REINHOLD ENVIRONMENTAL Ltd.

2019 NOx-Combustion-CCR Round Table Presentation

February 11 & 12, 2019, in Salt Lake City, Utah / Hosted by PacifiCorp

UNITED CONVEYOR CORPORATION

Industry Update: Lessons Learned from Newly Commissioned Systems and Wet-to-Dry Ash Conversion Projects

Prepared for: 2019 NOx-Combustion-CCR Round Table

Presented By: Kevin L. McDonough

11 February 2019

Safety Moment

Discussion Overview

Presentation Prepared For:

- WTD Market Update
- Lessons Learned: CDR Systems
- Lessons Learned: Remote SFC / Clarifier Systems
- Lessons Learned: PAX Dry Pneumatic Systems

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Discussion Overview

Presentation Prepared For:

- **WTD Market Update**
- Lessons Learned: CDR Systems
- Lessons Learned: Remote SFC / Clarifier Systems
- Lessons Learned: PAX Dry Pneumatic Systems

UCC Wet-to-Dry Ash Conversion Update

Coal Units: Dry Ash Handling Systems

Presentation Prepared For: RE

Project Type	Unit Conversion %
% of U.S. Fleet installed with or converted to Dry Fly Ash (Includes Projects In Progress)	**>98%**
% of U.S. Fleet installed with or converted to Dry Bottom Ash (Includes Projects In Progress)	**Approx. 50%**

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Bottom Ash Wet-To-Dry Conversions

Technology Alternatives

Presentation Prepared For:

Submerged Flight Conveyor

- 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)

100% Dry Pneumatic / Mechanical Conveying

- No Water, Maintains O&M Flexibility, Reduces LOI
- Elimination of Long-term Environmental Wastewater Risk

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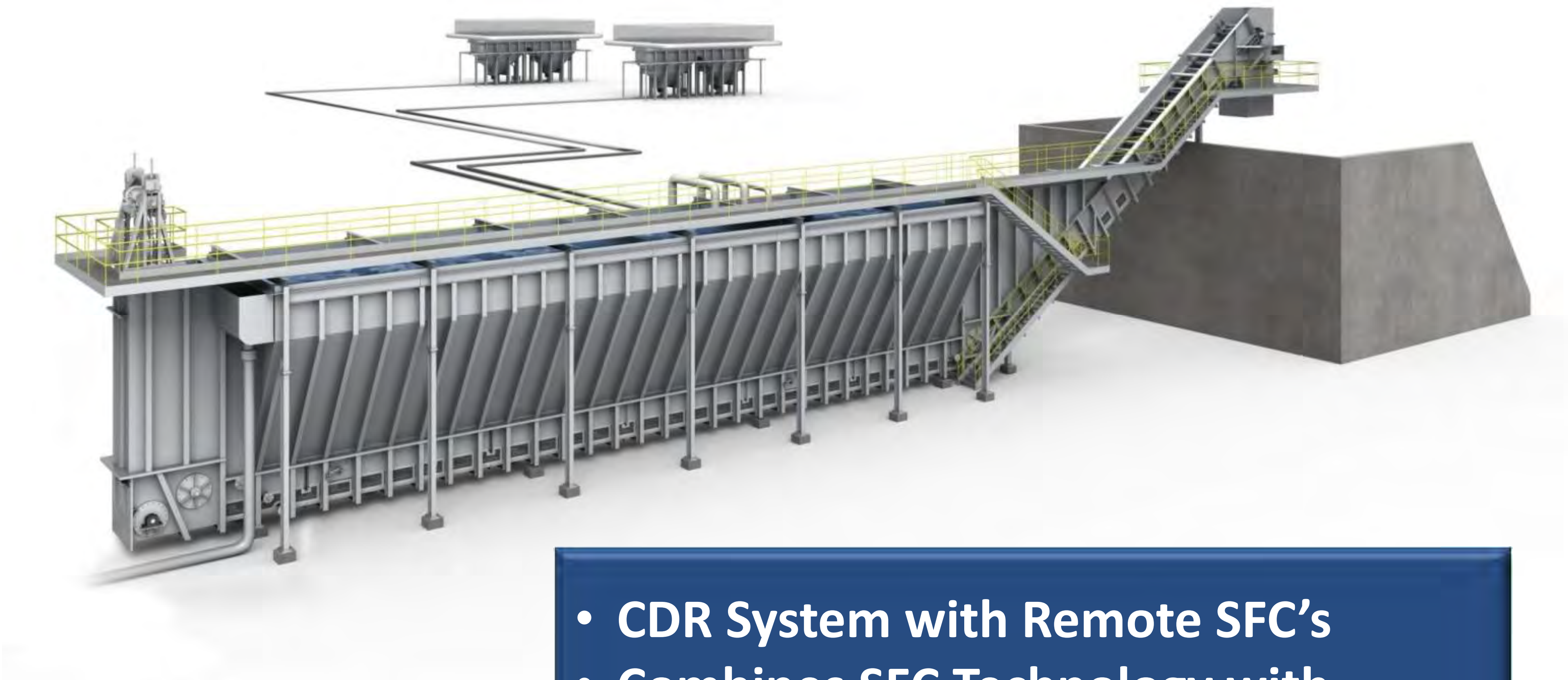
Continuous Dewatering & Recirculation (CDR) System

Bottom Ash WTD Conversion Alternatives

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

Presentation Prepared For:



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

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Water Balance/Wastewater Considerations

Bottom Ash Sluice Water Demands for CDR Systems

Presentation Prepared For:

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 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

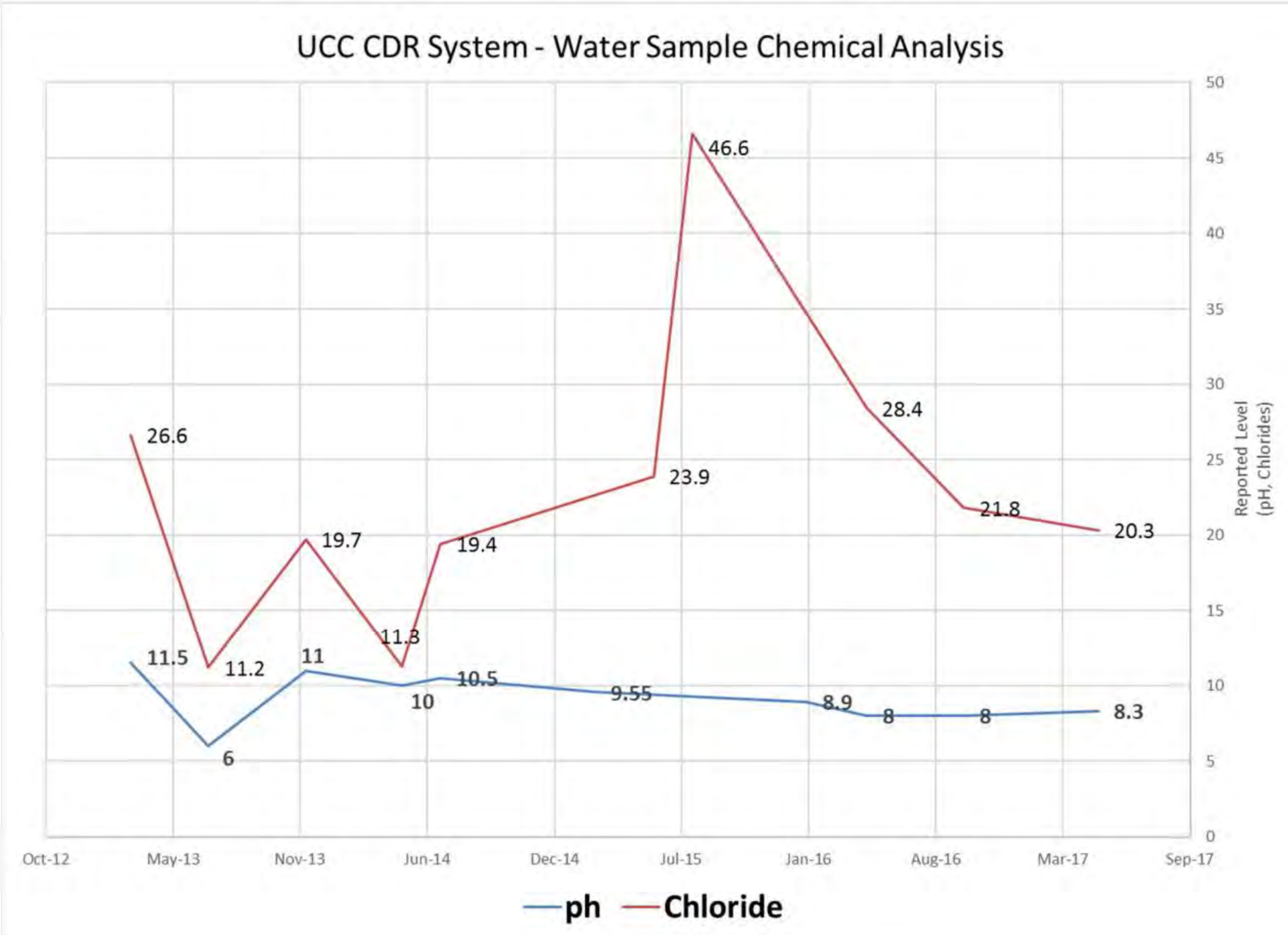
Bottom Ash Sluice Water Quality and Chemistry

Presentation Prepared For: RE

- **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 Acidic Conditions (NaOH)
  - Acid Addition for Alkaline Conditions (HCl to mitigate scaling risk)
  - Many legacy 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 (Fuel = Eastern Appalachian)



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Bottom Ash WTD Conversion Alternatives

Bottom Ash Sluice Water Quality and Chemistry

Presentation Prepared For: RE

- **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.

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CDR System Case Study

Presentation Prepared For:

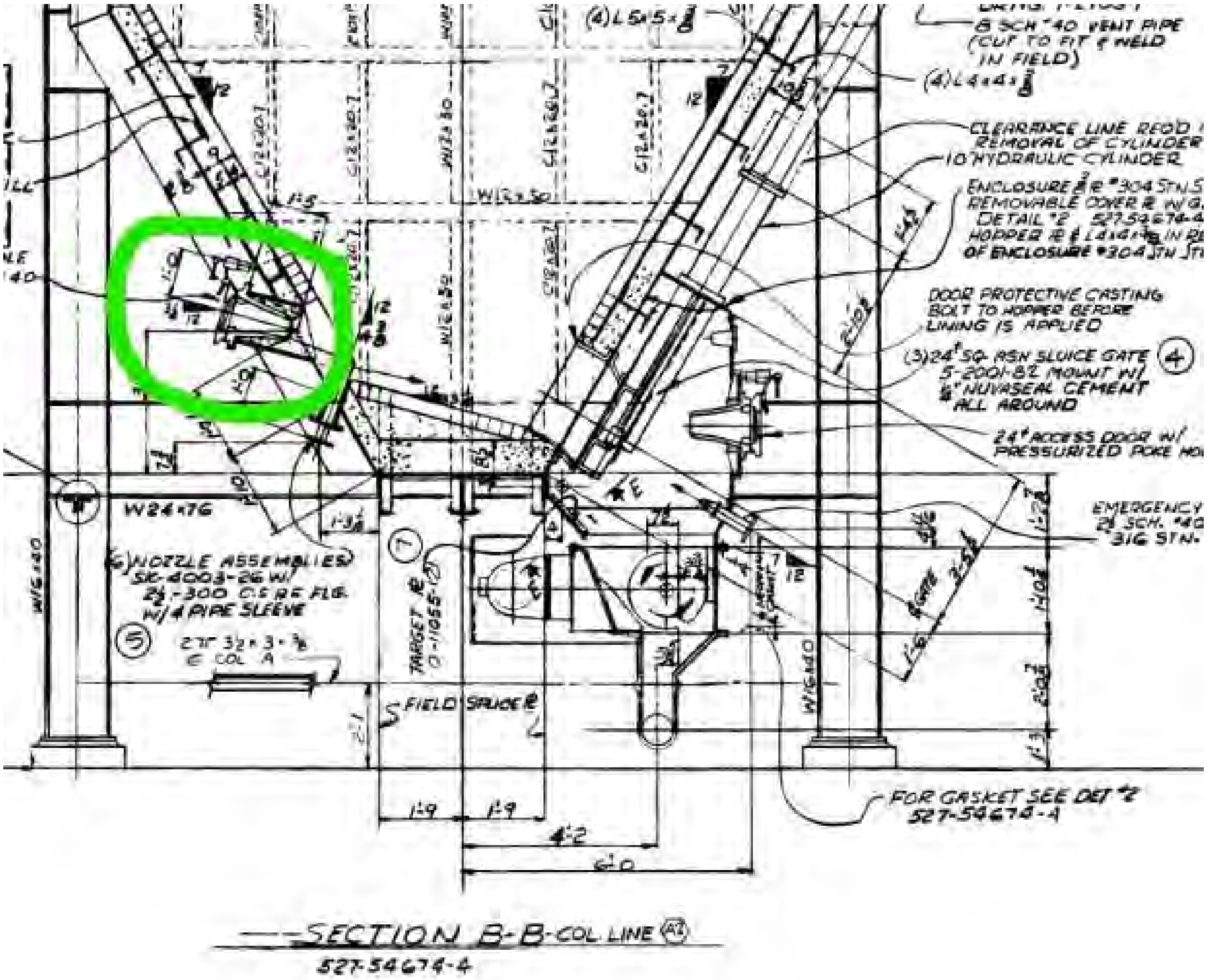
- Midwestern Installation: Testing included 3 Units
- Fuel: Illinois Basin Coal

Unit	High Load (MW)	Low Load (MW)
1	220	140
2	450	285
4	560	260

CDR System Case Study

Bottom Ash Hopper Water Sampling Location

Presentation Prepared For:



CDR System Case Study

Unit 1 Bottom Ash Hopper – Low Sampling Location

Presentation Prepared For:

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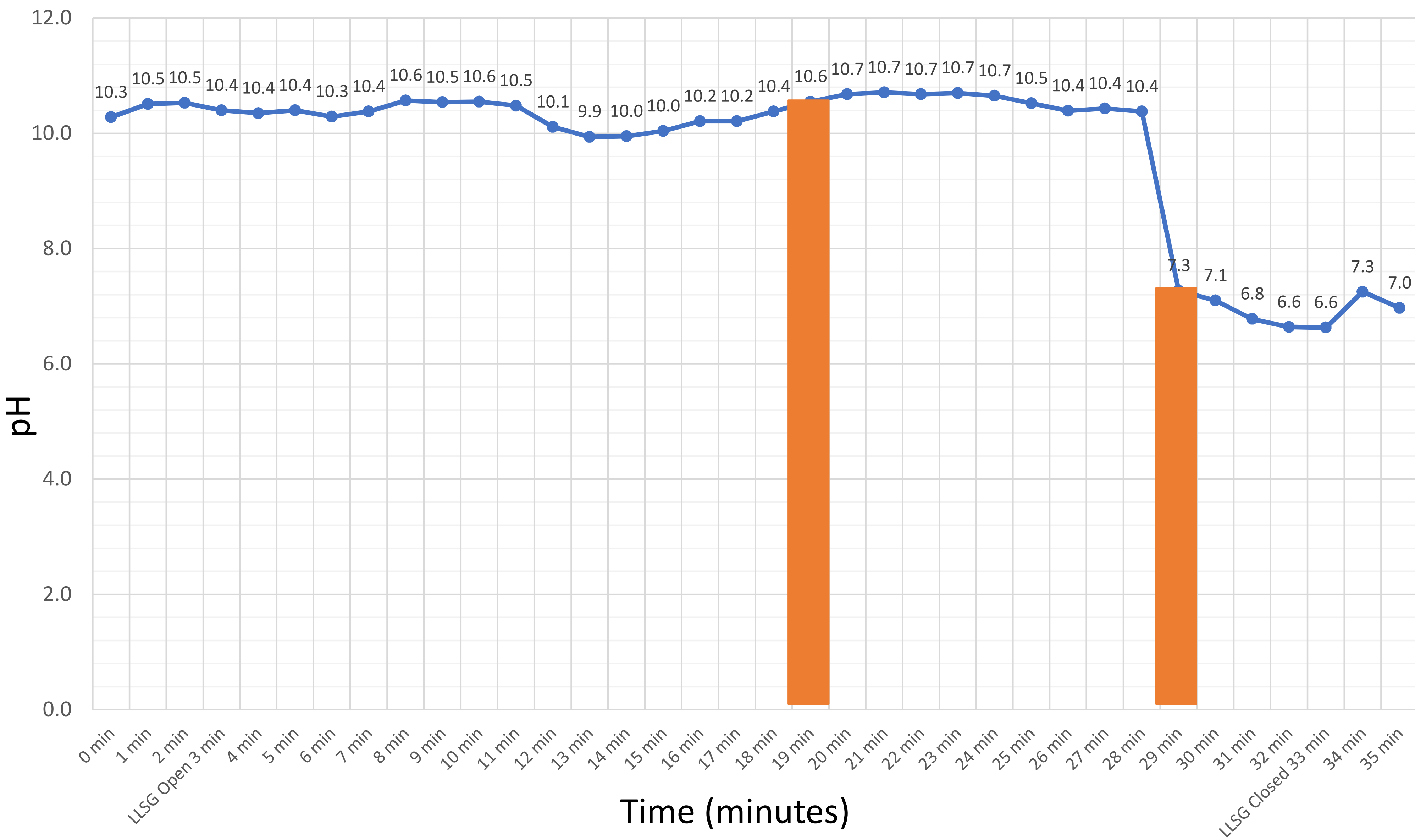
Unit 4 Bottom Ash Hopper

Measured pH during Conveying Sequence

Presentation Prepared For:



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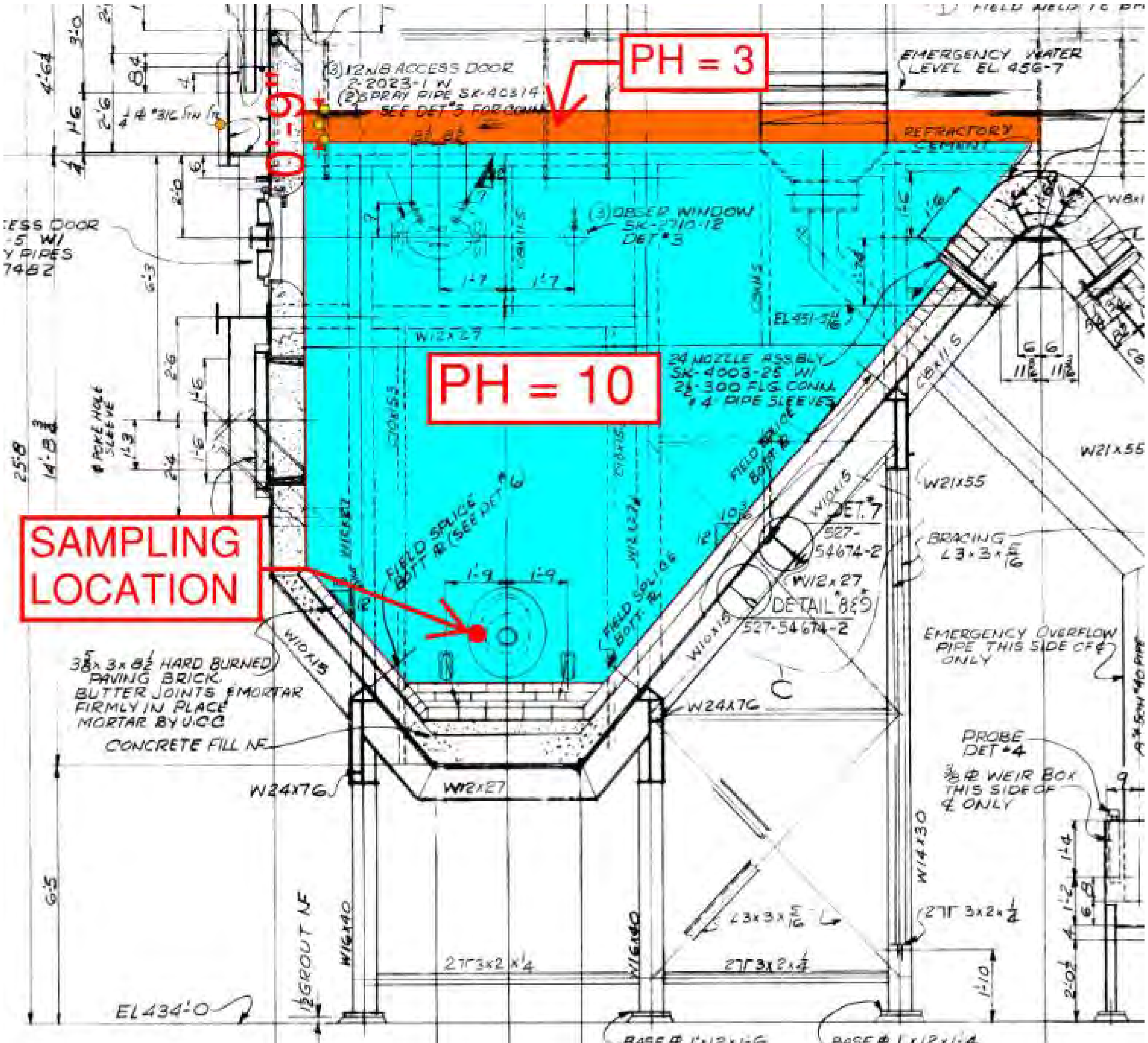
Unit 4 Bottom Ash Hopper

pH Stratification

Presentation Prepared For:



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CDR System Case Study

Bottom Ash Hopper Low Measuring Point pH Readings

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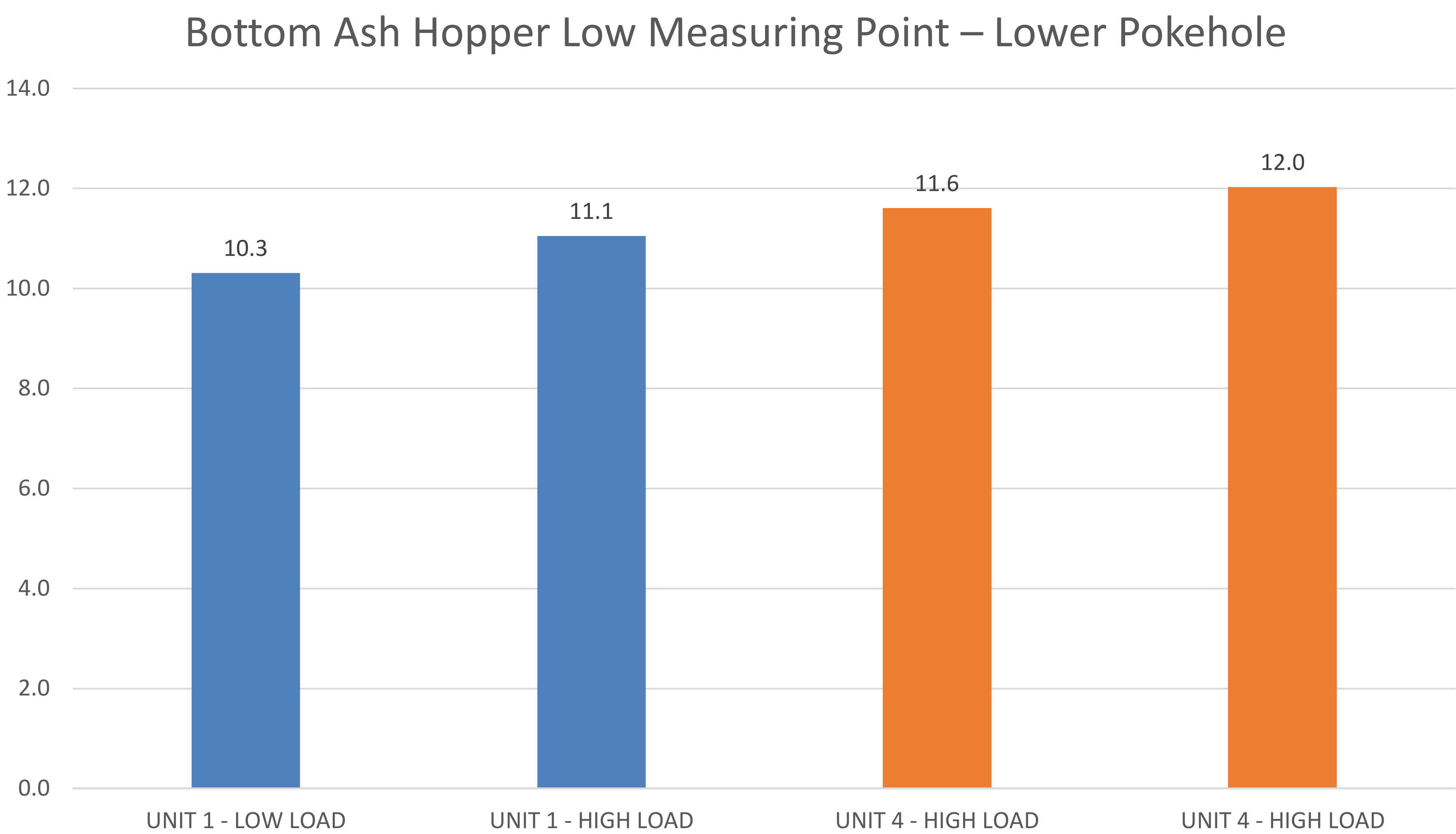

CDR System Case Study

Initial Observations

Presentation Prepared For:

- Bottom Ash was not Acidic, but measured as Basic
- Retention Time of Bottom Ash in Water raised pH

CDR System Case Study

Initial Observations

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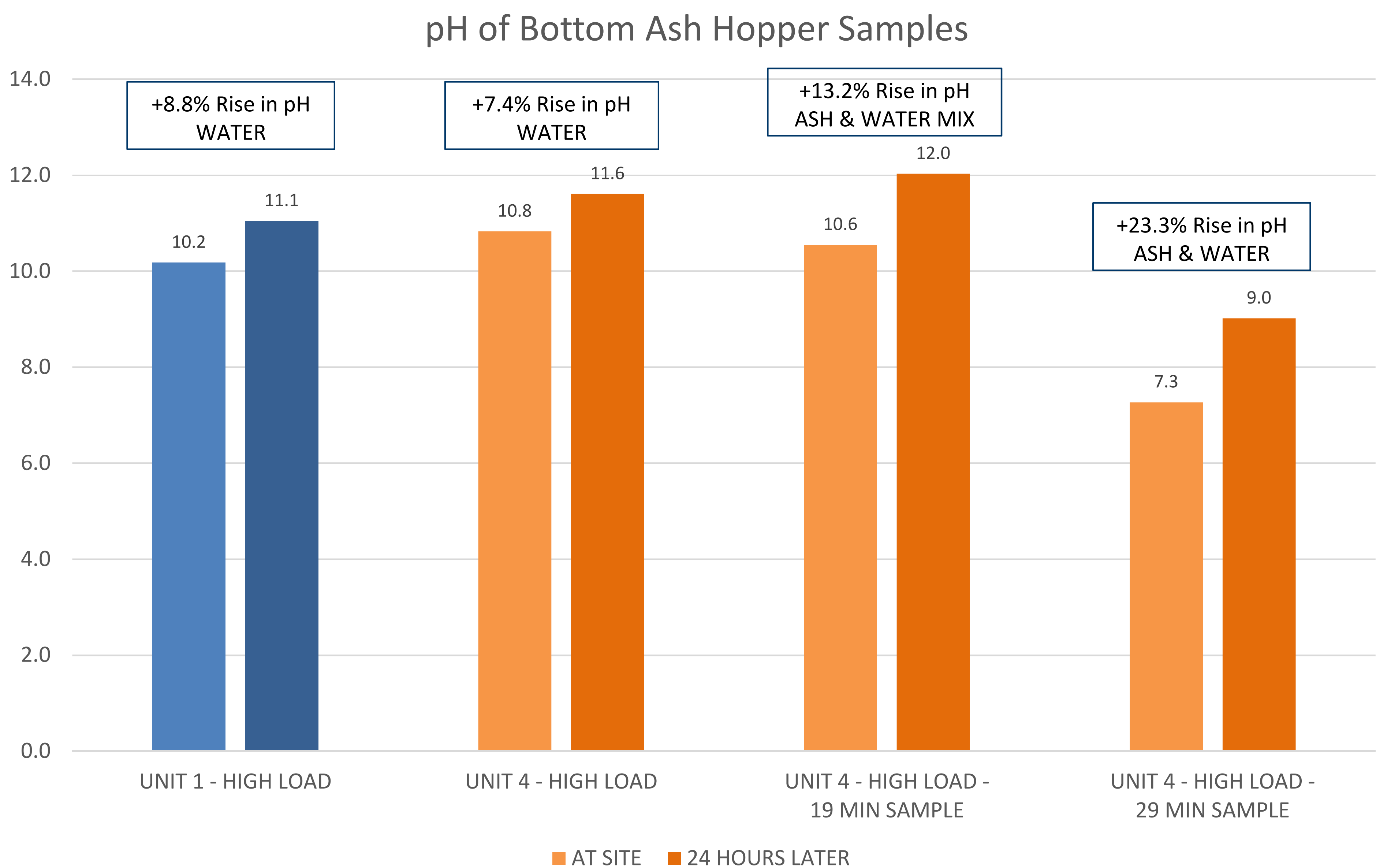

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CDR System Case Study

Overflow Pipe & Overflow Box Sampling Location

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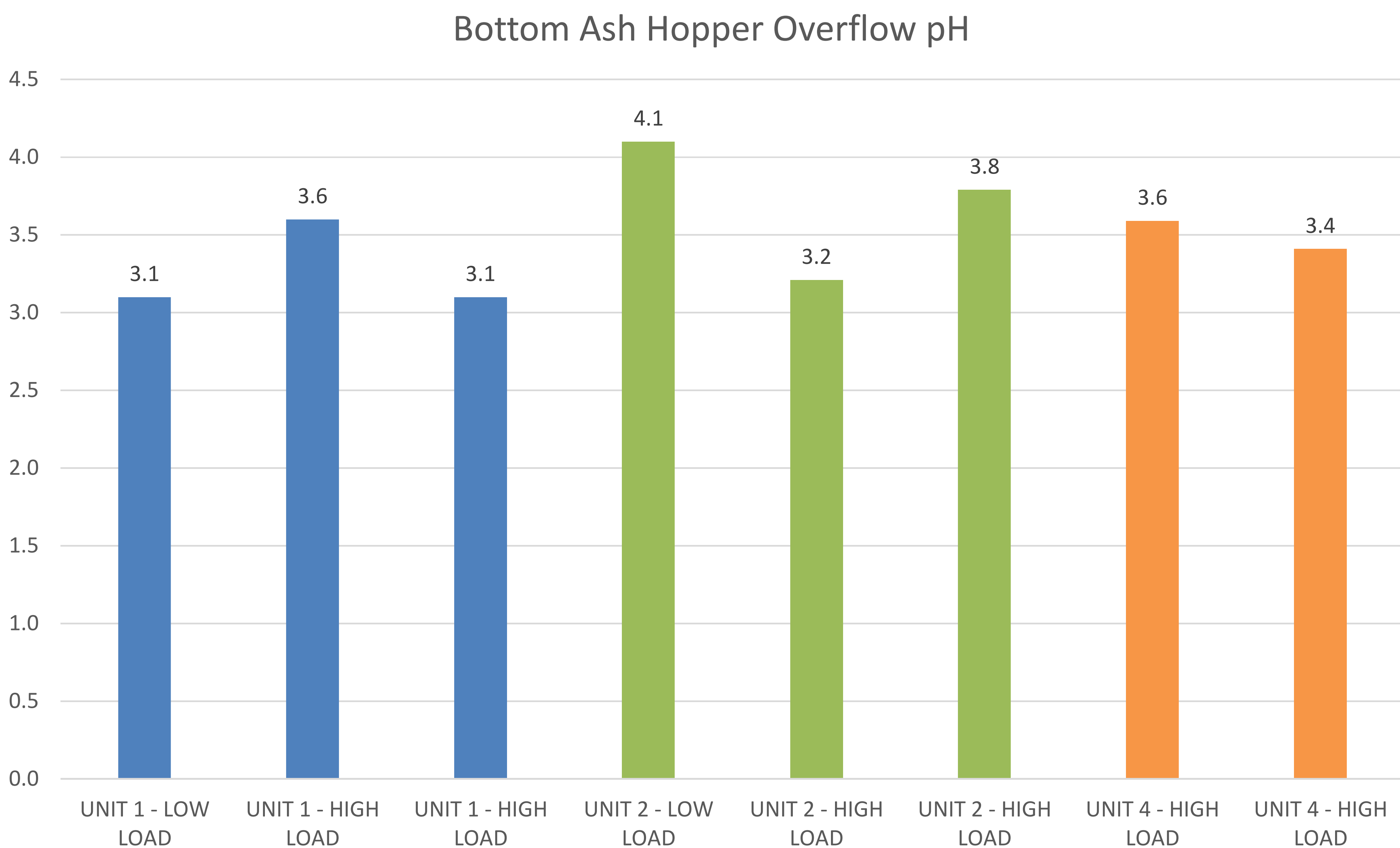
CDR System Case Study

Bottom Ash Hopper Overflow pH Measurements



Presentation Prepared For:

CDR System Case Study

Overflow Tank Sampling Location

Presentation Prepared For:

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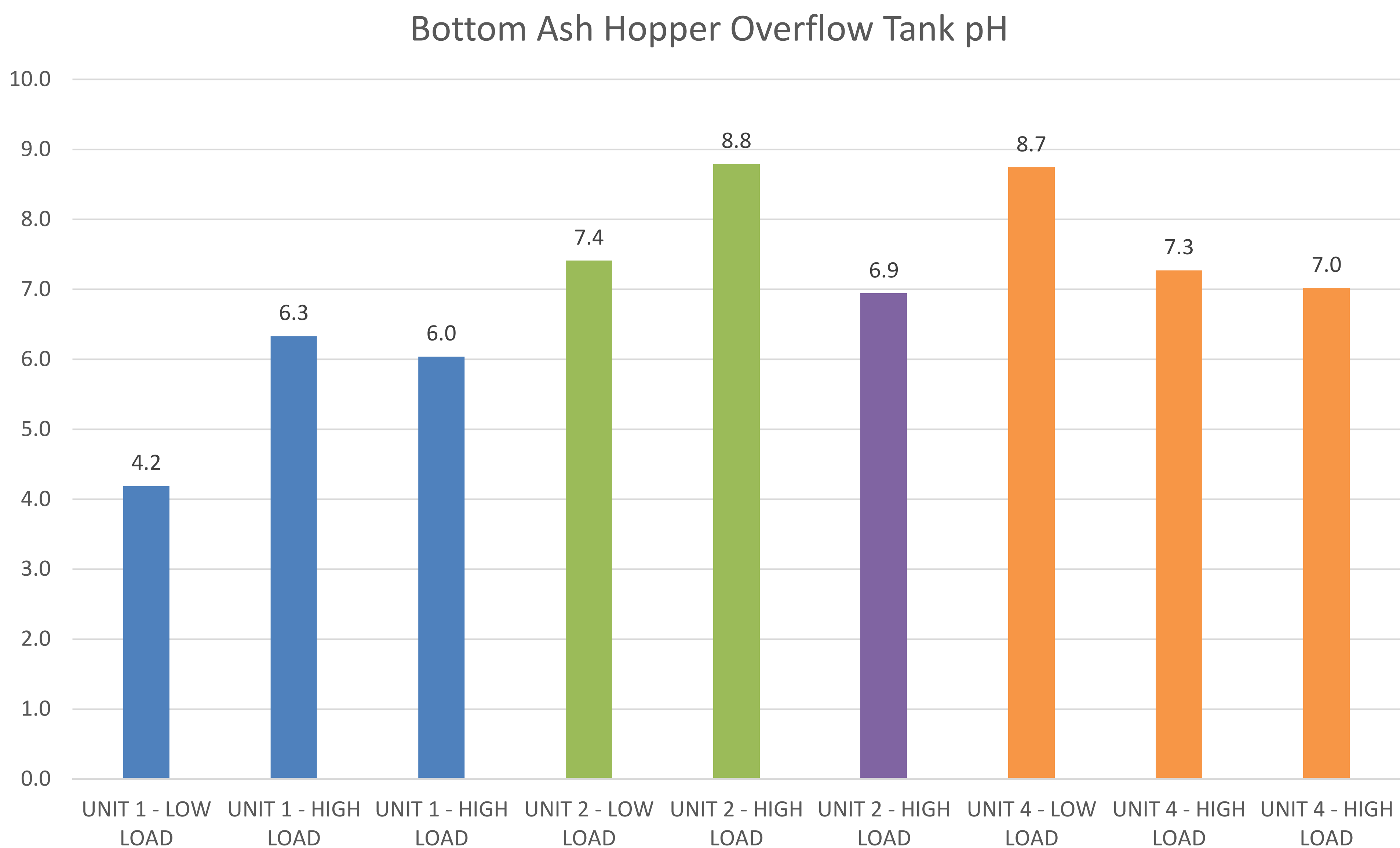
CDR System Case Study

Bottom Ash Hopper Overflow Tank pH Readings

Presentation Prepared For:



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CDR System Case Study

Bottom Ash Hopper Overflow Tank Initial Observations

Presentation Prepared For: RE

- Bottom Ash Hopper Overflow Tank is an ideal location for pH Control
  - As Close to Source of Acid Generation as possible
- When Caustic System is operated as intended, Acid is properly controlled
- Average pH of Overflow Tank with pH Control
  - Unit 1: 5.5
  - Unit 2: 8.1
  - Unit 3: 6.9 (from plant)
  - Unit 4: 7.7

CDR System Case Study

Pyrites/Economizer Ash Tank Sampling Location

Presentation Prepared For:

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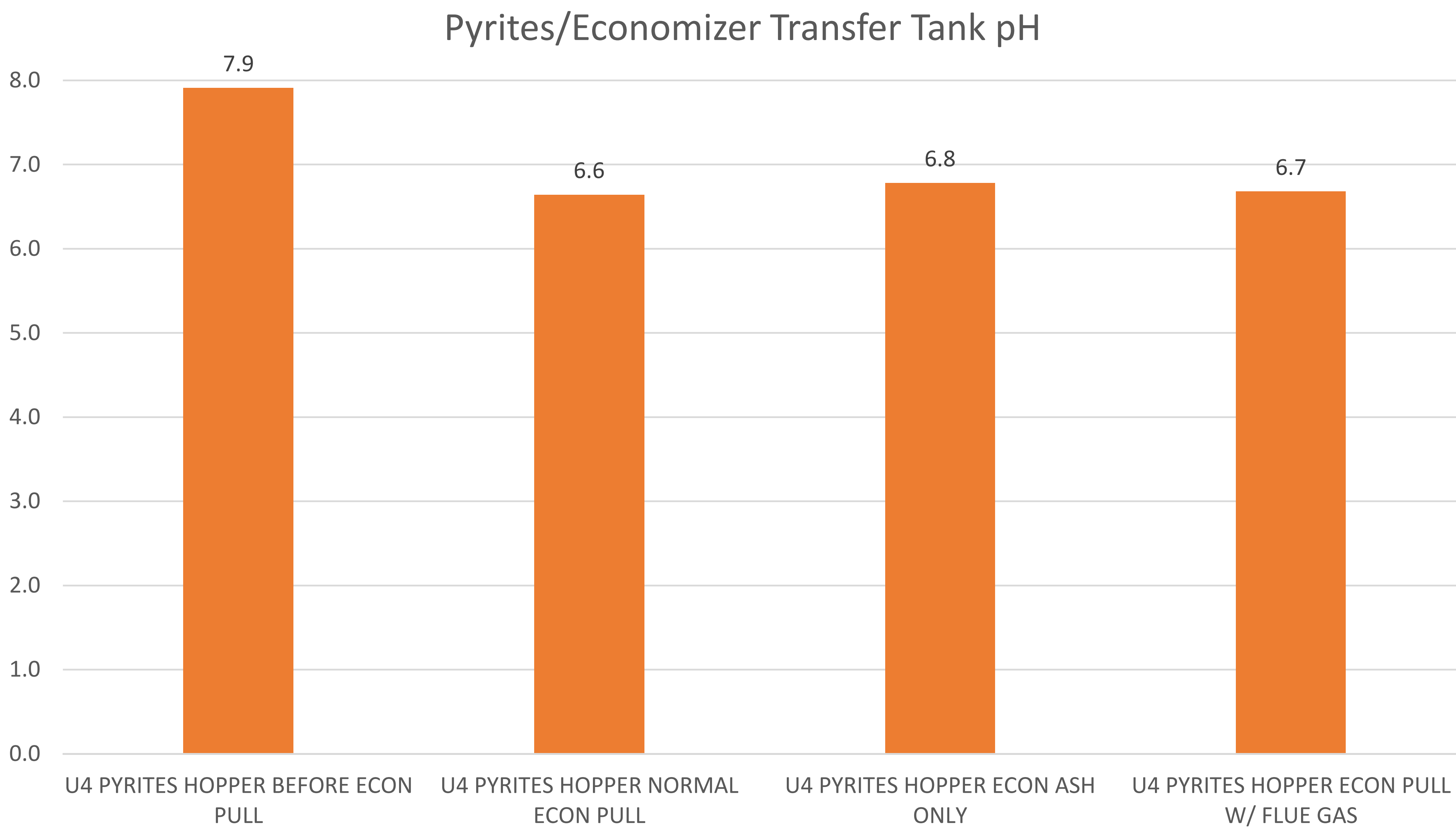
CDR System Case Study

Pyrites/Economizer Tank pH Readings

Presentation Prepared For:



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CDR System Case Study

Pyrites/Economizer Tank Initial Observations

Presentation Prepared For: RE

- Unit 4 Pyrites Conveyed to Holding Tank Periodically During Shift
  - pH of 7.9
  - Does not appear to be a significant source of acid
- Unit 4 Economizer Ash Conveyed to Pyrites Holding Tank Only When Conveying to SFC Using Hydroveyor
  - Pyrites tank with mix of pyrites and econ. ash/water: 6.6 pH
  - Pyrites tank after completely emptying tank of pyrites/econ. ash/water and refilled only from econ. system under normal operating condition of pulling until empty: 6.8 pH
  - Pyrites tank after continuing to pull same econ. hopper for an additional 5 minutes after empty to pull as much flue gas as the system would ever see: 6.7 pH
  - Economizer Ash conveyed does not appear to be a significant acid source

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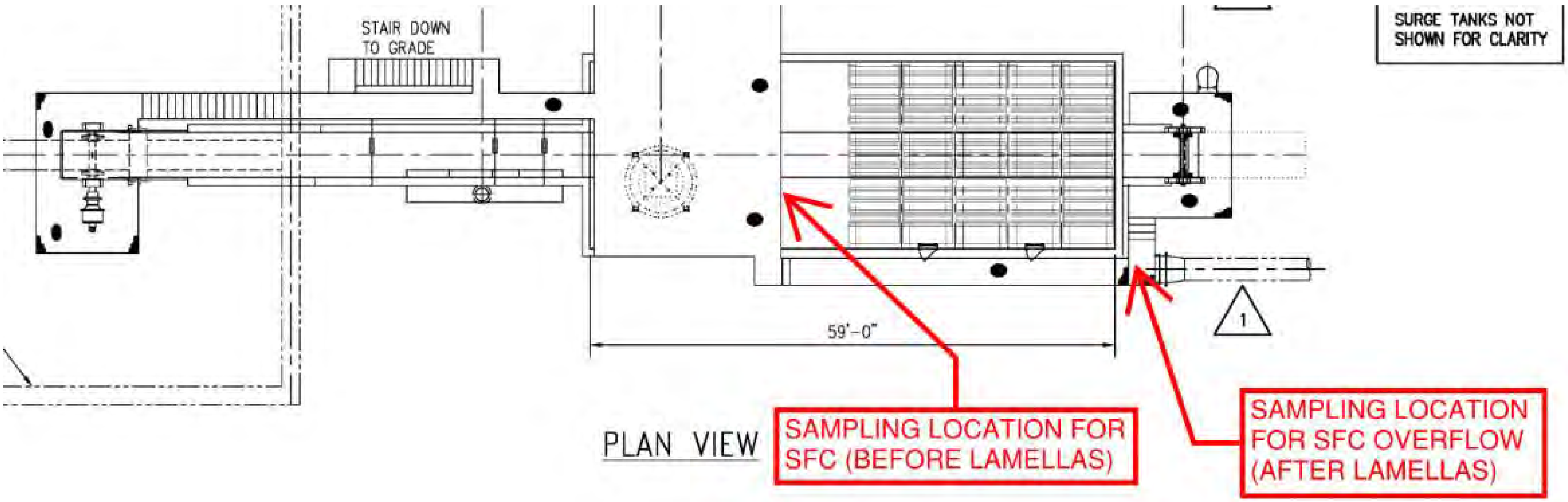
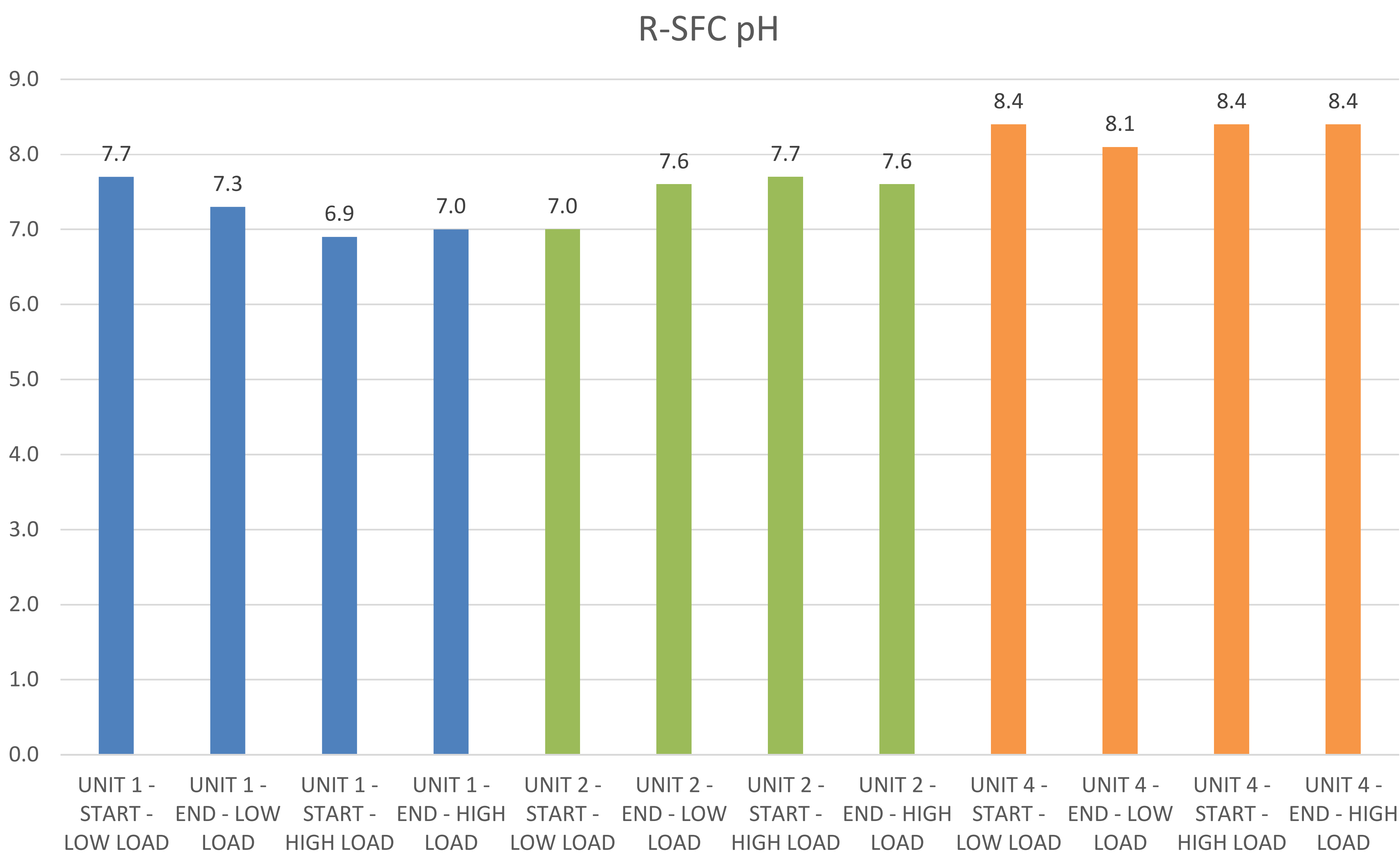
CDR System Case Study

Remote SFC Sampling Locations



CDR System Case Study

Remote SFC pH Readings



CDR System Case Study

Remote SFC pH Readings

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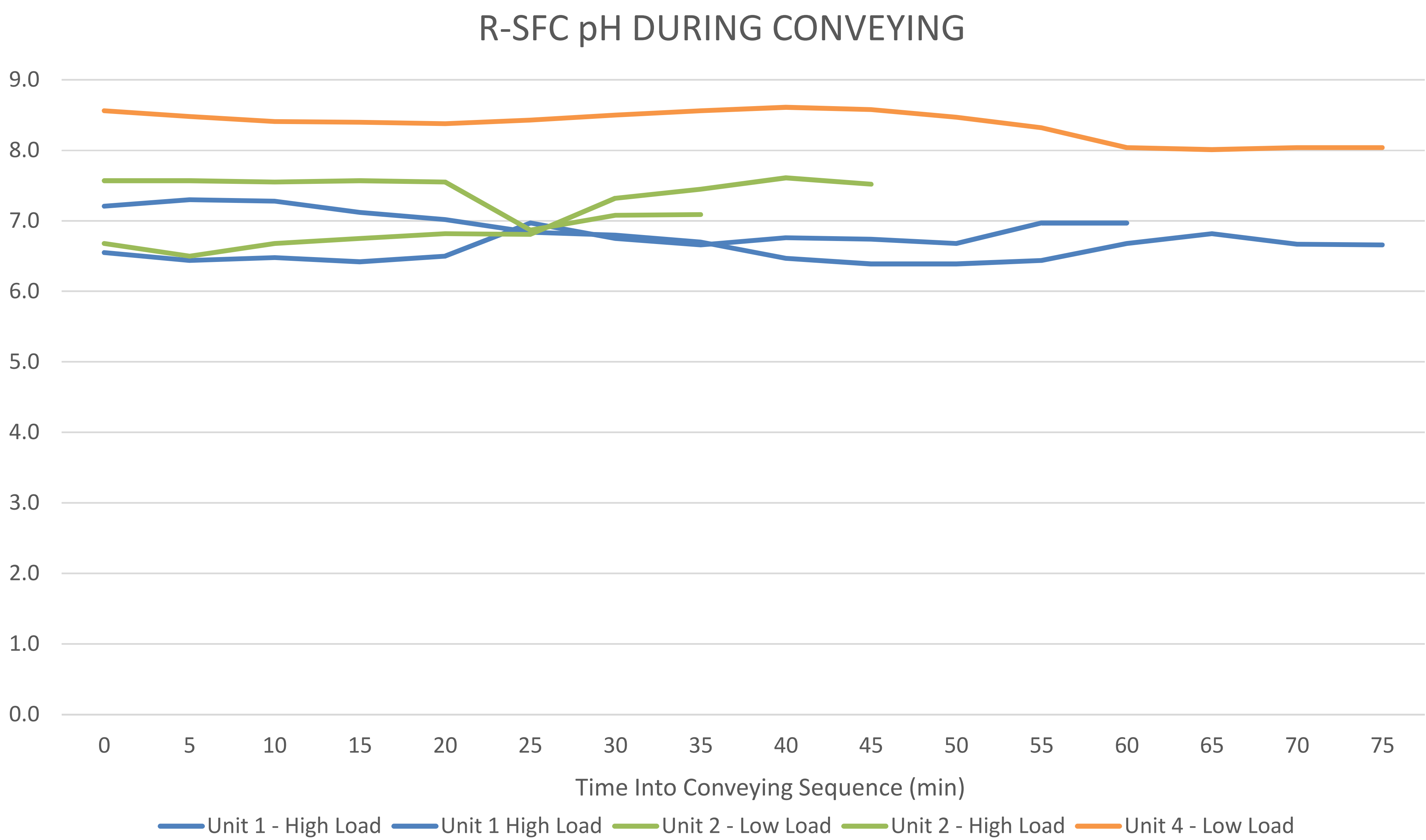
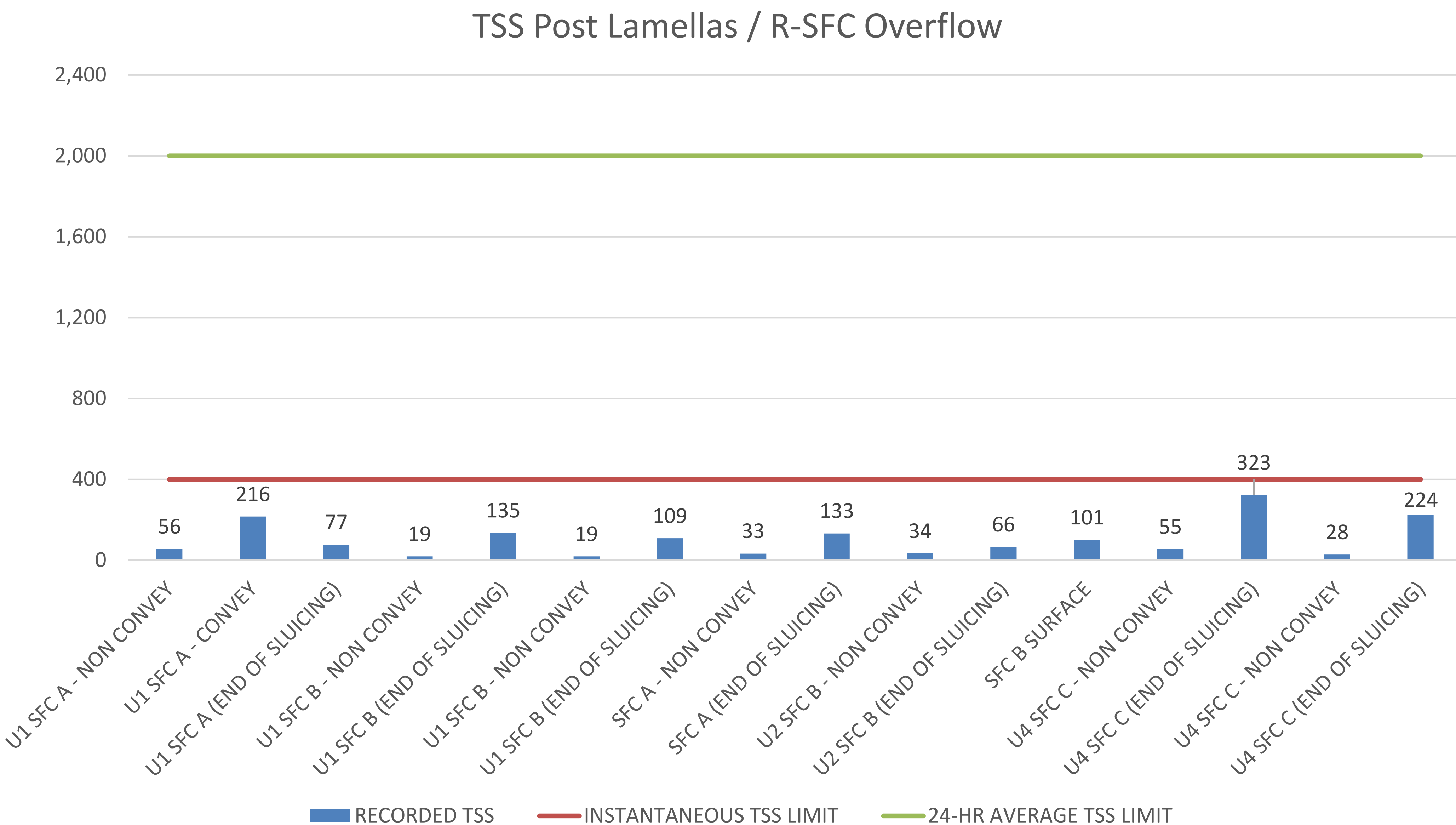


CDR System Case Study

Remote SFC Total Suspended Solids (TSS) Readings

Presentation Prepared For:



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Lessons Learned: CDR Systems

Summary

Presentation Prepared For: RE

- Collect Bottom Ash Hopper Overflow Water Samples prior to conversion over a range of operation conditions to confirm water chemistry (pH, Sulfates, $CaCO_3$, etc.)
- Thoroughly inspect existing Bottom Ash Hopper Overflow Weir Boxes and Overflow Piping for signs of past/ongoing corrosion
- Collect Ash Samples prior to conversion to confirm particle characteristics (chemical and physical)
- Include pH control instrumentation and chemical injection in initial system design, or plan for potential future addition
- Confirm pH probes/transmitters are calibrated properly and sending signals to control system
- Inject caustic as close to source of acid generation as possible

Discussion Overview

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- WTD Market Update
- Lessons Learned: CDR Systems
- **Lessons Learned: Remote SFC / Clarifier Systems**
- Lessons Learned: PAX Dry Pneumatic Systems

Remote SFC & Clarifier System

Bottom Ash WTD Conversion Alternatives

UCC CDR System with Remote SFCs and Clarifiers

Presentation Prepared For:

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Bottom Ash WTD Conversion Alternatives

UCC CDR System with Remote SFCs and Clarifiers

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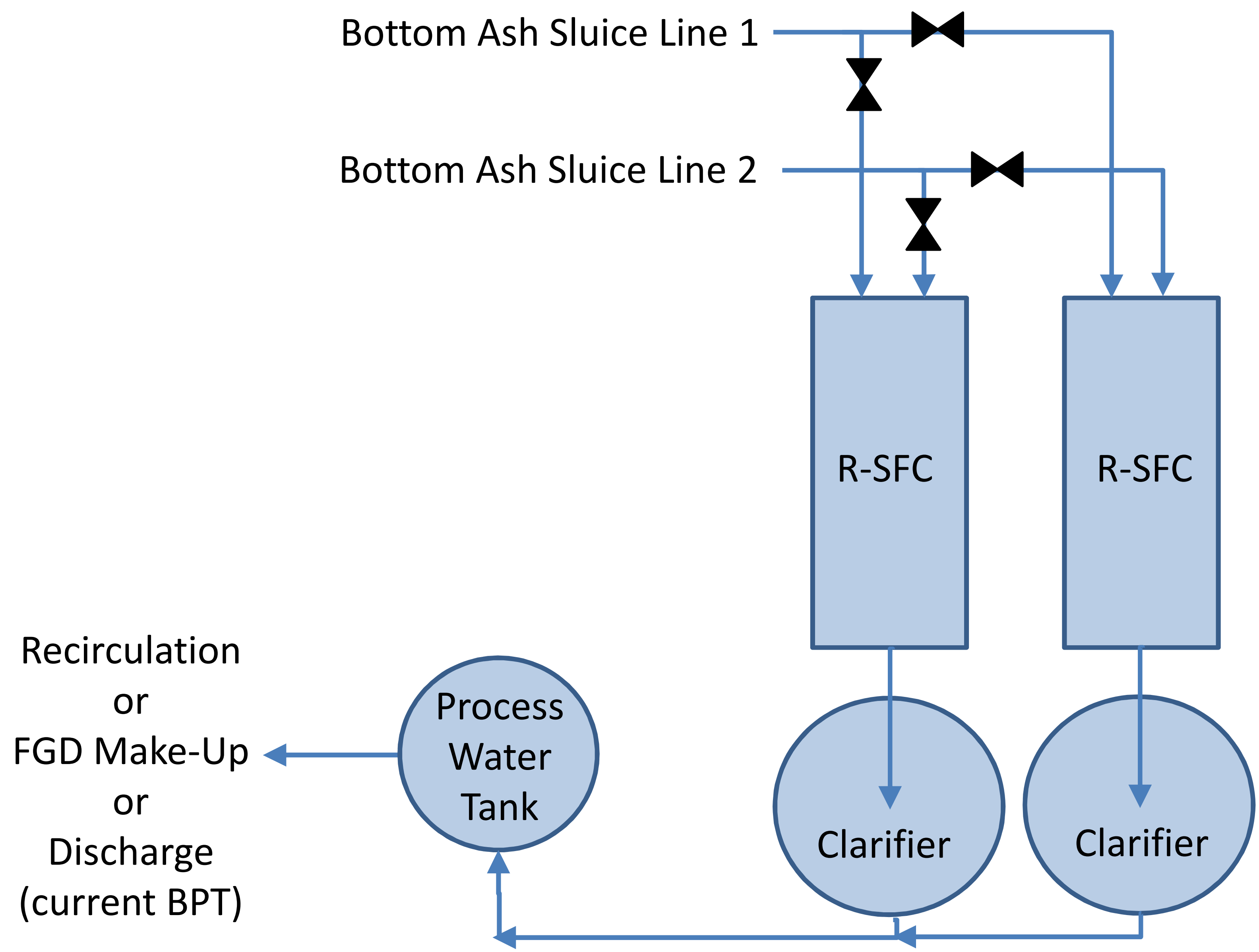


Design Basis Requirements

Typical Performance Guarantees

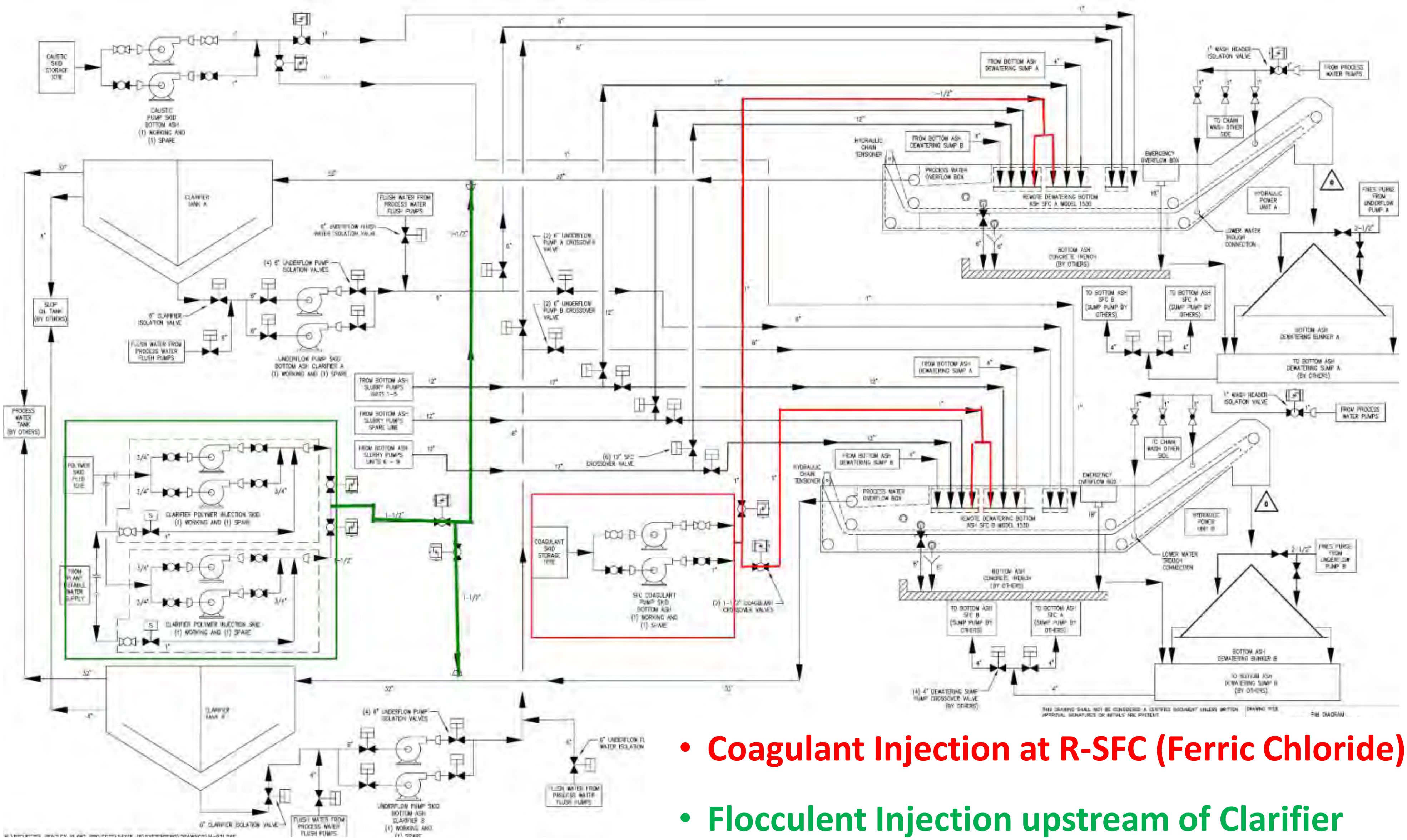
Presentation Prepared For:

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 Conversion Alternatives

UCC CDR System with Remote SFCs and Clarifiers

Presentation Prepared For:



- Coagulant Injection at R-SFC (Ferric Chloride)
- Flocculent Injection upstream of Clarifier

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UCC CDR System with Remote SFCs & Clarifiers

Design Requirements and Operating Results

Presentation Prepared For:

	Specified Design		Actual
	Maximum for any 1 day (mg/l)	Average of daily values for 30 consecutive days shall not exceed (mg/l)	Typical Daily Sample
TSS	100.0 ppm	30.0 ppm	<15ppm
Oil and Grease	20.0 ppm	15.0 ppm	<15ppm
pH	6-9		7.5

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Remote SFC and Clarifier System Case Study

Designing for Operating Flexibility

Presentation Prepared For:

- **Event #1: Upset Inlet Conditions**
- **Event #2: Boiler Washdown**

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Lessons Learned: Remote SFC / Clarifier Systems

Summary

- Collect Ash Samples prior to conversion to confirm range of particle characteristics (e.g. specific gravity, density, distr. etc.)
- Conduct Lab Testing to confirm likely settling velocities (with appropriate sequencing and varying dosing of chemicals)
- Size clarifiers in accordance with lab testing and associated target settling rates (gpm/sq. ft.)
- Include considerations for both Coagulant and Flocculent injection into overall system (operate each as required)
- Consider spare R-SFC / Clarifier Train for potential Boiler Washdown events
- For Boiler Washdown option, consider pre-treatment tank (w/caustic addition) for Iron/Other Metal Oxides precipitation

Discussion Overview

- WTD Market Update
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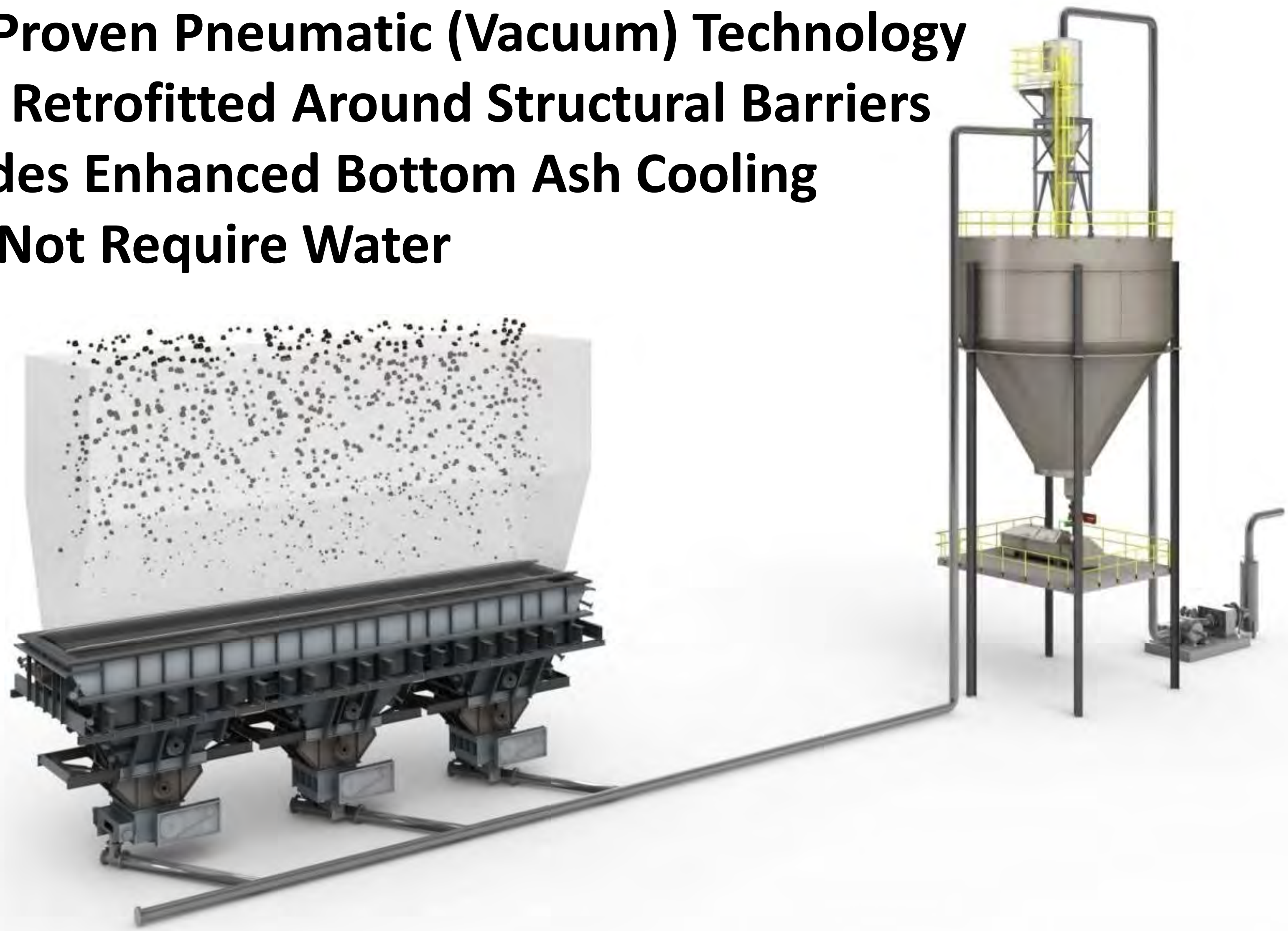
- Lessons Learned: Remote SFC / Clarifier Systems
- **Lessons Learned: PAX Dry Pneumatic Systems**

PAX Bottom Ash System Overview

Pneumatic Ash Extractor (PAX)

Presentation Prepared For:

- Uses Proven Pneumatic (Vacuum) Technology
- Easily Retrofitted Around Structural Barriers
- Provides Enhanced Bottom Ash Cooling
- Does Not Require Water



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PAX Bottom Ash System Overview

Pneumatic Ash Extractor (PAX)

Presentation Prepared For:

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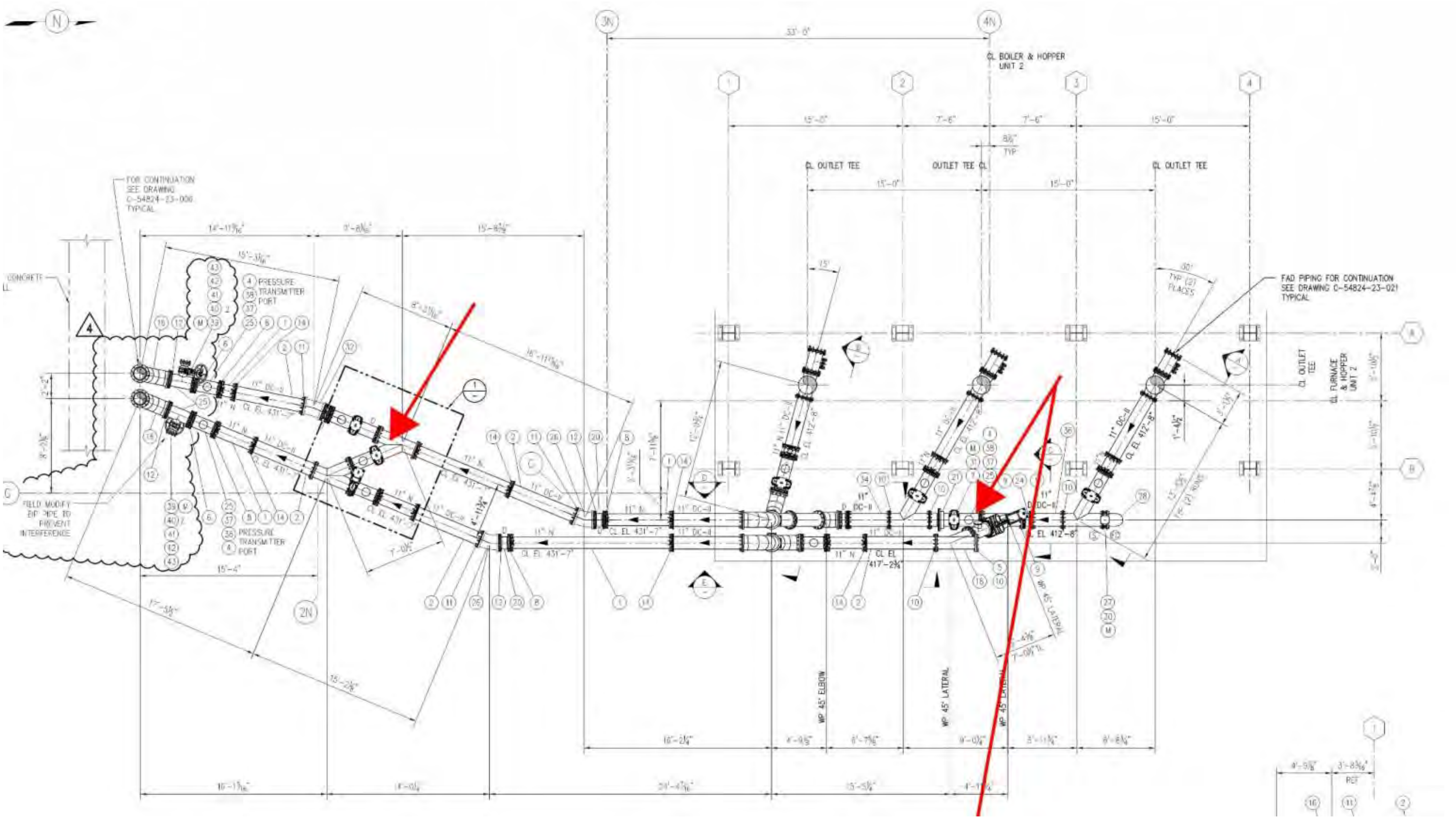
Lesson Learned: PAX Pneumatic Systems

Reducing Velocity in Vacuum Conveying Line

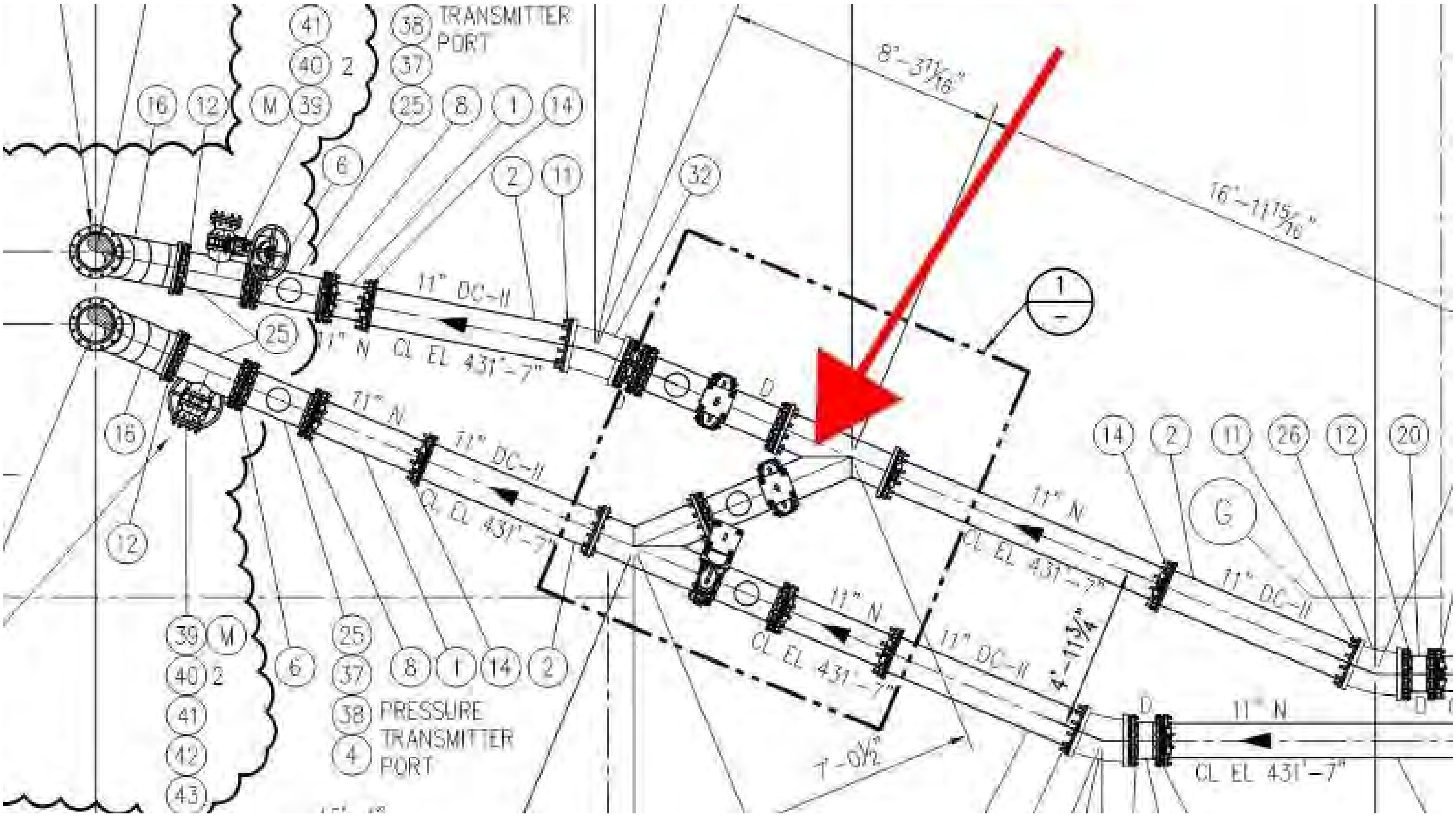
Presentation Prepared For:



Lesson Learned: PAX Pneumatic Systems

Reducing Velocity in Vacuum Conveying Line

Presentation Prepared For: RE



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Lesson Learned: PAX Pneumatic Systems

Fitting (Laterals) Improvements: Design & Materials of Construction

Presentation Prepared For: RE

- Original: DURA-CORE (Ceramic)
- Improved: DURALOY (Chromium Carbide Weld Overlay)
- New Lateral lasting twice as long as original design and counting
- Developing concepts for improved impact area

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Lesson Learned: PAX Pneumatic Systems

Reducing Velocity in Vacuum Conveying Line

$$Erosion = CV^N$$

- Published values for N vary from 2 for ductile materials to 6 for brittle materials. It is generally accepted N=3 for most industrial situations. These correlations are based on conveying particles in the sub millimeter scale. Other published study results indicate increased wear for larger particle sizes. Therefore, we have assumed N>6 for large bottom ash.

- Design velocity reduced by 18%

$$Change\ in\ Erosion = \frac{CV^6}{C(0.82V)^6} = 3.3$$

- Wear Rate is 3.3 times longer

Lessons Learned: PAX Pneumatic Systems

Summary

Presentation Prepared For:

- Collect Ash Samples prior to conversion to confirm range of particle specific gravity and density
- Conduct Lab Testing to confirm optimal pickup velocity and associated capacities
- Design Pneumatic System to have fewest changes in direction and most efficient routing
- Select appropriate fittings and wear sections for the pneumatic conveying system (materials of construction, etc.)
- Consider VFDs on Mechanical (Vacuum) Exhausters if particle testing has high variability in specific gravity/density
- Adjust Mechanical Exhauster settings to optimize velocities after confirming actual conveying conditions

Questions ?


THANK
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