The Potential for Achieving Low Hydrocarbon and NOx Exhaust Emissions from Large Light-Duty Gasoline Vehicles

(SAE Paper 2007-01-1261)

Joe Kubsh

Manufacturers of Emission Controls Association

(www.meca.org)

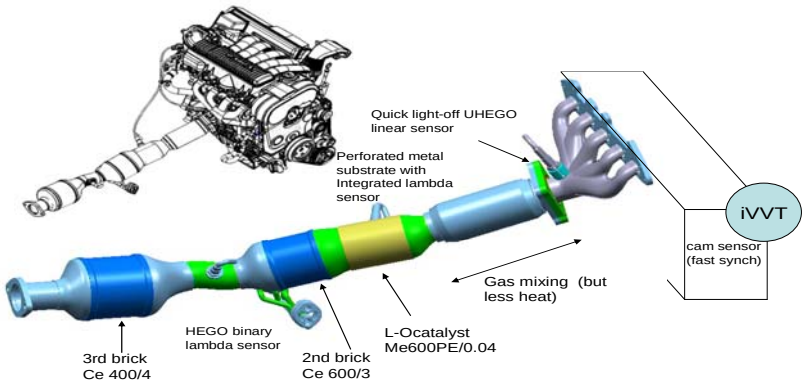
Joe Anthony

Southwest Research Institute

(www.swri.org)

PZEV Systems: State of the Art Emission Control Systems for Stoichiometric Gasoline Engines

MY 2007 Volvo S40/V50 2.4 Liter PZEV System



SAE Paper No. 2007-01-1260

Near-Zero Emission Systems Include Advanced Engine Designs and Emission Controls

- Advanced Emission Control Technologies include:
  - Advanced thermally stable, oxygen storage materials
  - In many cases, layered TWC coating architectures
  - In some cases, HC adsorber functions
  - High cell density substrates
  - Fast response oxygen sensors
  - Secondary air systems
  - Thermal management hardware including air-gap pipes & low heat capacity manifolds
- Advanced Engine Technologies include:
  - Improved fuel injectors
  - Variable valve technology
  - Lean start strategy with spark retard for fast catalyst heat-up
  - Electrically controlled EGR valve
  - Advanced control algorithms for precise A/F control

Large Diversity of PZEV/SULEV Models Available

- First wave of SULEVs/PZEVs introduced in 2001
  - Honda Accord SULEV
  - Toyota Prius SULEV
  - Nissan Sentra-CA PZEV
  - Honda CNG Civic SULEV
- 40 different 2007 model PZEVs currently available
  - Ford, VW, Nissan, Toyota, Honda, Volvo, BMW, Hyundai, Mitsubishi, Subaru, GM, DaimlerChrysler, Mazda
  - 4, 5, and 6 cylinder engines
- **Heavier weight class LDTs currently limited to LEV II LEV or Tier 2, Bin 4 compliant models**
  - LEV II LEV: 5.4, 5.6, 5.7 liter V8s
  - Tier 2, Bin 4: 5.3, 5.4, 6.0 liter V8s

MECA LDT Test Program: Advanced Emission Technology Demonstration

- Goal – Ultra-low HC and NOx exhaust emissions on 2 large light-duty trucks:

2004 Ford F150, 5.4L Triton V8

2004 GMC Yukon Denali, 6.0L Vortec V8

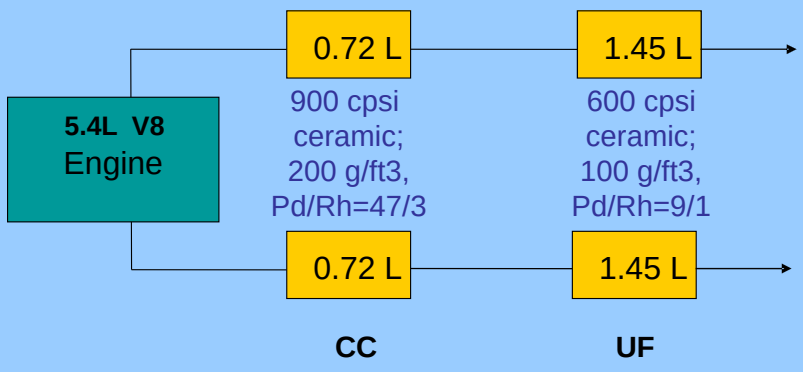
- Integration of advanced TWC systems with modified engine calibrations
- FTP/SFTP Evaluations on “de-greened” and engine aged advanced emission systems

Baseline Vehicle Configurations & Test Details

- Ford F-150, 5.4 L V8
  - 3 valves/cyl., CC+UF catalysts, spark retard start strategy, cast manifolds
- GMC Denali, 6.0 L V8
  - 2 valves/cyl., UF catalysts only, cast manifolds
- Exhaust emissions characterized in most cases using triplicate FTP testing
- California Phase III RFG with 17 ppm S used throughout the test program (mileage break-in, emissions testing, engine aging of emissions systems)

Ford F-150 Advanced Catalyst System Design

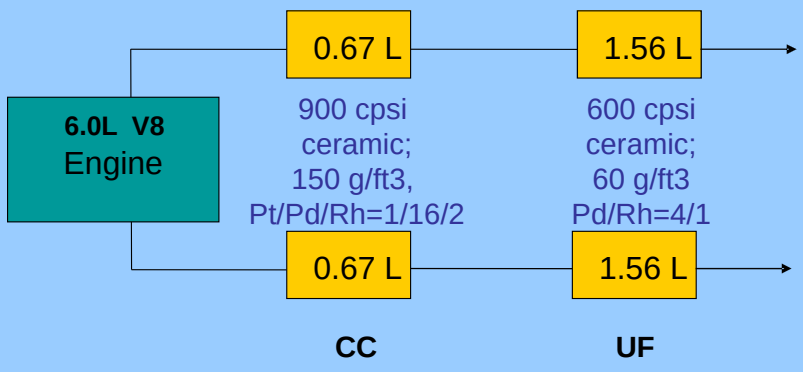
Total TWC Catalyst Volume: 4.34 L (0.80 SVR)



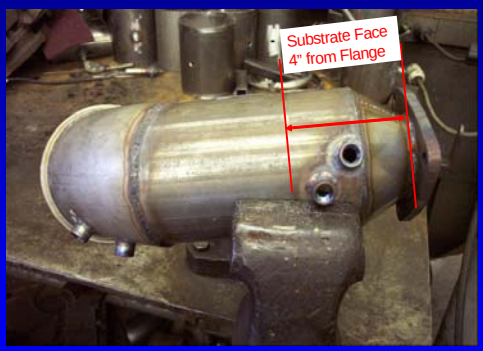
F-150 Advanced TWC System

GMC Denali Advanced Catalyst System Design

Total TWC Catalyst Volume: 4.46 L (0.74 SVR)



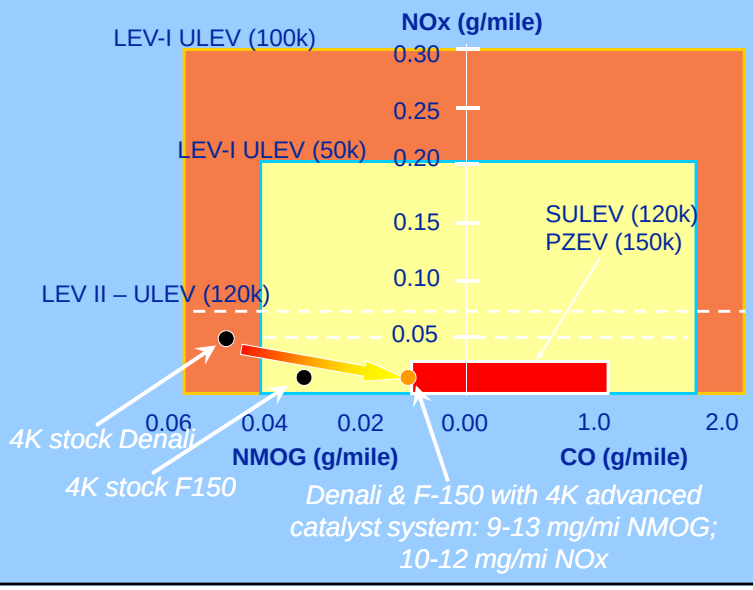
Denali Advanced TWC System



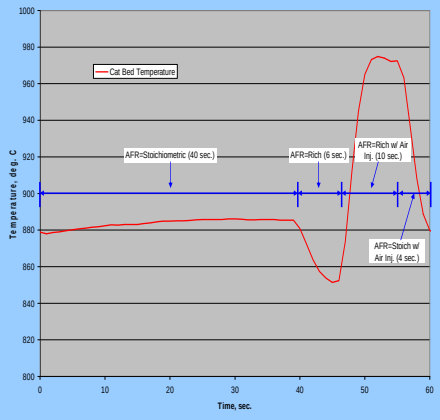
Denali Calibration Modified for Improved Cold-Start and Hot-Start Performance

- Cold idle speed increased from 900 to 1100 rpm
- Spark timing retarded during cold-start to accelerate catalyst light-off
- Less fuel enrichment during cold-start
- Closed-loop air-fuel control enabled right after cold crank
- Slight rich bias applied to first FTP hill after hot-start to reduce NOx spike

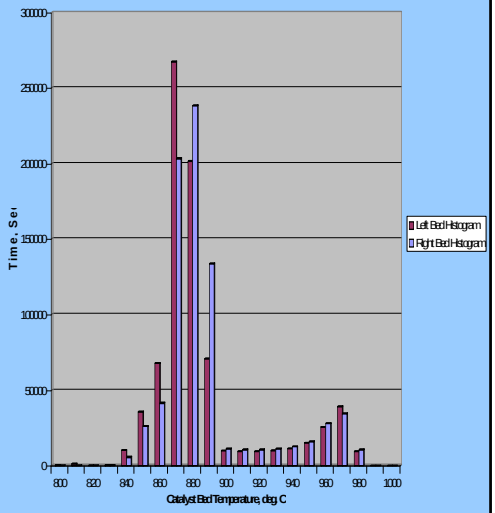
Baseline FTP Emissions (4K mi, stock) and Program Emission Targets



Advanced Emission Systems Aged for 220 hours Using an Accelerated Engine Aging Protocol

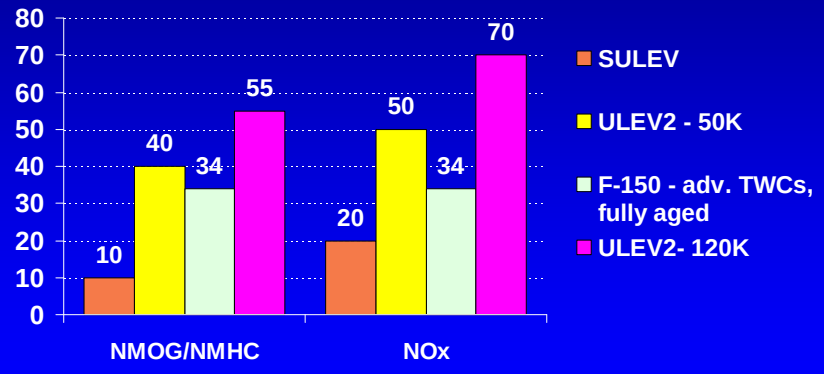


Denali System Aging History



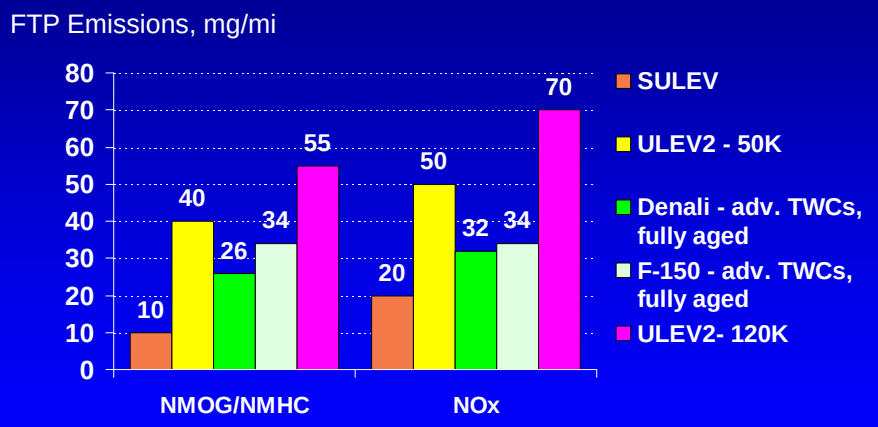
Ford F-150 Fully Aged Advanced Emission Systems FTP Performance - Below 50K ULEV2 Limits

FTP Emissions, mg/mi



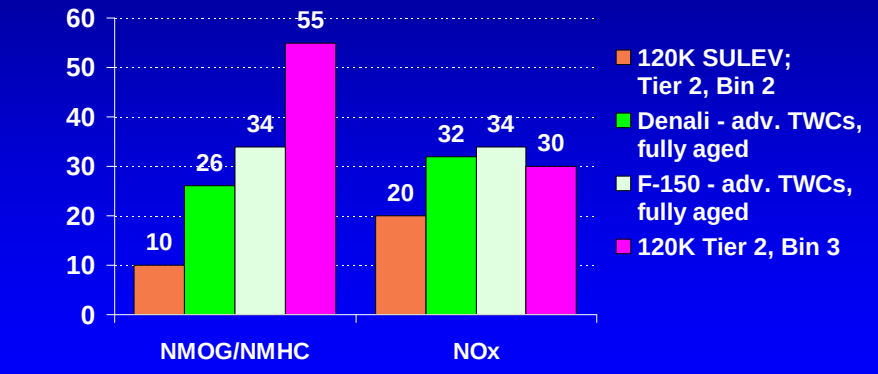
F-150 Results Using Stock Engine Calibration

GMC Denali & Ford F-150 Fully Aged Advanced Emission Systems FTP Performance - Below 50K ULEV2 Limits



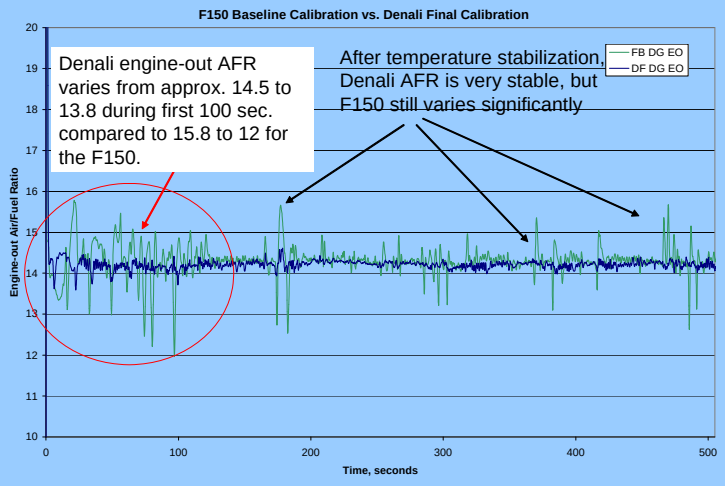
Denali Results Include Modified Calibration Strategy;
F-150 Results Using Stock Engine Calibration

GMC Denali & Ford F-150 Fully Aged Advanced Emission Systems FTP Performance – Near Tier 2, Bin 3 Limits

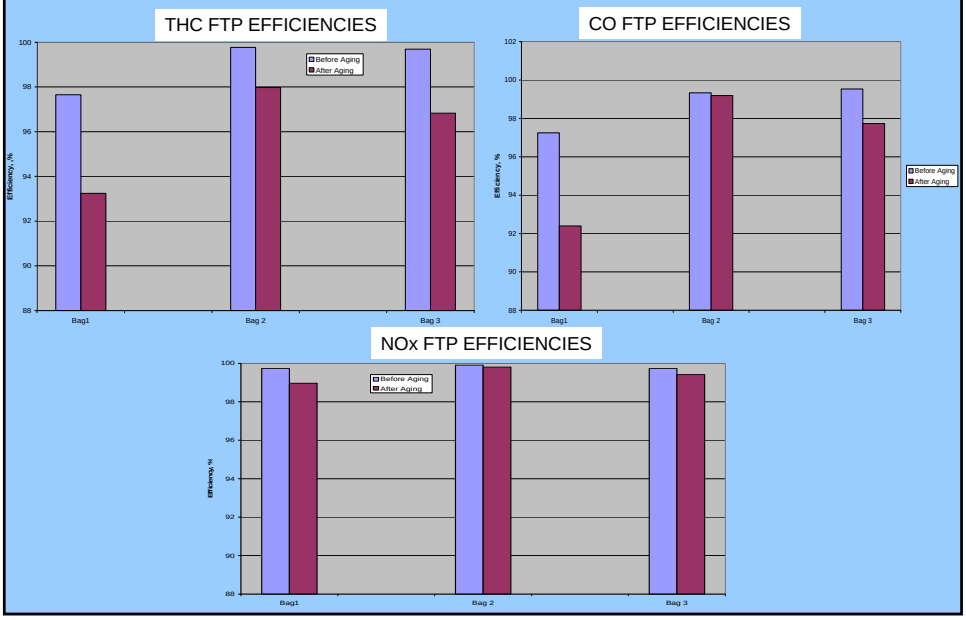


Denali Results Include Modified Calibration Strategy;
F-150 Results Using Stock Engine Calibration

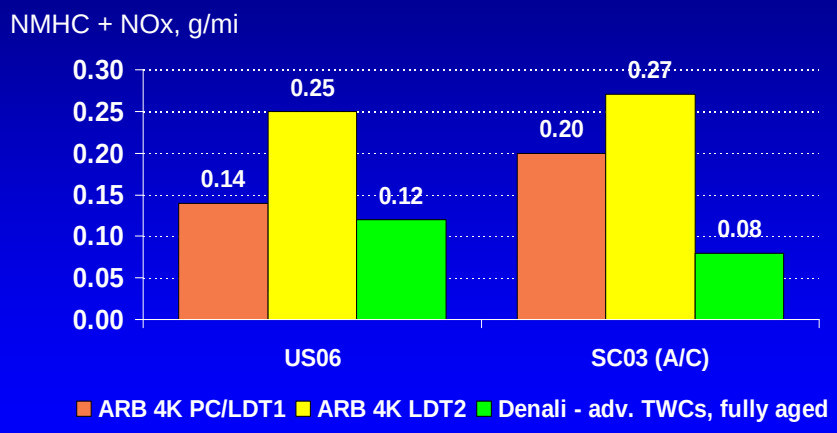
Tight Air-Fuel Control Important for Achieving and Maintaining Low Exhaust Emissions



Denali Catalyst System FTP Conversion Efficiencies Remain High After 220 h of Aging



GMC Denali Fully Aged Advanced Emission System SFTP Performance - Below Current ARB 4K Limits



SAE Paper No. 2007-01-1261 Summary and Conclusions

- Advanced emission control technologies can be combined with advanced engine controls to achieve ultra-low HC and NOx exhaust emissions on heavy, light-duty gasoline vehicles
- Tight air/fuel control is an important enabler to maintaining ultra-low exhaust emissions on gasoline vehicles

- Thank you to Joe Anthony, his colleagues at Southwest Research Institute, and the members of MECA for their support in completing this project