Combustion Generated Nanoparticles

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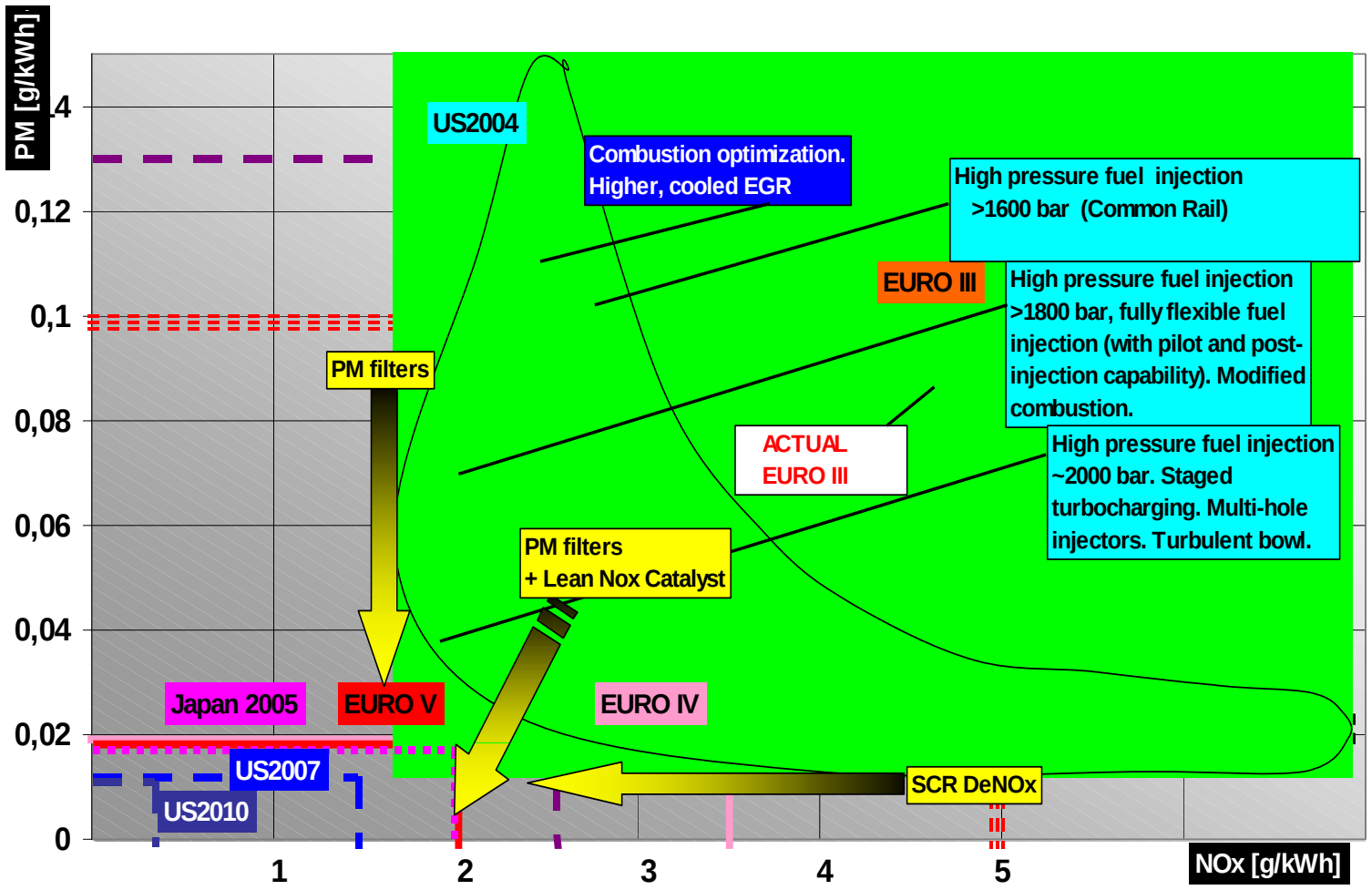
Evaluation methods for passive regeneration of particulate filters for the city bus

Regulations and the state of HDD engines

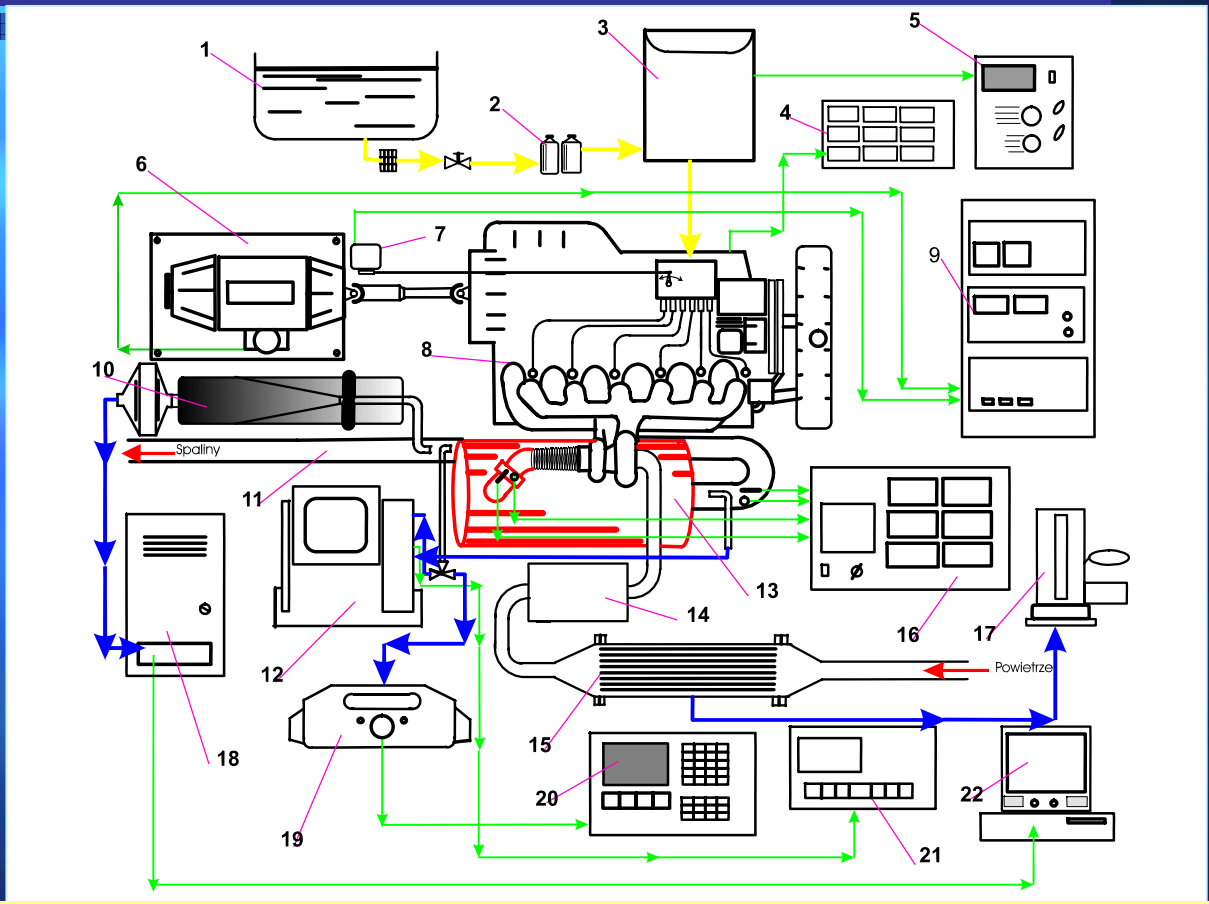


The focus of this work

Engine investigation of different types fuel additives and optimization their dosing for:

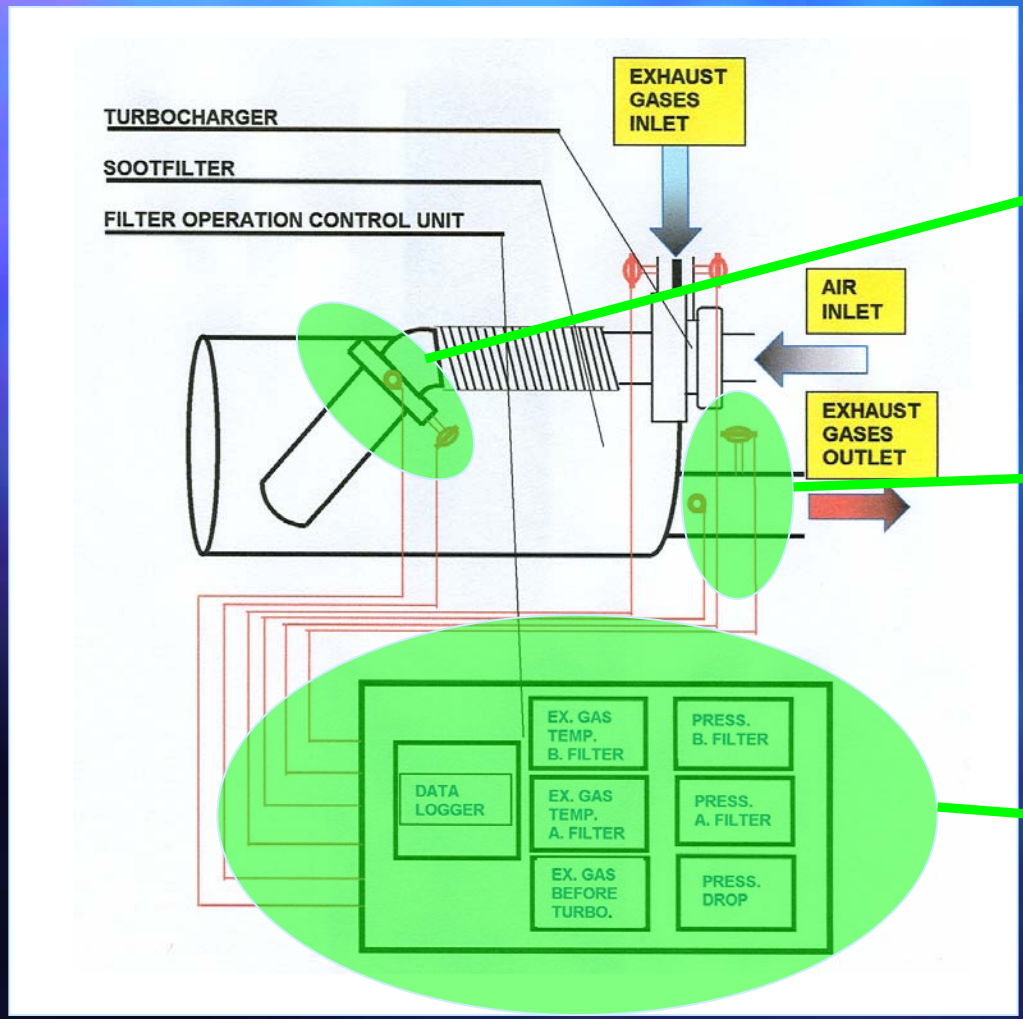
- ***inhibiting the formation of PM and their accumulation in the DPF***
- ***improvement performance of fuel additive for lowering the soot burning temperature to promote natural filter regeneration either continuously or at the regular intervals***
- ***evaluation of interaction and synergy between fuel additive components in oxidizing soot deposited on the filter***
- ***impact estimation of the additive type on the aiding filter regeneration process inside DPF developed for retrofitting of the city bus engine***

Measurement set-up on the engine test bench



1 – fuel tank, 2 – fuel filters, 3 - AVL fuel consumption meter 7130-03, 4 – set of engine parameters measurements, 5 – AVL balance controller 7030-A04.1 and fuel calculator 7030-A05, 6 – hydraulic brake, 7 - set of engine injection pump steering, 8 – Diesel engine SWT11/300/1, 9 – measure-steering cabinet SPS-1, 10 – dilution mini-tunnel AVL SPC 472 Smart Sampler PC, 11 – engine exhaust pipe, 12 - AVL 415S Smoke Meter, 13 – DPF, 14 – engine air filter, 15 – laminar flow element, 16 – set of measurements for exhaust system, 17 – measurement device of Laminar flow element, 18 – AVL SPC 472 Smart Sampler PC Cabinet, 19 – AVL DiGas 465C, 20 – AVL DiGas 465C Control Unit, 21 – AVL 4210 Instrument Controller, 22 - computer

Functional diagram of sootfilter operation control system



Test fuel and particulate filter

Fuel specifications

Fuel	Ekodiesel Plus 50
Full fuel specification	EN 590
Density (kg/m^3)	835
Flash point (^{o}C)	62
Cetan number	52,1
Sulfur content (weight %}	0,0048
Ash content (% m/m)	0,002
Water content (% m/m)	0,0015

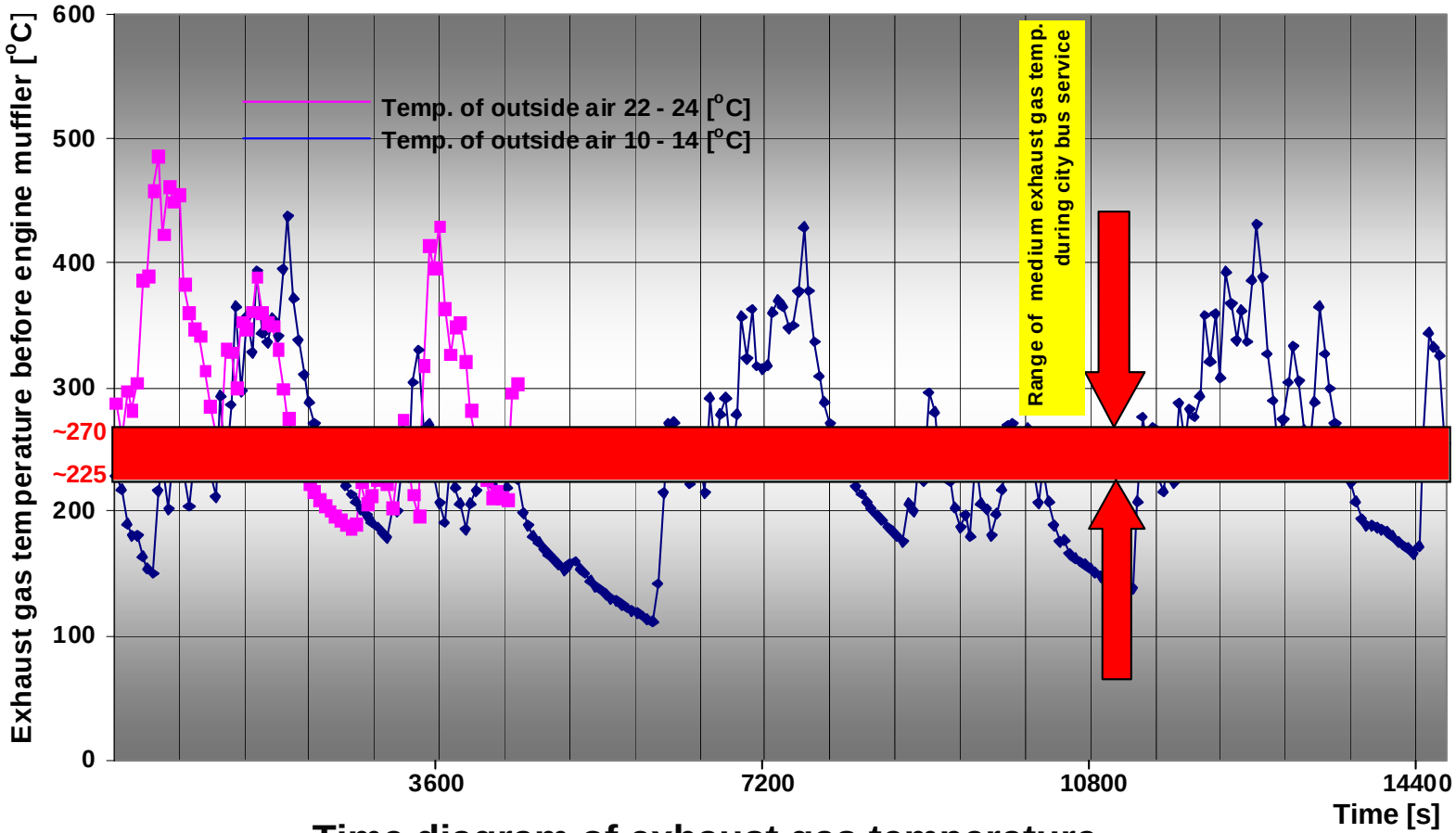
Cordierite filter monolith specifications

Type of filter	TBA (Uncoated)
Dimension of filter	11,25×14”
Volume	22,8 dm^3
Cell density	100 cpsi
Wall thickness	0,017”
Material	Cordierite
Total porosity	48%
Mean pore size	13 µm

Test fuel additives

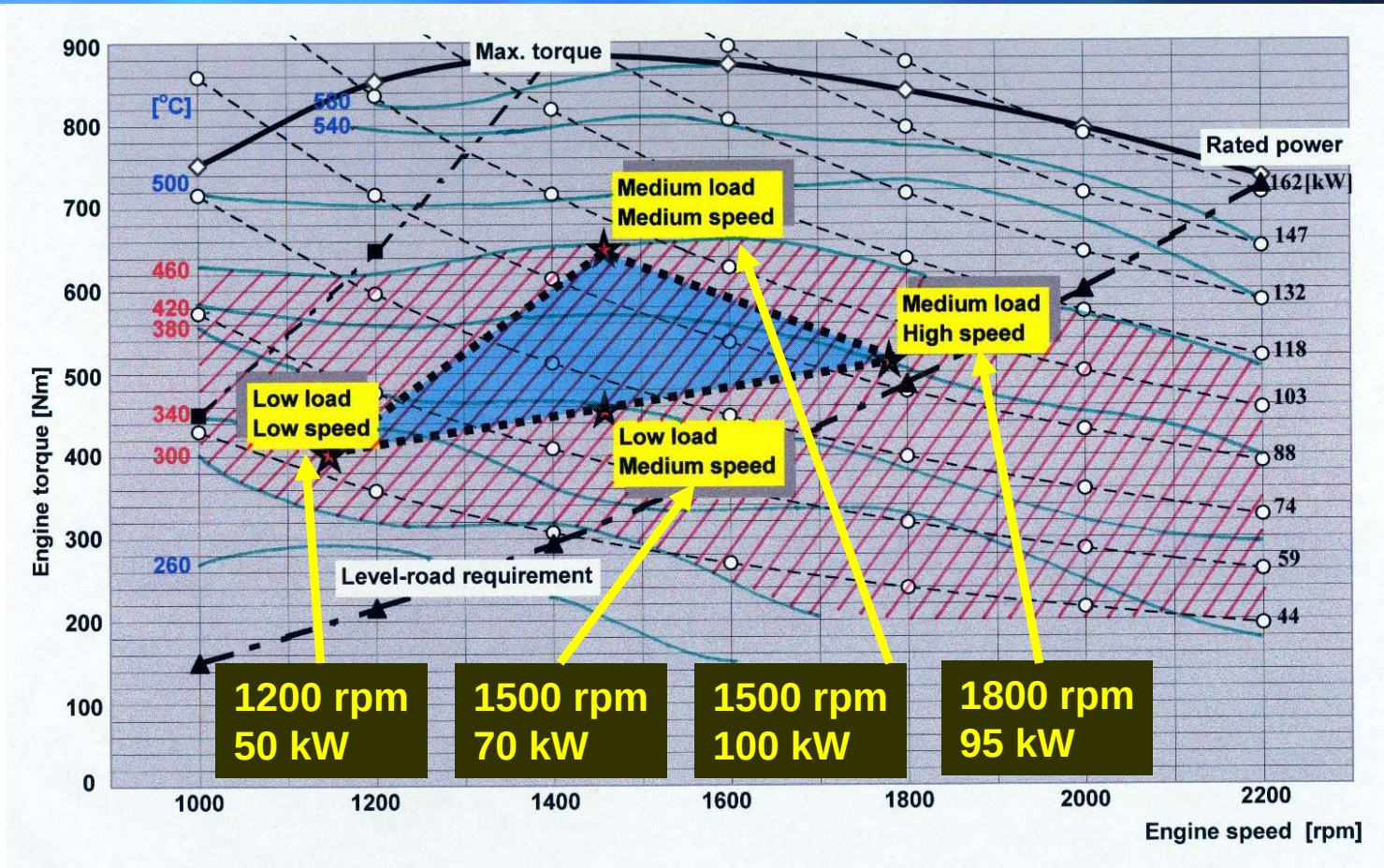
No	Additive components	Components concentration
	METAL	
1	IRON	4 levels: 5ppm Fe; 12ppm Fe; 17ppm Fe; 20ppm Fe
2	CERIUM	2 levels: 5ppm Ce; 20ppm Ce
3	CALCIUM	2 levels: 6,5ppm Ca; 20ppm Ca
4	COPPER	2 levels: 3ppm Cu; 5ppm Cu
5	IRON/CALCIUM	2 comb.: 10ppm Fe + 10ppm Ca; 5ppm Fe + 5ppm Ca
6	IRON/CERIUM	3 comb.: 3ppm Fe + 7ppm Ce; 30ppm Fe + 10ppm Ce; 10ppm Fe + 30ppm Ce
7	IRON/COPPER	2 comb.: 5ppm Fe + 1ppm Cu; 5ppm Fe + 5ppm Cu
8	IRON/MANGANESE	3 comb.: 5ppm Fe + 2ppm Mn; 5ppm Fe + 5ppm Mn; 10ppm Fe + 5ppm Mn
	METAL + COMBUSTION IMPROVER	
9	IRON/NITROCET	2 comb.: 5ppm + 200ppm Nitrocet; 5ppm Fe + 1000ppm Nitrocet
	ASHLESS COMPONENTS	
10	AMINA	20ppm Amine
11	AMINA C_8	31ppm Amine C_8
12	RFN-6	20ppm RFN-6
	METAL + ASHLESS COMPONENTS	
13	IRON/AMINA C_8	5ppm Fe + 31ppm Amine C_8
14	IRON/RFN-6	5ppm Fe + 20ppm RFN-6

Test method



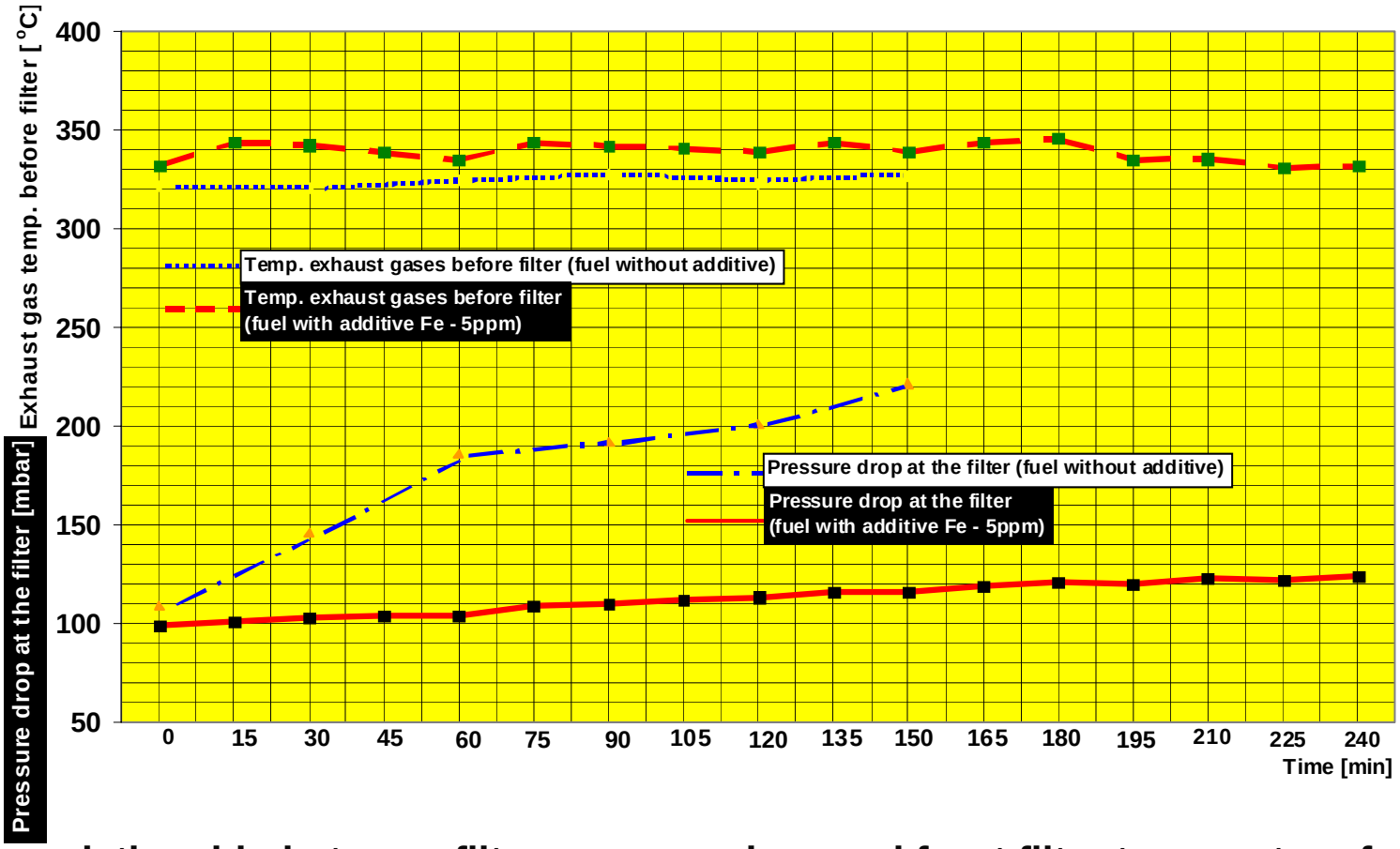
Time diagram of exhaust gas temperature measured during city bus service before engine muffler

Engine Test-Cycle and Procedure



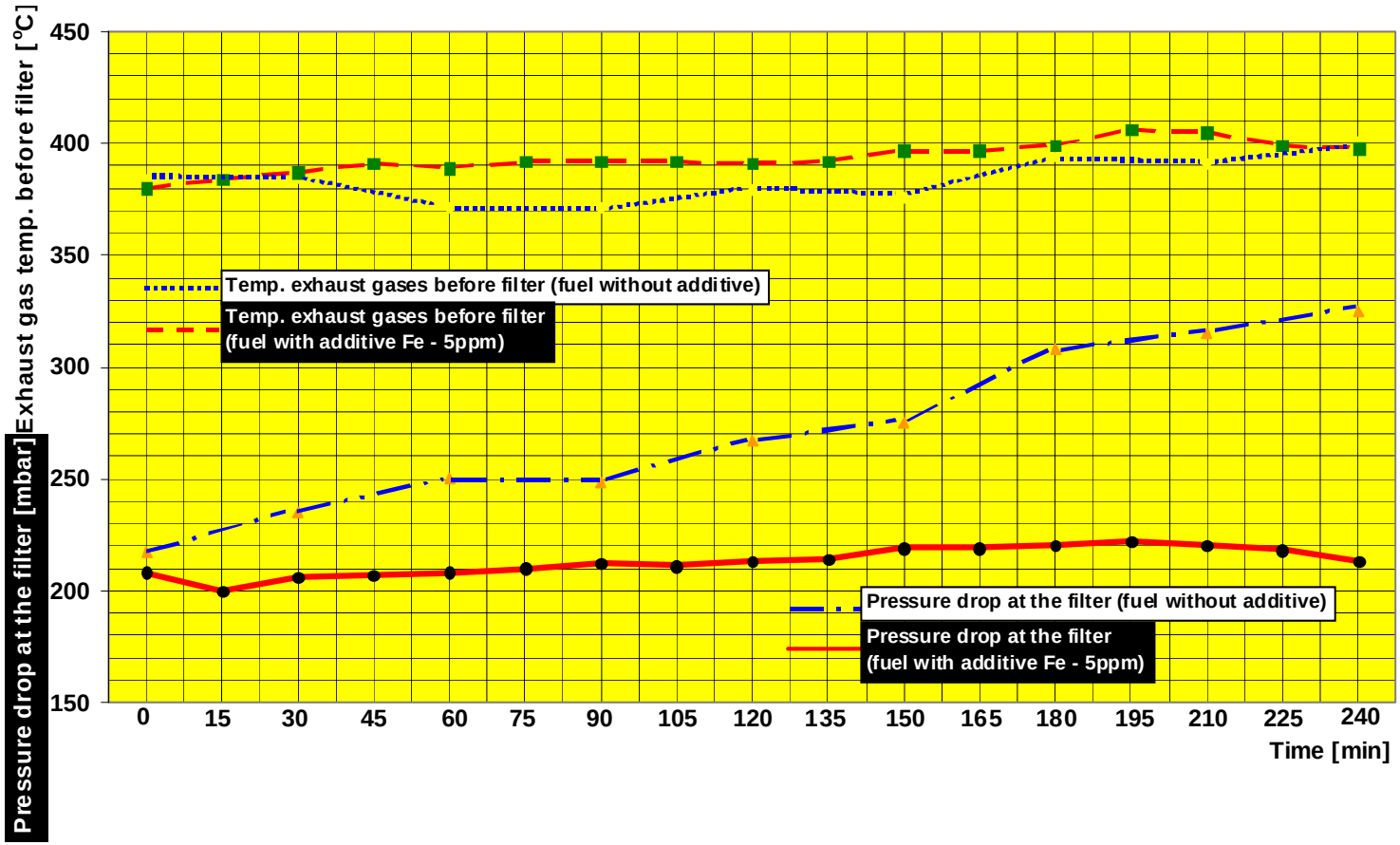
Performance map of SWT11/300/1 test engine with marked of four operating points of the engine bench test

Results



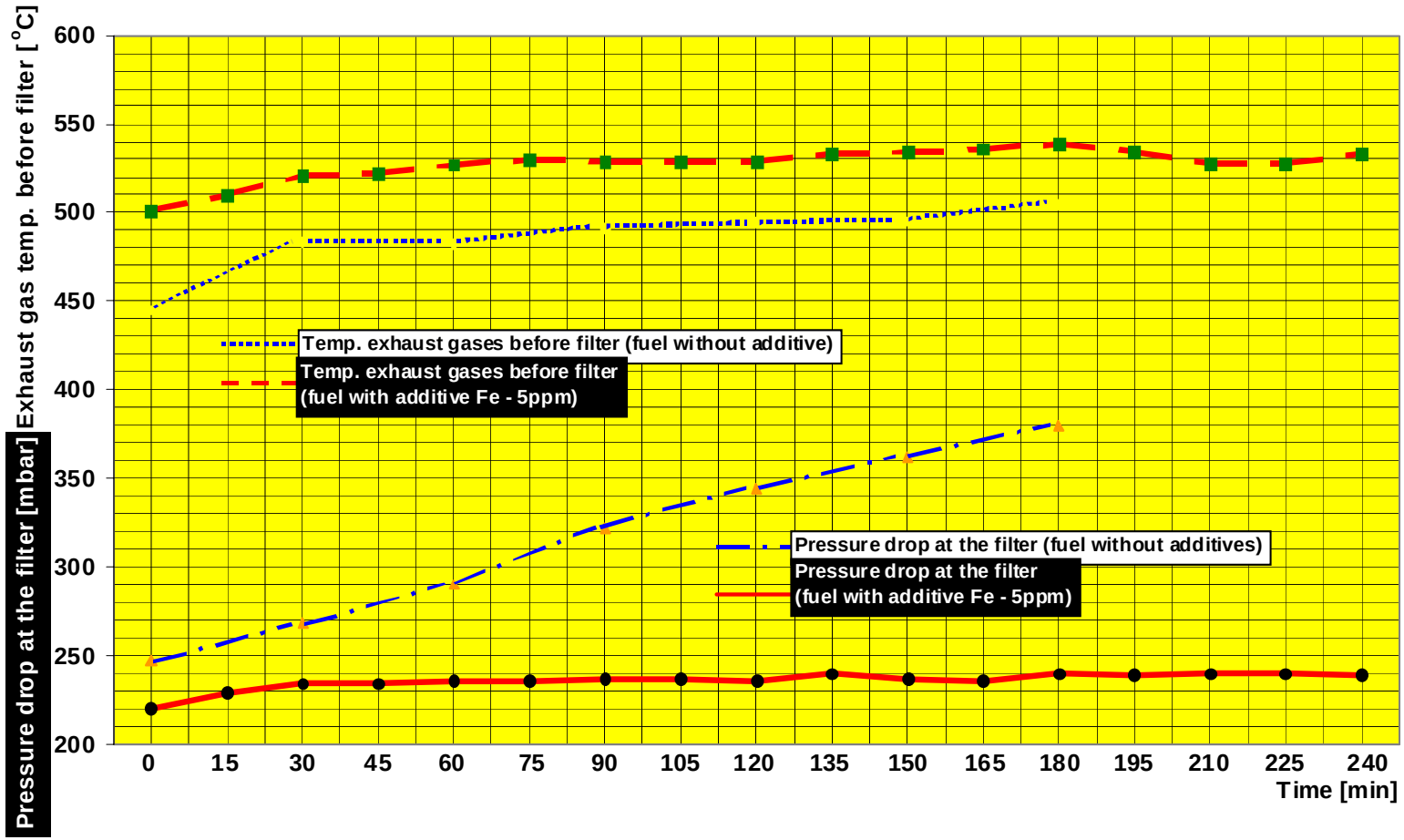
Time relationship between filter pressure drop and front filter temperature for fuel without additive and with additive (Fe-5ppm). 1200 rpm/50kW

Results



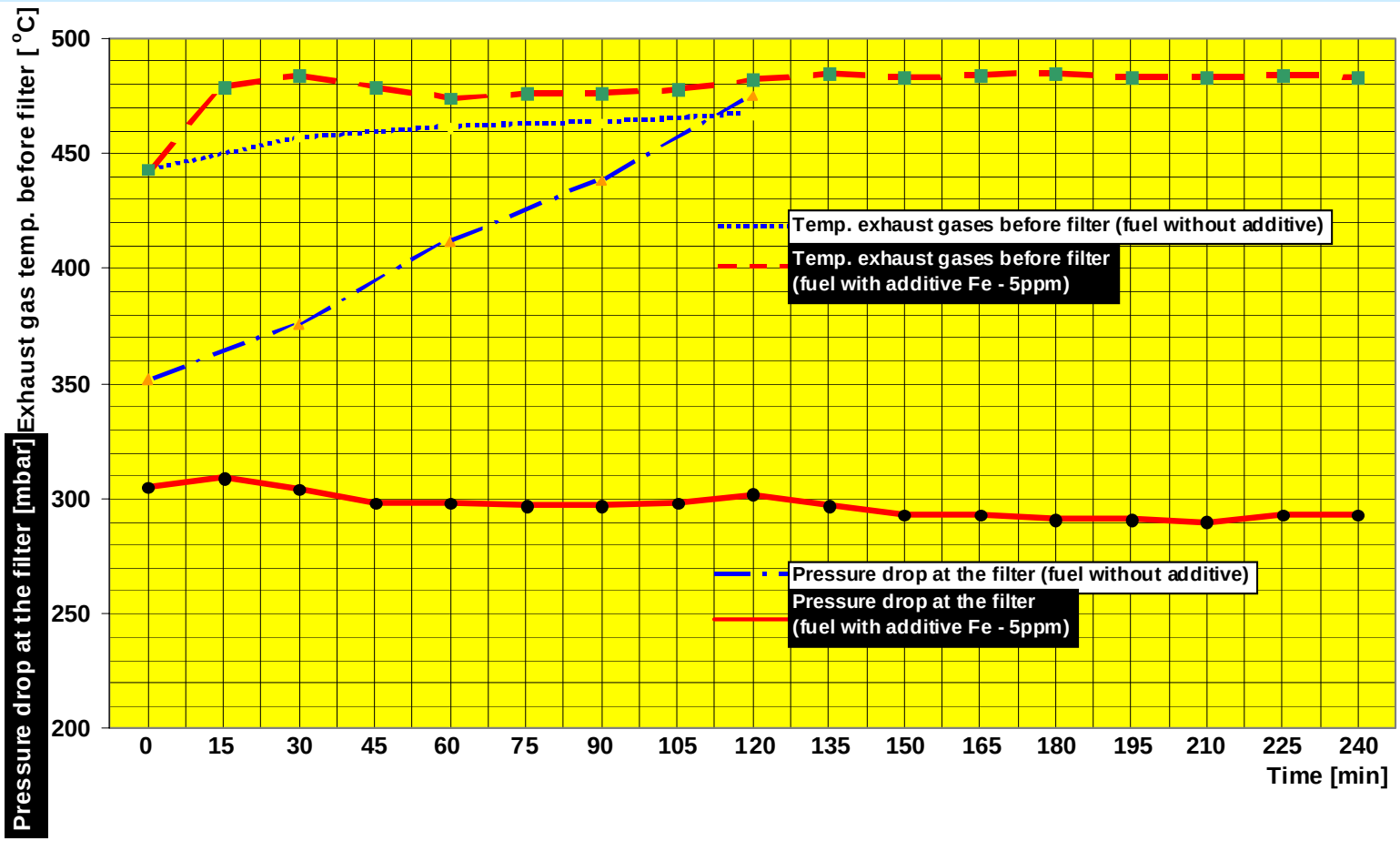
Time relationship between filter pressure drop and front filter temperature for fuel without additive and with additive (Fe-5ppm). 1500 rpm/70 kW

Results



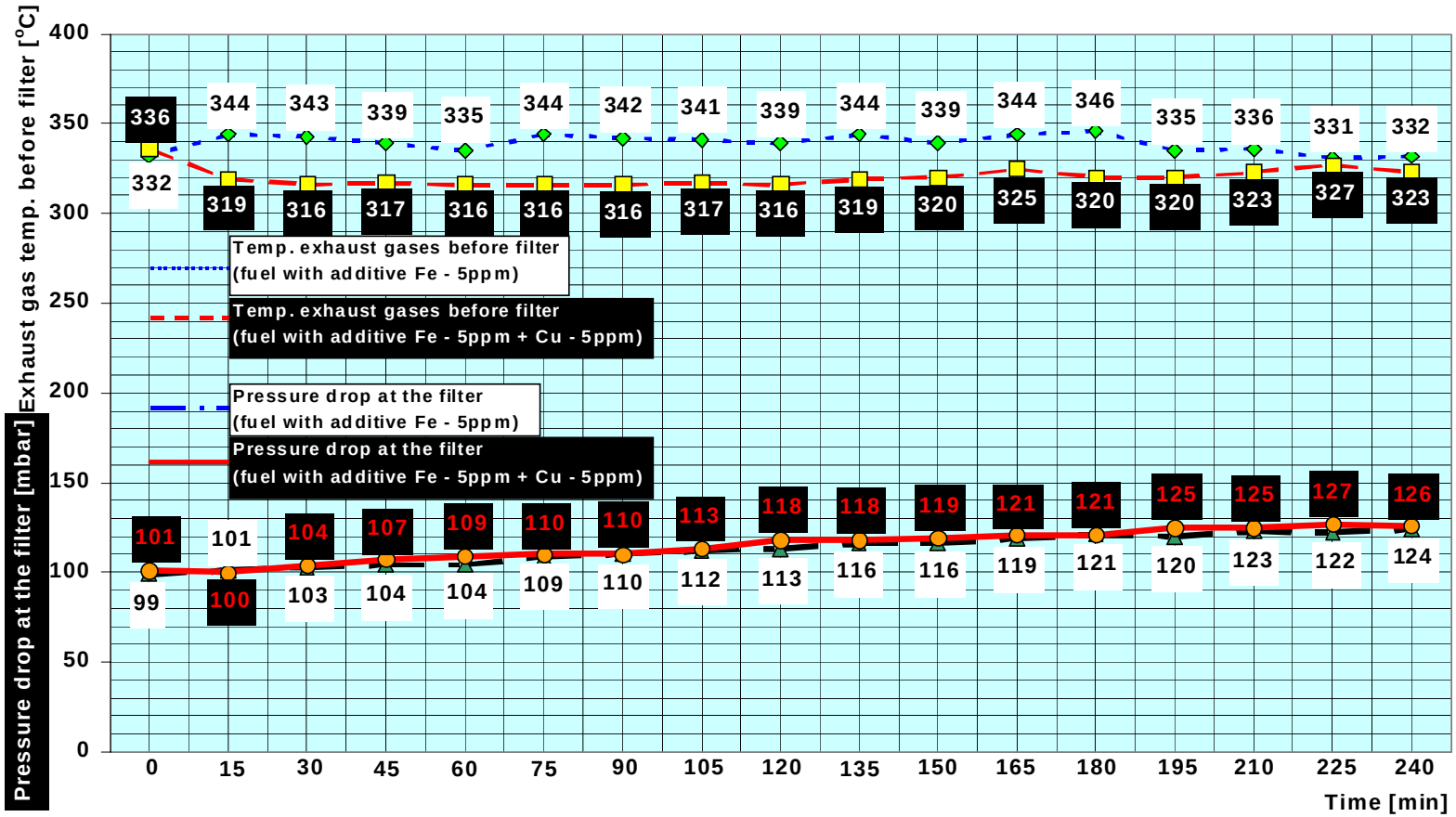
Time relationship between filter pressure drop and front filter temperature for fuel without additive and with additive (Fe-5ppm). 1500 rpm/100 kW

Results



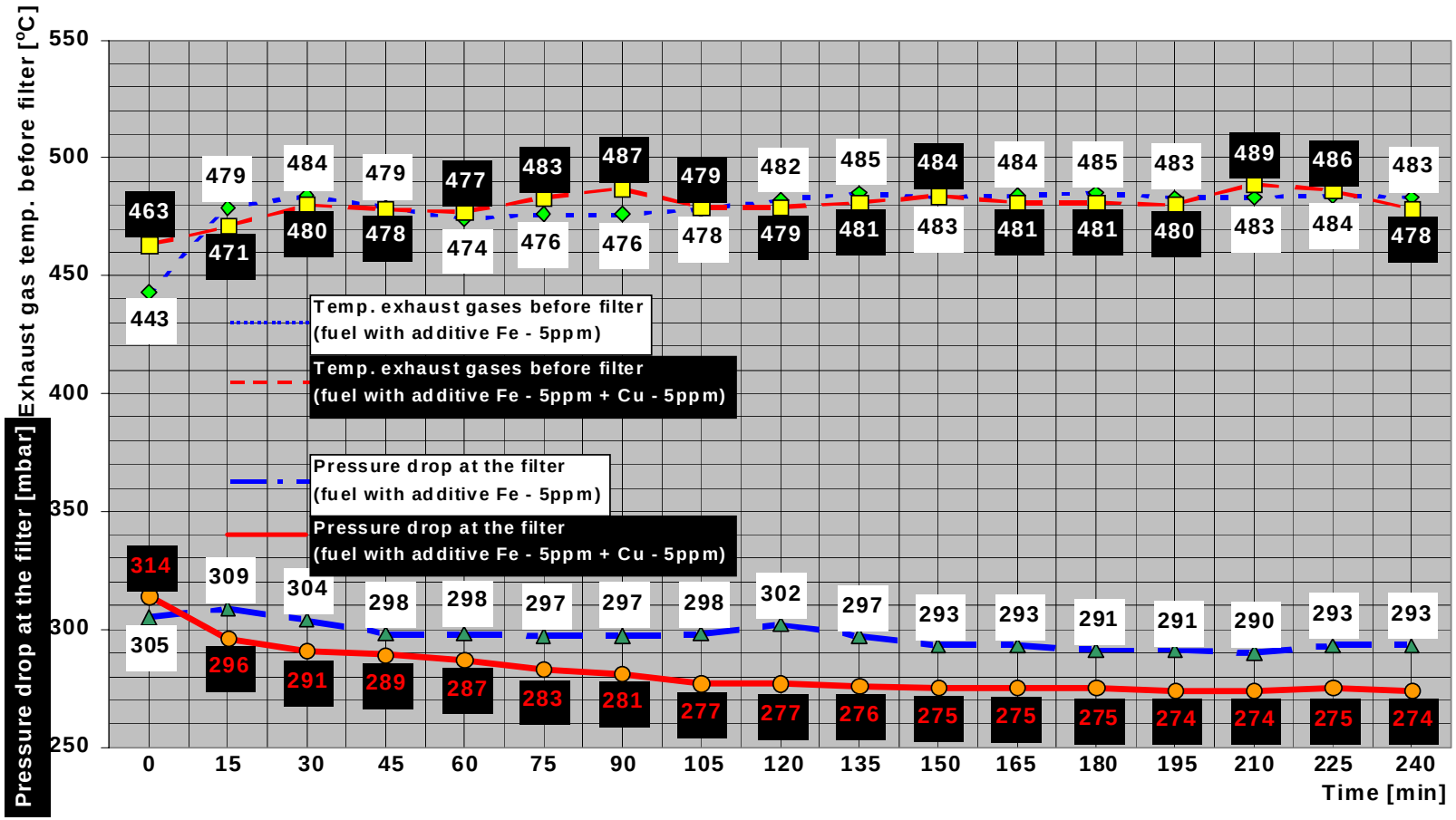
Time relationship between filter pressure drop and front filter temperature for fuel without additive and with additive (Fe-5ppm). 1800 rpm/95 kW

Results



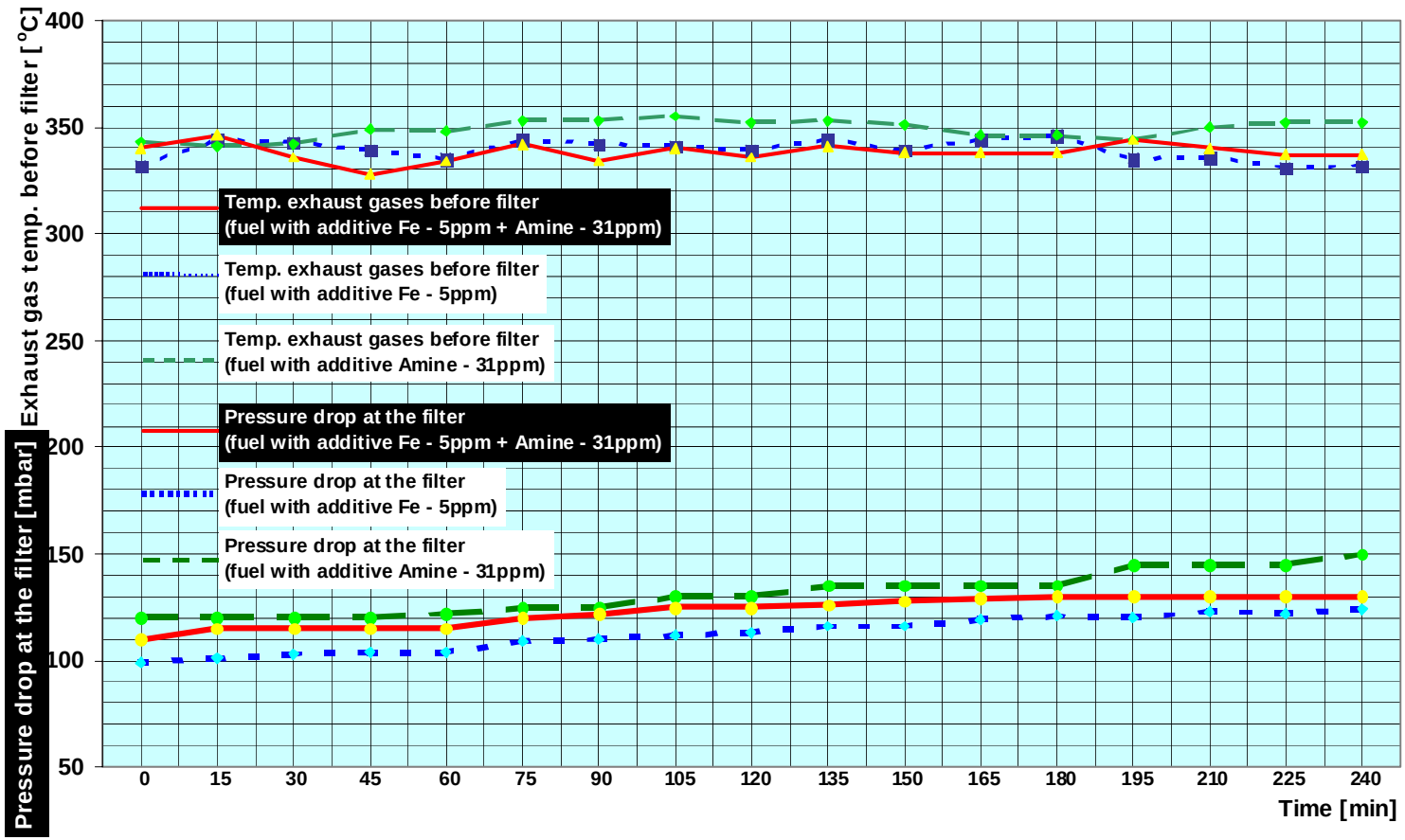
Time relationship between filter pressure drop and front filter temperature for fuel with additive (Fe-5ppm) and with additive (Fe-5ppm+Cu-5ppm). 1200 rpm/50 kW

Results



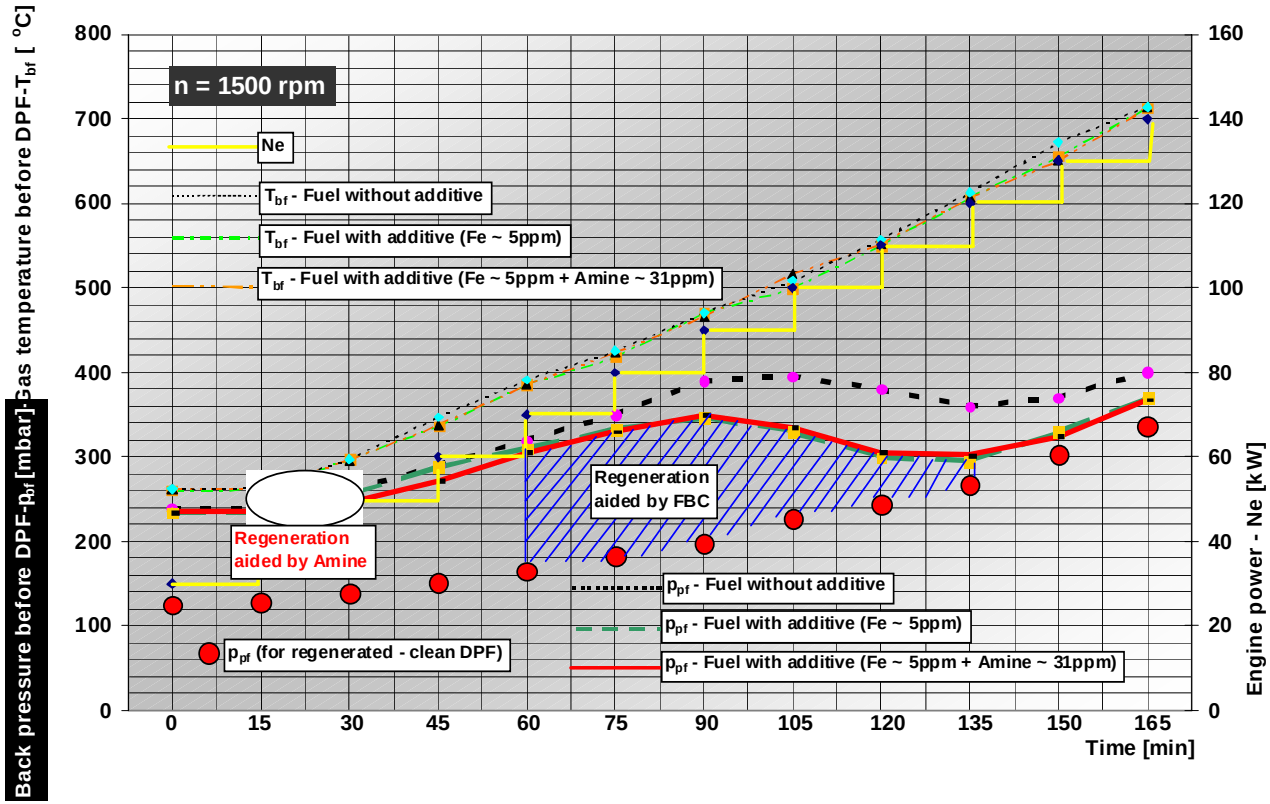
Time relationship between filter pressure drop and front filter temperature for fuel with additive (Fe-5ppm) and with additive (Fe-5ppm+Cu-5ppm).1800 rpm/95 kW

Results



Time relationship between filter pressure drop and front filter temperature for fuel with additive (Fe-5ppm), with additive (Amine-31ppm), and with additive (Fe–5ppm + Amine–31ppm). 1200 rpm/50 kW

Results



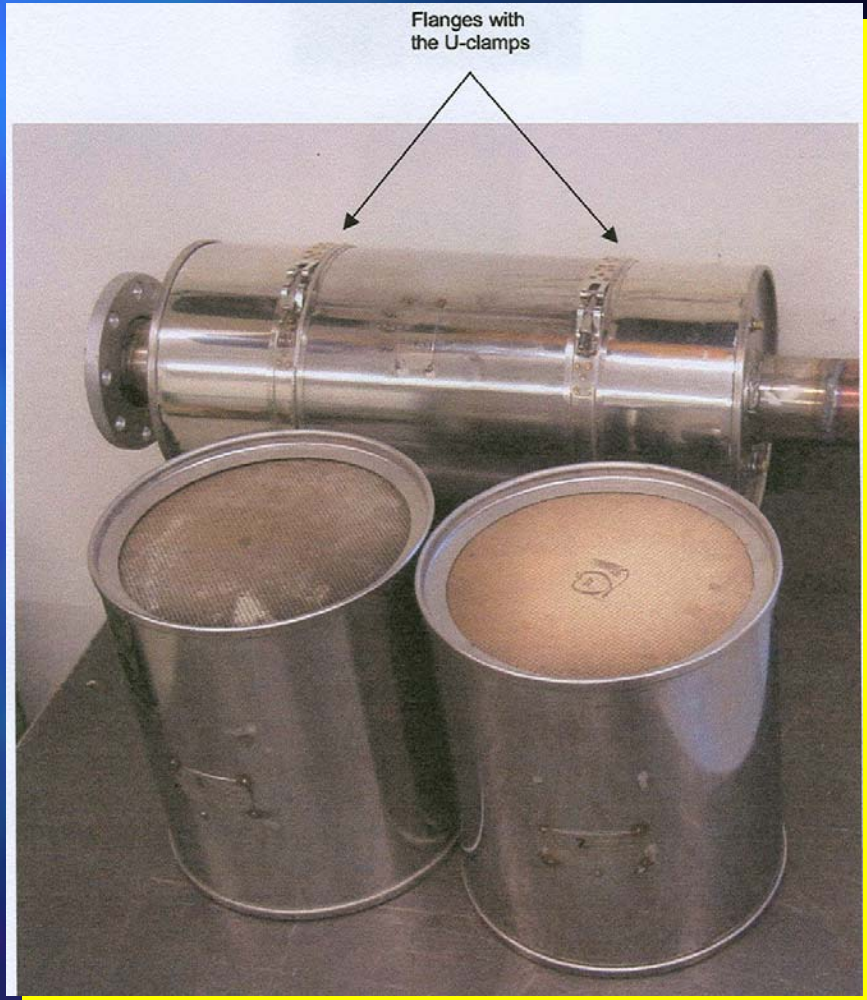
Diagrams of promoted regeneration of DPF for fuel without additive and with additive Fe – 5ppm or with additive Fe – 5ppm + Amine – 31ppm

Results

For investigations according to the VFT (VERT Filter Test) and VSET (VERT Secondary Emissions Test) have been Selected Diesel Particle Filter and Fuel Additives as follows:

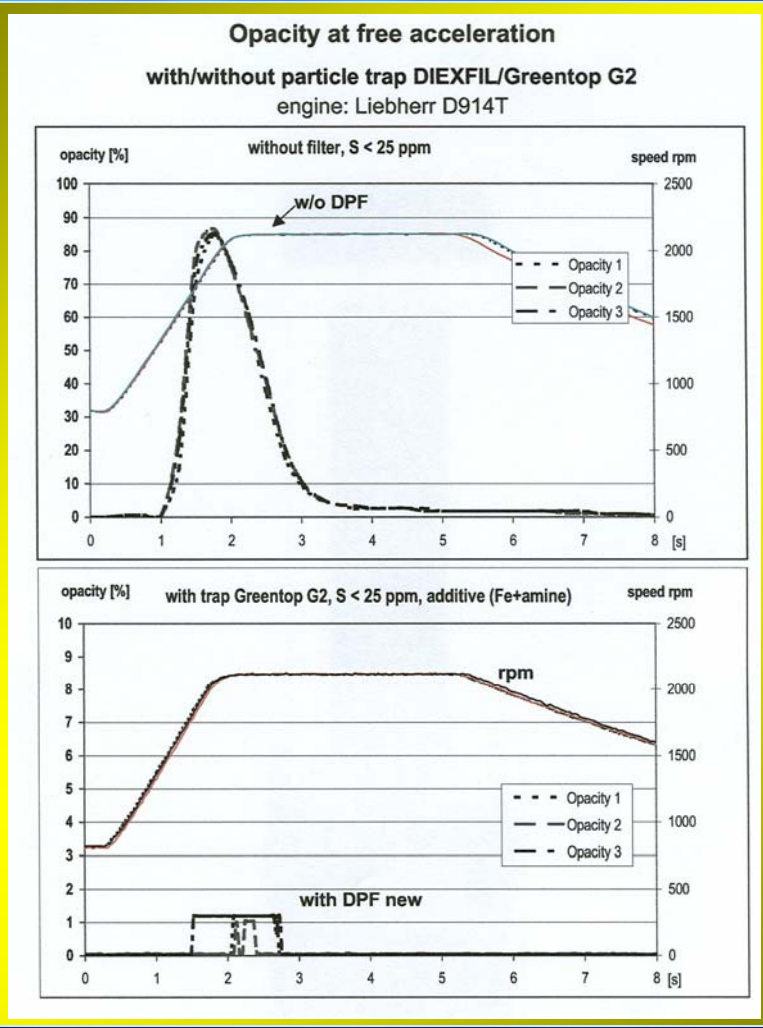
- DPF TBA, cordierite monolith, 100 cpsi pore size 13 µm, wall 0,017", porosity 48%, volume 22,8 dm^3
Manufacturer: Greentop GmbH

-Additive A (5ppm weight Fe in fuel)
-Additive B (5ppm weight Fe and 30ppm weight amine in fuel)
- Additive C (5ppm weight Fe and 5ppm weight Cu in fuel)
Manufacturer: Institute of Petroleum Processing



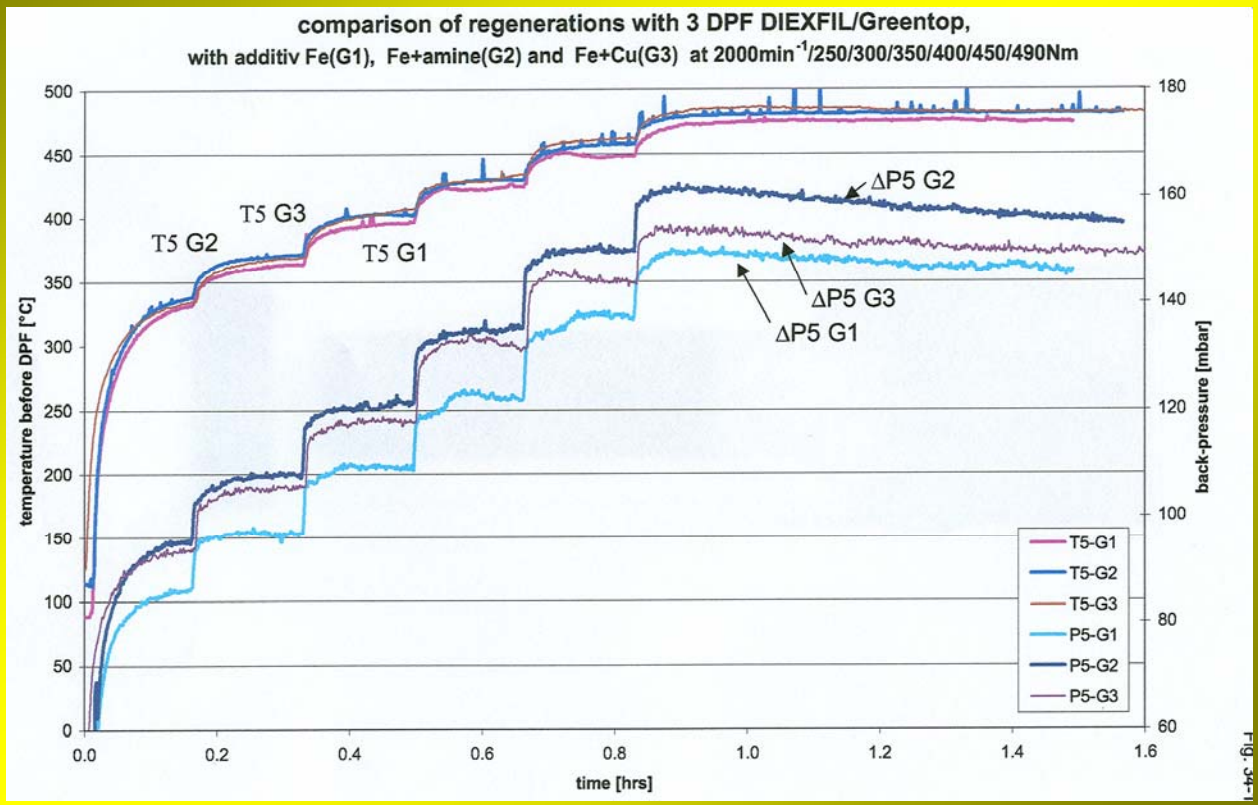
Results

VFT1 Test Report



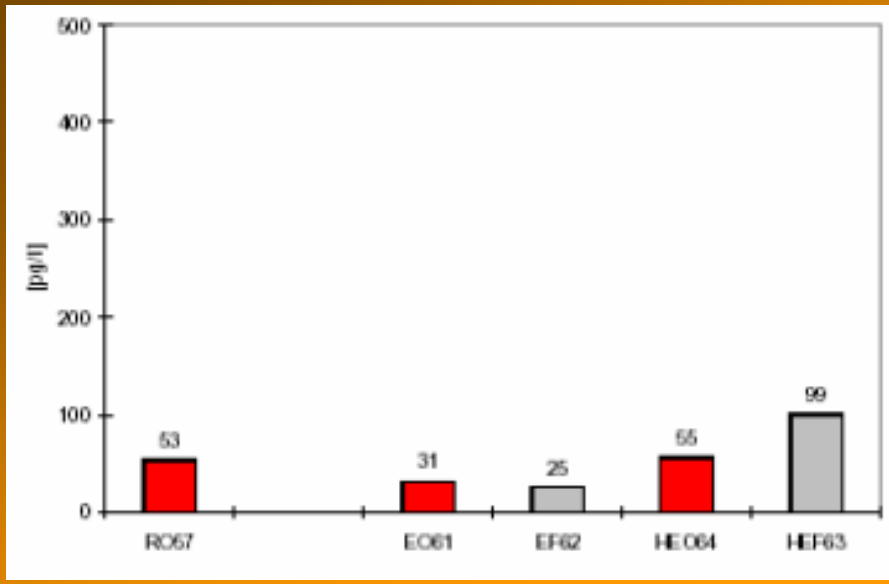
Results

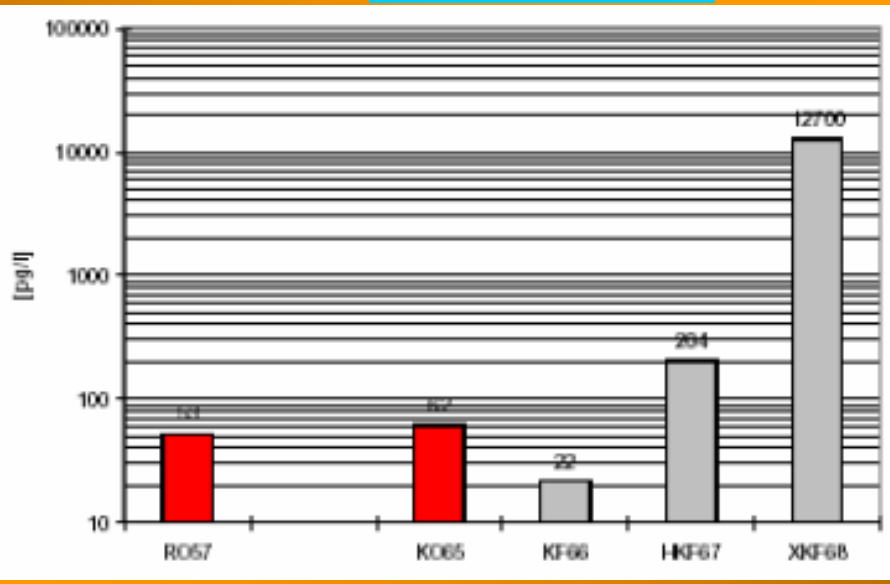
VFT1 Test Report



Results

VERT - VSET Test Protocol





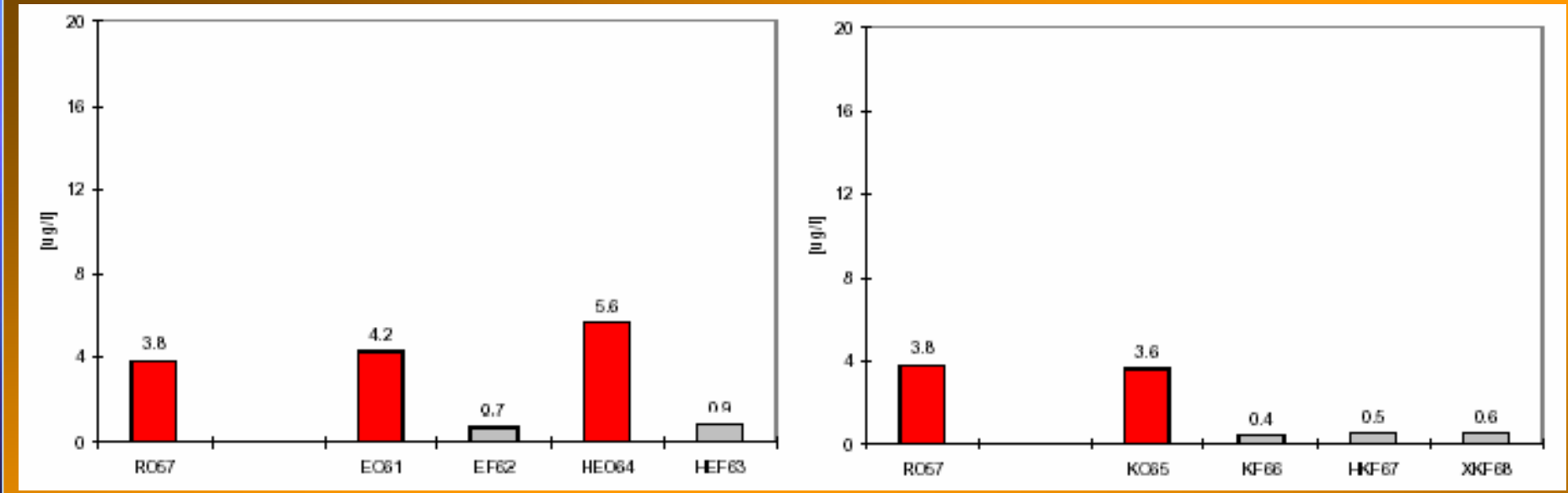
Mean emission factors: TEQ-sum of PCDD/F for Additive B (left) and Additive C (right)

RO 57 Reference Fuel no additive w/o DPF
EO 61 no Cl added Additive B: Fe w/o DPF
HEF 63 10ppm Cl added Additive B: Fe DPF G2
KO 65 no Cl added Additive C (Fe+Cu) w/o DPF
HKF 67 10ppm Cl added Additive C (Fe+Cu) DPF G3

HO 60 10ppm Cl added no additive w/o DPF
EF 62 no Cl added Additive B: Fe DPF G2
HEO 64 10ppm Cl added no additive w/o DPF
KF 66 no Cl added Additive C (Fe+Cu) DPF G3
XKF 68 100ppm Cl added Ad. C (Fe+Cu) DPF G3

Results

VERT - VSET Test Protocol



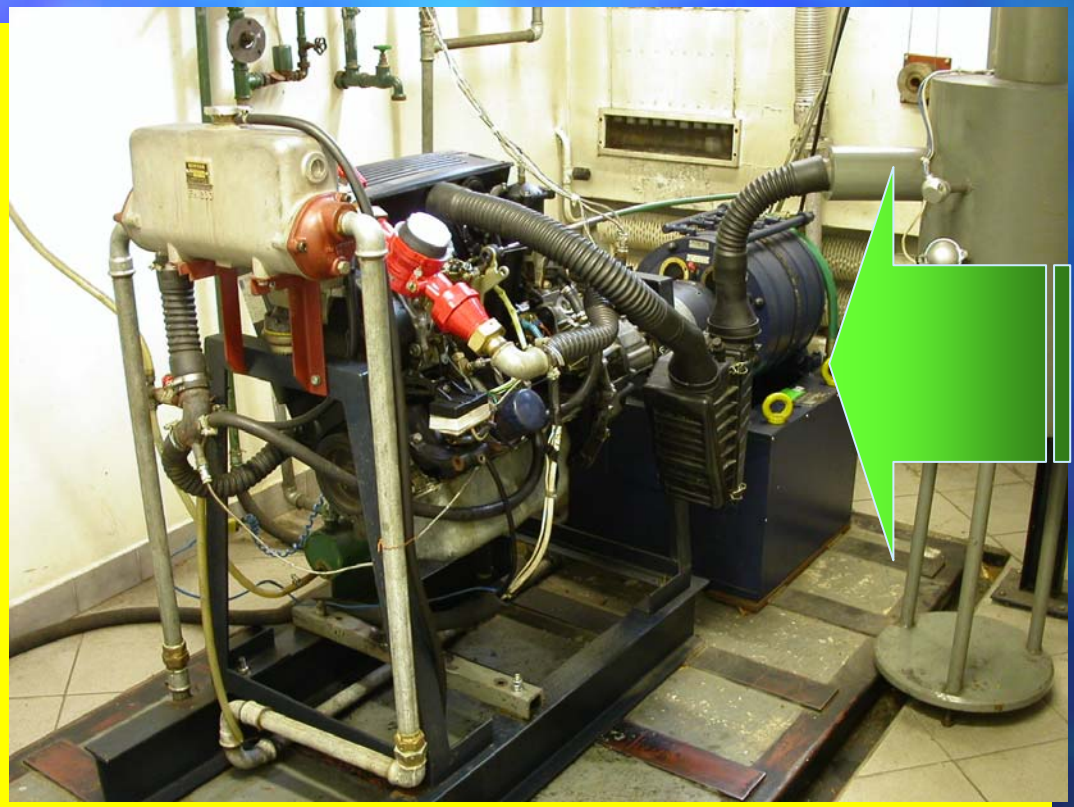
Emission factors for the sum of carcinogenic PAH (IARC) in µg/kWh, all configurations with the Fe – Additives B (left) and the Cu – Additive C (right)

RO 57 Reference Fuel no additive w/o DPF
EO 61 no Cl added Additive B: Fe w/o DPF
HEF 63 10ppm Cl added Additive B: Fe DPF G2
KO 65 no Cl added Additive C (Fe+Cu) w/o DPF
HKF 67 10ppm Cl added Additive C (Fe+Cu) DPF G3

HO 60 10ppm Cl added no additive w/o DPF
EF 62 no Cl added Additive B: Fe DPF G2
HEO 64 10ppm Cl added no additive w/o DPF
KF 66 no Cl added Additive C (Fe+Cu) DPF G3
XKF 68 100ppm Cl added Ad. C (Fe+Cu) DPF G3

Results

CEC F-23-A-01
Procedure for Diesel Engine Injector Nozzle Coking Test



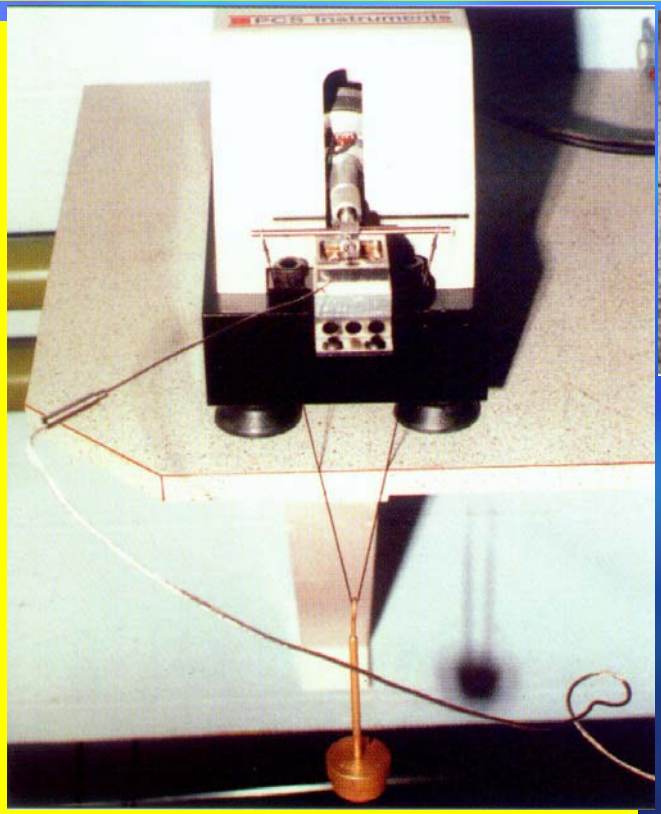
Fuel additives containes as follows:

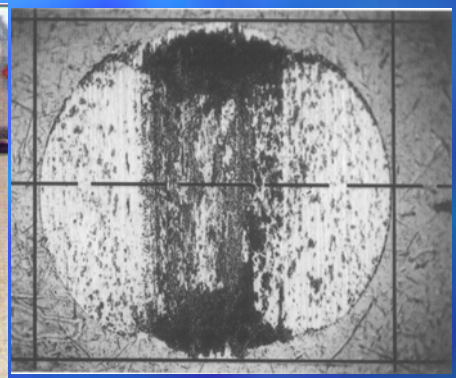
- **Fe**
- **Fe + amine**
- **Fe + Cu**

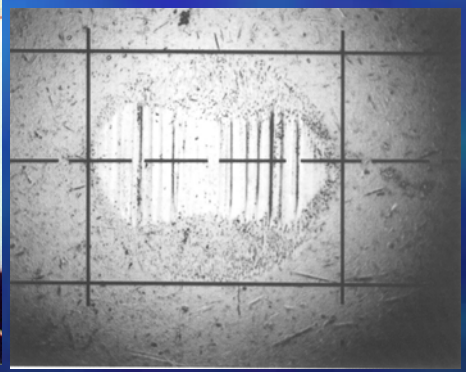
have no disadvantageous influence on the nozzle cooking propensity

Results

CEC F-06-A-96
Measurement of Diesel Fuel Lubricity (HFRR fuel lubricity tester)







All fuel additives presented in this work have undergone HFRR tests and shows **not any significant effect on fuel lubricity**

Conclusions

- The iron additive at a total dose rate of 5 ppm metal allow for effective filter regeneration at the relatively low temperature about 350 – 370 ^{o}C

- In conditions of carried out experiments, have been showed that the regeneration performance of iron additive could be further improved by the addition of a small quantity of copper to iron (5 ppm Fe + 5 ppm Cu)

- The regeneration performance of iron additive can be also further improved by addition of a small quantity of ashless additive – amine, this especially in the low load/low speed engine conditions

Conclusions

- The combination of iron and amine gave performance advantages over use of iron for DPF regeneration process. Synergy was demonstrated during bed engine tests, showing that the combination of 1 : 6 ratio of iron to amine gave better performance than the same total treat rate of either iron or amine alone

- The Greentop DPF used in this project reduce well the PM

- Filtration efficiency does not seem to be influenced by the additives at least not in a negative sense

- PAH are very effectively – up to 85% - reduced

- HC are reduced as well by about 40%, but CO was not affected

Conclusions

- There is no influence on NOx – NO_2/NO – ratio also did not change much

- The regeneration speed for all 3 additives (A – Fe; B – Fe+amine; C – Fe+Cu) investigated in the VERT Phase 1 Test is the same (approx. 10 mbar/h) and the efficient regeneration with all used additives is possible

- The investigated Greentop DPF with the additive supported regeneration fulfills the criteria of the VERT filter test Phase 1 and can be recommended to the users

Conclusions

- VERT Secondary Emission Test VSET has proved that PCDD/F (polychlorinated dibenzodioxins/furans)-emissions did not increase in case of the additive (5 ppm Fe + 30 ppm amine), but did remarkably increase by more than 3 orders of magnitude with aditive (5 ppm Fe + 5 ppm Cu) in combination with slightly increase chlorine additive in the used reference fuel

- Cu containing additive (5 ppm Fe + 5 ppm Cu) should not be put on the market in any combination with or without filters but additive consist of (5 ppm Fe + 30 ppm amine) shows very promising data and no sign of any formation of secondary toxic substaces

- FBCs have no disadvantageous influence on the fuel lubricity and the injector nozzle cooking propensity

ACKNOWLEDGMENTS

The autors want to express a gratitude for the valuable contribution to the projects especially Mr. A. Mayer

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THANK YOU !