

# Worldwide Pollution Control Association

IL Regional Technical Seminar  
August 3-4, 2010

W  
P  
C  
A



Visit our website at [www.wpca.info](http://www.wpca.info)

# **WPCA**

***90% Mercury Removal – Control Technologies***

***Amy Evans – Marsulex Environmental Technologies***

***Ken Jeffers – Johnson Matthey Catalysts***

***Don Stowe – Babcock Power***

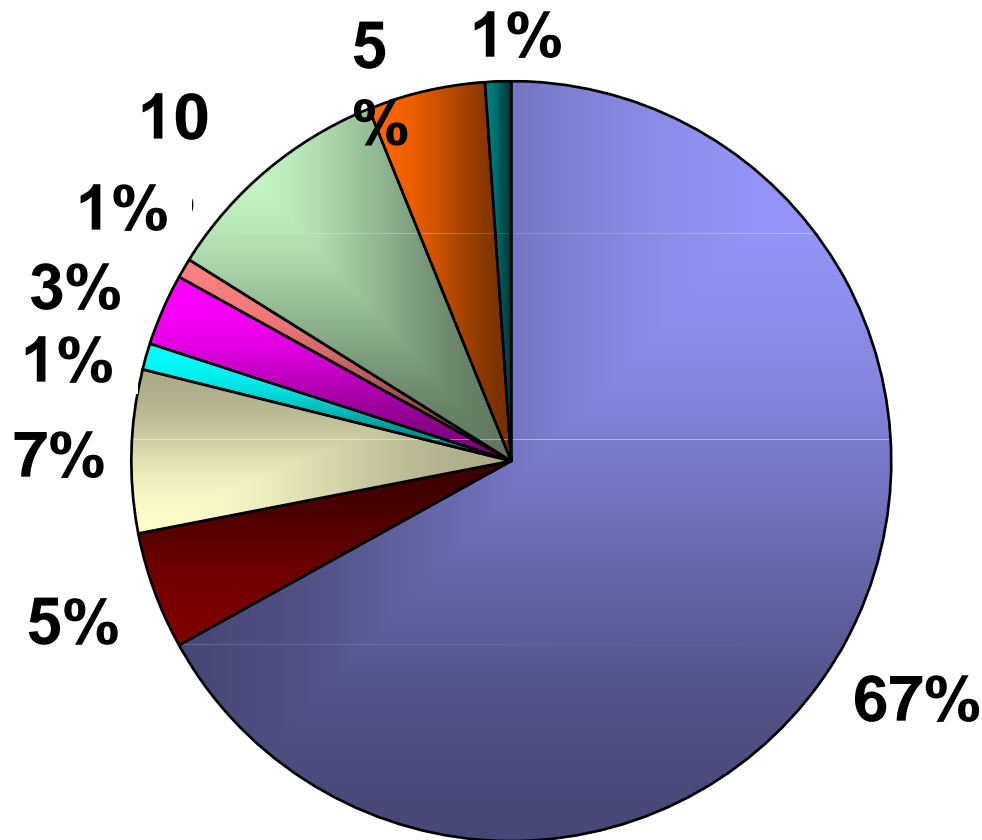
***Greg Bielawski – The Babcock & Wilcox Company***

**WPCA Regional Seminar**

**Springfield, Illinois**

**August 3, 2010**

# Man-made Sources of Mercury in the Environment – 2006



- 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

# What we do know?

- ▣ Federal Mercury MACT Standard
  - 3/16/2011 To be proposed
  - 11/16/2011 Final rule





## ***Houston Astrodome***

### ***A Hypothetical Example***

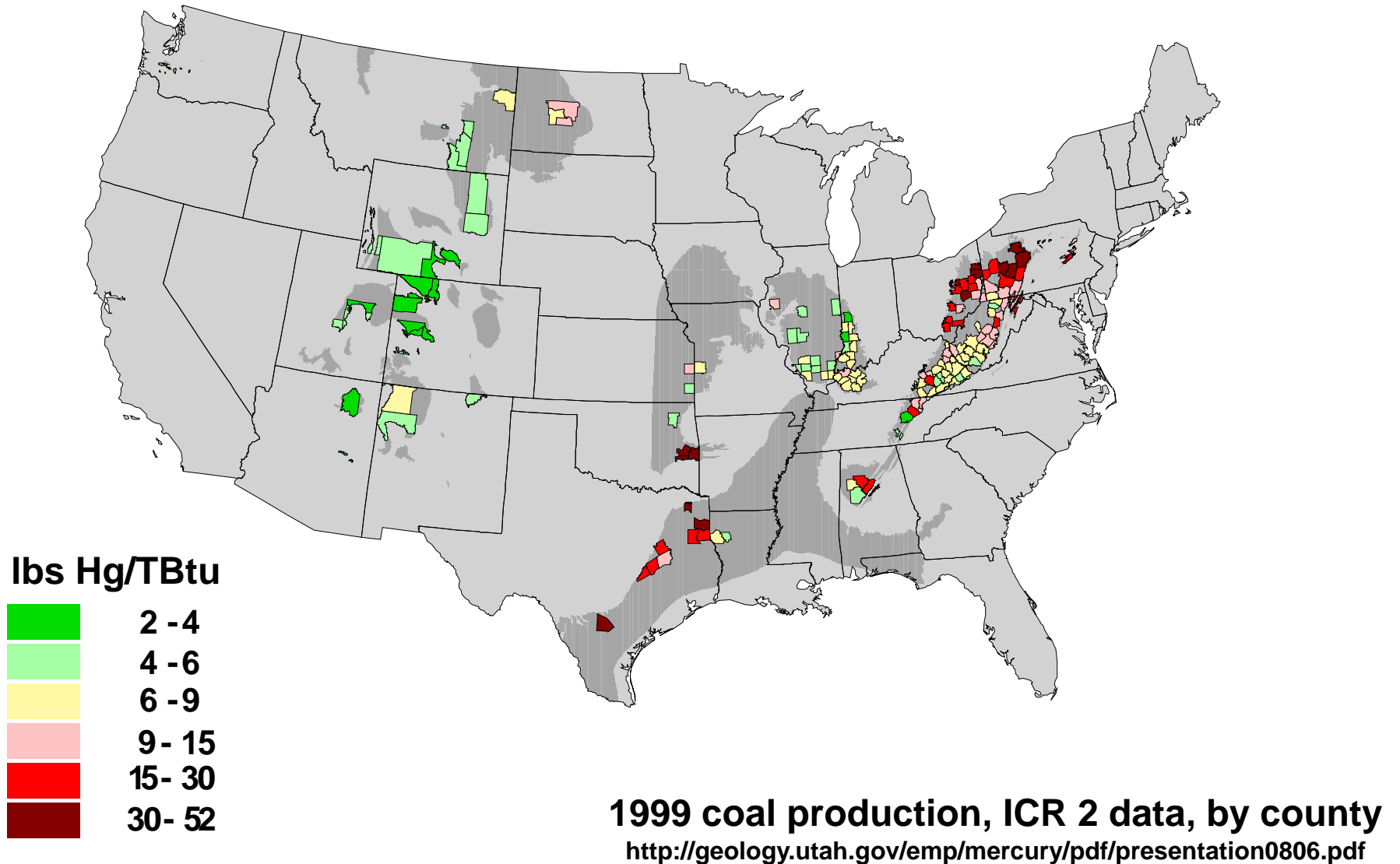
- Dome filled with 30 billion ping-pong balls
- 30 black mercury balls
- Find and remove 27 balls for 90% Hg capture

# Lessons learned in the past

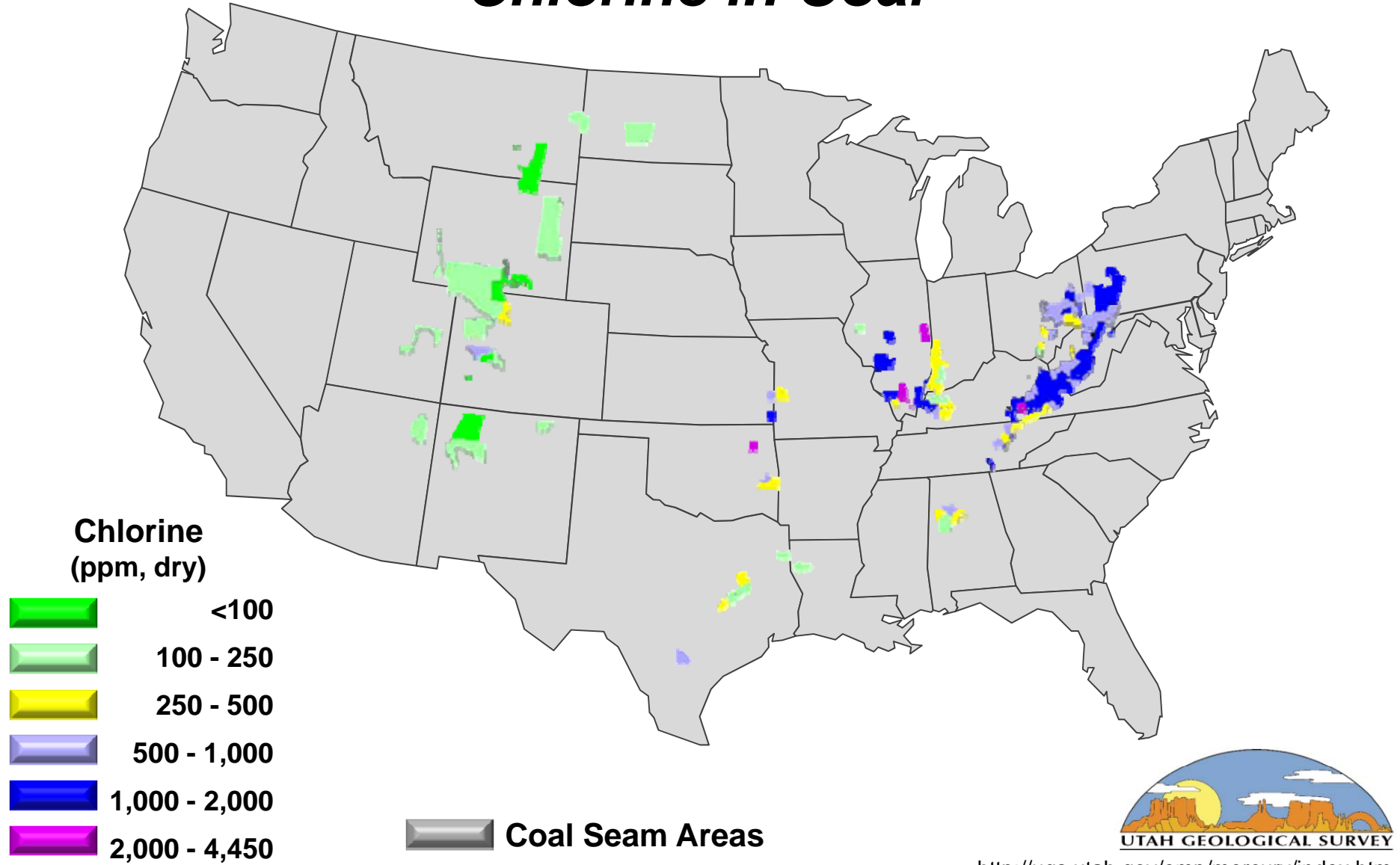
- ▣ 1970's & 1980's
  - Sulfur dioxide
    - ▣ 500-3000 ppm SO<sub>2</sub>
    - ▣ Early systems
      - 70%-85% capture
      - Very poor availability
- ▣ 1980's & 1990's
  - NO<sub>x</sub>
    - ▣ 200-600 ppm
    - ▣ Early systems
      - low capture rates
      - High ammonia slip
- ▣ 2000's
  - Mercury
    - ▣ ~1 ppb



# Coal Mercury Concentration



# Chlorine in Coal



# Mercury Speciation by Fuel Type

## Flue Gas Speciation

Bituminous



Subbituminous



Lignite



0% 20% 40% 60% 80% 100%



Elemental Hg



Oxidized Hg

2000 Data per NETL  
at 2002 EPRI Workshop

## Influences on Hg Speciation



Gas  
Composition  
(i.e., Chloride)

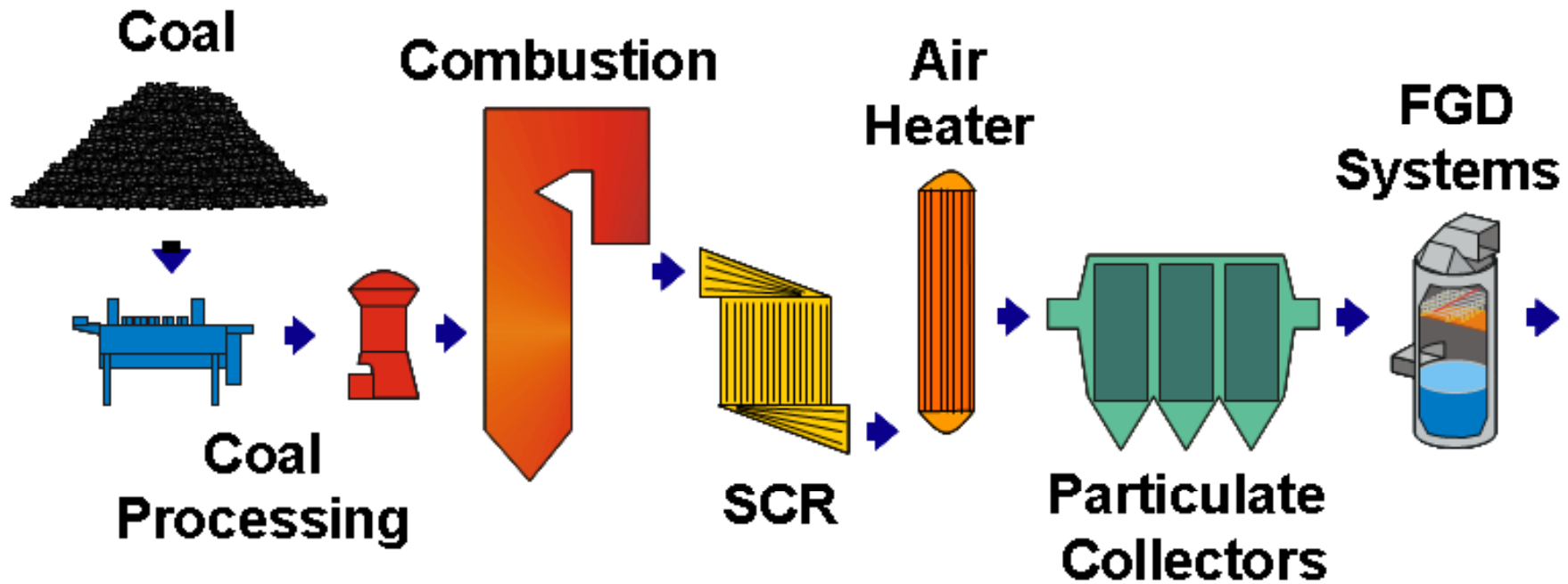


Unburned  
Carbon  
(UBC)

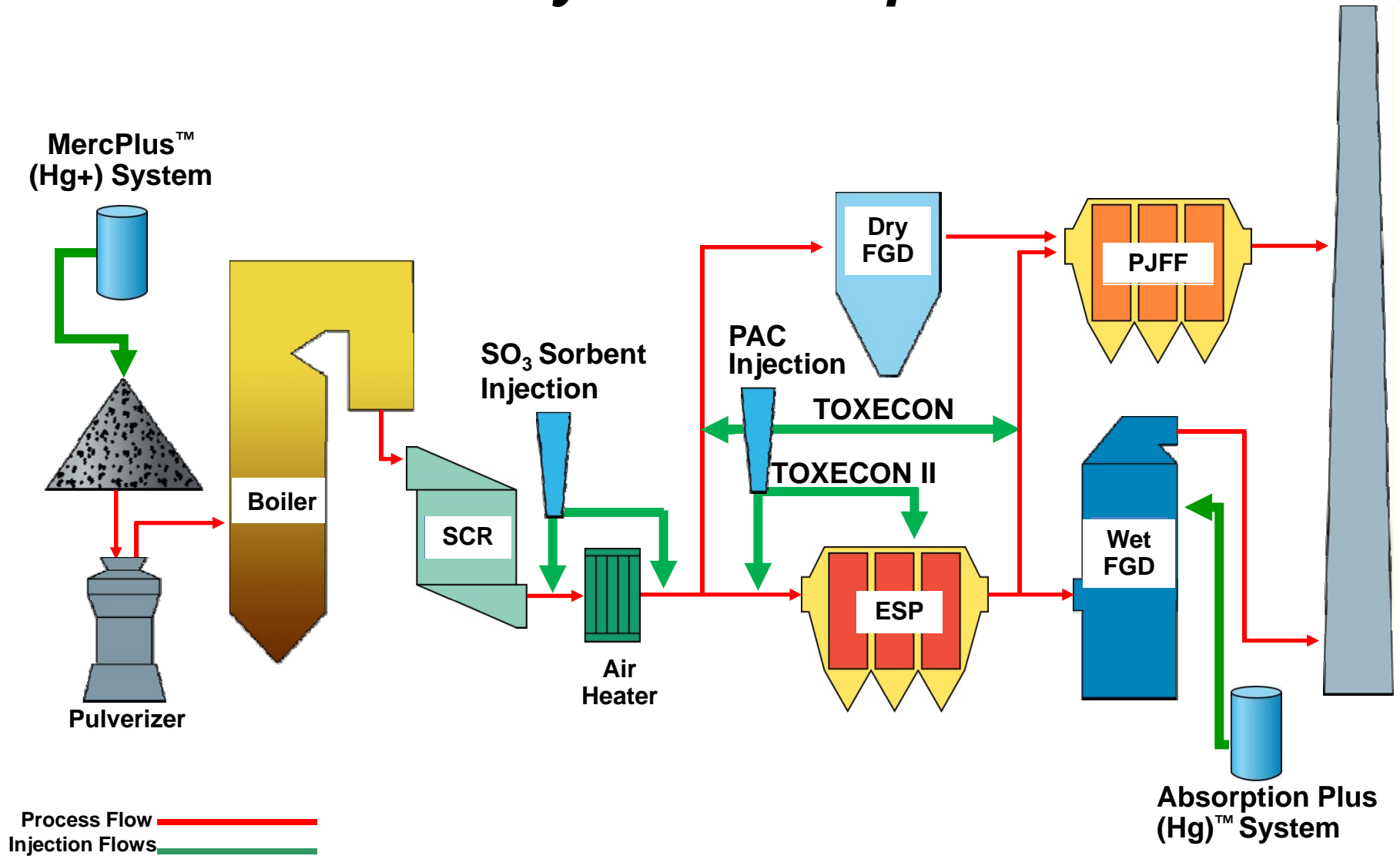


Catalysts  
(i.e., SCR, Ash,  
Boiler Metals)

# ***Power Plant “Co-benefits” Reduce Stack Mercury Emissions***



# Mercury Control Options



# ***90% Mercury Removal – SCR Effects***

***Ken Jeffers – Johnson Matthey Catalysts***

**WPCA Regional Seminar  
Springfield, Illinois  
August 3, 2010**

# Hg Oxidation across SCR Catalyst



Johnson Matthey  
Catalysts



**WPCA Illinois Technical APC Seminar**  
**Springfield, IL**  
**August 3, 2010**

Ken Jeffers

SCR Applications Engineer

ENVIRONMENTAL CATALYSTS AND TECHNOLOGIES



# Introduction – Mercury Emission Control from Coal-fired Sources



- Hg speciation
  - $Hg^0$  – elemental mercury
  - $Hg^{2+}$  – oxidized mercury
  - Total –  $Hg^T$  includes  $Hg^0$ ,  $Hg^{2+}$ ,  $Hg^P$
  - Strong influence on speciation by Cl/Br in flue gas
- Basic Capture/Removal Methods
  - Activated Carbon Injection, baghouse –  $Hg^0/Hg^{2+}$
  - Novel Sorbents, baghouse –  $Hg^0/Hg^{2+}$
  - Capture in wet-FGD –  $Hg^{2+}$  (water soluble, easier to absorb)
- Hg oxidation is a co-benefit of SCR catalyst
  - \*\*\*SCR catalyst does not capture or remove  $Hg^{***}$
  - Challenging as Hg is in trace amounts ~ ppb,  $\mu g/Nm^3$
  - $Hg^{2+}$  can re-emit to  $Hg^0$  downstream of SCR



# Reactions of Hg in SCR Catalyst



## Desired Reactions – Hg oxidation

- $\text{Hg} + 2 \text{HCl} + \frac{1}{2} \text{O}_2 \rightarrow \text{HgCl}_2 + \text{H}_2\text{O}$
- $\text{Hg} + \text{SO}_3 + \frac{1}{2} \text{O}_2 \rightarrow \text{HgSO}_4$

## Side Reactions

- $2 \text{HCl} + \frac{1}{2} \text{O}_2 \rightarrow \text{Cl}_2 + \text{H}_2\text{O}$
- $\text{Hg} + \text{Cl}_2 \rightarrow \text{HgCl}_2$

## Undesired Side Reactions

- $\text{Cl}_2 + \text{SO}_2 + \text{H}_2\text{O} \rightarrow 2 \text{HCl} + \text{SO}_3$ , inhibition of  $\text{Cl}_2$  formation
- $3 \text{HgCl}_2 + 2 \text{NH}_3 \rightarrow 3 \text{Hg} + 6 \text{HCl} + \text{N}_2$ , reduction of Hg by  $\text{NH}_3$
- $\text{HgCl}_2 + \text{SO}_2 + \text{H}_2\text{O} \rightarrow \text{Hg} + 2 \text{HCl} + \text{SO}_3$ , reduction of Hg by  $\text{SO}_2$



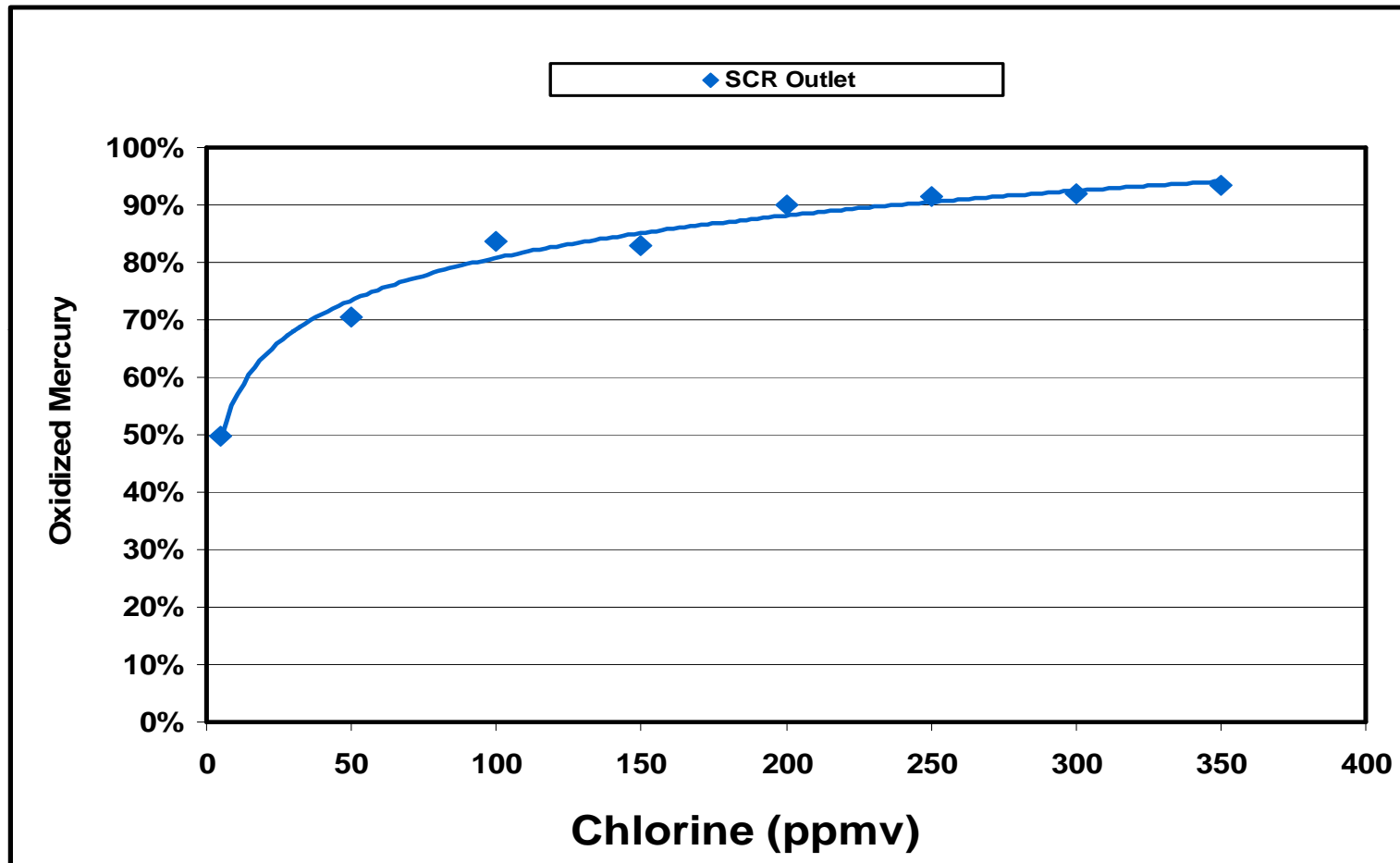
# Key Variables for Hg Oxidation in SCR Catalyst



- Flue gas Chlorine concentration (HCl/Cl<sup>-</sup>)
  - Influences speciation at SCR inlet → high Cl, increases Hg<sup>2+</sup> in Hg<sup>T</sup>
  - 50+ ppm HCl in flue gas → 80 – 90%+ Hg oxidation
  - Similar effect for 5+ ppm Bromine
  - Lower oxidation rates for low Cl fuels (PRB, low Cl bituminous)
- Flue gas Temperature < 700 °F favorable for Hg oxidation
- Ammonia competes for active sites in catalyst and inhibits Hg oxidation
  - NH<sub>3</sub>-NO<sub>x</sub> reaction favored in top catalyst layer(s)
  - Hg oxidation favored in lower catalyst layers as NH<sub>3</sub> is depleted
  - Filling spare catalyst layers good for Hg oxidation



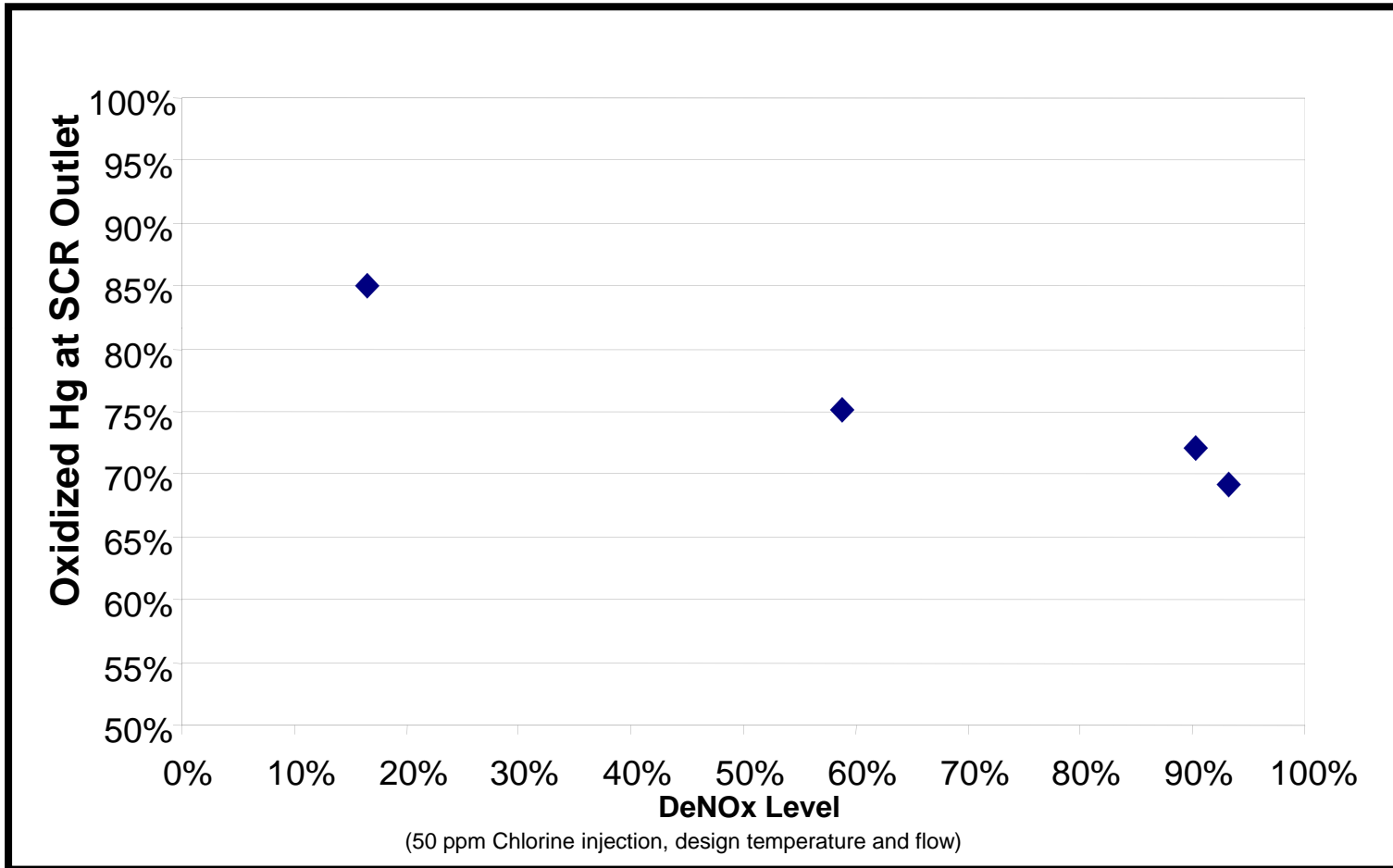
# Hg Oxidation in Catalyst – General Effect of Cl



Reproduced by permission from *Effects of Chlorine and other Flue Gas Parameters on SCR Catalyst Mercury Oxidation and Capture*, EPRI, Palo Alto, CA 2009. 1020591



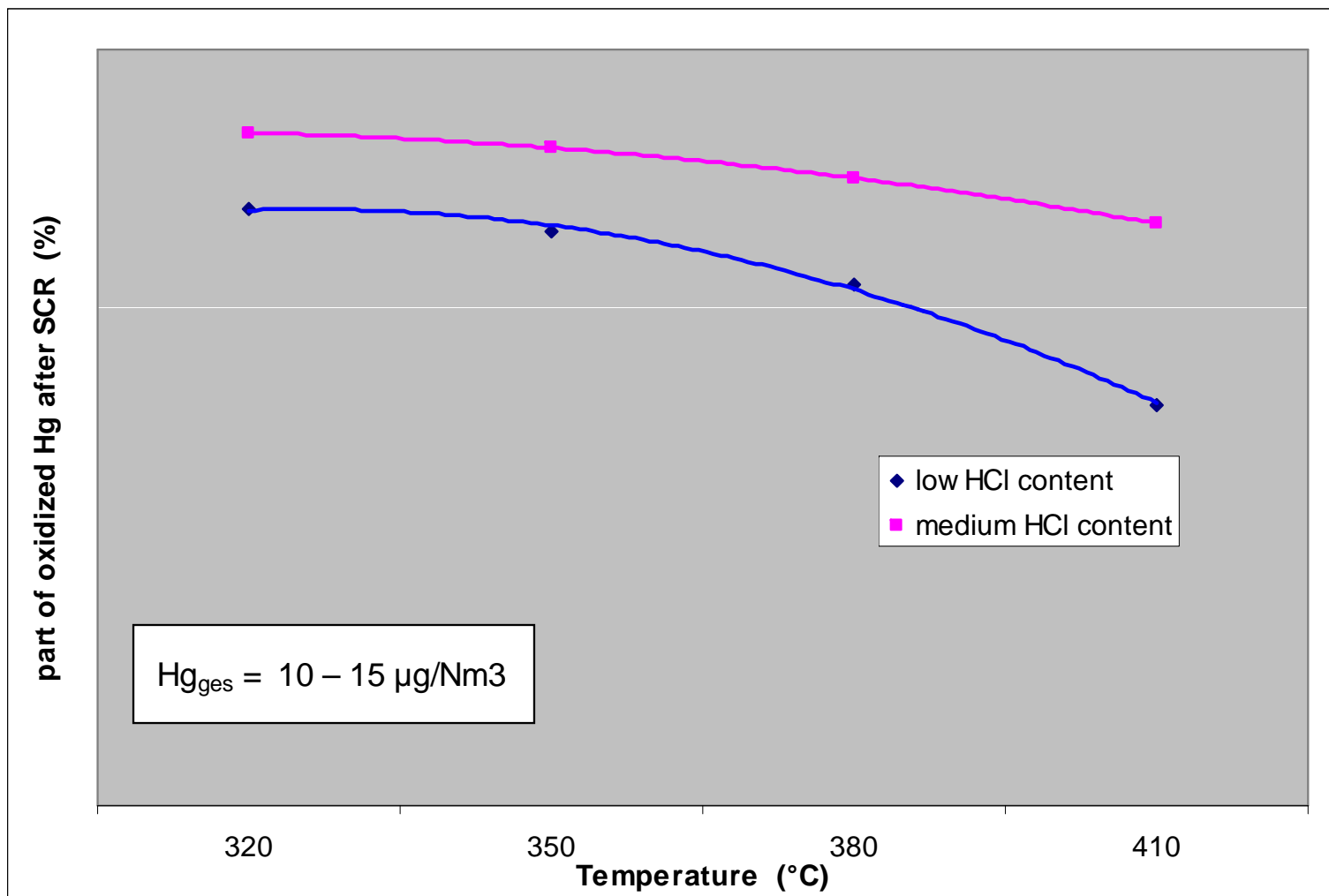
# Hg Oxidation in Catalyst – General Effect of NH<sub>3</sub>



Reproduced by permission from *Effects of Chlorine and other Flue Gas Parameters on SCR Catalyst Mercury Oxidation and Capture*, EPRI, Palo Alto, CA 2009. 1020591



# Hg Oxidation in Catalyst – Effects of Temperature and Cl



# Thank You!



Ken Jeffers

SCR Applications Engineer

[ken.jeffers@jmus.com](mailto:ken.jeffers@jmus.com)

678 341 7523

Johnson Matthey Catalysts, LLC

1121 Alderman Drive, Suite 204

Alpharetta, GA 30005

[www.jm-catalysts.com](http://www.jm-catalysts.com)



# ***90% Mercury Removal – Activated Carbon***

***Don Stowe – Babcock Power***

**WPCA Regional Seminar  
Springfield, Illinois  
August 3, 2010**

# Babcock Power Inc.



**90% Mercury Capture;**

**Can we get there?**

Don Stowe, Consultant –Babcock Power



[www.babcockpower.com](http://www.babcockpower.com)

# No Single Answer

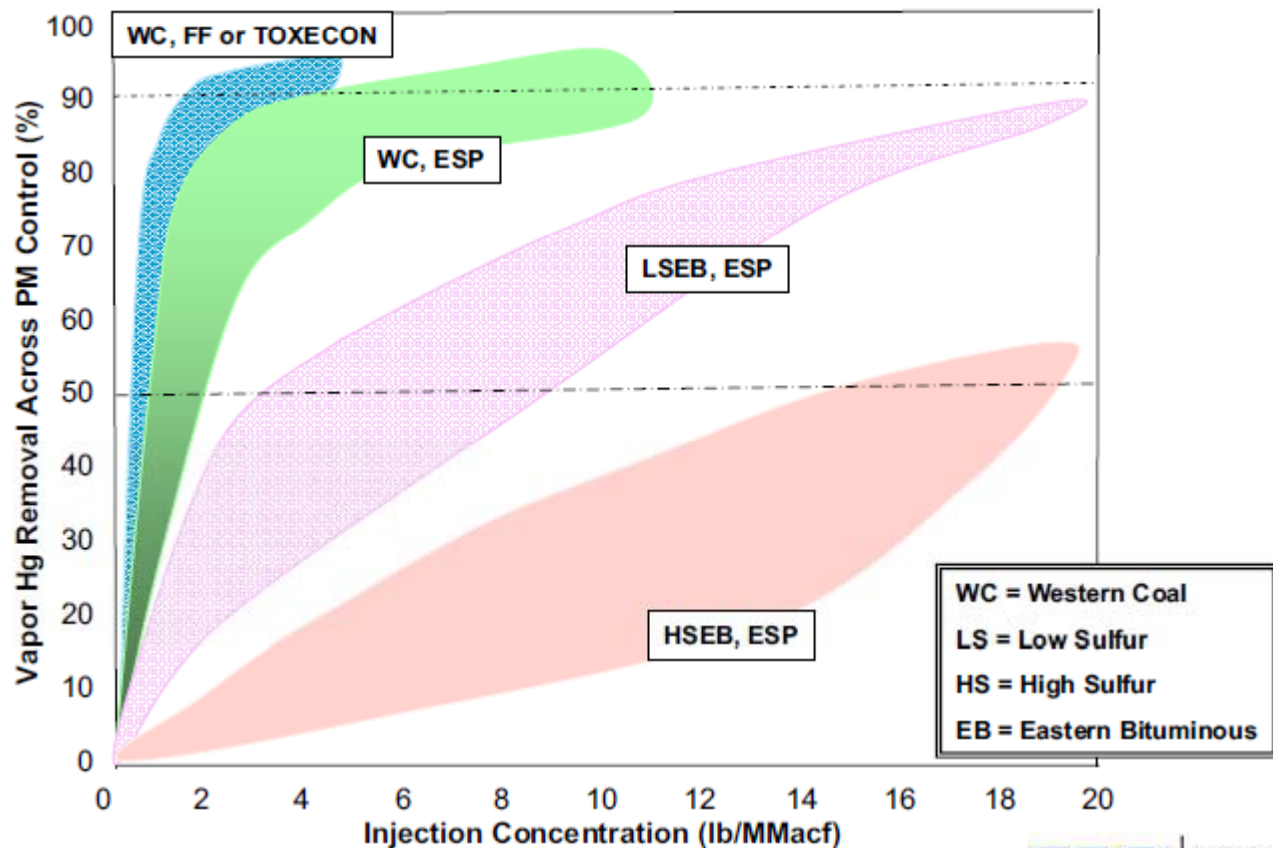
## Each unit is site specific

- ▣ Fuel
- ▣ Boiler type
- ▣ Plant layout
- ▣ Background Hg Capture (high LOI ash)
- ▣ Existing APC devices (co-benefits) `



## Similar Patterns Found to Hold for Hg Capture by Activated Carbon

(Most data from tests <1 month)



© 2005 Electric Power Research Institute, Inc. All rights reserved.

7

**EPRRI** | ELECTRIC POWER RESEARCH INSTITUTE



# Co-Benefits

- ▣ SCR
  - Reasonable job of oxidizing Hg
  - Also Oxidizes  $\text{SO}_2$  to  $\text{SO}_3$
- ▣ Wet FGD
  - Good job of capturing oxidized Hg
- ▣ Spray dryer/Fabric filter
- ▣ CDS technology



# Easy Answer is NOT the best answer

- ▣ Install baghouse/PAC injection
  - Most expensive
    - ▣ \$80-130/KW capital investment
    - ▣ Additional parasitic load
  - Not practical at many installations
    - ▣ Space constraints
    - ▣ Fan capacity



# What do we know?

- ▣ PAC extremely effective for capturing oxidized Hg
- ▣ PAC does poorer job of capturing elemental Hg
- ▣ PRB flue gas predominantly elemental Hg
- ▣ SO<sub>3</sub> proven to “poison” PAC

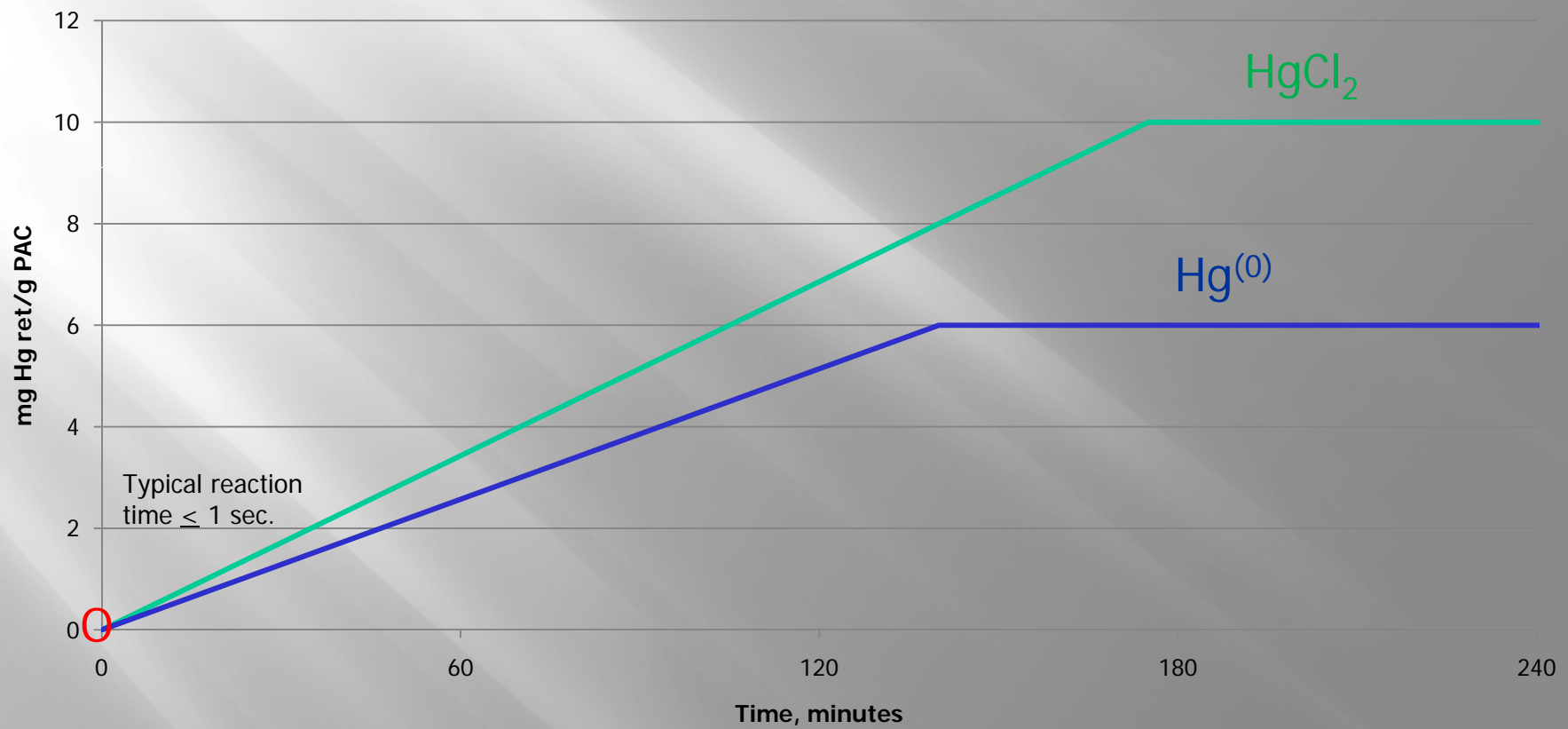


# What do we know?

- ▣ Carbon has the adsorption capacity
  - Fixed bed data – Hg loading up to 10%
    - ▣ 100,000  $\mu\text{g/g}$
  - Typical real world adsorption
    - ▣ 20-40  $\mu\text{g/g}$
- ▣ Challenge is kinetics (assure Hg contacts carbon)



## Hg Adsorption Fixed Bed Commercial PAC



Source: UK CAER



# Criteria for success

- ▣ Oxidation of Hg (bromine)
  - Coal blending
  - Furnace injection of oxidant
  - PAC/Br blends
- ▣ Elimination of “poisons” (SO<sub>3</sub>)
  - Trona/Hydrated Lime/Magnesium Oxide
    - ▣ Pre-blended PAC/alkali
    - ▣ Upstream alkali injection
- ▣ Selection of most cost effective carbon
  - ▣ Pore size critical parameter
  - ▣ Low ash
  - ▣ Low moisture



# Other possible means of improvement

- ▣ Reduce carbon particle size
  - Finer grind
    - ▣ Material handling issues
    - ▣ ESP “blow-by”
  - On site micronizing
    - ▣ Expensive / high maintenance
- ▣ Increase residence time
  - Install baghouse (Toxicon)
- ▣ Improve dispersion/mixing
  - CFD
  - Physical Modeling
  - Install mixing device

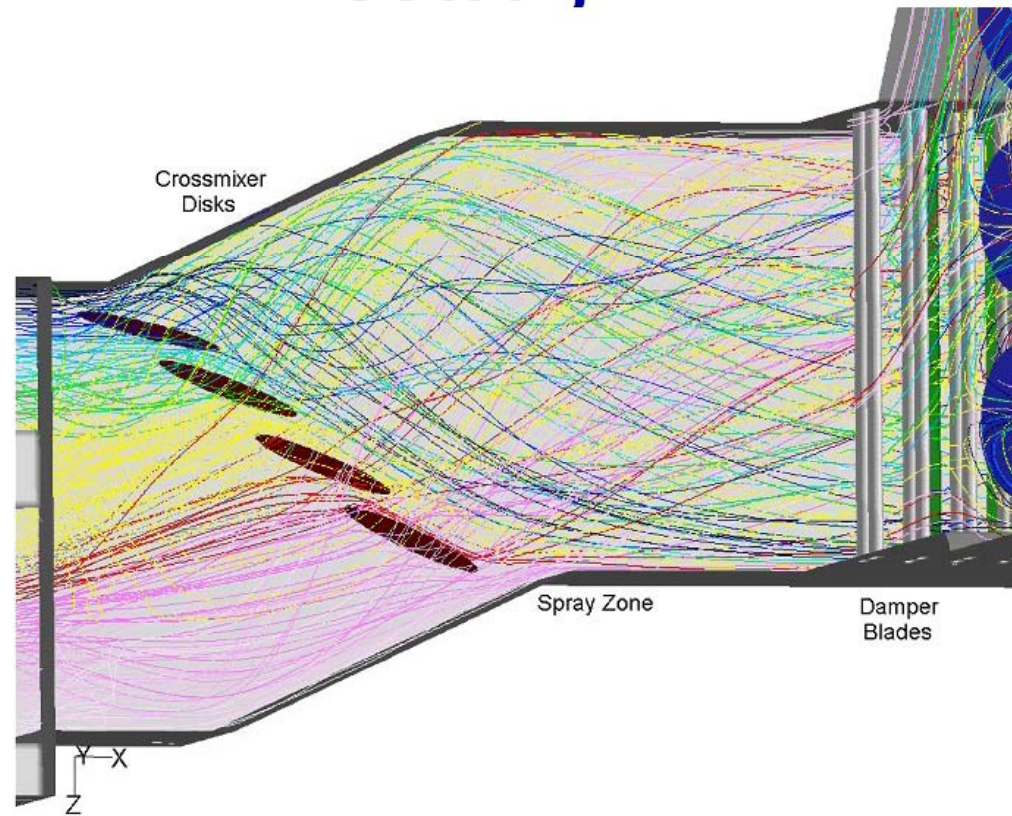


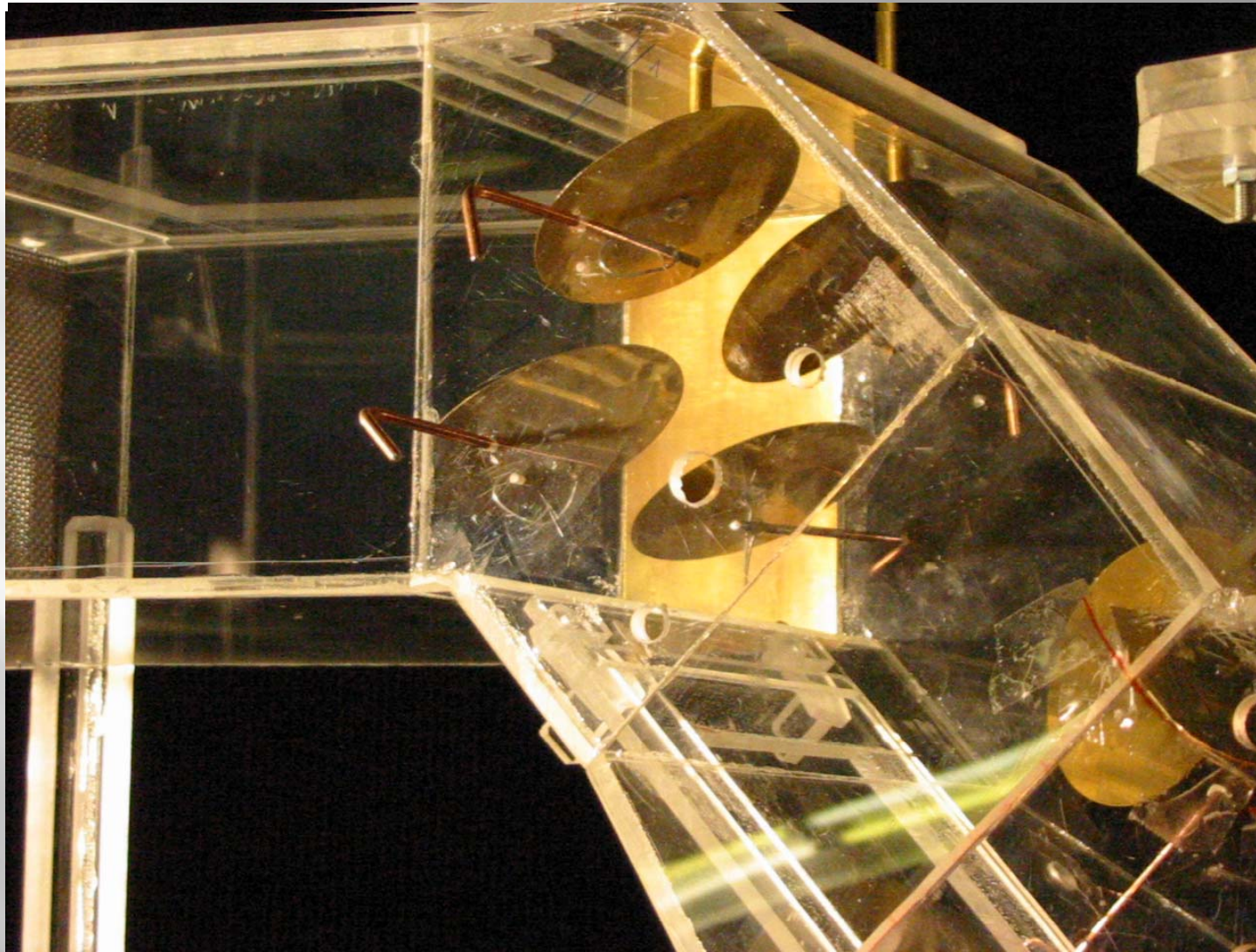
# Babcock Power Capabilities

- ▣ Design/engineer PAC dosing systems
  - CFD
  - Physical flow modeling
  - Delta Wing static mixer
- ▣ Low cost lignite based carbon – HOK
  - Bromine impregnated
  - Sulfur impregnated
  - Alkali impregnated



# Effect of Delta-Wing<sup>®</sup>





Slide 33

---

A5

scale 1:40

Author, 7/29/2010

# Delta Wing Full Scale Installation



Slide 34

---

A6

800 mw  
duct between X and Y  
dimensions -  
gas flow -  
Author, 7/29/2010

# The road to success

- ▣ Every unit is site specific
- ▣ Remove carbon “poisons” – SO<sub>3</sub>
- ▣ Oxidize Hg
- ▣ Put PAC in contact with oxidized Hg
  - Physical modeling
- ▣ Evaluate low cost PAC

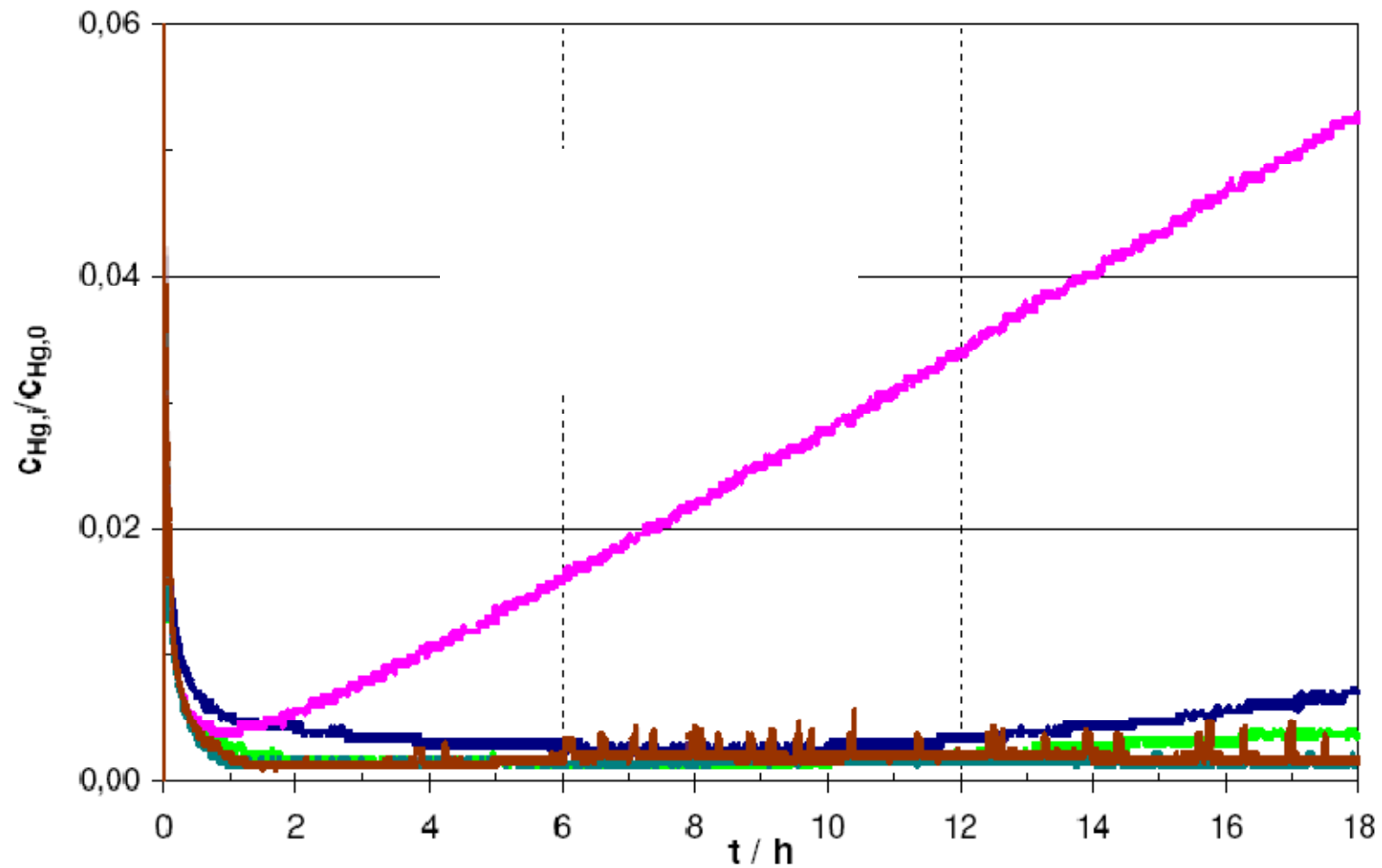


# PAC Evaluation

- ▣ Ultimate answer by testing
  - Lbs/hr required x \$/lb
- ▣ Data suggest most brominated perform similarly as well as non- brominated
- ▣ Ineffective measuring sticks
  - BET surface area
  - Bromination method



### Hg-Breakthrough curves (detail) ( $60 \text{ m}^3/(\text{m}^2 \cdot \text{h})$ , $150 \text{ }^\circ\text{C}$ , $1030 \text{ mbar}$ )



---

---

*Thank You*

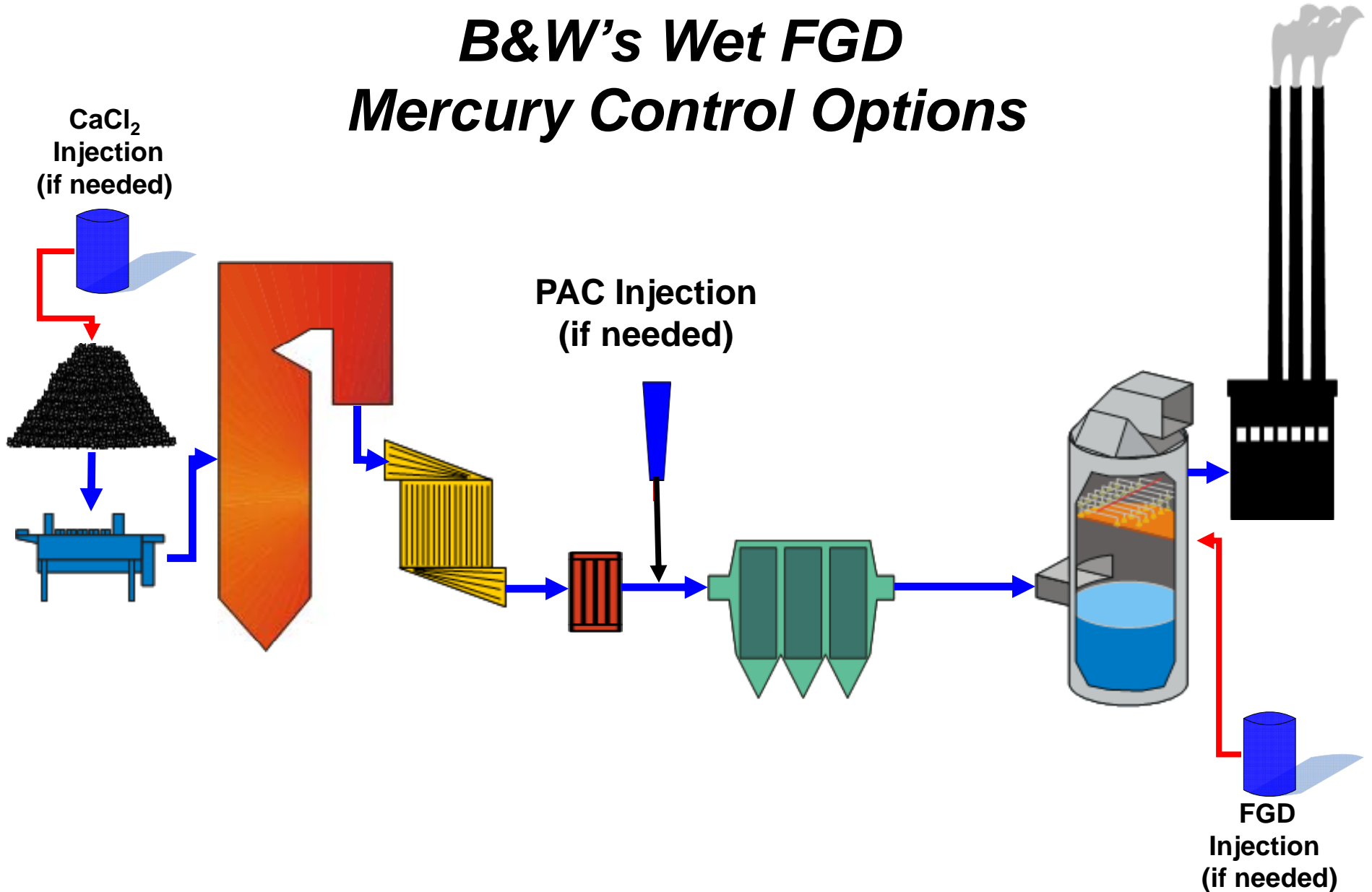




***90% Hg Removal with Wet or Dry FGD Systems***  
by  
***Greg Bielawski***

***WPCA Regional Seminar***  
***Springfield, Illinois***  
***August 3, 2010***

# *B&W's Wet FGD Mercury Control Options*

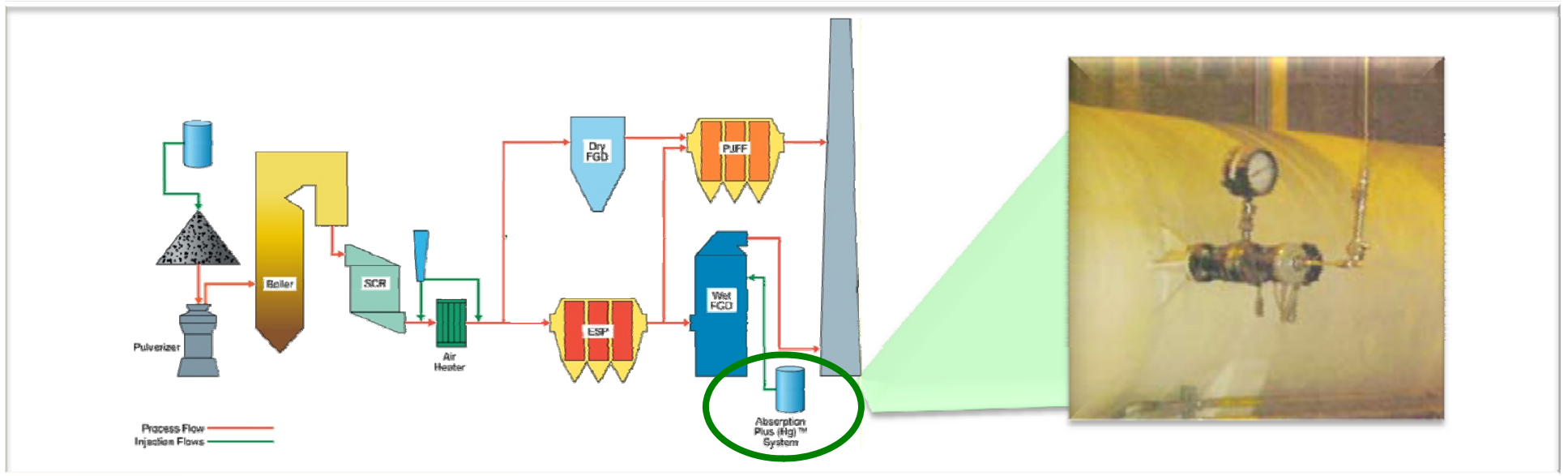


## ***Industry Challenges***

**Hg re-emission in WFGDs**

**PAC poisoning when  
burning high sulfur coal**

# *Absorption Plus (Hg)<sup>TM</sup> System for Enhanced Mercury Capture*

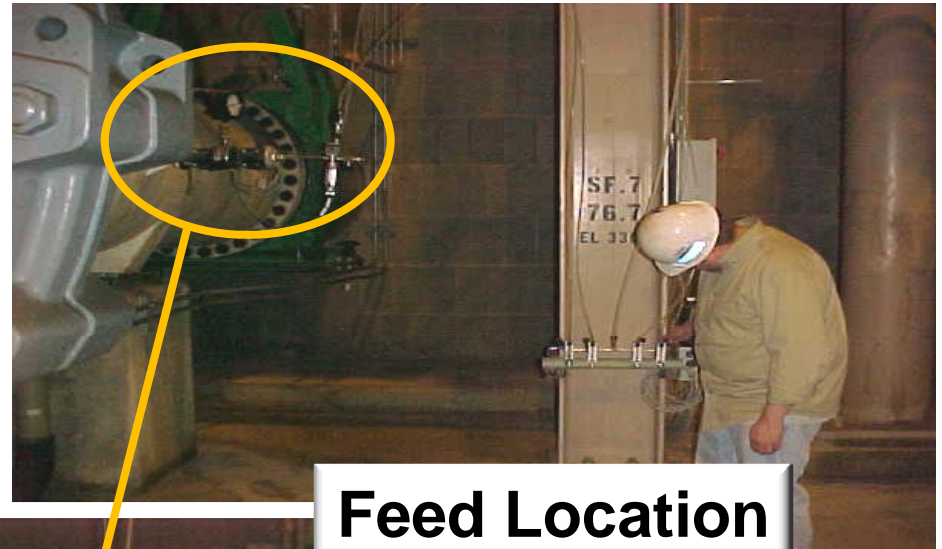


- **Proprietary technology prevents mercury re-emission from Wet FGD**
- **Removes and retains over 95% of oxidized mercury in FGD**
- **Mercury removed with solids from FGD system**
- **Cost effective reagent**

# Wet FGD Reagent Feed System



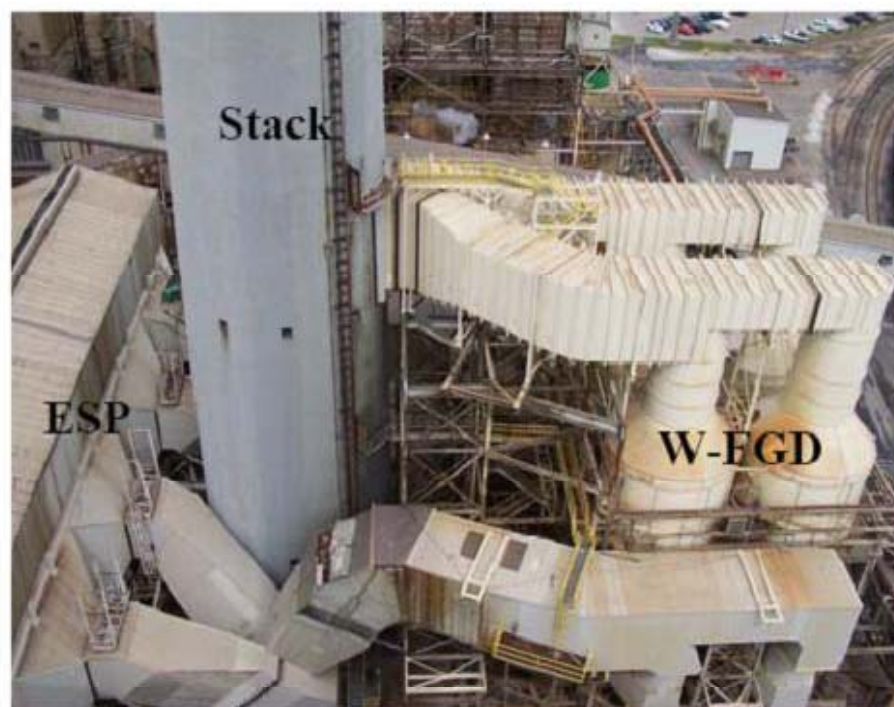
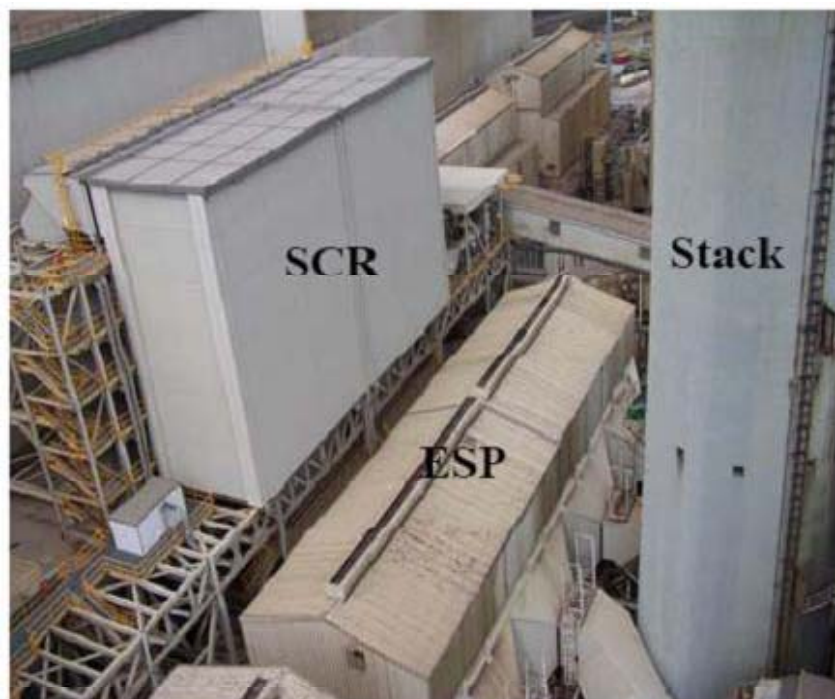
**Injection Skid**



**Feed Location**

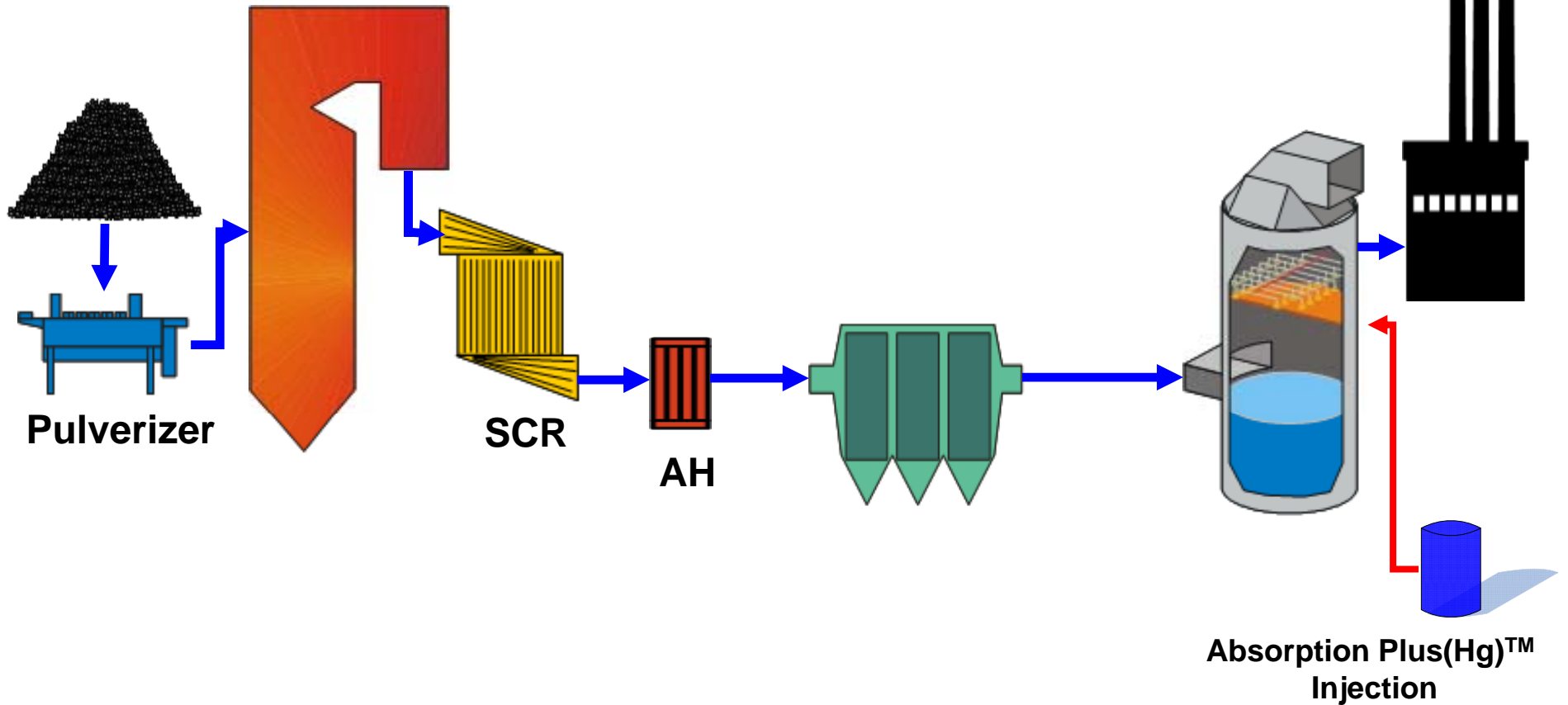


## ***E.ON America's Mill Creek Unit 4 Louisville, KY***

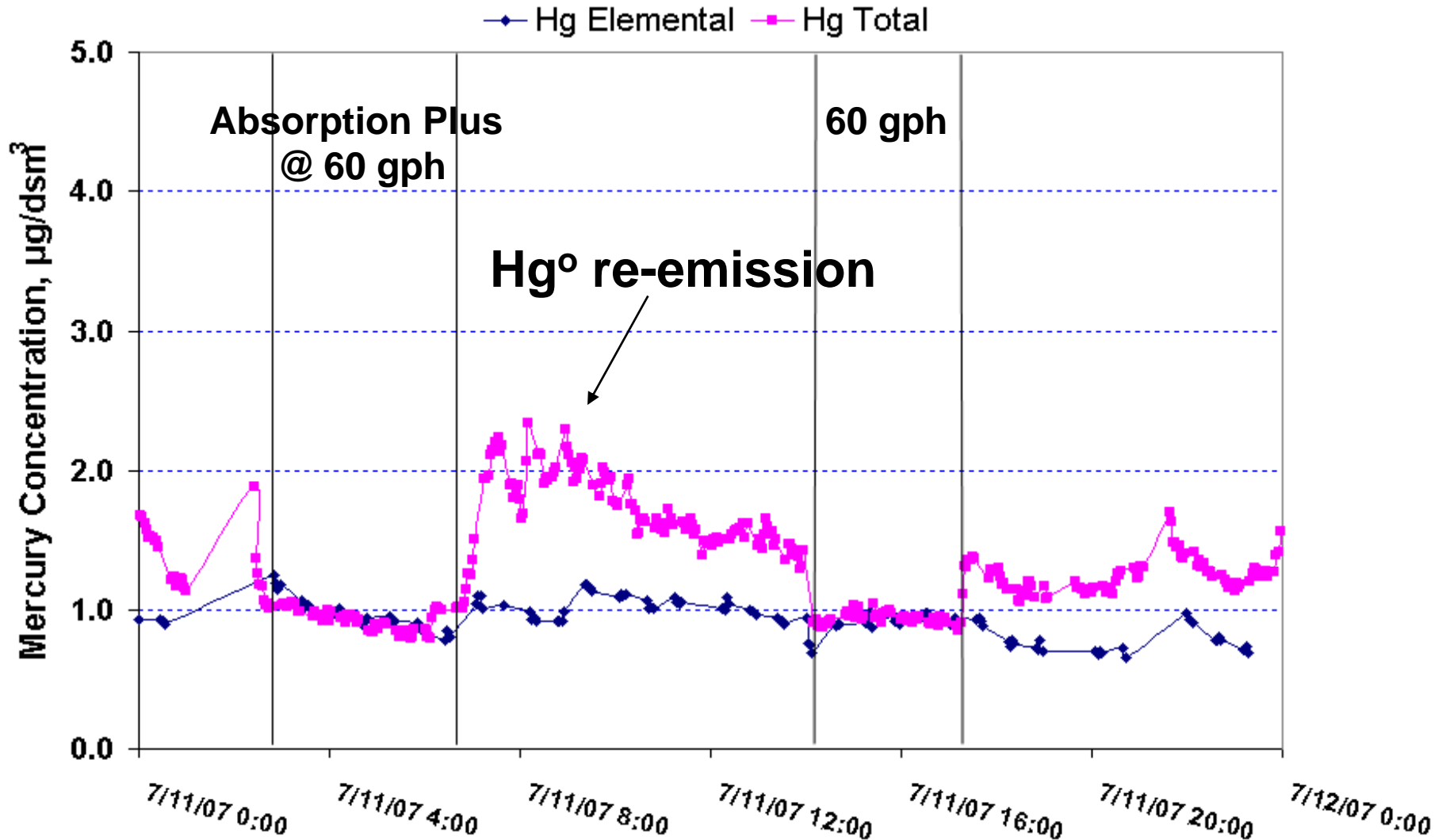


- 2007 DOE/EERC Phase III Mercury Testing
- B&W Wet FGD additive Absorption Plus(Hg)<sup>TM</sup>
- Mill Creek burns high sulfur bituminous coal
- Air quality control system consists of SCR + ESP + Wet FGD

# *E.ON. Mill Creek Mercury Control Tools*



# E.ON Mill Creek WFGD Outlet B&W WFGD Additive



# ***Powdered Activated Carbon Storage and Feed System***



**PAC Storage Silo**



**Feed System**



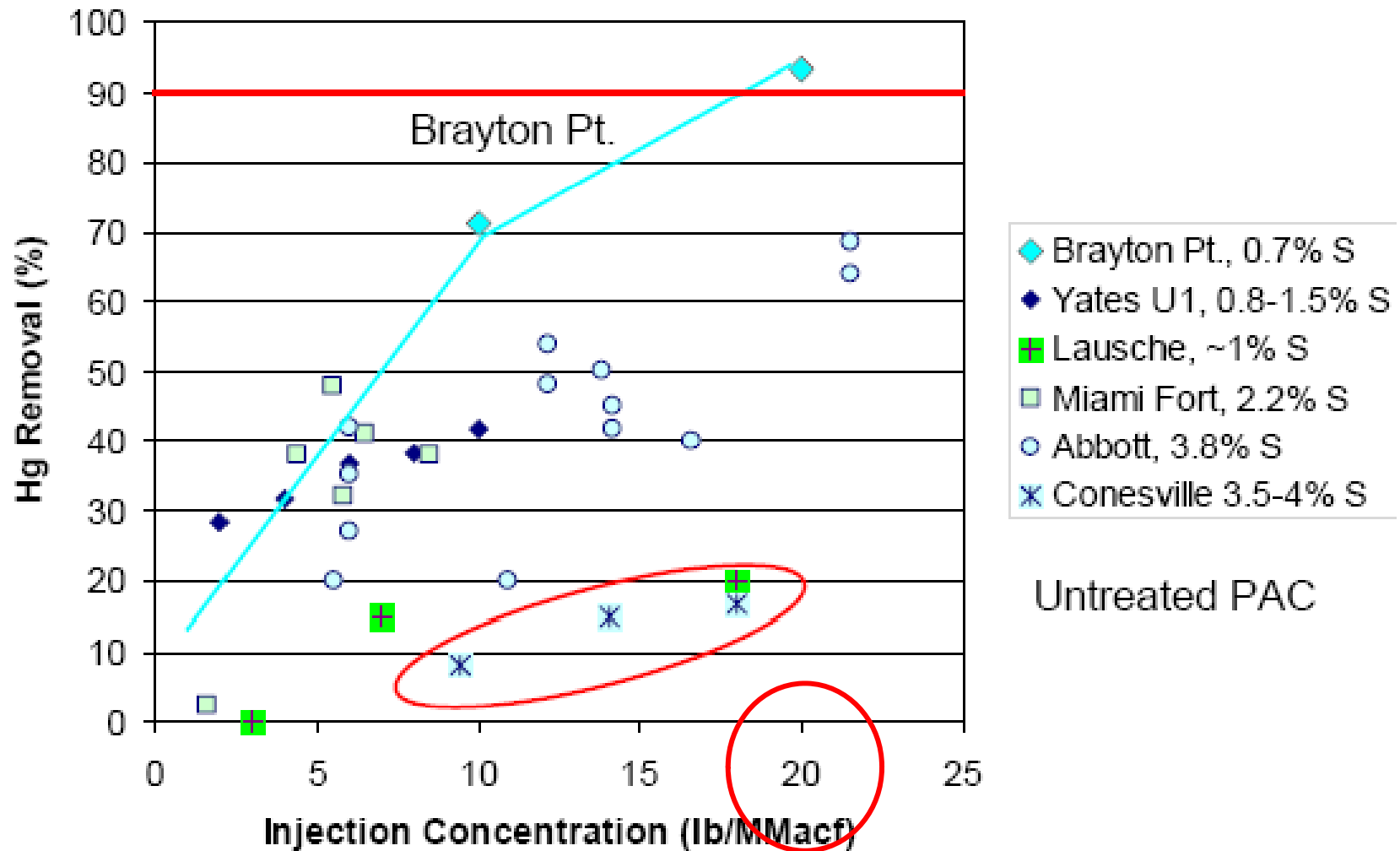
**Injection System**

## ***Industry Challenges***

**Hg re-emission in WFGDs**

**PAC poisoning when  
burning high sulfur coal**

## Influence of SO<sub>3</sub> on Mercury Removal with Activated Carbon



# ***Dry Sorbent Injection (DSI) Technology Overview***



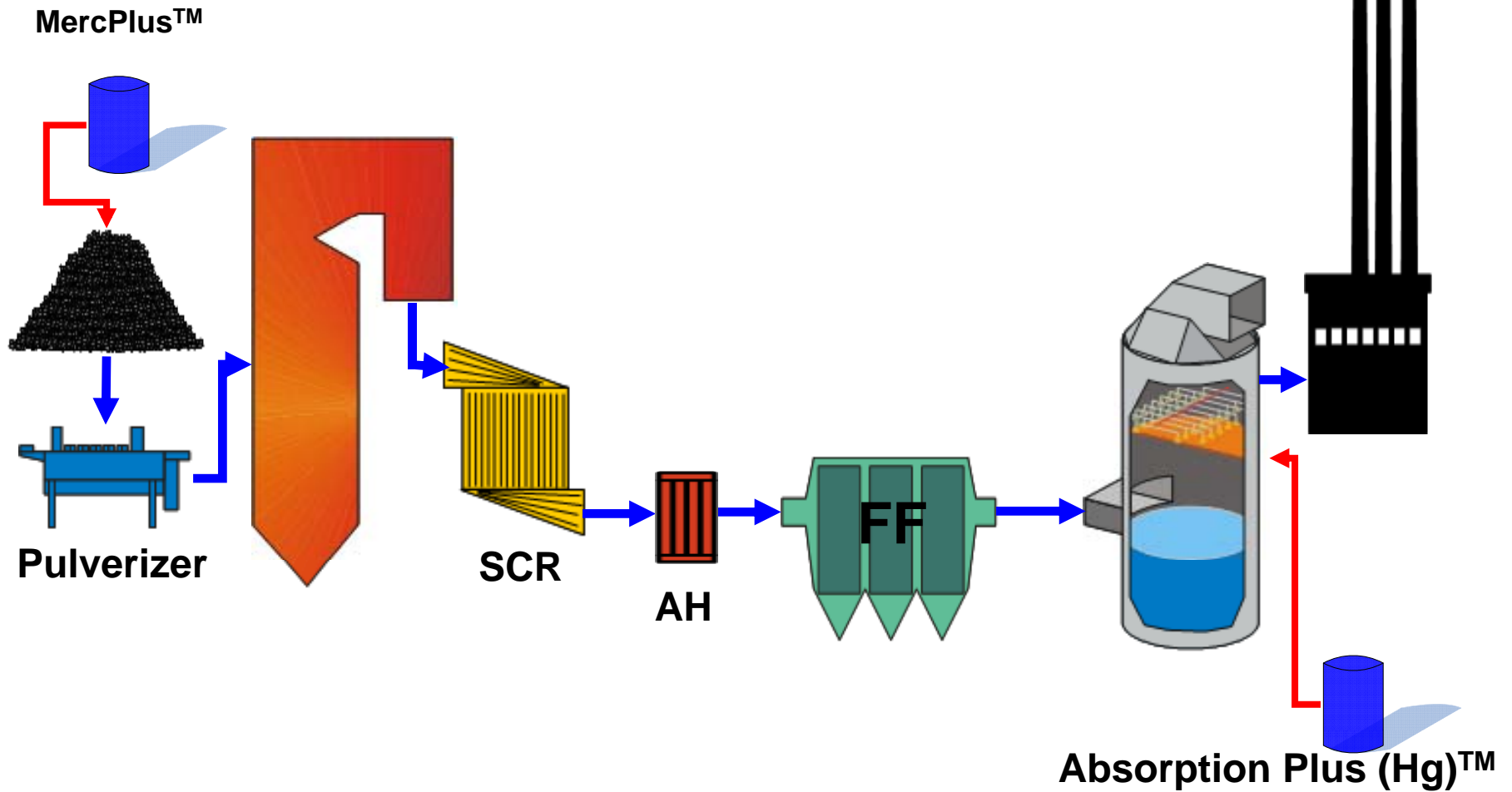
- **DSI = Dry Sorbent Injection**
- **DSI is based on dilute phase pneumatic conveying technology**
- **Major components are:**
  - Truck/rail unloading
  - Silo
  - Weigh hopper/Rotary feeder
  - Transport Air Blowers
  - Reagent milling (optional)
- **Not a new technology**
  - Used for SO<sub>2</sub> since 1980s
- **Current applications for SO<sub>2</sub>, SO<sub>3</sub>, HCl and Hg**
- **B&W mobile test unit available**

## ***Texas Genco, Parish Plant – Sub-bituminous Coal***

- 650 MW SCR / FF / Wet FGD
- Low Chlorine PRB Coal
- Limestone Wet FGD for SO<sub>2</sub> Control



# Parish Unit 8 Mercury Control Burns PRB Coal; Low Chlorine



## ***MercPlus™ Fuel Additive for Low Halogen Coals***

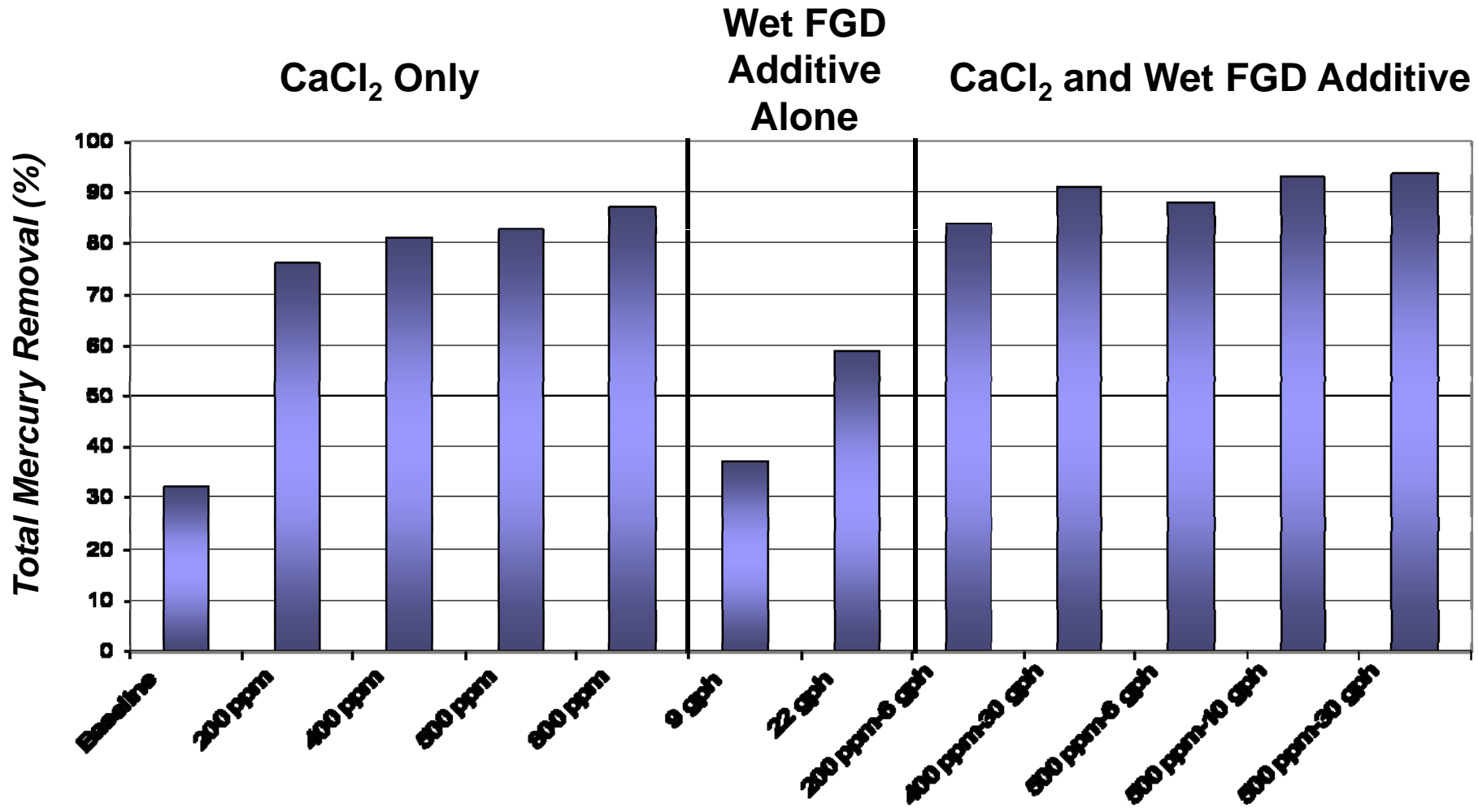


- **Injected onto coal in coal feeders**
- **Increases oxidation of elemental mercury**
- **Co-benefits Hg removal with FGD**
- **Reduces or eliminates PAC consumption**
- **May allow use of standard PAC versus more costly brominated PAC**
- **Typical payback less than one year by reducing PAC consumption**

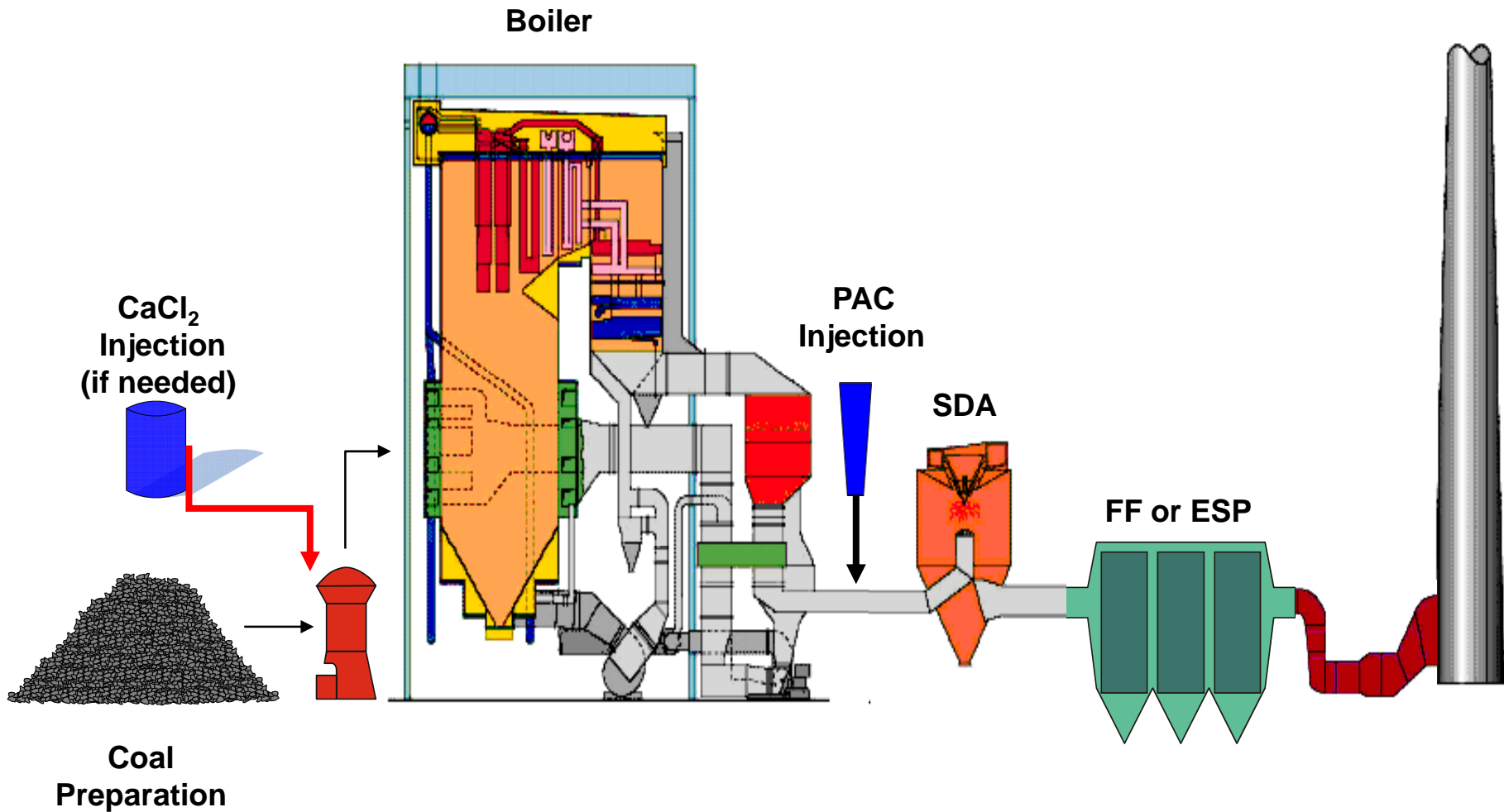
# Additive Injection Skid and Tank



# Total Mercury Removal Across Wet FGD Scrubber



# *B&W's Dry FGD Mercury Control Options*



## ***MercPlus™ Fuel Additive for Low Halogen Coals***



- **Injected onto coal in coal feeders**
- **Increases oxidation of elemental mercury**
- **Co-benefits Hg removal with FGD**
- **Reduces or eliminates PAC consumption**
- **May allow use of standard PAC versus more costly brominated PAC**
- **Typical payback less than one year by reducing PAC consumption**

# ***Powdered Activated Carbon Storage and Feed System***



**PAC Storage Silo**



**Feed System**



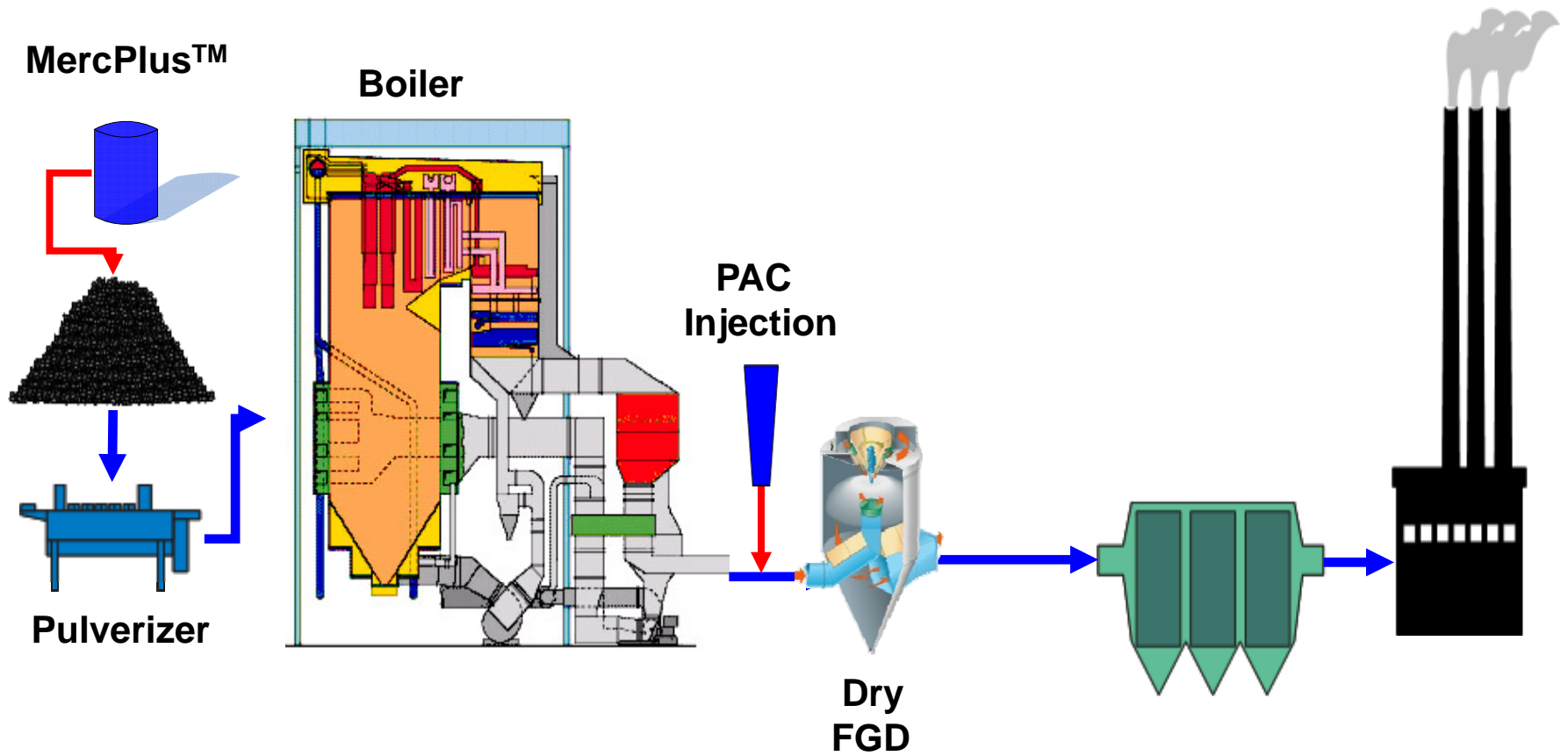
**Injection System**

## ***Black Hills Power – Wygen 1 Sub-bituminous Coal***

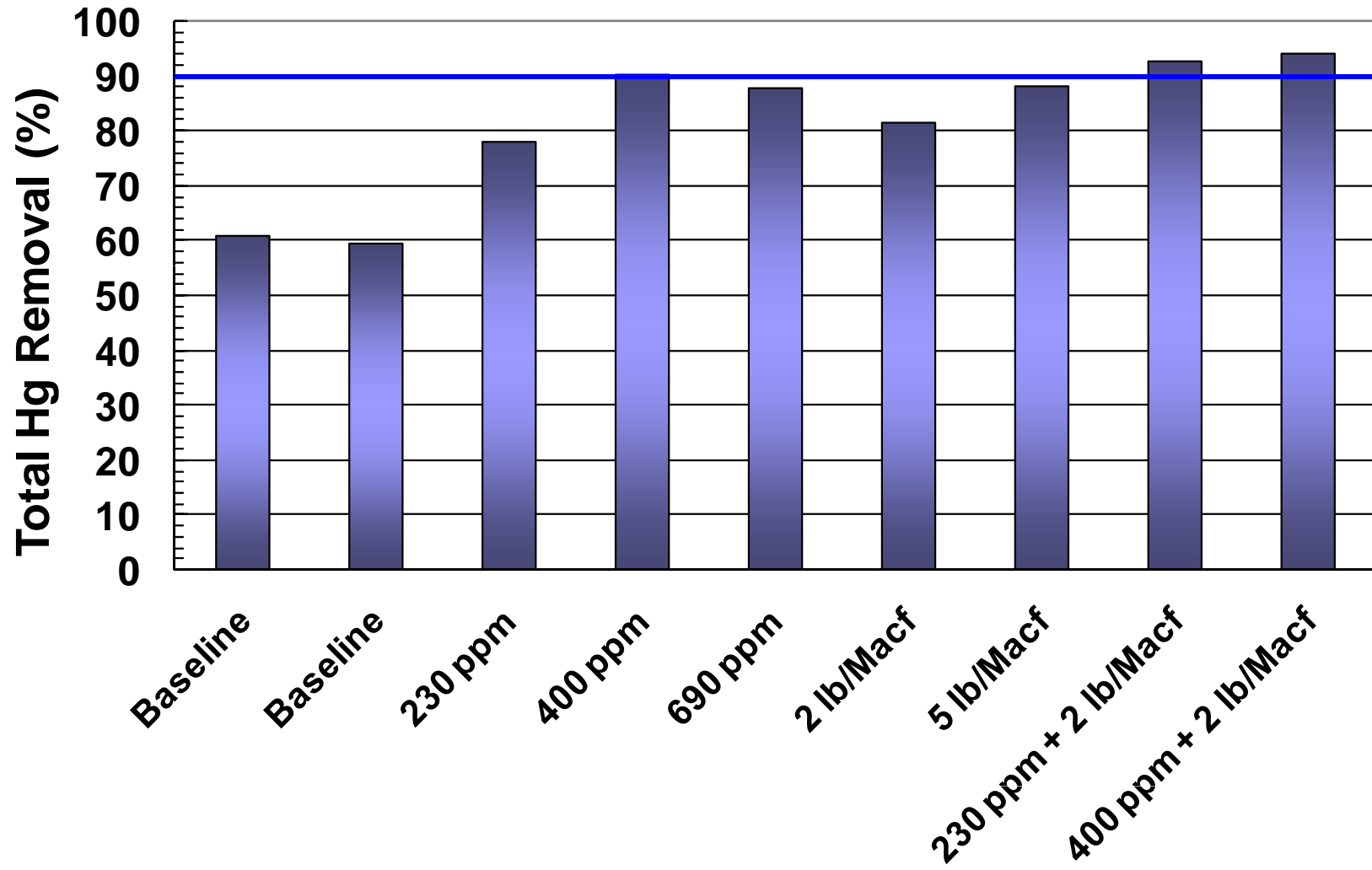


- ***Nominal 80 MW Unit***
- ***Wyodak Mine Coal***
- ***B&W Opposed Wall-Fired Boiler***
- ***SCR***
- ***B&W SDA and PJFF***

# Wygen 1 Mercury Controls



# Wygen 1 Parametric Mercury Tests



***Thank You!***

