Diesel Retrofit Programs for Heavy-Duty Diesel Vehicles

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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, NO_2
  - 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)

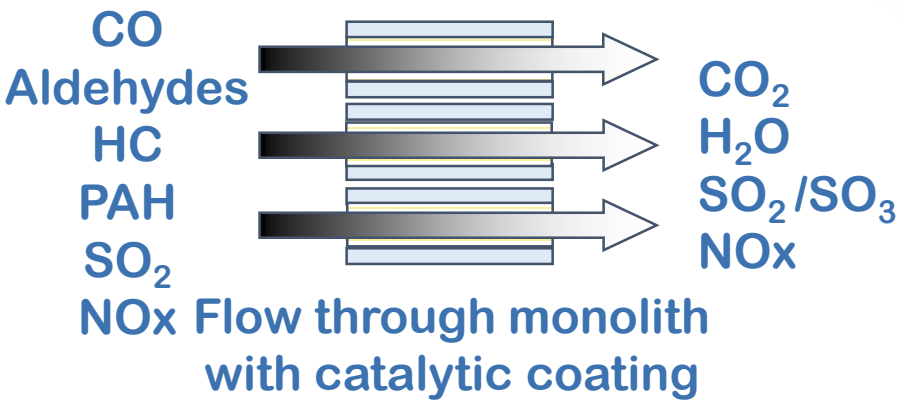
- Emission and Durability
  - WHTC or NRTC cycles
  - 1000 hr durability in field or on engine bench
  - Degreened and aged emissions
  - NO_2, secondary, NOx, PM emissions
- Production conformity but no in-use requirements
- Four Classes
  - PM, no NO_2
  - PM, < 30% or < 20% NO_2
  - NOx
  - PM & NOx

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

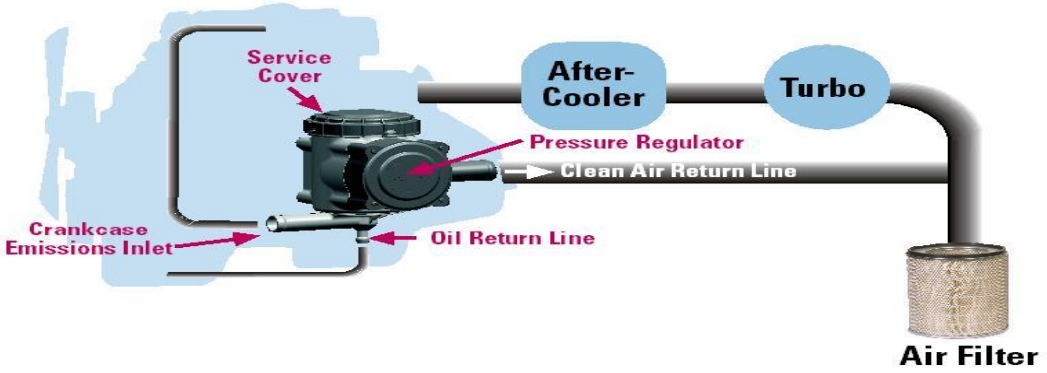
Diesel Oxidation Catalysts: 20-40% PM



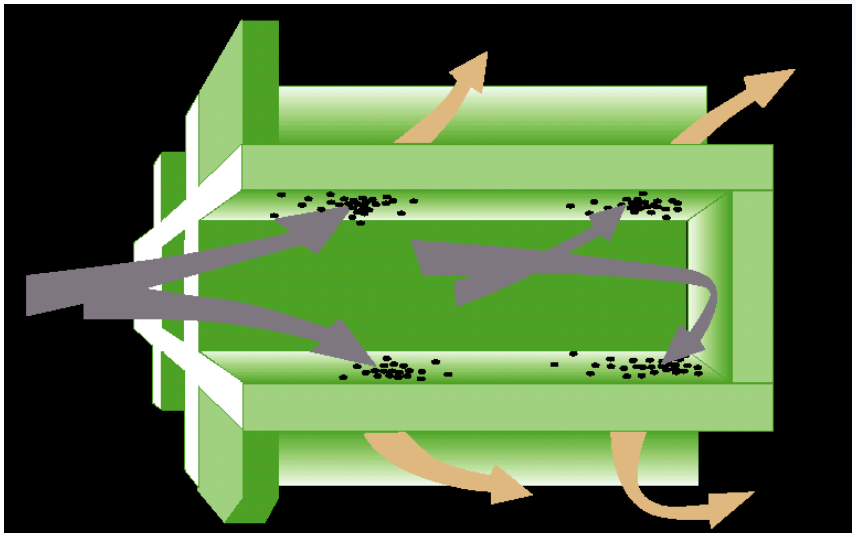
- Millions of DOC retrofits worldwide on on-road and off-road vehicles and equipment.
- Less sensitive to engine-out PM
- Fuel sulfur levels (<50 ppm)

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

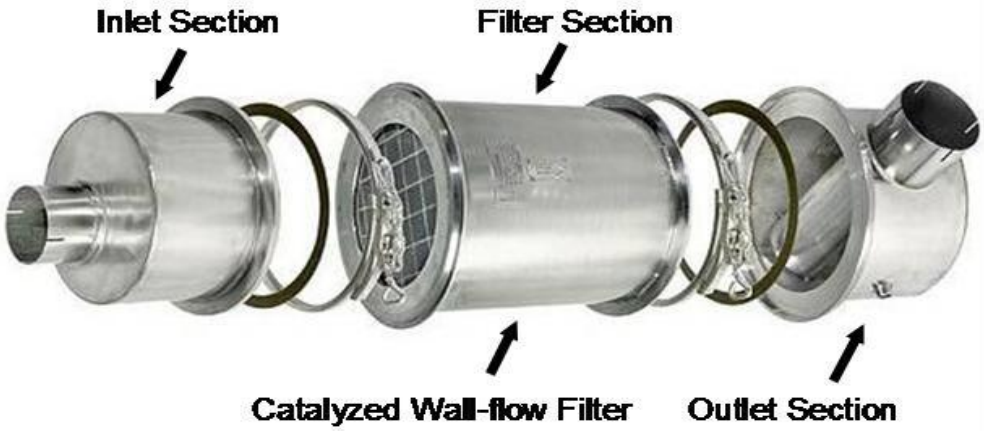
Emissions From Crankcase Breather Tubes



Wall-Flow Diesel Particulate Filters Offer the Highest PM Filtration Efficiency



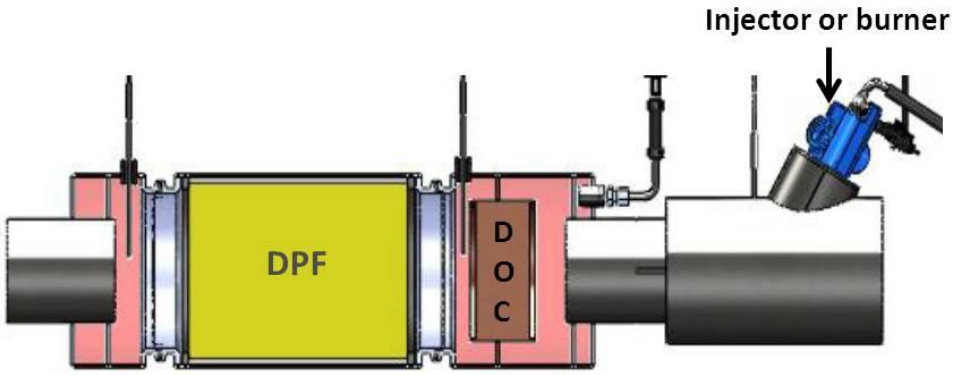
- Passively regenerated DPFs employ catalysts and available exhaust heat to burn soot
- Require specified exhaust temperature
- 50 ppm S limit



- 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

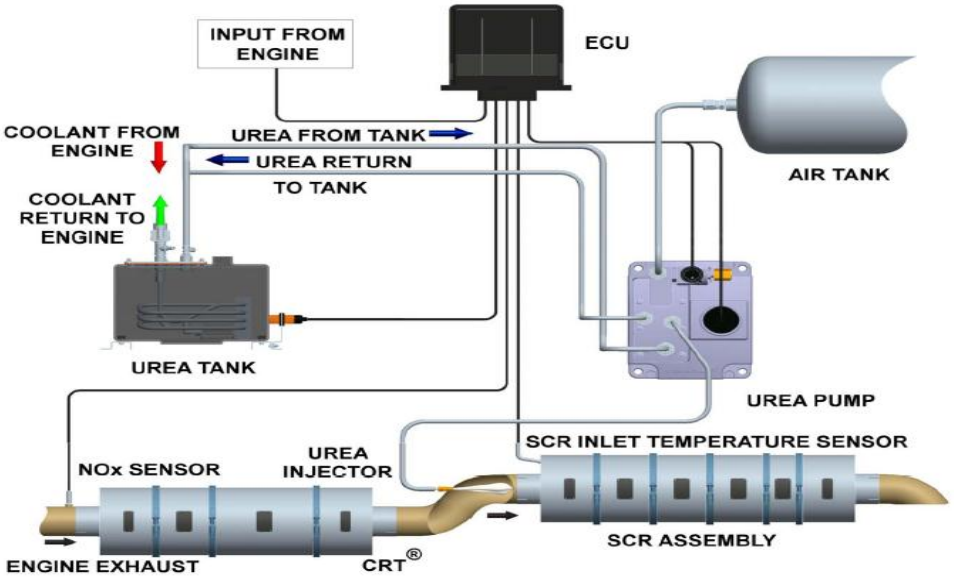
Range of Active DPFs Available for Low Exhaust Temperature Applications

- 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



60-90% NOx Efficiency

DPF + HC-SCR Retrofit System

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

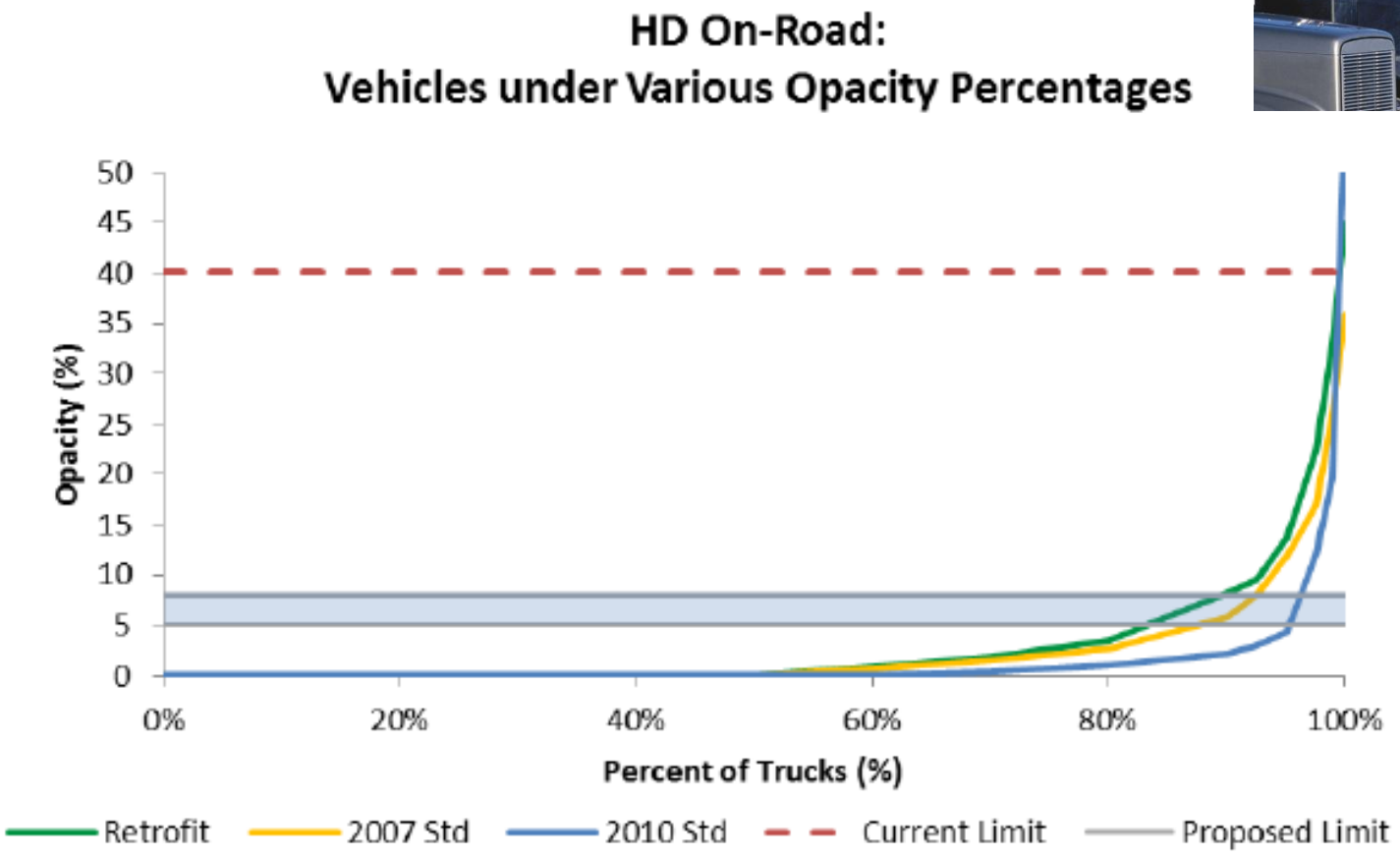
Proper Truck Maintenance is Important

- 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
- http://www.meca.org/galleries/files/Filter_Maintenance_White_Paper_605_final.pdf

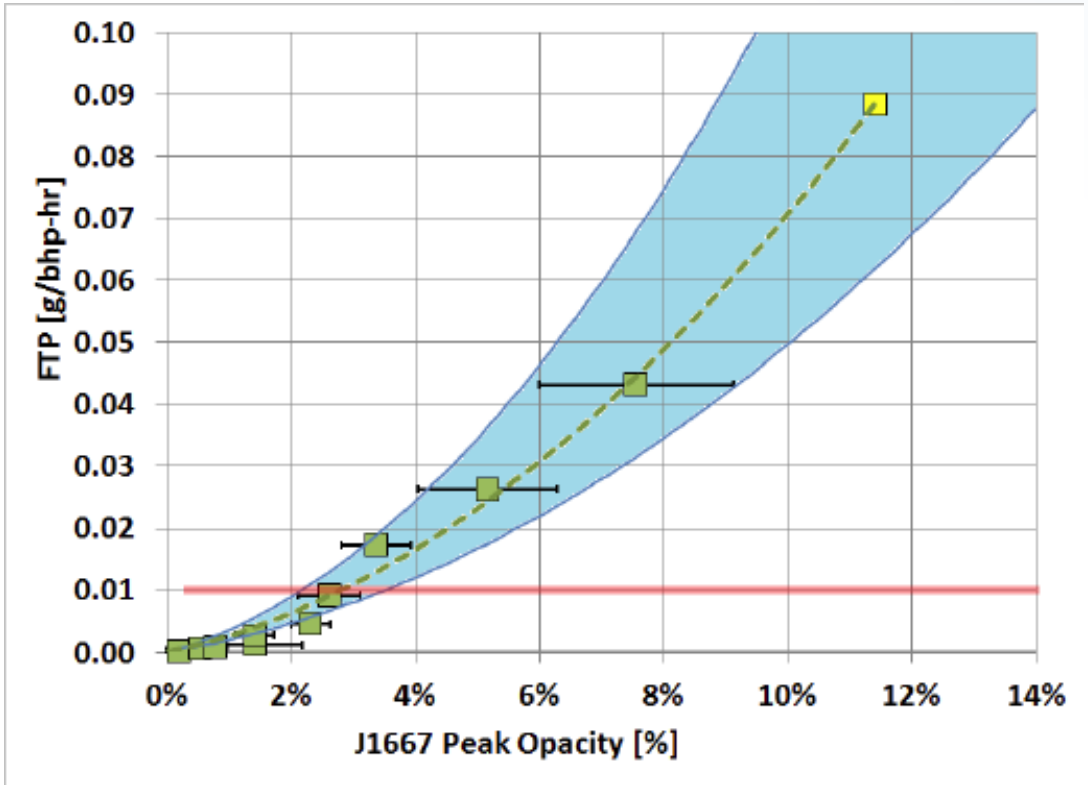
Truck Inspection Programs insure Compliance

- 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