

# Full Useful Life (120,000 miles) Exhaust Emission Performance of a NO<sub>x</sub> Adsorber and Diesel Particle Filter Equipped Passenger Car and Medium-duty Engine in Conjunction with Ultra Low Sulfur Fuel

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# Outline

- Project Overview
- Program goals and objectives
- Hardware overview
- Test procedures
- Test results
- Summary and outlook

# APBF-DEC Projects

NO <sub>x</sub> Adsorber/DPF		SCR/DPF		Lubes
				
FEV	SwRI	Ricardo	SwRI	AEI
1.9L TDI	6.6L Isuzu Duramax	15L Cummins ISX	Caterpillar C12	Cummins ISB
Audi A4 Avant	Chevrolet Silverado	<i>No vehicle</i>		

# APBF-DEC Organization

DOE, EPA, additive companies,  
automobile manufacturers, engine  
manufacturers, energy companies,  
emission control mfrs., Calif. agencies

**APBF-DEC  
Steering Committee**

**Unregulated  
emissions**

**Experimental design  
and data analysis**

**Fuel and lubricant  
provision**

**Fuels, engines,  
NO<sub>x</sub> adsorbers,  
and diesel  
particle filters**

**Fuels, engines,  
selective  
catalytic  
reduction and  
diesel particle  
filters**

**Lubricants**

**Communications**

# Project Objectives for LD NOx Adsorber Projects : Examine fuel property effects on NAC/DPF systems

## Approach:

- Demonstrate low emissions potential of diesel engines equipped with advanced fuel, NOx adsorbers, DPFs, EGR, double-wall exhaust
  - Goal: Tier 2 Bin 5 (0.07 g/mi NOx 0.01 g/mi PM)
- Age systems with Ultra Low S fuel for up to 2200 hrs
  - Periodic emissions evaluations during aging (before and after NOx adsorber desulfation)
  - Periodic unregulated emissions measurement with 15-ppm S refinery product
  - NOx adsorber desulfation performed on time based schedule

# Project Outline

Project divided into three Tasks:

- Hardware procurement and operational strategy development
- System integration and optimization
- Performance and aging evaluation
  - Age ECS to 2000-2200 hours with 15-ppm S Fuel
    - 2,200 hours equal full useful lifetime of 120,000 miles
  - Emissions evaluation procedures performed every 100-200 hrs
  - Desulfations performed every 150-200 hours to start then 100 hours (and every 50 hours at the end for the Passenger Car platform)

# Project Hardware Overview

## Passenger Car

### Engine Specification

**Arrangement:** In-Line 4-Cylinder

**Displacement:** 1.9 L

**Rated Power:** 100 kW @ 4000 rpm

**Max. Torque:** 330 Nm @ 2000 rpm



## Medium-Duty Engine



### Engine Specification

**Arrangement:** 8-Cylinder V

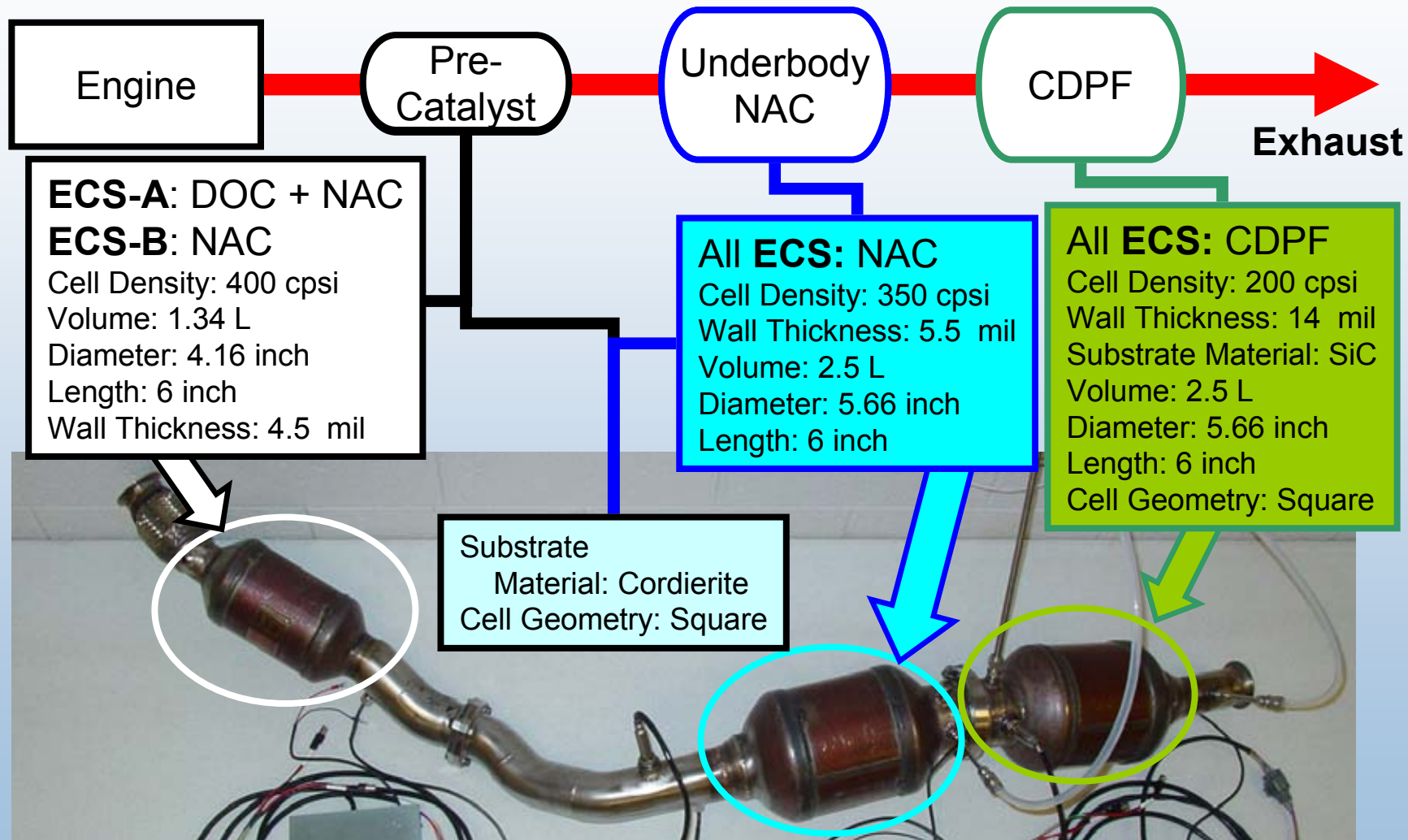
**Displacement:** 6.6 L

**Rated Power:** 224 kW @ 3100 rpm

**Max. Torque:** 705 Nm @ 1800 rpm



# Passenger Car Project In-Line Emission Control System



# Medium-Duty Engine Project Dual Leg Emission Control System

## NAC

Cell Density: 300 cpsi  
Wall Thickness: 8 mil  
Substrate Material: Cordierite  
Volume: 7 L x 2  
Diameter: 9.5 inch  
Length: 6 inch

## CDPF

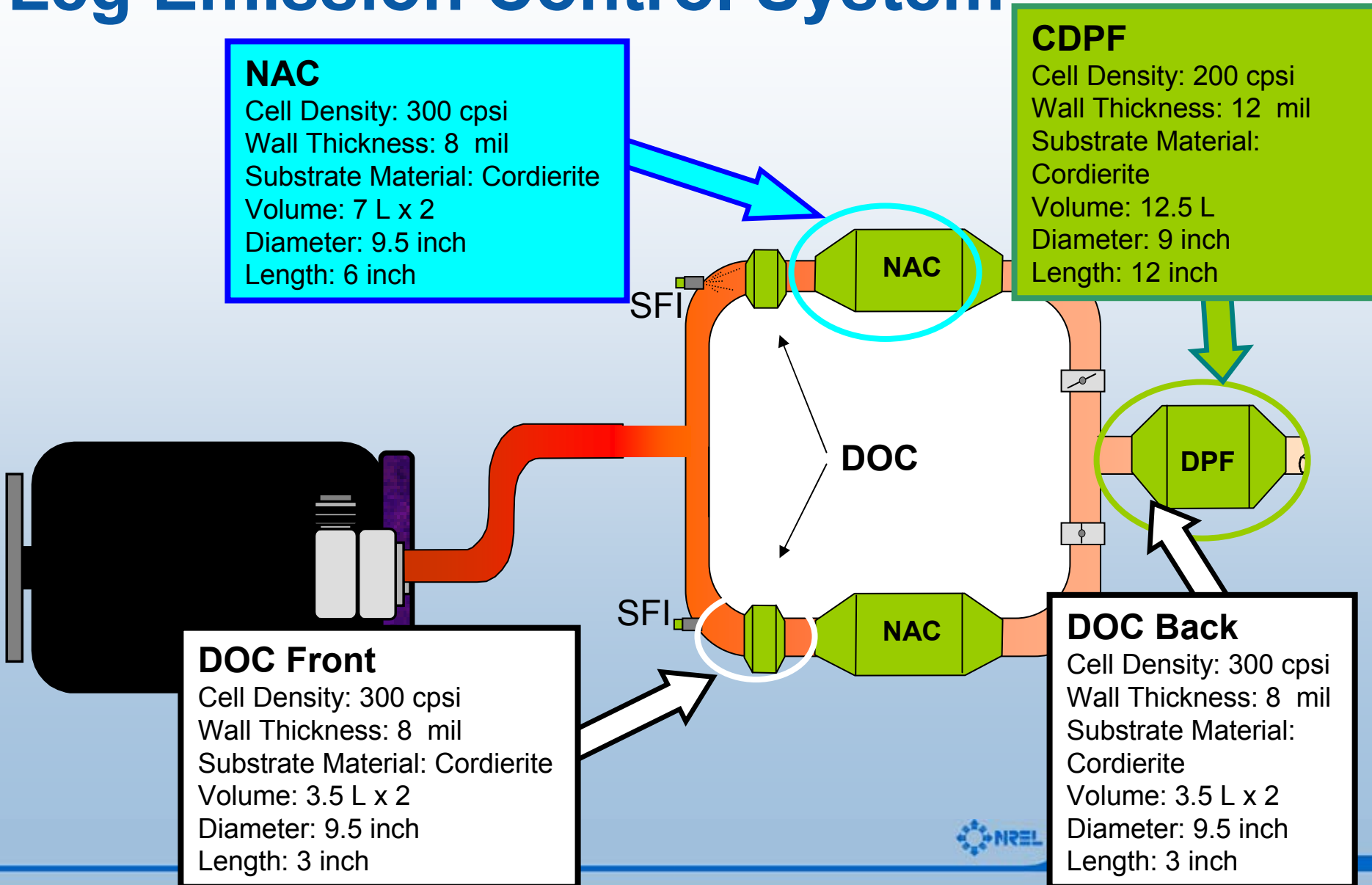
Cell Density: 200 cpsi  
Wall Thickness: 12 mil  
Substrate Material: Cordierite  
Volume: 12.5 L  
Diameter: 9 inch  
Length: 12 inch

## DOC Front

Cell Density: 300 cpsi  
Wall Thickness: 8 mil  
Substrate Material: Cordierite  
Volume: 3.5 L x 2  
Diameter: 9.5 inch  
Length: 3 inch

## DOC Back

Cell Density: 300 cpsi  
Wall Thickness: 8 mil  
Substrate Material: Cordierite  
Volume: 3.5 L x 2  
Diameter: 9.5 inch  
Length: 3 inch



# Test Procedures

## Engine Dynamometer Test Cell:

### Pre-Desulfation Procedure

Run 3x	1	CLA4	HLA4	US06	HFET
	2		HLA4	US06	HFET
	3		HLA4	US06	HFET
			1/3 PM sample	1 PM sample	1 PM sample

1 test cycle = 1 gas sample = 30 gas samples  
1 set of cycles = 1 PM sample = 10 PM samples

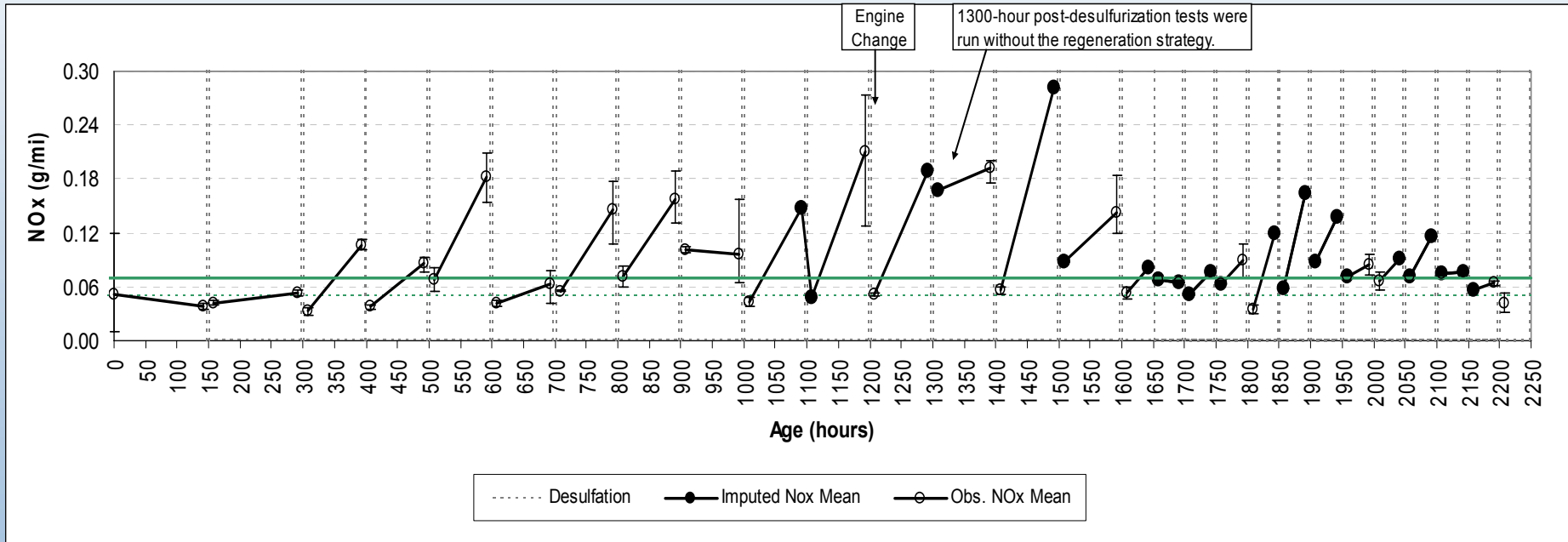
### Post-Desulfation Procedure

Run 2x	1	CLA4	HLA4	US06	HFET
	2		HLA4	US06	HFET
	3		HLA4	US06	HFET
			1/2 PM sample	1 PM sample	1 PM sample

1 test cycle = 1 gas sample = 20 samples  
1 set of cycles = 1 PM sample = 7 PM samples

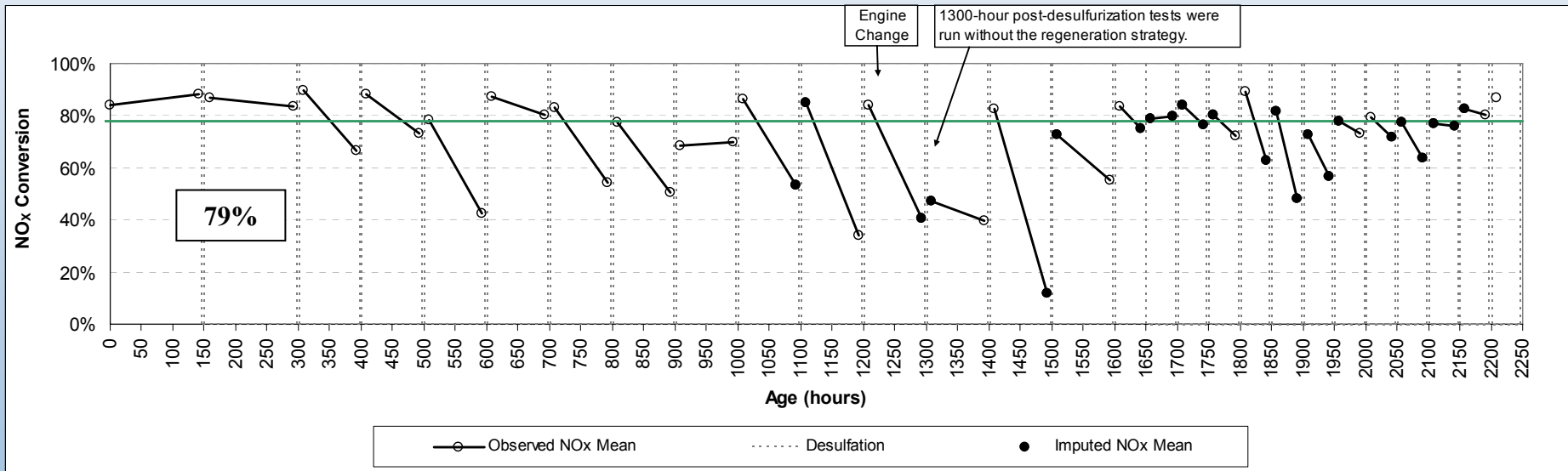
# Passenger Car Project Test Results

## NOx Emission Trends



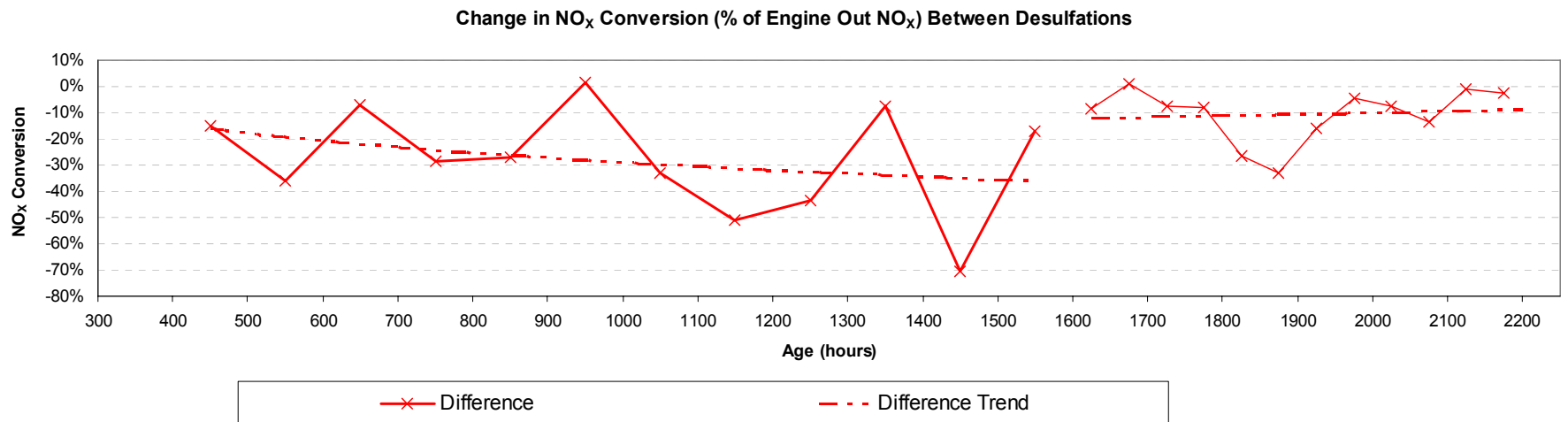
# Passenger Car Project Test Results

## NOx Adsorber Conversion Efficiency



# Passenger Car Project Test Results

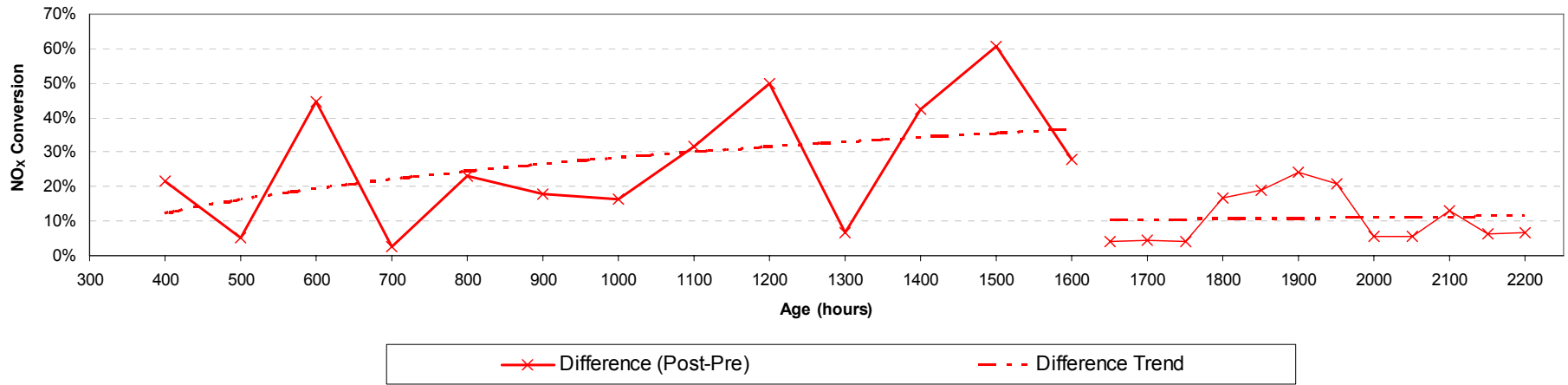
## NO<sub>x</sub> Adsorber Deterioration



# Passenger Car Project Test Results

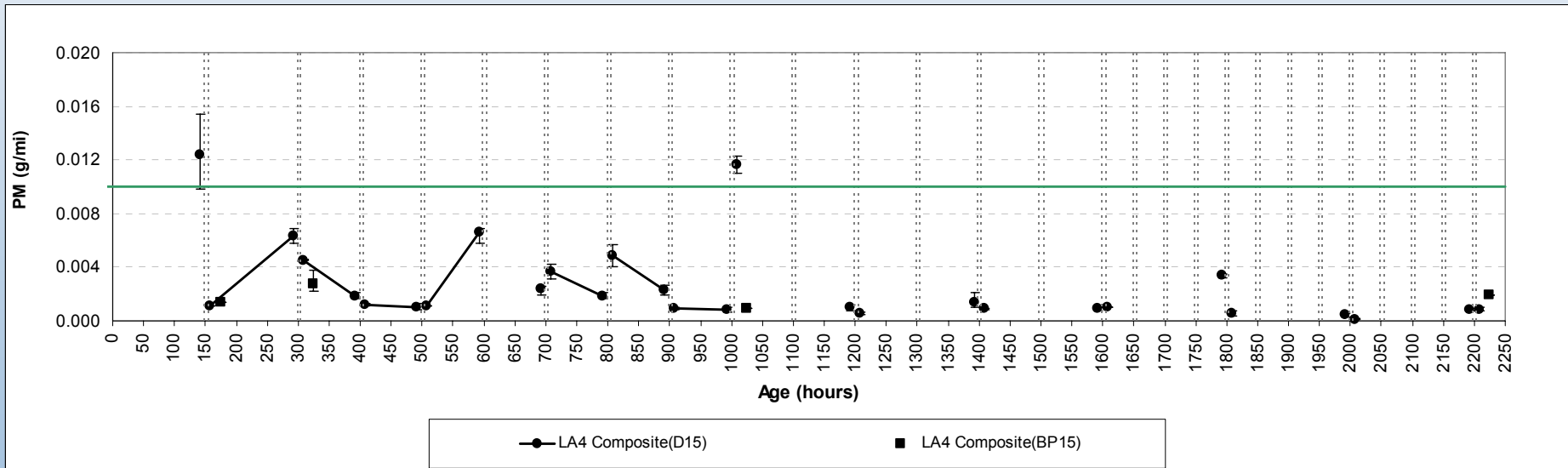
## Desulfation Effectiveness

Increase in NO<sub>x</sub> Conversion (% of Engine Out NO<sub>x</sub>) at Each Desulfation



# Passenger Car Project Test Results

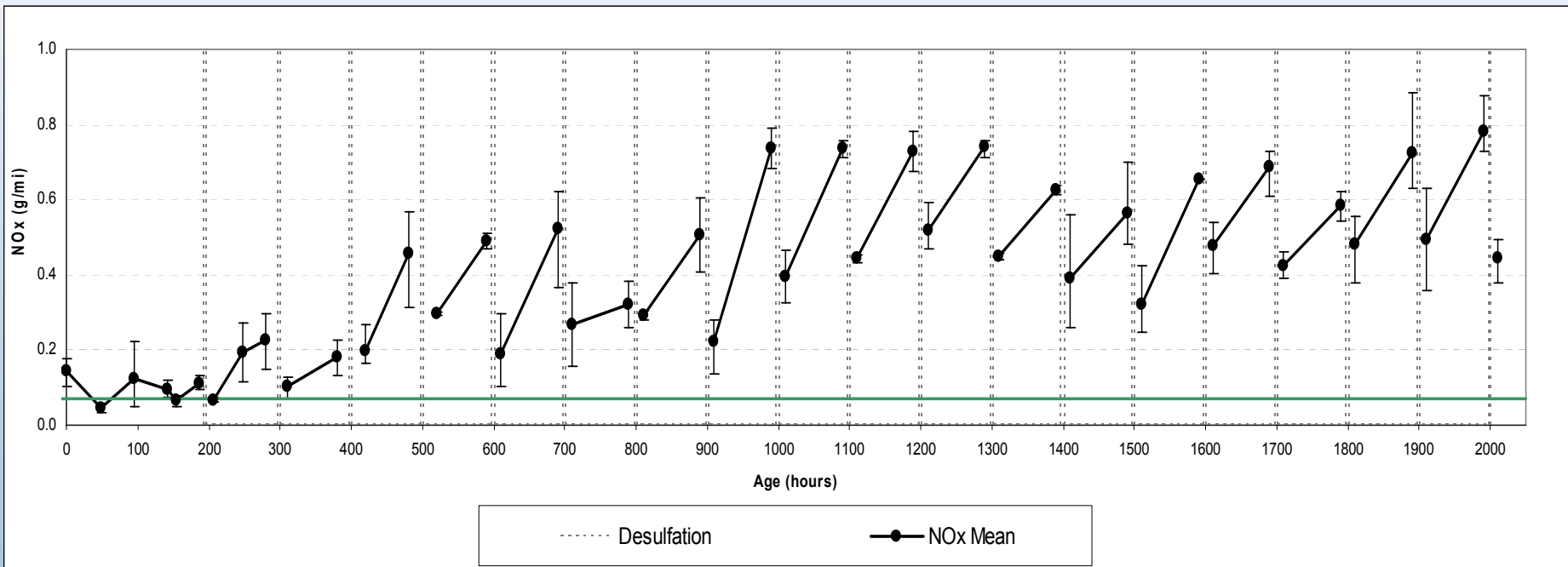
## PM Emission Trends





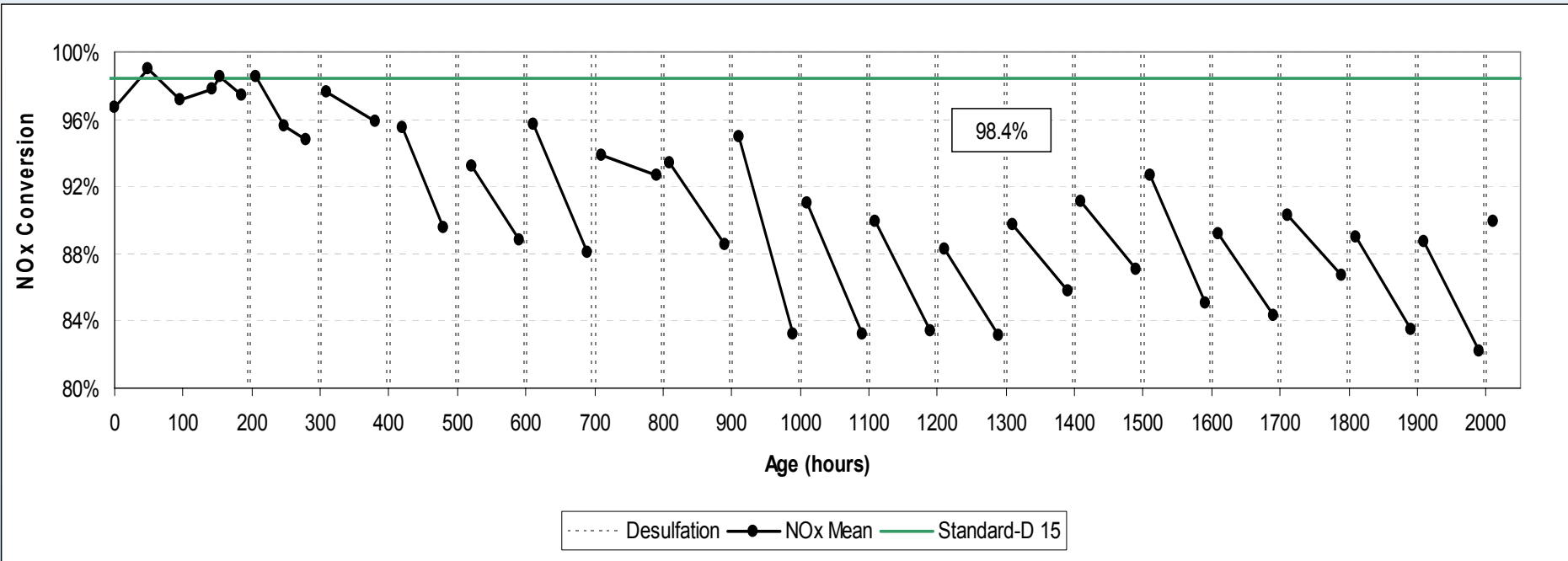
# Medium-Duty Engine Project Test Results

## NOx Emission Trends



# Medium-Duty Engine Project Test Results

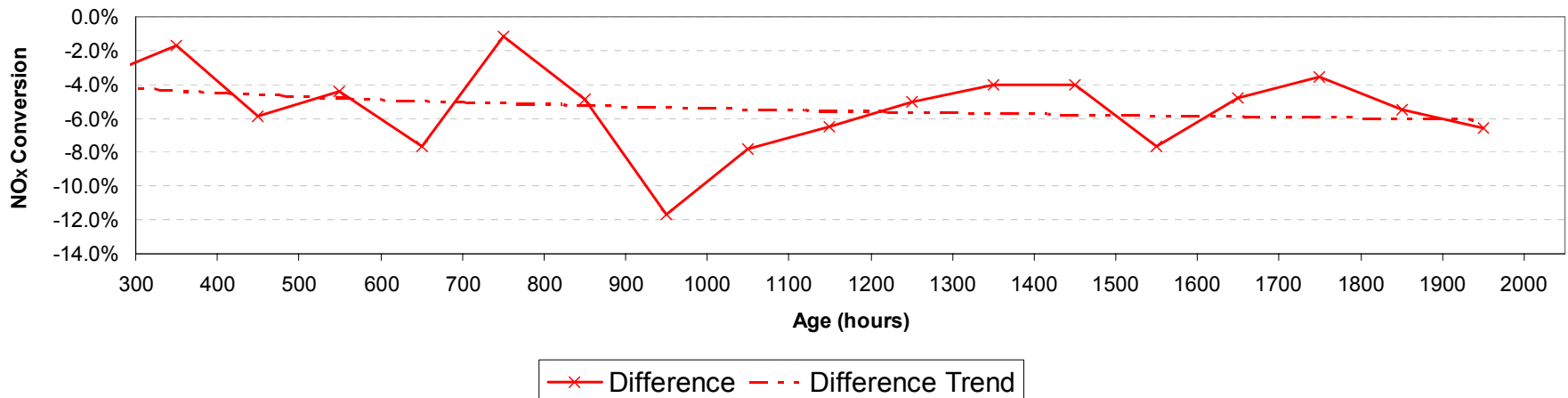
## NOx Adsorber Conversion Efficiency



# Medium-Duty Engine Project Test Results

## NO<sub>x</sub> Adsorber Deterioration

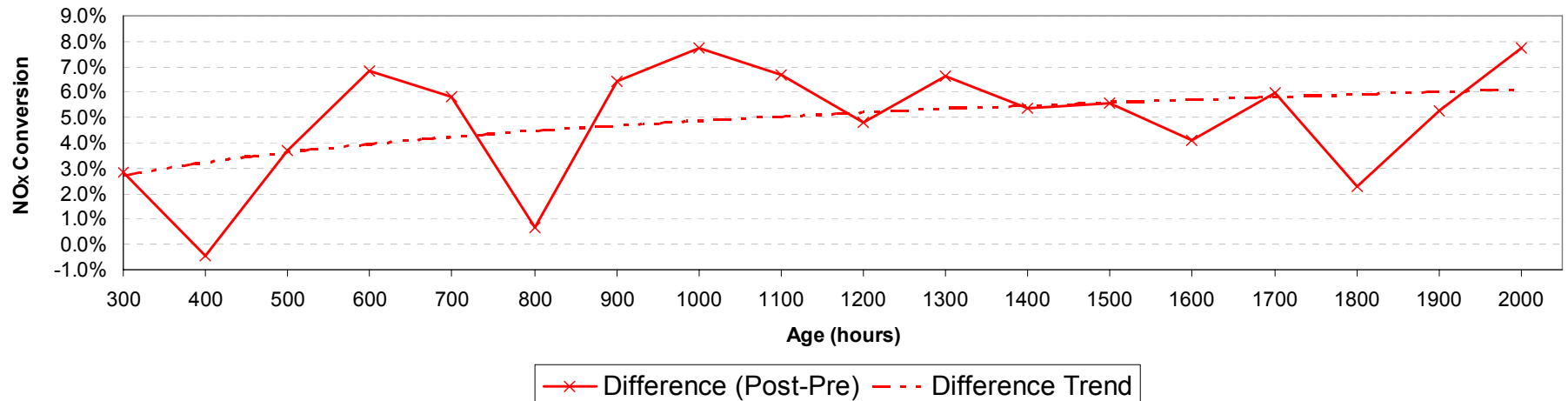
Change in NO<sub>x</sub> Conversion (% of Engine Out NO<sub>x</sub>) Between Desulfations



# Medium-Duty Engine Project Test Results

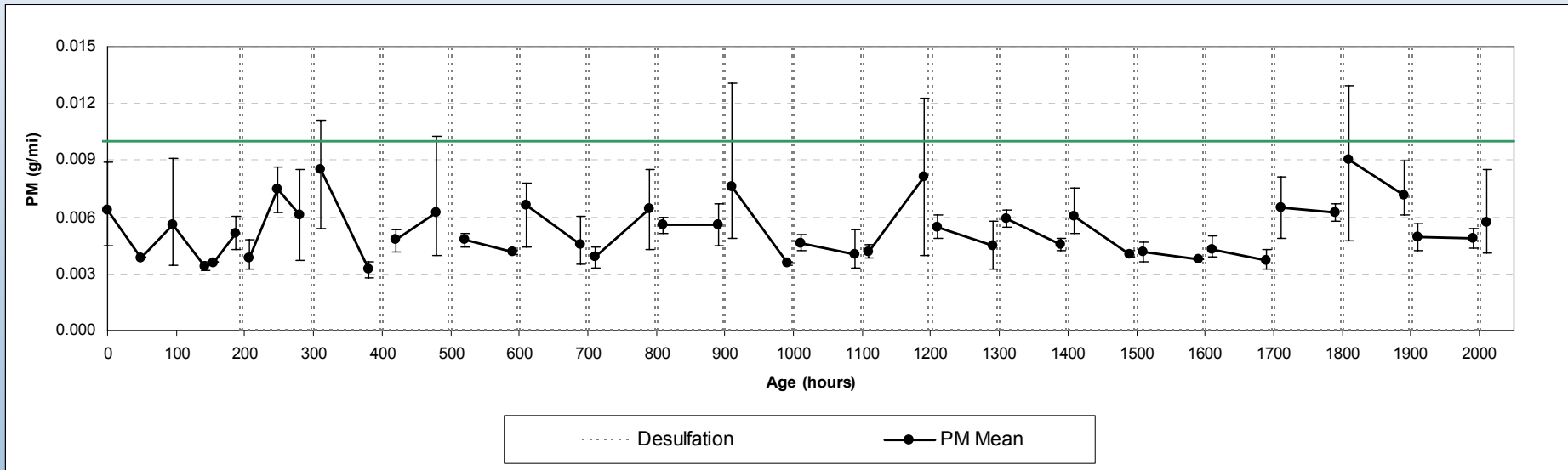
## Desulfation Effectiveness

Increase in NO<sub>x</sub> Conversion (% of Engine Out NO<sub>x</sub>) at Each Desulfation



# Medium-Duty Engine Project Test Results

## PM Emission Trends



# Summary

- Fresh NOx adsorber system in conjunction with 15ppm sulfur fuel can achieve Tier 2 Bin 5 NOx emission levels for both platforms
- Desulfation strategies are effective in recovering NOx adsorber performance with some deterioration through 2000 hours for both platforms
- Aged and desulfurized NOx adsorber system in conjunction with 15ppm sulfur fuel achieved Tier 2 Bin 5 NOx emission levels for the passenger car platform, achieved 85-90% NOx conversion for the MD Engine platform
- DPF in conjunction with 15ppm sulfur fuel can achieve Tier 2 Bin 5 PM emission levels throughout aging for both platforms
- Detailed emissions information (e.g. CO, HC, and Unregulated species) are included in final report

# Program Participants

## **Automobile:**

DaimlerChrysler  
Ford  
GM  
Toyota

## **Government:**

CARB/SCAQMD  
DOE  
EPA  
NREL  
ORNL

## **Emission Control:**

Argillon  
ArvinMeritor  
Benteler  
Clean Diesel Tech.  
Corning  
Delphi  
Donaldson Co.  
Engelhard  
Johnson Matthey  
MECA  
NGK  
Rhodia  
Robert Bosch Corp.  
STT Emtec AB  
Tenneco Automotive  
3M  
Umicore

## **Energy/ Additives:**

American Chemistry  
Council  
API  
BP  
Castrol  
Chevron Oronite  
Chevron  
Ciba  
Conoco-Phillips  
Crompton  
Ergon  
Ethyl  
ExxonMobil  
Infineum  
Lubrizol  
Marathon Ashland  
Motiva  
NPRA  
Pennzoil-Quaker State  
Shell Global Solutions  
Valvoline

## **Engines:**

Caterpillar  
Cummins  
Detroit Diesel  
EMA  
International Truck  
& Engine  
John Deere  
Mack Trucks

## **Technology:**

Battelle

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