# Durability of NOx Absorbers

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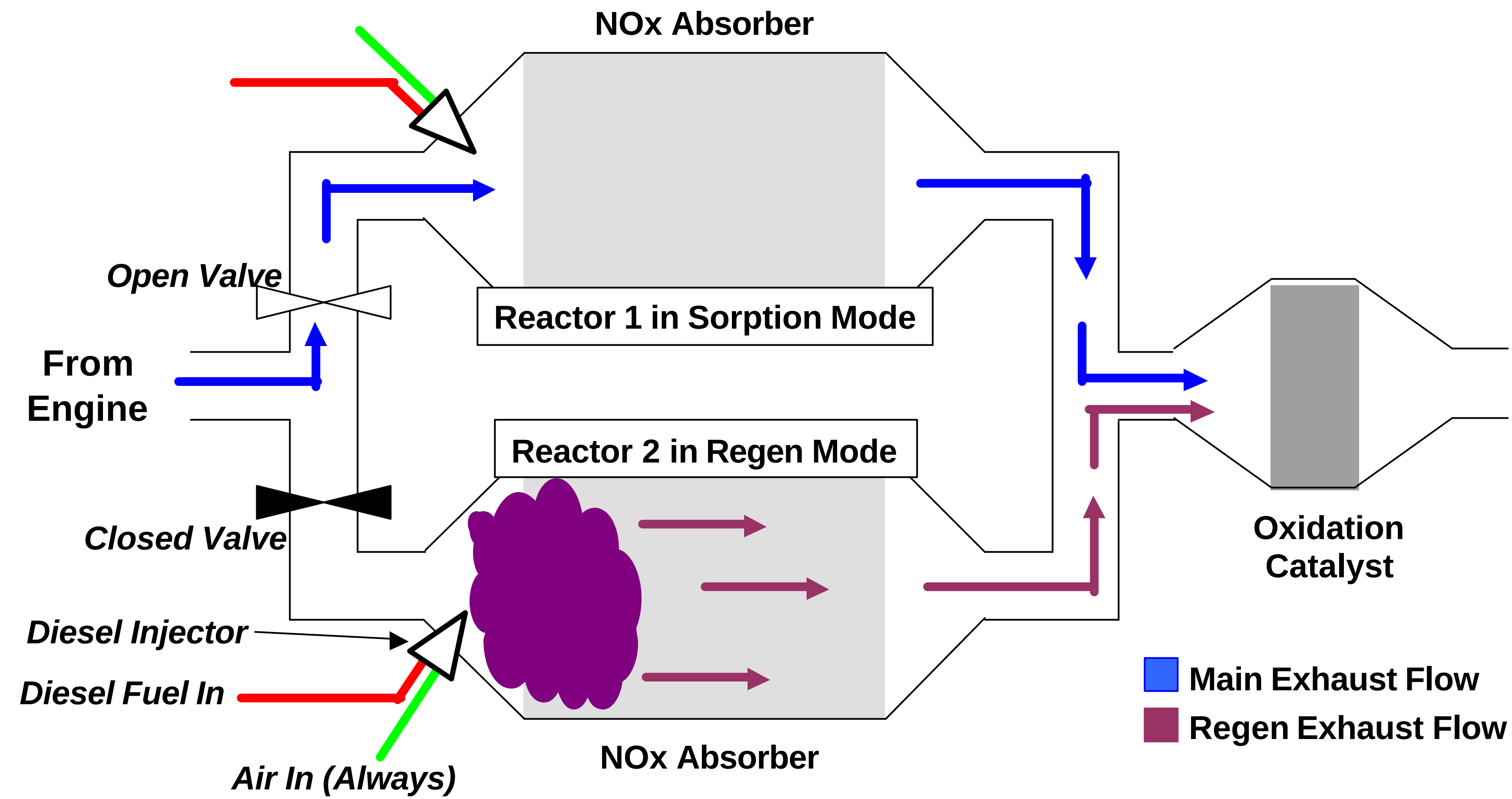
# Achieving Product Status with NOx Absorber Catalysts

- 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



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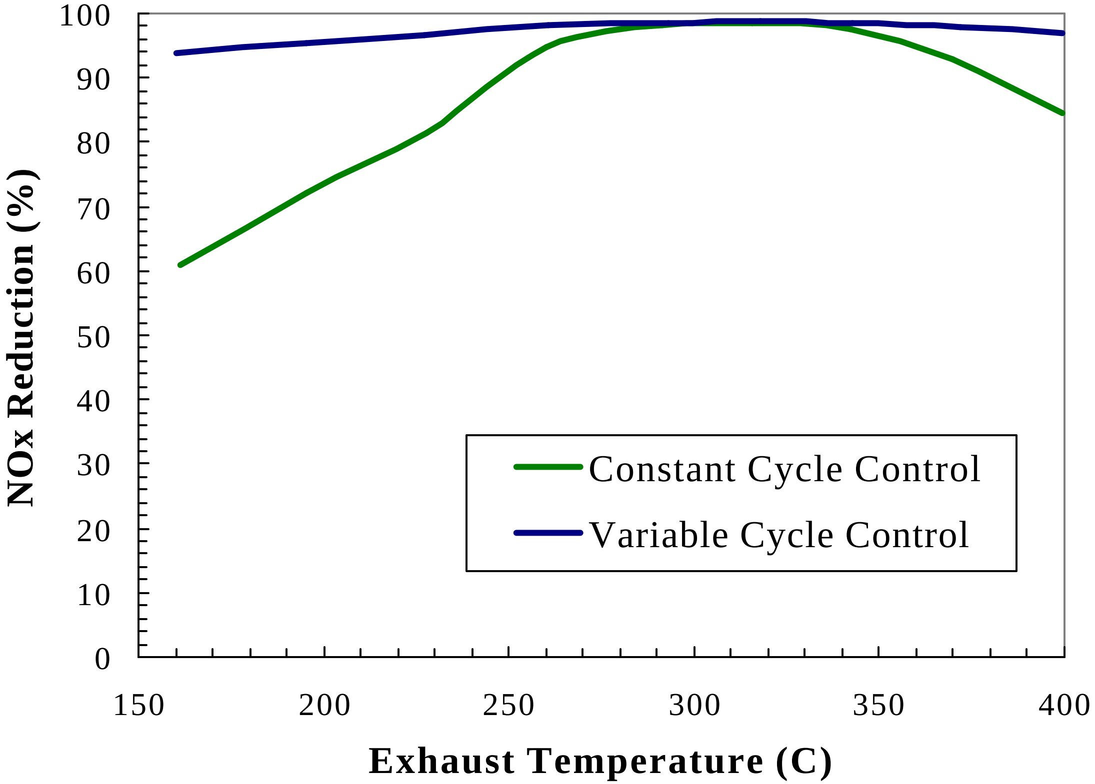
# NOx Absorber Performance for Diesel Exhaust

- 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



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# 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")



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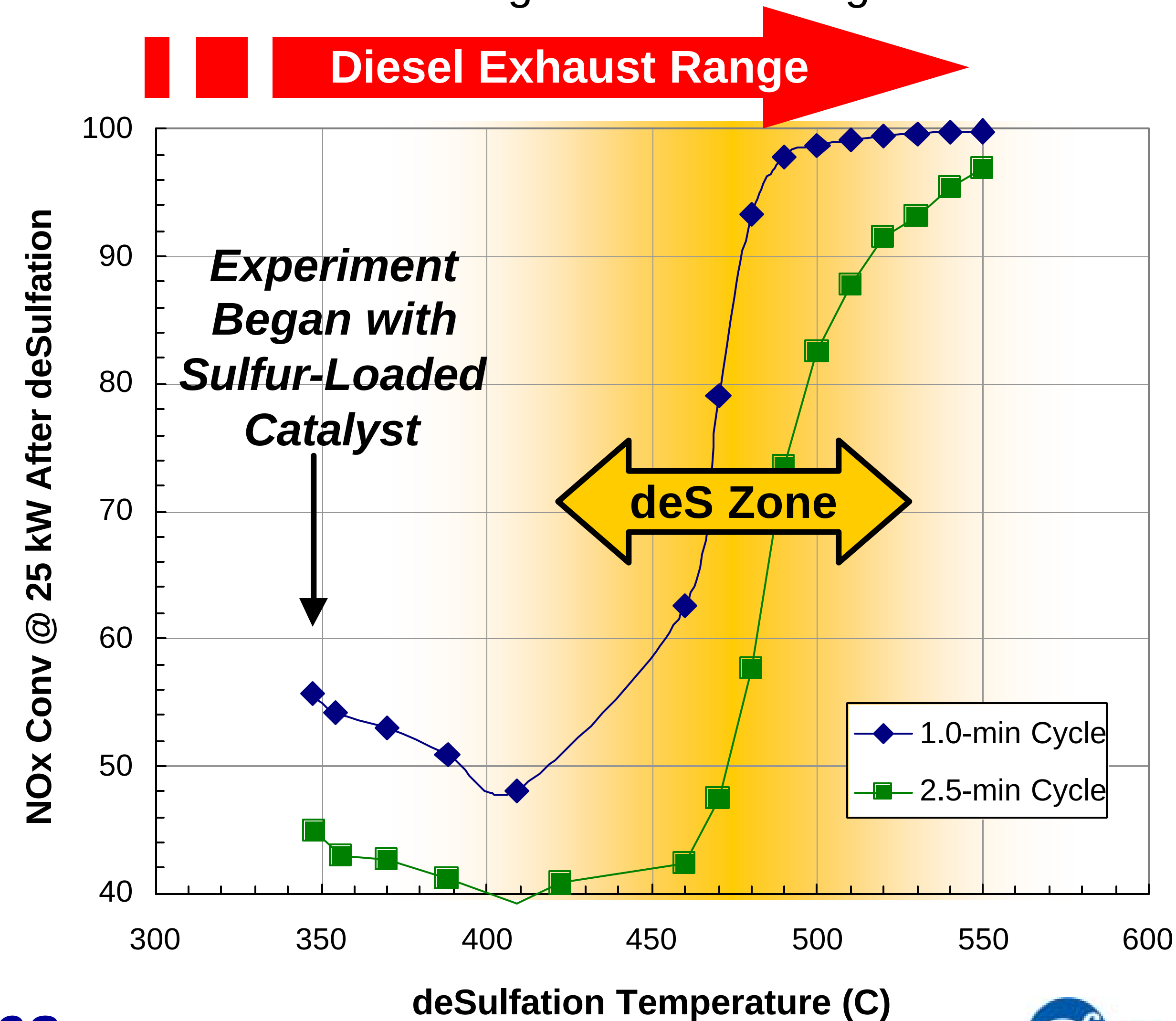
# Sulfur Masking and Control

- 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 NOx Engine*** with ***NOx Absorber Only*** in System
- Diesel Fuel Reductant Used for Regeneration During deSulfation



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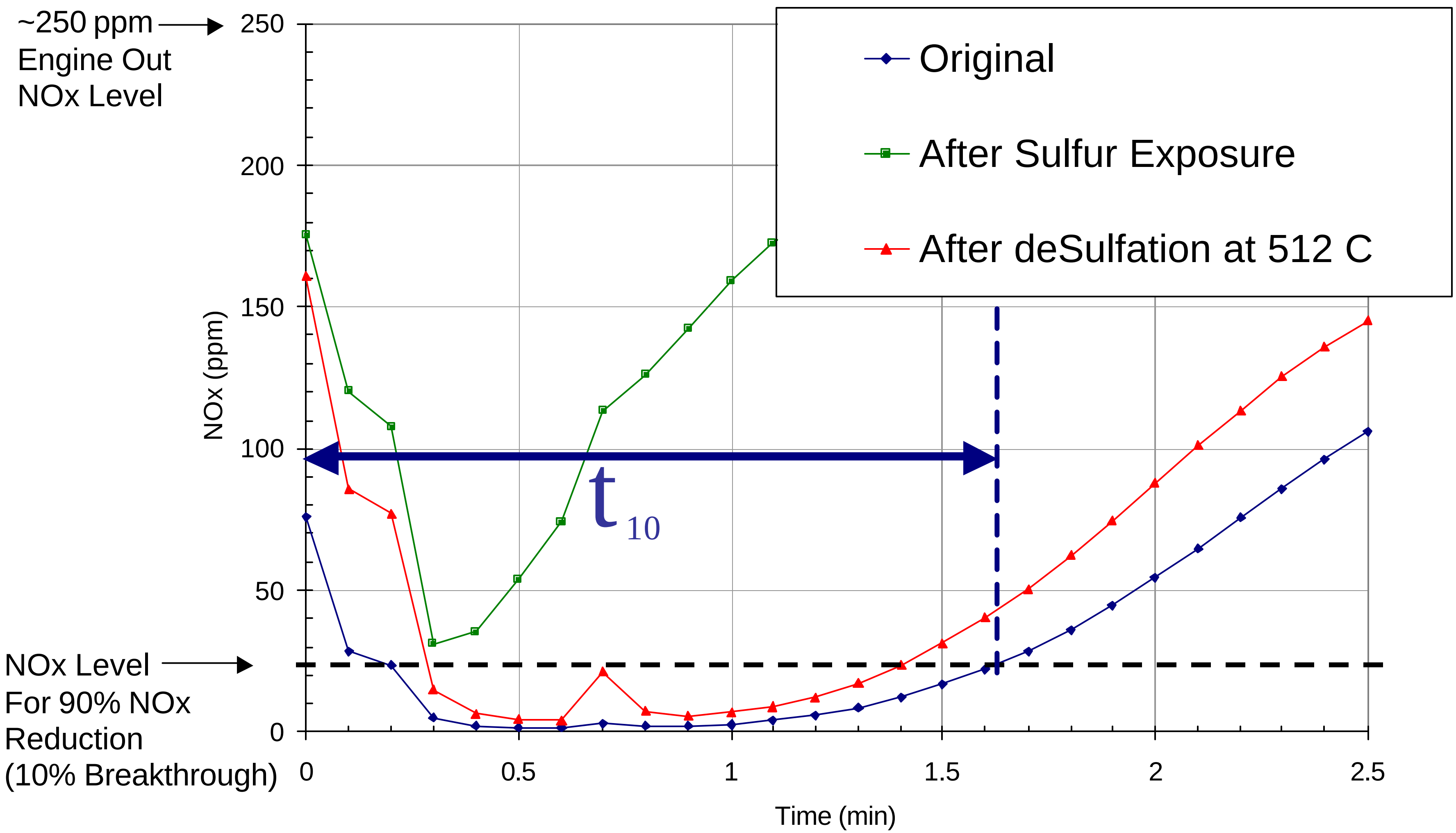
# deSulfation Recovery of NOx Capacity: NOx Profiles and Terminology

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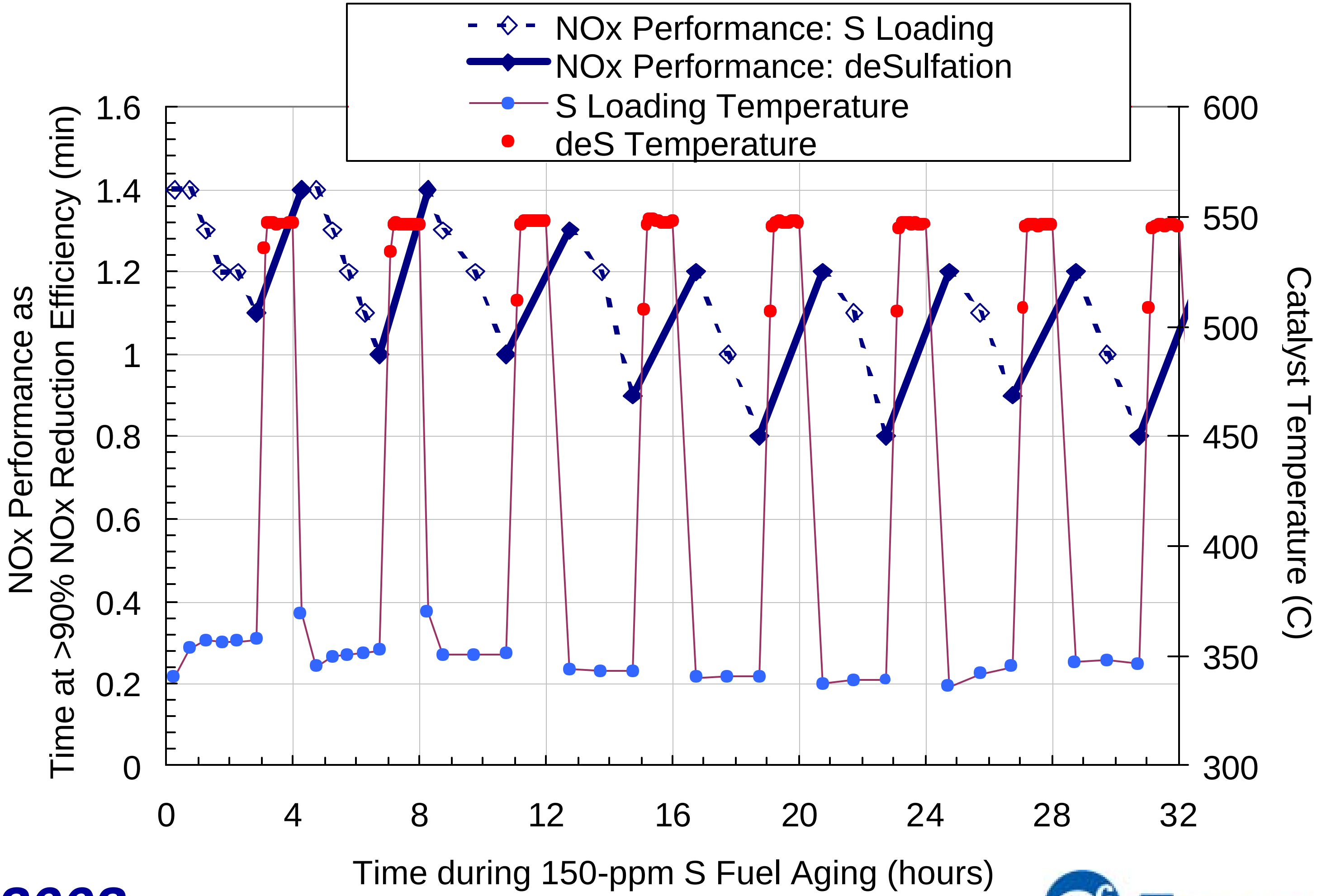
# Accelerated Sulfur Aging

- A: Sulfur Loading
  - 3 Hours at Medium Load (25 kW)
  - 350ºC Catalyst Temperature
  - Sorption-Regeneration Cycle Maintained
- B: deSulfation
  - 1 Hour at High Load (50 kW) with Supplemental Exotherm to Obtain 550ºC 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 550ºC Recovers Lost NOx Performance**
  - Repetitive Cycle Tested Over Time

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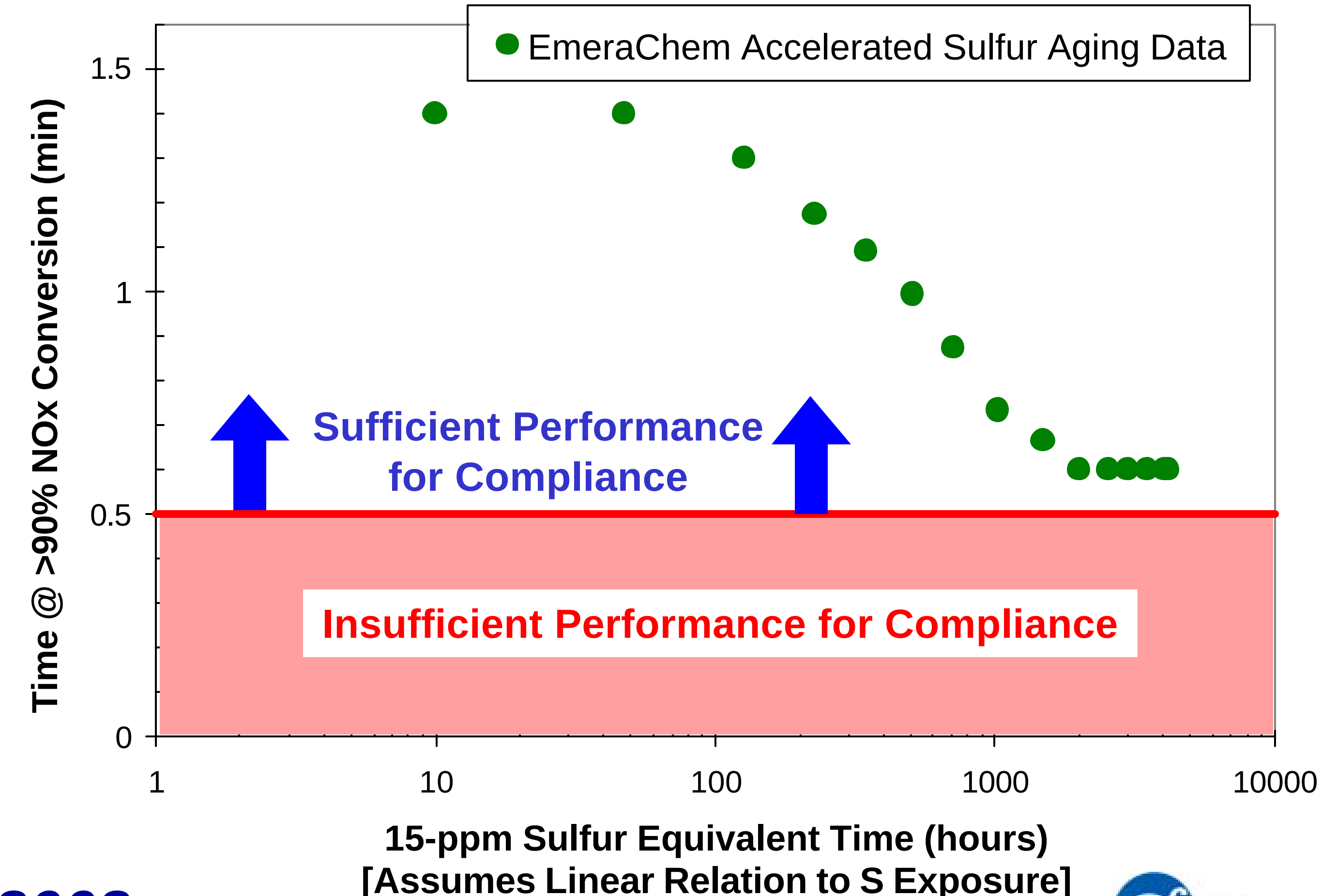
# Stable Performance Occurred After Aging: Lifetime Prediction for Clean Fuels Shown

- **Ability to Obtain >90% NOx Reduction Efficiency Maintained**
  - •Performance Stabilizes After Initial "Degreening"
  - •Degradation Primarily Attributed to Thermal Degradation from 550ºC deSulfations





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# 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