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Delegations will find attached document D045884/03 ANNEX 3 - PART3/3.

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ANNEX 3 – PART 3/3

ANNEX

to the

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supplementing 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, amending Directive 2007/46/EC of the European Parliament and of the Council, Commission Regulation (EC) No 692/2008 and Commission Regulation (EU) No 1230/2012 and repealing Regulation (EC) No 692/2008

Appendix 6

Verification of trip dynamic conditions and calculation of the final RDE emissions result 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/s²]

D_{WLTC} ....intercept of the Veline from WLTC

f_0, f_1, f_2 ....Driving resistance coefficients [N], [N/(km/h)], [N/(km/h)²]

i......................Time step for instantaneous measurements, minimum resolution 1Hz

j……………Wheel power class, j=1 to 9

k.....................Time step for the 3 second moving average values

k_{WLTC} Slope of the Veline from WLTC

$m_{gas,\,i}$ ....Instantaneous mass of the exhaust component “gas” at time step i, [g/s]; for PN in [#/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] ; for PN in [#/s]

$\bar{m}_{gas,j}$ ....Average emission value of an exhaust gas component in the wheel power class j, [g/s]; for PN in [#/s]

$\bar{m}_{gas,U}$ ....Weighted emission value of an exhaust gas component “gas” for the subsample of all seconds i with v_i < 60 km/h, [g/s]; for PN in [#/s]

$M_{w\,gas,d}$ ....Weighted distance-specific emissions for the exhaust gas component “gas” for the entire trip, [g/km]; for PN in [#/km]

$M_{w\,PN,d}$............Weighted distance-specific emissions for the exhaust gas component “PN” for the entire trip, [#/km]

$M_{w,gas,d,U}$ .... 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]

$M_{w,PN,d,U}$ .... Weighted distance-specific emissions for the exhaust gas component "PN" for the subsample of all seconds i with v_i < 60 km/h, [#/km]

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 vehicles wheel hubs to overcome driving resistances in time step i [kW]

$P_{w,3s,k}$ .... 3 second moving average power demand at the vehicles wheel hubs to overcome driving resistances in in time step k in 1 Hz resolution [kW]

P_{drive} .... Power demand at the wheel hubs for a vehicle at reference speed and acceleration [kW]

P_{norm} .... Normalised power demand at the wheel hubs [-]

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 seconds moving average of the vehicle velocity in time step k, [km/h]

$\bar{v}_U$ ....Weighted vehicle speed in the wheel power class j, [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

The 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. The reference point for measurement are the wheel hubs of the driven wheels.

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.

3.2. 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:

$$m_{gas,3s,k} = \frac{\sum_{i=k}^{k+2} m_{gas,i}}{3}$$

$$P_{w,3s,k} = \frac{\sum_{i=k}^{k+2} P_{w,i}}{3}$$

$$v_{3s,k} = \frac{\sum_{i=k}^{k+2} v_i}{3}$$

Where k............time step for moving average values

i.............time step from instantaneous test data

3.3. 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. For the later evaluation of the urban part of the trip, the three second moving averages calculated according to paragraph 3.2 shall be allocated to urban driving conditions according to the three second moving average of the velocity signal ($v_{3s,k}$) following the speed range defined in Table 1-1. The sample for the total trip evaluation shall cover all speed ranges including also the urban part.

Table 1-1

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

	Urban	Rural(1)	Motorway(1)
v_i [km/h]	0 to ≤ 60	> 60 to ≤ 90	> 90

(1)….not used in the actual regulatory evaluation

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 normalized power values to be representative for any LDV (Table 1).

Table 1

Normalized 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%	43.4582%
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 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] = $P_{c,norm,\,j}$ * P_{drive}

$$P_{drive} = \frac{v_{ref}}{3.6} \times \left(f_0 + f_1 \times v_{ref} + f_2 \times {v_{ref}}^2 + TM_{NEDC} \times a_{ref}\right) \times 0.001$$

Where:

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

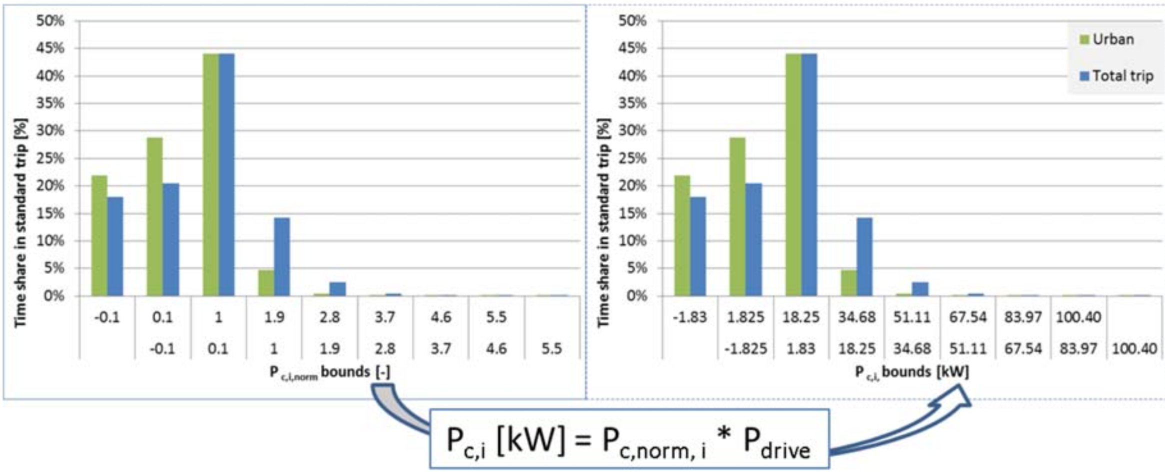
3.4.2. Correction of the wheel power classes

The maximum wheel power class to be considered is the highest class in Table 1 which includes (P_{rated} x 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 normalized 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]	1470
P_{rated} [kW]	120 (Example 1)
P_{rated} [kW]	75 (Example 2)

Corresponding results (see Table 2, Table 3):

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+1470[kg]*0.45[m/s²])*0.001

P_{drive} = 18.25 kW

Table 2

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

Power	$P_{c,j}$ [kW]	Urban	Total trip

class No.	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 [(1)]	100.375	All >100.375	0.00025%	0.0003%

[(1)] The highest wheel power class to be considered is the one containing 0.9 x Prated. Here 0.9 x 120 = 108.

Table 3

De-normalised standard power frequency values from Table 1.(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[(1)]	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	-	-

(1) The highest class wheel power class to be considered is the one containing 0.9 x Prated. Here 0.9 x 75 = 67.5.

3.5. Classification of the moving average values

The cold start emissions, defined according to Appendix 4, point 4.4, shall be excluded from the following evaluation.

Each moving average value calculated according to point 3.2 shall be sorted into the de-normalized 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 including also 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):

$$if \quad P_{C,j\ lower\ bound} < P_{w,3s,k} \leq P_{C,j\ upper\ bound}$$

then: class index for emissions and velocity = j

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

$$if \quad P_{C,j\ lower\ bound} < P_{w,3s,k} \leq P_{C,j\ upper\ bound}$$

then: $counts_j = n + 1$ ($counts_j$ is counting the number of 3 second moving average emission values 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

Power class No.	$P_{c,norm,j}$ [-]		Total trip		Urban trip parts	
	From >	to ≤	lower bound	upper bound	lower bound	upper bound
Sum 1+2[(1)]		0.1	15%	60%	5%[(1)]	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%

(1) 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 5 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 number 5 are less than 5, 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 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.

$$\bar{m}_{gas} = \sum_{j=1}^{9} \bar{m}_{gas,j} \times t_{c,j}$$

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

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

For the urban part of the trip: $M_{w,gas,d,U} = \frac{\bar{m}_{gas,U} \times 3600}{\bar{v}_U}$

For particle number the same method as for gaseous pollutants shall be applied but the unit [#/s] shall be used for $\bar{m}_{PN}$ and [#/km] shall be used for $M_{w,PN}$:

For the total trip: $M_{w,PN,d} = \frac{\bar{m}_{PN} \times 3600}{\bar{v}}$

For the urban part of the trip: $M_{w,PN,d,U} = \frac{\bar{m}_{PN} \times 3600}{\bar{v}_U}$

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. For this calculation the vehicle specific CO_2 line ("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 harmonized 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. For all wheel power values below the drag power shall be set to the drag power value.

$$\boldsymbol{P_{w,i}} = \frac{\boldsymbol{v_i}}{\boldsymbol{3.6}} \times \left(\boldsymbol{f_0} + \boldsymbol{f_1} \times \boldsymbol{v_i} + \boldsymbol{f_2} \times \boldsymbol{v_i^2} \quad + \boldsymbol{TM} \times \boldsymbol{a_i}\right) \times \boldsymbol{0.001}$$

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:

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

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]

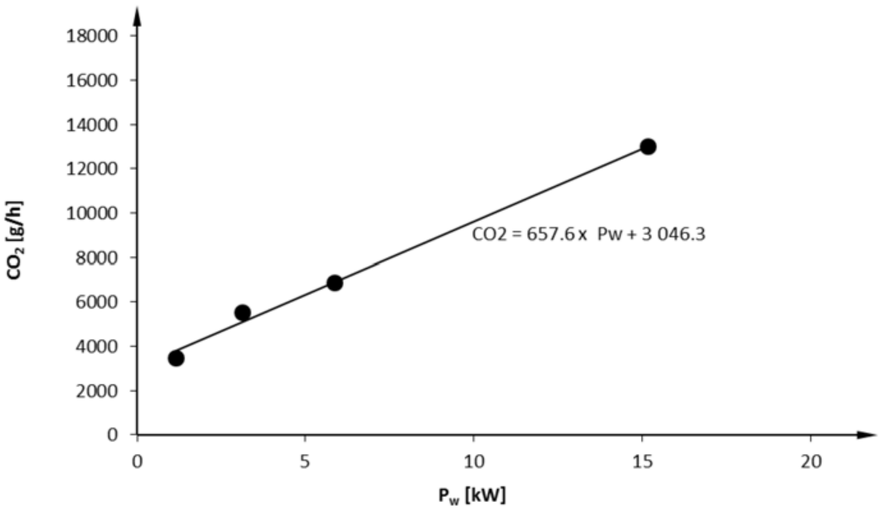
Where

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 CO2 test results in the 4 phases of the WLTC



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

$$P_{w,i} = \frac{CO2_i - D_{WLTC}}{k_{WLTC}}$$

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

(I) *if $v_i < 0.5$ and if $a_i < 0$ then $P_{w,i} = 0$* v in [m/s]

(II) *if $CO2_i < 0.5 \times D_{WLTC}$ then $P_{w,i} = P_{drag}$*

In time steps where (I) and (II) are valid, condition (II) shall be applied.

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 ('authority')

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 ≥1500 ccm and -32% from V_eng_max if V_eng_max <1500 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 …)

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

4.1.3. With agreement of the 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.

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 (4x4 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
from 11 to 49	NT = 3 + 0,1 x N (*)
more than 49	NT = 0,15 x N (*)

(*) 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 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 authority. Here *MS* is the distinguishing number of the Member State issuing the EC type-approval[1], 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 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 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

[1] 1 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

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.

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, PARAMETERS AND UNITS

RPA Relative Positive Acceleration

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]
Index (i)	-	discrete time step
Index (j)	-	discrete time step of positive acceleration datasets
Index (k)	-	refers to the respective category (t=total, u=urban, r=rural, m=motorway)

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]
T4253H	-	compound data smoother
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]
$(v \cdot \mathrm{a})_i$	-	actual vehicle speed per acceleration in time step i [m^2/s^3 or W/kg]
$(v \cdot \mathrm{a}_{pos})_{j,k}$	-	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% for all speed values above 3 km/h and a sampling frequency of 1 Hz. This accuracy requirement is generally fulfilled by signals obtained from a wheel (rotational) speed sensor.

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 calculated and ranked in ascending order, as 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 sufficiently accurate.

If $0.01\ m/s^2 < a_{res}$, data smoothing by using a T4253H Hanning filter shall be performed

The T4235 Hanning filter performs the following calculations: The smoother starts with a running median of 4, which is centred by a running median of 2. The filter 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 final speed values are computed by summing up the smoothed values obtained the first time through the process with the computed residuals.

The correct speed trace builds the basis for further calculations and binning as described in paragraph 8.1.2.

3.1.2. *Calculation of distance, acceleration and* $\boldsymbol{v \cdot a}$

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:

$$\boldsymbol{d_i = v_i/3.6,\ i = 1\ to\ N_t}$$

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:

$$a_i = (v_{i+1} - v_{i-1})/(2 \cdot 3.6), \qquad i = 1\ to\ N_t$$

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:

$$(v \cdot a)_i = v_i \cdot a_i/3.6, \qquad i = 1\ to\ N_t$$

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

The number of datasets with acceleration values $a_i > 0.1m/s^2$ 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:

$\bar{v}_k = \left(\sum_i v_{i,k}\right)/N_k$, $i = 1$ 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 $\boldsymbol{v \cdot a_{pos-}}[\mathbf{95}]$ 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 $a_{i,k} > 0.1 m/s^2$ $a_{i,k} \geq 0.1$ 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 $M_k/M_k = 100\%$.

$\left(v \cdot a_{pos}\right)_{k-}[95]$ is the $(v \cdot a_{pos})_{j,k}$ value, with $j/M_k = 95\%$. If $j/M_k = 95\%$ cannot be met, $\left(v \cdot a_{pos}\right)_{k-}[95]$ 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:

$$\boldsymbol{RPA_k = \sum_j (\Delta t \cdot (v \cdot a_{pos})_{j,k}) / \sum_i d_{i,k}}, \quad \boldsymbol{j = 1 \; to \; M_k, i = 1 \; to \; N_k, k = u, r, m}$$

where:

RPA_k	is the relative positive acceleration for urban, rural and motorway shares in [m/s² or kWs/(kg*km)]
Δt	is a time difference equal to 1 second
M_k	is the sample number for urban, rural and motorway shares with positive acceleration
N_k	is 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

$$(v \cdot a_{pos})_{k-}[95] > (0.136 \cdot \bar{v}_k + 14.44)$$

is fulfilled, the trip is invalid.

If $\bar{v}_k > 74.6 km/h$ and $(v \cdot a_{pos})_{k-}[95] > (0.0742 \cdot \bar{v}_k + 18.966)$ 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 $RPA_k < (-0.0016 \cdot \bar{v}_k + 0.1755)$ 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 PEMS trip

1. INTRODUCTION

This Appendix describes the procedure to determine the cumulative elevation gain of a PEMS trip.

2. SYMBOLS, PARAMETERS AND UNITS

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 and 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	-	kilometer per hour
m	-	meter
$road_{grade,1}(d)$	-	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 at a data point t [km/h]

3. General requirements

The cumulative positive elevation gain of a 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 a 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:

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

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:

$$|h(t) - h(t-1)| > \ (v(t)/3.6 * sin45°)$$

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 calculation of the cumulative positive elevation gain as described in Point 13.4.

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, characterized 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:

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

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 traveled 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:

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

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

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

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

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

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 meters [m]
d_e	-	cumulative distance travelled until the last discrete way point [m]

The second smoothing run shall be applied as follows:

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

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

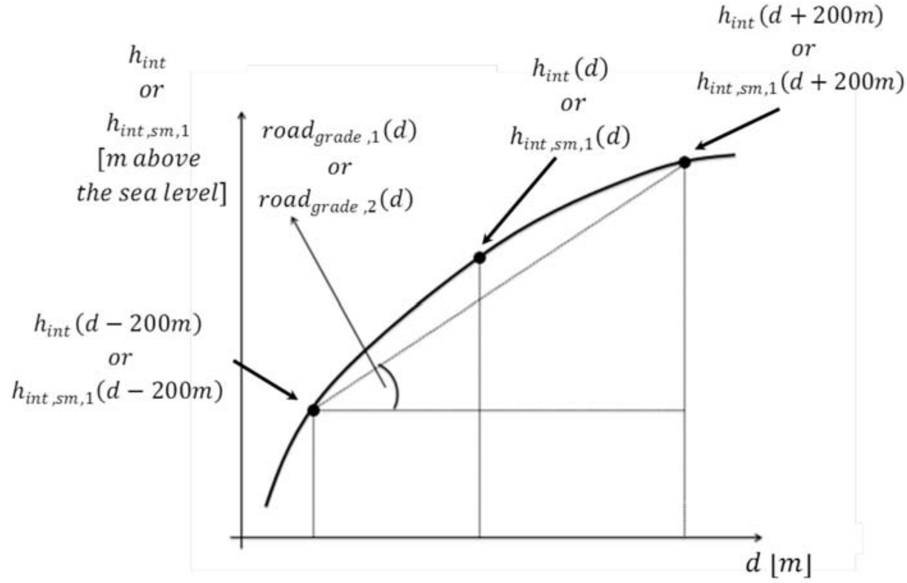
$$road_{grade,2}(d) = \frac{h_{int,sm,1}(d_e) - h_{int,sm,1}(d - 200m)}{d_e - (d - 200m)} \qquad for\ d \geq (d_e - 200m)$$

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 meters [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 normalized by the total test distance d_{tot} and expressed in meters of cumulative elevation gain per one hundred kilometers of distance.

5. NUMERICAL EXAMPLE

Tables 1 and 2 show how 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 800m and 160s 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:

$$h_{GPS}(t) - h_{map}(t) < -40m$$

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 for the altitude data in these time periods 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:

$$h_{int}(0) = 120.3 + \frac{120.3 - 120.3}{0.1 - 0.0} * (0 - 0) = 120.3000$$

$$h_{int}(520) = 132.5 + \frac{132.6 - 132.5}{523.6 - 519.9} * (520 - 519.9) = 132.5027$$

5.3.2. Additional data smoothing

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

$$road_{grade,1}(0) = \frac{h_{int}(200m) - h_{int}(0)}{(0 + 200m)} = \frac{120.9682 - 120.3000}{200} = 0.0033$$

$$chosen\ to\ demonstrate\ the\ smoothing\ for\ d \leq 200m$$

$$road_{grade,1}(320) = \frac{h_{int}(520) - h_{int}(120)}{(520) - (120)} = \frac{132.5027 - 121.0}{400} = 0.0288$$

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

$$road_{grade,1}(720) = \frac{h_{int}(799) - h_{int}(520)}{799 - (520)} = \frac{121.2000 - 132.5027}{279} = -0.0405$$

$$chosen\ to\ demonstrate\ the\ smoothing\ for\ d \geq (599m)$$

The smoothed and interpolated altitude is calculated as:

$$h_{int,sm,1}(0) = h_{int}(0) + road_{grade,1}(0) = 120.3 + 0.0033 \approx 120.3033m$$

$$h_{int,sm,1}(799) = h_{int,sm,1}(798) + road_{grade,1}(799) = 121.2550 - 0.0220 = 121.2330m$$

Second smoothing run:

$$road_{grade,2}(0) = \frac{h_{int,sm,1}(200) - h_{int,sm,1}(0)}{(200)} = \frac{119.9618 - 120.3033}{(200)} = -0.0017$$

$chosen\ to\ demonstrate\ the\ smoothing\ for\ d \leq 200m$

$$road_{grade,2}(320) = \frac{h_{int,sm,1}(520) - h_{int,sm,1}(120)}{(520) - (120)} = \frac{123.6809 - 120.1843}{400} = 0.0087$$

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

$$road_{grade,2}(720) = \frac{h_{int,sm,1}(799) - h_{int,sm,1}(520)}{799 - (520)} = \frac{121.2330 - 123.6809}{279} = -0.0088$$

$chosen\ to\ demonstrate\ the\ smoothing\ for\ d \geq (599m)$

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. values in the column $road_{grade,2}(d)$ in Table 2. For the entire data set the total covered distance was d_{tot}=139.7 km and all positive interpolated and smoothed road grades were of 516m. Therefore the positive cumulative elevation gain reached 516*100/139.7=370m/100km.

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

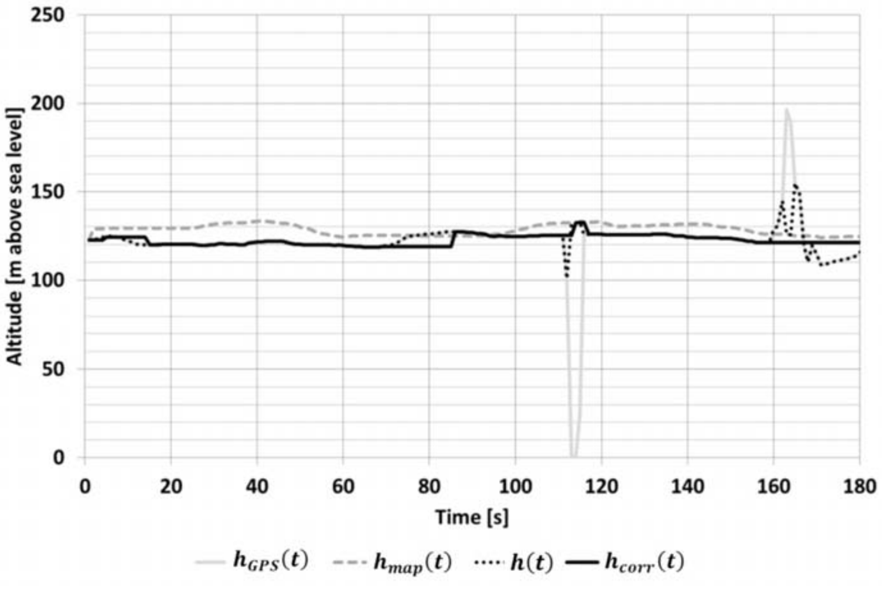


Figure 3

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

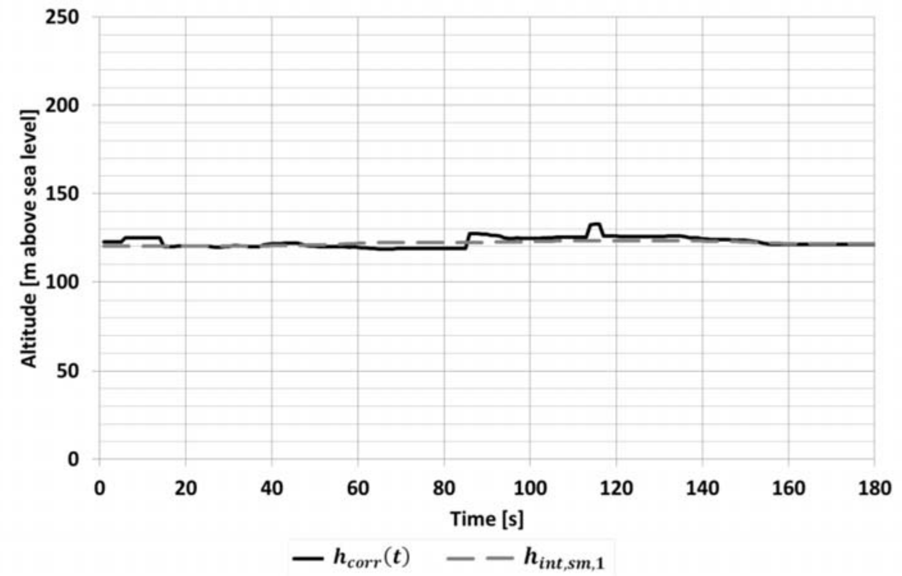


Table 2

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 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 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

$\left(v \cdot a_{pos}\right)_k$-[95] - 95th percentile of the product of vehicle speed and positive acceleration greater than 0.1 m/s^2 for urban, rural and motorway driving [m^2/s^3 or W/kg]

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

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

Summary parameters of intermediate results shall be recorded and structured as indicated 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 organization]
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 reading at test start	[km]
12	Odometer reading at test end	[km]
13	Vehicle category	[category]
14	Type approval emissions limit	[Euro X]
15	Engine type	[e.g., spark ignition, compression ignition]
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	Tire size	[width/height/rim diameter]
24	Front and rear axle tire pressure	[bar; bar]
25W	Road load parameters from WLTP,	[F_0, F_1, F_2]
25N	Road load parameters from NEDC	[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(1)	[kg;%(2)]
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]
40-50(3)	…	…
51	EFM manufacturer(4)	[name]
52	EFM sensor type(4)	[functional principle]
53	EFM serial number(4)	[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[(5)]	…	…
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]
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[(5)]	…	…
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	[#]
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;%][(6)]
133	PEMS validation – results CH_4	[mg/km;%][(6)]
134	PEMS validation – results NMHC	[mg/km;%][(6)]
135	PEMS validation – results PN	[#/km;%][(6)]
136	PEMS validation – results CO	[mg/km;%][(6)]
137	PEMS validation – results CO_2	[g/km;%][(6)]
138	PEMS validation – results NO_X	[mg/km;%][(6)]
…[(7)]	…[(7)]	…[(7)]

(1) Mass of the vehicle as tested on the road, including the mass of the driver and all PEMS components.

(2) Percentage shall indicate the deviation from the gross vehicle weight.

(3) 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.

(4) Mandatory if the exhaust mass flow rate is determined by an EFM.

(5) If required, additional information may be added here.

(6) PEMS validation is optional; distance-specific emissions as measured with the PEMS; Percentage shall indicate the deviation from the laboratory reference

(7) 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[1]	200	201
	Time	trip	[s]	[2]
	Vehicle speed[3]	Sensor	[km/h]	[2]
	Vehicle speed[3]	GPS	[km/h]	[2]
	Vehicle speed[3]	ECU	[km/h]	[2]
	Latitude	GPS	[deg:min:s]	[2]
	Longitude	GPS	[deg:min:s]	[2]
	Altitude[3]	GPS	[m]	[2]
	Altitude[3]	Sensor	[m]	[2]
	Ambient pressure	Sensor	[kPa]	[2]
	Ambient temperature	Sensor	[K]	[2]
	Ambient humidity	Sensor	[g/kg; %]	[2]
	THC concentration	Analyser	[ppm]	[2]
	CH_4 concentration	Analyser	[ppm]	[2]
	NMHC concentration	Analyser	[ppm]	[2]
	CO concentration	Analyser	[ppm]	[2]
	CO_2 concentration	Analyser	[ppm]	[2]
	NO_X concentration	Analyser	[ppm]	[2]
	NO concentration	Analyser	[ppm]	[2]
	NO_2 concentration	Analyser	[ppm]	[2]
	O_2 concentration	Analyser	[ppm]	[2]
	PN concentration	Analyser	[#/m^3]	[2]
	Exhaust mass flow rate	EFM	[kg/s]	[2]
	Exhaust temperature in the EFM	EFM	[K]	[2]
	Exhaust mass flow	Sensor	[kg/s]	[2]

	rate			
	Exhaust mass flow rate	ECU	[kg/s]	(2)
	THC mass	Analyser	[g/s]	(2)
	CH_4 mass	Analyser	[g/s]	(2)
	NMHC mass	Analyser	[g/s]	(2)
	CO mass	Analyser	[g/s]	(2)
	CO_2 mass	Analyser	[g/s]	(2)
	NO_X mass	Analyser	[g/s]	(2)
	NO mass	Analyser	[g/s]	(2)
	NO_2 mass	Analyser	[g/s]	(2)
	O_2 mass	Analyser	[g/s]	(2)
	PN	Analyser	[#/s]	(2)
	Gas measurement active	PEMS	[active (1); inactive (0); error (>1)]	(2)
	Engine speed	ECU	[rpm]	(2)
	Engine torque	ECU	[Nm]	(2)
	Torque at driven axle	Sensor	[Nm]	(2)
	Wheel rotational speed	Sensor	[rad/s]	(2)
	Fuel rate	ECU	[g/s]	(2)
	Engine fuel flow	ECU	[g/s]	(2)
	Engine intake air flow	ECU	[g/s]	(2)
	Coolant temperature	ECU	[K]	(2)
	Oil temperature	ECU	[K]	(2)
	Regeneration status	ECU	-	(2)
	Pedal position	ECU	[%]	(2)
	Vehicle status	ECU	[error (1); normal (0)]	(2)

	Per cent torque	ECU	[%]	(2)
	Per cent friction torque	ECU	[%]	(2)
	State of charge	ECU	[%]	(2)
	…(4)	…(4)	…(4)	(2,4)

(1) This column can be omitted if the parameter source is part of the label in column 198.

(2) Actual values to be included from line 201 onward until the end of data

(3) To be determined by at least one method

(4) 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	Altitude at start point of the trip	[m above sea level]
7	Altitude at end point of the trip	[m above sea level]
8	Cumulative elevation gain during the trip	[m/100 km]
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]
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]
38	$(v \cdot a_{pos})_k$–[95], k=urban	[m^2/s^3]

39	RPA_k, k=urban	[m/s^2]
40	Cumulative urban elevation gain	[m/100 km]
41	Average urban THC concentration	[ppm]
42	Average urban CH_4 concentration	[ppm]
43	Average urban NMHC concentration	[ppm]
44	Average urban CO concentration	[ppm]
45	Average urban CO_2 concentration	[ppm]
46	Average urban NO_X concentration	[ppm]
47	Average urban PN concentration	[#/m^3]
48	Average urban exhaust mass flow rate	[kg/s]
49	Average urban exhaust temperature	[K]
50	Maximum urban exhaust temperature	[K]
51	Cumulated urban THC mass	[g]
52	Cumulated urban CH_4 mass	[g]
53	Cumulated urban NMHC mass	[g]
54	Cumulated urban CO mass	[g]
55	Cumulated urban CO_2 mass	[g]
56	Cumulated urban NO_X mass	[g]
57	Cumulated urban PN	[#]
58	Urban THC emissions	[mg/km]
59	Urban CH_4 emissions	[mg/km]
60	Urban NMHC emissions	[mg/km]
61	Urban CO emissions	[mg/km]
62	Urban CO_2 emissions	[g/km]
63	Urban NO_X emissions	[mg/km]
64	Urban PN emissions	[#/km]
65	Distance rural part	[km]

66	Duration rural part	[h:min:s]
67	Stop time rural part	[min:s]
68	Average speed rural part	[km/h]
69	Maximum speed rural part	[km/h]
70	$(v \cdot a_{pos})_k$–[95], k=rural	[m^2/s^3]
71	RPA_k, k=rural	[m/s^2]
72	Average rural THC concentration	[ppm]
73	Average rural CH_4 concentration	[ppm]
74	Average rural NMHC concentration	[ppm]
75	Average rural CO concentration	[ppm]
76	Average rural CO_2 concentration	[ppm]
77	Average rural NO_X concentration	[ppm]
78	Average rural PN concentration	[$\#/m^3$]
79	Average rural exhaust mass flow rate	[kg/s]
80	Average rural exhaust temperature	[K]
81	Maximum rural exhaust temperature	[K]
82	Cumulated rural THC mass	[g]
83	Cumulated rural CH_4 mass	[g]
84	Cumulated rural NMHC mass	[g]
85	Cumulated rural CO mass	[g]
86	Cumulated rural CO_2 mass	[g]
87	Cumulated rural NO_X mass	[g]
88	Cumulated rural PN	[#]
89	Rural THC emissions	[mg/km]
90	Rural CH_4 emissions	[mg/km]
91	Rural NMHC emissions	[mg/km]
92	Rural CO emissions	[mg/km]

93	Rural CO_2 emissions	[g/km]
94	Rural NO_X emissions	[mg/km]
95	Rural PN emissions	[#/km]
96	Distance motorway part	[km]
97	Duration motorway part	[h:min:s]
98	Stop time motorway part	[min:s]
99	Average speed motorway part	[km/h]
100	Maximum speed motorway part	[km/h]
101	$(v \cdot a_{pos})_k$–[95], k=motorway	[m^2/s^3]
102	RPA_k, k=motorway	[m/s^2]
103	Average motorway THC concentration	[ppm]
104	Average motorway CH_4 concentration	[ppm]
105	Average motorway NMHC concentration	[ppm]
106	Average motorway CO concentration	[ppm]
107	Average motorway CO_2 concentration	[ppm]
108	Average motorway NO_X concentration	[ppm]
109	Average motorway PN concentration	[$\#/m^3$]
110	Average motorway exhaust mass flow rate	[kg/s]
111	Average motorway exhaust temperature	[K]
112	Maximum motorway exhaust temperature	[K]
113	Cumulated motorway THC mass	[g]
114	Cumulated motorway CH_4 mass	[g]
115	Cumulated motorway NMHC mass	[g]
116	Cumulated motorway CO mass	[g]
117	Cumulated motorway CO_2 mass	[g]
118	Cumulated motorway NO_X mass	[g]
119	Cumulated motorway PN	[#]

120	Motorway THC emissions	[mg/km]
121	Motorway CH_4 emissions	[mg/km]
122	Motorway NMHC emissions	[mg/km]
123	Motorway CO emissions	[mg/km]
124	Motorway CO_2 emissions	[g/km]
125	Motorway NO_X emissions	[mg/km]
126	Motorway PN emissions	[#/km]
…(1)	…(1)	…(1)

(1) Parameters may be added to characterize additional elements of the trip.

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	
6	Coefficient k_{11} of the weighing function	
7	Coefficient k_{21} of the weighing function	
8	Coefficient $k_{22}=k_{12}$ of the weighing function	
9	Primary tolerance tol_1	[%]
10	Secondary tolerance tol_2	[%]

11	Calculation software and version	(e.g. EMROAD 5.8)
…[1]	…[1]	…[1]

[1] Parameters may be added until line 95 to characterize additional 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 in the total number of windows higher than 15%	(1=Yes, 0=No)
109	Share of rural windows in the total number of windows higher than 15%	(1=Yes, 0=No)
110	Share of motorway windows in the total number of windows higher than 15%	(1=Yes, 0=No)
111	Number of windows within $\pm\ tol_1$	
112	Number of urban windows within $\pm\ tol_1$	
113	Number of rural windows within $\pm\ tol_1$	
114	Number of motorway windows within $\pm\ tol_1$	

115	Number of windows within $\pm tol_2$	
116	Number of urban windows within $\pm tol_2$	
117	Number of rural windows within $\pm tol_2$	
118	Number of motorway windows within $\pm tol_2$	
119	Share of urban windows within $\pm tol_1$	[%]
120	Share of rural windows within $\pm tol_1$	[%]
121	Share of motorway windows within $\pm tol_1$	[%]
122	Share of urban windows within $\pm tol_1$ greater than 50%	(1=Yes, 0=No)
123	Share of rural windows within $\pm tol_1$ greater than 50%	(1=Yes, 0=No)
124	Share of motorway windows within $\pm tol_1$ 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]
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]
152		Weighted PN emissions of motorway windows	[#/km]

…[1]	…[1]	…[1]

[1] 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]
…[1]	…[1]	…[1]

[1] 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]	[1]
	Window End Time		[s]	[1]
	Window Duration		[s]	[1]
	Window Distance	Source (1=GPS, 2=ECU, 3=Sensor)	[km]	[1]
	Window THC emissions		[g]	[1]
	Window CH_4		[g]	[1]

	emissions			
	Window NMHC emissions		[g]	(1)
	Window CO emissions		[g]	(1)
	Window CO_2 emissions		[g]	(1)
	Window NO_X emissions		[g]	(1)
	Window NO emissions		[g]	(1)
	Window NO_2 emissions		[g]	(1)
	Window O_2 emissions		[g]	(1)
	Window PN emissions		[#]	(1)
	Window THC emissions		[mg/km]	(1)
	Window CH_4 emissions		[mg/km]	(1)
	Window NMHC emissions		[mg/km]	(1)
	Window CO emissions		[mg/km]	(1)
	Window CO_2 emissions		[g/km]	(1)
	Window NO_X emissions		[mg/km]	(1)
	Window NO emissions		[mg/km]	(1)
	Window NO_2 emissions		[mg/km]	(1)
	Window O_2 emissions		[mg/km]	(1)
	Window PN emissions		[#/km]	(1)

	Window distance to CO2 characteristic curve h_j		[%]	(1)
	Window weighing factor w_j		[-]	(1)
	Window Average Vehicle Speed	Source (1=GPS, 2=ECU, 3=Sensor)	[km/h]	(1)
	…(2)	…(2)	…(2)	(1,2)

(1) Actual values to be included from line 501 to line onward until the end of data

(2) 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)
…(1)	…(1)	…(1)

(1) Additional parameters may be added until line 95 to characterize 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)
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]
123	Urban - Weighted average PN emissions	[#/s]
124	Urban - Weighted average Vehicle Speed	[km/h]
…[(1)]	…[(1)]	…[(1)]

[(1)] Additional parameters may be added until line 195

Table 8b

Header of reporting file #3 – Final emissions results according to Appendix 6

	Parameter	Unit
	Total trip - THC Emissions	[mg/km]
	Total trip - CH_4 Emissions	[mg/km]
	Total trip - NMHC Emissions	[mg/km]
	Total trip - CO Emissions	[mg/km]
	Total trip - NO_x Emissions	[mg/km]

	Total trip - PN Emissions	[#/km]
	…[1]	…[1]

[1] 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 [1]		-	
	Total trip - Lower power class limit[1]		[kW]	
	Total trip - Upper power class limit[1]		[kW]	
	Total trip - Goal pattern used (distribution) [1]		[%]	[2]
	Total trip - Power class occurrence [1]		-	[2]
	Total trip - Power class coverage >5 counts[1]		-	(1=Yes, 0=No) [2]
	Total trip - Power class normality[1]		-	(1=Yes, 0=No) [2]
	Total trip - Power class average THC emissions[1]		[g/s]	[2]

		Total trip - Power class average CH_4 emissions(1)		[g/s]	(2)
		Total trip - Power class average NMHC emissions(1)		[g/s]	(2)
		Total trip - Power class average CO emissions(1)		[g/s]	(2)
		Total trip - Power class average CO_2 emissions(1)		[g/s]	(2)
		Total trip - Power class average NO_X emissions(1)		[g/s]	(2)
		Total trip - Power class average NO emissions(1)		[g/s]	(2)
		Total trip - Power class average NO_2 emissions(1)		[g/s]	(2)
		Total trip - Power class average O_2 emissions(1)		[g/s]	(2)
		Total trip - Power class average PN emissions(1)		[#/s]	(2)
		Total trip - Power class average Vehicle Speed(1)	Source (1=GPS, 2=ECU, 3=Sensor)	[km/h]	(2)
		Urban trip - Power class number (1)		-	
		Urban trip - Lower power class limit(1)		[kW]	
		Urban trip - Upper power class limit(1)		[kW]	
		Urban trip - Goal pattern used (distribution) (1)		[%]	(2)
		Urban trip - Power class occurrence(1)		-	(2)

	Urban trip - Power class coverage >5 counts(3)		-	(1=Yes, 0=No) (2)
	Urban trip - Power class normality(1)		-	(1=Yes, 0=No) (2)
	Urban trip - Power class average THC emissions(1)		[g/s]	(2)
	Urban trip - Power class average CH_4 emissions(1)		[g/s]	(2)
	Urban trip - Power class average NMHC emissions(1)		[g/s]	(2)
	Urban trip - Power class average CO emissions(1)		[g/s]	(2)
	Urban trip - Power class average CO_2 emissions(1)		[g/s]	(2)
	Urban trip - Power class average NO_X emissions(1)		[g/s]	(2)
	Urban trip - Power class average NO emissions(1)		[g/s]	(2)
	Urban trip - Power class average NO_2 emissions(1)		[g/s]	(2)
	Urban trip - Power class average O_2 emissions(1)		[g/s]	(2)
	Urban trip - Power class average PN emissions(1)		[#/s]	(2)
	Urban trip - Power class average Vehicle Speed(1)	Source (1=GPS, 2=ECU, 3=Se	[km/h]	(2)

		nsor)		
	…[4]	…[4]	…[4]	[2,4]

[1] Results reported for each power class starting from power class #1 up to power class which includes 90% of P_{rated}

[2] Actual values to be included from line 501 to line onward until the end of data

[3] Results reported for each power class starting from power class #1 up to power class #5

[4] 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