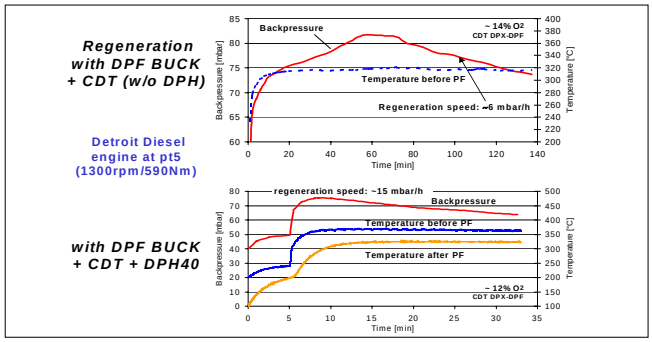
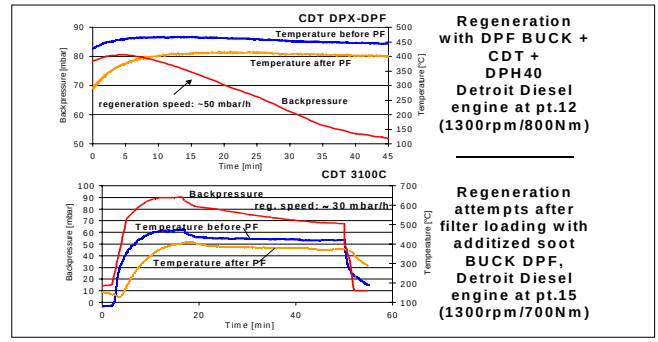
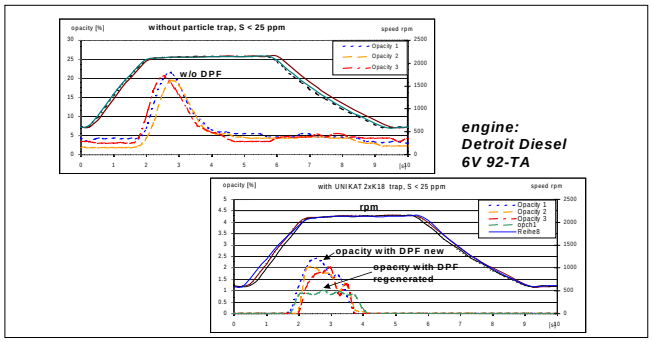
Particle emission of HD-2-stroke engines and reduction strategies for transit bus applications (2)

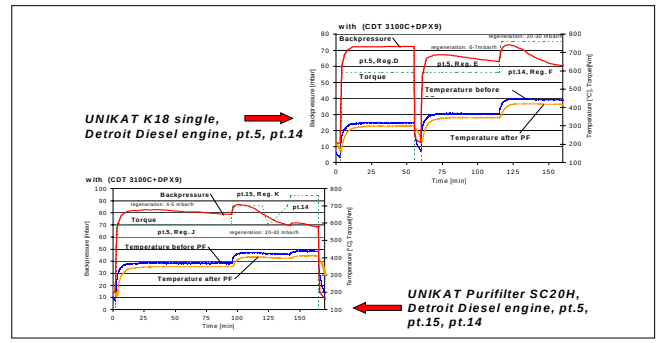
A. Mayer, TTM A. Hebert, CARB J. Czerwinski, AFHB J.-L. Pétermann AFHB







Opacity at free acceleration with/without PF UNIKAT 2xK18



Regeneration attempts after filter loading with additized soot

Organic (OC), elemental (EC) and total (TC) carbon

at operating point 5, 1300 rpm / 580 Nm

	[mg]	OC	EC	TC	PM
1	REF	0.870	0.159	1.029	0.845
2	CDT	0.810	0.135	0.945	0.887
3	DPH1	0.802	0.477	1.279	1.538
4	CAT	0.467	0.143	0.609	0.673
5	CAT+DPH1	0.218	0.265	0.483	0.640
6	CAT+CDT+DPH1	0.261	0.293	0.554	0.639

at operating point 8, 1300 rpm / 290 Nm

	[mg]	OC	EC	TC	PM
7	REF	0.503	0.164	0.667	0.643
8	CDT	0.475	0.091	0.566	0.714
9	DPH1	0.749	0.158	0.907	1.114
10	DPH2	0.668	1.856	2.524	2.710
11	DPH2+CDT	1.157	3.407	4.564	
12	CAT	0.388	0.107	0.495	0.653
13	CAT+DPH1	0.217	0.069	0.286	0.313
14	CAT+CDT+DPH1	0.213	0.058	0.271	0.322
15	CAT+DPH2	0.250	1.166	1.416	1.593
16	CAT+CDT+DPH2	0.248	1.165	1.414	1.600

Abbreviations:

WFC: Wire Mesh Filter Catalyst (BUCK-technology, here: CAT)
ITH: Intake throttle (between turbocharger and intercooler, here: DPH)
FBC: Fuel borne catalyst Ce/Pt < 10 ppm (CDT-technology, here: CDT)
OC: Organic Carbon (= carbon-content of HC deposited on particles)
EC: Elemental Carbon (= soot)

Major findings during engine bench tests in Biel

- WFC (in the reports referred to as “oxidation catalyst”) reduces OC and PM by > 40 %; in combination with ITH even by > 60 %, also EC is remarkably reduced- a very impressive and surprising result
- FBC reduces OC and EC, does not increase NO_2, will support WFC even more after longer conditioning
- PM-composition downstream of WFC in combination with FBC will be “dry” - similar to 4s-engines
- Solid particle trapping efficiency is well above 99 %
- Filtration is also perfect during free acceleration (worst case transient test)
- Filter characteristic for trapping nanoparticles of 20-300 nm mobility diameter is perfect (acc. to VERT)
- Catalytic activity of WFC and FBC is very active for CO, less for HC however without increasing NO_2
- Balance temperature during regeneration attempts is reached at 320 °C in the best case
- Regeneration rate is relatively low < 400 °C (which is good for perfect conversion – low CO and HC peaks - and also to avoid hot spot phenomena but might be insufficient during light load driving patterns)
- High regeneration rate is reached > 400 °C
- ITH increases the exhaust temperature by 100-200 °C depending on operation point – more throttling increases smoke formation progressively (in case of 4S-engines 200 - 300 °C increase can be reached)

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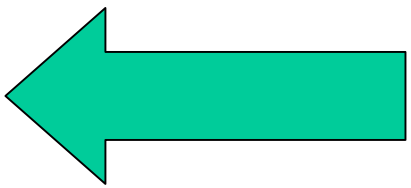

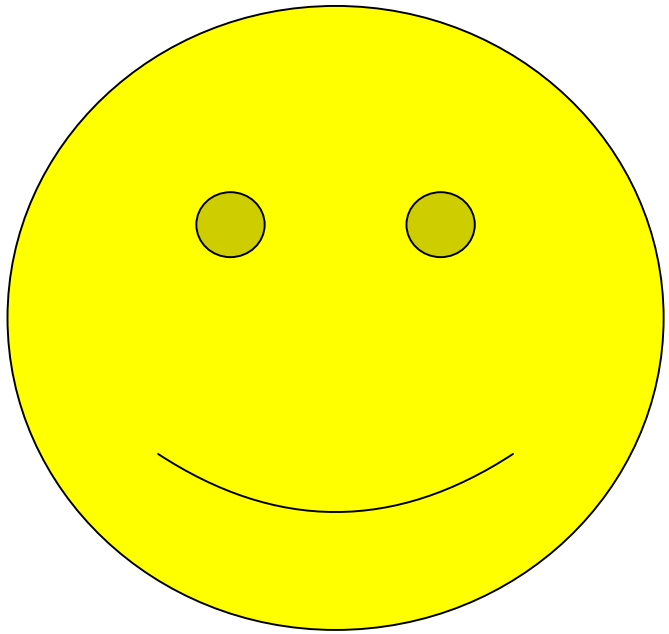

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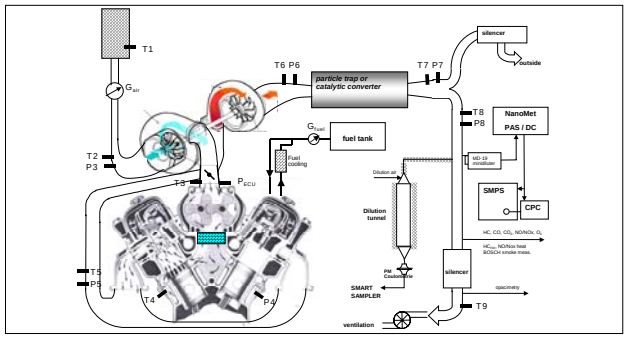
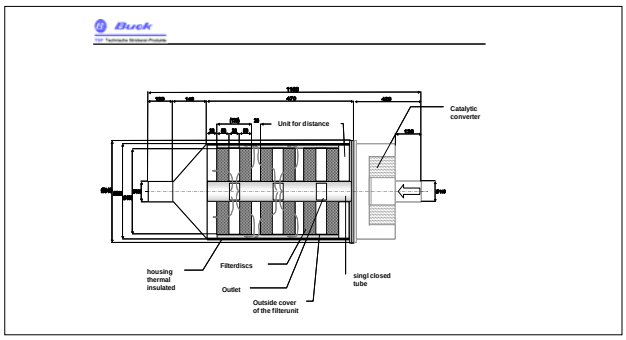


Detroit Diesel 2-S engine 6V 92 TA - measuring sep-up

- 2-stroke Diesel engines have the highest power density and best fuel economy but high particle emissions
- USA still has many transit buses in operation which should be cleaned from particle emissions- 2 stroke engines are still widely used in off road applications all over the world (in Switzerland many for mobile power generation and for boats)
- Emission Laboratory of Biel AFHB performed a project for Air Resources Board of California CARB to evaluate technical solutions to clean 2 stroke engines and came up with a quite effective toolbox.

Problems to retrofit 2 stroke-Diesel engines with Particulate Trap Systems

- PM consists of up to 80% volatile organic fraction (usually < 20 % with 4-stroke Diesel engines)
- Organic fraction is mainly lube oil, emitted in form of rather large droplets >> 1000 nm
- Back-pressure sensitivity is much higher than with 4s-engines – engine starts smoking soon
- Oil ash loading of the trap is very high
- Exhaust temperature is on average much lower than with 4s because of scavenging air, mixed to the exh.gas during each cycle
- lube-oil S+ Ca reactions (eg forming gypsum) could in the long run lead to trap plugging

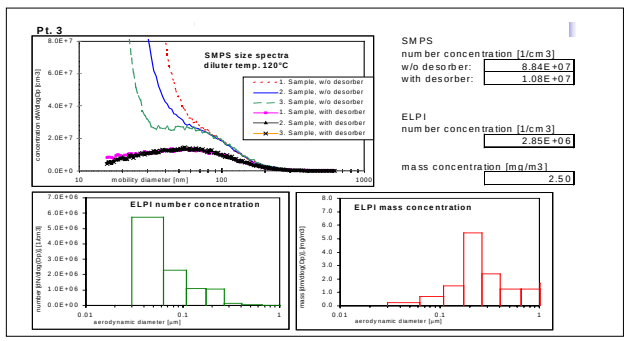


System Diesel soot Filter DD 2T engine USA
Variation 1 **Direction axlewise**

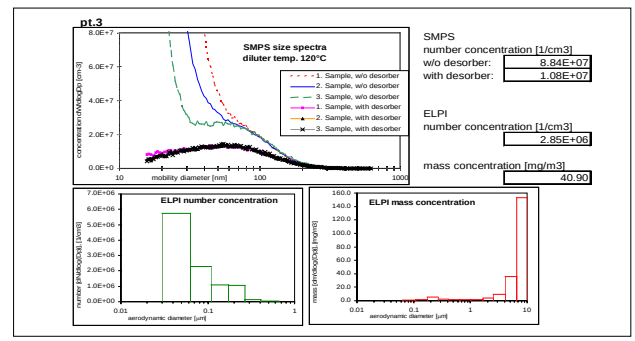
-a catalysed wire mesh - WFC, combining filtration and catalysis - upstream of the particle filter traps the large oil droplets, typical for 2-stroke engines, thereby drying the aerosol to a level which is acceptable for the filter. Oil droplets can form films and are slowly converted by catalytic activity.

-a deep bed knitted fibre filter in a novel very compact parallel filter plate arrangement filters the solid particles to an extent of > 99 % and provides a very high capacity for ash deposition. Alternatively to this filter type a sintered metal membrane filter could be used.

- a fuel borne Ce/Pt-catalyst supports the catalysis of the deposited lube oil on the WFC as well as the regeneration of the filter at temperatures of about 320 °C without forming NO2.



DETROIT diesel engine, operating point: 1000min-1 / 1120Nm
SMPS with NanoMet-diluter at exhaust pipe,ELPI with partial dilution tunnel



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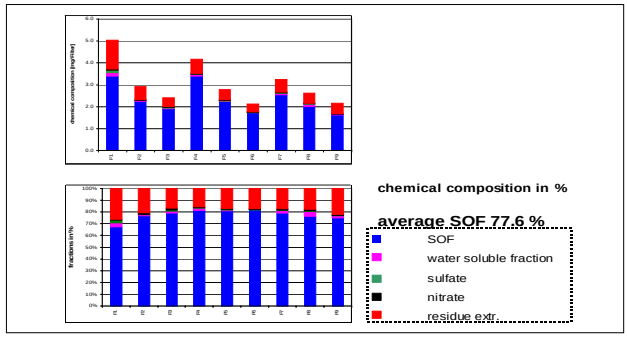
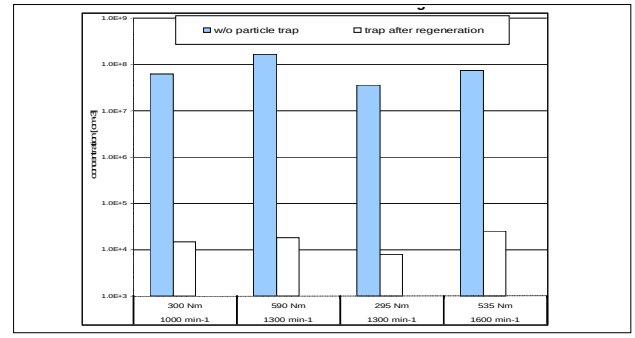


Chemical composition of filter samples, Detroit Diesel engine w/o DPF



Integrated numbers of particles in the size spectrum 20-300 nm
BUCK DPF at Detroit Diesel engine

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