Diesel Retrofit Programs for Heavy-Duty Diesel Vehicles

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ECT 2016: Emission Control Technology for Sustainable Growth
New Delhi, India
November 10, 2016
Outline

• Existing Diesel Retrofit Programs
• Verification Programs
• Retrofit Technologies
• Importance of Maintenance
• Insuring compliance
• Summary
U.S. Diesel Retrofit Programs

- **> 19 million in-use diesel engines** of all types throughout the U.S. – significant source of PM and NOx; long service life
  - U.S. retrofit programs and 2007 “clean diesel” turnover have impacted < 4 million engines

- **Mandatory Efforts**
  - California – all existing diesel engines impacted
  - New Jersey, New York State, New York City, Chicago metropolitan area (public fleets or public projects)
  - Green construction contracts/requirements spreading

- **Highly Incentivized Voluntary Programs**; mostly with available local, state, or federal funding; mostly focused on PM reductions
  - Everywhere else in the U.S.
Defined Verification Procedure is Essential

U.S. EPA/CARB Programs

• Application
• Test Plan Development
• Emission and Durability
  – HD-FTP or NRTC test cycle
  – PM, NOx, Secondary, NO₂
  – Degreened and Aged Emissions
  – 1000 hr. field aged device
• Data review
• Classification by PM and NOx emissions
• In-use testing after 500 sold
  – Four units @ 25% of life
  – Four units @ 75% of life
• Warranty and Recall

UN-Retrofit (REC)

• Emission and Durability
  – WHTC or NRTC cycles
  – 1000 hr durability in field or on engine bench
  – Degreened and aged emissions
  – NO₂, secondary, NOx, PM emissions
• Production conformity but no in-use requirements
• Four Classes
  – PM, no NO₂
  – PM, < 30% or < 20% NO₂
  – NOx
  – PM & NOx
List of Available EPA-/ARB-Verified Level 3 Retrofit Technologies Continues to Expand (as of October 2016)

• U.S. EPA (www.epa.gov/verified-diesel-tech/verified-technologies-list-clean-diesel) – 13 total DPFs and 3 NOx control-only devices
  – 6 on-road passive DPFs (includes 2 DPF+SCR)
  – 2 on-road active DPFs
  – 4 off-road passive DPFs (includes 1 DPF+SCR)
  – 1 off-road active DPF
  – 1 off-road SCR
  – 1 off-road and stationary engine SCR
  – 1 locomotive SCR

• California ARB (www.arb.ca.gov/diesel/verdev/vt/cvt.htm) – 48 total
  – 13 on-road passive DPFs (includes 1 DPF+LNC and 1 DPF+EGR)
  – 7 on-road active DPFs
  – 1 off-road passive DPF
  – 5 off-road active DPFs
  – 5 Level 3 devices for TRUs
  – 3 Level 3 devices for APUs
  – 1 Level 3 device for RTGs
  – 13 Level 3 devices for stationary engines
**DOCs and Crankcase Filters Offer PM Reductions from Older Engines**

**Diesel Oxidation Catalysts: 20-40% PM**

- CO
- Aldehydes
- HC
- PAH
- SO₂
- NOx

Flow through monolith with catalytic coating

- Millions of DOC retrofits worldwide on on-road and off-road vehicles and equipment.
- Less sensitive to engine-out PM
- Fuel sulfur levels (<50 ppm)

- Eliminates about 5% of total PM from vehicle
- Effective in combination with DOCs or DPFs

**Emissions From Crankcase Breather Tubes**
Wall-Flow Diesel Particulate Filters Offer the Highest PM Filtration Efficiency

- Passively regenerated DPFs employ catalysts and available exhaust heat to burn soot
- Require specified exhaust temperature
- 50 ppm S limit
- Large reduction in toxics from catalyzed DPFs
- Large reduction in black carbon (GHG)
- Same technology as on U.S. MY 2007 and newer and Euro VI OE trucks
Range of Active DPFs Available for Low Exhaust Temperature Applications

- Suited for on- and off-road applications with low exhaust temperatures.
- Uncatalyzed or catalyzed wall-flow filter with electrical regeneration.
  - Catalyzed filter + electrical element combines passive and active functions
  - On or off vehicle regeneration possible
- Wall-flow filter with a fuel burner for regeneration.
Retrofit Systems that Provide PM + NOx Reductions

DPF + Urea-SCR Retrofit System

- DPF + Urea-SCR Retrofit System
- DPF + HC-SCR Retrofit System

60-90% NOx Efficiency

25-40% NOx Efficiency
Key Considerations for Successful Retrofit Projects

- **Application engineering** – match the right technology to the vehicle or equipment
  - Vehicle must be well maintained before considering retrofit - gross emitters are not good retrofit candidates
  - Available fuel sulfur levels dictate retrofit options – 50 ppm S required for catalyzed retrofit DOCs and DPFs
  - Vehicle duty cycles and exhaust temperature define retrofit options
  - Use only verified retrofit technologies with **proven** performance/durability

- **Professional installation**

- **Maintenance** – vehicle/equipment and retrofit device require regular inspections and maintenance

- **On-vehicle monitors** – provide important user feedback on performance
Vehicle Pre-installation Inspection

• A pre-installation vehicle inspection is critical
• Examines the engine for potential pre-existing mechanical faults
  • Warning lights & codes
  • Air intake and exhaust system integrity
  • Visual turbocharger inspection
  • Fuel injector problems
  • Oil leak and consumption issues
• Typically includes opacity testing
• Data logging over 24 hours of typical duty-cycle
• A healthy engine equals a successful Retrofit!
• http://www.meca.org/galleries/files/MECA_On-Road_Pre-Assessment_Checklist_Final.pdf
Proper Truck Maintenance is Important

• To operate as designed, all engines require proper maintenance
• Benefits of conducting preventive maintenance:
  – Maintains low emissions
  – Helps save fuel costs
  – Maximizes truck performance
  – Maximizes engine life
  – Reduces down-time
• DPF not a “fit-and-forget” device
• Improper care of engine and emission controls can lead to:
  – Expensive repairs and replacement parts
  – Voided warranty
  – Engine malfunction or breakdown
  – Loss of horsepower and de-rated engine
Truck Inspection Programs insure Compliance

• Current smoke inspection requirements for older Heavy-Duty trucks in the US:
  – 40% opacity limit for 1991 and newer
  – 55% for 1990 and older
  – SAE J1667 snap acceleration smoke test procedure
Tighter Opacity Requirements for Filter Equipped Trucks

- Opacity above 3-5% is an indication of a damaged DPF
- Current smoke meters are adequate to measure opacity levels in 5% range

Source: Research conducted at NREL
Diesel Retrofit Summary

- Diesel retrofit programs provide policy makers with an important tool for cleaning-up in-use fleet and accelerating air quality improvements.

- A variety of retrofit technologies have been verified for reducing PM and NOx emissions from existing on-road and off-road diesel engines.

- Application engineering and pre-installation inspections are a necessary step to matching the vehicle with the correct retrofit solution.

- Engine and retrofit device maintenance is essential for achieving emission reductions and proper operation.

- Truck inspection and maintenance programs are important to prevent tampering and insure compliance.