REINHOLD ENVIRONMENTAL Ltd.

2016 NOx-Combustion-CCR Round Table Presentation

February 1 & 2, 2016, in Orlando, FL / Hosted by OUC

UNITED CONVEYOR CORPORATION

Options, Considerations and Implications of Wet-to-Dry Ash Conversions

Prepared for: 2016 NOx-Combustion-CCR/PCUG Meeting

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02 February 2016

Discussion Overview

- Regulatory Update & Implications
- Activity Summary & Technology Selection Criteria
- Ash Wet-to-Dry Conversion Technologies
- Water Balance & Wastewater Considerations

Safety Moment

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

Coal Combustion Residuals (CCR) Ruling

Overview

- **Regulation Focus Areas:**
  - Location Restrictions: Aquifer, Wetlands, Fault Zones, Seismic Zones, Unstable Areas
  - Design Criteria: Lined/Unlined, Leaking/Not Leaking, Structural Integrity
  - Operating Criteria: Flood Control, Fugitive Dust Control, Inspections (Weekly/Monthly/Annual)
  - Groundwater Monitoring and Corrective Action
  - Closure Requirements and Post-closure Care
  - Recordkeeping, Notification, and Internet Posting

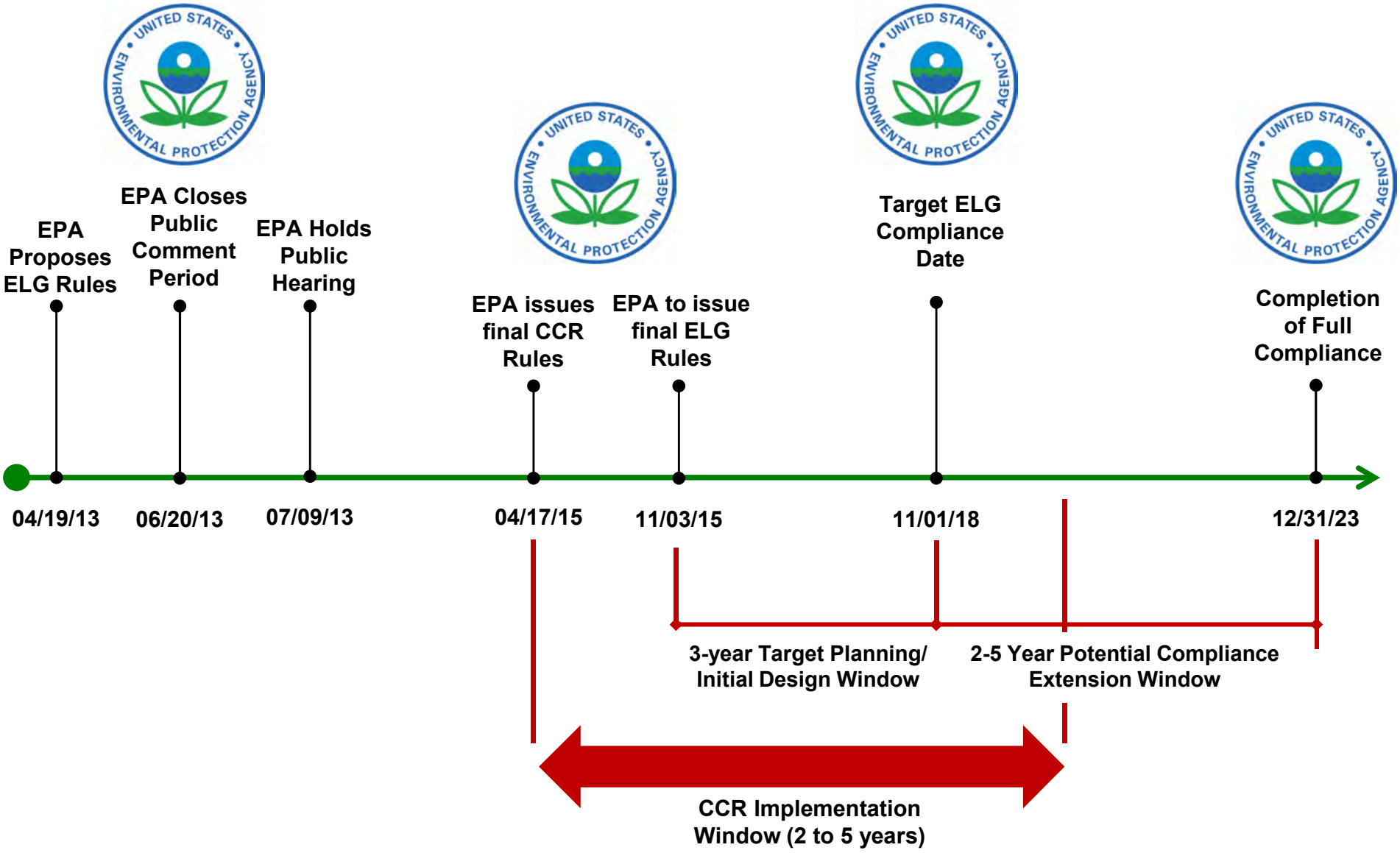
ELG Ruling

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

ELG & CCR Ruling

Regulatory Timeline



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Implications of ELG Ruling

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

Discussion Overview

- Regulatory Update & Implications
- **Activity Summary & Technology Selection Criteria**
- Ash Wet-to-Dry Conversion Technologies
- 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”

Discussion Overview

- Regulatory Update & Implications
- Activity Summary & Technology Selection Criteria
- **Ash Wet-to-Dry Conversion Technologies**
- Water Balance & Wastewater Considerations

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

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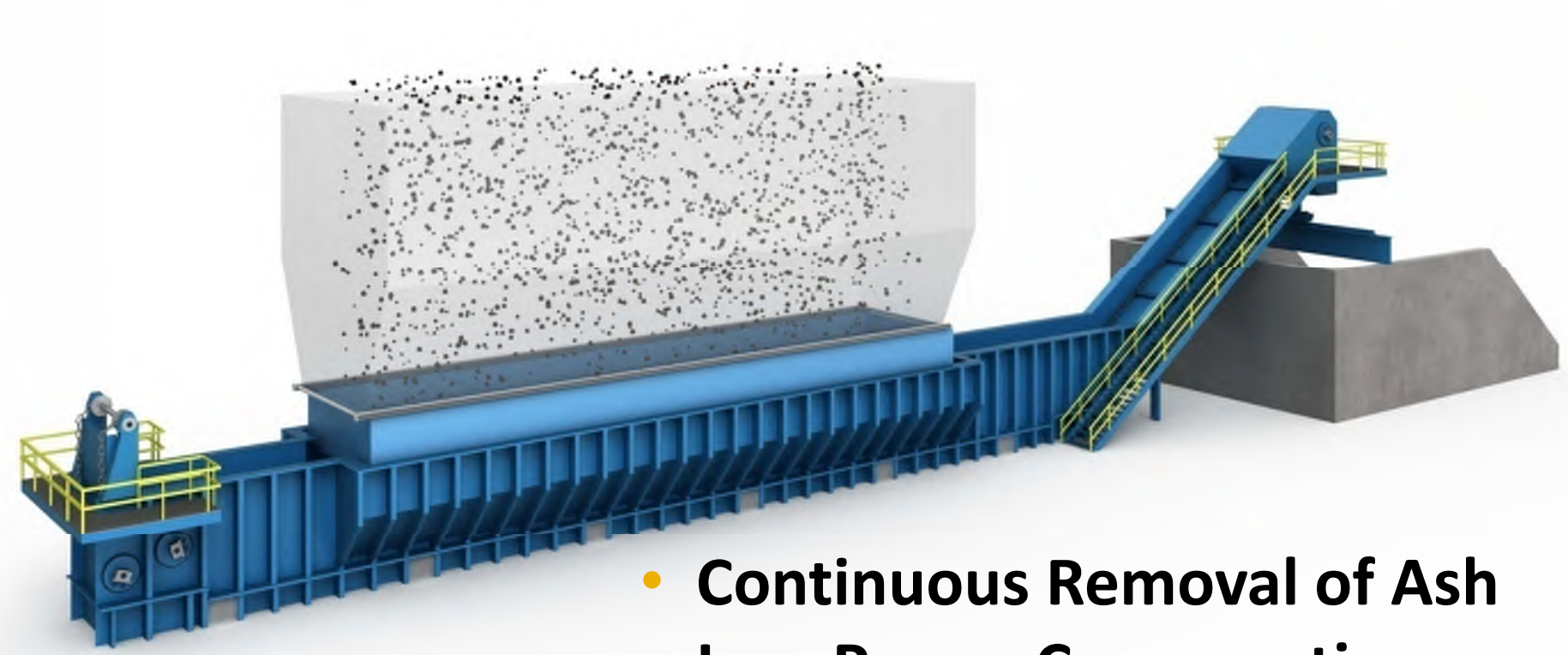
Submerged Flight Conveyor (SFC) System

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**

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Bottom Ash WTD Conversion Alternatives

Submerged Flight Conveyor (SFC)

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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)

Decision Analysis Favors SFC™ System

	Technology Alternatives								
1 = Worst, 5 = Best	Scale 1-5	SFC (Mechanical)		Re-Circ System (Hydraulic)		R-SFC/Clarifier (Hydraulic)		PAX (Pneumatic)	
Criteria for Determing									
W									
O									
T									
O									
P									
B									
M									
N									
Unburned Carbon / Boiler Efficiency	1	1	1	1	1	1	1	5	5
Weighted Total Score			90		85		69		72

Decision Analysis Favors SFC™ System if criteria are weighted for:

- Total Installed Cost
- Reduced O&M Costs
- Reduced Wastewater Profile

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**

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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

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Bottom Ash WTD Conversion Alternatives

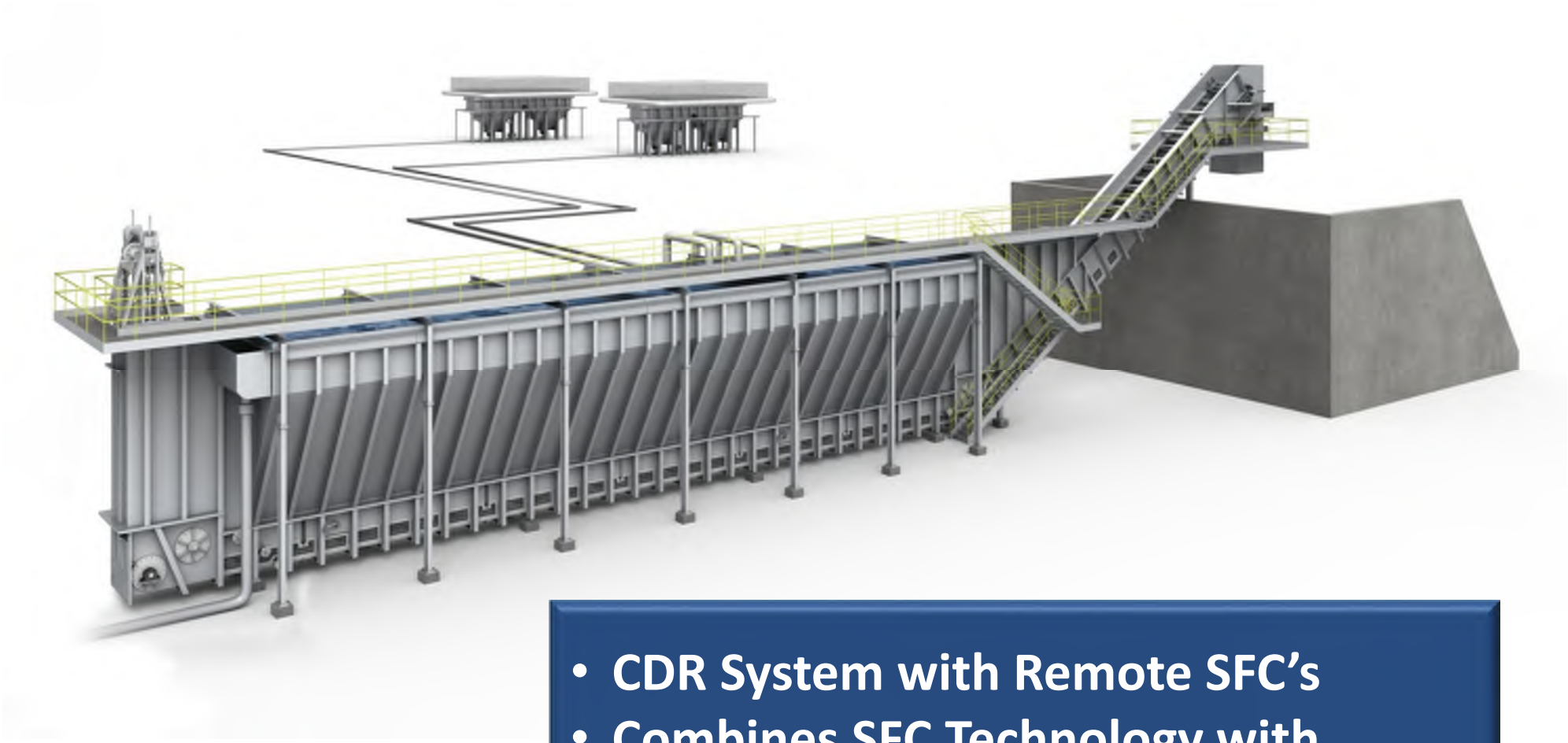
Conventional Dewatering & Recirculation System

- **Large Equipment Scope**
- **Greater Foundation Design Requirements**
- **Inconsistent Bottom Ash Dewatering**
- **Higher Maintenance**

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**

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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

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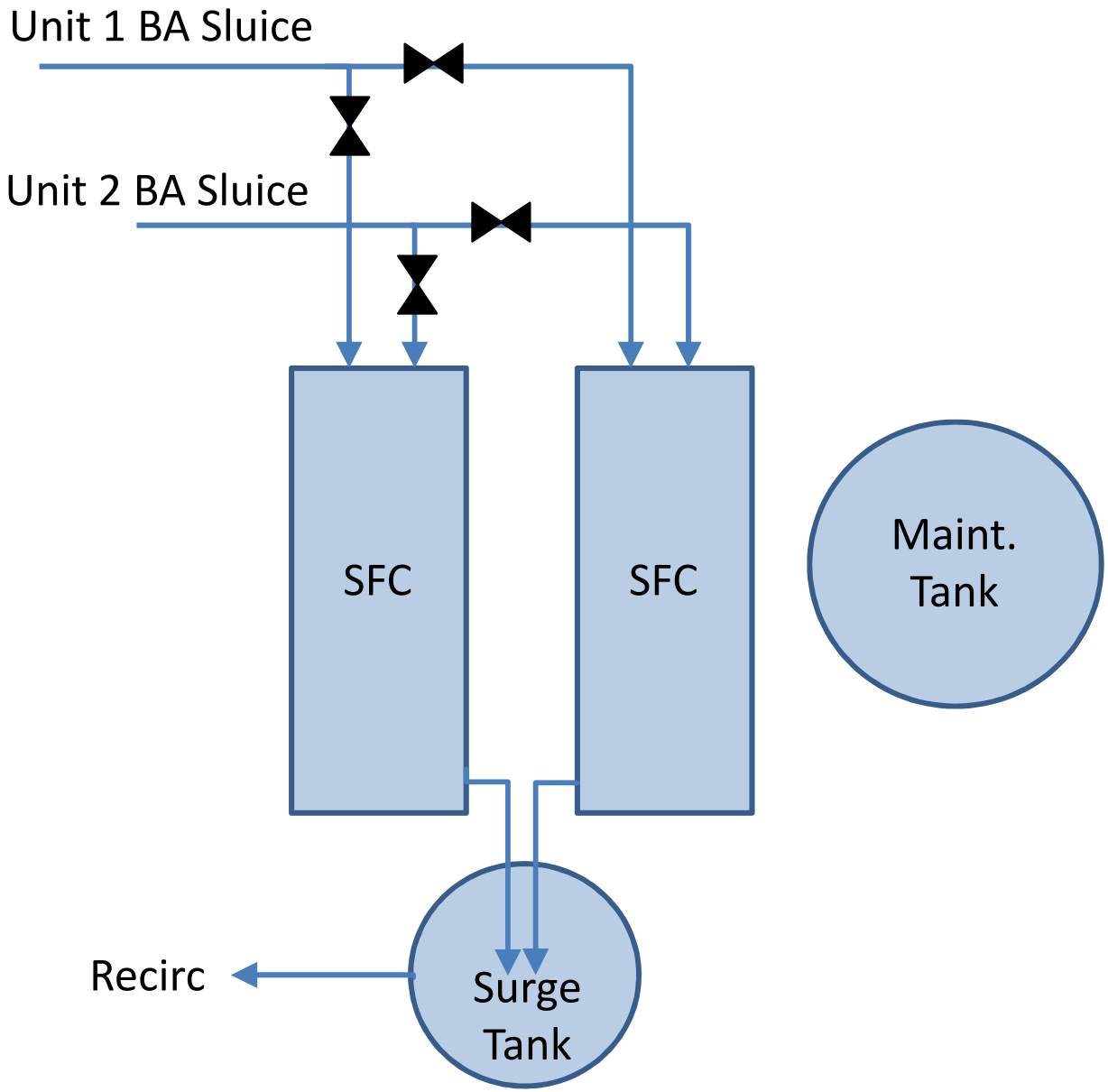
Design Basis Requirements

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
    - Dewaters 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

- **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)

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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/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
  - Rain
- **Will Have Net Loss of Water from System**
- **Water Balance can be complex**

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

Bottom Ash WTD Conversion Alternatives

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

	Technology Alternatives								
1 = Worst, 5 = Best	Scale 1-5	SFC (Mechanical)		Re-Circ System (Hydraulic)		R-SFC/Clarifier (Hydraulic)		PAX (Pneumatic)	
Criteria for Determing									
W									
O									
T									
O									
P									
B									
M									
N									
U									
Weighted Total Score			69		103		97		75

Decision Analysis Favors CDR™ System if criteria are weighted for:

- Reduced Outage Requirements
- Physical Space Limitations
- Multiple Unit Synergies

Remote SFC & Clarifier System

Bottom Ash WTD Conversion Alternatives

Bottom Ash Dewatering and Clarification System with Remote SFC's

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Bottom Ash WTD Conversion Alternatives

Bottom Ash Dewatering and Clarification System with Remote SFC's

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Bottom Ash WTD Conversion Alternatives

Bottom Ash Dewatering and Clarification System with Remote SFC's

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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

1 = Worst, 5 = Best	Technology Alternatives								
	Scale 1-5	SFC (Mechanical)		Re-Circ System (Hydraulic)		R-SFC/Clarifier (Hydraulic)		PAX (Pneumatic)	
									otal
Wa									10
Out									5
Tot									6
Ope									8
Pov									6
Boi									20
Mu									15
Nee									0
Unburned Carbon / Boiler Efficiency									5
Weighted Total Score			**69**		**103**		**117**		**75**

Decision Analysis Favors Clarification System if criteria are weighted for:

- **Need Clarified water for Plant Water Balance (Make-up Water Source)**
- **Prefer to Utilize Existing/New "Clean Water" Pumps**

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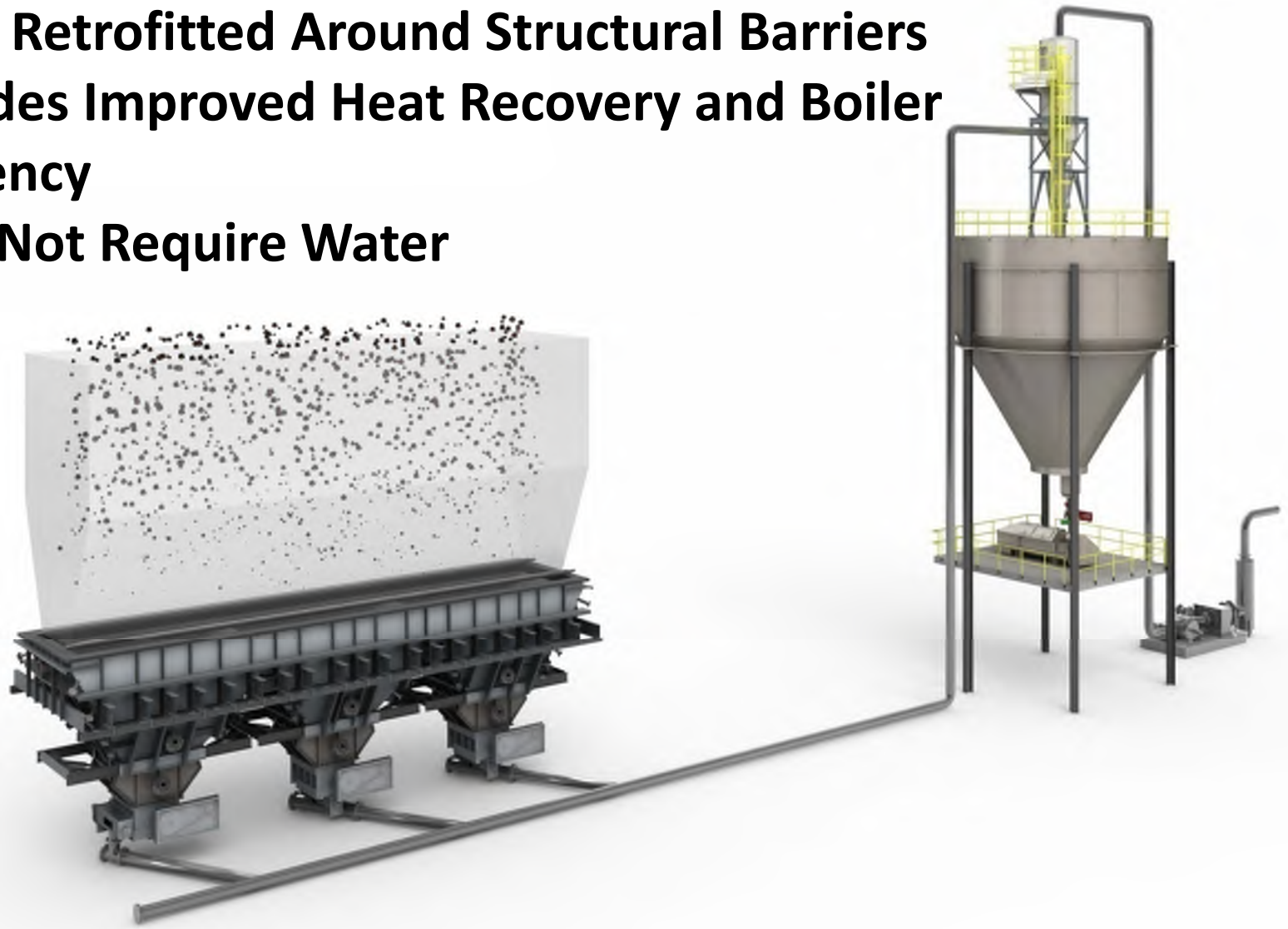
Pneumatic Ash Extractor (PAX) System

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

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

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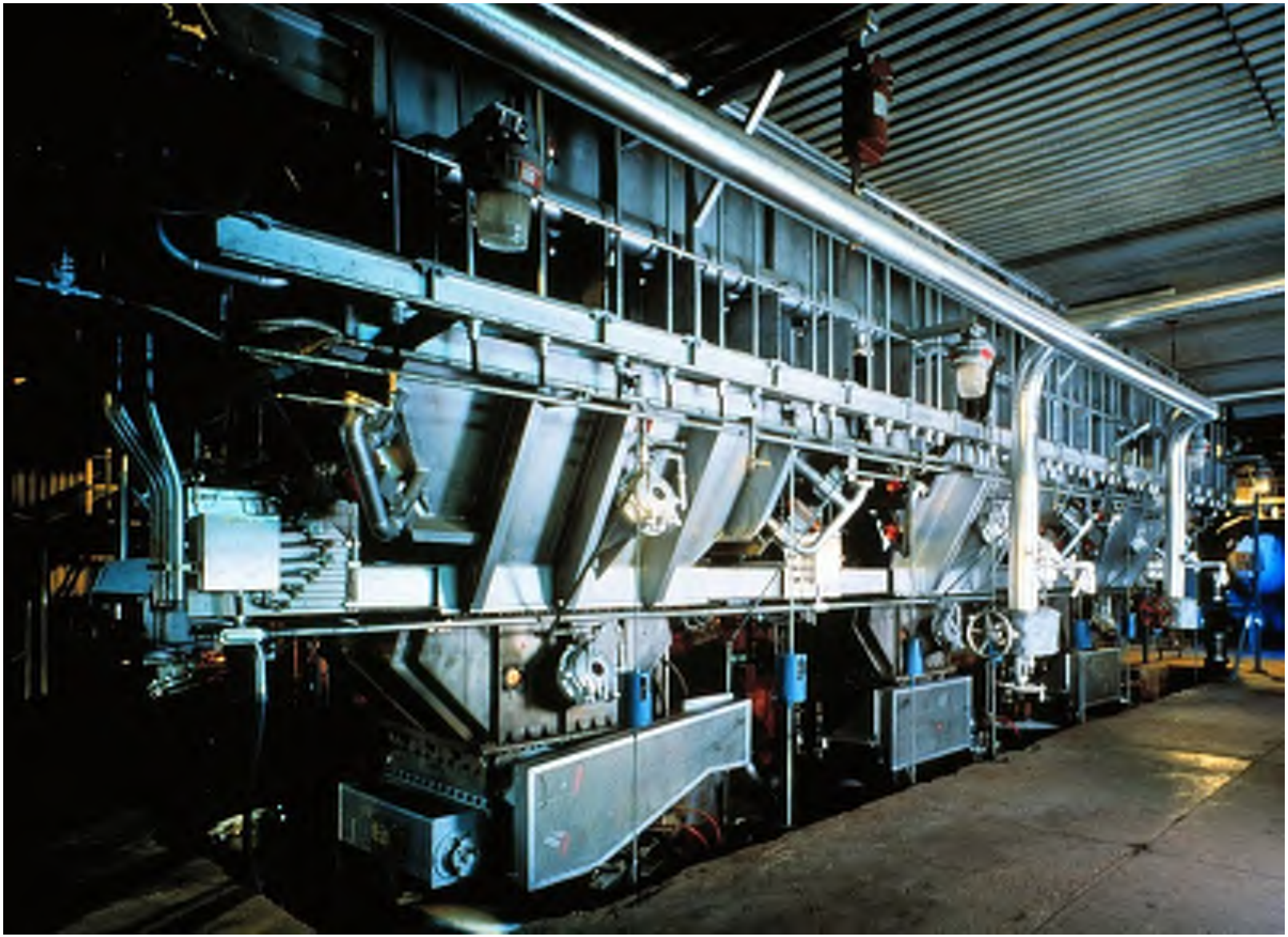
Bottom Ash WTD Conversion Alternatives

Pneumatic Ash Extractor (PAX)



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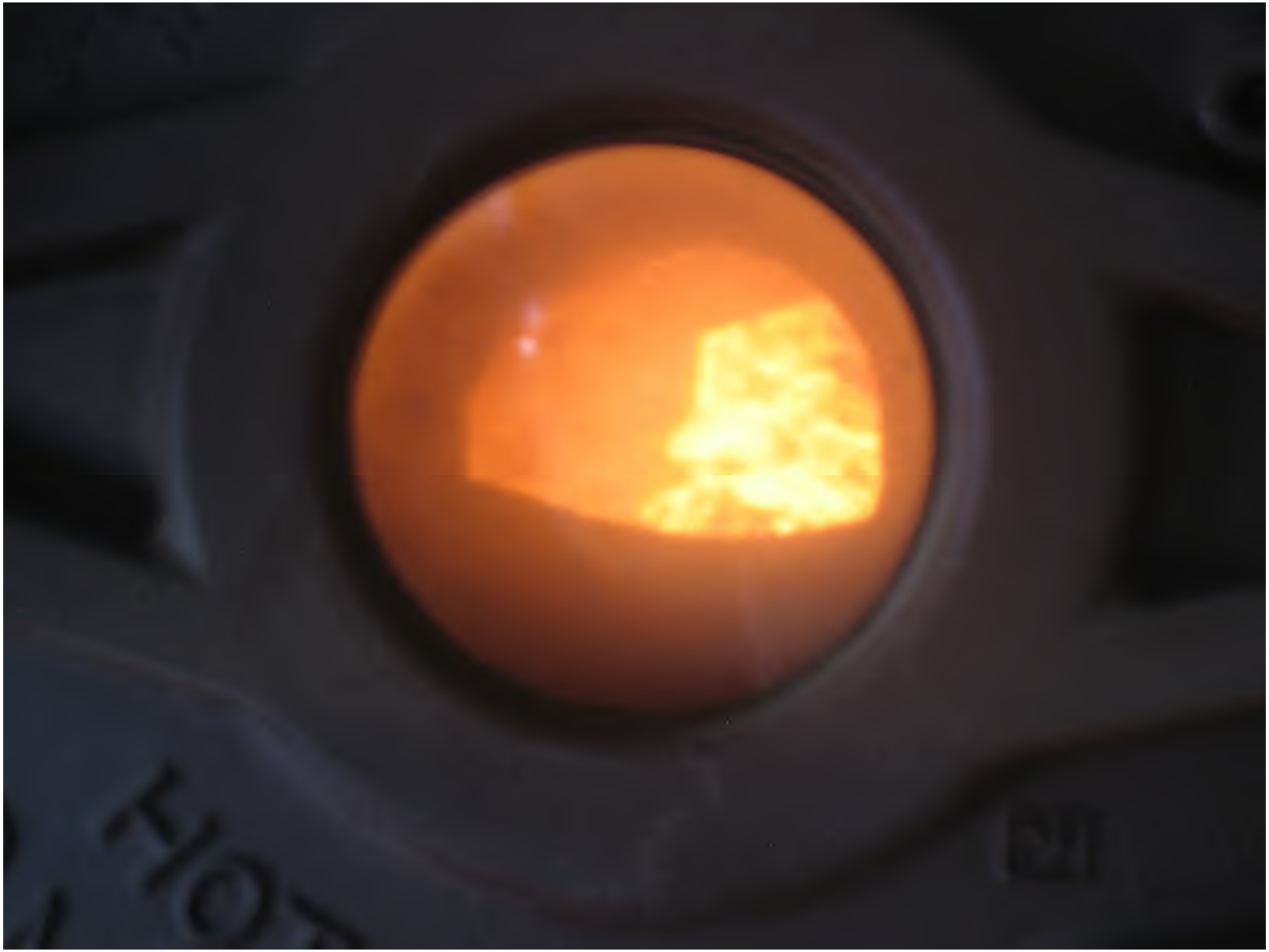
Bottom Ash WTD Conversion Alternatives

Pneumatic Ash Extractor (PAX)

Bottom Ash WTD Conversion Alternatives

Pneumatic Ash Extractor (PAX)



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Bottom Ash WTD Conversion Alternatives

Pneumatic Ash Extractor (PAX)

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Bottom Ash WTD Conversion Alternatives

Pneumatic Ash Extractor (PAX)

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Bottom Ash WTD Conversion Alternatives

Pneumatic Ash Extractor (PAX)

1 = Worst, 5 = Best	Technology Alternatives								
	Scale 1-5	SFC (Mechanical)		Re-Circ System (Hydraulic)		R-SFC/Clarifier (Hydraulic)		PAX (Pneumatic)	
									tal
W									5
O									
T									6
O									2
P									9
B									0
M									5
N									0
Unburned Carbon / Boiler Efficiency	4	0	0	0	0	0	0	5	20
Weighted Total Score			82		99		83		108

Decision Analysis Favors PAX™ System if criteria are weighted for:

- 100% Dry Solution
- Physical Space Limitations
- Unburned Carbon / Boiler Efficiency

Discussion Overview

- Regulatory Update & Implications
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- **Water Balance & Wastewater Considerations**

Additional Water Balance & Wastewater Considerations

Water Balance/Wastewater Considerations

Pyrites System Considerations

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

Water Balance/Wastewater Considerations

Pyrites System Considerations

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

Pyrites Dewatering Bins

Water Balance/Wastewater Considerations

Pyrites System Considerations

Bottom Ash Option	Pyrites Option(s)
Under-Boiler SFC	• Sluiced to Surface Impoundment • Sluiced to SFC • Sluiced to Dewatering Bins
Conventional Dewatering Bin System	• Sluiced to Surface Impoundment • Sluiced to Dewatering Bins
CDR System with Remote SFC	• Sluiced to Surface Impoundment • Sluiced to R-SFC • Sluiced to Dewatering Bins
PAX System	• Sluiced to Surface Impoundment • Sluiced to R-SFC / Dewatering Bins • Dry Handling Options

Water Balance/Wastewater Considerations

Economizer Ash Considerations: Sluice vs. Dry Systems

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

Water Balance/Wastewater Considerations

Economizer Ash Considerations: Sluice vs. Dry Systems

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

Water Balance/Wastewater Considerations

Economizer System Considerations

Bottom Ash Option	Economizer Option(s)
Under-Boiler SFC	• Downcomer / DFC / Sluiced to SFC • Dry Fly Ash System Tie-In • Separate Dry Vacuum System
Conventional Dewatering Bin System	• Sluiced to Dewatering Bins • Dry Fly Ash System Tie-In • Separate Dry Vacuum System
CDR System with Remote SFC	• Sluiced to R-SFC • Dry Fly Ash System Tie-In • Separate Dry Vacuum System
PAX System	• Pneumatic Vacuum System Tie-In

Additional Balance-of-Plant (BOP) Considerations

Balance of Plant (BOP) Considerations

Key Issues / Potential Critical Path Items

- Permitting
- Geotechnical Study
- Electrical Load Study
  - Power Supply & Distribution Equipment
- R-SFC / Silo Foundations
- DCS Interface
- Integration with Existing Equipment
- Service Water and Compressed Air Design
- Outage Tie-Ins

Technical Design Considerations

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

Questions

Questions ?

Wet-to-Dry Conversions