LOADING AND REGENERATION BEHAVIOUR OF THE **STOBBEDPF** / DIESEL PARTICULATE FILTER

PREPARED BY

S. Skopa & D. Zarvalis

Work Performed at the:
Aerosol & Particle Technology Laboratory (APTL)
Center for Research and Technology Hellas /
Chemical Process Engineering Research Institute (CERTH/CPERI)

PO Box 361
Thermi Thessaloniki 57001
GREECE

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1. SUMMARY

This report summarizes the testing activities carried out by the Aerosol & Particle Technology Laboratory (APTL) at CERTH/CPERI concerning the F-180 5.66x6 90 cpsi LIQTECH diesel particulate filter (StobbeDPF).

APTL tested the provided DPF with respect to its behavior during loading and regeneration and performed particle size measurements.

2. TECHNICAL DESCRIPTION

The Diesel Particulate Filter (StobbeDPF) delivered by LIQTECH was a SiC 5.66x6 monolith. The DPF provided has been tested in terms of its behavior under steady state loading and regeneration.

SOOT LOADING TESTS

The system was placed in the exhaust of a 1.9Lt JTD common rail engine (rated at 59 kW and 3000 rpm) and exposed to an exhaust flow rate of 65 kgr/hr (corresponding to an engine operating point of 1500 RPM and 75 NM) at a temperature around 375 C. An oxidation catalyst (OC) was placed in front of the filter. P_1 to P_3 are sampling points for gases and particles. The effect of the OC on the exhaust gases is directed mostly to the CO, HC, NO and particle concentrations.

The testing apparatus for loading and regeneration tests is shown in Figure 1 and the position of the thermocouples for temperatures' monitoring is shown in Figure 2.

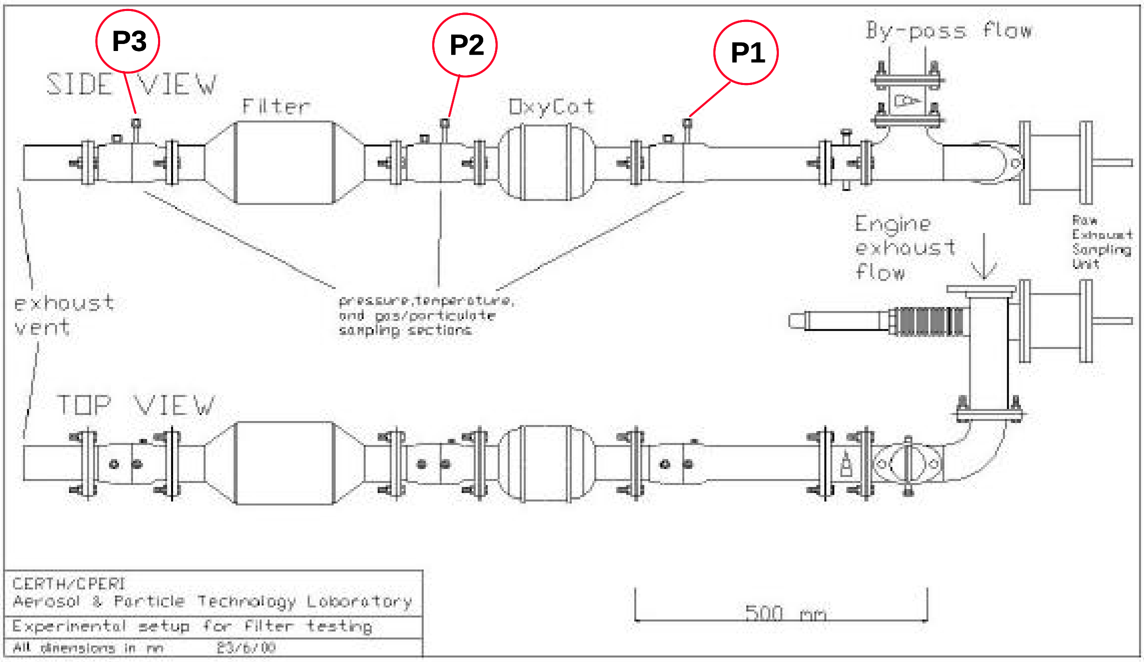

Figure 1. Experimental setup for loading and regeneration experiments. P_1 to P_3 are sampling points.

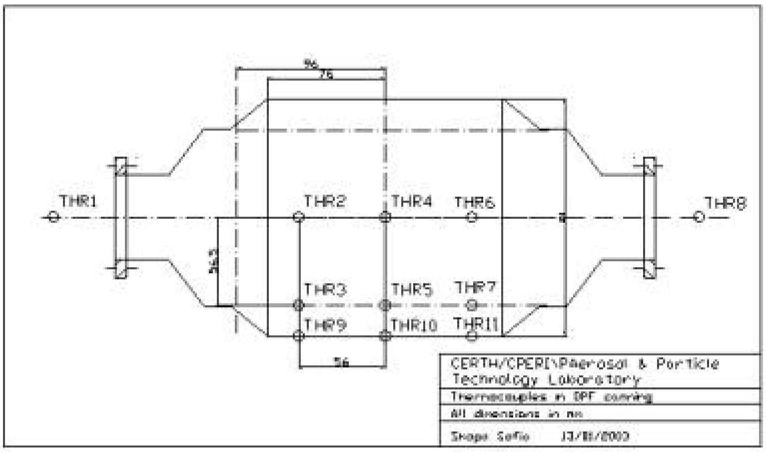

Figure 2. Thermocouples in canning of DPF for loading and regeneration experiments

During the first soot loading experiment the system was exposed to the exhaust flow for 1 3/4 hrs and was loaded by 20 gr/m^2 of soot. During the second soot loading experiment the system was exposed to the exhaust flow for 2 hrs and was loaded by 28 gr/m^2 of soot. The above values are well above of what is considered normal for a DPF soot load. The soot loading mass of the filter is calculated by weighting the DPF after the experiment.

Figure 3 reveals the pressure drop evolution with challenge mass load during the two different loading experiments.

Table 1. Soot loading experimental conditions

No.	Speed (rpm)	Torque (Nm)	$T_{up\ DPF}$ (C) [1]	$\dot{m}$ exhaust (kg/h)	S.E.R. (g/h) [2]	Soot mass loaded (g/m2)
1	1510	76	375	65	13.6	20.2
2	1507	76	350	66	16.4	27.7

[1] $T_{up\ DPF}$ (C) = Temperature upstream DPF

[2] S.E.R. = Soot Emission Rate

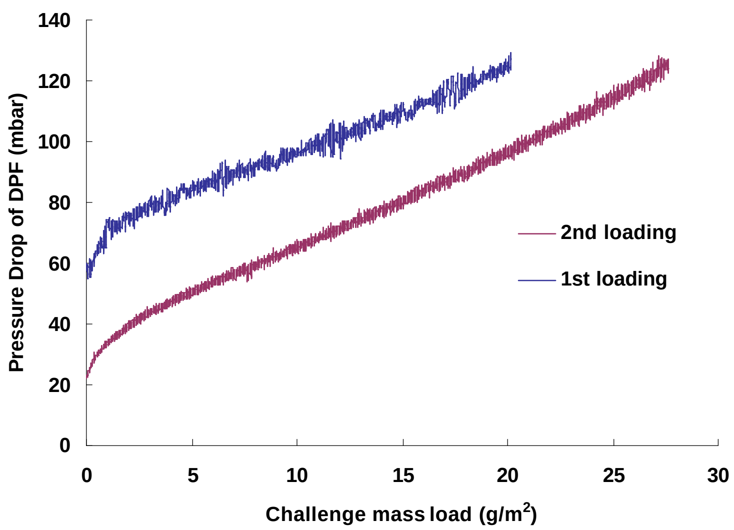

Figure 3. Soot loading behavior of StobbeDPF during the two loading experiments

Table 2 shows the baseline gaseous concentration (P_1), the gaseous concentration downstream of the oxidation catalyst (P_2) and downstream of the DPF (P_3), during the 1st loading experiment.

Table 2. Gaseous emissions at 1500 RPM and 75NM

Gas	Concentration at P_1	Concentration at P_2	Concentration at P_3
CO	150 ppm	0 ppm	0 ppm
CO_2	11.3 %	11.5 %	11.5%
NO_x	287 ppm	196 ppm	265 ppm
NO	285 ppm	134 ppm	231 ppm
NO_2	2 ppm	62 ppm	34 ppm
O_2	6.2 %	6.2 %	6.1 %

Particle size measurements were carried out with the use of a TSI Scanning Mobility Particle Sizer (SMPS), consisting of a long Differential Mobility Analyzer (DMA) 3080 and an Ultra-fine Condensation Particle Counter (UCPC) 3025. Figure 4 shows the particle size distribution upstream and downstream of the DPF measured with the SMPS, while Figure 5 shows the filtration efficiency calculated during the first loading experiment. The DPF showed excellent filtration efficiency (>98%).

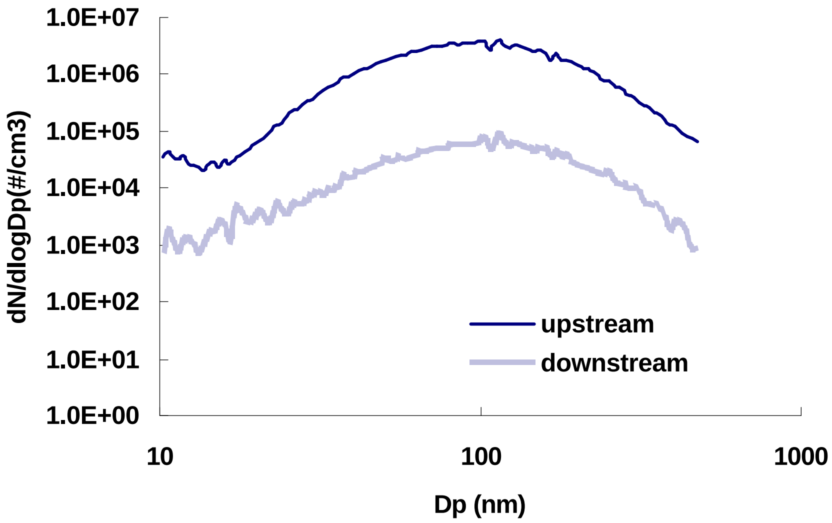

Figure 4. Particle size distribution upstream and downstream of the DPF, measured with SMPS, during the first soot loading experiment of StobbeDPF.

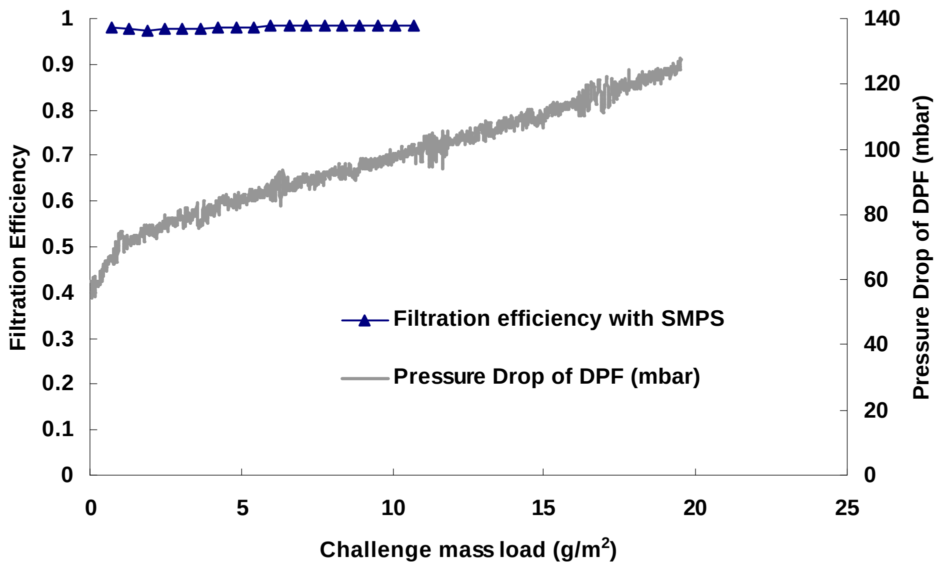

Figure 5. Filtration Efficiency measurement during the 1st soot loading test.

REGENERATION TESTS

The Regeneration tests of the DPF were performed in two ways:

a) By means of hydrocarbon injection upstream of the diesel oxidation catalyst and
b) Operating the engine in full load rated speed at high exhaust temperature and suddenly cut it to idle.

a) The engine operation point used was 2500 RPM and 75 NM. At this specific engine operating point, exhaust temperature is approximately 335C (with no HC injection). Exhaust gas flow is 143 Kg/hr and the soot emission rate is 1.8 gr/hr. Exhaust temperature was increased in steps of approximately 25 C. The system was left to reach constant temperature for 15 min at each temperature step. HC injection varied between the value of 0 gr/min (initial temperature) and 16 gr/min (exhaust temperature 600 C approximately). Pressure drop across the DPF and inlet, outlet and inside DPF temperatures were monitored (Figure 2). Figure 6 shows the regeneration experiment for the tested DPF. From 1000 to 1800 seconds a malfunction of the data acquisition system occurred and data are missing from the graph.

It is interesting that the increase in pressure drop due to soot accumulation stops at exhaust temperature of approximately **440 C** indicating soot oxidation. For normal soot loaded (10 gr/m^2) non-catalyzed DPFs the soot ignition temperature is usually higher than **500 C** at this engine operating point.

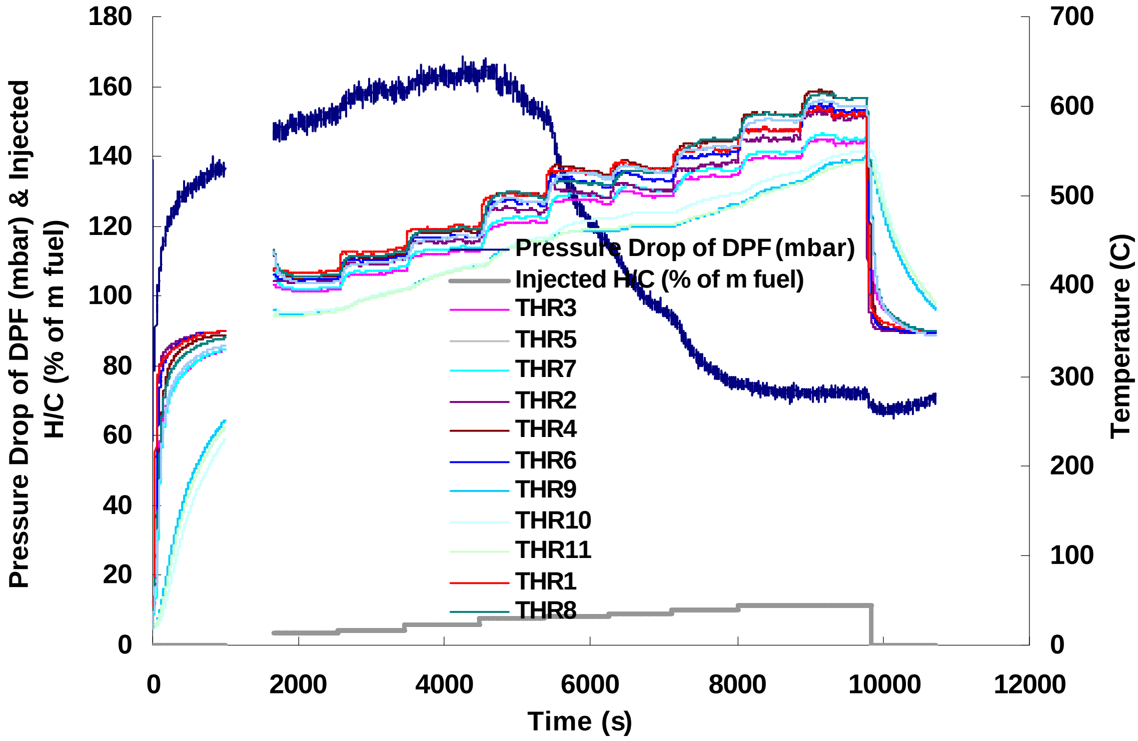

Figure 6. Evolution of Pressure Drop of the DPF during Regeneration with H/C injections

Table 3 summarizes the baseline gaseous emissions (P_1) at the engine point where the regeneration experiments were made, as well as the gaseous emissions at point P_2 (upstream of the DPF and downstream of the OC) during the regeneration experiment.

Table 3. Gaseous emissions at 2500 RPM and 75NM

Gas	Concentration at P_1	Concentration at P_2
CO	21 ppm	0 ppm
CO_2	8.1 %	8.1 %
NO_x	328 ppm	270 ppm
O_2	10.3 %	10.2 %

Figure 7 shows the gaseous emissions downstream of the DPF during regeneration with H/C injections.

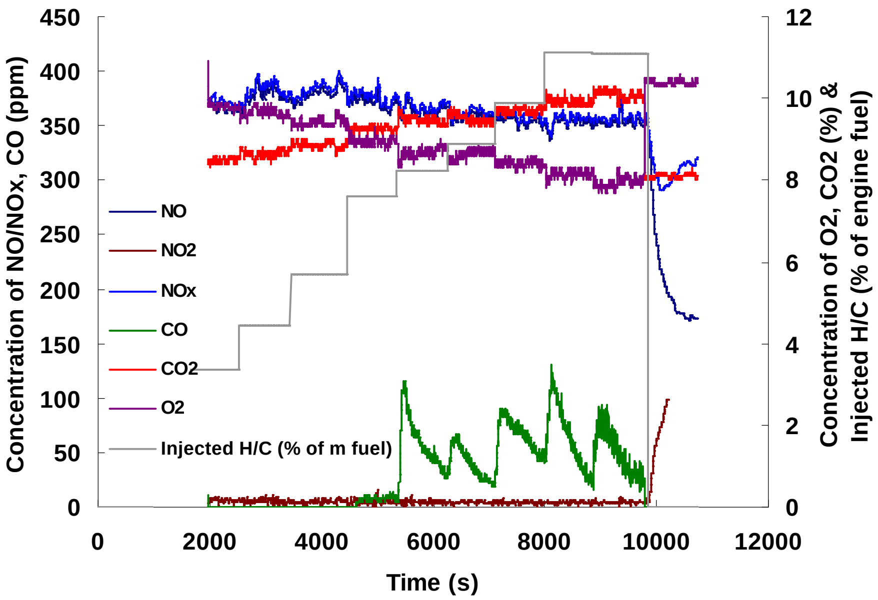

Figure 7. Gaseous emissions downstream of the DPF (P_3) during regeneration with H/C injections.

b) The engine is initially run at full load rated speed (3000 RPM, 185 NM). At this specific engine operation point, exhaust temperature was approximately 590C (with no HC injection). Exhaust gas flow was 260 Kg/hr and the soot emission rate is was gr/hr As soon as the temperatures inside the filter were stabilized, an injection of 15g/min Hydrocarbons took place. When the temperature of the DPF reached 700C, the injection stopped and the engine was cut to idle.

Pressure drop, inlet, outlet and inside DPF temperatures as well as particle concentrations were again monitored (Figure 8). THR6 was not properly functioning and therefore is not shown in the graph.

The maximum realized temperature was 800 C during this test. This temperature was recorded by the THR8 thermocouple placed at the filter exit. It could be assumed that the thermocouple placed at the central exit channel inside the DPF (THRR6) if properly functioned would show an even higher temperature. The maximum temperature gradient realized was 200 C. Despite the high maximum temperatures and temperature gradients during the test no actual effect on the filter performance occurred.

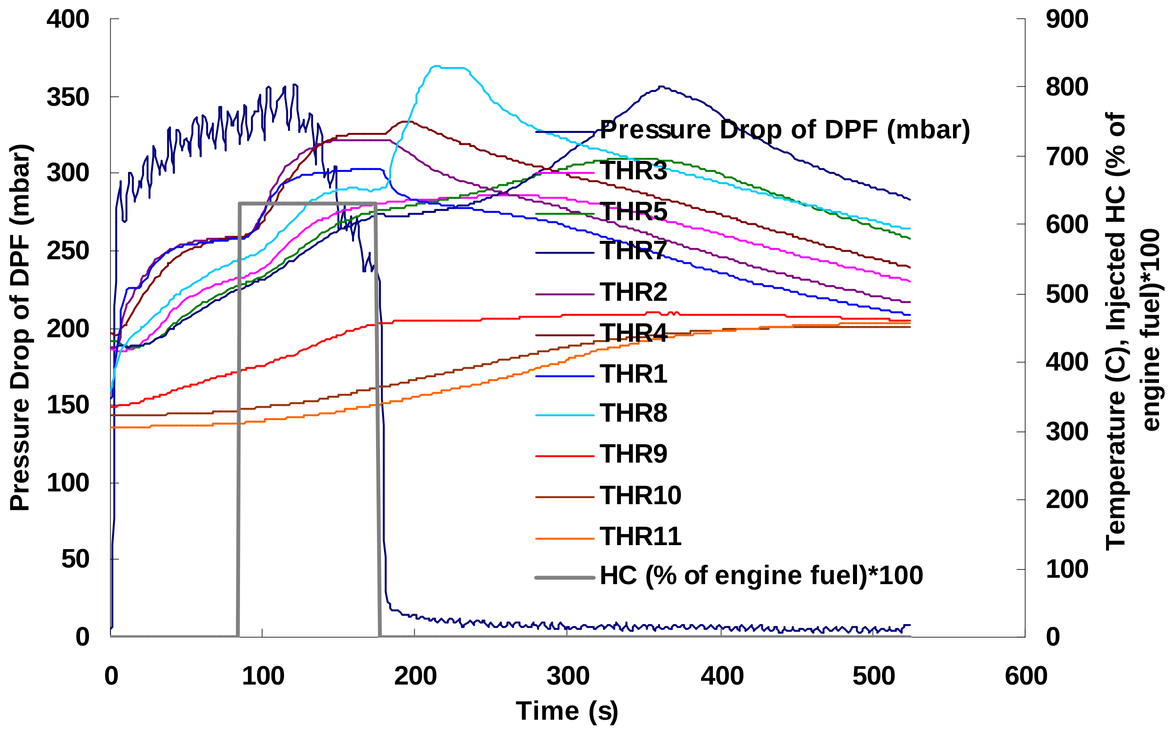

Figure 8. Evolution of Pressure Drop of the DPF during regeneration by cutting to idle

Table 4 summarizes the baseline gaseous emissions (P_1) at the engine point where the regeneration experiment initiated (3000 RPM and 185 NM), as well as the gaseous emissions at point P_2 (upstream of the DPF and downstream of the OC) when the engine is cut to idle.

Table 4. Gaseous emissions

Gas	Concentration at P_1 (3000 RPM and 185 NM)	Concentration at P_2 (idle)
CO	180 ppm	0 ppm
CO_2	11.5 %	4.3 %
NO_x	1100 ppm	130 ppm
O_2	6 %	14.8 %
HC	12 ppm	35 ppm

Gaseous emissions at P_3 during regeneration by cutting to idle are shown in figures 9-11.

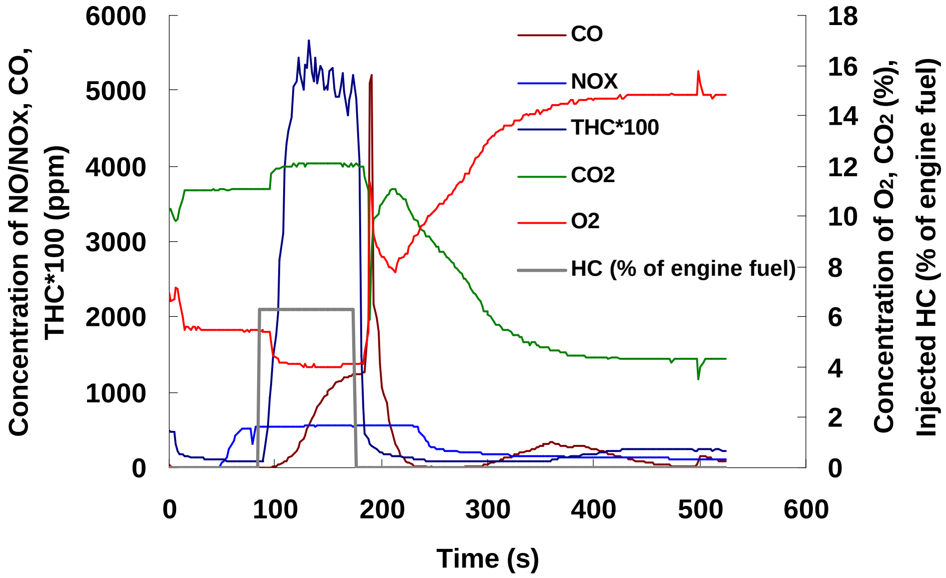

Figure 9. Gaseous emissions downstream of the DPF (P_3) during regeneration by cutting to idle

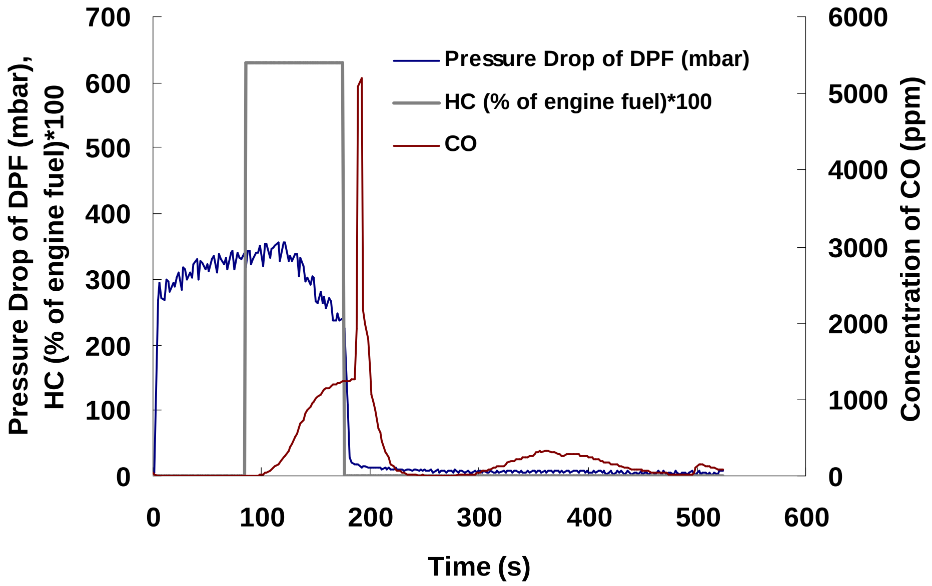

Figure 10. Gaseous emissions downstream of the DPF (P_3) during regeneration by cutting to idle

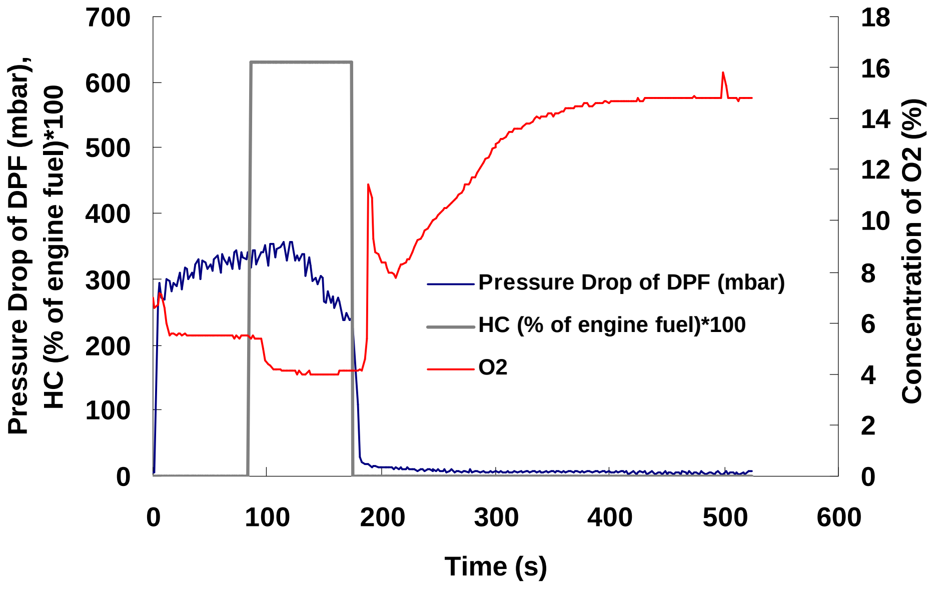

Figure 11. Gaseous emissions downstream of the DPF (P_3) during regeneration by cutting to idle