

REINHOLD ENVIRONMENTAL Ltd.



2010 APC Round Table & Expo Presentation

July 18-20, 2010, in Concord, NC / Hosted by Duke Energy

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 ALBEMARLE® | Sorbent Technologies

Concrete-Friendly™ Mercury Sorbents

Daryl Lipscomb

2010 Reinhold APC Conference



Presentation Agenda

A circular logo with a green border and a white center containing the chemical symbol 'Hg' in a green font. The logo is positioned in the top right corner of the slide, overlapping a blue sky background and a grey stone texture.

1. Concrete Composition & Types of Fly Ash
2. The Fly Ash Story and the Importance of Fly Ash Sales Preservation
3. The Options for Fly Ash Preservation
4. C-PAC™ Introduction
5. Concrete test data with fly ash containing C-PAC™
6. C-PAC™ commercial accounts



Concrete Composition & Types of Fly Ash

Typical Concrete Composition

Hg

■ **Entrained Air (5% -8%)**

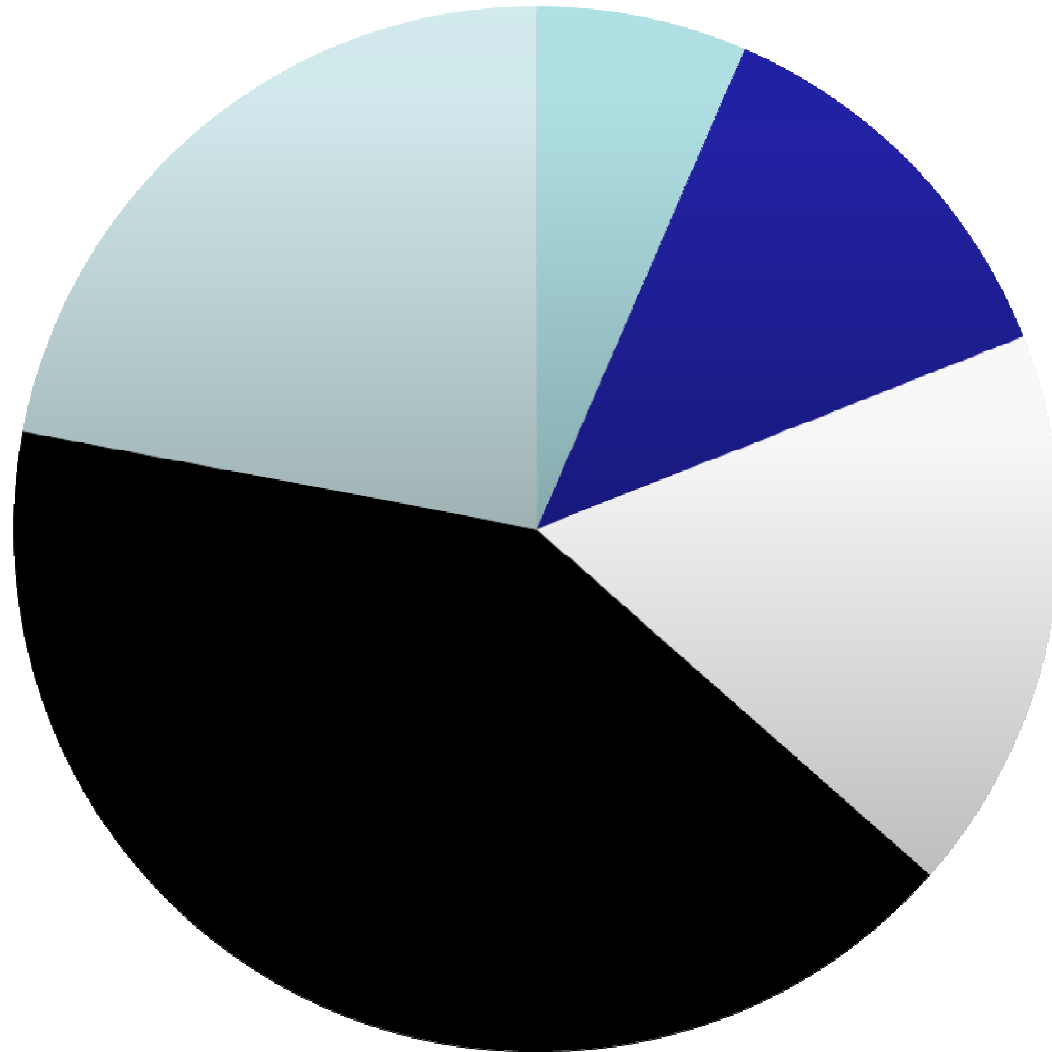
■ **Cement (10% - 15%)**
(Fly ash typically replaces 20% of cement)
(PAC ~ 1-3% of this 20% of this 10-15%)

■ **Water (15% - 20%)**

■ **Coarse Aggregate -
Gravel, Rocks (~40%)**

■ **Fine Aggregate - Sand
(~ 20%)**

~ 0.25% Chemicals



Two Classes of Fly Ash

A circular logo with a green border and a white center containing the chemical symbol 'Hg' in a green font.

Two major classes of fly ash (primary difference is amount of calcium, silica, alumina and iron content in the ash) are specified in ASTM C 618 on the basis of their chemical composition resulting from the type of coal burned:

Class C - normally produced from the burning of subbituminous coal and lignite

Class C fly ash usually has cementitious due to free lime (>20%)

Class F - normally produced from burning anthracite or bituminous coal

Class F is rarely cementitious when mixed with water alone (lack of free lime < 10%)



The Fly Ash Story and the Importance of Fly Ash Sales Preservation



A big success story of Reuse CCP – Use of Fly ash in concrete



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2008 Coal Combustion Product (CCP) Pro

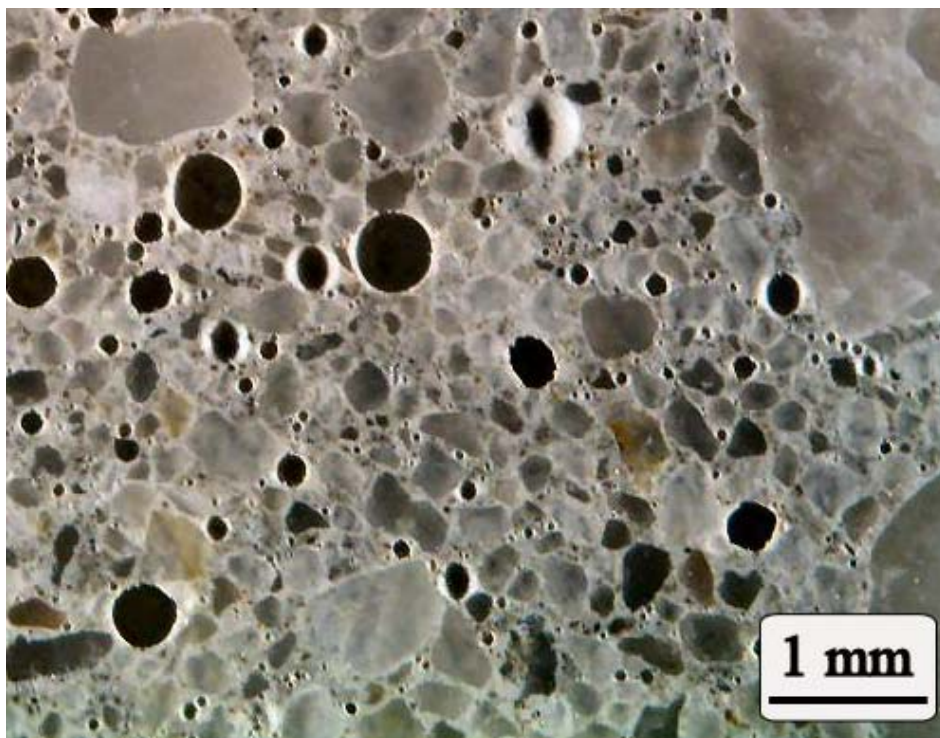
| Beneficial Utilization versus Production Totals (Short Tons) | | | | | | |
|--|------------|------------|-------------|------------|----------------------------|----------------------------|
| CCP Categories | Fly Ash | Bottom Ash | Boiler Slag | FGD Gypsum | FGD Material Wet Scrubbers | FGD Material Dry Scrubbers |
| 2008 Total CCPs Produced by Category** | 72,454,230 | 18,431,297 | 2,028,455 | 17,754,939 | 12,980,588 | 1,399,258 |
| 2008 Total CCPs Used by Category | 30,142,274 | 8,076,255 | 1,689,892 | 10,653,344 | 685,104 | 345,335 |
| Application Utilization Breakout | | | | | | |
| 1. Concrete/Concrete Products /Grout | 12,592,245 | 720,948 | 0 | 675,505 | 0 | 22,577 |
| 2. Blended Cement/ Raw Feed for Clinker | 3,174,264 | 610,194 | 0 | 413,740 | 0 | 0 |
| 3. Flowable Fill | 74,794 | 0 | 0 | 0 | 0 | 18,338 |
| 4. Structural Fills/Embankments | 8,012,825 | 2,996,388 | 178,363 | 0 | 0 | 130,566 |
| 5. Road Base/Sub-base | 1,027,568 | 767,013 | 0 | 0 | 0 | 0 |
| 6. Soil Modification/Stabilization | 627,810 | 431,664 | 0 | 0 | 0 | 60,115 |
| 7. Mineral Filler in Asphalt | 7,781 | 257,806 | 0 | 0 | 0 | 0 |

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, increased durability, added chemical resistance, and less global warming.
- Utilities are paid for cement-quality fly ash and avoid disposal expenses.



Air Voids Needed for Contraction and Expansion



Predictable, proper amount (4-8vol%),
proper size, & dynamic stability for freeze-
thaw capability



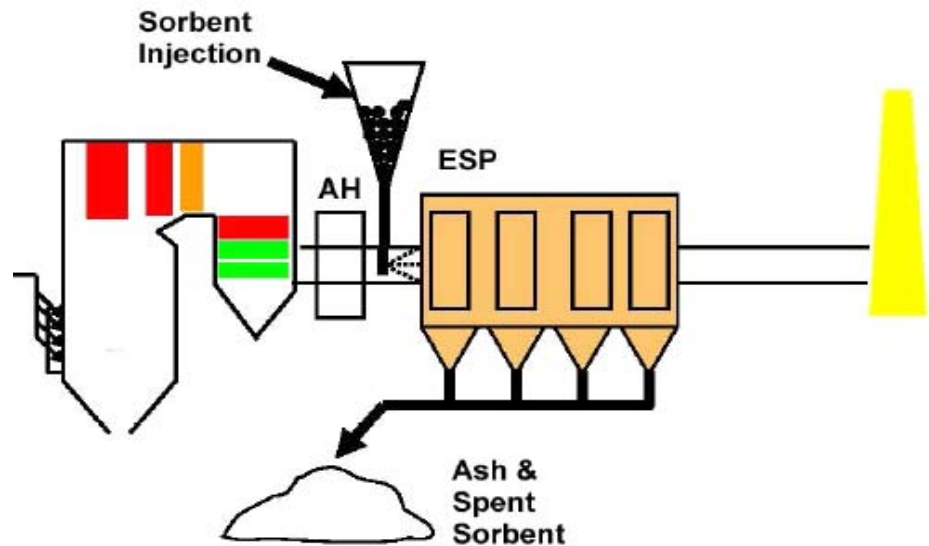
Compressed
Strength test

Mercury Emission and Control

Mercury Emission

- Coal-fired power plants are the largest federally unregulated source of mercury emissions.
- The leading mercury emission control technology is activated carbon injection (ACI).

Activated Carbon Injection (ACI)





Impact of ACI on Fly Ash Reuse

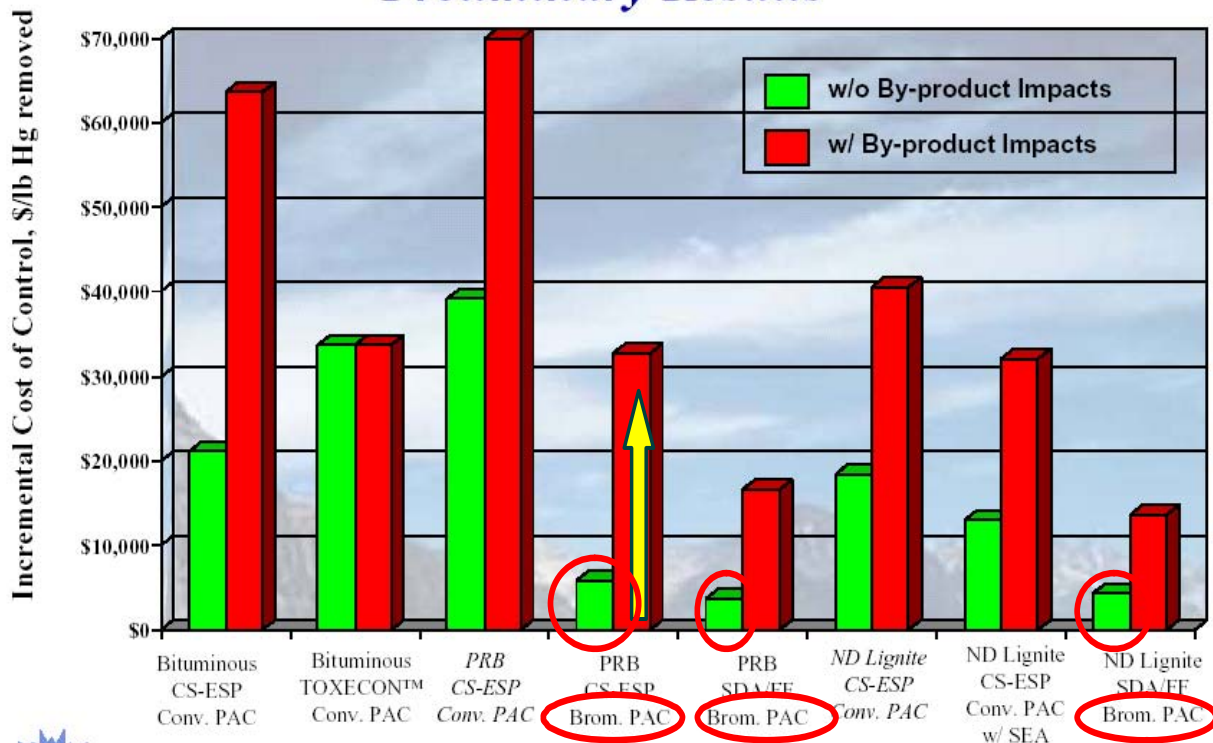
However, these mercury sorbents end up mixed in with the plants' fly ash, rendering it unsuitable for sale for concrete. This is due to the carbon's adsorption of air entraining admixture (AEA) chemicals included in the concrete mix.

Ash Problems with PAC Hg Sorbents and UBC

1. Adsorbs Air Entraining Admixtures (AEAs)
 - detergents added to concrete slurries to intentionally form bubbles for freeze-thaw capability
 - inevitable variations in the level of the effect
 - UBC or PAC adsorbs the AEAs
2. Carbon level per se - 6% ASTM LOI limit & 5% AASHTO limit - but the effective limit is much lower due to the AEA effects of the unburned carbon in the fly ash
3. Darkens the fly ash

High Impact of Lost of Ash Sale on Cost

Incremental Cost of 70% Mercury Control^a Preliminary Results



The loss of their fly ash sales along with the added cost of fly ash disposal poses both an economic and an environmental burden on the utilities, driving up the mercury emission control cost.



^a 60% mercury removal for italicized data labels.

T. Fooley, July 2005



The Options for Fly Ash Preservation

Potential Solutions

- Toxecon®
- A Concrete-Friendly™ mercury sorbent, C-PAC™
- Additives
- Mechanical/Magnetic Separation

Toxecon®

- Expensive to add an additional particulate collection device, fans, & pressure drop
- Loss of 15% - 20% of fly ash
- Potential for hopper fires due to high carbon/ash ratio



C-PAC™ Introduction

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 PAC sorbent so that it has minimal interfere with the AEA's -- while retaining its Hg performance
- Very effective even at elevated temperatures (> 800° F)
- In commercial use today

- Specifically designed to naturally be “concrete-friendly” to preserve fly ash sales
- Albemarle patent pending on concrete-friendly C-PAC™
- Somewhat more AEA required, but low effects & low truck-to-truck variability for consistent concretes
- C-PAC™ contains no added chemicals that can come off and unpredictably affect the concrete properties of the other fly ash components

C-PAC™ Properties

Table 1. Typical properties of C-PAC™

| | Properties |
|--|------------|
| Acid Blue 80 Index, mg/g | <15 |
| Bromine, wt% | 7 |
| Moisture, % | 8 |
| Iodine Number, mg/g | >500 |
| Tapped Bulk Density, lbs/ft ³ | 35 |
| Particle Size, less than 325mesh % | >95 |
| Ash Content, wt% | <12 |
| Ignition Temperature, °C | >400 |

Foam Index Testing – best used as an initial predictor for Concrete-Friendliness

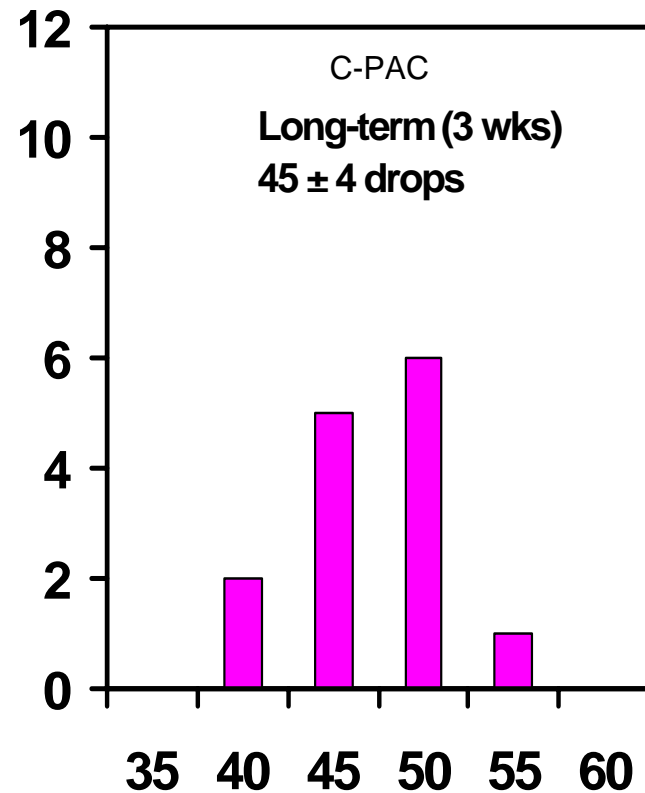
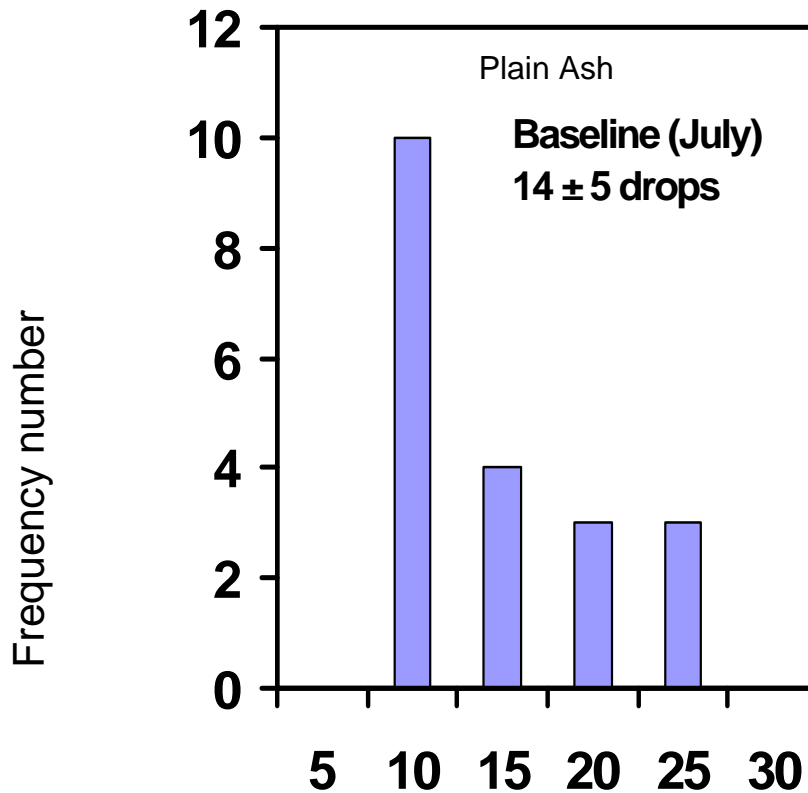
Problems with Foam Index test:

- Lack of repeatability
- Operator discretion
- Different & variable natural reagents
- Foam index is specific to the AEA
- Varying glassware & “drop” sizes,
- Non-standardized procedures,
- Dynamic, non-equilibrium test



Low Foam Index Variability

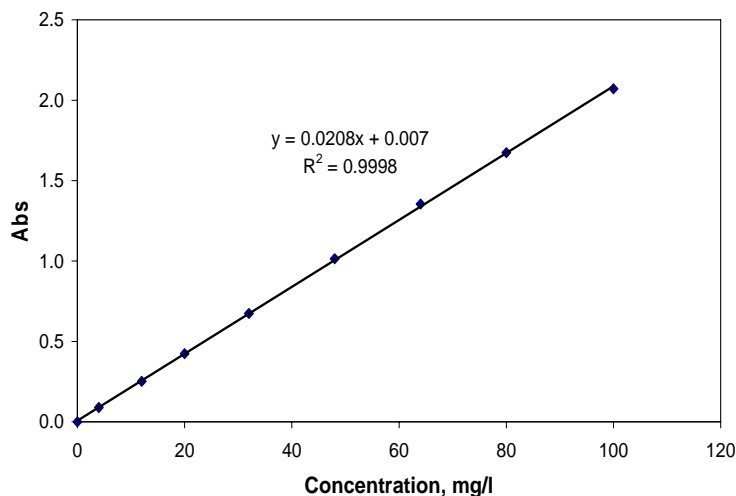
Data: Lafarge & Sorbtech



Standardized “Acid Blue 80 Index” Instead



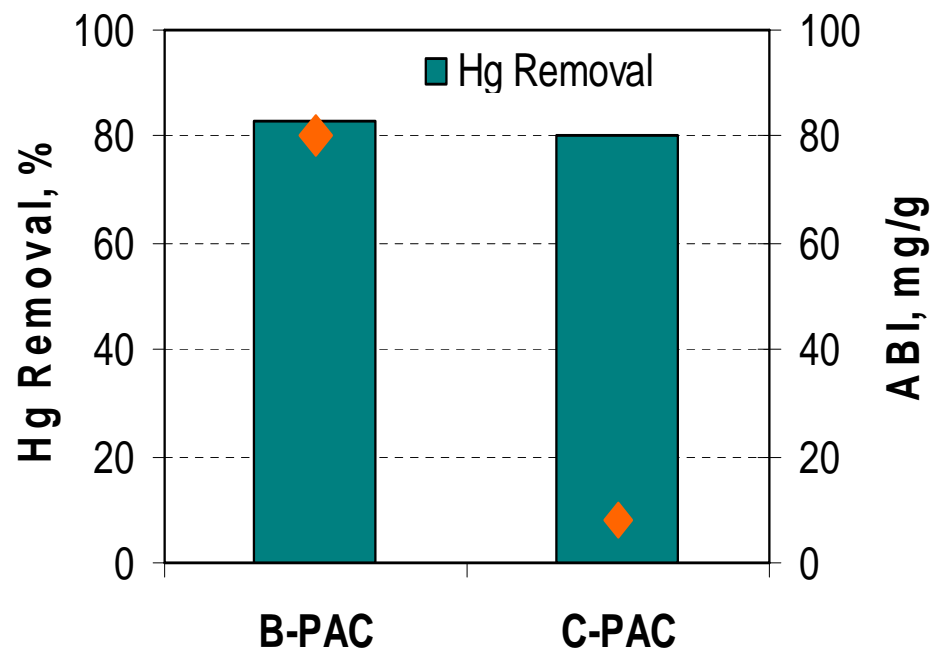
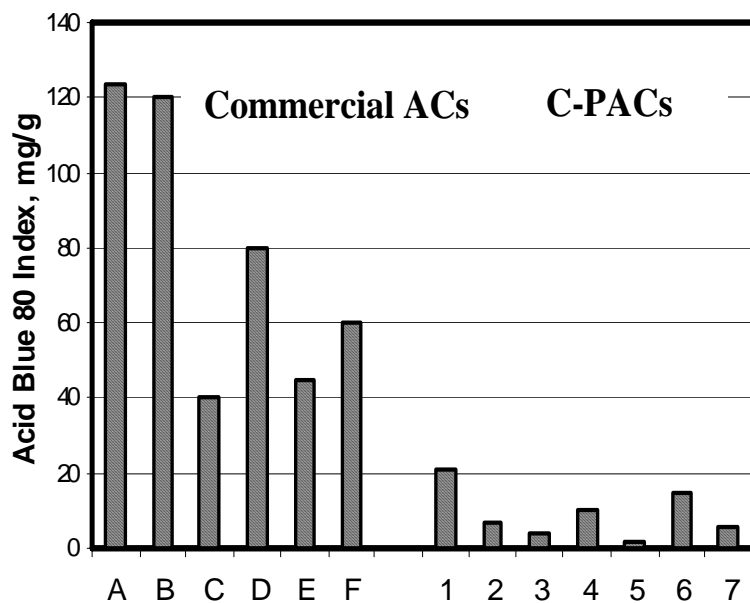
Working Curve of AB80 Solution



Similar to: ASTM D 3860-98 Standard Practice for Determination of Adsorptive Capacity of Activated Carbon by Aqueous Phase Isotherm Technique

1. Pre-dry sample at 150°C for 3 hours.
2. Add different dosages of dried PAC to 50ml of 100 mg/l AB80 solution and well stir.
3. Once an equilibrium, filter the carbon from the AB80.
4. Determine the concentration of the filtrate e.g. by a Perkin Elmer Lambda EZ201 Spectrophotometer.
5. Calculate the AB80 removed by the PAC from the change in the solution before & after PAC contact.
6. Plot the AB80 adsorption of the dosage carbon with the equilibrium concentration of AB80 solution.
7. Calculate the adsorptive capacity from a Freundlich isotherm plot at the original AB80 concentration, which is defined as Acid Blue Index (ABI).

C-PAC: Good Hg Sorbent with Minimum Impact on Fly Ash Concrete Application





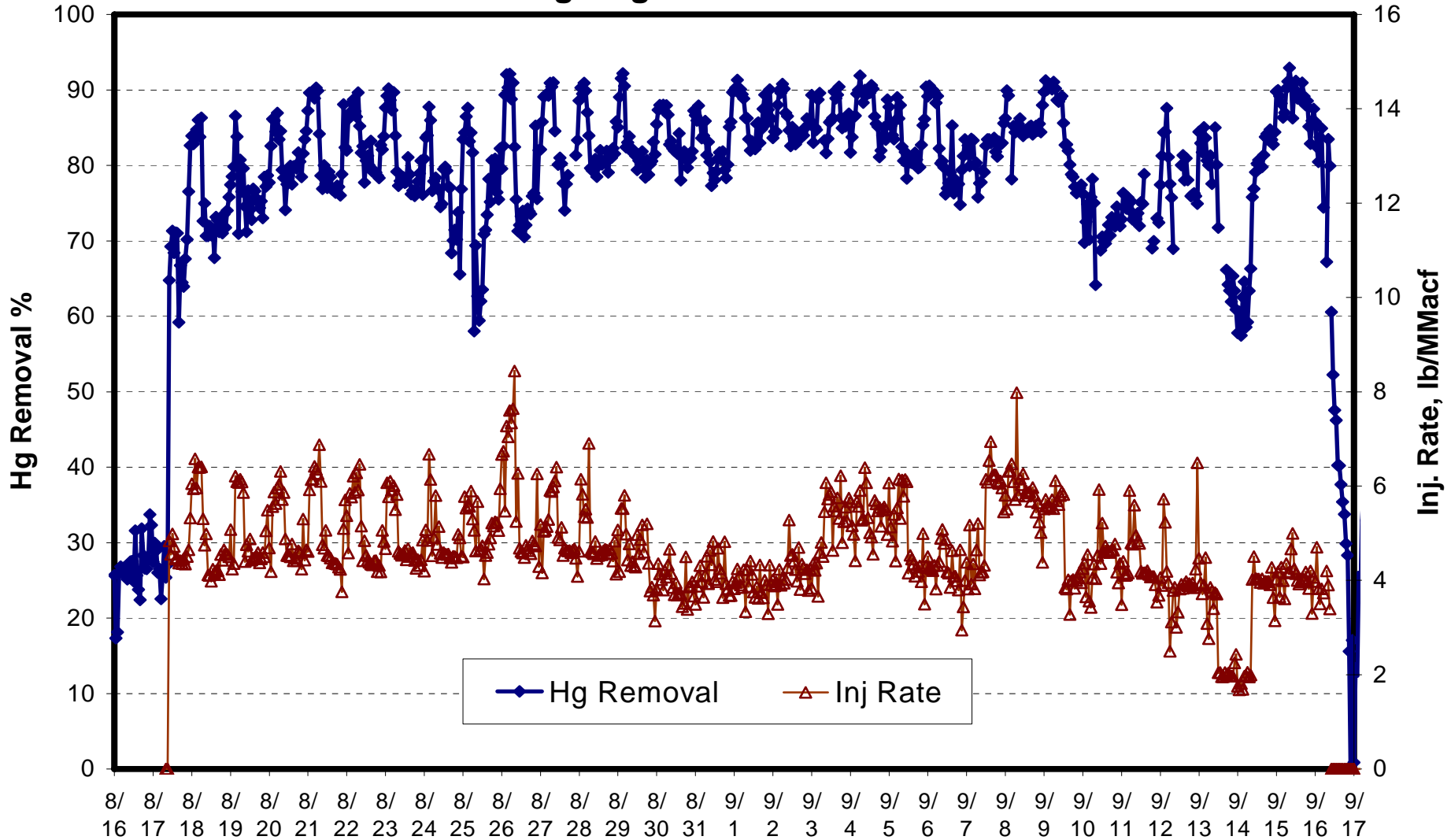
Hg

Concrete test data with fly ash containing C-PAC™

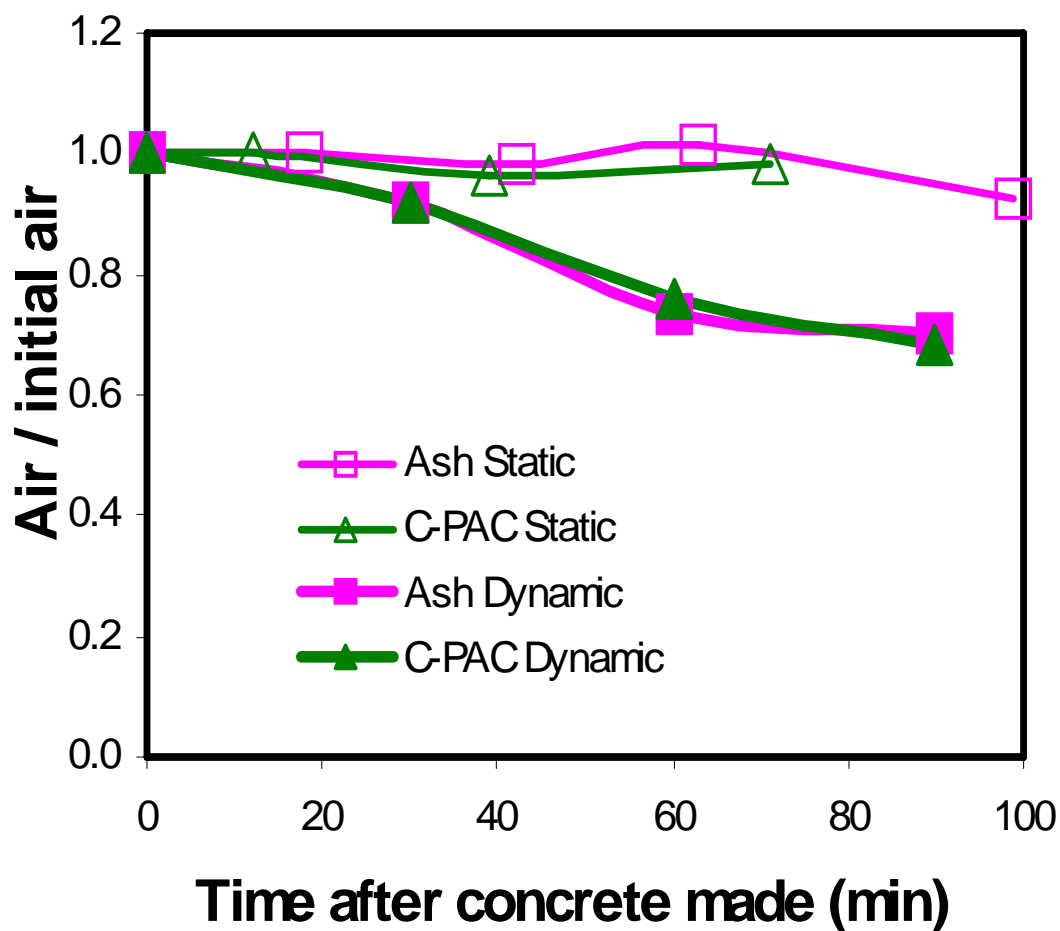
C-PAC™ at MWGen Crawford

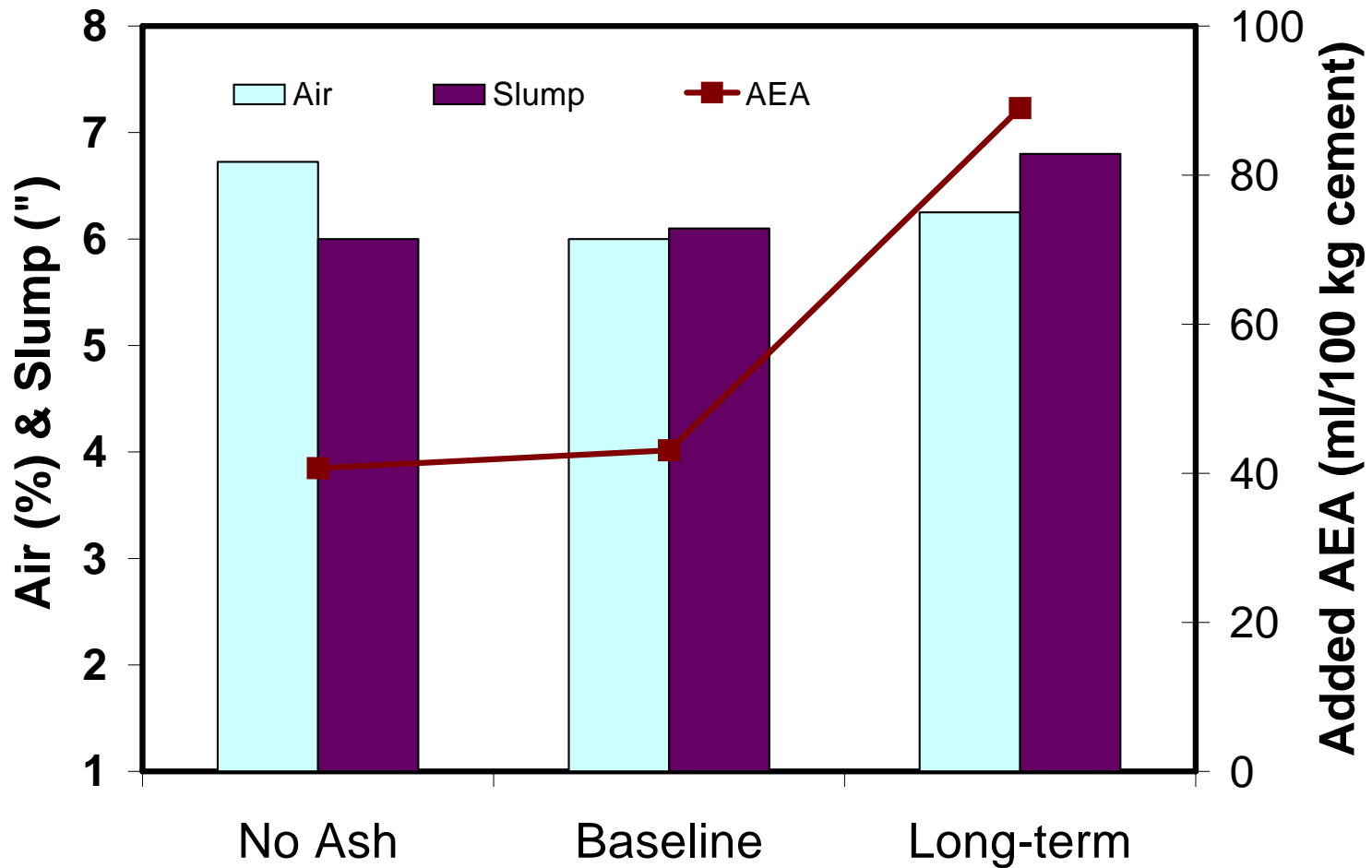


30-Day Hg Removal & Injection Rate
81% Average Hg Removal at 4.6 lb/MMacf



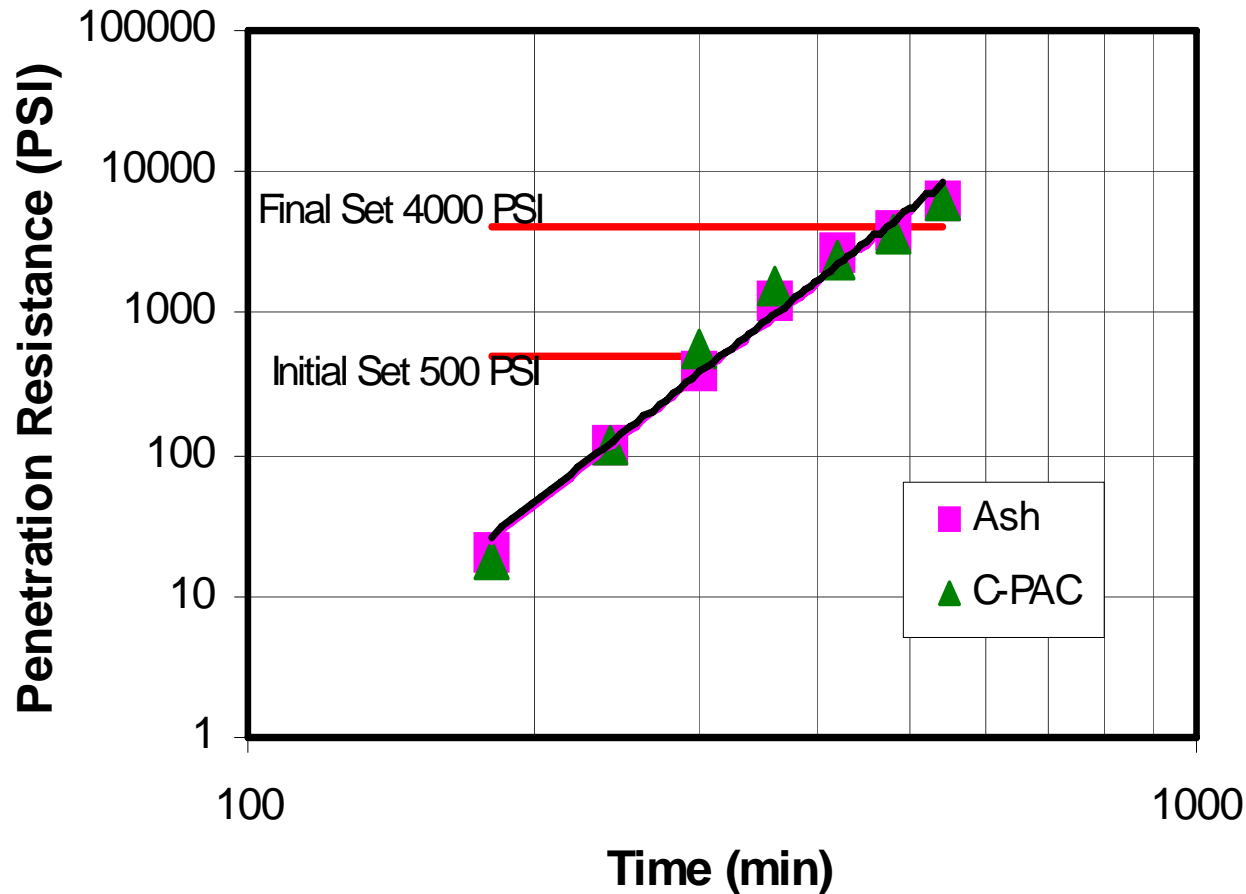
Identical Air Stability to Ash Without C-PAC





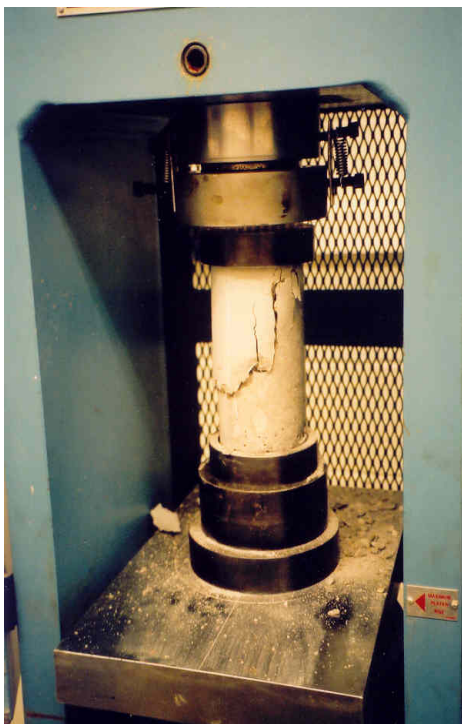


Setting Times the Same as Without C-PAC

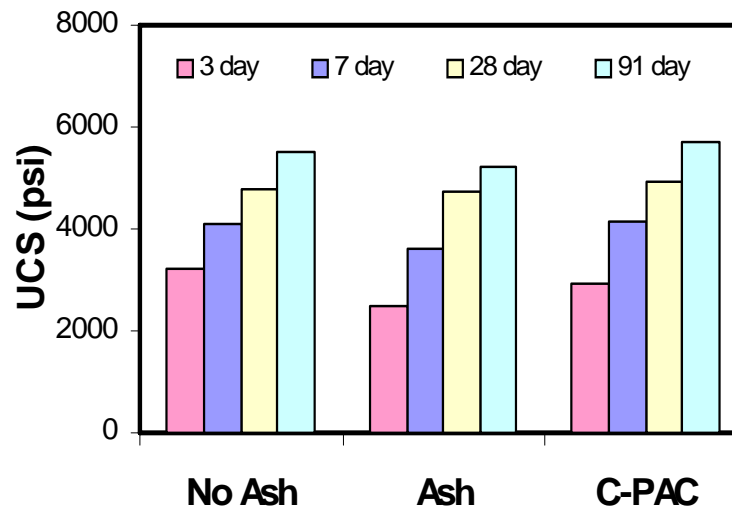


Same Compressive Strength

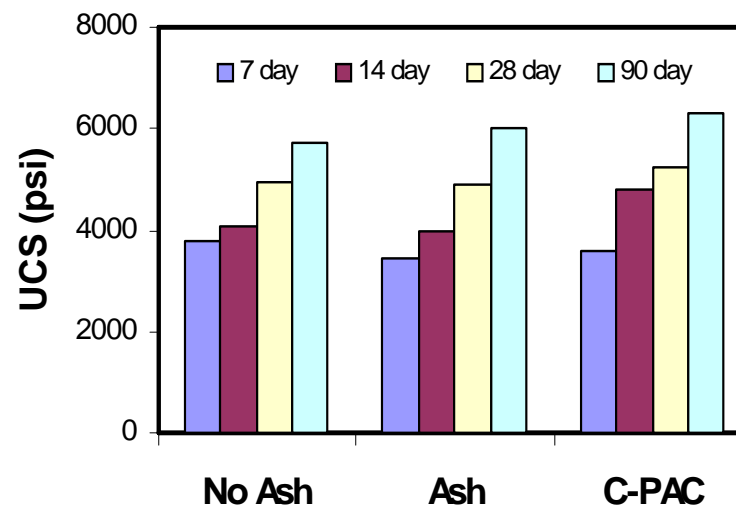
Hg



Headwaters data



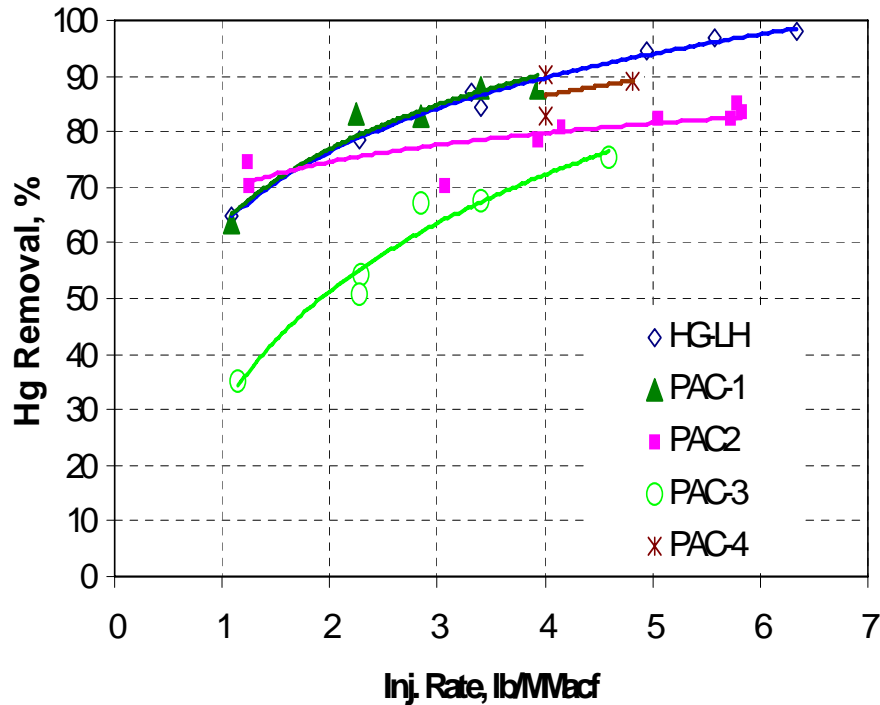
Albemarle data



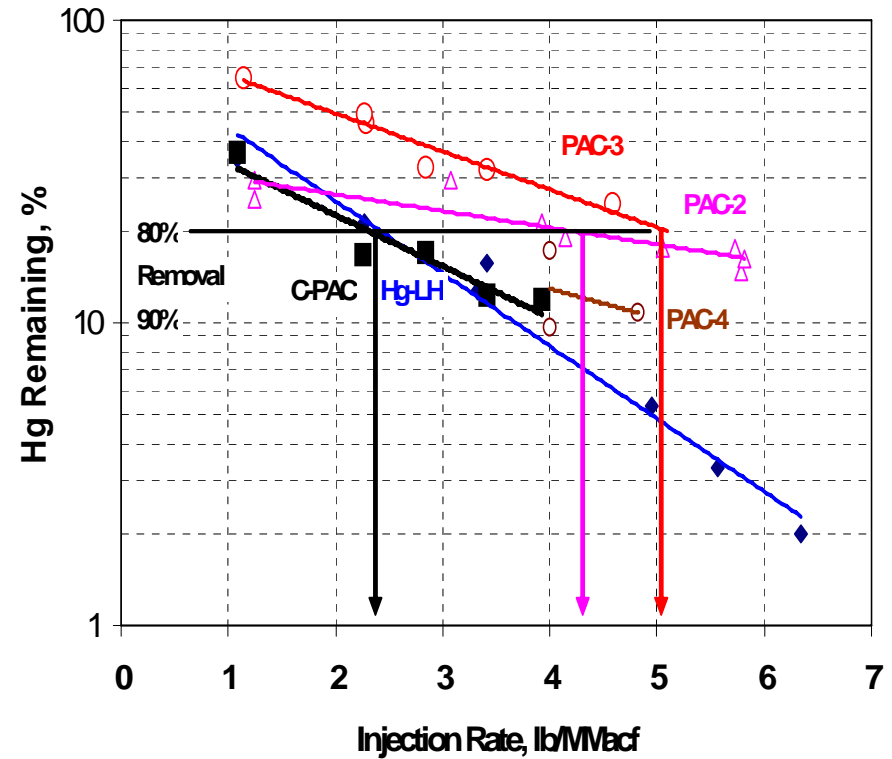
PGE Boardman Trials

Hg

Mercury Removal vs. Injection Rate at Boardman (ADAES)



Side-by-Side Testing at PGE Boardman Mercury Removal vs. Injection Rate



- PAC-1: Albemarle C-PAC
- PAC-2, PAC-3 and PAC-4 are competitive concrete compatible products

Data from ADA-ES' paper published at Air Quality VII

Foam Index (by ADA-ES)

| | Inj. Rate lb/MMacf | % C | Average Drops | Drop Variation from FA | Foam Index (ADA) |
|----------|-----------------------|------|------------------|---------------------------|---------------------|
| Cement | NA | NA | 5.7 | | 1.0 |
| Baseline | 0 | 0.21 | 6.3 | 0.0 | 1.1 |
| Hg-LH | NA | 1.25 | 35 | 29 | 6.6 |
| C-PAC | 3.5 | 1.4 | 6.7 | 0.4 | 1.2 |
| PAC-2 | 3.5 | 1.05 | 5.3 | -1.0 | 0.9 |
| PAC-3 | 3.5 | 1.26 | 3.7 | -2.6 | 0.6 |

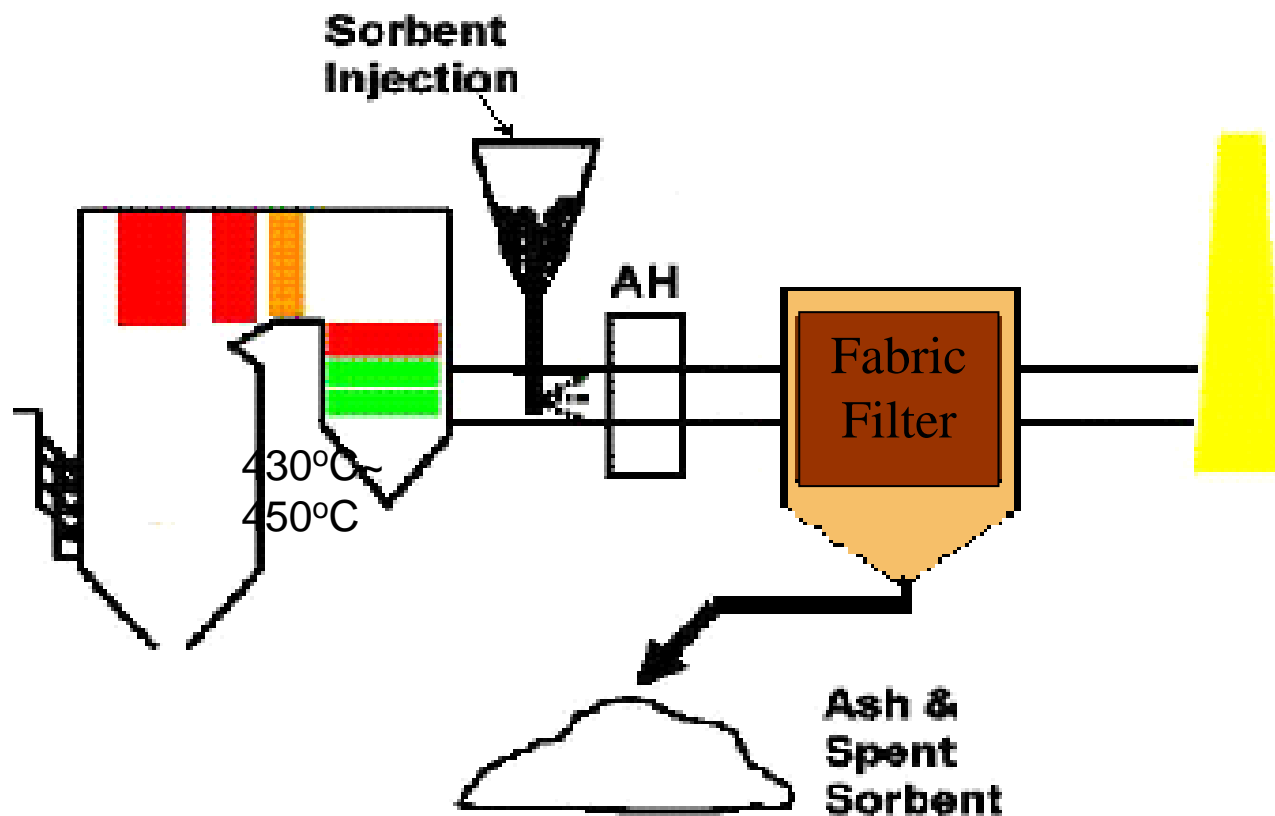


Hg

C-PAC™ Commercial Accounts

Weston Power Plant Unit 3

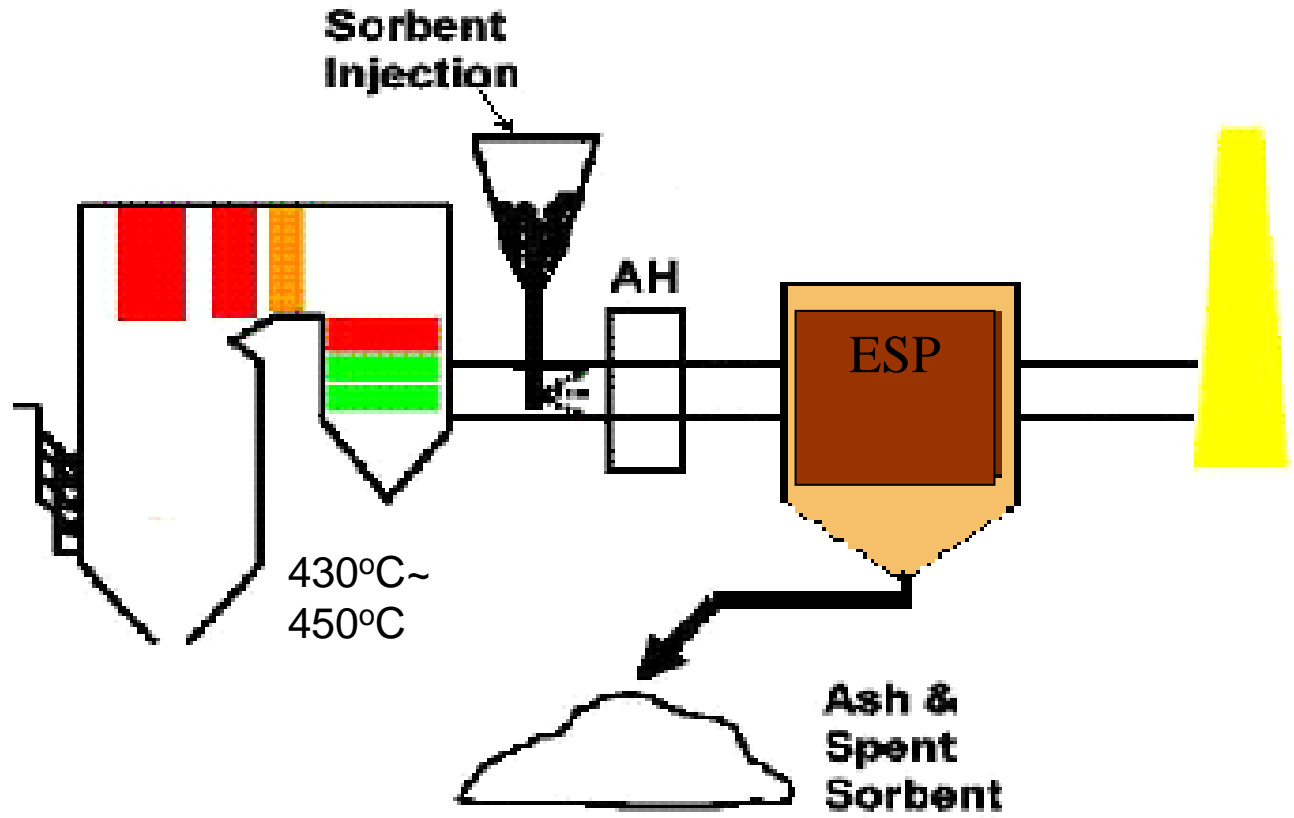
Hg



WPSC (Wisconsin Public Services) Weston 3 Station Overview

1. Weston 3 Plant Layout
 - Boiler – Economizer – C-PAC™ injection - APH – FF – Stack
 - Long residence times between PAC injection and APH, and between APH and fabric filter
 - 360 MW with PRB coal
2. C-PAC™ injection on hot-side of APH at 810° F to 840° F
3. Able to meet 80% to 85% mercury reduction target at 0.25 lbs/MMacf
4. Fly Ash has tested acceptable for use in Concrete and is currently being marketed by Lafarge

PPL Corette Plant



PPL Corette Station Overview

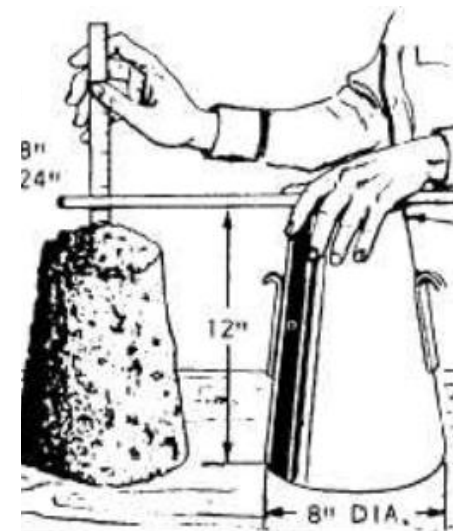
- 1. Corette Plant Layout**
 - **Boiler – Economizer – C-PAC™ injection - APH – ESP – Stack**
 - **163 MW with PRB coal**
- 2. Albemarle installed Injection System**
 - **CFD Modeling with field velocity traverses to verify flow patterns**
 - **Verification of PAC flow through lances to match CFD inputs**
 - **Field trial performed**
- 3. C-PAC™ injection on hot-side of APH at ~ 800° F**
 - **Positive pressure duct with difficult geometry**
- 4. Able to meet/exceed state regulation of 0.90 lbs/TBtu at ~ 2 lbs to 2.5 lbs /MMacf C-PAC™ injection.**
- 5. Fly ash accepted and sold by Headwaters for concrete**



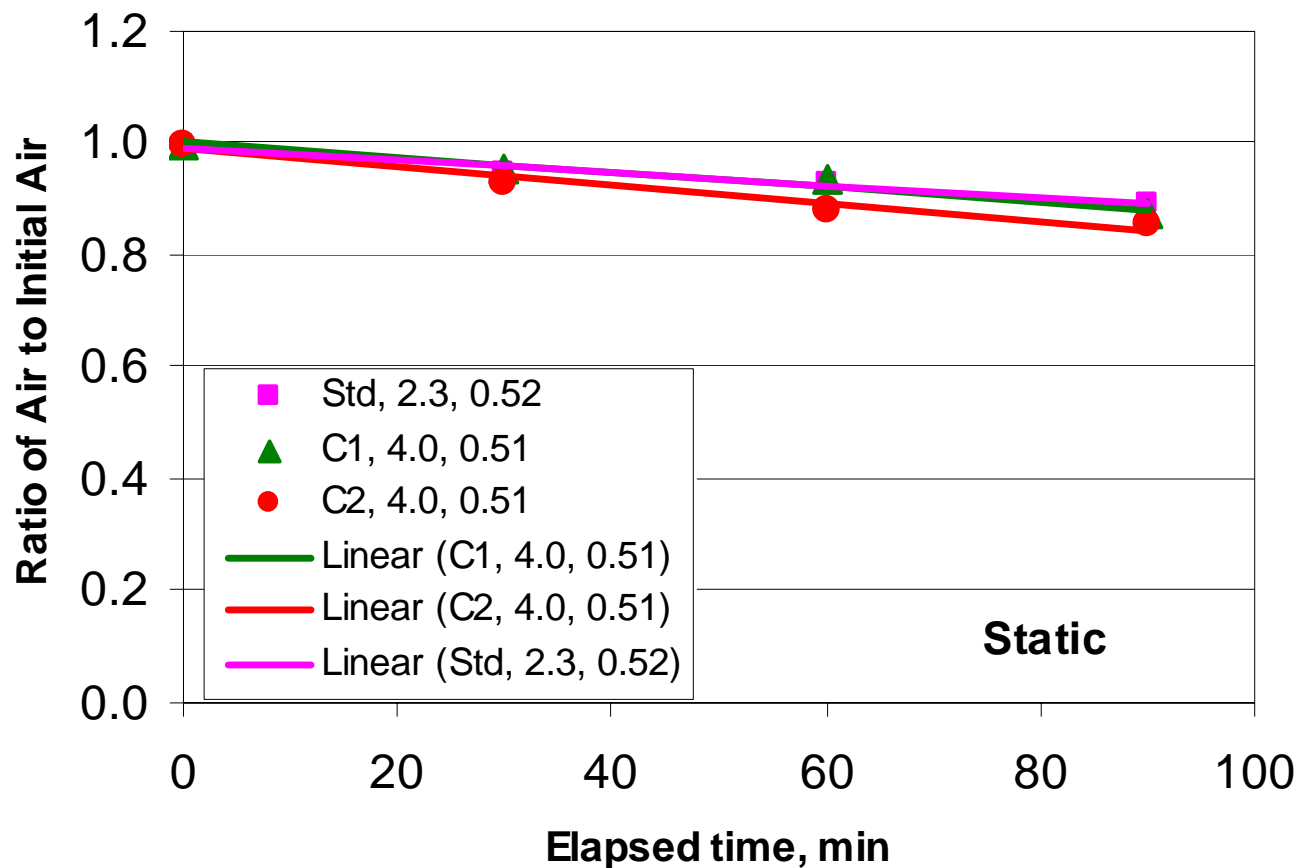
Recent Concrete Testing

Fly Ash: PPL Corette
Testing by: Concrete Research & Testing, LLC

| 450 lb Batches | Control | C-PAC1 | C-PAC2 |
|-------------------|------------|------------|-------------|
| PAC in Ash, wt% | 0% | 1% | 1% |
| Micro-Air, oz/cwt | 2.3 | 4.0 | 4.0 |
| Air, vol% | 9.5 | 8.9 | 8.4 |
| w/cm | 0.52 | 0.51 | 0.51 |
| Slump, in. | 7.5 | 7.5 | 7.25 |
| Unit wt., pcf | 134.7 | 135.9 | 136.9 |

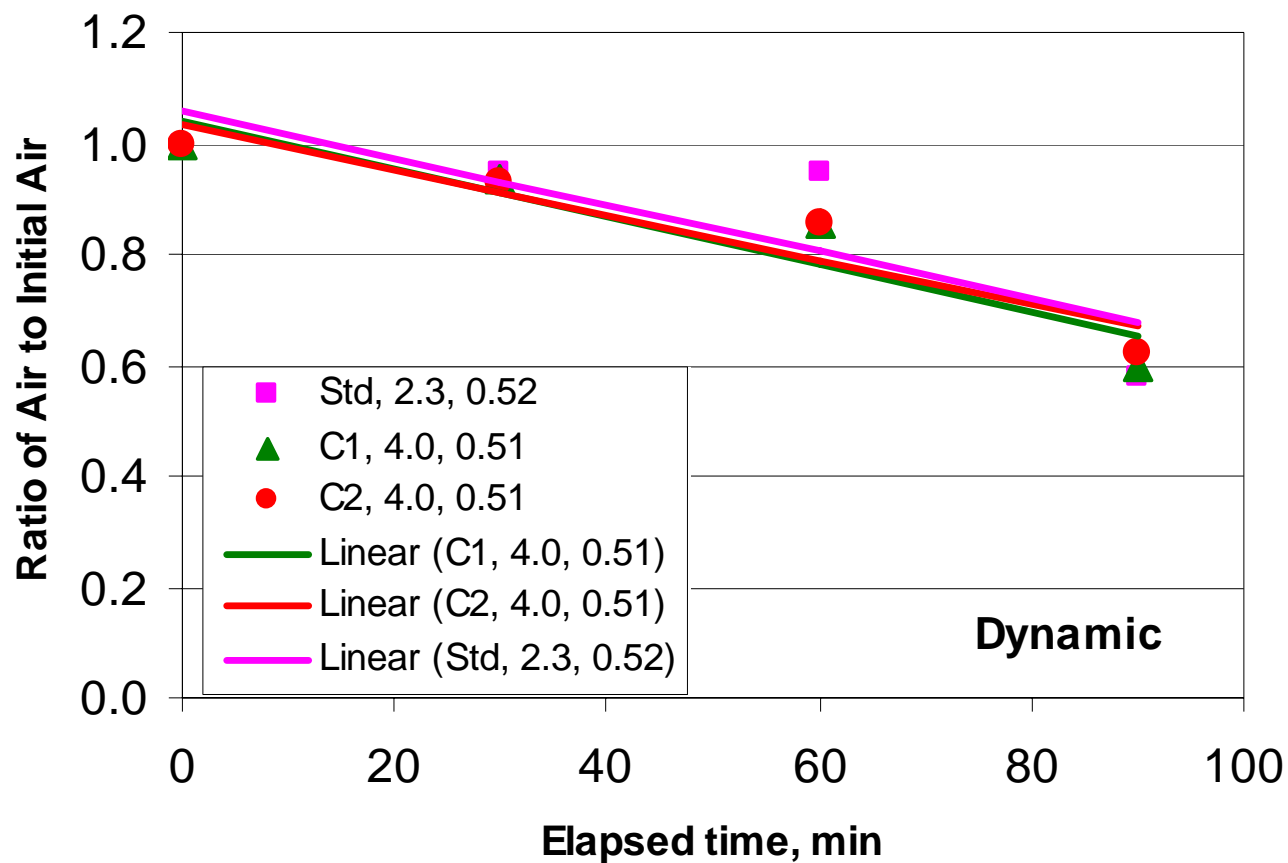


Static Air Stability



→ No Difference

Dynamic Air Stability



→ No Difference

1. Albemarle is currently selling C-PAC™ commercially with excellent mercury removal results and the fly ash is being sold.
2. C-PAC™ injection effective even at high temperatures (800° F).
3. C-PAC™ is approved for use by the Illinois EPA.
4. Albemarle continues to test C-PAC™ with ash marketers, utilities, and even cement manufacturers.
5. Albemarle has available capacity to meet your needs.

C-PAC Patent Pending

Hg

Patent pending on carbon-based concrete-friendly™ mercury sorbents

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
29 May 2008 (29.05.2008)

PCT

(10) International Publication Number
WO 2008/064360 A3

(51) International Patent Classification:
B01D 53/04 (2006.01)

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(21) International Application Number:
PCT/US2007/085474

(22) International Filing Date:
23 November 2007 (23.11.2007)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60860,563 22 November 2006 (22.11.2006) US

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IL, IS, IT, LT, LU, LV, MC, MT, NL, PL, PT, RO, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NI, SN, TD, TG).

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Published:
— with international search report
— before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments

(74) Agents: CUNIFFE, John J. et al.; One GOJO Plaza, Suite 309, Akron, OH 44311-1076 (US).

(88) Date of publication of the International search report:
17 July 2008

(54) Title: COMPOSITIONS AND METHODS TO SEQUESTER FLUE GAS MERCURY IN CONCRETE

- Questions???

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