REINHOLD ENVIRONMENTAL Ltd.

2014 NOx-Combustion Round Table & Expo Presentations

February 10 & 11, 2014, in Charlotte, NC / Hosted by Duke Energy

Mercury Oxidation in the SCR

Layer by Layer Performance

Reinhold NOx Conference 2014

February 10, 2014

Kyle Neidig

New Joint Venture Company

IS NOW

HITACHI
Inspire the Next

Hitachi Power Systems America

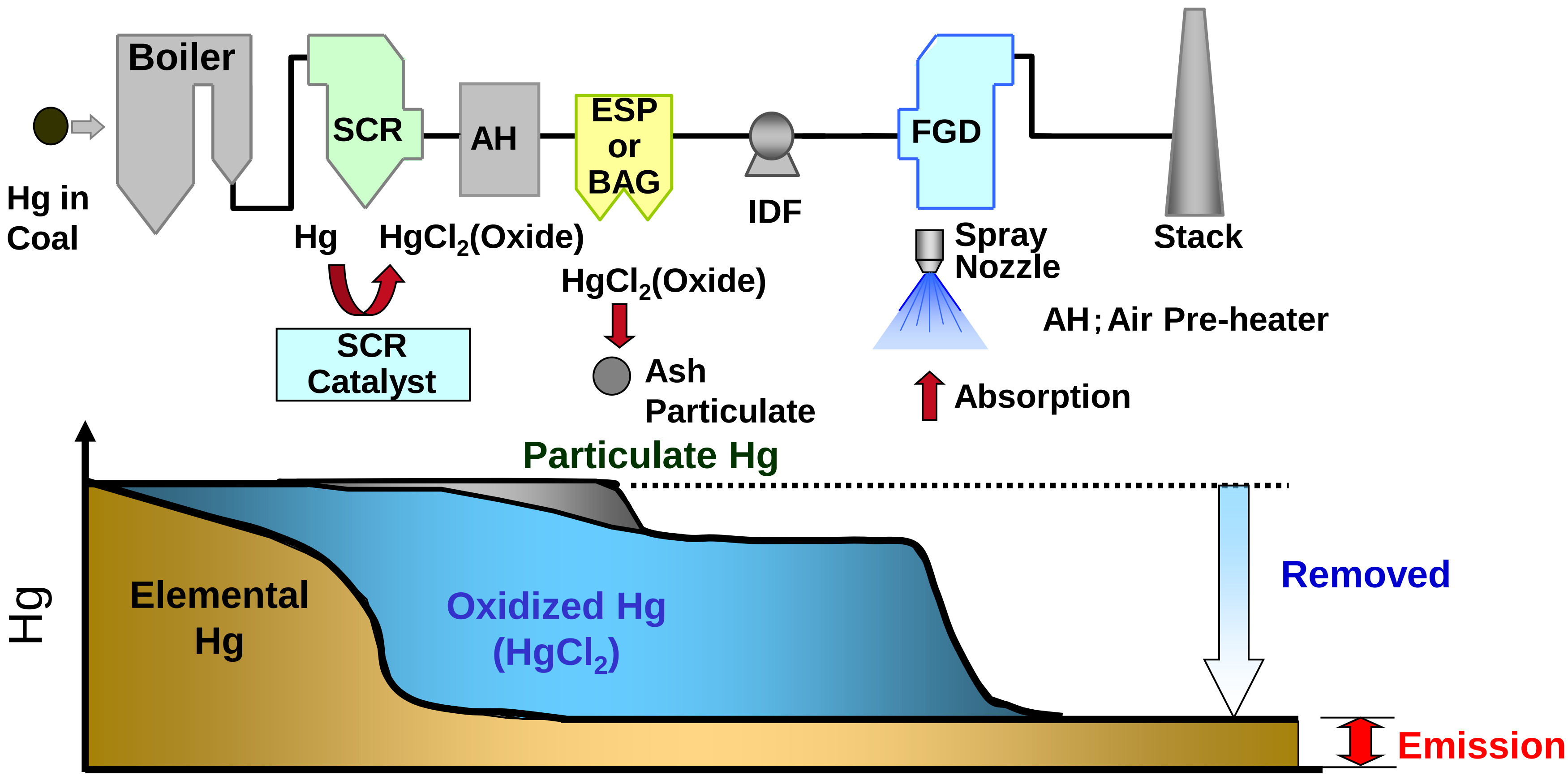
MITSUBISHI HITACHI POWER SYSTEMS AMERICA – ENERGY AND ENVIRONMENT

On Feb. 1, 2014 Mitsubishi Heavy Industries, Ltd. and Hitachi, Ltd. have officially merged their operations integrating the <u>thermal power generation businesses</u> of both companies into a single world class technology entity named Mitsubishi Hitachi Power Systems, Ltd. For the North American market, this includes, among others Mitsubishi Power Systems Americas Inc., Hitachi Power Systems America, Ltd., Hitachi Power Systems Canada, Ltd., and Mechanical Dynamics & Analysis, Ltd. <u>HPSA's new name will be "Mitsubishi Hitachi Power Systems America – Energy and Environment, Ltd."</u>

Outline

- Hg Oxidation Catalyst Experience (TRAC®)
- Key Parameters for Mercury Oxidation
- Layer by Layer Hg Oxidation Analysis
- TRAC® - Why It Works
- Full Scale TRAC® Results
- TRAC® Economics

Process of Hg Removal by SCR + FGD Co-Benefit



SCR Catalyst is a key component for mercury oxidation

The Co-Benefit of an SCR + FGD is the Most Cost-Effective MATS Compliance Strategy.

TRAC® Record

Owner	Plant	MW	Coal	Supply
A	Plant A	640	PRB	2008
B	Plant B	550	Bituminous	2010
Southern Company	Miller Unit 1	735	PRB	2011
Southern Company	Miller Unit 2	735	PRB	2011
Southern Company	Barry Unit 5	773	Bituminous	2011
AEP	Mountaineer Unit1	1,300	Bituminous	2011
Southern Company	Bowen Unit 3	950	Bituminous	2011
AEP	Cardinal Unit 2	600	Bituminous	2012
C	Plant C	800	Bituminous	2012
Southern Company	Hammond Unit 4	537	Bituminous	2012
Southern Company	Gaston Unit 5	910	Bituminous	2012
Southern Company	Bowen Unit 4	950	Bituminous	2012
LG&E	Ghent Unit 4	556	Bituminous	2013
Tucson Electric Power	Springerville Unit 3 (2 Layers)	400	PRB	2013
Southern Company	Scherer Unit 4	923	PRB	2013
Southern Company	Miller Unit 1	735	PRB	2013
Southern Company	Miller Unit 2	735	PRB	2013
Southern Company	Bowen Unit 2	756	Bituminous	2014

Installations of 19 Layers of TRAC® Catalyst, 8 more layers planned for install in next year

What are the Main Parameters Impacting Enhanced Mercury Oxidation?

Key Parameters for Mercury Oxidation

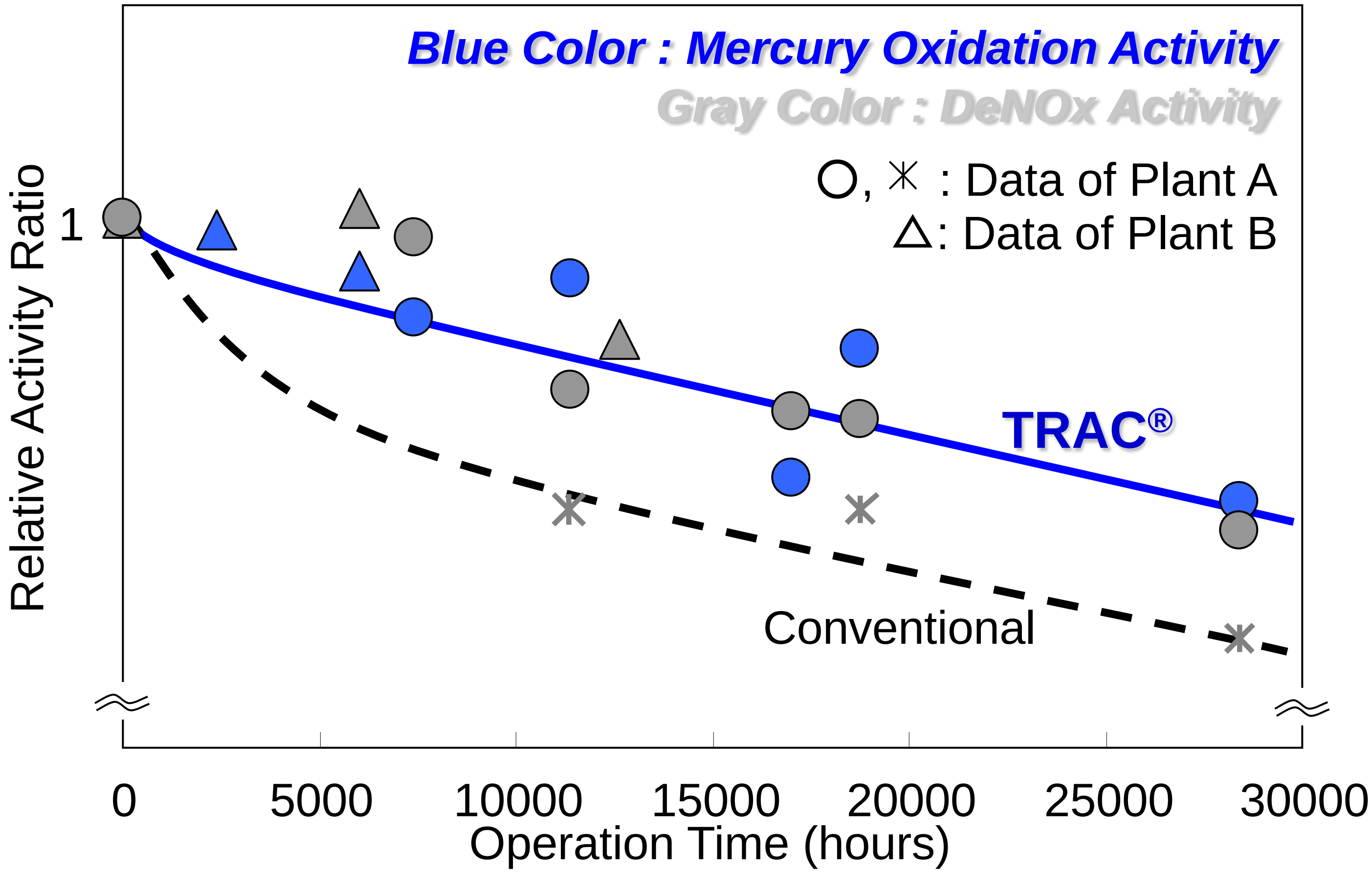
Hg Oxidation Rate

- NH_3/NOx ratio
- Catalyst Age/Deactivation
- Halogen concentration (HCl, HBr etc.)
- Temperature
- Hg(Elemental) / Hg(Total) ratio
- Others:
  Area velocity
  O_2, H_2O, and CO concentrations

Layer Specific

What is the Optimal Layer for Hg Oxidation?

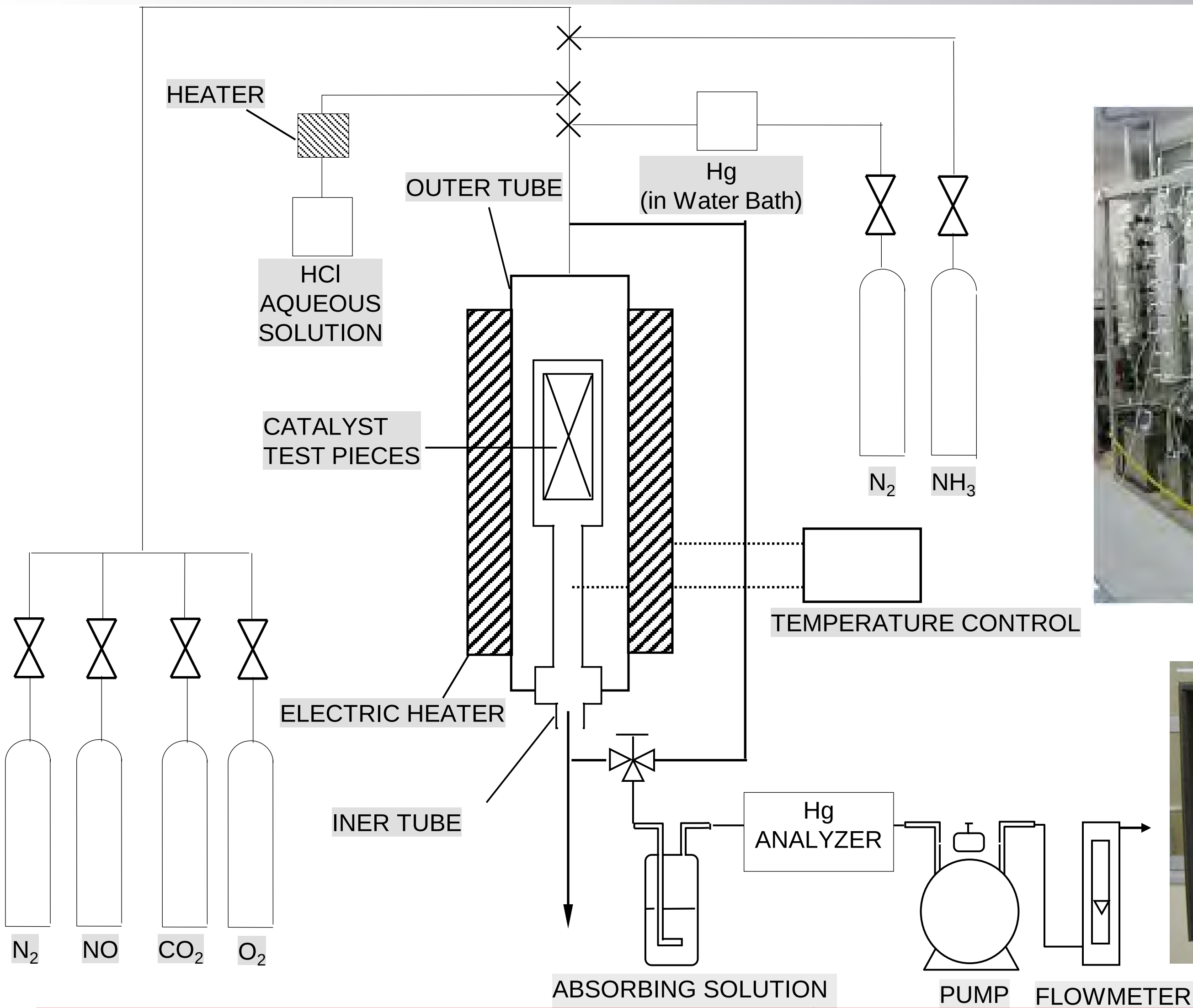
Deactivation Rate for NOx and Hg Oxidation



TRAC® Has Longer Life than Conventional Catalyst.
Deterioration of Hg Oxidation is the Same as DeNOx.

Hg Oxidation Lab Testing

Lab Test Setup for Mercury Oxidation Measurement



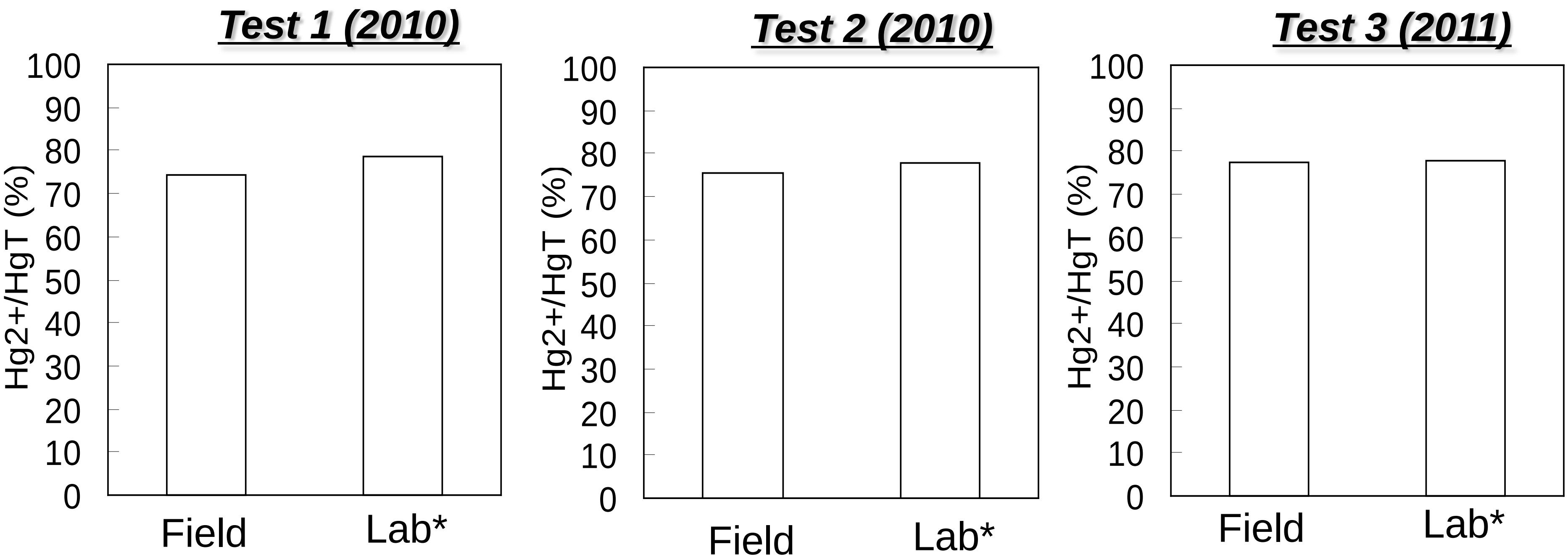
Test Apparatus

Hg Analyzer

Evaluated Layer Specific Performance in Lab

NOTE: Lab Tests Can Not Replicate All Field Conditions (Such as Ash)

Comparison – Field vs Lab Testing

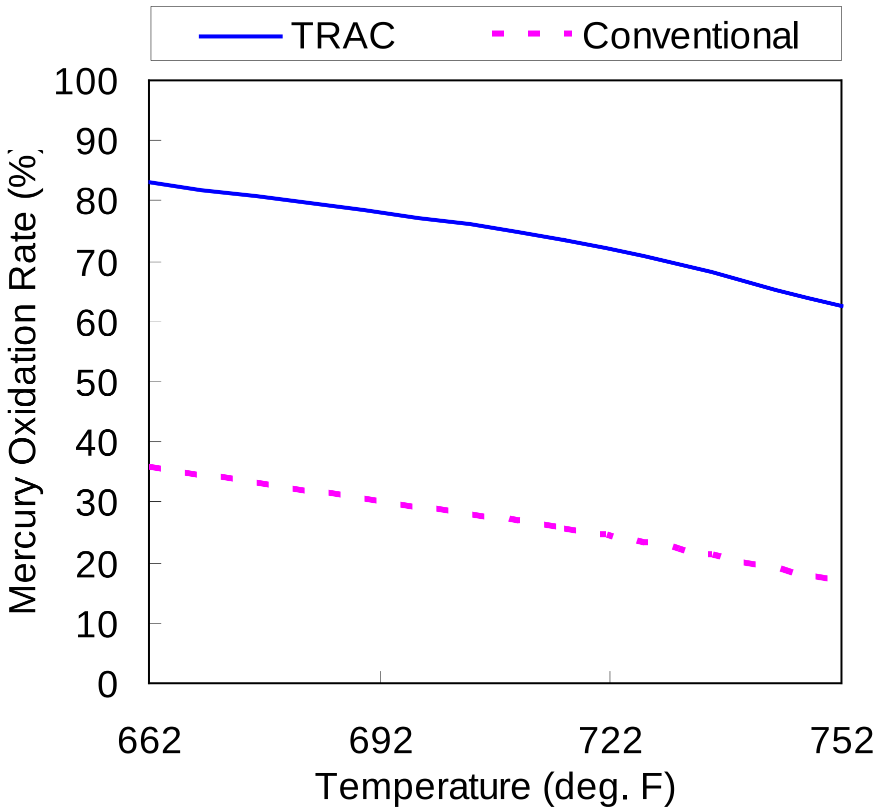


* : Adjusted with Correction Curves

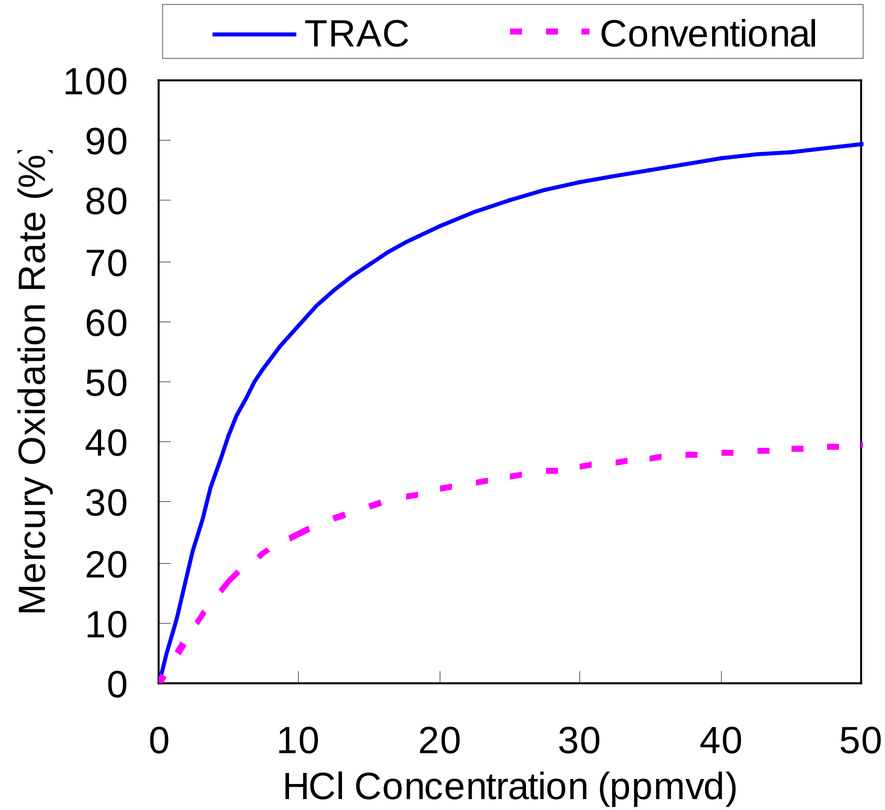
Excellent agreement was confirmed between the measured data in the field and the Corrected Lab Results

Characteristics of Temperature for Mercury Oxidation Rate

HCl Characteristics



Temperature Characteristics



TRAC® shows…

Higher Hg oxidation at lower HCl concentration

Higher Hg oxidation at higher temperature

Layer Specific Impacts

NH_3/NOx ratio

Hg(Elemental) / Hg(Total) ratio

Test Conditions

Eastern Bituminous

Item	Unit	Content
Coal	-	**Eastern Bituminous**
DeNOx Efficiency	%	**90**
Slip NH3	ppm	**2**
Temperature	deg. F	662
NO	ppm	300
SO2	ppm	2000
SO3	ppm	20
Hg(0)	ug/m3	**8**
Hg(2+)	ug/m3	**2**
HCl	ppm	**56**
O2	dry, %	3
CO2	dry, %	15
H2O	%	10

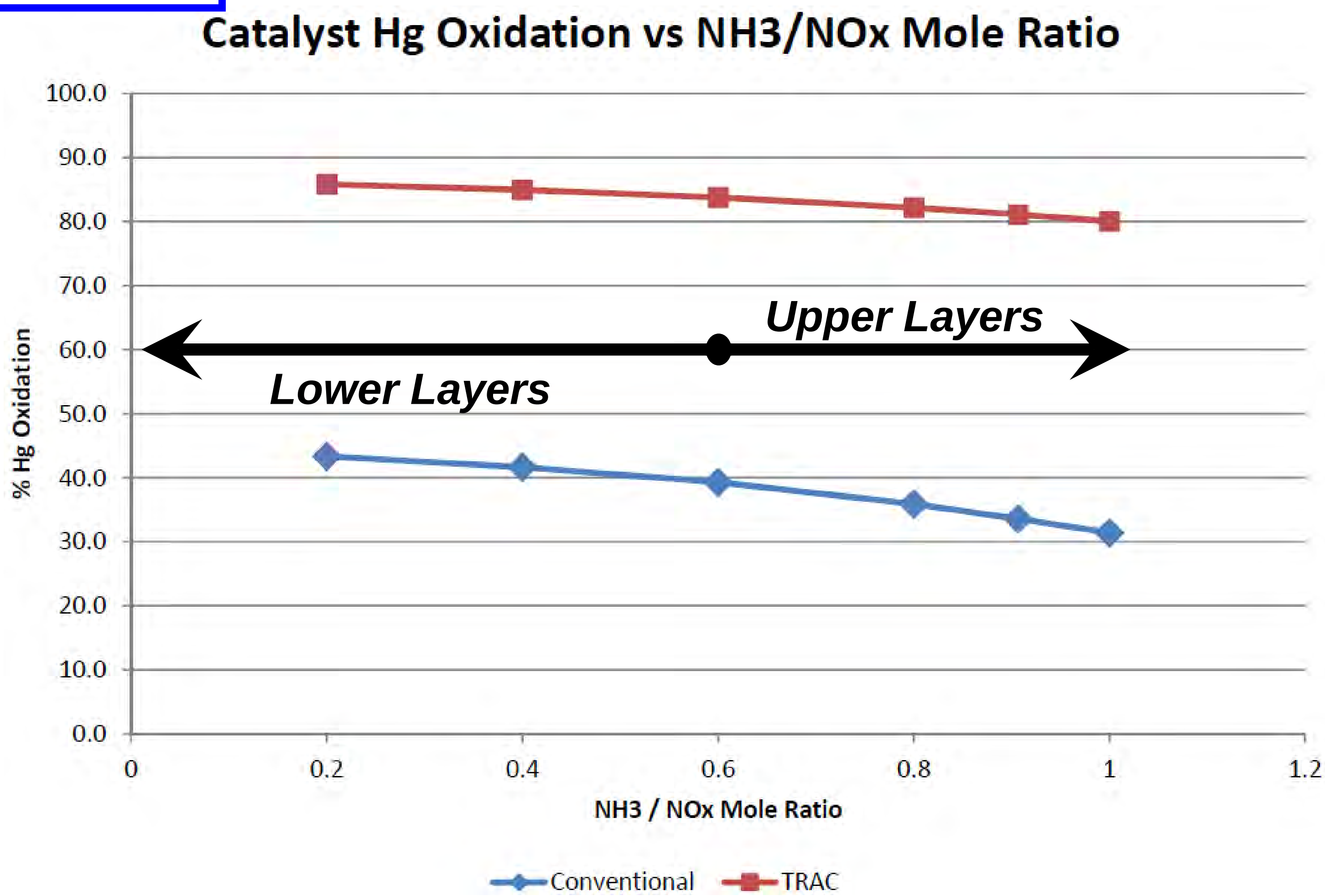
PRB

Item	Unit	Content
Coal	-	**PRB**
DeNOx Efficiency	%	**90**
Slip NH3	ppm	**2**
Temperature	deg. F	716
NO	ppm	300
SO2	ppm	500
SO3	ppm	5
Hg(0)	ug/m3	**9**
Hg(2+)	ug/m3	**1**
HCl	ppm	**5**
O2	dry, %	3
CO2	dry, %	15
H2O	%	10

Typical Eastern Bituminous and PRB Conditions were Evaluated

NH3 / NOx Ratio

Eastern Bituminous

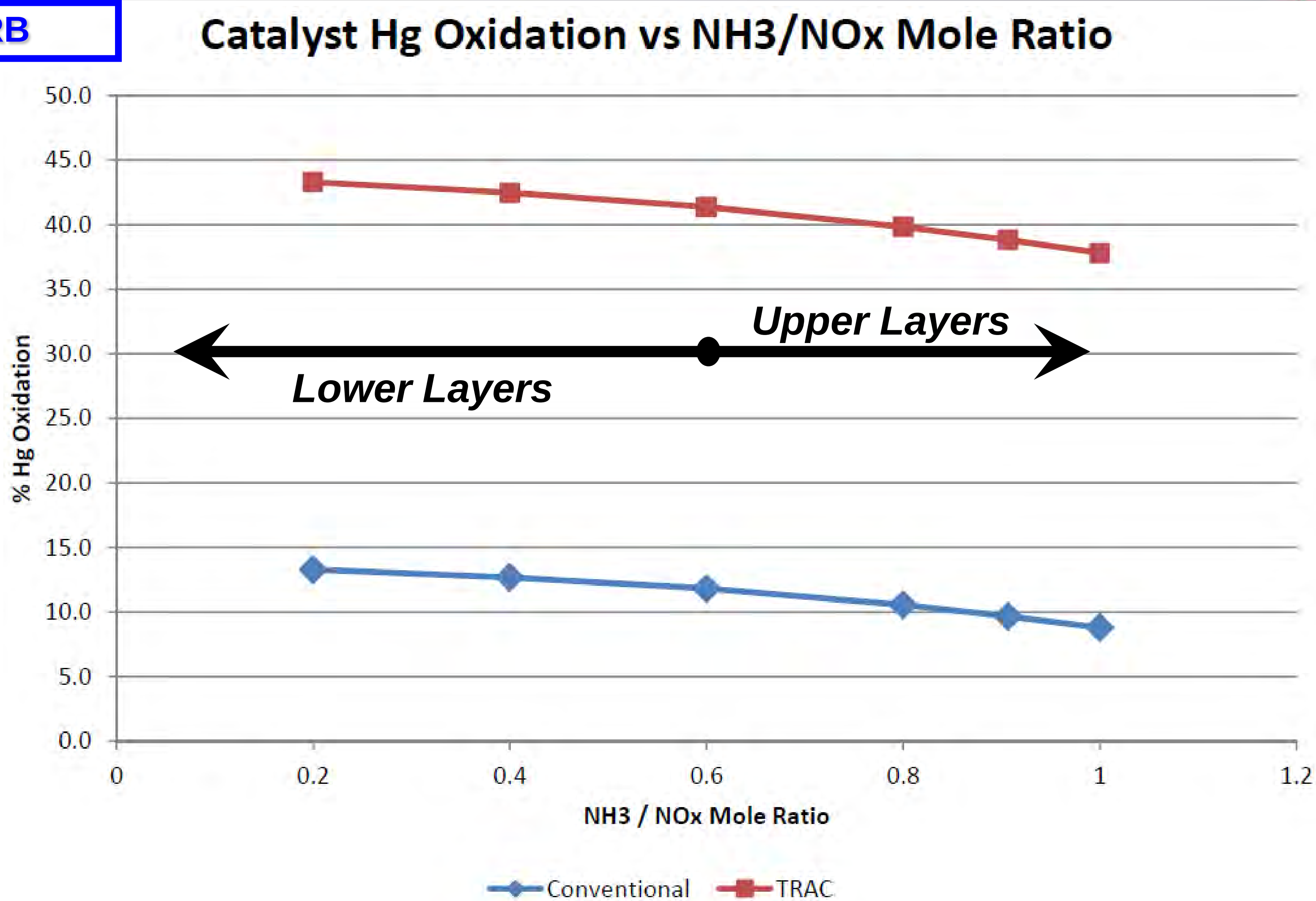


TRAC Catalyst Significantly Outperforms Conventional

At High NH3/NOx Ratios, Hg Oxidation is Slightly Reduced for all Catalyst

NH3 / NOx Ratio

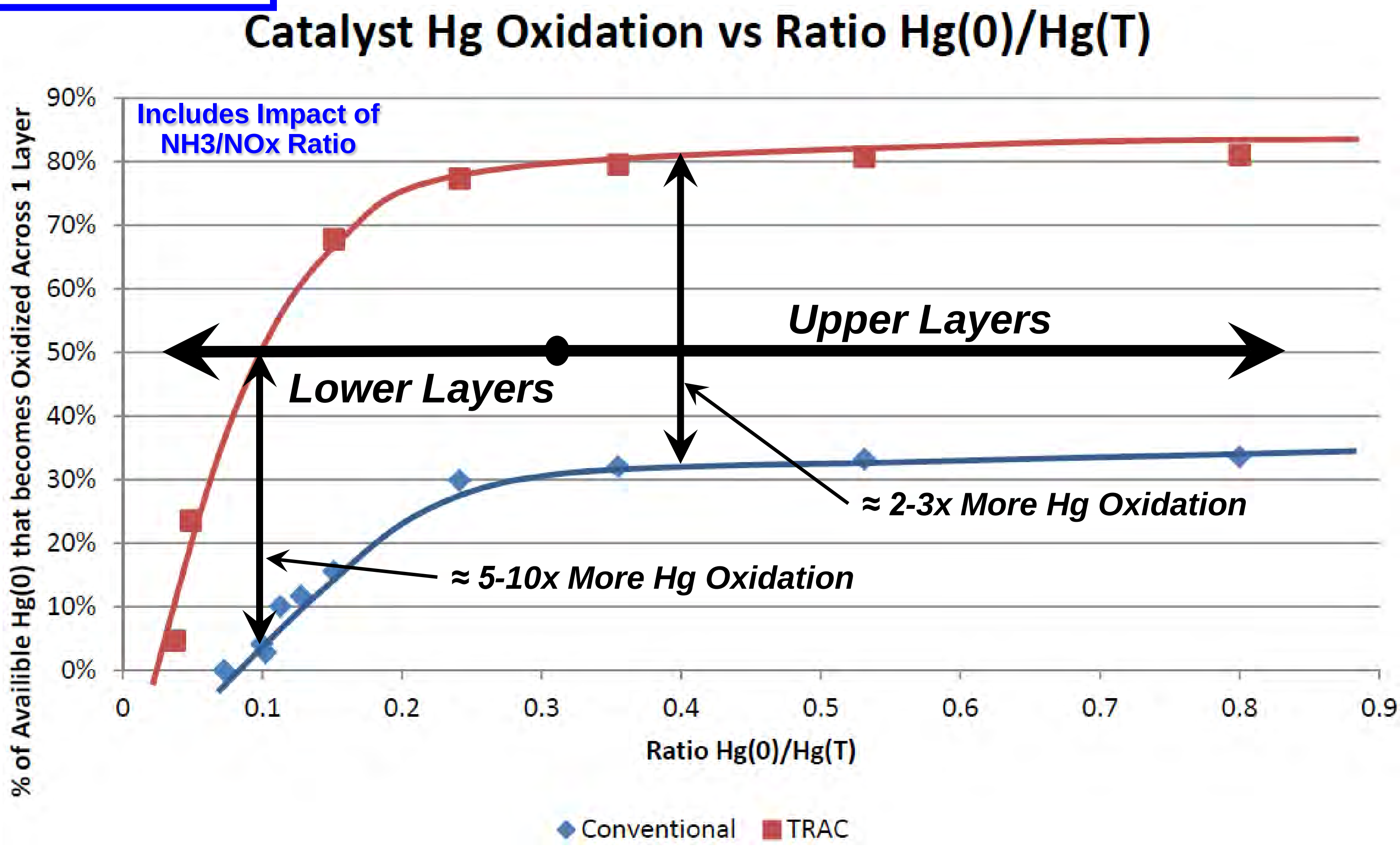
PRB



TRAC Catalyst Significantly Outperforms Conventional
At High NH3/NOx Ratios, Hg Oxidation is Slightly Reduced for all Catalyst

Hg(Elemental) / Hg(Total) Ratio

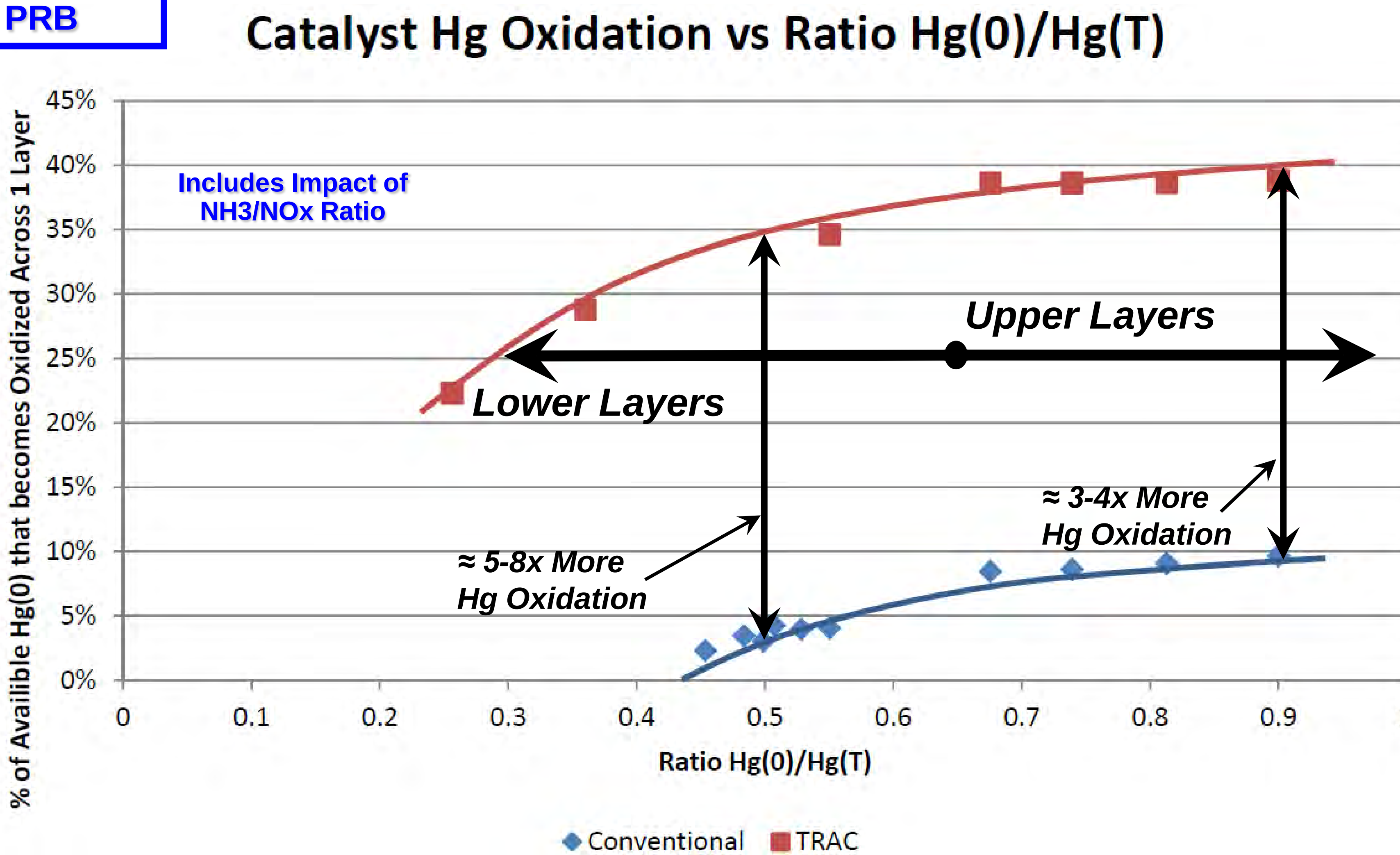
Eastern Bituminous



TRAC Catalyst Significantly Outperforms Conventional
At Very Low Hg(0)/Hg(T) Ratios, Hg Oxidation is a Challenge for all Catalyst

Hg(Elemental) / Hg(Total) Ratio

PRB



TRAC Catalyst Significantly Outperforms Conventional

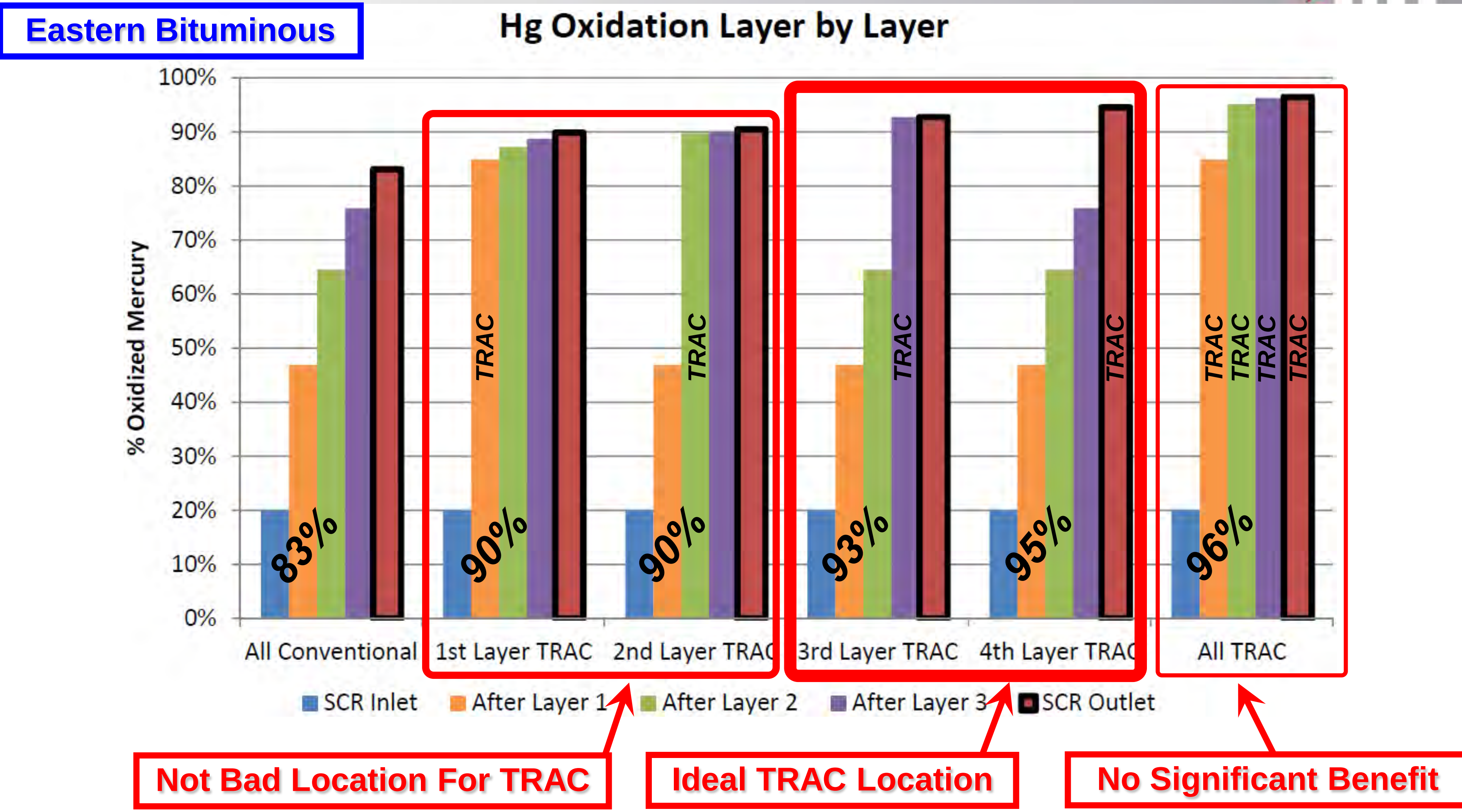
At Very Low Hg(0)/Hg(T) Ratios, Hg Oxidation is a Challenge for all Catalyst

Scenarios Evaluated

- All 4 Layers are Conventional Catalyst
- Layer 1 is TRAC and Layers 2-4 are Conventional
- Layer 2 is TRAC and Layers 1, 3, 4 are Conventional
- Layer 3 is TRAC and Layers 1, 2, 4 are Conventional
- Layer 4 is TRAC and Layers 1-3 and Conventional
- All 4 layers are TRAC

Above 6 Scenarios were Evaluated Under both Eastern Bituminous and PRB Conditions

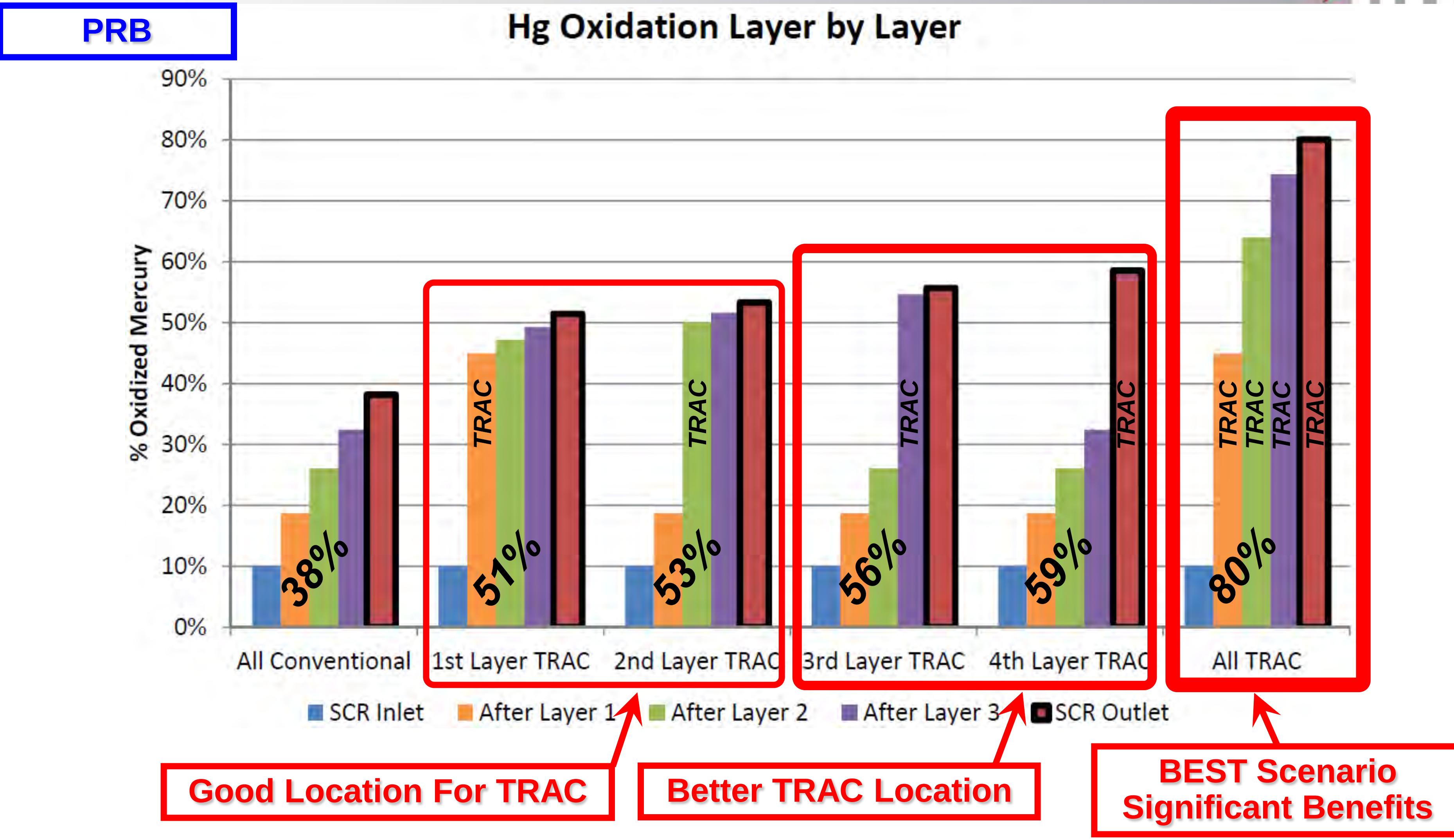
Layer by Layer Mercury Oxidation



TRAC Provides Benefits If Installed in ANY Layer

Lower Layers are the Best Location for TRAC

Layer by Layer Mercury Oxidation



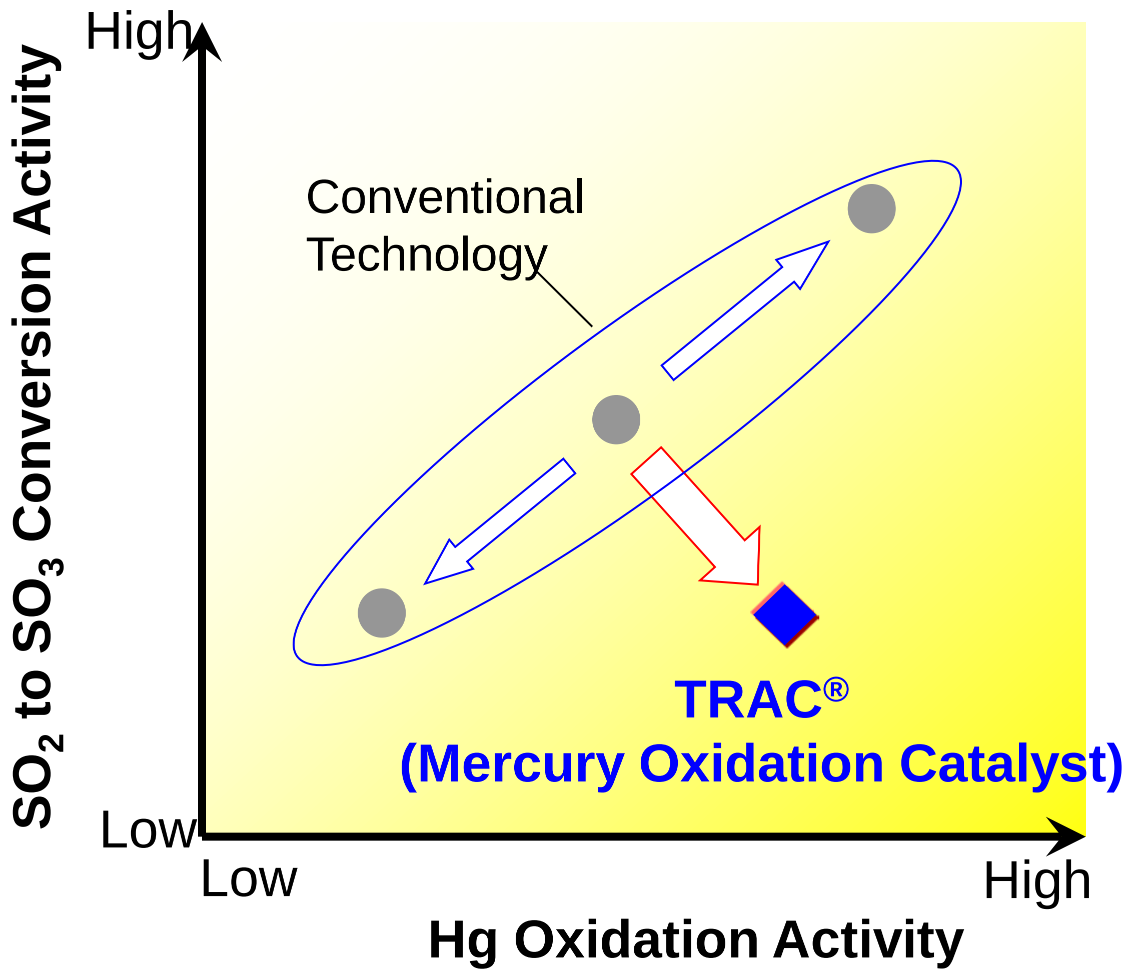
TRAC Provides Benefits If Installed in ANY Layer

Best Scenario is Installing TRAC for ALL Future Catalyst Replacements

What makes TRAC® Catalyst ***Different*** from Conventional Catalyst?

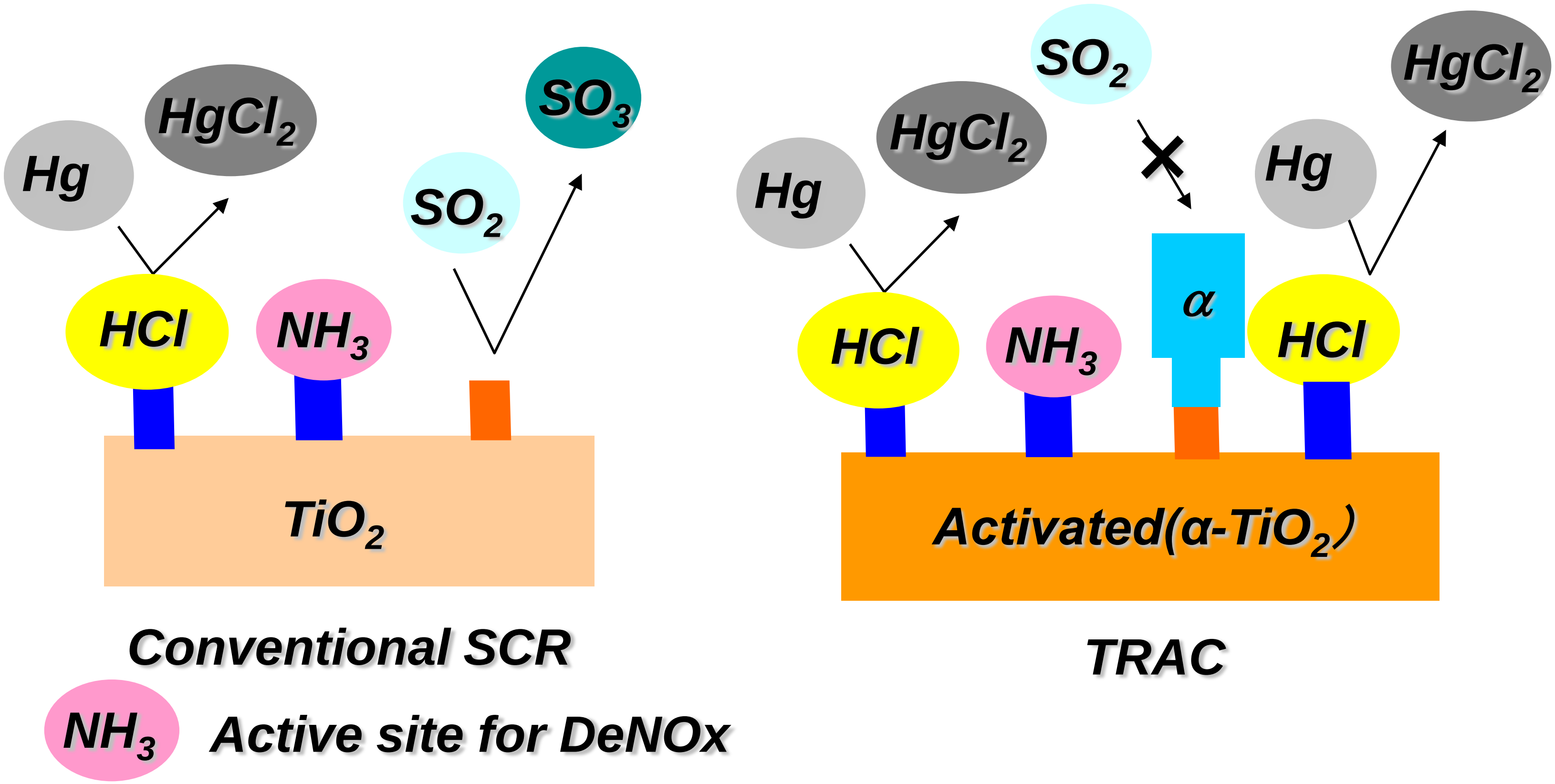
"Why It Works"

TRAC® - Mercury Oxidation Catalyst



TRAC® Has Higher Hg Oxidation & Maintains Low SO_2 Conversion

TRAC® Reaction Model



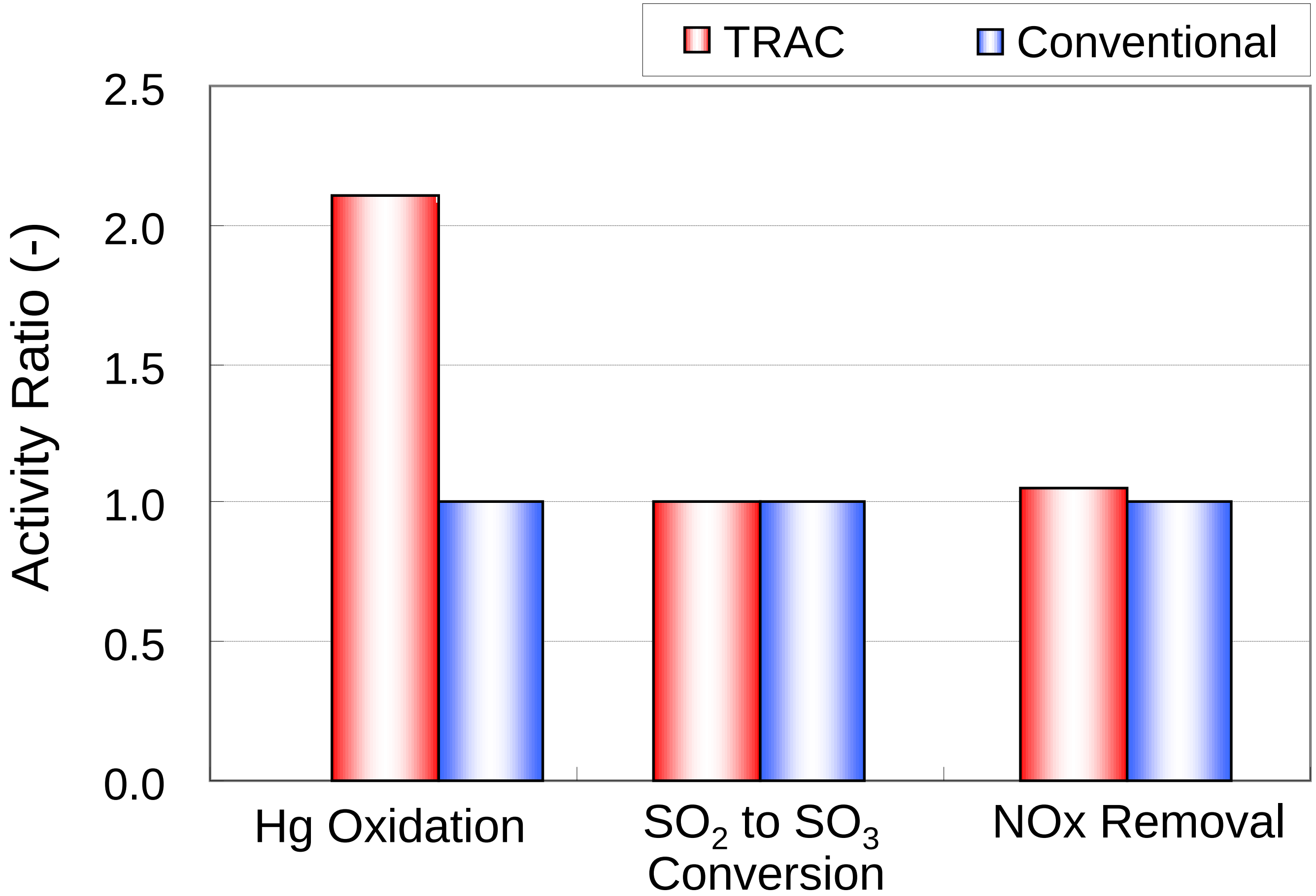
α Component Can Inhibit SO_2 Conversion Rate and Enhance Hg Oxidation Performance.

Relative Performance of TRAC®

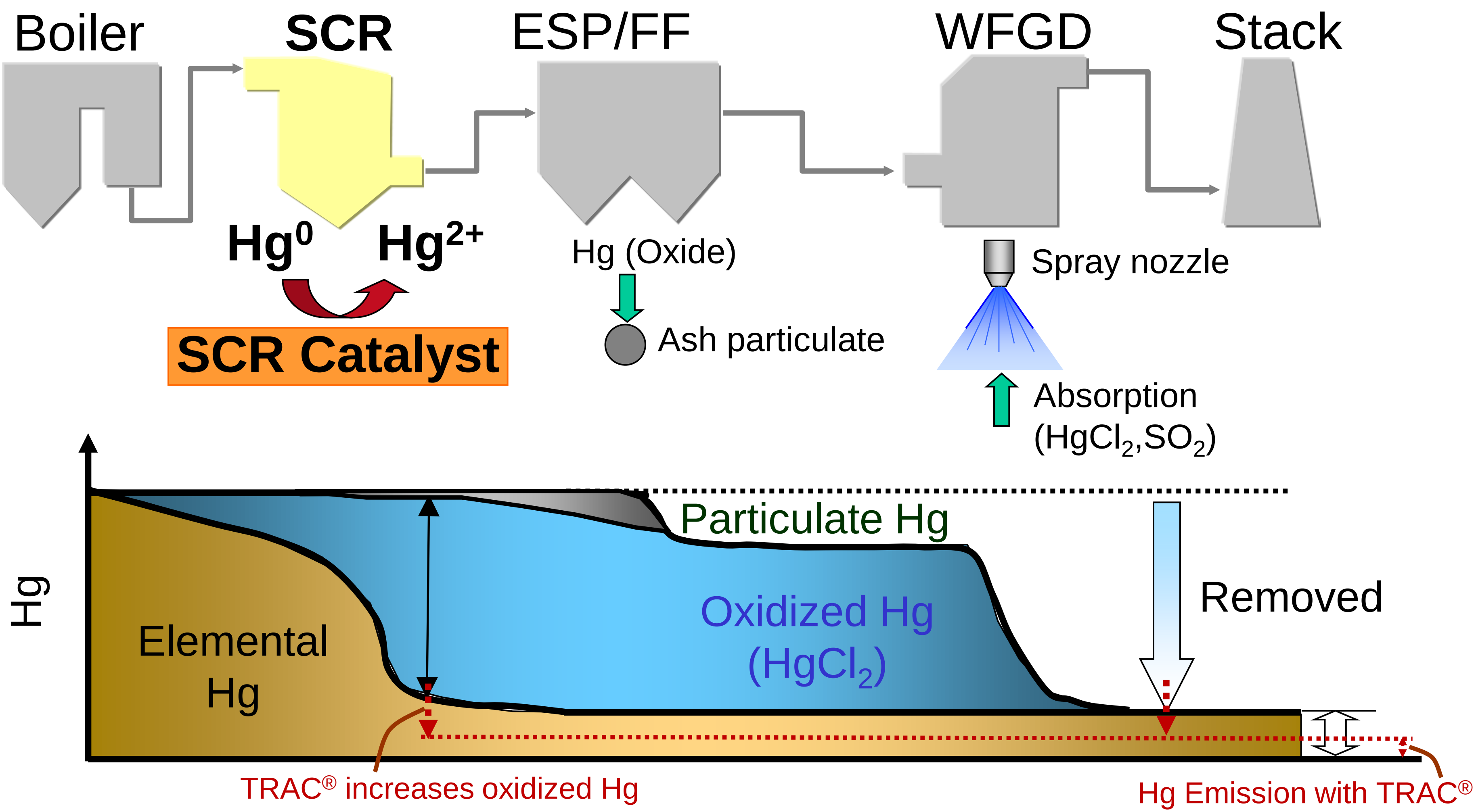
1st High Mercury Oxidation

2nd High DeNOx Performance

3rd Low SO_2 to SO_3 Conversion



SCR + FGD Co-Benefit with TRAC® Catalyst



SCR catalyst is a key component for mercury oxidation

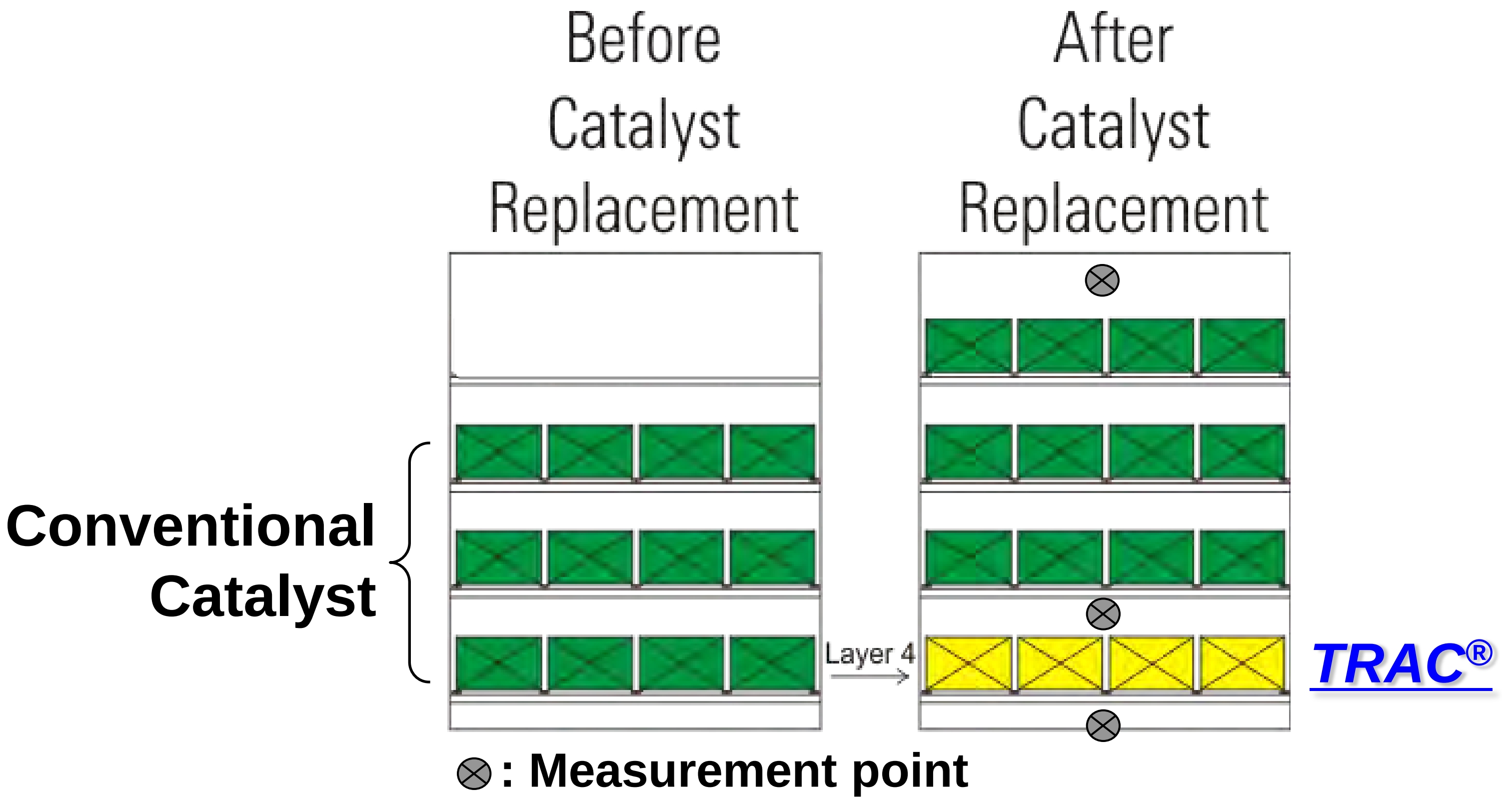
Full Scale Results on Eastern Bituminous Applications

Full Scale Results for a Bituminous Unit

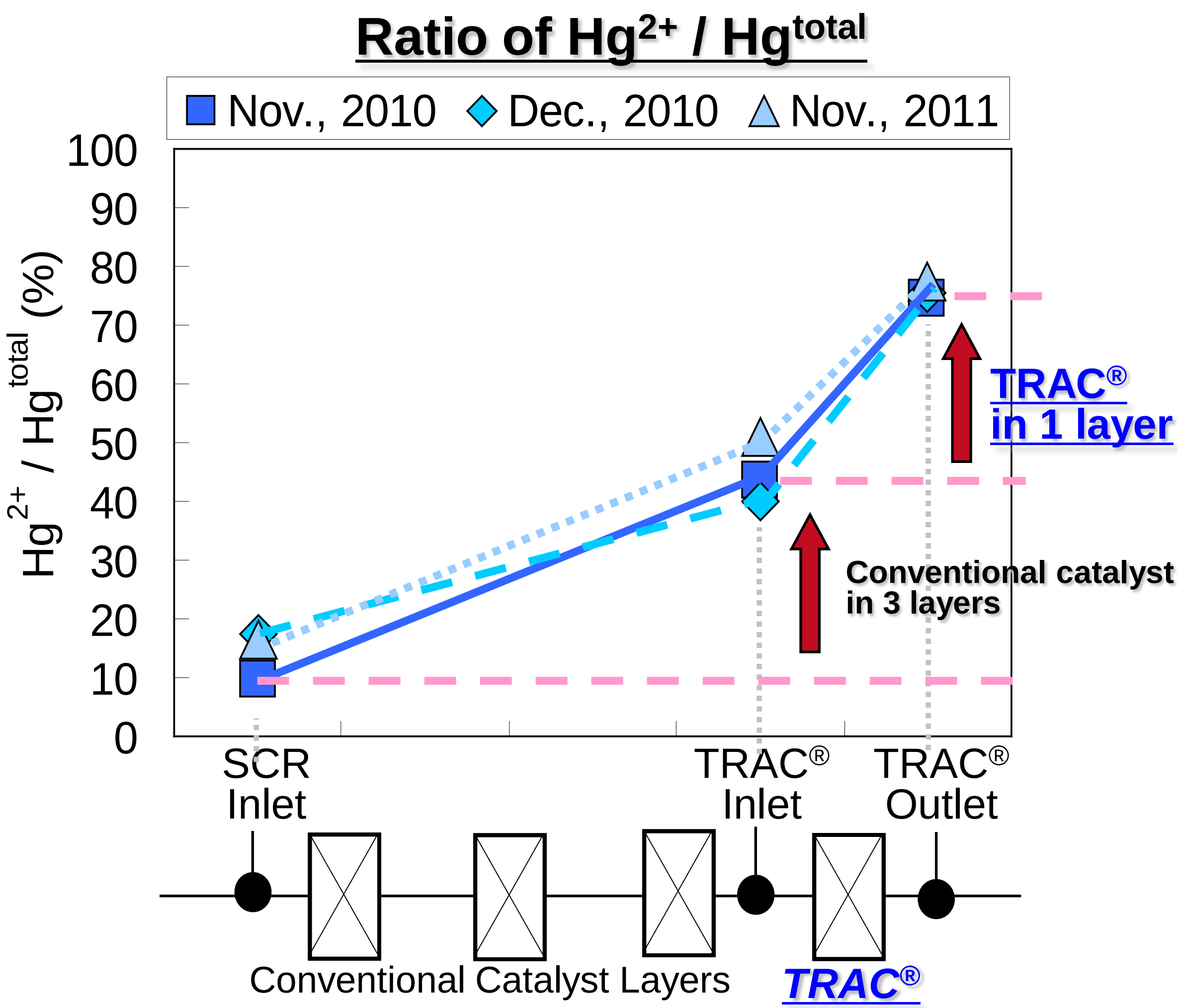
- Bituminous fired Plant (550 MW)
-TRAC® Supplied in spring 2010
-Measurement point :
SCR Inlet, TRAC® Inlet, TRAC® Outlet

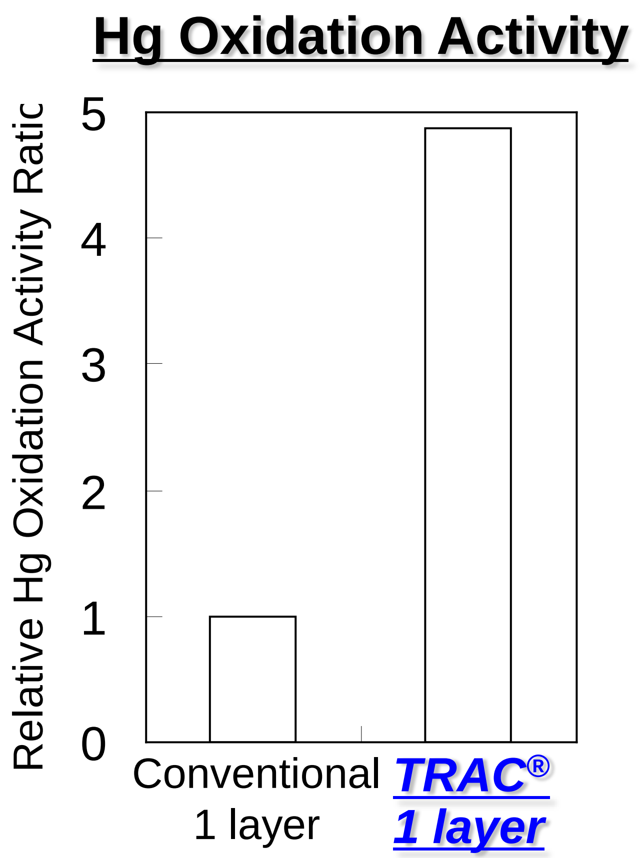
-Conditions

Temperature	725 F
Hg in coal	0.043 – 0.073 ppm
Cl in coal	43 – 120 ppm



Full Scale Results for Bituminous Units

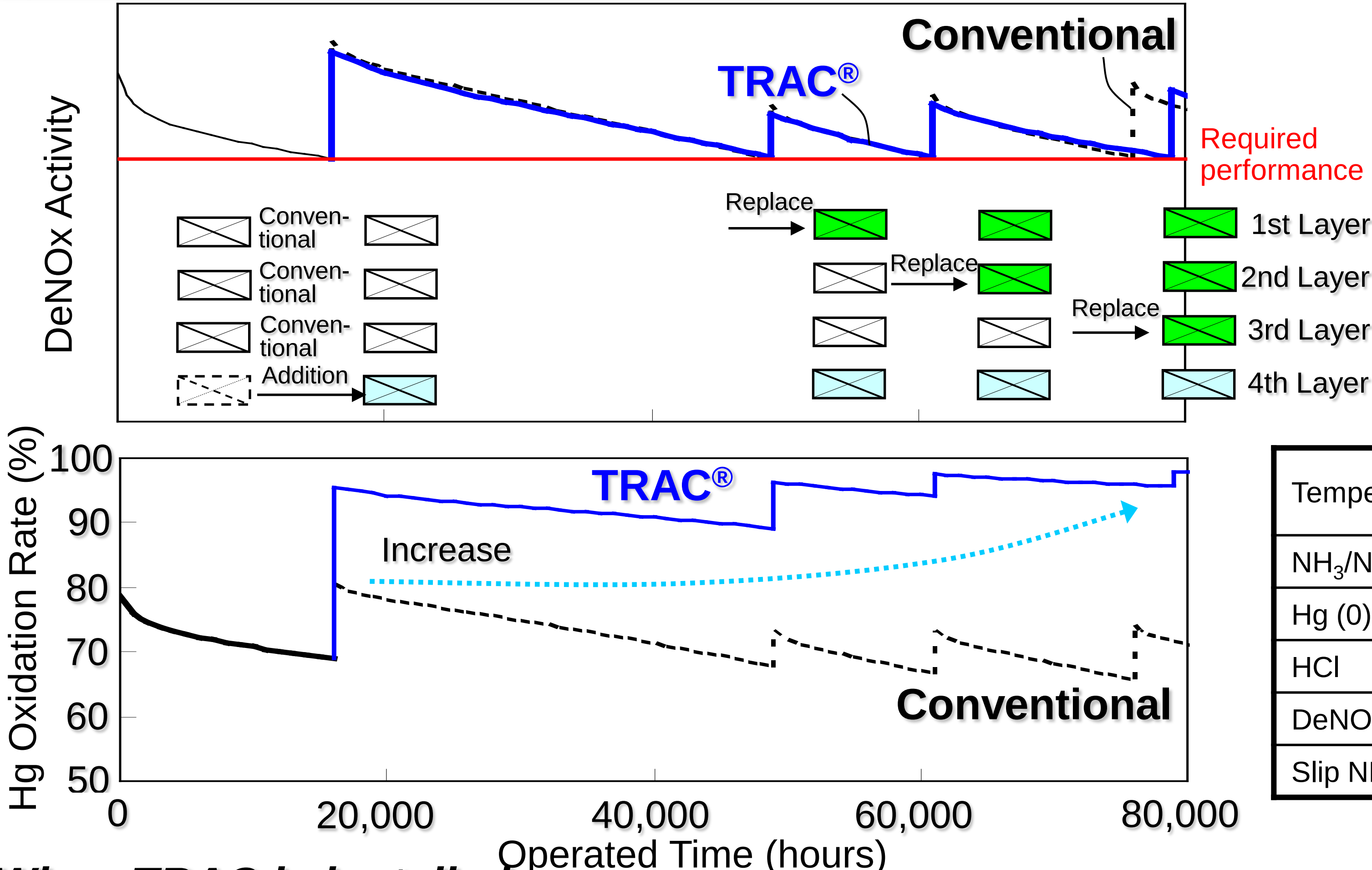




Hg oxidation activity of TRAC® was approx. 5 times higher than Conventional catalyst.

Catalyst Management Plan - Bituminous Coal

Typical CMP for Bituminous plant



Temperature	703 deg. F
NH_3/NOx	0.9
Hg (0) : Hg (2+)	7 : 3
HCl	56 ppmvd
DeNOx eff.	90%
Slip NH_3	2 ppmvd

When TRAC is installed…

Catalyst life is longer than Conventional Catalyst.
Mercury oxidation rate is significantly increased.

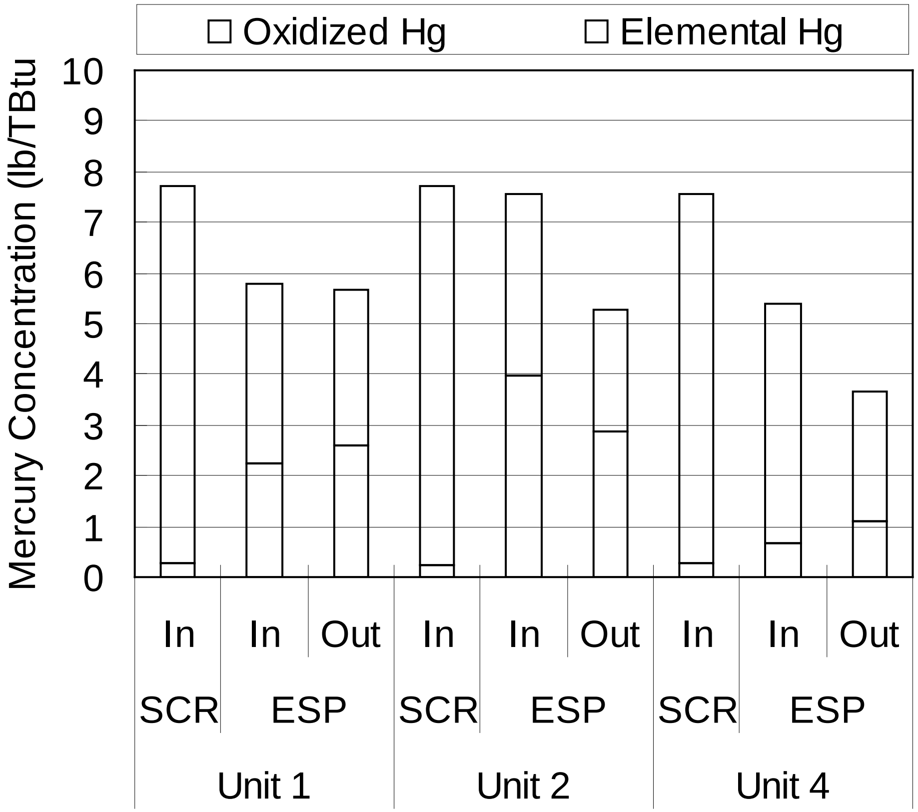
Full Scale Results on PRB Applications

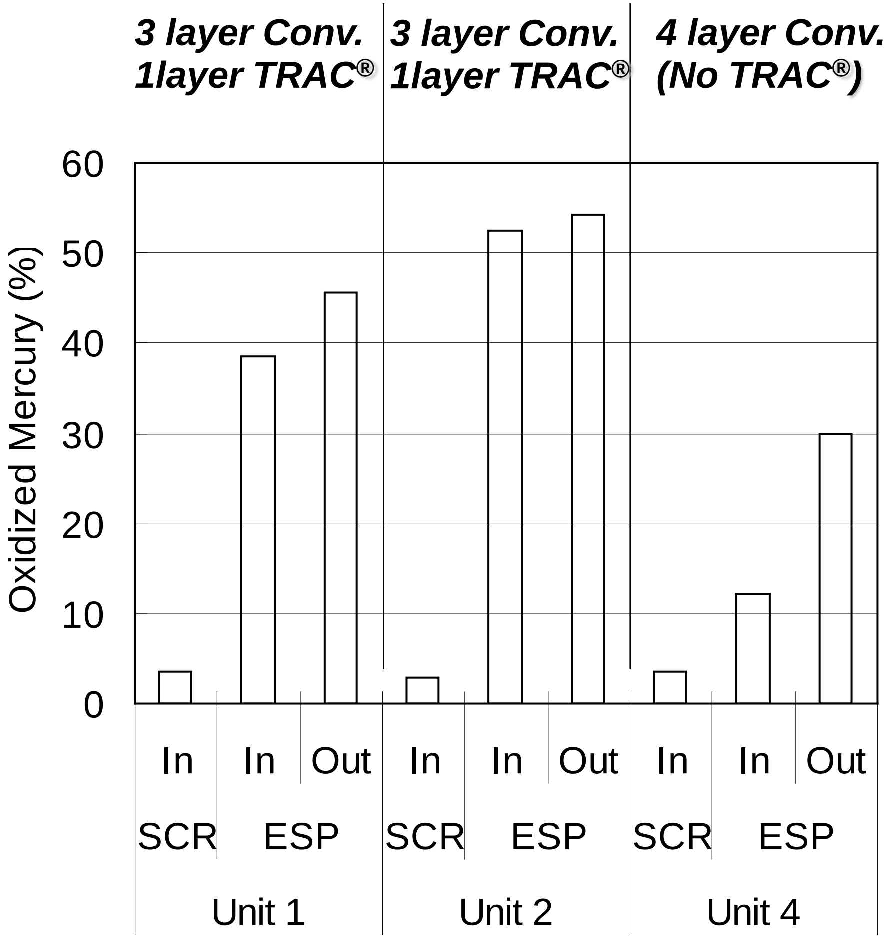
Full Scale Results for PRB Units

Plant Information

Coal Type	Powder River Basin (PRB) Coal		
Sulfur in Coal	0.40 %		
Chlorine in Coal	37 ppm		
Unit	Unit 1	Unit 2	Unit 4
Nominal Capacity	700 MW	700 MW	700 MW
Catalyst	3 Layers Conventional 1 Layer TRAC®	3 Layers Conventional 1 Layer TRAC®	4 Layers Conventional

Full Scale Results for PRB Units

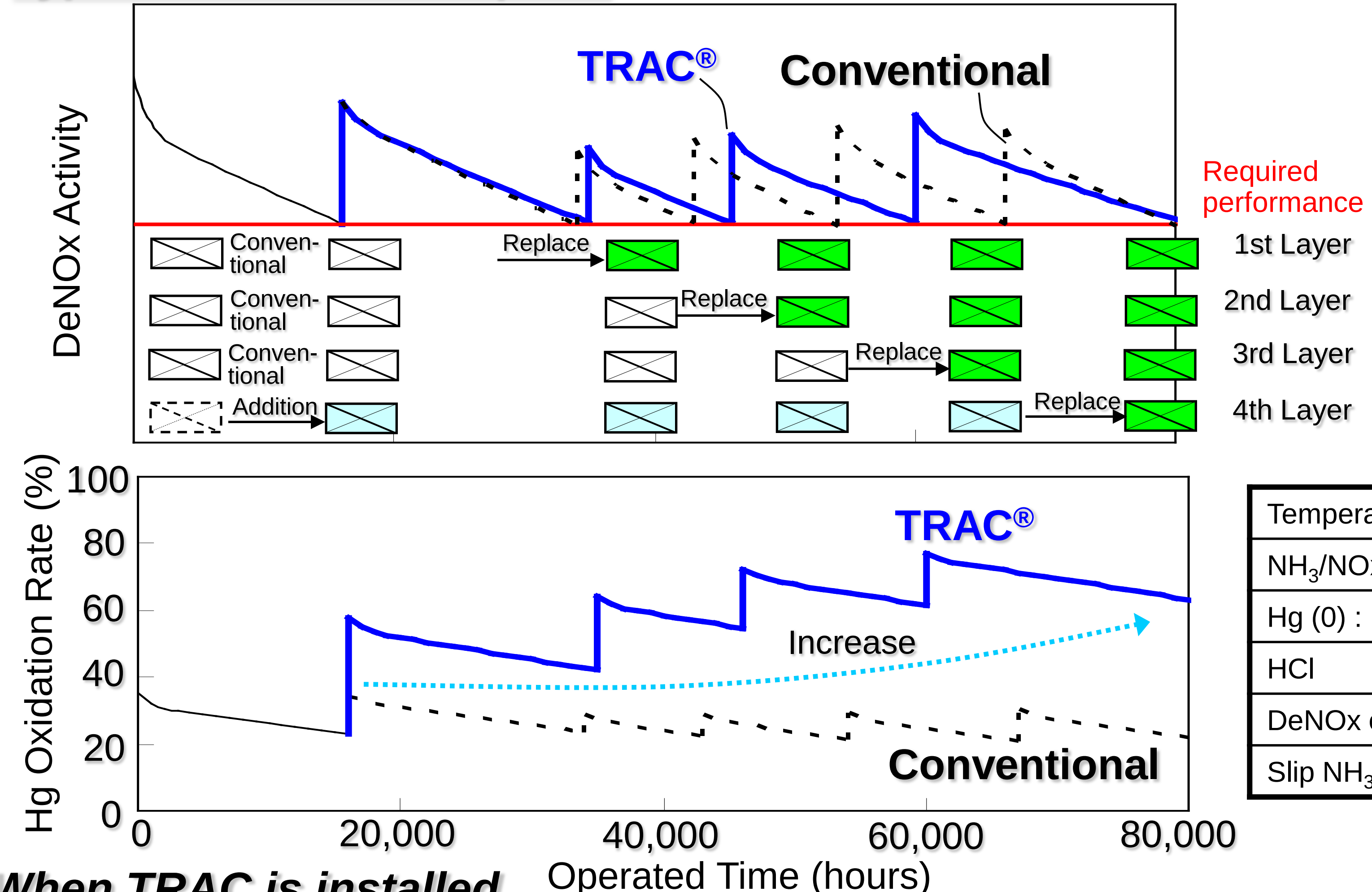




Oxidized mercury rate was increased significantly after 1 layer of TRAC® was installed in Units 1&2

Catalyst Management Plan - PRB Coal

Typical CMP for PRB plant



Temperature	700 deg. F
NH_3/NOx	0.9
Hg (0) : Hg (2+)	9 : 1
HCl	5 ppmvd
DeNOx eff.	90%
Slip NH_3	2 ppmvd

When TRAC is installed…

Interval of catalyst addition / replacement is longer.
Mercury oxidation rate is significantly increased.

TRAC® Hg Oxidation Economics

Contact us to have your specific application evaluated

TRAC® Economics for Bituminous Unit
- With ESP Case (No FF) -

Assumptions
1) Required total Hg removal = 90%
2) AC (Untreated) cost = $0.50 / lb
3) Oxidized mercury removal across FF/ESP, WFGD = 95%
4) Hg Oxidation across APH = 50% of remaining elemental Hg

TRAC with ESP (no FF) **500 MW Plant**	**Non-TRAC® Addition**	**1 Layer of TRAC® Addition/Replacement**
HG Oxidation (@ APH outlet),(%)	**≥ 88**	**≥ 95**
Hg Removal w/o ACI (@ Stack),(%)	**≥ 83**	**≥ 90**
AC injection, # / MMACF	**4.2**	**0**
AC Cost / year	**$4,352,000**	**$0**
Differential Cost of TRAC 1 Addition / Replacement	**$0**	**$200,000**
Cost of using AC and/or TRAC over an eight (8) year period	**$34,816,000**	**$800,000**

TRAC® Saves Approx. $34M in Operating Cost

TRAC® Economics for Bituminous Unit
- With FF Case -

Assumptions

1) Required total Hg removal = 90%
2) AC (Untreated) cost = $0.50 / lb
3) Oxidized mercury removal across FF/ESP, WFGD = 95%
4) Hg Oxidation across APH = 50% of remaining elemental Hg

TRAC with FF **500 MW Plant**	**Non-TRAC® Addition**	**1 Layer of TRAC® Addition/Replacement**
HG Oxidation (@ APH outlet),(%)	**≥ 88**	**≥ 95**
Hg Removal w/o ACI (@ Stack),(%)	**≥ 83**	**≥ 90**
AC injection, # / MMACF	**0.5**	**0**
AC Cost / year	**$520,000**	**$0**
Differential Cost of TRAC 1 Addition / Replacement	**$0**	**$200,000**
Cost of using AC and/or TRAC over an eight (8) year period	**$4,160,000**	**$800,000**

TRAC® Saves Approx. $3.4M in Operating Cost

TRAC® Economics for PRB Unit
- With ESP Case (No FF) -

Assumptions
1) Required total Hg removal = 90%
2) AC (Untreated) cost = $0.50 / lb
3) Oxidized mercury removal across FF/ESP, WFGD = 95%
4) Hg Oxidation across APH = 50% of remaining elemental Hg

TRAC with ESP (no FF) **500 MW Plant**	**Non-TRAC® Addition**	**1 Layer of TRAC® Addition/Replacement**		
		~ End of 1st Add./Rep. (for 2.3 years)	**~ End of 2nd Add./Rep. (for 1.4 years)**	**~ End of 4th Add./Rep. (for 4.3 years)**
HG Oxidation (@ APH outlet),(%)	**≥ 64**	**≥ 74**	**≥ 79**	**≥ 82**
Hg Removal w/o ACI (@ Stack),(%)	**≥ 61**	**≥ 70**	**≥ 75**	**≥ 78**
AC injection, # / MMACF	**6.2**	**4.3**	**3.4**	**2.8**
AC Cost / year	**$5,532,000**	**$3,868,000**	**$3,060,000**	**$2,520,000**
Differential Cost of TRAC , 1 Addition / Replacement	**$0**	**$200,000**	**$200,000**	**$200,000**
Cost of using AC and/or TRACover an eight (8) year period	**$44,256,000**	**$24,816,400**		

TRAC® Saves Approx. $19M in Operating Cost

TRAC® Economics for PRB Unit
- With FF Case -

Assumptions

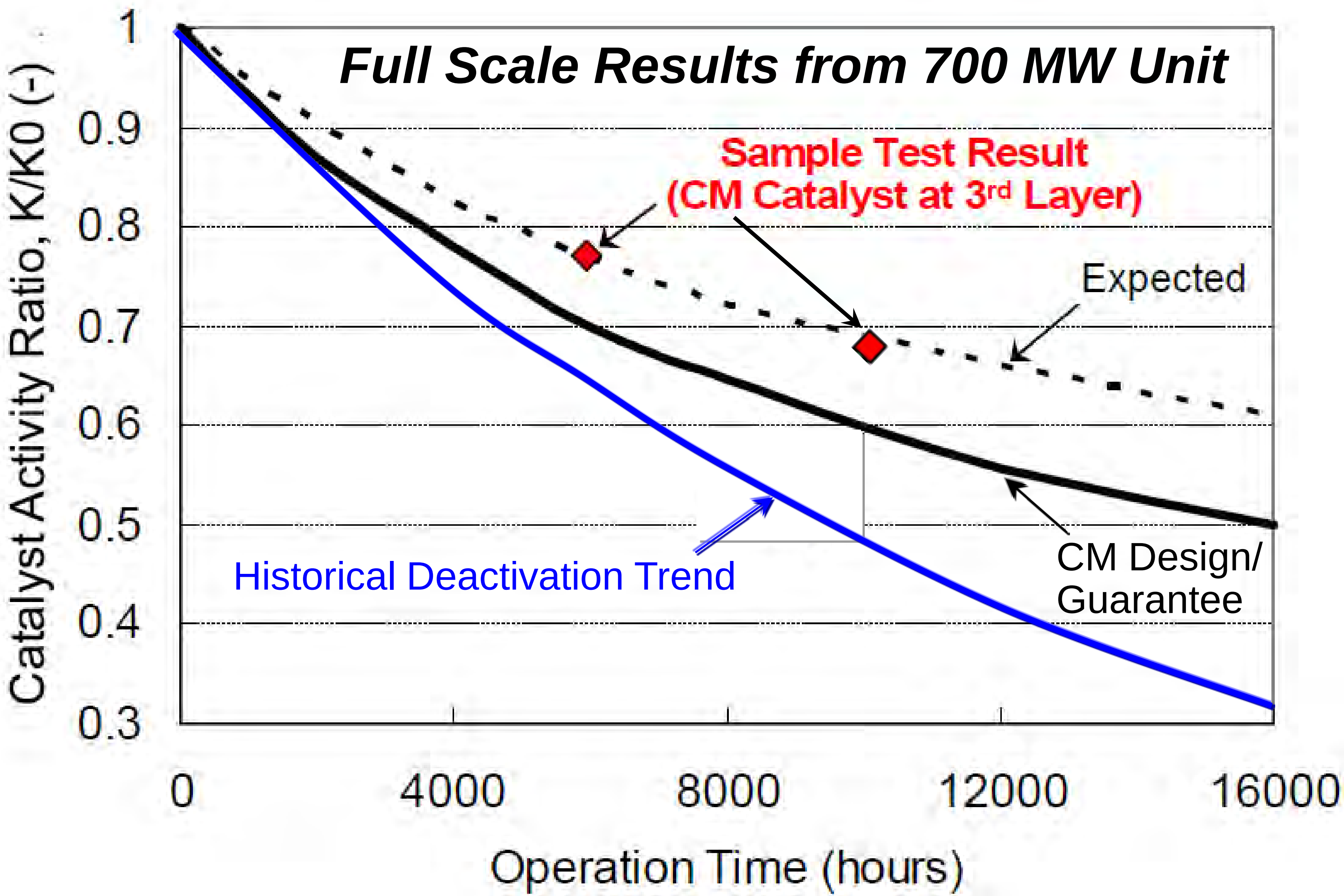
1) Required total Hg removal = 90%
2) AC (Untreated) cost = $0.50 / lb
3) Oxidized mercury removal across FF/ESP, WFGD = 95%
4) Hg Oxidation across APH = 50% of remaining elemental Hg

TRAC with FF **500 MW Plant**	**Non-TRAC® Addition**	**1 Layer of TRAC® Addition/Replacement**		
		~ End of 1st Add./Rep. (for 2.3 years)	**~ End of 2nd Add./Rep. (for 1.4 years)**	**~ End of 4th Add./Rep. (for 4.3 years)**
HG Oxidation (@ APH outlet),(%)	**≥ 64**	**≥ 74**	**≥ 79**	**≥ 82**
Hg Removal w/o ACI (@ Stack),(%)	**≥ 61**	**≥ 70**	**≥ 75**	**≥ 78**
AC injection, # / MMACF	**0.8**	**0.6**	**0.3**	**0.3**
AC Cost / year	**$748,000**	**$520,000**	**$296,000**	**$296,000**
Differential Cost of TRAC , 1 Addition / Replacement	**$0**	**$200,000**	**$200,000**	**$200,000**
Cost of using AC and/or TRACover an eight (8) year period	**$5,984,000**	**$3,683,200**		

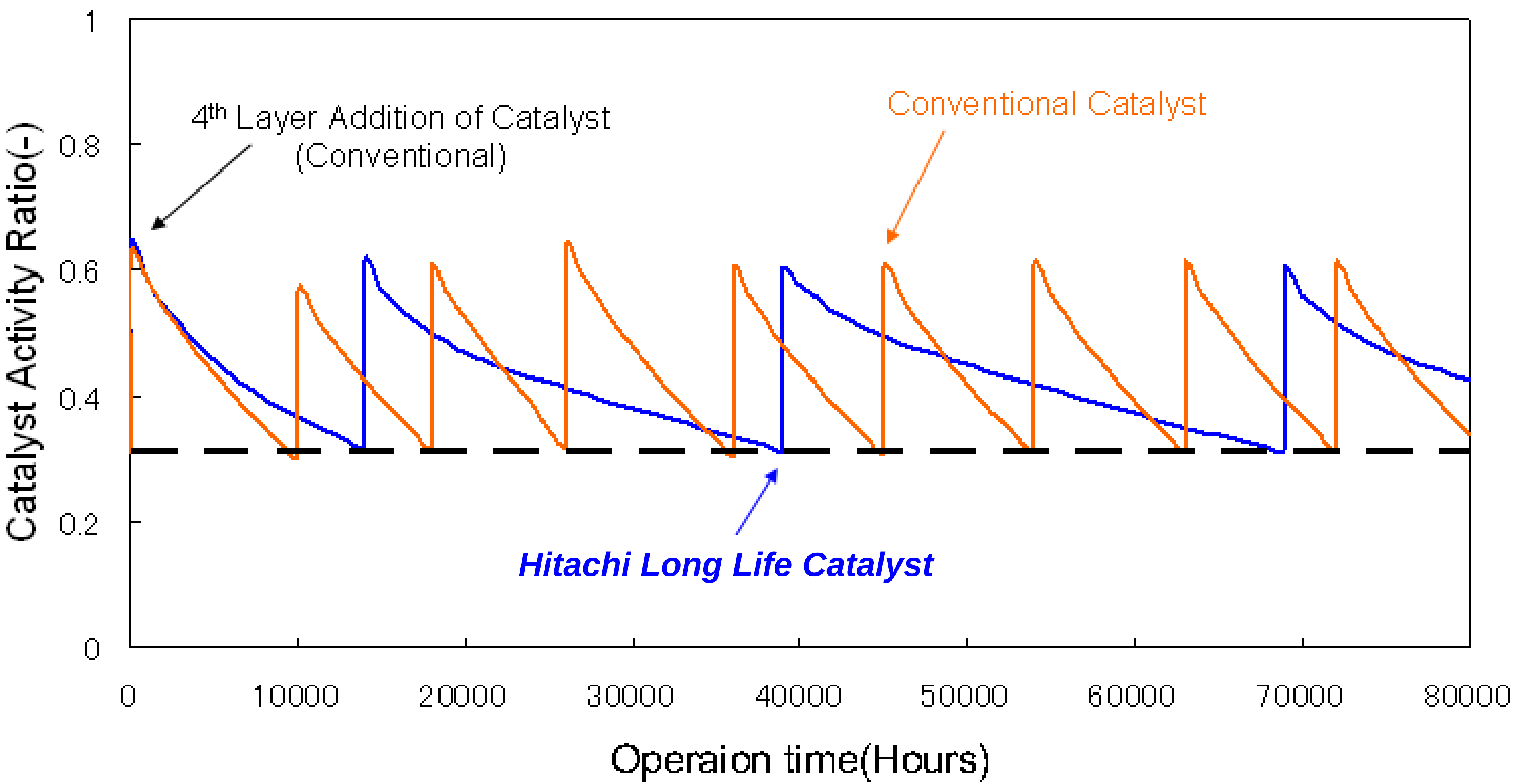
TRAC® Saves Approx. $2.3M in Operating Cost

Cost Impact of a Longer Life Catalyst

Slower Catalyst Deactivation Rate



Long Life Catalyst – CMP Economics – 700MW



Hitachi Catalyst Reduces 9 Catalyst Replacement Outages to 4

Long Life Catalyst – CMP Economics – 700MW

Hitachi Advanced Catalyst vs. Conventional and/or Regenerated Catalyst

Catalyst Type	Required number layers in next 10 years	Estimated Catalyst Material Cost (Per Layer)	Total Catalyst Material Cost (next 10 years)	Estimated Total Catalyst Loading Costs	10 Year Total Cost for Catalyst
Conventional Catalyst	9	$2,000,000	$18,000,000	$3,600,000 Assumes $400K / Layer	$21,600,000
Regenerated Catalyst	9	$1,200,000 Assumes 60% of New	$10,800,000	$3,600,000 Assumes $400K / Layer	$14,400,000
Hitachi	4	$2,000,000	$8,000,000	$1,600,000 Assumes $400K / Layer	$9,600,000

Hitachi Catalyst Saves $12M vs. Conventional Catalyst over a 10 year period

Hitachi Catalyst Saves $4.8M vs. Regenerated Catalyst over a 10 year period

Conclusions

- Actual Plant Applications have been tested and prove the following
    - TRAC® Achieves Higher Mercury Oxidation
    - TRAC® Maintains NOx Activity and SO2 Conversion Rate
    - TRAC® Deactivates Slower and Lasts Longer
- TRAC® Hg Oxidation Significantly Outperforms Conventional Catalyst in ALL Conditions
- For Eastern Bituminous Units, the Best Location for TRAC® is the Lower Layers
- For PRB Units, the Best Location for TRAC® is ANY Layer and the More the Better
- TRAC® Effectively Reduces Operating Costs by Lowering or Eliminating the Need for Sorbent Injection

For Units With Existing SCR and FGD Controls, TRAC® Is the MOST Economical MATS Compliance Strategy

MITSUBISHI HITACHI POWER SYSTEMS AMERICA – ENERGY AND ENVIRONMENT

Kyle Neidig
(330) 201 5459
kyle.neidig@psa.mhps.com

www.psa.mhps.com