REINHOLD ENVIRONMENTAL Ltd.

2010 APC Round Table & Expo Presentation

July 18-20, 2010, in Concord, NC / Hosted by Duke Energy

MISSISSIPPI LIME™
Discovering what's possible with calcium™

Handling Hydrated Lime from a Lime Supplier's Perspective

APC Roundtable & Expo
Reinhold Environmental

July 20, 2010

Agenda

- Background on Hydrated Lime
- Injection System Basics and Challenges
- Controlling Carbonate Scale Formation

Why Use Hydrated Lime

$$Ca(OH)_2 + SO_3 \longrightarrow CaSO_4 + H_2O$$

$$Ca(OH)_2 + HX \longrightarrow CaX_2 + H_2O$$

X = halogen

- Hydrate is used as received
- Cost effective
- Proven successful in various injection locations
  - Post-ESP
  - Pre-ESP
  - Pre-APH

Key Sorbent Criteria
Available Calcium and Surface Area

Property	Industry Typical	Flue Gas Grade
Surface Area, m^2/g	14 – 23	$\geq$ 21
Avail. Calcium Hydroxide, %wt	89 - 97%	> 95%
Total Calcium Hydroxide, %wt	92 - 99%	92 - 99%
Porosity, cm^3/g	0.07 – 0.14	0.12
Particle Size, -325 mesh, %wt	~ 92%	~ 92%
Moisture, %wt	$\leq$ 1.0%	$\leq$ 1.0%

SO_3 Mitigation requires high surface area hydrated lime
High % available ensures best utilization rates

Is High Surface Area Hydrate Necessary?

- EPRI*: Low surface area material not successful, high surface area hydrate successful

- MLC followed a low surface area hydrate injection trial and the site experienced <u>significant</u> improvement in SO_3 removal

- Use of low surface area material will require significantly more hydrate to meet SO_3 removal targets
  - Little to no multipollutant benefits

* *SO3 Mitigation: Current Utility Operating Experience.* EPRI, Palo Alto, CA: 2006. 1010754.

Hydrated Lime as SO_3 Sorbent

Key Factors for SO_3 Removal

- Sorbent reactivity
  - Surface Area
  - Available Calcium
- Conveying material from silo to duct
  - Handling system design
  - Hydrated lime characteristics
- Dispersion in flue gas
  - Residence time
  - Flow splitting
  - Injection lances

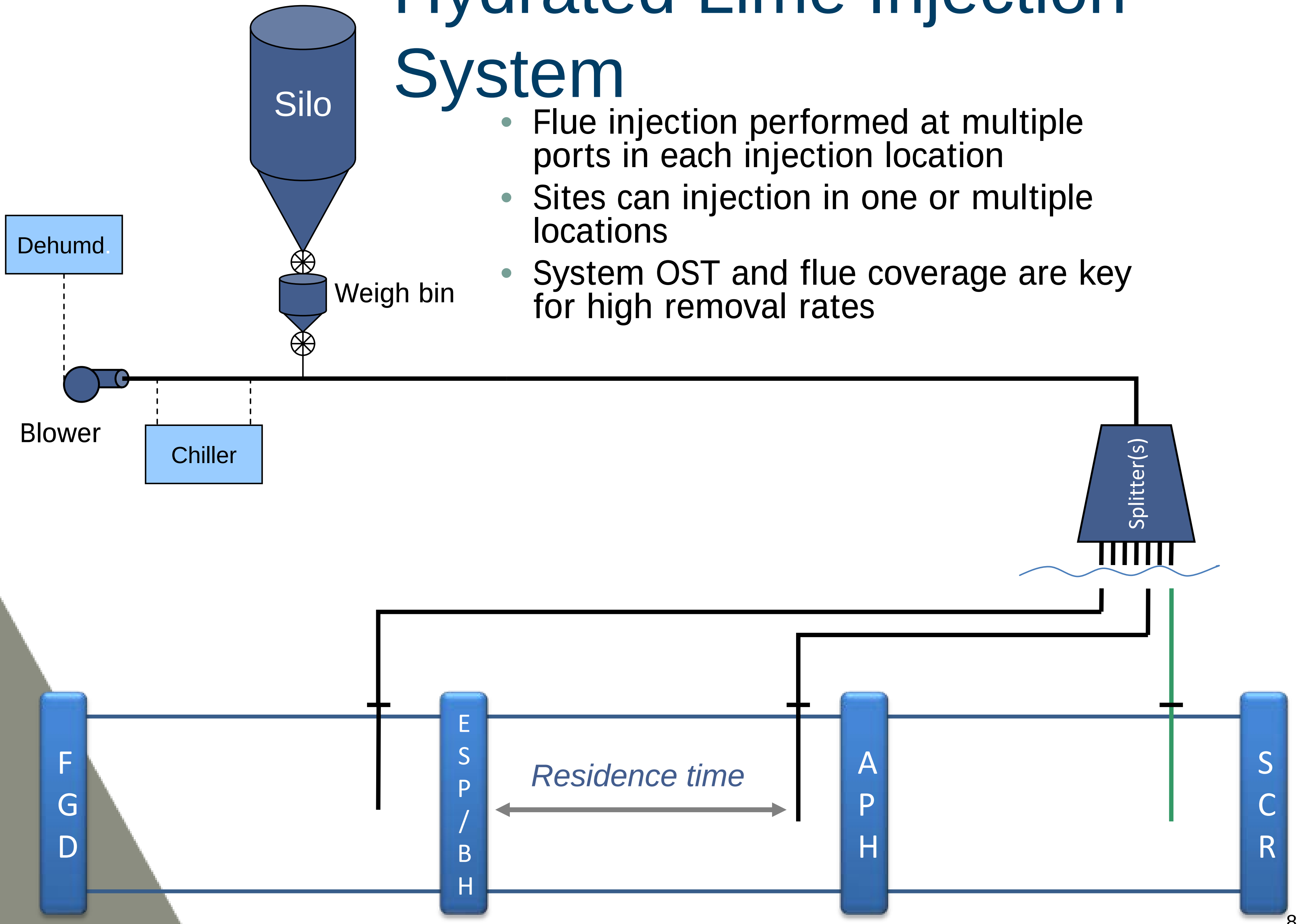
Why?

- Effectiveness of hydrate is highly dependant on conveying

- Raw material supplier
  - Handle hydrated lime every day
  - Produce and convey materials with variety of handling challenges
  - Exposure to wide array of conveying systems from existing customer base

Hydrated Lime 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



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

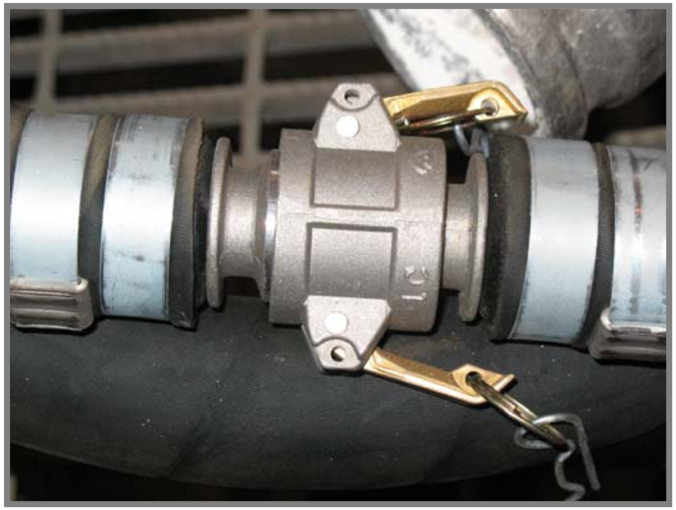
Design Challenges

- Two possible sorbents
  - Different properties and system requirements
- Alternate fuels
  - Oversized equipment
- Inflexible equipment
  - Single speed blowers
- Conveying distance
  - Site location
- Number of piping bends
- Flue coverage
  - High # of injection lances

System Installation

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

J. Wilson, DHUG, 2010



J. Wilson, DHUG, 2010

Conveying Problem Types

- Dry powder plugs
  - Design or conveying issue
  - Failure to maintain above pick-up velocity
- Calcium carbonate scale
  - Need to control reaction between hydrate and CO_2

Carbonation

$$Ca(OH)_2 + CO_2 \longrightarrow CaCO_3 + H_2O$$

Conveying hydrate

- Pneumatic conveying principles determined by <u>physical properties</u>

- Must also consider <u>chemical interactions</u>

- Carbon dioxide in ambient air is sufficient to cause scaling issues
  - Very Dilute Phase systems are most prone to scale

Case Comparison – Effect of Piping Bends

Case 1

Standard design with minimal bends

- Pick-up velocity of 3300 ft/min
- Hydrate:Air ratio of 0.31
- Theoretical scale produced:
  - 28 lbs/day

Case 2

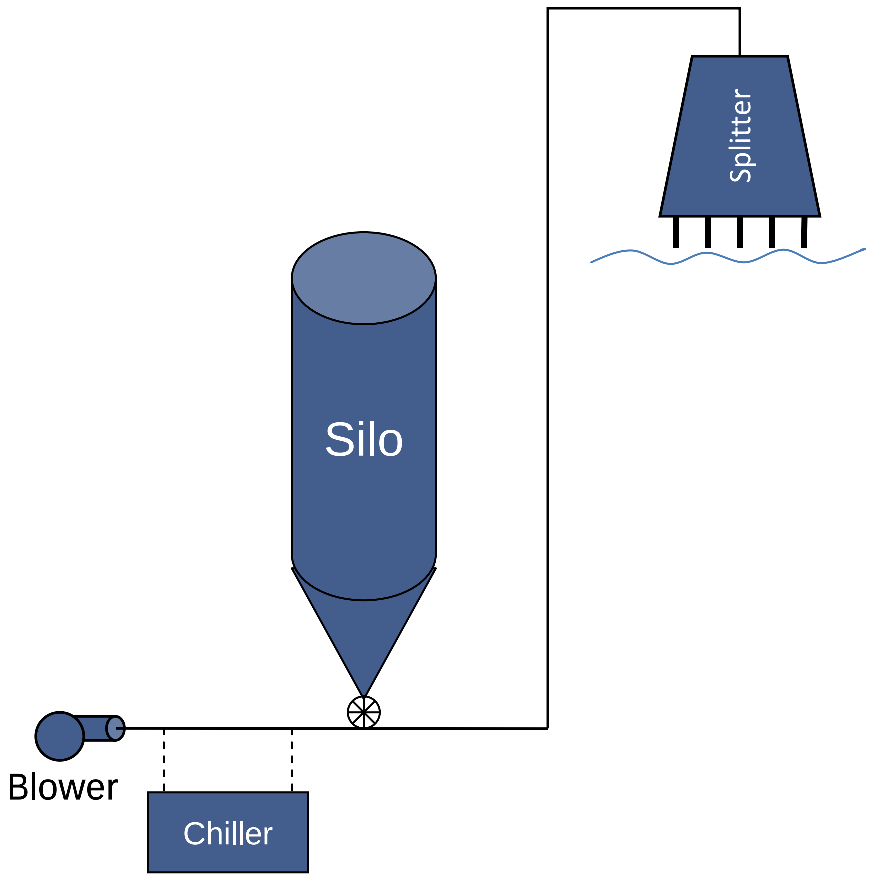
Large # of piping bends require higher blower rates

- Pick-up velocity now 4800 ft/min
- Hydrate:Air ratio of 0.22
- Theoretical scale produced
  - 40 lbs/day

Design or field modification issue leads to 43 % increase in potential calcium carbonate scale formation

MLC Current Efforts at Carbonate Scale R&D Test System - Scale at Rotary Valve

- Fresh hydrate **without recycle**
- Feed system with ability to vary conveying conditions



R&D Test System – Design of Experiments

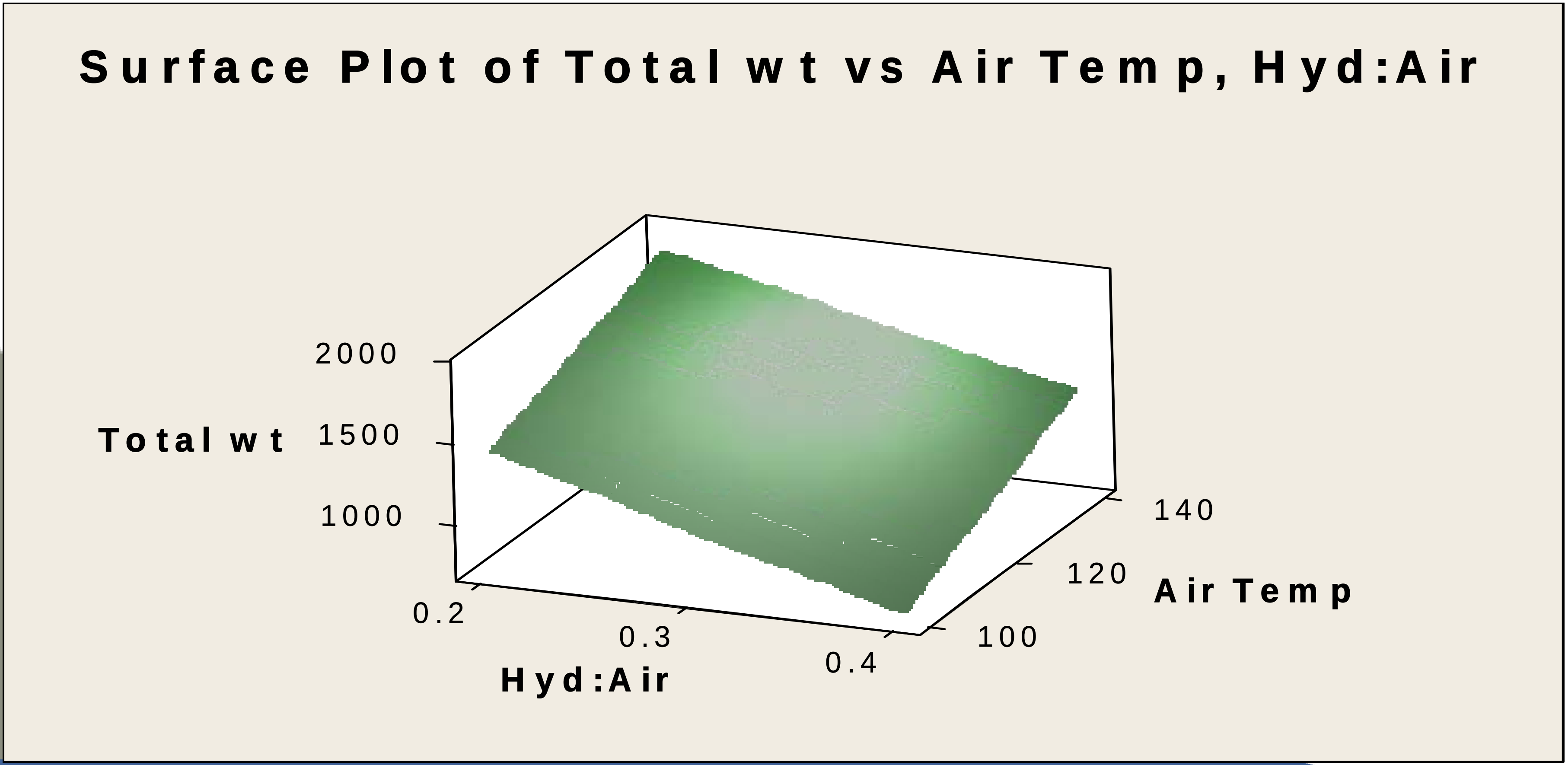
- Understand factors that drive scale formation
  - Hydrate:Air ratio (lb hydrate/lb air)
  - Conveying Air Temperature
- Run time = 100 hrs
  - Quantify scale by amount and type
    - RAL
    - Straight Pipe
    - Elbow
    - Rest of System (piping, splitter, lances)

DOE - Results

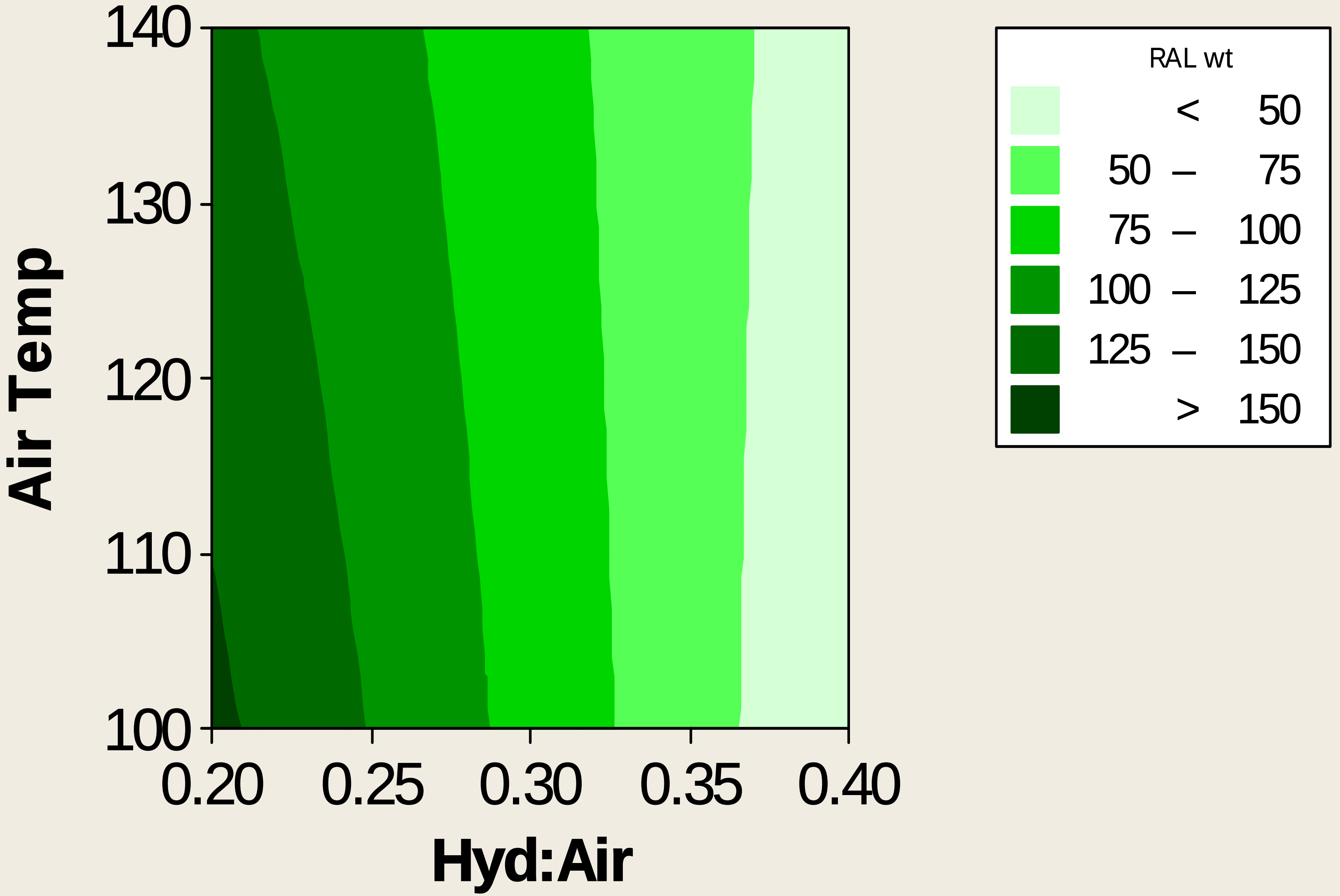
- Three runs made it the entire 100 hr test time
- One run shut down due to high pressure after 76 hrs
  - Low Hydrate:Air (0.20 lbs hydrate/lb air)
  - High Temperature (140 °F)
- Captured and weighed carbonate scale in each section

R&D Test System – DOE Conclusions

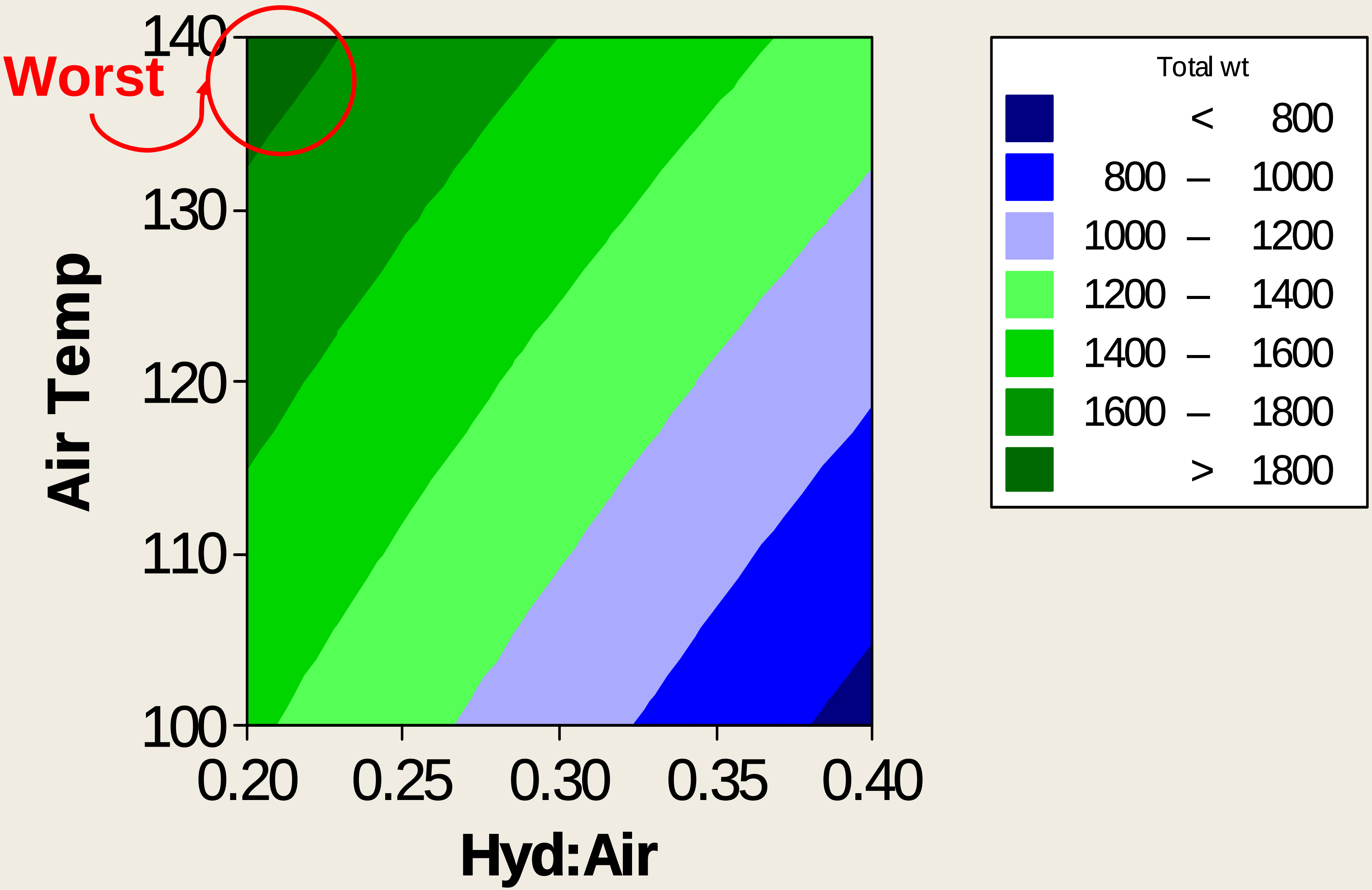
- Low Hydrate:Air systems are prone to scale formation
- Higher Temperature drives scale formation



Contour Plot of RAL wt vs Air Temp, Hyd:Air



Contour Plot of Total wt vs Air Temp, Hyd:Air



Best Way to Control Scaling Issue: Eliminate the CO_2 from the conveying air

Pre-treat air with hydrate

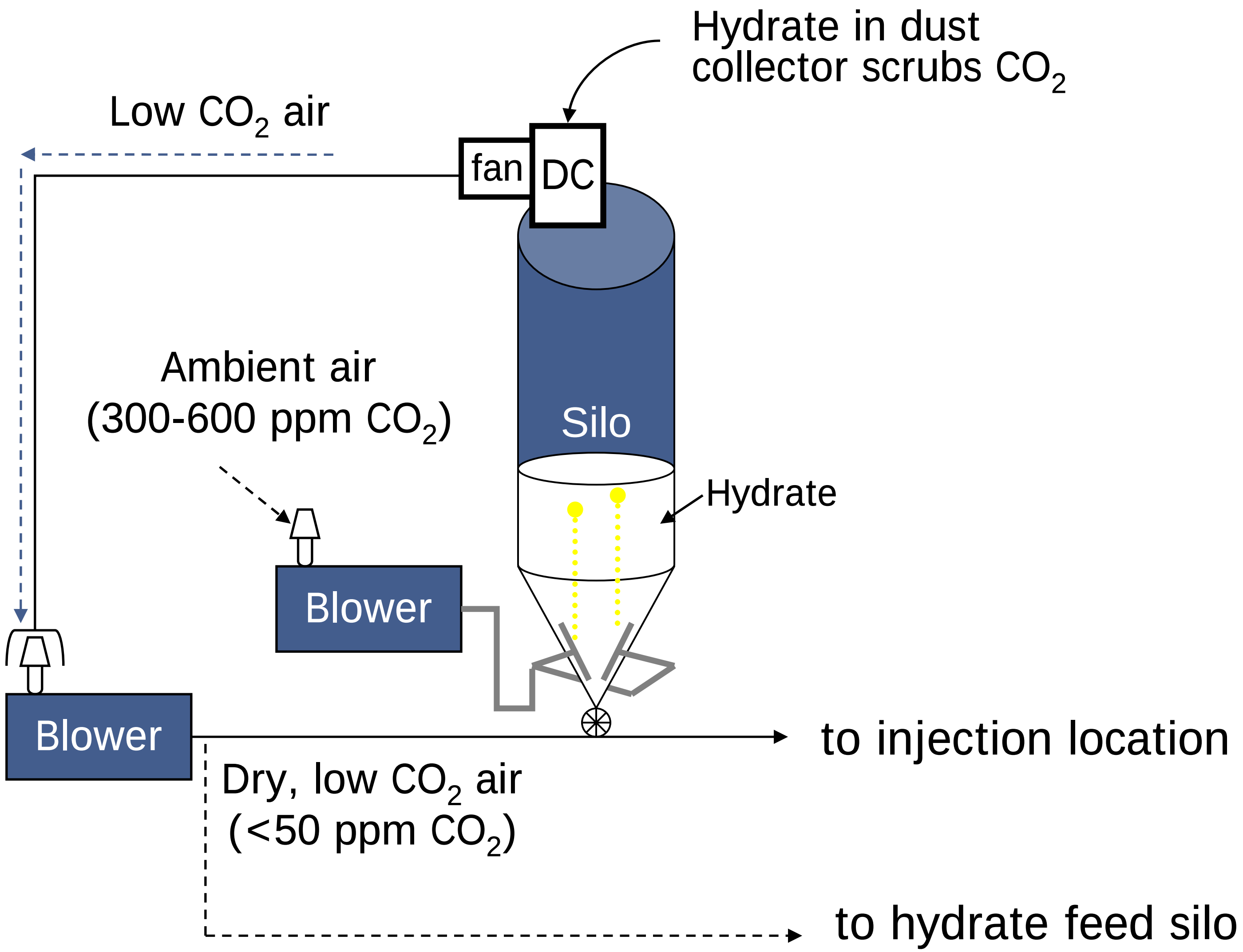
- Bubble air though hydrate in silo
- Filter air through dust collector
  - Also reduces water content, which attributes to ~10% of scaling

Mississippi Lime Patents

(5,678,959) Method of, and apparatus for, reducing scaling in pneumatic lime conveying systems

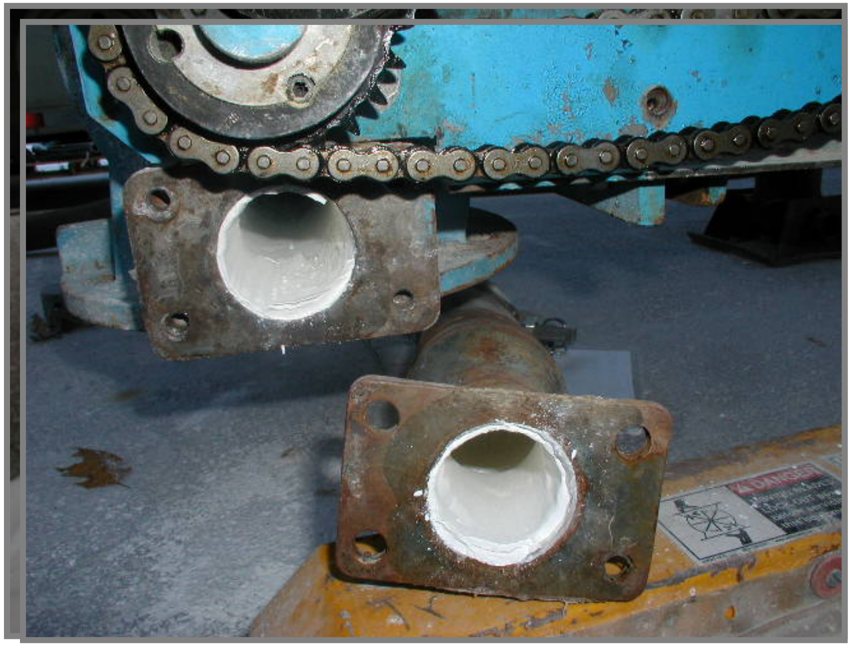
(6,200,543) Apparatus and methods for reducing carbon dioxide content of an air stream

CO_2 Scrubbing – Active System



Temporary System – 10 Day Test

- Ambient air + blow thru rotary valve
- Same system using low CO_2 air



Production Test System

- Plant process experienced scaling issues
- Unit relocated blower intake air to dust collector

Low CO_2 Conveying Air Gaining Utility Industry Acceptance

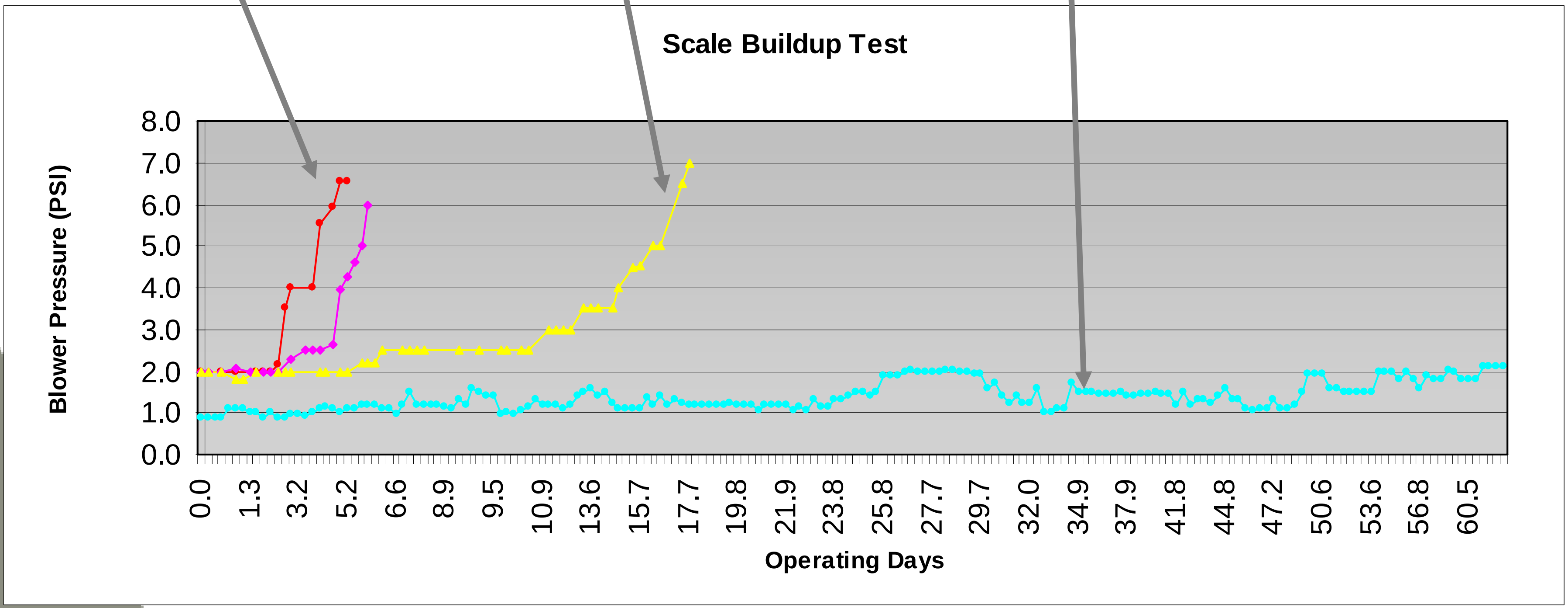
- 2007 - Initial skepticism
- 2008 - Limited success with field trial at MLC customer site
  - Passive, not active system (see next slide)
- 2009 - Equipment and hydrate were major focus items
  - EPRI testing identified criticality of CO_2 in late 2009
- 2010 – CO_2 control finally gaining a foothold?

Initial Test Results on R&D Test System

Runs A & B
Ambient air
~400ppm CO_2

Run C
Passive scrubbing
~150ppm CO_2

Run D
Active scrubbing, <50ppm CO_2
Shallow Pocket Drop Thru Rotary
Heat exchanger



What Can Low CO_2 Do For You?

Hydrate:Air of 0.20 and Conveying Air Temp of 140 °F

(Worst Conditions from DOE)

	76 hrs (fail)	*100 hrs*
	Ambient Air	***Low CO_2 Air***
Location	***Scale, g***	***Scale, g***
Airlock	100	21
Feeder pipe	25	2
Elbow	580	0
Rest of system	1,180	15
Total Weight	**1,885**	**38**

Recommendations Based on OST and SO_3 Removal Targets

- Equipment optimization
  - System OST of 6 weeks or more
  - Achieve low (<5 ppm) SO_3 at stack
- Equipment optimization + Low CO_2 Conveying
  - Longer system OST
  - Can 'fix' a marginal system
  - Key to very low SO_3 emissions
    - Next generation sorbents
    - Less system downtime
    - Better dispersion in flue

Summary

- Utilize hydrate supplier when troubleshooting or designing injection systems
- Recognize side effects of design criteria and change issues
- Conveying air with low CO_2 levels will reduce maintenance

Acknowledegements

- MLC
  - Randy Griffard, Kevin Bequette, Bill Allebach, Steve Schweigert, Mark Free, Dan Okenfuss, Eric Van Rens, Keith Espelien
- Others
  - Matt Wilson, Bryan Williams, Murray Gunter (TVA)
  - Jeff Wilson, Duane Blankenship (Southern Co.)
  - Carla Piening, Rob Wilson (EON & FPG)

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