

# Worldwide Pollution Control Association

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# Using Dry Sorbent Injection to Meet the Utility MACT

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# Overview

- Regulatory
- Options for Dry Sorbent Injection
- SO<sub>3</sub> and HCl removal rate examples
- Material Handling

# Regulatory Reasons for Acid Gas Mitigation (Pre-MACT)

- Offset additional  $\text{SO}_3$  generated from SCR installation
- Control blue plume at stack from Wet FGD addition
  - Appearance
  - Local concerns



# Regulatory

## Acid Gas Mitigation Outlook

- Consent decree on Acid gases
  - Specified amount at the stack
    - Limitations of Method 8A
- Particulate
  - 0.030 lb/MM Btu (filterable and condensable)
- HCl as acid gas surrogate
  - 0.002 lb/mmBTU (~3ppm)
- Consistency and OST of mitigation system will be critical

# Regulatory

## Options to meet requirements

- Fuel switch
- Equipment additions
  - Wet ESPs
- Dry scrubber
  - Unit size
  - Fuel

### ***Dry Sorbent Injection***

Many will opt for some form of alkaline injection to neutralize the acid gases

# Regulatory

## Most commonly selected options for DSI

- Hydrated lime
  - High BET surface area ( $> 20 \text{ m}^2/\text{g}$ )
  - Fine particle size ( $D_{50}$  of 2-4 microns)
  
- Trona
  - Larger particle size (40-60 microns)
    - On site milling to 15-25 microns

# Questions to answer

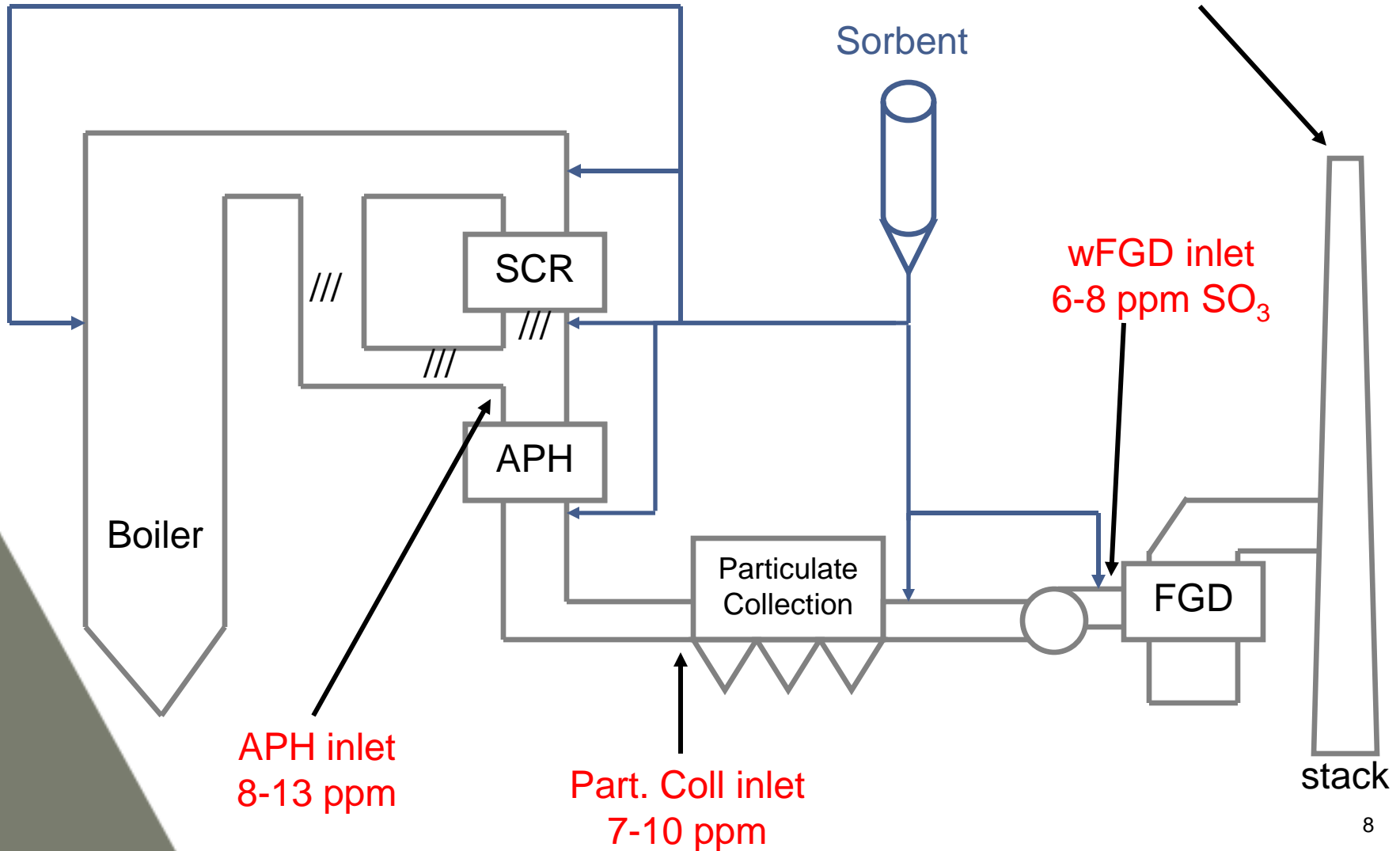
- Where are you and where do you have to get with pollutants?
  - Potential side benefits of acid gas mitigation
- What will your injection system look like?
  - Expectations on Operations and Maintenance
- Implications of sorbent choice
  - Supply
  - Logistics
  - Ash



# Removal - Consider working your way backwards

## Example for SO<sub>3</sub> mitigation

Stack limit: 5 ppm maximum



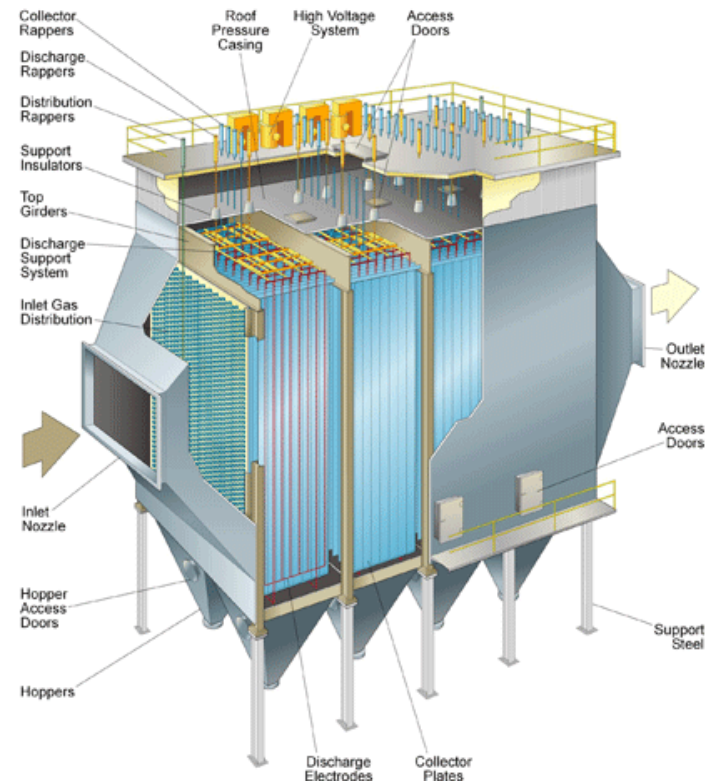
# Removal

## Consider additional benefits of early removal

- Pre-SCR
  - Minimum operating temperature
  - Reduce arsenic poisoning of catalyst (calcium)
- Pre-APH
  - Corrosion protection
  - ABS control
  - Heat rate
- Particulate collection
  - Corrosion
  - Operational
- Wet FGD
  - Corrosion
  - Effects of HCl on scrubber and wastewater treatment

## ESPs - “It depends...”

- Some SO<sub>3</sub> aids resistivity of ash
- Ash resistivity
  - Sodium reduces; Calcium increases
- Unit specific issues
  - Existing ash properties
  - ESP size and efficiency
    - Particulate loading with added sorbent
  - Residence time
    - Short -> more sorbent
      - Manage with split injection?
  - Best to test

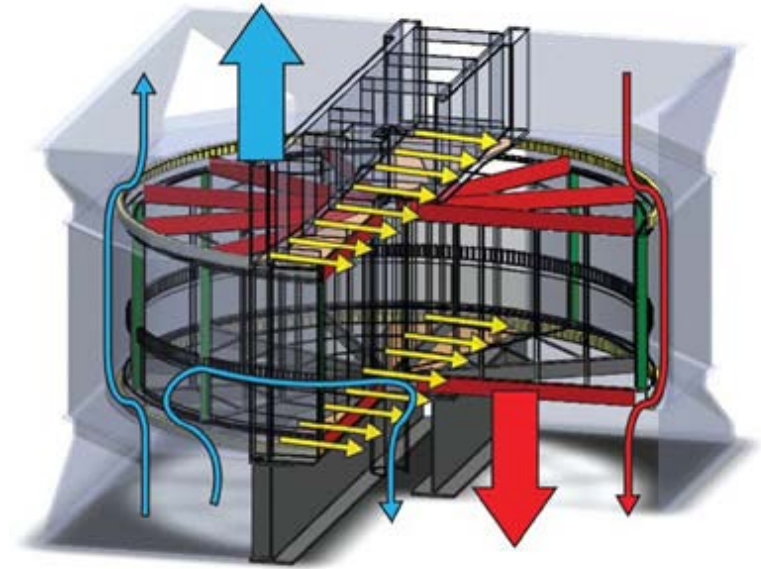


Courtesy B&W

- Lodge Cottrell presentation from 2011 APC conference
  - Reinholdenvironmental.com library section

# Air Preheater

Moving sorbent injection up in the process offers additional benefits:



*Courtesy BreenES*

- 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

# Using Sorbent Prior to APH

- Neutralization of  $\text{SO}_3$  will occur at Pre-APH temperatures
- Sodium sorbents:
  - Byproducts and intermediates can form without temperature and concentration control
  - URS reported on Pre-SCR injection of SBS
- Calcium sorbents
  - No issues with reaction byproducts or intermediates
  - Multiple trials of Pre-APH since '09
  - Utility – Pre-APH since 2010
    - No issues reported



*APH after 8 week trial of PreAPH hydrate injection*

# Hydrated Lime Data

## Pre-APH removals from 2009 trial

- Injection of hydrate at SCR outlet
  - 2 sec residence time before first Breen probe (Pre-APH)
  - Post-APH Breen probe
- Took periods of stabilized operation of feed system and boiler
  - Varied from 1-24 hours
  - Averaged data from Breen probes
  - Hydrate feed rates varied
    - Stoich ratios from 3 to 6 mol Ca/mol SO<sub>3</sub>
      - Unit load varied as well

# Demonstrated Reductions Using In-line Breen Probes

- Good reduction from injection point to Pre-APH measurement point
- In-flight capture results are very good

	<b>SO<sub>3</sub> (ppm)</b>		<b>% Reduction</b>		
	Pre-APH	Post-APH	Pre-APH	Thru APH	Overall In-flight
<i>baseline</i>	31.5	22.5	0%	28%	28%
<i>With hydrate treatment</i>	2.7	<1	>90%	<10%	>96%
	2.9	<1	>90%	<10%	>96%
	3.8	<1	>85%	<10%	>96%
	4.4	1.1	>85%	<10%	>96%
	3.2	<1	>90%	<10%	>96%



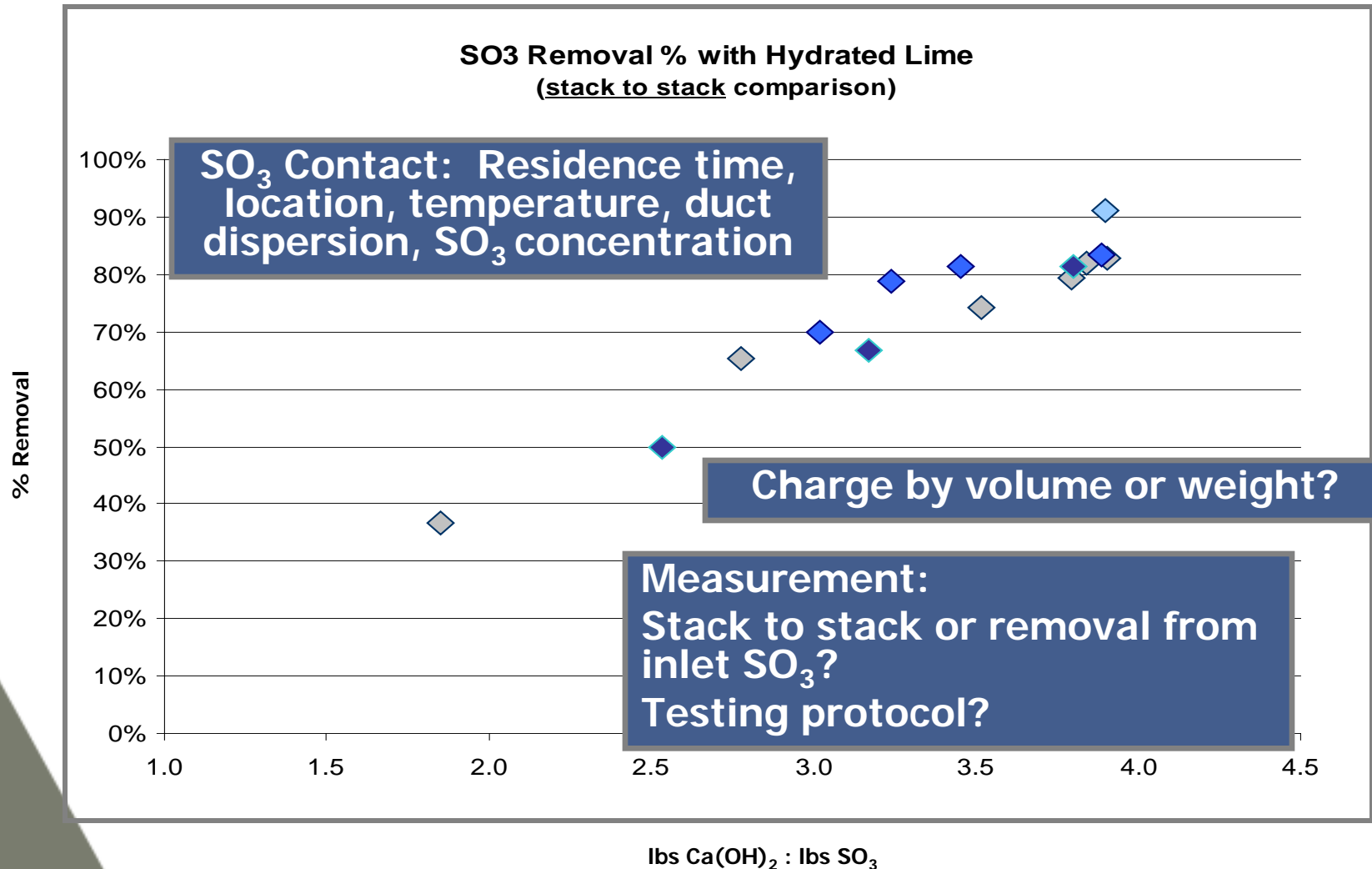
## Removal Rates





# Full Scale SO<sub>3</sub> Mitigation with Hydrated Lime

## Stack to Stack Removal Rates



# SO<sub>3</sub> Mitigation with Hydrated Lime

## Individual Examples

Plant	Location	SO <sub>3</sub> APH	SO <sub>3</sub> <i>Untreated Stack</i>	<i>mol Ca: mol SO<sub>3</sub></i>	<i>lb Ca: lb SO<sub>3</sub></i>	Removal Stack
550 MW	Pre-Wet FGD	20 ppm	12 ppm	4.2 : 1	3.9 : 1	92%
1300 MW	Pre-ESP	30 ppm	20 ppm	4.2 : 1	3.9 : 1	83%
704 MW	Post-ESP	35 ppm	21 ppm	3.8 : 1	3.5 : 1	83%
1150 MW						

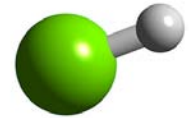
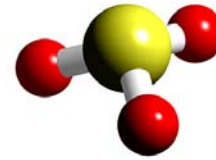
# Case Study - High Opacity with pre-ESP injection

- 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

# Baghouse Removal Data

- Midwestern Utility; med-high sulfur coal
- Injection post APH using temporary injection system
- Test runs measured at baghouse outlet



	Content, ppm		Reduction	
	$SO_3$	$HCl$	$SO_3$	$HCl$
<i>baseline inlet</i>	25	24	---	---
<i>baghouse outlet</i>	16	22.5	36%	<10%
<b>lb Ca: lb <math>SO_3</math></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**

**Lower emissions**

# Baghouse Follow-up Testing Mercury and HCl

- 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
- HCl Removal (SCR outlet ~45 ppm Cl)
  - Under typical conditions of 3 – 4 Ca / S ratios, little HCl removal was detected
  - On over-injection conditions (mid-load, high Ca / S ratios), some HCl removal in flight was detected, about 20 – 30 %.
  - Similar to results from a Southern Co. test program at Mercury Research Center

# Hydrated Lime for HCl Removal Trial at Shawnee



*Summary from report by Brian Williams (TVA) to PCUG, July 2011*

# Hydrated Lime Injection Demonstration

## Goals

- Low Cost HCl Control Desired to Avoid Expediting Scrubber Installation
- Hydrated Lime Injection Testing Program Chartered to:
  - Determine if Hydrated Lime Injection System can Achieve Proposed HAPs HCl Limits
  - Evaluate BOP Impacts on Baghouse and Ash Removal System if Lime Injection Reduces HCl Emissions
  - Evaluate Additional Total Particulate Margin Recovered from Reduced Condensable PM
    - Provides Filterable PM Margin to Allow Maximum Usable Bag Life (current bag life ~ 8 years per unit)
- **CHALLENGING TEST** – The Last Few PPMs Are The Hardest To Remove

# Project Overview and Regulatory Drivers

## Shawnee Plant Background

- Nine (9) 150-MW wall-fired units equipped with Baghouses
- Currently Burning up to 50% PRB Blended with Low Sulfur Colorado Coal
- Unit 6 Holds National Continuous Run Record of 1,093 days set in 2006

Emission	Proposed HAPs Limit	Shawnee U6-10 Stack Baseline (05/2011)
Total Particulate (lb/MMBTU)	0.03	<u>0.016 Total</u> 0.004 filterable 0.012 condensable
Mercury (lb/TBTU)	1.0	< 0.5
Acid Gas Surrogate - SO <sub>2</sub> OR HCl (lb/MMBTU)	0.2 SO <sub>2</sub> OR 0.002 HCl	0.63 SO <sub>2</sub> 0.003 HCl



# Emissions Control

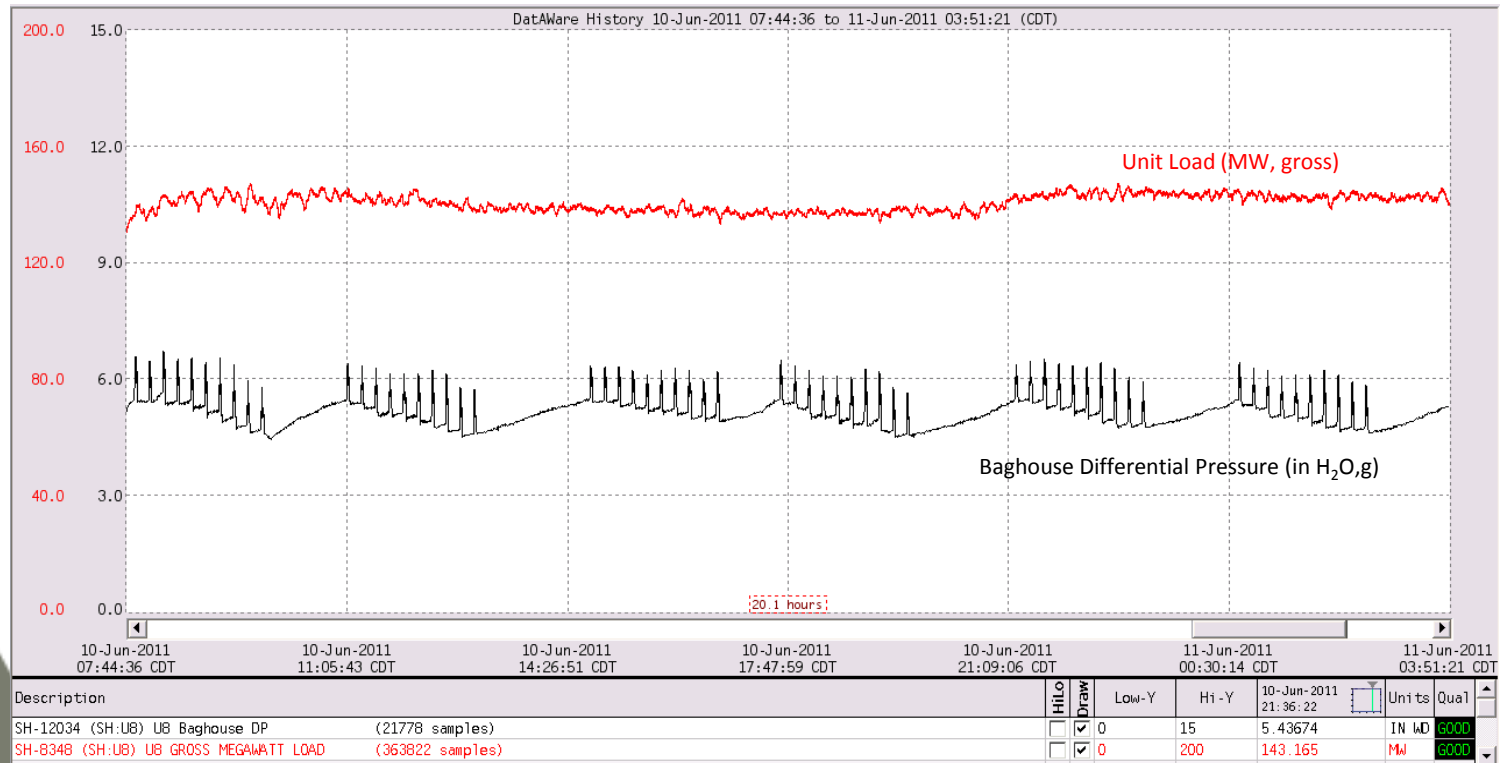
- HCl controlled, especially after one day seasoning of baghouse
- No balance of plant impacts in baghouse operations
- Particulate emissions reduced by 44%

Hydrate Injection Rate	HCl (lb/MMBTU)	HF (lb/MMBTU)	H <sub>2</sub> SO <sub>4</sub> (ppmvd)
<b>0 lb/hr - Baseline</b>	<b>0.0030</b>	<b>0.0045</b>	<b>1.3</b>
<b>350 lb/hr</b>	<b>0.0005</b>	<b>0.0006</b>	<b>0.37</b>
<b>350 lb/hr</b>	<b>0.0007</b>	<b>0.0007</b>	<b>0.35</b>
<b>300 lb/hr</b>	<b>0.0008</b>	<b>0.0006</b>	<b>0.35</b>

# Objective 2 - Balance of Plant Impacts

## Baghouse and Ash System Performance – No Issues Identified

- Full Pressure Loss Recovery Achieved (~4.4 in H<sub>2</sub>O,g)
- The DP Cleaning Cycle Dwell Time Shortened (~ 2hrs to ~1.5 hrs) as expected
- No Ash Handling System Impacts (Hoppers Pulling Empty)



# Conclusions and Path Forward

- Shawnee can achieve compliance with proposed HAPs regulations via a low cost hydrated lime injection system
  - Postpones unit idling/retirement or FGD installation.
- Hydrated Lime System
  - Can later be used with SCR installation to mitigate  $\text{SO}_3$
  - Consider longer term (~2 month) demonstration on temporary system with HCl CEMS
    - Longer-term BOP issues
    - Process variability to minimize project and operational risk.
- Consider Clean Air Strategy changes at other sites slated for dry scrubbers.

# Material Handling



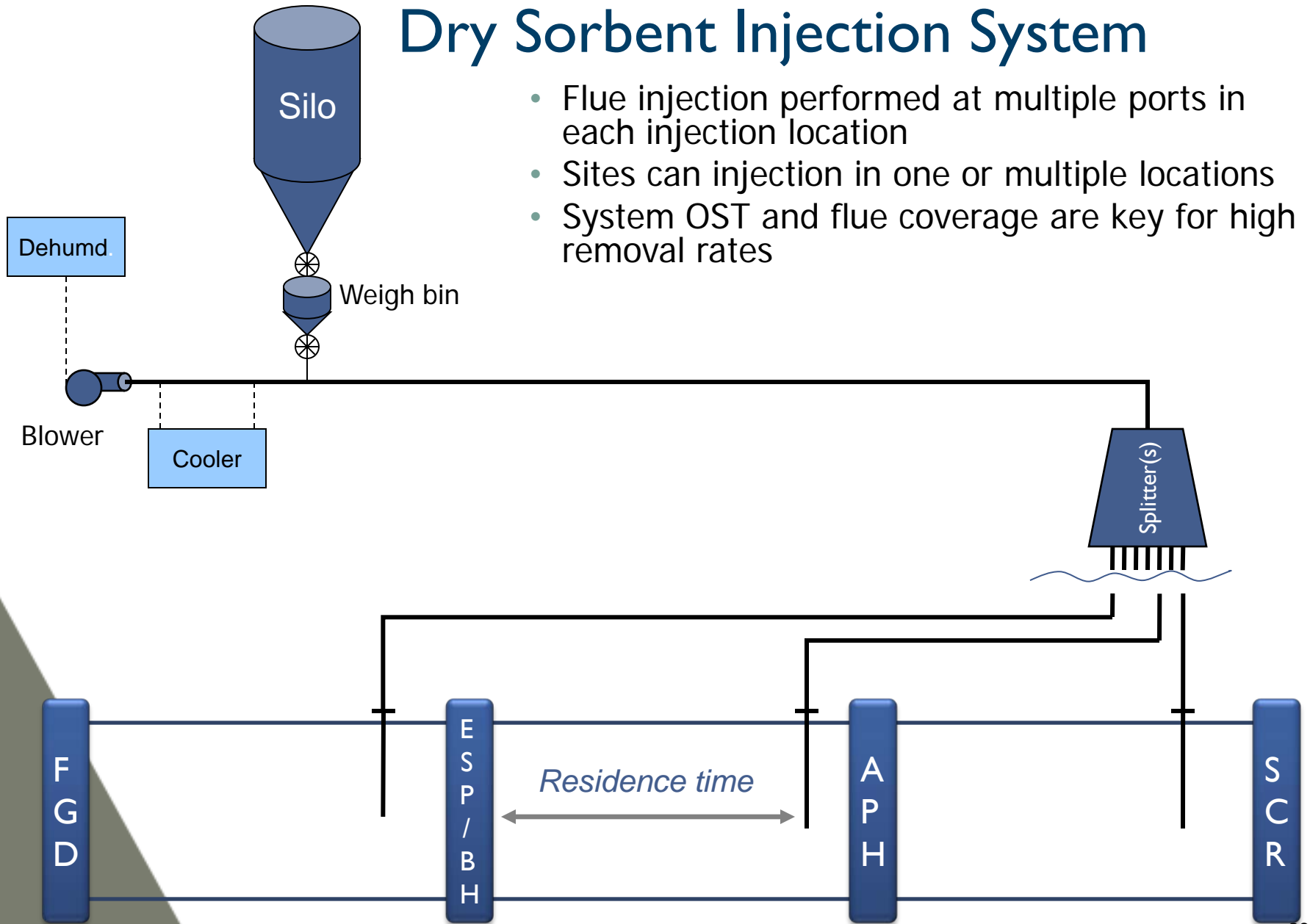
# Dense vs. Dilute Phase Conveying

- 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*

# Dry Sorbent Injection System

- Flue injection performed at multiple ports in each injection location
- Sites can injection in one or multiple locations
- System OST and flue coverage are key for high removal rates



# System Installation

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



*J. Wilson, DHUG, 2010*



*J. Wilson, DHUG, 2010*



# Design Challenges – Understanding Air Dilute Phase Systems

- 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





## Questions

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# Possible Explanations for Reduced PM Measured During Hydrated Lime Testing

- Triboelectric theory (Observed at Widows Creek, etc.)
  - Friction causes particles to become charged
  - One material positively charged, other material negatively charged
  - Fly ash (alumina and silica oxides) are typically negative
  - Hydrated lime, pneumatically conveyed, should be positive
  - Opposite charges attract, agglomerating fine particulate
- Measurement of Condensables on Particulate Filters (at Paradise)
  - Prescribed filter bake times do not eliminate all acid condensables
  - Baseline PMs include high acid concentrations
  - Hydrated lime injection PMs reduce acid on filters, lowering PMs
- Combination of the above and other unknown effects