Industry Update: Wet-to-Dry Bottom Ash Conversions & Byproduct Handling Case Studies

Prepared for: WPCA

06 June 2018

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Safety Moment
Discussion Overview

- Summary of Recent WTD Activity
- Bottom Ash Wet-to-Dry Conversion Technologies
- Byproduct Handling Case Studies
- Discussion / Questions
Key Regulatory Actions

Coal Combustion Residuals (CCR)
- Issued December 19, 2014
- CFR Publication: April 17, 2015
- Goals
  ✓ Groundwater Protection Benefits
  ✓ Preventing Future CCR Impoundment Catastrophic Failures

Effluent Limitations Guidelines (ELG)
- Proposed Rules Issued April 2013
- CFR Publication: November 03, 2015
- Goals
  ✓ Strengthen Steam Electric Power Plant Discharge Controls
  ✓ Reduce Surface Water Pollutant Discharges
<table>
<thead>
<tr>
<th>Wastestreams</th>
<th>Technology Basis</th>
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<tbody>
<tr>
<td><strong>FGD Wastewater</strong></td>
<td>Chemical Precipitation + Biological Treatment</td>
</tr>
<tr>
<td><strong>Fly Ash Transport Water</strong></td>
<td>Dry Handling / Closed-loop for units &gt;50W; Impoundment (equal to BPT) for units &lt;50MW</td>
</tr>
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<td><strong>Bottom Ash Transport Water</strong></td>
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</tr>
<tr>
<td><strong>Combustion Residual Leachate</strong></td>
<td>Impoundment (equal to BPT)</td>
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<tr>
<td><strong>FGMC Wastewater</strong></td>
<td>Dry Handling</td>
</tr>
<tr>
<td><strong>Gasification Wastewater</strong></td>
<td>Evaporation</td>
</tr>
<tr>
<td><strong>Nonchemical Metal Cleaning Wastes</strong></td>
<td>Chemical Precipitation</td>
</tr>
</tbody>
</table>
## UCC Wet-to-Dry Ash Conversion Update

**WTD Projects Awarded to UCC (2009-2018)**

<table>
<thead>
<tr>
<th>Project Type</th>
<th># of Projects Awarded</th>
<th># of Units Converted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bottom Ash Wet-to-Dry Conversions</td>
<td>52</td>
<td>112</td>
</tr>
<tr>
<td>Fly Ash Wet-to-Dry Conversions</td>
<td>25</td>
<td>56</td>
</tr>
</tbody>
</table>
# UCC Wet-to-Dry Ash Conversion Update

Summary of Recent UCC Bottom Ash WTD Activity

<table>
<thead>
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<tbody>
<tr>
<td><strong>UCC CDR System</strong></td>
<td>(8)</td>
<td>(12)</td>
<td>(since 2012)</td>
<td>Often Preferred if Under-Unit SFC will not fit</td>
</tr>
<tr>
<td><strong>UCC SFC System</strong></td>
<td>(18)</td>
<td>(7)</td>
<td></td>
<td>(2) Additional Pending Awards</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Likely First Choice if Space Permits</td>
</tr>
<tr>
<td><strong>UCC PAX System</strong></td>
<td>(5)</td>
<td>(4)</td>
<td>(Operational in 2018/2019/2020)</td>
<td>Increasing Utility &amp; Industrial Market Interest in 100% Dry Solution (eliminates wastewater)</td>
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</tbody>
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## Technical Design Considerations

<table>
<thead>
<tr>
<th>Wet-To-Dry Ash Conversion Project Design Criteria</th>
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<tbody>
<tr>
<td><strong>Budget</strong></td>
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<tr>
<td><strong>Outage Requirements</strong></td>
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<tr>
<td><strong>Physical Parameters</strong></td>
</tr>
<tr>
<td><strong>Site Environmental Considerations</strong></td>
</tr>
<tr>
<td><strong>Ash Characteristics</strong></td>
</tr>
<tr>
<td><strong>Ash Marketability/Beneficiation</strong></td>
</tr>
</tbody>
</table>

- Evaluate Criteria Against Multiple Alternatives
- Determine Optimal Solution for each Plant
- “One Size Does Not Fit All”
Current Project Drivers

- Market Conditions (e.g. Power Pricing)
- Estimated Plant Operating Life
- Plant Location
  - Operating Market
  - State Regulatory Approach
- Life-Cycle Costs (Capital vs. O&M)
- Condition of Existing Equipment
- Potential for CCR Beneficial Reuse
- Potential for Future Regulatory Actions (more stringent)
Discussion Overview

- Summary of Recent WTD Activity
- Bottom Ash Wet-to-Dry Conversion Technologies
- Byproduct Handling Case Studies
- Discussion / Questions
Bottom Ash Wet-To-Dry Conversions
Technical Alternatives

**Submerged Flight Conveyor – SFC™**
- Long-Term Economical Choice (Low O&M Costs)
- Simple Solution if Space Under Boiler is Available

**Re-Circulating Hydraulic System (3 Options)**
- No Changes Under Boiler, Uses Existing Hopper
- Minimizes Outage Requirements

**Clarifying Hydraulic System**
- No Changes Under Boiler, Uses Existing Hopper
- Minimizes Outage Requirements
- Allows for Water Reuse (FGD Makeup per ELG)

**Dry Hopper Pneumatic Conveying – PAX™ & DAX™**
- No Water, Returns Heat Back to Boiler
- Elimination of Long-term Environmental Wastewater Risk
Submerged Flight Conveyor (SFC) System

- (18) New SFC projects since 2013 (units)
- (7) New Projects in process
- Often the first choice if space is available under the boiler
Bottom Ash WTD Conversion Alternatives
Submerged Flight Conveyor (SFC)

- Continuous Removal of Ash
- Low Power Consumption
- Easily Incorporates Mill Rejects
- Industry Standard on New Units for past 30 years
Bottom Ash WTD Conversion Alternatives
Submerged Flight Conveyor (SFC)

Bottom Ash moisture content low enough to pass EPA Paint Filter Test after some storage time in bunker
SFC Cooling Water

- Water Addition to Maintain SFC Trough Water Temperature
- Per ELG, water is considered “quench water” (not transport water)
- Can direct overflow to Low Volume Waste Management System
- Can be Recirculated in Closed-loop (ZLD)
UCC Bottom Ash Wet-to-Dry Conversions
Unique Under Boiler SFC Designs
UCC Bottom Ash Wet-to-Dry Conversions
Unique Under Boiler SFC Designs

FOR EXISTING ASH HOPPER SEE DRAWINGS 527-55340-1 THRU -7
UCC Bottom Ash Wet-to-Dry Conversions
Unique Under Boiler SFC Designs
UCC Bottom Ash Wet-to-Dry Conversions
Unique Under Boiler SFC Designs
Conventional Dewatering Bin System
Bottom Ash WTD Conversion Alternatives
Conventional Dewatering & Recirculation System

• Minimal Outage Time for Conversion
• Continue to Use Existing Bottom Ash Hoppers
• Easily Incorporates Mill Rejects
Bottom Ash WTD Conversion Alternatives
Settling and Surge Tanks
Bottom Ash WTD Conversion Alternatives
Settling and Surge Tanks
Bottom Ash WTD Conversion Alternatives
Conventional Dewatering & Recirculation System

Bottom Ash may have to be moved and spread to enhance dewatering and achieve proper moisture content to pass EPA Paint Filter Test

Any Transport Water may need to be captured, collected and returned to the system
Bottom Ash WTD Conversion Alternatives
Conventional Dewatering & Recirculation System
Bottom Ash WTD Conversion Alternatives
Conventional Dewatering & Recirculation System
Continuous Dewatering & Recirculation (CDR) System

- (8) Operating Systems (since 2012)
- (13) Systems in Progress and to be operational in 2018/2019
Bottom Ash WTD Conversion Alternatives
Continuous Dewatering & Recirculation System (CDR) with Remote SFC’s

- CDR System with Remote SFC’s
- Combines SFC Technology with Conventional Recirculation System
Bottom Ash WTD Conversions
Continuous Dewatering & Recirculation System (CDR) with Remote SFC’s
Bottom Ash WTD Conversion Alternatives
Continuous Dewatering & Recirculation System (CDR) with Remote SFC’s
Bottom Ash WTD Conversion Alternatives
Continuous Dewatering & Recirculation System (CDR) with Remote SFC’s

UCC Remote SFCs
Bottom Ash WTD Conversion Alternatives
Continuous Dewatering & Recirculation System (CDR) with Remote SFC’s

UCC Bottom Ash and Pyrites Remote SFCs
Technical Design Features

- Reduced Equipment Scope
  - Combines Dewatering and Particulate Settling into Single Unit

- Provides Multiple Unit Synergies
  - Can Receive Sluice Lines from Multiple Units

- Reduced Foundation Design Requirements
  - Smaller Footprint than Traditional BA WTD Systems
  - Reduced Construction Costs

- Consistent Bottom Ash Dewatering
  - Continuous Dewatering Up SFC Incline Section
  - Dewatered Bottom Ash to Moisture Levels Suitable for Landfill Disposal or Beneficial Use
**Design Basis Requirements**

*Bottom Ash CDR System with Remote SFC’s (100% Redundancy)*

- Unit 1 BA Sluice
- Unit 2 BA Sluice
- Surge Tank
- Recirc
- SFC
- SFC
- Maint. Tank
## Design Basis Requirements

Typical Performance Guarantees

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Performance Requirement</th>
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<tbody>
<tr>
<td><strong>TSS</strong> (in R-SFC Overflow)</td>
<td>400 ppm (24-hour average)</td>
</tr>
<tr>
<td><strong>TSS</strong> (in Clarifier Overflow)</td>
<td>100 ppm (daily maximum)</td>
</tr>
<tr>
<td></td>
<td>30 ppm (monthly average)</td>
</tr>
<tr>
<td><strong>Moisture % (Bottom Ash)</strong></td>
<td>20% in bunker after 24 hours or Paint Filter Test</td>
</tr>
</tbody>
</table>
Bottom Ash WTD Conversions
Continuous Dewatering & Recirculation System (CDR) with Remote SFC’s
Bottom Ash moisture content low enough to readily pass EPA Paint Filter Test
Technical Design Features

- Uses Proven SFC Technology
  - Robust Design Suitable for Utility Applications
  - Standard Sections with Flexibility for Varying Sizes/Flows
  - Can be preassembled in larger sections to reduce installation costs and schedule

- Closed-Loop System
  - Sluice Water is Recirculated to Powerhouse
  - Runoff Water from Bunker is Returned to SFC
  - Zero Discharge to the Environment
Settling Velocity = The fluid velocity for which the particle is neither rising nor falling, and is calculated using Stokes Law.

\[ \Sigma F = 0 = F_b + F_d - F_g \]

- **Fg** = Gravitational Force  
  \((F = ma; \text{ mass } = \text{ particle density } \times \text{ particle volume})\)

- **Fd** = Force of Drag  
  \((F = \text{ rising fluid velocity } \times \text{ particle radius } \times \text{ fluid viscosity})\)

- **Fb** = Buoyancy Force  
  \((F = ma \{\text{weight of displaced fluid}\}; \text{ mass } = \text{ fluid density } \times \text{ particle volume})\)

**Stokes Law:**
**Settling Velocity** = The fluid velocity for which the particle is neither rising nor falling, and is calculated using Stokes Law.

\[ v_s = \frac{2g(\rho_p - \rho_f)r^2}{9\mu} \]

**Rising Velocity** = Basic Fluid Flow Equation

\[ \dot{V} = vA \]

Where:
- \( \dot{V} \) = volume flow rate of the fluid \((\text{ft}^3/\text{s})\), note: 1 \( \text{ft}^3 \) = 7.48 gallons
- \( A \) = Area the fluid is flowing through \((\text{ft}^2)\)
- \( v \) = velocity of the fluid \((\text{ft/s})\)
Typical Water Requirements:

- High Pressure Sluice Conveying Water = 2,500-3,500 gpm
- Low Pressure Cooling Water/Seal Trough Flushing/Make-Up Water Supply = 150-300 gpm/unit
Water Balance/Wastewater Considerations
Bottom Ash Sluice Water Demands for CDR & Dewatering Bin Systems

Water Balance Key Considerations

• **Losses**
  - Evaporation
  - Water Retention in Ash
  - Hopper Leakage
  - Seal Trough Flushing

• **Gains**
  - Chain Sprays – SFC (for CDR System)
  - Seal Water from Pumps (if not mechanical)
  - Rain

• **Will Have Net Loss of Water from System**
• **Water Balance can be complex**
• Comparing Average pH levels by Coal Type:
  ➢ Eastern Bituminous: 6.81
  ➢ Lignite: 5.40
  ➢ PRB: 7.22
  ➢ Western Coals (Non-PRB): 8.47

• pH Control Measures:
  ➢ Caustic Addition for High Sulfur Coals (NaOH)
  ➢ Acid Addition for PRB Coals
  ➢ Most installed systems not currently in use

• Chloride Concentrations:
  ➢ No consistent data for Chloride concentrating
  ➢ Potential blowdown considerations, but only if necessary
Water Balance/Wastewater Considerations
Bottom Ash Sluice Water Quality and Chemistry

UCC CDR System - Water Sample Chemical Analysis

- pH
- Chloride

- Reported Level (pH, Chlorides)

Oct-12 May-13 Nov-13 Jun-14 Dec-14 Jul-15 Jan-16 Aug-16 Sep-17

- 26.6
- 11.5
- 11.2
- 11
- 11.3
- 10.5
- 9.55
- 8.9
- 8
- 8
- 20.3
- 21.8
- 28.4
- 46.6
• Some plants have experienced low pH conditions in CDR Systems
• Seems to vary by boiler type and operating load
• UCC Solution: pH Control Modules
  ■ Design and Supply: $30-40K/Unit
  ■ Installation: $40-50K/Unit
  ■ Approximate Injection Rate (25% sodium hydroxide solution): 0.042 gallons/hour to 0.875 gallons/hour
  ■ The injection rate appears to corresponds to load. At lower loads, the rate goes up. At higher loads, the rate goes down.
Freeze Protection / Cold Weather Considerations

- Continuous Water Flow from Existing BA Hopper Overflows
- Heat Trace/Insulation for Service Water Piping
- Potential Enclosures/Buildings
Freeze Protection / Cold Weather Considerations

- Potential Enclosures/Buildings
Freeze Protection / Cold Weather Considerations

- Potential Enclosures/Buildings
Remote SFC & Clarifier System
Technical Design Features

- Uses Proven SFC & Clarifier Technologies
  - Similar features/benefits of CDR System
  - Additional Clarification Phase to reduce particulate carryover (TSS)
  - Can be recycled or designed for once-through system

- Once-Through System
  - Bottom Ash Sluice Water may be used as a make-up water source for FGD System (per Effluent Limitations Guidelines)
  - Can be designed for TSS levels suitable for Recirculation Pumps
Bottom Ash WTD Conversion Alternatives
UCC CDR System with Remote SFCs and Clarifiers
Bottom Ash WTD Conversion Alternatives
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Bottom Ash WTD Conversion Alternatives
UCC CDR System with Remote SFCs and Clarifiers
Bottom Ash WTD Conversion Alternatives
UCC CDR System with Remote SFCs and Clarifiers
Pneumatic Ash Extractor (PAX) System

- (9) Operating / Contracted PAX Systems covering (18) operating units
- Numerous additional proposals under Customer review
- Increasing Utility market interest in 100% dry solution
PAX Bottom Ash System Overview
Pneumatic Ash Extractor (PAX)
PAX Bottom Ash System Overview
Pneumatic Ash Extractor (PAX)

- Easily Retrofit Around Structural Barriers
- Provides Improved Heat Recovery and Boiler Efficiency
- Does Not Require Water
PAX Bottom Ash System Overview

Conceptual PAX Hopper (Elevation View)
PAX Bottom Ash System Overview
Pneumatic Ash Extractor (PAX)
Large Grid Doors Handle Large Clinkers

New doors shown prior to installation

Doors after 1.5 years of Service

Hopper Grid Doors Shown in Open and Closed Positions
PAX System Installed at Crystal River Station
PAX Bottom Ash System Overview
Pneumatic Ash Extractor (PAX)
Fused Tungsten Carbide Cams after 1.5 years of service
**Dry Seal Option**

- Includes new dry seal & insulation, attachment to scallop bar and new drip screens (heat shield)
PAX Bottom Ash System Overview
Dry Boiler Seal

- **Dry Seal Option**
  - Multi-layer seal, including wire mesh, insulating woven glass fabric, PTFE gas tight membranes and outer fabric with wire mesh protection
  - Insulation composed of high density glass wool encapsulated with fabric and wire mesh
  - Still need drip screens (heat shield)
Dry Seal Option (continued)

- Eliminates wall cooling water supply, largest source of overflow water
- High temperature refractory required above the normal water level
- Need to make sure overflows are in good, working condition
- Need to address cooling water requirements, since there will not be continuous water into hopper from wall cooling
PAX Bottom Ash System Overview
Hydraulic Enclosure Isolation Gate
PAX Bottom Ash System Overview

Pneumatic Ash Extractor (PAX) – Hydraulic Jaw Crusher
PAX Bottom Ash System Overview
Pneumatic Ash Extractor (PAX) – Hydraulic Jaw Crusher
PAX Bottom Ash System Overview
Pneumatic Ash Extractor (PAX)

- Ceramic (Alumina-tiled) Lined Elbows for Maximum High Temp Wear Life
PAX Bottom Ash System Overview
Pneumatic Ash Extractor (PAX)

UCC Dry Bottom Ash Silos
PAX Bottom Ash System Overview

Pneumatic Ash Extractor (PAX)

UCC PAX Hopper
PAX Bottom Ash System Overview
Pneumatic Ash Extractor (PAX)

UCC PAX Hopper Trial Erection
PAX Bottom Ash System Overview

Pneumatic Ash Extractor (PAX)

UCC PAX Hopper
PAX Bottom Ash System Overview
Pneumatic Ash Extractor (PAX)

UCC PAX Enclosure and Crusher
PAX Bottom Ash System Overview
Pneumatic Ash Extractor (PAX)

UCC PAX Enclosure and Crusher
UCC Fly Ash Fixation/Stabilization
Case Study #1

- Midwest installation, multiple units, Illinois Basin Coal
  - Implementing traditional ZLD for entire site
  - Converted all units to Dry fly ash
  - Site separates saleable vs. non-saleable fly ash

- WFGDs – Limestone based
  - Gypsum processed for sale or beneficial use

- Brine water – 5-10 gpm continuous
  - TDS: >300,000 mg/l
  - TSS: 20,000 mg/l
  - Chloride content in excess of 100,000 mg/l
Stabilization of WFGD Brine with Fly Ash
**Corrosion Resistant Mixer Design**  
**For High Chlorides**

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>DESCRIPTION</th>
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<tbody>
<tr>
<td>Body</td>
<td>Epoxy paint with HDPE liner</td>
</tr>
<tr>
<td>Cover</td>
<td>316L Stainless Steel</td>
</tr>
<tr>
<td>Shafts</td>
<td>HASTELLOY C-276</td>
</tr>
<tr>
<td>Pins</td>
<td>UHMW (TIVAR)</td>
</tr>
<tr>
<td>Nozzles</td>
<td>PerFluoroAlkoxy (PFA)</td>
</tr>
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**Equipment Designed to Handle High Chlorides**

<table>
<thead>
<tr>
<th>MATERIALS OF CONSTRUCTION</th>
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<tbody>
<tr>
<td>Brine Supply Piping</td>
<td>Fiberglass Reinforced Pipe (FRP)</td>
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<tr>
<td>Brine Flow Control Valve</td>
<td>PFA lined Ductile Iron and Stainless Steel</td>
</tr>
<tr>
<td>Brine Zone Flow On/Off Valve</td>
<td>PFA lined Ductile Iron and Stainless Steel</td>
</tr>
<tr>
<td>Instrumentation</td>
<td>Monel/Stainless Steel</td>
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Fixation of FGD Byproduct and Wastewater with Fly Ash and Lime
• **Overall Project Equipment Summary:**
  - Dry Fly Ash collection/transfer systems
  - Scrubber fixation building
  - Transfer & weigh belt conveyors for gypsum
  - Fly ash transfer and feed equipment
  - Lime Silos with fill and discharge feed equipment
  - Paddle Mixer/Unloaders with liquid feed valves
  - Discharge belt conveyors
UCC Fly Ash Fixation/Stabilization
Case Study #2

- WFGD Byproduct
  - 60 – 270 TPH
- FGD Wastewater
  - 55 – 350 GPM
- Dry Fly Ash Feed Rate
  - 30 – 125 TPH
- Lime Feed Rate
  - 3 – 20 TPH
UCC Fly Ash Fixation/Stabilization
Case Study #2

- Fixate discharged to bunker/pad for landfill
- Alternate use for fixated product as landfill cap
Discussion Overview

Summary of Recent WTD Activity

Bottom Ash Wet-to-Dry Conversion Technologies

Byproduct Handling Case Studies

Discussion / Questions
Questions ?
Thank You