

## Terms of reference and rules of procedure for the Informal Working Group on the Particle Measurement Programme

### 1 Background

1.1 Since the inception of the Particle Measurement Programme (PMP) group, the activities focused on development of an alternative metric with increased sensitivity compared to the existing Particulate Matter (PM) mass measurement system for Heavy Duty (HD) and Light Duty (LD) engines/vehicles (M and N category vehicles) were continued.

1.2 This phase concluded with the developed and adoption into UN Regulation Nos. 83 (emissions of  $M_1$  and  $N_1$  vehicles) (R83) and 49 (emissions of compression ignition and positive ignition (LPG and CNG) engines) (R49) of a particle number (PN) counting method for ultrafine solid particles, together with enhancements to the PM measurement procedure for R83. Initially the PN protocol was applied for diesel engines/vehicles only in the 06 series of amendments of R83 (R83.06) and R49 (R49.06) and subsequently has been extended to cover vehicles using spark ignition direct injection engines in R83.06.

The European Union (EU) and Switzerland requested in 2013 further investigation of particle number emissions from spark ignition engines relating to particle size (reduction of the 50% counting efficiency specification,  $d_{50}$ ) and to emissions under rich operation conditions. As follow-up of this request, the PMP IWG has monitored particle emissions from a large variety of LD engine technologies. The attention has been mainly focussed on the difference between the number of particles measured with the existing PMP methodology ( $d_{50}=23$  nm) and with systems with lower  $d_{50}$ s. The fraction of particles emitted by the monitored engines not captured/counted by the existing PMP methodology is extremely variable and it depends very much on the engine technology and on the  $d_{50}$  considered. The current legislative methodology with a  $d_{50}=23$  nm seems to be still suitable for current engine technologies to which the PN limit is applicable (i.e. diesel and G-DI), since high emitters are still unequivocally detected. Therefore, it appears that there is no urgent need to modify the  $d_{50}$  to lower values. However, there is evidence that specific technologies like PFI and CNG engines may exhibit, in some cases, particle emissions close to the existing emission limit and at the same time a significantly high fraction of sub-23 nm particles and even sub-10 nm particles. ~~In view of a possible extension of the particle number limit to all combustion engines, the European Commission has expressed the intention to lower the cut-off size in order to improve the control of particle emissions whatever is the average size of the particles emitted~~

1.3 Starting from mid-2018 a LD round robin exercise has been carried out to investigate the possibility to use the existing PMP methodology properly modified in order to count particles down to about 10 nm. The results have shown that in-lab, between-lab and reproducibility variabilities were at a similar range for particle emission measurements with  $d_{50}$  at 23nm and  $d_{50}$  at about 10nm PN-measurement systems. The results of the exercise suggest that the current methodology PN-systems can be adapted for sub-23 nm measurements by only changing the used [particle number counter \(PNC\)](#) and adapting the corresponding calibration procedure. As a result of the exercise and extensive field experience, a particle counting methodology with  $d_{50}$  at approximately 10 nm was suggested. In the exercises and in the field in general, the ~~CPC-PNC~~ particle counters with  $d_{50}$  at 7 nm were typically used for sub-23 nm measurements. The PMP IWG has concluded that it would be extremely challenging to develop a reliable particle counting methodology with a  $d_{50}$  significantly below 10 nm for a number of reasons (losses, artefacts, calibration...) that would increase the variability of the measurements

Additionally, concerns about the robustness of the volatile particle remover (VPR) under challenging emission conditions has led to the decision to introduce the use of a Catalytic Stripper instead of a simple non-catalyzed Evaporation Tube. The proposed new test procedure with a 65% ~~cut-off efficiency~~ size at about 10 nm (~~cut-off size – Minimum detectable particle size is about 4 nm; 50% cut-off size – particle diameter with 50% counting efficiency reading at about 7 nm~~) was submitted to GRPE in June 2020 and approved as an amendment to GTR 15.

Similarly, to light duty vehicles, questions about sub-23 nm particle number emissions in heavy-duty engines have been raised. In heavy-duty vehicles (HD), the enhanced sub-23 nm emissions are suspected to be associated to urea injection and related gas-to-particle conversion and to the crankcases emissions. As a part of an exercise studying a possibility of tail pipe sampling of particle number emissions for type approval purposes in HD tests, measurements with 10 nm PNC as a part of current methodology PN-systems have been conducted. The results of the exercise imply that ~~PN10 nm PN~~ measurement variabilities are within the same range as ~~PN23 nm PN~~ variabilities. Moreover, this exercise showed that sampling directly from the tailpipe is possible for HD engines, i.e. direct tailpipe sampling does not negatively affect the accuracy and variability of the PN measurements provided that the set up and conditions are properly defined. A similar assessment for light-duty vehicles is needed, especially considering that ~~PN –portable emission measurement systems (PEMS)~~ are sampling from the tailpipe but also for the purpose of harmonization of measurement method in different applications..

An extension of the methodology for sub-23 nm particles developed for light duty to heavy duty ~~has been discussed within the group and will be~~ submitted to GRPE session in ~~June-Jan 2022~~ as a Consolidated Resolution, along with the possibility to sample directly from the tailpipe with fixed dilution for the type approval of heavy-duty engines.

[A proposal for PN PEMS with d50 at approximately 10 nm was provided to the RDE group. In the Euro 7 proposal \(November 2022\) the European Commission \(EC\) proposed to lower the cut-off size to 10 nm for both light-duty and heavy-duty vehicles, in order to improve the control of particle emissions whatever is the average size of the particles emitted.](#)

- 1.4 It was also requested to consider whether there is a need to extend particle measurement procedures to additional sources such as brake wear and the interaction between tyres and road. The first step consisted of a literature survey having the objective of summarizing the current knowledge on the physical/chemical nature, mass, number and size distribution of non-exhaust particle emissions. One of the main issues identified during the literature survey is the large variety of methodologies and test conditions used in the published studies. This may explain why often these studies lead to very different or even contradicting conclusions. The group therefore agreed that a suggested common test procedure for sampling and investigating brake wear particles would be beneficial for future research purposes as well as for the development of low emitting brake systems. The group has worked on the development of such suggested methodology since the ~~last~~ mandate received from GRPE in the 73<sup>rd</sup> session. Considerable progress has been made with the identification of the most suitable approach (test rig), the development and assessment of a novel – representative of real world conditions – braking cycle (WLTP-Brake Cycle), and preliminary investigations with the aim of providing a set of minimum specifications regarding sampling and measurement methodologies. These have been summarized to the GRPE-81-12 Informal Document. In January 2021 several UNECE GRPE contracting parties have asked the PMP IWG to start considering a possible use of the proposed method as a regulatory tool. [With the latest ToR, the PMP group was tasked to prepare a Global Technical Regulation \(GTR\) on brake emissions from light-duty vehicles up to 3.5 t. The group worked intensively, and a proposal was presented to the PMP in May 2022 addressing sampling and measuring emissions from full friction braking systems. In October 2022, the formal document was submitted to the GRPE secretariat. In Jan 2023, the full proposal including a generic procedure for non-friction regenerative braking was adopted at GRPE level.](#)

- 1.5 On the other hand, measuring particle emissions generated by the interaction between tyres and road was considered much more challenging due to the difficulty of distinguishing the contributions from tyres, material deposited on the road, and the road itself. In the meantime, the EC has proposed in its European on the Move III initiative (Third Mobility Package) to develop a standard methodology to measure the abrasion rate of tyres in view of a possible future labelling scheme. This methodology will be developed through a ~~process still under discussion~~ [Task Force on Tyre Abrasion \(TFTA\) under GRBP and GRPE](#) but in any case, without the direct involvement of the PMP. The group proposes to continue monitoring all information relevant to tyre/road wear particles and once the abrasion rate methodology is developed, to investigate the possibility of establishing a relationship between different abrasion rates and particle emissions.

## 2 Terms of Reference

- ~~2.1 The group should prepare the update and integration of test procedure updates into UN Regulation Nos. 83, 49 and 96 (diesel emission (agricultural tractors)) as appropriate.~~
- ~~2.2 The group may consider, at a later stage, the transposition of the developed procedures into the UN Global Technical Regulation (UN GTR) No. 4 and the UN GTR 15 covering the Worldwide harmonized Light vehicles Test Procedure (WLTP) and Test Cycle (WLTC).~~
- ~~2.1 The group should monitor measurement and calibration topics for exhaust particle emissions.~~
- ~~2.2 The group should lead the development of an amendment to the UN Global Technical Regulation (UN GTR) on brake emissions from LDVs brake systems.~~
- 2.3 The group should monitor ~~development of~~ a UN Global Technical Regulation (UN GTR) addressing PM and PN emissions from all types of ~~LDVs-HDVs~~ brake systems.
- ~~2.4 The group should monitor tyre abrasion and emission related projects.~~

## 3 Timeline

- 3.1 The work of the group on Particle Measurement Programme should be completed by June ~~2023~~2025. A prolongation and extension of the mandate of the group, in relation to the development and validation of new test procedures, e.g. in relation to PN measurement systems compatible with PEMS, brake wear emissions, if necessary, should be considered in due time by GRPE.

## 4 Scope and work items

### A. Exhaust particle emissions

- 4.1 PM mass exhaust measurement

Note: [No need for adaptation of the mass method is foreseen.](#)

- (a) ~~HD and Non Road Mobile Machinery (NRMM) PM measurement excluded from PMP TOR as have recently been extensively revised in the respective UN GTRs. It is not foreseen that further major technical adaptation is required in the near term.~~

~~(b) LD could also be excluded on a similar basis owing to recent revisions into the WLTP draft UN GTR. It is not foreseen that further major technical adaptation is required in the near term.~~

## 4.2 PN exhaust measurement

4.2.1 ~~Existing scope of PN measurements to be adapted to technical progress, as appropriate. Note: No need for adaptation of the number methods is foreseen.~~

~~(a) LD Compression Ignition (CI) vehicles.~~

~~(b) HD CI engines/vehicles.~~

~~(c) LD Positive Ignition (PI) direct injection engine vehicles.~~

~~(d) HD PI direct injection engines/vehicles.~~

~~(e) Investigate particle number emissions from latest generation of CI and PI engines during normal operation and during regeneration of particle filters.~~

~~(f) Engine dyno raw exhaust PN measurements for HD for use at Type Approval. Possibility of extension of the raw measurements to light duty vehicle PN measurements.~~

~~(g) On road measurement of exhaust particle emissions~~

## 4.3 PN measurement equipment – HD and LD

4.3.1 Existing PMP PN measurement equipment d50 reduction.

(a) Monitoring the implementation of the modified procedures with reduced d50 and check in particular the robustness of the procedures in specific cases (e.g. regeneration events, effect of different fuels, crankcase emissions,...)

(b) Monitoring of the implementation of the procedure for HD engines based on direct sampling from raw exhaust via a fixed dilution and check in particular its robustness in specific cases (e.g. regeneration events, effect of different fuels, crankcase emissions,...)

~~(c) Determine what modifications are required to change the current PN-PEMS d50 of 23 nm to approximately 10 nm. Assess the impact of such modifications on particle number emissions/repeatability/reproducibility. Draft a new test procedure for PN emissions including the modified PN measurement methodology to be submitted to GRPE for consideration. Monitor performance of PN PEMS with d50 at 10 nm (e.g. regeneration events, effect of different fuels, crankcase emissions,...)~~

(d) -Determine whether LD vehicle PN measurements can be done reliably with direct tailpipe sampling

## 4.4 Calibration Guidelines

4.4.1 ~~Update of Monitor~~ existing calibration guidelines.

~~(a) Review and update of the calibration guidelines for CPC and VPR taking into consideration:~~

- ~~The modifications introduced in the PN measurement methodology for the reduction of the d50 cut off size to below 10 nm and the preferred possible usage of the catalytic stripper as VPR instead of ET as a consequence of its more robust volatile material removal capability (COMPLETED)~~
- ~~The use, if possible, of a standardized calibration material suitable for both stationary PN counting systems and PN PEMS~~
- ~~Development of an alternative, robust method (to tetracontane) for testing the VPR separation efficiency of semi-volatile compounds~~
- (b) ~~Review and update the calibration procedures for PN PEMS.~~
- (e) ~~Assess whether a common methodology can be applied for both laboratory and on-road systems.~~

## B. Non-exhaust particle emissions

### 4.5 Brake Wear PM and PN sampling and measurement

- 4.5.1 ~~Development of a~~ Monitoring of the application of the procedures of the UN GTR and development of an amendment to the UN GTR for sampling and assessing brake wear particles of light-duty vehicles both in terms of mass and number
- ~~(a) Validation of the developed novel test cycle for the investigation of Brake Wear Particles — Item completed~~
  - ~~(b) Investigation and selection of the appropriate instrumentation and sampling methodology for the measurement and characterization of brake wear particles — PM and PN measurement equipment~~
  - ~~(c) Definition of the minimum requirements for brake wear particles generation and sampling~~
  - ~~(d) Application of the proposed approach for the measurement and characterization of brake wear particles through an Interlaboratory Study — Creation of a dedicated Task Force (TF3)~~
  - (e) Adaptation Amendment of the proposed methodology to include regenerative non-friction braking methodology to include a method for the calculation of the vehicle ease-specific friction braking share coefficients — and — to the possible extent — future technologies. Creation of a dedicated Task Force (TF4)
  - ~~(f) Preparation of the PMP Brake protocol for sampling and measuring brake wear PM and PN emissions~~
  - (g) Refinement and validation of the PMP Brake protocol (e.g. WL/DM temperature boundaries for new brake materials, calibration procedures of PN and PM instrumentation, impact of individual F-Terms, improvements to brake wear sampling system) —

~~(h) Final Round Robin Exercise with GTR compliant laboratories and development of further GTR updates, if necessary. (to be confirmed at a later stage)~~

4.5.2 Development of a test procedure for sampling and assessing brake wear particles of heavy-duty vehicles both in terms of mass and number. A dedicated task force (TF-5) shall be created.

(a) Examination of the feasibility of the current setup for measuring brake wear particles of HDV, including emission data review from HDVs and trailers.

(b) Examination of relevant vehicle applications and realistic load profiles for relevant application scenarios

(c) Examination of existing HD cycles for their feasibility to measure brake wear particles of HDV.

(d) Assessment of the contribution of engine braking and non-friction braking, including related deceleration devices, i.e.g. foundation brake, engine brake, retarder, regenerative braking and others

#### 4.6. Tyre/Road Wear Particulate Matter (PM) measurement

(a) Continue monitoring on-going projects and published data regarding the physical nature and size distribution of particle emissions from tyre/road wear and the work of the TF on tyre abrasion of GRBP/GRPE.

### C. Deliverables and timing

The informal group on Particle Measurement Programme should complete the tasks described in this section as follow:

~~— Submissions of an informal proposal for LD PN PEMS 10 nm specifications : June 2021 (tbc)~~

- Updates from PMP group to GRPE on the monitoring of the implementation of the modified procedures for the measurement and calibration of sub-23 nm particles and tailpipe sampling (LD and HD) – June ~~2022~~2025

- ~~Finalization~~ Amendments of the test procedure for the measurement of particle brake emissions from LDVs: June ~~2022-2025~~ (First amendment on vehicle specific non-friction braking method: Jan 2024; further amendment to be confirmed at a later stage on the basis of the progress made)

- Development of first version of GTR on HDV particle brake emissions: June 2025 (vote at GRPE)

A prolongation and extension of the mandate of the group, in relation to the above tasks should be considered in due time by GRPE.

### 5. Rules of procedure

- 5.1. The informal group is open to all participants of GRPE. A limitation of the number of participants from any country or organisation to participate in the informal group is actually not foreseen.
- 5.2. A Chair and a Secretary will manage the informal group.
- 5.3. The working language of the informal group will be English.
- 5.4. All documents and/or proposals shall be submitted to the Secretary of the group in a suitable electronic format, preferably in line with the UNECE guidelines in advance of the meetings. The group may refuse to discuss any item or proposal which has not been circulated 5 working days in advance of the scheduled meeting.
- 5.5. The informal group shall meet regularly at the GRPE meetings in Geneva. Additional meetings will be organised upon demand.
- 5.6. An agenda and related documents will be circulated to all members of the informal group in advance of all scheduled meetings.
- 5.7. The work process will be developed by consensus. When consensus cannot be reached, the Chair of the informal group shall present the different points of view to GRPE. The Chair may seek guidance from GRPE as appropriate.
- 5.8. The progress of the informal group will be routinely reported to GRPE orally or as an informal document by the Chair or the Secretary.
- 5.9. All working documents shall be distributed in digital format. The specific PMP section on the UNECE website shall continue to be utilised.