Proposal for a new Supplement to the 05 and 06 series of amendments to Regulation No. 49 (Compression ignition and positive ignition (LPG and CNG) engines)

The text reproduced below was prepared by the expert from OICA to correct identified failures printing errors and wrong references in the text of Regulation No. 49. The modifications to the text are marked in bold for new characters and strikethrough for deleted characters. Additionally, corrections which are specific to formulas are marked in red. The modification to the 06 series of amendments could be considered as an additional proposal to amend ECE/TRANS/WP.29/GRPE/2017/6, which is presented at this GRPE-74 session.

I. Proposals

A. A new Supplement to the 05 series of amendments

Annex 4B, paragraph 7.8.4., amend to read:

"7.8.4.   Drift verification

As soon as practical but no later than 30 minutes after the test cycle is complete or during the soak period **(for (b) only)**, the zero and span responses of the gaseous analyser ranges used shall be determined. For the purpose of this paragraph, test cycle is defined as follows:

(a)   For the WHTC: the complete sequence cold – soak – hot;

(b)   For the WHTC hot start test (paragraph 6.6.): the sequence soak – hot;

(c)   For the multiple regeneration WHTC hot start test (paragraph 6.6.): the total number of hot start tests;

(d)   For the WHSC: the test cycle.

The following provisions apply for analyzer drift:

(a)   The pre-test zero and span and post-test zero and span responses may be directly inserted into equation 66 of paragraph 8.6.1. without determining the drift;

(b)   If the drift between the pre-test and post-test results is less than 1 per cent of full scale, the measured concentrations may be used uncorrected or may be corrected for drift according to paragraph 8.6.1. of this annex;

(c)   If the drift difference between the pre-test and post-test results is equal to or greater than 1 per cent of full scale, the test shall be voided or the measured concentrations shall be corrected for drift according to paragraph 8.6.1. of this annex."

Annex 4B, paragraph 8.4.1.7., amend to read:

"8.4.1.7. Carbon balance method

This involves exhaust mass calculation from the fuel flow and the gaseous exhaust components that include carbon. The calculation of the instantaneous exhaust gas mass flow is as follows:

$$q_{mew,i} = q_{mf,i} \times \left(\frac{w_{BET}^2 \times 1.4}{(1.0828 \times w_{BET} + k_{fd} \times k_c) \times k_c} \left(1 + \frac{H_a}{1000}\right) + 1 \right) \quad (33)$$

With

$$\cancel{k_c = (c_{CO2d} - c_{CO2da}) \times 0.5441 + \frac{c_{COd}}{18.522} + \frac{c_{HCw}}{17.355}} \quad (34)$$

And

$$\cancel{k_{fd} = -0.055594 \times w_{ALF} + 0.0080021 \times w_{DEL} + 0.0070046 \times w_{EPS}} \quad (35)$$

$k_c = (c_{CO2d} - c_{co2d,a}) \times 0,5441 + c_{COd}/\textcolor{red}{18522} + c_{HCw}/\textcolor{red}{17355}$ **(34)**

$k_{fd} = -0,0555\textcolor{red}{86} \times w_{ALF} + 0,0080021 \times w_{DEL} + 0,0070046 \times w_{EPS}$ **(35)**

Where:

$q_{mf,i}$ is the instantaneous fuel mass flow rate, kg/s

H_a is the intake air humidity, g water per kg dry air

w_{BET} is the carbon content of the fuel, per cent mass

w_{ALF} is the hydrogen content of the fuel, per cent mass

w_{DEL} is the nitrogen content of the fuel, per cent mass

w_{EPS} is the oxygen content of the fuel, per cent mass

c_{CO2d} is the dry CO2 concentration, per cent

$c_{CO2d,a}$ is the dry CO2 concentration of the intake air, per cent

c_{COd} is the dry CO concentration, ppm

c_{HCw} is the wet HC concentration, ppm"

Annex 4B, paragraph 9.3.9.4.1., amend to read:

"9.3.9.4.1. Sample dryer efficiency

For dry CLD analyzers, it shall be demonstrated that for the highest expected water vapour concentration Hm (see paragraph 9.3.9.2.2.), the sample dryer maintains CLD humidity at ≤ 5 g water/kg dry air (or about ~~0.008~~ **0.8 volume** per cent H_2O), which is 100 per cent relative humidity at 3.9 °C and 101.3 kPa. This humidity specification is also equivalent to about 25 per cent relative humidity at 25 °C and 101.3 kPa. This may be demonstrated by measuring the temperature at the outlet of a thermal dehumidifier, or by measuring humidity at a point just upstream of the CLD. Humidity of the CLD exhaust might also be measured as long as the only flow into the CLD is the flow from the dehumidifier."

Annex 4B, paragraph 9.4.2., amend to read:

"9.4.2.   General requirements of the dilution system

The determination of the particulates requires dilution of the sample with filtered ambient air, synthetic air or nitrogen (the diluent). The dilution system shall be set as follows:

(a) Completely eliminate water condensation in the dilution and sampling systems;

(b) Maintain the temperature of the diluted exhaust gas between 315 K (42 °C) and 325 K (52 °C) within 20 cm upstream or downstream of the filter holder(s);

(c) The diluent temperature shall be between 293 K and 325 K (20 °C to ~~42~~ **52** °C) in close proximity to the entrance into the dilution tunnel;

(d) The minimum dilution ratio shall be within the range of 5:1 to 7:1 and at least 2:1 for the primary dilution stage based on the maximum engine exhaust flow rate;

(e) For a partial flow dilution system, the residence time in the system from the point of diluent introduction to the filter holder(s) shall be between 0.5 and 5 seconds;

(f) For a full flow dilution system, the overall residence time in the system from the point of diluent introduction to the filter holder(s) shall be between 1 and 5 seconds, and the residence time in the secondary dilution system, if used, from the point of secondary diluent introduction to the filter holder(s) shall be at least 0.5 seconds.

Dehumidifying the diluent before entering the dilution system is permitted, and especially useful if diluent humidity is high."

Annex 4B, paragraph 9.5.5., amend to read:

"9.5.5.   Total system verification

The total accuracy of the CVS sampling system and analytical system shall be determined by introducing a known mass of a pollutant gas into the system while it is being operated in the normal manner. The pollutant is analyzed, and the mass calculated according to paragraph 8.5.2.3. except in the case of propane where a *u* factor of ~~0.000472~~ **0.000507** is used in place of ~~0.000480~~ **0.000483** for HC. Either of the following two techniques shall be used."

Annex 4B, Appendix 4, paragraph A.4.2., amend to read:

"A.4.2.   Regression analysis

The slope of the regression shall be calculated as follows:

$$a_1 = \frac{\sum_{i=1}^{n}\left(y_i - \overline{y}\right)\times\left(x_i - \overline{x}\right)}{\sum_{i=1}^{n}\left(x_i - \overline{x}\right)^2}$$

(94)

The y intercept of the regression shall be calculated as follows:

$$a_0 = \overline{y} - \left(a_1 \times \overline{x}\right)$$

(95)

The standard error of estimate (SEE) shall be calculated as follows:

$$SEE = \frac{\sqrt{\sum_{i=1}^{n}[y_i - a_0 - (a_1 \times x_i)]^2}}{n-2} \tag{96}$$

$$\boldsymbol{SEE = \sqrt{\frac{\sum_{i=1}^{n}[y_i - a_0 - (a_1 \times x_i)]^2}{n-2}}} \tag{96}$$

The coefficient of determination shall be calculated as follows:

$$r^2 = 1 - \frac{\sum_{i=1}^{n}[y_i - a_0 - (a_1 \times x_i)]^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2} \tag{97}$$"

B. A new Supplement to the 06 series of amendments

Annex 4, paragraph 7.8.4., amend to read:

"7.8.4. Drift verification

As soon as practical but no later than 30 minutes after the test cycle is complete or during the soak period **(for (b) only)**, the zero and span responses of the gaseous analyser ranges used shall be determined. For the purpose of this paragraph, test cycle is defined as follows:

(a) For the WHTC: the complete sequence cold – soak – hot;

(b) For the WHTC hot start test (paragraph 6.6.): the sequence soak – hot;

(c) For the multiple regeneration WHTC hot start test (paragraph 6.6.): the total number of hot start tests;

(d) For the WHSC: the test cycle.

The following provisions apply for analyzer drift:

(a) The pre-test zero and span and post-test zero and span responses may be directly inserted into equation 66 of paragraph 8.6.1. without determining the drift;

(b) If the drift between the pre-test and post-test results is less than 1 per cent of full scale, the measured concentrations may be used uncorrected or may be corrected for drift according to paragraph 8.6.1.;

(c) If the drift difference between the pre-test and post-test results is equal to or greater than 1 per cent of full scale, the test shall be voided or the measured concentrations shall be corrected for drift according to paragraph 8.6.1."

Annex 4, paragraph 8.4.1.7., amend to read:

"8.4.1.7.   Carbon balance method

This involves exhaust mass calculation from the fuel flow and the gaseous exhaust components that include carbon. The calculation of the instantaneous exhaust gas mass flow is as follows:

$$q_{mew,i} = q_{mf,i} \times \left(\frac{w_{BET}^2 \times 1.4}{(1.0828 \times w_{BET} + k_{fd} \times k_c) \times k_c} \left(1 + \frac{H_a}{1000}\right) + 1 \right) \quad (33)$$

With

$$\cancel{k_c = (c_{CO2d} - c_{CO2da}) \times 0.5441 + \frac{c_{COd}}{18.522} + \frac{c_{HCw}}{17.355}} \quad (34)$$

And

$$\cancel{k_{fd} = -0.055594 \times w_{ALF} + 0.0080021 \times w_{DEL} + 0.0070046 \times w_{EPS}} \quad (35)$$

$$\mathbf{k_c = (c_{CO2d} - c_{co2d,a}) \times 0,5441 + c_{COd}/18522 + c_{HCw}/17355} \quad \mathbf{(34)}$$

$$\mathbf{k_{f,d} = -0,055586 \times w_{ALF} + 0,0080021 \times w_{DEL} + 0,0070046 \times w_{EPS}} \quad \mathbf{(35)}$$

Where:

$q_{mf,i}$ is the instantaneous fuel mass flow rate, kg/s

H_a is the intake air humidity, g water per kg dry air

w_{BET} is the carbon content of the fuel, per cent mass

w_{ALF} is the hydrogen content of the fuel, per cent mass

w_{DEL} is the nitrogen content of the fuel, per cent mass

w_{EPS} is the oxygen content of the fuel, per cent mass

c_{CO2d} is the dry CO2 concentration, per cent

$c_{CO2d,a}$ is the dry CO2 concentration of the intake air, per cent

c_{COd} is the dry CO concentration, ppm

c_{HCw} is the wet HC concentration, ppm"

Annex 4, paragraph, 9.3.9.4.1., amend to read:

"9.3.9.4.1.   Sample dryer efficiency

For dry CLD analyzers, it shall be demonstrated that for the highest expected water vapour concentration Hm (see paragraph 9.3.9.2.2.), the sample dryer maintains CLD humidity at ≤ 5 g water/kg dry air (or about ~~0.008~~ **0.8 volume** per cent H$_2$O), which is 100 per cent relative humidity at 3.9 °C and 101.3 kPa. This humidity specification is also equivalent to about 25 per cent relative humidity at 25 °C and 101.3 kPa. This may be demonstrated by measuring the temperature at the outlet of a thermal dehumidifier, or by measuring humidity at a point just upstream of the CLD. Humidity of the CLD exhaust might also be measured as long as the only flow into the CLD is the flow from the dehumidifier."

Annex 4, paragraph 9.4.2., amend to read:

"9.4.2. General requirements of the dilution system

The determination of the particulates requires dilution of the sample with filtered ambient air, synthetic air or nitrogen (the diluent). The dilution system shall be set as follows:

(a) Completely eliminate water condensation in the dilution and sampling systems;

(b) Maintain the temperature of the diluted exhaust gas between 315 K (42 °C) and 325 K (52 °C) within 20 cm upstream or downstream of the filter holder(s);

(c) The diluent temperature shall be between 293 K and 325 K (20 °C to ~~42~~ **52** °C) in close proximity to the entrance into the dilution tunnel;

(d) The minimum dilution ratio shall be within the range of 5:1 to 7:1 and at least 2:1 for the primary dilution stage based on the maximum engine exhaust flow rate;

(e) For a partial flow dilution system, the residence time in the system from the point of diluent introduction to the filter holder(s) shall be between 0.5 and 5 seconds;

(f) For a full flow dilution system, the overall residence time in the system from the point of diluent introduction to the filter holder(s) shall be between 1 and 5 seconds, and the residence time in the secondary dilution system, if used, from the point of secondary diluent introduction to the filter holder(s) shall be at least 0.5 seconds.

Dehumidifying the diluent before entering the dilution system is permitted, and especially useful if diluent humidity is high."

Annex 4, paragraph 9.5.5., amend to read:

"9.5.5. Total system verification

The total accuracy of the CVS sampling system and analytical system shall be determined by introducing a known mass of a pollutant gas into the system while it is being operated in the normal manner. The pollutant is analyzed, and the mass calculated according to paragraph 8.5.2.3. except in the case of propane where a u factor of ~~0.000472~~ **0.000507** is used in place of ~~0.000480~~ **0.000483** for HC. Either of the following two techniques shall be used."

Annex 4, paragraph 10.4.2., amend to read:

"10.4.2. Determination of particle numbers with a partial flow dilution system

Where particle numbers are sampled using a partial flow dilution system according to the procedures set out in paragraph 8.4., the number of particles emitted over the test cycle shall be calculated by means of the following equation:

$$N = \frac{m_{edf}}{1.293} \cdot k \cdot \overline{c_s} \cdot \overline{f_r} \cdot 10^6 \tag{95}$$

Where:

N = number of particles emitted over the test cycle,

m_{edf} = mass of equivalent diluted exhaust gas over the cycle, determined according to paragraph **8.4.3.2.1. or** 8.4.3.2.2., kg/test,

k = calibration factor to correct the particle number counter measurements to the level of the reference instrument where this is not applied internally within the particle number counter. Where the calibration factor is applied internally within the particle number counter, a value of 1 shall be used for k in the above equation,

$\overline{c}_s$ = average concentration of particles from the diluted exhaust gas corrected to standard conditions (273.2 K and 101.33 kPa), particles per cubic centimetre,

$\overline{f}_r$ = mean particle concentration reduction factor of the volatile particle remover specific to the dilution settings used for the test.

$\overline{c}_s$ shall be calculated from the following equation:

$$\overline{c}_s = \frac{\sum_{i=1}^{i=n} c_{s,i}}{n} \tag{96}$$

Where:

$c_{s,i}$ = a discrete measurement of particle concentration in the diluted gas exhaust from the particle counter, corrected for coincidence and to standard conditions (273.2 K and 101.33 kPa), particles per cubic centimetre,

n = number of particle concentration measurements taken over the duration of the test."

Annex 4, Appendix 3, paragraph A.3.2., amend to read:

"A.3.2.   Regression analysis

The slope of the regression shall be calculated as follows:

$$a_1 = \frac{\sum_{i=1}^{n} \left(y_i - \overline{y} \right) \times \left(x_i - \overline{x} \right)}{\sum_{i=1}^{n} \left(x_i - \overline{x} \right)^2} \tag{104}$$

The y intercept of the regression shall be calculated as follows:

$$a_0 = \overline{y} - \left(a_1 \times \overline{x} \right) \tag{105}$$

The standard error of estimate (SEE) shall be calculated as follows:

$$\overline{SEE = \frac{\sqrt{\sum_{i=1}^{n}[y_i - a_0 - (a_1 \times x_i)]^2}}{n-2}}$$

(106)

$$\color{red}{SEE = \sqrt{\frac{\sum_{i=1}^{n}[y_i - a_0 - (a_1 \times x_i)]^2}{n-2}}}$$

(106)

The coefficient of determination shall be calculated as follows:

$$r^2 = 1 - \frac{\sum_{i=1}^{n}[y_i - a_0 - (a_1 \times x_i)]^2}{\sum_{i=1}^{n}(y_i - \overline{y})^2}$$

(107)"

Annex 8, Appendix 2, paragraph A.2.2.1., amend to read:

"A.2.2.1.   Gas analysers general specifications

The PEMS gas analysers specification shall meet the requirements set out in paragraph 9.3.1 of Annex 4. **The rise time of the analyser installed in the PEMS measurement system shall not exceed 3.5 seconds.**"

II.   Justification

1. OICA intends to propose corrections of identified failures in calculation formulas, wrong references and other editorial issues in the 05 and 06 series of amendments to Regulation No. 49.

2. In particular, for both series:

    a. Constants for equation (34) to calculate exhaust mass flow using carbon balance method were wrong and were corrected;

    b. Constants for CVS verification were corrected as well;

    c. The formula for regression analysis according to Annex 4, Appendix 3 was incorrect and was corrected.

3. In the 06 series, paragraph A.2.2.1., the rise time for the PEMS analysers should be corrected to 3.5 sec (instead of 2.5 sec as specified for test bench systems), the reason being that there is no commercial system capable, as of today, of achieving the 2.5 sec specification.

4. The corrections brought to the 06 series mentioned in this informal document could be considered as amendments to ECE/TRANS/WP.29/GRPE/2017/6, presented at the GRPE 74th session.

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