

# Worldwide Pollution Control Association

WPCA-Duke Energy  
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# Using Dry Sorbent Injection to Control SO<sub>3</sub> and HCl Emissions

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Discovering what's possible with calcium™

Duke -WPCA  
Plainfield IN  
October 12, 2011

# Overview

- Regulatory
- Removal Rates and Usage
  - ESP
  - Baghouse
  - Options for system flexibility
- DSI Trial – HCl removal on a baghouse unit
- Material handling recommendations



# 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

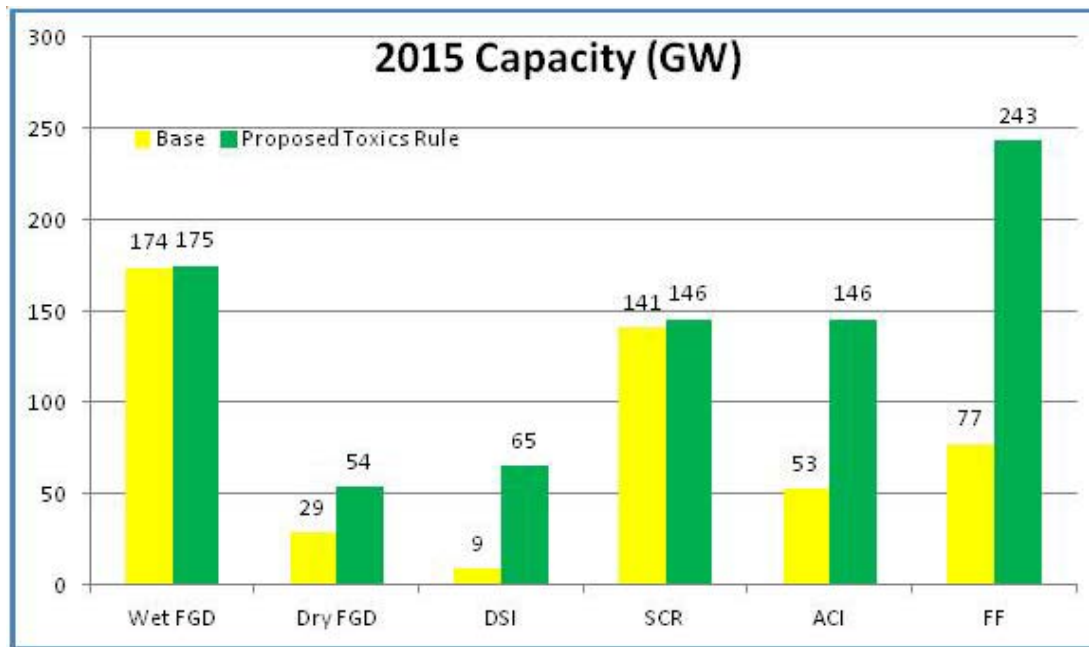


# Regulatory Acid Gas Mitigation Outlook

- 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

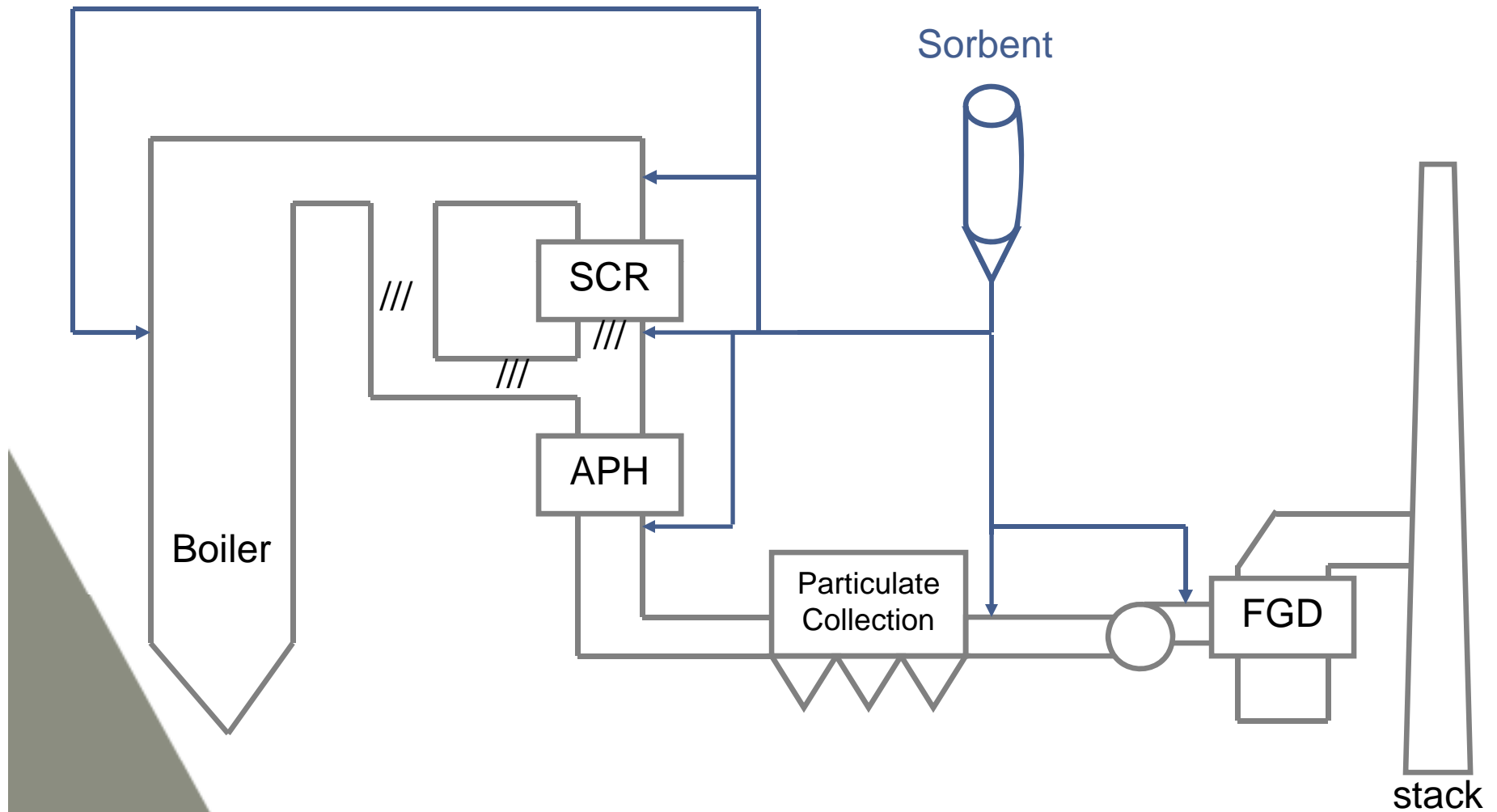
# Projected Pathways

- Fabric filter installations – 166 GW new
- ACI – 93 GW
- DSI – 54 GW



**Sorbent injection is key to meeting regulations  
in conjunction with these projections**

# Injection Location Options for Dry Sorbents



# Key Criteria for Hydrated Lime

<b>Property</b>	<b>Industry Typical</b>	<b>Flue Gas Grade</b>
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, -325 mesh, %wt	~ 92%	~ 92%
Moisture, %wt	≤ 1.0%	≤ 1.0%

**High surface area hydrated lime and high % Available Calcium ensure best utilization rates for acid gas mitigation**



## Removal Rates

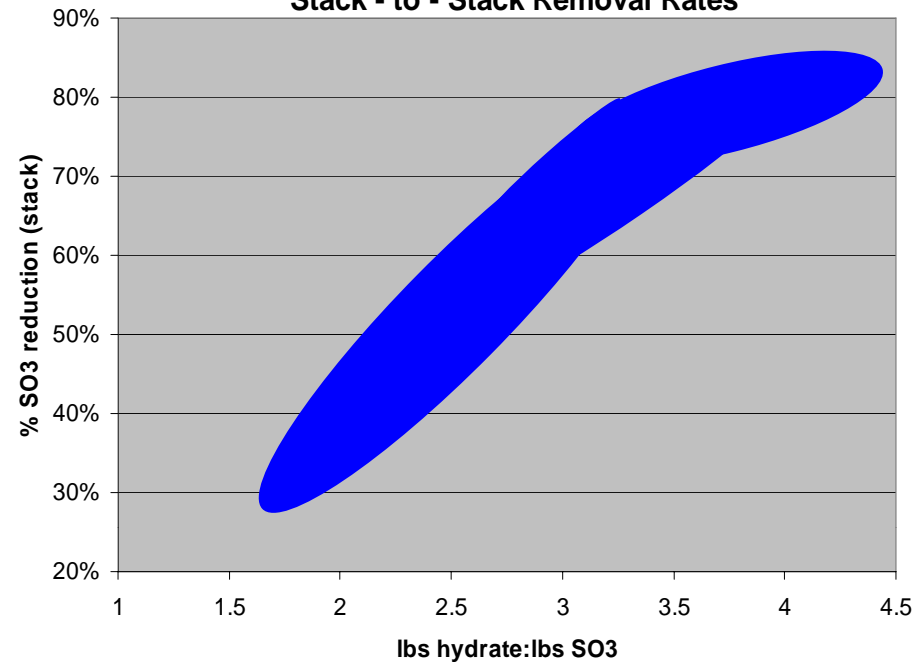


# Typical Removal Rates

## - ESP systems -

- Residence time effects
  - Short (<2 sec) will require more sorbent
- Injection system efficiencies
  - Flue gas coverage
  - Feed system
    - By weight or volume
- Baseline SO<sub>3</sub> level
  - Better % reduction on units with high baseline SO<sub>3</sub>

Hydrated Lime for SO<sub>3</sub> Mitigation  
Stack - to - Stack Removal Rates



### Removal Rate Examples

Plant	SO <sub>3</sub> <i>Untreated Stack</i>	<i>mol Ca: mol</i> SO <sub>3</sub>	Removal <i>Stack</i>
550 MW	12 ppm	4.2 : 1	92%
1300 MW	20 ppm	4.2 : 1	83%
700 MW	21 ppm	3.8 : 1	83%

# Benefits of Fabric Filters vs. ESP Sorbent Perspective

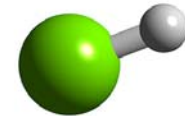
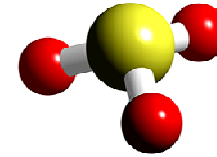
- Fixed bed of ash and sorbent effectively adds residence time
  - Improve utilization
  - Reduce emissions
- Resistivity is not an issue
  - Flexibility on sorbent type
  - Flexibility on amount of sorbent

## *Questions:*

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

# Baghouse Removal Data

- Midwestern Utility; med-high sulfur coal
- Hydrate injection post APH using temporary injection system
- Test runs measured at baghouse outlet
  - Controlled condensate ( $SO_3$ ) and 26A ( $HCl$ )



	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%

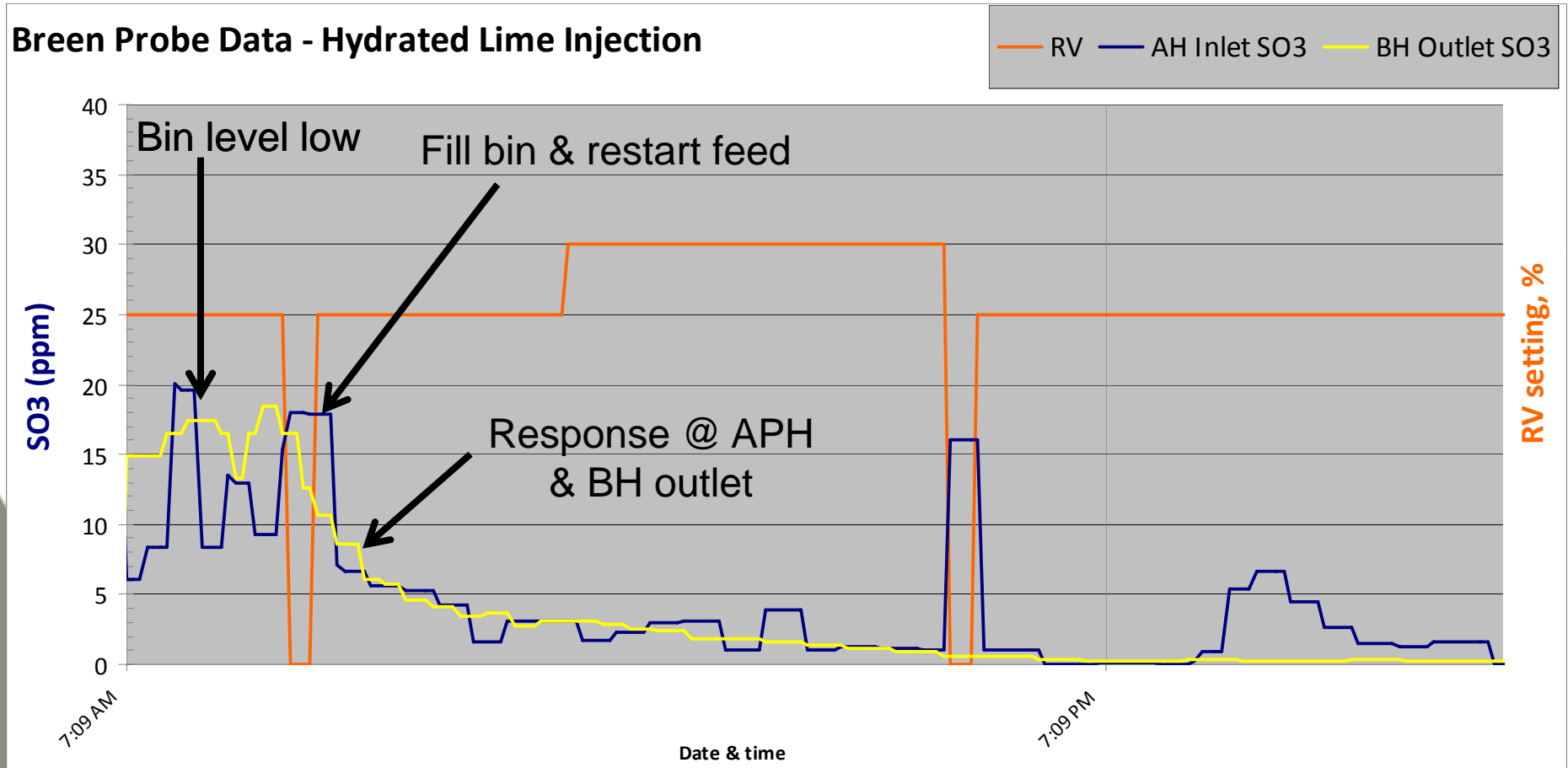
**Reduced sorbent usages vs ESP**

**Lower emissions**

# Baghouse Example

## Response to Starting Hydrate Lime Feed

### Hydrate Injection at SCR Outlet

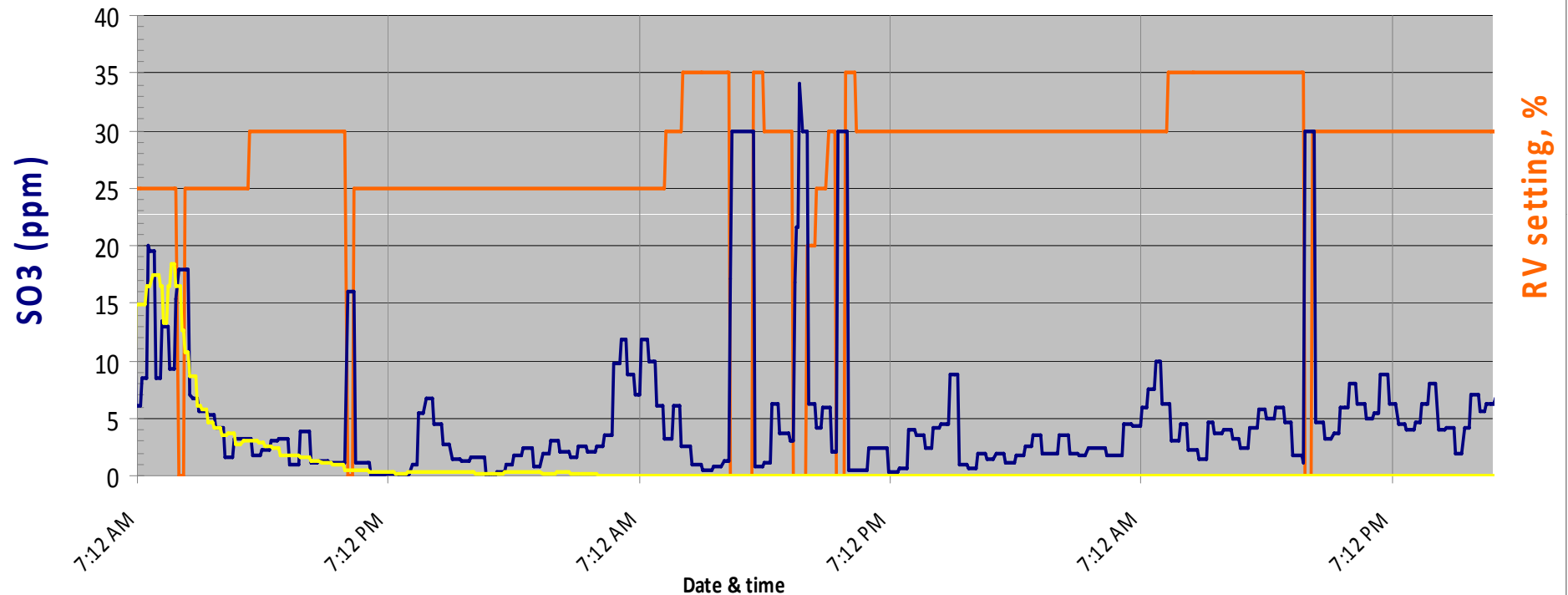


# Baghouse Outlet Performance Data

## Breen Probe Data - Hydrated Lime Injection

Injection at SCR outlet

RV AH Inlet SO<sub>3</sub> BH Outlet SO<sub>3</sub>



- BH outlet (yellow) shows steady control, even through brief feed stoppages
- Good in-flight capture of SO<sub>3</sub> (blue) at APH inlet test location

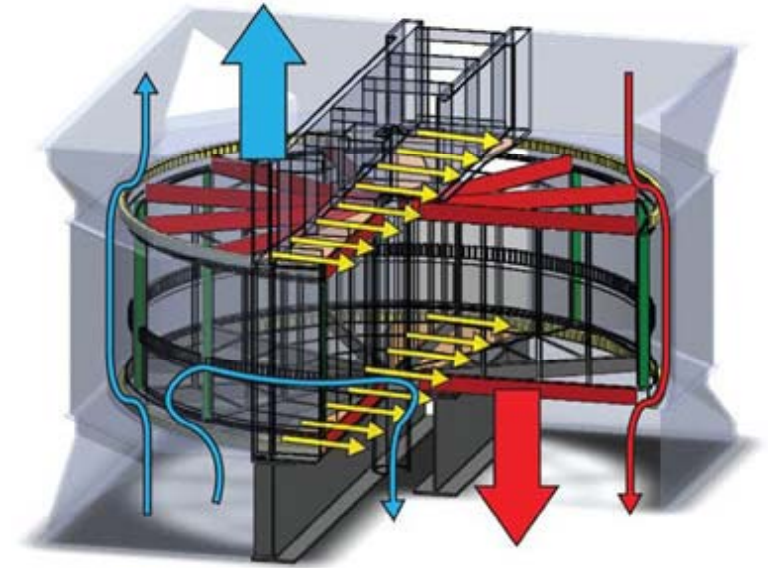


## Consider additional benefits of early removal

- Pre-SCR
  - Minimum operating temperature
  - Reduce arsenic poisoning of catalyst (calcium)
- Pre-APH
  - Corrosion protection
  - ABS control
  - Heat rate
- Activated Carbon Injection
  - Better utilization of carbon with SO<sub>3</sub> absorption
- Particulate collection
  - Corrosion
  - Operational
- Wet FGD
  - Corrosion
  - Effects of HCl on scrubber and wastewater treatment

# 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
- 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
  - Can utilize in conjunction with ACI for optimal SO<sub>3</sub> and Hg capture

	<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%

# Baghouse Testing

## Mercury and HCl with SO<sub>3</sub> present

- 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 *in-flight* 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

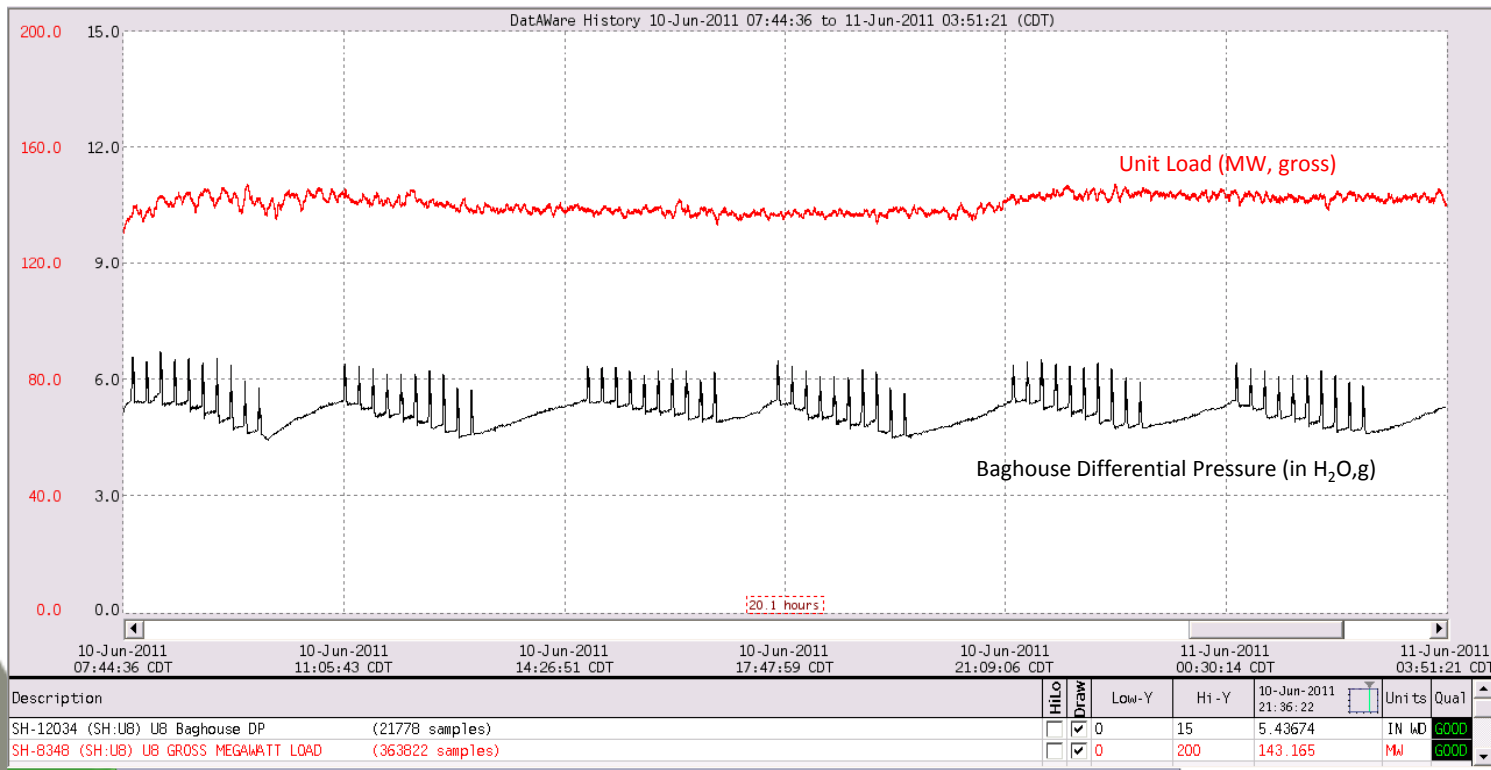
- HCl controlled, especially after one day seasoning of baghouse
- No balance of plant impacts in baghouse operations
- Particulate emissions reduced by 44%

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 SO<sub>3</sub>
  - 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



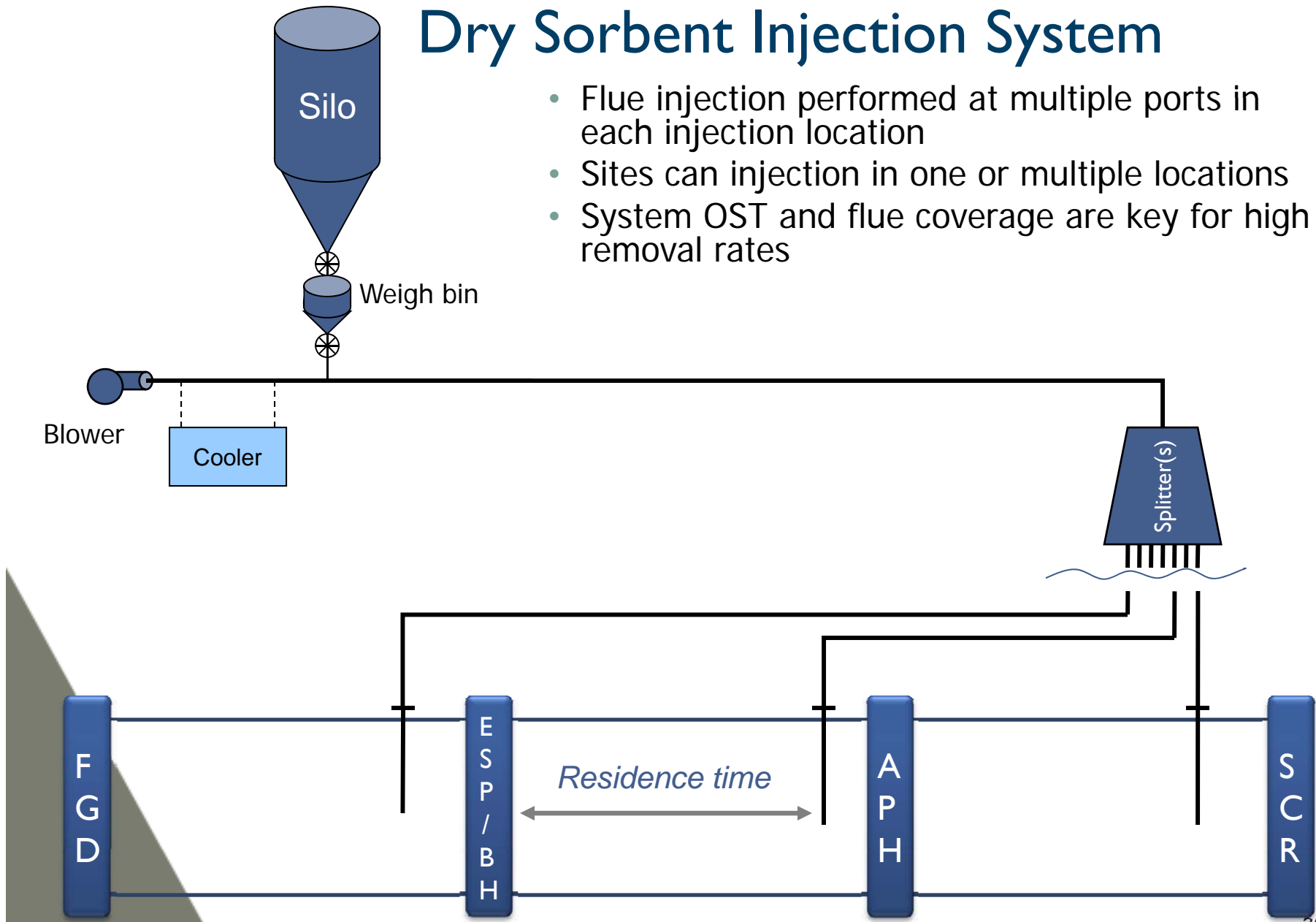
# Dense vs. Dilute Phase Conveying

- 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

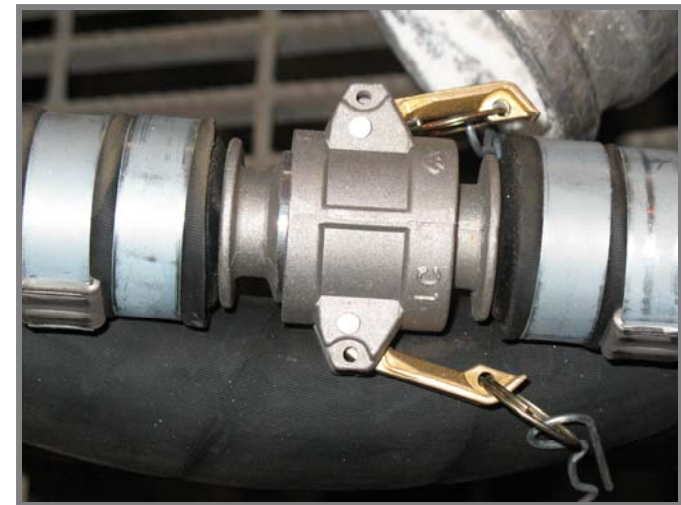


# System Installation

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



*J. Wilson, DHUG, 2010*



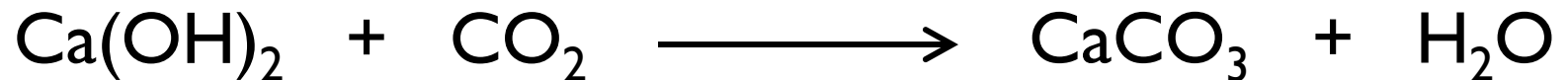
*J. Wilson, DHUG, 2010*

# 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

# Potential Conveying Challenges

- 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

## Recommended System

- Variable speed feed blower
- Conveying air temperature  $< 105$  °F
- 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  $> 3300$  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

- 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



## Questions

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