

Full Useful Life (120,000 miles) Exhaust Emission Performance of a NO_x Adsorber and Diesel Particle Filter Equipped Passenger Car and Medium-duty Engine in Conjunction with Ultra Low Sulfur Fuel

Diesel Engine Emissions Reduction Conference
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Outline

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

APBF-DEC Projects

| NO _x 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_x adsorbers,
and diesel
particle filters**

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

Lubricants

Communications

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

Approach:

- Demonstrate low emissions potential of diesel engines equipped with advanced fuel, NO_x adsorbers, DPFs, EGR, double-wall exhaust
 - Goal: Tier 2 Bin 5 (0.07 g/mi NO_x 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 NO_x adsorber desulfation)
 - Periodic unregulated emissions measurement with 15-ppm S refinery product
 - NO_x 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

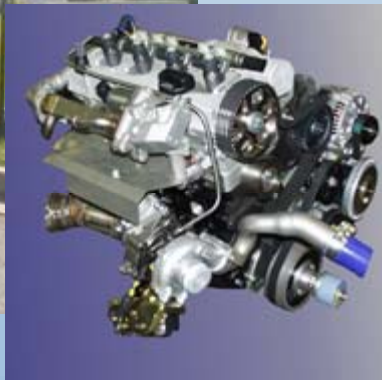
Engine Specification

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

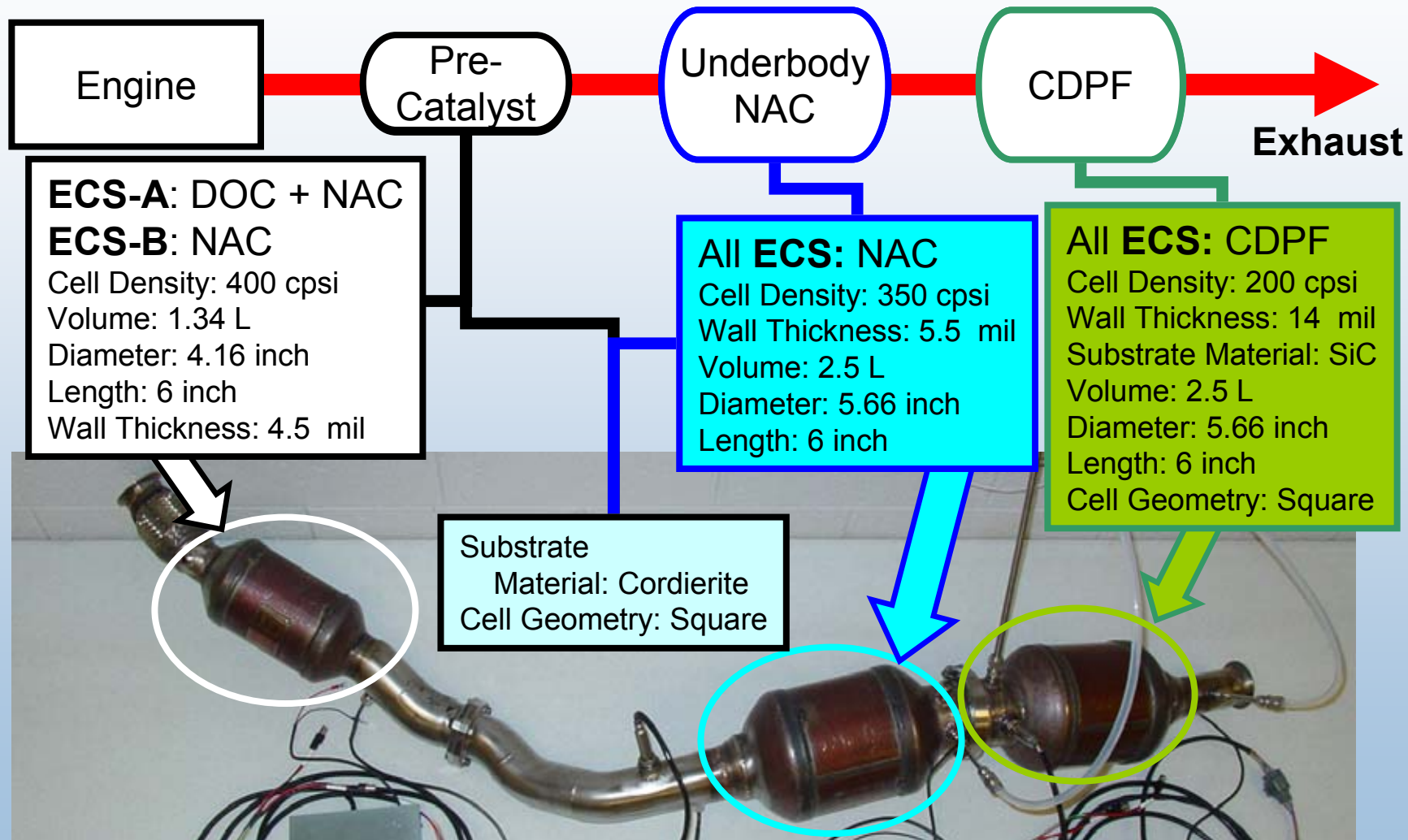
Arrangement: 8-Cylinder V

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

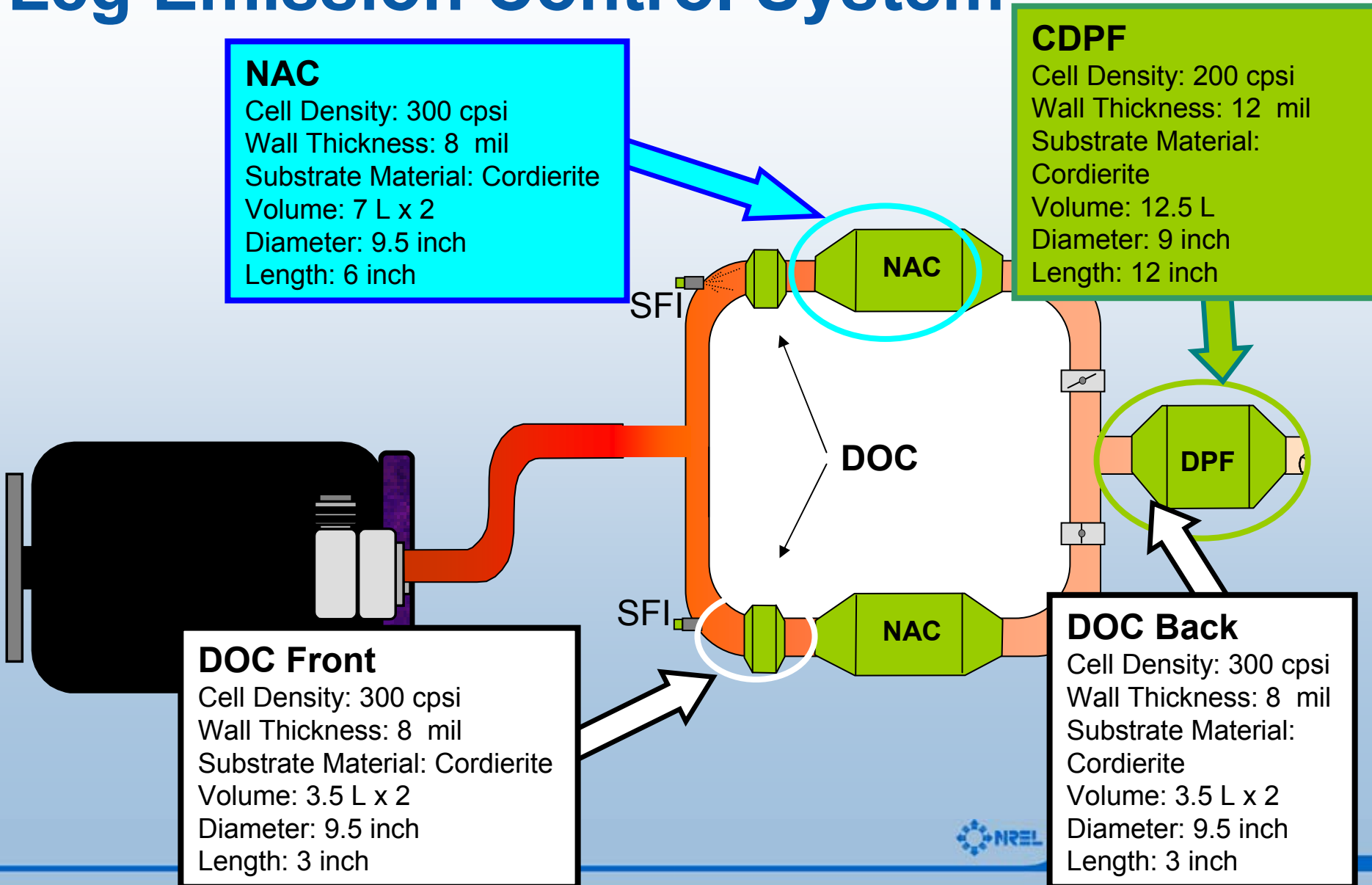
Cell Density: 200 cpsi
Wall Thickness: 12 mil
Substrate Material: Cordierite
Volume: 12.5 L
Diameter: 9 inch
Length: 12 inch

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

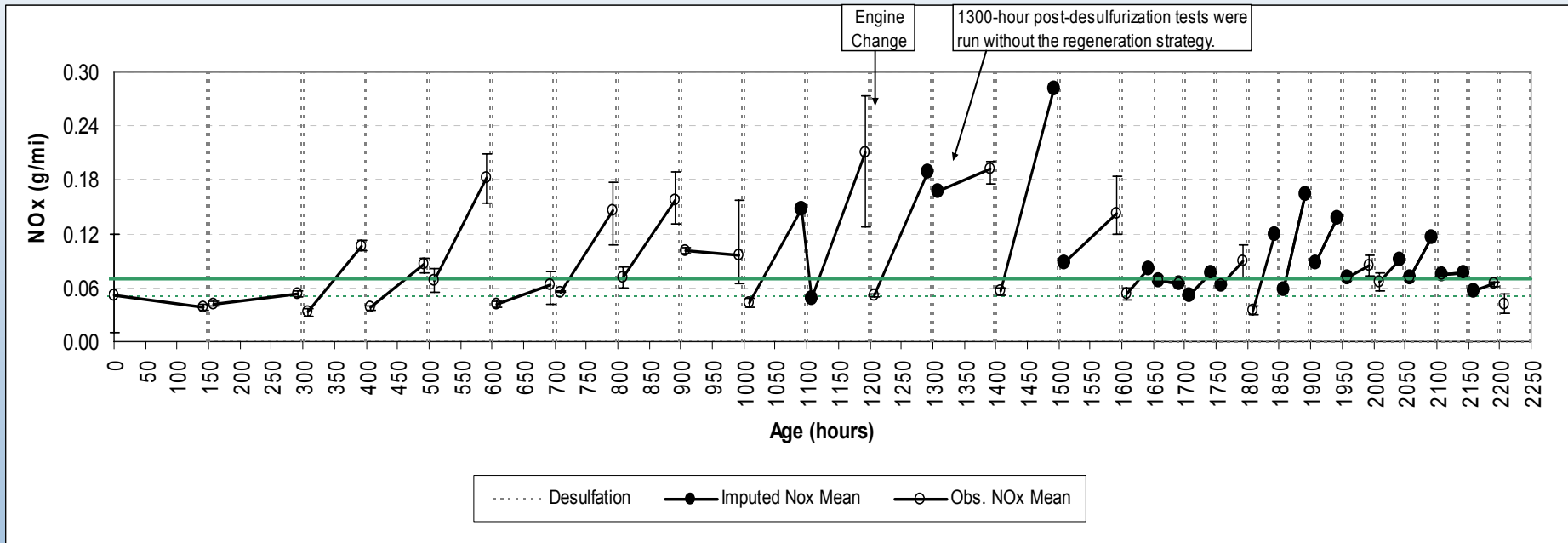
Post-Desulfation Procedure

| | | | | | |
|--------|---|------|---------------|-------------|-------------|
| 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

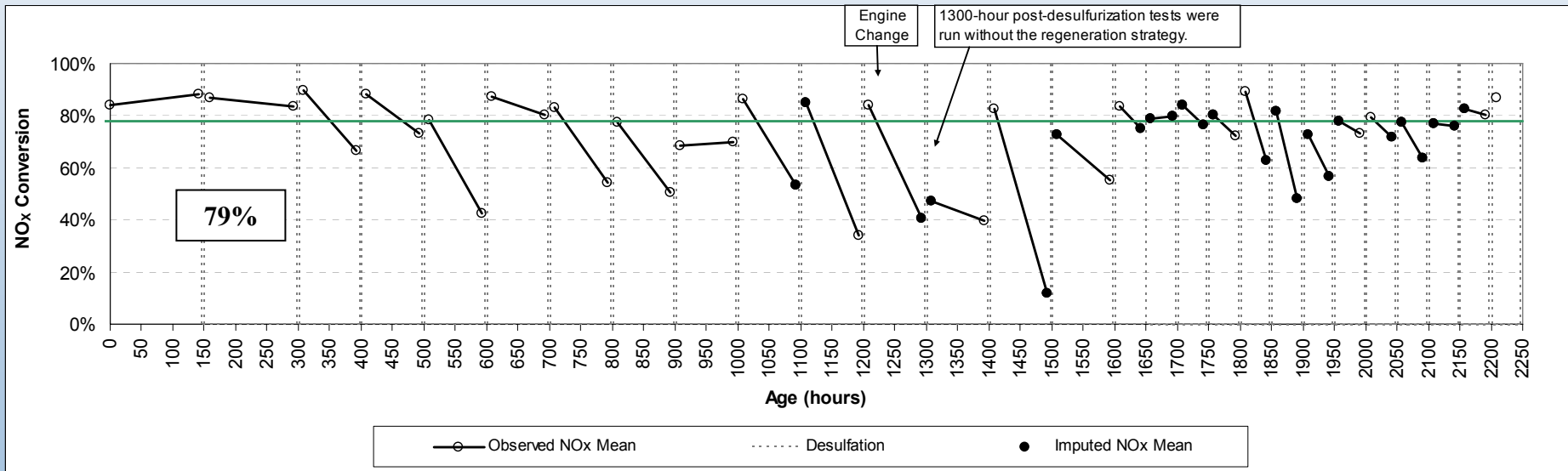
Passenger Car Project Test Results

NOx Emission Trends



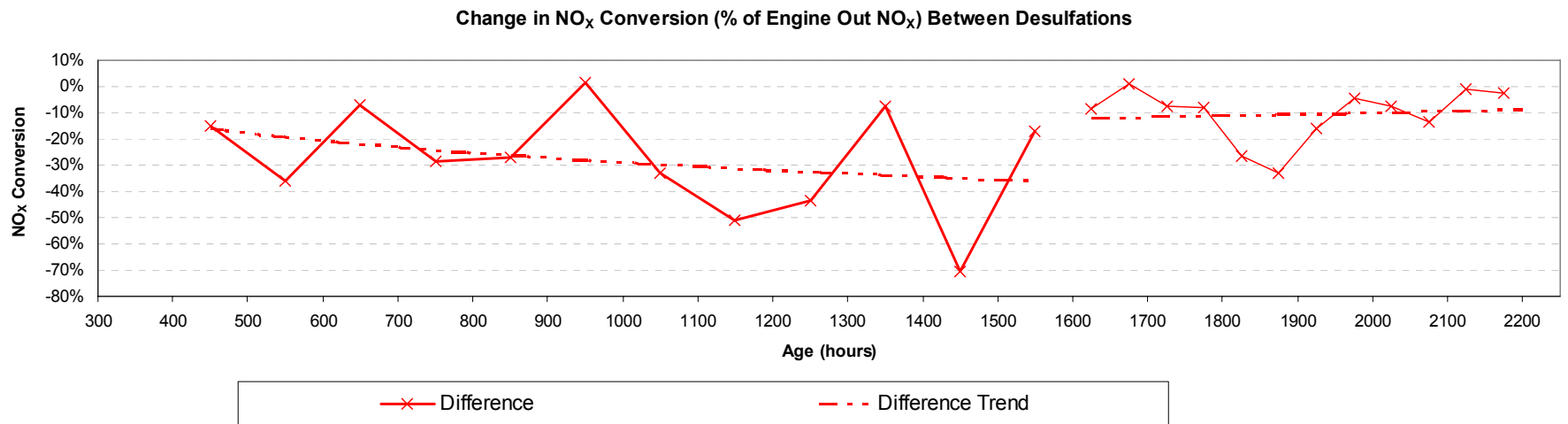
Passenger Car Project Test Results

NOx Adsorber Conversion Efficiency



Passenger Car Project Test Results

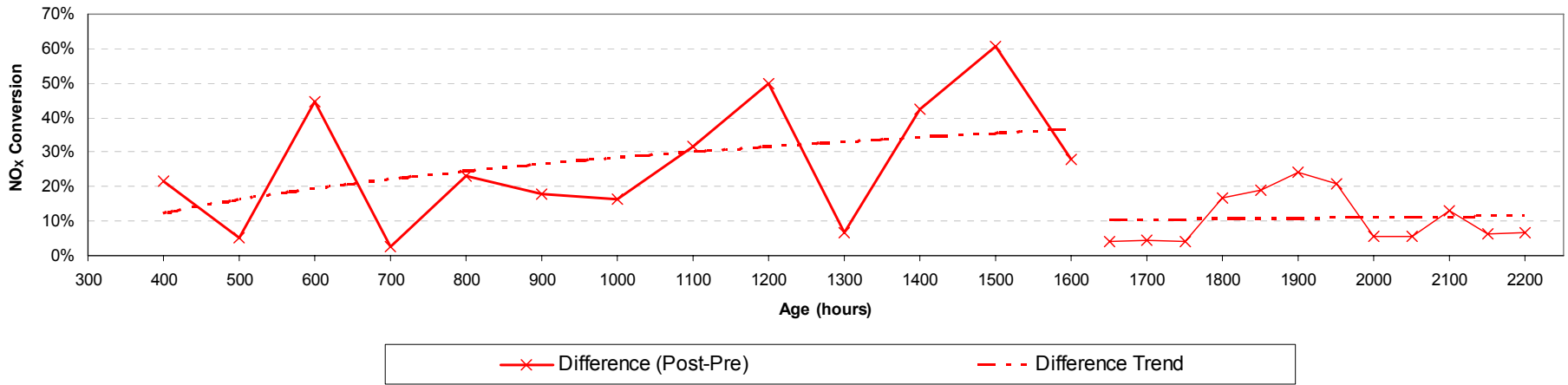
NO_x Adsorber Deterioration



Passenger Car Project Test Results

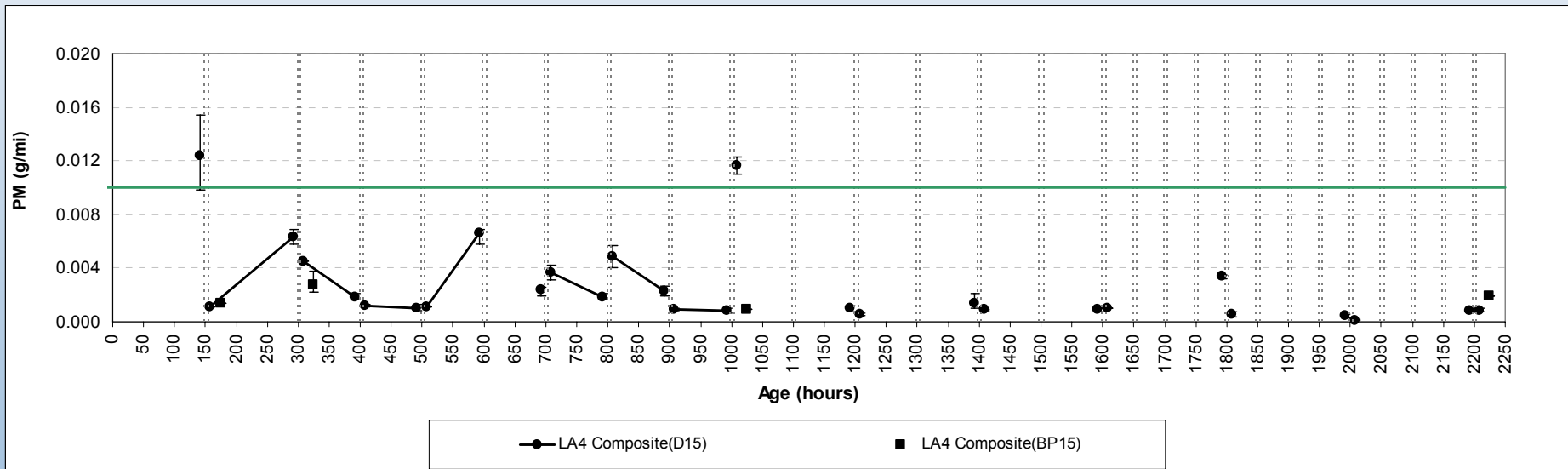
Desulfation Effectiveness

Increase in NO_x Conversion (% of Engine Out NO_x) at Each Desulfation



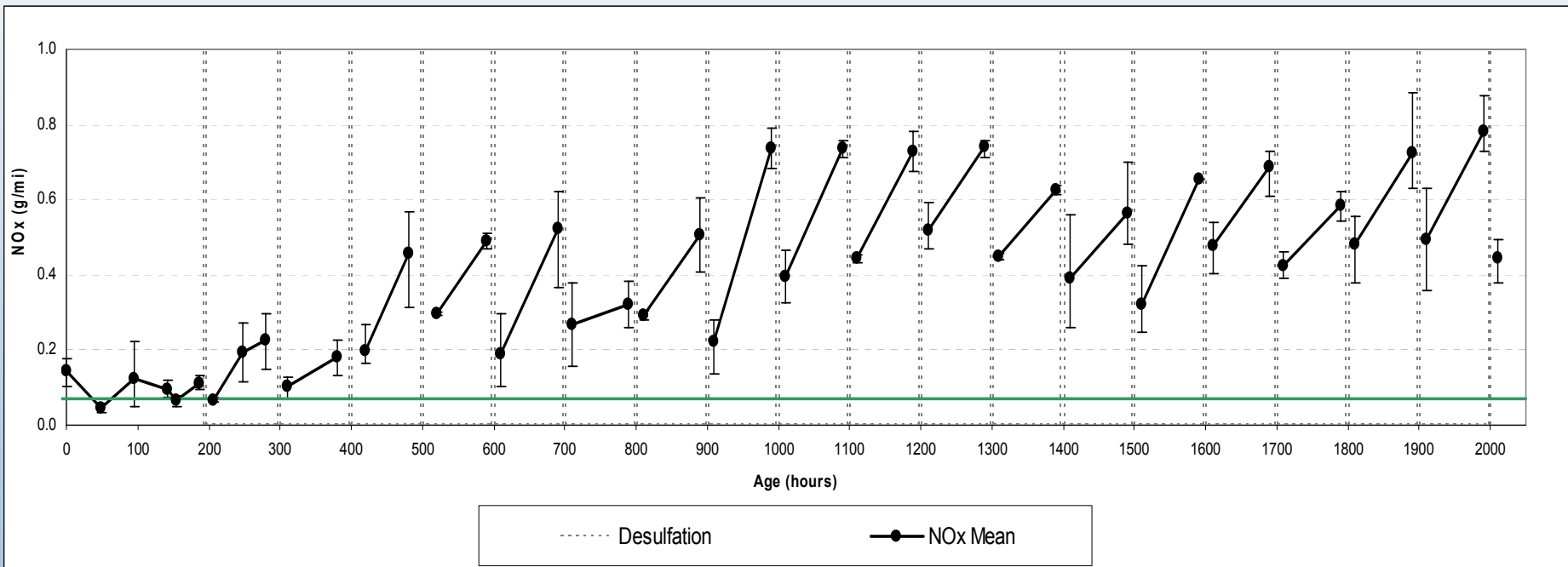
Passenger Car Project Test Results

PM Emission Trends



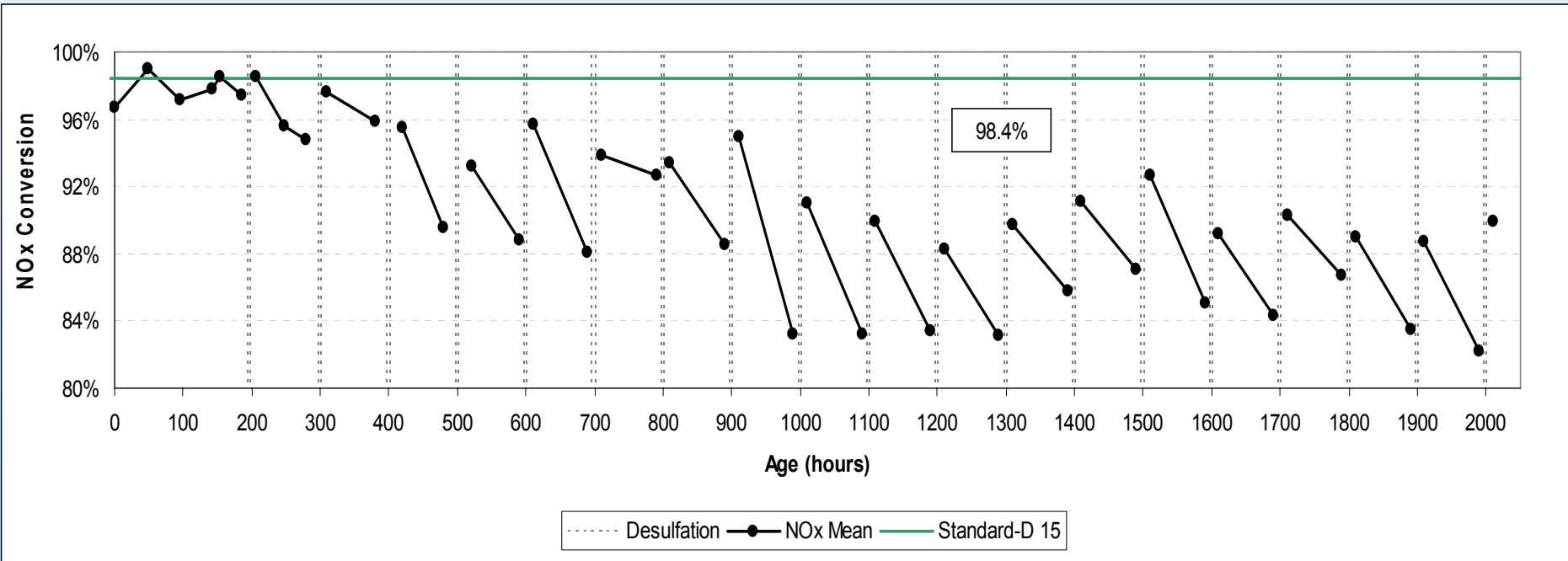
Medium-Duty Engine Project Test Results

NOx Emission Trends



Medium-Duty Engine Project Test Results

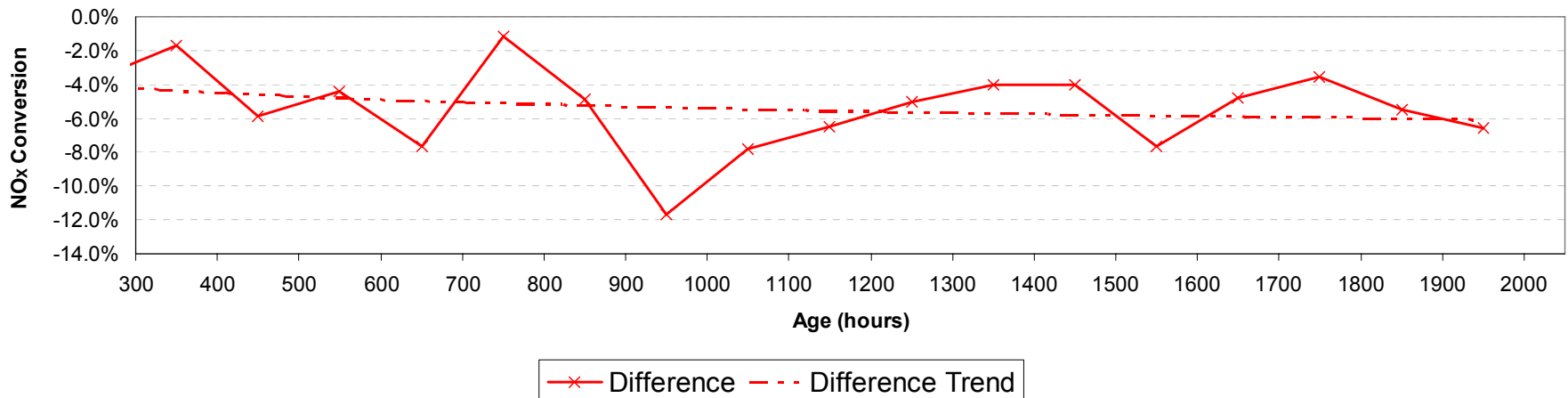
NOx Adsorber Conversion Efficiency



Medium-Duty Engine Project Test Results

NO_x Adsorber Deterioration

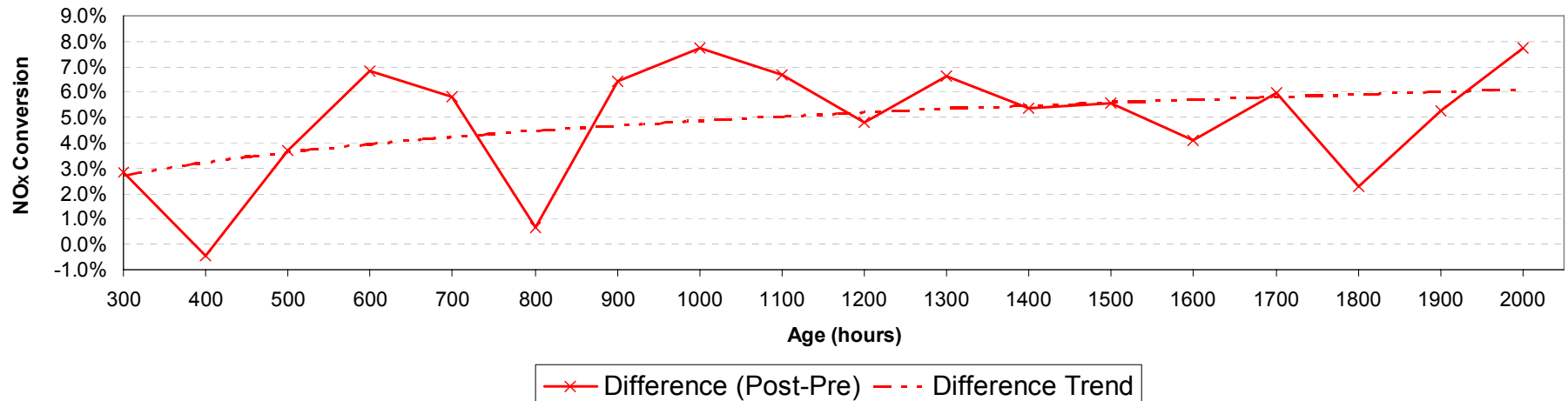
Change in NO_x Conversion (% of Engine Out NO_x) Between Desulfations



Medium-Duty Engine Project Test Results

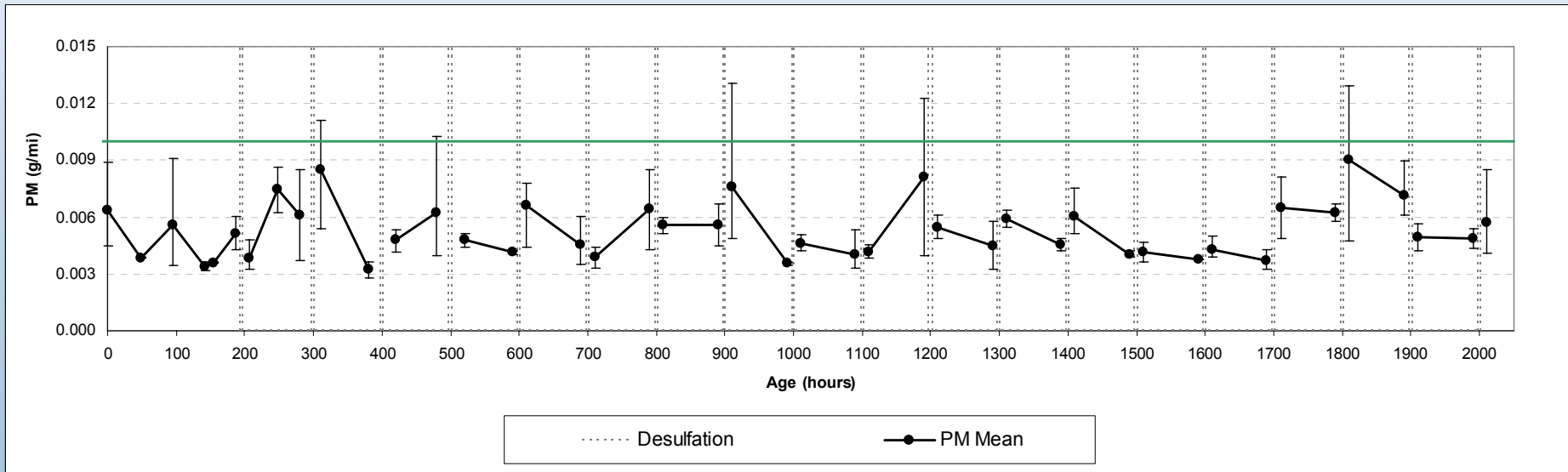
Desulfation Effectiveness

Increase in NO_x Conversion (% of Engine Out NO_x) 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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