Note: Potentials for reducing the measurement uncertainty of Portable Emissions Measurement Systems (PEMS)

JRC consultation with PEMS manufacturers on 8 January 2016

1. Participants

- AVL
- HORIBA
- MAHA
- SENSORS
- COM, DG-GROWTH
- COM, JRC

2. Introduction and Objective

Recital 14 of the proposed Real-Driving Emissions (RDE) Regulation requires the Commission to "keep under annual review the appropriate level of the final conformity factor (CF) in light of technical progress". It is proposed to introduce the RDE conformity factor in two stages, with the second-stage CF of 1.5 becoming effective from 2020/2021 and granting an allowance of 0.5 (i.e., 50% of the 80 mg NO_X/km Euro 6 emissions limit) for PEMS measurement uncertainty. DG-GROWTH commissioned the Joint Research Centre (JRC) to consult PEMS manufacturers and elicit the potential for reducing the PEMS measurement uncertainty in the future. This document presents the key results and conclusions of the consultation held on 8 January 2016. The information presented here reflects the technical insight and opinion of PEMS manufacturers at the time of the consultation and can, to a large extent, be supported by the JRC.

3. Approach

The consultation addressed two items. First, the technical improvement potential of PEMS equipment was discussed, focusing on the most relevant provisions of Appendices 1 and 2 of the proposed RDE Regulation. Second, cross-cutting issues were addressed, including the overall potential for reducing PEMS measurement uncertainty and the feasibility of amending test conditions to decrease measurement uncertainty without necessitating adaptations of the PEMS equipment.

4. Background

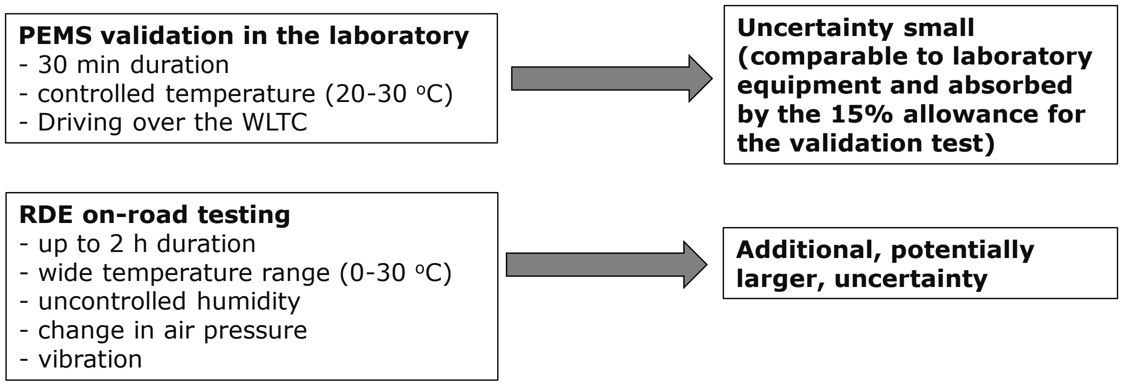
The emissions of light-duty vehicles are regulated as mass of pollutant emitted per distance driven by the vehicle and typically expressed in milligrams per kilometer [mg/km]. To determine distance-specific pollutant emissions, the mass of the emissions [mg] is determined by multiplying the concentration of a given pollutant in the exhaust as determined with a gas analyzer (typically expressed in parts per million) and the mass flow of the exhaust as determined with an exhaust flow meter (typically expressed in kilograms per second). The resulting mass emissions (expressed in milligrams per second) are in a second step divided by the vehicle speed. From these calculations follow three principle sources of uncertainty: (i) the pollutant concentration determined by the gas analyzer, (ii) the exhaust mass flow determined by the exhaust mass flow meter, and (iii) the vehicle speed typically determined by a GPS. A fourth source of uncertainty arises from the alignment of these parameters, i.e., the pollutant concentration needs to be multiplied with the exhaust mass flow and divided by the vehicle speed corresponding to precisely the same emission event. Appendices 1 to 4 of the proposed RDE Regulation specify (i) requirements for PEMS equipment and (ii) calculation steps to ensure a correct determination of distance-specific pollutant emissions. Appendix 3 recommends conducting a validation test of the installed PEMS equipment against standard equipment in the laboratory, allowing a deviation margin of 15%.

The JRC had estimated in a meeting of the RDE Working Group that the overall additional uncertainty related to the determination of pollutant concentration, exhaust mass flow, and vehicle speed with PEMS equipment is, 6%, 4%, and 3% respectively. Additional allowances have to be made for analyzer drift during an on-road test (up to 20%) and alignment of parameters (up to 3%), resulting in an overall error surface of up to 30%, which however disregards uncertainty that may arise from measuring emissions, e.g., at a wider range of exhaust mass flow values than observed in the laboratory, under potentially more transient driving, and a higher variability in altitude, temperature, and ambient humidity.

4. Results

PEMS manufacturers support in substance the results of the above mentioned uncertainty analysis and emphasize that the variability of on-road test conditions makes it difficult to specify average or maximum error margins of general validity. Margins may vary depending on the specific test characteristics and could under exceptional conditions even be higher than assumed if, e.g., analyzer drift occurs in parallel of very high exhaust flow rates.

PEMS manufacturers emphasize that **under controlled laboratory conditions**, **current PEMS equipment achieves a similar performance as standard laboratory equipment used for type approval purposes**. Available PEMS equipment performs within the tolerance margins of 15% or 15 mg NO_X/km prescribed for the validation test in Appendix 3 of the RDE Regulation. The accuracy of analyzers is more-or-less limited by gas bottle standards (i.e., 1-2% uncertainty being the industry norm). Thus, there is limited potential to improve the performance of PEMS equipment under laboratory conditions. However, additional measurement uncertainty results from the extended test duration and the variability of test conditions on the road (the PEMS equipment is used for rather long periods of up to 2 h and may be exposed to a range of temperatures, air pressures and humidity; engine parameters may vary over a wider range of values).



PEMS manufacturers confirm that there exists potential to decrease this additional measurement uncertainty in the future. They confirm that, **analyzer drift is by far the largest contributor to measurement uncertainty. PEMS manufacturers regard it feasible to reduce analyzer drift by 50% if the requirements in Appendices 1 and 2 unanimously specify a margin of 5 ppm for NO_X measurements (replacing the current drift provisions for NO and NO_2).**

PEMS manufacturers also agree that it is feasible to reduce the overall measurement uncertainty caused by changes in temperature and air pressure. To do so, the RDE Regulation should demand that measurement performance of PEMS equipment, e.g., with respect to accuracy and drift is maintained at that entire range of temperatures and ambient air pressure values experienced during on-road testing.

Future but more long-term reductions of measurement uncertainty may be achieved through the introduction of direct exhaust flow measurements and a more precise dry-wet correction of pollutant measurements. PEMS manufacturers agree that experience and technological learning will shape PEMS performance and design in the future. The intrusivity of PEMS equipment (e.g., related to size, weight, and power requirements) will continue to decrease following market pressure form users, specifically car manufacturers.

4. Conclusions

From the consultations, the following conclusions can be drawn:

- Under controlled laboratory conditions, laboratory and PEMS equipment are subject to similar measurement uncertainty that is absorbed by the Euro 6 emissions limit.
- No major further improvements are expected in the PEMS instrumentation performance under laboratory conditions. However, room for improvement exists in view of limiting measurement uncertainty and equipment "deviations" during on-road testing.

- On the road, an allowance for measurement uncertainty of 50% can easily be achieved by PEMS equipment even under exceptional and rare test conditions. In most cases, the additional measurement uncertainty of PEMS equipment can be expected to remain within 20%.
- Specifying a drift allowance of 5 ppm for NO_X measurements can be achieved by state-of-the art PEMS analyzers and would reduce the uncertainty related to drift from around 20% to 10%.
- A specification of ranges for, e.g., ambient temperature, pressure and humidity under which the PEMS equipment hast to maintain its performance should be added to the RDE Regulation to ensure the correct functioning of equipment under any permissible RDE test conditions.