REINHOLD ENVIRONMENTAL Ltd.

# 2014 NOx-Combustion Round Table & Expo Presentations

February 10 & 11, 2014, in Charlotte, NC / Hosted by Duke Energy

# Pre-APH Injection of Hydrated Lime

## *Update on Recent Testing*

Curt Biehn (Mississippi Lime) and Adam Harris (TVA)

MISSISSIPPI® LIME

Discovering what's possible with calcium

**$NO_x$ Conference – Charlotte NC**

***February 11, 2014***

# Workshop Overview

- Benefits of Pre-APH Control of $SO_3$
- Development of the Pre-APH market
- Recent TVA programs
  - Paradise
  - Cumberland
- Recent testing at other Utilities

# If you have to control $SO_3$…

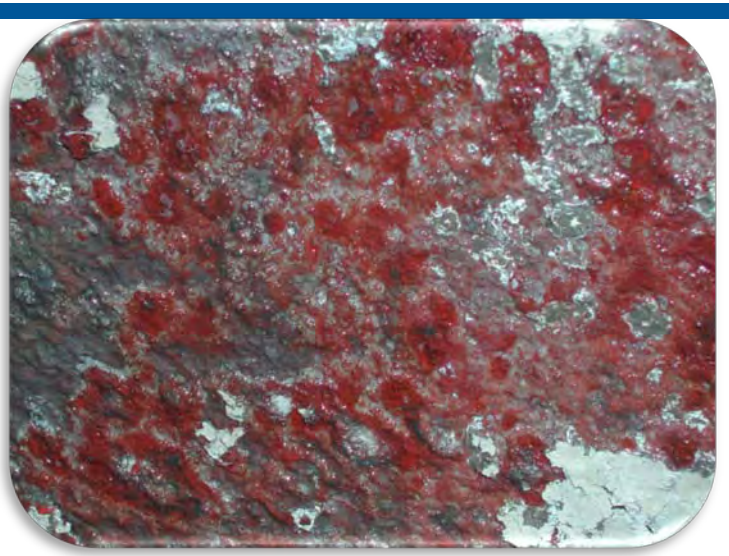
***You might as well take advantage of it.***

- Original DSI systems installed to control $SO_3$ stack emissions

- Why not
  - Protect equipment and duct work
  - Maintain Air Preheater cleanliness
  - Reduce operating costs

# Benefits of $SO_3$ Removal prior to the APH

## Corrosion protection

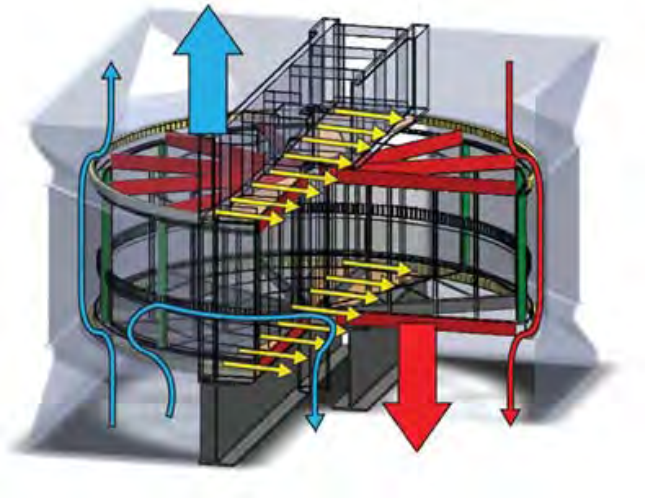




$Ca(OH)_2 + SO_3 \rightarrow CaSO_4 + H_2O$

# Benefits of $SO_3$ Removal prior to the APH

**APH operations**

- Eliminate ABS buildup from ammonia slip
- Reduce Dp growth over time
- Eliminate outages for cleaning



# Two Layer APH with SCR

GAS INLET TEMP = 700F

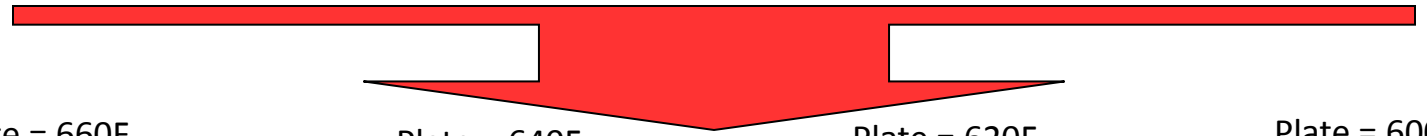


Plate = 660F

Plate = 640F

Plate = 620F

Plate = 600F

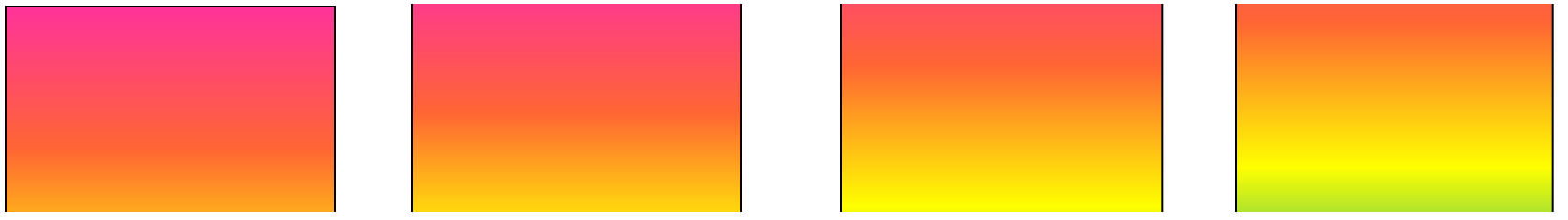



Plate = 260F

Plate = 230F

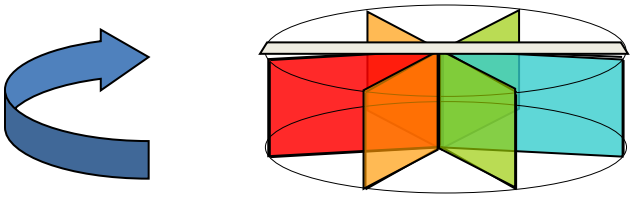
Plate = 190F

Plate = 160F

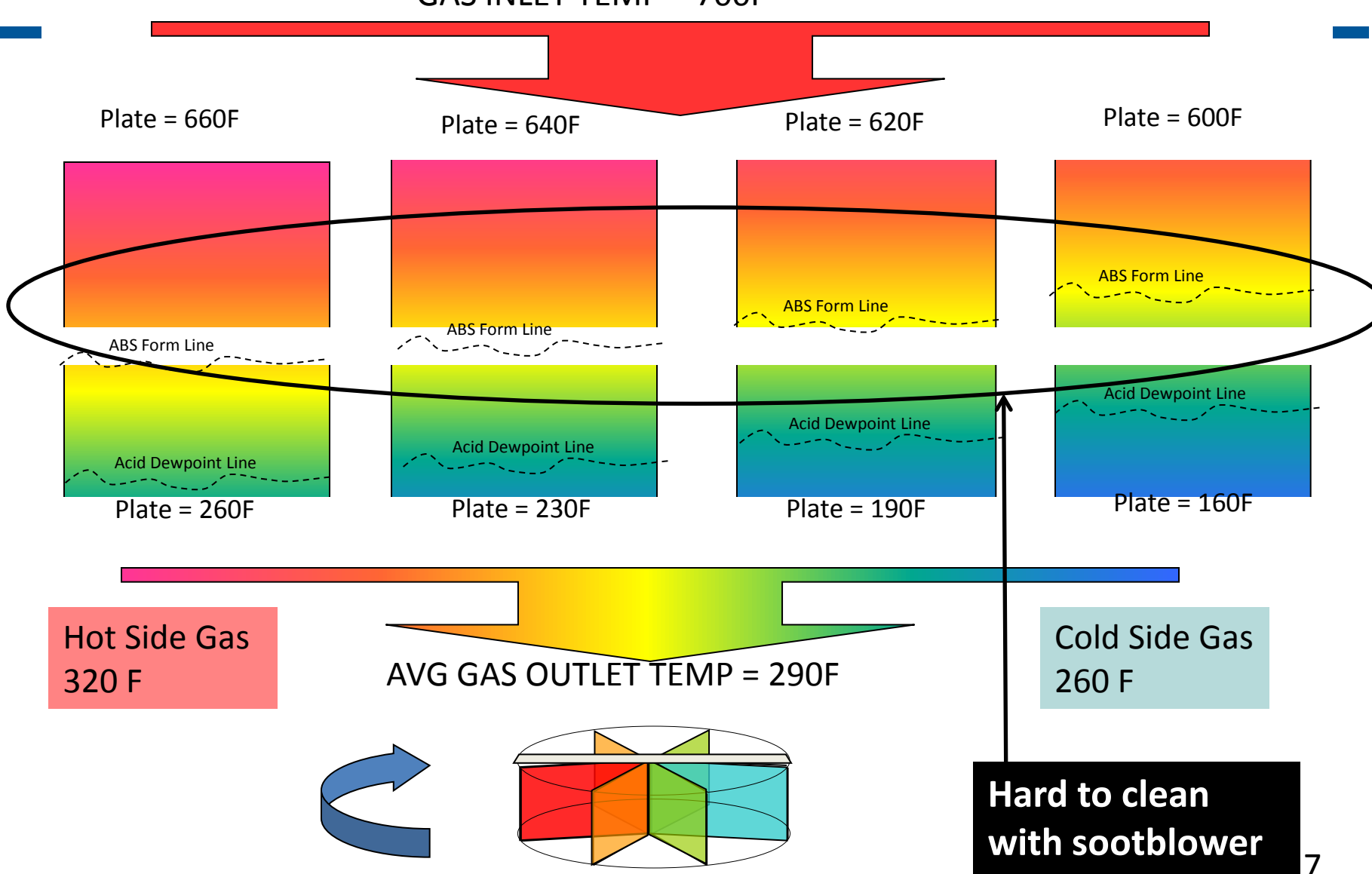
Hot Side Gas
320 F

AVG GAS OUTLET TEMP = 290F

Cold Side Gas
260 F



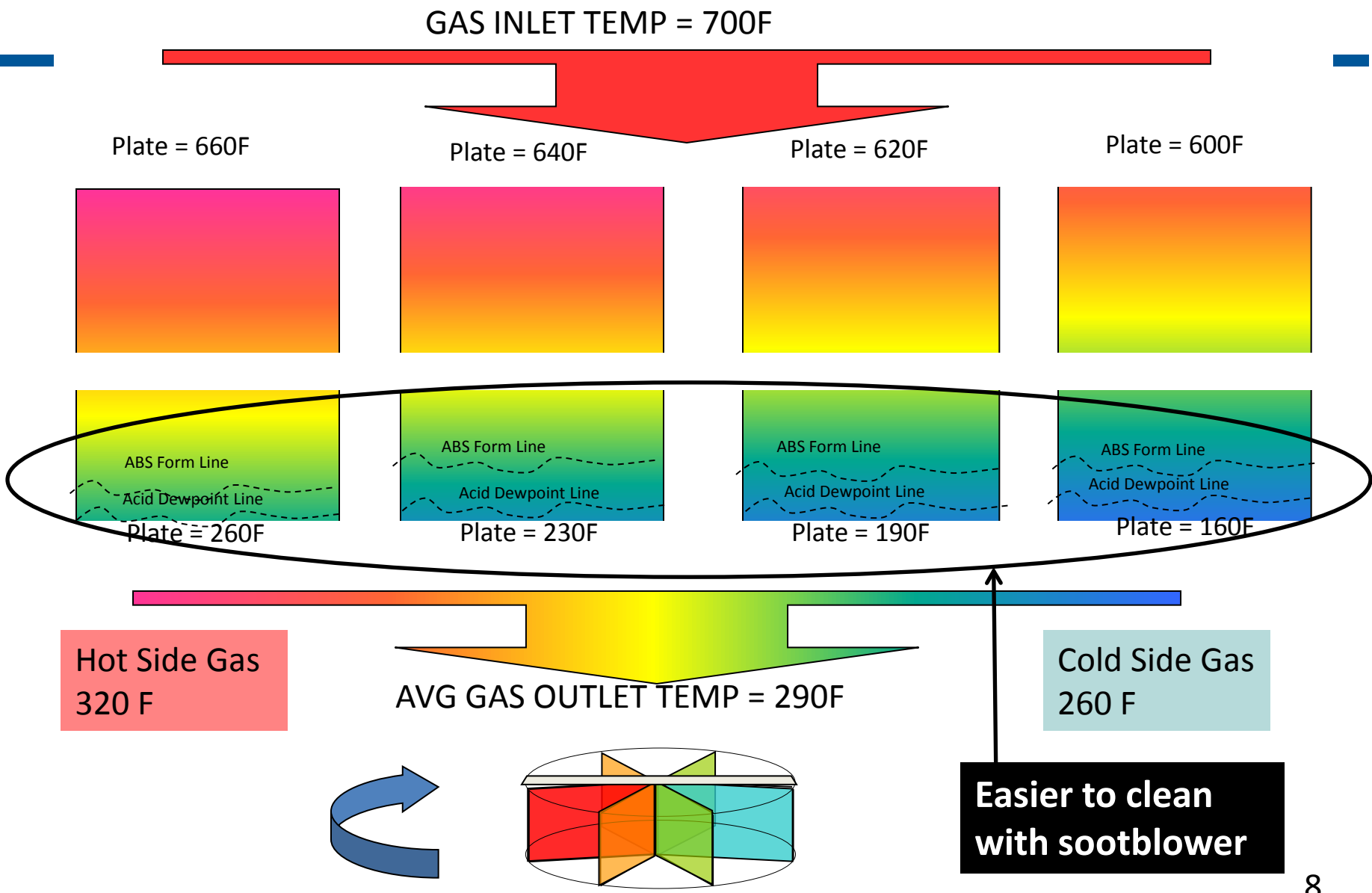
# Two Layer APH with SCR and Increased $NH_3$ Slip






Courtesy Mark Thomas – Mark Thomas & Associates – Breen AGW - July 2013

# Previous Case PLUS **Pre-APH $SO_3$ Mitigation**



# Hydrated Lime DSI – Impacts on Air Preheater

- Primary Mechanism is $SO_3$ Reduction
  - Reduction of sticky $H_2SO_4$ on ash & plates
- Secondary Benefit - Additional particulate for condensation
  - Reacts quickly with any condensed $H_2SO_4$ to form a dry solid
- Gypsum pluggage has not proved to be an issue.
- No sticky compounds as seen with sodium-based sorbents

# Benefits of Pre-APH Removal of $SO_3$

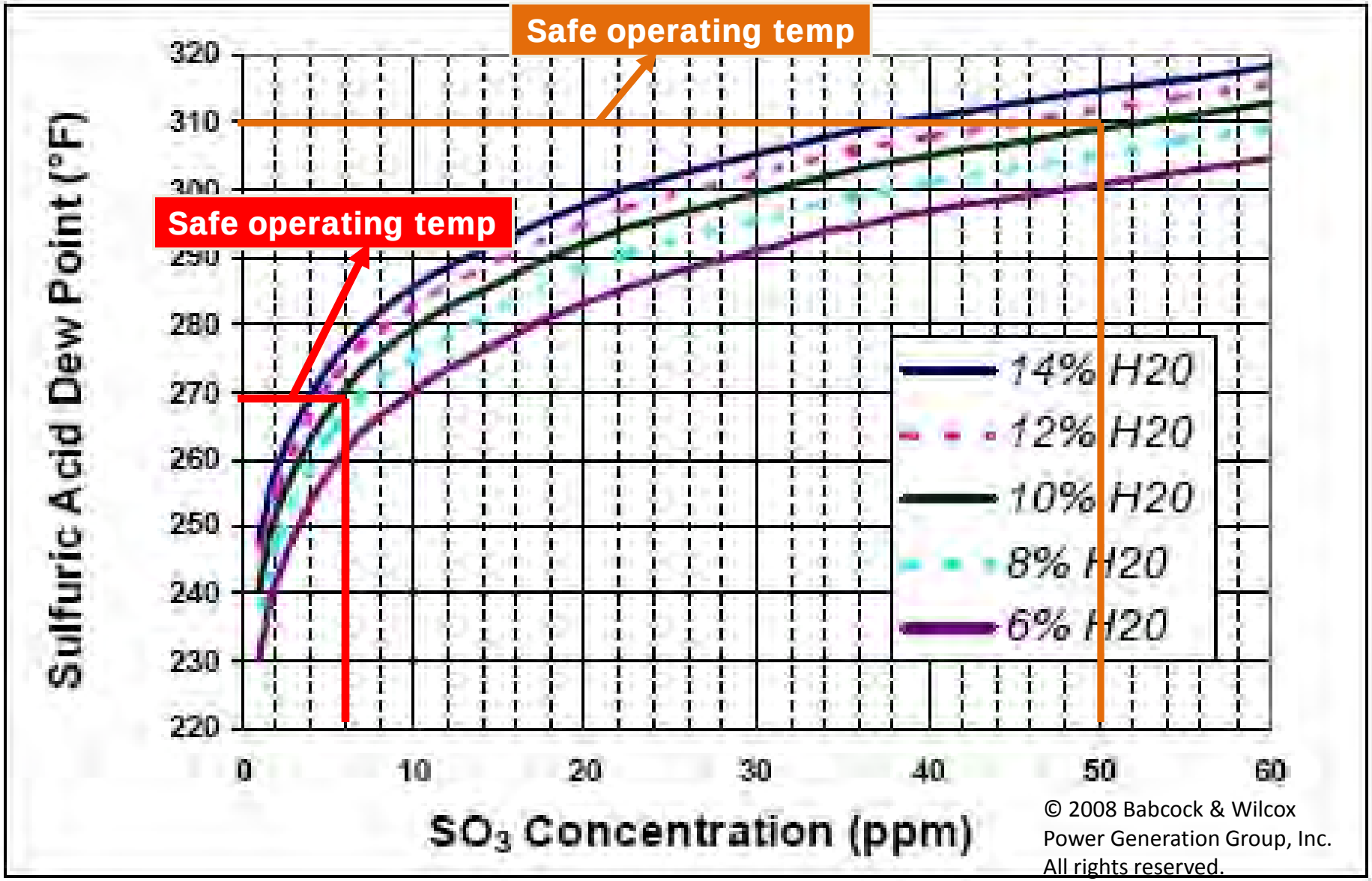
**Improve Heat Rate/Reduce $CO_2$ Emissions**

- Reduce $SO_3$ Dew Point prior to APH
- Reduce operating temperature of APH

**40°F reduction → 1% heat rate improvement → 1% savings on fuel budget**

- Reduction in $CO_2$ emissions
  - 1 lb coal → 2.5 lb $CO_2$

# $SO_3$ Acid Dew Point Curve



# Growth of Pre-APH Injection with Hydrated Lime

- Preliminary work
  - Furnace sorbent injection
  - Anti-slagging chemicals in the boiler
  - Brief plant trials

*APH after 7 week test, 2009*

- First tests in 2008 and 2009 – Mississippi Lime
  - One day testing in 2008
  - Successful seven week test in 2009
    - MLC/Southern Co./B&W/Breen/BCSI/Utility

- Subsequent evaluations/conversions starting in 2010

# Pre-APH with Hydrated Lime: Where are We Now?

- Significant testing, retro-fits, and installations in past 3 years
  - Over 35 units (~23 GW)
- Many units have operated with Pre-APH injection of hydrate for over 12 months and multiple outage cycles
- $SO_3$ is being controlled
- Units are recognizing additional benefits

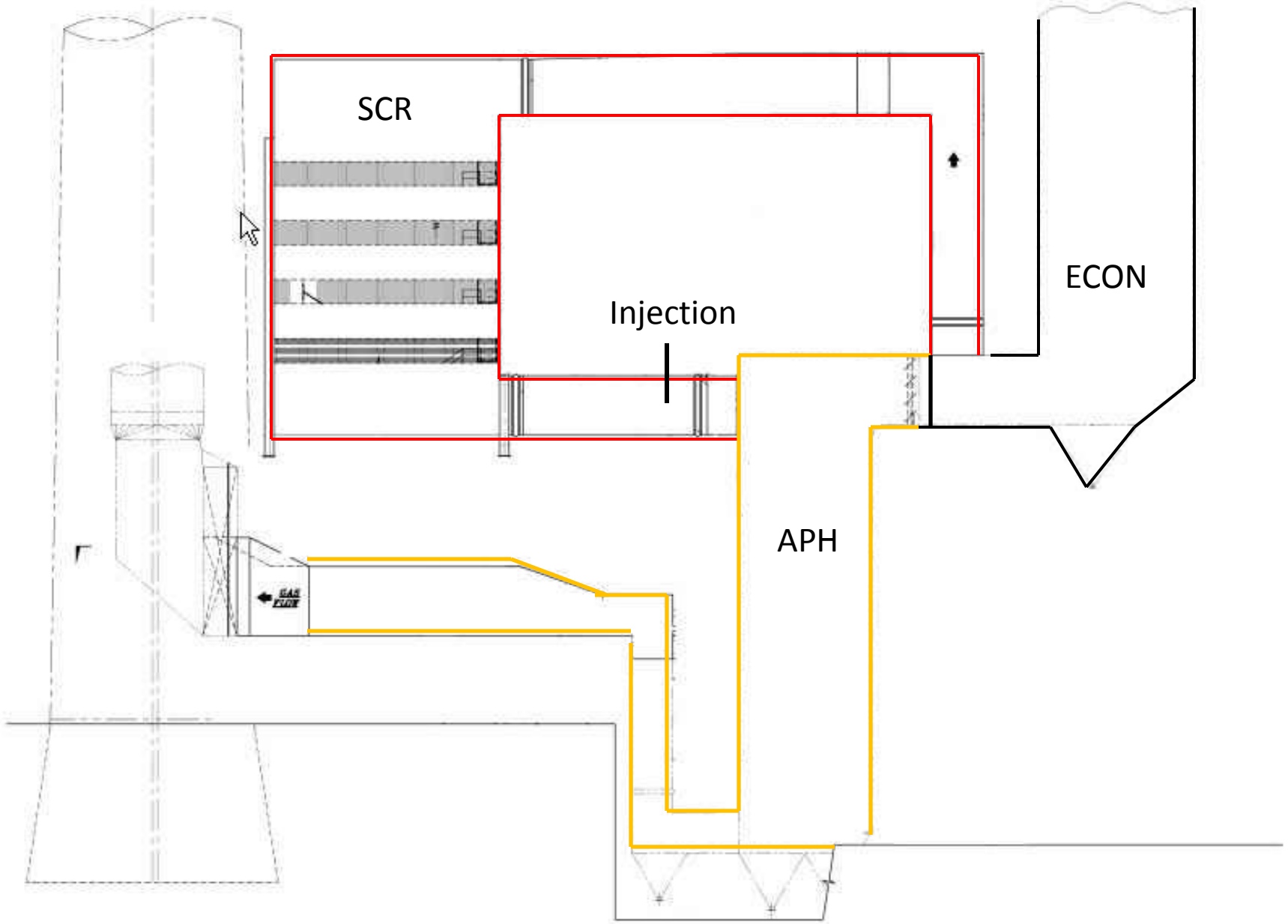
# Test Program Discussion – Hydrated Lime Pre-APH

- Recent results from several plants
- Extended benefits
- Improvement potential from a next-generation hydrated lime
  - High Reactivity Hydrated Lime
  - Designed for ‘high stress’ applications
    - Shorter residence times
    - Rapid, high level $SO_3$ removal required


# TVA Trials – Paradise

- 2 Units – 700MW
- 5 lb/MMBTu coal
- Recuperative Air Heater

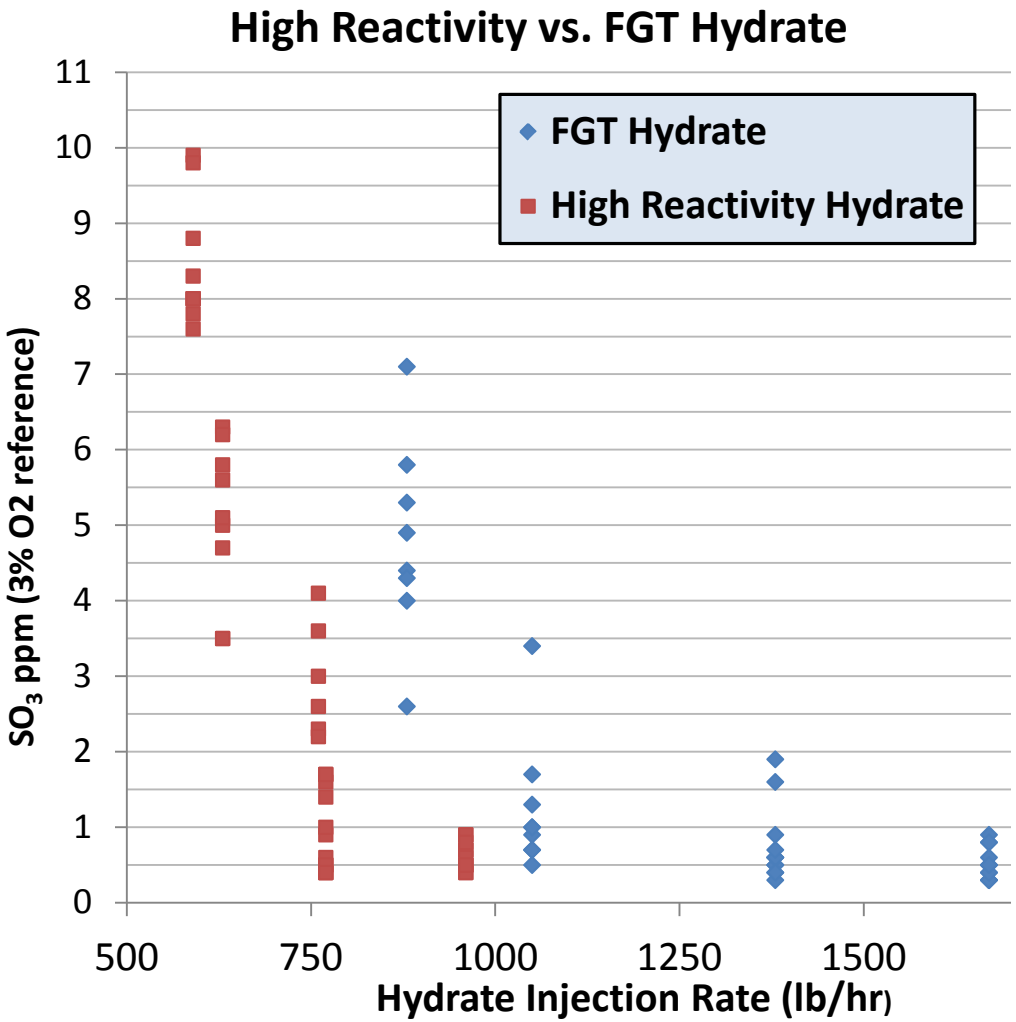
- No PPTR or Bag House
- Venturi Scrubber


SCR
Injection
ECON
APH

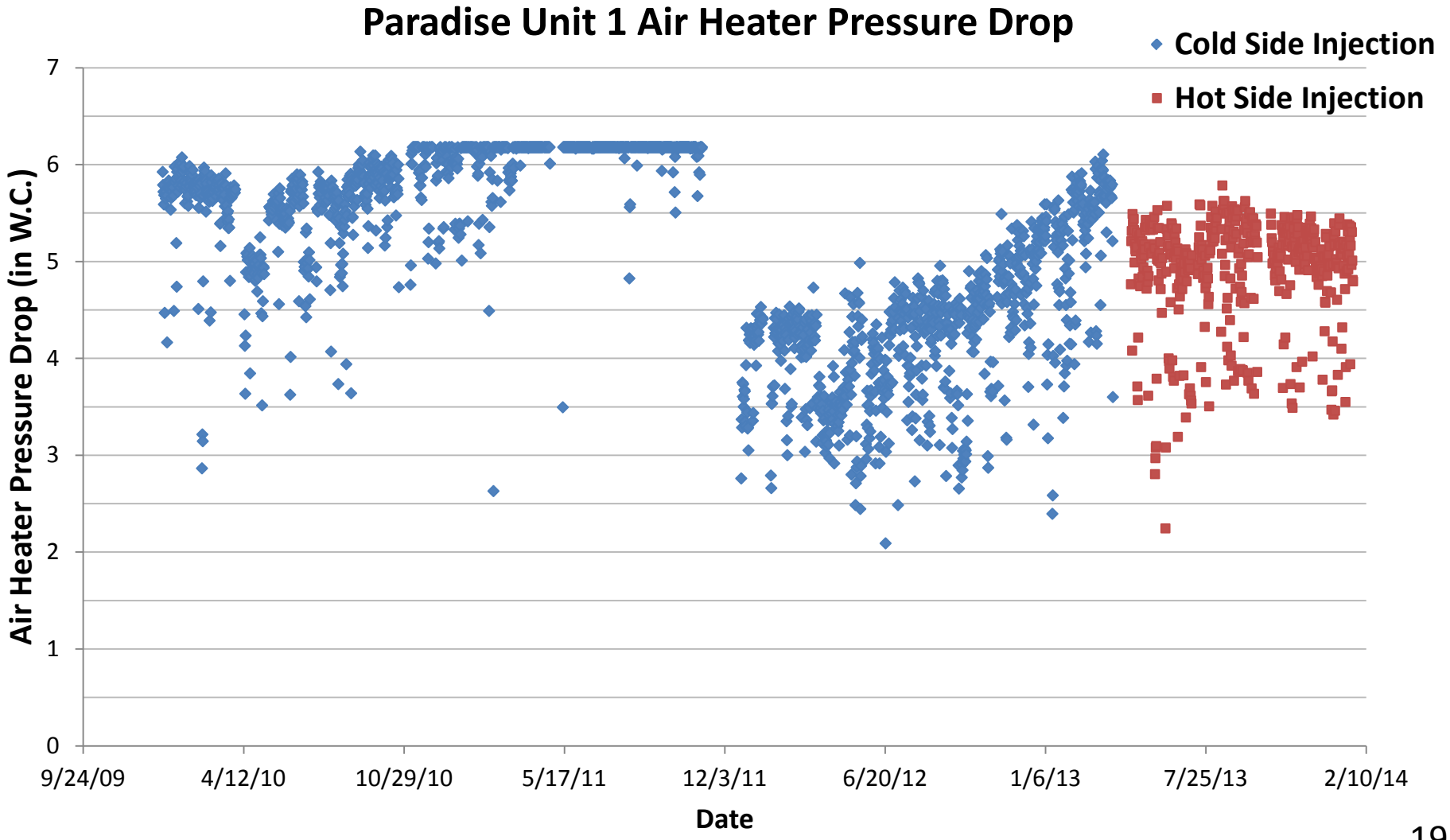
# Typical Injection Set Up

# FGT vs. High Reactivity Hydrate

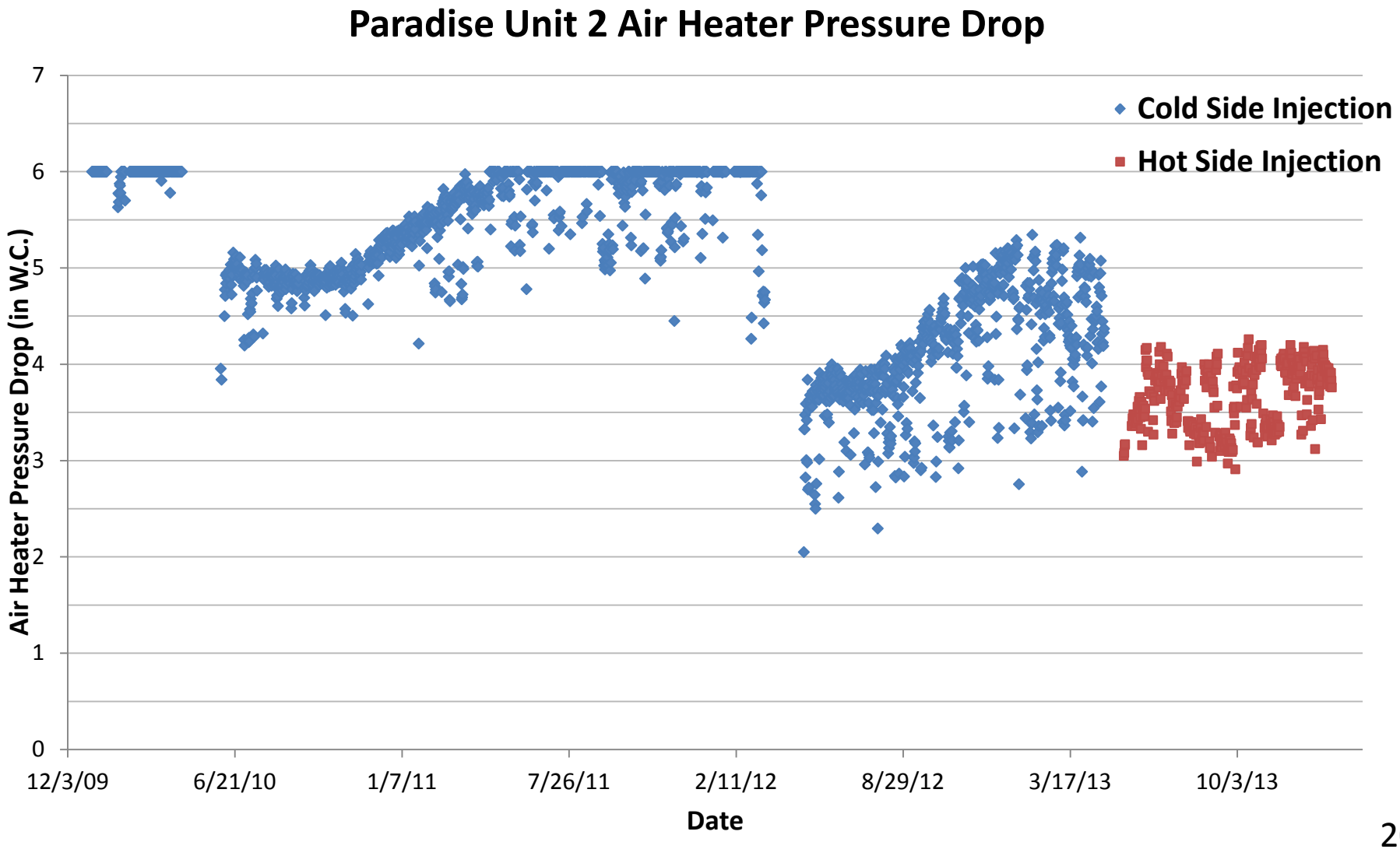
- Both FGT and HR hydrate achieved **94%-98%** reduction in $SO_3$ concentration across the APH
- FGT injection Rate = 1,000-1,100 lb/hr
- **HR injection rate = 750-800 lb/hr**
- Acid dew-point reduction from 300°F to ~275°F



# Unit 1 Extended Results



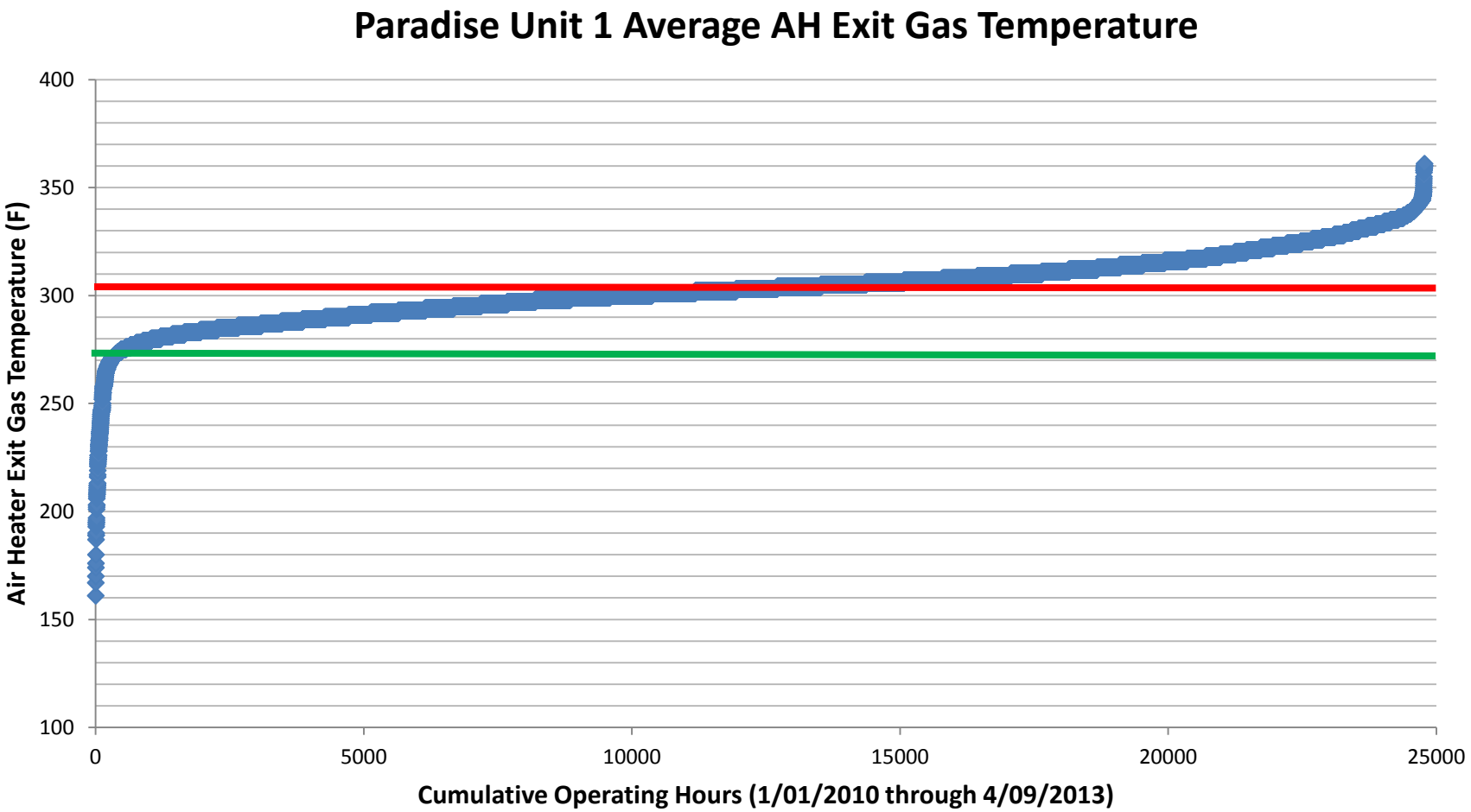
# Unit 2 Extended Results



# Unit Performance Impacts

- Since January, 2011, over **570,000 MWh** have been lost as a result of air heater fouling from both units.
- Since hot side injection has been started, **0 MWh** have been lost as a result of air heater fouling.
- Contributing Factors:
  - Air Heater maintenance
  - Combustion Tuning
  - SCR catalyst replacement/ Tuning

# Air Heater Exit Gas Temperatures



# Benefits

- Benefits of lowering the acid dew point are:
  - Slowing of APH corrosion mechanism
  - Increased chance of minimizing APH fouling by slowing the development of Ammonia-Bisulfate (ABS) driven fouling
  - $SO_3$ emissions at stack will continue to be mitigated

# Paradise Unit 3

- Temporary hot-side injection system has been installed
- Split injection system as a result of downstream precipitators
- Initial testing will begin when unit returns to service
- Risks:
  - Fly ash resistivity
  - Hydroveyor pluggage

# Cumberland

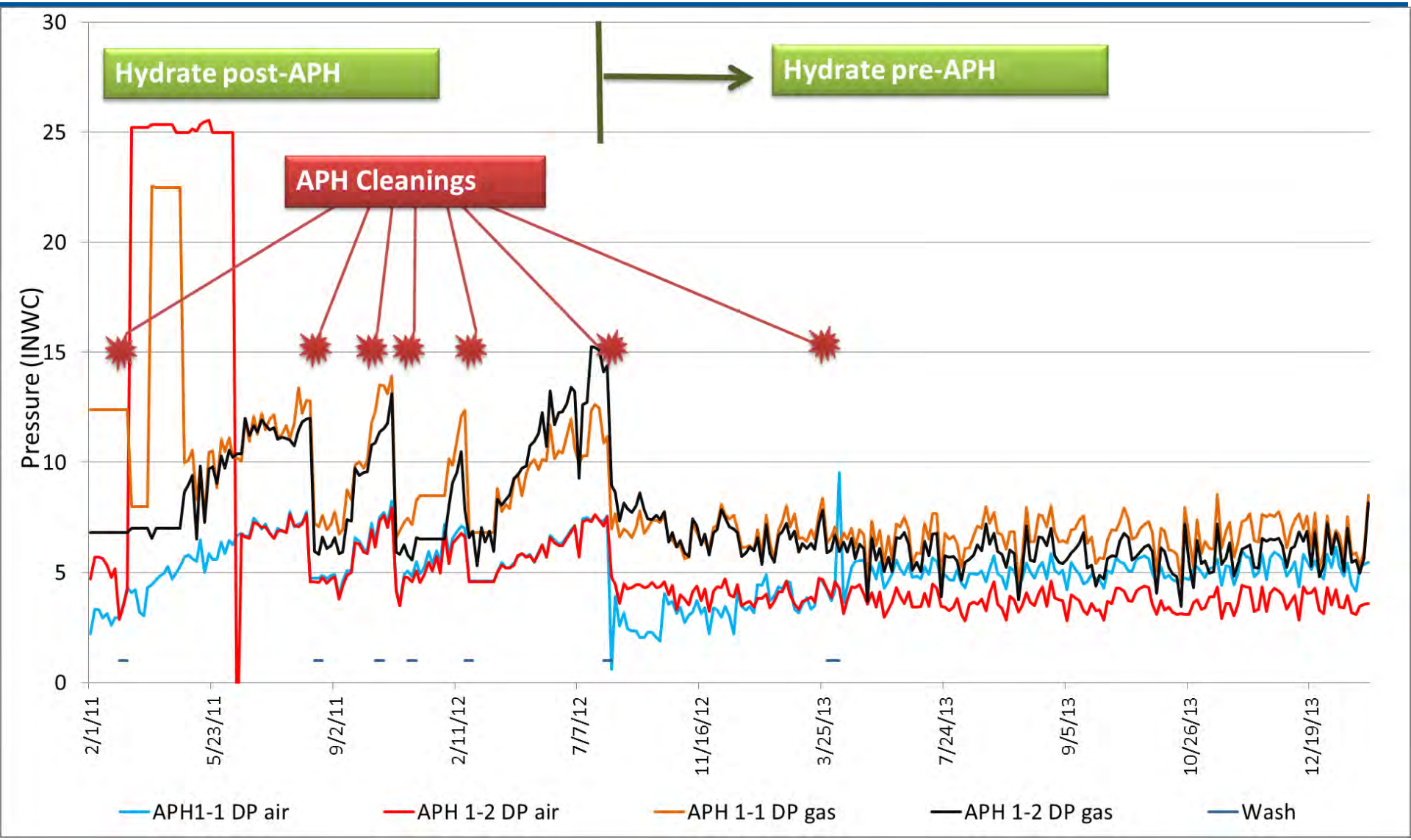
- Unit 2 hot side injection started in September of 2012.
- Air heater dP has increased at a lower rate compared to Unit 1 with downstream injection.
- Equipment on site to set up hot side injection on Unit 1.
- Opportunities for improvement:
  - Modify injection rate to maximize APH benefit while minimizing PPTR performance impacts.
  - Potential heat rate improvement by lowering APH exit gas temperature.
  - Injection logic changes to alleviate “morning sickness” effect.

# Other Programs in 2013

# Trial: Use of Hydrated Lime Pre-APH

- Large plant (>400 MW)
  - High Sulfur Coal, SCR, Cold side ESP, Wet FGD
- Post-APH injection of hydrated lime
  - APH Dp increase from Day 1
  - About 2-3 months before cleaning required
- Hydrated lime injection pre-APH
  - APH Dp steady
  - APH clean “outage to outage”

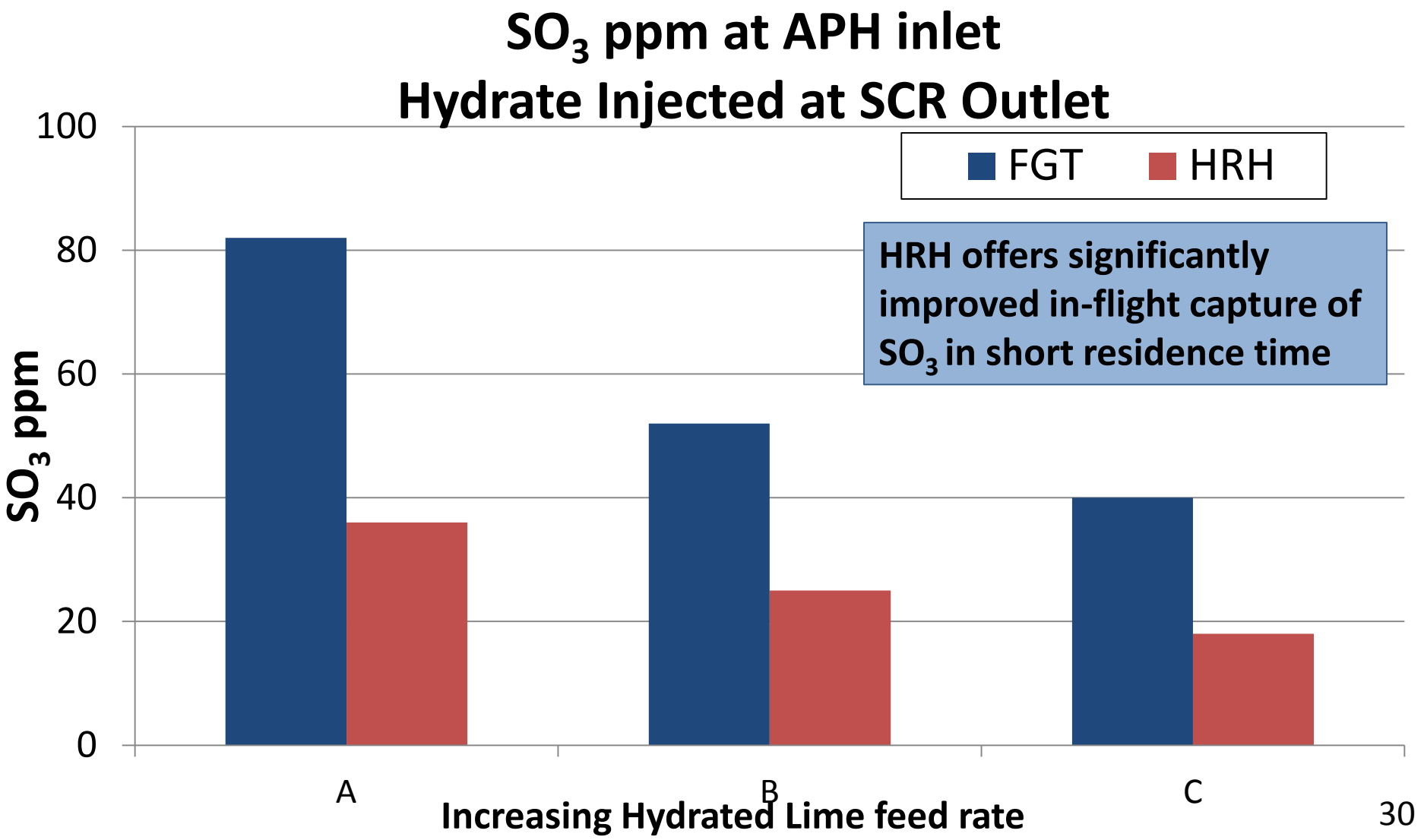
# Hydrated Lime Pre-APH – Effects on APH dP



# Trial: Pre-APH Comparison with FGT and HR Hydrate

- Large plant (>400 MW)
  - High Sulfur Coal, SCR, Cold side ESP, Wet FGD
- Injection Pre-APH, with $SO_3$ measurement at APH inlet using a Breen probe.
- Two hydrated limes evaluated at three feed rates each
  - FGT hydrate ('typical' DSI-grade hydrate)
  - High Reactivity hydrate (next generation hydrate)
- Averaged results at varying feed rates and unit loads

# $SO_3$ Reduction at APH Inlet



# Other Discussion Items

- Pre-APH hydrate injection benefits units using DSI for mercury control
- Flue gas coverage is another key to good removal rates
- $SO_3$ levels can vary due to fuel, boiler, and SCR ops throughout the day
  - Reaction byproduct/intermediates have not proven to be an issue with hydrated lime

# Summary

- Use of hydrated lime for $SO_3$ control prior to the APH is a rapidly growing practice for Utility boilers
- The advantages of hot side $SO_3$ control go beyond regulatory-mandated mitigation
- Pre-APH injection of hydrated lime offers significant cost saving potential to Utilities
- Use of a high quality, rapid reacting hydrated lime should be targeted for this process requiring in-flight capture of $SO_3$

# Questions

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