

REINHOLD ENVIRONMENTAL Ltd.



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Challenges and Considerations for Wet-to-Dry Ash Conversions

Prepared for: 2016 APC-Wastewater/PCUG Conference

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18 July 2016



Regulatory Update & Implications

Overview of Technology Selection Criteria

Technical Design Challenges & Considerations

Water Balance & Wastewater Considerations



Safety Moment

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



Key Regulation Provisions

- Definition of Transport Water (ELG)
- Zero Liquid Discharge for Fly Ash & Bottom Ash Transport Water (ELG)
- Transport Water Exclusions (ELG)
- Free Liquid Restriction (CCR)
- Parking Lot Test / Tank Storage (CCR)



Transport Water

- “Any wastewater that is used to *convey* fly ash, bottom ash, or economizer ash from the ash collection or storage equipment, or boiler, and has *direct contact* with the ash.”



Fly Ash Transport Water

- Except for those discharges to which paragraph (h)(2) of this section applies (<50MW), or when the fly ash transport water is used in the FGD scrubber, ***there shall be no discharge of pollutants in fly ash transport water.***
- Dischargers must meet the discharge limitation in this paragraph by a date determined by the permitting authority that is as soon as possible beginning November 1, 2018, but no later than December 31, 2023.



Bottom Ash Transport Water

- Except for those discharges to which paragraph (h)(2) of this section applies (<50MW), or when the fly ash transport water is used in the FGD scrubber, ***there shall be no discharge of pollutants in bottom ash transport water.***
- Dischargers must meet the discharge limitation in this paragraph by a date determined by the permitting authority that is as soon as possible beginning November 1, 2018, but no later than December 31, 2023.



Mechanical Drag System (MDS)

- An MDS is a “Bottom ash handling system that collects bottom ash from the bottom of the boiler in a water-filled trough. The water bath in the trough quenches the hot bottom ash as it falls from the boiler and seals the boiler gases. A drag chain operates in a continuous loop to drag bottom ash from the water trough up an incline, which dewateres the bottom ash by gravity, draining the water back to the trough as the bottom ash moves upward. The dewatered bottom ash is often conveyed to a nearby collection area, such as a small bunker outside the boiler building, from which it is loaded onto trucks and either sold or transported to a landfill. *The MDS is considered a dry bottom ash handling system because the ash transport mechanism is mechanical removal by the drag chain, not the water.*”



Mechanical Drag System (MDS)

- In addition, the EPA Technical Development Document for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category (EPA-821-R-15-007) specifically notes (page 7-41 attached), *“The MDS does not need to operate as a closed-loop system because it does not use water as the transport mechanism to remove the bottom ash from the boiler; the conveyor is the transport mechanism. Therefore, any water leaving with the bottom ash does not fall under the definition of “bottom ash transport water,” but rather, is a low volume waste.”*



Low Volume Wastewater

- “Transport water does not include *low volume, short duration* discharges of wastewater from minor leaks (e.g. leaks from valve packing, pipe flanges, or piping) or minor maintenance events (e.g., replacement of valves or pipe sections).”

Low Volume Waste Sources include:

- Boiler blowdown
- Floor drains
- Recirculating house service water systems



Operating Criteria

- “If the owner or operator operates a CCR landfill or any lateral expansion of a CCR landfill, the CCR fugitive dust control plan must include procedures to emplace CCR as conditioned CCR. Conditioned CCR means wetting CCR with water to a moisture content that will prevent wind dispersal, but *will not result in free liquids.*”

Closure and Post-Closure Care

- “*Free liquids must be eliminated* by removing liquid wastes or solidifying the remaining wastes and waste residues.”

Paint Filter Test

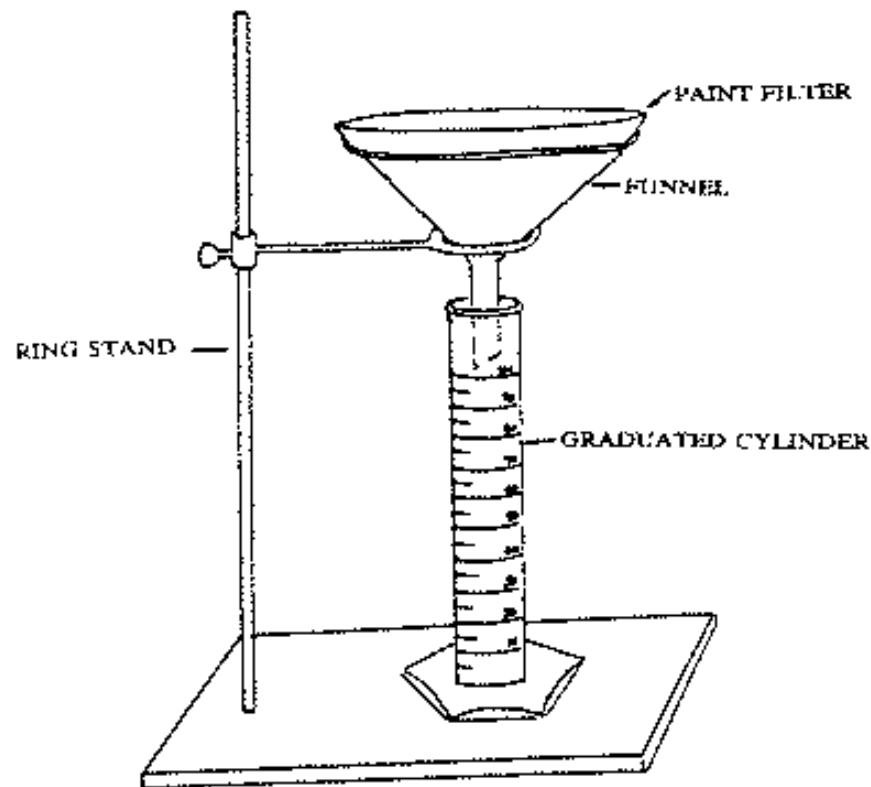
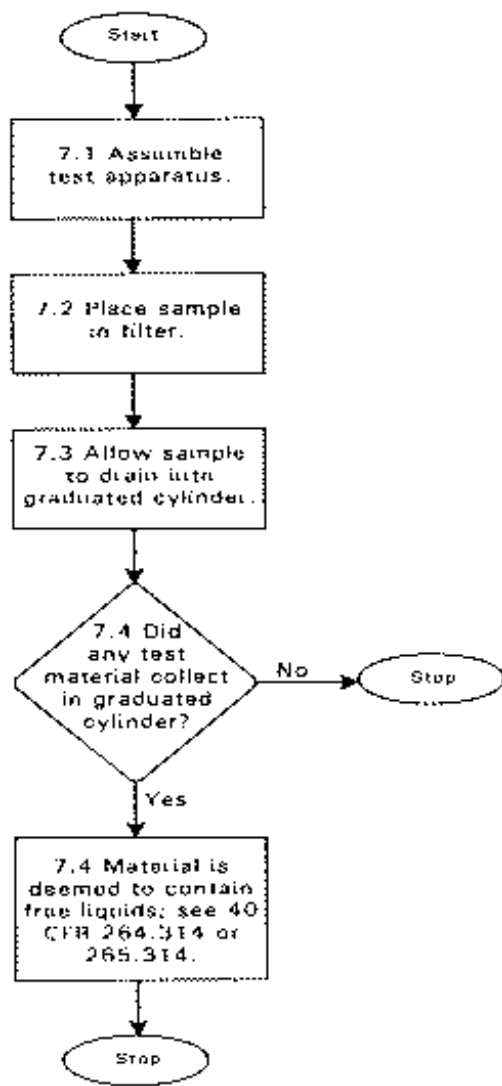
EPA Test Method 9095B



- US EPA approved test method (EPA 9095B) to determine the presence of free liquids in a representative sample of waste.
- A pre-determined amount of material is placed in a paint filter. If any portion of the sample passes through and drops from the filter in a five (5) minute period, then the material is deemed to contain free liquids.

Paint Filter Test

EPA Test Method 9095B





CFR Subpart 257.2 Definitions

- CCR surface impoundment means a “natural topographic depression, man-made excavation, or diked area, which is designed to hold an accumulation of CCR and liquids, and the unit treats, stores, or disposes of CCR.”
- Per EPA, concrete basins can be considered a tank if they are structurally designed to be self-supporting (i.e. the “parking lot” test)



EPA Guidance on Concrete Basins:

- References to Subtitle C program (“tanks”)
- “In making this assessment, the unit should be evaluated as if it were free standing, and filled to its design capacity with the material it is intended to hold. If the walls or shell of the unit along provide sufficient structural support to maintain the structural integrity of the unit under these conditions, *the unit can be considered a tank.*”



EPA Guidance on Concrete Basins (continued):

- “Accordingly, if the unit is not capable of retaining its structural integrity without supporting earthen materials, *it must be considered a surface impoundment.*”
- “So, using the same logic, if the concrete basin were free standing, and filled to its design capacity with the material it is intended to hold and the walls or shell of the unit alone provide sufficient structural support to maintain the structural integrity of the unit under these conditions, the unit would likely not be considered to be a surface impoundment.”



Fly Ash Wet-to-Dry Conversions

- Existing generating units >50 MW must implement system modifications to achieved Zero Liquid Discharge (ZLD) for Fly Ash sluice water (with exception of FGD makeup water) or convert systems to dry
- Remaining wet fly ash systems will likely be converted to dry systems
- Existing wet back-up systems will likely be decommissioned and may require additional redundancy for primary dry systems

Bottom Ash Wet-to-Dry Conversions

- Existing generating units >50 MW must implement system modifications to achieved Zero Liquid Discharge (ZLD) for Bottom Ash sluice water (with exception of FGD makeup water) or convert systems to dry
- For generating units < 50 MW, system must meet BPT requirements



WFGD Wastewater Handling

- Utilities will attempt to utilize dry fly ash unloading systems as a means to fixate a portion of the WFGD wastewater stream
- EPA reported 311 existing WFGD systems currently operating
- UCC has recently and is currently commissioning FGD wastewater fixation systems



Regulatory Update & Implications

Overview of Technology Selection Criteria

Technical Design Challenges & Considerations

Water Balance & Wastewater Considerations

Technical Design Considerations



Wet-To-Dry Ash Conversion Project Design Criteria

Budget	Plant Water Balance Considerations
Outage Requirements	Ash Conveying Capacities
Physical Parameters	Conveying Distance Considerations
Site Environmental Considerations	Operations & Maintenance Issues
Ash Characteristics	Multiple Unit Synergies
Ash Marketability/Beneficiation	Unburned Carbon Concerns

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



Regulatory Update & Implications

Overview of Technology Selection Criteria

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Bottom Ash Wet-To-Dry Conversions

Technical Alternatives



Submerged Flight Conveyor – SFC™

- Long-Term Economical Choice (Low O&M Costs)
- Simple Solution if Space 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™

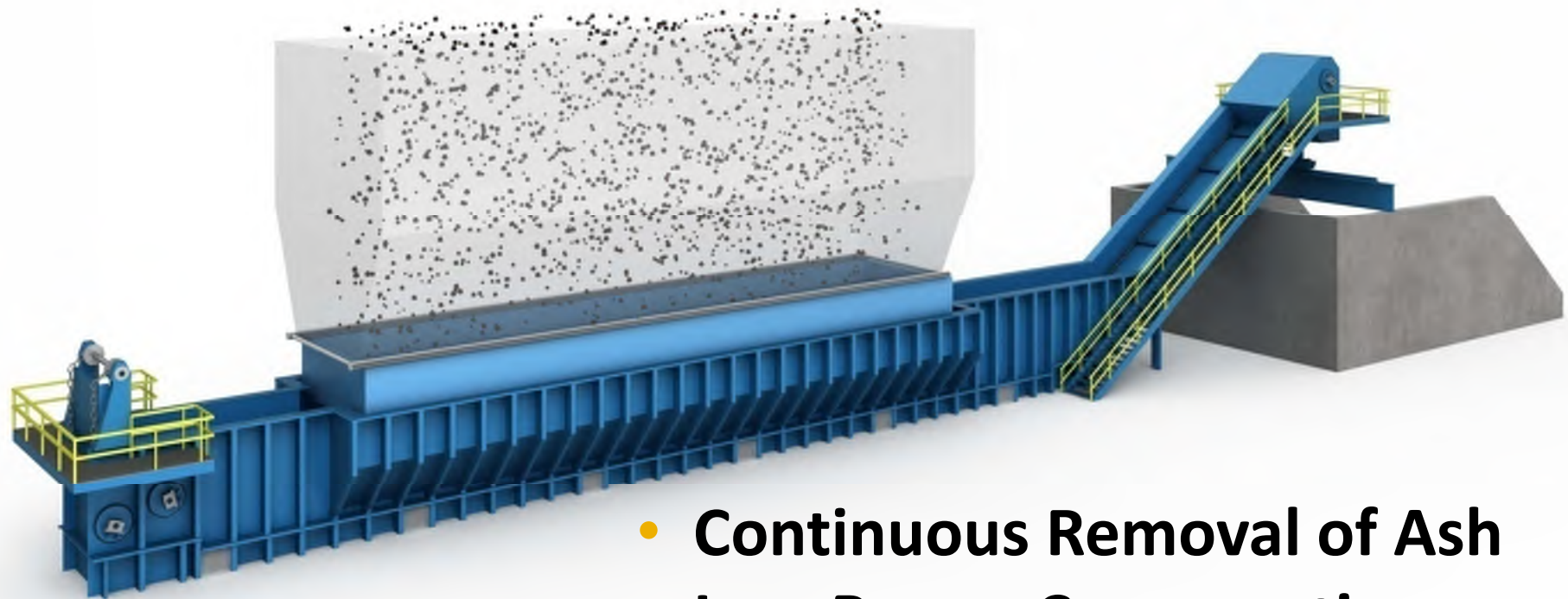
- No Water, Returns Heat Back to Boiler
- Easiest 100% Dry Option to Move Ash Out of Boiler Building



Submerged Flight Conveyor (SFC) System

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

Bottom Ash WTD Conversion Alternatives

Submerged Flight Conveyor (SFC)



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)



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



- **Inconsistent Bottom Ash Dewatering**
- **Paint Filter Test Compliance Concerns**
- **Secondary Containment to meet ELG ZLD requirements**

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 must be captured, collected and returned to the system





Continuous Dewatering & Recirculation (CDR) System

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



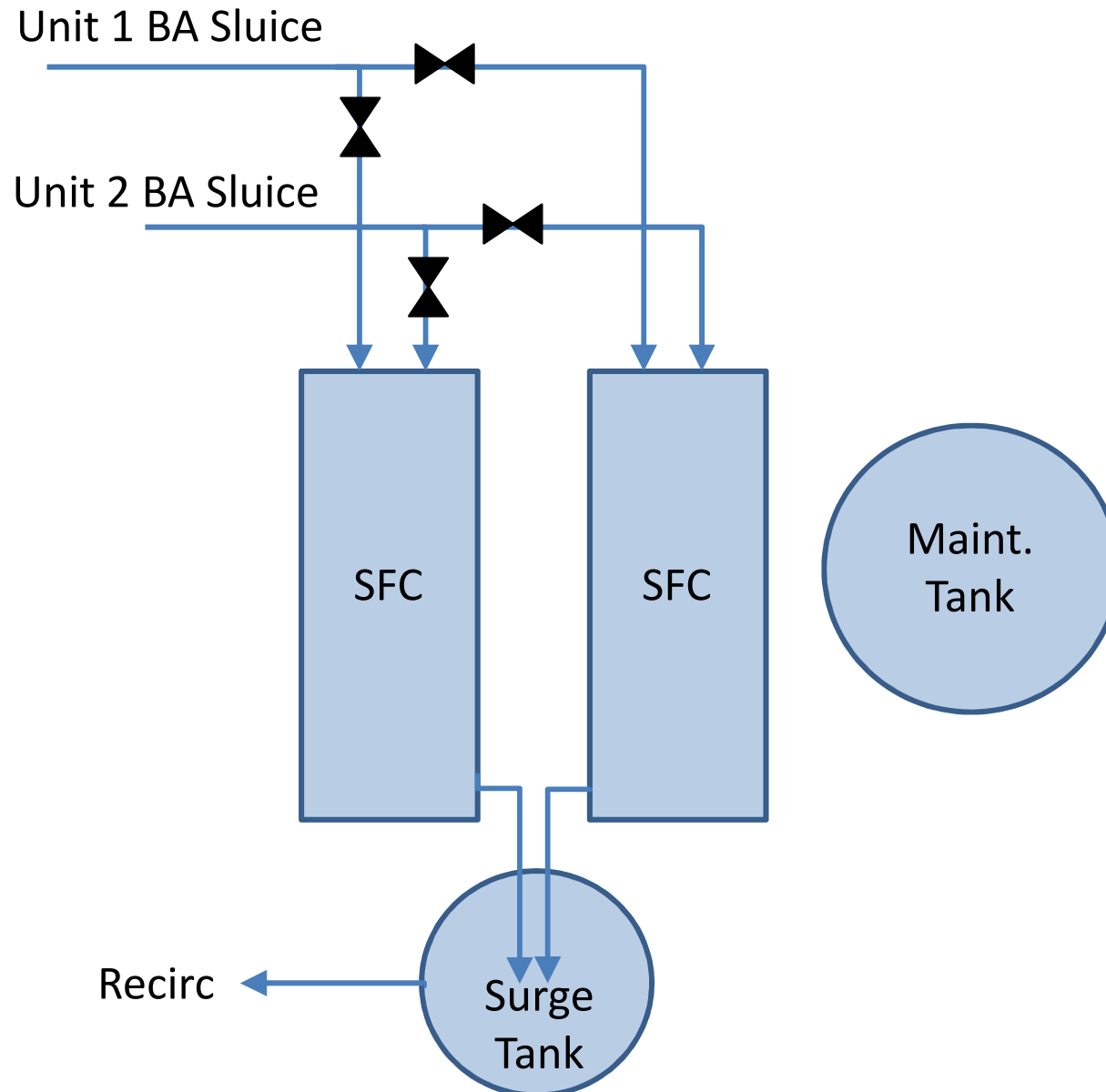
Bottom Ash WTD Conversions

Continuous Dewatering & Recirculation System (CDR) with Remote SFC's



Design Basis Requirements

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



Bottom Ash WTD Conversions

Continuous Dewatering & Recirculation System (CDR) with Remote SFC's



■ 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
- Dewateres Bottom Ash to Moisture Levels Suitable for Landfill Disposal or Beneficial Use

Bottom Ash WTD Conversions

Continuous Dewatering & Recirculation System (CDR) with Remote SFC's



Bottom Ash WTD Conversions

Continuous Dewatering & Recirculation System (CDR) with Remote SFC's



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

■ Closed-Loop System

- Sluice Water is Recirculated to Powerhouse
- Runoff Water from Bunker is Returned to SFC
- Zero Discharge to the Environment

Bottom Ash WTD Conversion Alternatives

Continuous Dewatering & Recirculation System (CDR) with Remote SFC's



■ Technical Design Features

- Achieves Particulate Removal Suitable for Closed-Loop System
 - 400 ppm (24-hour average)



Design Basis Requirements

Particulate Settling Design Approach



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

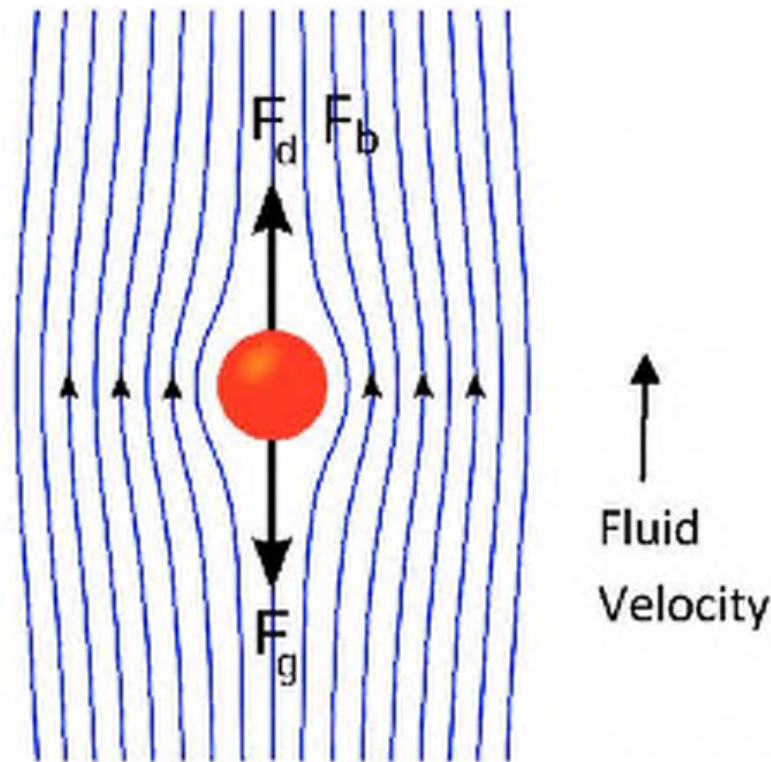


Figure 3: Free Body Diagram of a fine particle in rising fluid.

F_g = Gravitational Force

($F = ma$; mass = particle density * particle volume)

F_d = Force of Drag

($F =$ rising fluid velocity x particle radius x fluid viscosity)

F_b = Buoyancy Force

($F = ma$ {weight of displaced fluid}; mass = fluid density x particle volume)

Stokes Law:

$$\Sigma F = 0 = F_b + F_d - F_g$$

Design Basis Requirements

Particulate Settling Design Approach



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 (ft³/s), note: 1 ft³ = 7.48 gallons
A = Area the fluid is flowing through (ft²)
v = velocity of the fluid (ft/s)

Water Balance/Wastewater Considerations

Bottom Ash Sluice Water Demands for CDR & Dewatering Bin Systems



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 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**

Water Balance/Wastewater Considerations

Bottom Ash Sluice Water Quality and Chemistry





Freeze Protection / Cold Weather Considerations

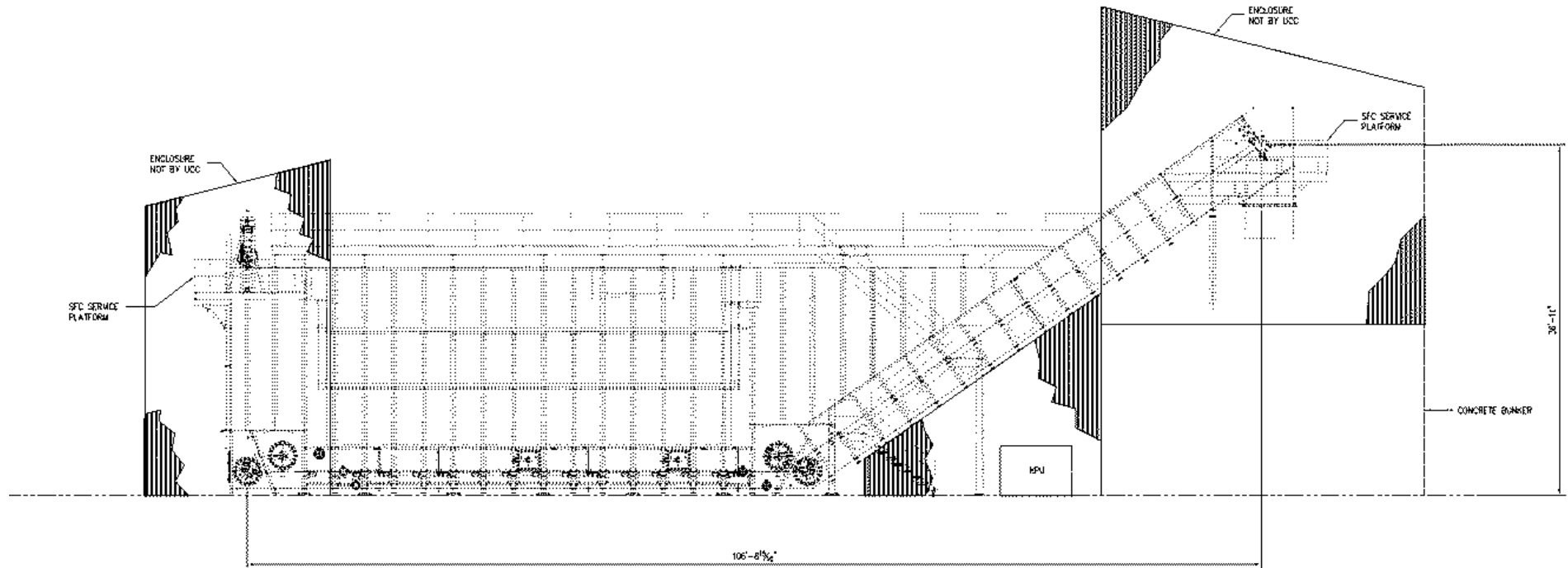
- Continuous Water Flow from Existing BA Hopper Overflows
- Heat Trace/Insulation for Service Water Piping
- Potential Enclosures/Buildings





Freeze Protection / Cold Weather Considerations

- Potential Enclosures/Buildings





Freeze Protection / Cold Weather Considerations

- Potential Enclosures/Buildings

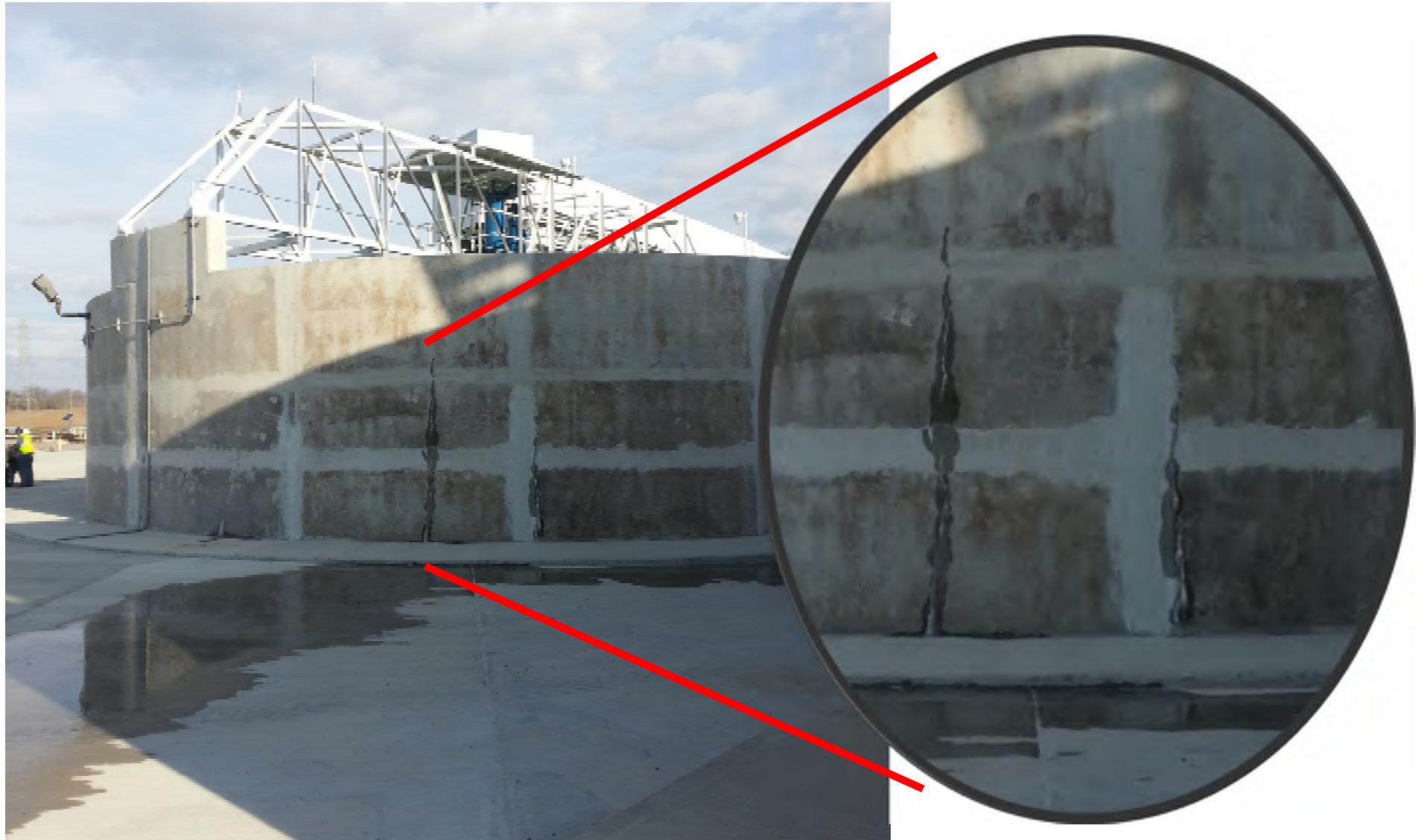




Concrete Dewatering Basins

Coal Combustion Residuals (CCR) Ruling

Surface Impoundment vs. Tank



Bottom Ash WTD Conversion Alternatives

Bottom Ash Dewatering Basins



Bottom Ash Dewatering Basins

Design/Performance Considerations



**Coarse material will settle out first
and readily dewater**

Bottom Ash Dewatering Basins

Design/Performance Considerations



Medium and fine particulates may not achieve desired moisture content of 15-20% in basins



Bottom Ash Dewatering Basins

Design/Performance Considerations



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

Bottom Ash Dewatering Basins

Design/Performance Considerations



Must ensure settling area is sufficient to limit fines carryover

Bottom Ash Dewatering Basins

Design/Performance Considerations



Must clear ash collection basins to ensure proper settling area and minimum upward rise velocity

Bottom Ash WTD Conversion Alternatives

Particulate Settling Design Approach



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

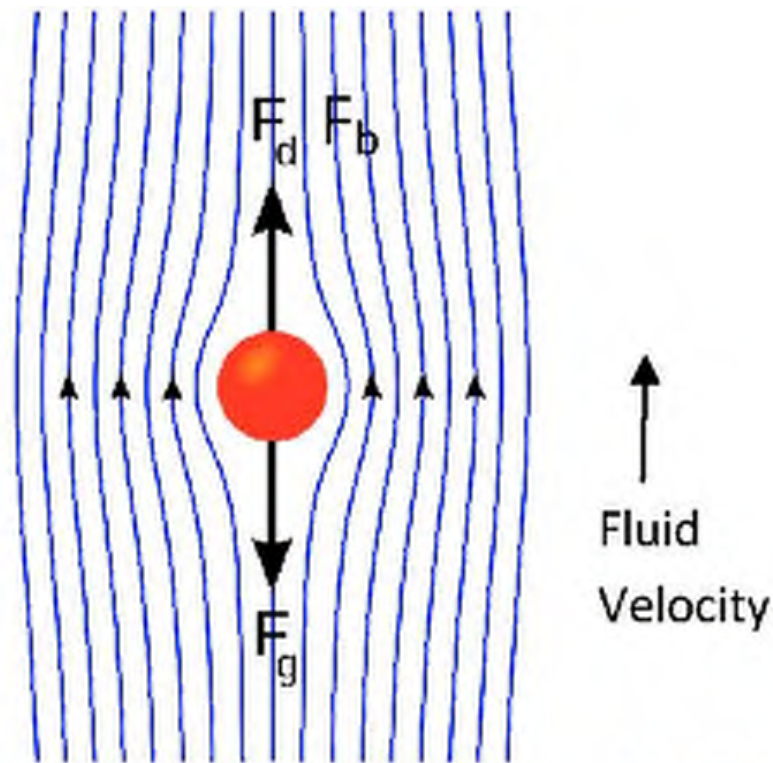


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($F =$ rising fluid velocity x particle radius x fluid viscosity)

F_b = Buoyancy Force

($F = ma$ {weight of displaced fluid}; mass = fluid density x particle volume)

Stokes Law:

$$\Sigma F = 0 = F_b + F_d - F_g$$

Bottom Ash WTD Conversion Alternatives

Particulate Settling Design Approach



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

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

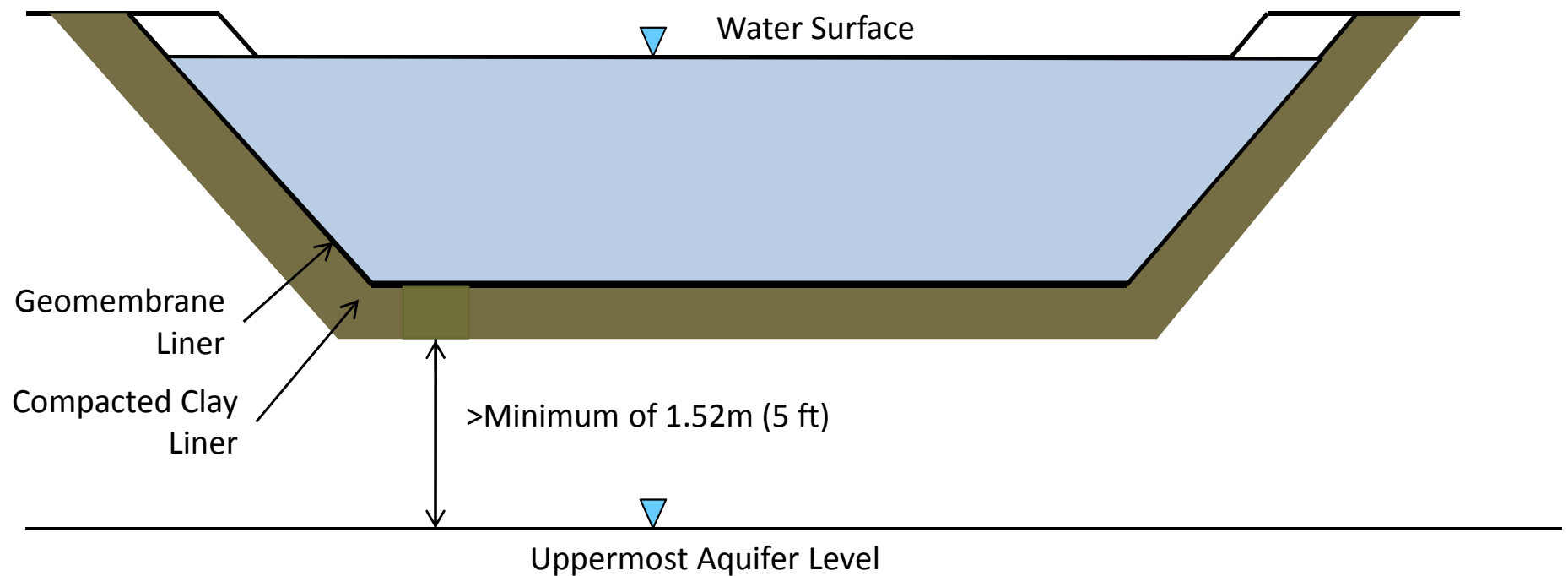
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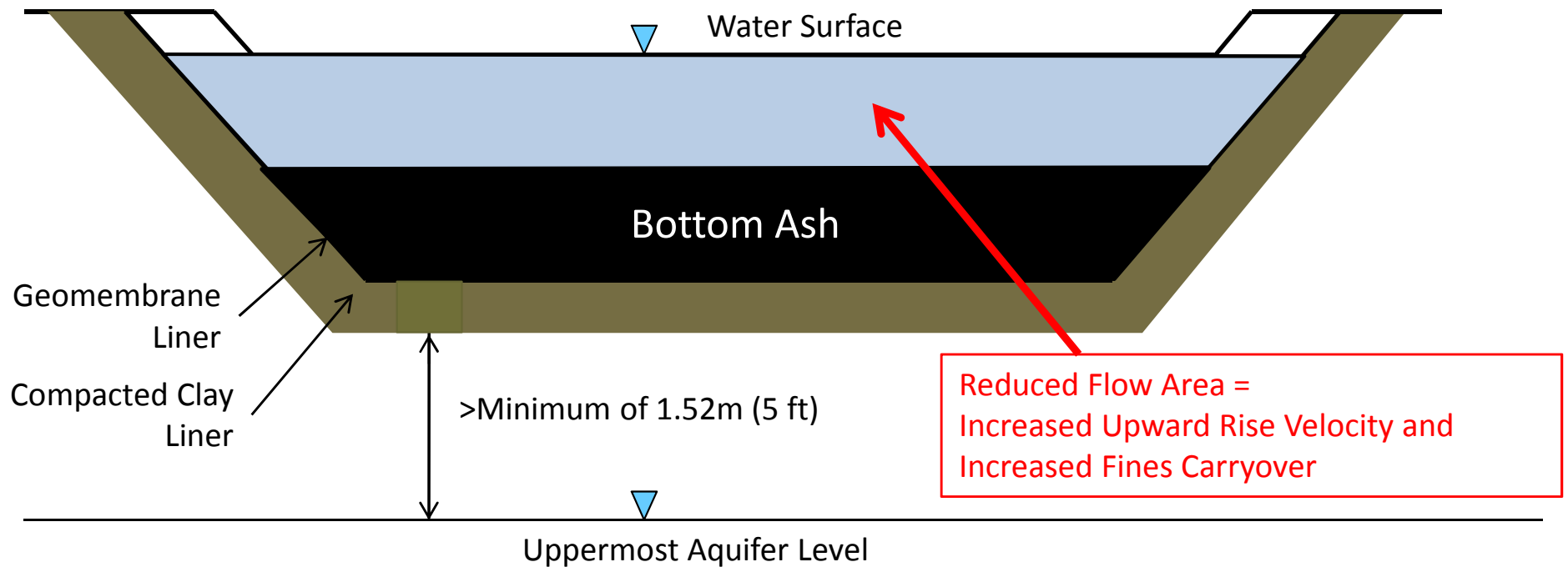
Bottom Ash Dewatering Basins

New & Existing CCR Surface Impoundment Design



Bottom Ash Dewatering Basins

New & Existing CCR Surface Impoundment Design



Bottom Ash Dewatering Basins

Design/Performance Considerations



Fines carryover will result in increased wear on return water system and increased likelihood of plugging of bottom ash area piping (e.g. wall cooling piping, seal trough flushing)

Bottom Ash Dewatering Basins

Design/Performance Considerations



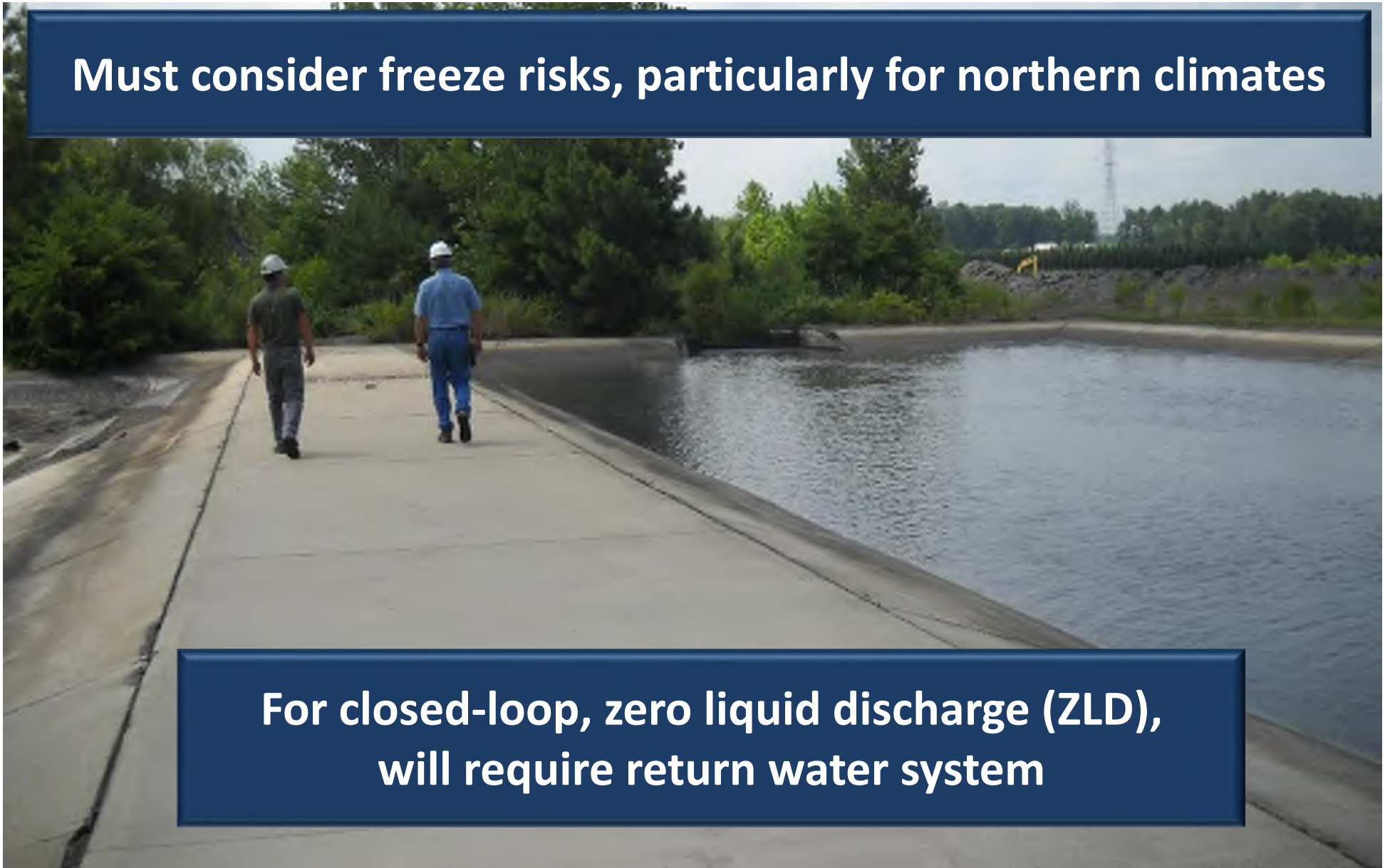
Must consider potential plugging of dewatering screens

Bottom Ash Dewatering Basins

Design/Performance Considerations



Must consider freeze risks, particularly for northern climates



**For closed-loop, zero liquid discharge (ZLD),
will require return water system**

Bottom Ash Dewatering Basins

Design/Performance Considerations / Risk Analysis



Per CCR requirements, basins may still require subsurface liner system and groundwater monitoring system, and be 5 ft above uppermost aquifer



Bottom Ash Dewatering Basins

Design/Performance Considerations / Risk Analysis



Risk Analysis must consider relative proximity to local waterways/flood plain for potential migration of ash wastewater and solids during a peak storm event, particularly relative to ELG ZLD requirements



Remote SFC & Clarifier System

Bottom Ash WTD Conversion Alternatives

Bottom Ash Dewatering and Clarification System with Remote SFC's





■ 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

Bottom Ash Dewatering and Clarification System with Remote SFC's



Bottom Ash WTD Conversion Alternatives

Bottom Ash Dewatering and Clarification System with Remote SFC's



Bottom Ash WTD Conversion Alternatives

Bottom Ash Dewatering and Clarification System with Remote SFC's





Pneumatic Ash Extractor (PAX) System

Bottom Ash WTD Conversion Alternatives

Pneumatic Ash Extractor (PAX)



Bottom Ash WTD Conversion Alternatives

Pneumatic Ash Extractor (PAX)

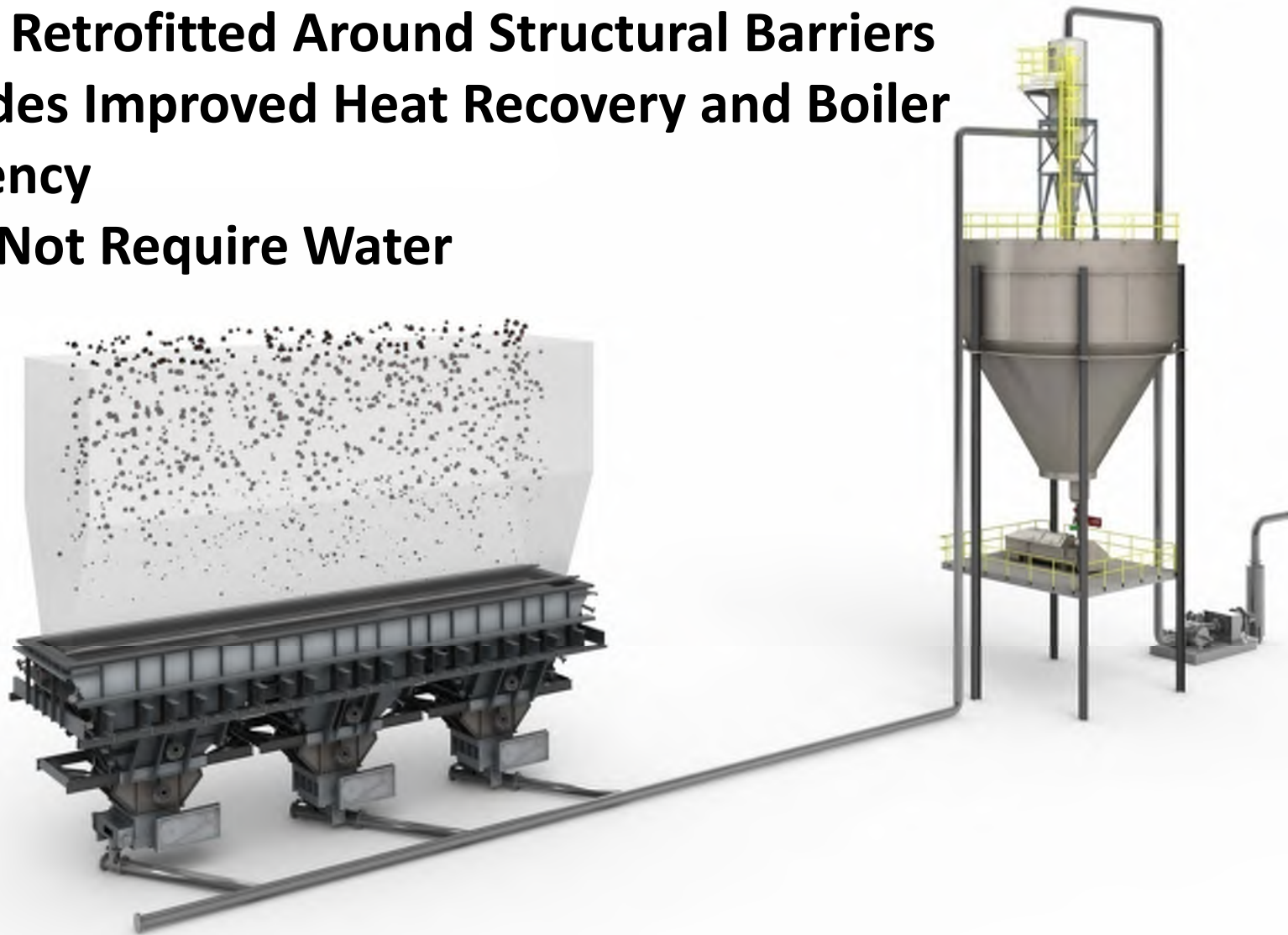


Bottom Ash WTD Conversion Alternatives

Pneumatic Ash Extractor (PAX)



- Easily Retrofitted Around Structural Barriers
- Provides Improved Heat Recovery and Boiler Efficiency
- Does Not Require Water



Bottom Ash WTD Conversion Alternatives

Pneumatic Ash Extractor (PAX)



Bottom Ash WTD Conversion Alternatives

Pneumatic Ash Extractor (PAX)



Bottom Ash WTD Conversion Alternatives

Pneumatic Ash Extractor (PAX)



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Bottom Ash WTD Conversion Alternatives

Pneumatic Ash Extractor (PAX)

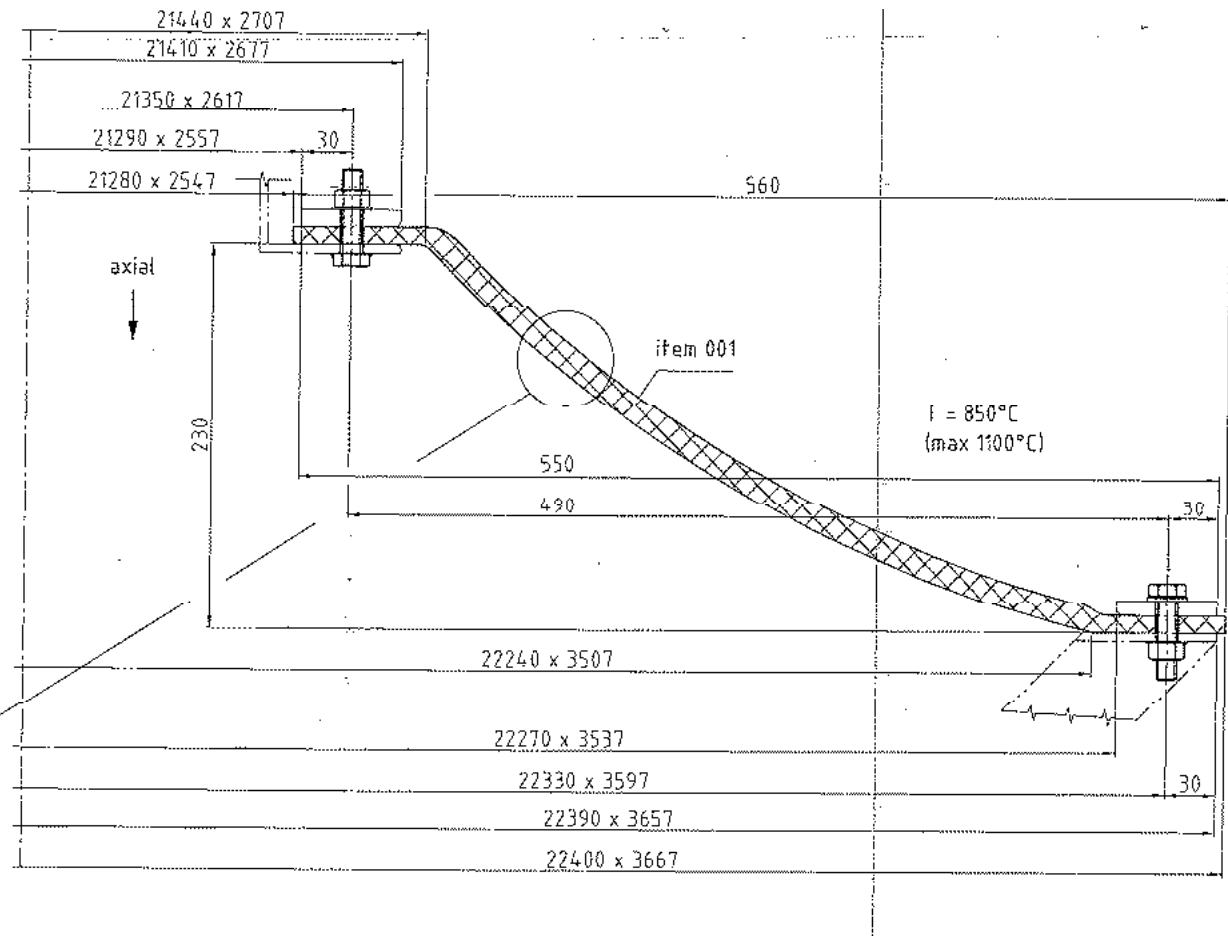


Bottom Ash WTD Conversion Alternatives



Pneumatic Ash Extractor (PAX)

medium: flue gas, ash, conglomerate
temperature: +850°C to max. +1100°C
pressure: max. -250 daPa
movement: axial -460 mm
lateral Y=61 mm, Z=50 mm



Construction of layers from inner to outer:

- 1 ply stainless steel wire mesh, INCONEL 600, appr 0.36 mm thick
- 1 ply stainless steel wire mesh, appr 0.15 mm thick
- 1 ply isoTHERM 1000 fabric
- 1 ply Stainless steel foil, appr. 0,005 mm thick, 1.4401
- 1 ply isoTHERM 800 fabric, steel reinforced
- 1 ply Stainless steel foil, appr. 0,065 mm thick, 1.4401
- 1 ply isoTHERM 800 fabric, steel reinforced
- 1 ply stainless steel wire mesh, appr 0,3 mm thick
- border stiffened as cuff type, width 75 mm
- from 1 ply isoGLAS fabric, appr 2,0 mm thick

Dry Flexible Seal



Discussion Overview



Regulatory Update & Implications

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Water Balance & Wastewater Considerations



Additional Water Balance & Wastewater Considerations



Existing Systems:

- Over half of Economizer Ash removal systems use sluice conveying
- Of these wet systems, most are connected to the Bottom Ash Sluice Conveying System or SFC's
- Some systems collect Economizer Ash with Dry Flight Conveyors (DFC) and transfer to Vacuum System or Sluice Conveying System
- Balance are typically connected to Dry Fly Ash Vacuum System



Key Considerations:

- No new definition per CCR/ELG
 - Economizer Ash = Fly Ash (when collected with Fly Ash System)
 - Economizer Ash = Bottom Ash (when collected with Bottom Ash System)
- 100% Dry Solutions can likely be tied into existing Fly Ash Systems
- Dry collection eliminates potential concern for fines concentrations in closed-loop dewatering systems
- UCC recommends collecting Air Heater Ash with Precipitator/Fabric Filter Fly Ash Systems



Existing Systems:

- Most Mill Reject (Pyrites) removal systems use sluice conveying
- Most are connected to the Bottom Ash Sluice Conveying System and ponds, while some are independent sluice systems that discharge to separate ponds
- Some plants have Pyrites Dewatering Bins
- 100% Dry Solutions require separate systems



Key Considerations:

- No new definition per CCR/ELG (not a “CCR”)
- Many plants are now requesting separation of Bottom Ash and Mill Rejects to ensure Bottom Ash Marketability
- 100% Dry Systems can be difficult retrofits (physical space, cost)
- Can be readily connected to CDR or SFC systems
- Can have an independent pyrites dewatering system

Water Balance/Wastewater Considerations

Pyrites System Considerations



Pyrites Dewatering Bins





Understand Regulatory Requirements & Implications

Define Criteria As Early As Possible

Evaluate Criteria Against Multiple Alternatives

Determine Optimal Solution for each Plant

“One Size Does Not Fit All”

Determine Fleetwide Synergies

Begin Schedule Planning ASAP

Wet-to-Dry Ash Conversions

Challenges & Considerations



Questions ?

Wet-to-Dry Ash Conversions

Challenges & Considerations

