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Coal & Gas Seminar

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Sorbent Injection for Low Load Operating Flexibility

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Introduction

Performance & Benefits

Gibson Enhanced SCR Performance Testing

Questions

Overview

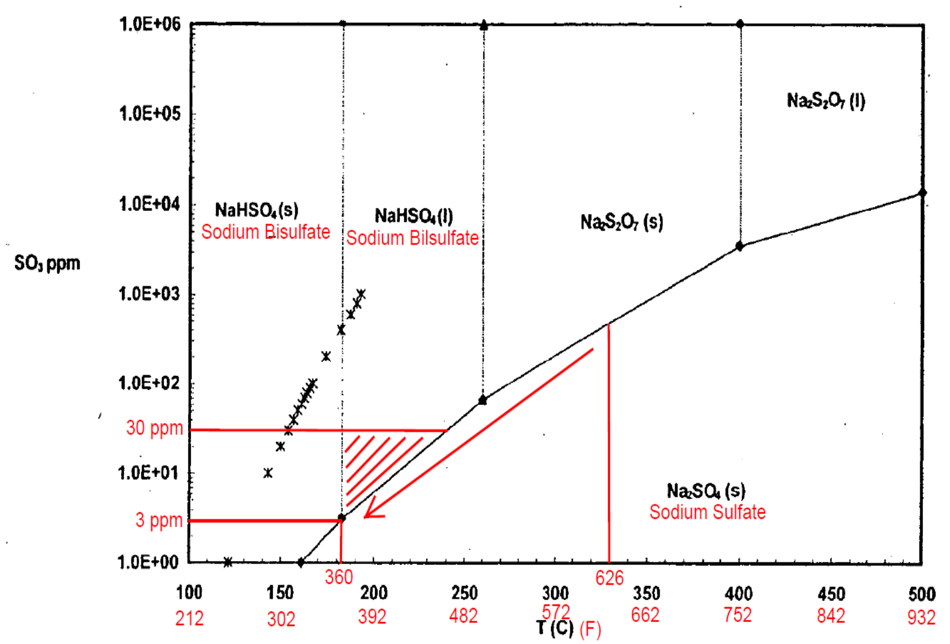
Sorbent Injection Strategic Approach

SBS System Background

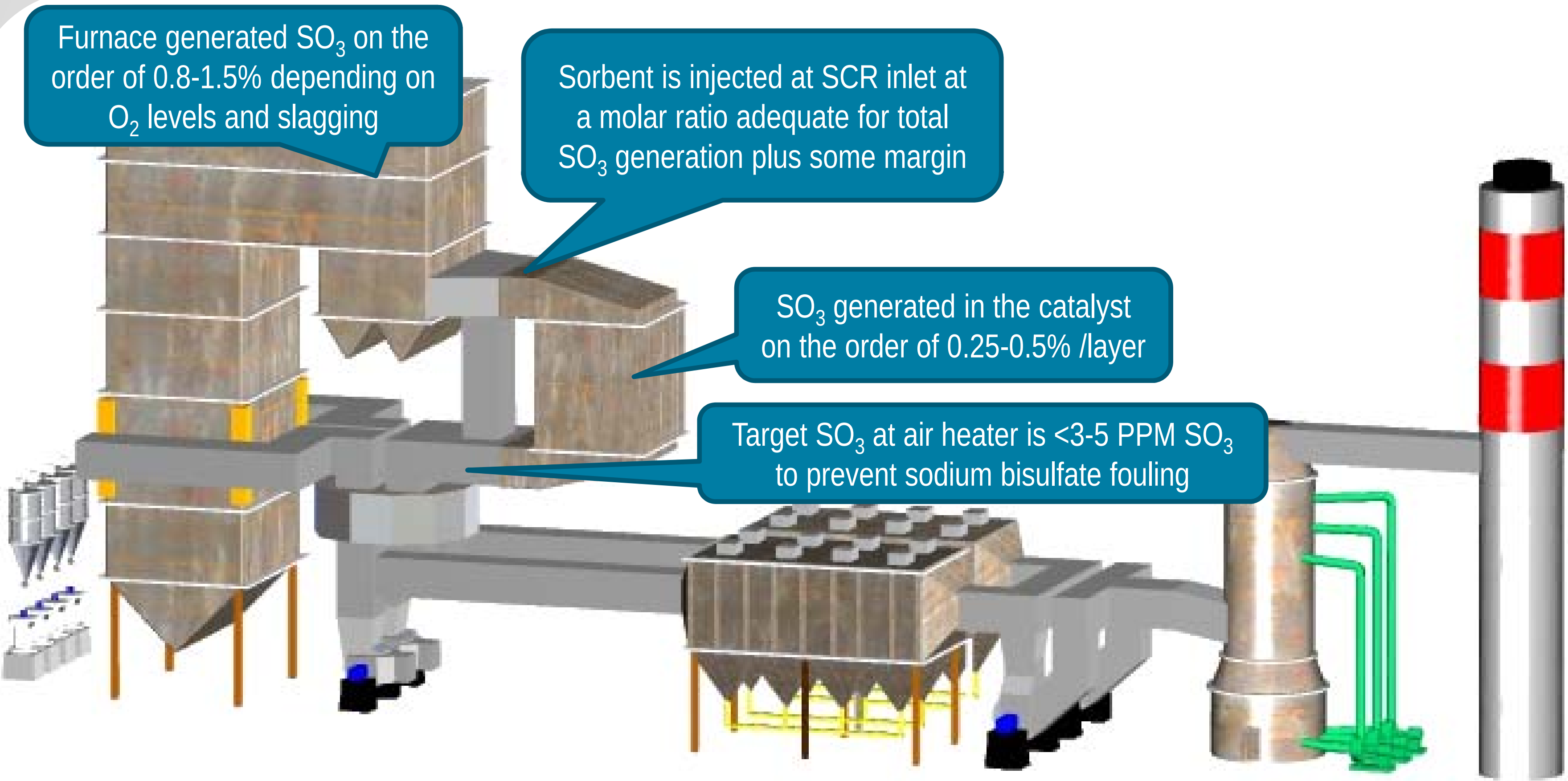
Introduction

- "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 with this temperature range occurring in the air heater and possibly in the air heater outlet duct
- The preferential reaction is to form solid sodium sulfate 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
- Pre-SCR SO_3 control can also be achieved using hydrated lime DSI without risk of liquid byproduct, however, high rates of control (90^{+}%) can be difficult to achieve using DSI



SBS System Background



Reduced Catalyst MOT

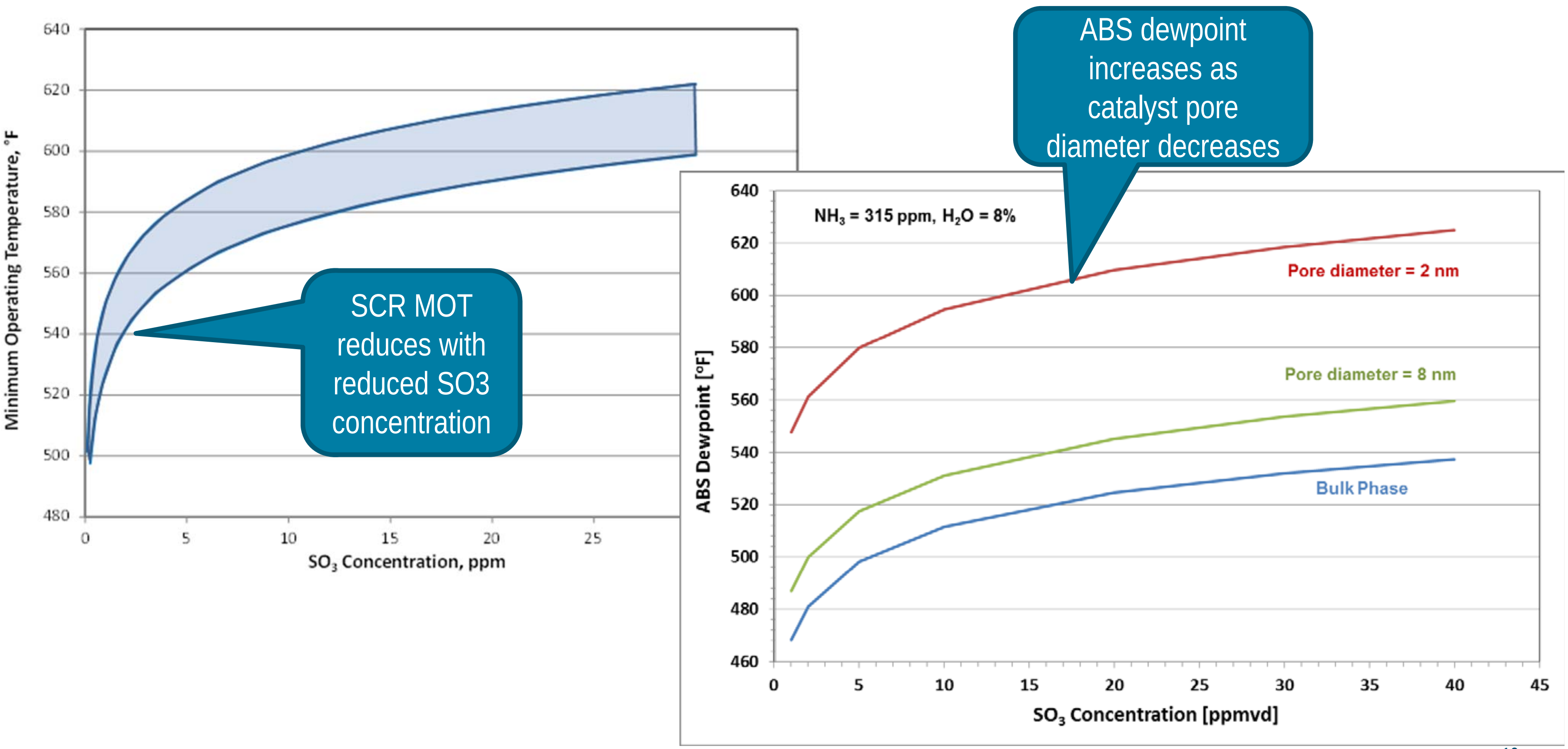
Air Heater Fouling / Enhanced Nox Removal

Heat Rate Improvement

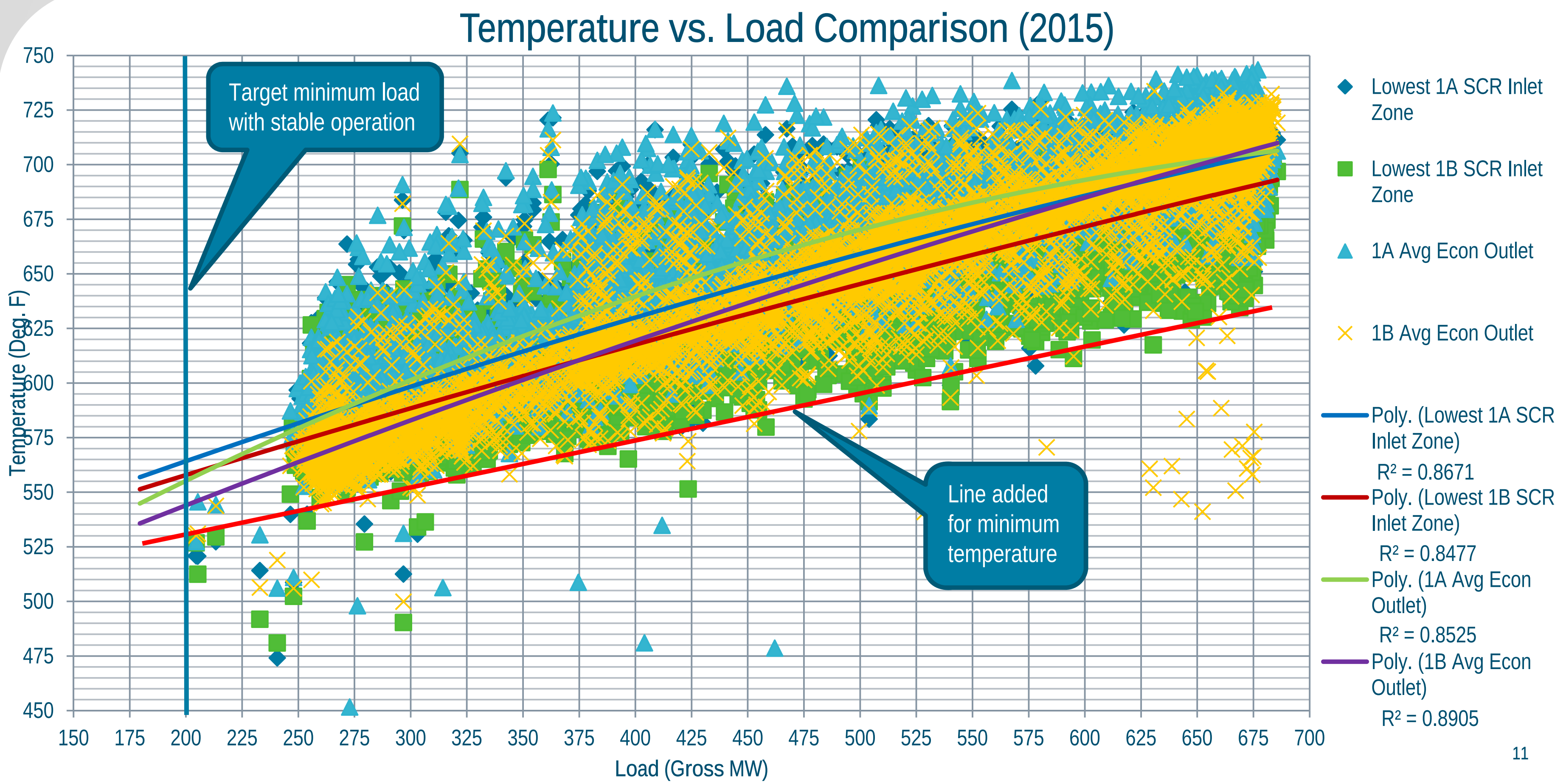
Performance & Benefits

- Low load SCR operation is constrained by Ammonia Bisulfate (ABS)
  - Capillary condensation of ABS occurs in the micropores of the catalyst and can cause loss of activity that is reversible to a point
- Variables affecting ABS condensation
  - Flue gas temperature and the relative concentrations of NH_3 and SO_3
  - Catalyst pore size (capillary condensation)
- Variables affection SCR minimum operating load
  - SCR inlet temperature and Nox distribution
  - Load cycle and SCR operating strategy
  - Boiler SO_3 concentrations can increase at lower loads due to high O_2
- Options for low load SCR operation
  - Reduce the NH_3 at the SCR inlet by reducing inlet Nox (gas co-firing) or NOx removal rate
  - Increase the SCR inlet temperature at low load by economizer modifications and/or bypass systems either water/gas, would result in a full time or part-time heat rate penalty depending on the technology chosen
  - Restrict the operating time below the MOT for limit the amount of ABS formed and operate at a set time at full load to “burn-off” the ABS essentially managing an ABS Inventory Calculation
  - Remove the SO_3 prior to the SCR to low levels which can greatly reduce the MOT without heat rate penalty

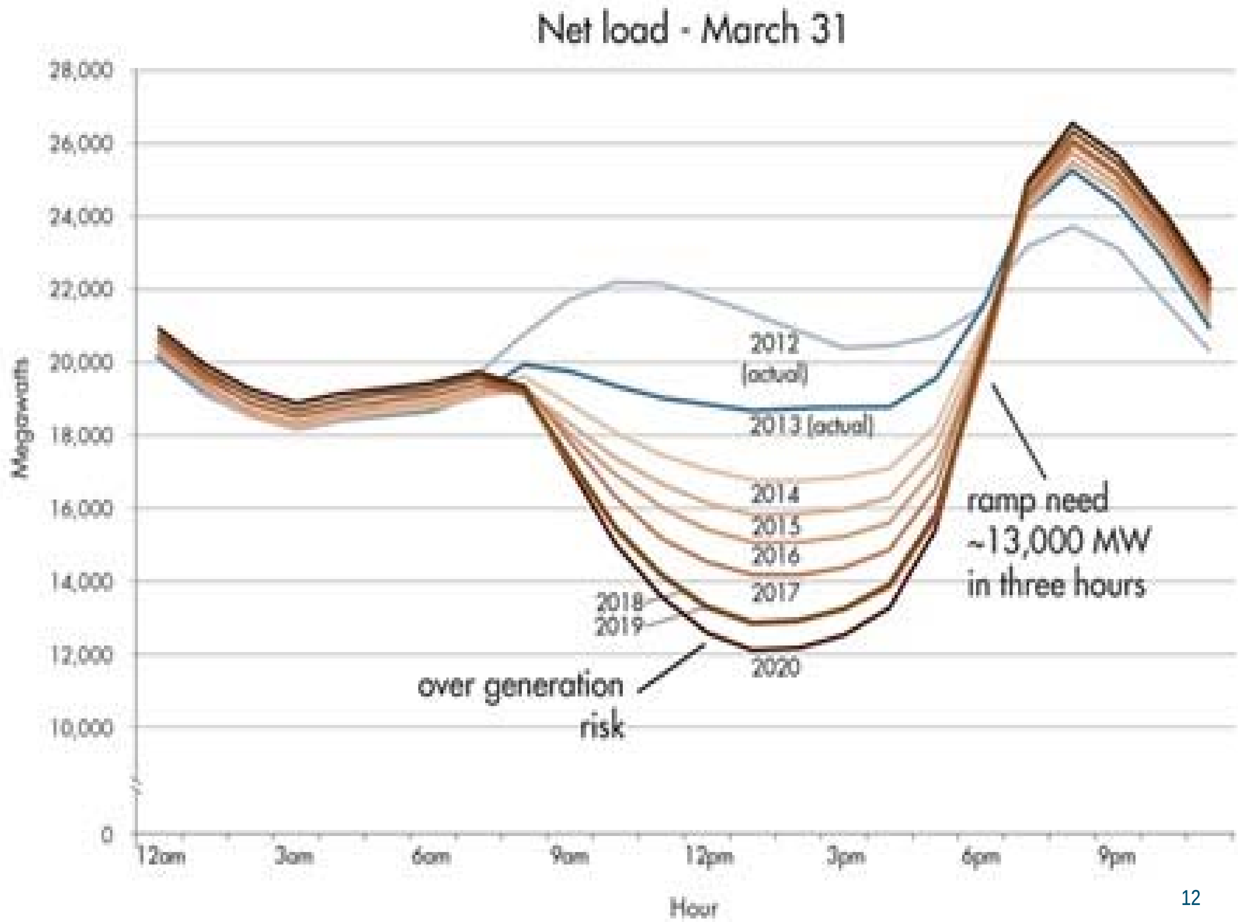
Reduced Catalyst MOT



Reduced Catalyst MOT



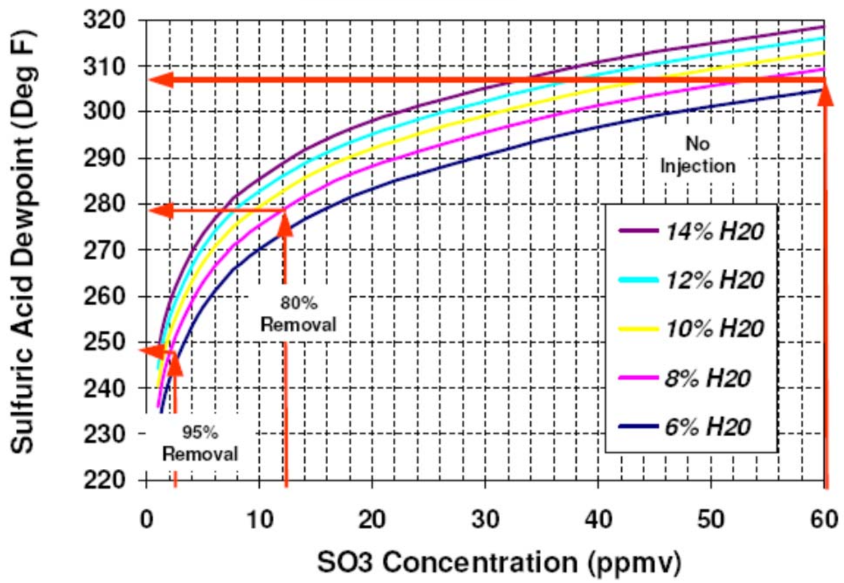
- Why???
  - Solar and wind have created large amounts of peak generation that are priority
  - Coal must now load follow to a degree and be more nimble for turndown and ramp rate
  - New Ozone season limits will require pushing the SCR's harder and keeping them in service longer

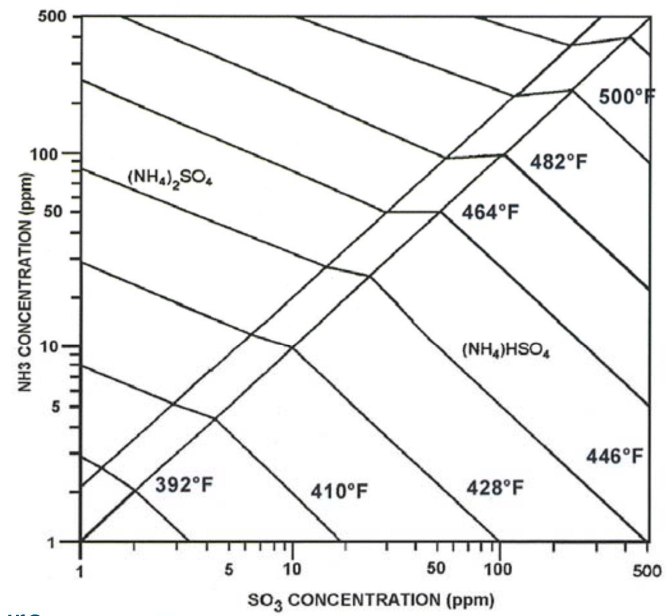


- Benefits of pre-air heater removal of SO_3
  - Converts SO_3 to the limiting reactant instead of NH_3
  - Allows operation above the typical 2 ppm NH_3 slip increasing catalyst management plan flexibility
  - Provides flexibility needed to reduce NOx outlet setpoint without fear of air heater pluggage
  - Reduces the possibility of air heater pluggage due to ammonia bisulfate and/or sulfuric acid
  - Can provide a heat rate benefit by allowing the air heater cold end average temperature to be reduced minimizing dry gas loss

- Options for Enhanced NOx removal
  - Perform more frequent SCR tuning and cleaning to ensure good distribution for higher catalyst utilization
  - Increase the reactor potential by adding an additional layer or replacing layers more frequently which would result in higher catalyst life cycle costs, increased pressure drop and SO_3 generation
  - Reduce the stack outlet NOx setpoint / increase the NOx removal rate effectively increases the reactor potential by allowing the NH_3 slip rise above the typical 2 ppm, however, air heater pluggage is likely without pre-airheater SO_3 mitigation

Air Heater Fouling / Enhanced Nox Removal



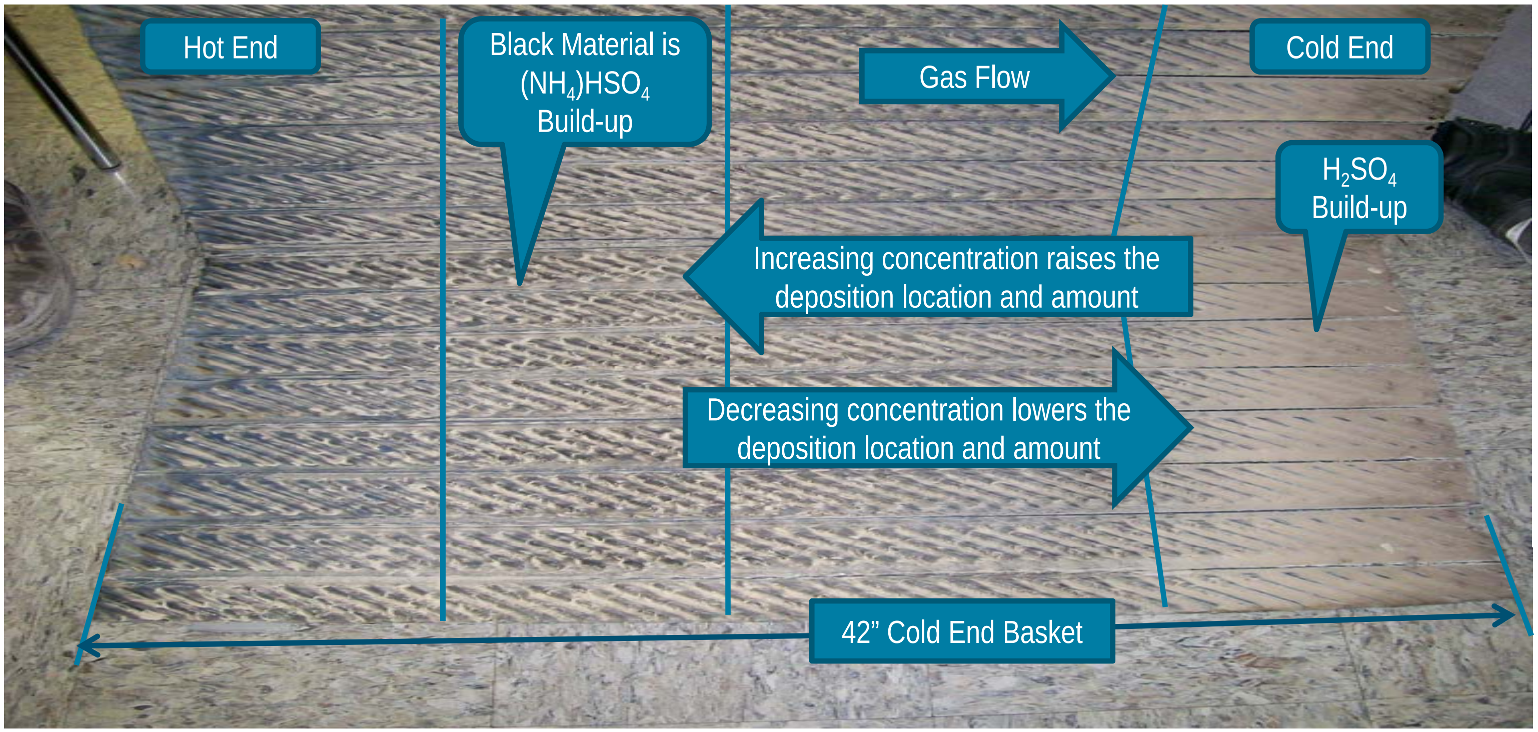


$(NH_4)_2SO_4$ = Ammonium Sulfate
$(NH_4)HSO_4$ = Ammonium Bisulfate

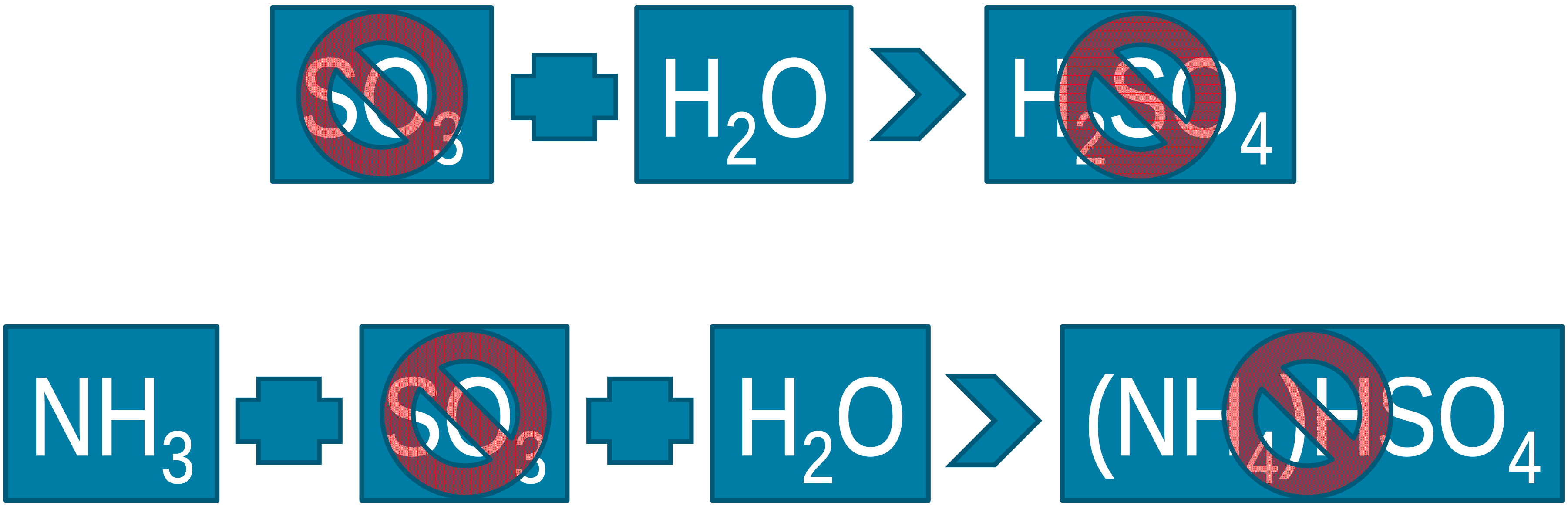
- Two different fouling mechanisms as a function of SO_3 & temperature
  - Ammonia & Sulfuric Acid
- Sorbent Injection works to reduce or eliminate air heater fouling by reducing the SO_3 in the flue gas
  - Assuming SO_3 is neutralized prior to the air heater
- Testing at Zimmer has shown Sulfuric Acid 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



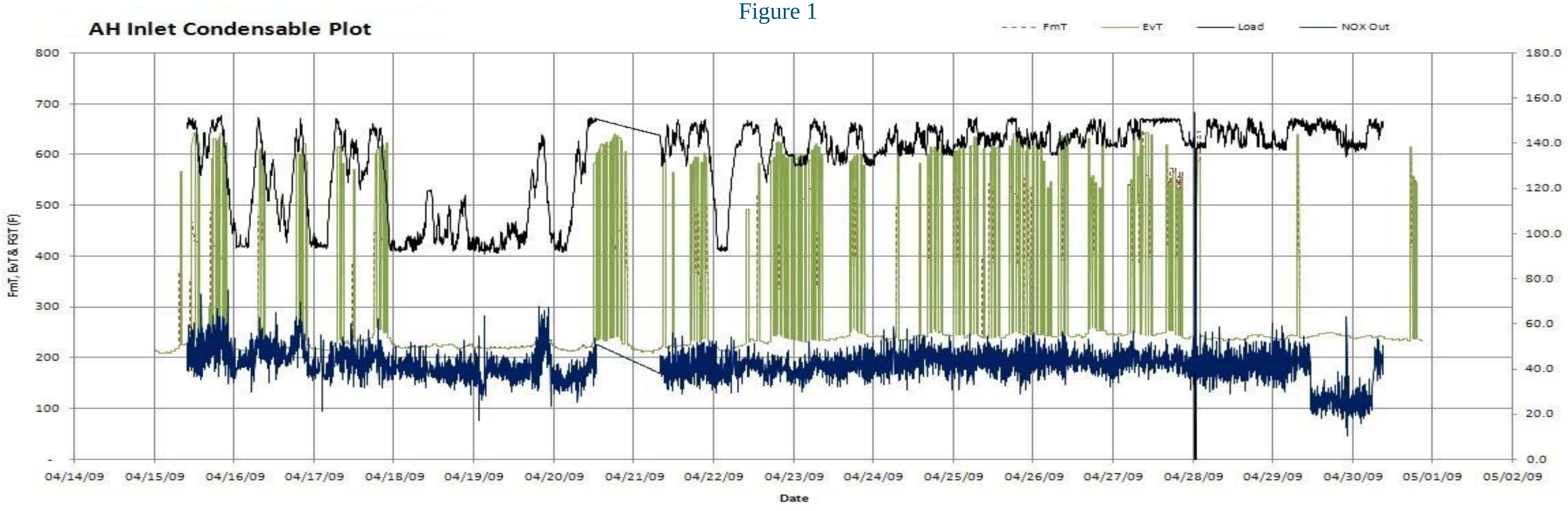
Air Heater Fouling / Enhanced Nox Removal



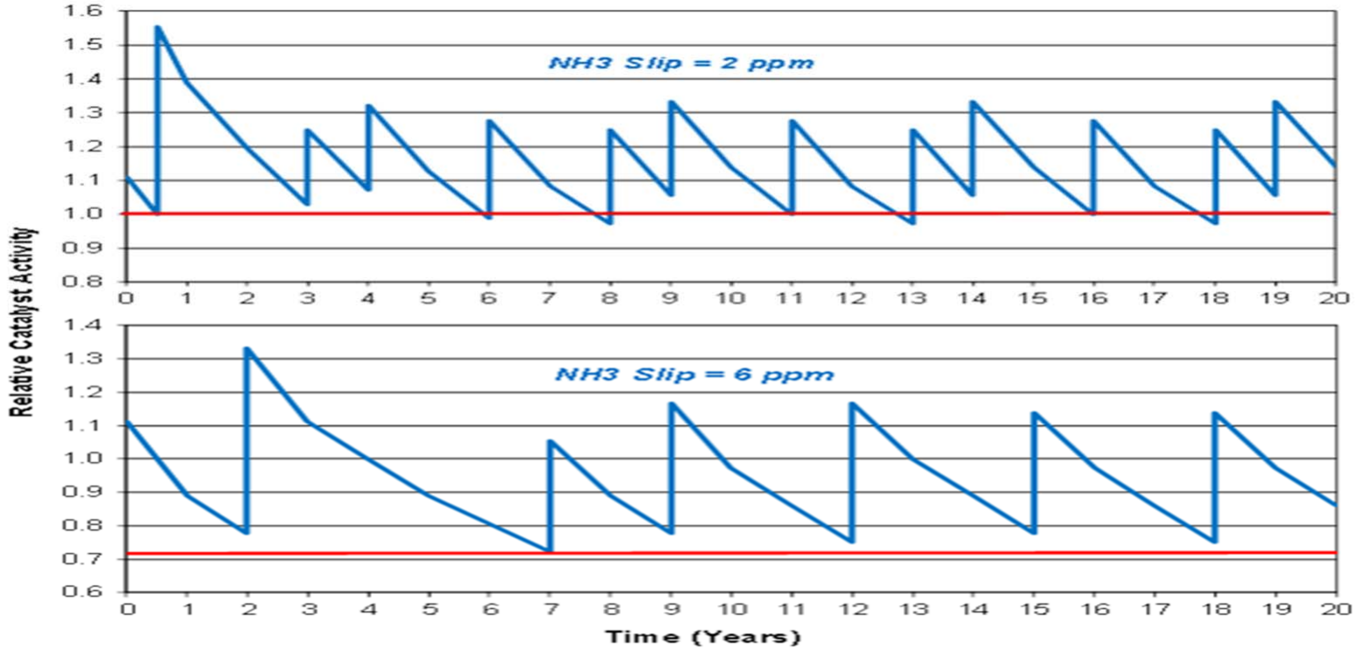
Air Heater Fouling / Enhanced Nox Removal

- 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

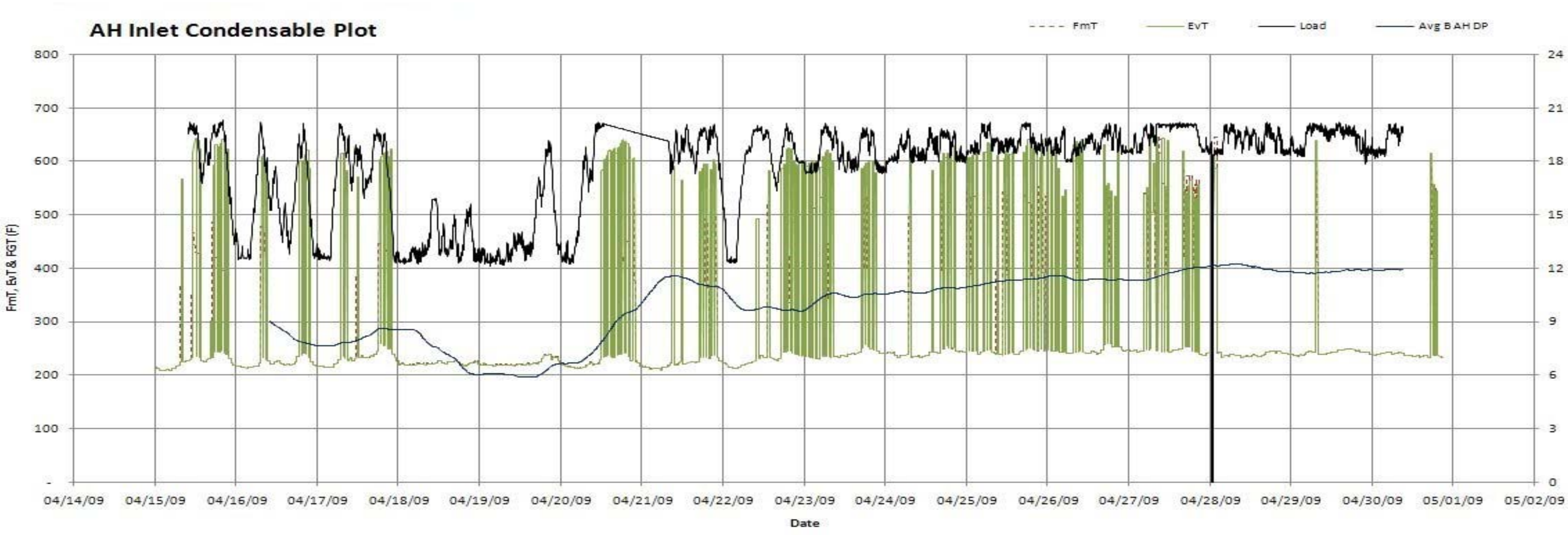


- Reduced air heater pluggage potential allows for increased NH_3 slip and catalyst management plan flexibility
  - Affects of increased NH_3 in FGD liquor would need to be evaluated for possible Hg re-emission effects and wastewater impacts



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

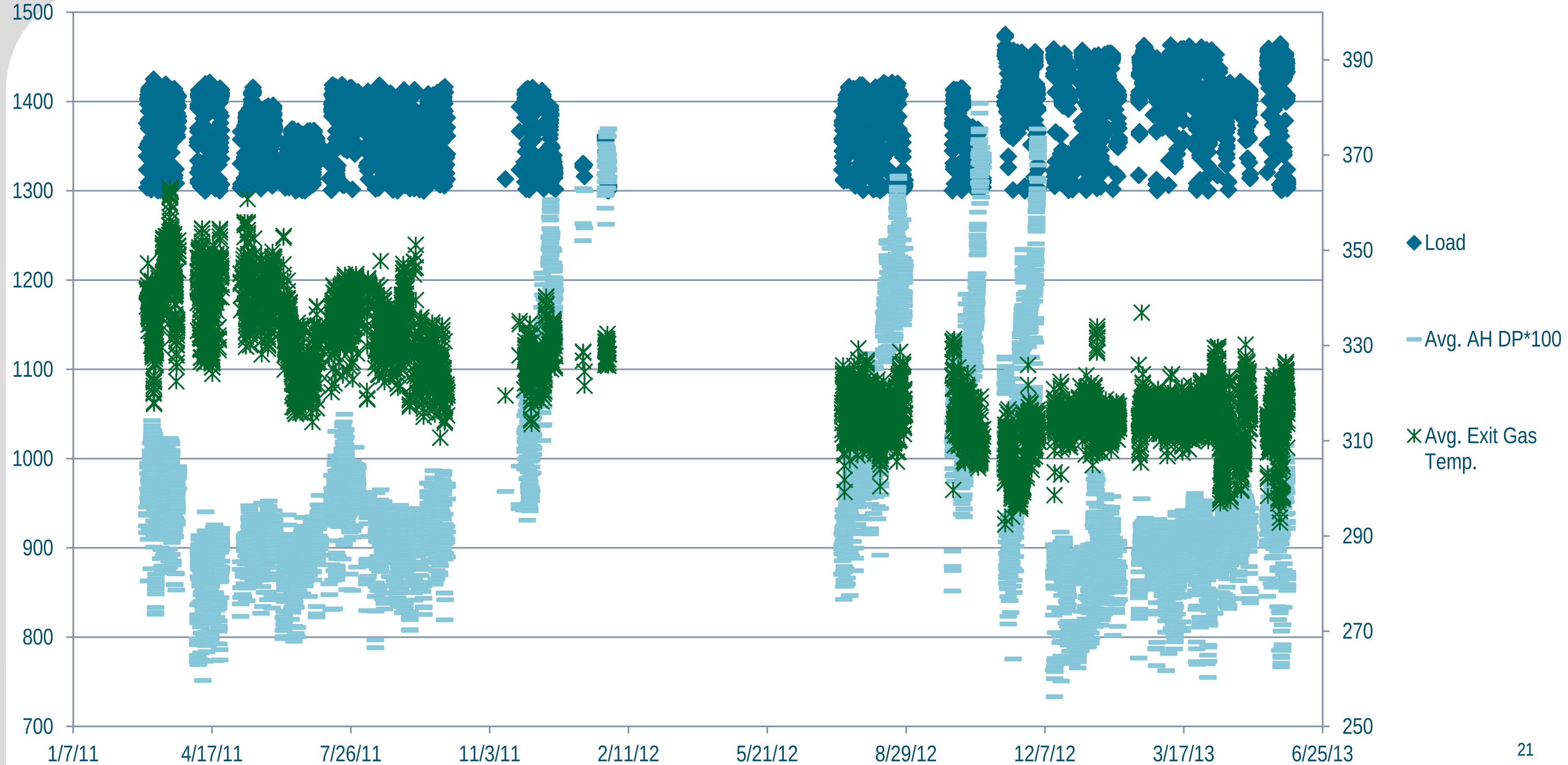


Air Heater Fouling / Enhanced Nox Removal

- 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



- 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

Plant Overview

Testing Overview/Goals

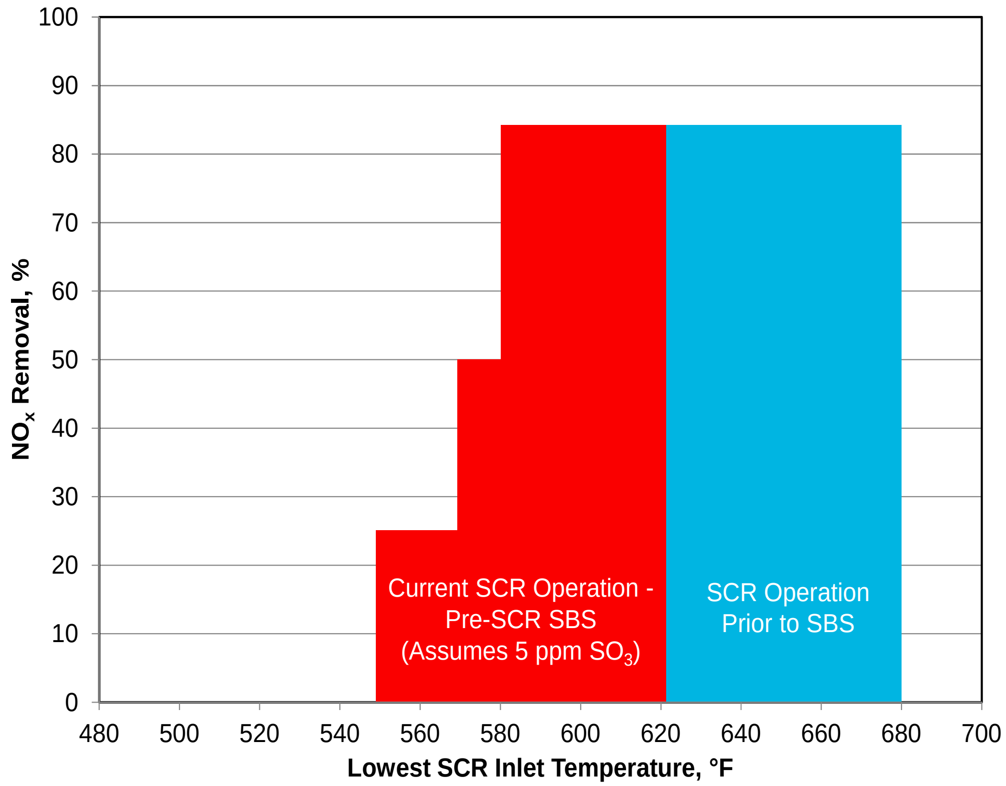
Lab Results

Full Scale Results

Summary

Gibson Enhanced SCR Performance Testing

- Five Units, 660 MWg, 4.0-6.0 lb/Mmbtu coal
- High-dust Foster Wheeler SCR's designed for 3 layers of catalyst and 85% Nox removal
  - Have historically had poor distribution
- Horizontal shaft air heaters with cold side ESP's
- SBS was installed post AH in 2005 and relocated Pre-SCR from '09-'14
  - Original MOT was 622F and was modified to 550F with tiered Nox removal at low load based on the assumption of 5 ppm SO_3
  - Min load was changed from 440 MWg to 250 MWg

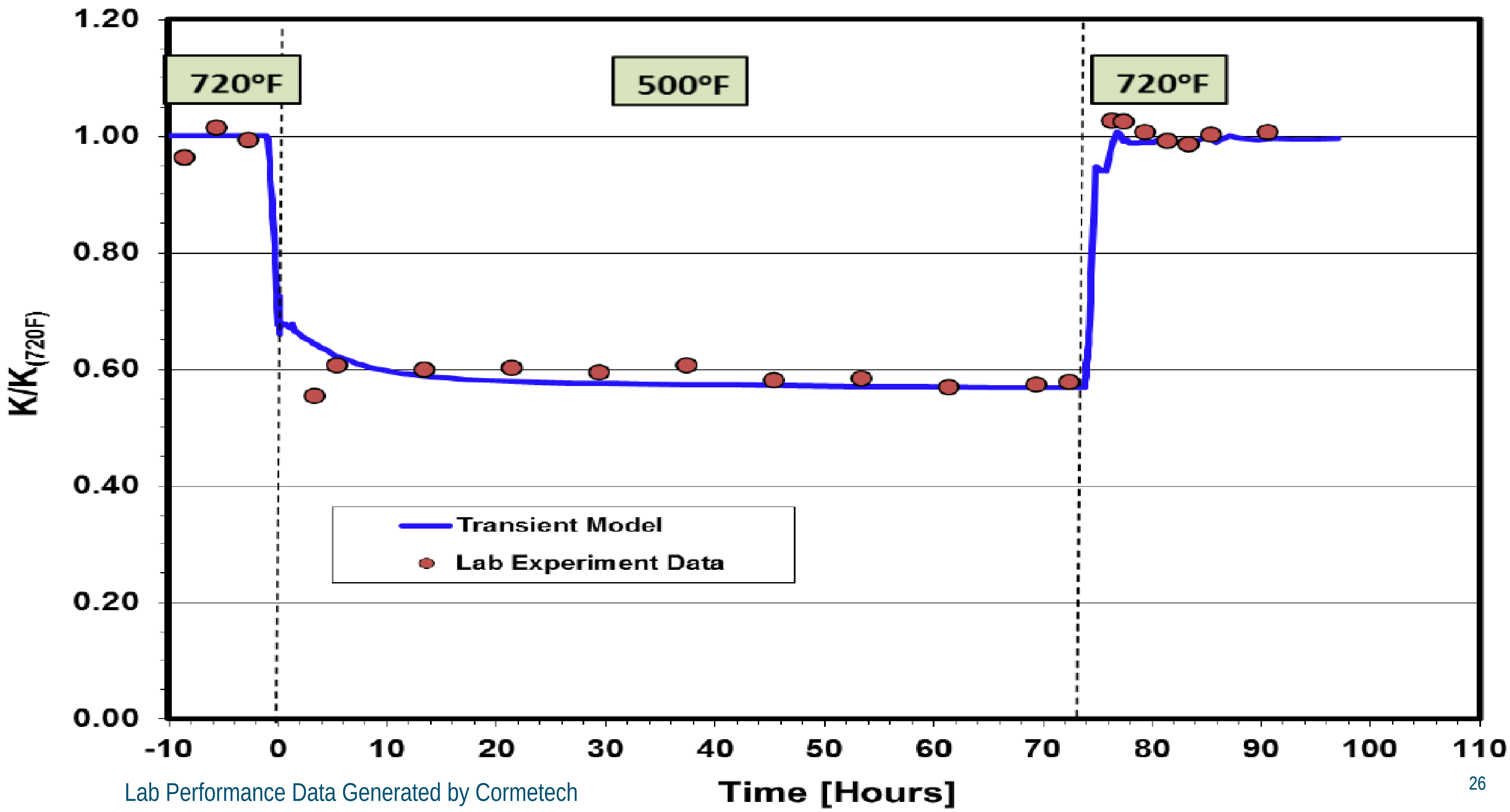


Testing Overview/Goals

- Laboratory catalyst testing performed by Cormetech
  - Demonstrated 72-hour operation to simulate a holiday weekend at full 85% Nox removal at 500F flue gas temp
- Two-week test program on Gibson Unit 1 (July 2016)
  - AECOM performed gas testing with modified CCS procedure to validate SO_3 concentrations around the SCR at full and low load
  - Breen probes for condensable monitoring
- Used Cormetech transient modeling coupled with the field and lab data to determine reasonable operating parameters

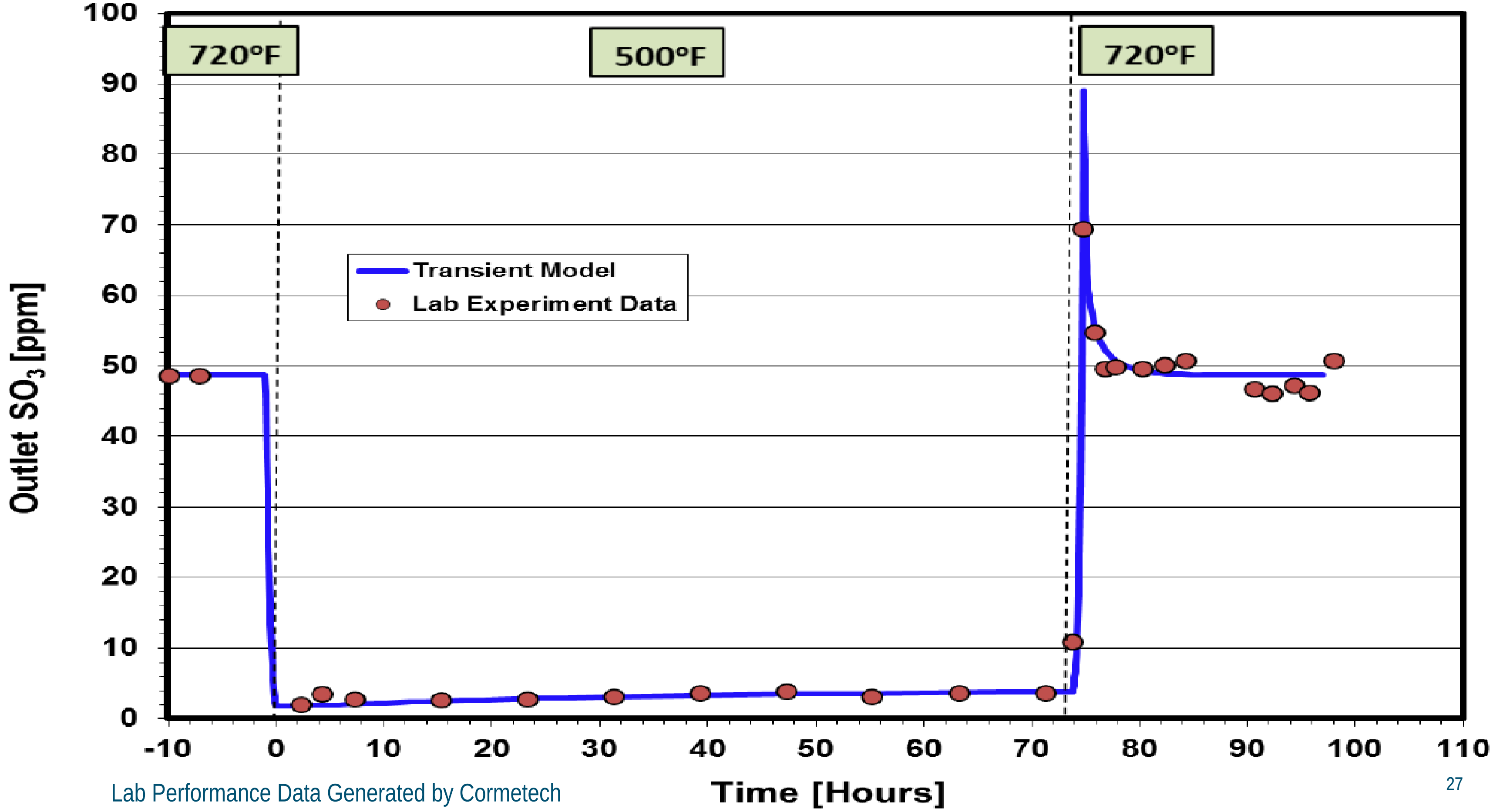
- Test objectives and goals
  - Quantify the boiler and SCR SO_2 conversion at full and low load
  - Evaluate operation at elevated NH_3 slip and increased NOx removal
  - Evaluate operation at reduced air heater gas outlet temperatures
  - Measure SO_3 and Na compounds in the primary air stream for NH_3 dilution to possibly eliminate the in duct heat exchanger
  - Evaluate the feasibility of permanently blanking the economizer bypass duct to eliminate an O&M burden
  - Run a full scale 72 hour test at 200 MWg to simulate a long holiday weekend

Lab Results



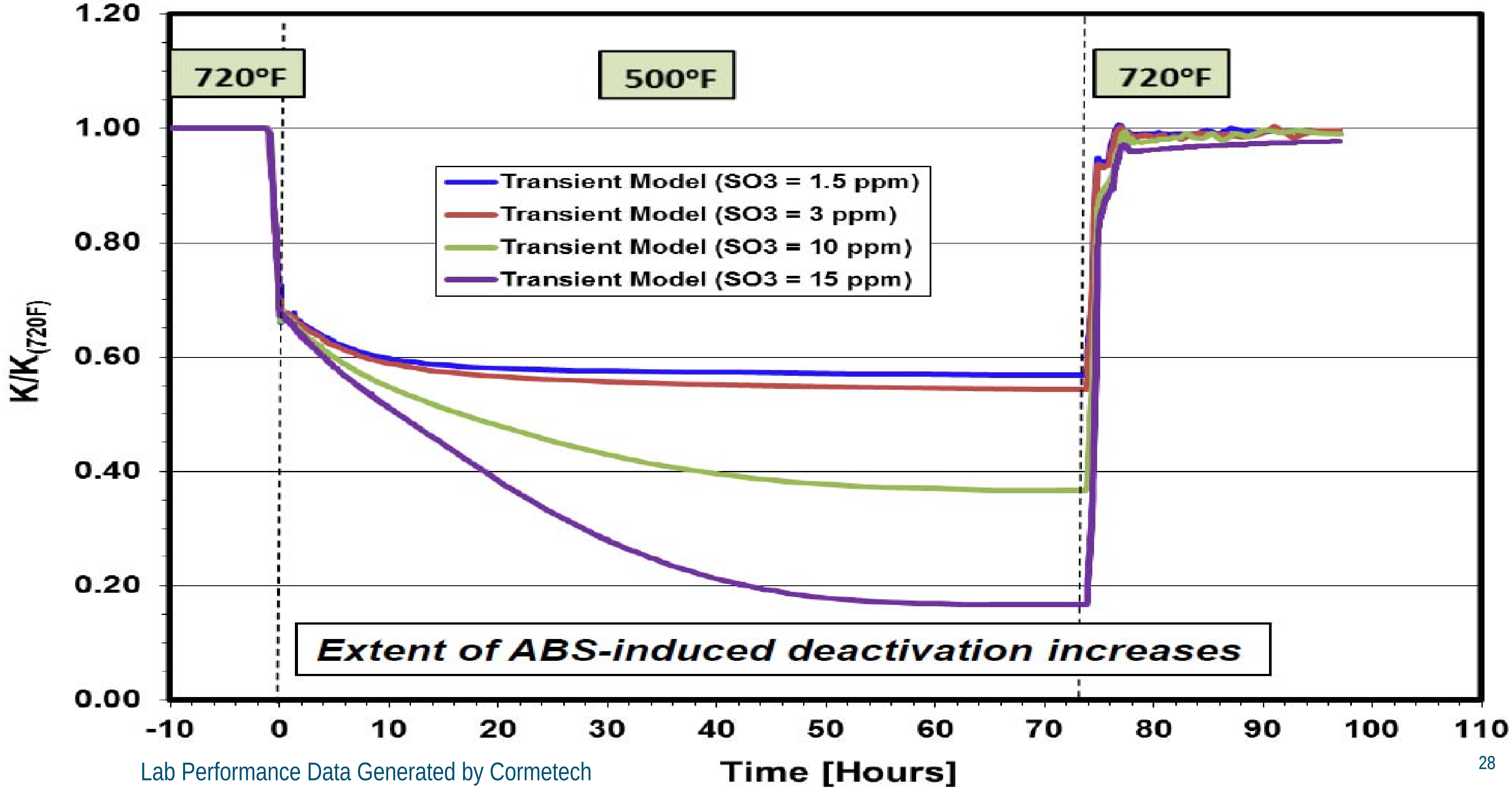
Lab Performance Data Generated by Cormetech

Lab Results

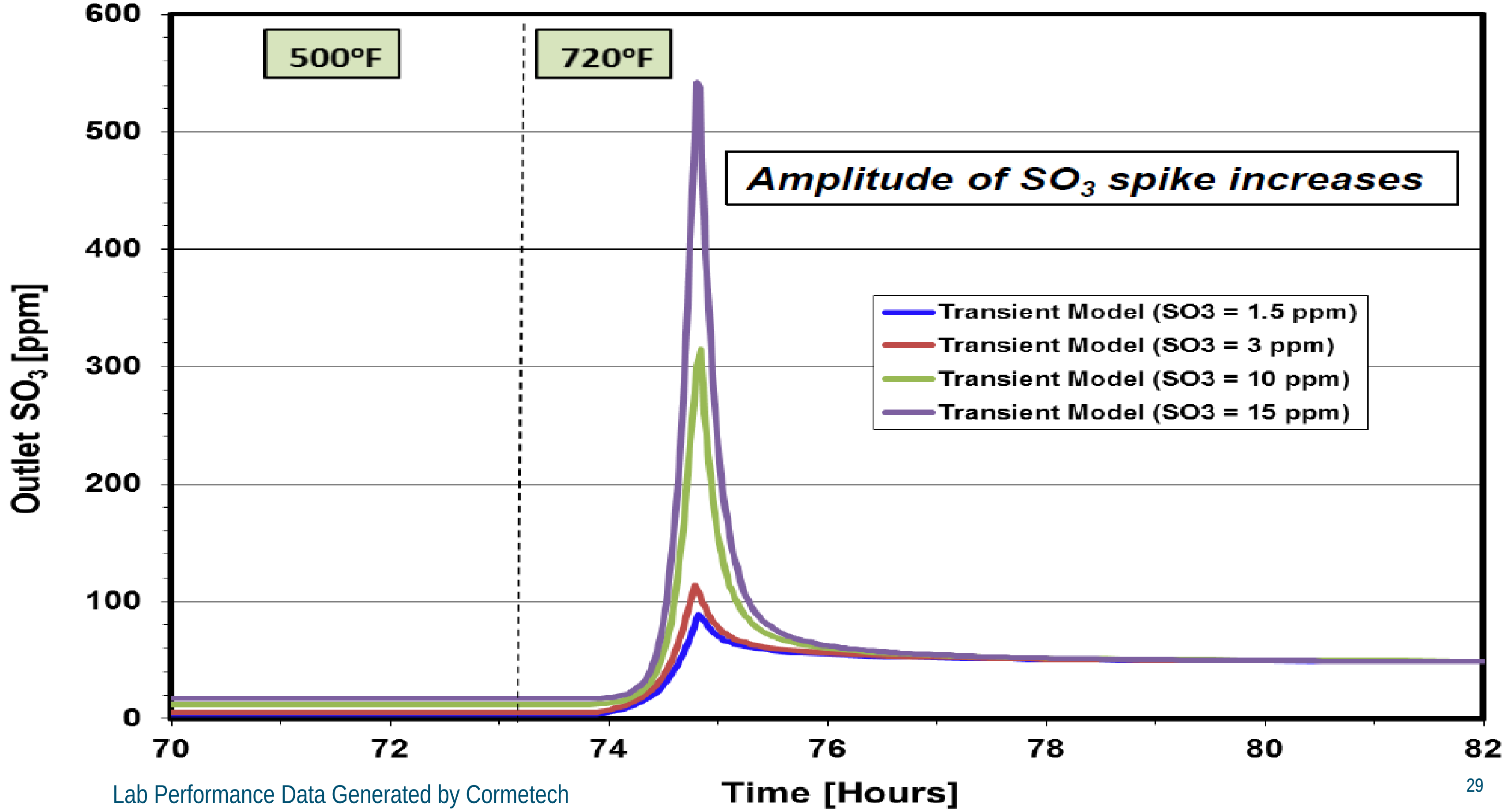


Lab Performance Data Generated by Cormetech

Lab Results



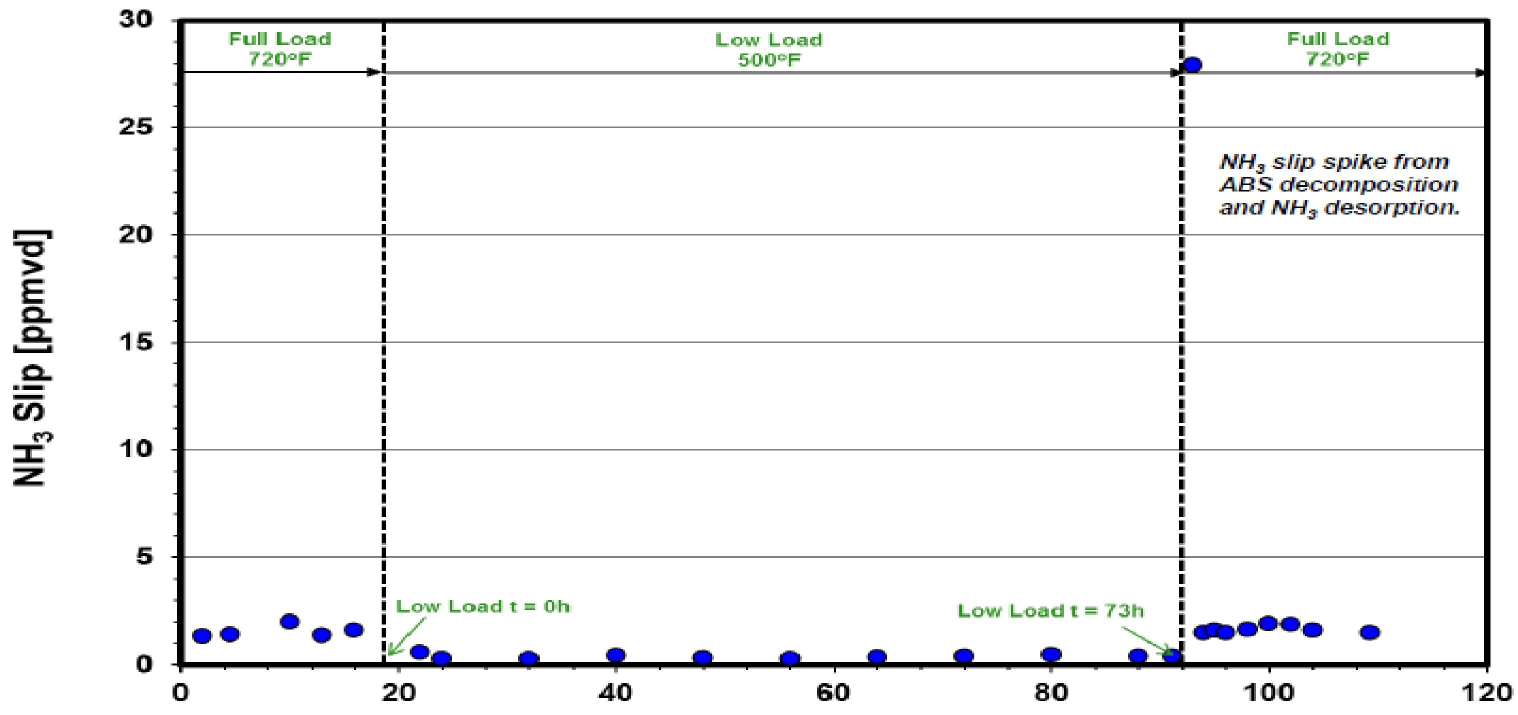
Lab Performance Data Generated by Cormetech



Lab Performance Data Generated by Cormetech

Three Layers Cycle Test Data

CORMETECH



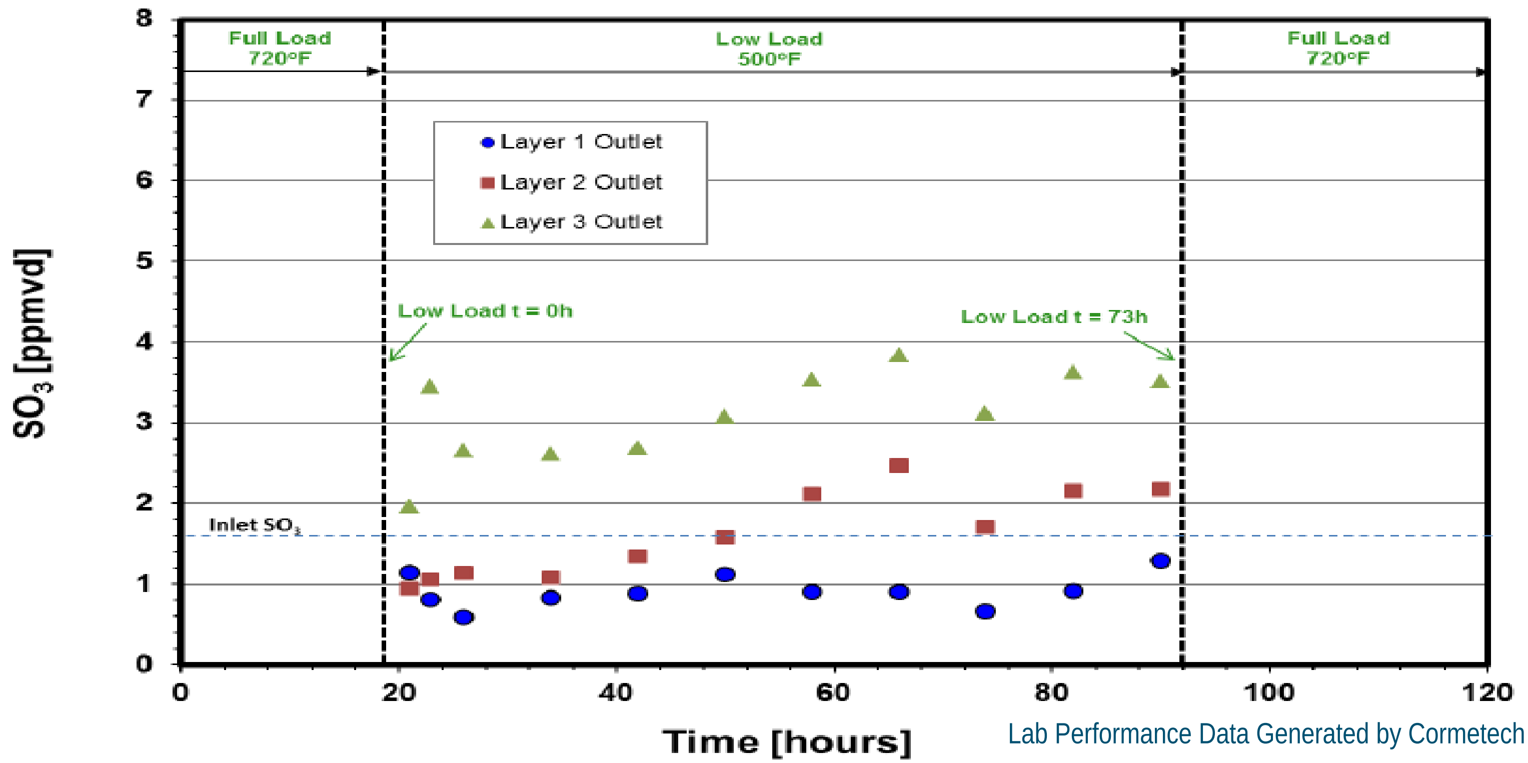
B

Lab Performance Data Generated by Cormetech

Data will be used to calibrate the ABS deactivation model.

Three Layers Cycle Test Data

CORMETECH

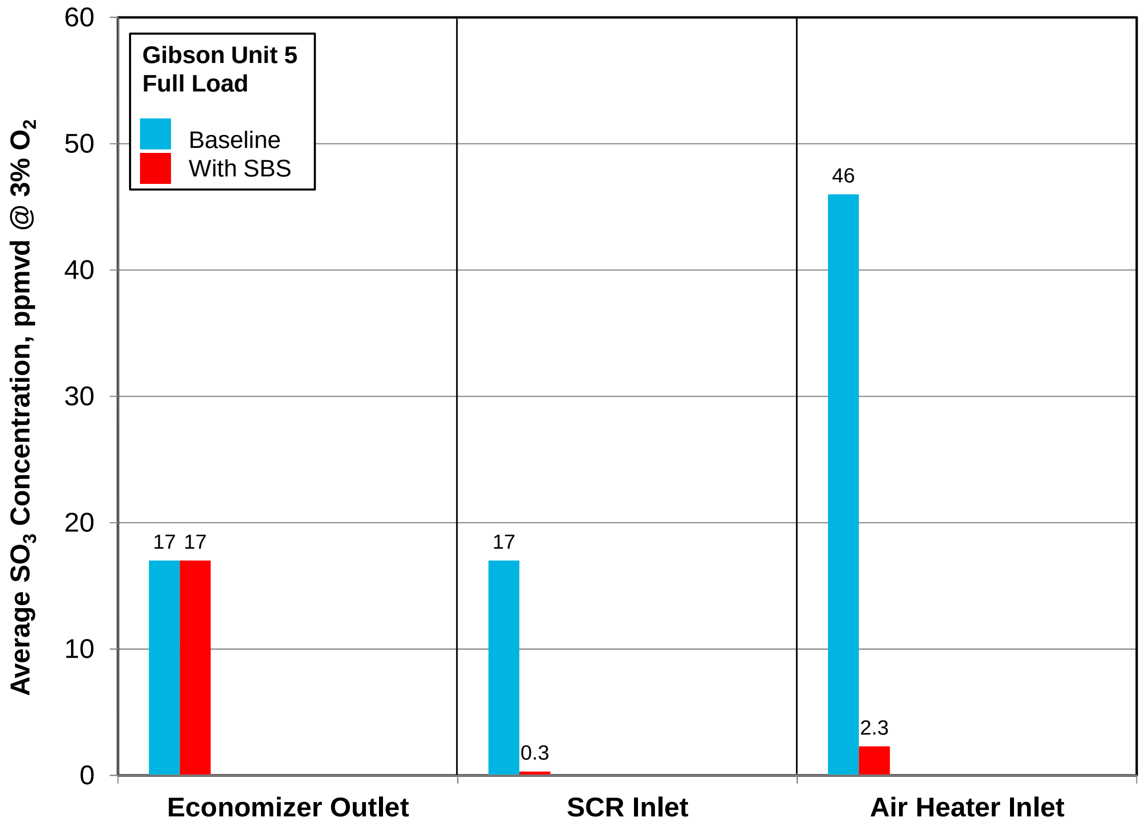


B

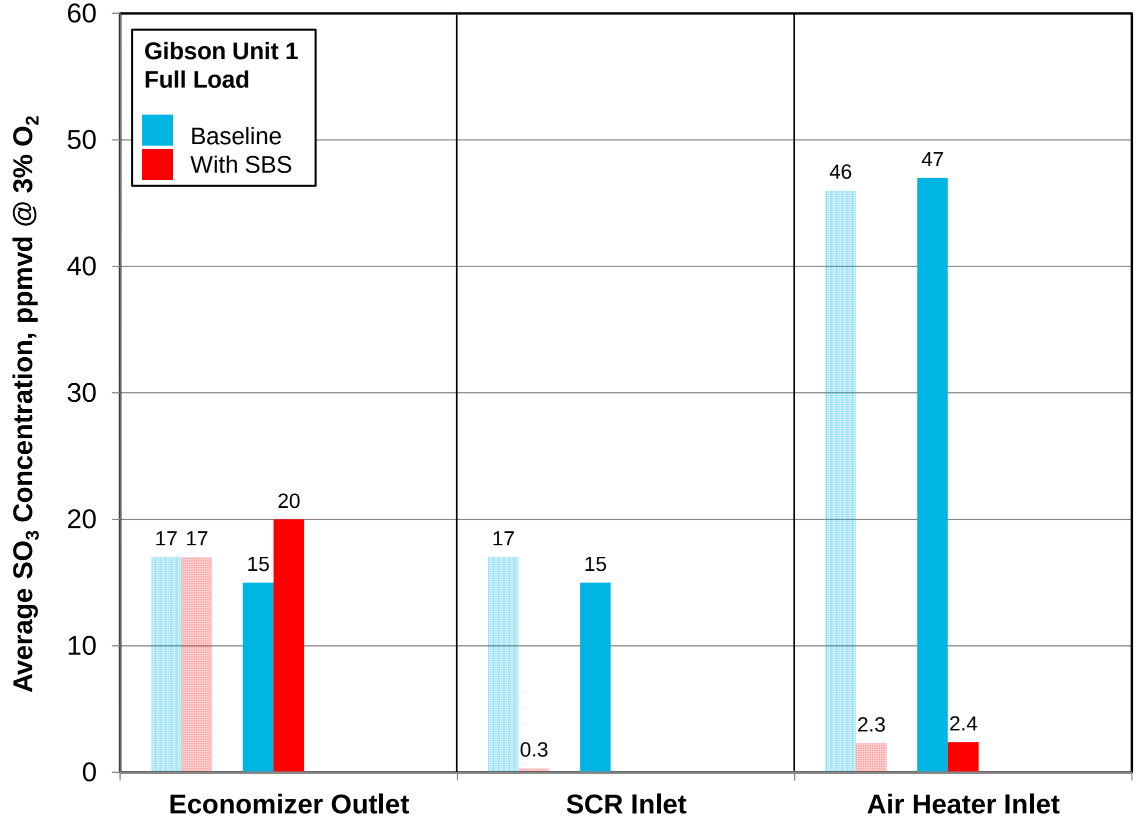
Lab Performance Data Generated by Cormetech

Data will be used to calibrate the ABS deactivation model.

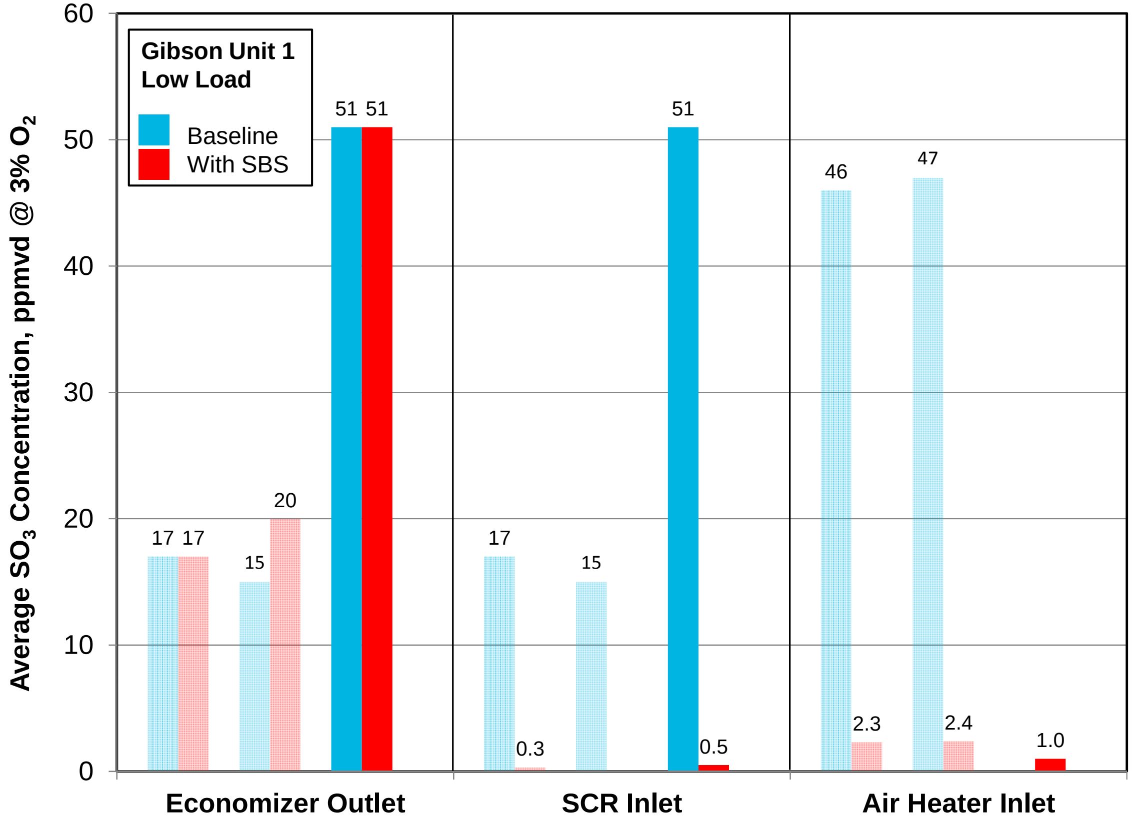
- Gibson Unit 5 full load test data from 2009 showing very low SCR inlet SO_3



- Gibson Unit 1 full load test data from 2016 very similar to the Unit 5 data



- Gibson Unit 1 low load test data shows very low inlet SO_3 and the effect of high O_2 on boiler SO_3



Full Scale Results

Gibson Preliminary SO3 Results

Results from the on-site titration analysis

Date	Test #	Load	SBS	NH3	AH temp	Econ Out			SCR In South (Outside wall)			SCR In North (Inside wall)			APH In E				APH In W				Primary Air				
						1	2	3	1	2	3	1	2	3	1	2	3	4	1	2	3	4	1	2	3	4	5
07/14/16	1	Full	Off	Normal	Normal	15.8	15.1	14.5							57	46	47		39	44	41						
	2	Full	High	Normal	Normal	20.9	21.0	19.9							~~12.0~~	2.7	2.1		~~8.8~~	3.6	3.0						
07/15/16	3	Full	Normal	Normal	Low				0.8	0.6	5.2				9.8	10.8	9.8		10.1	11.5	9.8						
	4	Full	Normal	High	Low				7.1	2.0	2.1				9.0	11.0	11.3		8.9	10.0	9.7						
	5	200	Off	Normal	Normal				2.1	2.1	1.9				16.2	13.8	14.5		16.3	13.9	14.1						
07/16/16	6	250	Normal	Off	Normal	43.7	44.4	48.2	0.6	0.8	0.6	0.8	0.7	0.5													
	7	200	Normal	Off	Normal	50.3	50.6	51.6	0.7	0.5	0.5	0.9	1.3	1.0													
	8	200	High	Off	Normal	52.0	49.2	53.2	0.5	0.4	0.4	1.0	1.0	1.0													
07/17/16	9	200	Normal	Normal	Normal										1.2	1.6	0.6		1.9	2.1	2.1		0.1	0.1	0.1		
	10	200 - Full	Normal	Normal	Normal										1.4	2.0	5.3	15.8	1.8	1.1	3.4	11.5	0.9	0.8	2.3	7.6	14.7
	11	Full	Normal	Normal	Normal										13.7	13.1	11.6		9.8	9.2	7.6		5.6	5.3	5.4		

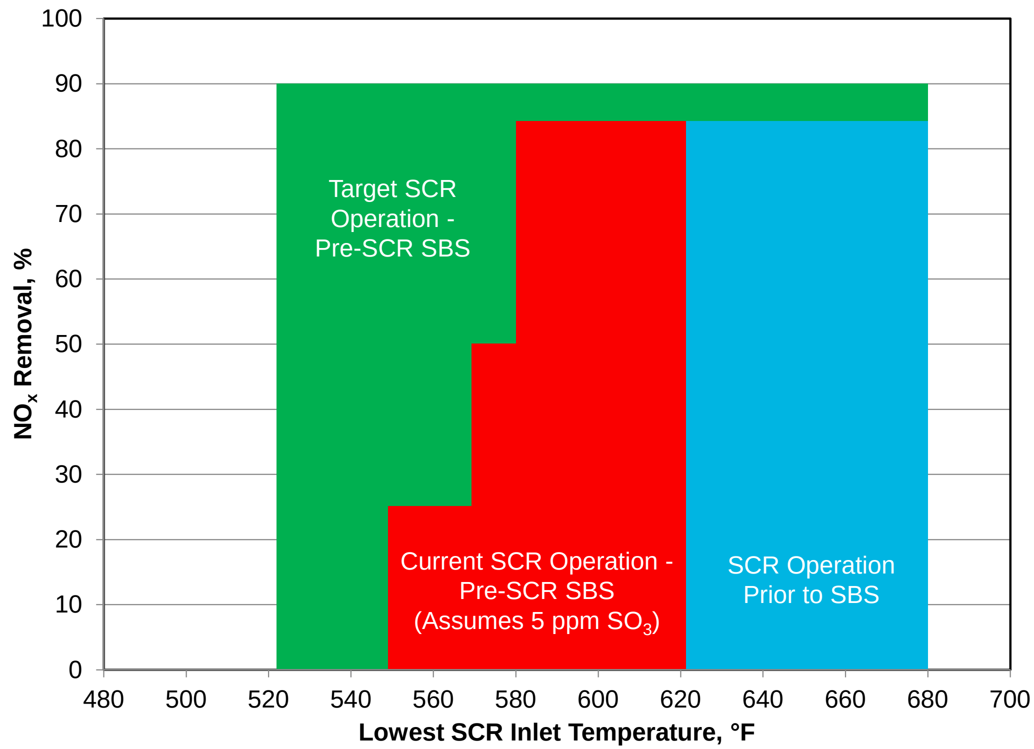
(Yellow) If econ SO3 was 40-50 ppm, then would expect to see condensation of ABS in bulk gas. It appears likely that this is what happened.

(Green) This is not as good as we would like to see.

(Grey) These results look good for allowing reduction in MOT.

(Orange) Rising, but perhaps just back to the full load level at the normal ratio.

- Field testing resulted in SO_3 numbers lower than the lab testing providing confidence in the enhanced operation mode
- Recommendation will be made to further modify the low load constraints from 250 MWg to 200 MWg with full NOx removal
- Economizer outlet SO_3 was much higher than expected due to the very low load and high O_2
- Approach will be implemented across remaining Gibson Units with minimal additional testing



Questions?

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