Portable Nano-Particle Emission Measurement System

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Publishable Executive Summary

The PEMs4Nano project addresses the challenge to develop detectors and robust procedures to reliably measure the particle number concentration down to 10 nm in the exhaust gas. To achieve this, and to make the progress to that overall objective more transparent, the project is structured in three focus areas:

- model-guided application (MGA),
- preparation of measurement technology (MT),
- development of measurement procedure and application (MPA).

The simulation approach in *model-guided application* supports building up fundamental understanding of the particle formation, composition, size distribution and transport and generates vital recommendations on the measurement procedure. *Preparation of measurement technology* focuses on the development of the PN measurement system itself while *development of measurement procedure and application* addresses the implementation of the new measurement system in the engine & vehicle development process in terms of application and usage.

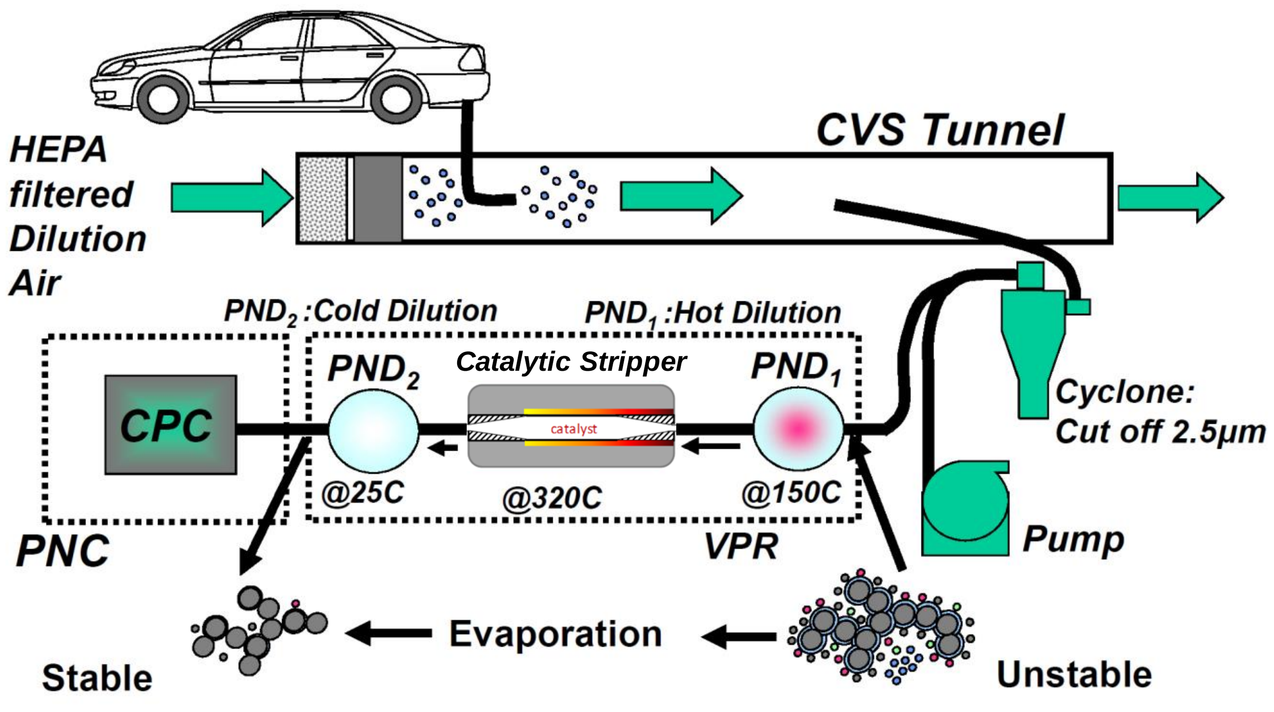

Figure 1: Principle of catalytic stripper and dilution for preparation of exhaust gas[1]

The current state-of-the-art in particle number (PN) measurement for Type Approval of vehicles in Europe is based upon the method developed by the Particle Measurement Program (PMP), authorized by GRPE within the UNECE for the measurement of emitted particles. The method has originally been developed for diesel-fueled light duty vehicles. The ECE regulation No. 83, to which PN has been added, specifies that the PN measurement system counts only solid particles, removing any volatile particles (consisting of high molecular weight hydrocarbons and sulfate) by means of what is called the volatile particle remover (VPR). The VPR consists of two dilution stages and an evaporation unit as can be seen in Figure 1.

[1] Source: PEMs4Nano proposal

In order to ensure that the measurement procedures robust and reliable down to 10 nm, the PEMs4Nano project uses an optimized laboratory system based on the HORIBA SPCS2100, see D2.4. This involves a 10 nm condensation particle counter (CPC) with a high counting efficiency (≥ 50 %) at 10 nm (see D2.2). The (typically) high number of volatile particles need to be removed to ensure robust and reliable measurements of the solid particles. An evaporation tube (ET) has been found to be not the best solution for particle measurements at particle sizes <23 nm as it cannot prevent the nucleation of particles downstream of the ET. For this reason, a catalytic stripper (CS) has been introduced to remove the volatile components by oxidation. A similar or even better removal efficiency according to the latest legislation requirements can be achieved. Particle losses in the CS (even more significant for smaller particles <23 nm) will be investigated and optimized for the PEMS unit by University of Cambridge within the PEMs4Nano project. The schematic of measurements at the roller tests bench with the PEMs4Nano laboratory PN>10 nm system is illustrated in Figure 1.

The scope of this report is to identify and resolve the differences between PN measurements from the CVS dilution tunnel, as used for Type Approval, and from the exhaust and tailpipe sources as applied for engine and vehicle R&D and for Real Driving Emissions. Any difference in the PN measurements between sampling from the CVS and sampling from the vehicle tailpipe needs to be determined and resolved, so that the PN emissions from Real Driving Emissions correlates closely to those made during the Type Approval (or vice-versa depending on the reader's view point). Any differences between these measurements are resolved by modifying the laboratory system, so that the Type Approval PN values correlate with those in the Real World. This will clearly enable the industry to get closer to the emissions targets in an early phase in the development of new engines. That would lead to either a more efficient development process or more elegant solutions to reducing particle emissions (or both), due to the better understanding of particles in the exhaust line.

This report ties in with the previous report D3.3 with a particular focus on investigations of vehicles on the chassis dyno with the following objectives:

- Generate experimental data to train and validate the models of the focus area *model-guided application.*
- Application of the new PEMs4Nano PN>10 nm lab measurement systems at the chassis dyno together with the standard PN>23 nm lab systems.
- Evaluation of the PN>10 nm emission behavior of GDI vehicles during various driving cycles and sensitivity analysis for different operating temperatures and fuels.

For the investigations, two state-of–the-art medium sized cars[2], one of the C-segment and one of the E-segment, have been operated on the roller test bench. Both cars are equipped with a 35 MPa injection system, an exhaust gas aftertreatment consisting of a three-way catalyst (TWC) and a gasoline particulate filter (GPF).

Comprehensive variations of the driving cycles WLTC and RDE aggressive have been performed for two different certification fuels (EU5 and EU6) and three different operating temperature conditions (ambient 23 °C ± 3 °C, 0 °C and -7 °C). The PN>23 nm tailpipe emissions have been compared to the PN>10 nm, and PN>23 nm emissions at the dilution tunnel with constant volume sampling (CVS).

The gathered findings summarized in this report will be used to further improve the measurement technology on the one hand and to contribute to a recommendation for a PN >10 nm measurement procedure for the application in the engine and vehicle development process on the other.

[2] According to the European car segment definition (https://en.wikipedia.org/wiki/Euro_Car_Segment); Homepage accessed on 25th of August.

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Project partners:

#	Type	Partner	Partner Full Name
1	IND	HORIBA	Horiba Europe GmbH
2	IND	Bosch	Robert Bosch GmbH
3	IND/SME	CMCL	Computational Modelling Cambridge Limited
4	IND	TSI	TSI GmbH
5	HE	UCAM	The Chancellor, Masters and scholars of the University of Cambridge
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7	IND	IDIADA	Idiada Automotive Technologie SA
8	IND	HORJY	Horiba Jobin Yvon S.A.S.
9	IND/SME	UNR	Uniresearch BV

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