Reinhold Environmental Ltd.

2008 APC Round Table & Expo Presentation

July 13-15, 2008, in Savannah, GA

TVA Experience in Solving Hydrated Lime System O & M Issues

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July 14, 2008
APC Roundtable & Expo
Reinhold Environmental

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Agenda

- TVA and Mississippi Lime Hydrated Lime Background
- O & M Background & Resolution
  - Material Handling Solutions
    - Conveying air velocity
    - Temperature
    - Conveying air makeup
  - Opacity
- Summary

Background
SO_3 Mitigation with Hydrated Lime

Plant	Location	SO_3 *APH*	SO_3 *Untreated Stack*	*mol Ca: mol SO_3*	*lb Ca: lb SO_3*	Removal *Stack*
Widows Creek #8 (550 MW)	**Pre-Wet FGD**	20 ppm	12 ppm	4.2 : 1	3.9 : 1	92%
Cumberland #1 & 2 (1300 MW ea)	Pre-ESP	30 ppm	20 ppm	4.2 : 1	3.9 : 1	83%
Paradise #1 & 2 (704 MW ea) # 3 (1150 MW)	Post-ESP (#3) Pre-Wet FGD (#1-#2)	35 ppm	21 ppm	3.8 : 1	3.5 : 1	83%

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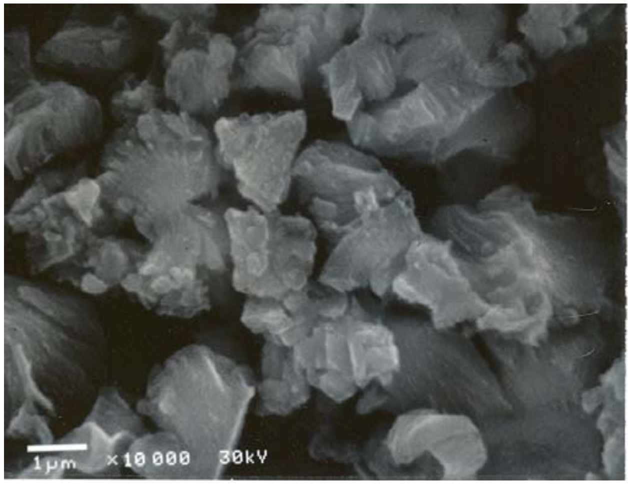
Background
Mississippi Lime Hydrated Lime

- Properties
  - Injected as dry powder
  - Higher surface area material yields better SO_3 removal rates
  - Bulk density varies based on aeration during storage and transfer
  - On-site processing not required
- Bulk Storage and Transport
  - Storage silo with dust collection
  - Weigh bin
  - Rotary airlock and feeder
  - Dilute phase conveying system
  - Duct injection

Hydrated Lime for Flue Gas Treatment

Lower Performance



Higher Performance

Identical particle size

Lower Performance

Surface area

14 – 19 m²/g

Available Calcium Hydroxide

89 – 92%

Higher Performance

Surface area

21 - 24 m²/g

Available Calcium Hydroxide

94+%

Hydrated lime reactivity is dictated by Surface Area and % Available, <u>not necessarily particle size</u>

Overview
O & M Challenges and Resolutions

Challenge	Plant	Resolution	Current State
Material handling	Widows Creek	•Saltation velocity (2,500 ft/min horiz.) •Low moisture lime (<1%) •Control temperature of conveying air	Reduced equipment downtime
Scaling at valve discharge point	Cumberland	Treat conveying air to remove CO_2	Reduced equipment downtime
High opacity with pre-ESP injection	Paradise	Inject hydrated lime after the ESP	Post-ESP injection successful without increase in particulate

Joint effort between TVA and Mississippi Lime to find resolutions

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Challenge
Material Handling

- Material flow from silo
  - Low moisture hydrated lime
- Inconsistent release of product from rotary valves due to light bulk density
  - Blow thru rotary valves
- Material settles in conveying lime
  - Design to exceed saltation velocity
  - Saltation velocity determined to be 2,500 ft/min for horizontal flow

Loose sorbent settled out in conveying line

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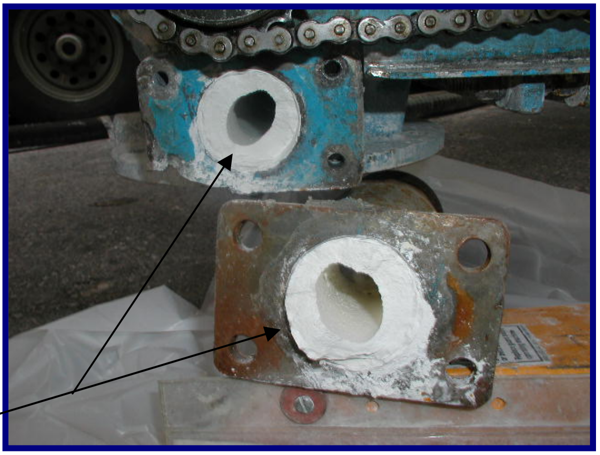
Scale Challenge
Scale at Valve Discharge Point

- Reaction forms a hard scale of calcium carbonate

$$Ca(OH)_2 + CO_2 \xrightarrow[H_2O]{Heat} CaCO_3 + H_2O$$

- Affects some dilute phase conveyance systems
  - Scale build-up over time
  - Downtime to remove
- Occurs at initial air/hydrate contact
  - Close to rotary airlock
  - Not evident downstream



Calcium carbonate scale generated at MLC’s Ste. Genevieve R&D facility

Factors Affecting Carbonation Reaction

- Hydrate reactivity
  - High surface area ($\geq$ 22 m^2/g)
    - Necessary for effective SO_3 removal
    - Also more reactive towards CO_2
- Temperature & Pressure Effects
  - Heat accelerates reaction
    - Impact of dehumidification of conveying air
  - Higher pressure accelerates reaction
    - Impact of high blower speeds
    - Impact of constriction at rotary valve discharge
  - Hydrate/Air conveying ratio
- Minimize presence of CO_2 at reaction location

Optimization of Conveying Air Flow

$CaCO_3$ Concentrations at Widows Creek

Hydrated Lime	CO_2 (%wt)	H_2O (%wt)	$CaCO_3$ (%wt)
Delivered Material	0.70	0.73	1.59
Deposit at Airlock Discharge	4.60	1.62	10.46

- Conveying air blower
  - Running at arbitrary high speed
  - Need to optimize velocity
    - 10% more than pulse-piston flow
- Dehumidifier
  - In use to prevent moisture contamination
  - Increased conveying air temperatures by 30 °F or more.

Reduce blower speed and stop dehumidification

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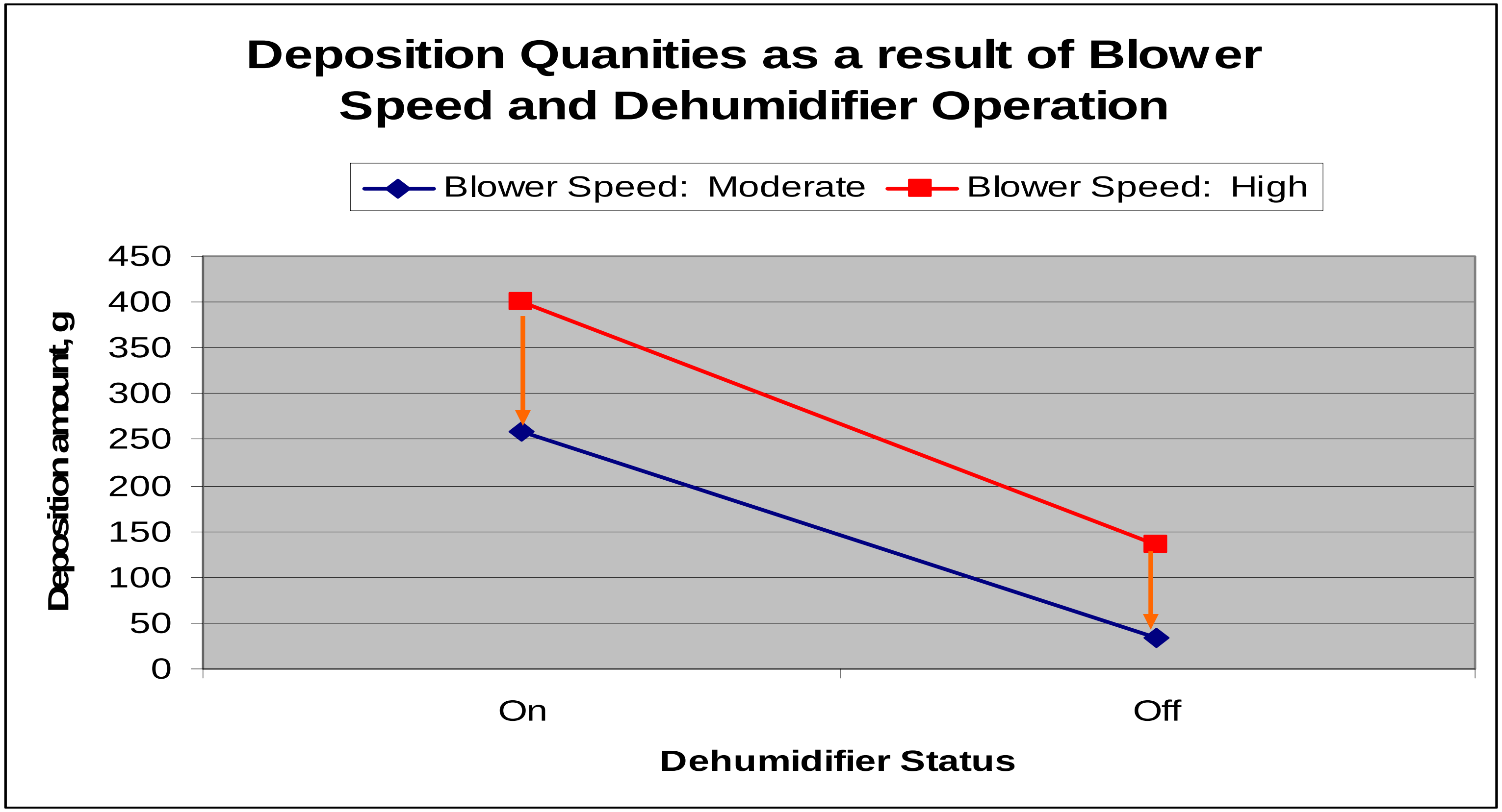
Widows Creek Resolution
Optimize Air Flow and Temperature

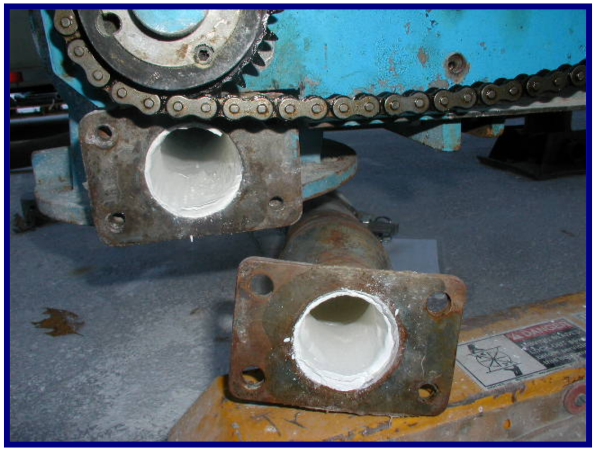


Minimize deposits using controlled air flow without the need to dehumidify

Cumberland Resolution
Utilize Low CO_2 Air - Mississippi Lime Patent

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

- Pretreat air with lime
- Filter blower intake air through dust collector on hydrate storage silos
    - Carbonate formed in DC and diluted in storage
- Also reduces water content, which attributes to ~10% of scaling.



Limited scale after processing with low CO_2 air

Conveying air has CO_2 content significantly lower than ambient conditions

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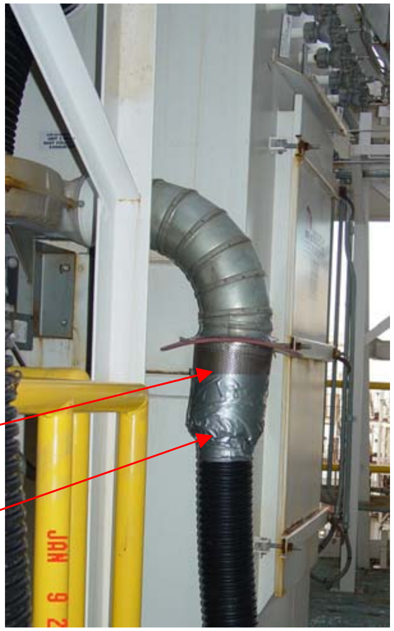
CO_2 Concentrations at CUF-2 Using Mississippi Lime Technology

Measured Concentration Using MLC Low CO_2 Air Process

Date	Ambient CO_2 (ppm)	Dust Collector Exhaust Outlet CO_2 (ppm)
Nov 2007	200	50
Jan 2008	300	75

- CUF installed the piping necessary for low CO_2 conveying air on Unit 2.
- CO_2 levels dropped accordingly
- Reduced maintenance downtime to clear restrictions due to scaling at the rotary valve.



Perforated Pipe

Universal Coupling

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Hydrate Feed System Cleaning

Mean Time Between Service at CUF

- Dehumidifier in service + high air flow
    - MTBS = **~8 days**
- Dehumidifier out of service + reduced air flow
    - MTBS = **~50 days**

Low CO_2 Conveying (no dehumd. + reduced air flow)

- Ambient air
    - MTBS = **~50 days**
- Low CO_2 System
    - MTBS = **~86 days**

Challenge at Paradise
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_3
  - Stack particulate emissions were not negatively affected

Load (MW)	NSR	Stack Particulate (lb/MMBtu)
1039	2.54	Not Published
1030	4.75	Not Published

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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

Take Home Lessons

Material Handling

- High surface area lime reacts with SO_3
- Must minimize carbonation during conveying
  - Conveying air temperature
  - Conveying air velocity
  - CO_2 content

Particulate Control

- Hydrated lime successful at mitigating SO_3 using post-ESP injection
  - Particulate emissions not increased

Hydrated lime is an effective sorbent for SO_3 mitigation. Handling issues are manageable with good supplier-customer interaction.

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Discussion and Backup Slides

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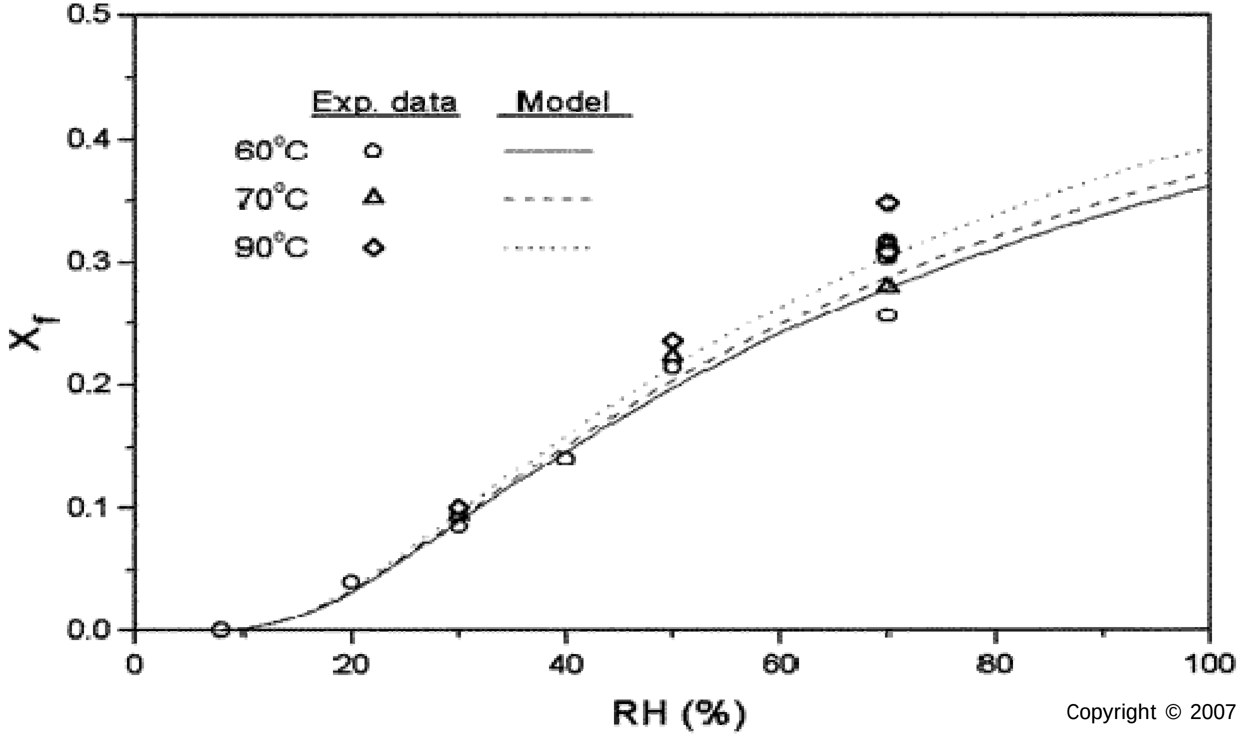
Factors Affecting Carbonation Reaction

Conversion of $Ca(OH)_2$ to $CaCO_3$

Relative Humidity & Temperature Effects



Dry, cool air is best to minimize carbonation reaction.