Reinhold Environmental Ltd.

2009 APC Round Table & Expo Presentation

July 12-14, 2009, in The Woodlands, TX

Options for Hg Removal for Units with PRB and FF's

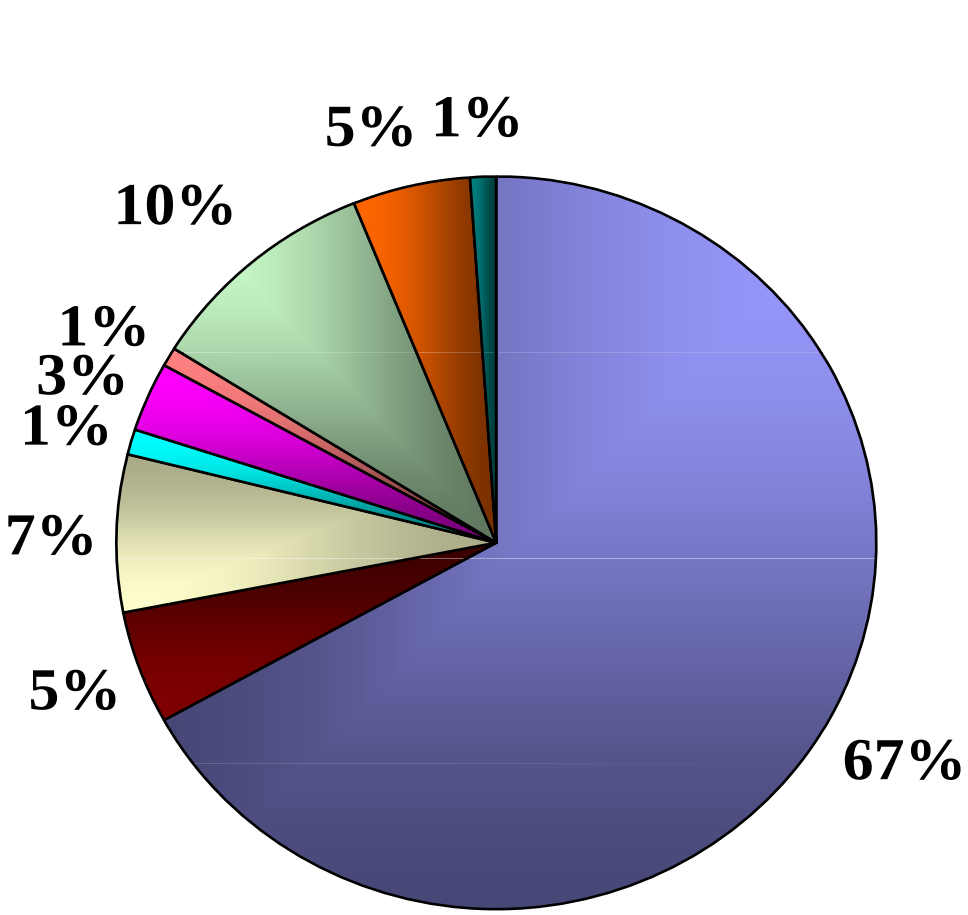
Bryan J. Jankura
(bjankura@babcock.com)

The Babcock and Wilcox Co.

Presentation Overview

- Why mercury is regulated
- Background on Mercury Control
- Industry Challenges
- Mercury Removal Tools
- Field Test Results for Sub-Bituminous Coal
- Operating Costs for Hg Removal

Global Man-made Sources of Mercury in the Environment

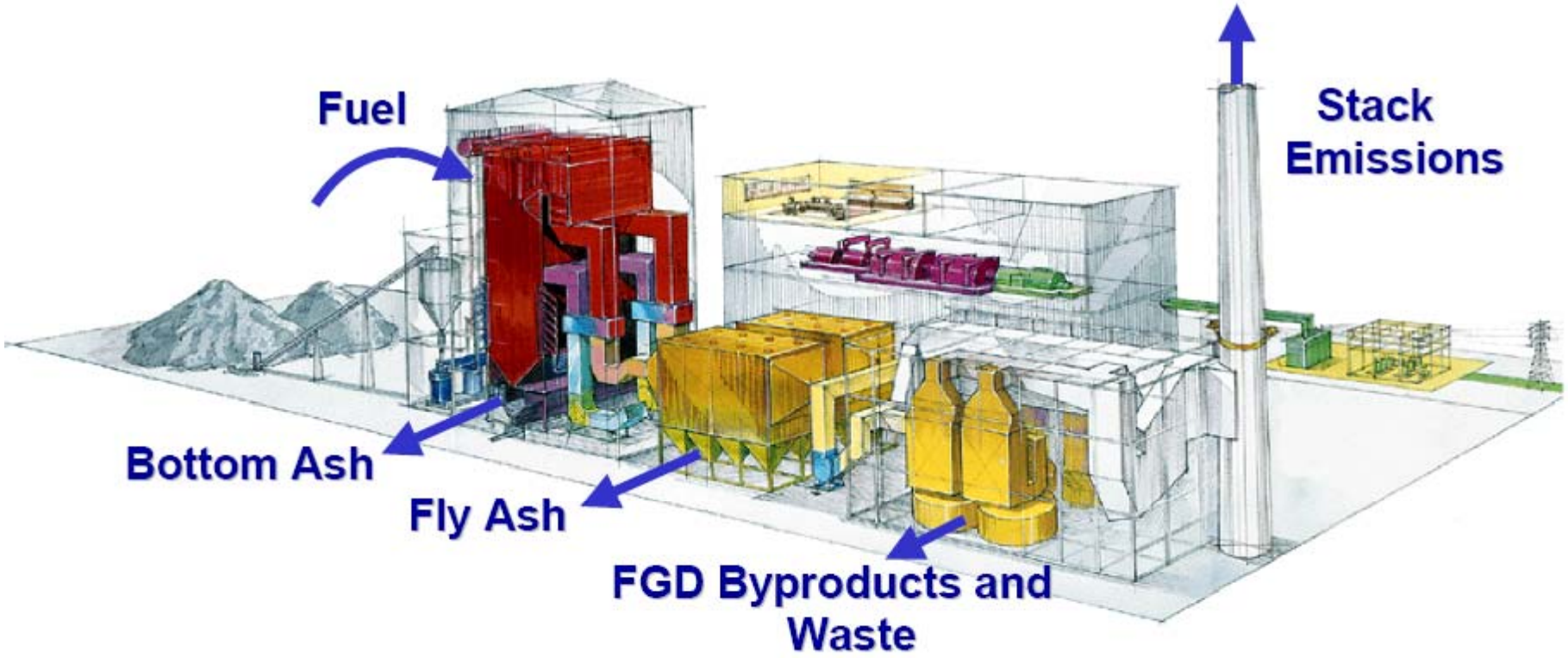


2009 Total = 2,500 Ton/yr

- Fossil Fuel Combustion (Primarily Coal)
- Cement Industry
- Non-Ferrous Metal Production
- Pig Iron & Steel Production
- Caustic Soda Production
- Mercury Production
- Gold Production
- Waste Disposal
- Other

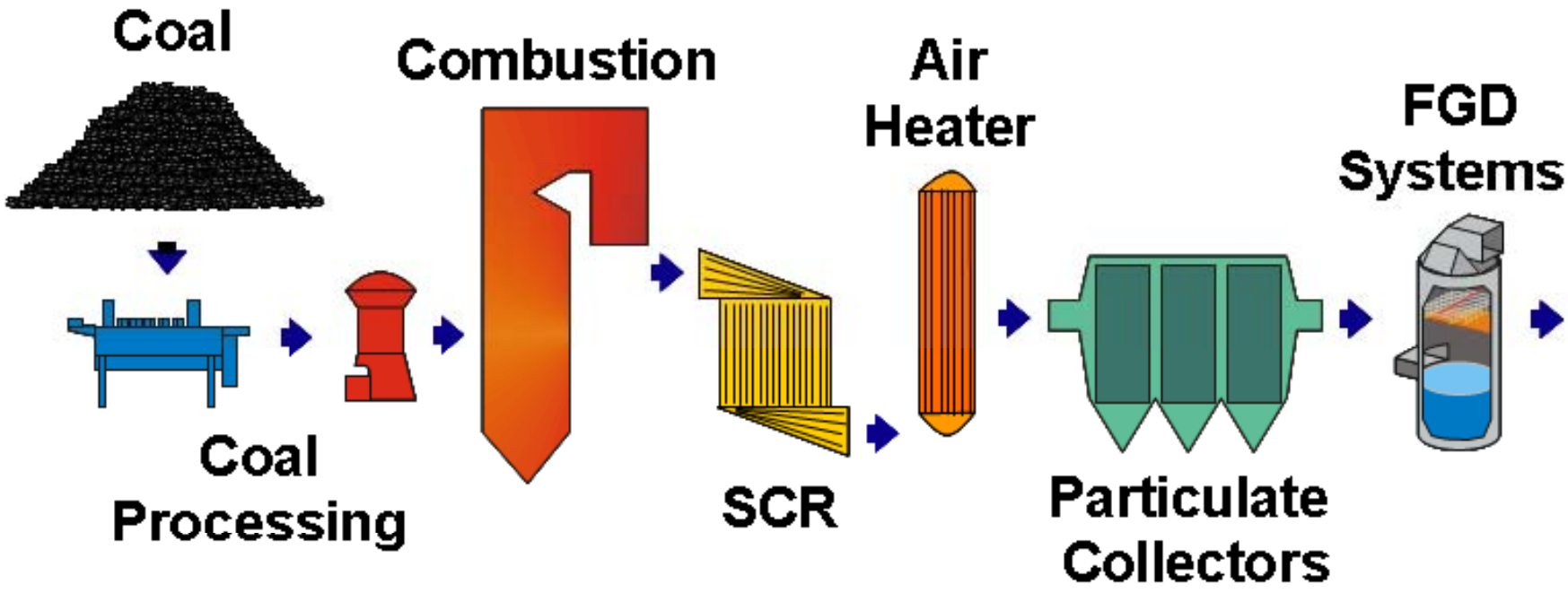
Where Does Mercury from Coal Combustion Go?

It starts with the fuel…

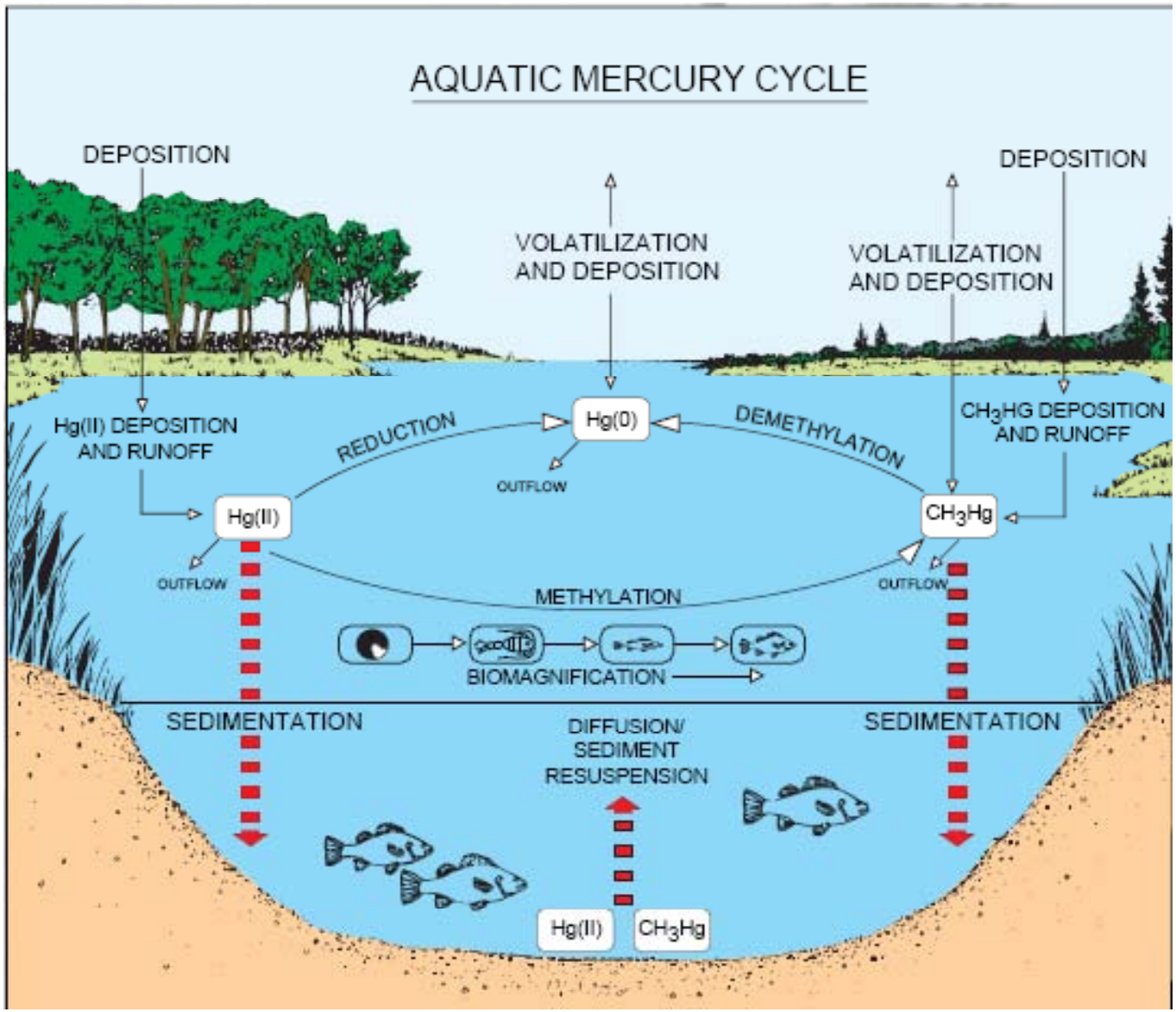


"Co-benefits"…

Power Plant “Co-benefits” Reduce Stack Mercury Emissions

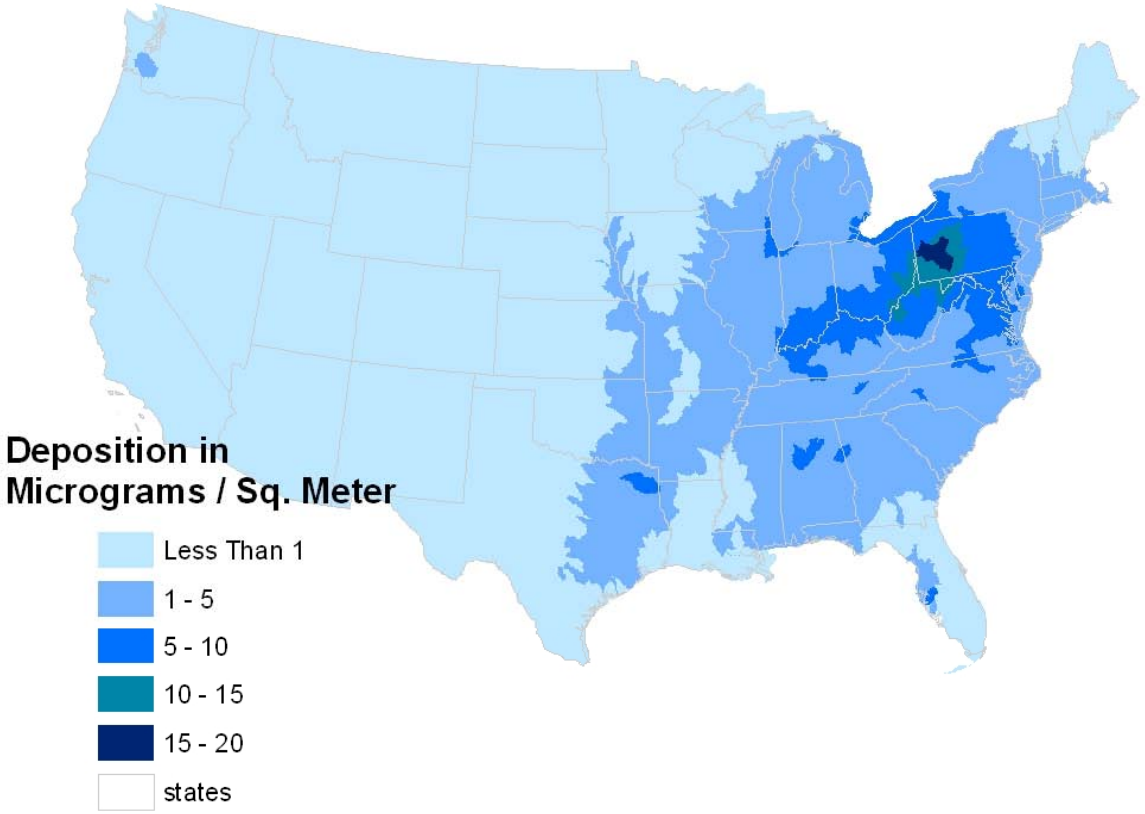


The Aquatic Mercury Cycle



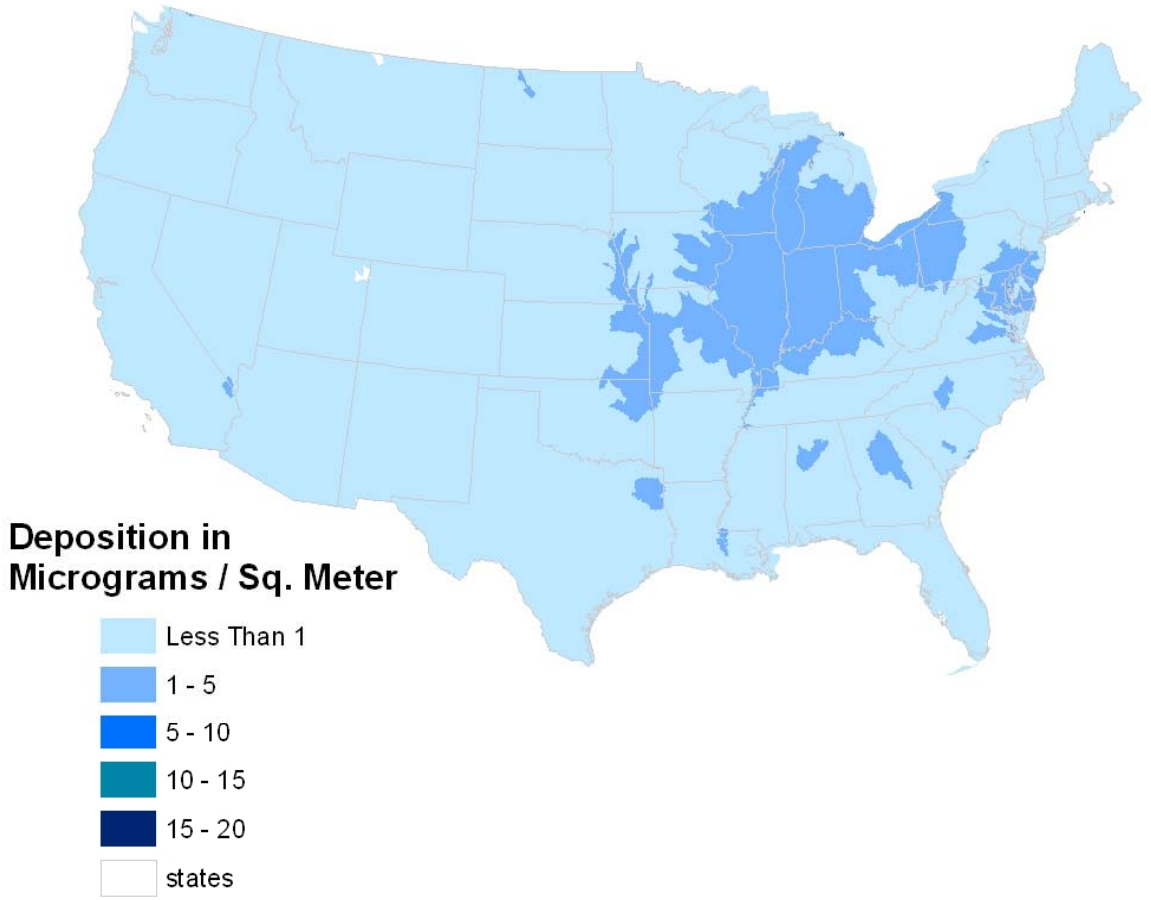
Why Control Mercury Emissions??

2005 CAMR Mercury Emissions Reductions Plan - Baseline Deposition

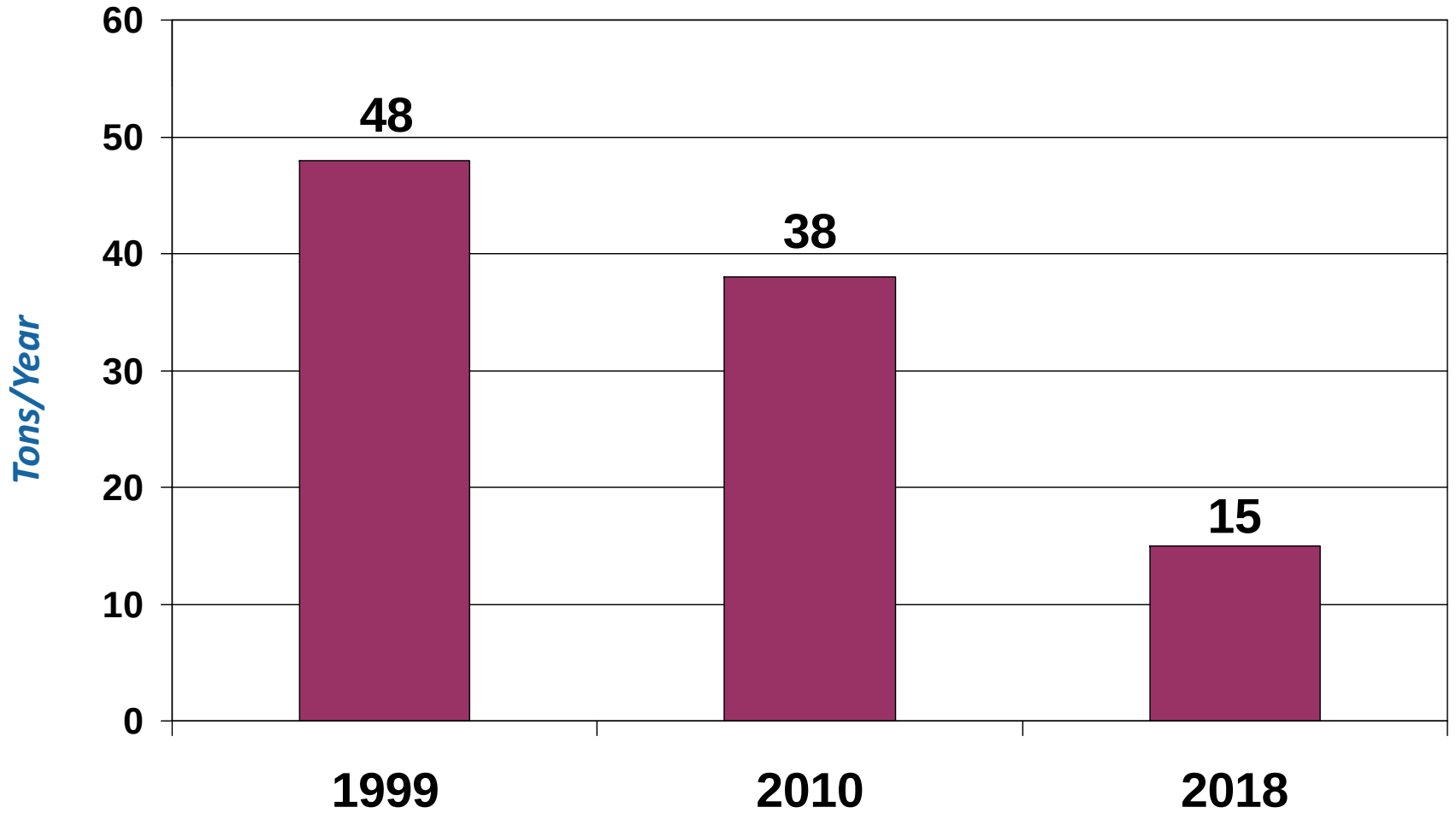


Why Control Mercury Emissions??

2005 CAMR Mercury Emissions Reductions Plan – Target Deposition



CAMR Coal Plant Hg Emissions Reductions Plan



CAMR Gives Way to MACT ???

Feb 8, 2008 – U.S. Court of Appeals Vacates the 2005 CAMR Rule

The EPA ignored its legal obligation to require the strictest possible "MACT" controls as required by the 2000 Clean Air Act, or to justify an alternative approach.

Feb 6, 2009 – USEPA Withdraws Appeal to the Supreme Court.

Jul 7, 2009 – USEPA Issues Draft Information Collection Request.

ICR Required to understand current mercury removal MACT technologies capabilities.

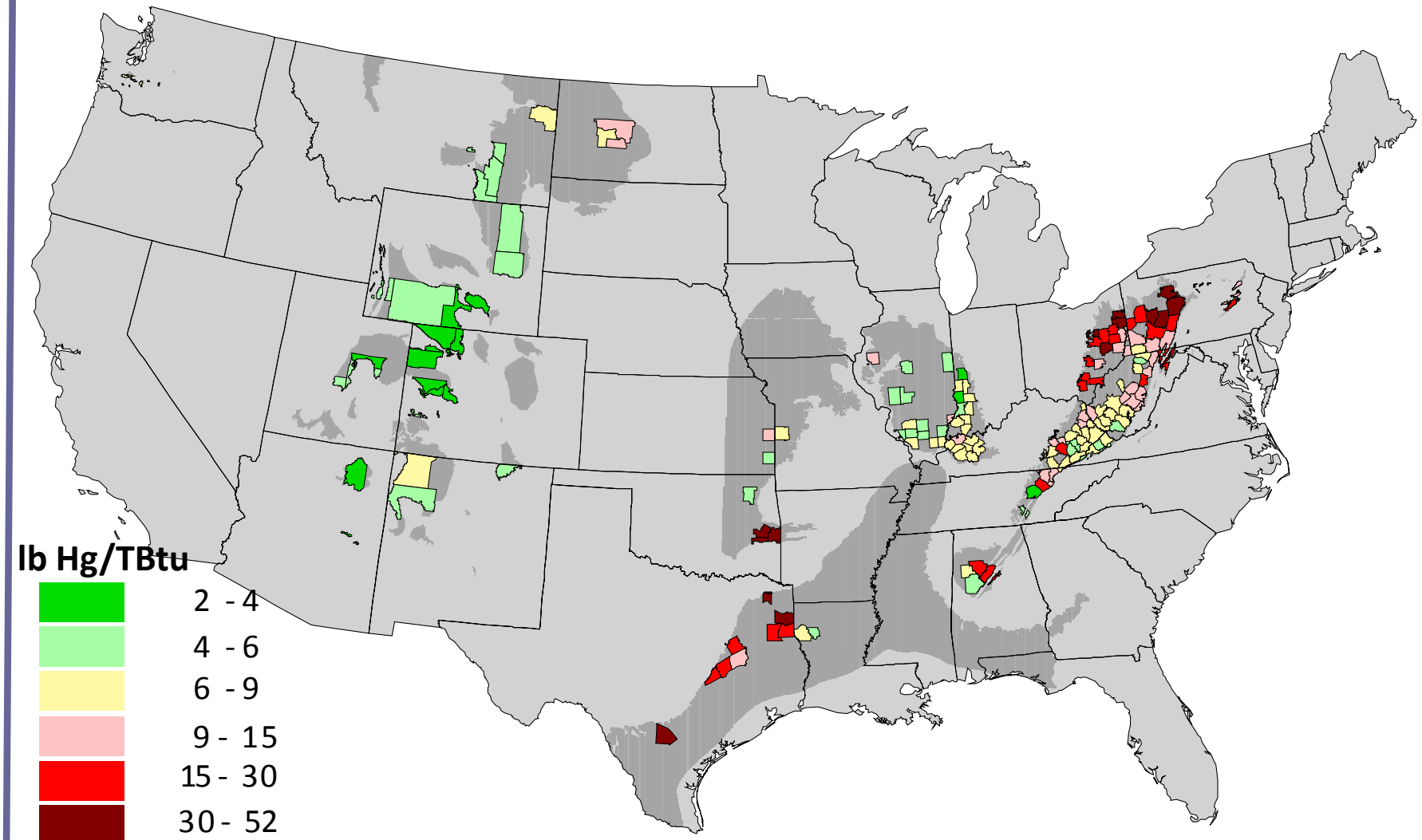
Find "Best Performing, Top 12% Operating Systems

MACT Rule Expected by December, 2011

Presentation Overview

- Why mercury is regulated
- Background on Mercury Control
- Industry Challenges
- Mercury Removal Tools
- Field Test Results for Sub-Bituminous Coal
- Operating Costs for Hg Removal

USA Coal Mercury Concentration



1999 coal production, ICR 2 data, by county

http://geology.utah.gov/emp/mercury/pdf/presentation0806.pdf

USA Coal Mercury Concentration

Coal Rank	USGS Coal Resource	Mercury Concentration (ppm)	Heating Value (Btu/lb)	Hg Content by Heating Value (lb Hg per 10^{12} Btu)
Anthracite	Pennsylvania Anthracite	0.18	12,400	15.4
Bituminous	Uinta	0.08	10,800	7.3
	Raton Mesa	0.09	12,320	6.6
	Eastern Interior	0.1	11,400	8.2
	Western Interior	0.18	10,970	16.1
	Appalachian	0.2	12,790	15.4
Subbituminous	San Juan River	0.08	9,610	7.7
	Hams River	0.09	10,570	4.8
	Green River	0.09	9,580	6.6
	Powder River	0.1	8,090	12.6
	Southwest Utah	0.1	9,290	11
	Wind River	0.19	9,560	18.7
Lignite	Fort Union	0.13	6,360	21.8
	Texas and Mississippi	0.22	6,490	36.4

Typical PRB Power Plant Hg Emissions

- *90 – 900 MWgross Plant*
- *0.05 – 0.30 ppm PRB coal Hg*
- *10 - 30 ppm Coal Chlorine*
- *FF + WFGD*
- *SDA + FF*
- *SCR (Maybe)*

- ***Stack Hg Emissions Typically 4 – 15 ug/M³***
- ***Stack Hg emissions of 0.20 lb/day (100 MW)***
- ***~70% of coal Hg exits the Stack***

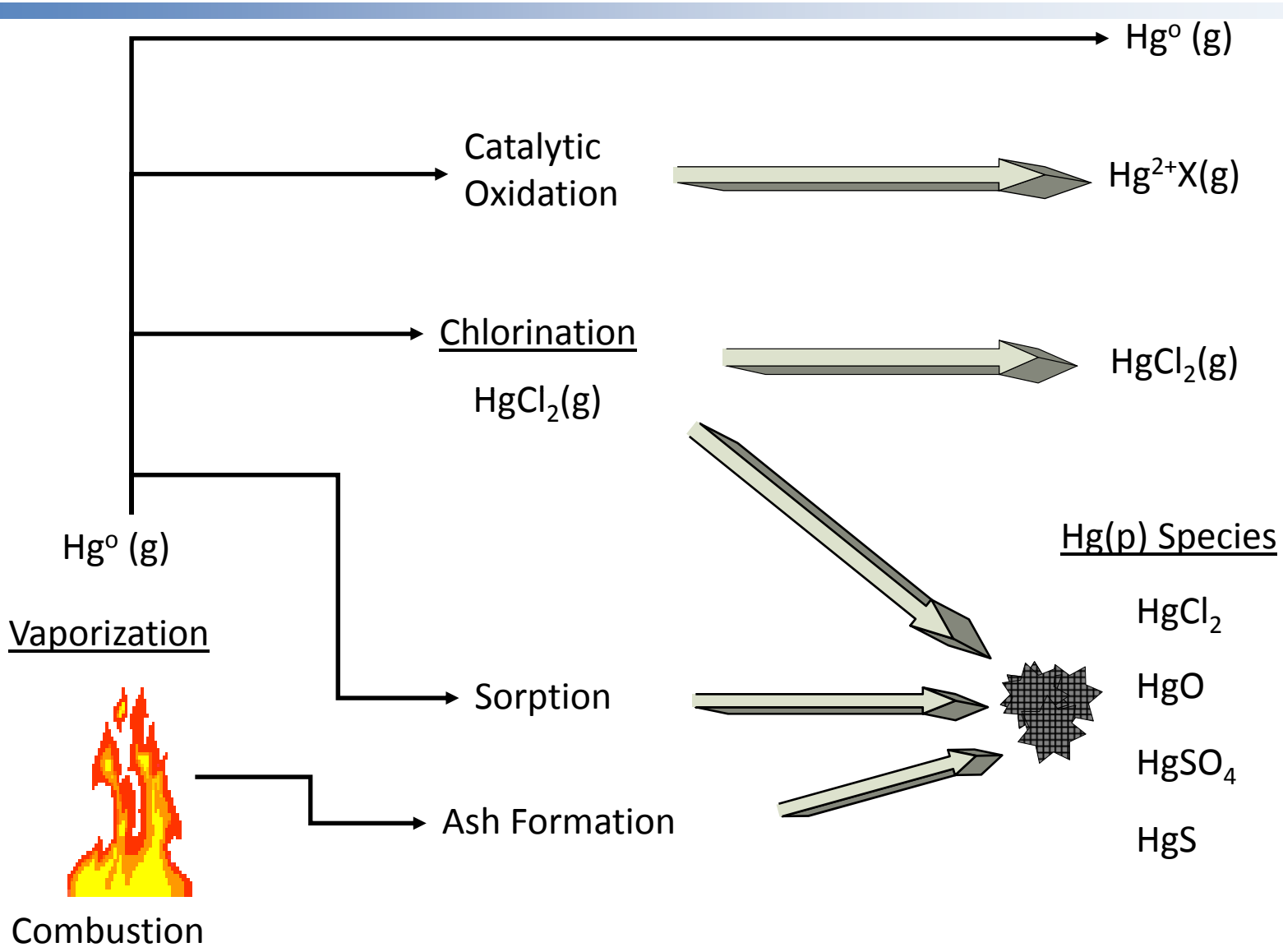
Ultra-Low Boiler Flue Gas Mercury Concentrations

Houston Astrodome

A Hypothetical Example

- **Dome filled with 30 billion ping-pong balls**
- **30 black mercury balls**
- **Find and remove 27 balls for 90% Hg capture**

Fate of Mercury in Coal Combustion



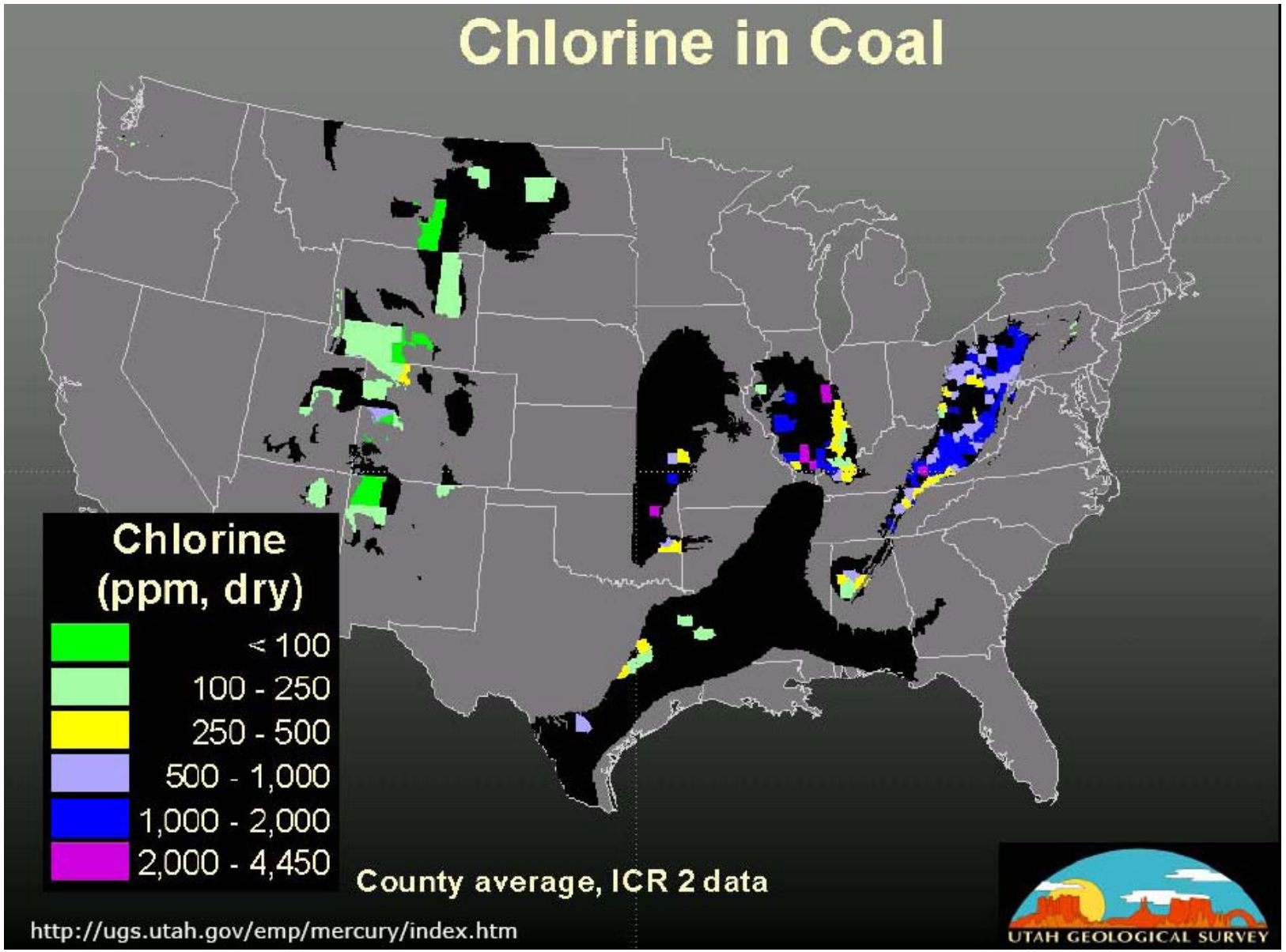
Coal Chlorine Promotes Mercury Removal

The form of mercury in the flue gas is critical to performance of emissions control systems

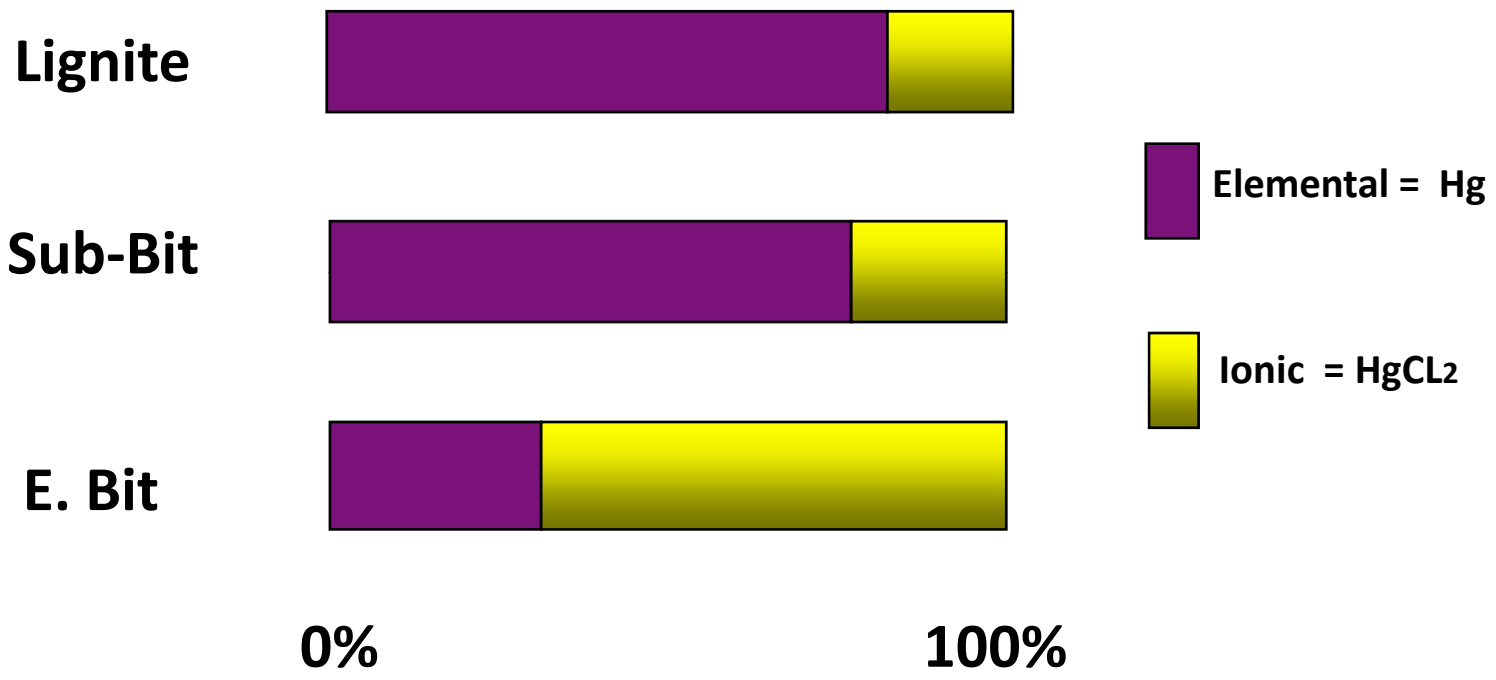
1. Particulate
2. Vapor Phase Elemental Mercury - Hg^0
3. Vapor Phase Ionic Mercury - Hg^{++} ($HgCl_2$)

Coal Chlorine Plays a Significant Role

USA Coal Chlorine Concentration



Typical Mercury Speciation vs. Coal Types



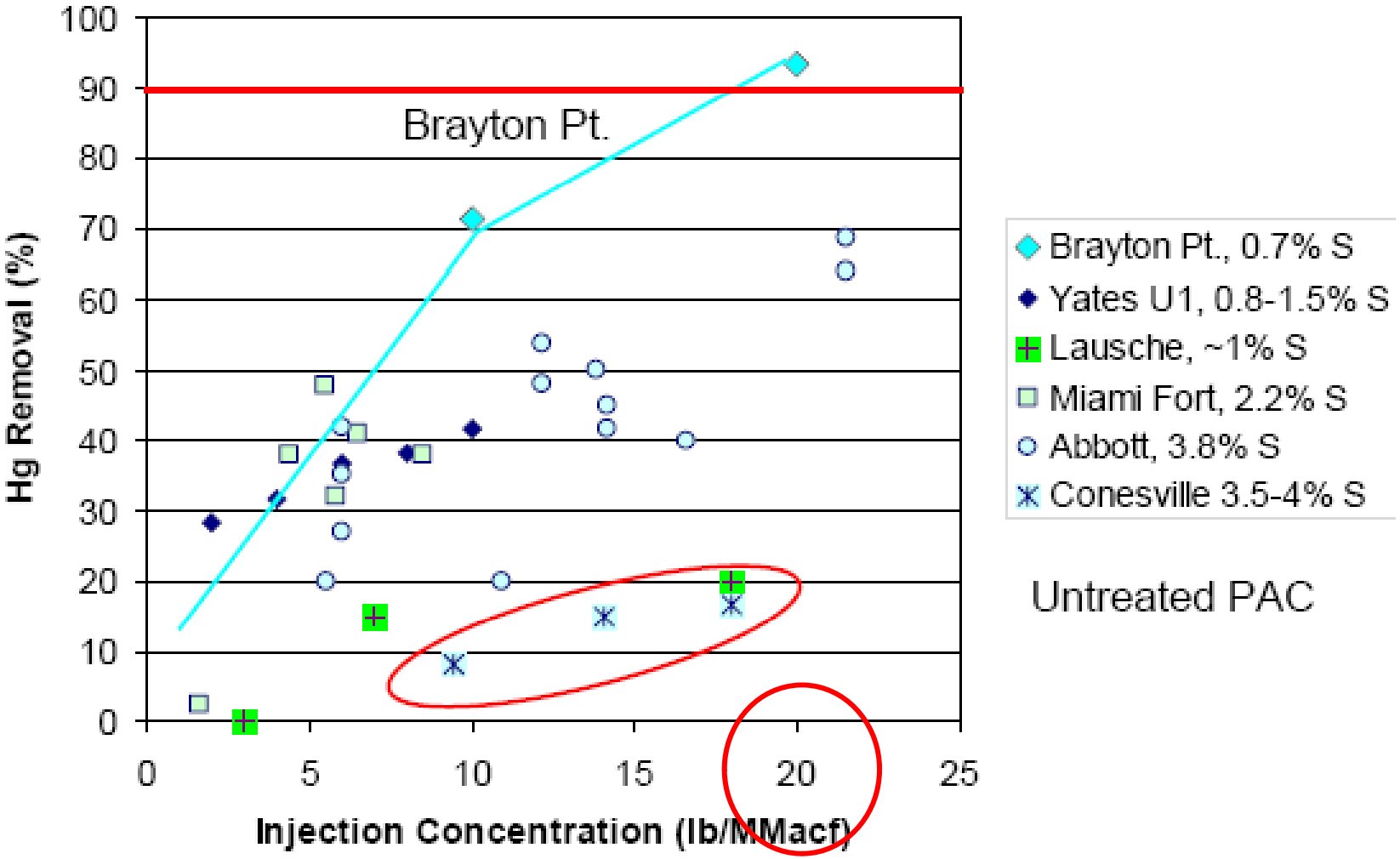
Presentation Overview

- Why mercury is regulated
- Background on Mercury Control
- Industry Challenges
- Mercury Removal Tools
- Field Test Results for Sub-Bituminous Coal
- Operating Costs for Hg Removal

Mercury Control Industry Challenges

- Sulfur trioxide (SO_3) poisons activated carbon at levels generated by high-sulfur coal
- Mercury re-emission occurs in WFGDs

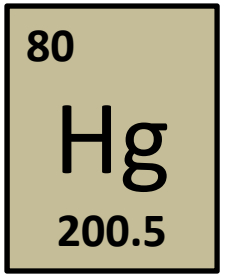
Effect of SO_3 on Hg Removal with PAC and ESP.



Mercury Re-emission Chemistry in WFGD

Overall Reactions:

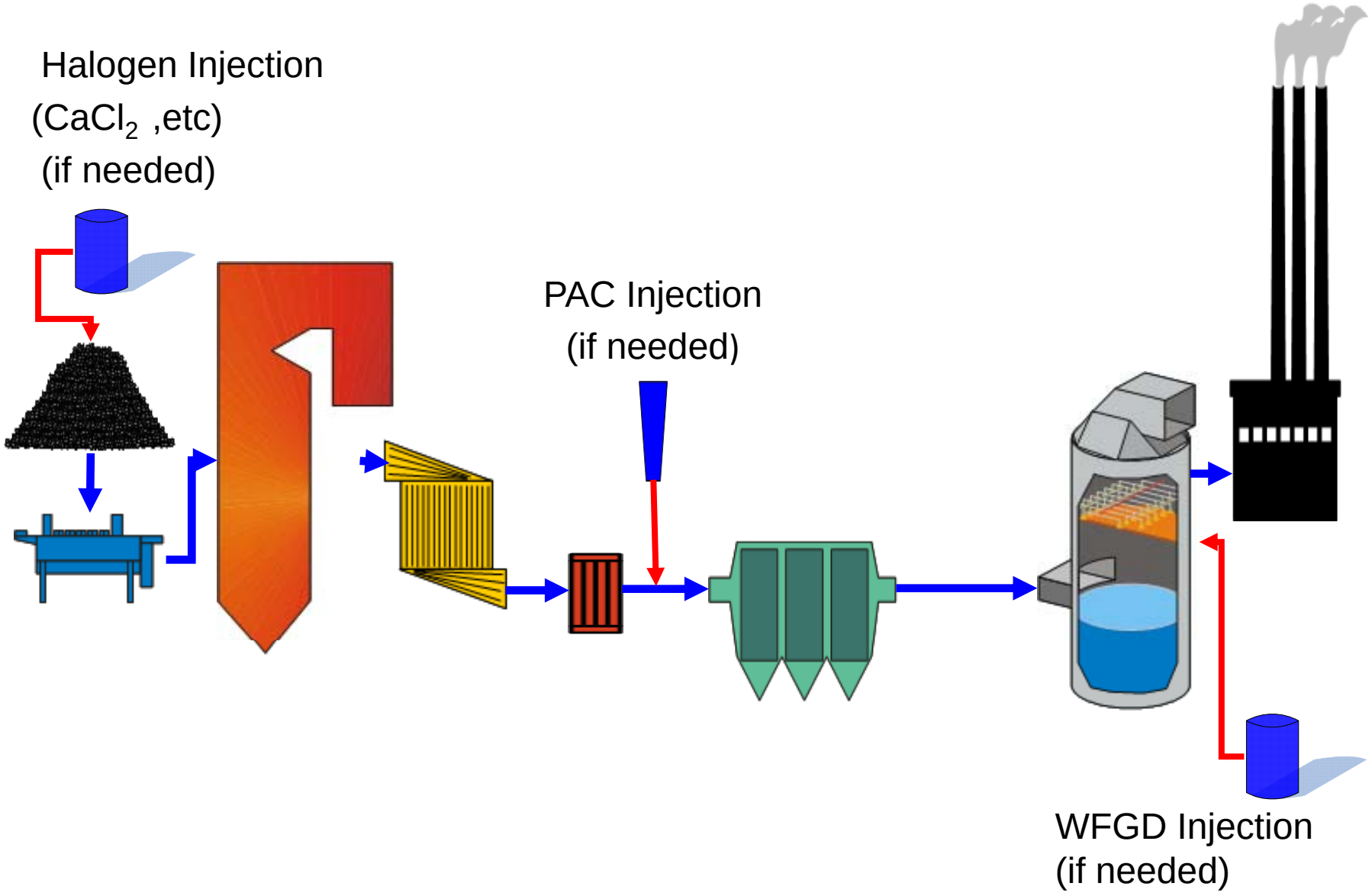
1. $HgCl_2 + HSO^{3-} + H_2O \rightarrow Hg^o\uparrow + SO_4^{2-} + 3H^+ + 2Cl^-$
2. $Hg^{2+} + 2Me^{2+} \rightarrow Hg^o\uparrow + 2Me^{3+}$



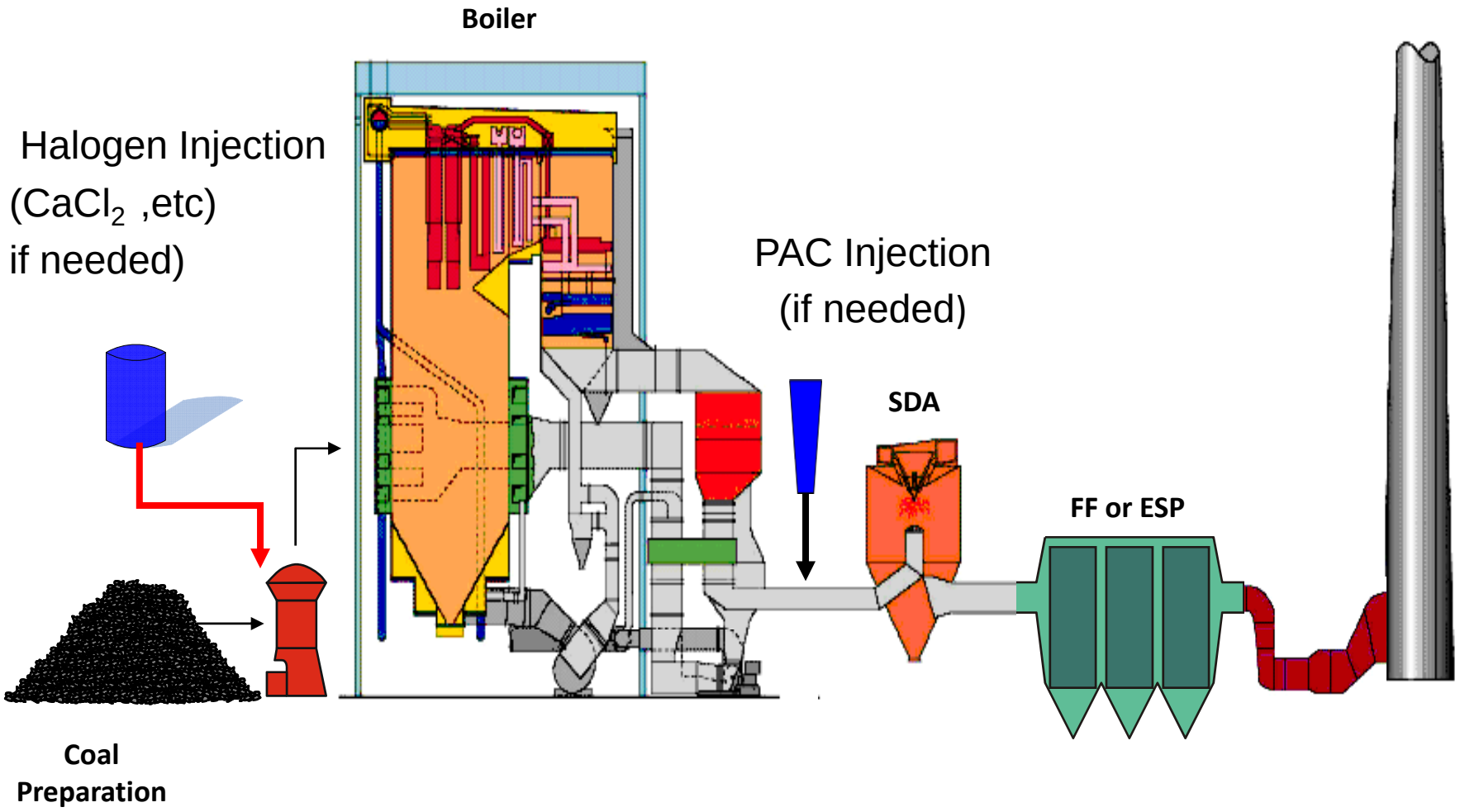
Presentation Overview

- Why mercury is regulated
- Background on Mercury Control
- Industry Challenges
- Mercury Removal Tools
- Field Test Results for Sub-Bituminous Coal
- Operating Costs for Hg Removal

Power Plant WFGD Mercury Control Options

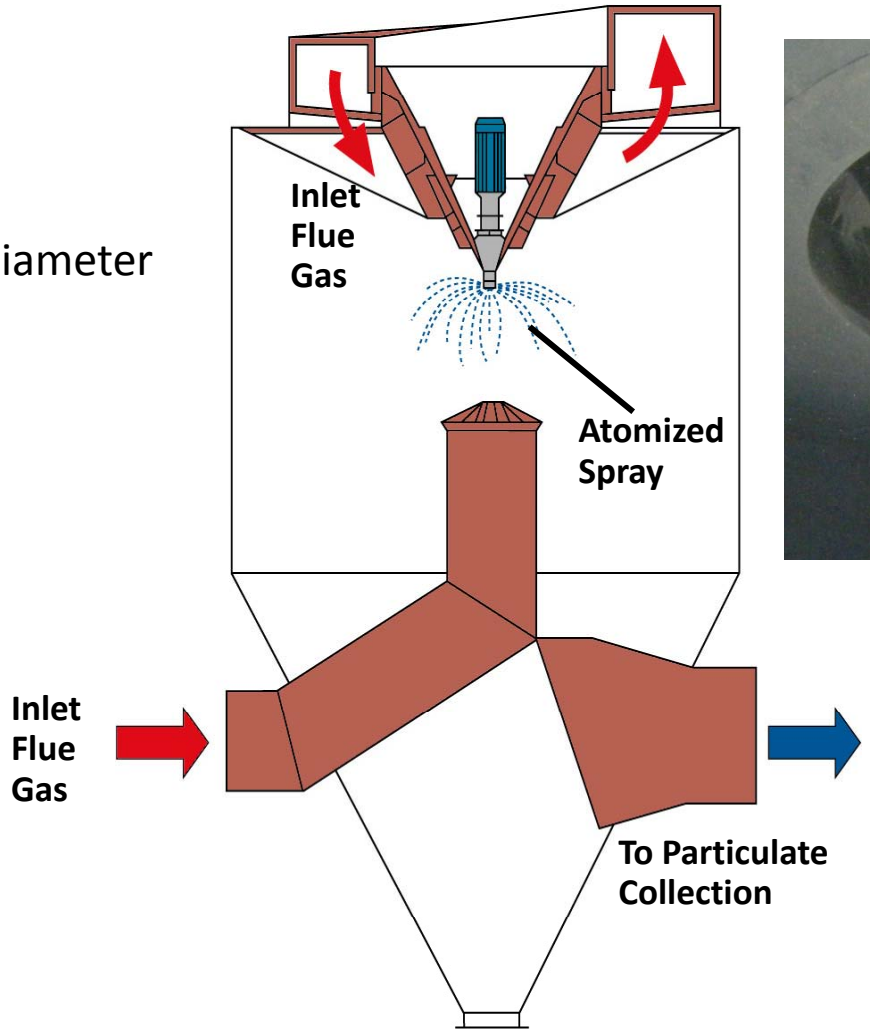


Power Plant DFGD Mercury Control Options



B&W/Niro Spray Dryer Vessel Design

43 ft – 65 ft Diameter



Total Mercury Removal Sub-Bituminous Coal

AQCS Configuration	Average Baseline Hg Removal	Mercury Control	Expected Total Hg Removal
PJFF	30% - 50%	$CaCl_2$	50% - 70%
		$CaCl_2$/PAC	70% - 90%
		BACI	70% - 90%
SDA/PJFF	30% - 50%	$CaCl_2$	50% - 70%
		$CaCl_2$/PAC	70% - 90%
		BACI	70% - 90%
CS-ESP/WFGD	15%	$CaCl_2$	50% - 60%
		$CaCl_2$/PAC	70% - 90%
		BACI	70% - 90%
SCR/CS-ESP/WFGD	20% - 30%	$CaCl_2$	60% - 80%
		$CaCl_2$/PAC	90%
		BACI	90%
HS-ESP/WFGD	20-30%	$CaCl_2$	30% - 50%
SCR/SDA/PJFF	50%-70%	$CaCl_2$	70%-90%
		$CaCl_2$/PAC	90%

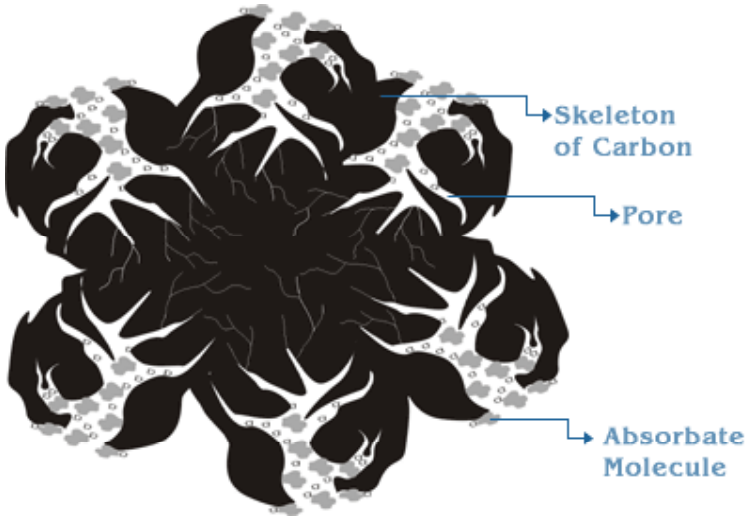
Powdered Activated Carbon for Hg Control

- **Standard PAC**
  - **Removes 90% of total Hg when virtually all mercury is oxidized**
  - **Used predominately when burning bituminous coals**
  - **PRB coals need coal additives to increase oxidized Hg concentration**
  - **Used on low-sulfur fuel**
  - **High SO_3 concentrations reduces or eliminates PAC effectiveness (High S coals)**

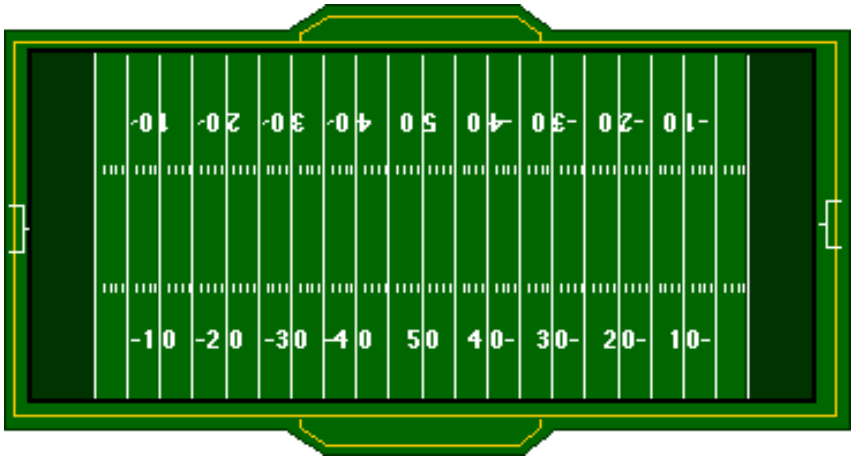
- **Brominated PAC**
  - **Removes 90%+ of elemental and oxidized mercury**
  - **More reactive**
  - **Use coal additive to reduce PAC consumption**
  - **Used predominately on low-sulfur fuels**

Powdered Activated Carbon for Hg Control

40 microns MMD



Surface Area of 9 grams =



Powdered Activated Carbon Storage and Feed Systems

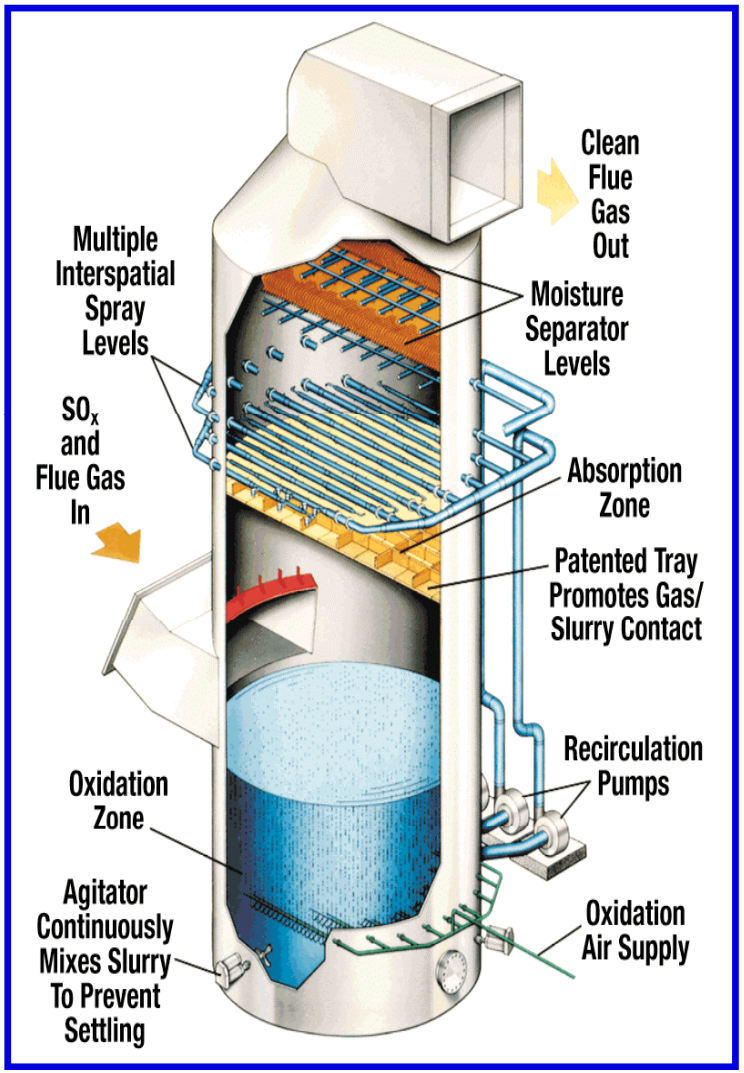
- PAC Storage Silo
- Feed System
- Injection System

PAC Injection Lances for Initial Distribution to Flue Gas

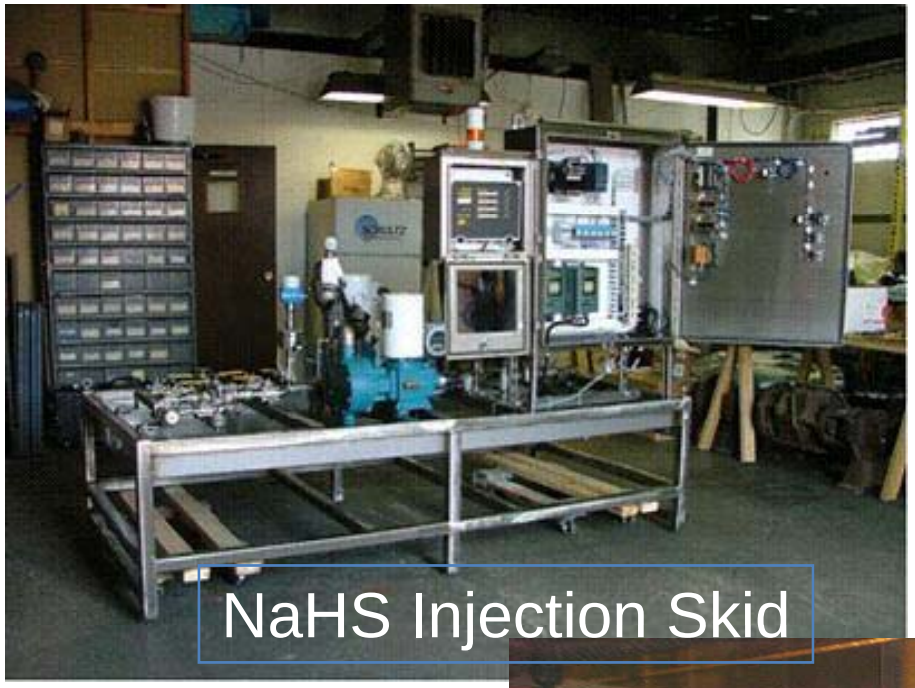
WFGD Additive to Minimize Re-emission

–B&W Absorption Plus(Hg)™

- Commercially available from B&W
- Prevents mercury re-emission
- Increases WFGDs total remove of Oxidized Hg to above 95%
- Results in an overall 10-15% increase in total mercury capture
- NaHS is readily available and inexpensive



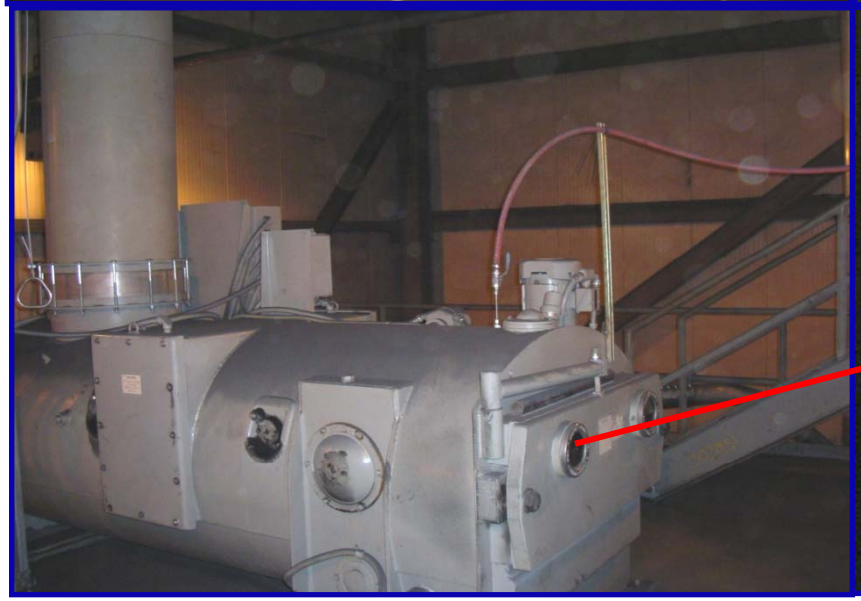
B&W WFGD Additive Feed System



Halogen Based Coal Additives

- **Chlorine injection onto the coal**
  - Improves DFGD System performance
  - For low-chlorine coal, less than 300ppmd
  - Oxidizes Hg in the boiler and across the SCR
  - Increases Hg solubility for capture in the WFGD
  - Increases Hg capture in bag-houses
  - Increases reactivity of PAC and Br-PAC
  - Total Removals of 90-95% are achievable
- **Bromine injection onto the coal**
  - Increases reactivity of PAC and Br-PAC
  - Total Removals of 90-95% are achievable

Coal Additive Injection and Storage

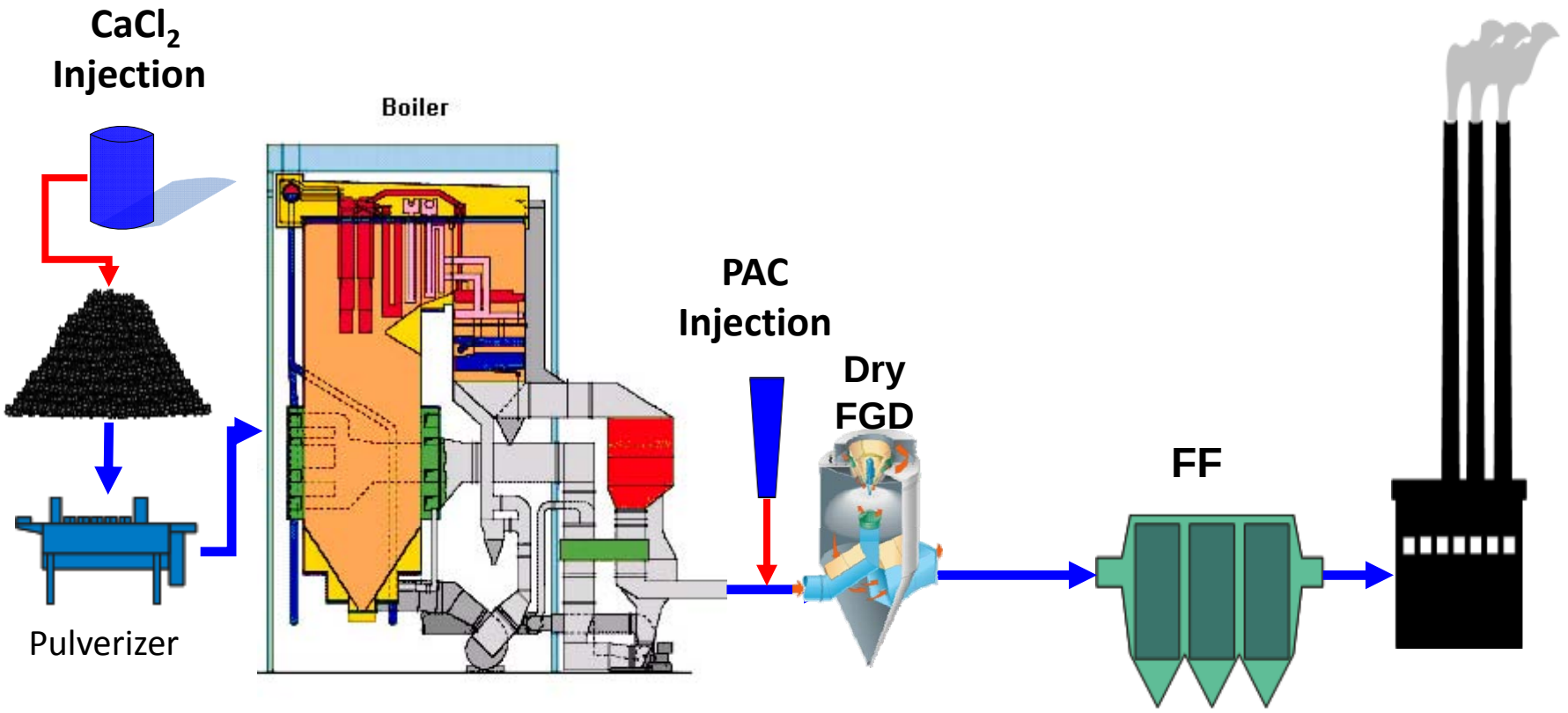


Presentation Overview

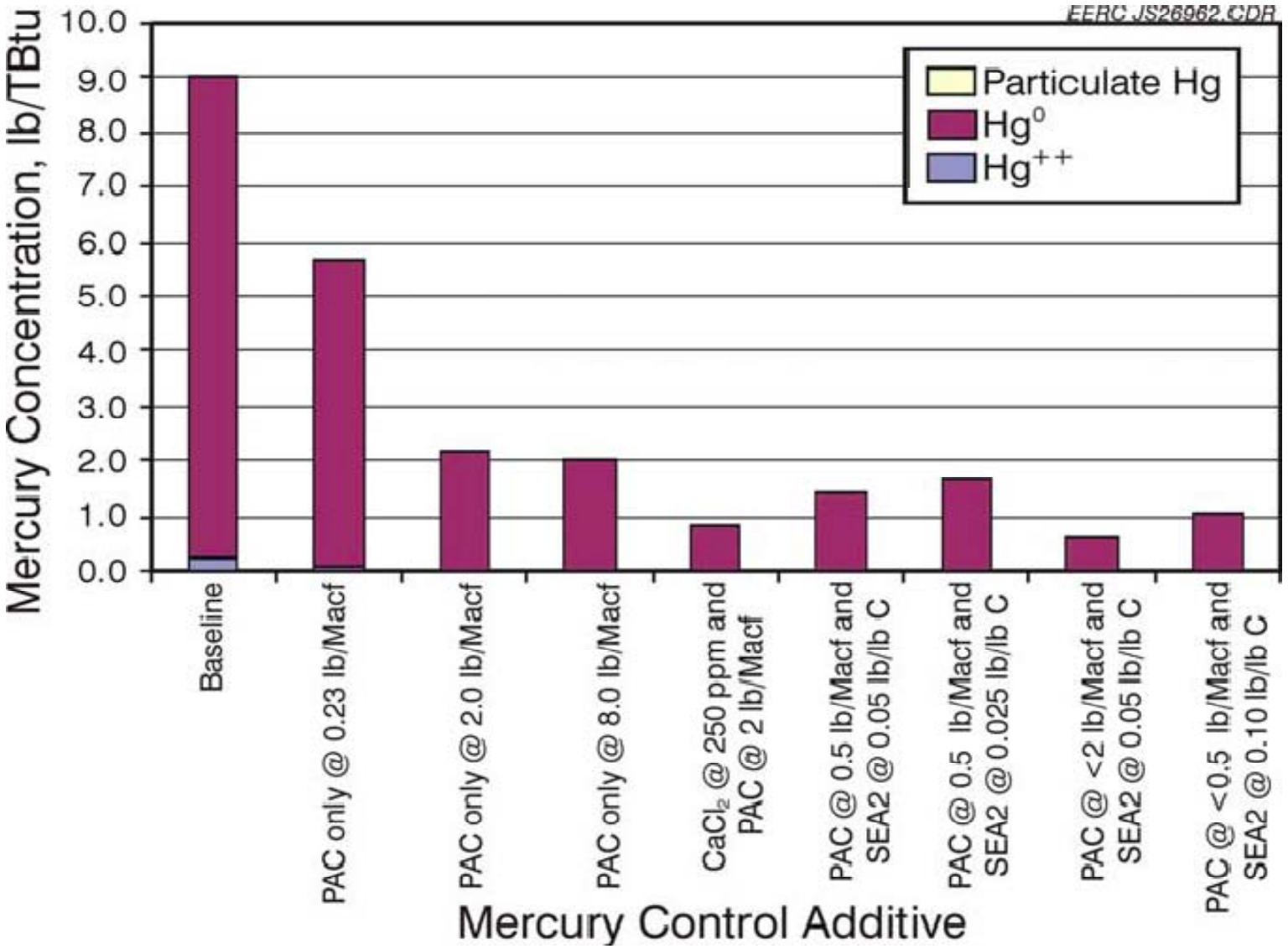
- Why mercury is regulated
- Background on Mercury Control
- Industry Challenges
- Mercury Removal Tools
- Field Test Results for Sub-Bituminous Coal
- Operating Costs for Hg Removal

KCP&L Hawthorn5 Plant with DFGD + FF

Hawthorn5 Recommended Mercury Controls

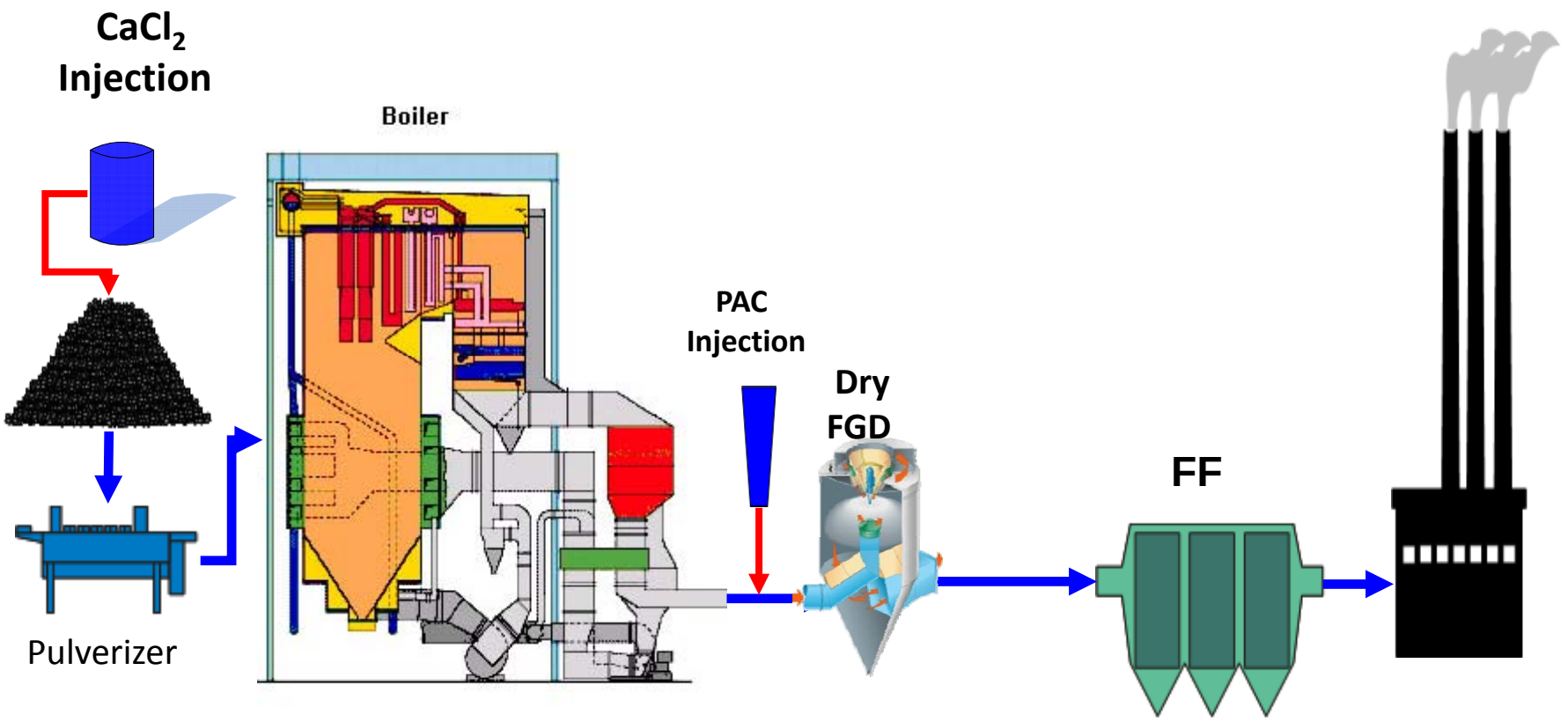


Hawthorn5 Mercury Emissions with PAC and Additives

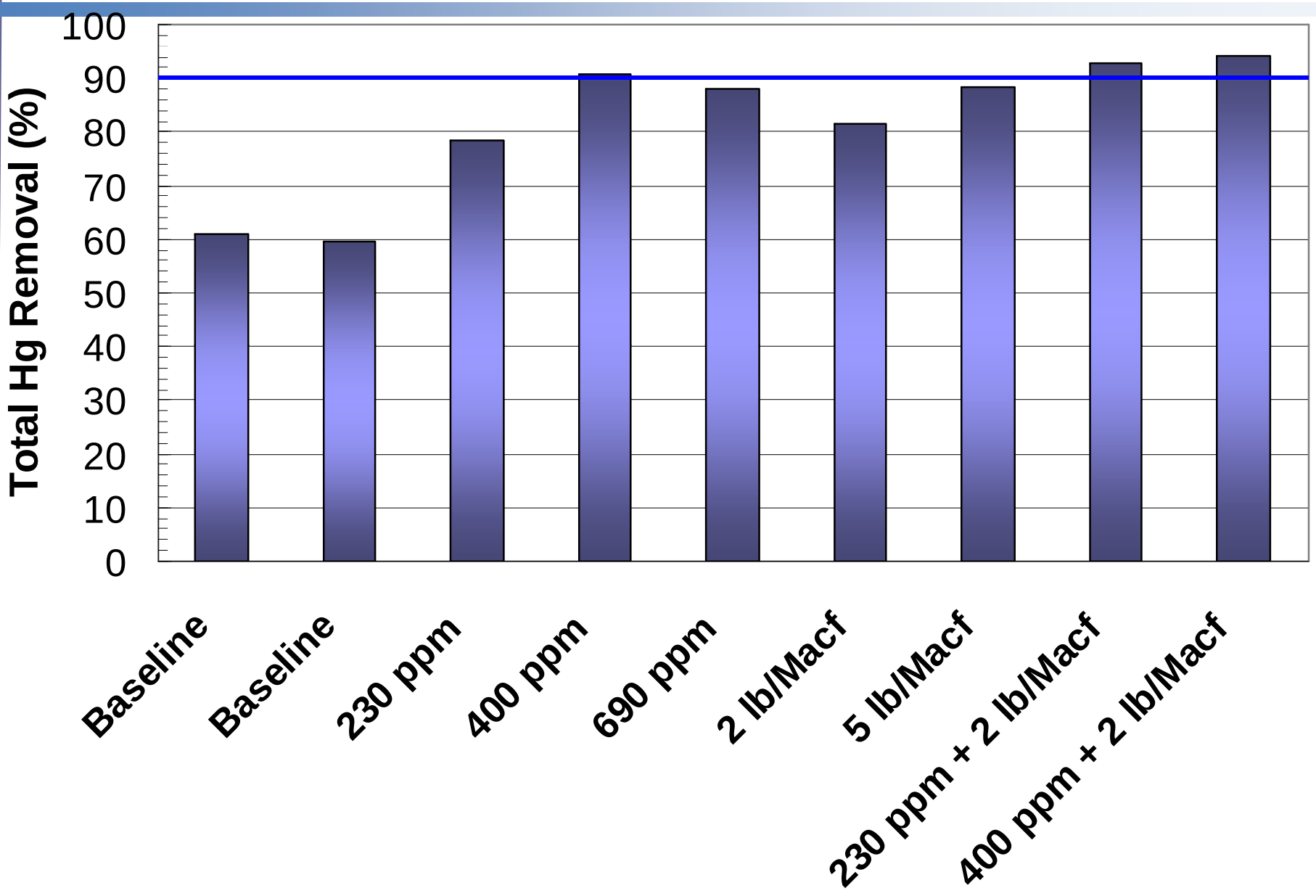


Black Hills Power – Wygen1 – Sub-Bituminous Coal

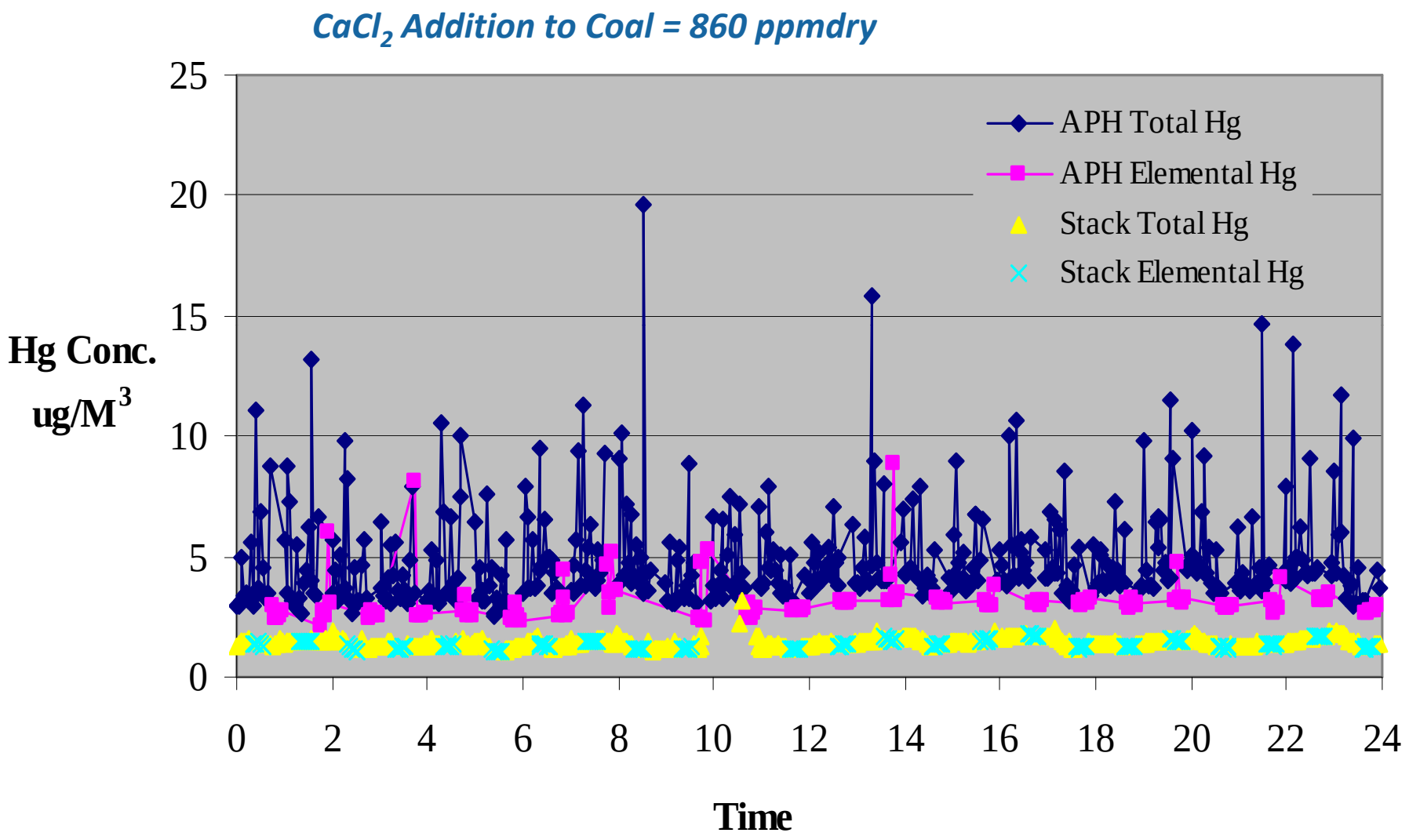
Wygen1 Mercury Controls



Wygen1 Parametric Mercury Tests

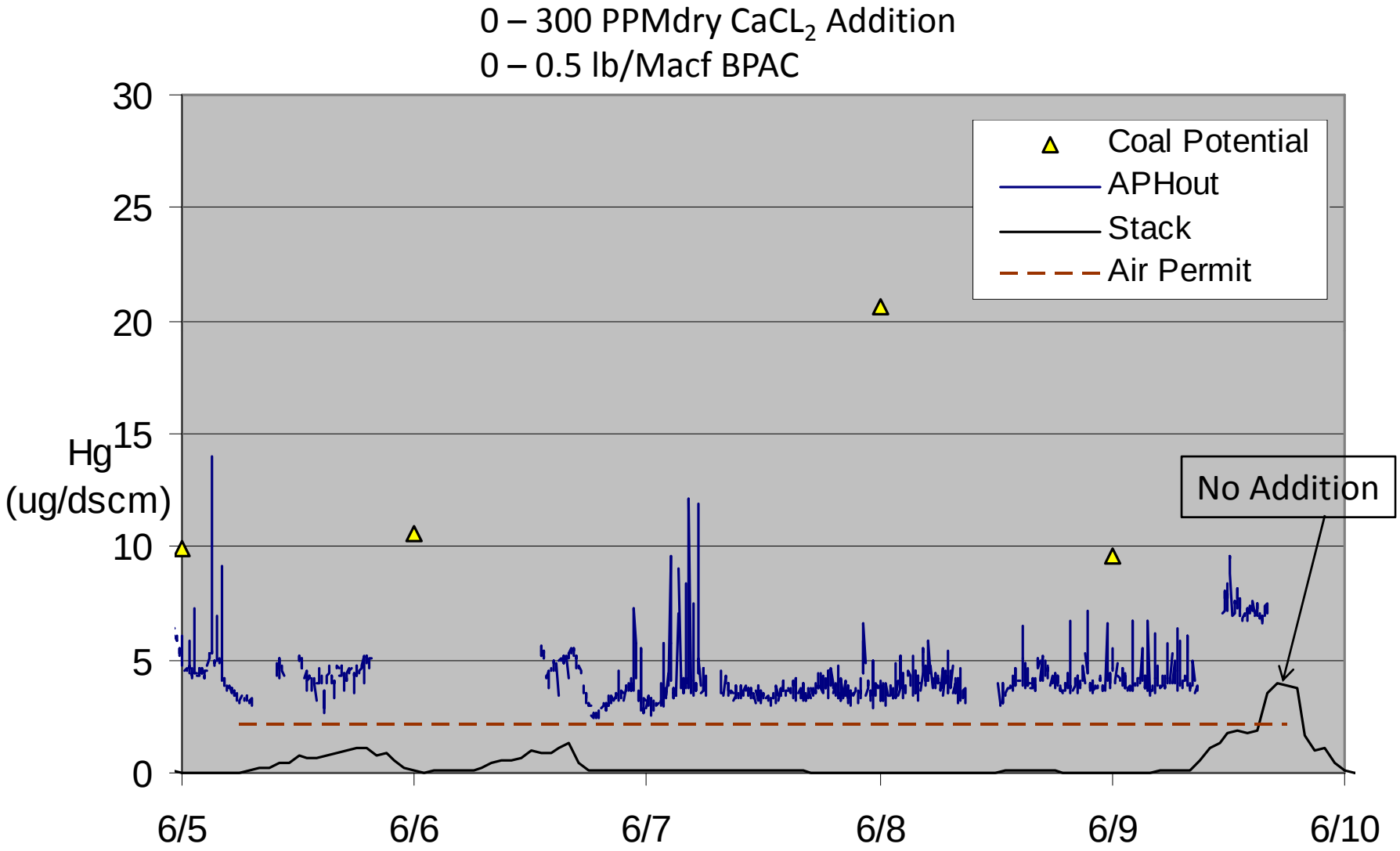


Wygen1 Mercury Removal and Emissions



Newmont DFGD System Side View (220MW – PRB)

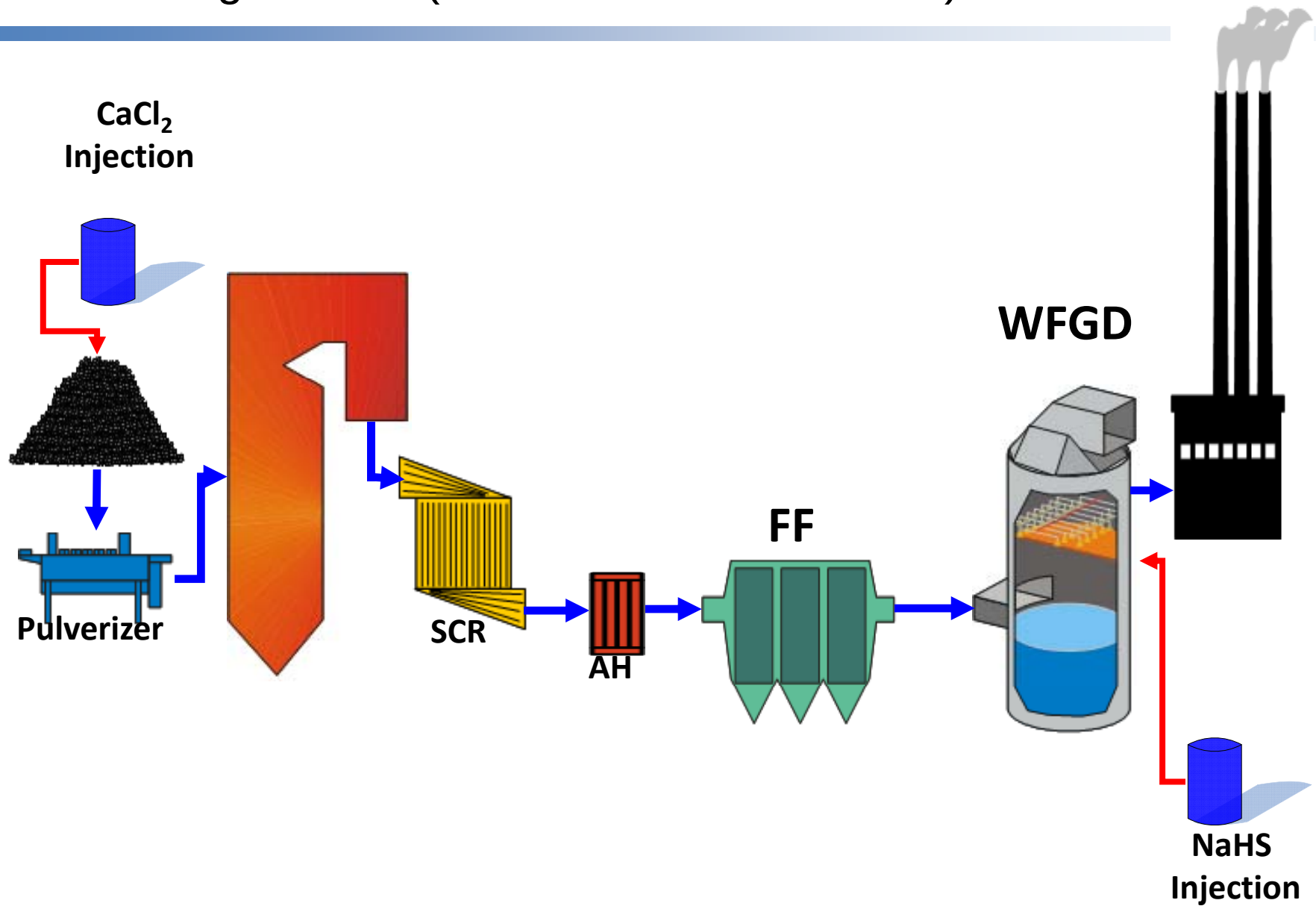
Newmont Mining Coal-to-Stack Boiler System Hg Emissions



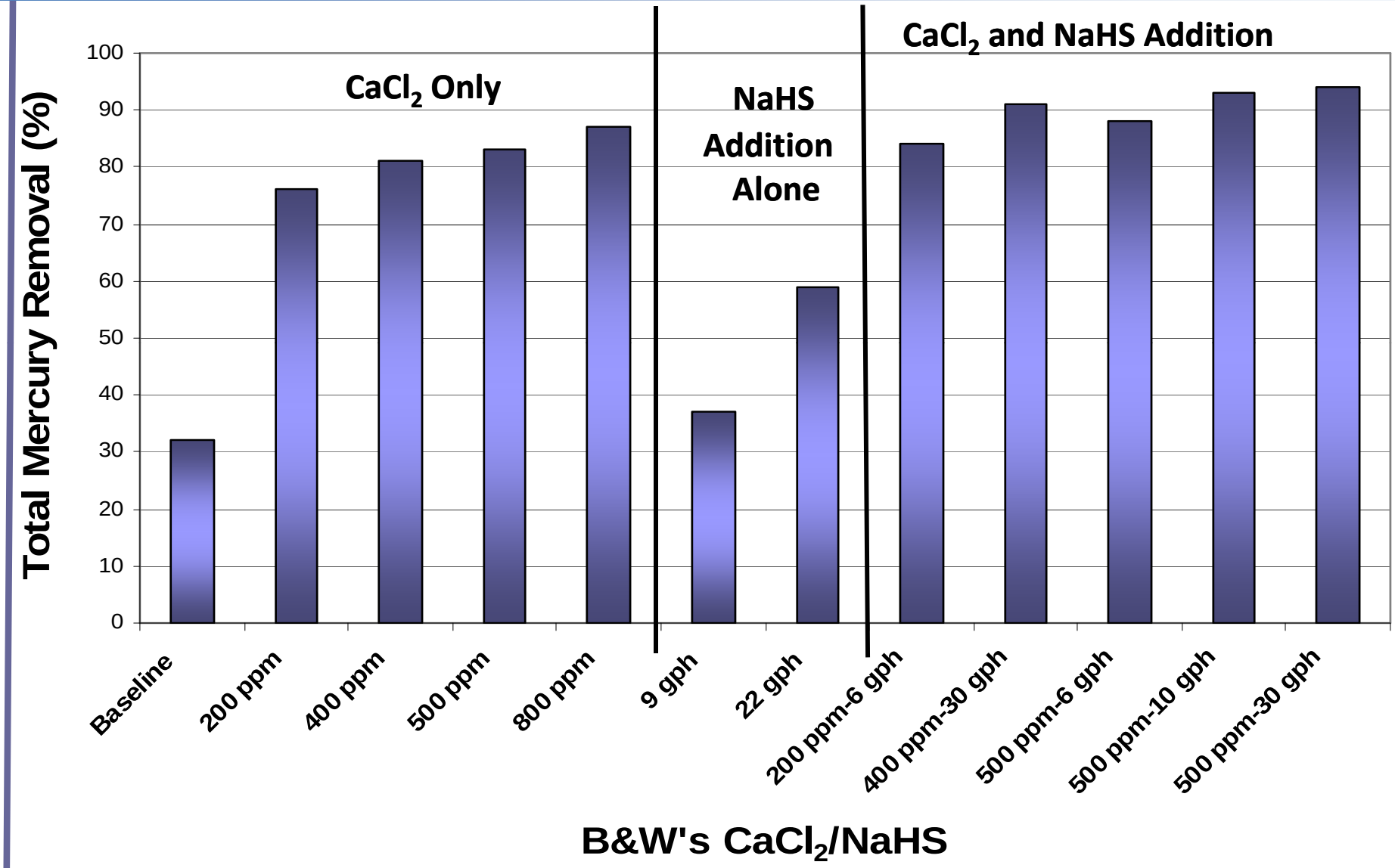
Texas Genco Parish Plant – Sub-Bituminous PRB Coal

- 650 MW SCR/FF/WFGD
- Low Chlorine PRB Coal
- 3 Limestone Natural-Ox WFGD for SO_2 Control

Parish 8 Hg Control (Low-Chlorine PRB Coal)



Total Mercury Removal Across the WFGD Scrubber



Presentation Overview

- Why mercury is regulated
- Background on Mercury Control
- Industry Challenges
- Mercury Removal Tools
- Field Test Results for Sub-Bituminous Coal
- Operating Costs for Hg Removal

Reinhold 2007 Workshop Hg Control Costs Predictions

(600 MWg Plant with DFGD + FF)

	Base Case Norit Hg-LH PAC	Norit Standard PAC & CaCl2 Addition	Norit Hg-LH PAC & CaCl2 Addition
Mercury Removal (% of vapor phase, APH to stack)	90	90	90
Activated Carbon Cost ($/lb delivered)	$1.10	$0.65	$1.10
Activated Carbon Flow Rate (lb/10^6 ACF)	4	3	2
Activated Carbon Flow Rate (lb/hr)	424	318	212
CaCl2 30% Soln ($/gal delivered)	NA	$1.10	$1.10
Cl Addition to Coal (ppmdry)	NA	750	500
CaCl2 flow rate (gpm)	NA	1.36	0.91
Annual Capacity Factor	90%	90%	90%
Annual Operating Hours	7884	7884	7884
Average Annual cost - Activated Carbon	$3,677,098	$1,629,623	$1,838,549
Average Annual cost - CaCL2	$0	$707,668	$473,513
Annual Reagent Cost ($M)	**$3.7**	**$2.3**	**$2.3**
Annual Reagent Cost ($/MW.hr)	**$0.78**	**$0.49**	**$0.49**
Installed Capital Cost ($M)	**$2.1**	**$3.7**	**$2.7**

Newmont Mining Mercury Control Reagent Costs

2006 Base Case Br-PAC Injection System Only

	PAC Cost/hr	CaCl2 Cost/hr	Total Cost/hr
2.0 lb/Macf Brom PAC + 0 CaCl2	$150	$0.00	$150

Brominated PAC assumed = $0.71/lb

$150/hr = $0.68/MW.hr

2009 Site Testing For <0.02 lb/GWhr

	PAC Cost/hr	CaCl2 Cost/hr	Total Cost/hr
0.50 lb/Macf standard PAC + 400 ppm CaCl2	$26	$36	$62
1.00 lb/Macf standard PAC + 200 ppm CaCl2	$52	$18	$70
0.50 lb/Macf Brom PAC +100 ppm CaCl2	$31	$9	$40
0.75 lb/Macf Brom PAC + 0 CaCl2	$47	$0	$47
2.00 lb/Macf Standard PAC + 0 CaCl2	$104	$0	$104

$40/hr = $0.18/MW.hr

Brominated PAC delivered = $1.07/lb
Standard PAC delivered = $0.75/lb
Calcium chloride solution (30%) delivered = $1.20/gal

Jul 9, 2009 – GAO Indicated that "sorbent injection for Hg control is a mature technology that can achieve 90 percent reductions at $1.00 per household per month.


? Questions ?