

Reinhold Environmental Ltd.



2009 APC Round Table & Expo Presentation

July 12-14, 2009, in The Woodlands, TX

All presentations posted on this website are copyrighted by Reinhold Environmental, Ltd (RE). Any unauthorized downloading, attempts to modify or to incorporate into other presentations, link to other websites, or obtain copies for any other uses than the training of attendees to RE's Conferences is expressly prohibited, unless approved in writing by RE or the original presenter. RE does not assume any liability for the accuracy or contents of any materials contained in this library which were presented and/or created by persons who were not employees of RE.

SO₃ Measurement & Management

Closed Loop Integrated Control



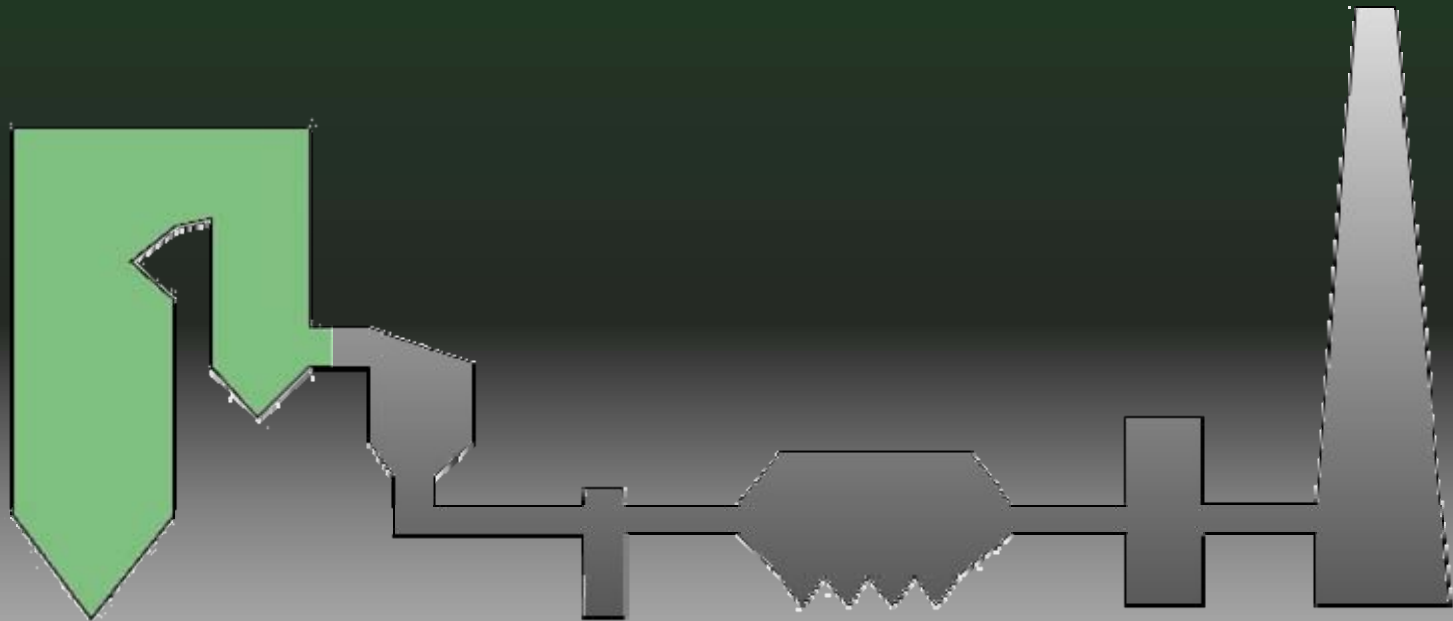
Agenda

- SO₃ measurement
 - What is SO₃?
 - What technologies exist to measure it?
- SO₃ Measurement Experience
 - Comparison of CCS & AbSensor Principles
 - Comparative Testing Experience
- Targeted Deposition Depth/Closed Loop Control
 - Case Study/Experience

What is SO₃?

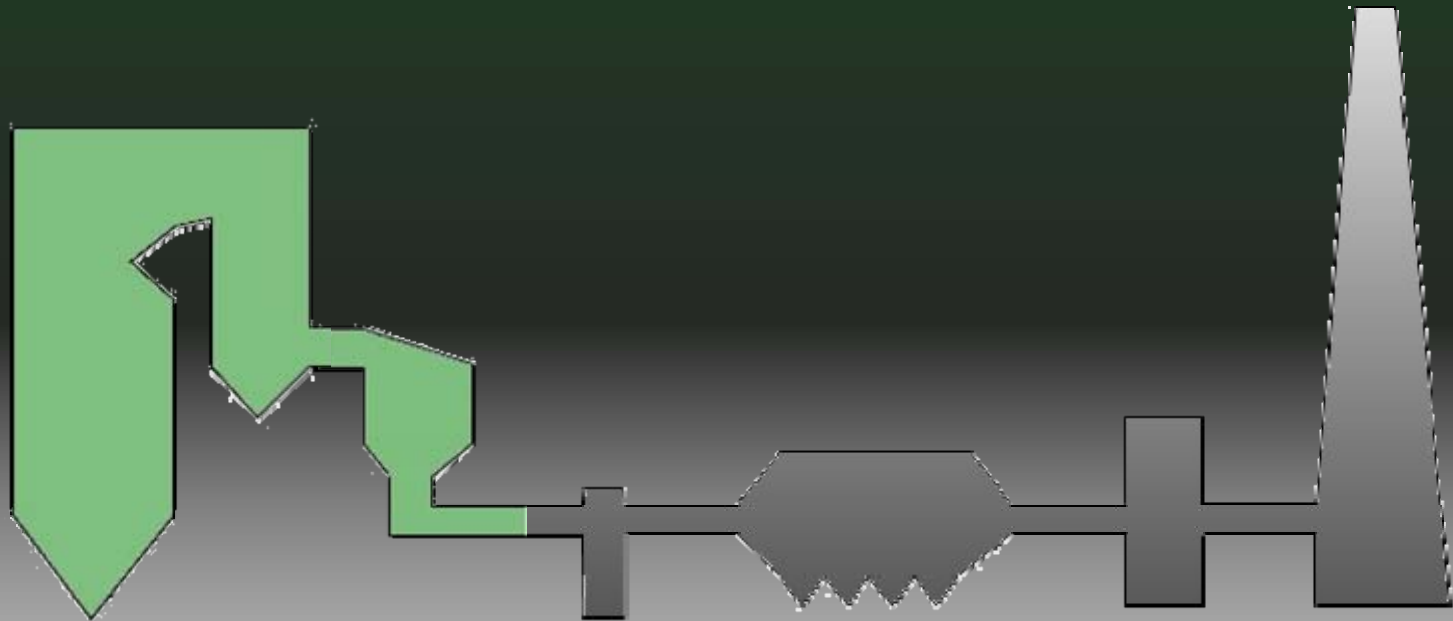
What is SO_3 ?

1. Sulfur in the fuel oxidizes to form SO_2 and SO_3 in gas form.



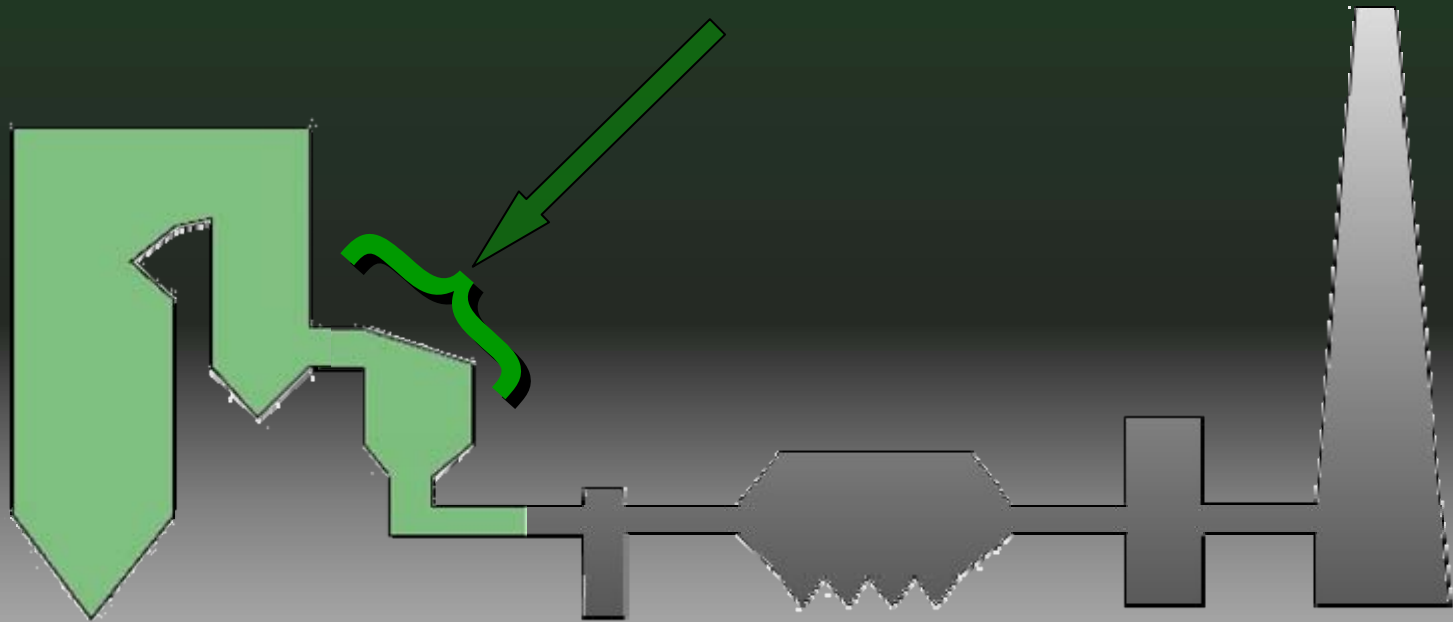
What is SO_3 ?

2. Further conversion of SO_2 to SO_3 occurs as the flue gas passes through the SCR!



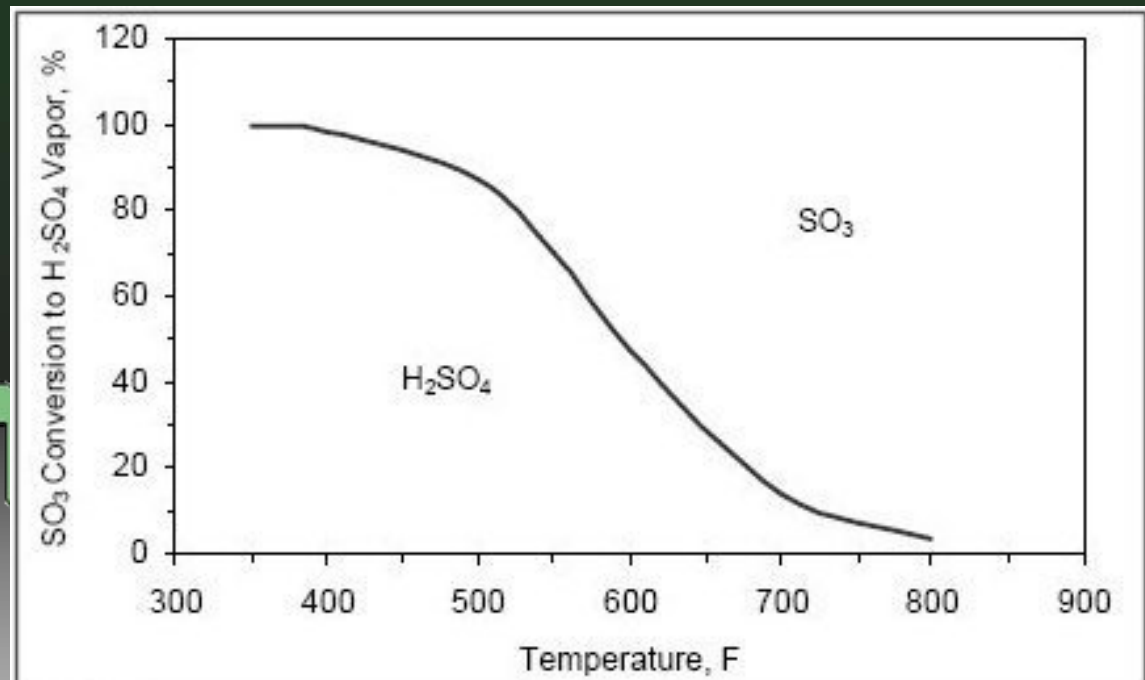
What is SO₃?

3. Between 800° F and 400° F the SO₃ gas combines with available water vapor to form H₂SO₄ Vapor.



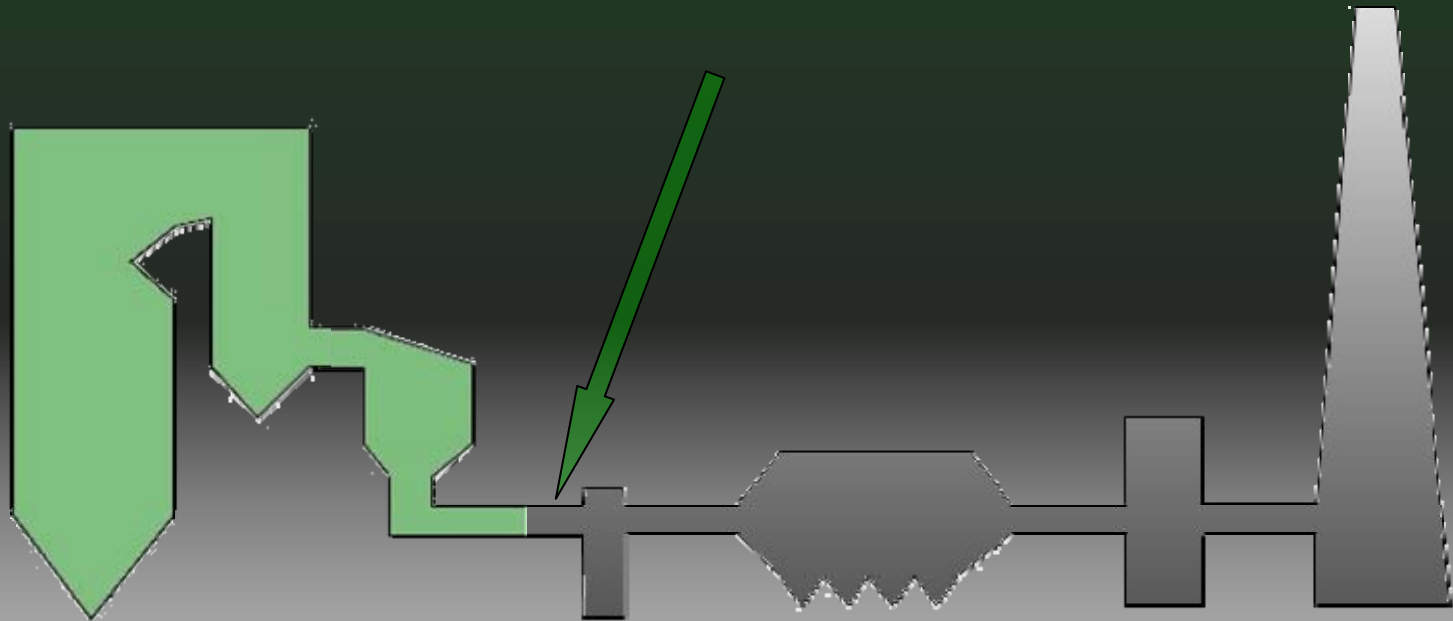
What is SO_3 ?

4. The rate of conversion is a well documented function of flue gas temperature.



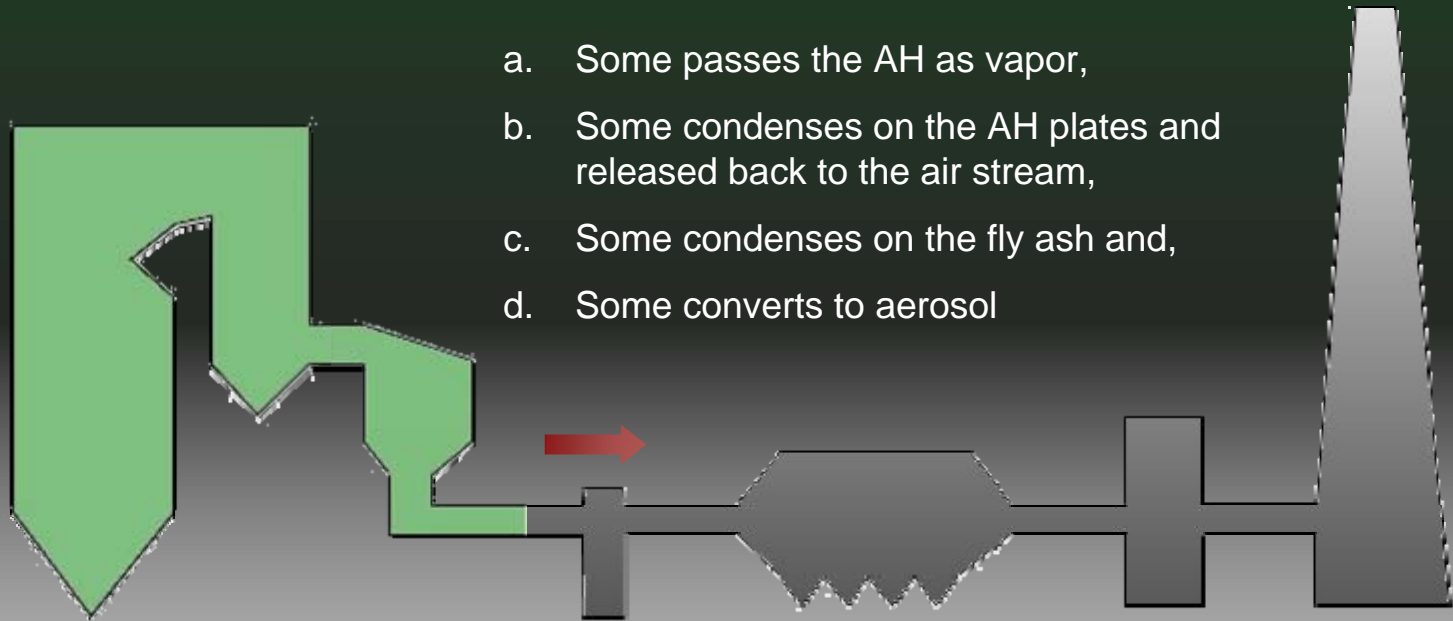
What is SO_3 ?

5. At the inlet to the Air Heater, then, there is a mixture of SO_3 gas, H_2SO_4 Vapor, and let's not forget about Ammonia byproducts



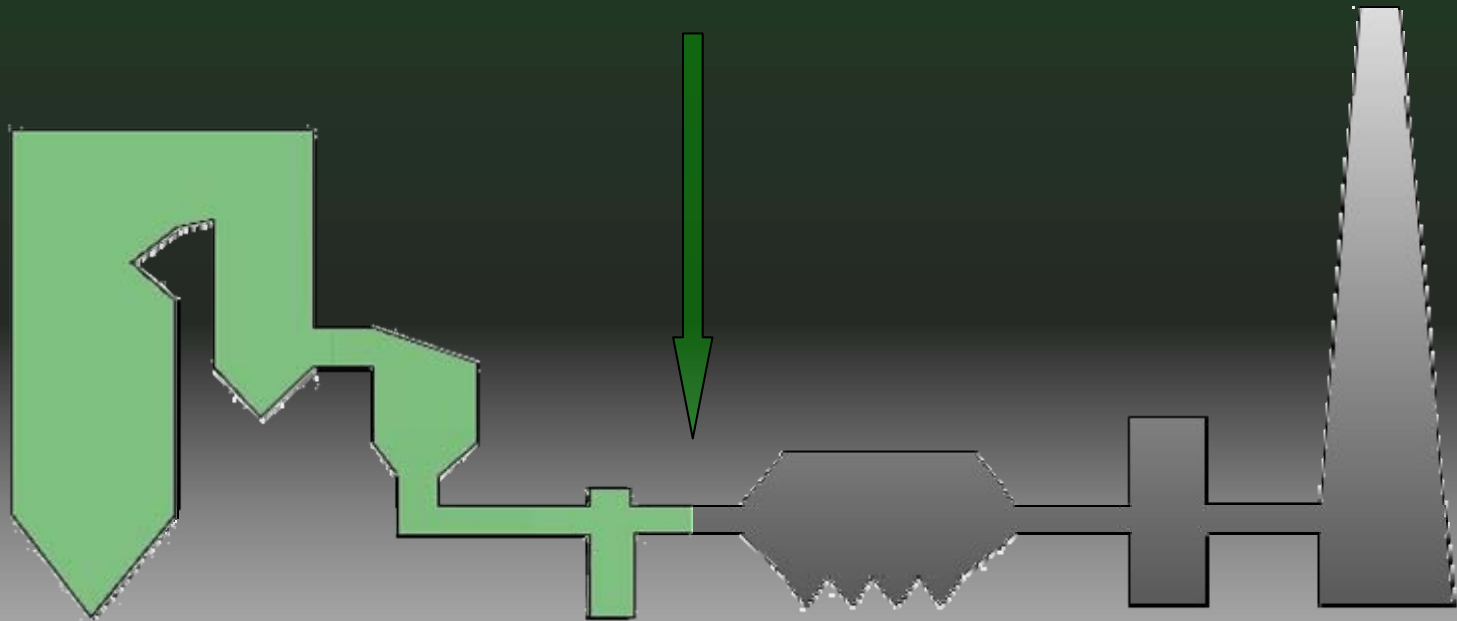
What is SO₃?

6. As the vapor mixture passes through the air heater, gas temperature drops and the vapor changes form.
 - a. Some passes the AH as vapor,
 - b. Some condenses on the AH plates and released back to the air stream,
 - c. Some condenses on the fly ash and,
 - d. Some converts to aerosol



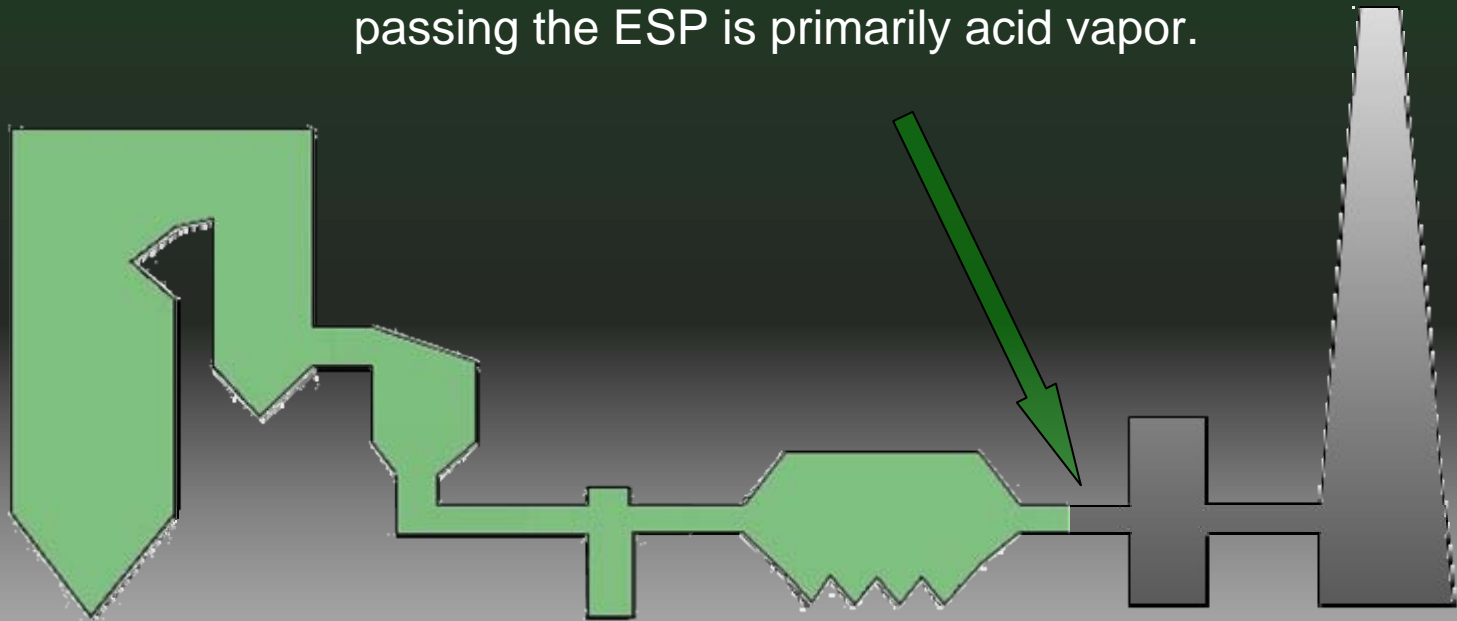
What is SO_3 ?

7. The amount of vapor that condenses onto the fly ash varies but seems to be strongly influenced by the ash alkalinity.



What is SO_3 ?

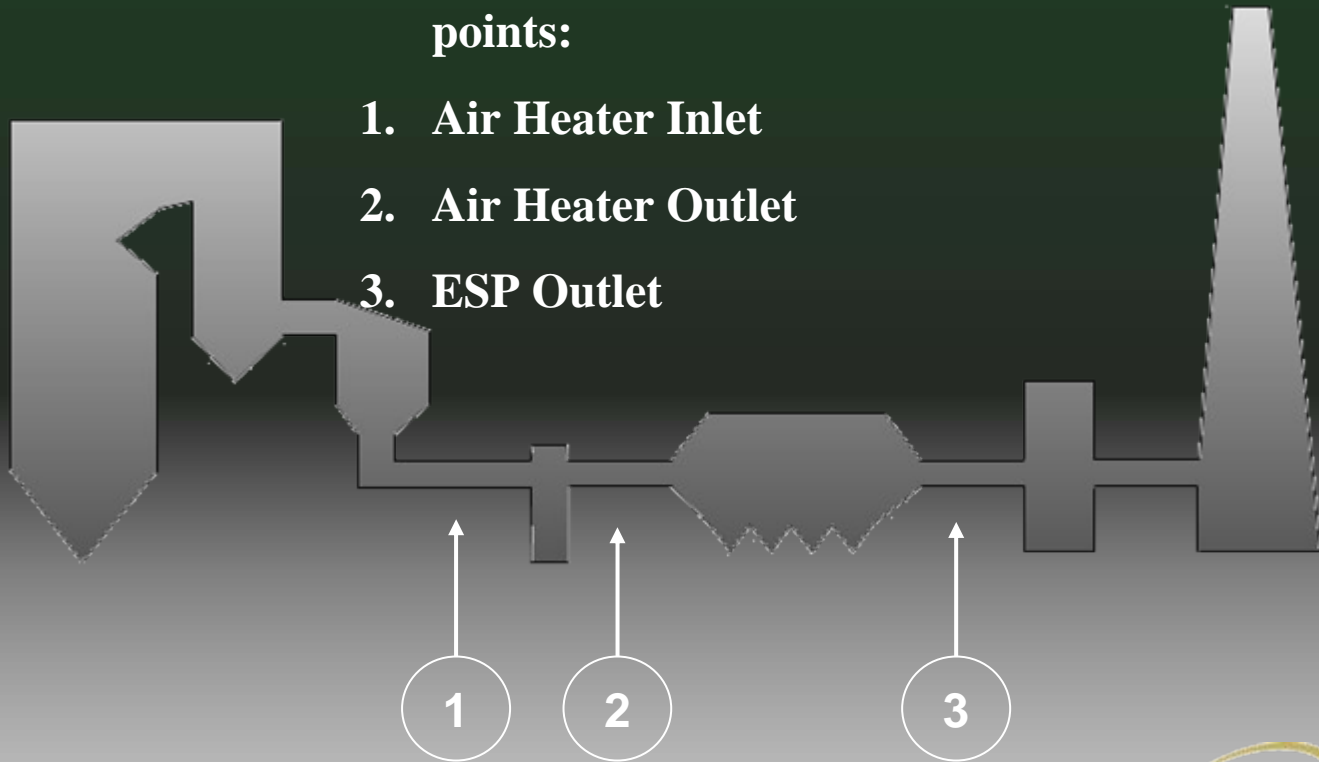
8. The ESP captures virtually all of the fly ash and the acid condensed on it, as well as some portion of the aerosol. The acid material passing the ESP is primarily acid vapor.



Typical Measurement Locations

The three typical measurement points:

1. Air Heater Inlet
2. Air Heater Outlet
3. ESP Outlet



Measurement Options

Controlled Condensate /Condensables Comparison



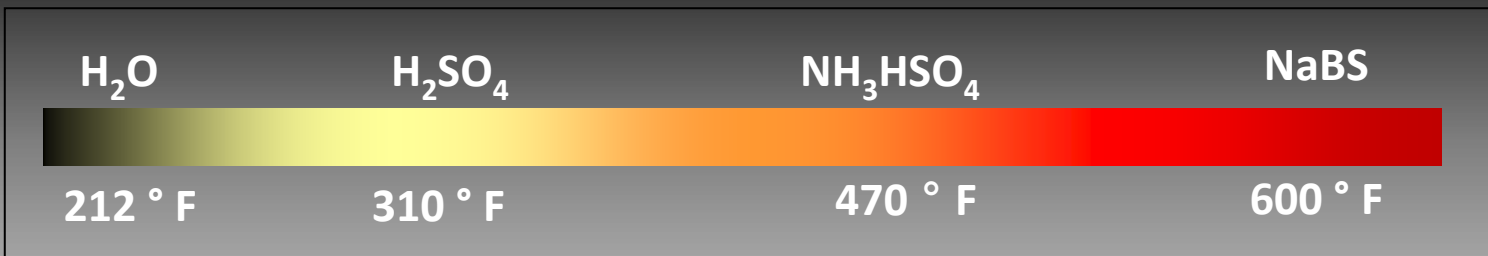
AbSensor – Condensables Measurement

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!

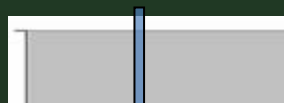
Condensables Measurement

Condensation = Evaporation

Equilibrium



Tip Temp



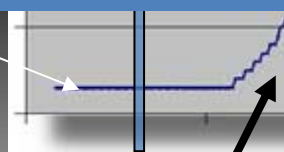
The Condensables System Output is:

Formation Temp: The temperature at which material will first form

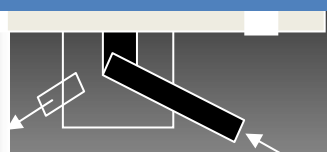
The Equilibrium Dewpoint

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

Tip Current



Cooling Air Return



Cooling Air Inlet

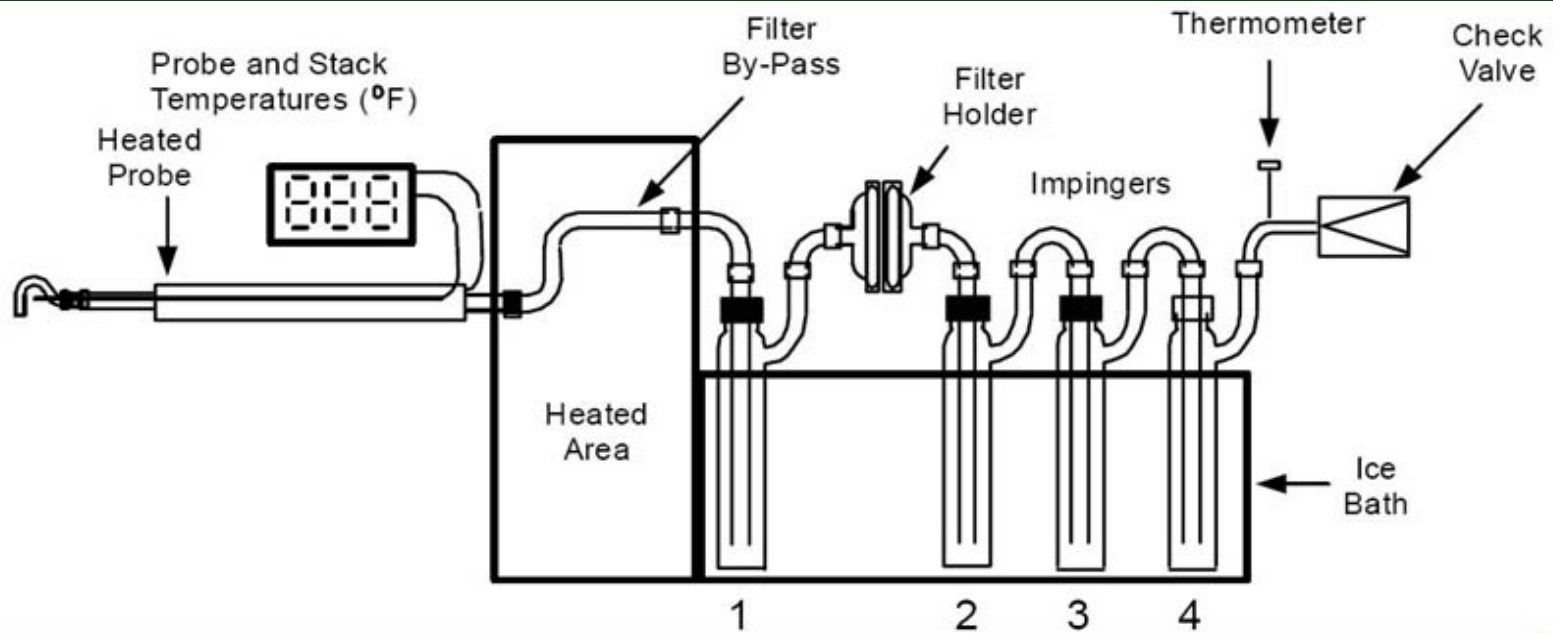
A hot probe is precisely cooled until condensation current is detected. (Formation Point).

Condensation > Evaporation

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

Evaporation > Condensation

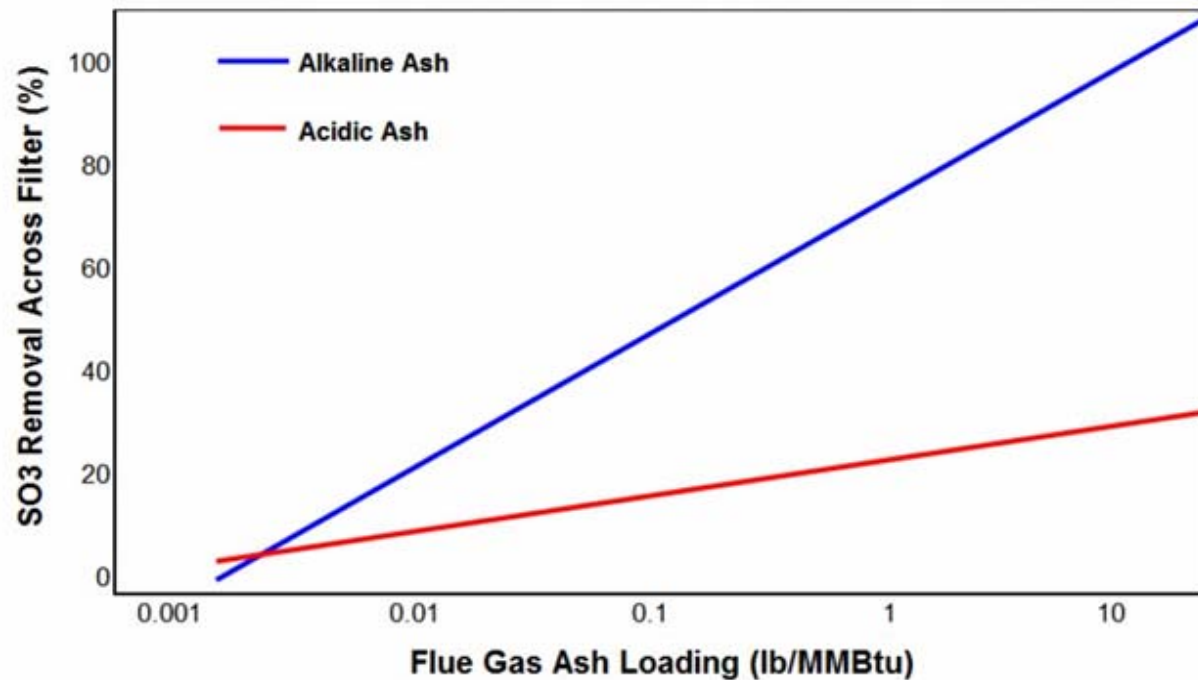
Controlled Condensate



Copyright 2005 Clean Air Engineering, Inc.

CCS Ash Filter Bias

CCS Bias – Ash Filter Cake Effects



CCS Quick Fixes

Quick Fixes

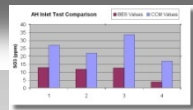
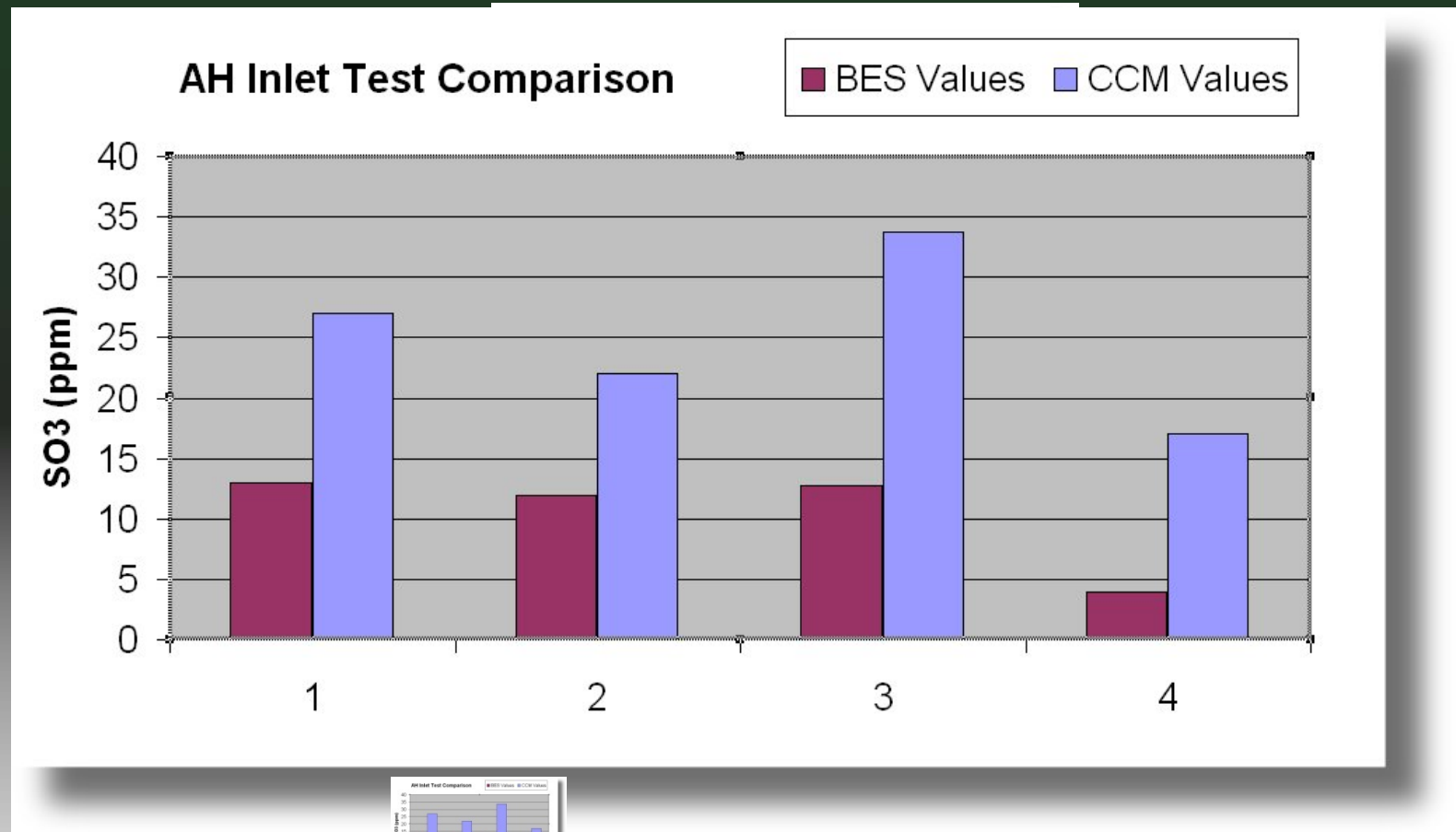
- Adjust Sampling Temps to avoid Phase Shift
- Alter Extraction Mechanisms to Remove Particulate without Filter Cake
 - Inertial Separators
 - Mini-ESPs????



Copyright 2005 Clean Air Engineering, Inc.

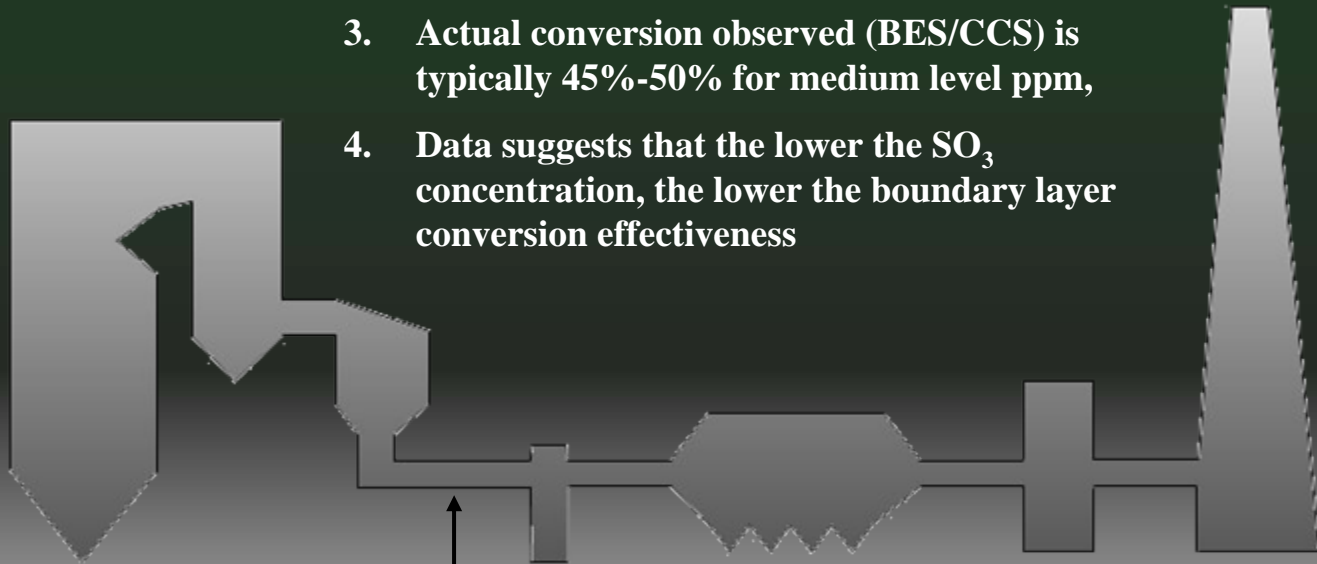
CCS Condensables Comparison

Air Heater Inlet Comparison

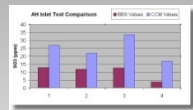


Air Heater Inlet Comparison

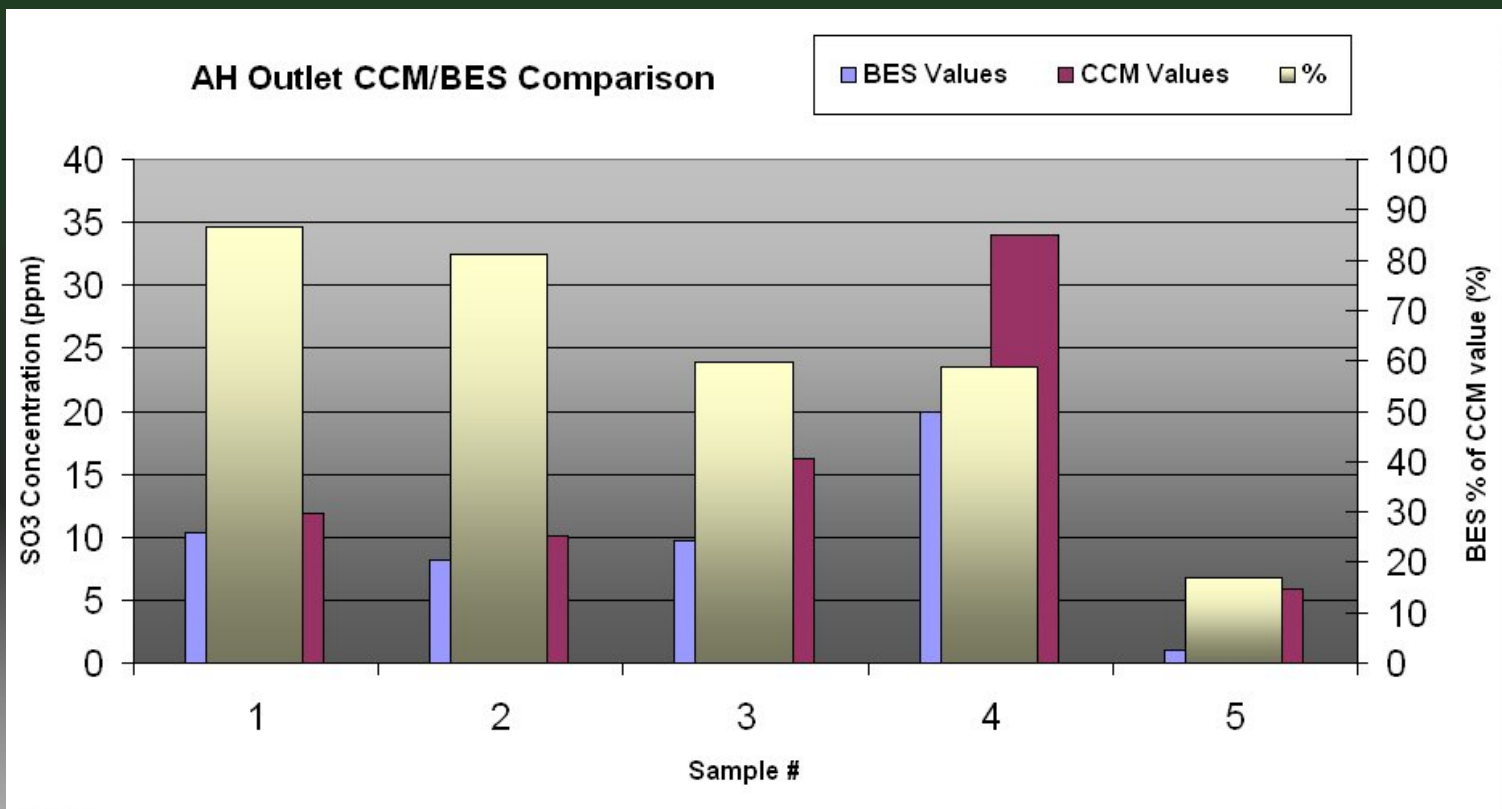
1. All material is in gas phase, but only partially converted to Acid/AbS vapor
2. Expected conversion based on gas temperature would be approximately 25%
3. Actual conversion observed (BES/CCS) is typically 45%-50% for medium level ppm,
4. Data suggests that the lower the SO_3 concentration, the lower the boundary layer conversion effectiveness



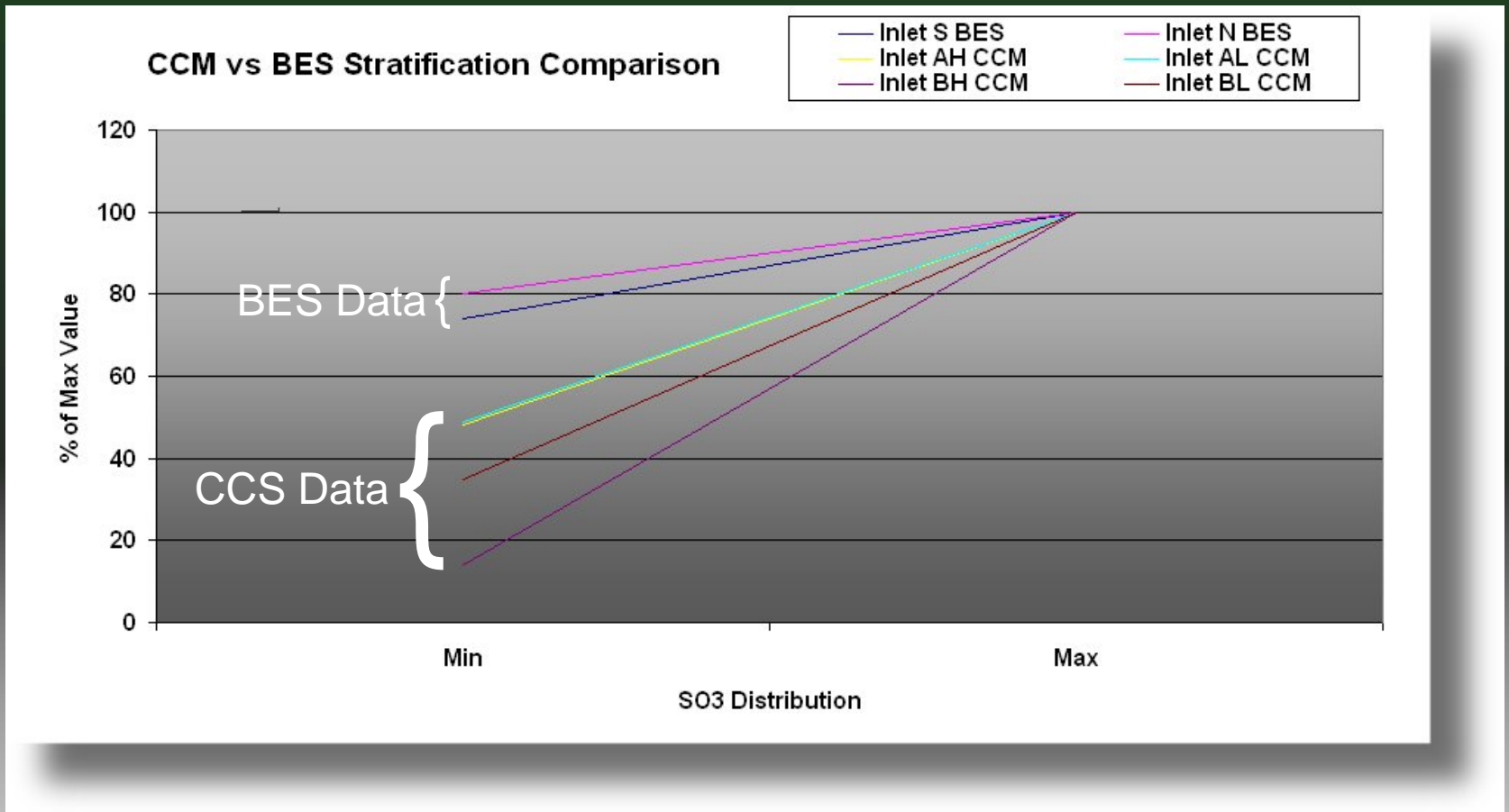
1



Air Heater Outlet Comparison

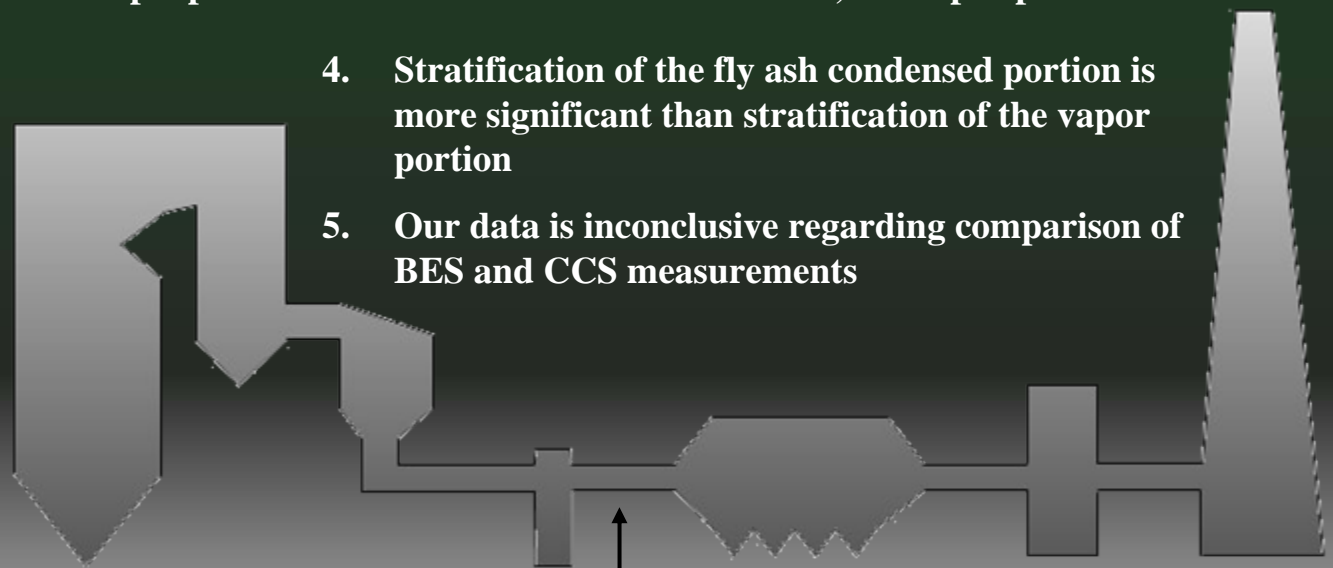


Air Heater Outlet Stratification Δ

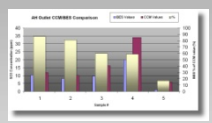


Air Heater Outlet Comparison

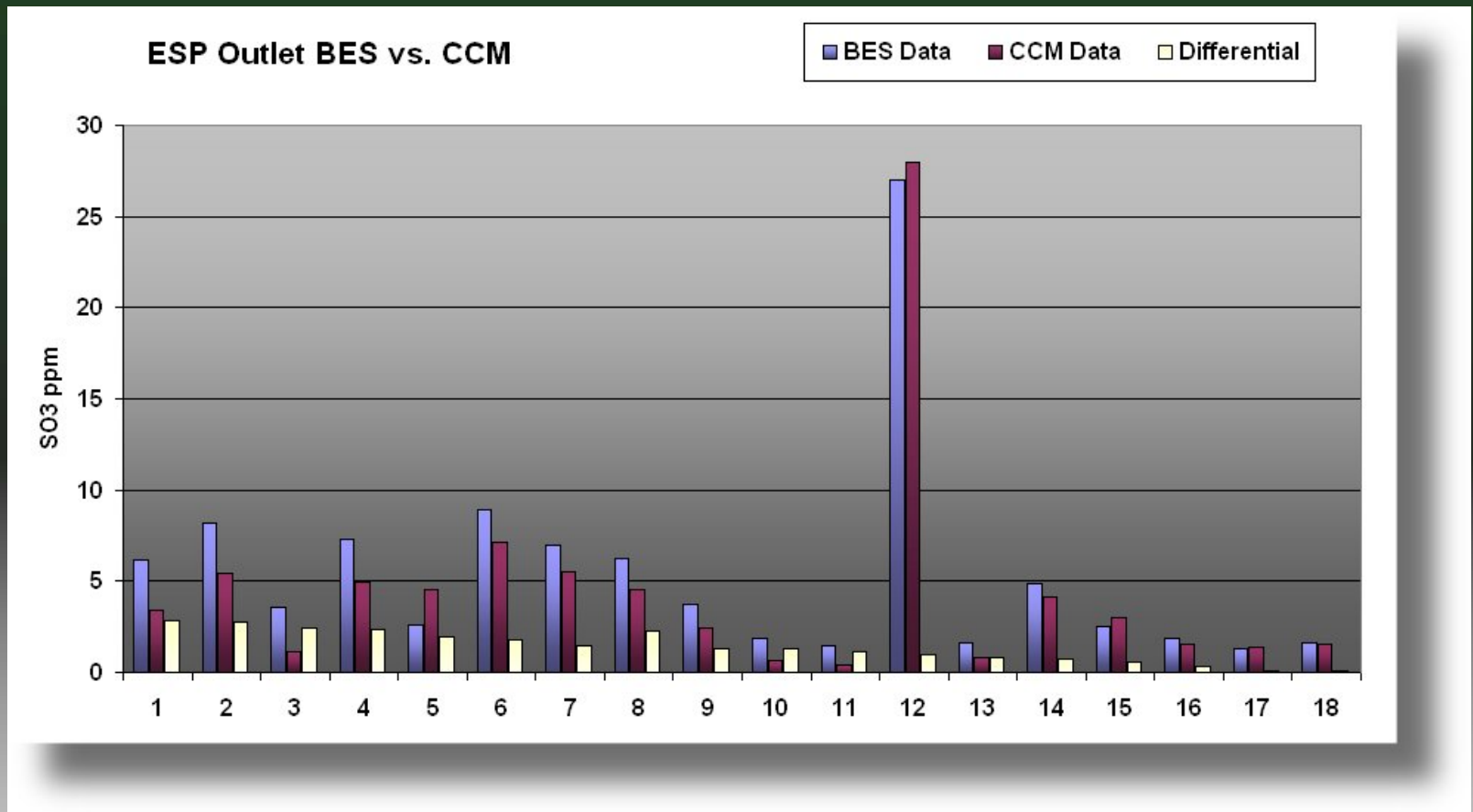
1. Total SO₃ includes acid vapor and acid material condensed on the fly ash
2. For purposes of ESP performance the condensed portion is critical
3. For purposes of corrosion or Blue Plume control, the vapor portion is critical
4. Stratification of the fly ash condensed portion is more significant than stratification of the vapor portion
5. Our data is inconclusive regarding comparison of BES and CCS measurements



2



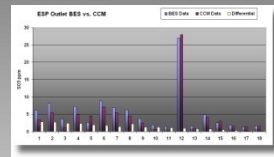
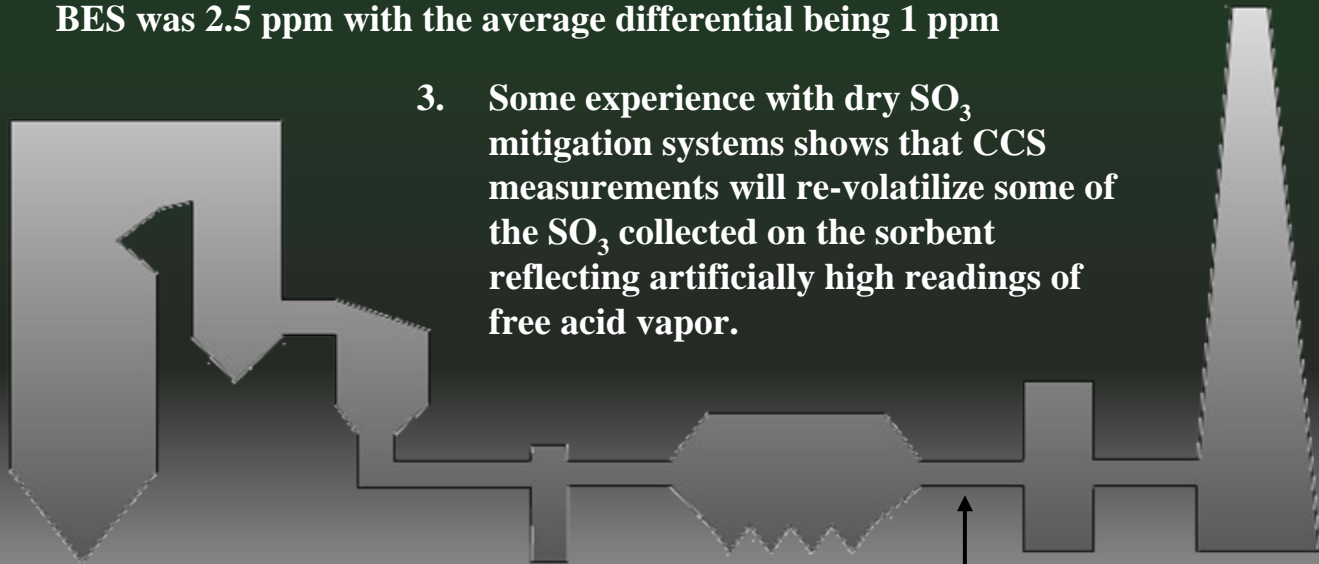
ESP Outlet Comparison



ESP Outlet Comparison

1. With the fly ash, and the acid condensed on the fly ash, removed the CCM and BES data should both reflect the vapor portion only
2. Covering the data collected so far, the maximum differential between CCM and BES was 2.5 ppm with the average differential being 1 ppm

3. Some experience with dry SO_3 mitigation systems shows that CCS measurements will re-volatilize some of the SO_3 collected on the sorbent reflecting artificially high readings of free acid vapor.



3

SO₃ Measurement Comparison

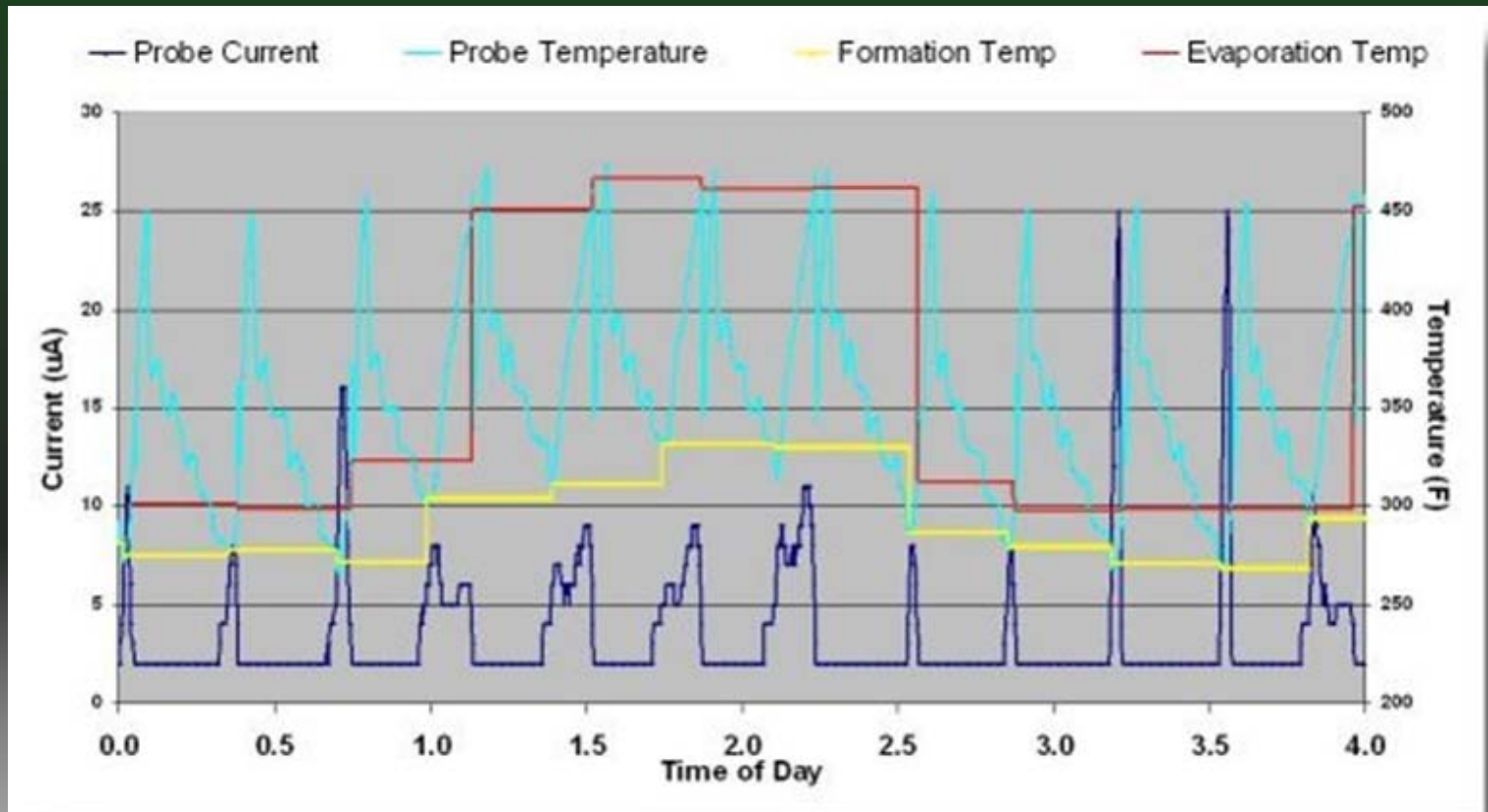
- The readings between CCS and BES can be correlated if the location in the gas train is considered:
 - Pre-Air Heater the BES readings will be lower due to temperature equilibrium effects. The magnitude of the differential should be site specific
 - Post Air Heater the BES readings will be lower due to fly ash condensed vapor factors. The stratification and position in the duct must be considered
 - Post ESP the CCS and BES readings are virtually identical

Ammonia Effects

- Ammonium Bisulfate measurements can only be made at the Pre-Air Heater location
- If AbS is present, the free SO₃ reading at the Pre-Air Heater location will be reduced by the amount of AbS formed. In some instances, with high levels of AbS, there may be zero free SO₃ vapor

Targeted Deposition Depth

Condensables Concentration



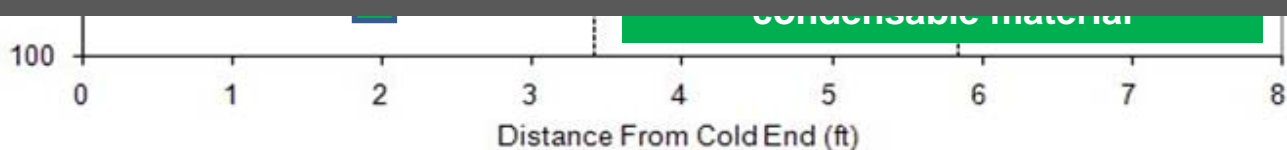
Condensables Deposition

Two Layer APH Model

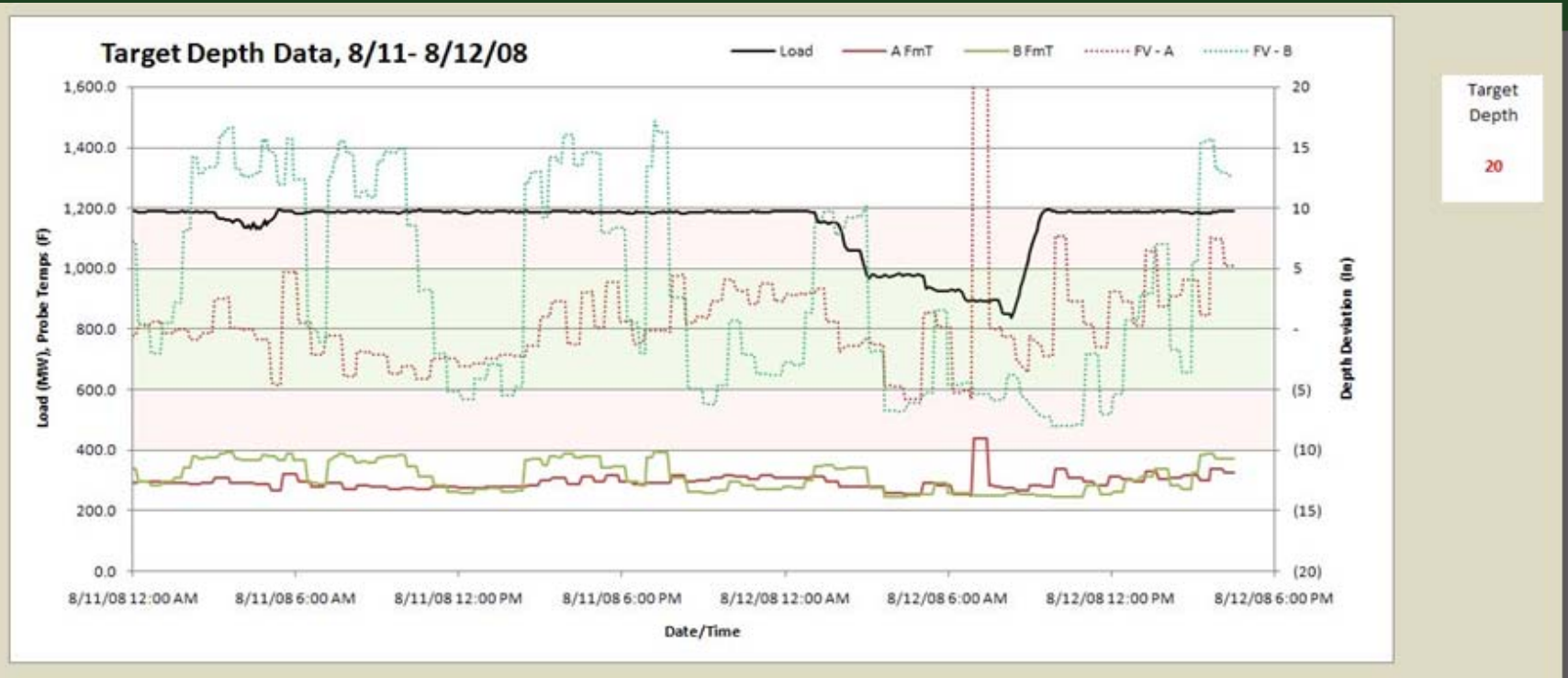


The Targeted Deposition Depth process controls the ammonia to the SCR so that:

- the Evaporation Temperature/MAX metal temperature intersection is always within cleanable end of the air heater, and
- The Formation Temperature/MIN metal temperature intersection is at a fixed depth regardless of load



TDD Aged Catalyst



TDD New Catalyst



Conclusions

Condensables Measurement

- Regardless of method, SO₃ measurement is actually the measurement of sulfuric acid,
- The CCS methodology is historical accepted, but subject to bias issues due to temperature and ash cake
- Comparison of the CCS and Dewpoint measurements require an understanding of the measurement location.

Targeted Deposition Depth

- Condensable Material WILL form in the air heater baskets,
- The issue is not “IF”, but “WHERE”, it will form.
- Closed Loop control of the ammonia injection to achieve tight control of the deposition depth maximizes the NOx reduction within the constraint of avoided air heater fouling.

Thank You

Questions?

