

Comment on Working Document No ECE/TRANS/WP.29/GRPE/2007/8

Proposal for Draft Supplement to the 05 Series of Amendments to Regulation No. 83

General

We appreciate the work of PMP and support the new technology of particle counting in addition to the improvements in the particulate measurement. However, it is required that the new procedure is very clearly written and no ambiguities can be found. Otherwise it might be suspected that the procedure is not yet fully established and more experimental evidence would be necessary before this test procedure could be introduced for standard homologation testing.

It should also be considered that, although R83 is an ECE Regulation, it is used worldwide and especially in the newly emerging large markets in Asia. Therefore the wording of the regulation must not contain any inconsistencies or unclear points, especially for parties that have not participated in the PMP group. In several cases a more detailed formulation will be advantageous.

Therefore we propose some improvements to the current text. A “water-tight” wording and a fully consistent description of the particle counting system is required before the amendments can be released.

Details:

Annex 4a, paragraph 6.6.8, page 19

6.6.8 Determination of Particle Numbers

Number emission of particles shall be calculated by means of the following equation:

$$N = \frac{V \cdot \bar{C}_s \cdot DR_{tot} \cdot 10^3}{d}$$

where:

N = particle number emission expressed in particles per kilometre

V = volume of the diluted exhaust gas expressed in litres per test and corrected to standard conditions (273.2 K and 101.33 kPa)

Particle number concentrations shall continue to be recorded for at least 20s after the completion of the drive cycle.

\bar{C}_s = Corrected concentration of particles from the diluted exhaust gas expressed as the average particles per cubic centimetre figure >from the emissions test including the full duration of the drive cycle plus an additional 20s sampling period after completion of the drive cycle. If the volumetric mean concentration results (\bar{C}) from the particle number counter are not output at standard conditions (273.2 K and 101.33 kPa), then the concentrations should be corrected to those conditions (\bar{C}_s)

DF_{tot} = total dilution factor of the diluter in the volatile particle remover, calculated as the product of the dilution factor in the first particle number diluter and the dilution factor in the second particle number diluter ($PNDF_1 * PNDF_2$)

$$N = \frac{V.C_p.DR_{tot}.10^3}{d}$$

Typographical error: DRtot should read DFtot in the formula

Appendix 5 – Particle Number Measurement Equipment, paragraph 1.1.2, page 62

- 1.1.2. It is recommended that a particle size pre-classifier (e.g. cyclone, impactor etc) be located prior to the inlet of the sample pre-conditioning unit. However, a sample probe acting as an appropriate size-classification device, such as that shown in Figure 13, is an acceptable alternative to the use of a particle size pre-classifier.

The sample probe shown in Figure 13 has an internal diameter of 12mm at minimum; in paragraph 1.2.1 the sampling probe should have an internal diameter of 8mm at minimum; in paragraph 1.2.4 abrupt changes in cross section and the minimisation of the length of the sampling line should be included in the PTS. With respect to incorporation of good aerosol sampling practice the minimum diameter of the sample probe shown in Figure 13 should be equivalent to the minimum sampling probe diameter defined in 1.2.4. Just for curiosity: What is the reason for specifying the flow Reynolds number to 1500 +/- 200.

Appendix 5 – Particle Number Measurement Equipment, paragraph 1.2.1, page 65

- 1.2.1 ... Any other sampling configuration for the POT for which equivalent particle penetration at 30nm can be demonstrated will be considered acceptable.

Maybe it might be useful to define the penetration of 30nm particles for the POT in more detail (e.g. achieve greater than xy% solid particle penetration at 30nm particle diameter). Since the penetration for solid particles for the sample pre-conditioning unit as a whole is defined in paragraph 1.3.3.3, what is the reason for defining the penetration for the POT separately? Is the POT part of the sample pre-conditioning unit as a whole? A definition in more detail concerning the components (POT, sample pre-conditioning unit, particle number measurement device) with respect to their properties (penetration, etc.) would be important.

Appendix 5 – Particle Number Measurement Equipment, paragraph 1.3.3.3, page 63

- 1.3.3.3 Include elements which operate under conditions that achieve greater than 50, 55 and 60 per cent solid particle penetration respectively at 30, 50 and 100nm particle diameters for the sample pre-conditioning unit as a whole

The solid particles should be defined in more detail. What should the monodispersity of the particle distributions be (GSD<1.2)? What kind of equivalence diameter for the size classification should be used (electrical mobility diameter, (aerodynamic diameter, Stokes diameter, etc.))?

A formula defining penetration might be helpful (e.g.:

$PE = \text{Downstream number concentration} * DF_{tot} / \text{upstream number concentration} * 100\%$,

whereas the upstream concentration is the particle number concentration at the inlet of the sample pre-conditioning system (or inlet of the POT) and the downstream concentration is the particle number concentration at the inlet of the PNC).

The settings of the sample pre-conditioning system for the determination of the Particle Penetration should be specified (e.g.: The downstream concentration of solid particles should

be >10 particles per ccm and the upstream concentration of solid particles should be <10000 particles per ccm respectively).

Appendix 5 – Particle Number Measurement Equipment, paragraph 1.3.3.3, page 63

1.3.3.4 Also achieve greater than 99% reduction of an aerosol comprising 30nm n-C40 alkane particles.

What should the monodispersity of the particle distributions be (GSD<1.2)? The settings of the sample pre-conditioning system for the determination of the Volatile Particle Reduction should be specified (e.g. The upstream concentration of solid particles should be <10000 particles/ccm). The n-C40 Alkane should be named correctly according to IUPAC (Tetracontane; $\text{CH}_3(\text{CH}_2)_{38}\text{CH}_3$).

Appendix 5 – Particle Number Measurement Equipment, paragraph 1.4.2, page 65

1.4.2 ...

Any other sampling configuration for the PTS for which equivalent particle penetration at 25nm can be demonstrated will be considered acceptable.

...

Any other sampling configuration for the POT for which equivalent particle penetration at 25nm can be demonstrated will be considered acceptable.

There is inconsistency with paragraph 1.2.1. Paragraph 1.2.1 defines a particle penetration for 30nm particles in stead of 25nm particles. Maybe the recommended system should achieve better penetrations.

Appendix 5 – Particle Number Measurement Equipment, paragraph 1.4.4.1, page 66

1.4.4.1 First Particle Number Dilution Device (PND₁)

The first particle number dilution device shall be specifically designed to dilute particle number concentration and **operate at a (wall) temperature of 150°C - 380°C. The wall temperature setpoint should not exceed the wall temperature of the ET (Section 1.4.4.2).** The diluter should be supplied with HEPA filtered dilution air and be capable of a dilution **factor of 10 to 500** times.

There is inconsistency with paragraph 1.3.3.2. Paragraph 1.3.3.2 defines an output temperature of the diluted sample <= 400°C. The PND1 of the recommended system should operate at a (wall) temperature of 150°C-380°C.

Appendix 5 – Particle Number Measurement Equipment, paragraph 2.2.2, page 67

2.2.2 Calibration shall be undertaken by measuring the concentration of the standard gas with a calibrated gas monitor at the inlet and outlet of the diluter. Calibration shall be undertaken at least 5 dilution **factors** spaced **logarithmically** across the dilution **factor** range >from **10 to 500**. Measured dilution **factors** shall be within ± 10 per cent of nominal dilution factor settings. If a diluter is to be used **at a fixed dilution setting, then it shall be calibrated at the set-point.**

If a standard gas with known concentration (calibration gas) is used, why is it necessary to measure the gas concentration at the inlet and the outlet of the diluter? The dilution factor range is not defined in paragraph 1.3.3.1. Why is a calibration of the dilution factor ranging from 10 to 500 defined in paragraph 2.2.2? Maybe it would be better to define the calibration over the whole range of the (primary) diluter. How should the secondary diluter (if existing) be calibrated then?

Appendix 5 – Particle Number Measurement Equipment, paragraph 2.3.2, page 68

2.3.2 The test aerosol for these measurements shall be solid particles of diameters 30, 50 and 100 nm and a minimum concentration of 1,000 particles cm^{-3} **at the VPR inlet**. Particle concentrations shall be measured upstream and downstream of the components. **Minimum penetration efficiencies of 50, 55 and 60** per cent respectively shall be achieved at the three test particle diameters.

See comment on “Appendix 5 – Particle Number Measurement Equipment, paragraph 1.3.3.3, page 66”

Appendix 5 – Particle Number Measurement Equipment, paragraph 2.3.3, page 68

2.3.3 The Technical Service shall ensure the existence of a calibration certificate for the **evaporation tube** demonstrating effective volatile particle removal efficiency within a 6 months period prior to the emissions test. The **ET** shall demonstrate greater than 99 per cent reduction of 30nm **n-C₄₀ alkane** particles at an upstream particle concentration of a **minimum of 10,000 cm^{-3} when operated at the following fixed conditions: evaporation tube temperature 300°C, secondary dilution factor 10**

See comment on “Appendix 5 – Particle Number Measurement Equipment, paragraph 1.3.3.3 page 63”. Since a secondary dilution is not defined in paragraph 1.3.3.1, why are the conditions for calibration set to a secondary dilution factor of 10?

Appendix 5 – Particle Number Measurement Equipment, paragraph 2.4.1, page 68

2.4.1 Linearity of the particle counter response shall be validated monthly. This validation shall be carried out with two different particle number concentrations and a nominal zero point. The zero point (infinite dilution at zero concentration) shall be achieved by applying a HEPA filter to the inlet of the PNC. The first concentration shall be achieved by directly measuring a stable particle concentration source of at least 1,000 cm^{-3} (dilution factor 1). The second concentration shall be achieved by diluting the source concentration through the unheated VPR system including both PND₁ and PND₂ (the dilution factor is calculated as PND_{F1} * PND_{F2}). The measured PNC concentrations shall be compared with the concentrations corrected for apparent dilution. The gradient from a linear regression of the two data sets shall be within ± 10 per cent of that calculated from the annual calibration data. The Pearson product moment correlation coefficient (R^2) of the two data sets shall be equal to or greater than 0.97.

Since PND2 is not defined in 1.3.3.1 it might be necessary to change the wording to e.g.: The second concentration shall be achieved by diluting the source concentration through the unheated sample pre-conditioning unit.

Our further remarks are motivated by the following targets:

- Keep a good reproducibility between different laboratories for example between customer labs and supplier labs.
- Keep the measurement systems simple to use and maintain while keeping the best capability.

Annex 4a: TYPE I test.

Remark 1

para. 6.2.4 Background particulate measurement. and para. 6.2.5 Background particle number measurements.

We feel that to allow subtraction or not of backgrounds may lead to problems of reproducibility between laboratories. Background measurements always account for a measurement error which is then added to the sample measurement. Therefore we consider that to forbid background measurements and force the use of HEPA filters in dilution air would improve detection limits and accuracy in all Labs.

Remark 2

para. 6.2.8.2 *...when the inlet is equipped with a HEPA filter, it shall be demonstrated that the entire particle sampling system is free from any leaks.*

We recommend that a method and a limit be mentioned for proving that the system is free from any leak.

A very simple way would be to take the same method and limits as the CFO checks. The injection of propane or CO would then be made in front of the HEPA filter.

Remark 3

para. 6.3.1 Conditioning procedure. Conditioning of compression ignition engines.

The particulate measurements described in this proposal may be applied also to positive ignition engines with direct injection. We recommend that the conditioning described as three consecutive Part two cycles be applied to all vehicles for the purpose of measuring particulates and not only to compression ignition engines.

Cleaning of the tunnel with 20 minutes at 120 km/h.

The cleaning of the systems makes sense only before the test run. As no measurement is made during conditioning we do not understand the purpose of cleaning the system before conditioning. We recommend to specify a system cleaning before the test run and not before the conditioning procedure.

Remark 4

para. 6.6.6 Determination of HC for compression ignition engines

According to our knowledge, the purpose of having a tunnel HFID system is to measure volatile particulate contribution to HC mass.

This should also be valid for positive ignition engines with direct injection technology. Therefore, we propose to replace the title of 6.6.6 with **Determination of HC for particulates emitting vehicles.**

Remark 5

para. 6.6.8 Determination of particle number

...

Particle number concentrations shall continue to be recorded for at least 20 s after the completion of the drive cycle.

To record 20s more will imply some strong modifications of actual test cell controllers. The part two test is already ending with a 20s idle period ensuring that all conditions are stabilized when the test ends. Moreover, the regulation does not specify if the CVS volume used for the calculation includes or not these 20s. If it would be so, it would also make mandatory a modification of actual CVS software systems. The State of the engine is also not specified (engine Off or On).

We can recognize a necessity to account for gases transfer times and T90 time of the particulate counter. The actual systems can easily perform this operation.

As we do not recognize the scientific ground for these additional 20s, we strongly recommend to suppress these 20s. We propose to replace it by taking into account transfer times from the entry of the tunnel to the particulate counter and T90 time from the particulate counter.

Remark 6

Appendix 2

para. 1.2.4. ... *Should any component in the system (heat exchanger, cyclone separator, blower, etc.) change the concentration of any of the pollutants in the diluted exhaust gases and the fault cannot be corrected, then sampling for that pollutant shall be carried out upstream from that component.*

Remark 7

Appendix 3

para. 1.2.1. *The sample of dilute exhaust gases shall be taken upstream from the suction device but downstream from the conditioning devices (if any).*

It seems to us that these 2 paragraphs state opposite recommendations. We would recommend to include in Appendix 3 - para. 1.2.1 an exception conformed to Appendix 2 - para. 1.2.4.

Remark 8

This sample point appears on Figure 10 from Appendix 3 at the same place than the HFID. on figure 10 from Appendix 3: we suggest not to draw the S2/SV sample point at the same point than the HFID sample point: this could lead to confusion as it is recommended to place it after any conditioning device while the HFID is placed close to the particulate mass sample probe.

Remark 9

Appendix 3

para. 3.1 and 3.2 pure and calibration gases

The actual tolerance and purity specification of gases stated in the regulation can lead to very unaccurate results. It also gives the liberty to gas suppliers to provide very low quality gases. We recommend to improve the specifications in order to have testing methods in accordance with today low emissions standards. Please find hereafter our recommendations:

3.1. Pure gases

The following pure gases shall be available, if necessary, for calibration and operation:

purified nitrogen: (**purity: ± 0.1 ppm C, ± 0.1 ppm CO, ± 1 ppm CO₂, ± 0.1 ppm NO**);

purified synthetic air: (**purity: ± 0.1 ppm C, ± 1 ppm CO, ± 1 ppm CO₂, ± 0.1 ppm NO**); oxygen content 20% **$\pm 0.2\%$ absolute**

purified oxygen: (purity > 99.5 per cent vol. O₂);

purified hydrogen (and mixture containing helium): (purity ± 0.1 ppm C, ± 400 ppm CO₂).

Hydrogen content in mixtures: $\pm 0.5\%$ absolute.

carbon monoxide: (minimum purity 99.5 per cent)

propane: (minimum purity 99.5 per cent).

3.2. Calibration and span gases

Mixtures of gases having the following chemical compositions shall be available:

(i) C₃H₈ and purified synthetic air (see paragraph 3.1. above);

(ii) CO and purified nitrogen;

(iii) CO₂ and purified nitrogen;

NO and purified nitrogen. (**The amount of NO₂ contained in this calibration gas shall not exceed 1 per cent of the NO content.**)

The true concentration of a calibration gas shall be within ± 1 per cent of the stated figure.

Remark 10

Appendix 4

para. 1.3.4.3 Neutralization of static electricity.

The recommended method is the use of a polonium 210 neutralizer. This radioactive device is expensive and very hard to get. The use of such a radioactive element is not harmonized within the ECE. The specification of a different method would be more realistic.

Appendix 5 - Particulate counting -

Remark 11

Use of a preclassifier for removal of particulates greater than 2.5 micrometer:

For particulates counting, it is now very well known that the number of particulates with sizes over 2.5 micrometer that can be counted is totally neglectable. Therefore the use of a preclassifier does not make any sense for this measurement but makes the system more complicated.

Remark 12

para. 1.3.3.1 ...achieve a particle number concentration below 10,000/cm³...

To specify such a dilution constrains us to use a system with a 10,000/cm³ range measurement system. The dilution ratio should be decided by good engineering practice, depending on the most accurate range of the device which is used for particulate counting.

Remark 13

para. 1.3.4.2 have a counting accuracy of ± 10 per cent across the range 100 cm⁻³ to 10000 cm⁻³, ± 10 cm⁻³ across the range 10 cm⁻³ to 100 cm⁻³ and ± 2 cm⁻³ below this concentration range against a traceable standard.

The specification for the accuracy of the particulate counter does not go over 10000/cm³ particles. We recommend to also specify accuracies for concentrations greater than 10000/cm³. Depending on the maximum range of the system, we propose to specify the required accuracy as following.

- $\pm 10\%$ of measurement from 10 to 100% of full scale.
- $\pm 1\%$ of full scale from 1 to 10% of full scale.
- $\pm 0.02\%$ of full scale from 0 to 1% of full scale.

Remark 14

para. 1.3.4.3 *have a readability of 0.1 particles cm⁻³.*

A readability of 0.1 particles per cm³ is not necessary if the best accuracy of the particulate counter is +/-2 / cm³. We recommend a readability better than 0.02% of full scale.

Remark 15

para. 1.3.4.4 *have a linear response to particle concentration over 1 to 10,000 particles cm⁻³.*

Limits should be specified for the linearity of the system.

Remark 16

para. 1.3.4.5. have a data logging frequency equal to or greater than 0.5 Hz.

para. 1.3.4.6. have a T90 response time over the measured concentration range of less than 15 s.

para. 1.3.4.7. have a data-averaging period of between 1 and 6 s.

The specification of a data averaging period should be linked to the data logging frequency. Therefore we recommend that the data averaging period be greater than 0.5 times the data logging frequency but not more than one third of the T90 time of the system.

Remark 17

para. 1.3.4.10. The fluid within the particle number counter shall be replaced at the frequency specified by the instrument manufacturer.

This specification does not make sense if the particulate counter does not use any fluid. Any maintenance should be made as recommended by the manufacturer. We recommend to delete this paragraph.

Remark 18

We propose to include in the regulation, in appendix 5, that the pump used to sample particulates shall be placed after the particulate counter device and not between the tunnel and the particulate number counter.

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