Reinhold Environmental Ltd.

2009 NOx-Combustion Round Table & Expo Presentation

February 9 & 10, 2009, Cleveland, OH

INTEGRATED CONDENSABLES MANAGEMENT

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Condensables Measurement System

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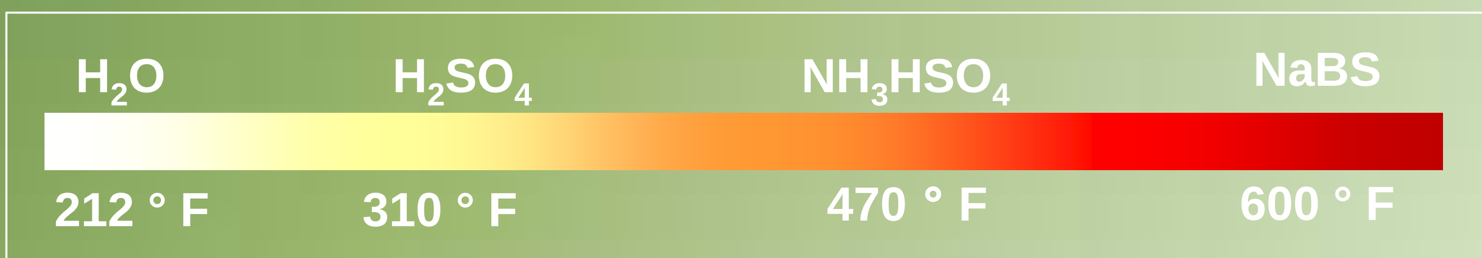
AbSensor – AbS/SO3
What is it? What does it do?

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

This material could be:

- Moisture (H_2O),
- Sulfuric Acid (H_2SO_4) ($H_2O + SO_3$)
- Ammonium Bisulfate (NH_3HSO_4) ($NH_3 + H_2O + SO_3$)
- Sodium Bisulfate



The same device measures condensables across the spectrum!

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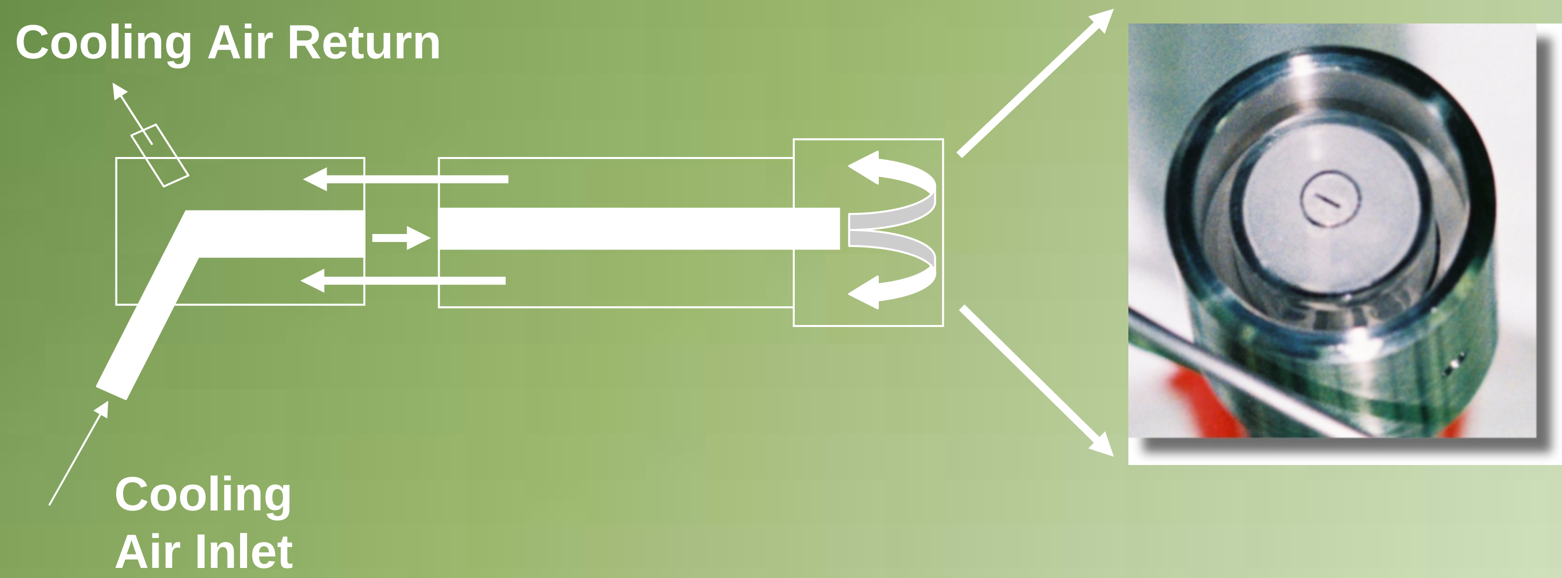
How does it work? - I



Cooling air flow to the probe tip is precisely controlled to induce condensation on the probe surface

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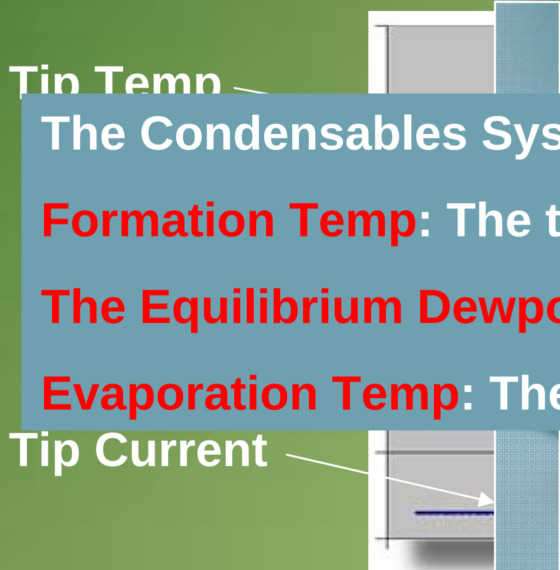
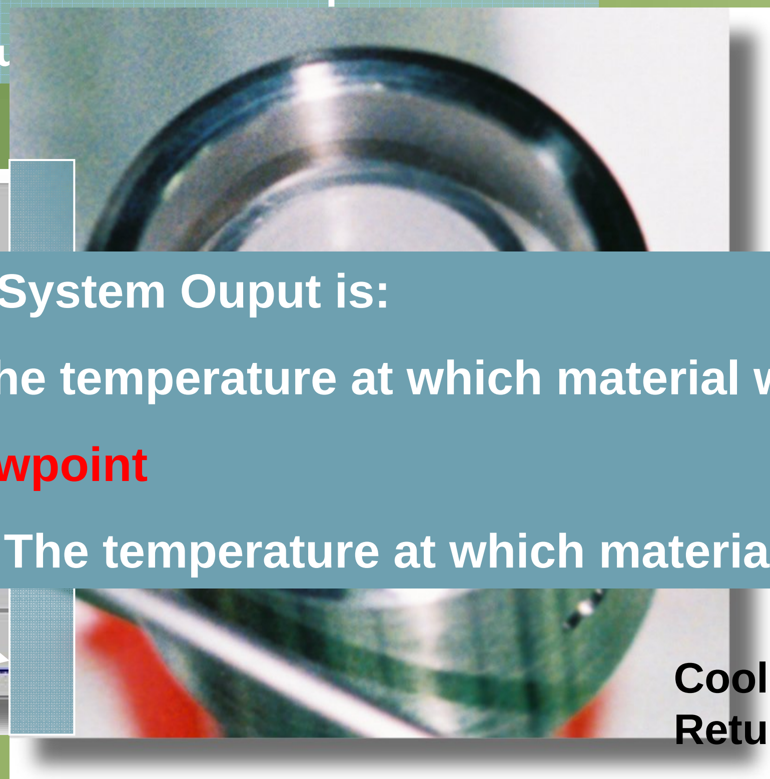
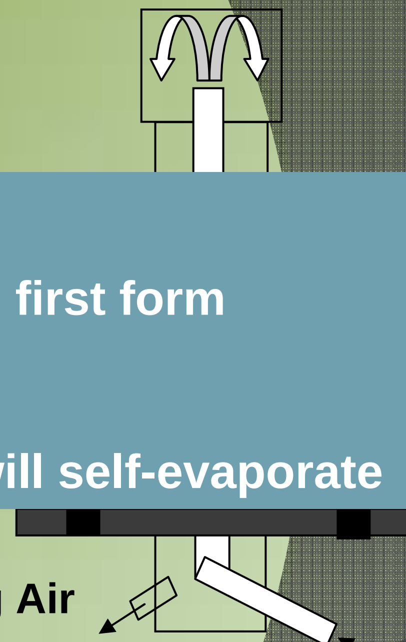
AbSensor - Introduction

Condensation = Evaporation

Equ







The Condensables System Ouput is:

Formation Temp: The temperature at which material will first form

The Equilibrium Dewpoint

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

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

AbSensor – AbS/SO3 System

- 4” 150 lb 8-bolt flanged port
- 50 psi service air
- 12 cfm air consumption
- 110 VAC power supply

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MOT

What is SCR Minimum Operating Temperature (MOT)?

- This is the recommended temperature below which there is a concern of catalyst plugging due to condensation of Ammonium Bisulfate in the catalyst pores leading to deactivation of the catalyst and reduced SCR performance
- Below this temperature the NH_3 injection is turned off

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What is the AbS Dewpoint?

- AbS Dewpoint$_{BULK}$ = func(SO_3, NH_3, Moisture)
- AbS Dewpoint$_{CAPILLARY}$ = func(AbS Dewpoint$_{BULK}$, Pore Size, Activity?)
- Typically in the range of 330 to 550 DegF, but could be higher

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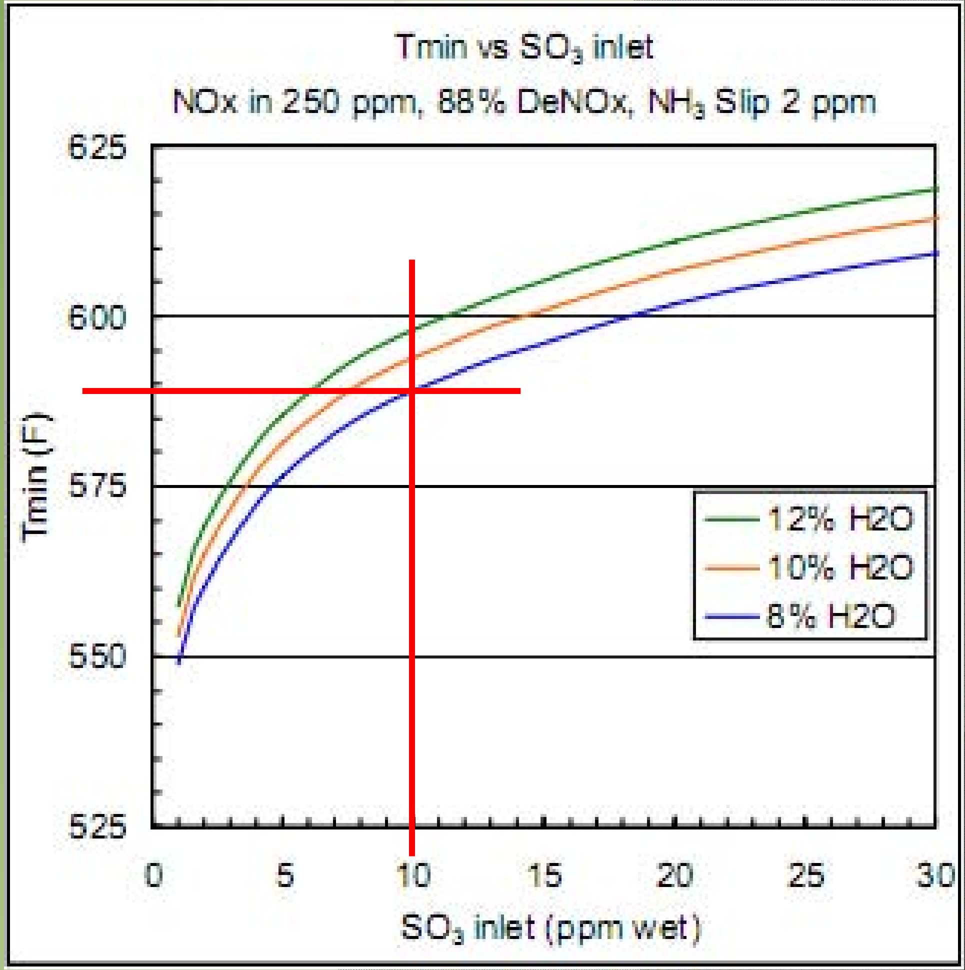
Vendor MOT Curves

- **Typical catalyst vendor curve showing minimum operating temperature based on a 2 ppm NH_3 slip at various SO_3 and moisture levels.**
- **A typical case of 10 ppm SO_3 at 8 % moisture yields a MOT of 595 DegF**
- **These curves take into account the pore size of the specific catalyst design**

Source: Argillon Presentation at the Reinhold Environmental NO_x Round Table 2008



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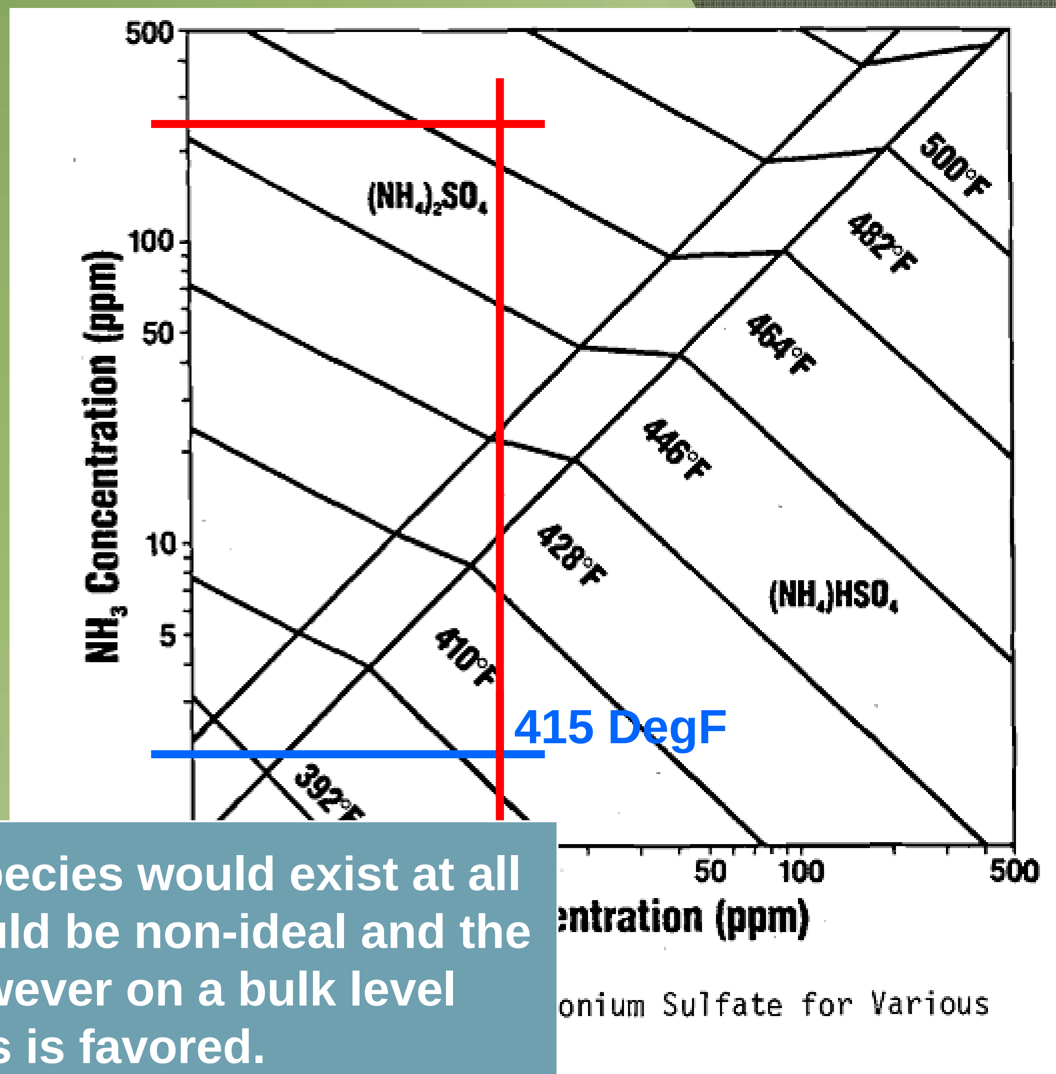
AbS – AS Phase Diagram Hitachi-Zosen Paper

- 2 ppm NH3 Slip, 10 ppm SO3 = Formation Temp of 415 DegF with potential for AbS

- At SCR inlet the NH3 would be 250 ppm with 10 ppm SO3 = Formation Temp of 485 DegF and potential for AS



In reality, it is expected that both species would exist at all times as the spatial distribution would be non-ideal and the equilibria could shift locally. However on a bulk level one or the other species is favored.

AbS Dewpoint Lab Tests by Matsuda et. al.

- The apparatus shown here was used by Matsuda et. al. to determine the formation of AS v/s AbS and the dewpoint of AbS in 1982 using a Quartz Tube Reactor

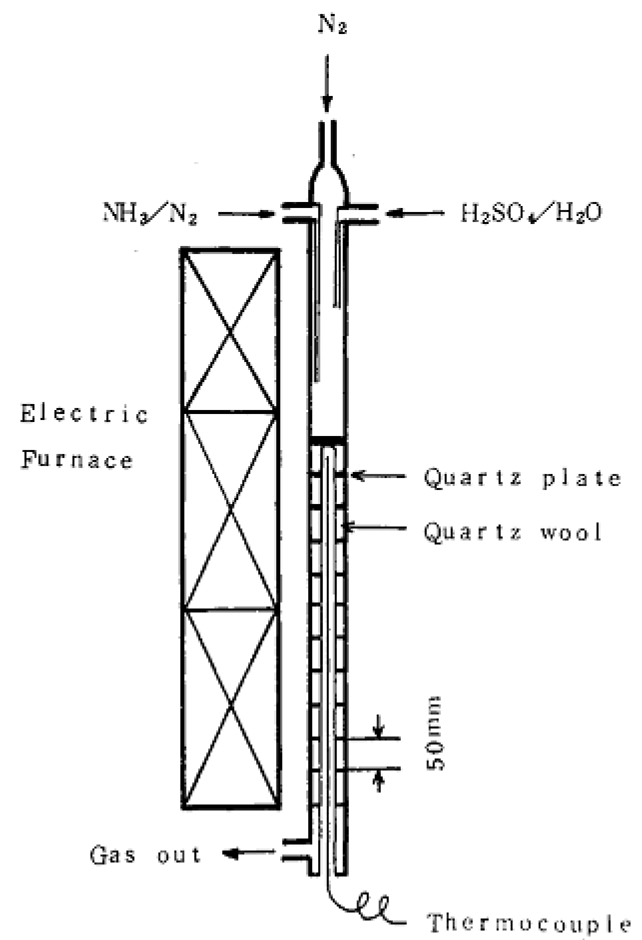


Figure 2. Apparatus for measurement of ammonium bisulfate deposition.

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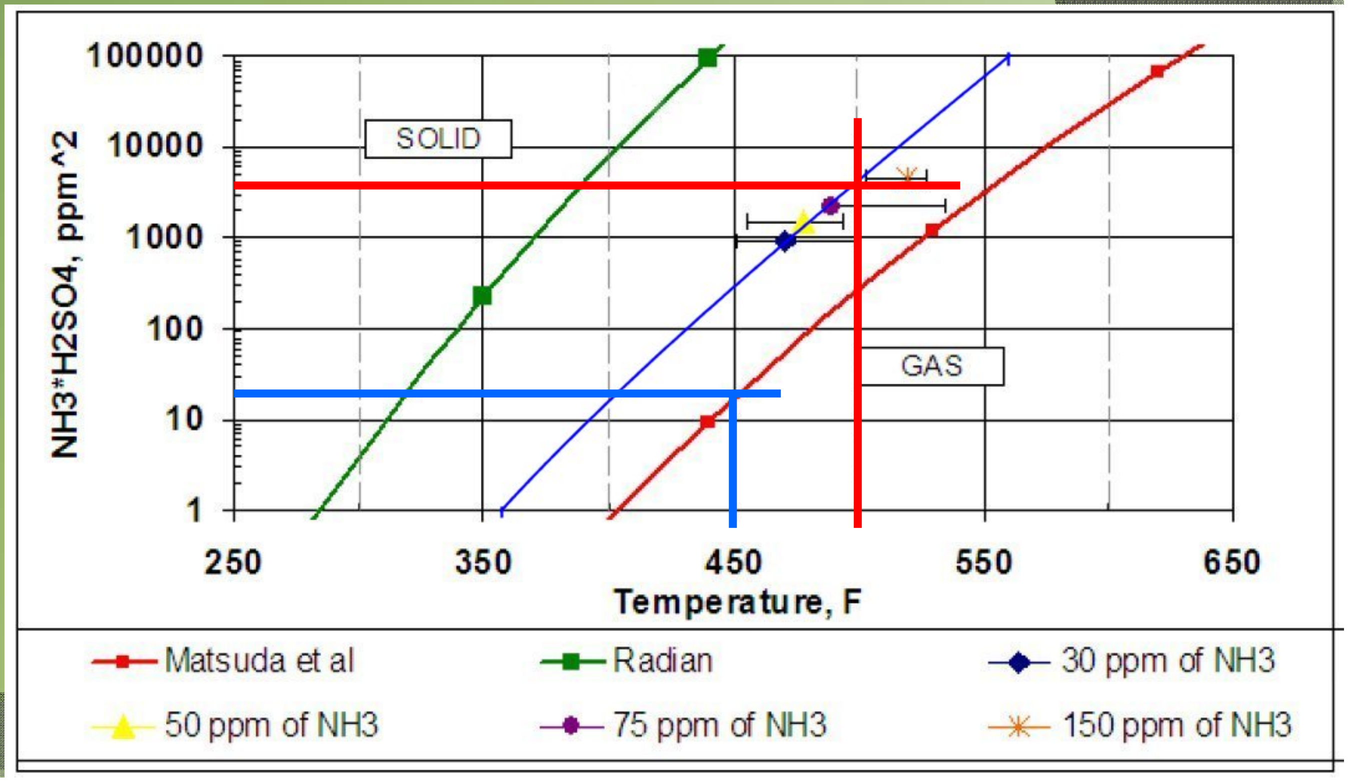
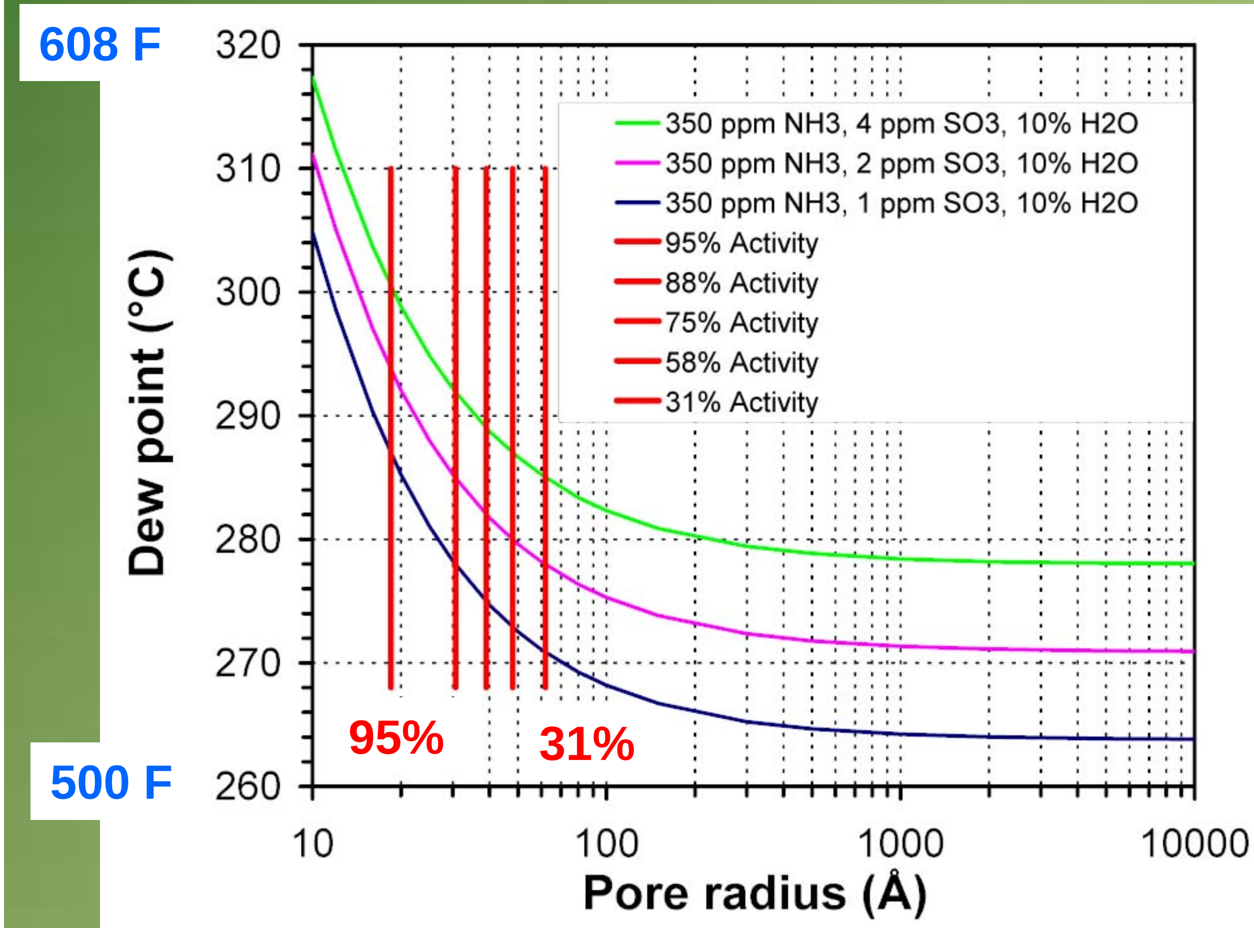
$NH_3 * SO_3 = AbS$

- UCI work in conjunction with FERCO, EPRI and Breen Energy produced the graph below showing AbS dewpoint as a function of NH_3 and SO_3 ppm. The data varies widely between Radian, Matsuda and those collected under this program

- 2 ppm NH_3 * 10 ppm SO_3 = 20 ppm^2 NH3*SO3
- AbS Dewpoint of 450 DegF
- SCR inlet 250 ppm NH_3 * 10 ppm SO_3 = 2500 ppm^2 NH3*SO3
- AbS Dewpoint of 500 DegF



Capillary Dewpoint = Func(SO3, Pore Size, Activity)



The effective pore size increases as Catalyst Activity decreases

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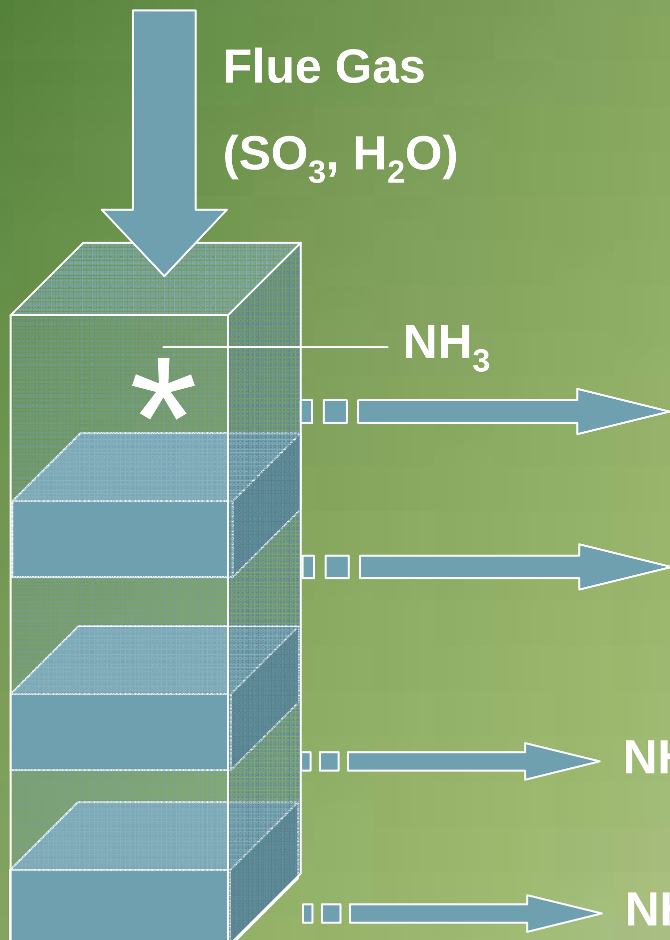
Equilibrium within the SCR



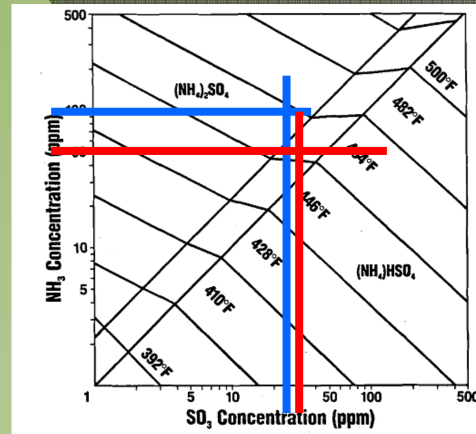


Figure 22-7. Formation of Ammonium Sulfate for Various Concentrations of NH_3 and SO_3

NH3 = 250 ppm, SO3 = 10 ppm, AS Potential

NH3 = 100 ppm, SO3 = 15 ppm, Mixed Potential

NH3 = 50 ppm, SO3 = 20 ppm, Mixed/AbS Potential

NH3 = 2 ppm, SO3 = 20 ppm, AbS Potential

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Have I confused you enough by now?

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Can you measure AbS Dewpoint?

- Yes! AbSensor – AbS can measure the bulk dewpoint of Ammonium Bisulfate

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Why lower MOT?

- Allow the SCR to continue operating at lower loads:
  - Higher Load turn-down – AGC, Wind Energy
  - Regulatory compliance for SCR operation
  - Tradable NO_x Credits
- Heat Rate improvement, if the temperatures are held higher artificially using Air Bypass or Heating coils

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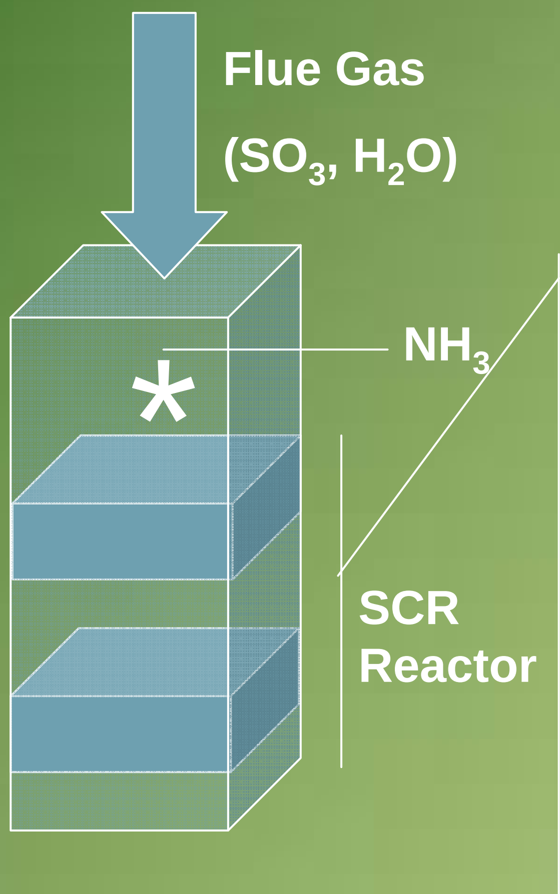
How can you lower MOT?

- Burn Low-S Coal
- Lower the SO_3 coming into the SCR using chemical reagents such as Na, Ca or Mg compounds
- Measure the SO_3 coming into the SCR and the AbS dewpoint post-NH_3 injection prior to the SCR and run the SCR just above the AbS dewpoint

SCR Operation - Reactions



$$4\,NO + 4\,NH_3 \xrightarrow{\text{Catalyst}} 4\,N_2 + 6\,H_2O$$

$$2\,NO_2 + 4\,NH_3 + O_2 \xrightarrow{\text{Catalyst}} 3\,N_2 + 6\,H_2O$$

$$2\,SO_2 + O_2 \xrightarrow{\text{Catalyst}} 2\,SO_3$$

$$NH_3 + SO_3 + H_2O \longrightarrow NH_4HSO_4 \text{ (AbS)}$$

$$NH_4HSO_4 + NH_3 \longrightarrow (NH_4)_2SO_4 \text{ (AS)}$$

$$2NH_3 + SO_3 + H_2O \longrightarrow (NH_4)_2SO_4 \text{ (AS)}$$

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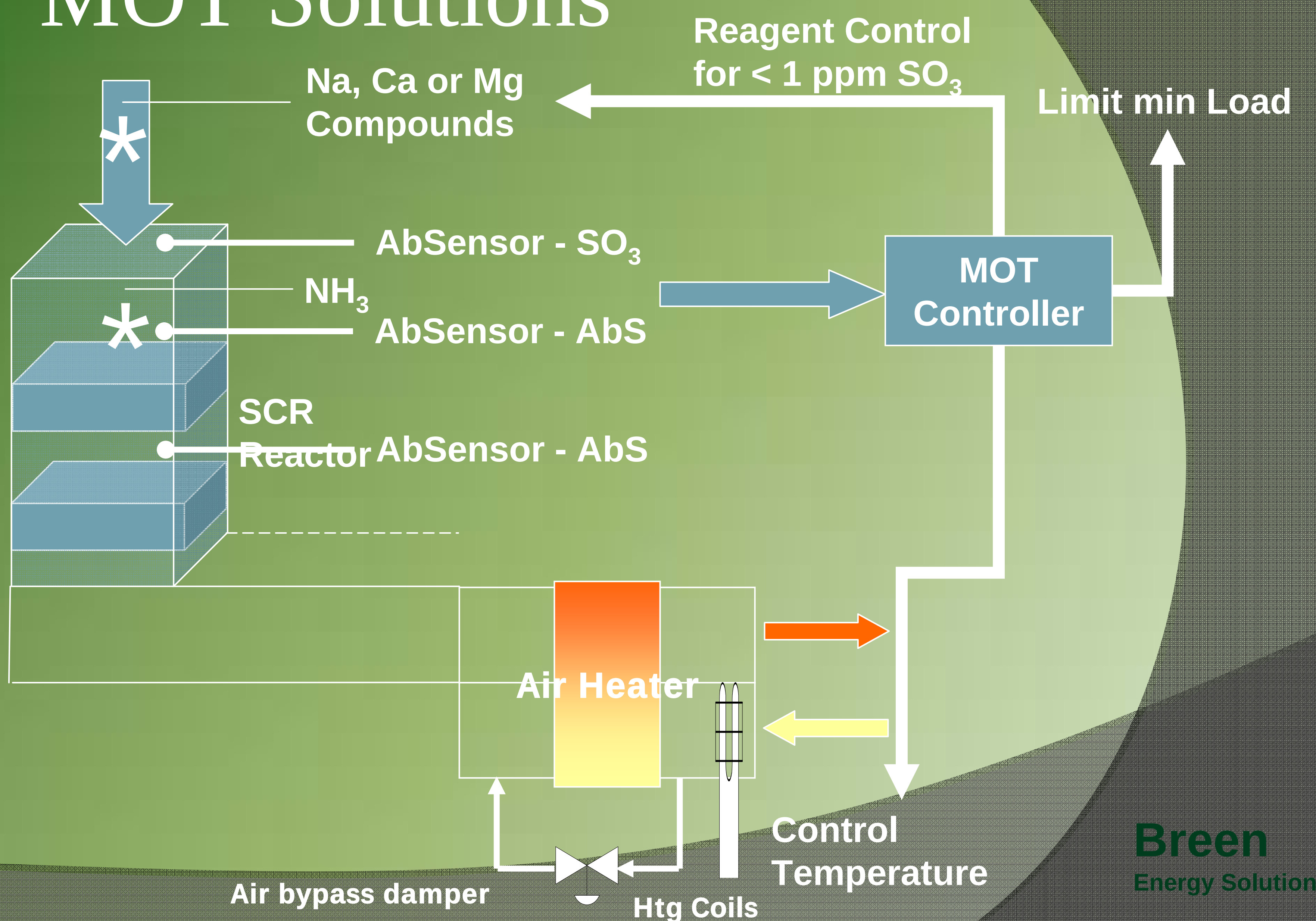
MOT Solutions



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Ideal solution

- Reduce the SO3 coming into the SCR down to 1 ppm thereby shifting the equilibrium heavily towards AS throughout the SCR

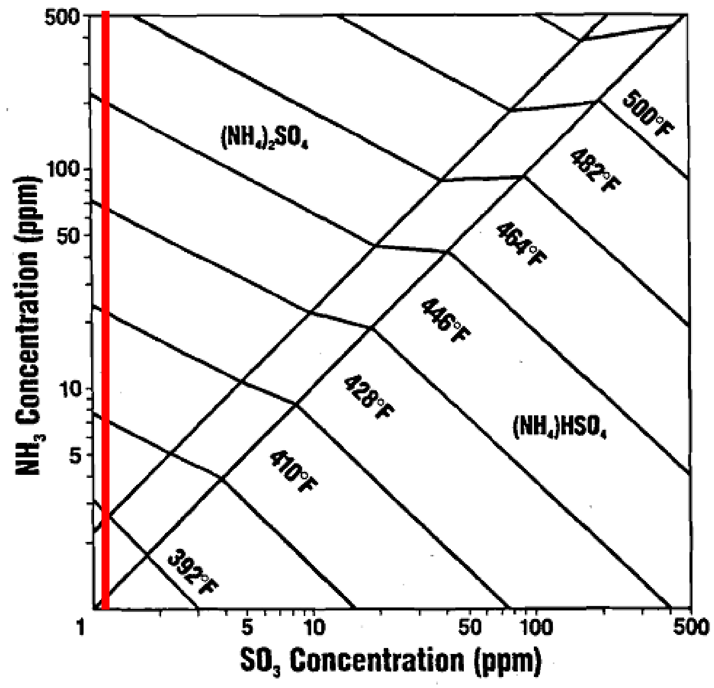

Figure 22-7. Formation of Ammonium Sulfate for Various Concentrations of NH_3 and SO_3

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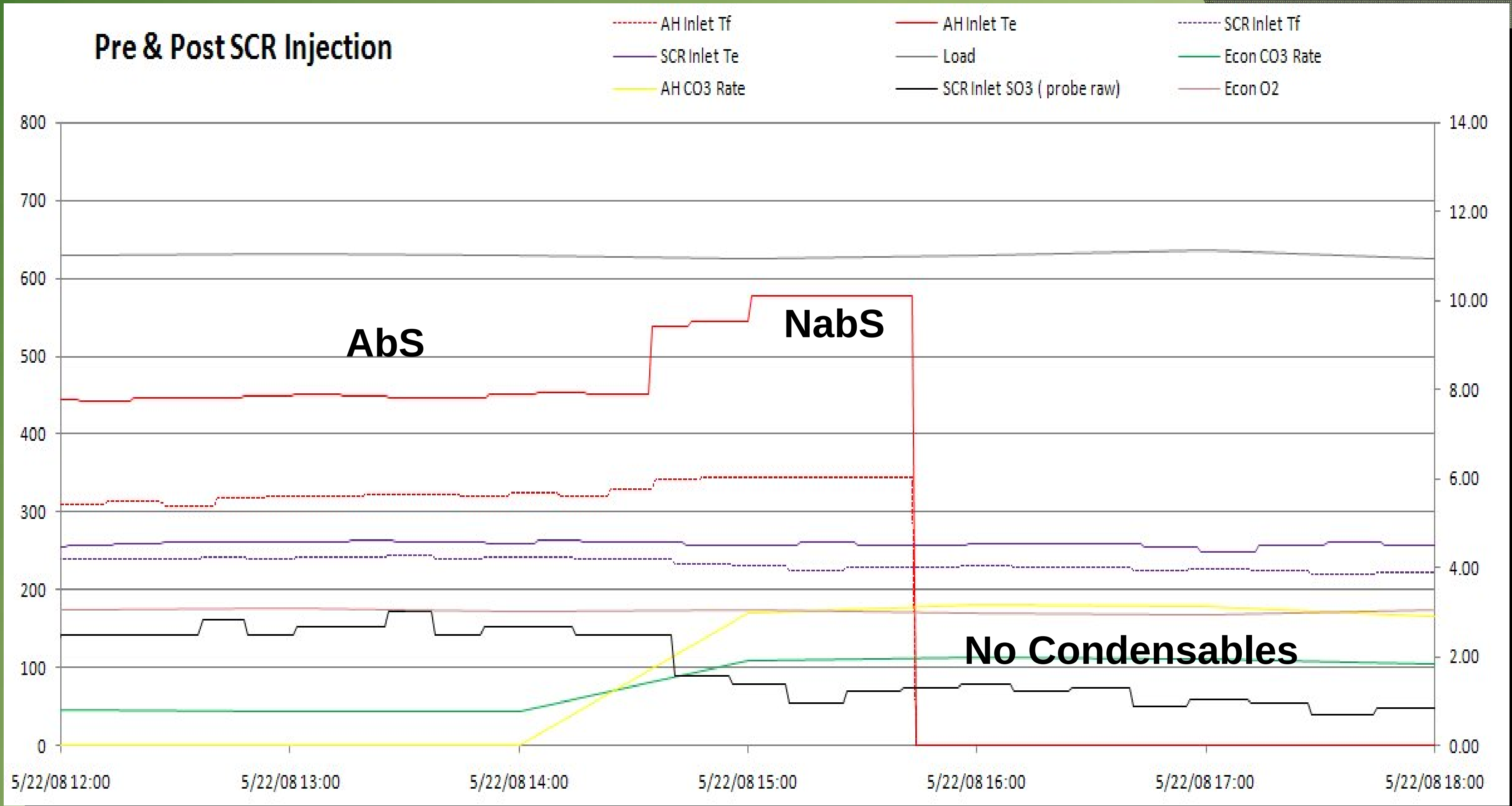
SCR Inlet SO3 control – Na* Example



* URS SBS Injection System

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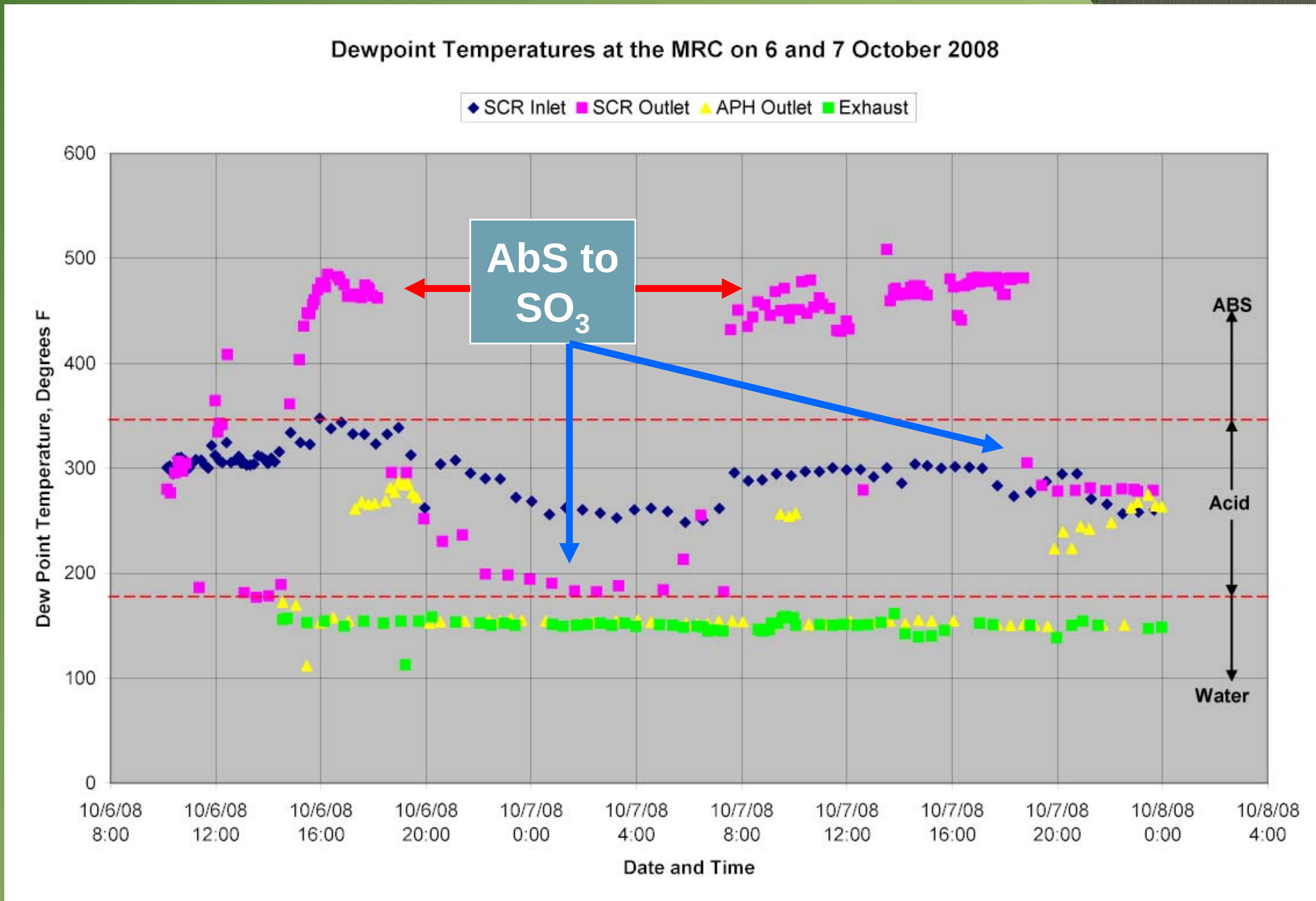
SCR Inlet SO3 control – Ca* Example



*** Test conducted at Mercury Research Center at Southern Company Plant Crist with Chemical Lime**

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Breen Tool for SO_3

	A	C	D	E
2		Common		
3		Duct Pressure=	-10	"H2O
4		Duct Pressure=	741.3176008	mmHg
5		P(H2O)=	10.0%	mol %
6		P(H2O)=	74.13176008	mmHg
8	-0.130932	SO3 to DP		
9	2.570214	**Given:**		
10	2.439282	SO3 =	**10**	ppm
11	136.8066	**Calculate:**		
12	278.2519	Calc-Tdp =	**278**	°F
14	4.70142	DP to SO3		
15	3485.245	**Given:**		
16	-5.659217	Tdp =	**265**	°F
17	0.334481	**Calculate:**		
18		SO3 =	**4.7**	ppm

Factors	
A	2.276
B	0.0294
C	0.0858
D	0.0062

	Min (>0)	Max
Range:	1	100

Plot Curves

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Measured DP	Measure SO3
250	5
260	7
270	9
280	17
290	25

Factors		Tune:	10%
A	2.276	2.5036	2.048
B	0.0294	0.03234	0.0264
C	0.0858	0.09438	0.0772
D	0.0062	0.00682	0.0055

Dewpoint to SO3 ppm

And

SO3 ppm to Dewpoint

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Breen Tool for AbS

AbS Dewpoint = f(NH3, SO3)		
Given:		
NH3	1	ppm
SO3	3	ppm
Intermediate:		
P(NH3)	0.000001	atm
P(SO3)	0.000003	atm
Calculate Bulk Dewpoint:		
AbS Dewpoint:	491.2725503	DegK
AbS Dewpoint:	424.6205906	DegF
Calculate Capillary Dewpoint:		
Pore Radius:	25	Angstrom
Pore Activity:	0.150000908	
Capillary AbS Dewpoint:	509.0597113	DegK
Capillary AbS Dewpoint:	456.6374804	DegF

SO3 = f(AbS Dewpoint, NH3)		
Given:		
NH3	1	ppm
AbS Dewpoint	424	DegF
AbS Dewpoint	490.9277778	DegK
Flue Gas Temp		DegF
Intermediate:		
P(NH3)	0.000001	atm
Calculate:		
SO3	2.887762439	ppm

NH3 = f(AbS Dewpoint, SO3)		
Given:		
SO3	3	ppm
AbS Dewpoint	424	DegF
AbS Dewpoint	490.9278	DegK
Flue Gas Temp		DegF
Intermediate:		
P(SO3)	0.000003	atm
Calculate:		
NH3	0.962587	ppm

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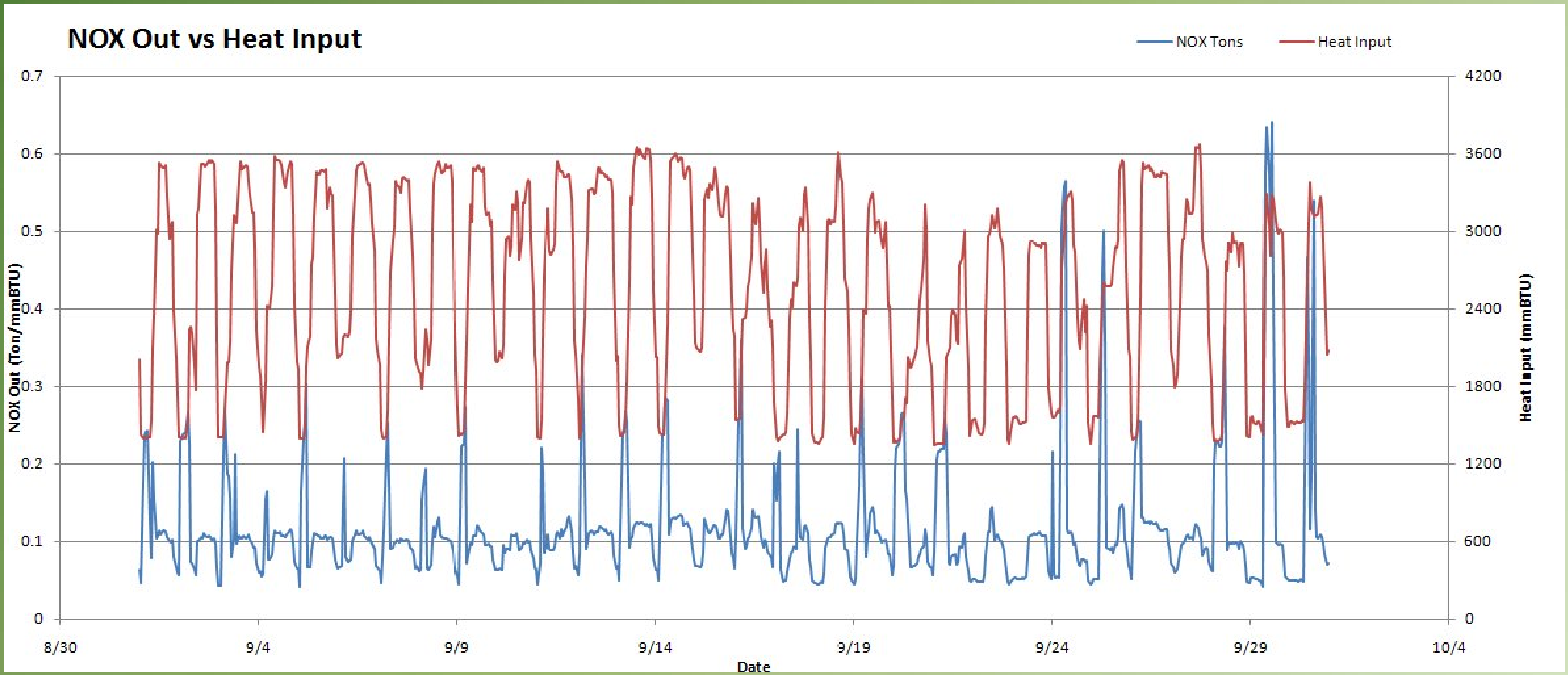
By: Chetan Chothani

- **AbS Bulk Dewpoint from NH_3 and SO_3**
- **AbS Capillary Dewpoint from Bulk Dewpoint and Pore Size**
- **SO_3 ppm from AbS Bulk Dewpoint and NH_3 Slip**
- **NH_3 slip from AbS Bulk Dewpoint and SO_3 ppm**

NOX Out vs. Heat Input



Reduction of overnight NOX spikes can exceed 250 Tons/Year on a 600MW Plant!!

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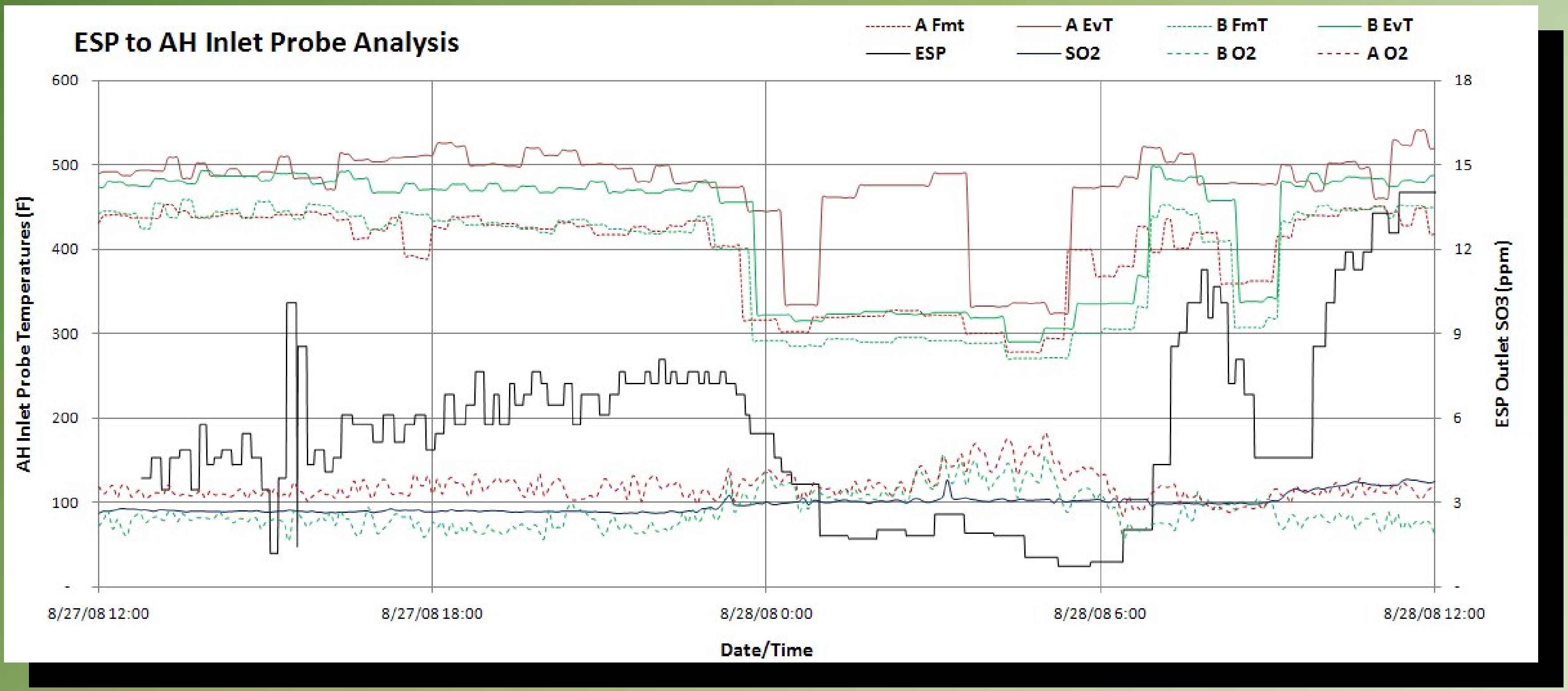
Morning Sickness Surge



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Dynamic Air Heater Cleaning

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Air Heater Sootblowing

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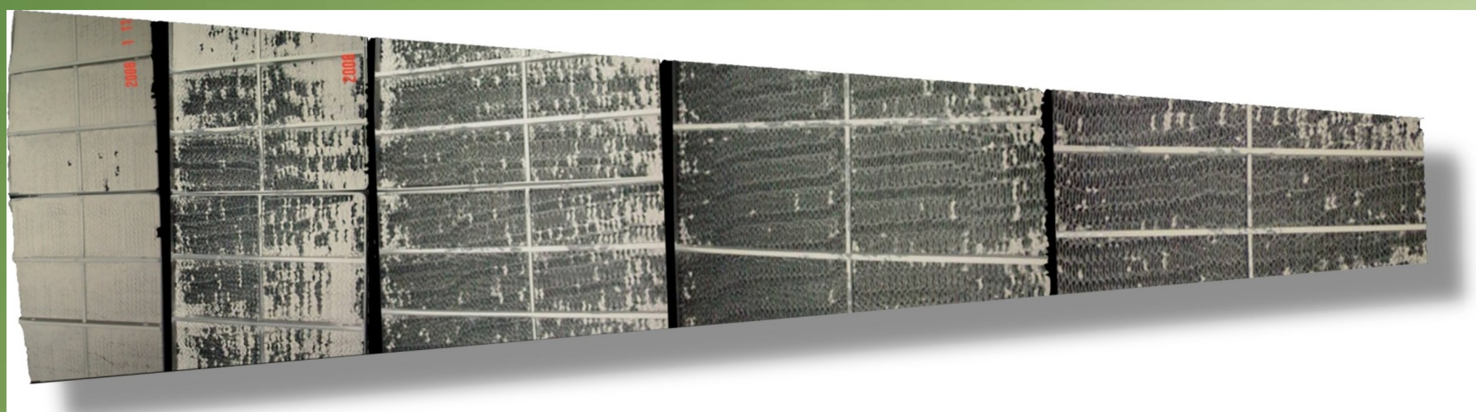
Fouling Distance from Hub



Outermost Baskets

Increasing Fouling

Innermost Baskets

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Patent Pending Process

The Breen DySC AH Cleaning Process:

- **Positions the Cleaning head at a fixed incremental position**
- **Controls the AH rotational speed to match the indexed position of the cleaning head**
- **Assures complete penetration of the cleaning media**
- **Eliminates AH Pressure Drop problems**
- **Gives a real time display of individual seal adjustment**
- **Allows for control of particulate release due to air heater cleaning**

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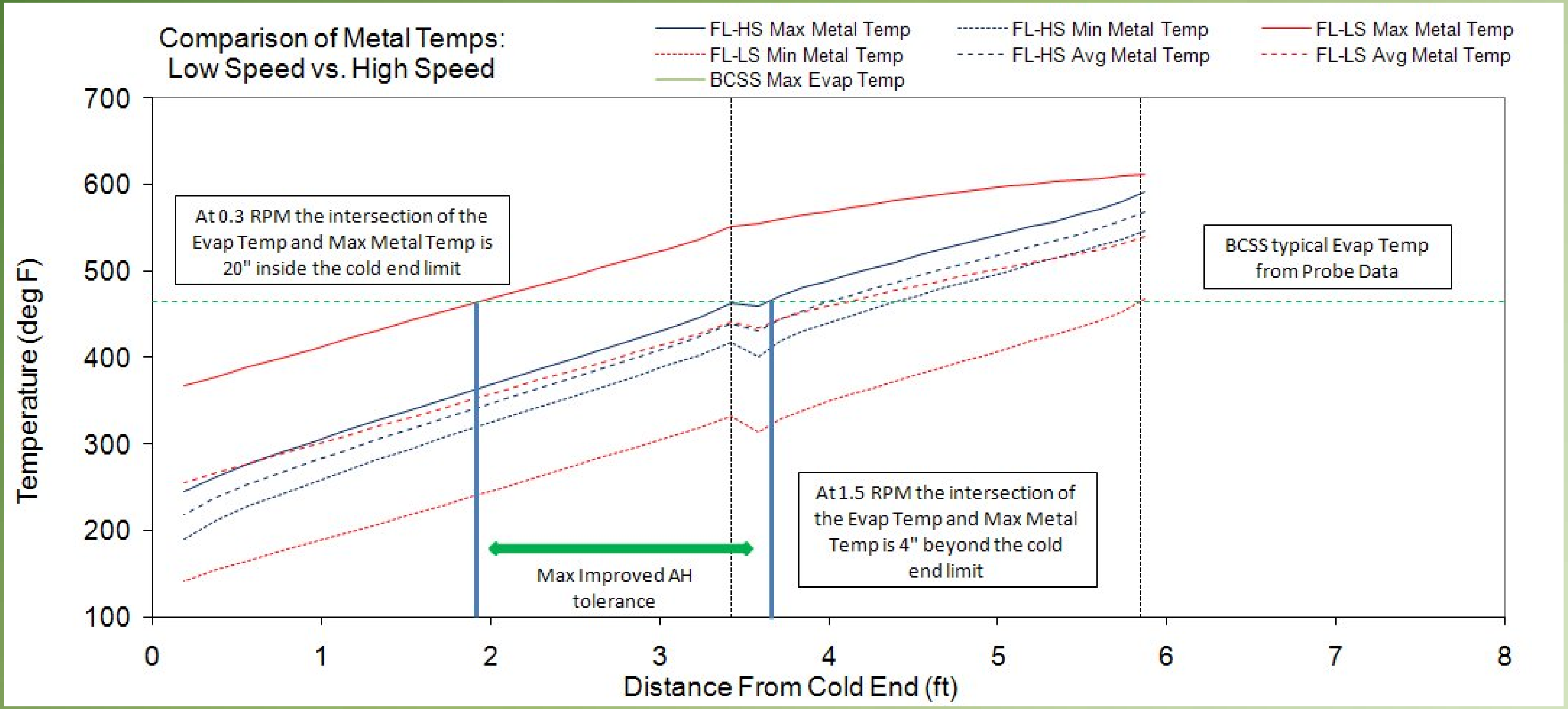
Metal Temperature Adjustment



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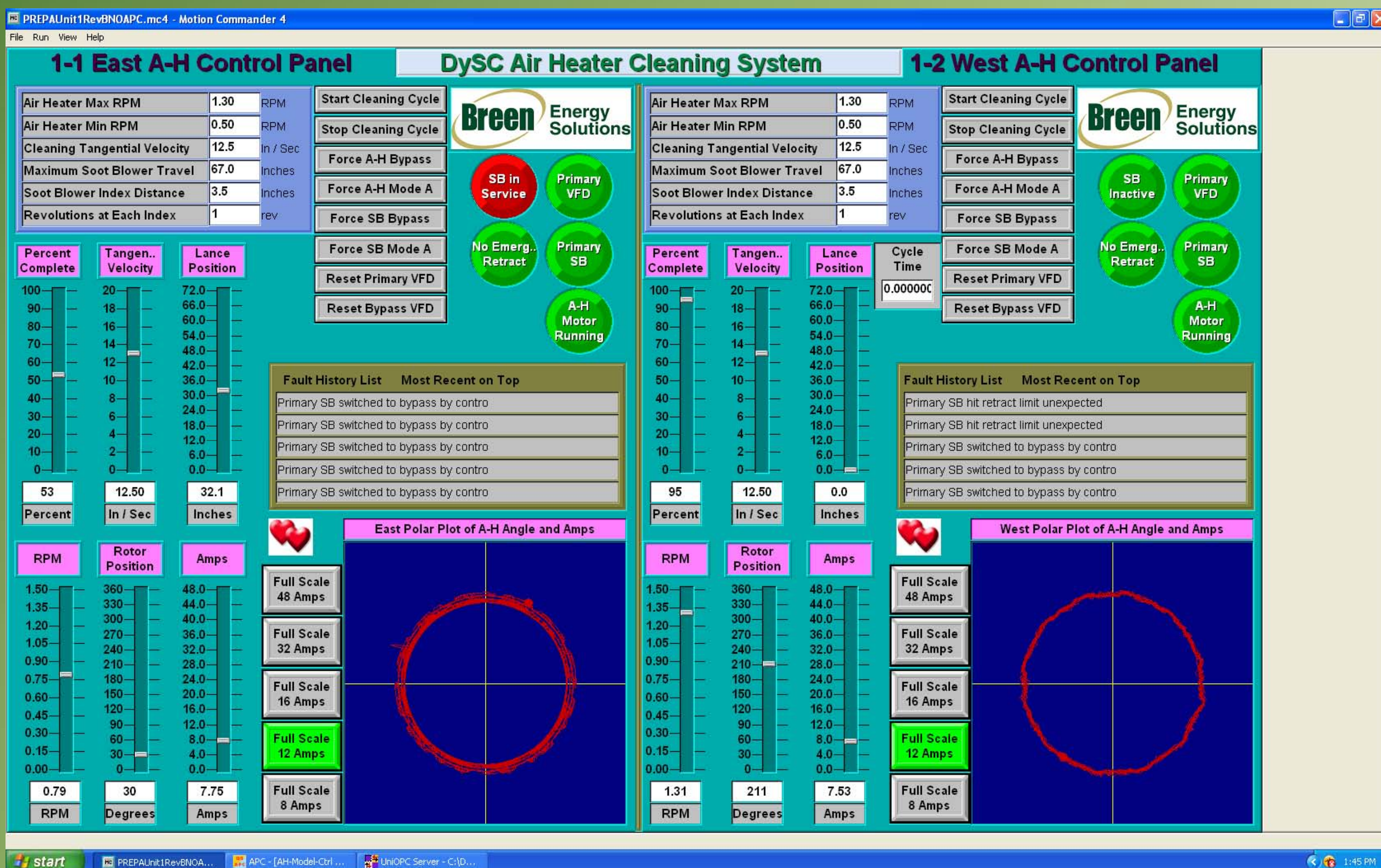
DySC Control



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Conclusions

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Conclusions

- Integrated Condensables Management can provide significant benefit to SCR operation,
- When constraints exist that prohibit full range of control, Dynamic Sootblowing can provide additional benefit,
- In the end, air heater fouling should cease to be a concern.

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Thank You Questions

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