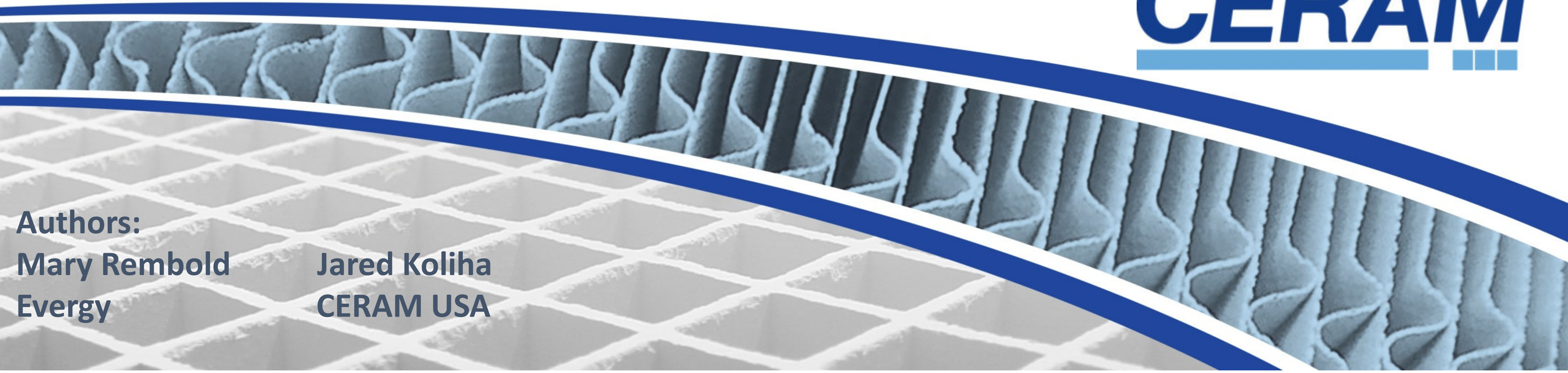
REINHOLD ENVIRONMENTAL ®

2022 Reinhold/PCUG Round Table Presentation

Hosted by Duke Energy in the Charlotte Sheraton/Le Meridien
Hotel, Charlotte, NC on June 27-28, 2022

Reinhold Environmental 2022 APC Round Table

Practical Considerations of SCR Low Load Testing: A Real-World Case Study



Authors:
Mary Rembold
Evergy

Jared Koliha
CERAM USA

Introduction

Keeping your SCR in service at low loads has become economically critical for coal fired power plants. There is a lot of information on SCR minimum operating temperature…

How should you collect and interpret minimum operating temperature data *__in the real world?__*

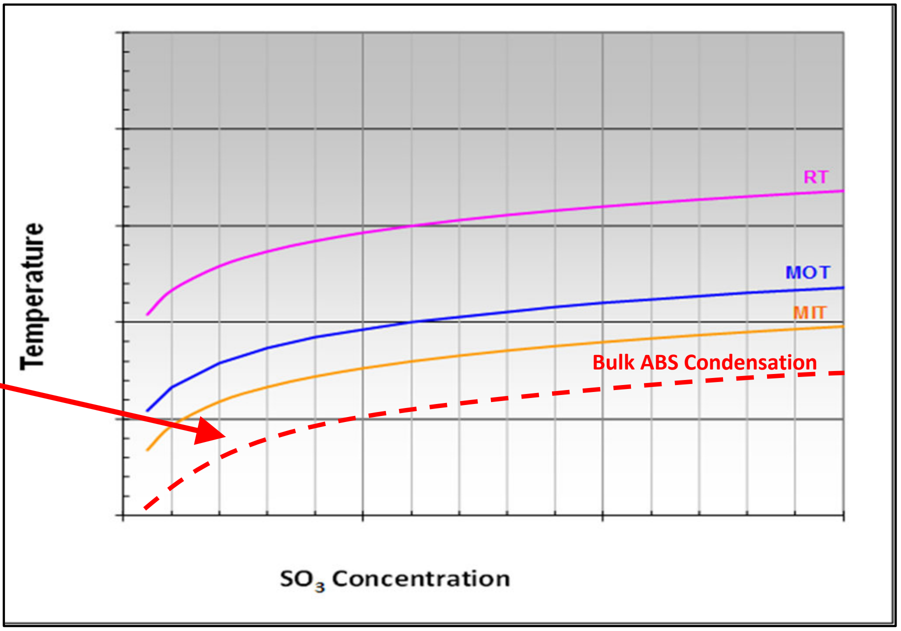
- Presentation Road Map
  - SCR Minimum Operating Temperature
  - 580 MW Case Study
  - Results and Analysis
  - Opportunities for Improvement
  - Questions and Answers

SCR Minimum Operating Temperature

- Minimum SCR Operating Temperatures Defined by Ammonium Bisulfate (ABS) Formation
  - Depends on Temperature, Ammonia, Moisture and SO_3 Concentrations, and Catalyst Pore Size (Capillary Condensation, Kelvin Equation)
  - Catalyst Pores Accumulate ABS First
    - Starts with Smallest Pores
    - Below Saturation Pressures, Above Bulk Condensation Temperatures
  - Bulk Flue Gas ABS Forms Below Pore Condensation Temperatures
- Initial ABS Formation Temp Defined by Catalyst OEM and Original Design Basis
- Traditional Operation Allows SCR Injection only to a Minimum Continuous Operating Temperature (MOT)

MIT, MOT, and RT

- ABS Deposition Below MOT is Reversable Provided Temperature isn't to far Below MOT
    - The Minimum Temperature for ABS to be Reversible is the Minimum Injection Temperature (MIT)
    - MIT is Less than MOT but Above Bulk ABS Condensation Temp
    - As ABS Builds up in the Pore Structure, some Activity is Lost
- SCR can Operate Between MIT/MOT for a Limited Amount of Time (Site Specific) Before Full Recovery of Activity Becomes Problematic
- Recovery Requires Operating Time at a Temperature above MOT to Facilitate ABS Decomposition
    - Recovery Temperature (RT)



Temperature of ABS Condensation at AIG Nozzles, Duct, Etc.

MIT…
Why is there a limit to what is/isn't reversible?

- Deactivation from ABS Deposition is Reversible… to a Point
- Time and Temperature Dependent Migration of ABS into Catalyst Pores
  - ABS Causing Physical Deactivation
    - ABS Formation is not a Phase Change
    - Chemical Reaction Facilitated by Phase Change
    - "Stuck" in the Pore Structure (Mechanical Deactivation)
    - Fly Ash Aggregation
  - ABS Facilitating Chemical Deactivation
    - Soluble Catalyst Poisons (Chemical Deactivation)
- Some Units have Lower Risks to Irreversible Deactivation
  - Thermal Profile
  - Flue Gas Composition
  - Consistent Operation (combustion and ammonia control)

Applying the Chemistry

Awesome Information…

But how do you actually use it???

Two Goals:

Maintaining Compliance
Maintaining SCR Performance

at Turndown Conditions

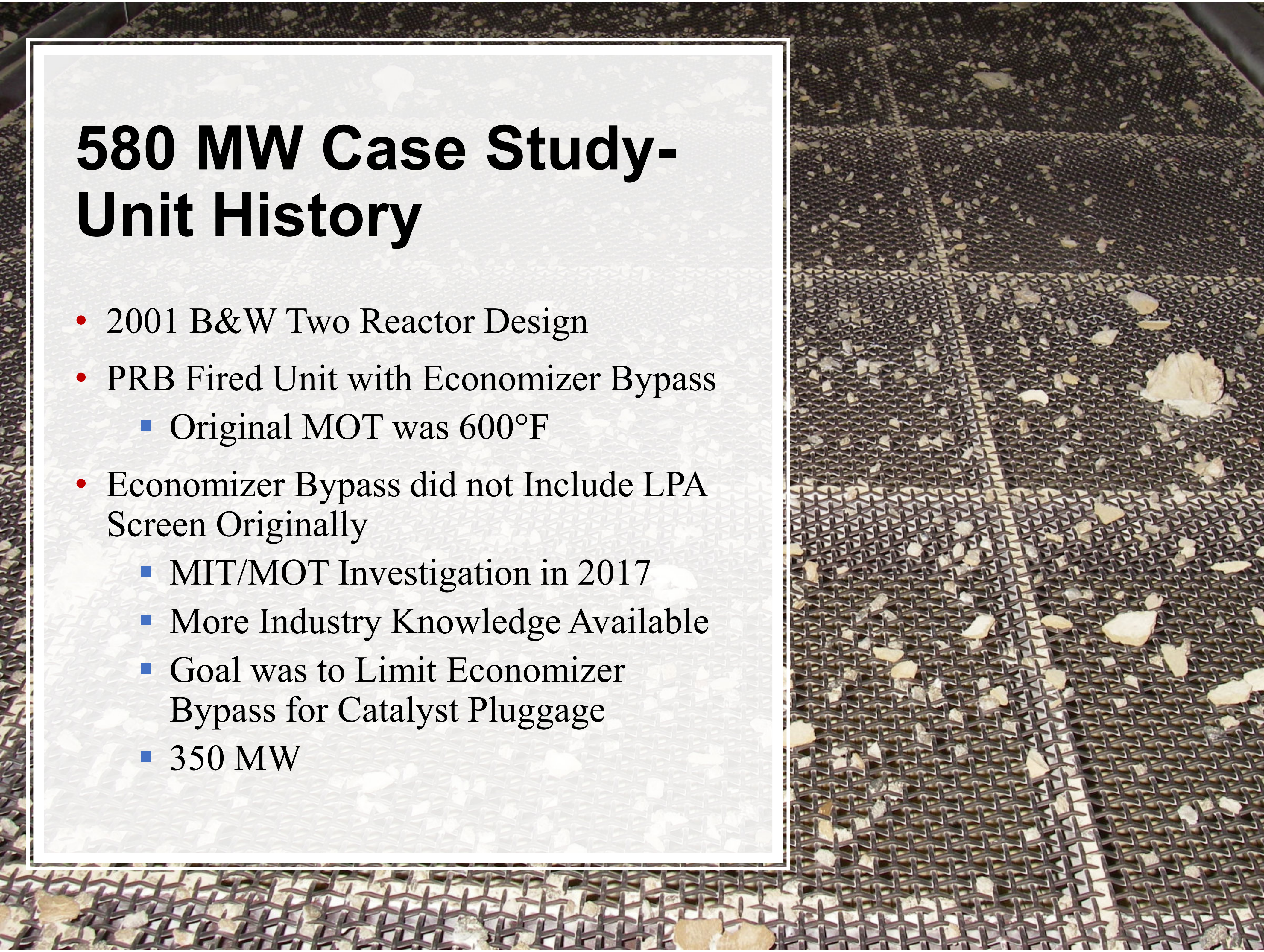
Defining Actual Operation with MIT/MOT/RT

- Key Considerations
  - Is the Reduced Activity Between MIT/MOT Acceptable?
  - What NOx Reduction do you Need?
  - What is the Ammonia Distribution?
  - How Consistent is your Temperature Profile?
  - What is the Actual SO_3?
    - At low load?
    - <u>How Accurate is your Measurement???</u>
- Localized ABS Formation is still ABS Formation
- Localized Deactivation is still Deactivation

Avoiding ABS: You are Only as Good as Weakest Point

Case Study

580 MW PRB-fired unit

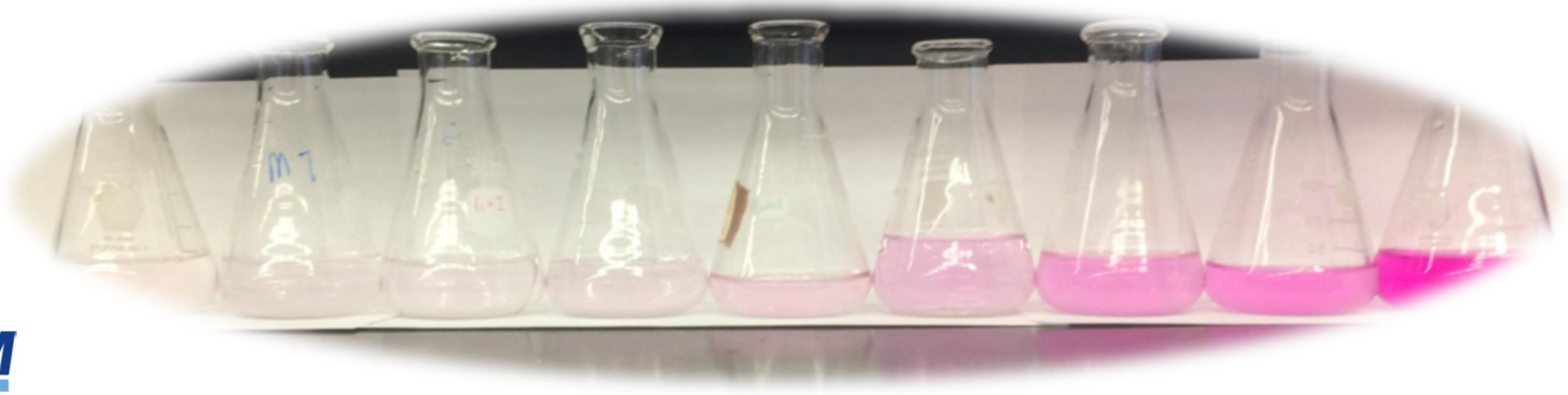


580 MW Case Study-Unit History

- 2001 B&W Two Reactor Design
- PRB Fired Unit with Economizer Bypass
  - Original MOT was 600°F
- Economizer Bypass did not Include LPA Screen Originally
  - MIT/MOT Investigation in 2017
  - More Industry Knowledge Available
  - Goal was to Limit Economizer Bypass for Catalyst Pluggage
  - 350 MW

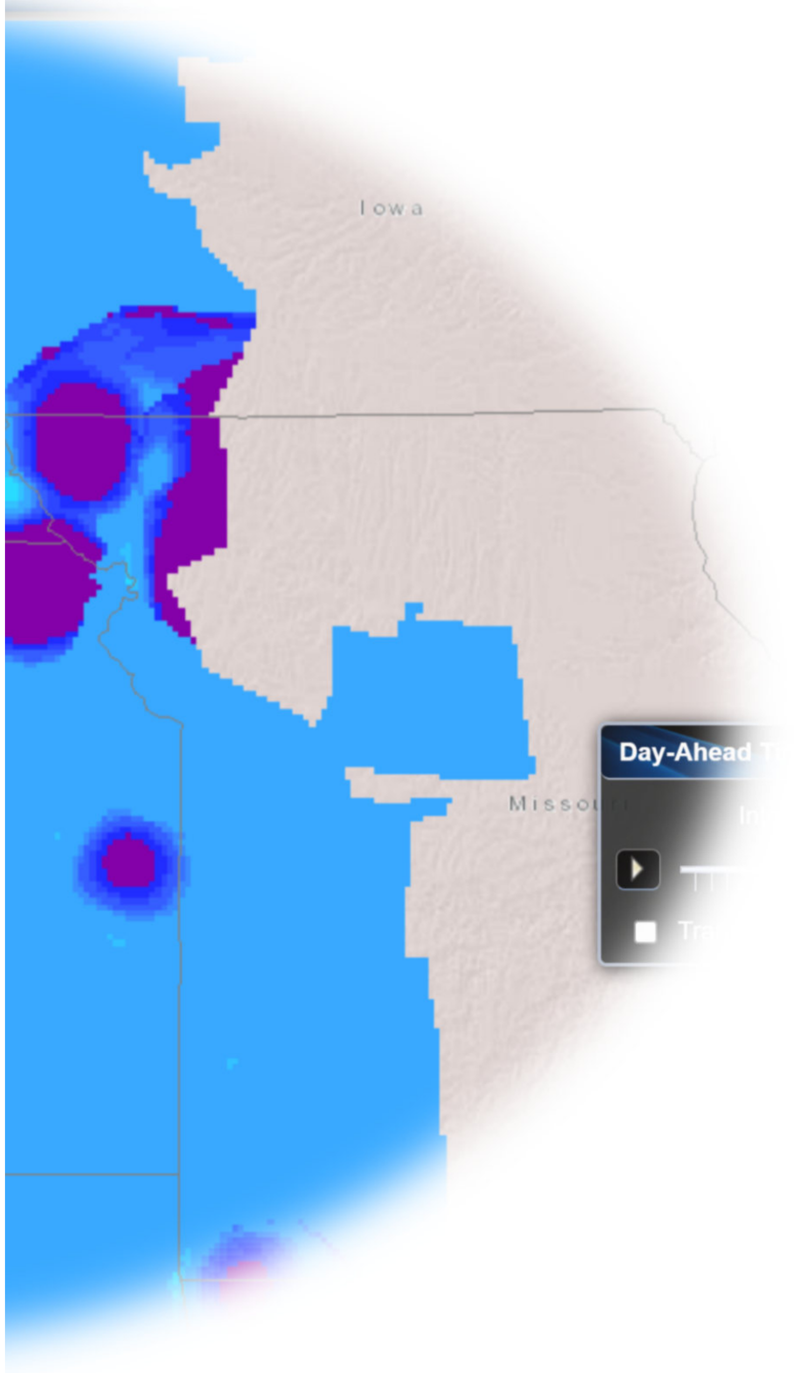
580 MW Case Study- Existing MOT Strategy

- 2017 Testing Indicated Low SO_3
  - 0.5 ppm Used for MOT Analysis
  - Results were Lower than 0.5 ppm but How Much Lower?
  - MOT Identified from Catalyst OEM Design Curves
  - MOT Changed to 565°F
- "Salt Timer" Established between 517°F and 565°F
  - Total Hours of Operation in Low Temp Range Limited
  - Low Temp Operating Timer Reversed at Temp Above 605°F



580 MW Case Study- Existing MOT Strategy

- Economizer Bypass LPA Screen Installed 2018
- More Push to Reduce Turndown (180 MW)
- Incremental Minimum Load Turndown
- 2021 Opportunity to Update Strategy
  - Refine Operating Window as Dispatch Changes
  - Improve Data Quality from Previous Assessment
  - Define Limitations of Data
  - Identify Barriers to Low Load Operation
- Established History Made Single Load Testing more Reasonable (and cost effective!)



580 MW Case Study- 2022 MIT/MOT Testing

- Check Outlet NOx Distribution at Full Load (Tune AIG if possible/necessary)
- Reduced Load (180 MW) Data Collection
  - DCS Monitoring of O_2, CO_2, NOx, Temp, Combustion
  - Temperature Grid Measurement at SCR
  - NOx Distribution Measurement at SCR Outlet
  - Testing EPA Methods 1, 2, 3/3B, 4, and 8A Upstream of AIG (SO_3, O_2, CO_2, H_2O, Temp, Flow)

CERAM

Results and Analysis

580 MW PRB-fired unit

580 MW Case Study- Results

$$MOT = F\left(SO_3, \frac{NH_3}{NOx}, H_2O\right)_{Theoretical}$$

$$+\ Error(SO_3)$$

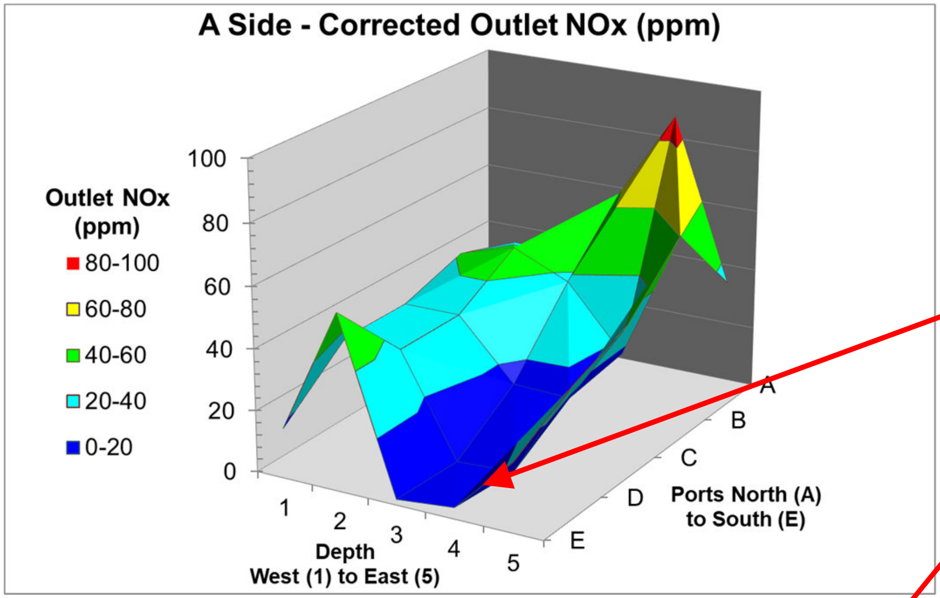
$$+Variability\left(\frac{NH3}{NOx}\right)$$

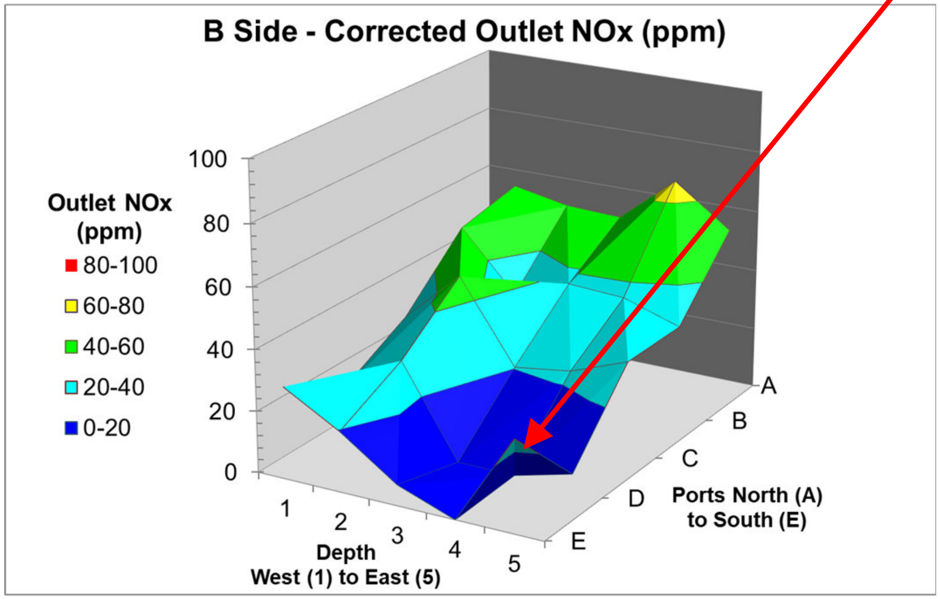
$$+Variability(Inlet\ NOx)$$

$$+Distribution(T)$$

Real World

580 MW Case Study- 180MW Test Data





Dodge ABS
Account for Localized
ABS Formation!!!

CERAM

580 MW Case Study- 180MW Test Data

Low Load Test SO_3 Measured Concentration (IC Analysis)						
	Run 1	**Run 2**	**Run 3**	**Average**	**St. Dev.**	**Avg. +2 St. Dev.**
A-Side Duct						
SO_3 Concentration (ppmv)	0.0092	0.0093	0.0193	0.0126	0.0058	0.0242
B-Side Duct						
SO_3 Concentration (ppmv)	0.0213	0.011	0.0101	0.0141	0.0062	0.0265
Overall						
SO_3 Concentration (ppmv)	0.0153	0.0101	0.0147	0.0134	0.0028	0.0189

- SO_3 much Lower than Design
  - Confirms 2017 Analysis
- SO_3 Concentrations are so low- Could they be Accurate???
  - Titration Values Essentially Non-Detect
  - Ion Chromatography, more Accurate
    - Catch Error
    - Sample Bias
    - Large Spray (in tiny data…)

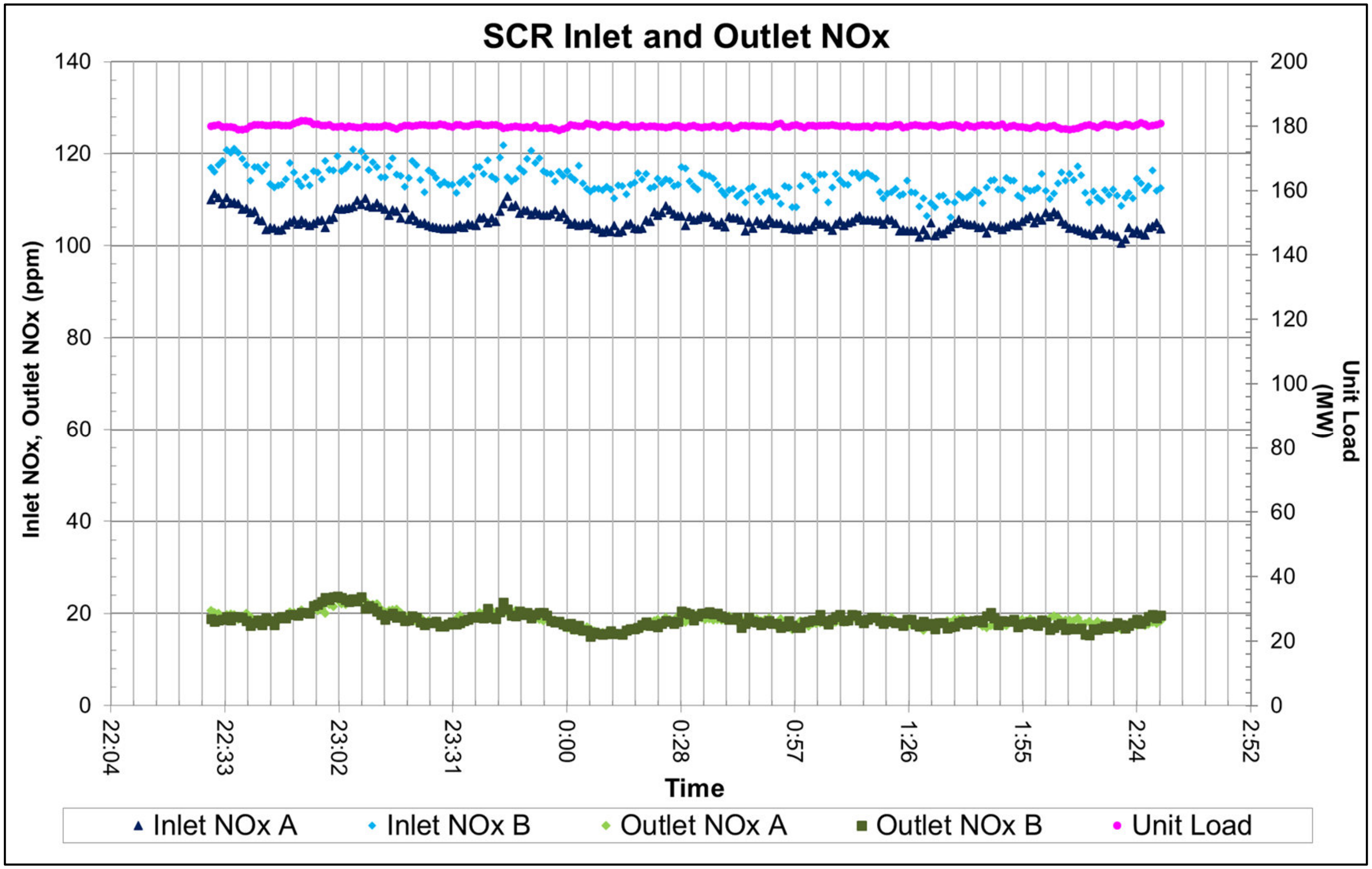
Method 8 Defined Error: 0.05 mg/m3 (~0.012 ppm) *not reasonable*

Practical LOQ: 0.1 – 0.5 ppm

Utilized 0.25 ppm for Analysis

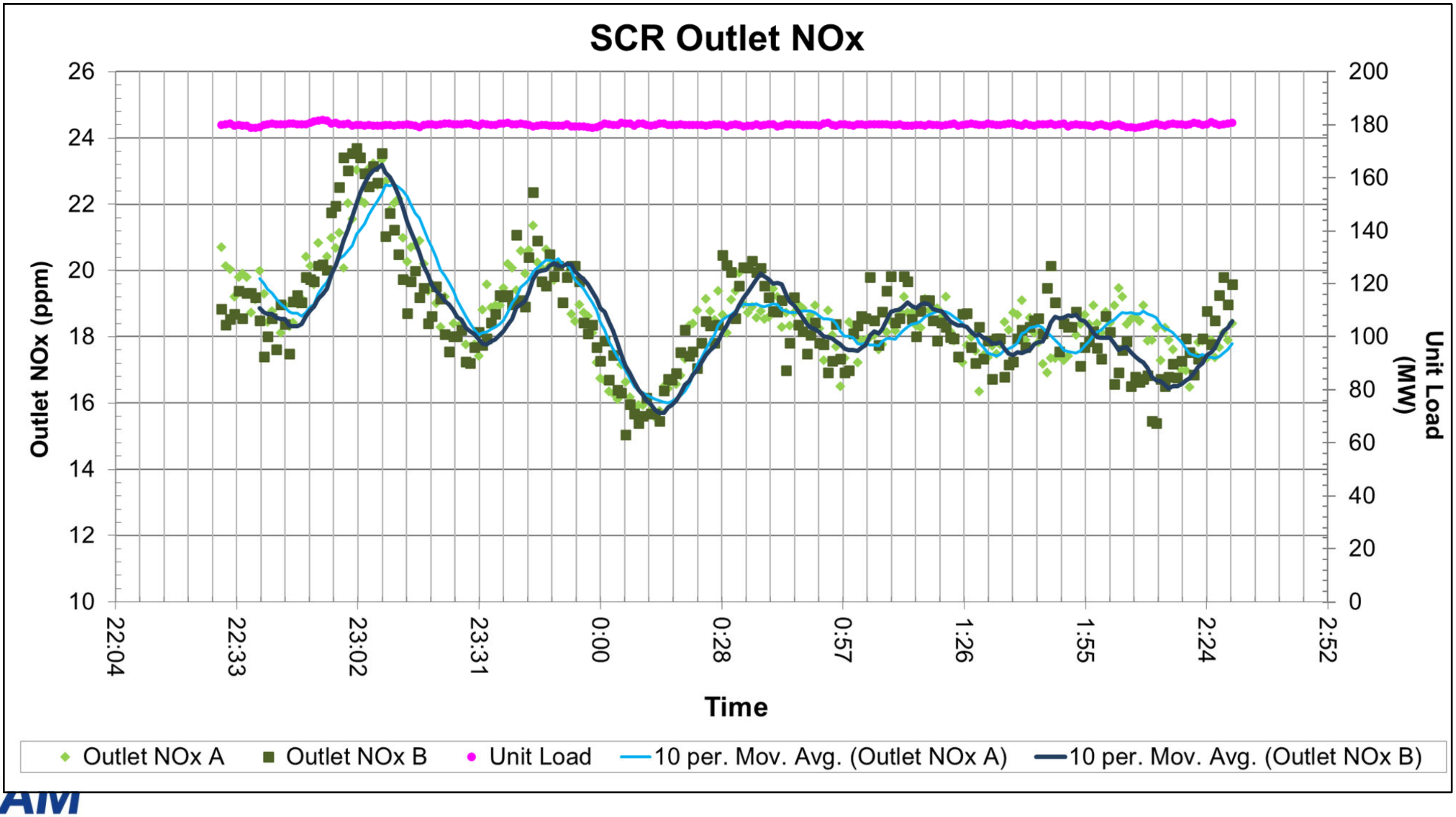
580 MW Case Study- 180MW Inlet NOx Test Data

- SCR Inlet NOx Varied Between Reactors
  - Maybe a Function of location of NOx analyzers
- Station Indicates that Inlet NOx should be Lower
  - Indication is that it is possible to remedy



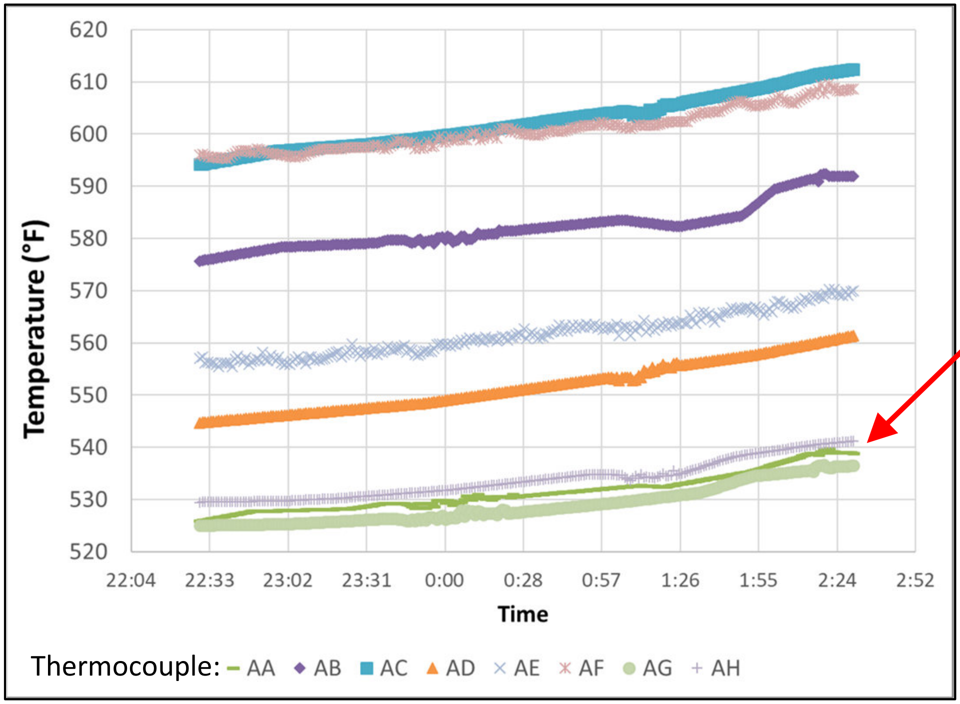
580 MW Case Study- 180MW Outlet NOx Data

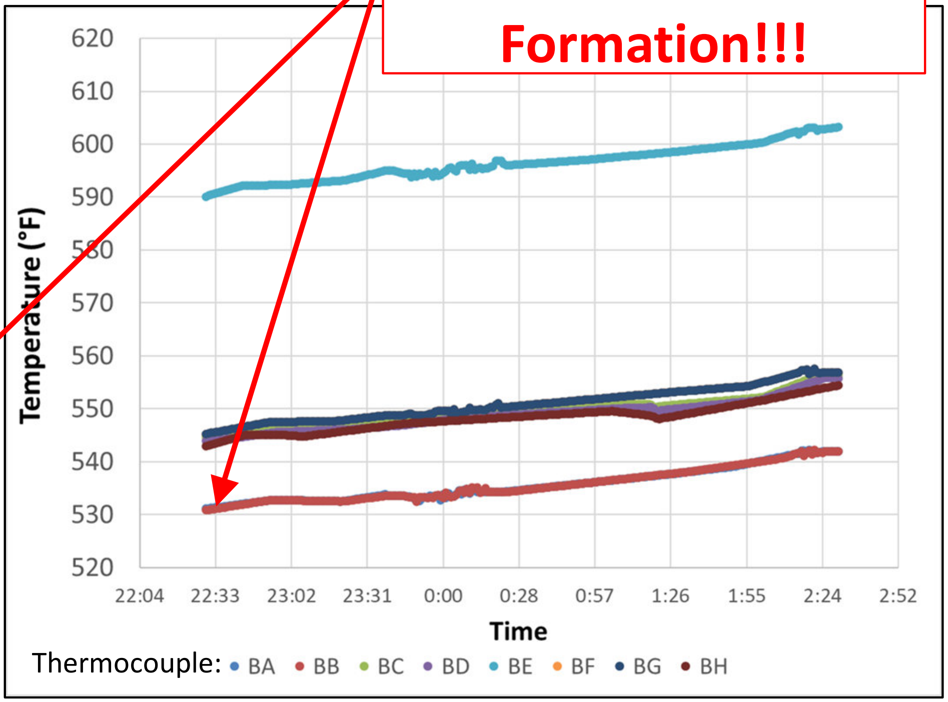
- SCR Outlet NOx Agrees between Reactors
- Ammonia Control “Hunts” at Low Load
- Oscillating Periods of Over/Under Injection



580 MW Case Study- 180MW Inlet Temp Test Data

- Eight Thermocouples per Reactor at SCR Inlet
- Data Logged to DCS



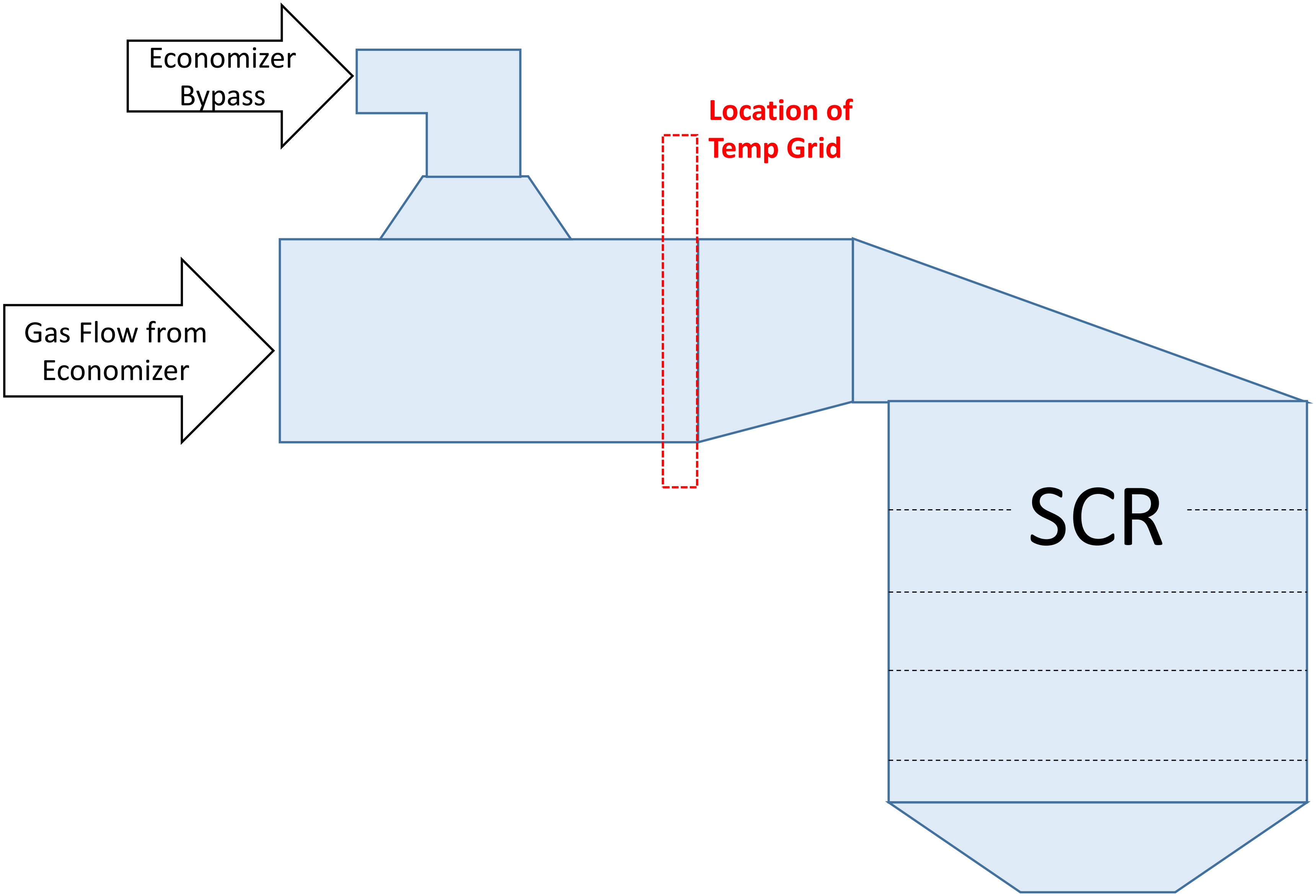


Account for Localized ABS Formation!!!

- Temperature Data Ranging from 525°F to 610°F
- Does not Change MOT but Changes Implementation Strategy

CERAM

580 MW Case Study- 180MW Inlet Temp Test Data

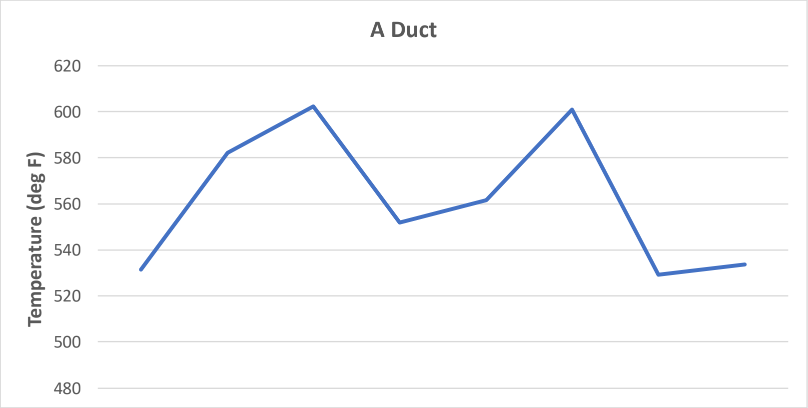


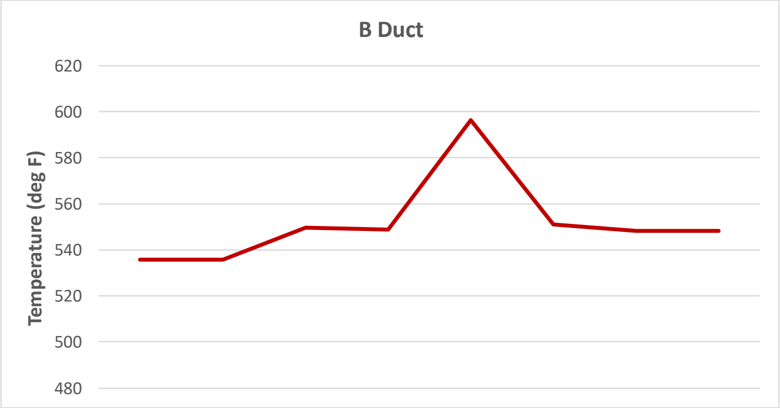
580 MW Case Study- 180MW Inlet Temp Test Data

- Eight Thermocouples per Reactor at SCR Inlet

West *East*

	A Duct								B Duct							
Thermocouple Designation	A	B	C	D	E	F	G	H	A	B	C	D	E	F	G	H
Average Low Load Temperature (deg F)	**532**	**582**	**602**	**552**	**562**	**601**	**529**	**534**	**536**	**536**	**549**	**549**	**596**	**551**	**548**	**548**



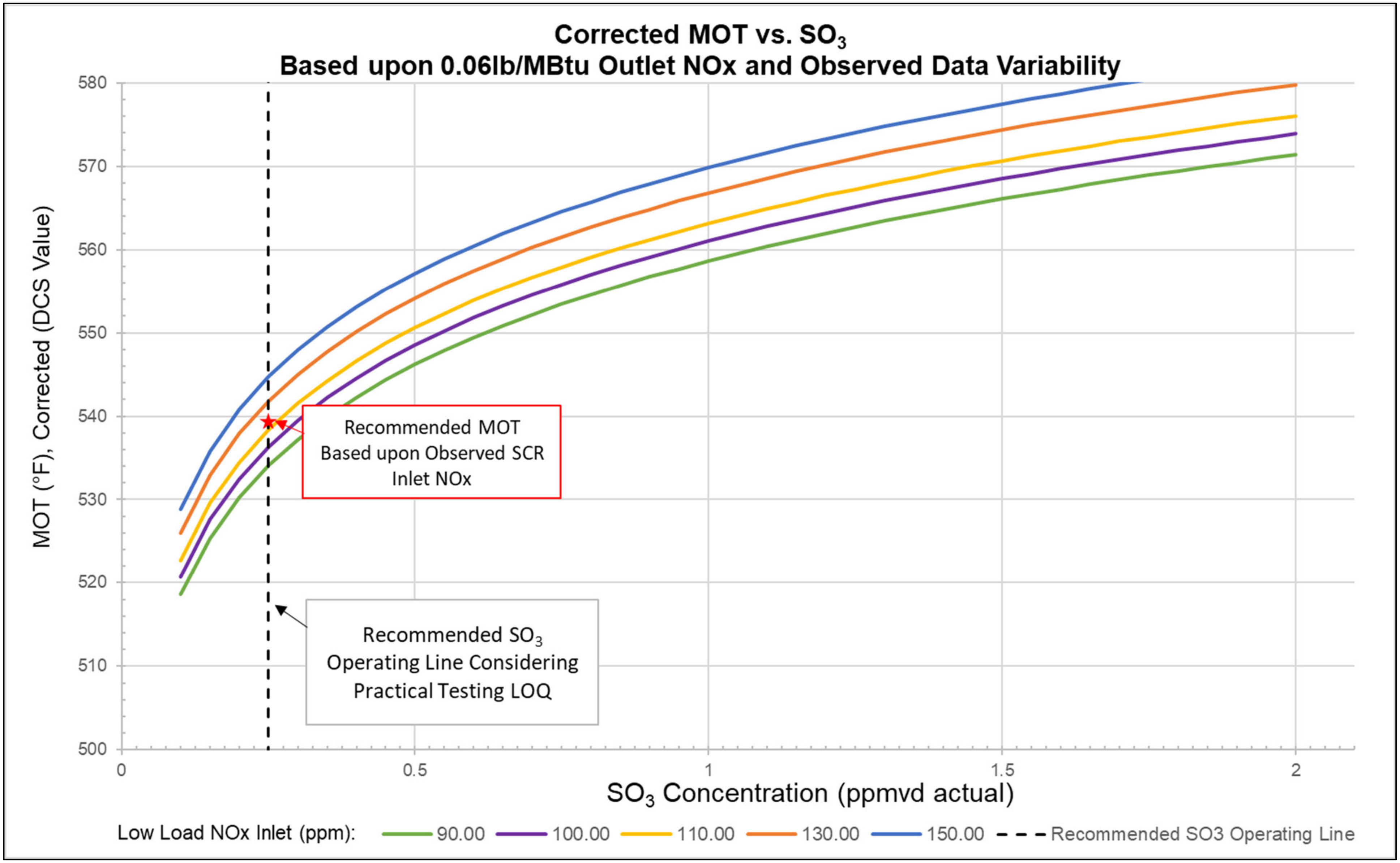


West *East*

580 MW Case Study- Results

- Big Disparity in SCR Inlet Temperature- Cold Corners
- Economizer Bypass/Mill Configuration Related
- Eight Thermocouples per Reactor at SCR Inlet
  - Average Used in Control Scheme
    - *Theoretically* Should use Lowest Thermocouple when Optimizing MOT/MIT
  - Two Options for MIT/MOT Temperature Strategy
    - Modify the Control Scheme to Lowest Thermocouple
    - Account for Temperature Profile in Updated Equations

580 MW Case Study- Results



CERAM

580 MW Case Study- Results

SCR Low Load Operating Guidelines

Temperature Criteria	**Previous Guidance**	**New Guidance**	**Description**
Minimum Continuous Operating Temperature (MOT)	565 °F	539 °F	Continuous ammonia flow acceptable above this temperature (MOT).
Minimum Intermittent Injection Temperature (MIT)	517 °F	517 °F	Minimum Intermittent injection Temperature (MIT).
SCR Recovery Temperature (MRT)	605 °F	589 °F	Recovery temperature to account for periods of ammonia injection between MOT and MIT

580 MW Case Study- Results

- 2017 Data is Validated
  - Salt Timer Initiation Temperature Lowered
  - SCR Shutoff Temperature Unchanged
- SCR is not Turndown Limitation
  - Turndown Effectively Reduced to 180 MW
  - Potential for Even Lower Load?
  - Site SDA Turndown Limited
- Salt Timer Hours Since Implementation
- Operational Confidence

✓ Maintaining Compliance
✓ Maintaining SCR Performance

580 MW Case Study- Improving the Results

- Additional Improvements can be made to MIT/MOT
  - Reducing Temperature Variability
  - Improving Ammonia to NOx Ratio
  - Improving Low Load Ammonia Control
  - Improving NOx Measurements at Inlet
    - Combustion or Instrumentation
    - Finite Limits because of Mill Configuration and Operational Variability

Thank You for Your Time!

Questions?