Full Useful Life (120,000 miles) Exhaust Emission Performance of a NOx 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

<table>
<thead>
<tr>
<th>NO$_x$ Adsorber/DPF</th>
<th>SCR/DPF</th>
<th>Lubes</th>
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<tr>
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<tr>
<td>1.9L TDI</td>
<td>6.6L Isuzu Duramax</td>
<td>15L Cummins ISX</td>
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<td>Audi A4 Avant</td>
<td>Chevrolet Silverado</td>
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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

**Engine**

**Pre-Catalyst**

**Underbody NAC**

**CDPF**

**ECS-A:** DOC + NAC
- Cell Density: 400 cpsl
- Volume: 1.34 L
- Diameter: 4.16 inch
- Length: 6 inch
- Wall Thickness: 4.5 mil

**ECS-B:** NAC
- Cell Density: 350 cpsl
- Volume: 2.5 L
- Diameter: 5.66 inch
- Length: 6 inch
- Wall Thickness: 5.5 mil

**All ECS:** NAC
- Cell Density: 350 cpsl
- Volume: 2.5 L
- Diameter: 5.66 inch
- Length: 6 inch
- Wall Thickness: 5.5 mil

**All ECS:** CDPF
- Cell Density: 200 cpsl
- Wall Thickness: 14 mil
- Substrate Material: SiC
- Volume: 2.5 L
- Diameter: 5.66 inch
- Length: 6 inch
- Cell Geometry: Square

Substrate Material: Cordierite
Cell Geometry: Square
# Test Procedures

## Engine Dynamometer Test Cell:

### Pre-Desulfation Procedure

<table>
<thead>
<tr>
<th>Run</th>
<th>1/3 PM Sample</th>
<th>1 PM Sample</th>
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<tr>
<td>1</td>
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1 test cycle = 1 gas sample = 30 gas samples  
1 set of cycles = 1 PM sample = 10 PM samples

### Post-Desulfation Procedure

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<tr>
<th>Run</th>
<th>1/2 PM Sample</th>
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</table>

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

NOx Adsorber Deterioration

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

-80%  -70%  -60%  -50%  -40%  -30%  -20%  -10%  0%  10%  20%  30%  40%  50%  60%  70%  80%

Age (hours)

NOx Conversion

- Difference

- Difference Trend
Passenger Car Project Test Results

Desulfation Effectiveness

![Chart showing increase in NOx conversion (% of engine out NOx) at each desulfation over age (hours). The chart displays data points and trend lines for the difference (post-pre) and the difference trend.]
Passenger Car Project Test Results

PM Emission Trends

![Graph showing PM emission trends](image-url)
Medium-Duty Engine Project Test Results

NOx Emission Trends

![Graph showing NOx emission trends over time.](image-url)
Medium-Duty Engine Project Test Results

NOx Adsorber Conversion Efficiency
Medium-Duty Engine Project Test Results

NOx Adsorber Deterioration

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

-14.0%  -12.0%  -10.0%  -8.0%  -6.0%  -4.0%  -2.0%  0.0%

300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000

NOx Conversion

Age (hours)

Difference  Difference Trend
Medium-Duty Engine Project Test Results

Desulfation Effectiveness

Increase in NO\textsubscript{X} Conversion (% of Engine Out NO\textsubscript{X}) at Each Desulfation

![Graph showing NO\textsubscript{X} conversion over time with desulfation effectiveness]
Medium-Duty Engine Project Test Results

PM Emission Trends

![Graph showing PM emission trends over age (hours)]
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

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<tr>
<th><strong>Automobile:</strong></th>
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Acknowledgments

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