REINHOLD ENVIRONMENTAL Ltd.

2016 APC-Wastewater Round Table & Expo Presentation

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Sorbent Injection for Low Load Operating Flexibility

2016 Reinhold APC/PCUG Conference

Chad Donner – Sorbent Injection SME July 19, 2016

Introduction

Performance & Benefits

Gibson Optimization Test

Questions

Overview

Sorbent Injection Strategic Approach

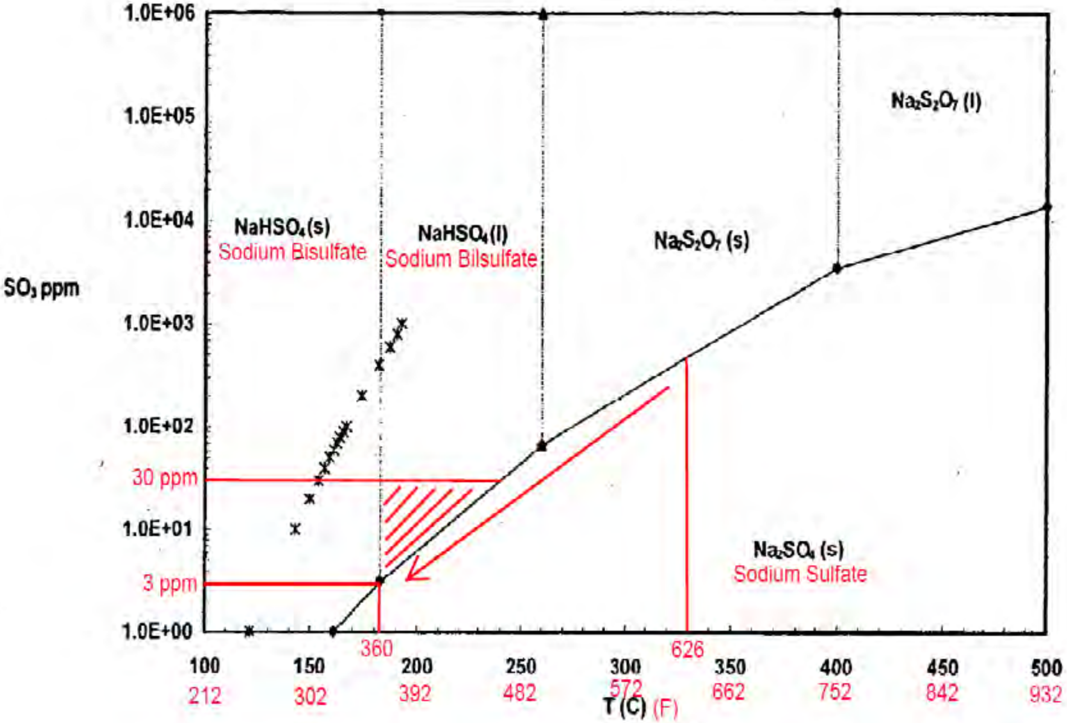
SBS System Background

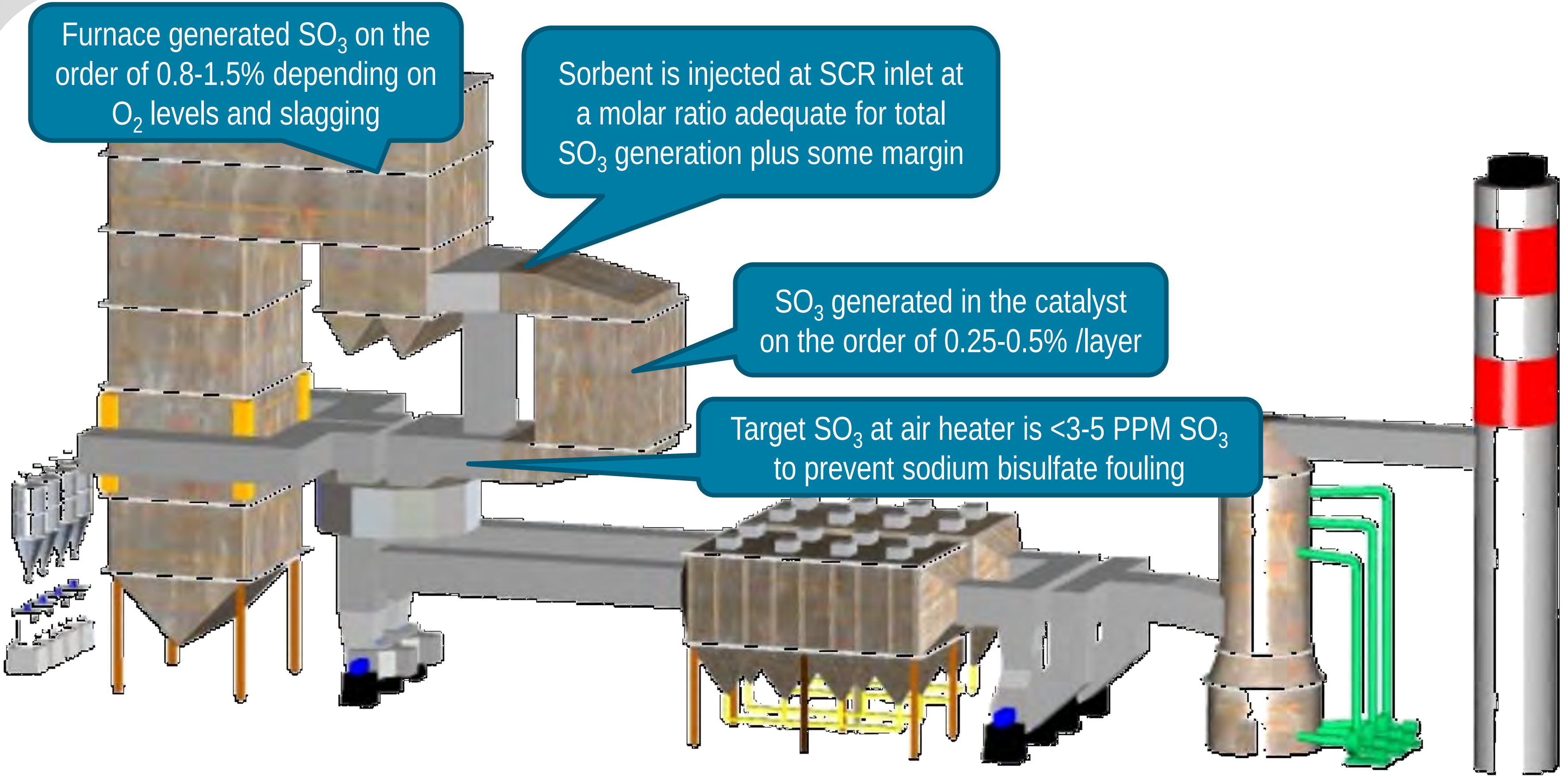
Introduction

Sorbent Injection Strategic Approach

- "Everything effects SO_3 and SO_3 effects everything"
  - Boiler/SCR SO_2 Oxidation, O_2%, SCR MOT, Nox Removal, ABS Formation/AH Pluggage, Heat Rate, HCl Removal, Mercury Capture, Precipitator Performance, FGD, Blue Plume
  - Quantifying all benefits of Heat Rate improvement, less coal, less ash, less landfill, credits etc…
  - No DSI requirements…hmmm…
- Sorbent Injection systems need to be thought of as an integrated control technology not just a Sorbent Injection System as they have potential to impact the entire plant both positively and negatively.
  - Siloed vs. Holistic
- Past sorbent injection systems have fallen short on effective means of control and long term reliability
  - As plants begin rely on these systems in order to operate they need to be reliable and the new 3rd Generation systems have proven to be reliable with availability greater than 99%
  - 3rd Generation systems have much better controls that greatly reduce the amount of daily operator involvement in system operation from feedrate controls to system monitoring

- Liquid sodium bisulfate forms between ~360-500F at a 2:1 ratio with SO_3 with this temperature range occurring in the air heater and possibly in the air heater outlet duct
- The preferential reaction is to form a 1:1 solid sodium sulfate with SO_3 at higher temperatures, however sodium sulfate will continue to react with residual SO_3 so a high level of control (<3 ppm) is needed to prevent conversion to the liquid sodium bisulfate
- This was the primary reason URS relocated their process to the higher temperature region and maintains a high rate of control to capture residual SO_3 from the SCR




Furnace generated SO_3 on the order of 0.8-1.5% depending on O_2 levels and slagging
Sorbent is injected at SCR inlet at a molar ratio adequate for total SO_3 generation plus some margin
SO_3 generated in the catalyst on the order of 0.25-0.5% /layer
Target SO_3 at air heater is <3-5 PPM SO_3 to prevent sodium bisulfate fouling

Reduced Catalyst MOT

Air Heater Fouling / Enhanced Nox Removal

Heat Rate Improvement

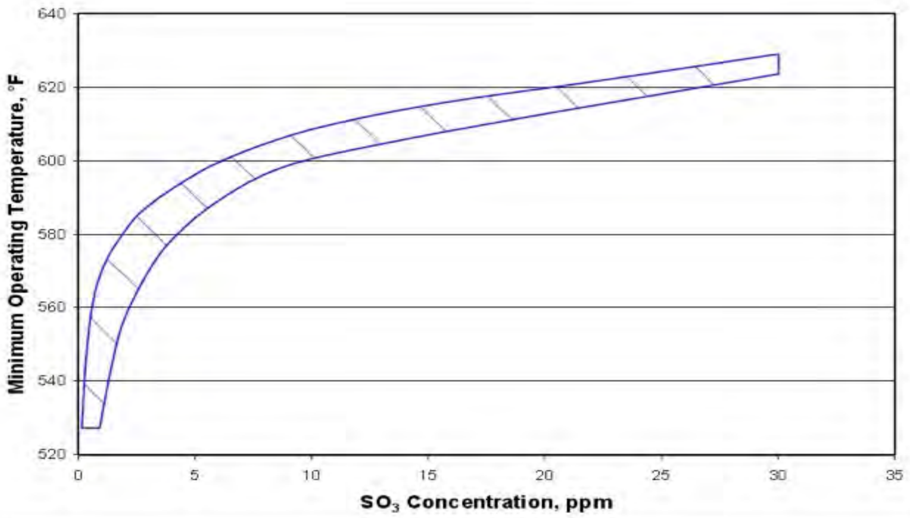
Performance & Benefits

Reduced Catalyst MOT

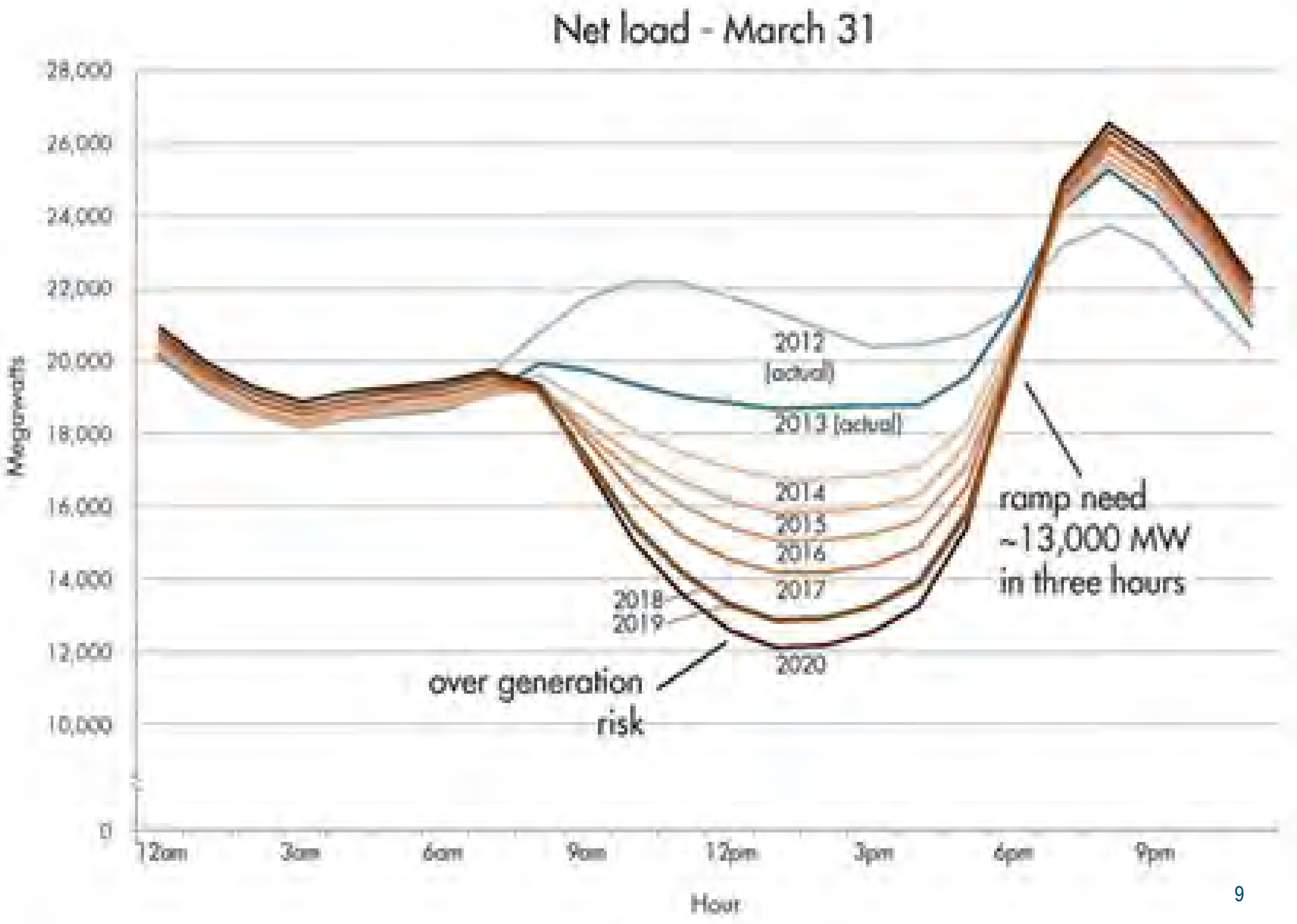
- SCR MOT is a function of NH_3 and SO_3 concentration in the flue gas
- Currently Gibson uses the philosophy in Table 1 by reducing the ammonia concentration to allow limited operation at 550F from 622F.
- MOT is also affected by SO_3 as seen in the graph below
- Since the sorbent injection has been moved to the pre-SCR location, Gibson should be able to recognize greater Nox removal at lower loads currently as past SO_3 inlet data has indicated levels <1ppm
- It may be possible to operate the SCR at a low enough temperature to permanently eliminate the economizer bypass ducts removing a large O&M burden and operate down to 200MW increasing unit turndown flexibility

Table 1

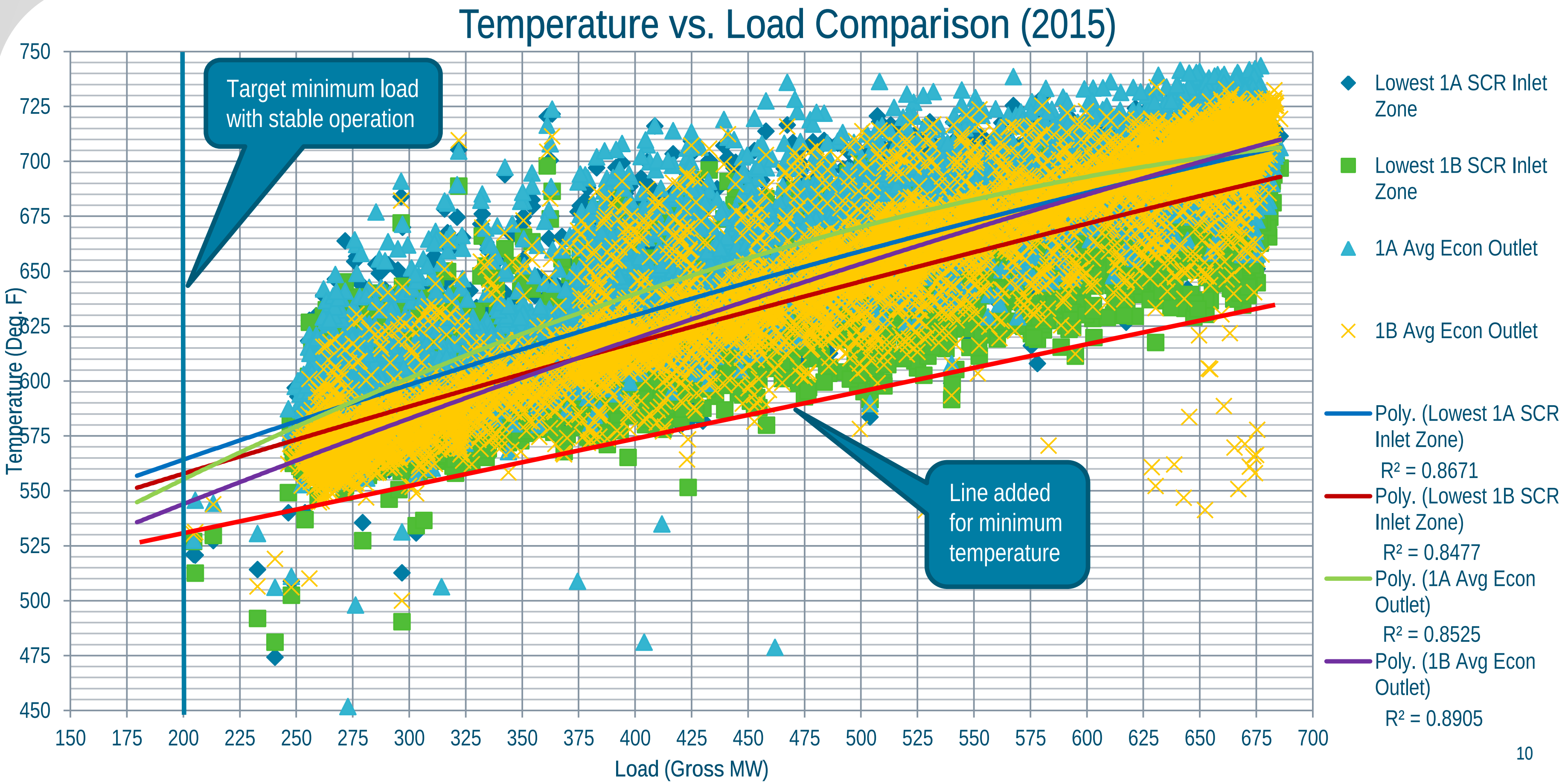
Unit 1 Dual Duct SO_3 Mitigation	
Operator must adjust setpoint	
85% NO_x Removal	> 580° Lowest Grid TC
50% NO_x Removal	=< 580°
25% NOx Removal	=< 570°
Ammonia Cut Out	550°



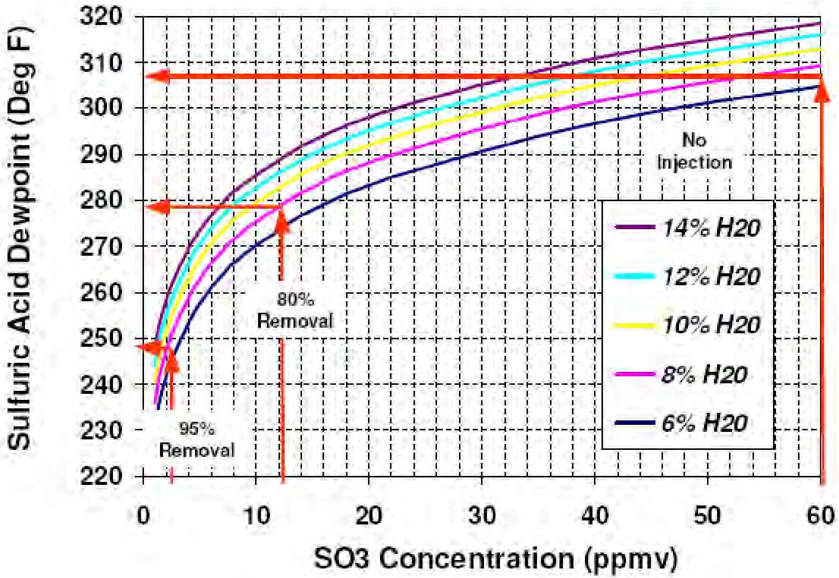
- Why???
  - Solar and wind have created large amounts of peak generation that are priority
  - Coal must now load follow to a degree and be more nimble for turndown and ramp rate
  - New Ozone season limits will require pushing the SCR's harder and keeping them in service longer

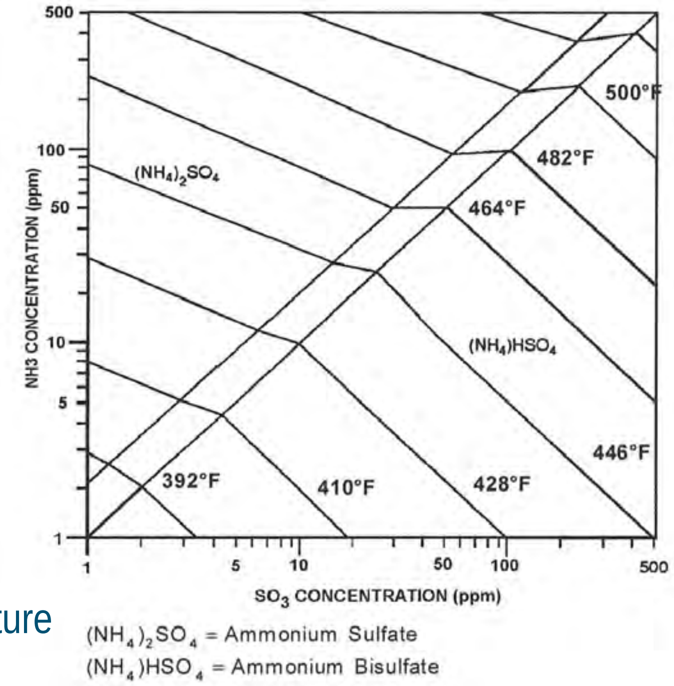


Reduced Catalyst MOT



Air Heater Fouling / Enhanced Nox Removal

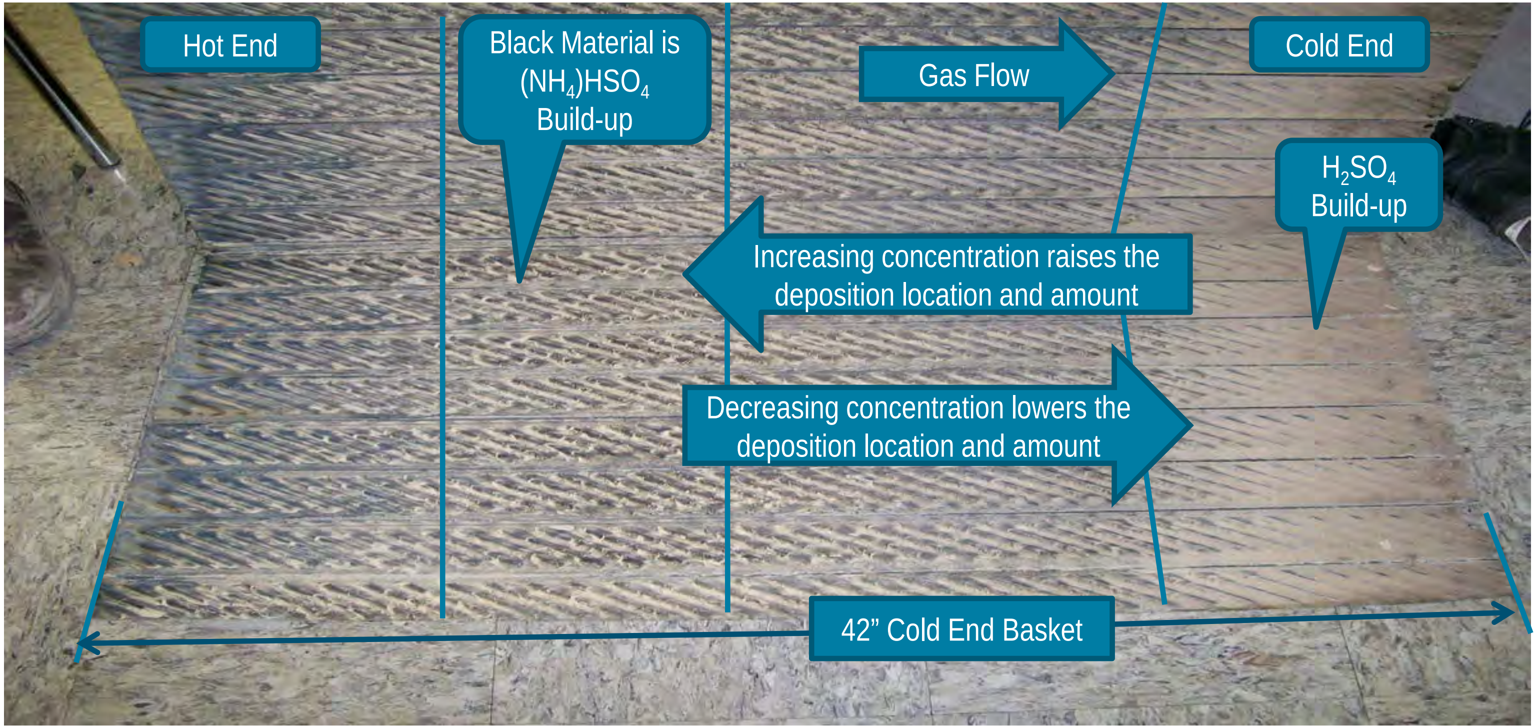




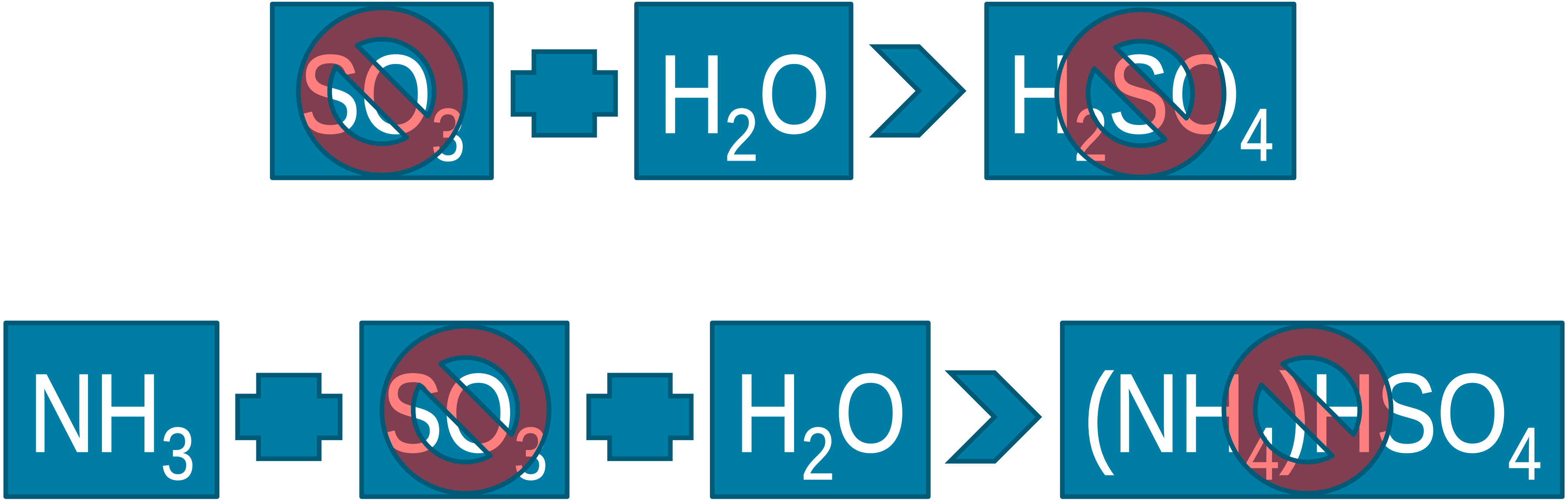
- Two different fouling mechanisms as a function of SO_3 & temperature
  - Ammonia & Sulfuric Acid
- Sorbent Injection works to reduce or eliminate air heater fouling by reducing the SO_3 in the flue gas
  - Assuming SO_3 is neutralized prior to the air heater
- Testing at Zimmer has shown Sulfuric Acid dewpoints down to 220-230F measured on Breen Probe with high injection rates

Air Heater Fouling / Enhanced Nox Removal

- East Bend air heater basket plate dissected showing $(NH_4)HSO_4$ and H_2SO_4 build-up
- HSESP air heaters are more prone to pluggage as there is little ash for condensables to condense on which results in more condensation on the plates



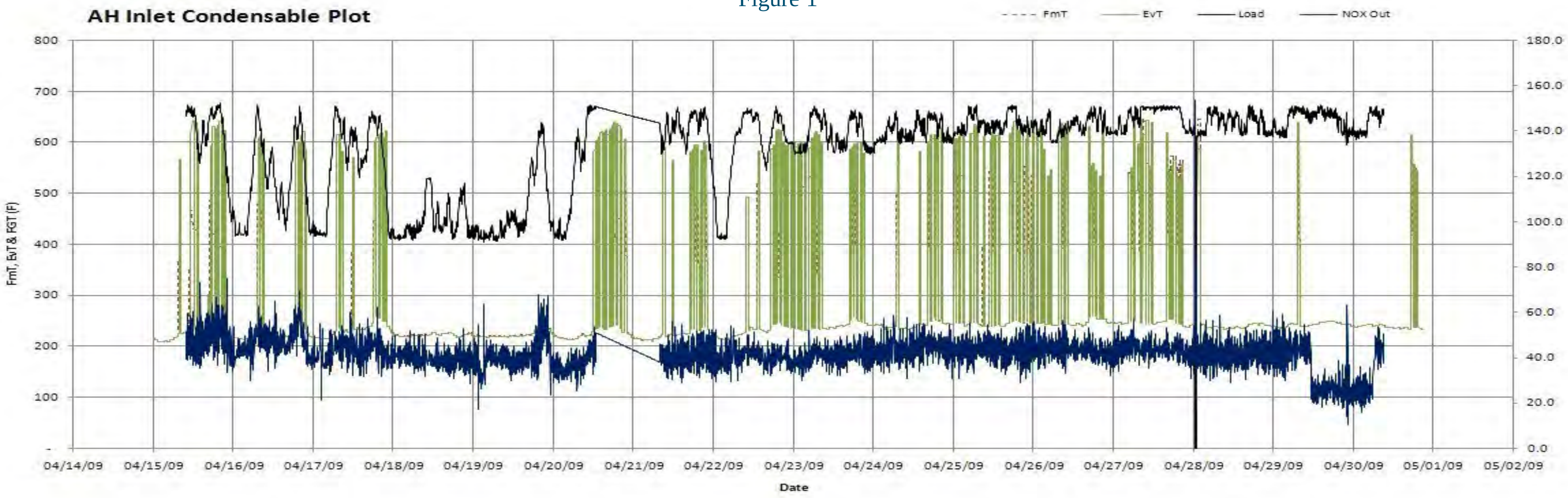
Air Heater Fouling / Enhanced Nox Removal



Air Heater Fouling / Enhanced Nox Removal

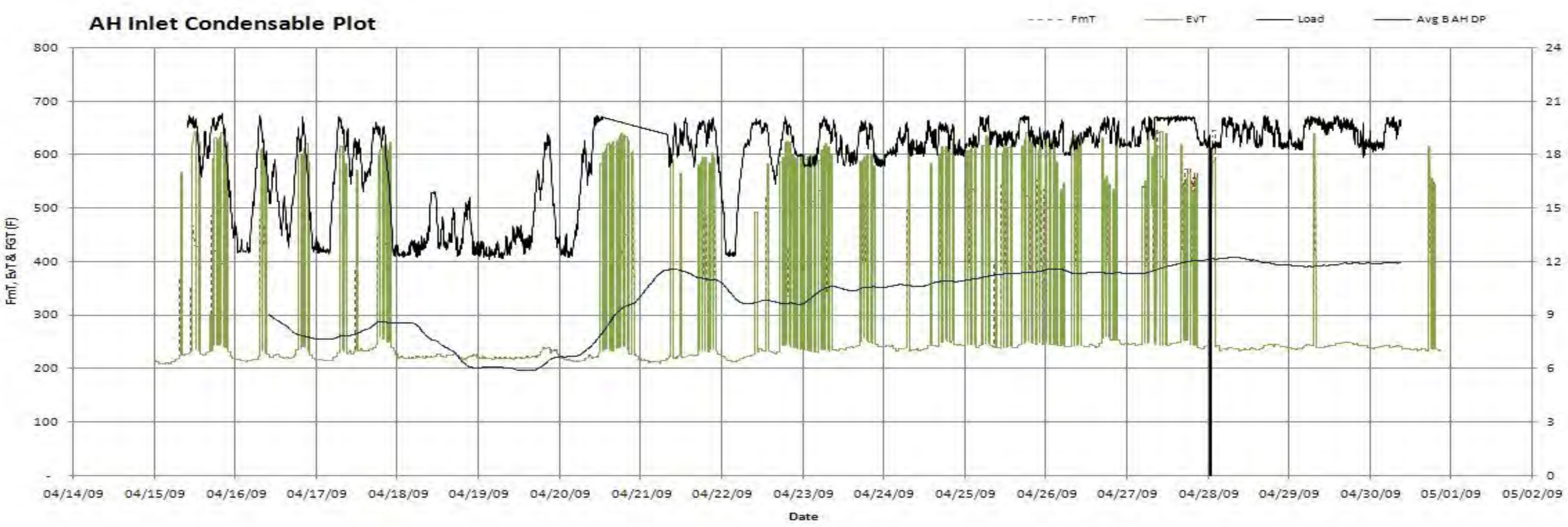
- Gibson 5 SBS injection and condensables trends while being manually controlled from April 28th-30th
- Continuously adjusted the SBS injection molar ratio so no current was observed on the Breen probe (Green line) which indicates potential fouling
- Tested enhanced Nox removal by increasing the ammonia injection rate and increasing the removal from 85% to 93% for a period of 24 hrs

Figure 1



Air Heater Fouling / Enhanced Nox Removal

- Gibson has always struggled with Nox removal and air heater pluggage
- Trend shows air heater DP levels off when the SO_3 mitigation system was increased to make the condensable formation stop

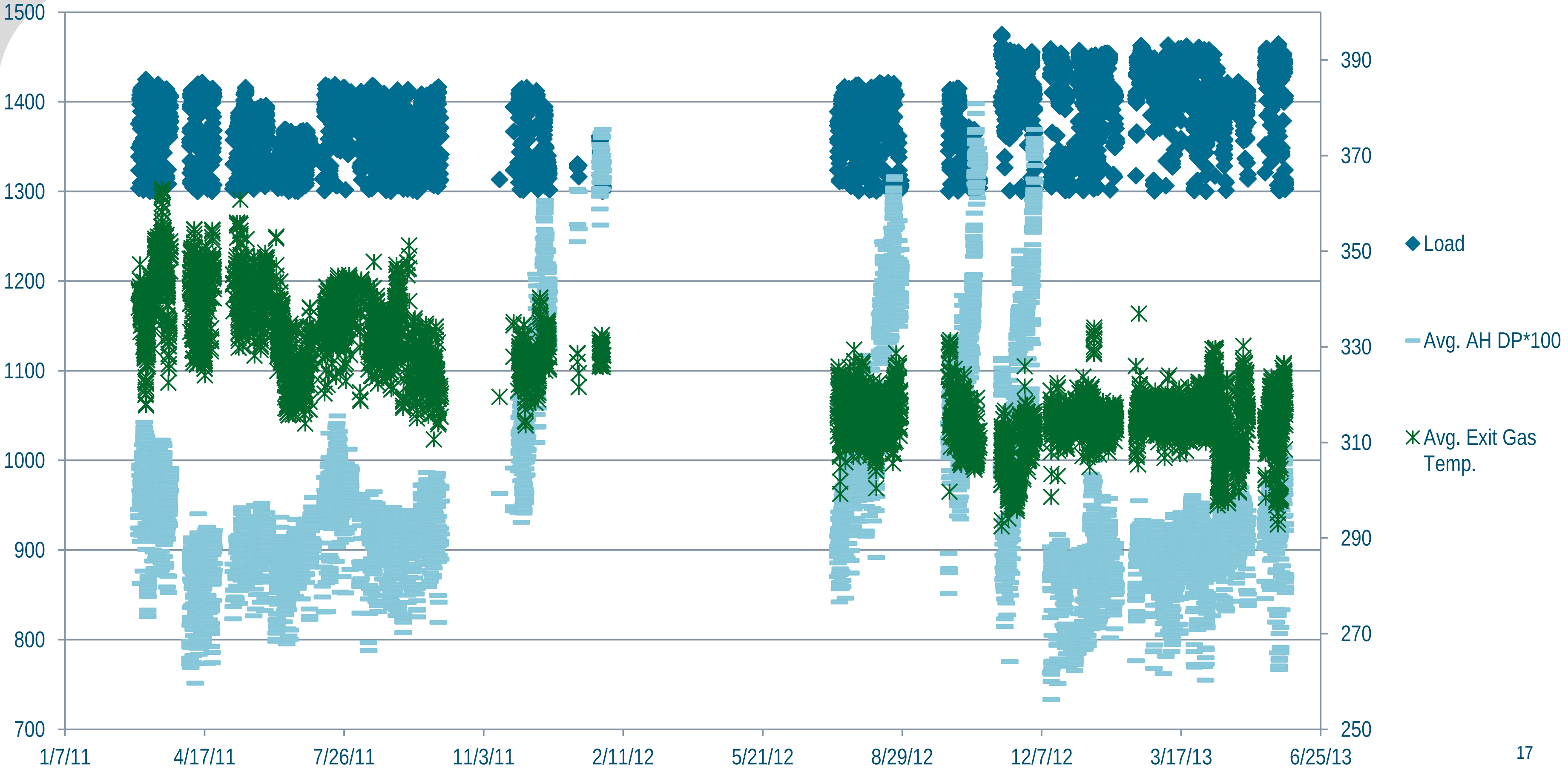


Air Heater Fouling / Enhanced Nox Removal

- Installed 4th layer in Fall '11, removed 3rd layer in Spring '12
  - Later discovered the 4th layer that was installed had double the SO_2 oxidation rate, increasing SO_3 to the AH
- Air heater rebuild with new seals and partial basket replacement
  - Tightened AH's and dropped outlet temp
  - Started having significant sulfuric acid pluggage
- Fuel flexibility drove decision to reverse direction of rotation on tri-sector air heater for more PA temp
- Installation of an intermediate reheater reduce economizer outlet temps
  - Further reduced AH outlet temps
- Made the decision to move the current Sorbent Injection upstream of the SCR/AH to mitigate air heater pluggage

Air Heater Averages	Pre 2012 Outage	Post 2012 Outage	Δ
Primary Air Temp.	504	574	+70
Secondary Air Temp.	553	546	-7
Gas Inlet Temp.	653	644	-9
Gas Outlet Temp.	335	313	-22

Air Heater Fouling / Enhanced Nox Removal



Heat Rate Improvement

- A reduction of 30 degrees F on air heater exit gas temp is approximately a 1% savings in unit heat rate
- Improved heat rate has benefits beyond coal cost
  - Decreased fuel handling
  - Decreased ash & waste handling and stabilization
  - Decreased CO_2 emissions
  - Better native Hg capture
  - Better precip performance
  - Decreased emissions overall
- Sustainability
  - People, Planet, and Profits

	Baseline	Less 1% HR	Savings
Heat Rate (BTU/KWh)	10,000	9,900	100
Yearly Fuel (TN's)	1,368,750	1,355,063	13,688
Yearly Ash (TN's)	109,500	108,405	1,095
Coal & Ash Cost ($'000)	87,600	86,724	876
CO_2 Emissions (TN's)	3,367,125	3,333,454	33,671

Assumptions:

500 MW Unit
12,000 BTU/lb fuel heating value
75% Capacity Factor
$60/ton coal cost
10% ash content
$50/ton ash processing cost
205 lb/Mmbtu CO_2 Emissions per EIA

Testing Overview/Goals

Test Plan Details

Lab Results

Things to Consider

Gibson Optimization Testing

Testing Overview/Goals

- Gibson catalyst was run in the lab on a bench reactor by Cormetech to evaluate low temperature impacts prior to full scale testing and to develop an operating model for testing different conditions
- Proposed testing planned on unit 1 for 2 weeks beginning May 23rd was delayed to week of 7/11
- Data will be collected, evaluated, and modeled so that the results could be correlated to additional operating conditions and applied to the other units with limited additional testing
- Full scale data collection was completed this week and is in the process of being analyzed to validate the lab model
- Once results have been evaluated and station concurrence is achieved, operating model updates will be made so Gibson can begin realizing benefits
- Goals
  - Model SCR minimum operating temperature conditions with Pre-SCR SO_3 mitigation in mind to determine the lowest reasonable operating temperature and associated Nox removal
  - Perform gas testing for SO_3, SO_2, NH_3 to feed into the SCR model and to determine boiler & SCR oxidation at high and low load, SBS system performance at SCR Inlet and AH inlet, slip levels for potential AH impacts and to monitor catalyst, acid dewpoint evaluation for reduced AH outlet temp operation
  - Measure SO_3 and Na compounds in the hot air duct to determine if hot air duct can be used in lieu of the in duct heat exchanger without possibility for plugging NH_3 nozzles
  - Perform pre & post SCR catalyst sampling to determine any possible deactivation
  - Operate for a minimum of 72 hrs at 200MW to simulate a long holiday weekend
  - Evaluate temperatures with economizer bypass isolated/blanked to determine if they can be permanently blanked once allowable catalyst MOT is determined
  - Utilize additional Breen Probe data at the SCR inlet and AH inlet to evaluate real time unit data throughout operating range and transient conditions for duration of test

Test Plan Details

- Cormetech will provide Phase 1 & 2 (data collection and lab bench scale work) prior to the start of gas testing so that initial results can be modeled prior to testing with ammonia full scale
- Day 1 will focus on boiler oxidation and SCR inlet conditions at low and low-low load with different SBS MR's to collect data for the catalyst model prior to introduction of ammonia
- Day 2 will focus on full load SBS system performance at various MR's in addition to full load boiler and SCR oxidation
- Day 3 will focus on low-low load operation with ammonia and the transition to full load monitoring for ABS burnoff and hot PA burnoff
- Day 4 will focus on low-low load SCR oxidation with ammonia, reduced gas outlet temp and enhanced Nox removal operation
- Day 5 will be a contingency day in case something is found that warrants further investigation

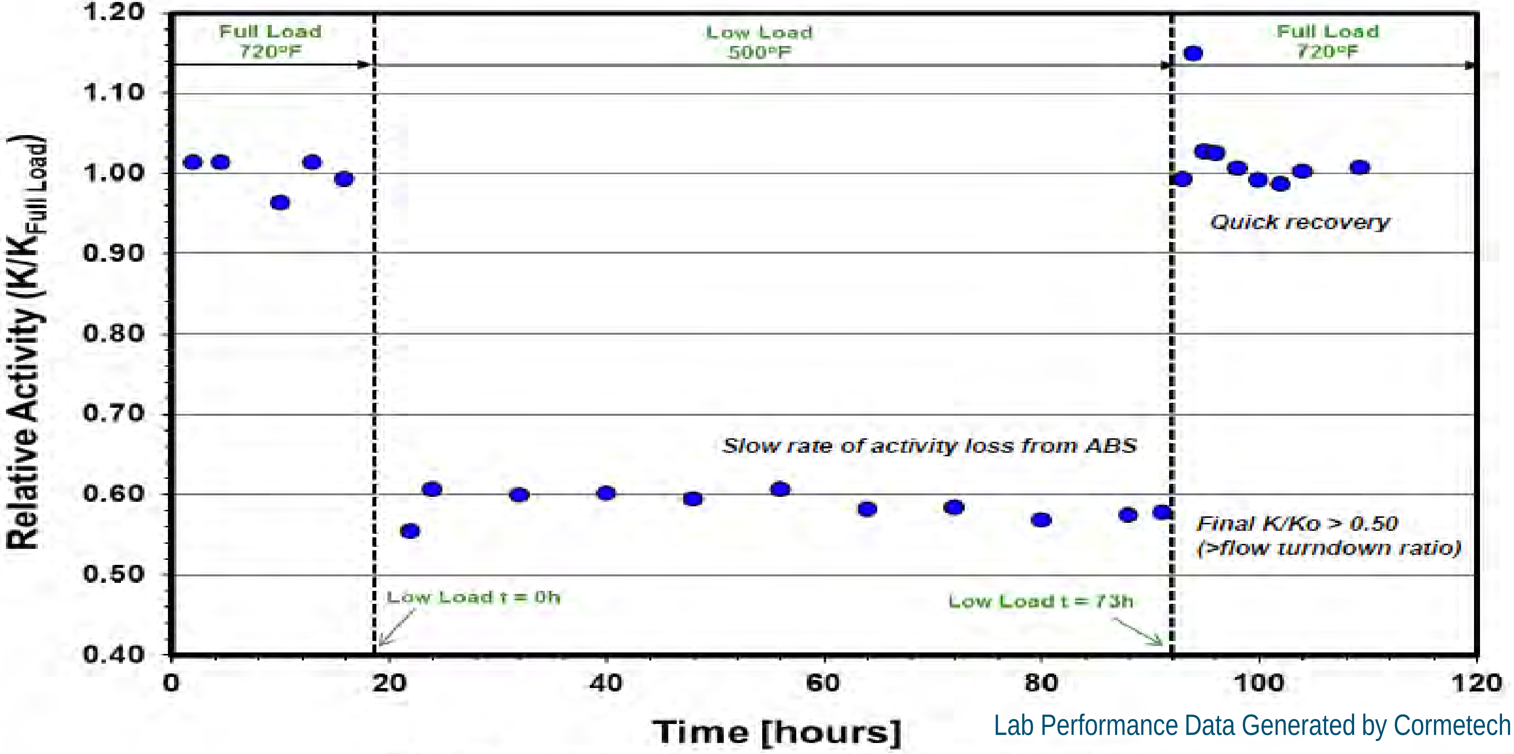
Test Plan Details

Gibson Unit 1 SCR Test Plan Rev.3 7/1/16 - For Planning Purposes Only

	Collection	Analysis	Location	Week of	Thursday			Friday			Saturday	Sunday				Monday	Tuesday		Wednesday		Thursday		Friday		Extended
				7/4/16	7/14/16			7/15/16			7/16/16	7/17/16				7/18/16	7/19/16		7/20/16		7/21/16		7/22/16		
				REO Time(00:00)	0700-1900			1200-2000		2100-2400	2000-2400	0100-0800		2000-0200		Slowly Transition 0200-0500									
Test Type Test Condition					1	2	3	1	2	3	1	2	3	1	2	3	1	2	1	2	1	2	1	2	Various
Fuel (consistant supply)					X	X	X	X	X	X	X	X	X	X	X	X									
Full Load					X	X	X	X	X							X			X	X	X	X	X	X	
Low Load (250MW)												X	X												
Low Low Load (200MW)										X	X			X	X		X	X							
SBS Off					X					X															
Normal SBS MR							X	X			X	X		X	X	X		X	X		X		X		
High SBS MR						X							X							X		X		X	
Ammonia Off											X	X	X												
ReducedNox Removal																	X								
Normal Nox Removal					X	X	X	X		X				X	X	X		X							
High Nox Removal									X										X	X			X	X	
Reduced Gas Outlet Temp								X	X												X	X	X	X	
# of samples locations																									
Breen Probes	Breen	Breen	SCR In	X	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Breen Probes	Breen	Breen	AH In	X	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Breen Probes	Breen	Breen	Hot PA	X	1+1	1+1	1+1	1+1	1+1	1+1	1+1	1+1	1+1	1+1	1+1	1+1	1	1	1	1	1	1	1	1	1
Gas Sampling (SO3, SO2, H20, O2)	AECOM	AECOM	Econ Out		1	1	1				1	1	1												
Gas Sampling (SO3, SO2, H20, O2)	AECOM	AECOM	SCR In					1	1	1	2	2	2												
Gas Sampling (SO3, SO2, NH3, H20, O2)	AECOM	AECOM	AH IN		2	2	2	2	2	2				2	2	2									
Gas Sampling (SO3, SO2, NH3, H20, O2)	AECOM	AECOM	Hot PA											1	1	1									
Phase 2 Catalyst Testing	Cormetech	Cormetech	SCR	X																					
Phase 3 Catalyst Testing	Cormetech	Cormetech	SCR		X	X	X	X	X	X	X	X	X	X	X	X									
Flyash Sample	Duke	Standard	ESP Hopper		1	1	1	1	1	1	1	1	1	1	1	1									
Coal Samples	Duke	Standard	Feeder		1	1	1	1	1	1	1	1	1	1	1	1									

Three Layers Cycle Test Data

CORMETECH



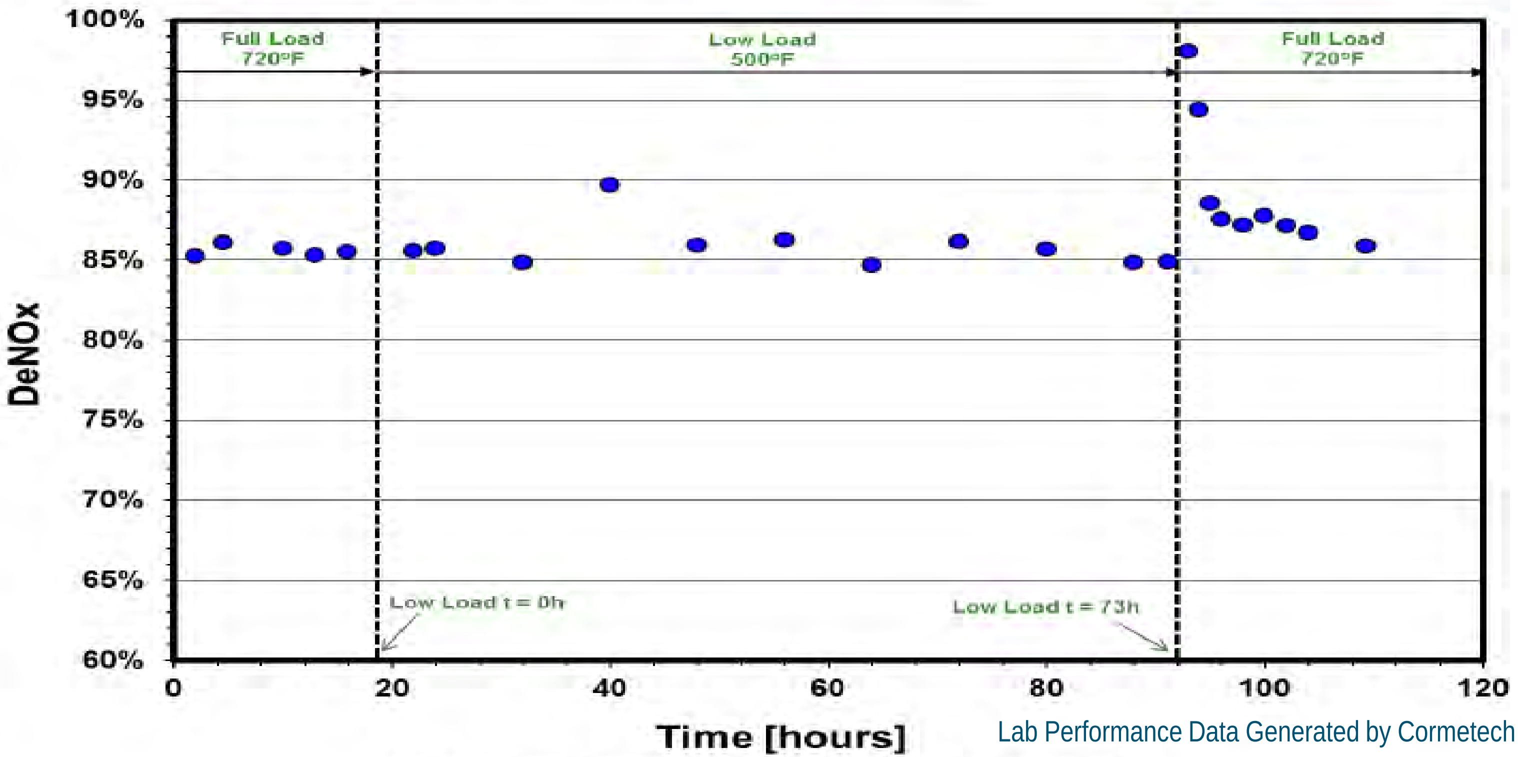
B

Lab Performance Data Generated by Cormetech

Data will be used to calibrate the ABS deactivation model.

Three Layers Cycle Test Data

CORMETECH



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Lab Performance Data Generated by Cormetech

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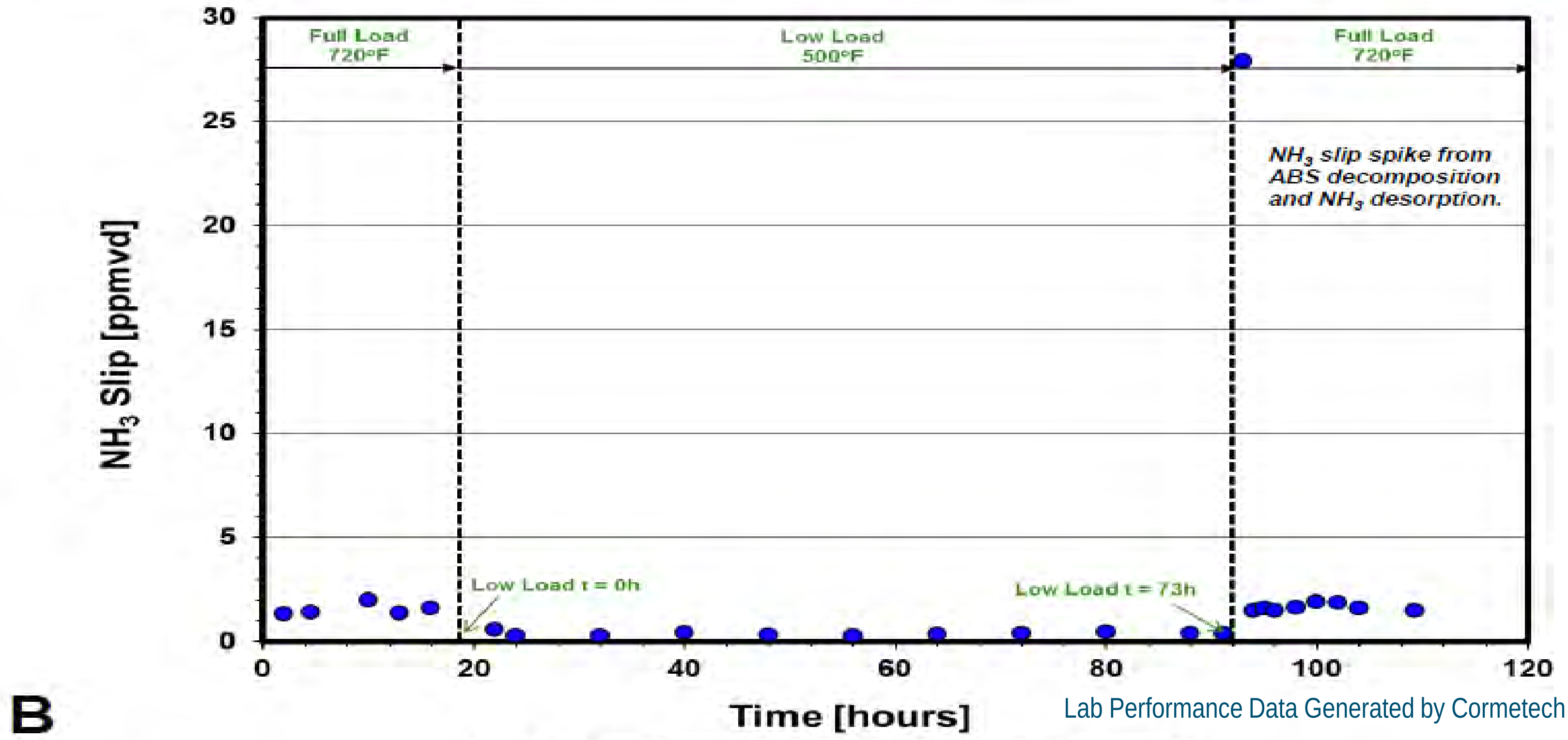

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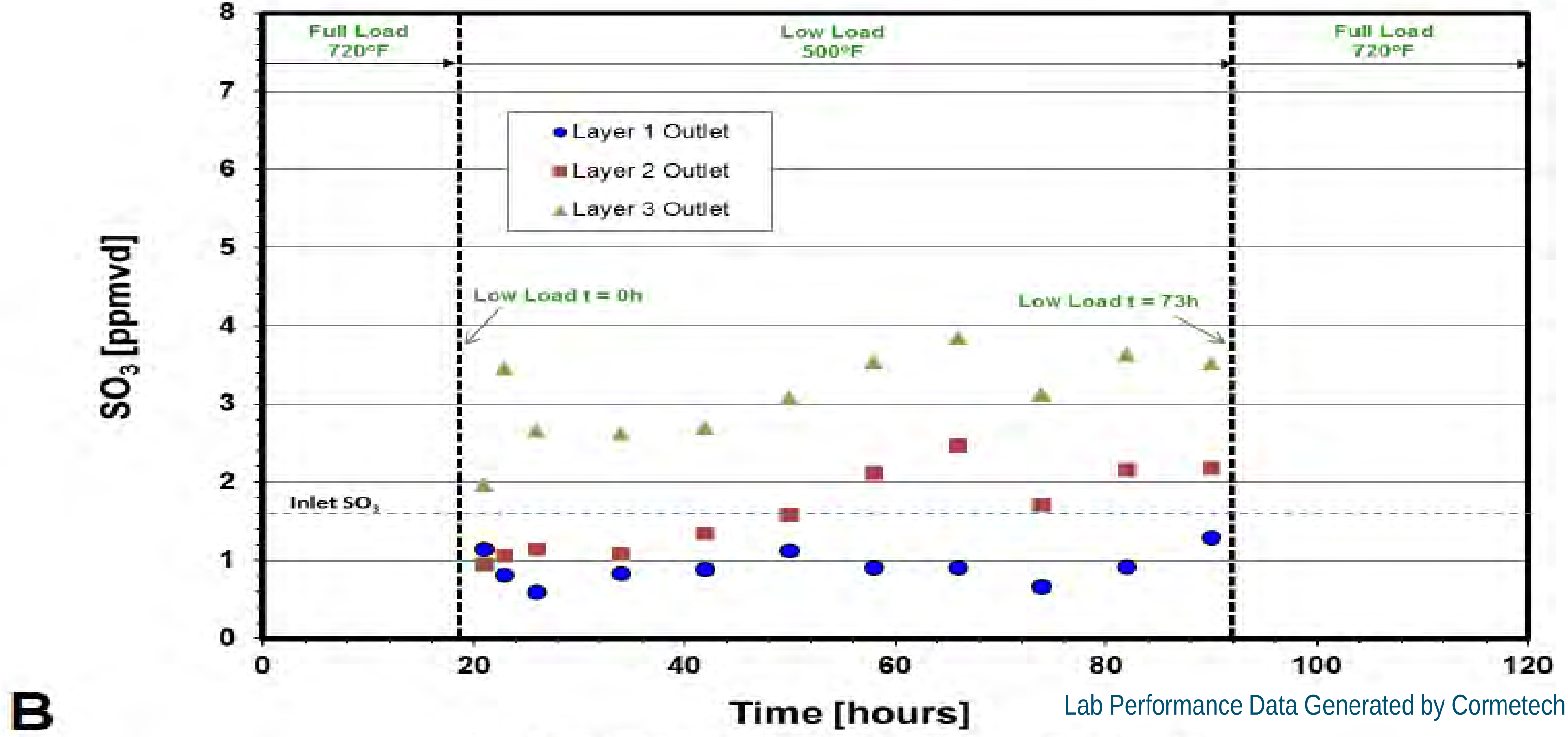

Lab Performance Data Generated by Cormetech

Data will be used to calibrate the ABS deactivation model.

Things to Consider

- As the SCR catalyst is operated at low temperatures, the catalyst continues to oxidize SO_2>SO_3 deep within the catalyst pores. Although at lower temperatures the oxidation is much less, it is unlikely the sorbent injection will mitigate this SO_3 prior to it exiting the catalyst and it is likely some of this SO_3 will result in capillary condensation of ammonia bisulfate. To a degree this is a normal occurrence and once temperature is raised the ammonia bisulfate will “burn off”, however, there is a potential risk that at some point the condensation cannot be “burnt off” and can result in permanent catalyst deactivation. This point is a limiting factor which is largely unknown across the industry and is a driver for the testing at Gibson coupled with the benefits of extremely low SCR inlet SO_3.
- In regards to lowering the air heater outlet temperature or cold end average, air heater pluggage is only a problem if it’s a problem. During all normal operating ranges the airheater cycles through temperatures that are below the acid dewpoint of the gas and condense acid on the baskets, however, this material is naturally evaporated off and/or blown off with the air heater soot blower to a certain depth. When air heater pluggage begins to be an issue is when the dewpoint is high enough that the material forms higher in the basket than the sootblowers can reach or the metal temperature doesn’t cycle high enough to evaporate the deposited material. This is where the sorbent injection helps out by drastically reducing the dewpoint of both H_2SO_4 and $(NH_4)HSO_4$.
- Other BOP limitations to operating at low load, FGD, Precip Rappers, etc.
- Enhanced Nox removal can have an impact on Hg oxidation due to catalyst surface area being used up

Questions?

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