Dry Sorbent Injection with Hydrated Lime for Acid Gas Control to Achieve regulatory compliance while burning various coals

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AGENDA

- Introduction
- Proven, Versatile, Mature & Attractive Technology
- Balance Of Plant Impacts & Improvement
- Cost Effectiveness of Advanced Hydrate Limes
- Applications and Case Studies
- Discussion/Questions

Introduction

Introduction

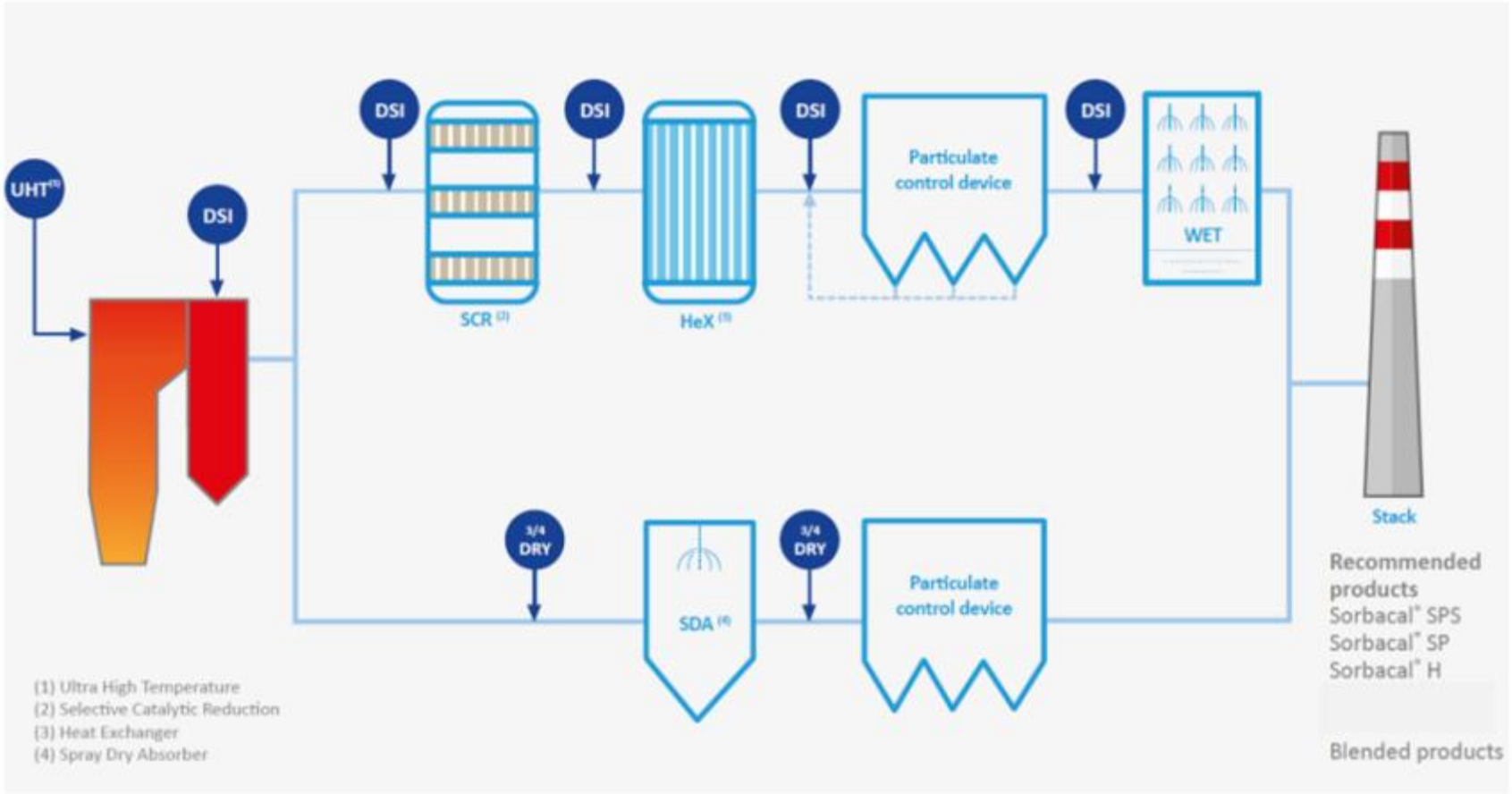
- **Dry Sorbent Injection (DSI) is a technology of choice…**
  - Low CapEx solution
  - Easy retrofit – small installed foot print
  - Flexible and customizable
- **…that continues to evolve as an economical solution…**
  - Improved equipment design based on years of operating experience
  - Enhanced sorbents provide solutions for new applications and better cost to old ones
  - Improved mixing technologies optimize operating costs/performance
- **…providing solution for new and existing customers.**
  - Regulatory compliance
  - High removal performance capability of enhanced hydrated limes
  - Likely the most economical solution for short life-cycle cost analysis
  - Low by-product/CCR concerns/costs

Proven, Versatile, Mature & Attractive

Proven Technology

- **Hundreds of DSI systems installed in the United States**
  - Widely installed in the coal-fired Utility Sector
  - Growing penetration in the Industrial Sector
  - Considerable interest from the Industrial Boiler Sector
    - IB MACT applications
    - Comfortably achieving compliance levels
- **Versatility**
  - Broad application: CFB, PC-fired, Stoker
  - 20MW to 800MW applications
  - Control Hydrogen Chloride (HCl) …plus, SO_3 HF and SO_2

Versatile Technology



Mature Technology

> Pioneered in the late 1980's and early 1990s

- > DOE National Energy Technology Laboratory (NETL) began studying "DSI with calcium sorbents"
- > Response to the compliance challenge from CAAA of 1990
- > Duct injection of hydrated lime for SO_2 control
- > First systems were crude, material-handling approaches to a chemical application problem

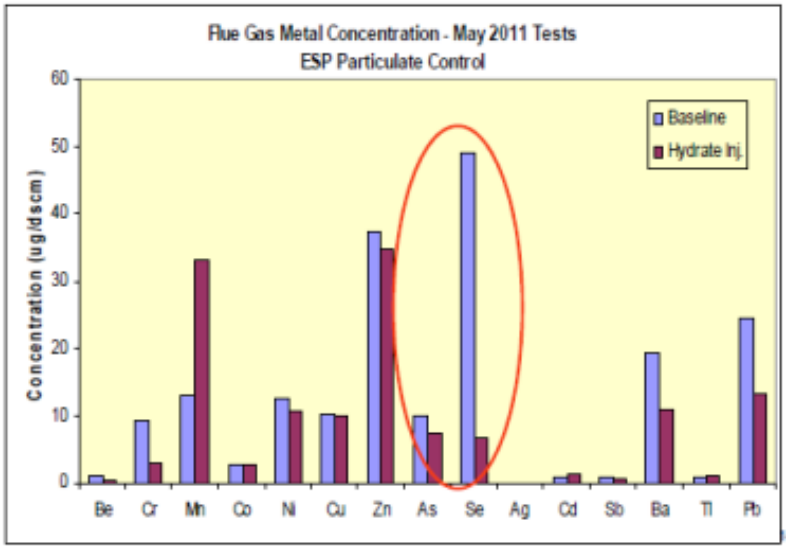
> Second-Gen Systems

- > Early 2000's – Hydrated lime for SO_3 control
  - > e.g., TVA Widows Creek
  - > Corrosion control, plume mitigation, acid deposition, enhanced PM control Dilute-phase conveyance with a more sophisticated destitution

> Current State of the Art

Air Island	Material Storage Island	Delivery and Distribution
Optimized dilute-phase conveyance	Advanced multi-stage LIW	Engineered manifolds
Dehumidifiers - Aftercoolers	Precise feeds	Modelled lance placement
	Feed forward-feed back logic	Installed diagnostics
	Flow enhancing technologies	In-duct Static Mixers (low dP)

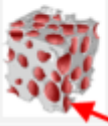
Attractive Technology



- **Low Capital Cost**
- **Small Footprint**
- **Broad Co-Benefits**
  - Heat rate reduction through lower Air Heater (AH) deposition
  - Lower AH outlet temps facilitate better electrostatic precipitator (ESP) operations
  - Vapor-phase trace metal collection
  - Greater fuel flexibility
  - Enhance Mercury (Hg) capture effectiveness

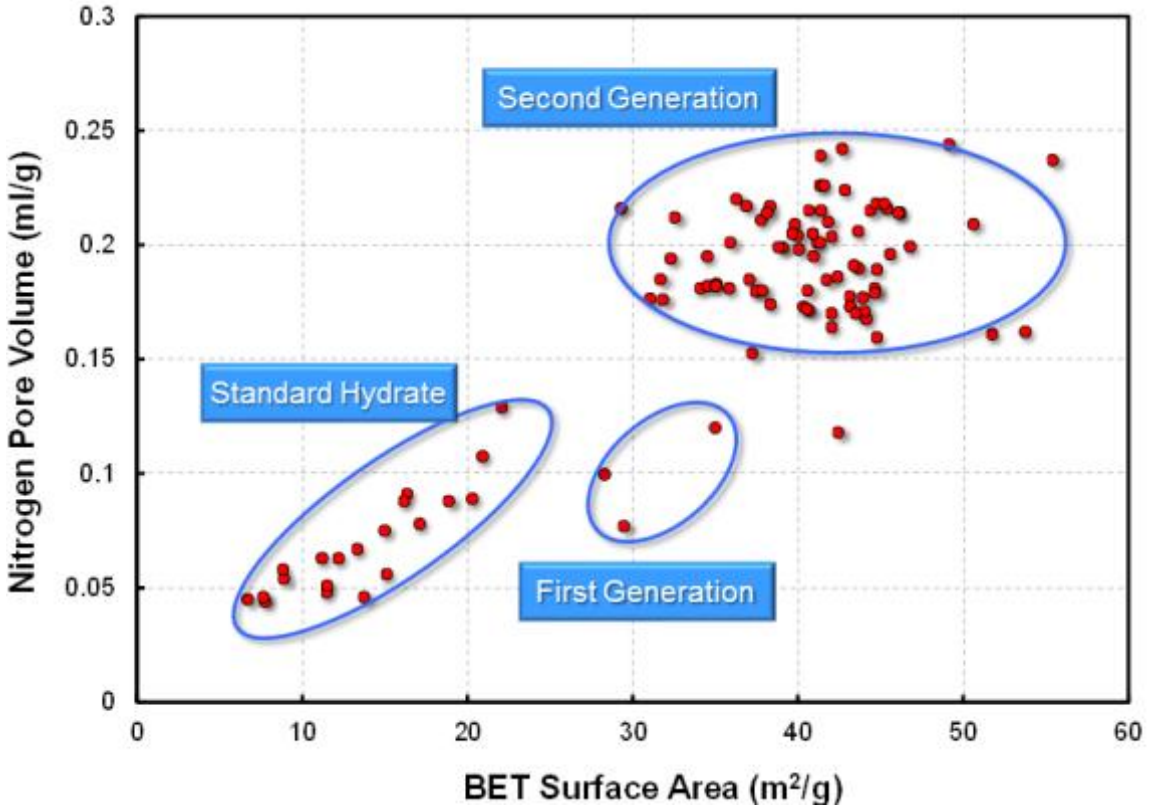
Enhanced Hydrated Lime

- **Hydrate lime suppliers have pursued numerous products enhancement to improve performance**
  - Improved reactivity
  - Increased chemical utilization
  - Physical modification
  - Surface additives

Sorbent	Standard Hydrated Lime	Sorbacal® H	Sorbacal® SP	Sorbacal® SPS	Units
Figure					–
Typical Available $Ca(OH)_2$	92 – 95	93	93	93	%
Typical Surface Area	14 – 18	> 20	~40	~40	m^2/g
Typical Pore Volume	~0.07	0.08	~0.20	~0.20	cm^3/g

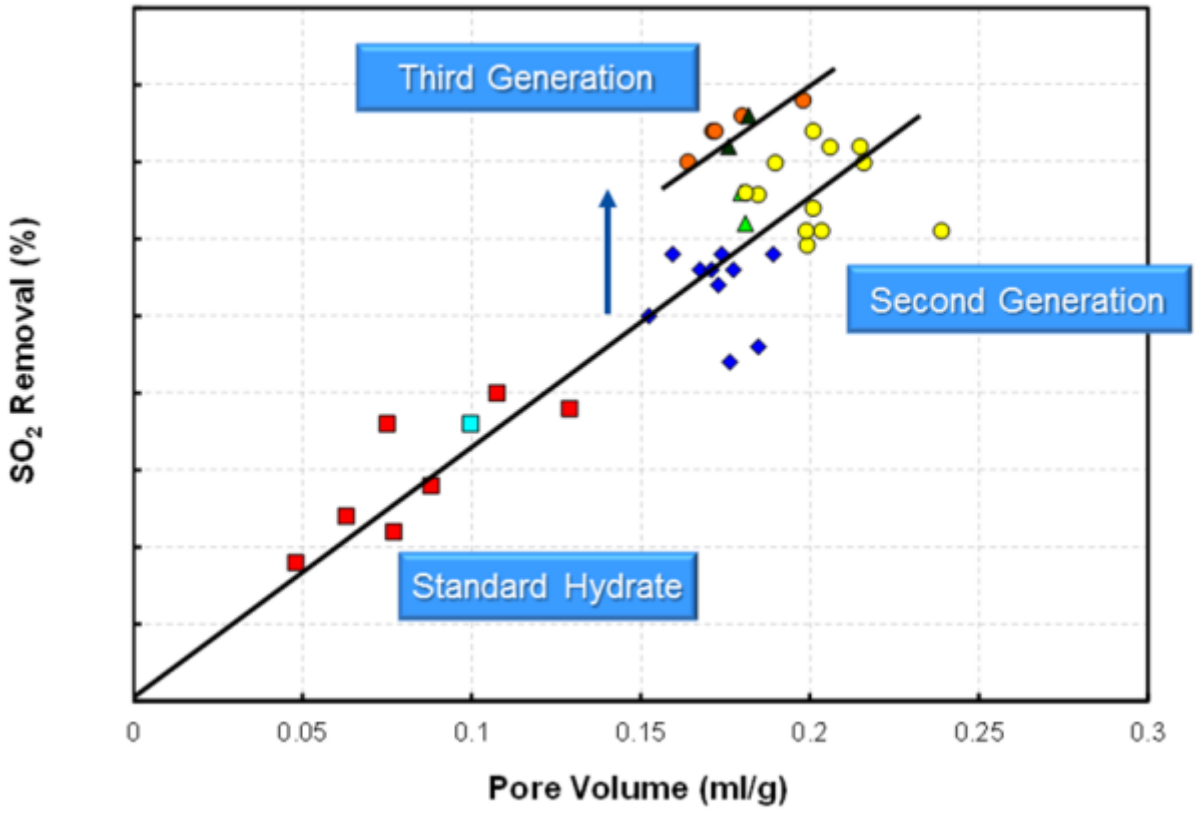
Reactivity Property Relationships

> Surface Area and Pore Volume Product Development



Evolution of High Performance Products

> Surface Area and Pore Volume Product Development



Balance of Plant Impact/Improvements

Balance of Plant

- **Reduced O&M on downstream equipment**
  - Reduced corrosion
  - Reduced fouling

Protect Equipment and Ductwork - corrosion protection

Maintain AH cleanliness - lower dP thru condensable removal

Improved Operating Costs – heat rate improvement

Lower heat rate means less coal burned and lower CO_2 emissions
1 lb coal ~ 2.5 lb of CO_2 emitted

Improved Cost Effectiveness with Enhanced Hydrated Limes

Cost Effectiveness

- **Greater sorbent efficacy means less sorbent consumed for equal performance**
  - Better $USD/lb of acid gas removed
  - Higher chemical utilizations
  - Lower stoichiometric ratios
  - Lower mass injection ratios
- **Lower mass loading means**
  - Less wear and tear on particulate control devices
  - Lower ash/CCR volumes to dispose of or manage
  - Lower truck/delivery traffic
  - Lower incidences of system maintenance

Cost Effectiveness

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Hydrated Lime is a Value Choice not a Price Decision

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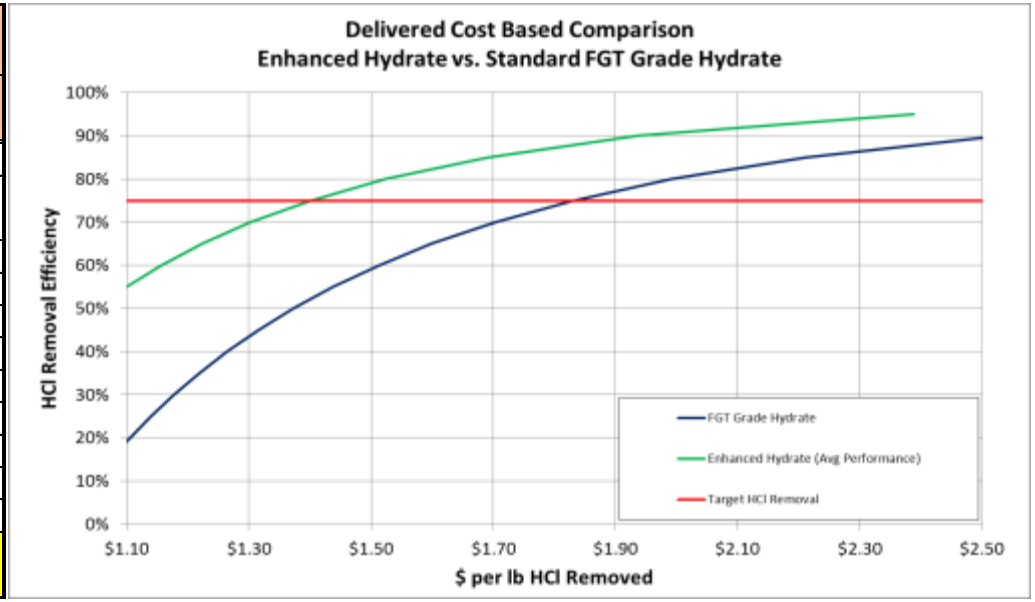
Cost Effectiveness

> A recent University procurement example…

Sorbent	Enhanced Hydrate	Standard Hydrate	
	Avg Performance	Base	
Delivered Price	$246.05	$193.00	per Ton
Improvement in Performance	40%	0%	
Usage	450	750	Tons
Operating Hours	5,760	5,760	Hours
Average Usage	0.078	0.130	Tons/Hour
Average Inlet HCl	40	40	ppmv
	18.3	18.3	lb/hr
Target HCl	10	10	ppmv
Target HCl Removal	75%	75%	
HCl Removed	13.7	13.7	lb/hr
Delivered Sorbent Cost	$19.22	$25.13	per Hour
Delivered Sorbent Cost per lb HCl Removed	**$1.40**	**$1.83**	**per lb HCl Removed**

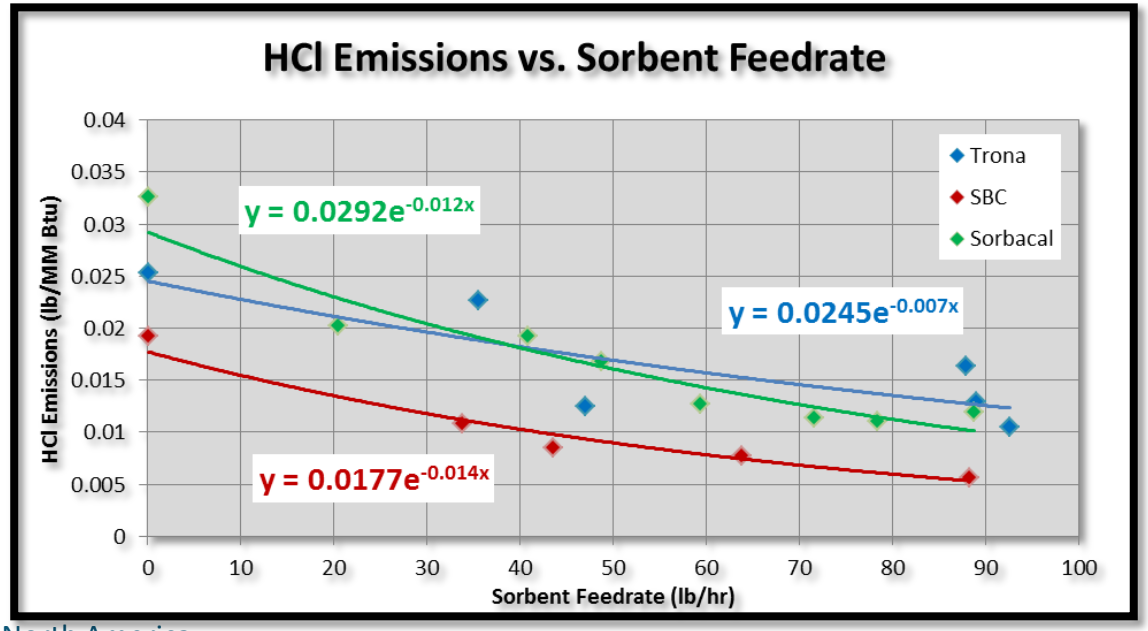


Hydrated Lime is a Value Choice not a Price Decision

Case Studies

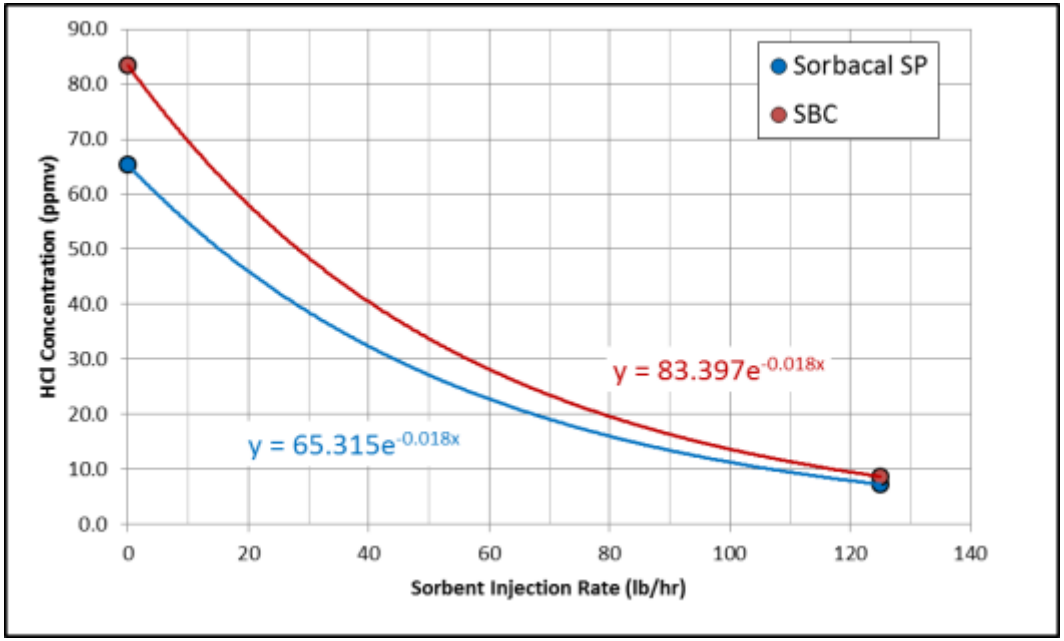
Case Study #1

- **Biomass-fired boiler – HCl control study**
  - Three sorbents were tested: enhanced hydrate, trona and SBC
  - Injection at the BHF inlet: 350-375F
  - Enhanced hydrate was within 15% of the relative performance of SBC & twice as effective as trona



Case Study #2

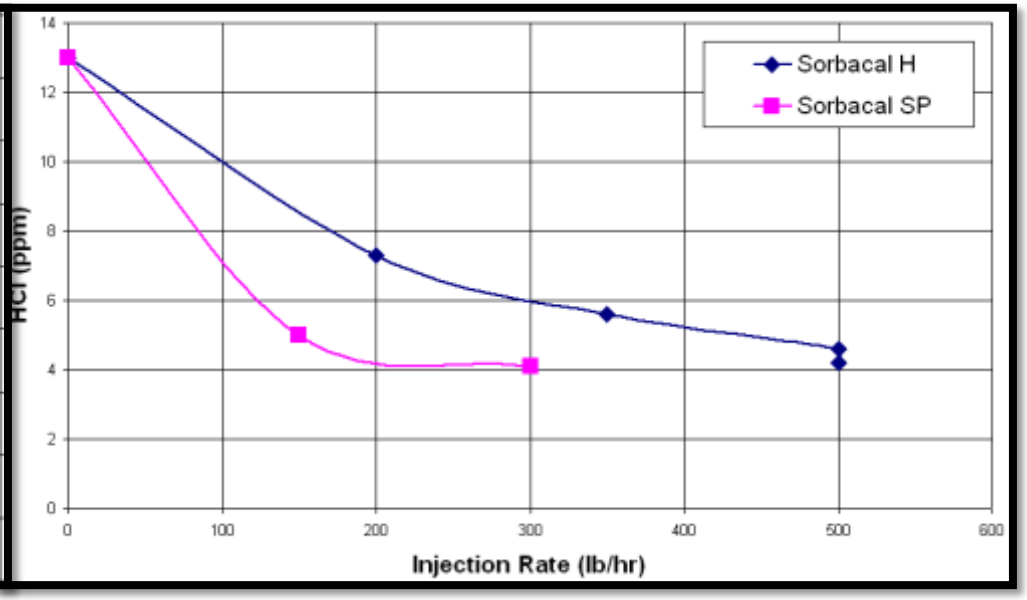
- **CFB boiler – HCl control study**
  - Enhanced hydrate and SBC were tested
  - Injection at the BHF inlet: 350-375F
  - Enhanced hydrate performed similarly to SBC



Case Study #3

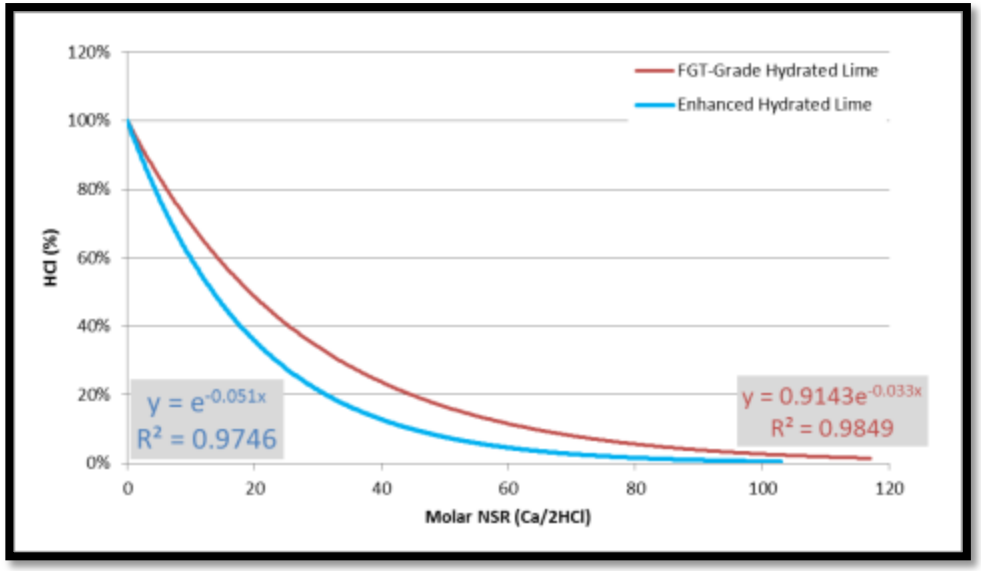
- **Stoker boiler – HCl control study**
  - Two enhanced hydrates were tested
  - Injection immediately upstream of the AH: 440F
  - Enhanced hydrate performed similarly to SBC

Type	Spreader stoker with ESP (circa 1975)
Fuel	low sulfur coal (1.8% S) *
Heat Input (mmBTU), max. heat	206.3
Econ. Inlet Temp. (°F)	610
Air Heater Inlet Temp. (°F)	440
Dust Collection Inlet Temp (°F)	350
Gas Volume Flow (acfm) ESP/ baghouse inlet	120,000
HCl – baseline (ppm)	15
Hg – Baseline (ppt/mmBTU)	4



Case Study #4

- **Stoker boiler – HCl control study**
  - Enhanced hydrate and FGT-Grade Hydrate were evaluated
  - Injection at the AH outlet/RAFF inlet
  - Enhanced hydrate performed roughly 30% better than std hydrate



Gas temp = 540°F
H2O in wet gas, % by wt. = 11.75%
SO2-to-HCl ratio (lb/lb) = 92.6

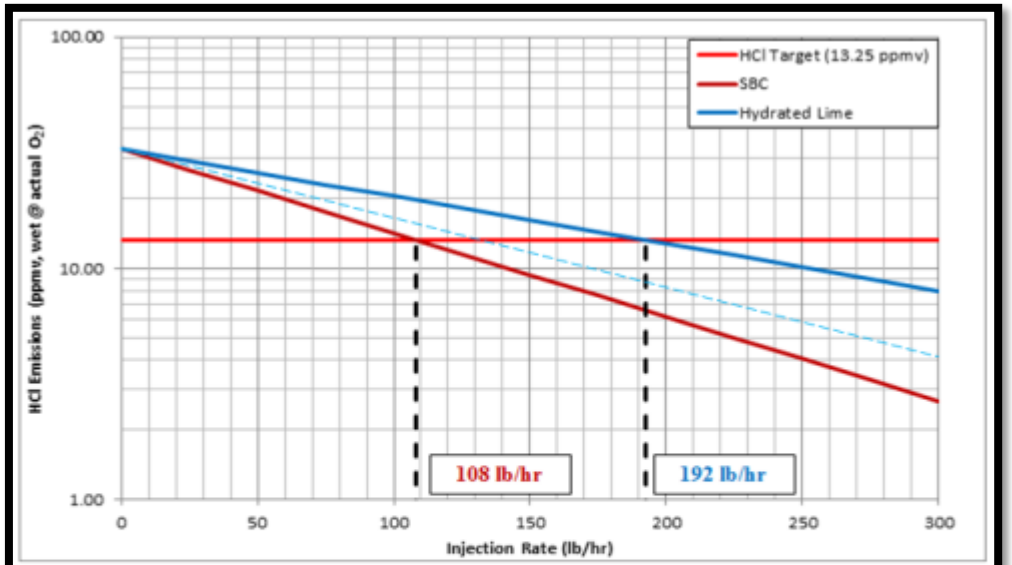
Case Study #5

> PC Wall-fired boiler – HCl control study

> Standard hydrate and pre-milled SBC were tested

> Injection upstream of the fabric filter post air pre-heater @ 360 F

> Substantial cost differential between the sorbents.



SORBENT	Price per Ton Delivered ($USD)	Sorbent Injection Rate (lb/hr)	Expense to achieve compliance ($USD/hr)
pre-milled SBC (note - price assumed)	$ 334.00	108	$ 18.04
Standard Grade Hydrated Lime	$ 193.00	192	$ 18.53
Enhanced Hydrated Lime(projected)	$ 246.05	134	$ 16.49

Summary

- **Dry Sorbent Injection (DSI) is a broadly implemented acid gas control technology**
- **The higher efficacy of enhanced hydrated limes means:**
  - Reduced O&M due to reduced corrosion and fouling
  - Lower ash/CCR generation rates
  - Improved operating cost
  - Greater assurance of obtaining compliance goals
- **Enhanced hydrated lime is a for cost-effective choice for acid gas control**

Hydrated Lime is a Value Choice not a Price Decision

Discussion/Questions?

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