Fly Ash Supply and Quality.

NCC RENO meeting, 4/20/2015
“The Reports of my death are greatly exaggerated!”

Samuel Langhorne Clemons (Mark Twain) June 1897
• New study by American Road & Transportation Builders Association will forecast continued fly ash production greater than 50 million tons annually.

• Current fly ash utilization is 23.3 million tons annually; 43.7 percent of production.

**Fly Ash Availability Mirrors Coal Consumption**

*SOURCE: American Road & Transportation Builders Association, 2015*
Industry Challenges

- During the last 5 years: The concrete industry consumed ~20% of the fly ash produced in US.
- Another 25% was beneficially used in lesser value markets.
- The remaining 45% was disposed in landfills and wet impoundments.

- Low natural gas prices and pollution control regulations are resulting in some coal-fired plant closures, changing dispatch and emissions testing is impacting seasonal and regional supplies.
• Wet Scrubber (Wet FGD) 80% reduction in SO2.
• Dry Scrubber (Dry FGD) 90+% reduction in SO2
• Dry Sorbent Injection (Trona) 40-75% reduction in SO2
• Selective Non Catalytic Reduction (SNCR) 35% reduction in NOx (Ammonia)
• Selective Catalytic Reduction (SCR) 90% reduction in NOx (Ammonia)
• Powdered Activated Carbon (PAC) 90% mercury removal
• Trona: Raises alkalis. May effect set times
• Ammonia: Health concern, no issue with Concrete.
• PAC: May create entrained air issues, depending on PAC used.

• All create use issues and may cause the material to be out of spec or to be removed from the market.
• Plant testing for emissions controls, (1 week- 3 months)
Mercury and Air Toxics Standards (MATS) final rule went into effect in December 2011 requiring coal fired power plants to control mercury emissions within 3 years (April 2015):

- States may grant 4th year (2016)
- USEPA administrative order would allow 5th year (2017) for critical units.

Powdered Activated Carbon (PAC) injection is the primary control technology for mercury.

Fuel change, wet scrubber w/ additives and other options might be available.
Activated Carbon Injection
Post Fly Ash Collection

Carbon Injected after ESP

Boiler
Electrostatic Precipitator
Flue Gas
Fly Ash
Fly Ash Only
C + Hg
Baghouse
Stack
Sorbent Vendors

Top players vying for this $10 billion/year market

Mercury Control:
- Cabot (Norit) – DARCO-Hg family of sorbents
- Calgon – Flue PAC family of sorbents
- ADA carbon Solution: Power PAC, Fast Pac
- Albemarle: B-PAC, C-PAC, H-PAC,
- BASF – Mercury Sorbent HX – Brominated mineral sorbent
- Novinda: Amended Silicates
- EM2C: Additive & PAC
- ADA ES: coal additive, engineering solutions and consulting
- Others: Shaw, Nalco (scrubber additives)
Lower PAC injection rates and a tighter control range = less PAC in ash + Improved consistency (AEA demand)

Improvements in Activated Carbon Technology

ACI Rate lb per million acf of flue gas
Class C ash samples containing variable levels of PAC treated to acceptable foam index level.
### Beneficiated ash with RestoreAir® 2.2

<table>
<thead>
<tr>
<th>Sample Description</th>
<th>Control</th>
<th>C-Ash</th>
<th>C-Ash with PAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foam Index (conc MBVR)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AEA dosage (oz/cw)</td>
<td>1.2</td>
<td>1.4</td>
<td>4.2</td>
</tr>
<tr>
<td>Air Content (6%±1%)</td>
<td>7.0%</td>
<td>7.0%</td>
<td>6.25%</td>
</tr>
<tr>
<td>Bulk Density, lb/ft³</td>
<td>144.8</td>
<td>145.6</td>
<td>147.2</td>
</tr>
<tr>
<td>Slump, inches (6±1)</td>
<td>6.25</td>
<td>6.0</td>
<td>6.25</td>
</tr>
<tr>
<td>3 day, psi</td>
<td>2814</td>
<td>2858</td>
<td>3039</td>
</tr>
<tr>
<td>7 day, psi</td>
<td>3433</td>
<td>3689</td>
<td>3592</td>
</tr>
<tr>
<td>28 day, psi</td>
<td>4594</td>
<td>4802</td>
<td>4764</td>
</tr>
</tbody>
</table>

Ash treatment restored the AEA dosage to same level expected with ash containing NO activated carbon.
Examples of plants in Service Meeting current emissions regs

- Port Neal plant: Ammonia, PAC and Trona
- Newton Power station: PAC
- WoodRiver Plant: PAC
• High Sulfur coal, More class F ash?
  Dependent on installation of scrubbers
• Blended ash C/F
  Would require mods to state and industry specs.
• Ash from ponds or landfills
• Imported ashes from other countries
<table>
<thead>
<tr>
<th>Chemical</th>
<th>Class F</th>
<th>Class C</th>
<th>Class F/Class C</th>
<th>ASTM C 618 Class F</th>
<th>ASSHTO M295 - 06 Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicon Dioxide, SiO₂</td>
<td>47.73%</td>
<td>39.32%</td>
<td>42.74%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aluminum Oxide, Al₂O₃</td>
<td>28.19%</td>
<td>19.24%</td>
<td>23.21%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iron Oxide, Fe₂O₃</td>
<td>11.92%</td>
<td>6.22%</td>
<td>9.28%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sum SiO₂, Al₂O₃ &amp; Fe₂O₃</td>
<td>87.84%</td>
<td>64.78%</td>
<td>75.23%</td>
<td>70 Min</td>
<td>70 Min</td>
</tr>
<tr>
<td>Sulfur Trioxide, SO₃</td>
<td>0.32%</td>
<td>1.52%</td>
<td>1.03%</td>
<td>5.0 Max</td>
<td>5.0 Max</td>
</tr>
<tr>
<td>Calcium Oxide, CaO</td>
<td>4.02%</td>
<td>23.25%</td>
<td>13.56%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium Oxide, Na₂O</td>
<td>0.66%</td>
<td>1.70%</td>
<td>1.16%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnesium Oxide, MgO</td>
<td>1.44%</td>
<td>5.55%</td>
<td>3.49%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potassium Oxide, K₂O</td>
<td>2.65%</td>
<td>0.67%</td>
<td>1.64%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phosphorus Pentoxide, P₂O₅</td>
<td>0.68%</td>
<td>1.21%</td>
<td>0.95%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Titanium Dioxide, TiO₂</td>
<td>1.49%</td>
<td>1.33%</td>
<td>1.45%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moisture %</td>
<td>0.13%</td>
<td>0.106%</td>
<td>0.1%</td>
<td>3.0 Max</td>
<td></td>
</tr>
<tr>
<td>LOI %</td>
<td>2.13%</td>
<td>0.31%</td>
<td>1.09%</td>
<td>6% Max</td>
<td>5% Max</td>
</tr>
</tbody>
</table>

### Physical Analysis

<table>
<thead>
<tr>
<th></th>
<th>Class F</th>
<th>Class C</th>
<th>Class F/Class C</th>
<th>ASTM C 618 Class F</th>
<th>ASSHTO M295 - 06 Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fineness %</td>
<td>24.02%</td>
<td>25.1%</td>
<td>23.76%</td>
<td>34% Max</td>
<td></td>
</tr>
<tr>
<td>Water Requirement % Control</td>
<td>95%</td>
<td>99%</td>
<td>96%</td>
<td>105% Max</td>
<td></td>
</tr>
<tr>
<td>Specific Gravity gm/cm³</td>
<td>2.38</td>
<td>2.49</td>
<td>2.42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Autoclave Expansion %</td>
<td></td>
<td></td>
<td></td>
<td>.8% Max</td>
<td></td>
</tr>
<tr>
<td>Strength Activity Index</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>With Portland Cement 7 Day</td>
<td>78%</td>
<td>81%</td>
<td>93%</td>
<td>75% Min</td>
<td></td>
</tr>
<tr>
<td>28 Day</td>
<td>89%</td>
<td>88%</td>
<td>97%</td>
<td>75% Min</td>
<td></td>
</tr>
</tbody>
</table>
Ternary/Perm Data

Ternary Mix Design - Lab Study
Permeability AASHTO T277 - Virginia Cure Method

Coulombs

<table>
<thead>
<tr>
<th>Material</th>
<th>Permeability</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% Cement</td>
<td>High</td>
</tr>
<tr>
<td>15% C Ash</td>
<td>Moderate</td>
</tr>
<tr>
<td>30% C Ash</td>
<td>Low</td>
</tr>
<tr>
<td>Type IS(25) 20% C Ash</td>
<td>Very Low</td>
</tr>
<tr>
<td>Type IS(35) 15% C Ash</td>
<td>Negligible</td>
</tr>
</tbody>
</table>

w/c = 0.41

- 100% Cement: >4000
- 15% C Ash: 2000-4000
- 30% C Ash: 1000-2000
- Type IS(25) 20% C Ash: 100-1000
- Type IS(35) 15% C Ash: <100
- Type IPF(25) 20% C Ash: Negligible

w/c = 0.426

- 100% Cement: >4000
- 15% C Ash: 2000-4000
- 30% C Ash: 1000-2000
- Type IS(25) 20% C Ash: 100-1000
- Type IS(35) 15% C Ash: <100
- Type IPF(25) 20% C Ash: Negligible
• 310 GW coal fired capacity 1990-2010
• 70 GW to be retired by 2025
• 50 GW has yet to occur
• 240 GW are being retrofitted with advanced pollution control systems.
U.S. government forecasts show coal will remain largest energy resource for electricity generation at least through 2040.

Coal’s *share* of electricity generation continues to decline, but *volume* of generation remains stable.

Worst case scenario, 1 Billion tons still to be produced.
• Benjamin J. Franklin
• Director of Technical Services
• Mobile: 314-974-5095
• Email: bfranklin@headwaters.com