Southwest Power Conference
SCR Catalyst Management

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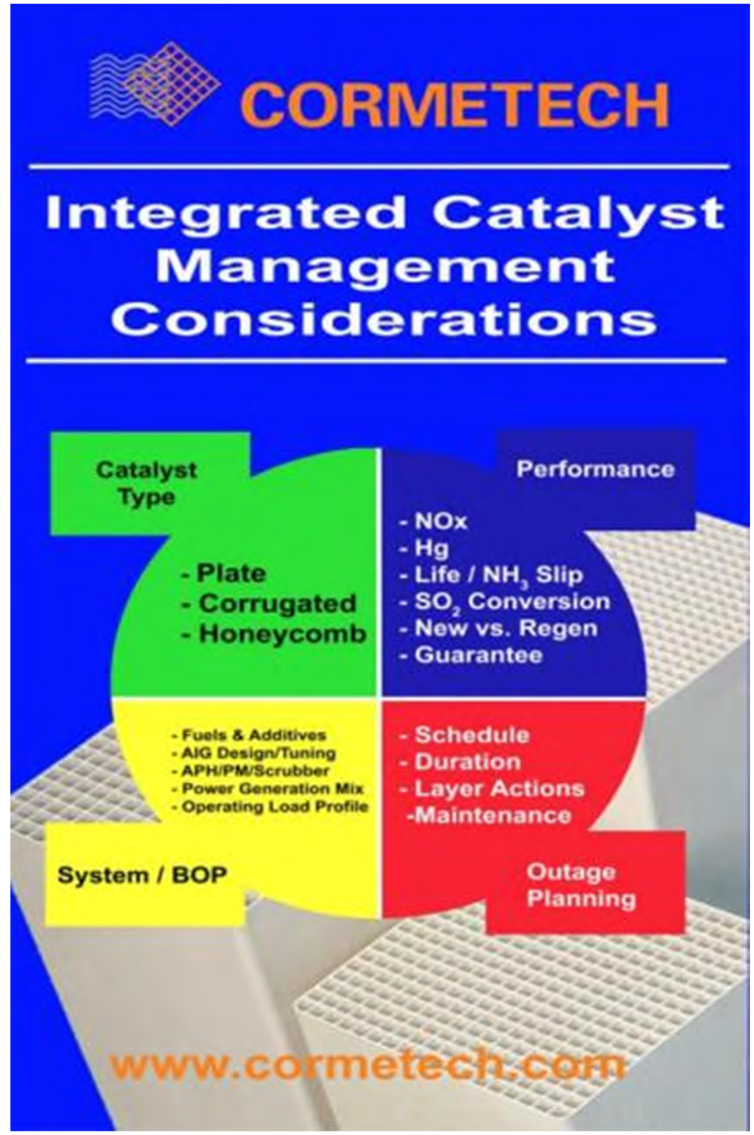
CORMETECH, INC.

SCR Leadership

- Industry
  - Experience: Over 1200 installations worldwide
  - Leadership: Largest installation base and capacity
  - Performance: Technological leader
- Natural Gas & Process Systems
  - NO_x Efficiency: > 95% Removal
  - Experience: > 750 installations worldwide
  - NH_3 Emissions: < 2 ppm and Zero-Slip™
  - Product Families: Operating temp's from Tail-end to 1,100˚F
- Solid Fuel Systems
  - NO_x Efficiency: > 95% Removal
  - Experience: > 175 installations worldwide
  - Largest experience in PRB Coals, First commercial mercury oxidation
  - SO_2 oxidation: guarantees of < 0.2%

SCR Catalyst Management

- Catalyst Design & Engineering
- Custom Module Systems
- Flow Modeling Service
- Just-in-time Delivery Management
- SCR System Design & Service
  - AIG/Mixers, Flue Gas Flow Devices, Static Mixers
- Performance Lifecycle Guarantees
- Installation Services
- Field Testing
- SCR Start-up Services
- Catalyst Lifecycle Management
- Laboratory Performance Testing & Diagnostic Services
- Restoration, Repair and Regeneration Services
- COMET™ – Cormetech Oxidized Mercury Emission Technology



SCR Catalyst Management

Overview

- SCR Catalyst Process
- NOx Reduction - System Design
- SCR System Management Plan
  - Performance Tracking
  - Preventative Maintenance
  - Replacement

SCR Catalyst –NOx Control

Nitrogen Oxides

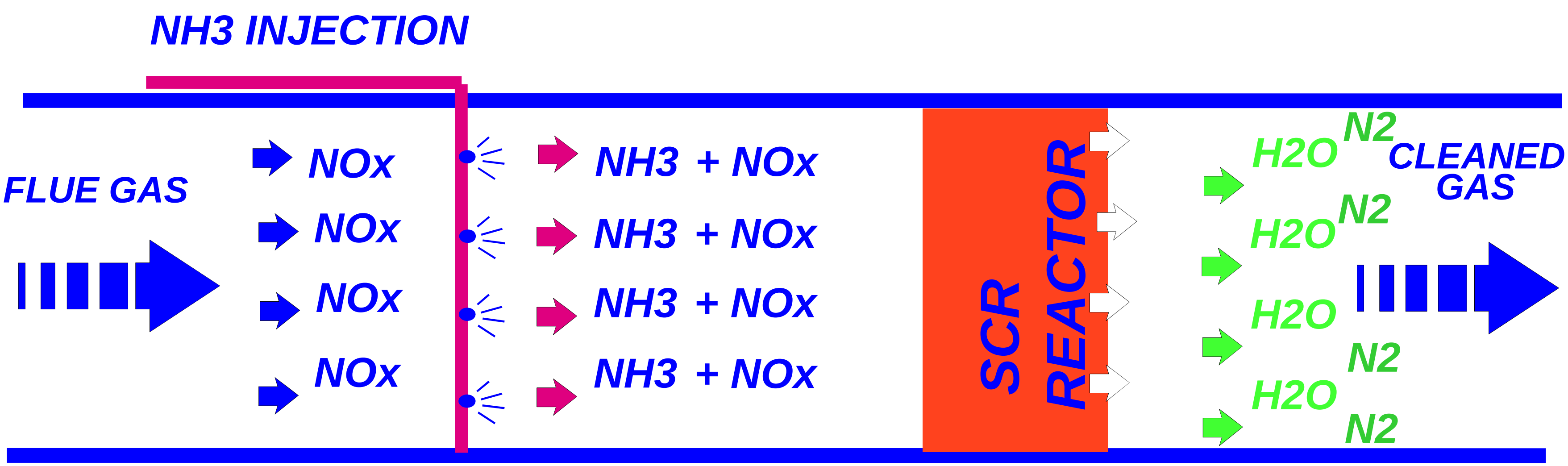
- NOx emissions are created during the combustion of fossil fuels.
- Environmental Protection Agency began to regulate NOx emissions in the early 1990's via the Clean Air Act. Site air permits limit the amount of NOx and possibly, ammonia which can be discharged into the air.
- The SCR system is designed to lower the outlet NOx concentrations to meet the air permit criteria.

SCR Catalyst Process

$$NO + NO_2 + 2NH_3 \xrightarrow{\text{Cormetech Catalyst}} 2N_2 + 3H_2O$$

$$4NO + O_2 + 4NH_3 \xrightarrow{\text{Cormetech Catalyst}} 4N_2 + 6H_2O$$

$$6NO_2 + 8NH_3 \xrightarrow{\text{Cormetech Catalyst}} 7N_2 + 12H_2O$$



SCR Catalyst – Materials

- Catalytically active components
  - V_2O_5, WO_3
- Types include:
  - Homogeneous honeycomb- all catalyst
  - Coated substrates – plate/fiberglass
- Design temperatures: 350 - 1000^{o}F

Product Selection: Formulation

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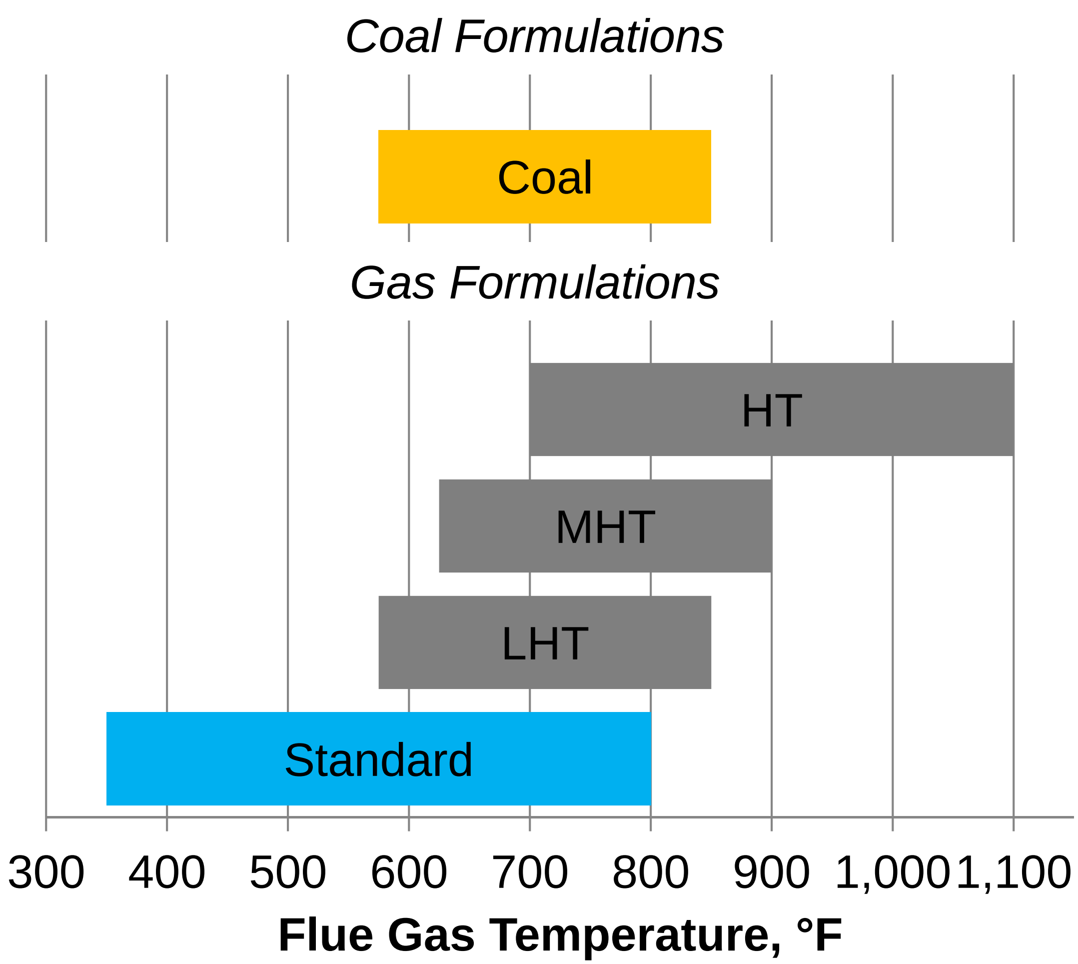
Product Selection Based on Application and Operating Temperature Ranges



*These are **guidelines** only. Product selection may be impacted by the operating scenario, design approach, and time at a given temperature.*

What drives the temperature limits?

Low temperature

- Coal: ABS formation
- Gas: ABS formation and catalyst activity

High temperature

- Coal: SO_2 Oxidation
- Gas: thermal degradation, NH_3 oxidation, and catalyst activity (different formulations for different maximum operating temperatures)

SCR Catalyst Modules-Gas

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SCR Catalyst Modules-Coal

SCR Catalyst – Design

- SCR catalyst design is very site specific
- Key parameters:
  - Flow
  - Duct configuration
  - Pressure drop
  - Temperature
  - Inlet NOx
  - Life

SCR System Design

- Operating Characteristics:
  - Maldistribution Criteria
    - » Flue Gas Flow
    - » Temperature
    - » NH_3:NOx molar ratio

SCR System Design

- Sources of Maldistribution
  - Flow
    - Turbine
    - Duct configuration
    - Poor modeling
    - Damaged or missing seals
  - NOx
    - Turbine
    - Duct Burners
    - Transient loads

SCR System Design

- Sources of Maldistribution
  - Ammonia
    - Lance design
    - Structure
    - Edge effects
    - Thermal
    - Balancing
    - Fouling
    - Flow

SCR System Design

- Performance Guarantees
  - NOx Outlet, ppmvdc
  - NH3 Slip, ppmvdc
  - Pressure Drop – across catalyst
  - Design Life, hours

SCR System Design -HRSG Example

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Product:	Honeycomb CM 2.1
Fuel:	Natural Gas / Oil
Flow Rate:	4,000,000 lbs/hr
Temperature:	650° F
Inlet NOx:	45 ppm
Distribution:	Velocity - 10% RMS
	Temperature +/- 20 F
	NH3/NOx - 15%RMS
Field Performance:	Outlet NOx - 2 ppm – NG
	- 8 ppm No. 2 Oil
	NH3 slip - 5 ppm
	Pressure Drop - 1.9 " wg
	Warranty - Five years

HRSG Units

2 Units *- (360 MW) Gas Turbines (Frame 7FA)*
NOx*: 45 → 2.0 ppmvd*
NH_3 Slip*: 5.0 ppmvd*
Guaranteed Operating Time*: 35,000 hrs (5 years)*

SCR Design –Simple Cycle Example

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Product:	Honeycomb CM MHT 2.1
Fuel:	Natural Gas
Flow Rate:	1,000,000 lbs/hr
Temperature:	845° F
Inlet NOx:	25 ppmvdc
Distribution:	Velocity - 15% RMS
	Temperature +/- 30 F
	NH3/NOx - 10%RMS
Field Performance:	Outlet NOx - 2.5 ppm – NG
	NH3 slip - 5 ppm
	Pressure Drop – 3.5 “ wg
	Warranty - 12,000 hrs /five years

Simple Cycle Units

4 Units *- (45 MW) Gas Turbines (LM6000)*
NOx*: 30 → 2.5 ppmvd*
NH_3 Slip*: 5.0 ppmvd*
Guaranteed Operating Time*: 10,000 hrs (5 years)*

SCR Catalyst Management

- Performance Baseline
  - Site Data
    - Reporting Data - CEMS
    - Ammonia Flow
    - Pressure Drop
    - Annual RATA

SCR System Performance

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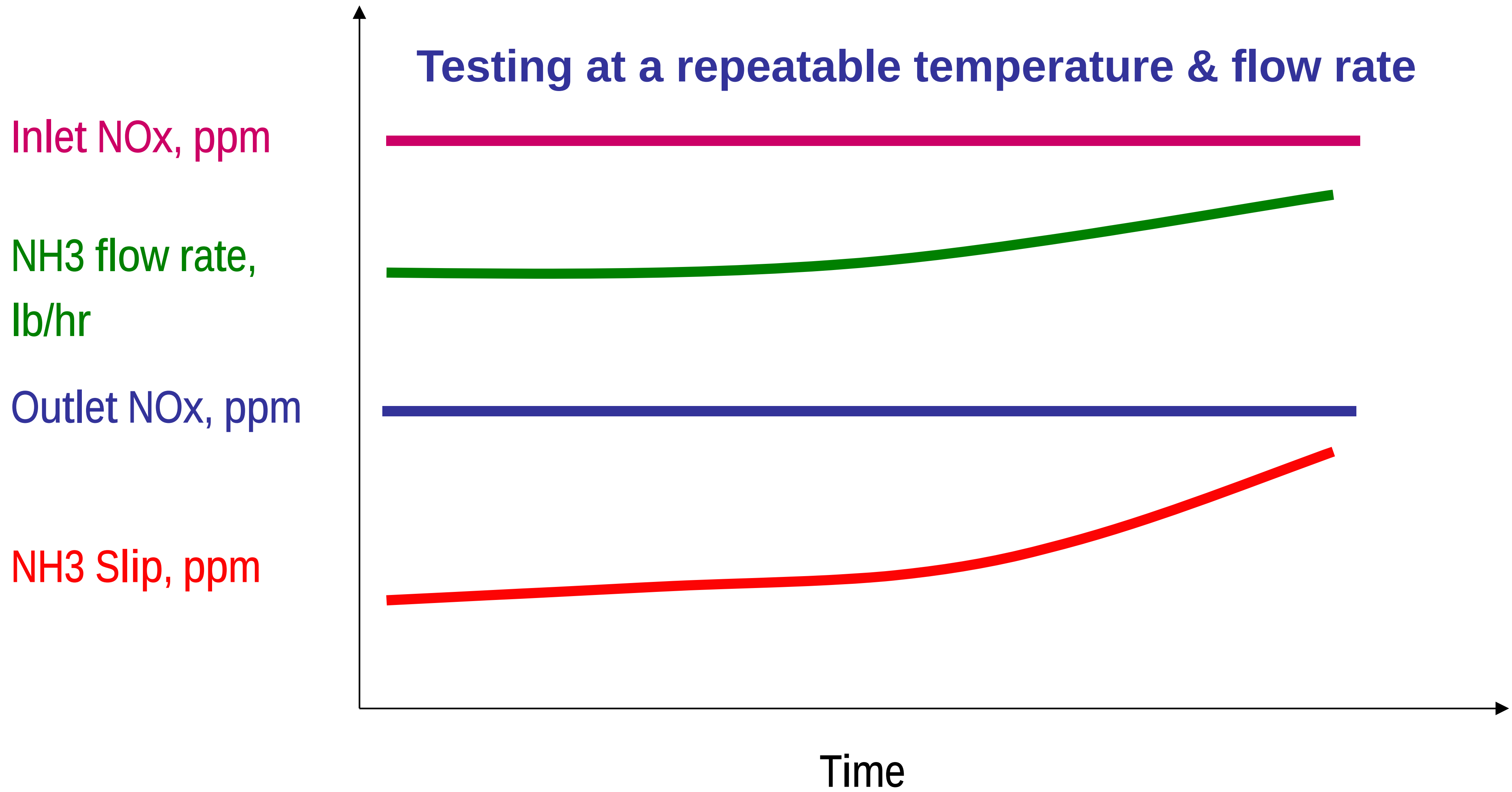


SCR Catalyst Management

- Performance Baseline- Operating System
  - SCR Catalyst
    - Testing
    - Deactivation
    - Inspection
  - Ammonia Injection
  - Distribution Devices

Catalyst Testing

- Catalyst Performance Evaluation and Reporting:
  - Assessment of Field Operating Data
  - Diagnostic Laboratory Testing - determines remaining catalyst potential in controlled environment
  - Prediction of Remaining Life – analysis of trends in laboratory test results and field operating data over time is compared to engineering models and data from similar units to make prediction

Growth and Resources

Laboratory & Services

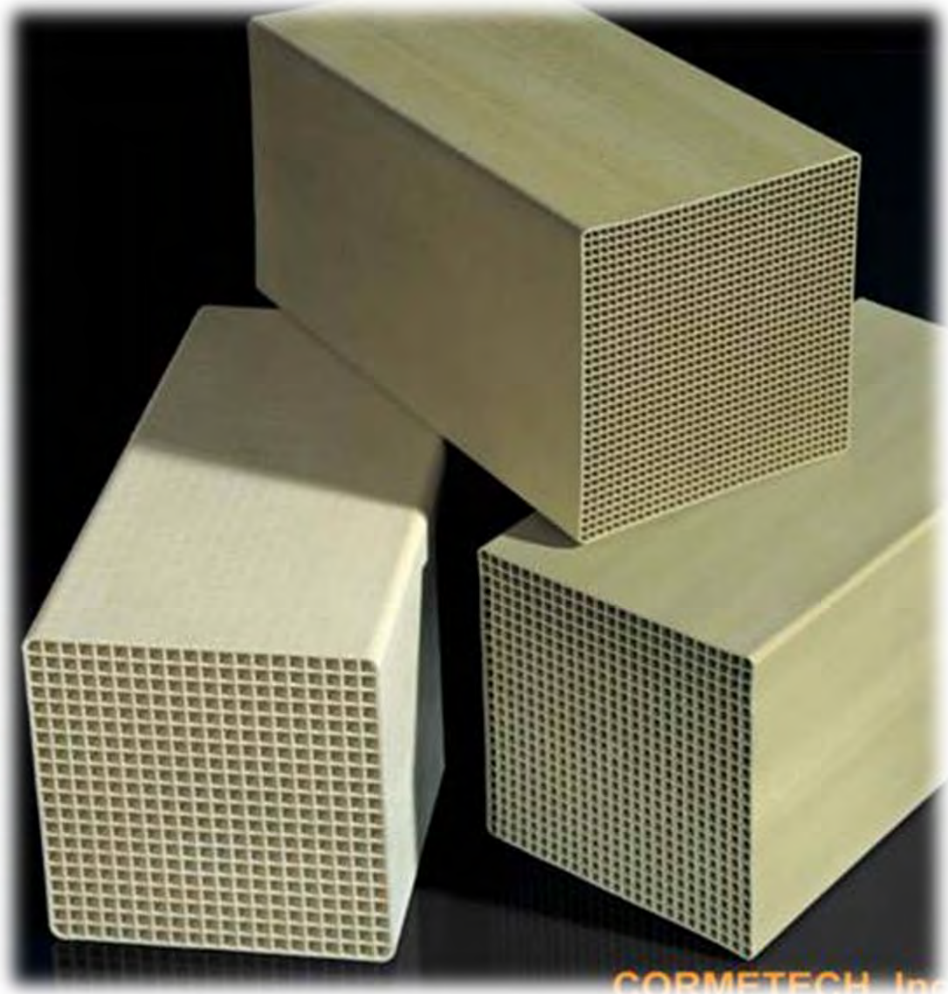
- Laboratory and Resource Improvements
  - Renovated laboratory and added equipment
    - CCSEM
    - TGA
  - Single and multi-channel micro
  - Pilot reactors
  - Bench reactors
  - BET Surface area analysis
  - Hg Porosimetry Analysis
- Comsol® – Multiphysics and Modeling Simulation Software
- Continued collaboration with MHI, universities, slipstreams, etc. to advance knowledge in areas such as Hg oxidation, biomass co-firing, etc.

Catalyst Activity Testing

Predict Working Life

Evaluate Field Performance

Evaluate Additional Capability



SCR Catalyst Management

- SCR Catalyst Testing
  - Evaluate under operating conditions
  - Sample frequently
  - Reporting – require clarity
  - As Part of Root cause analysis

SCR Catalyst Testing Example

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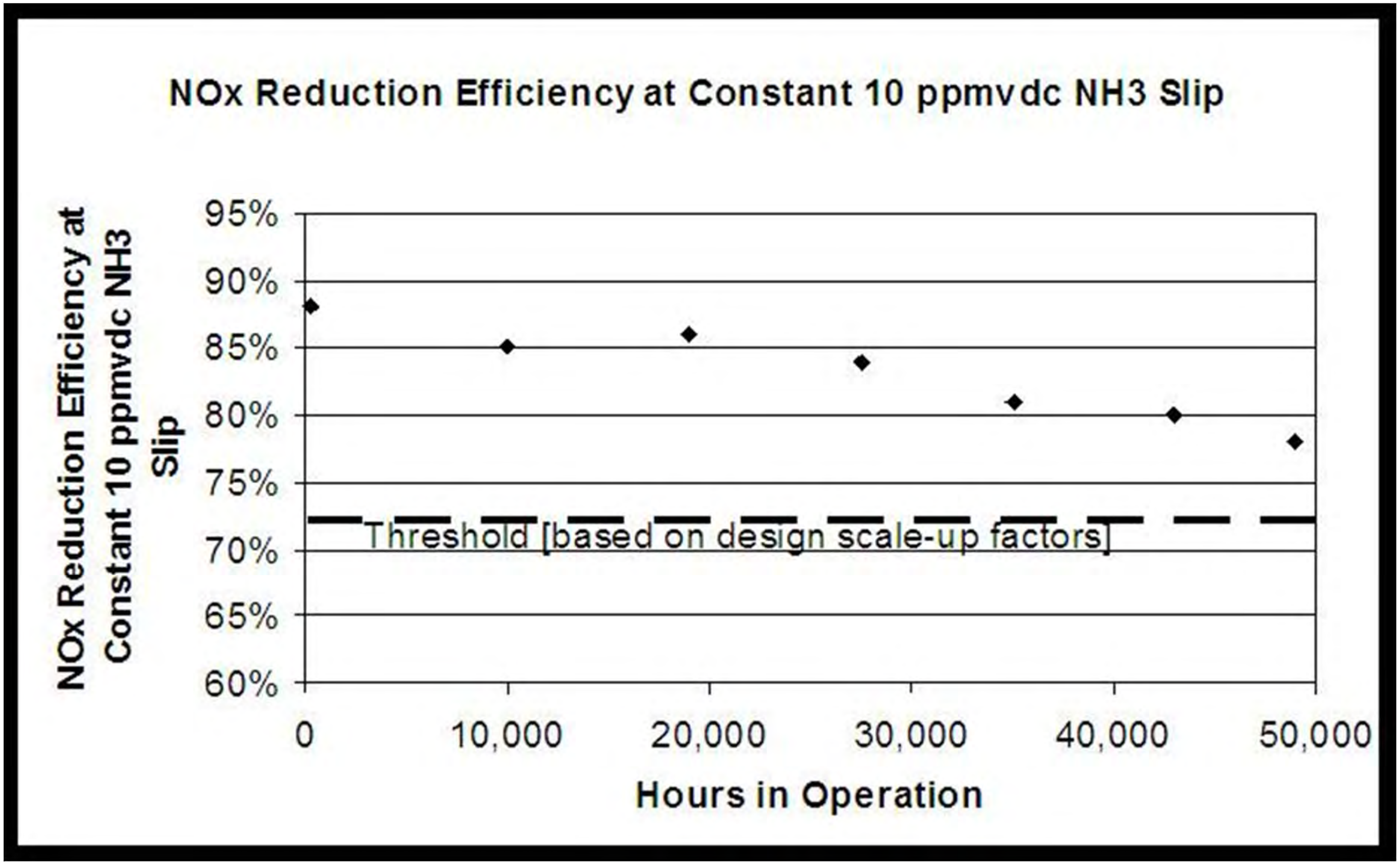

Deactivation Mechanisms

- Liquid Contact
- Thermal Excursions
- Poisons

SCR Catalyst Management

- SCR Module Inspection
  - Sealing
    - Within SCR module – catalyst elements
    - SCR module to reactor frame
    - SCR reactor frame to duct wall housing ("skin")
  - Cleanliness
    - Fouling of catalyst inlet

SCR Catalyst Management

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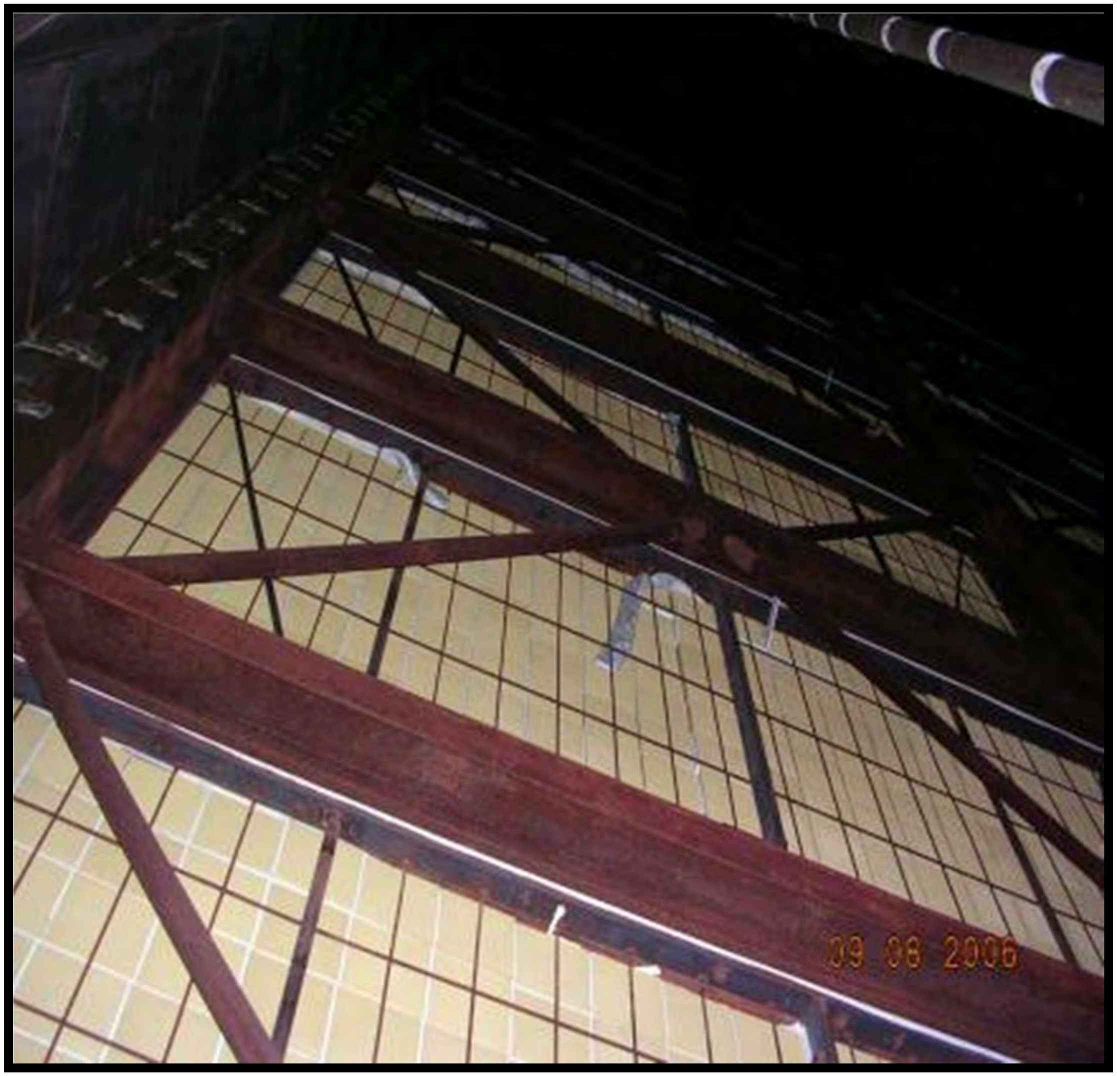
- With frame sealing loss



SCR Catalyst Management

- Cracked duct seal

- Repaired top seal

SCR Catalyst Management

Insulation buildup – inlet to catalyst

SCR Catalyst Management

- Ammonia Injection System
  - Distribution
  - Minimum Temperature
  - Capacity

SCR Catalyst Management

- Ammonia Injection Grid (AIG)
  - The ammonia injection system *delivers ammonia gas across the inlet flue gas stream.*
  - The ammonia must *mix thoroughly with the flue gas to enable the NOx reduction.*
  - Ammonia maldistribution may result in
    - Excessive ammonia conc. (high ammonia slip) or
    - Starved areas (high NOx outlet) in localized areas
    - Usually some combination of the above

AIG Distribution- External

AIG Distribution- Internal

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Vertical - HRSG

Horizontal – Simple Cycle

SCR Catalyst Management

Demand aqueous ammonia quality!

- **<u>Technical grade</u>**
- Deionized water
- Chemical analysis certification

Fouled Ammonia Vaporizer Pall Ring

SCR Catalyst Management

Ammonia System Maintenance

Inspection points:

- Lances
- Vaporizers
- Piping network
- Air blowers

Hot Dilution Air Fan.

SCR Catalyst Management

AIG performance…do you need to perform ammonia injection tuning?

- Are you meeting performance?
- Save money on ammonia?
  - Tuning cost are high
  - Site specific i.e. permanent grid, test ports, etc.
- Economizer tubes salting up?

NH3-NOx Modeling

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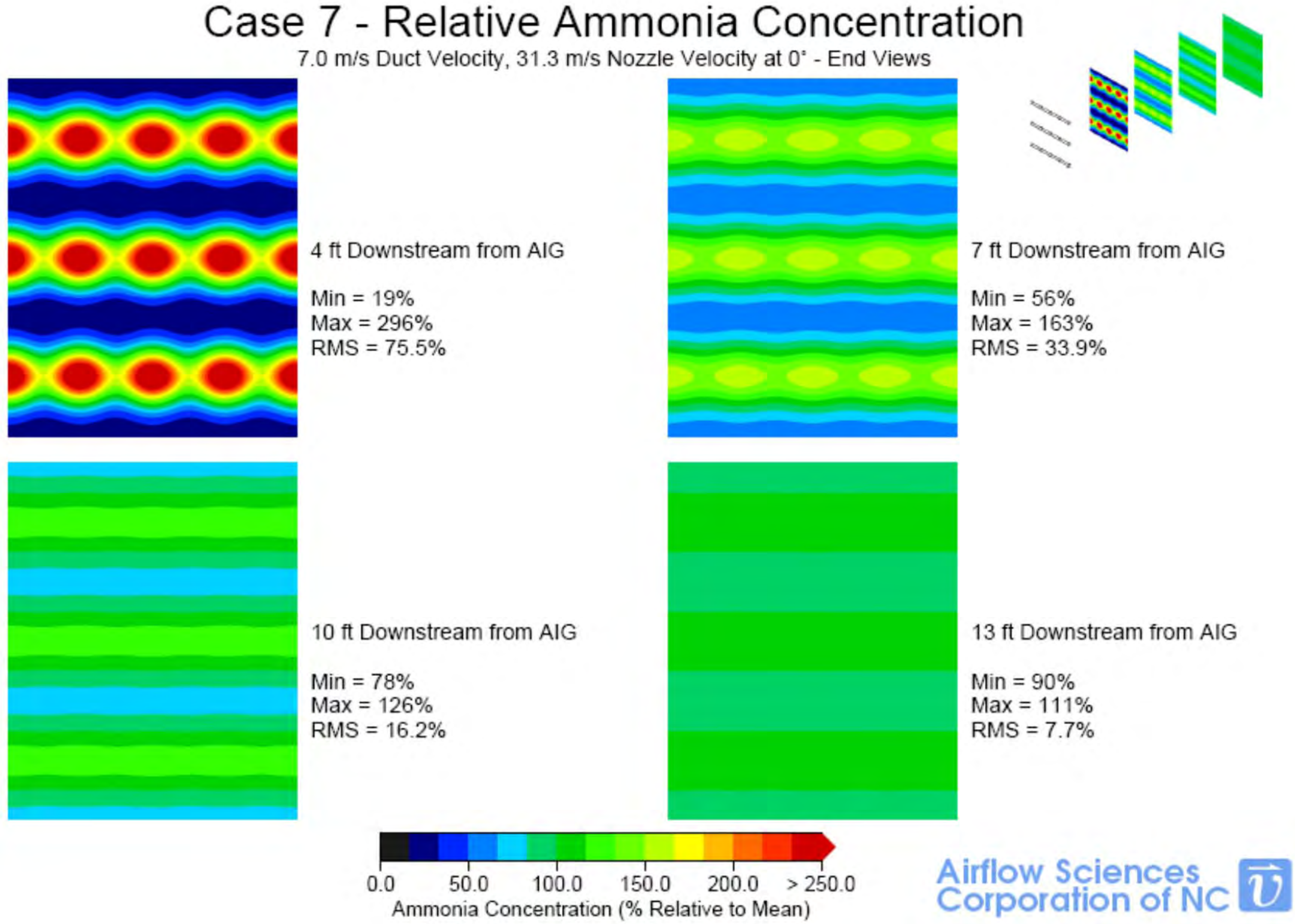


AIG Modification

Before

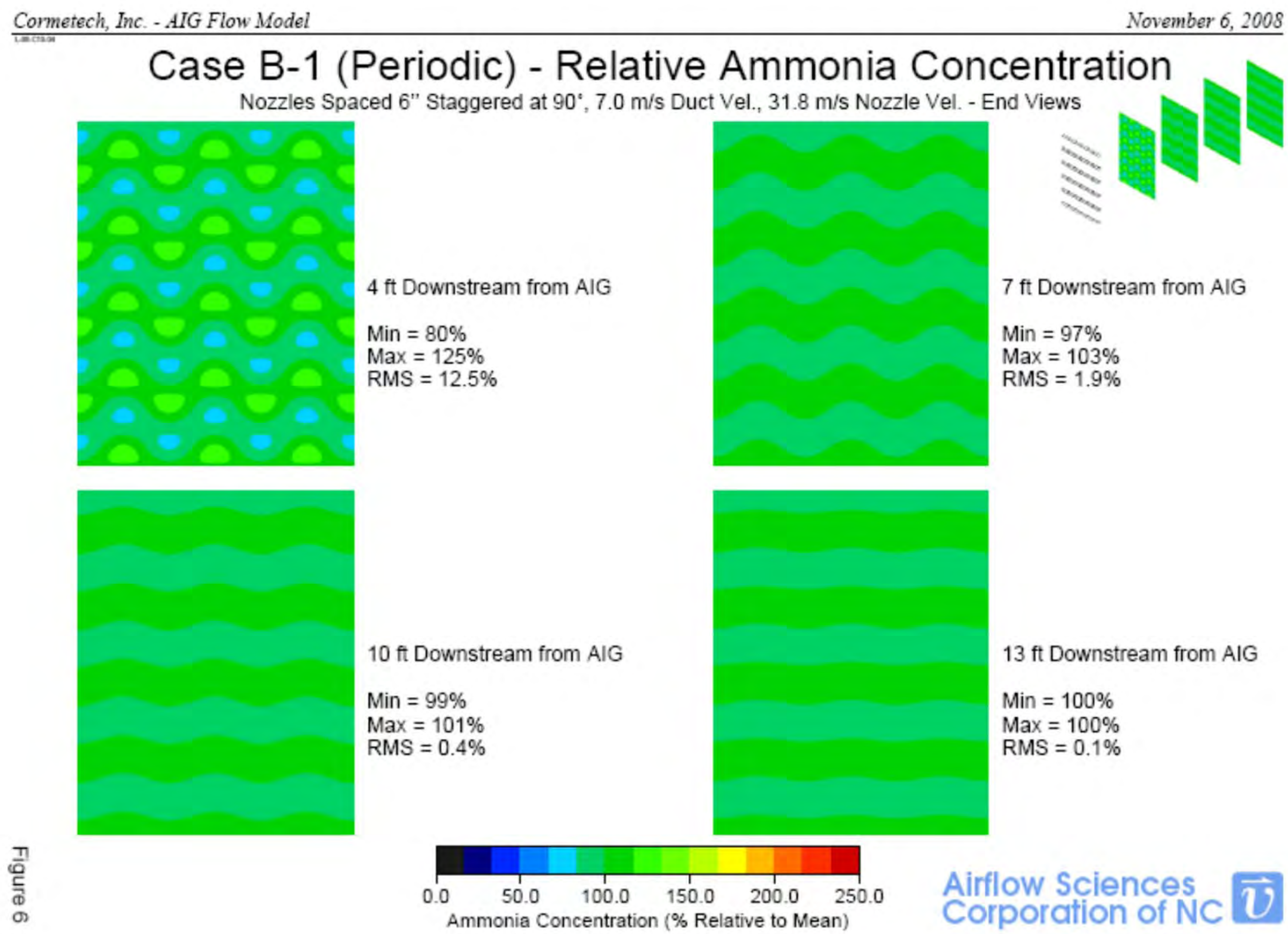
1) ***Increased pipe/nozzle density***

2) ***Minimized header bypass***

3) ***Confirmed applicability of perforated plate influence***

After

Optimized NH3-NOx Mixing



SCR Catalyst Replacement

Budgeting

- Post performance warranty period

Planning

- Catalyst testing reveals loss of performance
- High ammonia flow: indicator of concerns, *investigate*
- Changing operational conditions

Timing

- Twelve to eighteen months

SCR Catalyst Replacement

SCR Catalyst Replacement

SCR Catalyst Management

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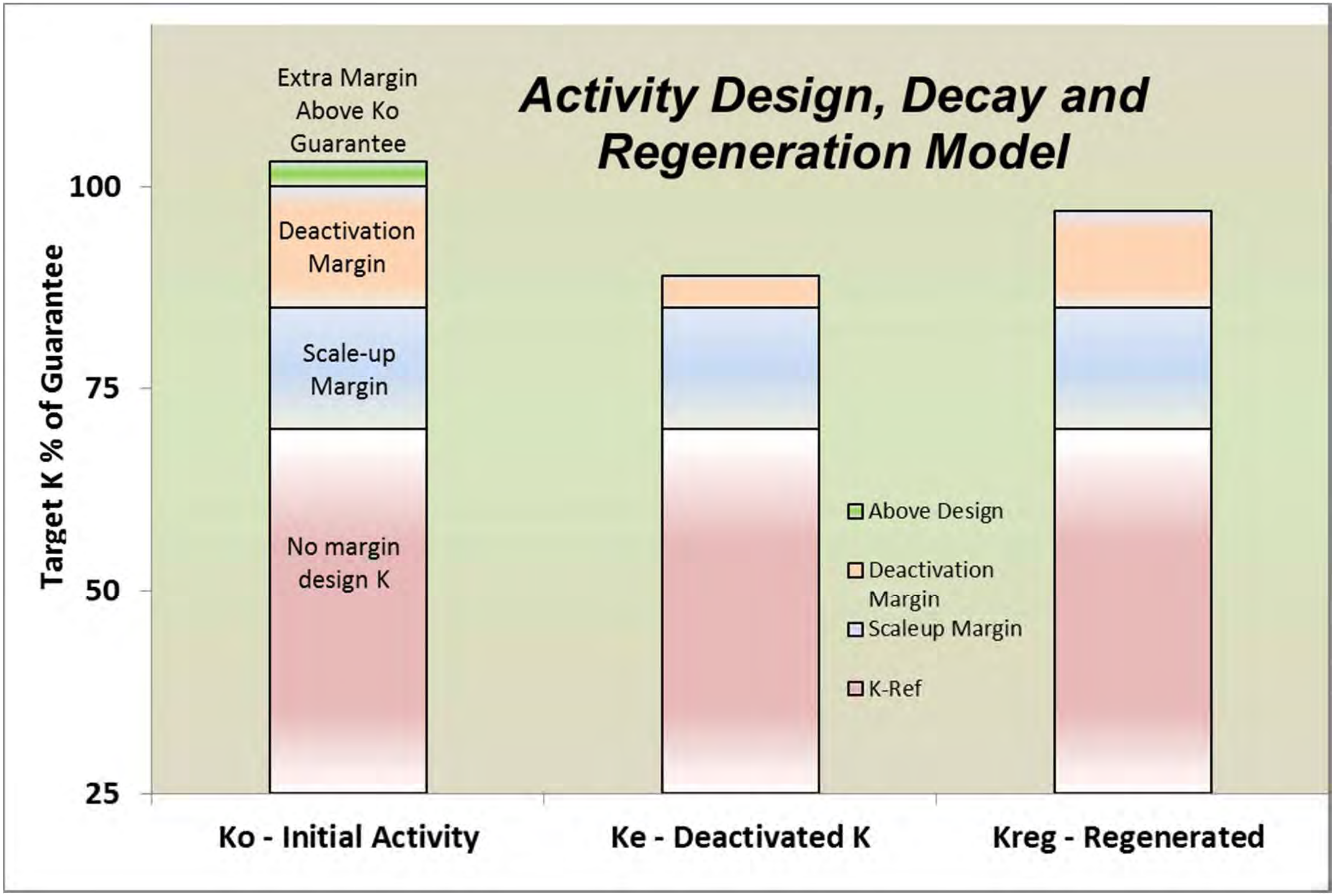
Spent Catalyst Options

- Regeneration
- Disposal

Regeneration – Coal Experience



Regeneration vs. Alternative Actions

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- Applicability Considerations
- Regeneration Processes are Designed for **Coal-Oil Fired Catalysts**
  - Deactivation caused by Fouling, Ash Build-up, Arsenic, Phosphorous, Calcium Sulfates
  - Clean with aqueous based solution in acid/base
  - Re-apply catalyst metals in a low concentration bath
  - Balance trade-off of NO_x and SO_3
  - Catalyst Deactivation of 30-60% vs New before Processing
  - Regeneration of a single layer of 3 or 4 reduces measured impact of a given action
  - Catalyst modules are standardized, easing logistics

Regeneration vs. Alternative Actions

- Applicability Considerations
- **Challenges of Regenerating Gas-Fired Catalysts**
  - Deactivation predominately caused by Loss in Reactive Surface Area from thermal fatigue or catalyst material loss (coated materials).
  - Formulation balance is notably different and may not benefit from vanadium addition
  - Deactivation of 10-20% vs New before Processing
  - Consistency and stability required
  - Most gas-fired systems operate with a single layer, therefore the reliability and long-term behavior stability is more critical.
  - Modules are customized for each facility therefore the process tanks and equipment may not be as efficient, a case by case consideration

Catalyst Disposal

- TCLP analysis to determine waste characteristics:
    - *<u>Hazardous</u>* or *<u>Non-hazardous</u>*
- Disposal – Landfill Option
- Recycle – Opportunity TBD?
    - (Economics of Recovery)
- Landfill Cost < Recycle

SCR Catalyst Management

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- Track Ongoing SCR Catalyst Performance
- Establish SCR System Preventative Maintenance Program including Routine Testing
- Replace Gas Catalyst only as required per above. Typical time is five- seven days per unit.
- Gas Catalyst Regeneration – Unproven; requires trial and evaluation of suitability (qualification testing)

SCR Catalyst Management

SCR catalyst management of gas fired vs. coal fired units is substantially different.

Today's presentation has focused on issues concerning gas fired units.

I am available to discuss coal fired SCR catalyst management- please contact me.

SCR Catalyst Management

Questions ???