

Overview of Diesel Emission Control Retrofit Options

Tim Johnson
December 2004



Diesel emission control retrofit programs are spreading throughout the world

- California and Switzerland are mandating retrofits of all diesel vehicles by end of decade
- Sweden, Tokyo, and Hong Kong require retrofits for city vehicles
- US EPA has voluntary retrofit program
 - Formal school bus program
 - Spreading into other applications
- Korea
- Dozens of city programs
 - Buses
 - NY construction equipment

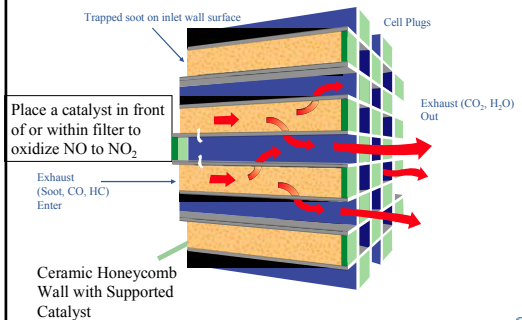


Diesel Particulate Filters (DPF)

- 100,000+ retrofits worldwide
- Many regions are mandating
- Variety of technologies for a variety of applications
- Still not universally applied, but coming



Diesel particulate filters use porous ceramics and catalyst to collect and burn the soot



DPF systems are comprised of several components - ceramic, catalyst (depending), mat, can



Bare diesel particulate filter substrate. Depending on the technology, it is used as is, or with catalyst. Corning



Filter is placed in a can with retaining rings to facilitate removal for ash cleaning. Lubrizol - Canada



Canned systems can have DOCs (here), or NOx catalysts in the same can as the filter. Courtesy Johnson Matthey

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Numbers are interesting, but seeing is believing



Filter Inlet



Filter Outlet



Filter Can Inlet Section

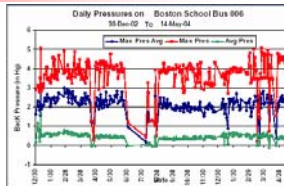
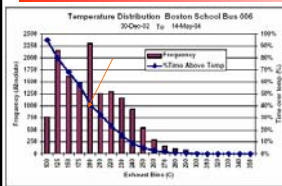


Filter Can Outlet Section

Courtesy of Johnson Matthey

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Filter technology is expanding range of passive operation: stable Δp with T at 200C



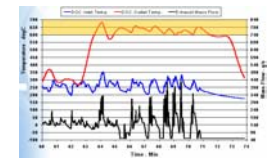
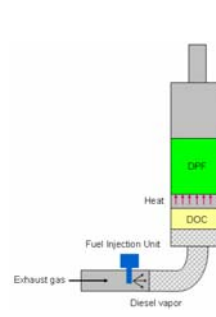
- Passive regeneration, despite the exhaust temperature distribution is greater the 200C only 40% of time.
- With system, NOx/soot > 15 is needed, at least much of the time.

Johnson Matthey, SAE 2004-01-2959

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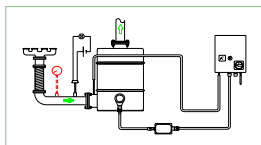
HDD is moving toward auxiliary heating of DPFs in the exhaust system

Donaldson, DEER 8-04



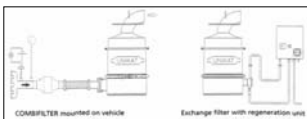
On-board electrical heating or off-line cleaning can be used to regenerate filters

On-board auxiliary electrical regeneration



V-Type: Cordierite filter, 8 hours regeneration
 K-Type: SiC filter, 8 hours regeneration
 S-Type: SiC filter, 60 minutes regeneration

Off-line regeneration



V-Type: Cordierite filter, 8 hours regeneration
 K-Type: SiC filter, 8 hours regeneration
 S-Type: SiC filter, 60 minutes regeneration

Lubrizol-Canada

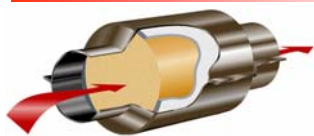
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Diesel Oxidation Catalysts (DOC)

- Long track record
- Readily Available and Effective



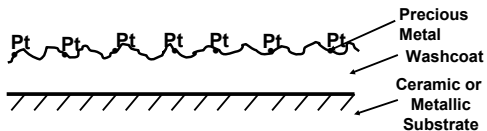
Diesel oxidation catalysts are passive devices comprised of substrate, catalyst, and can



Flow-through diesel oxidation catalyst in a can.



Each cell (400 per sq. in.), contains a washcoat and catalyst coating

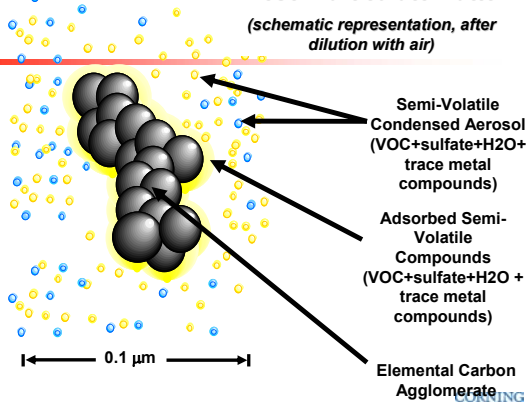


Slide courtesy of Lubrizol - Canada

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Diesel Particulate Matter

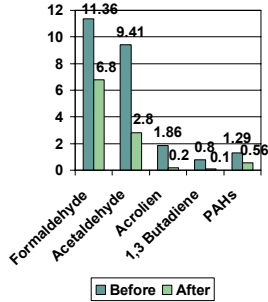
(schematic representation, after dilution with air)



Source: EPA

DOCs Destroy Large Fractions of Toxic Emissions

mg/bhp-hr



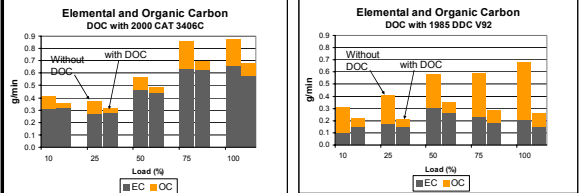
- Toxic Hydrocarbon Compounds Reduced by 68%
- PAH Emissions Reduced by 56%
- Greater Reductions Possible with Low Sulfur Fuel

350 ppm sulfur fuel

Source: MECA 1999

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Diesel oxidation catalysts are very effective in removing organic fraction of PM (HC toxins), but not carbon soot fraction



Depending on load, DOC eliminates 16 to 23% total PM, but 50 to 75% of organic fraction of PM. Elemental carbon largely unaffected. 350 ppm sulfur fuel

For old engine technology, DOC eliminates 30 to 63% of PM, but up to 75% of organic fraction of PM. Slight elemental carbon reductions. 150 ppm sulfur fuel

CE-CERT, Univ CA Riverside

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Water-blended fuel with DOC provides balanced emission reductions.

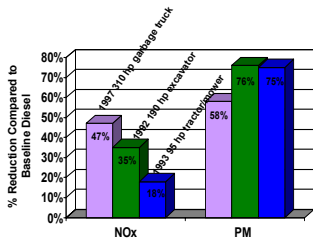


Depiction of how water emulsions improve combustion.

Results on Euro II Olymion bus, g/km					
	HC	CO	NOx	PM	CO ₂
Baseline (ULSD)	0.654	1.616	1.400	0.182	1.404
20% WBF	-11%	+6%	-18%	-43%	-3%
DOC	-62%	-66%	-1%	-22%	+3%
20% WBF + DOC	-92%	-97%	-21%	-79%	-4%

Using emulsion plus DOC drops HC and CO by >92%, NOx by 20%, PM by 70%.

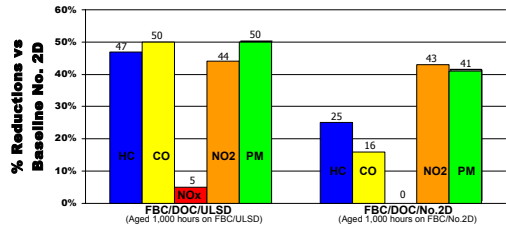
Lubrized-Canada SAE2000-01-0182



courtesy of Lubrizol-Canada

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Fuel Borne Catalysts and DOC can provide impressive results with or without ULSD fuel



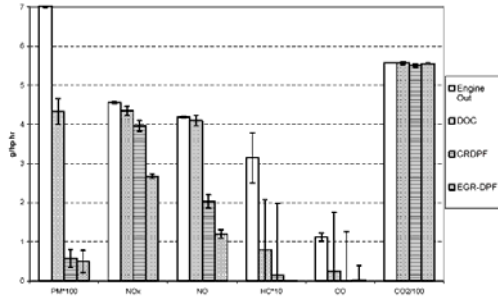
1998 DDC Series 60 engine

No. 2D = 350ppm Sulfur
ULSD = <15ppm Sulfur
FBC = Platinum/Cerium Fuel Borne Catalyst
DOC = Lightly Catalyzed Diesel Oxidation Catalyst

Courtesy of Clean Diesel Technologies Inc.

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Performance of DOCs and DPFs are compared



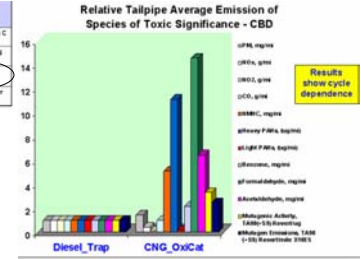
Cost numbers are Johnson's estimates

Environment Canada SAE 2004-01-1085

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Diesel filter retrofits are available that can drop toxic emissions to natural gas bus levels, or less

	Diesel Bus (Diesel Trap)	CNG Bus (CNG, OxidCat)
engine	1998 DDC Series 80	2001 Cummins Westport C Series Fuel
Exhaust	BPMARCO's BCD-1 (20 ppm soot/ft)	Upstream CNG meeting California standards
after-treatment	JAF's DFTM	DEM Catalyst
Chassis	New Flyer 40 passenger	New Flyer 40 passenger



- CNG is better for NOx, NO₂, and light PAHs.
- Retrofit diesel is better for PM, HCs, heavy PAHs, benzene, formaldehyde, acetaldehyde, and mutagenicity.

Results show cycle dependence

California Air Resources Board, Caltrux Conference 3/03

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Costs and applications are compared

- 1985 bus emitting 1 g PM / km; 50,000 km/yr: 50 kg PM
- \$700 DOC takes out 50% of PM: **\$28/kg**
- \$15,000 CNG engine replacement takes out 97%: **\$309/kg**
- 1995 diesel bus emitting 0.5 g PM/km: 25 kg PM/yr
- \$5000 DPF takes out 90%: **\$222/kg**
- \$15,000 CNG engine takes out 97%: **\$618/kg**

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