

Title: Supporting Euro 7 emission regulation by improved metrological traceability for key gaseous, particulate pollutants, and exhaust flow

Abstract

The Euro 7 exhaust emission regulation for road transport introduces requirements for monitoring new pollutants (NO_x, ultra-fine particles and NH₃) and strengthens the accuracy requirements for the real driving emission (RDE) tests for the type-approval (TA) of motor vehicles. Despite calibration and measurement capabilities for portable emission measurement systems (PEMS) already being in place for nitrogen oxides and particle number, the Euro 7 regulation demands lower uncertainties, which should be addressed. Therefore, proposals addressing this SRT should develop adequate calibration strategies and should develop and support infrastructure for PEMS validation and TA tests. Outputs should be provided to standards developing organisations (DIN, CEN, ISO, UNECE-GRPE-PMP, OIML) and end users (e.g. the automotive industry).

Keywords

Air quality, calibration, Euro 7, exhaust flow, NH₃, nitrogen oxides, particle number, PEMS, RDE, validation

Background to the Metrological Challenges

Air pollution can cause adverse impacts on human health and the environment. To address this, and to tighten existing regulations, the EC created more RDE TA tests using PEMS. They have recently reached agreement on new Euro 7 standards. These aim to improve air quality and to reduce emissions of additional pollutants like NO_x, ultra-fine particles and NH₃ from transport. Significant steps have already been made to improve vehicle exhaust quantification through the application of PEMS metrology and by providing the traceable measurement standards and calibrations required to improve the quality of measurement data for the emission of the pollutants covered by the Euro 6 standards. However, significant gaps remain in the accurate quantification of the controlled pollutants and metrology efforts are required to achieve adequate calibration strategies and to develop and support infrastructure for PEMS validation and TA tests.

The analytical techniques used by PEMS to measure different pollutants can differ substantially from each other and from the stationary lab-based TA instrumentation that is used for dynamometer tests. Also, some gas PEMS dry the sample gas before analysis, whilst other do not. This generates differences in matrix dependence, temperature behaviour, selectivity and sensitivity. Therefore, standardisation and improved metrological validation is required over a wide range of matrix compositions and operational conditions. Drift modelling and drift correction is also required. The measurement of the controlled chemical pollutants needs to be accurate over a wide range of amount fractions, which poses challenges to the analysers, especially related to linearity, accuracy and precision. Ammonia is difficult to prepare accurately at low amount fractions. It can also interact with water, NO₂ and other acidic tailpipe gases, therefore work is needed to evaluate cross interference effects and potential nano- or micro-particle formation. To reliably quantify vehicle emissions at levels close to the limit of quantification, the response and baseline drifts need to be minimised. Therefore, overall, the suitability of PEMS need to be investigated for measuring the new pollutants stated in the Euro 7 regulation. This needs to include an investigation of the stability of multicomponent static gas standards and whether dynamic mixtures can be used to improve the measurement accuracy of PEMS. The effect of in-situ particle formation on the measurement accuracy, in model tailpipe conditions, also needs to be determined using dynamically generated mixtures. In addition, the combined measurement uncertainty, and compliance

with RDE test requirements, need to be evaluated.

Diffusion Charging (DC) and Condensation Particle Counting (CPC) approaches are used in particle number quantification by PEMS, but these methods have different size-dependencies, which produce increased uncertainties. Therefore, comparability between these approaches and stationary particle number counters will require improved calibration methods, a better-defined reference aerosol and tightened system requirements. One issue relates to the size dependence of particle losses in the aerosol sampling lines and the penetration efficiency. Consequently, improved characterisation methods need to be developed. This is especially important given the plans to lower the size of regulated particles from 23 nm to 10 nm in the Euro 7 regulation and the fact that calibrations currently use the manufacturers' own standards. Therefore, existing traceable particle number calibration facilities need to be adapted so that they can be used with counting efficiencies down to 5 nm. The performance and traceability of diffusion chargers also need to be assessed, for their properties, and for different types of aerosols. Additionally, novel instrumentation needs to be developed to quantify semi-volatile particle emissions, if these pollutants are to be included in future regulations.

Exhaust flow meters (EFM), which are part of the PEMS, are used to determine the total emitted mass from the tailpipe, therefore they directly affect the estimation of the total emitted pollutants during on-road tests. Consequently, the uncertainty of the EFM (e.g. 8 %–10 % ($k = 2$) for NO_x emission measurements, without full traceability, can be the limiting factor in reducing the overall uncertainty of the PEMS. Another contributing factor is that EFMs are calibrated by manufacturers in laboratory conditions, which deviate from real-world driving conditions. Therefore, an uncertainty budget for an EFM, needs to be established which demonstrates compliance with the Euro 7 regulations. Also, direct SI-traceable calibration, and dedicated influencing variable tests (cold start, extended boundary conditions, EFM drift), needs to be investigated to determine whether a 7 %–10 % ($k = 2$) uncertainty in on-road conditions is achievable. Reductions in the uncertainty of EFM in on-road conditions is also limited by the lack of traceable uncertainty information, and the current technology may be reaching its limits. Therefore, alternatives to EFMs need to be investigated.

The PEMS test procedure includes pre- and post-tests to account for any analyser drift over the test period. The PEMS calibration procedure needs to be refined so that several span ranges can be simultaneously accounted for. In addition, the response of PN analysers needs to be revised as the Euro 7 regulation specifies a size threshold down to 10 nm. It should also be noted that commercial PEMS are only compatible with Euro 6 tests. State-of-the-art calibration standards are available for PEMS, but they are not applicable to the new gaseous components, such as NH₃, N₂O and hydrocarbons, which are being proposed in the Euro 7 regulation, nor to other types of particle number counters (i.e. with counting efficiencies down to 10 nm). In order to understand this further, the overall performance of state-of-the-art devices (e.g. PEMS, optical transfer standards) needs to be assessed in relation to the Euro 7 regulation.

Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the protocol.

The proposal shall focus on the traceable measurement and characterisation of gaseous, particulate and total emitted vehicle exhaust emissions.

The specific objectives are

1. To evaluate the suitability of portable emission measurement systems (PEMS), for measuring the key pollutants (e.g. NH₃, NO₂) stated in the emission standards of the Euro 7 regulation. This should include an investigation of the stability of multicomponent static gas standards and whether dynamic mixtures can be used to improve the measurement accuracy of PEMS. The effect of in-situ particle formation on the measurement accuracy, in model tailpipe conditions, should also be determined using dynamically generated mixtures. In addition, the combined measurement uncertainty, and compliance with real driving emission (RDE) test requirements, should be evaluated.
2. To adapt existing traceable particle number calibration facilities so that they can be used at the ultra-fine particle setting (i.e. counting efficiencies down to 5 nm) and to improve the characterisation of particle size dependence in aerosol sampling lines. Novel instrumentation should also be developed for the quantification of semi-volatile particle emissions. In addition, the performance, and traceability, of diffusion chargers should be assessed for their properties and for different types of aerosol particles.

3. To establish an uncertainty budget for an exhaust flow meter (EFM), which demonstrates compliance with the Euro 7 emission measurement regulations. Direct SI-traceable calibration, and dedicated influencing variable tests (cold start, extended boundary conditions, EFM drift), should also be investigated to determine whether a 7 %–10 % ($k = 2$) uncertainty in on-road conditions is achievable. In addition, alternatives to EFMs, should be investigated for traceable exhaust mass flow determination with a target uncertainty of 5 % ($k = 2$).
4. To assess the overall performance of state-of-the-art devices in relation to the Euro 7 regulation: i) PEMS technologies should be compared with laboratory-grade equipment in a chassis dynamometer environment, ii) the performance of PEMS technologies should be evaluated in real on-road conditions for heavy-duty vehicles, and iii) the performance of an optical transfer standard for the determination of exhaust gases should be evaluated both in a test stand and in real on-road conditions.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (instrument manufacturers, PEMS users, such as car manufacturers and accredited calibration laboratories), standards developing organisations (DIN, CEN, ISO, UNECE-GRPE-PMP, OIML), and end users (e.g. the automotive industry).

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. Proposers shall give priority to work that meets documented needs, in particular those supporting the European Green Deal. To enhance the impact of the research, the involvement of the appropriate user community such as industry, standardisation and regulatory bodies is strongly recommended, both prior to and during methodology development.

Proposers should establish the current state of the art and explain how their proposed project goes beyond this. In particular, proposers should outline the achievements of the EMPIR project 19ENV09 MetroPEMS and how their proposal will build on this.

Proposers should note that the programme funds the activity of researchers to develop the capability, not the required infrastructure and capital equipment, which must be provided from other sources.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 2.8 M€ and has defined an upper limit of 3.5 M€ for this proposal.

EURAMET also expects the EU Contribution to the external funded beneficiaries to not exceed 35 % of the total EU Contribution across all selected projects in this TP.

Any industrial beneficiaries that will receive significant benefit from the results of the proposed project are expected to be beneficiaries without receiving funding or associated partners.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the 'end user' community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the "end user" community (e.g. letters of support) is also encouraged.

You should detail how your proposal's results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Facilitate improved industrial capability, or improved quality of life for European citizens in terms of personal health, protection of the environment and the climate, or energy security,
- Transfer knowledge to the automotive sector.

You should detail other impacts of your proposed JRP as specified in the document "Guide 4: Writing Joint Research Projects (JRPs)"

You should also detail how your approach to realising the objectives will further the aim of the Metrology Partnership to develop a coherent approach at the European level in the field of metrology and include the best available contributions from across the metrology community. Specifically, the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work.

Timescale

The project should be of up to 3 years duration.