

# Nanoparticle-Emission of EURO 4 and EURO 5 HDV Compared to EURO 3 With and Without DPF

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## SUMMARY

Emissions from three modern HDV vehicles were investigated on a chassis-dynamometer. One of the vehicles uses PM-Kat and is certified according to EURO4. The second one is EURO5 compliant and uses SCR. The third one is was a EURO3 HDV, which was tested with and without VERT-certified DPF. The investigation focussed on solid particles in the mobility size range of 10-400nm. The instruments were SMPS, NanoMet, PASS and ELPI. Sampling conformed to PMP for SMPS and NanoMet, PASS and ELPI were used with FPS-dilution. Metallic emissions were measured using ICP-MS. Also measured were inherent secondary emissions, especially NO<sub>2</sub> and NH<sub>3</sub>.

For the majority of operating points for EURO4 with PM-Kat and EURO5 with SCR, a moderate curtailment of nanoparticle emissions was observed compared to EURO3 without DPF. However, at full load the EURO5 engine emitted higher concentrations than a EURO3 engine without DPF. A stochastic particle release was observed from the PM-Kat of the EURO4 engine. Its penetration scatter was very much dependant on the soot burden and the testing history. Compared to a EURO3 engine with a DPF conforming to VERT criteria, both modern engines EURO4 and EURO5 emitted 100-500 times more nanoparticles.

The gaseous emissions of the EURO5 engine exhibited very good results. There were no deleterious effects observed due to the SCR. The concentrations of NH<sub>3</sub> and N<sub>2</sub>O remained close to the detection limit. However, the EURO4 engine emitted rather high concentrations of NO<sub>2</sub> at about half load range. Emissions of Vanadium with EURO5 and Platinum with EURO4 were low in both cases, even below detection limit.

## INTRODUCTION

Solid state particles occur in IC-engine exhaust at concentrations of  $10^7 - 10^8$  particles per cm<sup>3</sup>. Their pertinent size range is about 10 - 400 nm and the average size is 60 – 80 nm. Particles of this size intrude

the alveoli. Subsequently, they rapidly infiltrate the cell membranes and are transported into human organs, even penetrating the blood/brain barrier and the placenta-barrier. Apart from causing cancer, nanoparticles may trigger a variety of diseases, e.g. cardiac infarct, Alzheimer and Parkinson disease [1]. In 1989 the WHO classified these particles as carcinogenic. Indeed, P. Pott observed soot to be carcinogenic already in 1775 during his famous studies with chimney sweeps. Researchers and authorities in occupational health [2] recognised the importance of particle size as early as 1910. Environmental legislation mandates minimizing such emissions using the best available technology BAT.

Aitkin proposed high resolutions methods, already in 1888, to determine aerosol number concentrations. Separation into solid state particles and condensed droplets, characteristic for IC engine exhaust when cooling down, is reliably done using the PMP-measuring method evaluated by UN-ECE-GRPE in 2002-2006 [4].

European legislation, for IC-engine exhaust, initially specified the EURO-1 particle emissions limits in 1992 using the US EPA definition of PM, dating from 1982. PM is a metric that does not differentiate according to particle size or chemical composition. Hence, it is not well suitable for toxicity evaluations. The Swiss metric for DPF-evaluation is the number concentration of solids in the nanoscale range [6].

European Union legislation also does not limit secondary noxious pollutants, unlike the US Clean Air Act 202 which precludes the release of poisonous by-products [5], when deploying new technologies. Since 1990, the Swiss also require testing of possible secondary emissions if there are catalytic processes involved in the engine exhaust [7]. DPF retrofit of construction equipment or of road vehicles is only acceptable when the filter systems comply with both the filtration and secondary emission criteria according to best available technology.

Meanwhile, European emission criteria have been tightened but the PM metric is still inappropriate. The EU