We Energies
Quality Management and Beneficiation Processes for the Use of CCPs in Construction Materials

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CCP Producing Plants
CCP Quality Focus

- Largest quantities of Coal Combustion Products (CCP) produced by We Energies and most other coal power plants:
  - Fly Ash
  - Bottom Ash
  - Flue gas desulfurization (Scrubber) products

- Fly Ash and FGD products have greatest chance of being impacted by current and future plans
Our relationship may be recorded for quality assurance.
Fly Ash Contracts and Quality Control

- We Energies has contracts with fly ash management companies to provide marketing, sales, distribution and quality control services.
  - Lafarge
  - Mineral Resource Technologies
Quality of CCP’s – Fly Ash

● Regular/routine sampling of fly ash

● Importance of Consistency – routine tests
  – Loss on Ignition (LOI – carbon content)
  – Foam Index (impact of carbon)
  – Fineness (particle size - reactivity)
  – Ammonia content (if necessary)

● Performance testing of fly ash to meet specifications and standards of end users (ASTM C618)
LOI (Loss on Ignition)

- LOI is an indication of the carbon content.
- Small sample of fly ash is ignited at 750 ± 50 degrees C.
- The loss in mass is expressed as a percentage of the total initial mass.
- ASTM C 618: 6.0% max
  12% for class F based on acceptable service records or lab testing.

In real practice, fly ash used in most concrete in the upper Midwest has LOI below 2%.
Foam Index

- Measures how the carbon in fly ash may impact air entraining agents.
- Each ash source has a foam index limit.
- LOI may not change but foam index could fluctuate.
- Consistency is important to end user.
Effects of Carbon in Fly Ash for Concrete

- Impact air entraining
- Impact freeze/thaw durability
- Admixture quantities
- Color
- Water demand and strength
Fineness

- Amount retained on #325 sieve
- Amount retained considered too coarse to react.
- ASTM C 618: 34% maximum retained.
Strength Activity & Water Requirement

- Mortar cubes vs. cement control
  - 20% fly ash by weight, equal flow
  - water requirement as a percent of the control calculated
- ASTM C618
  - Strength Activity, min. % of control: 75% of control at 7 or 28 days (meeting 7 days satisfies C618)
  - Water Requirement, max. % of control: 105
Potential Impacts to CCP

Quality and Availability

- Coal source: Where did it come from? How consistent?
- Plant equipment age, maintenance and reliability
- Operator decisions
- Air Quality Control Systems
  - Emission reductions (NOx, SOx, Mercury)
Should the tail wag the dog?

A dramatic breakthrough in the world of alternative energy: canine tail power.
Coal Source: 
Class C Fly Ash

- Produced from burning sub-bituminous (western) coal
- Higher calcium oxide content, lower silicate content
- Not only pozzolanic, but has cementitious properties as well
- Concrete quality Class C fly ash currently produced at We Energies Oak Creek, Pleasant Prairie and Presque Isle Power Plant
Coal Source: 
Class F Fly Ash

- Produced from burning bituminous (eastern) coal
- Lower calcium oxide content, higher silicate content
- Has pozzolanic properties in concrete mixtures (not cementitious on its own)
- Expecting concrete quality Class F fly ash from the new Oak Creek units under construction
We Energies Coal Procurement

Coal source based on economics and emissions limits:

- Evaluate coal sources for potential impacts on CCP quality
- Involve Fly Ash Management company
- Plan test burns and segregate CCP as necessary for evaluation
- Sample, test and determine actual impacts on CCP quality and manage accordingly
Plant Equipment, Maintenance and Operator Decisions

Challenges to ash quality:

- Poorly maintained equipment (coal pulverizers/burners) can negatively impact fly ash

- Boiler Operators may have varying priorities/goals while operating (max load, emission limit, reliability)

- Inability to segregate or manage poor quality fly ash
Plant Equipment, Maintenance and Operator Decisions

We Energies approach:

Utilize fly ash quality feedback to plan maintenance needs and make operational adjustments

- Educate plant operators on CCP use and value (training)
  - Make quality data available to them

- Involve fly ash management companies on site

- Segregate lower or suspect quality fly ash
  - Ability to direct ash to specific silos or storage and manage end use

- Maximize quality of CCP while balancing various priorities
Quality Feedback
Changing Power Plant Landscape

- Regulations and efforts to decrease plant emissions are changing power plants.

Fear, barriers to CCP utilization...

- What is being done at the plant that creates my CCP materials?
Older Model

- Burn coal
- Make electricity
- Capture fly ash and bottom ash
- Beneficially utilize fly ash and bottom ash if possible
- Dispose/landfill what could not be used
Older Model

FOSSIL FUEL POWER PLANT SCHEMATIC

- Overburden
- Coal Seam
- Plant Surge Pile
- Coal Pulverizer (~150)
- Smokestack
- Electrostatic Precipitator
- Boiler
- Flue Gas
- Fly Ash
- Bottom Ash
- Fly Ash
- Bottom Ash

Flowchart showing the process of fossil fuel power plant operation.
More Recently and in the Future

- Burn coal
- Make electricity
- Increase control NOx, SOx, and mercury emissions
- Capture fly ash, bottom ash, and FGD products
- Beneficially utilize fly ash, bottom ash, and FGD products if possible
Air Quality Control System

Baghouse Filters or Precipitators remove Fly Ash

Mercury Control

NOx Control

SOx Control
Focus on Air Quality Control (AQCS) Impacts on CCP

- Can power plants control NOx, SOx, and mercury and maintain or produce high quality CCP for beneficial use?

- Depends on technology implemented

- We Energies path includes consideration of CCP quality and investment toward maintaining value of beneficial use (tail can play a part in wagging the dog)
Technologies/Strategies to Reduce NOx

- Low NOx burners and combustion control systems (typical at many utilities)
  - Could increase potential for carbon on fly ash and cause air entraining issues in concrete use

- SNCR (Selective Non Catalytic Reduction) Systems (relatively low capital investment)
  - High likelihood of increasing ammonia on fly ash
  - Could make fly ash unattractive for or limit its use in concrete

- SCR (Selective Catalytic Reduction) Systems (higher capital investment)
  - Could increase ammonia on fly ash
  - Could make fly ash unattractive for or limit its use in concrete
Ammonia on Fly Ash

- Ammonia (NH3) is a colorless gas with a pungent odor
- NIOSH permissible exposure limit is 25 ppm (8hrs.) with 35 ppm peak
- At 50 ppm, slight eye and throat irritation, coughing
- Can volatilize from fly ash when it gets wet or is mixed in concrete
- Not a problem for concrete quality, but can be a problem for end users depending on where concrete is being placed
We Energies NOx Reduction

- Utilize low NOx burners and combustion controls
- Maintain and optimize systems to limit negative impacts on fly ash (maintain low carbon fly ash – regular testing)
- Install SCR technology at Pleasant Prairie and Oak Creek
- Test for ammonia on fly ash and manage accordingly through segregation and alternative uses or blending (regular testing)
- Remove ammonia from fly ash through beneficiation technique in future if it becomes necessary (Ammonia Liberation Process – more to come…)
Pleasant Prairie Air Quality Control System

- **Existing Boiler** (within P4*)
  - Removes 90% of NOx

- **SCR** (Selective Catalytic Reduction Unit)
  - Removes 99.7% of Fly Ash

- **ESP** (Electrostatic Precipitator)
  - Removes 85% of SO2

- **FGD** (Flue Gas Desulfurization)
  - <1% flue gas from one boiler unit

- **Continuous Emission Monitoring System**
- **Two-Step Carbon Capture Pilot**
  - Step 1: Chiller
    - Cooling flue gas
  - Step 2: CO2 Capture
    - Isolating CO2 from flue gas
  - Potential to remove 90% of CO2

- **Existing Chimney**

*Pleasant Prairie Power Plant*
Selective Catalytic Reduction (SCR)

- Removes NOx
- >90% Removal Efficiency
- Catalytic Reaction
- Ammonia Injection
Technologies/Strategies to Reduce SOx

- **Burn lower sulfur coals (typical strategy at many utilities)**
  - Can limit future coal/fuel flexibility

- **Dry Scrubber/Spray Dry Scrubber (relatively low capital cost)**
  - Inject sorbent/reagent (powdered or slurry lime) into flue gas stream to react with sulfur
  - Frequently installed upstream of main fly ash removal
  - Can result in fly ash being mixed with used scrubber reagent (calcium sulfite)
  - Markets for dry/spray dry scrubber products are uncertain
  - Existing use of fly ash may be compromised
Dry Scrubber – Not implemented at We Energies
We Energies SO\textsubscript{x} Reduction

- Install Wet Limestone, Forced Oxidation Flue Gas Desulfurization Systems downstream of fly ash removal equipment (currently in operation at Pleasant Prairie)
- Preserve fly ash quality
- Produce FGD Gypsum with known and accepted uses/markets
- Take advantage of additional emissions reductions (more to come…)
Wet Limestone FGD

- Primarily Removes SO$_2$
- >90% Removal Efficiency
- Removes Particulate, Chlorides, Fluorides and Mercury
- Limestone Reaction
- Produces Gypsum

SO$_2$ + CaCO$_3$ + $\frac{1}{2}$O$_2$ + H$_2$O $\rightarrow$ CaSO$_4$$\cdot$2H$_2$O + CO$_2$
Technologies/Strategies to Reduce Mercury Emissions

- Inject a mercury sorbent (activated carbon) and capture with common fly ash removal system
  - Proven technology, relatively low capital cost
  - Fly Ash becomes co-mingled with spent mercury sorbent
  - May impact ability to use fly ash in typical concrete applications (consistent control of air entraining agent may be compromised, color may become an issue)

This technology was tested at Pleasant Prairie several years ago and significant impacts were seen on the fly ash in terms of carbon content and impact on air entraining in concrete.
PAC Injection with Fly Ash – Not implemented on We Energies Units

Sorbent (AC) Injection

ESP or FF

CEM - Hg Measure.

Ash and Sorbent
Activated Carbon Injection – Hg Control
We Energies Mercury control at PIPP

- Inject a mercury sorbent (activated carbon) DOWNSTREAM of the fly ash removal system - Toxecon™
  - Preserves 99% of the fly ash captured upstream of addition of mercury sorbent
  - Capture sorbent in downstream fabric filter baghouse
  - No impact on existing fly ash quality
  - Preserves ability to beneficially utilize fly ash in typical concrete applications

This technology is installed and operating at PIPP and is part of a full scale demonstration project
TOXECON™ Configuration — Mercury Capture

Presque Isle Power Plant

Coal

Fly Ash (99%)

PJFF

Fly Ash (1%) + PAC

Sorbent Injection

TOXECON™

APH
Another Option for Mercury Control?

- Wet FGD scrubbers can remove large percentage of oxidized mercury from flue gas

- Employ techniques to oxidize mercury in flue gas
  - Halogen addition (CaBr)
  - Install mercury oxidizing catalyst in SCR

- CaBr addition recently tested at Pleasant Prairie with promising results
  - Large reduction in mercury air emissions
  - No measured impact on fly ash quality or use in concrete

Additional testing is on going and being planned...stay tuned...
Daily sampling of gypsum
Routine analysis includes:
- Moisture
- Purity (% CaSO4 - gypsum)
- Chlorides
Operate equipment with a goal to maintain wallboard quality gypsum
Summary - We Energies CCP Quality Management

- Regular sampling and testing
- Involve CCP Management Companies in plans and decisions
- Maintain Plant equipment that impacts CCP
- Educate plant personnel on the impact they can have on CCP quality
- Choose AQCS technologies with minimal impact on CCP quality and end use
- Balance competing priorities
Through Quality Management, we hope to avoid...

45 metres of rope and you're finding fault with this little bit?
Lower Quality CCP’s?

- No users, low value?
- Solution = Change the CCP to a material that is needed and can be beneficially used (Beneficiate it)
Why Beneficiate?

- Quality Enhancement/Consistency
- Economics
- Environmental
Economic Benefits

- Avoided Landfill Expenses
- Additional Revenue from Concrete Quality Fly Ash Produced near Market
Environmental Benefits

- Preserve Existing Landfill Capacity
- Reduce Need for New Landfills
- Reduce Mining and Transportation of Coal
Environmental Benefits

- Provide Additional Improved Fly Ash for Concrete
  - Reduce Emissions from Cement Kilns ($\text{CO}_2$, $\text{NO}_x$, $\text{HCl}$, $\text{SO}_x$)
  - Reduce Limestone and Clay Quarried for Portland Cement Production
Other Benefits

- Recover Otherwise Lost Energy
- Raw Fuel is Conserved for Future Generations
- Higher Quality/Strength Concrete
Fly Ash Carbon (LOI) Reduction

Technologies

- Fluidized Bed Combustion
- Electrostatic Separation
- Froth Floatation
- Ash Fuel Reburn
Ash Fuel Reburn Process

Patent # 5,992,336
Valley Power Plant

- Located near downtown Milwaukee
- Responsible for 280 megawatts of power for the downtown area
- Provides all of the steam for the district heating system
- Fly Ash has LOI near 25 %, bottom ash has LOI near 40 %
Pleasant Prairie Power Plant

- Wisconsin’s largest power plant (2 units)
- Located near Wisconsin-Illinois border
- Serves as baseload plant for system
- Fly ash has LOI of less than 1%
Coal

High Carbon Ash From Other Plants

New System

Energy

Power Plant

Building Materials
Wet Process
Dry Process
Typical Reburn Results

- **Bottom Ash**
  - VAPP LOI In = 40%
  - PPPP LOI Out < 1%

- **Fly Ash**
  - VAPP LOI In = 25%
  - PPPP LOI Out < 1%
Recovering Ash Stored In Landfills
Coal fired power plants have existed for several decades, but only recently has ash utilization become prominent.

The question is, where is all the ash from years past?
In Landfills!
Licensing and constructing landfills is becoming less attractive as an option because:

➤ There is less space for new construction of landfills

➤ Increased regulations make landfills more expensive to license and build

➤ People do not want landfills to be built near their homes or businesses
In addition to the expense of building and maintaining landfills, hundreds of thousands of acres of landfills contain significant amounts of ash that either was not or could not be utilized.

Much of this ash has a high L.O.I. value, and is therefore WASTED ENERGY
Ash Recovery Process
(Patent #6,637,354)

Coal

Stored Ash

Pleasant Prairie Power Plant

Construction Materials

Energy

Environmental Benefits
Ash Recovery at Former Landfill Site
By recovering, reburning, and treating ash from landfills:

- Landfill space is recovered and is available for more productive uses
- Energy is recovered
- Concrete quality fly ash is produced
- Raw fuel is conserved for future generations
P4 Ash Fuel Reburn Results
Ash Fuel Reburn – Blended Fly Ash

- PRB Coal typically has 5% Ash Content
  
  4,900,000 tons coal creates 245,000 tons ash  
  80% as Fly Ash = 196,000 tons Fly Ash (Class C)

- 2% Ash Fuel rate is about 100,000 tons high carbon ash addition to boiler

- High Carbon Supplemental Ash Fuel has 80% Ash Content
  
  100,000 tons ash fuel creates 80,000 tons of ash  
  80% as Fly Ash = 64,000 tons Fly Ash (Class F)

- Therefore, 2% Ash Fuel Addition results in a blended fly ash:
  
  196,000 tons (C) + 64,000 tons (F) = 260,000 tons FA  
  75% Class C and 25% Class F Blended Fly Ash
SiO₂ & Al₂O₃ & Fe₂O₃, and SAI

Ash Fuel Addition (%)

SAI, 7 days (% of control)  SiO₂ & Al₂O₃ & Fe₂O₃ (%)  Ash Fuel Addition (%)
Compressive Strength Versus Age – Blended Fly Ash

Compressive Strength, psi

Age, days

1-day 7-day 28-day 91-day 365-day

No Fly Ash
35% FA
25% F/75% C
50% F/50% C
75% F/25% C
Reburn and Displaced Coal

Annual Totals

Displaced more than 2,284 railcars of coal, since 2000!
New Oak Creek Plant
Reburn Process

- Constructed with ability to add 5% ash fuel
- Continue beneficial use of high carbon ash as fuel/volume reduction
- Recover previously landfilled ash for use as fuel
- Create valuable construction materials
Benefits of Ash Reburn

- Recover Otherwise Lost Energy
- Preserve Existing Landfill Capacity
- Reduce Need for New Landfills
- Provide Additional Improved Fly Ash for Concrete
- Reduce Additional CO₂ and other Emissions from Cement Production
- Avoided Cost of Landfilling
Fly Ash and Ammonia Liberation Technology
Technologies to Manage Ammonia

- Reburning in a dedicated FBC Unit
- Washing/Humidification
- Ozone Treatment
- Ambient Wet Aggregate Production
- Reburning in an Ash Fuel System
- Lightweight Aggregate Process
- Ammonia Mitigation with reagent
- Ammonia Liberation Process
Ammonia Removal Temperatures

- Ammonium Bisulfate: 434°C
- Ammonium Sulfate: 431°C
- Ammonium Chloride: 310°C
- Ferric Ammonium Sulfate: 166°C
- Ammonium Bicarbonate: 143°C
- Ammonium Carbonate: 121°C
- Ferrous Ammonium Sulfate: 118°C

Temperature, C
Ammonia Removal Test Set-up
# Ammonia Liberation Process Laboratory Results

<table>
<thead>
<tr>
<th>Test #1 - ASTM C 618 Class C Fly Ash</th>
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<tbody>
<tr>
<td>Prior to Processing</td>
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<tr>
<td>After Processing</td>
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<table>
<thead>
<tr>
<th>Test #2 - ASTM C 618 Class F Fly Ash</th>
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<tbody>
<tr>
<td>Prior to Processing</td>
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<tr>
<td>After Processing</td>
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</tbody>
</table>
Ammonia Liberation Process
Laboratory Results

Ammonia, mg/kg

ASTM C 618 Class C Fly Ash  
ASTM C 618 Class F Fly Ash

Before Processing  
After Processing
## Ammonia Liberation Process Laboratory Results

<table>
<thead>
<tr>
<th>Test #3 - ASTM C 618 Class F Fly Ash</th>
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<tbody>
<tr>
<td>Prior to Processing</td>
<td>160 mg/kg</td>
</tr>
<tr>
<td>After Processing - Bag house</td>
<td>16 mg/kg</td>
</tr>
<tr>
<td>After Processing - Product Bin</td>
<td>Less than 2 mg/kg</td>
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</tbody>
</table>
Ammonia Summary

- $\text{NO}_x$ reduction techniques can result in less accepted CCP materials
- High ammonia ash can have serious and far reaching financial ramifications
- ALP process can remove undesirable effects of $\text{NO}_x$ reduction techniques on ash, and the undesirable financial ramifications
We Energies Fly Ash and Sorbent Mercury Removal Technology

- Thermal process making use of high temperature air slide
- Similar to Ammonia Liberation Process
- Released mercury captured in a mercury condenser and scrubber system
Mercury Removal Benefits

- Potential to re-use expensive sorbent material
- Maintain fly ash availability as a raw feed material for cement manufacture
Summary

- CCP quality management processes are in place between We Energies and their CCP management companies.
- Changes in response to emission control requirements and equipment may impact some CCP producers and end users nationally and regionally.
- Emission controls can be implemented while minimizing the impact on CCP quality.
- CCP beneficiation technologies exist or are being developed to address potential issues with CCP.

A reliable supply of high quality CCP will continue to exist despite some bumps in the path.
“We believe that a profitable company is truly successful when it also excels at serving people and protecting the environment. Our program for using coal combustion products is one of the ways we meet this responsibility. We are honored to receive the Edison Award.”

Gale Klappa
Chairman, President and CEO
Wisconsin Energy Corporation
Thank you

Questions?
CO2 Capture at Pleasant Prairie

- Demonstration project
  - Alstom Power
  - EPRI
  - We Energies (Host Site)
- Chilled ammonia technology
- 1% of flue gas from 1 boiler
CO2 Capture Process

- Cool and condition flue gas
- CO2 removed through contact with ammonium carbonate solution
- Solution with CO2 is heated under pressure to remove CO2
- Solution is recycled in system
- CO2 compressed for alternate use