

REINHOLD ENVIRONMENTAL®



2025 Reinhold/PCUG Round Table Presentation

Hosted by AEP and Buckeye Power

in The Hilton Columbus Polaris Hotel, Columbus, OH

on June 23-24, 2025

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HYDRATED LIME DRY SORBENT INJECTION

War Stories and Case Studies

Curt Biehn, Business Director
Workshop 24 - Reinhold Conference Round Table
June 24, 2025



Safety - Clearing Hydrated Lime Line Plugs



KNOWN RISK FOR SEVERE EYE INJURIES

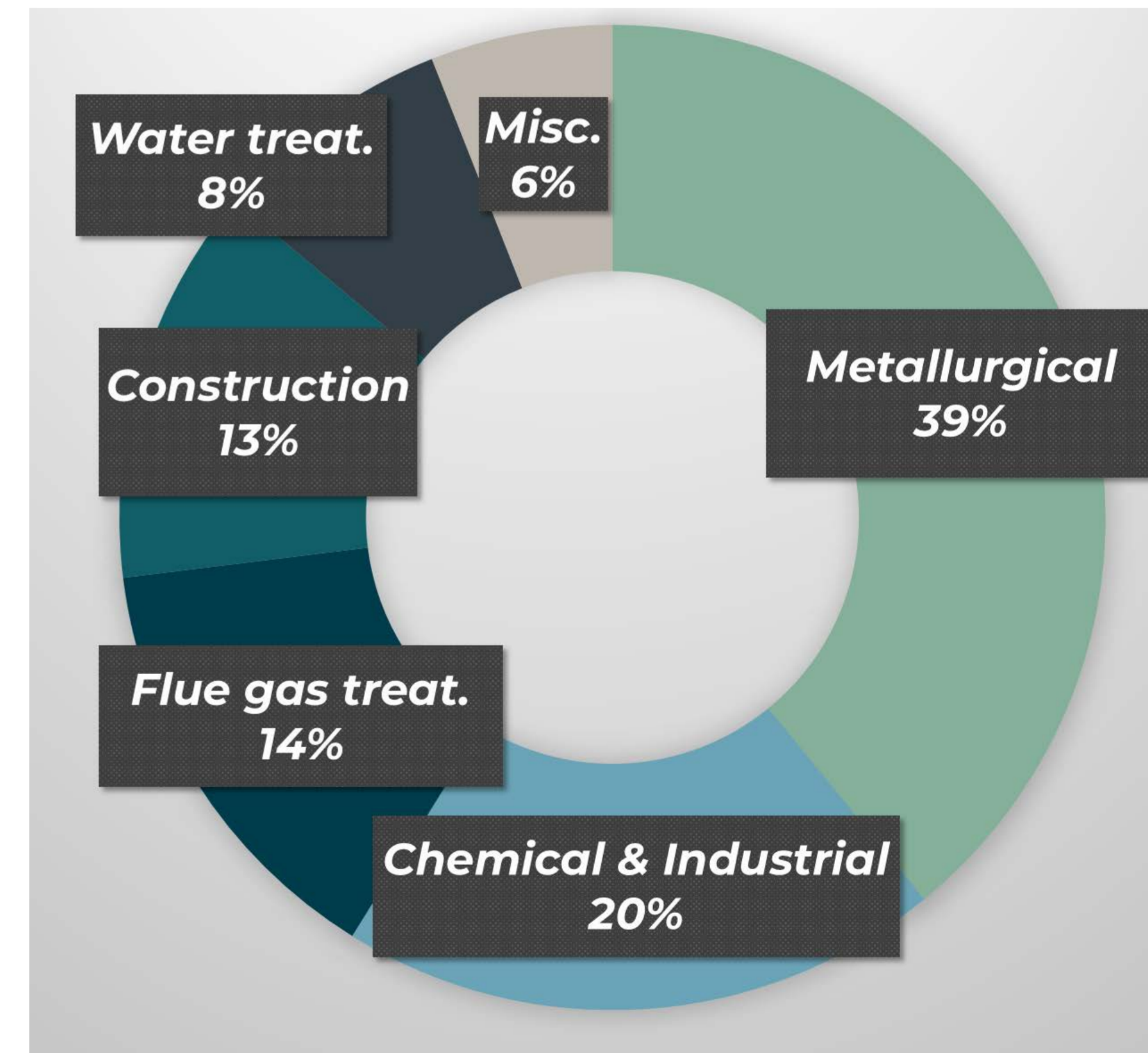
- **Wear the proper PPE**
 - Protect your **face and eyes**. Goggles, dust mask, and face shield should be worn
 - Consider the **buddy system** –if overcome by exposure; one may need assistance
- **Eliminate any pressure** in line before attempting to break the line
 - Position yourself to be protected in event of **unexpected discharge**
 - When breaking seal, **act as if the line is pressurized**

USGS Annual Survey of Lime Production



- Steel is leading market for lime
- Top five lime producers ~80% of US volume
- Annual production of ~17M tons
 - AL, MO, OH, and TX are major centers of lime production
- Current demand drivers
 - Construction
 - Data centers
 - Warehouses
 - Infrastructure
 - Renewable-based
 - EV battery minerals

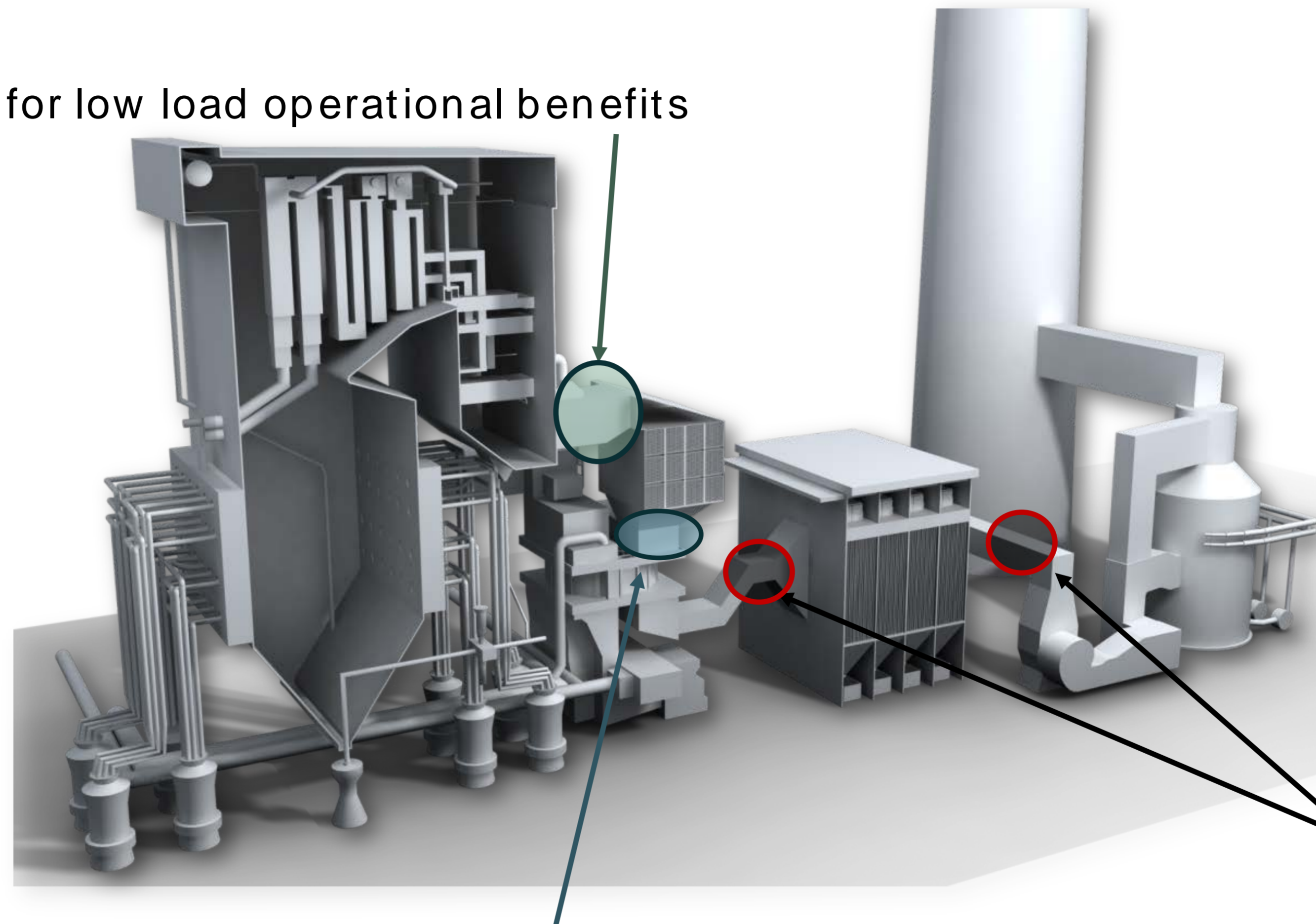
U.S. HiCal Lime Markets 2023



Dry Sorbent Injection Using Hydrated Lime



Pre-SCR injection for low load operational benefits



Post-APH injection to meet regulatory requirements

Pre-APH injection for APH cleanliness and other operational benefits

DSI Conveying System Components



Feed Bin



Convey Air



Feeder



Convey Pipe



Splitter



Injection



Also used: dehumidifier, chiller/air-air heat exchanger, in-duct mixing devices, high dispersion lance tips

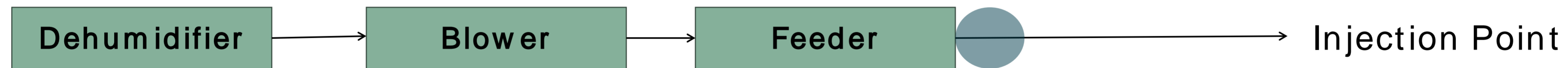
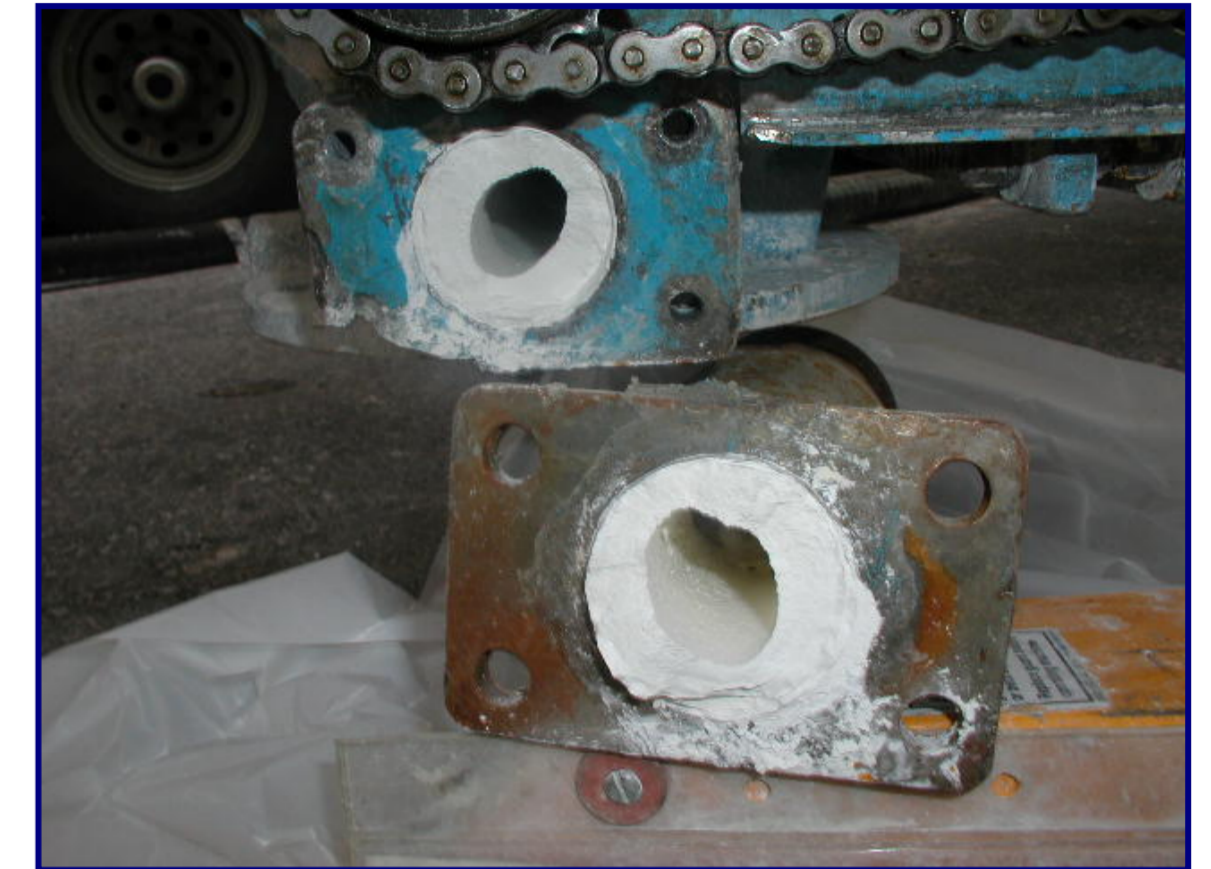
War Story – Carbonation Scale at Rotary Feeder



Utility experienced severe scaling just downstream of the hydrated lime rotary feeder drop off point.

Issue is close to rotary airlock and not evident downstream.

Scale built over time, increased line pressure, and required downtime to clean.



What factors need controlled to reduce scaling?

TVA Widows Creek Resolution: Optimize Air Flow and Temperature



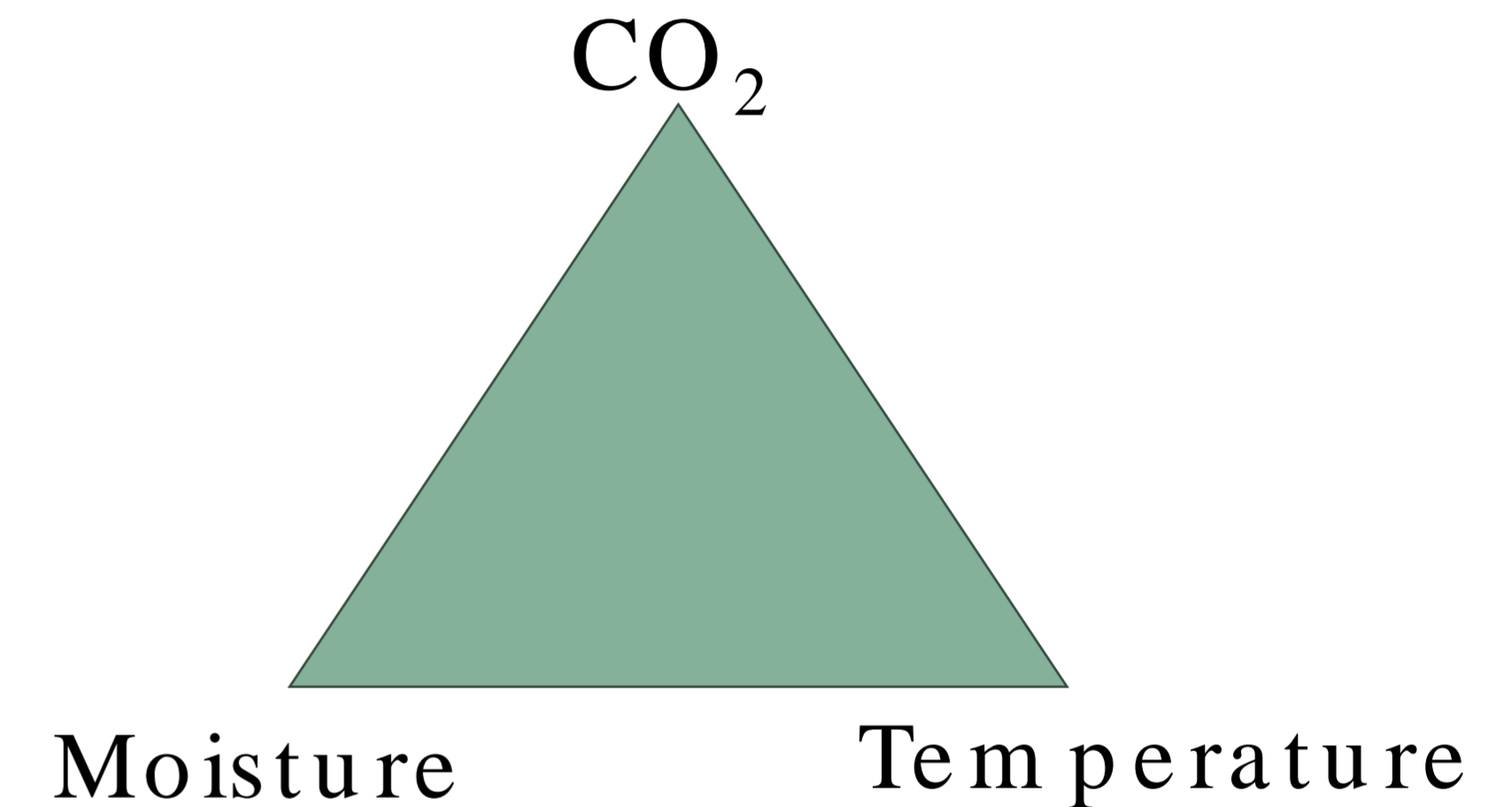
M. Wilson and B. Williams, TVA, 2007

Minimize deposits using controlled air flow without the need to dehumidify

Conveying System Issues – Deposit in Piping



- Hard Scale (calcium carbonate)
 - Short term formation – convey air effects
 - Quality
 - Quantity
 - Long term formation
 - Minimize physical ‘hot spots’
 - Unions and elbows
- Soft scale (hydrated lime powder)
 - Saltation velocity ~2,400 ft/min
 - Target 3,300-4,000 ft/min to keep hydrate suspended



Scale formation is observed generally in Dry Sorbent Injection systems and usually not an issue in Circulating Dry Scrubbers



MLC™

AN HBM COMPANY

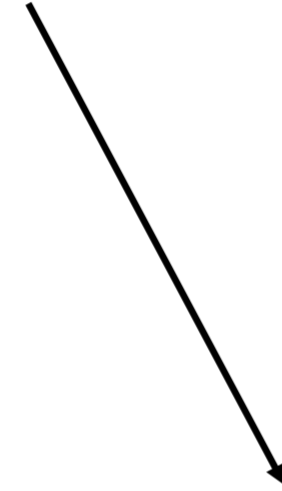
Extended Run on MLC Test System - Remove CO₂



Runs A & B

Ambient air

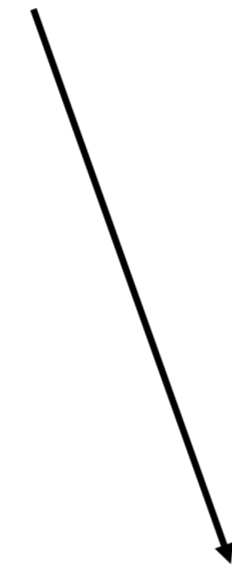
~400ppm CO₂



Run C

Passive scrubbing

~150ppm CO₂



Run D

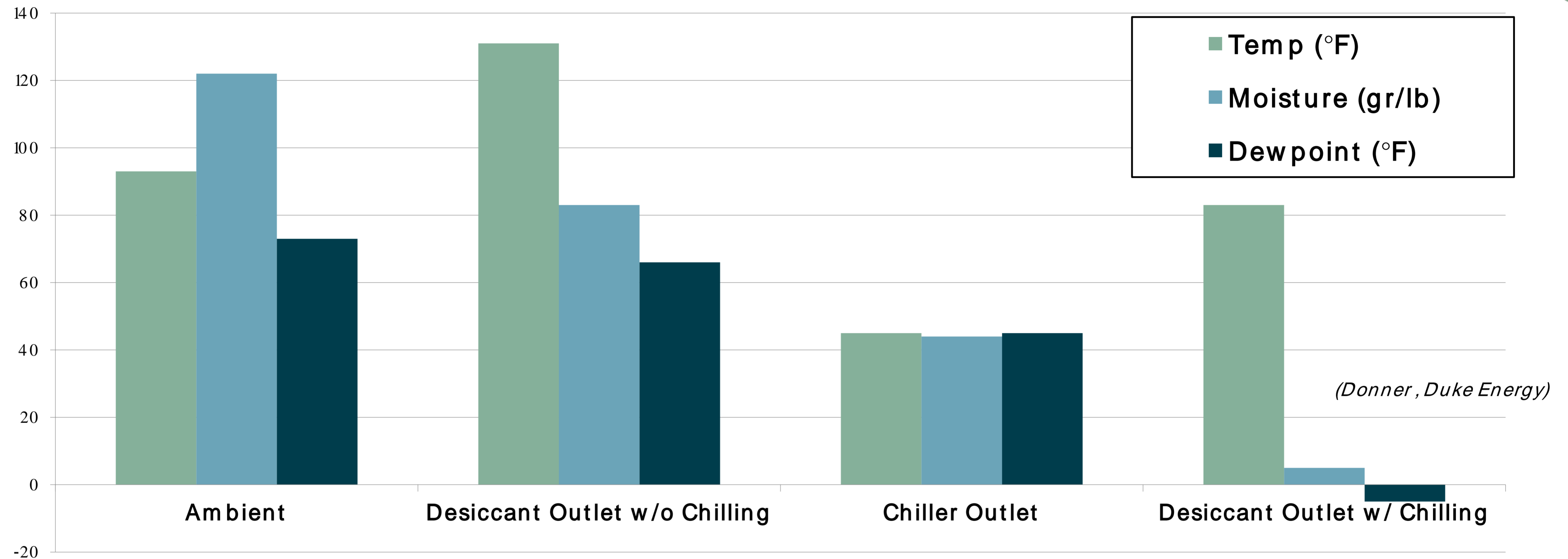
Active scrubbing, <50ppm CO₂

Shallow Pocket Drop Thru Rotary

Heat exchanger



Conveying Air Quality – Control Temp and Moisture



Pre-chill + desiccant dryer: very effective moisture removal

- Dewpoints near dry compressed air quality
- Greatly reduced possibility of “Condensation Event”

Case Study 2 – Hydrate Deposits Downstream of Splitter

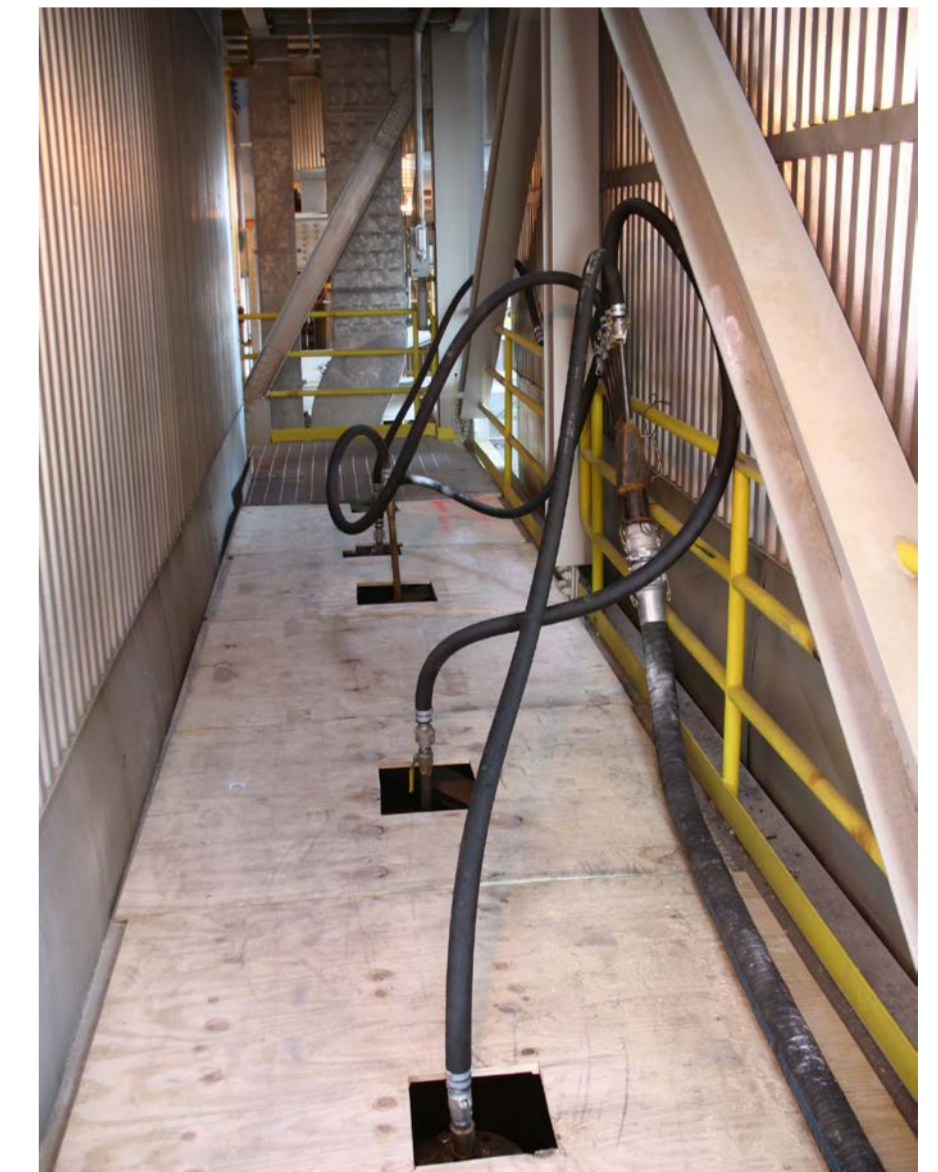


A poor technical sales engineer from a lime company is trying to run a DSI demonstration using a rented horizontal trailer with four rotary feeders. As the trial progresses, he becomes repeatedly plagued by dry powder plugs in the lances downstream of this splitter. The plugs cause issue with inconsistent SO_3 removal and require stopping feed to unplug. Injection point was under vacuum.

Reasons for the dry powder plugs?



(Instructor's note: duplicating this set up is not recommended!)



Upon completion of the trial, the contractor said he 'needed to replace a couple of rotaries' because the system was in service for iron prior to use at our hydrate trial. The feeders were worn and housing scored.

Beware of Conveying Air “Leaks”



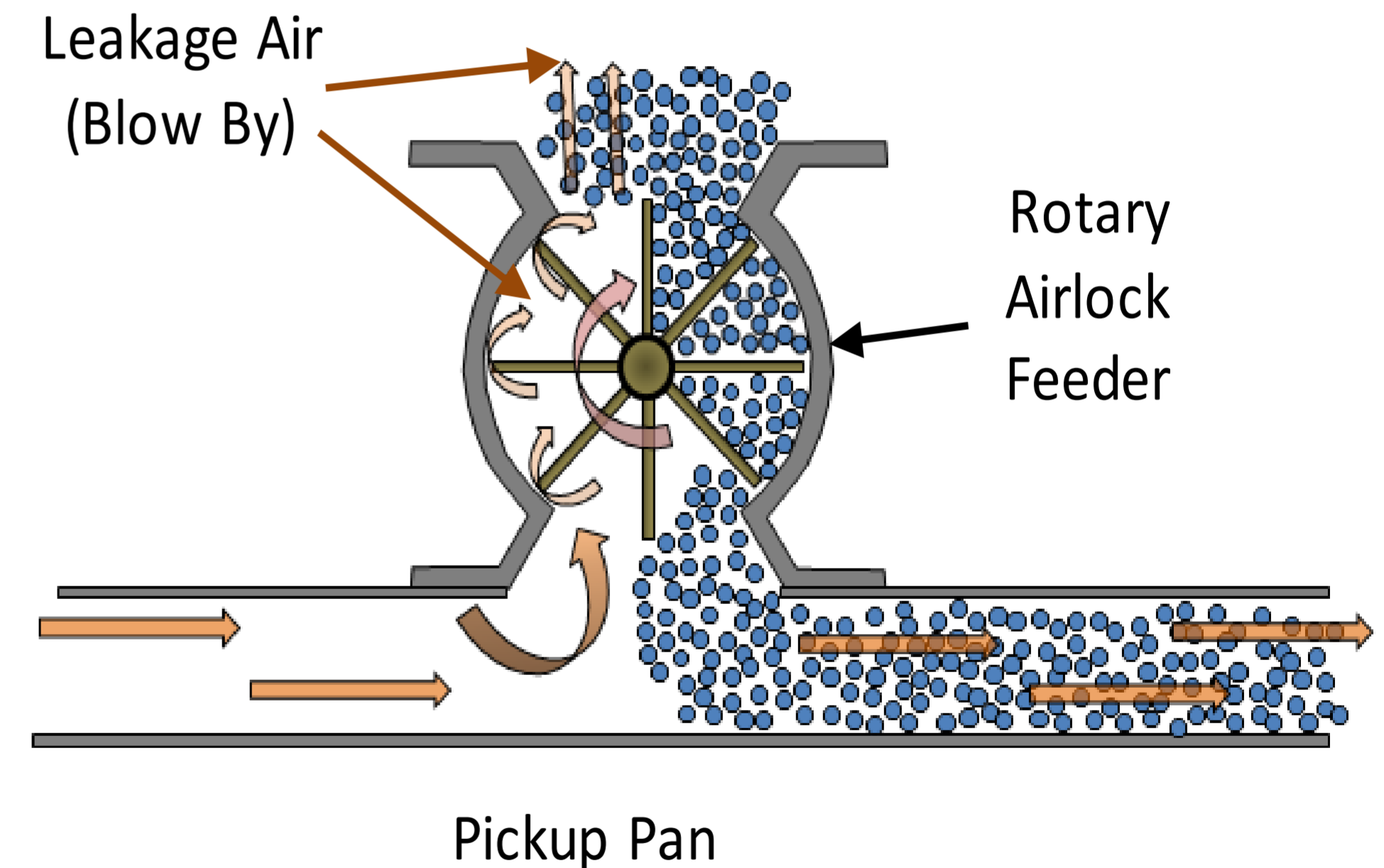
Valve body and rotor vanes develop wear from abrasive and/or erosive effects over time

Result: Reduction in conveying air velocity

- Product deposits in conveying line
- Gradual increase in conveying air pressure
- Periodic spikes in conveying pressure

Target conveying rate is 3300 – 4900 ft/m in

- Above saltation velocity for hydrate
- Avoids excessive air that could lead to carbonate scale formation



Case Study 3 – Identifying Benefits of High Reactivity Hydrate



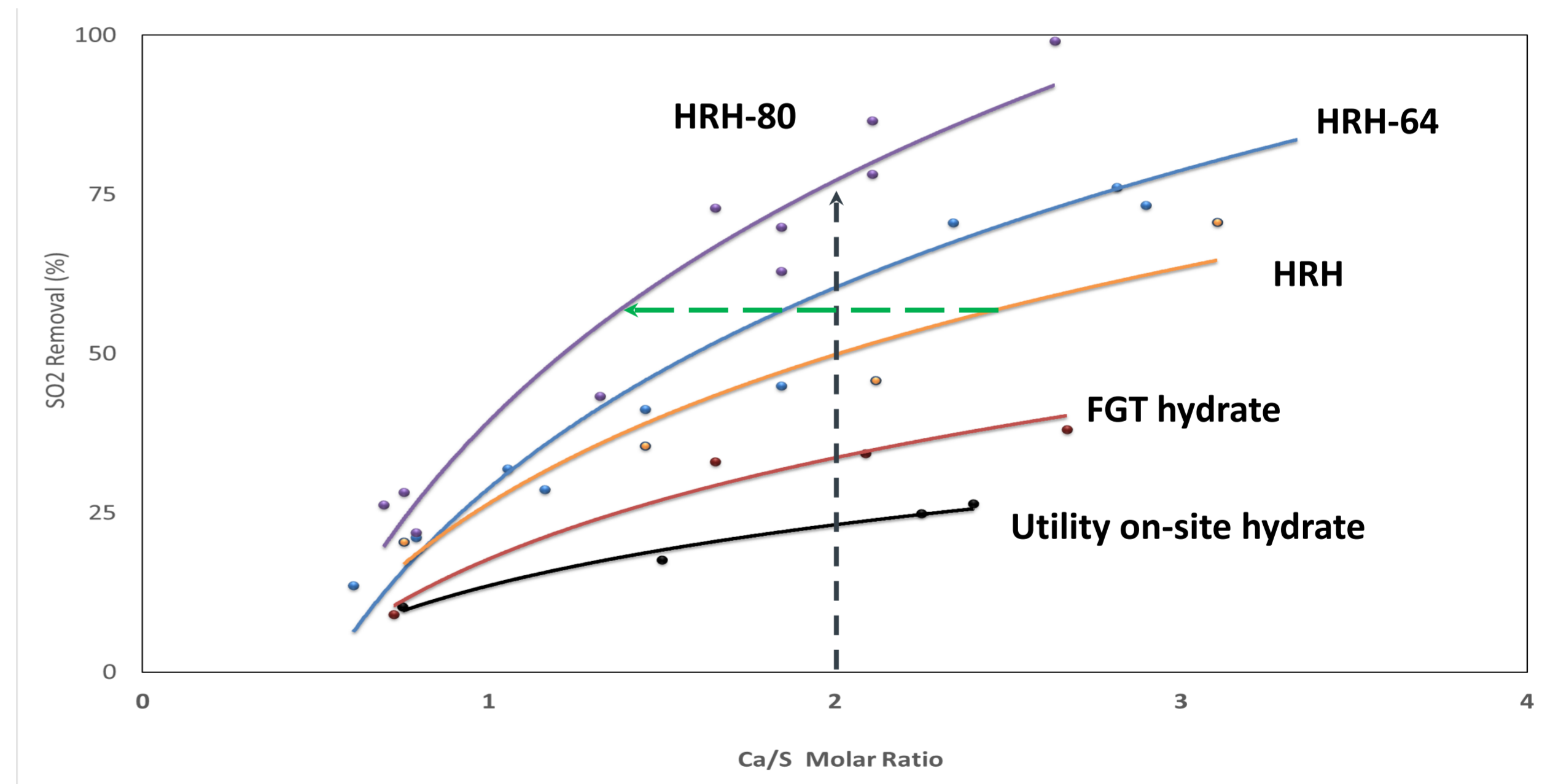
Where you capture pollutants can be more important than how you capture them. Slower reacting or slower to disperse hydrated limes can present usage penalties or limit benefits

Pilot Scale Comparison of In-Flight Capture of SO₂ by MLC High Reactivity Hydrated Limes

Note that this chart is for SO₂ removal; curves will be different for SO₃ and HCl

Considerations

- Residence time
- Reaction window



Higher performance at equivalent feed

Reduced usage for equivalent removal rate

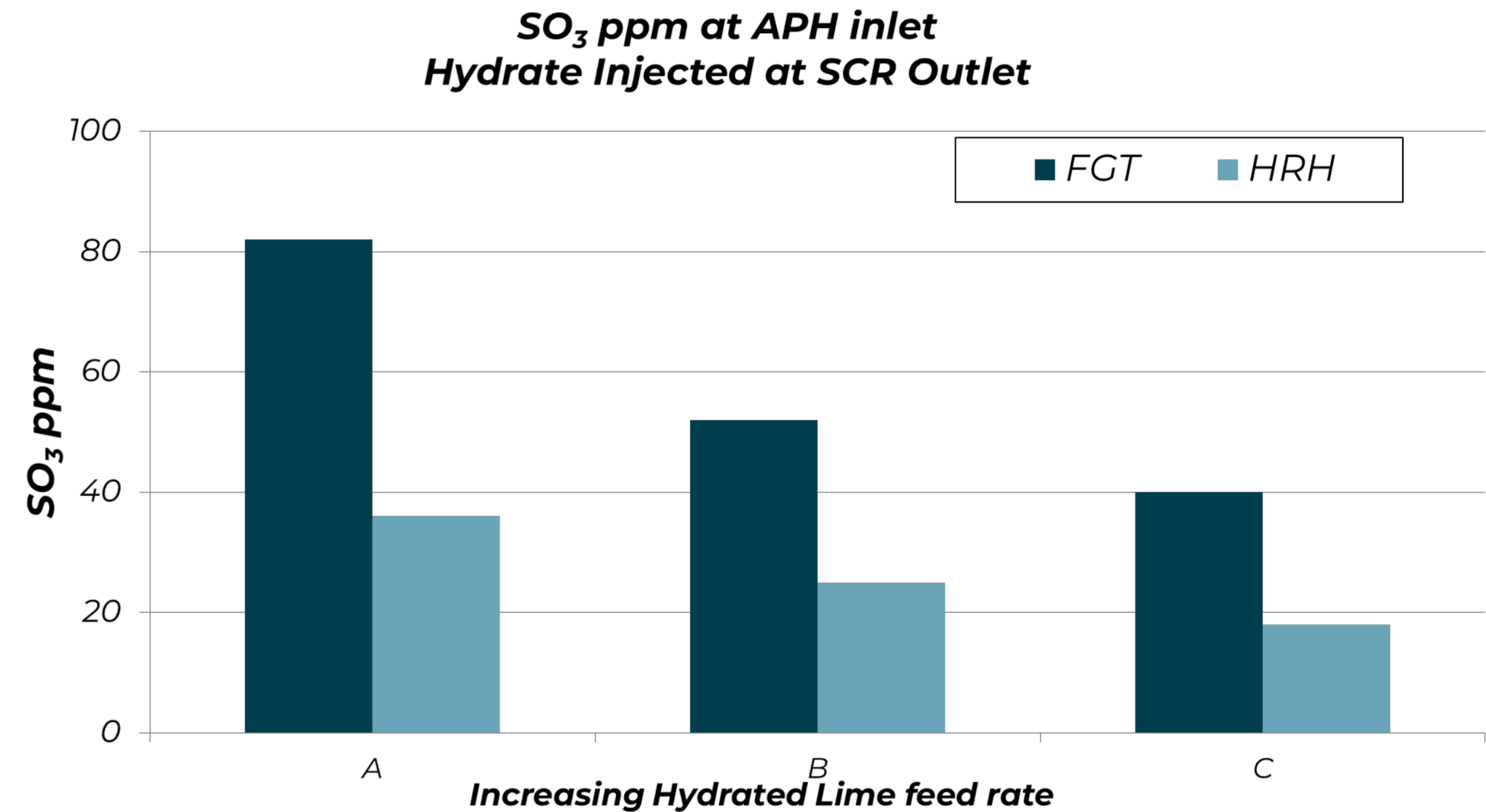
HRH Works Better in a Tight Reaction Window



Utility desired high SO_3 capture at Air Preheater inlet so they evaluated HRH versus their existing hydrate, FGT (Flue Gas Treatment)

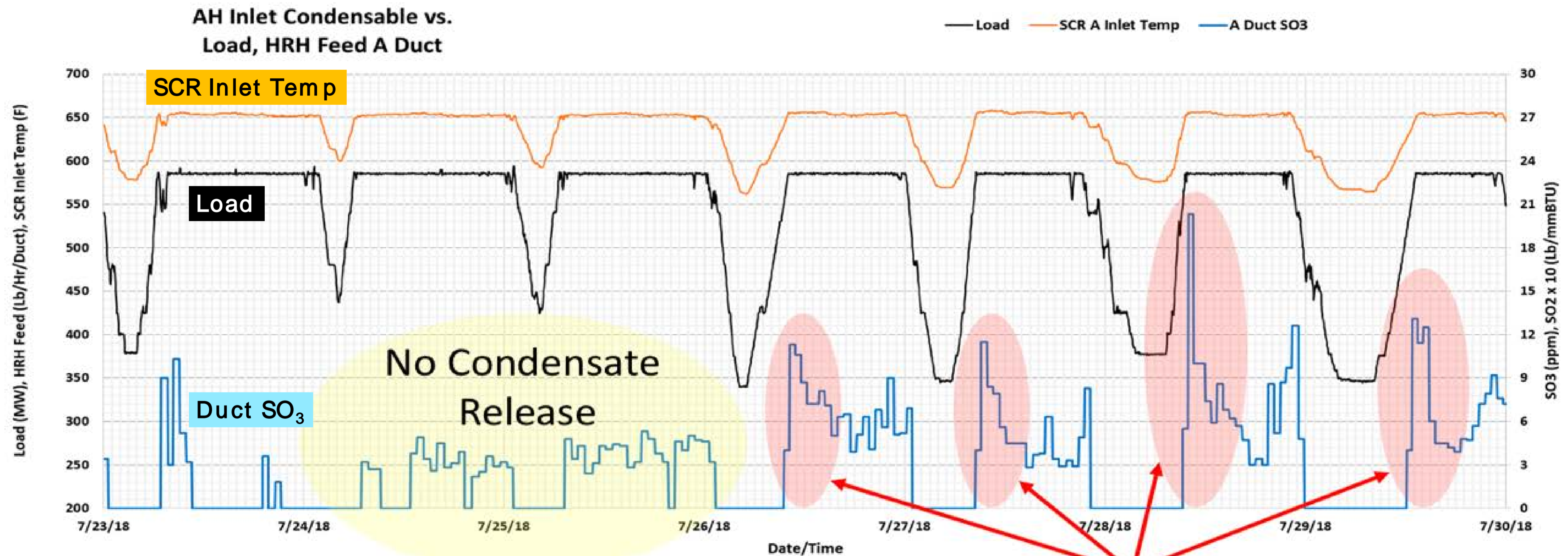
HRH reduced SO_3 significantly compared to FGT hydrate

Customer had confidence the high reactivity sorbent would better prevent APH buildup



Understand the in-flight capture of your hydrated lime

Sidebar – Flue Gas Characteristics During Testing



Not the same plant or test as previous slide

Variable Condensate Release

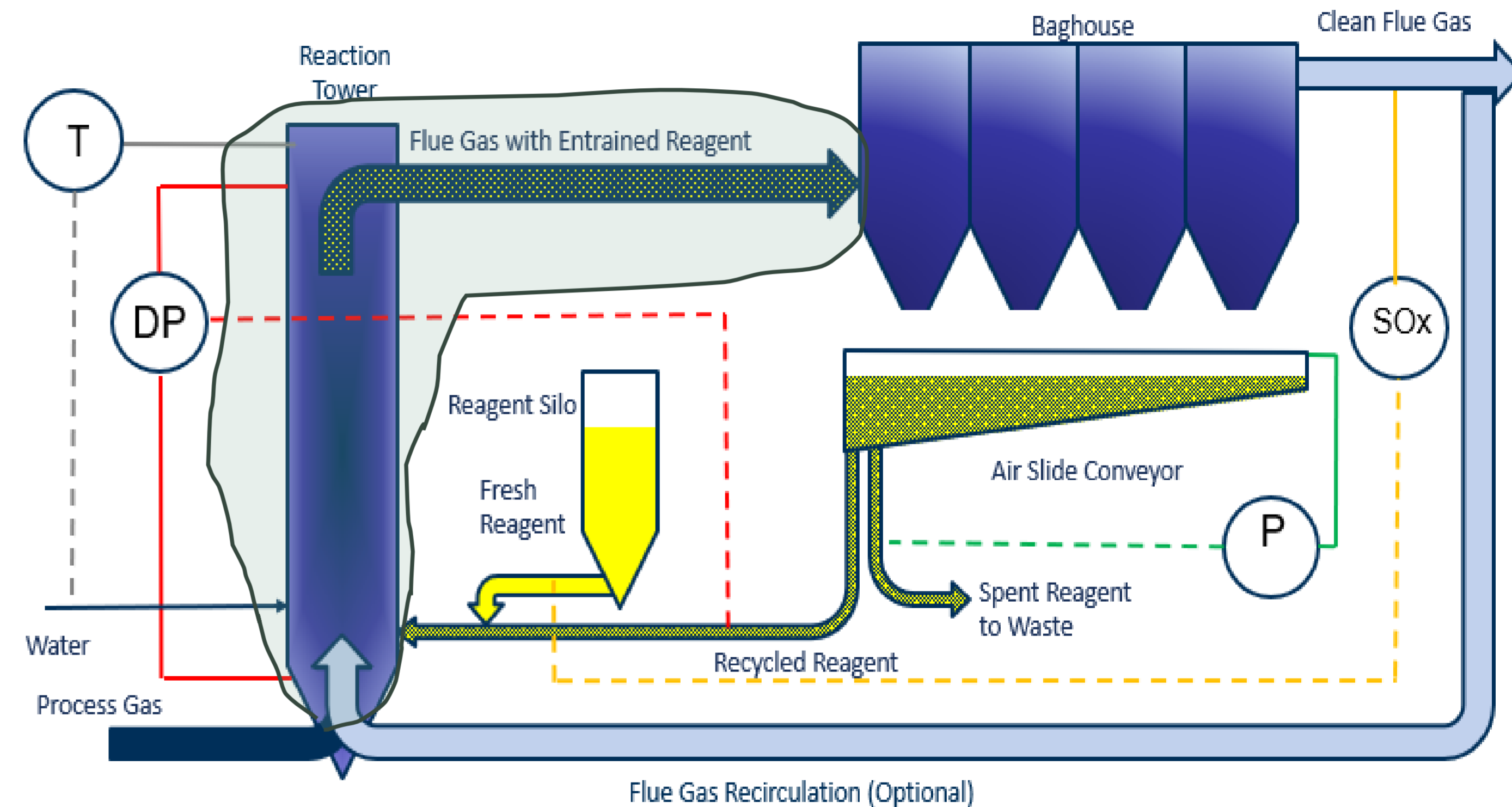
Load ramp can cause condensable acid burn-off
Make sure to account for this when stack testing

More Evidence That In-flight Capture is Key



Circulating Dry Scrubber

- Hydrated lime enters the flue gas typically at post-Air Heater temperatures (< 400 °F)
- Water spray aids in SO₂ capture via wetting of hydrate and temperature reduction

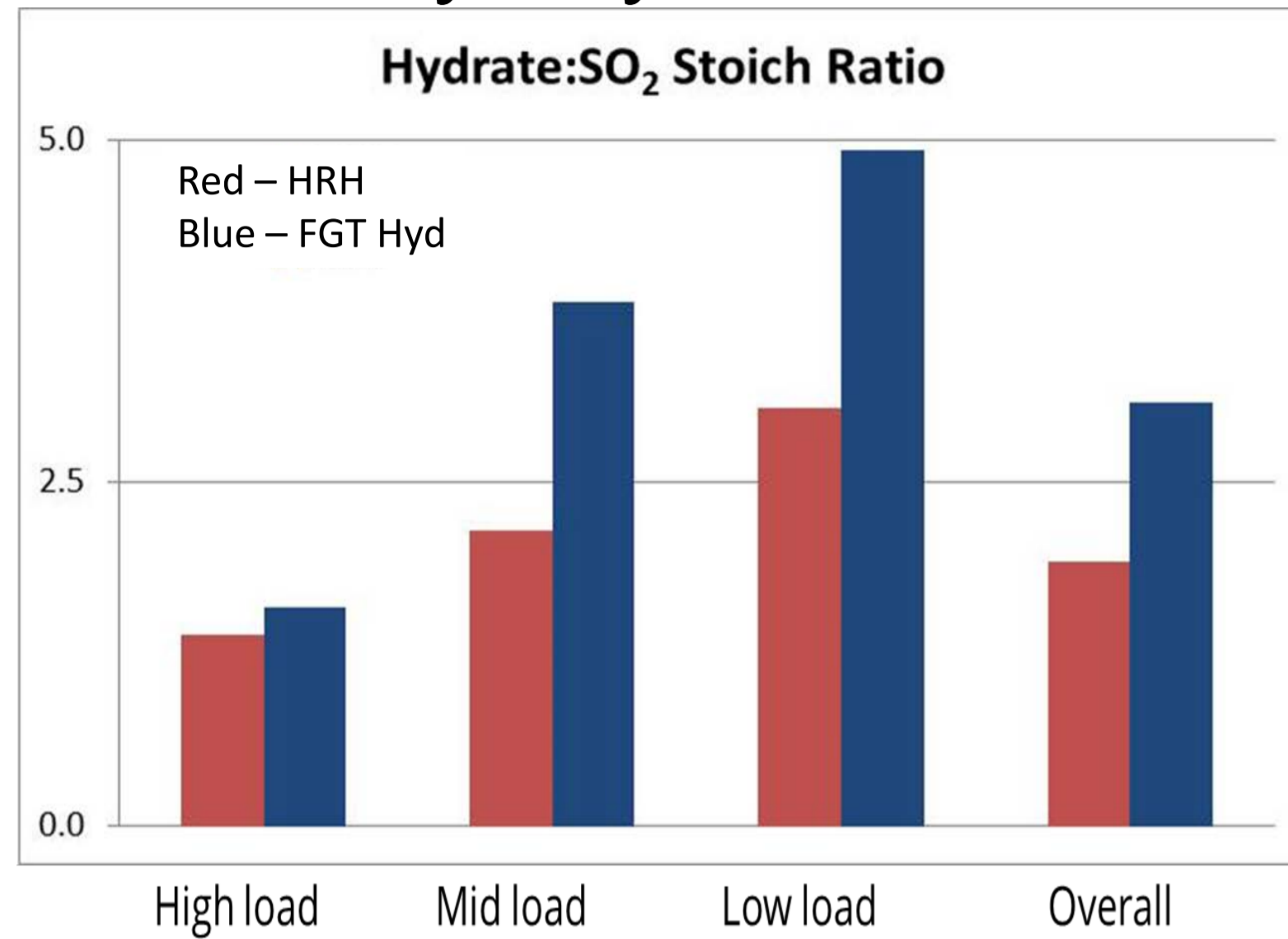


Does reactivity make a difference in an environment where sorbent is recycled?

Reactivity of Fresh Sorbent Does Benefit a CDS



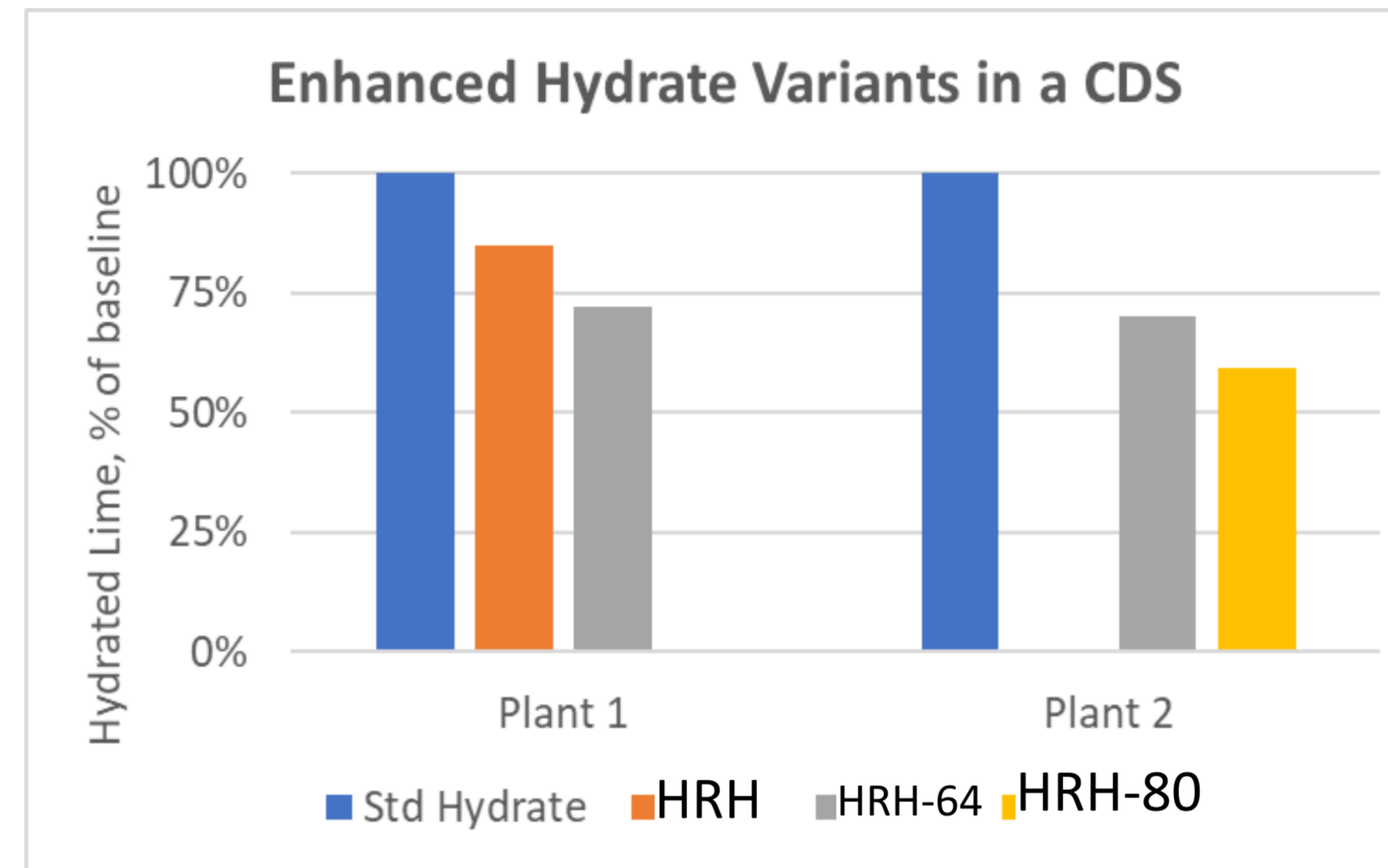
Utility Dry Scrubber



Comparison vs purchased FGT hydrated lime

- Averages over multiple weeks
- 25-30% overall less hydrate with HRH
- Note effects of Load on performance
- Site converted due to significant cost savings and ash disposal benefits
- Continue to use HRH (6+ years)

Industrial CDS



Comparison of hydrate variants

- Multiple evaluations of HRH types
- Significantly less hydrate with upgrades
- Significant ash disposal savings
- Additional operational benefits with improved HRH performance
- Have used HRH products for several years

Industrial CDS

Comparison of HRH vs FGT

- HRH: 10% performance improvement over FGT hydrate
- Site used ~20% less soda ash in furnace -> **additional cost savings**
- HRH allowed CDS to operate at higher SO₂ loading -> **greater ability to manage 'spike' events**
- Site noted reduced ash -> **cost savings**

War Stories: Benefitting from a Reliable Feed System



Several Utility and Industrial DSI systems were established in the 2000's. Both industries leaned toward sodium-based systems (milled and unmilled trona/sodium bicarbonate) for high removal rates of SO_3 or HCl. The advent of enhanced hydrated limes (High Reactivity, high surface area) opened opportunities for more economical acid gas control using a more ash-friendly sorbent.

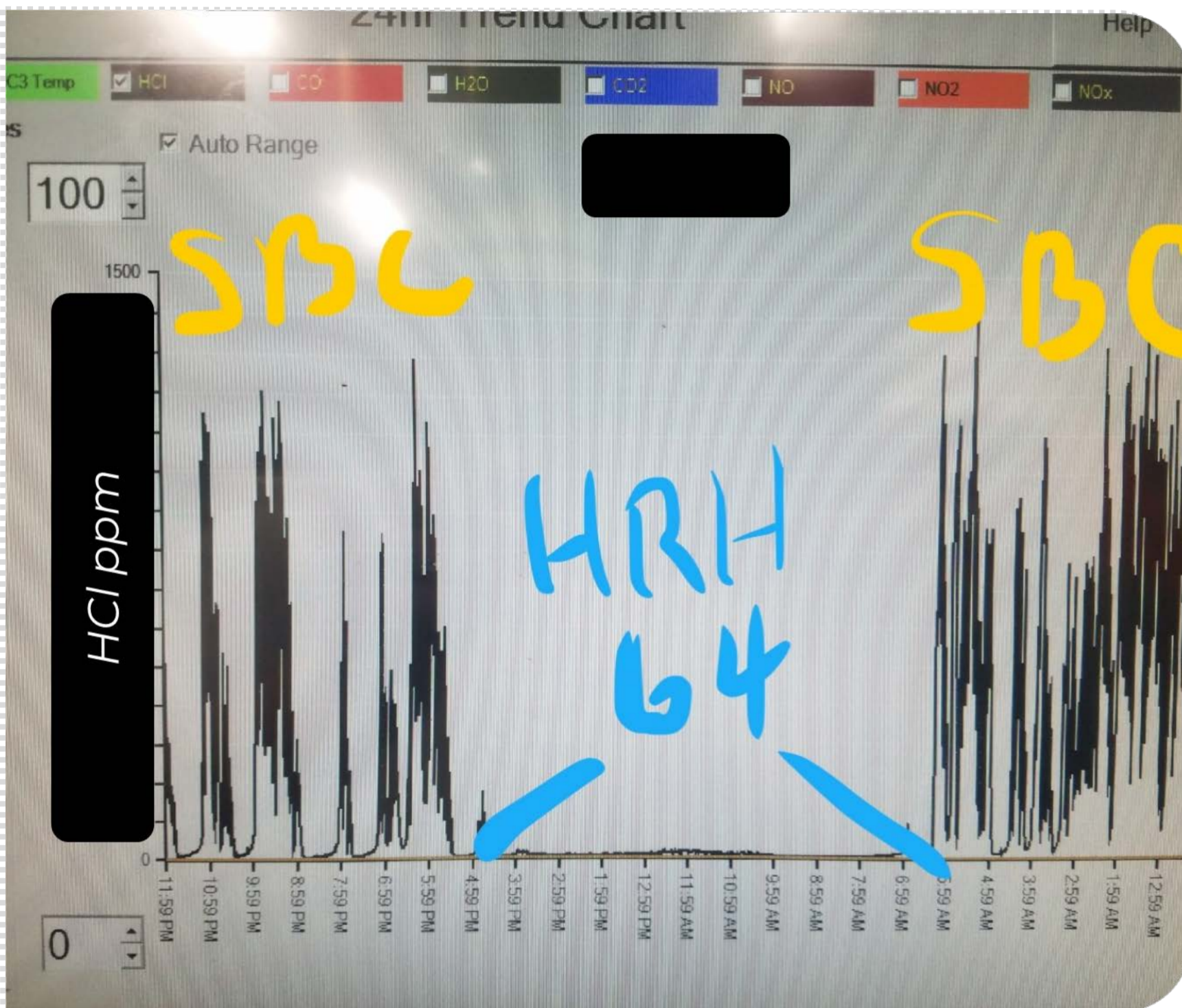
Story 1: An incinerator was using milled bicarb to control HCl emitted in high concentration bursts. The site was interested in lower annual sorbent cost and eliminating a maintenance headache on the mill.

Proposal

- MLC temporary feed system
- HRH-64
 - High Reactivity Hydrated Lime
 - Surface Area 40-45 m^2/g



Incinerator Demonstration Results



Good News:

- Feed system worked great
- HRH-64 performed exceptionally well vs incumbent sorbent

Switching to HRH-64 reduced annual sorbent costs, improved pollutant capture, and eliminated a maintenance headache

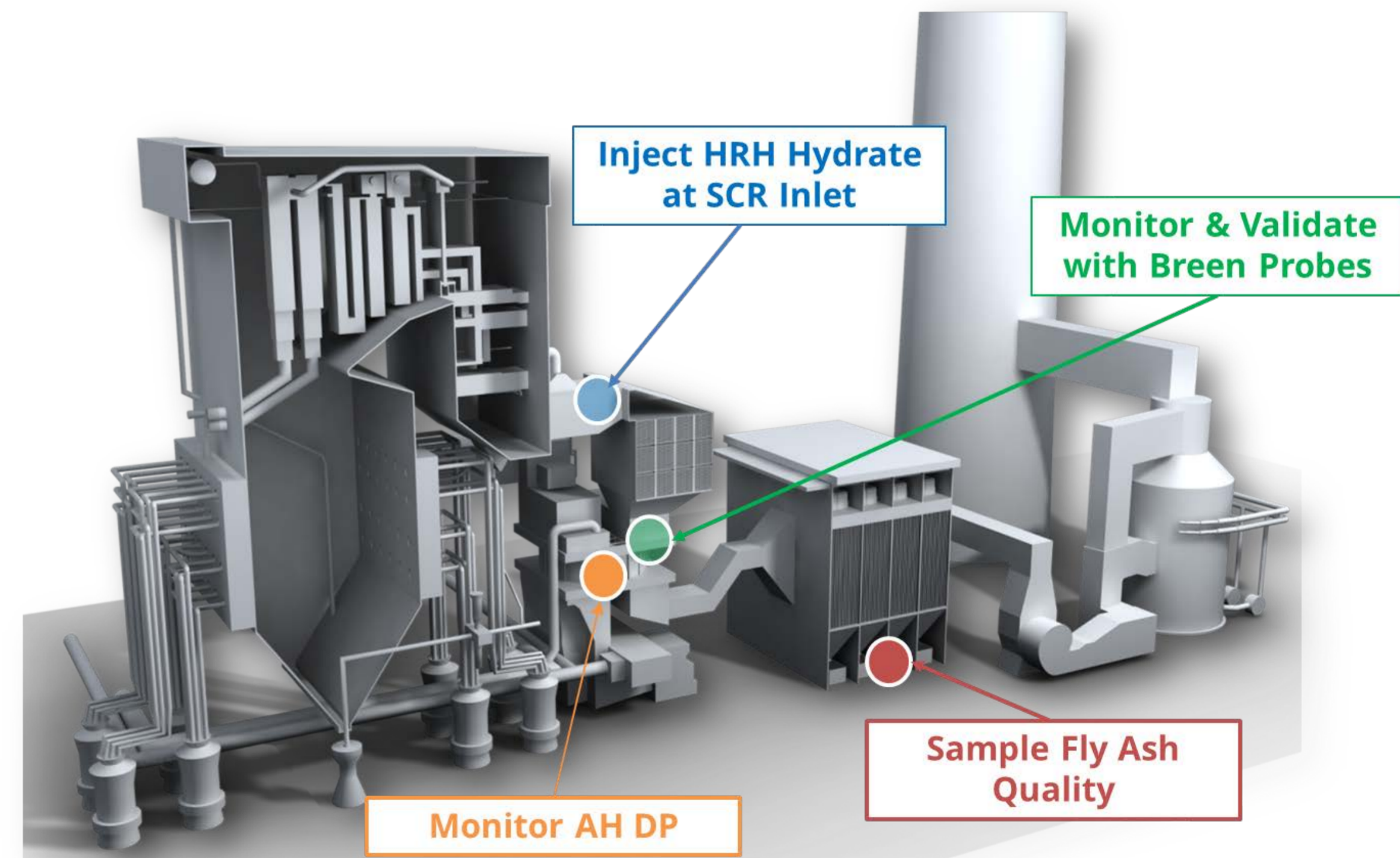
War Stories: Benefitting from a Reliable Feed System



Story 2: A Utility power plant used trona to control SO_3 for many years. Use of trona only provided for environmental benefits, with no ability to control Air Preheater buildup. The site wanted flexibility on injection location, operational benefits, ash sale potential, and a shorter supply chain.

Proposal

- MLC temporary feed system
- High Reactivity Hydrate (HRH) produced in the customer's region
- 30 day demonstration and try to quantify all potential benefits



Utility Demonstration Results



All Good News:

- HRH feed rates Pre-SCR performed equivalent to trona fed post APH
 - SO₃ condensables < 10 ppm at APH inlet
 - Could reach below detectable on Breen probe with 200 lbs/hr more HRH
 - APH bypass dampers closed and on Dp increase in APH
- Sodium in ash < 1.0%
- Site converted to HRH; full scale implementation matched demonstration results

The use of a reliable feed system for demonstrations is imperative to establish performance capabilities of the hydrated lime

War Stories: Benefitting from a Reliable Feed System



Story 3: An Industrial customer uses hydrated lime to control SO_2 emissions needed improved capture to gain fuel flexibility while meeting tighter regulations. They “can’t get there from here” with the existing 2010s-era DSI system; maximum feed rates of HRH still yield SO_2 emissions outside of regulatory



Proposal

- Upgrade to a conical splitter in upward direction
- Add a fourth injection lance



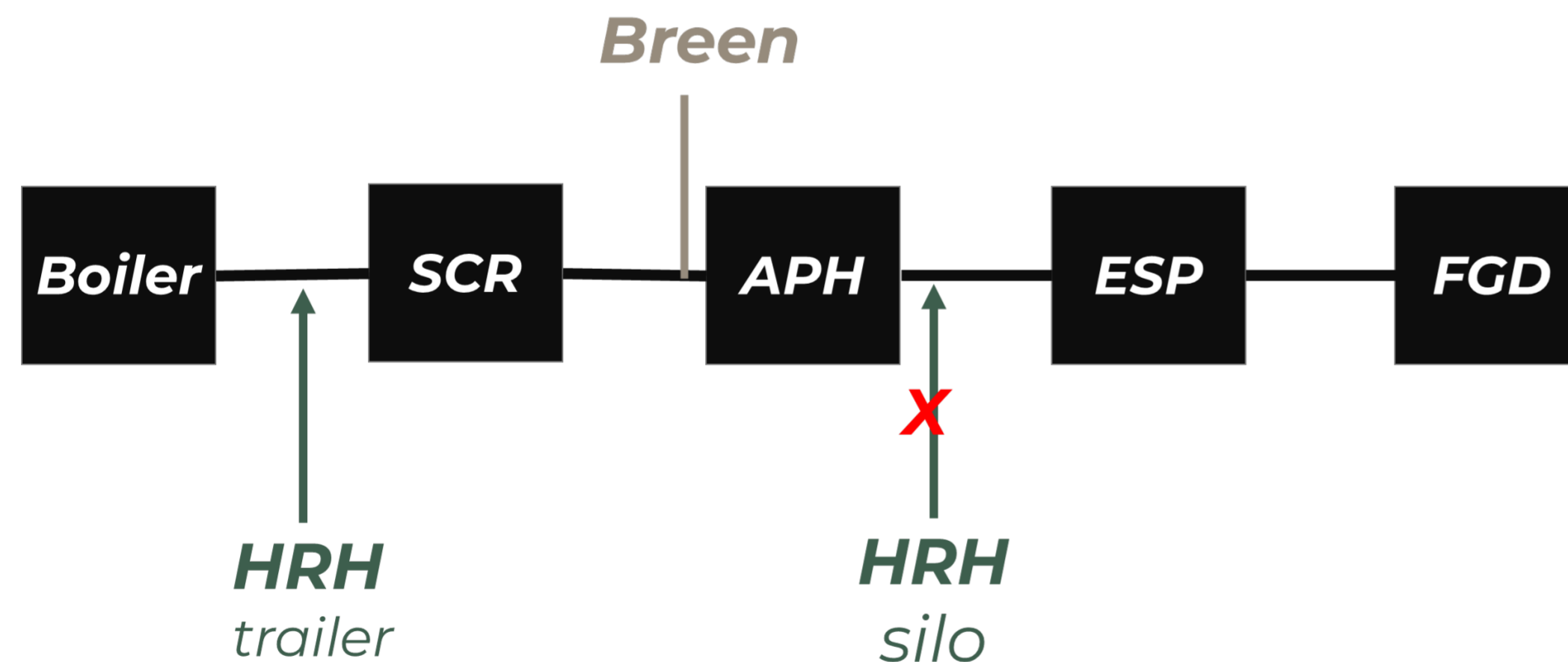
Customer met SO_2 removal target on first day of the test

War Story: Injection Grid and Flue Gas Measurement

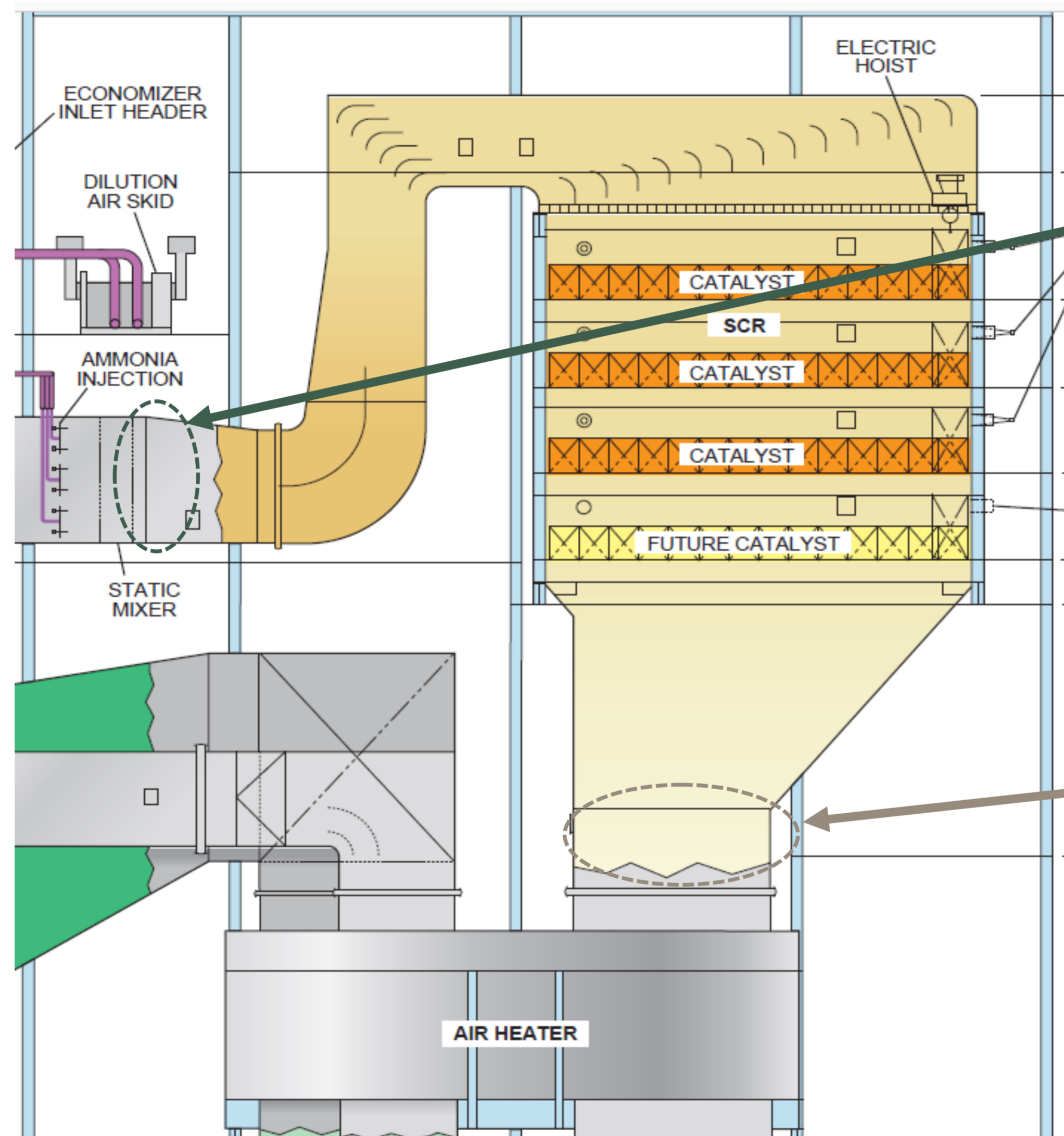


A large plant using high sulfur, high ash coal and tight limits on sulfuric acid emissions wanted to evaluate hydrated lime injection upstream of the APH.

Strategy: Incorporate new injection location upstream of SCR and use temporary equipment for HRH injection. Measure condensables using a Breen probe at the APH inlet.



Changes for the Demonstration

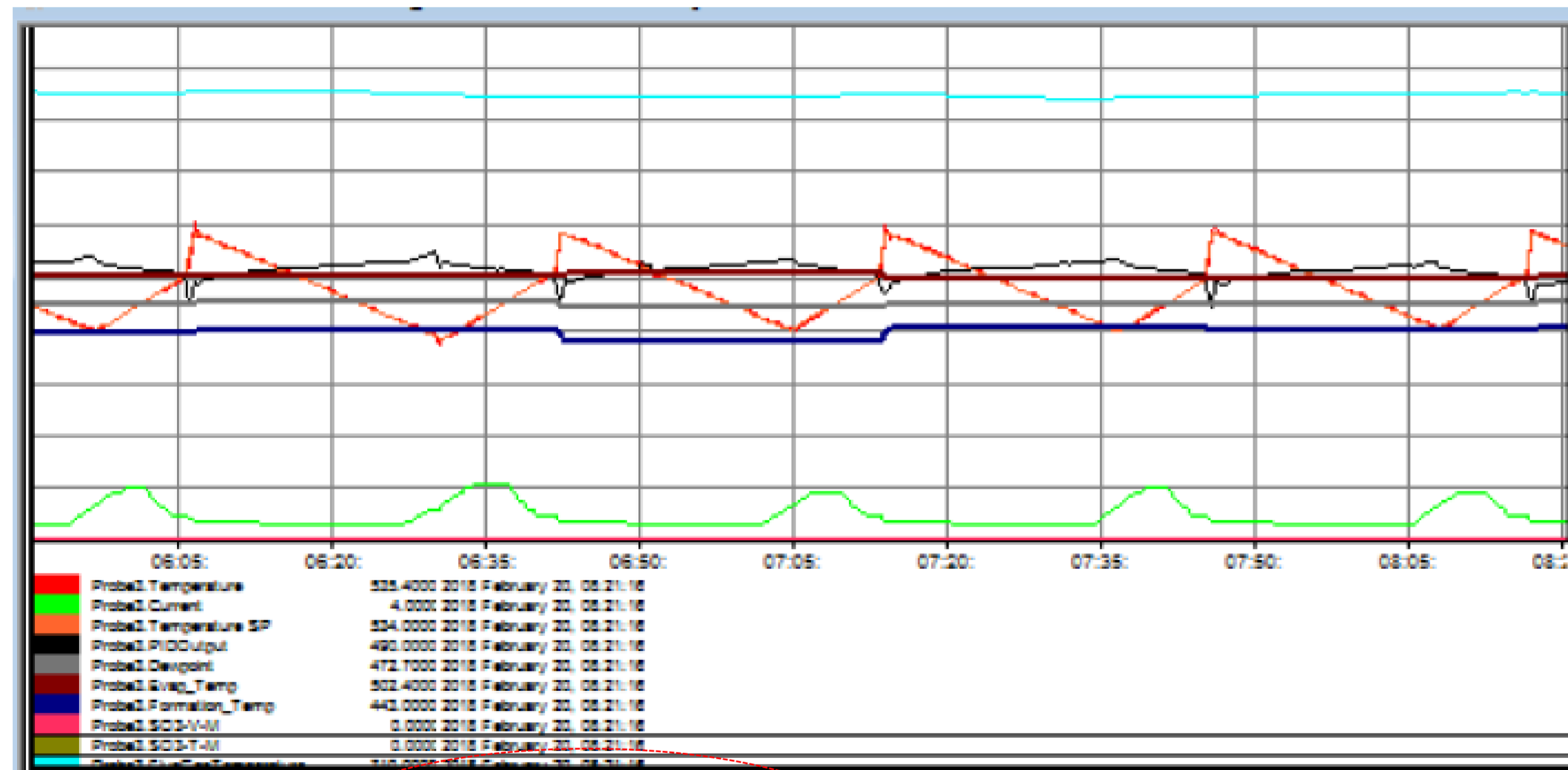
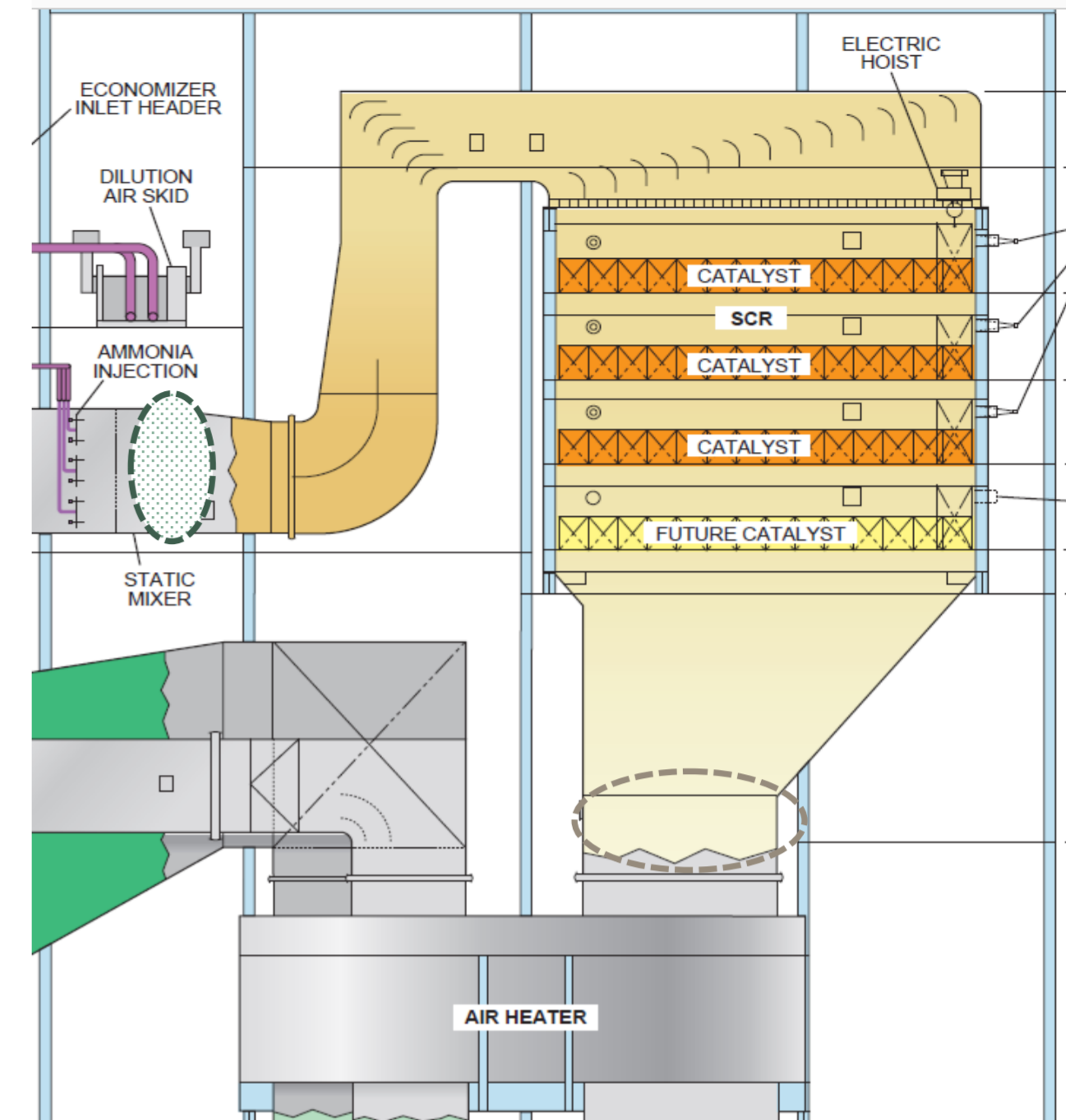


New Injection Location
8 high dispersion lances
Alternating long/short

Breen probe
7 ft long
Chosen by traverse

Losing the Battle Early

Pre-trial estimate of 2000-3000 lb/hr per duct for SO₃ control. 'Maxed out' trailer feed and could not mitigate all SO₃



PC 4 uA
PV 536.3 F
SP 533 F
Out 498

Formation Temp = 443.0 F

Evaporation Temp = 502.4 F
mDewpoint(avg) = 463.2 F
mSO3(Tavg) = 0.00 ppm

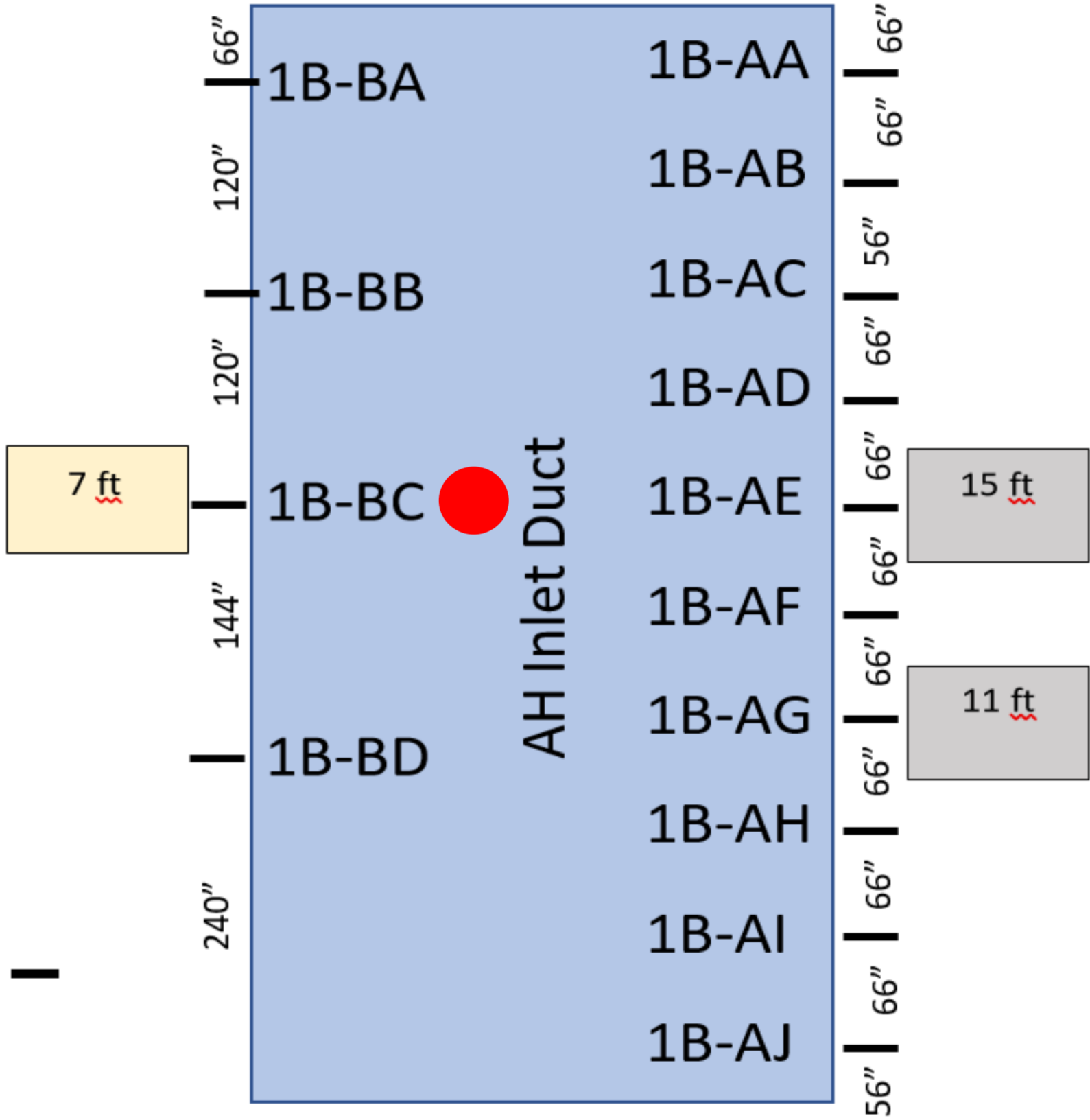
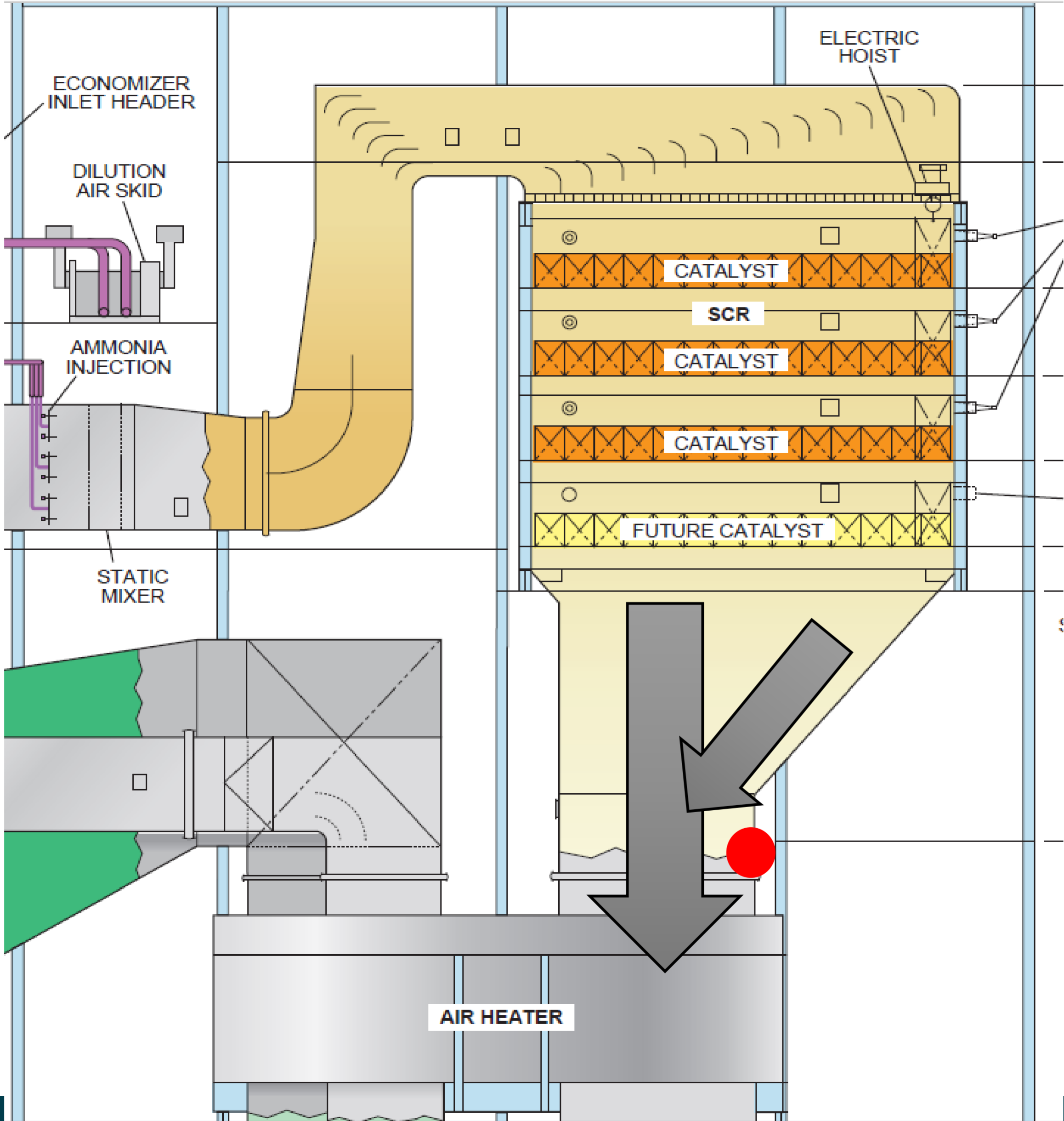
What's our problem?

Suspects



- Feed trailer
- Probe
- Splitter or lance pluggage
- Inherent issues with injecting pre-SCR
- Others?

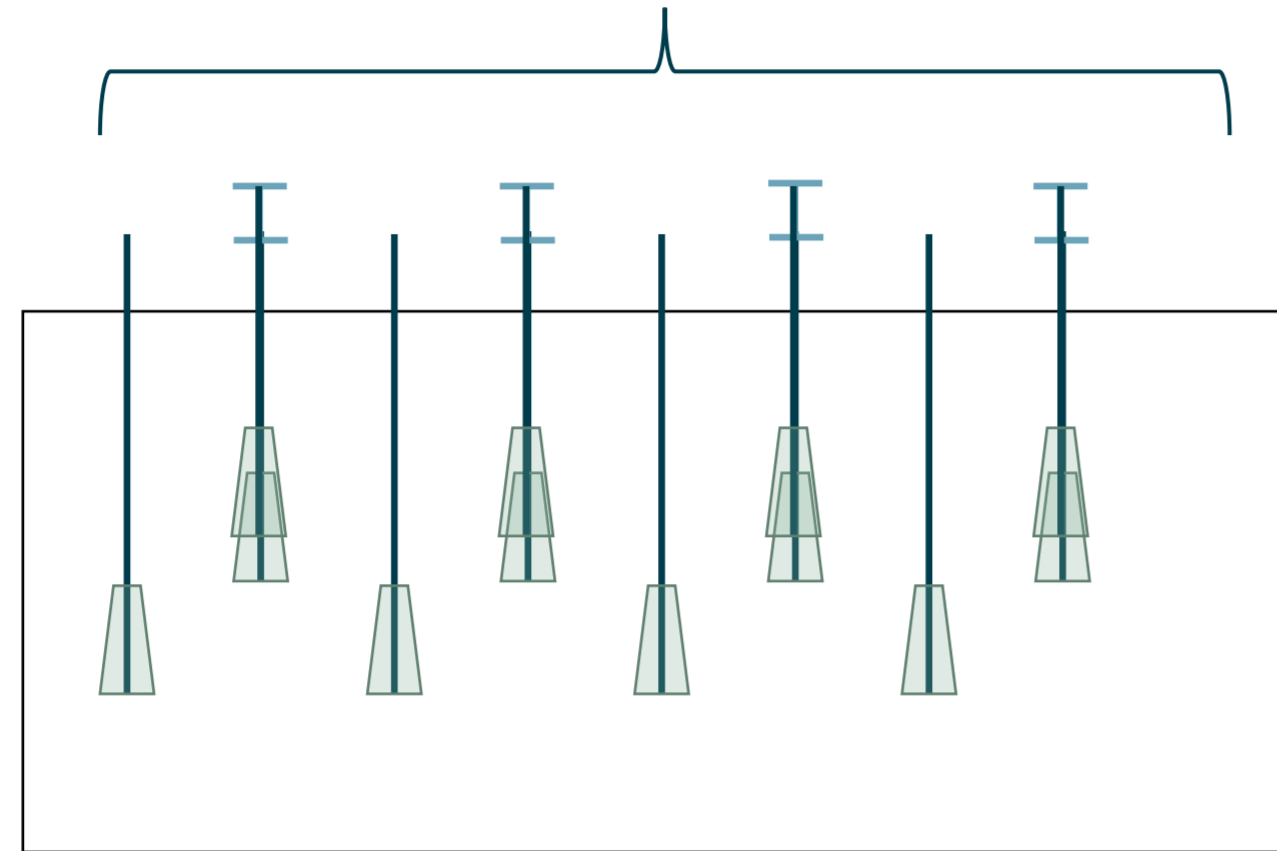
NEED PROBE IN BULK FLUE GAS



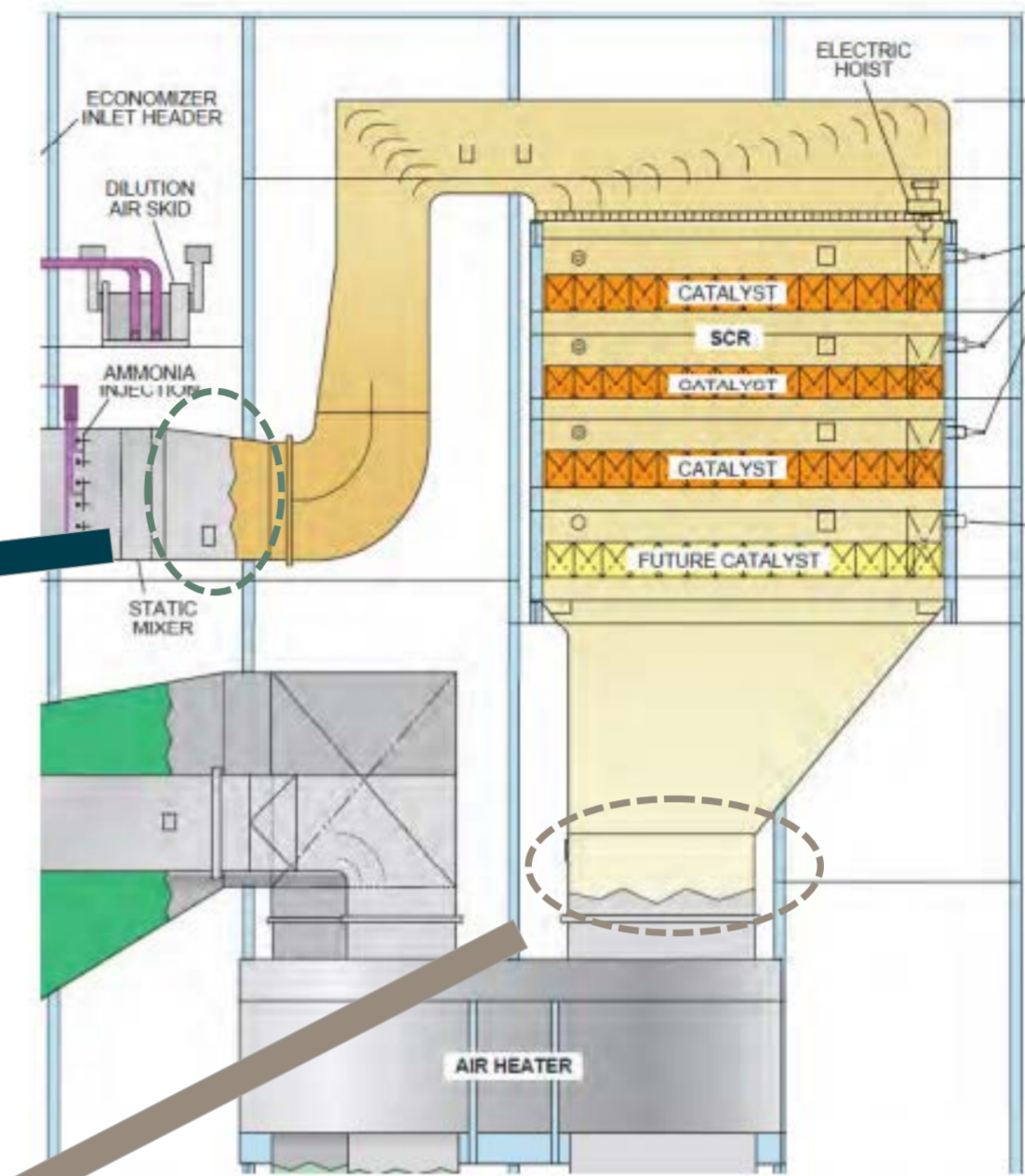
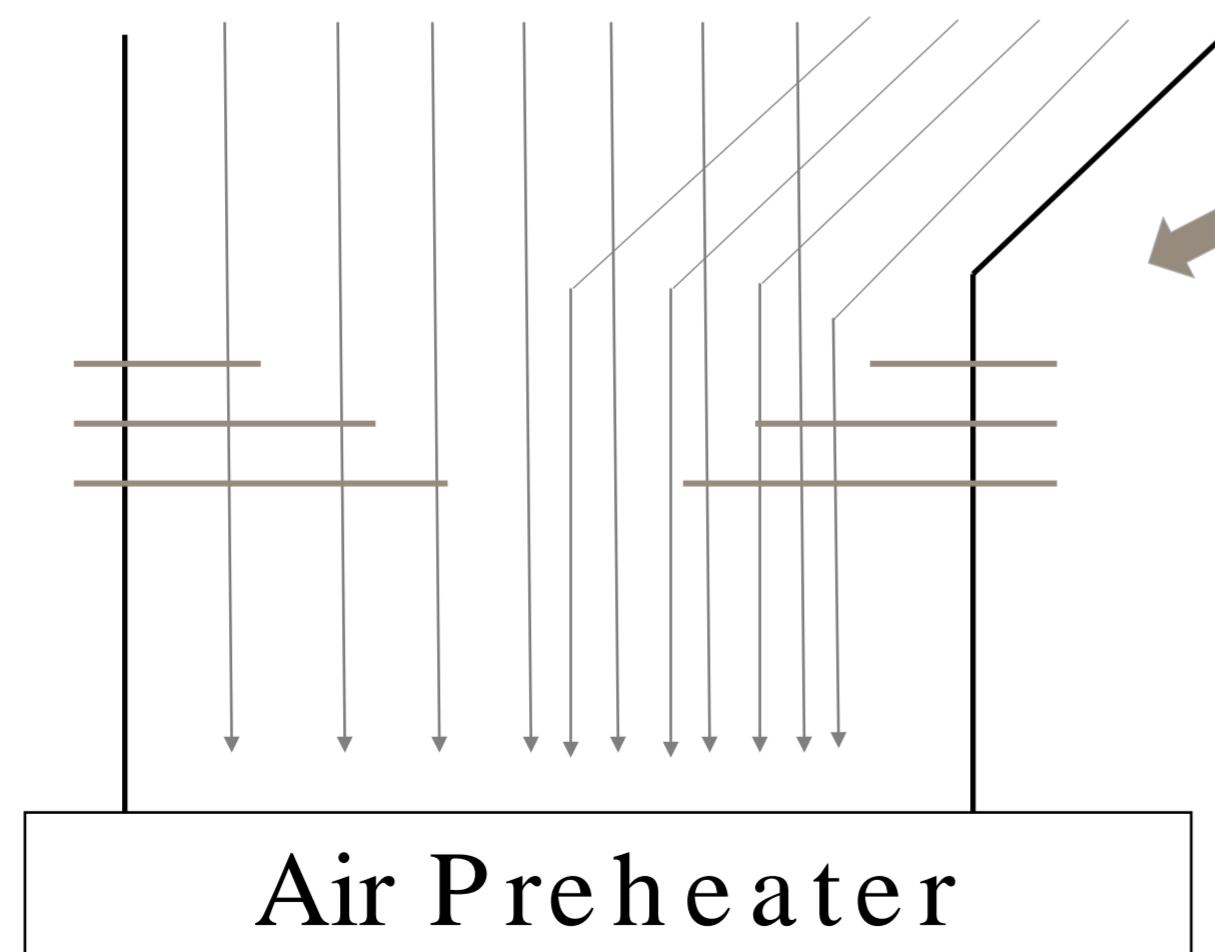
OPTIMIZATION



Hydrate Injection Upstream of the SCR



Modified lance depth based on probe feedback

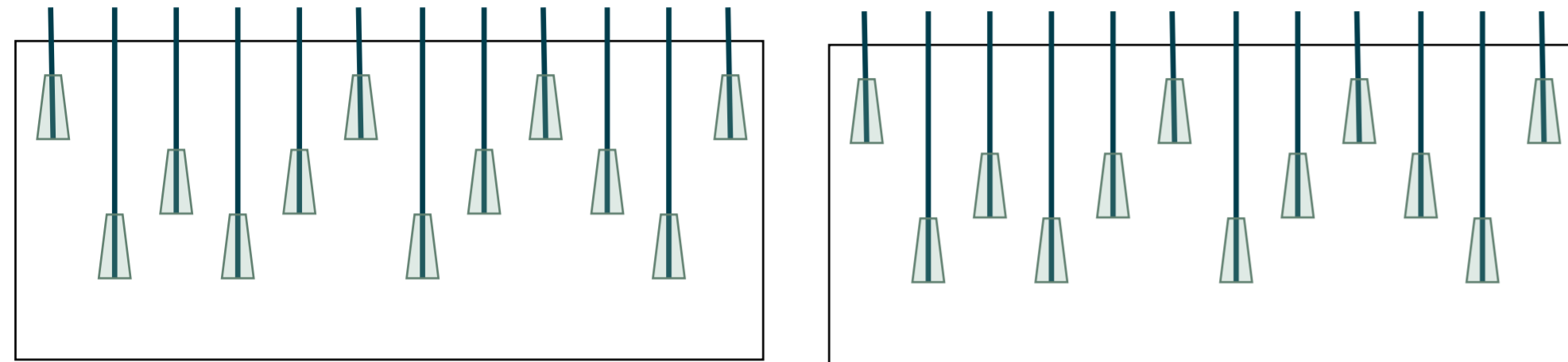


Result:
Successful control of condensables
Optimization of HRH feed rates

Optimization



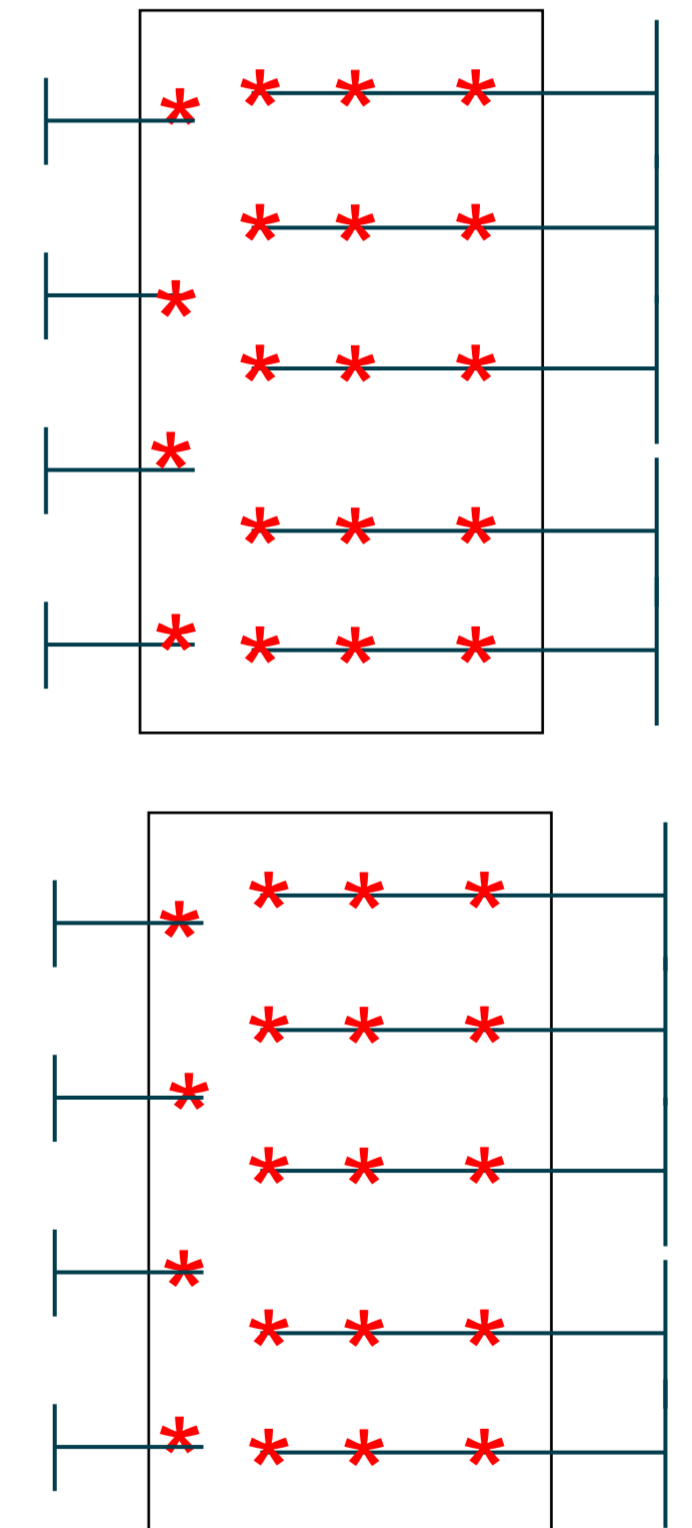
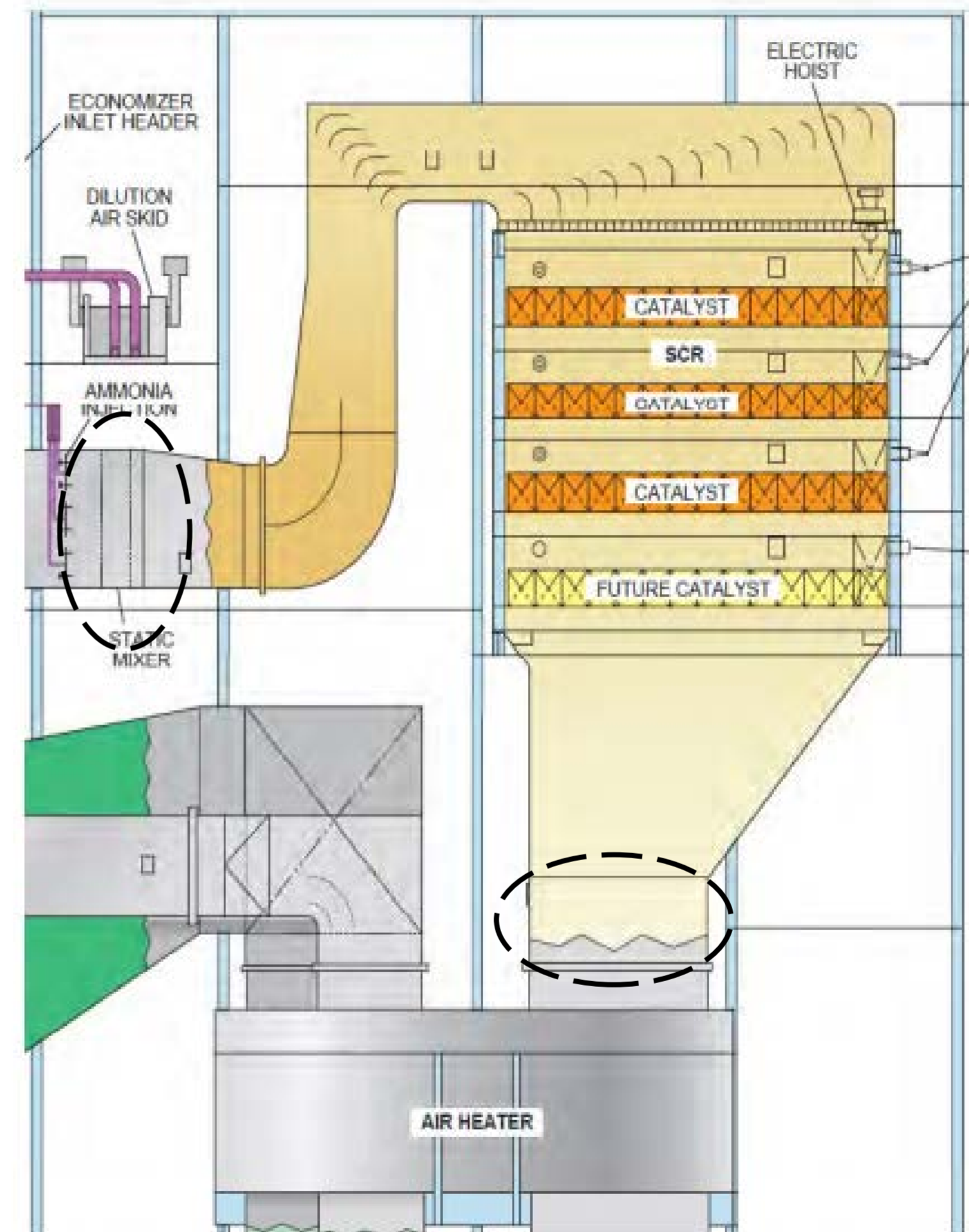
Hydrate Injection Upstream of the SCR



Injection grid configured based upon CFD model

Condensable formation determined through extensive traverse at Air Heater inlet

1. Front and back of duct
2. Four total depths
3. Enhanced hydrate ON and OFF



Traverse – Comparison of EHL OFF vs ON



EHL OFF

Colorized from 240F to 300F in all Groupings

Values shown are condensable formation temperature (°F)
Lower is better; > 260 °F indicates increasing presence of sulfuric acid

A Duct

Hydrate at 0 Hz

	2A-AA	2A-AB	2A-AC	2A-AD	2A-AE	2A-AF	2A-AG	2A-AH	2A-AI	2A-AJ	
Row Avg											
276.4	268	283	277	271	277	274	277	278	280	279	
286.0	277	292	284	275	277	290	288	291	294	292	
309.3	305	310	320	310	305	310	309	308	308	308	
290.5667											

Some bias to South wall on A duct

B Duct

Hydrate at 0 Hz

North

Depth

7'
11'
15'
-7'

	2B-AA	2B-AB	2B-AC	2B-AD	2B-AE	2B-AF	2B-AG	2B-AH	2B-AI	2B-AJ	Row Avg
7'	288	301	295	298	301	287	290	295	303	291	294.9
11'	288	299	297	296	299	286	293	301	305	287	295.1
15'	315	307	299	293	286	285	305	324	307	286	300.7
-7'											296.9

Marginal bias of condensables to B duct

EHL ON

Depth

7'
11'
15'
-7'

	2A-AA	2A-AB	2A-AC	2A-AD	2A-AE	2A-AF	2A-AG	2A-AH	2A-AI	2A-AJ	
7'	0	0	0	0	0	0	244	255	265	276	
11'	0	0	0	0	0	0	0	241	252	263	
15'	0	0	0	0	0	0	0	0	0	268	
-7'	0	0	0	0	0	0	0	0	250	272	

	2B-AA	2B-AB	2B-AC	2B-AD	2B-AE	2B-AF	2B-AG	2B-AH	2B-AI	2B-AJ	
7'	298	268	239	225	0	0	0	0	0	0	
11'	264	253	236	0	0	0	0	251	0	0	
15'	0	0	0	0	0	0	0	0	0	0	
-7'	262	249	236	0	0	0	241	249	235	222	

Outboard sides of ducts have very little condensables

Relatively high amount of condensables on inboard sides indicate likelihood of inefficient split of EHL flow in conveying system

Ineffective splitting of flow hydrate conveying system will reduce the performance improvements of the enhanced hydrated lime

Thank you



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