



Measuring Particle Number during Periodic Technical Inspection In the Exhaust of Passenger Cars

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Introduction

- Discrepancies between emissions over a driving cycle and real driving emissions show the need for a compulsory annual emissions test
- Exhaust aftertreatment systems (diesel particulate filters) may fail due to aging, poor maintenance, poisoning or manipulation [2].
- Opacimeters are too insensitive to detect DPF errors in the latest vehicle generations, i.e. EURO 5/6.
- New exhaust directive in Germany: Introduction of particle number limit values for cyclic exhaust emission testing for diesel vehicles on 1.1.2021
- The measurement technology in our proposed instrument is a condensation particle counter (CPC), already proven in automotive applications:
 - Used for the type approval of new vehicles according to EURO 5b/6 since 2011 [3].
 - Preferably used for PEMS measurements of vehicles in real operation (RDE)
 - Switzerland: Certified portable system (NPET) for particle number measurement on construction machinery in field operation (SR 941.242)

Measurement Technology

The measuring system is designed such that only solid soot particles are measured:

- Sampling probe with immediate dry air dilution prevents condensation of water
- 1 μm cyclone with water trap prevents large particles or water droplets from interfering with the measurement or contaminating the measuring system
- Catalytic Stripper removes volatile components of the exhaust emission
- **Condensation Particle Counter** detects and counts each individual particle. A working liquid (Isopropanol) is used to convert the particles into much larger droplets and measure them with optical light scattering. It also keeps the sensor clean and reduces maintenance

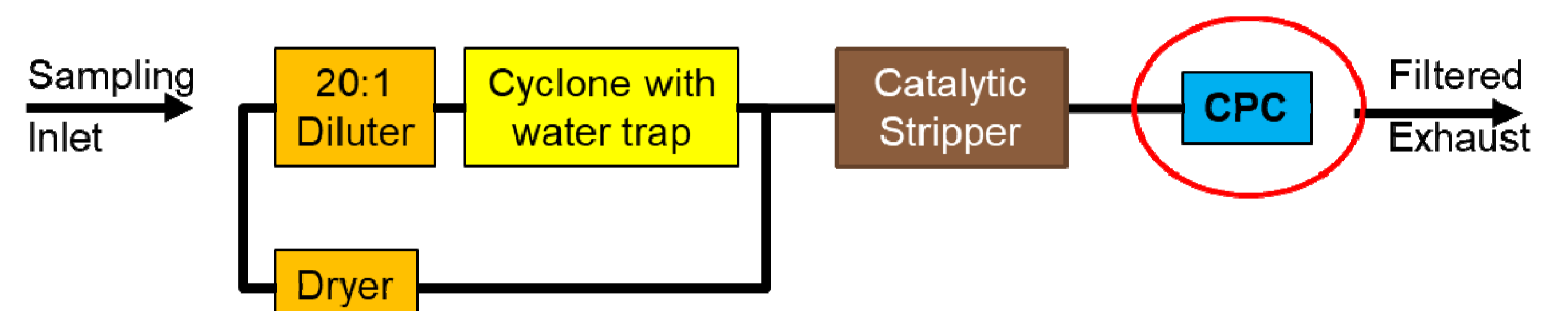


Fig. 1: Schematic of the particle number measurement system for tailpipe exhaust

Calibration and Validation

- ISO 27891 [4] describes the traceable calibration of CPCs
- Implemented for PEMS measurement systems by JRC [5] (see Fig. 2)
- Measurement results correlate with type approval (see Fig. 3)

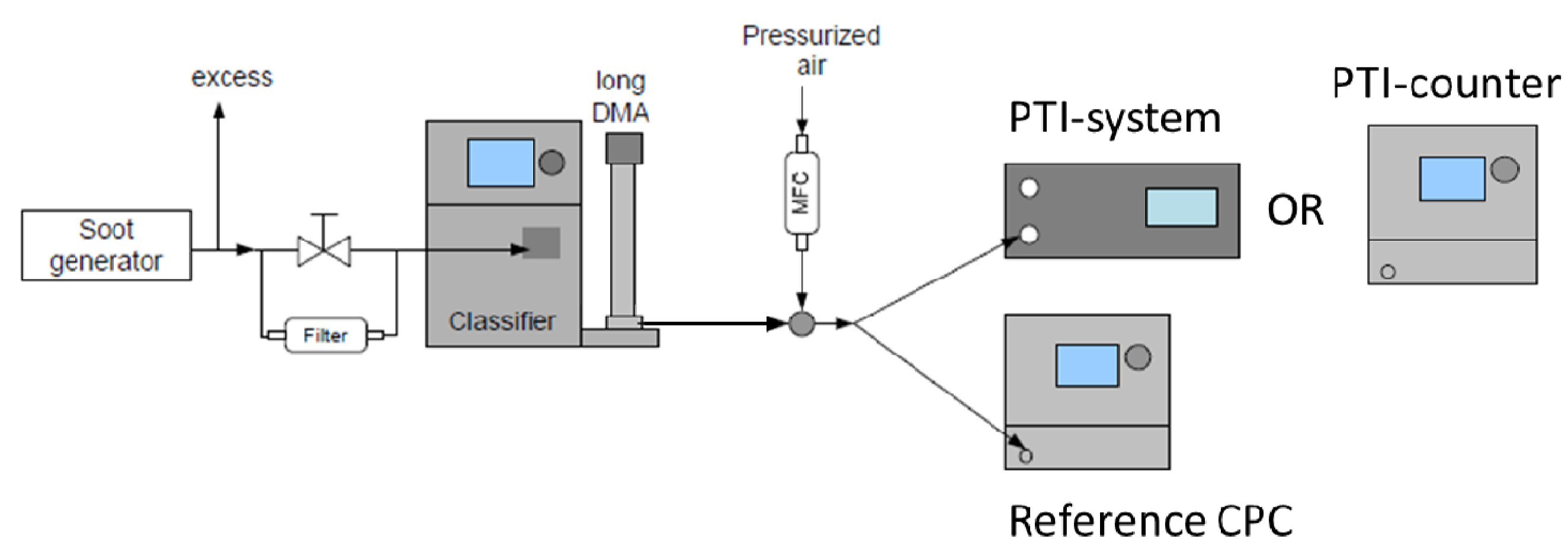


Fig. 2: Calibration setup for particle number-based measuring systems for PTI, adapted from Joint Research Center Technical Report 2018, Real Driving Emissions (RDE) B. Giechaskiel

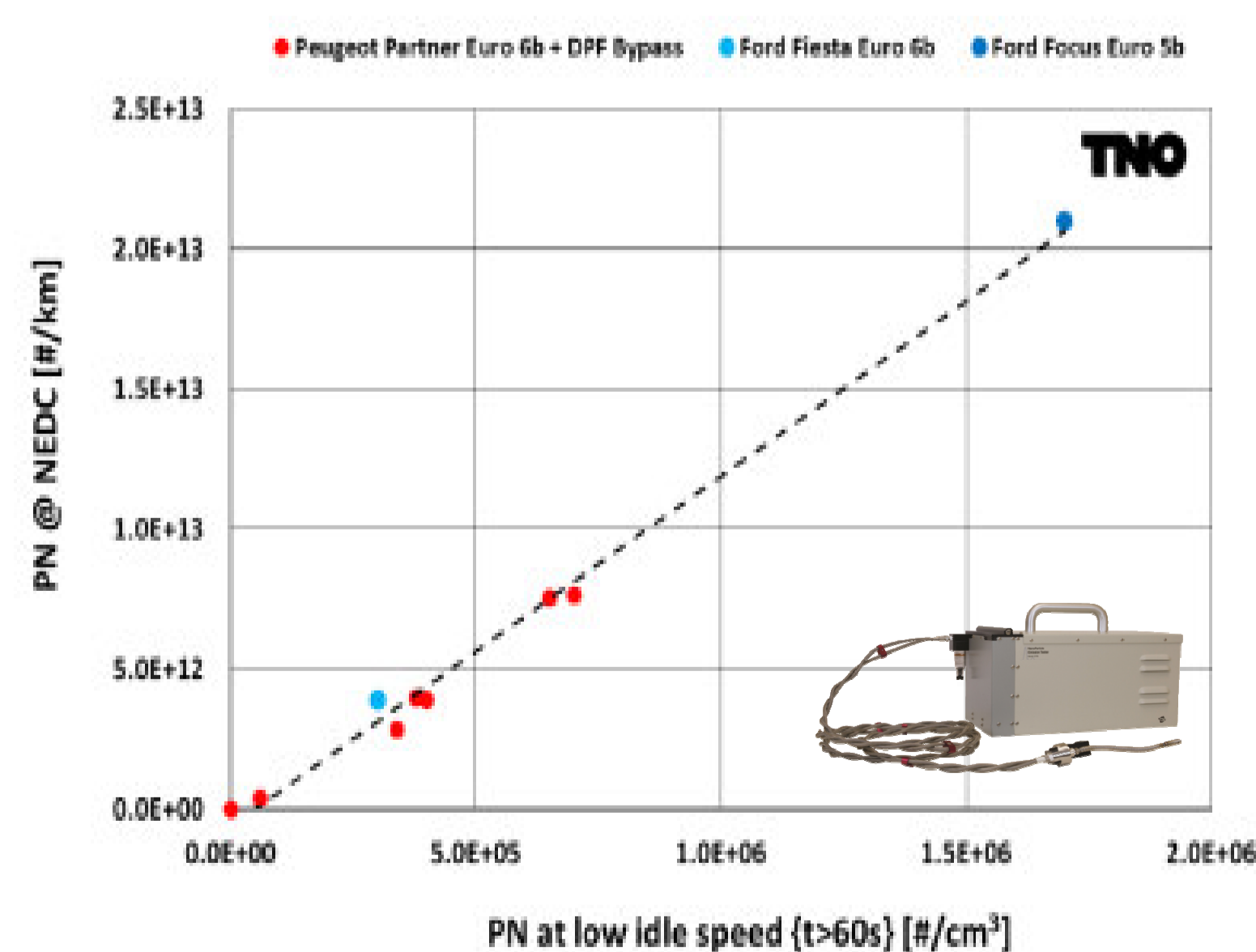


Fig. 3: PMP measurement results for type approval compared to NPET measurements on the tailpipe. Presented by Gerrit Kadijk at VERT-Forum 2018

Literature

- [1] Engineers develop cheap, simple tests for car emissions, Dübendorf, Schweiz, Reuters 2019 <https://uk.reuters.com/article/us-autos-emissions/engineers-develop-cheap-simple-tests-for-car-emissions-idUKKCN1QW17M>
- [2] Kadijk et al, NPET – the New Periodic Technical Inspection emission test procedure for vehicles with emission control systems, TNO White Paper 2017
- [3] Bischof O.F.: Recent Developments in the Measurement of Low Particulate Emissions from Mobile Sources: A Review of Particle Number Legislations. Emission Control Science & Technology, Vol. 1, Issue 2, 203–212, 2015
- [4] ISO 27891:2015 Aerosol particle number concentration – Calibration of condensation particle counters, www.iso.org
- [5] B. Giechaskiel, Real Driving Emissions (RDE): Particle Number (PN) Portable Measurement Systems (PEMS) calibration, EUR 29036 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-77482-9, JRC110424

Measurement Results

- Measurement campaigns in Belgium (GOCA) and Holland (TNO)
- Comparison of measurement results between
 - Automotive Particle Emission Tester (APET) - developed for PTI
 - Nanoparticle Emission Tester (NPET) - certified by METAS

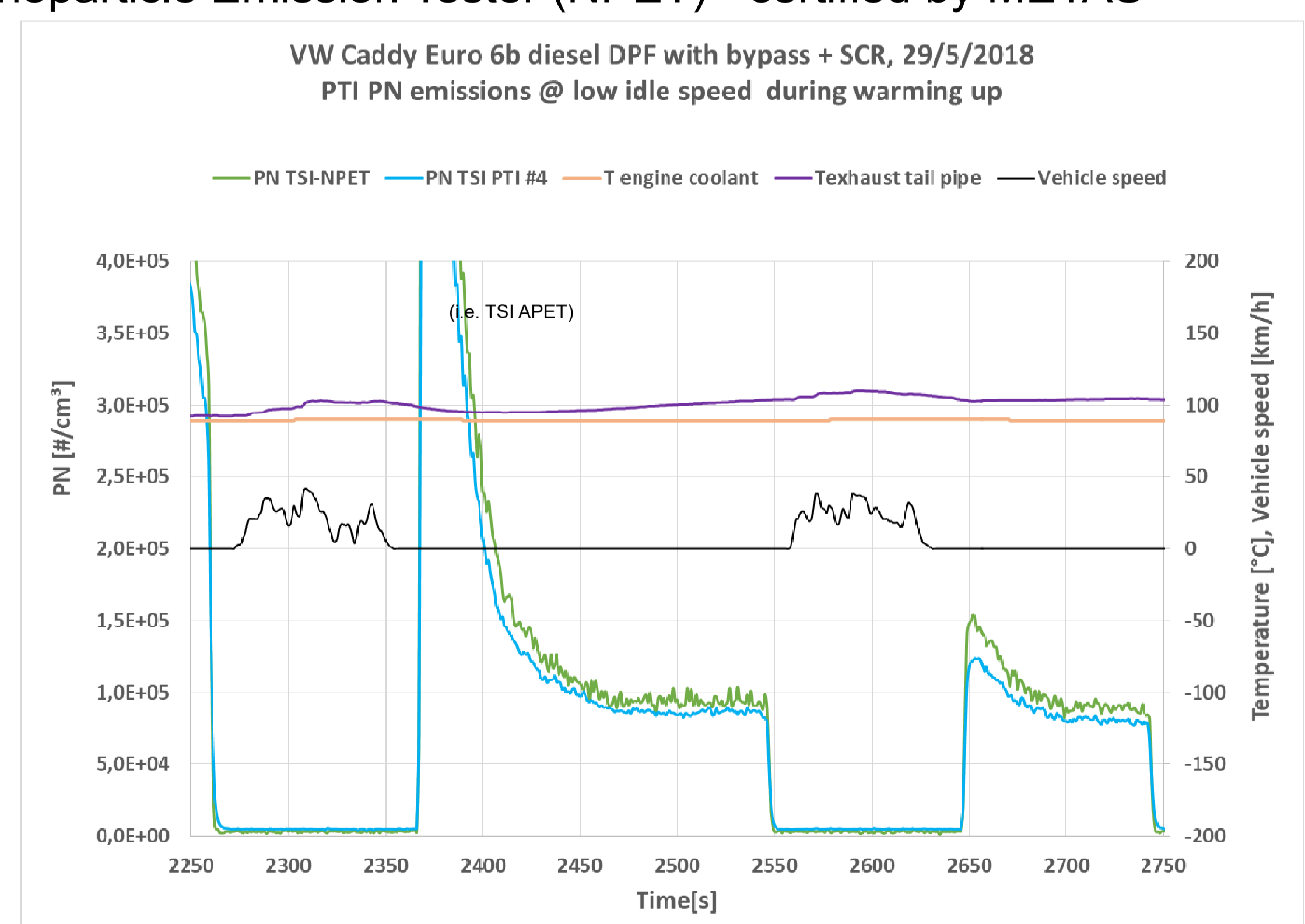


Fig. 4: Example of a particle number measurement in the exhaust (TNO) of a Euro 6b diesel vehicle with DPF bypass

Summary

- Presentation of a measuring device for particle number concentration in tailpipe exhaust for use in workshops and test centers
- The use of the proven CPC measurement technology means:
 - Accurate counting of every single particle in tailpipe exhaust
 - Insensitive to size changes in exhaust due to aging engines
 - No interference from large particles or urea injection for the SCR
 - Maintenance-free measuring system (period ≥ 1 year)
 - The liquid helps keeping the sensor clean inside
 - Comparable and reliable results due to traceable calibration according to ISO 27891
- Future-proof technology also suitable for gasoline vehicles, stricter requirements, and counting particles down to 10 nm

