Light Duty Truck Aftertreatment - Experience and Challenges

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Detroit Diesel’s test experience on light duty truck PM aftertreatment technology development will be presented. The Tier-II extremely low emissions standards combined with the light-duty test cycle impose a significant challenge for the development of production-viable emissions technologies.

A robust general path to achieve these emissions targets will be outlined.
Light Duty Emissions
Aftertreatment

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Presented by: Charles Freese
Detroit Diesel Corporation
Outline

• Light Duty Emissions Challenges
  – Tier 2 Targets
  – Vehicle Inertia
  – Fuel Quality
  – Light Duty Cycle
    » Effects on Regeneration

• Progress Toward Targets

• Future Technical Path
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U.S. Light-Duty Standards
Automotive Emissions (Under 8,500 lb GVW)

New Tier 2 Allows Interim Standards in 2004, which Ultimately Lead to California LEV2 Standard

- California LEV 2
- U.S. Federal LEV 1 (LDT2 Vehicle Weight)
- U.S. Federal Tier 2 Max BIN 10
- U.S. Federal Tier 1 (LDT2 Vehicle Weight)
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Vehicle Inertia Effects

• Vehicle Inertia Dramatically Affects Vehicle Emissions

• ≤ 8,500 lb Held to Same Standards

• Must Demonstrate Technology Scalability
Effect of Vehicle Inertia Weight

$\text{NO}_x$ Emissions

Inertia Weight (lb)

$\text{NO}_x$ (g/mile)
Personal Transportation Engine Technologies

Scalability

1.5L HEV, 1.5L I-3, & 2.0L I-4 0.5L/cylinder

Other Available Engines:
- 2.5L 4-Cylinder
- 4.2L 6-Cylinder
- 3.0L V6 VECTER 0.5 L/cylinder
- 4.0L V6 DELTA 0.67 L/cylinder

Scale

Technology

0.5L per Cylinder

Technology

Share
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Aftertreatment
CRT Sulfur Sensitivity

![Graph showing the conversion of NO to NO2 at different sulfur concentrations and temperatures. The graph plots NO conversion to NO2 (%) on the y-axis and temperature (°C) on the x-axis. The lines represent different sulfur concentrations: 10 ppm, 50 ppm, 100 ppm, 500 ppm, and 1500 ppm. The graph indicates an optimal temperature range for each sulfur concentration.](Image)
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Exhaust Temperature Distribution
Light-Duty vs. Heavy-Duty

Exhaust Temperature Range (Deg C)

Frequency %

Heavy Duty Cycle
Light Duty Cycle

Particulate Trap Regeneration
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Light-Duty Emissions
4.0L V6 Vehicle Results
Exhaust System
Eliminated Exhaust Muffler

- Replaced Muffler with a Continuously Regenerating Trap (CRT)

PM Aftertreatment Device in Exhaust System

Original Muffler
Detroit Diesel DELTA 4.0L V6
Preliminary PM Aftertreatment Results

- Off the Shelf, Non-Optimized PM Aftertreatment System
- Catalyst 6’ from Engine (Too Far)
- Directional Test Only
- Optimized Systems Currently Under Development

Baseline Air System w/o PM Aftertreatment

Air System Improvements w/o PM Aftertreatment

With PM Aftertreatment

With CRT
Aftertreatment Performance
Cycle Effects

FTP Bag 1 and 2: CRT Inlet Temperature (deg C)
Aftertreatment Performance
Cycle Effects & Catalyst Position

FTP Bag 3: Exhaust Temperature Evolution

- CRT Outlet
- Turbo Outlet
- CRT Inlet

Temperature (Deg C)
Time (sec)
Particulate Aftertreatment Regeneration

EGR Influence

DELTA 4.0L V6 - Particulate Trap Regeneration
Effect of EGR Quantity on Soot Burning
During 20 min Highway Runs
DELTA 4.0L V6 - Particulate Trap Regeneration
Effect of Thermal Inertia
(After a 20 min Highway Run)
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Aftertreatment Development Program
Systems Approach

- Aftertreatment Focus
- Low Light-Duty Exhaust Temperatures Complicate Aftertreatment Operation
- Developing Analytical Tools
Aftertreatment Virtual Lab Technical Path

Three-Level Development Strategy

3D- CFD Base
- Detailed physics & design
- Extremely time consuming
- Technology is not mature yet

1D- CFD Base
- Focus on system integration with
- Overall physical dimensions
- General control strategies
- Practical & fast, but sacrifices detail

0D- Mean Value Base
- Focus on Detailed Control Strategies
- Considers Engine, Vehicle, & Aftertreatment
- Practical & Computationally Fast
- Relies on test data & 1-D results for look-up tables
Integrated System Modeling
Complete Vehicle, Engine, & Aftertreatment System

Power, AF ratio

Pre-Catalyst
NO → NO₂

Injector
Lean-NOx Catalyst

Oxidation Catalyst
Tailpipe

Fuel (mile/gal)
Speed (Mile/h)
NOₓ (g/mile)

NOₓ, PM
HC, CO, O₂

O₂
NO
NO₂
PM
HC
CO

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Conclusions

- Light-Duty PM Aftertreatment Remains a Challenging Goal
- Progress is Encouraging
- Regulations are Problematic with Respect to Vehicle Weight
- Must Address Fuel Quality Issues
- Unique Light-Duty Cycle Parameters Must Be Addressed, to Achieve Reliable Regeneration
- Analytical Tools Required to Optimize Complete System