

Beyond PM Retrofit Technologies

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Dieselization of Goods Movement

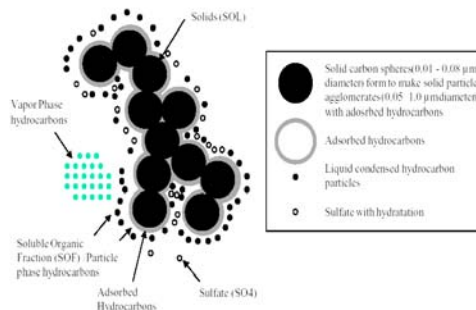
1. Ocean going container/cargo ships
2. Harbor craft (Tug boats)
3. Cargo Handling Equipment
4. Port Hauler Trucks
5. Locomotives/Rail Transport

Diesel Exhaust Emissions

- Particulate Matter (PM)
 - Toxic air contaminant
 - Ultrafine components are of concern
 - Dramatic reductions in PM from diesel engines are critical for California's Attainment and Risk Reduction goals
 - Possible link to Climate Change
- Oxides of Nitrogen (NO_x)
 - Precursor to Ozone
 - Leads to secondary PM formation in the atmosphere
 - Dramatic reductions in NO_x from diesel engines are critical for California's Attainment goals
- Nitrogen Dioxide (NO₂)
 - Respiratory irritant
- Carbon Monoxide (CO) and Hydrocarbon (HC)
 - Also emitted but typically at much lower rates

About PM

- Composition (Solid, Condensed fuel and lube oil, inorganic ash)
- Size
- Toxicity

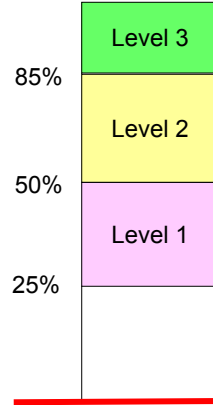


Johnson, Konstandoplos, 1994, SAE 940233

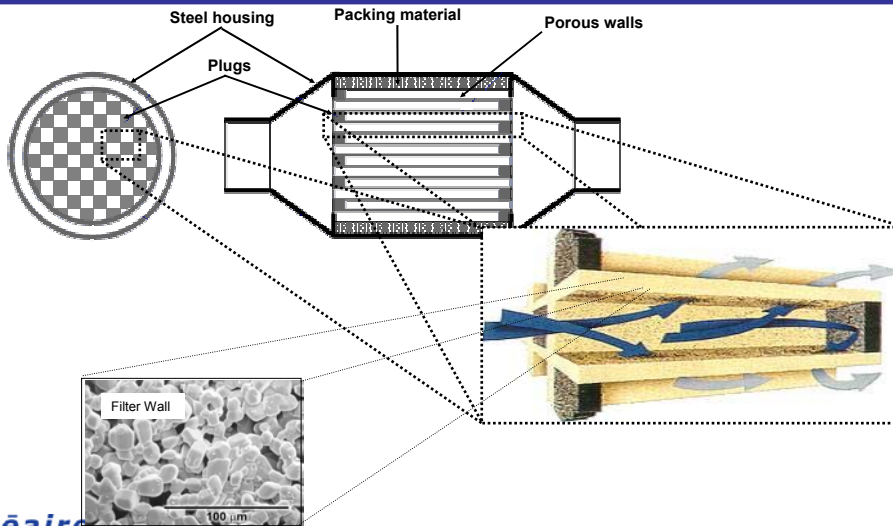
PM Control Solutions

CARB Performance Designations

Level	PM Reduction	Technology	Description
3	>85%	Diesel Particulate Filter (DPF)	Wall flow filters (Silicon Carbide, Mullite, Cordierite) Ceramic paper, Sintered Metal
2	>50%	Partial Filter	Torturous path monolith and wire mesh filter
1	>25%	Diesel Oxidation Catalyst (DOC)	Catalytic coating on ceramic or metallic monolith



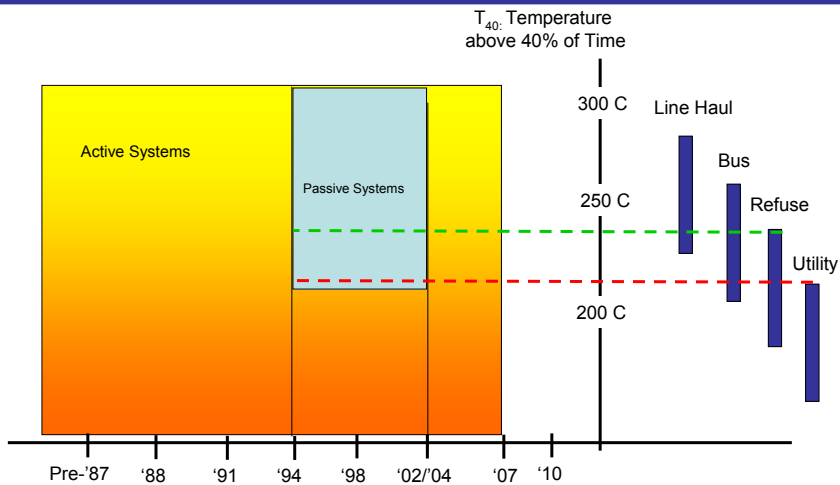
Design of a Wall Flow DPF



DPF Regeneration Approaches

- Passive Systems
 - Pre-filter catalyst or catalyzed DPF
 - Relies on exhaust temperature and NO₂ to regenerate DPF
- Active Systems
 - Plug-in Electric
 - Burner
 - Hydrocarbon injection/Catalytic Combustion
- Combinations of Passive and Active Systems

Applicability of On-Road PM Retrofits



Plug-in Electric Active DPF



2006 MY Elgin Sweeper



Shore Power:
208 Volt, Single Phase

Is this the bridge to the plug-in heavy-duty hybrid?

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Beyond PM: Nitrogen Dioxide

- Exposure to breathers near tailpipes
- NO₂ “hot spots” near roads and areas of heavy use
- 2007 CARB NO₂ Standard:

$$\%NO_2 \text{ Make} = \frac{NO_2 \text{ Device Out} - NO_2 \text{ Engine Out}}{NOX \text{ Engine Out}} < 30\% \text{ by 2007, } < 20\% \text{ by 2009}$$

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Beyond PM: NOx Control can be integrated with PM Controls

NOx Reduction	PM Reduction	Technology
25-40%	Level 3	NOx Reduction Catalyst (NRC), aka Lean NOx Catalyst (LNC), aka Hydrocarbon-SCR (HC-SCR)
40-60%	Level 3	Exhaust Gas Recirculation (EGR)
50-90%	Level 3	Urea or ammonia-SCR

Beyond PM Retrofits: Deployment

- CARB or EPA verification is critical
- Retrofits are Cost effectiveness compared to
 - Equipment replacement
 - Engine replacement (diesel or alt. fuels)
- Distribution to handle
 - Sales
 - Installation
 - Service & Maintenance
 - Support



Beyond PM Retrofits: Rules, Incentives, Program related to Goods Movement & Ports

- Rules
 - Private Heavy-Duty Rule
 - Targets both NOx and PM Reductions – passage in 2008
 - Port drayage Trucks
 - Expected in 2008 – may target both NOx and PM
 - Cargo Handling Equipment Rule
 - Currently being implemented – targets only PM
 - Construction Equipment Rule
 - Targets both NOx and PM – passage in May, 2007
- Incentives
 - Carl Moyer (funds NOx and PM reductions)
 - State Infrastructure Bond
 - Port Drayage Trucks & Possibly Other Trucks in the Valley

Closing Remarks: What

- DPFs virtually eliminate PM emissions
 - >85% by mass
 - >99% by number
- NOx and PM retrofits are available now
 - Verified by ARB
 - Commercially available
 - Very cost effective relative to truck or engine replacement

Closing Remarks: How

- Immediately:
 - Retrofit is complementary to other approaches such as fleet replacement and alternative fuels, so
 - There is no reason to wait. Retrofit now while also pursuing other strategies.
- Focused:
 - Trucks and cargo handling equipment
 - Marine and Locomotive solutions are more difficult but will follow