Worldwide Pollution Control Association

Ameren Seminar

August 19–20, 2008

Effingham, IL

WPCA

Vist our website at www.wpca.info

Mercury Control Methods and Issues

Presented by: W. Scott Hinton, Ph.D., P.E.
W.S. Hinton & Associates
850-936-0037 shinton@wshinton.com

Challenges for Utilities

- Underlying Science/Chemistry
- Extremely low levels of pollutant
- Variability from site to site
- Cost effective approaches
- Minimization of technical risk
- Regulations – moving target !!!

MERCURY CHEMISTRY

"SPECIATION"

- Gas-phase mercury:
  - Elemental: Hg^0
  - Oxidized: Hg^{+2} ($HgCl_2$, other species?)
- Particulate mercury
  - Hg_p
  - Mercury (adsorbed on particles)

Primary Chemical Equations

$$Hg + F_2 = HgF_2 \quad (2)$$

$$Hg + Cl_2 = HgCl_2 \quad (3)$$

$$Hg + Br_2 = HgBr_2 \quad (4)$$

$$Hg + I_2 = HgI_2 \quad (5)$$

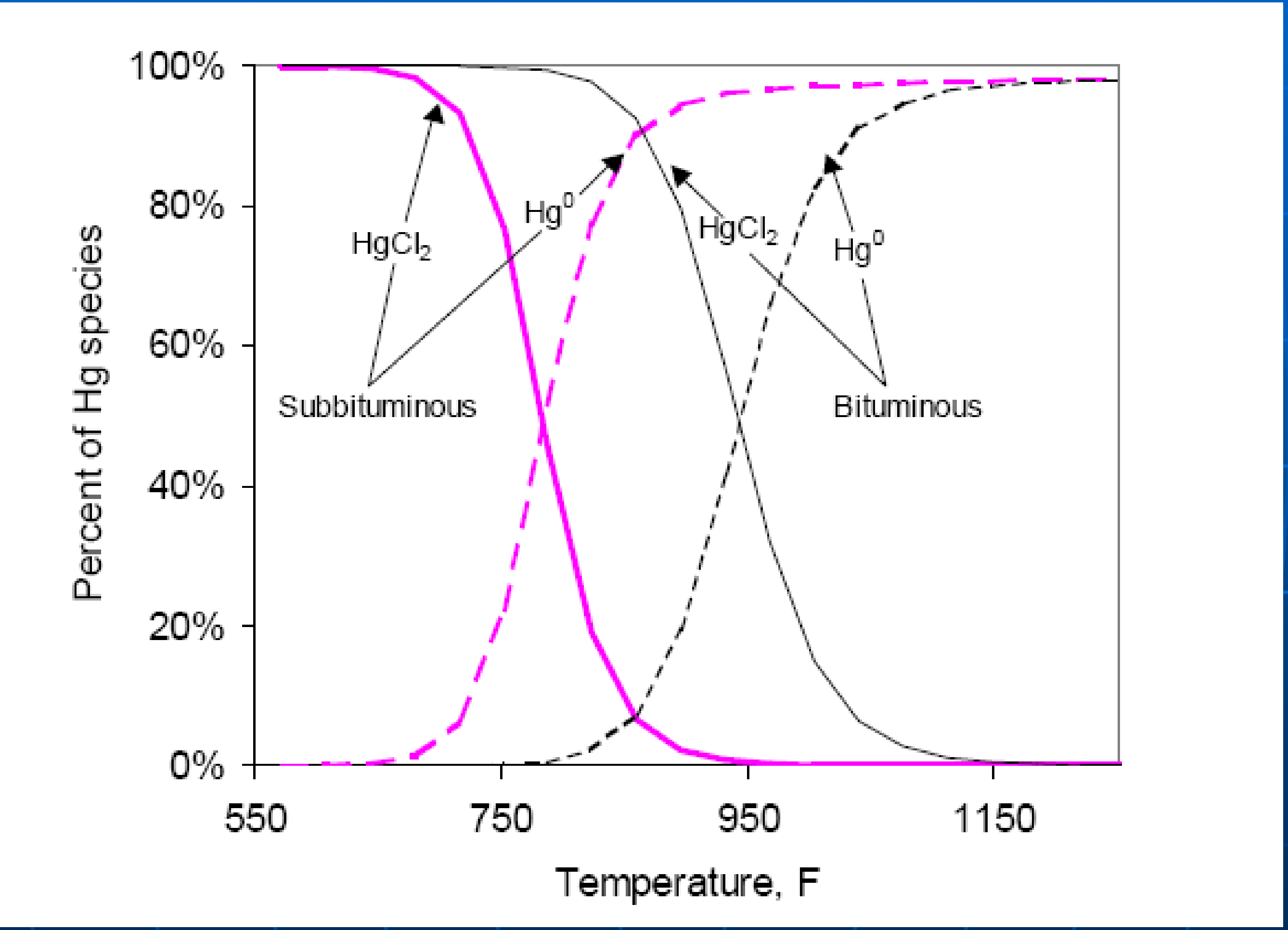
$$Hg + 2HF + ½O_2 = HgF_2 + H_2O \quad (6)$$

$$Hg + 2HCl + ½O_2 = HgCl_2 + H_2O \quad (7)$$

$$Hg + 2HBr + ½O_2 = HgBr_2 + H_2O \quad (8)$$

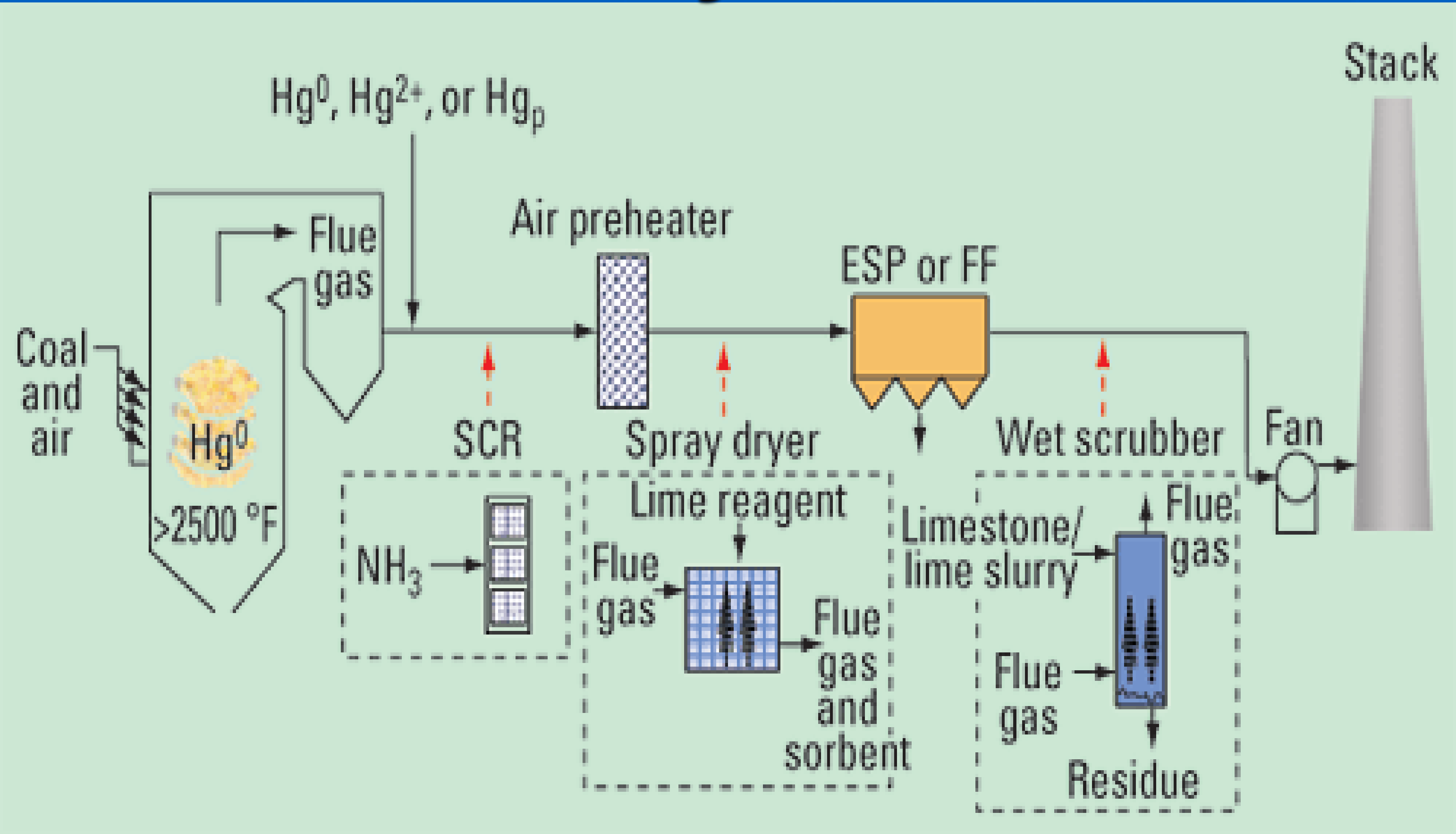
$$Hg + 2HI + ½O_2 = HgI_2 + H_2O \quad (9)$$

MERCURY SPECIES EQUILIBRIUM



Example equilibrium curves – shifts depending on flue gas concentrations – slow to reach equilibrium

Potential Areas for Mercury Control



Control Equipment and the Effect on Mercury

- SCR – potential to oxidize mercury under the right conditions

- APH – changes temperature with subsequent changes in mercury equilibrium and sorption

- ESP – provides platform for mercury sorption on fly ash or sorbents

Control Equipment and the Effect on Mercury (cont'd)

FF – provides platform for mercury sorption - very good ash/gas contacting, very good sorbent contacting

SDA – usually coupled with FF, provides additional particulate and potential sorption sites, cooling of flue gas, changes chemistry

Wet FGD – usually very good at removing oxidized mercury – very poor elemental mercury removal

Table 2. Projected Coal-Fired Capacity by APC Configuration

APC Configuration	Current Capacity, MW	2010 Capacity, MW	2020 Capacity, MW
Cold-side ESP	111,616	75,732	48,915
Cold-side ESP + Wet Scrubber	41,745	34,570	33,117
Cold-side ESP + Wet Scrubber + ACI	-	379	379
Cold-side ESP + Dry Scrubber	2,515	3,161	5,403
Cold-side ESP + SCR	45,984	35,312	22,528
Cold-side ESP + SCR + Wet Scrubber	27,775	62,663	98,138
Cold-side ESP + SCR + Dry Scrubber	-	11,979	13,153
Cold-side ESP + SNCR	7,019	4,576	2,534
Cold-side ESP + SNCR + Wet Scrubber	317	2,830	6,088
Fabric Filter	11,969	10,885	7,646
Fabric Filter + Dry Scrubber	8,832	8,037	9,163
Fabric Filter + Wet Scrubber	4,960	4,960	4,960
Fabric Filter + Dry Scrubber + ACI	-	195	195
Fabric Filter + SCR	2,210	2,950	1,330
Fabric Filter + SCR + Dry Scrubber	2,002	2,601	4,422
Fabric Filter + SCR + Wet Scrubber	805	805	2,363
Fabric Filter + SNCR	267	267	345
Fabric Filter + SNCR + Dry Scrubber	559	557	557
Fabric Filter + SNCR + Wet Scrubber	932	932	1,108
Hot-side ESP	18,929	11,763	10,160
Hot-side ESP + Wet Scrubber	8,724	10,509	10,398
Hot-side ESP + Dry Scrubber	-	538	538
Hot-side ESP + SCR	5,952	3,233	1,847
Hot-side ESP + SCR + Wet Scrubber	688	6,864	9,912
Hot-side ESP + SNCR	684	1,490	1,334
Hot-side ESP + SNCR + Wet Scrubber	474	474	627
Total Existing Units	**304,955**	**298,263**	**297,161**
New Builds of Coal Steam Units	**Current Capacity, MW**	**2010 Capacity, MW**	**2020 Capacity, MW**
Fabric Filter + SCR + Wet Scrubber	-	221	17,292
Total All Units	**304,955**	**298,484**	**314,453**

Note: IGCC units are not included as part of this list.
Note: Current capacity includes some SCR and FGD projected to be built in 2005 and 2006
Note: 2010 and 2020 is capacity projected for final CAIR rule
Note: IPM projects some coal retirements and new coal in 2010 and 2020

Basic Fuel Types and Mercury Behavior

PRB – High Calcium, low halogen – little native Hg oxidation

Bituminous – Low calcium, higher halogen – greater native Hg oxidation

Examples of native Hg removal with PRB vs. Bituminous coal

Table 2. ICR Data Comparing Native Mercury Removal Efficiencies between Bituminous and Subbituminous Coals.

Controls	Average Removal Efficiency	
	Bituminous	Subbituminous (PRB)
Cold-Side Electrostatic Precipitator (ESP)	46%	16%
Fabric Filter (FF)	83%	72%
Spray Dryer Absorber (SDA) and FF	98%	25%

Examples of native Hg removal with PRB vs. Bituminous coal – wet and dry FGD

Post-Combustion Controls			Mercury Capture Efficiency		
PM	*NO_x*	*SO_2*	*Bituminous*	*Subbituminous*	*Lignite*
ESP	None	Wet FGD	66%	16%	44%
ESP	None	Dry FGD	36%	35%	0%
ESP	SCR	Wet FGD	90%	66%	44%
ESP	SCR	Dry FGD	36%	35%	0%
None	None	Wet FGD	42%	30%	0%
None	None	Dry FGD	40%	15%	0%
None	SCR	Wet FGD	90%	51%	0%
None	SCR	Dry FGD	40%	15%	0%

Control Approaches

Fuel Management

SCR

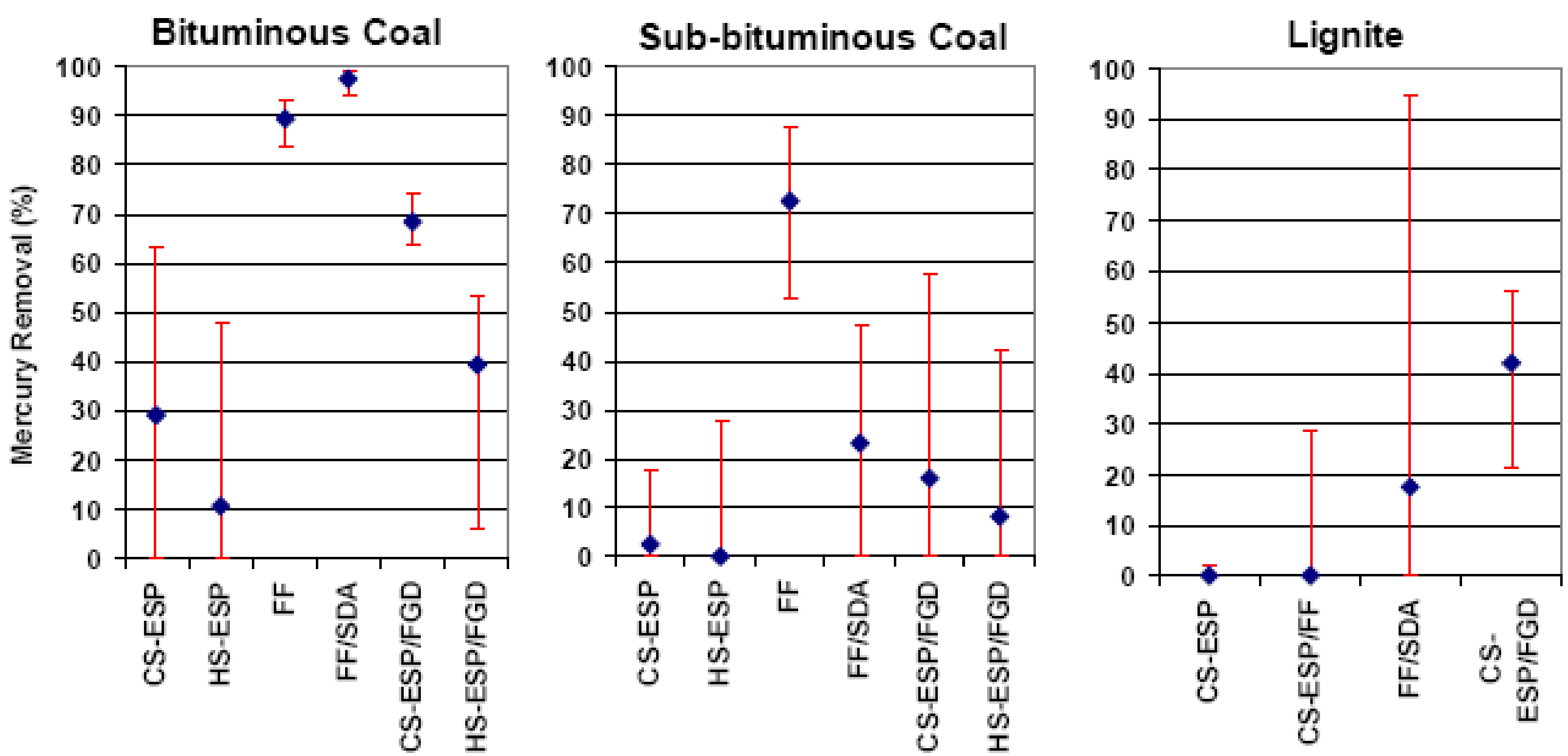
ESP/Baghouse

Sorbent Injection

Wet/Dry Scrubbers

Control Variabilities

Figure 3. Mercury removal rates measured for various coal types and air pollution control configurations (from EPA ICR data, 1999).



Fuel Management

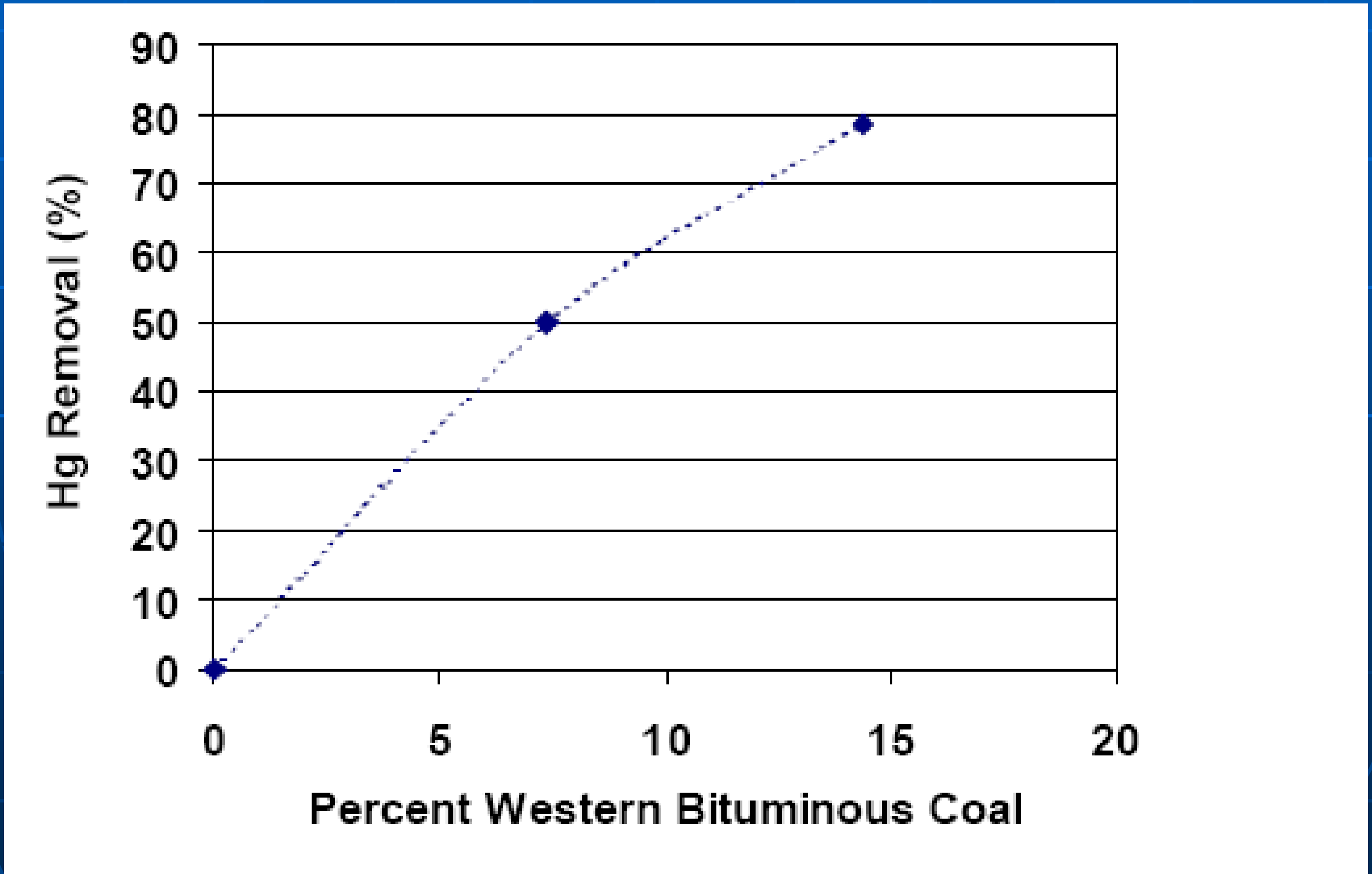
1. Stand alone control method
2. Integral to other control schemes

Fuel Management

- Buy low-Hg coals (stand alone control method) ?
- Look for reasonable halogen levels
- Avoid high Hg – low halogen coals
- *Bottom Line* - Correlate coal quality to potential Hg emissions for the control scheme implemented !

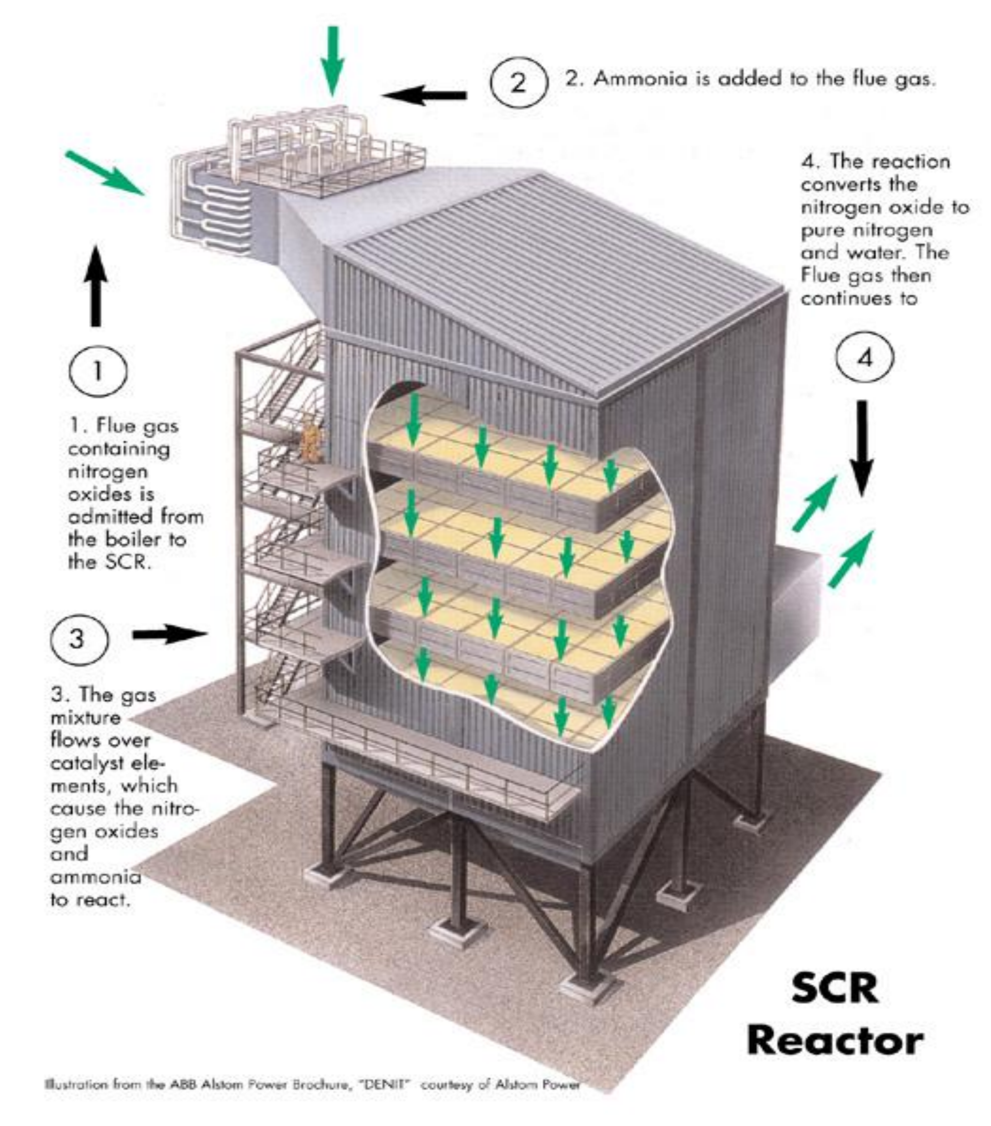
Fuel Blending

Example of blending PRB w/ high halogen bituminous on SDA/FF unit

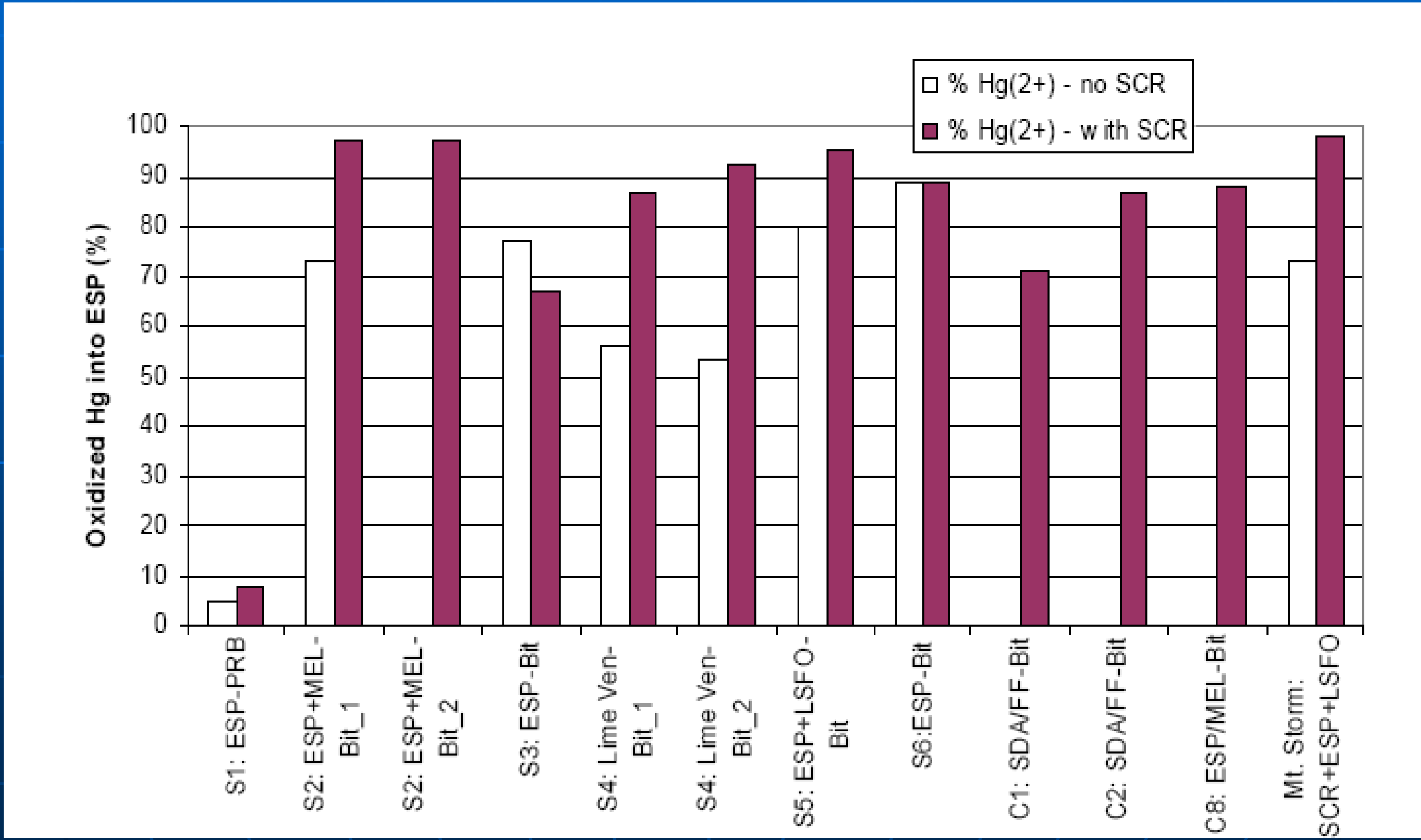


Control Method:
SCR to oxidize mercury

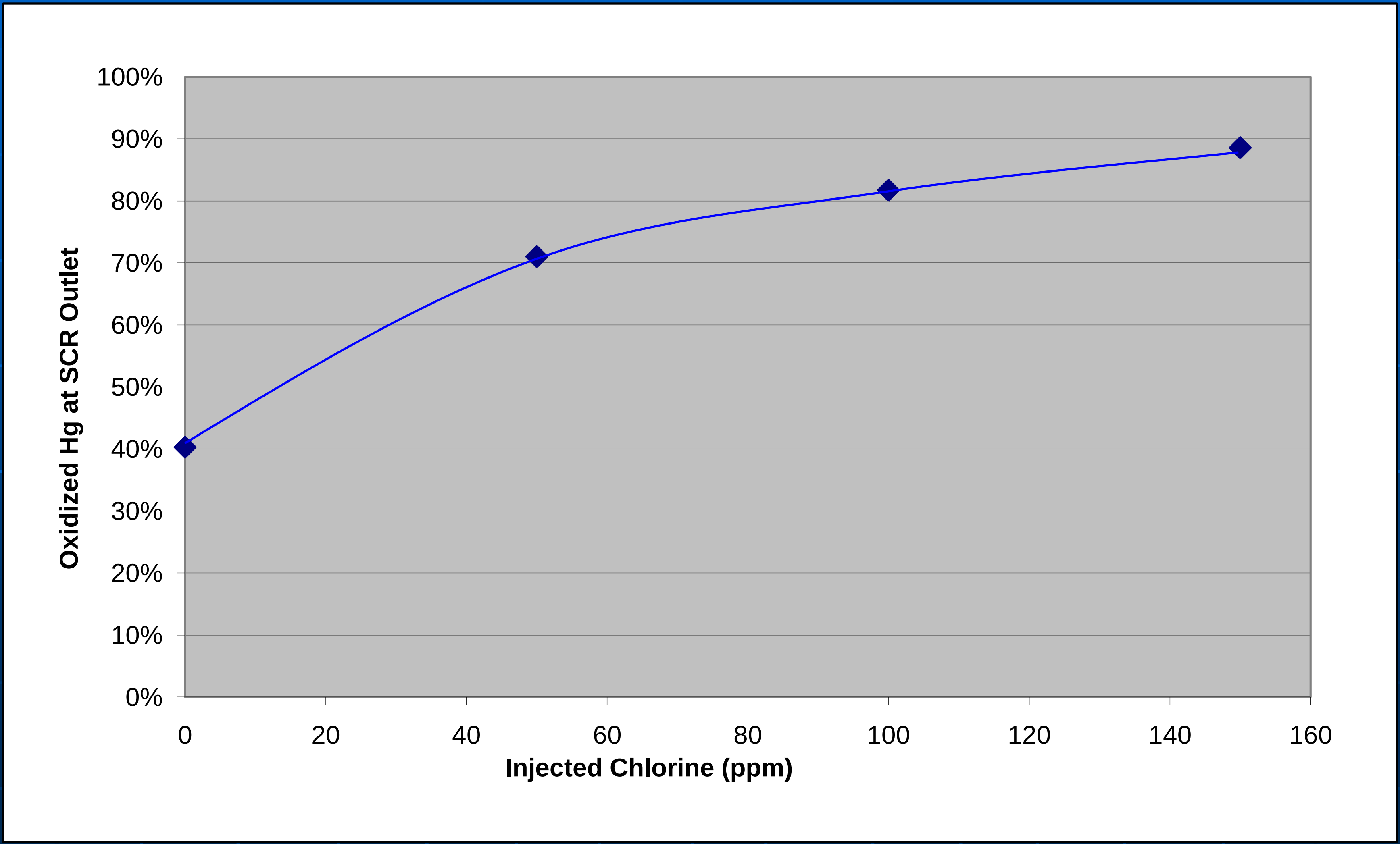
Uses catalyst to oxidize mercury to improve capture in downstream equipment – not a stand-alone control method



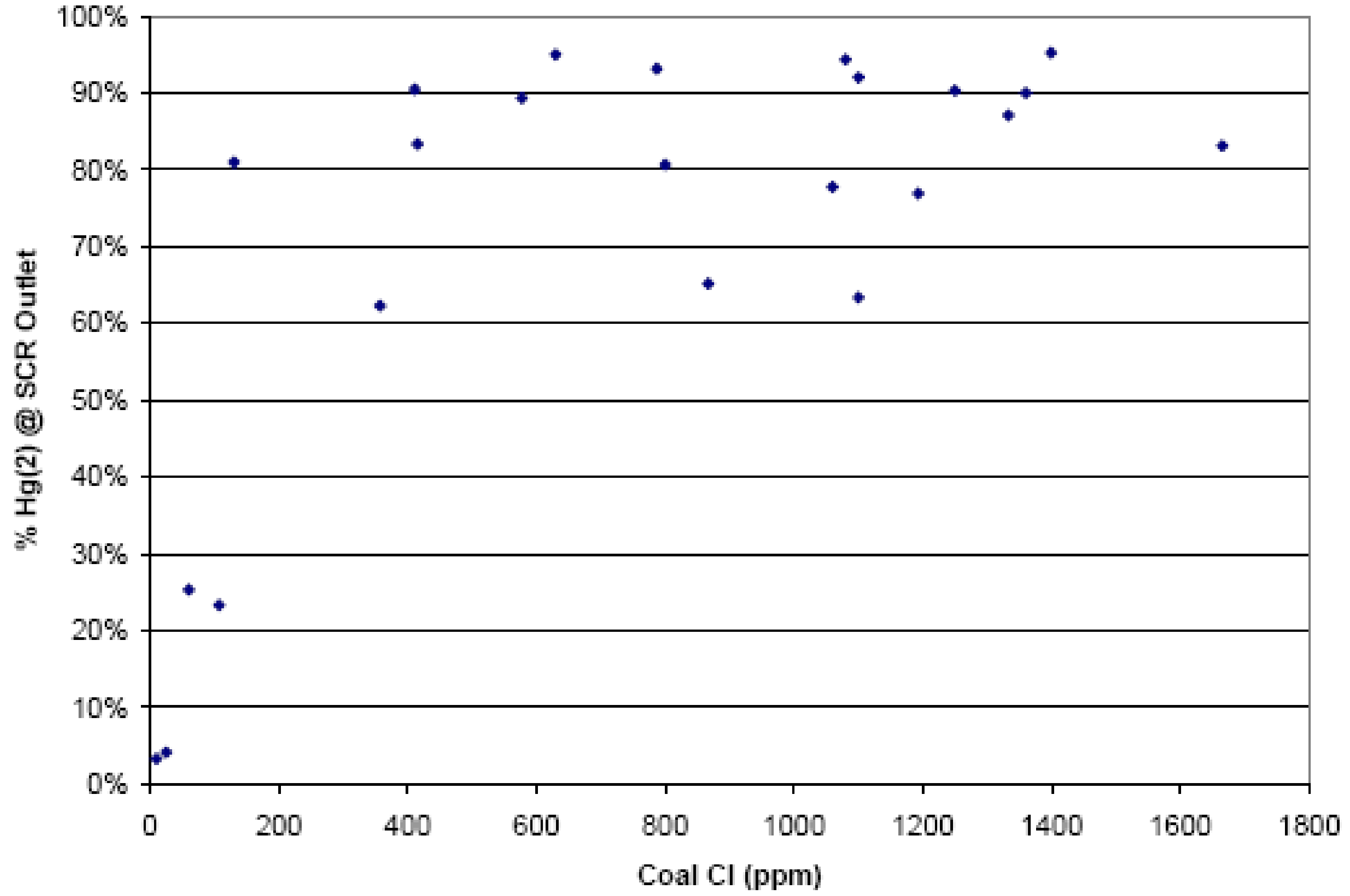
Example Oxidized Mercury Levels with and without SCR



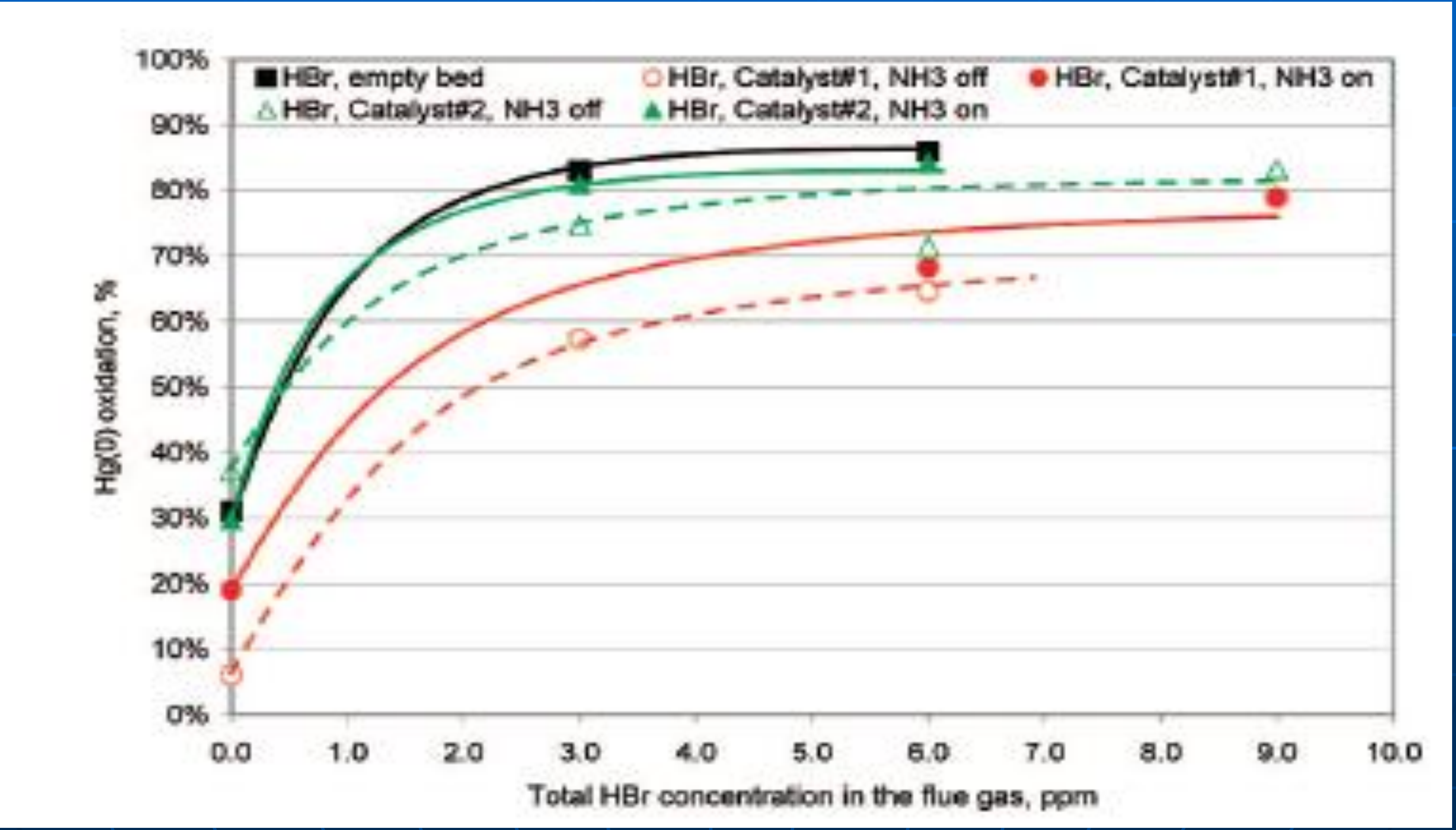
Example Effect of Chlorine Addition on SCR Mercury Oxidation



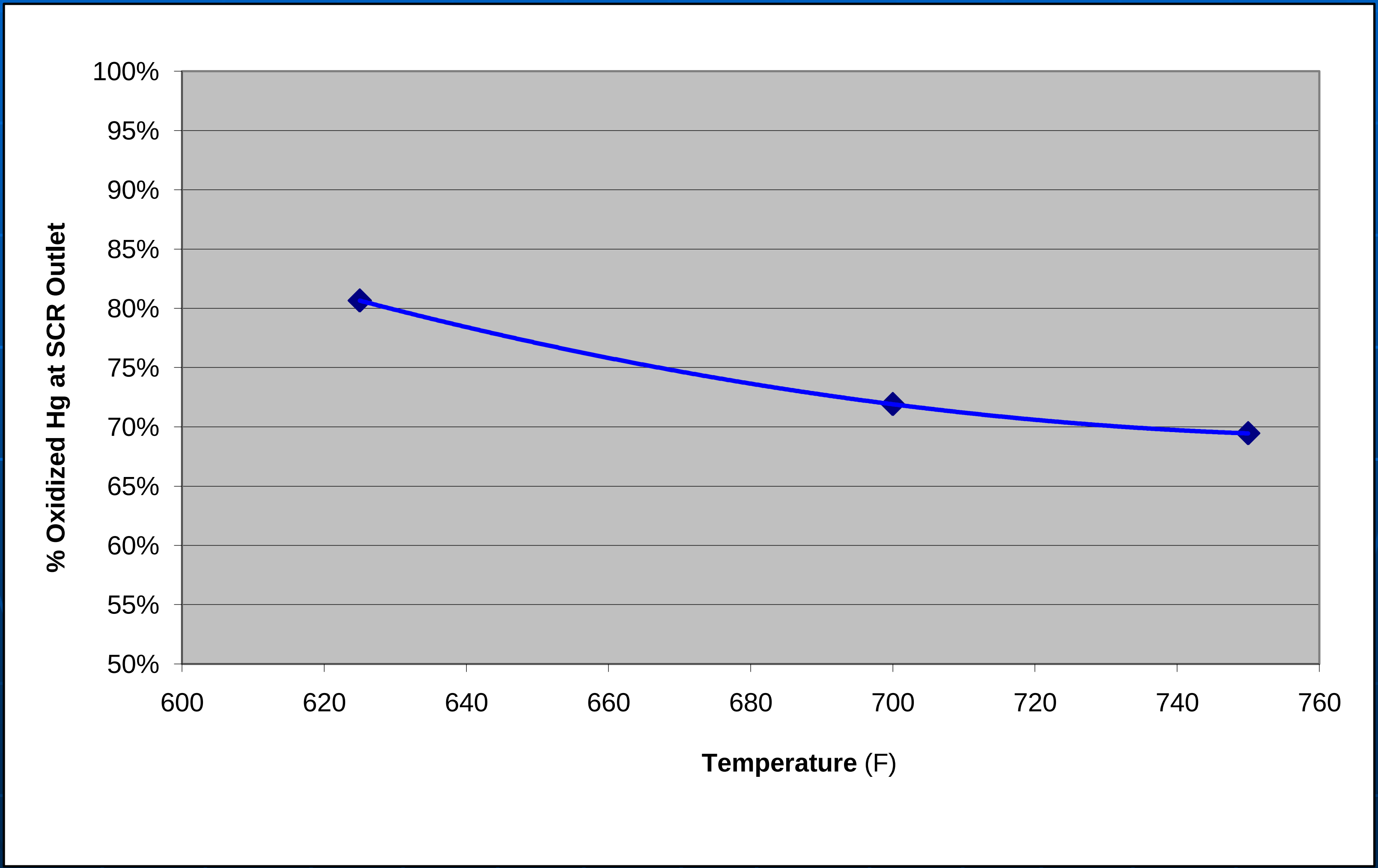
Effect of Native Chlorine
(SCR oxidation with multiple coals)



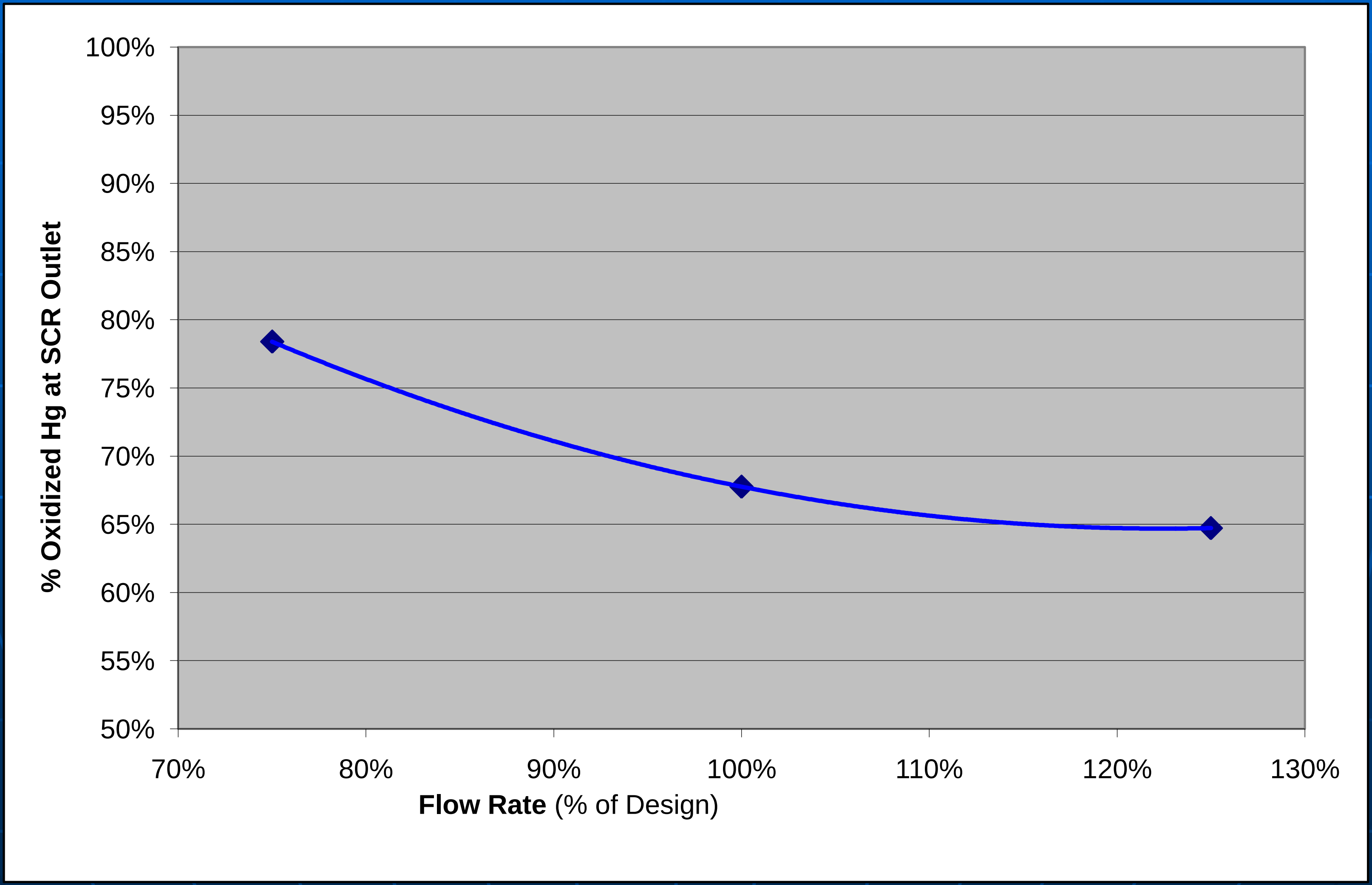
Example Effect of Bromine Addition



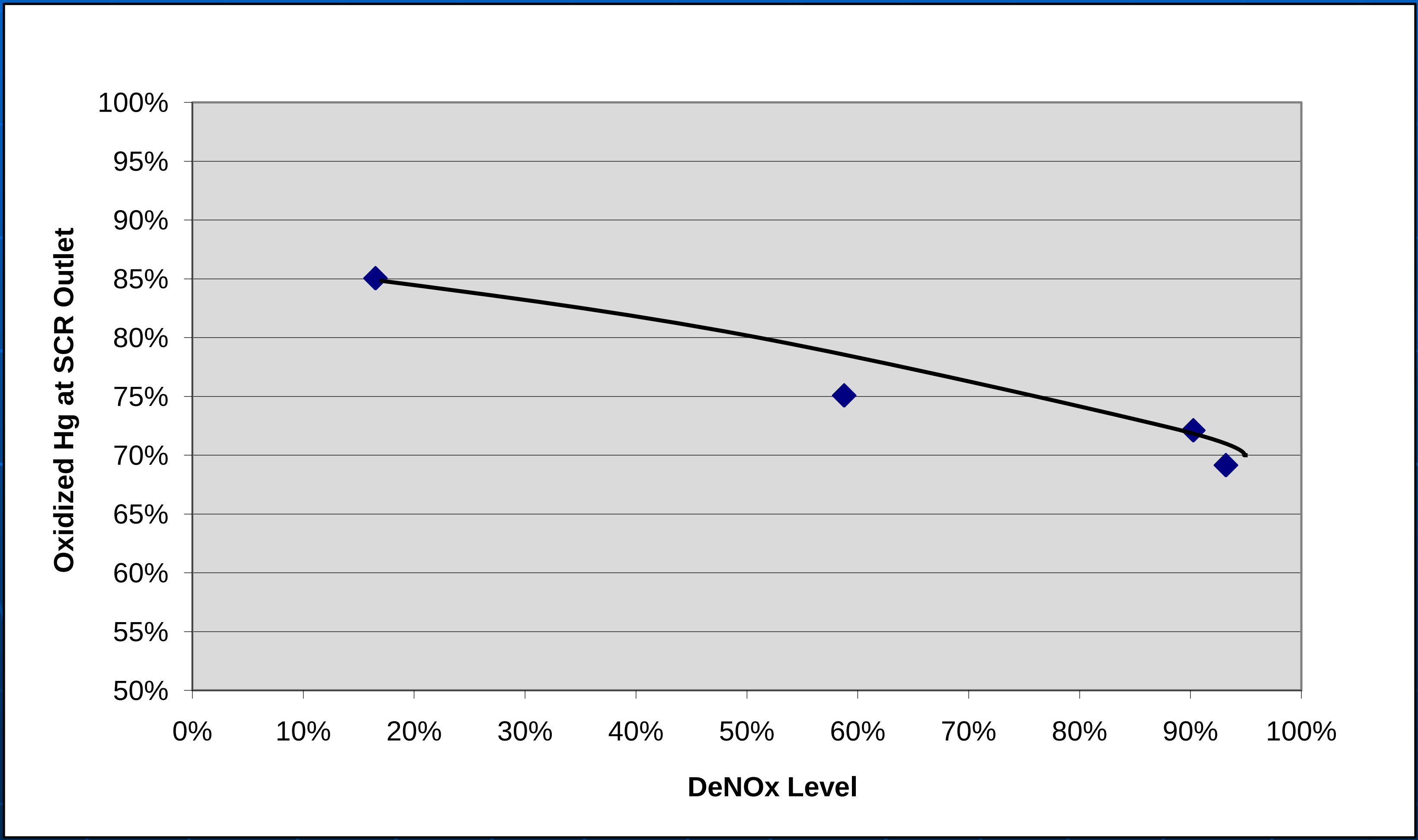
Example Effect of Temperature on SCR Mercury Oxidation



Example Effect of Flow Rate on SCR Mercury Oxidation



Example Effect of DeNOx on SCR Mercury Oxidation



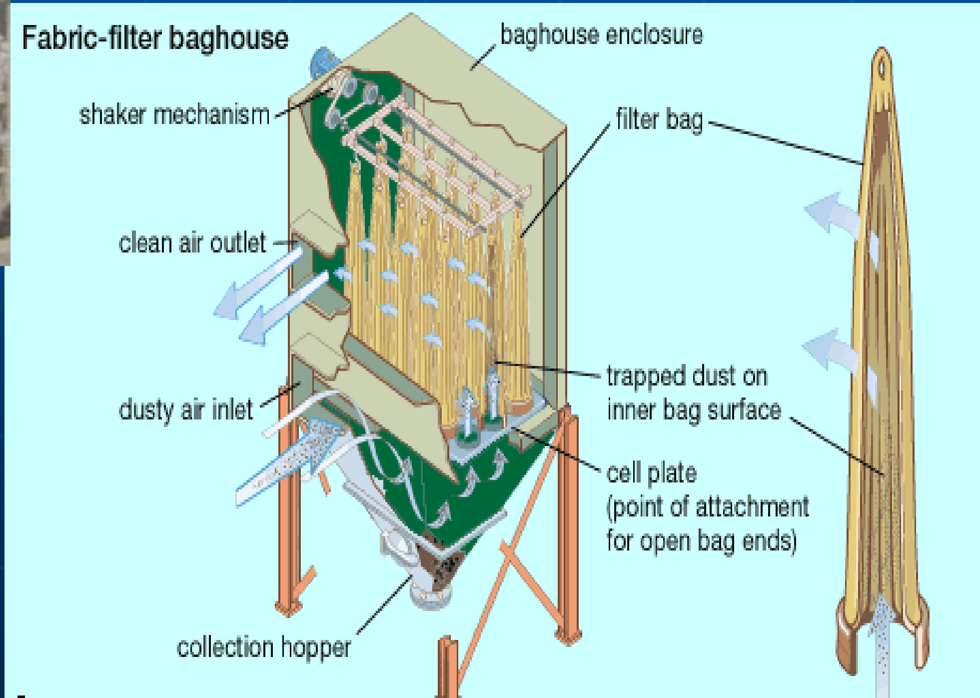
SCR Issues

- Not a stand-alone technology – must be coupled with removal device
- Variable oxidation rate according to fuel/flue gas characteristics
- Performance difficult to predict for various fuels and catalyst type (including aging and regeneration)
- Oxidation rate varies according to boiler load

SCR Summary

- SCR catalysts oxidize mercury – oxidation level can be high under optimal circumstances (90%+)
- Halogen injection may be option to improve performance
- Must be coupled with other devices to effect mercury removal – i.e. wet scrubbers
- Very low cost since the control devices are typically already present
- Improved catalysts being developed/offered that include oxidation rate guarantees

Control Method: Particulate Collection Devices



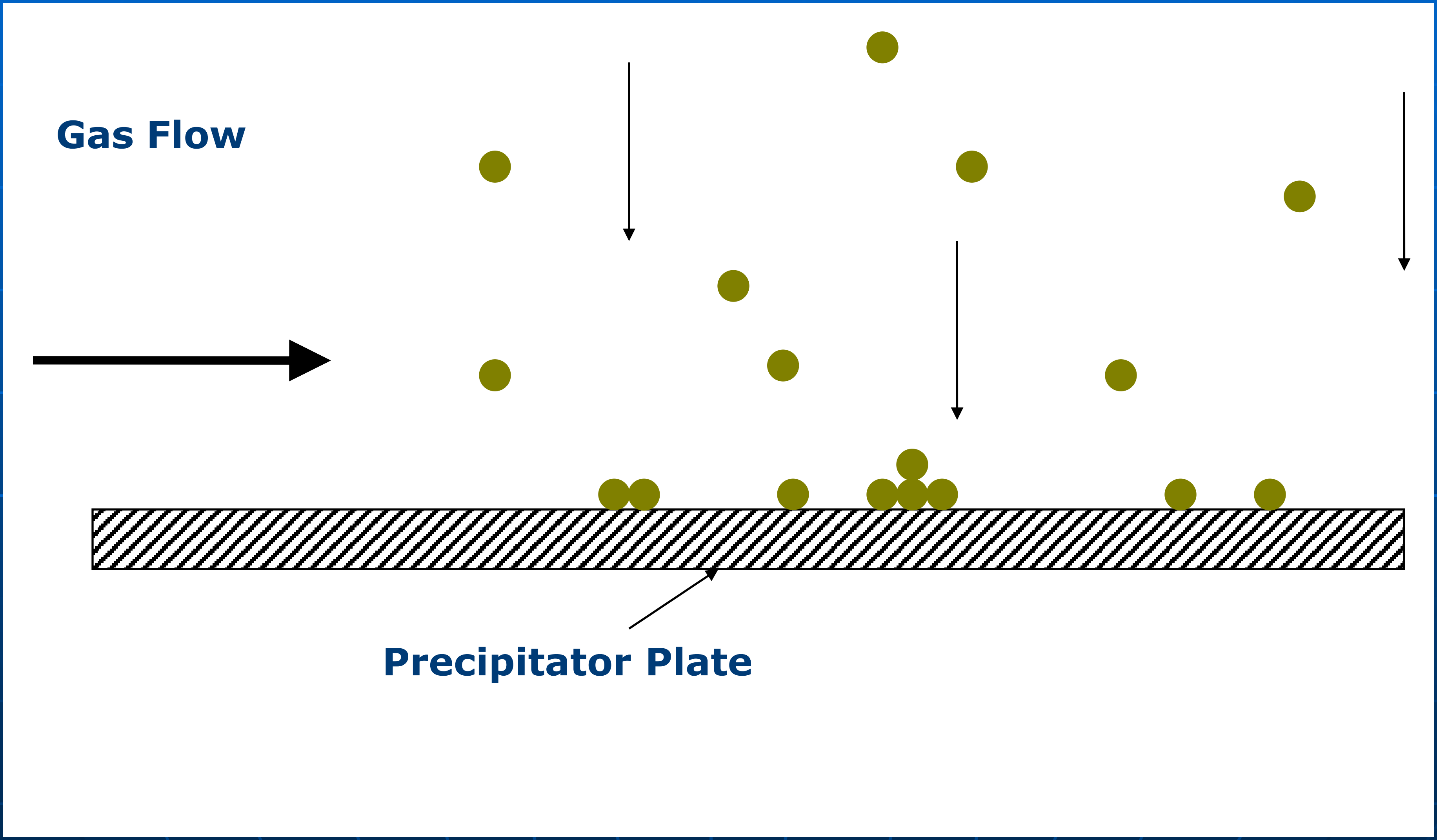
Example Removals for ESPs and FFs

NESCAUM
Northeast States for Coordinated Air Use Management

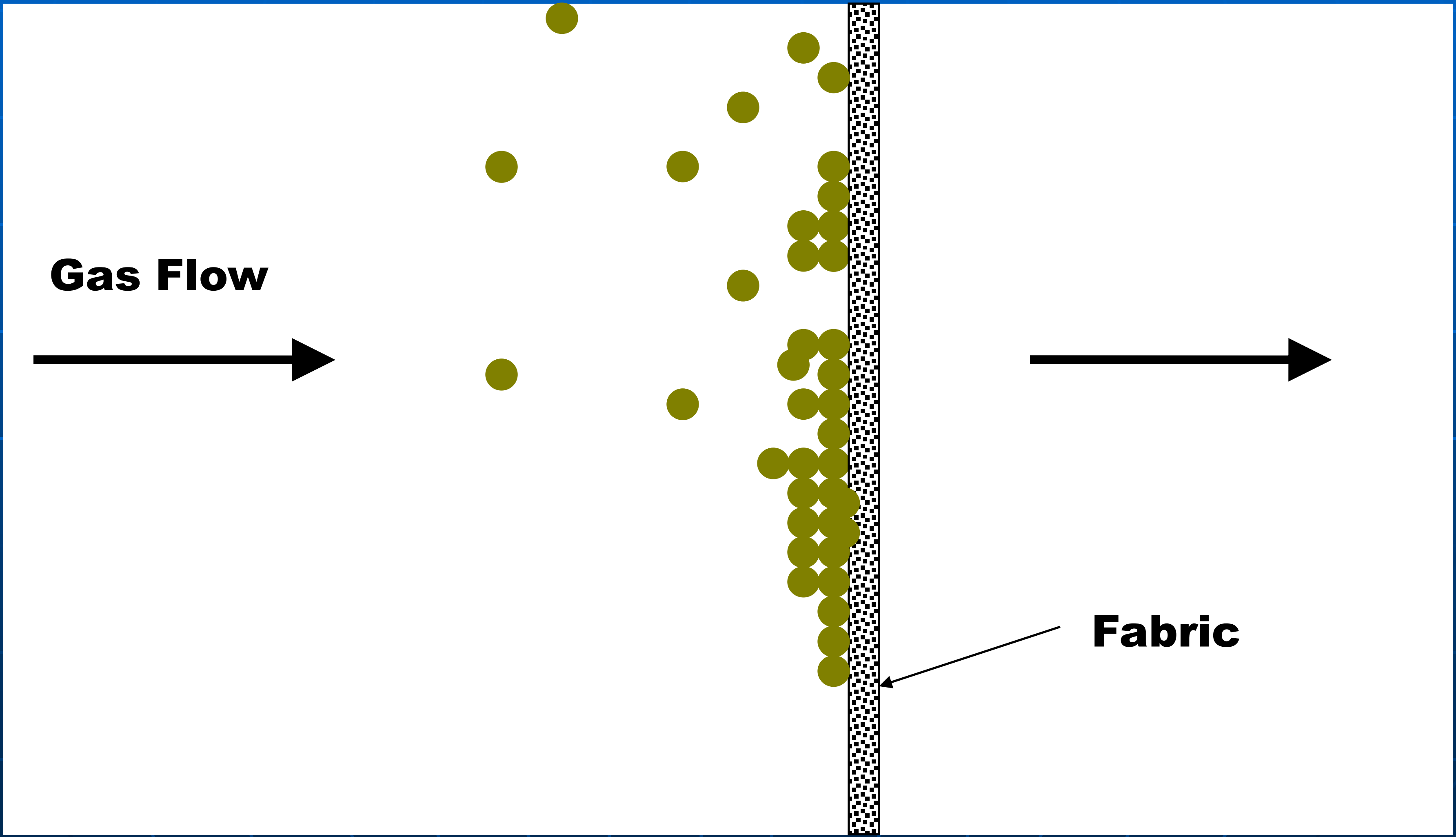
Hg Removal with Existing Equipment

Controls	Bituminous	Subbituminous
PM Only		
CS-ESP	46%	16%
HS-ESP	12%	13%
FF	83%	72%

ESP PHYSICS



FF PHYSICS



ESP/FF Issues

- Limited and variable mercury removal
- Removal may not be high enough to meet requirements
- Mostly oxidized mercury removal

ESP/FF Summary

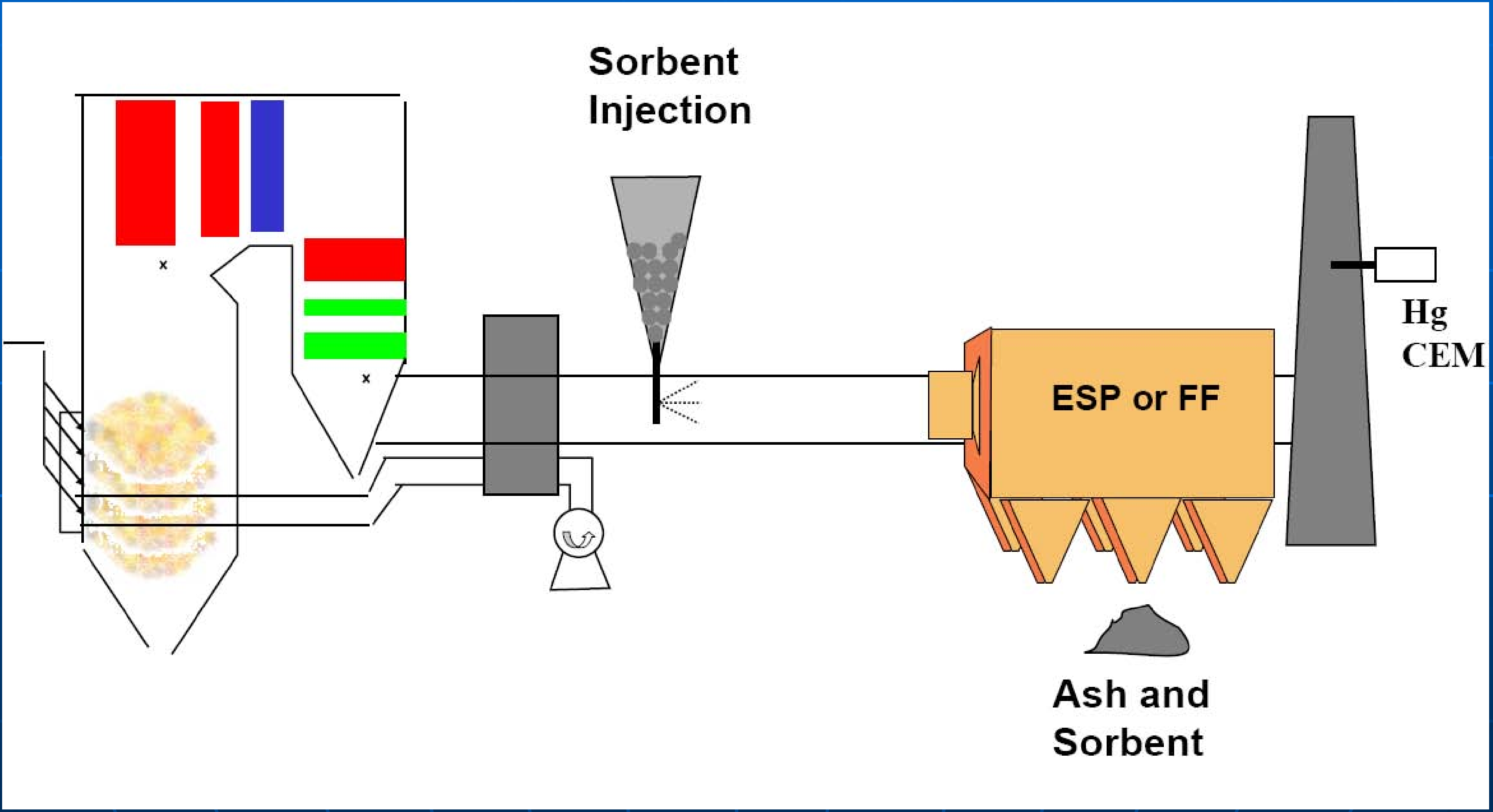
- Baghouse typically provides much better mercury capture
- Variable performance depending on speciation and flue gas characteristics
- Works best in conjunction with sorbent injection
- Very low cost since the control devices are typically already present
- Typically not adequate as stand-alone control devices for high mercury removal

Control Method:
Sorbent Injection

Configurations

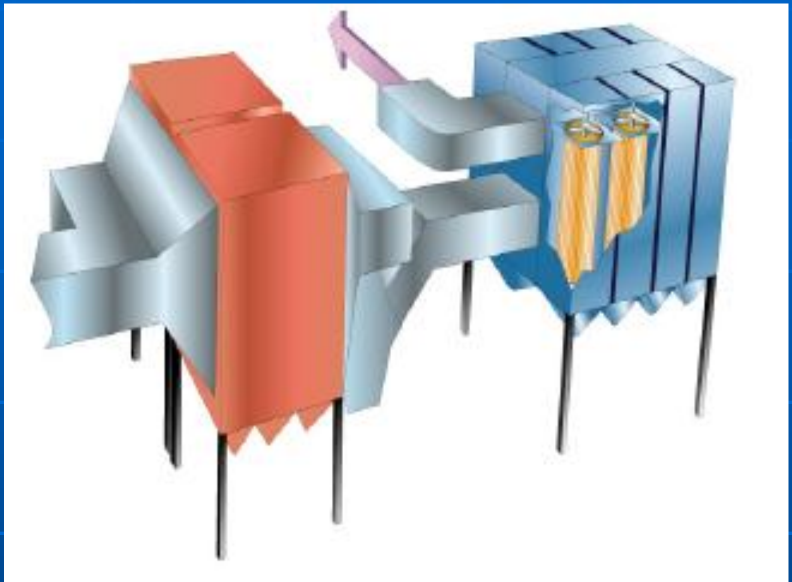
- Ahead of ESP
- Ahead of baghouse
- Between ESP and small dedicated baghouse (TOXICON -COHPAC I)
- Baghouse incorporated into ESP
  (TOXICON – COHPAC II)

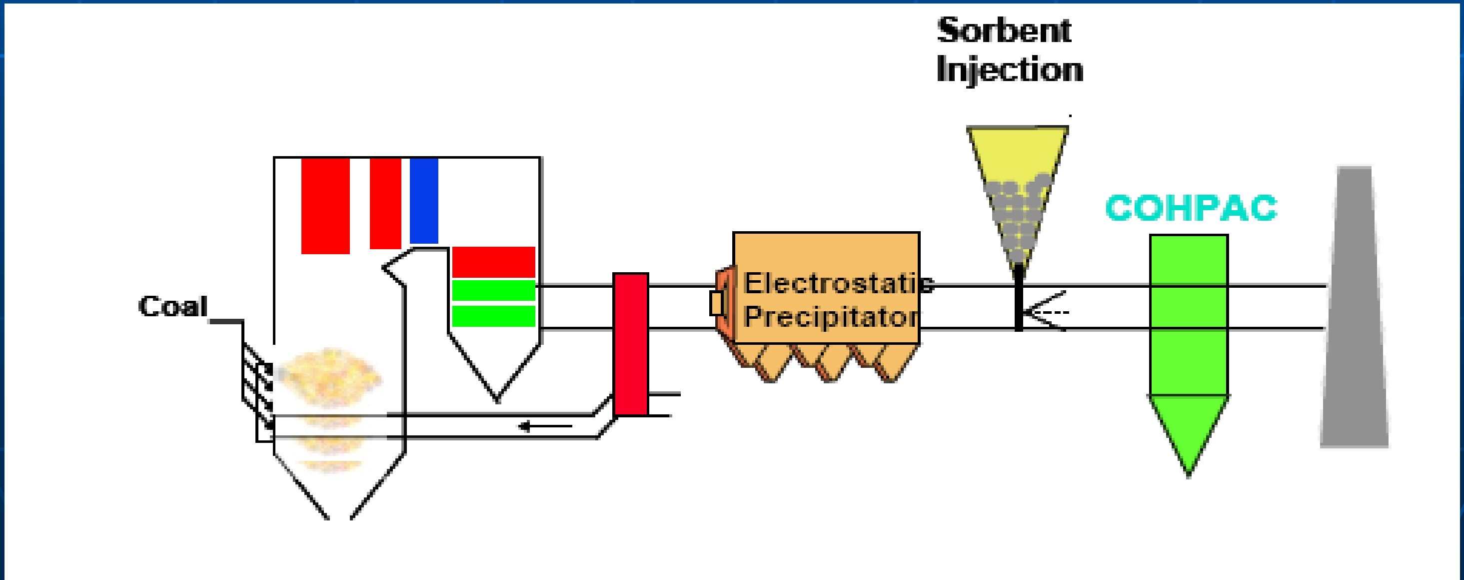
Traditional Sorbent Injection



TOXECON - COHPAC I

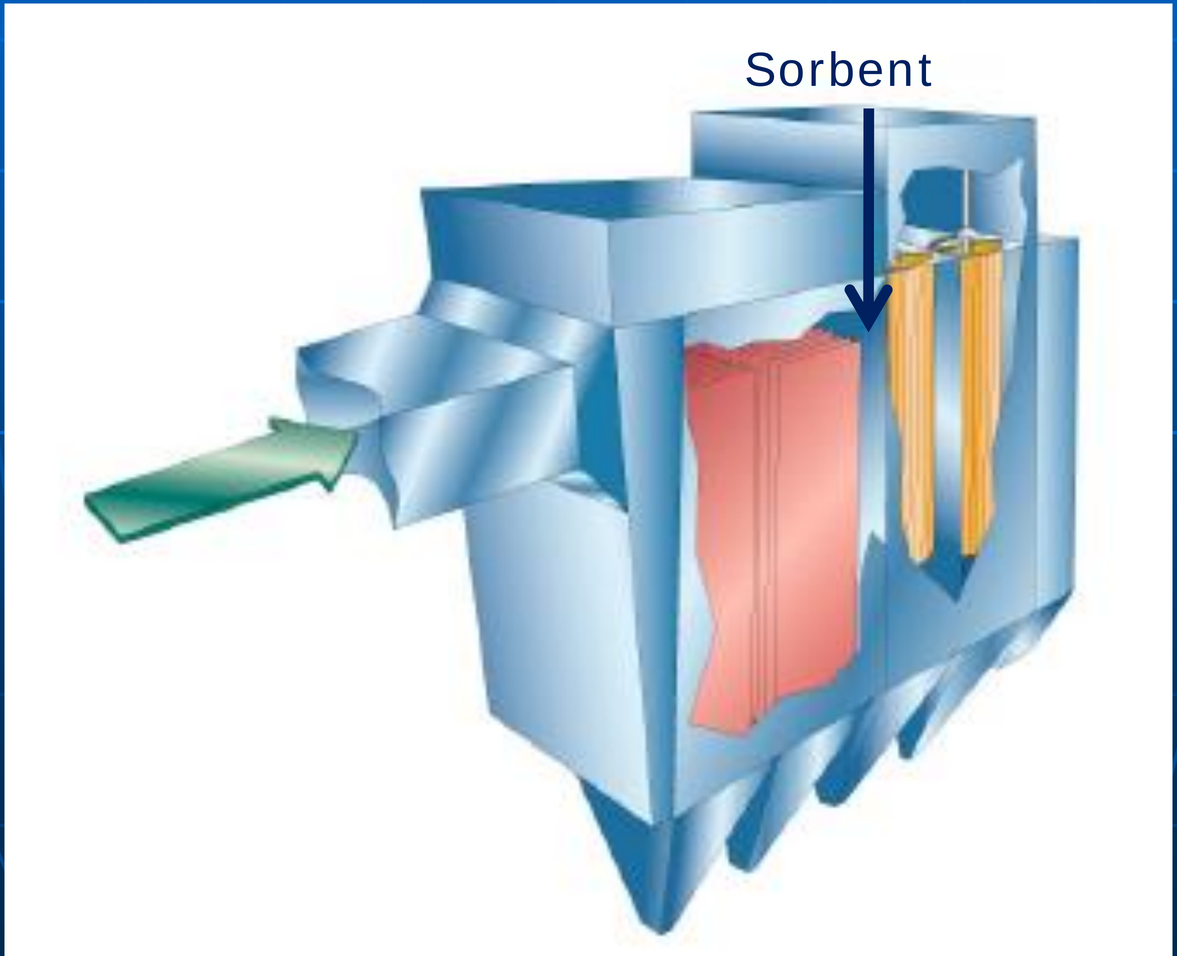
Sorbent Injection Between ESP and Baghouse



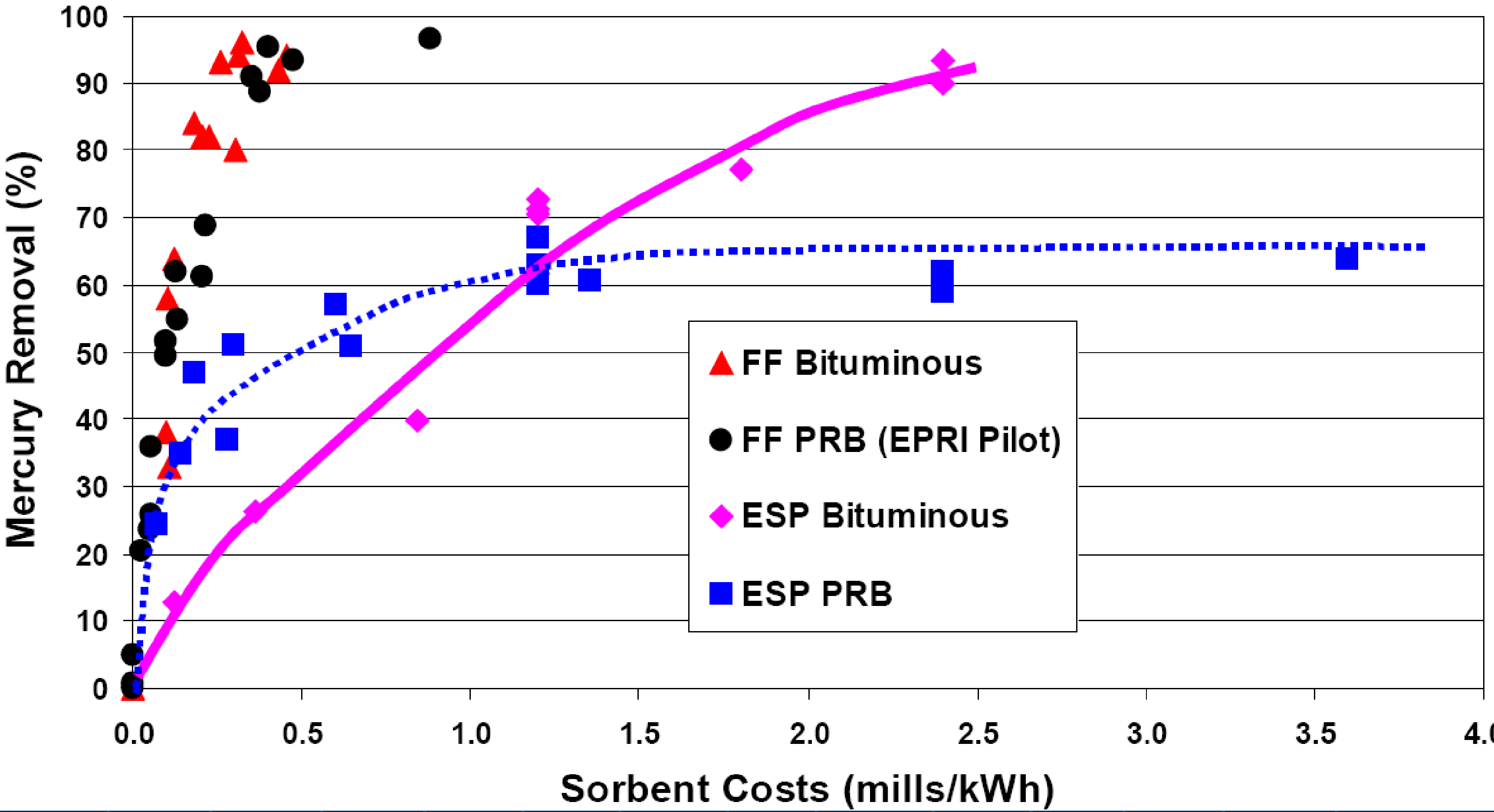


COHPAC II

Sorbent Injection in Hybrid ESP/Baghouse



Cost and Performance of Sorbent-Based Mercury Control



ACI Cost Estimates for Bituminous Coals

- Assumptions:
  - 250 MW Plant; 80% Capacity Factor
- Capital and Operating Costs for ESP:
  - 70% Mercury Removal: PAC Injection @ 10 lb/Macf
  - PAC Injection: $790,000
  - Carbon costs: $2,562,000/yr
- Capital and Operating Costs for FF:
  - Add COHPAC Fabric Filter at $50/kW: $12,500,000
  - 90% Mercury Removal: PAC Injection @ 3 lb/Macf
  - PAC Injection: $790,000
  - Carbon costs: $769,000/yr

Standard Activated Carbon Injection Issues

- Cost
- SO_3 adversely affects many sorbents
- Ash/sorbent waste
- Adverse fly ash sales impacts

Other Mercury Sorbents

- Sodium Tetrasulfide
  - Commercially used in Europe on waste incinerators
  - Avoids ash disposal issues
- Amended Silicates
  - Similar cost/performance as PAC is projected
  - Avoids ash disposal issues
  - To be tested by Cinergy at Miami Fort 6 under DOE program
- Enhanced PAC
  - PAC-based sorbent with higher efficacy due to added chemicals
  - May avoid ash disposal issues
  - To be tested by Duke Power and DTE Energy under DOE program
- Mercury Control Absorption Process (MerCAP)
  - Sorbent-coated (gold) metal plates suspended in flue gas
  - Slipstream tests at Great River Power, WEPCO and Minnesota Power plants

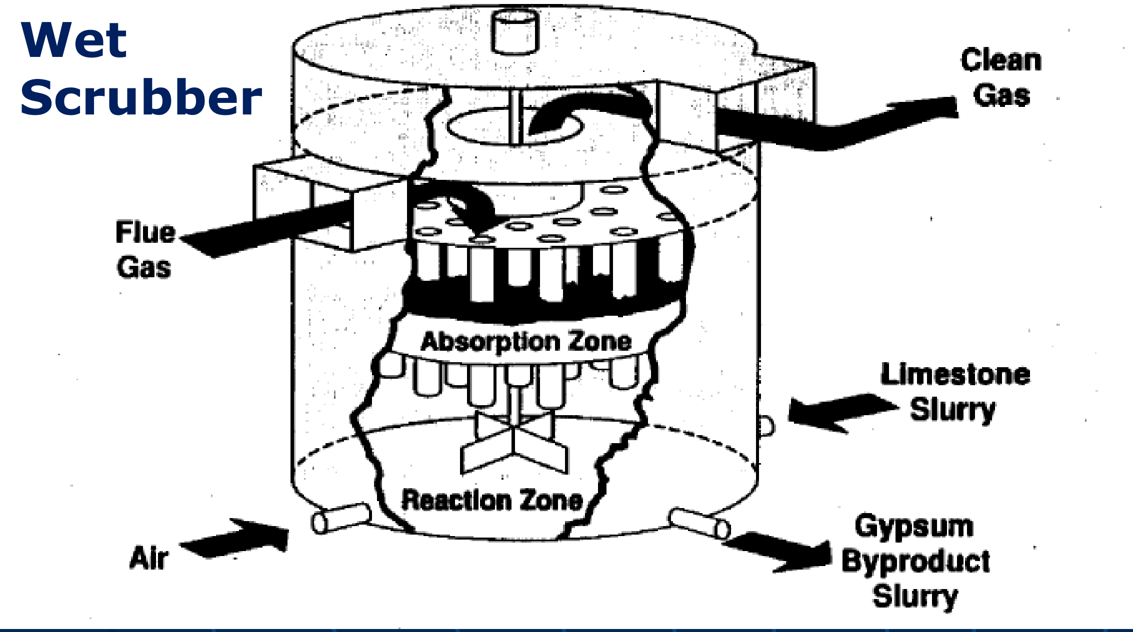
Sources: Babcock Power, Mega Symposium, DOE releases

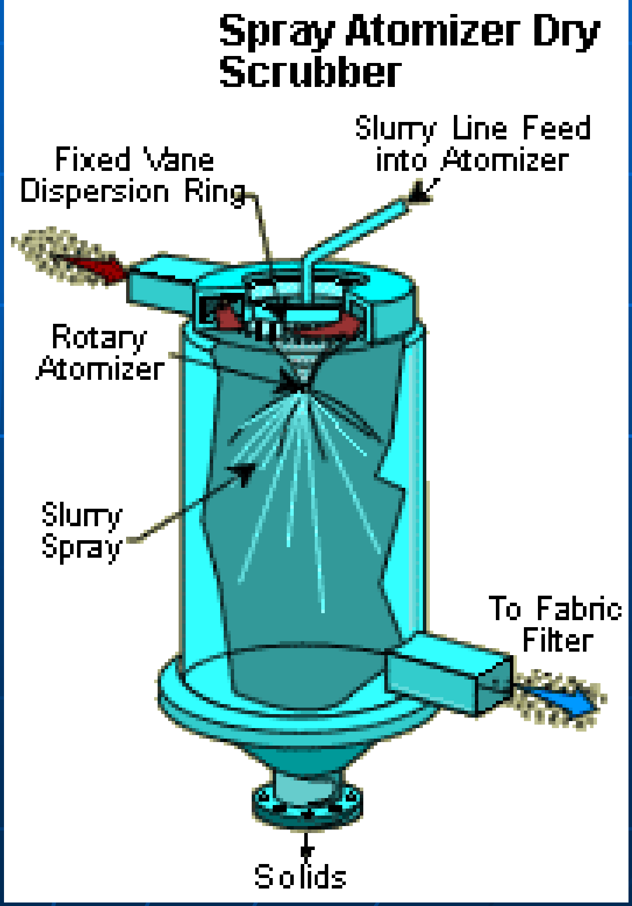
Sorbent Injection Summary

- High removal efficiencies (90%+) for both oxidized and elemental mercury
- Most conservative control method – wide applicability (if enough sorbent of the right type is used)
- High cost and balance of plant issues make the technology unattractive economically compared to some other methods

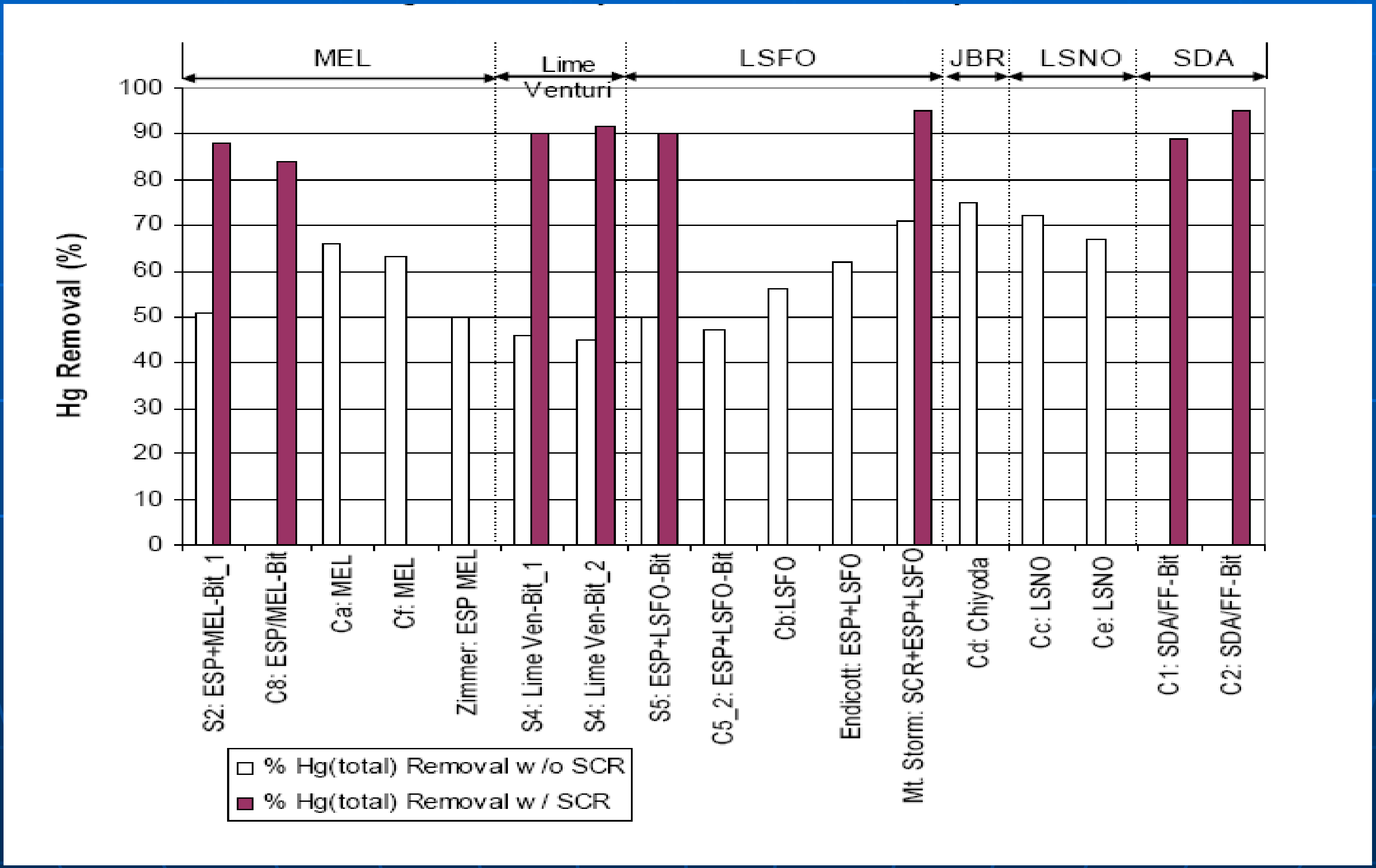
Control Method: Wet/Dry Scrubbers

- Use wet scrubber to remove oxidized mercury
- Use dry scrubber to remove oxidized and some elemental mercury





Example Mercury Capture vs. Scrubber Type



MEL: magnesium enhanced limestone scrubber LSFO: Limestone forced oxidation scrubber LSNO: Limestone natural oxidation scrubber

Projected SCR and Wet FGD Installation

Figure 1. Projected coal-fired capacity with FGD

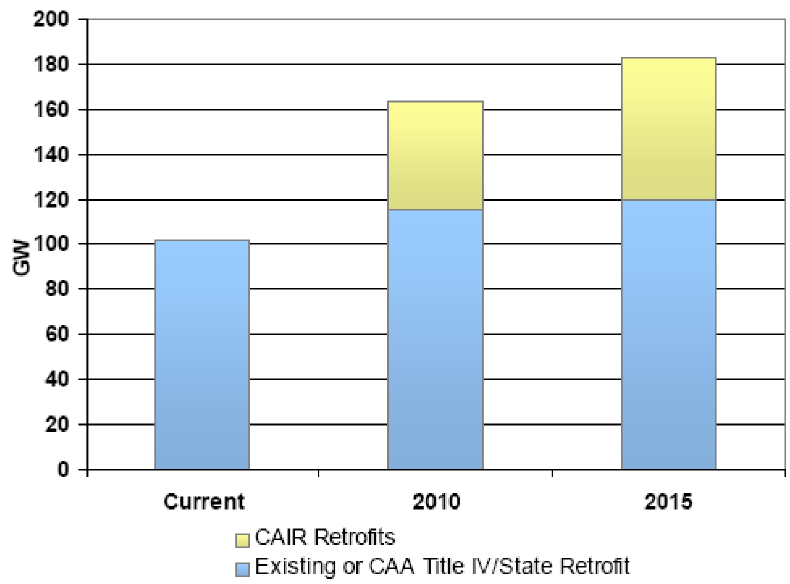


Figure 2. Projected coal-fired capacity with SCR

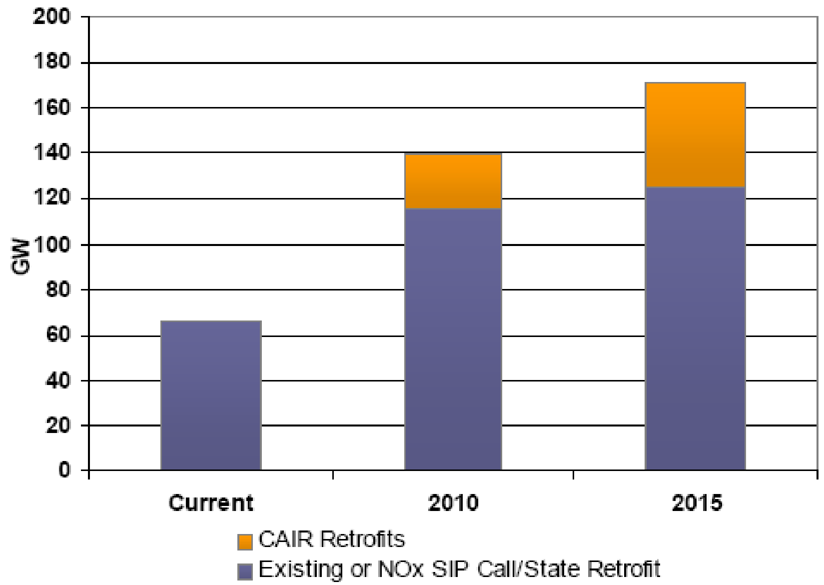
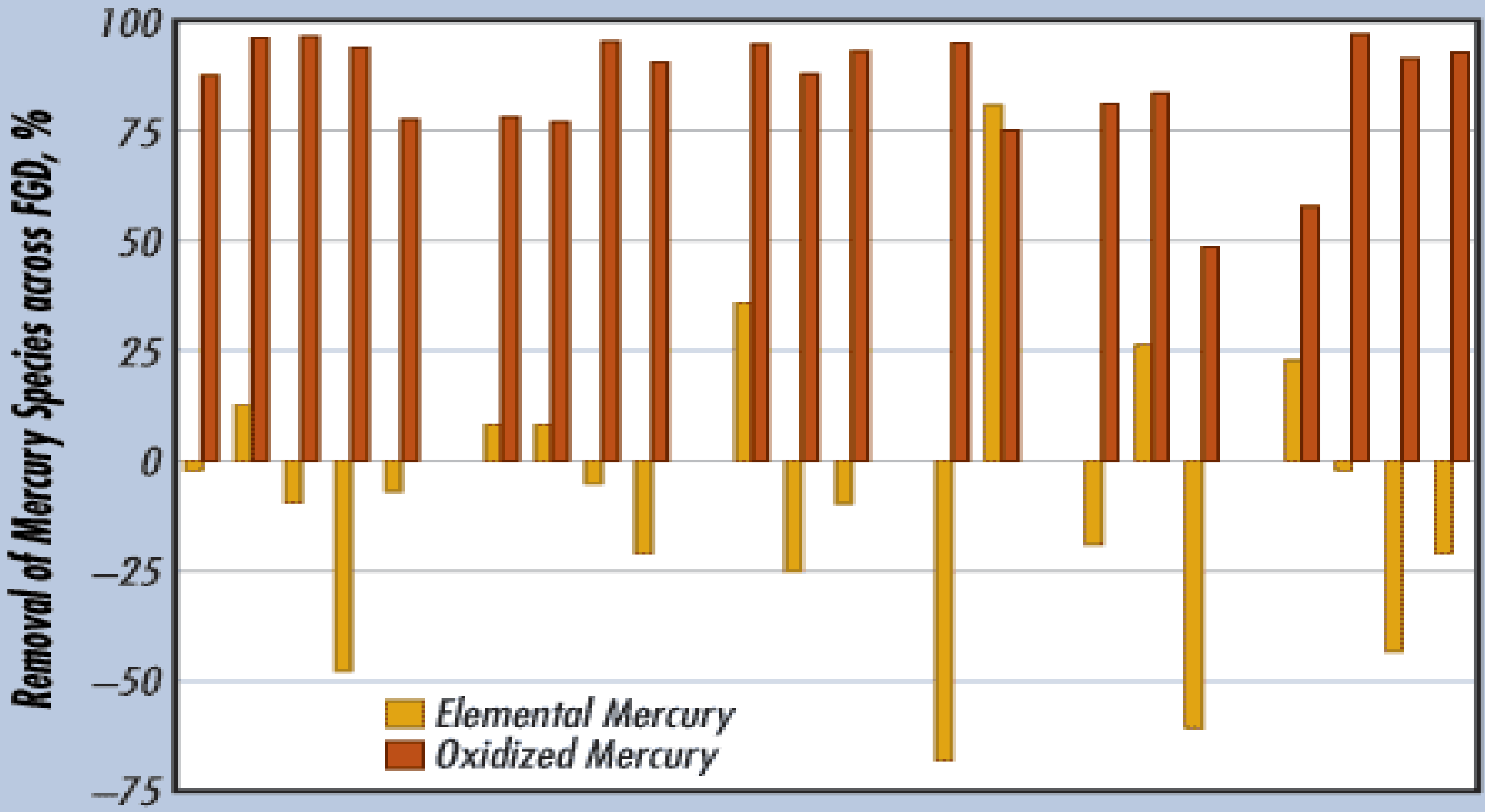


FIGURE 1
REMOVAL OF MERCURY SPECIES ACROSS WET FGDs



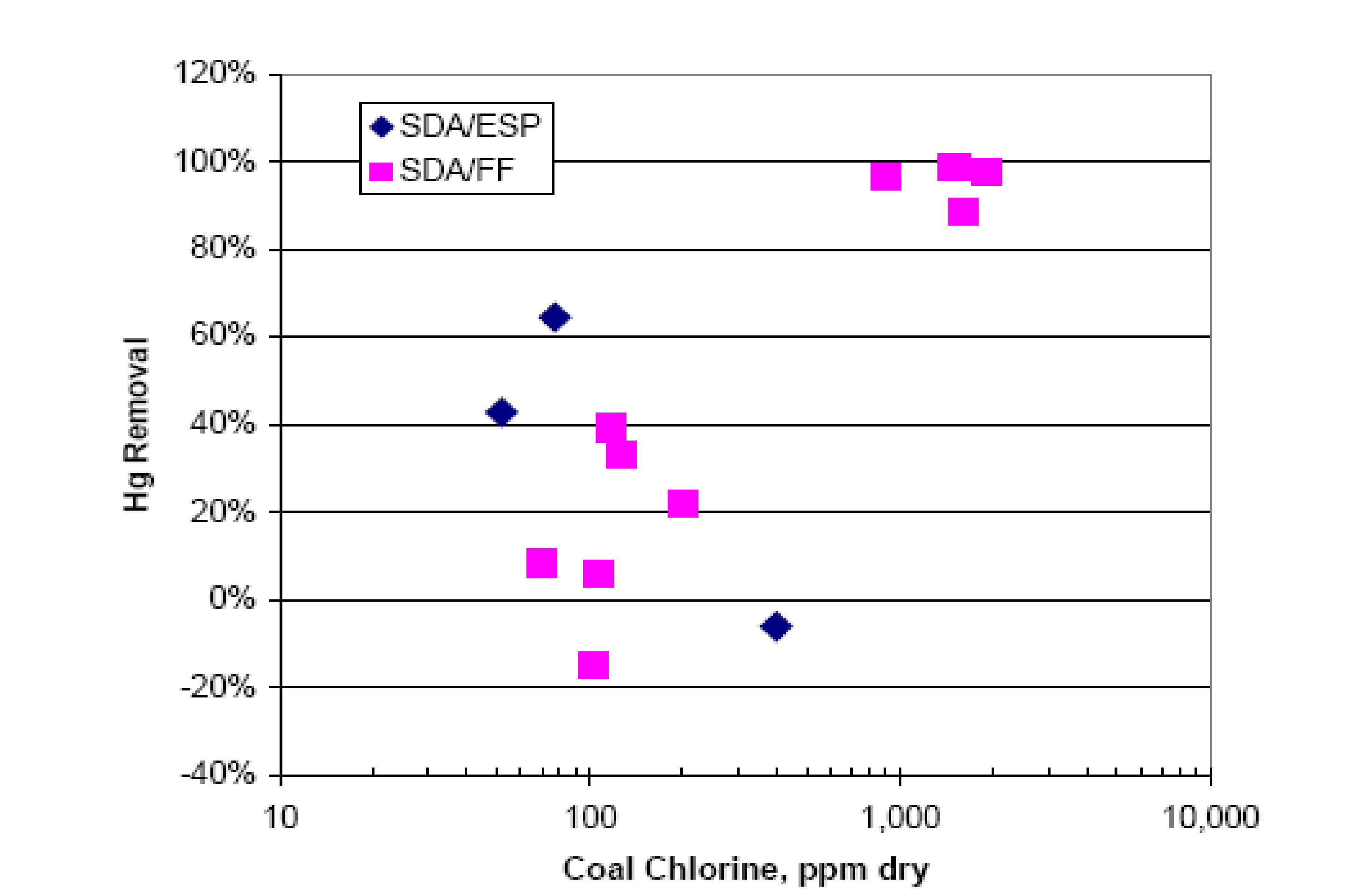
Source: ICR and Control Technology Demonstrations

Wet Scrubber Issues

- Elemental Mercury Re-emission – Additives ?
- Predicting and maintaining performance
- Mercury fate ?

Dry Scrubbing (SDA)

Halogens help - good at removing oxidized mercury - reasonable elemental capture



Scrubber Summary

- Variable but often high rates of oxidized mercury removal

  (90%+ removal - sometimes !)

- Wet scrubbers can not capture elemental mercury well – possible improvements to come ?

- Hope to optimize operations for all scrubbers for mercury removal

Overall Summary

- Many control options are available, but it’s difficult to consistently achieve 90%+ removal rates.
- Fuel plays a major role, if not controlling role, in almost all control technologies.
- Under some circumstances, optimized SCR and scrubber operation is a very good control scheme, but not universal.
- Sorbent injection is probably the most conservative approach to high mercury removal, but cost and potential adverse impacts are high.
- In a fully implemented trading environment, optimization of all control equipment for mercury removal may be important.
- Final regulations will play a decisive role in the mix of mercury control that the industry will implement.

QUESTIONS ???