

Publishable Summary for 19ENV09 MetroPEMS Improved vehicle exhaust quantification by portable emission measurement systems metrology

Overview

Nitrogen Oxides (NO_x) and fine particles emitted from cars are the leading causes of air pollution. In recognition of this, EC legislation was recently introduced for on-road type approval (TA) real driving emission (RDE) tests using portable emissions measurement systems (PEMS), however metrological validation is lacking. In order to support the accuracy and comparability of vehicle emission values procedures for metrological PEMS characterisation (for NO_x, particle number (PN) and exhaust gas flow) and the development of the associated infrastructure is required. This is particularly relevant for the accurate verification of vehicle emission limits in TA, and thus vital for (i) European vehicle manufacturers, (ii) the associated measurement device industries and (iii) the legislative bodies responsible for ensuring adequate air quality despite increasing traffic emissions.

Need

The European car industry currently provides jobs to more than 6 % of the employable population. It is a growing sector of European economy that produces a trade surplus of € 90.3 billion. Furthermore, it is predicted that for decades to come, vehicles powered by internal combustion engine will remain dominant over electrically driven ones, which in 2018 have only reached a 2.0 % share of the total registered vehicles across the EU [1]. The burden of internal combustion vehicles to the environment has decreased in recent years thanks to stricter regulations and the implementation of more effective pollution control systems. However, these reductions have not been as large as anticipated due to emission standards not delivering the expected reductions under real-world driving conditions. As a result, this sector is still responsible for an important amount of NO_x and fine particles [2]. According to the latest European Environment Agency (EEA) report [2], severe violations of World Health Organization (WHO) air quality guidelines (AQG) for Particulate Matter (PM₁₀ and PM_{2.5}) were recorded in almost all EU Member States. Moreover, for NO₂, 88 % of concentrations observed at traffic stations were above AQG limit values.

In 2016, an additional TA test procedure called RDE test was introduced by the EC. This is an on-road test using PEMS and complements in-laboratory TA tests for light-duty vehicles [4]. This regulation was amended later to introduce conformity factors for NO_x and PN [5-6, respectively]. These conformity factors establish “not to exceed” limits for on-road tests compared to laboratory tests. Currently, PEMS measurement uncertainties are expected to be considered in the conformity factors. However, a comprehensive and metrologically validated uncertainty estimation yet has not been documented. From 2020, new conformity factors will apply to TAs and therefore there is increasing need from end-users (e.g. car manufacturers) for the development of accurate and metrologically validated calibration standards and guidelines for vehicle emission on-road TA RDE testing.

Objectives

The overall goal of the project is to develop the necessary metrology for PEMS to support newly introduced vehicle emission legislation for on-road TA RDE testing. The specific objectives of the project are:

1. To develop traceable methods to validate and calibrate portable NO_x emissions measurement systems (PEMS), in particular for NO₂, for concentrations from below 10 μmol/mol up to at least 2500 μmol/mol. This should include the generation of a ‘state-of-the-art’ PEMS with respect to high accuracy reference gases, development of improved gas standards, calibration methods and uncertainty evaluations, as well as the validation of commercial NO_x-PEMS.
2. To evaluate the performance of commercial particle number (PN) PEMS by comparison with traceable PN facilities; to include the characterisation of i) linearity and counting efficiencies ii) particle size dependence (at least up to 10⁴ particles/cm³ and four sizes), iii) dynamic flow behaviour including the determination of aerosol sampling and handling effects.

3. To develop application-oriented calibration procedures and uncertainty budgets for PEMS exhaust flow meters (EFM) for relevant carrier gases and to investigate the effect of dynamic flow behaviour on PEMS uncertainty.
4. To quantify the correlation between: i) RDE-PEMS measurements and laboratory dynamometer test results, ii) individual PEMS “channels” for CO₂, CO, NO, NO₂, PN, exhaust mass flow and iii) validated ‘golden’ (reference) PEMS and commercially available PEMS.
5. To facilitate the take up of the technology and standards developed in the project by: the measurement supply chain (instrument and car manufacturers, accredited calibration laboratories), standards developing organisations (e.g. CEN, ISO) and end users (automotive industry).

Progress beyond the state of the art and results

The current state of the art expresses the combined uncertainty of a PEMS device and the associated RDE test as 50 % for PN, and 43 % for NO_x. These values are portrayed in current legislation by conformity factors that are used to yield “not to exceed” values from the results of the in-laboratory dynamometer test over the current Worldwide Harmonised Light Vehicle Test Procedure (WLTP) test cycle for a given car. Hence, over the complete on-road, real-world in-use RDE test, the results should not be greater than those “not to exceed” values in order to achieve a “pass” declaration by the testing authority.

This project will address the 3 key components of a PEMS system: i.e. modules for the determination of (i) NO/NO₂ concentrations and (ii) PN, as well as (iii) exhaust mass flow. By studying existing commercial PEMS devices and comparing the performance of their components with known and fully traceable laboratory-scale instruments, the project will develop uncertainty budgets for each of these three key parts. Furthermore, based on these uncertainly budgets the major contributing elements to the uncertainty of the PEMS device will be identified, and best practices will be developed to improve the underlying factors of these uncertainties. This will allow this project to go beyond the current state of the art and develop a more comprehensive understanding of the entity that the PEMS instrument forms. Thereby, this will allow the development of more appropriate and robust calibration procedures, as well as methods and gauges for in-use checking of PEMS performance.

Based on the deeper understanding of the uncertainty sources, this project will develop and intends to qualify a ‘golden’ PEMS instrument, which will represent the best available level of accuracy that can be achieved and will use the procedures developed in the project. This qualification will make use of the project’s newly developed gas and particle standards, optical transfer standards, exhaust mass flow standards and metrologically sound calibration procedures. It will also be based on a commercial instrument that will be validated with available procedures on a chassis dynamometer and constant volume sampler (CVS) system set-up. This will be done in order to maximise transfer and applicability for end-users. Then, each of the main system components (NO_x, PN, EFM) for the ‘golden’ PEMS instrument will be recalibrated by the partners’ best capability calibration procedures on that particular module. After the completed recalibration, the instrument will next be validated against SI-traceable transfer standards and independent measurement methodologies. Including an additional dyno test, as well as on road using the project’s newly developed RDE procedures.

Using single devices qualified to become a ‘golden’ PEMS, this project will go beyond the state of the art by designing and facilitating a ‘golden’ PEMS architecture that will support the dissemination of the achieved accuracy of the golden PEMS to further transfer PEMS standards and subsequent standard PEMS. In practice this architecture will consist of comparisons of commercial PEMS, set up according to the manufacturers’ guides which the project will then compare against the ‘golden’ PEMS.

Impact

Impact on industrial and other user communities

The most recent regulations on RDE for TA [4-6] have put significant pressure on research and development throughout the whole automotive manufacturing supply chain. This project will create impact by supporting this research and developments and by providing traceable calibration methods as well as a support infrastructure for NO_x/NO₂ (objective 1), PN emission measurements (objective 2), and EFM (objective 3). These traceable calibration methods will be tested in real-world applications (objective 4) and calibration guidelines will be produced. The consortium has good connections with PEMS manufacturers and intends to include them as part of the project’s stakeholder committee (to provide feedback and guidance for the

project). As a result, the project's outputs will be aimed at and will benefit industrial end users and products by providing enhanced quality to measure vehicle exhaust emission.

This project will also significantly extend the measurement capabilities of the participating NMIs, by the development of a support infrastructure for NO_x, PN and EFM. This will include improved flow calibration services for PEMS exhaust flow for partner VSL. New measurement services for primary reference materials of NO₂ from 1 – 2500 µmol/mol for partners NPL and VSL. New calibration services for PN-PEMS for partners PTB, NPL and METAS. In addition, PTB will introduce a 'Golden PEMS' calibration service for use by end-users.

The project's outcomes will be disseminated to stakeholders and industrial end users through public training courses and workshops focusing on good practices and methods for PEMS calibration. In addition, via publications at scientific conferences and in scientific journals as well as via trade journals.

Impact on the metrology and scientific communities

The partners in this consortium are active in the BIPM Consultative Committee for Amount of Substance: Metrology in Chemistry and Biology (CCQM) Working Group on Gas Analysis (GAWG) and EURAMET Technical Committee of Metrology in Chemistry (TC- MC), subcommittee on Gas Analysis, therefore the outputs of this project will be presented to both groups. The improvements of high accuracy primary reference materials of NO₂ and the validation of PEMS PN measurements will support future activities of the metrology community to assure comparability among SI traceable standards, e.g. via key comparisons. Improved NO₂, PN and exhaust flow calibration and measurement capabilities will be made available to the scientific community via partners NPL, PTB and VSL.

The main outputs of this project are improved standards for the determination of NO/NO₂ concentrations, PN and exhaust mass flow (objectives 1-3), real-world comparison of PEMS performance (objective 4) and the production of calibration guidelines for PEMS. The improved calibration standards will include static and dynamic references, as well as transfer standards. These improved reference standards and the real-world assessment of PEMS performance will significantly advance and improve confidence in the traceability of PEMS measurements.

Impact on relevant standards

The TCs predominantly targeted by this project are ISO/TC 158 (Gas Analysis), ISO TC24/SC4, WG12 on aerosol measurements and CEN TC 301/WG16 (Road vehicles), as well as the related national standardisation committees in gas and particle analysis i.e. UNECE WP29 Global RDE IWG, DIN NA 052- 00- 34-53 AK, Performance assessment of PEMS and DIN NA 062-05-73 AA, Gas Analysis and Gas Quality. This is where the work performed in this project will be the most relevant and where it will have the most impact. The partners are members of these committees and will ensure that the knowledge developed within the project is fed to the committees. This will ensure that the project's outputs feed directly into the standardisation activities, and the requirements emerging from the standardisation committees will be used to refine the project in order to maximise its impact.

Longer-term economic, social and environmental impacts

Vehicle emissions contribute to atmospheric PM, NO_x and tropospheric ozone pollution, which in turn affect the climate, human health and agricultural yields. In particular, diesel combustion vehicles produce a significant amount of NO_x. Stricter European regulations have been established to tackle emissions, but vehicles are emitting under real-world driving conditions compared to laboratory tests and therefore current results are not fully comparable. By providing high-quality reference standards and traceability to PEMS measurements, this project will support the improvement of air quality across the EU and will potentially facilitate their uptake by other countries that adopt similar TA tests for light-duty vehicles.

In addition to the environmental benefits, economic and social impacts are also expected. The European car industry is a growing sector that provided the EU with a trade surplus of € 90.3 billion in 2018 [1]. Last year, more than 15 million light-duty vehicles were registered in the EU, of which 56.7 % are fuelled with gasoline and 35.9 % with diesel. The European TA regulations require these vehicles to be tested by RDE PEMS for TA. Therefore, the creation of calibration guidelines and a metrological infrastructure for such testing will support its role out and provide confidence in the results.

List of publications*Not yet available*

This list will also available here: <https://www.euramet.org/repository/research-publications-repository-link/>

Project start date and duration:		01 September 2020, 36 months
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Internal Funded Partners:	External Funded Partners:	Unfunded Partners:
<ol style="list-style-type: none"> 1. PTB, Germany 2. LNE, France 3. METAS, Switzerland 4. NPL, United Kingdom 5. VSL, Netherlands 6. VTT, Finland 	<ol style="list-style-type: none"> 7. Air Liquide, France 8. DTI, Denmark 9. KIT, Germany 10. TU-DA, Germany 	-
RMG: -		