

REINHOLD ENVIRONMENTAL Ltd.



**2015 NO_x-Combustion Round Table
& Expo Presentations**

February 23 & 24, 2015, in Richmond, VA / Hosted by Dominion

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Pre-AH DSI Impact on Heat Rate

Presented by: Cal Lockert

Presented to: Reinhold Environmental NOx Conference

February/2015



Technical Support Document (TSD) for
Carbon Pollution Guidelines for Existing Power Plants:
Emission Guidelines for Greenhouse Gas Emissions from Existing Stationary Sources:
Electric Utility Generating Units

Docket ID No. EPA-HQ-OAR-2013-0602

GHG Abatement Measures

U.S. Environmental Protection Agency
Office of Air and Radiation

June 10, 2014

2.3.1.5 Air Heaters

A second method to improve the heat rate is to lower the air heater outlet temperature by controlling the acid dew point.

Typically the air heater outlet is maintained at 20-30° F above the sulfuric acid dew point to prevent corrosion of cold-end baskets. Injection of sorbents such as Trona or hydrated lime can be used to lower the dew point.

Depending on the sizing of the air heater, it may need to be modified in order to optimize the lower outlet temperature. The capital costs can range from \$1.5-18M for heat rate reductions of 50-120 Btu/kWh.

From the GHG Abatement Measures - Section 2.3.1.5

CO₂ Emission Factors by Fuel Type per Unit Volume, Mass, and Energy

<i>Fossil Fuel</i>	<i>Emission Factor</i>	<i>Emission Factor</i>	<i>Carbon Factor</i>	<i>Heat Content (HHV)</i>	<i>Carbon Content Coefficient</i>
Coal	(lb CO ₂ / short ton)	(lb CO ₂ / MMBtu)	(kg C/ short ton)	(MMBtu/ short ton)	(kg C/ MMBtu)
Anthracite Coal	5,675.29	226.16	709.04	25.09	28.26
Bituminous Coal	5,086.36	203.99	635.47	24.93	25.49
Sub-bituminous Coal	3,656.14	211.91	456.78	17.25	26.48
Lignite	2,991.33	210.47	373.72	14.21	26.30
Unspecified (industrial coking)	5,444.58	205.11	680.22	26.54	25.63

For a 500MW plant with a Capacity Factor of 70%

85 BTU/kWH =

\$781,830 in Annual Fuel Cost

26,582 Tons reduction in CO₂ release

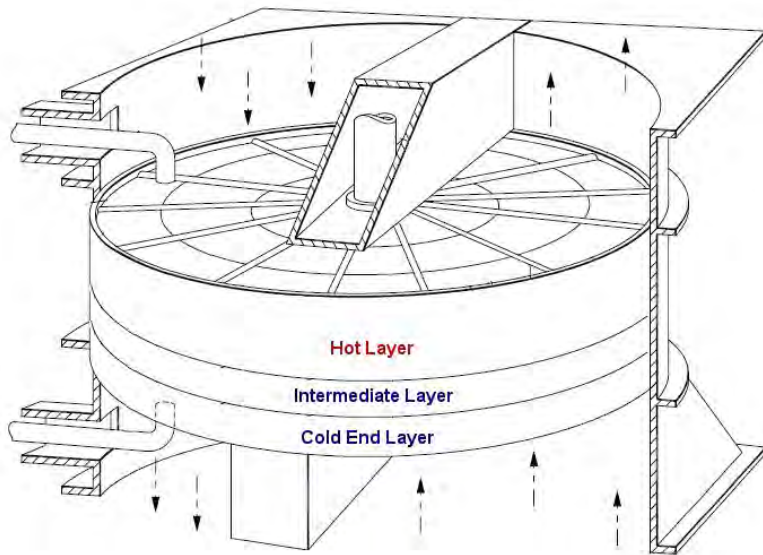
- **The ability to capture the benefits of lower AH Outlet temperature is dependent on a way to lower the AH Outlet temperature.**
- **For Plants using steam coils or air bypass dampers, these tools can be minimized or eliminated.**
- **If no artificial mechanism to raise AH Outlet temperature exists, then a redesign of the AH itself can yield significant long term results.**
- *The above analysis does not take into account the impact of reduced AH Differential Pressure on forced outage reduction and reduced parasitic load on ID/FD fans.*



Why Artificially Raise AH Outlet Temperature?



Vapor condenses into a liquid when it encounters a nucleation site below its dewpoint. In the Air Heater transition, vapor condenses on the flyash and onto the metal plates.



Air Heater fouling occurs when:

1. Condensable material (sulfuric acid or ABS) 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

Avoiding air heater fouling requires:

- 1. Lowering the condensable concentration (dewpoint) below the AH metal temperature, and/or**
- 2. Raising the AH metal temperature above the condensation temperature, and/or**
- 3. Improving the AH Sootblowing system**

For this discussion we will focus Item 1 above using Pre-AH injection of alkali material.



Air Heater Metal Temperature

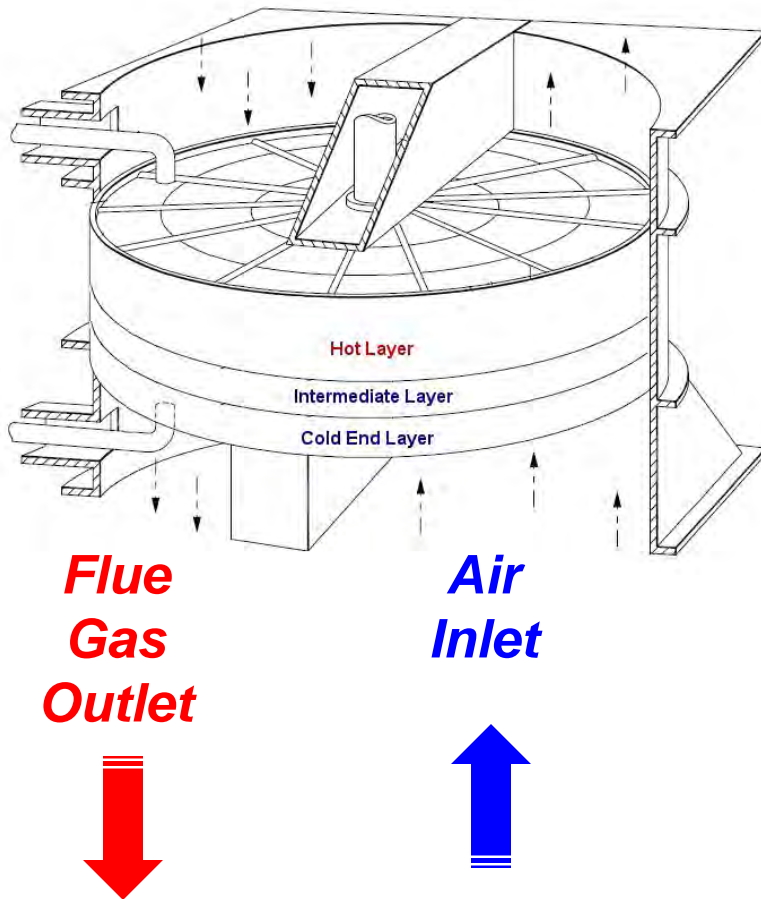


Average Cold End Temperature

This is the average of the Air Inlet Temperature and the Flue Gas Outlet Temperature

Legacy beliefs hold that this should be kept at, or above, 200F

If: Air = 70F, then FG = 330F
Air = 120F then FG = 280F
Etc., etc.



SO₃ EXIT CONC. vs. Avg. AH Gas Out

This graph confirms that higher outlet temperatures allow more acid to pass the AH, but rotational speed is also important. We need to look at the metal temperatures as well!

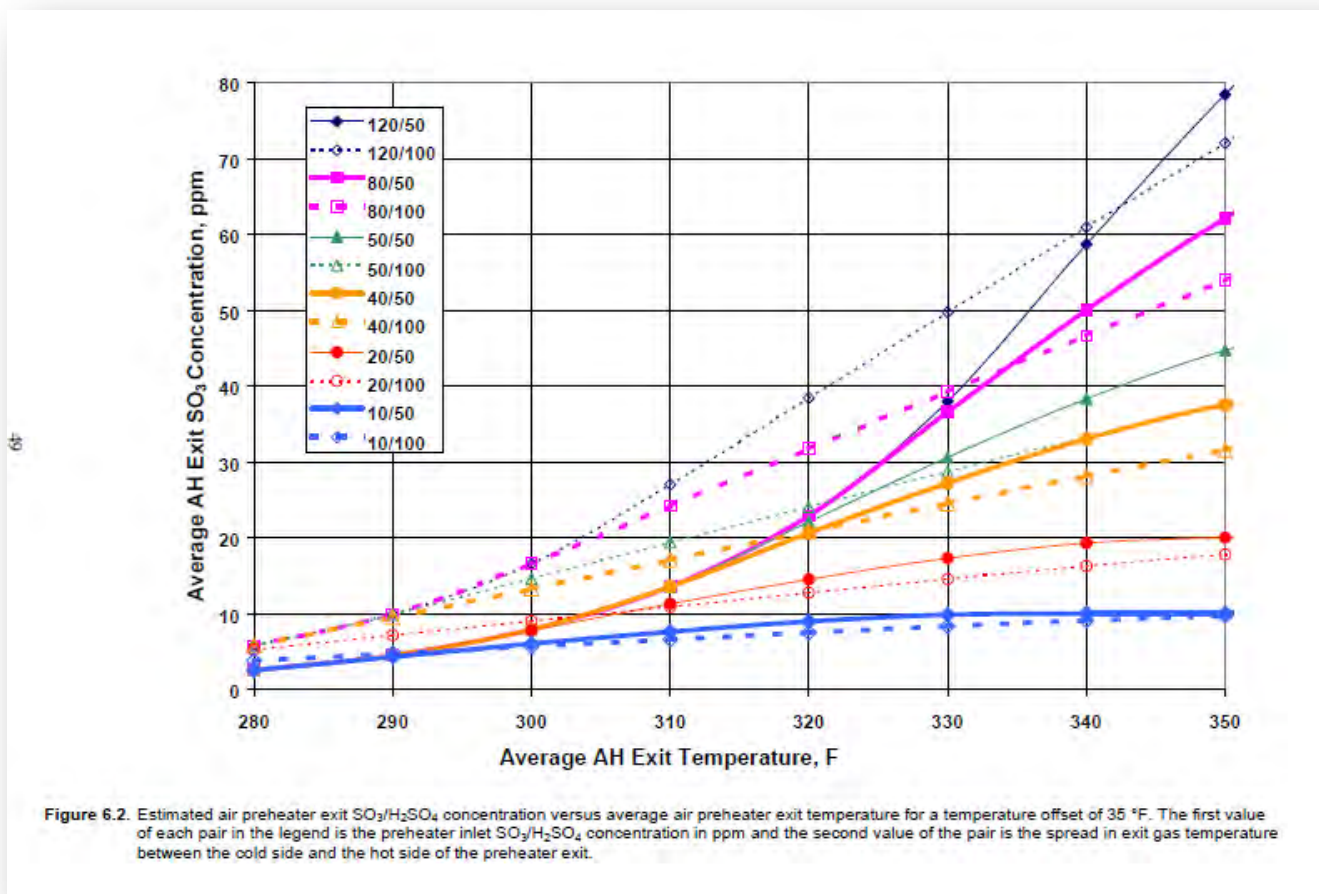
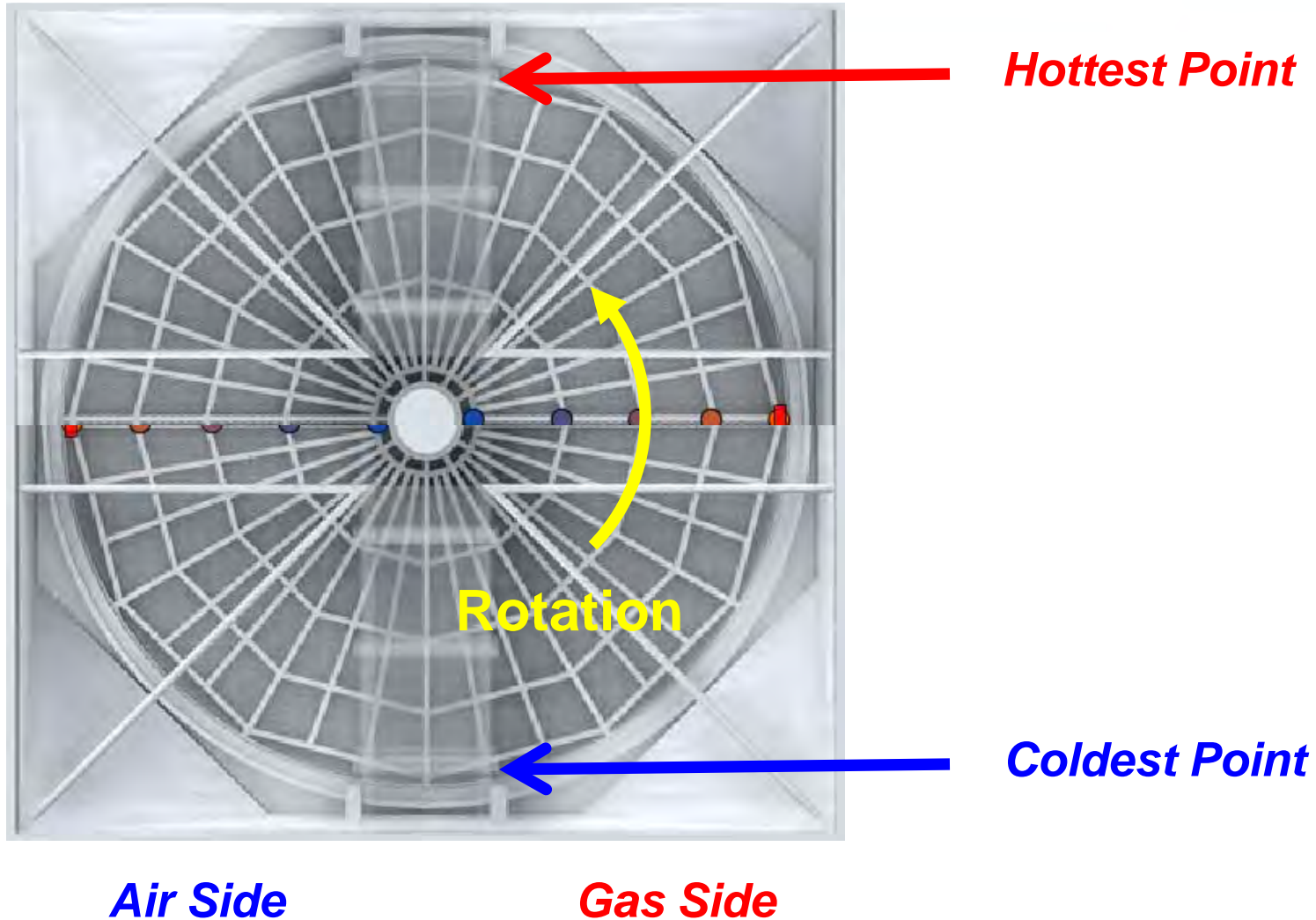


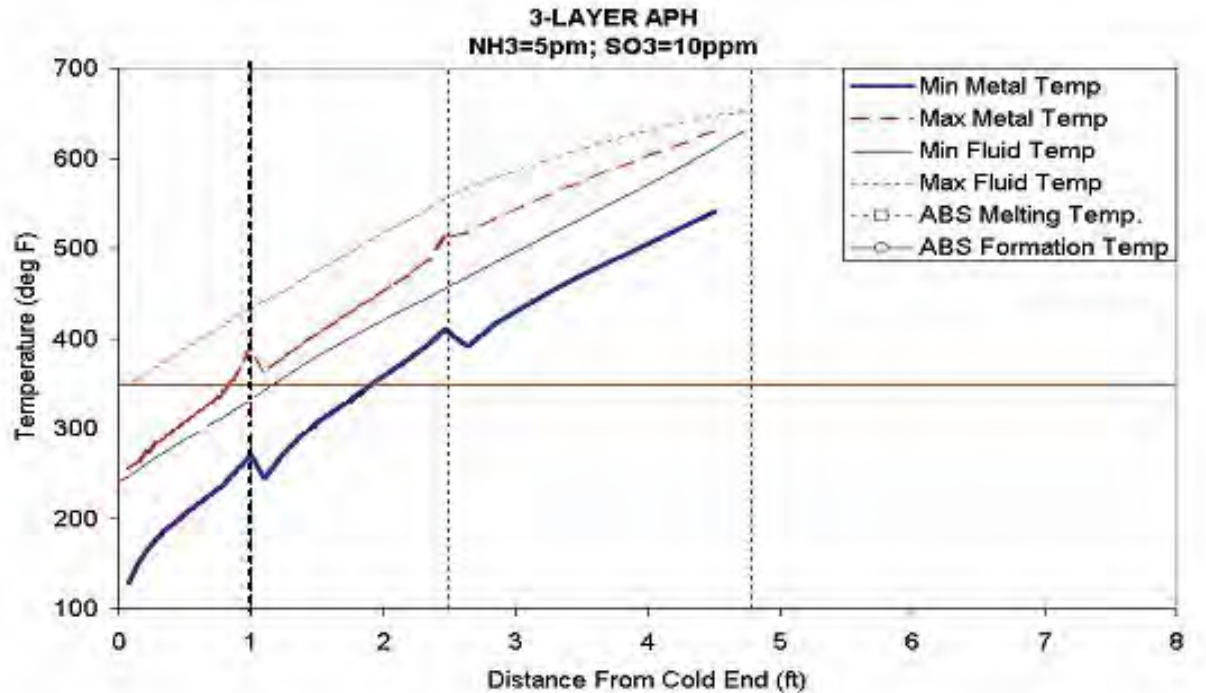
Figure 6.2. Estimated air preheater exit SO₃/H₂SO₄ concentration versus average air preheater exit temperature for a temperature offset of 35 °F. The first value of each pair in the legend is the preheater inlet SO₃/H₂SO₄ concentration in ppm and the second value of the pair is the spread in exit gas temperature between the cold side and the hot side of the preheater exit.

AH Metal Temperature Variation

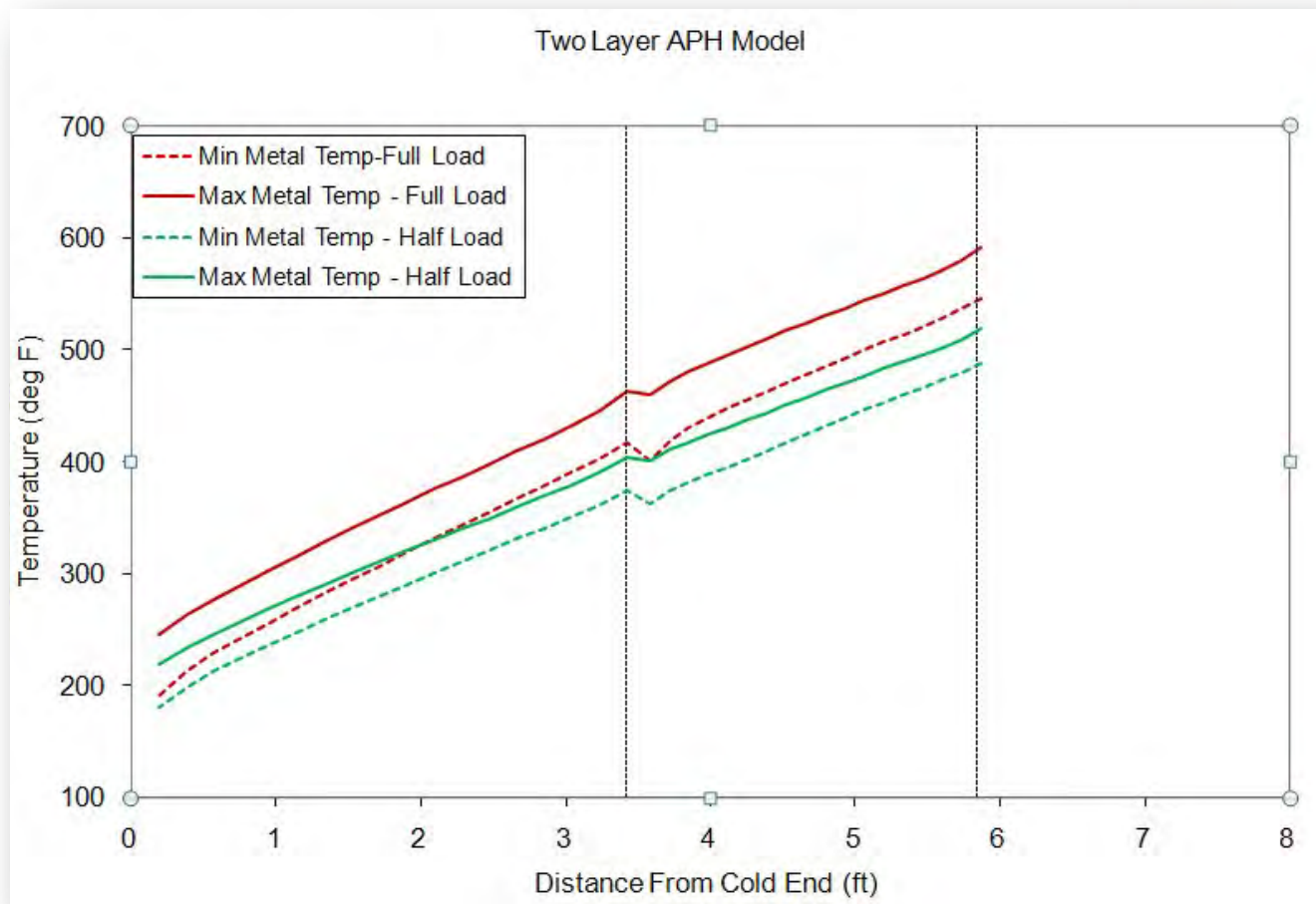


AH Temperature Dynamics

Traditional 3 layer design w/12” cold end.



In this case, the average gas outlet temperature is 295 F (by empirical basis), 35 F of artificial heat is required to get to 330 F (raise temp of ET = 200)



As load is reduced, the corresponding max and min metal temperatures also reduce.

So we now understand that:

- **Raising the average exit gas temperature will not eliminate acid/ABS deposition on the AH plates,**
- **Material will, always, condense onto the AH plates if/when the metal temperature is lower than the dewpoint of the vapor,**
- **As long as the AH sootblower is operating properly, and the deposition depth of the condensed material is within its range, the cleaning system will remove the material,**

What we don't know is, on a real time basis, how deep will the actual vapor in the gas condense?



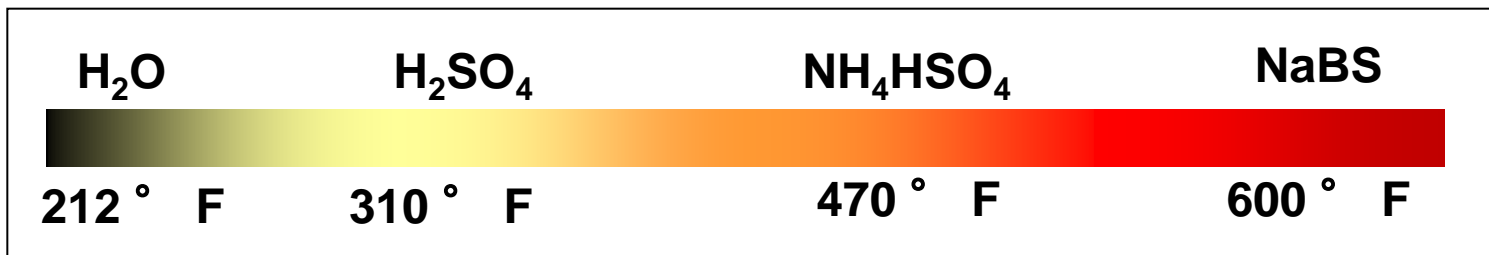
On-line Measurement of Vapor Concentration

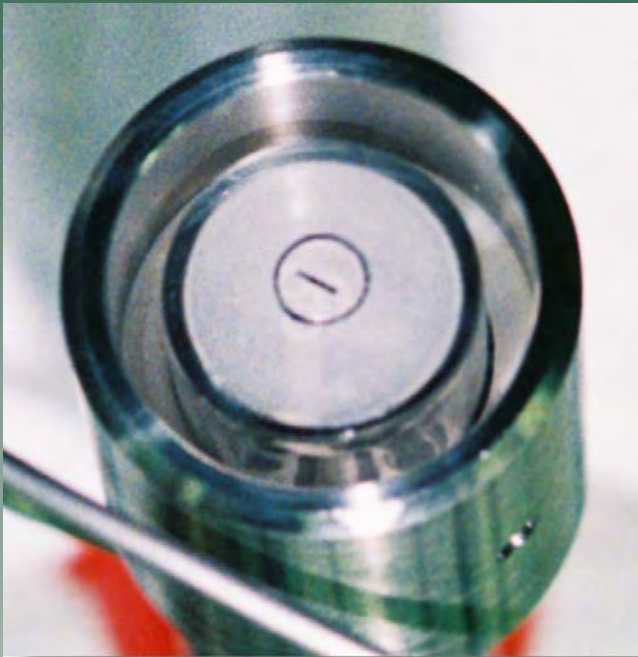


What are Condensables?

This material could be:

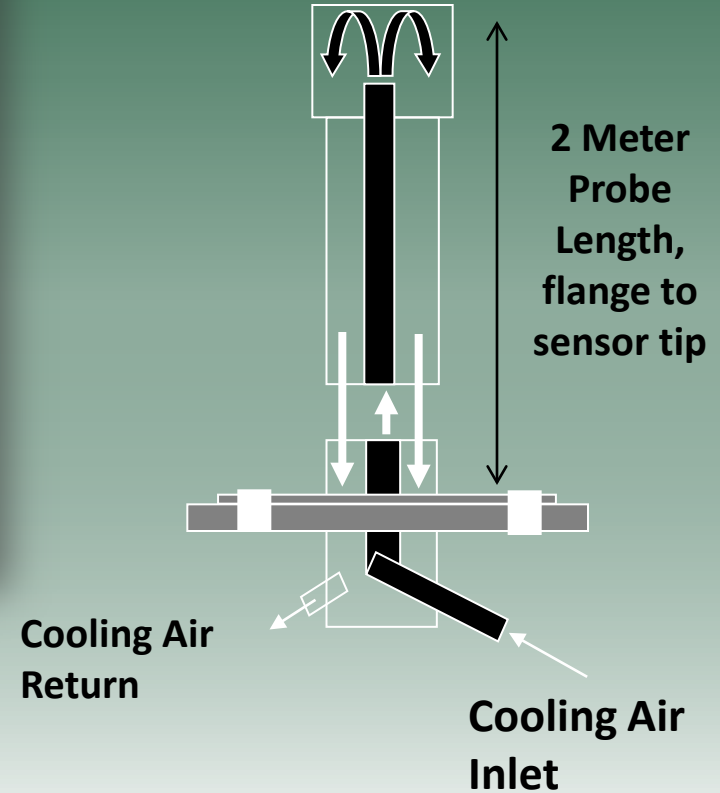
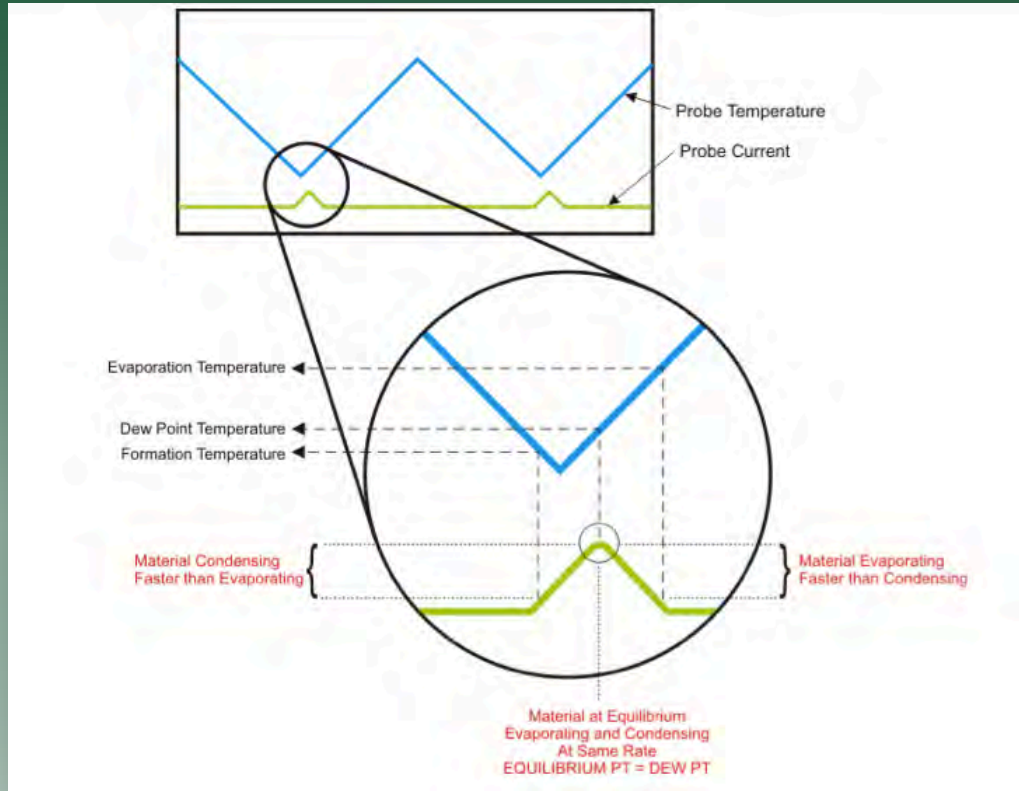
- Moisture (H_2O),
- Sulfuric Acid (H_2SO_4) ($\text{H}_2\text{O} + \text{SO}_3$)
- Ammonium Bisulfate (NH_3HSO_4) ($\text{NH}_3 + \text{H}_2\text{O} + \text{SO}_3$)
- Sodium Bisulfate





- **The Sensor Tip looks for the presence of condensed liquid between the two electrodes on a polished glass surface**
- **Condensate is encourage or discouraged by controlling the sensor temperature via cooling air on the back side of the sensor,**
- **The next slide shows the physical components and the process cycle to detect the formation and evaporation of flue gas condensate**

AbSensor – The Process



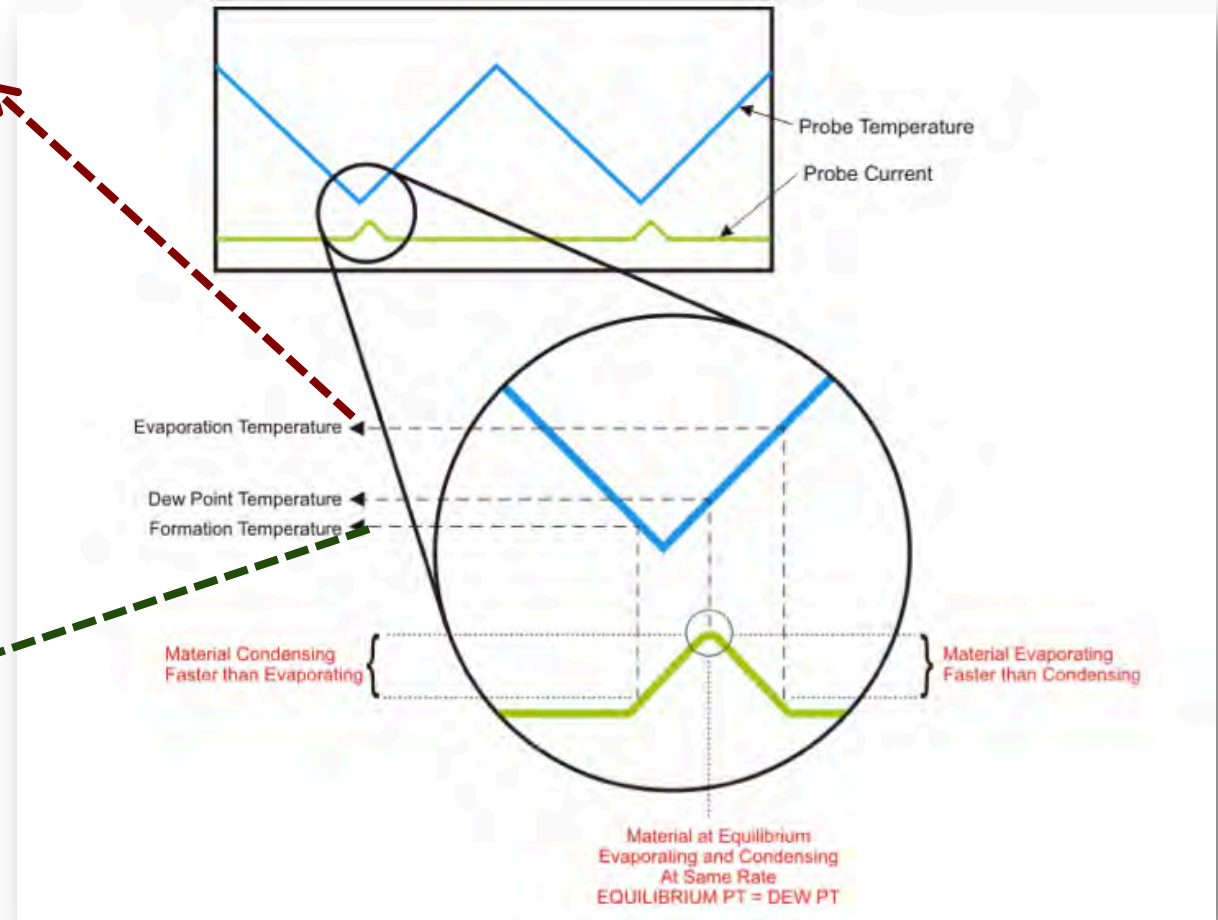
Dewpoint Hysteresis

Evaporation Temp:

The temperature where Condensed, liquid, material will return to its vapor state

Formation Temp:

The temperature where vapor will condense onto a cooler nucleation site.



- From the Dynamic Air Heater Model we know the exact metal temperature at any depth/rotation point,
 - From the Breen Probe we know the Formation Temperature and the Evaporation Temperature of the dominant condensable vapor present,
 - The deposition depth of the condensable material is known from the intersection of the *Minimum Metal Temperature* curve and the measured **Formation Temperature**.
-

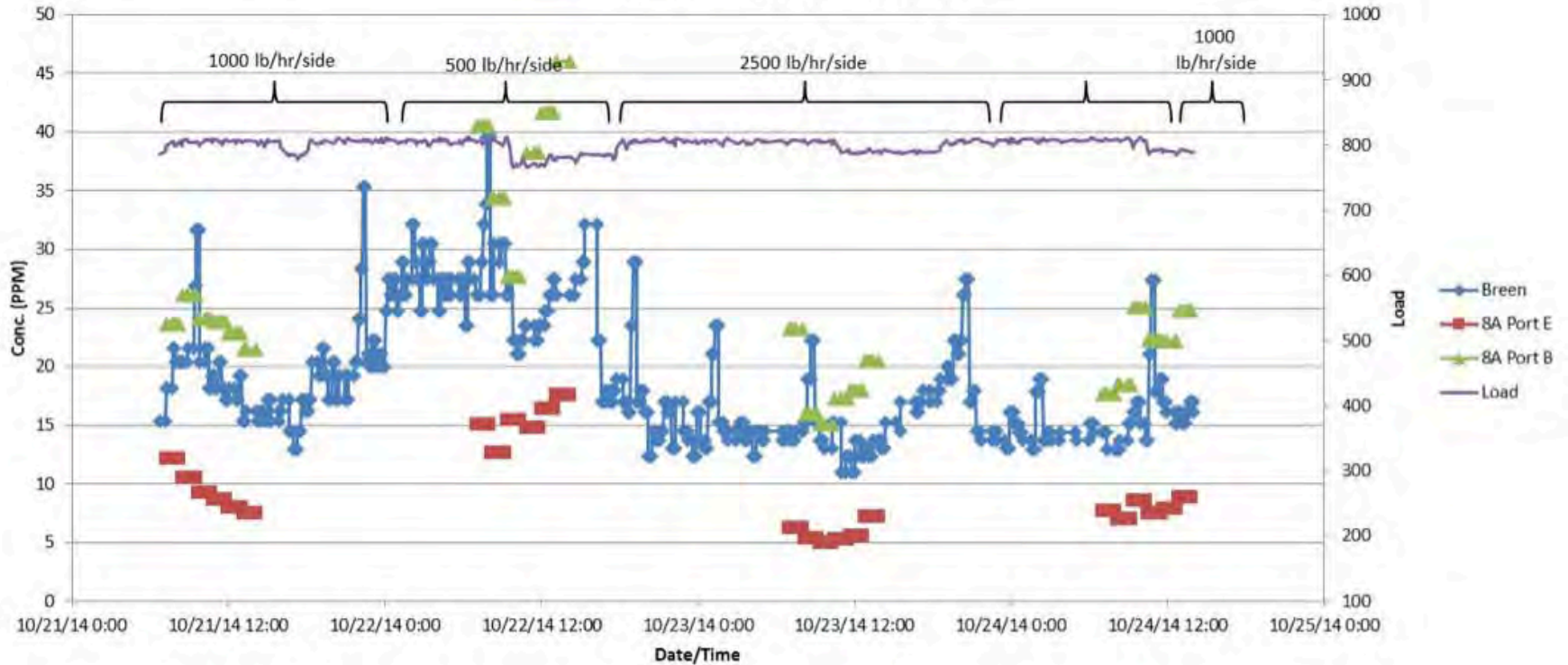


FmT vs. DSI Feed Rate

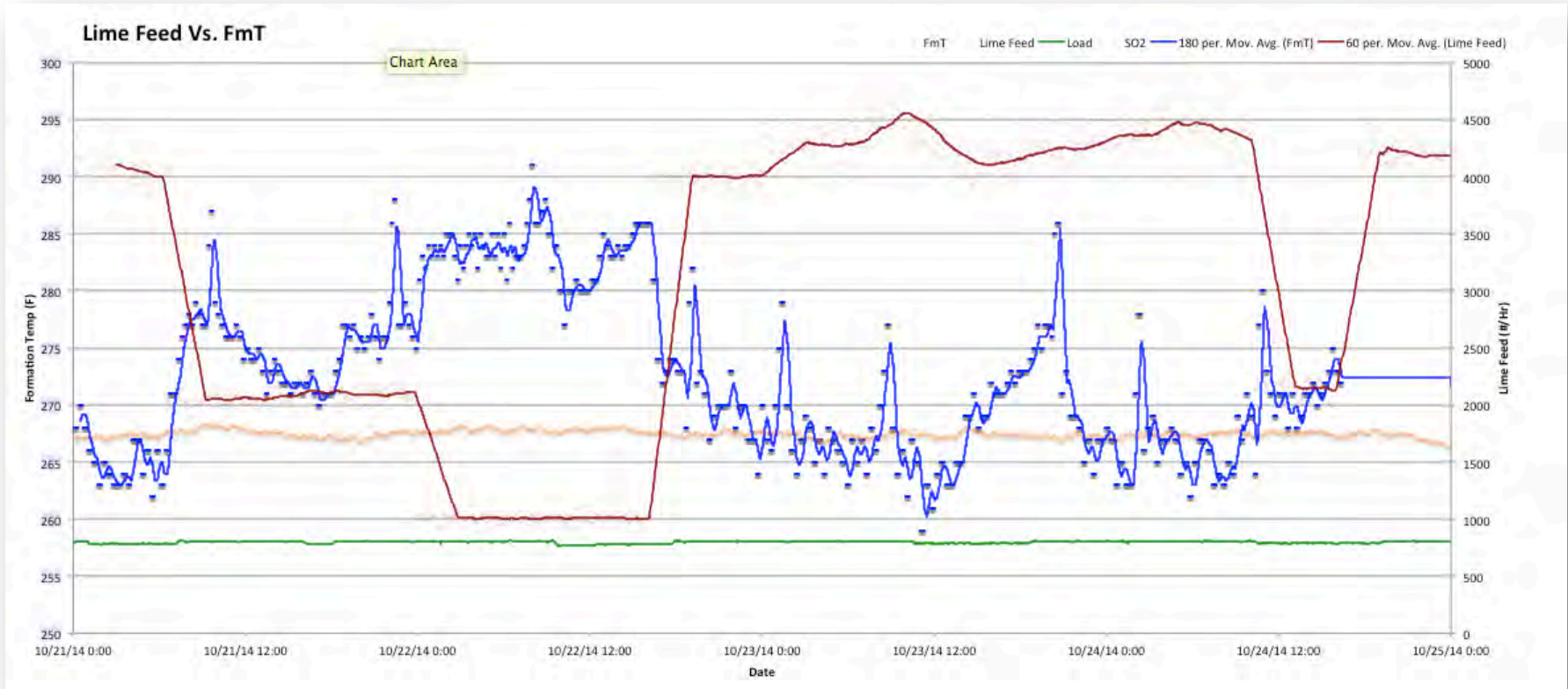


Independent Testing

SO3 Testing (10/21-10/24)



Same Data vs FmT



Small Load Changes can have big impacts!
DSI feed rate changed the FmT by 20F – 25F



Targeted Deposition Depth

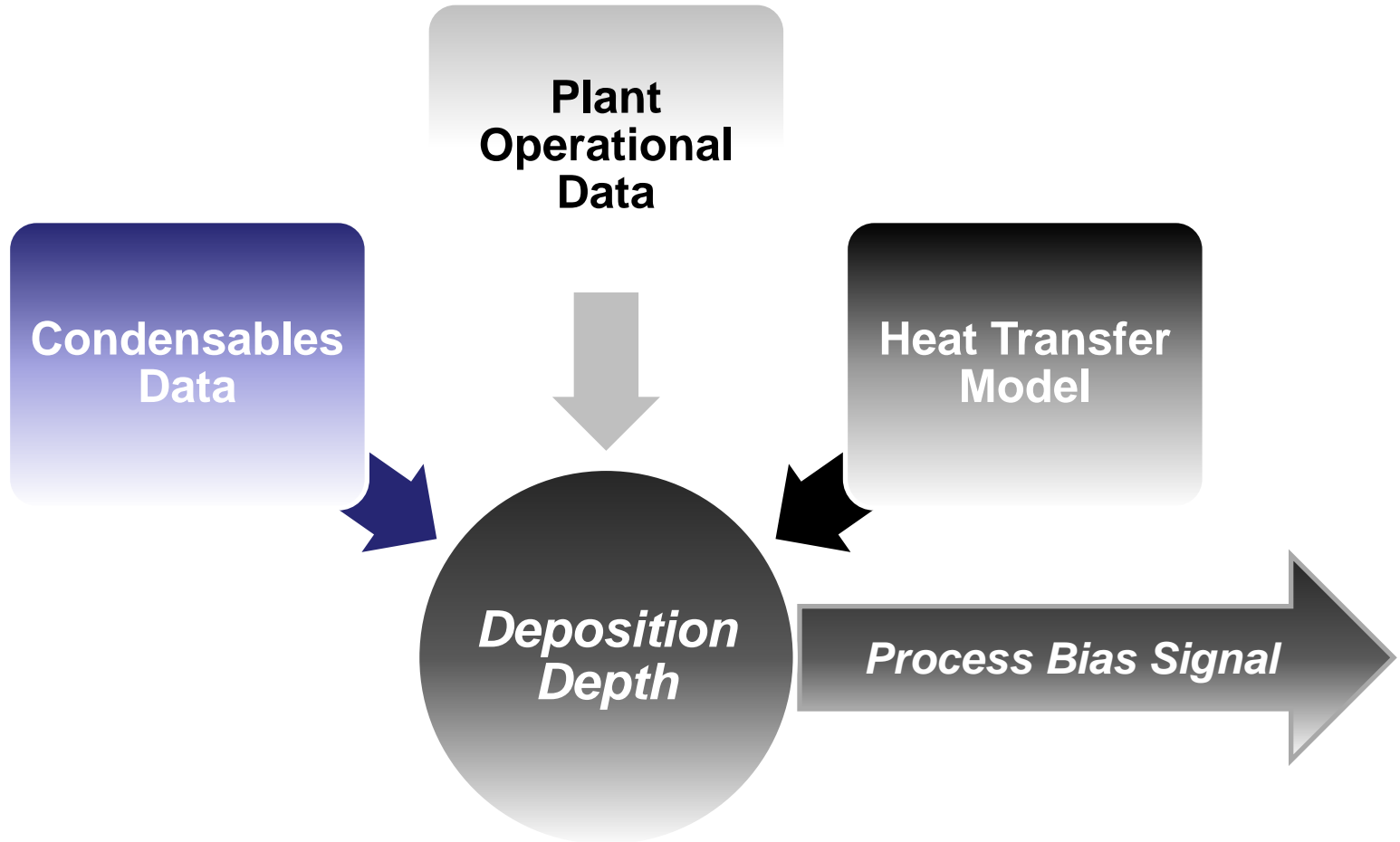


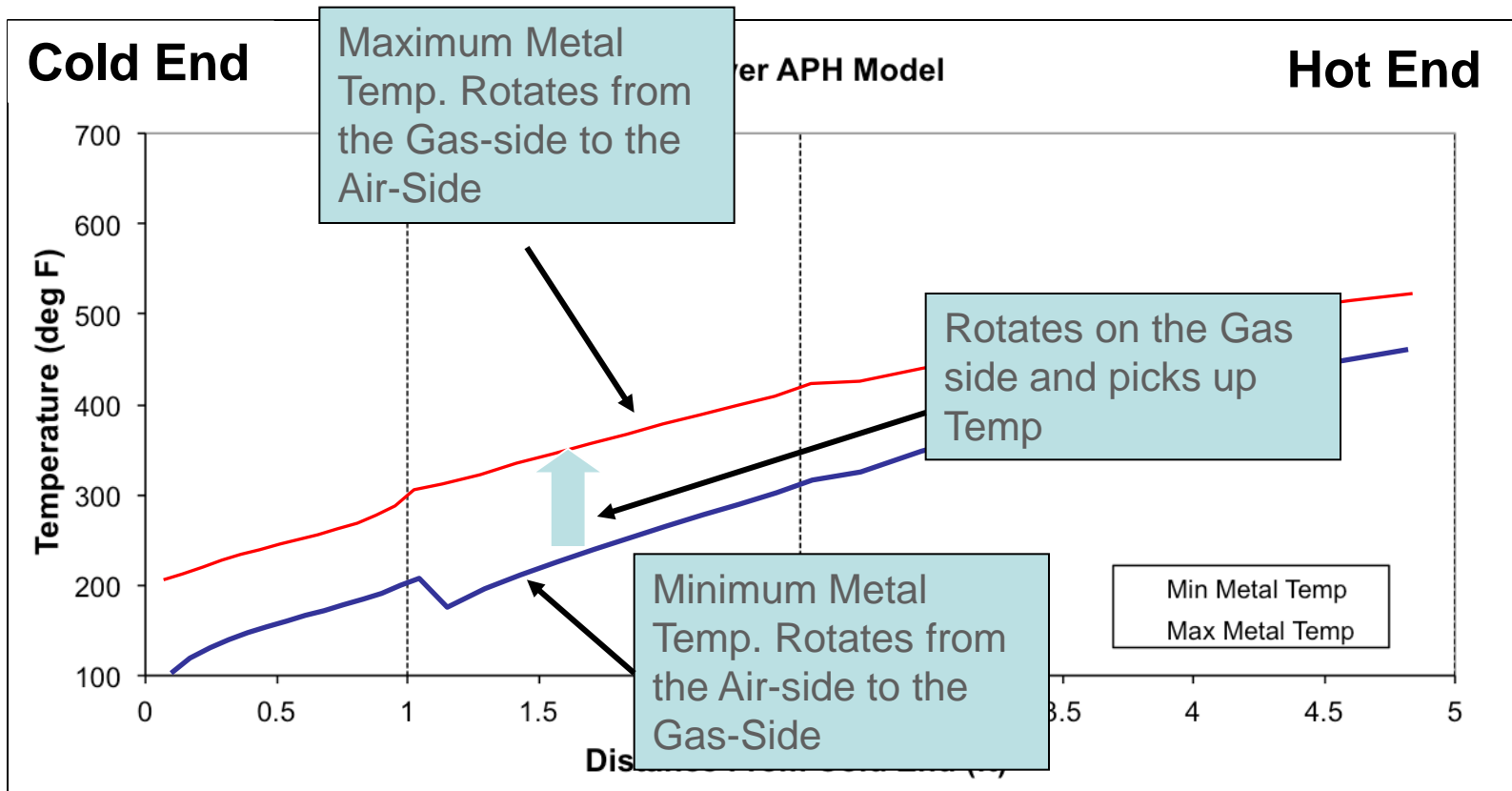
- **Targeted Deposition Depth Control allows:**
 - Closed loop control of ammonia injection rates at the SCR inlet to result in a desired formation temperature
 - Closed loop control of pre-AH sorbent injection to control acid/salt formation temperature

TDD Control allows the plant DCS to automatically control the deposition location for maximum plant performance with minimum air heater fouling



TDD Block Diagram





Multiple Model Generation



Linear-CO	0.01081239	1.00384574				0.611574046	0.176068358	0.17716817					
Linear-C1	0.04921274		-22.727445			0.595365195	0.160416403	0.24008078					
Linear-H0	-0.1406551			13.0966259		0.553132701	-0.133491832	0.66991038					
Linear-H1	-0.1121568				0.147735452	0.496383603	-0.118914921	0.71344232					
Modeling Table													
Load	C,0	C,1	H,0	H,1	Sec Air Temp In	Pri Air In	Gas Temp In	Linear-Model-C0	Error-C0	Error-Sq-C0	Linear-Model-C1	Error-C1	Error-Sq-C1
530	240.24	281.92	515.14	542.92	146	70	751	241.4023053	1.162305289	1.35095359	281.8084368	-0.000000000	0.000000000
423	241.41	273.52	494.15	514.45	159	79	702	241.0992169	-0.310783133	0.09658616	273.9622111	-0.000000000	0.000000000
321	233.72	258.43	482.13	498.36	163	84	644	233.047237	-0.672762984	0.45261003	258.2013696	-0.000000000	0.000000000
530	292.15	333.28	558.25	584.78	206	116	781	291.5109376	-0.639062357	0.4084007	332.1119264	-0.000000000	0.000000000
423	292.52	327.27	576.01	600.16	206	116	781	290.3540118	-2.165988219	4.69150497	326.8461636	-0.000000000	0.000000000
321	284.3	319.69	595.13	614.39	206	116	781	289.2511479	4.951147875	24.5138653	321.8264645	-0.000000000	0.000000000
530	258.35	301.42	540.72	569.2	164	74	781	258.4299567	0.079956679	0.00639307	300.3690993	-0.000000000	0.000000000
423	258.29	295.08	558.02	584.18	164	74	781	257.2730308	-1.016969183	1.03422632	295.1033365	-0.000000000	0.000000000
321	260.3	293.14	578.42	599.32	164	74	781	256.1701669	-4.129833089	17.0555213	290.0836375	-0.000000000	0.000000000
530	224.02	269.07	522.67	553.13	122	32	781	225.3489757	1.328975715	1.76617645	268.6262722	-0.000000000	0.000000000
423	224.14	262.69	535.55	563.75	122	32	781	224.1920499	0.052049853	0.00270919	263.3605095	-0.000000000	0.000000000
321	223.95	257.46	560.75	583.34	122	32	781	223.0891859	-0.860814053	0.74100083	258.3408104	-0.000000000	0.000000000
530	272.05	304.98	486.28	507.46	206	116	668	271.4909343	-0.559065681	0.31255444	304.9827984	-0.000000000	0.000000000
423	272.62	300.6	491.31	508.58	206	116	668	270.3340085	-2.285991543	5.22575734	299.7170357	-0.000000000	0.000000000
321	264.15	291.68	515.41	530.87	206	116	668	269.2311446	5.081144551	25.8180299	294.6973366	-0.000000000	0.000000000
530	237.99	272.97	468.77	491.88	164	74	668	238.4099534	0.419953355	0.17636082	273.2399713	-0.000000000	0.000000000
423	237.94	267.92	473.7	492.6	164	74	668	237.2530275	-0.686972507	0.47193123	267.9742086	-0.000000000	0.000000000
321	237.28	263.32	498.73	515.8	164	74	668	236.1501636	-1.129836413	1.27653032	262.9545095	-0.000000000	0.000000000
530	203.48	240.52	450.74	475.8	122	32	668	205.3289724	1.848972391	3.4186989	241.4971443	-0.000000000	0.000000000
423	203.51	235.26	455.22	475.8	122	32	668	204.1720465	0.662046529	0.43830561	236.2313815	-0.000000000	0.000000000
321	203.06	230.64	480.13	498.93	122	32	668	203.0691826	-0.009182623	8.4321E-05	231.2116824	-0.000000000	0.000000000
530	252.1	276.94	414.6	430.45	206	116	554	251.2937628	-0.806237176	0.65001838	277.6135897	-0.000000000	0.000000000
423	252.87	274.18	418.84	432.02	206	116	554	250.136837	-2.733163038	7.47018019	272.3478269	-0.000000000	0.000000000
321	245.56	265.92	435.36	447.07	206	116	554	249.0339731	3.473973056	12.0684888	267.3281278	-0.000000000	0.000000000
530	218	245.05	397.45	415.14	164	74	554	218.2127819	0.21278186	0.04527612	245.8707626	-0.000000000	0.000000000

Max, Mid and Low Load iterations
 Varied by changes in AH inlet air/gas temps

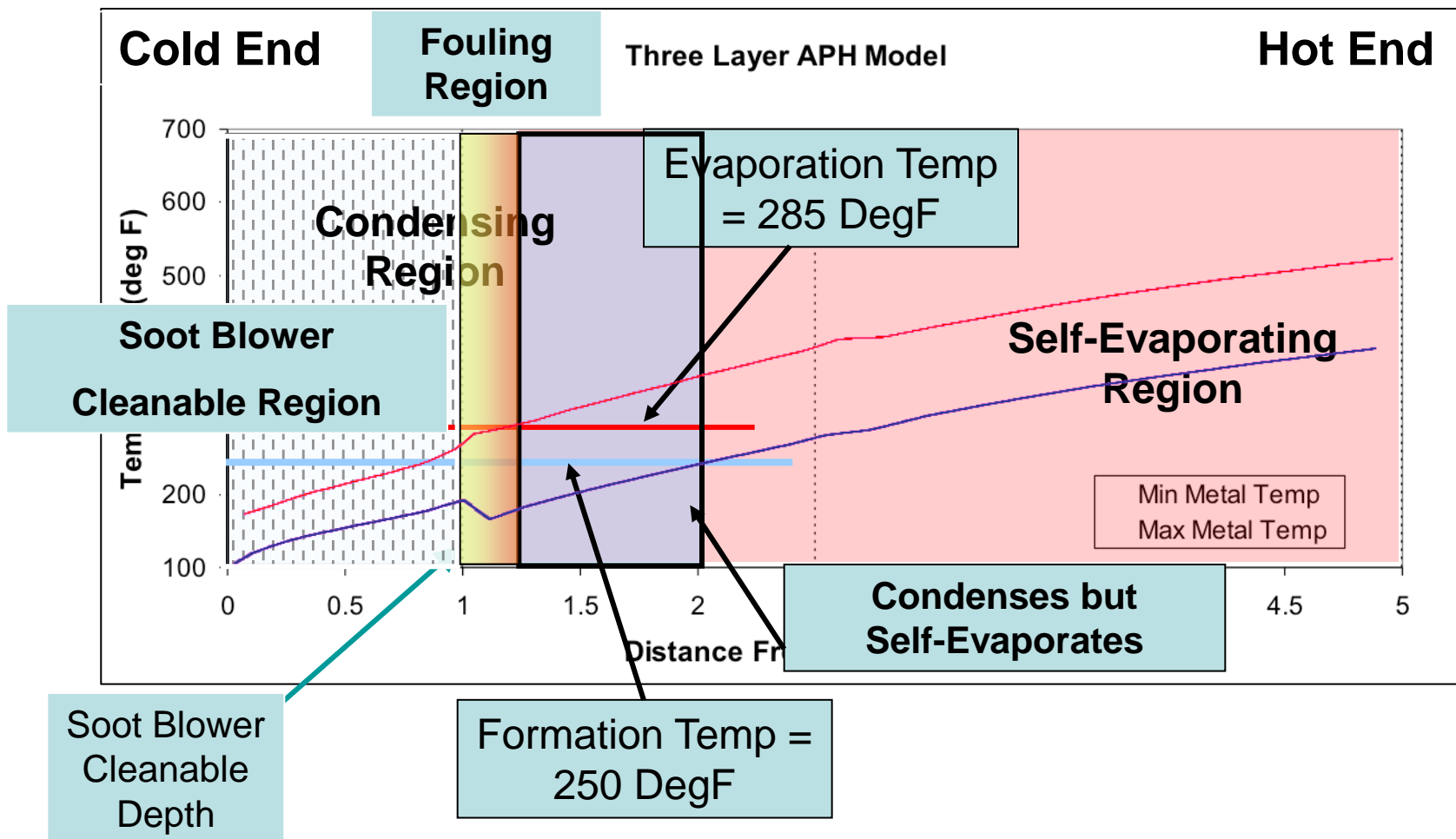
Formation Depth Calculation

Enter Data					
Load	530	MW	AH Depth:	7.17	Feet
Secondary Air Inlet Temp:	151	DegF	AH Depth:	86	inches
Primary Air Inlet Temp:	73	DegF			
Gas Inlet Temperature:	754	DegF			
Formation Temp:	240	DegF			
Evaporation Temp:	275	DegF			

Calculations:		
C0:	229.129295	DegF
C1:	267.428913	DegF
H0:	496.15703	DegF
H1:	524.82826	DegF

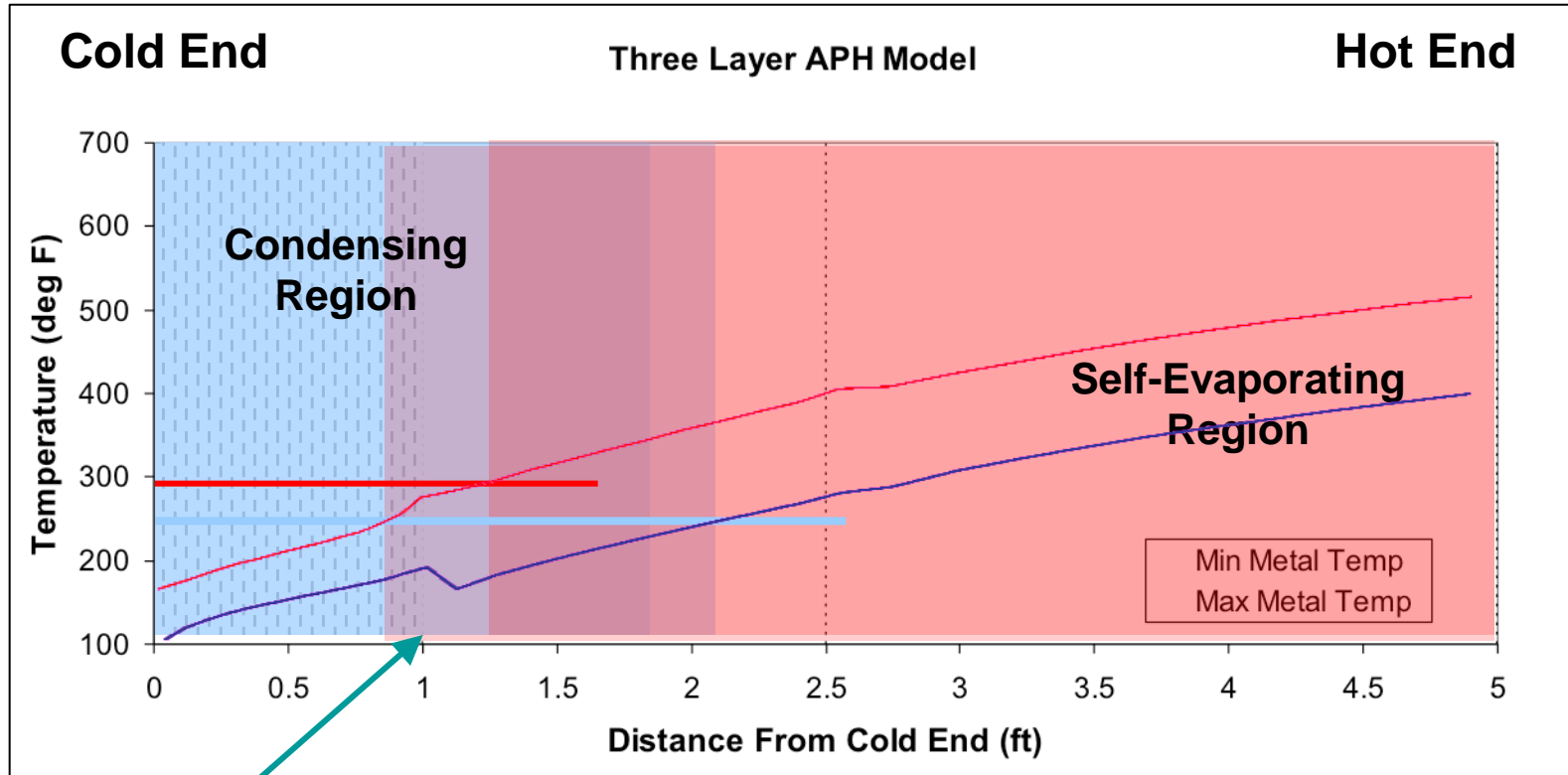
Formation Depth:	3.50	Inches	0.29	Feet
Evaporation Depth:	2.53	Inches	0.21	Feet

- Tool continuously polls DCS data for load and AH gas/air temps,
- Compares the metal temps to the measured gas FmT and derives the deposition depth
- Setting a limit on the deposition depth allows feedback to DSI for closed loop rate control

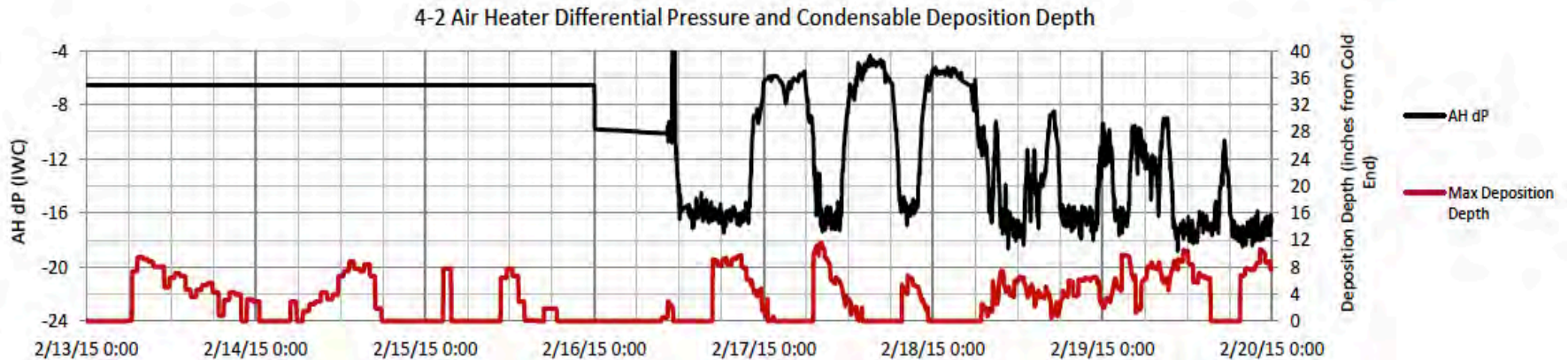


What can you do?

Reduce NH₃ / SO₃



Soot Blower
Cleanable
Depth



Typical display of Deposition Depth (Red Line) as plotted against AH Differential Pressure

This system is currently running in manual loop control but will be placed into automatic loop soon

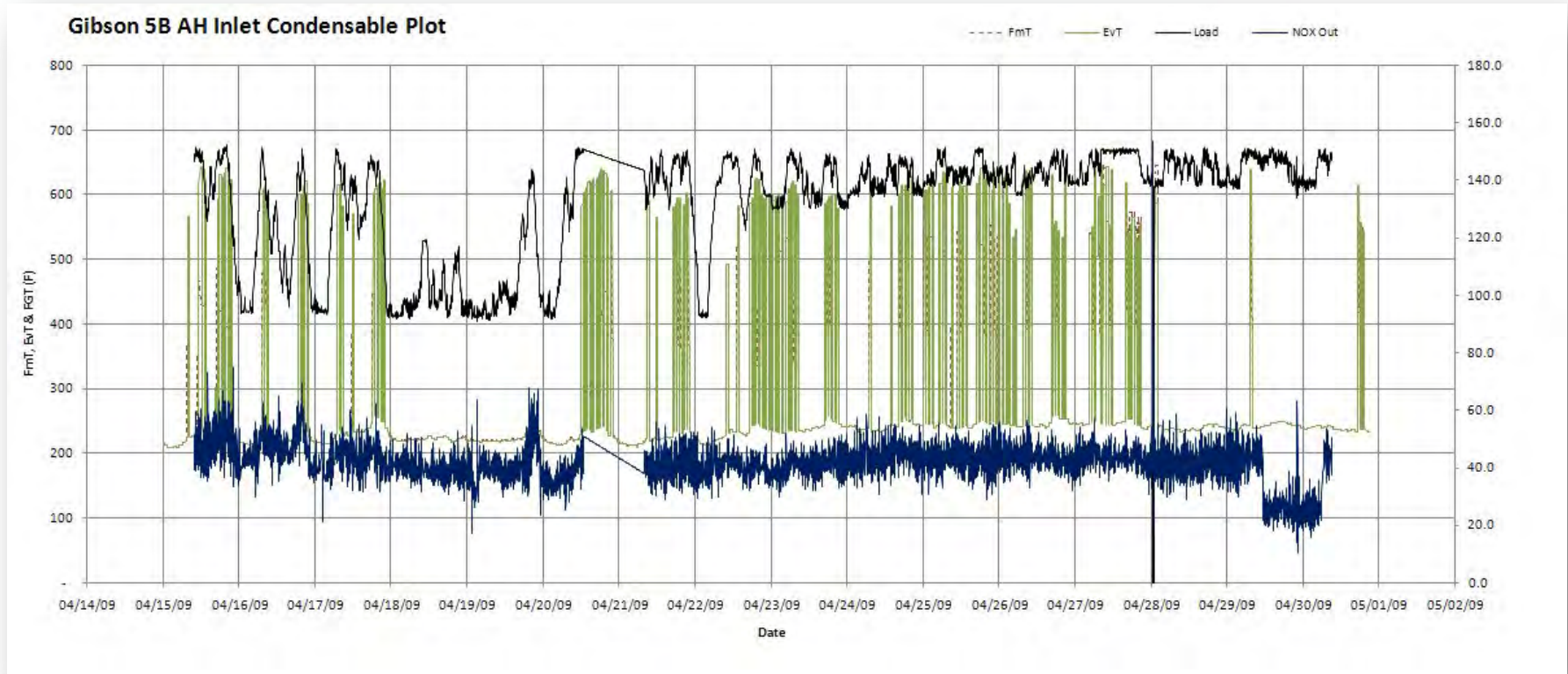


A Different Sorbent Approach

AECOMM – SBS Injection System



Some Old Data



2010 Data Showing Manual Control of Feed Rate with NOx reduction incentive.

The point is, with no condensable worry, what can happen?

- **This discussion is about heat rate and the effect that Pre-AH SO₃ mitigation can have on heat rate and plant performance.**
- **It is often asked “what is the point if I am not artificially raising my AH Outlet Temperature?”**
- **The answer is that Pre-AH removal of SO₃ will generate improvement in CO₂ reduction and heat rate that can pay for capital modifications to the AH.**



A Case Study on what May Be Possible

Sterling Gray - AECOM





Conclusions



- 1. Pre-AH Reduction/Removal of SO₃ has significant impact on:**
 1. AH Outlet temperatures
 2. CO₂ Emissions
 3. Fuel Cost Savings
 4. The Fuel Cost Savings is greater than the cost of the Sorbent, and, if DSI is already in use post-AH, movement to Pre-AH would provide virtually FREE fuel and CO₂ improvement
- 2. Closed Loop control of Pre-AH SO₃ Mitigation is viable and proven,**
- 3. Improvements in AH Differential Pressure drop and improved NO_x performance are free co-benefits.**



Questions?

