Progress Report - December 2006

"Brominated Sorbents for Small Cold-Side ESPs, Hot-Side ESPs, and Fly Ash Use in Concrete "

DOE National Energy Technology Laboratory

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Sorbent Technologies Corporation

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Acknowledgement & Disclaimer

This presentation was prepared with the support of the U.S. Department of Energy, under Award No. DE-FC26-05NT42308 and the participation of Progress Energy and Midwest Generation.

Project Participants

Host Utilities

- Progress Energy, Peter Hoeflich & Gary Moore
- Midwest Generation, Kent Wanninger & Luke Ford

Project Contractors

- W. Kentucky Univ., (CMMs)
- Fuel Tech Inc. (CFD)

Field Test Partners

- Headwaters Resources (Byproducts)
- Lafarge (Byproducts)
- Ohio Lumex (CMM)

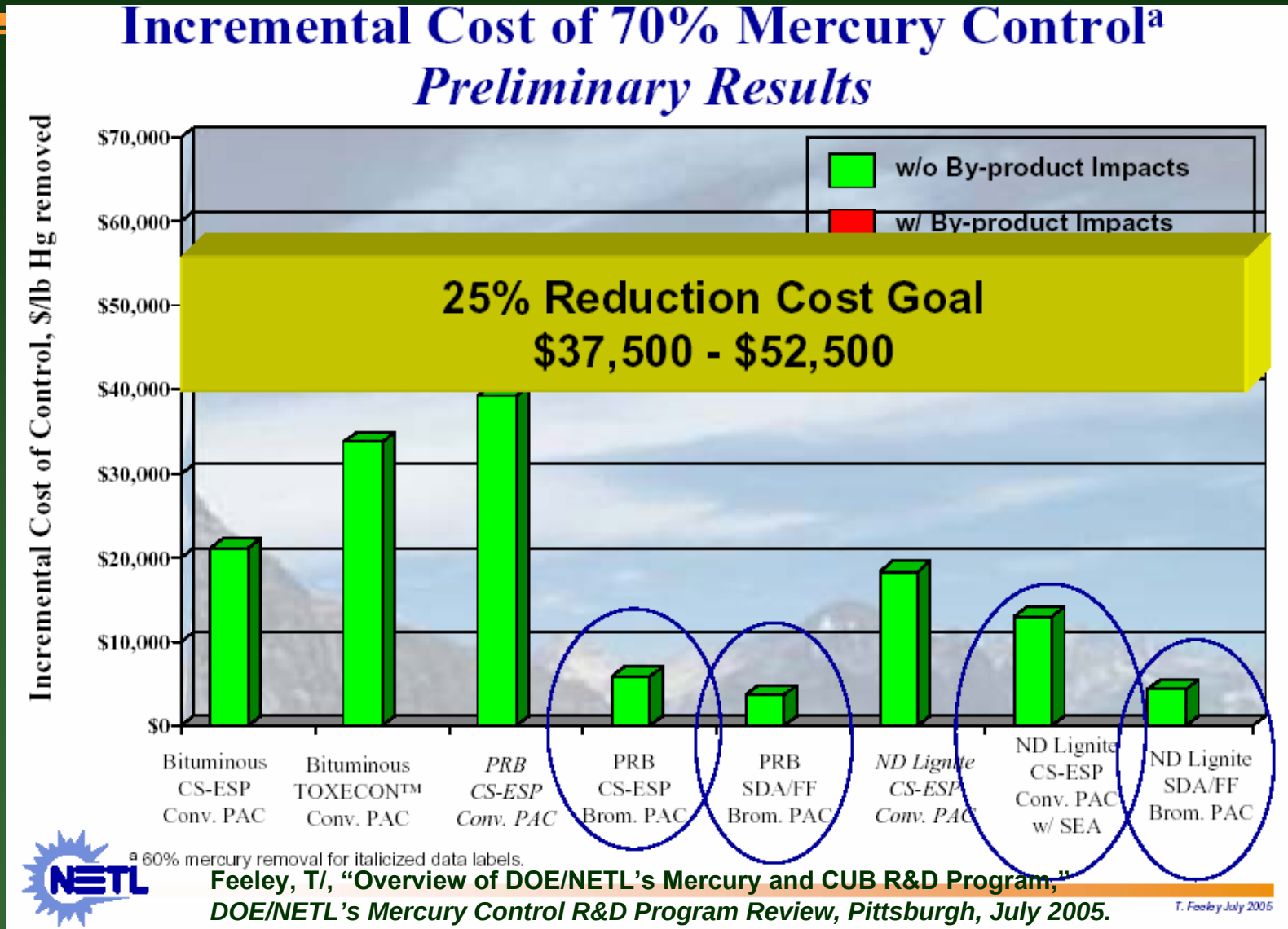
Full-Scale Trials

- Progress Energy - Lee Unit 1
- Midwest Generation - Crawford Unit 7
- Midwest Generation - Will County Unit 3

Unique Features

- Brominated PAC (B-PAC™)
- Bituminous Coal & SO_3 FGC
- Small ESPs
- Concrete-Friendly PAC (C-PAC™)
- Hot-Side ESP

Brominated PAC Dramatically Lowers Costs with Subbituminous Coals & ND Lignites



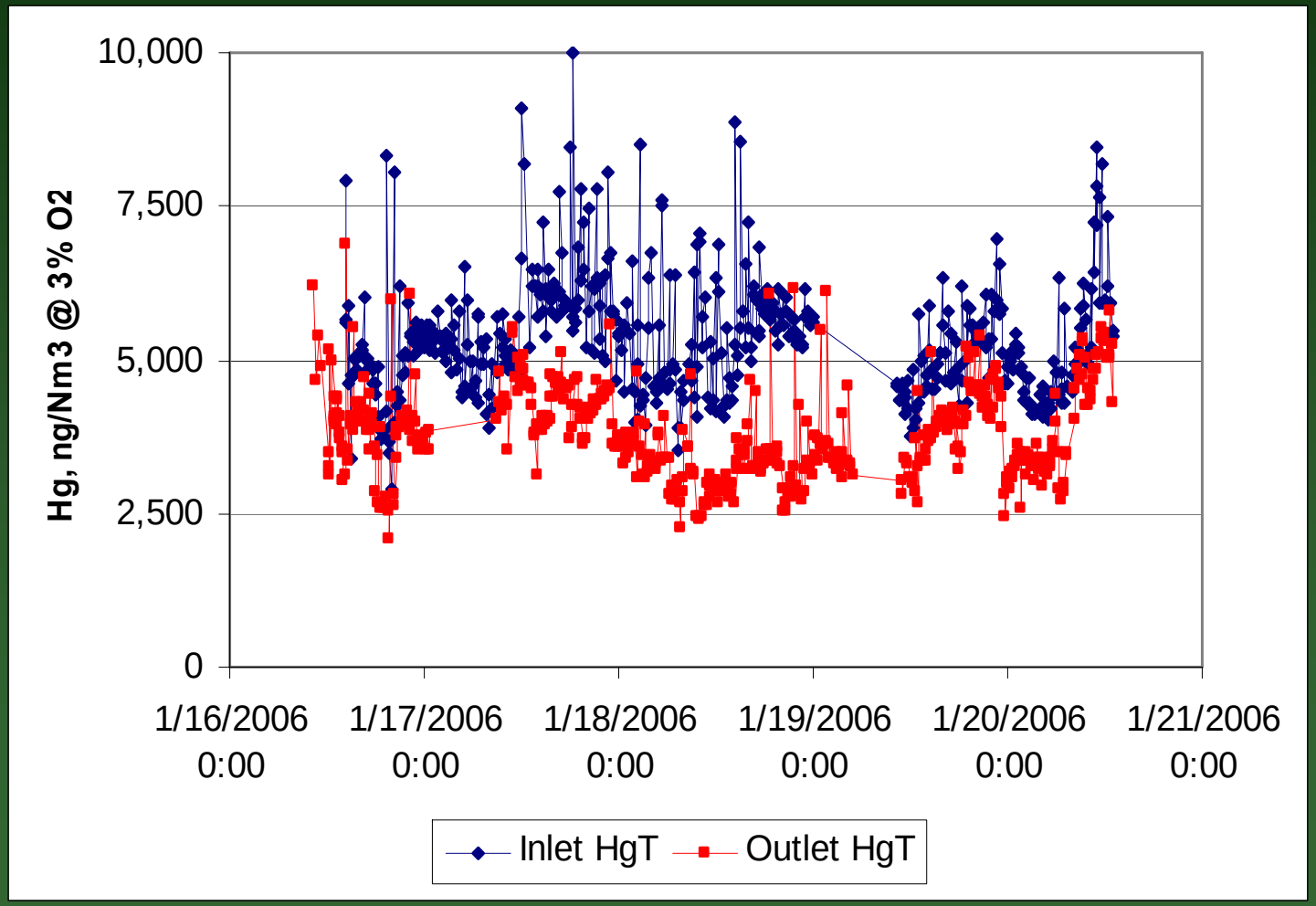
Progress Energy Lee Unit 1: Bituminous Coal

Coal Type	Eastern Bituminous
Boiler	79 MWe Tangential
NOx Control	Underfired Air
SO_2 Control	None
Particulate Control	Cold-Side ESP
ESP Assistance	SO_3 Flue Gas Conditioning
Gas Flow	320,000 acfm
ESP Inlet Temp.	300°F
SCA @ 320°F	330 ft^2/K acfm (3 fields)
Coal Suppliers	Multiple Seams
Hg Average	0.044 ppm
Chlorine	>1000 ppm
Sulfur	0.85%
Fly Ash L.O.I.	26%
Disposal	No Ash Sales

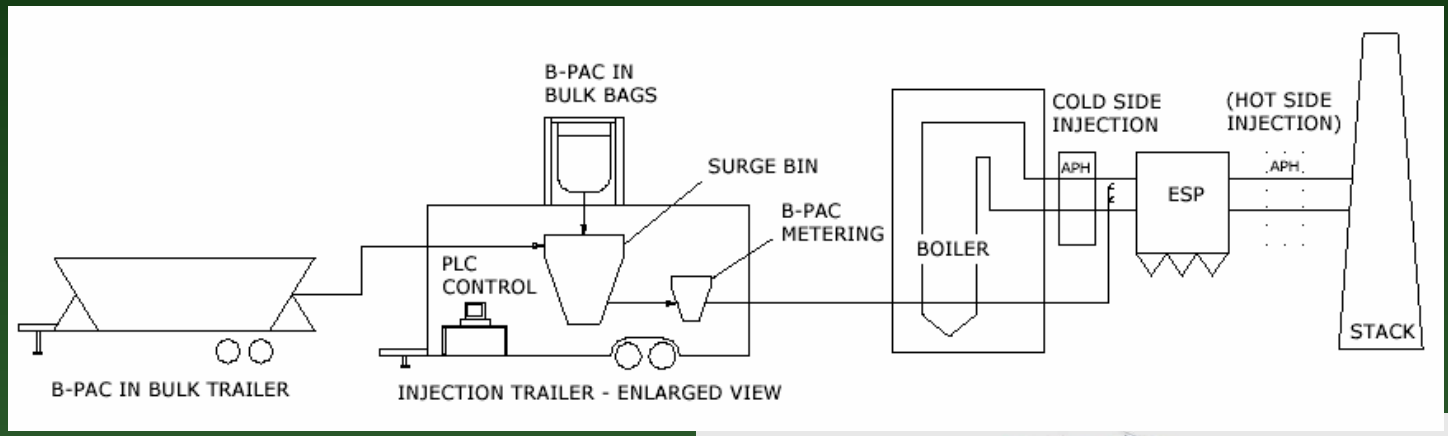
Mercury Measurements

- W. Kentucky University
- 2x PS Analytical Ltd. CMMs
- Dual Wet/Dry $Hg^{(+2)}$ Converter
- Baldwin and QSIS
  Inertial Separators
- Appendix K/Method 324
  Sorbent Trap Samplers
- Ohio Lumex CMM (Sorbtech)

Lee 1 Baseline: ~20-30% Native Hg Removal



Mobile Injection Trailer Used



Our mobile injection trailer (patent pending) is easily moved from site to site and hooked up for inexpensive full-scale B-PAC injection trials with actual plant equipment and actual coals.

Can be used on CS-ESP gas streams of up to about 400 MW.

Lee B-PAC™ Injection Lance Array

Parametric Testing – B-PAC™ Sorbent

Flue Gas Conditioning Issue – SO_3 at 8-15 ppm

- FGC was before the air preheater
- Temperature below the acid dew point on the cold side

1 - cold-side B-PAC™ injection with FGC on

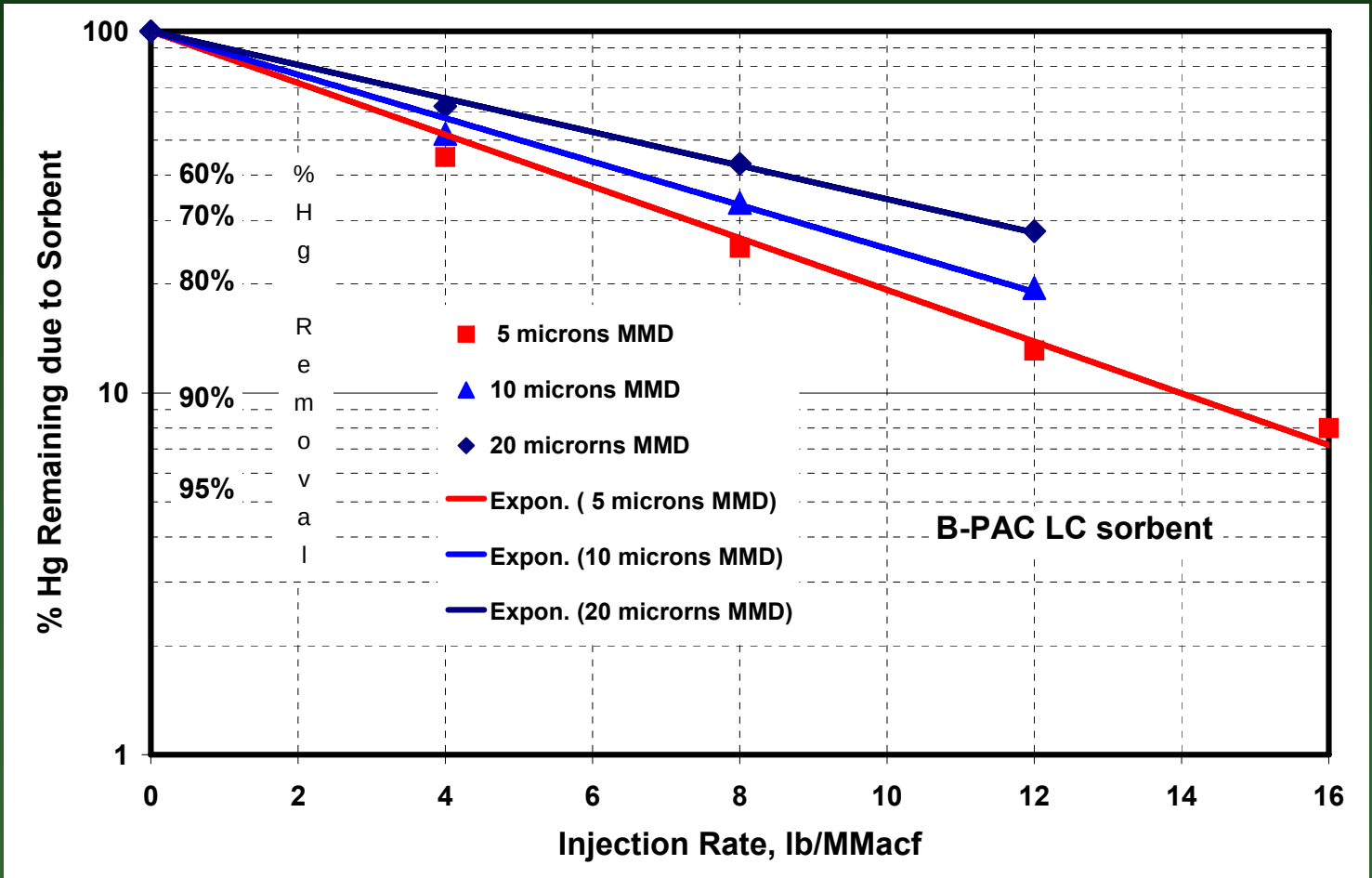
2 - hot-side H-PAC™ injection with FGC on (but no room)

3 - cold-side B-PAC™ injection with FGC off (but opacity?)

4 - move FGC to ESP plenum, but expensive

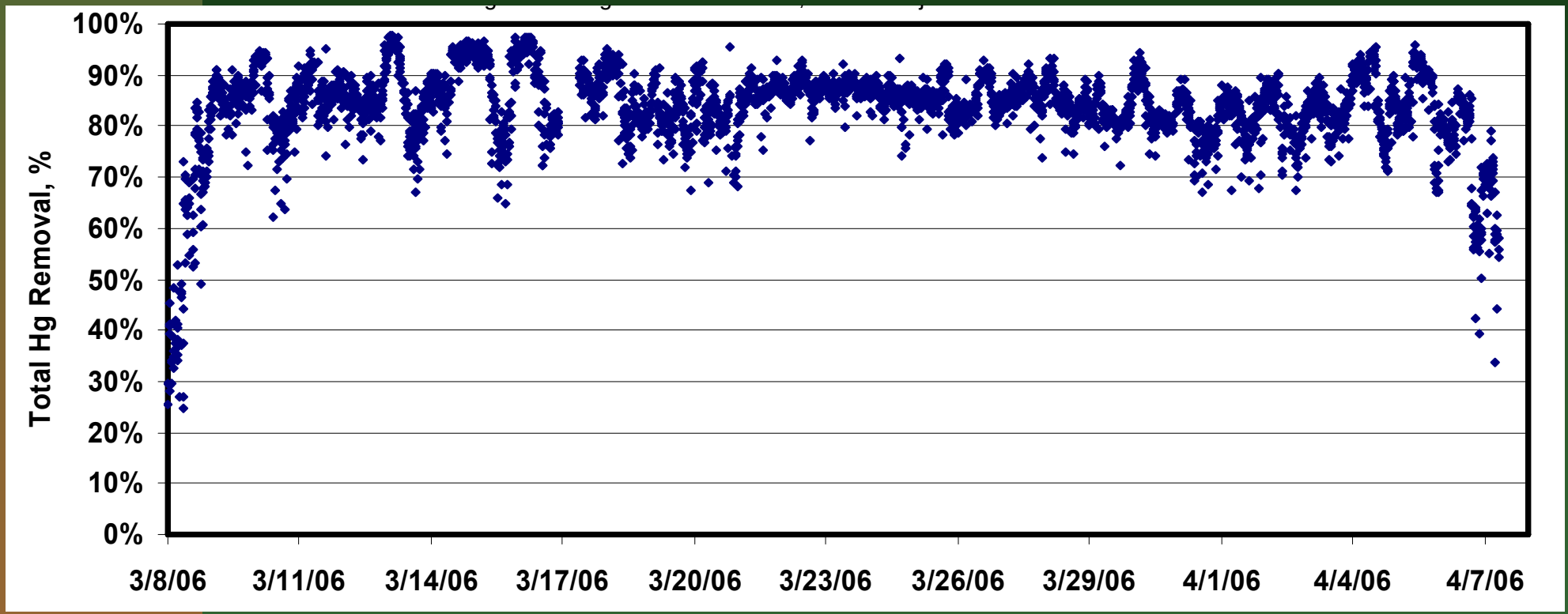
- Observed poor Hg-results with option 1 due to SO_3
- Parametric results during Panel Discussion

Sorbent Size Fraction – experimental B-PAC LC



Standard, Commercially-Available B-PAC™

B-PAC™ & Bituminous: 85% Removal at 8 lb/MMacf



Sorbtech Appendix K Hg Measurement Tubes

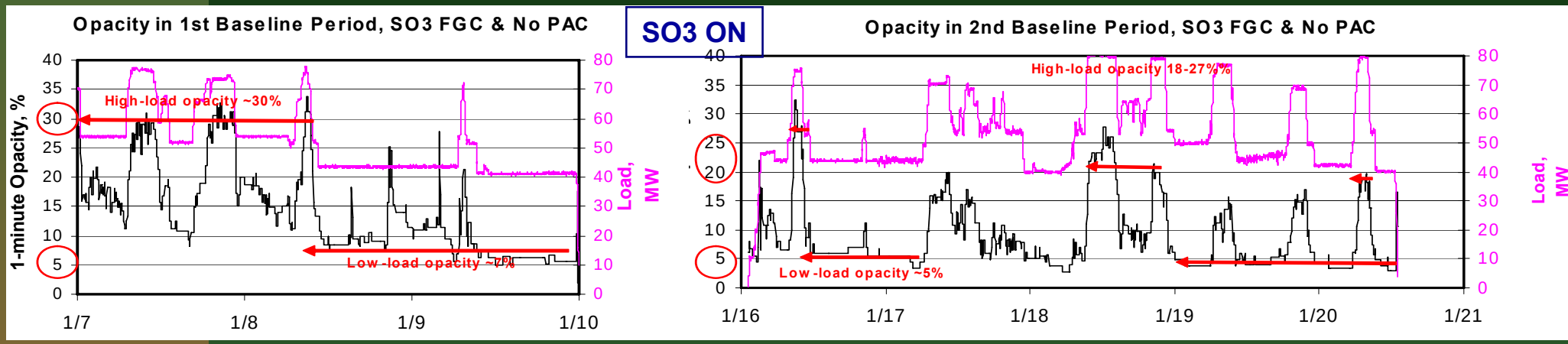
- Appendix K with a spiked section & Method 324 without
- Special brominated carbon instead of an iodinated carbon
- <u>Lower total cost</u> due to much cheaper tube analysis methods

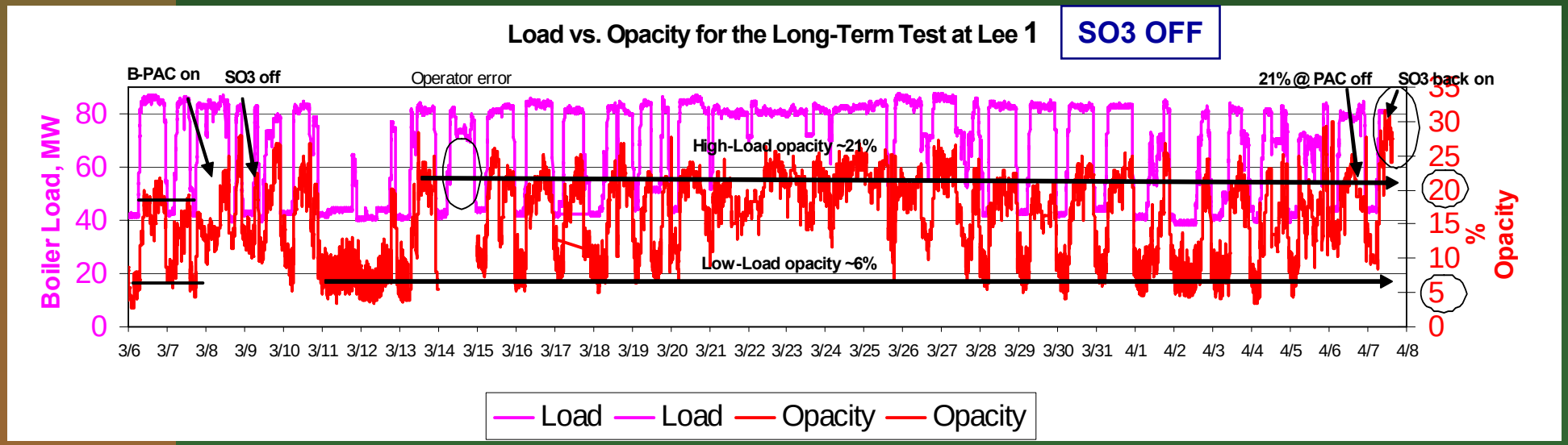
Long-Term Test – Method 324 Measurements

Measurement	Hg Inlet	Hg Outlet	Avg.Hg Removal
PSA SCEM	5.86	0.92	85%
(14 days of paired inlet/outlet measurements)			
Method 324	5.89	0.77	88%

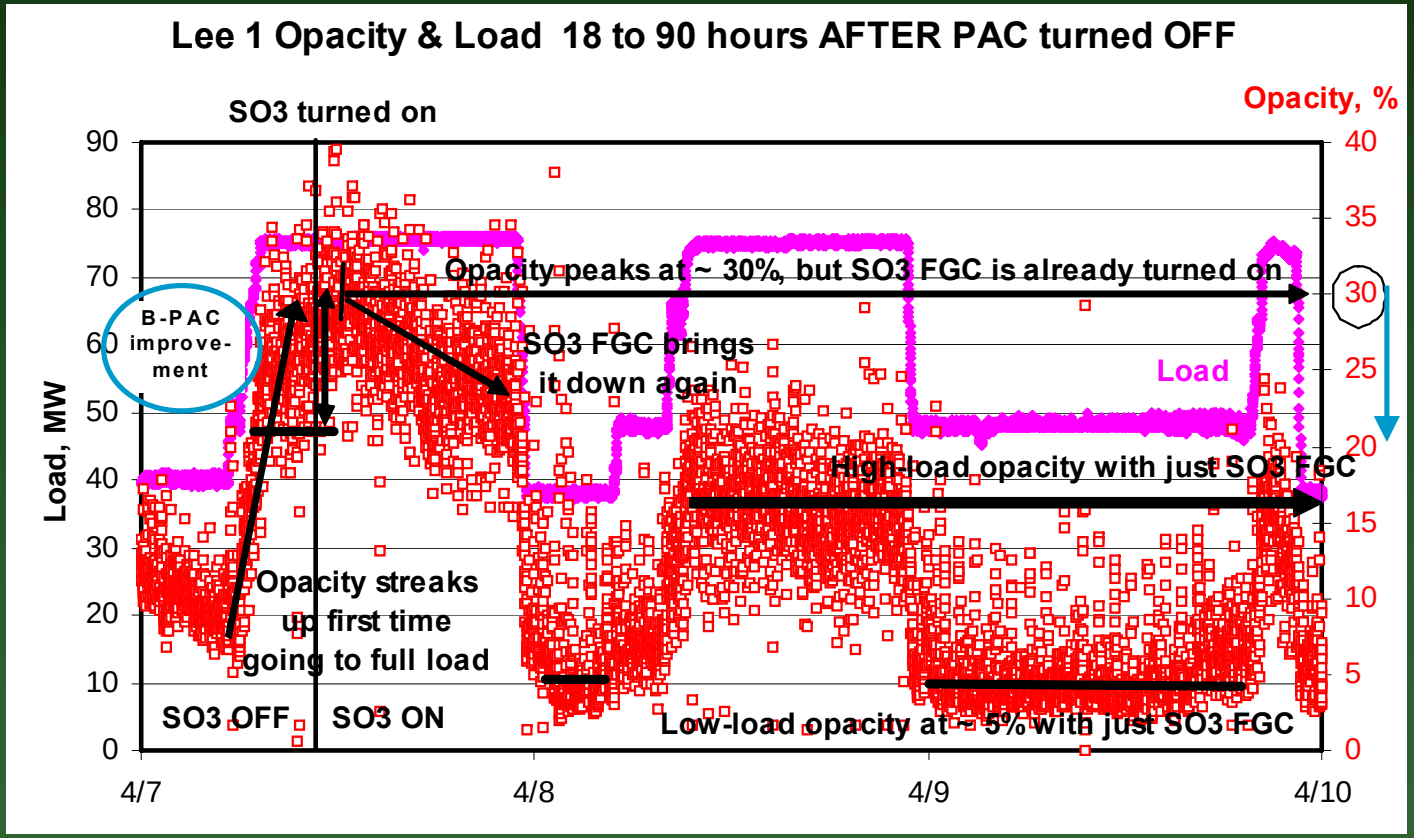
(Hg Concentrations in µg/Nm^3 @ 3% O_2)

ESP Effects: Baseline Opacity vs. 30-Day





No B-PAC, No SO_3 FGC → ~10% Higher Opacity



Due to opacity level constraints, we could not run at high load for an extended time without SO_3 to measure the independent opacity effect of B-PAC.

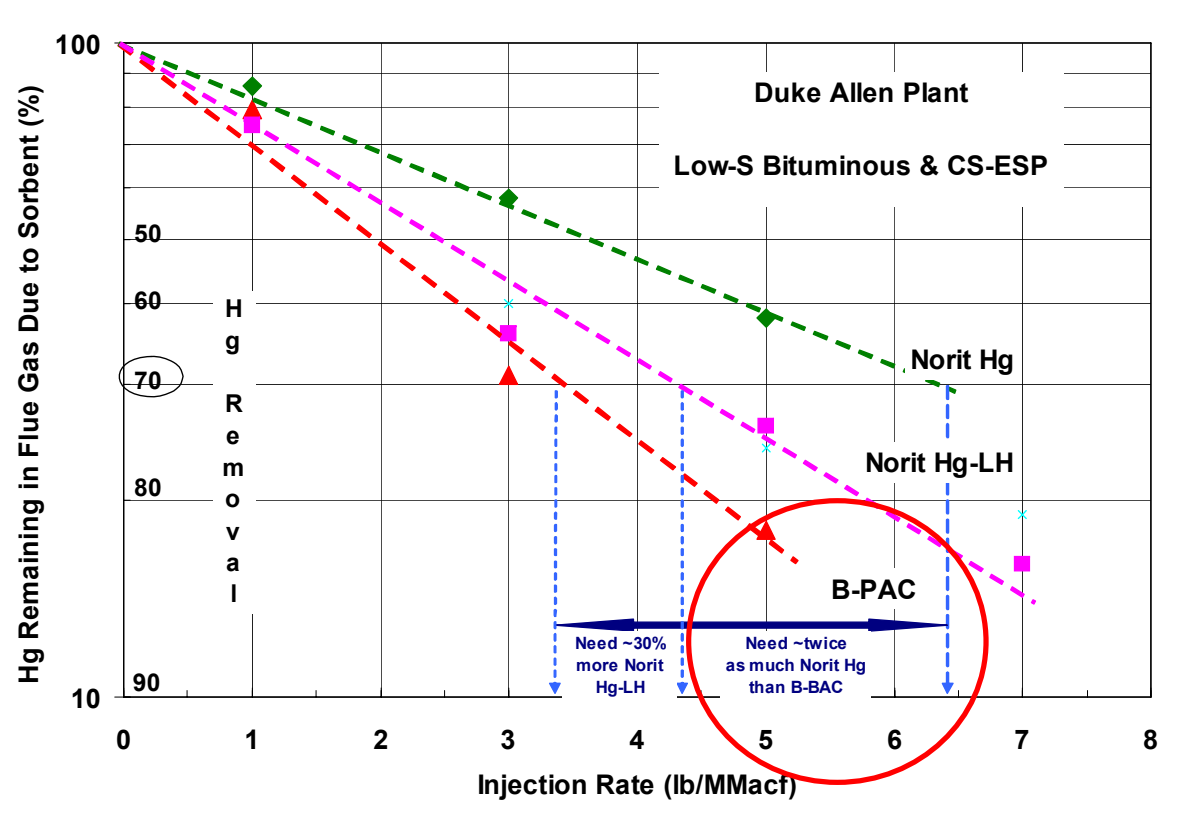
SO_3 FGC Impact on Corrosion

Coupon	Weight Loss (mg/day)
Baseline (FGC)	1.674
Baseline (FGC)	1.748
Baseline (FGC)	2.348
Baseline (FGC)	1.617
BL Avg.	**1.847**
Long-Term (B-PAC)	0.383
Long-Term (B-PAC)	0.367
Long-Term (B-PAC)	0.308
Long-Term (B-PAC)	0.258
LT Avg.	**0.329**

Conclusions – Lee 1

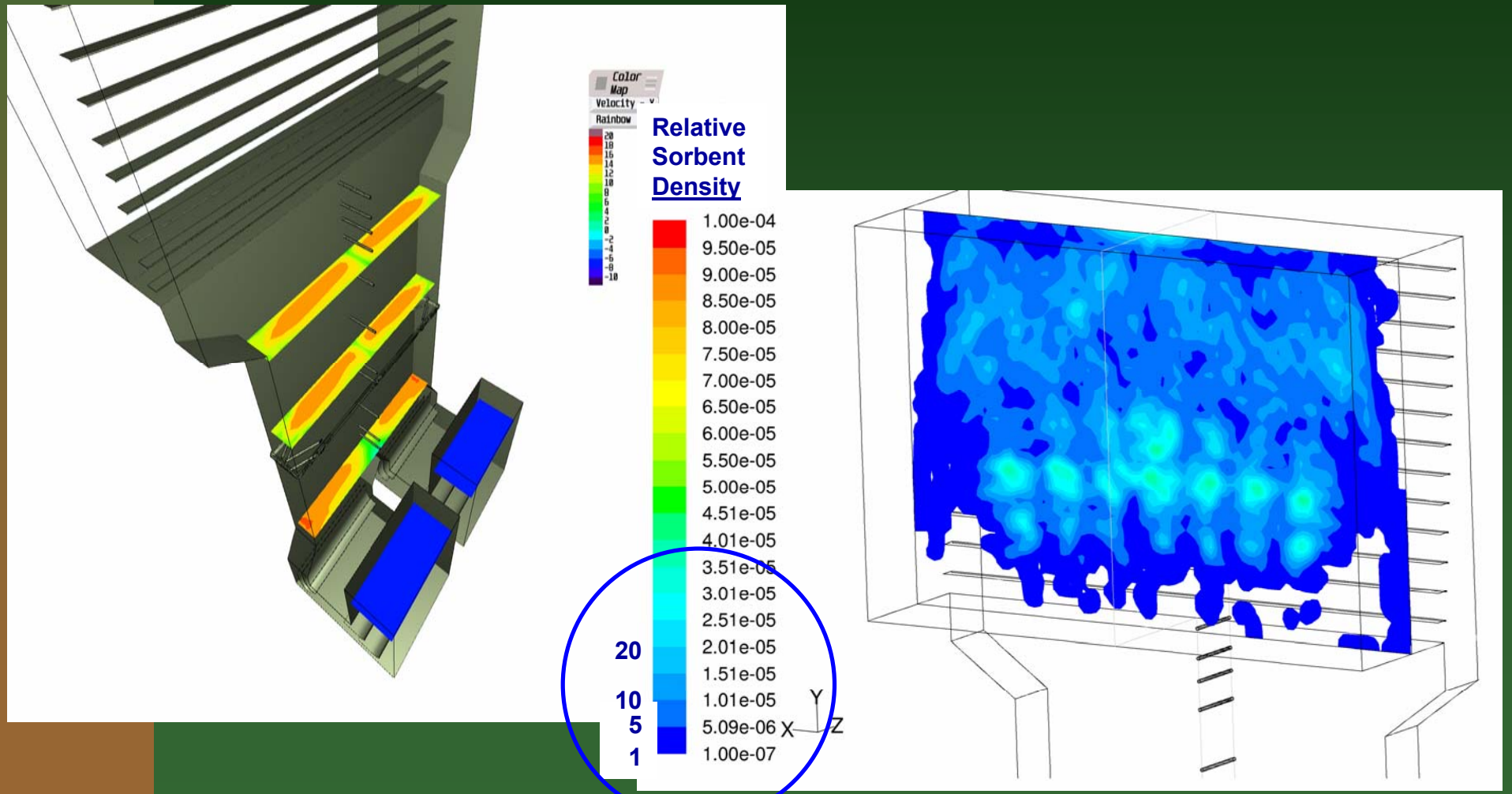
- B-PAC had good mercury removal without SO_3 FGC, but SO_3 reduced the mercury removal rate of the sorbent
- Hg performance could be improved with the SO_3 FGC on by injecting H-PAC on the hot-side of the air preheater
- B-PAC had a significantly positive impact on ESP performance so that SO_3 was not required during the long-term test
- 85-88% Hg removal was achieved with B-PAC at an injection rate of 8 lb/MMacf during the long-term test

Higher Rates Required than at Duke's Allen Plant



- Non-DOE short-term injection tests with bituminous coal & CS-ESP
- Measurements by Apogee Scientific

Lee 1 CFD Flow Model



Midwest Generation Crawford C-PAC™ Trial

Coal Type	Subbituminous
Unit 7 Boiler	234 MWe Tangential
Configuration	Reheat & Superheat
Particulate Control	Cold-Side ESP
ESP Stream Size	117 MWe x 2
Treated Gas Flow	460,000 acfm
ESP Temperature	310°F (full load)
SCA	118 ft^2/K acfm
Hg Average	0.08 ppm
Coal S & Cl	0.3% & 80 ppm
Fly Ash Sales	Yes

Fly Ash: U.S.'s Biggest Recycling Success

>12,000,000 Tons per year (~20%) of utility Fly Ash is used to replace expensive Cement in Concrete.

Provides greater strength, better mix workability, added chemical resistance, and less global warming.

Utilities are paid for cement-quality fly ash and avoid disposal expenses.

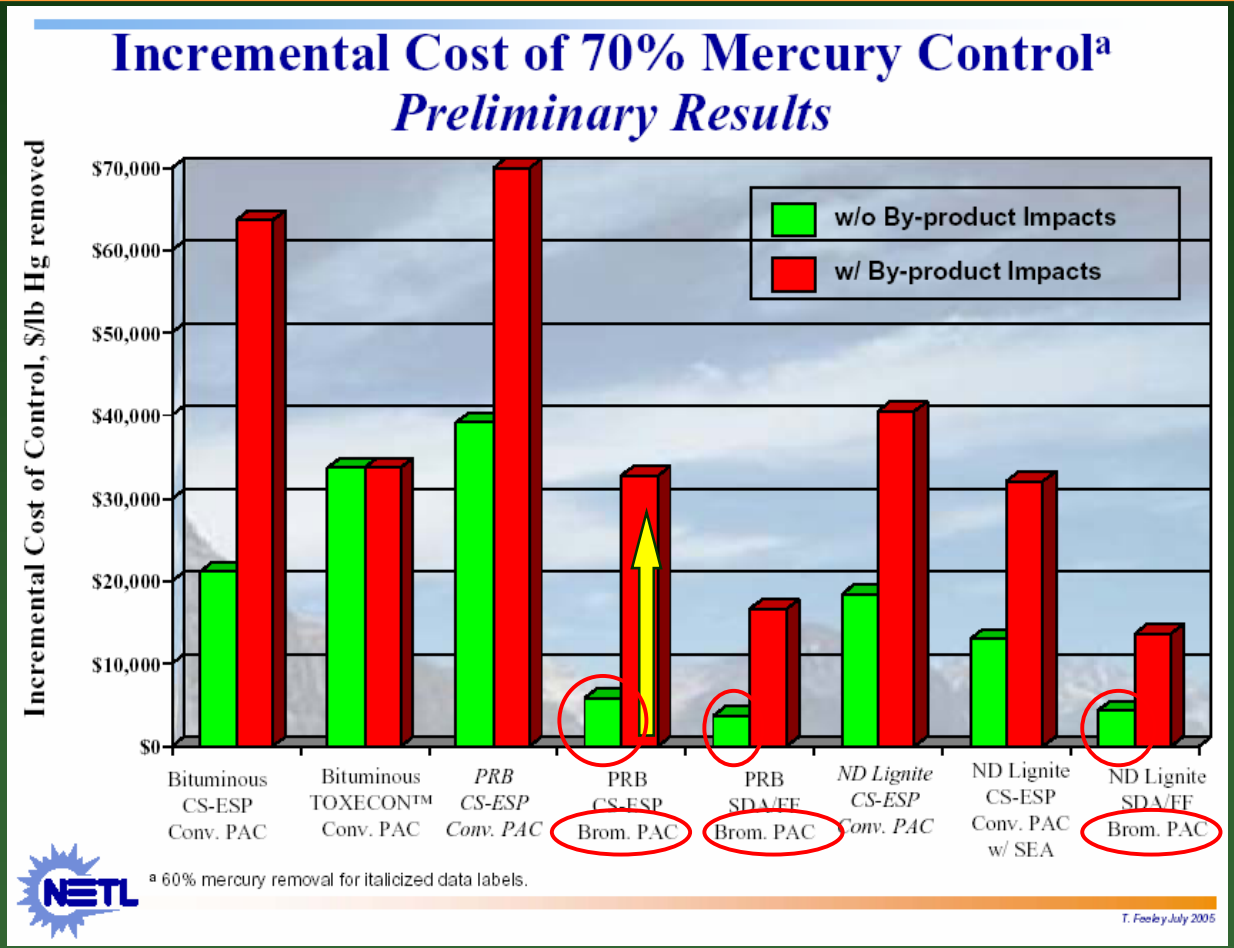
But PAC (& B-PAC) Cannot Be Used in Concrete

DOE/ADA-ES Pleasant Prairie Plant Foam Index Tests

Inj. Rate (lbs PAC/MMacf)	Carbon in Ash	Foam Index (Drops of AEA)	Comment
0	0.6%	15	Normal
1	1.1%	>72	Maxed out
3	1.6%	>72	Maxed out
10	3.6%	>72	Maxed out

Coughlin, T., "Operational & Maintenance Impacts of Hg Control," Scientech Hg Emissions Workshop, Clearwater, FL, Jan. 2002.

If Cannot Sell for Concrete, Big Costs



Feeley, T., "Overview of DOE/NETL's Mercury and CUB R&D Program," Mercury Control Technology R&D Program Review, Pittsburgh PA, July 2005. *(Circles & arrow added.)*

Ash Problems with PAC Hg Sorbents

1. Carbon level per se - 6% ASTM LOI & 5% AASHTO limit
   - but the effective limit is much lower due to the AEA effects

2. Adsorbs Air Entraining Admixtures (AEAs)

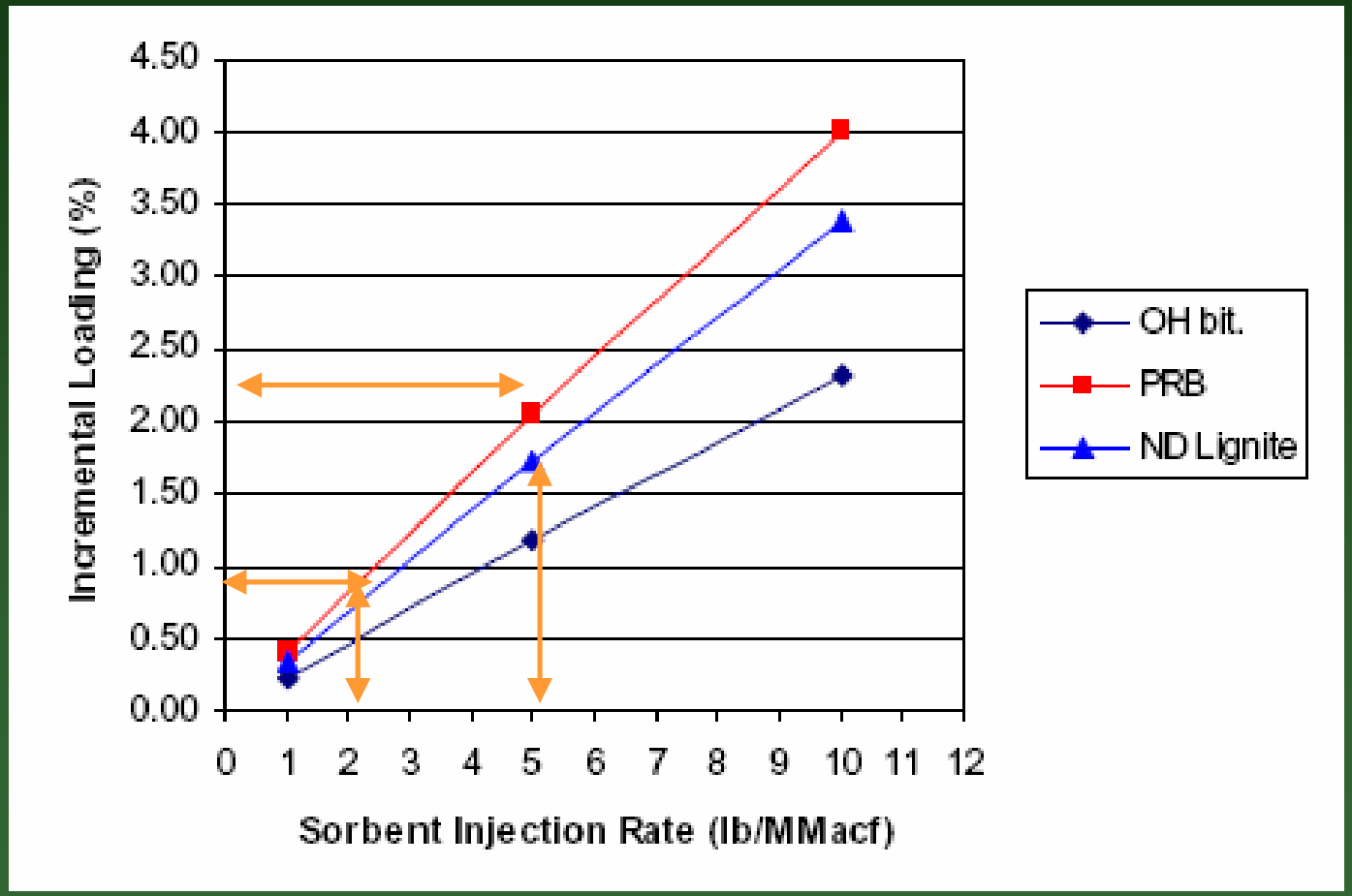
   -- detergents added to concrete slurries to
   intentionally form bubbles for freeze-thaw capability
   -- UBC or PAC adsorbs the AEAs
   -- inevitable variations in the level of the effect (std.dev.)

3. Darkens the fly ash

The Foam Index Test

- Titrate a mix of fly ash, cement, & water
- Add AEA standard, agitate, repeat until a stable foam forms
- Foam Index (FI) = amount of AEA needed to saturate the ash
- Specific Foam Index (SFI) = FI / carbon in the sample

With PAC for Hg, How Much Added Carbon?



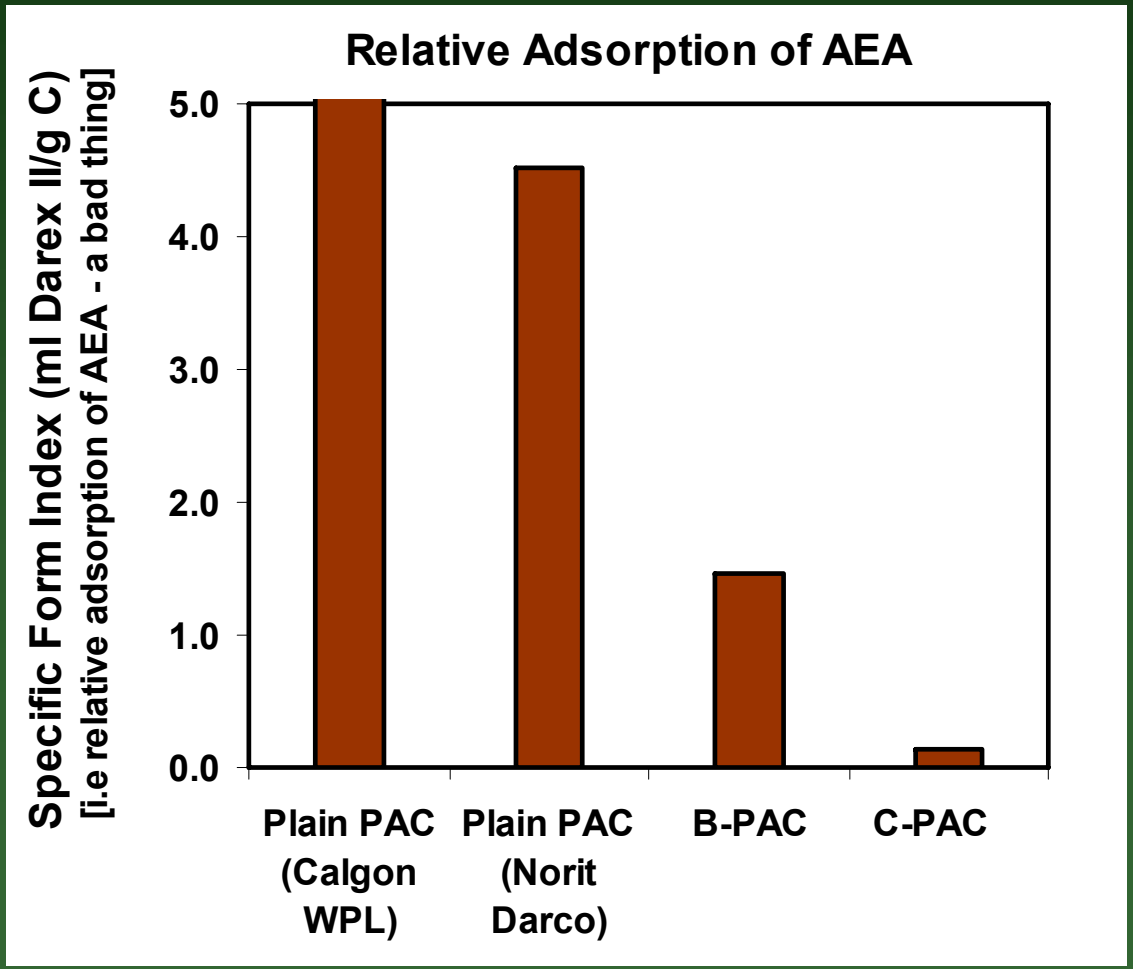
Source: U.S. EPA. Note: adjust for bottom ash fraction.

Answer: Concrete-Friendly C-PAC™

- Rather than process the entire gas stream (Toxecon®), or the entire fly ash load (post-processing), just concentrate on the offending 1% to 3% C: the sorbent.

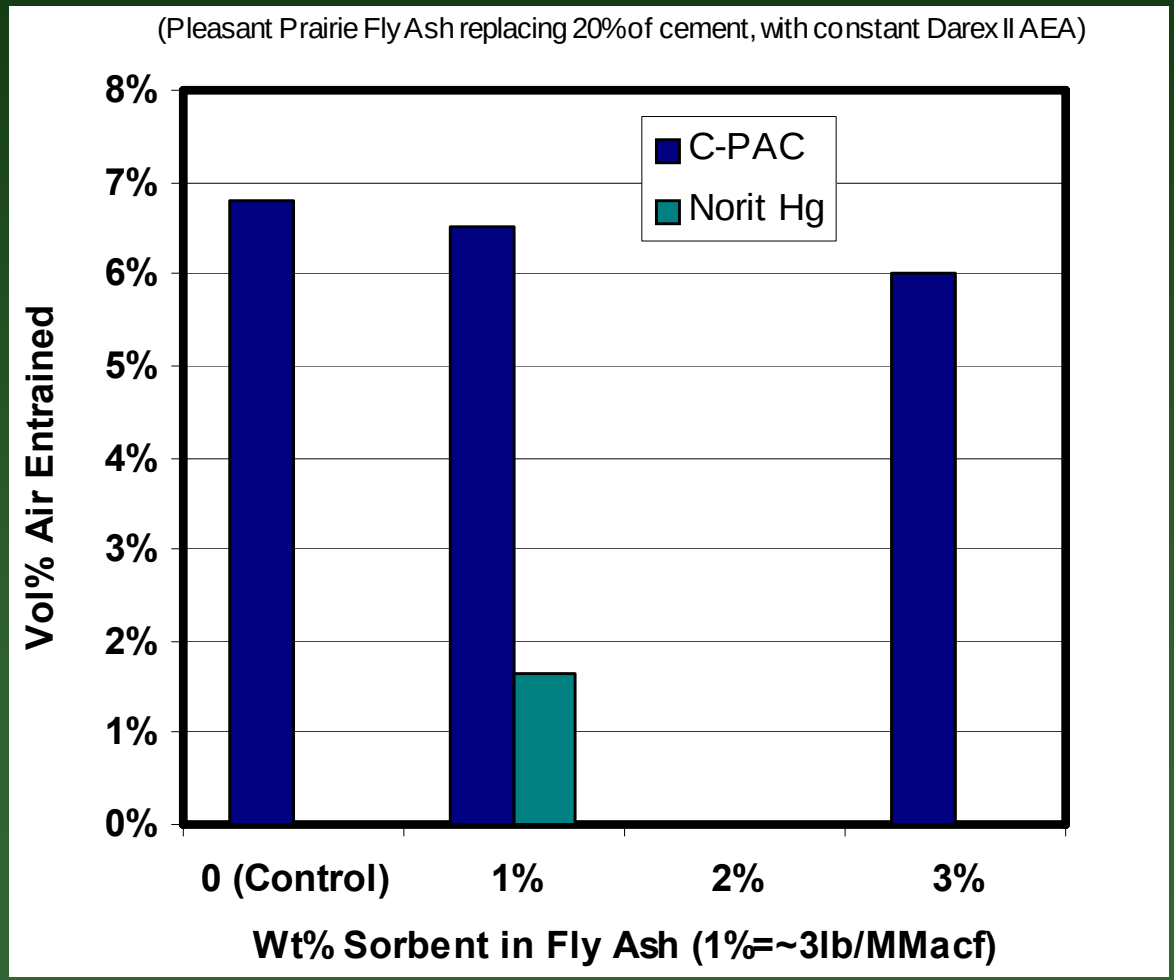
- Process the sorbent so that it does not interfere with the AEAs -- while retaining its Hg performance.

C-PAC™ has a Miniscule Foam Index

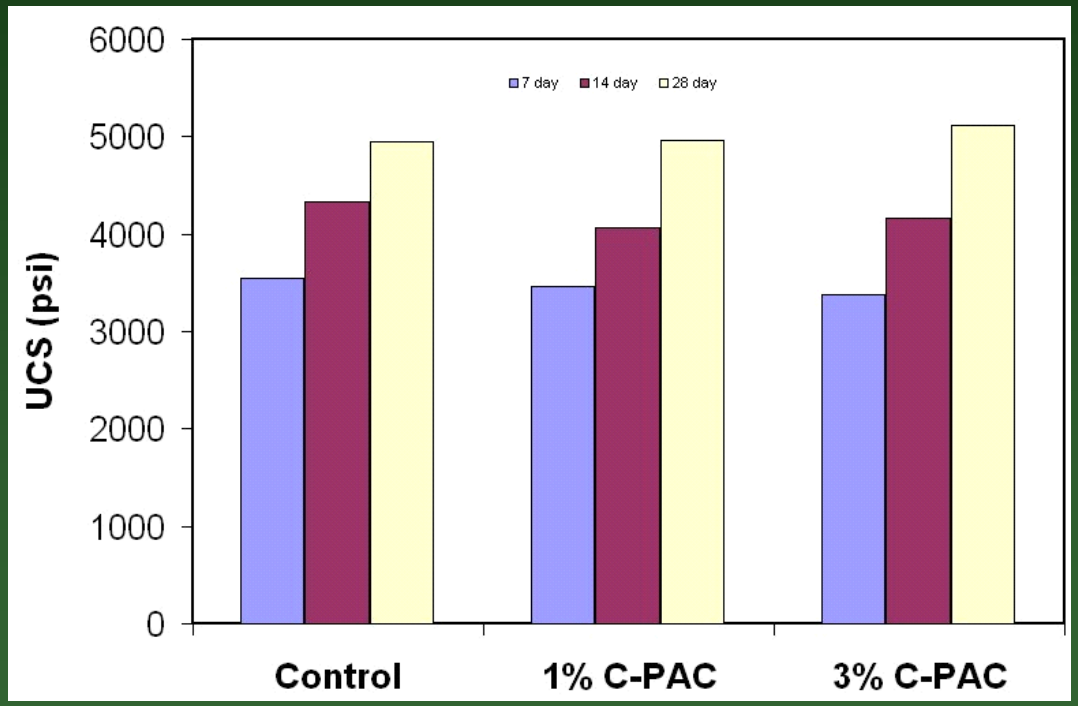


Tested with typical 20% substitution of Pleasant Prairie Plant fly ash for cement & 1-wt% PAC in the fly ash.

Air in Synthetic Concrete with C-PAC™

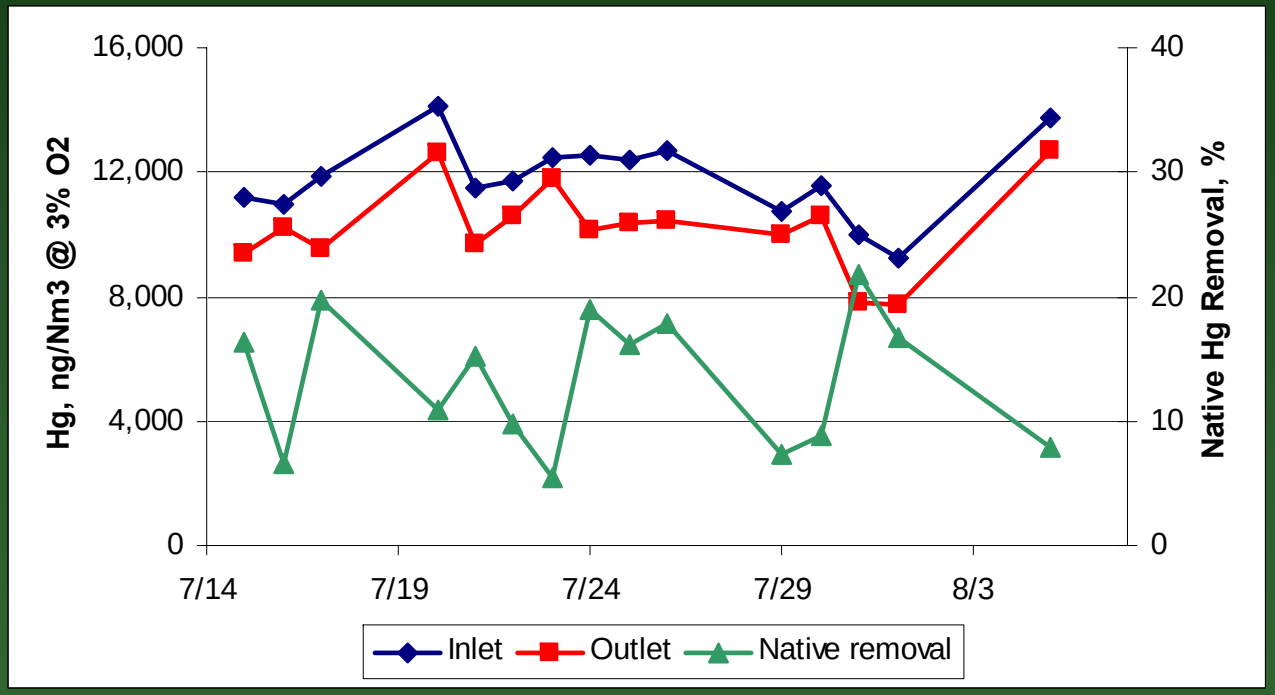


Compressive Strength Not a Issue

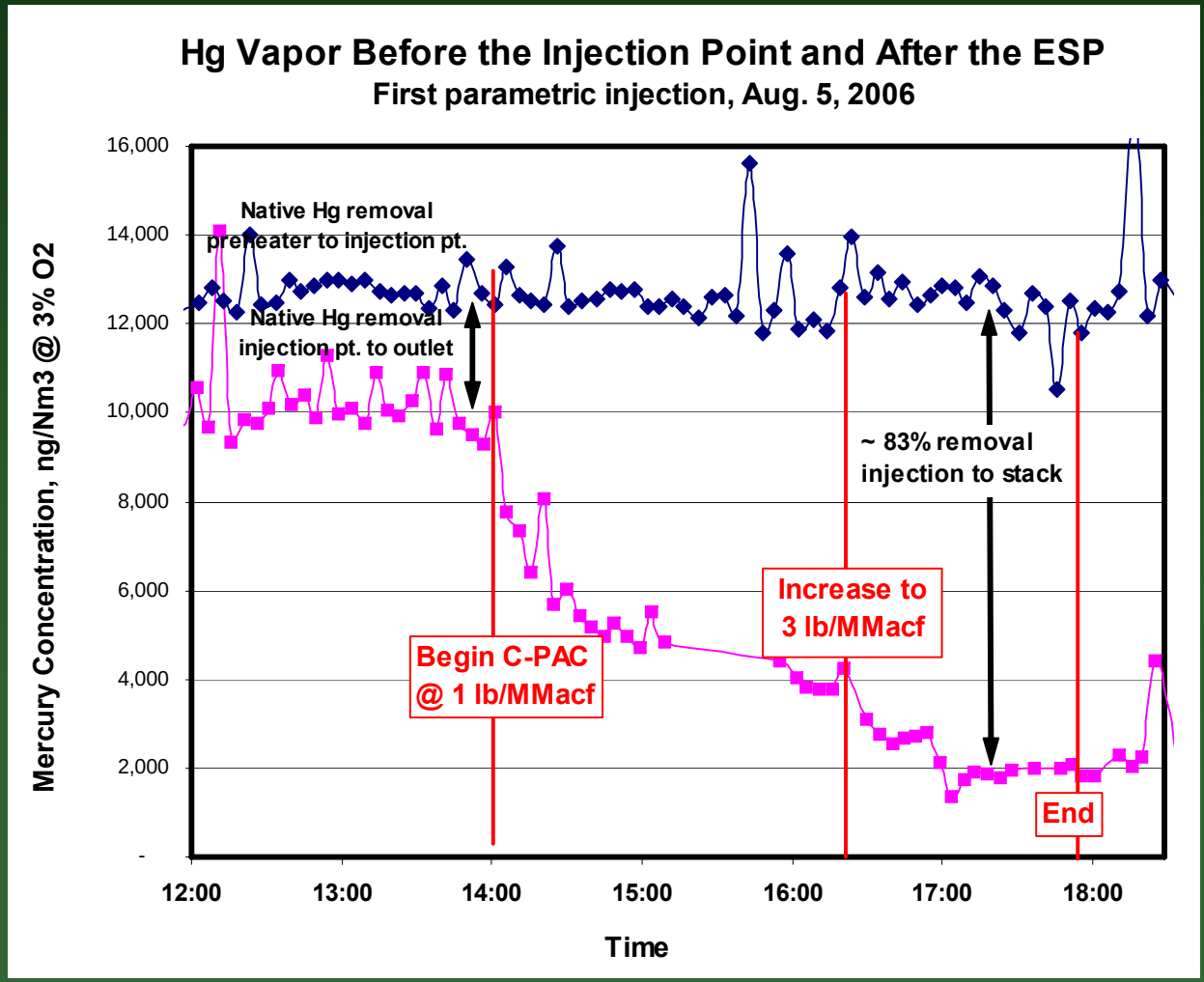


Chicago Trials

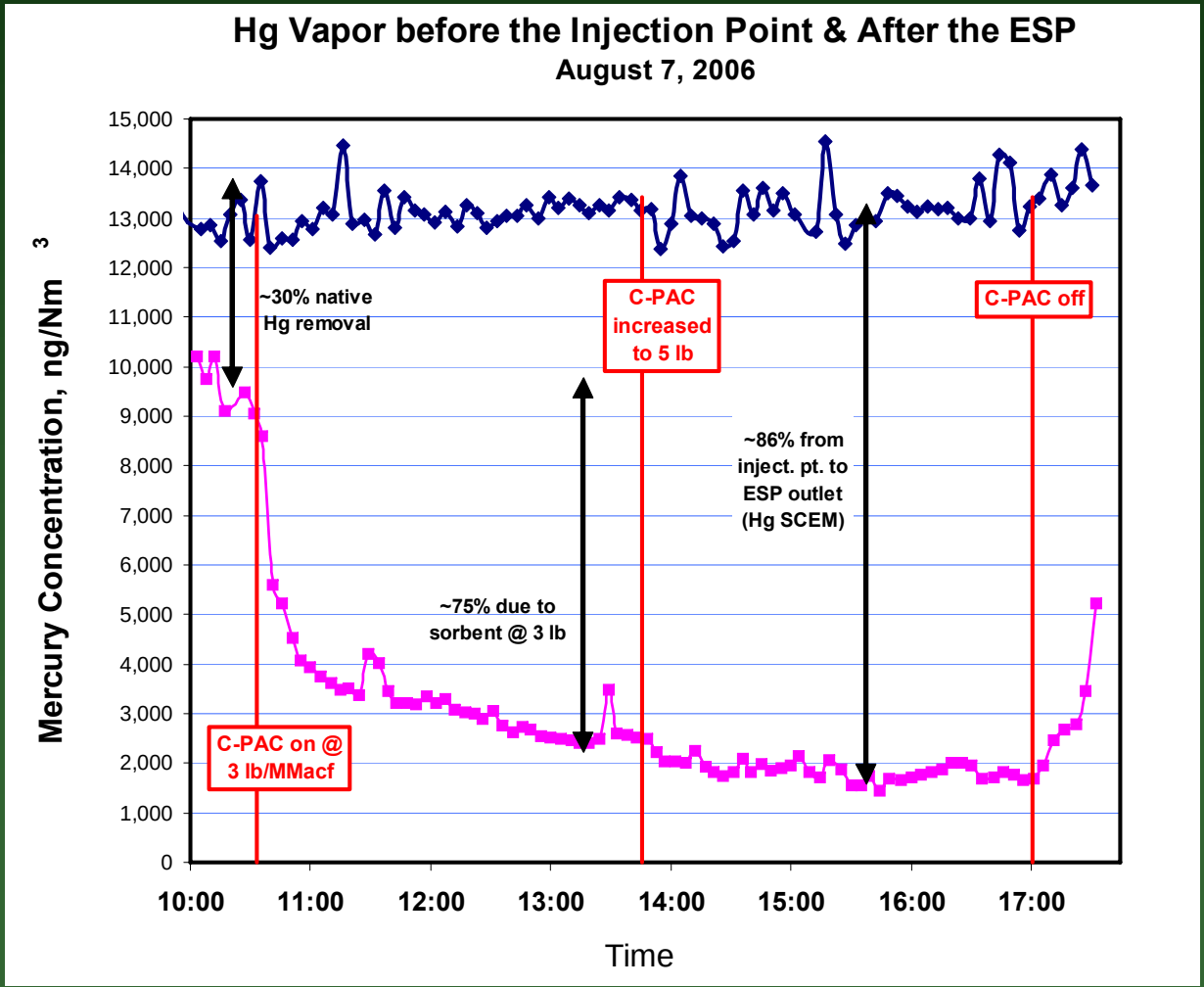
About 5-20% Native Hg Removal at Crawford



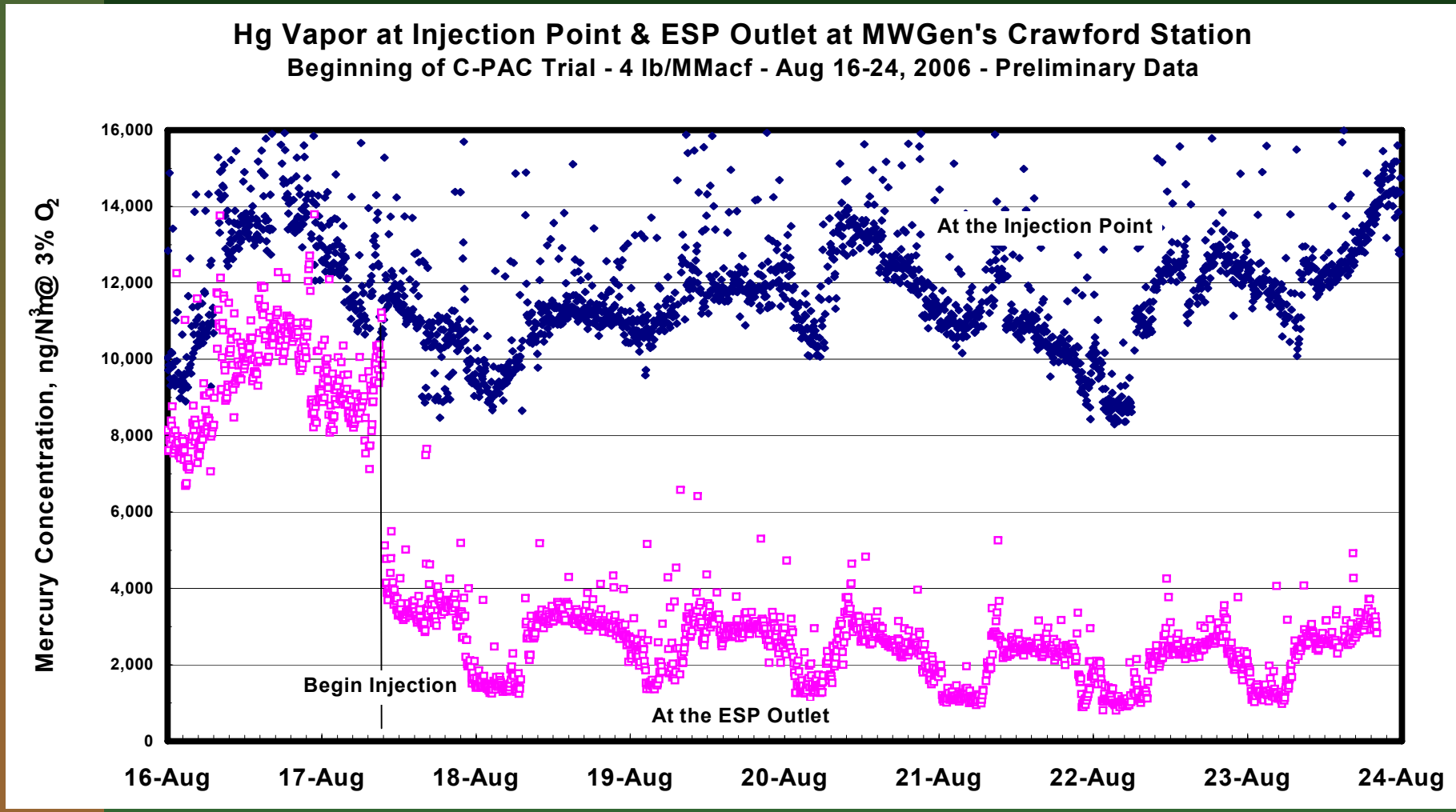
Preliminary Parametric Hg Removal Results



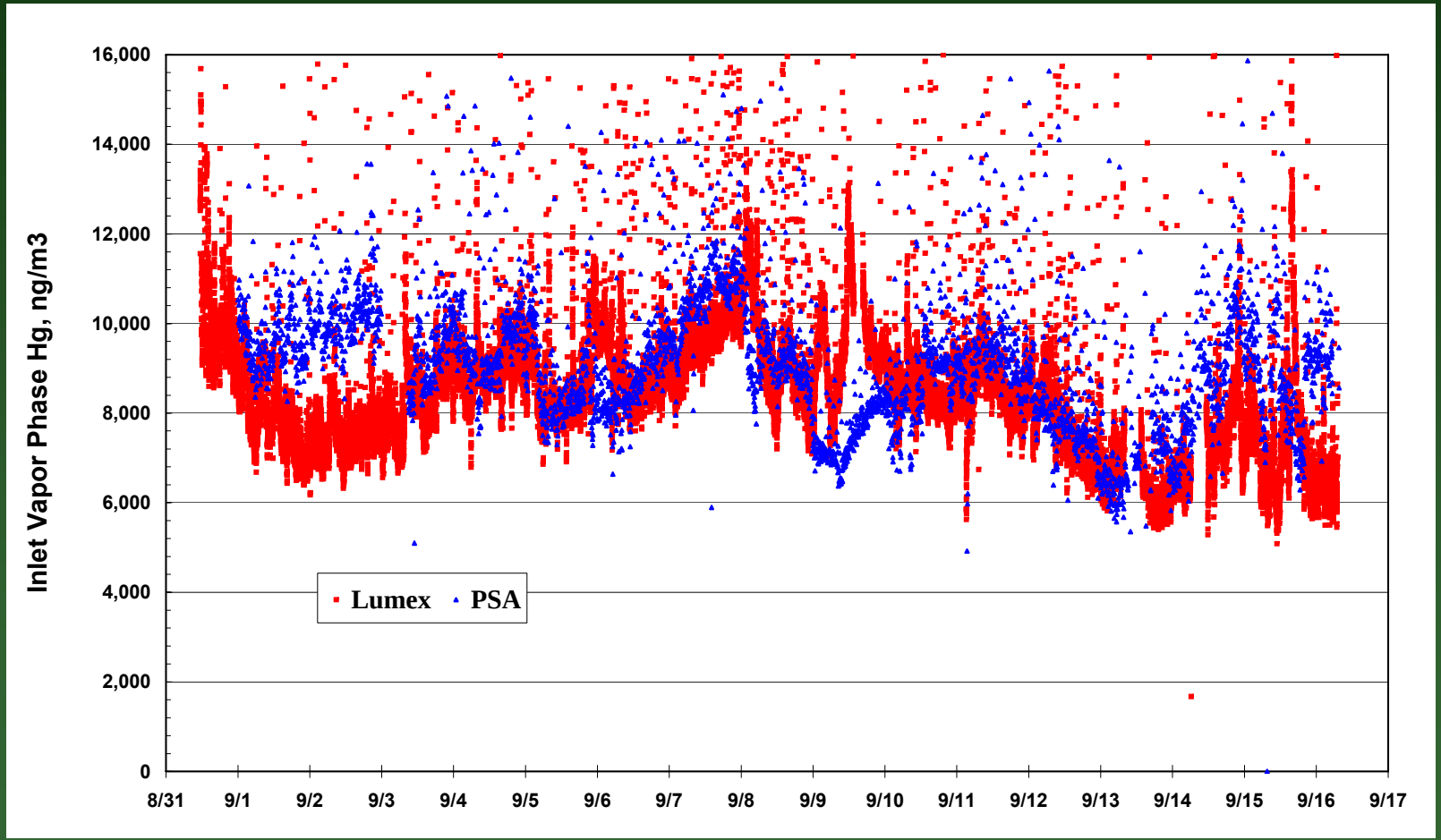
Additional Preliminary Parametric Results



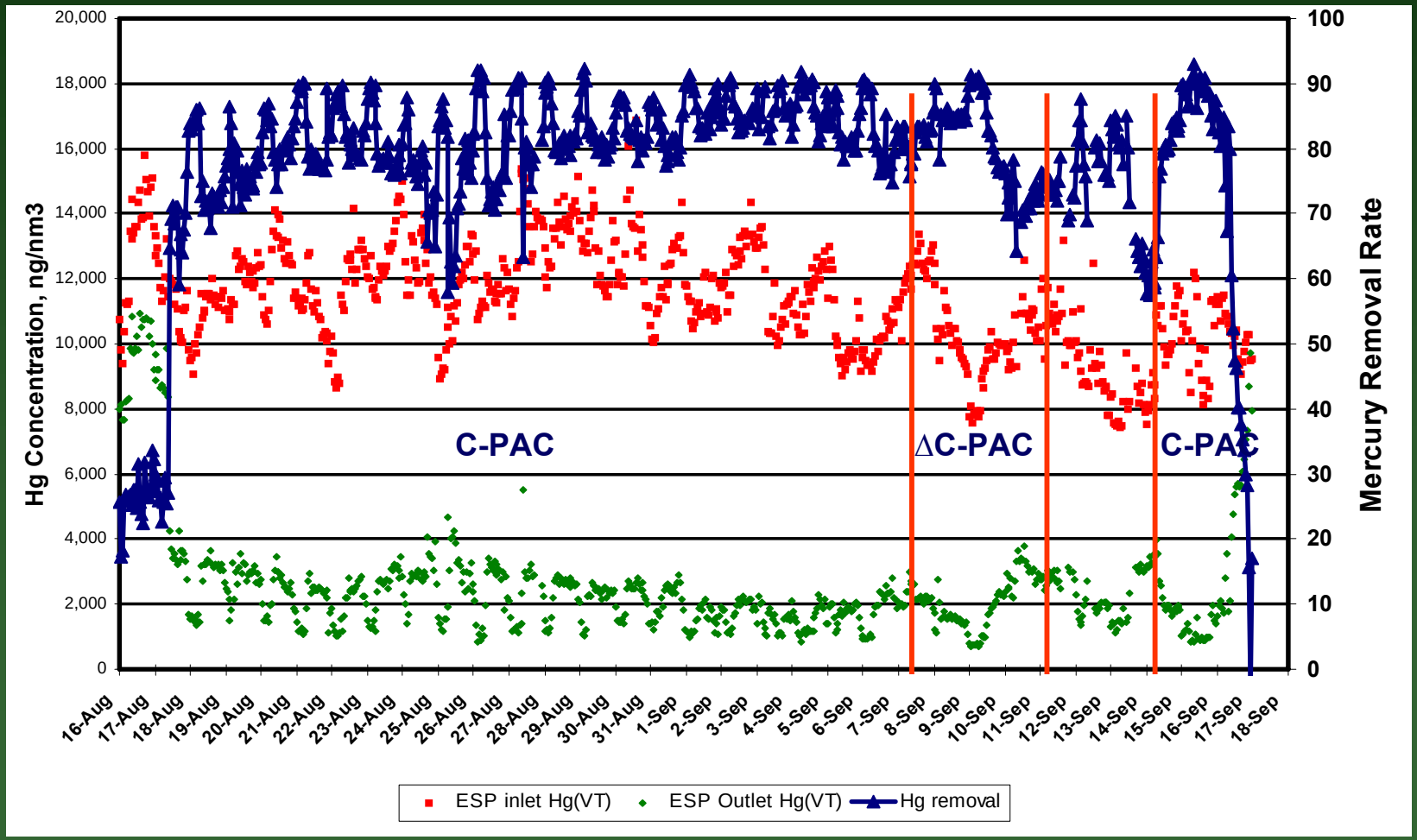
Beginning of the 30-Day Continuous Trial



Ohio Lumex vs. PSA on Inlet

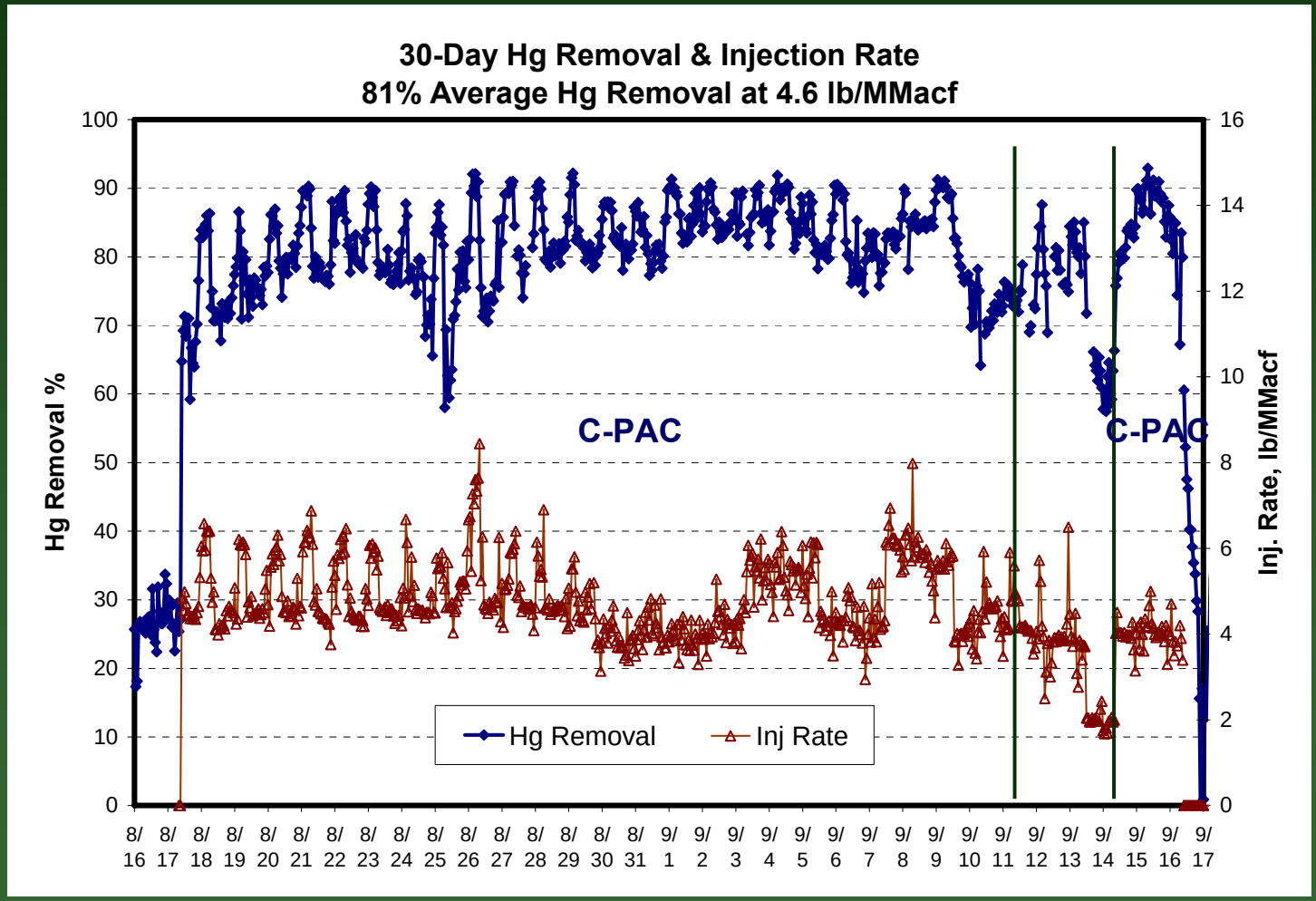


C-PAC Avg.: 81% Hg Removal at 4.6 lb/MMacf

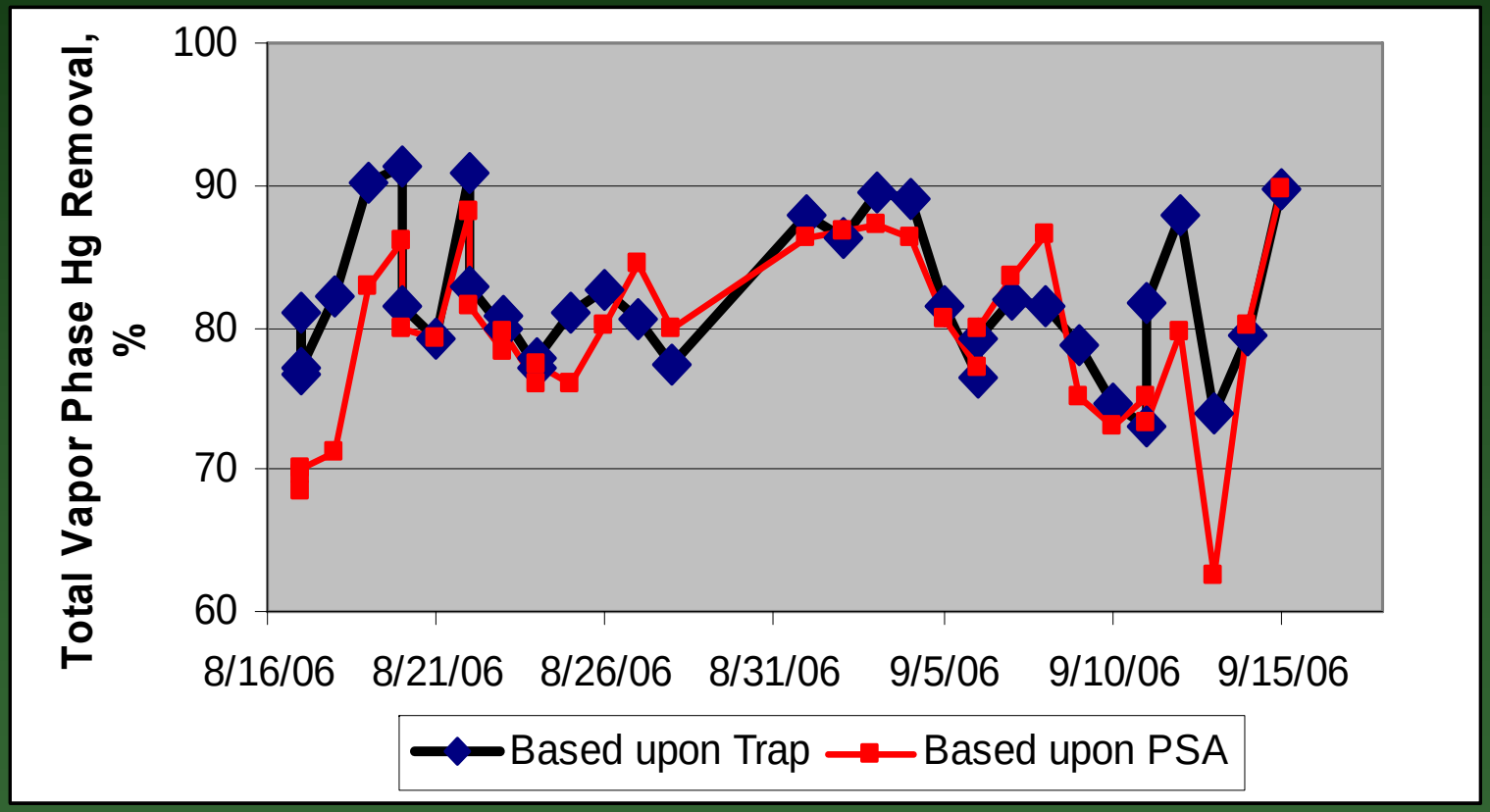


Vapor-Phase Hg Reduction Between Injection Point and ESP Outlet

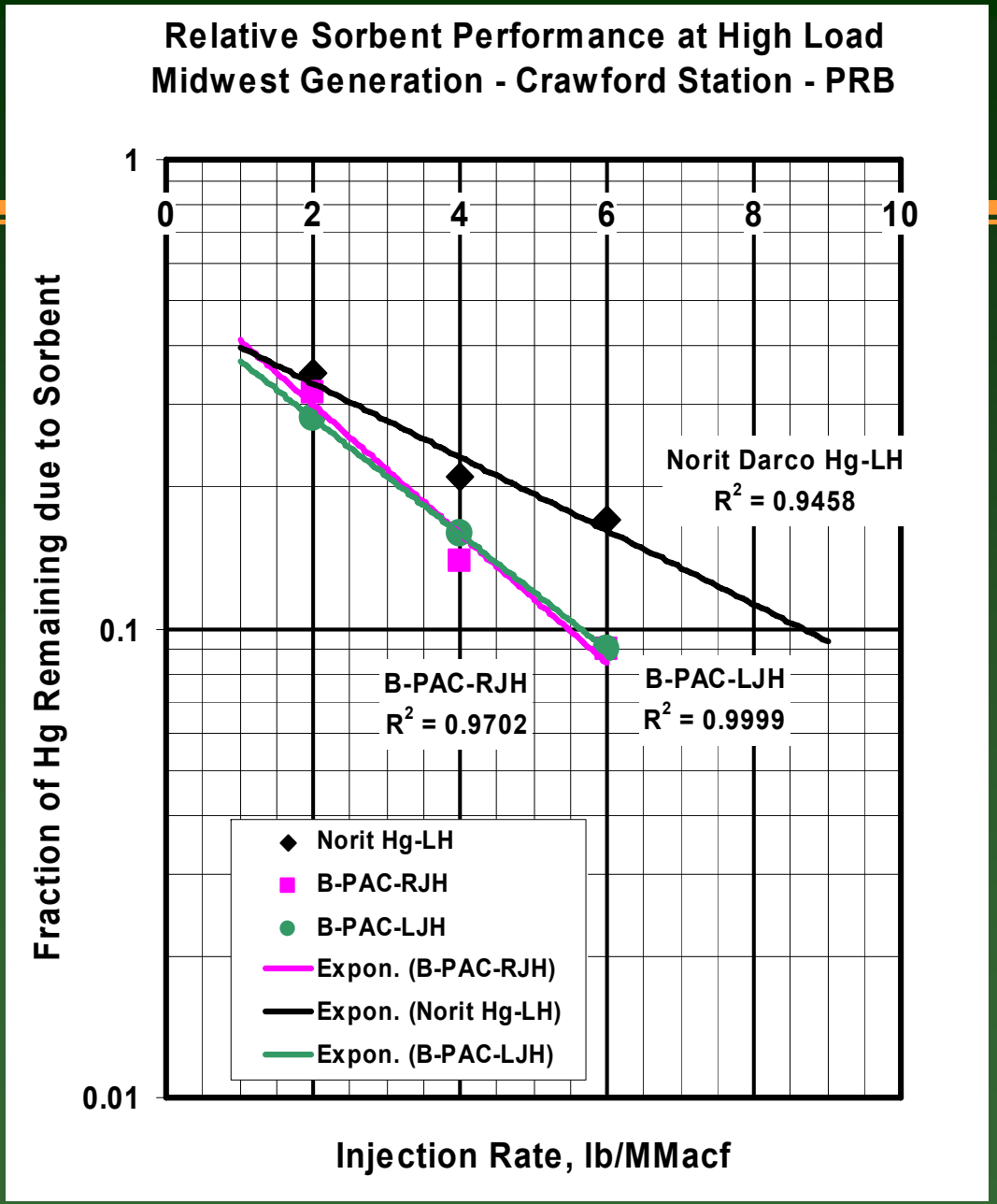
Results

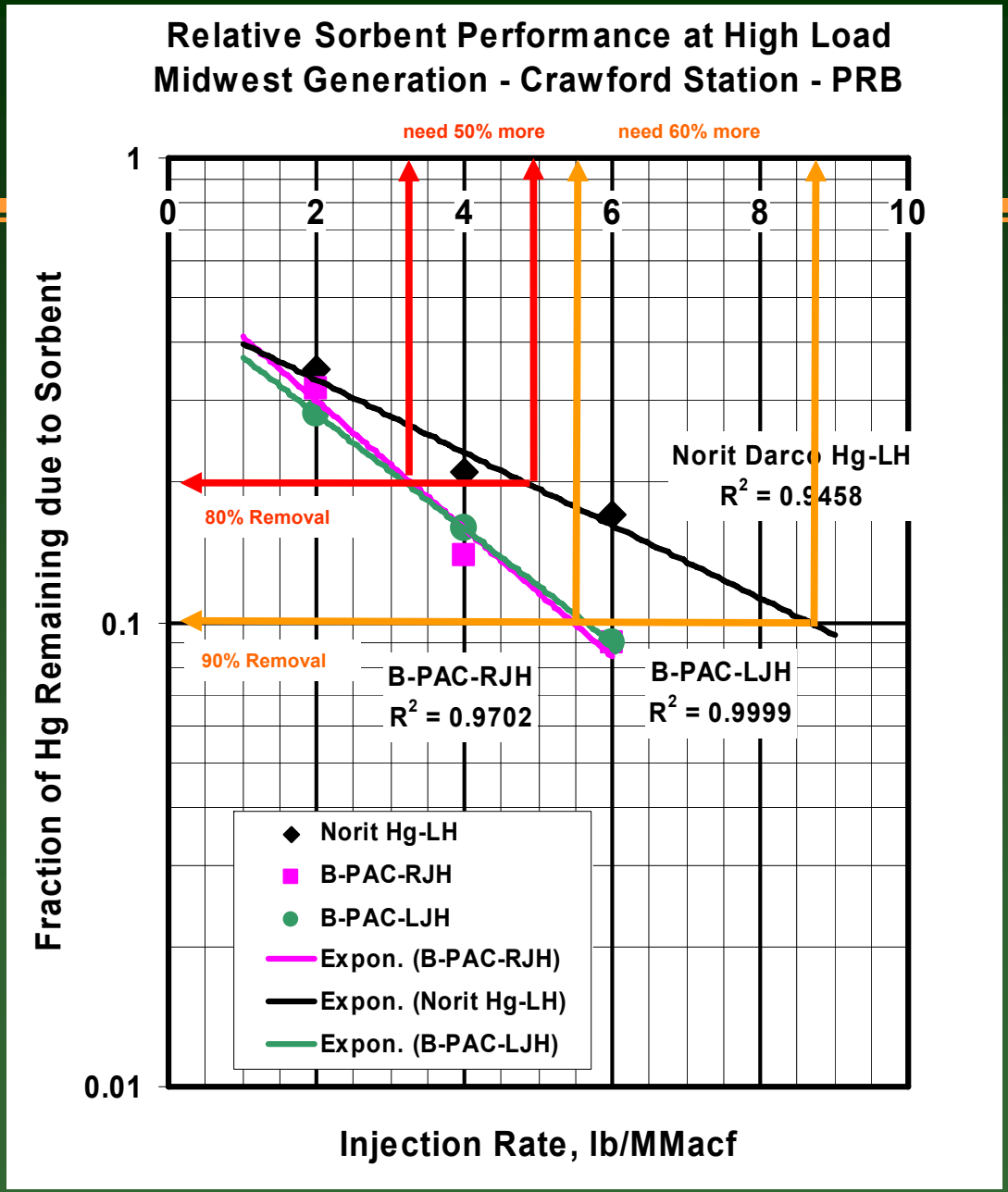

30-Day Hg Removal & Injection Rate
81% Average Hg Removal at 4.6 lb/MMacf
Hg Removal %
Inj. Rate, lb/MMacf
C-PAC
C-PAC
Hg Removal
Inj Rate
100
90
80
70
60
50
40
30
20
10
0
16
14
12
10
8
6
4
2
0
8/16 8/17 8/18 8/19 8/20 8/21 8/22 8/23 8/24 8/25 8/26 8/27 8/28 8/29 8/30 8/31 9/1 9/2 9/3 9/4 9/5 9/6 9/7 9/8 9/9 9/10 9/11 9/12 9/13 9/14 9/15 9/16 9/17

Appendix K Hg Removals Slightly > than CMMs



B-PAC™ Parametrics




Relative Sorbent Performance at High Load
Midwest Generation - Crawford Station - PRB
need 50% more
need 60% more
1
0.1
0.01
0
2
4
6
8
10
Fraction of Hg Remaining due to Sorbent
Injection Rate, lb/MMacf
80% Removal
90% Removal
Norit Darco Hg-LH
R2 = 0.9458
B-PAC-RJH
R2 = 0.9702
B-PAC-LJH
R2 = 0.9999
Norit Hg-LH
B-PAC-RJH
B-PAC-LJH
Expon. (B-PAC-RJH)
Expon. (Norit Hg-LH)
Expon. (B-PAC-LJH)

B-PAC™ at GRE's Stanton 1 with PRB

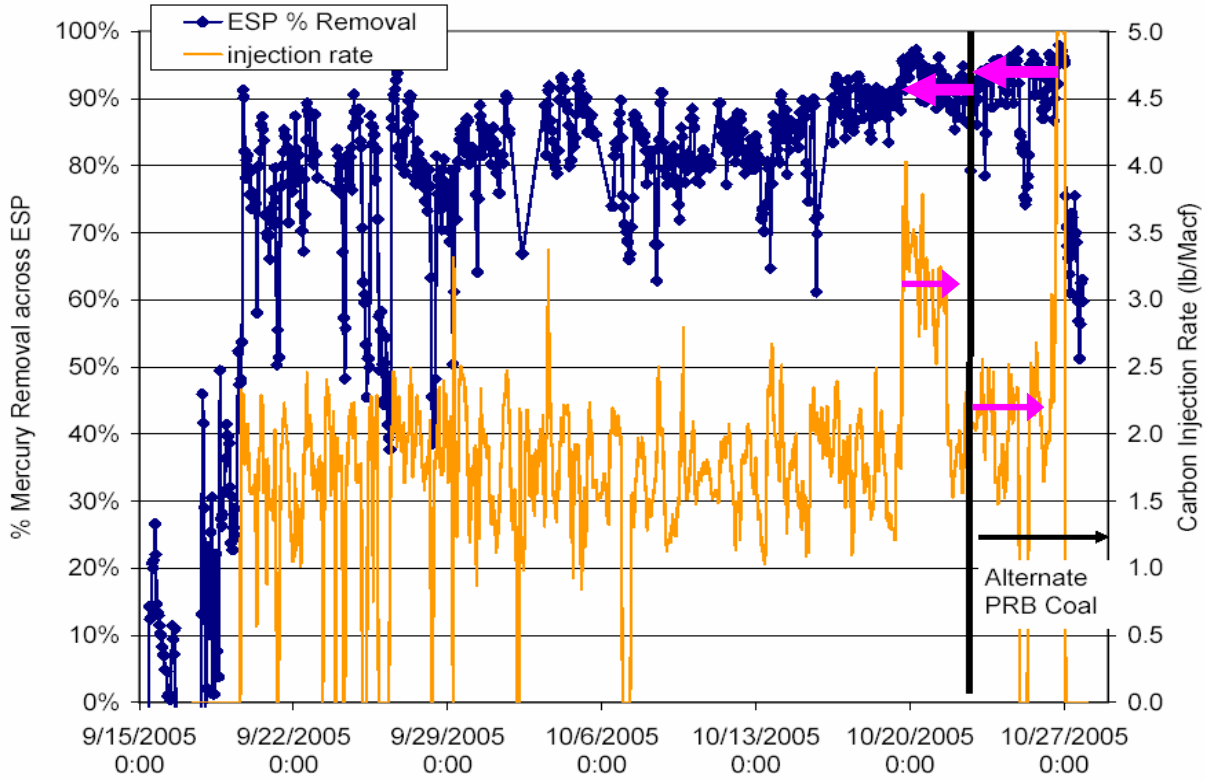


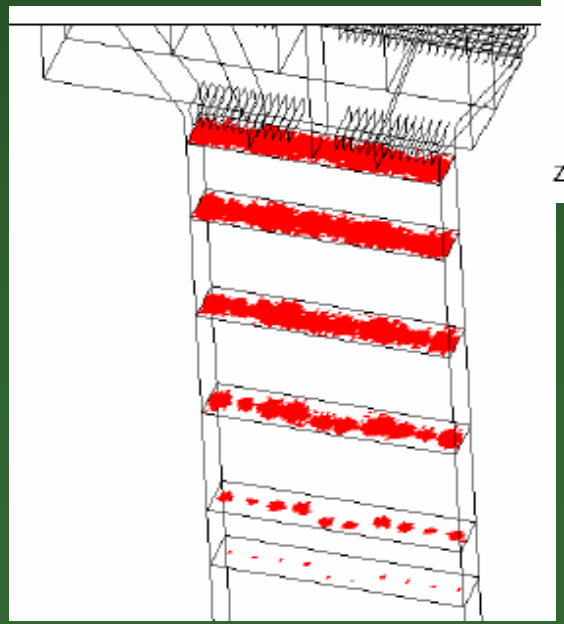
Figure 5-19. Mercury Removal Across the ESP during Long-term Evaluation of BPAC Injection.

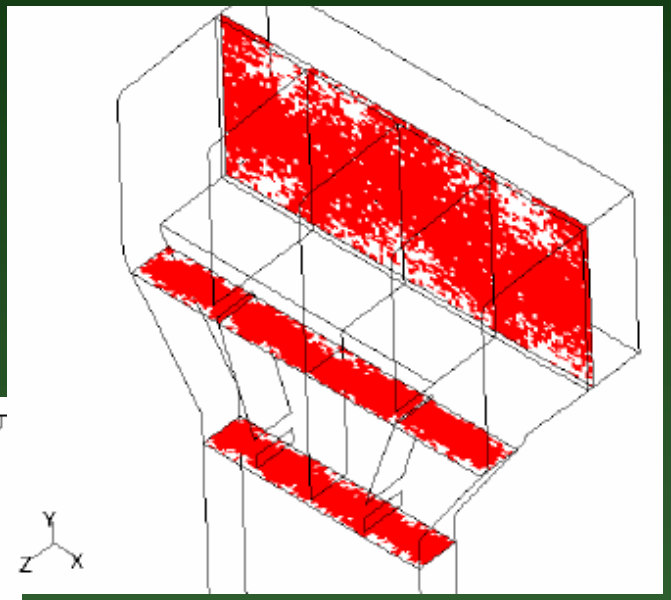
From: C. Richardson, et al., "Mercury Control Field Testing at Stanton Station Unit 1," Draft Site Report, Prepared for: Lynn Brickett, U.S. Department of Energy, Prepared by: URS Corporation, April 2006. (Purple added.)

Possible Sorbent Distribution Problems

Crawford, like Lee, with an abrupt ductwork expansion

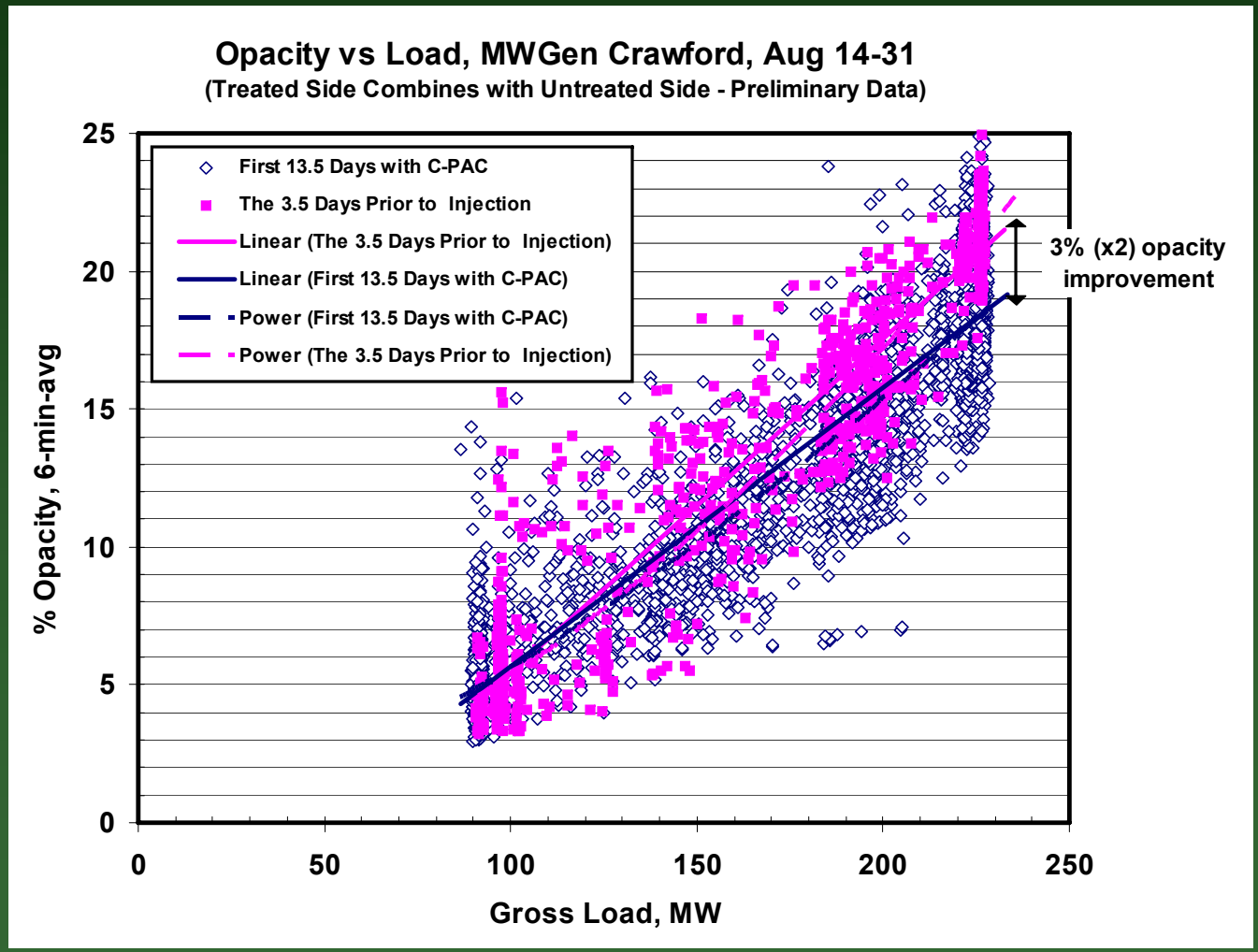
(These plots for coverage, not sorbent density)



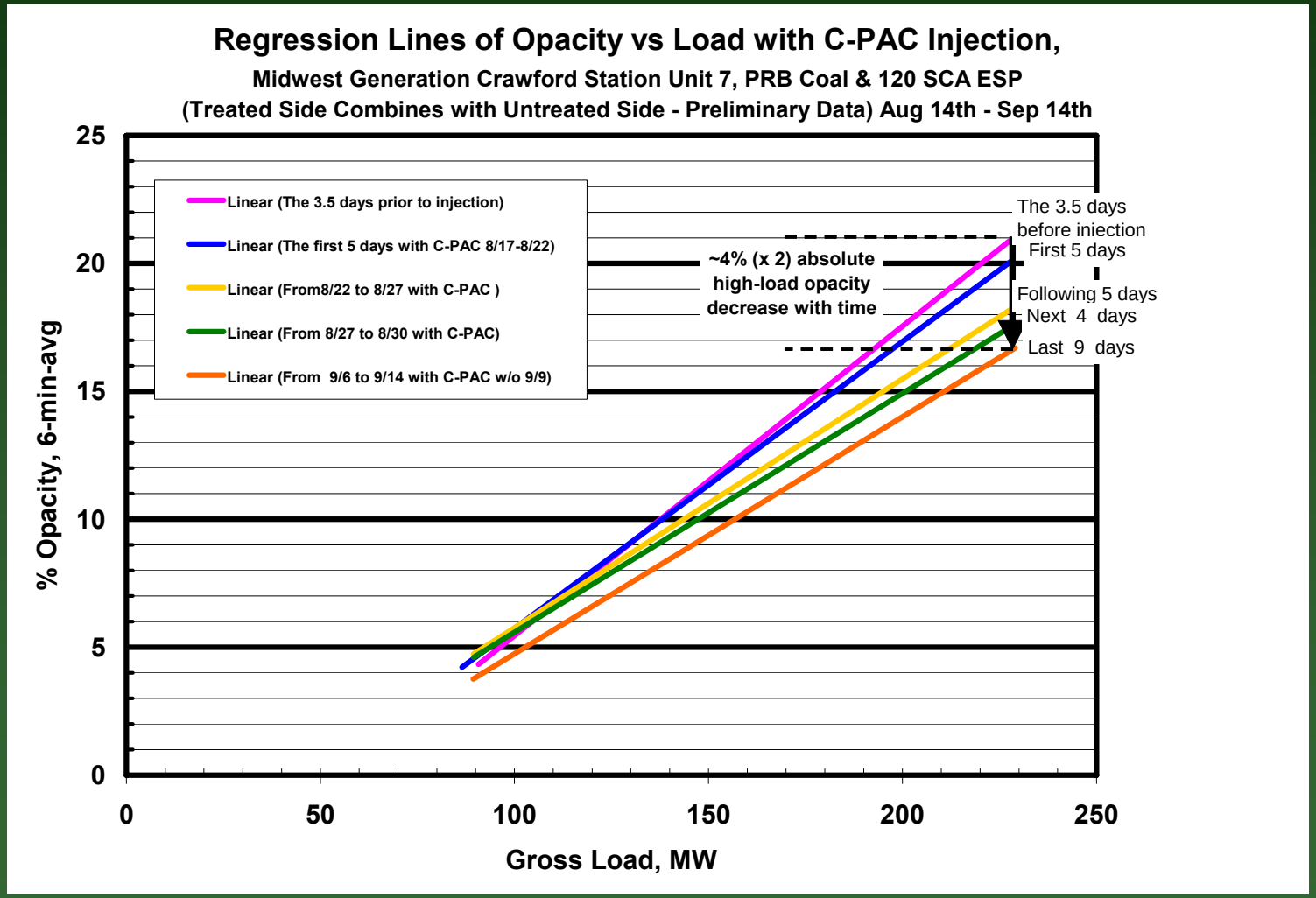


Ideas for better sorbent distribution & large reductions in sorbent needs - interest in a trial site?

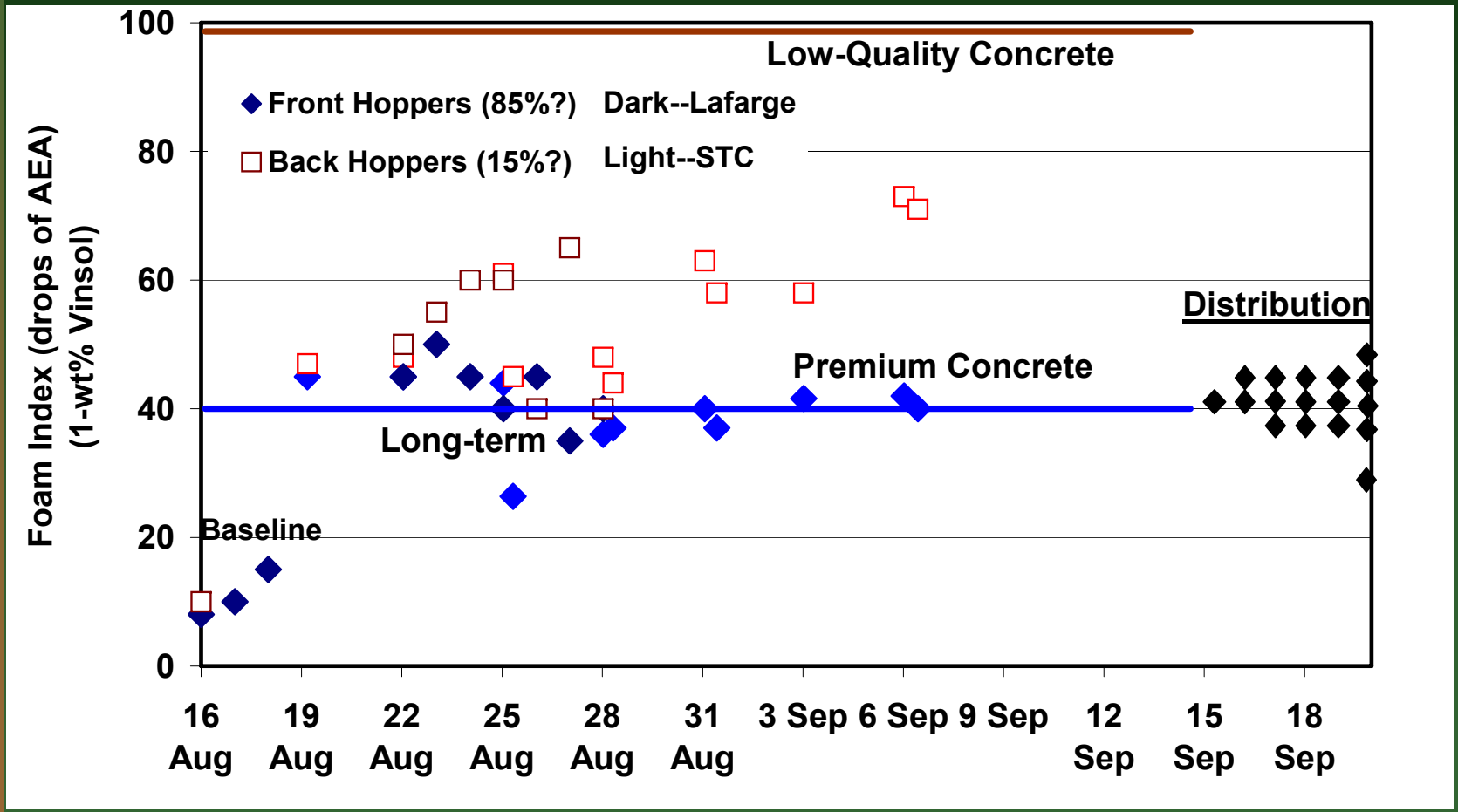
Crawford Opacity with a 118 SCA ESP



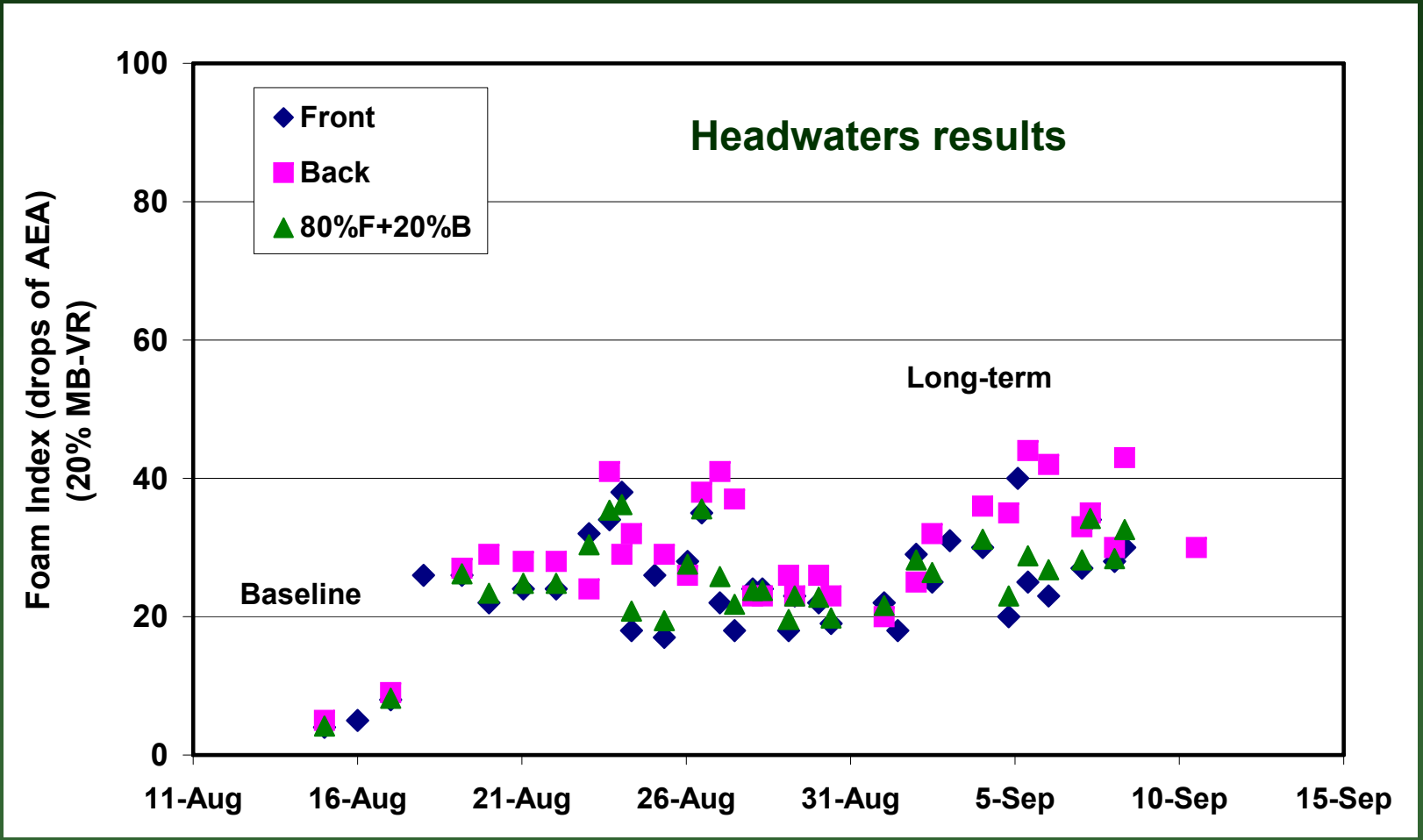
Crawford: - 8% Abs. Opacity on a 118-SCA ESP?



C-PAC Foam Index Results @ 4.6 lb/MMacf



C-PAC Foam Index Results @ 4.6 lb/MMacf



Crawford: Preliminary Conclusions:

1. C-PAC™ appears to be able to achieve high-level mercury reductions with existing CS-ESPs while retaining the capability of fly ash sales for concrete.

2. With Sorbent Technologies' brominated sorbents, high mercury removal rates (80-90+%) are achievable even with CS-ESPs with very small SCAs. Opacity may even significantly improve.

Future Work

Sorbent Technologies is looking for a utility site to test F-PAC, a sorbent specially-designed for plants burning bituminous coal and selling F-type fly ash for concrete use.

Next: MWGen's Will County 3 – Hot-Side C-PAC

Coal Type	Subbituminous
Boiler Size	278 MWe Tangential
Particulate Control	Hot-Side ESP
ESP Stream Size	140 MWe
Gas Flow	690,000 acfm
ESP Temp.	610°F (full load)
SCA	200 ft^2/K acfm
Hg Range (ppm)	0.02-0.11 ppm
Coal S & Cl	0.4% & 100 ppm
Fly Ash Sales	Yes

DOE NETL Project DE-FC26-05NT42308