

# Reinhold Environmental Ltd.



## 2010 NO<sub>x</sub>-Combustion Round Table & Expo Presentation

***February 8 & 9, 2010***

***Chattanooga, TN***

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# *Hot Side SO<sub>3</sub> Management*

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## Discussion Outline

- ***Traditional SO<sub>3</sub> Mitigation Background***
  - *Sorbent Choice*
  - *Injection Location*
- ***Some Lessons learned from five years of experience***
- ***Hot Side Control – Why?***
- ***Questions***



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# ***Sorbent Choice***

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# Primary Materials Available

## ⦿ Magnesium

- MgOH – Slurry/On Fuel/At Flame

## ⦿ Sodium

- Sodium Carbonates (wet) - URS
- Sodium Carbonates (dry) - Trona
  - Milled
  - Unmilled

## ⦿ Calcium

- Hydrated Lime

## ⦿ Ammonia



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# ***Injection Location***

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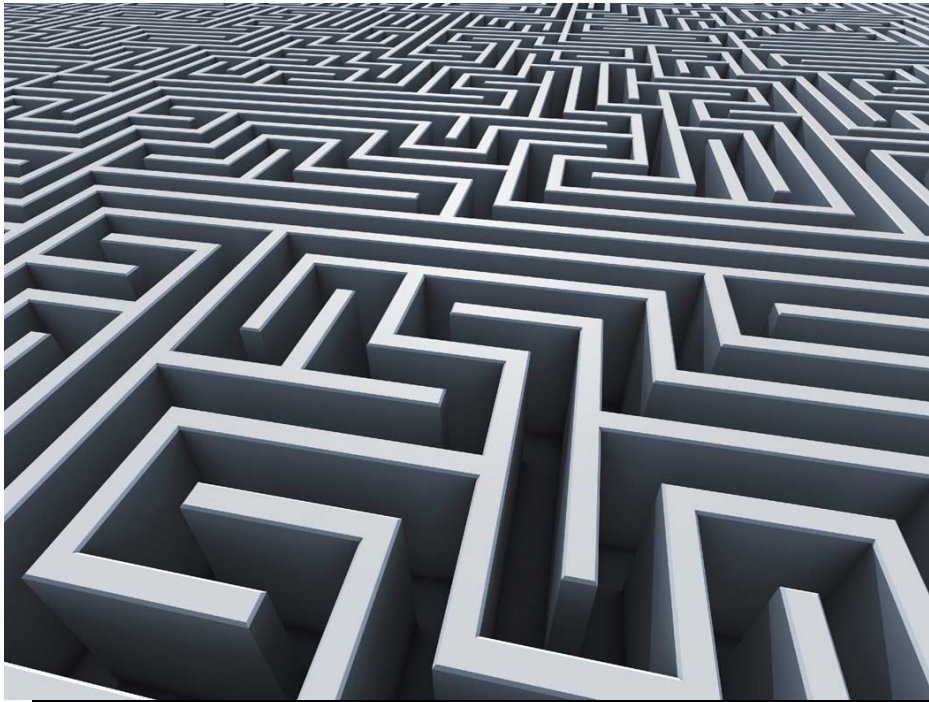
# Not One-size-fits-all

## Injection Location History





# What is the right Solution?



The right combination of sorbent choice and injection location is generally site specific



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# ***Some Industry Lessons Learned***

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From 5 years of permanent injection experience



# Lesson Learned #1

## ***1. Identify the real driver(s)***

- a) Blue Plume
- b) Duct Corrosion
- c) Mercury Capture
- d) Air Heater Fouling
- e) SCR Performance
- f) Fuel Flexibility
- g) Heat Rate (back end temperature)



## Lesson Learned #2

- 2. *Understand the difference between  $SO_3$  and Condensable Compounds***
  - a)  $SO_3$  is only an issue after it condenses,
  - b) Where, and at what temperature, it condenses depends on factors beyond  $SO_3$  ppm (i.e., water vapor, ammonia slip, reactive minerals)
  - c) Changes in both  $SO_3$  and these secondary compounds at any one point in the flue gas effects plant components at other locations.



## Lesson Learned #3

### ***3. Ammonia Slip is not the same as ABS***

- a) Industry wisdom suggests that maintenance of 2ppm NH<sub>3</sub> slip will assure no ABS in the air heater.
- b) ABS concentration is a function of:
  - a) SO<sub>3</sub> concentration,
  - b) NH<sub>3</sub> concentration,
  - c) Flue Gas moisture content,



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# *Hot Side SO<sub>3</sub> Control*

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Why?



## Impacts of High SO<sub>3</sub>

- **Visible Plume: Opacity & Buoyancy Issues**
- **SCR Performance Impacts (MOT, Dispatch & NOx limitations)**
- **Air Heater Fouling**
- **High Back End Temperatures (Heat Rate, CO<sub>2</sub>)**
- **Compromised Mercury Capture via ACI**
- **Duct and ESP Internal Corrosion**



## Impacts of High SO<sub>3</sub>

- **For this discussion:**
  - **SCR Performance Impacts (MOT, Dispatch & NOx limitations)**
  - **Air Heater Fouling**



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# *Measurement Background*

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A Probe Primer



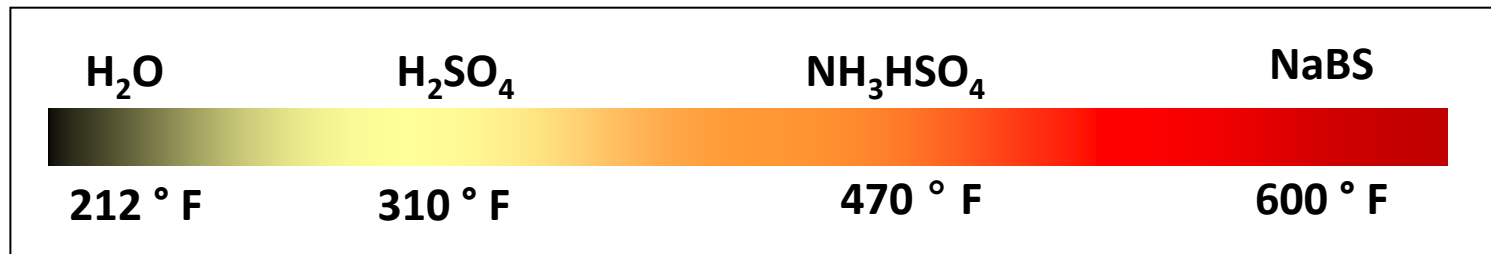
# AbSensor – AbS/SO<sub>3</sub>

## What is it? What does it do?

- ⦿ In-Situ, Continuous measurement
- ⦿ Temp at which material condenses out from flue gas

This material could be:

- ⦿ Moisture (H<sub>2</sub>O),
- ⦿ Sulfuric Acid (H<sub>2</sub>SO<sub>4</sub>) (H<sub>2</sub>O + SO<sub>3</sub>)
- ⦿ Ammonium Bisulfate (NH<sub>3</sub>HSO<sub>4</sub>) (NH<sub>3</sub> + H<sub>2</sub>O + SO<sub>3</sub>)
- ⦿ Sodium Bisulfate



The same device measures condensables across the spectrum!

# AbSensor - Introduction

Condensation = Evaporation

Equ

Tip Temp

The Condensables System Output is:

**Formation Temp:** The temperature at which material will first form

**The Equilibrium Dewpoint**

**Evaporation Temp:** The temperature at which material will self-evaporate

Tip Current

Cooling Air Return

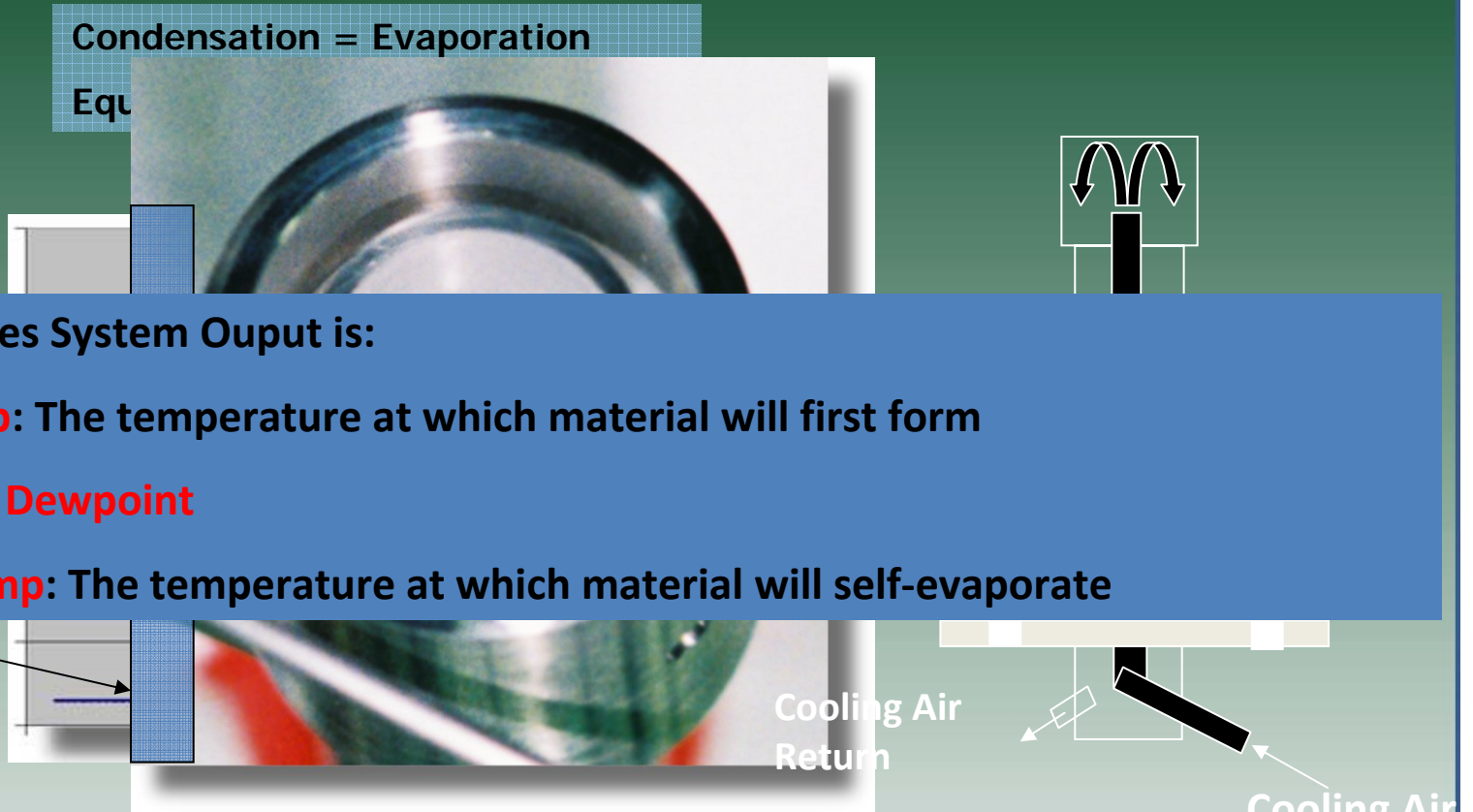
Cooling Air Inlet

A hot probe is precisely cooled until condensation current is detected. (Formation Point).

Condensation > Evaporation

The probe is allowed to heat in the Flue Gas until the current goes below a threshold (Evaporation Point).

Evaporation > Condensation



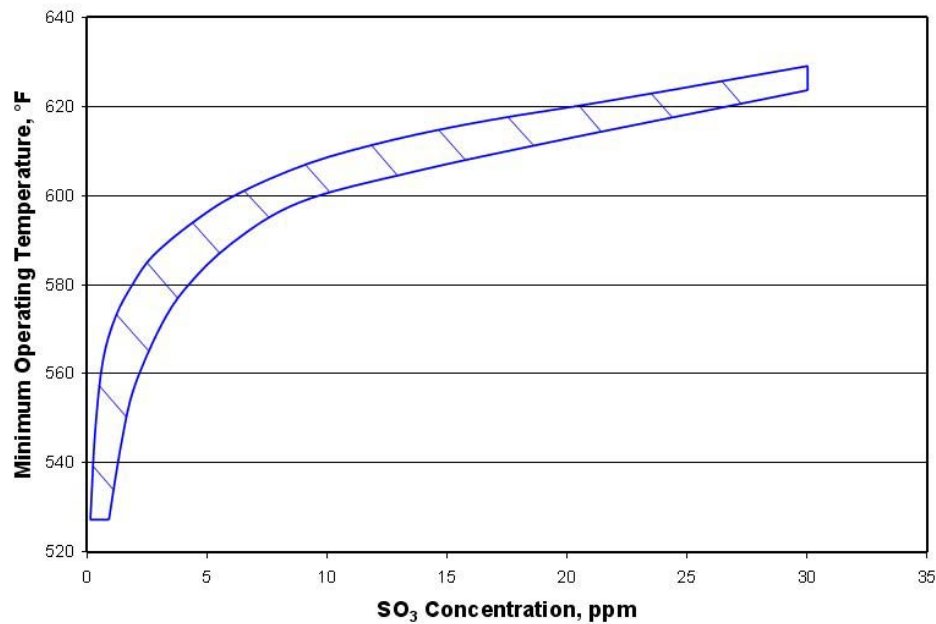


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# MOT EFFECTS



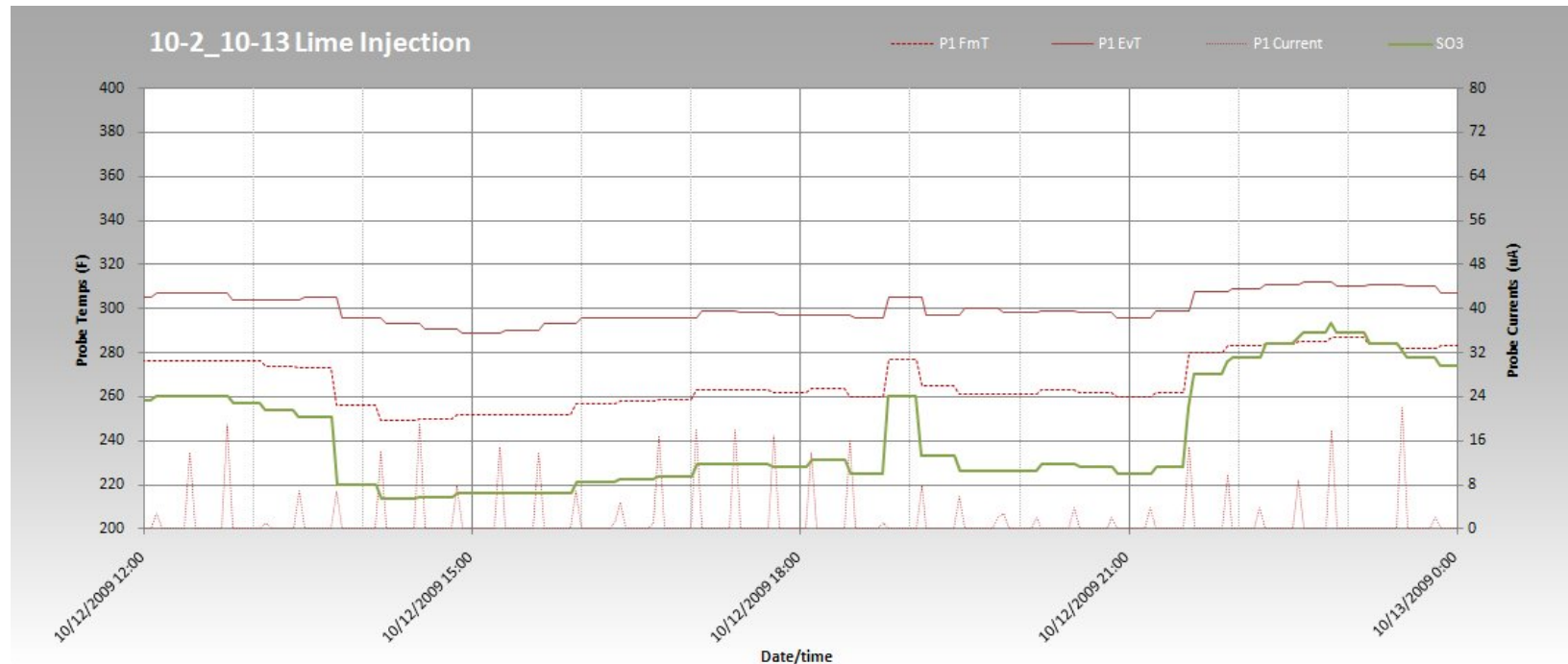
## MOT Issues vs. SO<sub>3</sub>



- NO<sub>x</sub> reduction during loads below floor,
- Unit dispatch flexibility
- Catalyst life due to ABS capillary condensation



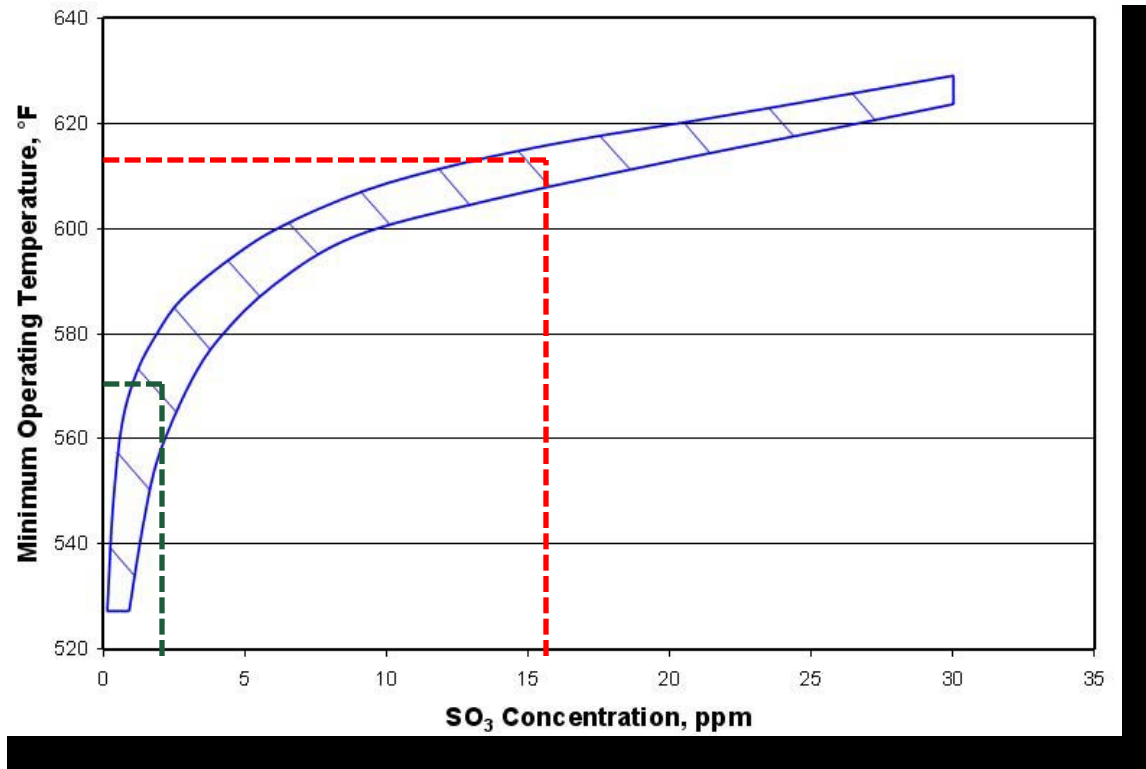
# Pre-AH Response to $\text{Ca}(\text{OH})_2$



- Hydrated Lime Injection at the economizer outlet resulted in a 65% - 70% drop in  $\text{SO}_3$  at the AH Inlet.
- With an  $\text{SO}_2$  level around 2400 ppm and low conversion catalyst, it can be assumed that the SCR inlet  $\text{SO}_3$  was dropped to near zero.



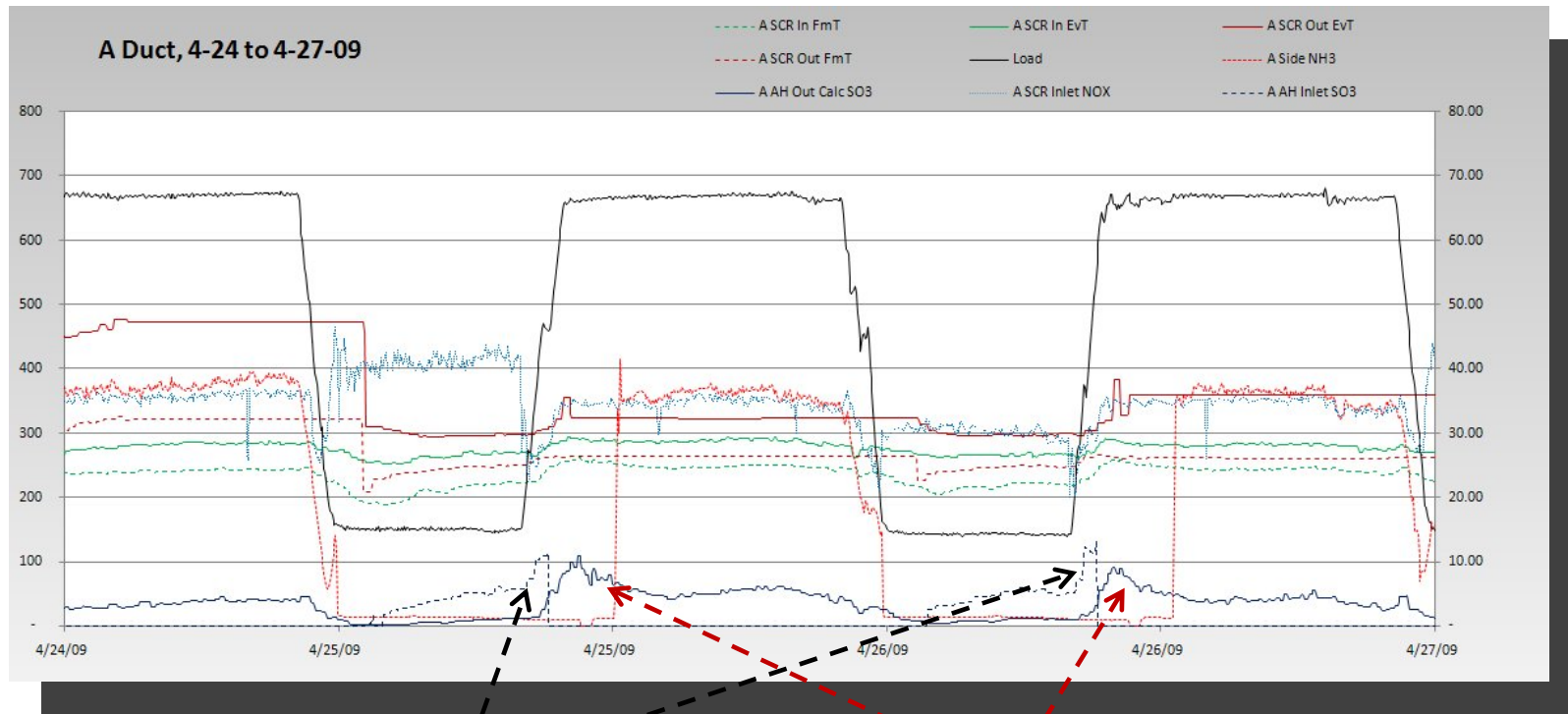
## MOT Issues vs. SO<sub>3</sub>



- A drop in pre-SCR SO<sub>3</sub> could result in a drop of 45° - 50° in MOT
- Data from Trona Injection at the same location was similar or better but masked by high level condensable formation.



# Enhanced Mode Baseline

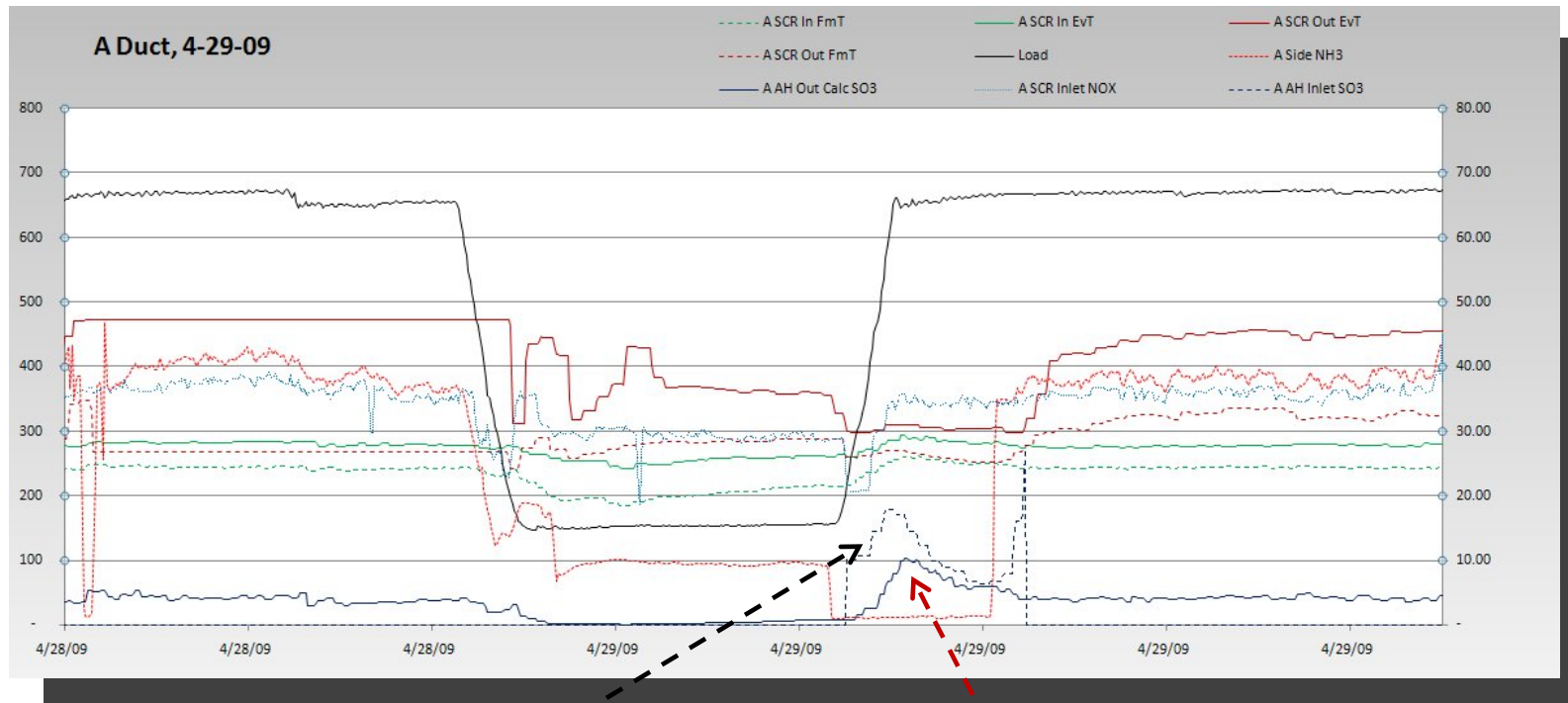


**SCR Release SO<sub>3</sub>**  
~ 22/24 ppm

**AH Release SO<sub>3</sub>**  
~ 11/9 ppm



# Enhanced Mode Release



**SCR Release SO<sub>3</sub>**  
~ 36 ppm

**AH Release SO<sub>3</sub>**  
~ 10 ppm



## Enhanced Mode Work

- Enhanced Mode Operation:
  - The  $\text{SO}_3$  release from load ramp after operation in Enhanced Mode is measurable and verifiable with  $\text{NH}_3$  off.
  - Our experience is that if a plant is generally in an ABS condition, then the magnitude of the  $\text{SO}_3$  release is insignificant when compared to the base ABS
  - To combat the release in both cases, work is being done to bias the reagent injection rate from a leading signal



## MOT Effects Summary

- Reduction in differential between Unit Operating Floor and Unit SCR Minimum Operating Load,
  - Greatly enhanced unit dispatch flexibility
  - Improved NOx reduction at reduced load
  - Reduced or eliminated reliance on Economizer Bypass
  - Extended Catalyst life due to minimized ABS poisoning



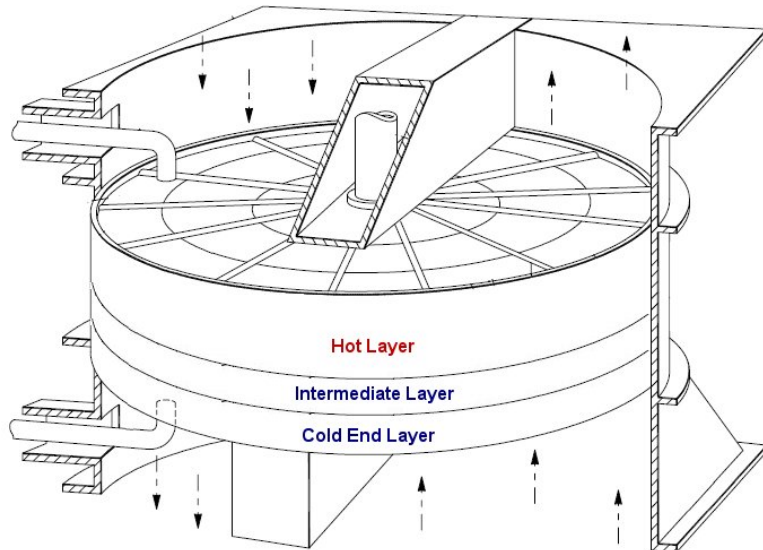
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# AIR HEATER FOULING EFFECTS

# Air Heater Fouling, Why?

Air Heater fouling occurs when:

1. Condensable material (sulfuric acid, ABS or NaBS) deposits in the Intermediate or Hot layers, and/or
2. Condensable material deposits in the cold end but beyond the effective reach of the cold end sootblower





# Fouling Avoidance

Avoiding air heater fouling requires:

- Lowering the condensable temperature to a point where the condensate forms close enough to the cold end to be cleanable by the sootblowing system.
- This can be done by:
  - Reducing ammonia flow to reduce ABS concentration,
  - Reducing SO<sub>3</sub> levels by introducing a suitable sorbent



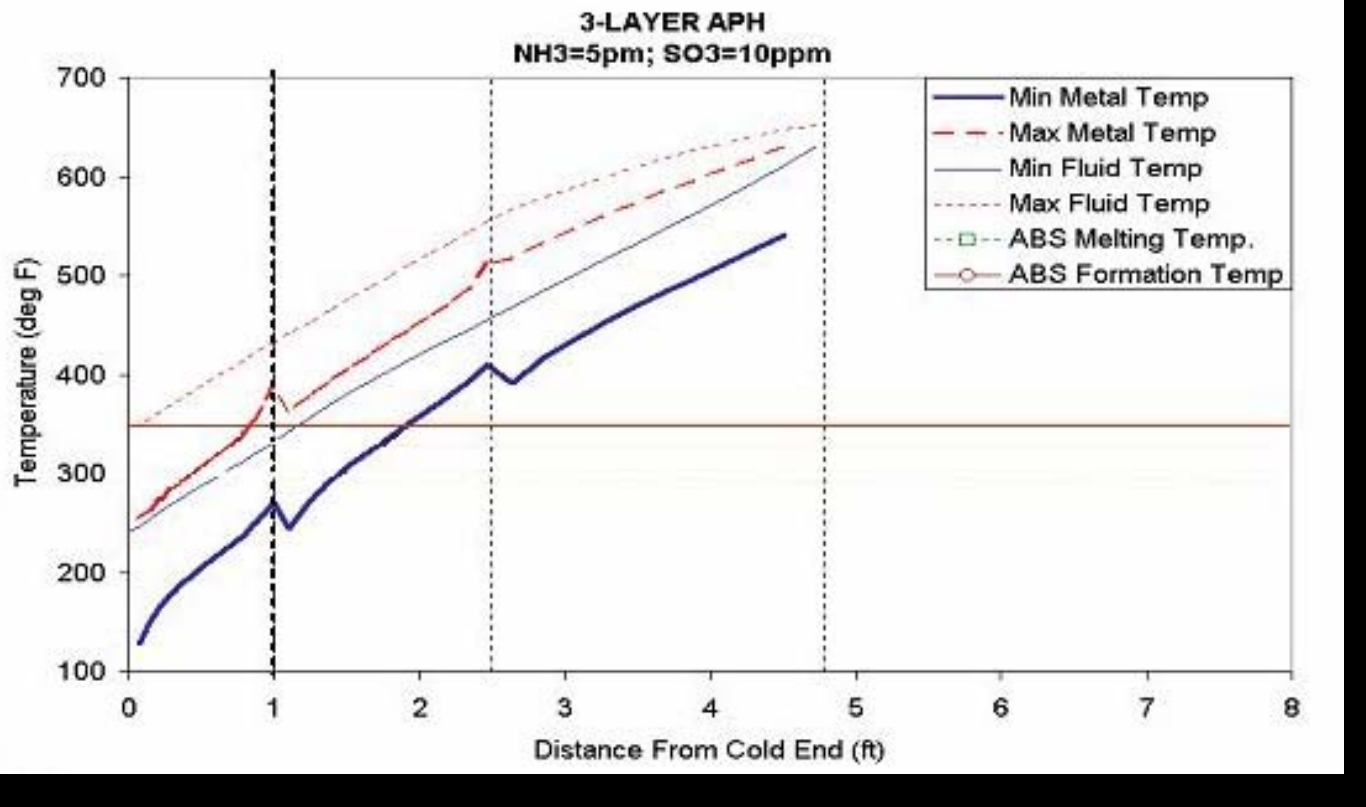
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# ***Air Heater Metal Temperature***

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# Heat Transfer Modeling

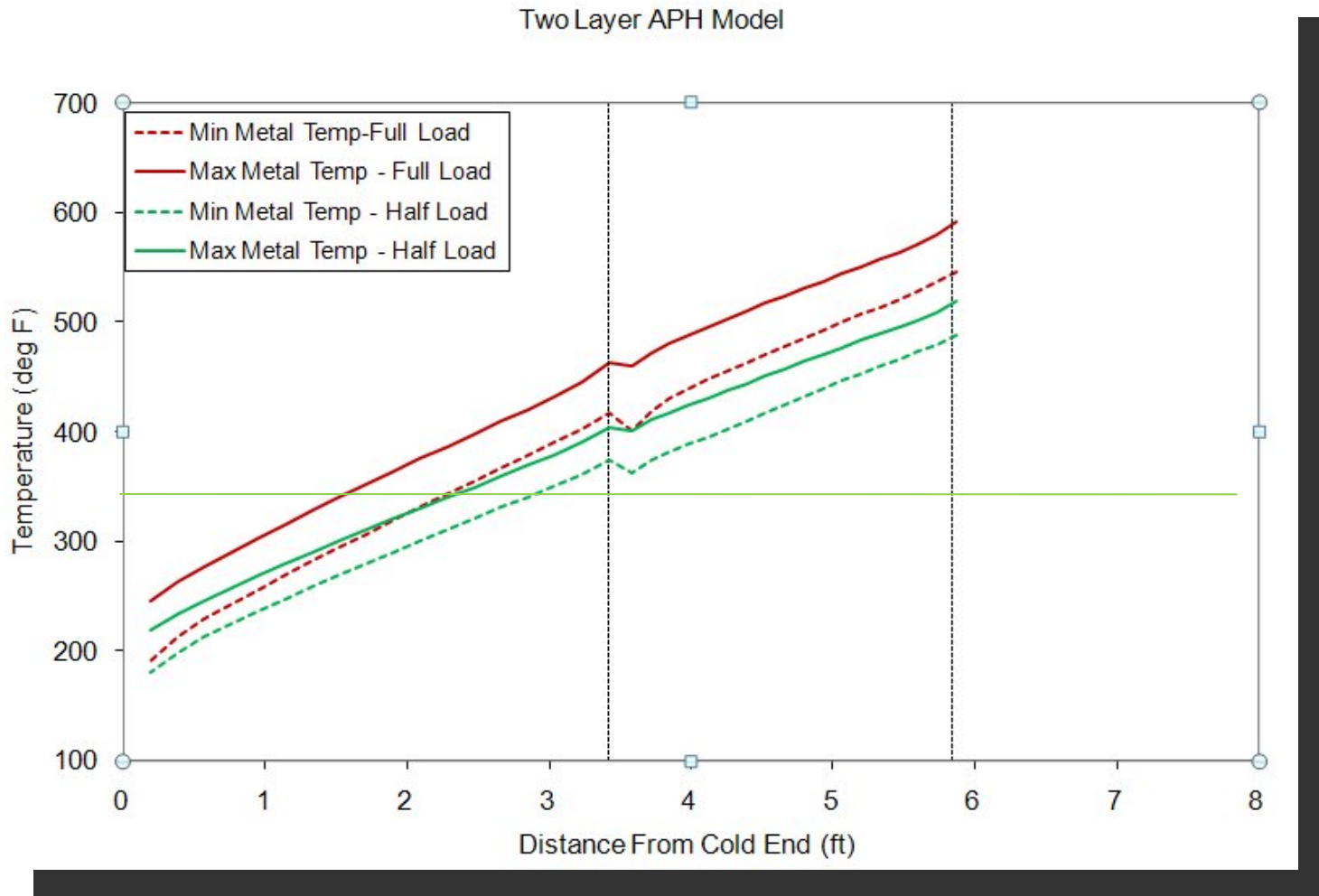


Traditional 3 layer design w/12" cold end.

Source: EPRI APFG



# Heat Transfer Modeling – Load Effects



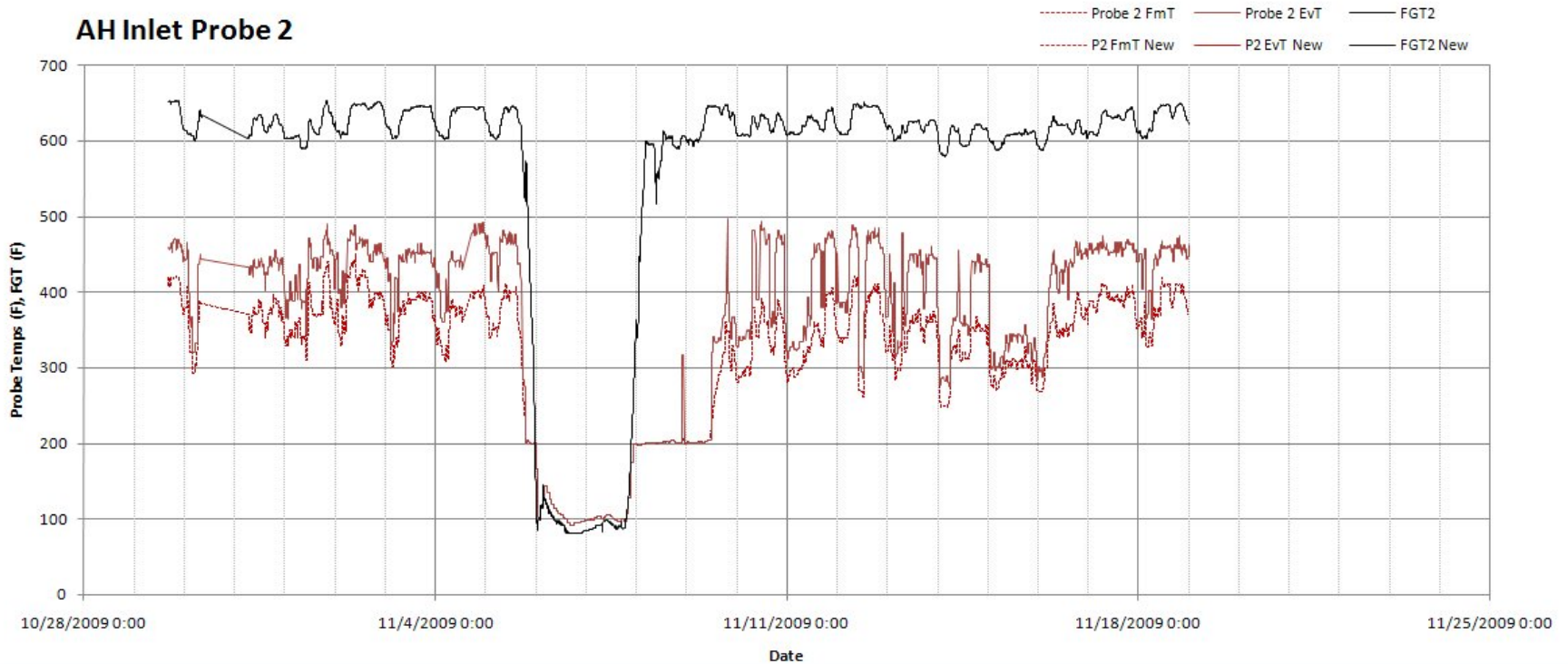


## Deposition Location?

- Knowing the precise metal temperatures at any given load and/or speed allows control of the deposition zone, but
- The actual, real-time, formation and evaporation temperature must be known

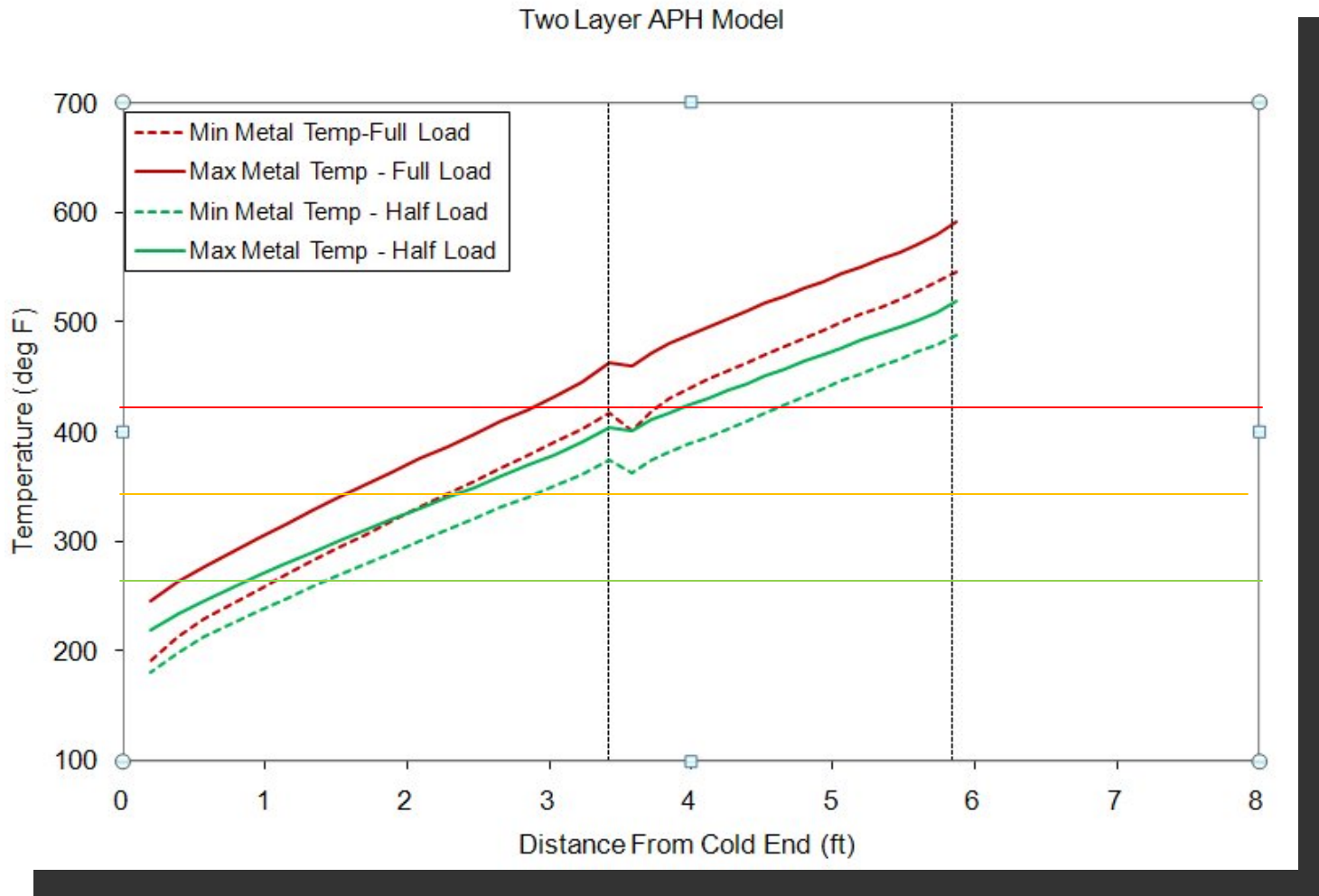


# ABS Formation



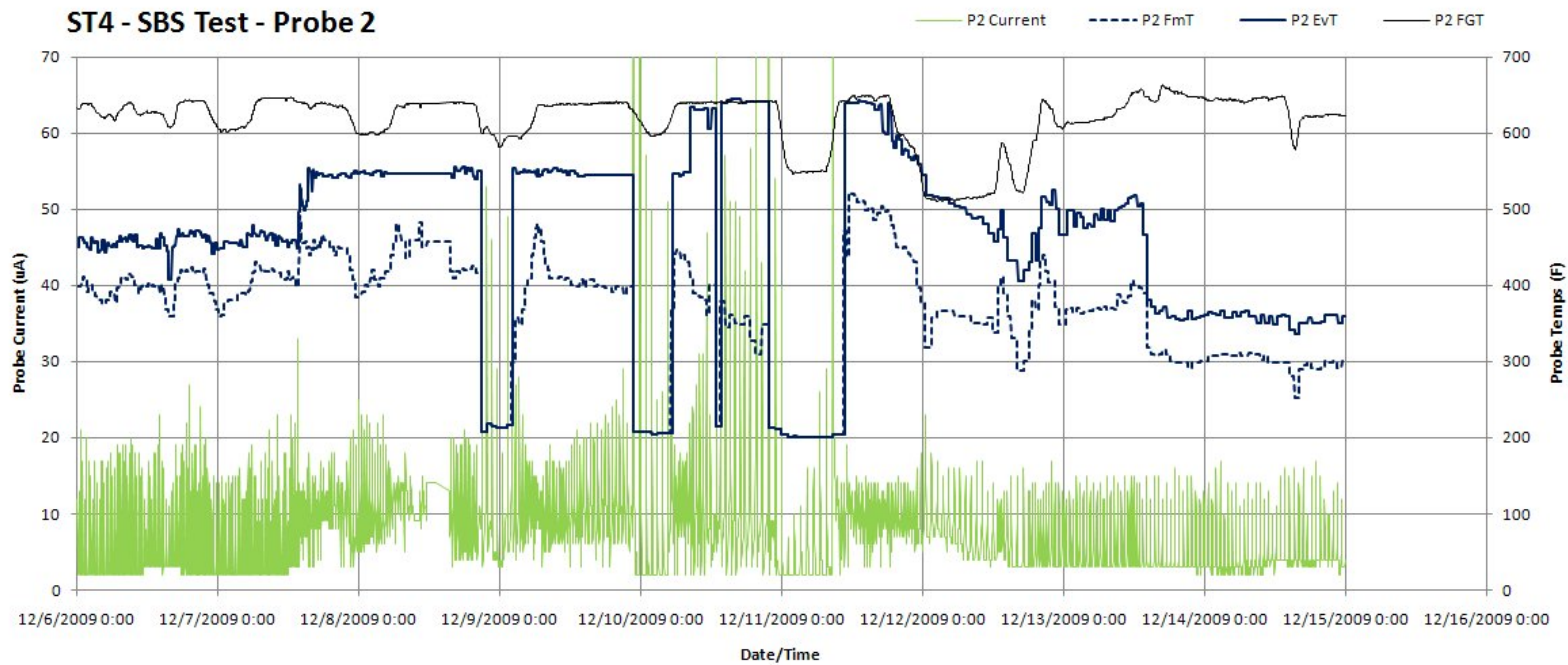


# Heat Transfer Modeling – Load Effects



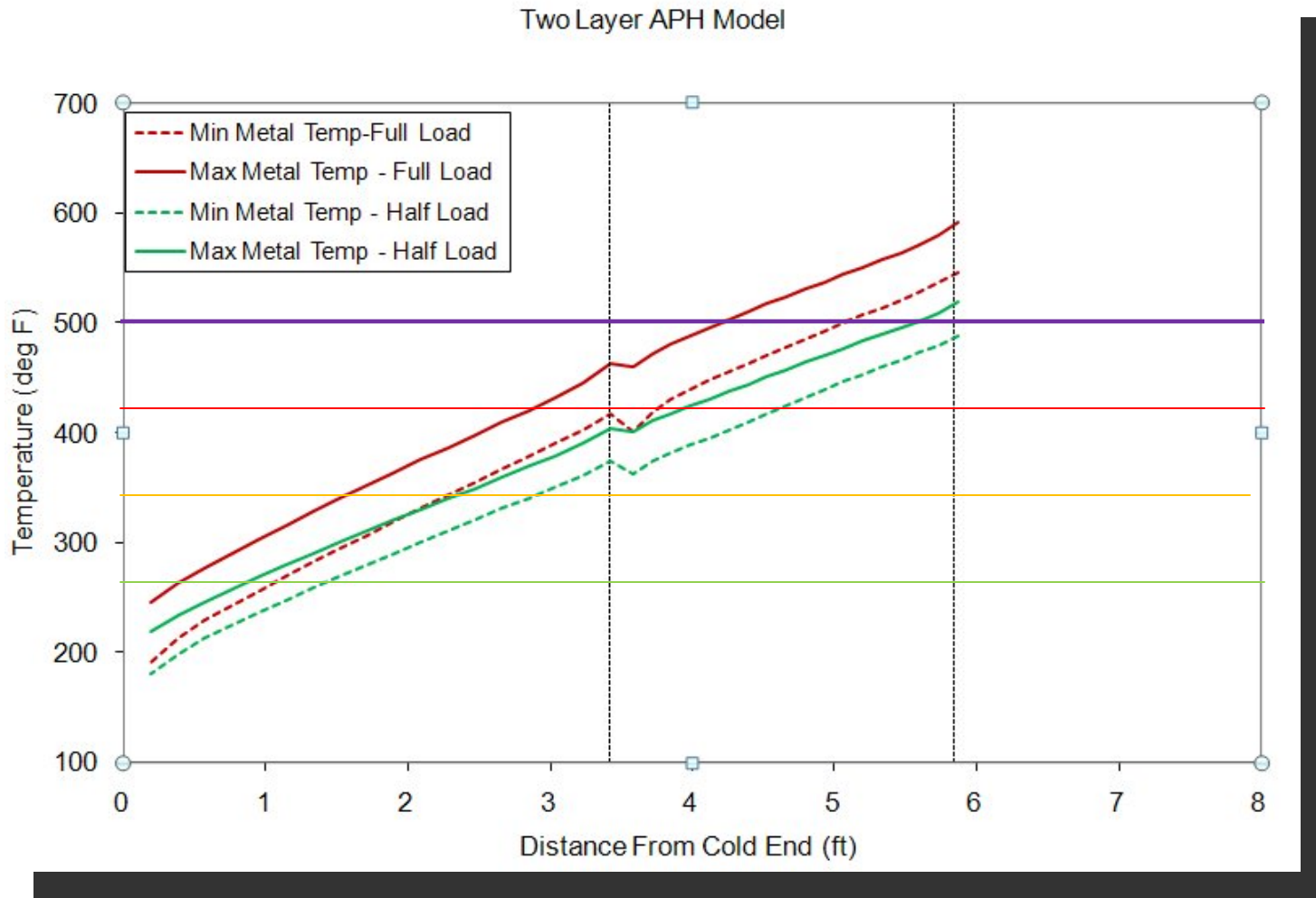


# Even High Condensables



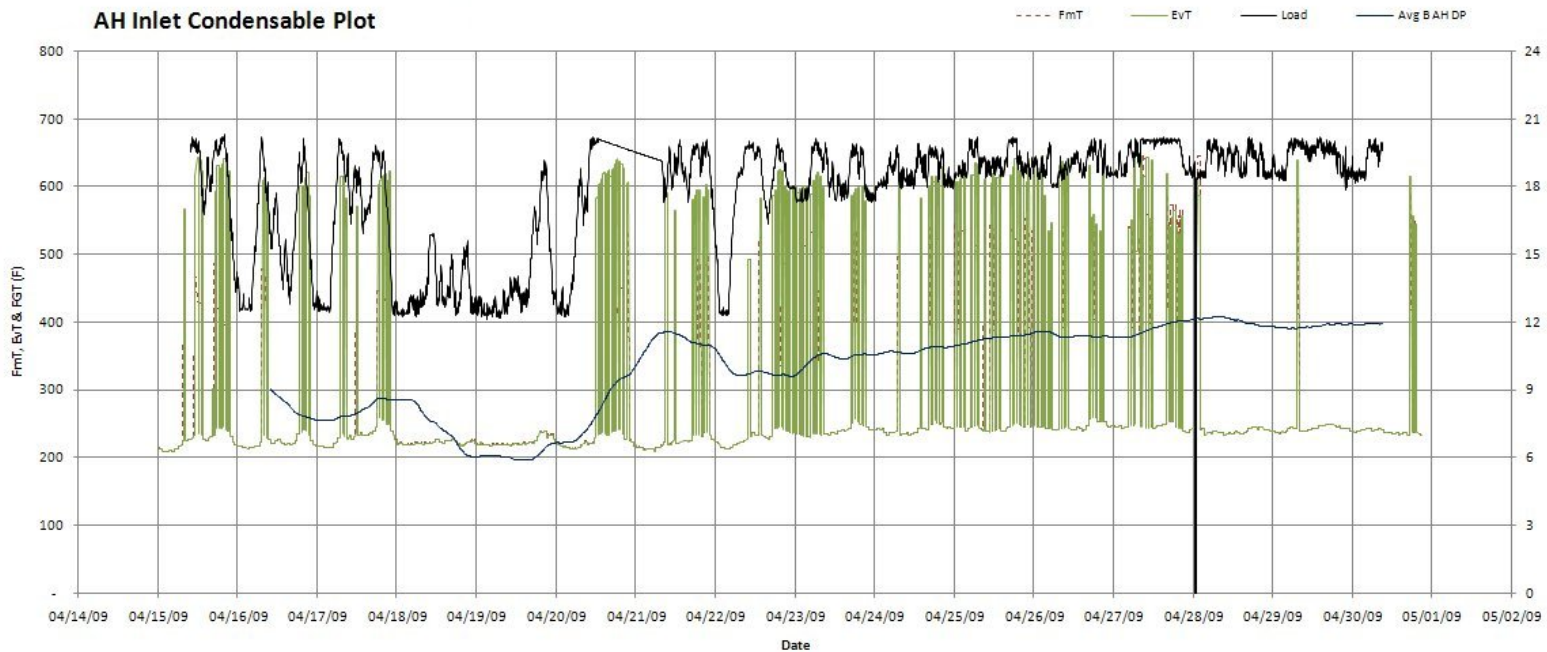


# Uncontrolled NaBS



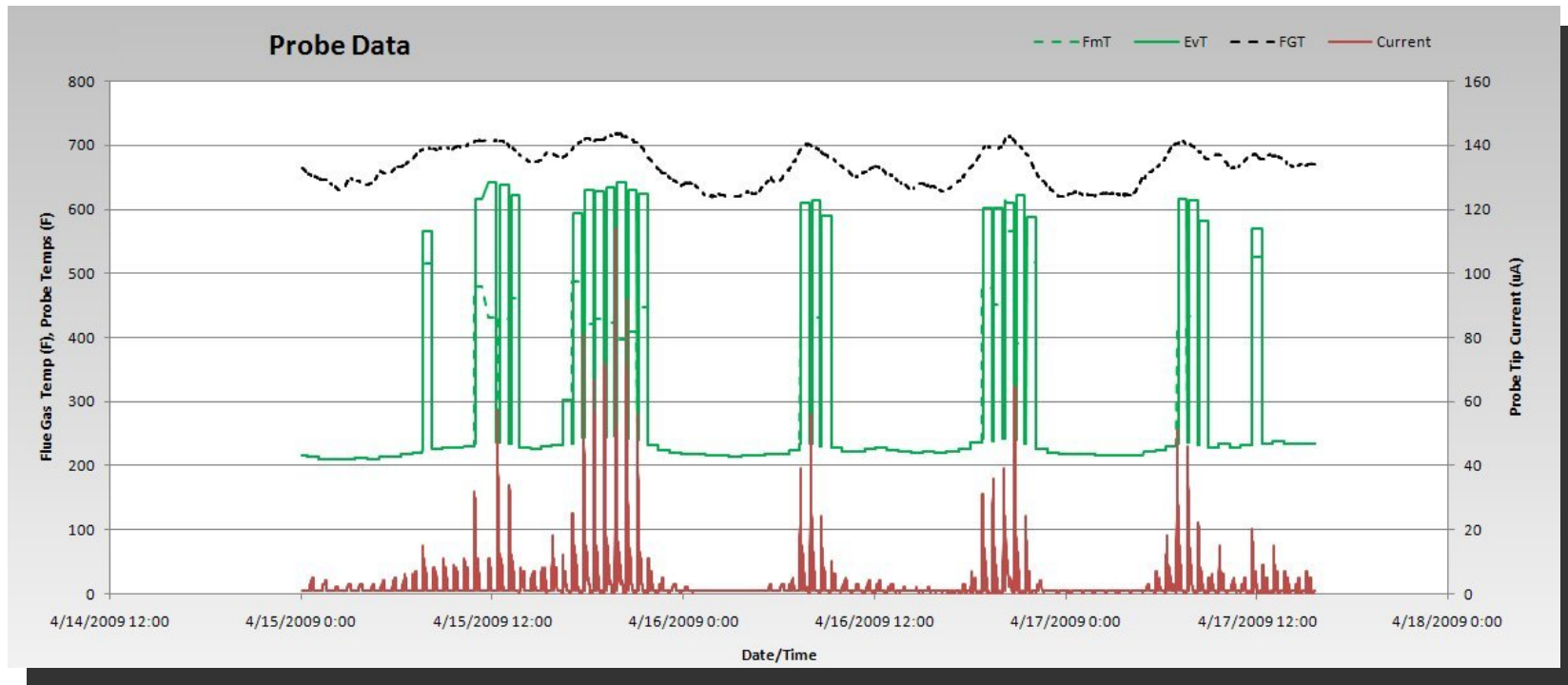


# Na Injection with Control



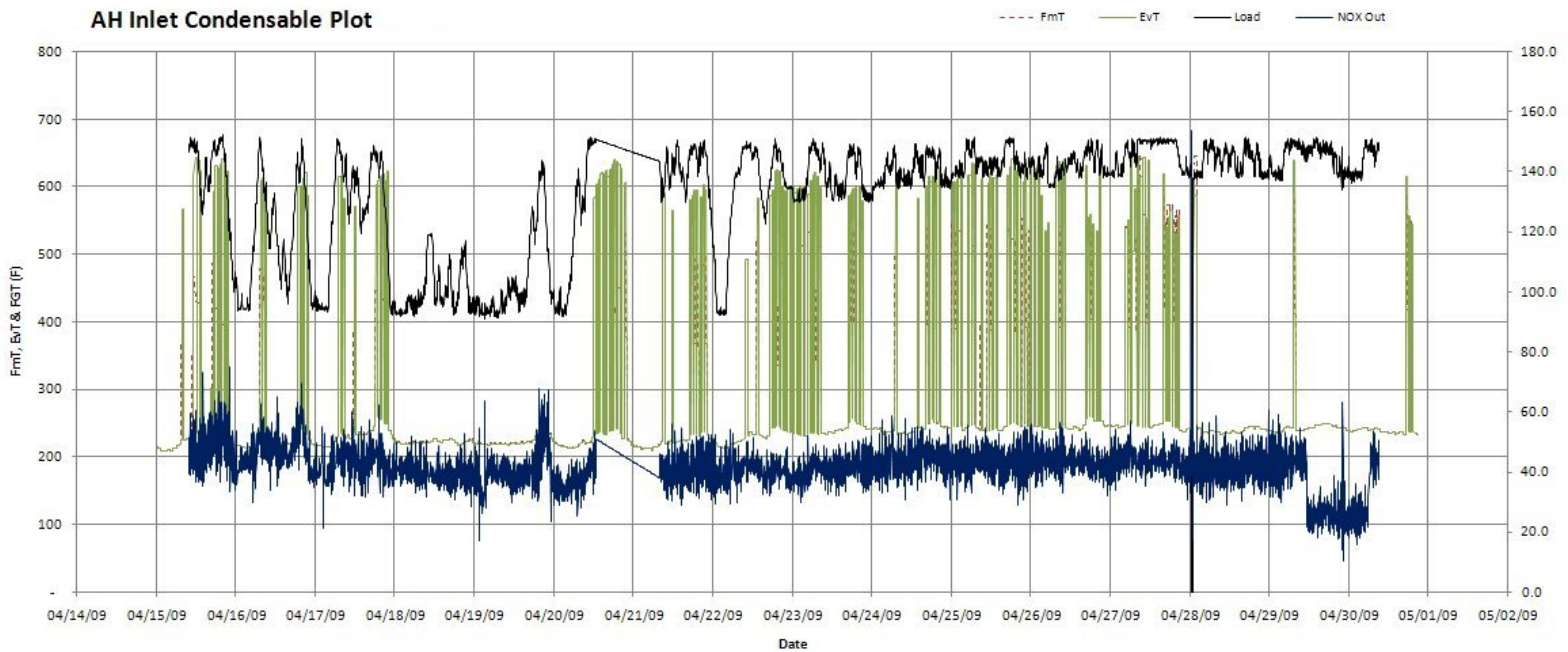


# Control Process Input





# Positive Effects of Control





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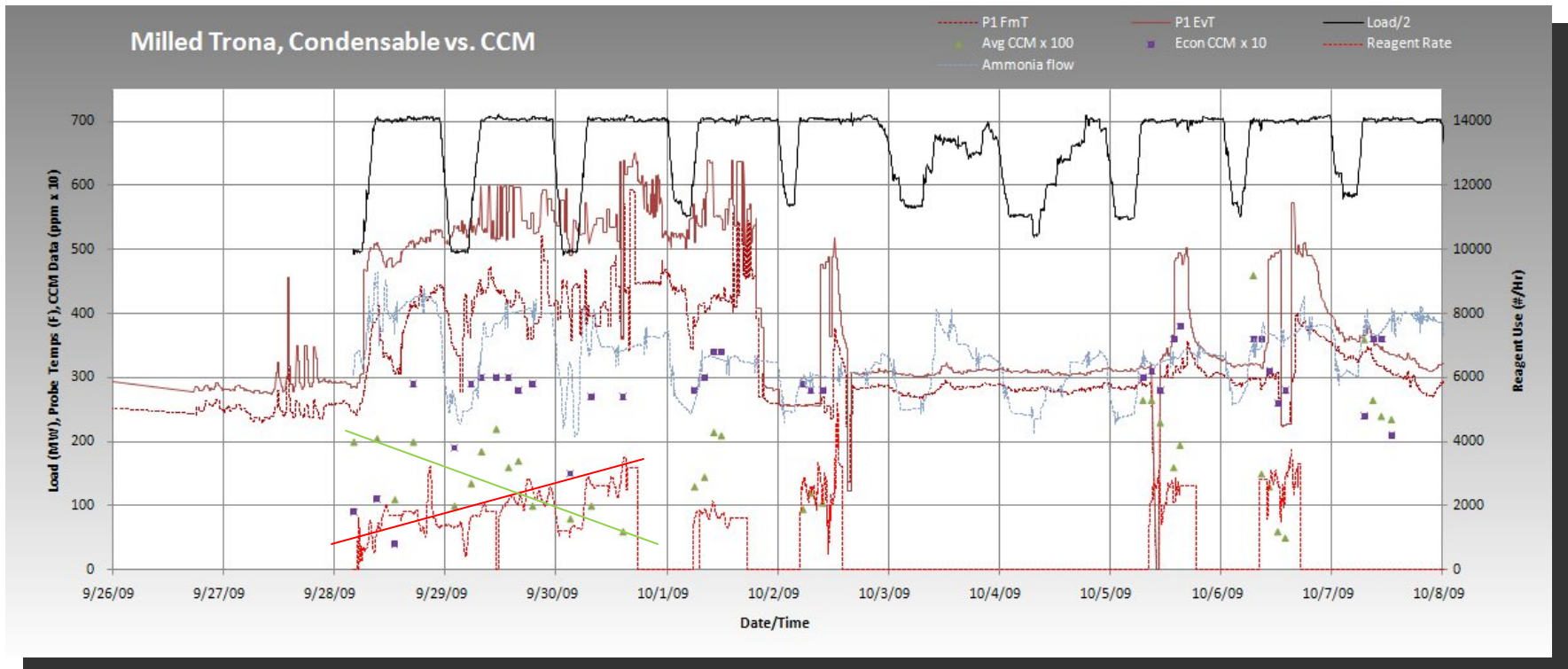
# *Hot Side Injection*

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A Case Study



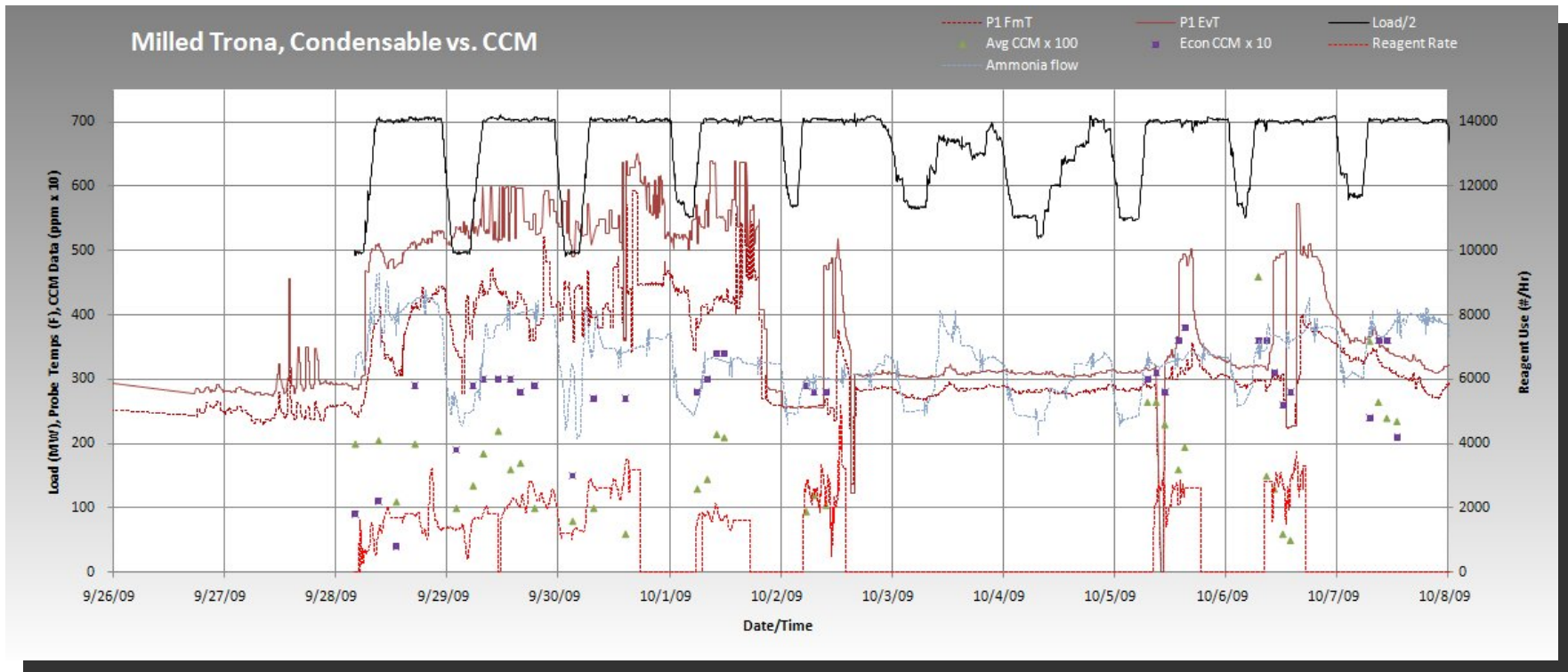
# Hot Side Na Injection





# Hot Side Na Injection

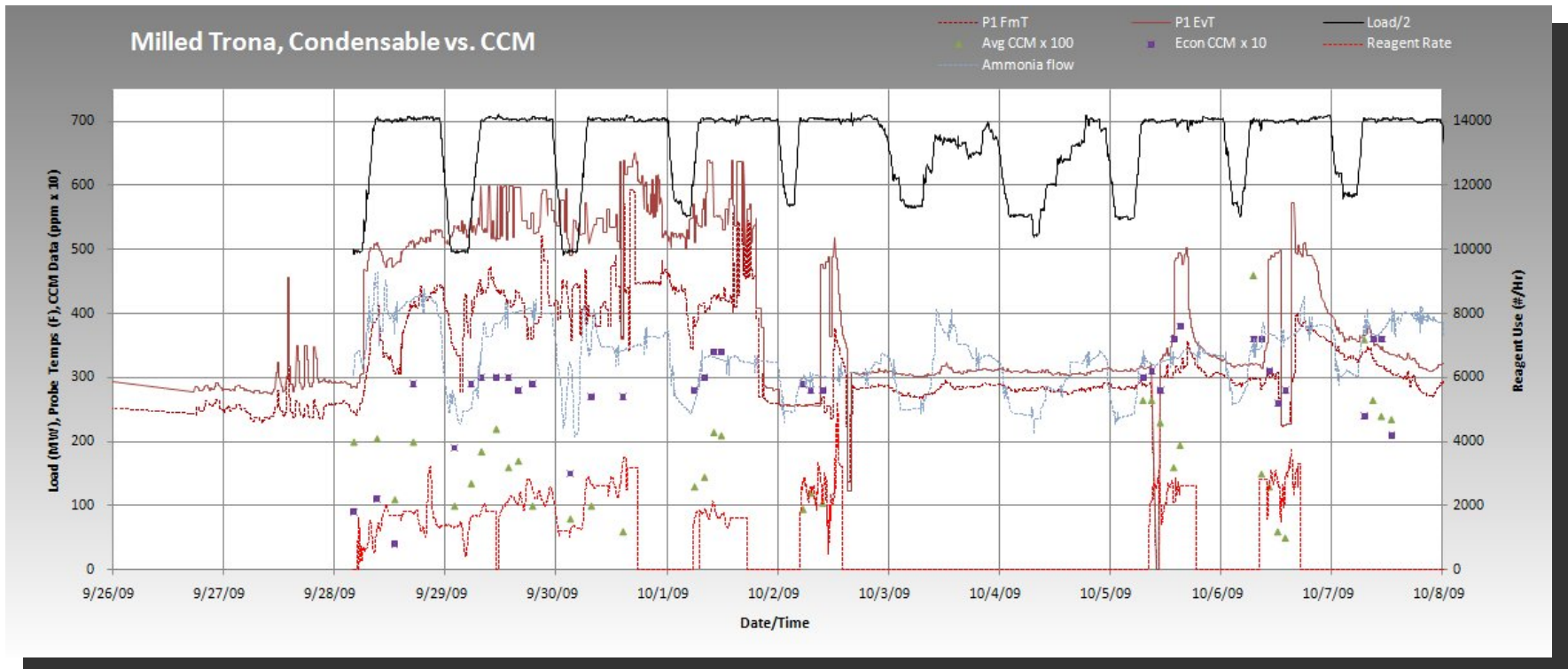
Note the presence of High Temperature condensables and the relationship between sodium injection and ammonia injection!





# Hot Side Na Injection

Now, notice the similarity between the condensable on 10/5 and the condensable during midday on 9/28.

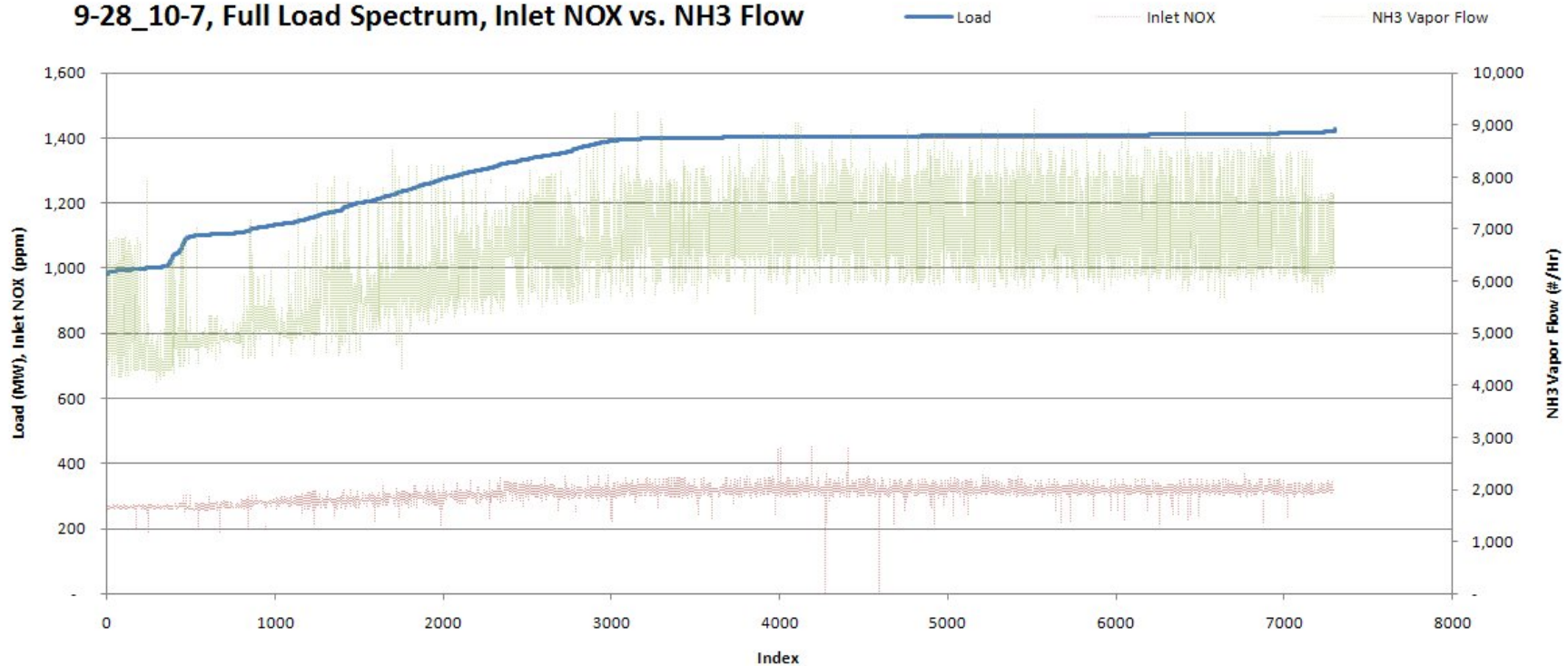


While the condensable value is nearly the same, the trona injection level is markedly higher and the ammonia level is markedly lower.



# Load/NH3/NOX Histogram

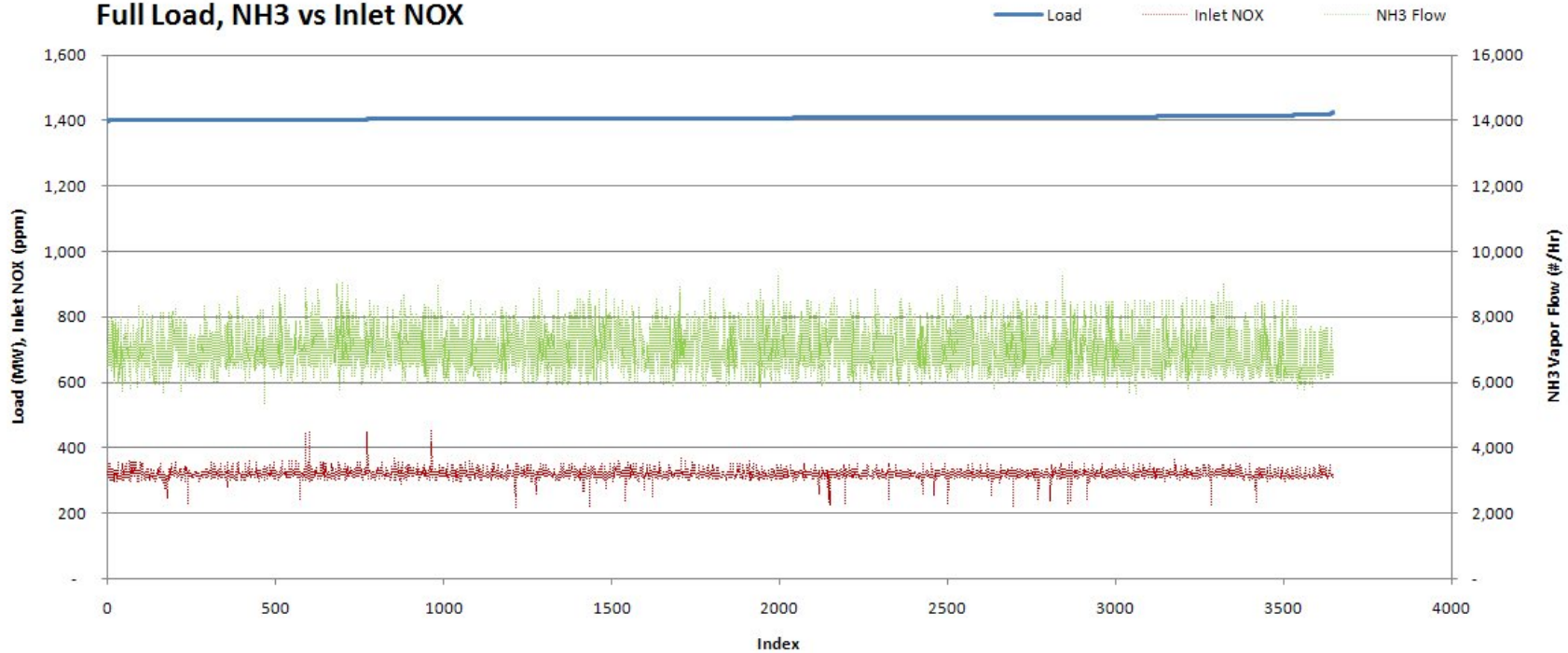
9-28\_10-7, Full Load Spectrum, Inlet NOX vs. NH3 Flow





# Full Load Only- Load/NH3/NOX Histogram

Full Load, NH3 vs Inlet NOX





## Case Study Summary

- 1. The Trona injection at the SCR Inlet was effective in lowering the free SO<sub>3</sub> at the AH Inlet,**
- 2. The Trona injection resulted in formation of certain sodium and ammonium-sodium condensables,**
- 3. These condensables may, or may not, have an impact on the Air Heater DP over time,**
- 4. Tighter control of the NH<sub>3</sub>/NO<sub>x</sub> process may allow more aggressive use of Trona while minimizing condensable formation temps,**
- 5. In the right circumstances, and with the right NSR, pre-air heater condensables were shown to be eliminate.**



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# *Summary and Conclusion*

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# Controllability and Take Aways

- Electronics and Feedback can only go so far! The mechanical systems must be capable of proper response.

## Mechanical System Requirements:

- Proper Material distribution grid,
  - Improved, engineered flow splitters
  - Improved ability to place the reagent where the condensables are located
  - Injection lance cleanliness and reliability
  - Improved system turn down response



## Conclusion

- Reagent Injection ahead of the Air Heater, or ahead of the SCR, can provide significant additional performance benefits to the plant for the same cost as an injection system at the ESP inlet,
- However, SO<sub>3</sub>, NH<sub>3</sub>, SCR and Air Heater processes all interact with each other creating a non-trivial control challenge,
- The proper marriage of process knowledge, system interaction and injection equipment capability is necessary



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***Thank You!***

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Questions?