

# **REINHOLD ENVIRONMENTAL Ltd.**



## **2012 APC Round Table & Expo Presentation**

July 16-17, 2012, in Baltimore, MD / Hosted by Duke Energy, Entergy,  
FirstEnergy, Southern Company & TVA

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# DRY SORBENT INJECTION FOR SO<sub>3</sub> AND MATS

Training Class 4  
APC Conference

July 16, 2012

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# Agenda



- SO<sub>3</sub> and HCl Generation
- Dry Sorbents
- Typical Removal Rates
- Usage Considerations
- DSI Systems
- DSI Design Considerations

# SO<sub>3</sub> and HCl Generation

## *System Generation and Removal*

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### Generation

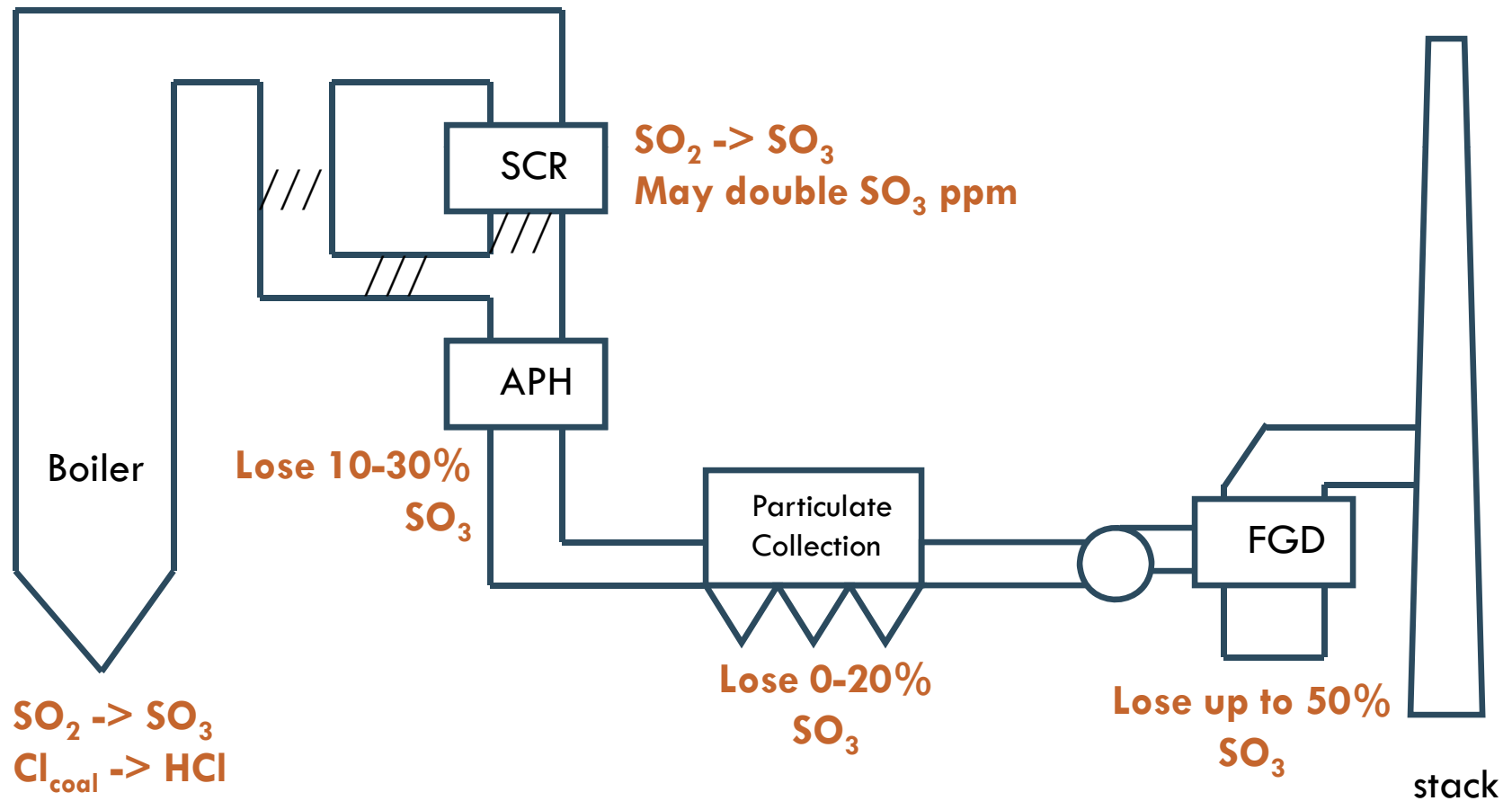
- SO<sub>3</sub>
  - ▣ Sulfur in Coal
  - ▣ SO<sub>2</sub> conversion in SCR
  - ▣ Iron
  
- HCl
  - ▣ Chlorides in coal

### Removal

- SO<sub>3</sub>
  - ▣ Absorption onto ash
  
- HCl
  - ▣ Absorption/neutralization with ash
  - ▣ Wet FGD

# SO<sub>3</sub> and HCl Generation System Generation and Removal

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## Consider additional benefits of early removal

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- Pre-SCR
  - ▣ Minimum operating temperature
- Pre-APH
  - ▣ Corrosion protection
  - ▣ ABS control
  - ▣ Heat rate
- Activated Carbon Injection
  - ▣ Better utilization of carbon with SO<sub>3</sub> absorption
- Particulate collection
  - ▣ Corrosion
  - ▣ Operational
- Wet FGD
  - ▣ Corrosion



# HCl

## Removal benefits

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- Particulate collection
  - ▣ Corrosion
  - ▣ Operational
  
- Wet FGD
  - ▣ Corrosion
  - ▣ Effects of HCl on scrubber and wastewater treatment

# Dry Sorbents



# Identify Your Needs

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- Buying tons or mole of sorbent?
  - ▣ Make final determinations in tons
- Where are you and where do you have to get with pollutants?
  - ▣ Potential side benefits of acid gas mitigation
- What will your injection system look like?
  - ▣ Expectations on Operations and Maintenance
- Implications of sorbent choice
  - ▣ Supply
  - ▣ Logistics
  - ▣ Ash

# Key Sorbent Criteria for Hydrated Lime

## Available Calcium and Surface Area

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Property	Industry Typical	Flue Gas Grade
Surface Area, m <sup>2</sup> /g	14 – 23	≥ 21
Avail. Calcium Hydroxide, %wt	89 - 97%	> 95%
Total Calcium Hydroxide, %wt	92 - 99%	92 - 99%
Porosity, cm <sup>3</sup> /g	0.07 – 0.14	0.12
Particle Size, D <sub>50</sub> , microns	~ 4 - 6	~ 2.0
Particle Size, -325 mesh, %wt	~ 92%	~ 92%
Moisture, %wt	≤ 1.0%	≤ 1.0%

**SO<sub>3</sub> Mitigation requires high surface area hydrated lime**  
**High % Available ensures best utilization rates**

# Key Sorbent Characteristics for Trona

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<b>Property</b>	<b>Typical</b>	<b>Milled Trona</b>
Sodium Sesquicarbonate, %wt	97%	95% (min)
Recommended Handling Temperature °F	100	125
Particle Size, D <sub>50</sub> , microns	25	35
Particle Size, D <sub>90</sub> , microns	100	120
Free Moisture, %wt	0.03%	0.05% (max)

Courtesy: NatronX Technologies

**At temperatures above 275°F, Trona is calcined into porous sodium carbonate. High surface area enables fast gas-solid reaction between the calcined sorbent and the acid gases.**

# Typical Pollutant Removal

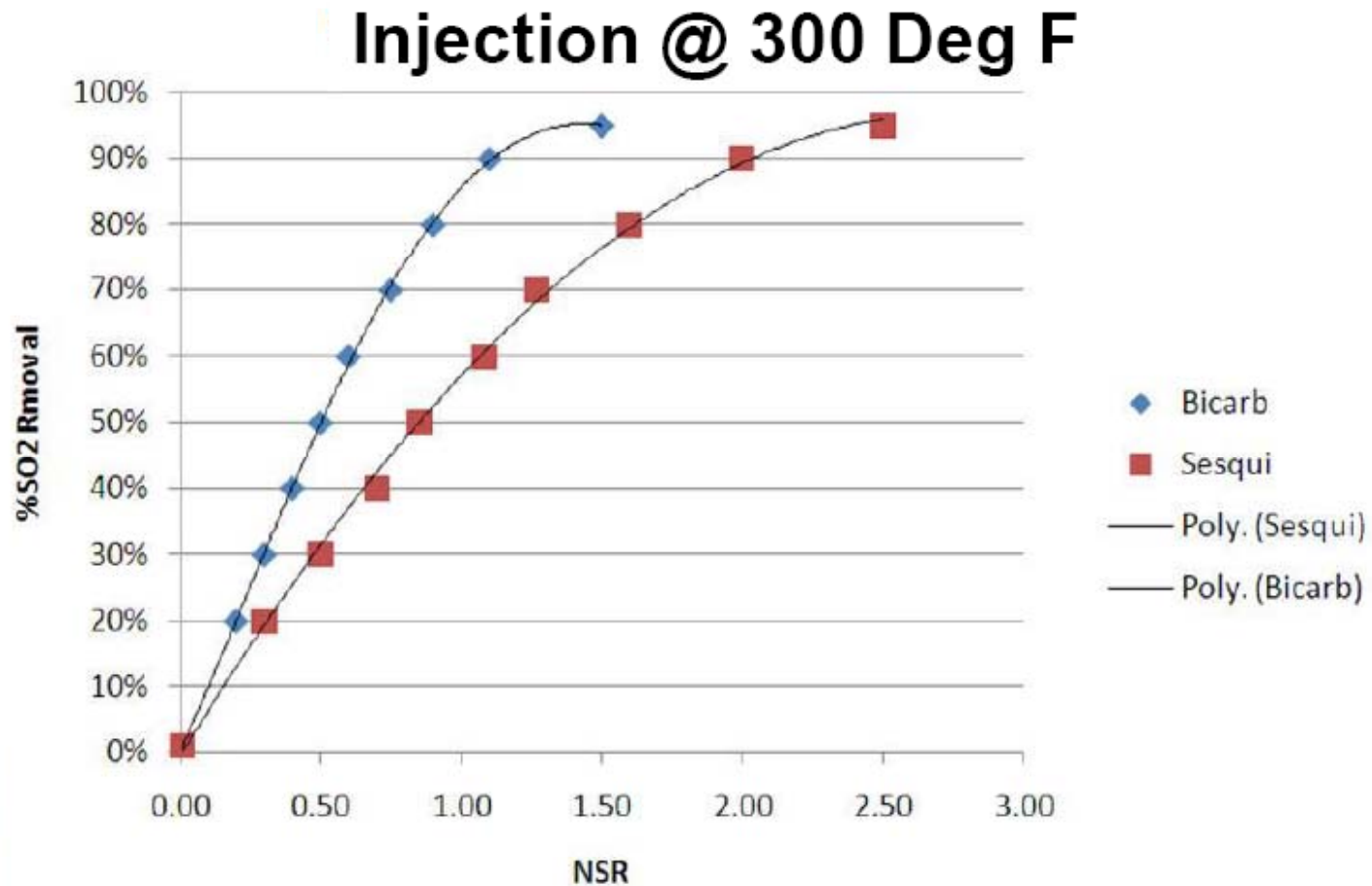
Dry Alkaline Injection for Acid Gas Control



# Sodium Sorbents

## Bicarbonate vs. Trona for SO<sub>2</sub> removal

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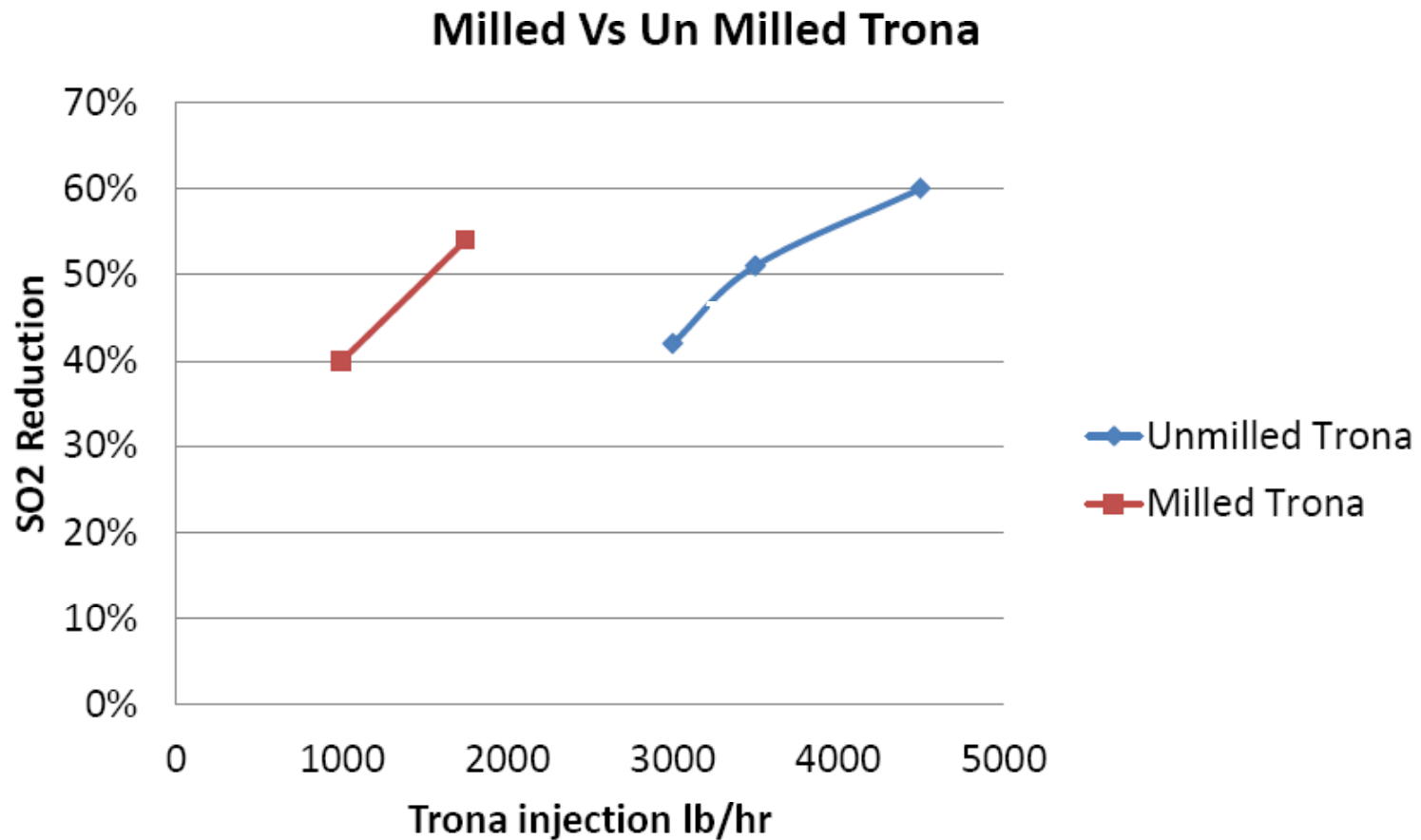


Courtesy: NatronX Technologies

# Sodium Sorbents

## Benefits of Milling for SO<sub>2</sub> Removal

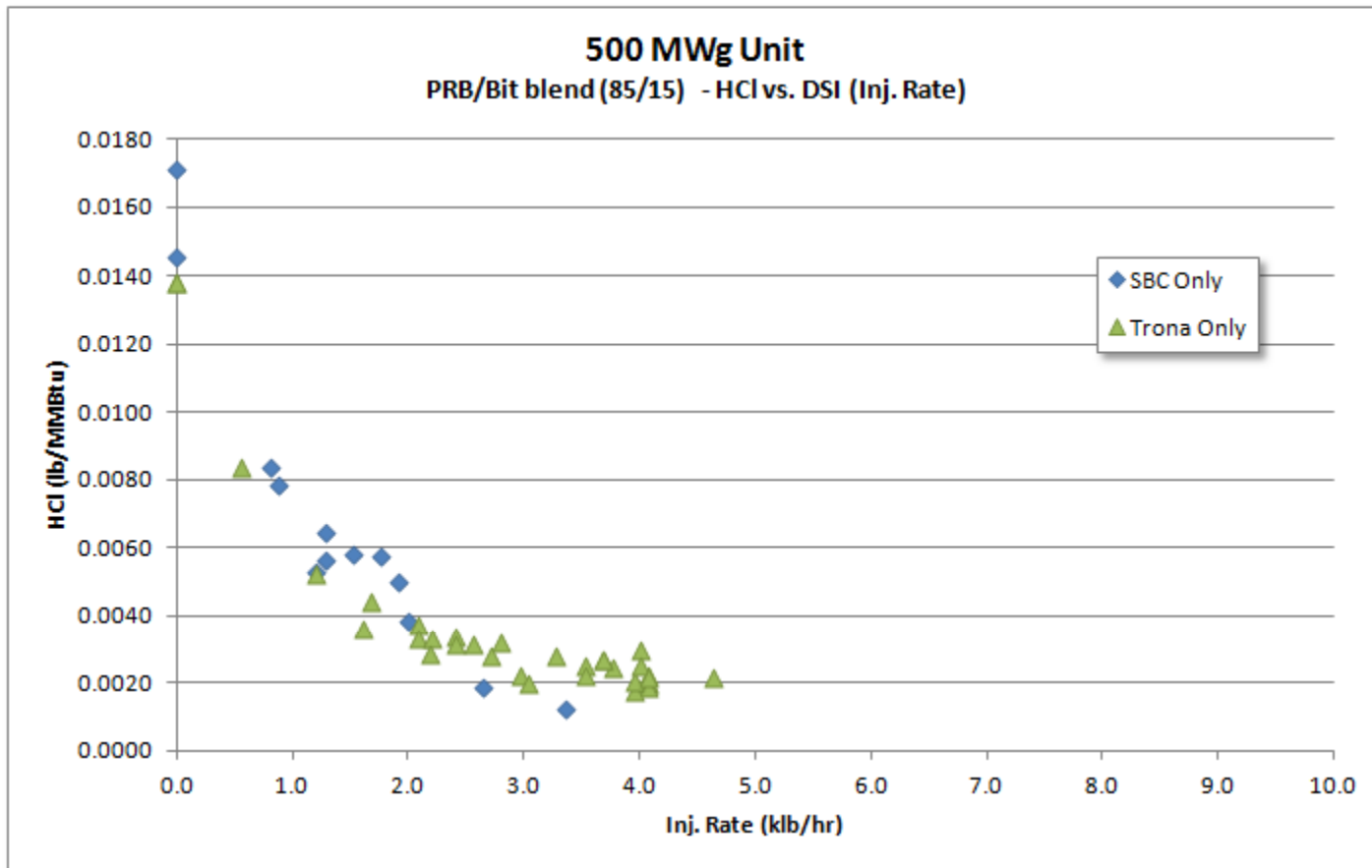
13



Courtesy: NatronX Technologies

# Sodium Sorbents

## HCl Removal

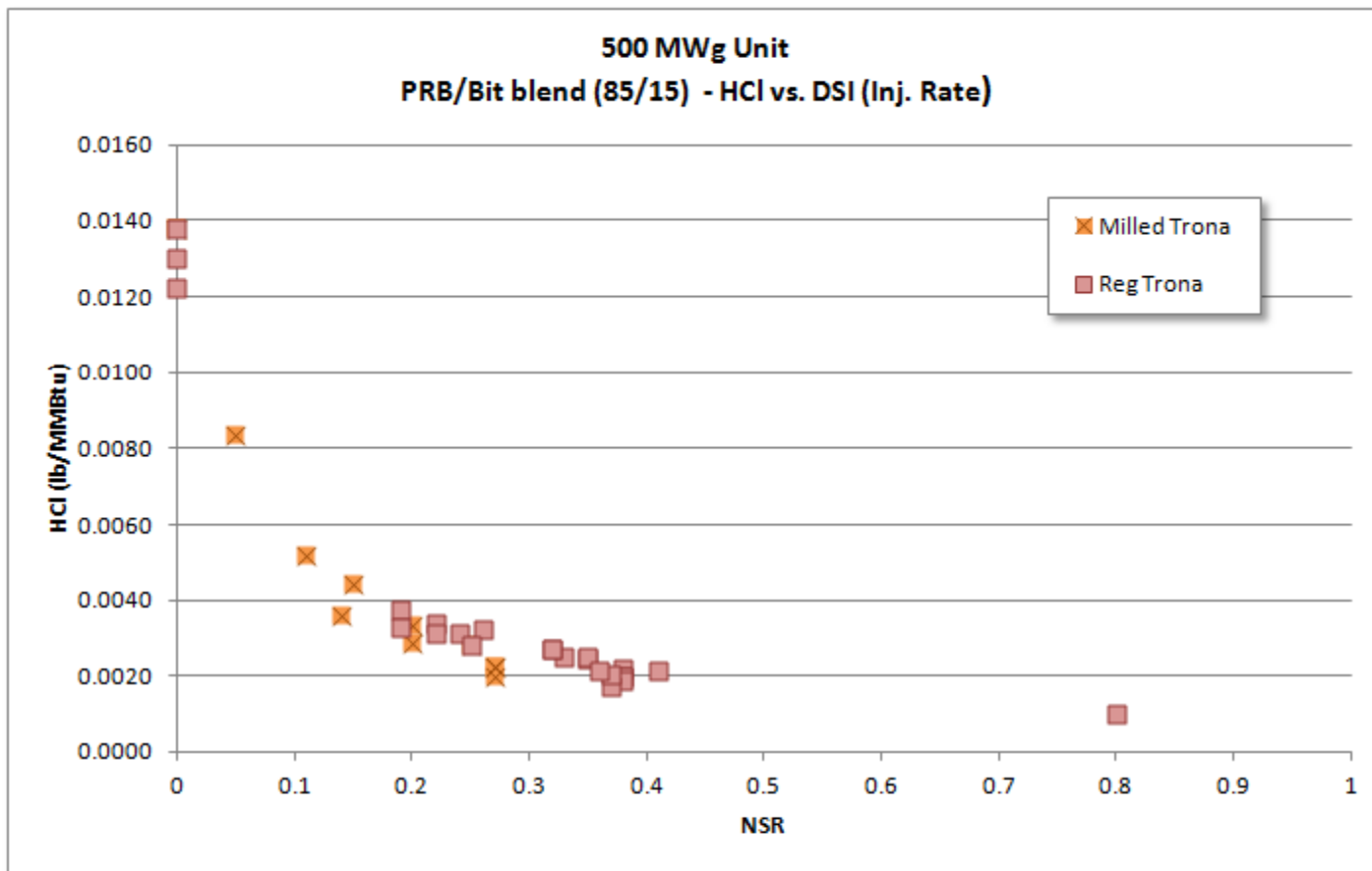


Source: ADA Environmental Technologies

# Sodium Sorbents

## HCl Reduction – Milled vs. Unmilled Trona

### HCl Control using milled and unmilled Trona

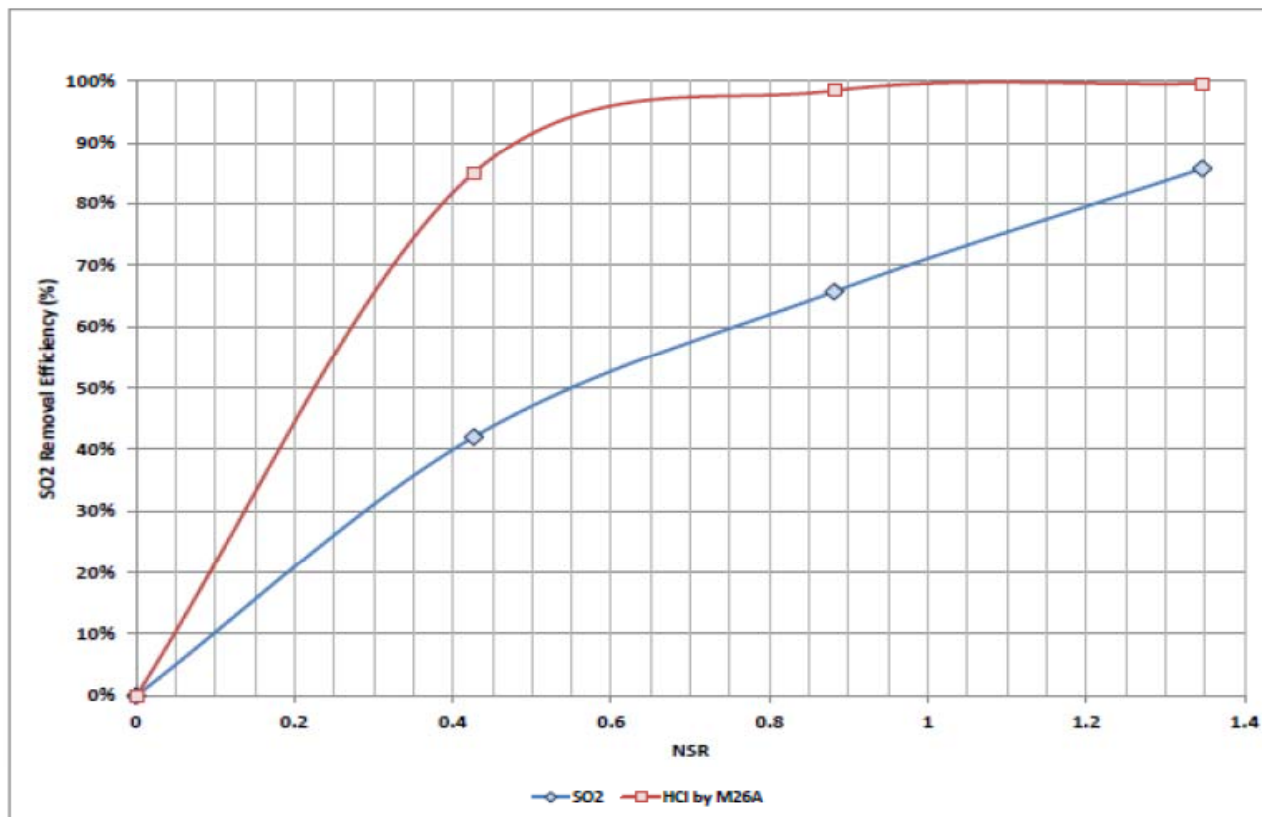


Source: ADA Environmental Technologies

# Sodium Sorbents

## SO<sub>2</sub> and HCl Removal

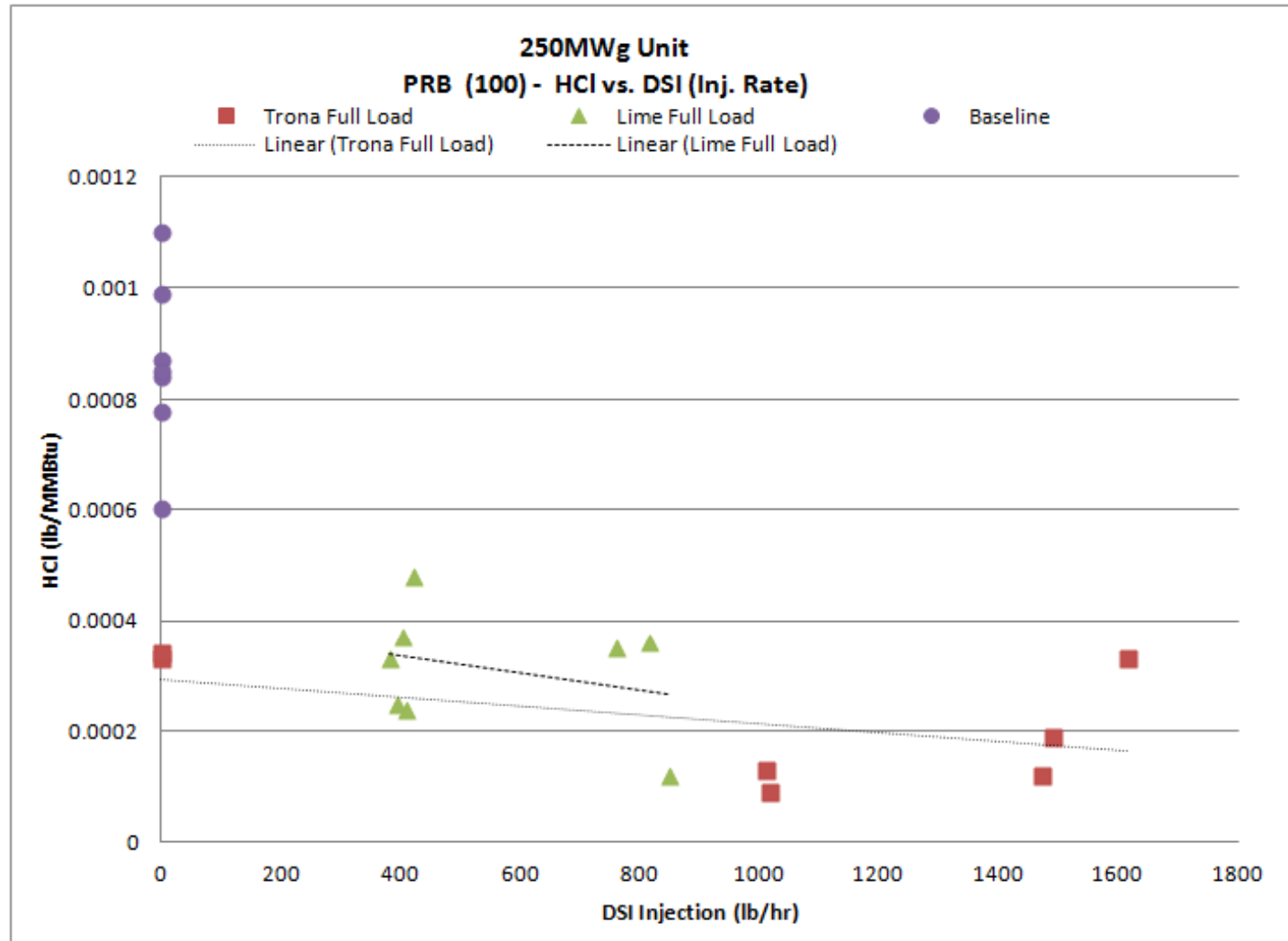
**Performance of Milled Trona for SO<sub>2</sub> and HCl removal**



Courtesy: NatronX Technologies

# Alkaline Sorbent Performance

## Hydrated Lime and Trona



Source: ADA Environmental Technologies

# Hydrated Lime

## Typical SO<sub>3</sub> Removal Rates - ESP systems

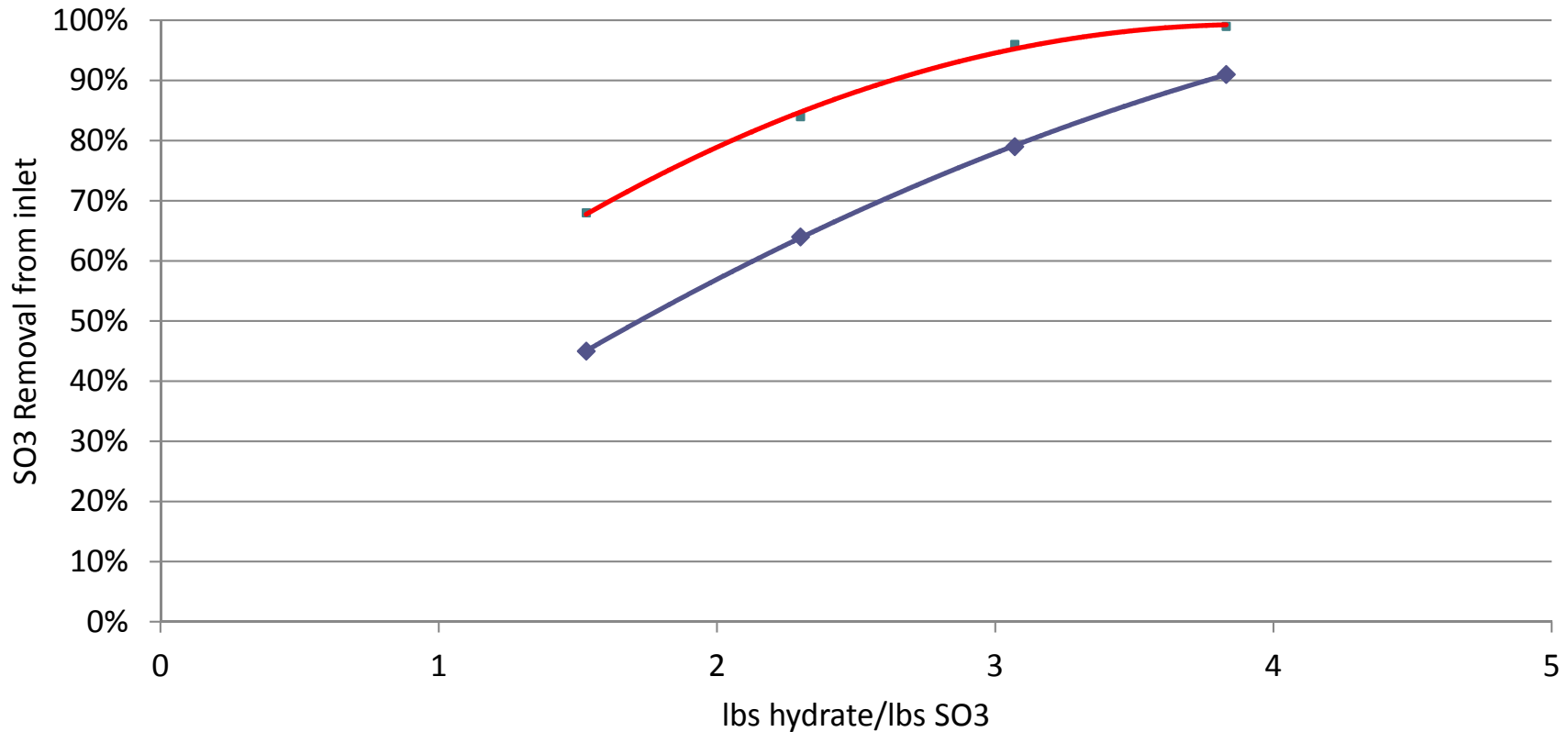
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- Residence time effects
  - ▣ Short (<2 sec) will require more sorbent
- Injection system efficiencies
  - ▣ Flue gas coverage
  - ▣ Feed system

### *Removal Rate Examples Using Hydrated Lime*

Plant	<i>lb hydrate: lb SO<sub>3</sub></i>	Treated Stack
550 MW	3.9 : 1	<1.5 ppm
1300 MW	3.9 : 1	3 ppm
700 MW	3.5 : 1	3.5 ppm
>500 MW	1.9 : 1	<6 ppm
	3.8 : 1	<2 ppm
>500 MW	2.5 : 1	4 ppm
	3.9 : 1	<2 ppm

# SO<sub>3</sub> Removal with Hydrate



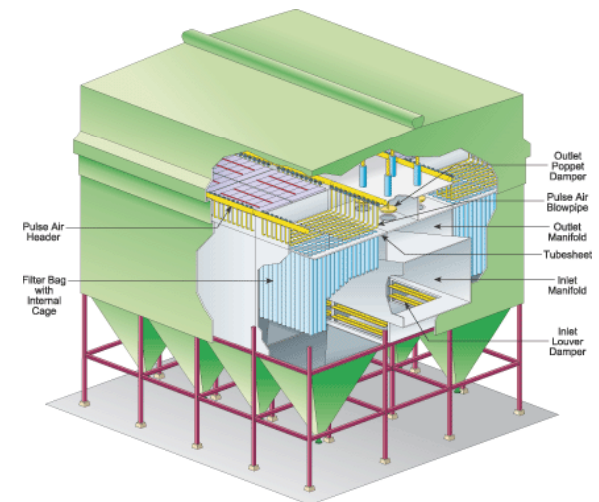
Flue Gas grade hydrate gives good removal (blue line)

Improved reactivity offers better utilization or high level removal capabilities (red line)

# Benefits of Fabric Filters vs. ESP Sorbent Perspective

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- Fixed bed of ash and sorbent effectively adds residence time
  - ▣ Improve utilization
  - ▣ Reduce emissions
- Resistivity is not an issue
  - ▣ Flexibility on sorbent type
  - ▣ Flexibility on amount of sorbent

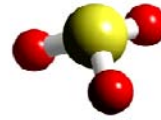


Courtesy B&W

## Questions:

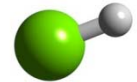
- ❖ **What is the typical sorbent usage?**
- ❖ **How soon can baghouse respond to sorbent injection?**
- ❖ **What is performance over a longer period?**

# Hydrated Lime Baghouse Removal Data



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- Midwestern Utility; med-high sulfur coal
- Hydrate injection post APH using temporary injection system
- Test runs measured at baghouse outlet
  - ▣ *Controlled condensate (SO<sub>3</sub>) and 26A (HCl)*



	Content, ppm		Reduction	
	SO <sub>3</sub>	HCl	SO <sub>3</sub>	HCl
<i>baseline inlet</i>	25	24	---	---
<i>baghouse outlet</i>	16	22.5	36%	<10%
<b>lb Ca: lb SO<sub>3</sub></b>				
2.15	4.9	21.9	80%	<10%
2.70	1.4	24.7	94%	<10%
3.24	<1	<1	98%	>98%

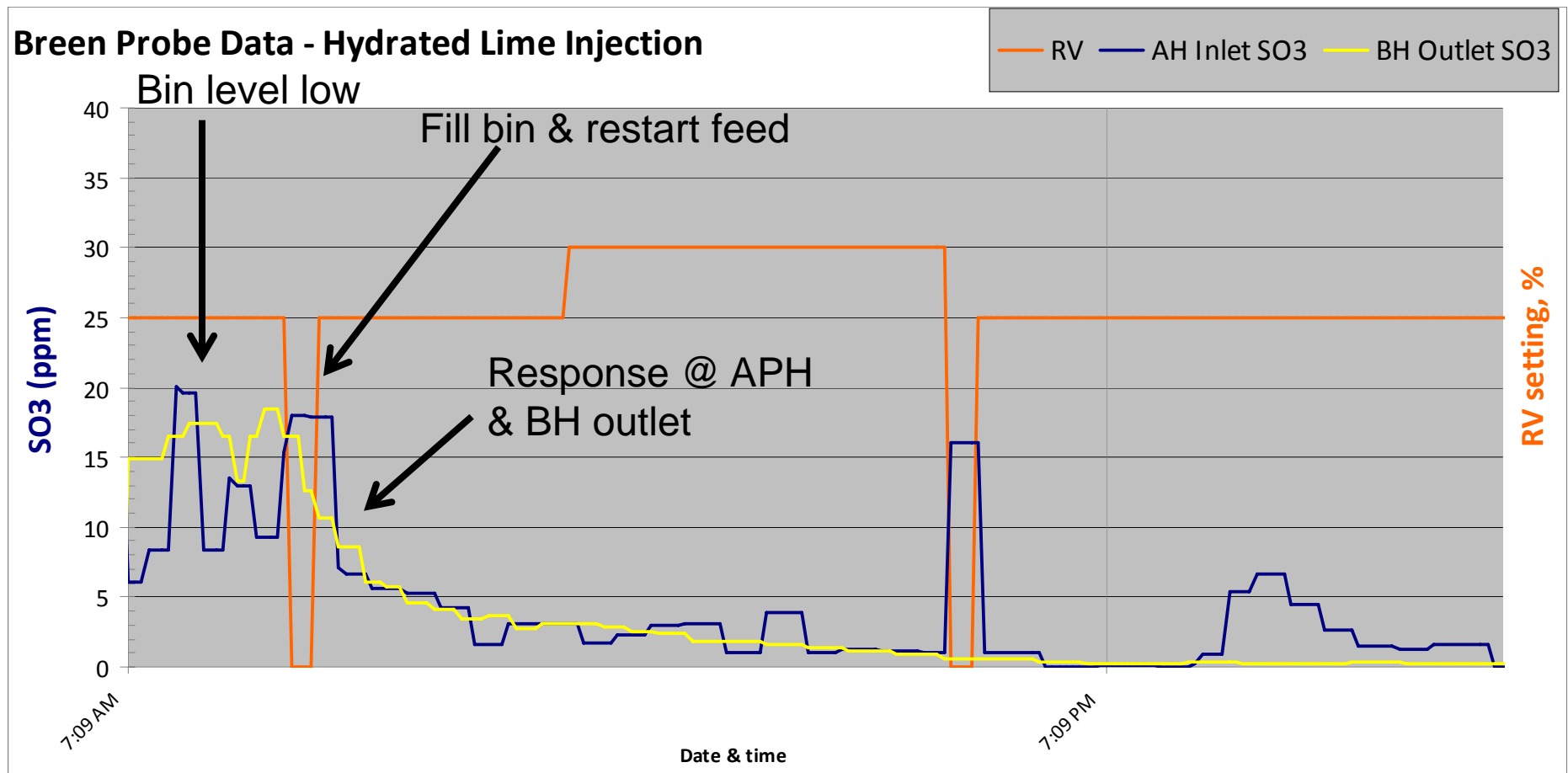
**Reduced sorbent usages vs. ESP**  
**Low emission capability**

# Baghouse Example

## Response to Starting Hydrate Lime Feed

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### Hydrate Injection at SCR Outlet – SO<sub>3</sub> Removal



# Hydrated Lime for HCl Removal

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## Benefits

- Low reactivity with  $\text{SO}_2$  at DSI temps
  - ▣ No competing reaction
  - ▣ Improved utilization
- Ash compatibility
  - ▣ Ca fly ash compatibility
  - ▣ Ca landfill stability
- Supply availability
  - ▣ Regional production
  - ▣ Lower working capital
- Cost

## Challenges

- Low reactivity with  $\text{SO}_2$  at DSI temps
- Ash resistivity for ESPs
  - ▣ Marginal ESPs
  - ▣ Short residence time



# Acid Gas Emission Control – Baghouse Shawnee 2011

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## DSI Program targeting HCl emissions to meet 2015 MATS

- Baghouse seasoning is essential for test program (*yellow vs green*)
- HCl limits easily met with low hydrate requirements
  - Lower limit of feeder capability for consistency
- Results of follow-up study also optimistic

Hydrate Injection Rate	HCl (lb/MMBTU)	HF (lb/MMBTU)	H <sub>2</sub> SO <sub>4</sub> (ppmvd)
0 lb/hr - Baseline	0.0030	0.0045	1.3
600 lb/hr (in flight)	0.0016	0.0046	0.46
1,000 lb/hr (in flight)	0.0016	0.0043	0.42
350 lb/hr	0.0005	0.0006	0.37
350 lb/hr	0.0007	0.0007	0.35
300 lb/hr	0.0008	0.0006	0.35

# Shawnee – March 2012 Test Program

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*New year, new coal, same story*

- Higher Cl coal evaluated (6-10X more baseline HCl than 2011 test)
- Met MATS requirements with only ~3X hydrate feed
- Preliminary results, final report to be developed

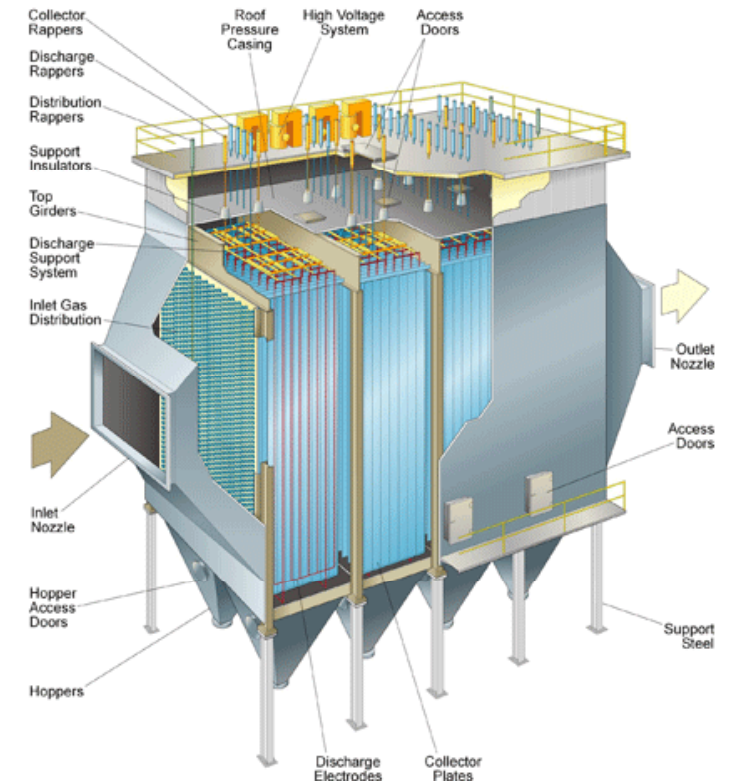


# Usage considerations

# SO<sub>3</sub> Control ESPs

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- SO<sub>3</sub> conditions ESP
- Ash resistivity
  - ▣ Sodium reduces; Calcium increases
- Strategy for Unit-specific issues
  - ▣ Distribution of particulate in duct
  - ▣ Balance hydrate feed and SO<sub>3</sub> levels
    - Important to maintain ESP conditioning
    - ~3ppm SO<sub>3</sub> at ESP inlet
  - ▣ Short Residence time in front of ESP
    - Manage with split injection



Courtesy B&W

# What About Particulate?

## Case Study with Post ESP Injection on Wet FGD Unit

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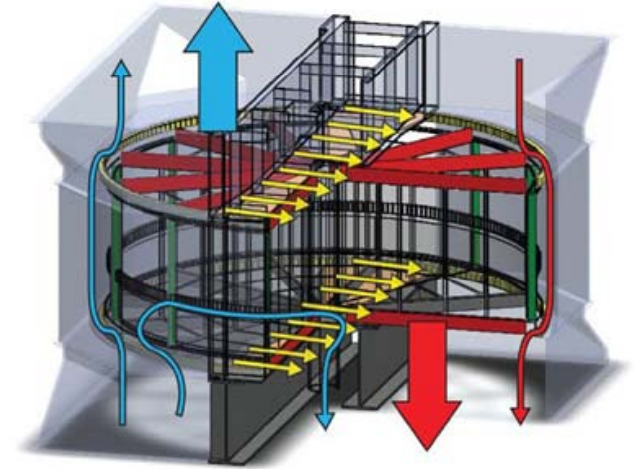
- Cold side ESP not capable of handling of sorbent injection / increased loading
  - Cyclone-fired boiler
    - ESP designed for ~20% fly ash
  - Sorbent injection increases ash by another 5%
    - Overwhelms ESP (since designed for low fly ash loading)
    - Opacity concerns
- Injected hydrated lime post ID fan, after the ESP
  - Achieved good removal of SO<sub>3</sub>
  - Stack particulate emissions were not negatively affected

Load (MW)	NSR	Stack Particulate (lb/MMBtu)
1039	2.54	x
1030	4.75	0.40x

# DSI Prior to the Air Preheater Benefits

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- Better utilization of sorbent
  - ▣ Longer reaction time
  
- APH operation
  - ▣ Eliminate ABS buildup from ammonia slip
  - ▣ Flexibility on SCR operation
  
- Lower heat rate
  - ▣ Reduce acid dew point through APH

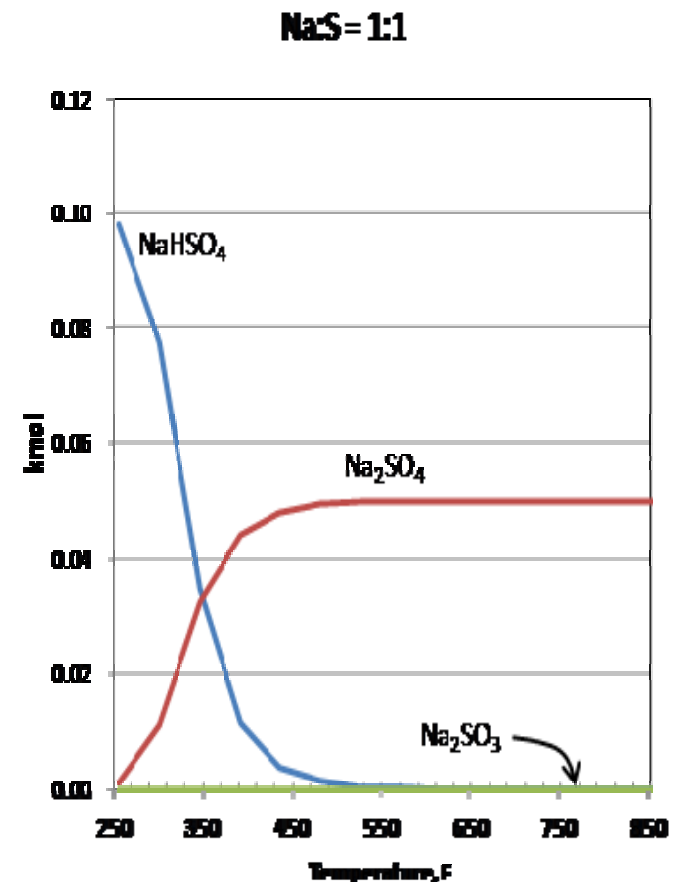


*Courtesy BreenES*

# Sodium DSI Prior to Air Preheater

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- **SO<sub>2</sub> control is mainly the domain of the sodium sorbents**
  - ▣ Sodium sorbents begin to decompose at temperatures above 130°F; at temperatures above 275°F sodium sorbents become most effective
  - ▣ Anhydrous sodium carbonate predominates at temperatures above 320°F
  - ▣ The more rapidly CO<sub>2</sub> and H<sub>2</sub>O are liberated during the decomposition, the more reactive the resulting carbonate due to enhanced surface area
- **Bisulfate formation; Sodium Starved Conditions**
  - ▣ Trona may not completely react to sodium sulfate (Na<sub>2</sub>SO<sub>4</sub>):
  - ▣ Sodium bisulfate (NaHSO<sub>4</sub>) could be formed.
  - ▣ In the presence of ammonia, ammonium bisulfate (ABS), a sticky particle that can cause plugging in the air preheater
- **Localized mal-distribution of sorbent must be avoided**

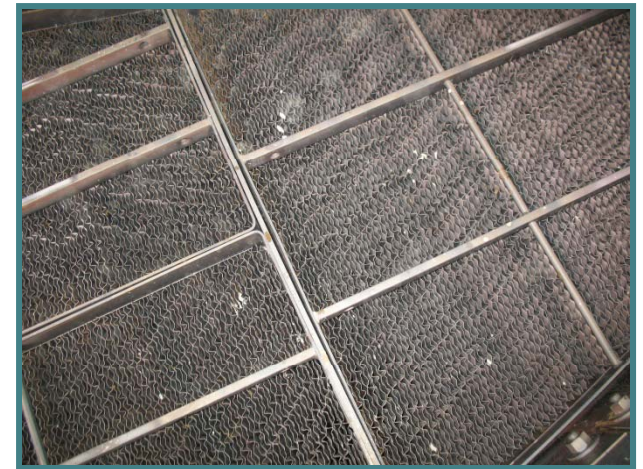


# Hydrate Prior to Air Preheater

Neutralization of  $\text{SO}_3$  will occur at pre-APH temperature

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- Byproducts are  $\text{CaSO}_4$  and  $\text{CaCl}_2$ 
  - No issues with these or other intermediates
  
- Multiple trials of Pre-APH since '09
  
- Utility – Pre-APH since 2010
  - No issues reported



APH after 8 week hydrated lime pre-APH injection trial

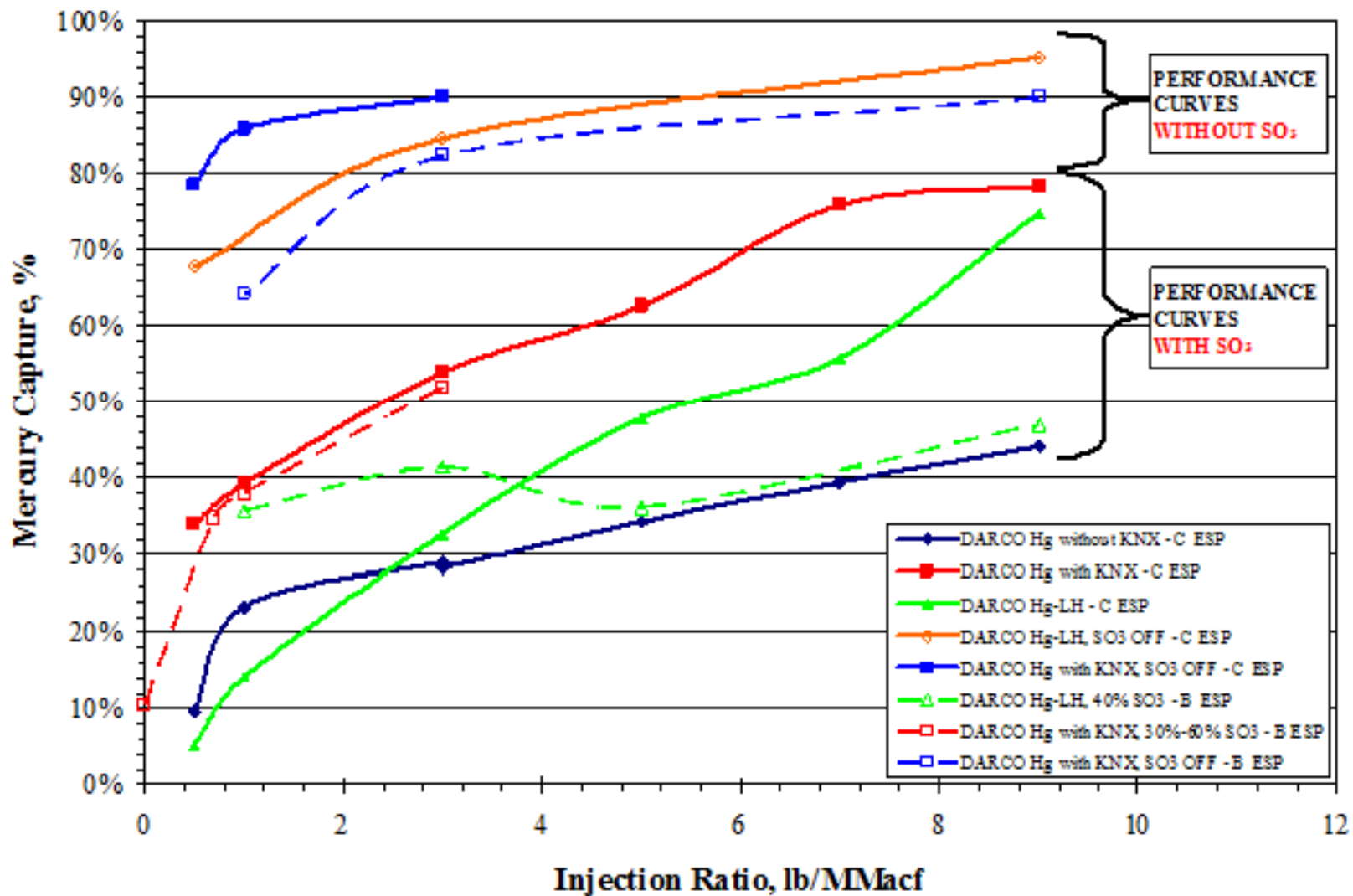
# Baghouse Testing

## Mercury with $\text{SO}_3$ present

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- Hydrated Lime DSI for  $\text{SO}_3$  Mitigation
  - Hg Removal = ~ 40% removal from coal to Particulate Collection outlet (no carbon injection)
    - 3% LOI
  
- Baseline (no hydrate injection, 2008):
  - No Hg removal with 10% LOI

# The Impact of SO<sub>3</sub> on Mercury Control





# DSI Systems

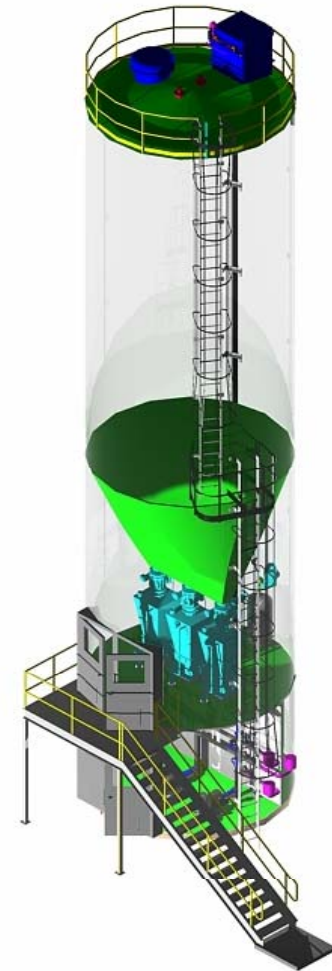
## Configuration and Components

# System Design Elements

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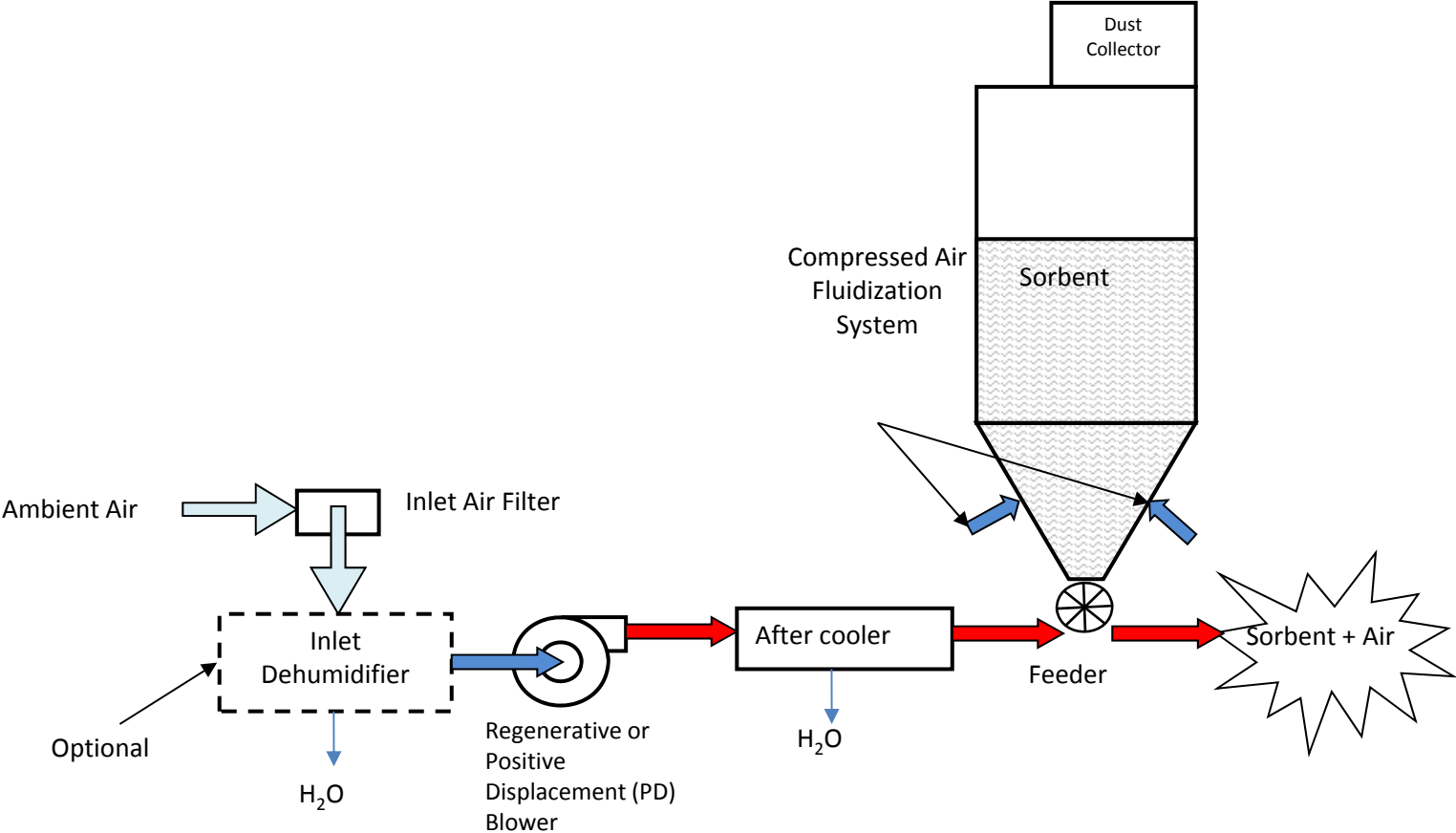
## Alkaline Sorbent Injection System

- ▣ Solids Island
  - Storage
  - Feed
- ▣ Air Island
  - Motive Air
  - Conditioning/quality
- ▣ Distribution System
  - Piping
  - Manifold & Lances

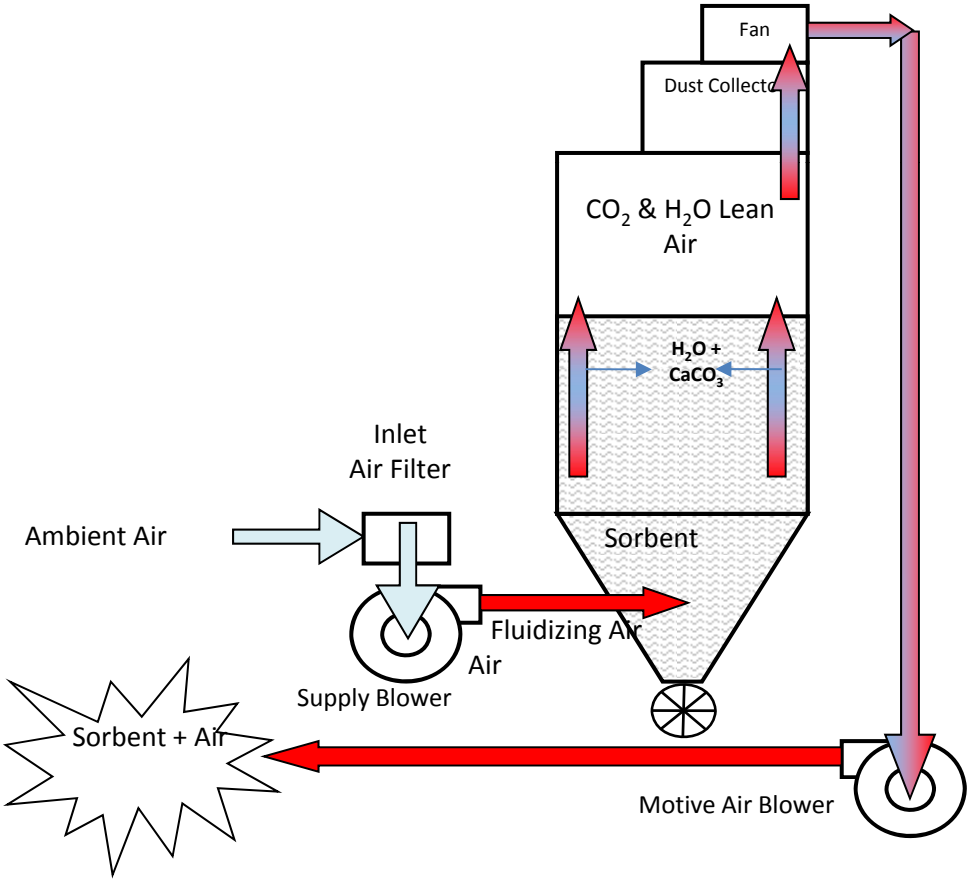


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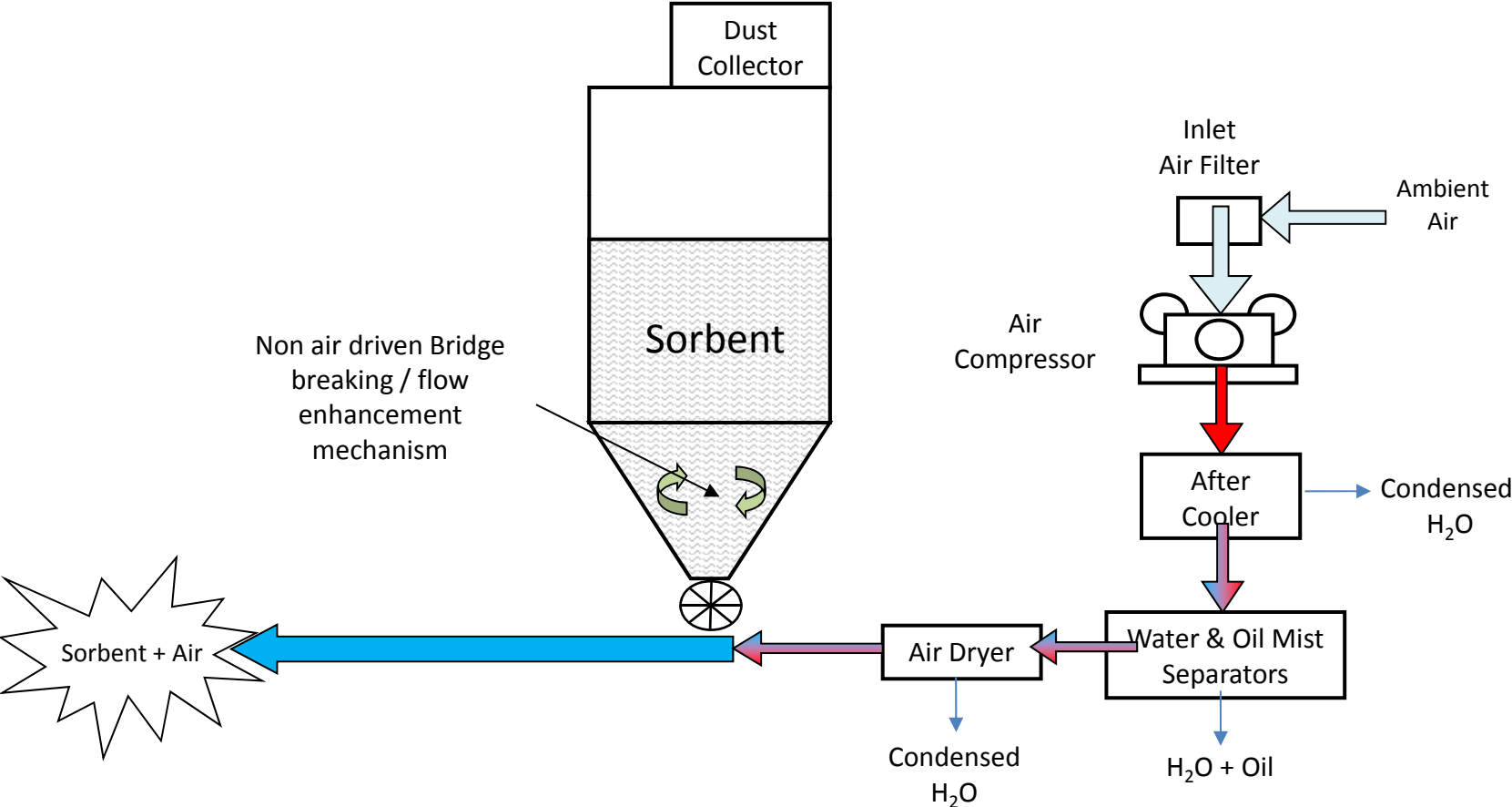
# Typical DSI System Configuration



# CO<sub>2</sub> Mitigating DSI System Design

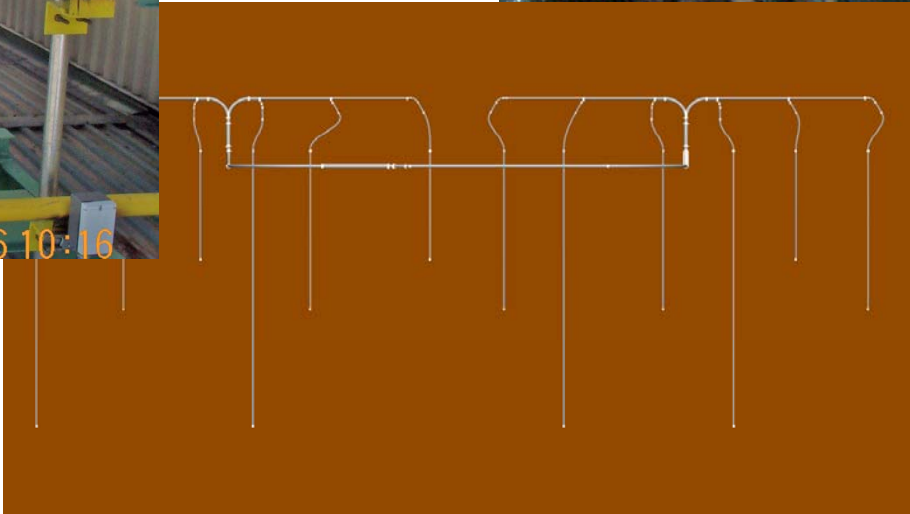


# Conditioned-Air DSI System Configuration



# Distribution System

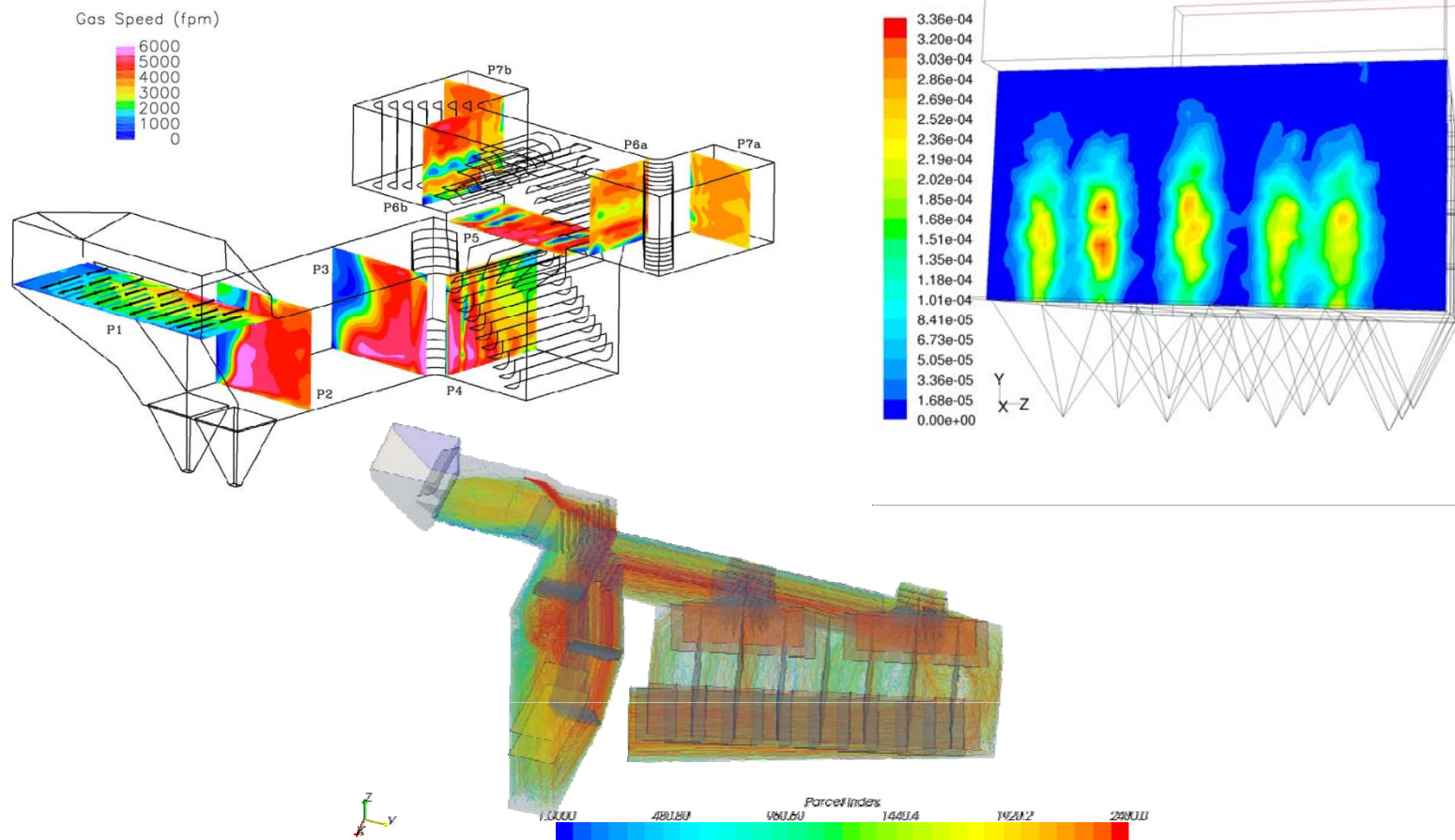
## □ Manifold & Lances Design



# Distribution System

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## Gas Velocity Information & Modeling





# Design

## Considerations

# Dense vs. Dilute Phase Conveying

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## □ Dense Phase Conveying

- Material: Air of 99 to 6.2 (two phase) or 1,239 to 62 (piston) lbs material/lb of air
- Truck Unloading

## □ Dilute Phase Conveying

- Material: Air 6.2 to 0.10 lbs material/lb of air
- Pneumatic Injection Systems

*Source: Solt, P. E., Pneumatic Points to Ponder, Powder and Bulk Engineering*

# Design Challenges – Understanding Air Dilute Phase Systems

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- Flue coverage
  - ▣ High # of injection lances
- Two sorbent option
  - ▣ Different properties and system requirements
- Alternate fuels
  - ▣ Oversized equipment
- Inflexible equipment
  - ▣ Single speed blowers
- Conveying distance and pathway
  - ▣ # of bends require increased air

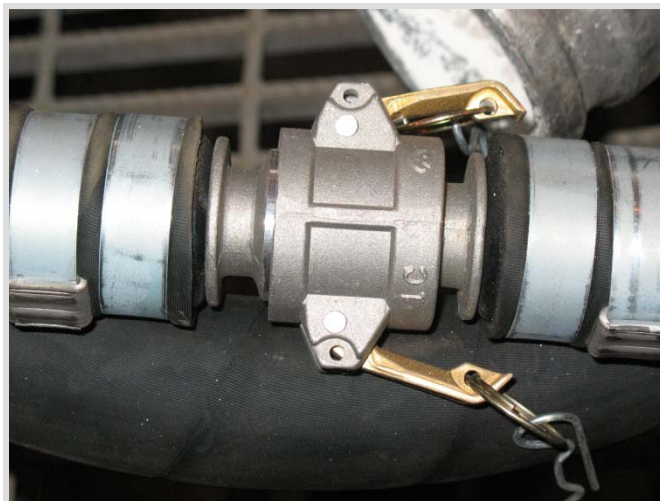
# System Installation

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- Wet air
  - ▣ Conveying
  - ▣ Rotary Airlock seals
- Piping joints
  - ▣ Shelf
- Field modifications
  - ▣ Added bends



*J. Wilson, DHUG, 2010*



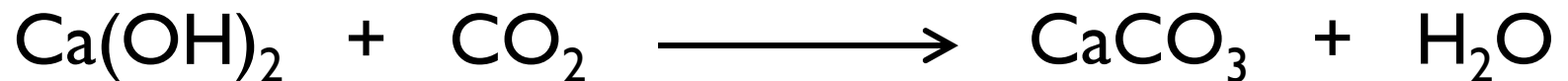
*J. Wilson, DHUG, 2010*

# Hydrated Lime

## Potential Conveying Challenges

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- Dry powder plugs (physical)
  - ▣ Failure to maintain above pick-up velocity
  - ▣ Design or conveying issue
    - Address with equipment supplier
- Calcium carbonate scale (chemical)
  - ▣ Need to control reaction between hydrate and CO<sub>2</sub> in conveying air



- ▣ Address with design and optimized conveying conditions

# Results on Hydrate Conveying Test System

## Run D

Active scrubbing, <50ppm CO<sub>2</sub>

Shallow Pocket DT RV

Air Cooler

**Success**

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## Run C

Moderate CO<sub>2</sub>

~150ppm CO<sub>2</sub>

**Fail within ~3 weeks**

## Runs A & B

Ambient air

~400ppm CO<sub>2</sub>

**Fail within ~1 week**

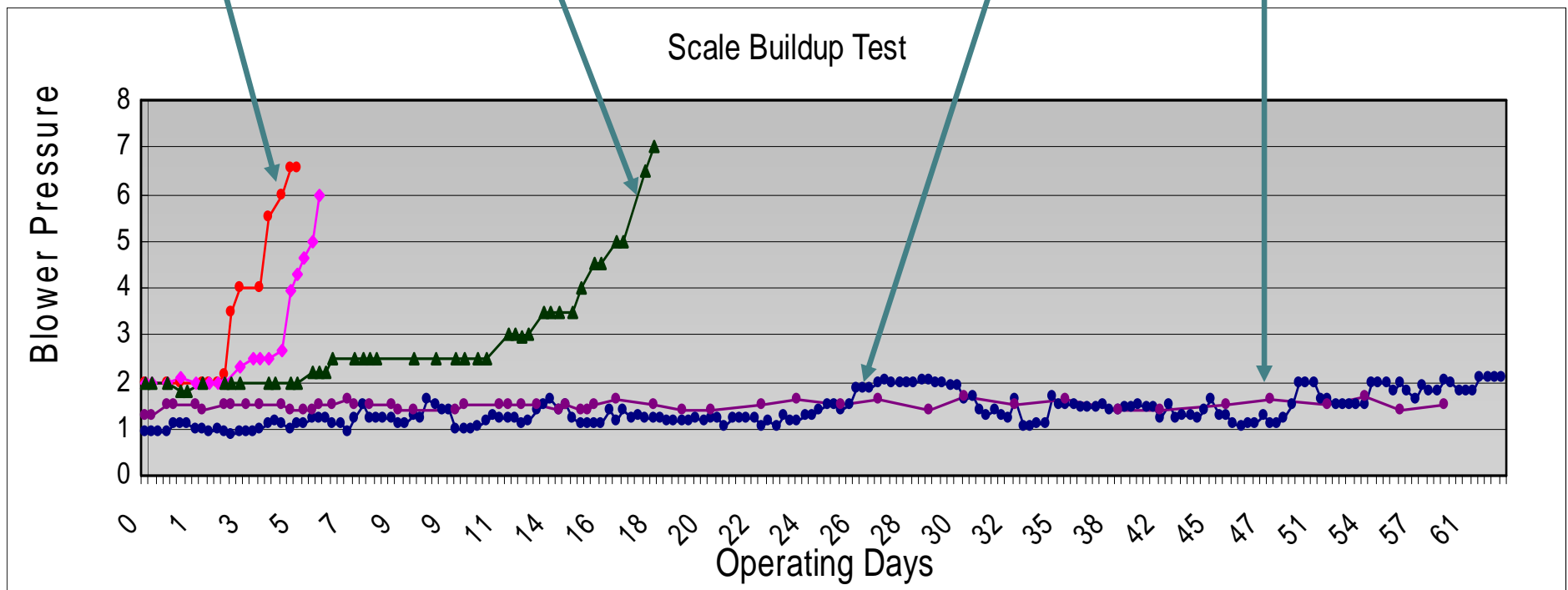
## Run E

Ambient air & Air Cooler

Shallow Pocket DT RV

3660 ft/min; 0.57 hydrate/air

**Success**



# Hydrated Lime Recommended System

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- Variable speed feed blower
- Use Air-to-air heat exchanger for temperature control
- Myrlen air sweeps on cone of weigh bin
- Shallow Pocket Drop Through Rotary Valve
  - ▣ Monitor wear on vanes
- Hydrate:Air  $\geq 0.6$  lbs hyd:lb air
  - ▣ Pickup velocity  $>3000$  ft/min
- Minimal bends; smooth unions
  - ▣ T bends preferred
- Piping/Lance diameter  $\geq 1.25$ "



# Recommendations

## Based on OST and SO<sub>3</sub> Removal Targets

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- Equipment optimization
  - ▣ System OST of 6 weeks or more
  
- Equipment optimization + Low CO<sub>2</sub> Conveying
  - ▣ Longer system OST
  - ▣ Can 'fix' a marginal system
  - ▣ Key to very low SO<sub>3</sub> emissions?
    - Next generation sorbents
    - Less system downtime
    - Better dispersion in flue gas

# Sodium Sorbent

## Potential Conveying Challenges

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- Sodium sorbent injection systems have historically been plagued by plugging and caking
- Sufficient heat is required to drive moisture from the sodium sorbents; Consistent higher bulk fluid temperature intensifies the fouling rate
- Above 130°F, trona begins to dehydrate (above 125°F for SBC)
- Heat gain in the conveying system makes water available for agglomeration and caking

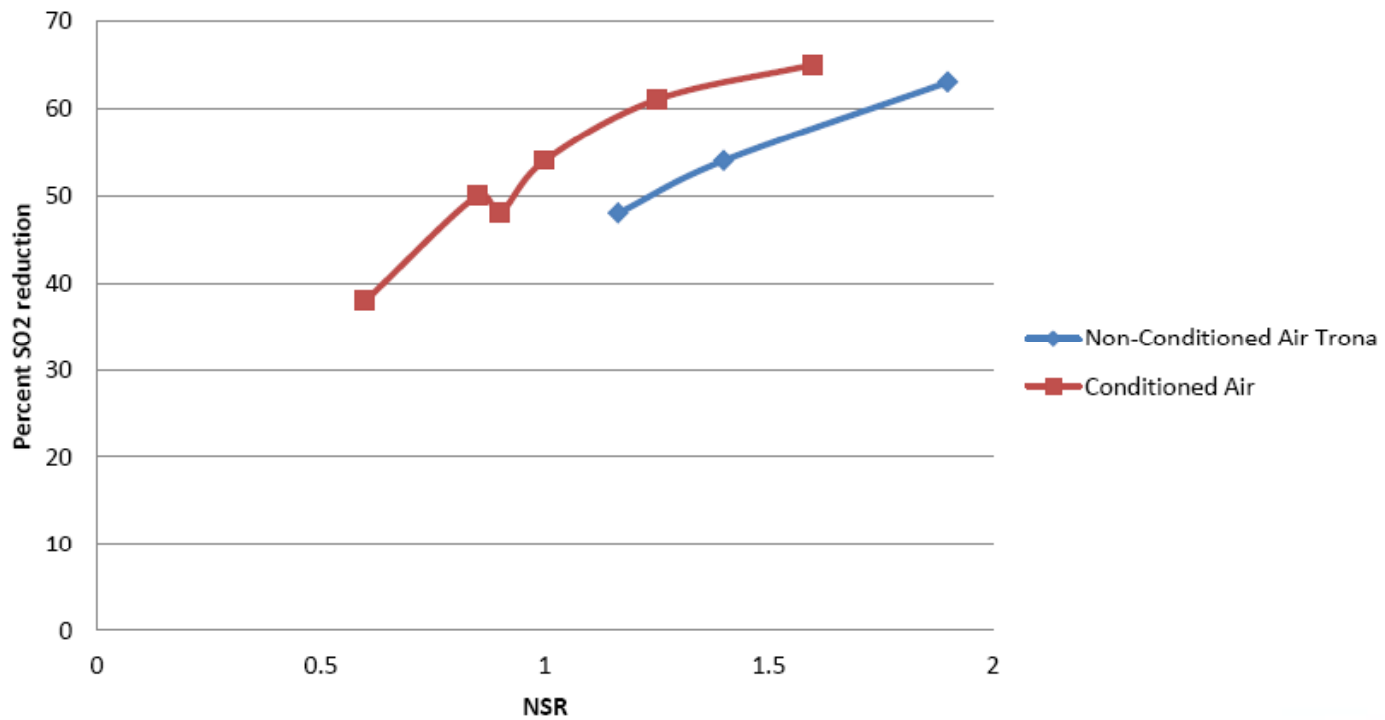


- To promote optimum acid gas mitigation & reagent utilization, sodium sorbent *should* dehydrate and decompose in the duct not in the unloading or conveying system
- Minimizing heat gain in conveyance system
  - ▣ Decreases agglomeration
  - ▣ Increases system reliability

# Sodium Sorbents

## Benefits of Conditioned Air

Effect of Conditioned Air on Trona Upstream APH

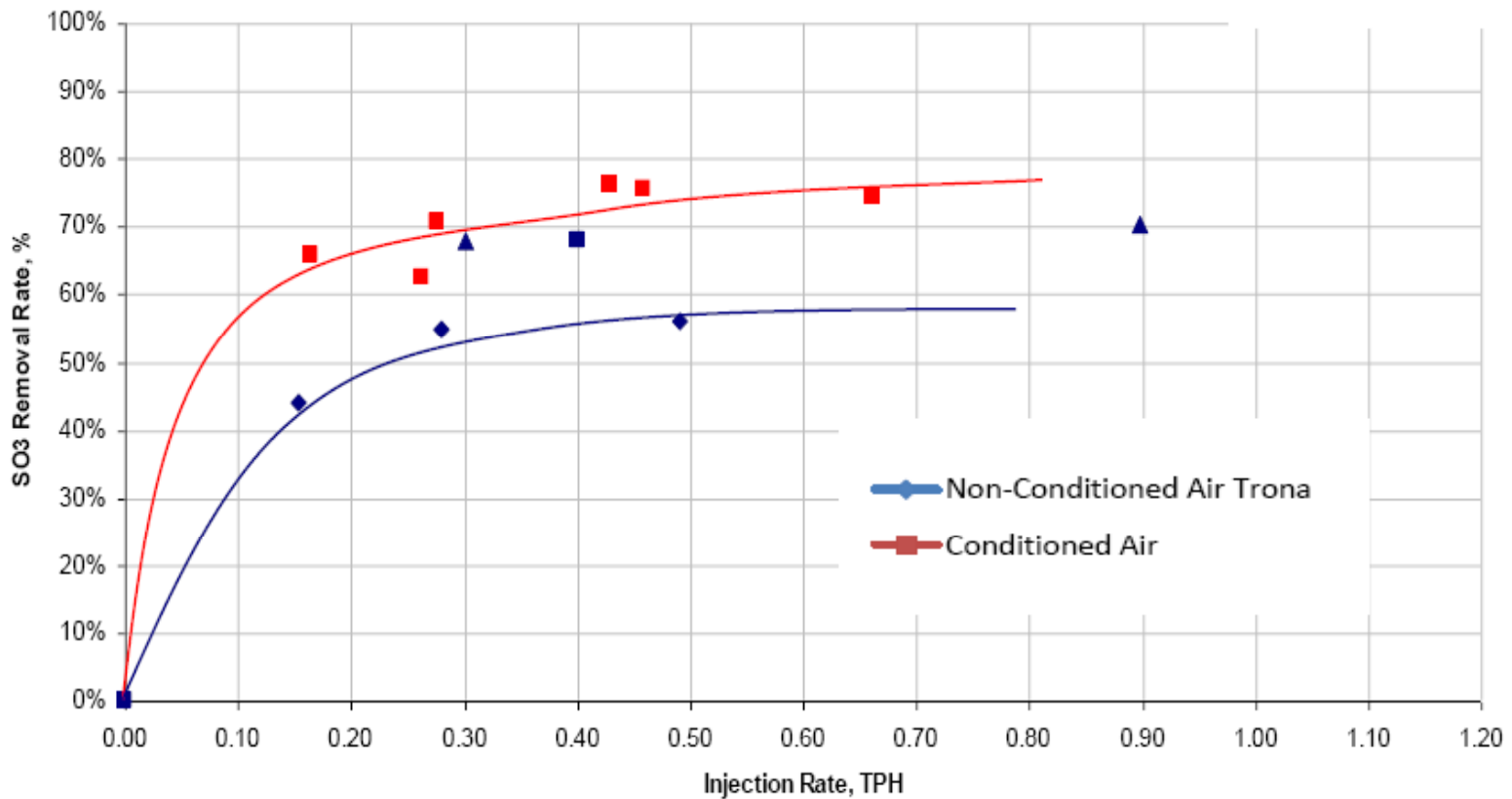


Courtesy: NatronX Technologies

# Sodium Sorbents

## Benefits of Conditioned Air

### SO<sub>3</sub> reduction using Trona



Courtesy: NatronX Technologies

# Summary

- Dry Sorbent Injection is a viable technology for meeting regulatory requirements
  - MATS
  - Consent decrees for sulfuric acid
  - Some SO<sub>2</sub> reduction for CSAPR
- DSI system requirements are well understood
  - Basic equipment for storage, dilute phase conveying, and dispersion in flue gas
  - Each sorbent has handling characteristics that must be considered for optimal O&M

# Questions

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