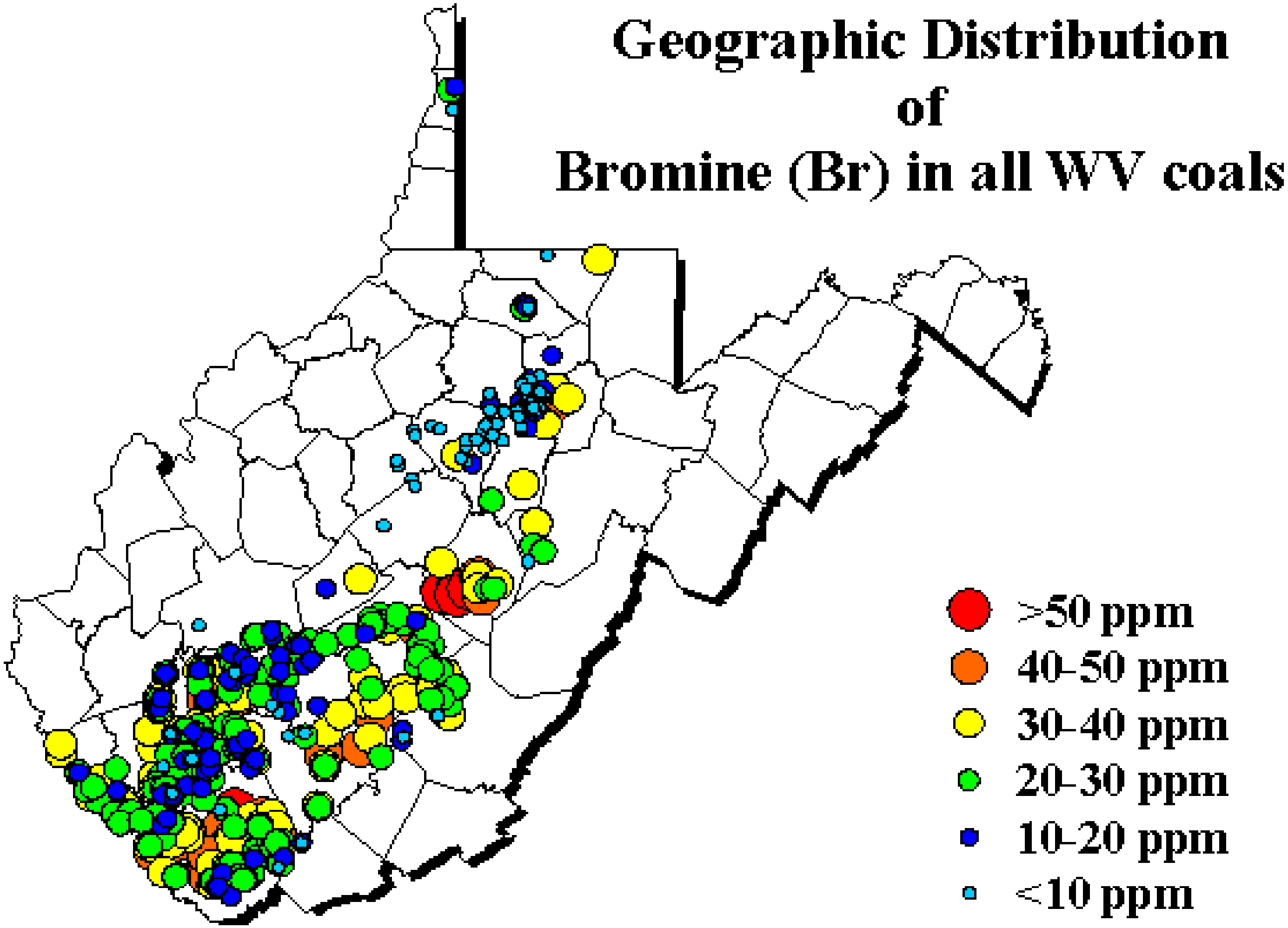
(1,000 ppmw on coal ≈ 70 ppmv in flue gas)



Example Chlorine Variability
large eastern bituminous plant
(highlight of coals below 1,000 ppmw Cl)

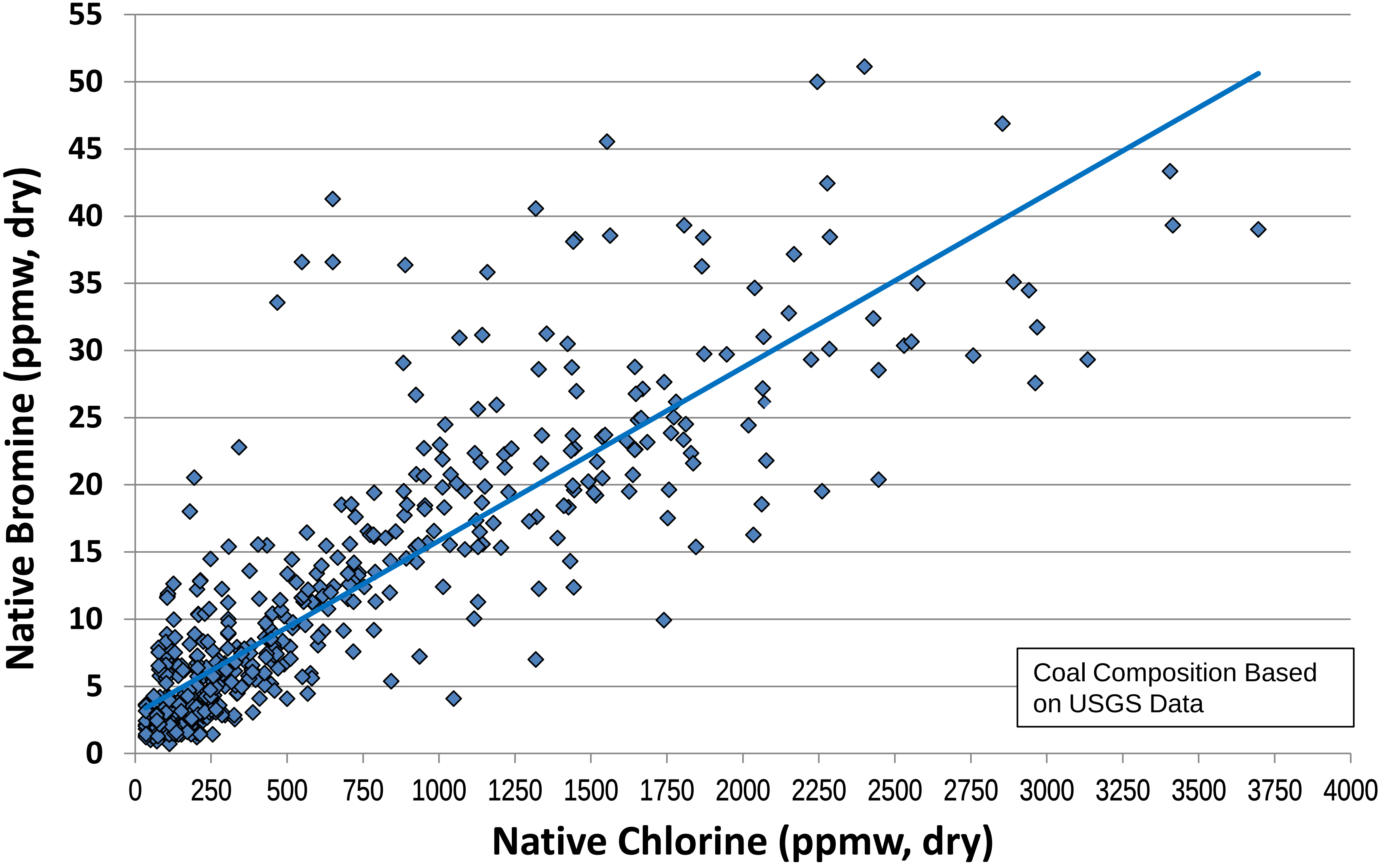


Fuel Composition – Distribution of Bromine



Bromine and Chlorine Inter-Relationship

Coals low in Chlorine will also generally be low in Bromine



Primary Coal Types for Mercury Considerations

1. **Eastern Bituminous (mid to high chlorine)**
2. **Southern Appalachian (low chlorine)**
3. **South American (very low chlorine)**
4. **Powder River Basin (very low chlorine)**

Comparative Representative Coal Analyses

Ultimate Properties

Ultimate Properties	High Chlorine Eastern Bituminous	Low Chlorine Southern Appalachian & S.A.	Power River Basin
Total Moisture (%)	6.54	6.95	27.03
Ash Dry (%)	11.48	13.67	6.88
HOC Dry (Btu/lb)	13,009	13,019	12,040
Total Sulfur Dry (%)	1.17	1.39	0.37
Carbon Dry (%)	73.78	73.67	70.37
Hydrogen Dry (%)	4.79	4.52	4.67
Nitrogen Dry (%)	1.50	1.56	1.00
Oxygen Dry (%)	6.26	5.19	16.71
Volatiles Dry (%)	34.06	29.88	42.92
Fixed Carbon Dry (%)	53.43	56.57	50.20
Ash Fusion IT (%)	2,530	2,396	2,143
Ash Fusion ST (%)	2,612	2,530	2,171
Ash Fusion HT (%)	2,654	2,397	2,186
Ash Fusion FT (%)	2,709	2,741	2,254
Grindability Index (HGI)	43.66	59.81	49.82

Comparative Representative Coal Analyses
Ash Mineral Properties

Ash Mineral (%)	High Chlorine Eastern Bituminous	Low Chlorine Southern Appalachian & S.A.	Power River Basin
Al2O3	26.64	27.03	16.46
Fe2O3	9.15	11.22	5.60
CaO	**1.64**	**1.47**	**20.47**
MgO	1.05	1.21	4.54
MnO2	5.15	3.11	0.03
P2O5	0.33	0.45	1.04
K2O	2.51	2.70	0.42
SiO2	52.57	52.36	34.37
Na2O	0.42	0.39	1.42
SO3	1.29	1.48	12.62
TiO2	1.41	1.35	1.16

Comparative Representative Coal Analyses
Trace Element Properties

Trace Element (ppm, dry, whole coal)	High Chlorine Eastern Bituminous	Low Chlorine Southern Appalachian & S.A.	Power River Basin
As	11.67	37.55	0.70
Ba	150.81	305.78	345.24
B	2.40	1.92	0.31
B	0	0	0
Cd	0.080	0.100	0.056
Cl	1,000-3,500	50-350	~50
Co	8.18	10.26	2.73
Cr	16.73	20.97	3.90
Cu	21.12	25.76	11.92
F	97.93	91.87	58.00
Hg	0.084	0.171	0.081
Li	0	0	0
Mg	0.073	0.101	0.191
Mn	29.56	34.93	12.10
Mo	0	0	0
Na	0.032	0.037	0.074
Ni	14.07	17.56	3.90
Pb	8.17	8.40	2.70
Sb	1.15	2.40	0.05
Se	3.25	1.97	0.66
Sr	0.0049	0.0116	0.0075
V	35.64	46.87	14.83
Zn	17.31	19.14	10.60

Fuel Effects on Mercury Speciation in the Boiler, Convective Pass, and Economizer

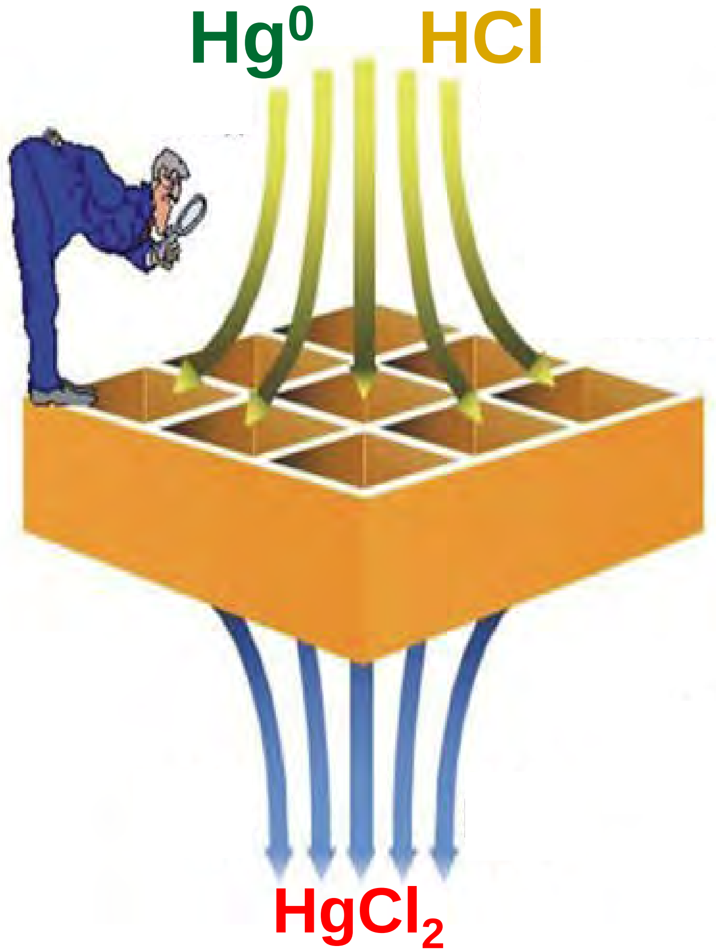
Location	High Chlorine EB	Low Chlorine EB & South American	PRB
Boiler	Complete conversion to elemental mercury	Complete conversion to elemental mercury	Complete conversion to elemental mercury
Convective Pass	Little driving force for mercury oxidation	Little driving force for mercury oxidation	Little driving force for mercury oxidation
Economizer to SCR	Some mercury oxidation (20-40%)	Possible mercury oxidation, but limited (10-20 %)	Very little mercury oxidation (<10%)

Fuel Effects on SCR Mercury Oxidation

Location	High Chlorine EB	Low Chlorine EB & South American	PRB
SCR	Strong potential for mercury oxidation, SCR less sensitive to catalyst, ammonia, temperature, etc. (Hg^{2+} = 80%+)	Moderate potential for oxidation, usually highly sensitive to operating parameters, especially actual halogen levels, ammonia, NOx, temperature, etc. (Hg^{2+} = 40-80%)	Mercury oxidation severely limited by low halogens, alkali nature of ash seems to further suppress Hg-halogen reactions, advanced catalyst may help, and halogen supplementation will have dramatic effect ($Hg^{2+} < 40\%$)

SCR Mercury Oxidation

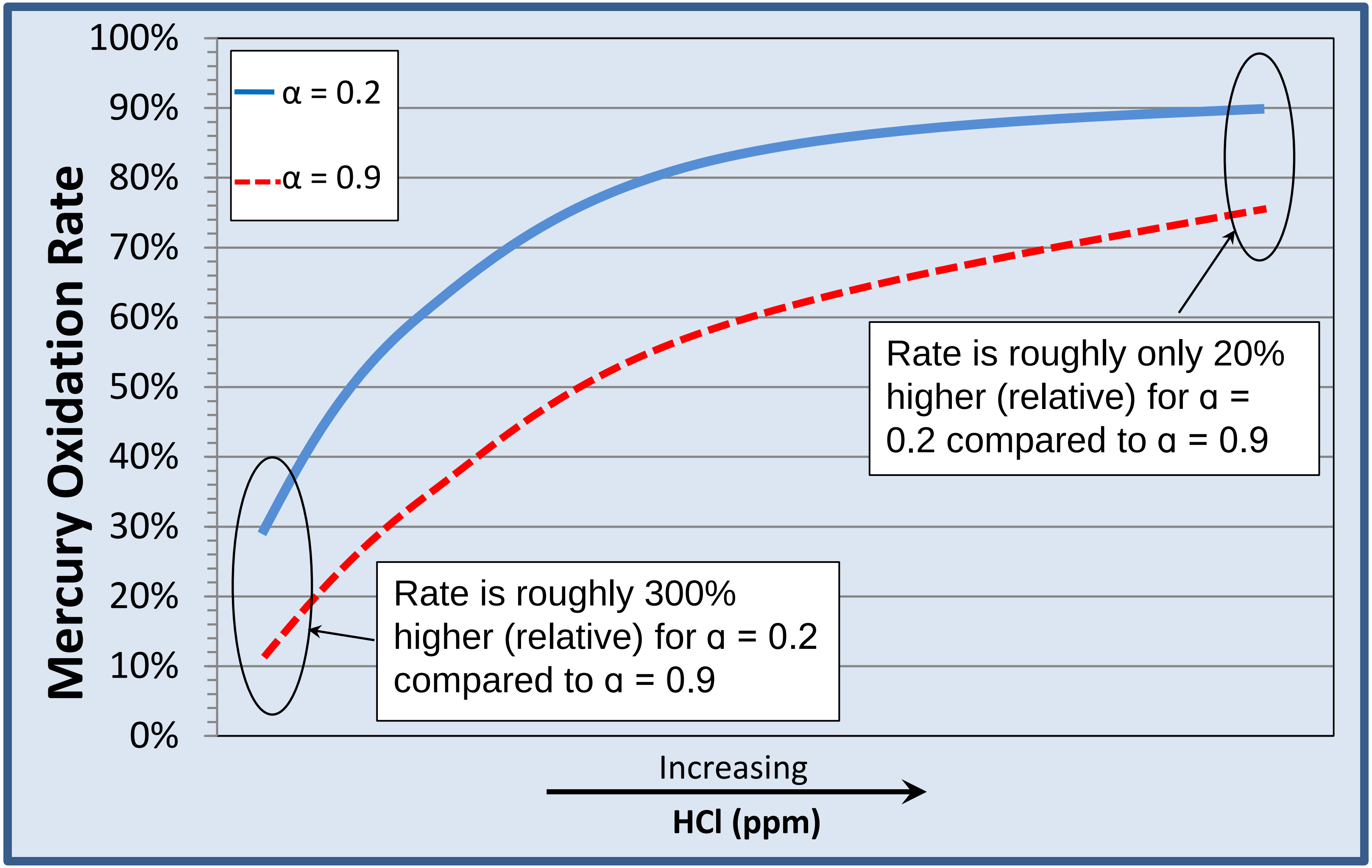
1. Operating Conditions
2. Catalyst Design
3. Aging
4. Catalyst
   Management
5. Modeling Efforts



SCR Operating Parameter Effects on Mercury Oxidation

Parameter (increasing)	Qualitative Effect	Notes
Temperature	**Negative**	Higher temperatures lead to reduced mercury oxidation, opposite of the effect on deNOx.
Flow Rate	**Negative**	Higher flow rates lead to reduced residence time and higher mass throughput, leading to lower mercury oxidation, similar to deNOx. Flow rate usually associated with load, which has multiple effects.
Ammonia	**Negative**	Ammonia inhibits mercury oxidation, but this is strongly a function of other operating conditions.
Chlorine/ Bromine	**Positive**	Quantitative effect is variable – with certain ranges, effect can be very strong, while with other ranges, effect is limited.
CO, SO_2, H_2O	**Negative**	Quantitative effect dependent on other operating parameters.
O_2	**Positive**	Quantitative effect dependent on other operating parameters.
Load	**Negative**	Complex effect: load change leads to possible changes in flow rate, temperature, O_2, CO, ammonia.

Example: Relative Effect of Chlorine as a Function of Ammonia

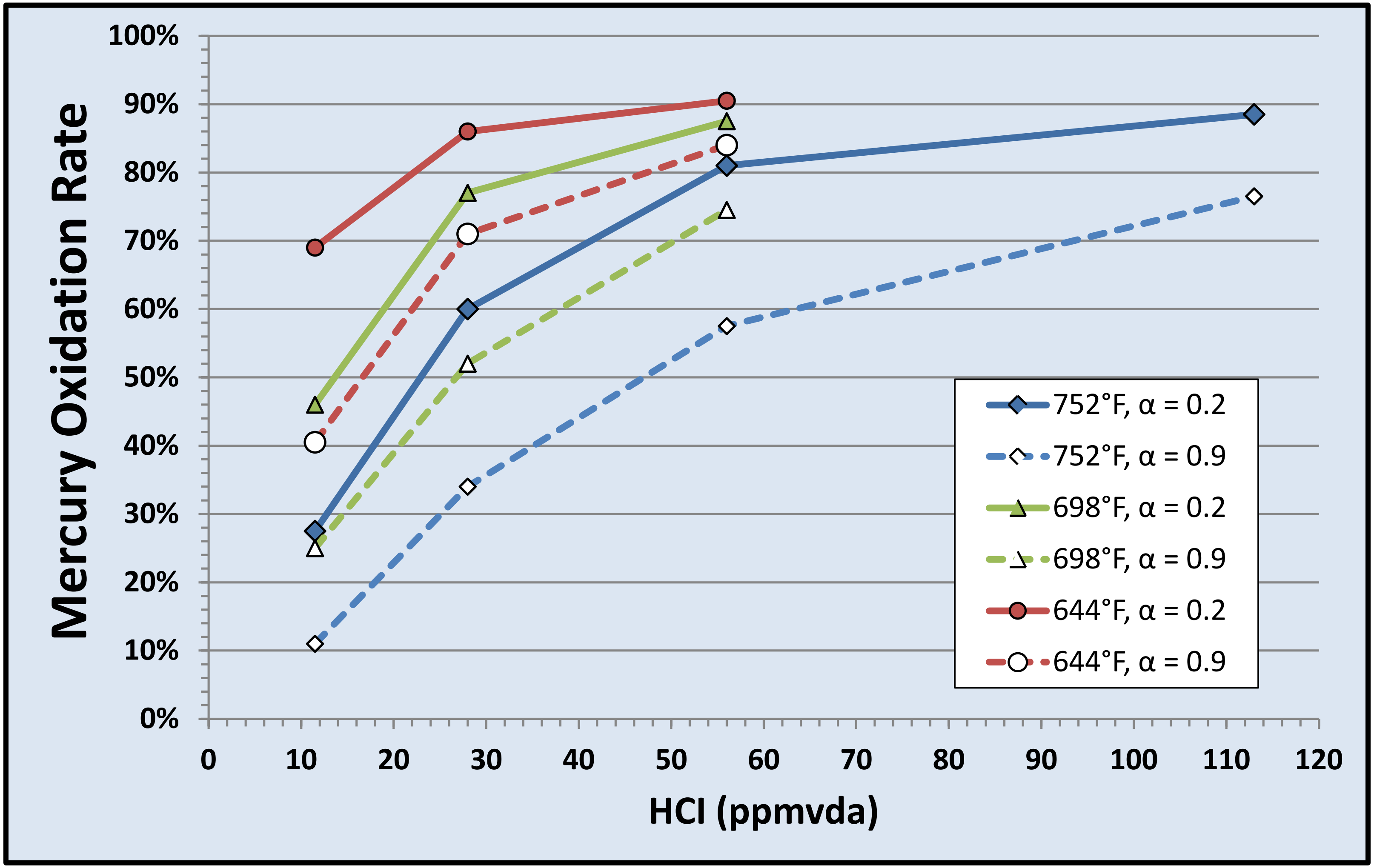


Rate is roughly only 20% higher (relative) for α = 0.2 compared to α = 0.9

Rate is roughly 300% higher (relative) for α = 0.2 compared to α = 0.9

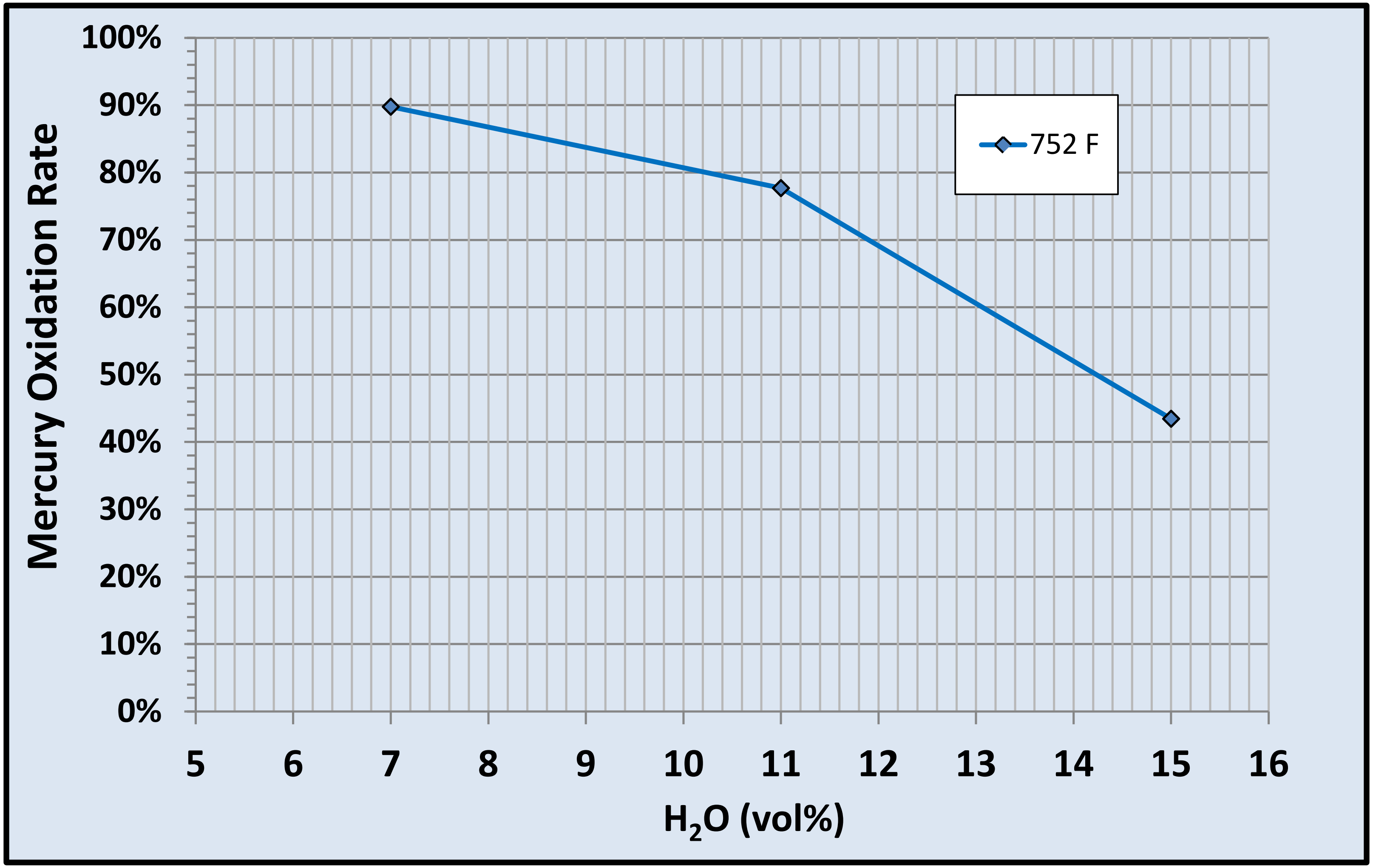
Data Courtesy Cormetech, Inc.

Example: Relative Effect of Chlorine as a Function of Temperature and Ammonia



Data Courtesy Cormetech, Inc.

Example: Relative Effect of H_2O dependent on Temp., NH_3, HCl, O_2, etc., etc…



Data Courtesy Cormetech, Inc.

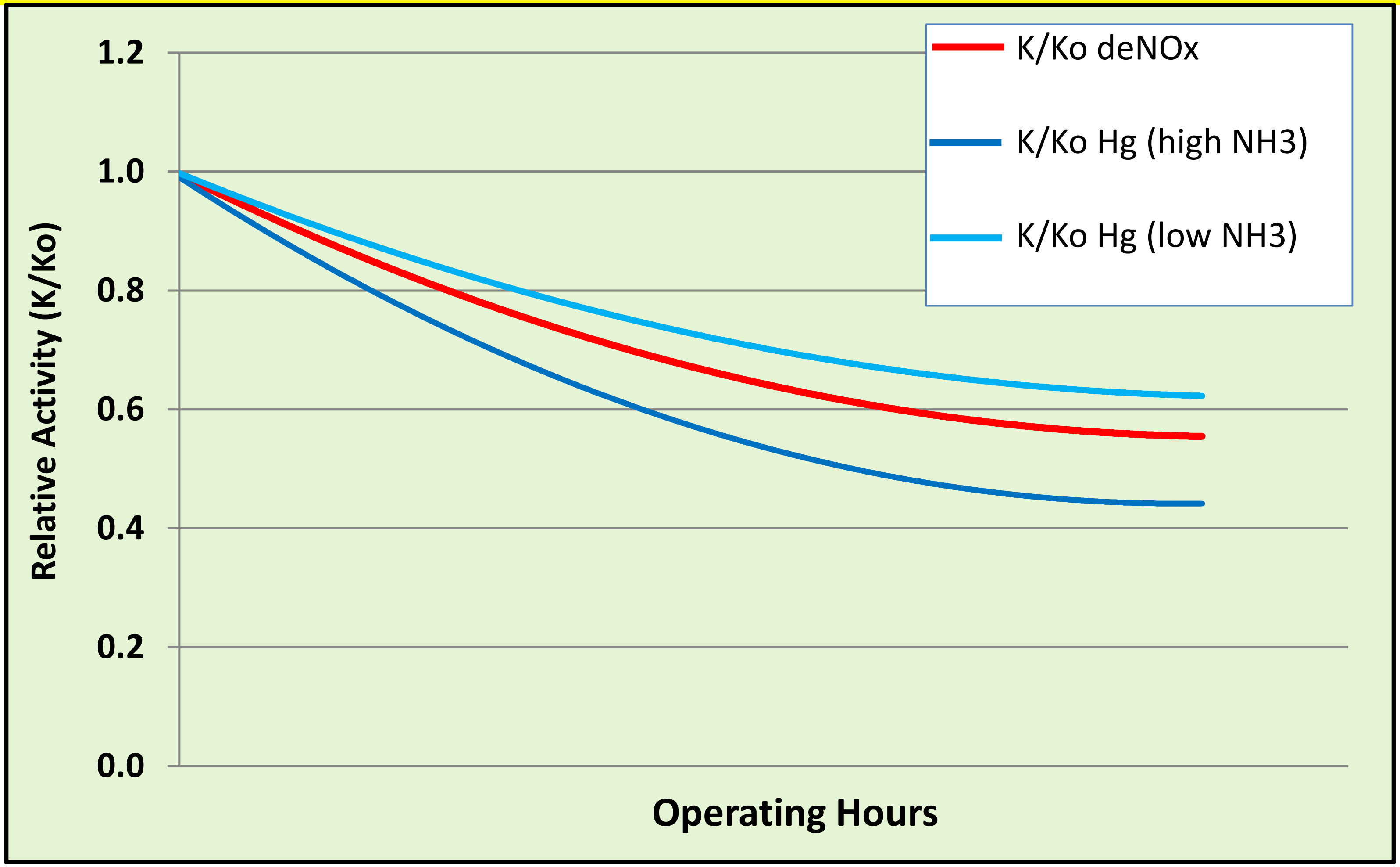
Catalyst Design

- **Mercury oxidation capability inter-related with deNOx activity and SO_2 conversion.**
- **All other factors being equal, more deNOx potential results in more mercury oxidation potential. But, relative improvement in mercury oxidation rate is strongly a function of absolute levels of oxidized mercury.**
- **Advanced catalysts seek to independently improve mercury oxidation, especially at low halogen levels.**
- **Predicting mercury oxidation for a given catalyst, even if formulation details are known, is difficult without benchmark data.**

Catalyst Aging

Apparent deactivation rate for mercury oxidation depends on operation conditions!

Example: Deactivation curve for mercury as a function of ammonia. Effect will change as function of other operating conditions such as halogens, etc.



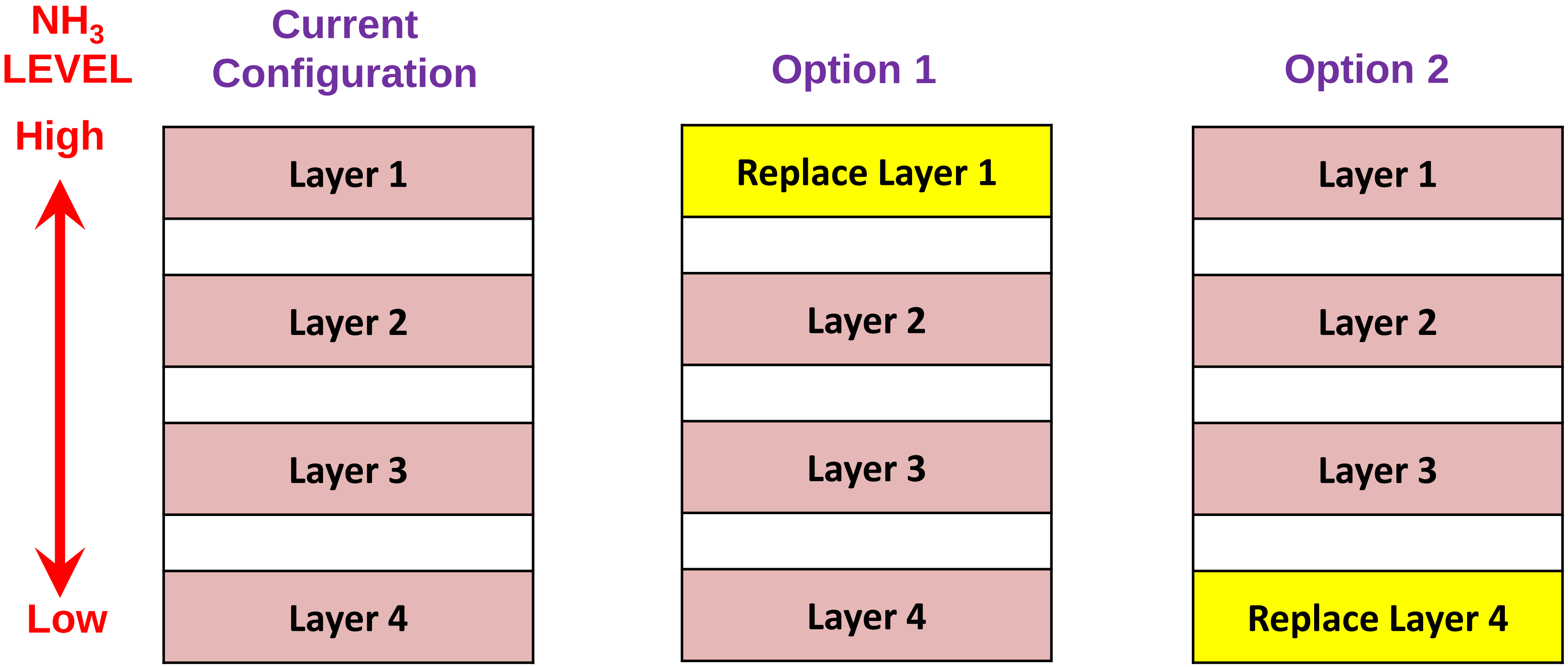
Catalyst Management

(predicting management effects on mercury oxidation much more complicated than for deNOx)

- Absolute deactivation rate (w/o the ammonia effect) affected by fuel and layer location, similar to deactivation for deNOx.
- Apparent deactivation rate affected by many operational parameters, especially ammonia (see catalyst aging) – these effects are in turn affected by other operational parameters.
- Due to the ammonia effect, a change in one layer affects the mercury oxidation activity of all subsequent layers – relative placement of a layer changes the outcome, i.e. the potentials for each layer are dependent on their specific operating conditions, simply summing of absolute potential does not work unless potential for each layer is calculated for its specific operating conditions.
- Robust model needed to accurately predict the effects of catalyst management activities.

Example Management Scenarios

(predicting management effects on mercury oxidation is much more complicated than for deNOx)



NH_3 LEVEL

High

Low

Current Configuration

Layer 1

Layer 2

Layer 3

Layer 4

Current status: all layers have same remaining activity, time to replace one layer, which one?

Option 1

Replace Layer 1

Layer 2

Layer 3

Layer 4

New catalyst placed in position of inhibited Hg oxidation, but all lower layers benefit from lower NH_3.

Option 2

Layer 1

Layer 2

Layer 3

Replace Layer 4

New catalyst placed in position of high Hg oxidation, but upper layers do not benefit from lower NH_3.

Practical Considerations for Catalyst Management

- Must address the long-term mercury oxidation rate for a particular scenario, not just the initial rate.
- Must consider the difference in rate as a function of absolute deactivation due to layer position (i.e. in eastern bituminous units the upper layer will deactivate faster).
- Apparent deactivation rate a function of the above plus the ammonia conditions of the particular layer, which may change as a function of other operating conditions.
- “Pinch-points” for mercury oxidation may differ from pinch-points for deNOx due to differences in rates of deactivation for deNOx and mercury.
- Advanced catalysts may not follow same trends as conventional catalysts.
- Generally, when using conventional catalysts, replacing the layer with the highest amount of deactivation for deNOx is also the best choice when mercury oxidation is considered, assuming that the replacement catalyst is similar in performance to the original.

EPRI Mercury Oxidation Modeling

(robust models required to assess all of the complicated effects due to the inter-relationship of parameters)

1. Predict the effect of a change in operational conditions
2. Predict the effect of routine long-term aging
3. Predict the effect of various management scenarios

EPRI Model for Operational Changes (Input)

MERCURY OXIDATION BENCHMARK DATAPOINT

COAL DATA		
Parameter	**Value**	**Units**
Coal Chlorine	150	ppmw (dry basis)
Coal Sulfur	0.70%	% (dry basis)
Coal Ash Content	10.00%	% (dry basis)

UNIT OPERATIONAL DATA		
Parameter	**Value**	**Units**
Full Load Capacity	500	MW
Actual Load	500	MW
Flue Gas Moisture	9.0%	%
Flue Gas CO Concentration	50	ppmvd

SCR OPERATIONAL DATA		
Parameter	**Value**	**Units**
Temperature	700	^{o}F
Average O_2	3.0%	%, dry
DeNOx Setpoint	90.0%	%, (dry basis)
Inlet NOx	375	ppmvd at 3% O_2
Ammonia Slip (approx.)	2	ppmvd at 3% O_2

FULL LOAD CATALYST DENOX POTENTIAL	
Layer	**DeNOx Potential**
1	0.80
2	0.80
3	0.80
4	0.80

MERCURY DATA		
Parameter	**Value**	**Units**
SCR Inlet % Oxidized Mercury	10.0%	%
SCR Outlet % Oxidized Mercury	60.0%	%

NEW OPERATIONAL CONDITIONS FOR MERCURY OXIDATION PERFORMANCE PREDICTION

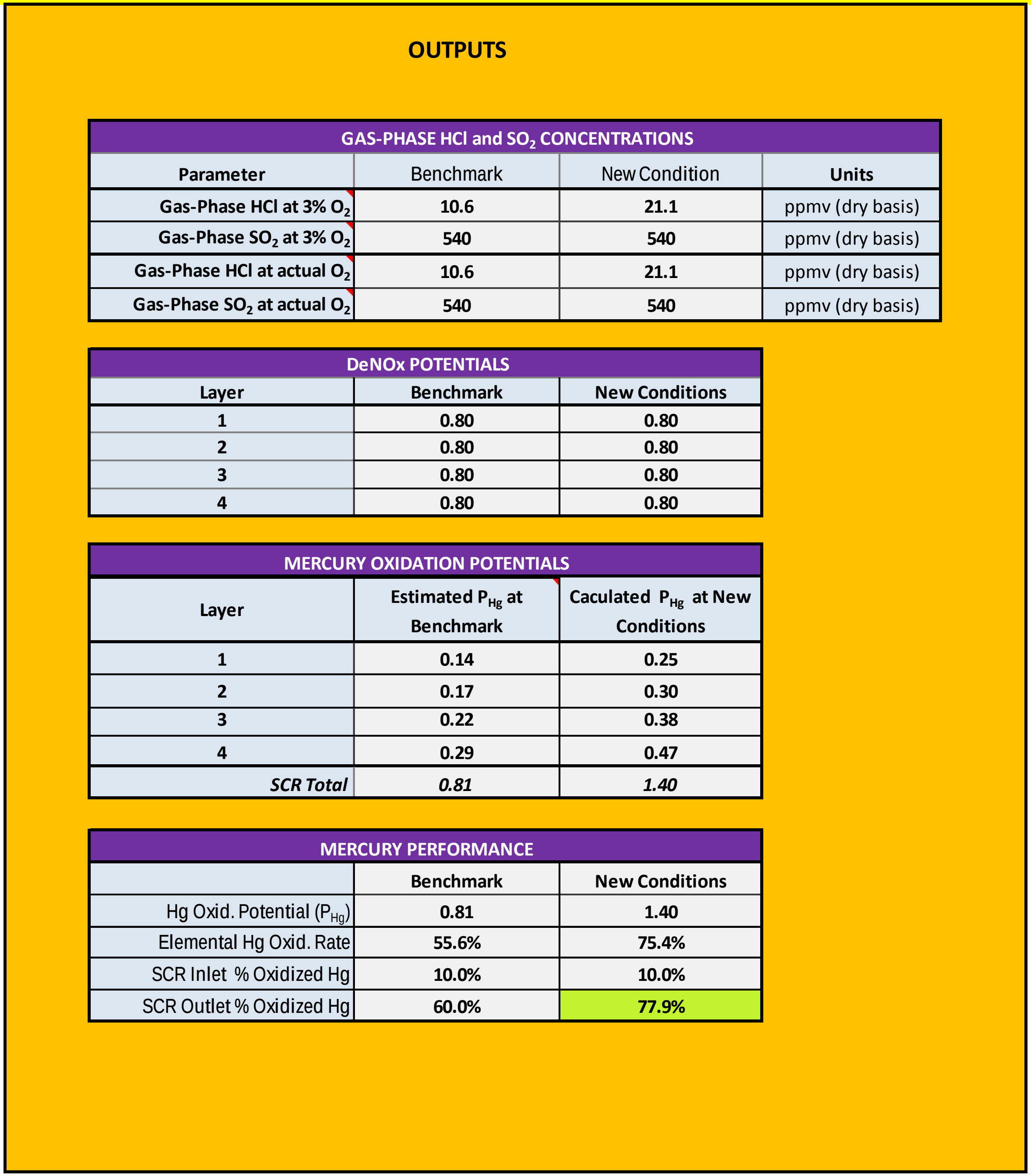
COAL DATA		
Parameter	**Value**	**Units**
Coal Chlorine	300	ppmw (dry basis)
Coal Sulfur	0.70%	% (dry basis)
Coal Ash Content	10.00%	% (dry basis)

UNIT OPERATIONAL DATA		
Parameter	**Value**	**Units**
Actual Load	500	MW
Flue Gas Moisture	9.0%	%
Flue Gas CO Concentration	50	ppmvd

SCR OPERATIONAL DATA		
Parameter	**Value**	**Units**
Temperature	700	^{o}F
Average O_2	3.0%	%, (dry basis)
DeNOx Setpoint	90.0%	%
Inlet NOx	375	ppmvd at 3% O_2
Ammonia Slip (approx.)	2	ppmvd at 3% O_2

Current model can address effect of: load, temperature, H_2O, CO, SO_2, HCl, NOx, %deNOx, slip

EPRI Model for Operational Changes (Output)



OUTPUTS

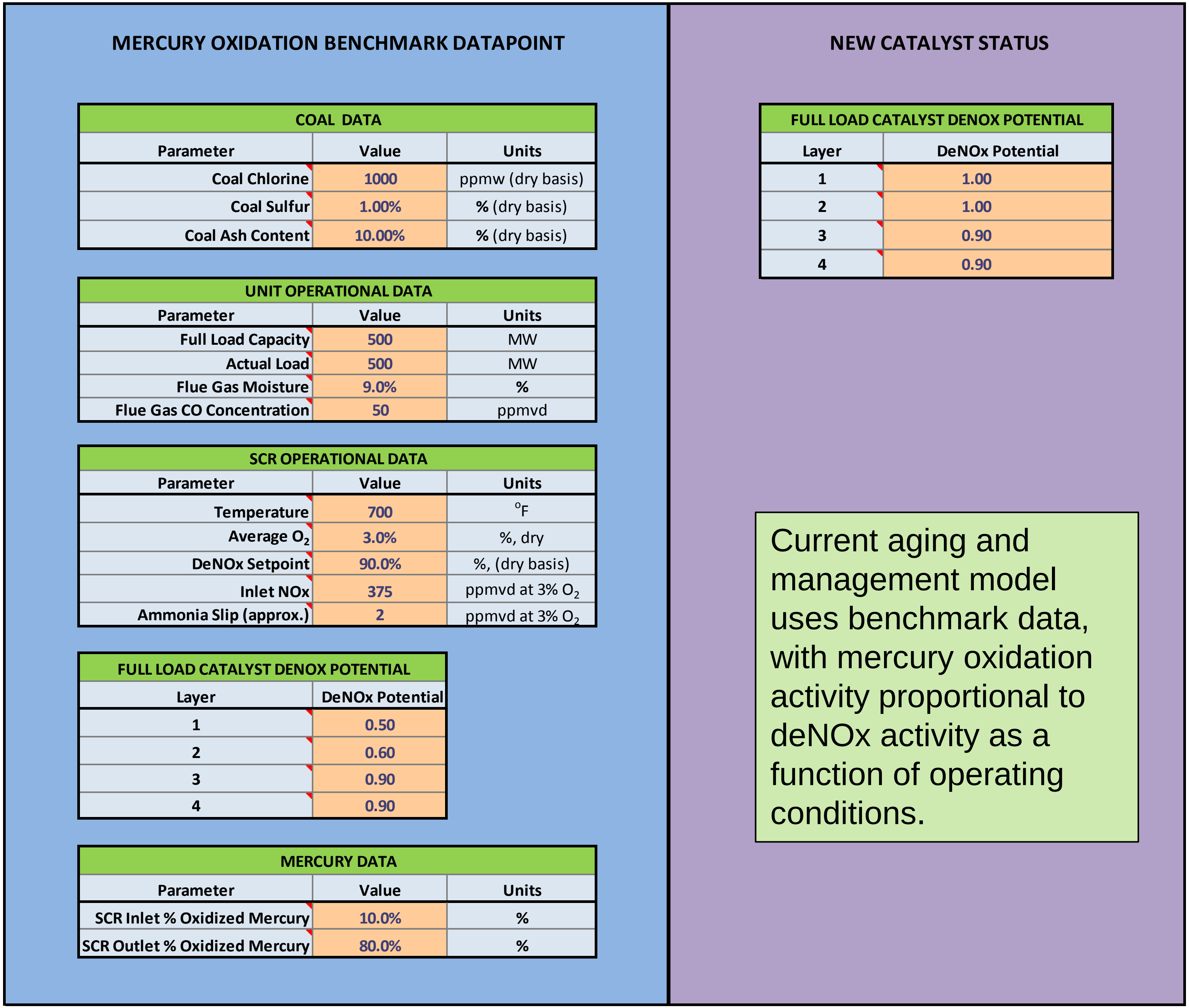
GAS-PHASE HCl and SO_2 CONCENTRATIONS			
Parameter	Benchmark	New Condition	**Units**
Gas-Phase HCl at 3% O_2	**10.6**	**21.1**	ppmv (dry basis)
Gas-Phase SO_2 at 3% O_2	**540**	**540**	ppmv (dry basis)
Gas-Phase HCl at actual O_2	**10.6**	**21.1**	ppmv (dry basis)
Gas-Phase SO_2 at actual O_2	**540**	**540**	ppmv (dry basis)

DeNOx POTENTIALS		
Layer	**Benchmark**	**New Conditions**
1	**0.80**	**0.80**
2	**0.80**	**0.80**
3	**0.80**	**0.80**
4	**0.80**	**0.80**

MERCURY OXIDATION POTENTIALS		
Layer	**Estimated P_{Hg} at Benchmark**	**Caculated P_{Hg} at New Conditions**
1	**0.14**	**0.25**
2	**0.17**	**0.30**
3	**0.22**	**0.38**
4	**0.29**	**0.47**
SCR Total	***0.81***	***1.40***

MERCURY PERFORMANCE		
	Benchmark	**New Conditions**
Hg Oxid. Potential (P_{Hg})	**0.81**	**1.40**
Elemental Hg Oxid. Rate	**55.6%**	**75.4%**
SCR Inlet % Oxidized Hg	**10.0%**	**10.0%**
SCR Outlet % Oxidized Hg	**60.0%**	**77.9%**

EPRI Model for Aging and Management (Input)



MERCURY OXIDATION BENCHMARK DATAPOINT

COAL DATA		
Parameter	Value	Units
Coal Chlorine	1000	ppmw (dry basis)
Coal Sulfur	1.00%	% (dry basis)
Coal Ash Content	10.00%	% (dry basis)

UNIT OPERATIONAL DATA		
Parameter	Value	Units
Full Load Capacity	500	MW
Actual Load	500	MW
Flue Gas Moisture	9.0%	%
Flue Gas CO Concentration	50	ppmvd

SCR OPERATIONAL DATA		
Parameter	Value	Units
Temperature	700	^{o}F
Average O_2	3.0%	%, dry
DeNOx Setpoint	90.0%	%, (dry basis)
Inlet NOx	375	ppmvd at 3% O_2
Ammonia Slip (approx.)	2	ppmvd at 3% O_2

FULL LOAD CATALYST DENOX POTENTIAL	
Layer	DeNOx Potential
1	0.50
2	0.60
3	0.90
4	0.90

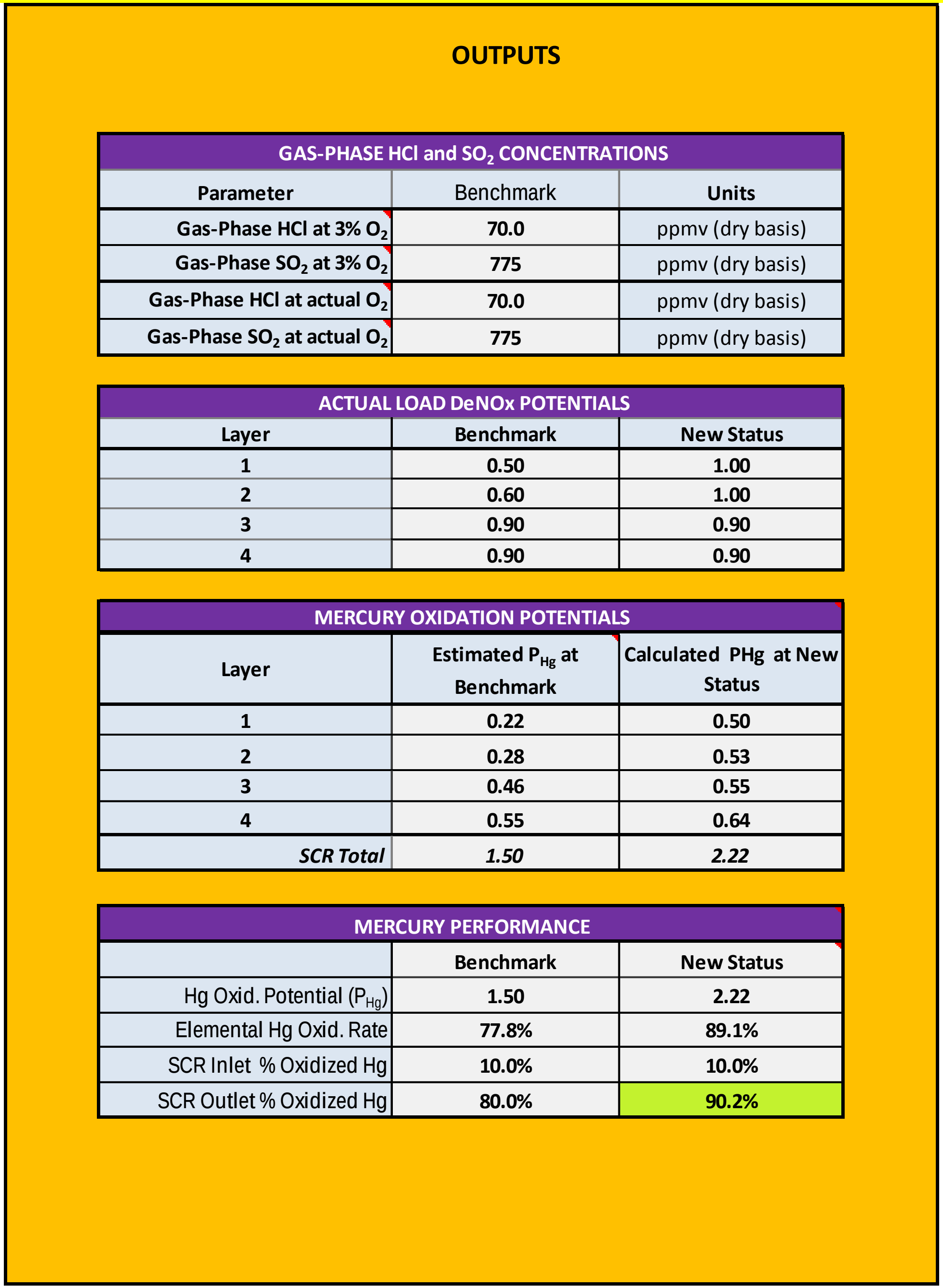
MERCURY DATA		
Parameter	Value	Units
SCR Inlet % Oxidized Mercury	10.0%	%
SCR Outlet % Oxidized Mercury	80.0%	%

NEW CATALYST STATUS

FULL LOAD CATALYST DENOX POTENTIAL	
Layer	DeNOx Potential
1	1.00
2	1.00
3	0.90
4	0.90

Current aging and management model uses benchmark data, with mercury oxidation activity proportional to deNOx activity as a function of operating conditions.

EPRI Model for Aging and Management (Output)



OUTPUTS

GAS-PHASE HCl and SO_2 CONCENTRATIONS		
Parameter	Benchmark	**Units**
Gas-Phase HCl at 3% O_2	**70.0**	ppmv (dry basis)
Gas-Phase SO_2 at 3% O_2	**775**	ppmv (dry basis)
Gas-Phase HCl at actual O_2	**70.0**	ppmv (dry basis)
Gas-Phase SO_2 at actual O_2	**775**	ppmv (dry basis)

ACTUAL LOAD DeNOx POTENTIALS		
Layer	**Benchmark**	**New Status**
1	**0.50**	**1.00**
2	**0.60**	**1.00**
3	**0.90**	**0.90**
4	**0.90**	**0.90**

MERCURY OXIDATION POTENTIALS		
Layer	**Estimated P_{Hg} at Benchmark**	**Calculated PHg at New Status**
1	**0.22**	**0.50**
2	**0.28**	**0.53**
3	**0.46**	**0.55**
4	**0.55**	**0.64**
SCR Total	***1.50***	***2.22***

MERCURY PERFORMANCE		
	Benchmark	**New Status**
Hg Oxid. Potential (P_{Hg})	**1.50**	**2.22**
Elemental Hg Oxid. Rate	**77.8%**	**89.1%**
SCR Inlet % Oxidized Hg	**10.0%**	**10.0%**
SCR Outlet % Oxidized Hg	**80.0%**	**90.2%**

Mercury Measurement around the SCR

Important Considerations

1. Attempt to preserve the speciation as is present in-situ – speciation is a moving target!
2. Avoid ash cakes which may adsorb mercury, or change speciation.
3. Minimize residence time that will skew speciation (function of temperature and flue gas composition).
4. Accurately distinguish between elemental Hg and oxidized Hg.

Measurement Options

1. **Speciated Traps**
   (similar to Method 30B, with air cooling)
2. **Semi-Continuous Systems**
   (wet impinger system, typically with inertial separation probe)
3. **Continuous Systems**
   (dry CEMS-type system, typically with inertial separation probe)

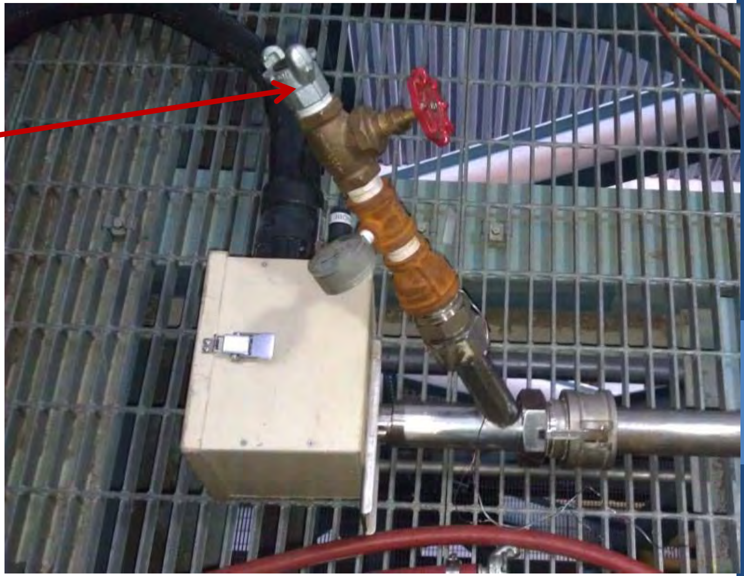
Speciated Traps (air cooled)

Air-cooled, dual-trap probe

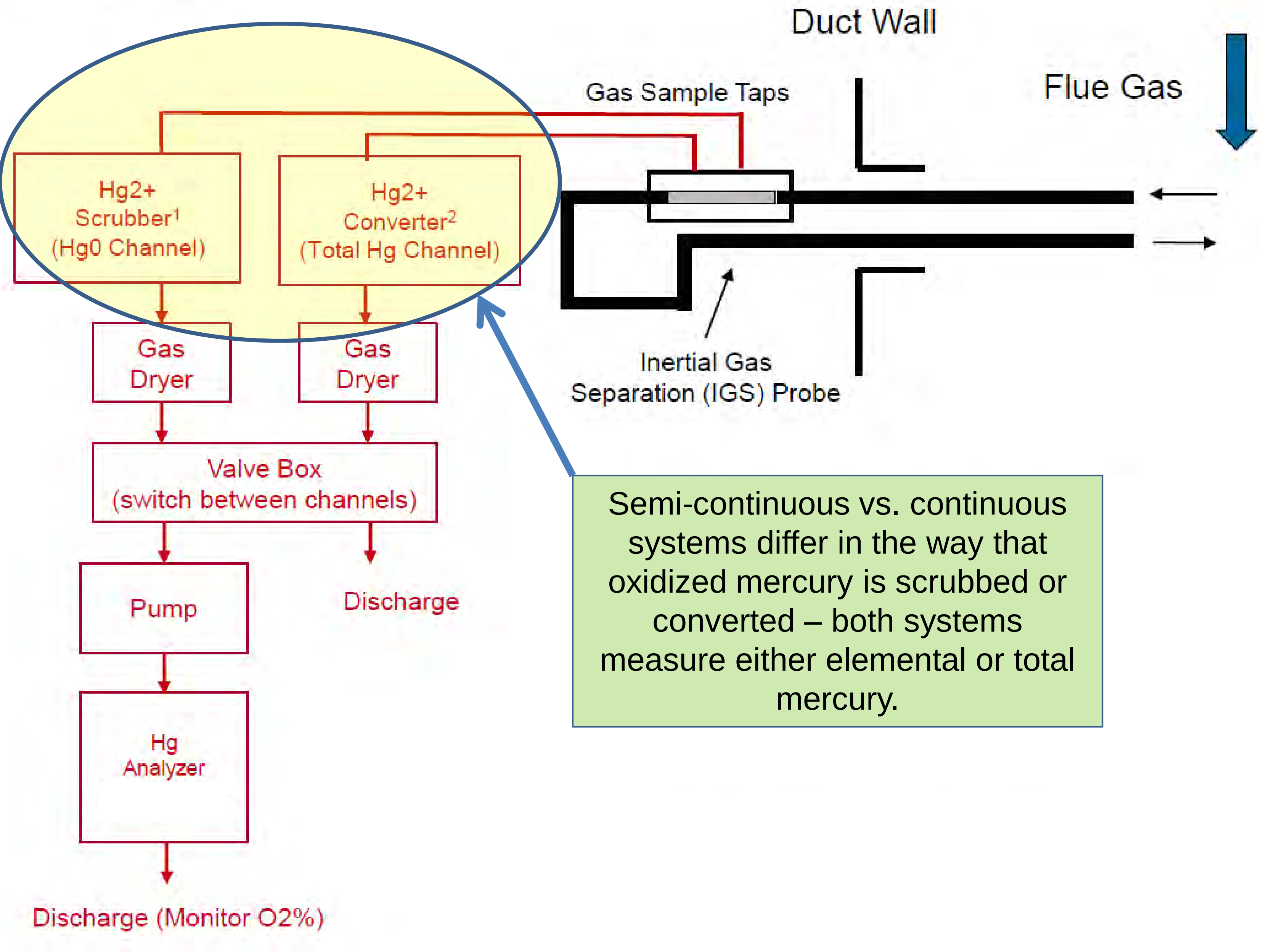
Dry gas meter box

Multi-bed trap

Compressed air fittings



Semi-Continuous and Continuous Systems



Duct Wall

Flue Gas

Gas Sample Taps

Hg2+ Scrubber[1] (Hg0 Channel)

Hg2+ Converter[2] (Total Hg Channel)

Gas Dryer

Gas Dryer

Valve Box (switch between channels)

Pump

Discharge

Hg Analyzer

Discharge (Monitor O2%)

Inertial Gas Separation (IGS) Probe

Semi-continuous vs. continuous systems differ in the way that oxidized mercury is scrubbed or converted – both systems measure either elemental or total mercury.

Measurement Options Pros and Cons

Technique	Pros	Cons
Speciated Trap	Low-cost system, good for multiple simultaneous measurements. Relatively unaffected by ammonia, close coupled to the flue gas.	Concerns about the presence of ash cake and how that might affect speciation, delay in getting information, not applicable for real-time transitionary measurements. Limited dynamic spiking options.
Semi-Continuous (wet conversion)	Gives near continuous feed-back, very good for transitionary measurements and parametric testing. Compatible with initial probes, numerous dynamic spiking options available.	Relatively large systems that can be cumbersome in some locations, costly if attempting multiple simultaneous measurement points, requires liquid reagents. Ammonia interference: not good for interlayer locations or inlet location after ammonia injection.
Continuous (dry conversion)	Gives near continuous feed-back, very good for transitionary measurements and parametric testing. No liquid reagents required. Compatible with initial probes, numerous dynamic spiking options available.	Relatively large systems that can be cumbersome in some locations, costly if attempting multiple simultaneous measurement points. Ammonia interference: not good for interlayer locations or inlet location after ammonia injection.

EPRI Field Mercury Measurement Best Practices Document

Practical guideline for making speciated mercury field measurements and interpreting results. Focus is on special testing upstream of the stack, not continuous stack emissions measurements.

- Description of potential test methods.
- Applicability of test methods to location and testing purpose.
- Best practices for each test method.
- Determine potential pitfalls and methodology concerns.
- Establish data analysis and reporting conventions.

Laboratory Testing for Mercury Oxidation

- Extremely important tool for co-benefit efforts.
- Valuable for numerous purposes including long-term tracking and catalyst management, prediction of field performance, guarantee testing, and parametric response to operational changes.
- Need to establish:

a. what size systems are most appropriate and how data compare.

b. what conditions are most appropriate (can reference conditions ultimately be utilized, similar to deNOx testing?).

c. how sensitive the measurements are to the various operating parameters.

d. what measurement techniques are most appropriate and what their required accuracy.

e. what equilibrium/conditioning times are required.

EPRI Mercury Oxidation Testing Guideline

Outline of Current Publication

1 INTRODUCTION

2 DEFINITIONS AND CONVENTIONS

3 INDUSTRY STATUS

4 PURPOSE OF LABORATORY TESTING

5 TEST APPARATUS

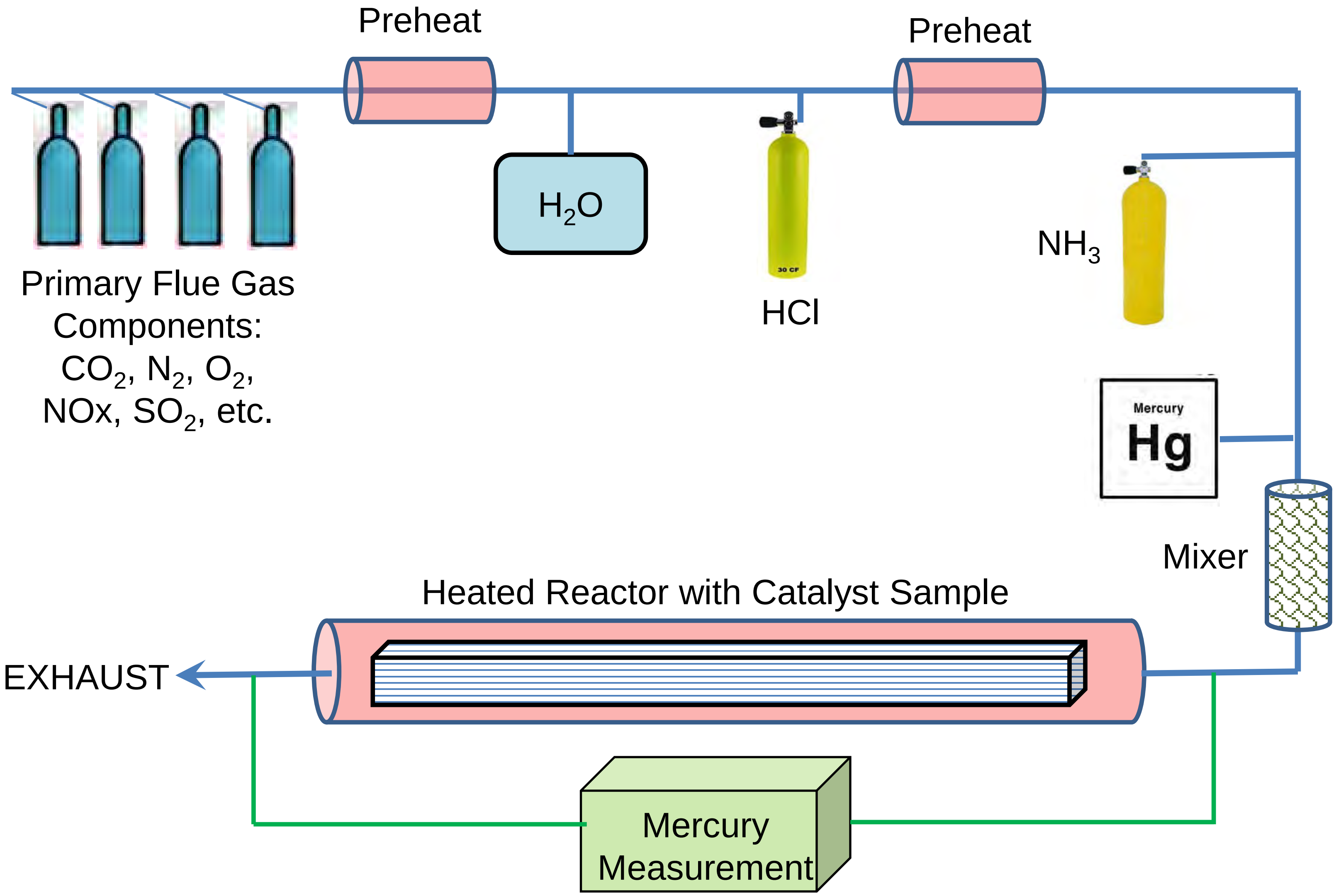
6 MERCURY OXIDATION SENSITIVITIES AND SELECTION OF TEST CONDITIONS

7 EQUILIBRIUM CONSIDERATIONS AND REPORTABLE DATA

8 REFERENCE TEST CONDITIONS AND FACILITY PERFORMANCE REQUIREMENTS

9 SAMPLE PREPARATION, REPORTING, AND QUALITY ASSURANCE/ QUALITY CONTROL

Conceptual Diagram of Semi-Bench Facility



W. Scott Hinton, Ph.D., P.E.
W.S. HINTON & ASSOCIATES
1612 Smugglers Cove Circle
Gulf Breeze, FL 32563
Office: 850-936-0037
Cell: 850-261-5239
email: shinton@wshinton.com