REINHOLD ENVIRONMENTAL ®

2025 Reinhold/PCUG Round Table Presentation

Hosted by AEP and Buckeye Power

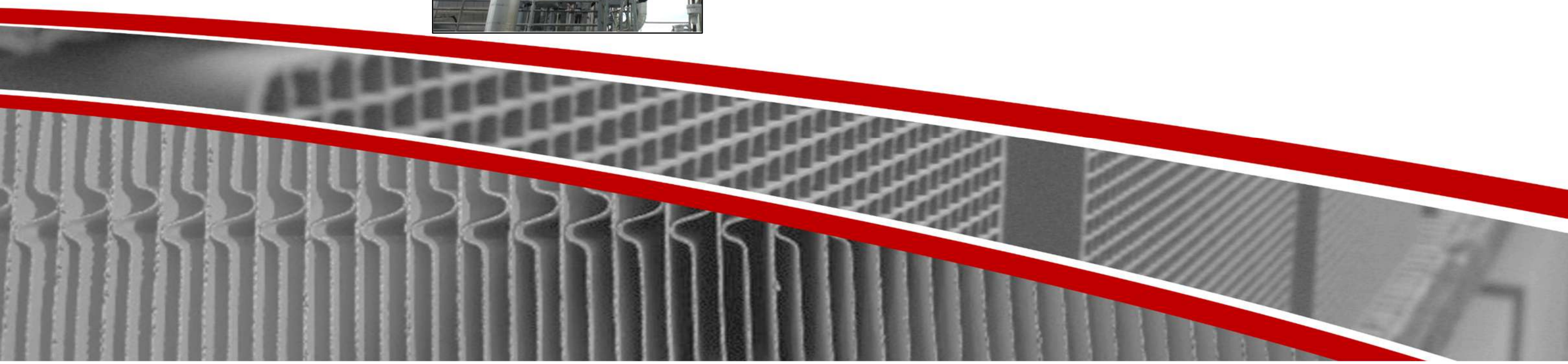
in The Hilton Columbus Polaris Hotel, Columbus, OH

on June 23-24, 2025

2025 Reinhold Environmental Round Table

Check Your SCR Report Card

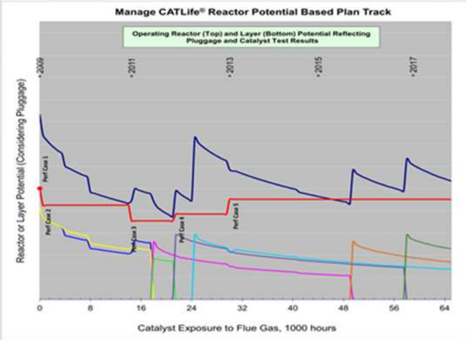
Presented by
Noel Rosha and Jared Koliha (CERAM)
June 24, 2025



Introduction

Minimizing coal-fired SCR capital and O&M expenditures is a top priority. Accurately assessing the impacts of increased unit reserve and reduced capacity factors and properly evaluating the actual SCR system demand and performance are critical considerations in SCR operating cost and CapEx optimization.

- Presentation Road Map
  - Assessing SCR demand and performance
  - Accurate catalyst assessment
  - Ammonia and auxiliary systems
  - Achieving SCR performance with confidence



SCR Class Syllabus

Assessing SCR Demand

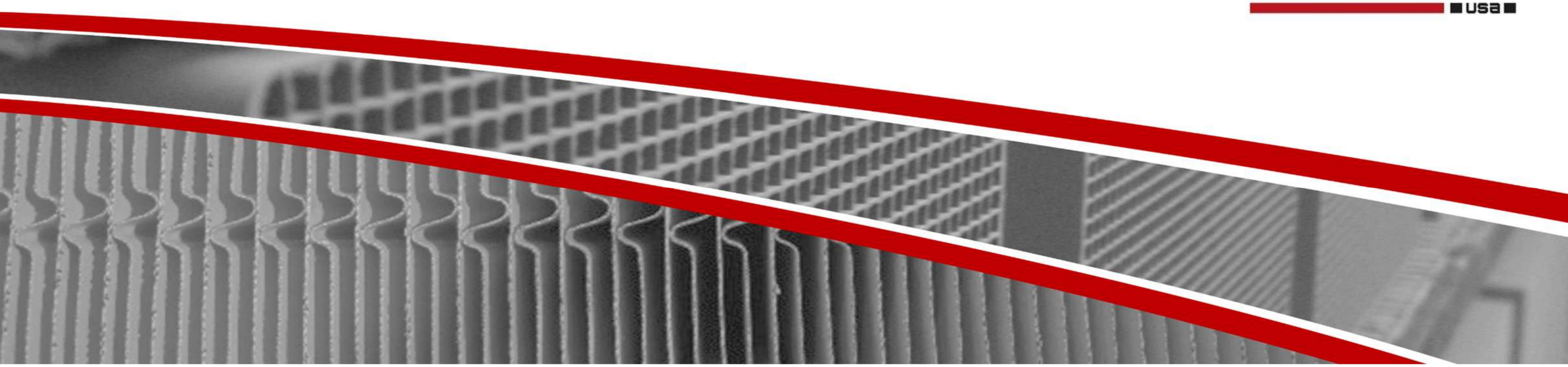
Assessing Catalyst Performance

Ammonia Distribution and Control

Auxiliary Systems and Equipment

Final Exam: Meeting Performance and Reducing Costs

Assessing SCR Demand and Performance



DeNOx Demand and Reactor Potential

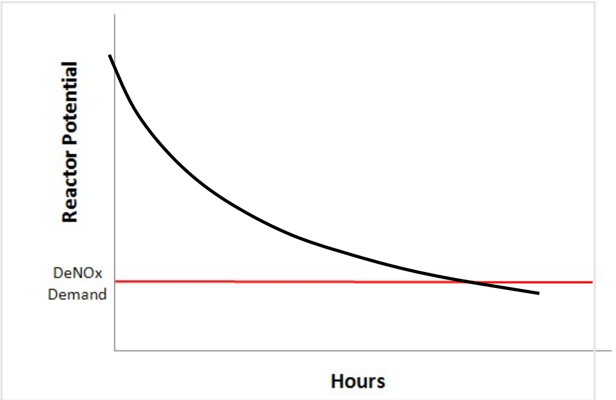
Reactor Potential

- The current NOx reduction capabilities of the catalyst
- Takes K and trends in K and applies results over field geometry
- Dependent on operating and mechanical conditions (temperature, distributions, pluggage, etc.)
- Catalyst management depends on accurate assessment for each layer
- Established (accurate) test history → more accurate deactivation

$$P = K/Av$$

DeNOx Demand

- The reactor potential required to meet NOx removal and NH_3 slip requirements



$$DeNOx\ Demand = P_{req} = K_{req}/Av_{actual}$$

CATLife® Services Operations Assessment

Comprehensive Analysis to Assess DeNOx Demand, SCR System Performance, Identify Trends and Troubleshoot System Issues

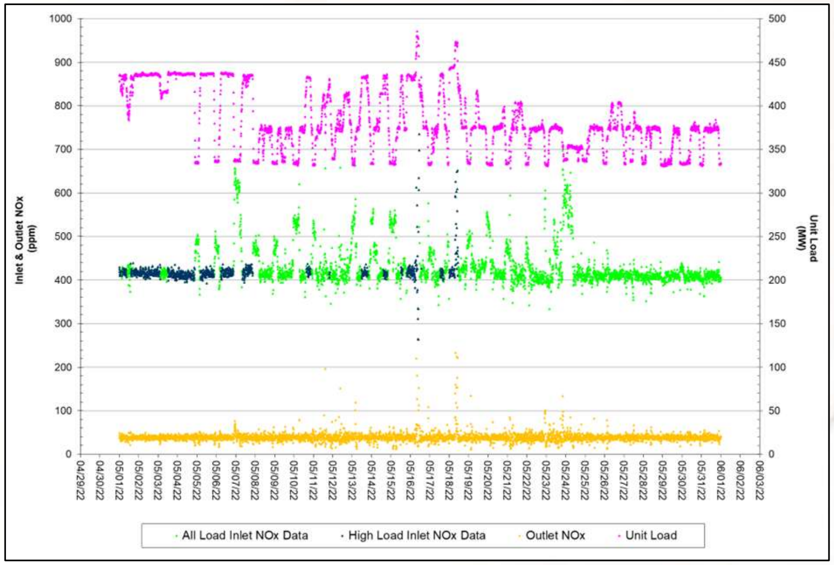
Short and Long-Term Data Trending

Evaluation of Pertinent Statistics

Scenario-Based Analysis

Combustion Calculation Analysis

DCS / CEMS DAHS / Fuels Data



Critical Engineering Analysis while Optimizing Plant Resources

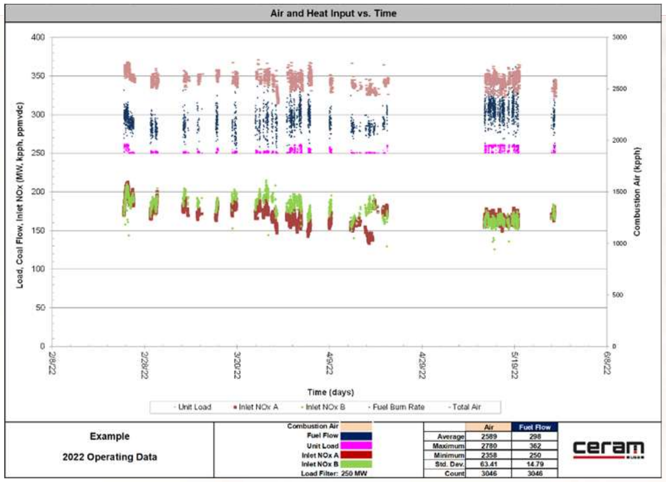
Applying Data

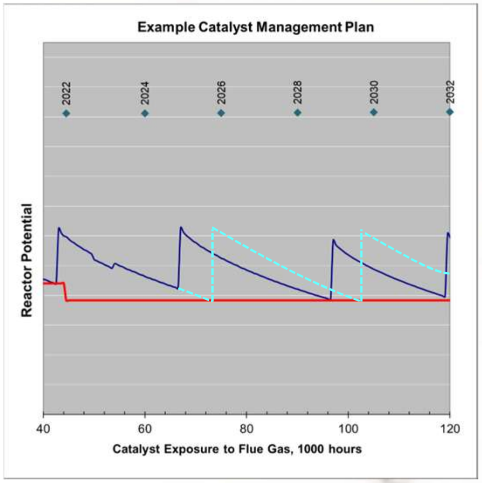
Breaking Down Data Results

- Creating a composite operating case
  - DeNOx demand limiting (excursion but REALISTIC)
- Using data confidence to define operating case margin
- Perform combustion calc to verify data

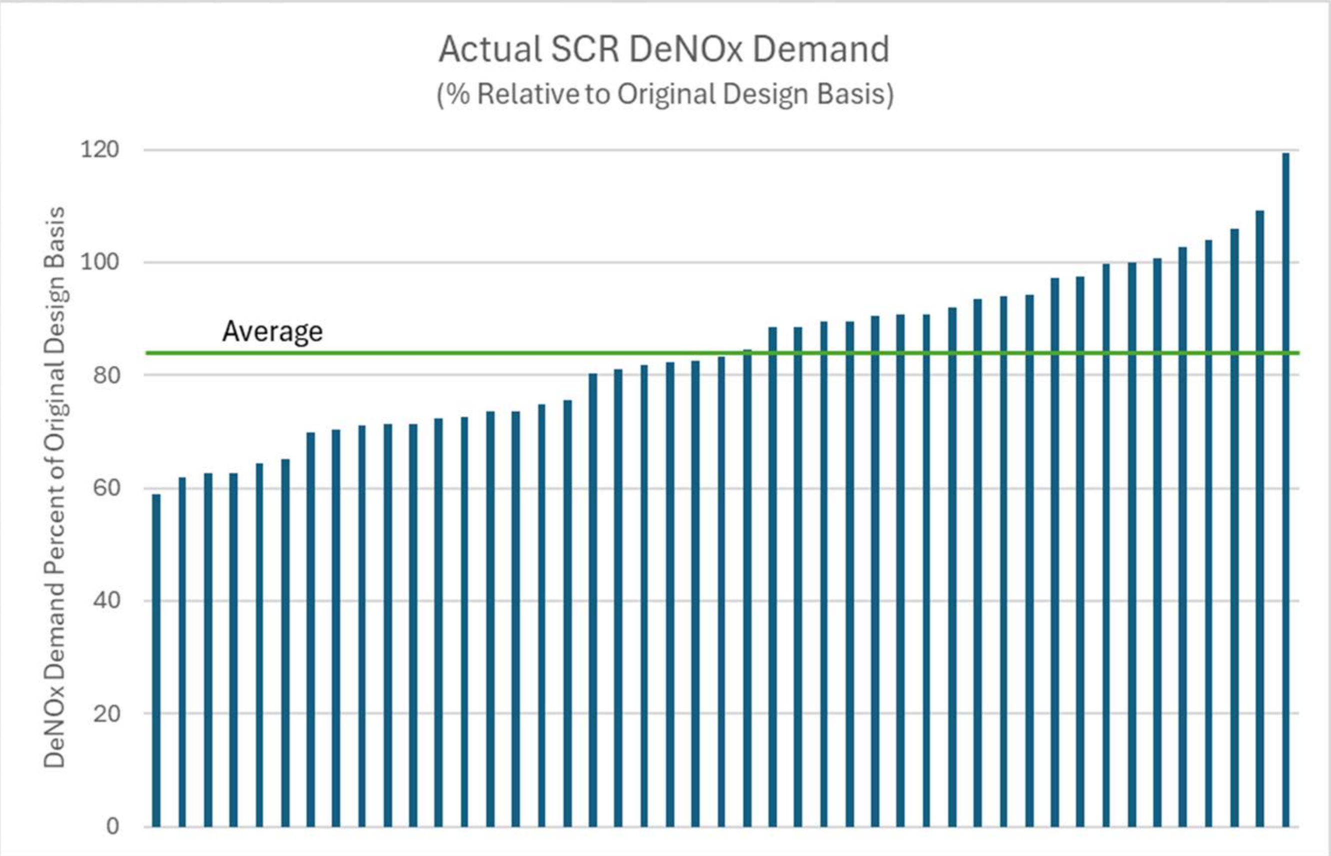
Scenario Evaluation

- Impacts of outage schedules and operating hours
- Sensitivity analysis – best and worst case
- What if?, What now?
  - **Recognizing opportunities where small changes have big benefits**
  - How the change in runtime or fuel burn rate impact the ability to defer a replacement from one outage to the next



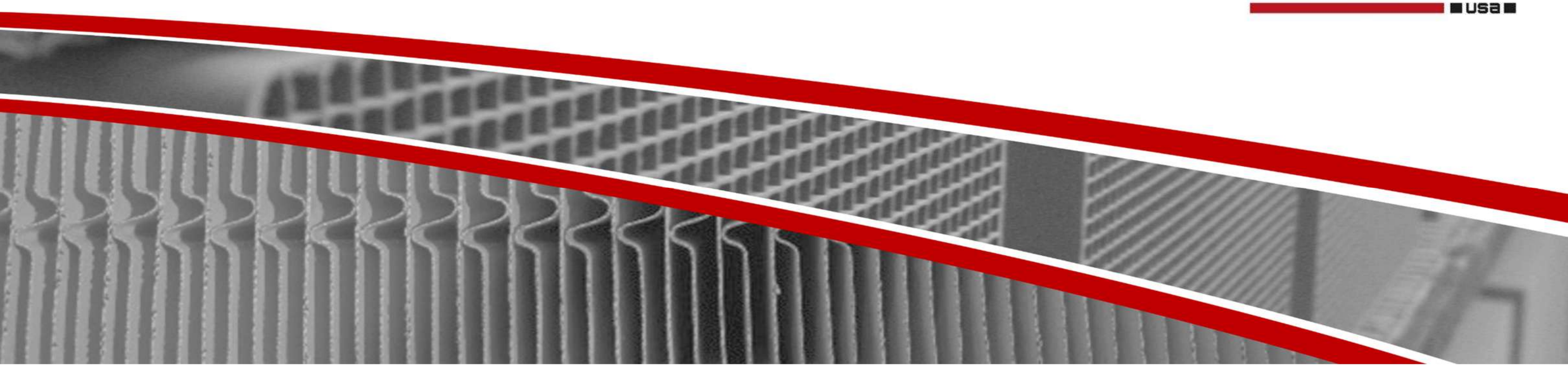


Actual vs. Design DeNOx Demand



- Industry Survey of 45 Coal-Fired SCR Systems (500 Unit-yrs)
- Average DeNOx Demand is 84% of Original Design

Assessing Catalyst Performance

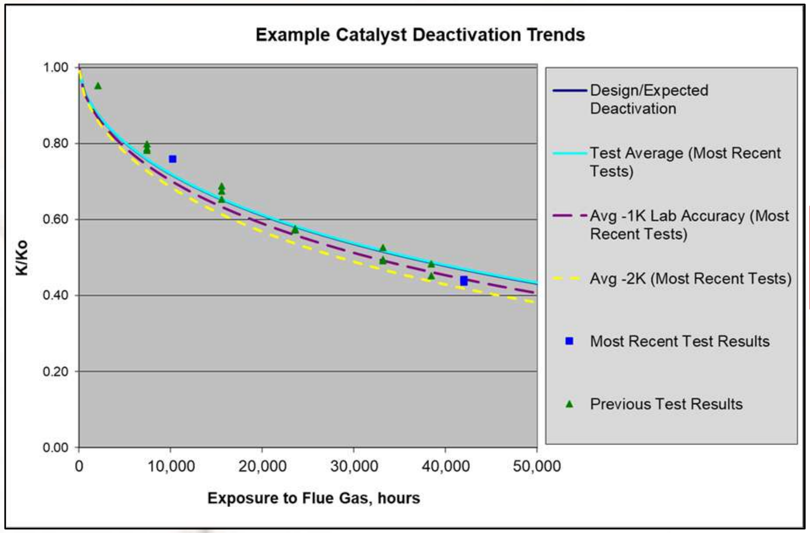


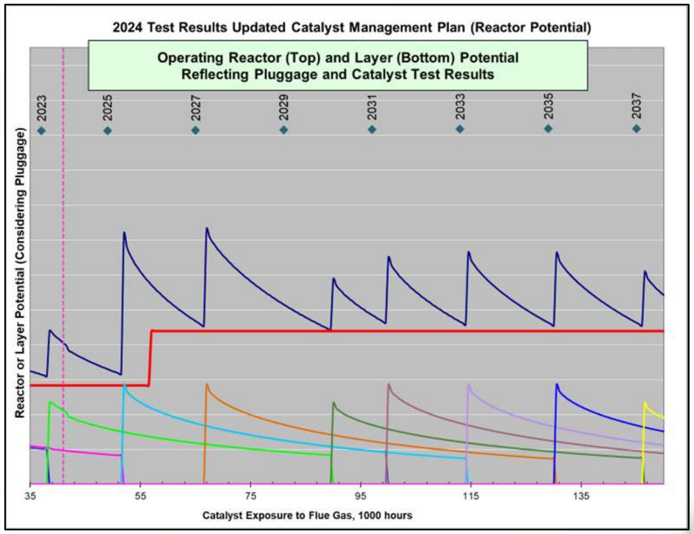
Catalyst Activity Trends and Analysis

Most Recent Test Data

Catalyst Type	Reactor Level	Hours of Catalyst Exposure to Flue Gas	Activity (K-bench at 410 C), m/h	K/Ko	Std Deactivation K/Ko @ 16khr	-1K/-2K Based K/Ko @ 16khr
2021 Plate	1	10,233	38.0	0.760	0.700	0.677 / 0.653
Original	2	42,003	19.4	0.436	0.623	0.604 / 0.586
Original	3	42,003	19.7	0.443	0.628	0.61 / 0.591

Consistent Analysis Provides Better Context to All Test Data





Using Test Results

The Temptation is to Oversimplify Results- "Do we need Catalyst or Not?"

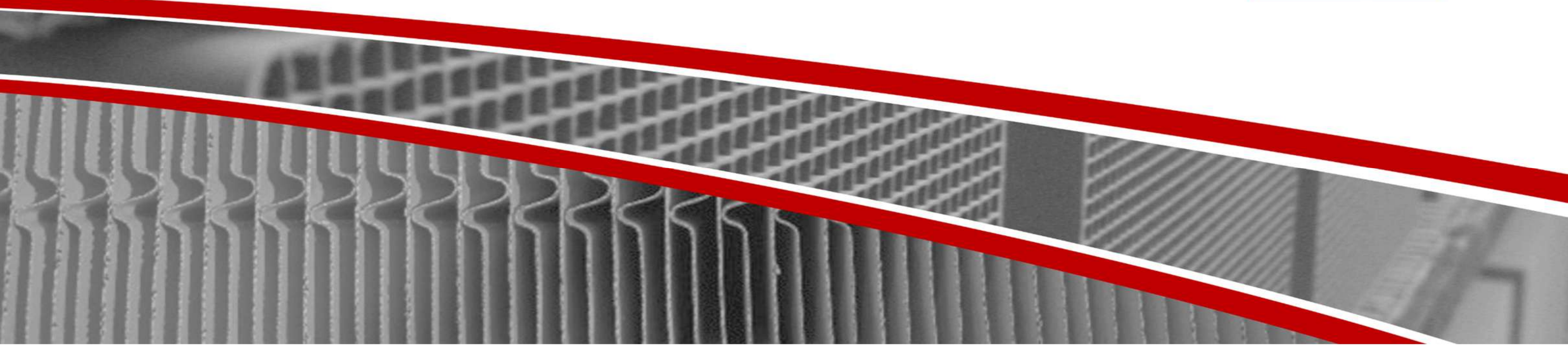
- Testing is about the long game
- Missing or low-quality analysis impacts future analysis

To be Universally Useful, Test Data should Include:

- Measured K-value for each layer
- Test conditions (AV, temp, H_2O, O_2, NOx, molar ratio)
  - Consistent with industry standards
- Initial K-value (as available, otherwise must be estimated)
- Operating time for each layer
- Sufficient information for the same analysis by third party

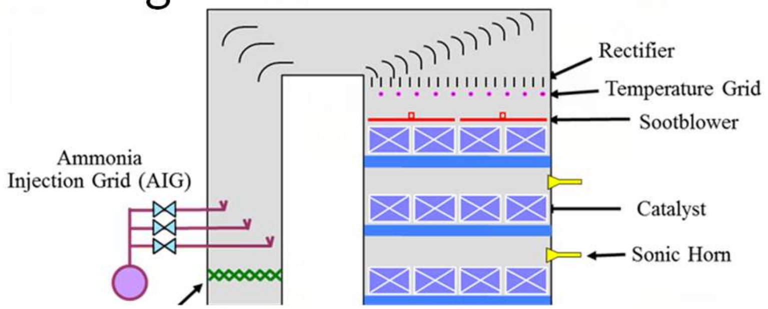
Relative Activity (K/Ko) or Potential (P/Po) Alone is Insufficient

Ammonia Distribution and Control



Ammonia Injection Grid (AIG)

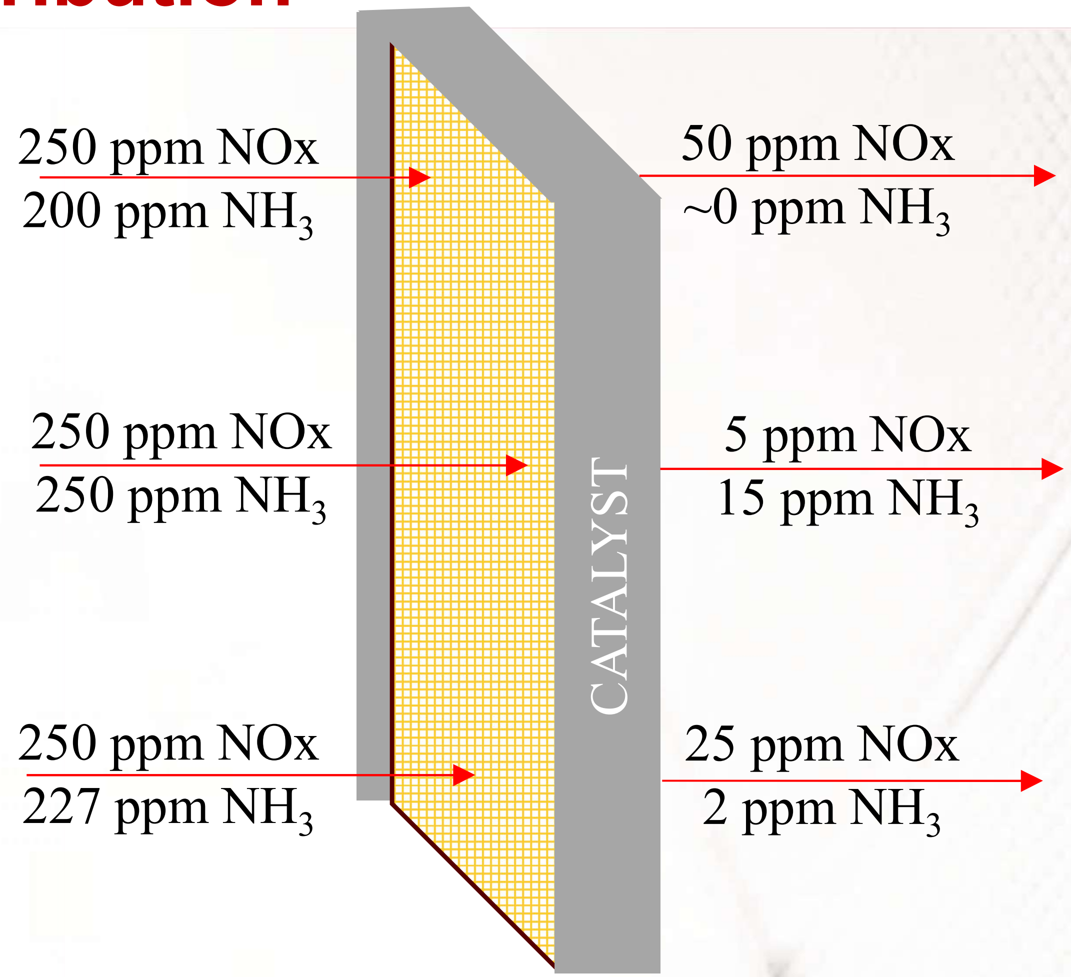
- Know the Physical Design and Tuning Capability
  - Multi-Zone control
  - Mixers
- Know Original Design NH_3:NOx Distribution
  - Consider impacts of better or worse
- Routine (min. Annual) Check Recommended
  - Perform AIG tuning if needed
  - Inspect AIG for damage



Ammonia to NOx Distribution

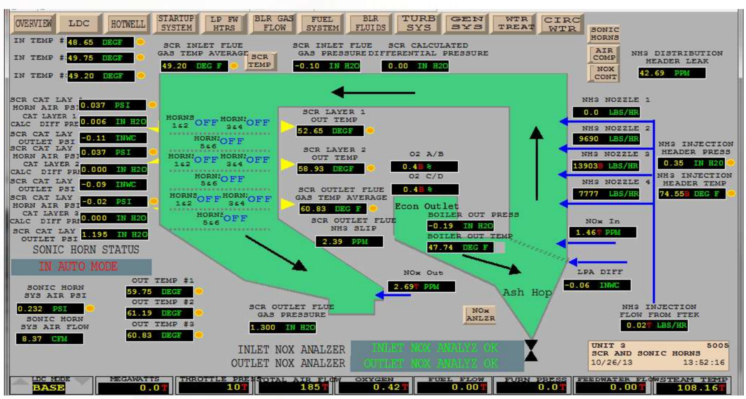
- Variability Does not Average Out
  - NH_3:NOx 1:1 utilization
  - Ammonia slip locally
- Flow and Temperature Distribution Complicate
- Only as Good as Weakest Points

Ammonia and NOx need to be at the same place at the same time.



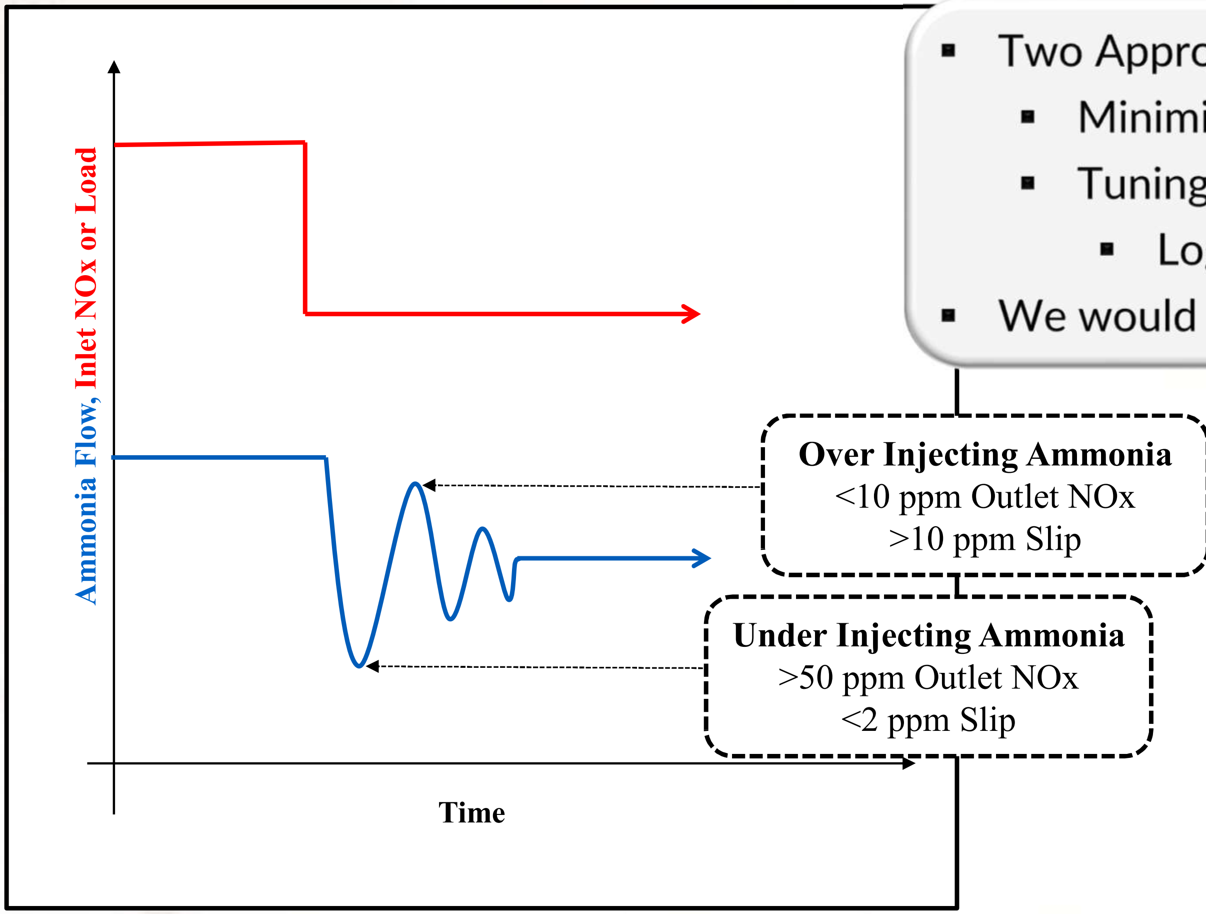
NH_3 Flow Control Logic – Know How it Works

- Typical Flow Control
  - Feed forward signal (NOx reduction & load indication)
  - Feed back signal (SCR outlet NOx)
  - Final control trim (Stack Setpoint)



- Logic Inputs may Include:
  - NOx analyzers
  - CO_2 & O_2 analyzers
  - Stack CEMS
  - Load indication (coal flow, air flow, unit load, etc.)
- Any of these not working properly will impact NH_3 flow control

Ammonia Control During Load/Flow Swings



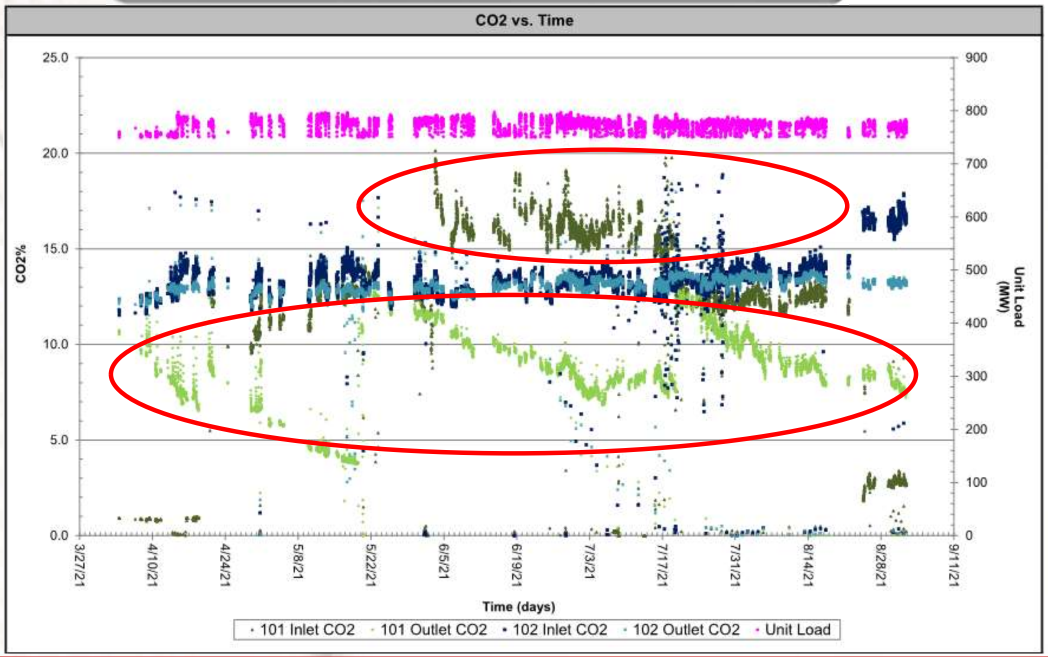
- Two Approaches to Control Oscillation
  - Minimize severity of process changes
  - Tuning the control system
    - Logic, instrumentation, AIG
- We would Recommend Evaluating Both

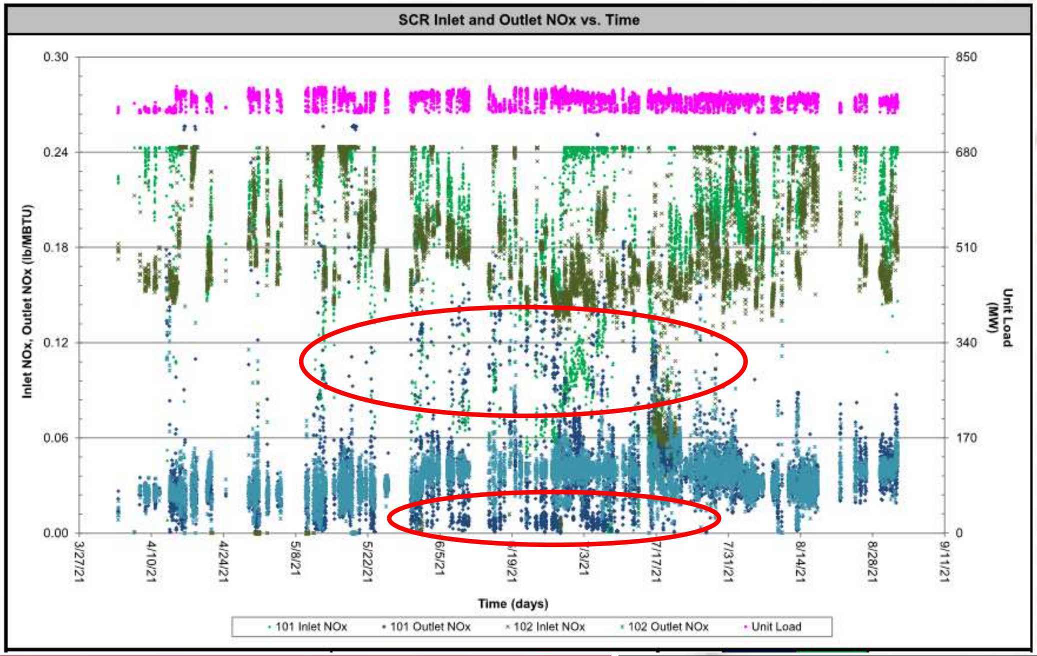
NH3 Flow Control Logic and Monitoring

- Know the Inputs (Inlet/Outlet NOx, CEMS, CO_2/O_2 %)
  - Impact to Method 19 calculation (ppm to lb/Mbtu)
- Monitor Input Accuracy and Ammonia Flow Consistency

101 Reactor CO_2% Measurement Error
Inlet and Outlet (Dark & Light Green)

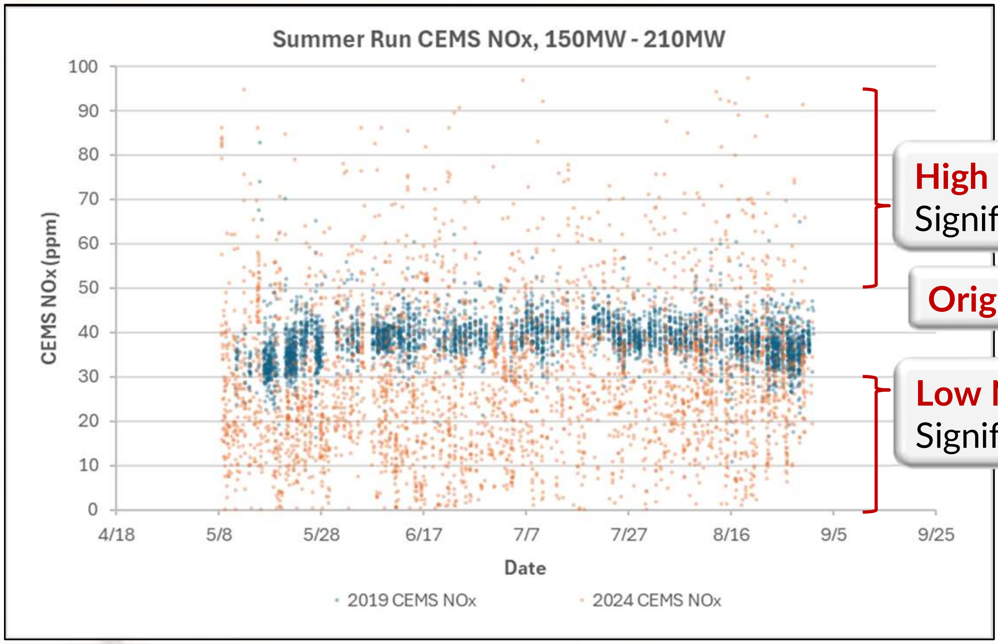
101 Reactor Outlet NOx Spray
101 Dark Blue, 102 Light Blue





Impact of Simplifying Controls

- Removal of SCR Inlet Transmitter (Cost Savings)
- Elimination of Feedforward NH_3 Flow Component
- We See Similar Impacts with Control Mass Balance Inaccuracies
  - Low load issues are common



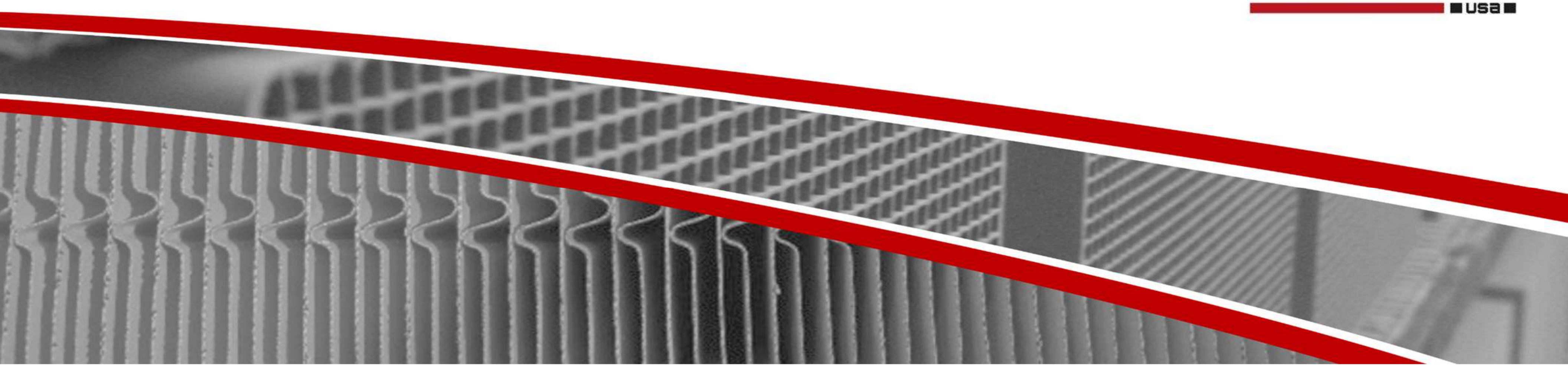
High NOx Data Spray
Significant Impact to NOx Rolling Averages

Original Control

Low NOx Data Spray
Significant Increases to Average Ammonia Slip

Overcoming 'Average Error' becomes a Catalyst Management Consideration (margin needed)

Auxiliary Systems and Equipment



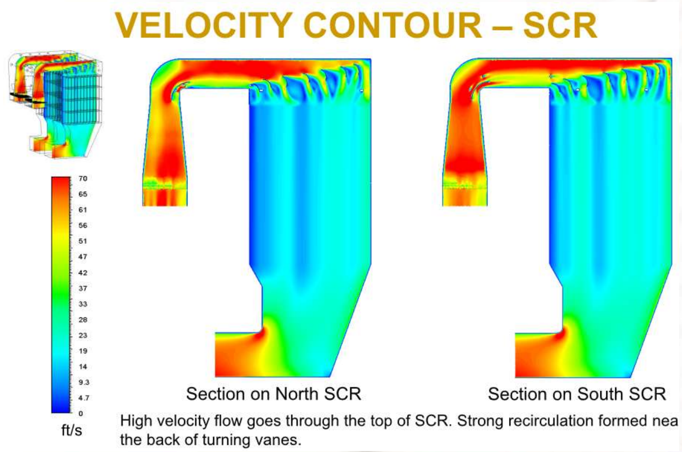
Online Catalyst Cleaning Devices

- Preventative Maintenance Critical!!!
  - Catalyst cleanliness not recoverable online after equipment outages
- No Remedy for Root Causes of Pluggage
  - Flow distribution
  - Low velocity
    - Bulk or localized
  - Upstream impedances

Air Cannons In/Out of Service

Sonic Horn Filled/Covered with Ash

Air Cannon Valved out for Maintenance



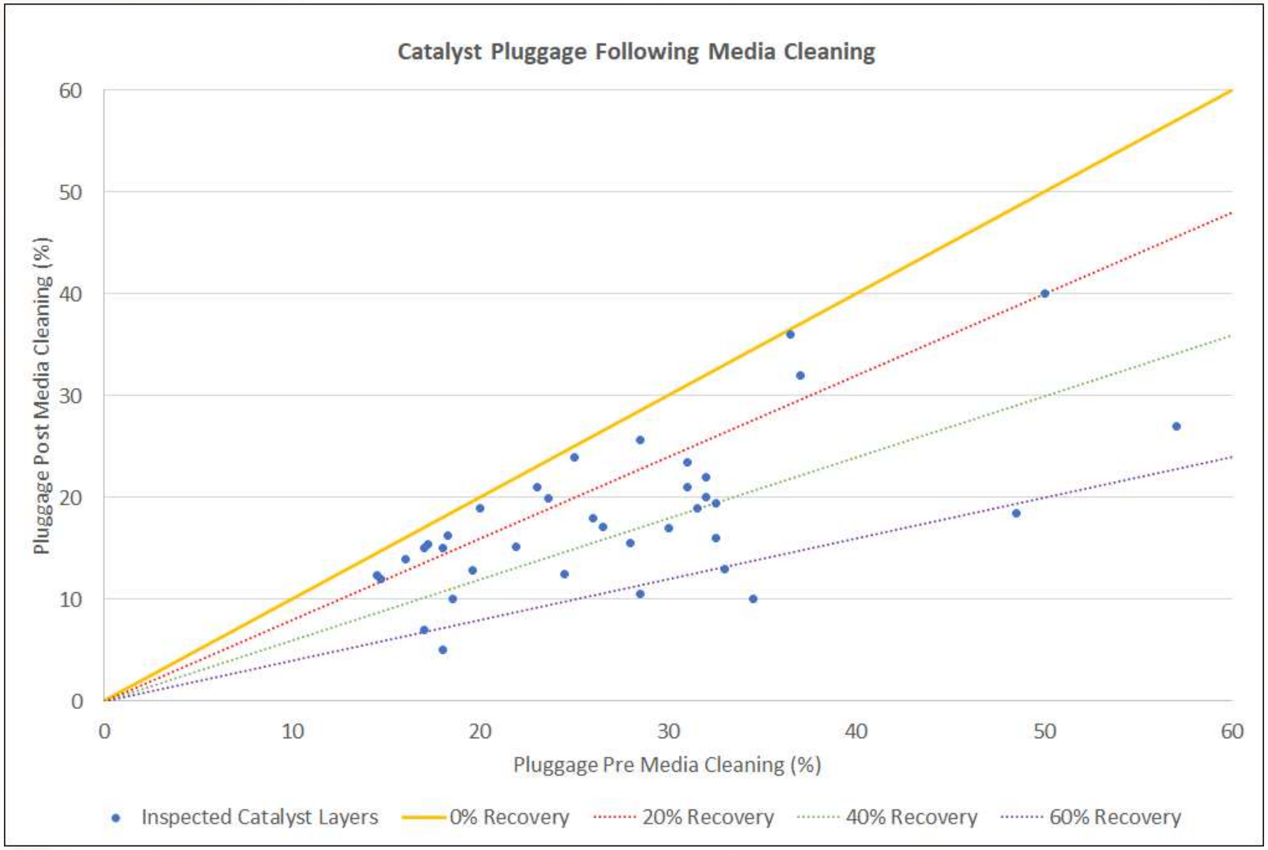
Catalyst Outage Cleaning

Cleaning Techniques

- Vacuuming
- Air lancing
- Dry ice cleaning
- Alternative methods
  - Media blasting
  - Vibration cleaning
- In development
  - Explosive cleaning (ethylene, detonation cord)

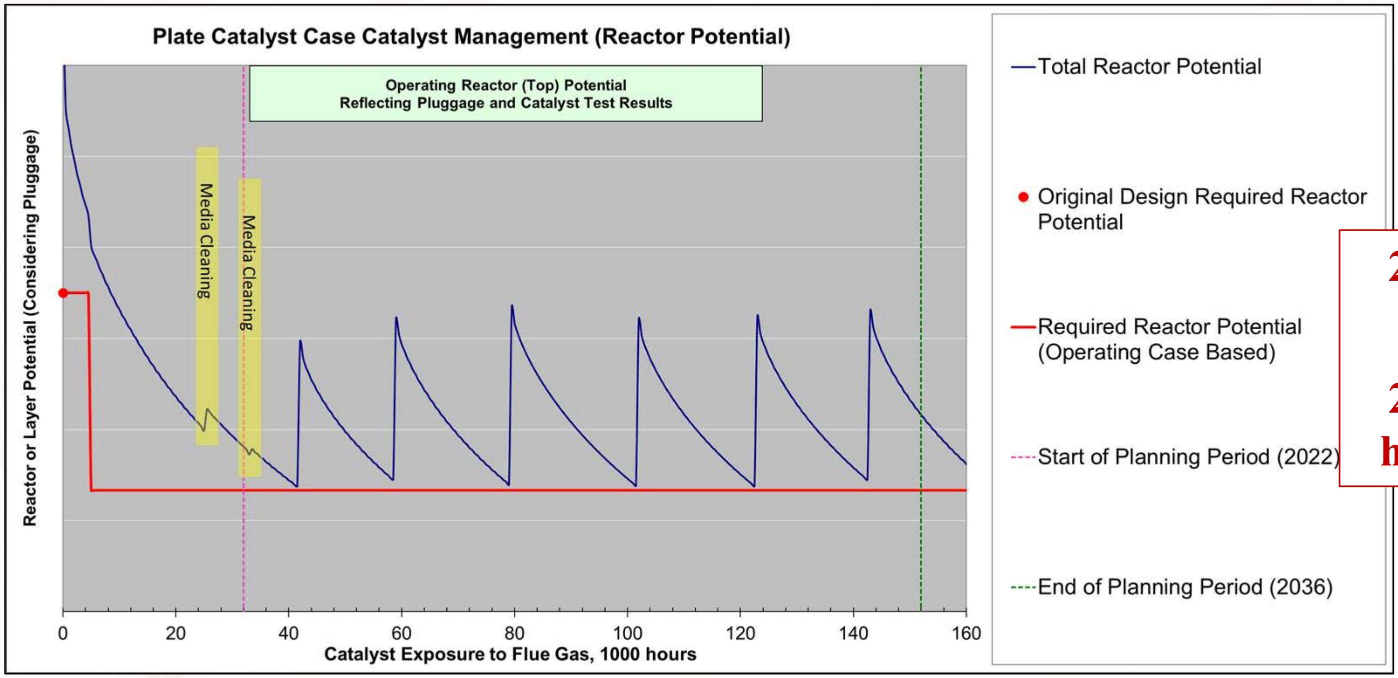
See CERAM 2023 Reinhold Presentation: Media Cleaning SCR Catalyst for High Dust Applications: Industry Observations and Best Practices

Media Cleaning Recovery Data



Do the Benefits Outweigh Costs & Risks?

- 7 mm Pitch 2 x 625 mm Plate
- 2021 Media Cleaning Reduced Pluggage from 23% to 15%
- 2022 Media Cleaning Reduced 20% to 17%



2021 Media Cleaning Improved the CMP

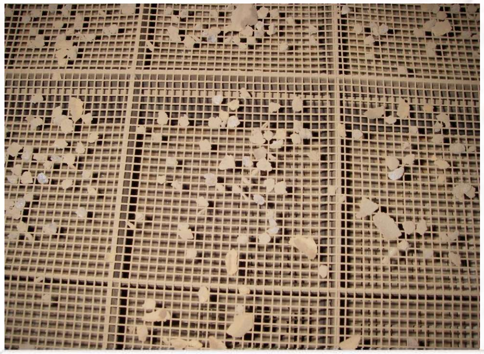
2022 Media Cleaning had Negligible Impact

LPA Screen – Regular Inspection and Repair

- Large Particle Ash (LPA)
  - Formed upstream of SCR
  - Readily plugs catalyst cells
- Some SCR Installations Require a Protective Screen
  - Upstream of catalyst, downstream of economizer
  - NOT catalyst cover grates
- Routinely Inspect and Repair
  - Cleaning reduces damage

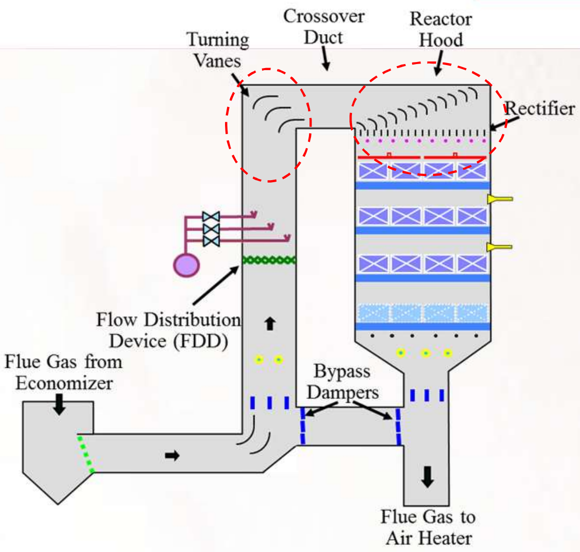
Clean Plugged LPA Screen Areas

A Small Hole Can Create Big Problems



LPA on Cover Grate (Last Defense)

Flow Distribution Devices



Seal Repair

> Seal Repair is Necessary to Prevent Flue Gas Bypass and Damage to the Catalyst Modules and Reactor Walls

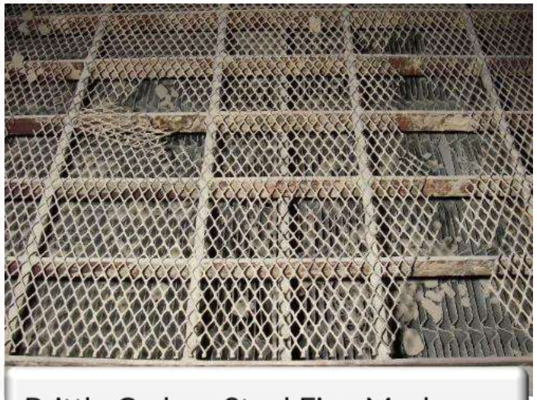
Module Damage

Wall Damage

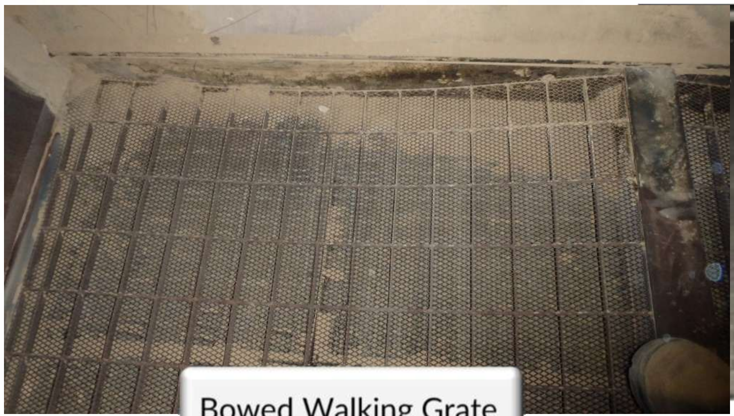
Module Shifting

Cover Grate Design

- Heavy Duty Walking Grate
- Large Open Area
- Fine Stainless-Steel Welded Wire
- No Clips or Welding
- Easy Removal For Inspection and Maintenance



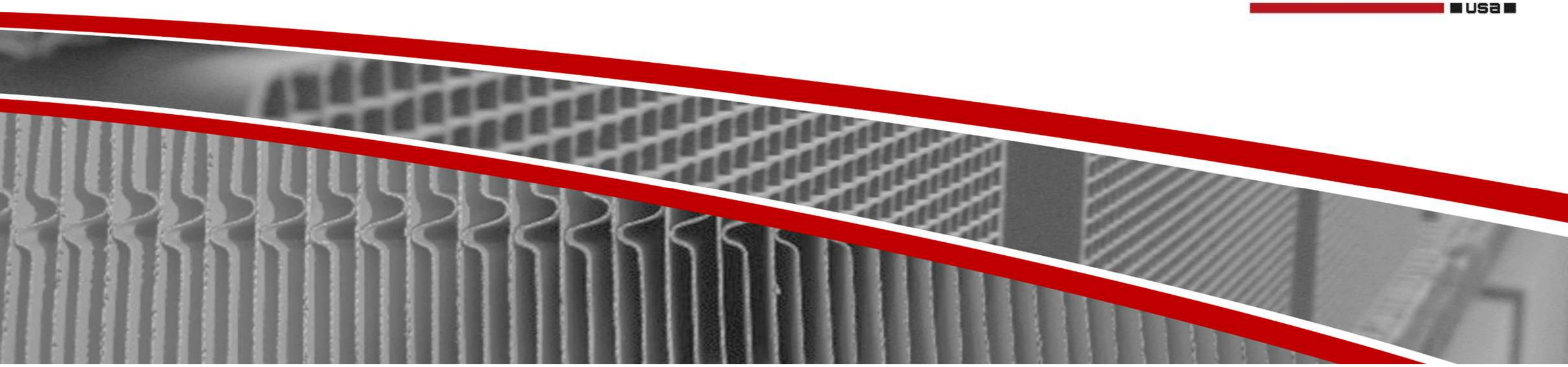
Brittle Carbon Steel Fine Mesh



Bowed Walking Grate

CERAM Cover Grate Easily Removed

Final Exam: Bringing it all Together



SCR System Operations Objectives

Maintain Desired Performance

- NOx Reduction Efficiency
- Ammonia Slip
- SO_2 Oxidation Rate
- System Pressure Drop

Maintain Unit Reliability

- Avoid Air Heater Pluggage
- Minimize SCR Catalyst Pluggage
- Meet Planned Unit Outage Schedule

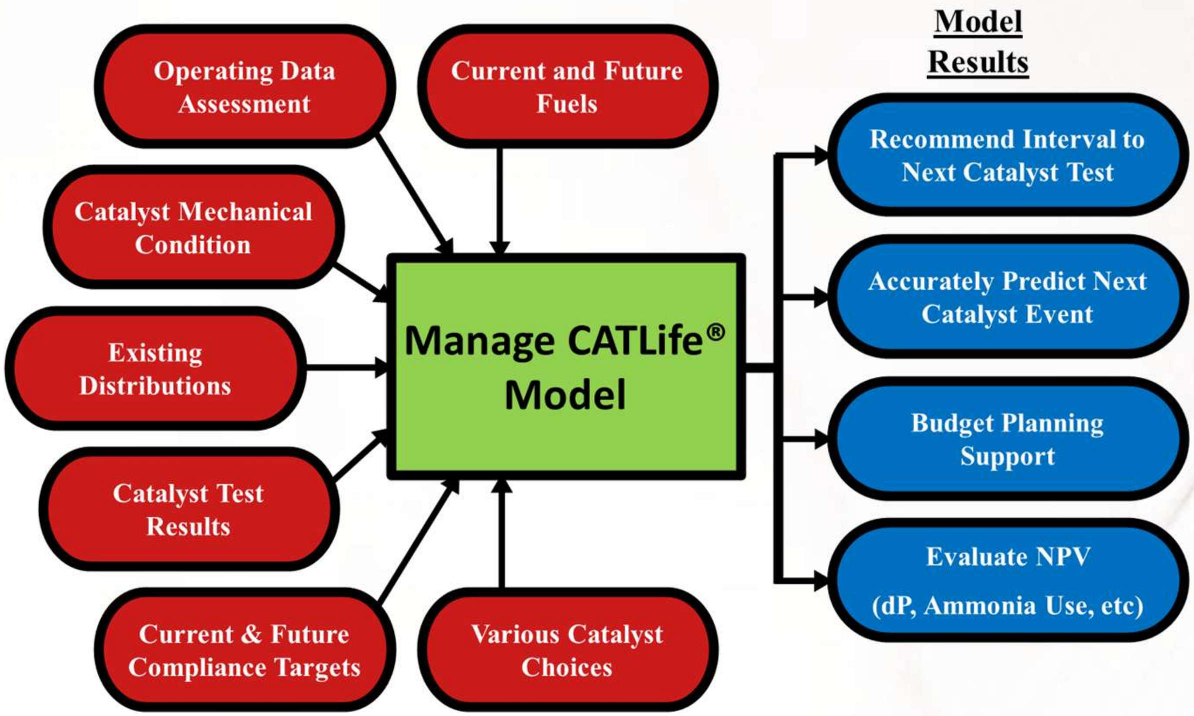
Reduce SCR Operating Costs and Risks

- Maximize Catalyst Utilization (Chemical and Mechanical)
- Minimize Pressure Drop (Aux Power) Impact
- Avoid BOP Problems (Air Heater / Visible Emissions)

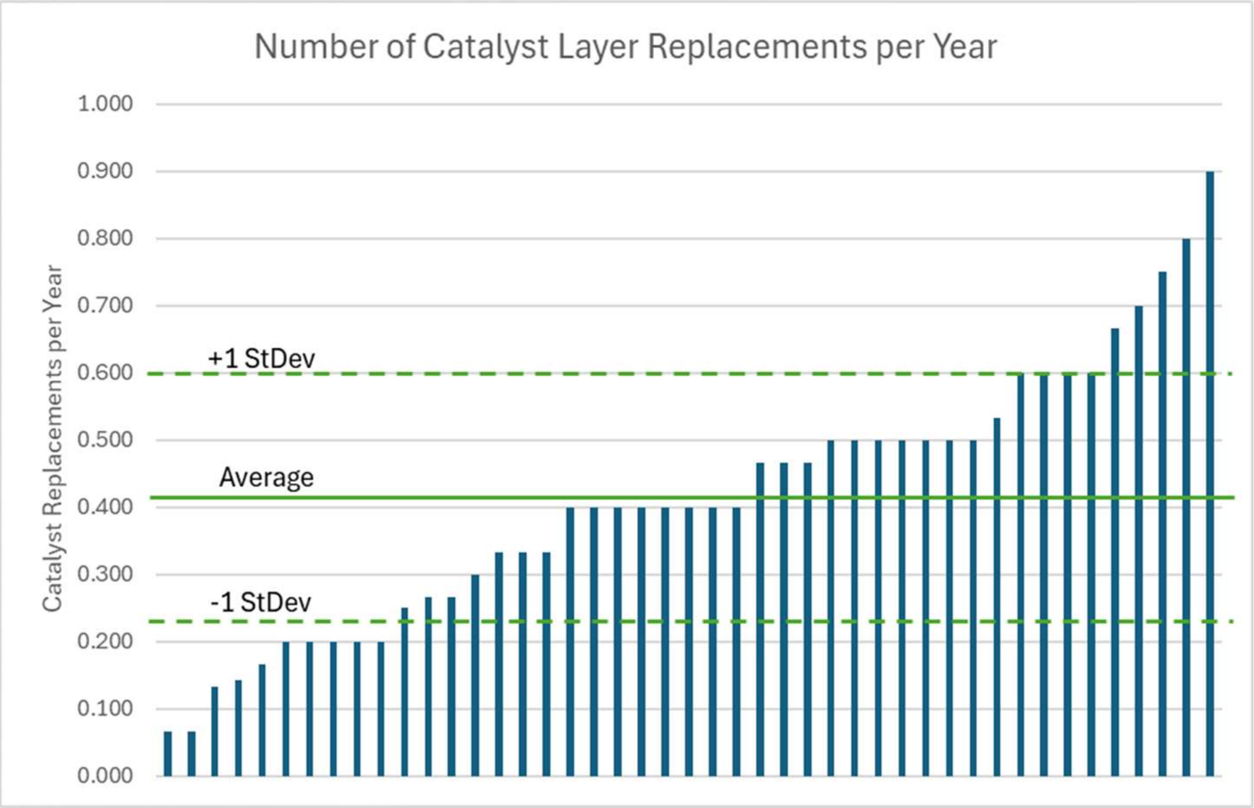
Catalyst Management
– Bringing it all Together

Actual Evaluation of:

- SCR Demand
- Catalyst Capabilities
- Ammonia Distribution and Control
- Aux System Ability



Proper Management = Reduced Catalyst Needs



- Summary of 45 CERAM Managed SCRs on Coal Fired Units (500 Unit-yrs)
  - Average 0.41 layer replacements per year
  - +1 Standard deviation 0.6 layers per year
  - ≤18 Month replacement cycles are rare

Case Study 1

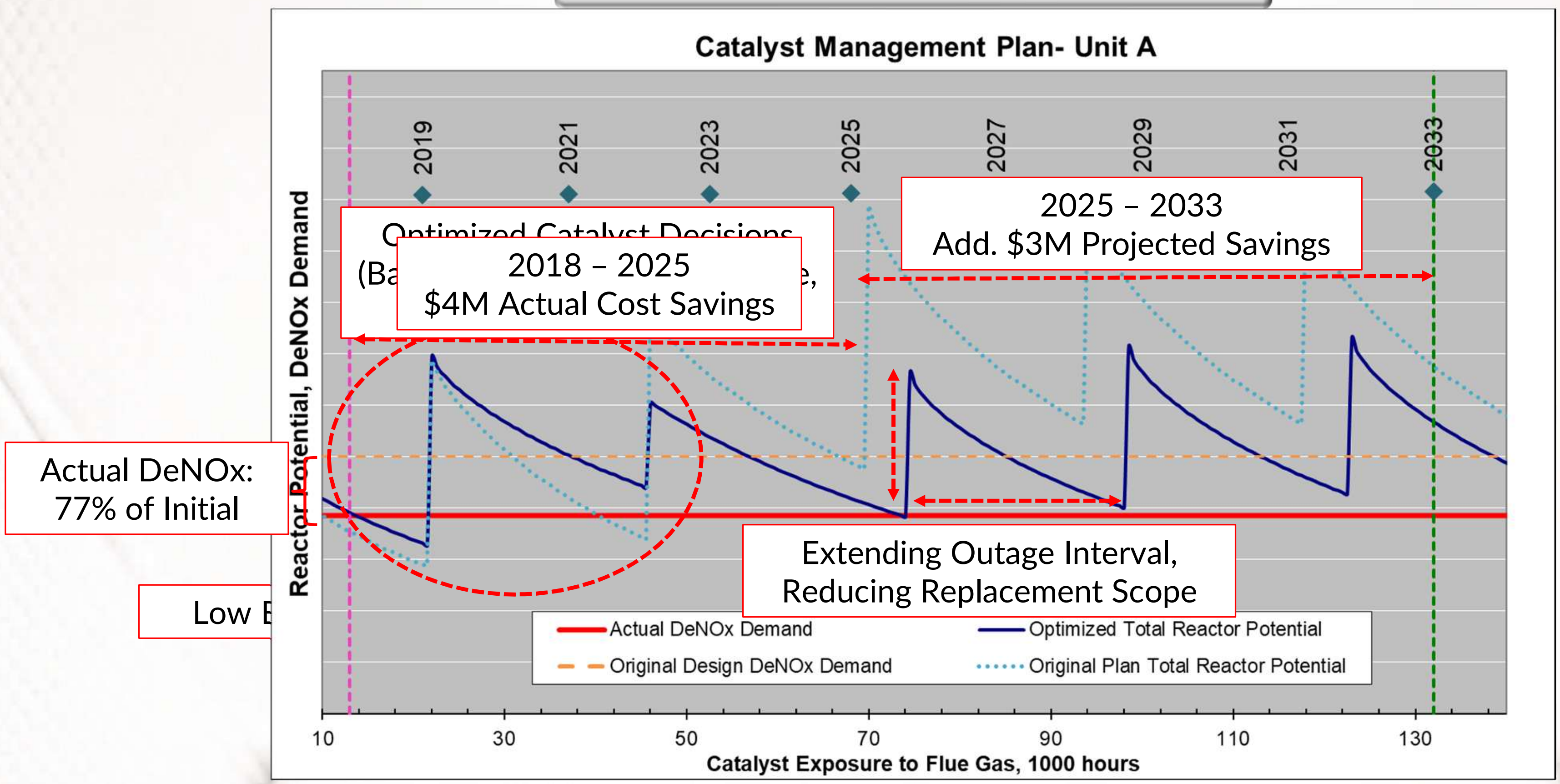
- Multi-unit Station >2,000 MW
  - ‘Shuffling’ cleaned and washed catalyst between units in cost savings effort
  - Installations of three layers per 30-month outage interval (washed and new)
- Catalyst Performance Evaluation
  - Over-valuation of used catalyst RP pre/post washing
  - Reactive cleaning vs. proactive new catalyst design choices
- DeNOx Demand Evaluation
  - Actual DeNOx demand ranged from 72% - 95% of design
- AIG Tuning and Ammonia System Performance Evaluation

Case Study 1

- Implemented Catalyst Management Plan
  - Multiple strategies developed
  - Focused on actual DeNOx demand and current operating reactor potential
  - Reduced replacements to one to two new layers per outage
  - Potential for $13M - $26M cost reduction over 15-year economic plan
    - ❖ Catalyst, in/out, aux fan costs, etc.
    - ❖ Does not include reduction in cleaning costs
- Realizations
  - Actual cost savings well within range
  - Increased outage interval to 36 months
  - Models continuously updating results with additional refinement
    - ❖ Operating hours, fuels changes, combustion changes, etc.

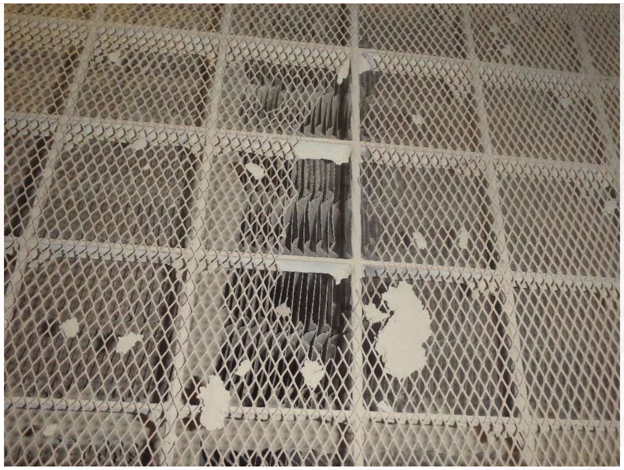
Case Study 1

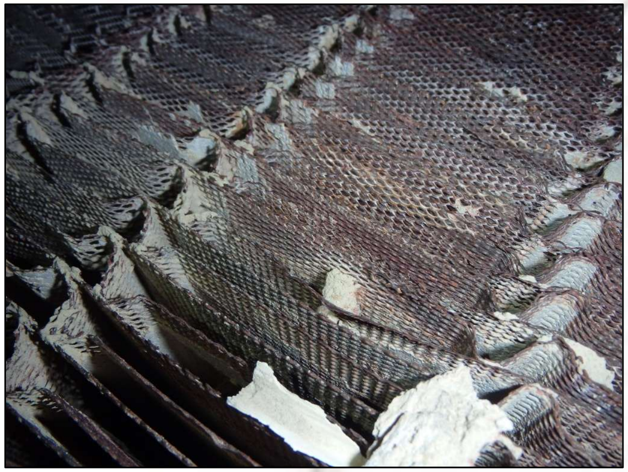
Optimized Plan



Case Study 2

- Single Unit, ~700 MW
  - High temperature (~820°F), high pluggage rates
  - Elevated slip
  - Actual DeNOx demand is 80% - 90% of design
    - But having trouble meeting performance?
- Catalyst Performance Evaluation
  - Original plate catalyst –lower temperature design
  - High rates of deactivation
  - Thermal sintering component
  - Poor mechanical condition of catalyst facilitating pluggage
    - Substrate metallurgy leading to delamination and brittle catalyst





Case Study 2

- Whole System Evaluation
  - LPA system performance and poor flow into SCR
  - Catalyst cleaning device maintenance
    - Removing ash sweepers from service spreads pluggage
  - Control system and operations oversight
    - Min load capability & high load performance
  - Catalyst selection is critical for operating life
  - Realizing reduced DeNOx opportunities takes BOP commitment
    - LPA screen upgrades, CFD, instrument maintenance
- Realizations
  - Pluggage and deactivation can be managed (not eliminated)
  - Longterm decrease in slip (20 ppm to 5 ppm)
  - 36-month outage interval, one – two layers per outage
  - $3M savings in 10-year economic plan

SCR Report Card

- SCR Demand is Frequently Lower than Design
  - Calculate actual demand based on operating data and SCR performance required
- Accurate and Routine Testing Needed to Confirm Catalyst Performance
  - Routine testing provides statistical representation and deactivation accuracy
  - Consider laboratory bias and testing tolerances
- Ammonia Distribution and Control
  - Ammonia and NOx need to be at the same place at the same time in the correct ratio
  - Know your ammonia control system logic and inputs
- Auxiliary Systems can Impact CMP – Know where problem areas exist
  - Flow correction devices, seals, cover grates, catalyst cleaning
- Bringing it All Together – How often do you replace catalyst?
  - Evaluate the entire SCR system (economizer through air heater)
  - Proper evaluation is proven to reduce CapEx and O&M costs while reducing performance risk