UNITED CONVEYOR CORPORATION

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

Prepared for: WPCA

06 June 2018

Safety Moment

Presentation Prepared For:

Discussion Overview

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

Discussion Overview

Presentation Prepared For:

- **Summary of Recent WTD Activity**
- Bottom Ash Wet-to-Dry Conversion Technologies
- Byproduct Handling Case Studies
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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

ELG Ruling

Final Rule Basis

Wastestreams	Technology Basis
FGD Wastewater	Chemical Precipitation + Biological Treatment
Fly Ash Transport Water	Dry Handling / Closed-loop for units >50W; Impoundment (equal to BPT) for units <50MW
Bottom Ash Transport Water	Dry Handling / Closed-loop for units >50W; Impoundment (equal to BPT) for units <50MW
Combustion Residual Leachate	Impoundment (equal to BPT)
FGMC Wastewater	Dry Handling
Gasification Wastewater	Evaporation
Nonchemical Metal Cleaning Wastes	Chemical Precipitation

UCC Wet-to-Dry Ash Conversion Update

WTD Projects Awarded to UCC (2009-2018)

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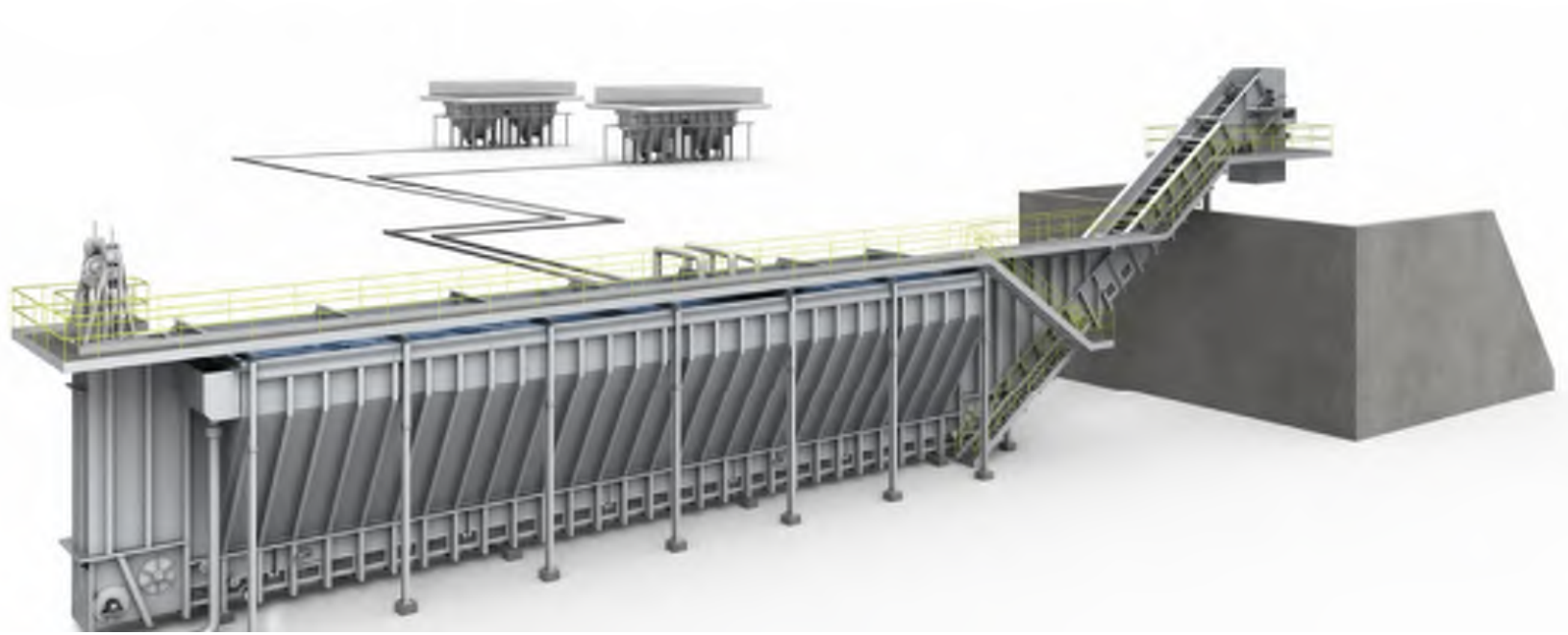
Project Type	# of Projects Awarded	# of Units Converted
Bottom Ash Wet-to-Dry Conversions	**52**	**112**
Fly Ash Wet-to-Dry Conversions	**25**	**56**



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UCC Wet-to-Dry Ash Conversion Update

Summary of Recent UCC Bottom Ash WTD Activity

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UCC CDR System	• (8) Operating Systems (since 2012) • (12) New Projects in Progress with Systems Operational in 2018/2019/2020 • Often Preferred if Under-Unit SFC will not fit
UCC SFC System	• (18) New SFC projects in last (4) years • (7) New Projects in Progress • (2) Additional Pending Awards • Likely First Choice if Space Permits
UCC PAX System	• (5) Operating Systems • (4) New Projects in Progress with Systems Operational in 2018/2019/2020 • Increasing Utility & Industrial Market Interest in 100% Dry Solution (eliminates wastewater)

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”

UCC Wet-to-Dry Ash Conversion Update

Project Drivers

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)

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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

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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

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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)

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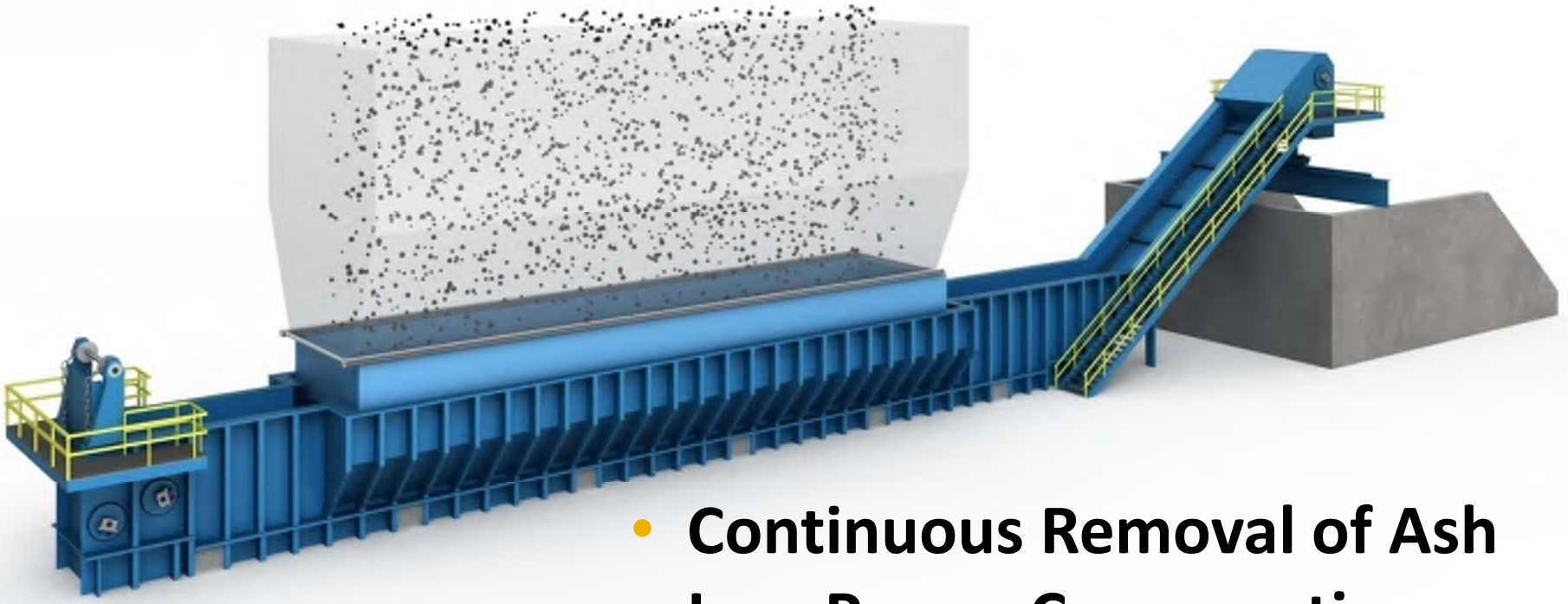

- **Continuous Removal of Ash**
- **Low Power Consumption**
- **Easily Incorporates Mill Rejects**
- **Industry Standard on New Units for past 30 years**

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Bottom Ash WTD Conversion Alternatives

Submerged Flight Conveyor (SFC)

Presentation Prepared For:

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

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Bottom Ash WTD Conversion Alternatives

Submerged Flight Conveyor (SFC)

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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

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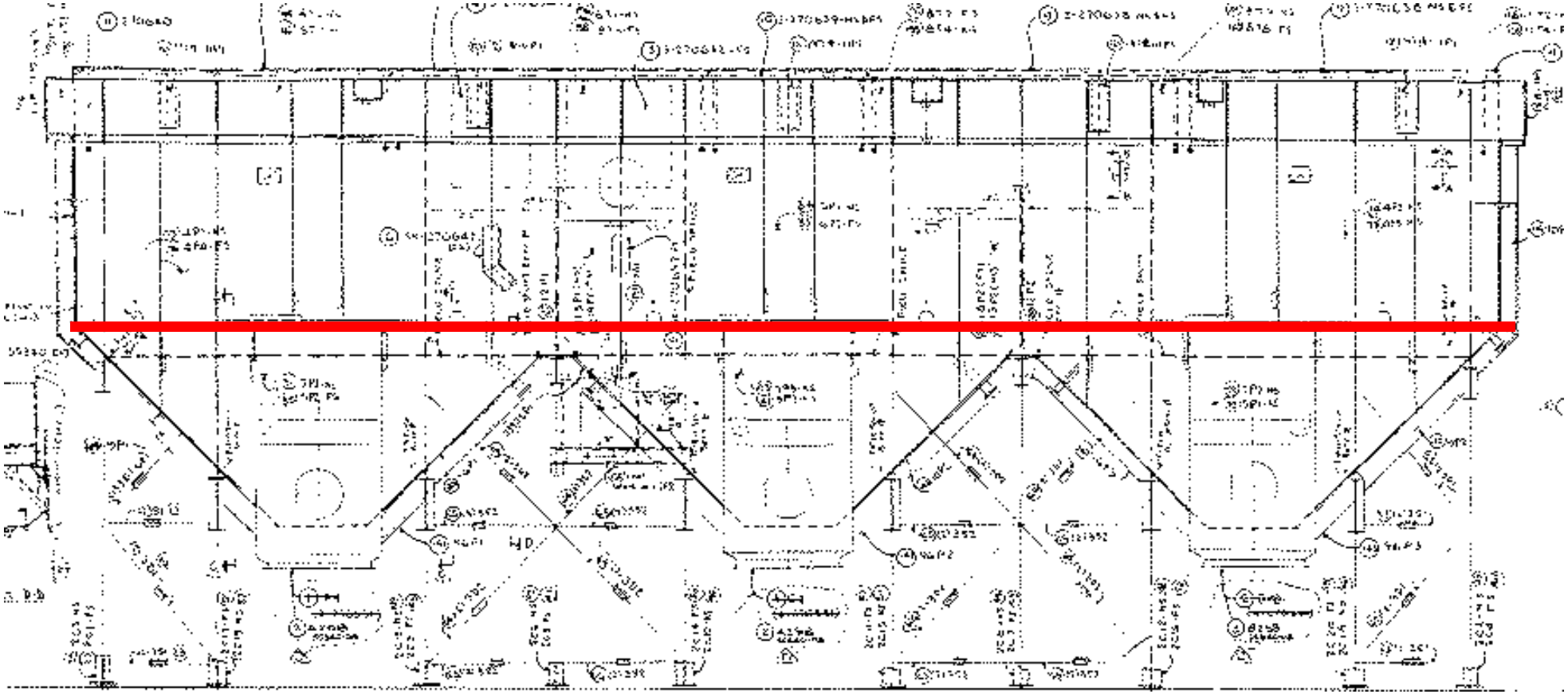

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UCC Bottom Ash Wet-to-Dry Conversions

Unique Under Boiler SFC Designs

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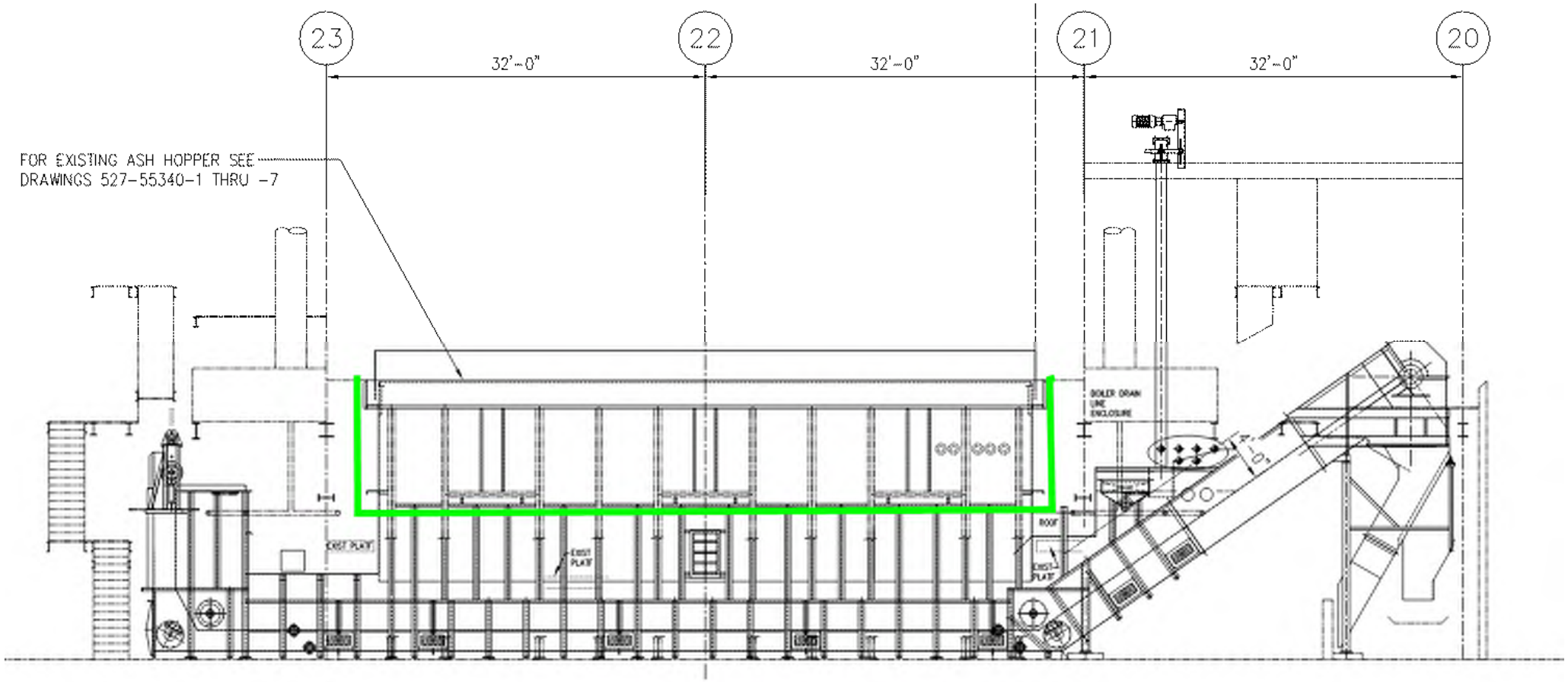

UCC Bottom Ash Wet-to-Dry Conversions

Unique Under Boiler SFC Designs

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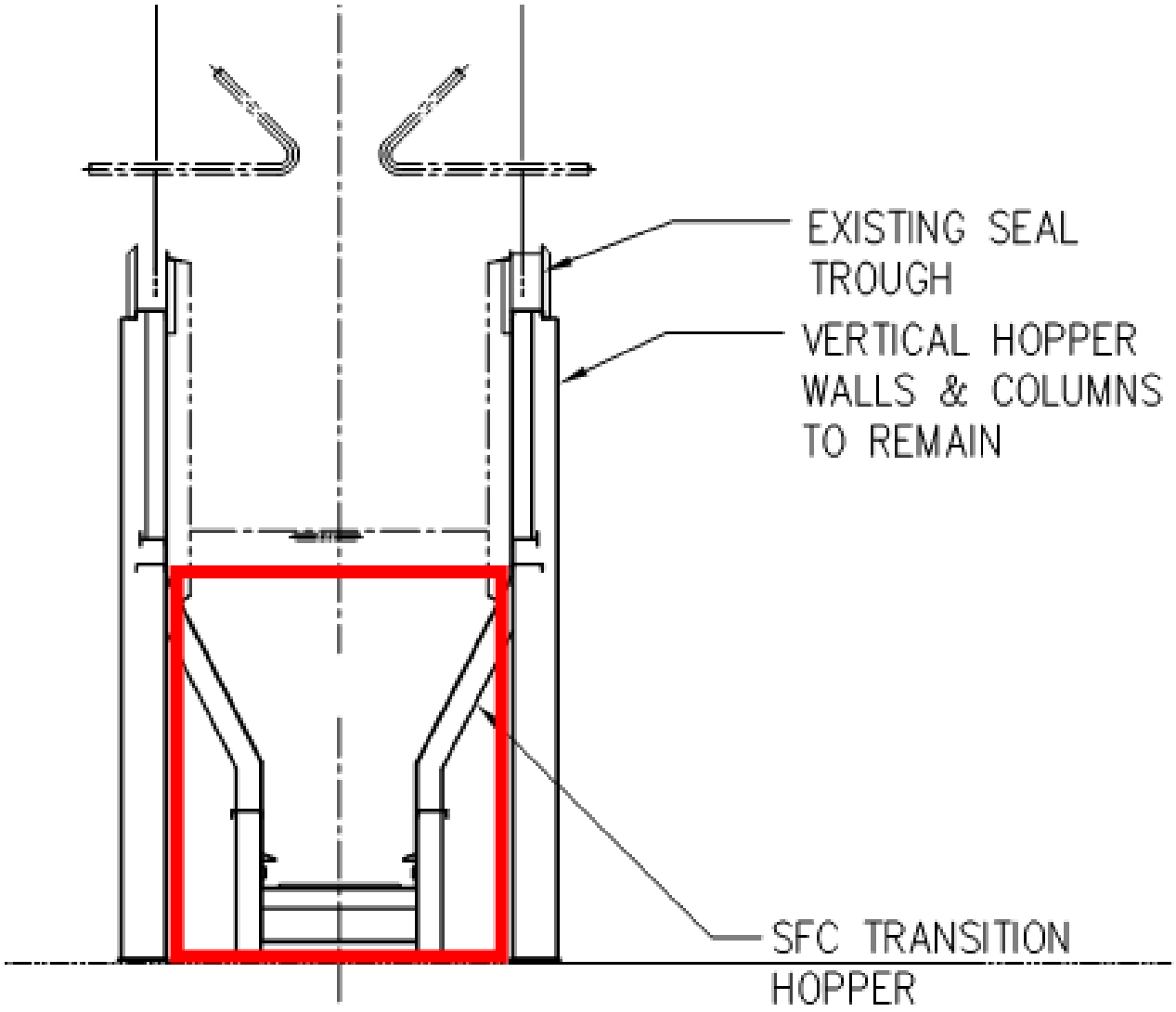

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UCC Bottom Ash Wet-to-Dry Conversions

Unique Under Boiler SFC Designs

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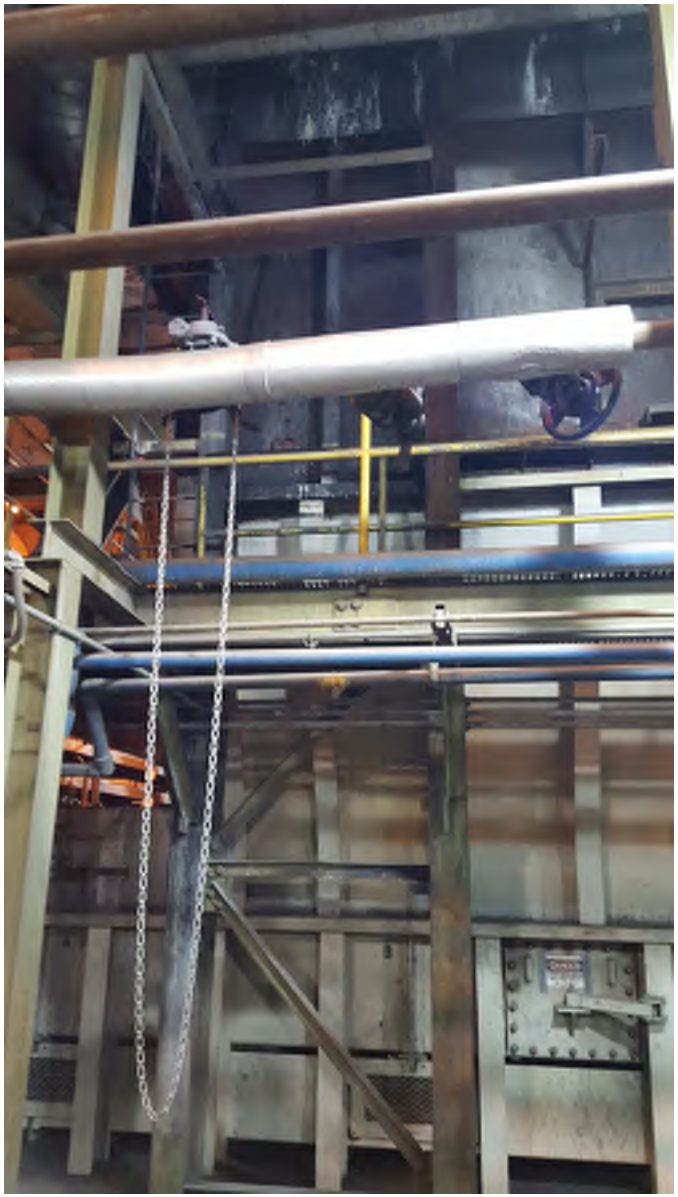

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Conventional Dewatering Bin System

Bottom Ash WTD Conversion Alternatives

Conventional Dewatering & Recirculation System

Presentation Prepared For:

- **Minimal Outage Time for Conversion**
- **Continue to Use Existing Bottom Ash Hoppers**
- **Easily Incorporates Mill Rejects**

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Bottom Ash WTD Conversion Alternatives

Settling and Surge Tanks

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Bottom Ash WTD Conversion Alternatives

Settling and Surge Tanks

Presentation Prepared For:

Bottom Ash WTD Conversion Alternatives

Conventional Dewatering & Recirculation System

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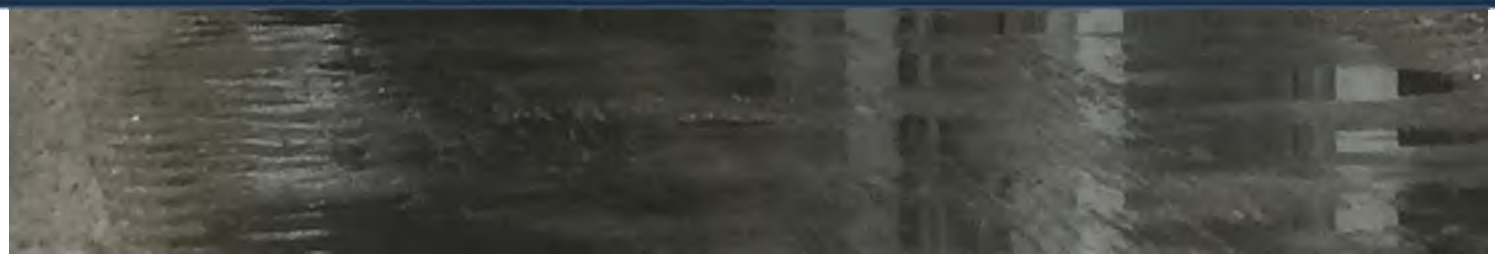
Bottom Ash may have to be moved and spread to enhance dewatering and achieve proper moisture content to pass EPA Paint Filter Test

Any Transport Water may need to be captured, collected and returned to the system



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Bottom Ash WTD Conversion Alternatives

Conventional Dewatering & Recirculation System

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Bottom Ash WTD Conversion Alternatives

Conventional Dewatering & Recirculation System

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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

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- CDR System with Remote SFC's
- Combines SFC Technology with Conventional Recirculation System

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Bottom Ash WTD Conversions

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

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Bottom Ash WTD Conversion Alternatives

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

Presentation Prepared For:

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Bottom Ash WTD Conversion Alternatives

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

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UCC Remote SFCs

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Bottom Ash WTD Conversion Alternatives

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

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UCC Bottom Ash and Pyrites Remote SFCs

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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
  - Dewaters 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)

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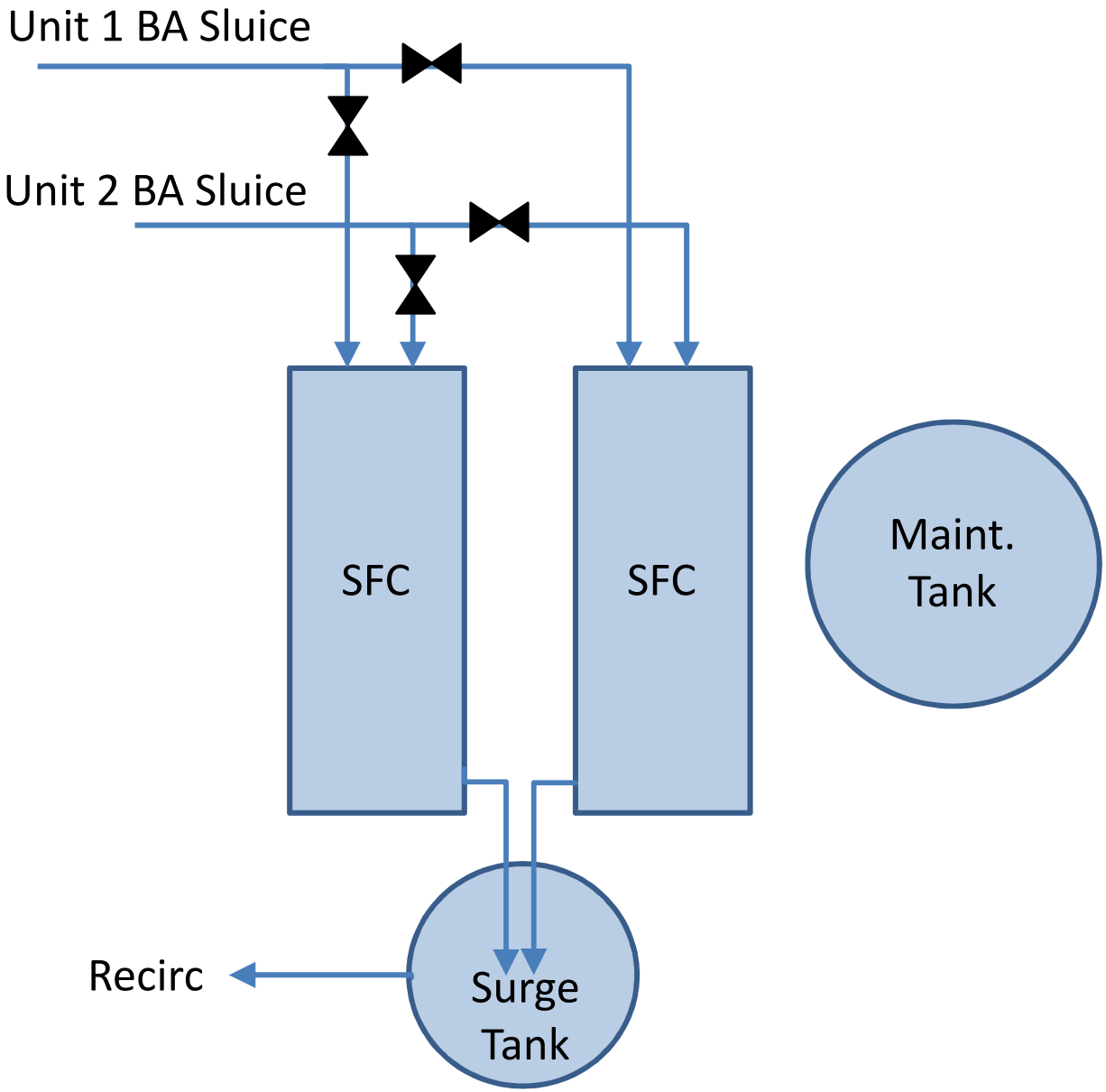

Design Basis Requirements

Typical Performance Guarantees

Parameter	Performance Requirement
TSS (in R-SFC Overflow)	400 ppm (24-hour average)
TSS (in Clarifier Overflow)	100 ppm (daily maximum) 30 ppm (monthly average)
Moisture % (Bottom Ash)	20% in bunker after 24 hours or Paint Filter Test

Bottom Ash WTD Conversions

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

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Bottom Ash WTD Conversions

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

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Bottom Ash WTD Conversions

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

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Bottom Ash WTD Conversions

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

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

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.

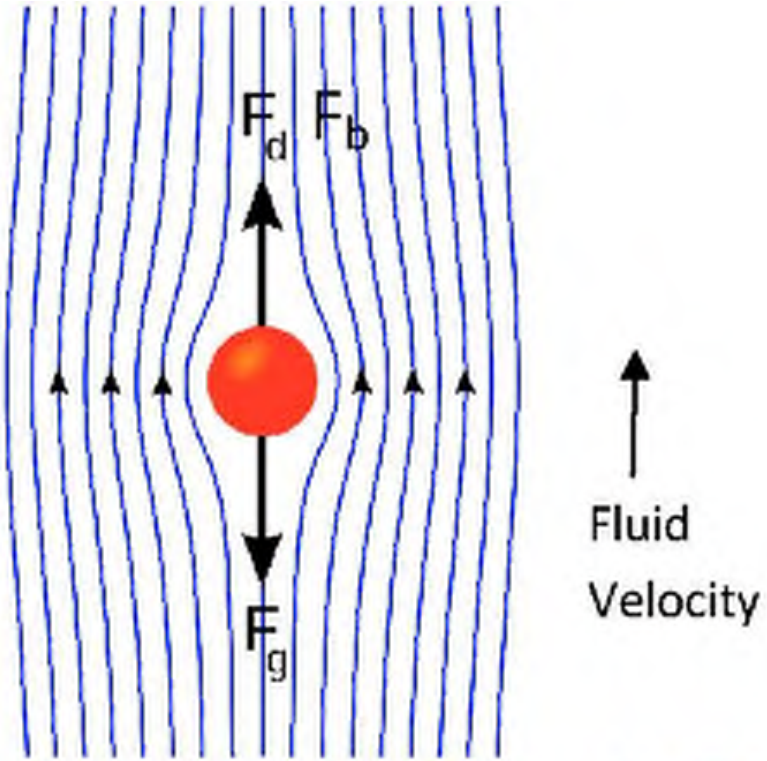

Figure 3: Free Body Diagram of a fine particle in rising fluid.

Fg = Gravitational Force
(F = ma; mass = particle density * particle volume)

Fd = Force of Drag
(F = rising fluid velocity x particle radius x fluid viscosity)

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

Stokes Law:

$$\Sigma F = 0 = Fb + Fd - Fg$$

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 (ft^3/s), note: 1 ft^3 = 7.48 gallons

A = Area the fluid is flowing through (ft^2)

v = velocity of the fluid (ft/s)

Water Balance/Wastewater Considerations

Bottom Ash Sluice Water Demands for CDR & Dewatering Bin Systems

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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

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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**

Water Balance/Wastewater Considerations

Bottom Ash Sluice Water Quality and Chemistry

- **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

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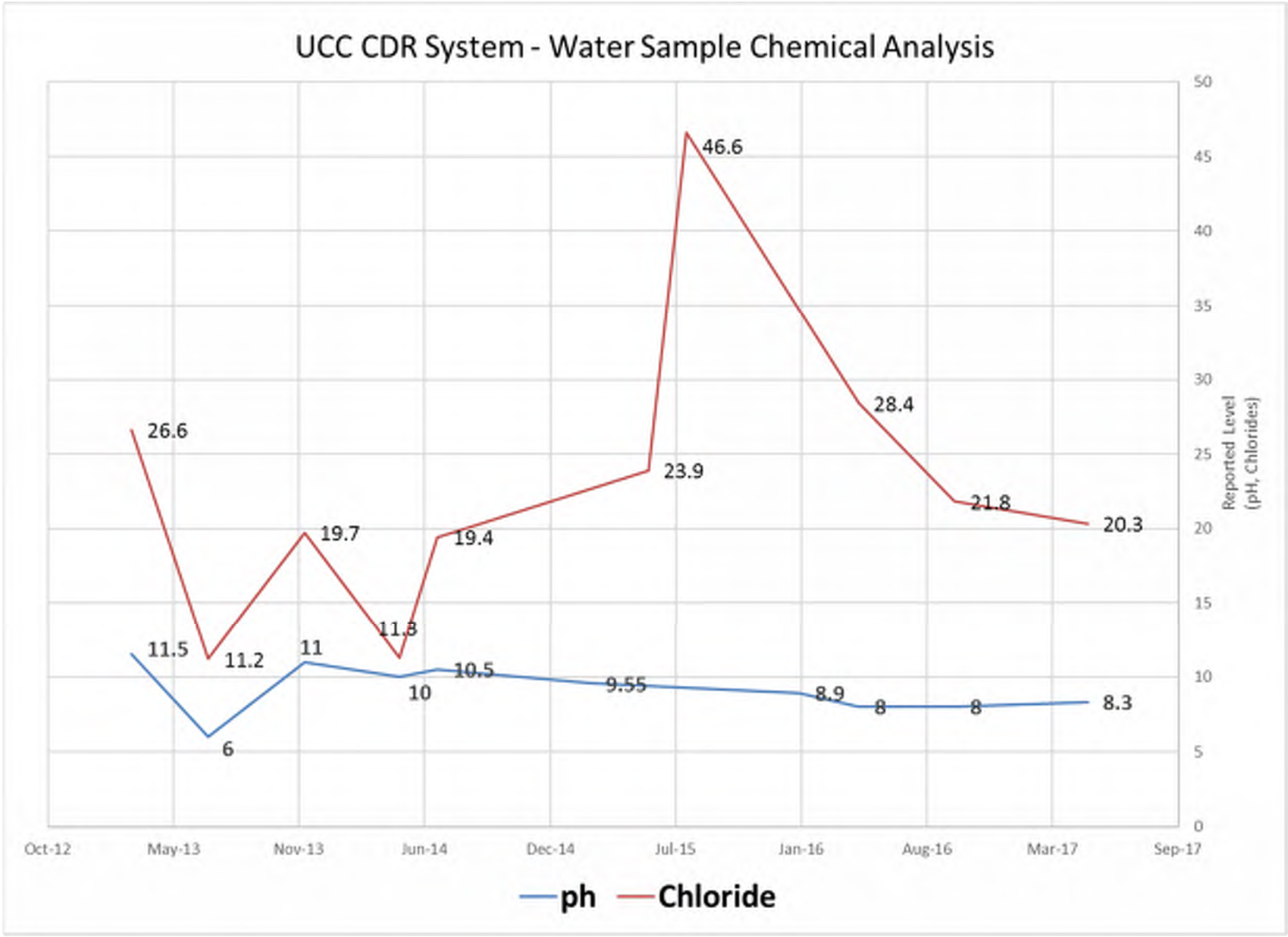


UCC Bottom Ash WTD Conversions

CDR / Remote SFC Systems

- **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

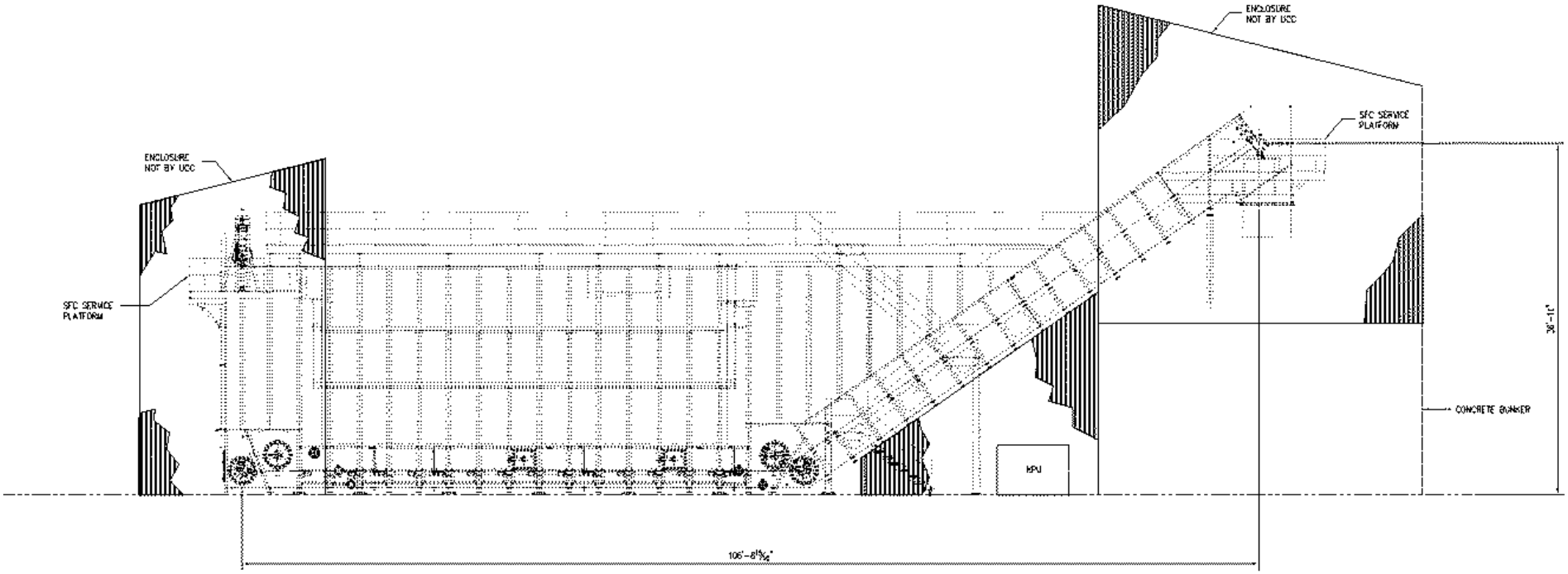
- Continuous Water Flow from Existing BA Hopper Overflows
- Heat Trace/Insulation for Service Water Piping
- Potential Enclosures/Buildings

Water Balance/Wastewater Considerations

Closed-Loop System Design Considerations

Freeze Protection / Cold Weather Considerations

- Potential Enclosures/Buildings



Freeze Protection / Cold Weather Considerations

- Potential Enclosures/Buildings

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

UCC CDR System with Remote SFCs and Clarifiers

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Bottom Ash WTD Conversion Alternatives

UCC CDR System with Remote SFCs and Clarifiers

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Bottom Ash WTD Conversion Alternatives

UCC CDR System with Remote SFCs and Clarifiers

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Bottom Ash WTD Conversion Alternatives

UCC CDR System with Remote SFCs and Clarifiers

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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)

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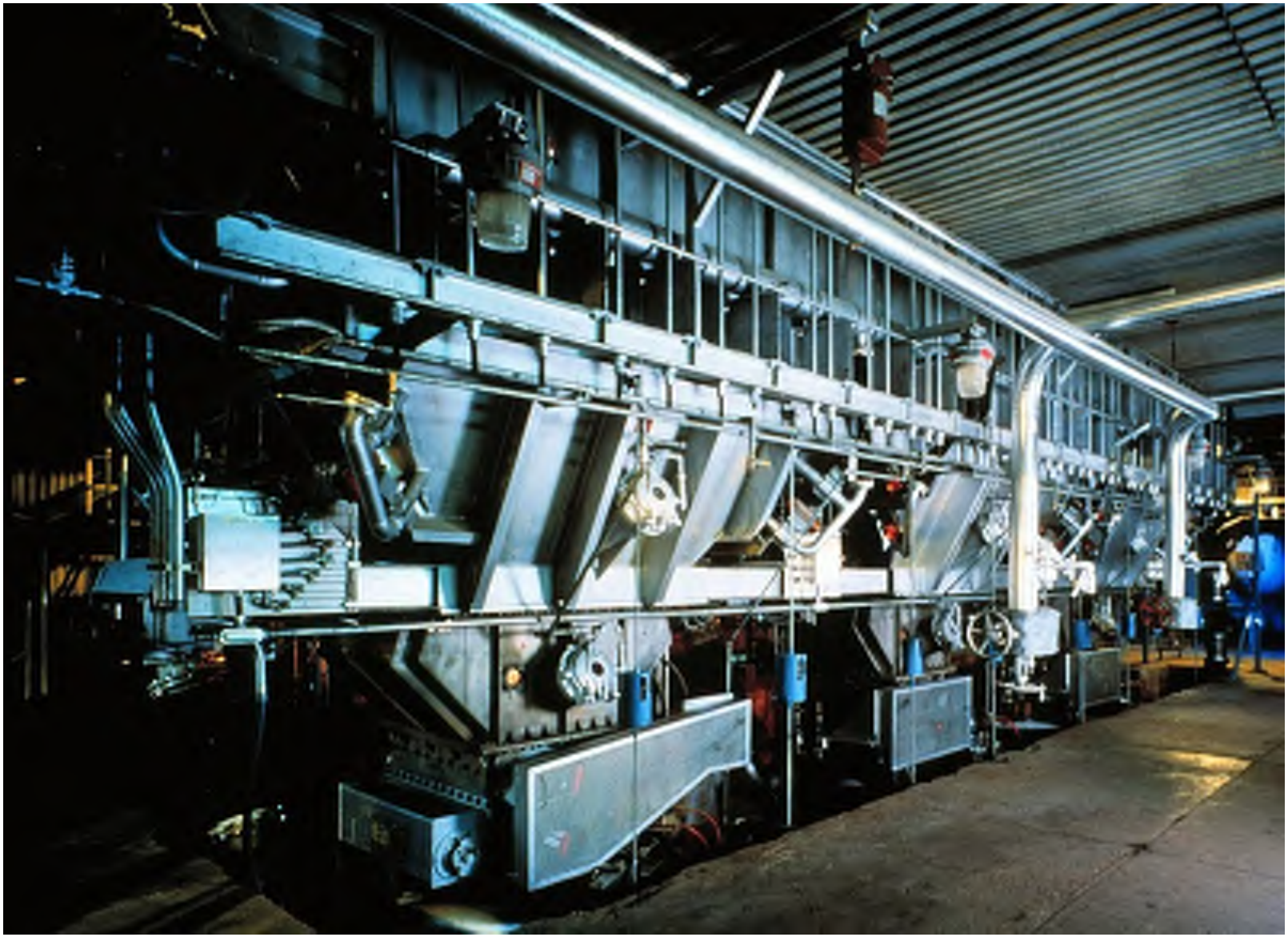

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PAX Bottom Ash System Overview

Pneumatic Ash Extractor (PAX)

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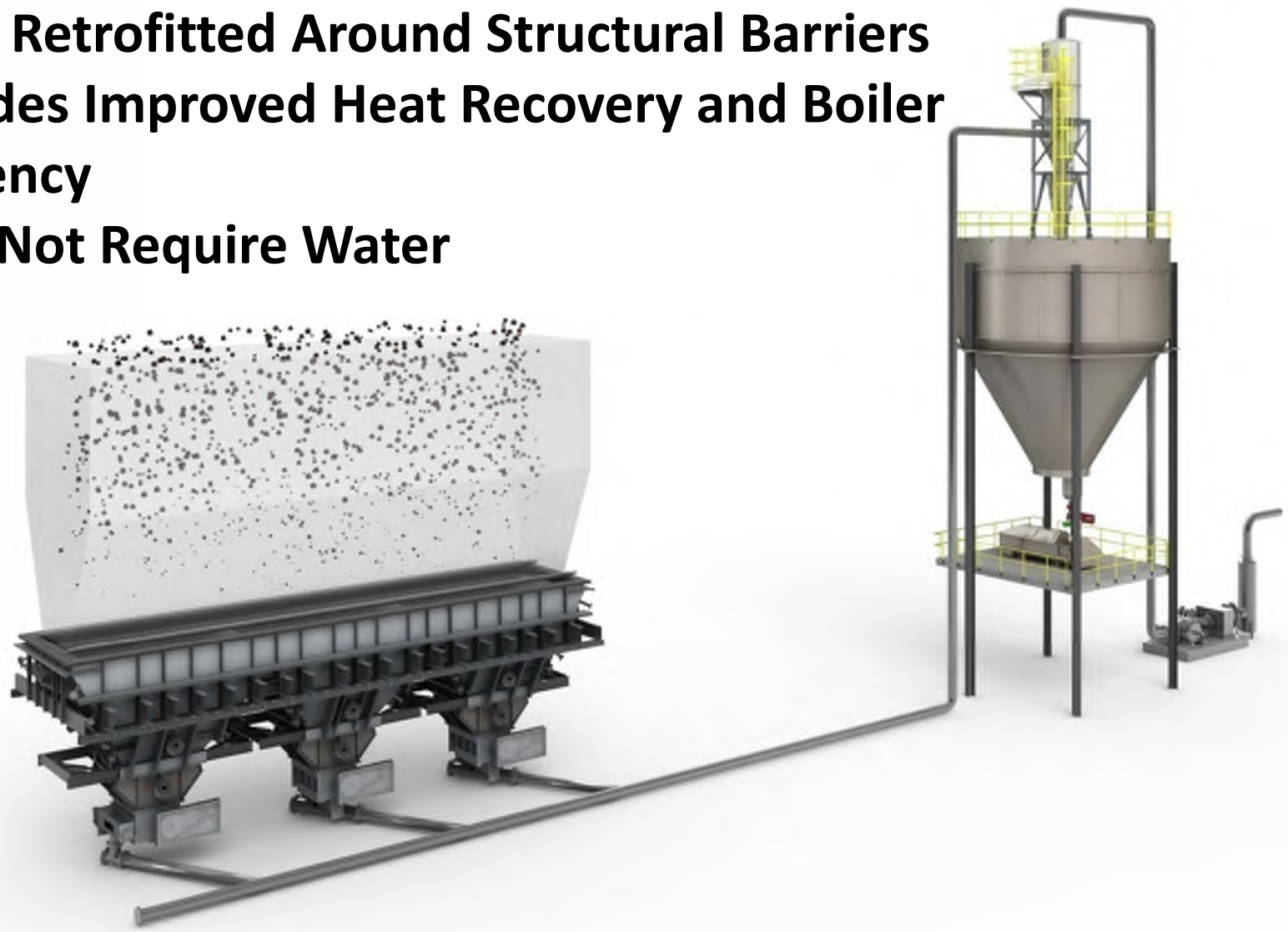
- **Easily Retrofitted Around Structural Barriers**
- **Provides Improved Heat Recovery and Boiler Efficiency**
- **Does Not Require Water**



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PAX Bottom Ash System Overview

Pneumatic Ash Extractor (PAX)

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PAX Bottom Ash System Overview

Conceptual PAX Hopper (Elevation View)

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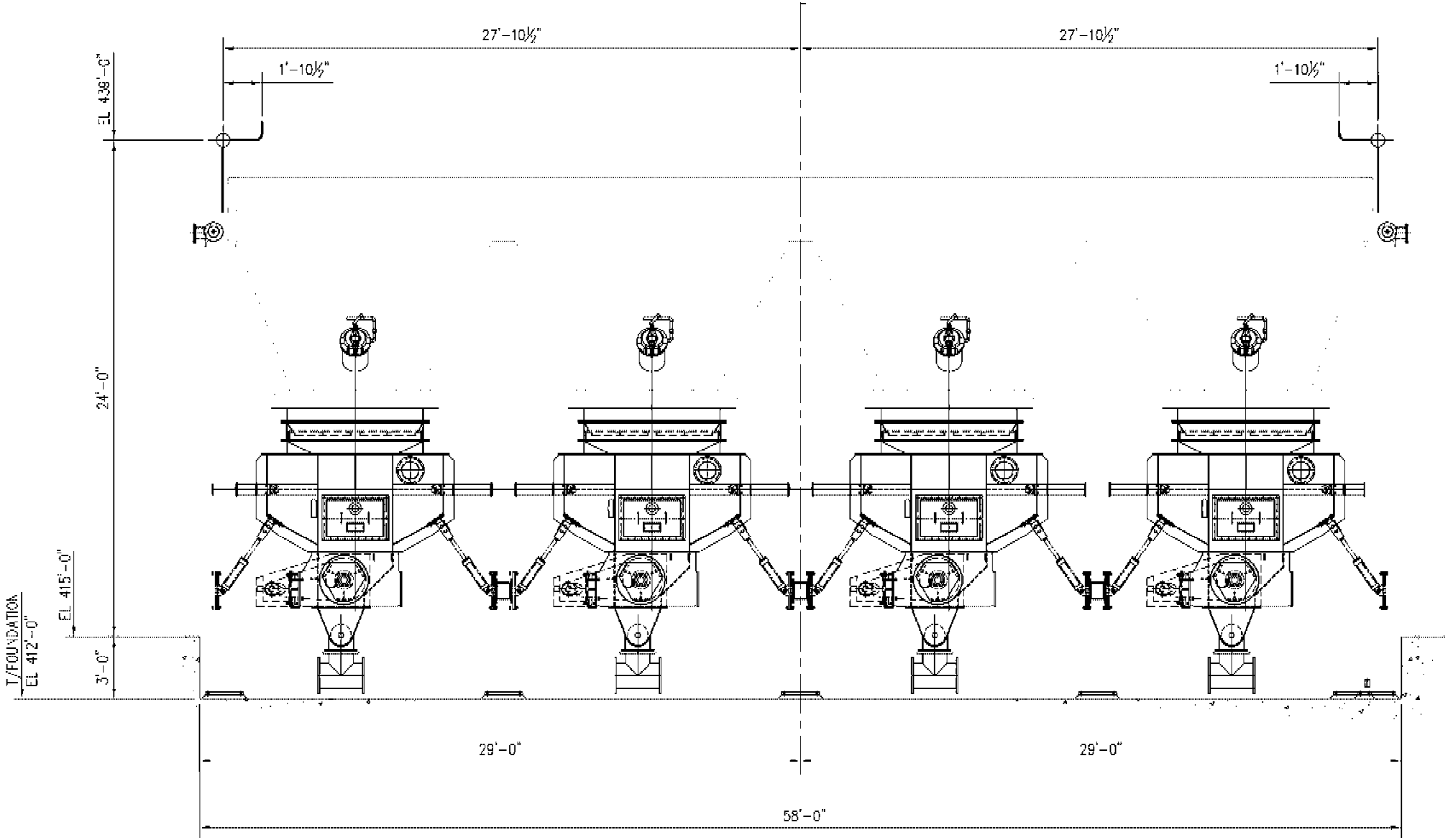

PAX Bottom Ash System Overview

Pneumatic Ash Extractor (PAX)

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PAX Bottom Ash System Overview

Pneumatic Ash Extractor (PAX)

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- 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)

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PAX Bottom Ash System Overview

Pneumatic Ash Extractor (PAX)

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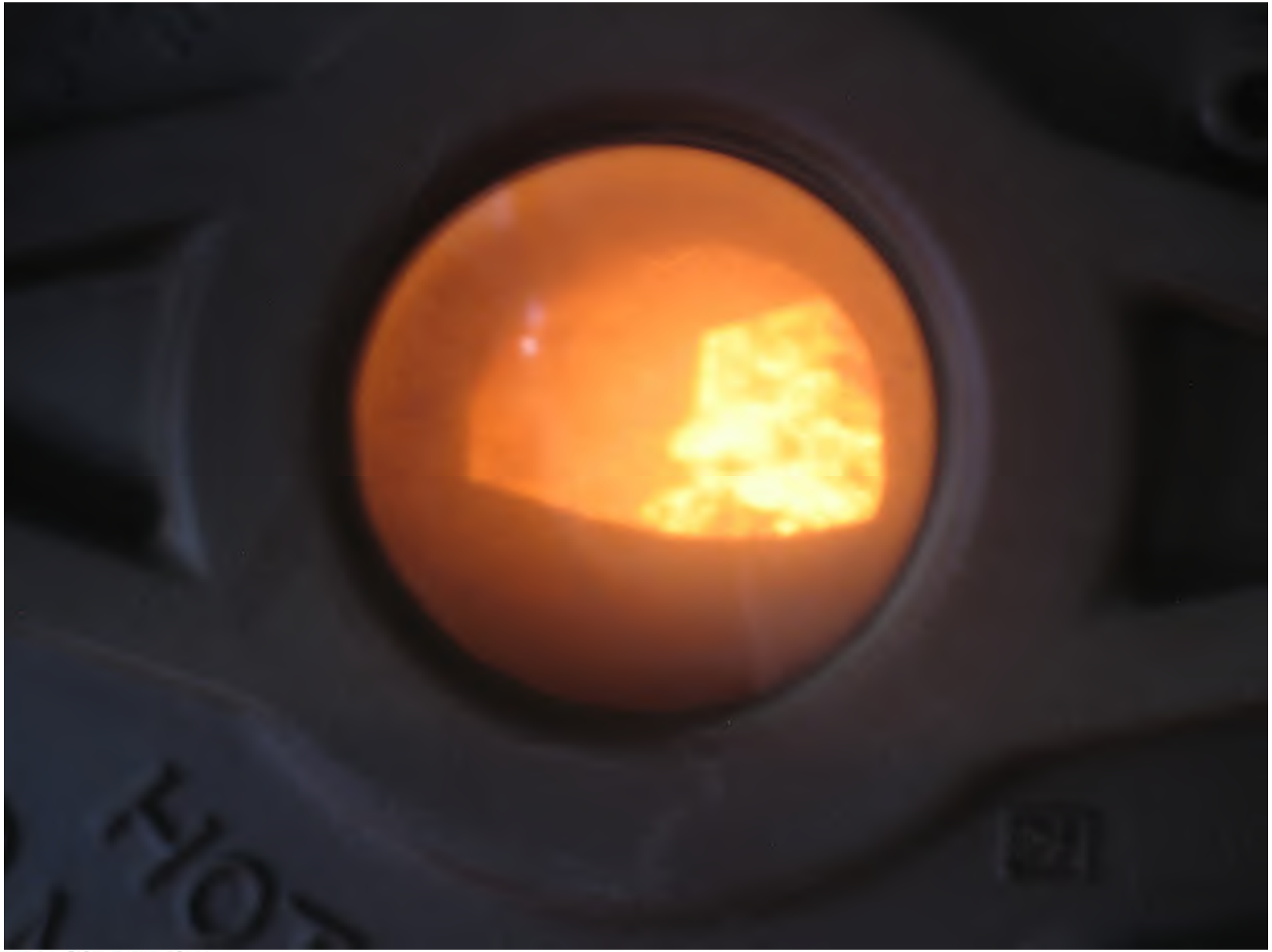

PAX Bottom Ash System Overview

Pneumatic Ash Extractor (PAX)

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PAX Bottom Ash System Overview

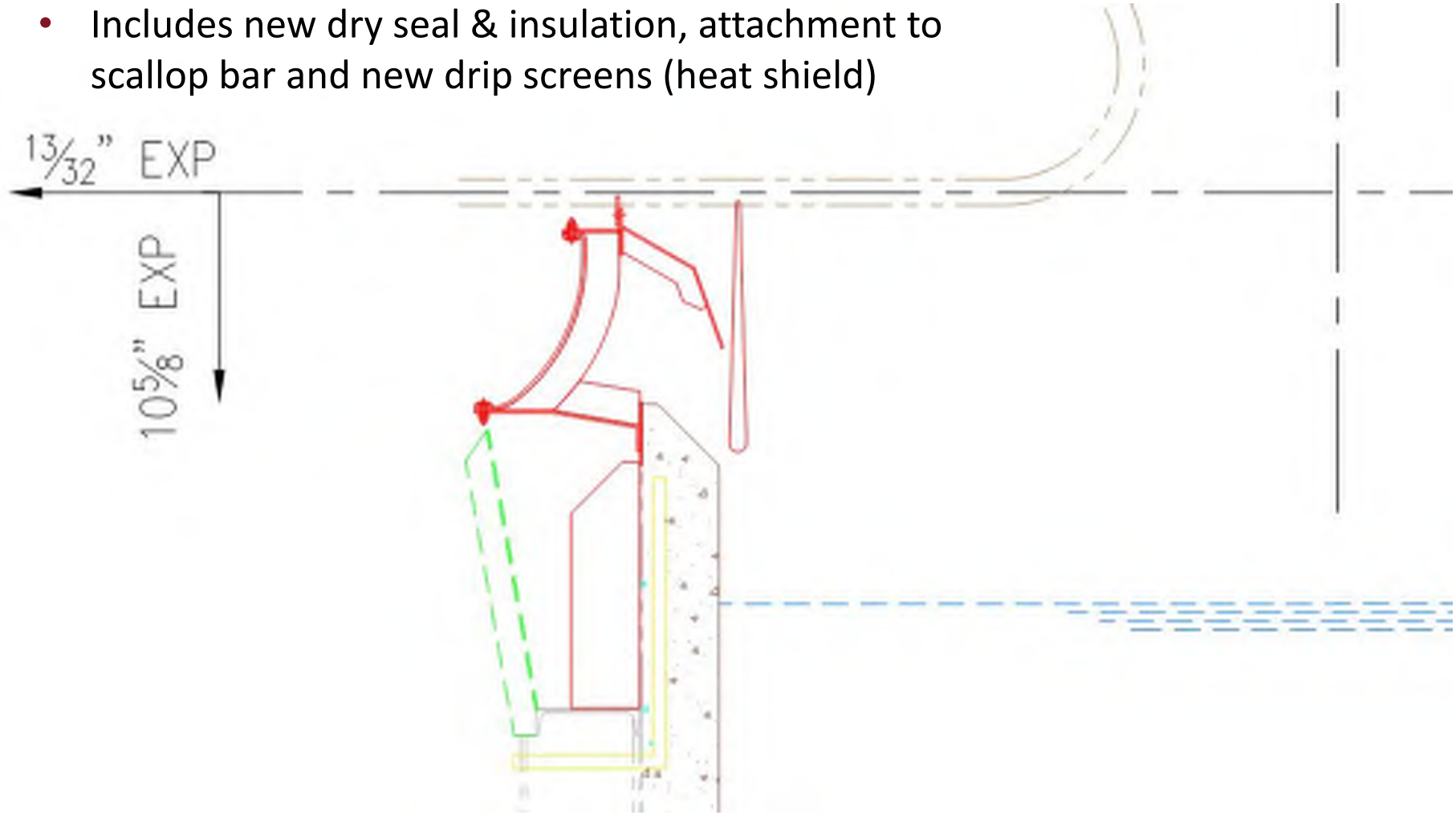
Pneumatic Ash Extractor (PAX)

- Fused Tungsten Carbide Cams after 1.5 years of service

PAX Bottom Ash System Overview

Dry Boiler Seal

- **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)



PAX Bottom Ash System Overview

Dry Boiler Seal

- **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

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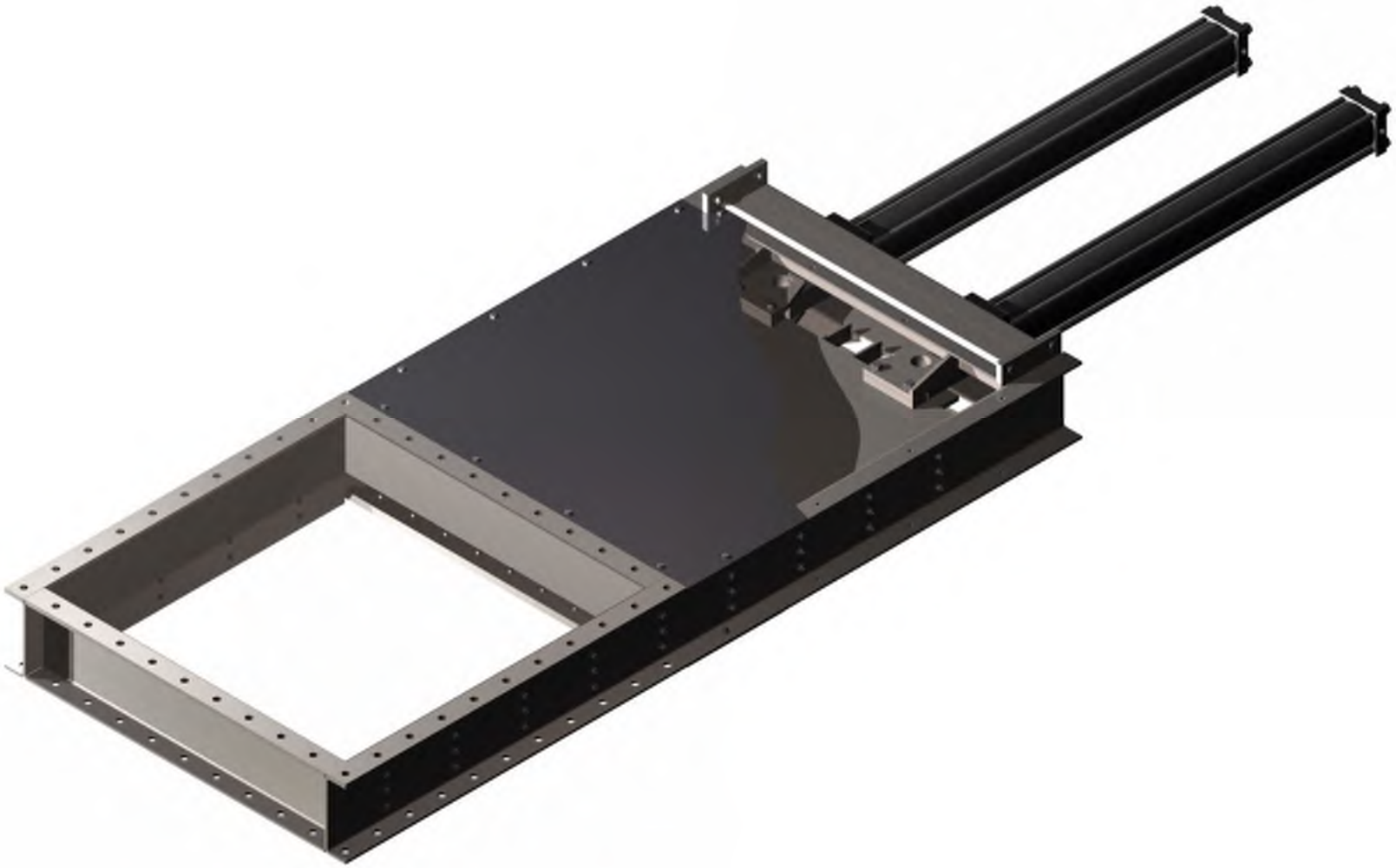

PAX Bottom Ash System Overview

Pneumatic Ash Extractor (PAX) – Hydraulic Jaw Crusher

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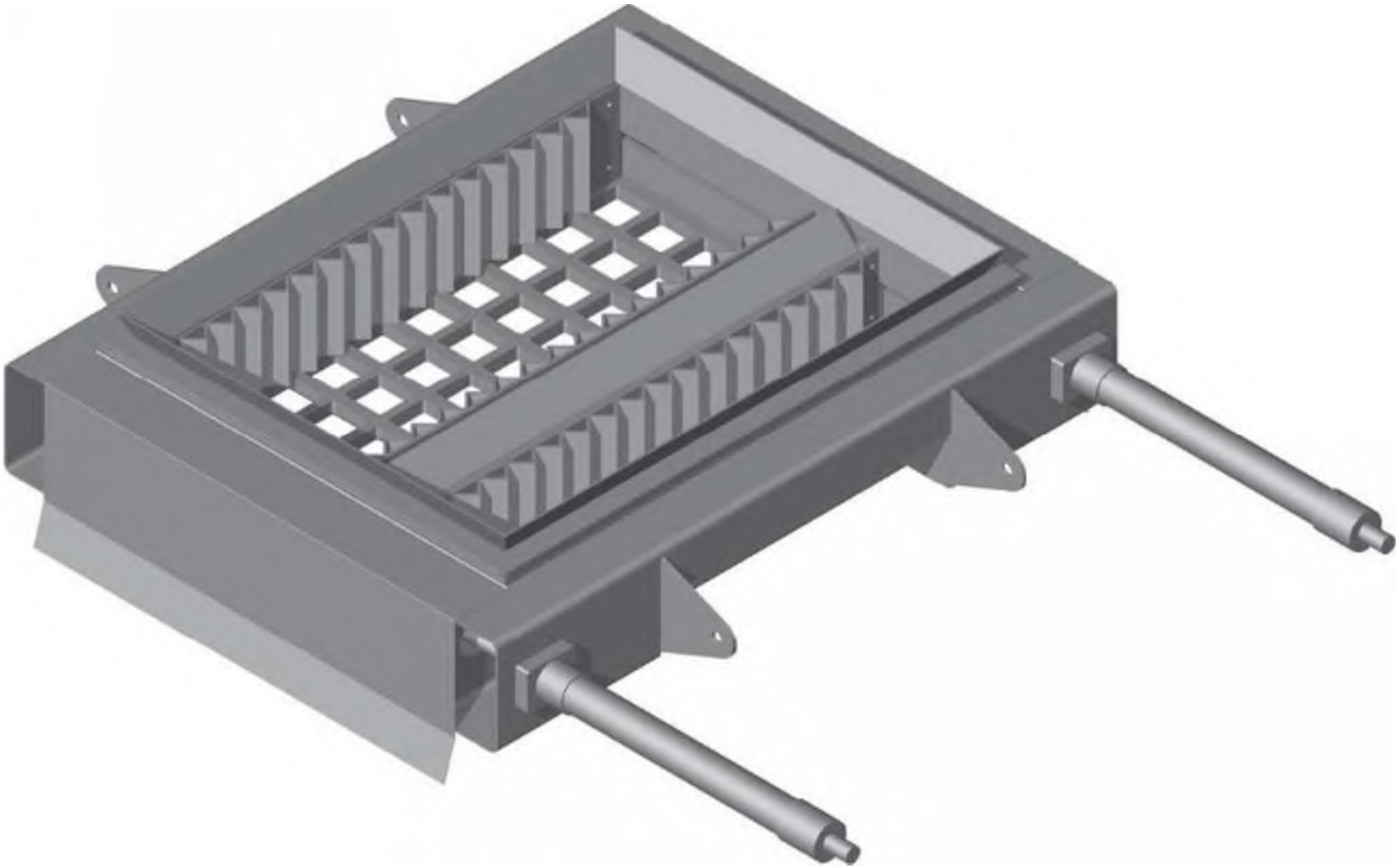

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PAX Bottom Ash System Overview

Pneumatic Ash Extractor (PAX) – Hydraulic Jaw Crusher

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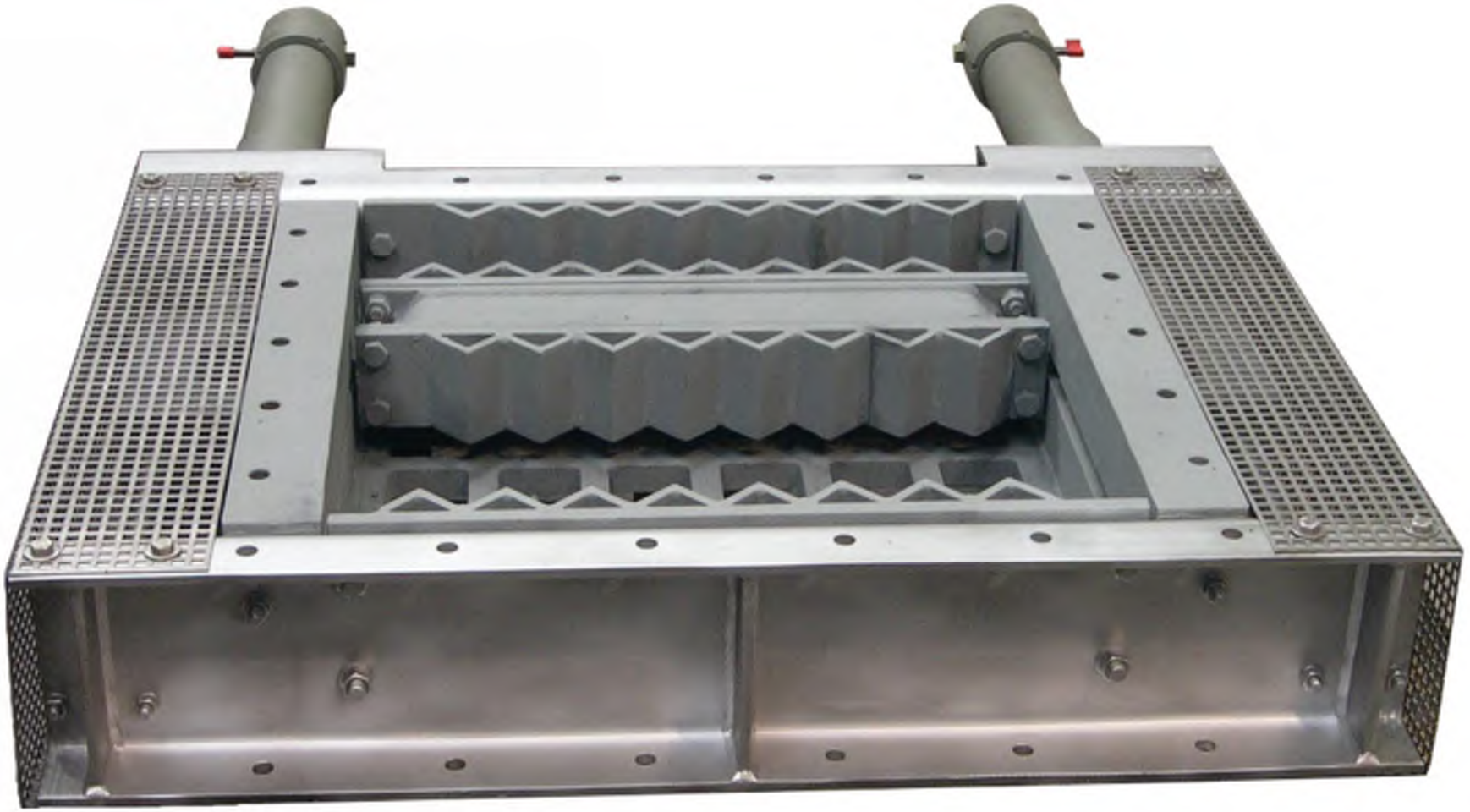

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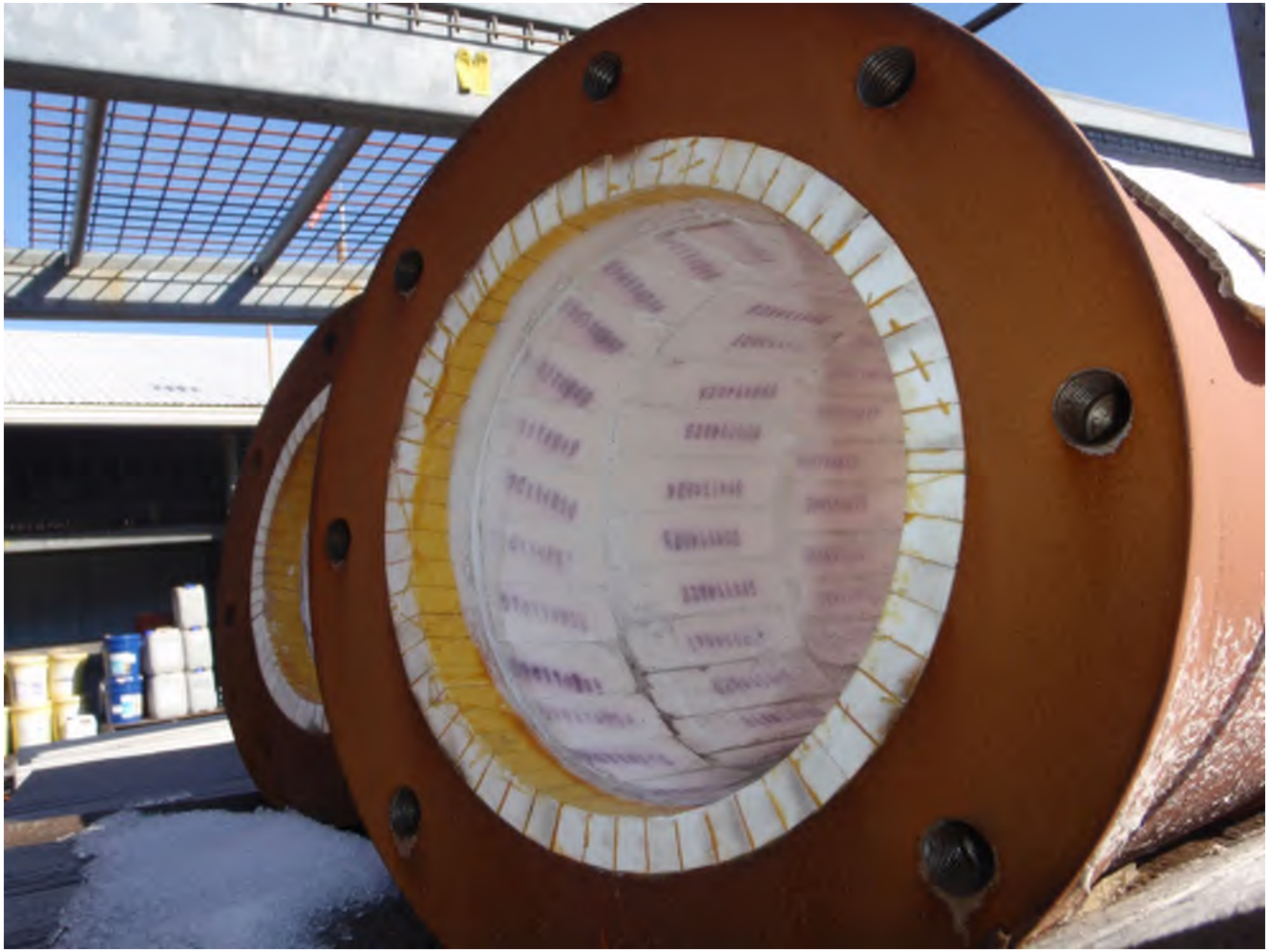
PAX Bottom Ash System Overview

Pneumatic Ash Extractor (PAX)

- Ceramic (Alumina-tiled) Lined Elbows for Maximum High Temp Wear Life



PAX Bottom Ash System Overview

Pneumatic Ash Extractor (PAX)

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UCC Dry Bottom Ash Silos

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PAX Bottom Ash System Overview

Pneumatic Ash Extractor (PAX)

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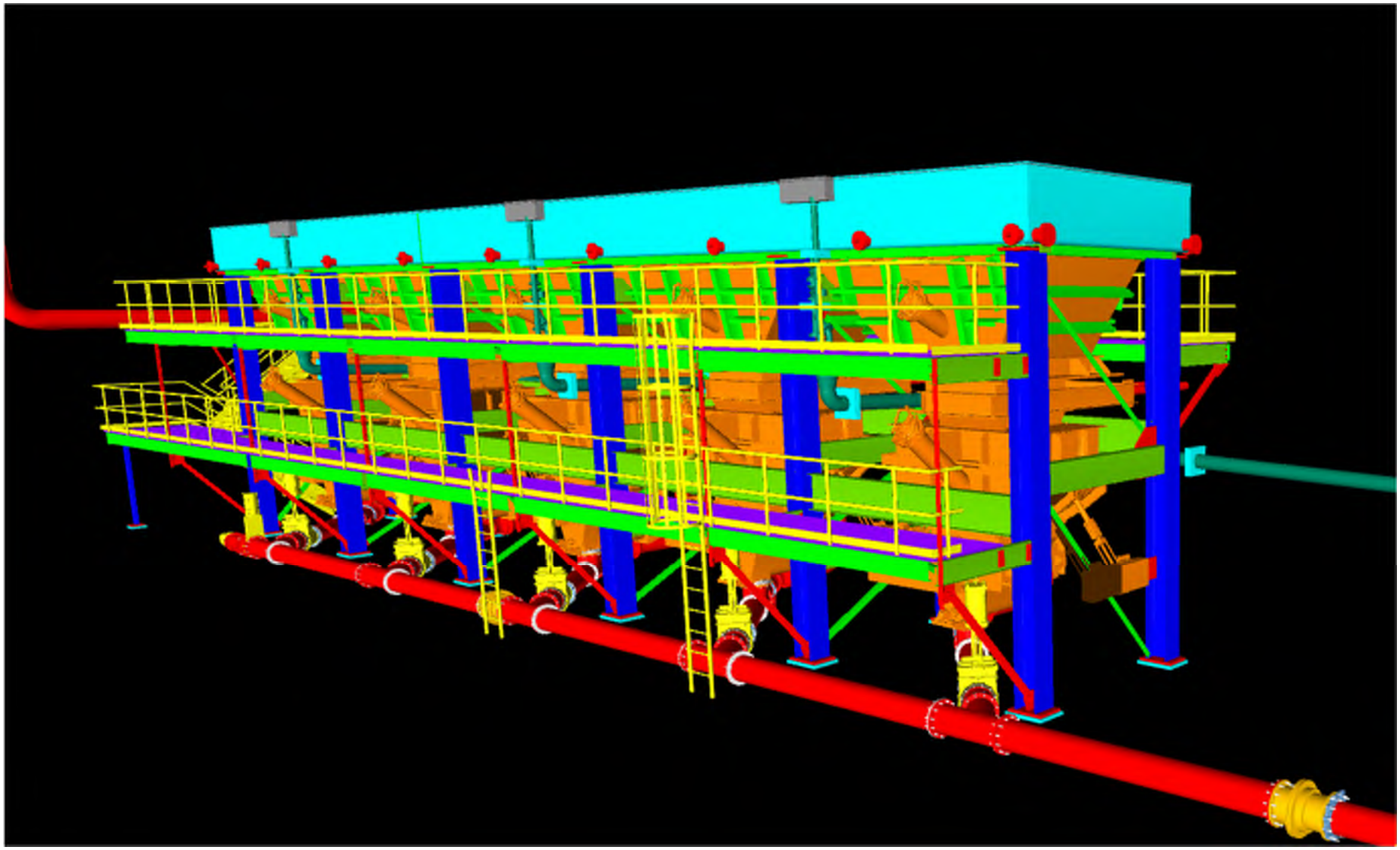

UCC PAX Hopper

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PAX Bottom Ash System Overview

Pneumatic Ash Extractor (PAX)

Presentation Prepared For:

UCC PAX Hopper Trial Erection

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PAX Bottom Ash System Overview

Pneumatic Ash Extractor (PAX)

Presentation Prepared For:

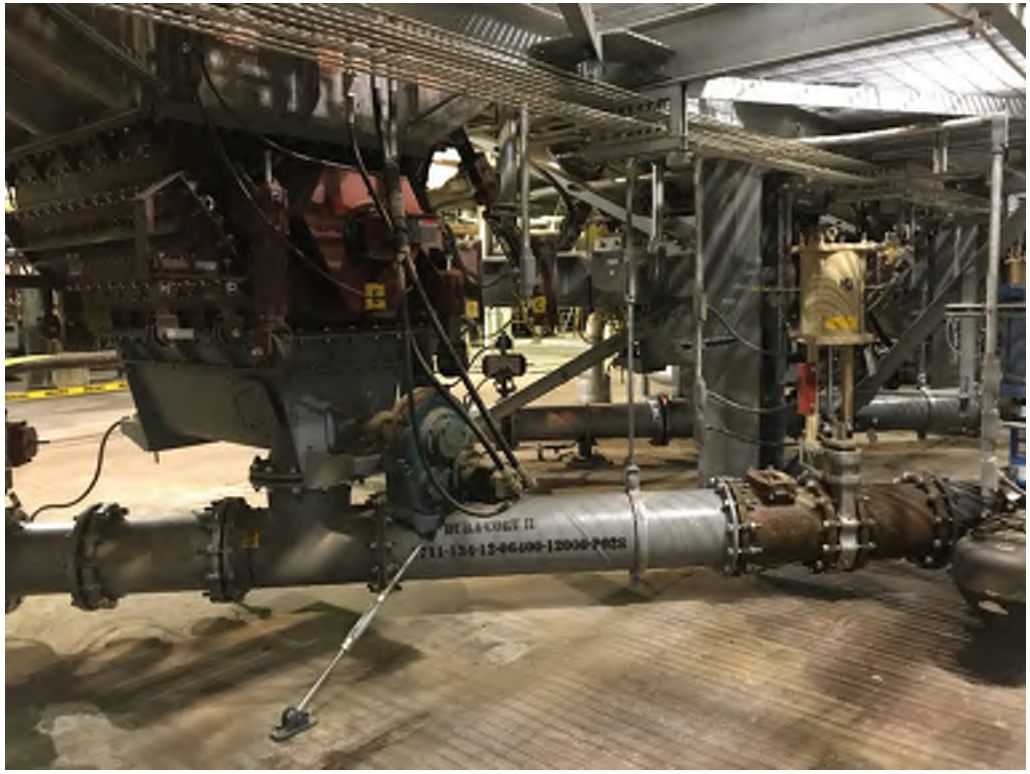
UCC PAX Hopper

UNITED CONVEYOR CORPORATION

PAX Bottom Ash System Overview

Pneumatic Ash Extractor (PAX)

Presentation Prepared For:



UCC PAX Enclosure and Crusher

PAX Bottom Ash System Overview

Pneumatic Ash Extractor (PAX)

Presentation Prepared For:

UCC PAX Enclosure and Crusher

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Discussion Overview

Presentation Prepared For:

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

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UCC Fly Ash Fixation/Stabilization

Case Study #1

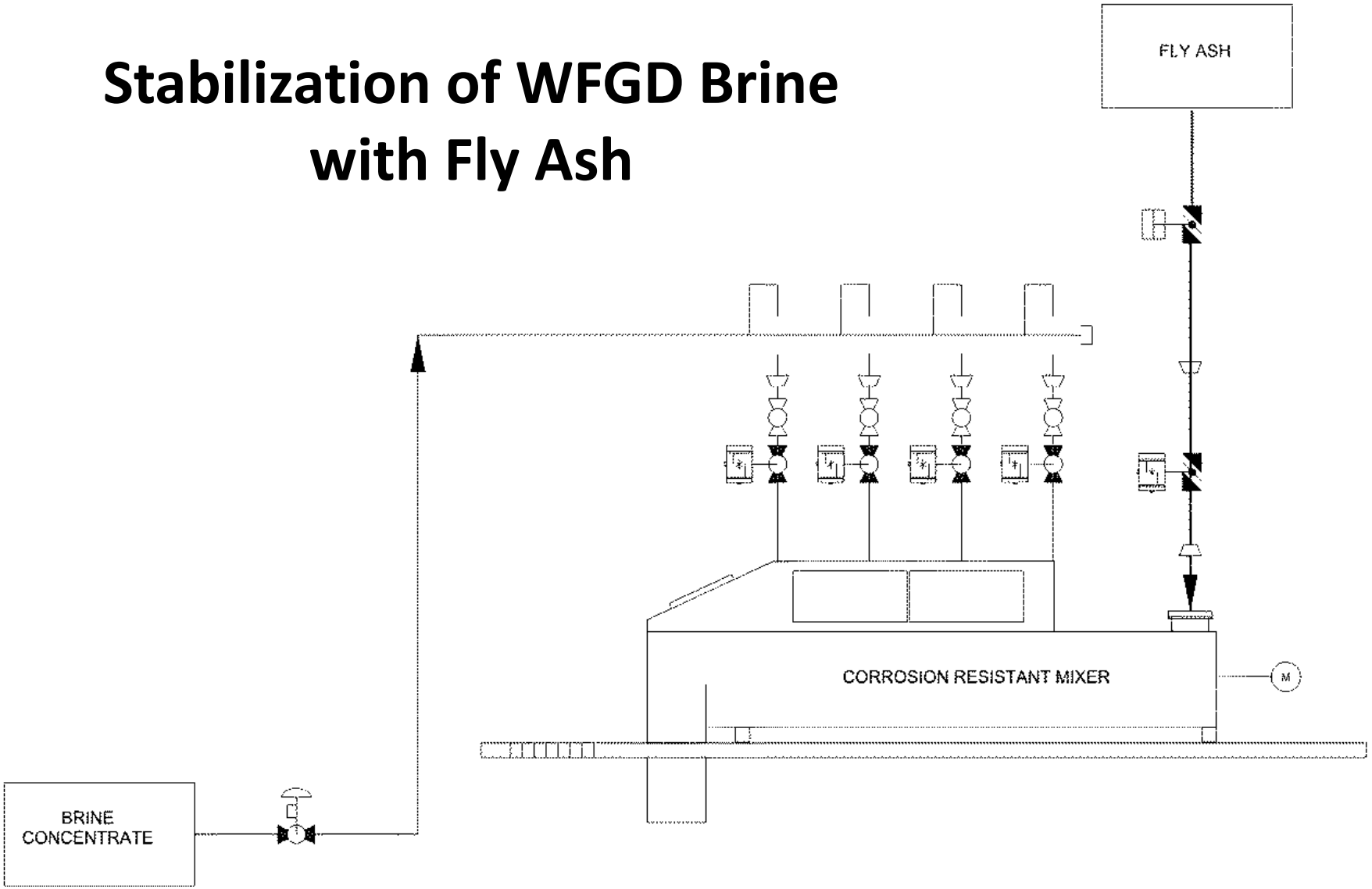
Presentation Prepared For:

- 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

UCC Fly Ash Fixation/Stabilization

Case Study #1

Stabilization of WFGD Brine with Fly Ash



UCC Fly Ash Fixation/Stabilization

Case Study #1

Presentation Prepared For:

WPCA

Corrosion Resistant Mixer Design For High Chlorides

MIXER MATERIALS OF CONSTRUCTION	
Body	Epoxy paint with HDPE liner
Cover	316L Stainless Steel
Shafts	HASTELLOY C-276
Pins	UHMW (TIVAR)
Nozzles	PerFluoroAlkoxy (PFA)

UCC Fly Ash Fixation/Stabilization

Case Study #1

Equipment Designed to Handle High Chlorides

MATERIALS OF CONSTRUCTION	
Brine Supply Piping	Fiberglass Reinforced Pipe (FRP)
Brine Flow Control Valve	PFA lined Ductile Iron and Stainless Steel
Brine Zone Flow On/Off Valve	PFA lined Ductile Iron and Stainless Steel
Instrumentation	Monel/Stainless Steel

UCC Fly Ash Fixation/Stabilization

Case Study #2

Fixation of FGD Byproduct and Wastewater with Fly Ash and Lime

UCC Fly Ash Fixation/Stabilization

Case Study #2

Presentation Prepared For:

WPCA

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UCC Fly Ash Fixation/Stabilization

Case Study #2

- **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

Presentation Prepared For:

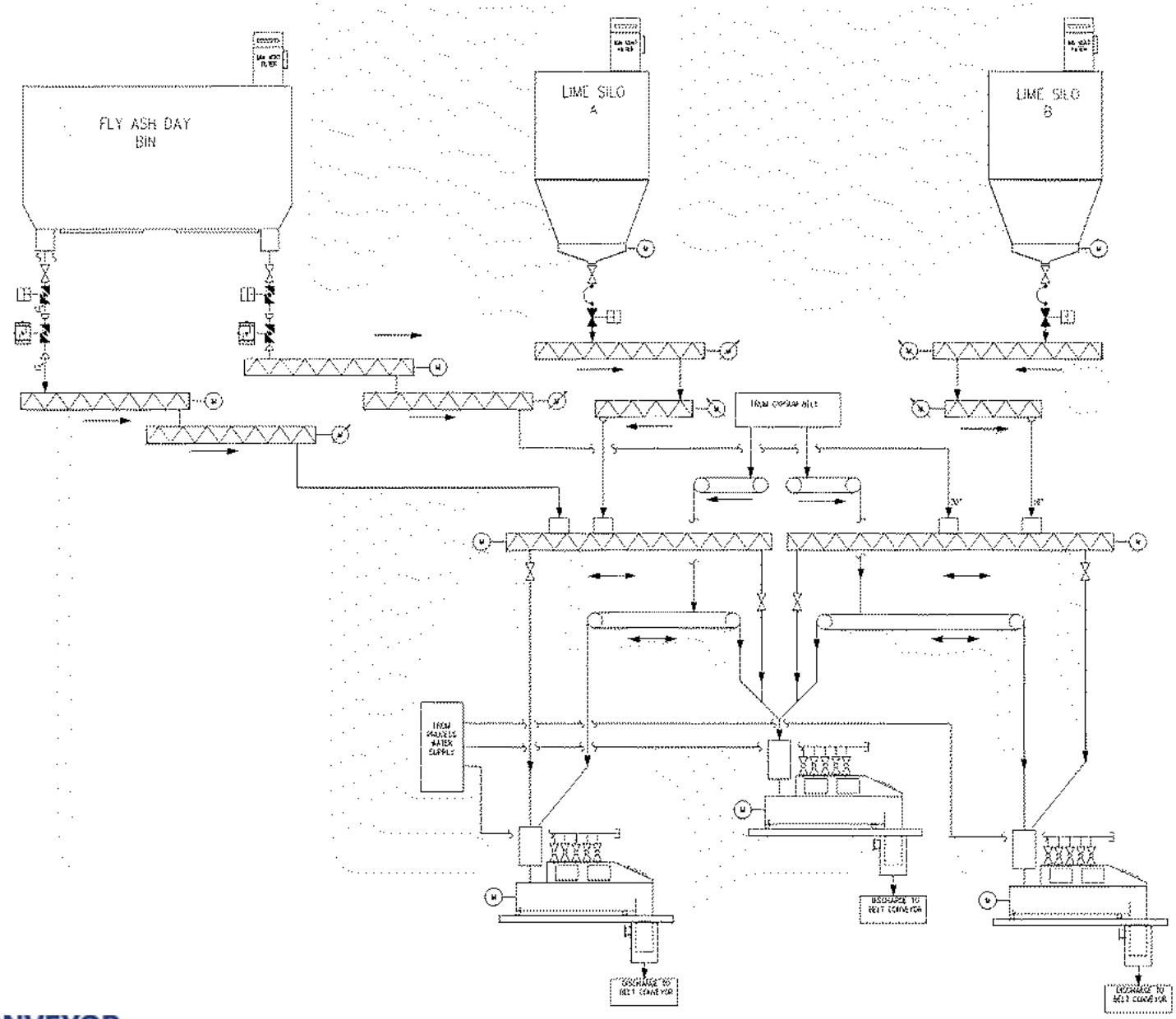
WPCA

- 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

Presentation Prepared For:



UCC Fly Ash Fixation/Stabilization

Case Study #2

Presentation Prepared For:

WPCA

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

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Discussion Overview

Presentation Prepared For:

WPCA

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

Questions ?