

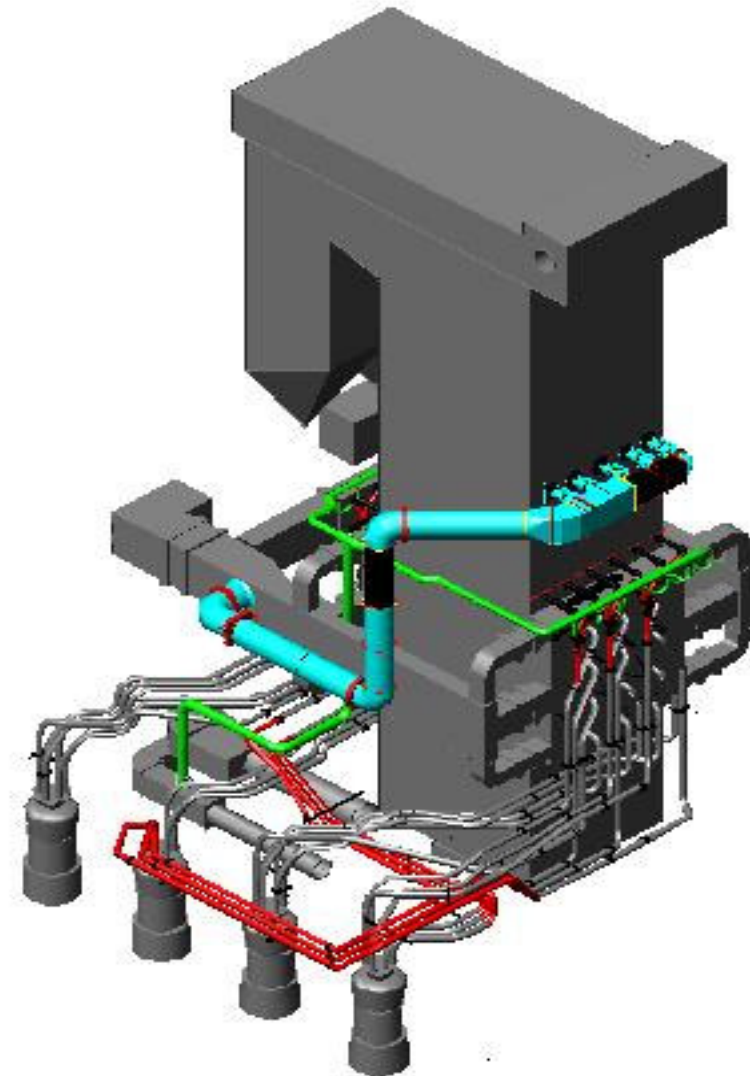
Integrated Cost-Effective Approach to Mercury Control

Bob Taylor
Director Engineering
GE Environmental Services

July 2005



imagination at work



Presentation Outline

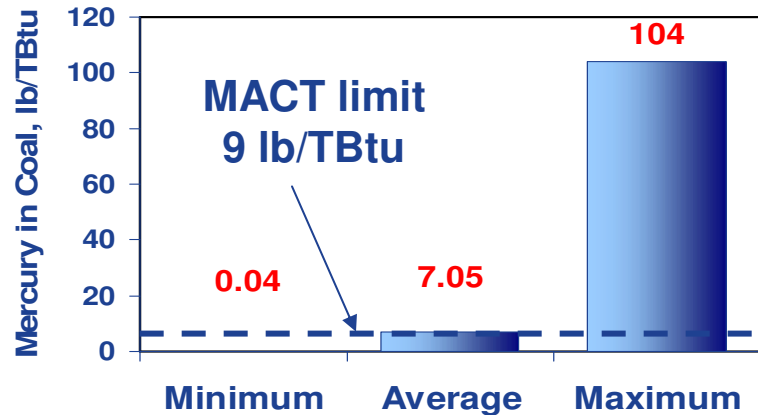
- Our objective is to present a variety of mercury control options.
- The combination of solutions implemented depends on plant specific criteria.
- Goal is to maximize use of existing equipment.
- Level of control can be adjusted to meet prevailing emission requirements.

US EPA Federal Regulations

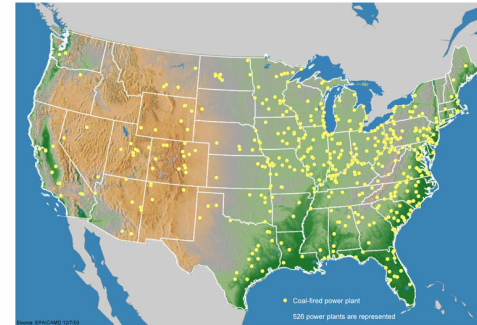
Mercury MACT for Industrial Sources

- Promulgated Sept 2004
- Impacted 2,500 industrial coal fired units
- September 2007 compliance
- Mercury MACT floor level: 9lb/TBtu
- Also impacts PM and HCl

Bituminous Coal (EPA data)



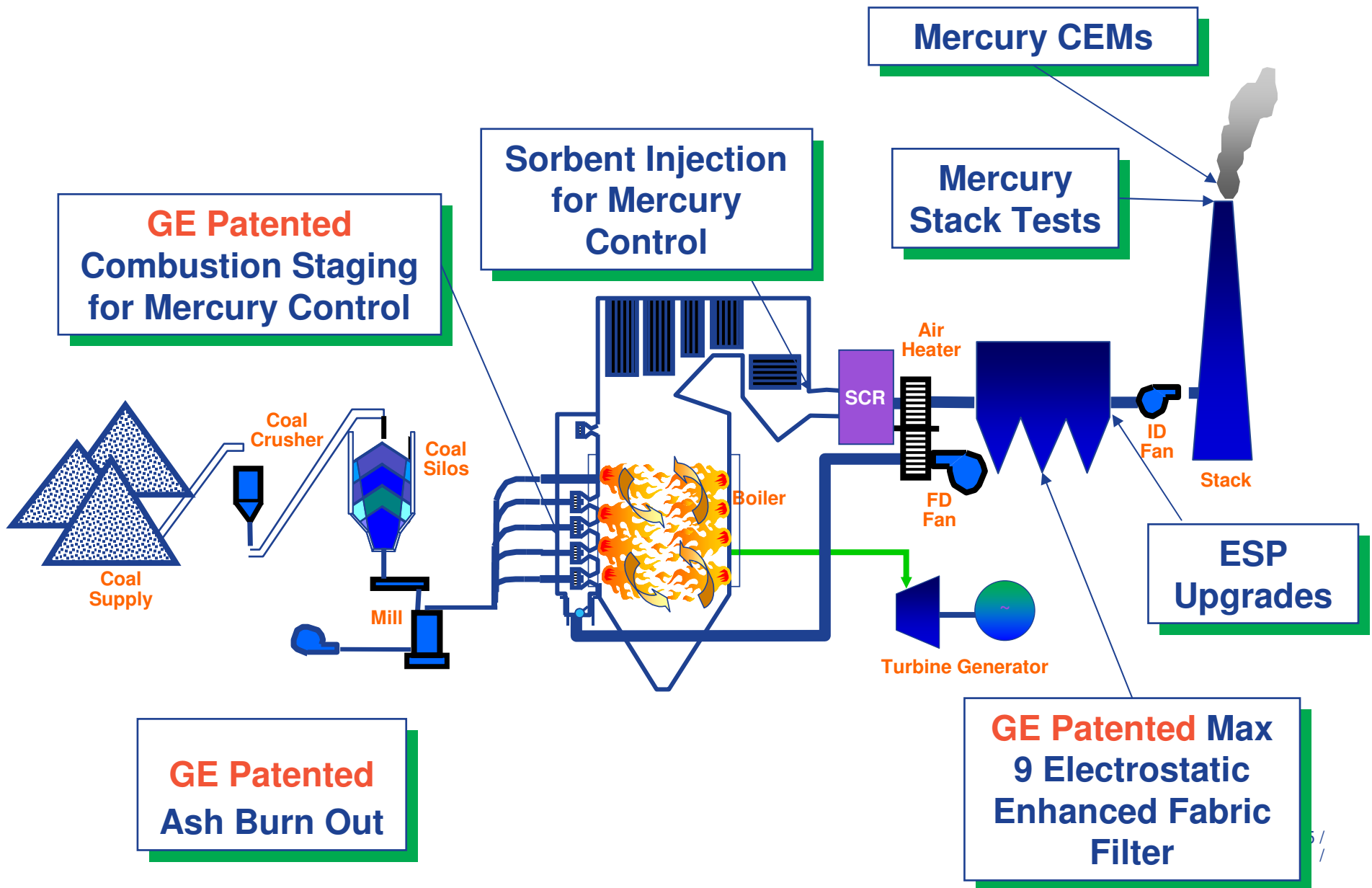
Clean Air Mercury Rule (CAMR)



U.S. Coal-Fired Power Plants

- Finalized March 2005
- Impacts ~500 Utility plants, 1500 units
- Integrated with CAIR
- Cap and trade provisions:
 - ✓ Baseline (1999 @ 48TPY Hg)
 - ✓ Cap #1 at 38TPY in 2010 (22%) – co-benefit of CAIR
 - ✓ Cap #2 at 15TPY in 2018 (70%)
- Mercury monitoring is required by 2009

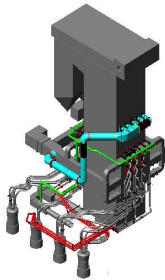
GE Integrated Mercury Solution



Flexible & Cost-Effective Control Solutions

Engineered system upgrades with guaranteed results for....

NO_x
SO_x



Technologies

- Tailored Layered Solutions
- “Matched” Turbine Upgrades

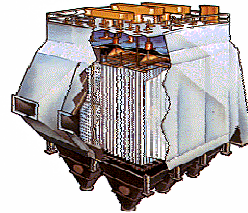
Life cycle benefits & services

- 0.10 lb/MMBtu at 50% of SCR cost
- Improved heat rate & flexibility

GE Technology Synergies

- Integrated GE sorbents additives
- Sorbent Injection for SO_x trim
- GE sensors, software & controls enable self tuning system

PM



Technologies

- ESP Control Upgrades
- Max 9 ESFF

Life cycle benefits & services

- Low Cost PM reduction
- Extend filter interval - 3 to 5 years

GE Technology Synergies

- Address PM impacts of NO_x control
- PM monitoring CEMS

Hg



Technologies

- GE Patented Comb+PM Solutions
- Integrated Sorbent Trim

Life cycle benefits & services

- 90% Hg Control
- 20% lower cost than ACI

GE Technology Synergies

- Mercury CEMS
- Multi-pollutant (PM, NO_x, Hg)

GE pilot-scale combustor

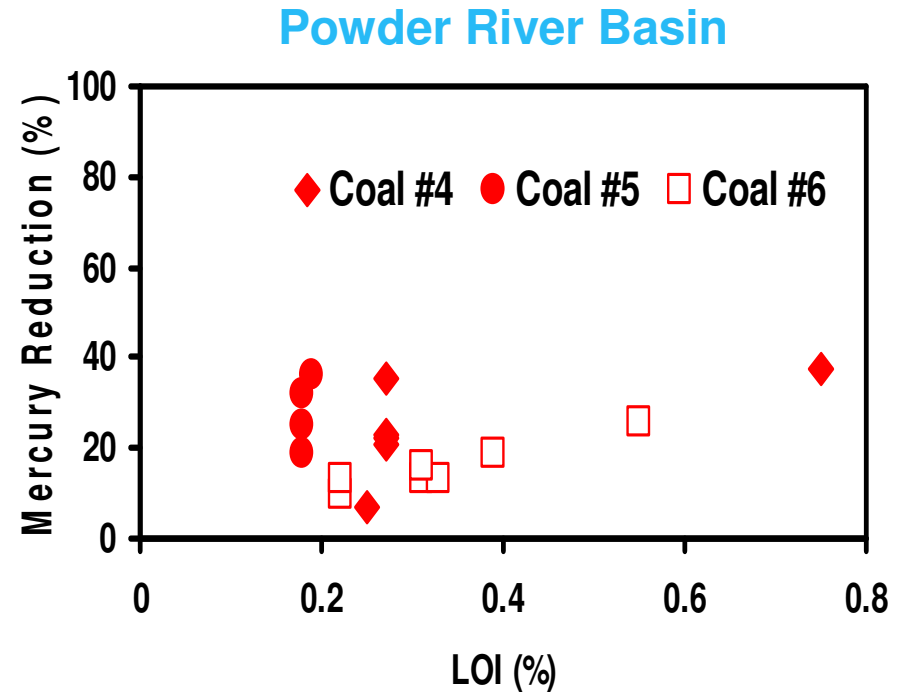
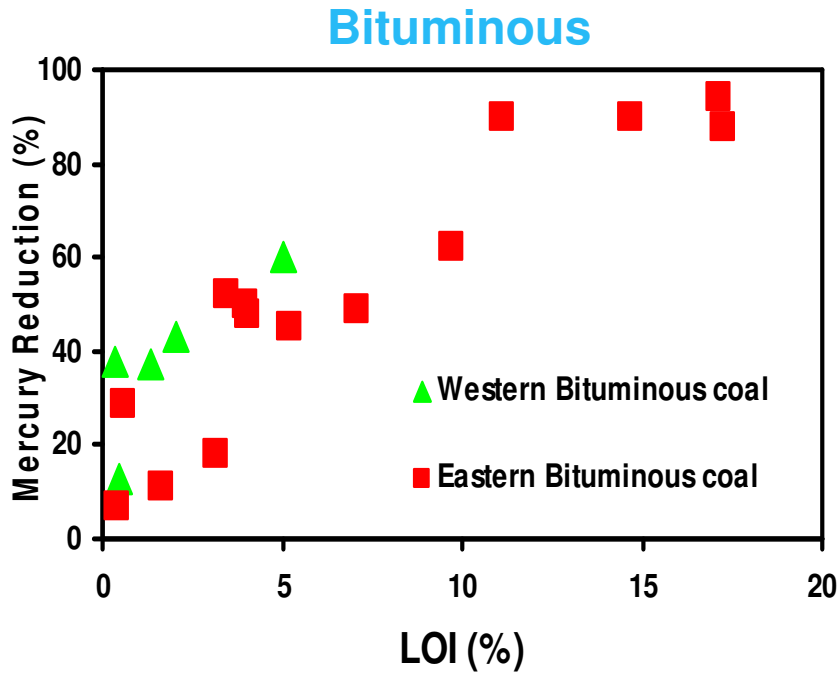
- Boiler Simulator Facility
(1×10^6 Btu/hr, 300kW)
- Simulation of combustion conditions and time-temperature profile in full-scale utility boiler
- Test variables include combustion conditions, coal type and blending, particulate control conditions
- Continuous mercury measurements



Composition of some tested coals

Coal Type		Bituminous			PRB			Lignite			
Fuel Name		1	2	3	4	5	6	7	8	9	10
Ultimate Analysis	Units										
C	wt%	66.94	72.40	66.54	55.95	58.25	52.74	50.40	50.35	39.4	47.75
H	wt%	4.74	4.20	4.90	3.49	3.56	4.00	3.39	3.89	2.89	3.2
N	wt%	1.32	1.21	1.07	0.77	0.86	0.75	0.77	0.84	0.7	0.85
S	wt%	0.63	1.22	0.54	0.30	0.36	0.52	0.72	0.68	0.58	0.71
Ash	wt%	7.17	10.85	7.11	6.16	6.39	5.74	13.28	10.54	31.53	19.87
O	wt%	10.52	7.02	12.18	13.13	13.74	12.61	14.35	12.38	10.83	11.93
H ₂ O	wt%	8.68	3.10	7.66	20.20	16.84	23.64	17.09	21.32	14.07	15.69
Wet HV	Btu/lb	11,806	12,390	11,494	9,495	9,803	9,075	8,530	8,588	6,656	8,123
Volatiles	wt%	46.44	33.78	51.70	46.66	46.31	47.71	49.25	50.44	57.1	54.22
Fixed C	wt%	53.56	66.22	48.30	53.34	53.69	52.29	50.75	49.56	42.9	45.78
CaO	wt% dry	4.71	1.47	26.94	19.32	21.39	21.92	17.03	17.29	5.77	5.87
Na ₂ O in ash	wt% dry	1.71	0.33	0.39	1.40	1.49	1.57	3.44	0.59	0.29	0.31
Cl in coal	wt%dry	0.018	0.12	0.0038	0.004	0.01	0.005	0.006	0.0039	0.0043	0.0029
Hg in coal	ppb	45	240	30	60	110	80	53	159	235	385

Coal Type Impacts Mercury Characteristics



- ❑ Higher Cl content in Bituminous coal
- ❑ Bituminous coals generate higher LOI fly ash
- ❑ Extent of mercury oxidation is more significant for Bituminous coals

Mercury control for bituminous coal

Enhancement of naturally occurring mercury removal and oxidation on fly ash

- carbon in fly ash is an effective mercury sorbent and can be enhanced with combustion modification, e.g.
 - Separated Overfire Air (SOFA)
 - Coal Reburn
- mercury removal on particles more effective $T < 300\text{F}$

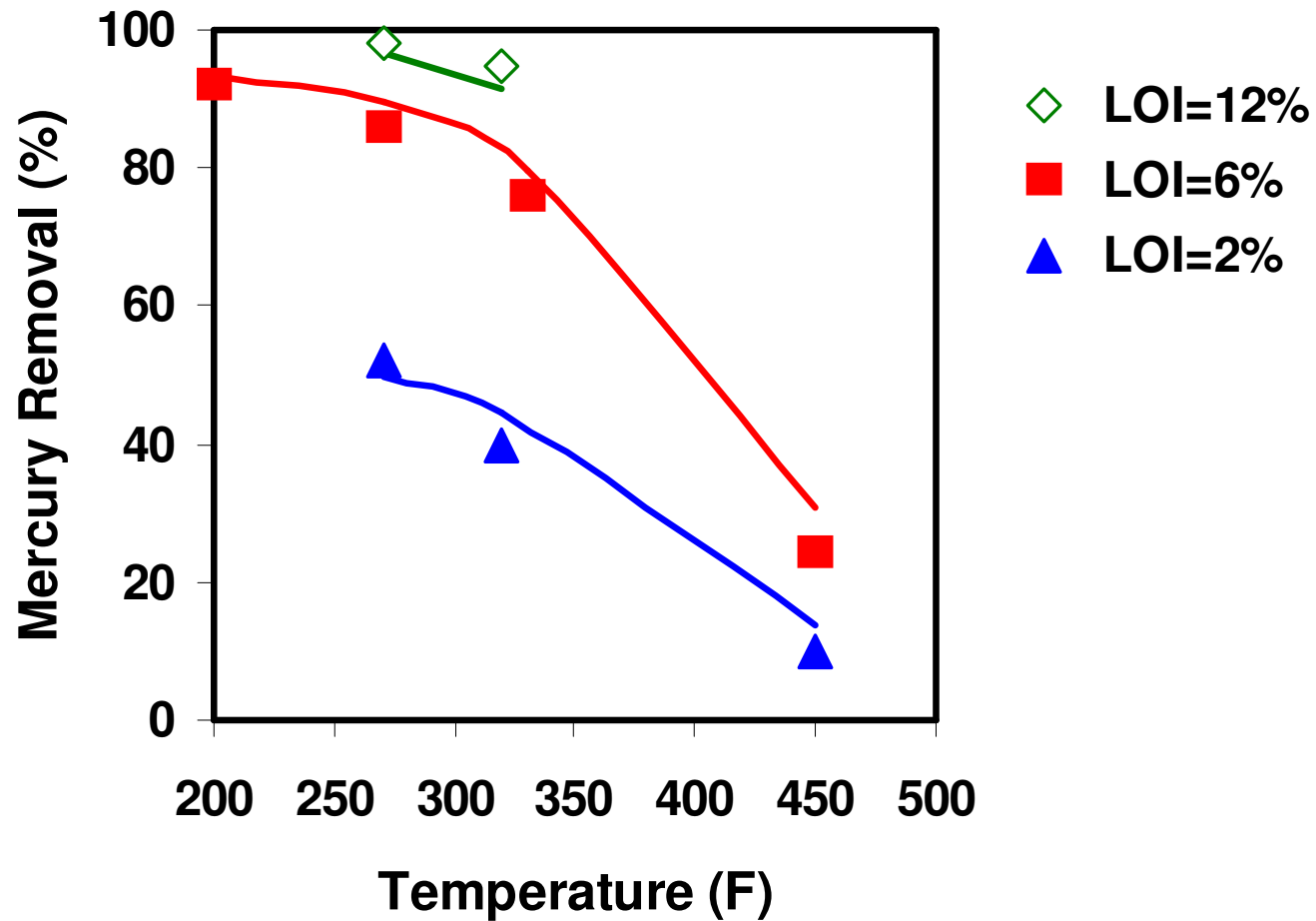
Activated carbon injection to trim mercury emissions

- upstream of particulate removal device
- integrated with Fabric Filter, ESP, or “Max 9”

Mercury Management System (GE Patented)

- Deep staging and ash burnout to manage mercury

Effects of LOI and temperature: bituminous coal



Effects of LOI and ESP temperature – BSF Data

Mercury reduction in coal reburn

DOE NETL/GE Cooperative Agreement

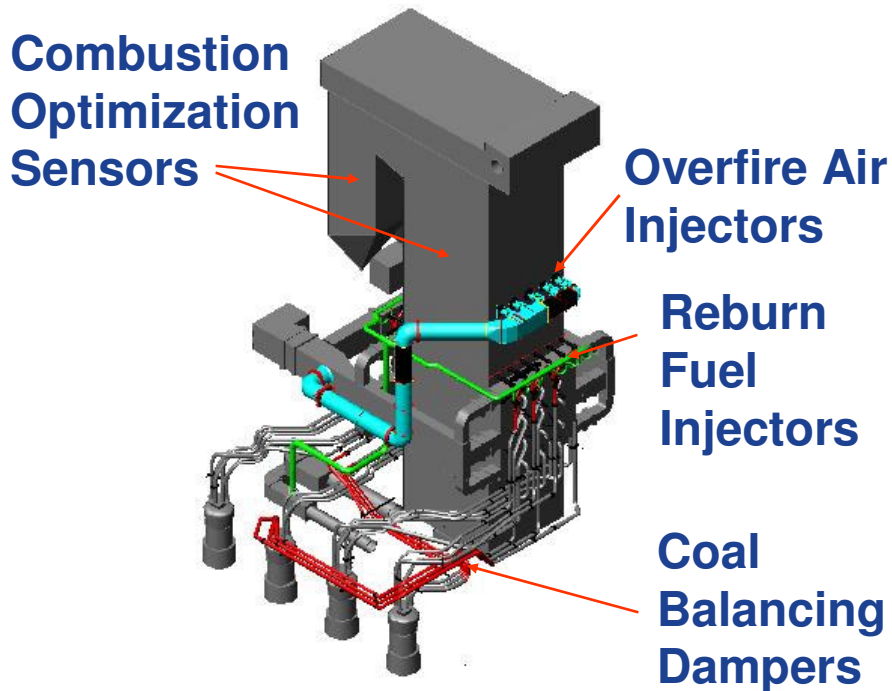
Western Kentucky Energy Green Unit in Henderson KY

- 250 MW
- Mix of Bituminous Coals
- Utility Boiler

Goals

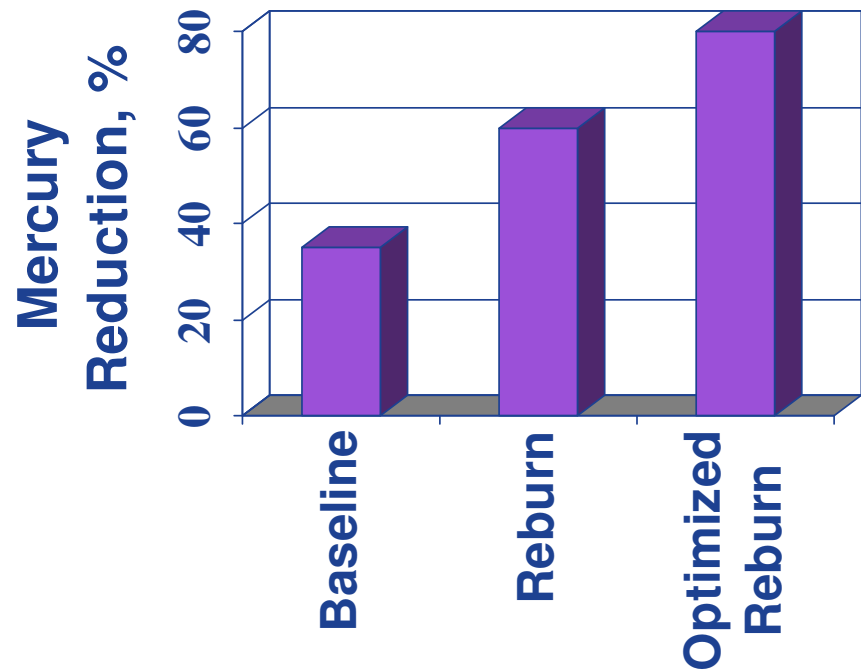
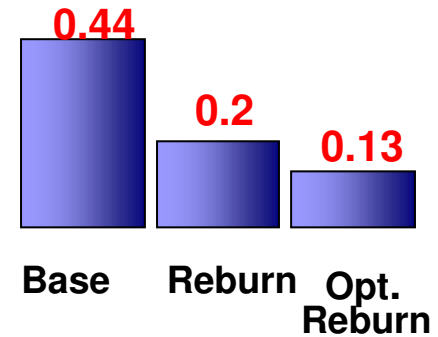
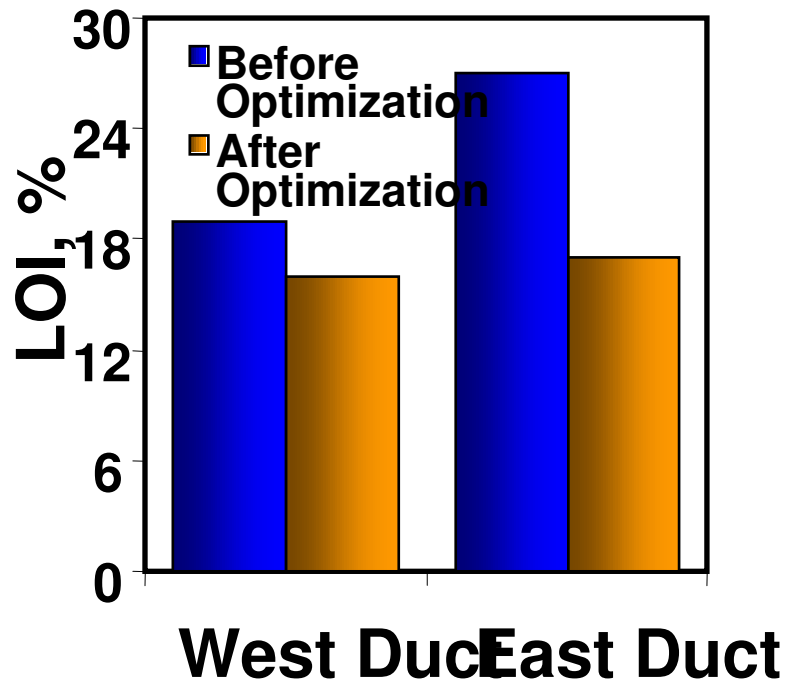
- 80% Hg removal
- NO_x reduction from 0.42 lb/MMBtu to < 0.20 lb/MMBtu

GE Solution: Design/Supply Coal Reburn, Advanced Combustion Sensors, Coal Balancing Dampers



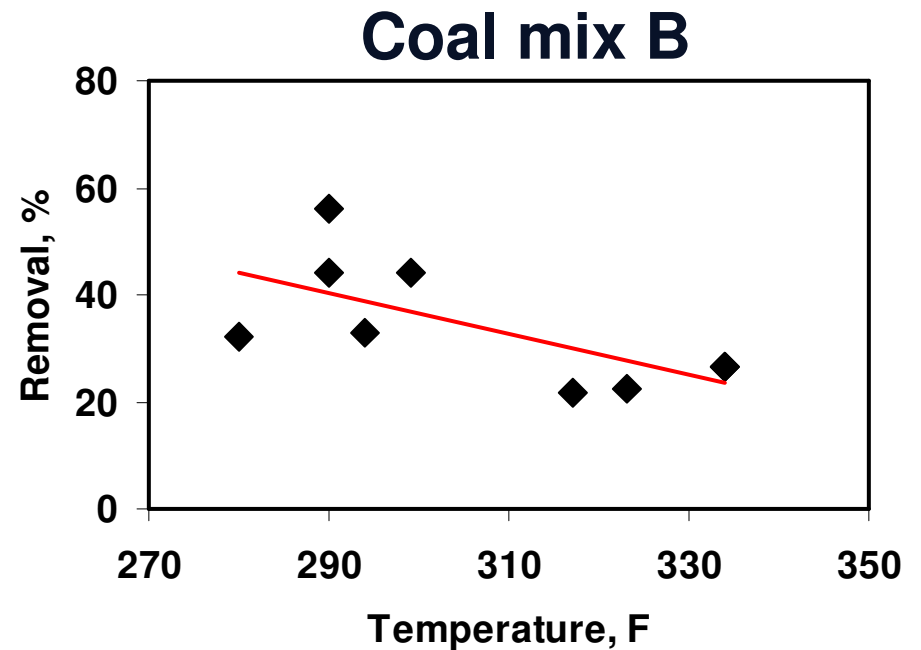
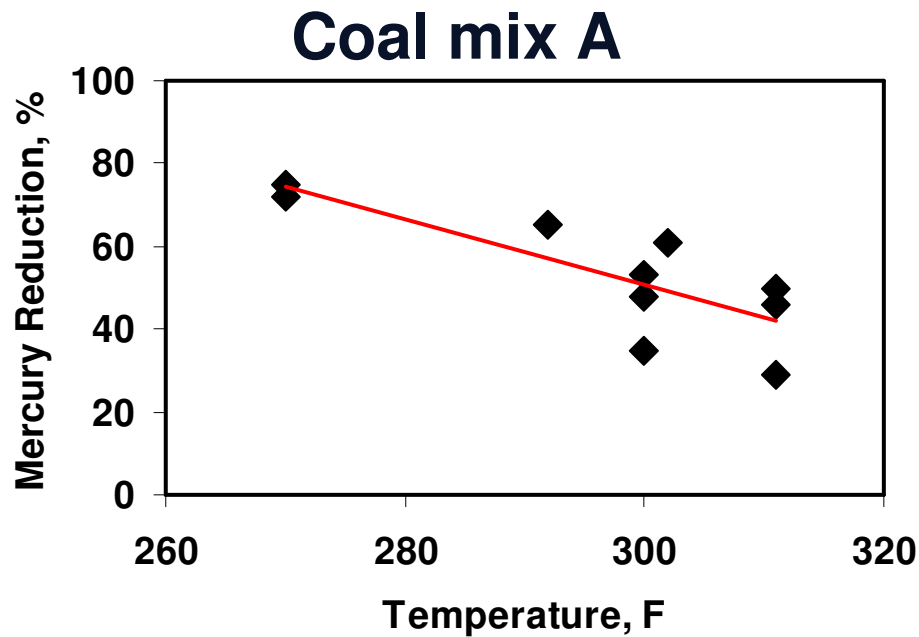
Field trials at Green station

NO_x, Ib/MBtu



Zonal Combustion Tuning reduces NO_x and mercury

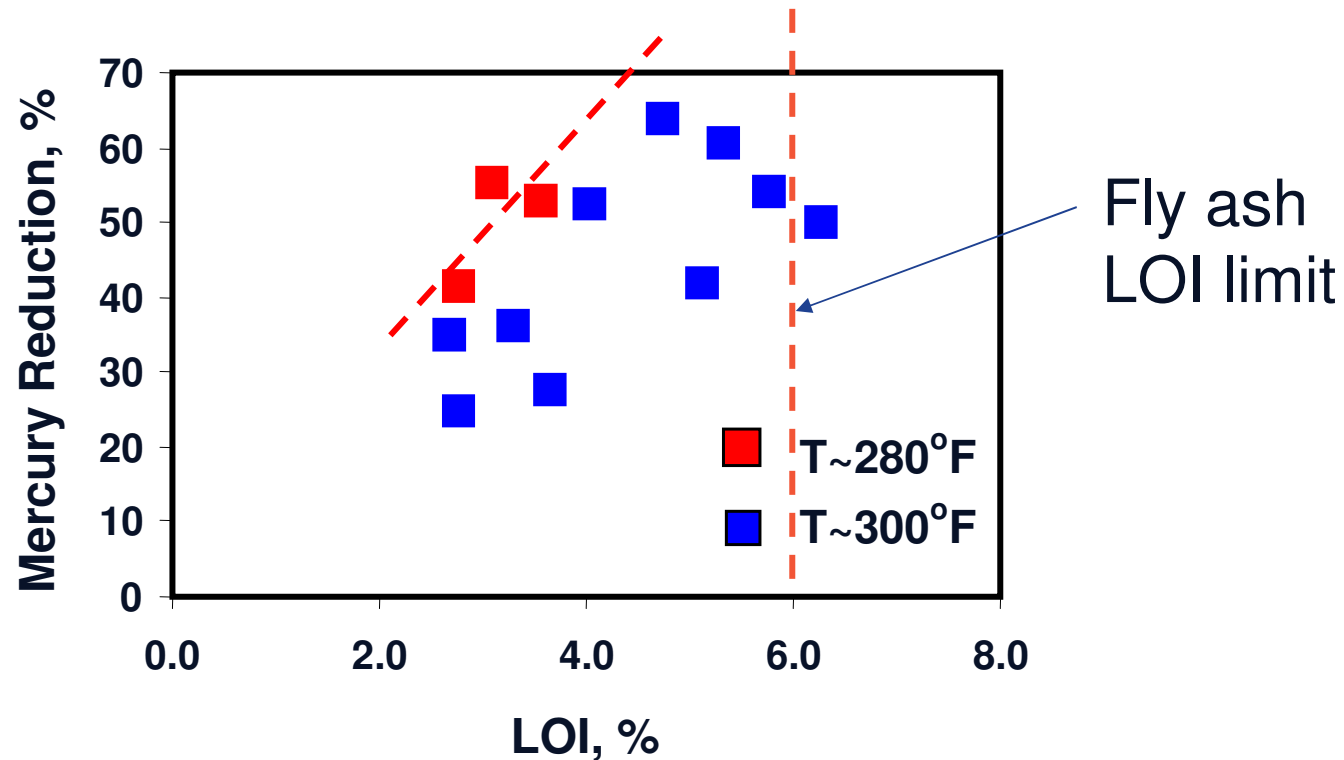
Effect of ESP temperature on mercury removal



Decreasing ESP temperature improves mercury removal

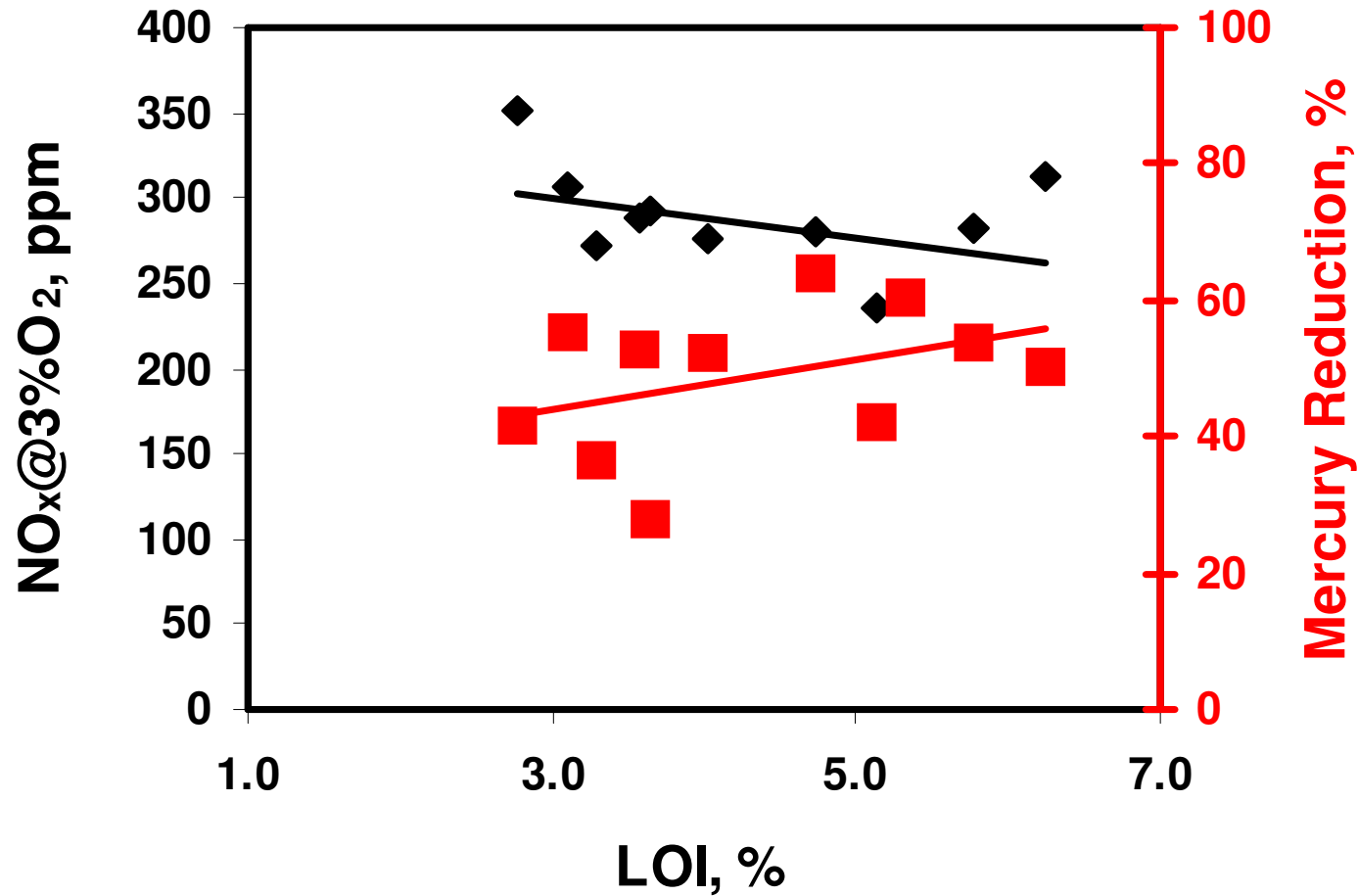
Mercury reduction in air staging

- Dual furnace 200 MW t-fired unit equipped with SOFA
- Low sulfur bituminous coal
- c-s ESP
- Carbon tubes (EPA method 324)
- ESP inlet and outlet



Mercury removal increases with LOI increase
Decreasing temperature improves mercury removal

Mercury and NO_x emissions (SOFA)



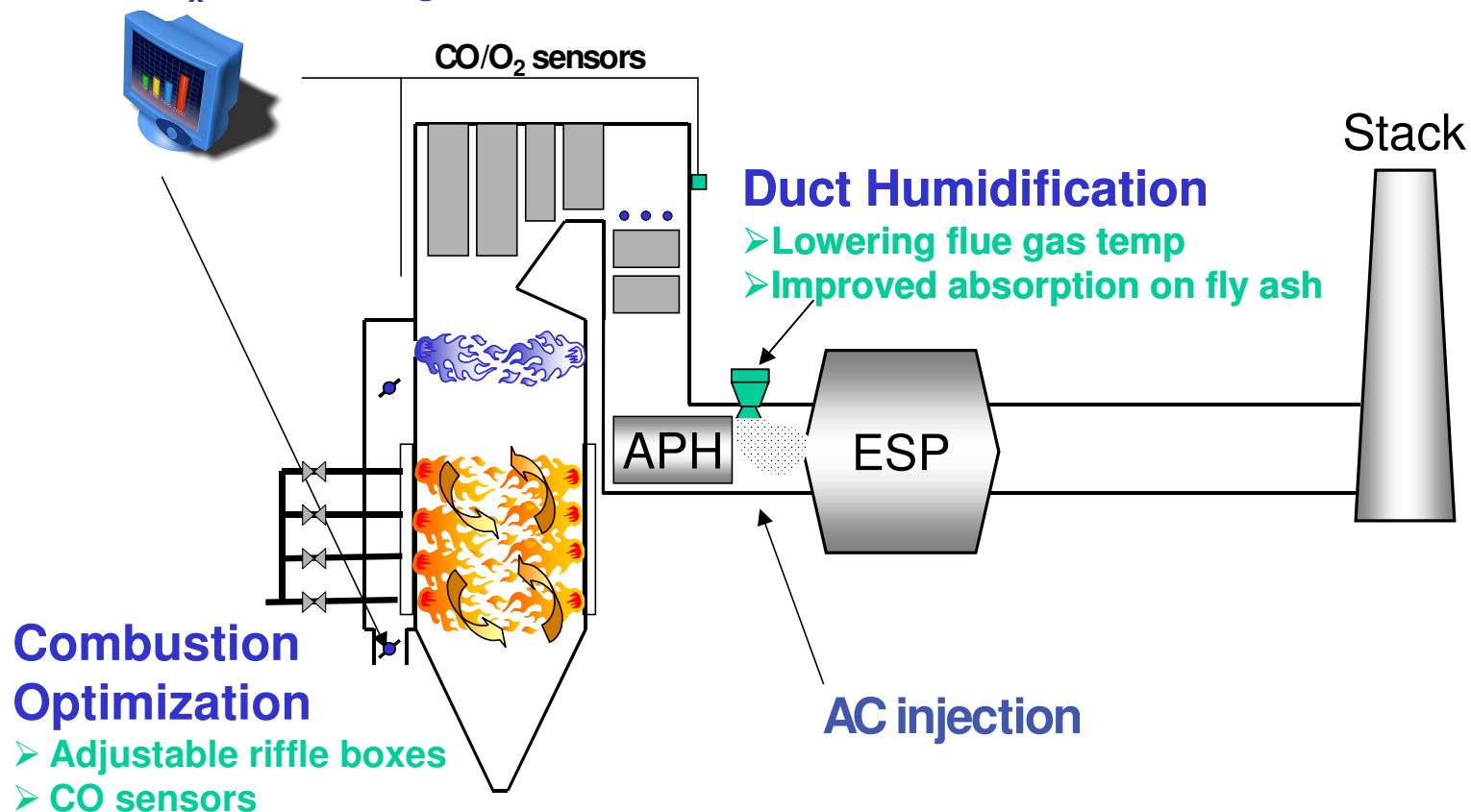
GE, DOE, Progress Energy Cooperation

Program Objectives

- Enhance “natural” Hg capture on fly ash by 50-70% over current baseline
- Demonstration of 90% Hg control
- Improved Unit 3 combustion performance
- Reduced NO_x, PM and Hg emission

Site Description

- Lee Station unit 3
- 250 MW wall-fired
- Eastern Bituminous coal
- Cold-side ESP



Mercury control for low-rank coal

Enhancement of mercury oxidation on fly ash

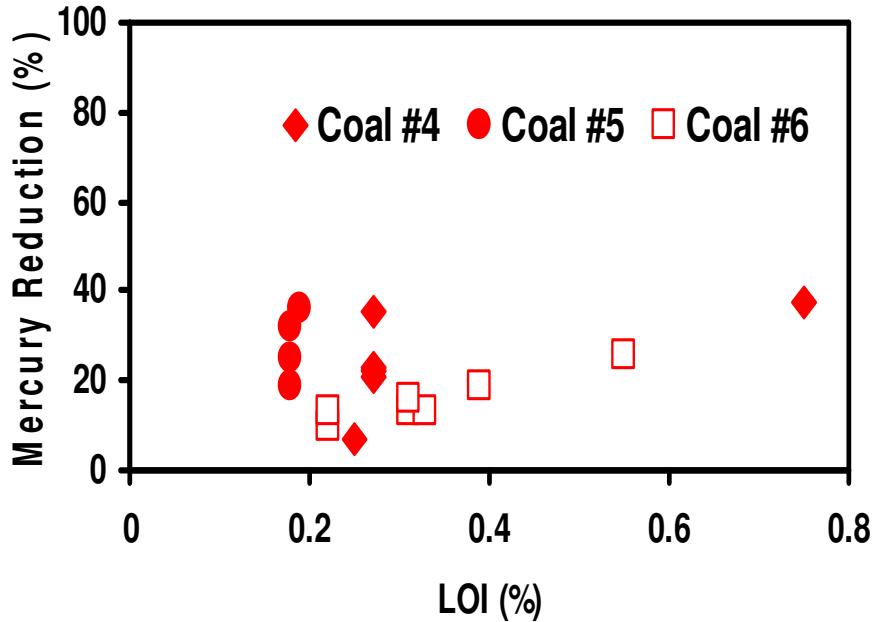
- carbon in fly ash can catalyze mercury oxidation
 - carbon content increases under staging conditions
 - fly ash surface area increases under staging conditions
- Coal blending
 - Increase carbon in ash content
 - Increase Cl concentration
- Oxidizing additives
 - Halogen containing
 - $\text{H}_2\text{O}_2/\text{CH}_3\text{OH}$

Activated carbon injection to trim mercury emissions

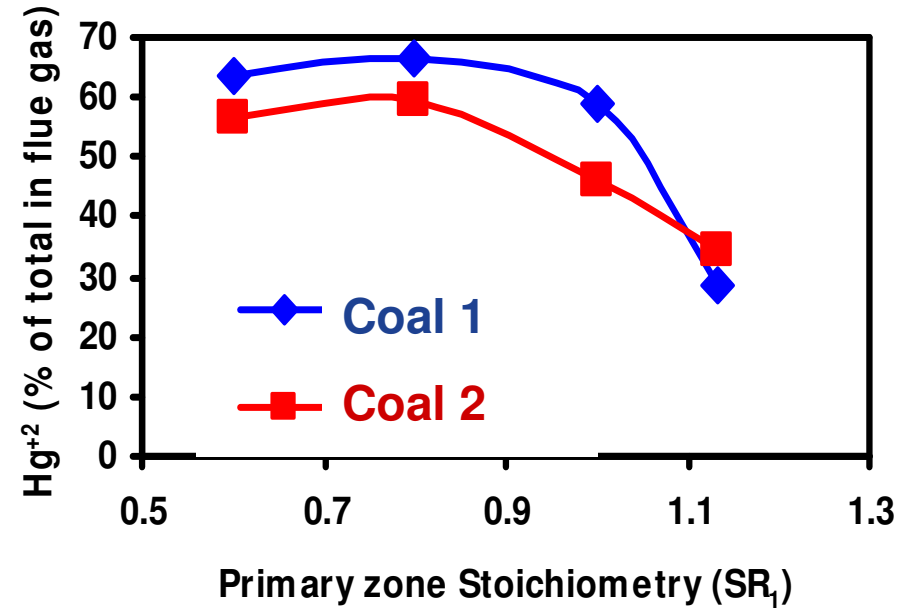
- promoted and un-promoted sorbents
- upstream of particulate removal device
- integrated with Fabric Filter, ESP, or “Max 9”

PRB: mercury removal in air staging (SOFA)

Mercury removal on fly ash in ESP



Effect of SOFA on Hg oxidation



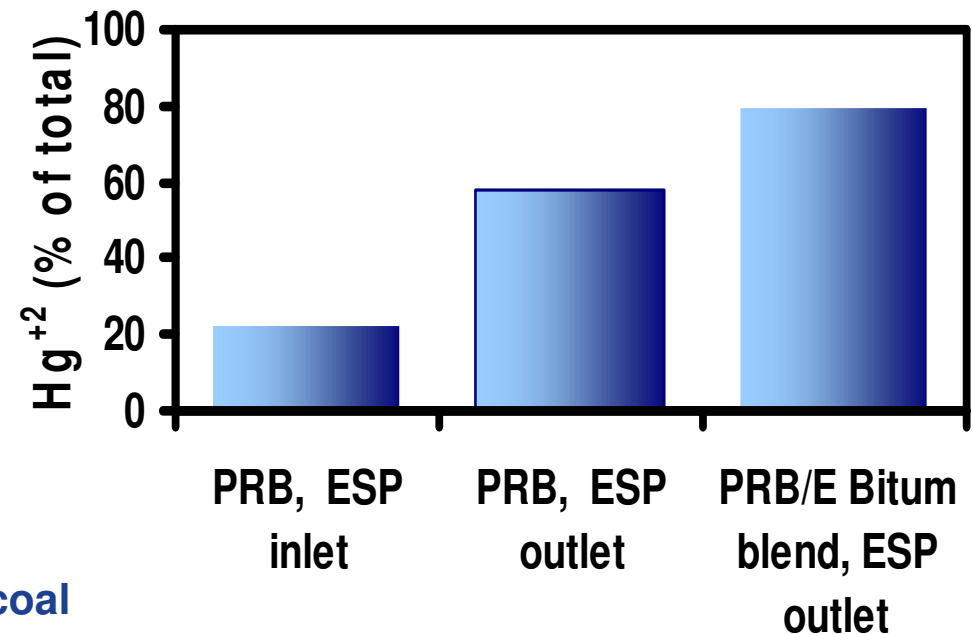
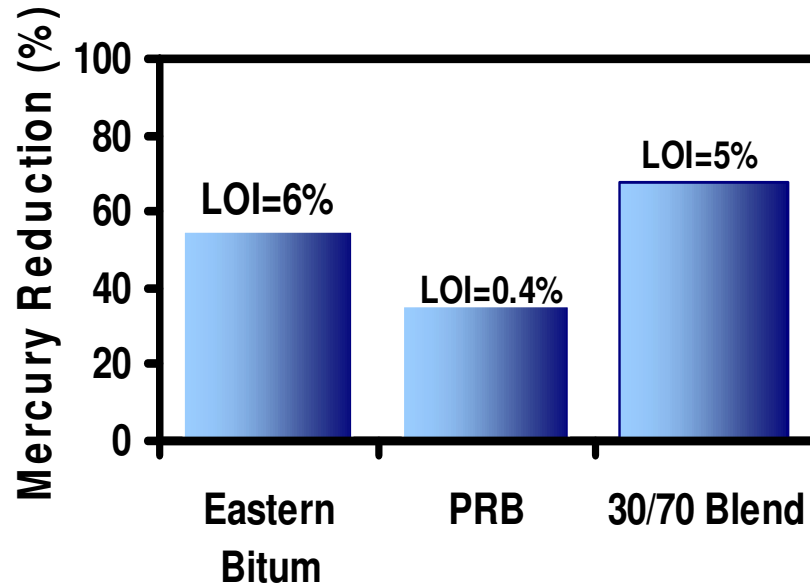
- ❑ 20-30% mercury removal in air staging
- ❑ Improvement in Hg oxidation under deep staging

Boiler Simulation Facility data

Blending PRB with Eastern Bituminous Coal

70PRB / 30 Eastern Bituminous

Mercury Speciation



Eastern Bituminous coal – low reactivity coal with high Cl content

Blending improves Hg removal and catalyzes Hg oxidation

Basic overview of Max-9

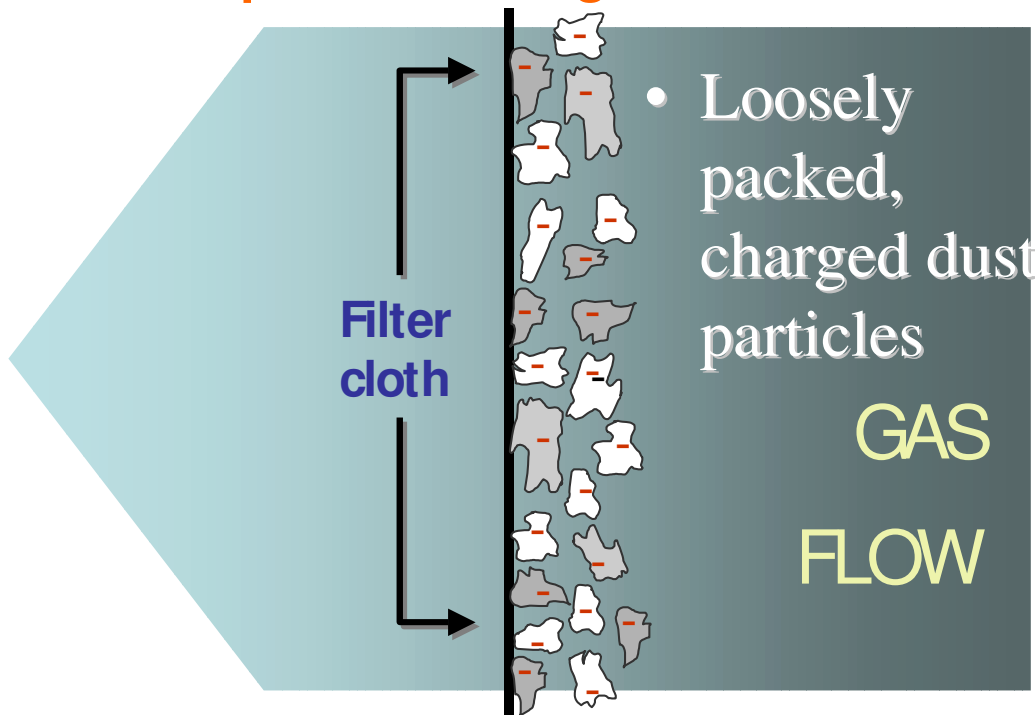
Max-9 is a dust collection technology combining

Discharge Electrodes and Fabric Filters

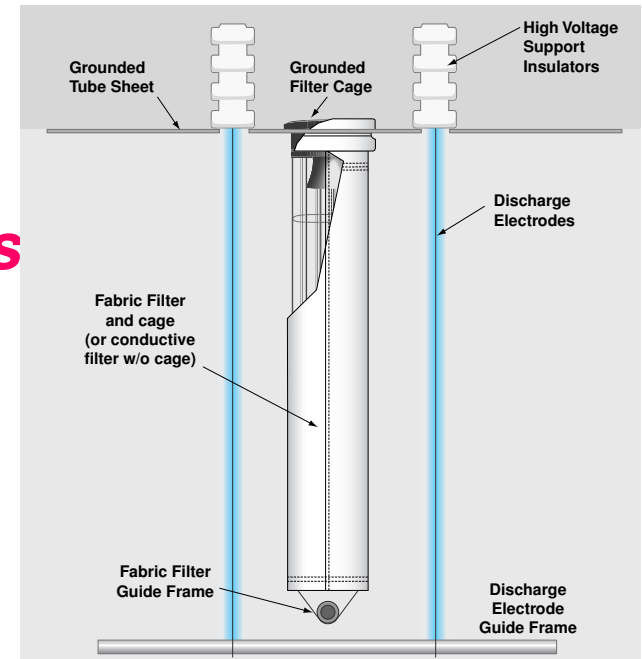
60-80% reduction in pressure drop

>90% reduction in particles below 1 micron

Allows operation at high air-to-cloth ratio



Typical MAX-9 Arrangement



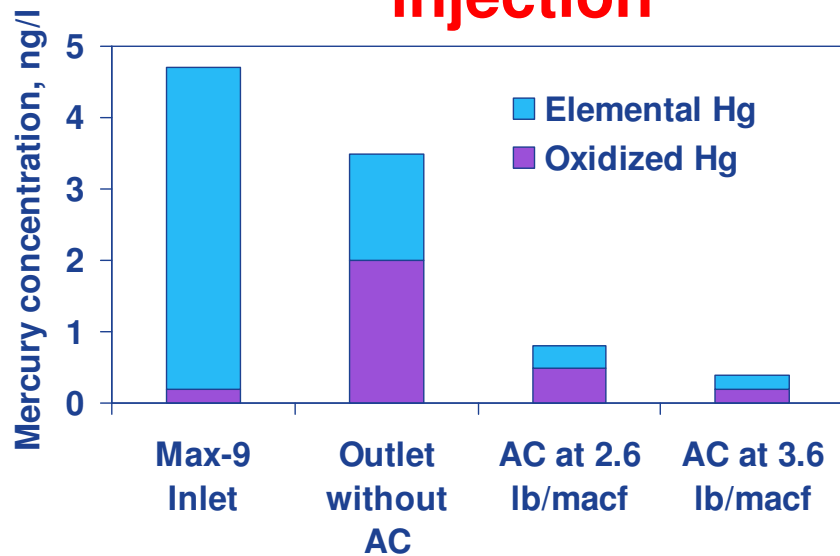
Top view of MAX-9



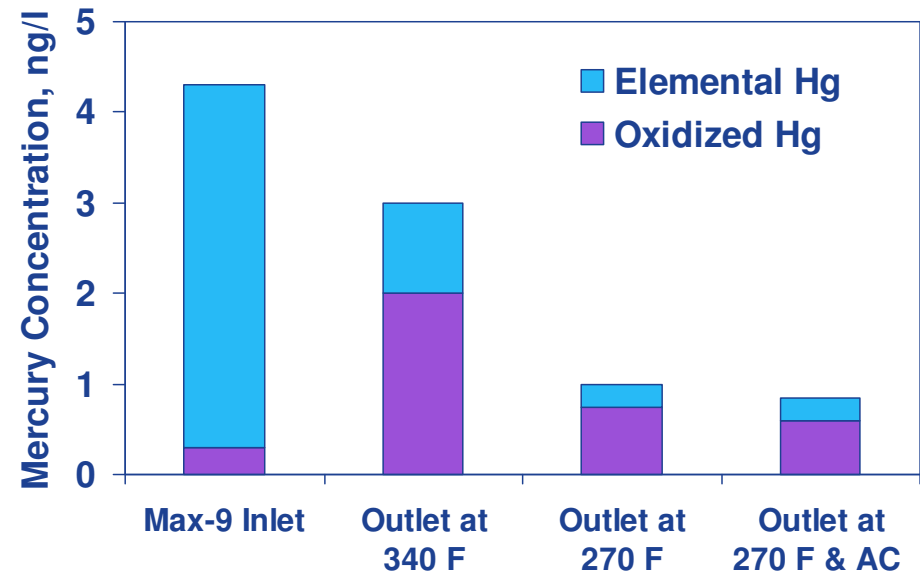
Max-9 performance

- Alabama Power - Miller
- 5,000 acfm
- PRB coal, LOI < 1%

Effect of Activated Carbon injection

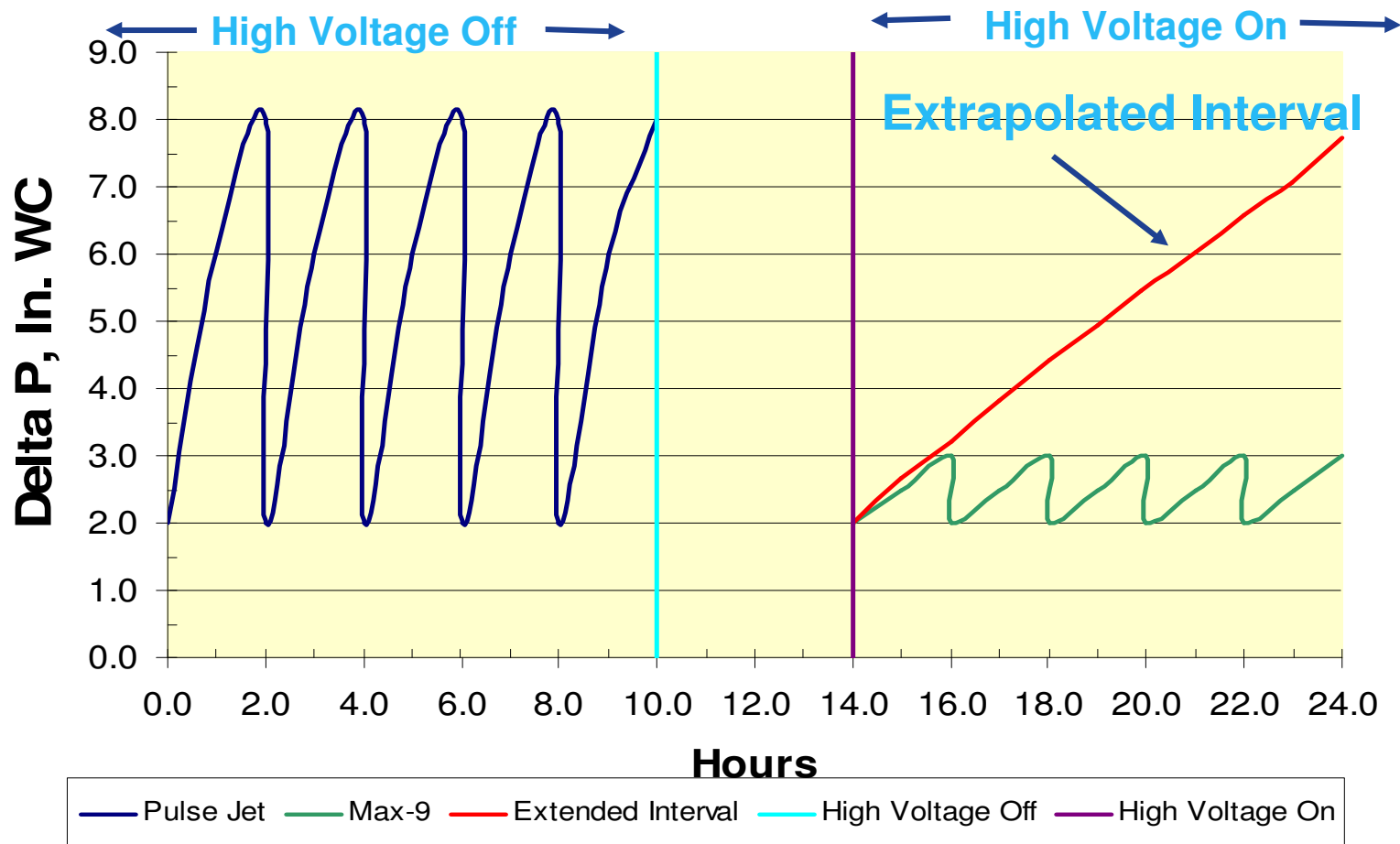


Effect of temperature



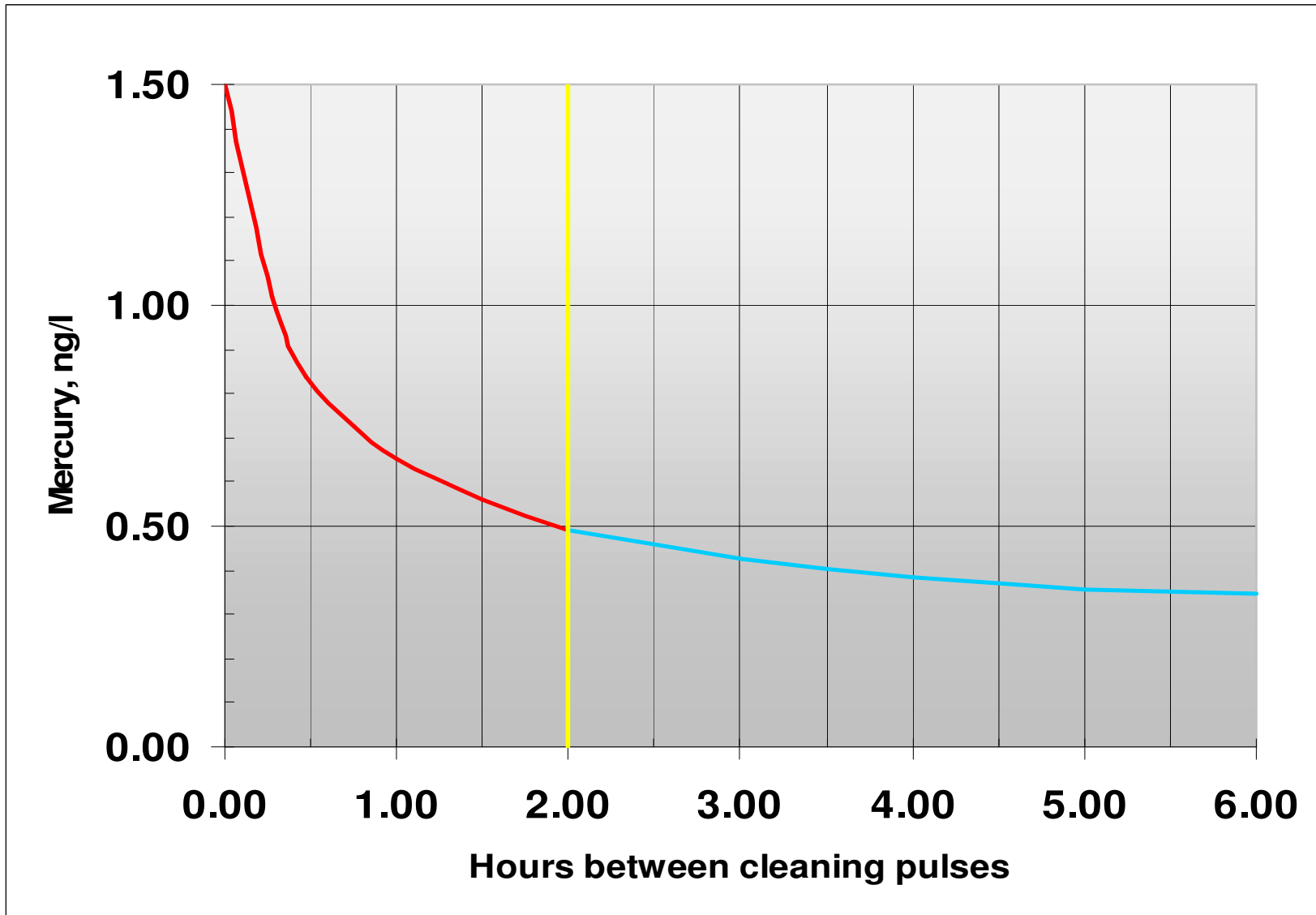
- More than 90% mercury removal with activated carbon injection
- Lowering Max-9 temperature improves mercury removal even with very low carbon in ash

Max-9 Reduced Pressure Drop



- Longer time between cleaning cycles
- Lower operating cost
- Higher efficiency of mercury reduction

Mercury versus Cleaning Interval



GE technology offering matrix

		Technology Elements						
		Staging with Zonal Combustion Tuning	Duct Humidification (lowering PCD temperature)	Coal Blending	Oxidizing Additive	Carbon Trim	ESP Upgrade	Max 9
Combustion Configuration	Bituminous with wet scrubber (FF or ESP)	Needed	Potentially can be applied	Not needed	Not needed	Not needed	Not needed	Not needed
	Bituminous coal with FF	Needed	Potentially can be applied	Not needed	Not needed	Potentially can be applied	Potentially can be applied	Not needed
	Bituminous coal with ESP	Needed	Needed	Not needed	Not needed	Potentially can be applied	Potentially can be applied	Potentially can be applied
	Low-rank with scrubber	Needed	Potentially can be applied	Needed	Needed	Potentially can be applied	Potentially can be applied	Potentially can be applied
	Low-rank without scrubber	Needed	Potentially can be applied	Needed	Needed	Needed	Needed	Potentially can be applied

Needed	Potentially can be applied	Not needed
--------	----------------------------	------------

Summary

- **Integration of proven technologies to meet emission performance objectives.**
- **Solution is tailored to plant configuration.**
- **Take maximum advantage of existing equipment**
- **Patented and Proprietary Technology – Monitoring, combustion staging, additive trim techniques and Max 9 for deep mercury control**
- **Implement technologies to “ratchet” down to meet future regulations**
- **Continuous Emissions Monitoring of mercury for compliance and emissions trading**
- **Integrated approach can reduce NOx, PM and Mercury emissions**