



Durability of NOx Absorbers

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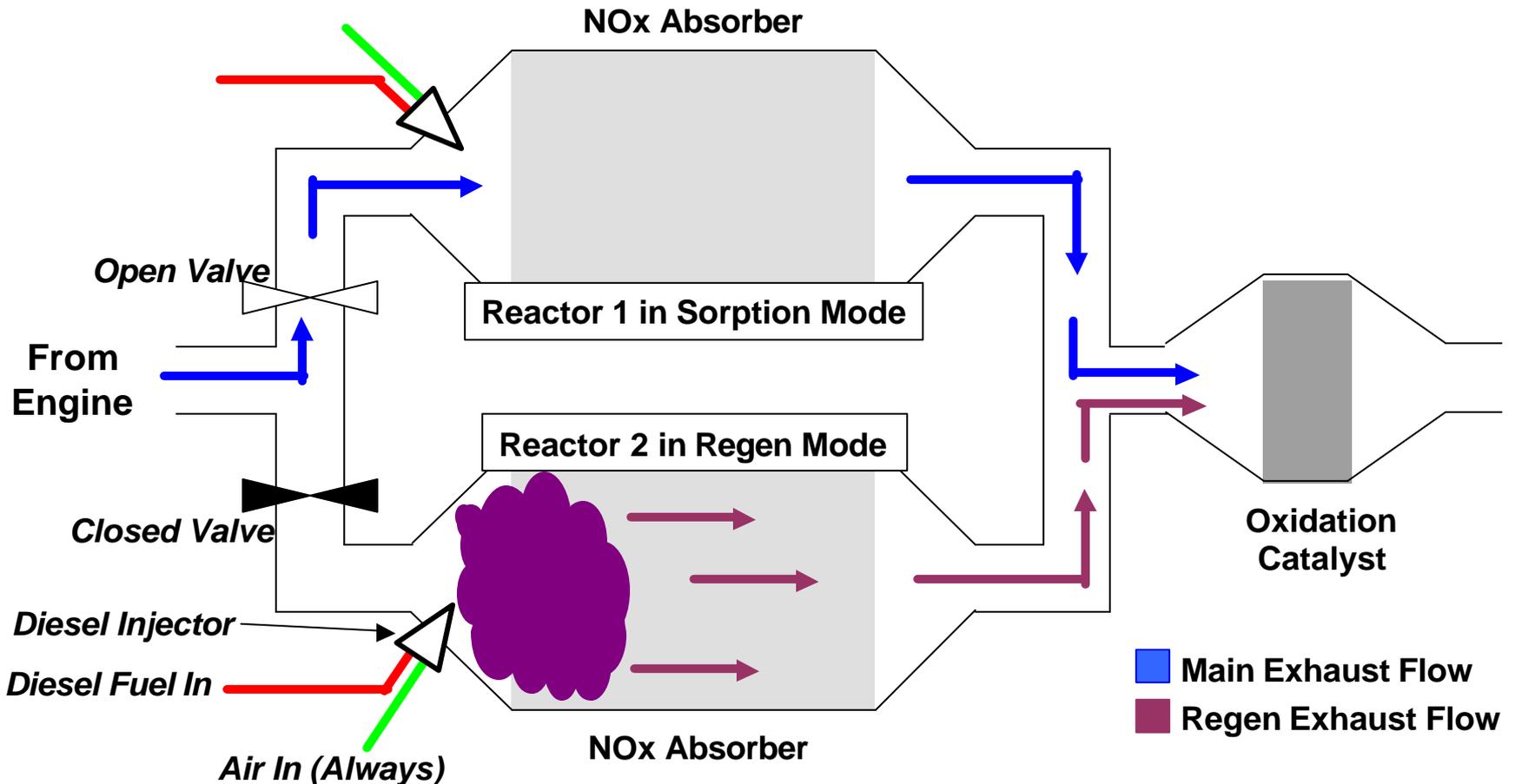


Achieving Product Status with NOx Absorber Catalysts

- NOx Absorber Technology is Clean Enough for NOx Emission Regulations
 - >90% NOx Reduction Demonstrated
- Durability is Main Criteria to be Demonstrated
 - Sulfur Masking of NOx Storage Sites is Most Significant Durability Issue
 - Other Degradation/Deactivation Mechanisms Are Also Important

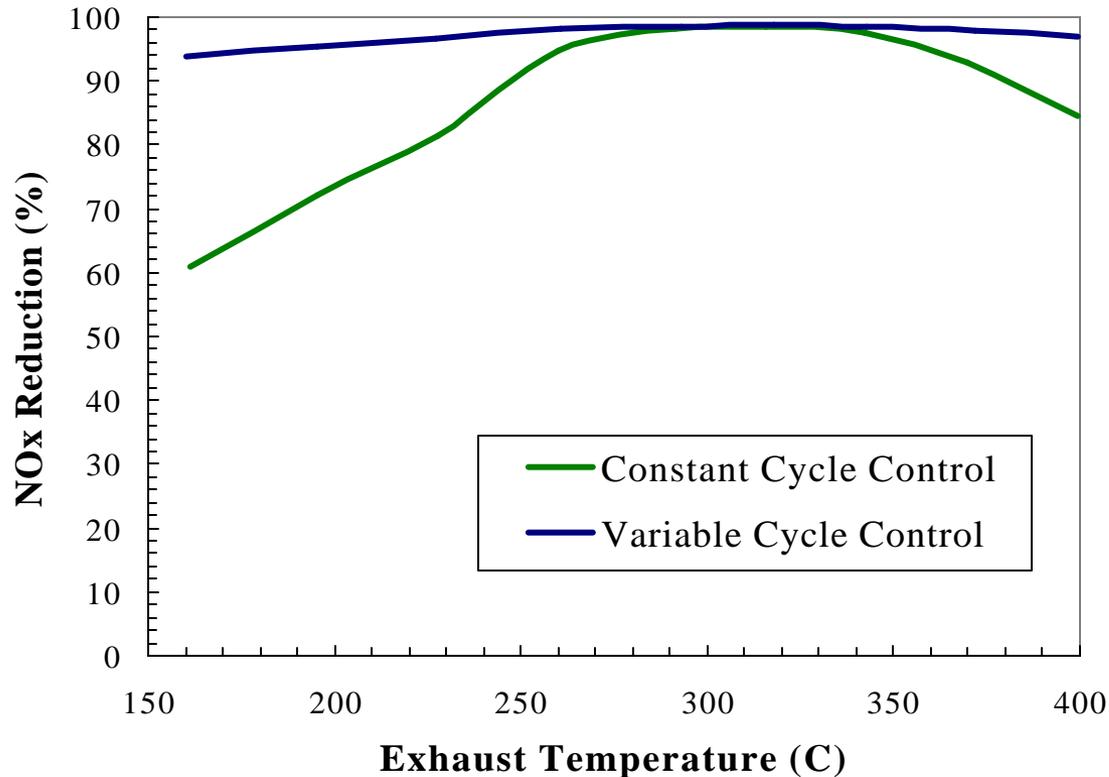
Test Platform: Regeneration with Diesel Fuel

- **Net-Reducing Atmosphere Required for Regeneration**
 - Diesel Fuel Reductant Delivered with Air-Assisted Injector
 - Valve on Exhaust Decreases Exhaust Flow Through Catalyst During Regen



NOx Absorber Performance for Diesel Exhaust

- Data Obtained on **11.9 g/bhp-hr NOx Engine** with **Diesel Fuel Reductant**
- Constant Cycle Control Data Represents Catalyst Capacity
- Variable Cycle Control Data Represents Engineered Performance
- Fuel Penalties for Constant Cycle and Variable Cycle Data were Similar
 - 3.6% and 3.8%, respectively



Factors in Durability: NOx Absorber Deactivation

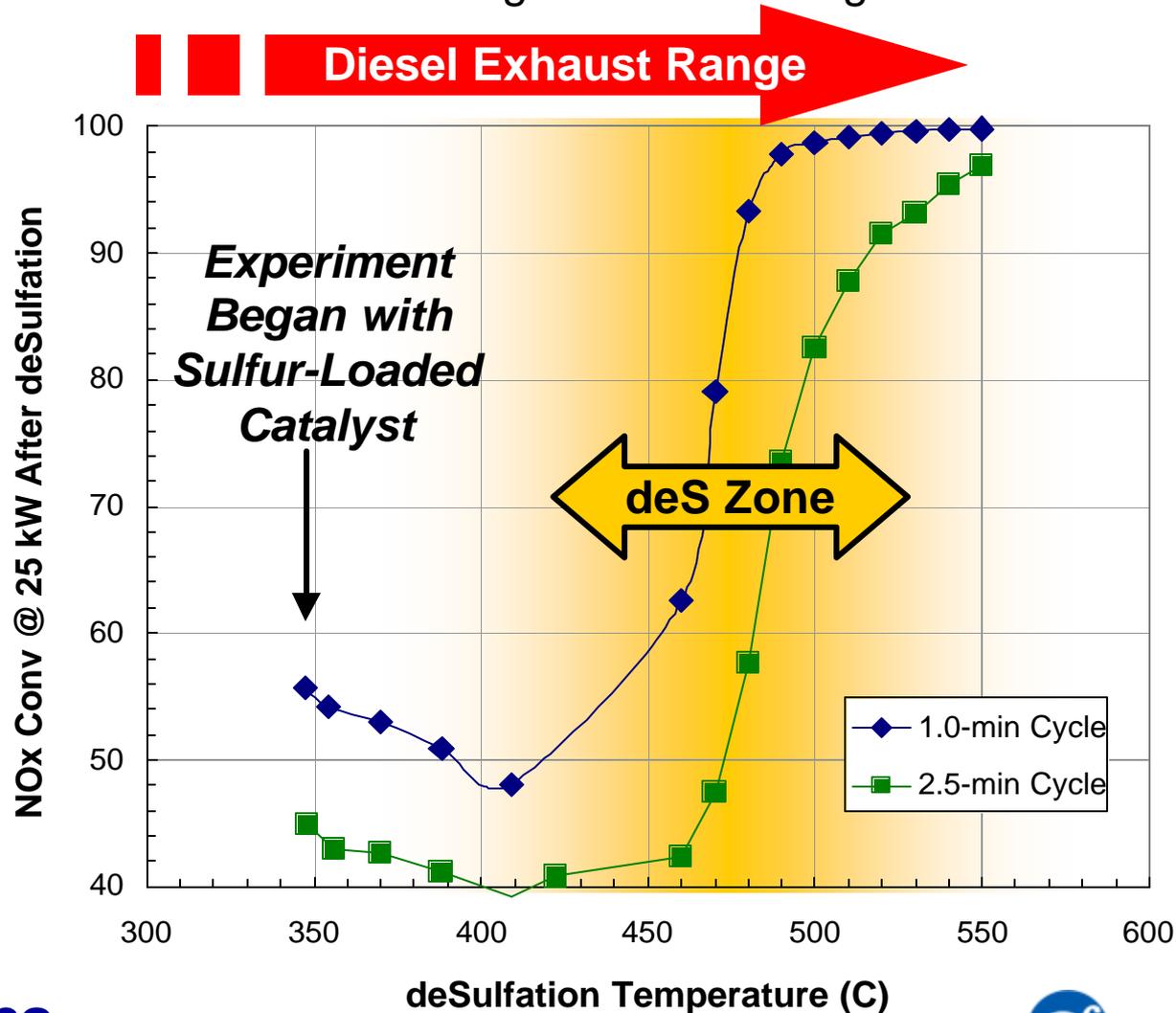
- Sulfur Masking (“Poisoning”) ★ **Most Significant**
- Surface Area Loss “Thermal”
- Particulate Matter “Fouling”
- Diesel Fuel “Fouling”
- Lube Masking (“Poisoning”/”Vapor-Solid”)
- Sorbate-Washcoat Reaction (“Solid-Solid”)
- Physical Loss of Catalyst
 (“Attrition/Crushing”)

Sulfur Masking and Control

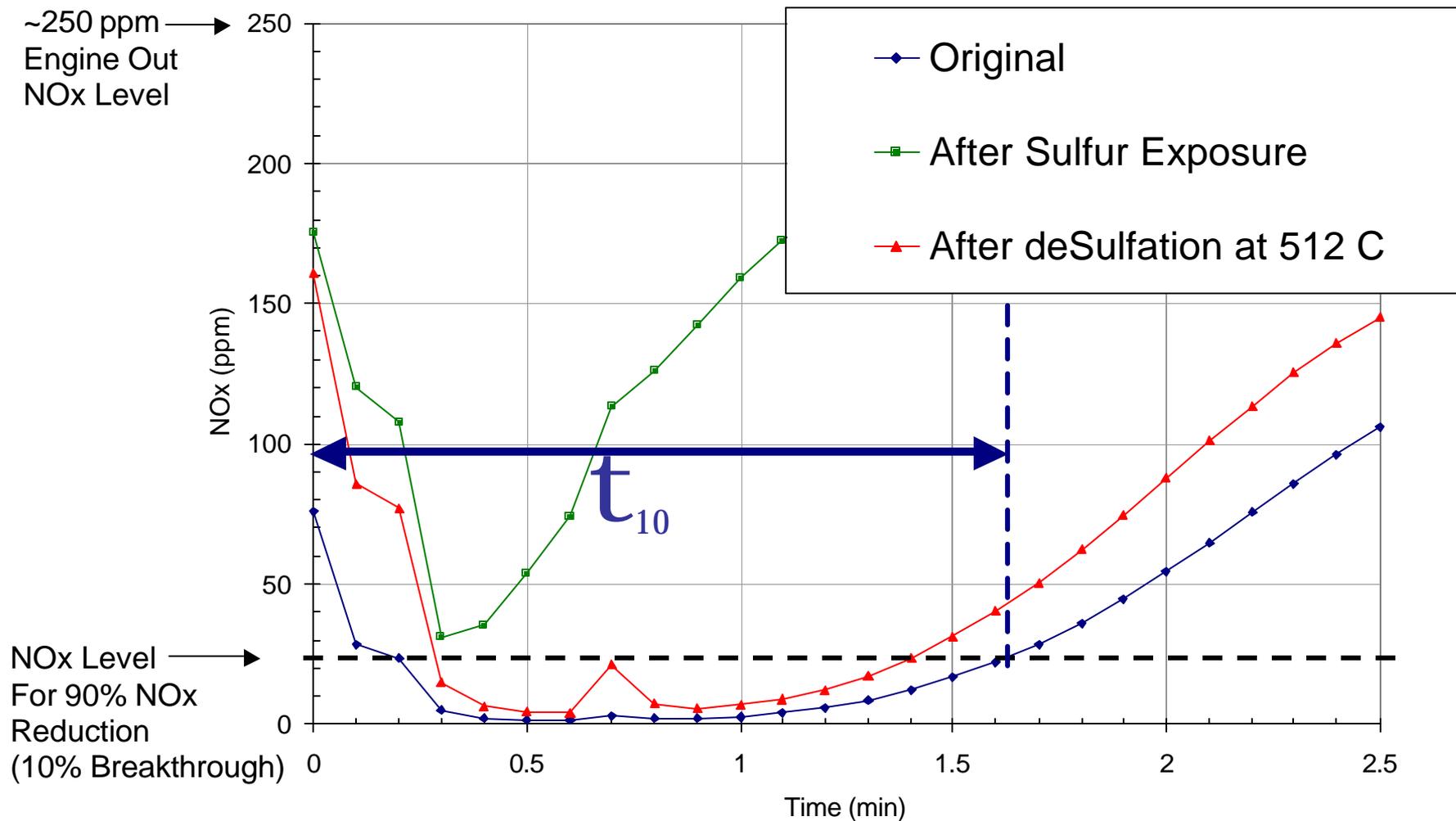
- Problem: Sulfur Masks Ability of Catalyst to Absorb NOx
 - Sulfur Absorbed by NOx Sorption Sites
 - Sulfur More Difficult to Release from Catalyst
- Solution: “deSulfation” - On-Line Removal of Sulfur with Elevated Catalyst Temperature
 - Release of Sulfur Frees NOx Sorption Sites for Continued NOx Reduction

deSulfation in Diesel Exhaust Range

- Data from **6.9 g/bhp-hr NO_x Engine** with **NO_x Absorber Only** in System
- Diesel Fuel Reductant Used for Regeneration During deSulfation



deSulfation Recovery of NOx Capacity: NOx Profiles and Terminology

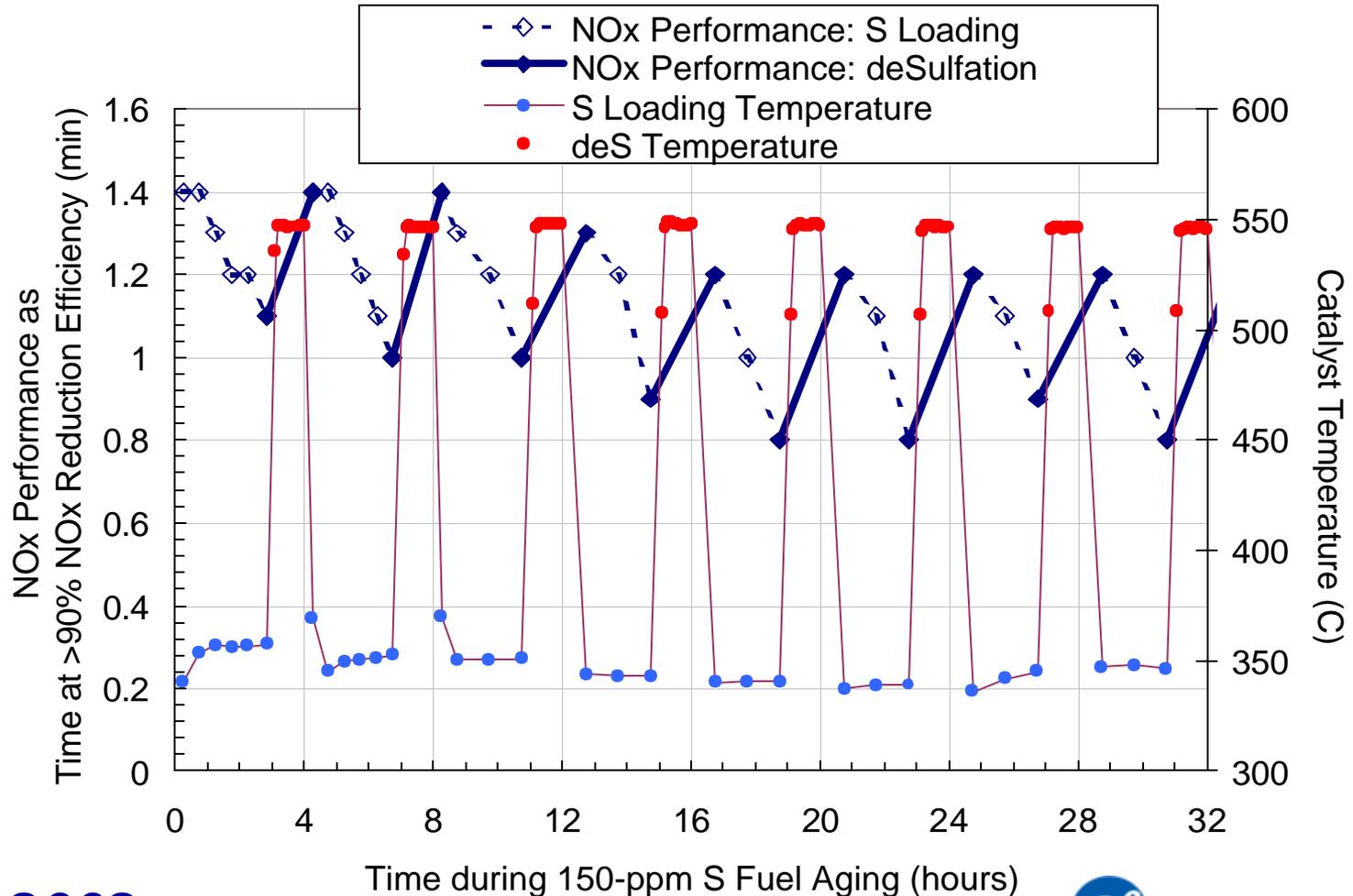


Accelerated Sulfur Aging

- A: Sulfur Loading
 - 3 Hours at Medium Load (25 kW)
 - 350°C Catalyst Temperature
 - Sorption-Regeneration Cycle Maintained
- B: deSulfation
 - 1 Hour at High Load (50 kW) with Supplemental Exotherm to Obtain 550°C Catalyst Temperature
 - Sorption-Regeneration Cycle Maintained
- Repeat A-B-A-B-A-B Sequence
- Engine Fuel: 150-ppm S DECSE Fuel
 - Reference: www.ott.doe.gov/decse

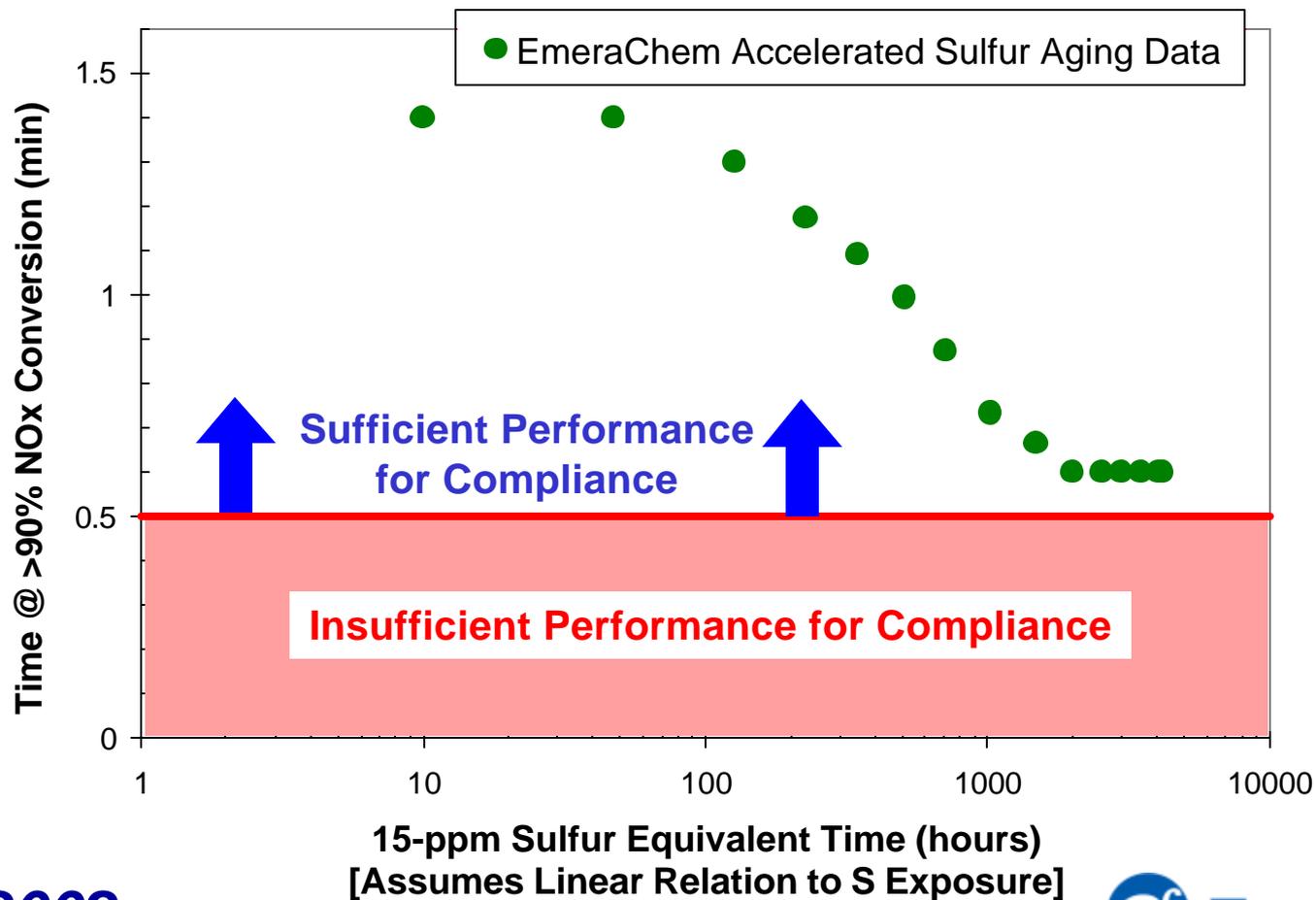
Sequential Sulfur Loading – deSulfation Cycle

- Sulfur Loading Causes NOx Performance to Decline
- deSulfation at 550°C Recovers Lost NOx Performance
- Repetitive Cycle Tested Over Time



Stable Performance Occurred After Aging: Lifetime Prediction for Clean Fuels Shown

- **Ability to Obtain >90% NO_x Reduction Efficiency Maintained**
 - Performance Stabilizes After Initial “Degreening”
 - Degradation Primarily Attributed to Thermal Degradation from 550°C deSulfations



Post Aging Analysis

- Thermal Degradation Occurred
 - 25% of Total Surface Area Lost during Aging
 - 44% of Active Metal Surface Area Lost during Aging
- deSulfation Efficient and Repeatable
 - S Levels on Catalyst at 1-7% of Saturation Levels
- Other Degradation May Have Occurred
 - Phosphorus and Zinc Detected on Upstream Face

Conclusions

- NOx Absorber Catalysts Enable High NOx Reduction for a **Clean Diesel Future**
- Durability is Key Element of Performance for Success
- **Stability** Against Sulfur Effects Demonstrated
 - Represents Milestone in NOx Absorber Development
 - Other Degradation Mechanisms Need Consideration
- Forward Focus: Cost and System Optimization