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Amendment 2 To
AIS 137 (Part 3): Test Method, Testing Equipment and Related Procedures for Type Approval and Conformity of Production (COP) Testing of M and N Category Vehicles having GVW not exceeding 3500 kg for Bharat Stage VI (BS VI) Emission Norms as per CMV Rules 115, 116 and 126

1.0	**Page 295/296**
	Insert chapter 20 after chapter 19:
	CHAPTER 20 **VERIFYING REAL DRIVING EMISSIONS**
1.0	**INTRODUCTION, DEFINITIONS AND ABBREVIATIONS**
1.1.	Introduction
	This chapter describes the procedure to verify the Real Driving Emissions (RDE) performance of light passenger and commercial vehicles for all M and N Categories of vehicles with GVW up to 3.5 Tons.
	Note: - This regulation shall apply to vehicles of categories M1, M2, N1 and N2 with reference mass not exceeding 2610 kg. However, at the manufacturer's request, type approval granted under this regulation may be extended from vehicles mentioned above to M1, M2, N1 & N2 vehicles with a reference mass not exceeding 2840 kg and which meet the condition laid down in GSR 889 (E) dated 16th September 2016.
1.2.	Definitions : For the purposes of this Chapter, in addition to definitions in Chapter 1 of this Part, following definitions shall apply:
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 ($a0$) means:
	$$a_o = \bar{y} - (a_1 \times \bar{x})$$
	where:
	a_1 = slope of the regression line
	$\bar{x}$= mean value of the reference parameter

	$\bar{y}$= 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:		
	$$r^2 = 1 - \frac{\sum_{i=1}^{n}[y_i - a_0 - (a_1 \times X_i)]^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2}$$		
	where:		
	a_0	=	Axis intercept of the linear regression line
	a_1	=	Slope of the linear regression line
	X_i	=	Measured reference value
	y_i	=	Measured value of the parameter to be verified
	$\bar{y}$	=	Mean value of the parameter to be verified
	n	=	Number of values
1.2.6.	**"Cross-correlation coefficient" (r) means:**		
	$$r = \frac{\sum_{i=1}^{n-1}(x_i - \bar{x}) \times (y_i - \bar{y})}{\sqrt{\sum_{x=1}^{n-1}(x_i - \bar{x})^2} \times \sqrt{\sum_{i=1}^{n-1}(y_i - \bar{y})^2}}$$		
	where:		
	x_i	=	Measured reference value
	y_i	=	Measured value of the parameter to be verified
	$\bar{x}$	=	Mean reference value
	$\bar{y}$	=	Mean value of the parameter to be verified
	n	=	Number of values
1.2.7.	**"Delay time"** means the time from the gas flow switching (t_0) until the response reaches 10 % (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 clause 3.4.5. of Appendix 1 of this Chapter.		
1.2.9.	**"Engine control unit"** means the electronic unit that controls various actuators to ensure the optimal performance of the power train.		

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, characterized 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 s.
1.2.17.	**"Non-methane hydrocarbons"** (NMHC) means the total hydrocarbons (THC) excluding methane (CH4).
1.2.18.	**"Particle number emissions"** (PN) means the total number of solid particles emitted from the vehicle exhaust quantified according to the dilution, sampling and measurement methods as specified in Part 3 of AIS-137.
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 % and 90 % 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:

	$$x_{rms} = \sqrt{\frac{1}{n}({x_1}^2 + {x_2}^2 + \cdots + {x_n}^2)}$$	
	x =	Measured or calculated value
	n =	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 to adjust an instrument so that it gives a proper response to a calibration standard that represents between 75 % and 100 % of the maximum value in the instrument range or expected range of use.	
1.2.26.	**"Span response"** means the mean response to a span signal over a time interval of at least 30 s.	
1.2.27.	**"Span response drift"** means the difference between the mean responses 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 (a1) means:**	
	$$a_1 = \frac{\sum_{i=1}^{n}(y_i - \bar{y}) \times (x_i - \bar{x})}{\sum_{i=1}^{n}(x_i - \bar{x})^2}$$	
	where:	

	$\bar{x}$	=	Mean value of the reference parameter.
	$\bar{y}$	=	Mean value of the parameter to be verified.
	x_i	=	Actual value of the reference parameter.
	y_i	=	Actual value of the parameter to be verified.
	n	=	Number of values.
1.2.29.	**"Standard error of estimate" (SEE) means:**		
	$$SEE = \frac{1}{x_{max}} \times \sqrt{\frac{\sum_{i=1}^{n}\sqrt{(y_i - \acute{y})^2}}{(n-2)}}$$		
	Where:		
	$\acute{y}$	=	Estimated value of the parameter to be verified
	y_i	=	Actual value of the parameter to be verified

	x_{max}	=	Maximum actual values of the reference parameter
	n	=	Number of values

1.2.30.	**"Total hydrocarbons"** (THC) means the sum of all volatile compounds measurable by a flame ionization 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 % 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 30s.
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.
1.2.40	**"Off-vehicle charging hybrid electric vehicle" (OVC-HEV)** means a hybrid electric vehicle that can be charged from an external source."
1.2.41.	**"Not off-vehicle charging hybrid electric vehicle" (NOVC- HEV)** means a vehicle with at least two different energy converters and two different energy storage systems that are used for the purpose of vehicle propulsion and that cannot be charged from an external source.

1.2.42	**M1/M2/ N1 Low Powered Vehicles;** As per GTR 15, class 1 vehicles having a power to kerb weight ratio ≤ 22 W/kg and max design speed ≤ 70 kmph.	
1.2.43	**"Real driving emissions (RDE)"** means the emissions of a vehicle under its normal conditions of use;	
1.2.44	**'"Portable emissions measurement system (PEMS)"** means a portable emissions measurement system meeting the requirements specified in Appendix 1 to this chapter	
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 analyser
	NDUV	Non-Dispersive UltraViolet analyser
	MIDC	Modified Indian 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
	RPA	Relative Positive Acceleration
	SCR	Selective Catalytic Reduction
	SEE	Standard Error of Estimate
	THC	Total Hydro Carbons
	VIN	Vehicle Identification Number

2.0	**GENERAL REQUIREMENTS**
2.1	**Not-to-exceed Emission Limits**
	Throughout the normal life of a vehicle type approved according to this Part, its emissions determined in accordance with the requirements of this Chapter and emitted at any possible RDE test performed in accordance with the requirements of this chapter, shall not be higher than the following not-to-exceed (NTE) values:
	$NTE_{pollutant} = CF_{pollutant} \text{ X Limit}$
	where Limit is the applicable emission limit laid down in Gazette Notification.

2.1.1.	Final Conformity Factors
	The conformity factor $CF_{pollutant}$ for the respective pollutant will be notified which will be applicable from 1st April 2023 as amended from time to time.
2.2	The manufacturer shall confirm compliance with clause 2.1 of this Chapter by completing the certificate set out in Appendix 9 of this Chapter.
2.3	The RDE tests required by this Chapter 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	Test Agency shall ensure that vehicles can be tested with PEMS on public roads in accordance with the procedures under national law, while respecting local road traffic legislation and safety requirements.
2.5	Manufacturers shall ensure that vehicles can be tested with PEMS by a Test Agency on public roads, e.g. by making available suitable adapters for exhaust pipes, granting access to ECU signals and making the necessary administrative arrangements.
3.0	**RDE TEST TO BE PERFORMED**
3.1	The following requirements apply to PEMS tests
3.1.0	The requirements of clause 2.1 of this Chapter 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 clause 3.1.0.1 or 3.1.0.2 below shall be fulfilled. OVC-HEVs shall fulfil the conditions of point 3.1.0.3.
3.1.0.1	$M_{gas,d,t} \leq NTE_{pollutant}$ and $M_{gas,d,u} \leq NTE_{pollutant}$ with the definitions of clause 2.1 of this Chapter and clause 6.1 and 6.3 of Appendix 5 of this Chapter and the setting gas = pollutant. **Note:** For M1 and N1 Low Powered vehicles, the phase-1 shall be considered as “Urban” phase and shall comply as per this clause.
3.1.0.2	$M_t \leq$ NTE pollutant and $M_u \leq$ NTE pollutant with the definitions of clause 2.1 of this Chapter and clause 4 of Appendix 7C of this Chapter.
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 clause 7.2 of Appendix 2 of this Chapter.

3.1.2	If the Test Agency is not satisfied with the data quality check and validation results of a PEMS test conducted according to Appendices 1 and 4 of this Chapter, the Test Agency 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 Test Agency.
3.1.3.	Reporting and Dissemination of RDE Test Information.
3.1.3.1.	A technical report shall be prepared in accordance with Appendix 8 of this Chapter.
3.1.3.2	The manufacturer shall ensure that the following information is made available on a publicly accessible website without costs from April 2023.
3.1.3.2.1.	Reserved.
3.1.3.2.2.	Reserved.
3.1.3.3.	Reserved.
3.1.3.4.	Reserved.
4.0	**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 Test Agency that the chosen vehicle, driving patterns, conditions and payloads are representative for the PEMS Test family. The payload and altitude requirements, as specified in clause 5.1 and 5.2 of this Chapter, shall be used ex-ante to determine whether the conditions are acceptable for RDE testing.
4.3	The Test Agency shall propose a test trip in urban, rural and motorway environments meeting the requirements of clause 6 of this Chapter. 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 test shall be considered as non-compliant. Such functionality shall be considered as a 'defeat device' as defined in clause 2.16 of Chapter 1 of this Part.
4.5	In order to assess emissions during trips in hot start, vehicle shall be tested without conditioning the vehicle as described in clause 5.3 of this Chapter, but with a warm engine with engine coolant temperature and/or engine oil temperature above 70 °C.
4.6	For RDE tests the vehicle should be run-in for minimum 3000 km or as per manufacturer’s recommendation.

4.7	The tyre types and pressure shall be according to the vehicle manufacturer's recommendations. The tyre pressure shall be checked prior to the pre-conditioning and adjusted to the recommended values if needed.
4.8	For diesel vehicles, if the urea tank level does not guarantee the completion of the RDE testing, the reagent must be refilled prior to testing. Warnings/reagent level in the dashboard shall be checked prior the test.
4.9	For RDE tests, the vehicle On-Board Diagnostics (OBD) shall be checked and documented at the selection stage.
4.10	RDE Test shall be carried out, during Type Approval as per Appendix 7 of this chapter. During monitoring phase, IRDE testing will be conducted on one vehicle out of the three samples for all COP models until fixation of conformity factor.
5.0	**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 all categories of vehicles, 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 maximum payload. The term “maximum payload” shall be referred as defined in IS 9211.
5.2	**Ambient Conditions**
5.2.1	The test shall be conducted under ambient conditions laid down in this clause 5.2. The ambient conditions become "extended" when at least one of the temperature and altitude conditions is extended. The correction factor for extended conditions for temperature and altitude shall only be applied once. If a part of the test or the entire test is performed outside of normal or extended conditions, the test shall be invalid.
5.2.2	Moderate altitude conditions: Altitude lower or equal to 700 m above sea level.
5.2.3	Extended altitude conditions: Altitude higher than 700 m above sea level and lower or equal to 1300 m above sea level.
5.2.4	Moderate temperature conditions: Greater than or equal to 283 K (10°C) and lower than or equal to 313 K (40°C)
5.2.5	Extended temperature conditions: Greater than or equal to 281 K (8^0C) and lower than 283 K (10°C) or greater than 313 K (40°C) and lower than or equal to 318 K (45°C) .

5.3	Vehicle conditioning for cold engine-start testing Before RDE testing, the vehicle shall be preconditioned in the following way: Driven for at least 30 min, parked with doors and bonnet closed and kept in engine-off status within moderate or extended altitude and temperatures in accordance with clause 5.2.2 to 5.2.5 of this Chapter between 6 and 56 hours. Exposure to extreme atmospheric conditions (heavy snowfall, storm, hail) and excessive amounts of dust should be avoided. Before the test start, the vehicle and equipment shall be checked for damages and the absence of warning signals, suggesting malfunctioning. When several RDE tests are conducted in consecutive days, the previous day RDE test can be used as pre-conditioning drive for the current day test, if requested by manufacturer.
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 2 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 Chapter.
5.4.2	If the trip results are valid following the verifications in accordance with clause 5.4.1 of this Chapter, the methods for verifying the normality of the test conditions as laid down in Appendices 5, 6, 7A and 7B to this Chapter shall be applied. For OVC-HEVs only, the validity of a trip and the normality of test conditions are verified in accordance with Appendix 7C of this Chapter, while Appendices 5 and 6 of this Chapter do not apply.
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 clause 2.20 of Chapter 1 of this Part.
5.5.2.2.	All results will be corrected with the Ki factors or with the Ki offsets developed by the procedures in Chapter 15 of this Part for type-approval of a vehicle type with a periodically regenerating system.
5.5.2.3.	If the emissions do not fulfil the requirements of clause 3.1.0 of this Chapter, then the occurrence of regeneration shall be verified. The verification of regeneration may be based on expert judgement through cross-correlation of several of the following signals, which may include exhaust temperature, PN, CO_2, O_2 measurements in combination with vehicle speed and acceleration. If periodic regeneration occurred during the test, the result without the application of either the Ki factor of the Ki offset shall be checked against the requirements of clause 3.1.0 of this Chapter. If the resulting emissions do not fulfil the requirements, then the test shall be voided and repeated once at the request of the manufacturer. The manufacturer may ensure the completion of the regeneration. The second test is considered valid even if regeneration occurs during it.
5.5.2.4.	At the request of the manufacturer, even if the vehicle fulfils the requirements of clause 3.1.0 of this Chapter, the occurrence of regeneration may be verified as in clause 5.5.2.3 above. If the presence of regeneration can be proved and with the agreement of the Type Approval, the final results will be shown without the application of either the Ki factor or the Ki offset.
5.5.2.5.	The manufacturer may ensure the completion of the regeneration and precondition the vehicle appropriately prior to the second test.
5.5.2.6.	If regeneration occurs during the second RDE test, pollutants emitted during the repeated test shall be included in the emissions evaluation.
5.5.3	Vehicle models having a selectable option for 4x2 and 4x4 modes, the test will be carried out in 4x2 mode. Vehicle having permanent 4x4 mode / all-wheel drive mode will be tested in 4x4 mode.
5.5.4	Vehicle models having multiple performance modes such as City, Eco, Sports etc., the test will always be conducted in default mode. In vehicles, where default mode is not available, the test will be conducted in anyone mode based on mutual discussion and agreement between manufacturers and the Test Agency.

6.0	**TRIP REQUIREMENTS**
6.1	The shares of urban, rural and motorway driving, classified by instantaneous speed as described in clause 6.3 to 6.5 of this Chapter, shall be expressed as a percentage of the total trip distance.
6.2	The trip shall always start with urban driving followed by rural and motorway driving in accordance with the shares specified in clause 6.6 of this Chapter. The urban, rural and motorway operation shall be run continuously, but may also include a trip which starts and ends at the same point. 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.
6.3	Urban operation (Phase I) is characterized by vehicle speeds lower than 45 km/h for M, 40 km/h for N1, and 45 km/h for M1/N1 low powered categories of vehicles.
6.4	Rural operation (Phase II) is characterized by vehicle speeds higher than or equal to 45 km/h and lower than 65 km/h for M, speeds higher than or equal to 40 km/h and lower than 60 km/h for N1 and for M1/N1 low powered categories of vehicles since only 2 phases considered will be higher than or equal to 45 km/h.
6.5	Motorway operation (Phase III) is characterized by speeds higher than or equal to 65 km/h for M, higher than or equal to 60 km/h for N1.
6.6	The trip shall consist of approximately 34 % urban (Phase I), 33 % rural (Phase II) and 33 % motorway (Phase III) driving for M and N1 categories; 50 % Phase I and 50 % Phase II driving for M1/N1 low powered classified by speed as described in Points 6.3 to 6.5 above. "Approximately" shall mean the interval of ±10 % points around the stated percentages.
6.7	Wherever legal max speed limit permits, the vehicle of M category can be driven above 100 km/h but not for more than 3 % of the time duration of the Phase III driving. For N1 Category of vehicles, the vehicle velocity shall not normally exceed 80 km/h and for M1/N1 low powered category vehicles, it should not exceed 70 km/h. Local speed limits remain in force during a PEMS test, notwithstanding other legal consequences. Violations of local speed limits per se do not invalidate the results of a PEMS test.
6.8	The average speed (including stops) of the urban driving part of the trip should be between 15 km/h and 30 km/h for M, N1 and M1/N1 low powered categories of vehicles. Stop periods, defined as vehicle speed of less than 1 km/h, shall account for 6 to 30 % of the time duration of urban operation. Urban operation shall contain several stop periods of 10 s or longer. However, individual stop periods shall not exceed 300 consecutive seconds; else the trip shall be voided. Vehicle should not be driven

	continuously below 20 km/h for 20 minutes.
6.9	(i) For M category vehicles and the speed range of the motorway driving shall properly cover a range between 65 km/h and up to the applicable legal limit, if possible, based upon the test route. The vehicle's velocity shall be above 75 km/h for at least 5 min. (ii) For N1 category vehicles and the speed range of the motorway driving shall properly cover a range between 60 km/h and up to 80 km/h. The vehicle's velocity shall be above 70 km/h for at least 5 min. (iii) For M1/N1 low powered category vehicles and the speed range of the Phase II driving shall properly cover a range between 45 km/h and up to 70 km/h. The vehicle's velocity shall be above 55 km/h for at least 5 min.
6.10	The trip duration shall be between 90 and 120 min.
6.11	The start and the end point of a trip shall not differ in their elevation above sea level by more than 100 m. In addition, the proportional cumulative positive altitude gain over the entire trip and over the urban part of the trip as determined in accordance with point 4.3 shall be less than 1200 m/100km and be determined according to Appendix 7B of this Chapter.
6.12	The minimum distance of each, the urban, rural and motorway operation shall be 16 km for M and N1 categories vehicles. For M1/N1 low powered category of vehicle, the minimum distance of each, Phase I and Phase II operation shall be 24 km.
6.13	The average speed (including stops) during cold start period as defined in clause 4 of Appendix 4 of this Chapter, shall be between 15 and 30 km/h. The maximum speed during the cold start period shall not exceed 45 km/h for M, M1/N1 Low Powered and 40 km/h for N1 category of vehicles.
7.0	**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 clause 6.10 of this Chapter.
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 minimize the mass of the installed equipment and potential aerodynamic modifications of the test vehicle. The vehicle payload shall be in accordance with clause 5.1 of this

	Chapter.
7.4.	RDE tests shall be conducted on working days.
7.5	RDE tests shall be conducted on paved roads and streets (e.g. off road operation is not permitted).
7.6.	The idling immediately after the first ignition of the combustion engine shall be kept to the minimum possible and it shall not exceed 15 s. The vehicle stop during the entire cold start period, as defined in point 4 of Appendix 4, shall be kept to the minimum possible and it shall not exceed 90 s. If the engine stalls during the test, it may be restarted, but the sampling shall not be interrupted.
8.0	**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. During monitoring phase, the test shall be carried out either with commercial fuel or reference fuel based on manufacturer's request. From April 2023 (compliance phase), the test will be carried out with commercial fuel. However, in case of failure of the test, the same can be repeated with reference fuel on manufacturer's request.
8.2	At the discretion of manufacturer, samples of fuel, lubricant and reagent (if applicable) shall be taken and kept for at least 1 year by the manufacturer.
9.0	**EMISSIONS AND TRIP EVALUATION**
9.1	The test shall be conducted in accordance with Appendix 1 of this Chapter.
9.2	The trip shall fulfill the requirements set out in clause 4 to 8 of this Chapter.
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 in accordance with clause 9.2 of this Chapter emission results shall be calculated using the methods laid down in Appendices 5 of this Chapter. For OVC-HEVs the emission results shall be calculated using the method laid down in Appendix 7C of this Chapter.
9.5	If during a particular time interval the ambient conditions are extended in accordance with clause 5.2 of this Chapter, the emissions during this particular time interval, calculated according to Appendix 4 of this Chapter, shall be divided by a value of 1.6 before being evaluated (i.e., to the raw emissions) for compliance with the requirements of this Chapter.

	This provision does not apply to carbon dioxide emissions.
9.6	The cold start is defined in accordance with clause 4 of Appendix 4 of this Chapter. Gaseous pollutant and particle number emissions during cold start shall be included in the normal evaluation in accordance with Appendix 5 and 6 of this Chapter. For OVC-HEVs the emission results shall be calculated using the method laid down in Appendix 7C of this Chapter. If the vehicle was conditioned for the last three hours prior to the test at an average temperature that falls within the extended range in accordance with clause 5.2 of this Chapter, then the provisions of clause 9.5 of this Chapter apply to the cold start period, even if the running conditions are not within the extended temperature range. The corrective factor of 1.6 shall be applied only once. The corrective factor of 1.6 applies to pollutant emissions but not to CO_2.

CHAPTER 20 - APPENDIX 1

TEST PROCEDURE FOR VEHICLE EMISSIONS TESTING WITH A PORTABLE EMISSIONS MEASUREMENT SYSTEM (PEMS)

1.0 INTRODUCTION

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

2.0 SYMBOLS, PARAMETERS AND UNITS

≤	-	Smaller or equal
#	-	Number
$\#/m^3$	-	Number per cubic meter
%	-	Per cent
°C	-	Degree centigrade
g	-	Gram
g/s	-	Gram per second
h	-	Hour
Hz	-	Hertz
K	-	Kelvin
kg	-	Kilogram
kg/s	-	Kilogram per second
km	-	Kilometer
km/h	-	Kilometer per hour
kPa	-	Kilopascal
kPa/min	-	Kilopascal per minute
l	-	Liter
l/min	-	Liter per minute
m	-	Meter
m^3	-	Cubic-meter
mg	-	Milligram
min	-	Minute

	p_e	-	Evacuated pressure [kPa]
	qvs	-	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
	Vs	-	System volume [*l*]
3.0	**GENERAL REQUIREMENTS**		
3.1.	**PEMS**		
	The test shall be carried out with a PEMS, composed of components specified in clause 3.1.1 to 3.1.5 of this Appendix. If applicable, a connection with the vehicle ECU may be established to determine relevant engine and vehicle parameters as specified in clause 3.2. of this Appendix.		
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 Appendix shall be measured, recorded at a constant frequency of 1.0 Hz or higher and reported according to the requirements of Appendix 8 of this Chapter. 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 Chapter.		

Table 1 Test Parameters

Parameter	Recommended unit	Source [8]
THC [1][4] concentration	$ppmC_1$	Analyser
CH_4 [1][4] concentration	$ppmC_1$	Analyser
NMHC [1][4] concentration	$ppmC_1$	Analyser [6]
CO concentration [1][4]	Ppm	Analyser
CO_2 concentration [1]	Ppm	Analyser
NO_X concentration [1][4]	Ppm	Analyser [7]
PN concentration [4]	$\#/m^3$	Analyser
Exhaust mass flow rate	kg/s	EFM, any methods described in clause 7 of Appendix 2 of this Chapter
Ambient humidity	%	Sensor
Ambient temperature	K	Sensor
Ambient pressure	kPa	Sensor
Vehicle speed	km/h	Sensor, GPS, or ECU[3]
Vehicle latitude	Degree	GPS
Vehicle longitude	Degree	GPS
Vehicle altitude [5][9]	M	GPS or Sensor
Exhaust gas[5] temperature	K	Sensor
Engine coolant[5] temperature	K	Sensor or ECU
Engine speed [5]	rpm	Sensor or ECU
Engine torque [5]	Nm	Sensor or ECU
Torque at driven axle [5]	Nm	Rim torque meter
Pedal position [5]	%	Sensor or ECU

	Engine fuel flow [2]	g/s	Sensor or ECU
	Engine intake air flow [2]	g/s	Sensor or ECU
	Fault status [5]	-	ECU
	Intake air flow temperature	K	Sensor or ECU
	Regeneration status [5]	-	ECU
	Engine oil temperature [5]	K	Sensor or ECU
	Actual gear [5]	#	ECU
	Desired gear (e.g. gear [5] shift indicator)	#	ECU
	Other vehicle data [5]	unspecified	ECU

	Notes:	
	(1)	To be measured on a wet basis or to be corrected as described in clause 8.1 of Appendix 4 of this Chapter.
	(2)	To be determined only if indirect methods are used to calculate exhaust mass flow rate as described in clause 10.2 and10.3 of Appendix 4 of this Chapter.
	(3)	Method to be chosen according to clause 4.7 of this Appendix.
	(4)	Parameter only mandatory if measurement required by clause 2.1 of this Chapter.
	(5)	To be determined only if necessary to verify the vehicle status and operating conditions.
	(6)	May be calculated from THC and CH4 concentrations according to clause 9.2 of Appendix 4 of this Chapter.
	(7)	May be calculated from measured NO and NO2 concentrations.
	(8)	Multiple parameter sources may be used.
	(9)	The preferable source is the ambient pressure sensor.

3.3.	**Preparation of the Vehicle**
	The preparation of the vehicle shall include a general verification of the correct technical functioning of the test vehicle.

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 minimize, 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 minimize 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 no contact with the exhaust gas to avoid artefacts at high engine load.
3.4.2.	Permissible Backpressure The installation and operation of the PEMS sampling probes shall not unduly increase the pressure at the exhaust outlet in a way that may influence the representativeness of the measurements. It is thus recommended that only one sampling probe is installed in the same plane. 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 than the exhaust pipe. If the sampling probes obstruct a significant area of the tailpipe cross-section, backpressure measurement may be requested by the Test Agency.
3.4.3	Exhaust Mass Flow Meter (EFM)
	Whenever used, the EFM shall be attached to the vehicle's tailpipe(s) in accordance with 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 at either side of the flow-sensing element. When testing a multi-cylinder engine with a branched exhaust manifold, it is recommended to position the exhaust mass flow meter downstream of where the manifolds combine and to increase the cross section of the piping such as to have an equivalent, or larger, cross sectional area from which to sample. If this is not feasible, exhaust flow measurements with several exhaust mass flow meters may be used, if approved by the Test Agency. The wide variety of exhaust pipe configurations, dimensions and exhaust mass flow rates may require compromises, guided by good engineering judgement, when selecting and installing the EFM(s). 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 improves measurement accuracy and does not adversely affect the operation or the exhaust after-treatment as specified in clause 3.4.2 of this Appendix. It is recommended to document the EFM set-up using photographs.

	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. It is recommended to clean the EFM by purging the pressure transducer connections with pressurized clean air or nitrogen. This back-flush procedure is used to remove condensation and diesel particulate matter from the pressure lines and associated flow tube pressure measurement ports.
3.4.4.	**Global Positioning System (GPS)** 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 (ECU)** If desired, relevant vehicle and engine parameters listed in Table 1 of this Appendix can be recorded by using a data logger connected with the ECU or the vehicle network through standards, such as ISO 15031-5 or SAE J1979, OBD-II, EOBD or WWH-OBD. If applicable, manufacturers shall disclose 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. 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 inner diameter of the exhaust pipe, whichever is larger, upstream of 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 of the nature of the exhaust gas at the sampling point(s). If the length of the sampling 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 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 sampling probe shall be positioned downstream of where the manifolds combine. If this is technically not feasible, multi-point sampling at locations of well-mixed exhaust may be used, if approved by the Test Agency. In this case, the number and location of sampling probes shall match as far as possible those 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 center of the exhaust stream. If several probes are used for emissions sampling, the particle sampling probe should be placed upstream of the other sampling probes. The particle sampling probe should not interfere with the sampling of gaseous pollutants. The type and specifications of the probe and its mounting shall be documented in detail. 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) 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 and not diluted at the tailpipe, the sampling line from the raw exhaust sample point to the point of dilution or particle detector 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 detector. All parts of the sampling system from the exhaust pipe up to the particle detector, which are in contact with raw or diluted exhaust gas, shall be designed to minimize deposition of particles. All parts shall be made from antistatic material to prevent electrostatic effects.
4.0	**PRE-TEST PROCEDURE**
4.1.	PEMS Leak Check
	After the installation of the 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 stabilization period all flow meters shall read approximately zero in the absence of a leak. Else, the sampling lines shall be

	checked and the fault be corrected.
	The leakage rate on the vacuum side shall not exceed 0.5 % 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 rate.
	Alternatively, the system may be evacuated to a pressure of at least 20 kPa vacuum (80 kPa absolute). After an initial stabilization period the pressure increase Δp (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 % compared to the introduced concentration, the leakage problem shall be corrected.
4.2.	**Starting and Stabilizing the PEMS**
	The PEMS shall be switched on, warmed up and stabilized in accordance with the specifications of the PEMS manufacturer until key functional parameters, e.g., pressures, temperatures and flows have reached their operating set points before test start. To ensure correct functioning, the PEMS may be kept switched on or can be warmed up and stabilized during vehicle conditioning. The system shall be free of errors and critical warnings.
4.3.	**Preparing the Sampling System**
	The sampling system, consisting of the sampling probe and sampling lines, 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 Exhaust mass Flow Meter (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 clause 5 of Appendix 2 of this Chapter. The calibration gases shall be chosen to match the range of pollutant concentrations expected during the RDE test. To minimize 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 at an appropriate sampling point, usually at the inlet of the sampling line. The signal shall be recorded at a constant frequency of at least 1.0 Hz averaged over a period of 2 minutes; the final concentration shall be within the manufacturer's specifications, but shall not exceed 5000 particles per cubic- centimeter.
4.7.	**Determining Vehicle Speed**
	Vehicle speed shall be determined by at least one of the following methods:
	(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 clause 7 of Appendix 4 of this Chapter.
	(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 clause 8 of Appendix 2 of this Chapter, 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 clause 3 of Appendix 3 of this Chapter and the ECU speed signal adjusted, if necessary to fulfil the requirements of clause 3.3 of Appendix 3 of this Chapter. Alternatively, the total trip distance as determined by the ECU can 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	**Checking 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.

5.0	**EMISSIONS TEST**
5.1.	**Test Start**
	Sampling, measurement and recording of parameters shall begin prior to the 'ignition on' 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 and directly after 'ignition on', 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. If any error signal(s) appear during the test, the test shall be voided. 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 ignition is switched off. Excessive idling of the engine after the completion of the trip shall be avoided. The data recording shall continue until the response time of the sampling systems has elapsed.
6.0	**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 clause 4.5 of this Appendix to evaluate the analyser's 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 of this Appendix.

	Table 2			
	Permissible Analyser Drift Over a PEMS Test			
	Pollutant	Absolute Zero response drift	Absolute Span response drift (1)	
	CO_2	≤2000 ppm per test	≤2% of reading or ≤2000 ppm per test, whichever is larger	
	CO	≤75 ppm per test	≤2% of reading or ≤75 ppm, per test, whichever is larger	
	NO_X	≤5 ppm per test	≤2% of reading or ≤5 ppm per test, whichever is larger	
	CH_4	≤10 ppmC1 per test	≤2% of reading or ≤10 ppmC1 per test, whichever is larger	
	THC	≤10 ppmC1 per test	≤2% of reading or ≤10 ppmC1 per test, whichever is larger	
	(1) 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 in accordance with clause 4.6 of this Appendix.			
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.			

CHAPTER 20 - APPENDIX 2

SPECIFICATIONS AND CALIBRATION OF PEMS COMPONENTS AND SIGNALS

1.0 INTRODUCTION

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

2.0 SYMBOLS, PARAMETERS AND UNITS

>	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) [ppmC1]
$C_{FS,d}$	Full scale HC concentration in Step (d) [ppmC1]
$C_{HC(w/NMC)}$	HC concentration with CH_4 or C_2H_6 flowing through the NMC [ppmC1]
$C_{HC(w/o\ NMC)}$	HC concentration with CH_4 or C_2H_6 bypassing the NMC [ppmC_1]
$C_{m,b}$	Measured HC concentration in Step (b) [ppmC1]
$C_{m,d}$	Measured HC concentration in Step (d) [ppmC1]
$C_{ref,b}$	Reference HC concentration in Step (b) [ppmC1]
$C_{ref,d}$	Reference HC concentration in Step (d) [ppmC1]
°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

	$E_{(dp)}$	PEMS-PN analyser efficiency
	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	Gram
	gH_2O/kg	Gram water per kilogram
	h	Hour
	H	Water vapour concentration [%]
	Hm	Maximum water vapour concentration [%]
	Hz	Hertz
	K	Kelvin
	kg	Kilogram
	km/h	Kilometer per hour
	kPa	Kilopascal
	max	Maximum value
	$NO_{x,dry}$	Moisture-corrected mean concentration of the stabilized NO_X recordings
	$NO_{x,m}$	Mean concentration of the stabilized NO_X recordings
	$NO_{x,ref}$	Reference mean concentration of the stabilized 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
	X_{min}	Minimum value
	y	Dependent variable or measured value
3.0	**LINEARITY VERIFICATION**	
3.1.	**General**	

The accuracy and 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 of this Appendix. 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 of this Appendix.

Table 1
Linearity Requirements of Measurement Parameters and Systems

Measurement parameter/ instrument	$\|\chi_{min} \times (a_1 - 1) + a_0\|$	Slope a_1	Standard error SEE	Coefficient of determination (r^2)
Fuel flow rate (1)	≤1% max	0.98 -1.02	≤2%	≥0.990
Air flow rate (1)	≤1% max	0.98 -1.02	≤ 2 %	≥0.990
Exhaust Mass flow rate	≤2% max	0.97 - 1.03	≤ 3 %	≥0.990
Gas analysers	≤0.5% max	0.99 - 1.01	≤1%	≥0.998
Torque (2)	≤1% max	0.98 -1.02	≤2%	≥0.990
PN analysers (3)	≤5% max	0.85- 1.15 (4)	≤10%	≥0.950

(1) Optional to determine exhaust mass flow

(2) Optional parameter

(3) The linearity check shall be verified with soot-like particles, as these are defined in clause 6.2 of this Appendix.

(4) To be updated based on error propagation and traceability charts.

3.3.	**Frequency of Linearity Verification**
	The linearity requirements according to clause 3.2 of this Appendix shall be verified:
	(a) for each gas analyser at least every twelve months or whenever a system repair or component change or modification is made that could influence the calibration;
	(b) for other relevant instruments, such as PN analysers exhaust mass flow meters and traceably calibrated sensors, whenever damage is observed, as required by internal audit procedures or by the instrument manufacturer but no longer than one year before the actual test.
	The linearity requirements according to clause 3.2 of this Appendix for sensors or ECU signals that are not directly traceable shall be performed with a traceably calibrated measurement device on the chassis dynamometer once for each PEMS vehicle setup.
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 to 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 linearity shall be verified 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 clause 5 of this Appendix 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 1.0Hz over a period of 30s.
	(g) The arithmetic mean values over the 30s 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 = Actual value of the measurement system
	a_1 = Slope of the regression line
	x = Reference value
	a_0 = 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 of this Appendix.
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 a chassis dynamometer. The procedure shall follow as far as applicable, the requirements of Chapter 3 of this Part. 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 of this Chapter. The calibration procedure shall follow whenever possible the requirements of clause 3.4.2 of this Appendix; 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 RDE 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 clause 3.4.3 of Appendix 1 of this Chapter. The vehicle shall be operated by applying constant throttle at a constant gear selection and chassis dynamometer load.

4.0	**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 clause 1.3.1 to 1.3.5 of Chapter 7 of this Part. 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 clause 4.1.1 of this Appendix is permissible provided that it fulfills the requirements of clause 4.2 of this Appendix. 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 RDE testing as specified in clause 5, 6 and 7 of this Chapter. 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 clause 4.1.1 of this Appendix over the expected range of pollutant concentrations and ambient conditions of the type-approval test defined in Chapter 3 of this Part as well as a validation test as described in clause 3 of Appendix 3 of this Chapter 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 clause 3.3 of Appendix 3 of this Chapter.
	(c) A demonstration of equivalency with the respective standard analyser specified in clause 4.1.1 of this Appendix 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 clause 5.2 of this Chapter. Such a test can be performed in an altitude environmental test chamber.

	(d) A demonstration of equivalency with the respective standard analyser specified in clause 4.1.1 of this Appendix over at least three on-road tests that fulfill the requirements of this chapter.
	(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 clause 4.2.4. of this Appendix. Test Agency 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 clause 3 of this Appendix, the compliance of analyser types with the specifications laid down in clause 4.2.2 to 4.2.8 of this Appendix 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 s, shall not exceed 2 % of full scale. Each of the 10 measurement periods shall be interspersed with an interval of 30 s 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 s, shall comply with the specifications given in Table 2 of this Appendix.
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 30s, shall comply with the specifications given in Table 2 of this Appendix.

Table 2

Permissible Zero and Span Response Drift of Analysers for Measuring Gaseous Components Under Laboratory Conditions

Pollutant	Absolute Zero response drift	Absolute Span response drift
CO_2	≤ 1000 ppm over 4h	≤ 2% of reading or ≤ 1000 ppm over 4h,whichever is larger
CO	≤ 50 ppm over 4h	≤ 2% of reading or ≤ 50 ppm over 4h, whichever is larger
PN	5000 particles per cubic centimeter over 4h	According to manufacturer specifications
NO_X	≤5 ppm over 4h	≤2% of reading or 5ppm over 4h,whichever is larger
CH_4	≤ 10 $ppmC_1$	≤ 2% of reading or ≤ 10 $ppmC_1$ over 4h, whichever is larger
THC	≤ 10 $ppmC_1$	≤ 2% of reading or ≤ 10 $ppmC_1$ over 4h, whichever is larger

4.2.7.	**Rise Time**
	The rise time, defined as the time between the 10 % and 90 % response of the final reading (t_{90} – t_{10}; see clause 4.4 of this Appendix), the rise time of PEMS analysers shall not exceed 3 s.
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 clause 4.3.2 to 4.3.5 of this Appendix define additional performance requirements for specific analyser types and apply only to cases,

	in which the analyser under consideration is used for RDE 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 clause 2.4 of Chapter 7 of this Part. 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 (FID)**
	(a) Optimization 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 Chapter 7 of AIS 137 Part 3. A propane-in-air or propane-in- nitrogen span gas shall be used to optimize 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 clause 2.3.3 of Chapter 7 of this Part, 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 a FID 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 %. The test shall be conducted with the oven temperature set as required. The specifications of the oxygen interference check gases are described in clause 5.3 of this Appendix.
	The following procedure applies:
	(i) The analyser shall be set at zero;
	(ii) The analyser shall be spanned with a 0 % oxygen blend for positive ignition engines and a 21 % oxygen blend for compression ignition engines;
	(iii) The zero response shall be rechecked. If it has changed by more than 0.5 % of full scale, Steps (i) and (ii) shall be repeated;
	(iv) The 5 % and 10 % oxygen interference check gases shall be introduced;
	(v) The zero response shall be rechecked. If it has changed by more than ±1% of full scale, the test shall be repeated;
	(vi) The oxygen interference EO_2 shall be calculated for each oxygen interference check gas in step (iv) 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:	
	Cref,b =	Reference HC concentration in Step (ii) [ppmC_1]
	$C_{ref,d}$ =	Reference HC concentration in Step (iv) [ppmC_1]
	$C_{FS,b}$=	Full scale HC concentration in Step (ii) [ppmC_1]
	$C_{FS,d}$ =	Full scale HC concentration in Step (iv) [ppmC_1]
	$C_{m,b}$ =	Measured HC concentration in Step (ii) [ppmC_1]
	Cm,d =	Measured HC concentration in Step (iv) [ppmC1]
	(vii) The oxygen interference E_{O2} shall be less than ±1.5% for all required oxygen interference check gases.	
	(viii) If the oxygen interference E_{O2} is higher than ±1.5%, 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 oxidizing all hydrocarbons except methane. Ideally, the conversion for methane is 0% and for the other hydrocarbons represented by ethane is 100%. For the accurate measurement of NMHC, the two efficiencies shall be determined and used for the calculation of the NMHC emissions (see clause 9.2 of Appendix 4 of this Chapter. It is not necessary to determine the methane conversion efficiency in case the NMC-FID is calibrated according to method (b) in clause 9.2 of Appendix 4 of this Chapter 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:	

	$$E_M = 1 - \frac{C_{HC(\frac{w}{NMC})}}{C_{HC(\frac{w}{oNMC})}}$$	
	where:	
	$C_{HC(w/NMC)}$ =	HC concentration with CH4 flowing through the NMC [ppmC1]
	$C_{HC(w/o\ NMC)}$ =	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:	
	$$E_E = 1 - \frac{C_{HC\left(\frac{w}{NMC}\right)}}{C_{HC\left(\frac{w}{oNMC}\right)}}$$	
	where:	
	$C_{HC(w/NMC)}$ =	HC concentration with C_2H_6 flowing through the NMC [$ppmC_1$]
	$C_{HC(w/o\ NMC)}$ =	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 clause (b) to (f) of this Appendix.	
(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% 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% of the mean CO concentration expected during normal on-road testing or ±50ppm, 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 utilize 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 % 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% 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 percent quench shall be calculated as:
	$$E_{CO_2} = [1 - \left(\frac{C \times A}{(D \times A) - (D \times B)}\right)] \times 100$$
	where:
	A = Undiluted CO_2 concentration measured with the NDIR [%]
	B = Diluted CO_2 concentration measured with the NDIR [%]
	C = Diluted NO concentration measured with the CLD or HCLD [ppm]
	D = 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 Test Agency.
(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 % to 100 % 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 percent water quench shall be calculated as
	$$E_{H2O} = \left(\left(\frac{D_e - C}{D_e}\right) \times \left(\frac{H_m}{H}\right)\right) X100$$
	where:
	D_e = Expected diluted NO concentration [ppm]
	C = Measured diluted NO concentration [ppm]
	H_m = Maximum water vapour concentration [%]
	H = Actual water vapour concentration [%]
(iii)	Maximum allowable quench
	The combined CO_2 and water quench shall not exceed 2 % 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 stabilized NO_X recordings over a period of 30s shall be calculated and recorded as $NO_{X,ref}$.

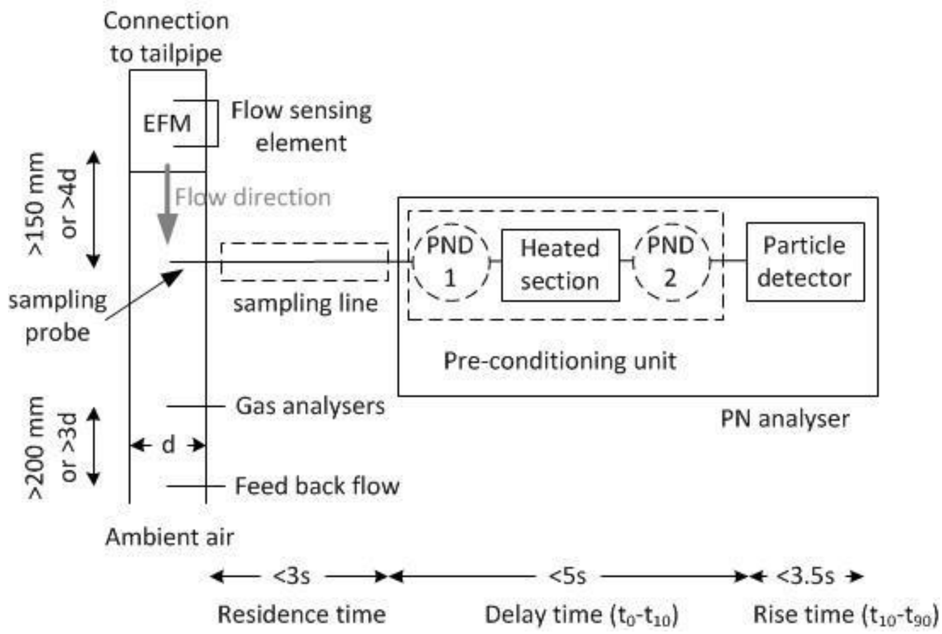
	(vi) The flow of the NO_2 calibration gas shall be stopped and the sampling system saturated by overflowing with a dew point generator's output, set at a dew point of 50°C. The dew point generator's output shall be sampled through the sampling system and chiller for at least 10min until the chiller is 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 stabilized.
	(viii) The mean concentration of the stabilized NOX recordings over a period of 30s 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 % H_2O), which is 100 % relative humidity at 3.9°C and 101.3 kPa or about 25 % 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% 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 s. The gases used for the test shall cause a concentration change of at least 60 % 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 % of the final reading (t_{10}). The rise time is defined as the time between 10% and 90 % 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 % of the final reading (t_{50}).
	The system response time shall be $\leq$ 12 s with a rise time of $\leq$ 3 s for all components and all ranges used. When using a NMC for the measurement of NMHC, the system response time may exceed 12 s.
5.0	**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 clause 3.1 and 3.2 of Chapter 7 of this Part. In addition, NO_2 calibration gas is permissible. The concentration of the NO_2 calibration gas shall be within 2% of the declared concentration value. The amount of NO contained in the NO_2 calibration gas shall not exceed 5% 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 %. The verification shall be performed at between 15 and 50 % 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 % 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 of this Appendix; 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%

6.0	**ANALYSERS FOR MEASURING (SOLID) PARTICLE EMISSIONS**
6.1	**General** The PN analyser shall consist of a pre-conditioning unit and a particle detector that counts with 50 % efficiency from approximately 23 nm. It is permissible that the particle detector also pre-conditions the aerosol. 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 and shall be clearly stated by the equipment manufacturer in its support material. The PN analyser shall only be used within its manufacturer's declared parameters of operation.
	 **Figure 1** **Example of a PN Analyser Setup:** **Dotted lines depict optional parts.** **EFM = Exhaust mass Flow Meter,** **d = inner diameter,** **PND = Particle Number Diluter.**
	The PN analyser shall be connected to the sampling point via a sampling probe which extracts a sample from the centerline of the tailpipe tube. As specified in clause 3.5 of Appendix 1 of this Chapter, if particles are not diluted at the tailpipe, the sampling line shall be heated to a minimum temperature of 373 K (100 °C) until the point of first dilution of the PN analyser or the particle detector of the analyser. The residence time in the sampling line shall be less than 3 s. All parts in contact with the sampled exhaust gas shall be always kept at a temperature that avoids condensation of any compound in the device. This can be achieved, e.g. by heating at a higher temperature and diluting the sample or oxidizing the (semi)volatile species.

	The PN analyser shall include a heated section at wall temperature ≥ 573K. The unit shall control the heated stages to constant nominal operating temperatures, within a tolerance of ±10 K and provide an indication of whether or not heated stages are at their correct operating temperatures. Lower temperatures are acceptable as long as the volatile particle removal efficiency fulfils the specifications of 6.4. Pressure, temperature and other sensors shall monitor the proper operation of the instrument during operation and trigger a warning or message in case of malfunction. The delay time of the PN analyser shall be ≤ 5 s. The PN analyser (and/or particle detector) shall have a rise time of ≤ 3.5 s. Particle concentration measurements shall be reported normalised to 273 K and 101.3 kPa. If necessary, the pressure and/or temperature at the inlet of the detector shall be measured and reported for the purposes of normalizing the particle concentration. PN systems that comply with the calibration requirements of this Part automatically comply with the calibration requirements of this chapter.
6.2	**Efficiency requirements** The complete PN analyser system including the sampling line shall fulfil the efficiency requirements of Table 3 A. of this Appendix

Table 3 A
PN Analyser (Including The Sampling Line) System Efficiency Requirements

dp [nm]	**Sub-23**	**23**	**30**	**50**	**70**	**100**	**200**
$E(d_p)$ PN analyser	To be determined	0.2–0.6	0.3–1.2	0.6–1.3	0.7–1.3	0.7–1.3	0.5–2.0

Efficiency $E(d_p)$ is defined as the ratio in the readings of the PN analyser system to a reference Condensation Particle Counter (CPC)'s ($d_{50\%}$=10 nm or lower, checked for linearity and calibrated with an electrometer) or an Electrometer's number concentration measuring in parallel monodisperse aerosol of mobility diameter dp and normalized at the same temperature and pressure conditions.

The efficiency requirements will need to be adapted, in order to make sure that the efficiency of the PN analysers remains consistent with the margin PN. The material should be thermally stable soot-like (e.g. spark discharged graphite or diffusion flame soot with thermal pre-treatment). If the efficiency curve is measured with a different aerosol (e.g. NaCl), the correlation to the soot-like curve must be provided as a chart, which compares the efficiencies obtained using both test aerosols. The differences in the counting efficiencies have to be taken into account by adjusting the measured efficiencies based on the

	provided chart to give soot-like aerosol efficiencies. The correction for multiply charged particles should be applied and documented but shall not exceed 10 %. These efficiencies refer to the PN analysers with the sampling line. The PN analyser can also be calibrated in parts (i.e. the pre-conditioning unit separately from the particle detector) as long as it is proven that PN analyser and the sampling line together fulfil the requirements of Table 3 A of this Appendix. The measured signal from the detector shall be > 2 times the limit of detection (here defined as the zero level plus 3 standard deviations).

6.3	**Linearity requirements**
	The PN analyser including the sampling line shall fulfil the linearity requirements of clause 3.2 in this Appendix using monodisperse or polydisperse soot-like particles. The particle size (mobility diameter or count median diameter) should be larger than 45 nm. The reference instrument shall be an Electrometer or a Condensation Particle Counter (CPC) with d_{50}=10 nm or lower, verified for linearity. Alternatively, a particle number system compliant with Appendix 2 of Chapter 8 of this Part In addition the differences of the PN analyser from the reference instrument at all points checked (except the zero point) shall be within 15% of their mean value. At least 5 points equally distributed (plus the zero) shall be checked. The maximum checked concentration shall be the maximum allowed concentration of the PN analyser. If the PN analyser is calibrated in parts, then the linearity can be checked only for the PN detector, but the efficiencies of the rest parts and the sampling line have to be considered in the slope calculation.
6.4	**Volatile removal efficiency**
	The system shall achieve > 99% removal of ≥ 30 nm tetracontane (CH3(CH2)38CH3) particles with an inlet concentration of ≥10,000 particles per cubic-centimetre at the minimum dilution. The system shall also achieve a > 99% removal efficiency of polydisperse alcane (decane or higher) or emery oil with count median diameter > 50 nm and mass >1 mg/m^3. The volatile removal efficiency with tetracontane and/or polydisperse alcane or oil have to be proven only once for the instrument family. The instrument manufacturer though has to provide the maintenance or replacement interval that ensures that the removal efficiency does not drop below the technical requirements. If such information is not provided, the volatile removal efficiency has to be checked yearly for each instrument.
7.0	**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 minimize 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 clause 3 of this Appendix. Furthermore, the instrument manufacturer shall demonstrate the compliance of each type of exhaust mass flow meter with the specifications in clause 7.2.3 to 7.2.9. of this Appendix.
	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 clause 3 of this Appendix, the accuracy requirements of clause 8 of this Appendix and if the resulting exhaust mass flow rate is validated according to clause 4 of Appendix 3 of this Chapter.
	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 clause 3 of this Appendix and is validated according to clause 4 of Appendix 3 of this Chapter.
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 clause 7.2.3 and 7.2.9 of this Appendix 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 not exceed 1 % 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 s, shall not exceed 2 % of the maximum calibrated flow value. Each of the 10 measurement periods shall be interspersed with an interval of 30 s in which the EFM is exposed to the maximum calibrated flow.
7.2.6.	Zero Response Drift
	The zero response drift is defined as the mean response to zero flow during a time interval of at least 30 s. 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 4h shall be less than ± 2 % of the maximum value of the primary signal recorded at the flow at which the EFM was calibrated.
7.2.7.	Span Response Drift
	The span response drift is defined as the mean response to a span flow during a time interval of at least 30 s. 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 h shall be less than ± 2 % 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 clause 4.2.7 of this Appendix but shall not exceed 1 s.
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 s. The gas flow rate used for the test shall cause a flow rate change of at least 60 % full scale 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 % (t_{10}) of the final reading. The rise time is defined as the time between 10 % and 90 % 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 s with a rise time ($t_{90} – t_{10}$) of ≤ 1 s in accordance with clause 7.2.8. of this Appendix.

8.0 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 of this Appendix. 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[1]	±1% of reading[3]
Air flow[1]	±2% of reading
Vehicle speed[2]	±1.0km/h absolute
Temperatures ≤600K	±2K absolute
Temperatures >600K	±0.4% of reading in Kelvin
Ambient pressure	±0.2kPa absolute
Relative humidity	±5% absolute
Absolute humidity	±10% of reading or, 1gH_2O/kg dry air, whichever is larger

(1) Optional to determine exhaust mass flow

(2) This 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.

(3) The accuracy shall be 0.02 % of reading if used to calculate the air and exhaust mass flow rate from the fuel flow according to clause 10 of

	Appendix 4 of this Chapter.

CHAPTER 20 - APPENDIX 3

VALIDATION OF PEMS AND NON-TRACEABLE EXHAUST MASS FLOW RATE

1.0	**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.	
2.0	**SYMBOLS, PARAMETERS AND UNITS**	
	%	Per cent
	#/km	Number per kilometer
	a_0	y intercept of the regression line
	a_1	Slope of the regression line
	g/km	Gram per kilometer
	Hz	Hertz
	km	Kilometer
	m	Meter
	mg/km	Milligram per kilometer
	r^2	Coefficient of determination
	x	Actual value of the reference signal
	y	Actual value of the signal under validation
3.0	**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 test or, alternatively, after the completion of the 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 of this Chapter. The PEMS installation shall be kept unchanged in the time period between the validation and the RDE test.
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 Chapter 3 of this Part or any other adequate measurement method. The ambient temperature shall be within the range specified in Clause 5.2 of this Chapter.
	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 Chapter 3 of this Part. The emissions as measured with the PEMS shall be calculated according to clause 9 of Appendix 4 of this Chapter, 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 clause 3.3 of this Appendix. For the validation of NO_X emission measurements, humidity correction shall be applied following clause 6.6.5 of Chapter 3 of this Part.
3.3	**Permissible Tolerances for PEMS Validation**
	The PEMS validation results shall fulfil the requirements given in Table 1 of this Appendix. 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][(1)]	±250m of the laboratory reference
THC[(2)] [mg/km]	±15mg/km or 15% of the laboratory reference, whichever is larger
CH_4[(2)] [mg/km]	±15mg/km or 15% of the laboratory reference, whichever is larger

	NMHC[2] [mg/km]	±20mg/km or 20% of the laboratory reference, whichever is larger
	PN[2] [#/km]	$\pm 1 \cdot 10^{11}$ p/km or 50% of the laboratory reference[3] whichever is larger
	CO[2] [mg/km]	±150mg/km or 15% of the laboratory reference, whichever is larger
	CO_2 [g/km]	±10g/km or 10% of the laboratory reference, whichever is larger
	NOx[2] [mg/km]	±15mg/km or 15% of the laboratory reference, whichever is larger
	(1) 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. (2) Parameter only mandatory if measurement required by clause 2.1 of this Chapter. (3) PMP System.	
4.0	**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 clause 3 of Appendix 2 of this Chapter 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 Chapter 3 of this Part and the requirements pertinent to exhaust mass flow meters defined in Appendix 1 of this Chapter.	
4.2	**Validation Procedure**	
	The validation shall be conducted on a chassis dynamometer under type approval conditions, as far as applicable, by following the requirements of Chapter 3 of this Part. The test cycle shall be the MIDC. 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 chapter. The installation of the exhaust mass flow meter and the execution of the test shall fulfil the requirement of clause 3.4.3 of Appendix 1 of this Chapter.	
	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 clause 3	

	of Appendix 4 of this Chapter.
	(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 = Actual value of the signal under validation
	a_1 = Slope of the regression line
	x = Actual value of the reference signal
	a_0 = 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 of this Appendix.
4.3	**Requirements**
	The linearity requirements given in Table 2 of this Appendix 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 error SEE	Coefficient of determination r^2
Exhaust mass flow	0.0 ± 3.0 kg/h	1.00 ± 0.075	≤10% max	≥0.90

CHAPTER 20 - APPENDIX 4 DETERMINATION OF EMISSIONS

1.0 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 of this Chapter.

2.0 SYMBOLS, PARAMETERS AND UNITS

%	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)
ρe	Density of the exhaust
ρgas	Density of the exhaust component "gas"
λ	Excess air ratio
λi	Instantaneous excess air ratio
A/Fst	Stoichiometric air-to-fuel ratio [kg/kg]
°C	Degrees centigrade
CCH4	Concentration of methane
CCO	Dry CO concentration [%]
CCO2	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
EE	Ethane efficiency
EM	Methane efficiency
g	Gram
g/s	Gram per second
Ha	Intake air humidity [g water per kg dry air]
i	Number of the measurement
kg	Kilogram
kg/h	Kilogram per hour
kg/s	Kilogram per second
kw	Dry-wet correction factor
m	Meter
$m_{gas,i}$	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]
$q_{maw,i}$	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
	rh	Hydrocarbon response factor
	rpm	Revolutions per minute
	s	Second
	u_{gas}	u value of the exhaust component "gas"
3.0	**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 clause 5.1 of Appendix 1 of this Chapter. The time correction and alignment of parameters shall be carried out by following the sequence described in clause 3.1 to 3.3 of this Appendix.	
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 clause 4.4 of Appendix 2 of this Chapter:	
	$$C_{i,c}(t-\Delta t_{t,i})=C_{i,r}(t)$$	
	where:	

	$C_{i,c}$	=	Time-corrected concentration of component i as function of time t
	$C_{i,r}$	=	Raw concentration of component i as function of time t
	$\Delta t_{t,i}$	=	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 clause 4.4 of Appendix 2 of this Chapter:
	$$q_{m,c}(t-\Delta t_{t,m})=q_{m,r}(t)$$
	where:

	$q_{m,c}$	=	Time-corrected exhaust mass flow rate as function of time t
	$q_{m,r}$	=	Raw exhaust mass flow rate as function of time t
	$\Delta t_{t,m}$	=	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 clause 4 of Appendix 3 of this Chapter.		
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 cross-correlation between the exhaust mass flow rate and the product of vehicle speed 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.		
4.0	**COLD START**		
	Cold start is the period from the first start of the combustion engine until the point when the combustion engine has run cumulatively for 5 min and in case of OVC & NOVC HEV's vehicle has run for 5 mins. If the coolant temperature is determined, the cold start period ends once the coolant has reached 343K (70°C) for the first time but no later than the point at which the combustion engine has run cumulatively for 5min after initial engine start		
5.0	**EMISSION MEASUREMENTS DURING STOP OF THE COMBUSTION ENGINE**		

	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 <50rpm; the exhaust mass flow rate is measured at < 3kg/h; the measured exhaust mass flow rate drops to <15% of the typical steady-state exhaust mass flow rate at idling.
6.0	**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 clause 5.2 of this Chapter 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 40m from the altitude depicted in the topographic map shall be manually corrected and marked.
7.0	**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 120s or a total of 300s. 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.
8.0	**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} = Wet concentration of a pollutant in ppm or per cent volume
	C_{dry} = Dry concentration of a pollutant in ppm or per cent volume

	K_w =	dry-wet correction factor
	The following equation shall be used to calculate kw:	
	$$k_w = \left(\frac{1}{1 + a \times 0.005 \times (C_{co_2} + C_{co})} - k_{w1}\right) \times 1.008$$	
	where:	
	$$K_{w1} = \frac{1.608 \times H_a}{1000 + (1.608 \times H_a)}$$	
	Ha	Intake air humidity [g water per kg dry air]
	C_{CO2}	Dry CO_2 concentration [%]
	C_{CO}	Dry CO concentration [%]
	a	Molar hydrogen ratio
8.2	**Correction of NOx for Ambient Humidity and Temperature**	
	NOx emissions shall not be corrected for ambient temperature and humidity.	
9.0	**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 of this Chapter. The raw concentrations of relevant components shall be measured in accordance with Appendix 1 of this Chapter. The data shall be time corrected and aligned in accordance with clause 3 of this Appendix.	
9.2	**Calculating NMHC and CH4 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/N2 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 CH4 and NMHC shall be calculated as follows:	

	$$C_{CH4} = \frac{C_{HC(\frac{w}{oNMHC})} \times (1 - E_M) - C_{HC(\frac{w}{NMC})}}{(E_E - E_M)}$$
	$$C_{NMHC} = \frac{C_{HC(\frac{w}{NMC})} - C_{HC(\frac{w}{oNMC})} \times (1 - E_E}{r_h \times (E_E - E_M)}$$
	In method (b), the concentration of CH4 and NMHC shall be calculated as follows:
	$$C_{CH4} = \frac{C_{HC(\frac{w}{ONMC})} \times r_h \times (1 - E_M) - C_{HC(\frac{w}{ONMC})} \times (1 - E_E)}{r_h \times (E_E - E_M)}$$
	$$C_{NMHC} = \frac{C_{HC(\frac{w}{ONMC})} \times (1 - E_M) - C_{HC(\frac{w}{NMC})} \times r_h \times (1 - E_M)}{(E_E - E_M)}$$
	where:

$C_{HC(w/oNMC)}$	=	HC concentration with CH_4 or C_2H_6 bypassing the NMC [ppmC_1]
$C_{HC(w/NMC)}$	=	HC concentration with CH_4 or C_2H_6 flowing through the NMC [ppmC_1]
r_h	=	Hydrocarbon response factor as determined in clause 4.3.3.(b) of Appendix 2 of this Chapter.
E_M	=	Methane efficiency as determined in clause 4.3.4. (a) Of Appendix 2 of this Chapter.
E_E	=	Ethane efficiency as determined in clause 4.3.4(b) of Appendix 2 of this Chapter.

	If the methane FID is calibrated through the cutter (Method b), then the methane conversion efficiency as determined in clause 4.3.4. (a) of Appendix 2 of this Chapter is zero. The density used for calculating the NMHC mass shall be equal to that of total hydrocarbons at 293.15 K and 101.325 kPa and is fuel-dependent.
10.0	**DETERMINATION OF EXHAUST MASS FLOW**
10.1	**Introduction**
	The calculation of instantaneous mass emissions according to clause 11 and 12 of this Appendix requires determining the exhaust mass flow rate. The exhaust mass flow rate shall be determined by one of the direct measurement methods specified in clause 7.2 of Appendix 2 of this Chapter. Alternatively, it is permissible to calculate the exhaust mass flow rate as described in clause 10.2 to 10.4 of this Appendix.
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:

$q_{mew,i}$	instantaneous exhaust mass flow rate [kg/s]
$q_{maw,i}$	instantaneous intake air mass flow rate [kg/s]
$q_{mf,i}$	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 clause 3 of Appendix 2 of this Chapter and the validation requirements specified in clause 4.3 of Appendix 3 of this Chapter.

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:

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

where:

$$\frac{A}{F_{st}} = \frac{138.0 \times \left(1 + \frac{\alpha}{4} - \frac{\varepsilon}{2} + \gamma\right)}{12.011 + 1.008 \times \alpha + 15.9994 \times \varepsilon + 14.0067 \times \delta + 32.0675 \times \Upsilon}$$

$$\lambda_i = \frac{\left(100 - \frac{C_{CO} \times 10^{-4}}{2} - C_{HC_W} \times 10^{-4}\right) + \left(\frac{\alpha}{4} \times \frac{1 - \frac{2 \times C_{CO} \times 10^{-4}}{3.5 \times C_{CO2}}}{1 + \frac{C_{Co} \times 10^{-4}}{3.5 \times C_{CO2}}} - \frac{\varepsilon}{2} - \frac{\delta}{2}\right) \times (C_{CO2} + C_{CO} \times 10^{-4})}{4.764 \times \left(1 + \frac{\alpha}{4} - \frac{C}{2} + \Upsilon\right) \times (C_{CO2} + C_{CO} \times 10^{-4} + C_{HCW} \times 10^{-4})}$$

where:

$q_{maw,i}$	Instantaneous intake air mass flow rate [kg/s]
A/F_{st}	Stoichiometric air-to-fuel ratio [kg/kg]
λ_i	Instantaneous excess air ratio
C_{CO2}	Dry CO_2 concentration [%]
C_{co}	Dry CO concentration [ppm]
C_{HCW}	Wet HC concentration [ppm]
α	Molar hydrogen ratio (H/C)
β	Molar carbon ratio (C/C)

	γ	Molar sulphur ratio (S/C)
	δ	Molar nitrogen ratio (N/C)
	ε	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 λ_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 clause 3 of Appendix 2 of this Chapter and the validation requirements specified in Point 4.3 of Appendix 3 of this Chapter.	
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 λ_i according to clause 10.3 of this Appendix) as follows:	
	$$q_{mew,i} = q_{mf,i} \times \left(1 + \frac{A}{F_{st}} \times \lambda_i\right)$$	
	The calculated instantaneous exhaust mass flow rate shall meet the linearity requirements specified for the exhaust gas mass flow rate in clause 3 of Appendix 2 of this Chapter and the validation requirements specified in clause 4.3 of Appendix 3 of this Chapter.	
11.0	**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 of this Appendix. If measured on a dry basis, the dry-wet correction according to clause 8.1 of this Appendix 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 instantaneous emissions. The following equation shall be applied:	
	$$m_{gas,i} = u_{gas} \cdot c_{gas.i} \cdot q_{mew.i}$$	
	where:	
	$m_{gas,i}$ =	mass of the exhaust component "gas" [g/s]

u_{gas}	=	ratio of the density of the exhaust component "gas" and the overall density of the exhaust as listed in Table 1 of this Appendix.
$c_{gas,i}$	=	measured concentration of the exhaust component "gas" in the exhaust [ppm]
$q_{mew,I}$	=	measured exhaust mass flow rate [kg/s]
gas	=	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/m3] and the Density of the Exhaust Gas [kg/m3](6)

Fuel	ρe [kg/m^3]	Component or pollutant i					
		NO_X	CO	HC	CO_2	O_2	CH_4
		ρgas [kg/m^3]					
		2.053	1.250	(1)	1.9636	1.4277	0.716
		u_{gas} (2)(6)					
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(3)	1.2661	0.001621	0.000987	0.000528(4)	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(5)	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

(1) Depending on fuel

(2) at λ = 2, dry air, 273K, 101.3kPa

(3) u values accurate within 0.2% for mass composition of: C=66-76%; H=22-25%; N=0-12%

(4) NMHC on the basis of $CH_{2.93}$ (for THC the u_{gas} coefficient of CH_4 shall be used)

(5) u accurate within 0.2% for mass composition of: C_3=70 - 90%; C_4 = 10 - 30%

(6) ugas 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

12.0	**CALCULATING THE INSTANTANEOUS PARTICLE NUMBER EMISSIONS**
	Calculating the instantaneous particle number emissions. The instantaneous particle number emissions [particles/s] shall be determined by multiplying the instantaneous concentration of the pollutant under consideration [particles/cm3] with the instantaneous exhaust mass flow rate [kg/s], both corrected and aligned for the transformation time. 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 apply: $PN,i = C_{PN,i} q_{mew,i} / \rho_e$ where:

	PN,I	=	particle number flux [particles/s]
	$C_{PN,i}$	=	measured particle number concentration [#/m3] normalized at 0°C
	$q_{mew,i}$	=	measured exhaust mass flow rate [kg/s]
	ρ_e	=	density of the exhaust gas [kg/m3] at 0°C (Table 1)";

13.0	**DATA REPORTING AND EXCHANGE**
	The data shall be exchanged between the measurement systems and the data evaluation software by a standardized reporting file as specified in clause 2 of Appendix 8 of this Chapter. Any pre-processing of data (e.g. time correction according to clause 3 of this Appendix or the correction of the GPS vehicle speed signal according to clause 7 of this Appendix) 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.

CHAPTER 20 - APPENDIX 5

VERIFICATION OF TRIP DYNAMIC CONDITIONS AND CALCULATION OF THE FINAL RDE EMISSIONS RESULT WITH METHOD

(MOVING AVERAGING WINDOW)

1.0	**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 (1) 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).
	(1) For hybrids, the total energy consumption shall be converted to CO_2. The rules for this conversion will be introduced in a second step.
	Step 1. Segmentation of the data;
	Step 2. Calculation of emissions by sub-sets or "windows" (clause 3.1 of this Appendix);
	Step 3. Identification of normal windows; (clause 4 of this Appendix);
	Step 4. Verification of test completeness and normality (clause 5 of this Appendix);
	Step 5. Calculation of emissions using the normal windows (clause 6 of this Appendix);
2.0	**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. NOx, CO, PN)

Δ	Difference
$\geq$	Larger or equal

	#	Number
	%	Per cent
	≤	Smaller or equal
	a_1, b_1	Coefficients of the CO2 characteristic curve
	a_2, b_2	Coefficients of the CO2 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 CO2 characteristic curve [%]
	h_j	Distance of window j to the CO2 characteristic curve [%]
	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
	N_k	number of windows for urban, rural, and motorway shares
	P_1, P_2, P3	reference points
	t	time [s]
	$t_{1,j}$	first second of the jth averaging window [s]
	$t_{2,j}$	last second of the jth averaging window [s]
	t_i	total time in step i [s]
	$t_{i,j}$	total time in Step i considering window j [s]

	t_{ol1}	primary tolerance for the vehicle CO_2 characteristic curve [%]
	t_{ol2}	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]
	$\overline{v_{P1}}$ = 19 km/h	average speed of the Urban Driving Cycle (UDC) phase of the Modified Indian Driving (MIDC) cycle
	v_t	actual vehicle speed in time step i [km/h]
	$\bar{v}_J$	average vehicle speed in window j [km/h]
	$\overline{v_{P2}}$ =59.3 km/h	For M Category of Vehicle. $\overline{v_{P2}}$ = 59.3 km/h average speed of the Extra Urban Driving cycle (EUDC) phase of the Modified Indian Driving (MIDC) cycle. For N1 and M1/N1 low powered vehicles, $\overline{v_{P2}}$ = will be vehicle dependent and will be the actual average speed attained during the Extra-Urban cycle (Part two) phase of the Modified Indian Driving Cycle (MIDC).
	$\overline{v_{P3}}$ =	120 km/h
	w	weighing factor for windows w_j
	w_j	weighing factor of window j.
3.0	**MOVING AVERAGING WINDOWS**	
3.1.	**Definition of Averaging Windows**	
	The instantaneous emissions calculated according to Appendix 4 of this Chapter 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 Δt 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 shall be run from the first point (forwards).	
	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;
	- Vehicle ground speed <1km/h;
	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 of this Chapter.

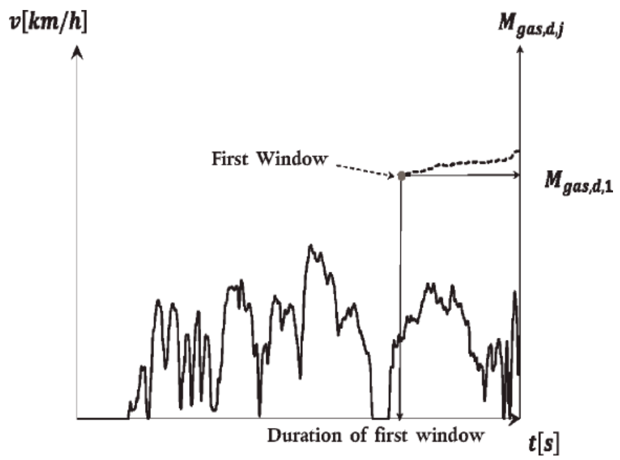


Figure 1
Vehicle Speed Versus Time – Vehicle Averaged Emissions Versus Time, tarting from the First Averaging Window

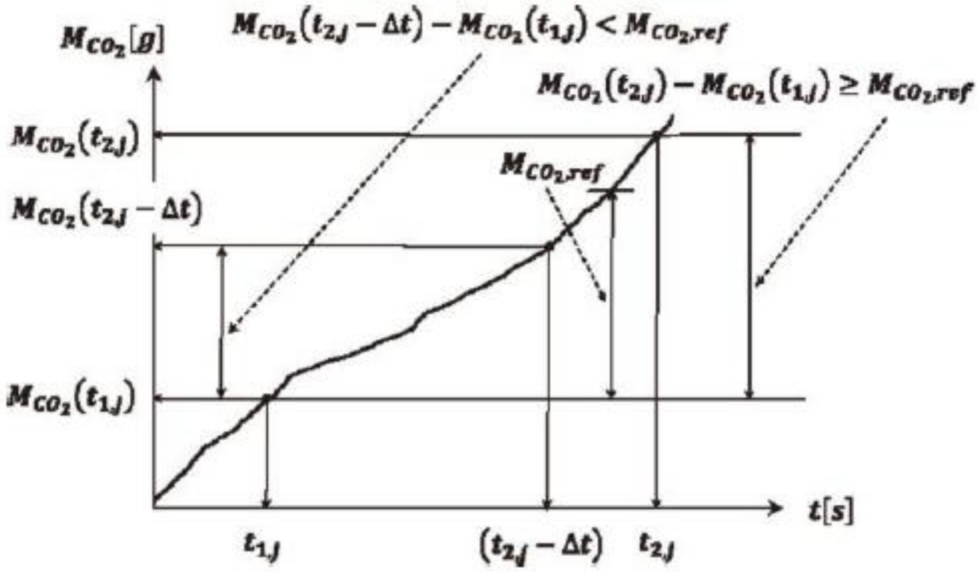


Figure 2
Definition of CO_2 Mass Based Averaging Windows

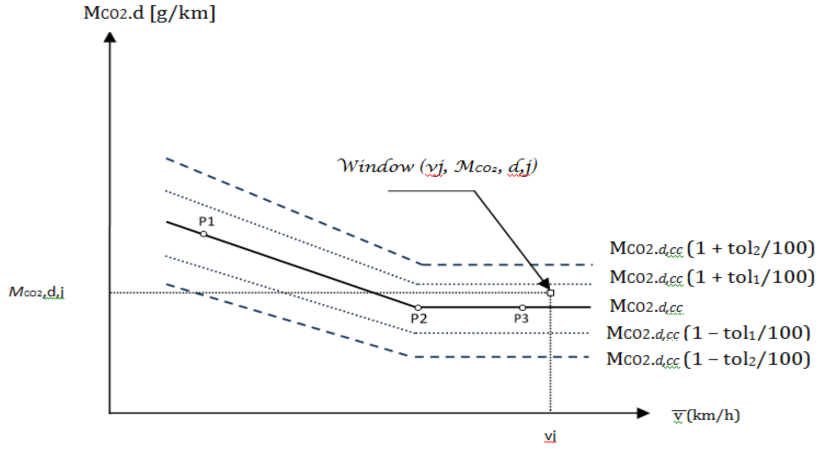
The duration ($t_{2,j} – t_{1,j}$) of the j^{th} averaging window is determined by:

	$M_{CO2\,(t2,\,j)} - M_{CO2\,(t1,\,j)} \geq M_{CO2,ref}$
	where:
	$M_{CO_2\,(t1,\,j)}$ is the CO_2 mass measured between the test start and time $(t_{1,\,j})$, [g];
	$M_{CO_2,ref}$ is the CO_2 mass [g] emitted by the vehicle over the Modified Indian Driving Cycle (MIDC) 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 Chapter.
3.2	**Calculation of Window Emissions and Averages**
	The following shall be calculated for each window determined in accordance with clause 3.1 of this Appendix.
	The distance-specific emissions $M_{gas,d,j}$ for all the pollutants specified in this chapter;
	The distance-specific CO_2 emissions $M_{CO2,d,j}$;
	The average vehicle speed $\overline{v}_j$ In case a NOVC-HEV is tested, the window calculation shall start at the point of ignition on and include driving events during which no CO_2 is emitted.
4.0	**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 on the chassis dynamometer by applying the vehicle road load settings as determined following the procedure prescribed in Appendix 2 of Chapter 5 of this Part. The road loads shall not account for the mass added to the vehicle during the RDE test, e.g. the co-pilot and the PEMS equipment.
4.2	**CO2 Characteristic Curve Reference Points**
	The reference Points P_1, P_2 and P3 required to define the curve shall be

	established as follows:
4.2.1.	Point P_1
	$\overline{V_{P1}}$=19 km/h (average speed of the urban cycle (Part one) phase of the Modified Indian Driving Cycle (MIDC).
	For M Category of vehicles, $M_{CO2,d,P1}$ = Vehicle CO_2 emissions over the urban cycle (Part one) phase of the Modified Indian Driving Cycle (MIDC) x 1.1 [g/km] For N1 Category of vehicles, $M_{CO2,d,P1}$ = Vehicle CO_2 emissions over the urban cycle (Part one) phase of the Modified Indian Driving Cycle (MIDC) x 1.05 [g/km] For M1/N1 low powered Category of vehicles, $M_{CO2,d,P1}$ = Vehicle CO_2 emissions over the urban cycle (Part one) phase of the Modified Indian Driving Cycle (MIDC) x 1.05 [g/km]

4.2.2.	Point P_2
4.2.3	For M Category of vehicles $\overline{V_{p2}}$= 59.3 km/h (average Speed of the Extra-urban cycle (Part two) phase of the Modified Indian Driving Cycle (MIDC). For N1 and M1/N1 low powered Category of vehicles, V_{p2}= will be vehicle dependent and will be the actual average speed attained during the Extra-Urban cycle (Part two) phase of the Modified Indian Driving Cycle (MIDC).
	For M Category of vehicles, $M_{CO2,d,P2}$ = Vehicle CO_2 emissions over the Extra Urban cycle (Part two) phase of the Modified Indian Driving cycle (MIDC) x 1.1[g/km] For N1 Category of vehicles, $M_{CO2,d,P2}$ = Vehicle CO_2 emissions over the Extra Urban cycle (Part two) phase of the Modified Indian Driving cycle (MIDC) x 1.05[g/km] For M1/N1 low powered Category of vehicles, $M_{CO2,d,P2}$ = Vehicle CO_2 emissions over the Extra Urban cycle (Part two) phase of the Modified Indian Driving cycle (MIDC) x 1.05[g/km]
4.2.4.	Point P3
4.2.5.	V_{p3}= 120 km/h
	$M_{CO2,d,P3} = M_{CO2,d,P2}$

4.3	**CO_2 characteristic curve definition**
	Using the reference points defined in clause 4.2 of this Appendix, the characteristic curve CO_2 emissions are calculated as a function of the average speed using two linear sections (P_1, P_2) and (P2, P3). The section (P2, P3) is limited to 120 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:
	$a_1 = (M_{CO2,d,p2} - M_{CO_2,d,p1})/(\overline{v_{p2}} - \overline{v_{p1}})$
	and
	$b_1 = M_{Co2,d,p1} - a_1\overline{v_{p1}}$

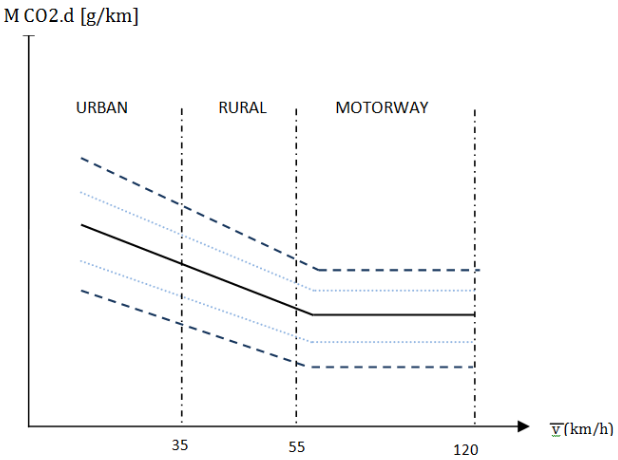


P2 = P3

Figure 3

Vehicle CO2 Characteristic Curve

4.4	**Urban, Rural and Motorway Windows**
4.4.1.	Urban windows are characterized by average vehicle ground speeds $\bar{v}_j$ smaller than 35 km/h for M, N1 & M1/N1 Low powered categories of vehicles.
4.4.2.	Rural windows are characterized by average vehicle ground speeds $\bar{v}_j$ greater than or equal to 35 km/h and smaller than 55 km/h for M & N1 categories of vehicles and for M1/N1 low powered categories of vehicles since only 2 phases considered will be higher than or equal to 35 km/h.
4.4.3.	Motorway windows are characterized by average vehicle ground speeds $\bar{v}_j$ greater than or equal to 55 km/h and smaller than 120 km/h for M category vehicles & $\bar{v}_j$ greater than or equal to 55km/h and smaller than 80km/h for N1

	category vehicles.
	 **Figure 4** **Vehicle CO2 Characteristic Curve: Urban, Rural and Motorway Driving Definitions**
5.0	**VERIFICATION OF TRIP COMPLETENESS AND NORMALITY**
5.1	**Tolerances Around the Vehicle CO2 Characteristic Curve**
	The primary tolerance and the secondary tolerance of the vehicle CO2 characteristic curve are respectively tol1 = 25 % and tol2 = 50 %.
5.2	**Verification of Test Completeness**
	The test shall be complete when it comprises at least 10% of urban, rural and motorway windows, out of the total number of windows for all categories of vehicles.
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 tol1 may be increased by steps of 1 percentage point until the 50 % of normal windows target is reached. When using this approach, tol1 shall never exceed 30 %. When testing a NOVC-HEV and only if the specified minimum requirement of 50 % is not met, the upper positive tolerance tol1 may be increased by steps of 1 percentage point until the 50 % of normal windows target is reached. When using this approach, tol1 shall never exceed 50 %.
6.0	**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
	$$M_{CO2,d,cc}(\overline{v_j}).\left(1 - \frac{tol_1}{100}\right) \leq M_{CO2,dj} \leq M_{CO_2,d,cc}\,(\overline{v_1}).\left(1 + \frac{tol_1}{100}\right)$$
	Then w_j=1
	If
	$$M_{CO2,d,cc}(\overline{v_j}).\left(1 + \frac{tol_1}{100}\right) < M_{CO2,dj} \leq M_{CO_2,d,cc}\,(\overline{v_j}).\left(1 + \frac{tol_2}{100}\right)$$
	Then $w_j = k_{11}h_j + k_{12}$
	With $k_{11} = \left(\frac{1}{\{tol_1 - tol_2\}}\right)$ and $k_{12} = \left(\frac{tol_2}{\{tol_2 - tol_1\}}\right)$
	If
	$$M_{CO2,d,cc}(\overline{v_j}).\left(1 - \frac{tol_2}{100}\right) \leq M_{CO2,d,j} < M_{CO2,d,cc}(\overline{v_j}).\left(1 - \frac{tol_1}{100}\right)$$
	Then $w_j = k_{21}h_j + k_{22}$
	With $k_{21} = \left(\frac{1}{\{tol_2 - tol_1\}}\right)$ and $k_{22} = k_{12} = \left(\frac{tol_2}{\{tol_2 - tol_1\}}\right)$
	If
	$$M_{CO2,d,j} < M_{CO2,d.cc}(\overline{v_j}).(1 - \left(\frac{tol_2}{100}\right)$$
	Or
	$$M_{CO2,d,j} > M_{CO2,d.cc}(\overline{v_j}).(1 + \left(\frac{tol_2}{100}\right)$$
	then $w_j = 0$ For all averaging windows including cold start data points, as defined in clause 4 of Appendix 4 of this Chapter, the weighting function is set to 1.
	Where:
	$$h_j = 100 \cdot \frac{M_{CO2,dj} - M_{CO2,dcc}(\overline{v_j})}{M_{CO2,dcc}(\overline{v_j})}$$

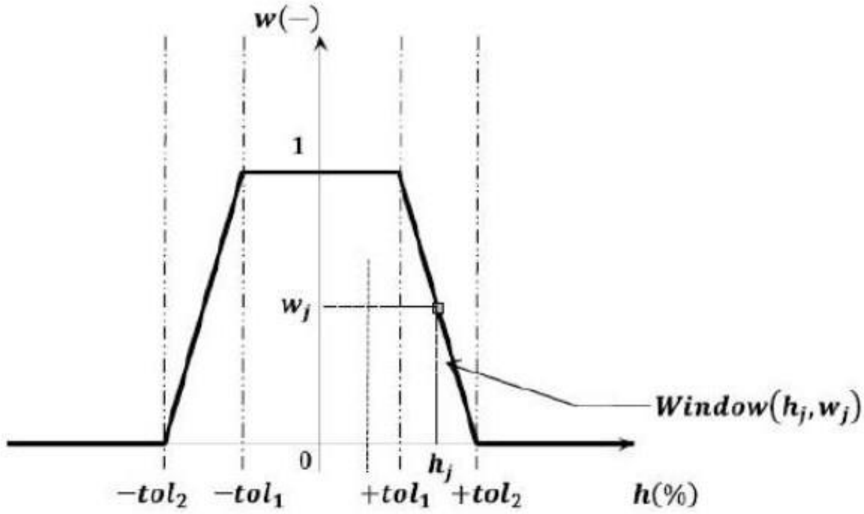


Figure 5
Averaging Window Weighing Function

6.2	**Calculation of Severity Indices**
	The severity indices shall be calculated separately for the urban, rural and motorway categories :
	$$\overline{h_k} = \frac{1}{N_k}\sum h_j k = u, r, m$$
	and the complete trip
	$$\bar{h_t} = \frac{f_u\overline{h_u} + f_r\overline{h_r} + f_m\overline{h_m}}{f_u + f_r + f_m}$$
	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 clause 6.1 of this Appendix, the distance-specific emissions in [mg/km] shall be calculated for the complete trip each gaseous pollutant in the following way:
	$$M_{gas,d,t} = 1000\ \frac{f_u \cdot M_{gas,d,u} + f_r \cdot M_{gas,d,r} + f_m \cdot M_{gas,d,m}}{f_u + f_r + f_m}$$
	And for particle number:
	$$M_{PNd,t} = \frac{f_u \cdot M_{PN,d,u} + f_r \cdot M_{PN,d,r} + f_m \cdot M_{PN,d,m}}{f_u + f_r + f_m}$$
	Where f_u, f_r f_m are respectively equal to 0.34, 0.33 and 0.33.

7.0	**NUMERICAL EXAMPLES**

7.1	**Averaging Window Calculations**

Table 1
Main Calculation Settings

M_{CO2ref} [g]	1157.2
Direction for averaging window calculation	Forward
Acquisition frequency [Hz]	1

Figure 6 of this Appendix 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 1200 s 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 $t_{2,1}$ = 524s (Table 3 of this Appendix).

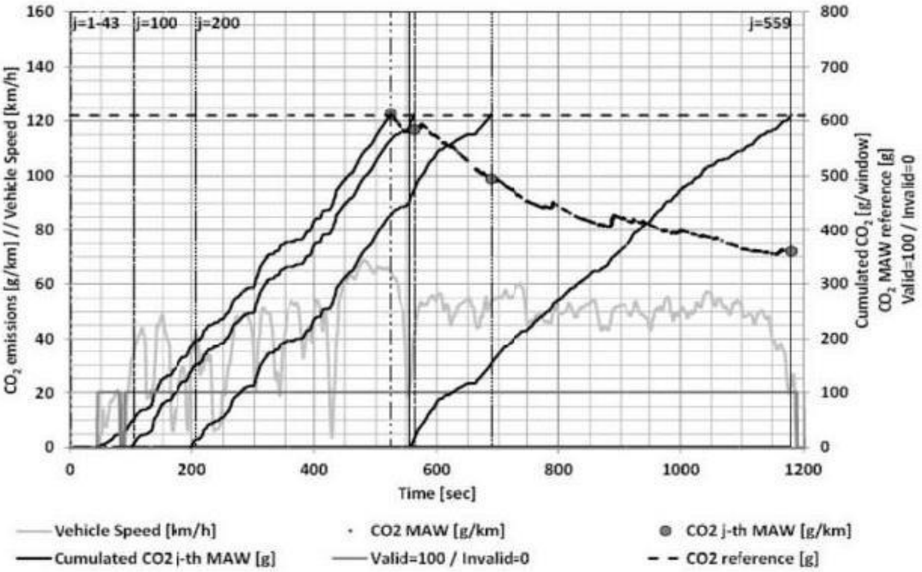


Figure 6

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 urban cycle (Part one) MIDC (P1) [g/km]	138.72
CO_2 Extra Urban cycle (Part two) MIDC (P2) [g/km]	91.49
CO_2 Extra Urban cycle (Part two) MIDC CO_2 Extra-High Speed WLTC (P3) [g/km]	91.49

Reference Point

P_1	$\overline{V_{P1}}$= 19.0 km / h	$M_{CO2,d,P1}$ = 138.72 g/km
P_2	$\overline{V_{P2}}$= 59.3 km / h	$M_{CO2,d,P2}$ = 91.49 g/km
P_3	$\overline{V_{P3}}$ = 120 km/h	$M_{CO2,d,P3}$ = 91.49 g/km

The definition of the CO_2 characteristic curve is as follows:

For the section (P_1, P_2):

$$M_{CO2,d}(\bar{v}) = a_1\bar{v} + b_1$$

With

$$a_1 = \frac{91.49 - 138.72}{59.3 - 19.0} = -\frac{47.23}{40.3} = -1.172$$

and : b_1 = 138.72 – (-1.172) x 19.0 = 138.72 + 22.267 = 160.987

For the section (P_2, P_3):

$$M_{CO2,d}(\bar{v}) = a_2\bar{v} + b_2$$

with

$$a_2 = \frac{91.49 - 91.49}{120 - 59.3} = \frac{0}{60.7} = 0$$

and : b_2 = 91.49 –0 x 59.3 = 91.49 –0 = 91.49

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

For window #45:

$M_{CO2,d,45}$ = 145.86 g / km

$\overline{v_{45}}$ = 26.47 km/h

The average speed of the window is lower than 35km/h, therefore it is an urban window.

For the characteristic curve:

	$M_{CO2,d,cc}(\overline{V_{45}}) = a_1\overline{v_{45}} + b_1 = -1.172 \times 26.47 + 160.987 = 129.964$
	Verification of:
	$M_{CO2,d,cc}(\overline{v_j}).\left(1 - \frac{tol_1}{100}\right) \leq M_{CO2,d,j} \leq M_{CO2,d,cc}(\overline{v_j}).\left(1 + \frac{tol_1}{100}\right)$
	$M_{CO2,d,cc}(\overline{v_{45}}).\left(1 - \frac{tol_1}{100}\right) \leq M_{CO2,d,45} \leq M_{CO2,d,cc}(\overline{v_{45}}).\left(1 + \frac{tol_1}{100}\right)$
	129.964 × (1 – 25/100) ≤ 145.86 ≤ 129.964 × (1 + 25/100)
	97.473 ≤ 145.86 ≤ 162.455
	Leads to: $w_{45} = 1$
	For window #5074:
	$M_{CO2,d,5074} = 141.84$ g/km
	$\overline{v_{5074}} = 52.44$ km/h
	The average speed of the window is higher than 35 km/h but lower than 55 km/h, therefore it is a rural window.
	For the characteristic curve:
	$M_{CO_2,d,CC}(\bar{v}_{5152}) = a_1\ \bar{v}_{5152} + b_1 = -1.172 \times 52.44 + 160.987 = 99.527\ g/km$
	Verification of:
	$M_{CO2,d,cc}(\bar{v}_j) \cdot \left(1 + \frac{tol_1}{100}\right) \leq\ M_{CO2,d,cc,5074} \leq\ M_{CO2,d,cc}(\bar{v}_j) \cdot \left(1 + \frac{tol_2}{100}\right)$
	$M_{CO2,d,cc}(\bar{v}_{5074}) \cdot \left(1 + \frac{tol_1}{100}\right) \leq\ M_{CO2,d,cc,5074} \leq\ M_{CO2,d,cc}(\bar{v}_{5074}) \cdot \left(1 + \frac{tol_2}{100}\right)$
	99.527×(1+25/100)≤141.84≤99.527×(1+50/100)
	124.4091≤141.84≤149.291
	Leads to:
	$h_{5074} = 100 \cdot \frac{M_{CO2,d.5074} - M_{CO2,d.cc(\overline{V_{5074}})}}{M_{CO2,d.cc(\overline{V_{5074}})}} = 100 \cdot \frac{141.84 - 99.527}{99.527} = 42.514$
	$W_{5074} = k_{11}h_{5074} + k_{12}$ = -0.04 (42.514)+2 = 0.3
	With $k_{11} = \left(\frac{1}{\{tol_1 - tol_2\}}\right) = \left(\frac{1}{\{25-50\}}\right)$ = -0.04
	And $k_{12} = \left(\frac{tol_2}{\{tol_2 - tol_1\}}\right) = \left(\frac{50}{\{50-25\}}\right)$ = 2

	Table 3					
	Emissions Numerical Data					
	Window [#]	**$t_{1,j}$ [s]**	**$t_{2,j}$ - Δt [s]**	**$t_{2,j}$ [s]**	$M_{CO2}(t_{2,j} – \Delta t)$ - $M_{CO2}(t_{1,j})$ < $M_{CO2,ref}$ **[g]**	$M_{CO2}(t_{2,j})$ – $M_{CO2}(t_{1,j}) \geq$ MCO2,ref **[g]**
	1	1	1211	1212	1156.04	1158.06
	2	2	1210	1212	1156.04	1158.06
	…	…		…	…	…
	43	43	1239	1282	1156.01	1158.10
	44	44	1239	1283	1156.02	1158.10
	45	45	1238	1283	1156.05	1158.04
	46	46	1238	1284	1156.05	1158.04
	47	47	1237	1284	1156.03	1158.07
	…	…		…	…	…
	100	100	1247	1347	1156.12	1158.03
	…	…		…	…	…
	200	200	1264	1464	1156.15	1158.12
	…	…		…	…	…
	474	474	1207	1681	1156.14	1158.04
	475	475	1207	1682	1156.11	1158.07
	…	…		…	…	…
	556	556	1231	1787	1156.04	1158.02
	557	557	1232	1789	1156.04	1158.04
	558	558	1231	1789	1156.02	1158.03
	559	559	1234	1793	1156.03	1158.06

7.3.	**Urban, Rural and Motorway Windows – Trip Completeness**
	In this numerical example, the trip consists of 7036 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 CO2 characteristic curve. The trip is complete since it comprises at least 105 % of urban, rural and motorway windows out of the total number of windows. In addition the trip is characterized as normal since at least 50 % of the urban, rural and motorway windows are within the primary tolerances defined for the characteristic curve.
	Table 4 **(Reserved)**
	Table 5 **Verification of Trip Completeness and Normality**

Driving Conditions	**Numbers**	**Percentage of windows**
All Windows		
Urban	3,112	3,112/6,073 x 100 = 51.2 > 10
Rural	2,054	2,054/6,073 x 100 = 33.8 > 10
Motorway	907	907/6,073 x100 = 14.9 > 10
Total	3,112 + 2,054 + 907 = 6073	
Normal Windows		
Urban	3,112	3,112/3,112x 100 = 100> 50
Rural	1,963	1,963/2,054 x 100 = 95.6 > 50
Motorway	257	257/907 x 100 = 24.6< 50 (Fail)
Total	3,112 + 1,963 + 257 =5,332	

CHAPTER 20 - APPENDIX 6
(Reserved)

CHAPTER 20 - APPENDIX 7

SELECTION OF VEHICLES FOR PEMS TESTING AT INITIAL TYPE APPROVAL

1.0	**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" 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 clause 3 of this Appendix, which shall be validated according to the requirements of Point 4.		
2.0	**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
3.0	**PEMS TEST FAMILY BUILDING**		
	A PEMS test family shall comprise finished vehicles with similar emission characteristics. Vehicle emission types may be included in a PEMS test family only as long as the completed vehicles within a PEMS test family are identical with respect to the characteristics in clause 3.1. and 3.2 of this Appendix.		
3.1.	**Administrative criteria**		
3.1.1.	The Test Agency issuing the emission type approval as per AIS 137.		
3.1.2.	A Single Vehicle Manufacturer having received the emission type approval as per AIS 137.		
3.2.	**Technical Criteria**		
3.2.1.	Propulsion Type (e.g. ICE, HEV, PHEV)		
3.2.2.	Type(s) of fuel(s) (e.g. gasoline, 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 volume of vehicles in the PEMS test family shall not deviate more than -5% from V_eng_max if V_eng_max ≥ 1500 cc and -7% from V_eng_max if V_eng_max < 1500 cc.
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 fulfill the requirements of clause 3 and 4 of this Appendix. This may in particular require the PEMS testing of additional vehicles to validate the extended PEMS test family according to clause 4 of this Appendix.
4.0	**VALIDATION OF A PEMS TEST FAMILY**
4.1.	**General Requirements for Validating a PEMS Fest family**
4.1.1.	The vehicle manufacturer presents a representative vehicle of the PEMS test family to the Test Agency. The vehicle shall be subject to a PEMS test carried out by a Test Agency to demonstrate compliance of the representative vehicle with the requirements of this Chapter

4.1.2.	The Test Agency selects additional vehicles according to the requirements of clause 4.2 of this Appendix for PEMS testing carried out by a Test Agency to demonstrate compliance of the selected vehicles with the requirements of this Chapter. The technical criteria for selection of an additional vehicle according to clause 4.2 of this Appendix shall be recorded with the test results.
4.1.3.	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 Test Agency according to the requirements of this Part and this Test Agency 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. gasoline-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 and of the reference mass. 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, CVT, AMT) 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	All RDE test shall be conducted in Cold & Hot conditions. For hot condition 50% of the selected vehicles to be tested and shall be rounded to the next higher integer number.	
4.2.8	At least 1 vehicle with Minimum & 1 vehicle with Maximum Road Load forces at 80 Km/h shall be selected for RDE testing.	
4.2.9.	Notwithstanding the provisions in Points 4.2.1 to 4.2.8, 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 = 3 + 0.15 x N(*)
	(*) NT shall be rounded to the next higher integer number	
4.2.10	If required, based on mutual agreement between manufacturer & test agency additional test may be conducted for validating the PEMS Family.	
5.0	**REPORTING**	
5.1.	The vehicle manufacturer provides a full description of the PEMS test family, which includes in particular the technical criteria described in clause 3.2 of this Appendix and submits it to the Test Agency.	
5.2.	The manufacturer attributes a unique identification number of the format TA-OEM-X-Y to the PEMS test family and communicates it to the Test Agency. Here TA is the distinguishing number of the Test Agency issuing Approval, 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 Test Agency 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 shall be provided.
5.4.	The Test Agency 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 clause 4 of this Appendix, which also provides the necessary information on how the selection criteria of clause 4.2 of this Appendix are covered.

	CHAPTER 20 - APPENDIX 7A **VERIFICATION OF OVERALL TRIP DYNAMICS**
1.0	**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.
2.0	**SYMBOLS, PARAMETERS AND UNITS**

RPA	Relative Positive Acceleration
Δ	Difference
>	Larger
≥	Larger or equal
%	Per cent
<	Smaller
≤	Smaller or equal
a	Acceleration [m/s2]
a_i	Acceleration in time Step i [m/s^2]
a_{pos}	Positive acceleration greater than 0.1m/s^2 [m/s^2]
$a_{pos,i,k}$	Positive acceleration greater than 0.1m/s^2 in time Step i considering theurban, 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)	Refers to the time step
Index (j)	Refers to the 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
Nk	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)]

	tk	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]
	$(v \cdot a)_i$	Actual vehicle speed per acceleration in time Step i [m^2/s^3 or W/kg]
	$(v \cdot apos)j,k$	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]	95^{th} 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]
	$\overline{v_k}$	average vehicle speed for urban, rural and motorway shares [km/h]
3.0	**TRIP INDICATORS**	
3.1.	Calculations	
3.1.1.	Data Pre-processing	
	Dynamic parameters like acceleration, v*apos_95 or RPA shall be determined with a speed signal of an accuracy of 0.1 % for all speed values above 3km/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 accurate enough.	
	If $0.01\ m/s^2 < a_{res} \leq r_{max}\ m/s^2$, smoothing by using a T4253 Hanning filter shall be performed	
	$a_{res} > r_{max}\ m/s^2$ 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 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 clause 3.1.2. of this Appendix.
3.1.2.	Calculation of distance, acceleration and v·a
	The following calculations shall be performed over the whole time based speed trace (1Hz resolution) from second 1 to second t_t (last second).
	The distance increment per data sample shall be calculated as follows:
	$d_i = \frac{v_i}{3.6}$, i =1 to N_t
	where:
	d_i — Distance covered in time step i [m]
	v_i — Actual vehicle speed in time step i [km/h]
	N_t — Total number of samples
	The acceleration shall be calculated as follows:
	$$a_i = \frac{v_{i+1} - v_{i-1}}{(2) \cdot (3.6)}\ , i = 1\ to\ Nt$$
	where:
	ai — Acceleration in time step i [m/s^2]. For i = 1: v_{i-1}= 0, for i = Nt: v_{i+1}= 0.
	The product of vehicle speed per acceleration shall be calculated as follows:
	$(v \cdot a)_i$ = vi · ai /3.6, i = 1 to Nt
	where:
	$$(v \cdot a)_i = \left(\frac{v_i \cdot a_i}{3.6}\right), i = 1\ to\ Nt$$
	$(v \cdot a)_i$ — 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 ai and $(v \cdot a)_i$, the values vi, di, ai and $(v \cdot a)_i$ shall be ranked in ascending order of the vehicle speed.

	For M category vehicles, All datasets with vi < 45 km/h belong to the Phase I speed bin, all datasets with 45 km/h ≤ vi < 65 km/h belong to the Phase II speed bin and all datasets with vi ≥ 65 km/h belong to the Phase III speed bin. For N1 category vehicles, all datasets with vi < 40 km/h belong to the Phase I speed bin, all datasets with 40 km/h ≤ vi < 60 km/h belong to the Phase II speed bin and all datasets with vi ≥ 60 km/h belong to the Phase III speed bin. For M1/N1 Low powered category vehicles, all datasets with vi < 45 km/h belong to the Phase I speed bin and all datasets with vi ≥ 45 km/h belong to the Phase II speed bin.	
	For M & N1 category vehicles, The number of datasets with acceleration values ai > 0.1m/s2 shall be bigger or equal to 150 in each Phase I & Phase II speed bin and bigger or equal to 100 in Phase III speed bin. For M1/N1 Low powered category vehicles, the number of datasets with acceleration values ai > 0.1 m/s2 shall be bigger or equal to 150 in Phase I speed bin and bigger or equal to 100 in Phase II speed bin.	
	For each speed bin the average vehicle speed $\overline{V_k}$ shall be calculated as follows:	
	$$\overline{V_k} = \frac{(\sum v_{ik})}{N_k}, i = 1\ to\ Nk, k = u, r, m$$	
	Where:	
	N_k	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 $(v \cdot apos)_{j,k}$ values with $a_{i,k} \geq 0.1$m/s^2 as follows:	
	The lowest $v \cdot apos$ 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%.	
	$(v \cdot apos)_k$_[95] is the $(v \cdot apos)_{j,k}$ value, with j/ M_k = 95%. If j/ M_k = 95% cannot be met, $(v \cdot apos)_k$_[95] shall be calculated by liner 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:	

	$RPA_k = \sum(\Delta t \cdot (v \cdot a_{pos})_{j,k}) / \sum d_{i,k}$, 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/s^2 or kWs/(kg*km)]
	Δt is a time difference equal to 1s
	M_k is the sample number for urban, rural and motorway shares with positive acceleration
	Nk is the total sample number for urban, rural and motorway shares
4.0	**VERIFICATION OF TRIP VALIDITY**
4.1.1.	**Verification of $v*a_{pos\_}[95]$ per speed bin (with v in [km/h])**
	For M category of vehicles, If $\overline{v_k} \leq 56.9$ km/h and $(v \cdot a_{pos})_{k\_}[95] > (0.0467 \cdot \overline{v_k} + 12.2490)$ is fulfilled, the trip is invalid. If $\overline{v_k} > 56.9$ km/h and $(v \cdot a_{pos})_{k\_}[95] > (0.1665 \cdot \overline{v_k} + 5.4352)$ is fulfilled, the trip is invalid. **For N1 category of vehicles,** If $\overline{v_k} \leq 51.4$ km/h and $(v \cdot a_{pos})_{k\_}[95] > (0.0614 \cdot \overline{v_k} + 6.9439)$ is fulfilled, the trip is invalid. If $\overline{v_k} > 51.4$ km/h and $(v \cdot a_{pos})_{k\_}[95] > (0.0045 \cdot \overline{v_k} + 9.8664)$ is fulfilled, the trip is invalid. **For M1 / N1 low powered category of vehicles,** If $(v \cdot a_{pos})_{k\_}[95] > (0.0142 \cdot \overline{v_k} + 4.6214)$ is fulfilled, the trip is invalid.
4.1.2.	**Verification of RPA per speed bin**
	For M category of vehicles, If $\overline{v_k} \leq 55.9$ km/h and RPA < $(-0.001825. \overline{v_k} + 0.1755)$ is fulfilled, the trip is invalid. If $\overline{v_k} > 55.9$ km/h and RPA < $(-0.0011. \overline{v_k} + 0.1350)$ is fulfilled, the trip is invalid.

	For N1 category of vehicles, RPA < (-0.0016. $\overline{v_k}$+ 0.1406) is fulfilled, the trip is invalid. **For M1/N1 low powered category of vehicles,** If $\overline{v_k}$ ≤ 54.76 km/h and RPA < (-0.0022 . $\overline{v_k}$+ 0.1271) is fulfilled, the trip is invalid. If $\overline{v_k}$ > 54.76 km/h and RPA < 0.0066 is fulfilled, the trip is invalid.
	During monitoring phase, tests which are not able to comply with IRDE trip dynamics criteria, will not be considered void. This conclusion shall be drawn after conducting at least 3 trials.

CHAPTER 20 - APPENDIX 7B

PROCEDURE TO DETERMINE THE CUMULATIVE POSITIVE ELEVATION GAIN OF A TRIP

1.0 INTRODUCTION

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

2.0 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]
di	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	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 at a data point t [km/h]
3.0	**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 1Hz and the corresponding time t [s] that has passed since test start.	
4.0	**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 clause 7 of Appendix 4 of this Chapter; 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:	
	$$\lvert h_{GPS}(t) - h_{map}(t)\rvert > 40m$$	
	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 40m. Any instantaneous altitude data h(t) shall be corrected if the following condition applies:	
	$$\lvert h(t) - h(t-1)\rvert > \frac{v(t)}{3.6} * \sin 45°$$	
	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 calculation of the cumulative positive elevation gain as described in clause 13.4 pf this Appendix.
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 di. The instantaneous distance di shall be determined as:
	$$d_i = \frac{V_i}{3.6}$$
	Where:
	di = Instantaneous distance [m]
	Vi = Instantaneous vehicle speed [km/h]
	The cumulative elevation gain shall be calculated from data of a constant spatial resolution of 1m starting with the first measurement at the start of a trip d(0). The discrete data points at a resolution of 1m 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:
	$$h_{int}(d) = h_{corr}(0) + \frac{h_{corr}(1) - h_{corr}(0)}{d_1 - d_0} \cdot (d - d_0)$$
	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]
	$h_{corr}(1)$	Corrected altitude directly before 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; da and de denote the first and last data point respectively (Figure 1 of this Appendix). The first smoothing run shall be applied as follows:	
	$road_{grade,1(d)} = \frac{h_{int}(d+200m) - h_{int}(da)}{(d+200m)}$	For d ≤ 200m
	$road_{grade,1(d)} = \frac{h_{int}(d+200m) - h_{int}(d-200m)}{(d+200m)-(d-200m)}$	For 200 m < d < (d_e - 200m)
	$road_{grade,1(d)} = \frac{h_{int}(d_e) - h_{int}(d-200m)}{(d_e)-(d-200m)}$	For d ≥ (de -200m)
	$h_{int,sm,1}(d) = h_{int,sm,1}(d-1m) + road_{grade,1}(d), d = d_a + 1 \; to \; d_e$	
	$h_{int,sm,1}(d) = h_{int}(d_a) += road_{grade,1}(da)$	
	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]
	hint,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 a distance of zero at meters [m]
	d_e	Cumulative distance travelled until the last discrete way point [m]

	The second smoothing run shall be applied as follows :
	$road_{grade,2(d)} = \frac{h_{int,sm,1}(d+200m)-h_{int,sm,1}(d_a)}{(d+200\ m)}$, for d$\leq 200m$
	$road_{grade,2(d)} = \frac{h_{int,sm,1}(d+200m)-h_{int,sm,1}(d-200)}{(d+200\ m)-(d-200m)}$, for 200m$< d < (d_e - 200m)$
	$road_{grade,2(d)} = \frac{h_{int,sm,1}(d_e)-h_{int,sm,1}(d-200)}{d_e-(d-200m)}$, for d$\geq (d_e - 200m)$

	Where:	
	roadgrade,2(d)	Smoothed road grade at the discrete way point under consideration after the second smoothing run [m/m]
	hint,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].

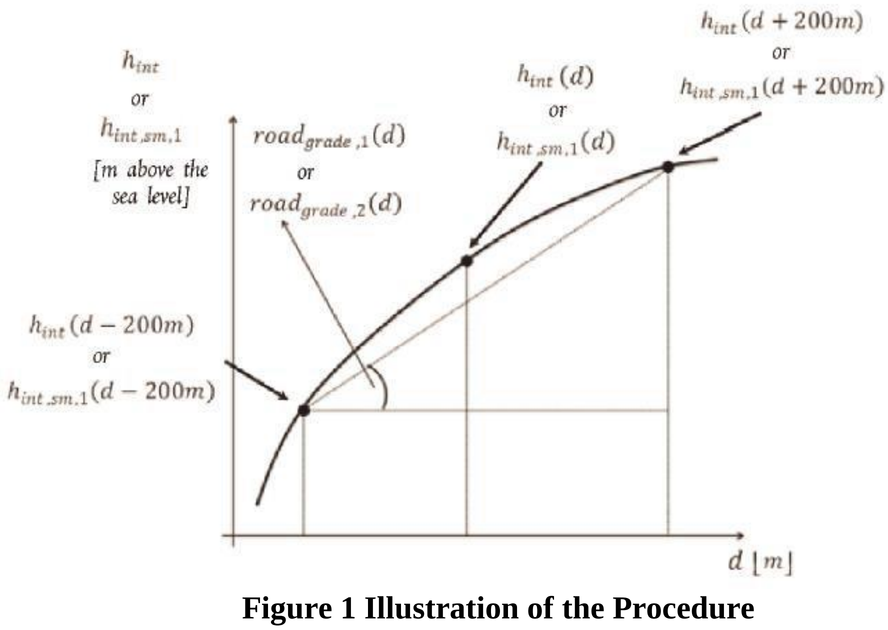


Figure 1 Illustration of the Procedure to Smooth the Interpolated Altitude Signals

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 normalized by the total test distance d_{tot} and expressed in meters of cumulative elevation gain per 100 kilometers of distance.

5.0	**NUMERICAL EXAMPLE**
	Tables 1 and 2 of this Appendix show the steps performed in order to 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 of this Appendix). 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:
	$$\lvert h(t) - h(t-1) \rvert > \left(\frac{v(t)}{3.6} * \sin 45°\right)$$
	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 of this Appendix.
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 of this Appendix). Recalculating the altitude data to obtain a uniform spatial resolution of 1m yields the discrete way points d (Column 1 in Table 2 of this Appendix) and their corresponding altitude values $h_{int}(d)$ (Column 7 in Table 2 of this Appendix). The altitude of each discrete way Point d is calculated through interpolation of the measured instantaneous altitude h_{corr} as:
	$$h_{int}(0) = 120.3 \frac{120.3 - 120.3}{0.1 - 0} * (0 - 0) = 120.3$$

	$$h_{int}(520) = 132.5\frac{132.6 - 132.5}{523.6 - 519.9} * (520 - 519.9) = 132.5027$$
5.3.2.	**Additional Data Smoothing**
	In Table 2 of this Appendix, the first and last discrete way points are: da=0 m and de=799 m, respectively. The altitude data of each discrete way point is smoothed by applying a two steps procedure. The first smoothing run consists of:
	$road_{grade,1}(o) = \frac{h_{int}(200m) - h_{int}(o)}{(0)+(200m)} = \frac{120.9682 - 120.3000}{200}$=0.0033
	chosen to demonstrate the smoothing for d ≤ 200m
	$road_{grade,1}(320) = \frac{h_{int}(520) - h_{int}(120)}{(520)+(120)} = \frac{132.5027 - 121.9808}{400}$=0.0288
	chosen to demonstrate the smoothing for 200 m < d < (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 ≥ (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 ≈ 120 .3033 m
	h $_{int,sm,1}$ (799) = h $_{int,sm,1}$ (798) + road $_{grade,1}$ (799) = 121.2550 - 0.0220 = 121.2330m
	Second smoothing run:
	$road_{grade,2}(o) = \frac{h_{int,sm,1}(200) - h_{int,sm,1}(o)}{200} = \frac{119.9618 - 120.3033}{200} = -0.0017$
	chosen to demonstrate the smoothing for d ≤ 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 < (599m)
	$road_{grade,2}(720) = \frac{h_{int,sm,1}(799) - h_{int,sm,1}(520)}{799 - 520} = \frac{121.2330 - 123.6809}{279} = -0.0088$
	chosen to demonstrate the smoothing for d ≥ (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. $road_{grade,2}(d)$. For the presented example total covered distance was d_{tot} = 139.7km and all positive interpolated and smoothed road grades were of 516 m. Therefore the positive cumulative elevation gain reached 516*100/139.7 = 370m/100km was achieved.

Table 1

Correction of Instantaneous Vehicle Altitude Data

Time (t)	**v(t)**	**$h_{GPS(t)}$**	**$h_{map}(t)$**	**h(t)**	**$h_{corr}(t)$**	**di**	**Cum.d**
[s]	**[km/h]**	**[m]**	**[m]**	**[m]**	**[m]**	**[m]**	**[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	796.8
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	0.11	120.3	120.4	120.3	0.0035	120.3	–0.0015
…	…	…	…	…	…	…	…	…	…
120	37	117.91	125.7	120.9	121.2	121.0	–00.0019	120.2	0.0035
…	…	…	…	…	…	…	…	…	…
200	46	193.41	204.1	121.4	120.7	121.0	–00.0040	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	–00.0405	122.9	–0.0086
…	…	…	…	…	…	…	…	…	…
798	158	796.1	798.8	121.2	121.2	121.2	–00.0219	121.3	–0.0151
799	159	798.8	800.0	121.2	121.2	121.2	–00.0220	121.3	–0.0152

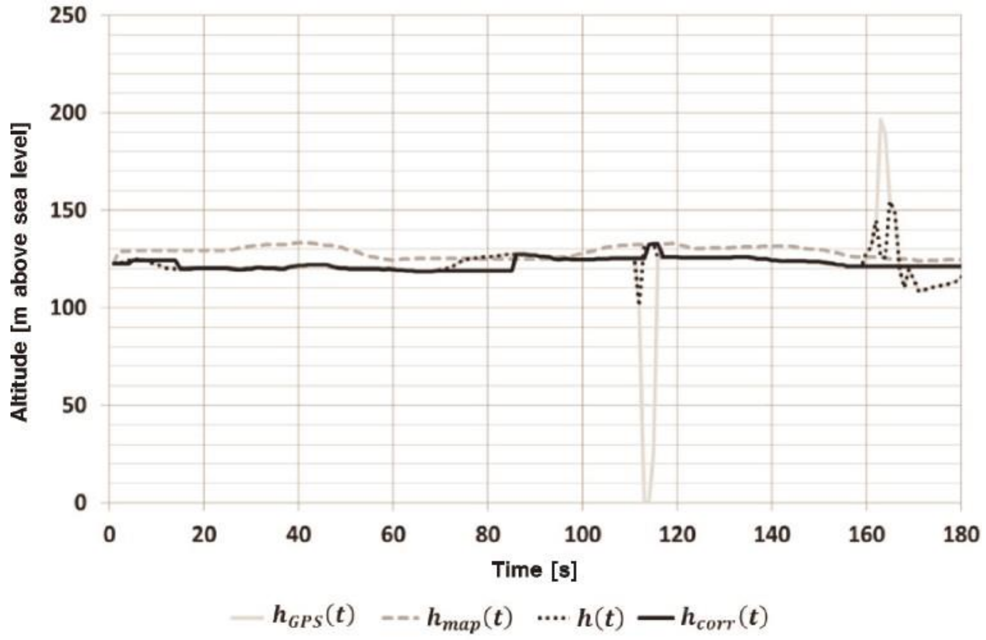


Figure 2
The Effect of Data Verification and Correction – The Altitude Profile Measured by GPS hGPS(t), the Altitude Profile Provide by the Topographic Map h_{map}(t), the Altitude Profile Obtained after the Screening and Principle Verification of Data Quality at a h(t) and the Correction h_{corr}(t) of Data Listed in Table 1 of this Appendix

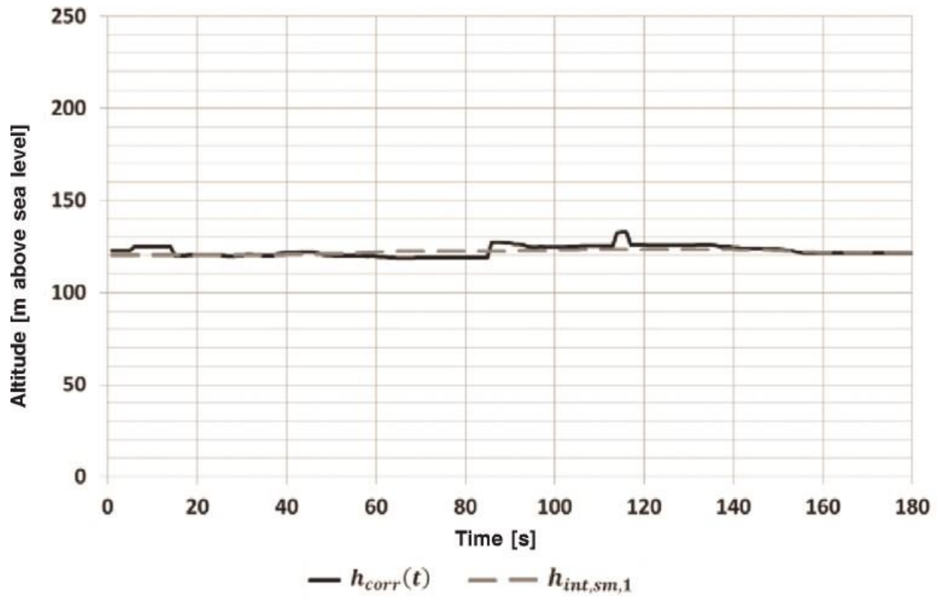


Figure 3
Comparison between the Corrected Altitude Profile h_{corr}(t) and the Smoothed Interpolated Altitude $h_{int,sm,1}$

Table 3
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

CHAPTER 20 – APPENDIX 7C

VERIFICATION OF TRIP CONDITIONS AND CALCULATION OF THE FINAL RDE EMISSIONS RESULT FOR OVC-HEVS

1.0	**INTRODUCTION**	
	This Appendix describes the verification of trip conditions and the calculation of the final RDE emissions result for OVC-HEVs. The method proposed in the Appendix will undergo review in order to find a more complete one.	
2.0	**SYMBOLS, PARAMETERS AND UNITS**	
	M_t	Weighted distance-specific mass of gaseous pollutants [mg/km] or particle number [#/km], respectively emitted over the complete trip.
	m_t	Mass of gaseous pollutant [g] or particle number [#] emissions, respectively emitted over the complete trip.
	m_t,CO2	Mass of CO_2 [g] emitted over the complete trip.
	Mu	Eeighted distance-specific mass of gaseous pollutants [mg/km] or particle number [#/km], respectively emitted over the urban part of the trip.
	m_u	Mass of gaseous pollutant or the particle number emissions, respectively emitted over the urban part of the trip [mg]
	m_u,CO2 =	mass of CO_2 [g] emitted over the urban part of the trip
	$M_{\mathbf{MIDC}}$,CO2 =	distance-specific mass of CO2 [g/km] for a test in charge sustaining mode over the MIDC
3.0	**GENERAL REQUIREMENTS**	
	The gaseous and particle pollutant emissions of OVC-HEVs shall be evaluated in two steps. First, the trip conditions shall be evaluated in accordance with clause 4 of this Appendix. Second, the final RDE emissions result is calculated in accordance with clause 5 of this Appendix. It is recommended to start the trip in charge-sustaining battery status to ensure that the third requirement of clause 4 of this Appendix is fulfilled. The battery shall not be charged externally during the trip.	
4.0	**VERIFICATION OF TRIP CONDITIONS**	
	It shall be verified in a simple three-step procedure that:	

	(1) The trip complies with the general requirements, boundary conditions, trip and operational requirements, and the specifications for lubricating oil, fuel and reagents defined in clause 4 to 8 of this Chapter;
	(2) The trip complies with the trip conditions defined in Appendices 7A and 7B of this Chapter. (3) The combustion engine has been working for a minimum cumulative distance of 12 km under urban conditions.
	If the at least one of the requirements is not fulfilled, the trip shall be declared invalid and repeated until the trip conditions are valid.
5.0	**CALCULATION OF THE FINAL RDE EMISSIONS RESULT**
	For valid trips, the final RDE result is calculated based on a simple evaluation of the ratios between the cumulative gaseous and particle pollutant emissions and the cumulative CO2 emissions in three steps:
	(1) Determine the total gaseous pollutant and particle number emissions [mg;#] for the complete trip as m_t and over the urban part of the trip as m_u.
	(2) Determine the total mass of CO_2 [g] emitted over the complete RDE trip as $m_{t,CO2}$ and over the urban part of the trip as $m_{u,CO2}$.
	(3) Determine the distance-specific mass of CO_2 $M_{MIDC,CO2}$ [g/km] in charge-sustaining mode for the individual vehicles including cold start.
	(4) Calculate the final RDE emissions result as:
	$M_t = (m_t / m_{t,CO2}) \cdot M_{MIDC,CO2}$ for the complete trip
	$M_u = (m_u / m_{u,CO2}) \cdot M_{MIDC,CO2}$ for the urban part of the trip

CHAPTER 20 - APPENDIX 8

DATA EXCHANGE AND REPORTING REQUIREMENTS

1.0	**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 clause 3.2 of Appendix 1 of this Chapter. The data specified in the exchange and reporting files of clause 3 of this Appendix shall be reported to ensure traceability of final results.
2.0	**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
	k22	Coefficient of the weighing function
	tol_1	Primary tolerance
	tol_2	Secondary tolerance
	$(v \cdot a_{pos})_{k\_}[95]$	95^{th} 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]
	RPAk	Relative positive acceleration for urban, rural and motorway driving [m/s^2 or kWs/(kg*km)]

3.0	**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. Sub-parameter values shall be separated by a colon, ASCII-Code #h3B. 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 of this Appendix). 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 of this Appendix). 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 of this Appendix. The information in Table 3 shall be obtained prior to the application of the data evaluation methods laid down in Appendices 5 and 6 of this Chapter.
	The vehicle manufacturer shall record the results of the MAW data evaluation methods in separate files. The results of the data evaluation with the method described in Appendix 5 of this Chapter shall be reported according to Tables 4, 5 and 6 of this Appendix. 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.
4.0	**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 value at test start	[km]
12	Odometer value at test end	[km]
13	Vehicle category	[category]
14	Type approval emissions limit	[Bharat Stage XX]
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	Tyre size[width/height/rim diameter]	[width/height/rim diameter]
	24	Front and rear axle tyre pressure	[bar; bar]
	25 b	Road load parameters from MIDC	[F0, F1, F2]
	26	Type-approval test cycle	[MIDC, WLTC]
	27	Type-approval CO_2 emissions	[g/km]
	28	CO2 emissions in MIDC mode Low Urban	[g/km]
	29	CO2 emissions in MIDC mode Extra urban	[g/km]
	30	Reserved	
	31	Reserved	
	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 characterize 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	[#/m³]	(2)
		Exhaust mass flow rate	EFM	[kg/s]	(2)
		Exhaust temperature in the EFM	EFM	[K]	(2)
		Exhaust mass flow rate	Sensor	[kg/s]	(2)
		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	ECU	[K]	(2)
		temperature			
		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/100km]
9	Average THC concentration	[ppm]
10	Average CH_4 concentration	[ppm]
11	Average NMHC concentration	[ppm]
12	Average CO concentration	[ppm]
13	Average CO_2 concentration	[ppm]
14	Average NO_X concentration	[ppm]
15	Average PN concentration	[#/m3]
16	Average exhaust mass flow rate	[kg/s]
17	Average exhaust temperature	[K]
18	Maximum exhaust temperature	[K]
19	Cumulated THC mass	[g]
20	Cumulated CH_4 mass	[g]
21	Cumulated NMHC mass	[g]
22	Cumulated CO mass	[g]
23	Cumulated CO_2 mass	[g]
24	Cumulated NO_X mass	[g]
25	Cumulated PN	[#]
26	Total trip THC emissions	[mg/km]
27	Total trip CH_4 emissions	[mg/km]
28	Total trip NMHC emissions	[mg/km]
29	Total trip CO emissions	[mg/km]
30	Total trip CO_2 emissions	[g/km]
31	Total trip NO_X emissions	[mg/km]
32	Total trip PN emissions	[#/km]
33	Distance urban part	[km]
34	Duration urban part	[h:min:s]
35	Stop time urban part	[min:s]

36	Average speed urban part	[km/h]
37	Maximum speed urban part	[km/h]
38	$(v \cdot a_{pos})_k$_[95], k = urban	[m2/s3]
39	RPA_k,k = urban	[m/s2]
40	Cumulative urban elevation gain	[m/100km
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 NOx concentration	[ppm]
47	Average urban PN concentration	[#/m3]
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 NOx 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 NOx 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	[m2/s3]
71	RPA_{k},k = rural	[m/s2]
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	[#/m3]
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	[m2/s3]
102	RPA_k,k = motorway	[m/s2]
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	[#/m3]
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) 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 of this Chapter

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_{12} 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. EMROA D 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 of this Chapter

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 greater than 10%	(1 = Yes, 0 = No)
109	Share of rural windows in the total number of windows greater than 10%	(1 = Yes, 0 = No)
110	Share of motorway windows in the total number of windows greater than 10%	(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	
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 ± tol2	
118	Number of motorway windows within ± tol_2	
119	Share of urban windows within ± tol_1	[%]
120	Share of rural windows within ± tol1	[%]
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]
	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)]Additional parameters may be added until line 195		

Table 5B
Header of Reporting File #2 –
Final Emission Results According to Appendix 5 of this Chapter

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 of this Chapter; 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 emissions		[g]	[1]
	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 O2 emissions		[mg/km]	(1)
	Window PN emissions		[#/km]	(1)
	Window distance to CO_2 characteristic curve h_j		[%]	(1)
	Window weighing factor w_j		[-]	(1)

		Window Average Vehicle Speed	Source (1=GPS, 2=ECU,	[km/h]	[1]
			3=Sensor)		
		…..[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.				
4.3	Vehicle and Engine Description				
	The manufacturer shall provide the vehicle and engine description in accordance with AIS-007, as amended form time to time.				

<table>
<tr><td colspan="2">CHAPTER 20 - APPENDIX 9
MANUFACTURER'S DECLERATION OF COMPLIANCE</td></tr>
<tr><td colspan="2">Manufacturer's certificate of compliance with the Real Driving Emissions requirements</td></tr>
<tr><td>(Manufacturer):</td><td>...</td></tr>
<tr><td>(Address of the Manufacturer):</td><td>...</td></tr>
<tr><td colspan="2">Certifies that</td></tr>
<tr><td colspan="2">CONTENT TO BE ADDED</td></tr>
<tr><td colspan="2">Done at [.... (Place)]
On[....(Date)]</td></tr>
<tr><td colspan="2">..
(Stamp and signature of the manufacturer's representative)</td></tr>
<tr><td colspan="2">Annex:</td></tr>
<tr><td colspan="2">- List of vehicle types to which this certificate applies</td></tr>
</table>