Progress Report - December 2007

"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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Acknowledgement & Disclaimer

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Project Participants

Host Utilities

- Progress Energy, Peter Hoeflich & Gary Moore
- Midwest Generation, Kent Wanninger, Karl Kulpinski & 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

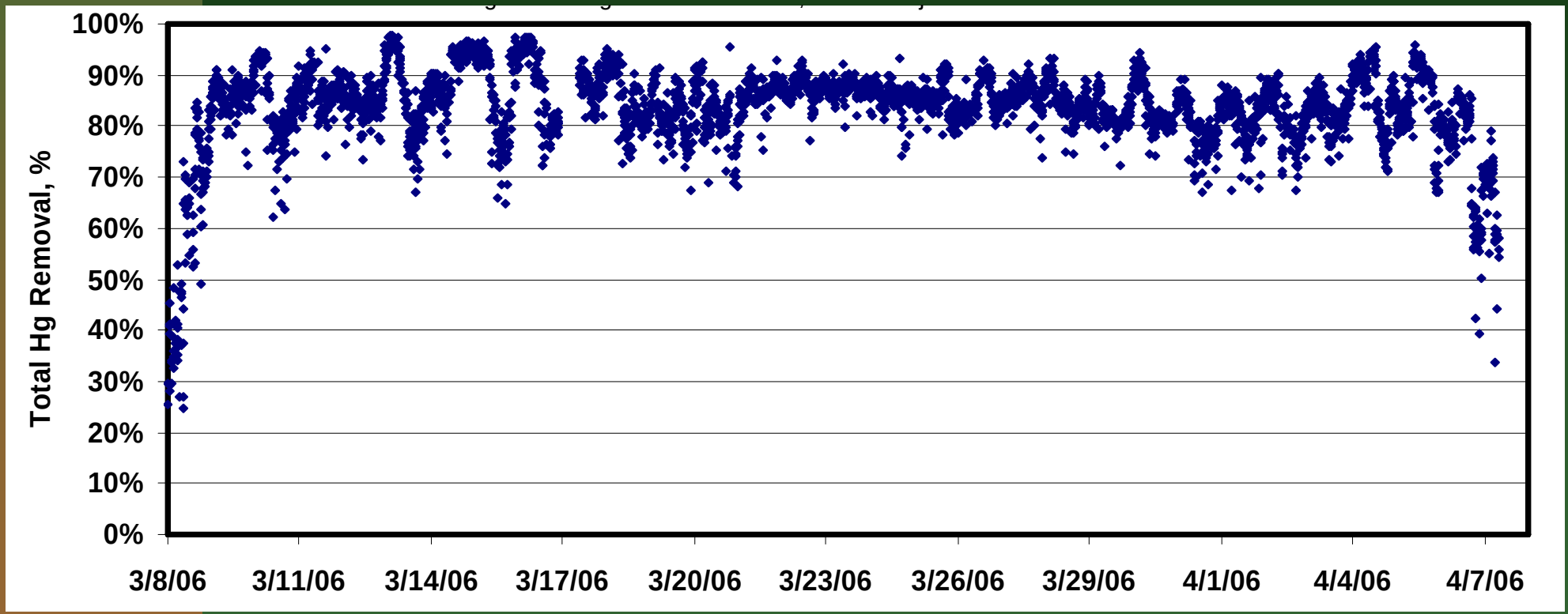
- Gas-Phase-Brominated PAC (B-PAC™)
- Bituminous Coal & SO_3 FGC
- Small ESPs
- Concrete-Friendly PAC (C-PAC™, patent pending)
- Hot-Side ESP (H-PAC™)

Standard, Commercially-Available Sorbents

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

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



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)

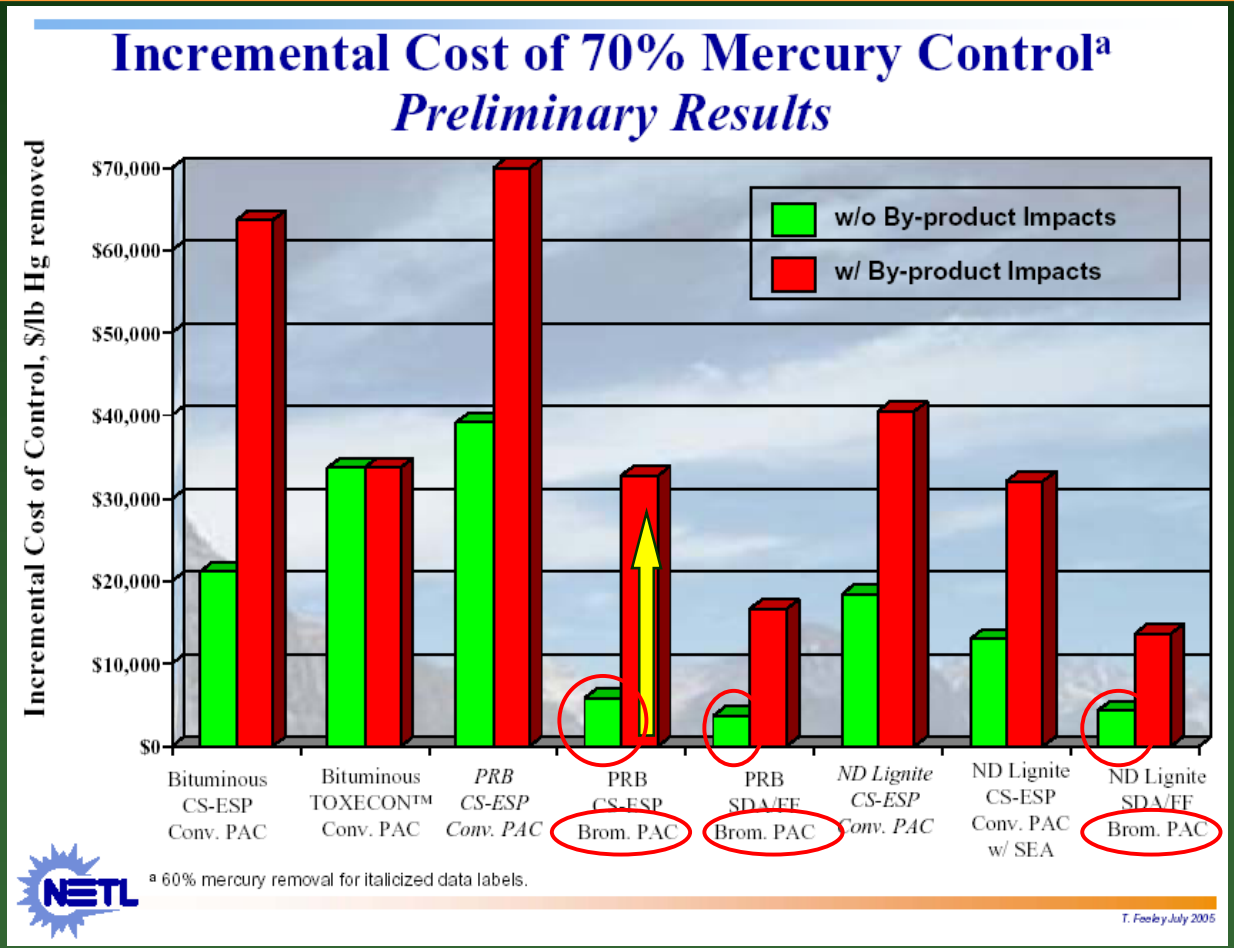
Lee Station Unit 1 Conclusions

- 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

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^{o}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

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

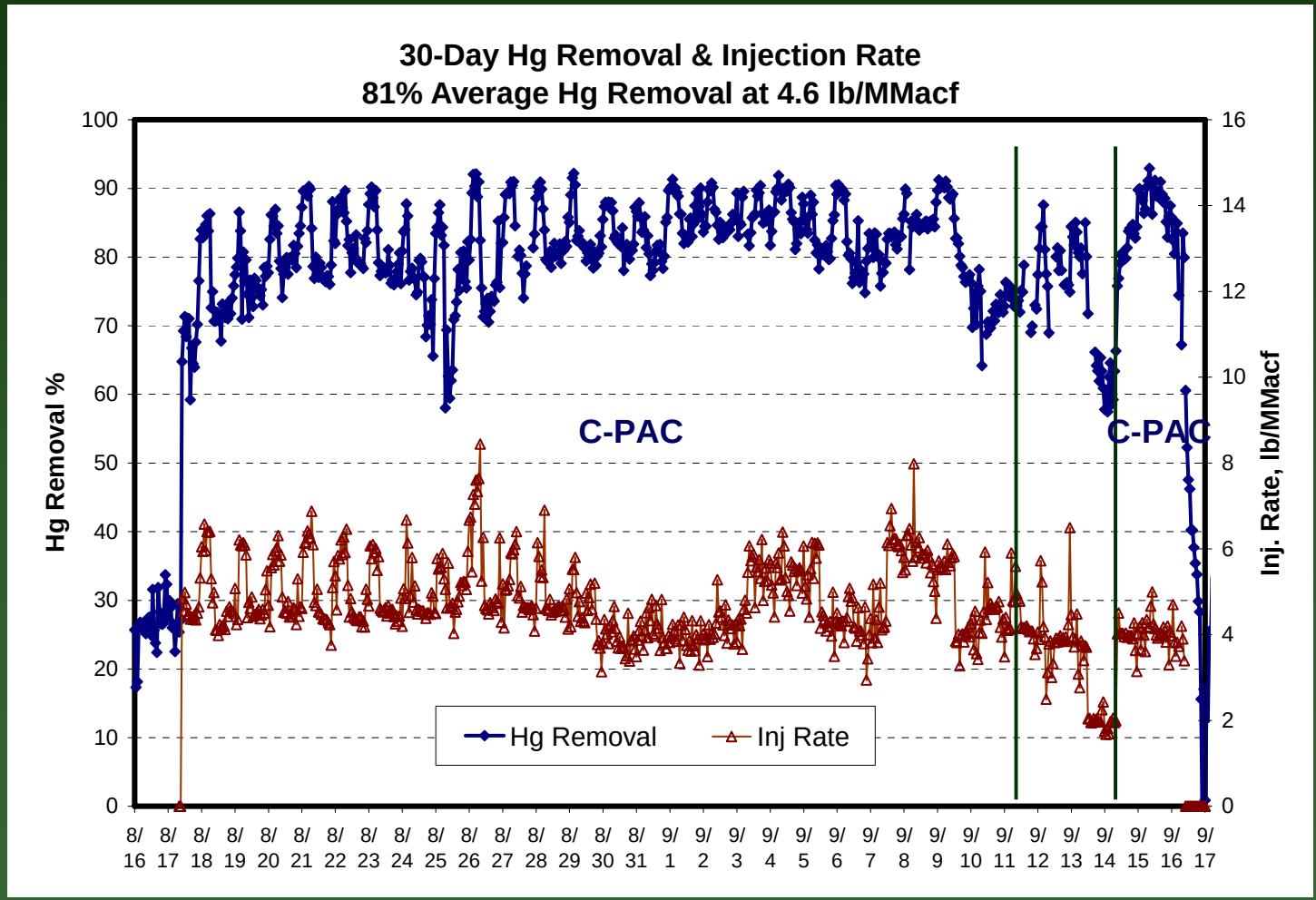
1. Carbon level per se - 6% ASTM LOI & 5% AASHTO limit
   - but the effective limit is much lower due to the AEA effects

2. Adsorbs Air Entraining Admixtures (AEAs)

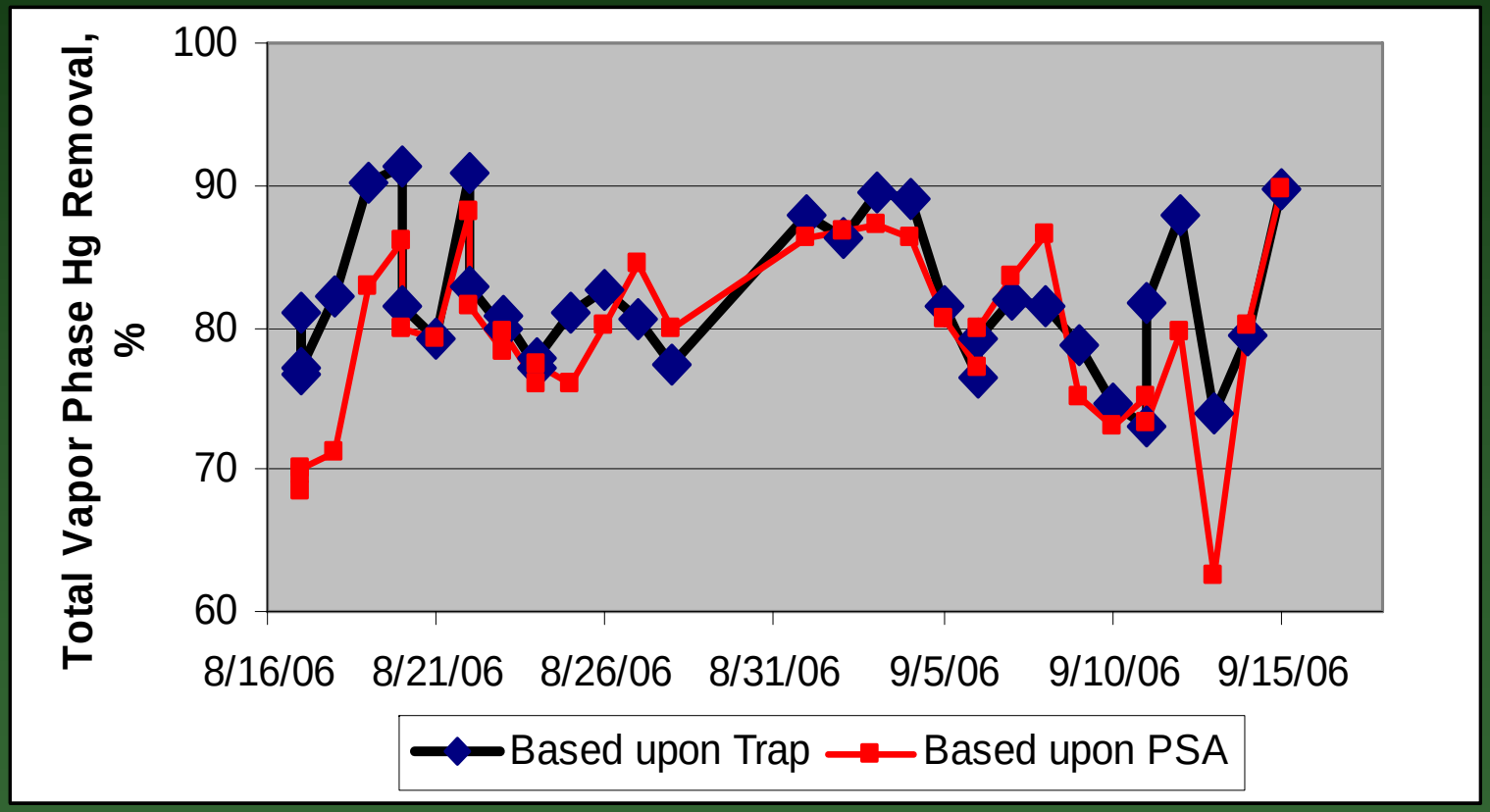
   -- detergents added to concrete slurries to
   intentionally form bubbles for freeze-thaw capability
   -- UBC or PAC adsorbs the AEAs
   -- inevitable variations in the level of the effect (std.dev.)

3. Darkens the fly ash

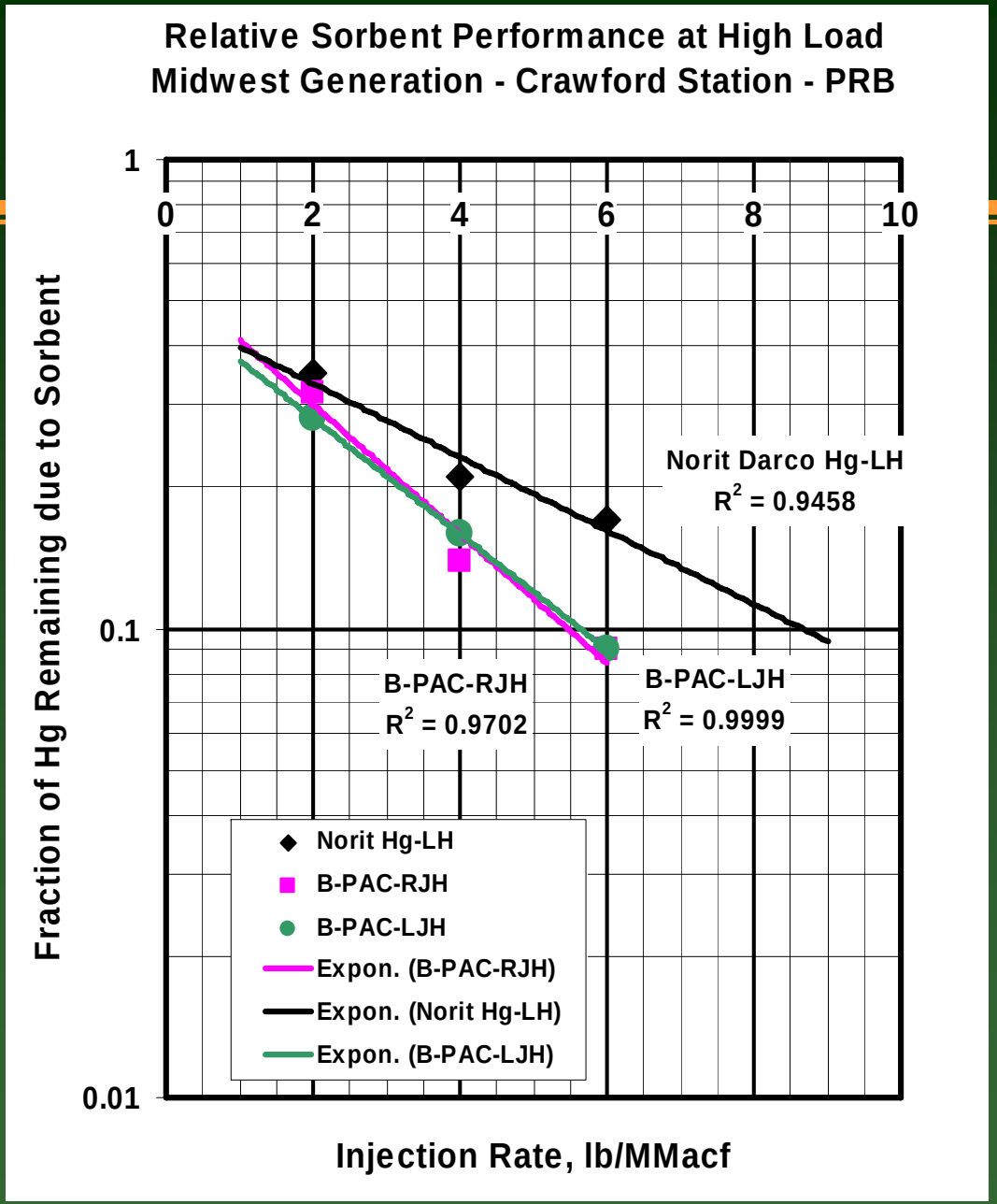
Results

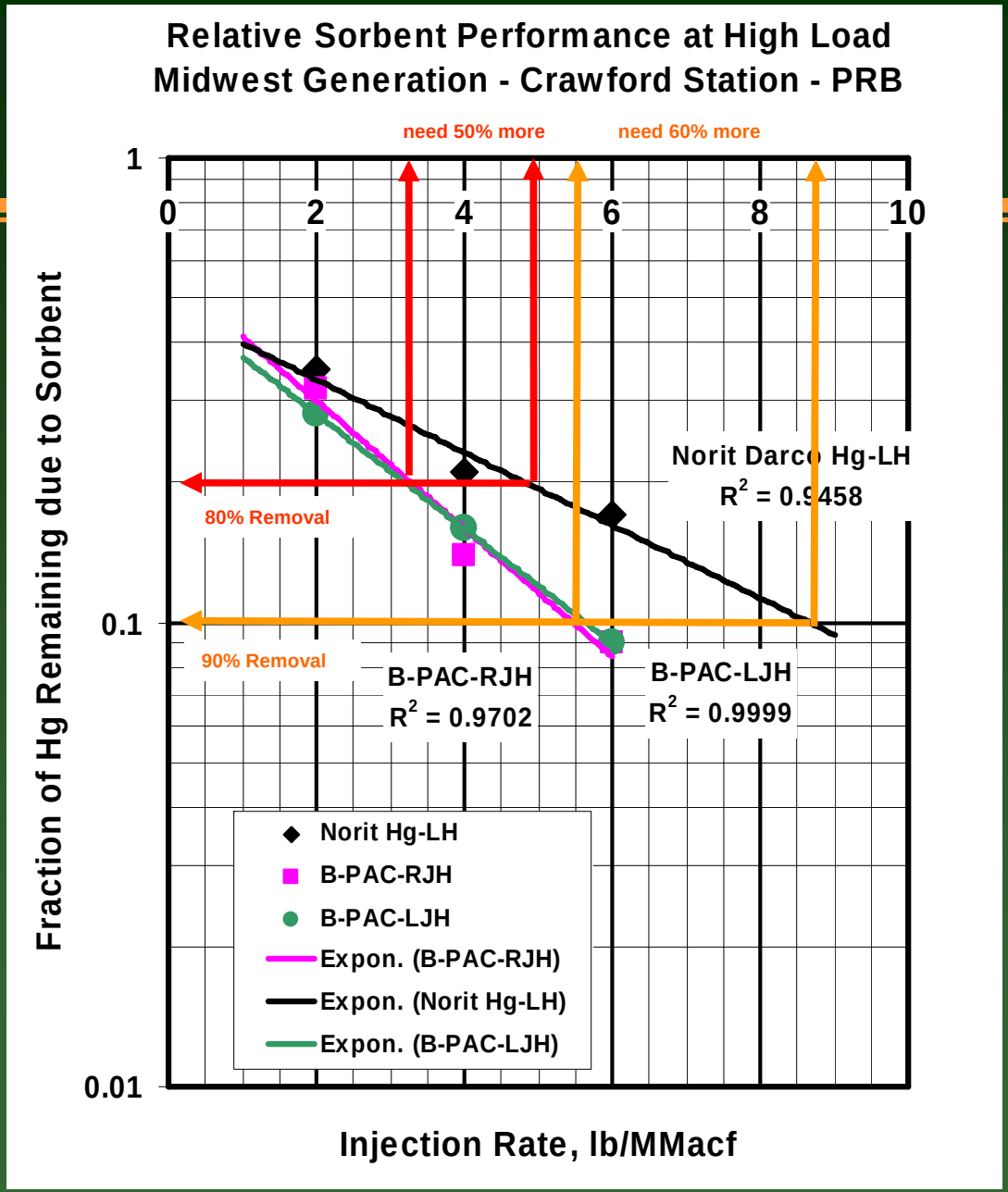

30-Day Hg Removal & Injection Rate
81% Average Hg Removal at 4.6 lb/MMacf
Hg Removal %
Inj. Rate, lb/MMacf
C-PAC
C-PAC
Hg Removal
Inj Rate
100
90
80
70
60
50
40
30
20
10
0
16
14
12
10
8
6
4
2
0
8/16 8/17 8/18 8/19 8/20 8/21 8/22 8/23 8/24 8/25 8/26 8/27 8/28 8/29 8/30 8/31 9/1 9/2 9/3 9/4 9/5 9/6 9/7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

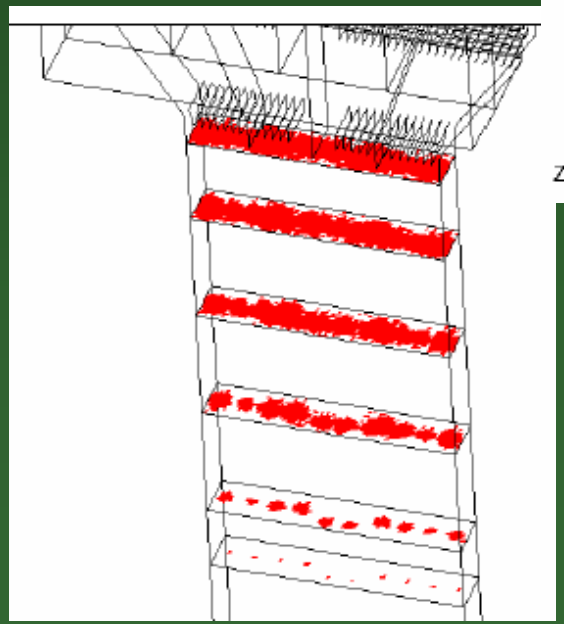


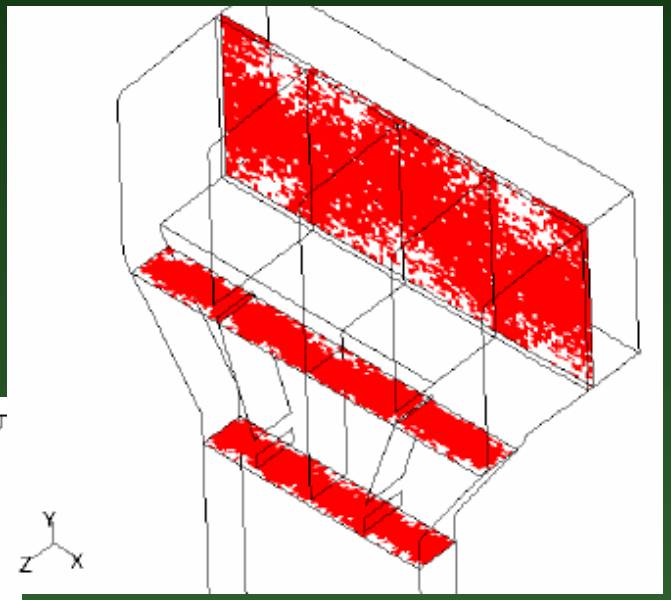

Relative Sorbent Performance at High Load
Midwest Generation - Crawford Station - PRB
need 50% more
need 60% more
1
0.1
0.01
0
2
4
6
8
10
Fraction of Hg Remaining due to Sorbent
Injection Rate, lb/MMacf
80% Removal
90% Removal
Norit Darco Hg-LH
R2 = 0.9458
B-PAC-RJH
R2 = 0.9702
B-PAC-LJH
R2 = 0.9999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

Possible Sorbent Distribution Problems

Crawford, like Lee, with an abrupt ductwork expansion

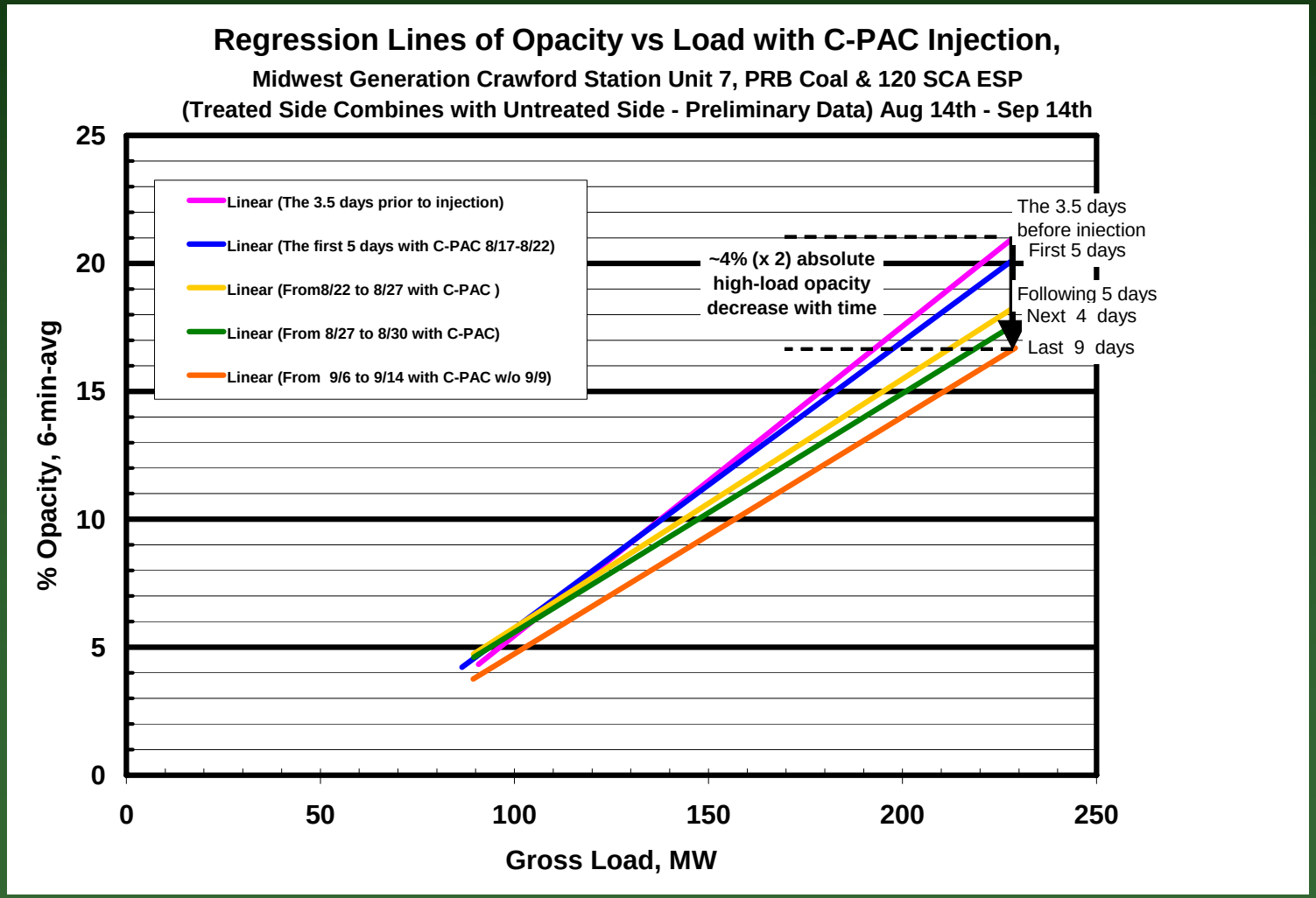
(These plots for coverage, not sorbent density)



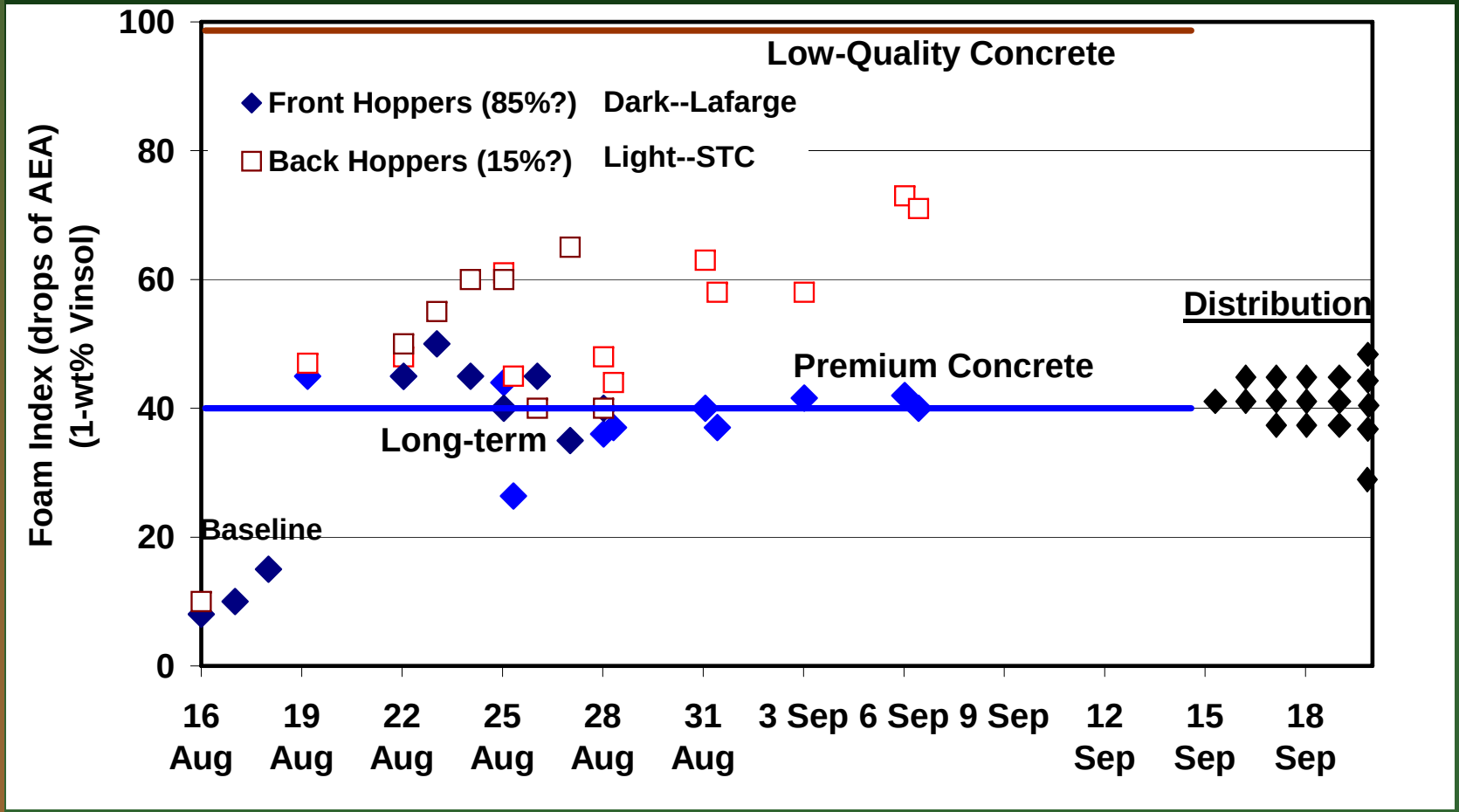


So improvements were made to the lances used at the Will County trial; X-a-Lances™.

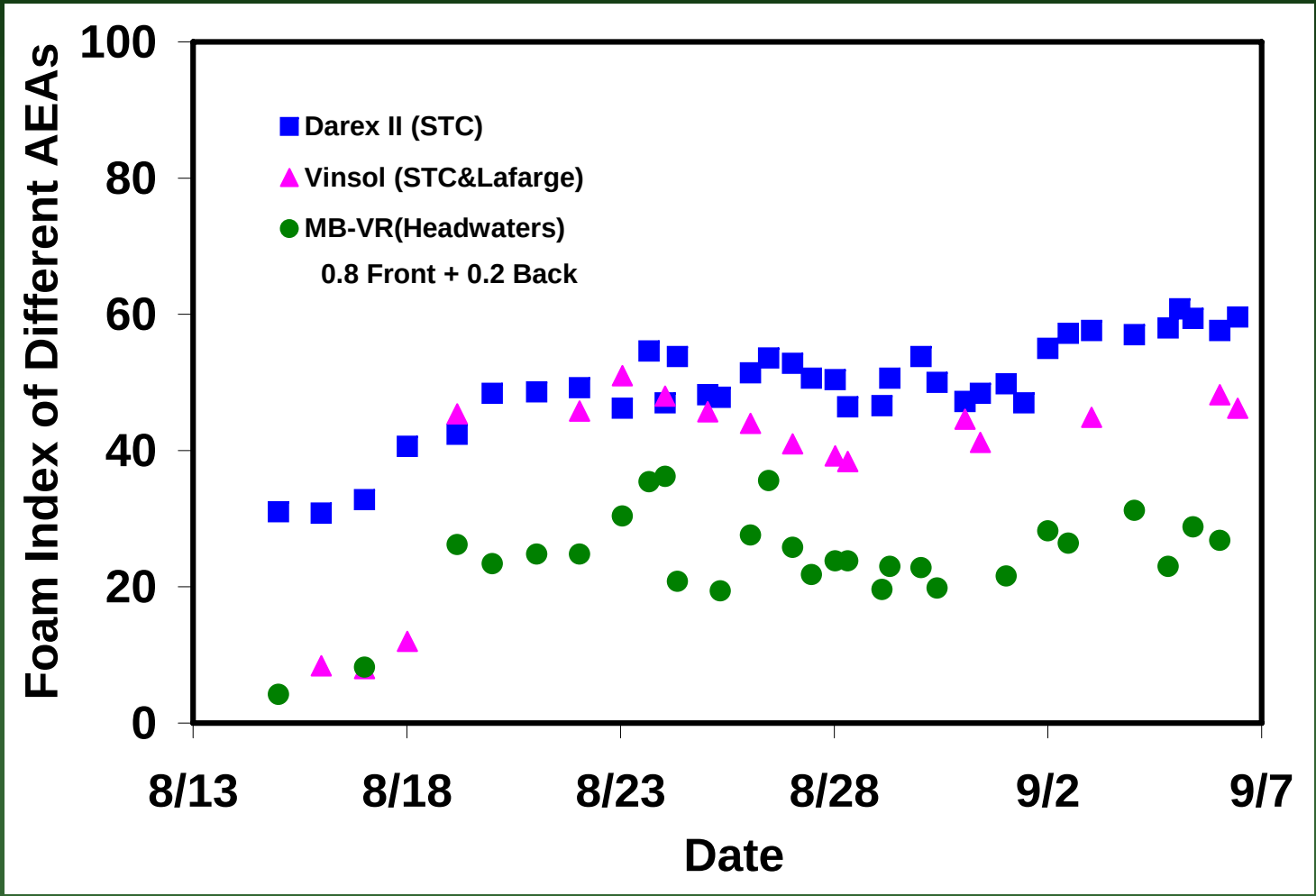
Crawford: - 8% Abs. Opacity on a 118-SCA ESP



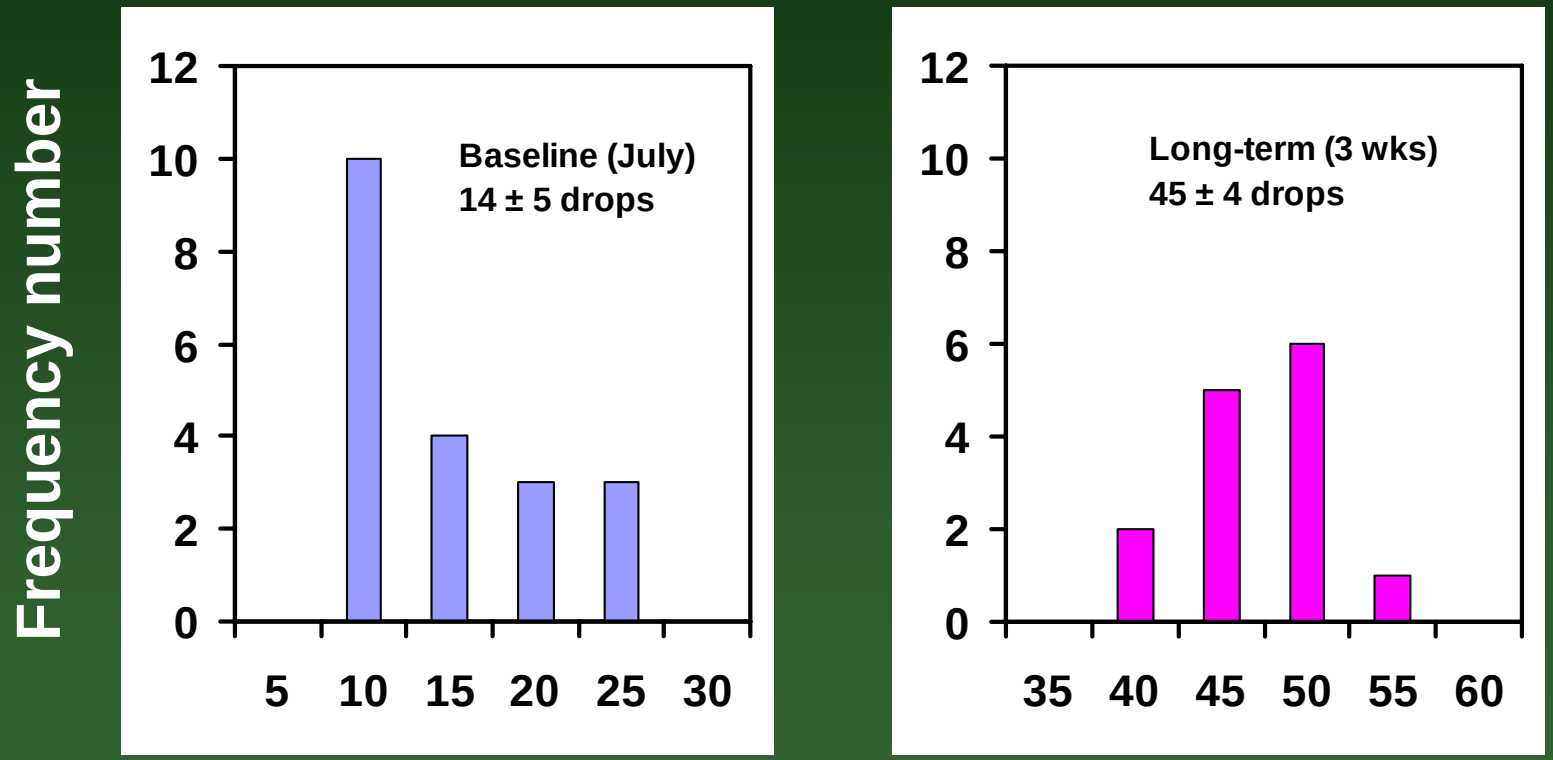
C-PAC Foam Index Results @ 4.6 lb/MMacf



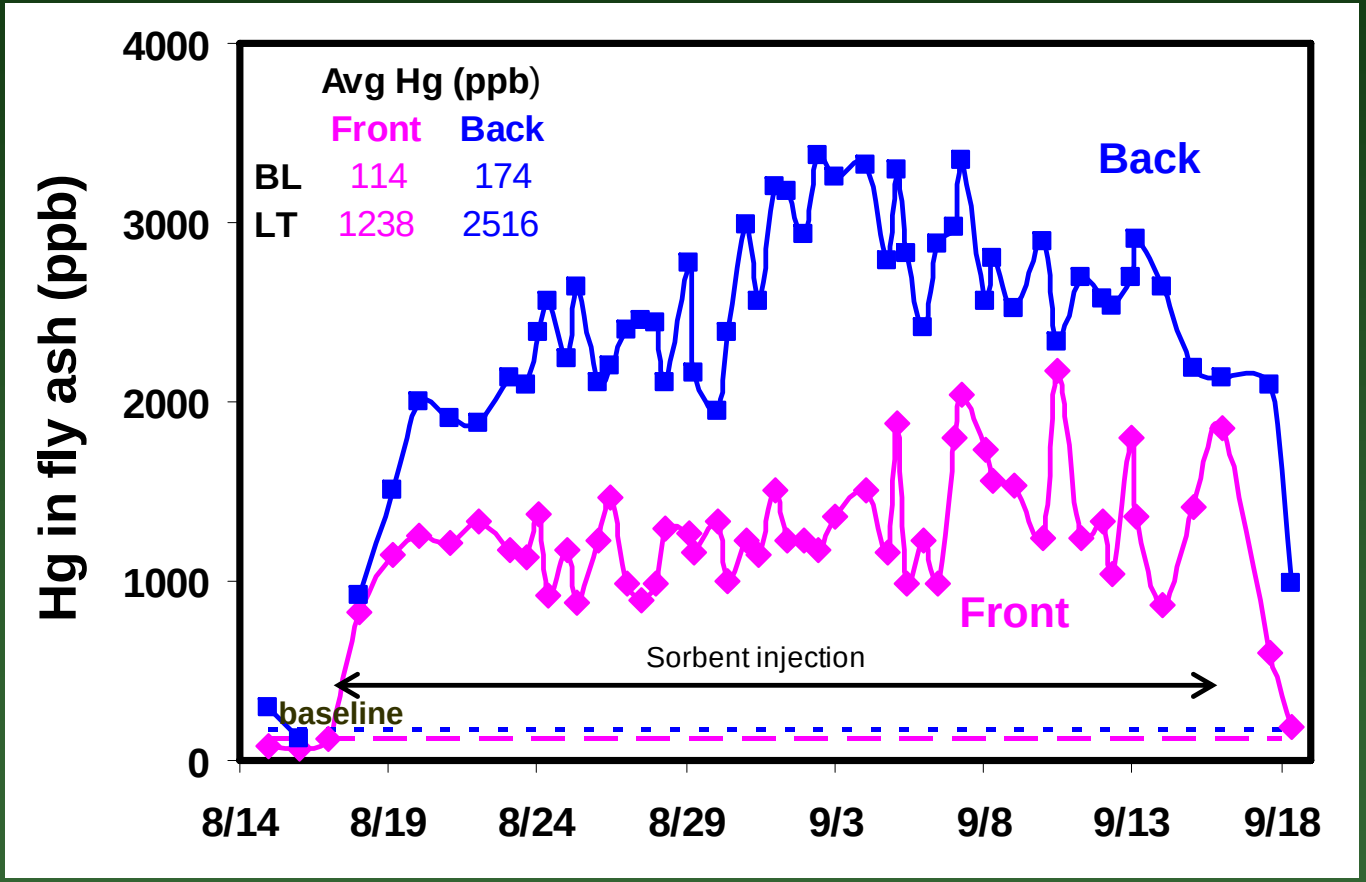
Similar Concrete-Friendliness with Other AEAs



Lower C-PAC Foam Index Variation

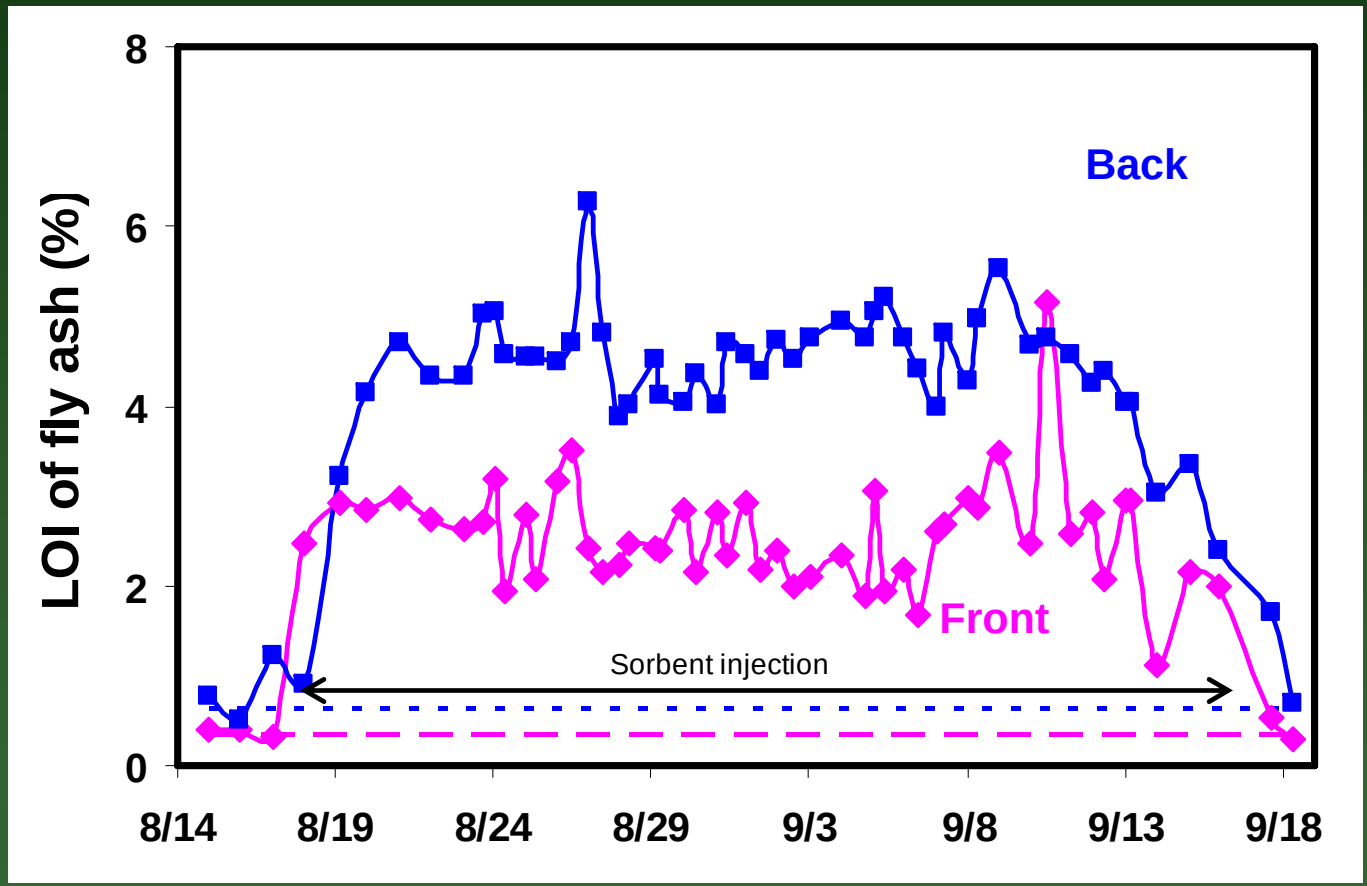


Fly Ash Mercury



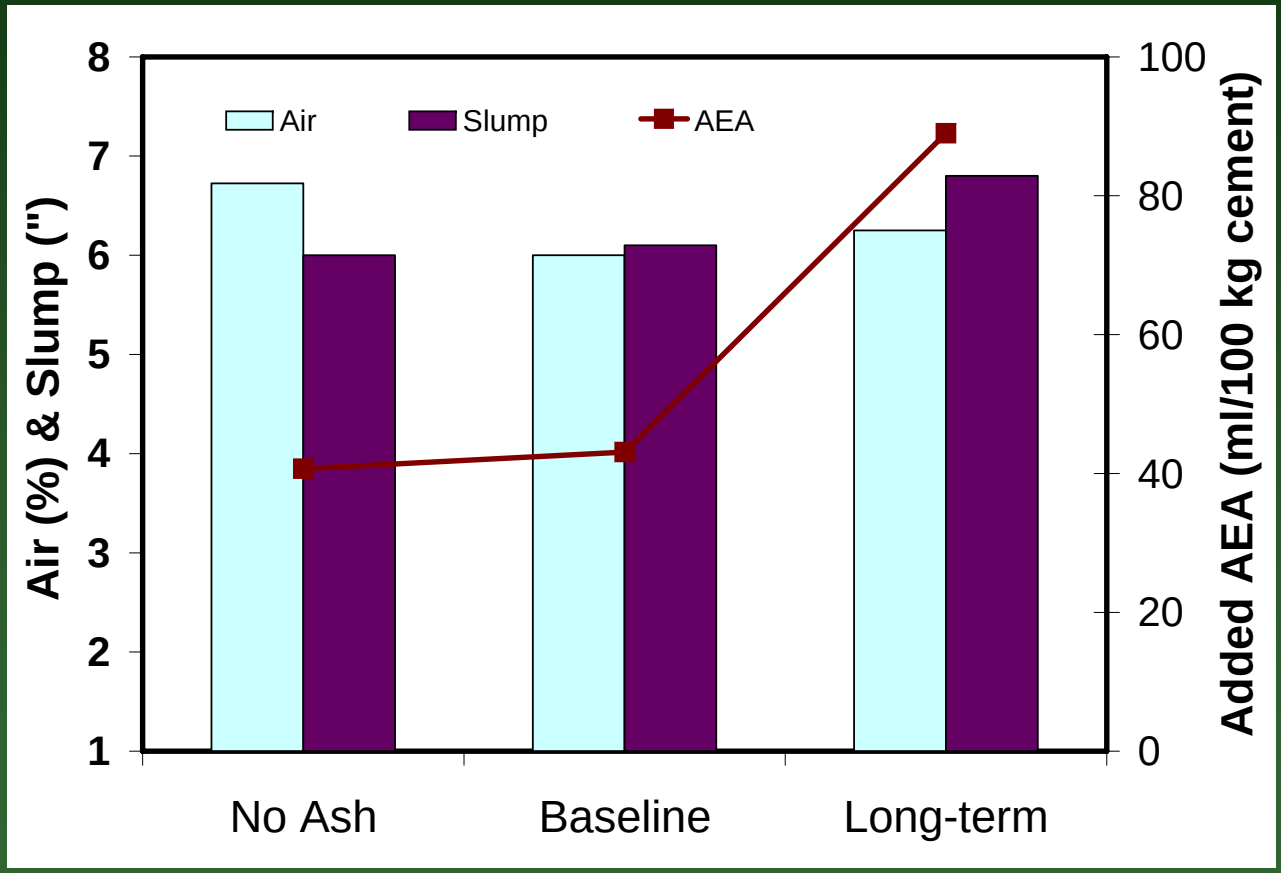
10 times more Hg in the long-term trial ash than in the baseline ash

LOI of Fly Ash (~90% in Front Hoppers)



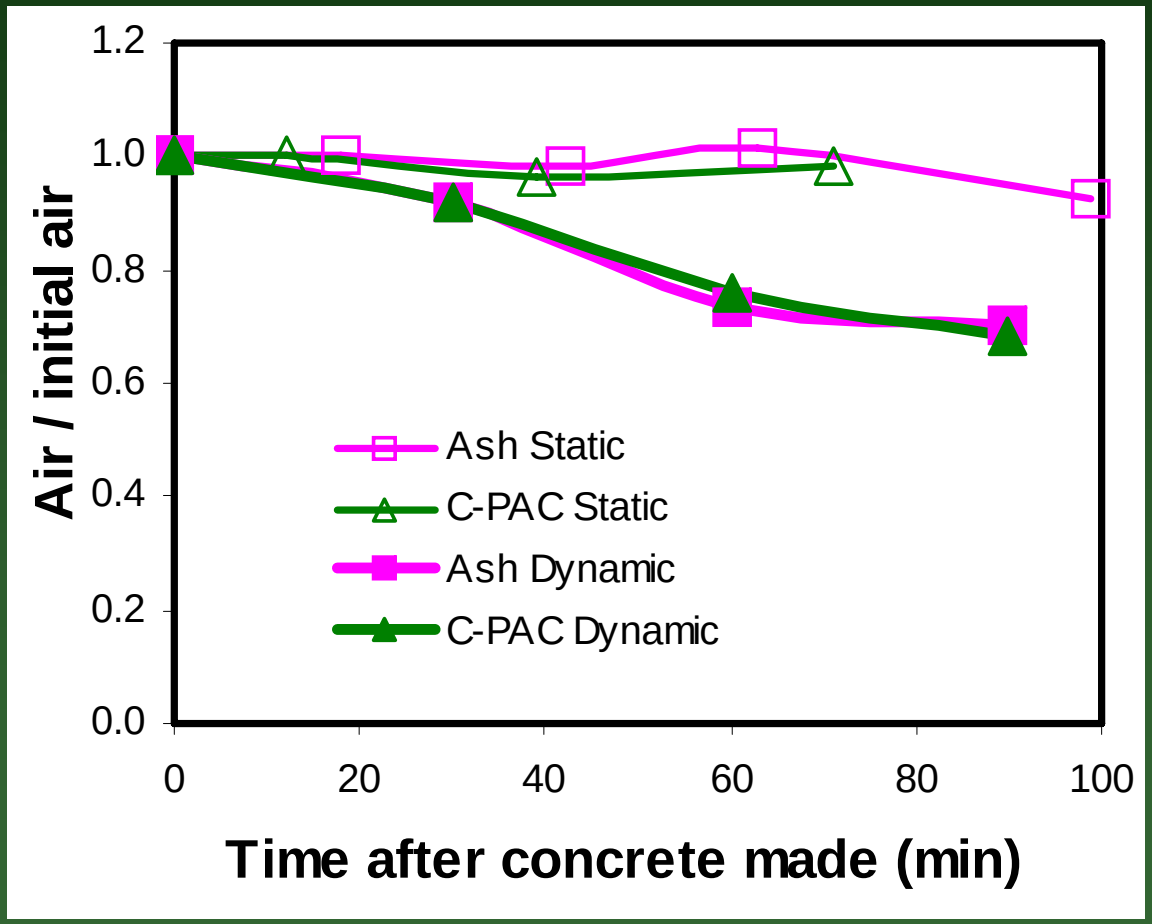
Average C-PAC injection rate = 4.6 lb/Mmacf

Air Voids & Slump the Same as Baseline



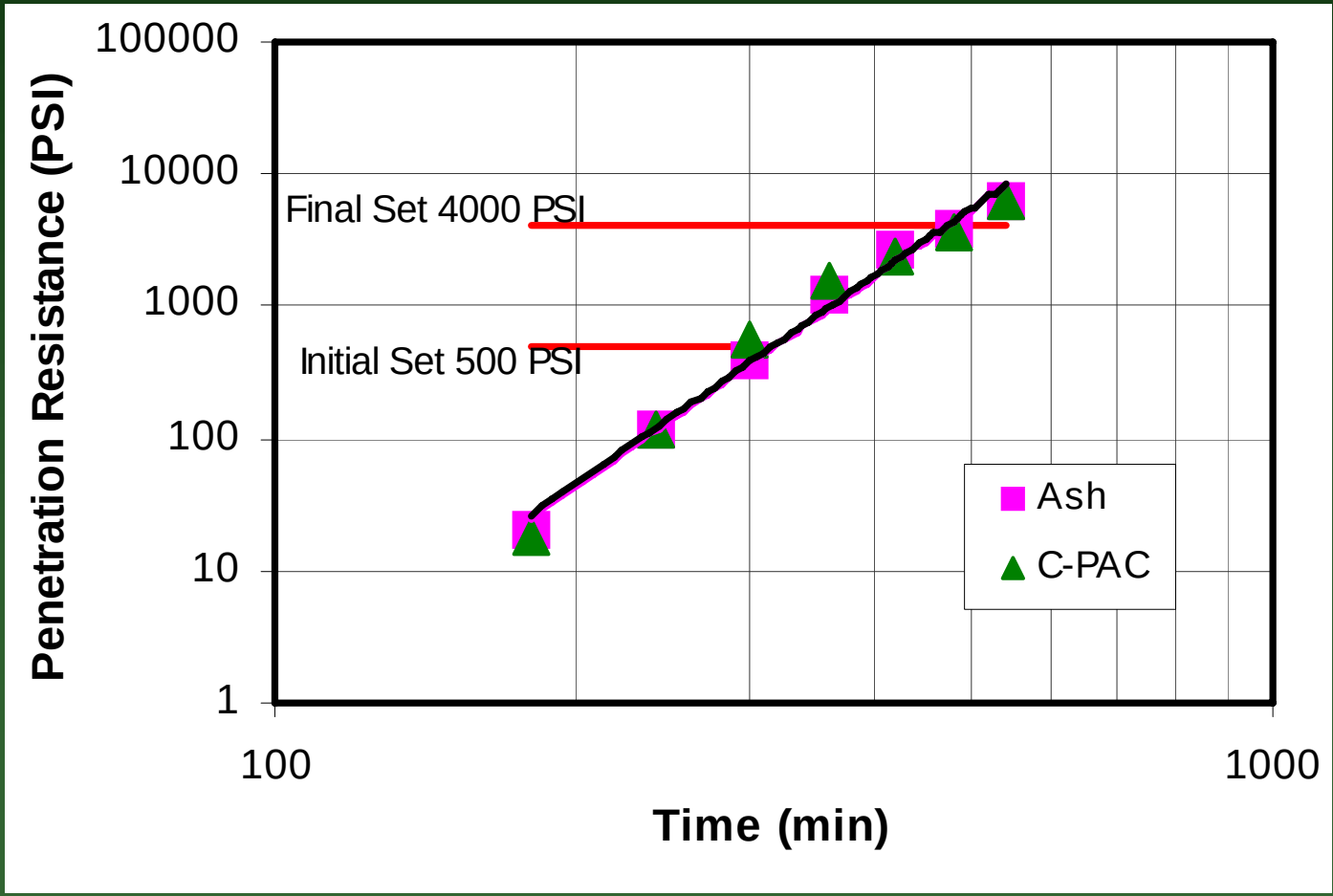
With a little more AEA, the C-PAC air volume is identical to ash control

Identical Air Stability to Ash Without C-PAC



Headwaters data

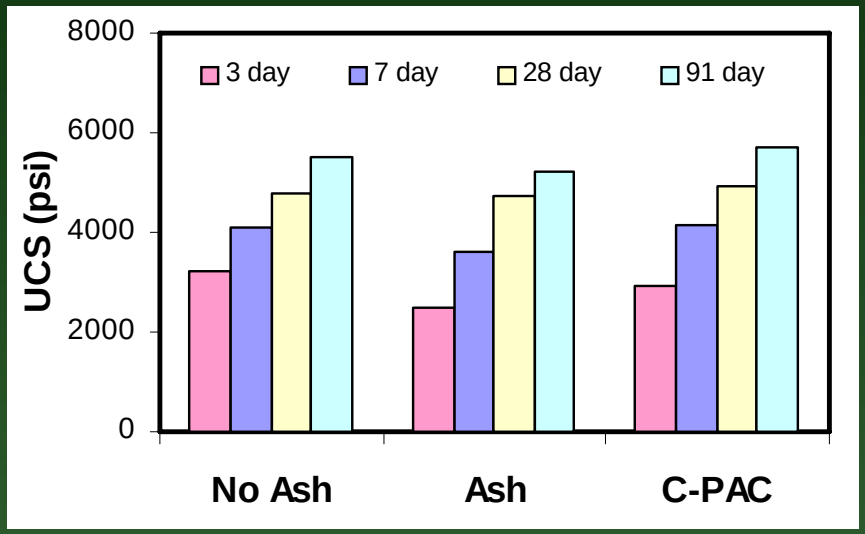
Setting Times the Same as Without C-PAC



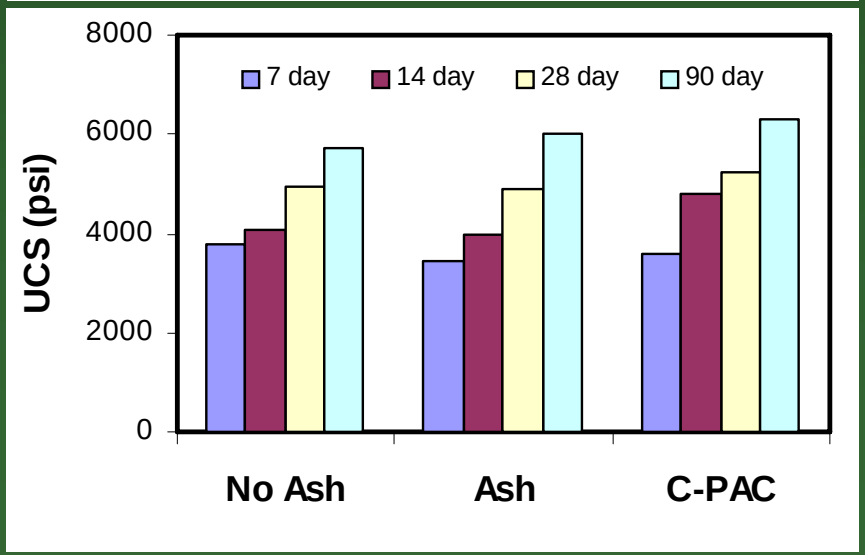
Headwaters data

Even Higher Compressive Strength

Headwaters data



Sorbent Technologies data



Concrete Laboratory Microanalysis

	Baseline Concrete	C-PAC Concrete	Acceptable Range
Total Air Void Content, vol%	4.5%	5.6%	4.0 - 6.0
Voids >1 mm, %	0.71%	0.65%	
Void Frequency, voids/in.	11.0	12.0	
Spacing Factor, inches	0.0055	0.0054	0.0040 - 0.0080
Cement Paste Content, %	31.3%	28.3%	
Specific Surface Area, m^2	984	865	>600

Crawford Station Summary

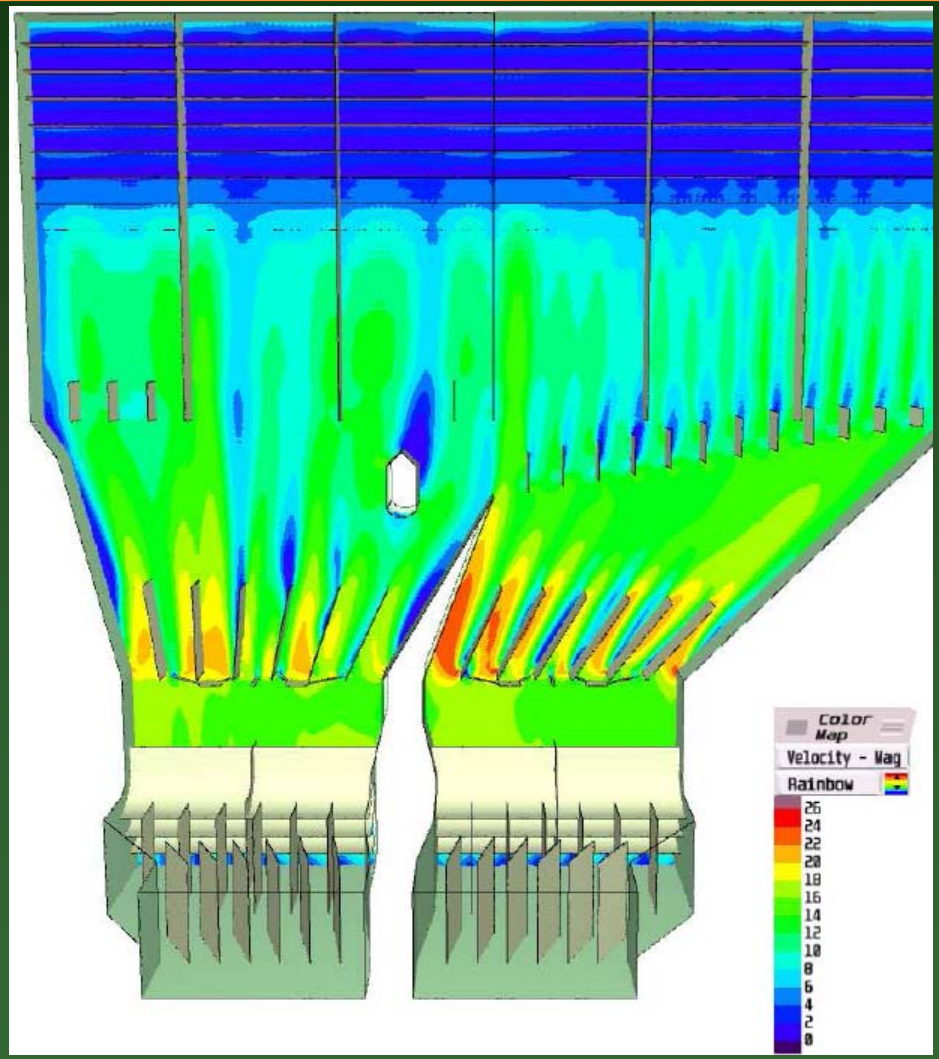
- The standard deviations of foam index values of fly ashes with C-PAC™ were no higher than with baseline fly ash.
- Concrete with & without C-PAC™-fly ash exhibited the same air content, slump, air stabilities, setting times, and concrete strengths with only a modestly higher AEA dose.
- With gas-phase-brominated B-PAC™, an opacity reduction co-benefit may be observed with some ESPs.
- C-PAC™ appears to achieve high mercury reductions while preserving continued fly ash sales for concrete.

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

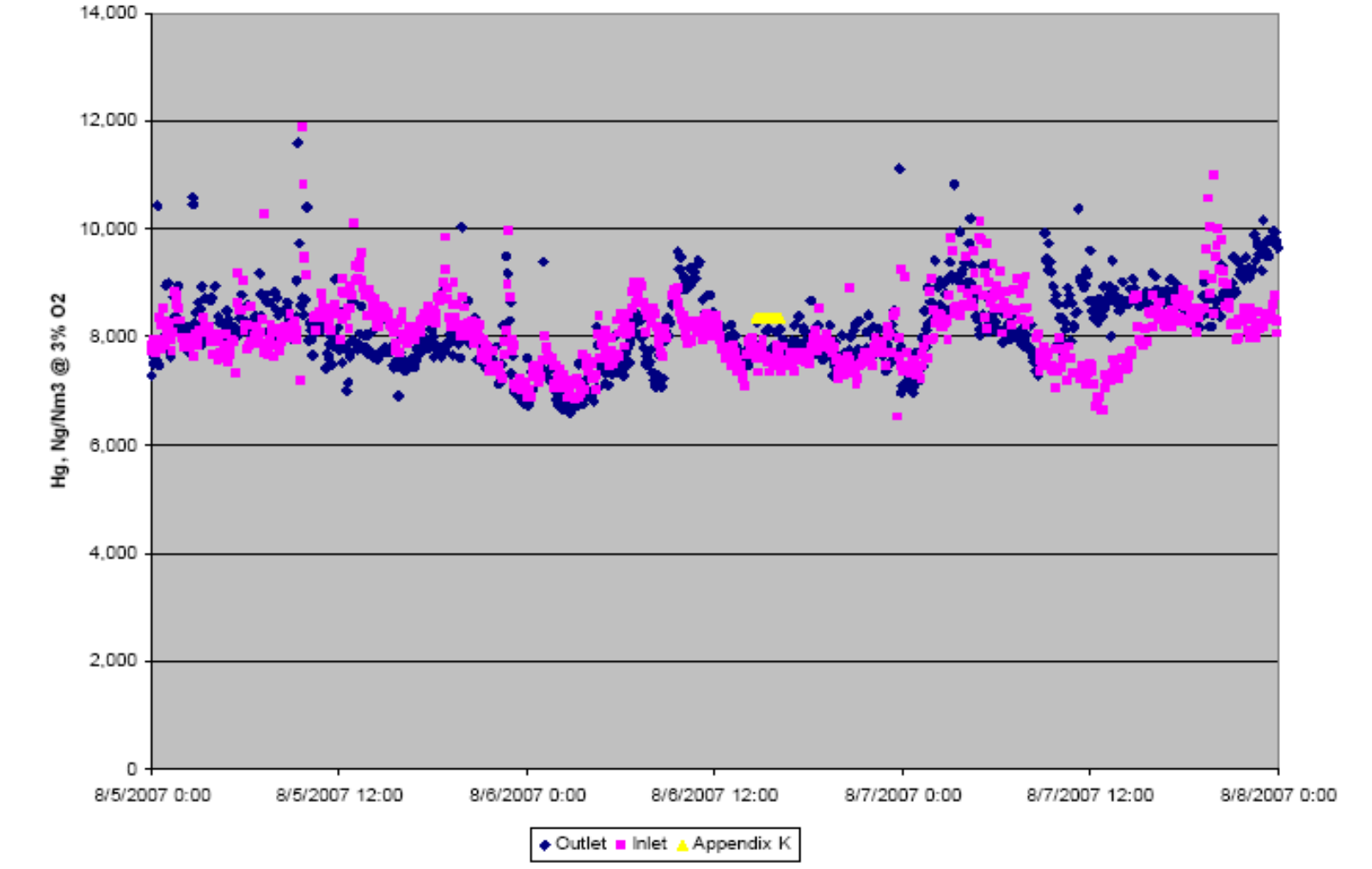
Coal Type	Subbituminous
Boiler Size	278 MWe Tangential
Particulate Control	Hot-Side ESP
ESP Stream Size	140 MWe
Gas Flow	690,000 acfm
ESP Temp.	700°F (full load)
SCA	200 ft^2/K acfm
Hg Range (ppm)	0.02-0.11 ppm
Coal S & Cl	0.4% & 100 ppm
Fly Ash Sales	Yes

DOE NETL Project DE-FC26-05NT42308

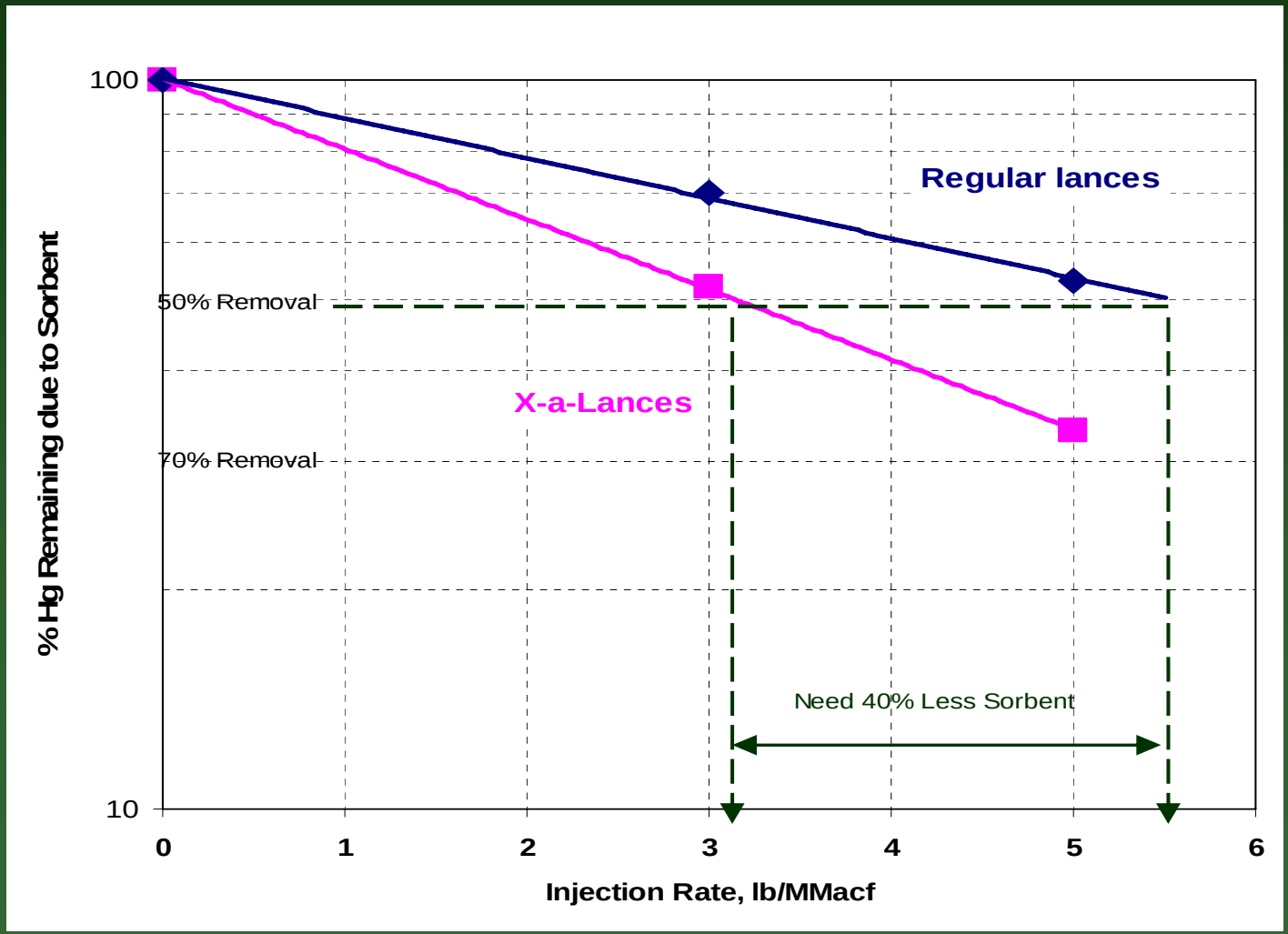
Will County Flue Gas Velocity



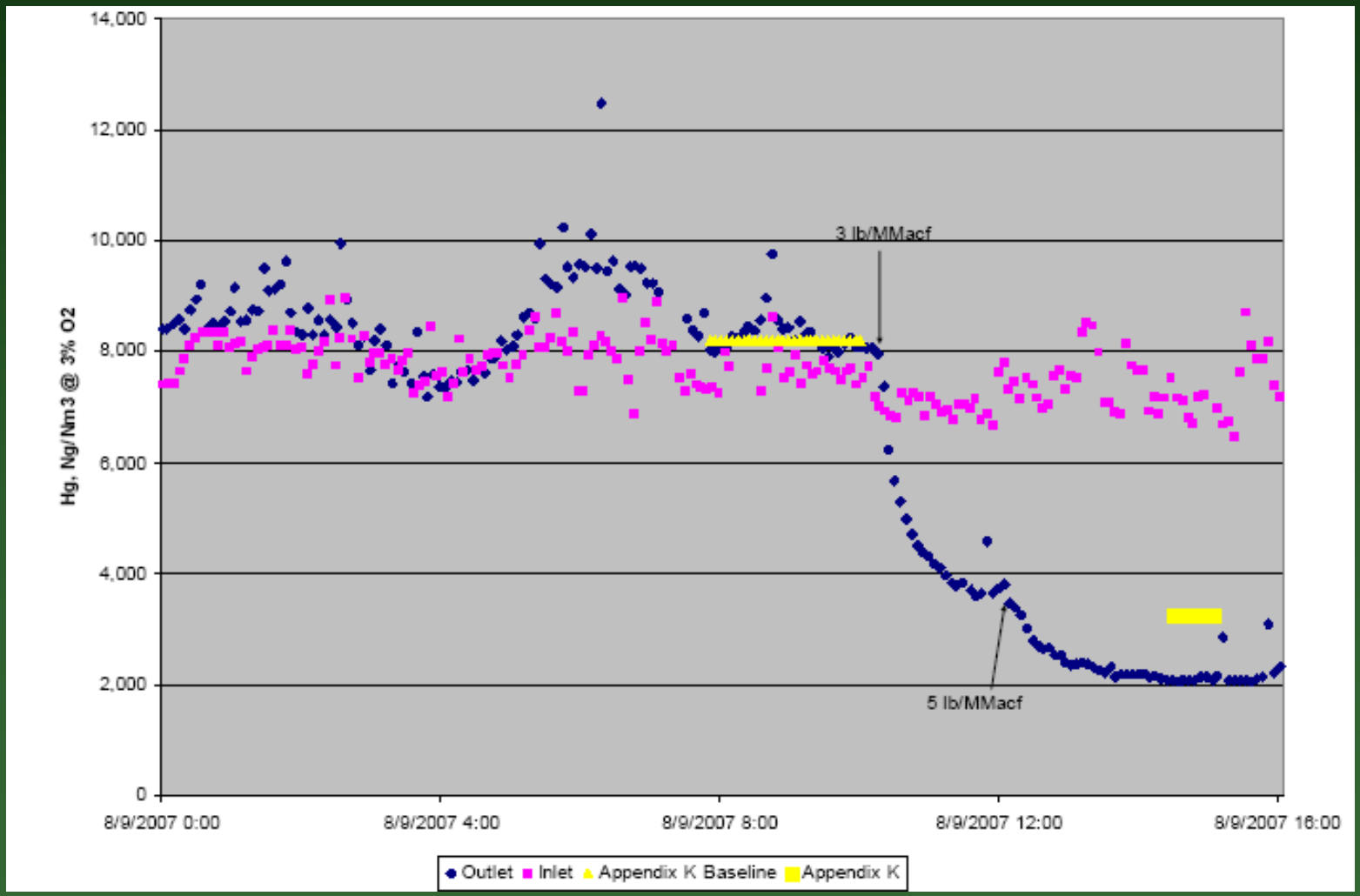
Will County Baseline Hg Measurements



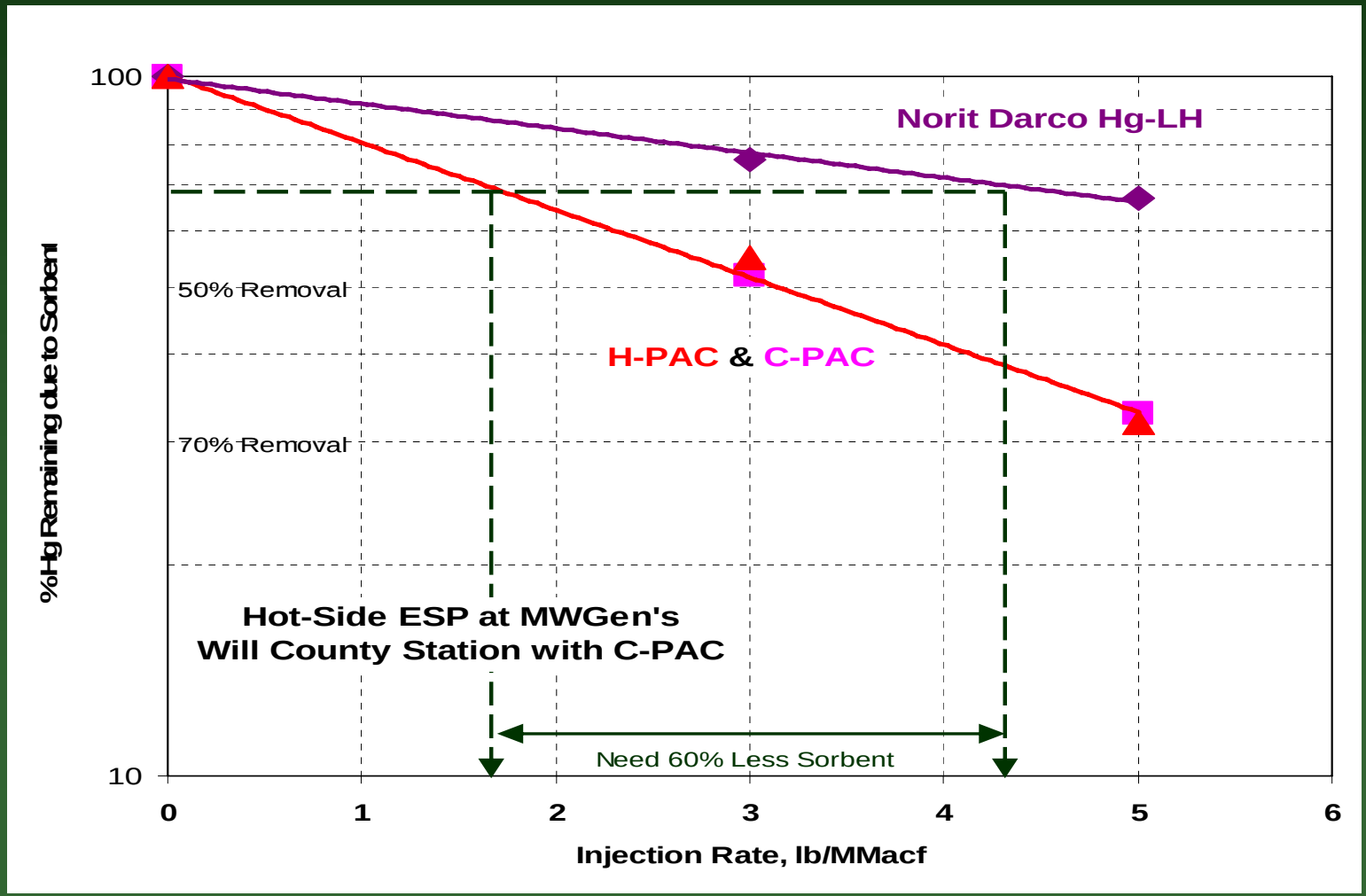
X-a-Lances versus Regular Lances



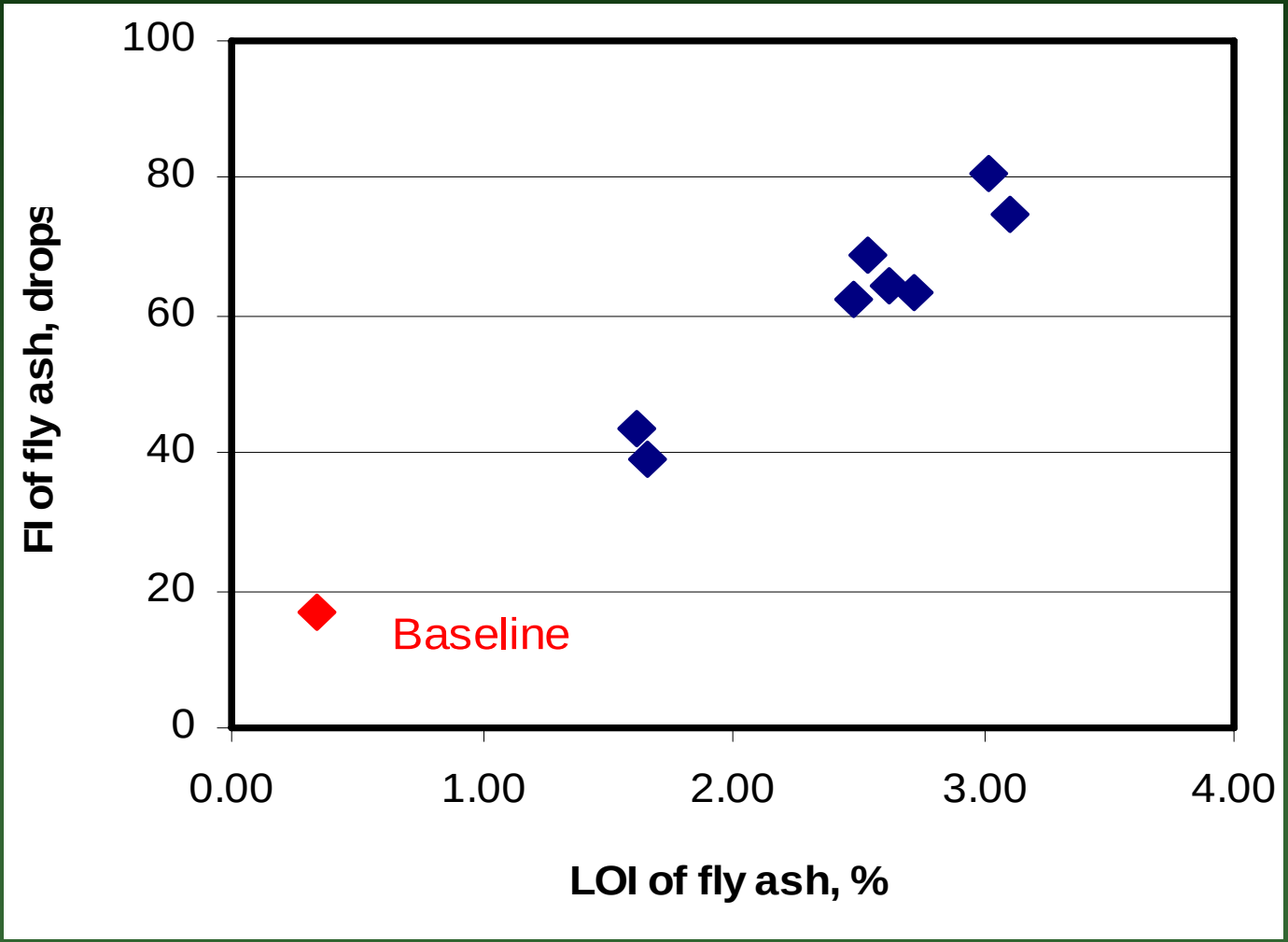
C-PAC™ (high Temperature version) Test



Parametric Test Results



Foam Index and LOI Results



Will County Station Conclusions

- H-PAC™ and a high temperature version of C-PAC™ achieved Hg removal rates of 65%-70% at an injection temperature of 700^{O}F
- The X-a-Lances significantly improved Hg removal performance in the first parametric tests and were used throughout the test
- It required 60% less B-PAC™ to achieve the same Hg removal as achieved with the Norit Darco Hg-LH