Commission Regulation (EC) No 692/2008 of 18 July 2008 implementing and amending Regulation (EC) No 715/2007 of the European Parliament and of the Council on type-approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information (Text with EEA relevance)

Status: *Point in time view as at 31/01/2020.*
Changes to legislation: *There are currently no known outstanding effects for the Commission Regulation (EC) No 692/2008, ANNEX IIIA. (See end of Document for details)*

[F1ANNEX IIIA

VERIFYING REAL DRIVING EMISSIONS

Textual Amendments

F1 Inserted by Commission Regulation (EU) 2016/427 of 10 March 2016 amending Regulation (EC) No 692/2008 as regards emissions from light passenger and commercial vehicles (Euro 6) (Text with EEA relevance).

1. INTRODUCTION, DEFINITIONS AND ABBREVIATIONS

1.1. Introduction

This Annex describes the procedure to verify the Real Driving Emissions (RDE) performance of light passenger and commercial vehicles.

1.2. Definitions

1.2.1. 'Accuracy' means the deviation between a measured or calculated value and a traceable reference value.

1.2.2. 'Analyser' means any measurement device that is not part of the vehicle but installed to determine the concentration or the amount of gaseous or particle pollutants.

1.2.3. 'Axis intercept' of a linear regression (a_0) means:

$$a_0 = \bar{y} - (a_1 \times \bar{x})$$

where:

a_1	is the slope of the regression line
$\bar{x}$	is the mean value of the reference parameter
$\bar{y}$	is the mean value of the parameter to be verified.

1.2.4. 'Calibration' means the process of setting the response of an analyser, flow-measuring instrument, sensor, or signal so that its output agrees with one or multiple reference signals.

1.2.5. 'Coefficient of determination' (r^2) means:

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

where:

a_0	is the axis intercept of the linear regression line
a_1	is the slope of the linear regression line
x_i	is the measured reference value
y_i	is the measured value of the parameter to be verified
$\bar{y}$	is the mean value of the parameter to be verified
n	is the number of values

1.2.6. 'Cross-correlation coefficient' (r) means:

$$r = \frac{\sum_{n-1}^{i=1} (x_i - \bar{x}) \times (y_i - \bar{y})}{\sqrt{\sum_{n-1}^{i=1} (x_i - \bar{x})^2} \times \sqrt{\sum_{n-1}^{i=1} (y_i - \bar{y})^2}}$$

where:

x_i	is the measured reference value
y_i	is the measured value of the parameter to be verified
$\bar{x}$	is the mean reference value
$\bar{y}$	is the mean value of the parameter to be verified
n	is the number of values

1.2.7. ‘Delay time’ means the time from the gas flow switching (t_0) until the response reaches 10 per cent (t_{10}) of the final reading.

1.2.8. ‘Engine control unit (ECU) signals or data’ means any vehicle information and signal recorded from the vehicle network using the protocols specified in point 3.4.5.of Appendix 1.

1.2.9. ‘Engine control unit’ means the electronic unit that controls various actuators to ensure the optimal performance of the powertrain.

1.2.10. ‘Emissions’ also referred to as ‘components’, ‘pollutant components’ or ‘pollutant emissions’ means the regulated gaseous or particle constituents of the exhaust.

1.2.11. ‘Exhaust’, also referred to as exhaust gas, means the total of all gaseous and particulate components emitted at the exhaust outlet or tailpipe as the result of fuel combustion within the vehicle's internal combustion engine.

1.2.12. ‘Exhaust emissions’ means the emissions of particles, characterised as particulate matter and particle number, and of gaseous components at the tailpipe of a vehicle.

1.2.13. ‘Full scale’ means the full range of an analyser, flow-measuring instrument or sensor as specified by the equipment manufacturer. If a sub-range of the analyser, flow-measuring instrument or sensor is used for measurements, full scale shall be understood as the maximum reading.

1.2.14. ‘Hydrocarbon response factor’ of a particular hydrocarbon species means the ratio between the reading of a FID and the concentration of the hydrocarbon species under consideration in the reference gas cylinder, expressed as $ppmC_1$.

1.2.15. ‘Major maintenance’ means the adjustment, repair or replacement of an analyser, flow-measuring instrument or sensor that could affect the accuracy of measurements.

1.2.16. ‘Noise’ means two times the root mean square of ten standard deviations, each calculated from the zero responses measured at a constant recording frequency of at least 1,0 Hz during a period of 30 seconds.

1.2.17. ‘Non-methane hydrocarbons’ (NMHC) means the total hydrocarbons (THC) excluding methane (CH_4).

1.2.18. ‘Particle number’ (PN) means as the total number of solid particles emitted from the vehicle exhaust as defined by the measurement procedure provided for by this Regulation for assessing the respective Euro 6 emission limit defined in Table 2 of Annex I to Regulation (EC) No 715/2007.

1.2.19. ‘Precision’ means 2,5 times the standard deviation of 10 repetitive responses to a given traceable standard value.

1.2.20. ‘Reading’ means the numerical value displayed by an analyser, flow-measuring instrument, sensor or any other measurement devise applied in the context of vehicle emission measurements.

1.2.21. ‘Response time’ (t_{90}) means the sum of the delay time and the rise time.

1.2.22. ‘Rise time’ means the time between the 10 per cent and 90 per cent response ($t_{90} - t_{10}$) of the final reading.

1.2.23. ‘Root mean square’ (x_{rms}) means the square root of the arithmetic mean of the squares of values and defined as:

$$x_{rms} = \sqrt{\frac{1}{n}\left(x_2^1 + x_2^2 + \ldots + x_2^n\right)}$$

where:

x	is the measured or calculated value
n	is the number of values

1.2.24. ‘Sensor’ means any measurement device that is not part of the vehicle itself but installed to determine parameters other than the concentration of gaseous and particle pollutants and the exhaust mass flow.

1.2.25. ‘Span’ means the calibration of an analyser, flow-measuring instrument, or sensor so that it gives an accurate response to a standard that matches as closely as possible the maximum value expected to occur during the actual emissions test.

1.2.26. ‘Span response’ means the mean response to a span signal over a time interval of at least 30 seconds.

1.2.27. ‘Span response drift’ means the difference between the mean response to a span signal and the actual span signal that is measured at a defined time period after an analyser, flow-measuring instrument or sensor was accurately spanned.

1.2.28. ‘Slope’ of a linear regression (a_1) means:

$$a_1 = \frac{\sum_n^{i=1} (y_i - \bar{y}) \times (x_i - \bar{x})}{\sum_n^{i=1} (x_i - \bar{x})^2}$$

where:

$\bar{x}$	is the mean value of the reference parameter
$\bar{y}$	is the mean value of the parameter to be verified
x_i	is the actual value of the reference parameter
y_i	is the actual value of the parameter to be verified
n	is the number of values

1.2.29. ‘Standard error of estimate’ (*SEE*) means:

$$SEE = \frac{1}{x_{max}} \times \sqrt{\frac{\sum_n^{i=1} \left(y_i - \acute{y}\right)^2}{(n-2)}}$$

where:

$\acute{y}$	is the estimated value of the parameter to be verified
y_i	is the actual value of the parameter to be verified
x_{max}	is the maximum actual value of the reference parameter

n	is the number of values

1.2.30. 'Total hydrocarbons' (THC) means the sum of all volatile compounds measurable by a flame ionisation detector (FID).

1.2.31. 'Traceable' means the ability to relate a measurement or reading through an unbroken chain of comparisons to a known and commonly agreed standard.

1.2.32. 'Transformation time' means the time difference between a change of concentration or flow (t_0) at the reference point and a system response of 50 per cent of the final reading (t_{50}).

1.2.33. 'Type of analyser', also referred to as 'analyser type' means a group of analysers produced by the same manufacturer that apply an identical principle to determine the concentration of one specific gaseous component or the number of particles.

1.2.34. 'Type of exhaust mass flow meter' means a group of exhaust mass flow meters produced by the same manufacturer that share a similar tube inner diameter and function on an identical principle to determine the mass flow rate of the exhaust gas.

1.2.35. 'Validation' means the process of evaluating the correct installation and functionality of a Portable Emissions Measurement System and the correctness of exhaust mass flow rate measurements as obtained from one or multiple non-traceable exhaust mass flow meters or as calculated from sensors or ECU signals.

1.2.36. 'Verification' means the process of evaluating whether the measured or calculated output of an analyser, flow-measuring instrument, sensor or signal agrees with a reference signal within one or more predetermined thresholds for acceptance.

1.2.37. 'Zero' means the calibration of an analyser, flow-measuring instrument or sensor so that it gives an accurate response to a zero signal.

1.2.38. 'Zero response' means the mean response to a zero signal over a time interval of at least 30 seconds.

1.2.39. 'Zero response drift' means the difference between the mean response to a zero signal and the actual zero signal that is measured over a defined time period after an analyser, flow-measuring instrument or sensor has been accurately zero calibrated.

1.3. Abbreviations

Abbreviations refer generically to both the singular and the plural forms of abbreviated terms.

CH_4	— Methane
CLD	— Chemiluminescence Detector
CO	— Carbon Monoxide
CO_2	— Carbon Dioxide
CVS	— Constant Volume Sampler
DCT	— Dual Clutch Transmission
ECU	— Engine Control Unit
EFM	— Exhaust mass Flow Meter
FID	— Flame Ionisation Detector
FS	— full scale
GPS	— Global Positioning System
H_2O	— Water
HC	— Hydrocarbons
HCLD	— Heated Chemiluminescence Detector

HEV	— Hybrid Electric Vehicle
ICE	— Internal Combustion Engine
ID	— identification number or code
LPG	— Liquid Petroleum Gas
MAW	— Moving Average Window
max	— maximum value
N_2	— Nitrogen
NDIR	— Non-Dispersive Infrared
NDUV	— Non-Dispersive Ultraviolet
NEDC	— New European Driving Cycle
NG	— Natural Gas
NMC	— Non-Methane Cutter
NMC-FID	— Non-Methane Cutter in combination with a Flame-Ionisation Detector
NMHC	— Non-Methane Hydrocarbons
NO	— Nitrogen Monoxide
No	— number
NO_2	— Nitrogen Dioxide
NO_X	— Nitrogen Oxides
NTE	— Not-to-exceed
O_2	— Oxygen
OBD	— On-Board Diagnostics
PEMS	— Portable Emissions Measurement System
PHEV	— Plug-in Hybrid Electric Vehicle
PN	— particle number
RDE	— Real Driving Emissions
SCR	— Selective Catalytic Reduction
SEE	— Standard Error of Estimate
THC	— Total Hydrocarbons
UN/ECE	— United Nations Economic Commission for Europe
VIN	— Vehicle Identification Number
WLTC	— Worldwide harmonised light vehicles test cycle
WWH-OBD	— Worldwide Harmonised On-Board Diagnostics

2. GENERAL REQUIREMENTS

[F2 2.1 Not-to-exceed emission limits

Throughout the normal life of a vehicle type approved according to Regulation (EC) No 715/2007, its emissions determined in accordance with the requirements of this Annex and emitted at any possible RDE test performed in accordance with the requirements of this Annex, shall not be higher than the following not-to-exceed (NTE) values:

$NTE_{pollutant} = CF_{pollutant} \times TF(p_1, \ldots, p_n) \times \text{EURO-6}$

where EURO-6 is the applicable Euro 6 emission limit laid down in Table 2 of Annex I to Regulation (EC) No 715/2007.]

[F3 2.1.1 Final conformity factors

The conformity factor $CF_{pollutant}$ for the respective pollutant is specified as follows:

Pollutant	Mass of oxides of nitrogen (NO_x)	Number of particles (PN)	Mass of carbon monoxide (CO)[a]	Mass of total hydrocarbons (THC)	Combined mass of total hydrocarbons and oxides of nitrogen ($THC + NO_x$)
$CF_{pollutant}$	1 + *margin* with *margin* = 0,5	to be determined	—	—	—

a CO emissions shall be measured and recorded at RDE tests.

'*margin*' is a parameter taking into account the additional measurement uncertainties introduced by the PEMS equipment, which are subject to an annual review and shall be revised as a result of the improved quality of the PEMS procedure or technical progress.

Textual Amendments

F3 Inserted by Commission Regulation (EU) 2016/646 of 20 April 2016 amending Regulation (EC) No 692/2008 as regards emissions from light passenger and commercial vehicles (Euro 6) (Text with EEA relevance).

2.1.2 Temporary conformity factors

By way of exception to the provisions of point 2.1.1, during a period of 5 years and 4 months following the dates specified in Article 10(4) and (5) of Regulation (EC) No 715/2007 and upon request of the manufacturer, the following temporary conformity factors may apply:

Pollutant	Mass of oxides of nitrogen (NO_x)	Number of particles (PN)	Mass of carbon monoxide (CO)[a]	Mass of total hydrocarbons (THC)	Combined mass of total hydrocarbons and oxides of nitrogen ($THC + NO_x$)
$CF_{pollutant}$	2,1	to be determined	—	—	—

a CO emissions shall be measured and recorded at RDE tests.

The application of temporary conformity factors shall be recorded in the certificate of conformity of the vehicle.

2.1.3 Transfer functions

The transfer function $TF(p1,\ldots, p_n)$ referred to in point 2.1 is set to 1 for the entire range of parameters p_i $(i = 1,\ldots,n)$.

If the transfer function $TF(p_1,\ldots, p_n)$ is amended, this shall be done in a manner which is not detrimental to the environmental impact and the effectiveness of the RDE test procedures. In particular the following condition shall hold:

$$\int TF\,(p1,\ldots,pn) * Q\,(p1,\ldots,pn)\,dp = \int Q\,(p1,\ldots,pn)\,dp$$

Where:

— *dp* represents the integral over the entire space of the parameters p_i $(i = 1,\ldots,n)$

— $Q(p_1,\ldots, p_n)$, is the probability density of an event corresponding to the parameters p_i $(i = 1,\ldots,n)$ in real driving.**]**

Textual Amendments

F2 Substituted by Commission Regulation (EU) 2016/646 of 20 April 2016 amending Regulation (EC) No 692/2008 as regards emissions from light passenger and commercial vehicles (Euro 6) (Text with EEA relevance).

2.2. The manufacturer shall confirm compliance with point 2.1 by completing the certificate set out in Appendix 9.

2.3. The RDE tests required by this Annex at type-approval and during the lifetime of a vehicle provide a presumption of conformity with the requirement set out in point 2.1. The presumed conformity may be reassessed by additional RDE tests.

2.4. Member States shall ensure that vehicles can be tested with PEMS on public roads in accordance with the procedures under their own national law, while respecting local road traffic legislation and safety requirements.

2.5. Manufacturers shall ensure that vehicles can be tested with PEMS by an independent party on public roads fulfilling the requirements of point 2.4, e.g. by making available suitable adapters for exhaust pipes, granting access to ECU signals and making the necessary administrative arrangements. If the respective PEMS test is not required by this Regulation the manufacturer may charge a reasonable fee as set out in Article 7(1) of Regulation (EC) No 715/2007.

3. RDE TEST TO BE PERFORMED

3.1. The following requirements apply to PEMS tests referred to in Article 3(10), second sub-paragraph.

[F3 3.1.0. The requirements of point 2.1 shall be fulfilled for the urban part and the complete PEMS trip. Upon the choice of the manufacturer the conditions of at least one of the two points below shall be fulfilled:

3.1.0.1 $M_{gas,d,t} \leq NTE_{pollutant}$ and $M_{gas,d,u} \leq NTE_{pollutant}$ with the definitions of point 2.1 of this Annex and points 6.1 and 6.3 of Appendix 5 and the setting *gas* = *pollutant*.

3.1.0.2 $M_{w,gas,d} \leq NTE_{pollutant}$ and $M_{w,gas,d,U} \leq NTE_{pollutant}$ with the definitions of point 2.1 of this Annex and point 3.9 of Appendix 6 and the setting *gas* = *pollutant*.**]**

3.1.1. For type-approval, the exhaust mass flow shall be determined by measurement equipment functioning independently from the vehicle and no vehicle ECU data shall be used in this respect. Outside the type-approval context, alternative methods to determine the exhaust mass flow can be used according to Appendix 2, Section 7.2.

3.1.2. If the approval authority is not satisfied with the data quality check and validation results of a PEMS test conducted according to Appendices 1 and 4, the approval authority may consider the test to be void. In such case, the test data and the reasons for voiding the test shall be recorded by the approval authority.

3.1.3. Reporting and dissemination of RDE test information

3.1.3.1. A technical report prepared by the manufacturer in accordance with Appendix 8 shall be made available to the approval authority.

3.1.3.2. The manufacturer shall ensure that the following information is made available on a publicly accessible website without costs:

3.1.3.2.1. By entering the vehicle type-approval number and the information on type, variant and version as defined in sections 0.10 and 0.2 of the vehicle's EC certificate of conformity provided by Annex IX of Directive 2007/46/EC, the unique identification number of a PEMS test family to which a given vehicle emission type belongs, as set out in point 5.2 of Appendix 7,

3.1.3.2.2. By entering the unique identification number of a PEMS test family:

— the full information as required by point 5.1 of Appendix 7,
— the lists described in points 5.3 and 5.4 of Appendix 7;
— the results of the PEMS tests as set out in points 6.3 of Appendix 5 and 3.9 of Appendix 6 for all vehicle emission types in the list described in point 5.4 of Appendix 7.

3.1.3.3. Upon request, without costs and within 30 days, the manufacturer shall make available the technical report referred to in point 3.1.3.1 to any interested party.

3.1.3.4. Upon request, the type-approval authority shall make available the information listed under points 3.1.3.1 and 3.1.3.2 within 30 days of receiving the request. The type-approval authority may charge a reasonable and proportionate fee, which does not discourage an inquirer with a justified interest from requesting the respective information or exceed the internal costs of the authority for making the requested information available.

4. GENERAL REQUIREMENTS

4.1. The RDE performance shall be demonstrated by testing vehicles on the road operated over their normal driving patterns, conditions and payloads. The RDE test shall be representative for vehicles operated on their real driving routes, with their normal load.

4.2. The manufacturer shall demonstrate to the approval authority that the chosen vehicle, driving patterns, conditions and payloads are representative for the vehicle family. The payload and altitude requirements, as specified in points 5.1 and 5.2, shall be used ex-ante to determine whether the conditions are acceptable for RDE testing.

4.3. The approval authority shall propose a test trip in urban, rural and motorway environments meeting the requirements of point 6. For the purpose of trip selection, the definition of urban, rural and motorway operation shall be based on a topographic map.

4.4. If for a vehicle the collection of ECU data influences the vehicle's emissions or performance the entire PEMS test family to which the vehicle belongs as defined in Appendix 7 shall be considered as non-compliant. Such functionality shall be considered as a 'defeat device' as defined in Article 3(10) of Regulation (EC) No 715/2007.

5. BOUNDARY CONDITIONS

5.1. Vehicle payload and test mass

5.1.1. The vehicle's basic payload shall comprise the driver, a witness of the test (if applicable) and the test equipment, including the mounting and the power supply devices.

5.1.2. For the purpose of testing some artificial payload may be added as long as the total mass of the basic and artificial payload does not exceed 90 % of the sum of the 'mass of the passengers' and the 'pay-mass' defined in points 19 and 21 of Article 2 of Commission Regulation (EU) No 1230/2012[(1)].

5.2. Ambient conditions

5.2.1. The test shall be conducted under ambient conditions laid down in this section. The ambient conditions become 'extended' when at least one of the temperature and altitude conditions is extended.

5.2.2. Moderate altitude conditions: Altitude lower or equal to 700 metres above sea level.

5.2.3. Extended altitude conditions: Altitude higher than 700 metres above sea level and lower or equal to 1 300 metres above sea level.

5.2.4. Moderate temperature conditions: Greater than or equal to 273 K (0 °C) and lower than or equal to 303 K (30 °C)

5.2.5. Extended temperature conditions: Greater than or equal to 266 K (– 7 °C) and lower than 273 K (0 °C) or greater than 303 K (30 °C) and lower than or equal to 308 K (35 °C)

5.2.6. By way of derogation from the provisions of points 5.2.4 and 5.2.5 the lower temperature for moderate conditions shall be greater or equal to 276K (3 °C) and the lower temperature for extended conditions shall be greater or equal to 271 K (– 2 °C) between the start of the application of binding NTE emission limits as defined in Section 2.1 and until five years after the dates given in paragraphs 4 and 5 of Article 10 of Regulation (EC) No 715/2007.

F4 5.3. . . . .

Textual Amendments

F4 Deleted by Commission Regulation (EU) 2016/646 of 20 April 2016 amending Regulation (EC) No 692/2008 as regards emissions from light passenger and commercial vehicles (Euro 6) (Text with EEA relevance).

[F2 5.4. Dynamic conditions

The dynamic conditions encompass the effect of road grade, head wind and driving dynamics (accelerations, decelerations) and auxiliary systems upon energy consumption and emissions of the test vehicle. The verification of the normality of dynamic conditions shall be done after the test is completed, using the recorded PEMS data. This verification shall be conducted in two steps:

5.4.1. The overall excess or insufficiency of driving dynamics during the trip shall be checked using the methods described in Appendix 7a to this Annex.

5.4.2. If the trip results as valid following the verifications according to point 5.4.1, the methods for verifying the normality of the dynamic conditions and laid down in Appendices 5 and 6 to this Annex must be applied. Each method includes a reference for dynamic conditions, ranges around the reference and the minimum coverage requirements to achieve a valid test.**]**

5.5. Vehicle condition and operation

5.5.1. Auxiliary systems

The air conditioning system or other auxiliary devices shall be operated in a way which corresponds to their possible use by a consumer at real driving on the road.

5.5.2. Vehicles equipped with periodically regenerating systems

5.5.2.1. ‘Periodically regenerating systems’ shall be understood according to the definition in Article 2(6).

5.5.2.2. If periodic regeneration occurs during a test, the test may be voided and repeated once at the request of the manufacturer.

5.5.2.3. The manufacturer may ensure the completion of the regeneration and precondition the vehicle appropriately prior to the second test.

5.5.2.4. If regeneration occurs during the repetition of the RDE test, pollutants emitted during the repeated test shall be included in the emissions evaluation.

6. TRIP REQUIREMENTS

6.1. The shares of urban, rural and motorway driving, classified by instantaneous speed as described in points 6.3 to 6.5, shall be expressed as a percentage of the total trip distance.

6.2. The trip sequence shall consist of urban driving followed by rural and motorway driving according to the shares specified in point 6.6. The urban, rural and motorway operation shall be run continuously. Rural operation may be interrupted by short periods of urban operation when driving through urban areas. Motorway operation may be interrupted by short periods of urban or rural operation, e.g. when passing toll stations or sections of road work. If another testing order is justified for practical reasons, the order of urban, rural and motorway operation may be altered, after obtaining approval from the approval authority.

6.3. Urban operation is characterised by vehicle speeds up to 60 km/h.

6.4. Rural operation is characterised by vehicle speeds between 60 and 90 km/h.

6.5. Motorway operation is characterised by speeds above 90 km/h.

6.6. The trip shall consist of approximately 34 % per cent urban, 33 % per cent rural and 33 % per cent motorway operation classified by speed as described in points 6.3 to 6.5 above. ‘Approximately’ shall mean the interval of ± 10 per cent points around the stated percentages. The urban operation shall however never be less than 29 % of the total trip distance.

6.7. The vehicle velocity shall normally not exceed 145 km/h. This maximum speed may be exceeded by a tolerance of 15 km/h for not more than 3 % of the time duration of the motorway driving. Local speed limits remain in force at a PEMS test, notwithstanding other legal consequences. Violations of local speed limits per se do not invalidate the results of a PEMS test.

[F2 6.8. The average speed (including stops) of the urban driving part of the trip should be between 15 and 40 km/h. Stop periods, defined as vehicle speed of less than 1 km/h, shall account for 6-30 % of the time duration of urban operation. Urban operation shall contain several stop periods of 10 s or longer. If a stop period lasts more than 180 s, the emission events during the 180 s following such an excessively long stop period shall be excluded from the evaluation.]

6.9. The speed range of the motorway driving shall properly cover a range between 90 and at least 110 km/h. The vehicle's velocity shall be above 100 km/h for at least 5 minutes.

6.10. The trip duration shall be between 90 and 120 minutes.

6.11. The start and the end point shall not differ in their elevation above sea level by more than 100 m.

[F3 In addition, the proportional cumulative positive altitude gain shall be less than 1 200 m/100km) and be determined according to Appendix 7b.]

6.12. The minimum distance of each operation: urban, rural and motorway, shall be 16 km.

7. OPERATIONAL REQUIREMENTS

7.1. The trip shall be selected in such a way that the testing is uninterrupted and the data continuously recorded to reach the minimum test duration defined in point 6.10.

7.2. Electrical power shall be supplied to the PEMS by an external power supply unit and not from a source that draws its energy either directly or indirectly from the engine of the test vehicle.

7.3. The installation of the PEMS equipment shall be done in a way to influence the vehicle emissions or performance or both to the minimum extent possible. Care should be exercised to minimise the mass of the installed equipment and potential aerodynamic modifications of the test vehicle. The vehicle payload shall be in accordance with point 5.1.

7.4. RDE tests shall be conducted on working days as defined for the Union in Council Regulation (EEC, Euratom) No 1182/71[(2)].

7.5. RDE tests shall be conducted on paved roads and streets (e.g. off-road operation is not permitted).

7.6 Prolonged idling shall be avoided after the first ignition of the combustion engine at the beginning of the emissions test. If the engine stalls during the test, it may be restarted, but the sampling shall not be interrupted.

8. LUBRICATING OIL, FUEL AND REAGENT

8.1. The fuel, lubricant and reagent (if applicable) used for RDE testing shall be within the specifications issued by the manufacturer for vehicle operation by the customer.

8.2. Samples of fuel, lubricant and reagent (if applicable) shall be taken and kept for at least 1 year.

9. EMISSIONS AND TRIP EVALUATION

9.1. The test shall be conducted in accordance with Appendix 1 of this Annex.

9.2. The trip shall fulfil the requirements set out in points 4 to 8.

9.3. It shall not be permitted to combine data of different trips or to modify or remove data from a trip.

9.4. After establishing the validity of a trip according to Point 9.2 emission results shall be calculated using the methods laid down in Appendix 5 and Appendix 6 of this Annex.

[[F2]9.5. If during a particular time interval the ambient conditions are extended in accordance with point 5.2, the emissions during this particular time interval, calculated according to Appendix 4, shall be divided by a value of 1,6 before being evaluated for compliance with the requirements of this Annex.**]**

9.6. The cold start is defined in accordance with point 4 of Appendix 4 of this Annex. Until specific requirements for emissions at cold start are applied, the latter shall be recorded but excluded from the emissions evaluation.

Appendix 1

Test procedure for vehicle emissions testing with a Portable Emissions Measurement System (PEMS)

1. INTRODUCTION

This Appendix describes the test procedure to determine exhaust emissions from light passenger and commercial vehicles using a Portable Emissions Measurement System.

2. SYMBOLS

≤	— smaller or equal
#	— number
$\#/m^3$	— number per cubic metre
%	— per cent
°C	— degree centigrade
g	— gramme
g/s	— gramme per second
h	— hour
Hz	— hertz
K	— kelvin
kg	— kilogramme
kg/s	— kilogramme per second
km	— kilometre
km/h	— kilometre per hour
kPa	— kilopascal
kPa/min	— kilopascal per minute
l	— litre
l/min	— litre per minute
m	— metre
m^3	— cubic-metre
mg	— milligram
min	— minute
p_e	— evacuated pressure [kPa]
q_{vs}	— volume flow rate of the system [l/min]
ppm	— parts per million
$ppmC_1$	— parts per million carbon equivalent
rpm	— revolutions per minute
s	— second
V_s	— system volume [l]

3. GENERAL REQUIREMENTS

3.1. **PEMS**

The test shall be carried out with a PEMS, composed of components specified in points 3.1.1 to 3.1.5. If applicable, a connection with the vehicle ECU may be established to determine relevant engine and vehicle parameters as specified in point 3.2.

3.1.1. Analysers to determine the concentration of pollutants in the exhaust gas.

3.1.2. One or multiple instruments or sensors to measure or determine the exhaust mass flow.

3.1.3. A Global Positioning System to determine the position, altitude and, speed of the vehicle.

3.1.4. If applicable, sensors and other appliances being not part of the vehicle, e.g. to measure ambient temperature, relative humidity, air pressure, and vehicle speed.

3.1.5. An energy source independent of the vehicle to power the PEMS.

3.2. **Test parameters**

Test parameters as specified in Table 1 of this Annex shall be measured, recorded at a constant frequency of 1,0 Hz or higher and reported according to the requirements of Appendix 8. If ECU parameters are obtained, these should be made available at a substantially higher frequency than the parameters recorded by PEMS to ensure correct sampling. The PEMS analysers, flow-measuring instruments and sensors shall comply with the requirements laid down in Appendices 2 and 3 of this Annex.

TABLE 1

Test parameters

Parameter	Recommended unit	Source[h]
THC concentration[ad]	ppm	Analyser
CH_4 concentration[ad]	ppm	Analyser
NMHC concentration[ad]	ppm	Analyser[f]
CO concentration[ad]	ppm	Analyser
CO_2 concentration[a]	ppm	Analyser
NO_X concentration[ad]	ppm	Analyser[g]
PN concentration[d]	$\#/m^3$	Analyser
Exhaust mass flow rate	kg/s	EFM, any methods described in point 7 of Appendix 2
Ambient humidity	%	Sensor
Ambient temperature	K	Sensor
Ambient pressure	kPa	Sensor
Vehicle speed	km/h	Sensor, GPS, or ECU[c]

Notes:

a	To be measured on a wet basis or to be corrected as described in point 8.1 of Appendix 4.
b	To be determined only if indirect methods are used to calculate exhaust mass flow rate as described in paragraphs 10.2 and 10.3 of Appendix 4.
c	The method to determine vehicle speed shall be chosen according to point 4.7.
d	Parameter only mandatory if measurement required by Annex IIIA, Section 2.1.
e	To be determined only if necessary to verify the vehicle status and operating conditions.
f	May be calculated from THC and CH_4 concentrations according to point 9.2 of Appendix 4.
g	May be calculated from measured NO and NO_2 concentrations.
h	Multiple parameter sources may be used.
i	The preferable source is the ambient pressure sensor.

Vehicle latitude	Degree	GPS
Vehicle longitude	Degree	GPS
Vehicle altitude[ei]	M	GPS or Sensor
Exhaust gas temperature[e]	K	Sensor
Engine coolant temperature[e]	K	Sensor or ECU
Engine speed[e]	rpm	Sensor or ECU
Engine torque[e]	Nm	Sensor or ECU
Torque at driven axle[e]	Nm	Rim torque meter
Pedal position[e]	%	Sensor or ECU
Engine fuel flow[b]	g/s	Sensor or ECU
Engine intake air flow[b]	g/s	Sensor or ECU
Fault status[e]	—	ECU
Intake air flow temperature	K	Sensor or ECU
Regeneration status[e]	—	ECU
Engine oil temperature[e]	K	Sensor or ECU
Actual gear[e]	#	ECU
Desired gear (e.g. gear shift indicator)[e]	#	ECU
Other vehicle data[e]	unspecified	ECU

Notes:

a To be measured on a wet basis or to be corrected as described in point 8.1 of Appendix 4.

b To be determined only if indirect methods are used to calculate exhaust mass flow rate as described in paragraphs 10.2 and 10.3 of Appendix 4.

c The method to determine vehicle speed shall be chosen according to point 4.7.

d Parameter only mandatory if measurement required by Annex IIIA, Section 2.1.

e To be determined only if necessary to verify the vehicle status and operating conditions.

f May be calculated from THC and CH_4 concentrations according to point 9.2 of Appendix 4.

g May be calculated from measured NO and NO_2 concentrations.

h Multiple parameter sources may be used.

i The preferable source is the ambient pressure sensor.

3.3. **Preparation of the vehicle**

The preparation of the vehicle shall include a general technical and operational check.

3.4. **Installation of PEMS**

3.4.1. *General*

The installation of the PEMS shall follow the instructions of the PEMS manufacturer and the local health and safety regulations. The PEMS should be installed as to minimise during the test electromagnetic interferences as well as exposure to shocks, vibration, dust and variability in temperature. The installation and operation of the PEMS shall be leak-tight and minimise heat loss. The installation and operation of PEMS shall not change the nature of the exhaust gas nor unduly increase the length of the tailpipe. To avoid the generation of particles, connectors shall be thermally stable at the exhaust gas temperatures expected during the test. It is recommended not to use elastomer connectors to connect the vehicle exhaust outlet and the connecting tube. Elastomer connectors, if used, shall have a minimum exposure to the exhaust gas to avoid artefacts at high engine load.

3.4.2. *Permissible backpressure*

The installation and operation of the PEMS shall not unduly increase the static pressure at the exhaust outlet. If technically feasible, any extension to facilitate the sampling or connection with the exhaust mass flow meter shall have an equivalent, or larger, cross-sectional area as the exhaust pipe.

3.4.3. *Exhaust mass flow meter*

Whenever used, the exhaust mass flow meter shall be attached to the vehicle's tailpipe(s) according to the recommendations of the EFM manufacturer. The measurement range of the EFM shall match the range of the exhaust mass flow rate expected during the test. The installation of the EFM and any exhaust pipe adaptors or junctions shall not adversely affect the operation of the engine or exhaust after-treatment system. A minimum of four pipe diameters or 150 mm of straight tubing, whichever is larger, shall be placed either side of the flow-sensing element. When testing a multi-cylinder engine with a branched exhaust manifold, it is recommended to combine the manifolds upstream of the exhaust mass flow meter and to increase the cross section of the piping appropriately as to minimise backpressure in the exhaust. If this is not feasible, exhaust flow measurements with several exhaust mass flow meters shall be considered. The wide variety of exhaust pipe configurations, dimensions and expected exhaust mass flow rates may require compromises, guided by good engineering judgement, when selecting and installing the EFM(s). If measurement accuracy requires, it is permissible to install an EFM with a diameter smaller than that of the exhaust outlet or the total cross-sectional area of multiple outlets, providing it does not adversely affect the operation or the exhaust after-treatment as specified in point 3.4.2.

3.4.4. *Global Positioning System*

The GPS antenna should be mounted, e.g. at the highest possible location, as to ensure good reception of the satellite signal. The mounted GPS antenna shall interfere as little as possible with the vehicle operation.

3.4.5. *Connection with the Engine Control Unit*

If desired, relevant vehicle and engine parameters listed in Table 1 can be recorded by using a data logger connected with the ECU or the vehicle network following standards, e.g. ISO 15031-5 or SAE J1979, OBD-II, EOBD or WWH-OBD. If applicable, manufacturers shall disclose parameter labels to allow the identification of required parameters.

3.4.6. *Sensors and auxiliary equipment*

Vehicle speed sensors, temperature sensors, coolant thermocouples or any other measurement device not part of the vehicle shall be installed to measure the parameter under consideration in a representative, reliable and accurate manner without unduly interfering with the vehicle operation and the functioning of other analysers, flow-measuring instruments, sensors and signals. Sensors and auxiliary equipment shall be powered independently of the vehicle.

[[F3]It is permitted to power any safety-related illumination of fixtures and installations of PEMS components outside of the vehicle's cabin by the vehicle's battery.**]**

3.5. **Emissions sampling**

Emissions sampling shall be representative and conducted at locations of well-mixed exhaust where the influence of ambient air downstream of the sampling point is minimal. If applicable, emissions shall be sampled downstream of the exhaust mass flow meter, respecting a distance of at least 150 mm to the flow sensing element. The sampling probes shall be fitted at least 200 mm or three times the diameter of the exhaust pipe, whichever is larger, upstream of the vehicle's exit of the exhaust outlet, which is the point at which the exhaust exits the PEMS sampling installation into the environment. If the PEMS feeds back a flow to the tail pipe, this shall occur downstream of the sampling probe in a manner that does not affect during engine operation the nature of the exhaust gas at the sampling point(s). If the length of the sample line is changed, the system transport times shall be verified and if necessary corrected.

If the engine is equipped with an exhaust after-treatment system, the exhaust sample shall be taken downstream of the exhaust after-treatment system. When testing a vehicle with a multi-cylinder engine and branched exhaust manifold, the inlet of the sampling probe shall be located sufficiently far downstream so as to ensure that the sample is representative of the average exhaust emissions of all cylinders. In multi-cylinder engines, having distinct groups of manifolds, such as in a ‘V’ engine configuration, the manifolds shall be combined upstream of the sampling probe. If this is technically not feasible, multi-point sampling at locations of well-mixed exhaust free of ambient air shall be considered. In this case, the number and location of sampling probes shall match as far as possible that of the exhaust mass flow meters. In case of unequal exhaust flows, proportional sampling or sampling with multiple analysers shall be considered.

If particles are measured, the exhaust shall be sampled from the centre of the exhaust stream. If several probes are used for emissions sampling, the particle sampling probe shall be placed upstream of the other sampling probes.

If hydrocarbons are measured, the sampling line shall be heated to 463 ± 10 K (190 ± 10 °C). For the measurement of other gaseous components with or without cooler, the sampling line shall be kept at a minimum of 333 K (60 °C) as to avoid condensation and to ensure appropriate penetration efficiencies of the various gases. For low pressure sampling systems, the temperature can be lowered corresponding to the pressure decrease provided that the sampling system ensures a penetration efficiency of 95 % for all regulated gaseous pollutants. If particles are sampled, the sampling line from the raw exhaust sample point shall be heated to a minimum of 373 K (100 °C). The residence time of the sample in the particle sampling line shall be less than 3 s until reaching first dilution or the particle counter.

4. PRE-TEST PROCEDURES

4.1. **PEMS leak check**

After the installation of PEMS is completed, a leak check shall be performed at least once for each PEMS-vehicle installation as prescribed by the PEMS manufacturer or as follows. The probe shall be disconnected from the exhaust system and the end plugged. The analyser pump shall be switched on. After an initial stabilisation period all flow meters shall read approximately zero in the absence of a leak. Else, the sampling lines shall be checked and the fault corrected.

The leakage rate on the vacuum side shall not exceed 0,5 per cent of the in-use flow rate for the portion of the system being checked. The analyser flows and bypass flows may be used to estimate the in-use flow rates.

Alternatively, the system may be evacuated to a pressure of at least 20 kPa vacuum (80 kPa absolute). After an initial stabilisation period the pressure increase *Dp* (kPa/min) in the system shall not exceed:

$$\Delta p = \frac{p_e}{V_s} \times q_{vs} \times 0{,}005$$

Alternatively, a concentration step change at the beginning of the sampling line shall be introduced by switching from zero to span gas while maintaining the same pressure conditions as under normal system operation. If for a correctly calibrated analyser after an adequate period of time the reading is ≤ 99 per cent compared to the introduced concentration, the leakage problem shall be corrected.

4.2. **Starting and stabilising the PEMS**

The PEMS shall be switched on, warmed up and stabilised according to the specifications of the PEMS manufacturer until, e.g. pressures, temperatures and flows have reached their operating set points.

4.3. **Preparing the sampling system**

The sampling system, consisting of the sampling probe, sampling lines and the analysers, shall be prepared for testing by following the instruction of the PEMS manufacturer. It shall be ensured that the sampling system is clean and free of moisture condensation.

4.4. **Preparing the EFM**

If used for measuring the exhaust mass flow, the EFM shall be purged and prepared for operation in accordance with the specifications of the EFM manufacturer. This procedure shall, if applicable, remove condensation and deposits from the lines and the associated measurement ports.

4.5. **Checking and calibrating the analysers for measuring gaseous emissions**

Zero and span calibration adjustments of the analysers shall be performed using calibration gases that meet the requirements of point 5 of Appendix 2. The calibration gases shall be chosen to match the range of pollutant concentrations expected during the emissions test.

[[F3]To minimise analyser drift, one should conduct the zero and span calibration of analysers at an ambient temperature that resembles, as closely as possible, the temperature experienced by the test equipment during the RDE trip.**]**

4.6. **Checking the analyser for measuring particle emissions**

The zero level of the analyser shall be recorded by sampling HEPA filtered ambient air. The signal shall be recorded at a constant frequency of at least 1,0 Hz over a period of 2 min and averaged; the permissible concentration value shall be determined once suitable measurement equipment becomes available.

4.7. **Measuring vehicle speed**

Vehicle speed shall be determined by at least one of the following methods:

(a) a GPS; if vehicle speed is determined by a GPS, the total trip distance shall be checked against the measurements of another method according to point 7 of Appendix 4,

(b) a sensor (e.g. optical or micro-wave sensor); if vehicle speed is determined by a sensor, the speed measurements shall comply with the requirements of point 8 of Appendix 2, or alternatively, the total trip distance determined by the sensor shall be compared with a reference distance obtained from a digital road network or topographic map. The total trip distance determined by the sensor shall deviate by no more than 4 % from the reference distance,

(c) the ECU; if vehicle speed is determined by the ECU, the total trip distance shall be validated according to point 3 of Appendix 3 and the ECU speed signal adjusted, if necessary to fulfil the requirements of point 3.3 of Appendix 3. Alternatively, the total trip distance as determined by the ECU shall be compared with a reference distance obtained from a digital road network or topographic map. The total trip distance determined by the ECU shall deviate by no more than 4 % from the reference.

4.8. **Check of PEMS set-up**

The correctness of connections with all sensors and, if applicable, the ECU shall be verified. If engine parameters are retrieved, it shall be ensured that the ECU reports values correctly (e.g. zero engine speed (rpm) while the combustion engine is in key-on-engine-off status). The PEMS shall function free of warning signals and error indication.

5. EMISSIONS TEST

5.1. **Test start**

Sampling, measurement and recording of parameters shall begin prior to the start of the engine. To facilitate time alignment, it is recommended to record the parameters that are subject to time alignment either by a single data recording device or with a synchronised time stamp. Before as well as directly after engine start, it shall be confirmed that all necessary parameters are recorded by the data logger.

5.2. **Test**

Sampling, measurement and recording of parameters shall continue throughout the on-road test of the vehicle. The engine may be stopped and started, but emissions sampling and parameter recording shall continue. Any warning signals, suggesting malfunctioning of the PEMS, shall be documented and verified. Parameter recording shall reach a data completeness of higher than 99 %. Measurement and data recording may be interrupted for less than 1 % of the total trip duration but for no more than a consecutive period of 30 s solely in the case of unintended signal loss or for the purpose of PEMS system maintenance. Interruptions may be recorded directly by the PEMS but it is not permissible to introduce interruptions in the recorded parameter via the pre-processing, exchange or post-processing of data. If conducted, auto zeroing shall be performed against a traceable zero standard similar to the one used to zero the analyser. It is strongly recommended to initiate PEMS system maintenance during periods of zero vehicle speed.

5.3. **Test end**

The end of the test is reached when the vehicle has completed the trip and the combustion engine is switched off. The data recording shall continue until the response time of the sampling systems has elapsed.

6. POST-TEST PROCEDURE

6.1. **Checking the analysers for measuring gaseous emissions**

The zero and span of the analysers of gaseous components shall be checked by using calibration gases identical to the ones applied under point 4.5 to evaluate the analyser response drift compared to the pre-test calibration. It is permissible to zero the analyser prior to verifying the span drift, if the zero drift was determined to be within the permissible range. The post-test drift check shall be completed as soon as possible after the test and before the PEMS, or individual analysers or sensors, are turned off or have switched into a non-operating mode. The difference between the pre-test and post-test results shall comply with the requirements specified in Table 2.

TABLE 2

Permissible analyser drift over a PEMS test

Pollutant	Zero response drift	Span response drift[a]
CO_2	≤ 2 000 ppm per test	≤ 2 % of reading or ≤ 2 000 ppm per test, whichever is larger
CO	≤ 75 ppm per test	≤ 2 % of reading or ≤ 75 ppm per test, whichever is larger
NO_2	≤ 5 ppm per test	≤ 2 % of reading or ≤ 5 ppm per test, whichever is larger
NO/NO_X	≤ 5 ppm per test	≤ 2 % of reading or ≤ 5 ppm per test, whichever is larger
CH_4	≤ 10 $ppmC_1$ per test	≤ 2 % of reading or ≤ 10 $ppmC_1$ per test, whichever is larger
THC	≤ 10 $ppmC_1$ per test	≤ 2 % of reading or ≤ 10 $ppmC_1$ per test, whichever is larger

a If the zero drift is within the permissible range, it is permissible to zero the analyser prior to verifying the span drift.

If the difference between the pre-test and post-test results for the zero and span drift is higher than permitted, all test results shall be voided and the test repeated.

6.2. Checking the analyser for measuring particle emissions

The zero level of the analyser shall be recorded by sampling HEPA filtered ambient air. The signal shall be recorded over a period of 2 min and averaged; the permissible final concentration shall be defined once suitable measurement equipment becomes available. If the difference between the pre-test and post-test zero and span check is higher than permitted, all test results shall be voided and the test repeated.

6.3. Checking the on-road emission measurements

The calibrated range of the analysers shall account at least for 90 % of the concentration values obtained from 99 % of the measurements of the valid parts of the emissions test. It is permissible that 1 % of the total number of measurements used for evaluation exceeds the calibrated range of the analysers by up to a factor of two. If these requirements are not met, the test shall be voided.

Appendix 2

Specifications and calibration of PEMS components and signals

1. INTRODUCTION

This appendix sets out the specifications and calibration of PEMS components and signals.

2. SYMBOLS

>	— larger than
≥	— larger than or equal to
%	— per cent
≤	— smaller than or equal to
A	— undiluted CO_2 concentration [%]
a_0	— y-axis intercept of the linear regression line
a_1	— slope of the linear regression line
B	— diluted CO_2 concentration [%]
C	— diluted NO concentration [ppm]
c	— analyser response in the oxygen interference test
$c_{FS,b}$	— full scale HC concentration in step (b) [$ppmC_1$]
$c_{FS,d}$	— full scale HC concentration in step (d) [$ppmC_1$]
$c_{HC(w/NMC)}$	— HC concentration with CH_4 or C_2H_6 flowing through the NMC [$ppmC_1$]
$c_{HC(w/o\ NMC)}$	— HC concentration with CH_4 or C_2H_6 bypassing the NMC [$ppmC_1$]
$c_{m,b}$	— measured HC concentration in step (b) [$ppmC_1$]
$c_{m,d}$	— measured HC concentration in step (d) [$ppmC_1$]
$c_{ref,b}$	— reference HC concentration in step (b) [$ppmC_1$]
$c_{ref,d}$	— reference HC concentration in step (d) [$ppmC_1$]
°C	— degree centigrade
D	— undiluted NO concentration [ppm]
D_e	— expected diluted NO concentration [ppm]
E	— absolute operating pressure [kPa]
E_{CO2}	— per cent CO_2 quench
E_E	— ethane efficiency
E_{H2O}	— per cent water quench
E_M	— methane efficiency
E_{O2}	— oxygen interference
F	— water temperature [K]
G	— saturation vapour pressure [kPa]
g	— gramme
gH_2O/kg	— gramme water per kilogram
h	— hour
H	— water vapour concentration [%]
H_m	— maximum water vapour concentration [%]
Hz	— hertz
K	— kelvin
kg	— kilogramme
km/h	— kilometre per hour
kPa	— kilopascal
max	— maximum value
$NO_{X,dry}$	— moisture-corrected mean concentration of the stabilised NO_X recordings
$NO_{X,m}$	— mean concentration of the stabilised NO_X recordings
$NO_{X,ref}$	— reference mean concentration of the stabilised NO_X recordings

ppm — parts per million
$ppmC_1$ — parts per million carbon equivalents
r^2 — coefficient of determination
s — second
t_0 — time point of gas flow switching [s]
t_{10} — time point of 10 % response of the final reading
t_{50} — time point of 50 % response of the final reading
t_{90} — time point of 90 % response of the final reading
x — independent variable or reference value
χ_{min} — minimum value
y — dependent variable or measured value

3. LINEARITY VERIFICATION

3.1. **General**

The linearity of analysers, flow-measuring instruments, sensors and signals, shall be traceable to international or national standards. Any sensors or signals that are not directly traceable, e.g. simplified flow-measuring instruments shall be calibrated alternatively against chassis dynamometer laboratory equipment that has been calibrated against international or national standards.

3.2. **Linearity requirements**

All analysers, flow-measuring instruments, sensors and signals shall comply with the linearity requirements given in Table 1. If air flow, fuel flow, the air-to-fuel ratio or the exhaust mass flow rate is obtained from the ECU, the calculated exhaust mass flow rate shall meet the linearity requirements specified in Table 1.

TABLE 1

Linearity requirements of measurement parameters and systems

Measurement parameter/ instrument	$\lvert \chi_{min} \times (a_1 - 1) + a_0 \rvert$	**Slopea_1**	**Standard errorSEE**	**Coefficient of determinationr^2**
Fuel flow rate[a]	≤ 1 % max	0,98 - 1,02	≤ 2 % max	≥ 0,990
Air flow rate[a]	≤ 1 % max	0,98 - 1,02	≤ 2 % max	≥ 0,990
Exhaust mass flow rate	≤ 2 % max	0,97 - 1,03	≤ 2 % max	≥ 0,990
Gas analysers	≤ 0,5 % max	0,99 - 1,01	≤ 1 % max	≥ 0,998
Torque[b]	≤ 1 % max	0,98 - 1,02	≤ 2 % max	≥ 0,990
PN analysers[c]	tbd	tbd	tbd	tbd

a Optional to determine exhaust mass flow.

b Optional parameter.

c To be decided once equipment becomes available.

3.3. **Frequency of linearity verification**

The linearity requirements according to point 3.2 shall be verified:

(a) for each analyser at least every three months or whenever a system repair or change is made that could influence the calibration;

(b) for other relevant instruments, such as exhaust mass flow meters and traceably calibrated sensors, whenever damage is observed, as required by internal audit procedures, by the instrument manufacturer or by ISO 9000 but no longer than one year before the actual test.

The linearity requirements according to point 3.2 for sensors or ECU signals that are not directly traceable shall be performed once for each PEMS set-up with a traceably calibrated measurement device on the chassis dynamometer.

3.4. **Procedure of linearity verification**

3.4.1. *General requirements*

The relevant analysers, instruments and sensors shall be brought to their normal operating condition according to the recommendations of their manufacturer. The analysers, instruments and sensors shall be operated at their specified temperatures, pressures and flows.

3.4.2. *General procedure*

The linearity shall be verified for each normal operating range by executing the following steps:

(a) The analyser, flow-measuring instrument or sensor shall be set at zero by introducing a zero signal. For gas analysers, purified synthetic air or nitrogen shall be introduced to the analyser port via a gas path that is as direct and short as possible.

(b) The analyser, flow-measuring instrument or sensor shall be spanned by introducing a span signal. For gas analysers, an appropriate span gas shall be introduced to the analyser port via a gas path that is as direct and short as possible.

(c) The zero procedure of (a) shall be repeated.

(d) The verification shall be established by introducing at least 10, approximately equally spaced and valid, reference values (including zero). The reference values with respect to the concentration of components, the exhaust mass flow rate or any other relevant parameter shall be chosen to match the range of values expected during the emissions test. For measurements of exhaust mass flow, reference points below 5 % of the maximum calibration value can be excluded from the linearity verification.

(e) For gas analysers, known gas concentrations in accordance with point 5 shall be introduced to the analyser port. Sufficient time for signal stabilisation shall be given.

(f) The values under evaluation and, if needed, the reference values shall be recorded at a constant frequency of at least 1,0 Hz over a period of 30 seconds.

(g) The arithmetic mean values over the 30-second period shall be used to calculate the least squares linear regression parameters, with the best-fit equation having the form:

$$y = a_1 x + a_0$$

where:

y	is the actual value of the measurement system
a_1	is the slope of the regression line
x	is the reference value
a_0	is the y intercept of the regression line

The standard error of estimate (SEE) of *y* on *x* and the coefficient of determination (r^2) shall be calculated for each measurement parameter and system.

(h) The linear regression parameters shall meet the requirements specified in Table 1.

3.4.3. *Requirements for linearity verification on a chassis dynamometer*

Non-traceable flow-measuring instruments, sensors or ECU signals that cannot directly be calibrated according to traceable standards, shall be calibrated on the chassis dynamometer. The procedure shall follow as far as applicable, the requirements of Annex 4a to UN/ECE Regulation No 83. If necessary, the instrument or sensor to be calibrated shall be installed on the test vehicle and operated according to the requirements of Appendix 1. The calibration procedure shall follow whenever possible the requirements of point 3.4.2; at least 10 appropriate reference values shall be selected as to ensure that at least 90 % of the maximum value expected to occur during the emissions test is covered.

If a not directly traceable flow-measuring instrument, sensor or ECU signal for determining exhaust flow is to be calibrated, a traceably calibrated reference exhaust mass flow meter or the CVS shall be attached to the vehicle's tailpipe. It shall be ensured that the vehicle exhaust is accurately measured by the exhaust mass flow meter according to point 3.4.3 of Appendix 1. The vehicle shall be operated by applying constant throttle at a constant gear selection and chassis dynamometer load.

4. ANALYSERS FOR MEASURING GASEOUS COMPONENTS

4.1. **Permissible types of analysers**

4.1.1. *Standard analysers*

The gaseous components shall be measured with analysers specified in points 1.3.1 to 1.3.5 of Appendix 3, Annex 4A to UN/ECE Regulation No 83, 07 series of amendments. If an NDUV analyser measures both NO and NO_2, a NO_2/NO converter is not required.

4.1.2. *Alternative analysers*

Any analyser not meeting the design specifications of point 4.1.1 is permissible provided that it fulfils the requirements of point 4.2. The manufacturer shall ensure that the alternative analyser achieves an equivalent or higher measurement performance compared to a standard analyser over the range of pollutant concentrations and co-existing gases that can be expected from vehicles operated with permissible fuels under moderate and extended conditions of valid on-road testing as specified in points 5, 6 and 7. Upon request, the manufacturer of the analyser shall submit in writing supplemental information, demonstrating that the measurement performance of the alternative analyser is consistently and reliably in line with the measurement performance of standard analysers. Supplemental information shall contain:

(a) a description of the theoretical basis and the technical components of the alternative analyser;

(b) a demonstration of equivalency with the respective standard analyser specified in point 4.1.1 over the expected range of pollutant concentrations and ambient conditions of the type-approval test defined in Annex 4a to UN/ECE Regulation No 83, 07 series of amendments as well as a validation test as described in point 3 of Appendix 3 for a vehicle equipped with a spark-ignition and compression-ignition engine; the manufacturer of the analyser shall demonstrate the significance of equivalency within the permissible tolerances given in point 3.3 of Appendix 3;

(c) a demonstration of equivalency with the respective standard analyser specified in point 4.1.1 with respect to the influence of atmospheric pressure on the measurement performance of the analyser; the demonstration test shall determine the response to span gas having a concentration within the analyser range to check the influence of atmospheric pressure under moderate and extended altitude conditions defined in point 5.2. Such a test can be performed in an altitude environmental test chamber;

(d) a demonstration of equivalency with the respective standard analyser specified in point 4.1.1 over at least three on-road tests that fulfil the requirements of this Annex;

(e) a demonstration that the influence of vibrations, accelerations and ambient temperature on the analyser reading does not exceed the noise requirements for analysers set out in point 4.2.4.

Approval authorities may request additional information to substantiate equivalency or refuse approval if measurements demonstrate that an alternative analyser is not equivalent to a standard analyser.

4.2. **Analyser specifications**

4.2.1. *General*

In addition to the linearity requirements defined for each analyser in point 3, the compliance of analyser types with the specifications laid down in points 4.2.2 to 4.2.8 shall be demonstrated by the analyser manufacturer. Analysers shall have a measuring range and response time appropriate to measure with adequate accuracy the concentrations of the exhaust gas components at the applicable emissions standard under transient and steady state conditions. The sensitivity of the analysers to shocks, vibration, aging, variability in temperature and air pressure as well as electromagnetic interferences and other impacts related to vehicle and analyser operation shall be limited as far as possible.

4.2.2. *Accuracy*

The accuracy, defined as the deviation of the analyser reading from the reference value, shall not exceed 2 % of reading or 0,3 % of full scale, whichever is larger.

4.2.3. *Precision*

The precision, defined as 2,5 times the standard deviation of 10 repetitive responses to a given calibration or span gas, shall be no greater than 1 % of the full scale concentration for a measurement range equal or above 155 ppm (or $ppmC_1$) and 2 % of the full scale concentration for a measurement range of below 155 ppm (or $ppmC_1$).

4.2.4. *Noise*

The noise, defined as two times the root mean square of ten standard deviations, each calculated from the zero responses measured at a constant recording frequency of at least 1,0 Hz during a period of 30 seconds, shall not exceed 2 % of full scale. Each of the 10 measurement periods shall be interspersed with an interval of 30 seconds in which the analyser is exposed to an appropriate span gas. Before each sampling period and before each span period, sufficient time shall be given to purge the analyser and the sampling lines.

4.2.5. *Zero response drift*

The drift of the zero response, defined as the mean response to a zero gas during a time interval of at least 30 seconds, shall comply with the specifications given in Table 2.

4.2.6. *Span response drift*

The drift of the span response, defined as the mean response to a span gas during a time interval of at least 30 seconds, shall comply with the specifications given in Table 2.

TABLE 2

Permissible zero and span response drift of analysers for measuring gaseous components under laboratory conditions

Pollutant	Zero response drift	Span response drift
CO_2	≤ 1 000 ppm over 4 h	≤ 2 % of reading or ≤ 1 000 ppm over 4 h, whichever is larger
CO	≤ 50 ppm over 4 h	≤ 2 % of reading or ≤ 50 ppm over 4 h, whichever is larger
NO_2	≤ 5 ppm over 4 h	≤ 2 % of reading or ≤ 5 ppm over 4 h, whichever is larger
NO/NO_X	≤ 5 ppm over 4 h	≤ 2 % of reading or 5 ppm over 4h, whichever is larger
CH_4	≤ 10 ppmC_1	≤ 2 % of reading or ≤ 10 ppmC_1 over 4 h, whichever is larger
THC	≤ 10 ppmC_1	≤ 2 % of reading or ≤ 10 ppmC_1 over 4 h, whichever is larger

4.2.7. *Rise time*

Rise time is defined as the time between the 10 per cent and 90 per cent response of the final reading ($t_{90} – t_{10}$; see point 4.4). The rise time of PEMS analysers shall not exceed 3 seconds.

4.2.8. *Gas drying*

Exhaust gases may be measured wet or dry. A gas-drying device, if used, shall have a minimal effect on the composition of the measured gases. Chemical dryers are not permitted.

4.3. **Additional requirements**

4.3.1. *General*

The provisions in points 4.3.2 to 4.3.5 define additional performance requirements for specific analyser types and apply only to cases, in which the analyser under consideration is used for PEMS emission measurements.

4.3.2. *Efficiency test for NO_X converters*

If a NO_X converter is applied, for example to convert NO_2 into NO for analysis with a chemiluminescence analyser, its efficiency shall be tested by following the requirements of point 2.4 of Appendix 3 of Annex 4a to UN/ECE Regulation No 83, 07 series of amendments. The efficiency of the NO_X converter shall be verified no longer than one month before the emissions test.

4.3.3. *Adjustment of the Flame Ionisation Detector*

Status: *Point in time view as at 31/01/2020.*
Changes to legislation: *There are currently no known outstanding effects for the Commission Regulation (EC) No 692/2008, ANNEX IIIA. (See end of Document for details)*

(a) Optimisation of the detector response

If hydrocarbons are measured, the FID shall be adjusted at intervals specified by the analyser manufacturer by following point 2.3.1 of Appendix 3 of Annex 4a to UN/ECE Regulation No 83, 07 series of amendments. A propane-in-air or propane-in-nitrogen span gas shall be used to optimise the response in the most common operating range.

(b) Hydrocarbon response factors

If hydrocarbons are measured, the hydrocarbon response factor of the FID shall be verified by following the provisions of point 2.3.3 of Appendix 3 of Annex 4a to UN/ECE Regulation No 83, 07 series of amendments, using propane-in-air or propane-in-nitrogen as span gases and purified synthetic air or nitrogen as zero gases, respectively.

(c) Oxygen interference check

The oxygen interference check shall be performed when introducing an analyser into service and after major maintenance intervals. A measuring range shall be chosen in which the oxygen interference check gases fall in the upper 50 per cent. The test shall be conducted with the oven temperature set as required. The specifications of the oxygen interference check gases are described in point 5.3.

The following procedure applies:

(i) The analyser shall be set at zero.

(ii) The analyser shall be spanned with a 0 per cent oxygen blend for positive ignition engines and a 21 per cent oxygen blend for compression ignition engines.

(iii) The zero response shall be rechecked. If it has changed by more than 0,5 per cent of full scale, steps (i) and (ii) shall be repeated.

(iv) The 5 per cent and 10 per cent oxygen interference check gases shall be introduced.

(v) The zero response shall be rechecked. If it has changed by more than ± 1 per cent of full scale, the test shall be repeated.

(vi) The oxygen interference E_{O2} shall be calculated for each oxygen interference check gas in step (d) as follows:

$$E_{O_2} = \frac{(c_{ref,d} - c)}{(c_{ref,d})} \times 100$$

where the analyser response is:

$$c = \frac{(c_{ref,d} \times c_{FS,b})}{c_{m,b}} \times \frac{c_{m,b}}{c_{FS,d}}$$

where:

$c_{ref,b}$	is the reference HC concentration in step (b) [ppmC_1]
$c_{ref,d}$	is the reference HC concentration in step (d) [ppmC_1]
$c_{FS,b}$	is the full scale HC concentration in step (b) [ppmC_1]
$c_{FS,d}$	is the full scale HC concentration in step (d) [ppmC_1]
$c_{m,b}$	is the measured HC concentration in step (b) [ppmC_1]
$c_{m,d}$	is the measured HC concentration in step (d) [ppmC_1].

(vii) The oxygen interference E_{O2} shall be less than ± 1,5 per cent for all required oxygen interference check gases.

(viii) If the oxygen interference E_{O2} is greater than ± 1,5 per cent, corrective action may be taken by incrementally adjusting the air flow (above and below the manufacturer's specifications), the fuel flow and the sample flow.

(ix) The oxygen interference check shall be repeated for each new setting.

4.3.4. *Conversion efficiency of the non-methane cutter (NMC)*

If hydrocarbons are analysed, a NMC can be used to remove non-methane hydrocarbons from the gas sample by oxidising all hydrocarbons except methane. Ideally, the conversion for methane is 0 per cent and for the other hydrocarbons represented by ethane is 100 per cent. For the accurate measurement of NMHC, the two efficiencies shall be determined and used for the calculation of the NMHC emissions (see point 9.2 of Appendix 4). It is not necessary to determine the methane conversion efficiency in case the NMC-FID is calibrated according to method (b) in point 9.2 of Appendix 4 by passing the methane/air calibration gas through the NMC.

(a) Methane conversion efficiency

Methane calibration gas shall be flown through the FID with and without bypassing the NMC; the two concentrations shall be recorded. The methane efficiency shall be determined as:

$$E_M = 1 - \frac{c_{HC(w/NMC)}}{c_{HC(w/oNMC)}}$$

where:

$c_{HC(w/NMC)}$	is the HC concentration with CH_4 flowing through the NMC [ppmC$_1$]
$c_{HC(w/o NMC)}$	is the HC concentration with CH_4 bypassing the NMC [ppmC$_1$]

(b) Ethane conversion efficiency

Ethane calibration gas shall be flown through the FID with and without bypassing the NMC; the two concentrations shall be recorded. The ethane efficiency shall be determined as:

$$E_E = 1 - \frac{c_{HC(w/NMC)}}{c_{HC(w/oNMC)}}$$

where:

$c_{HC(w/NMC)}$	is the HC concentration with C_2H_6 flowing through the NMC [ppmC$_1$]
$c_{HC(w/o NMC)}$	is the HC concentration with C_2H_6 bypassing the NMC [ppmC$_1$]

4.3.5. *Interference effects*

(a) General

Other gases than the ones being analysed can affect the analyser reading. A check for interference effects and the correct functionality of analysers shall be performed by the analyser manufacturer prior to market introduction at least once for each type of analyser or device addressed in points (b) to (f).

(b) CO analyser interference check

Water and CO_2 can interfere with the measurements of the CO analyser. Therefore, a CO_2 span gas having a concentration of 80 to 100 per cent of full scale of the maximum operating range of the CO analyser used during the test shall be bubbled through water at room temperature and the analyser response recorded. The analyser response shall not be more than 2 per cent of the mean CO concentration expected during normal on-road testing or ± 50 ppm, whichever is larger. The interference check for H_2O and CO_2 may be run as separate procedures. If the H_2O and CO_2 levels used for the interference check are higher than the maximum levels expected during the test, each observed interference value shall be scaled down by multiplying the observed interference with the ratio of the maximum expected concentration value during the test and the actual concentration value used during this check. Separate interference checks with concentrations of H_2O that are lower than the maximum concentration expected during the test may be run and the observed H_2O interference shall be scaled up by multiplying the observed interference with the ratio of the maximum H_2O concentration value expected during the test and the actual concentration value used during this check. The sum of the two scaled interference values shall meet the tolerance specified in this point.

(c) NO_X analyser quench check

The two gases of concern for CLD and HCLD analysers are CO_2 and water vapour. The quench response to these gases is proportional to the gas concentrations. A test shall determine the quench at the highest concentrations expected during the test. If the CLD and HCLD analysers use quench compensation algorithms that utilise H_2O or CO_2 measurement analysers or both, quench shall be evaluated with these analysers active and with the compensation algorithms applied.

(i) CO_2 quench check

A CO_2 span gas having a concentration of 80 to 100 per cent of the maximum operating range shall be passed through the NDIR analyser; the CO_2 value shall be recorded as A. The CO_2 span gas shall then be diluted by approximately 50 per cent with NO span gas and passed through the NDIR and CLD or HCLD; the CO_2 and NO values shall be recorded as B and C, respectively. The CO_2 gas flow shall then be shut off and only the NO span gas shall be passed through the CLD or HCLD; the NO value shall be recorded as D. The per cent quench shall be calculated as:

$$E_{CO_2} = \left[1 - \left(\frac{C \times A}{(D \times A) - (D \times B)}\right)\right] \times 100$$

where:

A	is the undiluted CO_2 concentration measured with NDIR [%]
B	is the diluted CO_2 concentration measured with NDIR [%]
C	is the diluted NO concentration measured with the CLD or HCLD [ppm]
D	is the undiluted NO concentration measured with the CLD or HCLD [ppm].

Alternative methods of diluting and quantifying of CO_2 and NO span gas values such as dynamic mixing/blending are permitted upon approval of the approval authority.

(ii) Water quench check

This check applies to measurements of wet gas concentrations only. The calculation of water quench shall consider dilution of the NO span gas with water vapour and the scaling of the water vapour concentration in the gas mixture to concentration levels that are expected to occur during an emissions test. A NO span gas having a concentration of 80 per cent to 100 per cent of full scale of the normal operating range shall be passed through the CLD or HCLD; the NO value shall be recorded as *D*. The NO span gas shall then be bubbled through water at room temperature and passed through the CLD or HCLD; the NO value shall be recorded as *C*. The analyser's absolute operating pressure and the water temperature shall be determined and recorded as E and F, respectively. The mixture's saturation vapour pressure that corresponds to the water temperature of the bubbler *F* shall be determined and recorded as *G*. The water vapour concentration *H* [%] of the gas mixture shall be calculated as:

$$H = \frac{G}{E} \times 100$$

The expected concentration of the diluted NO-water vapour span gas shall be recorded as D_e after being calculated as:

$$D_e = D \times \left(1 - \frac{H}{100}\right)$$

For diesel exhaust, the maximum concentration of water vapour in the exhaust gas (in per cent) expected during the test shall be recorded as H_m after being estimated, under the assumption of a fuel H/C ratio of 1,8/1, from the maximum CO_2 concentration in the exhaust gas A as follows:

$$H_m = 0{,}9 \times A$$

The per cent water quench shall be calculated as:

$$E_{H_2O} = \left(\left(\frac{D_e - C}{D_e}\right) \times \left(\frac{H_m}{H}\right)\right) \times 100$$

where:

D_e	is the expected diluted NO concentration [ppm]
C	is the measured diluted NO concentration [ppm]
H_m	is the maximum water vapour concentration [%]
H	is the actual water vapour concentration [%].

(iii) Maximum allowable quench

The combined CO_2 and water quench shall not exceed 2 per cent of full scale.

(d) Quench check for NDUV analysers

Hydrocarbons and water can positively interfere with NDUV analysers by causing a response similar to that of NO_X. The manufacturer of the NDUV analyser shall use the following procedure to verify that quench effects are limited:

(i) The analyser and chiller shall be set up by following the operating instructions of the manufacturer; adjustments should be made as to optimise the analyser and chiller performance.

(ii) A zero calibration and span calibration at concentration values expected during emissions testing shall be performed for the analyser.

(iii) A NO_2 calibration gas shall be selected that matches as far as possible the maximum NO_2 concentration expected during emissions testing.

(iv) The NO_2 calibration gas shall overflow at the gas sampling system's probe until the NO_X response of the analyser has stabilised.

(v) The mean concentration of the stabilised NO_X recordings over a period of 30 s shall be calculated and recorded as $NO_{X,ref}$.

(vi) The flow of the NO_2 calibration gas shall be stopped and the sampling system saturated by overflowing with a dew point generator's output, set at a dew point of 50 °C. The dew point generator's output shall be sampled through the sampling system and chiller for at least 10 minutes until the chiller is expected to be removing a constant rate of water.

(vii) Upon completion of (iv), the sampling system shall again be overflown by the NO_2 calibration gas used to establish $NO_{X,ref}$ until the total NO_X response has stabilised.

(viii) The mean concentration of the stabilised NO_X recordings over a period of 30 s shall be calculated and recorded as $NO_{X,m}$.

(ix) $NO_{X,m}$ shall be corrected to $NO_{X,dry}$ based upon the residual water vapour that passed through the chiller at the chiller's outlet temperature and pressure.

The calculated $NO_{X,dry}$ shall at least amount to 95 % of $NO_{X,ref}$.

(e) Sample dryer

A sample dryer removes water, which can otherwise interfere with the NO_X measurement. For dry CLD analysers, it shall be demonstrated that at the highest expected water vapour concentration H_m the sample dryer maintains the CLD humidity at ≤ 5 g water/kg dry air (or about 0,8 per cent H_2O), which is 100 per cent relative humidity at 3,9 °C and 101,3 kPa or about 25 per cent relative humidity at 25 °C and 101,3 kPa. Compliance may be demonstrated by measuring the temperature at the outlet of a thermal sample dryer or by measuring the humidity at a point just upstream of the CLD. The humidity of the CLD exhaust might also be measured as long as the only flow into the CLD is the flow from the sample dryer.

(f) Sample dryer NO_2 penetration

Liquid water remaining in an improperly designed sample dryer can remove NO_2 from the sample. If a sample dryer is used in combination with a NDUV analyser without an NO_2/NO converter upstream, water could therefore remove NO_2 from the sample prior to the NO_X measurement. The sample dryer shall allow for measuring at least 95 per cent of the NO_2 contained in a gas that is saturated with water vapour and consists of the maximum NO_2 concentration expected to occur during a vehicle test.

4.4. **Response time check of the analytical system**

For the response time check, the settings of the analytical system shall be exactly the same as during the emissions test (i.e. pressure, flow rates, filter settings in the analysers and all other parameters influencing the response time). The response time shall be determined with gas switching directly at the inlet of the sample probe. The gas switching shall be done in less than 0,1 second. The gases used for the test shall cause a concentration change of at least 60 per cent full scale of the analyser.

The concentration trace of each single gas component shall be recorded. The delay time is defined as the time from the gas switching (t_0) until the response is 10 per cent of the final reading (t_{10}). The rise time is defined as the time between 10 per cent and 90 per cent response of the final reading ($t_{90} - t_{10}$). The system response time (t_{90}) consists of the delay time to the measuring detector and the rise time of the detector.

For time alignment of the analyser and exhaust flow signals, the transformation time is defined as the time from the change (t_0) until the response is 50 per cent of the final reading (t_{50}).

The system response time shall be ≤ 12 s with a rise time of ≤ 3 seconds for all components and all ranges used. When using a NMC for the measurement of NMHC, the system response time may exceed 12 seconds.

5. GASES

5.1. **General**

The shelf life of calibration and span gases shall be respected. Pure and mixed calibration and span gases shall fulfil the specifications of points 3.1 and 3.2 of Appendix 3 of Annex 4A to UN/ECE Regulation No 83, 07 series of amendments. In addition, NO_2 calibration gas is permissible. The concentration of the NO_2 calibration gas shall be within two per cent of the declared concentration value. The amount of NO contained in NO_2 calibration gas shall not exceed 5 per cent of the NO_2 content.

5.2. **Gas dividers**

Gas dividers, i.e. precision blending devices that dilute with purified N_2 or synthetic air, can be used to obtain calibration and span gases. The accuracy of the gas divider shall be such that the concentration of the blended calibration gases is accurate to within ± 2 per cent. The verification shall be performed at between 15 and 50 per cent of full scale for each calibration incorporating a gas divider. An additional verification may be performed using another calibration gas, if the first verification has failed.

Optionally, the gas divider may be checked with an instrument which by nature is linear, e.g. using NO gas in combination with a CLD. The span value of the instrument shall be adjusted with the span gas directly connected to the instrument. The gas divider shall be checked at the settings typically used and the nominal value shall be compared with the concentration measured by the instrument. The difference shall in each point be within ± 1 per cent of the nominal concentration value.

5.3. **Oxygen interference check gases**

Oxygen interference check gases consist of a blend of propane, oxygen and nitrogen and shall contain propane at a concentration of 350 ± 75 ppmC_1. The concentration shall be determined by gravimetric methods, dynamic blending or the chromatographic analysis of total hydrocarbons plus impurities. The oxygen concentrations of the oxygen interference check gases shall meet the requirements listed in Table 3; the remainder of the oxygen interference check gas shall consist of purified nitrogen.

TABLE 3

Oxygen interference check gases

	Engine type	
	Compression ignition	**Positive ignition**
O_2 concentration	21 ± 1 %	10 ± 1 %
	10 ± 1 %	5 ± 1 %
	5 ± 1 %	0,5 ± 0,5 %

6. ANALYSERS FOR MEASURING PARTICLE EMISSIONS

This section will define future requirements for analysers for measuring particle emissions, once their measurement becomes mandatory.

7. INSTRUMENTS FOR MEASURING EXHAUST MASS FLOW

7.1. **General**

Instruments, sensors or signals for measuring the exhaust mass flow rate shall have a measuring range and response time appropriate for the accuracy required to measure the exhaust mass flow rate under transient and steady state conditions. The sensitivity of instruments, sensors and signals to shocks, vibration, aging, variability in temperature, ambient air pressure, electromagnetic interferences and other impacts related to vehicle and instrument operation shall be on a level as to minimise additional errors.

7.2. **Instrument specifications**

The exhaust mass flow rate shall be determined by a direct measurement method applied in either of the following instruments:

(a) Pitot-based flow devices;

(b) pressure differential devices like flow nozzle (details see ISO 5167);

(c) ultrasonic flow meter;

(d) vortex flow meter.

Each individual exhaust mass flow meter shall fulfil the linearity requirements set out in point 3. Furthermore, the instrument manufacturer shall demonstrate the compliance of each type of exhaust mass flow meter with the specifications in points 7.2.3 to 7.2.9.

It is permissible to calculate the exhaust mass flow rate based on air flow and fuel flow measurements obtained from traceably calibrated sensors if these fulfil the linearity requirements of point 3, the accuracy requirements of point 8 and if the resulting exhaust mass flow rate is validated according to point 4 of Appendix 3.

In addition, other methods that determine the exhaust mass flow rate based on not directly traceable instruments and signals, such as simplified exhaust mass flow meters or ECU signals are permissible if the resulting exhaust mass flow rate fulfils the linearity requirements of point 3 and is validated according to point 4 of Appendix 3.

7.2.1. *Calibration and verification standards*

The measurement performance of exhaust mass flow meters shall be verified with air or exhaust gas against a traceable standard such as, e.g. a calibrated exhaust mass flow meter or a full flow dilution tunnel.

7.2.2. *Frequency of verification*

The compliance of exhaust mass flow meters with points 7.2.3 and 7.2.9 shall be verified no longer than one year before the actual test.

7.2.3. *Accuracy*

The accuracy, defined as the deviation of the EFM reading from the reference flow value, shall not exceed ± 2 % of the reading, 0,5 % of full scale or ± 1,0 % of the maximum flow at which the EFM has been calibrated, whichever is larger.

7.2.4. *Precision*

The precision, defined as 2,5 times the standard deviation of 10 repetitive responses to a given nominal flow, approximately in the middle of the calibration range, shall be no greater than ±1 per cent of the maximum flow at which the EFM has been calibrated.

7.2.5. *Noise*

The noise, defined as two times the root mean square of ten standard deviations, each calculated from the zero responses measured at a constant recording frequency of at least 1,0 Hz during a period of 30 seconds, shall not exceed 2 per cent of the maximum calibrated flow value. Each of the 10 measurement periods shall be interspersed with an interval of 30 seconds in which the EFM is exposed to the maximum calibrated flow.

7.2.6. *Zero response drift*

Zero response is defined as the mean response to zero flow during a time interval of at least 30 seconds. The zero response drift can be verified based on the reported primary signals, e.g. pressure. The drift of the primary signals over a period of 4 hours shall be less than ± 2 per cent of the maximum value of the primary signal recorded at the flow at which the EFM was calibrated.

7.2.7. *Span response drift*

Span response is defined as the mean response to a span flow during a time interval of at least 30 seconds. The span response drift can be verified based on the reported primary signals, e.g. pressure. The drift of the primary signals over a period of 4 hours shall be less than ± 2 per cent of the maximum value of the primary signal recorded at the flow at which the EFM was calibrated.

7.2.8. *Rise time*

The rise time of the exhaust flow instruments and methods should match as far as possible the rise time of the gas analysers as specified in point 4.2.7 but shall not exceed 1 second.

7.2.9. *Response time check*

The response time of exhaust mass flow meters shall be determined by applying similar parameters as those applied for the emissions test (i.e. pressure, flow rates, filter settings and all other response time influences). The response time determination shall be done with gas switching directly at the inlet of the exhaust mass flow meter. The gas flow switching shall be done as fast as possible, but highly recommended in less than 0,1 second. The gas flow rate used for the test shall cause a flow rate change of at least 60 per cent full scale (FS) of the exhaust mass flow meter. The gas flow shall be recorded. The delay time is defined as the time from the gas flow switching (t_0) until the response is 10 per cent (t_{10}) of the final reading. The rise time is defined as the time between 10 per cent and 90 per cent response ($t_{90} - t_{10}$) of the final reading. The response time (t_{90}) is defined as the sum of the delay time and the rise time. The exhaust mass flow meter response time (t_{90}) shall be ≤ 3 seconds with a rise time ($t_{90} - t_{10}$) of ≤ 1 second in accordance with point 7.2.8.

8. SENSORS AND AUXILIARY EQUIPMENT

Any sensor and auxiliary equipment used to determine, e.g. temperature, atmospheric pressure, ambient humidity, vehicle speed, fuel flow or intake air flow shall not alter or unduly affect the performance of the vehicle's engine and exhaust after-treatment system. The accuracy of sensors and auxiliary equipment shall fulfil the requirements of Table 4. Compliance with the requirements of Table 4 shall be demonstrated at intervals specified by the instrument manufacturer, as required by internal audit procedures or in accordance with ISO 9000.

TABLE 4

Accuracy requirements for measurement parameters

Measurement parameter	Accuracy
Fuel flow[a]	± 1 % of reading[c]
Air flow[a]	± 2 % of reading
Vehicle ground speed[b]	± 1,0 km/h absolute
Temperatures ≤ 600 K	± 2 K absolute
Temperatures >600 K	± 0,4 % of reading in Kelvin
Ambient pressure	± 0,2 kPa absolute
Relative humidity	± 5 % absolute
Absolute humidity	± 10 % of reading or, 1 gH_2O/kg dry air, whichever is larger

a Optional to determine exhaust mass flow.

b [F2This general requirement applies to the speed sensor only; if vehicle speed is used to determine parameters like acceleration, the product of speed and positive acceleration, or RPA, the speed signal shall have an accuracy of 0,1 % above 3 km/h and a sampling frequency of 1 Hz. This accuracy requirement can be met by using the signal of a wheel rotational speed sensor.]

c The accuracy shall be 0,02 per cent of reading if used to calculate the air and exhaust mass flow rate from the fuel flow according to point 10 of Appendix 4.

Appendix 3

Validation of PEMS and non-traceable exhaust mass flow rate

1. INTRODUCTION

This appendix describes the requirements to validate under transient conditions the functionality of the installed PEMS as well as the correctness of the exhaust mass flow rate obtained from non-traceable exhaust mass flow meters or calculated from ECU signals.

2. SYMBOLS

%	—	per cent
#/km	—	number per kilometre
a_0	—	y intercept of the regression line
a_1	—	slope of the regression line
g/km	—	gramme per kilometre
Hz	—	hertz
km	—	kilometre
m	—	metre
mg/km	—	milligramme per kilometre
r^2	—	coefficient of determination
x	—	actual value of the reference signal
y	—	actual value of the signal under validation

3. VALIDATION PROCEDURE FOR PEMS

3.1. **Frequency of PEMS validation**

It is recommended to validate the installed PEMS once for each PEMS-vehicle combination either before the test or, alternatively, after the completion of an on-road test. The PEMS installation shall be kept unchanged in the time period between the on-road test and the validation.

3.2. **PEMS validation procedure**

3.2.1. *PEMS installation*

The PEMS shall be installed and prepared according to the requirements of Appendix 1. After the completion of the validation test until the start of the on-road test, the PEMS installation shall not be changed.

3.2.2. *Test conditions*

The validation test shall be conducted on a chassis dynamometer, as far as applicable, under type-approval conditions by following the requirements of Annex 4a to UN/ECE Regulation No 83, 07 series of amendments or any other adequate measurement method. It is recommended to conduct the validation test with the worldwide harmonised light vehicles test cycle (WLTC) as specified in Annex 1 to UNECE Global Technical Regulation No 15. The ambient temperature shall be within the range specified in point 5.2 of this Annex.

It is recommended to feed the exhaust flow extracted by the PEMS during the validation test back to the CVS. If this is not feasible, the CVS results shall be corrected for the extracted exhaust mass. If the exhaust mass flow rate is validated with an exhaust mass flow meter, it is recommended to cross-check the mass flow rate measurements with data obtained from a sensor or the ECU.

3.2.3. *Data analysis*

The total distance-specific emissions [g/km] measured with laboratory equipment shall be calculated following Annex 4a to UN/ECE Regulation No 83, 07 series of amendments. The emissions as measured with the PEMS shall be calculated according to point 9 of Appendix 4, summed to give the total mass of pollutant emissions [g] and then divided by the test distance [km] as obtained from the chassis dynamometer. The total distance-specific mass of pollutants [g/km], as determined by the PEMS and the reference laboratory system, shall be compared and evaluated against the requirements specified in point 3.3. For the validation of NO_X emission measurements, humidity correction shall be applied following point 6.6.5 of Annex 4a to UN/ECE Regulation No 83, 07 series of amendments.

3.3. **Permissible tolerances for PEMS validation**

The PEMS validation results shall fulfil the requirements given in Table 1. If any permissible tolerance is not met, corrective action shall be taken and the PEMS validation shall be repeated.

TABLE 1

Permissible tolerances

Parameter [Unit]	Permissible tolerance
Distance [km][a]	± 250 m of the laboratory reference
THC[b] [mg/km]	± 15 mg/km or 15 % of the laboratory reference, whichever is larger
CH_4[b] [mg/km]	± 15 mg/km or 15 % of the laboratory reference, whichever is larger
NMHC[b] [mg/km]	± 20 mg/km or 20 % of the laboratory reference, whichever is larger
PN[b] [#/km]	[c]
CO[b] [mg/km]	± 150 mg/km or 15 % of the laboratory reference, whichever is larger
CO_2 [g/km]	± 10 g/km or 10 % of the laboratory reference, whichever is larger
NO_x[b] [mg/km]	± 15 mg/km or 15 % of the laboratory reference, whichever is larger

a Only applicable if vehicle speed is determined by the ECU; to meet the permissible tolerance it is permitted to adjust the ECU vehicle speed measurements based on the outcome of the validation test.

b Parameter only mandatory if measurement required by Annex IIIA, Section 2.1.

c Still to be determined.

4. VALIDATION PROCEDURE FOR THE EXHAUST MASS FLOW RATE DETERMINED BY NON-TRACEABLE INSTRUMENTS AND SENSORS

4.1. **Frequency of validation**

In addition to fulfilling the linearity requirements of point 3 of Appendix 2 under steady-state conditions, the linearity of non-traceable exhaust mass flow meters or the exhaust mass flow rate calculated from non-traceable sensors or ECU signals shall be validated under transient conditions for each test vehicle against a calibrated exhaust mass flow meter or the CVS. The validation test procedure can be executed without the installation of the PEMS but shall generally follow the requirements defined in Annex 4a to UN/ECE Regulation No 83, 07 series of amendments and the requirements pertinent to exhaust mass flow meters defined in Appendix 1.

4.2. **Validation procedure**

The validation test shall be conducted on a chassis dynamometer under type-approval conditions, as far as applicable, by following the requirements of Annex 4a to UN/ECE Regulation No 83, 07 series of amendments. The test cycle shall be the worldwide harmonised light vehicles test cycle (WLTC) as specified in Annex 1 to UNECE Global Technical Regulation No 15. As reference, a traceably calibrated flow meter shall be used. The ambient temperature can be any within the range specified in point 5.2 of this Annex. The installation of the exhaust mass flow meter and the execution of the test shall fulfil the requirement of point 3.4.3 of Appendix 1 of this Annex.

The following calculation steps shall be taken to validate the linearity:

(a) The signal under validation and the reference signal shall be time corrected by following, as far as applicable, the requirements of point 3 of Appendix 4.

(b) Points below 10 % of the maximum flow value shall be excluded from the further analysis.

(c) At a constant frequency of at least 1,0 Hz, the signal under validation and the reference signal shall be correlated using the best-fit equation having the form:

$y = a_1 x + a_0$

where:

y	is the actual value of the signal under validation
a_1	is the slope of the regression line
x	is the actual value of the reference signal
a_0	is the y intercept of the regression line

The standard error of estimate (SEE) of y on x and the coefficient of determination (r^2) shall be calculated for each measurement parameter and system.

(d) The linear regression parameters shall meet the requirements specified in Table 2.

4.3. **Requirements**

The linearity requirements given in Table 2 shall be fulfilled. If any permissible tolerance is not met, corrective action shall be taken and the validation shall be repeated.

TABLE 2

Linearity requirements of calculated and measured exhaust mass flow

Measurement parameter/ system	**a_0**	**Slope a_1**	**Standard errorSEE**	**Coefficient of determinationr^2**
Exhaust mass flow	0,0 ± 3,0 kg/h	1,00 ± 0,075	≤ 10 % max	≥ 0,90

Appendix 4

Determination of emissions

1. INTRODUCTION

This appendix describes the procedure to determine the instantaneous mass and particle number emissions [g/s; #/s] that shall be used for the subsequent evaluation of a test trip and the calculation of the final emission result as described in Appendices 5 and 6.

2. SYMBOLS

%	— per cent
<	— smaller than
#/s	— number per second
α	— molar hydrogen ratio (H/C)
β	— molar carbon ratio (C/C)
γ	— molar sulphur ratio (S/C)
δ	— molar nitrogen ratio (N/C)
$\Delta t_{t,i}$	— transformation time t of the analyser [s]
$\Delta t_{t,m}$	— transformation time t of the exhaust mass flow meter [s]
ε	— molar oxygen ratio (O/C)
r_e	— density of the exhaust
r_{gas}	— density of the exhaust component 'gas'
l	— excess air ratio
l_i	— instantaneous excess air ratio
A/F_{st}	— stoichiometric air-to-fuel ratio [kg/kg]
°C	— degrees centigrade
c_{CH4}	— concentration of methane
c_{CO}	— dry CO concentration [%]
c_{CO2}	— dry CO_2 concentration [%]
c_{dry}	— dry concentration of a pollutant in ppm or per cent volume
$c_{gas,i}$	— instantaneous concentration of the exhaust component 'gas' [ppm]
c_{HCw}	— wet HC concentration [ppm]
$c_{HC(w/NMC)}$	— HC concentration with CH_4 or C_2H_6 flowing through the NMC [$ppmC_1$]
$c_{HC(w/oNMC)}$	— HC concentration with CH_4 or C_2H_6 bypassing the NMC [$ppmC_1$]
$c_{i,c}$	— time-corrected concentration of component *i* [ppm]
$c_{i,r}$	— concentration of component *i* [ppm] in the exhaust
c_{NMHC}	— concentration of non-methane hydrocarbons
c_{wet}	— wet concentration of a pollutant in ppm or per cent volume
E_E	— ethane efficiency
E_M	— methane efficiency
g	— gramme
g/s	— gramme per second
H_a	— intake air humidity [g water per kg dry air]
i	— number of the measurement
kg	— kilogram
kg/h	— kilogramme per hour
kg/s	— kilogramme per second
k_w	— dry-wet correction factor
m	— metre
$m_{gas,i}$	— mass of the exhaust component 'gas' [g/s]
$q_{maw,i}$	— instantaneous intake air mass flow rate [kg/s]

$q_{m,c}$	—	time-corrected exhaust mass flow rate [kg/s]
$q_{mew,i}$	—	instantaneous exhaust mass flow rate [kg/s]
$q_{mf,i}$	—	instantaneous fuel mass flow rate [kg/s]
$q_{m,r}$	—	raw exhaust mass flow rate [kg/s]
r	—	cross-correlation coefficient
r^2	—	coefficient of determination
r_h	—	hydrocarbon response factor
rpm	—	revolutions per minute
s	—	second
u_{gas}	—	*u* value of the exhaust component 'gas'

3. TIME CORRECTION OF PARAMETERS

For the correct calculation of distance-specific emissions, the recorded traces of component concentrations, exhaust mass flow rate, vehicle speed, and other vehicle data shall be time corrected. To facilitate the time correction, data which are subject to time alignment shall be recorded either in a single data recording device or with a synchronised timestamp following point 5.1 of Appendix 1. The time correction and alignment of parameters shall be carried out by following the sequence described in points 3.1 to 3.3.

3.1. **Time correction of component concentrations**

The recorded traces of all component concentrations shall be time corrected by reverse shifting according to the transformation times of the respective analysers. The transformation time of analysers shall be determined according to point 4.4 of Appendix 2:

$$c_{i,c}(t - \Delta t_{t,i}) = c_{i,r}(t)$$

where:

$c_{i,c}$	is the time-corrected concentration of component i as function of time *t*
$c_{i,r}$	is the raw concentration of component i as function of time *t*
$\Delta t_{t,i}$	is the transformation time t of the analyser measuring component i.

3.2. **Time correction of exhaust mass flow rate**

The exhaust mass flow rate measured with an exhaust flow meter shall be time corrected by reverse shifting according to the transformation time of the exhaust mass flow meter. The transformation time of the mass flow meter shall be determined according to point 4.4.9 of Appendix 2:

$$q_{m,c}(t - \Delta t_{t,m}) = q_{m,r}(t)$$

where:

$q_{m,c}$	is the time-corrected exhaust mass flow rate as function of time t
$q_{m,r}$	is the raw exhaust mass flow rate as function of time t
$\Delta t_{t,m}$	is the transformation time t of the exhaust mass flow meter.

In case the exhaust mass flow rate is determined by ECU data or a sensor, an additional transformation time shall be considered and obtained by cross-correlation between the calculated exhaust mass flow rate and the exhaust mass flow rate measured following point 4 of Appendix 3.

3.3. **Time alignment of vehicle data**

Other data obtained from a sensor or the ECU shall be time-aligned by cross-correlation with suitable emission data (e.g. component concentrations).

3.3.1. *Vehicle speed from different sources*

To time align vehicle speed with the exhaust mass flow rate, it is first necessary to establish one valid speed trace. In case vehicle speed is obtained from multiple sources (e.g. the GPS, a sensor or the ECU), the speed values shall be time aligned by cross-correlation.

3.3.2. *Vehicle speed with exhaust mass flow rate*

Vehicle speed shall be time aligned with the exhaust mass flow rate by means of cross-correlation between the exhaust mass flow rate and the product of vehicle velocity and positive acceleration.

3.3.3. *Further signals*

The time alignment of signals whose values change slowly and within a small value range, e.g. ambient temperature, can be omitted.

4. COLD START

The cold start period covers the first 5 minutes after initial start of the combustion engine. If the coolant temperature can be reliably determined, the cold start period ends once the coolant has reached 343 K (70 °C) for the first time but no later than 5 minutes after initial engine start. Cold start emissions shall be recorded.

5. EMISSION MEASUREMENTS DURING ENGINE STOP

Any instantaneous emissions or exhaust flow measurements obtained while the combustion engine is deactivated shall be recorded. In a separate step, the recorded values shall afterward be set to zero by the data post processing. The combustion engine shall be considered as deactivated if two of the following criteria apply: the recorded engine speed is < 50 rpm; the exhaust mass flow rate is measured at < 3 kg/h; the measured exhaust mass flow rate drops to < 15 % of the steady-state exhaust mass flow rate at idling.

6. CONSISTENCY CHECK OF VEHICLE ALTITUDE

In case well-reasoned doubts exist that a trip has been conducted above of the permissible altitude as specified in point 5.2 of Annex IIIA and in case altitude has only been measured with a GPS, the GPS altitude data shall be checked for consistency and, if necessary, corrected. The consistency of data shall be checked by comparing the latitude, longitude and altitude data obtained from the GPS with the altitude indicated by a digital terrain model or a topographic map of suitable scale. Measurements that deviate by more than 40 m from altitude depicted in the topographic map shall be manually corrected and marked.

7. CONSISTENCY CHECK OF GPS VEHICLE SPEED

The vehicle speed as determined by the GPS shall be checked for consistency by calculating and comparing the total trip distance with reference measurements obtained from either a sensor, the validated ECU or, alternatively, from a digital road network or topographic map. It is mandatory to correct GPS data for obvious errors, e.g. by applying a dead reckoning sensor, prior to the consistency check. The original and uncorrected data file shall be retained and any corrected data shall be marked. The corrected data shall not exceed an uninterrupted time period of 120 s or a total of 300 s. The total trip distance as calculated from the corrected GPS data shall deviate by no more than 4 % from the reference. If the GPS data do not meet these requirements and no other reliable speed source is available, the test results shall be voided.

8. CORRECTION OF EMISSIONS

8.1. **Dry-wet correction**

If the emissions are measured on a dry basis, the measured concentrations shall be converted to a wet basis as:

$c_{wet} = k_w \cdot c_{dry}$

where:

c_{wet}	is the wet concentration of a pollutant in ppm or per cent volume
c_{dry}	is the dry concentration of a pollutant in ppm or per cent volume
k_w	is the dry-wet correction factor

The following equation shall be used to calculate k_w:

$$k_w = \left(\frac{1}{1 + \alpha \times 0{,}005 \times (c_{CO_2} + c_{CO})} \right) \times 1{,}008$$

where:

$$k_{w1} = \frac{1{,}608 \times H_a}{1000 + (1{,}608 \times H_a)}$$

where:

H_a	is the intake air humidity [g water per kg dry air]
c_{CO2}	is the dry CO_2 concentration [%]
c_{CO}	is the dry CO concentration [%]
α	is the molar hydrogen ratio.

8.2. **Correction of NOx for ambient humidity and temperature**

NO_x emissions shall not be corrected for ambient temperature and humidity.

9. DETERMINATION OF THE INSTANTANEOUS GASEOUS EXHAUST COMPONENTS

9.1. **Introduction**

The components in the raw exhaust gas shall be measured with the measurement and sampling analysers described in Appendix 2. The raw concentrations of relevant components shall be measured in accordance with Appendix 1. The data shall be time corrected and aligned in accordance with point 3.

9.2. **Calculating NMHC and CH_4 concentrations**

For methane measurement using a NMC-FID, the calculation of NMHC depends on the calibration gas/method used for the zero/span calibration adjustment. When a FID is used for THC measurement without a NMC, it shall be calibrated with propane/air or propane/N_2 in the normal manner. For the calibration of the FID in series with a NMC, the following methods are permitted:

(a) the calibration gas consisting of propane/air bypasses the NMC;

(b) the calibration gas consisting of methane/air passes through the NMC.

It is strongly recommended to calibrate the methane FID with methane/air through the NMC.

In method (a), the concentrations of CH_4 and NMHC shall be calculated as follows:

$$c_{CH_4} = \frac{c_{HC(w/oNMC)} \times (1 - E_M) - c_{HC(w/NMC)}}{(E_E - E_M)}$$

$$c_{NMHC} = \frac{c_{HC(w/NMC)} - c_{HC(w/oNMC)} \times (1 - E_E)}{r_h \times (E_E - E_M)}$$

In case (b), the concentration of CH_4 and NMHC shall be calculated as follows:

$$c_{HC_4} = \frac{c_{HC(w/NMC)} \times r_h \times (1 - E_M) - c_{HC(w/oNMC)} \times (1 - E_E)}{r_h \times (E_E - E_M)}$$

$$c_{NMHC} = \frac{c_{HC(w/oNMC)} \times (1 - E_M) - c_{HC(w/NMC)} \times r_h \times (1 - E_M)}{(E_E - E_M)}$$

where:

$c_{HC(w/oNMC)}$	is the HC concentration with CH_4 or C_2H_6 bypassing the NMC [$ppmC_1$]
$c_{HC(w/NMC)}$	is the HC concentration with CH_4 or C_2H_6 flowing through the NMC [$ppmC_1$]
r_h	is the hydrocarbon response factor as determined in point 4.3.3(b) of Appendix 2
E_M	is the methane efficiency as determined in point 4.3.4(a) of Appendix 2
E_E	is the ethane efficiency as determined in point 4.3.4(b) of Appendix 2.

If the methane FID is calibrated through the cutter (method b), then the methane conversion efficiency as determined in point 4.3.4(a) of Appendix 2 is zero. The density used for NMHC mass calculations shall be equal to that of total hydrocarbons at 273,15 K and 101,325 kPa and is fuel-dependent.

10. DETERMINATION OF EXHAUST MASS FLOW

10.1. **Introduction**

The calculation of instantaneous mass emissions according to points 11 and 12 requires determining the exhaust mass flow rate. The exhaust mass flow rate shall be determined by one of the direct measurement methods specified in point 7.2 of Appendix 2. Alternatively, it is permissible to calculate the exhaust mass flow rate as described in points 10.2 to 10.4.

10.2. **Calculation method using air mass flow rate and fuel mass flow rate**

The instantaneous exhaust mass flow rate can be calculated from the air mass flow rate and the fuel mass flow rate as follows:

$$q_{mew,i} = q_{maw,i} + q_{mf,i}$$

where:

$q_{mew,i}$	is the instantaneous exhaust mass flow rate [kg/s]
$q_{maw,i}$	is the instantaneous intake air mass flow rate [kg/s]
$q_{mf,i}$	is the instantaneous fuel mass flow rate [kg/s].

If the air mass flow rate and the fuel mass flow rate or the exhaust mass flow rate are determined from ECU recording, the calculated instantaneous exhaust mass flow rate shall meet the linearity requirements specified for the exhaust mass flow rate in point 3 of Appendix 2 and the validation requirements specified in point 4.3 of Appendix 3.

10.3. **Calculation method using air mass flow and air-to-fuel ratio**

The instantaneous exhaust mass flow rate can be calculated from the air mass flow rate and the air-to-fuel ratio as follows:

$$q_{mew,i} = q_{maw,i} \times \left(1 + \frac{1}{A/F_{st} \times \lambda_i}\right)$$

where:

$$A / F_{st} = \frac{138{,}0 \times \left(1 + \frac{\alpha}{4} - \frac{\varepsilon}{2} + \gamma\right)}{12{,}011 + 1{,}008 \times \alpha + 15{,}9994 \times \varepsilon + 14{,}0067 \times \delta + 32{,}0675 \times \gamma}$$

$$\lambda_i = \frac{\left(100 - \frac{c_{CO} \times 10^{-4}}{2} - c_{HCw} \times 10^{-4}\right) + \left(\frac{\alpha}{4} \times \frac{1 - \frac{2 \times c_{CO} \times 10^{-4}}{3{,}5 \times c_{CO_2}}}{1 + \frac{c_{CO} \times 10^{-4}}{3{,}5 \times c_{CO_2}}} - \frac{\varepsilon}{2} - \frac{\delta}{2}\right) \times \left(c_{CO_2} + c_{CO} \times 10^{-4}\right)}{4{,}764 \times \left(1 + \frac{\alpha}{4} - \frac{\varepsilon}{2} + \gamma\right) \times \left(c_{CO_2} + c_{CO} \times 10^{-4} + c_{HCw} \times 10^{-4}\right)}$$

where:

$q_{maw,i}$	is the instantaneous intake air mass flow rate [kg/s]
A/F_{st}	is the stoichiometric air-to-fuel ratio [kg/kg]
l_i	is the instantaneous excess air ratio
c_{CO2}	is the dry CO_2 concentration [%]
c_{CO}	is the dry CO concentration [ppm]
c_{HCw}	is the wet HC concentration [ppm]
α	is the molar hydrogen ratio (H/C)
β	is the molar carbon ratio (C/C)
γ	is the molar sulphur ratio (S/C)
δ	is the molar nitrogen ratio (N/C)
ε	is the molar oxygen ratio (O/C).

Coefficients refer to a fuel $C_\beta H_\alpha O_\varepsilon N_\delta S_\gamma$ with $\beta = 1$ for carbon-based fuels. The concentration of HC emissions is typically low and may be omitted when calculating l_i.

If the air mass flow rate and air-to-fuel ratio are determined from ECU recording, the calculated instantaneous exhaust mass flow rate shall meet the linearity requirements specified for the exhaust mass flow rate in point 3 of Appendix 2 and the validation requirements specified in point 4.3 of Appendix 3.

10.4. Calculation method using fuel mass flow and air-to-fuel ratio

The instantaneous exhaust mass flow rate can be calculated from the fuel flow and the air-to-fuel ratio (calculated with A/F_{st} and l_i according to point 10.3) as follows:

$$q_{mew,i} = q_{mf,i} \times (1 + A/F_{st} \times \lambda_i)$$

The calculated instantaneous exhaust mass flow rate shall meet the linearity requirements specified for the exhaust gas mass flow rate in point 3 of Appendix 2 and the validation requirements specified in point 4.3 of Appendix 3.

11. CALCULATING THE INSTANTANEOUS MASS EMISSIONS

The instantaneous mass emissions [g/s] shall be determined by multiplying the instantaneous concentration of the pollutant under consideration [ppm] with the instantaneous exhaust mass flow rate [kg/s], both corrected and aligned for the transformation time, and the respective *u* value of Table 1. If measured on a dry basis, the dry-wet correction according to point 8.1 shall be applied to the instantaneous component concentrations before executing any further calculations. If applicable, negative instantaneous emission values shall enter all subsequent data evaluations. All significant digits of intermediate results shall enter the calculation of the instantaneous emissions. The following equation shall be applied:

$m_{gas,i} = u_{gas} \cdot c_{gas,i} \cdot q_{mew,i}$

where:

$m_{gas,i}$	is the mass of the exhaust component 'gas' [g/s]
u_{gas}	is the ratio of the density of the exhaust component 'gas' and the overall density of the exhaust as listed in Table 1
$c_{gas,i}$	is the measured concentration of the exhaust component 'gas' in the exhaust [ppm]
$q_{mew,i}$	is the measured exhaust mass flow rate [kg/s]
gas	is the respective component
i	number of the measurement.

TABLE 1

Raw exhaust gas *u* values depicting the ratio between the densities of exhaust component or pollutant [kg/m^3] and the density of the exhaust gas [kg/m^3][0]

Fuel	**ρ_e [kg/m^3]**	**Component or pollutant i**					
		NO_x	**CO**	**HC**	**CO_2**	**O_2**	**CH_4**
		ρ_{gas} [kg/m^3]					
		2,053	1,250	[a]	1,9636	1,4277	0,716
		u_{gas}[bf]					
Diesel (B7)	1,2943	0,001586	0,000966	0,000482	0,001517	0,001103	0,000553
Ethanol (ED95)	1,2768	0,001609	0,000980	0,000780	0,001539	0,001119	0,000561
CNG[c]	1,2661	0,001621	0,000987	0,000528[d]	0,001551	0,001128	0,000565
Propane	1,2805	0,001603	0,000976	0,000512	0,001533	0,001115	0,000559
Butane	1,2832	0,001600	0,000974	0,000505	0,001530	0,001113	0,000558
LPG[e]	1,2811	0,001602	0,000976	0,000510	0,001533	0,001115	0,000559
Petrol (E10)	1,2931	0,001587	0,000966	0,000499	0,001518	0,001104	0,000553
Ethanol (E85)	1,2797	0,001604	0,000977	0,000730	0,001534	0,001116	0,000559

a Depending on fuel.

b At *l* = 2, dry air, 273 K, 101,3 kPa.

c *u* values accurate within 0,2 % for mass composition of: C = 66 – 76 %; H = 22 – 25 %; N = 0 – 12 %.

d NMHC on the basis of $CH_{2,93}$ (for THC the u_{gas} coefficient of CH_4 shall be used).

e *u* accurate within 0,2 % for mass composition of: C_3 = 70 – 90 %; C_4 = 10 – 30 %.

f u_{gas} is a unitless parameter; the u_{gas} values include unit conversions to ensure that the instantaneous emissions are obtained in the specified physical unit, i.e. g/s.

12. CALCULATING THE INSTANTANEOUS PARTICLE NUMBER EMISSIONS

This section will define future requirements for calculating instantaneous particle number emissions, once their measurement becomes mandatory.

13. DATA REPORTING AND EXCHANGE

The data shall be exchanged between the measurement systems and the data evaluation software by a standardised reporting file as specified in point 2 of Appendix 8. Any pre-processing of data (e.g. time correction according to point 3 or the correction of the GPS vehicle speed signal according to point 7) shall be done with the control software of the measurement systems and shall be completed before the data reporting file is generated. If data are corrected or processed prior to entering the data reporting file, the original raw data shall be kept for quality assurance and control. Rounding of intermediate values is not permitted. Instead, intermediate values shall enter the calculation of instantaneous emissions [g/s; #/s] as reported by the analyser, flow-measuring instrument, sensor or the ECU.

Appendix 5
Verification of trip dynamic conditions with method 1 (Moving Averaging Window)

1. INTRODUCTION

The Moving Averaging Window method provides an insight on the real-driving emissions (RDE) occurring during the test at a given scale. The test is divided in sub-sections (windows) and the subsequent statistical treatment aims at identifying which windows are suitable to assess the vehicle RDE performance.

The 'normality' of the windows is conducted by comparing their CO_2 distance-specific emissions[(3)] with a reference curve. The test is complete when the test includes a sufficient number of normal windows, covering different speed areas (urban, rural, motorway).

Step 1.	Segmentation of the data and exclusion of cold start emissions;
Step 2.	Calculation of emissions by sub-sets or 'windows' (point 3.1);
Step 3.	Identification of normal windows; (point 4)
Step 4.	Verification of test completeness and normality (point 5);
Step 5.	Calculation of emissions using the normal windows (point 6).

2. SYMBOLS, PARAMETERS AND UNITS

Index (i) refers to the time step

Index (j) refers to the window

Index (k) refers to the category (t=total, u=urban, r=rural, m=motorway) or to the CO_2 characteristic curve (cc)

Index 'gas' refers to the regulated exhaust gas components (e.g. NO_x, CO, PN)

Δ	— difference
$\geq$	— larger or equal
#	— number
%	— per cent
$\leq$	— smaller or equal
a_1, b_1	— coefficients of the CO_2 characteristic curve
a_2, b_2	— coefficients of the CO_2 characteristic curve
d_j	— distance covered by window j [km]
f_k	— weighing factors for urban, rural and motorway shares
h	— distance of windows to the CO_2 characteristic curve [%]
h_j	— distance of window j to the CO_2 characteristic curve [%]
$\bar{h}_k$	— severity index for urban, rural and motorway shares and the complete trip
k_{11}, k_{12}	— coefficients of the weighing function
k_{21}, k_{21}	— coefficients of the weighing function
$M_{CO2,ref}$	— reference CO_2 mass [g]
M_{gas}	— mass or particle number of the exhaust component 'gas' [g] or [#]
$M_{gas,j}$	— mass or particle number of the exhaust component 'gas' in window j [g] or [#]
$M_{gas,d}$	— distance-specific emission for the exhaust component 'gas' [g/km] or [#/km]
$M_{gas,d,j}$	— distance-specific emission for the exhaust component 'gas' in window j [g/km] or [#/km]
N_k	— number of windows for urban, rural, and motorway shares

P_1, P_2, P_3 — reference points
t — time [s]
$t_{1,j}$ — first second of the j[th] averaging window [s]
$t_{2,j}$ — last second of the j[th] averaging window [s]
t_i — total time in step i [s]
$t_{i,j}$ — total time in step *i* considering window *j* [s]
tol_1 — primary tolerance for the vehicle CO_2 characteristic curve [%]
tol_2 — secondary tolerance for the vehicle CO_2 characteristic curve [%]
t_t — duration of a test [s]
v — vehicle speed [km/h]
$\bar{v}$ — average speed of windows [km/h]
v_i — actual vehicle speed in time step i [km/h]
$\bar{v}_j$ — average vehicle speed in window j [km/h]
$\bar{v}_{P1} = 19\ km/h$ — average speed of the Low Speed phase of the WLTP cycle
$\bar{v}_{P2} = 56{,}6\ km/h$ — average speed of the High Speed phase of the WLTP cycle
$\bar{v}_{P3} = 92{,}3\ km/h$ — average speed of the Extra High Speed phase of the WLTP cycle
w — weighing factor for windows
w_j — weighing factor of window j.

3. MOVING AVERAGING WINDOWS

3.1. **Definition of averaging windows**

The instantaneous emissions calculated according to Appendix 4 shall be integrated using a moving averaging window method, based on the reference CO_2 mass. The principle of the calculation is as follows: the mass emissions are not calculated for the complete data set, but for sub-sets of the complete data set, the length of these sub-sets being determined so as to match the CO_2 mass emitted by the vehicle over the reference laboratory cycle. The moving average calculations are conducted with a time increment corresponding to the data sampling frequency. These sub-sets used to average the emissions data are referred to as 'averaging windows'. The calculation described in the present point may be run from the last point (backwards) or from the first point (forward).

The following data shall not be considered for the calculation of the CO_2 mass, the emissions and the distance of the averaging windows:

— the periodic verification of the instruments and/or after the zero drift verifications,
— the cold start emissions, defined according to Appendix 4, point 4.4,
— vehicle ground speed < 1 km/h,
— any section of the test during which the combustion engine is switched off.

The mass (or particle number) emissions $M_{gas,j}$ shall be determined by integrating the instantaneous emissions in g/s (or #/s for PN) calculated as specified in Appendix 4.

Figure 1

Vehicle speed versus time — Vehicle averaged emissions versus time, starting from the first averaging window

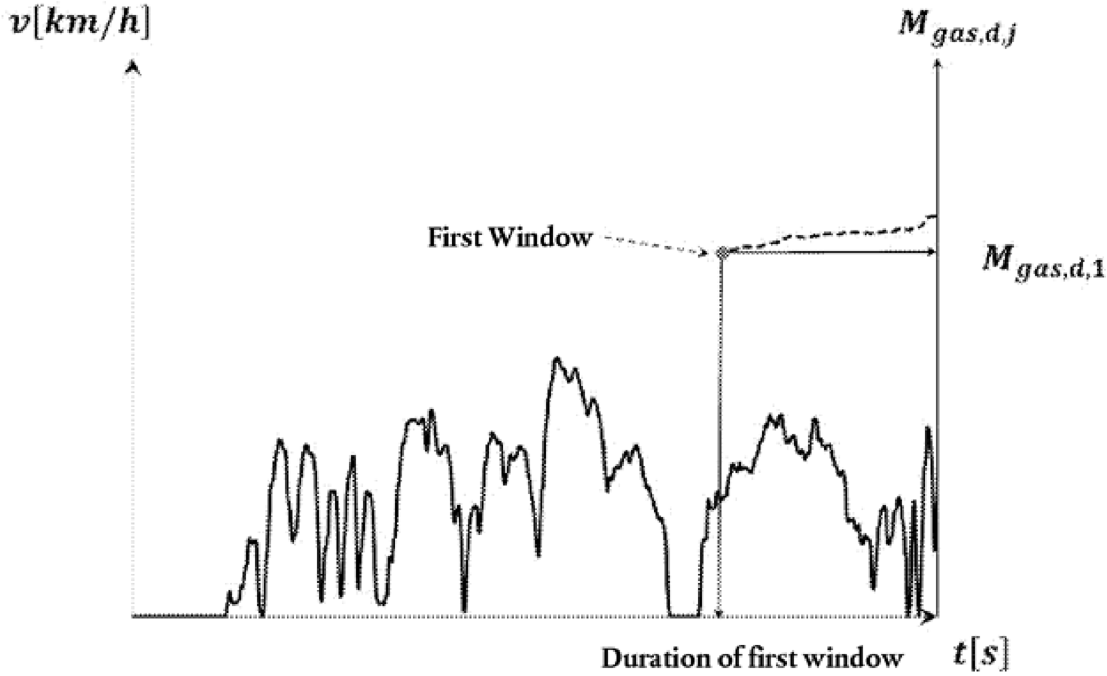
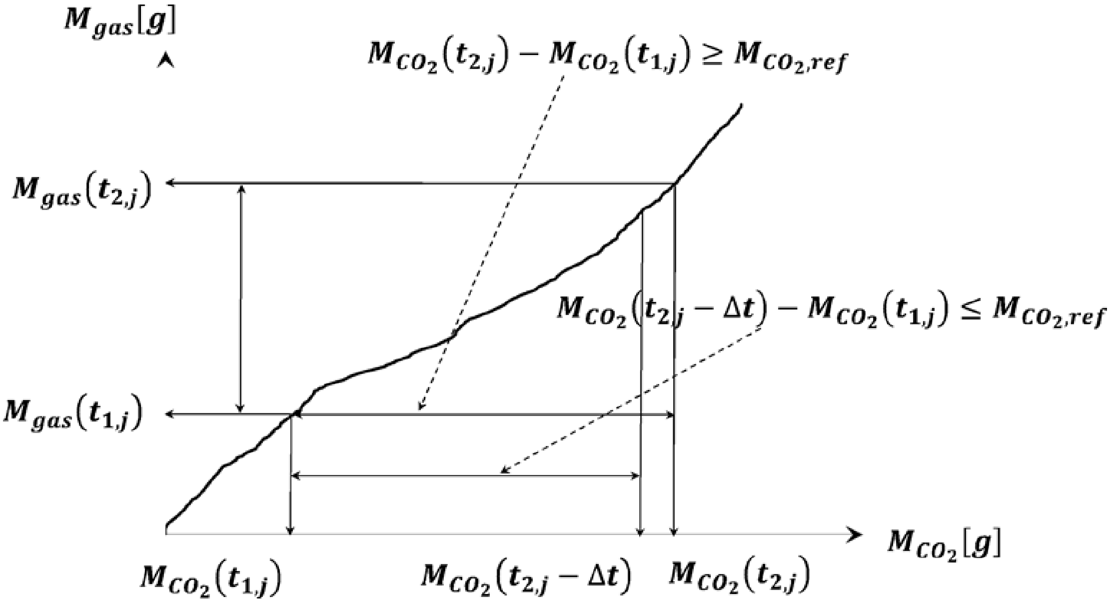


Figure 2

Definition of CO_2 mass based averaging windows



The duration ($t_{2,j} - t_{1,j}$) of the j[th] averaging window is determined by:

$M_{CO_2}(t_{2,j}) - M_{CO_2}(t_{1,j}) \geq M_{CO_2,ref}$

Where:

$M_{CO_2}(t_{i,j})$

is the CO_2 mass measured between the test start and time $(t_{i,j})$, [g];

$M_{CO_2,ref}$

is the half of the CO_2 mass [g] emitted by the vehicle over the WLTP cycle (Type I test, including cold start);

$t_{2,j}$ shall be selected such as:

$$M_{CO_2}(t_{2,j} - \Delta t) - M_{CO_2}(t_{1,j}) < M_{CO_2,ref} \leq M_{CO_2}(t_{2,j}) - M_{CO_2}(t_{1,j})$$

Where Δt is the data sampling period.

The CO_2 masses are calculated in the windows by integrating the instantaneous emissions calculated as specified in Appendix 4 to this Annex.

3.2. **Calculation of window emissions and averages**

The following shall be calculated for each window determined in accordance with point 3.1:

— the distance-specific emissions $M_{gas,d,j}$ for all the pollutants specified in this annex,

— the distance-specific CO_2 emissions $M_{CO2,d,j}$,

— the average vehicle speed

$\bar{v}_j$

4. EVALUATION OF WINDOWS

4.1. **Introduction**

The reference dynamic conditions of the test vehicle are set out from the vehicle CO_2 emissions versus average speed measured at type approval and referred to as 'vehicle CO_2 characteristic curve'.

To obtain the distance-specific CO_2 emissions, the vehicle shall be tested using the road load settings prescribed in the UNECE Global Technical Regulation No 15 — worldwide harmonised light vehicles test procedure (ECE/TRANS/180/Add.15).

4.2. **CO_2 characteristic curve reference points**

The reference points P_1, P_2 and P_3 required to define the curve shall be established as follows:

4.2.1. *Point P_1*

$\bar{v}_{P1} = 19\, km / h$

(average speed of the Low Speed phase of the WLTP cycle)

M_{CO_2,d,P_1}

= Vehicle CO_2 emissions over the Low Speed phase of the WLTP cycle × 1,2 [g/km].

4.2.2. *Point P_2*

4.2.3. $\bar{v}_{P2} = 56{,}6\, km / h$

(average speed of the High Speed phase of the WLTP cycle)

M_{CO_2,d,P_2}

= Vehicle CO_2 emissions over the High Speed phase of the WLTP cycle × 1,1 [g/km].

4.2.4. *Point P_3*

4.2.5. $\bar{v_{P3}} = 92,3\,km / h$

(average speed of the Extra High Speed phase of the WLTP cycle)

M_{CO_2,d,P_3}
= Vehicle CO_2 emissions over the Extra High Speed phase of the WLTP cycle × 1,05 [g/km]

4.3. **CO_2 characteristic curve definition**

Using the reference points defined in point 4.2, the characteristic curve CO_2 emissions are calculated as a function of the average speed using two linear sections (P_1, P_2) and (P_2, P_3). The section (P_2, P_3) is limited to 145 km/h on the vehicle speed axis. The characteristic curve is defined by equations as follows:

For the section (P_1, P_2):

$$M_{CO_2,d,CC}(\bar{v}) = a_1\bar{v} + b_1$$

with:

$$a_1 = \left(M_{CO_2,d,P_2} - M_{CO_2,d,P_1}\right)/\left(\bar{v_{P2}} - \bar{v_{P1}}\right)$$

and:

$$b_1 = M_{CO_2,d,P_1} - a_1\bar{v_{P1}}$$

For the section (P_2, P_3):

$$M_{CO_2,d,CC}(\bar{v}) = a_2\bar{v} + b_2$$

with:

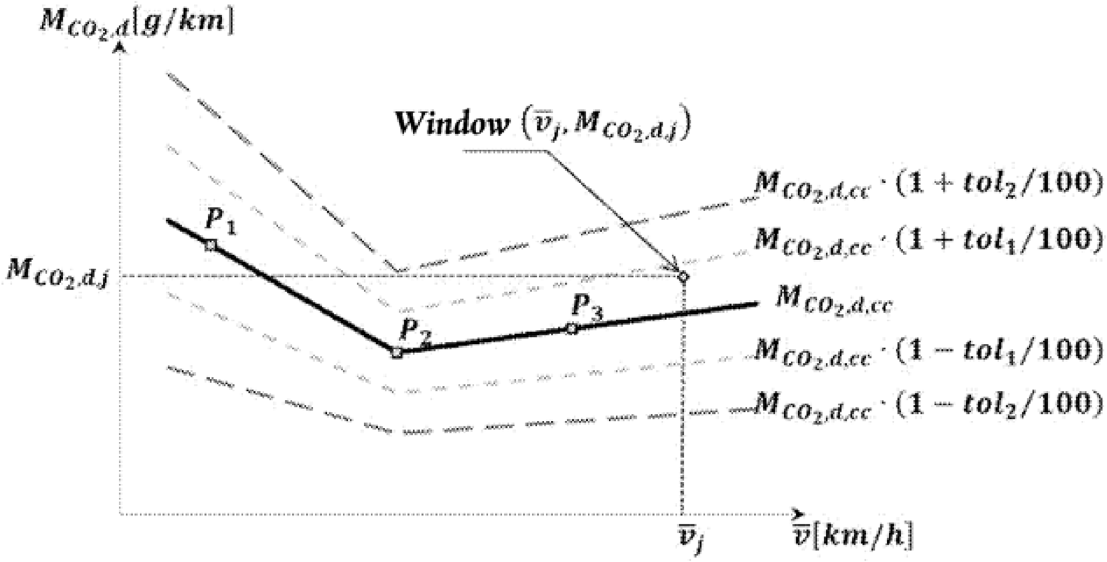
$$a_2 = \left(M_{CO_2,d,P_3} - M_{CO_2,d,P_2}\right)/\left(\bar{v_{P3}} - \bar{v_{P2}}\right)$$

and:

$$b_2 = M_{CO_2,d,P_2} - a_2\bar{v_{P2}}$$

Figure 3

Vehicle CO_2 characteristic curve



4.4. **Urban, rural and motorway windows**

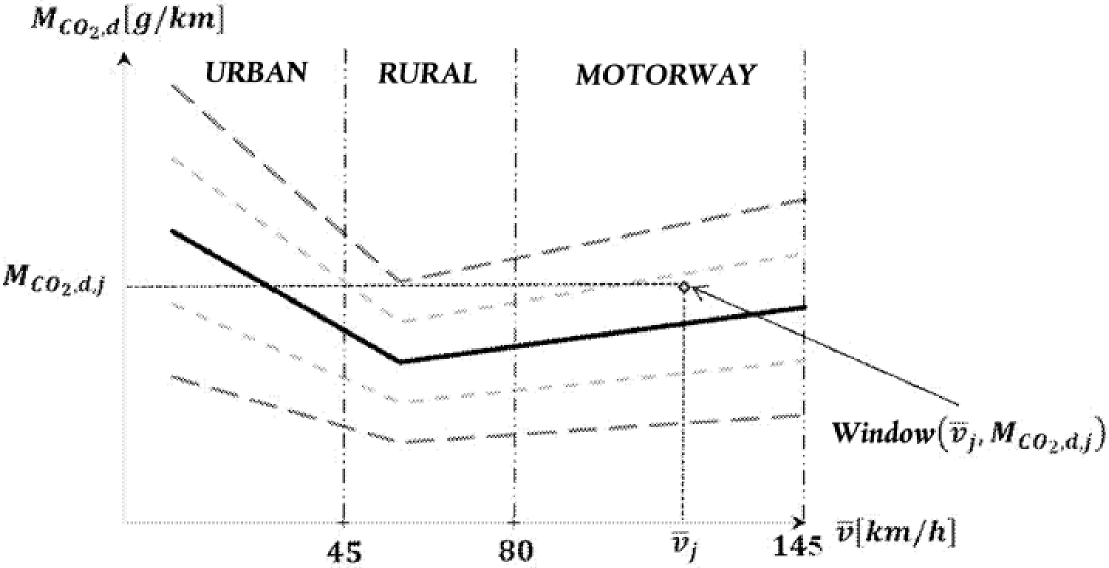
4.4.1. Urban windows are characterised by average vehicle ground speeds $\bar{v}_j$ smaller than 45 km/h,

4.4.2. Rural windows are characterised by average vehicle ground speeds $\bar{v}_j$ greater than or equal to 45 km/h and smaller than 80 km/h,

4.4.3. Motorway windows are characterised by average vehicle ground speeds $\bar{v}_j$ greater than or equal to 80 km/h and smaller than 145 km/h

Figure 4

Vehicle CO_2 characteristic curve: urban, rural and motorway driving definitions



5. VERIFICATION OF TRIP COMPLETENESS AND NORMALITY

5.1. **Tolerances around the vehicle CO_2 characteristic curve**

The primary tolerance and the secondary tolerance of the vehicle CO_2 characteristic curve are respectively tol_1= 25 % and tol_2 = 50 %.

5.2. **Verification of test completeness**

The test shall be complete when it comprises at least 15 % of urban, rural and motorway windows, out of the total number of windows.

5.3. **Verification of test normality**

The test shall be normal when at least 50 % of the urban, rural and motorway windows are within the primary tolerance defined for the characteristic curve.

If the specified minimum requirement of 50 % is not met, the upper positive tolerance tol_1 may be increased by steps of 1 % until the 50 % of normal windows target is reached. When using this mechanism, tol_1 shall never exceed 30 %.

6. CALCULATION OF EMISSIONS

6.1. Calculation of weighted distance-specific emissions

The emissions shall be calculated as a weighted average of the windows distance-specific emissions separately for the urban, rural and motorway categories and the complete trip.

$$M_{gas,d,k} = \frac{\sum (w_j M_{gas,d,j})}{\sum w_j} k = u,r,m$$

The weighing factor w_j for each window shall be determined as such:

If

$$M_{CO_2,d,CC}(\bar{v}_j) \times (1 - tol_1 / 100) \leq M_{CO_2,d,j} \leq M_{CO_2,d,CC}(\bar{v}_j) \times (1 + tol_1 / 100)$$

Then $w_j = 1$

If

$$M_{CO_2,d,CC}(\bar{v}_j) \times \left(1 + \frac{tol_1}{100}\right) \leq M_{CO_2,d,j} \leq M_{CO_2,d,CC}(\bar{v}_j) \times \left(1 + \frac{tol_2}{100}\right)$$

Then $w_j = k_{11}h_j + k_{12}$

with $k_{11} = 1/(tol_1 - tol_2)$

and k_{12}: $tol_2/(tol_2 - tol_1)$

If

$$M_{CO_2,d,CC}(\bar{v}_j) \times (1 - tol_2 / 100) \leq M_{CO_2,d,j} \leq M_{CO_2,d,CC}(\bar{v}_j) \times (1 - tol_1 / 100)$$

Then $w_j = k_{21}h_j + K_{22}$

with $k_{21} = 1/(tol_2 - tol_1)$

and $k_{22} = k_{21} = tol_2/(tol_2 - tol_1)$

If

$$M_{CO_2,d,j}(\bar{v}_j) \leq M_{CO_2,d,CC}(\bar{v}_j) \times (1 - tol_2 / 100)$$

or

$$M_{CO_2,d,j}(\bar{v}_j) \geq M_{CO_2,d,CC}(\bar{v}_j) \times (1 + tol_2 / 100)$$

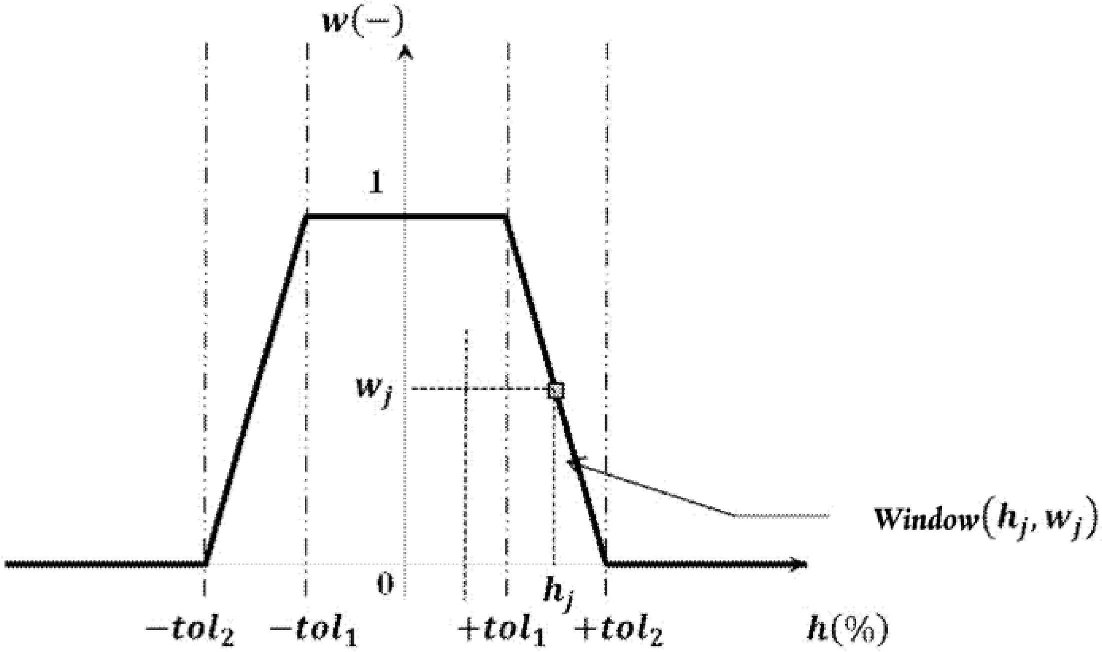
Then $w_j = 0$

Where:

$$h_j = 100 \times \frac{M_{CO_2,d,j} - M_{CO_2,d,CC}(\bar{v}_j)}{M_{CO_2,d,CC}(\bar{v}_j)}$$

Figure 5

Averaging window weighing function



6.2. **Calculation of severity indices**

The severity indices shall be calculated separately for the urban, rural and motorway categories:

$$\bar{h}_k = \frac{1}{N_k} \sum h_j k = u,r,m$$

and the complete trip:

$$\bar{h}_t = \frac{f_u \bar{h}_u + f_r \bar{h}_r + f_m \bar{h}_m}{f_u + f_r + f_m}$$

Where f_u, f_r f_m are equal to 0,34, 0,33 and 0,33 respectively.

6.3. **Calculation of emissions for the total trip**

Using the weighted distance-specific emissions calculated under point 6.1, the distance-specific emissions in [mg/km] shall be calculated for the complete trip each gaseous pollutant in the following way:

$$M_{gas,d,t} = 1000 \times \frac{f_u \times M_{gas,d,u} + f_r \times M_{gas,d,r} + f_m \times M_{gas,d,m}}{(f_u + f_r + f_m)}$$

And for particle number:

$$M_{PN,d,t} = \frac{f_u \times M_{PN,d,u} + f_r \times M_{PN,d,r} + f_m \times M_{PN,d,m}}{(f_u + f_r + f_m)}$$

Where f_u, f_r f_m are respectively equal to 0,34, 0,33 and 0,33.

7. NUMERICAL EXAMPLES

7.1. **Averaging window calculations**

TABLE 1

Main calculation settings

$M_{CO2\,ref}$ [g]	610
Direction for averaging window calculation	Forward
Acquisition frequency [Hz]	1

Figure 6 shows how averaging windows are defined on the basis of data recorded during an on-road test performed with PEMS. For sake of clarity, only the first 1 200 seconds of the trip are shown hereafter.

Seconds 0 up to 43 as well as seconds 81 to 86 are excluded due to operation under zero vehicle speed.

The first averaging window starts at $t_{1,1}$ = 0s and ends at second $t_{2,1}$ = 524 s (Table 3). The window average vehicle speed, integrated CO and NO_x masses [g] emitted and corresponding to the valid data over the first averaging window are listed in Table 4.

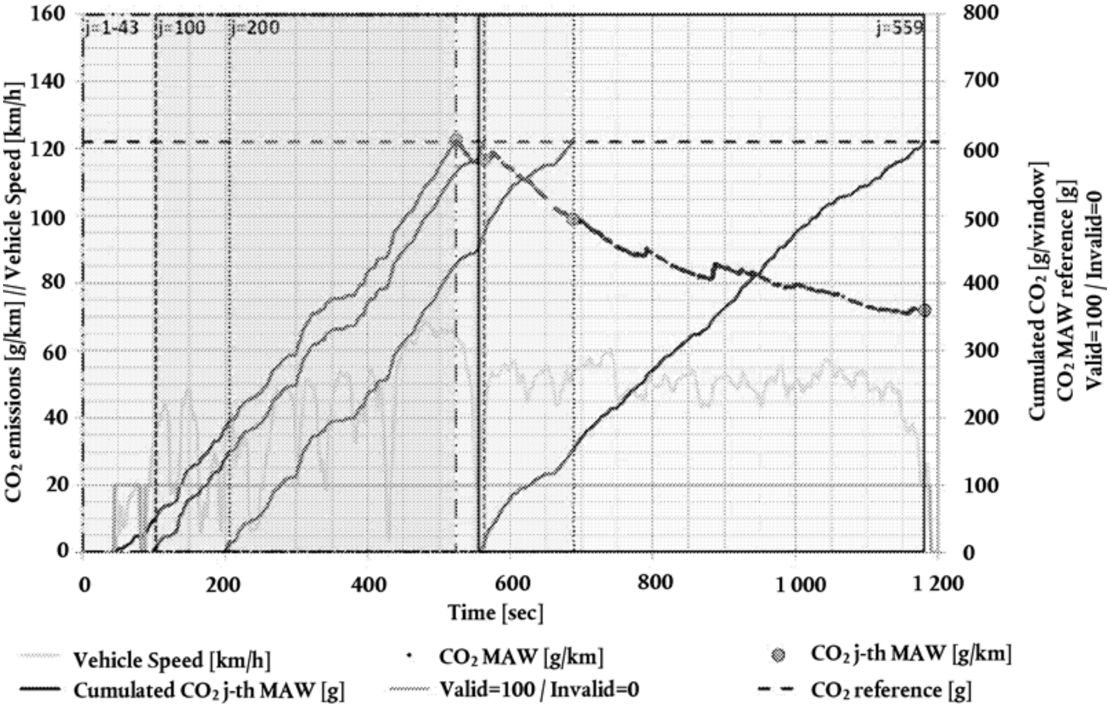
$$M_{CO_2,d,1} = \frac{M_{CO_2,1}}{d_1} = \frac{610{,}217}{4{,}977} = 122{,}61 g / km$$

$$M_{CO_2,d,1} = \frac{M_{CO,1}}{d_1} = \frac{2{,}25}{4{,}98} = 0{,}45 g / km$$

$$M_{NO_x,d,1} = \frac{M_{NO_x,1}}{d_1} = \frac{3{,}51}{4{,}98} = 0{,}71 g / km$$

Figure 6

Instantaneous CO_2 emissions recorded during on-road test with PEMS as a function of time. Rectangular frames indicate the duration of the j^{th} window. Data series named 'Valid=100 / Invalid=0' shows second by second data to be excluded from analysis



7.2. **Evaluation of windows**

TABLE 2

Calculation settings for the CO_2 characteristic curve

CO_2 Low Speed WLTC (P_1) [g/km]	154
CO_2 High Speed WLTC (P_2) [g/km]	96
CO_2 Extra-High Speed WLTC (P_3) [g/km]	120

Reference Point		
P_1	$\bar{v}_{P1} = 19{,}0\ km / h$	$M_{CO_2,d,P_1} = 154 g / km$
P_2	$\bar{v}_{P2} = 56{,}6\ km / h$	$M_{CO_2,d,P_2} = 96 g / km$
P_3	$\bar{v}_{P3} = 92{,}3\ km / h$	$M_{CO_2,d,P_3} = 120 g / km$

The definition of the CO_2 characteristic curve is as follows:

For the section (P_1, P_2):

$$M_{CO_2,d}(\bar{v}) = a_1 \bar{v} + b_1$$

with

$$a_1 = (96 - 154)/(56{,}6 - 19{,}0) = -\frac{58}{37{,}6} = 1{,}543$$

and: b_1 = 154 – (– 1,543) × 19.0 = 154 + 29,317 = 183,317

For the section (P_2, P_3):

$$M_{CO_2,d}(\bar{v}) = a_2\bar{v} + b_2$$

with

$$a_2 = (120 - 96)/(92,3 - 56,6) = \frac{24}{35,7} = 0,672$$

and: b_2 = 96 – 0,672 × 56,6 = 96 – 38,035 = 57,965

Examples of calculation for the weighing factors and the window categorisation as urban, rural or motorway are:

For window #45:

$$M_{CO_2,d,45} = 122,62 g / km$$

$$\bar{v_{45}} = 38,12 \, km / h$$

For the characteristic curve:

$$M_{CO_2,d,CC}(\bar{v_{45}}) = a_1\bar{v_{45}} + b_1 = 1,543 \times 38,12 + 183,317 = 124,498 g / km$$

Verification of:

$$M_{CO_2,d,CC}(\bar{v}_j) \times (1 - tol_1 / 100) \leq M_{CO_2,d,j} \leq M_{CO_2,d,CC}(\bar{v}_j) \times (1 + tol_1 / 100)$$

$$M_{CO_2,d,CC}(\bar{v_{45}}) \times (1 - tol_1 / 100) \leq M_{CO_2,d,45} \leq M_{CO_2,d,CC}(\bar{v_{45}}) \times (1 + tol_1 / 100)$$

124,498 × (1 – 25/100) ≤ 122,62 ≤ 124,498 × (1 + 25/100)

93,373 ≤ 122,62 ≤ 155,622

Leads to: w_{45}= 1

For window #556:

$$M_{CO_2,d,556} = 72,15 g / km$$

$$\bar{v_{556}} = 50,12 \, km / h$$

For the characteristic curve:

$$M_{CO_2,d,CC}(\bar{v_{556}}) = a_1\bar{v_{556}} + b_1 = -1,543 \times 50,12 + 183,317 = 105,982 g / km$$

Verification of:

$$M_{CO_2,d,CC}(\bar{v}_j) \times (1 - tol_2 / 100) \leq M_{CO_2,d,j} \leq M_{CO_2,d,CC}(\bar{v}_j) \times (1 - tol_1 / 100)$$

$$M_{CO_2,d,CC}(\bar{v}_{556}) \times (1 - tol_2 / 100) \leq M_{CO_2,d,556} \leq M_{CO_2,d,CC}(\bar{v}_{556}) \times (1 - tol_1 / 100)$$

105,982 × (1 – 50/100) ≤ 72,15 ≤ 105,982 × (1 + 25/100)

52,991 ≤ 72,15 ≤ 79,487

Leads to:

$$h_{556} = 100 \times \frac{M_{CO_2,d,556} - M_{CO_2,d,\,CC}(\bar{v}_{556})}{M_{CO_2,d,\,CC}(\bar{v}_{556})} = 100 \times \frac{72{,}15 - 105{,}982}{105{,}982} = -31{,}922$$

$w_{556} = k_{21}h_{556} + k_{22} = 0{,}04 \cdot (-31{,}922) + 2 = 0{,}723$

with $k_{21} = 1/(tol_2 - tol_1) = 1/(50 - 25) = 0{,}04$

and $k_{22} = k_{21} = tol_2/(tol_2 - tol_1) = 50/(50 - 25) = 2$

TABLE 3

Emissions numerical data

Window [#]	$t_{1,j}$**[s]**	$t_{2,j} - \Delta t$**[s]**	$t_{2,j}$**[s]**	$M_{CO_2}(t_{2,j} - \Delta t) - M_C$ **[g]**	$M_{CO_2}(t_{2,j}) - M_{CO_2}(t_{1,j}) \geq M_{CO_2,ref}$ **[g]**
1	0	523	524	609,06	610,22
2	1	523	524	609,06	610,22
…	…		…	…	…
43	42	523	524	609,06	610,22
44	43	523	524	609,06	610,22
45	44	523	524	609,06	610,22
46	45	524	525	609,68	610,86
47	46	524	525	609,17	610,34
…	…		…	…	…
100	99	563	564	609,69	612,74
…	…		…	…	…
200	199	686	687	608,44	610,01
…	…		…	…	…
474	473	1 024	1 025	609,84	610,60
475	474	1 029	1 030	609,80	610,49
	…		…	…	…
556	555	1 173	1 174	609,96	610,59
557	556	1 174	1 175	609,09	610,08
558	557	1 176	1 177	609,09	610,59
559	558	1 180	1 181	609,79	611,23

TABLE 4

Window numerical data

Window [#]	$t_{1,j}$ **[s]**	$t_{2,j}$ **[s]**	d_j **[km]**	$\bar{v}_j$ **[km/h]**	$M_{CO_2,j}$ **[g]**	$M_{CO,j}$ **[g]**	$M_{NOx,j}$ **[g]**	$M_{CO_2,d,j}$ **[g/km]**	$M_{CO,d,j}$ **[g/km]**	$M_{NOx,d,j}$ **[g/km]**	$M_{CO_2,d,cc}(\bar{v}_j)$ **[g/km]**	**Window (U/R/M)**	h_j **[%]**	w_j **[%]**

1	0	524	4,98	38,12	610,22	2,25	3,51	122,61	0,45	0,71	124,51	URBAN	–1,53	1,00
2	1	524	4,98	38,12	610,22	2,25	3,51	122,61	0,45	0,71	124,51	URBAN	–1,53	1,00
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
43	42	524	4,98	38,12	610,22	2,25	3,51	122,61	0,45	0,71	124,51	URBAN	–1,53	1,00
44	43	524	4,98	38,12	610,22	2,25	3,51	122,61	0,45	0,71	124,51	URBAN	–1,53	1,00
45	44	524	4,98	38,12	610,22	2,25	3,51	122,62	0,45	0,71	124,51	URBAN	–1,51	1,00
46	45	525	4,99	38,25	610,86	2,25	3,52	122,36	0,45	0,71	124,30	URBAN	–1,57	1,00
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
100	99	564	5,25	41,23	612,74	2,00	3,68	116,77	0,38	0,70	119,70	URBAN	–2,45	1,00
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
200	199	687	6,17	46,32	610,01	2,07	4,32	98,93	0,34	0,70	111,85	RURAL	–11,55	1,00
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
474	473	1 025	7,82	52,00	610,60	2,05	4,82	78,11	0,26	0,62	103,10	RURAL	–24,24	1,00
475	474	1 030	7,87	51,98	610,49	2,06	4,82	77,57	0,26	0,61	103,13	RURAL	–24,79	1,00
	…	…	…	…	…	…	…	…	…	…	…	…	…	…
556	555	1 174	8,46	50,12	610,59	2,23	4,98	72,15	0,26	0,59	105,99	RURAL	–31,93	0,72
557	556	1 175	8,46	50,12	610,08	2,23	4,98	72,10	0,26	0,59	106,00	RURAL	–31,98	0,72
558	557	1 177	8,46	50,07	610,59	2,23	4,98	72,13	0,26	0,59	106,08	RURAL	–32,00	0,72
559	558	1 181	8,48	49,93	611,23	2,23	5,00	72,06	0,26	0,59	106,28	RURAL	–32,20	0,71

7.3. Urban, rural and motorway windows — Trip completeness

In this numerical example, the trip consists of 7 036 averaging windows. Table 5 lists the number of windows classified in urban, rural and motorway according to their average vehicle speed and divided in regions with respect to their distance to the CO_2 characteristic curve. The trip is complete since it comprises at least 15 % of urban, rural and motorway windows out of the total number of windows. In addition the trip is characterised as normal since at least 50 %

of the urban, rural and motorway windows are within the primary tolerances defined for the characteristic curve.

TABLE 5

Verification of trip completeness and normality

Driving Conditions	Numbers	Percentage of windows
All Windows		
Urban	1 909	1 909/7 036 × 100 = 27,1 > 15
Rural	2 011	2 011/7 036 × 100 = 28,6 > 15
Motorway	3 116	3 116/7 036 × 100 = 44,3 > 15
Total	1 909 + 2 011 + 3 116 = 7 036	
Normal Windows		
Urban	1 514	1 514/1 909 × 100 = 79,3 > 50
Rural	1 395	1 395/2 011 × 100 = 69,4 > 50
Motorway	2 708	2 708/3 116 × 100 = 86,9 > 50
Total	1 514 + 1 395 + 2 708 = 5 617	

Appendix 6

Verification of trip dynamic conditions with method 2 (Power Binning)

1. INTRODUCTION

This Appendix describes the data evaluation according to the power binning method, named in this appendix 'evaluation by normalisation to a standardised power frequency (SPF) distribution'.

2. SYMBOLS, PARAMETERS AND UNITS

a_{ref}	Reference acceleration for P_{drive}, [0,45 m/s^2]
D_{WLTC}	intercept of the Veline from WLTC
f_0, f_1, f_2	Driving resistance coefficients
i	Time step for instantaneous measurements, minimum resolution 1Hz
j	Wheel power class, j = 1 to 9
k_{WLTC}	Slope of the Veline from WLTC
$m_{gas, i}$	Instantaneous mass of the exhaust component 'gas' at time step i, [g/s]
$m_{gas, 3s, k}$	3-second moving average mass flow of the exhaust gas component 'gas' in time step k given in 1 Hz resolution [g/s]
$\bar{m}_{gas,j}$	Average emission value of an exhaust gas component in the wheel power class j, g/s
$M_{gas,d}$	Distance-specific emissions for the exhaust gas component 'gas' [g/km]
[F3 $\bar{m}_{gas,U}$	Weighted emission value of an exhaust gas component 'gas' for the subsample of all seconds i with v_i < 60 km/h, g/s
$M_{w,gas,d,U}$	Weighted distance-specific emissions for the exhaust gas component 'gas' for the subsample of all seconds i with v_i < 60 km/h, g/km
$\bar{v}_U$	Weighted vehicle speed in the wheel power class j, km/h]
p	phase of WLTC (low, medium, high and extra-high), p = 1 – 4
P_{drag}	Engine drag power in the Veline approach where fuel injection is zero, [kW]
P_{rated}	Maximum rated engine power as declared by the manufacturer, [kW]
$P_{required,i}$	Power to overcome road load and inertia of a vehicle at time step i, [kW]
$P_{r,,I}$	Same as $P_{required,i}$ defined above used in longer equations
$P_{wot}(n_{norm})$	Full load power curve, [kW]
$P_{c,j}$	Wheel power class limits for class number j, [kW] ($P_{c,j,\ lower\ bound}$ represents the lower limit $P_{c,j,\ upper\ bound}$ the upper limit)
$P_{c,norm, j}$	Wheel power class limits for class j as normalised power value, [-]
$P_{r, I}$	Power demand at the vehicle's wheel to overcome driving resistances in time step i [kW]
$P_{w,3s,k}$	3-second moving average power demand at the vehicle's wheel to overcome driving resistances in in time step k in 1 Hz resolution [kW]
P_{drive}	Power demand at the wheel hub for a vehicle at reference speed and acceleration [kW]
P_{norm}	Normalised power demand at the wheel hub [-]
t_i	Total time in step i, [s]
$t_{c,j}$	Time share of the wheel power class j, [%]
ts	Start time of the WLTC phase p, [s]
te	End time of the WLTC phase p, [s]
TM	Test mass of the vehicle, [kg]; to be specified per section: real test weight in PEMS test, NEDC inertia class weight or WLTP masses (TM_L, TM_H or TM_{ind})

SPF	Standardised Power Frequency distribution
v_i	Actual vehicle speed in time step i, [km/h]
$\bar{v}_j$	Average vehicle speed in the wheel power class j, km/h
v_{ref}	Reference velocity for P_{drive}, [70 km/h]
$v_{3s,k}$	3-second moving average of the vehicle velocity in time step k, [km/h].

3. EVALUATION OF THE MEASURED EMISSIONS USING A STANDARDISED WHEEL POWER FREQUENCY DISTRIBUTION

The power binning method uses the instantaneous emissions of the pollutants, $m_{gas,\ i}$ (g/s) calculated in accordance with Appendix 4.

The $m_{gas,\ i}$ values shall be classified in accordance with the corresponding power at the wheels and the classified average emissions per power class shall be weighted to obtain the emission values for a test with a normal power distribution according to the following points.

3.1. **Sources for the actual wheel power**

[F2The actual wheel power $P_{r,i}$ shall be the total power to overcome air resistance, rolling resistance, road gradients, longitudinal inertia of the vehicle and rotational inertia of the wheels.**]**

When measured and recorded, the wheel power signal shall use a torque signal meeting the linearity requirements laid down in Appendix 2, point 3.2.

As an alternative, the actual wheel power may be determined from the instantaneous CO_2 emissions following the procedure laid down in point 4 of this Appendix.

[F23.2 **Classification of the moving averages to urban, rural and motorway**

The standard power frequencies are defined for urban driving and for the total trip (see paragraph 3.4) and a separate evaluation of the emissions shall be made for the total trip and for the urban part. The three second moving averages calculated according to paragraph 3.3 shall therefore be allocated later to urban and extra-urban driving conditions according to the velocity signal (v_i) from the actual second i as outlined in Table 1-1.

TABLE 1-1

Speed ranges for the allocation of test data to urban, rural and motorway conditions in the power binning method

	Urban	**Rural**	**Motorway**
v_i [km/h]	0 to ≤ 60	> 60 to ≤ 90	> 90**]**

3.3. **Calculation of the moving averages of the instantaneous test data**

Three-second moving averages shall be calculated from all relevant instantaneous test data to reduce influences of possibly imperfect time alignment between emission mass flow and wheel power. The moving average values shall be computed in a 1 Hz frequency:

$$m_{gas,3s,k} = \frac{\sum_{k+3}^{i=k} m_{gas,i}}{3}$$

$$P_{w,3s,k} = \frac{\sum_{k+3}^{i=k} P_{w,i}}{3}$$

$$v_{3s,k} = \frac{\sum_{k+3}^{i=k} v_i}{3}$$

Where

k	time step for moving average values
i	time step from instantaneous test data.

3.4. **Set up of the wheel power classes for emission classification**

3.4.1. The power classes and the corresponding time shares of the power classes in normal driving are defined for normalised power values to be representative for any LDV (Table 1-2).

TABLE 1-2

Normalised standard power frequencies for urban driving and for a weighted average for a total trip consisting of 1/3 urban, 1/3 road, 1/3 motorway mileage

Power class No	**$P_{c,norm,j}$ [-]**		**Urban**	**Total trip**
	From >	**to ≤**	**Time share, $t_{C,j}$**	
1		– 0,1	21,9700 %	18,5611 %
2	– 0,1	0,1	28,7900 %	21,8580 %
3	0,1	1	44,0000 %	43,45 %
4	1	1,9	4,7400 %	13,2690 %
5	1,9	2,8	0,4500 %	2,3767 %
6	2,8	3,7	0,0450 %	0,4232 %
7	3,7	4,6	0,0040 %	0,0511 %
8	4,6	5,5	0,0004 %	0,0024 %
9	5,5		0,0003 %	0,0003 %

The $P_{c,norm}$ columns in Table 1-2 shall be de-normalised by multiplication with P_{drive}, where P_{drive} is the actual wheel power of the tested car in the type approval settings at the chassis dynamometer at v_{ref} and a_{ref}.

$P_{c,j}$ [kW] = $P_{c,norm,\,j} \times P_{drive}$

$$P_{drive} = \frac{v_{ref}}{3{,}6} \times \left(f_0 + f_1 \times v_{ref} + f_2 \times v_2^{ref} + TM_{NEDC} \times a_{ref}\right) \times 0{,}001$$

Where:

— *j* is the power class index according to Table 1-2

— The driving resistance coefficients f_0, f_1, f_2 should be calculated with a least squares regression analysis from the following definition:

$P_{Corrected}/v = f_0 + f_1 \times v + f_2 \times v^2$

with ($P_{Corrected}/v$) being the road load force at vehicle velocity *v* for the NEDC test cycle defined in point 5.1.1.2.8 of Appendix 7 to Annex 4a of UNECE Regulation 83 — 07 series of amendments.

— TM_{NEDC} is the inertia class of the vehicle in the type approval test, [kg].

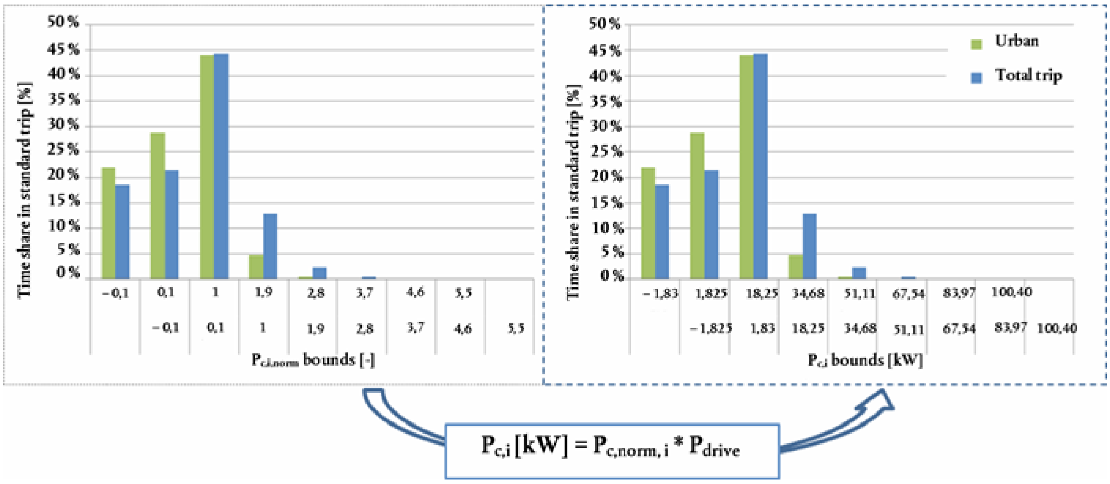
3.4.2. *Correction of the wheel power classes*

The maximum wheel power class to be considered is the highest class in Table 1-2 which includes (P_{rated} × 0,9). The time shares of all excluded classes shall be added to the highest remaining class.

From each $P_{c,norm,j}$ the corresponding $P_{c,j}$ shall be calculated to define the upper and lower bounds in kW per wheel power class for the tested vehicle as shown in Figure 1.

Figure 1

Schematic picture for converting the normalised standardised power frequency into a vehicle specific power frequency



An example for this de-normalisation is given below.

Example for input data:

Parameter	Value
f_0 [N]	79,19
f_1 [N/(km/h)]	0,73
f_2 [N/(km/h)^2]	0,03
TM [kg]	1 470
P_{rated} [kW]	120 (Example 1)
P_{rated} [kW]	75 (Example 2)

Corresponding results:

P_{drive} = 70 [km/h]/3,6 × (79,19 + 0,73 [N/(km/h)] × 70[km/h] + 0,03 [N/(km/h)^2] × (70 [km/h])^2 + 1 470 [kg] × 0,45[m/s^2]) × 0,001

P_{drive} = 18.25 kW

TABLE 2

De-normalised standard power frequency values from Table 1-2 (for Example 1)

Status: Point in time view as at 31/01/2020.
Changes to legislation: There are currently no known outstanding effects for the Commission Regulation (EC) No 692/2008, ANNEX IIIA. (See end of Document for details)

Power class No	$P_{c,j}$ [kW]		Urban	Total trip
	From >	to ≤	Time share, $t_{C,j}$ [%]	
1	All < – 1,825	– 1,825	21,97 %	18,5611 %
2	– 1,825	1,825	28,79 %	21,8580 %
3	1,825	18,25	44,00 %	43,4583 %
4	18,25	34,675	4,74 %	13,2690 %
5	34,675	51,1	0,45 %	2,3767 %
6	51,1	67,525	0,045 %	0,4232 %
7	67,525	83,95	0,004 %	0,0511 %
8	83,95	100,375	0,0004 %	0,0024 %
9[a]	100,375	All > 100,375	0,00025 %	0,0003 %

a The highest class wheel power class to be considered is the one containing 0,9 × P*rated*. Here 0,9 × 120 = 108.

TABLE 3

De-normalised standard power frequency values from Table 1-2 (for Example 2)

Power class No	$P_{c,j}$ [kW]		Urban	Total trip
	From >	to ≤	Time share, $t_{C,j}$ [%]	
1	All < – 1,825	– 1,825	21,97 %	18,5611 %
2	– 1,825	1,825	28,79 %	21,8580 %
3	1,825	18,25	44,00 %	43,4583 %
4	18,25	34,675	4,74 %	13,2690 %
5	34,675	51,1	0,45 %	2,3767 %
6[a]	51,1	All > 51,1	0,04965 %	0,4770 %
7	67,525	83,95	—	—
8	83,95	100,375	—	—
9	100,375	All > 100,375	—	—

a The highest class wheel power class to be considered is the one containing 0,9 × P*rated*. Here 0,9 × 75 = 67,5.

3.5. Classification of the moving average values

Each moving average value calculated according to point 3.2 shall be sorted into the de-normalised wheel power class into which the actual 3-second moving average wheel power $P_{w,3s,k}$ fits. The de-normalised wheel power class limits have to be calculated according to point 3.3.

The classification shall be done for all three-second moving averages of the entire valid trip data as well as for the all urban trip parts. Additionally all moving averages classified to urban according to the velocity limits defined in Table 1-1 shall be classified into one set of urban power classes independently of the time when the moving average appeared in the trip.

Then the average of all three-second moving average values within a wheel power class shall be calculated for each wheel power class per parameter. The equations are described below and shall be applied once for the urban data set and once for the total data set.

Classification of the 3-second moving average values into power class j (j = 1 to 9):

if

$$P_{c,j_{lower\ bound}} < P_{w,3s,k} \leq P_{c,j_{upper\ bound}}$$

then: class index for emissions and velocity = j.

The number of 3-second moving average values shall be counted for each power class:

if

$$P_{c,j_{lower\ bound}} < P_{w,3s,k} \leq P_{c,j_{upper\ bound}}$$

then: $counts_j$ = n + 1 ($counts_j$ is counting the number of 3-second moving average emission value in a power class to check later the minimum coverage demands).

3.6. **Check of power class coverage and of normality of power distribution**

For a valid test the time shares of the single wheel power classes shall be in the ranges listed in Table 4.

TABLE 4

Minimum and maximum shares per power class for a valid test

	$P_{c,norm,j}$ [-]		**Total trip**		**Urban trip parts**	
Power class No	**From >**	**to ≤**	**lower bound**	**upper bound**	**lower bound**	**upper bound**
Sum 1 + 2[a]		0,1	15 %	60 %	5 %[a]	60 %
3	0,1	1	35 %	50 %	28 %	50 %
4	1	1,9	7 %	25 %	0,7 %	25 %
5	1,9	2,8	1,0 %	10 %	> 5 counts	5 %
6	2,8	3,7	> 5 counts	2,5 %	0 %	2 %
7	3,7	4,6	0 %	1,0 %	0 %	1 %
8	4,6	5,5	0 %	0,5 %	0 %	0,5 %
9	5,5		0 %	0,25 %	0 %	0,25 %

a Representing the total of motoring and low power conditions

In addition to the requirements in Table 4, a minimum coverage of 5 counts is demanded for the total trip in each wheel power class up to the class containing 90 % of the rated power to provide a sufficient sample size.

A minimum coverage of five counts is required for the urban part of the trip in each wheel power class up to class No 5. If the counts in the urban part of the trip in a wheel power class above No 5 are less than five, the average class emission value shall be set to zero.

3.7. **Averaging of the measured values per wheel power class**

The moving averages sorted in each wheel power class shall be averaged as follows:

$$\bar{m}_{gas,j} = \frac{\sum_{all\ k\ in\ class_j} m_{gas,3s,k}}{counts_j}$$

$$\bar{v}_j = \frac{\sum_{all\ k\ in\ class\ j} v_{3s,k}}{counts_j}$$

Where

j	wheel power class 1 to 9 according to Table 1
$\bar{m}_{gas,j}$	average emission value of an exhaust gas component in a wheel power class (separate value for total trip data and for the urban parts of the trip), [g/s]
$\bar{v}_j$	average velocity in a wheel power class (separate value for total trip data and for the urban parts of the trip), [km/h]
k	time step for moving average values.

3.8. **Weighting of the average values per wheel power class**

The average values of each wheel power class shall be multiplied with the time share, $t_{C,j}$ per class according to Table 1-2 and summed up to produce the weighted average value for each parameter. This value represents the weighted result for a trip with the standardised power frequencies. The weighted averages shall be computed for the urban part of the test data using the time shares for urban power distribution as well as for the total trip using the time shares for the total.

The equations are described below and shall be applied once for the urban data set and once for the total data set.

$$\bar{m}_{gas} = \sum_9^{j=1} \bar{m}_{gas,j} \times t_{c,j}$$

$$\bar{v} = \sum_{j=1}^{9} \bar{v}_j \times t_{c,j}$$

[F2 3.9. **Calculation of the weighted distance-specific emission value**

The time-based weighted averages of the emissions in the test shall be converted into distance-based emissions once for the urban data set and once for the total data set as follows:

For the total trip:

$$M_{w,gas,d} = 1000 \times \frac{\bar{m}_{gas} \times 3600}{\bar{v}}$$

For the urban part of the trip:

$$M_{w,gas,d,U} = 1000 \times \frac{\bar{m}_{gas,U} \times 3600}{\bar{v}_U}$$

Using these formulas, weighted averages shall be calculated for the following pollutants for the total trip and for the urban part of the trip:

$M_{w,NOx,d}$	weighted NO_x test result in [mg/km]
$M_{w,NOx,d,U}$	weighted NO_x test result in [mg/km]
$M_{w,CO,d}$	weighted CO test result in [mg/km]
$M_{w,CO,d,U}$	weighted CO test result in [mg/km]**]**

4. ASSESSMENT OF THE WHEEL POWER FROM THE INSTANTANEOUS CO_2 MASS FLOW

The power at the wheels ($P_{w,i}$) can be computed from the measured CO_2 mass flow in 1 Hz basis. For this calculation the vehicle-specific CO_2 lines ('Veline') shall be used.

The Veline shall be calculated from the vehicle type approval test in the WLTC according to the test procedure described in UNECE Global Technical Regulation No 15 — worldwide harmonised light vehicles test procedure (ECE/TRANS/180/Add.15).

The average wheel power per WLTC phase shall be calculated. in 1 Hz from the driven velocity and from the chassis dynamometer settings. All wheel power values below the drag power shall be set to the drag power value.

$$P_{w,i} = \frac{v_i}{3{,}6} \times \left(f_0 + f_1 \times v_i + f_2 \times v_2^i + TM \times a_i\right) \times 0{,}001$$

With

f_0, f_1, f_2	road load coefficients used in in the WLTP test performed with the vehicle
TM	test mass of the vehicle in the WLTP test performed with the vehicle in [kg]

$P_{drag} = -0{,}04 \times P_{rated}$

$if\ P_{w,i} < P_{drag}\ then\ P_{w,i} = P_{drag}$

The average power per WLTC phase is calculated from the 1 Hz wheel power according to:

$$\bar{P}_{w,p} = \frac{\sum_{ts}^{j=te} P_{w,i}}{te - ts}$$

With

p	phase of WLTC (low, medium, high and extra-high)
ts	Start time of the WLTC phase p, [s]
te	end time of the WLTC phase p, [s].

Then a linear regression shall be made with the CO_2 mass flow from the bag values of the WLTC on the y-axis and from the average wheel power $P_{w,p}$ per phase on the x-axis as illustrated in Figure 2.

The resulting Veline equation defines the CO_2 mass flow as function of the wheel power:

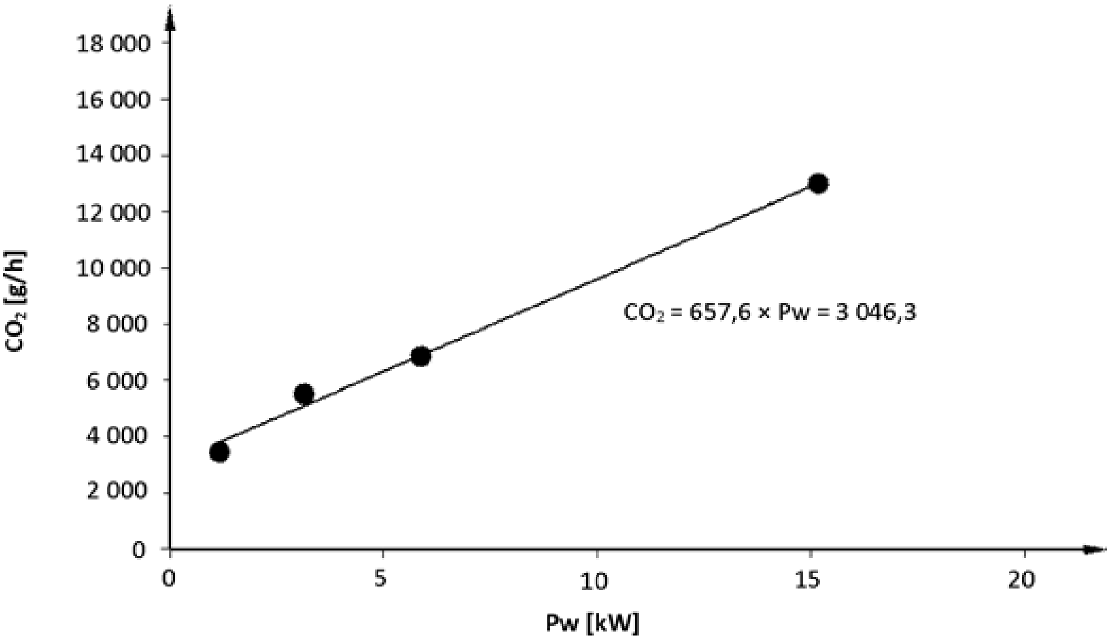
$CO_{2_i} = k_{WLTC} X\ P_{w,i} + D_{WLTC}$	CO_2 in [g/h]

Where

k_{WLTC}	slope of the Veline from WLTC, [g/kWh]
D_{WLTC}	intercept of the Veline from WLTC, [g/h].

Figure 2

Schematic picture of setting up the vehicle-specific Veline from the CO_2 test results in the four phases of the WLTC



The actual wheel power shall be calculated from the measured CO_2 mass flow according to:

$$P_{w,i} = \frac{CO_{2_i} - D_{WLTC}}{k_{WLTC}}$$

With

CO_2 in [g/h]

$P_{W,j}$ in [kW]

The above equation can be used to provide P_{Wi} for the classification of the measured emissions as described in point 3 with following additional conditions in the calculation

if $v_i < 0{,}5$ and if $a_i < 0$ then $P_{w,i} = 0$	v in [m/s]
if $CO2_i < 0{,}5\ X\ D_{WLTC}$ then $P_{w,i} = P_{drag}$	v in [m/s].

Appendix 7

Selection of vehicles for PEMS testing at initial type approval

1. INTRODUCTION

Due to their particular characteristics, PEMS tests are not required to be performed for each *'vehicle type with regard to emissions and vehicle repair and maintenance information'* as defined in Article 2(1) of this Regulation, which is called in the following *'vehicle emission type'*. Several vehicle emission types may be put together by the vehicle manufacturer to form a *'PEMS test family'* according to the requirements of point 3, which shall be validated according to the requirements of point 4.

2. SYMBOLS, PARAMETERS AND UNITS

N	— Number of vehicle emission types
NT	— Minimum number of vehicle emission types
PMR_H	— highest power-to-mass-ratio of all vehicles in the PEMS test family
PMR_L	— lowest power-to-mass-ratio of all vehicles in the PEMS test family
V_eng_max	— maximum engine volume of all vehicles within the PEMS test family.

3. PEMS TEST FAMILY BUILDING

A PEMS test family shall comprise vehicles with similar emission characteristics. Upon the choice of the manufacturer vehicle emission types may be included in a PEMS test family only if they are identical with respect to the characteristics in points 3.1 and 3.2.

3.1. **Administrative criteria**

3.1.1. The approval authority issuing the emission type approval according to Regulation (EC) 715/2007.

3.1.2. A single vehicle manufacturer.

3.2. **Technical criteria**

3.2.1. Propulsion type (e.g. ICE, HEV, PHEV).

3.2.2. Type(s) of fuel(s) (e.g. petrol, diesel, LPG, NG, …). Bi- or flex-fuelled vehicles may be grouped with other vehicles, with which they have one of the fuels in common.

3.2.3. Combustion process (e.g. two stroke, four stroke)

3.2.4. Number of cylinders

3.2.5. Configuration of the cylinder block (e.g. in-line, V, radial, horizontally opposed)

3.2.6. Engine volume

The vehicle manufacturer shall specify a value V_eng_max (= maximum engine volume of all vehicles within the PEMS test family). The engine volumes of vehicles in the PEMS test family shall not deviate more than – 22 % from V_eng_max if V_eng_max ≥ 1 500 ccm and – 32 % from V_eng_max if V_eng_max < 1 500 ccm.

3.2.7. Method of engine fuelling (e.g. indirect or direct or combined injection)

3.2.8. Type of cooling system (e.g. air, water, oil)

3.2.9. Method of aspiration such as naturally aspirated, pressure charged, type of pressure charger (e.g. externally driven, single or multiple turbo, variable geometries, …)

Status: Point in time view as at 31/01/2020.
Changes to legislation: There are currently no known outstanding effects for the Commission Regulation (EC) No 692/2008, ANNEX IIIA. (See end of Document for details)

3.2.10. Types and sequence of exhaust after-treatment components (e.g. three-way catalyst, oxidation catalyst, lean NO_x trap, SCR, lean NOx catalyst, particulate trap).

3.2.11. Exhaust gas recirculation (with or without, internal/external, cooled/non-cooled, low/high pressure).

3.3. **Extension of a PEMS test family**

An existing PEMS test family may be extended by adding new vehicle emission types to it. The extended PEMS test family and its validation must also fulfil the requirements of points 3 and 4. This may in particular require the PEMS testing of additional vehicles to validate the extended PEMS test family according to point 4.

3.4. **Alternative PEMS test family**

As an alternative to the provisions of points 3.1 to 3.2 the vehicle manufacturer may define a PEMS test family, which is identical to a single vehicle emission type. In this the requirement of point 4.1.2 for validating the PEMS test family shall not apply.

4. VALIDATION OF A PEMS TEST FAMILY

4.1. **General requirements for validating a PEMS test family**

4.1.1. The vehicle manufacturer presents a representative vehicle of the PEMS test family to the type-approval authority. The vehicle shall be subject to a PEMS test carried out by a Technical Service to demonstrate compliance of the representative vehicle with the requirements of this Annex.

4.1.2. The authority responsible for issuing the emission type-approval in accordance with Regulation (EC) No 715/2007 selects additional vehicles according to the requirements of point 4.2 of this Appendix for PEMS testing carried out by a Technical Service to demonstrate compliance of the selected vehicles with the requirements of this Annex. The technical criteria for selection of an additional vehicle according to point 4.2 of this Appendix shall be recorded with the test results.

[X1 4.1.3. With agreement of the type-approval authority, a PEMS test can also be driven by a different operator witnessed by a Technical Service, provided that at least the tests of the vehicles required by points 4.2.2 and 4.2.6 of this Appendix] and in total at least 50 % of the PEMS tests required by this Appendix for validating the PEMS test family are driven by a Technical Service. In such case the Technical Service remains responsible for the proper execution of all PEMS tests pursuant to the requirements of this Annex.

Editorial Information

X1 Substituted by Corrigendum to Commission Regulation (EU) 2016/427 of 10 March 2016 amending Regulation (EC) No 692/2008 as regards emissions from light passenger and commercial vehicles (Euro 6) (Official Journal of the European Union L 82 of 31 March 2016).

4.1.4. A PEMS test results of a specific vehicle may be used for validating different PEMS test families according to the requirements of this Appendix under the following conditions:

— the vehicles included in all PEMS test families to be validated are approved by a single authority according to the requirements of Regulation (EC) 715/2007 and this authority agrees to the use of the specific vehicle's PEMS test results for validating different PEMS test families,

— each PEMS test family to be validated includes a vehicle emission type, which comprises the specific vehicle;

For each validation the applicable responsibilities are considered to be borne by the manufacturer of the vehicles in the respective family, regardless of whether this manufacturer was involved in the PEMS test of the specific vehicle emission type.

4.2. **Selection of vehicles for PEMS testing when validating a PEMS test family**

By selecting vehicles from a PEMS test family it should be ensured that the following technical characteristics relevant for pollutant emissions are covered by a PEMS test. One vehicle selected for testing can be representative for different technical characteristics. For the validation of a PEMS test family vehicles shall be selected for PEMS testing as follows:

4.2.1. For each combination of fuels (e.g. petrol-LPG, petrol-NG, petrol only), on which some vehicle of the PEMS test family can operate, at least one vehicle that can operate on this combination of fuels shall be selected for PEMS testing.

4.2.2. The manufacturer shall specify a value PMR_H (= highest power-to-mass-ratio of all vehicles in the PEMS test family) and a value PMR_L (= lowest power-to-mass-ratio of all vehicles in the PEMS test family). Here the 'power-to-mass-ratio' corresponds to the ratio of the maximum net power of the internal combustion engine as indicated in point 3.2.1.8 of Appendix 3 to Annex I of this Regulation and of the reference mass as defined in Article 3(3) of Regulation (EC) No 715/2007. At least one vehicle configuration representative for the specified PMR_H and one vehicle configuration representative for the specified PMR_L of a PEMS test family shall be selected for testing. If the power-to-mass ratio of a vehicle deviates by not more than 5 % from the specified value for PMR_H, or PMR_L, the vehicle should be considered as representative for this value.

4.2.3. At least one vehicle for each transmission type (e.g. manual, automatic, DCT) installed in vehicles of the PEMS test family shall be selected for testing.

4.2.4. At least one four-wheel drive vehicle (4 × 4 vehicle) shall be selected for testing if such vehicles are part of the PEMS test family.

4.2.5. For each engine volume occurring on a vehicle in the PEMS family at least one representative vehicle shall be tested.

4.2.6. At least one vehicle for each number of installed exhaust after-treatment components shall be selected for testing.

4.2.7. Notwithstanding the provisions in points 4.2.1 to 4.2.6, at least the following number of vehicle emission types of a given PEMS test family shall be selected for testing:

Number N of vehicle emission types in a PEMS test family	Minimum number NT of vehicle emission types selected for PEMS testing
1	1
from 2 to 4	2
from 5 to 7	3
from 8 to 10	4

a NT shall be rounded to the next higher integer number.

from 11 to 49	NT = 3 + 0,1 × N[a]
more than 49	NT = 0,15 × N[a]

a NT shall be rounded to the next higher integer number.

5. REPORTING

5.1. The vehicle manufacturer provides a full description of the PEMS test family, which includes in particular the technical criteria described in point 3.2 and submits it to the responsible type approval authority.

5.2. The manufacturer attributes a unique identification number of the format *MS-OEM-X-Y* to the PEMS test family and communicates it to the type approval authority. Here *MS* is the distinguishing number of the Member State issuing the EC type-approval[(4)], OEM is the 3 character manufacturer, *X* is a sequential number identifying the original PEMS test family and *Y* is a counter for its extensions (starting with 0 for a PEMS test family not extended yet).

5.3. The type approval authority and the vehicle manufacturer shall maintain a list of vehicle emission types being part of a given PEMS test family on the basis of emission type approval numbers. For each emission type all corresponding combinations of vehicle type approval numbers, types, variants and versions as defined in Sections 0.10 and 0.2 of the vehicle's EC certificate of conformity shall be provided as well.

5.4. The type approval authority and the vehicle manufacturer shall maintain a list of vehicle emission types selected for PEMS testing in order validate a PEMS test family in accordance with point 4, which also provides the necessary information on how the selection criteria of point 4.2 are covered. This list shall also indicate whether the provisions of point 4.1.3 were applied for a particular PEMS test.

[F3 Appendix 7a

Verification of overall trip dynamics

1. INTRODUCTION

This Appendix describes the calculation procedures to verify the overall trip dynamics, to determine the overall excess or absence of dynamics during urban, rural and motorway driving.

2. SYMBOLS

RPA	relative positive acceleration
‘acceleration resolution a_{res}’	minimum acceleration > 0 measured in m/s^2
T4253H	compound data smoother
‘positive acceleration a_{pos}’	acceleration [m/s^2] greater than 0,1 m/s^2

Index (i) refers to the time step

Index (j) refers to the time step of positive acceleration datasets

Index (k) refers to the category (t = total, u = urban, r = rural, m = motorway)

Δ	— difference
>	— larger
≥	— larger or equal
%	— per cent
<	— smaller
≤	— smaller or equal
a	— acceleration [m/s^2]
a_i	— acceleration in time step i [m/s^2]
a_{pos}	— positive acceleration greater than 0,1 m/s^2 [m/s^2]
$a_{pos,i,k}$	— positive acceleration greater than 0,1 m/s^2 in time step i considering the urban, rural and motorway shares [m/s^2]
a_{res}	— acceleration resolution [m/s^2]
d_i	— distance covered in time step i [m]
$d_{i,k}$	— distance covered in time step i considering the urban, rural and motorway shares [m]
M_k	— number of samples for urban, rural and motorway shares with positive acceleration greater than 0,1 m/s^2
N_k	— total number of samples for the urban, rural and motorway shares and the complete trip
RPA_k	— relative positive acceleration for urban, rural and motorway shares [m/s^2 or kWs/(kg × km)]
t_k	— duration of the urban, rural and motorway shares and the complete trip [s]
v	— vehicle speed [km/h]
v_i	— actual vehicle speed in time step i [km/h]
$v_{i,k}$	— actual vehicle speed in time step i considering the urban, rural and motorway shares [km/h]
$(v \cdot a)_i$	— actual vehicle speed per acceleration in time step i [m^2/s^3 or W/kg]

$(v \cdot a_{pos})_{j,k}$ — actual vehicle speed per positive acceleration greater than 0,1 m/s^2 in time step j considering the urban, rural and motorway shares [m^2/s^3 or W/kg].

$(v \cdot a_{pos})_{k}$_[95] — 95th percentile of the product of vehicle speed per positive acceleration greater than 0,1 m/s^2 for urban, rural and motorway shares [m^2/s^3 or W/kg]

$\bar{v}_k$ — average vehicle speed for urban, rural and motorway shares [km/h]

3. TRIP INDICATORS

3.1. **Calculations**

3.1.1. *Data pre-processing*

Dynamic parameters like acceleration, $v \cdot a_{pos}$ or RPA shall be determined with a speed signal of an accuracy of 0,1 % above 3 km/h and a sampling frequency of 1 Hz. This accuracy requirement is generally fulfilled by wheel (rotational) speed signals.

The speed trace shall be checked for faulty or implausible sections. The vehicle speed trace of such sections is characterised by steps, jumps, terraced speed traces or missing values. Short faulty sections shall be corrected, for example by data interpolation or benchmarking against a secondary speed signal. Alternatively, short trips containing faulty sections could be excluded from the subsequent data analysis. In a second step the acceleration values shall be ranked in ascending order, in order to determine the acceleration resolution a_{res} = (minimum acceleration value > 0).

If $a_{res} \leq 0{,}01$ m/s^2, the vehicle speed measurement is accurate enough.

If $0{,}01 < a_{res} \leq r_{max}$ m/s^2, smoothing by using a T4253 Hanning filter.

If $a_{res} > r_{max}$ m/s^2, the trip is invalid.

The T4253 Hanning filter performs the following calculations: The smoother starts with a running median of 4, which is centred by a running median of 2. It then re-smoothes these values by applying a running median of 5, a running median of 3, and Hanning (running weighted averages). Residuals are computed by subtracting the smoothed series from the original series. This whole process is then repeated on the computed residuals. Finally, the smoothed residuals are computed by subtracting the smoothed values obtained the first time through the process.

The correct speed trace builds the basis for further calculations and binning as described in paragraph 3.1.2.

3.1.2. *Calculation of distance, acceleration and v · a*

The following calculations shall be performed over the whole time-based speed trace (1 Hz resolution) from second 1 to second t_t (last second).

The distance increment per data sample shall be calculated as follows:

$d_i = v_i/3{,}6,\ i = 1\ to\ N_t$

Where:

d_i is the distance covered in time step i [m]

v_i is the actual vehicle speed in time step i [km/h]

N_t is the total number of samples

The acceleration shall be calculated as follows:

$a_i = (v_{i+1} - v_{i-1})/(2 \cdot 3{,}6)$, $i = 1$ *to* N_t

Where:

a_i is the acceleration in time step i [m/s^2]. For $i = 1$: $v_{i-1} = 0$, for $i = N_t$: $v_{i+1} = 0$.

The product of vehicle speed per acceleration shall be calculated as follows:

$(v \cdot a)_i = v_i \cdot a_i/3{,}6$, $i = 1$ *to* N_t

Where:

$(v \cdot a)_i$ is the product of the actual vehicle speed per acceleration in time step i [m^2/s^3 or W/kg].

3.1.3. *Binning of the results*

After the calculation of a_i and $(v \cdot a)_i$, the values v_i, d_i, a_i and $(v \cdot a)_i$ shall be ranked in ascending order of the vehicle speed.

All datasets with $v_i \leq 60$ *km/h* belong to the 'urban' speed bin, all datasets with 60 *km/h* $< v_i \leq 90$ *km/h* belong to the 'rural' speed bin and all datasets with $v_i > 90$ *km/h* belong to the 'motorway' speed bin.

The number of datasets with acceleration values $a_i > 0{,}1$ m/s^2 shall be bigger or equal to 150 in each speed bin.

For each speed bin the average vehicle speed
$\bar{v}_k$
shall be calculated as follows:

$\bar{v}_k = (\sum_i v_{i,k})/N_k$
, $i = 1$ *to* $N_k, k = u,r,m$

Where:

N_k is the total number of samples of the urban, rural, and motorway shares.

3.1.4. *Calculation of* $v \cdot a_{pos}$*_[95] per speed bin*

The 95th percentile of the $v \cdot a_{pos}$ values shall be calculated as follows:

The $(v \cdot a)_{i,k}$ values in each speed bin shall be ranked in ascending order for all datasets with $a_{i,k} \geq 0{,}1$ *m/s*^{2} and the total number of these samples M_k shall be determined.

Percentile values are then assigned to the $(v \cdot a_{pos})_{j,k}$ values with $a_{i,k} \geq 0{,}1$ *m/s*^{2} as follows:

The lowest $v \cdot a_{pos}$ value gets the percentile $1/M_k$, the second lowest $2/M_k$, the third lowest $3/M_k$ and the highest value M_k/M_k =100 %.

$(v \cdot a_{pos})_k$_[95] is the $(v \cdot a_{pos})_{j,k}$ value, with $j/M_k = 95$ %. If $j/M_k = 95$ % cannot be met, $(v \cdot a_{pos})_k$_[95] shall be calculated by linear interpolation between consecutive samples j and j + 1 with $j/M_k < 95$ % and $(j + 1)/M_k > 95$ %.

The relative positive acceleration per speed bin shall be calculated as follows:

$RPA_k = \Sigma_j(\Delta t \cdot (v \cdot a_{pos})_{j,k})/\Sigma_i d_{i,k}, j = 1 \text{ to } M_k, i = 1 \text{ to } N_k, k = u,r,m$

Where:

RPA_k is the relative positive acceleration for urban, rural and motorway shares in [m/s^2 or kWs/(kg*km)]

Δt	time difference equal to 1 second
M_k	the sample number for urban, rural and motorway shares with positive acceleration
N_k	the total sample number for urban, rural and motorway shares.

4. VERIFICATION OF TRIP VALIDITY

4.1.1. *Verification of v*$a_{pos\_[95]}$ per speed bin (with v in [km/h])*

If
$\bar{v}_k \leq 74{,}6\, km / h$

and

$(v \times a_{pos})_{k}\_[95] > (0{,}136 \times \bar{v}_k + 14{,}44)$

is fulfilled, the trip is invalid.

If
$\bar{v}_k > 74{,}6\, km / h$
and
$(v \times a_{pos})_{k}\_[95] > (0{,}0742 \times \bar{v}_k + 18{,}966)$
is fulfilled, the trip is invalid.

4.1.2. *Verification of RPA per speed bin*

If
$\bar{v}_k \leq 94{,}05\, km / h$
and
$RPA_k < (-0{,}0016 \times \bar{v}_k + 0{,}1755)$
is fulfilled, the trip is invalid.

If
$\bar{v}_k > 94{,}05\, km / h$
and $RPA_k < 0{,}025$ is fulfilled, the trip is invalid.

Appendix 7b

Procedure to determine the cumulative positive elevation gain of a trip

1. INTRODUCTION

This Appendix describes the procedure to determine the cumulative elevation gain of an RDE trip.

2. SYMBOLS

$d(0)$	—	distance at the start of a trip [m]
d	—	cumulative distance travelled at the discrete way point under consideration [m]
d_0	—	cumulative distance travelled until the measurement directly before the respective way point d [m]
d_1	—	cumulative distance travelled until the measurement directly after the respective way point d [m]
d_a	—	reference way point at $d(0)$ [m]
d_e	—	cumulative distance travelled until the last discrete way point [m]
d_i	—	instantaneous distance [m]
d_{tot}	—	total test distance [m]
$h(0)$	—	vehicle altitude after the screening and principle verification of data quality at the start of a trip [m above sea level]
$h(t)$	—	vehicle altitude after the screening and principle verification of data quality at point t [m above sea level]
$h(d)$	—	vehicle altitude at the way point d [m above sea level]
$h(t-1)$	—	vehicle altitude after the screening and principle verification of data quality at point t-1 [m above sea level]
$h_{corr}(0)$	—	corrected altitude directly before the respective way point d [m above sea level]
$h_{corr}(1)$	—	corrected altitude directly after the respective way point d [m above sea level]
$h_{corr}(t)$	—	corrected instantaneous vehicle altitude at data point t [m above sea level]
$h_{corr}(t-1)$	—	corrected instantaneous vehicle altitude at data point t-1 [m above sea level]
$h_{GPS,i}$	—	instantaneous vehicle altitude measured with GPS [m above sea level]
$h_{GPS}(t)$	—	vehicle altitude measured with GPS at data point t [m above sea level]
$h_{int}(d)$	—	interpolated altitude at the discrete way point under consideration d [m above sea level]
$h_{int,sm,1}(d)$	—	smoothed interpolated altitude, after the first smoothing run at the discrete way point under consideration d [m above sea level]
$h_{map}(t)$	—	vehicle altitude based on topographic map at data point t [m above sea level]
Hz	—	hertz
km/h	—	kilometre per hour
m	—	metre
$road_{grade,1}(d)$	—	smoothed road grade at the discrete way point under consideration d after the first smoothing run [m/m]
$road_{grade,2}(d)$	—	smoothed road grade at the discrete way point under consideration d after the second smoothing run [m/m]
sin	—	trigonometric sine function
t	—	time passed since test start [s]

t_0	—	time passed at the measurement directly located before the respective way point *d* [s]
v_i	—	instantaneous vehicle speed [km/h]
$v(t)$	—	vehicle speed of data point t [km/h].

3. GENERAL REQUIREMENTS

The cumulative positive elevation gain of an RDE trip shall be determined based on three parameters: the instantaneous vehicle altitude $h_{GPS,i}$ [m above sea level] as measured with the GPS, the instantaneous vehicle speed v_i [km/h] recorded at a frequency of 1 Hz and the corresponding time *t* [s] that has passed since test start.

4. CALCULATION OF CUMULATIVE POSITIVE ELEVATION GAIN

4.1. **General**

The cumulative positive elevation gain of an RDE trip shall be calculated as a three-step procedure, consisting of: (i) the screening and principle verification of data quality; (ii) the correction of instantaneous vehicle altitude data; and (iii) the calculation of the cumulative positive elevation gain.

4.2. **Screening and principle verification of data quality**

The instantaneous vehicle speed data shall be checked for completeness. Correcting for missing data is permitted if gaps remain within the requirements specified in Point 7 of Appendix 4; else, the test results shall be voided. The instantaneous altitude data shall be checked for completeness. Data gaps shall be completed by data interpolation. The correctness of interpolated data shall be verified by a topographic map. It is recommended to correct interpolated data if the following condition applies:

$$|h_{GPS}(t) - h_{map}(t)| > 40\ m$$

The altitude correction shall be applied so that:

$$h(t) = h_{map}(t)$$

where:

$h(t)$	—	vehicle altitude after the screening and principle verification of data quality at data point t [m above sea level]
$h_{GPS}(t)$	—	vehicle altitude measured with GPS at data point t [m above sea level]
$h_{map}(t)$	—	vehicle altitude based on topographic map at data point t [m above sea level].

4.3. **Correction of instantaneous vehicle altitude data**

The altitude $h(0)$ at the start of a trip at $d(0)$ shall be obtained by GPS and verified for correctness with information from a topographic map. The deviation shall not be larger than 40 m. Any instantaneous altitude data $h(t)$ shall be corrected if the following condition applies:

$$|h(t) - h(t-1)| > (v(t)/3{,}6 * \sin 45°)$$

The altitude correction shall be applied so that:

$$h_{corr}(t) = h_{corr}(t-1)$$

where:

h(t) — vehicle altitude after the screening and principle verification of data quality at data point t [m above sea level]
h(t-1) — vehicle altitude after the screening and principle verification of data quality at data point t-1 [m above sea level]
v(t) — vehicle speed of data point t [km/h]
$h_{corr}(t)$ — corrected instantaneous vehicle altitude at data point t [m above sea level]
$h_{corr}(t-1)$ — corrected instantaneous vehicle altitude at data point t-1 [m above sea level].

Upon the completion of the correction procedure, a valid set of altitude data is established. This data set shall be used for the final calculation of the cumulative positive elevation gain as described in point 4.4.

4.4. **Final calculation of the cumulative positive elevation gain**

4.4.1. *Establishment of a uniform spatial resolution*

The total distance d_{tot} [m] covered by a trip shall be determined as sum of the instantaneous distances d_i. The instantaneous distance d_i shall be determined as:

$$d_i = \frac{v_i}{3,6}$$

Where:

d_i — instantaneous distance [m]
v_i — instantaneous vehicle speed [km/h]

The cumulative elevation gain shall be calculated from data of a constant spatial resolution of 1 m starting with the first measurement at the start of a trip *d(0)*. The discrete data points at a resolution of 1 m are referred to as way points, characterised by a specific distance value d (e.g., 0, 1, 2, 3 m…) and their corresponding altitude *h(d)* [m above sea level].

The altitude of each discrete way point *d* shall be calculated through interpolation of the instantaneous altitude $h_{corr}(t)$ as:

$$h_{int}(d) = h_{corr}(0) + \frac{h_{corr}(1) - h_{corr}(0)}{d_1 - d_0} \times (d - d_0)$$

Where:

$h_{int}(d)$ — interpolated altitude at the discrete way point under consideration *d* [m above sea level]
$h_{corr}(0)$ — corrected altitude directly before the respective way point *d* [m above sea level]
hcorr(1) — corrected altitude directly after the respective way point *d* [m above sea level]
d — cumulative distance travelled until the discrete way point under consideration *d* [m]
d_0 — cumulative distance travelled until the measurement located directly before the respective way point *d* [m]
d_1 — cumulative distance travelled until the measurement located directly after the respective way point *d* [m].

4.4.2. *Additional data smoothing*

The altitude data obtained for each discrete way point shall be smoothed by applying a two-step procedure; d_a and d_e denote the first and last data point respectively (Figure 1). The first smoothing run shall be applied as follows:

$$road_{grade,1}(d) = \frac{h_{int}(d+200m) - h_{int}(d_a)}{(d+200m)}$$
for $d \leq 200\ m$

$$road_{grade,1}(d) = \frac{h_{int}(d+200m) - h_{int}(d-200m)}{(d+200m)-(d-200m)}$$
for $200\ m < d < (d_e - 200\ m)$

$$road_{grade,1}(d) = \frac{h_{int}(d_e) - h_{int}(d-200m)}{d_e-(d-200m)}$$
for $d \geq (d_e - 200\ m)$

$h_{int,sm,1}(d) = h_{int,sm,1}(d - 1\ m) + road_{grade,1}(d)$, $d = d_a + 1$ *to* d_e

$h_{int,sm,1}(d_a) = h_{int}(d_a) + road_{grade,1}(d_a)$

Where:

$road_{grade,1}(d)$	—	smoothed road grade at the discrete way point under consideration after the first smoothing run [m/m]
$h_{int}(d)$	—	interpolated altitude at the discrete way point under consideration *d* [m above sea level]
$h_{int,sm,1}(d)$	—	smoothed interpolated altitude, after the first smoothing run at the discrete way point under consideration *d* [m above sea level]
d	—	cumulative distance travelled at the discrete way point under consideration [m]
d_a	—	reference way point at a distance of zero metres [m]
d_e	—	cumulative distance travelled until the last discrete way point [m].

The second smoothing run shall be applied as follows:

$$road_{grade,2}(d) = \frac{h_{int,sm,1}(d+200m) - h_{int,sm,1}(d_a)}{(d+200m)}$$
for $d \leq 200\ m$

$$road_{grade,2}(d) = \frac{h_{int,sm,1}(d+200m) - h_{int,sm,1}(d-200m)}{(d+200m)-(d-200m)}$$
for $200\ m < d < (d_e - 200\ m)$

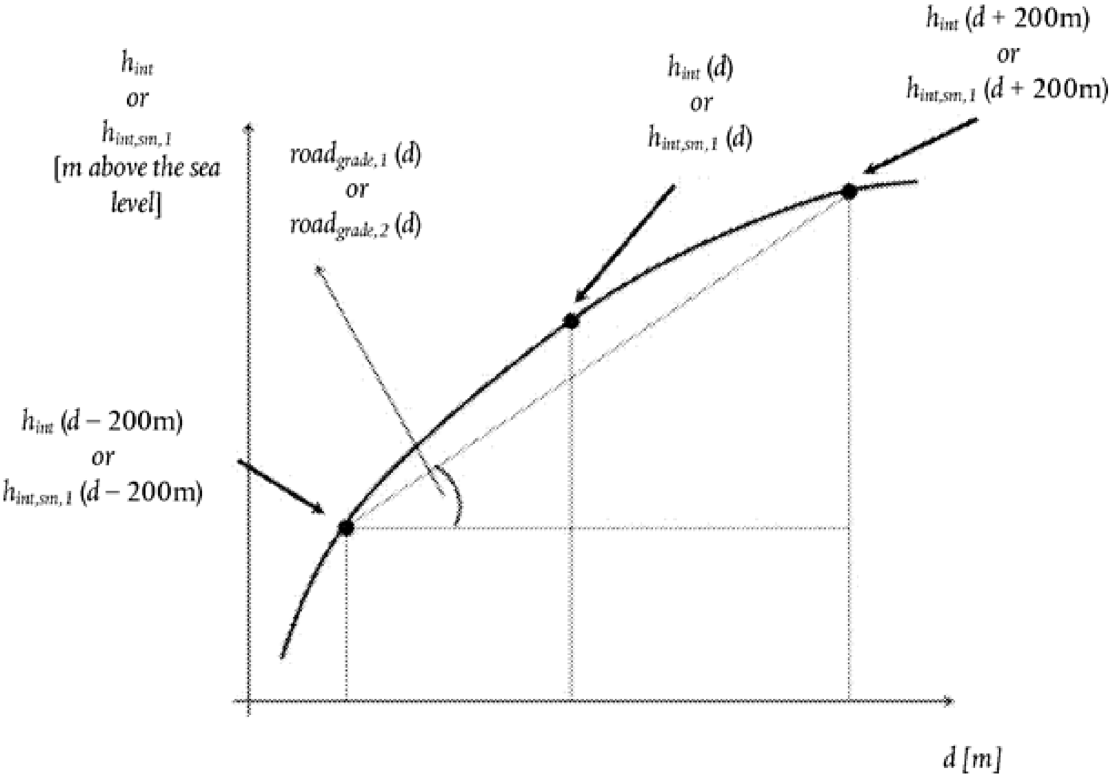
$$road_{grade,2}(d) = \frac{h_{int,sm,1}(d_e) - h_{int,sm,1}(d-200m)}{d_e-(d-200m)}$$
for $d \geq (d_e - 200\ m)$

Where:

$road_{grade,2}(d)$	—	smoothed road grade at the discrete way point under consideration after the second smoothing run [m/m]
$h_{int,sm,1}(d)$	—	smoothed interpolated altitude, after the first smoothing run at the discrete way point under consideration *d* [m above sea level]
d	—	cumulative distance travelled at the discrete way point under consideration [m]
d_a	—	reference way point at a distance of zero metres [m]
d_e	—	cumulative distance travelled until the last discrete way point [m].

Figure 1

Illustration of the procedure to smooth the interpolated altitude signals



4.4.3. *Calculation of the final result*

The positive cumulative elevation gain of a trip shall be calculated by integrating all positive interpolated and smoothed road grades, i.e. $road_{grade,2}(d)$. The result should be normalised by the total test distance d_{tot} and expressed in meters of cumulative elevation gain per 100 kilometres of distance.

5. NUMERICAL EXAMPLE

Tables 1 and 2 show the steps performed in order to calculate the positive elevation gain on the basis of data recorded during an on-road test performed with PEMS. For the sake of brevity an extract of 800 m and 160 s is presented here.

5.1. **Screening and principle verification of data quality**

The screening and principle verification of data quality consists of two steps. First, the completeness of vehicle speed data is checked. No data gaps related to vehicle speed are detected in the present data sample (see Table 1). Second, the altitude data are checked for completeness; in the data sample, altitude data related to seconds 2 and 3 are missing. The gaps are filled by interpolating the GPS signal. In addition, the GPS altitude is verified by a topographic map; this verification includes the altitude $h(0)$ at the start of the trip. Altitude data related to seconds 112-114 are corrected on the basis of the topographic map to satisfy the following condition:

$h_{GPS}(t) – h_{map}(t) < – 40\ m$

As result of the applied data verification, the data in the fifth column $h(t)$ are obtained.

5.2. **Correction of instantaneous vehicle altitude data**

As a next step, the altitude data *h(t)* of seconds 1 to 4, 111 to 112 and 159 to 160 are corrected assuming the altitude values of seconds 0, 110 and 158 respectively since the following condition applies:

$|h(t) - h(t-1)| > (v(t)/3{,}6 * sin45°)$

As result of the applied data correction, the data in the sixth column $h_{corr}(t)$ are obtained. The effect of the applied verification and correction steps on the altitude data is depicted in Figure 2.

5.3. Calculation of the cumulative positive elevation gain

5.3.1. *Establishment of a uniform spatial resolution*

The instantaneous distance d_i is calculated by dividing the instantaneous vehicle speed measured in km/h by 3,6 (Column 7 in Table 1). Recalculating the altitude data to obtain a uniform spatial resolution of 1 m yields the discrete way points d (Column 1 in Table 2) and their corresponding altitude values $h_{int}(d)$ (Column 7 in Table 2). The altitude of each discrete way point d is calculated through interpolation of the measured instantaneous altitude h_{corr} as:

$$h_{int}(0) = 120{,}3 + \frac{120{,}3 - 120{,}3}{0{,}1 - 0{,}0} \times (0 - 0) = 120{,}3000$$

$$h_{int}(520) = 132{,}5 + \frac{132{,}6 - 132{,}5}{523{,}6 - 519{,}9} \times (520 - 519{,}9) = 132{,}5027$$

5.3.2. *Additional data smoothing*

In Table 2, the first and last discrete way points are: d_a = 0 m and d_e = 799 m, respectively. The altitude data of each discrete way point is smoothed by applying a two-step procedure. The first smoothing run consists of:

$$road_{grade,1}(0) = \frac{h_{int}(200m) - h_{int}(0)}{(0 + 200m)} = \frac{120{,}9682 - 120{,}3000}{200} = 0{,}0033$$

chosen to demonstrate the smoothing for d ≤ 200 *m*

$$road_{grade,1}(320) = \frac{h_{int}(520) - h_{int}(120)}{(520) - (120)} = \frac{132{,}5027 - 121{,}9808}{400} = 0{,}0288$$

chosen to demonstrate the smoothing for 200 *m* < *d* < (599 *m*)

$$road_{grade,1}(720) = \frac{h_{int}(799) - h_{int}(520)}{799 - (520)} = \frac{121{,}2000 - 132{,}5027}{279} = -0{,}0405$$

chosen to demonstrate the smoothing for d ≥ (599 *m*)

The smoothed and interpolated altitude is calculated as:

$h_{int,sm,1}(0) = h_{int}(0) + road_{grade,1}(0) = 120{,}3 + 0{,}0033 \approx 120{,}3033\ m$

$h_{int,sm,1}(799) = h_{int,sm,1}(798) + road_{grade,1}(799) = 121{,}2550 - 0{,}0220 = 121{,}2330\ m$

Second smoothing run:

$$road_{grade,2}(0) = \frac{h_{int,sm,1}(200) - h_{int,sm,1}(0)}{(200)} = \frac{119{,}9618 - 120{,}3033}{(200)} = -0{,}0017$$

chosen to demonstrate the smoothing for d ≤ 200 *m*

$$road_{grade,2}(320) = \frac{h_{int,sm,1}(520) - h_{int,sm,1}(120)}{(520) - (120)} = \frac{123{,}6809 - 120{,}1843}{400} = 0{,}0087$$

chosen to demonstrate the smoothing for 200 *m* < *d* < (599 *m*)

$$road_{grade,2}(720) = \frac{h_{int,sm,1}(799) - h_{int,sm,1}(520)}{799 - (520)} = \frac{121{,}2330 - 123{,}6809}{279} = -0{,}0088$$

chosen to demonstrate the smoothing for d ≥ (599 *m*)

5.3.3. *Calculation of the final result*

The positive cumulative elevation gain of a trip is calculated by integrating all positive interpolated and smoothed road grades, i.e. $road_{grade,2}(d)$. For the presented example the total covered distance was d_{tot} = 139,7 km and all positive interpolated and smoothed road grades were of 516 m. Therefore a positive cumulative elevation gain of 516 × 100/139,7 = 370 m/100 km was achieved.

TABLE 1

Correction of instantaneous vehicle altitude data

Time t [s]	***v(t) [km/h]***	***$h_{GPS}(t)$ [m]***	***$h_{map}(t)$ [m]***	***h(t) [m]***	***$h_{corr}(t)$ [m]***	***d_i [m]***	***Cum. d [m]***
0	0,00	122,7	129,0	122,7	122,7	0,0	0,0
1	0,00	122,8	129,0	122,8	122,7	0,0	0,0
2	0,00		129,1	123,6	122,7	0,0	0,0
3	0,00		129,2	124,3	122,7	0,0	0,0
4	0,00	125,1	129,0	125,1	122,7	0,0	0,0
…	…	…	…	…	…	…	…
18	0,00	120,2	129,4	120,2	120,2	0,0	0,0
19	0,32	120,2	129,4	120,2	120,2	0,1	0,1
…	…	…	…	…	…	…	…
37	24,31	120,9	132,7	120,9	120,9	6,8	117,9
38	28,18	121,2	133,0	121,2	121,2	7,8	125,7
…	…	…	…	…	…	…	…
46	13,52	121,4	131,9	121,4	121,4	3,8	193,4
47	38,48	120,7	131,5	120,7	120,7	10,7	204,1
…	…	…	…	…	…	…	…
56	42,67	119,8	125,2	119,8	119,8	11,9	308,4
57	41,70	119,7	124,8	119,7	119,7	11,6	320,0
…	…	…	…	…	…	…	…
110	10,95	125,2	132,2	125,2	125,2	3,0	509,0
111	11,75	100,8	132,3	100,8	125,2	3,3	512,2
112	13,52	0,0	132,4	132,4	125,2	3,8	516,0
113	14,01	0,0	132,5	132,5	132,5	3,9	519,9

- denotes data gaps

Status: *Point in time view as at 31/01/2020.*
Changes to legislation: *There are currently no known outstanding effects for the Commission Regulation (EC) No 692/2008, ANNEX IIIA. (See end of Document for details)*

114	13,36	24,30	132,6	132,6	132,6	3,7	523,6
…	…	…	…	…	…	…	
149	39,93	123,6	129,6	123,6	123,6	11,1	719,2
150	39,61	123,4	129,5	123,4	123,4	11,0	730,2
…	…	…	…	…	…	…	
157	14,81	121,3	126,1	121,3	121,3	4,1	792,1
158	14,19	121,2	126,2	121,2	121,2	3,9	796,1
159	10,00	128,5	126,1	128,5	121,2	2,8	798,8
160	4,10	130,6	126,0	130,6	121,2	1,2	800,0

- denotes data gaps

TABLE 2

Calculation of road grade

d[m]	t_0 [s]	d_0 [m]	d_1 [m]	h_0 [m]	h_1 [m]	$h_{int}(d)$ [m]	$road_{grade,1}(d)$ [m/m]	$h_{int,sm,1}(d)$ [m]	$road_{grade,2}(d)$ [m/m]
0	18	0,0	0,1	120,3	120,4	120,3	0,0035	120,3	–0,0015
…	…	…	…	…	…	…	…	…	…
120	37	117,9	125,7	120,9	121,2	121,0	–0,0019	120,2	0,0035
…	…	…	…	…	…	…	…	…	…
200	46	193,4	204,1	121,4	120,7	121,0	–0,0040	120,0	0,0051
…	…	…	…	…	…	…	…	…	…
320	56	308,4	320,0	119,8	119,7	119,7	0,0288	121,4	0,0088
…	…	…	…	…	…	…	…	…	…
520	113	519,9	523,6	132,5	132,6	132,5	0,0097	123,7	0,0037
…	…	…	…	…	…	…	…	…	…
720	149	719,2	730,2	123,6	123,4	123,6	–0,0405	122,9	–0,0086
…	…	…	…	…	…	…	…	…	…
798	158	796,1	798,8	121,2	121,2	121,2	–0,0219	121,3	–0,0151
799	159	798,8	800,0	121,2	121,2	121,2	–0,0220	121,3	–0,0152

Figure 2

The effect of data verification and correction — The altitude profile measured by GPS $h_{GPS}(t)$, the altitude profile provided by the topographic map $h_{map}(t)$, the altitude profile obtained after the screening and principle verification of data quality $h(t)$ and the correction $hcorr(t)$ of data listed in Table 1

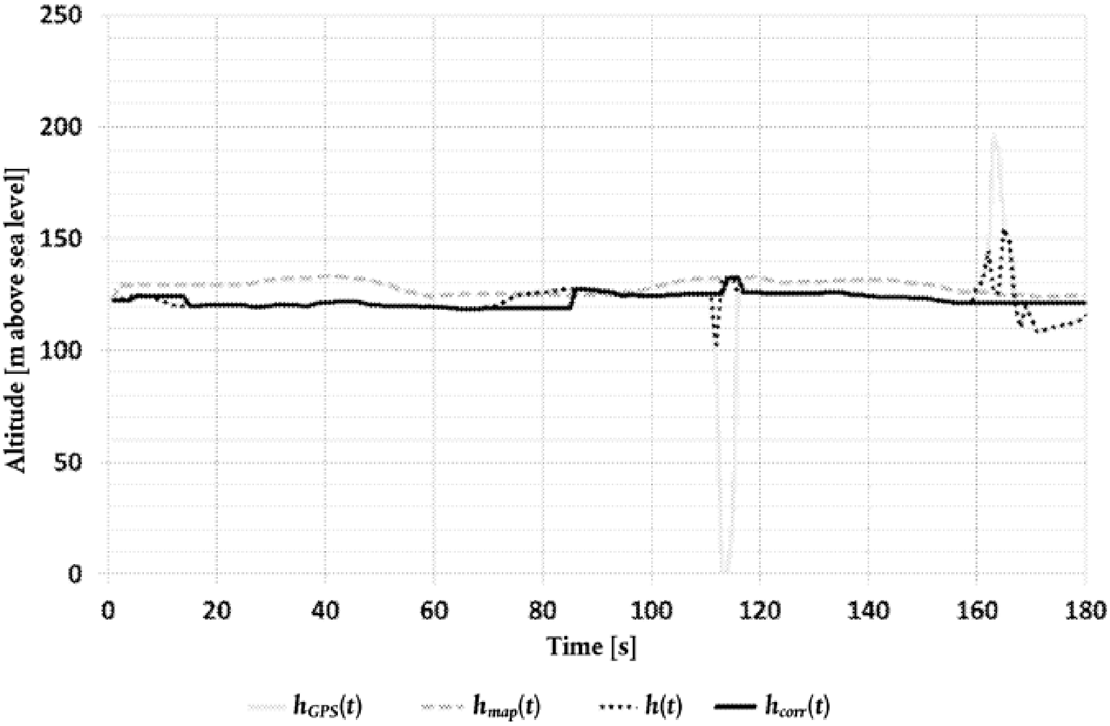


Figure 3

Comparison between the corrected altitude profile $h_{corr}(t)$ and the smoothed and interpolated altitude $h_{int,sm,1}$

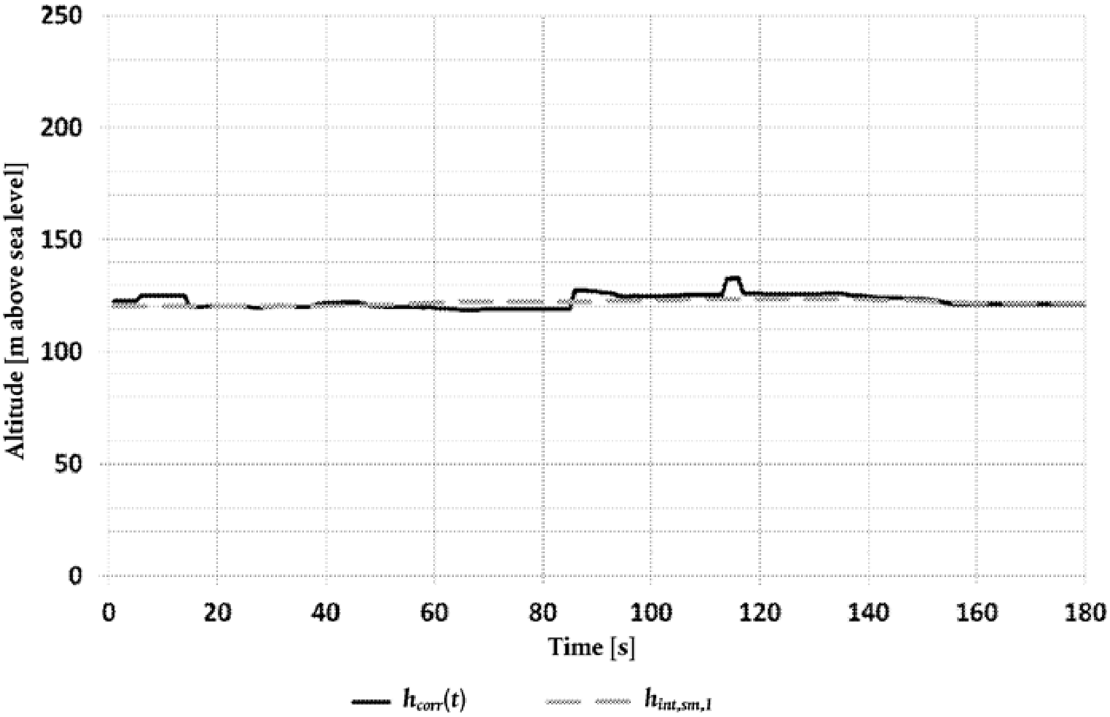


TABLE 2

Calculation of the positive elevation gain

d[m]	t_0 [s]	d_0 [m]	d_1 [m]	h_0 [m]	h_1 [m]	$h_{int}(d)$ [m]	$road_{grade,1}(d)$ [m/m]	$h_{int,sm,1}(d)$ [m]	$road_{grade,2}(d)$ [m/m]
0	18	0,0	0,1	120,3	120,4	120,3	0,0035	120,3	–0,0015
…	…	…	…	…	…	…	…	…	…
120	37	117,9	125,7	120,9	121,2	121,0	–0,0019	120,2	0,0035
…	…	…	…	…	…	…	…	…	…
200	46	193,4	204,1	121,4	120,7	121,0	–0,0040	120,0	0,0051
…	…	…	…	…	…	…	…	…	…
320	56	308,4	320,0	119,8	119,7	119,7	0,0288	121,4	0,0088
…	…	…	…	…	…	…	…	…	…
520	113	519,9	523,6	132,5	132,6	132,5	0,0097	123,7	0,0037
…	…	…	…	…	…	…	…	…	…
720	149	719,2	730,2	123,6	123,4	123,6	–0,0405	122,9	–0,0086

…	…	…	…	…	…	…	…	…	…
798	158	796,1	798,8	121,2	121,2	121,2	– 0,0219	121,3	– 0,0151
799	159	798,8	800,0	121,2	121,2	121,2	– 0,0220	121,3	– 0,0152]

Appendix 8

Data exchange and reporting requirements

1. INTRODUCTION

This Appendix describes the requirements for the data exchange between the measurement systems and the data evaluation software and for the reporting and exchange of intermediate and final results after the completion of the data evaluation.

The exchange and reporting of mandatory and optional parameters shall follow the requirements of point 3.2 of Appendix 1. The data specified in the exchange and reporting files of point 3 shall be reported to ensure a complete traceability of final results.

2. SYMBOLS, PARAMETERS AND UNITS

a_1	— coefficient of the CO_2 characteristic curve
b_1	— coefficient of the CO_2 characteristic curve
a_2	— coefficient of the CO_2 characteristic curve
b_2	— coefficient of the CO_2 characteristic curve
k_{11}	— coefficient of the weighing function
k_{12}	— coefficient of the weighing function
k_{21}	— coefficient of the weighing function
k_{22}	— coefficient of the weighing function
tol_1	— primary tolerance
tol_2	— secondary tolerance.

3. DATA EXCHANGE AND REPORTING FORMAT

3.1. **General**

Emission values as well as any other relevant parameters shall be reported and exchanged as csv-formatted data file. Parameter values shall be separated by a comma, ASCII-Code #h2C. The decimal marker of numerical values shall be a point, ASCII-Code #h2E. Lines shall be terminated by carriage return, ASCII-Code #h0D. No thousands separators shall be used.

3.2. **Data exchange**

Data shall be exchanged between the measurement systems and the data evaluation software by means of a standardised reporting file that contains a minimum set of mandatory and optional parameters. The data exchange file shall be structured as follows: The first 195 lines shall be reserved for a header that provides specific information about, e.g. the test conditions, the identity and calibration of the PEMS equipment (Table 1). Lines 198-200 shall contain the labels and units of parameters. Lines 201 and all consecutive data lines shall comprise the body of the data exchange file and report parameter values (Table 2). The body of the data exchange file shall contain at least as many data lines as the test duration in seconds multiplied by the recording frequency in Hertz.

3.3. **Intermediate and final results**

Manufacturers shall record summary parameters of intermediate results as structured in Table 3. The information in Table 3 shall be obtained prior to the application of the data evaluation methods laid down in Appendices 5 and 6.

The vehicle manufacturer shall record the results of the two data evaluation methods in separate files. The results of the data evaluation with the method described in Appendix 5 shall be reported according to Tables 4, 5 and 6. The results of the data evaluation with the method described in Appendix 6 shall be reported according to Tables 7, 8 and 9. The header of the data reporting file shall be composed of three parts. The first 95 lines shall be reserved for specific information about the settings of the data evaluation method. Lines 101-195 shall report the results of the data evaluation method. Lines 201-490 shall be reserved for reporting the final emission results. Line 501 and all consecutive data lines comprise the body of the data reporting file and shall contain the detailed results of the data evaluation.

4. TECHNICAL REPORTING TABLES

4.1. **Data exchange**

TABLE 1

Header of the data exchange file

Line	Parameter	Description/unit
1	TEST ID	[code]
2	Test date	[day.month.year]
3	Organisation supervising the test	[name of the organisation]
4	Test location	[city, country]
5	Person supervising the test	[name of the principal supervisor]
6	Vehicle driver	[name of the driver]
7	Vehicle type	[vehicle name]
8	Vehicle manufacturer	[name]
9	Vehicle model year	[year]
10	Vehicle ID	[VIN code]
11	Odometer value at test start	[km]
12	Odometer value at test end	[km]
13	Vehicle category	[category]
14	Type approval emissions limit	[Euro X]
15	Engine type	[e.g. spark ignition, compression ignition]

a Mass of the vehicle as tested on the road, including the mass of the driver and all PEMS components.

b Percentage shall indicate the deviation from the gross vehicle weight.

c Placeholders for additional information about analyser manufacturer and serial number in case multiple analysers are used. Number of reserved rows is indicative only; no empty rows shall occur in the completed data reporting file.

d Mandatory if the exhaust mass flow rate is determined by an EFM.

e If required, additional information may be added here.

f PEMS validation is optional; distance-specific emissions as measured with the PEMS; Percentage shall indicate the deviation from the laboratory reference.

g Additional parameters may be added until line 195 to characterise and label the test.

16	Engine rated power	[kW]
17	Peak torque	[Nm]
18	Engine displacement	[ccm]
19	Transmission	[e.g. manual, automatic]
20	Number of forward gears	[#]
21	Fuel	[e.g. gasoline, diesel]
22	Lubricant	[product label]
23	Tyre size	[width/height/rim diameter]
24	Front and rear axle tire pressure	[bar; bar]
25	Road load parameters	[F_0, F_1, F_2]
26	Type-approval test cycle	[NEDC, WLTC]
27	Type-approval CO_2 emissions	[g/km]
28	CO_2 emissions in WLTC mode Low	[g/km]
29	CO_2 emissions in WLTC mode Mid	[g/km]
30	CO_2 emissions in WLTC mode High	[g/km]
31	CO_2 emissions in WLTC mode Extra High	[g/km]
32	Vehicle test mass[a]	[kg; %[b]]
33	PEMS manufacturer	[name]
34	PEMS type	[PEMS name]
35	PEMS serial number	[number]
36	PEMS power supply	[e.g. % battery type]
37	Gas analyser manufacturer	[name]
38	Gas analyser type	[type]
39	Gas analyser serial number	[number]

a Mass of the vehicle as tested on the road, including the mass of the driver and all PEMS components.

b Percentage shall indicate the deviation from the gross vehicle weight.

c Placeholders for additional information about analyser manufacturer and serial number in case multiple analysers are used. Number of reserved rows is indicative only; no empty rows shall occur in the completed data reporting file.

d Mandatory if the exhaust mass flow rate is determined by an EFM.

e If required, additional information may be added here.

f PEMS validation is optional; distance-specific emissions as measured with the PEMS; Percentage shall indicate the deviation from the laboratory reference.

g Additional parameters may be added until line 195 to characterise and label the test.

40-50[c]	…	…
51	EFM manufacturer[d]	[name]
52	EFM sensor type[d]	[functional principle]
53	EFM serial number[d]	[number]
54	Source of exhaust mass flow rate	[EFM/ECU/sensor]
55	Air pressure sensor	[type, manufacturer]
56	Test date	[day.month.year]
57	Start time of pre-test procedure	[h:min]
58	Start time of trip	[h:min]
59	Start time of post-test procedure	[h:min]
60	End time of pre-test procedure	[h:min]
61	End time of trip	[h:min]
62	End time of post-test procedure	[h:min]
63-70[e]	…	…
71	Time correction: Shift THC	[s]
72	Time correction: Shift CH_4	[s]
73	Time correction: Shift NMHC	[s]
74	Time correction: Shift O_2	[s]
75	Time correction: Shift PN	[s]
76	Time correction: Shift CO	[s]
77	Time correction: Shift CO_2	[s]
78	Time correction: Shift NO	[s]
79	Time correction: Shift NO_2	[s]

a Mass of the vehicle as tested on the road, including the mass of the driver and all PEMS components.

b Percentage shall indicate the deviation from the gross vehicle weight.

c Placeholders for additional information about analyser manufacturer and serial number in case multiple analysers are used. Number of reserved rows is indicative only; no empty rows shall occur in the completed data reporting file.

d Mandatory if the exhaust mass flow rate is determined by an EFM.

e If required, additional information may be added here.

f PEMS validation is optional; distance-specific emissions as measured with the PEMS; Percentage shall indicate the deviation from the laboratory reference.

g Additional parameters may be added until line 195 to characterise and label the test.

80	Time correction: Shift exhaust mass flow rate	[s]
81	Span reference value THC	[ppm]
82	Span reference value CH_4	[ppm]
83	Span reference value NMHC	[ppm]
84	Span reference value O_2	[%]
85	Span reference value PN	[#]
86	Span reference value CO	[ppm]
87	Span reference value CO_2	[%]
88	Span reference value NO	[ppm]
89	Span Reference Value NO_2	[ppm]
90-95[e]	…	…
96	Pre-test zero response THC	[ppm]
97	Pre-test zero response CH_4	[ppm]
98	Pre-test zero response NMHC	[ppm]
99	Pre-test zero response O_2	[%]
100	Pre-test zero response PN	[#]
101	Pre-test zero response CO	[ppm]
102	Pre-test zero response CO_2	[%]
103	Pre-test zero response NO	[ppm]
104	Pre-test zero response NO_2	[ppm]
105	Pre-test span response THC	[ppm]
106	Pre-test span response CH_4	[ppm]
107	Pre-test span response NMHC	[ppm]
108	Pre-test span response O_2	[%]
109	Pre-test span response PN	[#]

a Mass of the vehicle as tested on the road, including the mass of the driver and all PEMS components.

b Percentage shall indicate the deviation from the gross vehicle weight.

c Placeholders for additional information about analyser manufacturer and serial number in case multiple analysers are used. Number of reserved rows is indicative only; no empty rows shall occur in the completed data reporting file.

d Mandatory if the exhaust mass flow rate is determined by an EFM.

e If required, additional information may be added here.

f PEMS validation is optional; distance-specific emissions as measured with the PEMS; Percentage shall indicate the deviation from the laboratory reference.

g Additional parameters may be added until line 195 to characterise and label the test.

110	Pre-test span response CO	[ppm]
111	Pre-test span response CO_2	[%]
112	Pre-test span response NO	[ppm]
113	Pre-test span response NO_2	[ppm]
114	Post-test zero response THC	[ppm]
115	Post-test zero response CH_4	[ppm]
116	Post-test zero response NMHC	[ppm]
117	Post-test zero response O_2	[%]
118	Post-test zero response PN	[#]
119	Post-test zero response CO	[ppm]
120	Post-test zero response CO_2	[%]
121	Post-test zero response NO	[ppm]
122	Post-test zero response NO_2	[ppm]
123	Post-test span response THC	[ppm]
124	Post-test span response CH_4	[ppm]
125	Post-test span response NMHC	[ppm]
126	Post-test span response O_2	[%]
127	Post-test span response PN	[#]
128	Post-test span response CO	[ppm]
129	Post-test span response CO_2	[%]
130	Post-test span response NO	[ppm]
131	Post-test span response NO_2	[ppm]
132	PEMS validation — results THC	[mg/km;%][f]
133	PEMS validation — results CH_4	[mg/km;%][f]

a Mass of the vehicle as tested on the road, including the mass of the driver and all PEMS components.

b Percentage shall indicate the deviation from the gross vehicle weight.

c Placeholders for additional information about analyser manufacturer and serial number in case multiple analysers are used. Number of reserved rows is indicative only; no empty rows shall occur in the completed data reporting file.

d Mandatory if the exhaust mass flow rate is determined by an EFM.

e If required, additional information may be added here.

f PEMS validation is optional; distance-specific emissions as measured with the PEMS; Percentage shall indicate the deviation from the laboratory reference.

g Additional parameters may be added until line 195 to characterise and label the test.

134	PEMS validation — results NMHC	[mg/km;%][f]
135	PEMS validation — results PN	[#/km;%][f]
136	PEMS validation — results CO	[mg/km;%][f]
137	PEMS validation — results CO_2	[g/km;%][f]
138	PEMS validation — results NO_X	[mg/km;%][f]
…[g]	…[g]	…[g]

a Mass of the vehicle as tested on the road, including the mass of the driver and all PEMS components.

b Percentage shall indicate the deviation from the gross vehicle weight.

c Placeholders for additional information about analyser manufacturer and serial number in case multiple analysers are used. Number of reserved rows is indicative only; no empty rows shall occur in the completed data reporting file.

d Mandatory if the exhaust mass flow rate is determined by an EFM.

e If required, additional information may be added here.

f PEMS validation is optional; distance-specific emissions as measured with the PEMS; Percentage shall indicate the deviation from the laboratory reference.

g Additional parameters may be added until line 195 to characterise and label the test.

TABLE 2

Body of the data exchange file; the rows and columns of this table shall be transposed in the body of the data exchange file

Line	198	199[a]	200	201
	Time	trip	[s]	[b]
	Vehicle speed[c]	Sensor	[km/h]	[b]
	Vehicle speed[c]	GPS	[km/h]	[b]
	Vehicle speed[c]	ECU	[km/h]	[b]
	Latitude	GPS	[deg:min:s]	[b]
	Longitude	GPS	[deg:min:s]	[b]
	Altitude[c]	GPS	[m]	[b]
	Altitude[c]	Sensor	[m]	[b]
	Ambient pressure	Sensor	[kPa]	[b]

a This column can be omitted if the parameter source is part of the label in column 198.

b Actual values to be included from line 201 onward until the end of data

c To be determined by at least one method

d Additional parameters may be added to characterise vehicle and test conditions.

	Ambient temperature	Sensor	[K]	b
	Ambient humidity	Sensor	[g/kg; %]	b
	THC concentration	Analyser	[ppm]	b
	CH_4 concentration	Analyser	[ppm]	b
	NMHC concentration	Analyser	[ppm]	b
	CO concentration	Analyser	[ppm]	b
	CO_2 concentration	Analyser	[ppm]	b
	NO_X concentration	Analyser	[ppm]	b
	NO concentration	Analyser	[ppm]	b
	NO_2 concentration	Analyser	[ppm]	b
	O_2 concentration	Analyser	[ppm]	b
	PN concentration	Analyser	[#/m^3]	b
	Exhaust mass flow rate	EFM	[kg/s]	b
	Exhaust temperature in the EFM	EFM	[K]	b
	Exhaust mass flow rate	Sensor	[kg/s]	b
	Exhaust mass flow rate	ECU	[kg/s]	b
	THC mass	Analyser	[g/s]	b
	CH_4 mass	Analyser	[g/s]	b
	NMHC mass	Analyser	[g/s]	b
	CO mass	Analyser	[g/s]	b

a	This column can be omitted if the parameter source is part of the label in column 198.
b	Actual values to be included from line 201 onward until the end of data
c	To be determined by at least one method
d	Additional parameters may be added to characterise vehicle and test conditions.

	CO_2 mass	Analyser	[g/s]	[b]
	NO_X mass	Analyser	[g/s]	[b]
	NO mass	Analyser	[g/s]	[b]
	NO_2 mass	Analyser	[g/s]	[b]
	O_2 mass	Analyser	[g/s]	[b]
	PN	Analyser	[#/s]	[b]
	Gas measurement active	PEMS	[active (1); inactive (0); error (>1)]	[b]
	Engine speed	ECU	[rpm]	[b]
	Engine torque	ECU	[Nm]	[b]
	Torque at driven axle	Sensor	[Nm]	[b]
	Wheel rotational speed	Sensor	[rad/s]	[b]
	Fuel rate	ECU	[g/s]	[b]
	Engine fuel flow	ECU	[g/s]	[b]
	Engine intake air flow	ECU	[g/s]	[b]
	Coolant temperature	ECU	[K]	[b]
	Oil temperature	ECU	[K]	[b]
	Regeneration status	ECU	—	[b]
	Pedal position	ECU	[%]	[b]
	Vehicle status	ECU	[error (1); normal (0)]	[b]
	Per cent torque	ECU	[%]	[b]
	Per cent friction torque	ECU	[%]	[b]
	State of charge	ECU	[%]	[b]
	…[d]	…[d]	…[d]	[bd]

a	This column can be omitted if the parameter source is part of the label in column 198.
b	Actual values to be included from line 201 onward until the end of data
c	To be determined by at least one method
d	Additional parameters may be added to characterise vehicle and test conditions.

4.2. Intermediate and final results

4.2.1. *Intermediate results*

TABLE 3

Reporting file #1 — Summary parameters of intermediate results

Line	Parameter	Description/unit
1	Total trip distance	[km]
2	Total trip duration	[h:min:s]
3	Total stop time	[min:s]
4	Trip average speed	[km/h]
5	Trip maximum speed	[km/h]
6	Average THC concentration	[ppm]
7	Average CH_4 concentration	[ppm]
8	Average NMHC concentration	[ppm]
9	Average CO concentration	[ppm]
10	Average CO_2 concentration	[ppm]
11	Average NO_X concentration	[ppm]
12	Average PN concentration	[#/m^3]
13	Average exhaust mass flow rate	[kg/s]
14	Average exhaust temperature	[K]
15	Maximum exhaust temperature	[K]
16	Cumulated THC mass	[g]
17	Cumulated CH_4 mass	[g]
18	Cumulated NMHC mass	[g]
19	Cumulated CO mass	[g]
20	Cumulated CO_2 mass	[g]
21	Cumulated NO_X mass	[g]
22	Cumulated PN	[#]
23	Total trip THC emissions	[mg/km]
24	Total trip CH_4 emissions	[mg/km]
25	Total trip NMHC emissions	[mg/km]

a Additional parameters may be added to characterise additional elements.

26	Total trip CO emissions	[mg/km]
27	Total trip CO_2 emissions	[g/km]
28	Total trip NO_X emissions	[mg/km]
29	Total trip PN emissions	[#/km]
30	Distance urban part	[km]
31	Duration urban part	[h:min:s]
32	Stop time urban part	[min:s]
33	Average speed urban part	[km/h]
34	Maximum speed urban part	[km/h]
35	Average urban THC concentration	[ppm]
36	Average urban CH_4 concentration	[ppm]
37	Average urban NMHC concentration	[ppm]
38	Average urban CO concentration	[ppm]
39	Average urban CO_2 concentration	[ppm]
40	Average urban NO_X concentration	[ppm]
41	Average urban PN concentration	[#/m^3]
42	Average urban exhaust mass flow rate	[kg/s]
43	Average urban exhaust temperature	[K]
44	Maximum urban exhaust temperature	[K]
45	Cumulated urban THC mass	[g]
46	Cumulated urban CH_4 mass	[g]
47	Cumulated urban NMHC mass	[g]
48	Cumulated urban CO mass	[g]
49	Cumulated urban CO_2 mass	[g]
50	Cumulated urban NO_X mass	[g]
51	Cumulated urban PN	[#]

a Additional parameters may be added to characterise additional elements.

52	Urban THC emissions	[mg/km]
53	Urban CH_4 emissions	[mg/km]
54	Urban NMHC emissions	[mg/km]
55	Urban CO emissions	[mg/km]
56	Urban CO_2 emissions	[g/km]
57	Urban NO_X emissions	[mg/km]
58	Urban PN emissions	[#/km]
59	Distance rural part	[km]
60	Duration rural part	[h:min:s]
61	Stop time rural part	[min:s]
62	Average speed rural part	[km/h]
63	Maximum speed rural part	[km/h]
64	Average rural THC concentration	[ppm]
65	Average rural CH_4 concentration	[ppm]
66	Average rural NMHC concentration	[ppm]
67	Average rural CO concentration	[ppm]
68	Average rural CO_2 concentration	[ppm]
69	Average rural NO_X concentration	[ppm]
70	Average rural PN concentration	[#/m^3]
71	Average rural exhaust mass flow rate	[kg/s]
72	Average rural exhaust temperature	[K]
73	Maximum rural exhaust temperature	[K]
74	Cumulated rural THC mass	[g]
75	Cumulated rural CH_4 mass	[g]
76	Cumulated rural NMHC mass	[g]
77	Cumulated rural CO mass	[g]

a Additional parameters may be added to characterise additional elements.

78	Cumulated rural CO_2 mass	[g]
79	Cumulated rural NO_X mass	[g]
80	Cumulated rural PN	[#]
81	Rural THC emissions	[mg/km]
82	Rural CH_4 emissions	[mg/km]
83	Rural NMHC emissions	[mg/km]
84	Rural CO emissions	[mg/km]
85	Rural CO_2 emissions	[g/km]
86	Rural NO_X emissions	[mg/km]
87	Rural PN emissions	[#/km]
88	Distance motorway part	[km]
89	Duration motorway part	[h:min:s]
90	Stop time motorway part	[min:s]
91	Average speed motorway part	[km/h]
92	Maximum speed motorway part	[km/h]
93	Average motorway THC concentration	[ppm]
94	Average motorway CH_4 concentration	[ppm]
95	Average motorway NMHC concentration	[ppm]
96	Average motorway CO concentration	[ppm]
97	Average motorway CO_2 concentration	[ppm]
98	Average motorway NO_X concentration	[ppm]
99	Average motorway PN concentration	[#/m^3]
100	Average motorway exhaust mass flow rate	[kg/s]
101	Average motorway exhaust temperature	[K]
102	Maximum motorway exhaust temperature	[K]

a Additional parameters may be added to characterise additional elements.

103	Cumulated motorway THC mass	[g]
104	Cumulated motorway CH_4 mass	[g]
105	Cumulated motorway NMHC mass	[g]
106	Cumulated motorway CO mass	[g]
107	Cumulated motorway CO_2 mass	[g]
108	Cumulated motorway NO_X mass	[g]
109	Cumulated motorway PN	[#]
110	Motorway THC emissions	[mg/km]
111	Motorway CH_4 emissions	[mg/km]
112	Motorway NMHC emissions	[mg/km]
113	Motorway CO emissions	[mg/km]
114	Motorway CO_2 emissions	[g/km]
115	Motorway NO_X emissions	[mg/km]
116	Motorway PN emissions	[#/km]
…[a]	…[a]	…[a]

a Additional parameters may be added to characterise additional elements.

4.2.2. *Results of the data evaluation*

TABLE 4

Header of reporting file #2 — Calculation settings of the data evaluation method according to Appendix 5

Line	Parameter	Unit
1	Reference CO_2 mass	[g]
2	Coefficient a_1 of the CO_2 characteristic curve	
3	Coefficient b_1 of the CO_2 characteristic curve	
4	Coefficient a_2 of the CO_2 characteristic curve	
5	Coefficient b_2 of the CO_2 characteristic curve	

a Additional parameters may be added until line 95 to characterise calculation settings.

6	Coefficient k_{11} of the weighing function	
7	Coefficient k_{12} of the weighing function	
8	Coefficient $k_{22} = k_{21}$ of the weighing function	
9	Primary tolerance tol_1	[%]
10	Secondary tolerance tol_2	[%]
11	Calculation software and version	(e.g. EMROAD 5.8)
…[a]	…[a]	…[a]

a Additional parameters may be added until line 95 to characterise calculation settings.

TABLE 5A

Header of reporting file #2 — Results of the data evaluation method according to Appendix 5

Line	Parameter	Unit
101	Number of windows	
102	Number of urban windows	
103	Number of rural windows	
104	Number of motorway windows	
105	Share of urban windows	[%]
106	Share of rural windows	[%]
107	Share of motorway windows	[%]
108	Share of urban windows greater than 15 %	(1=Yes, 0=No)
109	Share of rural windows greater than 15 %	(1=Yes, 0=No)
110	Share of motorway windows greater than 15 %	(1=Yes, 0=No)
111	Number of windows within ± tol_1	
112	Number of urban windows within ± tol_1	
113	Number of rural windows within ± tol_1	

a Additional parameters may be added until line 195.

114	Number of motorway windows within ± tol_1	
115	Number of windows within ± tol_2	
116	Number of urban windows within ± tol_2	
117	Number of rural windows within ± tol_2	
118	Number of motorway windows within ± tol_2	
119	Share of urban windows within ± tol_1	[%]
120	Share of rural windows within ± tol_1	[%]
121	Share of motorway windows within ± tol_1	[%]
122	Share of urban windows within ± tol_1 greater than 50 %	(1=Yes, 0=No)
123	Share of rural windows within tol_1 ± greater than 50 %	(1=Yes, 0=No)
124	Share of motorway windows within ± tol_1 greater than 50 %	(1=Yes, 0=No)
125	Average severity index of all windows	[%]
126	Average severity index of urban windows	[%]
127	Average severity index of rural windows	[%]
128	Average severity index of motorway windows	[%]
129	Weighted THC emissions of urban windows	[mg/km]
130	Weighted THC emissions of rural windows	[mg/km]
131	Weighted THC emissions of motorway windows	[mg/km]

a Additional parameters may be added until line 195.

132	Weighted CH_4 emissions of urban windows	[mg/km]
133	Weighted CH_4 emissions of rural windows	[mg/km]
134	Weighted CH_4 emissions of motorway windows	[mg/km]
135	Weighted NMHC emissions of urban windows	[mg/km]
136	Weighted NMHC emissions of rural windows	[mg/km]
137	Weighted NMHC emissions of motorway windows	[mg/km]
138	Weighted CO emissions of urban windows	[mg/km]
139	Weighted CO emissions of rural windows	[mg/km]
140	Weighted CO emissions of motorway windows	[mg/km]
141	Weighted NO_x emissions of urban windows	[mg/km]
142	Weighted NO_x emissions of rural windows	[mg/km]
143	Weighted NO_x emissions of motorway windows	[mg/km]
144	Weighted NO emissions of urban windows	[mg/km]
145	Weighted NO emissions of rural windows	[mg/km]
146	Weighted NO emissions of motorway windows	[mg/km]
147	Weighted NO_2 emissions of urban windows	[mg/km]
148	Weighted NO_2 emissions of rural windows	[mg/km]
149	Weighted NO_2 emissions of motorway windows	[mg/km]
150	Weighted PN emissions of urban windows	[#/km]
151	Weighted PN emissions of rural windows	[#/km]

a Additional parameters may be added until line 195.

152	Weighted PN emissions of motorway windows	[#/km]
…[a]	…[a]	…[a]

a Additional parameters may be added until line 195.

TABLE 5B

Header of reporting file #2 — Final emission results according to Appendix 5

Line	Parameter	Unit
201	Total trip — THC Emissions	[mg/km]
202	Total trip — CH_4 Emissions	[mg/km]
203	Total trip — NMHC Emissions	[mg/km]
204	Total trip — CO Emissions	[mg/km]
205	Total trip — NO_x Emissions	[mg/km]
206	Total trip — PN Emissions	[#/km]
…[a]	…[a]	…[a]

a Additional parameters may be added.

TABLE 6

Body of reporting file #2 — Detailed results of the data evaluation method according to Appendix 5; the rows and columns of this table shall be transposed in the body of the data reporting file

Line	498	499	500	501
	Window Start Time		[s]	[a]
	Window End Time		[s]	[a]
	Window Duration		[s]	[a]
	Window Distance	Source (1=GPS, 2=ECU, 3=Sensor)	[km]	[a]
	Window THC emissions		[g]	[a]
	Window CH_4 emissions		[g]	[a]
	Window NMHC emissions		[g]	[a]

a Actual values to be included from line 501 to line onward until the end of data.

b Additional parameters may be added to characterise window characteristics.

	Window CO emissions		[g]	[a]
	Window CO_2 emissions		[g]	[a]
	Window NO_X emissions		[g]	[a]
	Window NO emissions		[g]	[a]
	Window NO_2 emissions		[g]	[a]
	Window O_2 emissions		[g]	[a]
	Window PN emissions		[#]	[a]
	Window THC emissions		[mg/km]	[a]
	Window CH_4 emissions		[mg/km]	[a]
	Window NMHC emissions		[mg/km]	[a]
	Window CO emissions		[mg/km]	[a]
	Window CO_2 emissions		[g/km]	[a]
	Window NO_X emissions		[mg/km]	[a]
	Window NO emissions		[mg/km]	[a]
	Window NO_2 emissions		[mg/km]	[a]
	Window O_2 emissions		[mg/km]	[a]
	Window PN emissions		[#/km]	[a]
	Window distance to CO_2 characteristic curve h_j		[%]	[a]

a Actual values to be included from line 501 to line onward until the end of data.

b Additional parameters may be added to characterise window characteristics.

	Window weighing factor w_j		[-]	[a]
	Window Average Vehicle Speed	Source (1=GPS, 2=ECU, 3=Sensor)	[km/h]	[a]
	…[b]	…[b]	…[b]	[ab]

a Actual values to be included from line 501 to line onward until the end of data.

b Additional parameters may be added to characterise window characteristics.

TABLE 7

Header of reporting file #3 — Calculation settings of the data evaluation method according to Appendix 6

Line	Parameter	Unit
1	Torque source for the power at the wheels	Sensor/ECU/'Veline'
2	Slope of the Veline	[g/kWh]
3	Intercept of the Veline	[g/h]
4	Moving average duration	[s]
5	Reference speed for de-normalisation of goal pattern	[km/h]
6	Reference acceleration	[m/s^2]
7	Power demand at the wheel hub for a vehicle at reference speed and acceleration	[kW]
8	Number of power classes including the 90 % of P_{rated}	—
9	Goal pattern layout	(stretched/shrank)
10	Calculation software and version	(e.g. CLEAR 1.8)
…[a]	…[a]	…[a]

a Additional parameters may be added until line 95 to characterise calculation settings.

TABLE 8A

Header of reporting file #3 — Results of data evaluation method according to Appendix 6

Line	Parameter	Unit
101	Power class coverage (counts >5)	(1=Yes, 0=No)
102	Power class normality	(1=Yes, 0=No)

a Additional parameters may be added until line 195.

103	Total trip — Weighted average THC emissions	[g/s]
104	Total trip — Weighted average CH_4 emissions	[g/s]
105	Total trip — Weighted average NMHC emissions	[g/s]
106	Total trip — Weighted average CO emissions	[g/s]
107	Total trip — Weighted average CO_2 emissions	[g/s]
108	Total trip — Weighted average NO_X emissions	[g/s]
109	Total trip — Weighted s average NO emissions	[g/s]
110	Total trip — Weighted average NO_2 emissions	[g/s]
111	Total trip — Weighted average O_2 emissions	[g/s]
112	Total trip — Weighted average PN emissions	[#/s]
113	Total trip — Weighted average Vehicle Speed	[km/h]
114	Urban — Weighted average THC emissions	[g/s]
115	Urban — Weighted average CH_4 emissions	[g/s]
116	Urban — Weighted average NMHC emissions	[g/s]
117	Urban — Weighted average CO emissions	[g/s]
118	Urban — Weighted average CO_2 emissions	[g/s]
119	Urban — Weighted average NO_X emissions	[g/s]
120	Urban — Weighted s average NO emissions	[g/s]
121	Urban — Weighted average NO_2 emissions	[g/s]
122	Urban — Weighted average O_2 emissions	[g/s]

a Additional parameters may be added until line 195.

123	Urban — Weighted average PN emissions	[#/s]
124	Urban — Weighted average Vehicle Speed	[km/h]
…[a]	…[a]	…[a]

a Additional parameters may be added until line 195.

TABLE 8B

Header of reporting file #3 — Final emissions results according to Appendix 6

Line	Parameter	Unit
201	Total trip — THC Emissions	[mg/km]
202	Total trip — CH_4 Emissions	[mg/km]
203	Total trip — NMHC Emissions	[mg/km]
204	Total trip — CO Emissions	[mg/km]
205	Total trip — NO_x Emissions	[mg/km]
206	Total trip — PN Emissions	[#/km]
…[a]	…[a]	…[a]

a Additional parameters may be added.

TABLE 9

Body of reporting file #3 — Detailed results of the data evaluation method according to Appendix 6; the rows and columns of this table shall be transposed in the body of the data reporting file

Line	498	499	500	501
	Total trip — Power class number[a]		—	
	Total trip — Lower power class limit[a]		[kW]	
	Total trip — Upper power class limit[a]		[kW]	
	Total trip — Goal		[%]	[b]

a Results reported for each power class starting from power class #1 up to power class which includes 90 % of P_{rated}.

b Actual values to be included from line 501 to line onward until the end of data.

c Results reported for each power class starting from power class #1 up to power class #5.

d Additional parameters may be added.

	pattern used (distribution)[a]			
	Total trip — Power class occurrence[a]		—	[b]
	Total trip — Power class coverage > 5 counts[a]		—	(1=Yes, 0=No)[b]
	Total trip — Power class normality[a]		—	(1=Yes, 0=No)[b]
	Total trip — Power class average THC emissions[a]		[g/s]	[b]
	Total trip — Power class average CH_4 emissions[a]		[g/s]	[b]
	Total trip — Power class average NMHC emissions[a]		[g/s]	[b]
	Total trip — Power class average CO emissions[a]		[g/s]	[b]
	Total trip — Power class average CO_2 emissions[a]		[g/s]	[b]
	Total trip — Power class average NO_X emissions[a]		[g/s]	[b]
	Total trip — Power class average NO emissions[a]		[g/s]	[b]

a Results reported for each power class starting from power class #1 up to power class which includes 90 % of P_{rated}.

b Actual values to be included from line 501 to line onward until the end of data.

c Results reported for each power class starting from power class #1 up to power class #5.

d Additional parameters may be added.

	Total trip — Power class average NO_2 emissions[a]		[g/s]	[b]
	Total trip — Power class average O_2 emissions[a]		[g/s]	[b]
	Total trip — Power class average PN emissions[a]		[#/s]	[b]
	Total trip — Power class average Vehicle Speed[a]	Source (1=GPS, 2=ECU, 3=Sensor)	[km/h]	[b]
	Urban trip — Power class number[a]		—	
	Urban trip — Lower power class limit[a]		[kW]	
	Urban trip — Upper power class limit[a]		[kW]	
	Urban trip — Goal pattern used (distribution)[a]		[%]	[b]
	Urban trip — Power class occurrence[a]		—	[b]
	Urban trip — Power class coverage > 5 counts[c]		—	(1=Yes, 0=No)[b]
	Urban trip — Power class normality[a]		—	(1=Yes, 0=No)[b]

a Results reported for each power class starting from power class #1 up to power class which includes 90 % of P_{rated}.

b Actual values to be included from line 501 to line onward until the end of data.

c Results reported for each power class starting from power class #1 up to power class #5.

d Additional parameters may be added.

	Urban trip — Power class average THC emissions[a]		[g/s]	[b]
	Urban trip — Power class average CH_4 emissions[a]		[g/s]	[b]
	Urban trip — Power class average NMHC emissions[a]		[g/s]	[b]
	Urban trip — Power class average CO emissions[a]		[g/s]	[b]
	Urban trip — Power class average CO_2 emissions[a]		[g/s]	[b]
	Urban trip — Power class average NO_X emissions[a]		[g/s]	[b]
	Urban trip — Power class average NO emissions[a]		[g/s]	[b]
	Urban trip — Power class average NO_2 emissions[a]		[g/s]	[b]
	Urban trip — Power class average O_2 emissions[a]		[g/s]	[b]
	Urban trip — Power class average PN emissions[a]		[#/s]	[b]

a Results reported for each power class starting from power class #1 up to power class which includes 90 % of P_{rated}.

b Actual values to be included from line 501 to line onward until the end of data.

c Results reported for each power class starting from power class #1 up to power class #5.

d Additional parameters may be added.

	Urban trip — Power class average Vehicle Speed[a]	Source (1=GPS, 2=ECU, 3=Sensor)	[km/h]	[b]
	…[d]	…[d]	…[d]	[bd]

a Results reported for each power class starting from power class #1 up to power class which includes 90 % of P_{rated}.

b Actual values to be included from line 501 to line onward until the end of data.

c Results reported for each power class starting from power class #1 up to power class #5.

d Additional parameters may be added.

4.3. Vehicle and engine description

The manufacturer shall provide the vehicle and engine description in accordance with Appendix 4 of Annex I.

Appendix 9

Manufacturer's certificate of compliance

Manufacturer's certificate of compliance with the Real Driving Emissions requirements

(Manufacturer):

(Address of the Manufacturer):

Certifies that

The vehicle types listed in the attachment to this Certificate comply with the requirements laid down in point 2.1 of Annex IIIA to Regulation (EC) No 692/2008 relating to real driving emissions for all possible RDE tests, which are in accordance to the requirements of this Annex.

Done at […(Place)]

On […(Date)]

(Stamp and signature of the manufacturer's representative)

Annex:

— List of vehicle types to which this certificate applies.**]**

(1) [F1Commission Regulation (EU) No 1230/2012 of 12 December 2012 implementing Regulation (EC) No 661/2009 of the European Parliament and of the Council with regard to type-approval requirements for masses and dimensions of motor vehicles and their trailers and amending Directive 2007/46/EC of the European Parliament and of the Council (OJ L 353, 21.12.2012, p. 31).]

(2) [F1Regulation (EEC, Euratom) No 1182/71 of the Council of 3 June 1971 determining the rules applicable to periods, dates and time limits (OJ L 124, 8.6.1971, p. 1).]

(3) [F1For hybrids, the total energy consumption shall be converted to CO_2. The rules for this conversion will be introduced in a second step.]

(4) [F11 for Germany; 2 for France; 3 for Italy; 4 for the Netherlands; 5 for Sweden; 6 for Belgium; 7 for Hungary; 8 for the Czech Republic; 9 for Spain; 11 for the United Kingdom; 12 for Austria; 13 for Luxembourg; 17 for Finland; 18 for Denmark; 19 for Romania; 20 for Poland; 21 for Portugal; 23 for Greece; 24 for Ireland. 25 for Croatia; 26 for Slovenia; 27 for Slovakia; 29 for Estonia; 32 for Latvia; 34 for Bulgaria; 36 for Lithuania; 49 for Cyprus; 50 for Malta.]

Textual Amendments

F1 Inserted by Commission Regulation (EU) 2016/427 of 10 March 2016 amending Regulation (EC) No 692/2008 as regards emissions from light passenger and commercial vehicles (Euro 6) (Text with EEA relevance).