Large Scale Mercury Control Field Testing – Phase II

"Advanced Utility Mercury-Sorbent Field-Testing Program"

DE-FC26-03NT41990

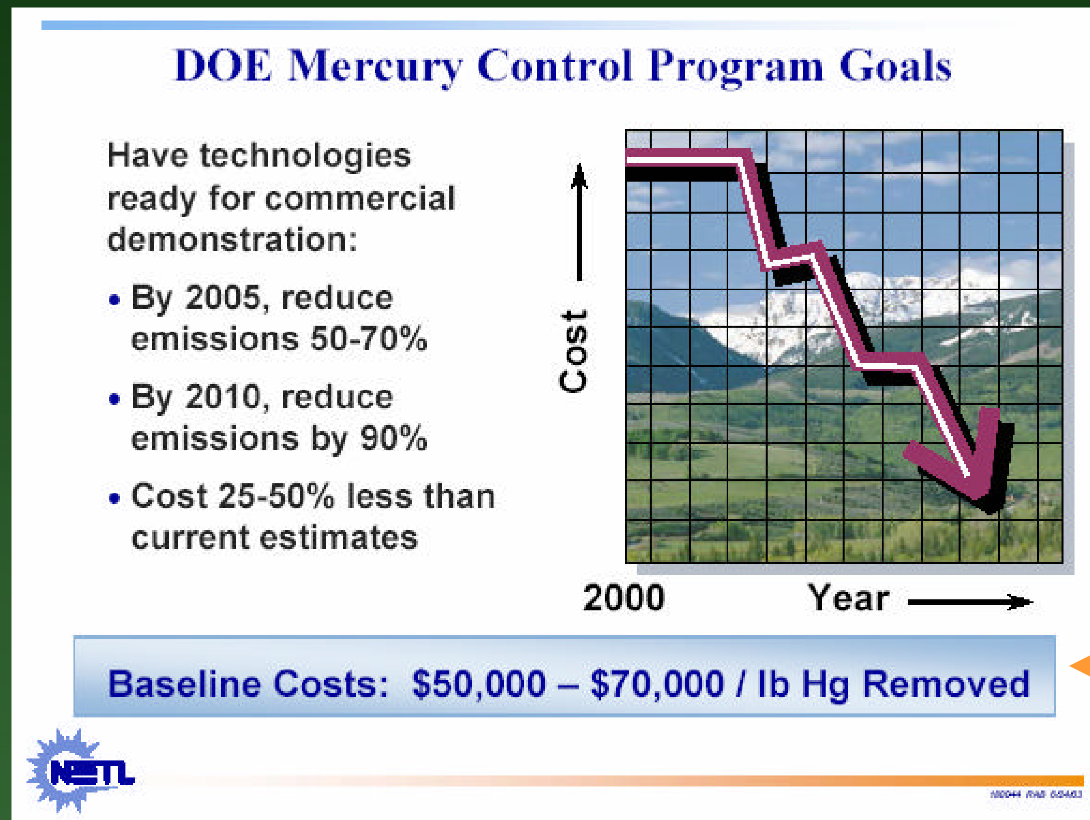
DOE National Energy Technology Laboratory
Jose Figueroa, COR

Sorbent Technologies Corporation
Sid Nelson Jr., Project Manager

Presentation Outline

1. Overview of the Problem & Technology
2. Overview of the Project
3. Project Progress to Date

Overview of the Problem & Technology



Bajura, R.,
"New Horizons in Coal RD&D,"
Low-Rank Fuels Symposium,
Billings, Mont., June 2003.

Current costs of $50,000 to $70,000/lb-Hg-Removed

More Recently…

Preliminary Cost Estimate of Activated Carbon Injection for Controlling Mercury Emissions from an Un-Scrubbed 500 MW Coal-Fired Power Plant

Prepared for

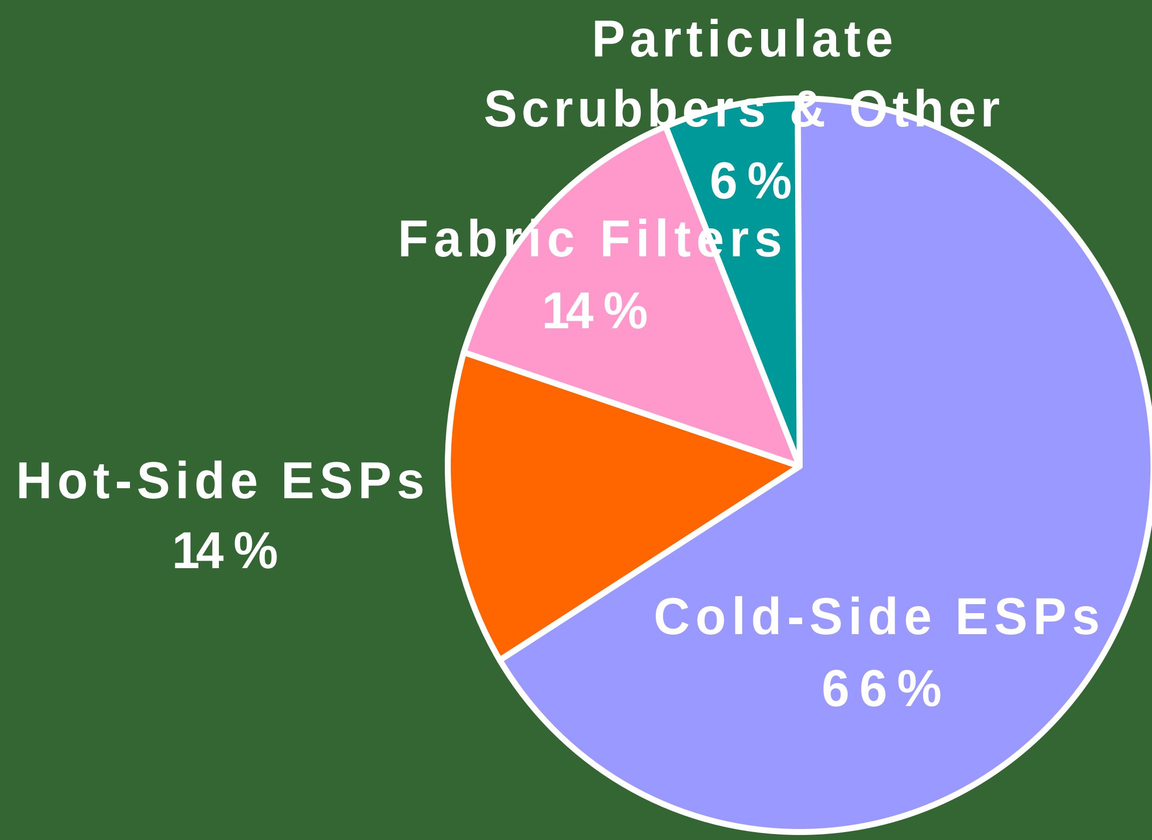
U.S. Department of Energy

November 2003

Final Report

Fuel	Mercury Reduction	Unit Configuration	Incremental Cost of Control, $/lb mercury removed	
			w/o by-product impact	with by-product impact
Bituminous	50%	ACI/ESP	$32,598	$245,731
	70%	ACI/ESP	$45,740	$133,796
	70%	ACI/COHPAC	$68,575	$68,602
	90%	ACI/ESP	$130,649	$185,962
	90%	ACI/COHPAC	$49,005	$49,022
Subbituminous	50%	ACI/ESP	$17,472	$54,950
	60%	ACI/ESP	$48,086	$79,318
	60%	ACI/COHPAC	$54,837	$54,837
	90%	ACI/COHPAC	$39,672	$39,672

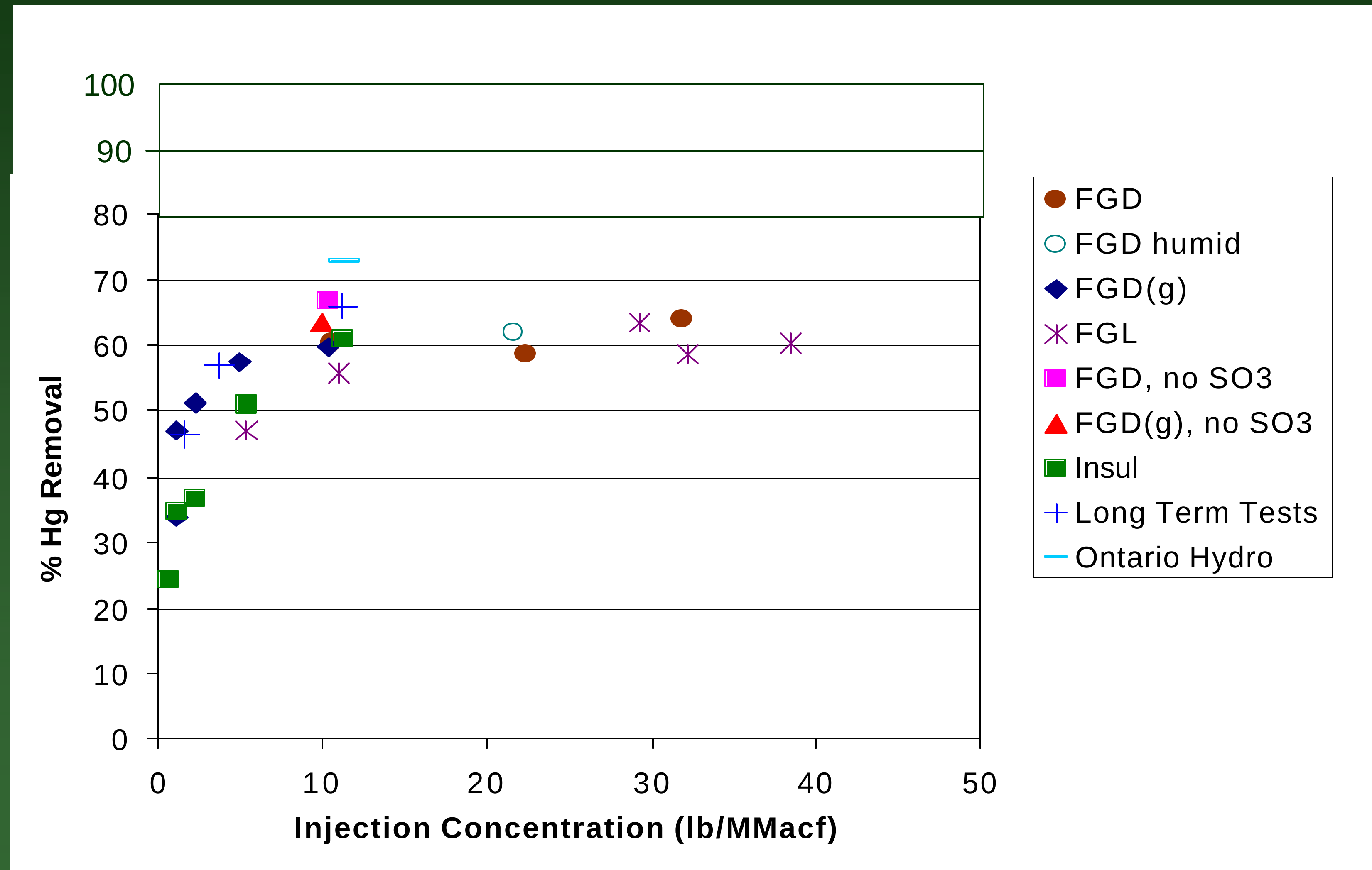
Applying PAC Injection on 1,100 U.S. Boilers



DOE-Identified Problems with ACI

- high removal not possible with low-Cl Western coals

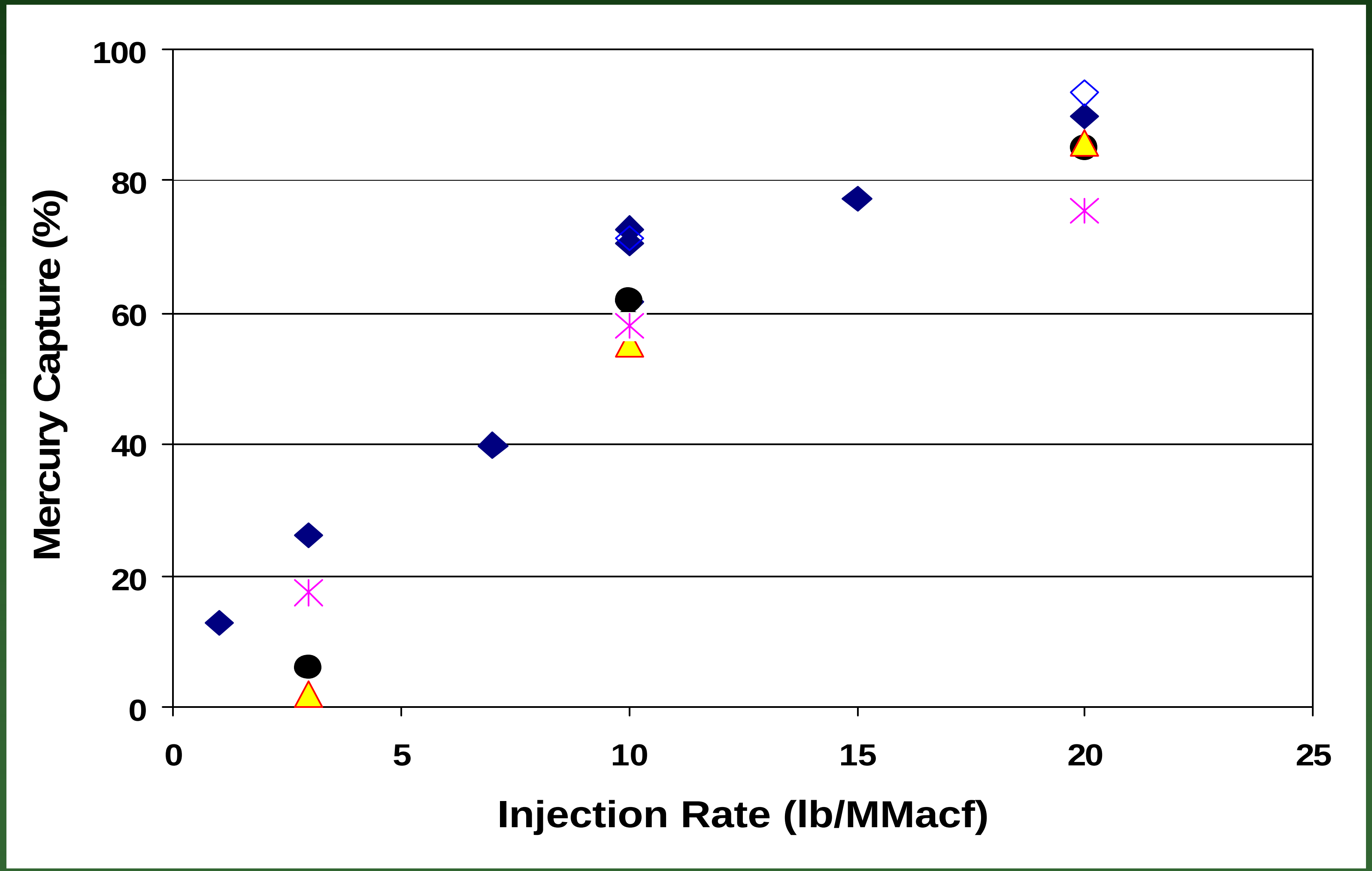
Pleasant Prairie Subbituminous– DOE/ADA-ES



DOE-Identified Problems with ACI

- high removal not possible with low-Cl Western coals
- $$$ high injection rates req'd for high removal with bitum. coals

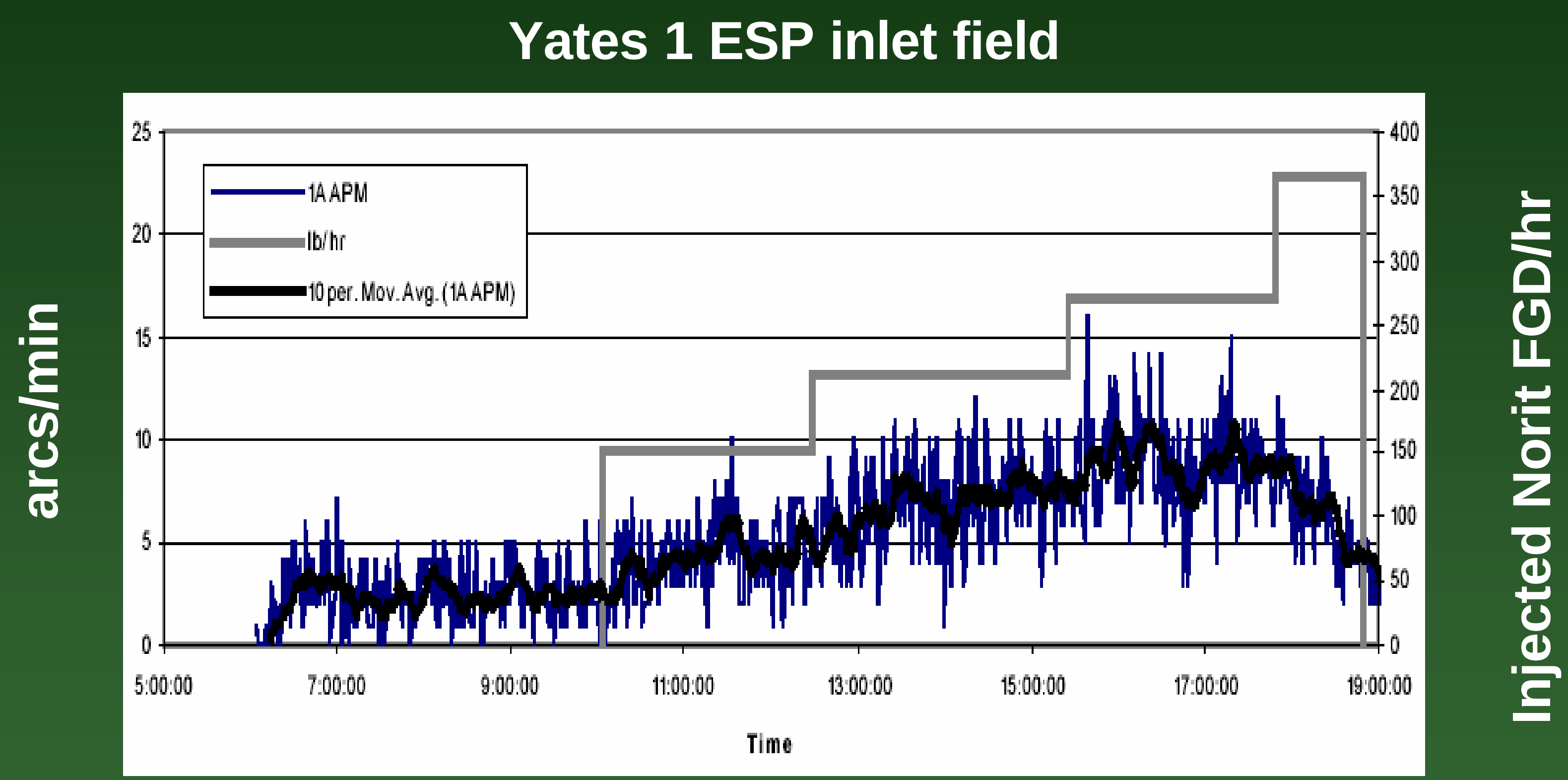
Brayton Point Bituminous - DOE/ADA-ES



DOE-Identified Problems with ACI

- high removal not possible with low-Cl Western coals
- $$$ high injection rates req’d for high removal with bitum. coals
- opacity increases are possible with high injection rates

Degraded Performance on a Small ESP



Yates 1 ESP has 4 fields with total SCA = 177 ft^2/K acfm.

Richardson, C., URS, "Sorbent Injection for Small ESP Mercury Control in Low Sulfur Eastern Bituminous Coal Flue Gas," DOE-NETL Quarterly Technical Progress Report, Jan – March 2004, April 2004.

DOE-Identified Problems with ACI

- high removal not easily possible with low-Cl Western coals
- $$$ high injection rates req’d for high removal with bitum. coals
- opacity increases are possible with high injection rates
- renders fly ash unusable in concretes

Pleasant Prairie Foam Index Tests

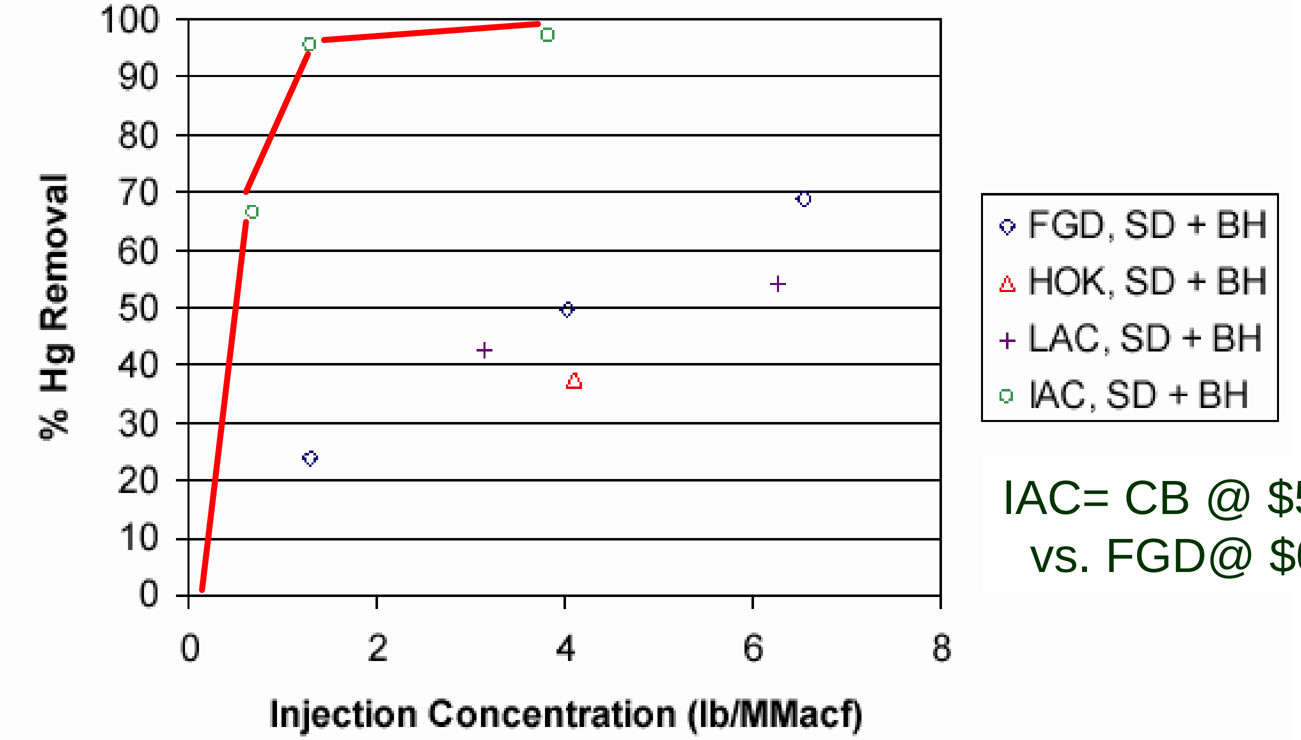
Inj. Rate (lbs PAC/MMacf)	Hg Removal Effic. (%)	Carbon in Ash	Foam Index (Drops of AEA)	Comment
0	-	0.6%	15	Normal
1	40 – 50%	1.1%	>72	Maxed out
3	50 – 60%	1.6%	>72	Maxed out
10	60 – 70%	3.6%	>72	Maxed out

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

DOE-Identified Problems with ACI

- high removal not possible with low-Cl Western coals
- $$$ high injection rates req'd for high removal with bitum. coals
- opacity increases are possible with high injection rates
- renders fly ash unusable in concretes
- iodine carbons can help, but very expensive $$$

Iodine PAC on Lignite at Stanton 10 SD/FF



IAC= CB @ $5.00/lb
vs. FGD@ $0.50/lb

Figure 4. Mercury removal measured across the spray dryer and baghouse at Stanton Station during parametric testing..

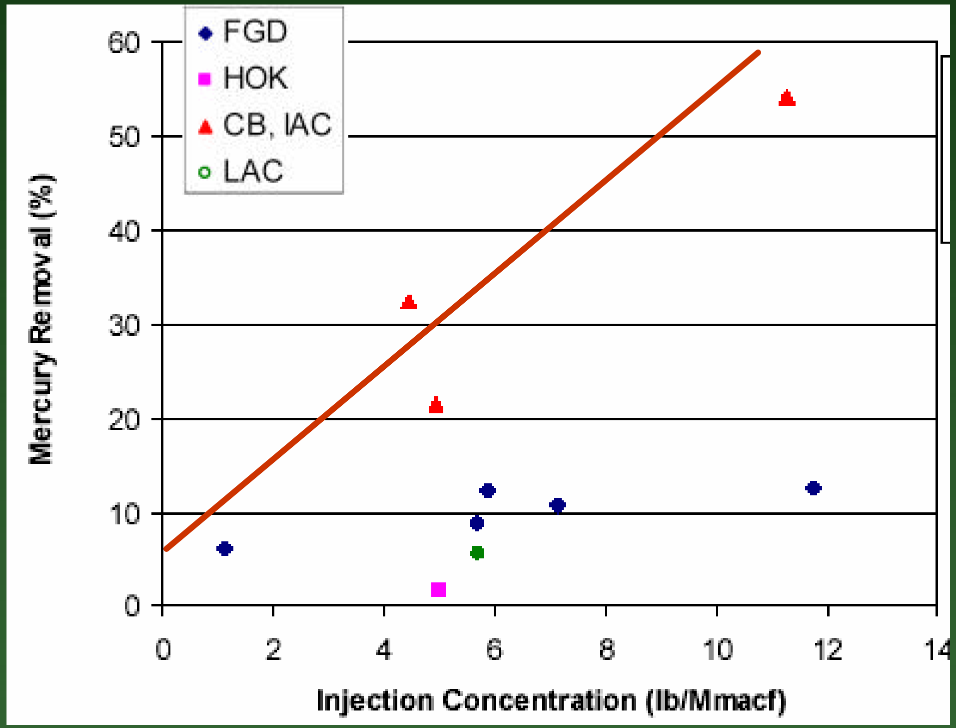
Sjostrom, S., et al., "Full-Scale Evaluation of Mercury Control at Great River Energy's Stanton Generating Station Using Injected Sorbents and a Spray Dryer/Baghouse," Air Quality III, Sept. 2002.

DOE-Identified Problems with ACI

- high removal not possible with low-Cl Western coals
- $$$ high injection rates req'd for high removal with bitum. coals
- opacity increases are possible with high injection rates
- renders fly ash unusable in concretes
- iodine carbons can help, but very expensive $$$
- iodine & oxidized Hg can evolve off

Iodine PAC at Laskin & EERC

Minnesota Power's Laskin Energy Center



EERC Pilot Plants

Poor Hg Removal with IAC		
Coal	FF	ESP
Comanche	0% - oxidized	N.A.
Blackville	15% - 70%	0%
Absaloka	80%	15%- oxidized

Sjostrom, S., et al., "Full-Scale Evaluation Of Mercury Control Across A Wet Particulate Scrubber," 4th DOE-EPRI-U.S.EPA-AWMA "Mega" Symposium, Washington, D.C., May 19-22, 2003.

Dunham, G., et al., EERC, "Investigation of Sorbent Injection for Mercury Control in Coal-Fired Boilers," Final Report for EPRI & DOE FETC, September 1998.

Part of the Solution: Brominated PAC

- low-grade PACs with an inexpensive bromination step
- stable, but highly-Hg-reactive surface compounds on carbon
- work on both elemental & oxidized Hg
- faster Hg kinetics than PACs for use in cold-side ESP
- wide temperature operating range
- projected price of $0.50-1.00/lb (vs. e.g. $0.50 Norit FGD)
- multiple patents pending

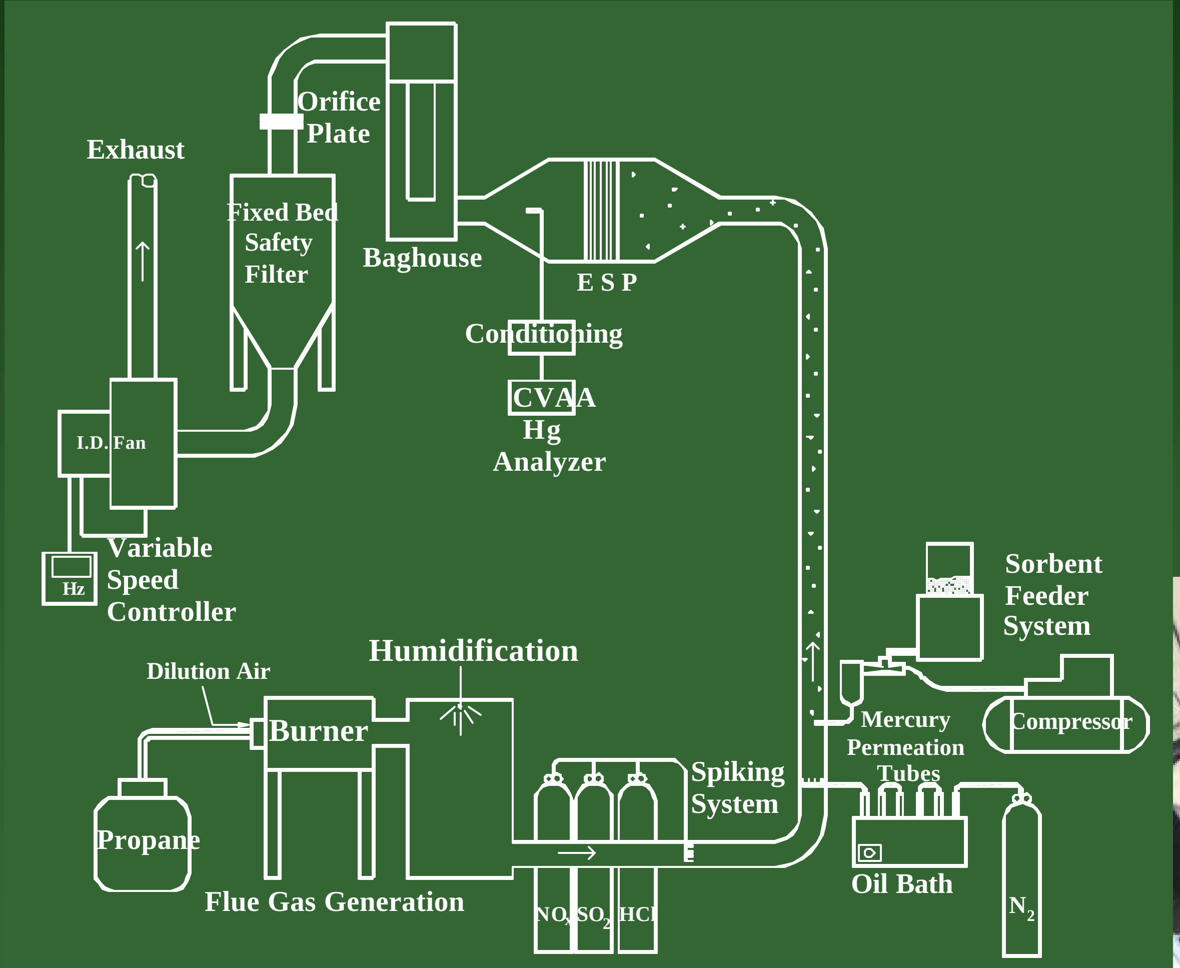
Sorbent Technologies' B-PAC™

- simple, dry exposure of PAC to bromine gas at ~350ºF
- the Type "A" sorbents in previous presentations
- standard B-PAC proving highly cost-effective for typical use
- in addition, we have 2 specialized versions of B-PAC:
  - developing a high-temp. version for use in hot-side ESPs
  - "concrete-safe" version allowing fly ash use in concrete

How Can a Halogenated PAC Cost < $1/lb?

Iodine PAC	Bromine PAC
(E.g. Barnebey-Sutcliffe CB 200XF)	(Sorbent Technologies B*PAC)
Coconut-Shell PAC (e.g. $2.00 /lb)	Cheap Coal PAC (e.g. $0.25 /lb)
Iodide @ $7.00 /lb	Bromine @ $0.70 /lb
(not enough iodine produced)	(no bromine supply problems)
Expensive Solvent Process	Cheap Gas-Phase Process
(Iodine Unstable in Hot Gas)	(Bromine Stable in Hot Gas)
$5.00 / lb	$0.50 - $1.00 / lb

Developed on Our Duct Injection Pilot Plant



Conditions

30 acfm, 3 sec

300F @ ESP

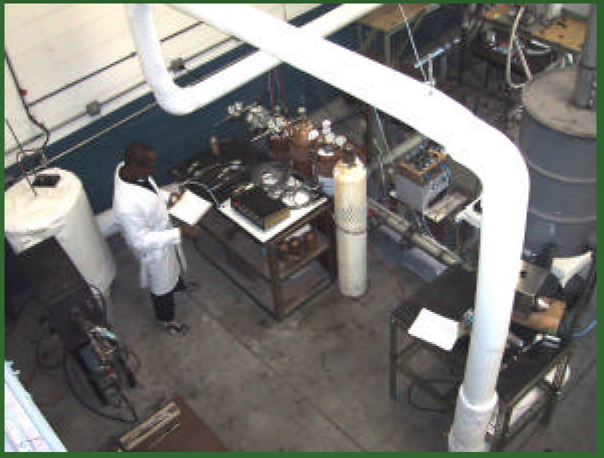
Hg(0)=25ug/Nm3

SO2 = 1400 ppm

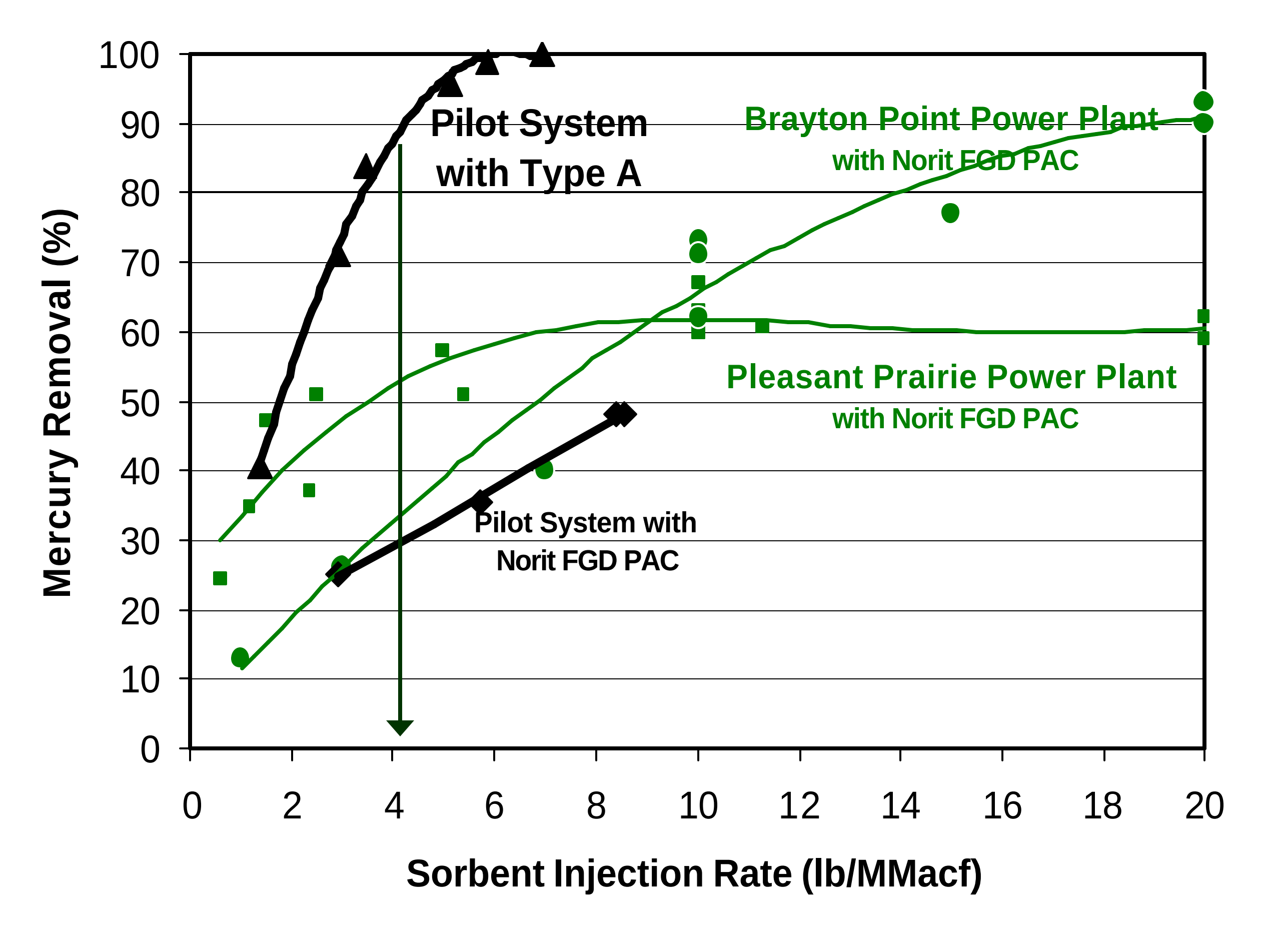
NOx = 500 ppm

HCl = 5 ppm

No fly ash



B-PAC Performed Best in ESP Pilot Testing



Hg(0) = 14 µg/Nm^3
300^{o}F

B-PAC Best in Apogee FF Slipstream – $Hg^{(+2)}$

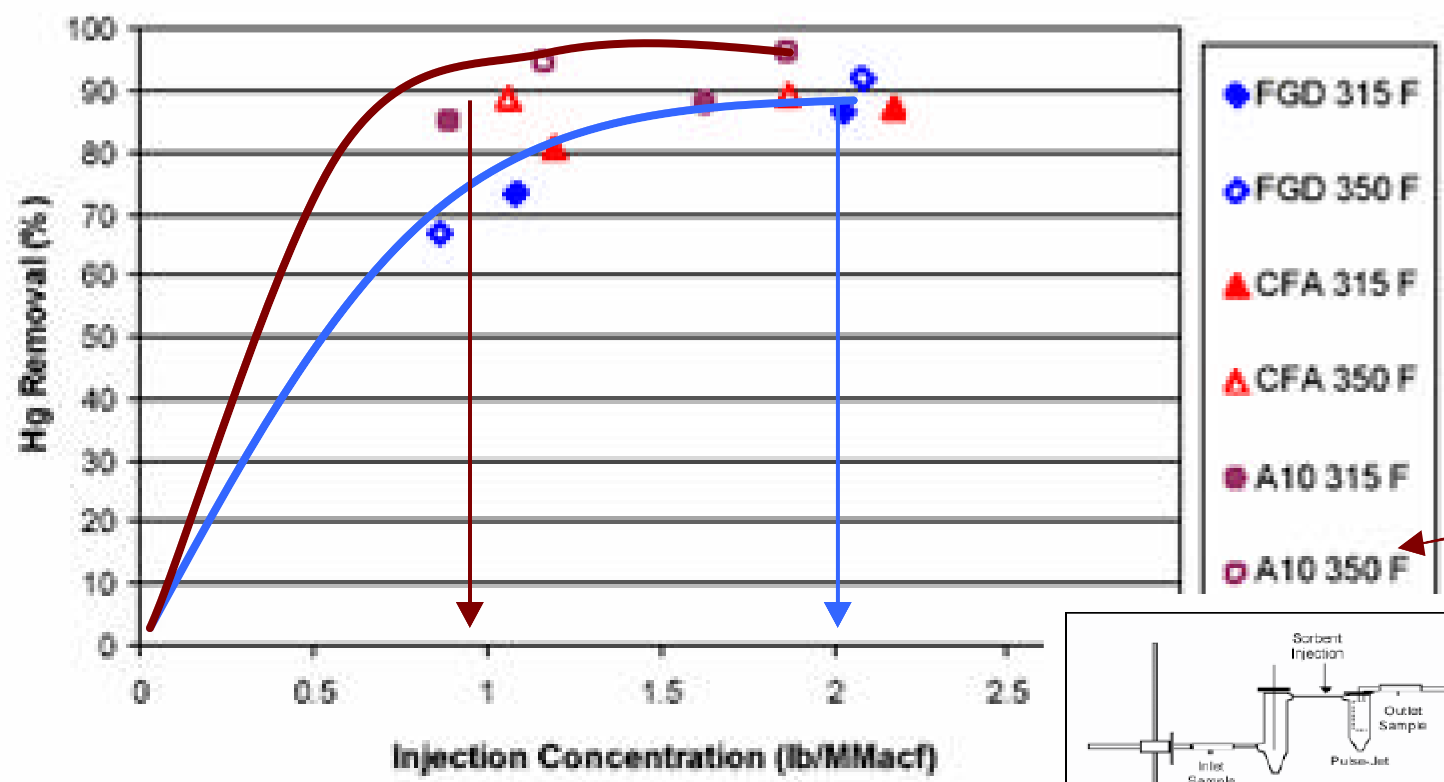


Fig. 5. Valley results from parametric tests.

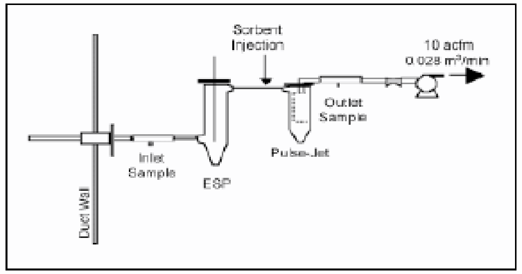
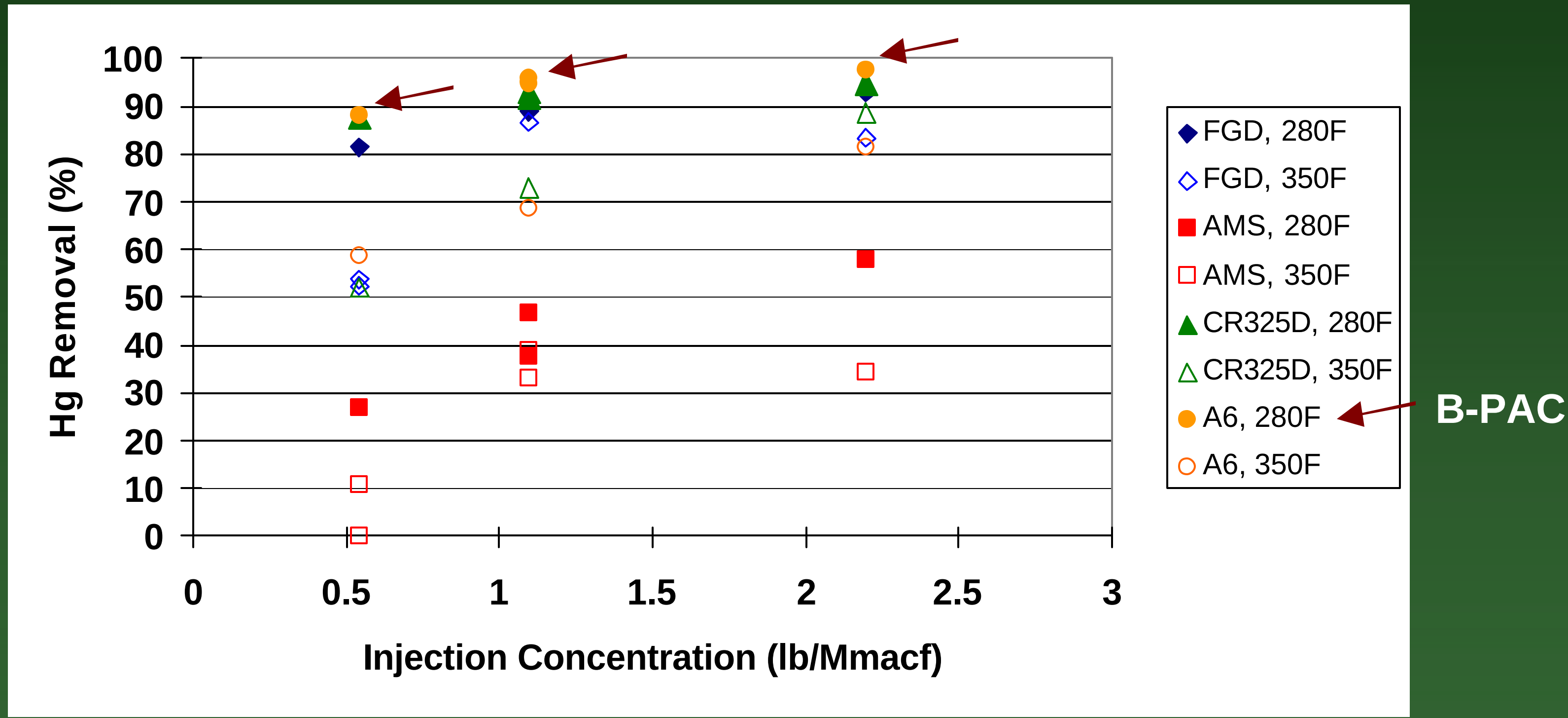


Figure 4. PoCT modules configured for COHPAC testing.

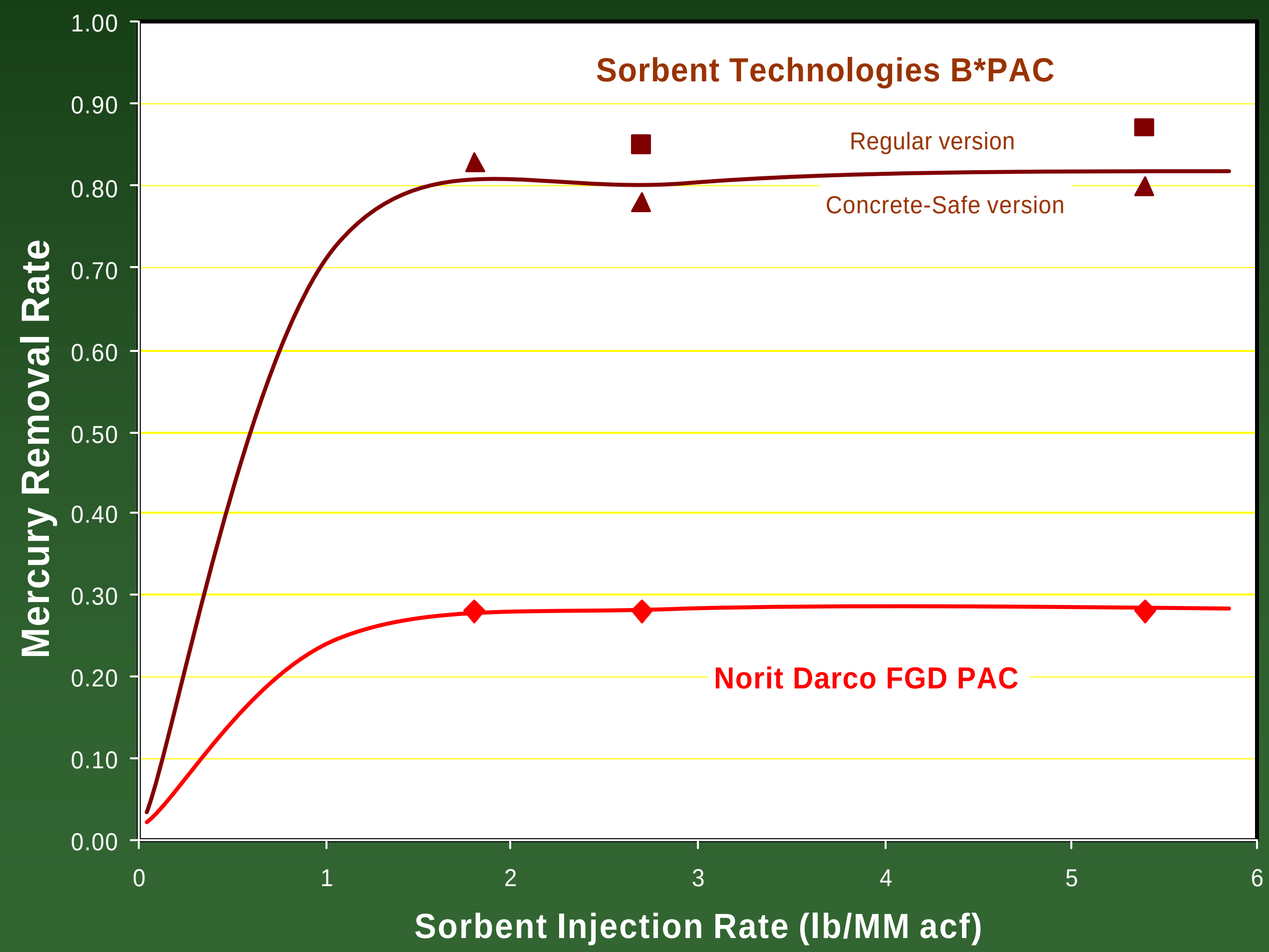
T. Ley, et al., Apogee Scientific, "Evaluation & Comparison of Novel Low-Cost Sorbents for Mercury Control," Air Quality IV Conference, Sept. 2003.

B-PAC Best in Apogee P4 Slipstream FF – $Hg^{(0)}$



T. Ley, Apogee Scientific, "Evaluation & Comparison of Novel Low-Cost Sorbents for Mercury Control," Electric Utility Environmental Conference, Jan. 2004.

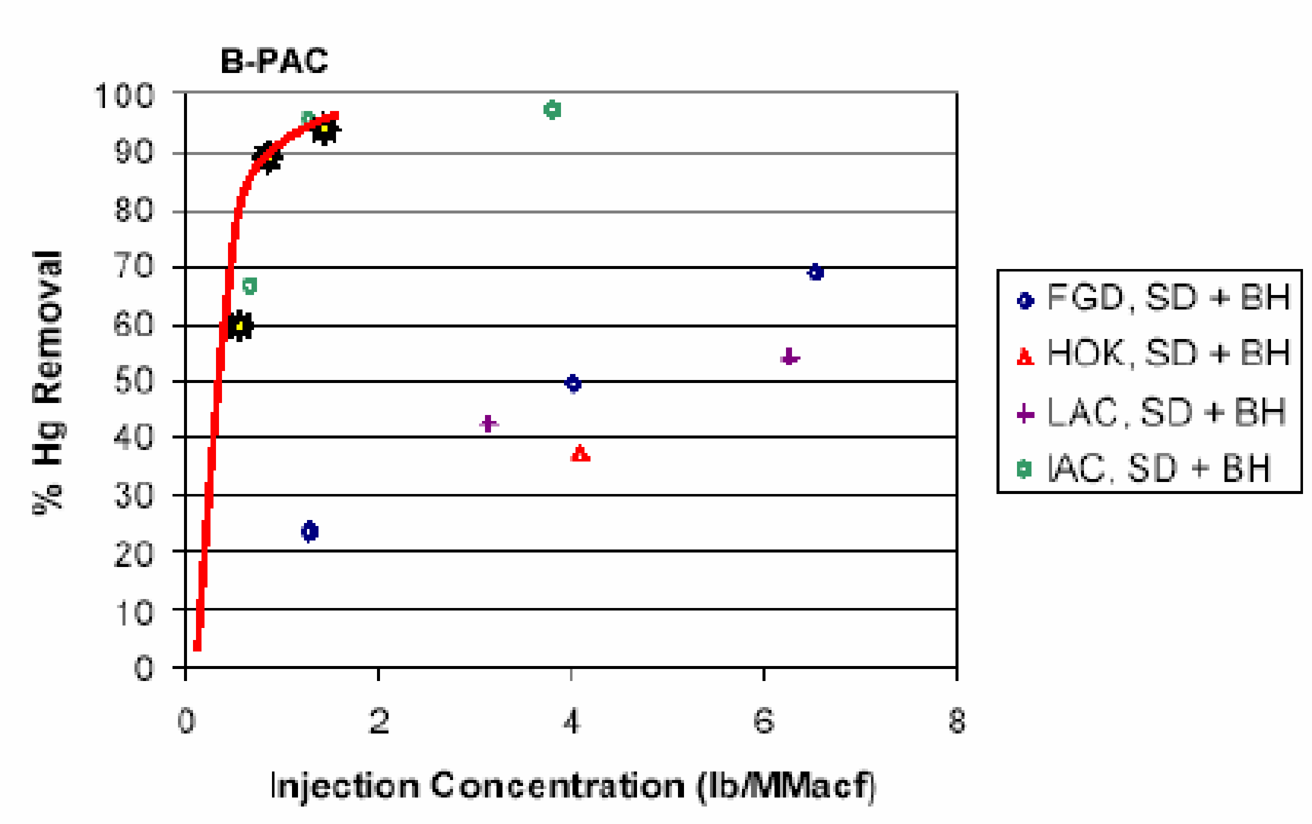
Sunflower Holcomb Plant (PRB/SD-Fabric Filter) - ADA-ES Slipstream Testing

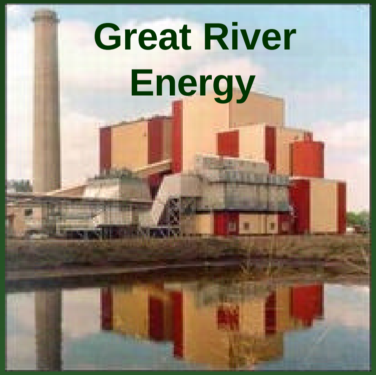


(No in-duct removal opportunity and the gas slipstream was taken between the spray dryer and fabric filter.)

Full-Scale at Stanton 10 SD/FF with Lignite

** Preliminary & Confidential ** Preliminary & Confidential ** Preliminary & Confidential **





Superimposed on:
Sjostrom, S., et al., "Full-Scale Evaluation of Mercury Control at Great River Energy's Stanton Generating Station Using Injected Sorbents and a Spray Dryer/Baghouse," Air Quality III, Sept. 2002.

EERC/URS DOE Project "Enhancing Carbon Reactivity in Lignite Systems," in progress.

Full-Scale In-Duct Hg Removal across SD

** Preliminary & Confidential ** Preliminary & Confidential ** Preliminary & Confidential **

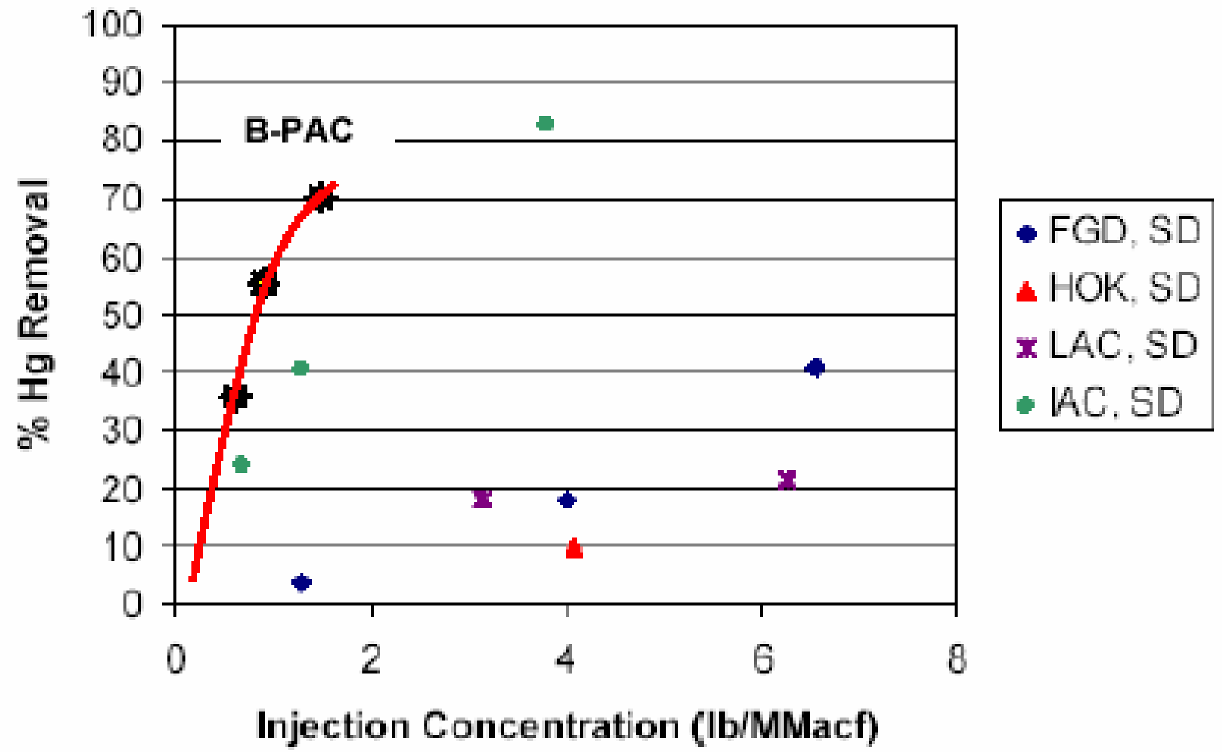


Figure 3. Mercury removal measured across the spray dryer at Stanton Station during parametric testing.

EERC/URS DOE Project “Enhancing Carbon Reactivity in Lignite Systems,” in progress.

Cost Effectiveness with Lignite at Stanton

If 1.0 lb/MMacf of $0.75/lb B-PAC injected is into a SD/FF with 8.5 µg Hg/Nm³ provides 87% Hg removal:

$$\left(\frac{1.0\,lb\,sorbent}{1{,}000{,}000\,acf}\right)\left(\frac{Nm3}{(87\%)8.5mg\ Hg}\right)\left(\frac{\$0.75}{lb\,sorbent}\right)\left(\frac{1.5\,acf\ @300F}{1\,scf}\right)\left(\frac{35.3scf}{Nm^3}\right)\left(\frac{10^9\ mgHg}{2.2lb\ Hg\ removed}\right)=\$2{,}500/lbHg.$$

Cost = $2,500 /lb Hg removed,

95% cost reduction from the current technology baseline.

Similarly, if 2.0 lb/MMacf of B-PAC injected into a cold-side ESP provides 80% Hg removal:

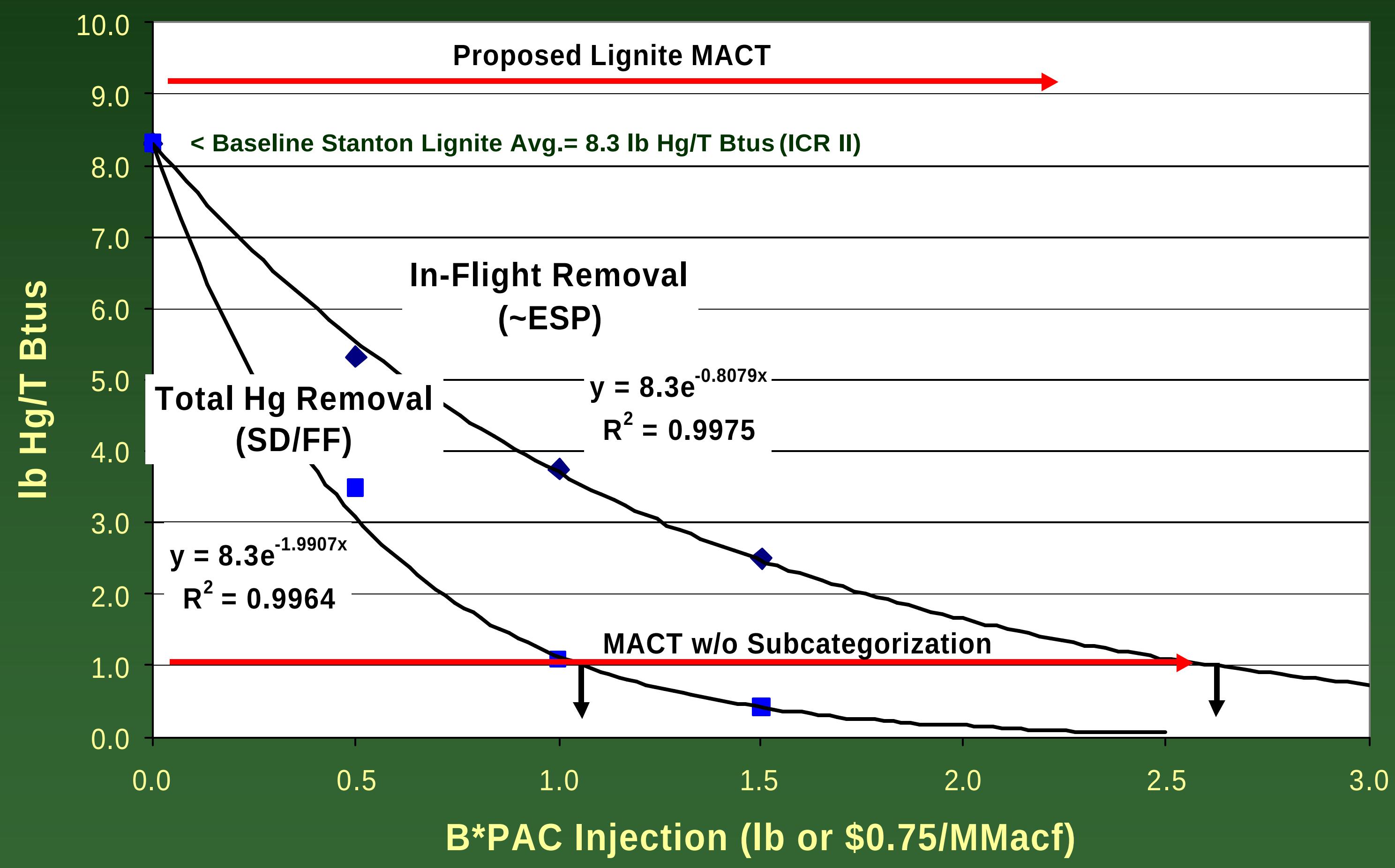
Cost = $5,300 /lb Hg removed,

90% cost reduction from the current technology baseline.

Currently-Proposed Hg Limits

Coal	lb Hg/T Btus
Lignite	**9.2**
Subbituminous	**5.8**
Bituminous	**2.0**

Stanton 10 Lignite Compliance with MACT



B-PAC Best on the Lausche Plant ESP

Mercury (in µg/Nm³)

$Hg^{(p)}$	$Hg^{(+2)}$	$Hg^{(0)}$	Hg_{tot}
0	8-9	1-2	10

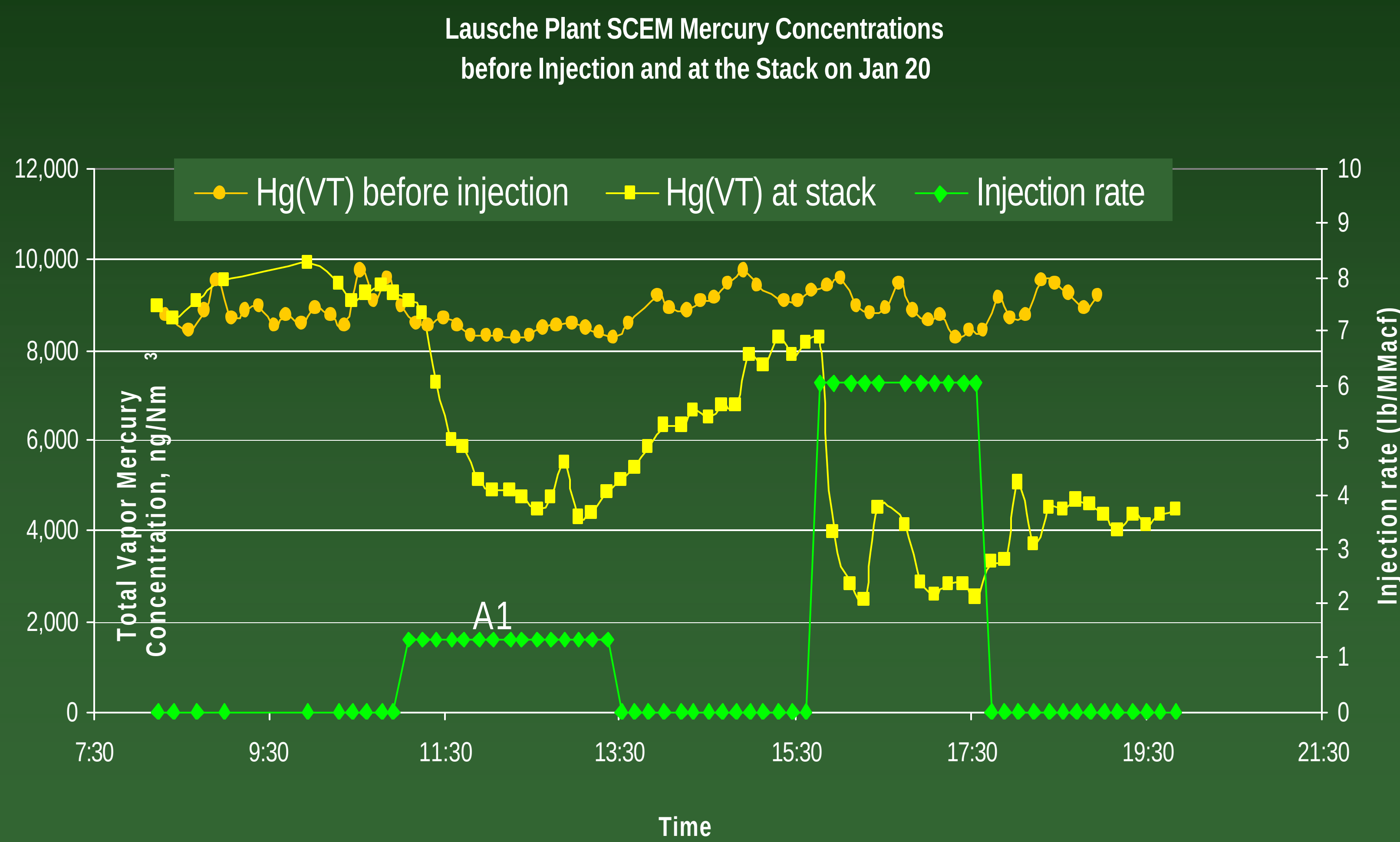
Lausche Plant Injection Conditions

Scale	18 MW	Gas	60,000 acfm
SO_2	1000 ppm	ESP temp.	320 ºF
NOx	250 ppm	SCA	370 ft^2/Kacfm
HCl	25 ppm	Opacity	5%
SO_3	20 ppm	Resid.time	2.5 Sec

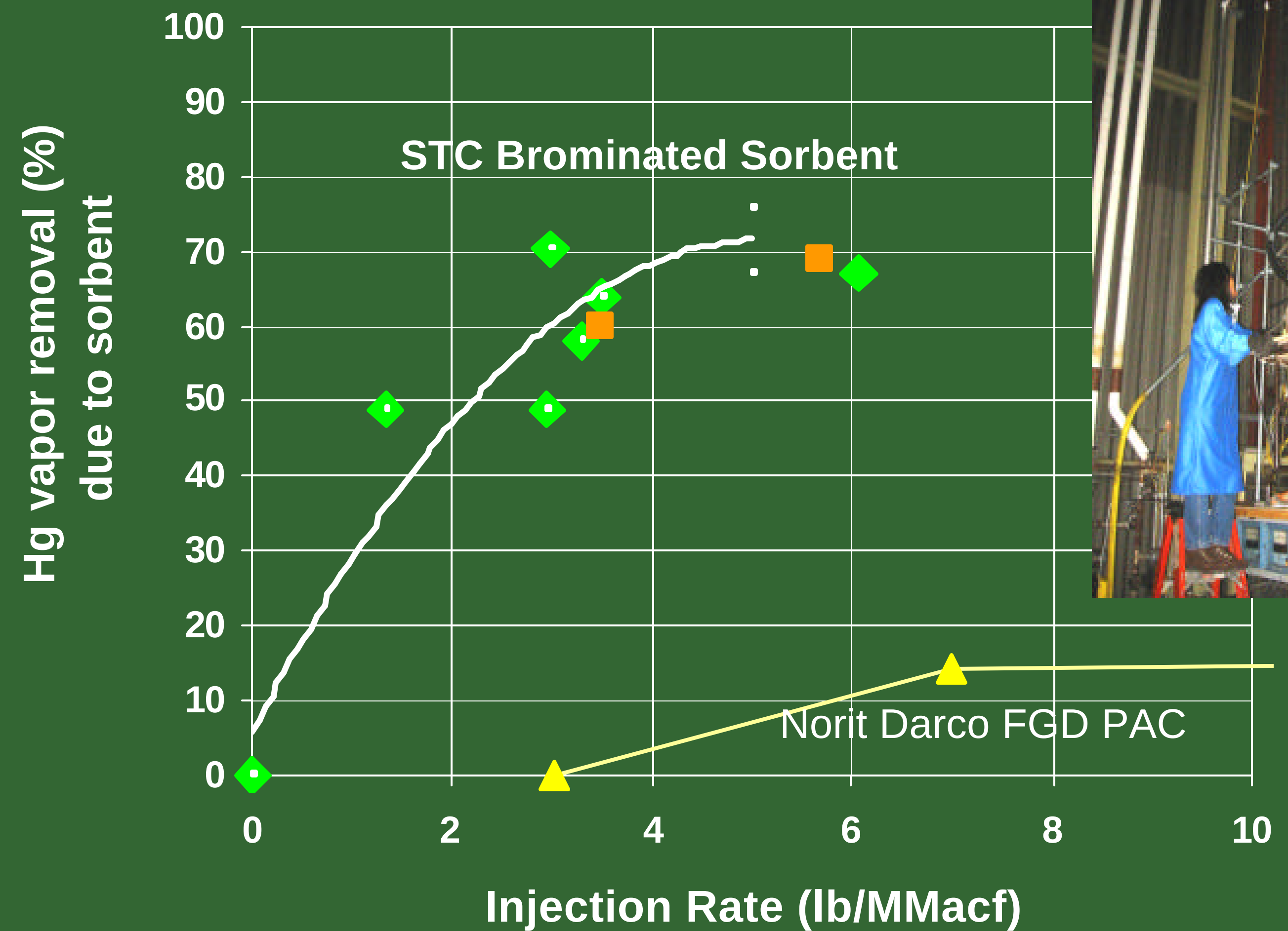
- 18 MWe, CS-ESP, High-Sulfur Ohio Bituminous
- January 2003 Test Program
- Hg measurements by Western Kentucky University

Nelson, S., R. Landreth, Q. Zhou, and J. Miller, "Mercury Sorbent Test Results at the Lausche Plant," 4th DOE-EPRI-U.S.EPA-AWMA "Mega"Symposium, Washington, D.C., May 19-22, 2003.

Individual Test Data – WKU PSA CMMs



Lausche Plant Test Results



Costs with High-S Bitum. Coal & CS-ESP

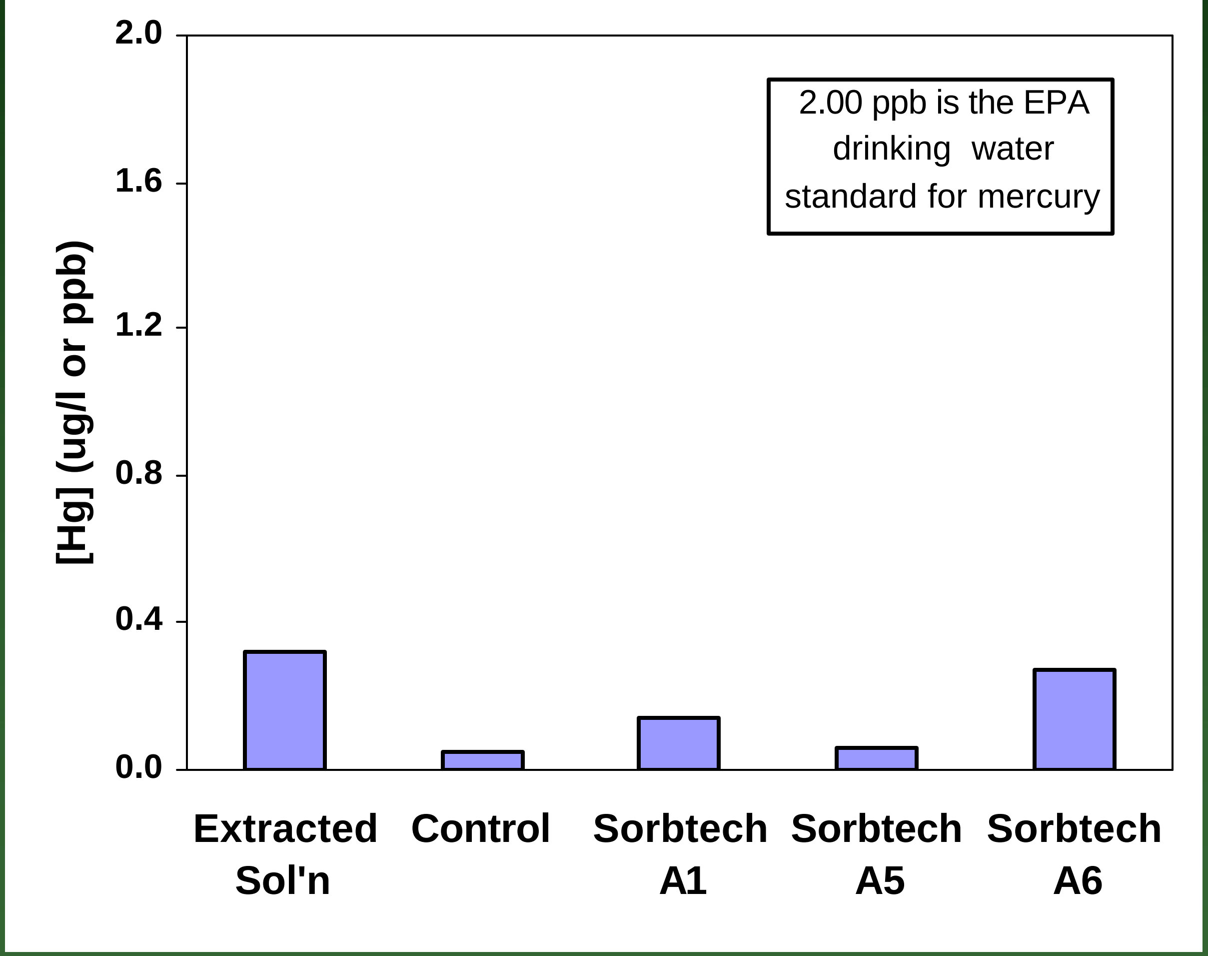
If 4 lb/MMacf of $0.75/lb Brominated B-PAC™ sorbent injected into 10 µg/Nm³ of Hg at Lausche provides 70% Hg removal:

$$\left(\frac{4\,lb\,sorbent}{1{,}000{,}000\,acf}\right)\left(\frac{Nm3}{(70\%)10mg\,Hg}\right)\left(\frac{\$0.75}{lb\,sorbent}\right)\left(\frac{1.5\,acf\,@\,320F}{1\,scf}\right)\left(\frac{35.3scf}{Nm^3}\right)\left(\frac{10^9\,mgHg}{2.2lb\,Hg\,removed}\right)=\$10{,}300/lbHg.$$

Cost = $10,000 /lb Hg removed,

~80% cost reduction from the current technology baseline.

Toxic Characteristic Leaching Procedure



ACI Renders Fly Ash Unusable in Concretes

- STC National Science Foundation SBIR Project
- Objective: Adsorb Hg, but not AEAs
- Successful methods developed for B-PAC
- Phase II: to lower the costs of concrete-safe™ version

America’s Biggest Recycling Success

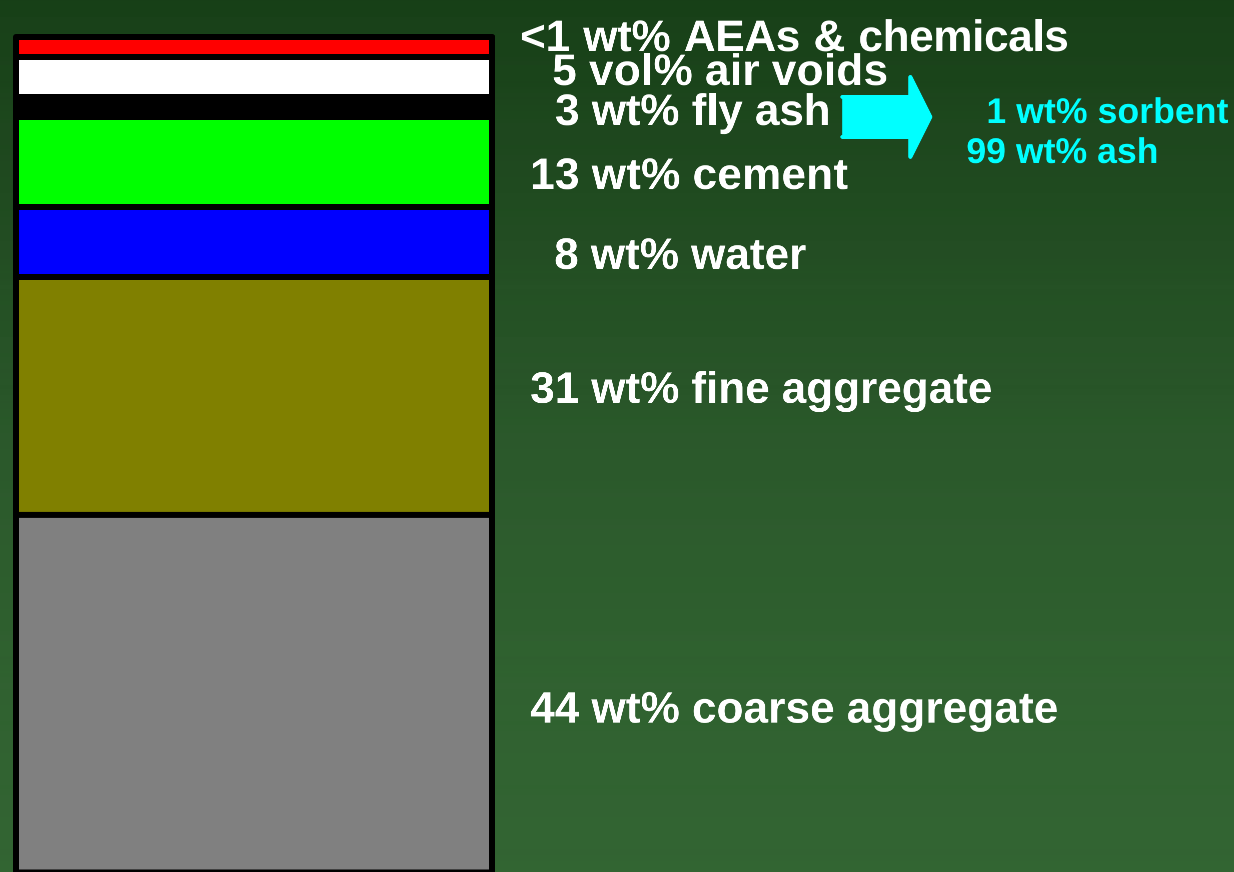
>14,000,000 Tons per year (18%) of utility Fly Ash is used to replace expensive Cement in Concrete.

> 90 lb / person / year.

Both Type F and Type C.

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

Concrete Composition



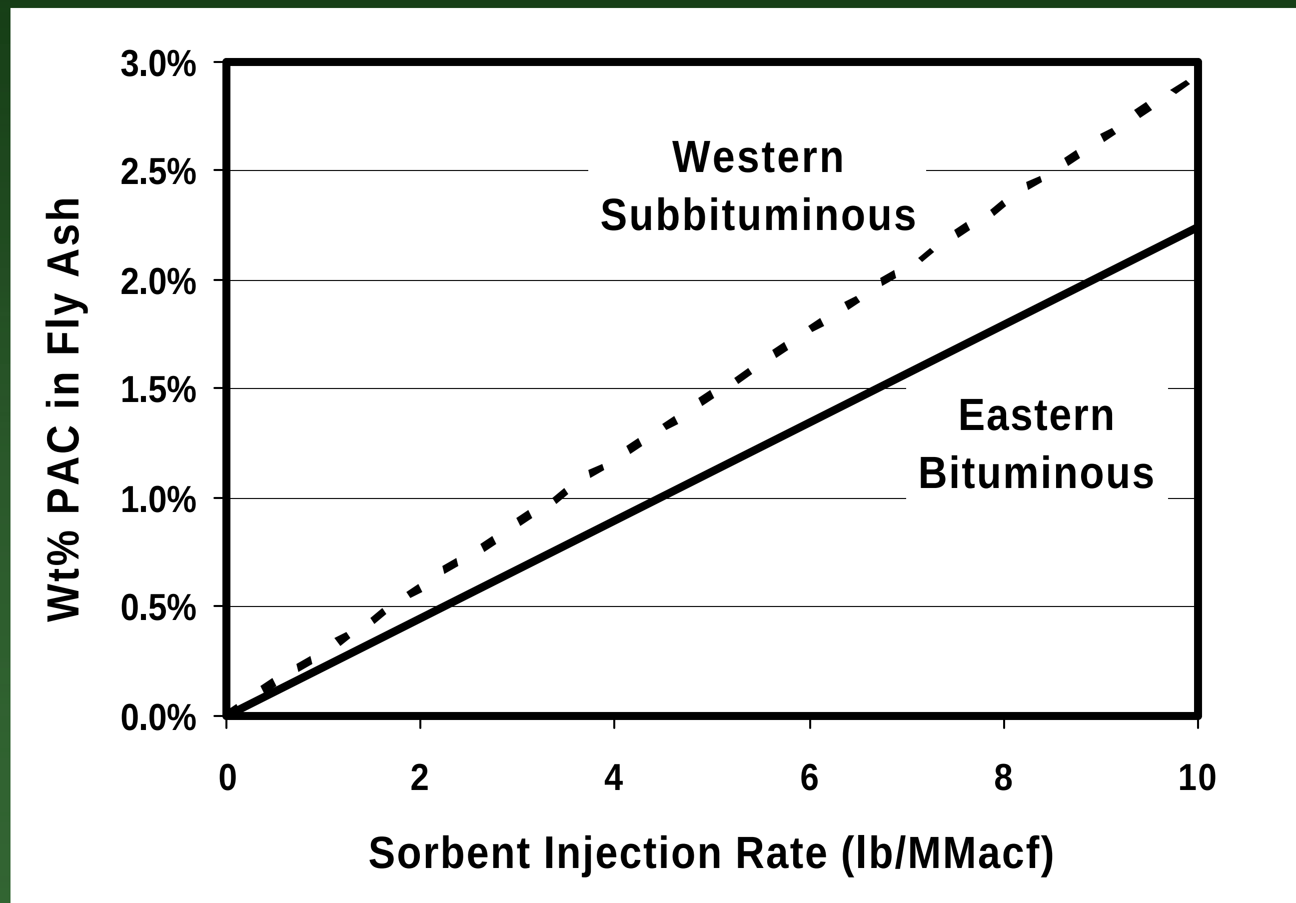
Ash Problems with PAC Hg Sorbents

1. Carbon level per se

2. Interferes with Air Entraining Admixtures (AEAs)
   -- with inevitable variations in the level of the effect

3. Can darken the fly ash

How much carbon are we adding?



AEA Interference: 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

Pleasant Prairie Foam Index Tests

Inj. Rate (lbs PAC/MMacf)	Hg Removal Effic. (%)	Carbon in Ash	Foam Index (Drops of AEA)	Comment
0	-	0.6%	15	Normal
1	40 – 50%	1.1%	>72	Maxed out
3	50 – 60%	1.6%	>72	Maxed out
10	60 – 70%	3.6%	>72	Maxed out

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

Cost Impacts of Lost Concrete Markets

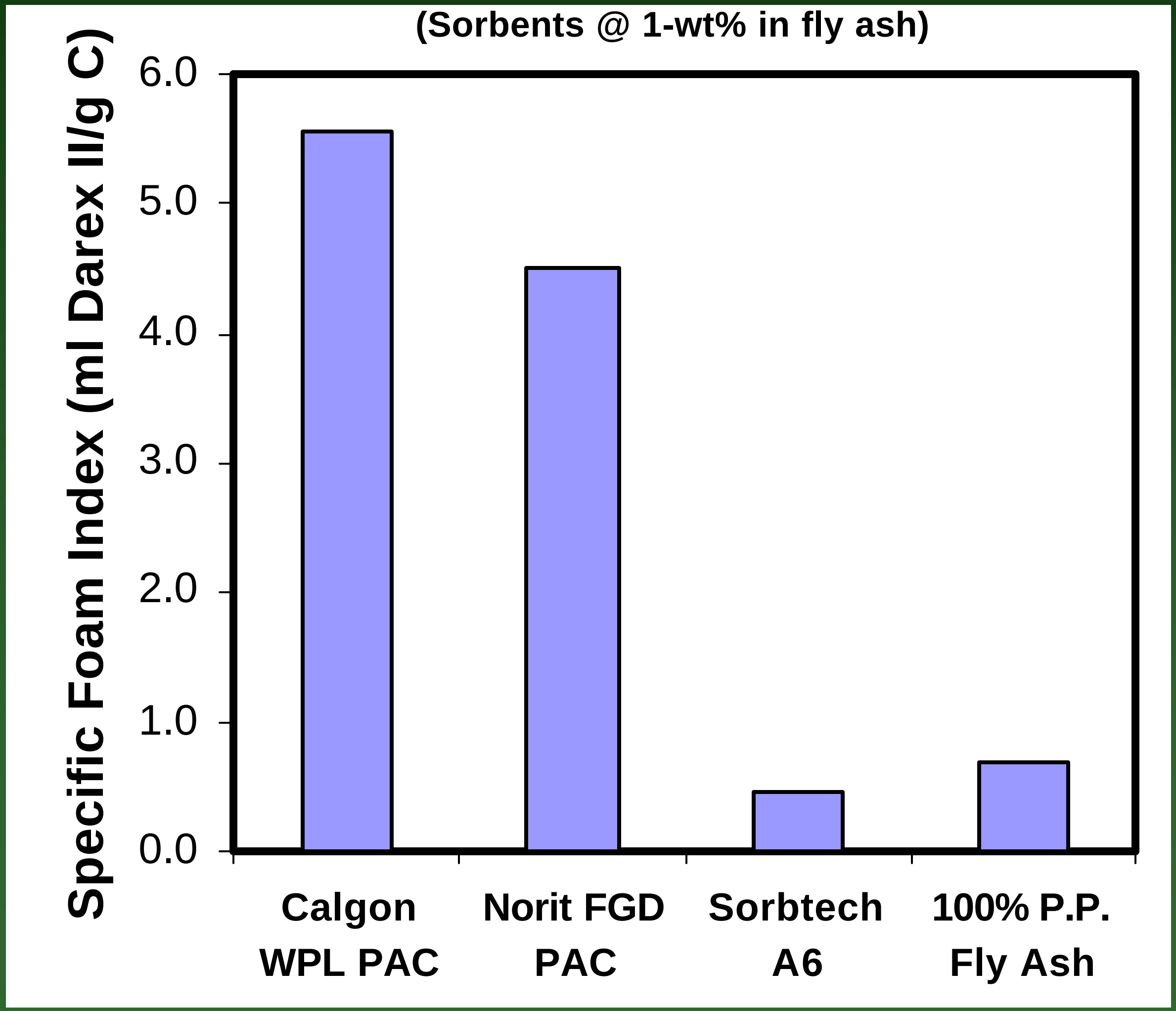
We Energies Pleasant Prairie Plant
1,200 MW with 200,000 Tpy of Fly Ash

Impact	Value	Annual Losses
Fly Ash Sales	\$ 13/ton	\$ 2.6 Million/yr
Avoided Disposal	\$ 33/ton	\$ 6.6 Million/yr
Total	\$ 46/ton	\$ 9.2 Million/yr

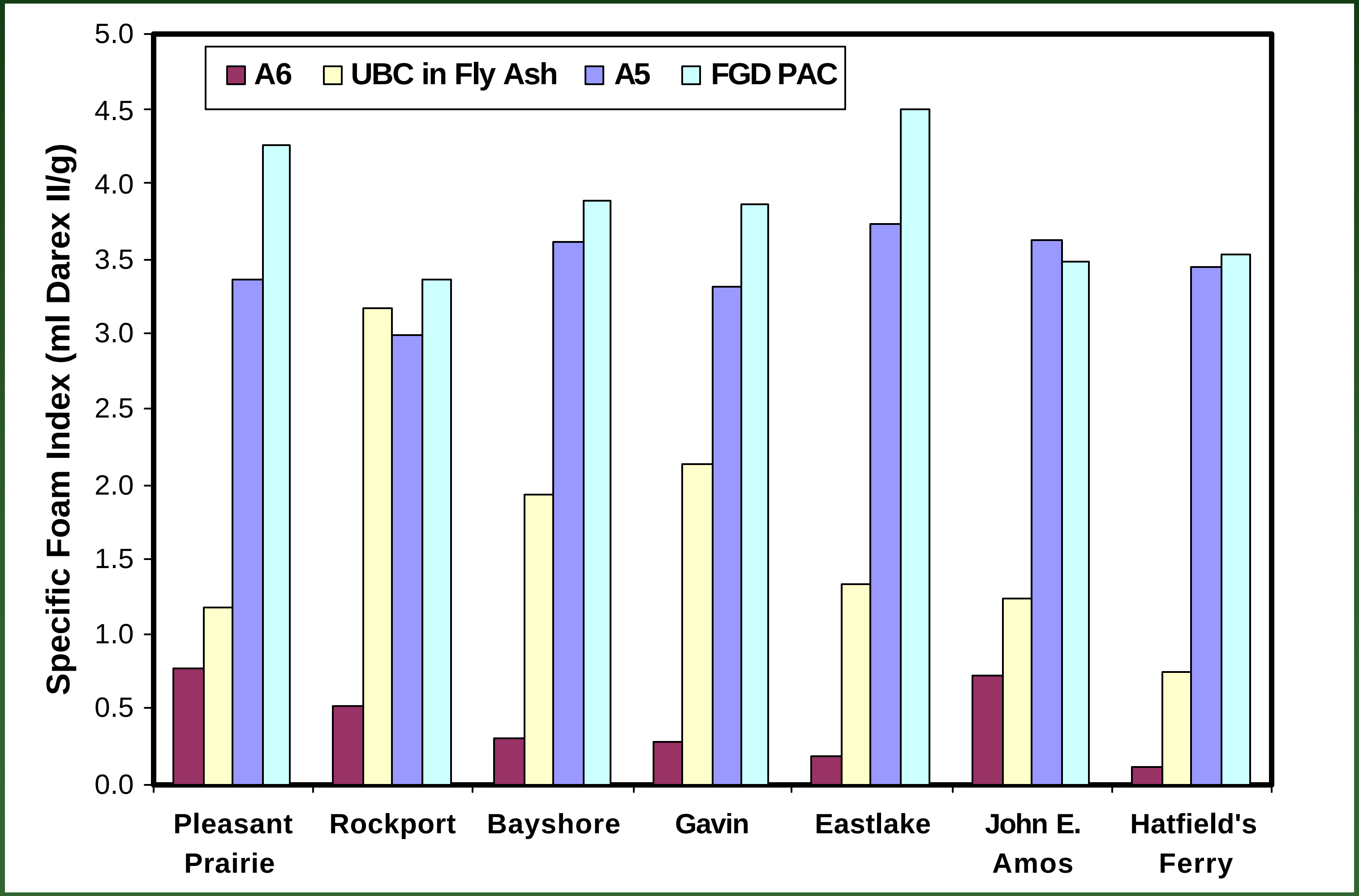
$$\frac{\$9.2\,Million/yr}{(700\ lb\ Hg/yr)(0.80\ Removed)} = \$16,000/lb-Hg-Removed\ \ By-Product\ \ Effect$$

Modified from: Coughlin, Ibid. and Ramme & Tharanyil,
Coal Combustion Products Handbook, A We Energies Publication, 2000.

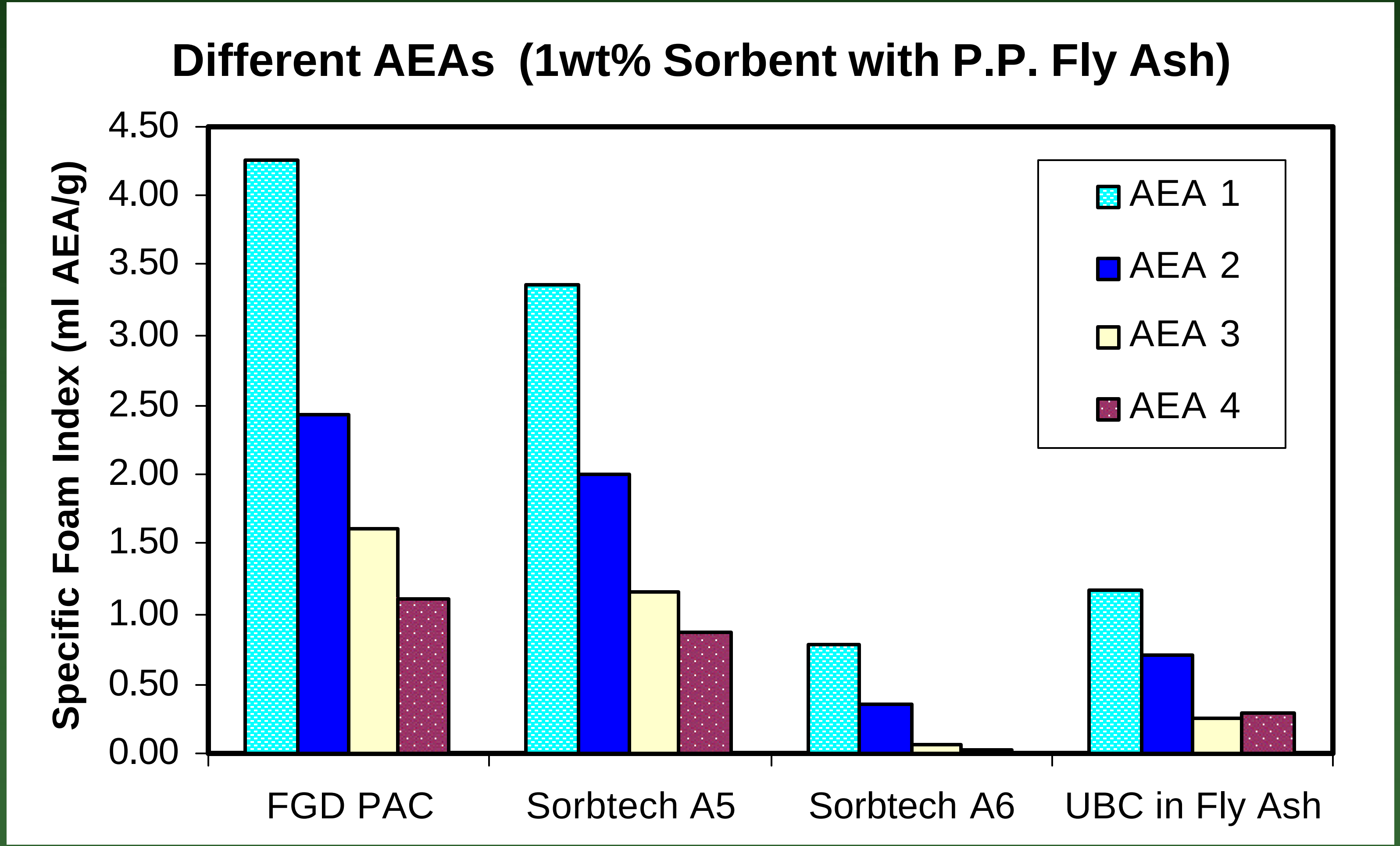
"A6" B-PAC Foam Indexes with P4 Fly Ash



Works with a Wide Range of Fly Ashes



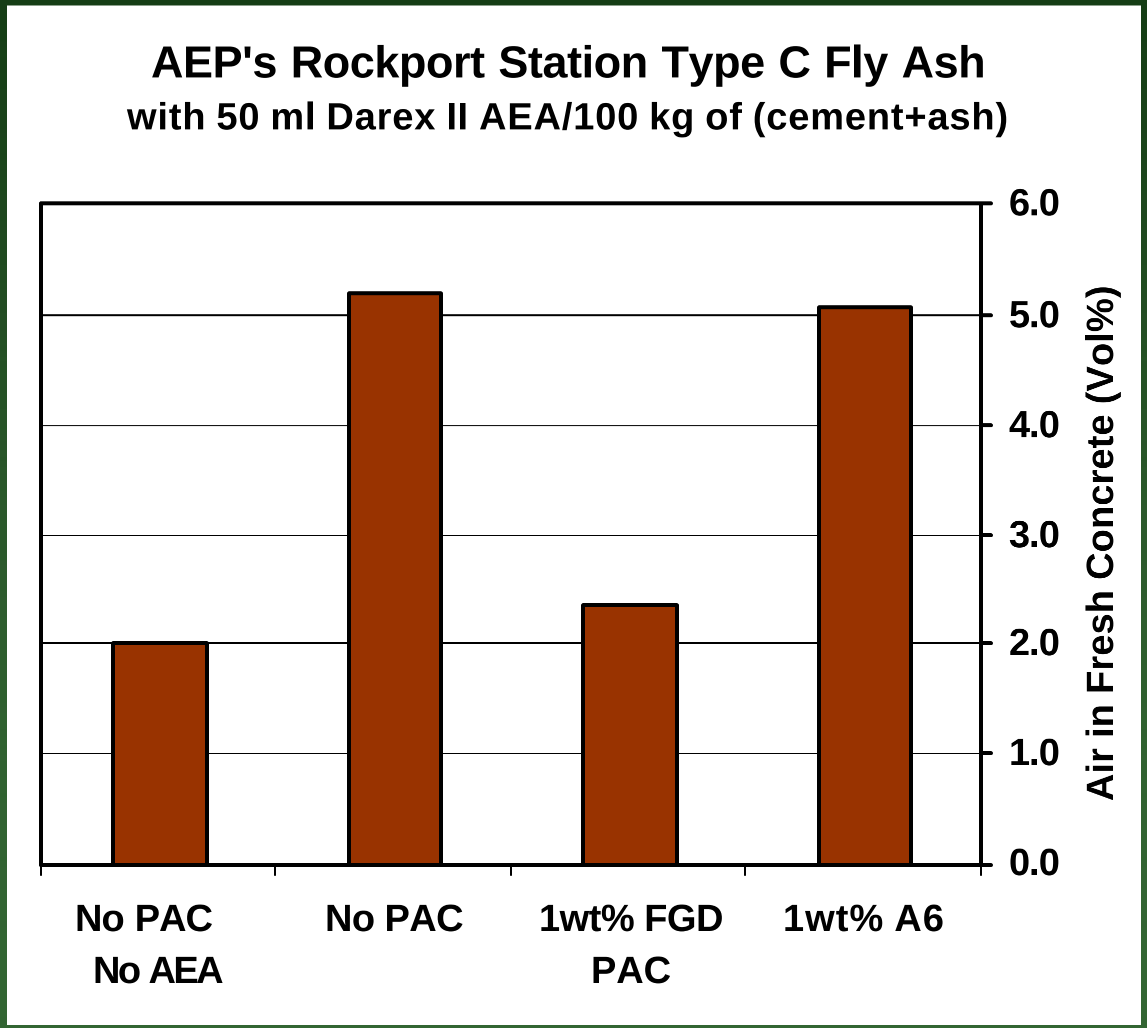
Works with Different AEAs



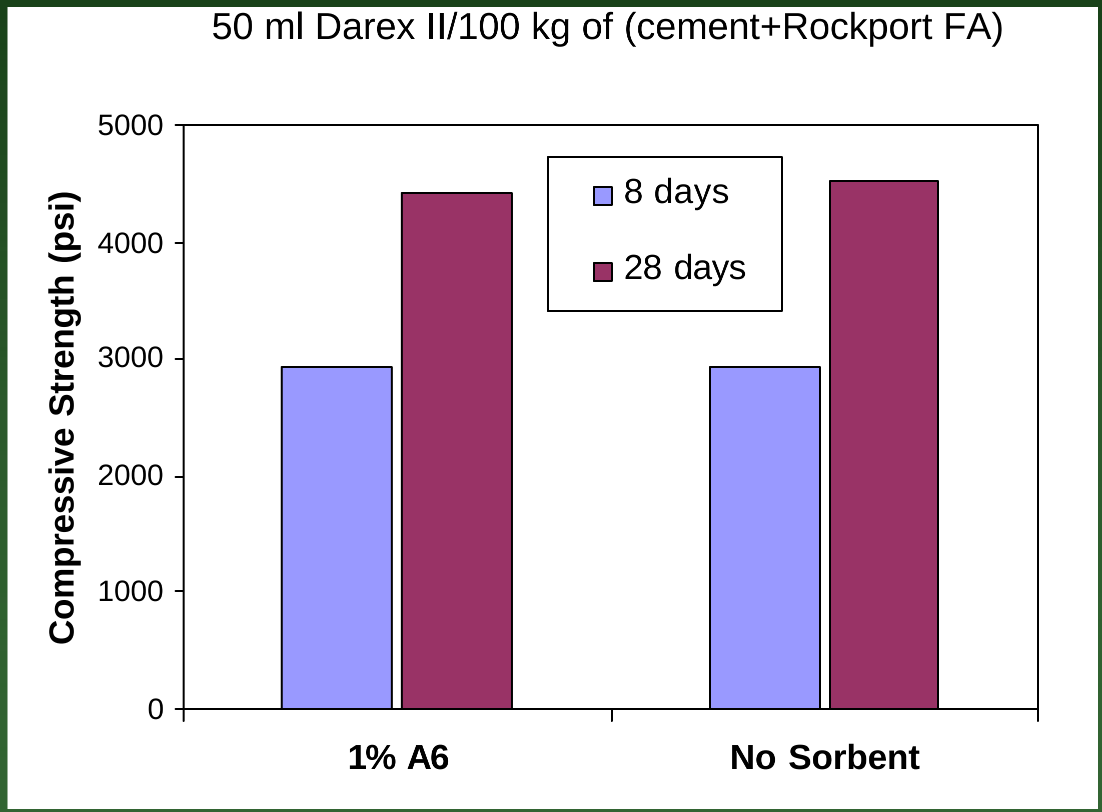
Measuring Air Entrainment

ASTM C-192
ASTM C-232

Air Entrainment Results

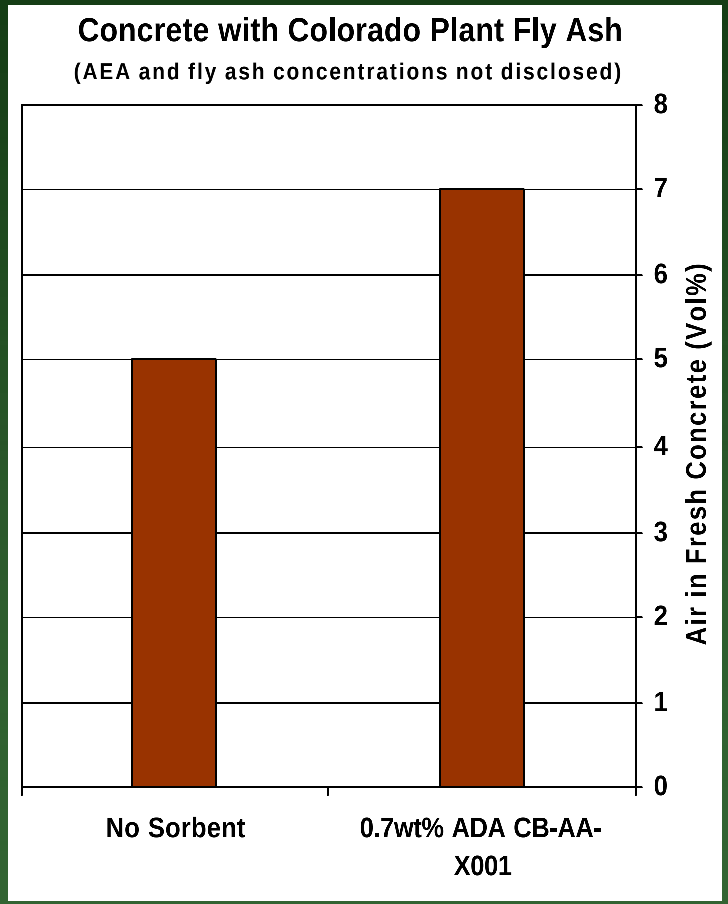


Same Compressive Strength



Compare: Amended Silicates®

- chemicals added to silicate materials
- concretes tested by Boral Materials Tech.*
- added to ash @ 0.67wt%
  (=~2.5 lb/MMacf=~60% FF removal)
- increased air by 40%
  (would lower strength significantly)
- air entrainment appears extremely sensitive to Amended Silicates



* Butz, et al., "Amended Silicates," Air Quality III Conference, Arlington VA, Sept. 2002.

Concrete-Safe Conclusions:

1. Mercury sorbent usage and fly ash sales are not mutually exclusive.
2. Brominated PAC is so efficient that little is needed and carbon levels in fly ash are only elevated ~1wt%.
3. Specially-processed B-PAC has practically no effect on AEAs or concrete strength.
4. Mercury reductions will be much less expensive at fly-ash-selling plants than is generally believed

Overview of the DOE Project

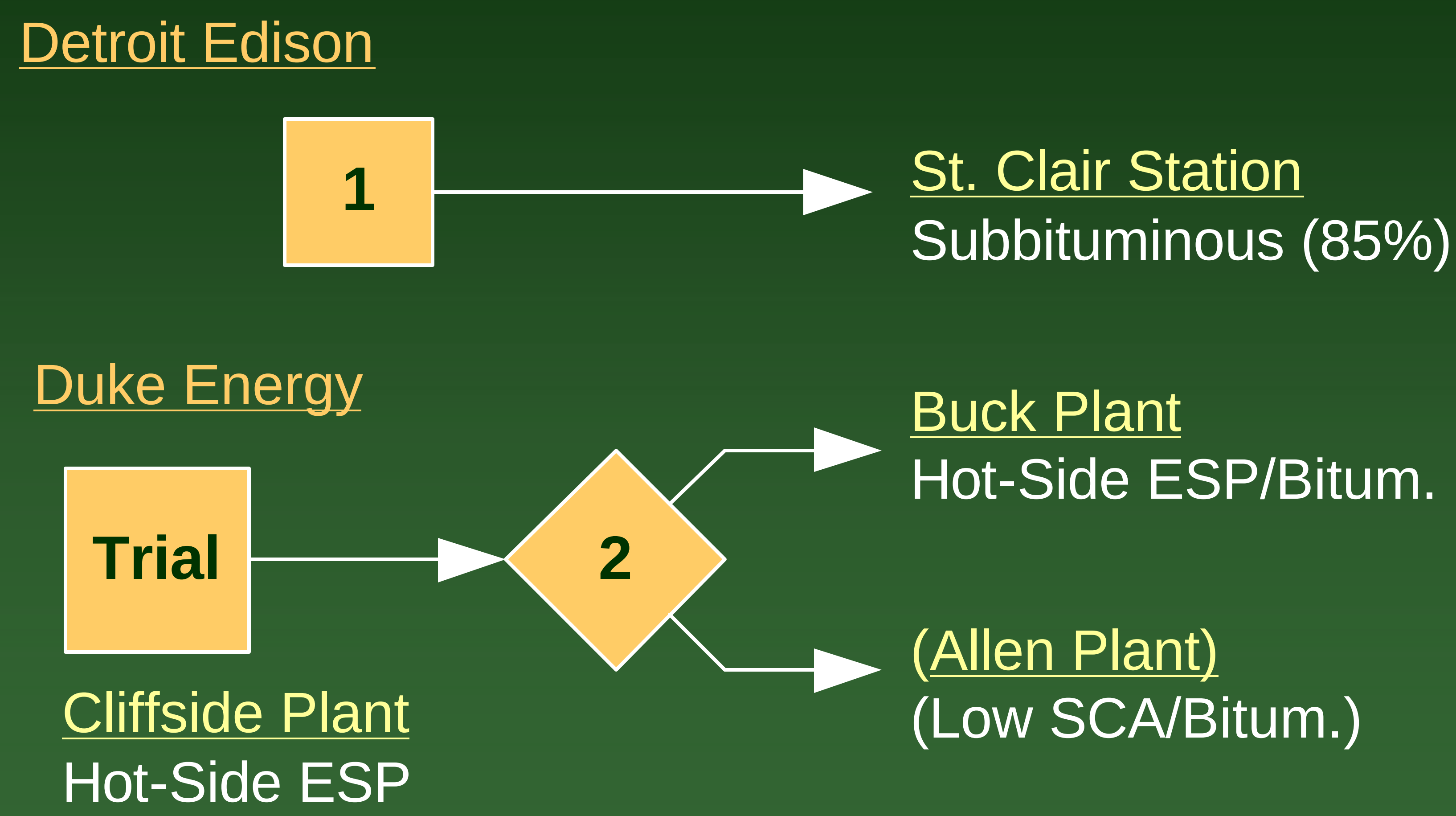
Objective:

To test advanced, brominated sorbents, specifically designed for retrofit utility mercury control with ESPs, at full-scale, in both parametric and extended (30-day continuous) evaluations in two significantly-different power plant situations, to establish the new material's mercury performance, cost-effectiveness, and balance-of-plant effects.

Unique Features

- Advanced Sorbents (Brominated PACs)
- Long-Term Site 1: Subbituminous (85%) Blend
- Long-Term Site 2: Hot-Side ESP
- Field-Testing Partners

Two Long-Term Test Sites



Project Participants

Host Sites

- Detroit Edison
- Duke Power

Project Contractors

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

Field Test Partners

- PS Analytical Ltd. (Dry Converter)
- Spectra Gases (Hg Standards)

DTE Energy – Detroit Edison

- 14th largest U.S. producer of power from coal
- 7 Michigan plants with 24 coal-fired boilers
- all cold-side ESPs with no FGD
- most burn primarily-subbituminous coal blends

Detroit Edison – St. Clair Station

Southeast Michigan
Cold-Side ESP
290^{o}F
85 Sub/15 Bitum. Blend
80 MW ESP stream
700 ft^2/K acfm SCA
1 ug/Nm^3 Stack Hg$^{(+2)}$
3 ug/Nm^3 Stack Hg$^{(0)}$
Sells some fly ash

Duke Energy – Duke Power

- 10th largest U.S. power producer from coal
- 8 North Carolina plants with 31 coal-fired boilers
- 18 hot-side ESPs, generally peaking plants
- burn low-sulfur Eastern bituminous coal

Duke Energy – Buck Plant

North Carolina
Hot-Side ESP
700^{o}F Inlet
Low-S Bituminous
140 MW (~200MW)
240 ft^2/K acfm SCA
0.06 ppm Hg
Mostly $Hg^{(+2)}$

W. Kentucky Univ. - CMMs

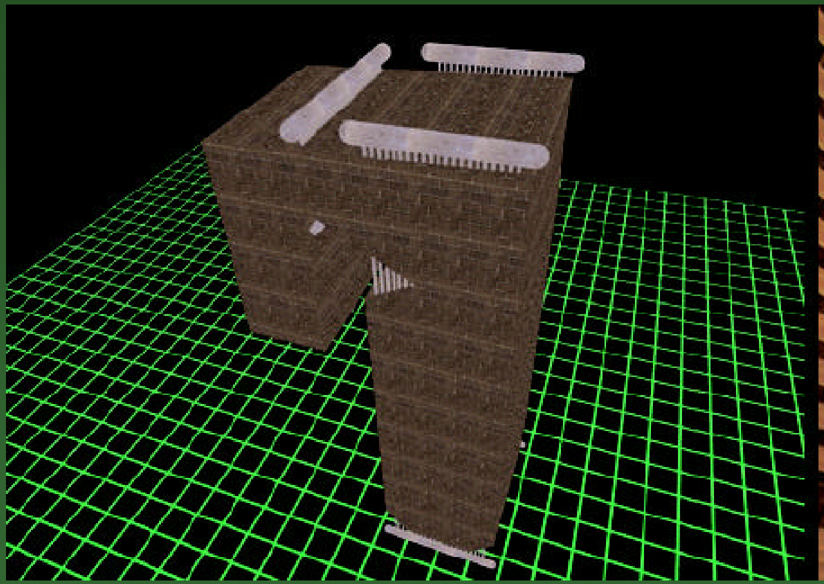
- Independent performance measurement
- More CMM experience than just about anyone

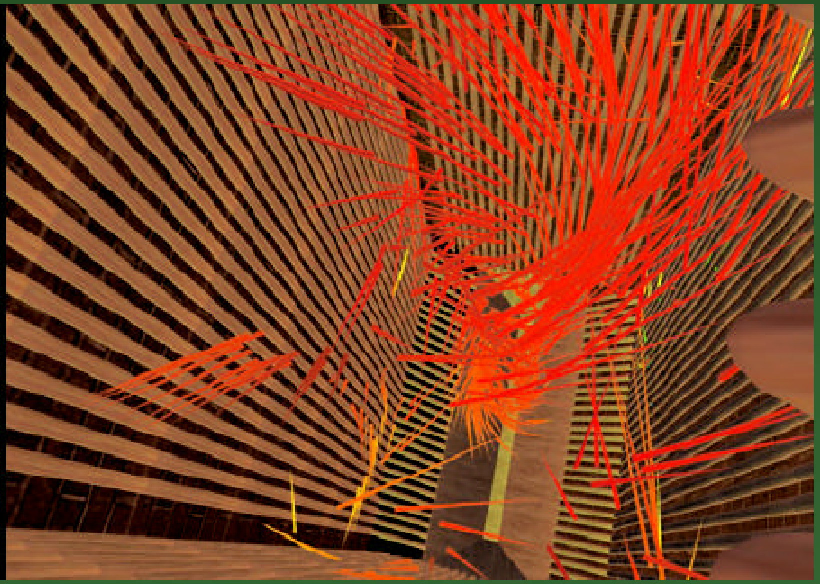
Continuous Mercury Monitoring Experience

Cinergy: Gallagher, Wabash River, Cayuga, Zimmer, Beckjord East Bend, & Miami Fort Plants
E. Ky. Power Coop: Cooper, Dale, & Spurlock Station
Hoosier Energy: Ratts & Merom Plants
TVA: Paradise Plant
LG&E: Ghent Plant
Dominion: Mt. Storm Station
Mirant: Birchwood Station

Fuel Tech – CFD & Injection

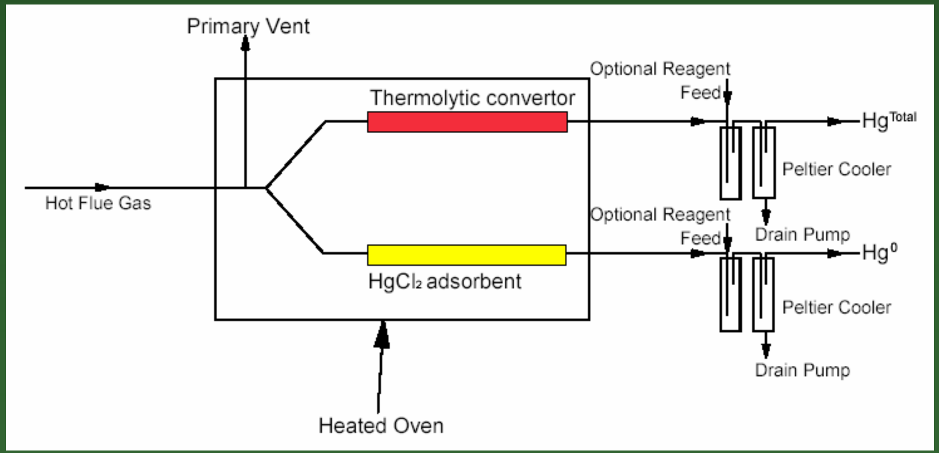
- Over 200 boiler SNCR injection installations
- Providing CFD modeling & injection consultation





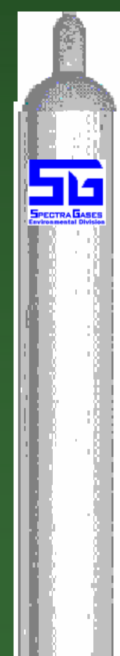
PS Analytical – Dry-Converter CMM

- Leading CMM supplier (Sir Galahad)
- Trying out new dry $Hg^{(+2)}$ converter

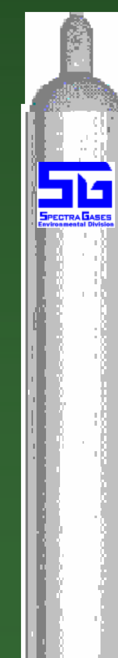


Spectra Gases – Oxidized-Hg Standard

- Leader in Hg calibration gas for CMMs
- Trying out new Mercal^{TM} $Hg^{(+2)}$ calibration system



$Hg^{(0)}$ + Cl_2



= $HgCl_2$

Program for Each Long-Term Test Site

- Qualification Testing
- Baseline Testing
- Parametric Testing
- Long-Term Testing (24 hrs x 30 days)
- Support Activities

Example Parametric Test Matrix

Example Parametric Test Matrix	Inj.Rates
PACs	
Norit Darco FGD (Standard)	XX X X
B-PAC Sorbents	
A5 with Base PAC 1 (Standard)	X X X X
A5 with Base PAC 2	X X X
A5 with Base PAC 3	X X X
A6	X X X
Condition or Production Variations	
Variation 1 (e,g. finer grind)	X X X
Variation 2 (e,g. higher Br)	X X X
Variation 3 (e,g. lower Br)	X X X
Variation 4 (e.g. other temp.)	X X X
Variation 5 or Repeats	X X X
100% Subbituminous	
A5 with Base PAC 1 (Standard)	X X X X
Norit Darco FGD	X X X

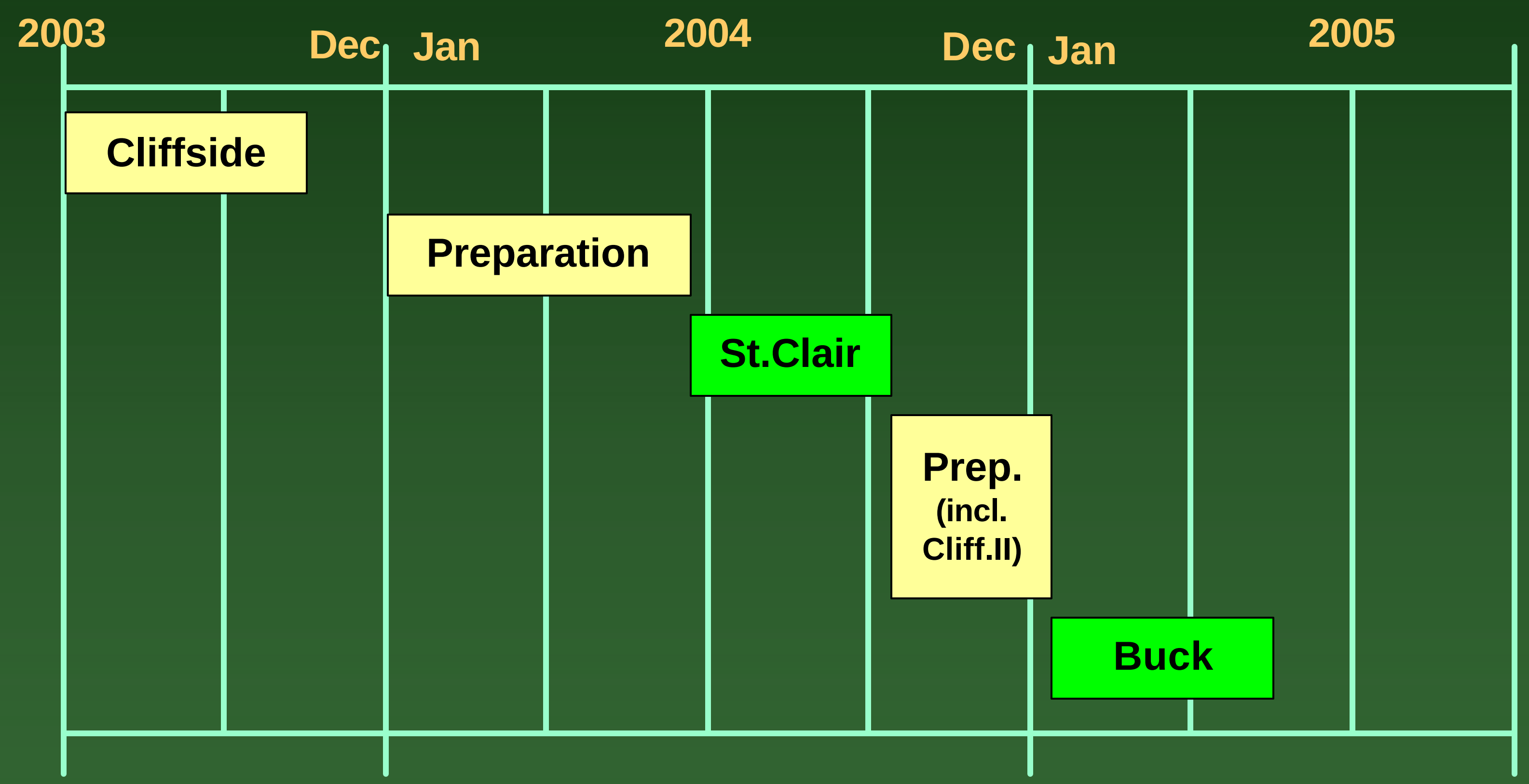
<u>Current Schedule</u>

Begin Baseline CMM	June 22, 2004
Parametric Testing	July 5 – Aug 20
Long-Term Testing	Sept 7 – Oct 6

<u>Testing Includes:</u>

- Corrosion coupon testing
- Flue-gas halogen testing

Schedule


2003
Dec
Jan
2004
Dec
Jan
2005
Cliffside
Preparation
St.Clair
Prep.
(incl.
Cliff.II)
Buck

Project Progress to Date

1. St. Clair Qualification Testing at Pleasant Prairie
2. Buck Qualification Testing at Cliffside
3. Equipment Assembly for Long-Term St. Clair Testing

St. Clair Qualification Tests at Pleasant Prairie

Apogee EPRI PoCT Slipstream Tests

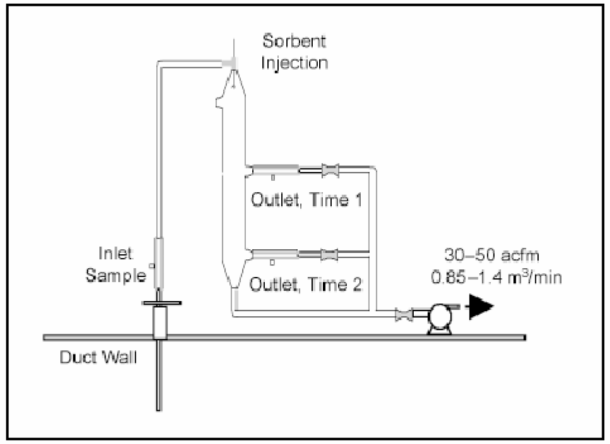
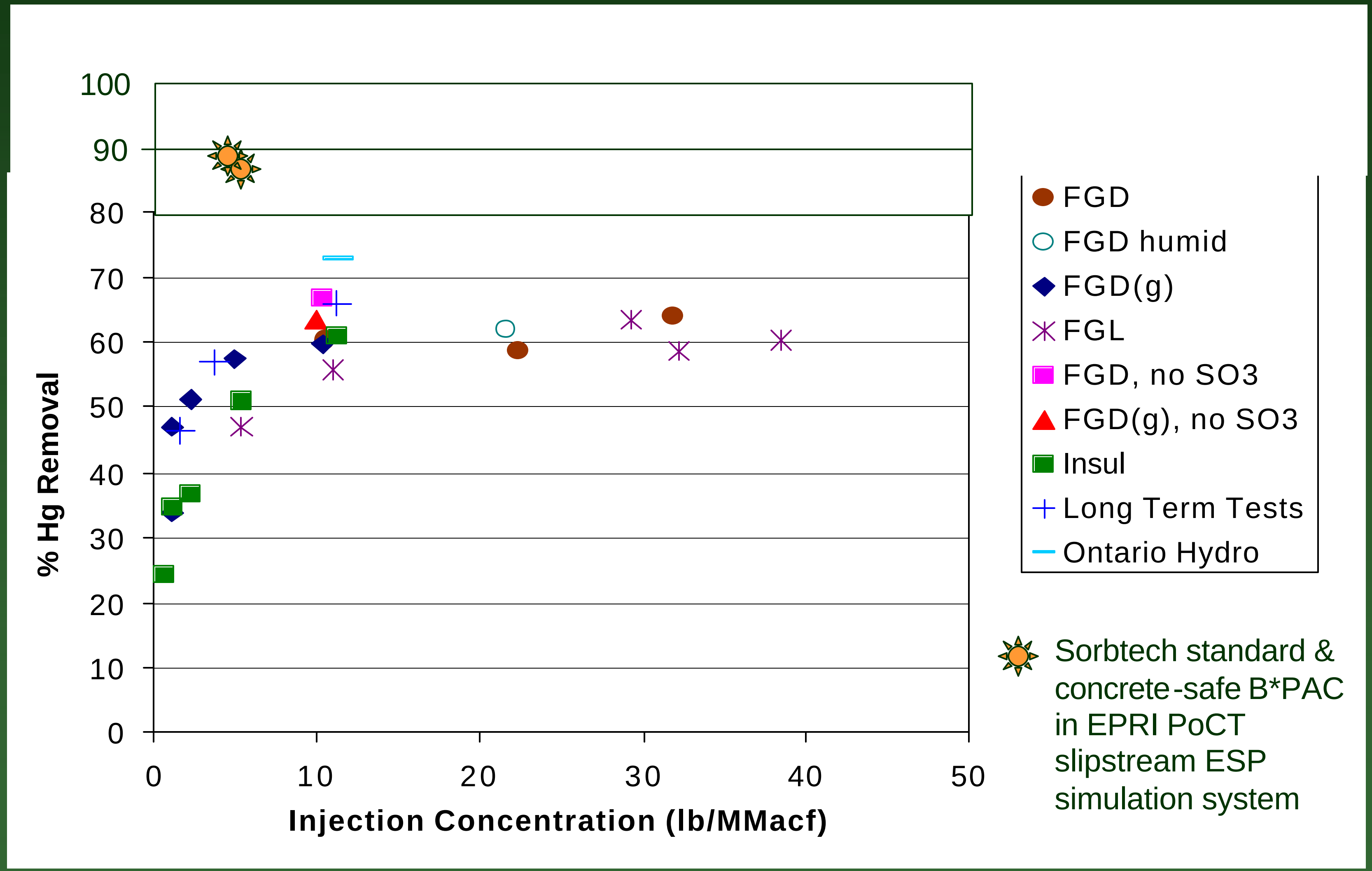


Figure 3. PoCT residence time module.

Using a slipstream of plant gas, the "residence chamber" module simulates in-duct Hg capture into a cold-side ESP.

Pleasant Prairie – ADA-ES & Recent Apogee Tests



Cost Effectiveness with an ESP and PRB

- For Subbituminous Coal with a CS-ESP:

If 4 lb/MMacf of $0.75/lb Brominated PAC injected into Pleasant Prairie's 12 µg Hg/Nm³ similarly provided 90% Hg removal with just an ESP:

$$\left(\frac{4\,lb\ sorbent}{1{,}000{,}000\,acf}\right)\left(\frac{Nm3}{(90\%)12mg\,Hg}\right)\left(\frac{\$0.75}{lb\ sorbent}\right)\left(\frac{1.5\ acf\ @\,300F}{1\,scf}\right)\left(\frac{35.3scf}{Nm^3}\right)\left(\frac{10^9\,mgHg}{2.2\,lb\ Hg\ removed}\right) = \$6{,}700 / lbHg.$$

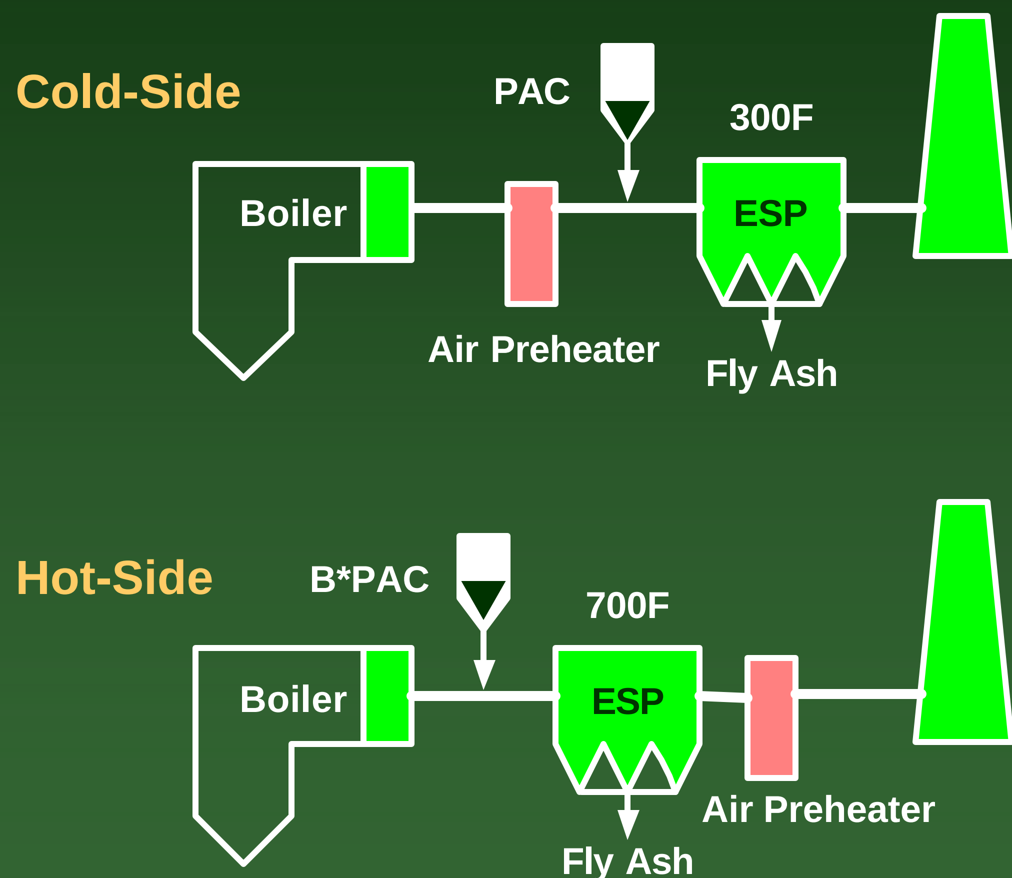
Avg. Control Cost: ~<u>$7,000 /lb Hg removed</u>

~90% less than current estimates.

We Need to Recalibrate Our Thinking:

- Most prior plain-PAC data is largely irrelevant now, and plain-PAC demonstrations are obsolete.
- With B*PAC, mercury reductions can be be much less expensive than is generally believed.
- Mercury control at lignite & subbit. plants will be the easiest and cheapest; it's the bituminous coal plants that will be the tougher and more expensive.

Buck HS-ESP Qualification Testing at Cliffside



ESP Temperature

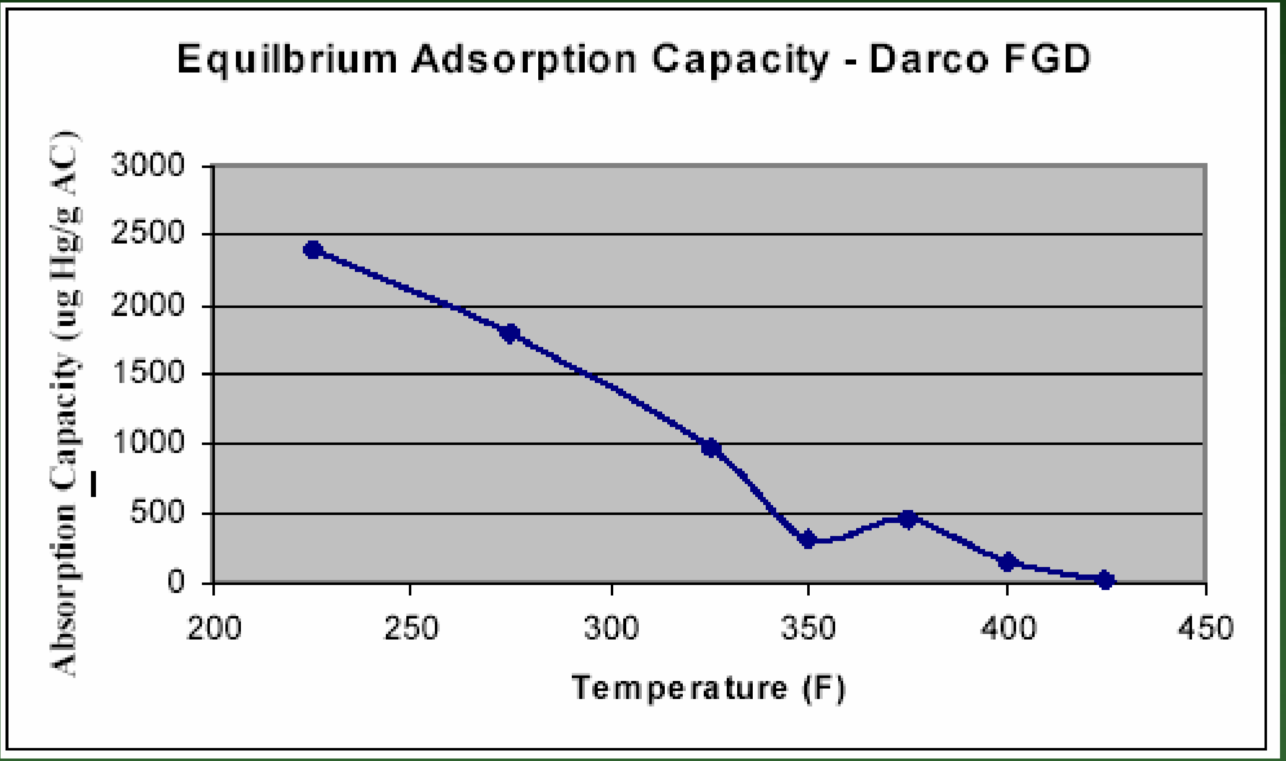
250 – 400 ^{o}F

500 – 800 ^{o}F

No Native Hg Removal in Hot-Side ESPs

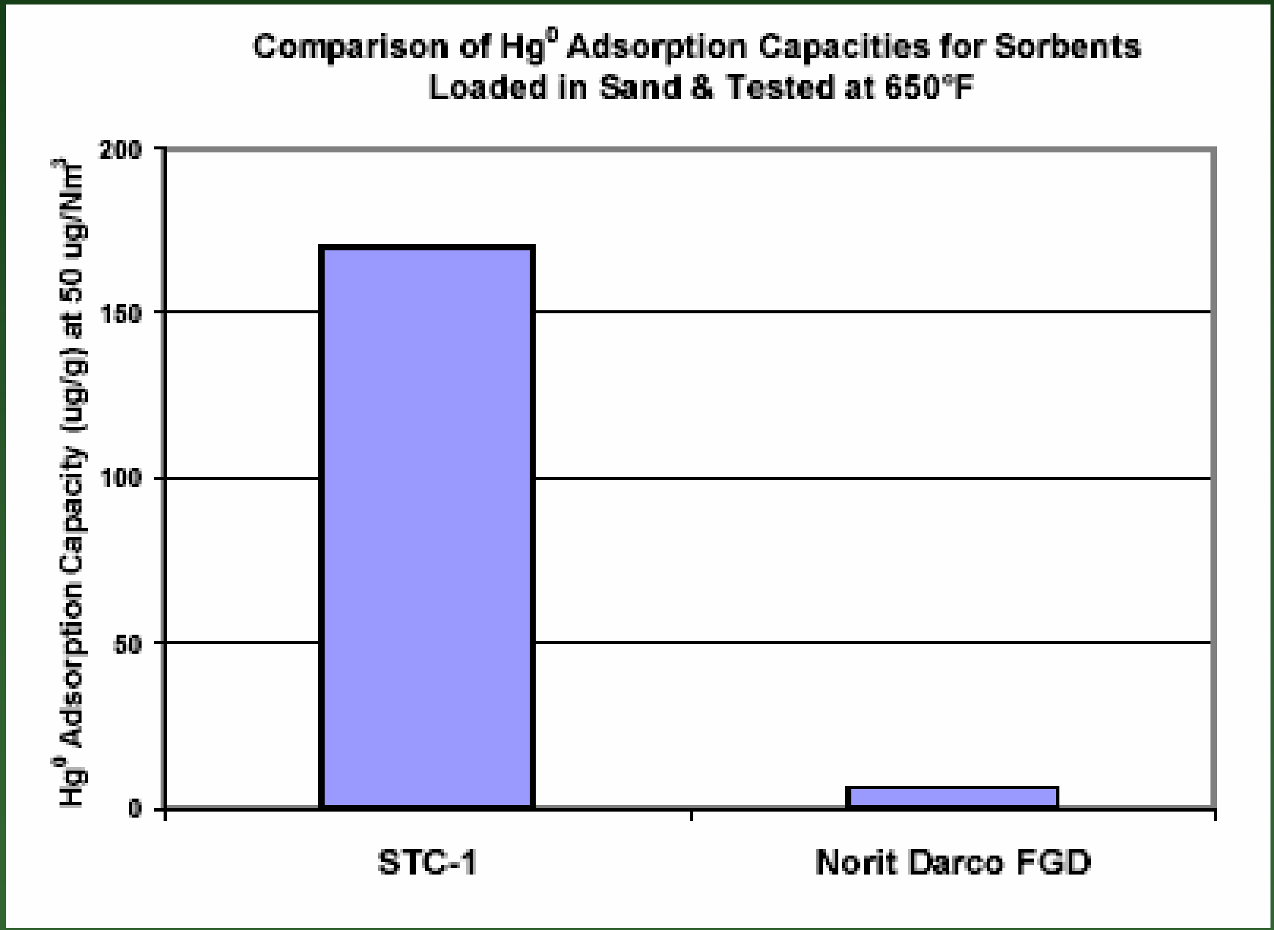
Of 14 Hot-Sides in ICR Testing: (Each plant avgs. 3 OH triplicates)		Hg (µg/Nm³) (p)	Hg (µg/Nm³) (+2)	Hg (µg/Nm³) (0)
Bitum. HS-ESP only, Avg. of 4 plants	In	0.7	3.7	2.8
	Out	0.3	3.7	2.5
Subbit. HS-ESP only, Avg. of 4 plants	In	0.1	2.3	10.7
	Out	0.1	2.3	9.2
Bitum. HS-ESP/Scrubber, 1 plant	In	0.0	8.7	3.9
	Out	0.0	1.7	4.9
Subbit.HS-ESP/Scrubber, Avg. of 5 plants	In	0.5	2.2	3.0
	Out	0.1	0.5	3.5

And Injected PAC Won't Adsorb Hg at 700ºF

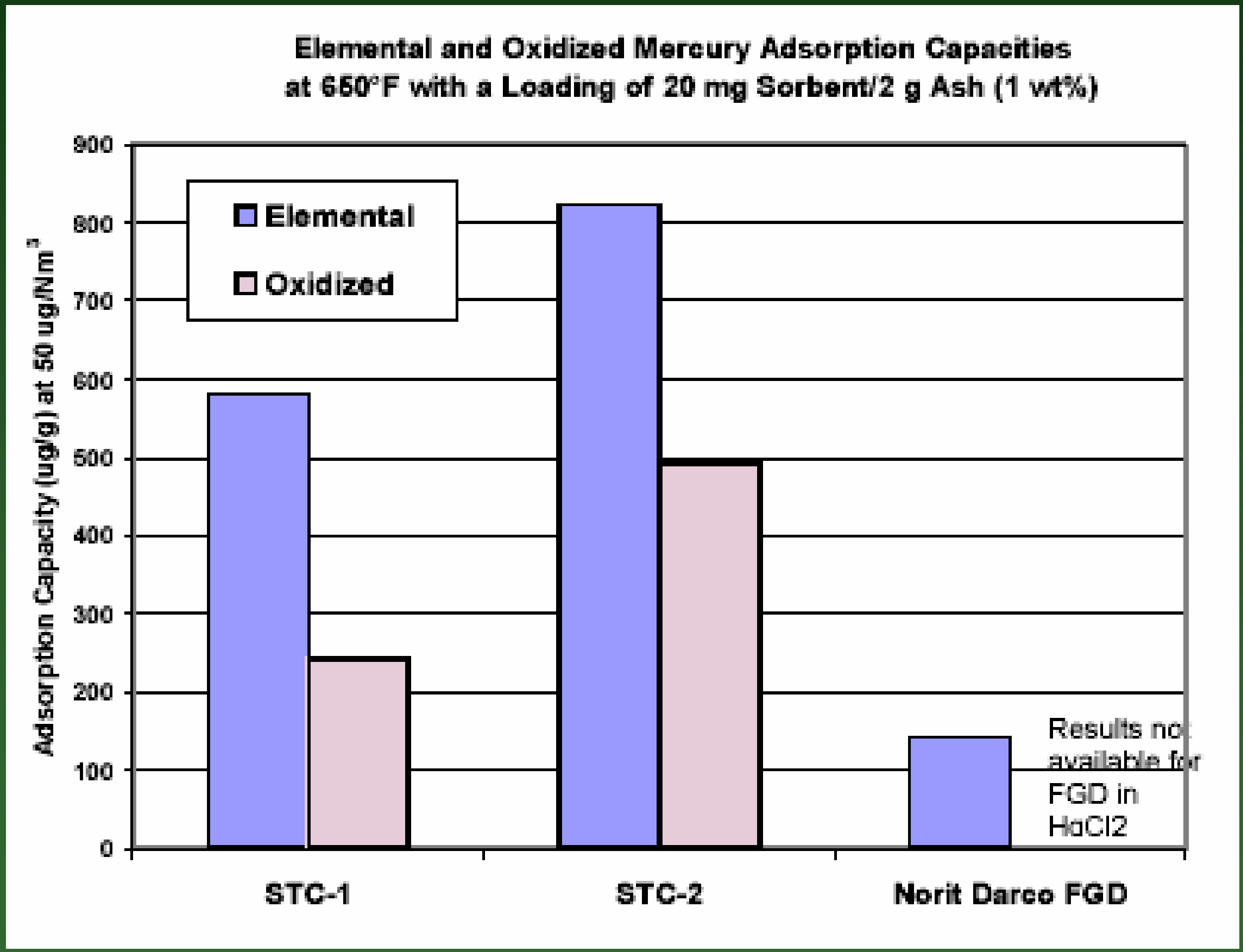


Durham, M., "Results from Four Full-Scale Field Tests of ACI for Control of Mercury Emissions," Utility MACT Working Group, Washington DC, March 4, 2003.

URS/EPRI High-Temp. Lab Fixed-Bed Test



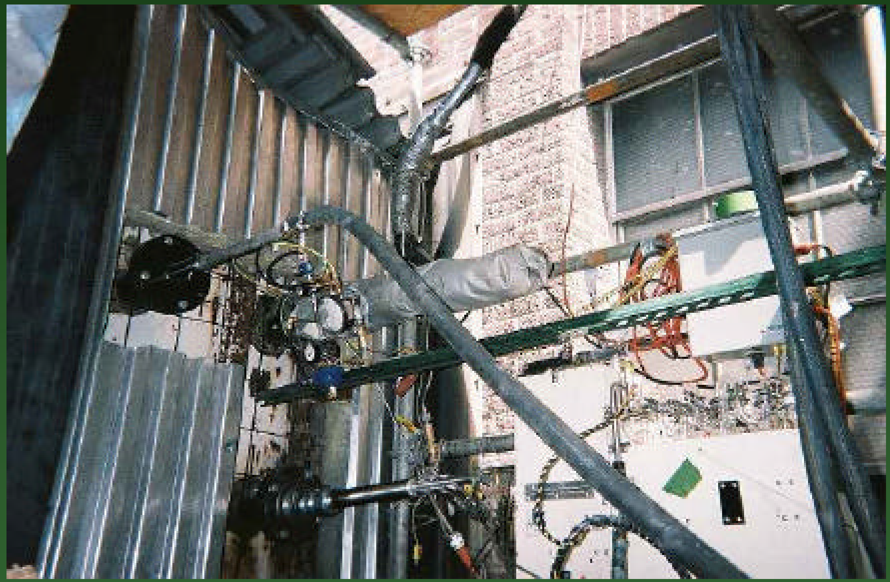
URS/EPRI High-Temp. Lab Fixed-Bed Test



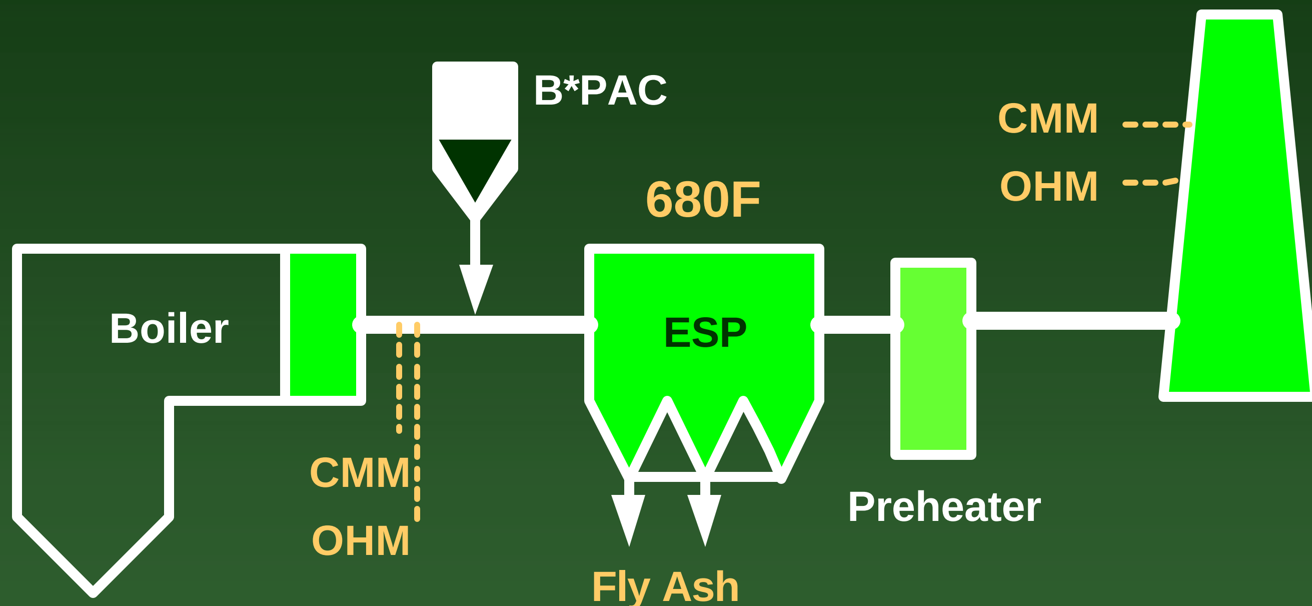
Hot-Side Testing at Duke's Cliffside Plant

Coal Type:	Low-S Bitumin.
Boiler:	No. 2 (Unit 2)
Boiler Type:	Tangential
Particulates:	Hot-Side ESP
ESP Stream Size:	40 MWe
ESP Inlet Temp.:	650-700^{o}F
SCA :	240 ft^2/K acfm
Avg. Coal Hg:	0.08 ppm
Avg. Coal Cl:	500 ppm

Cramped Retrofit & Uneven Flow

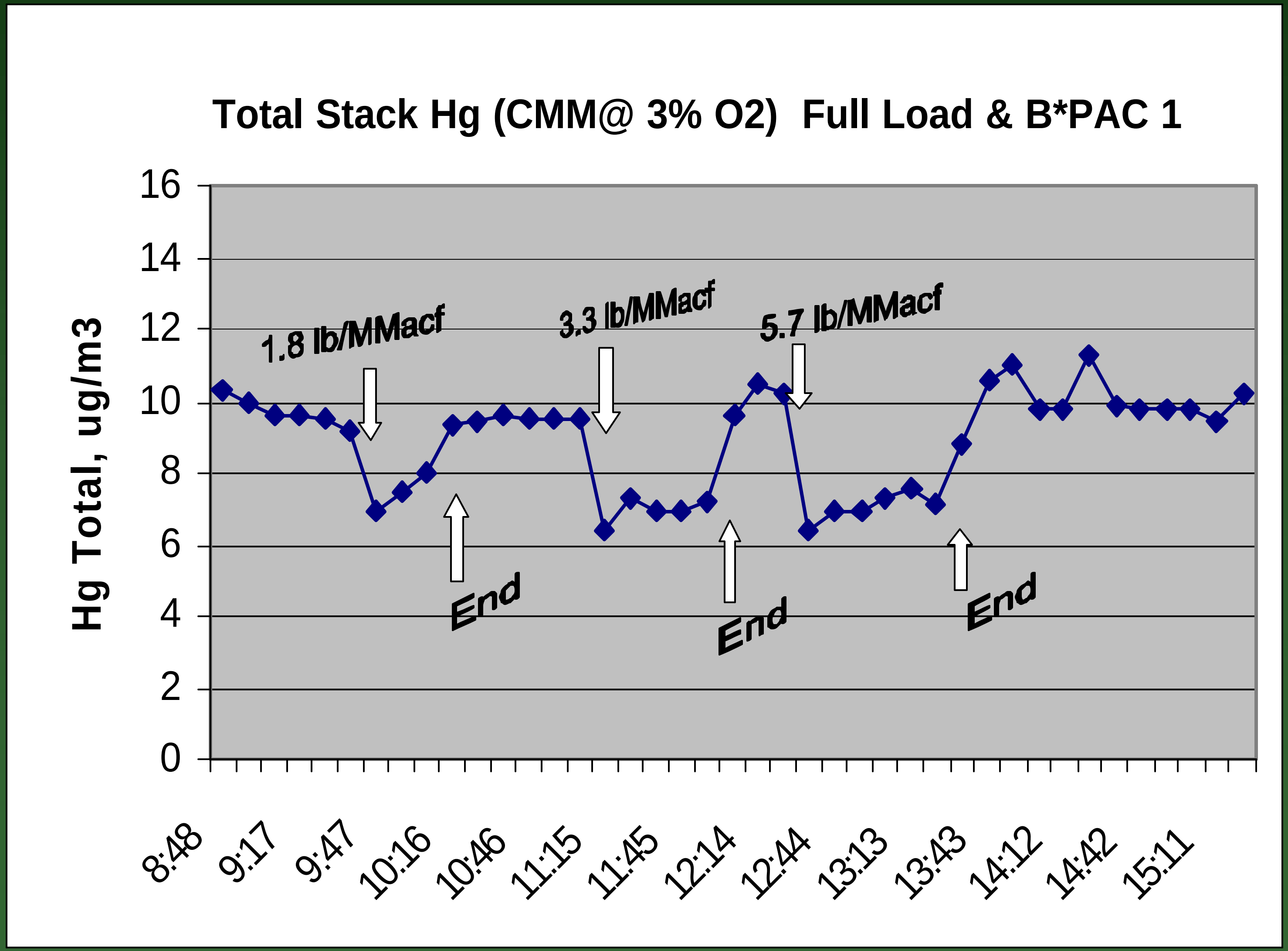


Measurements & Baseline

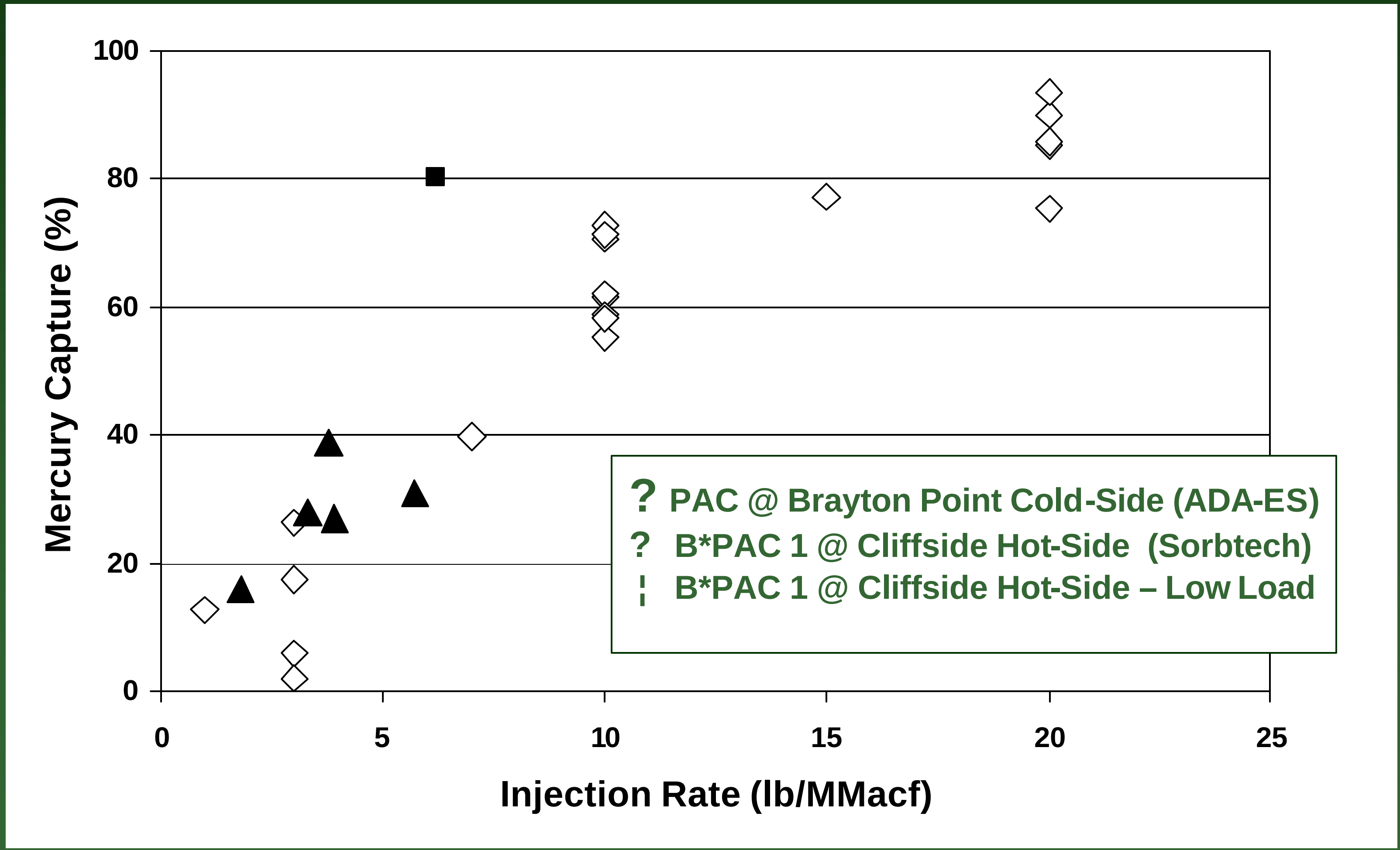


Baseline Mercury:	**~9 ug/Nm3 Hg(+2)**
	~1 ug/Nm3 Hg(0)
	0 ug/Nm3 Hg(p)
Baseline Hg Removal:	**0% - 4%**

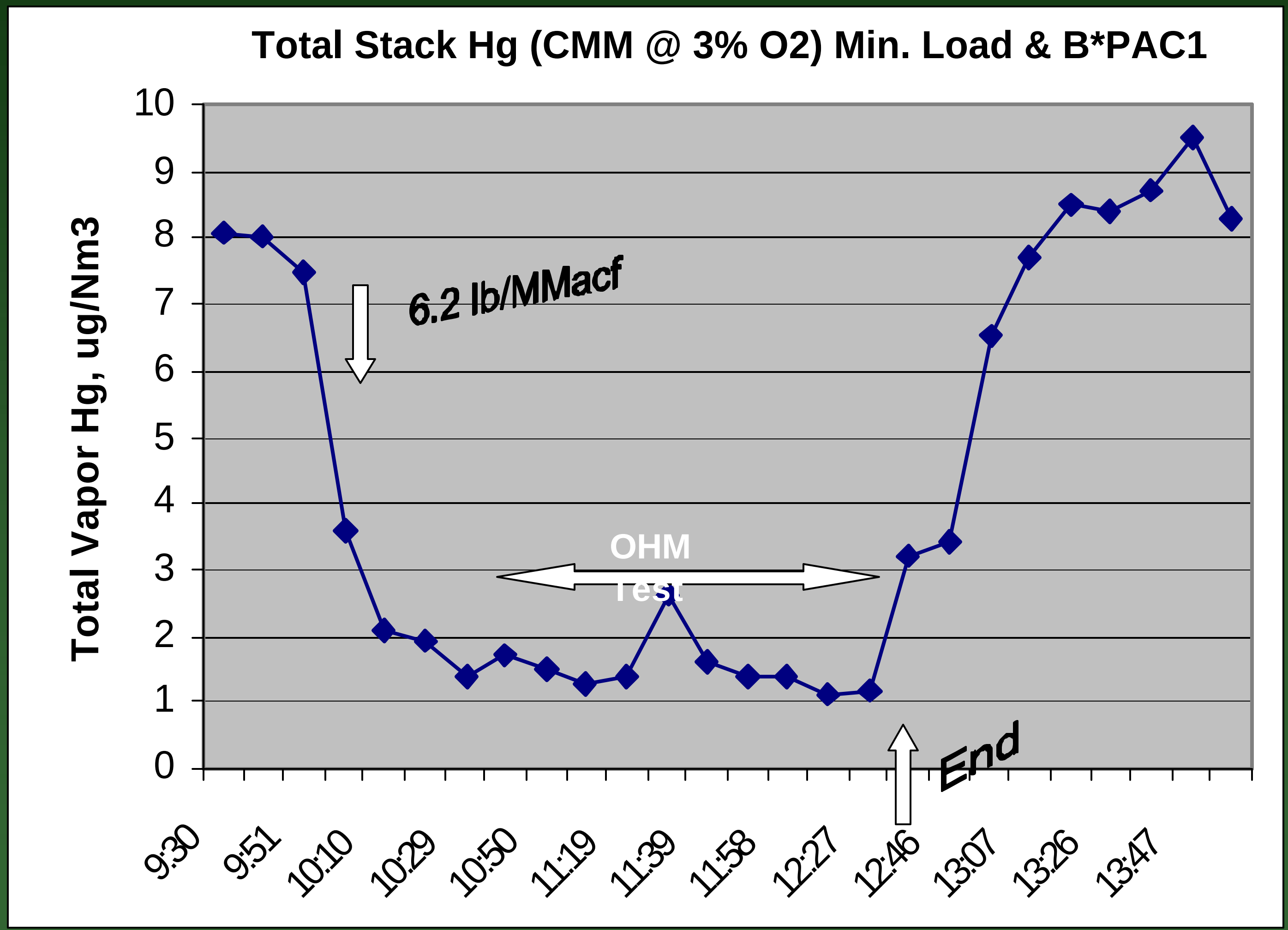
PS Analytical Sir Galahad CMM Results



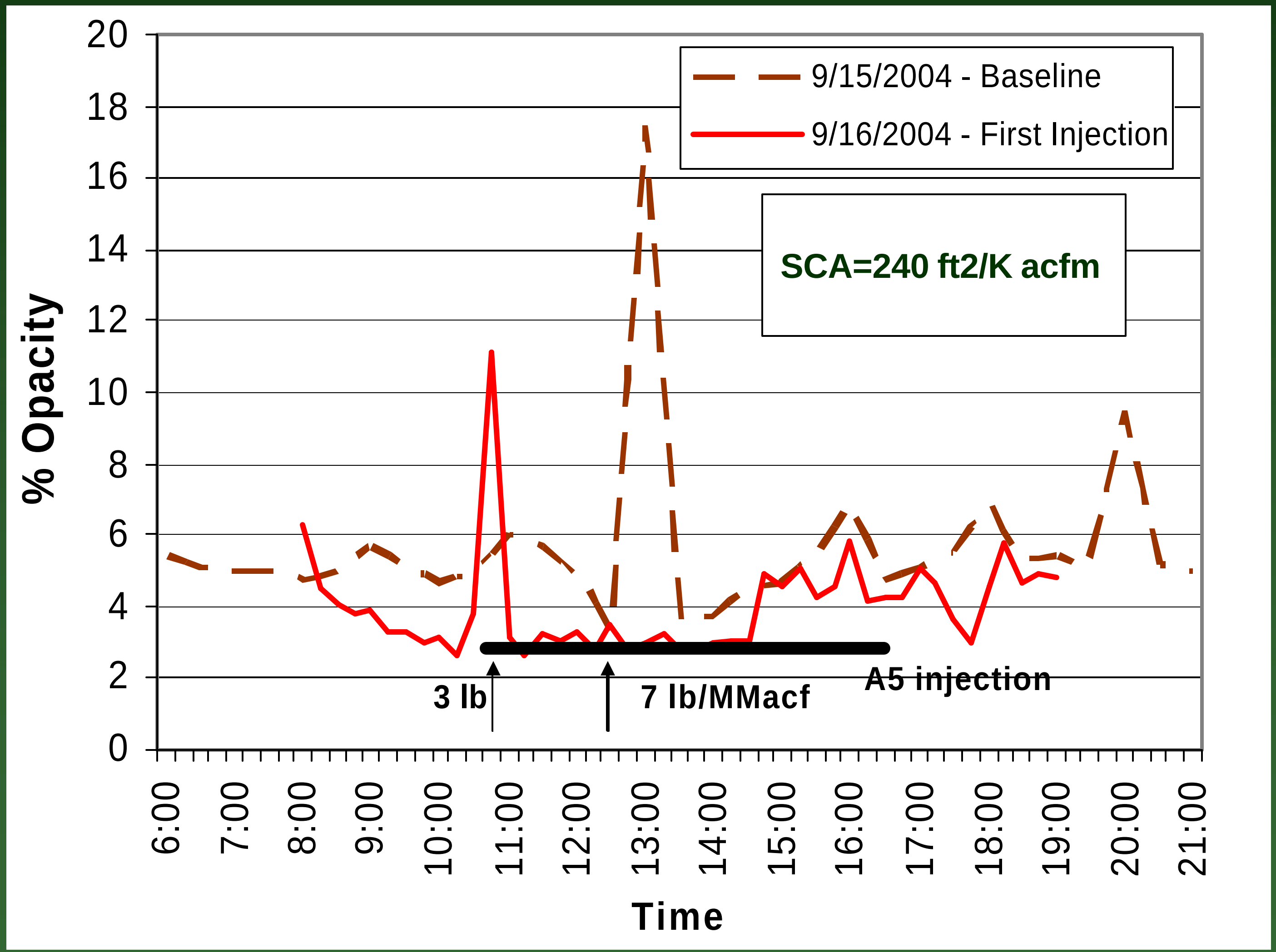
Performance Similar to a Cold-Side



Operating Condition Variation



Balance-of-Plant Effects: Opacity



Cost Effectiveness on Cliffside's HS-ESP

If 5 lb/MMacf of $0. 75/lb Brominated B-PAC™ sorbent injected into 10 µg/Nm³ of Hg at Cliffside provided 40% Hg removal:

$$\left(\frac{5\,lb\,sorbent}{1{,}000{,}000\,acf}\right)\left(\frac{Nm3}{(40\%)10mg\ Hg}\right)\left(\frac{\$0.75}{lb\,sorbent}\right)\left(\frac{2.5\,acf\ @\,700F}{1\ scf}\right)\left(\frac{35.3scf}{Nm^3}\right)\left(\frac{10^9\,mgHg}{2.2\,lb\ Hg\ removed}\right)=\$38{,}000/\,lbHg.$$

At 6 lb & 80% removal, costs = $22,000 /lb Hg removed.

And we are going to return this fall for add'l "Cliffside II" tests, aiming for 4 lb & 90%, for costs ~$14,000 /lb Hg.

Hot-Side ESP Conclusions

1. Hot-Side ESPs have little to no intrinsic Hg removal and little to none with injected PAC.

2. Brominated PACs, on the other hand, can remove Hg in hot-side ESPs: 30 - 40% Removal @ 5 lb/MMacf.

3. 80% Hg Removal @ 6 lb/MMacf in a hot-side ESP is possible under some conditions with B*PAC.

4. Opacity & waste disposal do not appear to be issues.

5. Of course, more testing of longer duration is needed to confirm and improve upon these results.

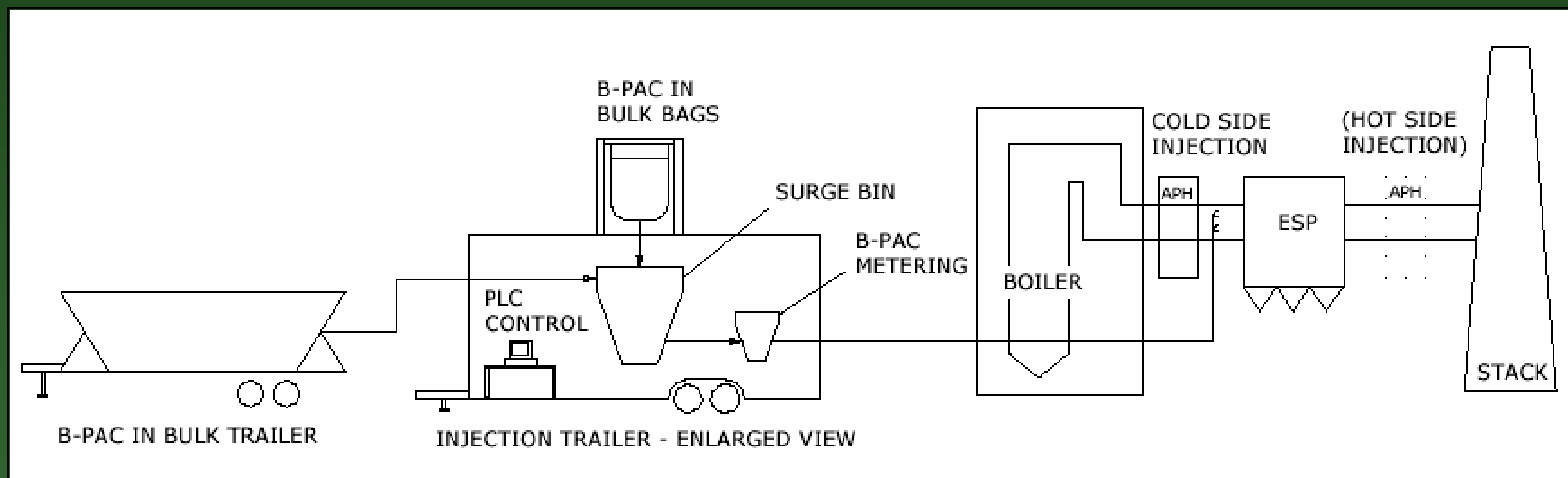
Preparations for Long-Term St. Clair Testing

*** Confidential & Trade Secret *** Confidential *** Confidential & Trade Secret ***

B-PAC Production for Long-Term Tests

*** Confidential & Trade Secret *** Confidential *** Confidential & Trade Secret ***

Injection System for Full-Scale Tests



Sorbent Technologies' Future Plans

DOE NETL Advanced Sorbent Demonstrations:

Dates	Testing	ESP	Coal	Plant	Owner .
(Spring 2004	Short	Cold-Side	Low-S Bitum.	Yates	Southern)
Summer 2004	Long	Cold-Side	Subbituminous	St. Clair	Detroit Ed.
Fall 2004	Short	Hot-Side	Low-S Bitum.	Cliffside	Duke
Winter 2004	Long	Hot-Side	Low-S Bitum.	Buck	Duke